SLOVENSKI STANDARD
SIST EN 13530-2:2003

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Kriogene posode - Velike premiļne, vakuumsko izolirane posode - 2. del: Naļrtovanje, izdelava, nadzor in preskus

Cryogenic vessels - Large transportable vacuum insulated vessels - Part 2: Design, fabrication, inspection and testing

Kryo-Behälter - Große ortsbewegliche vakuum-isolierte Behälter - Teil 2: Bemessung, Herstellung und Prüfung

Récipients cryogéniques - Grands récipients transportables isolés sous vide - Partie 2 : Conception, fabrication, inspection et essais

Ta slovenski standard je istoveten z: **EN 13530-2:2002**

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23.020.40	Proti mrazu odporne posode (kriogenske posode)	Cryogenic vessels

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EUROPEAN STANDARD

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English version

Cryogenic vessels - Large transportable vacuum insulated vessels - Part 2: Design, fabrication, inspection and testing

Récipients cryogéniques - Grands récipients transportables isolés sous vide - Partie 2: Conception, fabrication, contrôles et essais

Kryo-Behälter - Große ortsbewegliche, vakuum-isolierte Behälter - Teil 2: Bemessung, Herstellung und Prüfung

This European Standard was approved by CEN on 29 May 2002.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN 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 CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Contents

Foreword

This document EN 13530-2:2002 has been prepared by Technical Committee CEN/TC 268 "Cryogenic vessels", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2003, and conflicting national standards shall be withdrawn at the latest by March 2003.

The European Standard has been submitted for reference into the RID and/or in the technical annexes of the ADR.

Therefore the standards listed in the normative references and covering basic requirements of the RID/ADR not addressed within the present standard are normative only when the standards themselves are referred to in the RID and/or in the technical annexes of the ADR.

EN 13530 consists of the following parts under the general title, *Cryogenic vessels – Large transportable vacuum insulated vessels:*

— *Part 1: Fundamental requirements*

— *Part 2: Design, fabrication, inspection and testing*

— *Part 3: Operational requirements*

The annexes A, D and F are informative, the annexes B, C and E are normative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies requirements for the design, fabrication, inspection and testing of large transportable vacuum insulated cryogenic vessels of more than 1 000 l volume, which are permanently (fixed tanks) or not permanently (demountable tanks) attached to a vehicle, for carriage by road. However, it can be used for other mode of transport providing the specific regulations/requirements are complied with.

This European Standard applies to large transportable vacuum insulated cryogenic vessels for fluids specified in EN 13530-1:2002 and does not apply to vessels designed for toxic fluids.

This European Standard does not include the general vehicle requirements e.g. running gear, brakes, lighting etc. that should be in accordance with the relevant standards/regulations.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 287-1:1992, *Approval testing of welders - Fusion welding - Part 1: Steels*.

EN 287-2:1992, *Approval testing of welders - Fusion welding - Part 2: Aluminium and aluminium alloys*.

EN 288-3:1992, *Specification and approval of welding procedures for metallic materials - Part 3: Welding procedure tests for the arc welding of steels*.

EN 288-4:1992, *Specification and approval of welding procedures for metallic materials - Part 4: Welding procedure tests for the arc welding of aluminium and its alloys*.

EN 288-8:1992, *Specification and approval of welding procedures for metallic materials - Part 8: Approval by a pre-production welding test.*

EN 473:2000, *Non-destructive testing - Qualification and certification of NDT personnel - General principles*.

EN 875:1995, *Destructive tests on welds in metallic materials - Impact tests - Test specimen location, notch orientation and examination*.

EN 895:1995, *Destructive tests on welds in metallic materials - Transverse tensile test.*

EN 910:1996, *Destructive tests on welds in metallic materials – Bend tests.*

EN 1252-1:1998, *Cryogenic vessels - Materials - Part 1: Toughness requirements for temperatures below -80 °C*.

EN 1252-2:2001, *Cryogenic vessels - Materials - Part 2: Toughness requirements for temperatures between –80 °C and –20 °C.*

EN 1418:1997, *Welding personnel – Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanised and automatic welding of metallic materials.*

EN 1435:1997, *Non-destructive examination of weld – Radiographic examination of welded joints.*

EN 1626:1999, *Cryogenic vessels - Valves for cryogenic service.*

EN 1797:2001, *Cryogenic vessels - Gas/material compatibility.*

EN 10028-4:1994, *Flat products made of steels for pressure purposes – Part 4: Nickel alloy steels with specified low temperature properties.*

EN 10028-7:2000, *Flat products made of steels for pressure purposes - Part 7: Stainless Steels.*

EN 12300:1998, *Cryogenic vessels - Cleanliness for cryogenic service.*

EN ISO 6520-1:1998, *Welding and allied processes - Classification of geometrical imperfections in metallic materials – Part 1: Fusion welding (ISO 6520-1:1998).*

EN 13068-3:2001, *Non-destructive testing – Radioscopic testing – Part 3: General principles of radioscopic testing of metallic materials by X– and gamma rays.*

prEN 13445-3:1999, *Unfired pressure vessels – Part 3: Design.*

EN 13530-1:2002, *Cryogenic vessels - Large vacuum insulated vessels - Part 1: Fundamental requirements.*

prEN 13648-3:2001, *Cryogenic vessels – Safety devices for protection against excessive pressure – Part 3: Determination of required discharge capacity and sizing for relief devices.*

ISO 1106-1:1984, *Recommended practice for radiographic examination of fusion welded joints - Part 1: Fusion welded butt joints in steel plates up to 50 mm thick.*

3 Terms, definitions and symbols

For the purposes of this European Standard, the following terms, definitions and symbols apply.

3.1 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply in addition to those given in part 1 of this standard.

3.1.1
large transportable vacuum insulated vessel
vessel of more than 1 000 l volume intended for one or more cryogenic fluids, consisting of an inner vessel, an outer jacket, all of the valves and accessories and additional framework

3.1.2
fixed tank (tank vehicle)
large transportable vessel permanently attached to a vehicle or to units of running gear used in its stead

3.1.3
demountable tank
large transportable vessel non permanently attached to a vehicle. When attached to the carrier vehicle, the demountable tank meets the requirements prescribed for a fixed tank. It is designed to be lifted only when empty

3.1.4
inner vessel
pressure vessel proper intended to contain the cryogenic fluid

3.1.5
outer jacket
gas-tight enclosure which contains the inner vessel and enables a vacuum to be established

3.1.6
automatic welding
welding in which the parameters are automatically controlled. Some of these parameters may be adjusted to a limited extent, either manually or automatically, during welding to maintain the specified welding conditions

3.1.7
maximum allowable pressure, p_s
maximum pressure for which the equipment is designed, as specified by the manufacturer, defined at a location specified by the manufacturer, being the location of connection of protecting or limited devices or the top of the equipment

3.1.8
relief plate/plug
plate or plug retained by atmospheric pressure only which allows relief of excess internal pressure

3.1.9
bursting disc device
non-reclosing pressure relief device ruptured by differential pressure. It is the complete assembly of installed components including where appropriate the bursting disc holder

3.2 Symbols

For the purposes of this European Standard, the following symbols apply.

c	allowance for corrosion	mm
d_i	diameter of opening	mm
d_a	outside diameter of tube or nozzle	mm
f	narrow side of rectangular or elliptical plate	mm
l_b, l'_b	buckling length	mm
n	number of lobes	-
p	design pressure as defined in 4.3.2.2	bar
p_e	allowable external pressure limited by elastic buckling	bar
p_k	strengthening pressure	bar
p_p	allowable external pressure limited by plastic deformation	bar
p_T	pressure test (see 4.2.3.2)	bar
r	radius e.g. inside knuckle radius of dished end and cones	mm
s	minimum thickness	mm
s_e	actual wall thickness	mm
v	factor indicative of the utilisation of the permissible design stress in joints or factor allowing for weakenings	-
x	(decay-length zone) distance over which governing stress is assumed to act	mm
A	cross sectional area of reinforcing element	mm^2
C, β	design factors	-
D	shell diameter	mm

D_a	outside diameter e.g. of a cylindrical shell	mm
D_i	internal diameter e.g. of a cylindrical shell	mm
E	Young's modulus	N/mm^2
I	moment of inertia of reinforcing element	mm^4
R_e	apparent yield stress or 0,2 % proof stress (1 % proof stress for austenitic steel)	N/mm^2
R_m	minimum tensile strength (actual or guaranteed)	N/mm^2
K	material property used for design	N/mm^2
R	radius of curvature e.g. inside crown radius of dished end	mm
S	safety factor at design pressure, in relation with Re	-
S_k	safety factor against elastic buckling at design pressure	-
S_p	safety factor against plastic deformation	-
Z	auxiliary value	-
v	Poisson's ratio	-
u	out of roundness	-

4 Design

4.1 Design options

4.1.1 General

The design shall be carried out in accordance with one of the options given in 4.1.2, 4.1.3 or 4.1.4.

Metallic materials used at cryogenic temperatures shall meet the requirements of the relevant sections of EN 1252-1:1998 or EN 1252-2:2001.

In the case of 9 % Ni steel, the additional requirements of annex B shall be satisfied.

4.1.2 Design by calculation

Calculation of all pressure and load bearing components shall be carried out. The pressure part thicknesses of the inner vessel and outer jacket shall not be less than required by 4.3. Additional calculations may be required to ensure the design is satisfactory for the operating conditions including an allowance for dynamic loads.

4.1.3 Design by calculation and pressure strengthening

The pressure retaining capability of inner vessels manufactured from austenitic stainless steel, strengthened by pressure, shall be calculated in accordance with annex C.

4.1.4 Design by calculation supplemented with experimental methods

Where it is not possible to design by calculation alone planned and controlled experimental means may be used providing that the results confirm the safety factors required in 4.3. An example would be the application of strain gauges to assess stress levels.

4.2 Common design requirements

4.2.1 General

The requirements of 4.2.2 to 4.2.7 are applicable to all vessels irrespective of the design option used.

In the event of an increase in at least one of the following parameters:

— maximum allowable pressure;

— specific mass (density) of the densest gas for which the vessel is designed;

— maximum tare weight of the inner vessel;

— nominal length and/or diameter of the inner shell;

or, in the event of any change relative:

— to the type of material or grade (e.g. stainless steel to aluminium);

— to the fundamental shape;

— to the decrease in the minimum mechanical properties of the material being used;

— to the modification of the design of an assembly method concerning any part under stress, particularly as far as the support systems between the inner vessel and the outer jacket or the inner vessel itself or the protective frame, if any, are concerned;

the initial design programme shall be repeated to take account of these modifications.

4.2.2 Design specification

To enable the design to be prepared the following information which defines a vessel type shall be available:

— maximum allowable pressure;

— fluids intended to be used;

— liquid capacity;

— dimensions and allowable weight, taking characteristics of the vehicle into account;

— location of fastening points and loads allowable on these points;

— filling and emptying rate;

— range of ambient temperature, if differing from 7.2 of EN 13530-1:2002.

A design document in the form of drawings with text if any shall be prepared, it shall contain the information given above plus the following where applicable:

— definition of which components are designed by calculation, by pressure strengthening, by experiment and by satisfactory in service experience;

— drawings with dimensions and thicknesses of load bearing components;

— specification of all load bearing materials including grade, class, temper, testing etc. as relevant;

— type of material test certificates;

— location and details of welds and other joints, welding and other joining procedures, filler, joining materials etc. as relevant;

— calculations to verify compliance with this standard;

— design test programme;

— non destructive testing requirements;

— pressure test requirements;

— piping configuration including type, size and location of all valves and relief devices;

— details of fastenings.

4.2.3 Design loads

4.2.3.1 General

The large transportable cryogenic vessel shall be able to withstand safely the mechanical and thermal loads encountered during pressure test and normal operation.

In considering design loads during transport, static loads shall be substituted for static plus dynamic loads. The static loads used shall be as follows:

— in the direction of travel : twice the total mass;

— at right angles to the direction of travel : the total mass;

— vertically upwards: the total mass;

— vertically downwards: twice the total mass.

Each of these loads is considered to act in isolation and includes the mass of the component under consideration.

4.2.3.2 Inner vessel

With the exception of a) the following loads shall be considered to act in combination where relevant:

a) test pressure : the value used for validation purposes shall be:

$$p_T \geq 1{,}3(p_s + 1)\text{bar} \quad (1)$$

considered for each element of the vessel e.g. shell, courses, head, etc.

p_s is the maximum allowable pressure, in bar.

The 1 bar is added to allow for the external vacuum.

The inner vessel shall be capable of holding the pressure test fluid without plastic deformation.

The minimum test pressure shall be 3 bar.

b) pressure during operation, p_C, where:

$$p_C = p_s + p_L + 1 \text{ bar} \quad (2)$$

p_L is the pressure, in bar, exerted by the mass of the liquid contents when the vessel is filled to capacity and subject to each load defined in 4.2.3.1, with either:

1) boiling liquid at atmospheric pressure; or

2) cryogenic fluid at its equilibrium triple point or melting point temperature at atmospheric pressure;

c) reaction at the support points of the inner vessel due to the mass of the inner vessel and its contents when subject to each of the loads defined in 4.2.3.1;

d) load imposed by the piping due to the differential thermal movement of the inner vessel, the piping and the outer jacket.

The following cases shall be considered:

— cooldown (inner vessel warm - piping cold);

— filling and withdrawal (inner vessel cold - piping cold); and

— transport and storage (inner vessel cold - piping warm);

e) load imposed on the inner vessel at its support points when cooling from ambient to operating temperature and during operation.

4.2.3.3 Outer jacket

The following loads shall be considered to act in combination where relevant:

a) an external pressure of 1 bar;

b) an internal pressure equal to the set pressure of the outer jacket pressure relief device;

c) load imposed by the inner vessel and its contents at the support points in the outer jacket when subject to each of the loads in 4.2.3.1;

d) load imposed by piping as defined in 4.2.3.2 d);

e) load imposed at the inner vessel support points in the outer jacket when the inner vessel cools from ambient to operating temperature and during operation;

f) reactions at the outer jacket fastening points due to the mass of the transportable cryogenic vessel and its contents when filled to capacity and subject to each dynamic load.

4.2.3.4 Self supporting vessels

In the case of vehicles in which the inner vessel and possibly the outer jacket constitute stressed self-supporting members of the vehicle, these shall be designed to withstand the stresses thus imposed in addition to stresses from other sources, (see 4.2.3.2 c) and 4.2.3.3 f)).

4.2.3.5 Inner vessel supports

The inner vessel supports shall be suitable for each load defined in 4.2.3.2 c) plus loads due to differential thermal movements.

4.2.3.6 Surge plates

The inner vessel shall be divided by surge plates to provide stability and limit dynamic loads to the requirements of 4.2.3, unless it is to be filled equal to or more than 80 % of its capacity or nominally empty. The cross sectional area of the surge plate shall be at least 70 % of that of the vessel.

Current experience with surge plates limiting the capacity to 7 500 l has been shown to meet these requirements.

Surge plates and their attachments to the shell shall be designed to resist the stresses caused by a pressure evenly distributed across the area of the surge plate. The pressure is calculated by considering the mass of liquid between the plates decelerating at 2 g (4.2.3).

4.2.3.7 Outer jacket supports

The outer jacket supports shall be suitable for the load defined in 4.2.3.3.

4.2.3.8 Fastening points

Fastening points shall be suitable for fastening the large transportable cryogenic vessel to the vehicle when filled to capacity and subject to each of the loads defined in 4.2.3.

4.2.3.9 Protection of upper fittings

The fittings and accessories mounted on the upper part of the vessel shall be protected in such a way that damage caused by overturning cannot impair operational integrity. This protection may take the form of strengthening rings, protective canopies or transverse or longitudinal members so shaped that effective protection is given.

4.2.3.10 Stability

The overall width of the ground-level bearing surface (distance between the outer points of contact with the ground of the right-hand tyre and the left-hand tyre of the same axle) shall be at least equal to 90 % of the height of the centre of gravity of the fully laden tank-vehicle. In an articulated vehicle the mass on the axles of the load-carrying unit of the laden semi-trailer shall not exceed 60 % of the nominal total laden mass of the complete articulated vehicle.

4.2.3.11 Piping and valves

Piping including valves, fittings and supports shall withstand the following loads. With the exception of a) the loads shall be considered to act in combination where relevant.

a) pneumatic pressure test : not less than the allowable working pressure p_S plus 1 bar for piping inside the vacuum jacket;

b) pressure during operation : not less than the set pressure of the system pressure relief device;

c) thermal loads defined in 4.2.3.2 d);

d) dynamic loads;

e) set pressure of thermal relief devices where applicable;

f) loads generated during pressure relief discharge.

This equipment shall be protected or positioned so as to be protected against the risk of being wrenched off or damaged during transport.

In the particular case of liquid hydrogen the possibility of air condensing on uninsulated cold parts shall be considered.

The leakproofness of this equipment shall be ensured in the event of overturning of the vehicle. The gaskets shall be made of a material compatible with the fluid carried, in accordance with EN 1797:2001.

Each bottom-filling or bottom-discharge opening shall be provided with at least two independent shut-off devices in series, the first being a stop valve situated as close as possible to the outer jacket and provided with protection against mechanical damage at least equal to that afforded by the outer jacket.

In order to prevent leaks of flammable fluids the first stop valve shall be an instant-closing safety device which closes automatically in the event of an unintended movement of the vehicle or of fire during the filling/emptying operation. It shall also be possible to operate the closing device by remote control. All vent pipes including pressure relief devices and purge valves shall be connected to a vent pipe allowing safe discharge. The control cabinet shall be vented so that flammable gas cannot accumulate therein.

4.2.4 Fatigue

The design shall take into account the effect of cyclic stress on the inner vessel, outer jacket and their attachments during normal conditions of operation.

When considering the case of fatigue, the common requirement of dimensioning with loads according to 4.2.3 shall be such as to accommodate the effects of fatigue. Particular attention may be necessary to specific details in the supports and piping systems to avoid stress raisers.

4.2.5 Corrosion allowance

Corrosion allowance is not required on surfaces in contact with the operating fluid. Corrosion allowance is not required on other surfaces if they are adequately protected against corrosion.

4.2.6 Inspection openings

Inspection openings are not required in the inner vessel or the outer jacket, providing the requirements of prEN 13530–3:— are followed.

NOTE 1 Due to the combination of materials of construction and operating fluids, internal corrosion connot occur.

NOTE 2 The inner vessel is inside the evacuated outer jacket and hence external corrosion of the inner vessel connot occur.

NOTE 3 The elimination of inspection openings also assists in maintaining the integrity of the vacuum in the interspace.

4.2.7 Pressure relief

Relief systems shall be designed to meet the requirements given in 4.2.7.1 to 4.2.7.3:

4.2.7.1 Inner vessel

The inner vessel shall be provided with not less than two independent pressure relief devices at least one of which shall be a relief valve, and shall open at no more than p_s. The devices may be mounted on a common line.

A device shall protect the vessel against excess pressure due to:

normal heat leak, and the devices acting together shall protect the vessel against excess pressure due to;

a) heat leak with loss of vacuum; or

b) heat leak, without loss of vacuum, and the pressure build up system being in the open position.

Excess pressure means a pressure in excess of 110 % of the maximum allowable pressure for condition a) and in excess of the test pressure for condition b) and in excess of the test pressure, minus 1 bar, for condition c).

Relief devices for the inner vessel shall be in accordance with prEN 13648-3:2001 for calculation of sizing.

The pressure relief system shall be sized so that the pressure drop during discharge does not cause the valve to reseat instantly.

4.2.7.2 Outer jacket

Relief devices for the outer jacket shall be in accordance with annex F.

A pressure relief device shall be fitted to the outer jacket. The device shall be set to open at a pressure which prevents collapse of the inner vessel and is not more than 0,5 bar. The discharge area of the pressure relief device shall be not less than 0,34 mm^2/l capacity of the inner vessel and in any case need not exceed 5 000 mm^2.

4.2.7.3 Piping

Any section of pipework containing cryogenic fluid which can be isolated shall be protected by a relief valve or other suitable relief device.

4.2.8 Valves

Valves shall conform to EN 1626:1999.

4.2.9 Insulation

For oxygen or gases having a boiling point below - 182 °C at atmospheric pressure, all materials (including the thermal insulation) in the interspace between inner vessel and outer jacket shall be in accordance with EN 1797:2001 as oxygen enrichment can occur.

4.2.10 Degree of filling

The degree of filling of large transportable vacuum insulated vessels intended for the carriage of flammable gases shall remain below the level at which, if the contents were raised to the temperature at which the vapour pressure equalled the opening pressure of the safety valve, the volume of the liquid would reach 95 % of the vessel's capacity at that temperature. Large transportable vacuum insulated vessels may be filled with non-flammable gases to 98 % of its total volume at the loading temperature and the loading pressure.

Means shall be provided to ensure that the above limits are not exceeded.

4.2.11 Electrical continuity

All metallic components of large transportable vacuum insulated vessels intended for the carriage of flammable gases shall be electrically continuous. The large transportable vacuum insulated vessels shall be provided with the means of attachment to earthing devices so that the resistance to the earthing connection is less than 5 ohms. Any metal contact capable of causing electrochemical corrosion shall be avoided.

4.3 Design by calculation

4.3.1 General

The dimensions of the inner vessel and outer jacket shall not be less than that determined in accordance with this subclause.