

**GLUE-FASTENING OF INSULATING BLOCKS FOR A LIQUEFIED-GAS
STORAGE TANK USING UNDULATING BEADS**

The present invention relates to a sealed, thermally insulated tank and to a method for the production thereof. In particular, the present invention relates to a terrestrial tank for the storage of liquefied gases and, in particular, of liquefied natural gas having a high methane content.

Documents FR 2 265 603, FR 2 798 902, FR 2 683 786, FR 2 691 520 and FR 2 724 623 have already described the production of a sealed, thermally insulated tank built into a transportation ship. The tank consists of two successive sealing barriers alternated with two thermal insulation layers called insulating barriers. A first sealing barrier, termed primary sealing barrier, is in contact with liquefied gas while a second sealing barrier, termed secondary sealing barrier, is arranged between the two insulating barriers. The various barriers are fastened to one another and the secondary insulating barrier is fastened to the bearing structure formed by the inner hull of the ship using various methods known to a person skilled in the art.

Terrestrial tanks for the storage of liquefied gas which also have two successive leakproof barriers alternating with two layers of thermal insulation are also known. In the case of terrestrial tanks, the bearing structure is generally made of concrete.

In these embodiments, the primary and secondary insulating barriers consist of a succession of insulating blocks which are either closed parallelepipedal caissons filled with a heat insulator or consist of insulating foam blocks adhesively bonded to a carrier panel. The material used to produce the panels of the caissons or the carrier panels is

generally plywood, for reasons of cost and for its insulating qualities. However, one of the drawbacks with plywood is that it is anisotropic and that its mechanical properties differ according to whether a stress is exerted in the direction of, or else transversely to, the grain of its outer plies.

The insulating blocks of the secondary barrier are fastened to the bearing structure, in the first case by assembly with the aid of studs incorporated in the bearing structure and, in the second case, by being quite simply adhesively bonded, via their outer panel, to the said structure. In that case, the material used for the adhesive bonding is generally an epoxy resin mastic which is deposited in the form of beads on that face of the insulating block which is placed facing the bearing structure. In the prior art the beads are arranged rectilinearly on the panels of the insulating blocks, parallel to one another.

The function of these beads of mastic, apart from maintaining the insulating block on the bearing structure, is to compensate for the inevitable irregularities of this hull by adapting to its shape. During the mounting operation, the insulating block is positioned on the bearing structure with the aid of known means such that the beads of mastic are compressed, prior to polymerization, against the bearing structure and thus perfectly follow its shape. It is thus a certainty that high-quality adhesive bonding will be obtained. With the polymerization the beads of mastic cure and then behave as perfectly rigid materials.

Since the forces originating from within the tank are transmitted to the bearing structure via the panels of the insulating blocks, these panels need to withstand the pressures and tensile stresses which are applied to

them without the structure of the plywood being ruptured. It is therefore necessary not to space the beads of mastic too far apart from one another and thus prevent forces being applied to the wood at too large a distance from a bead.

Moreover, the multiplicity of beads has the disadvantage of significantly increasing the cost of producing the tank, owing to the large quantity of mastic that is needed. The beads must, on the one hand, have a relatively large cross section so as to compensate for the irregularities of the bearing structure and, on the other hand, the total length of the beads, if they were placed end to end, would amount to several tens of kilometres, or even around a hundred kilometres, for an average-sized ship or terrestrial tank.

The object of the present invention is to overcome these disadvantages by providing a less expensive method of adhesively bonding insulating blocks to the bearing structure using beads of mastic, while at the same time retaining a strong resistance of the panels of the said insulating blocks to the compressive or tensile forces which are exerted on them, or even improving this resistance.

Accordingly, the subject of the invention is a method of adhesively bonding insulating blocks to a bearing structure of a terrestrial tank, using beads of mastic, for the production of a sealed, thermally insulated terrestrial tank for the storage of liquefied gases on land, the said tank comprising a thermally insulating barrier comprising a plurality of insulating blocks, each insulating block comprising a plywood panel and containing or carrying thermally insulating material, the said method comprising

- a) the application of beads of mastic to the panel of the said insulating blocks or to the bearing structure, along mutually parallel lines,
- b) the positioning of the said insulating blocks against the bearing structure of the tank, and
- c) the pressing thereof against the said bearing structure until polymerization of the said mastic, characterized in that at least two of the said beads are arranged along wavy parallel lines between the panel of at least one of the said insulating blocks and the bearing structure.

Advantageously, the distance between two consecutive wavy lines is greater than or equal to 100 mm.

Preferably, the wavy lines are sinusoids.

Advantageously, the sinusoid has a ratio substantially equal to 8 between its period and its amplitude.

Another subject of the invention is a sealed, thermally insulated terrestrial tank built into a bearing structure, comprising a thermally insulating barrier comprising a plurality of insulating blocks, each insulating block comprising a plywood panel and containing or carrying thermally insulating material, the said insulating blocks being fastened directly against the bearing structure by means of beads of mastic positioned on the panels of the said insulating blocks along mutually parallel lines, characterized in that at least two of the said beads on the panel of at least one of the said insulating blocks are arranged along wavy parallel lines.

The invention will be better understood and other objects, details, features and advantages thereof will become more clearly apparent in the course of the following detailed explanatory description of an

embodiment of the invention that is given by way of purely illustrative and non-limiting example with reference to the appended schematic drawings, in which:

- Figure 1 is a sectional view of a tank according to one embodiment of the invention;
- Figure 2 is a perspective view representing the different layers of a tank of the prior art;
- Figure 3 is a view similar to Figure 2, representing the case of the tank in Figure 1,
- Figure 4 is a bottom view of a secondary insulating block of the tank in Figure 1;
- Figure 5 is a view of a detail of the form of a bead of mastic of the tank in Figure 1.

With reference to Figure 1, there can be seen the bearing structure 1 of a terrestrial tank for storing liquefied gas. The bearing structure 1 is made of concrete. Within the context of the present description, "terrestrial tank" denotes a tank built on foundations fixed to the soil, whether it be terrestrial soil, the shore or a sub-sea soil. The tank may be constructed above the soil level or be partially or completely embedded.

With reference to Figure 3, the bottom wall of the tank has successively, from the inside of the tank towards the bearing structure 1:

- a primary leaktight barrier 7, made of corrugated metal sheet,
- a primary insulating barrier 2, comprising a plywood panel 8 and a foam layer 9,
- a secondary leaktight barrier 6, made of triplex,

- a secondary insulating barrier, comprising a plywood panel 11 and a foam layer 10.

According to a technique which is known, in particular from the documents cited in the introduction, the primary insulating barrier 2, the secondary leaktight barrier 6 and the secondary insulating barrier 4 are produced with the aid of prefabricated panels assembled on the bearing structure 1. As shown in Figure 1, the primary insulating barrier 2 is completed by insulating elements 12 placed between the prefabricated panels. The secondary leaktight barrier 6 is not represented in Figure 1, but its position is indicated by the bottom of the insulating elements 12.

As shown in Figure 1, in the example represented, the lateral wall of the tank also comprises, in a lower part, a primary leaktight barrier, a primary insulating barrier, a secondary leaktight barrier and a secondary insulating barrier and, in an upper part, a single leaktight barrier and a single insulating barrier. In a variant which is not shown, the lateral wall of the tank comprises over its full height a primary leaktight barrier, a primary insulating barrier, a secondary leaktight barrier and a secondary insulating barrier.

It is also possible to produce a terrestrial tank according to another known technique, in which the insulating barriers are produced with the aid of caissons filled with insulating material.

In the remainder of the description, "insulating block 14" refers to an element of the secondary leaktight barrier which may comprise, according to the technique used, either a foam layer and a plywood panel (case of Figures 1 and 3) or a caisson filled with insulating material (case not shown). In both cases,

the insulating block 14 comprises, at its face directed towards the bearing structure, a plywood panel.

The insulating blocks 14 are fastened to the bearing structure with the aid of mastic beads 3. Two wavy mastic beads 3 can be seen in Figure 3. By way of comparison, Figure 2 represents a tank according to the prior art, in which the mastic beads 3 are rectilinear. In Figure 2, the same reference numbers as in Figure 3 have been used to denote corresponding elements.

With reference to Figure 4, there can be seen a bottom view of a panel of an insulating block 14 on which beads of mastic 3 have been arranged, transversely to the largest dimension. Owing to the method of constructing plywood panels, there is always an uneven number of plies and the wood grain on the outer plies is oriented along the axis of the smallest dimension of the panel. This orientation is represented by the axis A-A in Figure 4.

With reference to Figure 5, there can be seen a detail of the shape of a bead of mastic 3, wherein the wavy shape shown is a sinusoidal shape of period "L" and amplitude "a".

The gain afforded by the invention over the prior art will now be described.

In the prior embodiments, the beads of mastic are rectilinear and spaced regularly apart by a length which varies according to the location where the corresponding second insulating block will be placed in the tank, in other words according to the pressure to which it will be subjected. In the case of the tank bottom walls (floor and lower parts of the side walls), it is necessary to bring the beads of mastic closer together to prevent the wood from rupturing between two

beads. A spacing of 100 mm is generally adopted between two consecutive beads on the same insulating block. In those regions where the pressure to be borne will be less (upper parts of the side walls, and ceiling), a looser spacing is acceptable. The spacing generally adopted is then 140 mm.

The panels of wood constituting the faces of the insulating blocks 14 are subjected in use to compressive forces owing to the weight of the liquid contained in the tank.

The weak points of a plywood panel are of two types:

- in compression it may break by bending along a line parallel to the beads since the lower face, which is subjected to a uniformly distributed pressure, is supported only by the linear edges formed by the beads, with a non-supported spacing between them. This fragility is further accentuated when the beads are oriented in the same direction as the grain of the outer ply of the plywood (cf. Fig. 4), this frequently being the case in practice. This is because the yards where ships for transporting liquefied gas are built are required to manipulate the insulating blocks equipped with their beads of mastic, in particular to turn them over so as to reposition the lower face to the bottom after the operation of depositing the mastic. This manoeuvre proceeds more reliably if the beads of mastic remain in the same plane during this rotation, in other words if they are placed in the direction of the smallest dimension of the lower face. This orientation is precisely, owing to the construction of the plywood, the direction of the grain of the outer ply;
- in tension the wood of a plywood panel may delaminate, with part of the wood of the outer ply

remaining attached to the bead of mastic, the remainder separating therefrom, thus allowing the insulating block to become detached from the inner hull.

These weaknesses of the plywood prevent too much spacing between the beads of mastic and thus prevent a reduction in the volume of mastic employed to provide the insulation for a tank.

The invention solves this problem by replacing the rectilinear beads employed beforehand with beads 3 having waves, which may, for example, be sinusoidal as shown in Figures 4 and 5.

Tests were conducted on panels which were equipped with sinusoidal beads, having various spacings, of which the period L is 372 mm and the amplitude a is 46.5 mm. The length of such a sinusoid, which is characterized by a ratio L/a equal to 8, is greater by 14% than that of the corresponding straight line segment of length L .

The resistance of the panels to inter-bead flexural rupture and to delamination was evaluated and compared with that of panels equipped with rectilinear beads spaced 100 or 140 mm apart. The same flexural rupture pressure is found with these sinusoidal beads only with a spacing between them that is greater by 35% than that observed with rectilinear beads.

Likewise, the delamination resistance tests showed that, with such a sinusoidal shape (ratio L/a equal to 8), the delamination resistance is increased by 48% with respect to straight beads which are themselves also placed parallel to the grain of the plywood. This means that a reduction by 35% in the length of mastic deposited on the panel of a second insulating block is possible, without the effect achieved in terms of

delamination being more unfavourable than with rectilinear beads.

Overall, the use of sinusoidal beads having a ratio L/a equal to 8 allows a saving of 18% in the amount of mastic necessary by comparison with rectilinear beads, while maintaining the same flexural rupture strength and even obtaining better delamination resistance.

It is obvious that other sinusoids may be selected, with ratios L/a other than 8, or else any alternating periodic shapes (chevrons, squares, etc.). The amount of mastic necessary will be greater or lesser depending on the shape of these wavy lines. However, the spacing between the lines should be adapted so that sufficient flexural rupture resistance can be maintained with the wavy shape adopted.

Although the invention has been described in relation to a number of specific embodiments, it is obvious that it is not at all restricted thereto and that it comprises all the technical equivalents of the means described along with their combinations if these come within the scope of the invention.

CLAIMS

1. Method of adhesively bonding insulating blocks to a bearing structure of a terrestrial tank, with the aid of beads (3) of mastic, for the production of a sealed, thermally insulated terrestrial tank for the storage of liquefied gases on land, the said tank comprising a thermally insulating barrier comprising a plurality of insulating blocks (14), each insulating block comprising a plywood panel and containing or carrying thermally insulating material, the said method comprising

- a) the application of beads (3) of mastic to the panel of the said insulating blocks (14) or to the bearing structure along mutually parallel lines,
- b) the positioning of the said insulating blocks (14) against the bearing structure of the tank (1), and
- c) the pressing thereof against the said bearing structure until polymerization of the said mastic, characterized in that at least two of the said beads (3) are arranged along wavy parallel lines between the panel of at least one of the said insulating blocks (14) and the bearing structure.

2. Adhesive bonding method according to Claim 1, in which the distance between two consecutive wavy lines is greater than or equal to 100 mm.

3. Adhesive bonding method according to either of the preceding claims, in which the wavy lines are sinusoids.

4. Adhesive bonding method according to Claim 3, in which the sinusoid has a ratio substantially equal to 8 between its period and its amplitude.

5. Sealed, thermally insulated terrestrial tank built into a bearing structure (1), comprising a thermally

insulating barrier comprising a plurality of insulating blocks (14), each insulating block comprising a plywood panel and containing or carrying thermally insulating material, the said insulating blocks (14) being fastened directly against the bearing structure (1) by means of beads (3) of mastic positioned on the panels of the said insulating blocks along mutually parallel lines,

characterized in that at least two of the said beads (3) on the panel of at least one of the said insulating blocks (14) are arranged along wavy parallel lines.

6. Sealed, thermally insulating tank according to Claim 5, in which the distance between two consecutive wavy parallel lines is greater than or equal to 100 mm.

7. Sealed, thermally insulating tank according to either of Claims 5 and 6, in which the wavy lines are sinusoids.

8. Sealed, thermally insulating tank according to Claim 7, in which the sinusoid has a ratio substantially equal to 8 between its period and its amplitude.