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(54) **MINERAL FIBER INSULATION HAVING THERMOPLASTIC POLYMER BINDER AND METHOD OF MAKING THE SAME**

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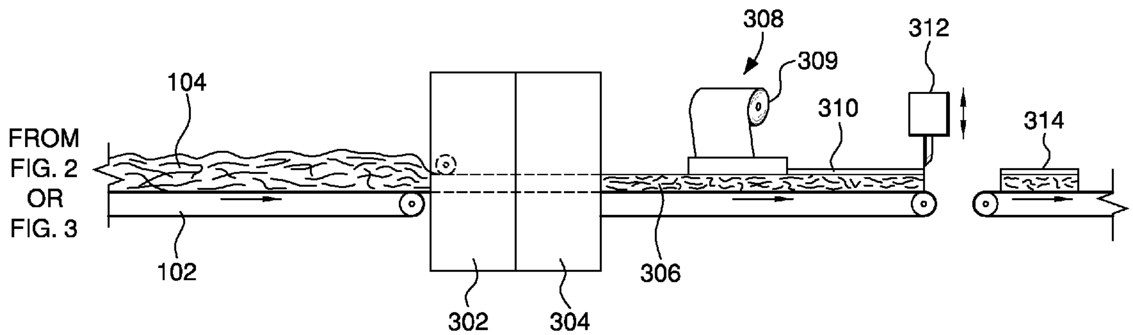
(57) **ABSTRACT**

A method of forming a fibrous insulation product includes forming at least one fibrous veil including first fibers and blowing a non-aqueous, formaldehyde-free, thermoplastic binder in powder, liquid or fibrous form into said veil during said forming step to form a mixture of the binder and the first fibers. When in fibrous form, the binder fibers have average length of less than or equal to about 15 mm. The mixture is collected on the forming belt and formed into an insulation batt, board or molding media.



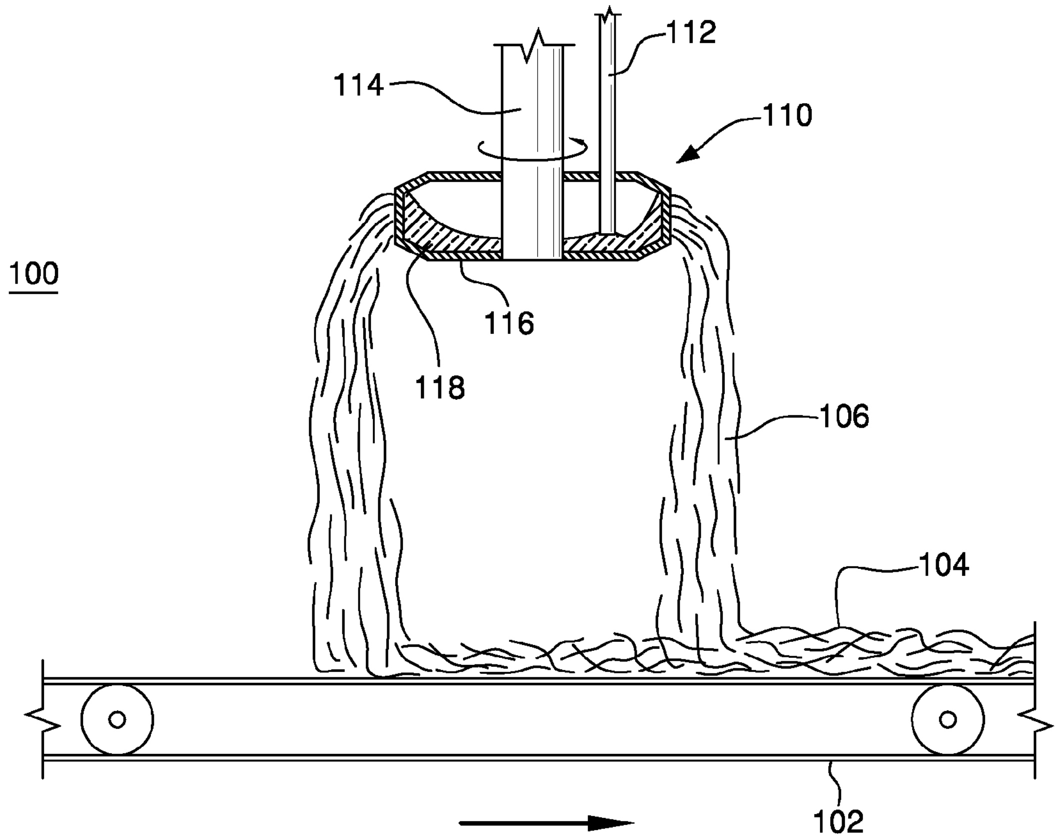


FIG. 1

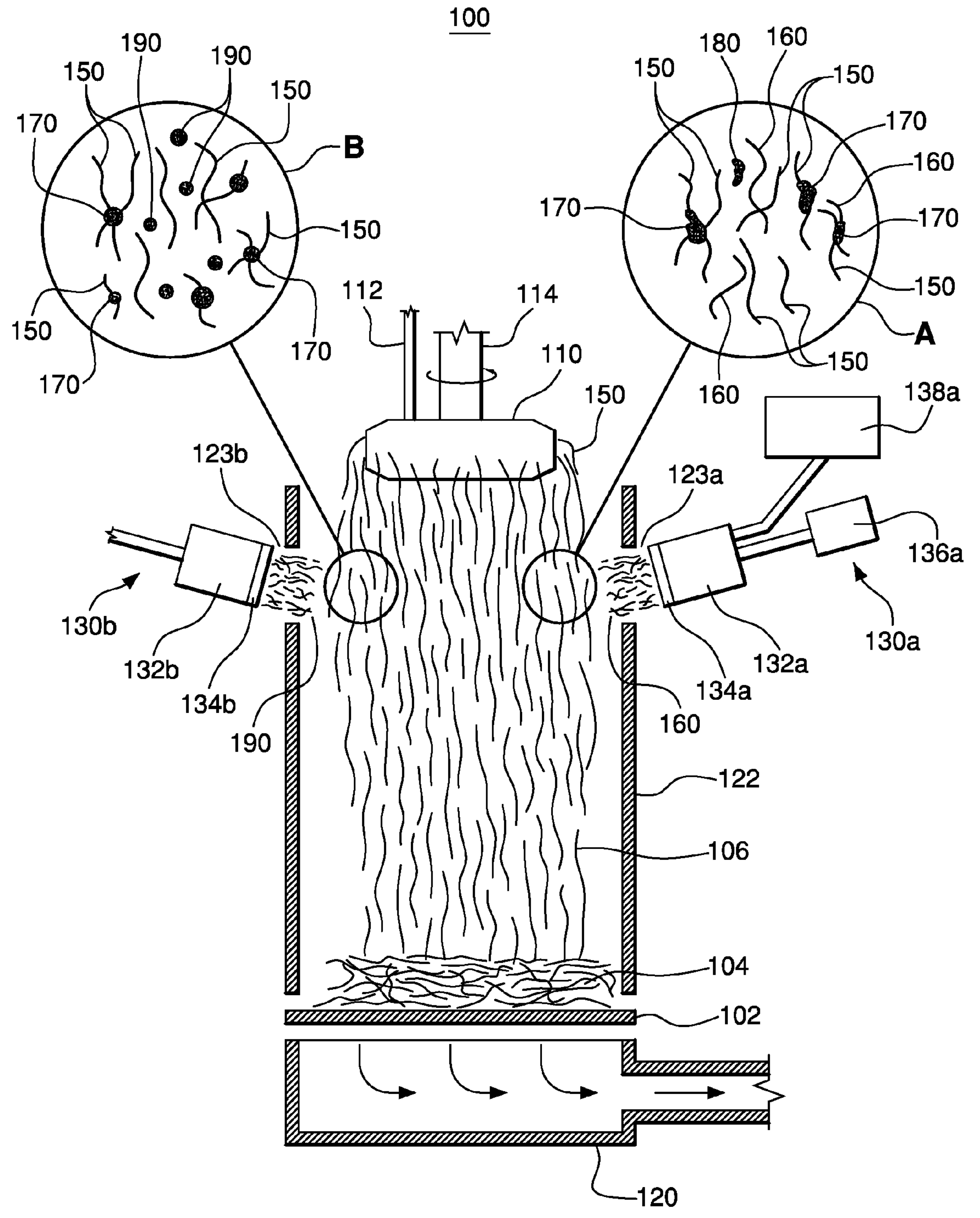

100
190
190
150
150
170
B
150
150
170
150
170
170
180
160
150
150
170
160
170
170
150
A
150
160
112
114
110
150
138a
123b
123a
136a
130b
132b
134b
190
134a
132a
130a
160
122
106
104
102
120

FIG. 2

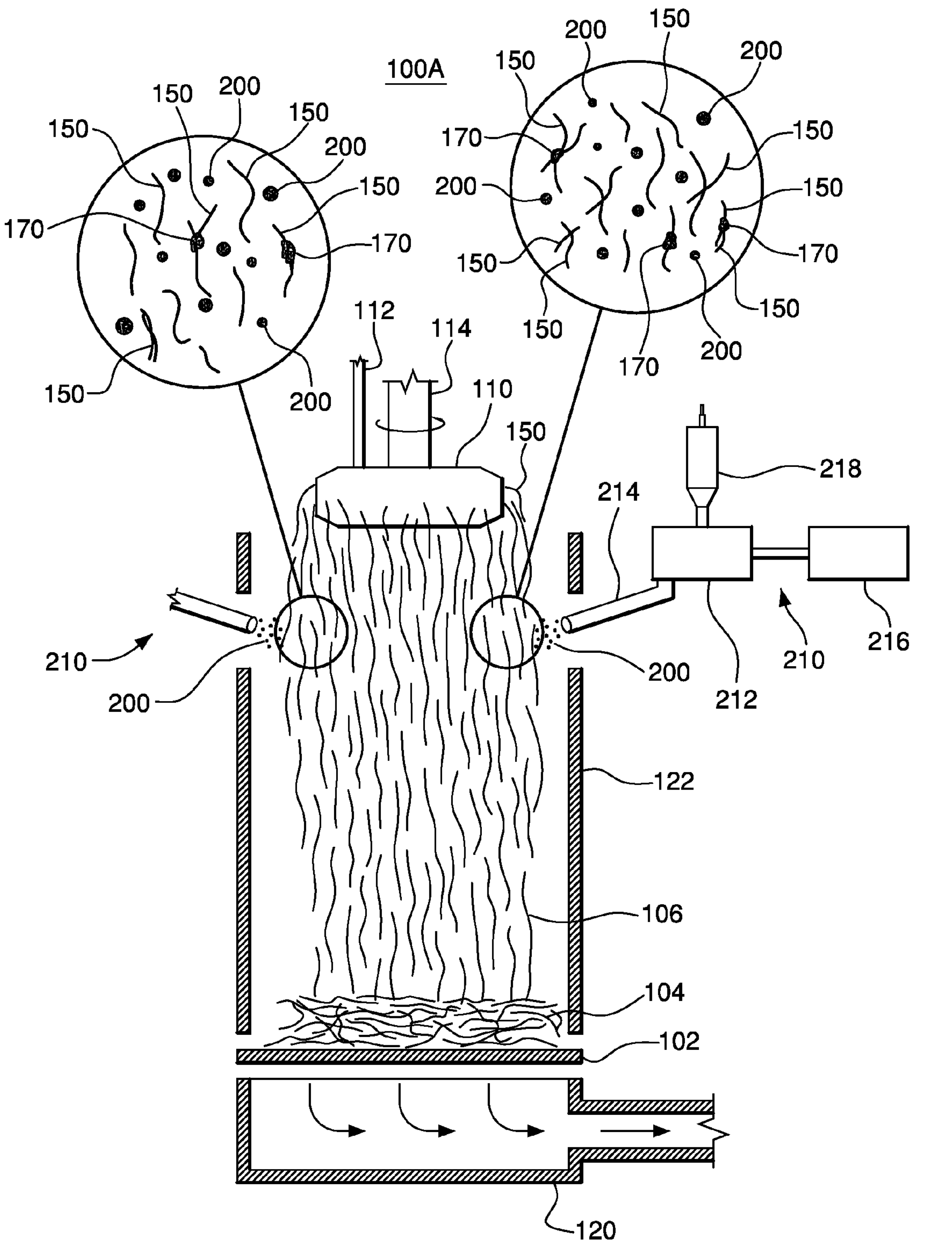

100A
150
200
170
112
114
110
218
214
212
210
216
122
106
104
102
120

FIG. 3

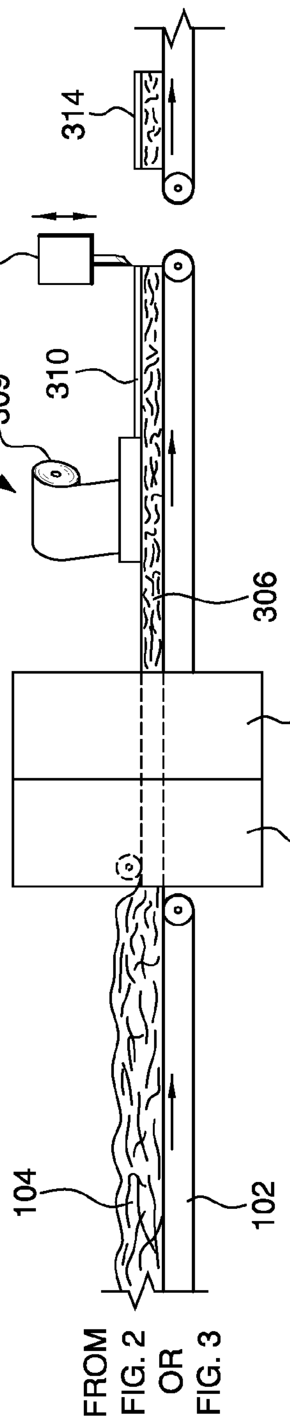

FROM
FIG. 2
OR
FIG. 3
104
102
302
304
306
308
309
310
312
314

FIG. 4

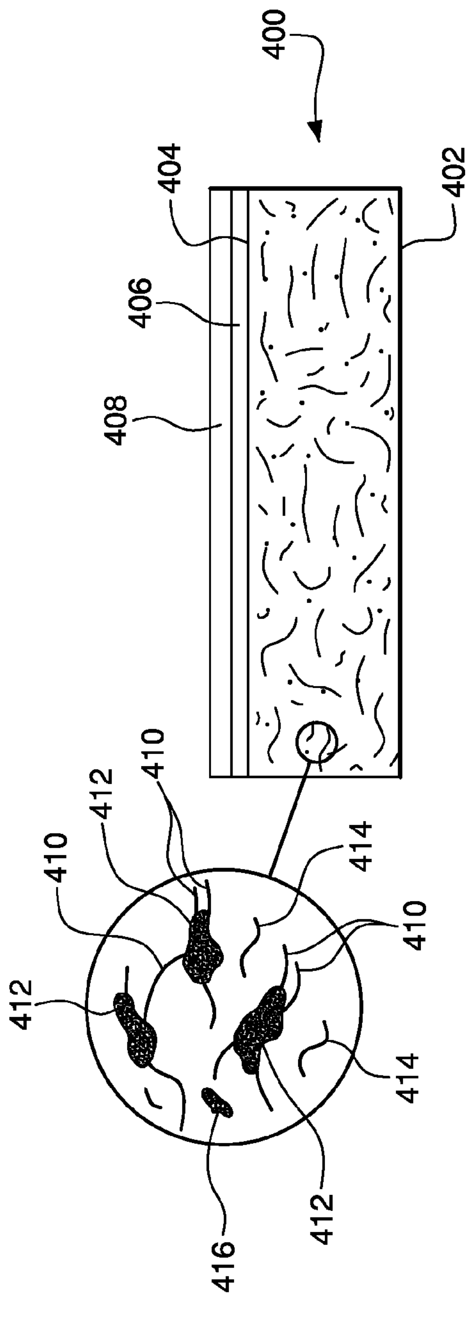

400
402
404
406
408
410
410
410
412
412
412
414
414
416

FIG. 5

MINERAL FIBER INSULATION HAVING THERMOPLASTIC POLYMER BINDER AND METHOD OF MAKING THE SAME

FIELD OF THE INVENTION

[0001] The present invention relates generally to mineral fiber insulation products and methods of making the same.

BACKGROUND OF THE INVENTION

[0002] Batt insulation is commonly manufactured by fiberizing mineral fibers from a molten mineral bath (e.g., molten glass) by forcing them through a spinner rotating at a high number of revolutions per minute. The fine fibers are then contacted by a pressurized hot gas to draw the fibers to a useable diameter and length. The fibers are typically sprayed with an organic material, such as a phenol/formaldehyde binder. The fibers are then collected and distributed on a conveyor to form a mat. The resin is then cured in a curing oven. The mat is then sliced into lengthwise strips having desired widths and chopped into individual batts. In some cases, a facing material, such as Kraft paper coated with a bituminous material or other vapor retarder, is added to the mat prior to the cutting step.

[0003] Often, the organic material is provided in an aqueous solution and sprayed onto the cylindrical veils of rotary spun glass fibers. Typically, the phenol/formaldehyde binder contains urea, and has a molecular weight of around 600 in the uncured state in the aqueous solution being applied to the glass fibers.

[0004] One of the problems with applying aqueous organic binders to cylindrical veils of mineral fibers is that a portion of the binder tends to evaporate prior to contact between the liquid binder drop and a mineral fiber in the veil. This evaporated binder material becomes a contaminant in the exhaust air stream of the process and must be cleaned, adding significant expense to the manufacturing process. Further, the binder material on the mineral fibers tends to be sticky and necessitates extensive cleaning of the fiber collection apparatus in order to avoid the formation of product defects.

[0005] Another problem associated with the application of the thermosetting phenolic binder material is that a curing process is required. Typical problems associated with curing include operational costs associated with the curing oven, the cost of handling pollution issues, degree of cure problems and product integrity problems.

[0006] Aqueous-based formaldehyde-free binders have been proposed in the art. For example, acrylic binders that are formaldehyde-free have been proposed in place of the phenol/formaldehyde resin binders. Examples of formaldehyde-free binders used in such applications can be found in U.S. Pat. Nos. 5,932,665 and 6,331,350. However, because these acrylic binders are applied in aqueous form, they are difficult to use since a low PH is required for storage and application, at least when compared with binders in dry form.

[0007] U.S. Pat. No. 5,595,584 to Loftus et al. proposes an insulation manufacturing system that aligns centrifugal spinnerets for mineral fibers and organic fibers above a collection surface to form alternating mineral and organic fiber veils. The organic and mineral fibers commingle and accumulate on the collection surface. The collected fibers are then processed to form an insulation product. It is very difficult to obtain uniformly blended mats of glass and organic fibers using this system.

[0008] Finally, U.S. Pat. No. 5,983,586 to Berdan, II et al. discloses a fibrous insulation manufacturing system for forming a binderless, encapsulated insulation blanket. The binderless insulation blanket includes organic fibers and very long (about 1-3 meters in length) thermoplastic fibers. As with the system of the '584 patent, it is very difficult to obtain uniformly blended mats of glass and organic fibers using this system.

[0009] Improved methods of manufacturing a formaldehyde-free insulation product are desired. Improved insulation products are also desired.

SUMMARY OF THE INVENTION

[0010] A method of forming a fibrous insulation product includes forming at least one fibrous veil including first fibers and blowing a non-aqueous, formaldehyde-free, thermoplastic binder in powdered, liquid or fibrous form into the veil during said forming step to form a mixture of the binder and the first fibers. When in fibrous form, the binder fibers have average length of less than or equal to about 15 mm. The mixture is collected on the forming belt and formed into an insulation batt, board or molding media.

[0011] A system for forming a fibrous insulation product is also provided. The system includes at least one fiberizing apparatus for forming a fibrous veil comprising first fibers and means for blowing a non-aqueous, formaldehyde-free, thermoplastic binder in powder, liquid or fibrous form into the veil to form a mixture of the binder and the first fibers, the fibrous form having average length of less than or equal to about 15 mm. A forming belt is disposed below the fiberizing apparatus for collecting the mixture. The system also includes an oven for heating the mixture to a temperature at or above the melting temperature of the thermoplastic binder.

[0012] The manufacturing system and method avoids or substantially reduces contamination and other problems associated with phenolic resins by using a non-aqueous, formaldehyde-free thermoplastic polymer binder to bind the insulation fibers. Use of a non-aqueous solution lessens the storage area needed for the binder and generally provides a simpler, cleaner, more efficient process. Further, the final insulation product is formaldehyde-free, or substantially free.

[0013] In one particular embodiment of a method of forming an insulation product, a non-aqueous, formaldehyde-free, thermoplastic binder is directed from a hot melt applicator into the fibrous veil to form a mixture of the binder and the first fibers. The mixture is heated to a temperature above the melting temperature of the thermoplastic binder in an oven, wherein at least a majority of the thermoplastic binder is melted, whereby the melted thermoplastic binder forms melt-bonds with the first fibers when cooled.

[0014] In one embodiment, the thermoplastic binder is provided as a powder, which is formed using a gas atomization process.

[0015] The above and other features of the present invention will be better understood from the following detailed description of the preferred embodiments of the invention that is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The accompanying drawings illustrate preferred embodiments of the invention, as well as other information pertinent to the disclosure, in which:

[0017] FIG. **1** is a schematic side view in elevation of a fiber spinner disposed over a collecting belt;

[0018] FIG. **2** is a schematic front view in elevation of an apparatus for mixing glass fibers with a blown thermoplastic binder according to a first embodiment of the present invention;

[0019] FIG. **3** is a schematic front view in elevation of a second embodiment of the present invention of an apparatus for mixing glass fibers with a blown thermoplastic binder;

[0020] FIG. **4** is a side elevation view of a portion of an insulation manufacturing system disposed after the apparatus of FIG. **2** or FIG. **3**; and

[0021] FIG. **5** is a side elevational view of an exemplary insulation batt according to the present invention.

DETAILED DESCRIPTION

[0022] This description of the exemplary embodiments is intended to be read in connection with the accompanying drawings, which are to be considered part of the entire written description. In the description, relative terms such as "lower," "upper," "horizontal," "vertical," "above," "below," "up," "down," "top" and "bottom" as well as derivative thereof (e.g., "horizontally," "downwardly," "upwardly," etc.) should be construed to refer to the orientation as then described or as shown in the drawing under discussion. These relative terms are for convenience of description and do not require that the apparatus be constructed or operated in a particular orientation. Terms concerning attachments, coupling and the like, such as "connected" and "interconnected," refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise.

[0023] FIG. **1** is a schematic side cross-section view of a portion of an insulation manufacturing system **100**. FIGS. **2** and **3** are schematic front elevational views of first and second embodiments of the manufacturing system and show additional features of the system of FIG. **1**. The manufacturing system **100** includes a conventional fiberizing apparatus **110**, which is known, per se, in the art. Briefly, the fiberizing apparatus **110** includes a spinneret **116**, which spins around axle **114**. Molten glass **118** is provided to an interior of the spinneret **116** through pipe **112**, which is connected to a glass melting system (not shown). The glass fibers formed by the fiberizing apparatus **110** travel in a downwardly moving veil **106**, which is generally cylindrical in shape, and which contains not only the glass fibers, but also rapidly moving air and gases of combustion from a burner (not shown). The veil **106** initially has a diameter slightly larger than the diameter of the spinneret **106**. The size or diameter of the veil **106**, and the rotational speed of the gases and fibers within the veil **106**, change as the veil **106** moves downwardly. These changes are due to dissipation of the original energy of the gases within the veil **106** and to external forces influencing the veil **106**.

[0024] In embodiments, the veil **106** can be formed using a veil forming process as described in, for example, WO 2002/070417 entitled "Process and Device for Formation of Mineral Wool Products," the entirety of which is incorporated by reference herein. The process described therein is known as "internal centrifugation."

[0025] Nozzles (not shown) can optionally be positioned to direct liquid sprays into the veil **106**. Such sprays could include water or other evaporative liquid to cool the fibers and associated gases within the veil **106**. The nozzles could also spray a lubricant onto the fibers to reduce fiber-to-fiber friction in the ultimate insulation product, which could thereby prevent fiber damage.

[0026] Another common device (not shown) for affecting the veil **106** is a set of air lappers that are positioned on either side of the veil **106**. The air lappers discharge air to sweep or direct the veil **106** from side to side of the forming hood **122** (shown in FIGS. **2-3**) so that the pack **104** collected on the moving collection surface or forming chain **102** will have an even distribution across the width of the forming chain, from one hood wall to the other. The forming chain **102** is mounted for movement as a conveyor, and is foraminous so that a suction box **120** (shown in FIGS. **2-3**), positioned beneath the forming chain, can evacuate gasses from the forming hood **122** and pack **104**.

[0027] FIG. **2** is a schematic front elevational view of a first embodiment of the insulation manufacturing system **100**. The system **100** includes thermoplastic binder applicator devices **130*a*** and/or **130*b*** disposed to introduce thermoplastic binder directly into the veil **106**. More specifically, the applicator devices **130*a***, **130*b*** introduce a non-aqueous, formaldehyde-free thermoplastic binder to the veil **106**. In one embodiment, the applicator **130*a*** is a hot melt applicator which blows thermoplastic binder fibers **160** into veil **106** to commingle with rotary fibers **150** from fiberizing apparatus **110**. Applicator **130*a*** includes a hot melt gun **132*a*** with a die head or nozzle labeled **134*a*** connected thereto. A source of hydraulic and/or pneumatic pressure **136*a*** is coupled to the gun **132*a*** for use in extruding the thermoplastic and/or blowing the extruded thermoplastic. A thermoplastic polymer melter or extruder **138*a*** is also coupled to the gun **132*a***. Melted thermoplastic binder is provided to the gun **132*a*** from polymer melter **138*a*** and forced through die head/nozzle **134*a*** to form thermoplastic binder fibers **160** that are blown into veil **106**. The thermoplastic binder fibers can be solid, semi-solid or molten streams which become sold or semi-solid as they mix with the veil **106**. Alternatively, the binder fibers **160** are molten until after they are collected onto the belt **102**.

[0028] Pneumatic pressure, i.e., air, can be provided from source **136*a*** to attenuate thermoplastic binder fibers extruded from die **134*a*** and to blow the fibers into the veil **106**. Hydraulic pressure can be provided from source **136*a*** to provide drive pressure in gun **132*a*** for pushing the melted polymer through die/nozzle head **134*a***. This pressure may also be supplied by an electrically driven pressure means, as opposed to pneumatically.

[0029] Window A of FIG. **2** is an enlarged view of a portion of the fibrous veil **106** where the thermoplastic binder fibers **160** are blown into the veil **106** to meet the first fibers **150**. As can be seen in window A, some first fibers **150** and thermoplastic fibers **160** entangle. Some thermoplastic fibers **160** partially melt due to the heat of the gasses within veil **106** and/or the heat of the attenuated fibers **160** to form initial melt bonds **170** with either first fibers **150** or other thermoplastic fibers **160**. Still further, some of the thermoplastic fibers **160** can fully or partially melt or be molten before or upon entry into the veil **106** to form non-fibrous thermoplastic binder bodies **180**.

[0030] Melt blown applicator **130*b*** is similar to melt blown applicator **130*a***, in that it includes a gun **132*b***, a pneumatic or hydraulic source (not shown) and a thermoplastic polymer melter (also not shown). Unlike melt blown applicator **130*a***, however, the melt blown applicator **130*b*** is configured, such as by a selected die or nozzle **134*b***, to provide the thermoplastic binder in droplet rather than fibrous form. The applicator **130***b* blows droplets **190** into veil **106** to coat the rotary fibers **150**, as best seen in enlarged window B. As can be seen in window B, the droplets **190** can form melt bonds **170** with the rotary fibers **170** or simply coat or partially coat the fibers.

[0031] In an exemplary embodiment, the hot melt applicators **130***a* and **130***b* use the Nordson ProBlue® hot melt unit available from Nordson Corporation of Westlake, Ohio as polymer melter **138***a*. These melters have tank capacities up to 50 liters. This device melts the thermoplastic polymer and pumps the melted polymer to hot melt gun **132***a*. Appropriate applicators can be selected for die **134***a* and gun **132***a* in order to form the melted polymer into fibers **160** and/or droplets **190**. One exemplary Nordson applicator is the Nordson Series MB-200 Meltblown Applicator which utilizes air jets to create blown fibers ranging in size from 0.2-50 μm in diameter and shorter than 200 mm in length. Various dies and number of dies can be attached to the MB-200 Meltblown Applicator to adjust fiber size and coverage. Another exemplary applicator is the Nordson MELTEX® Series EP 11 Slot Gun applicator, which has an application width of 400 mm or more. Still further, another exemplary applicator is the Nordson CONTROL COAT® System applicator, which produces fine fibers by impinging heated air on the hot melt as it is extruded through slot openings to stretch and shred the blown adhesive.

[0032] Exemplary nozzles for die **134***a* include Nordson UNIVERAL™ CF® (Controlled Fiberization) nozzles, Nordson EP nozzles, and Nordson UNIVERSAL™ SUMMIT™ nozzles. The same nozzles can be used for applicator **134***b* by adjusting the temperature and pressure, flow rate and/or other process parameters to form droplets **190**.

[0033] The diameter and length of the thermoplastic polymer fibers **160** and the diameter of the thermoplastic droplets **190** may be controlled by several process parameters, including polymer temperature, fluid pressure, atomizing air pressure, fluid flow rate, and nozzle orifice size. The choice of the polymer and its melt index may also affect the fiber and particle size.

[0034] In one embodiment, the thermoplastic binder fibers **160** have average diameters between about 0.2 to about 20 μm, and more preferably between about 0.5 to about 15 μm. These fibers have average lengths between about 0.1 to about 15 mm, and more preferably between about 0.1 to about 6 mm.

[0035] In one embodiment, the thermoplastic binder droplets **190** have average diameters between about 0.5 to about 10 μm, and more preferably between about 0.5 to about 6 μm.

[0036] An opening **123***a* can be provided in the wall of a closed forming hood **122** through which melt blown applicator **130***a* blows fibers **160** into veil **106**. It will be understood that no opening is needed in an open forming hood. Alternatively, part or all of the applicator **130***a* could be disposed within the hood **122**. Likewise, an opening **123***b* is provided in the wall of forming hood **122** through which melt blown applicator **130***b* blows droplets **190** into veil **106**. Alternatively, part or all of the applicator **130***b* could be disposed within the hood **122**. In exemplary embodiments, a sufficient number of applicators **130***a* and/or **130***b* are provided around the circumference of the veil **106**, such as at spaced increments, so as to provide a substantially homogenous mix of fibers **160** and thermoplastic polymer binder in mixture or pack **104**. The melt blown applicators may be positioned such that they are in an approximately 15-45° angle, and more preferably a 30° angle from the horizontal plane in order to blow into the veil **106** at a downward angle towards the forming belt **102**. In one embodiment, the applicators **130***a* and/or **130***b* are disposed between about 100-200 mm, and more preferably about 150 mm, laterally away from the veil. In one embodiment, the applicators are positioned so that the blown fibers or droplets intersect the veil **106** at about 500-700 mm, and preferably at about 600 mm, from the spinneret (i.e., from the beginning of the veil **106**).

[0037] In exemplary embodiments, the pack **104**, and thus the ultimate insulation product, includes between about 1-20% by weight of thermoplastic binder, and more preferably between about 3-15% by weight of thermoplastic binder. Preferred embodiments use no phenolic resin binder, though in some applications small amounts, such as 1-5% by weight phenolic resin binder, may be incorporated into the product using conventional methods of application.

[0038] FIG. **3** is a schematic front elevational view of an insulation manufacturing system **100**A according to a second embodiment of the system. The system is identical to that shown in FIG. **2** and described above except for replacement of some or all of melt blown applicators **130***a* and/or **130***b* with polymer powder provider apparatus **210**. Polymer powder provider apparatus **210** provides the thermoplastic binder in solid, powdered form, shown as particles **200**, which are blown into veil **106**. Some of the particles may melt upon contact with veil **106**, forming melt bonds **170** with the rotary fibers **106**.

[0039] In one embodiment, the apparatus **210** includes a chamber **212** for storage of the thermoplastic binder in powdered form. The binder particles **200** can be blown from the chamber **212** using air source (e.g., a blower) **216** through pipe or other conduit **214** into the forming hood **122** to veil **106**. In one embodiment, the powdered binder particles are ground from a source material using grinding techniques familiar to those in the art to a size of less than or equal to about 100 μm, and stored in bulk in chamber **212**. In an alternative embodiment, the powdered binder can be provided from what is known as a gas atomizer. A gas atomizer **218** is shown coupled directly to chamber **212**, though there is no reason the gas atomizer **218** could not simply be used to produce powdered binder particles that are later supplied to chamber **212**.

[0040] Gas atomizers are described in, for example, U.S. Pat. Nos. 6,171,433, 6,461,546 and 6,533,563, the entirety of each of which is hereby incorporated by reference herein. In one embodiment, the gas atomizer **218** includes a high pressure crucible where the thermoplastic polymer is heated under inert atmosphere and under high pressure until molten. The molten polymer is forced under pressure through a pour tube and into an atomization nozzle. The polymer is then atomized in an atomization chamber and molten droplets of polymer fall through the atomization chamber. As the droplets fall, they cool to form the polymer powder. The polymer powder is then collected in a collection chamber, such as chamber **212** or separate chamber for transport to chamber **212**. Various shapes and sizes of particle can be formed. In one embodiment, the gas atomizer forms uniform micron-sized spherical particles. The gas atomizer can form spherical particle sizes ranging from close to 0 μm to about 250 μm. In embodiments, the particles **200** have average diameters between about 0.2 to about 60 μm, and more preferably between about 2 to about 30 μm. The gas atomizer can also be configured to form elongated spheres or whisker particles.

Whisker particles formed by the gas atomizer have diameters of about 100 nm and lengths of a few millimeters. An exemplary material for use in the gas atomizer **218** is polyethylene.

[0041] In preferred embodiments, the rotary fibers **160** are mineral fibers, such as glass fibers, though other fibers, such as rock wool fibers, polymer fibers or other insulation fibers may also be utilized. In one embodiment, the average fiber diameter is between about 0.25 to 8 μm, and preferably between about 1 to 6 μm. The preferred average length of the fibers is between about 1 to 100 mm, and more preferably between about 5 to 75 mm.

[0042] As shown in FIG. **4**, the loose pack **104** from either FIG. **2** or FIG. **3** is provided to a product shaping oven **302** where the pack is exposed to hot gases blown through the pack to melt the thermoplastic polymer binder. The thermoplastic polymer binder melts to form a bond between the rotary fibers **150**, thereby forming an insulation product having good pack integrity. Preferably, the pack **106** is under vertical compression during the product shaping process so that the product thickness is defined.

[0043] The pack **106** is preferably heated to a temperature and for a period of time such that at least a majority, and preferably substantially all, of the polymeric binder therein melts, particularly when the polymeric binder is the only binder present in the pack **106**. Preferably, between about 50-100% of the thermoplastic binder is completely melted, and more preferably about 80-100%. Put another way, preferably between about 50-100%, and more preferably between about 80-100%, of the added thermoplastic binder is melted so that the binder flows to form melt bonds between fibers **150** once cooled.

[0044] Exemplary thermoplastic polymers for use as the thermoplastic binder include inonomer, ethylene methyl acrylate, ethylene acrylic acid, polyacetal (Acetal), polybutylene terephthalate (PBT), polyphthalate carbonate, polyethylene terephthalate (PET), polylactic acid, styrene acrylonitrile, acrylonitrile styrene acrylate, polyethersulfone, polystyrene, polyethylene, polypropylene, ethylene vinyl acetate, nylon, polyester, polyvinyl chloride, ethylene vinyl alcohol, polycarbonate, acrylonitrile butadiene styrene (ABS), polyoxymethylene, polyoxymethyl methacrylate, or a blend of two or more of these materials. The following table lists some exemplary commercially available thermoplastic polymers that may be used as the thermoplastic binder described above. The temperature inside the oven **302** is determined by the melting temperature of the selected material and the amount of time it takes for the pack to pass through the oven **302**.

Material
Basell "Metocene" MF650Y polyethylene, available from Basell, North America Inc. of Elkton, MD
Basell "Metocene" MF650X polyethylene
Honeywell A-C ® 925 nylon, available from Honeywell International Inc. of Morristown, NJ
Honeywell A-C ® 597 nylon
Dow STYRON ® 668 Polystyrene Resin, available from Dow Chemical Company of Midland, Michigan
Dow STYRON ® 675 Polystyrene Resin
Dow STYRON ® 678C Polystyrene Resin
Dow STYRON ® 685P Polystyrene Resin
Dow STYRON ® 615APR Polystyrene Resin
Dow STYRON ® 695 Polystyrene Resin
Dow High Density Polyethylene Resin 30460M
Dow High Density Polyethylene Resin DMDA-8920 NT7
Dow High Density Polyethylene Resin DMDA-8940 NT7
Dow High Density Polyethylene Resin DMDA-8965 NT7
Dow High Density Polyethylene Resin DMDA-8980 NT7
Dow Polypropylene Resin 5E420
Dow Polypropylene Resin 5D49
Dow Polypropylene Resin 5D98
Dow Polypropylene Resin NRD6-589
ExxonMobil ESCORENE ™ Ultra EVA Resin MV02528EH2, available from Exxon Mobil Chemical Company of Houston, Texas
ExxonMobil ESCORENE ™ Ultra EVA Resin AD 0433
ExxonMobil ESCORENE ™ Ultra EVA Resin AD 0428
ExxonMobil PP3546G
ExxonMobil PP3746G
Arkema RB8010 Polyvinyl Chloride, available from Arkema of France
GE Cycolac MG94 ABS available from GE Plastics of Pittsfield, Massachusetts
GE Valox 325M PBT
DuPont Surlyn 1702 lonomer available from duPont Engineering Polymers of Willmington, DE
ExxonMobil Optema TC 140 ethylene methyl acrylate
ExxonMobil Escor 5200 ethylene acrylic acid
GE Lexan 121 polycarbonate
GE LNP Stat-by K-E Acetal
GE Gesan CTS100 styrene acrylonitrile
GE LNP Thermotuf V-1000 Nylon
GE Geloy CR3020 acrylonitrile styrene acrylate
GE Lexan 4501 polyphthalate carbonate
GE Valox 365 polyethylene terephthalate
GE LNP Colorcomp Compound PDX-J-91550 polyethersulfone

[0045] Immediately following the oven **302** is a cooling section **304** where the fibrous product is cooled with ambient air that passes through the insulation through the use of a suction chamber below the mat. Cooled fibrous lane **306** exits the cooling section **304**. The fibrous lane **306** optionally can be passed through facing layer applicator **308** which takes a facing layer, such as a thin film of polyethylene or kraft material, from a roll **309** and applies the film to the insulation lane **306**, such as with an adhesive or bituminous layer. Alternatively, the fibrous lane **306** can be encapsulated in a material or left uncovered. Subsequently, the insulation lane **306** is cut into lengths by the chopper **312** to form batt products **314**, board products or roll products. The product can be rolled by a roll-up machine at the end of the insulation production line.

[0046] The rolls, batts, or board products may subsequently be used as a molding media where they are compressed and shaped with heat and pressure above the melting point of the thermoplastic binder and then cooled below that melting point to permit them to maintain the shape of the mold. By "molding media" it is meant an insulation mat that can be subsequently compressed and reshaped in a heated molding process to manufacture a dense flat board or a contoured insulation that is used as, for example, insulation in automobiles. A reshaped product can be referred to as a "molded media."

[0047] The batts (boards or molding media) **314** are preferably in a density range of about 0.35-8 lb/ft^3 (4.8-128 kg/m^3), and preferably about 0.3-6 lb/ft^3 (4.8-96 kg/m^3), and still more preferably about 0.4 to 4.0 lb/ft^3 (6.4-64 kg/m^3). The thickness of the insulation layer is generally proportional to the insulated effectiveness or "R-value" of the insulation. Low density batts may typically have a density between 0.3 and 2 lb/ft^3 and a thickness between 2 and 12 inches. Boards may typically have a density between 1 and 8 lb/ft3 and a thickness between 0.25 and 6 inches and may be produced as sheets about 2 to 4 feet wide by about 4 to 12 feet long. Molding media may typically have a density between 0.3 and 2 lbs/ft3 and a thickness between 1 and 4 inches and may be produced in rolls about 2 to 8 feet wide and 50 to 200 feet long.

[0048] FIG. **5** is a side elevation view of an insulation batt **400** according to one embodiment of the present invention. The batt **400** may be manufactured using the system of FIGS. **1**-**4**. The batt **400** includes top and bottom major surfaces **404** and **402**, respectively. A facing layer **408** is adhered to the top major surface **404** using an adhesive or bituminous layer **406**. As shown in the enlarged portion of the batt **400**, shown in the window of FIG. **5**, the insulation layer of the batt **400** includes first fibers **410** bonded to one another using a non-aqueous, formaldehyde-free thermoplastic binder, which forms melt or adhesive bonds **412** between the fibers **410**. As described above, it is preferred that most, if not all, of the thermoplastic binder that is mixed with the fibers **410** melts to form melt-bonds **412**, though, in embodiments, a small portion of the thermoplastic binder may survive as thermoplastic fibers **414** or cooled thermoplastic droplets or particles **416**.

[0049] Though low density batts are preferred candidates, as explained above the present disclosure also applies to higher density semi-rigid and rigid insulation boards ("high density" insulation) and molding media. It should be understood that the insulation batt, board or molding media can provide thermal and/or acoustic insulation properties.

[0050] The manufacturing system described herein avoids or substantially reduces contamination and other problems associated with phenolic resins by using a non-aqueous, formaldehyde-free thermoplastic polymer binder to bind the insulation fibers. Use of a non-aqueous solution lessens the storage area needed for the binder and generally provides a cleaner, more efficient process. The final insulation product is formaldehyde-free, or substantially free.

[0051] Although the invention has been described in terms of exemplary embodiments, it is not limited thereto. Rather, the appended claims should be construed broadly to include other variants and embodiments of the invention that may be made by those skilled in the art without departing from the scope and range of equivalents of the invention.

What is claimed is:

1. A method of forming a fibrous insulation product, comprising:

forming at least one fibrous veil comprising first fibers;

blowing a non-aqueous, formaldehyde-free, thermoplastic binder in powder, liquid or fibrous form into said veil during said forming step to form a mixture of said binder and said first fibers, said fibrous form having average length of less than or equal to about 15 mm;

collecting said mixture on said forming belt; and

forming said mixture into an insulation batt, board or molding media.

2. The method of claim **1**, wherein said binder is blown into said veil in liquid form as a hot melt.

3. The method of claim **2**, wherein said hot melt comprises droplets having average diameters between about 0.5 to about 10 μm.

4. The method of claim **3**, wherein said diameters are between about 0.5 to about 6 μm.

5. The method of claim **1**, wherein said binder is blown into said veil in fibrous form.

6. The method of claim **5**, wherein said binder fibers have average diameters between about 0.2 to about 20 μm and average length between about 0.1 to about 15 mm.

7. The method of claim **6**, wherein said diameters are between about 0.5 to about 15 μm and said length is between about 0.1 to about 6 mm.

8. The method of claim **1**, wherein said binder is blown into said veil in powder form.

9. The method of claim **8**, wherein the average diameter of particles in said powder form is between about 0.2 to about 60 μm.

10. The method of claim **9**, wherein the diameter is between about 2 to about 30 μm.

11. The method of claim **1**, wherein said forming step comprises shaping said mixture and heating said shaped mixture to melt said binder, whereby said binder bonds said first fibers together after cooling.

12. The method of claim **1**, wherein said insulation batt, board or molding media comprises between about 1-20% by weight of said thermoplastic binder.

13. The method of claim **12**, wherein said insulation batt, board or molding media comprises between about 3-15% by weight of said thermoplastic binder.

14. A system for forming a fibrous insulation product, comprising:

at least one fiberizing apparatus for forming a fibrous veil comprising first fibers;

means for blowing a non-aqueous, formaldehyde-free, thermoplastic binder in powder, liquid or fibrous form into said veil to form a mixture of said binder and said first fibers, said fibrous form having average length of less than or equal to about 15 mm;

a forming belt disposed below said fiberizing apparatus for collecting said mixture; and

an oven for heating said mixture to a temperature at or above the melting temperature of said thermoplastic binder.

15. The system of claim **14**, wherein said blowing means comprises a hot melt gun.

16. The system of claim **15**, wherein said hot melt gun is configured to provide said binder in droplet form, said droplets having average diameters between about 0.5 to about 10 μm.

17. The system of claim **16**, wherein said diameters are between about 0.5 to about 6 μm.

18. The system of claim **15**, wherein said hot melt gun is configured to provide said binder in fibrous form.

19. The system of claim **18**, wherein said binder fibers have average diameters between about 0.2 to about 20 μm and average length between about 0.1 to about 15 mm.

20. The system of claim **19**, wherein said diameters are between about 0.5 to about 15 μm and said length is between about 0.1 to about 6 mm.

21. The system of claim **16**, wherein said binder is blown into said veil in powder form, the system further comprising a gas atomizer for forming said thermoplastic fiber in powder form.

22. The system of claim **21**, wherein the average diameter of particles in said powder form is between about 0.2 to about 60 μm.

23. The system of claim **22**, wherein the diameter is between about 2 to about 30 μm.

24. The system of claim **14**, wherein said insulation product comprises between about 1-20% by weight of said thermoplastic binder.

25. The system claim **24**, wherein said insulation product comprises between about 3-15% by weight of said thermoplastic binder.

26. The system of claim **14**, wherein said providing means comprises a plurality of applicator apparatus disposed around the outer surface of said veil.

27. A method of forming a fibrous insulation product, comprising:

forming at least one fibrous veil comprising first fibers;

directing from a hot melt applicator a non-aqueous, formaldehyde-free, thermoplastic binder into said veil to form a mixture of said binder and said first fibers;

collecting said mixture on said forming belt;

heating said mixture to a temperature above the melting temperature of said thermoplastic binder in an oven, wherein at least a majority of said thermoplastic binder is melted, whereby said melted thermoplastic binder forms meltbonds with said first fibers when cooled; and

forming said mixture into an insulation batt, board or molding media.

28. A method of forming a fibrous insulation product, comprising:

forming at least one fibrous veil comprising first fibers;

forming a non-aqueous, formaldehyde-free, thermoplastic powdered binder using a gas atomization process;

directing said thermoplastic powdered binder into said veil to form a mixture of said binder and said first fibers;

collecting said mixture on said forming belt;

heating said mixture to a temperature above the melting temperature of said thermoplastic binder in an oven, wherein at least a majority of said thermoplastic binder is melted, whereby said melted thermoplastic binder forms meltbonds with said first fibers when cooled; and

forming said mixture into an insulation batt, board or molding media.

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