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THERMAL ROOF INSULATION AND METHOD OF PREPARING AN INSULATED BUILT-UP ROOF

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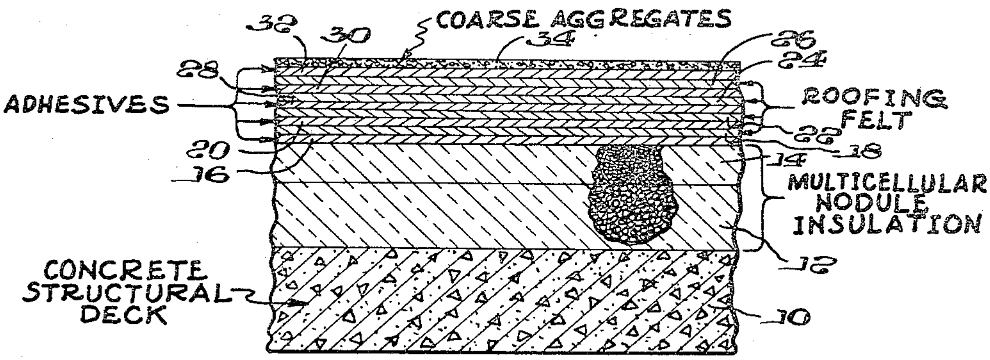

Fig. 1.

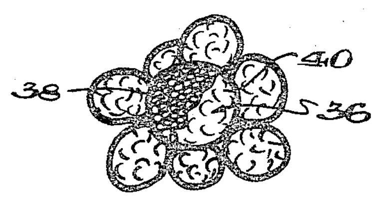

Fig. 2.

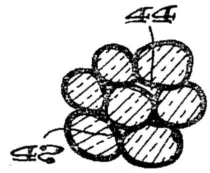

Fig. 3.

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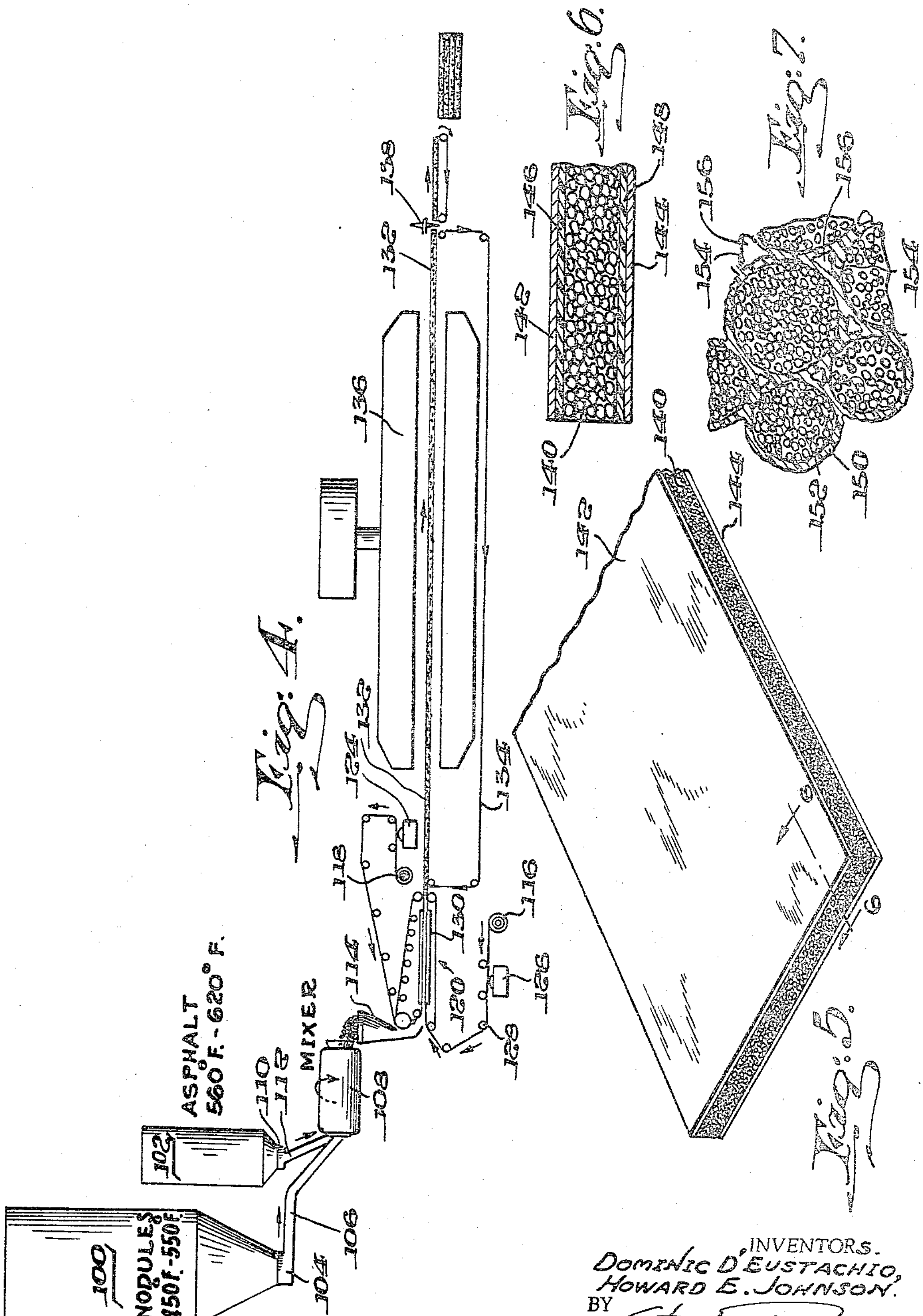

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

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Continuation-in-part of application Ser. No. 363,518, Apr. 29, 1964. This application July 27, 1965, Ser. No. 475,222
19 Claims. (Cl. 161—161)

ABSTRACT OF THE DISCLOSURE

Thermal insulation having interconnected interstitial voids for the flow of fluid between contiguous spherical nodules. The thermal insulation includes substantially spherical multicellular glass nodules arranged in contiguous relation and bonded to each other by a thermo-plastic bituminous material with interconnected interstitial voids between the nodules. The cellular glass nodules have thermal insulating properties and are themselves impervious to moisture. The thermo-plastic bonding material provides flexibility so that a layer of the thermal insulation can deflect and conform to irregular surfaces. The thermal insulation may be fabricated as a roof insulation board or may be applied directly to a substrate as a monolithic layer. The method of making the roof board includes admixing heated nodules and liquefied bitumen bonding material, forming a layer of this mixture and applying a compressive force thereto so that the nodules are bonded in contiguous relation with interconnected interstitial voids therebetween. The method of making a monolithic layer of the thermal insulation includes spreading an admixture of nodules and liquefied bitumen over a roof deck in a manner that the nodules are in contiguous relation with interconnected interstitial voids therebetween.

This application is a continuation-in-part of copending application S.N. 363,518, entitled, "Method of Preparing an Insulated Built-Up Roof," filed on Apr. 29, 1964, now abandoned.

This invention relates generally to an improved thermal roof insulation and more particularly to an improved cellular inorganic glass-like thermal roof insulation and a method of preparing a built-up roof therewith.

A thermally insulated built-up roof includes a layer of thermal insulation adhesively secured to a structural roof deck and several layers or plies of roofing felt cemented to the top surface of the thermal insulation. The conventional bonding material used to cement the roofing felts to the thermal insulation and adhesively secure the thermal insulation to the structural roof deck is a heat liquefied bituminous material such as pitch or asphalt heated to a temperature of about 400° F.

The structural roof deck may be fabricated from steel decking, wood planks, precast concrete slabs, or poured concrete decking. The thermal insulation used in a majority of the built-up roofs comprises elongated slabs or rigid boards that are adhesively secured to the roof deck in juxtaposed relation. The conventional insulation boards are porous and are usually formed from cellulose fibers, glass fibers, gypsum and the like. The insulation boards are arranged in parallel courses with the joints of the adjacent boards abutted and usually staggered between the parallel courses. When additional thermal insulation is desired, several layers of the insulation boards are applied. Usually the upper surface of the bottom layer is mopped with a hot pitch or asphalt and the second layer of insulation boards is adhesively secured thereto in parallel relation with the courses of the first layer, and the joints of the second layer are usually spaced from the joints of the first layer of insulation boards.

A mopping of hot adhesive bituminous material is spread on the top surface of the insulation boards and roofing felts are adhesively secured to the top surface by the hot adhesive bituminous material. The application of the adhesive bituminous material and the roofing felts is repeated until there are a plurality of alternate superimposed layers of adhesive bituminous material and roofing felts on the top surface of the insulation boards. The alternate superimposed layers of adhesive bituminous material and the roofing felts provide the waterproof membrane for the roof surface. Usually a layer of bituminous material is applied to the top surface of the top roofing felt and coarse particles of slag or gravel are imbedded in this final layer of bituminous material to protect the bitumens from excessive exposure to sunlight and other damaging elements.

There are a substantial number of difficulties or problems encountered with a built-up roof that includes the conventional materials such as the insulation boards formed of porous materials such as cellulose fibers, glass, gypsum, and certain of the cellular organic materials such as polystyrene and the like.

One of the problems encountered with the porous insulation boards used in a built-up insulated roof is the absorption of the heat liquefied bituminous material by the insulation boards. The bituminous material is heated to a temperature of about 400° F. and is applied in a semiliquid state by mopping the liquid bituminous material onto the top surface of the deck as an adhesive for the porous insulation boards and to the top surface of the insulation boards as an adhesive for the first layer of roofing felt. The heat liquefied bituminous material is absorbed by the porous insulation so that several moppings are required to provide an adequate adhesive layer for the roofing felts. The absorption of the heat liquefied bituminous material by the insulation boards reduces the thermal conductivity of the insulation boards and thereby reduces the overall insulation characteristics of the built-up roof. It has been suggested, as is described in U.S. Patent No. 3,125,479, to treat a surface of the porous insulation board with a sizing material to minimize the absorption of the liquefied adhesive bituminous material. The added step of treating the insulation boards increases the cost.

Where the insulation board is formed of a foamed organic plastic material such as foamed polystyrene, foamed polyethylene, foamed polyesters, foamed polyurethane or other foamed organic materials, it is not feasible to mop the surfaces of the foamed organic plastic material with a conventional bituminous material that is liquefied by heating to a temperature of 400° F. The foamed organic plastic material undergoes decomposition and the heated bituminous material will melt and collapse the foam structure of the organic plastic material in the presence of the hot bituminous material. Special organic adhesives are suggested for securing the foamed organic plastic insulation boards to the roof deck and for adhesively securing the roofing felts to the upper surface of the foamed organic plastic insulation boards. The use of the special adhesive for the foamed plastic insulation boards adds to the cost of the built-up roof. There have been suggestions in the past, as is described in U.S. Patents No. 3,094,447 and No. 3,111,787, for minimizing the above problems where a foamed organic plastic material is used as the thermal insulation. U.S. Patent No. 3,094,447 suggests applying an adhesive cement at a low temperature to the foamed plastic material, preferably at the location where the foamed plastic insulation boards are fabricated. Another solution suggested by U.S. Patent No. 3,111,787 is to adhesively secure plywood facing material to the surfaces of the foamed plastic core. The above suggested solutions add to the overall cost of the built-up roof and do not necessarily solve certain of the later discussed problems encountered with porous insulation boards.

Another difficulty encountered with the use of conventional insulation boards is the inability of the insulation boards to conform to irregular surfaces on the roof deck that results either in breakage of the relatively rigid insulation boards or in unadhered areas where the board bends over an uneven region but does not actually follow the roof contour. The roof deck on which the insulation boards are adhesively secured is seldom truly a planar surface without depressions, irregularities or even sharp local projections. In the assembly of the built-up roof it is also necessary, where relatively rigid insulation boards are utilized, to provide a surface that is free of small objects such as pieces of aggregate and the like that prevent the insulation boards from laying flat on the top surface of the structural roof deck. It is difficult where a mopping of hot bituminous material and an impermeable membrane are first applied to the roof deck to observe the small foreign objects such as pieces of aggregate and the like. Usually the aggregate or foreign object is covered before the rigid thermal insulation board is positioned on the deck. Only after trouble develops with the finished roof it is discovered that the roof board had not assumed a sufficiently flat position on the deck to adhere properly. To insure that all foreign objects are removed requires a degree of care on the part of the workman that is virtually impossible to obtain in practice.

One of the major problems encountered in a built-up roof is moisture between the roof deck and the roofing felts. The layers of roofing felt form a vapor tight and watertight membrane above the thermal insulation. Water trapped below the roofing membrane vaporizes at elevated temperatures developed during summer weather and expands to an extent that pressures of between 300 and 500 pounds per square foot are created unless widely distributed and controlled vents are provided. The conventional thermal insulation boards formed of cellulose fibers, gypsum and the like are not sufficiently porous material and do not have interconnecting air passages for dispersing the pressures created by moisture in local areas. Where foamed plastic insulation boards are used there is little if any moisture diffusion therethrough so that moisture remains in a relatively small localized area. The localized vapor pressures caused by the expanded moisture frequently damage the roofing materials by causing blisters in the roofing felts that eventually rupture and form openings in the watertight membrane through which water will enter and be absorbed by the insulation boards. Though roofs are not supposed to leak, small local leaks almost always develop on flat roof decks. The water soaked insulation is thereafter subjected to the cyclic freeze and thaw conditions during the winter months. During the freeze cycle the water expands just before freezing and can develop enormous local pressure which easily ruptures the cells of cellular materials. This failure is commonly called "freeze-thaw" damage. Under these conditions the insulation boards quickly deteriorate and become ineffective to serve their intended purpose.

In order to minimize these problems, the manufacturers of the conventional thermal insulation recommend that the insulation boards be transported, stored and handled so that they are subjected to a minimum amount of moisture but since most roofing insulating boards are hydroscopic to at least some degree, some water is nearly always picked up. It is further recommended that the roofs be assembled and sealed in dry weather to minimize the entrapment of moisture between the

structural roof deck and the roofing felt membrane but sudden rain showers, condensation from dew etc. effectively prevent really dry conditions. Even when built-up roofs are assembled under ideal weather conditions, enough water may be contained in the porous insulating material or get in between the roofing felt and the structural roof deck to cause trouble. The moisture causes the above discussed blistering by localized pockets of water vapor. The blisters raise the roofing felts and in warm weather allow the bitumens to drain away from the felt layers. The weakened material weathers seriously and is easily ruptured. Thus a leak develops and this in turn lets in more water and in this manner progressively the roof is seriously damaged or even destroyed.

The watertight membrane of the roofing felts is subjected to damage by traffic on the roof, damage by sharp objects during installation and the like. Therefore, even where the built-up roof is relatively moisture free upon completion, water eventually enters between the roofing felt and the structural roof deck and damage caused by water vapor and the cyclic freeze-thaw of the moisture within the thermal insulation eventually occurs and thus limits the useful life of a built-up roof.

Another serious problem with insulated roofs occurs when ordinary insulations are applied as finite sized blocks or slabs. These pieces are generally about 2 x 4 feet which limit is set by ease of handling. The relatively small size (compared to the size of the roof) means that many joints occur on a normal roof. Manufacturing tolerances, irregularities of the roof structure and many other practical details limit the minimum space between roof insulation pieces to an average of about 1/16 inch. Thus in a roof 100 feet long there will be 25 to 50 joints with a cumulative total gap space of 1½ inches to 3 inches. The felts, insulation and roof deck do not have the same coefficients of thermal expansion and as the felts heat and cool, come and go, they cause the blocks under them to shift slightly. Experience on many roofs has shown that unless the blocks effectively adhere to each other, this shifting causes ¼ inch to 1 inch gaps to develop in the roof insulation that underlies the felts. Now as the roof felts and deck structure expand and contract at different rates, wrinkles develop in the felts. Again bitumen drainage occurs at these wrinkles and as explained above, the felts weather at these points and in a year or two, leaks develop. This lets water into the insulation and as explained above, more trouble now develops.

Sharp wrinkles are also formed in the roofing felts as the felts contract and expand under cyclic weather conditions. The felts are adhesively secured to the insulating material by a bitumen mopping and the presently known insulating material is rigid and not subject to flow distortion. The conventional roofing felts are formed of loose fibers matted together and imbedded in a bitumen material. When the top felts on a conventional thermally insulated roof are subjected to cold weather, they shrink or contract and the matted fibers within the felts are placed under tension. Since the fibers are imbedded in a bitumen, which is a high viscosity liquid, the felts relieve the tension stresses by the sliding movement of the fibers relative to each other. This usually occurs in localized areas and in these areas the felts are elongated or stretched. When the felts are subsequently subjected to warm weather, they expand again and attempt to attain their former dimensions.

Because of the random arrangement of the fibers within the felts and the relative flexibility of the fibers, the fibers do not return or reorient themselves in the original position and the stretched portion of the felt does not contract to its original dimension. Instead, the expansion forces exerted on the felts cause the felts to lift from the insulation at locations where the felts have stretched and the fibers have moved relative to each other. The lifting of the felts results in sharp wrinkles at each location. When the felts are again subjected to cold weather, the shrinking or contraction of the felts is again repeated and normally one would expect the wrinkles to straighten out. Instead, however, experience shows that the felts stretch at different locations and cause additional wrinkles during the next cycle of warm weather.

A suggested solution to the above problem is to provide an elastic medium in the thermal insulation layer that would distort with the felt as it stretches. The energy that is required to distort the insulation would be stored therein. During the next cycle of warm weather, the stored energy would be available to reposition the fibers in their original position. Presently there are not any materials available that have this distortive property. It is further questioned whether it is possible to reposition the fibers by means of the energy retained in the distorted insulation because of the flexible properties of the fibers within the felts. It is believed that the fibers do not have sufficient stiffness to oppose the viscous bitumen material in which they are imbedded. As will be later discussed, the above problems are minimized with the improved thermal insulation hereinafter described.

There has also been proposed a method of forming a built-up roof by preparing a slurry of lightweight aggregate such as expanded perlite and vermiculite ores, cement and water. The slurry is poured directly on the structural roof deck and a substantial period of time is required for the concrete to cure and solidify. For example, on an average roof, up to three weeks of curing and drying time is required before the other materials can be applied to the roof provided the roof is protected from rain during this period. The expanded perlite and vermiculite have a substantial number of open cells and absorb both the water from the slurry and the heat liquefied bituminous material applied to the top surface of the poured thermal insulation so that the thermal conductivity of the poured thermal insulation is substantially increased. There has also been proposed a method of mixing open celled expanded perlite or vermiculite ores with a heated bituminous material to form a layer of thermal insulation on a structural roof deck. With this method, however, difficulty is encountered in the open celled perlite or vermiculite ores absorbing the heated bituminous material to thereby increase the thermal conductivity, reduce the insulating efficiency of the open celled perlite or vermiculite and require a substantial amount of heated bituminous material, thus increasing the cost of this type of insulated roof. The thermal conductivity of a layer of thermal insulation formed from expanded perlite or vermiculite mixed with a heated bituminous material is in the range of 0.8 to 1.0 B.t.u./hr./sq./ft.° F./in. at a means temperature of about 80° F.

A foamed or cellular asphalt having predominantly closed cells but with controlled, limited and uniformly distributed interconnected passageways therebetween would solve all of the previously discussed problems in a built-up roof. The cellular asphalt would conform to irregular surfaces when heated by the hot bituminous adhesive and the interconnected passageways would prevent pressure built up as water changes to water vapor and so effectively eliminate blisters in the overlying roofing felts. The foamed asphalt also would act as a high viscosity layer which would automatically limit the shear face, caused by movement of the roof deck or differential expansion between the roof deck and the roofing felts, that can be exacted on the felts to a face less than that needed to cause wrinkles in the felts or to lift the felts from any other cause. In addition the slight "give" of the bitumen is sufficient to absorb the expansion of water as water goes from 4° C. to 0° C. on the way to freezing. Hence so called "freeze-thaw" damage is avoided.

The cellular asphalt would have a suitable thermal conductivity and be relatively light in weight. U.S. Patent No. 1,874,674 describes an insulation board for a roof that is fabricated from asphalt and has a melting point of about 220° F. The asphalt is cellulated by adding sodium silicate in liquid form to the heated asphalt. An insulation board such as suggested in U.S. Patent No. 1,874,674 has several disadvantages. It is well known that at elevated temperatures the cellular asphalt or bituminous materials soften and melt, and the cellular structure would collapse in a manner similar to the organic foamed materials when they are subjected to an elevated temperature. In addition it is practically impossible to control size, number and distribution of interconnected voids to optimum values. The hereinafter described thermal roof insulation has unexpectedly been found to have the desirable properties of a cellular asphalt and the cellular structure of the thermal insulation is not subject to collapse at elevated temperatures. In addition, the size, distribution and number of interconnected voids are effectively controlled.

The thermal insulation comprises cellular, closed celled nodules encapsulated with a thin layer of bituminous material and positioned in contiguous relation with each other. The asphalt or bituminous material thus forms a substantially continuous matrix and a double cellular structure with certain of the cells having a cellular glass-like nodule therein and the other cells being interconnected to form passages for the flow of water vapor. The adjacent cellular nodules encapsulated with the hot bituminous material are in contiguous relation and provide the required strength to prevent collapse at elevated temperatures, and, because of their substantially spherical shape, permit relative but limited movement relative to each other at elevated temperatures so that the insulation material when applied to the roof as a fabricated board with hot bitumen softens sufficiently to truly conform to the irregular surfaces of the usual roof deck.

The herein disclosed thermal roof insulation may be fabricated as insulation boards or may be applied directly to the roof deck as a monolithic layer of thermal insulation. The insulation board comprises a layer of cellular nodules encapsulated with a relatively thin coating of bituminous material. The adjacent cellular nodules are in contiguous relation with each other and the bituminous coating serves as an adhesive to maintain the shape of the insulating board. To produce a handleable insulating board, a layer or layers of suitable sheet material such as paper, fiber glass matting or woven material, a film of suitable plastic or the like is applied to each side of a suitably thick layer. The thermal insulation that is applied directly to the roof deck comprises cellular glass nodules with a coating of bituminous material. As will be later described, the coated nodules are applied as a monolithic layer to the roof deck with the adjacent nodules in contiguous relation with each other.

With the herein described thermal insulation, either in the form of an insulation board or as a monolithic layer of thermal insulation, it is now possible to assemble an insulated built-up roof wherein the presence of moisture between the structural roof deck and the roofing felts does not have the deleterious effects of presently known built-up roofs. The herein described thermal insulation for a built-up roof includes a layer of insulating material that has between 10 and 50 percent void space by volume of distributed but connected interstitial voids through which water and water vapor may diffuse to thereby eliminate localized pockets of high vapor pressures that cause blisters in the roofing felts. The presence of the moisture within the insulation layer has no appreciable effect on the thermal conductivity of the insulation material. The principal volumetric constituent of the thermal insulation is impervious to water so that the thermal conductivity of the principal constituent is not adversely affected by the presence of water. The thermal conductivity of the thermal insulation does not change substantially in the presence of water or water vapor because of the impervious nature of the cellular material. The monolithic layer, of course, presents no joint problem. Surprisingly it has been observed that when the herein described invention is applied as a board, in a short time after application (less than 3 months on a small installation experimentally observed), the boards weld to each other and effectively prevent the shift with subsequent development of ¼ inch to 1 inch gaps and its attendant problems, which as described above, commonly occur when ordinary roof board insulation is used.

Briefly, the invention is directed to a thermal insulation that comprises an admixture of cellular glass nodules encapsulated in a suitable binder material. The admixture may be formed into an insulation board or applied as a monolithic layer of thermal insulation on the roof deck. The roof board or layer of thermal insulation may have any preselected thickness. A compressive force is applied to a surface of the admixture so that the adjacent multicellular glass nodules are in contiguous relation with each other and the thermal insulation has between about 10 percent and 50 percent by volume of distributed but connecting interstitial voids.

When the admixture is spread on a structural roof deck and a compressive force is applied thereto, a layer of roofing felt is positioned over the monolithic layer of thermal insulation and the bituminous material that encapsulates the cellular nodules serves as an adhesive for the first layer of roofing felt. A plurality of alternating superimposed layers of adhesive material and roofing felts are thereafter applied to the layer of thermal insulation to form a thermally insulated built-up roof. If desired, a topping of adhesive is applied to the top layer of roofing felt and coarse aggregate or mineral particles are imbedded in this topping layer. For certain applications, several layers of the admixture may be prepared using different sized multicellular glass nodules and the layers applied over each other to provide a layer of insulation that is not subjected to degradation by the presence of water and which is sufficiently permeable to permit entrapped water or water vapor to diffuse throughout the interstitial voids between the contiguously arranged, substantially spherical multicellular glass nodules.

Where the thermal insulation is in the form of insulation boards, layers of relatively thin sheet material are applied to the surfaces of the insulation boards. The insulation boards are positioned on a built-up roof in substantially the same manner as conventional insulation boards and layers of roofing felt are applied thereto in a conventional manner. The application of heated bituminous material to the surfaces of the insulation board made according to the herein described invention softens the bituminous material that encapsulates the cellular glass nodules so that the surface of the insulation board will conform to irregular surfaces by movement of the nodules relative to each other. After the bituminous adhesive and the insulation board have cooled, the bituminous material encapsulating the cellular glass nodules solidifies in its displaced position to conform to the irregular roof surface. Another surprising result has been the observation that with proper choice of the softening point of the bitumen the board can be made sufficiently rigid so that it can effectively span the small gaps that occur in sheet metal roof decking. These gaps are the result of the reinforcing corrugations used in this type of roof deck.

Accordingly, the principal object of this invention is to provide a thermal insulation for an insulated built-up roof that has between about 10 percent to 50 percent by volume of interstitial voids to provide for limited movement of water and water vapor therethrough.

Another object of this invention is to provide a thermal insulation for a built-up roof that comprises cellular substantially spherical multicellular glass nodules encapsulated in a hydrophobic adhesive material.

Another object of this invention is to provide a thermal insulation for a built-up roof which includes discrete substantially spherical multicellular glass nodules encapsulated with a layer of bituminous material positioned in contiguous relation and having substantially the same thermal conductivity as a slab of multicellular glass.

Another object of this invention is to provide an insulation board for an insulated built-up roof that has the desirable properties of a cellular bituminous material and none of the limitations of such a material.

A further object of this invention is to provide a method of preparing an insulated roof that includes spreading a layer of substantially spherical multicellular glass nodules coated with a hydrophobic adhesive material on the structural roof deck for thermally insulating the built-up roof.

These and other objects and advantages of this invention will be more completely disclosed and described in the following specification, the accompanying drawings and the appended claims.

In the drawings:

FIGURE 1 is a transverse section through a built-up roof having a layer of thermal insulation comprising spherical multicellular glass nodules coated with a hydrophobic adhesive material.

FIGURE 2 is a fragmentary view of a portion of the layer of thermal insulation between the structural roof deck and the layers or plies or roofing felt.

FIGURE 3 is a semidiagrammatic view in section through the thermal insulation illustrating the interstitial voids between the adjacent multicellular glass nodules.

FIGURE 4 is a diagrammatic representation of apparatus suitable for fabricating insulation boards of multicellular glass nodules and bituminous material.

FIGURE 5 is a perspective view of a segment of the improved thermal insulation board of the present invention.

FIGURE 6 is a fragmentary view in section taken along the lines **6—6** of FIGURE 5 illustrating the arrangement of the encapsulated cellular glass nodules in the thermal insulation boards.

FIGURE 7 is an enlarged view of a plurality of nodules encapsulated with the bituminous material.

Multicellular glass nodules are the principal constituent of the thermal insulation. The multicellular glass nodules are an inorganic material having substantially all closed cells and can be formed with densities varying from 10 pounds per cubic foot to about 25 pounds per cubic foot. The multicellular glass nodules may be formed in a variety of sizes as, for example, having diameters between ⅜ inch and ¹⁄₁₆ inch. The multicellular glass nodules may be made according to the process described in copending application Ser. No. 297,023, filed July 23, 1963, entitled "Cellular Glass Nodules," from glass cullet or other silica containing materials. For convenience, however, throughout the specification the nodules will be referred to as cellular glass nodules. It should be understood, however, that nodules having the hereinafter described physical and chemical properties formed from materials other than conventional formulated glass may also be used in the hereinafter described thermal insulation. The multicellular glass nodules are substantially spherical in shape, have a low density and are substantially all closed cells.

In preparing a thermally insulated built-up roof according to the invention herein disclosed, the multicellular glass nodules are admixed with a suitable binder material. An admixture of relatively solid discrete particles of asphalt can be admixed with the multicellular glass nodules, the admixture bagged and then transported to the job site in a conventional manner. At the job site the admixture of multicellular glass nodules and discrete particles of asphalt is placed in a mixing device and a sufficient amount of a suitable solvent for the asphalt is added to the mixing device and the material is admixed until the asphalt is softened and becomes tacky. The material is further mixed until the tacky softened mass of asphalt coats the multicellular glass nodules. The coated nodules are then spread over the structural roof deck in a monolithic layer. A compressive force is applied to the top surface of the monolithic layer by rolling or the like until adjacent multicellular glass nodules are in contiguous relation. The solvent for the asphalt is permitted to evaporate and the asphalt solidifies and bonds the contiguous multicellular glass nodules to each other into a relatively rigid monolithic layer of thermal insulation on the structural roof deck. Since the nodules have closed cells and are glass, the solvent for the asphalt does not penetrate the individual nodules.

Where a source of heat is readily available, a heat liquefied bituminous material such as pitch or asphalt can be used to coat the multicellular glass nodules. The multicellular glass nodules and the heat liquefied bituminous material are heated to an elevated temperature where the bituminous material is liquefied and coats the multicellular glass nodules. The heated admixture is then spread on the roof deck to form a monolithic layer of a preselected thickness. Before the heated admixture has cooled, a compressive force is applied so that adjacent multicellular glass nodules are in contiguous relation with each other.

Since the multicellular glass nodules are closed celled, the binder material, be it a solvent liquefied bituminous material or a heat liquefied bituminous material, does not penetrate into the interior portion of the multicellular glass nodules. The thermal conductivity of the multicellular glass nodules is, therefore, not adversely affected by the coating of bituminous material. When the adjacent multicellular glass nodules are in contiguous relation with each other in the layer of insulation, the thermal conductivity of the layer of insulation is substantially equal to that of a piece of multicellular glass having substantially the same thickness. For example, a layer of thermal insulation formed according to the process herein described has a thermal conductivity or k factor of 0.41 B.t.u./hr./sq. ft./° F./in. at a mean temperature of 85° F. A block of multicellular glass has a thermal conductivity of about 0.40 B.t.u./hr./sq. ft./° F./in. at a mean temperature of about 85° F.

Referring to the drawings and particularly FIGURE 1, a section of the thermally insulated built-up roof is illustrated, and the method of preparing the built-up roof will be described with reference thereto. The roof includes a structural deck **10** which may be formed of steel decking, wood planks, precast concrete slabs or poured concrete, and is illustrated herein as formed of concrete.

Roofing pitch, for example Koppers Roofing Pitch Composition #63–147, having a density of about 85 pounds per cubic foot, is heated to a temperature of about 400° F. where it melts and forms a heat liquefied bituminous material. Multicellular glass nodules having a density of about 13 pounds per cubic foot and a size between ¼ inch and ⅜ inch diameter are separately heated to about 300° F. Approximately equal parts by weight of the heated pitch and the multicellular glass nodules are mixed in a suitable mixing device until the multicellular glass nodules are coated with the hydrophobic roofing pitch. The admixture is spread on the upupper surface of the structural deck **10** in an insulation layer **12** of a preselected thickness while the pitch and nodules are at an elevated temperature. A compressive force is applied to the layer **12** by a roller or the like so that the adjacent nodules are in contiguous relation with each other. It may be convenient, to prevent the coated multicellular glass nodules from adhering to the roller, to cover the layer of the admixture with roofing felt, resin paper or the like, before the compressive force is applied thereto by the roller. The layer **12** is permitted to cool and the roofing pitch solidifies to bond the contiguous multicellular glass nodules to each other. There is provided between the contiguous multicellular glass nodules, because of their spherical configuration, between about 10 percent to 50 percent by volume of distributed but connecting interstitial voids providing passageways through which the water and water vapor may diffuse.

A second admixture is prepared by heating multicellular glass nodules having a diameter of about $\frac{1}{16}$ inch and a density of about 22 pounds per cubic foot to a temperature of about 300° F. The heated nodules are admixed in substantially equal parts by weight with the roofing pitch that has been previously heated to a temperature of about 400° F. The heated roofing pitch is admixed with the smaller sized multicellular glass nodules until the multicellular glass nodules are coated with the heat liquefied roofing pitch. The admixture is spread on the top surface of layer **12** to form a second insulation layer **14**. A compressive force is applied to the second insulation layer **14** to bond the insulation layer **14** to the other insulation layer **12** therebelow and to position adjacent smaller sized multicellular glass nodules in contiguous relation with interstitial voids between.

In the above process the multicellular glass nodules were preheated to a temperature of about 300° F. before they were admixed with the heated roofing pitch. It should be understood, where it is desired, the roofing pitch and cellular glass nodules can be heated to a higher temperature. As for example, the nodules can be heated to a temperature of between 450° F. and 650° F. and the pitch heated to between 560° F. and 620° F. At these elevated temperatures less pitch can be used in the admixture to provide a coating for the nodules. It is believed essential to separately heat the nodules and the pitch to provide a large heated surface, in the surface of the heated nodules, to permit the more volatile fractions of the pitch to volatilize. Although the nodule insulation illustrated in FIGURE 1 comprises a first layer **12** formed of multicellular glass nodules having a diameter of between ¼ inch and ⅜ inch and a second layer of multicellular glass nodules having a diameter of about $\frac{1}{16}$ inch, it should be understood that the layer of nodule insulation may be formed of a single layer of desired thickness with nodules of substantially the same size or of different sized multicellular glass nodules. It is desirable, however, that the nodules be selected so that there is at least about 10 percent by volume and preferably about 40 percent by volume of interstitial voids in the layer of nodule insulation through which the water vapor may diffuse.

On the upper surface of the insulation layer **14** a layer of adhesive bituminous material **16**, such as heated coal tar pitch, is applied by mopping or the like. The typical thickness of the layer of adhesive bituminous material **16** is about 0.05 inch and 0.08 inch. On the upper surface of the layer of adhesive bituminous material **16** there is applied a bituminous material saturated roofing felt **18** having a thickness of between 0.02 inch and 0.04 inch. A second layer of adhesive bituminous material **20** is applied to the top surface of the roofing felt **18**, and superimposed on the layer **20** is another layer of roofing felt **22**. Additional layers of roofing felt **24** and **26** are adhesively secured to the roofing felt positioned therebelow by layers of adhesive bituminous material, indicated as **28** and **30**. A topping layer of adhesive bituminous material **32** is positioned on the top layer of roofing felt **26** and coarse aggregates **34** are imbedded therein to thereby form a thermally insulated built-up roof having the previously discussed desirable characteristics.

FIGURE 2 illustrates the manner in which the multicellular glass nodules are bonded to each other by the hydrophobic carbonaceous material. It should be understood that other hydrophobic carbonaceous bonding materials may be used instead of the specific roofing pitch previously described. The multicellular glass nodules generally indicated by the numeral **36** are substantially spherical in shape and are formed of a glass having a plurality of closed cells **38**. The hydrophobic carbonaceous material designated **40** coats the outer surface of the multicellular glass nodules **36** and bonds the multicellular glass nodules to each other into a layer of thermal insulation. It should be noted that the carbonaceous material does not penetrate the individual nodules.

FIGURE 3 is a section of the randomly arranged multicellular glass nodules in the layer of thermal insulation illustrated in FIGURE 1. FIGURE 3 diagrammatically illustrates the typical interstitial voids **42** and **44** between the adjacent contiguous nodules **36**. It is desirable that the layer of insulation contain between 10 percent and 50 percent by volume of distributed and connected interstitial voids through which the water and water vapor may diffuse. As previously discussed, the interstitial voids being filled with the water or water vapor does not substantially affect the thermal conductivity of the insulation layer since the remaining volume of the insulation layer is formed of a material that is impervious to water and the thermal conductivity of the layer of insulation is dependent substantially on the insulating value of the multicellular glass nodules.

One of the advantages of the method previously described is the wide latitude for the installer in applying the thermal insulation. The top surface of the structural roof deck does not have to comply with the critical specifications now required where the insulation planks or boards are used. Further, the layer of the admixture may be applied so that there is the desirable slope to the top surface of the roof for proper water drainage. This may be accomplished by varying the thickness of the insulation layer between the edges and the center of the roof. Although, as previously discussed, the insulation layer has between 10 percent and 50 percent by volume interstitial voids between the contiguous multicellular glass nodules, the problem of the top surface of the layer of insulation absorbing the heat liquefied bituminous adhesive material applied thereon is eliminated in the heretofore described process. The step of mopping on a coating of the heat liquefied bituminous material as an adhesive for the first layer of felt is not necessary since a portion of the insulation material comprises the heat liquefied bituminous adhesive. If the bituminous material in the layer has solidified to an extent that it has lost its adhesive properties, localized application of heat to the top surface of the insulation layer before the roofing felt is applied may be practiced to provide the necessary adhesive qualities to the heat liquefied bituminous material. Another method for preventing penetration of the liquefied bitumen into the cellular insulating layer consists of applying a layer of thin lightly sized or unsized paper directly over the insulating layer and flooding this, as is common practice in roofing, with liquefied bitumen. Sufficient heat and bitumen penetrates the paper to adhere it strongly to the underlying insulation layer but no liquefied bitumen drips through to clog the interconnected voids.

Where it is desired to provide thermal insulation for the built-up roof in the form of insulation boards, the apparatus diagrammatically illustrated in FIGURE 4 may be utilized to form insulation boards. A hopper generally generally designated by the numeral **100** serves as a source of cellular glass nodules for the insulation board. The cellular glass nodules may have a spectrum of sizes or may be of a preselected single size, depending on the percent void space desired between the respective nodules in the insulation board. It is preferred that the nodules range in size between 4 and 12 mesh and have a spectrum of sizes. For example, a suitable size consists of the cellular glass nodules contains 45 percent by weight of the nodules that pass through a 4 mesh Tyler Standard screen and are retained on a 6 mesh Tyler Standard screen; 50 percent of the nodules pass through a 6 mesh Tyler Standard screen and are retained on an 8 mesh Tyler Standard screen; the remaining 5 percent by weight of the nodules are retained on a 12 mesh Tyler Standard screen. The hopper **100** may be provided with a suitable heating means to heat the cellular glass nodules to a temperature of between 450° F. and 650° F. The preferred temperature of the heated nodules is between 500° F. and 550° F.

A second hopper 102 is provided for the bituminous material. Any suitable bituminous material or asphalt that liquefies at a moderate elevated temperature and solidifies at ambient temperature is suitable for the thermal insulation. Fire retarded mixtures of bitumens and chlorinated hydrocarbons or phosphorous bearing fire retardants can also be used. The use of chlorine containing or phosphorous containing organic materials as fire retardants is well known and many such materials are commercially available. The Aroclor series of compounds manufactured by Monsanto Chemical Company is an example of these materials. A preferred bituminous material is generally defined as extra steep roof asphalt and has a softening point of between 180° F. and 200° F. and a penetration value at 77° F. measured by the standard of test of penetration of bituminous materials (ASTM D5–52) of between 20 and 30. The penetration value is measured as the tenths of a millimeter that a tapered standard needle (0.14 to 0.16 mm. tip diameter) will penetrate the asphalt in five seconds with a 100 gram load. The hopper **102** may have a suitable heating device associated therewith to heat the asphalt to a temperature of between 560° F. and 620° F. or molten asphalt may be pumped or otherwise transported to the hopper **102**.

The bottom of hopper **100** has a metering device **104** that controls the rate at which the heated nodules are fed through conduit **106** to a mixer **108**. Similarly, the hopper **102** has a metering device **110** that controls the rate at which the heated assphalt is fed through conduit **112** to the mixer **108**. The ratios of the cellular glass modules and asphalt may vary from 1.75 lbs. to 5 lbs. of asphalt to each cubic foot of cellular nodules. It has been found that the strength of the roof board decreases as the amount of asphalt is decreased. It has also been found where the amount of asphalt is increased, the thermal conductivity or *k* factor of the insulation board increases. The ratio of asphalt to nodules will also vary within limits depending on the size of the nodules used. A preferred ratio of 4.6 lbs. of asphalt to each cubic foot of cellular nodules is preferred where the cellular nodules have a true density of about 11.5 pounds per cubic foot and a bulk density of about 6.45 pounds per cubic foot.

The metering devices, therefore, control the rate at which the heated nodules and asphalt are fed to the mixer device **108** in the desired proportions. The nodules and liquefied asphalt are admixed in the mixer device **108** until the nodules are encapsulated or coated with a relatively thin layer of liquefied asphalt. It has been found when the above proportions of nodules and asphalt are used, that there is little, if any, run-off of surplus asphalt from the mixer device **108**. It appears that, with proper mixing in mixer **108**, substantially all of the asphalt is utilized in encapsulating the discrete cellular nodules. As illustrated in FIGURES 2 and 6 the cellular glass nodules have a relatively irregular surface so that the liquefied asphalt has an affinity for the surface of the nodules.

The cellular glass nodules coated or encapsulated with the liquefied asphalt are withdrawn from mixer **108** and fed to a leveling and metering device **114**. The leveling and metering device **114** is provided with a suitable heating means to maintain the nodules and asphalt at an elevated temperature.

There are provided two rolls of paper **116** and **118** positioned adjacent to the forming area designated generally by the numeral **120**. The rolls of paper may be of any suitable sheet material such as 50 lb. kraft paper or the like, or thin sheets of plastic film, between which the bituminous encapsulated cellular glass nodules are sandwiched. Generally, paper is preferred because of its lower cost, good adhesion to asphalt and high strength, but other sheet materials may be used. For example, fluorocarbon polymers in sheet form could be applied to one surface with the result that the board would not require further weather protection except for sealing the joints. The roll of paper **118** is guided about rollers **122** in the direction indicated by the arrow in FIGURE 4. The under surface of the paper from roll **118** is coated with an adhesive, preferably liquefied asphalt, by means of applicator **124**. Similarly, the paper from roll **116** has its under surface coated with liquefied asphalt by applicator **126** and is guided around rollers **128** and is fed to the forming area **120** in the direction indicated by the arrow in FIGURE 4. The metering device **114** feeds the heated cellular nodules coated with the liquefied asphalt between the sheets of paper from rolls **116** and **118**. The coated surfaces of the paper adhere to the surfaces of the encapsulated cellular glass nodules. Suitable compression means **130** in forming area **120** exerts a compressive force on the laminate structure of the paper with the encapsulated cellular glass nodules therebetween to form an endless ribbon of insulation board **132**. The ribbon of insulation board **132** is fed onto an endless cooling conveyor **134** that conveys the ribbon **132** into a cooling area **136** where the temperature of the ribbon **132** is reduced to rigidify the ribbon of insulation board. A traverse saw **138** cuts the ribbon **132** into preselected widths of insulation board.

FIGURES 5, 6 and 7 illustrate the insulation board with the encapsulated cellular glass nodules **140** sandwiched between the sheets of kraft paper **142** and **144**. FIGURE 6 is a view in section taken along the line **6—6** of FIGURE 5 wherein the coatings of asphalt **146** and **148** on the paper **142** and **144** are exaggerated for illustrative purposes. In FIGURE 7 the coating of asphalt **150** on the cellular glass nodules **152** is also exaggerated for illustrative purposes. In FIGURE 7 the substantially continuous matrix of heat liquefiable bituminous material or asphalt **150** is illustrated with certain of the matrix cells filled with cellular nodules **152** and other of the cells forming interconnected voids **154**. A meniscus **156** is formed by the liquefied asphalt coating of adjacent nodules to provide the empty or void cells of the asphalt matrix.

In flexural strength tests made on an insulation board fabricated in accordance with the above described process it was discovered that the insulation board may deflect as much as ½ inch without fracture. A slab of cellular glass insulation board fractures before the same deflection occurs. It is now possible to fabricate an insulation board that has a substantial volumetric amount of cellular glass in thicknesses less than 1 inch. Because of the fragile characteristic of cellular glass, unitary slabs of cellular glass having a thickness of less than 2 inches are not economically feasible.

The thermal conductivity of cellular glass insulation is about 0.40 B.t.u./hr./sq. ft./° F./in. at 75° F. The thermal conductivity of cellular glass nodules and air is about 0.34 B.t.u./hr./sq. ft./° F./in. at 75° F. The thermal conductivity of asphalt is about 1.1 B.t.u./hr./sq. ft./° F./in. at 75° F. The insulation board formed according to the above described process has a thermal conductivity of about 0.395 B.t.u./hr./sq. ft./° F./in. at 75° F. It is thus apparent that the insulation board has substantially the same thermal conductivity as cellular glass insulation.

The insulation board made according to the previously described process has a bulk density of about 12 pounds per cubic foot and contains between 80 percent and 95 percent by volume void space and cellular glass nodules that have highly desirable insulating properties. The remaining 5 percent to 20 percent by volume of the insulation board is a matrix of heat liquefiable bituminous material.

The insulation boards may be applied to the roof in a conventional manner wherein one ply of 15 lb. felt is first applied to the roof deck as a vapor barrier. The felt is mopped with liquefied asphalt heated to a temperature of about 400° F. It is conventional to apply about 30 lb. of liquefied asphalt per 100 sq. ft. of roof. The insulation board is positioned on the hot asphalt and the heat from the asphalt is transfered to the insulation boards. Since the cellular nodules have a lower thermal conductivity than the bituminous asphalt coating, the cellular glass nodules do not absorb the heat from the hot asphalt coating on the roof. The asphalt coating on the

nodules is therefore heated to an extent that the average temperature of the insulation board approaches 170° F. with the lower half of the board reaching a temperature of about 225° F. At this elevated temperature the softening point of the asphalt that encapsulates the nodules has been reached and the under side of the board is relatively flexible. The insulation board does not, therefore, exhibit the rigid characteristics of conventional roof boards and in this relatively flexible condition is capable of conforming to irregular surfaces. Where the roof deck has an irregular surface due to a foreign object such as an aggregate or the like positioned between the roof deck and the under surface of the insulation board, the physical properties of the insulation board make it possible for the under surface of the board to conform to the irregular rough surface. The mopping of hot asphalt softens the asphalt encapsulating the cellular glass nodules in the roof board and permits the nodules to move relative to each other. The substantially spherical shape of the nodules facilitates the movement of the nodules relative to each other and a pressure exerted on the top surface of the roof board will displace the nodules adjacent the under surface of the board around the irregular object so that the entire under surface of the insulation board will conform to the roof deck surface and adhere thereto. Insulation boards formed of materials other than spherical aggregates do not have the desirable physical properties since the aggregates are unable to move or roll relative to each other.

As is discussed in an article published in the "Architectural Record," December 1964, beginning page 176 and entitled "What's Happened to the Built-Up Roof" by Robert M. Safford, one of the mechanisms through which failure occurs in built-up roofs is the high stresses exerted on the built-up roof due to structural movement. It is well known that building structures, after the built-up roof has been applied, are subject to stresses due to the building structures settling or moving to a limited degree. With conventional roof boards or poured rigid thermal insulation, movement of the building structure results in cracks in the thermal insulation and a parting of the roofing felts. The herein described thermal insulation comprises a plurality of substantially spherical cellular nodules that are in contiguous relation and have a small area of contact between the adjacent nodules. When stresses are exerted on the thermal insulation the thermal insulation is capable of moving with the building structure. Cracks that may occur in the thermal insulation after it moves with the building structure are self-healing when the built-up roof is subjected to elevated temperatures during the summer months.

The ability of the nodules to move relative to each other when stress forces are exerted thereon also, it is believed, is a solution to the presently encountered problem of sharp wrinkles in the roofing felts caused by the relative movement of the fibers in the felt. The thermal insulation previously described has substantially spherical cellular glass nodules encapsulated in a bituminous material that has substantially the same viscous properties as the bitumen in the felt. When the felts expand during the warm weather cycle, instead of the felt pulling away from the insulation at small localized areas and forming sharp wrinkles, the expansion forces will be transmitted to the encapsulated nodules and the upper layers of the nodules will move relative to each other to permit the felts and thermal insulation to form smooth elongated waves in the upper surface of the roof instead of the sharp wrinkles, as presently occurs.

According to the provisions of the patent statutes, the principle, preferred construction and mode of operation of the invention has been illustrated and what is now considered to represent its best embodiment has been described. However, it should be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

We claim:

1. A method of preparing an insulated built-up roof which comprises,

preparing an admixture of multicellular glass nodules having substantially all closed cells and a liquefied carbonaceous material,

spreading said admixture over a roof deck and forming a monolithic layer of said admixture with said adjacent multicellular glass nodules in contiguous relation with each other so that said layer has substantially the same thermal insulating value as a unitary piece of multicellular glass of substantially the same thickness as said layer,

solidifying said liquefied carbonaceous material to bond said multicellular glass nodules to each other,

applying a layer of bituminous material saturated felt to said monolithic layer of said admixture,

applying an adhesive bituminous layer to said layer of bituminous material saturated felt, and

repeating the steps of applying bituminous material saturated felt and an adhesive bituminous layer until a plurality of alternate superimposed layers of adhesive bituminous material and bituminous material saturated felt are applied.

2. A method of preparing an insulated built-up roof as set forth in claim 1 in which said liquefied carbonaceous material comprises a hydrophobic carbonaceous material.

3. A method of preparing an insulated built-up roof which comprises,

preparing an admixture of substantially spherical multicellular glass nodules having substantially all closed cells and a liquefied carbonaceous material, said multicellular glass nodules in said admixture having a coating of said liquefied carbonaceous material,

forming a monolithic layer of said admixture on a roof deck with said multicellular glass nodules randomly arranged in said layer with said adjacent multicellular glass nodules in contiguous relation with each other, said layer having between about 10 percent to 50 percent by volume of distributed but connecting interstitial voids between said substantially spherical multicellular coated glass nodules,

solidifying said liquefied carbonaceous material to bond said multicellular glass nodules to each other,

applying a layer of bituminous material saturated felt to said continuous layer of said admixture,

applying an adhesive bituminous layer to said layer of bituminous material saturated felt, and

repeating the steps of applying bituminous material saturated felt and an adhesive bituminous layer until a plurality of alternate superimposed layers of adhesive bituminous material and bituminous material saturated felt are applied,

said monolithic layer of said admixture forming a layer of insulation between said roof deck and said layers of bituminous material saturated felt, said interstitial voids in said layer of said admixture providing for limited movement of water and water vapor therethrough.

4. A method of preparing an insulated built-up roof which comprises,

preparing an admixture of substantially spherical multicellular glass nodules having substantially all closed cells and a heat liquefied carbonaceous material, said multicellular glass nodules in said admixture having a coating of said heat liquefied carbonaceous material,

spreading said admixture over a roof deck and forming a monolithic layer of said admixture, said multicellular glass nodules randomly arranged in said layer with said adjacent multicellular glass nodules in contiguous relation with each other,

said layer of said contiguous multicellular glass nodules having substantially the same thermal insulating value as a unitary piece of multicellular glass to substantially the same thickness, said layer having between about 10 percent to 50 percent by volume of distributed but connecting interstitial voids between said substantially spherical multicellular coated glass nodules,

cooling said heat liquefied carbonaceous material to bond said multicellular glass nodules to each other,

applying a layer of bituminous material saturated felt to said monolithic layer of said admixture,

applying an adhesive bituminous layer to said layer of bituminous material saturated felt, and

repeating the steps of applying bituminous material saturated felt and an adhesive bituminous layer until a plurality of alternate superimposed layers of adhesive bituminous material and bituminous material saturated felt are applied,

said monolithic layer of said admixture forming a layer of insulation between said roof deck and said layers of bituminous material saturated felt, said interstitial voids in said layer of said admixture providing a passageway for the controlled movement of water and water vapor therethrough.

5. A method of preparing an insulated built-up roof as set forth in claim 4 which includes adjusting the height of said monolithic layer of said admixture to provide a slope to said built-up roof.

6. A method of preparing a built-up roof which comprises,

heating a heat liquefied bituminous material to an elevated temperature of between about 400° F. and 620° F.,

heating substantially spherical multicellular glass nodules having substantially all closed cells to an elevated temperature of between about 300° F. and 650° F.,

admixing said heat liquefied bituminous material and glass nodules and coating said multicellular glass nodules with said heat liquefied bituminous material,

spreading said admixture over a roof deck to form a monolithic layer of said admixture on said deck, said multicellular glass nodules randomly arranged in said layer,

applying a compressive force on the surface of said layer so that adjacent multicellular glass nodules are in contiguous relation with each other and said layer has a thermal conductivity about 0.41 B.t.u./hr./sq. ft./° F./in. at a temperature of about 85° F.,

cooling said heat liquefied bituminous material to bond said multicellular glass nodules to each other,

applying a layer of bituminous material saturated felt to the surface of said monolithic layer of said admixture,

applying an adhesive bituminous material to said layer of bituminous material saturated felt, and

repeating the steps of applying bituminous material saturated felt and an adhesive bituminous layer until a plurality of alternate superimposed layers of adhesive bituminous material and bituminous material saturated felt are applied.

7. A method of preparing an insulated built-up roof which comprises,

heating a heat liquefied adhesive bituminous material having a density of about 85 lb. per cubic foot to an elevated temperature of between about 400° F. and 620° F.,

heating substantially spherical multicellular glass nodules having a diameter of between about ¼ and ⅜ inch, said multicellular glass nodules having substantially all closed cells,

admixing said heat liquefied adhesive bituminous material and said multicellular glass nodules and coating said multicellular glass nodules with said heat liquefied bituminous material,

spreading said admixture over a roof deck to form a monolithic layer of said admixture on said deck, said multicellular glass nodules randomly arranged in said layers, applying a compressive force on the surface of said layer so that adjacent multicellular glass nodules are in contiguous relation with each other and said layer has a density of about 14 lb. per cubic foot, said layer of said contiguous multicellular glass nodules having between 10 percent to 50 percent by volume of distributed but connecting interstitial voids between said substantially spherical multicellular coated glass nodules,

cooling said heat liquefied adhesive bituminous material to bond said multicellular glass nodules to each other,

applying a layer of bituminous material saturated felt to said monolithic layer of said admixture,

applying an adhesive bituminous layer to said layer of bituminous material saturated felt, and

repeating the steps of applying bituminous material saturated felt and an adhesive bituminous layer until a plurality of alternate superimposed layers of adhesive bituminous material and said bituminous material saturated felt are applied,

said monolithic layer of said admixture forming a layer of insulation between said roof deck and said layers of bituminous material saturated felt, said interstitial voids in said layer of said admixture providing for limited movement of water and water vapor therethrough.

8. A method of preparing a built-up roof which comprises,

heating a heat liquefied adhesive bituminous material to an elevated temperature of between about 400° F. and 620° F.,

heating substantially spherical multicellular glass nodules having a diameter of between about 1/4 and 3/8 inch and a density of about 13 lb. per cubic foot, said multicellular glass nodules having substantially all closed cells,

admixing said heat liquefied bituminous material and said multicellular glass nodules and coating said multicellular glass nodules with said heat liquefied bituminous material to form a first admixture,

spreading said first admixture over a roof deck to form a monolithic layer of said first admixture on said deck,

applying a compressive force on the surface of said monolithic layer so that adjacent multicellular glass nodules are in contiguous relation with each other,

thereafter heating a heat liquefied bituminous material to an elevated temperature of between about 400° F. and 620° F.,

heating substantially spherical multicellular glass nodules having a diameter of about 1/16 of an inch and a density of about 22 lb. per cubic foot, said multicellular glass nodules having substantially all closed cells,

admixing substantially equal parts by weight of said heat liquefied bituminous material and said multicellular glass nodules having a density of about 22 lb. per cubic foot and coating said multicellular glass nodules with said heat liquefied bituminous material to form a second admixture,

spreading said second admixture over said monolithic layer of said first admixture to form a second monolithic layer of said second admixture,

applying a compressive force on the surface of said layers formed of said admixtures so that the adjacent multicellular glass nodules in said second admixture are in contiguous relation with each other, said layers of said first and second admixtures having a thermal conductivity of about 0.41 B.t.u./hr./sq. ft./° F./in. at a temperature of about 85° F., said layers of said first and second admixtures having between about 10 percent to 50 percent by volume of distributed but connecting interstitial voids between said substantially spherical multicellular coated glass nodules,

cooling said heat liquefied bituminous adhesive material to bond said multicellular glass nodules to each other,

applying a layer of bituminous material saturated felt to said monolithic layer of said second admixture,

applying an adhesive bituminous layer to said layer of said bituminous material saturated felt,

repeating the steps of applying bituminous material saturated felt and an adhesive bituminous layer until a plurality of alternate superimposed layers of adhesive bituminous material and bituminous material saturated felt are applied,

said monolithic layers formed of said first and second admixtures having a density of about 16 lb. per cubic foot, said monolithic layers of said first and second admixtures forming a single layer of insulation between said roof deck and said layers of bituminous material saturated felt, said interstitial voids in said layer of said admixtures providing for limited movement of water and water vapor therethrough.

9. A layer of thermal insulation comprising,

a plurality of substantially spherical multicellular glass nodules having substantially all closed cells encapsulated in a thermo-plastic heat liquefiable bituminous material.

said heat liquefiable bituminous material bonding said multicellular glass nodules to each other and forming a layer of a preselected thickness,

said heat liquefiable bituminous material forming a substantially continuous matrix with interstitial interconnected voids between certain of said nodules,

said layer having between about 10 percent to about 50 percent by volume of said interstitial voids,

said multicellular glass nodules arranged in said layer in substantially contiguous relation to adjacent nodules to provide support for said continuous matrix of heat liquefiable bituminous material and thermal insulating properties for said layer, and

said continuous matrix of heat liquefiable bituminous material and said contiguous multicellular glass nodules forming a flexible layer of thermal insulation adapted to deflect and conform to irregular surfaces.

10. A layer of thermal insulation comprising,

a plurality of substantially spherical multicellular glass nodules having substantially all closed cells encapsulated in a thermo-plastic heat liquefiable bituminous material,

said heat liquefiable bituminous material bonding said multicellular glass nodules to each other and forming a layer of preselected thickness,

said heat liquefiable bituminous material forming a substantially continuous matrix with interstitial interconnected voids between certain of said nodules,

said layer having between about 80 percent to 90 percent by volume of said multicellular glass nodules and said interconnected interstitial voids,

said multicellular glass nodules arranged in said layer in substantially contiguous relation with adjacent nodules to provide support for said matrix of heat liquefiable bituminous material and thermal insulating properties for said layer, and

said continuous matrix of heat liquefiable bituminous material and said contiguous multicellular glass nodules forming a flexible layer of thermal insulation adapted to deflect and conform to irregular surfaces.

11. A layer of thermal insulation comprising,

a plurality of substantially spherical multicellular glass nodules encapsulated in a thermo-plastic heat liquefiable bituminous material,

said multicellular glass nodules having a bulk density of about 7 pounds per square foot,

said heat liquefiable bituminous material bonding said multicellular glass nodules to each other and forming a layer of preselected thickness,

said layer having between about 5 percent by volume to about 20 percent by volume of said heat liquefiable bituminous material in the form of a substantially continuous matrix with interstitial interconnected voids between certain of said nodules,

said layer having between about 10 percent to about 50 percent by volume of said interstitial voids and between about 40 percent to about 60 percent by volume of said multicellular glass nodules,

said multicellular glass nodules arranged in said layer in substantially contiguous relation with adjacent nodules to provide support for said matrix of heat liquefiable bituminous material and thermal insulating properties for said layer, and

said continuous matrix of heat liquefiable bituminous material and said contiguous multicellular glass nodules forming a flexible layer of thermal insulation adapted to deflect and conform to irregular surfaces.

12. A layer of thermal insulation as set forth in claim **11** in which the layer has a thermal conductivity of about 0.40 B.t.u./hr./sq. ft./° F./in. at 75° F.

13. A thermal roof insulation board comprising,

a plurality of substantially spherical multicellular glass nodules having substantially all closed cells encapsulated in a thermo-plastic heat liquefiable bituminous material,

said heat liquefiable bituminous material bonding said multicellular glass nodules to each other and forming a layer of a preselected thickness,

a liner of sheet material adhesively secured to certain of the surfaces of said layer,

said heat liquefiable bituminous material forming a substantially continuous matrix with interstitial interconnected voids between certain of said nodules,

said multicellular glass nodules arranged in said layer in substantially contiguous relation to adjacent nodules to provide support for said continuous matrix of heat liquefiable bituminous material at elevated temperatures so that said layer is capable of supporting compressive loads, and

said substantially spherical multicellular glass nodules operable to move relative to each other at elevated temperatures so that a surface of said board conforms to an irregular surface.

14. A thermal roof insulation board comprising,

a plurality of substantially spherical multicellular glass nodules having substantially all closed cells encapsulated in a thermo-plastic heat liquefiable bituminous material,

said nodules having a spectrum of sizes capable of passing through a 4 mesh Tyler Standard screen and being retained on a 12 mesh Tyler Standard screen and having a true density of about 12 pounds per cubic foot and a bulk density of about 7 pounds per cubic foot,

said heat liquefiable bituminous material having a softening point above about 180° F. and a penetration value at 77° F. of between about 20 and 30,

said heat liquefiable bituminous material bonding said multicellular glass nodules to each other and forming a layer of preselected thickness,

said heat liquefiable bituminous material forming a substantially continuous matrix with interstitial interconnected voids between certain of said nodules,

said layer having about 50 percent by volume of said multicellular glass nodules and about 45 percent by volume of said interstitial voids,

said multicellular glass nodules arranged in said layer in substantially contiguous relation to adjacent nodules to provide support for said continuous matrix of heat liquefiable bituminous material at temperatures of about 160° F. so that said layer is capable of supporting compressive loads,

a pair of liners of sheet material adhesively secured to the top and bottom surfaces of said layer, and

said thermal roof insulation having a thermal conductivity of about 0.40 B.t.u./hr./sq. ft./° F./in. at 75° F.

15. A thermal roof insulation board comprising,

a plurality of substantially spherical multicellular glass nodules having substantially all closed cells encapsulated in a thermo-plastic heat liquefiable bituminous material,

said nodules having a spectrum of sizes capable of passing through a 4 mesh Tyler Standard screen and being retained on a 12 mesh Tyler Standard screen and having a true density of about 12 pounds per cubic foot and a bulk density of about 7 pounds per cubic foot,

said heat liquefiable bituminous material having a softening point above about 180° F. and a penetration value at 77° F. of between about 20 and 30,

said heat liquefiable bituminous material bonding said multicellular glass nodules to each other and forming a layer of a preselected thickness containing about 11.5 parts by weight multicellular glass nodules and about 4.6 parts by weight heat liquefiable bituminous material,

said heat liquefiable bituminous material forming a substantially continuous matrix with interstitial interconnected voids between certain of said nodules,

said multicellular glass nodules arranged in said layer in substantially contiguous relation to adjacent nodules to provide support for said continuous matrix of heat liquedfiable bituminous material at elevated temperatures so that said layer is capable of supporting compressive loads,

a pair of liners adhesively secured to the top and bottom surface of said layer,

said thermal roof insulation board having a thermal conductivity of about 0.40 B.t.u./hr./sq. ft./° F./in. at 75° F. and a bulk density of about 12 pounds per cubic foot, and

said thermal insulation board being relatively flexible at elevated temperatures to deflect and conform to irregular surfaces.

16. A layer of thermal insulation comprising,

a plurality of substantially spherical multicellular glass nodules having substantially all closed cells encapsulated in a thermo-plastic bituminous material, said spherical multicellular glass nodules being impervious to moisture,

said thermo-plastic bituminous material bonding said multicellular glass nodules to each other and forming a layer of a preselected thickness.

said layer having between about 10 percent to about 50 percent by volume of interstitial interconnected voids between said nodules in said layer so that liquid can pass through said voids in said layer,

said multicellular glass nodules arranged in said layer in substantially contiguous relation to adjacent nodules to provide thermal insulating properties for said layer, and

said contiguous multicellular glass nodules bonded by said thermo-plastic bituminous material forming a flexible layer of thermal insulation adapted to deflect and conform to irregular surfaces.

17. A process for making a thermal roof insulation board comprising,

heating multicellular glass nodules to a temperature of between about 450° F. and 650° F.,

heating a heat liquefiable bituminous material to a temperature of between about 550° F. and 620° F., and liquefying said heat liquefiable bituminous material,

admixing said heated multicellular glass nodules and said liquefied bituminous material to encapsulate said multicellular glass nodules with said liquefied bituminous material,

forming a layer of said admixture of a preselected thickness,

applying a compressive force to said layer to position said adjacent nodules in substantially contiguous relation and forming a substantially continuous matrix of said heat liquefiable bituminous material with interstitial interconnected voids between certain of said nodules, and

cooling said layer of said admixture.

18. A process for making a thermal roof insulation board comprising,

heating multicellular glass nodules having substantially all closed cells and a density of about 12 pounds per cubic foot to a temperature of between about 450° F. and 650° F.,

heating a heat liquefiable bituminous material having a softening point of between 180° F. and 200° F. to a temperature of between about 550° F. and 620° F.,

admixing about 11.5 parts by weight of said multicellular glass nodules with about 4.6 parts by weight of said liquefied bituminous material to encapsulate said multicellular glass nodules with said heat liquefiable bituminous material,

forming a layer of said admixture of a preselected thickness,

applying a compressive force to said layer to position said adjacent nodules in substantially contiguous relation and forming a substantially continuous matrix of said heat liquefiable bituminous material with interstitial interconnected voids between certain of said nodules, and

cooling said layer of said admixture.

19. A process for making a thermal roof insulation board comprising,

heating multicellular glass nodules to a temperature of between about 450° F. and 650° F.,

heating a heat liquefiable bituminous material having a softening point of between 180° F. and 200° F. to a temperature of between about 550° F. and 620° F.,

admixing said heated multicellular glass nodules and said liquefied bituminous material to encapsulate said multicellular glass nodules with said liquefied bituminous material,

coating a surface of a liner with liquefied bituminous material,

forming a layer of said admixture on said liner coated surface,

coating a surface of a second liner with liquefied bituminous material,

applying said liner coated surface to the top surface of said layer,

applying a compressive force to said layer between said liners to position said adjacent nodules in a substantially contiguous relation and forming a substantially continuous matrix of said heat liquefiable bituminous material with interstitial interconnected voids between certain of said nodules,

cooling said layer of said admixture, and

obtaining a thermal roof insulation board therefrom having a bulk density of about 12 pounds per cubic foot and a thermal conductivity of about 0.40 B.t.u./hr./sq. ft./° F./in. at 75° F.

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