April 9, 1957 N. L. DOLBEY ET AL 2,788,053

THERMAL INSULATING STRUCTURES AND METHODS FOR THE PRODUCTION THEREOF

Filed May 13, 1954 2 Sheets-Sheet 1

FIG. 1.

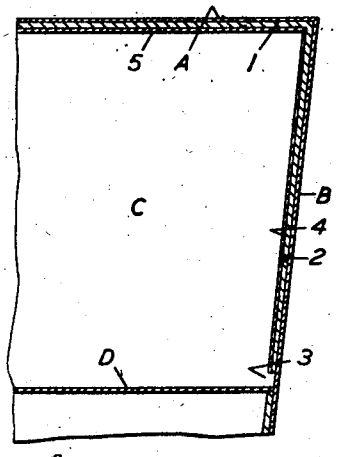


FIG. 2.

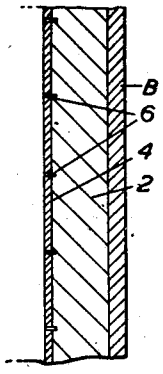


FIG. 3.

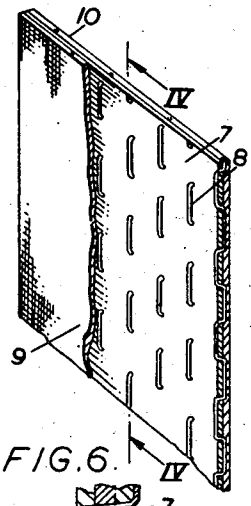


FIG. 4.

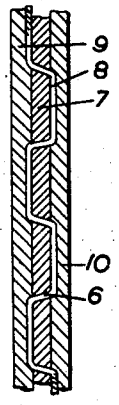


FIG. 5.

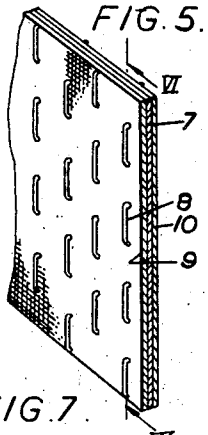


FIG. 6.

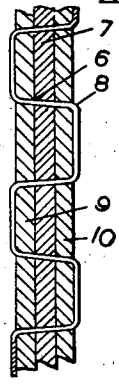
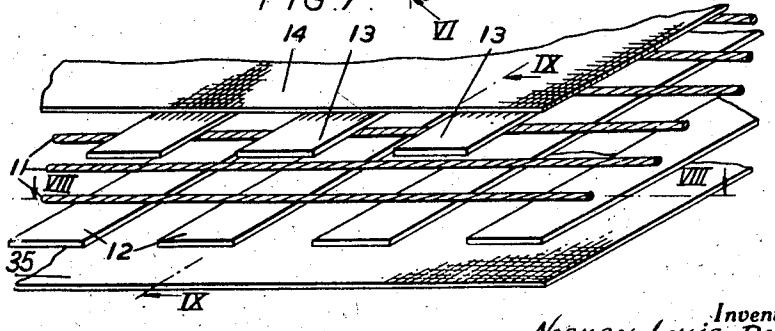


FIG. 7.



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THERMAL INSULATING STRUCTURES AND METHODS FOR THE PRODUCTION THEREOF

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FIG. 8.

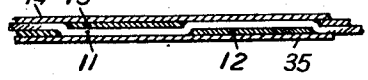


FIG. 9.

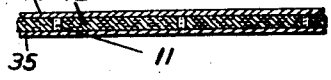


FIG. 10.

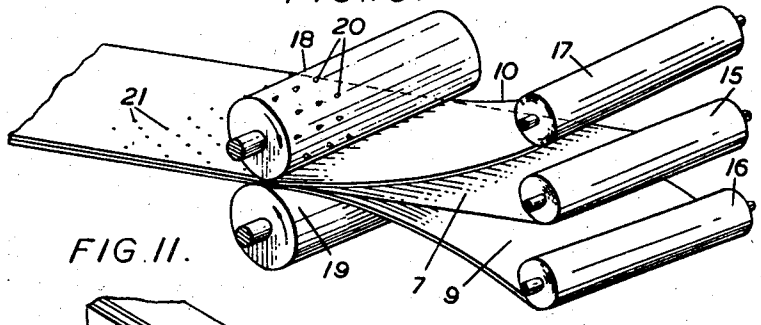


FIG. 11.

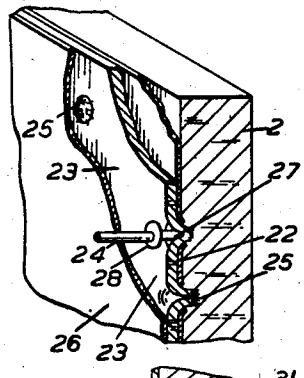


FIG. 12.

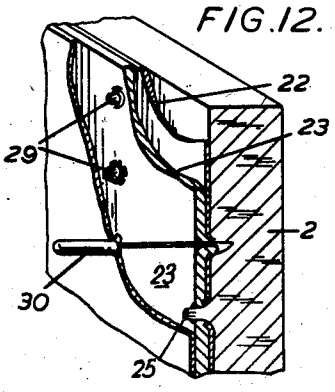


FIG. 14.

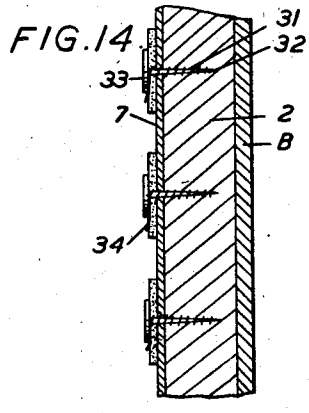
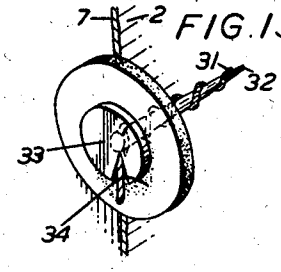


FIG. 13.



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THERMAL INSULATING STRUCTURES AND METHODS FOR THE PRODUCTION THEREOF

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Application May 13, 1954, Serial No. 429,611

Claims priority, application Great Britain May 15, 1953

15 Claims. (Cl. 154—28)

This invention relates to thermally insulated structures and methods of producing thermal insulation.

In some structures considerable temperature differences are likely to arise between an internal space and the outer atmosphere, e. g. in ships during cold weather, in high-flying aircraft and in some types of building during winter the interior may be at a much higher temperature than the atmosphere. In all such structures there is a metal or other impermeable shell forming a wall between the warm space and the atmosphere. This may be the side or deck of a ship, the skin of an airplane, or the roof of a building, such as corrugated iron or asphalt-coated concrete roof. It is common to line this shell with fibrous insulating material. In ships this is often done by spraying the undersides of exposed decks and the inside faces of exposed ship's sides with asbestos so as to form a layer varying in thickness from ½" to 1" or more. However, as the temperature of the outside air in cold weather is often below freezing point, and is almost always below the dew point of the air inside the warm space, some condensation will take place inside the porous layer of insulation, and if the outside temperature is low enough the condensed water in contact with and near to the outer shell will turn to ice. The amount of ice and condensed water collecting in the insulation depends partly on the thickness and density of the insulation and partly on the difference in the water vapour pressure at the opposite faces of the insulation. Under normal conditions there is a temperature gradient through the fibrous layer of insulation, the temperature rising from that of the cold plates to very nearly that of the inside air. Inside the layer of insulation, therefore, the range of temperatures in cold weather includes both freezing point and the dew point of the air inside the living or other space, and the inner surface of the insulation is above the dew point. Although water and occasionally ice may form in the insulation under these conditions, the sprayed asbestos will remain essentially dry because there is re-evaporation of condensed water to the inside air; but when the relative humidity begins to increase, as frequently happens in inadequately ventilated ships, the dew point will rise and so, within the layer, will approach the inner face. For the same reason the rate of re-evaporation from the surface of the insulation will be reduced, so that the gain in weight will be greater than the loss by evaporation. In consequence, the amount of water or ice or both in the layer will increase, and this added weight is very disadvantageous. If these conditions are maintained for an appreciable time, the layer of insulation may absorb as much as ten times its weight of water, some of which may freeze in aircraft and some ships, so causing grave danger, in addition to great discomfort to those occupying the warm space, if it is a cabin or other living space, or damage to the goods contained in the space.

Attempts to prevent build-up of ice or condensed water in the fibrous insulation by sealing its exposed face, i. e. forming a vapour barrier, are generally fruitless and only result in an initial delay in arriving at the dangerous

state because it is practically impossible to provide a barrier that is effective under the conditions prevailing in ships, aircraft and the like, where the outer shell is of metal or other non-permeable material so that the moisture is trapped between the barrier and the outer shell because it cannot escape to the outside air. These conditions do not arise in normal housing and building construction where the outer shell is porous and the effectiveness of a vapour barrier merely depends on reducing the rate of inlet of moisture to a figure less than that at which it can escape through the outer porous shell, though they may arise in certain types of buildings where the roofs are of metal or the normal masonry has been rendered substantially impervious to water vapour, e. g. by rendering it so with a layer of roofing felt or asphalt.

It is an object of this invention to provide an insulated structure from which condensed water may be re-evaporated into a warm space so as to avoid the hazzards referred to above.

Another object is to provide a novel method of producing an insulating structure.

In my invention I pass wicks through a vapour barrier separated from an impermeable shell by fibrous insulation. The function of the wicks is to conduct condensed water from the insulation to the warm side of the vapour barrier to be evaporated into the warm space. The vapour barrier itself should retard the passage of water vapour from the warm space to the insulation as far as possible, and there should be no spaces around the wicks through which vapour can easily pass from one face of the vapour barrier to the other.

Whereas the effect of a vapour barrier as used hitherto has been to permit saturation of the insulation in a longer or shorter time, even though it has been designed to prevent the passage of water vapour, the invention allows some water vapour to enter the insulation (while reducing the amount as far as possible over the time during which the rate of buildup is greater than the rate of re-evaporation), and provides means by which the water condensed from this vapour in the insulation can be re-evaporated into the warm space immediately this is permitted by changes in the physical conditions of the air outside or inside or both, that is either a rise in the external temperature or a decrease in the relative humidity in the warm space, or even an increased flow of air over the inner face of the vapour barrier such as can be set up by fans.

The preferred wick material is asbestos, the fibres of which have a remarkable capacity for transmitting water by capillary action. Other wick materials which may be used are bundles of parallel or twisted filaments, or fibres, of glass, rock wool, flax, silk, cotton or cellulose yarns made from any such filaments or fibres, or any other thread-like product with the necessary capillary value to produce an effective wick. Broadly, any material which can be used as a lamp or lighter wick can be used in the present invention, and so also can plaster-like products having fibres so embedded in them as to form continuous paths for moisture from one face to the opposite face.

The invention will be more readily understood by reference to the accompanying drawings, in which:

Figure 1 is a section through part of a ship's deck and side with insulation in place;

Figure 2 shows part of Figure 1 on a larger scale;

Figure 3 is a perspective view of one vapour barrier with wicks passing through it;

Figure 4 is an enlarged section on the line IV—IV in Figure 3;

Figure 5 is a view, similar to Figure 3, of another vapour barrier;

Figure 6 is an enlarged section on the line IV—IV in Figure 5;

Figure 7 shows one stage in the production of another vapour barrier containing wicks;

Figures 8 and 9 are cross-sections at right-angles to one another through the final vapour barrier made by the method illustrated in Figure 7, being taken on the lines VIII—VIII and IX—IX respectively;

Figure 10 illustrates another way of producing a vapour barrier containing wicks;

Figure 11 is a perspective view showing the production of wicks in yet another vapour barrier in position on fibrous insulation;

Figure 12 is a view similar to Figure 11, showing another way of producing the wicks;

Figure 13 shows another kind of wick; and

Figure 14 shows the wicks of Figure 13 in a vapour barrier.

Figure 1 shows part of an exposed deck A of a ship at the point where it joins the side B of the ship to form the ceiling and outer wall of a cabin C, the floor of which is formed by a lower deck D. The underside of the deck A and the inner face of the side B are coated with layers of fibrous insulation **1** and **2** respectively by spraying asbestos in the well-known way. The insulation **2** ends above the deck D so as to leave a small gap **3** and thus to prevent any water spilt on the deck D from coming into contact with, and being absorbed by, the insulation **2**. The warm face of the layer of insulation **2**, i. e. that directed to the cabin, is covered by a vapour barrier **4**, and that of the insulation **1** by a vapour barrier **5**. Wicks **6** pass through each vapour barrier to lead condensed water from the insulation to the space within the cabin C. The barrier and wicks are illustrated diagrammatically in Figure 2, and various forms they may take are shown in the other figures.

Figure 3 shows a vapour barrier of sheet material **7**, which may consist of neoprene, chlorinated rubber, polythene, polyvinyl chloride or the like. Wicks are produced by stitching blue asbestos yarn **8** about 1/16 inch in diameter through this in the manner shown. The points at which the wicks pass through the barrier **7** are 1½ inches apart in each line of stitches, and the stitch lines are themselves 1½ inches apart, thus making the number of wicks proper **6**, i. e. lengths of yarn passing through the barrier from one face to the other, about 70 to the square foot.

It is desirable to present as large an evaporating surface on the warm face of the vapour barrier as possible. Accordingly the wicks are preferably in contact with material which will spread the water over the warm face of the vapour barrier; such a material may be a layer of fibrous asbestos applied by spraying, a fabric, asbestos felt or paper, glass cloth, or even blotting paper. Any of these materials may be covered with a layer of water paint, which does not seriously interfere with the passage of water outwards.

Assuming that the vapour barrier shown in Figure 3 is applied to the insulation **2** on the side **3** of the ship, the warm face of the barrier may thus be covered by asbestos paper **9** as shown in Figures 3 and 4.

The vapour barrier with the wicks in it must be stuck to the insulation **2**. As a polythene or similar sheet cannot easily be stuck to a layer of sprayed asbestos it is convenient to stick on the cold face of the barrier a layer of material which will adhere readily to the insulation and provide a key for an adhesive used to stick the vapour barrier in position. The layer used for these purposes may be of the same kind as that used on the warm face of the barrier, and Figures 3 and 4 show a sheet of asbestos paper **10** so used.

The sheets of asbestos paper **9** and **10** may be stuck to the barrier sheet **7** by an adhesive or, if the barrier is

thermoplastic, by subjecting the assembly to heat and pressure, e. g. by passing it between two heated rollers.

It is, of course, desirable to ensure that water in the insulation **2** will pass to the wicks **6** as readily as possible, and the asbestos paper **10** interrupts the transmission somewhat. It is better to ensure that there are stitches of asbestos yarn in direct contact with the insulation **2**, and accordingly the yarn may be stitched through a composite material consisting of a barrier **7** and sheets of asbestos paper **9** and **10** as shown in Figures 5 and 6.

In the method illustrated by Figures 7 to 9, the wicks are formed by asbestos yarn or the like **11** woven between strips of polyvinyl chloride or other thermoplastic sheet arranged edge to edge. In carrying out this method, a series of identical strips **12** is first put on a sheet of asbestos paper **35**, being spaced apart from one another by the width of a strip. Then the wicks **11** are laid transversely across the strips at the desired spacing, and further strips **13** are laid on the wicks in the gaps between the strips **12**. A sheet of asbestos paper **14** is laid on top, and the whole assembly is then subjected to heat and pressure adequate to force the abutting edges of the strips **12** and **13** into contact with one another, except of course where the wicks prevent contact, and to weld the edges together.

It is not necessary to make the wicks of yarn or other material separate from the remaining elements of the whole assembly. Instead they may be produced by pulling or pushing fibres through the vapour barrier from a fibrous layer on one or other side of the vapour barrier. One way of doing this is shown in Figure 10. Here a thermoplastic sheet **7** is unwound from a roller **15** between sheets of asbestos paper **9** and **10** from rolls **16** and **17** respectively, and the three sheets are passed between two heated rollers **18** and **19**. The roller **18** has a series of spikes **20**. These spikes drive fibres of the paper into the sheet **7** to form wicks **21** while the three sheets are being united by passage between the rollers. The temperature to which the rollers are heated depends on the nature of the sheet **7**.

The asbestos paper shown in Figure 10 may be replaced by asbestos felt in thin sheet form. Again, instead of using sheet material, a thin covering of asbestos fibre may be formed on each side of the barrier. For instance, a chlorinated rubber sheet may be drawn from a roller through a pair of rollers which apply adhesive to both faces, asbestos fibre may be dusted onto both faces of the sheet and pressed into the adhesive by two further rollers, and then the coated sheet may pass between rollers such as **18** and **19** while they are unheated.

All the vapour barriers and wicks so far described must be preformed and then stuck to the insulation **2**, which may first be provided with a hard, though porous, surface of a fibrous plaster. The sticking presents a problem, in that if a water-soluble adhesive is used it dissolves in the condensed water and is conveyed to the wicks and may choke them. If a water-insoluble adhesive is used, it forms a barrier against the passage of water and hinders or even prevents the desired movement of the condensed water to and through the wicks. Preferably the adhesive is water-insoluble, e. g. a resinous emulsion, but is applied only locally, through a stencil or otherwise, in amounts that will just cause the barrier assembly to adhere firmly to the insulation while large areas remain uncoated by it and ensure the desired movement of water.

All difficulty with regard to an adhesive may be overcome by making the vapour barrier from a plastic material which will adhere to the fibrous insulation without difficulty. Thus the vapour barrier may be made from a plaster in which small pieces of asbestos are so embedded as to form continuous paths from one face of the plaster to the other. Such pieces or spicules of asbestos may be incorporated in a plastic asbestos-cement

mass applied to the insulation in any convenient way, and this mass will then form the vapour barrier. If a vapour-proofing compound is introduced into the plastic mass it will increase the resistance to the penetration of water vapour through the gaps between the fibre bundles, and yet have very little effect on the wick action, which depends on the existence of microscopic passages between the individual fibres.

A better material applied in plastic form to act as a vapour barrier is bitumen or the like. With such a material the wicks are most easily formed by fibres from a fibrous material in contact with bitumen or the like.

Figure 11 shows fibrous insulation **2** to which bitumen is applied by brushing or spraying and allowed to set to form a tough skin. Then another layer of bitumen is applied to form with the first layer the bituminous vapour barrier shown at **22**. While this second layer is still sticky, asbestos **23** is sprayed on. Then a tool **24** is pushed into the asbestos **23** and pushes fibres before it to form wicks **25**. Finally the exposed surface of the asbestos **23** is provided with a covering **26**, which may be done by applying to it a reinforcing fabric such as cotton cloth, or trowelling on asbestos-cement composition, or merely painting with a water permeable coating. If the fibres that form the wicks are pushed through the bitumen before it dries, the covering **26** may be stuck to the bitumen without the use of heat to cause adhesion.

The tool **24** may have a blunt blade **27** about 1/16 inch thick and a collar **28** to limit the extent to which the blade is plunged into the asbestos. The wicks can be formed at high speed by using this tool manually.

A layer of metal foil may be inserted between the two layers of bitumen, being applied on top of the first before it dries. This foil is easily penetrated by the tool **24**, and renders the barrier even more resistant to the passage of vapour than it would be otherwise.

Figure 12 shows the same layers as Figure 11, but in it wicks **29** are formed by pulling fibres from the main insulation **4** through a bituminous vapour barrier **22**. A tool **30** resembling a crochet hook is used. Because of the difficulty of working over a sticky layer, the outer layer of sprayed asbestos fibre **23** may be applied before fibres of the insulating layer are pulled through the barrier with the crochet hook **30**.

In the products shown in Figures 11 and 12, the vapour barrier is in effect embedded in the fibrous insulation instead of being on the surface of it. The barrier is thus protected against fire. Of course, the barrier must not lie so far inside the layer that the dew point would be on the warm side of it. If this were to happen, water condensing on the barrier would be transmitted to the cold side of it by the wicks. Therefore the insulation **2** must be thick enough to ensure that the dew point is on the cold side of the barrier.

Figure 13 shows a preformed wick and Figure 14 shows how such wicks can be driven through a vapour barrier **7** and into the insulation **2** behind it. Each of these wicks consists of asbestos yarn **31** wrapped around the shank **32** of a nail having a head **33**. A radial slot **34** is made in the head to receive one end of the yarn **31** and hold it in position. A large washer **34** of asbestos paper is provided under the head of each nail to spread the water laterally, these washers replacing the layer **9**. Alternatively, the washers may be omitted and a layer such as **9** held in place by the nails.

In all cases the wicks must be close enough together to ensure that all the water in the insulation **1** or **2** will flow to one or another wick. The insulation itself is preferably always in contact with the shell, though this is not necessary so far as the evaporative action of the wicks is concerned. This insulation need not consist of asbestos, but may be a mixture of rock wool and asbestos, or any other fibrous material such that water entering or formed in it by condensation will become distributed through it. This is important because for the best results the water should come into contact with all the wicks and so should not be localised in the insulation.

We claim:

1. A structure comprising an impermeable shell forming a wall between a warm space and the atmosphere, a vapour barrier, fibrous insulation of substantial capillarity separating the vapour barrier from the shell, and a plurality of wicks passing through the vapour barrier and in contact with said insulation to conduct condensed water from the insulation to the warm side of the barrier to be evaporated into the warm space.

2. A structure according to claim 1 in which the wicks consist of asbestos.

3. A structure according to claim 1 in which the fibrous insulation is directly adherent to the shell.

4. A structure comprising an impermeable shell forming a wall between a warm space and the atmosphere, a vapour barrier, fibrous insulation of substantial capillarity separating the vapour barrier from the shell, a plurality of wicks passing through the vapour barrier and in contact with said insulation to conduct condensed water from the insulation to the warm side of the barrier, and liquid-spreading material in contact with the wicks on the warm face of the vapour barrier and adapted to spread water from the wicks over that face to be evaporated into the warm space.

5. A structure according to claim 4 in which the spreading material is asbestos paper.

6. A structure according to claim 4 in which the spreading material is fibrous insulation.

7. A structure comprising an impermeable shell forming a wall between a warm space and the atmosphere, a vapour barrier, fibrous insulation of substantial capillarity separating the vapour barrier from the shell, a plurality of wicks passing through the vapour barrier and in contact with said insulation to conduct condensed water from the insulation to the warm side of the barrier, and a layer of material interposed between the vapour barrier and the fibrous insulation, the said layer adhering to this insulation and the vapour barrier being adhesively keyed to the said layer.

8. A structure according to claim 7 in which a water-insoluble adhesive is used to stick the vapour barrier to the insulation and is applied only locally.

9. A structure comprising an impermeable shell forming a wall between a warm space and the atmosphere, fibrous insulation of substantial capillarity in contact with the shell, a vapour barrier of a plastic material adherent to the fibrous insulation, and a plurality of wicks passing through the vapour barrier and adapted to conduct condensed water from the insulation to the warm side of the barrier to be evaporated into the warm space.

10. A structure according to claim 9 in which the vapour barrier is bituminous.

11. A structure according to claim 9 in which the wicks are constituted by fibres extending out of a fibrous layer in contact with the vapour barrier.

12. A structure comprising an impermeable shell forming a wall betwen a warm space and the atmosphere, a vapour barrier, fibrous insulation separating the vapour barrier from the shell, a fibrous layer on the warm face of the vapour barrier, and fibres extending from said fibrous layer through the vapour barrier and forming a plurality of wicks in contact with said insulation to conduct condensed water from the insulation to the warm side of the barrier to be evaporated into the warm space.

13. In the production of an insulating structure, the method which comprises applying an impermeable material to the face of fibrous insulation to form a vapour barrier and pulling fibres through the vapour barrier from the insulation to form wicks.

14. In the production of an insulating structure, the method which comprises applying an impermeable material to the face of fibrous insulation to form a vapour

barrier, covering the impermeable material with a fibrous layer, and pushing fibres from this layer through the impermeable material into contact with the fibrous insulation to form wicks.

15. A method according to claim 14 in which the impermeable material is bituminous and is applied as two layers, the first layer is allowed to form a skin before the second is applied, fibre is sprayed onto the second layer while it is still sticky, and the wicks are then formed by pushing some of the sprayed fibre through both layers.

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