

Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and –165 °C —

Part 4: Insulation components

The European Standard EN 14620-4:2006 has the status of a British Standard

ICS 23.020.10

National foreword

This British Standard was published by BSI. It is the UK implementation of EN 14620-4:2006. This standard, together with BS EN 14620-3:2006, supersedes BS 7777-3:1993 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PVE/15, Storage tanks for the petroleum industry.

A list of organizations represented on PVE/15 can be obtained on request to its secretary.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 December 2006

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ISBN 0 580 49778 X

Amendments issued since publication

Amd. No.	Date	Comments

English Version

Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and -165 °C -
Part 4: Insulation components

Conception et fabrication de réservoirs en acier à fond plat, verticaux, cylindriques, construits sur site, destinés au stockage des gaz réfrigérés, liquéfiés, dont les températures de service sont comprises entre 0 °C et -165 °C - Partie 4: Constituants isolants

Auslegung und Herstellung standortgefertigter, stehender, zylindrischer Flachboden-Stahltanks für die Lagerung von tiefkalt verflüssigten Gasen bei einer Betriebstemperatur zwischen 0 °C und -165 °C - Teil 4: Dämmung

This European Standard was approved by CEN on 20 February 2006.

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 Central Secretariat 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 Central Secretariat has the same status as the official versions.

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Foreword

This European Standard (EN 14620-4:2006) has been prepared by Technical Committee CEN/TC 265 “Site built metallic tanks for the storage of liquids”, the secretariat of which is held by BSI.

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 2007, and conflicting national standards shall be withdrawn at the latest by March 2007.

EN 14620 *Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and -165 °C* consists of the following parts:

- Part 1: General;
- Part 2: Metallic components;
- Part 3: Concrete components;
- Part 4: Insulation components;
- Part 5: Testing, drying, purging and cool-down.

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

1 Scope

This European Standard specifies the requirements for materials, design and installation of the insulation of refrigerated liquefied gas (RLG) storage tanks.

RLG storage tanks store liquefied gas with a low boiling point, i.e. below normal ambient temperature.

The concept of storing such products in liquid form and in non-pressurized tanks therefore depends on the combination of latent heat of vaporization and thermal insulation.

Consequently thermal insulation for RLG storage tanks is not an ancillary part of the containment system (as for most ambient atmospheric hydrocarbon tanks) but it is an essential component and the storage tank cannot operate without a properly designed, installed and maintained insulation system.

The main functions of the insulation in RLG storage tanks are:

- to maintain the boil off below the specific limits;
- to protect the non low temperature parts/materials of the tank (mainly the outer tank) by maintaining these parts at their required ambient temperature;
- to limit the cool-down of the foundations/soil underneath the tank to prevent damage by frost heave;
- to prevent/minimize condensation and icing on the outer surfaces of the tank.

A wide range of insulation materials is available. However the material properties differ greatly amongst the various generically different materials and also within the same generic group of materials.

Therefore within the scope of this European Standard, only general guidance on selection of materials is given.

NOTE For general guidance on selection of materials see Annex A.

This European Standard deals with the design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0 °C and – 165 °C.

2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 826:1996, *Thermal insulating products for building applications — Determination of compression behaviour*

EN 1604, *Thermal insulating products for building applications — Determination of dimensional stability under specified temperature and humidity conditions*

EN 1606, *Thermal insulating products for building applications — Determination of compressive creep*

EN 1607, *Thermal insulating products for building applications — Determination of tensile strength perpendicular to faces*

EN 1608, *Thermal insulating products for building applications — Determination of tensile strength parallel to faces*

EN 1609, *Thermal insulating products for building applications — Determination of short term water absorption by partial immersion*

EN 12066, *Installations and equipment for liquefied natural gas — Testing of insulating linings for liquefied natural gas impounding areas*

EN 12086, *Thermal insulating products for building applications — Determination of water vapour transmission properties*

EN 12087, *Thermal insulating products for building applications — Determination of long term water absorption by immersion*

EN 12088, *Thermal insulating products for building applications — Determination of long term water absorption by diffusion*

EN 12090:1997, *Thermal insulating products for building applications — Determination of shear behaviour*

EN 12091, *Thermal insulating products for building applications — Determination of freeze-thaw resistance*

EN 12667, *Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Products of high and medium thermal resistance*

EN 12939, *Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Thick products of high and medium thermal resistance*

EN 13468, *Thermal insulating products for building equipment and industrial installations — Determination of trace quantities of water soluble chloride, fluoride, silicate, sodium ions and pH*

EN 13471, *Thermal insulating products for building equipment and industrial installations — Determination of the coefficient of thermal expansion*

EN 14620-1:2006, *Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165 °C — Part 1: General*

EN ISO 62, *Plastics — Determination of water absorption (ISO 62:1999)*

EN ISO 3582, *Flexible cellular polymeric materials — Laboratory assessment of horizontal burning characteristics of small specimens subjected to a small flame (ISO 3582:2000)*

EN ISO 4590, *Rigid cellular plastics — Determination of the volume percentage of open cells and closed cells (ISO 4590:2002)*

EN ISO 4624, *Paints and varnishes — Pull-off test for adhesion (ISO 4624:2002)*

ISO 844, *Rigid cellular plastics — Determination of compression properties*

ISO 4897, *Cellular plastics — Determination of the coefficient of linear thermal expansion of rigid materials at sub-ambient temperatures*

ISO 8301, *Thermal insulation — Determination of steady-state thermal resistance and related properties — Heat flow meter apparatus*

ISO 8302, *Thermal insulation — Determination of steady-state thermal resistance and related properties — Guarded hot plate apparatus*

3 Terms and definitions

For the purpose of this European Standard, the terms and definitions given in EN 14620-1:2006 apply.

4 Design requirements, performance characteristics, testing and selection of insulating materials

4.1 General

The selection of the appropriate insulation system and materials shall be based on the following:

- analysis of design requirements (see 4.2).
- assessment of the performance characteristics of the materials (see 4.3).

For the insulation materials used, see Annex A.

4.2 Analysis of design requirements

4.2.1 General

The thermal insulation system as a whole and each component of it separately, shall be designed taking into account the following design requirements.

4.2.2 Thermal resistance

4.2.2.1 Normal operation of the tank

All factors contributing to heat in-leak through the insulation system shall be considered, such as:

- product temperature;
- external temperature and other climatic conditions (solar radiation, wind, humidity etc.);
- thermal conductivity;
NOTE A safety margin to be built in for influences of degradation through ageing.
- thermal convection;
- heat in-leak through radiation;
- heat in-leak through cold bridges (from insulation system or tank design).

4.2.2.2 Accidental conditions

In addition, accidental conditions shall be considered. These shall include:

- required thermal resistance, specified for each component of the insulation and the designed duration of the accidental condition;
- thermal resistance offered by the insulation under these conditions.

4.2.3 Structural requirements

The insulation system shall be designed for the following structural requirements:

- static and dynamic actions in all directions;
- liquid tightness (if required).

4.2.4 Specific design requirements

In addition to the above thermal and structural requirements, the tank insulation design shall fulfil all the specific design requirements that are inherent with the selected specific insulation system, material, installation method and type of containment. These shall be specified on a case-by-case basis.

4.3 Assessment of the performance characteristics

4.3.1 General

Based on the design requirements, the required performance characteristics of the insulation materials in the operating temperature range shall be determined. As a minimum the subjects described in 4.3.2 to 4.3.8 shall be considered.

4.3.2 Thermal resistance

The following shall be considered:

- thermal conductivity:
 - 1) over the required temperature range;
 - 2) in the intended environment, external and internal (product vapour space, purged space, contact with liquid product);
 - 3) taking into account ageing effects over the tank design lifetime;
- possible heat in-leak through radiation;
- possible heat in-leak through convection (permeability of the insulation material and of the complete insulation system);
- heat in-leak through cold bridges.

For testing of thermal resistance, see Table B.1.

4.3.3 Mechanical properties

The following shall be considered:

- compressive properties both at short- and at long-term (creep);
- tensile and shear properties for insulation on which lateral forces may act (e.g. earthquake).

NOTE Tensile properties may also be required for assessment of thermo-mechanical loads and thermal stresses.

- adhesive strength for insulation systems, which are installed by adhesion.

For testing of mechanical properties, see Table B.2.

4.3.4 Temperature resistance

The insulation shall withstand the temperatures (maximum and minimum service temperatures) and temperature variations to which it may be exposed. Therefore, shrinkage, expansion and possible cracking effects shall be determined, taking into account:

- coefficient of thermal expansion, contraction;
- tensile strength, tensile modulus in the designed temperature ranges.

For testing of temperature resistance, see Table B.3.

4.3.5 Resistance to water and water vapour

To assess the possible negative effects of water and water vapour on the insulation, the following characteristics shall be considered:

- closed cell content;
- permeability for water vapour;
- water absorption.

In addition, the consequential effects of water and water vapour penetration shall be assessed:

- reduction of thermal resistance;
- possible structural damage to the insulation by liquid water or by the process of freezing (possibly freeze/thaw cycles).

For testing permeability of water and water vapour, see Table B.4.

4.3.6 Influences of stored product

The following characteristics shall be assessed:

- closed cell content (as indication of open/closed cellular structure);
- absorption of product vapours and effect on other material properties (thermal conductivity, mechanical properties, fire resistance);
- absorption of/and permeability for liquid product;
- effects of long term liquid absorption on other material properties;
- desorption behaviour: time/percentage.

NOTE The influence of the stored product on an internal insulation system is critical, as it is often continuously in contact with product vapours and it can come in direct contact with the liquid product in case of an accidental leakage.

For testing of material behaviour in presence of product, see Table B.5.

4.3.7 Chemical properties

An assessment shall be made of the compatibility between and/or possible chemical reactions of:

- insulation system, including all its constituents:
 - 1) insulation materials;
 - 2) ancillary products (paints, adhesives, mastics, sealants, coatings etc.);
 - 3) its protective layer (cladding and fastening);
- its environment:
 - 1) for external insulation: ambient conditions, water, water vapour, contaminants in air and water;
 - 2) for internal insulation: the product vapours and liquid, inerting/purging gas;
- tank material and/or its coating in contact with the insulation system.

Typical chemical characteristics to be assessed shall be:

- for external insulation:
 - 1) resistance to corrosion of the insulation system itself (or parts of it) in conditions representative for the site location, e.g.: marine atmosphere, atmosphere polluted by chemical industries;
 - 2) corrosion protective or corrosion activating properties of the insulation, e.g.: possibility of dissolving or leaching out corrosive products from the insulation, corrosion protection in case of waterproof insulation system;
- for internal insulation:
 - 1) chemical resistance of the insulation system against the product vapours/liquids in the tank;
 - 2) insulation to be inert for the products stored in the tank (absence of contaminants, chemical reagents).

For methods of assessing the chemical properties, see Table B.6

4.3.8 Reaction to fire

The following important aspects shall be considered:

- fire risk during construction;
- behaviour in case of an external fire (if specified).

In view of this, the following characteristics shall be considered:

- reaction to fire:
 - 1) flammability;
 - 2) fire retarding properties;
 - 3) toxic gas generation;
- maximum temperature limits of the material: melting temperature, decomposition temperature, ignition temperature;
- fire resistance properties of the insulation (in case the thermal insulation is designed also for the dual role of fire protection).

For methods of assessing fire resistance and reaction to fire, see Table B.7

4.4 Testing of materials and systems

4.4.1 General

The performance characteristics of the insulation materials shall be demonstrated by:

- laboratory testing,
- mock-up testing of an insulation system,

NOTE 1 For evaluating the behaviour of a tank insulation system under a combination of various actions, the testing of single material properties may not be sufficient. Mock-up testing is an alternative solution.

or

- complete installed tank insulation system.

NOTE 2 Finite element calculations may provide additional information.

4.4.2 Test methods

Whenever available, standardized testing methods shall be in accordance with Annex B.

NOTE Annex B deals with testing of performance characteristics of insulation materials/insulation systems. Other tests, used only for specific products, are not covered e.g. measurements of density, dimensions etc. The insulation material manufacturer normally provides them.

5 Protection of insulation – water vapour barrier

5.1 General

As the insulation system is not a self-standing structural component of the tank, the insulation shall be fixed against, placed upon, poured in between or supported by other structural components (concrete and steel).

Furthermore insulation materials shall be protected against various types of possible deterioration and damage, such as:

- mechanical damages;
- water absorption by rain, snow etc.;
- deterioration by other climatic factors such as wind, hail, UV;
- water absorption and ice formation by penetration of water vapour;
- fire damage.

For this protection a protective cover shall be provided.

The complete package of insulation material and protective cover and fixing system is called the “Insulation system”.

5.2 Protective structure formed by the outer tank

In many containment types, the outer tank provides the protection and the supporting structure for the insulation and, in this case, it shall be confirmed that the outer tank provides sufficient tightness.

In cases where the outer tank is made of concrete, which is permeable for water vapour and product vapour, the necessary measures shall be taken to make the concrete water vapour and product vapour tight.

Water vapour and product vapour tightness shall be achieved by:

- either a metallic liner;
- or a Polymeric Vapour Barrier (PVB).

NOTE See also EN 14620-3:2006, Clause 9.

5.3 Protective cover for external insulation

Where the insulation is placed externally, an appropriate cover shall be provided. This cover shall give protection against all factors that could adversely affect the quality/efficiency and lifetime of the insulation.

The following factors shall be considered:

- weather factors:
 - 1) water vapour;
 - 2) rain, snow, hail;
 - 3) wind, storm;
 - 4) solar radiation, UV;

- other atmospheric factors:
 - 1) pollution;
 - 2) corrosion;
- mechanical damages by humans, birds etc.;
- fire damage.

Since for cold insulation, the most detrimental “aggressor”, being invisible and acting continuously, is water vapour, the penetration of water vapour shall be prevented/minimized. For most insulation systems, a good Water Vapour Barrier (WVB) shall be installed on the outside of the insulation to eliminate/minimize water vapour penetration. This WVB shall either be designed separately or as part of the protective cover.

The maximum WVB permeability shall be 0,5 g/m² 24 h under the average water vapour pressure differential of the area where the project is located.

The protective cover and water vapour barrier of external tank insulation shall be:

- metallic (insulation cladding), or
- non-metallic (polymeric vapour barrier, vapour barrier mastics), or
- a combination of both.

NOTE The need for this WVB may be waived for certain insulation systems if it is sufficiently proven that the insulation itself is and remains water vapour tight.

6 Design of insulation system

6.1 General

In general, the design of the tank insulation system shall be based on structural and thermal requirements. In addition, the installation method and the commissioning and decommissioning (purging, gas freeing) requirements shall be taken into account.

NOTE The insulation design can differ substantially, based on the type of containment selected and on the part of the tank under consideration (bottom, wall, roof). It is difficult to specify for each type of containment each subject to be considered and the approach has been taken that only general requirements are mentioned below.

As part of the total tank insulation design, all additional requirements inherent with the specific type of containment, part of the tank under consideration, insulation material selected and other project inherent factors shall be clearly specified in the project specification.

6.2 Thermal design

The thermal design shall take account of the requirements specified:

- maximum allowed boil off;
- minimum design temperature of outer tank components;
- prevention of icing/condensation on external surfaces of the tank;
- prevention of soil freezing.

For boil-off, the purchaser shall specify the maximum allowed boil-off per day and the external climatic conditions that shall be taken into account.

The thermal design shall result in an insulation system that, by spreading the total allowed heat in-leak over the various parts of the tank, shall satisfy all the above requirements.

If in the thermal design of the tank, in addition to the thermal resistance offered by the insulation system, allowance is also made for the thermal resistance of other parts of the tank such as constructional parts (concrete) or vapour spaces inside the tank, this shall only be done in as far as the thermal resistance of these components in the respective position in the tank and in the relevant temperature range is proven.

6.3 Structural design

6.3.1 General

The structural design of the insulation system shall be based on the allowable stress or limit state theory.

NOTE The limit state theory is recommended when earthquake conditions have a predominant influence.

6.3.2 Load bearing insulation/compressive action

6.3.2.1 General

Certain parts of the tank insulation shall be subjected to compressive loads:

- tank bottom insulation for all types of containment;
- tank bottom and tank wall for membrane tanks;
- TPS for bottom and wall.

6.3.2.2 Allowable stress theory

6.3.2.2.1 For brittle materials (e.g. cellular glass)

The minimum overall safety factors, between nominal compressive strength σ_n and design compressive stress shall be as follows:

normal operation: 3,00

hydrostatic test: 2,25

earthquake (OBE): 2,00

earthquake (SSE): 1,50

NOTE The overall safety factor makes allowance for influences of column effect, installation, variation on materials and difference of testing.

The nominal compressive strength σ_n shall be determined as follows:

- compressive strength shall be measured in accordance with EN 826:1996, Annex A; the results are expressed as maximum compressive strength σ_m ;
- average value of a statistically sufficient number of such tests is called the nominal compressive strength σ_n of this material; the manufacturer shall declare this value.

Also the lower specification limit (average value, less two times the standard deviation) shall be provided. If this value is lower than 67 % of σ_n then the σ_n shall be adjusted as 1,5 times the lower specification limit. Creep tests shall not be required; if it is proven that the material is not subject to creep.

6.3.2.2.2 For materials susceptible to creep (e.g. PUF, PVC etc.)

First the permissible load (PLD) of the material shall be established.

This shall be done in two steps and on the basis of two criteria:

— short term compressive test:

a) nominal compressive strength σ_n in short term compressive test;

- 1) compressive strength shall be measured in accordance with EN 826:1996; the results are expressed as σ_m (maximum compressive strength) or as σ_{10} (compressive stress at 10 % compression);
- 2) nominal compressive strength σ_n of the material shall be calculated as the average value of a statistically sufficient number of such tests; this value shall be declared by the manufacturer;

b) manufacturer shall also provide the lower specification limit (average value, less two times the standard deviation). If this value is lower than 67 % of σ_n then the σ_n shall be adjusted as 1,5 times the lower specification limit.

— Compressive creep test:

Compressive creep shall be measured in accordance with EN 1606.

The compressive stress σ_c applied during the creep tests shall be selected in function of the above nominal compressive strength σ_n and this shall be multiplied with the assumed permissible load factor (PLDF).

NOTE 1 For example, for load bearing PUF materials the PLDF is approximately 0,30.

The PLDF for a specific material shall be determined with repeated creep tests by trial and error. First a PLDF shall be assumed, based on knowledge of the physical structure of the material and/or on available data.

To verify whether this assumed PLDF is indeed correct, creep tests shall be carried out under a compressive stress equal to $\sigma_n \times \text{PLDF}$.

The creep tests shall confirm that the creep of the insulation material under this compressive stress, extrapolated to the design life time of the tank, shall not exceed the proportional limit of the material or 5 % of the material thickness (whichever is lower).

If the creep tests prove positive, then the PLDF for this material shall be used.

However, if the initial creep tests show that the creep is higher than the set limits, then the material has to be re-tested under lower compressive stress until the correct PLDF for this material has been determined.

Once the correct PLDF is determined, then the PLD shall be:

$$\text{PLD} = \sigma_n \times \text{PLDF}$$

Once the PLD of the material has been established, the following factors shall be applied between PLD and the design compressive loads:

normal operation: 1,25;

hydrostatic test: 1,00 (duration $\leq$ 1 month);

earthquake (OBE): to be provided by the material supplier;

NOTE 2 For PUF and PVC material, 0,50 may be used.

earthquake (SSE): to be provided by the material manufacturer.

NOTE 3 For PUF and PVC material, 0,33 may be used.

6.3.2.3 Limit state

The load bearing insulation design, based on limit state, shall be in accordance with Annex C.

6.3.3 Load bearing insulation/other actions

When the tank insulation shall be subjected to a combination of vertical and horizontal forces, shear stressing will take place. This applies to tank bottoms subject to earthquake action.

NOTE The insulation may also be subjected to other actions (e.g. wind, thermal, deformation etc.).

The resulting stresses shall be determined for each specific case.

The safety factors, both for allowable stress theory and for limit state theory shall be determined on a case-by-case basis.

6.4 Insulation for each tank component

6.4.1 General

In addition to the above mentioned general design requirements, the specific requirements for the various tank components listed below shall be considered.

6.4.2 Supporting ring beam

6.4.2.1 Structural design

The structural design shall take into account:

- lateral forces (tank shrinkage, earthquake);
- possible movement of the tank shell (wind, filling/emptying, earthquake);
- waterproofing and water vapour barrier for the ring-beam.

6.4.2.2 Thermal design

The thermal design of the ring-beam shall be carried out in conjunction with base slab heating system, if applicable. The design shall be such that a “cold spot” under the supporting ring is minimized/prevented. For a base slab supported by a raft foundation, the temperature under the foundation shall not drop below 0 °C.

NOTE This is to prevent possible frost heave.

6.4.2.3 Vertical anchors passing through the ring-beam

The following shall be considered:

- reduction of cold bridge effects;
- prevention of water/water vapour ingress;
- flexibility of the anchors.

6.4.3 Bottom insulation

6.4.3.1 Structural design

The structural design shall take into account:

- flatness of base slab (e.g. possible distortions of the steel liner);
- flatness of individual insulation layers;
- use of auxiliary materials to enhance the load bearing and transfer of loads (e.g. interleaving layers between layers of insulation material);
- waterproofing and water vapour barrier;
- purging facilities, if specified;
- TPS, if specified.

6.4.3.2 Thermal design

The thickness of the bottom insulation shall be determined, based on the total maximum heat in-leak specified and the requirement to minimise condensation/ice formation. This shall be done in conjunction with the wall and roof insulation.

Particular attention shall be paid to avoiding frost heave under the tank bottom.

6.4.4 Shell insulation (external)

6.4.4.1 Structural design

The structural design shall take into account:

- thermo-mechanical stresses imposed on the insulation by dimensional changes of the tank (and its anchors);
- method and strength of fixing the insulation around the tank shell, taking into account:
 - 1) its own dead load (incl. the weather protective covering);
 - 2) wind loading;
 - 3) effects of sun radiation, rain, snow, ice;
- incorporation and protection of adequate water vapour barrier.

6.4.4.2 Thermal design

The thickness of the shell insulation shall be determined based on the total maximum heat in-leak specified and the requirement to minimize condensation/ice formation. This shall be done in conjunction with the bottom and roof insulation.

6.4.4.3 The specified fire resistance

Based on local circumstances (adjacent facilities, piping etc.) the purchaser shall specify the fire resistance of the external shell insulation.

6.4.4.4 Installation considerations

The following shall be taken into consideration:

- suitability of the selected insulation system to withstand the external weather and atmospheric conditions in the designated location for the specified design lifetime of the insulation;
- anticipated weather conditions during insulation works shall be considered in the selection process of the insulation materials and system.

6.4.5 Shell/wall insulation (internal)**6.4.5.1 Thermal design**

The thickness of the shell insulation layer shall be determined based on the total maximum heat in-leak specified and the requirement to minimize condensation/ice formation. This shall be done in conjunction with the bottom and roof insulation. In some cases, the thickness shall be determined by practical considerations (loose fill insulation).

6.4.5.2 Insulation fixed against the inner face of the outer tank

The following shall be considered:

- method and strength of fixing the insulation against the outer tank wall, taking into account:
 - 1) its own dead load;
 - 2) thermal stresses;
- shrinkage/expansion of the outer tank wall;
- vapour tightness and liquid tightness of the insulation system;
- chemical resistance of the insulation in the annular space conditions.

6.4.5.3 Insulation fixed against the outer face of the inner tank

The following shall be considered:

- method and strength of fixing the insulation against the outer tank wall, taking into account:
 - 1) its own dead load;
 - 2) thermal stresses;
- shrinkage/expansion of the outer tank wall;

- water vapour tightness of the insulation system.

6.4.5.4 Loose fill insulation in the annular space

The following shall be considered:

- thermo-mechanical stresses imposed on the insulation by dimensional changes of the inner tank and possibly the outer tank;
- external pressure on the inner tank: this will increase due to cyclic loading of the tank or due to possible decommissioning (expansion). It can be reduced by the use of a resilient blanket. The contractor shall demonstrate by testing or calculations that the assumed pressure on the tank is conservative.
- settlement of the perlite can be reduced by the use of vibration during installation. However, some settlement will always occur and, in this respect, the use of perlite refill nozzles or the use of a so called 'hopper space' at the top of the tank shall be considered. The purchaser shall be advised of the minimum specified time before any top-up is required.

In the tank design, allowance shall be made for refill nozzles.

NOTE In case of loose fill insulation, the insulation thickness is often dictated by practical reasons (minimum working space in annular space).

6.4.5.5 Other design considerations

The following shall be considered:

- absorption/desorption of product by the insulation after normal operation or in case of leakage;
- possible need for purging of the insulation.

6.4.6 Roof insulation (external)

The following shall be considered:

- thickness of the roof insulation layer shall be determined based on the total maximum heat in-leak specified and the requirement to minimise condensation/ice formation;
- weather protective cover and water vapour barrier shall be included;
- suitability to withstand the external weather and atmospheric conditions in the designated location;
- thermo-mechanical stresses on the insulation by the dimensional changes of the tank;
- suitability for foot traffic and maintenance;
- fire resistance requirements specified by the purchaser.

6.4.7 Roof insulation on suspended roof

The following shall be considered:

- thickness of the roof insulation shall be determined based on the total maximum heat in-leak specified and the requirement to minimize condensation/ice formation;
- for temporary access, special arrangements like walkways etc. shall be made;

- for the thermal design not only the thermal conductivity of the selected insulation material shall be taken into account but also possible heat leak through convection, cold bridges (suspended roof hangers) etc.;
- possible settling (shrinkage) of the insulation.

Special attention shall be paid to tanks where internal product condensation can occur in the dome roof space, i.e. for those products and climates where the external ambient temperature is continuously or periodically lower than the product boiling point.

In this case the design of the suspended roof insulation (and of the deck itself) shall be such that it cannot be affected/damaged by condensation.

6.5 Design for different types of containment

The design of the insulation system for the different types of containment shall vary, as the design requirements are different.

NOTE Because of the multitude of possible containments, these will not be treated individually in this part of this European Standard.

As part of the tank and insulation design, an analysis shall be made on a case by case basis of all the design requirements for the specific selected type of containment and the design of the insulation system shall be made such that it complies with all these design requirements.

7 Installation

7.1 Introduction

Some requirements for installation are applicable to all types of insulation. They are summarised in this European Standard. Other requirements, which are applicable to particular types of insulation material, are not covered in this European Standard.

7.2 General requirements

7.2.1 Materials

All materials shall comply with the material specifications. This shall be proven by testing and be certified.

Transport and storage shall be in such conditions that no degradation (physical or chemical or any other) can occur between the stage of manufacturing and the stage of installation.

7.2.2 Conditions of work on site

The conditions in which the insulation works have to be carried out shall be such that the required quality of the work can be maintained.

7.2.3 Anti-corrosive protection

Anti-corrosive protection of all tank surfaces that require this treatment shall be finished and approved prior to start of insulation works.

Insulation works shall be carried out with such methods so as not to damage the anti-corrosive protection (or shall include procedures to repair it).

7.2.4 Construction tolerances

Wherever insulation has to be fixed against or laid upon constructional parts of the tank, the form/shape, level, dimensional tolerances of the tank part shall be defined and specified in the installation procedure.

The installation procedure shall include methods to correct unacceptable unevenness and dimensional deviations of the tank surfaces, particularly for all load-bearing insulations.

7.2.5 Prevention of damage

Insulation shall be safeguarded against damage.

NOTE In general, insulation materials are quite vulnerable to:

- mechanical damage;
- moisture/water/other weather elements (incl. also hydrostatic testing of the tank);
- fire.

Both the method of tank construction and the installation method of the insulation shall take due account of the risks outlined in the note above and shall eliminate them by taking proper measures in:

- tank design;
- insulation details;
- sequence of tank construction works;
- preventive measures during works subsequent to insulation works.

7.3 Inspection and testing

A detailed inspection and testing plan shall be made. It shall be coherent with the design requirements and performance characteristics on which the insulation design is based.

For methods of testing of the performance related material properties, see Annex B.

Material properties, not performance related, e.g. dimension control, shall be tested for conformity by test methods specified by the manufacturer.

Annex A (informative)

Insulation materials

Usage of insulation materials in various situations is given in Tables A.1 to A.3.

Table A.1 — Single and double containment tanks

Material	Support- ing ring	Bottom insulation	Roof		Shell	
			External	Internal (With susp. deck)	External of single steel tank	Tanks with double steel shell
Hard wood	X					
Perlite concrete blocks/beam	X					
Lightweight concrete blocks/beam	X					
Reinforced concrete	X ^a					
Cellular glass	X ^b	X	X		X	X
Expanded perlite				X		X
Mineral wool blankets				X		X ^c
PVC foam - MD		X				
- HD	X ^b	X				
PUF/PIR - ND BL-SPR-FIP			X		X	
- MD BL-SPR			X		X	
- HD BL-SPR	X ^b	X				
- GR BL	X ^b	X				
Phenolic foam					X	
Polystyrene – expanded					X ^d	
Polystyrene – extruded - ND					X ^d	
- HD		X				
^a To be used as load distribution plate over the underlying thermal insulation material. ^b A load distribution plate may be needed for this application. ^c Mineral wool blanket can be used as resilient blanket between perlite insulation and inner tank shell. ^d Only for double containment (limited temperature resistance).					Symbols/abbreviations BL = block-type FIP = foamed-in-place v GR = glass fibre reinforced HD = high density MD = medium density ND = normal density SPR = spray-type	

Table A.2 — Full containment tanks

Material	Ring-beam	Bottom (normal service)	Roof insulation		Shell/wall insulation (normal service)		Thermal protection system	
			On susp. deck	On inner tank dome	In inter-space	On inside of wall	Without 9 % nickel steel plate	With 9 % nickel steel plate
Hard wood	X							
Perlite concrete blocks/beam	X							
Lightweight concrete blocks/beam	X							
Reinforced concrete	X ^a							
Cellular glass	X ^b	X						X
Expanded perlite			X	X	X			
Mineral wool blankets			X	X	X ^c			
PVC foam - MD		X						X
- HD	X ^b	X						X
PUF/PIR - ND BL-SPR-FIP								
- MD BL-SPR						X ^d	X ^d	X
- HD BL-SPR	X ^b	X				X ^d	X ^d	X
- GR BL	X ^b	X					X ^d	X
^a To be used as load distribution plate over the underlaying thermal insulation material. ^b To be used underneath a load distribution plate. ^c Mineral wool blanket can be used as resilient blanket between perlite insulation and inner tank shell. ^d Only special grades of spray-applied, jointless, vapour tight, liquid tight systems.						Symbols/Abbreviations BL = block-type FIP = pour-in-place GR = glass fibre reinforced HD = high density MD = medium density ND = normal density SPR = spray-type		

Table A.3 — Membrane tanks

Material	Bottom Insulation	Wall Insulation	Roof insulation	
			Suspended deck	Inside of dome roof
Hard wood				
Cellular glass				
Expanded perlite			X	
Mineral wool blankets			X	
PVC foam - MD	X	X		
- HD	X	X		
PUF/PIR - ND BL		X ^a		X
- MD BL		X		
- HD BL	X	X		
- GR BL	X	X		
^a Only top of part of wall			Symbols/Abbreviations BL = block-type HD = high density MD = medium density ND = normal density GR = glass fibre reinforced	

Annex B (normative)

Test methods

Table B.1 — Testing thermal resistance properties

Properties	Particular requirements	Test methods
1. Thermal Conductivity	measured at ambient temperature - on new materials - after ageing under specified conditions - ageing in “tank conditions” i.e. - product vapours - liquid product	EN 12667 and EN 12939 or ISO 8301 or ISO 8302 EN 12667 and EN 12939 or ISO 8301 or ISO 8302 EN 12667 and EN 12939 or ISO 8301 or ISO 8302
	measured over temperature range ^a - on new materials - after ageing under specified conditions - after ageing in “tank conditions” i.e. - product vapours - liquid product	EN 12667 or ISO 8301 or ISO 8302 EN 12667 or ISO 8301 or ISO 8302 EN 12667 or ISO 8301 or ISO 8302
2. Air gas permeability	for permeable insulation materials (only as indication of convection)	^b
^a Temperature range: from ambient temperature down to the design temperature of the insulation. ^b Test method to be selected.		

Table B.2 — Testing mechanical properties

Properties	Particular requirements (to be specified case by case)	Test methods
1. Compressive strength	at ambient temperature	EN 826:1996
	over temperature range	EN 826:1996 ^a or ISO 844 ^{b c}
2. Compressive creep	at ambient temperature (loads and durations based on tank design)	EN 1606
3. Tensile properties		
a) Tensile strength	at ambient temperature	EN 1607 and EN 1608 ^d
b) Tensile elongation	and	
c) Tensile modulus	over temperature range	EN 1607 and EN 1608 ^d
4. Adhesion strength	at ambient temperature	EN 1607 or EN ISO 4624
	at applicable temperature (depending on position in the tank)	EN 1607 ^a or EN ISO 4624
5. Shear strength	at ambient temperature	EN 12090:1997
	over temperature range	EN 12090:1997 ^a
NOTE 1 Mechanical properties are to be tested all in the directions of loading in the tank. NOTE 2 For anisotropic materials, test data in all directions may be required. ^a Specified at 23 °C. However this test can, with the necessary changes, also be carried out at other temperatures. ^b Test methods for cellular plastics. ^c Test can be carried out at all required temperatures. ^d EN 1607 measures perpendicular to faces, EN 1608 measures parallel to faces.		

Table B.3 — Testing temperature resistance

Properties	Particular requirements	Test methods
1. Coefficient of thermal expansion/contraction	over temperature range	EN 13471 or ISO 4897
2. Tensile strength/tensile modulus	over temperature range	See Table B.2. – Item 3
3. Behaviour of insulation system exposed to temperature gradient	semi-industrial cryogenic test	To be proposed on a case by case basis EN 12066

Table B.4 — Testing permeability for/effects of water and water vapour properties

Properties	Particular requirements	Test methods
1. Moisture content	only for materials produced with water (concrete, perlite concrete,...)	To be proposed
2. Water absorption	short term – partial immersion long term – full immersion long term – absorption by diffusion general	EN 1609 EN 12087 EN 12088 EN ISO 62
3. Water vapour Transmission		EN 12086
4. Closed cell content		EN ISO 4590 ^a
5. Dimensional stability		EN 1604
6. Freeze-thaw Resistance		EN 12091
7. Reduction of thermal resistance	thermal resistance to be measured after exposure to water/water vapour	EN 12667
^a Only for cellular plastics.		

Table B.5 — Testing of material behaviour in presence of product

Properties	Particular requirements	Test methods
Absorption and desorption		
1. Closed cell content	before immersion after immersion	^a
2. Absorption/desorption of product liquids	immersion in liquid at specified temperature, pressure and duration	^a
Effects of immersion in vapours/liquids		
3. Change of closed cell content	before/after immersion under specified conditions	^a
4. Change of compressive strength	before/after immersion under specified conditions	^a
5. Change of thermal conductivity	before/after immersion under specified conditions	^a
^a Specific test methods to be proposed for each specific RLG product.		
NOTE DIN 53428 may be used until an ISO/EN standard is produced.		

Table B.6 — Testing chemical properties

Properties	Particular requirements	Test methods
1. Chemical resistance of the insulation to: a) water b) water + contaminants c) RLG - vapours - liquids d) purging gases		EN 12087 To be proposed To be proposed To be proposed To be proposed
2. Corrosion resistance of insulation components		To be proposed
3. Leachable substances in the insulation		EN 13468

Table B.7 — Testing fire resistance/reaction to fire

Properties	Particular requirements	Test methods
1. Reaction to fire of the insulation material		EN 13501-1 EN ISO 3582
2. Temperature limits - melting temperature - decomposition temp. - ignition temperature		To be proposed To be proposed To be proposed
3. Fire resistance properties		To be proposed

Annex C (normative)

Tank bottom insulation - Limit state theory

In the case of tank bottom insulation, the following equation shall be used:

$$\gamma_L S \leq \frac{R}{\gamma_m \cdot \gamma_c \cdot \gamma_t \cdot \gamma_i}$$

where

R is the characteristic strength of the insulation material;

S are the actions;

γ_c is the partial safety factor for the column effect;

γ_t is the partial safety factor for the installation;

γ_L is the partial safety factor to be applied on the load;

γ_m is the partial safety factor for the insulation material;

γ_i is the factor corresponding to a possible difference between the reference method of testing the insulation product and the method of installing it.

For the partial safety factor γ_L on actions see EN 1991-1.

The characteristic strength of the insulation material R shall be the average strength less 1,65 times the standard deviation.

Testing of brittle materials shall be in accordance with EN 826:1996.

Testing of materials susceptible to creep shall be in accordance with EN 826:1996 and with creep test in accordance with EN 1606.

To determine the partial safety factor of the material γ_m , it shall be verified that the statistical distribution of the property follows reasonably well the Gaussian model.

The partial safety factor, γ_m , shall be calculated in accordance with the following equation:

$$\gamma_m = \frac{1 - 1,65 \frac{\sqrt{s^2}}{\bar{x}}}{1 - 3,36 \frac{\sqrt{s^2}}{\bar{x}}}$$

where

s is the standard deviation;

$\bar{x}$ is the average value.

The partial safety factor for thermal insulation product compressive strength shall not be lower than 1,25.

NOTE 1 The formula is based on the assumption that a total failure risk of 10^{-6} is equally distributed between the actions and the resistance.

The partial safety factor χ for installation shall be at least 1,6.

NOTE 2 It may be reduced to 1,5 if the constructor can demonstrate an experience of at least 10 years with the same insulation system, using the same products, of constant origin.

The partial safety factor χ shall be based on a typical correct installation using products conforming to the relevant European Standards.

The factor for the column effect, γ_c , shall be 1 for one layer insulation, 1,05 for a three-layer insulation, 1,09 for an eight-layer insulation.

The factor χ shall be determined following statistically significant tests by the designer. If the installation method is the same as the reference method, χ shall be 1.

NOTE 3 The factor χ takes into account the possibility that the insulation product may be installed in the tank base with a different method than the one used in the reference test method.

NOTE 4 An example is found when cellular glass is applied with an interleaving material different from the capping specified in EN 826:1996, Annex A.

Whatever the values taken for γ_L , γ_m , γ_c , χ and γ_i , the product $\gamma_L \cdot \gamma_m \cdot \gamma_c \cdot \chi \cdot \gamma_i$ shall not be lower than 2,5.

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