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INSULATED BUILT UP ROOF AND INSULATION THEREFOR

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FIG. 1

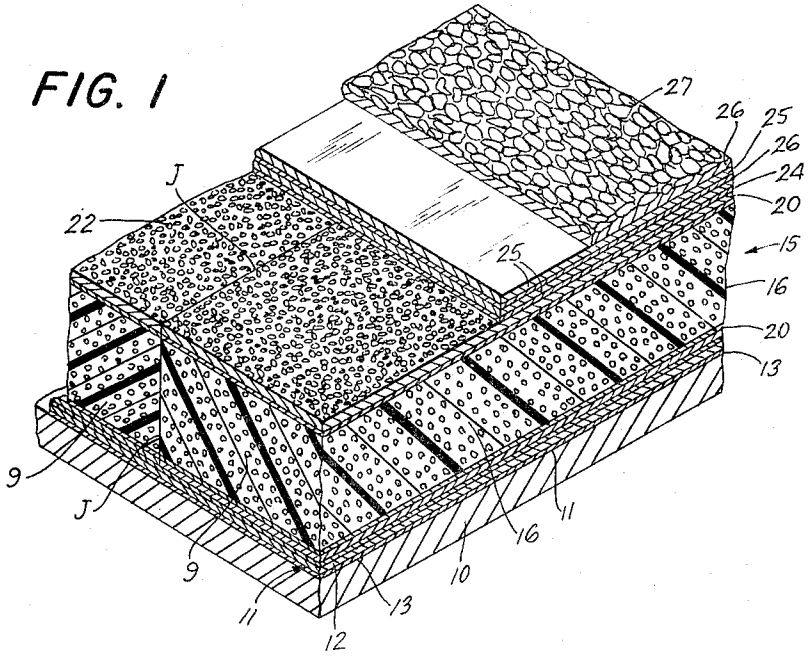
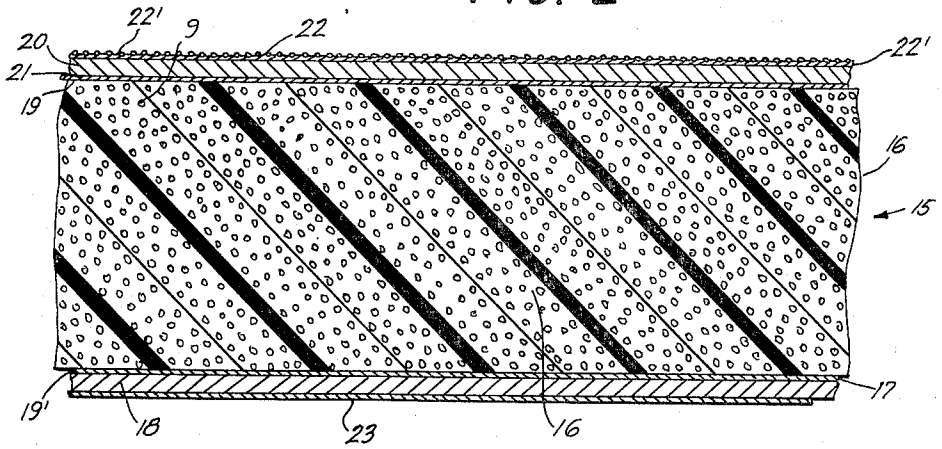


FIG. 2



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INSULATED BUILT UP ROOF AND INSULATION THEREFOR

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This invention relates to roof structure, and, more particularly, to roofs for homes, food markets, shopping centers and industrial buildings, many of which are air conditioned, and which roofs are provided with insulation to maintain the interior cooler during summer, with less load on the air conditioning system in the case of air conditioned buildings, and to conserve heat during winter. This invention includes such roof structures as well as the novel insulating material employed to form the heat insulating layer or portion thereof.

Built up flat roofs, comprising several alternate layers or plies of waterproofed roofing felt and coal tar pitch or asphalt coating layers, a top layer of pitch, asphalt or other binder in which is partially embedded gravel, slag, markle chips or tile forming the exposed or traffic surface, and having a layer of insulation between the roof deck and the lowermost felt layer are known. Fiberboard, foamed polystyrene, glass fiber, perlite and cellular glass have been suggested and used as insulating materials.

All of these known insulating materials have relatively high thermal conductivities. Cellular glass is rigid and brittle and frequently breaks in handling and in use due to the irregularities often present on a roof deck. Foamed polystyrene has the disadvantage and drawback that the molten bitumen employed in bonding the overlying felt layer to the insulation melts and destroys or damages the foamed polystyrene. Moreover, when cut back adhesives, i.e., adhesives containing solvents which evaporate and thus cause the adhesive to set, are employed as the bonding media in forming the built up roof, the solvents attack and damage the polystyrene.

It is a principal object of the present invention to provide a roof structure having an insulating layer beneath the alternate layers of waterproofed roofing felt and waterproofing binder, which insulating layer is of markedly greater thermal efficiency than other known types of insulation, including the insulating materials hereinabove mentioned.

It is a further object of the present invention to provide a roof insulation member in the form of a board or unit of suitable size and thickness having a unique combination of properties which make it a superior roof insulation, namely: it has markedly greater thermal efficiency; does not absorb water; can be mopped with hot pitch or asphalt without deleterious effect on the insulation in the course of the construction of the built up roof; provides a walk-on, work-on surface over which a workman can walk and transport in wheelbarrows, dump carts or other such equipment, necessary materials required in the construction of the roof, and on which can be placed buckets of waterproofing material, rolls of felt and other loads distributed over relatively small areas, all without crushing or forming deep impressions therein or destroying the insulating value of the insulation.

Still another object of this invention is to provide a roof having an insulating layer constituted of a plurality of board-like units of suitable size for easy handling adapted to be laid in abutting relation to produce the insulating layer which is mechanically strong, chemically

inert, resistant to heat, highly durable and practically impervious to water.

Other objects and advantages of this invention will be apparent from the following description thereof, taken in connection with the accompanying drawings in which is shown, for purposes of exemplification, a preferred embodiment of this invention without, however, limiting the claimed invention to this illustrative embodiment.

In the drawings,

FIGURE 1 is a fragmentary perspective of a vertical section showing the several layers, with portions broken away to show the interior structure, of a roof embodying the present invention; and

FIGURE 2 is a fragmentary vertical section through the novel roof insulation embodying this invention.

Referring to the drawings, **10** is the roof deck of a building, which deck may be of wood, poured gypsum or concrete, precast slabs or other structural decks, or, in the case of some industrial buildings, a fluted steel deck with the flutes spaced relatively close to each other, say, a few inches apart. The deck **10** is a flat or nearly flat, i.e., may be pitched slightly. Employing a fluted steel deck the upper edges of the flutes lie in substantially the same plane. The insulation layer **15** rests on these upper edges or on the deck **10**. Insulation layer **15** has sufficient structural strength not to be deformed or damaged by the loads to which it is subjected, both during the construction of the built up roof and in the finished roof, notwithstanding that the insulating layer **15** is supported at spaced areas by the edges or ridges of the flutes forming the fluted steel deck.

In the embodiment of the invention shown in FIGURE 1, the roof deck **10** is provided with a vapor barrier **11** consisting of a layer of bituminous saturated and coated roofing felt **12**, suitably bonded to the deck **10** by a layer of waterproofing material **13**, desirably asphalt or coal tar pitch. The vapor barrier thus produced completely covers the entire area of the roof deck. The present invention, however, is not confined to structures having such vapor barriers, although a vapor barrier construction is preferred. If desired, the roof insulation **15** can be applied directly to the roof deck **10** being bonded thereto by a layer of water proofing material such as pitch or asphalt, the same as layer **13**, in which case the felt layer **12** is omitted.

The roof insulation unit **15** contains a rigid urethane foam layer or core **16**, from ¼ inch to 8 inches thick, preferably ¾ inch to 2 inches thick, having at least 50% by volume and preferably at least 75% by volume closed cells, as up to 95% or more, a compressive strength of at least 10 pounds per square inch with no more than 5% by volume deflection, preferably at least about 20 pounds per square inch with no more than 5% deflection, a density of from 1.1 to 4, preferably 1.5 to 2.5 pounds per cubic foot, a flexural strength at least 20 pounds per square inch, preferably at least 40 pounds per square inch, for example, up to 80 to 100 pounds per square inch, and a k value not exceeding about 0.24, preferably about 0.13 B.t.u. per hr. per sq. ft. per inch thickness per ° F. The k values in this specification indicate the thermal conductivity of the material, the lower the k value, the lower the thermal conductivity, i.e., the better the insulating value.

For rigid urethane foams in which the cells **9** are filled with chlorofluoromethanes or chlorofluoroethanes, preferably monofluorotrichloromethane, the k value is 0.13; for such foams in which the cells are filled with CO_2, the k value is 0.24. A typical core **16** may be one inch thick, have closed pore volume of at least 95%, compressive strength of 22 pounds per square inch with less

than 5% by volume deflection, density of about 1.8 pounds per cubic foot, flexural strength of 40 pounds per square inch, and a *k* value of about 0.13 B.t.u. per hr. per sq. ft. per inch thickness per ° F.

The back **17** of rigid urethane core **16** has bonded thereto a sheet of waterproofed felt which completely covers the back **17** with the edges of the felt coterminal with the edges of the back **17**. The face or top surface **19** has bonded thereto a sheet **20** of waterproofed felt which completely covers face **19** with the edges of the felt coterminal with the edges of the face **19**. Preferably each of the cap sheets **18** and **20** is roofing felt saturated with a bituminous material and coated on the opposite sides with bituminous coating material, desirably asphalt or pitch. The top coating layer **19'** thus produced on felt **18** can be employed to effect the bonding of the felt sheet **18** to the back **17**. Similarly the coating layer **21** on the underside of the felt sheet **20** can be used to effect the bonding of this felt or cap sheet **20** to the face **19** of the core.

The surface of felt or cap sheet **20** has a layer of anti-stick material **22** in the coating layer **22'** thereon. Coating layer **23** on felt **18** may be free of such anti-stick material, but preferably has anti-stick material applied thereto. The layer of anti-stick material **22** and the top coating layer **22'** provide a protective wearing surface for the insulation layer **15** during laying of the built up roof when workmen walk over the insulation layer **15**, and this layer is subject to loads such as wheelbarrows, dump carts, etc., propelled thereover, or rolls of roofing felt. Preferably sheets **18** and **20** are each of roofing felt impregnated or saturated with a waterproofing material, such as asphalt or coal tar, and coated on the opposite sides thereof with a layer of waterproofing material, desirably bituminous material, such as asphalt or coal tar pitch.

The resulting sandwich-like unit or laminate is made of any desired dimension for easy handling, of rectangular shape so that the units can be laid in abutting relation. Typical size is 3 feet by 4 feet rectangular units having a total thickness of 1.1 inches, the core **16** being 1 inch thick, and the coated sheets **18** and **20** each being approximately 0.05 inch thick.

To the top of insulating layer **15**, i.e., to layer **22**, is applied a coating of waterproofing material **24** such as hot asphalt or hot coal tar pitch having a softening point of about 140° to 200° F. applied at a temperature of about 350° to 450° F. Instead of such hot application of the binder a cut-back adhesive containing a solvent can be applied at ambient temperatures to effect the bonding of the respective felt layers to each other and the lowermost felt layer to the insulation **15**. Coating **24** covers the entire area of the roof surface, including the joints J between abutting units of the insulating material. Applied to coating layer **24** are alternate layers of waterproof roofing felt **25** and waterproof coating layers **26**, each covering the entire area of the roof. Usually 2 or 3 waterproof felt layers are applied with waterproof coating layers between adjacent felt layers bonding the lowermost felt layer to the insulating layer **15** and on top of the top felt layer. The invention, however, is not limited to roof constructions having 3 or 4 layers of roofing felt alternating with coating layers. It includes roofs employing only 2 layers of roofing felt, or more than 4 layers of such felt, each bonded by a waterproof coating layer with the underlying felt layers.

To the top coating layer **26** is applied a layer of slag or gravel **27** forming a wearing or traffic surface. Instead of such gravel surface, tile can be laid in the top coating layer **26** and bonded thereby to the underlying roof construction.

The rigid urethane foam of which the layer or core **16** is constituted can be produced by known procedures of reacting a polyfunctional organic isocyanate and a high molecular weight polyol or polyether. Two types of process are generally used for producing such foams, namely, the "one shot" process and the so-called "prepolymer" method. In the "one shot" process, the diisocyanate, polyol or polyether are mixed simultaneously along with suitable catalysts, foam stabilizers, cell size control agents and blowing agent. In the prepolymer process, a portion of the polyol or polyether is mixed with the isocyanate to produce a prepolymer usually containing a large excess of unreacted isocyanate and the prepolymer thus formed reacted with the remainder of polyol or polyether in the presence of catalysts, foaming agents, stabilizers, cell size control agents, etc.

Isocyanates suitable for making such foams include, among many others, 2,4- and 2,6-tolylene diisocyanates, phenylene diisocyanate 3,3'-bitolylene-4,4'-diisocyanate, methylene di-p-phenyleneisocyanate, 1,5-naphthalene diisocyanate, and a triisocyanate prepared by reacting 3 mols of tolylene diisocyanate with one mol of hexanetriol.

Polyols and polyethers suitable for making rigid foams include (1) trihydric alcohols such as glycerin, castor oil, etc.; (2) polyalkylene ether glycols prepared from ethylene, propylene or tetramethylene glycols, including polybutylene glycol of molecular weight 3000, derived from 1,4-butylene glycol, known commercially as Teracol 30; (3) polyethers having hydroxyl numbers from 300 to 700, including polyethers derived from propylene oxide; and (4) polyesters which are the reaction products of dihydric alcohols and dicarboxylic acids, for example, polyesters prepared by copolymerizing a dicarboxylic acid, such as adipic, phthalic, sebacic, succinic, or oxalic acid, with a glycol or polyalkylene glycol, such as ethylene, diethylene, propylene and butylene glycols, or obtained by copolymerizing ethylene glycol or glycerin with a mixture of phthalic and adipic acids; the last mentioned polyesters are alkyd resins.

Catalysts used can be the amines, such as dimethylethanolamine, tetrahydroxypropylethylenediamine and other amines, including tertiary amines, used as catalysts in the production of urethane foams, and tin compounds such as stannous octoate, dibutyltin dioctoate and dibutyltin dilaurate.

Foam stabilizers and fine cell forming agents are the silicones, such as those of the dimethyl siloxane type, or alkylsilanepolyoxyethylene copolymers.

Blowing agents can be water, which react with the isocyanate to liberate carbon dioxide to produce the foam, nitrogen, air, carbon dioxide or the chlorofluoromethanes or chlorofluoroethanes; the latter blowing agents result in urethane foams of maximum insulation value. Particularly preferred is monofluorotrichloromethane. These chlorinated fluorinated hydrocarbons result in low density urethanes having a maximum cell size of about 30 mils and typically averaging 10–15 mils, diameter and unusually low thermal conductivity. The cells **9** are shown on the drawing greatly enlarged for illustrative purposes.

In general, such rigid urethane foams are produced employing a formulation containing sufficient polyfunctional molecules to produce cross-linking with consequent production of closed cells **9** in amount of at least 50% of the total cells in the body, preferably at least 75% and desirably up to 95% or more. A tri-functional molecule, e.g., glycerin, contributes 1 mol of cross links per mol equivalent, and a tetra-functional molecule, 2 mols, and so on. Since the production of such rigid foams is known to those skilled in the urethane art, it is believed that further description of the production of such foams is unnecessary.

Bonding of the rigid urethane core **16** to the roofing sheets **18** and **20** can be effected by sandwiching a slab of rigid urethane foam of desired thickness between the sheets **18** and **20** coated at least on the side to be applied to the core while the coating layers **19'** and **21** are still hot and plastic, and then subjecting the resultant assembly to pressure, for example by passage between press rolls,

to effect bonding of the waterproofing sheets **18** and **20** to the slab of foam. Alternatively, a coating layer of hot asphalt or pitch or cut-back adhesive of a bituminous character can be applied to the surfaces of the rigid urethane foam slab, the waterproof sheets **18** and **20** applied, and the assembly subjected to pressure, to produce firm bonding of the waterproofing cap sheets to the slab of foam **16**. The assembly thus produced, after cooling, is cut into units of the desired size, for example, three feet by four feet, or any other size that can be handled conveniently.

An important feature of this invention is that the opposite sides of the rigid urethane core or layer **16** have bonded thereto the waterproof cap sheets **18** and **20**. These sheets protect the surfaces of the urethane slab. For example, sheet **20** provides a walk-on, work-on surface for the roofer, and a protective surface against damage to the underlying urethane core by the workmen walking thereon and from the temporary deposition of rolls of felt, buckets of asphalt, wheelbarrows, carts and other loads distributed over small areas employed in producing a built up roof. The sheets **18** and **20** of waterproofing material impart balance to the resultant structure. Rigid urethane panels having a sheet on one side only tend to warp. The double sheet essentially eliminates expansion tendencies, the resultant product is substantially non-warping.

When urethane slabs provided with no facing sheet or with but a single upper sheet are laid on hot asphalt, the corners and edges of the panels warp or lift as much as an inch or more. Another serious problem with foam panels not having the double facer sheets of the product embodying this invention arises when such panels become wet before or during application. Steam formed from moisture that may be present when the urethane foam is contacted with hot asphalt further increases the expansion of the foam. The product of this invention does not have these objectionable properties; the opposed sheets prevent contact of the rigid foam with the hot asphalt, protect the rigid foam against heat and water, and provide a balanced structure which remains flat under all conditions normally encountered during handling and application.

The sheets **18** and **20** of waterproofed felt also provide protection from the standpoint that use of urethane foams without such covering layers can involve damage to the foam should the asphalt or other waterproof binder be applied at a higher than usual temperature. While the rigid urethane foams are not seriously damaged as a general rule by hot asphalt and in this respect are markedly superior to polystyrene foams, the application of asphalt at excessively high temperatures has a tendency to swell the foam. Using the product of this invention, protection is provided because the cap sheets or covering sheets of waterproof roofing felt are not damaged by the application of asphalt or other waterproofing material, even though the temperature thereof should be unusually high.

The sheets **18** and **20** are substantially impervious to water and vapor, being made from felt which is saturated with a waterproofing material and coated with layers of waterproofing material, preferably asphalt or coal tar pitch. They prevent diffusion of gases and vapor into the cells of the urethane foam, and the loss of foaming agent, which, as indicated, is preferably chlorofluoromethane or chlorofluoroethane, from the cells. Hence they maintain the high insulating value of the insulating layer **15**.

The roof insulation of this invention involving a rigid urethane layer or core, having bonded thereto on the opposite sides thereof waterproofed felt layers, has at least twice the thermal efficiency of other known types of roof insulation, does not absorb water, can be laid with hot pitch or asphalt without injury, and provides a walk-on, work-on surface for the roofer. Its thermal conductivity is so low that it can be used whereever the roof insulation requirements are the most rigid, such as electrically heated, air conditioned, or cold storage buildings and structures designed for optimum comfort. The preferred embodiment of this invention involving a rigid urethane foam in which the cells are filled with chlorofluoromethane or chlorofluoroethane, preferably monofluorotrichloromethane has a *k* value of 0.13 B.t.u. per hr. per sq. ft. per inch thickness per °F. This compares with 0.27 for glass fiber and 0.30 for polystyrene, 0.34 for expanded perlite, 0.36 for fiberboard, and 0.40 for cellular glass. Thus, as compared with polystyrene, for example, more than twice the thickness of polystyrene must be used to obtain substantially the same heat insulation as provided by the heat insulating layer embodying this invention. In addition to this important advantage, the combination of rigid urethane core or layer **16** with the waterproof sheets **18** and **20** bonded thereto has the advantage that the insulating value remains stable because of the protection given to the core by the facer sheets; the panels, typically of 3′ x 4′ size, are easy to handle and install; the greater insulating value permits use of thinner panels when desired; the units are dimensionally stable and rigid, permitting tight butting of adjacent panels to form joints which minimize loss of heat; and the panels when installed can have applied thereto hot pitch or asphalt which will not damage the heat insulation, or can have applied thereto cutback adhesives containing solvents without damage to the insulating layer.

Since different embodiments of the built up roof and the insulation therefor could be made without departing from the scope of this invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A composite roof structure comprising a roof deck, a layer of insulation of substantially uniform thickness covering the deck, the insulation a plurality of re'atively large, substantially rectangular units in edge abutting relation, each unit consisting of a rectangular core of rigid urethane foam of uniform composition throughout the core, containing at least 50% closed cells, having a thickness of from ¼ inch to 8 inches, a compressive strength of at least 10 pounds per square inch with no more than 5% deformation, a density of from 1.1 to 4 pounds per cubic foot, a flexural strength of at least 20 pounds per square inch, and a *k* value not exceeding 0.24 B.t.u. per hr. per sq. ft. per inch thickness per °F., and a layer of felt saturated with a bituminous water-proofing material and coated with a bituminous water-proofing coating material factory bonded to each of the opposite surfaces of said urethane foam so that said units as laid each have the foam core protected by said felt covering the opposite sides thereof, at least one of said layers of felt having a layer of anti-stick material on the side opposite the urethane foam core, said roof structure having on said layer of insulating alternating layers of waterproof coating and bonding material and felt with the top coating layer on the top felt layer having a wear-resistant surface.

2. A composite roof structure as defined in claim **1**, in which the core of rigid urethane foam contains at least 75% closed cells filled with chlorinated fluorinated hydrocarbons having from 1 to 2 carbon atoms, said core having a thickness of from ¾ inch to 2 inches, a density of from 1.5 to 2.5 pounds per cubic foot, a flexural strength of at least 20 pounds per square inch, and a *k* value of about 0.13 B.t.u. per hr. per sq. ft. per inch thickness per °F.

3. Roof insulation comprising a relatively large, substantially rectangular unit adapted to be laid with other such units in edge abutting relation to form a layer of insulation of substantially uniform thickness, each unit

consisting of a rectangular core of rigid urethane foam of uniform composition throughout, containing at least 50% closed cells, having a thickness of from ¼ inch to 8 inches, a compressive strength of at least 10 pounds per square inch with no more than 5% deformation, a density of from 1.1 to 4 pounds per cubic foot, a flexural strength of at least 20 pounds per square inch, and a *k* value not exceeding 0.24 B.t.u. per hr. per sq. ft. per inch thickness per °F., and a layer of felt saturated with a bituminous water-proofing material and coated with a bituminous water-proofing coating material factory bonded to each of the opposite surfaces of said urethane foam so that said units as laid each have the foam core protected by said felt covering the opposite sides thereof, at least one of said layers of felt having a layer of anti-stick material on the side opposite the urethane foam core.

4. The roof insulation as defined in claim **3**, in which the board-like core of rigid urethane foam contains at least 75% closed cells filled with chlorinated fluorinated

hydrocarbons having from 1 to 2 carbon atoms, said core having a thickness of from ¾ inch to 2 inches, a density of from 1.5 to 2.5 pounds per cubic foot, a flexural strength of at least 20 pounds per square inch, and a *k* value of about 0.13 B.t.u. per hr. per sq. ft. per inch thickness per °F.

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EARL J. WITMER, *Primary Examiner.*