

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
10 November 2005 (10.11.2005)

PCT

(10) International Publication Number
WO 2005/106089 A2

- (51) International Patent Classification⁷: **D04H 1/00**
- (21) International Application Number:
PCT/US2005/013979
- (22) International Filing Date: 25 April 2005 (25.04.2005)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
10/831,843 26 April 2004 (26.04.2004) US
- (71) Applicant (for all designated States except US): **CERTAIN TEED CORPORATION** [US/US]; 750 East Swedesford Road, Valley Forge, PA 19482 (US).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **TOAS, Murray, S.** [US/US]; 1901 Coles Boulevard, Norristown, PA 19401 (US). **YANG, Alain, X.** [US/FR]; 3932 Darby Raod, Bryn Mawr, PA 19010 (US). **DAVIS, Kim** [US/US]; 131 Rosemont Avenue, Norristown, PA n19401 (US).
- (74) Agents: **CRONK, Peter, J.** et al.; Duane, Morris LLP, One Liberty Place, Philadelphia, PA 19103 (US).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:**
— without international search report and to be republished upon receipt of that report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: FLAME RESISTANT FIBROUS INSULATION AND METHODS OF MAKING THE SAME

(57) Abstract: The invention relates to fibrous insulation products that exhibit improved flame resistance, relative to previously known products. The insulation product has a fibrous mineral matrix, into which is incorporated a phosphate-containing compound (e.g., an inorganic phosphate salt) and a refractory mineral filler (e.g., alumina or aluminum sulfate). The product exhibits flame resistance superior to the fibrous mineral matrix alone.

WO 2005/106089 A2

TITLE OF THE INVENTION

[0001] Flame Resistant Fibrous Insulation and Methods of Making the Same

BACKGROUND OF THE INVENTION

5 [0002] The invention relates generally to the field of fibrous mineral-based thermal insulating materials.

[0003] Fibrous insulation products are widely used in the building construction industries and as components of other manufactured goods such as automobiles, aircraft, and soundproofing products. Various naturally-occurring and synthetic fibrous minerals are used to
10 make fibrous insulation products, including fibers synthesized from glass, rock, slag, or basalt. Fibrous insulation products can be used in the form of loose bulk fibers. Commonly, mineral fibers are bound to one another using any of a variety of known adhesives. Bound mineral fibers are also commonly attached to supports or backings, such as paper and/or metal foils, to facilitate their handling and installation.

15 [0004] Fibrous insulation products are often used in environments (e.g., residences, office buildings, manufacturing facilities, and vehicles) in which fire is a hazard. Previous fibrous insulation products can melt, burn, or otherwise permit passage of flame therethrough when exposed to fire. A need exists for fibrous insulation products having improved flame
20 resistance.

BRIEF SUMMARY OF THE INVENTION

[0005] The invention relates to a flame resistant fibrous insulation product. The product comprises a fibrous mineral (e.g., fiberglass or glass wool) mixed with a phosphate-containing compound and a refractory mineral filler.

25 [0006] Numerous phosphate-containing compounds are suitable for use in such products, and inorganic phosphate salts are preferred. Examples of suitable phosphate-containing compounds include monoammonium phosphate, diammonium phosphate, ammonium polyphosphate, monocalcium phosphate, dicalcium phosphate, aluminum phosphate, monosodium dihydrogen phosphate, tetrasodium pyrophosphate, sodium hexametaphosphate,
30 sodium tripolyphosphate, tetrapotassium pyrophosphate, and potassium tripolyphosphate.

[0007] Similarly, numerous refractory mineral fillers are suitable for use in the flame-resistant fibrous insulation product described herein, and fine particulate refractory mineral fillers are preferred. Example of suitable refractory mineral fillers include alumina, silica, calcium oxide, magnesium oxide, titanium oxide, zirconia, and aluminum sulfate.

5 [0008] In one preferred embodiment, the phosphate-containing compound is monoammonium phosphate and the refractory mineral filler is either alumina or aluminum sulfate. For this combination, the phosphate-containing compound and the refractory mineral filler can be present in approximately equal weights, and the total weight of the two compounds should be at least about 6% (and preferably at least about 11%) of the weight of the fibrous
10 mineral in the insulation product.

[0009] The phosphate-containing compound and the refractory mineral filler can be simply interspersed within the fibers of the insulation products or incorporated into a binding composition that comprises an adhesive (e.g., a polymer commonly used for binding fiberglass in insulation products) for binding the fibrous mineral. Alternatively, the phosphate-containing
15 compound and the refractory mineral filler can be applied to the mineral fibers or the insulation product in the form of a slurry.

[0010] The invention also relates to methods of making such insulation products and to methods of treating existing insulation products in order to improve their flame resistance.

20 DETAILED DESCRIPTION OF THE INVENTION

[0011] The invention relates to fibrous insulation products that exhibit improved flame resistance, relative to previously known products. The insulation product has a fibrous mineral matrix, into which is incorporated a phosphate-containing compound ("PCC," e.g., an inorganic phosphate salt) and a refractory mineral filler ("RMF," e.g., alumina or aluminum sulfate). The
25 product exhibits flame resistance superior to the fibrous mineral matrix alone.

[0012] Definitions

[0013] As used herein, each of the following terms has the meaning associated with it in this section.

[0014] An "adhesive" is any composition which, in a wet or dried form, is able to bind mineral fibers to one another or to bind the phosphate-containing compound and/or the refractory mineral described herein to a mineral fiber.

5 [0015] "Flame resistance" of an insulation product refers to the time required for a flame to penetrate through the product from a Bunsen burner placed immediately beneath the horizontally-suspended product, such that the hottest part of the flame contacts the insulation product. It takes longer for a flame to penetrate a first fibrous insulation product than a second fibrous insulation product of the same thickness if the first product has greater flame resistance.

10 [0016] Detailed Description

[0017] The invention relates to an insulation product that comprises a fibrous mineral and that exhibits flame resistance greater than that of the fibrous mineral alone. The insulation product comprises, in addition to the fibrous mineral, a phosphate-containing compound and a refractory mineral filler.

15 [0018] The fibrous mineral, the phosphate-containing compound, and the refractory mineral filler can be present in their free forms (i.e., none bound to the others), such as the bulk fibrous mineral admixed with particulate phosphate-containing compound and particulate refractory mineral filler. Alternatively, the insulation product can comprise a binding composition adhered to one or more of the components. For example, fiberglass insulation products
20 commonly contain glass fibers bound to one another by a polymer matrix in order to give shape, form, and/or color to the fiberglass mass. One or both of the phosphate-containing compound and the refractory mineral filler can be incorporated into the binding composition, such that one or both is bound to the fibrous mineral of the insulation product. Adhesives suitable for use in such binding compositions are known in the art, and include polymers such
25 as acrylic polymers, phenol-formaldehyde, and melamine-based polymers.

[0019] The form of the insulation product is not critical. The product can be made in the form of a loose fibrous fill such as is used in wall-, attic-, and cavity-insulating applications. Alternatively, the product can be made in the form of blankets or batts to facilitate handling, cutting, and installation in defined spaces. The insulation can be molded, packaged, or
30 otherwise formed into defined shapes, such as a hollow cylinder for installation around air ducts

or an irregularly shaped panel for installation within an automobile frame or a soundproofing barrier.

5 [0020] The insulation product can comprise other components in addition to the fibrous mineral, the phosphate-containing compound, and the refractory mineral filler. By way of example, the product can be adhered to a backing made of paper and/or metal foil, as is common in insulation products intended for insulation of exterior walls, ceilings, or roofs of residential structures. The insulation product can be disposed, adhered, or laminated between two or more supports, such as an air-tight plastic sheet on one face and a deformable metal foil on the opposite face.

10 [0021] The product can be adhered to or bundled with another insulating material, such as the same fibrous mineral (or a different one) that does not have the phosphate-containing compound and/or the refractory mineral filler incorporated therein. As such, the insulation product described herein can form a flame-resistant layer of a multi-layer insulation product.

15 [0022] The Fibrous Mineral

[0023] The fibrous mineral used in the flame resistant insulation product described herein can be any of the fibrous mineral substances traditionally used in insulation products. For example, the fibrous mineral can be a wool formed from substances such as glass. In one embodiment, the fibrous mineral is glass fiber, such as in the form of glass wool. The glass used to make such fiberglass insulation can be any of the known insulation-grade glasses, including soda borosilicate glasses and alumina borosilicate glasses, for example.

20 [0024] The size of the mineral fibers will depend on the intended use, and can be substantially any of the sizes of known mineral fibers. For example, glass fibers used to make non-woven mats will often have a diameter in the range from 0.5 to 20 micrometers and a length of 0.5 to 3 inches. Further by way of example, glass wools can be made using fibers having a diameter in the range from 3 to 20 micrometers and indeterminate length (i.e., very long fibers).

25 [0025] The physical form of the mineral fibers is not critical. The fibers can be in the form of a wool, in the form of a woven or non-woven mat or fabric, or loose. In embodiments in which the flame resistant insulation product is expected to be handled (e.g., cut, arranged,

30

folded, or wrapped), the fibers are preferably held together, such as by weaving the fibers, entangling the fibers, or binding the fibers to one another using a binder (e.g., an adhesive polymeric binder).

5 [0026] The Phosphate-Containing Compound

[0027] The insulation product described herein comprises a phosphate-containing compound (PCC). The PCC should be a non-flammable compound that can be incorporated on or among the mineral fibers in a dispersed form. By way of example, the PCC can be incorporated into the insulation product as a particulate interspersed among the mineral fibers.

10 The PCC can be held in place by incorporating it into or mixing or contacting it with a binder (e.g., a phenolic resin) or a liquid component (e.g., a dust-suppressing oil additive) of the insulation product.

[0028] Preferably, the PCC is an inorganic phosphate salt. Suitable salts include monoammonium phosphate, diammonium phosphate, ammonium polyphosphate, monocalcium phosphate, dicalcium phosphate, aluminum phosphate, monosodium dihydrogen phosphate, tetrasodium pyrophosphate, sodium hexametaphosphate, sodium tripolyphosphate, tetrapotassium pyrophosphate, and potassium tripolyphosphate. Mixtures of multiple PCCs (e.g., mixtures of mono- and di-ammonium phosphates) can also be used. Hydrates of PCCs (e.g., monoammonium phosphate dihydrate) can be used, in which case water of hydration should not be considered in determining the content (e.g. % by weight) of the PCC in the insulation product.

[0029] The amount of PCC incorporated into the insulation product is not critical, and the flame resistance of the insulation product can be expected to increase as the proportion of PCC in the insulation product increases. If the proportion of PCC in the insulation product is very low (e.g., <8% of the weight of the insulation product is PCC), then minimal flame resistance can be expected. If the of PCC in the insulation product is very high (e.g., >30% of the weight of the insulation product is PCC), then the physical form of the insulation product may prove to be undesirable (e.g., too brittle, powdery, or rigid) for certain applications. A suitable range of PCC content is expected to from about 8% to about 30% by weight, if used alone, and from about 2% to about 30% if used in combination with at least about 2% RMF.

[0030] When a physical characteristic (e.g., thickness or flexibility) of the finished insulation product is of critical importance, the form and amount of the PCC incorporated into the insulation product should be selected so as not to unduly diminish the critical characteristic. For example, flexibility is an important characteristic of insulation products intended to form or surround ducts. When the flame resistant insulation product described herein is intended to be used as flexible duct insulation, the PCC content and the form in which the PCC is applied should be selected such that the finished product retains sufficient flexibility for its intended purpose. Selection of PCC form and content in view of such considerations is within the skill of the ordinary artisan assisted by the present disclosure.

10

[0031] The Refractory Mineral Filler

[0032] The insulation product described herein comprises a refractory mineral filler (RMF) in addition to the mineral fiber. The RMF can be fixed on or interspersed among the mineral fibers. By way of example, the RMF can be incorporated into the insulation product as a continuous or semi-continuous coating on the mineral fibers, as a salt precipitated on the mineral fibers, or in a particulate, flaked, or fibrous form interspersed among the mineral fibers. When the RMF is in a particulate form, the particles should be of a size sufficiently small that they can be thoroughly dispersed throughout the fibrous mineral matrix. For example, when the fibrous matrix is a fiberglass wool, RMF particles having a number average particle size in the range from about 1 to 2 micrometers are suitable, although larger and smaller particles can be used. The RMF can be held in place by incorporating it into or mixing or contacting it with a binder (e.g., a phenolic resin) or a liquid component (e.g., an dust-suppressing oil additive) of the insulation product.

15

20

[0033] The chemical identity of the RMF is not critical. It is important that the RMF be non-flammable and exhibit a higher melting temperature than the mineral fiber of the insulation product. Although not critical, it is preferred that the RMF be relatively biologically inert, so that human contact with the flame resistant insulation product is not especially hazardous or irritating. Suitable RMFs include alumina, calcium oxide, magnesium oxide, titanium oxide, zirconia, and aluminum sulfate. Fiberglass insulation products comprising mono- and/or di-ammonium phosphate as a PCC and alumina or aluminum sulfate as the RMF have proven

30

desirable. Hydrate forms of RMFs (e.g., aluminum sulfate hydrate) can be used, in which case water of hydration should not be considered in determining the content (e.g. % by weight) of the RMF in the insulation product. Silica and silicates should not be used as the RMF, since they are susceptible to formation of silicate phosphate compounds in the presence of heat
5 associated with a flame, whereby the refractory properties of the RMF can be altered.

[0034] The amount of the RMF incorporated into the insulation product is not critical, and the flame resistance of the insulation product can be expected to increase as the proportion of RMF in the insulation product increases. If the proportion of RMF in the insulation product is very low (e.g., <8% of the weight of the insulation product is RMF), then minimal flame
10 resistance can be expected. If the amount of RMF in the insulation product is very high (e.g., > 30% of the weight of the insulation product is RMF), then the physical form of the insulation product may prove to be undesirable (e.g., too brittle, powdery, or rigid) for certain applications. A suitable range of RMF content is expected to from about 8% to about 30% by weight when used alone, and from about 2% to about 30% when used in combination with at
15 least about 2% PCC.

[0035] It has been discovered that incorporation of both a PCC and an RMF into a fibrous mineral insulation significantly increases the flame resistance of the insulation, relative to incorporation of RMF alone. The PCC and the RMF are preferably present in approximately equal amounts by weight. However, various weight ratios of PCC/RMF can be used. For
20 example, the weight ratio can be in the range 0.1 to 10, and is more preferably in the range 0.5 to 2. Together, the PCC and the RMF will enhance the flame resistance of an insulation product containing a fibrous mineral if the product contains at least 4% PCC + RMF by weight (i.e., the sum of PCC and RMF content is at least 4% of the weight of the insulation). Preferably, the product contains at least about 6% PCC + RMF by weight, more preferably
25 about 8%, and even more preferably about 11-12%. For example, one desirable product demonstrated in the examples herein is a fiberglass insulation product wherein about 11-12% of the weight of the product is an approximately equal (by weight) mixture of ammonium phosphate (a PCC) and aluminum sulfate (an RMF). The insulation product can contain a greater amount of the PCC/RMF mixture without significantly reducing the insulating ability of
30 the insulation product. Although no explicit upper limit is placed on the PCC/RMF content of

the insulation product described herein, it is believed that this value can be as great as at least 30% by weight in a product useful for insulating purposes.

[0036] Other Components of the Insulation Product

5 **[0037]** The insulation product described herein need only contain a fibrous mineral, a PCC, and an RMF. However, it can comprise other components as well. For example, the insulation product can contain a binder for adhering components of the product. The binder can bind only the mineral fibers together or it can bind one or both of the PCC and the RMF with each other and/or the fibers. By way of example a binder that comprises one or both of the PCC and the
10 RMF can be applied to the fibers to adhere the fibers into a discrete mass, such as a blanket or mat. Numerous binders suitable for use in fibrous insulation products are known in the art (e.g., phenolic materials, like phenol-formaldehyde resins or phenol urea formaldehyde, and melamine formaldehyde, acrylic, polyester, urethane, and furan binders), and substantially any such binder can be used in the flame resistant insulation product described herein.

15 **[0038]** If desired, a colorant can be incorporated into the mineral fibers or into a portion thereof. Such a colorant can be simply mineral fibers formed in the presence of or coated with a colorant. The colorant can alternatively be applied to the finished insulation product or incorporated into a binder that adheres the mineral fibers to one another. The colorant can be uniform (i.e., coloring substantially all mineral fibers), particulate, or fibrous. The colorant can
20 distinguish the flame resistant insulation product described herein from insulation products having different properties and an otherwise similar appearance.

[0039] The insulation product can be adhered to a backing, such as a sheet of metal foil, plastic, paper, or the like. The backing can facilitate handling of the insulation product, serve a structural or sealing function (e.g., a vapor barrier for insulation to be installed in exterior
25 residential walls), or some combination of these functions. The insulation product can be entirely contained within one or more layers of backing and, optionally, combined with structural components. By way of example, a flame resistant insulated flexible duct can be formed by sandwiching a metal wire coil or screen and a layer of the insulation product described herein between two backings, such as plastic or metal foil. The backing on the
30 interior of the duct can be substantially impervious to mineral fibers and particles of the PCC

and/or RMF that may be shed by the insulation product during handling, in order to prevent entry of such fibers and particles into the lumen of the duct.

[0040] The insulation product described herein can be incorporated as a layer into known insulation products. By way of example, the flame resistant insulation product herein can be adhered to or contacted with a layer of typical fiberglass insulation or laminated between two layers of fiberglass insulation.

[0041] Methods of Making the Insulation Product

[0042] The method by which the minimum three components (fibrous mineral, PCC, and RMF) of the flame resistant insulation product described herein are combined is not critical. Methods such as those disclosed in international patent application publication number WO 02/092538 may be used, for example. It is important that the PCC and the RMF be thoroughly dispersed in the fibrous mineral matrix, or at least in that portion (e.g., one face) of the matrix for which enhanced flame resistance is desired. The components can, for example, be simply mixed (e.g., by stirring or tumbling) in wet or dry form to disperse the components among each other. Preferably, however, the PCC and the RMF are combined with the fibrous mineral in a manner that enhances the uniformity of the flame resistant properties of the insulation product, such as by applying substantially equal amounts of a relatively uniform mixture of PCC and RMF across the fibrous mineral matrix. Of course, in other embodiments, greater amounts of the PCC and the RMF can be applied to one portion of the fibrous mineral matrix, such as when that portion is more likely to be exposed to flame than are other portions of the matrix.

[0043] Substantially any known method of making a fibrous mineral insulation product can be relatively simply modified to incorporate steps whereby PCC and RMF are interspersed with the fibers. By way of example, it is common to make fiberglass insulation by collecting on a conveyor glass fibers formed by extrusion of molten glass through the walls of a spinning cylinder, spraying the collected fibers with an acrylic or phenolic binder, and subsequently curing the binder to form a unitary mat of bound fiberglass fibers. This process can be modified in at least several ways to accommodate addition of PCC and RMF to the fiberglass product. For example, each of the PCC and the RMF can be included in the binder composition that is sprayed onto the fibers prior to curing. Alternatively, particulate PCC and/or RMF can

be sprinkled (i.e., dry laid) onto the glass fibers as they are being collected or after they have been collected, prior to or after binder application, and prior to curing. PCC and/or RMF can be sprinkled, sprayed, spread, brushed, pressed, or otherwise applied to the binder-coated fiberglass prior to or after curing.

5 [0044] PCC and RMF can be combined with the other components of the insulation product independently or at the same time. They can be applied in solid form (e.g., mixed powder, granules, or flakes or as agglomerated particles containing both PCC and RMF) or as a slurry or liquid suspension. When applied in a wet or liquid form, the PCC and/or RMF is preferably not highly soluble in the liquid carrier, so that the carrier can deposit the compound on the mineral
10 fibers without the need for excessive drying. By way of example ammonium phosphate (a PCC) and alumina or aluminum sulfate (RMFs) can be applied as a suspension by spraying onto glass fibers prior to forming a fiberglass matrix, or a fiberglass matrix having liquid binder thereon (e.g., sprayed-on binder or melted thermoplastic binder) can be dusted with the PCC and the RMF. Any liquid carrier used to apply the PCC and/or RMF to the fibrous mineral
15 matrix should be drained, dried, or cured prior to use of the insulation product.

[0045] Methods of Improving the Flame Resistance of an Existing Insulation

[0046] The flame resistant insulation product described herein can be manufactured prior to installation of the product. However, in another embodiment the flame resistance of an existing
20 or installed fibrous insulation is improved by incorporating both a PCC and an RMF into at least a portion of the insulation. This can be achieved by spraying, spreading, or dusting a composition comprising the PCC and the RMF onto the existing insulation, either together or as separate compositions. By way of example a PCC suspension can be sprayed onto the surface of a fiberglass insulating sheet, and the surface can be dusted with powdered RMF while it is
25 still moist. This treatment can alleviate the need to remove relatively non-flame resistant insulation and replace it with a more flame-resistant insulation if it becomes more likely that flames can occur in the environment of the insulation.

[0047] When the PCC and the RMF are applied to an existing fibrous insulation, they can be applied primarily to a surface of the insulation and to fibers near that surface. Preferably,
30 however, the PCC and RMF are distributed within the insulation as well. This can be achieved

by mixing or agitating loose fiber insulation with PCC and RMF, by injecting or spraying the interior of a fused, bound, or cross-linked fiberglass slab, or otherwise. Alternatively, an existing fibrous insulation can be uninstalled, dipped, or immersed in a suspension of PCC and RMF, dried, and reinstalled.

5

[0048] Use of the Insulation Product

[0049] The flame resistant insulation product described herein can be used in place of substantially any other similar insulation product that does not exhibit its flame resistant properties. In view of those properties, the product described herein can also be used in many situations in which traditional mineral fiber insulations are unsuitable, including environments prone to fire, flame, sparks, and the like. The product can also be used as insulation or shielding near electrical connections. Because the products described herein exhibit greater flame resistance, including lower ignition tendency, they need not be as heavily or completely shielded from flame as known fibrous insulating materials.

[0050] Examples of purposes for which the insulation products described herein can be used include residential and commercial thermal and sound insulation (for both interior and exterior walls) and incorporation into sound- or thermally-insulated manufactured items, such as insulated flexible air ducts. The insulation can also be wrapped around or applied against pipes and other equipment.

20

[0051] Examples

[0052] The invention is now described with reference to the following Examples. These Examples are provided for the purpose of illustration only, and the invention is not limited to these Examples, but rather encompasses all variations which are evident as a result of the teaching provided herein.

25

[0053] Example 1

[0054] The effect of particulate alumina and aluminum sulfate on flame resistance of approximately one-inch-thick slices of R30 fiberglass insulation was assessed. The effect of particle size was assessed using alumina preparations having different average particle sizes –

30

either one micron ("1 micron pA" in Table 1) or two microns (2 micron pA" in Table 1). The effect of particle loading on flame resistance of the insulation was assessed by varying the particle content of the insulation.

[0055] The particulate refractory mineral filler was prepared by suspending either 7.3 or
5 14.6 grams of either aluminum sulfate or alumina (2 micrometer particle size Hydral H716 alumina or 1 micrometer particle size Hydral H710 alumina) in a solution consisting of 525 milliliters of water and 225 milliliters of isopropyl alcohol. For each sample, an approximately ten-inch-thick piece of R30 fiberglass insulation was divided into one-inch-thick layers, and individual layers were cut into twelve-inch square quarters, and 240 milliliters of the
10 suspension was poured onto the insulation quarters to evenly distribute the particles in the insulation. Each quarter was then divided into four six-inch squares for flame testing. The particulate content of each sample was determined by comparing the dry weight of the sample after drying at room temperature with the pre-treatment weight of the sample. Additive content values ("Add. Content" in Table 1) are expressed in terms of the percent weight of the dried,
15 treated sample. The insulation sample was dried prior to use in individual flame tests.

[0056] For each flame test, a six inch square insulation sample was suspended horizontally, and a Bunsen burner was placed under the sample, with the hottest part (ca. 1760 degrees Fahrenheit) of the flame contacting the lower surface of the sample. The time required for the flame to be visible at the top of the insulation sample ("Burn-Thru Time" in Table 1) was
20 measured in seconds and averaged over the number ("n" in Table 1) of samples tested.

[0057] Control samples were treated with the solution having no particulate refractory mineral filler suspended therein ("None" in Table 1).

[0058] The results of the experiments described in this Example are listed in Table 1. Samples containing refractory mineral fillers exhibited greater flame resistance than
25 corresponding control samples. The effect of particle size on flame resistance appeared to be minimal for the alumina particle sizes (1 and 2 microns) tested. At comparable additive content values, samples containing aluminum sulfate appeared to exhibit somewhat better flame resistance than did samples containing alumina. Significant increases in flame resistance were observed at particle content values of about 5%, 10%, and 20% for all mineral fillers tested.

Table 1

Sample Identifier	Additive	Pre-Add. Weight (g)	Post-Add. Weight (g)	Add. Content (% weight)	n	Average Burn-Thru Time (sec. per inch)
Control 1	None	18.24	18.25	0.05%	3	66
A-21-1	2 micron pA	21.74	24.19	10.13%	3	83
A-21-2	2 micron pA	19.39	21.76	10.89%	2	
A-22-1	2 micron pA	16.70	21.07	20.74%	3	105
A-22-2	2 micron pA	18.32	23.03	20.45%	3	
A-15-1	1 micron pA	18.46	19.59	5.77%	3	125
A-11-1	1 micron pA	18.10	20.54	11.88%	3	93
A-11-2	1 micron pA	19.85	22.39	11.34%	3	
A-12-1	1 micron pA	20.55	24.90	17.47%	3	105
A-12-2	1 micron pA	18.83	23.25	19.01%	3	
AS-5-1	pAS	19.27	20.30	5.07%	3	135
AS-1-1	pAS	18.03	20.32	11.27%	3	101
AS-1-2	pAS	21.32	23.67	9.93%	3	
AS-2-1	pAS	16.11	20.27	20.52%	3	145
AS-2-2	pAS	17.50	22.24	21.31%	3	

[0059] Example 2

[0060] The effect of particulate aluminum sulfate ("AS" in Table 2) combined with
 5 particulate ammonium phosphate ("AP" in Table 2) on flame resistance of approximately one
 inch-thick slices of R13 fiberglass insulation was assessed. The effect of particle loading on
 flame resistance of the insulation was assessed by varying the particle content of the insulation.

[0061] The particulate refractory mineral filler was prepared by suspending either 4.5 or 9.0
 grams each of aluminum sulfate and ammonium phosphate in a solution consisting of 525
 10 milliliters of water and 225 milliliters of isopropyl alcohol. For each sample, an approximately
 twelve inch square of one-inch-thick insulation was cut into six-inch square quarters, and 240
 milliliters of the suspension was poured onto the insulation to evenly distribute the particles in

the insulation. The particulate content of each sample was determined by comparing the dry weight of the sample after drying at room temperature with the pre-treatment weight of the sample. Additive content values ("Add. Content" in Table 2) are expressed in terms of the percent weight of the dried, treated sample. The insulation sample was dried prior to use in individual flame tests.

[0062] For each flame test, a six inch square insulation sample was suspended horizontally, and a Bunsen burner was placed under the sample, with the hottest part (ca. 1760 degrees Fahrenheit) of the flame contacting the lower surface of the sample. The time required for the flame to be visible at the top of the insulation sample ("Burn-Thru Time" in Table 2) was measured in seconds and averaged over the number ("n" in Table 2) of samples tested.

[0063] Control samples were treated with the solution having no particulate refractory mineral filler suspended therein ("None" in Table 2) or were treated with no solution ("N/A" in Table 2).

[0064] The results of the experiments described in this Example are listed in Table 2. Samples containing about 6-7% by weight AS+AP (i.e., 3-3.5% each of AS and AP) exhibited significantly greater flame resistance than corresponding control samples. The flame resistance of samples containing about 11-12% by weight AS+AP (i.e., 5.5-6% each of AS and AP) was dramatically greater than that of samples containing about 6-7% by weight AS+AP.

Table 2

Sample Identifier	Additive	Pre-Add. Weight (g)	Post-Add. Weight (g)	Add. Content (% weight)	n	Average Burn-Thru Time (sec. per inch)
Control 1	None	31.07	31.11	0.13%	2	94
Control 2	None	35.89	35.90	0.03%	2	
Control 3	None	31.41	31.47	0.19%	2	
Control 4	None	29.53	29.60	0.24%	2	
ASAP1-1	AS & AP	33.45	35.70	6.30%	2	220
ASAP1-2	AS & AP	31.91	34.30	6.97%	2	
ASAP2-1	AS & AP	31.97	35.89	10.92%	2	2256
ASAP2-2	AS & AP	32.97	37.50	12.08%	2	

[0065] The disclosure of every patent, patent application, and publication cited herein is hereby incorporated herein by reference in its entirety.

[0066] While this invention has been disclosed with reference to specific embodiments, it is
5 apparent that other embodiments and variations of this invention can be devised by others skilled in the art without departing from the true spirit and scope of the invention. The appended claims include all such embodiments and equivalent variations.

CLAIMS

What is claimed is:

1. A flame resistant insulation product comprising a fibrous mineral combined with a phosphate-containing compound and a non-silicate refractory mineral filler.
5
2. The insulation product of claim 1, wherein the fibrous mineral is glass wool.
3. The insulation product of claim 2, wherein the diameter of the glass wool fibers is in the range from about 0.5 to 20 micrometers.
10
4. The insulation product of any of claims 1-3, wherein the phosphate-containing compound is an inorganic phosphate salt.
5. The insulation product of claim 4, wherein the inorganic phosphate salt is selected from the group consisting of monoammonium phosphate, diammonium phosphate, ammonium polyphosphate, monocalcium phosphate, dicalcium phosphate, aluminum phosphate, monosodium dihydrogen phosphate, tetrasodium pyrophosphate, sodium hexametaphosphate, sodium tripolyphosphate, tetrapotassium pyrophosphate, and potassium tripolyphosphate.
15
20
6. The insulation product of claim 4, wherein the inorganic phosphate salt is selected from the group consisting of monoammonium phosphate and diammonium phosphate.
7. The insulation product of claim 4, wherein the inorganic phosphate salt is monoammonium phosphate.
25
8. The insulation product of any of claims 1-7, wherein the refractory mineral filler is in a particulate form.

9. The insulation product of any of claims 1-8, wherein the refractory mineral filler is selected from the group consisting of alumina, calcium oxide, magnesium oxide, titanium oxide, zirconia, and aluminum sulfate.
- 5 10. The insulation product of any of claims 1-9, wherein the refractory mineral filler is selected from the group consisting of alumina and aluminum sulfate.
11. The insulation product of any of claims 1-10, wherein the phosphate-containing compound is monoammonium phosphate and the refractory mineral filler is alumina.
- 10 12. The insulation product of claim 11, wherein the monoammonium phosphate and the alumina are present in approximately equal amounts by weight.
13. The insulation product of claim 12, wherein the combined weight of the monoammonium phosphate and the alumina is at least about 6% the weight of the insulation product.
- 15 14. The insulation product of claim 12, wherein the combined weight of the monoammonium phosphate and the alumina is at least about 11% the weight of the insulation product.
- 20 15. The insulation product of any of claims 1-14, wherein the phosphate-containing compound is monoammonium phosphate and the refractory mineral filler is aluminum sulfate.
16. The insulation product of claim 15, wherein the monoammonium phosphate and the aluminum sulfate are present in approximately equal amounts by weight.
- 25 17. The insulation product of claim 15, wherein the combined weight of the monoammonium phosphate and the aluminum sulfate is at least about 6% the weight of the insulation product.
18. The insulation product of claim 15, wherein the combined weight of the monoammonium phosphate and the aluminum sulfate is at least about 11% the weight of the insulation product.
- 30

19. The insulation product of any of claims 1-18, wherein the phosphate-containing compound and the refractory mineral filler are present in a binding composition that comprises an adhesive for binding the fibrous material.

5

20. The insulation product of claim 19, wherein the adhesive is a polymer.

21. The insulation product of any of claims 1-20, wherein the fibrous mineral is in a form selected from the group consisting of a blanket and a batt.

10

22. The insulation product of any of claims 1-21, wherein the fibrous mineral is in the form of a shaped article.

23. The insulation product of claim 22, wherein the shaped article is a duct.

15

24. The insulation product of any of claims 1-23, attached to a support.

25. The insulation product of claim 24, wherein the support is a sheet that comprises at least one of paper, a polymer, and metal foil.

20

26. The insulation product of claim 24, wherein the support is selected from the group consisting of the same fibrous mineral and a different fibrous mineral.

27. The insulation product of any of claims 1-26, wherein the insulation product is sandwiched between a pair of supports.

25

28. The insulation product of claim 27, wherein the supports are different materials.

29. The insulation product of any of claims 1-28, wherein the insulation product is flexible

30

30. A method of making a flame resistant insulation product, the method comprising combining a phosphate-containing compound and a non-silicate refractory mineral filler with a fibrous mineral matrix.
- 5 31. The method of claim 30, wherein a slurry comprising the phosphate-containing compound and the refractory mineral filler is applied to the matrix.
32. The method of any of claims 30-31, wherein a slurry comprising the phosphate-containing compound and the refractory mineral filler is applied to is sprayed onto mineral fibers prior to
10 forming the fibers into the matrix.
33. The method of any of claims 30-32, wherein the phosphate-containing compound and the refractory mineral filler are applied to the matrix in the form of dry particules.
- 15 34. The method of claim 33, wherein the particles are applied to the matrix while the matrix comprises a non-cured binder.
35. The method of any of claims 31-34, wherein the phosphate-containing compound and the refractory mineral filler are applied to the matrix in a composition comprising a non-cured
20 binder.
36. A method of improving the flame resistance of a fibrous mineral insulation product, the method comprising incorporating a phosphate-containing compound and a non-silicate refractory mineral filler into the insulation product.
25
37. The method of claim 36, wherein the phosphate-containing compound and the refractory mineral filler are incorporated into the insulation product during manufacture of the insulation product.

38. The method of any of claims 36-37, wherein a slurry comprising the phosphate-containing compound and the refractory mineral filler is applied to the surface of the insulation product.
39. The method of claim 38, wherein the slurry is sprayed onto the surface of the insulation
5 product.
40. A method of improving the flame resistance of a structure, the method comprising incorporating the insulation product of any of claims 1-29 in the structure.
- 10 41. The method of claim 40, wherein the insulation product is incorporated into the interior of the structure.
42. The method of any of claims 40-41, wherein the structure is a wall.
- 15 43. The method of any of claims 40-42, wherein the structure is a flexible duct.