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1 Scope

The Linde standard (LS) specifies the requirements for expanded perlite as bulk material, if it is used as insulating material in plant and vessel construction. Two types of perlite are described:

- Typ A: Expanded perlite for Coldboxes and double shell storage tanks
- Typ B: Expanded perlite for vacuum insulation of stationary tanks.

2 Normative references

This LS contains undated references to incorporate provisions of other publications. The normative references are cited at the respective place in the text and the publications are listed below. Issues valid at the effective date of contract shall apply.

DIN 4102-4	Fire behaviour of building materials and building components - synopsis and application of classified building materials, components and special components
EN 12664	Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Dry and moist products with medium and low thermal resistance
DIN 66145	Graphical representation of particle size distributions - RRSB-grid
ISO 787-11	General methods of test for pigments and extenders - Part 11: Determination of tamped volume and apparent density after tamping
AGI Q 118	Dämmarbeiten an Luftzerlegungsanlagen
AGI Q 141	Blähperlite als Dämmstoff für betriebstechnische Anlagen
TRGS 220	Sicherheitsdatenblatt
TRGS 905	Verz. krebserzeugender, erbgutverändernder oder fortpflanzungsgefährdender Stoffe
BGI 644 (BG Metall)	BG-Information - Gefahren durch Sauerstoff
BGI 617 (BG Chemie M034)	Gefahrstoffe Sauerstoff
EGV 1907/06	Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals
BGG 904	(G26) Atemschutzgeräte; Berufsgenossenschaftliche Grundsätze für arbeitsmedizinische Vorsorgeuntersuchungen

3 Terms and definitions

3.1 Expanded perlite

Expanded perlite will be produced from volcanic rock, mineralogical designation perlite, by shortly exposing the fine-ground perlite ore to temperatures up to 1100 °C in a furnace. During that process the water of crystallization evaporates and expands the softened perlite grain by 15 to 20 fold of its original volume. Thus, an expanded perlite grain with a glassy cellular structure is formed. The chemical analysis of perlite yields a composition of about 75 % SiO₂, about 15 % Al₂O₃ and insignificant parts of other oxides; the specific analysis however varies from mine to mine. Further properties of expanded perlite are listed in Table 2.

3.2 Coldbox-insulation

A Coldbox-insulation consists of a gastight casing, in which equipment and piping are installed, any remaining space is filled with insulating material and a slightly positive gas gage pressure is maintained. The temperatures of the equipment parts are usually between 77 K and 300 K.

3.3 Double-shell storage tank

A low temperature insulation for a double-shell storage tank consists of an annular gap in the cylinder and a spherical one in the roof area, which are filled with the insulating material, by maintaining a slight gas gage pressure. The temperature of the inner vessel is usually between 77 and 170 K, and that of the outer vessel at ambient temperature.

3.4 Vacuum insulation

A vacuum insulation for stationary tanks consists of a space between inner and outer vessel, which is filled with the insulating material, and the gas pressure is reduced far below the atmospheric pressure. The temperature of the inner vessel is usually between 20 and 170 K, and that of the outer vessel at ambient temperature.

4 Quality assurance

4.1 Aptitude test before order

The properties of expanded perlite are influenced by the specific chemical composition of the volcanic rock existing in the mine and by the individual control of the expansion process at the different manufacturers. For the quality assurance of our products, however, the used expanded perlite shall fulfill the properties required in Table 1. Therefore, in case of need, some of these properties are determined in a qualification test, and documented in a test report. A comparison between the determined and the required properties supplies the decision criteria for the use of the insulating material.

In case of perlite of the same location **and** the same manufacturer the aptitude test can be cancelled if the last test was no more than one year ago.

Therefore the dept. E-W needs minimum 5 liters of test material and additional 2 liters of each delivered charge. This shall be packed so, that it will be protected against pressure and shock as well as moisture-proof (in screw able containers or welded plastic bags). These shall be packed in cartons with wooden wool or another filling material.

Following information is required:

- Manufacturer (address, phone, E-mail etc.)
- Type of material
- Job number and job code

This information shall be well readable written on the containers or on the plastic bags and transmit if it is necessary in an additional covering letter. A clear identification e. g. by charge numbers shall be possible.

The comparison of the determined with the requested properties will deliver the decision criteria for the use of the insulation material.

The test material shall be send to the following address:

Linde AG
Linde Engineering Division
Dept. E-W
Dr.-Carl-von-Linde-Straße 6-14
82049 Pullach
Germany

4.2 Quality assurance for delivery on site

When the perlite will deliver on site by silo vehicles and / or in so called "big bags", the Linde site management shall take test material and send it early enough before start of the insulation work to the dept. E-W for testing. If it is impossible, only the loose density shall be determined in accordance with the dept. E-W. Details for packing, required data and delivery address shall be taken from Paragraph 4.1.

In case of mobile expansion furnaces the operator shall pull test material of the expanded perlite continuously (at stable operation nearly each 8 hours, in case of limiting values more), determine the loose density, document the test results and hand it over to the Linde site management. The test material shall be sent after filling to the dept. E-W. Details for packing, required data and delivery address shall be taken from Paragraph 4.1.

5 Required properties

5.1 General

The required properties are summarized in Table 1.

Table 1: Required properties for expanded perlite

No.	Property	Investigation method	Symbol [Unit]	Threshold values	
				Type A	Type B
1 *)	Loose density	Linde	ρ_{Sch} [kg/m ³]	45 to 60	50 to 60
2 *)	Compacted density (tamping volumeter)	ISO 787-11	ρ_{St} [kg/m ³]	55 to 90	65 to 90
3 *)	Compacted density after abrasion test	Linde	ρ_{StA} [kg/m ³]	<1.8 ρ_{St}	<1.8 ρ_{St}
4 *)	Mean particle diameter (RRSB-scale)	DIN 66145	d' [mm]	0,4≤d'≤0,8	0,2≤d'≤0,5
5	Angle of repose (h=100 mm)	Linde	α [degree]	33 to 37	33 to 40
6 *)	Capillarity (Pipe Ø 18,5 mm)	Linde	h [mm/h]	<290	<290
7	Thermal conductivity	EN 12664	λ [W/mK]	Figure 1	Figure 2
8 *)	Moisture content	PI 118 **)	[weight-%]	<1	≤0,2
9 *)	Organic material content	Linde	[weight-%]	≤0,3	≤0,3
*) Will be generally checked during a Linde qualification test as a rule.					
**) Perlite Institute, New York					

Table 2: Further properties of expanded perlite

Max. applicable temperature	800 °C
Softening temperature	870 °C
Melting temperature	1260 °C
Heat capacity between 77 and 300 K	0,50 J/g K
pH-value	6 to 8,5
Cellular structure	open-cellular
Porosity	~97 % by volume
Moisture content in the open air	Up to 1,5 % by weight
Max. moisture content	Up to 900 % by weight
Fire behaviour	A1 DIN 4102 Part 4
Density of the perlite ore	2200 to 2400 kg/m ³
Density of the fine-ground perlite ore	~1200 kg/m ³

5.2 Loose density and compacted density

Expanded perlite is available as bulk material with a certain grain distribution. The lowest bulk density, which is obtained when filling the material loosely, is known as loose density. By tamping the particles are moving against each other and the smaller ones remain in general in the gaps between the greater ones, until an optimum bulk density, known as compacted density, will be obtained. For all insulations with expanded perlite the compacted density should be achieved, as otherwise a subsequent settlement of the filled in material has to be expected. For perlite qualities which are suited for low temperature insulations the compacted density is about 30 to 50 % above the loose density.

By simply continuing the tamping operation the density of the filled in material cannot be increased. An increase is only possible by applying external forces such as e.g. by the proper weight of thick insulation layers, by contraction movements of vessels or by a sudden breakdown of the vacuum (flooding with air) for vacuum-insulations. In such a case the fracture of the cellular walls on the particle surface leads to a clamping together of individual particles, and the filled in material loses its flowability partly or even completely.

5.3 Compacted density after abrasion test

An expanded perlite grain has a cellular structure with thin glassy walls. At mechanical loading of the material, e.g. pneumatic conveying in a long pipeline, parts of the cellular walls break off and an unwanted fine abrasion is forming. The resistance against abrasion of an expanded perlite is influenced by the properties of the perlite ore and by the expansion process. The abrasion test carried out in Linde's laboratories is an internal comparison test against standard qualities and gives information if, in case of pneumatic conveying, a considerable increase in density has to be expected.

5.4 Mean particle diameter

The mean particle diameter of a bulk material of expanded perlite is determined from a sieve analysis and defines a mean grain size. If expanded perlite is used as a low-temperature insulation material, the mean particle diameter specified in Table 1 has to fulfill the standard requirements of practice. For a too small grain an increase of the density and in particular a higher flow resistance have to be expected when producing an insulating vacuum. For a too large grain the formation of convection and the radiation transmission are increased.

5.5 Thermal conductivity

Because of the involved cost, the thermal conductivity is not measured in a qualification test. For a material filled in at atmospheric pressure, it can be taken from Figure 1, approximatively as a function of the mean temperature for different densities as parameter; for an evacuated filled in material with a density of about 80 kg/m³ and wall temperatures between 76 and 304 K it can be taken from Figure 2, as a function of the gas pressure. Increasing grain size and higher moisture content increase the thermal conductivity.

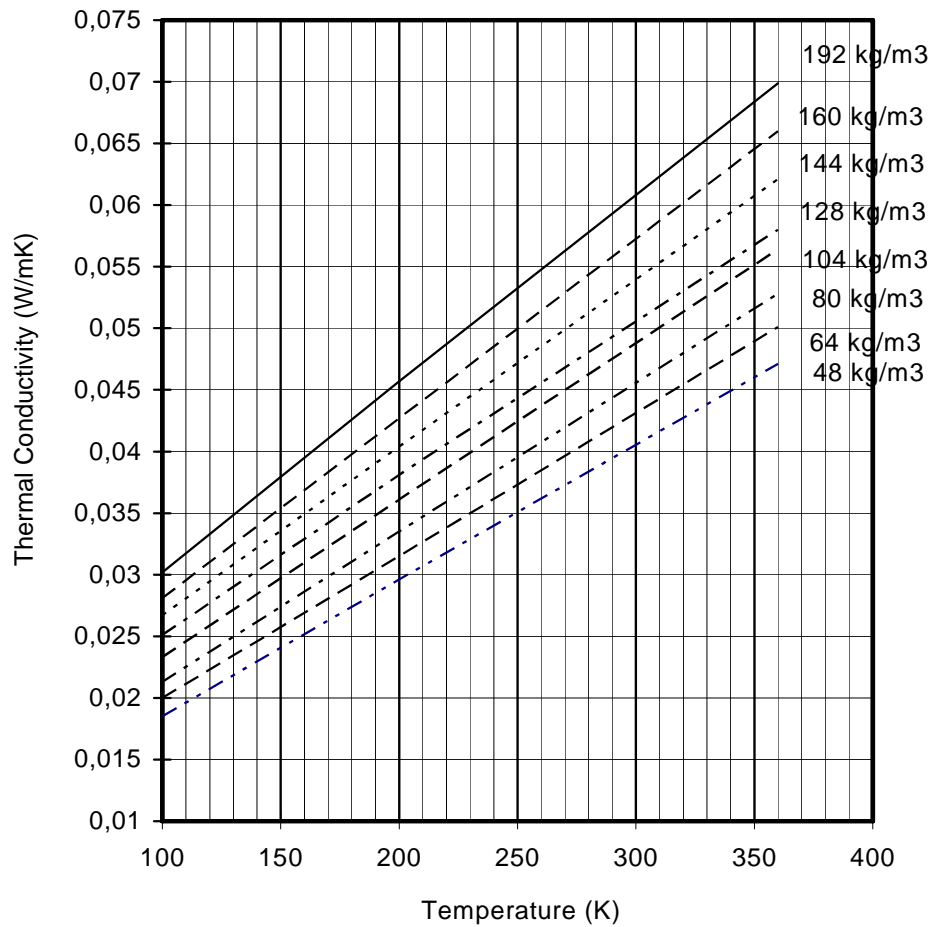


Figure 1: Thermal conductivity of expanded perlite as function of the temperature

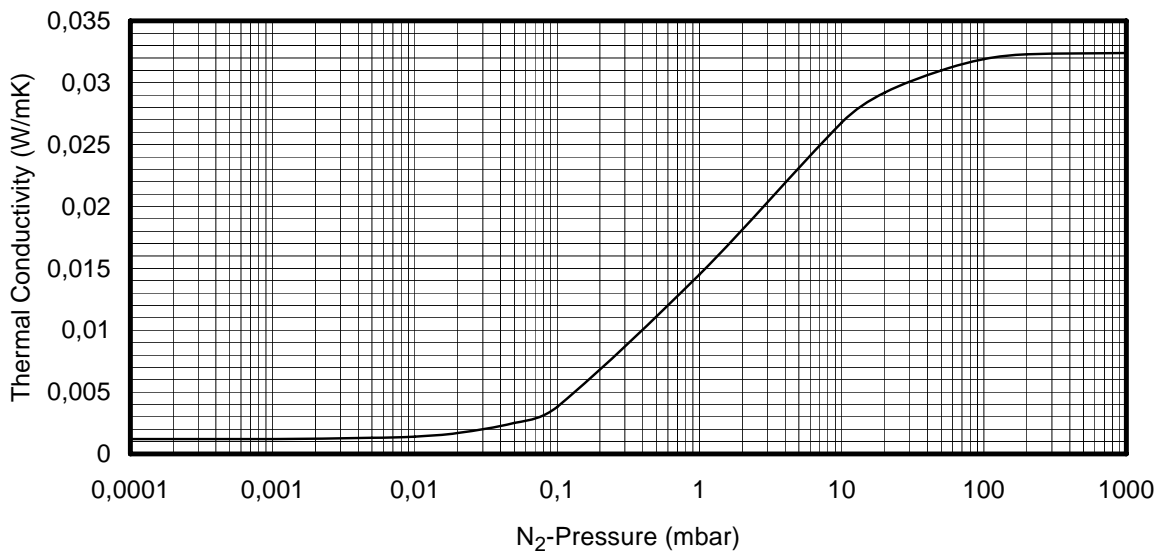


Figure 2: Thermal conductivity of expanded perlite as a function of the N₂-pressure and between 76 and 304 K ($\rho=80 \text{ kg /m}^3$) [2]

5.6 Moisture content

Material coming directly from the furnace has a very low moisture content of up to 0,2 % by weight. For long-time storage in the open air a balance of up to 1,5 % by weight is obtained, depending on ambient humidity. For that reason perlite shall be protected against moisture during transportation and storage.

If a still cold material is pneumatically conveyed when discharging a Coldbox, air humidity is condensing. Depending on the condition of the suction air, the moisture content can rise up to about 5 % by weight. Material being exposed to rain can reach the max. moisture content of up to 900 % by weight. In both cases the material is not usable any longer.

The whole moisture content in the insulating material when e.g. installed in a Coldbox, diffuses to the cold points of the vessels and precipitate there as ice.

5.7 Organic material content

Considering the perlite ore and the high temperature during expansion process, perlite does not contain any organic materials. The firing equipment of the expansion furnace is a source for contaminations. When using expanded perlite for air separation plants a maximum value of organic materials may not be exceeded, to comply with the TR (Technical Regulation) Gefahrenstoffe – Sauerstoff (BG-Information BGI 644 of BG Metall and BGI 617 with appendix 1,2 of BG Chemie).

Within Linde, this value has been fixed to 0,3 % by weight. Thus, the degree of contaminations is preset below the value of 0,5 % by weight, which is permissible acc. to UVV-Sauerstoff. The reason for that measure is due to the fact that an investigated sample is not absolutely representative for the whole quantity of insulating material, as an unequal distribution must be expected.

6 Insulation of Coldboxes and storage tanks

6.1 Bulk density at manufacture

The maximum allowable bulk density is as follows:

- in the stationary furnace in manufacturer's workshop: up to 55 kg/m³;
- in the portable furnace on site: up to 60 kg/m³; efforts should be made to obtain a bulk density of about 45 kg/m³.

6.2 Bulk density after filling

The maximum allowable bulk density after filling depends on transport and filling procedure and is as follows:

- For silo transport and pneumatic conveying: 70-90 kg/m³;
- For transport in sacks and manual filling: 55-70 kg/m³;
- For pneumatic filling directly from the furnace on site: 55-65 kg/m³ (Empirical values of Linde for calculating the weight of the filled in perlite).

6.3 Volume

The purchaser shall specify the insulating volume. The supplier shall determine the required perlite quantity to be delivered for that purpose. For an insulating volume > 1000 m³ and a considerable distance between manufacturer's workshops and site it shall be checked by the purchaser, whether the manufacture of expanded perlite on site by using a portable furnace is cheaper than a silo transport from manufacturer's workshops.

6.4 Recharging

In order to avoid recharging and / or to reduce the recharge quantity, it should be beaten against the box walls during filling by using a knocking device (rubber mallet and similar), in order to support the uniform distribution. For that purpose, different manufacturers use a specific vibrating procedure; in any case, the consent of the responsible design engineer shall be obtained.

7 Remarks to vacuum insulation

According to the curve of the thermal conductivity shown in Figure 2 a vacuum of 10^{-3} mbar shall be achieved, in order to obtain the optimum insulation effect. The pump down time and the final pressure are, however, influenced by the flow resistance, and in particular by the degassing of the bulk material. With increasing moisture content the pump down time will become considerably longer. An effective degassing of the surfaces can preferably be reached by heating (e.g. up to 300 °C). For that proceeding the consent of the responsible design engineer shall also be obtained.

8 Notes on safety

8.1 Classification of the hazardous potential of the insulating material

The manufacturer respectively the supplier shall examine, classify and identify the insulating material with respect to the hazardous potential. If the material is to be rated as potentially hazardous (e.g. in the EEA according to the valid TRGS 905), then a safety-datasheet must be delivered (e.g. for delivery from or to the EEA according to TRGS 220).

For the rating "harmless" a document of compliance shall be attached.

Anyway the manufacturer / supplier shall consider the subsequent handling of the insulating material (manual stuffing of chambers).

8.2 Handling of insulating material - Notice

The applicator of insulating material must prepare a risk assessment related to the job site considering the handling of insulating material. This is a legal requirement within the scope of European Directives. The above mentioned manufacturer's identification shall be observed.

8.3 Protective measures

If (on job sites outside of the EEA) no information regarding the hazardous potential of the material was supplied by the manufacturer / supplier and the rated insulating material is not available elsewhere, the use of a fine dust mask as below described is strongly recommended.

Perlit is not classified as hazardous substances regulation according to EGV 1907/06. When particles in the air are inhaled, an irritation of the respiratory tracts is possible. Therefore the use of a fine dust mask with a P2 filter is recommended when working with perlit.

Remark: The use of respiratory protection requires prior the industrial medicine ability test (e.g. for members of German contractors: (BGG 904 (G26 Group 1) – Atemschutzgeräte).

9 Marking

Marking according to AGI Q141 is required.

10 Bibliographical references

- [1] Perlite Institute Inc.: Technical Data Sheet No. 2-4 (1970) No. 2-4 (1977). Perlite Loose Fill Insulation. Technical Data Sheet No. 2-3 (1972) Expanded
Perlite Insulation for Low Temperatures in Atmospheric Service.
- [2] R. H. Kropschot, R. W. Burgess: Perlite for Cryogenic Insulation. Adv. Cryog. Eng. Vol. 8 (1962) S. 425.