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THERMAL INSULATION, BUILDING CONSTRUCTION, AND METHOD
OF PROTECTING THERMAL INSULATION
AGAINST MOISTURE ATTACK
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2,887,426

Fig. 2

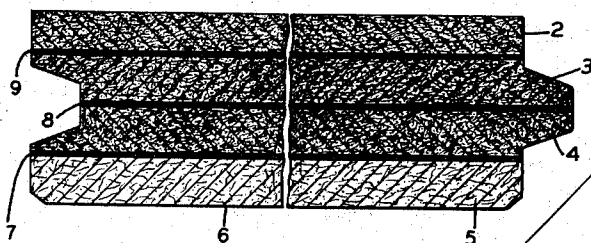


Fig. 1

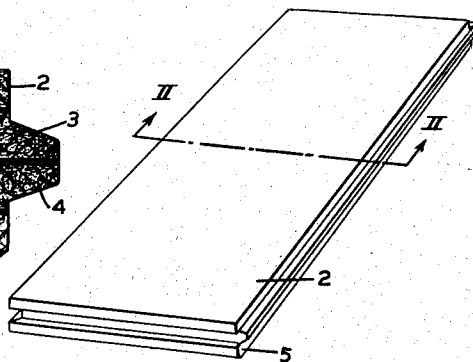


Fig. 3

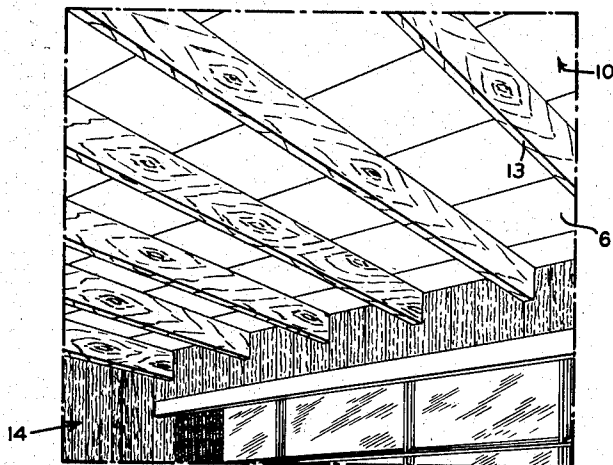
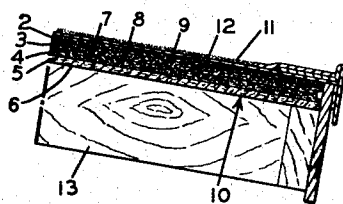


Fig. 4



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THERMAL INSULATION, BUILDING CONSTRUCTION, AND METHOD OF PROTECTING THERMAL INSULATION AGAINST MOISTURE ATTACK

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9 Claims. (Cl. 154—142)

This invention relates to a roof deck insulation or similar insulating structure which in normal use is subjected to cyclic humidity and temperature conditions. It also relates to a building structure including roof deck insulation and to a method of protecting a roof deck insulation against the action of moisture deposited therein.

Roof deck insulation is sometimes used as a structural material secured directly to the roof joists and exposed on the lower surface to the interior of the room below the roof. In school buildings and homes with so-called exposed beam construction, the roof deck insulation may be provided with a decorated surface which is exposed between the beams. In some cases, the inner surface may be perforated to enhance the sound absorbing qualities of the insulation, or it may be merely painted to provide a pleasing, light-reflecting surface.

Usually, a built-up roofing is applied directly to the roof deck insulation by the use of melted asphalt mopped onto the insulation and into which is pressed a layer of asphalt saturated roofing paper. A plurality of layers of this paper is usually applied in melted asphalt to build up a roof covering of the desired thickness.

There is thus formed a structure which comprises supporting beams or the like to which are fastened pieces of roof deck insulation, generally with tongue and groove joints on the edges of the pieces. The short edges are usually positioned so as to overlie the beams at the joints where adjacent pieces of the insulation abut. The insulation is exposed to the room below on its inner surface and is substantially completely sealed on its outer or upper surface by the roofing material.

In winter, the months when the upper surface of the insulation next to the roof covering is at a substantially lower temperature than that at the exposed inner surface, there is a tendency of the moisture in the air within the room to enter the insulation as water vapor, to condense in the insulation at the point where the dew point temperature is reached in the insulation, and to migrate toward the coldest portion of the insulation adjacent to the roof covering. A reverse action occurs in the summer months when the higher temperature at the outside roof surface creates a decreasing temperature gradient within the insulation from the upper surface engaged by the roof covering to the lower surface exposed in the room.

The average wintertime temperature in the area of Washington, D.C., for instance, will generally be about 44° F., and the inside temperature at the surface of the roof deck insulation in a home or school will generally be in the order of 65° to 75° F. The relative humidity inside may be in the range of 30 to 50%. These conditions will vary, but they are illustrative of typical conditions which may exist in service. There is a cyclic change in conditions from winter to summer, of course, and there are also changes in temperature and humidity conditions from day to day due to changes in climatic conditions as well as those created by the householder. For instance, if laundry is dried in the house, there will be a substantial increase in the humidity within the home.

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These changes are generally of short duration, however, and as a rule do not substantially affect the overall operation of the roof deck insulation. The conditions are not static, however. The ingress of moisture into the roof deck insulation is, therefore, a problem which is present and must be taken into consideration in the manufacture of the insulation and the construction of the buildings where such material is used.

In an effort to solve the problem, it has been proposed to vapor seal the insulation as by the use of a metal foil, polyester film (Mylar), vinyl resin film, or other vapor barrier sheets positioned within the insulation. This may be accomplished by adhesively joining two or more layers of insulation together with a layer or layers of metal foil or the like disposed at the joint or joints between the pieces. This is not a solution to the problem of moisture infiltration, however, since water vapor will find its way into the insulation along the edges where adjacent sections of the roof deck insulation abut; and with the vapor barrier between the adjacent layers of insulation provided by the metal foil or the like, this moisture will not be readily exhausted from within the insulation during the summer months.

For optimum results the water vapor barrier should prevent ingress of water vapor into the insulation to the greatest degree possible but should permit egress of the water vapor and moisture out of the insulation with the greatest ease possible. Thus, any moisture which may accumulate in the insulation may be readily expelled.

An object of the present invention is to provide an insulating structure for use under cyclic humidity and temperature conditions which will minimize the ingress of water vapor into the insulation but which will permit its rapid egress upon reversal of the humidity and temperature conditions which induce the ingress of water vapor.

Another object of the invention is to provide a building structure including a roof deck insulation or the like which may be directly exposed to the interior atmosphere of a building on one side, and in contact with an exposed roof covering on the other side, and which will not be subject to moisture deterioration upon cyclic changes of humidity and temperature conditions encountered by the insulation.

A further object of the invention is to provide a method of protecting insulating material against the deleterious action of water under service conditions where the insulation is subjected to cyclic temperature and humidity conditions.

In the accompanying drawing:

Figure 1 is a perspective view of a unit of roof deck insulation or the like embodying the invention;

Figure 2 is an enlarged sectional view taken along the line II—II of Figure 1;

Figure 3 is a perspective view of a building construction, broken away, and illustrating the invention; and

Figure 4 is a sectional view of a portion of the roof structure of Figure 3, showing the insulation with the applied roof covering.

Referring to the drawing, there is shown in Figures 1 and 2 a unit of roof deck insulation which may be two inches thick, two feet wide, and eight feet long, having a projecting tongue on one long and one short edge and a corresponding tongue receiving groove on the other long and short edges. The unit is made up of laminae or plies 2, 3, 4, and 5 of one-half inch thick insulating material. The plies 2, 3, and 4 may be asphalt impregnated fiber insulating board, and the ply 5 may be regular interior finish insulating board having a decorative coating 6 applied to one surface thereof which will constitute the interior surface of the insulation to be exposed

between the supporting roof joists, as shown in Figure 3. The insulation of these layers is water vapor pervious.

Between the plies there are disposed sealing layers 7, 8, and 9. In the embodiment illustrated these layers are formed as a composite joining and sealing medium.

In order to obtain the desired result, the sealing layers are compounded or constructed of a material which will minimize water vapor penetration into the insulation but which will permit relatively more rapid movement of the water vapor out of the insulation when humidity and temperature conditions at the sealing layer are increased.

A suitable sealing and adhesive material is compounded as follows:

Asphalt emulsion -----	46.7% (dry solids basis).
Keltex -----	0.3% (dry solids basis).
Total water -----	53.0%.

The asphalt emulsion may be formed by conventional procedures using a soap type emulsifying agent with an asphalt having a melting point in the order of 180° F., for example. The Keltex is a commercial alginate composition which may be dispersed in water and added to the emulsion. A small quantity of boric acid or other similar material may be added to reduce the pH of the asphalt emulsion which is alkaline and might otherwise be detrimental to the Keltex. About one part of boric acid for each four parts of Keltex in the above example was found to be adequate. This sealing material has the unique property of a much greater water vapor permeance under high humidity conditions than under low humidity conditions. This was determined on test specimens made up of insulating material as shown in Figures 1 and 2 and as described above, having the composition of the foregoing example applied between each of the plies as a combined adhesive and sealing material, the quantity of the sealing material used being 25 grams per square foot of joint between pairs of adjoining plies, on a dry solids basis. A specimen so prepared and tested in accordance with Proposed Tentative Method of Test for Water Vapor Transmission of Materials Used in Building Construction, Draft No. 5, as revised by the Editorial Committee of the ASTM, and dated September 11, 1954, using the "desiccant method" as therein described with a wet side condition of 70° F. $\pm$ 2° F. and relative humidity maintained at 50% $\pm$ 2%, and a dry side condition of 70° F. $\pm$ 2° F. and less than 1% relative humidity, had a water vapor permeance of 0.1 to 0.5 perm. A perm is defined in the ASTM specification referred to as a unit of permeance equivalent to 1 grain per square foot per hour per inch of mercury under stated test conditions.

A similar specimen of identical construction, when tested under conditions simulating summer drying conditions in an actual installation, and to which specimen, water had been added to represent the most severe moisture condition in the roof deck insulation due to winter-time conditions, had a water vapor permeance in the order of 3.0 to 6.0 perms, more than six times the water vapor permeance under the lower humidity conditions (the desiccant method) referred to in the paragraph above.

The reason for this action is not fully understood. It may be due to the presence of the alginate in the asphalt film, providing paths for the transmission of vapor more readily through the film at the higher humidities. It may also be related to the presence of actual moisture at the surface of the sealing film under such conditions, resulting in a much faster rate of water vapor transmission. This would explain the rapid passage of water vapor out of the insulating plies when the sealing layer is wet, as occurs in the uppermost ply of insulating material when moisture is condensed in that layer. Regardless of the theory involved, it is known that the rate is substantially higher and that it has an unusually salutary effect upon the ability of the installed insulation to expel its accumu-

lated moisture during the very periods when removal of moisture from within the insulation is desirable.

This action can be illustrated by reference to Figures 2, 3, and 4. The insulation is shown in Figure 2 as made up of four plies of one-half inch insulating board between each of which is disposed a sealing layer of the above composition. As mentioned above, the total water vapor permeance of this unit when tested in accordance with the ASTM proposed tentative "desiccant method" may be in the order of 0.1 to 0.5 perm.

Mounted upon the roof deck insulation 10, as shown in Figure 4, is a four ply built-up asphalt felt roof diagrammatically illustrated at 11, cemented directly to the upper surface of the roof deck insulation 10 and effectively sealing the insulation against the penetration of water vapor thereinto. The roof covering has a crushed or granular stone surfacing 12. The roof deck insulation 10 is supported directly upon roof beams 13 spaced on 32" centers. The interior surface 6 of the insulation is directly exposed to the conditions existing within the room area 14.

It will be assumed that under normal winter conditions in Washington, D.C. the temperature at the outer roof surface will average about 44° F., as noted above, and the temperature at the upper surface of the insulation will be about the same because the roofing material will have a very low insulating value. The temperature within the room 14 may average about 70° F., and the relative humidity may average about 40%, and thus the inner ply 5 of insulation will have these approximate temperature and humidity conditions at its exposed inner surface 6. Since the roof covering essentially fully seals the upper surface of the roof deck insulation, the vapor pressure in the upper ply 2 of insulation at the roof engaging surface will be lower than the vapor pressure in the room or at any other point within the roof deck insulation. There will, of course, be some small amount of moisture in the insulation. Now, with these temperature and vapor pressure differences, water vapor will move from the room area 14 into the inner ply 5 of the insulation (referring now to Figure 2 for consideration of the insulating structure) toward the first sealing layer 7 interposed between the inner ply 5 and the adjacent superimposed ply 4. Here the temperature will be somewhat less than the 70° F. temperature at the surface 6 of the ply 5 exposed in the room and the relative humidity normally will be slightly higher than exists in the room because of the temperature drop in the insulation from 70° F. at the surface 6 to about 62° F. within the insulation adjacent to the sealing layer 7, calculated for a 2" roof deck insulation, as shown in Figure 2, having a built-up roof covering thereon, the temperature of which on the outside is 44° F. Since the sealing layer 7 is not wholly impervious to the passage of water vapor, some small amount will pass through this layer 7 into the insulating ply 4 because of the slight water vapor permeability of the sealing layer 7, as noted above. The ingress of water vapor into ply 4 through such layer 7 will be very slow. The water vapor which passes through sealing layer 7 and is received in insulating ply 4 will in turn move through ply 4 towards sealing layer 8 disposed between plies 3 and 4 because of the existence of a vapor pressure differential between the plies 4 and 3 across the sealing layer 8. The vapor pressure difference between plies 4 and 3 across the sealing layer 8 normally will be less than the difference between plies 5 and 4 across the sealing layer 7 therebetween; and, therefore, a still lower rate of water vapor penetration through the sealing layer 8 will occur. This action is repeated at each of the sealing layers until the dew point temperature for the water vapor is reached, generally designed to occur in one of the plies above ply 5. Thereupon, the moisture is deposited in the insulation. There will be a gradual migration of the moisture toward the cold surface adjacent to the roof covering, and insulating ply 2 may contain as much as 20% of moisture

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or more under unusually severe conditions. There will be gradually lesser amounts of water in the other plies. It must be remembered that in actual use the roof covering will be exposed to the sun and, even in winter months, there is considerable solar radiation which will affect the temperature of the insulation. In other words, the conditions are not static as they are in a water vapor permeance test.

When spring comes and warm weather and bright sun heat up the surface of the roof, the moisture in the ply 2 will move toward the sealing layer 9 between plies 2 and 3. The vapor pressure within the ply 2 at the sealing layer 9 will be high under such conditions, and actual condensation of water on the surface of the sealing layer 9 may occur. As noted above, under such conditions the moisture passes at an accelerated rate through the sealing layer, since its transmission rate is much higher under conditions of high relative humidity. A similar action takes place at each of the sealing layers as the moisture is driven down through the insulation. In a relatively short time, the moisture within the insulation will be reduced to about the normal equilibrium value.

This unique result may be achieved with the present invention without substantial sacrifice in the insulating value of the structure; for, as noted above, the total permeance of the insulation will be in the order of 1 perm or less and may be as low as .1 perm, for instance.

To determine the suitability of any barrier or sealing material for use in the practice of the invention, a film of the material may be formed and subjected to both the so-called "desiccant method" and the so-called "water method" of the ASTM specification referred to above. These tests should be conducted under conditions in the test chamber of $70^{\circ}\text{F} \pm 1^{\circ}\text{F}$. and a relative humidity of $50\% \pm 2\%$. These two tests compare water vapor permeance (a) with a relative humidity of 50% on one side of the specimen under test and a relative humidity on the other side which is nominally 0%—the "desiccant method" and (b) with a relative humidity of 50% one one side of the test specimen and a relative humidity on the other side which is nominally 100%—the "water method." These two tests simulate winter and summer service conditions respectively which may be encountered in a roof deck insulation.

Any sealing layer which has a water vapor permeance by the "water method" which is five times or more greater than its water vapor permeance by the "desiccant method" and which provides an insulating unit which has a water vapor permeance at 70°F . of less than 1.0 perm by the "desiccant method" may be substituted for the asphalt emulsion-alginate composition described in the embodiment of the invention chosen for illustration. There is no reason why a material having a water vapor permeance 20 or 40 times as great by the "water method" as by the "desiccant method" should not be used. It will be clear, of course, that the water vapor permeance of sealing layers may vary depending upon their thickness; and where the difference in water vapor permeance (water method vs. desiccant method) is satisfactory but the total permeance of the insulating unit is found to be too high, the use of thicker layers of sealing material between the insulating plies generally will be effective to reduce the total permeance of the unit to the desired value without substantial sacrifice in moisture dissipation from within the insulation during the summer months. As low a water vapor permeance as commercially practicable should be achieved by the sealing material so as to avoid undesirably large quantities of moisture penetrating into the insulation during the winter months or under other conditions where water vapor will move into the insulation over prolonged periods. Likewise, a sealing layer having as high a water vapor permeance ratio, water method to desiccant method, as

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practicable should be selected to insure rapid moisture dissipation from within the insulation during the summer months.

The sealing material should be moisture-resistant. It should not lose its sealing characteristics under the temperature conditions encountered in use. When the sealing material also serves as an adhesive for joining the insulating plies, it should maintain its bonding characteristics under temperature conditions encountered in transportation from the manufacturing plant to the job site as well as in use. These conditions will be met for the Washington, D. C. area if the sealing material is resistant to temperature in the range of -20°F . to 160°F .

I claim:

1. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising a plurality of plies of water vapor pervious thermal insulating material disposed in superimposed relationship and water-resistant sealing material constituting a partial water vapor barrier interposed between said plies of insulating material, said sealing material being characterized by a water vapor permeance at 70°F . when tested in accordance with the "water method" as herein defined which is at least five times as great as its water vapor permeance at 70°F . when tested in accordance with the "desiccant method" as herein defined, said unit including said plies of insulating material and said interposed sealing material having a water vapor permeance of less than 1.0 perm at 70°F . when tested in accordance with said "desiccant method."

2. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising at least three plies of water vapor pervious fibrous thermal insulating material disposed in superimposed relationship and layers of water-resistant sealing material constituting a partial water vapor barrier interposed between adjacent plies of said insulating material, said sealing material being characterized by a water vapor permeance at 70°F . when tested in accordance with the "water method" as herein defined which is at least five times as great as its water vapor permeance at 70°F . when tested in accordance with the "desiccant method" as herein defined, said unit including said plies of insulating material and said interposed layers of sealing material having a water vapor permeance of less than 1.0 perm at 70°F . when tested in accordance with said "desiccant method."

3. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising a plurality of plies of water vapor pervious fibrous thermal insulating material disposed in superimposed relationship and adhesively joined together by water-resistant sealing material constituting a partial water vapor barrier interposed between said plies of insulating material, said combined adhesive and sealing material being characterized by a water vapor permeance at 70°F . when tested in accordance with the "water method" as herein defined which is at least five times as great as its water vapor permeance at 70°F . when tested in accordance with the "desiccant method" as herein defined, said unit including said plies of insulating material and said interposed sealing material having a water vapor permeance of less than 1.0 perm at 70°F . when tested in accordance with said "desiccant method."

4. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising at least three plies of water vapor pervious thermal insulating material disposed in superimposed relationship and adhesively joined together by layers of sealing material constituting a partial water vapor barrier interposed between said plies of insulating material, said combined adhesive and sealing material comprising a mixture of asphalt and an alginate and being characterized by a water vapor permeance at 70°F . when tested in ac-

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cordance with the "water method" as herein defined which is at least five times as great as its water vapor permeance at 70° F. when tested in accordance with the "desiccant method" as herein defined, said unit including said plies of insulating material and said interposed layers of sealing material having a water vapor permeance of less than 1.0 perm at 70° F. when tested in accordance with said "desiccant method."

5. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising the combination of claim 4 in which said asphalt is in the form of the dried residue of a soap type emulsion of asphalt in water.

6. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising an inner ply of water vapor pervious thermal insulating material having a decorated surface for exposure at the interior of a room ceiling, a plurality of plies of water vapor pervious fibrous thermal insulating material disposed in superimposed relationship to said inner ply, and water-resistant sealing material constituting a partial water vapor barrier interposed between said plies of insulating material, said sealing material being characterized by a water vapor permeance at 70° F. when tested in accordance with the "water method" as herein defined which is at least five times as great as its water vapor permeance at 70° F. when tested in accordance with the "desiccant method" as herein defined, said unit including said plies of insulating material and said interposed sealing material having a water vapor permeance of less than 1.0 perm at 70° F. when tested in accordance with said "desiccant method."

7. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising the combination of claim 6 in which said superimposed plies are waterproofed by the incorporation therein of asphalt with the fibers.

8. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising a plurality of plies of water vapor pervious thermal insulating material disposed in superimposed relationship and a combined adhesive and sealing material constituting a partial water vapor barrier interposed between said

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plies of insulating material and joining the same together, said combined adhesive and sealing material being water-resistant and characterized by a water vapor permeance at 70° F. when tested in accordance with the "water method" as herein defined which is at least five times as great as its water vapor permeance at 70° F. when tested in accordance with the "desiccant method" as herein defined, said unit including said plies of insulating material and said interposed sealing material having a water vapor permeance of less than 0.5 perm at 70° F. when tested in accordance with said "desiccant method."

9. A roof deck insulation unit for use under cyclic humidity and temperature conditions comprising at least three plies of water vapor pervious fibrous thermal insulating material disposed in superimposed relationship and adhesively joined together, a sealing layer between each of said plies, said sealing layer comprising a water-resistant sealing material constituting a partial water vapor barrier characterized by a water vapor permeance at 70° F. when tested in accordance with the "water method" as herein defined which is at least five times as great as its water vapor permeance at 70° F. when tested in accordance with the "desiccant method" as herein defined, said unit including said plies of insulating material and said interposed sealing material having a water vapor permeance of less than 1.0 perm at 70° F. when tested in accordance with said "desiccant method."

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