(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 043 670
B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: 11.01.84

(51) Int. Cl.³: B 22 D 41/02, B 22 D 41/10

(21) Application number: 81302810.7

(22) Date of filing: 23.06.81

(54) Metal casting and lined ladles therefor.

(30) Priority: 02.07.80 GB 8021684

(43) Date of publication of application:
13.01.82 Bulletin 82/2

(45) Publication of the grant of the patent:
11.01.84 Bulletin 84/2

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

(56) References cited:
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GB - A - 1 521 177
US - A - 4 216 944

(73) Proprietor: FOSECO TRADING A.G.
Langenjohnstrasse 9
CH-7000 Chur (CH)

(72) Inventor: Hearne, Bryan Howard
295 Lordswood Road
Harborne Birmingham 17 (GB)

(74) Representative: Shaw, Laurence
FOSECO MINSEP INTERNATIONAL LIMITED
Group Patents Department 285 Long Acre
Nechells Birmingham B7 5JR (GB)

EP 0 043 670 B1

Courier Press, Leamington Spa, England.

Metal casting and lines ladles therefor

The invention relates to the lining of metallurgical ladles of the type used in foundries to supply molten metal to, for example, a casting mould and especially to means for reducing the content of inclusions in molten metal emerging from such ladles and for reducing the need for preheating of the ladles. Typically such ladles are of generally bucket form, and have either an outlet i.e. nozzle in the floor or are shaped to be emptied over the lip of the ladle. The ladle usually consists of an outer metal shell on which is superimposed a relatively permanent lining of refractory brickwork or a rammed or cast refractory concrete to form a monolithic refractory lining.

In use, molten metal is poured from a furnace, such as a high frequency induction furnace, into the ladle and from there to a casting mould. The molten metal is held in the ladle while it is moved from one location to another, for example from a tapping position to various pouring positions. The molten metal may be held in the ladle for about 30 minutes; usually the ladle is filled and then emptied within 20 minutes. While the molten metal is present in the ladle it tends to attack the refractory lining and this generally means that each time the ladle is emptied the relatively permanent lining needs to be repaired and eventually it must be replaced. It is known that one can protect the relatively permanent lining by refractory dressing, this is cheap but not sufficiently erosion-resistant.

The foundryman is concerned with the quality of the metal in the castings he produces and to ensure this he takes certain precautions. One problem is the loss of temperature of the molten metal in the ladle; heat is lost while the metal is tapped from the furnace and the metal also loses heat when held in the ladle which may be moved from mould to mould. To ensure that the metal temperature is sufficiently high for a casting of correct quality to be formed it is standard practice to tap the metal at a temperature higher than that needed for casting and also to preheat the ladle to compensate for the thermal losses that will occur. Another problem concerns the risk of inclusions in the metal. It has been observed that little or no inclusions are present when a ladle with a virgin or freshly prepared lining is used but as the ladle is reused the risk of inclusions being present increases due to slag and other residues from previous use. A source of inclusions is the slag on top of the molten metal and each time the ladle is emptied an attempt is made to remove all the slag. This attempt is never completely successful since some slag is desposited on the ladle lining and when the ladle is filled again with molten metal the slag is remelted and contributes inclusions in that body of molten metal. Ideally the ladle should be rebricked each time it is used but this is not economic so the ladle is patched until the level of inclusions can no longer be tolerated.

It has been proposed in British patent specification 1454201 to form a permanent lining in a ladle for molten metal by the use of a lining in sleeve or tile form of a defined composition which is then heated and sintered. The composition is selected to be highly exothermic and heat-insulating as well as refractory so that it can be reused many times and so that slag will not adhere to the lining. So far as the Applicants are aware this proposal has not been practised and this may be due to several factors including the need to fire and sinter the composition prior to use of the lined ladle.

British patent specification 1364665 describes a tundish used in the continuous casting of molten metal comprising an outer metal casing, a permanent lining of refractory material adjacent the casing an an expendable lining made up of a set of slabs of refractory heat-insulating material. However in such a vessel it is necessary to line the so-called impact area, i.e. the area in which the molten metal enters the vessel, with erosion resistant or sacrificial material in order to withstand the stream of molten metal.

It is an object of the invention to provide means for the foundryman to cast molten metal from a ladle in such a way that quality castings can be made more easily and cheaply.

According to one feature of the invention, there is provided a vessel comprising an outer metal casing having a base and side walls, a permanent refractory lining located on the inside of the casing, and an inner protective discardable lining located in the vessel so as to shield the permanent lining characterised in that the vessel is a foundry ladle of generally bucket shape having arcuate side walls and that the inner lining is formed of one or more floorboards and one or more side boards, the side boards being arranged essentially vertically to form in horizontal section a polygonal array, the boards being wider at the top than at the base and being formed of a composition which is refractory and has relatively low thermal conductivity.

Ladles take several forms. In one form the ladle has a sealed bottom and the molten metal is poured into a casting mould from the top via a lip. A version of a lip pour ladle in which the metal is drawn from the bottom of the ladle is a so-called "teapot" ladle. In another form the ladle floor has an outlet containing a replaceable nozzle so that the metal is poured out from the bottom. The invention is applicable to all these forms of ladle.

As a general rule and especially where the quality of the metal being cast is important the used lining will be discarded after one use since the risk that the inclusions will have reached an unacceptable level cannot be tolerated. The lining may however, be used for more than one furnace tap and this can happen where economy is more important than the metallurgy of the cast metal. The decision when to discard the used lining is in the control of the foundryman who will balance his need for economy with the desire to achieve castings of a defined quality, in any event the use of the invention will reduce the cost and need for preheating and will simplify the relining when it is required. The lining may be used more than once when the time from one tap to another is very short and to meet this case the lining can be adapted for multiple use as there is insufficient time for relining. Linings which are to be used more than once will tend to be thicker than those used once only.

The ladle may be of any of the forms mentioned above. Where the ladle has a nozzle in the floor, the lining on the floor may have a bore into which the nozzle may key and this will lock the nozzle into position. This means that the usual self-setting or ramming composition to hold the nozzle is not needed — not only does this remove a dirty and time consuming job but we have found that the risk of inclusions is reduced.

The molten metal may be any metal or alloy composition commonly used in foundries, examples being steel, iron, copper, aluminium and alloys of these. An important advantage of this invention is that because the lining is heat-insulating to a desired extent, there is little or no need to superheat the metal in the furnace above a normal casting temperature.

It is an important feature of the invention that the protective discardable lining is preformed of one or more boards. In the case of very small ladles the lining may be formed as a one piece item. According to a much preferred feature of the invention, the lining is formed of a set of boards of the composition. The set of boards comprises one or more floorboards shaped and arranged to cover the ladle floor. Where the floor has an outlet nozzle, the floorboard will have a bore to key the nozzle so avoiding any ramming or setting material. The set also includes sideboards which are dimensioned to extend from the floorboard to the top of the ladle and most preferably the floorboard is shaped for example by edge recesses to receive or register with the side boards in sealed manner. As indicated above it is a feature of this invention that the side boards be shaped so that they are wider at the end remote from the floorboard than at the floorboard end so that they taper outwardly to the top of the ladle. This feature assists in the removal of the used inner lining after the ladle has been emptied of molten metal. Most preferably adjoining side walls of the boards are shaped to form a seal to prevent the passage of molten metal thereacross and it is much preferred that the boards be trapezoidal in section. For enhanced sealing it is possible to apply a refractory cement across the joints. It is a surprising feature of this invention that where the boards tend to sinter under the influence of heat from the molten metal in the interior of the ladle, a skin is formed across the joints which aids in the formation of a complete inner skin so helping to shield the molten metal from contact with the relatively permanent lining. Surprisingly the presence of the skin tends to prevent the total content of the organic material in the lining from being burned out and this coupled with the high insulation of the lining tends to keep the ladle cooler.

For the purposes of the invention the lining must be formed of a composition which is refractory and has a relatively low thermal conductivity. In the case of boards formed of a refractory heat-insulating composition these criteria can be satisfied by controlling physical parameters of the boards. In general, if has been found that the boards forming the inner protective lining should be at least 10 mm thick and preferably 15 mm to 20 or 25 mm thick. If they are more than 50 mm thick they tend to occupy a relativly high proportion of the volume of a small ladle which restricts the amount of molten metal it can hold. Preferably the boards have a density in the range of from about 0.3 to about 1.5 preferably about 0.5 to 1.1 g/cm^3. The thermal conductivity should be in the range of about 0.1 to 1.0 preferably 0.3 to 0.5 W/K. To be handled, especially when thin, the boards should have a transverse strength of about 5 to 25 bar (kg/cm^2), preferably 15 to 20 bar (kg/cm^2). Depending on the chemical composition the permeability of the boards may be important, in the case of boards formed from an organically bonded composition the premeability should be of the order of 10 AFS units (American Foundryman's Society).

The boards may be formed from a variety of compositions used to make boards for forming the expendable lining of a tundish. Such tundish linings are well known under the registered trade mark GARNEX and there is thus no need for a detailed explanation here of the chemical compositions of which they may be formed. In general, the inner protective discardable lining of this invention may be formed of fibrous materials, refractory fillers and binders. Preferred are, as fibrous materials organic fibres such as paper, and as inorganic fibres asbestos, calcium silicate, aluminium silicate fibres; as refractory fillers silica, alumina, magnesia, refractory silicates; and as binders both inorganic and organic, colloidal silica sol, sodium silicate, starch, phenolformaldehyde resin or urea-formaldehyde resin. The use of tundish lining boards for the purposes of this invention has not been proposed. Some reasons for this are clear: in a tundish the constant inflow of superheated molten metal keeps the temperature of the molten metal fairly uniform, and because the slabs and billets formed are subjected to secondary processing inclusions are removed and their presence in the molten metal is simply discounted. For the purpose of this invention, the boards must have the criteria of shape, thickness, density, thermal conductivity etc., mentioned above if the advantages of avoiding preheating and inclusions are to be optimised.

According to another feature of the invention there is provided for use in a foundry ladle, a set of boards to be fitted into the ladle to form an inner protective discardable lining, the boards comprising one or more floorboards and one or more side boards, each board being formed of a composition which is refractory, and has a density in the range of about 0.3 to 1.5 g/c^3, a thermal conductivity in the range of 0.1 to 1.0 W/mK and a thickness of from 10 to 25 mm.

In order that the invention may be well understood it will now be described with reference to the accompanying diagrammatic drawings in which,

Figure 1 is a vertical sectional view of a ladle having an inner protective lining before use,

Figure 2 is a top plan view of the ladle of Figure 1,

Figure 3 is a fragmentary view showing the lining after contact with molten metal.

Figure 4 is a photograph showing the results of using a ladle lined according to the invention and with reference to the Examples below in which parts are by weight unless otherwise specified.

The ladle of Figure 1, comprises a bucket-like vessel 1 having a base 2 and upwardly outward flared sidewall 3. A nozzle 4 is set in the floor 2, to receive a stopper rod 5.

The vessel base and sidewall are made up of an outer metal shell 6 on which is set a relatively permanent lining 7 of refractory bricks as shown or a shaped monolithic lining. Typically the vessel has an internal volume to accommodate about 0.3 to 10 tons of molten steel. For a three ton ladle, the inner diameter of the floor is about 80 cm and the diameter at the top is about 100 cm and the internal height of the sidewalls is about 120 cm.

An inner lining 10 is present within the vessel 1. The lining comprises a set of boards, each formed of refractory heat insulating material. The boards comprise a pair of floorboards 11 covering the whole of the floor area and ten upstanding side boards 12. Each side board is wider at its upper end than at its base which rests on a ledge formed in the floorboard 11. The side boards are each trapezoidal in section so that a tight joint A is formed between adjacent side boards when they are abutted together. The floorboards 11 are joined together in overlapping manner as at A. Sufficient side boards are present to cover the inner surface of the relatively permanent lining. Each board measures 108 cm high, and about 3 cm thick and the front surface measures 27 cm across and the rear surface 29 cm across. Each side board and the floorboard has a density of 1.1 g/c^3, and a thermal conductivity of 0.6 W/mK. Where the boards include an organic binder they are made from an aqueous slurry of the following (parts by weight):

silica sand/flour	84
slag wool	3
sintering aid	6
phenol-formaldehyde resin	3
urea-formaldehyde resin	3
urea-formaldehyde resin	1
paper	3

to form a damp shape which is then dried.

Loose sand 13 is located between the floor 2 of the vessel and the floorboards 11 and also in the gap between the inner surface of the relatively permanent lining and the set of the side boards 12. In the case of a lip-poured ladle, the sand at the top of the ladle, at least in the region of a cut out 14 in the upper corners of two adjacent side boards and defining a lip-pouring spout 15, is mixed with sodium silicate to harden it so that it will not fall out when the ladle is tilted. A preformed sealant such as a clay or alumino-silicate fibre rope may also be used to hold the loose sand in the desired position.

In use, molten steel at about 1650° C is tapped from a furnace into the ladle. The stream of steel impinges on the side and floorboards but despite this the boards are not severely eroded. As the molten steel enters the ladle it contacts the boards and the resin binder therein is carbonised but only a part of the binder suffers this fate since the front face of the boards sinters to form an impervious skin, or layer L which seals the inner lining from attack by molten metal.

When the ladle is filled to the desired level with the molten steel — which by then has cooled to about 1600° C — it may be stored for up to 20 minutes or more. When desired the metal is released via the nozzle 4 until the ladle is completely empty. The molten metal temperature falls much more slowly while it is in the ladle because of the thermal insulation of the inner protective discardable lining. Surprisingly, the inner protective lining retains its integrity and at the end of the pour when the ladle is fully inverted, the inner lining is discarded by falling out as a one-piece, bucket-like element together with the loose sand, leaving a clean relatively permanent lining 7. Because of the heat insulating properties of the lining the ladle can be reused more speedily than would be the case in the absence of a lining, and turn-around is generally improved. Between each pour the nozzle 4 is conveniently removed from the outside of the ladle without any need to have access to the interior.

In an evaluation, the ladle of the invention was used in comparison with a ladle having no inner protective lining to supply molten steel to a sand mould in a foundry. In the case of the ladle without the inner protective lining, it was found that there were slag and refractory inclusions in the castings made from the molten steel whilst in the case of the ladle of the invention no such inclusions were present.

Example 1

Two bottom pour ladles each having a capacity of 3000 kg were taken. One was lined with 65 mm refractory alumina cement lining. A nozzle was set in the outlet with a rammable silica cement. The other was lined with a 40 mm thick layer of the alumina cement, on top of which was superimposed a lining of boards of the following characteristics.

thickness	25	mm
density	1.1	g/c³
thermal conductivity	0.6	W/mK.
composition (parts of weight)		
silica sand	90	
paper	3	
resin binder	4	
slag wool	3	

The floorboard had a bore to register with the nozzle outlet and the nozzle was keyed in that bore so avoiding the need for ramming materials. The boards were trapezoidal in plan and were wedged together with their wider ends uppermost. The ladle having the 65 mm refractory cement lining was preheated to 600—700°C for 2 hours using gas burners. The other ladle was not preheated.

Carbon steel at 1650° C was tapped into both ladles. In the case of the ladle having the 65 mm refractory cement lining the steel cooled to 1600° C within 1 minute and the temperature fell at the rate of 4° C/min. In the case of the other ladle — according to the invention — the temperature after 1 minute was 1610° C and the cooling rate was 3° C/min. The effect of this was that after a period of time, say 20 minutes, there was a significant temperature difference between the metal in both ladles. These results show that even with the omission of preheating a ladle lined according to the invention has improved thermal characteristics. This can be taken advantage of in a variety of ways, including a lowering of the tapping temperature.

Example 2

Carbon steel was tapped into two ladles, prepared in the manner of Example 1 and the metal was run into test moulds formed of zircon sand and refractory holloware. The metal was allowed to cool and the castings were removed. The castings surface were machined level and then coated by the Dynatron technique to show exogenous inclusions arising from the erosion of ladle refractories and slag only. The surfaces were photographed and the results are shown in Figure 4 (no magnification) in which the lower photograph shows the results from a casting from the ladle having no inner protective lining and the upper photograph shows the results from a ladle of the invention. These results clearly show the advantages of using the lining to reduce the risk of inclusions.

Example 3

The method of Example 2 was repeated using a high alloy steel and the same results were obtained.

Claims

1. A vessel comprising an outer metal casing having a base and side walls, a permanent refractory lining located on the inside of the casing, and an inner protective discardable lining located in the vessel so as to shield the permanent lining, characterised in that the vessel is a foundry ladle of generally bucket shape having arcuate side walls and that the inner lining is formed of one or more floorboards and one or more side boards, the side boards being arranged essentially vertically to form in horizontal section a polygonal array, the boards being wider at the top than at the base and being formed of a composition which is refractory and has relatively low thermal conductivity.

2. A ladle according to Claim 1, characterised in that the protective discardable lining has been preformed and then fitted within the ladle.

3. A ladle according to Claim 1 or 2, characterised in that the boards are each from about 10 to about 25 mm thick and have a density of 0.3 to 1.5 g/cm³ and a thermal conductivity of 0.1 to 1.0 W/mK.

4. A ladle according to Claim 3, characterised in that the boards are from 15 mm to 20 mm thick and have a density of 0.5 to 1 g/cm³ and a thermal conductivity of 0.3 to 0.5 W/mK.

5. A ladle according to Claim 3 or 4, characterised in that the boards have a transverse strength of 5 to 25 bar (kg/cm²).

6. A ladle according to Claim 5, characterised in that the boards have a transverse strength of 15 to 20 bar (kg/cm²).

7. A ladle according to any of Claims 1 to 5, characterised in that the boards have a permeability of the order of 10 AFS units.

8. A ladle according to any of Claims 1 to 6, characterised by having an outlet in the floor to receive an outlet nozzle, and in which the floorboard includes a bore to receive and lock the nozzle in the absence of a setting material.

9. For use in a foundry ladle according to any of Claims 1 to 8, a set of lining boards characterised by being formed of a refractory composition which has a relatively low thermal conductivity, one or more boards being side boards and one or more of the boards being floorboards, in which each board has a density in the range of 0.3 to 1.5 g/cm³, and thermal con-

ductivity in the range of 0.1 to 1.0 W/mK, and a thickness of 10 mm to 25 mm.

10. A set of boards according to Claim 9, characterised in that having a density of 0.5 to 1.1 g/cm^3, and a thermal conductivity of 0.3 to 0.5 W/mK.

11. A set of boards according to Claim 9 or 10, characterised in that each board has a permeability of the order of 10 AFS units.

Revendications

1. Récipient comprenant une enveloppe extérieure métallique ayant une paroi de base et une paroi latérale, un garnissage réfractaire permanent disposé sur la face intérieure de cette enveloppe, de même qu'un garnissage intérieur protecteur pouvant être enlevé et disposé dans le récipient afin de protéger le garnissage permanent, caractérisé en ce que ce récipient est une poche de coulée de fonderie ayant généralement la forme d'un seau et comportant des parois latérales courbes, le garnissage intérieur étant formé d'une ou plusieurs plaques de base, ainsi que d'une plusieurs plaques latérales, les plaques latérales étant essentiellement disposées verticalement afin de former, en coupe horizontale, une zone polygonale, ces plaques étant plus larges à leur sommet qu'à leur base, tandis qu'elles sont constituées d'une composition qui est réfractaire et possède une conductibilité thermique relativement faible.

2. Poche de coulée suivant la revendication 1, caractérisée en ce que le garnissage protecteur pouvant être enlevé a été préformé, puis adapté à l'intérieur de la poche de coulée.

3. Poche de coulée suivant la revendication 1 ou 2, caractérisée en ce que les plaques ont chacune une épaisseur se situant entre environ 10 et environ 25 mm, une densité de 0,3 à 1,5 g/cm3 et une conductibilité thermique de 0,1 à 1 W/mK.

4. Poche de coulée suivant la revendication 3, caractérisée en ce que les plaques ont une épaisseur de 15 à 20 mm, une densité de 0,5 à 1 g/cm3 et une conductibilité thermique de 0,3 à 0,5 W/mK.

5. Poche de coulée suivant la revendication 3 ou 4, caractérisé en ce que les plaques ont, dans le sens transversal, une résistance de 5 à 25 bars (kg/cm2).

6. Poche de coulée suivant la revendication 5, caractérisée en ce que les plaques ont, dans le sens transversal, une résistance de 15 à 20 bars (kg/cm2).

7. Poche de coulée suivant l'une quelconque des revendications 1 à 5, caractérisée en ce que les plaques ont une perméabilité de l'ordre de 10 unités AFS.

8. Poche de coulée suivant l'une quelconque des revendications 1 à 6, caractérisée en ce qu'elle comporte, dans sa base, une sortie destinée à recevoir une buse de sortie, la plaque de base comportant un alésage destiné à recevoir et à bloquer la buse en absence d'une matière qui durcit.

9. Poche de coulée de fonderie suivant l'une quelconque des revendications 1 à 8, dans laquelle on utilise une série de plaques de garnissage qui sont caractérisées en ce qu'elles sont formées d'une composition réfractaire ayant une conductibilité thermique relativement faible, une ou plusieurs plaques étant des plaques latérales, tandis qu'une ou plusieurs de ces plaques sont des plaques de base, chaque plaque ayant une densité se situant dans l'intervalle allant de 0,3 à 1,5 g/cm3, une conductibilité thermique se situant dans l'intervalle allant de 0,1 à 1 W/mK et une épaisseur de 10 mm à 25 mm.

10. Série de plaques suivant la revendication 9, caractérisées en ce qu'elles ont une densité de 0,5 à 1,1 g/cm3 et une conductibilité thermique de 0,3 à 0,5 W/mK.

11. Série de plaques suivant la revendication 9 ou 10, caractérisées en ce que chaque plaque a une perméabilité de l'ordre de 10 unités AFS.

Patentansprüche

1. Behälter, bestehend aus einem Metallaussengehäuse mit einem Boden und Seitenwänden, einer auf der Innenseite des Gehäuses befindlichen, dauerhaften feuerfesten Zustellung und einem innen im Behälter angeordneten verbrauchbaren Schutzfutter zum Abschirmen der dauerhaften Zustellung, dadurch gekennzeichnet, dass der Behälter eine im wesentlichen kübelförmige Giesspfanne mit gekrümmten Seitenwänden ist und dass das Innenfutter aus einer oder mehreren Bodenplanken und einer oder mehreren Seitenplanken aufgebaut ist, wobei die Seitenplanken im wesentlichen senkrecht so angeordnet sind, dass sie im waagerechten Querschnitt eine vieleckige Anordnung bilden, wobei die Planken am oberen Ende breiter als unten sind und aus einer feuerfesten Masse verhältnismässig geringer Wärmeleitfähigkeit bestehen.

2. Pfanne nach Anspruch 1, dadurch gekennzeichnet, dass das verbrauchbare Schutzfutter vorgebildet und dann in der Pfanne angebracht wurde.

3. Pfanne nach Anspruch 1 oder 2, dadurch gekennzeichnet, dass die Planken je etwa 10 bis etwa 25 mm dick sind und eine Dichte von 0,3 bis 1,5 g/m^3 und eine Wärmeleitfähigkeit von 0,1 bis 1,0 W/mK aufweisen.

4. Pfanne nach Anspruch 3, dadurch gekennzeichnet, dass die Planken 15 mm bis 20 mm dick sind und eine Dichte von 0,5 bis 1 g/cm^3 und eine Wärmeleitfähigkeit von 0,3 bis 0,5 W/mK aufweisen.

5. Pfanne nach Anspruch 3 oder 4, dadurch gekennzeichnet, dass die Planken eine Scherfestigkeit von 5 bis 24 bar (kg/cm^2) aufweisen.

6. Pfanne nach Anspruch 5, dadurch gekenn-

zeichnet, dass die Planken eine Scherfestigkeit von 15 bis 20 bar (kg/cm^2) aufweisen.

7. Pfanne nach einem der Ansprüche bis 5, dadurch gekennzeichnet, dass die Planken eine Durchlässigkeit in der Grössenordnung von 10 AFS-Einheiten aufweisen.

8. Pfanne nach einem der Ansprüche 1 bis 6, gekennzeichnet durch einen Bodenablauf zur Aufname eines Pfannenausgusses, wobei die Bodenplanke eine Bohrung zur Aufnahme und Halterung des Ausgusses ohne Abbindemittel enthält.

9. Futterplankensatz zur Verwendung in einer Giesspfanne nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, dass er aus einer feuerfesten Masse verhältnismässig geringer Wärmeleitfähigkeit hergestellt ist, mit jeweils einer oder mehreren Seitenplanken bzw. Bodenplanken, wobei die Planken je eine Dichte im Bereich 0,3 bis 1,5 g/cm^3, eine Wärmeleitfähigkeit im Bereich 0,1 bis 1,0 W/mK und eine Dicke von 10 bis 25 mm aufweisen.

10. Plankensatz nach Anspruch 9, dadurch gekennzeichnet, dass die Dichte 0,5 bis 1,1 g/cm^3 und die Wärmeleitfähigkeit 0,3 bis 0,5 W/mK beträgt.

11. Plankensatznach Anspruch 9 oder 10, dadurch gekennzeichnet, dass die Planken jeweils eine Durchlässigkeit in der Grössenordnung von 10 AFS-Einheiten aufweisen.

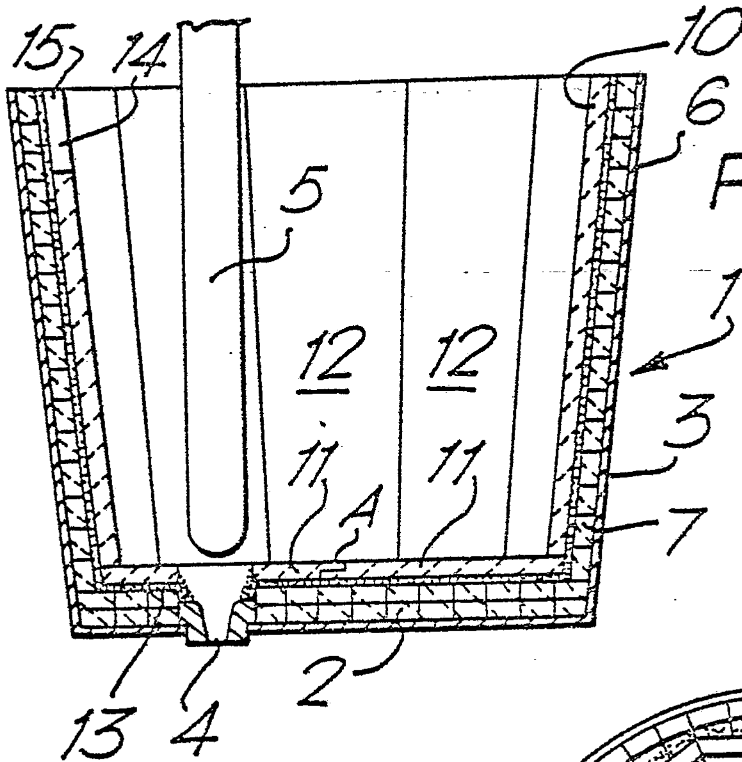
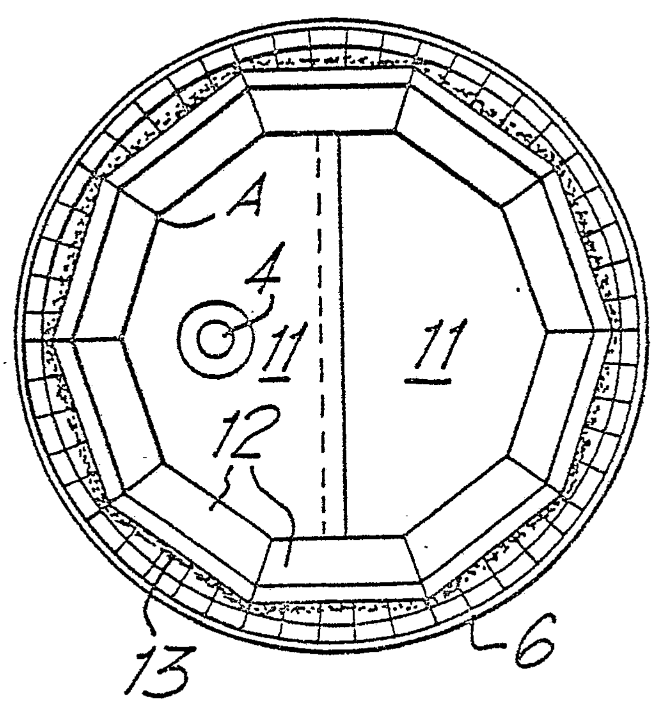


FIG.1.

FIG.2.



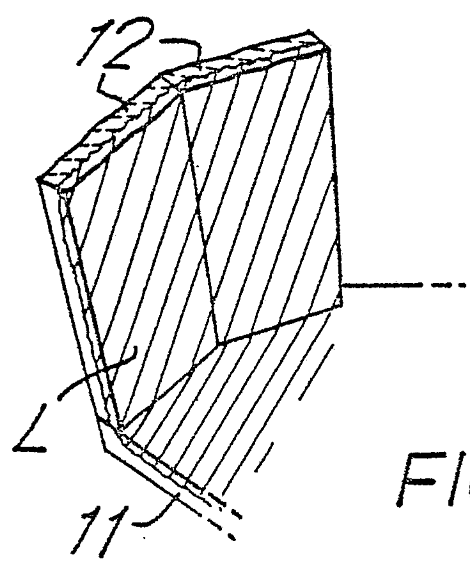


FIG.3.

FIG.4.