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(19) **United States**(12) **Patent Application Publication****Au**(10) **Pub. No.: US 2006/0070321 A1**(43) **Pub. Date: Apr. 6, 2006**(54) **FIRE-RESISTANT PANEL AND METHOD OF MANUFACTURE**(52) **U.S. Cl. 52/232; 52/741.1**(75) **Inventor: B. L. Au, Hong Kong (HK)**(57) **ABSTRACT**

Correspondence Address:
KOLISCH HARTWELL, P.C.
200 PACIFIC BUILDING
520 SW YAMHILL STREET
PORTLAND, OR 97204 (US)

(73) **Assignee: R E P Technologies Ltd.**(21) **Appl. No.: 10/954,249**(22) **Filed: Sep. 29, 2004****Publication Classification**

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A highly fire-resistant and environmentally-friendly panel of 2 mm to 28 mm may be manufactured by a blending of magnesium compounds, sodium silicate, kaolin, fillers, and additives to form the core materials, reinforced by 4 layers of fire-resistant glass fiber meshes and fabrics. Using a proprietary ITC process that accelerates the chemical reactions of the ingredients to generate sufficient heat without external supply of energy, the panels may be completely cured within 24 hours instead of 10 days. The use of waste materials, energy-saving curing system and no gas emission manufacturing process combined to make this panel an eco-friendly product which offers the world's highest-rated fire resistance of 5 hours, high flexural strength, low density, durability and effective water-resistance.

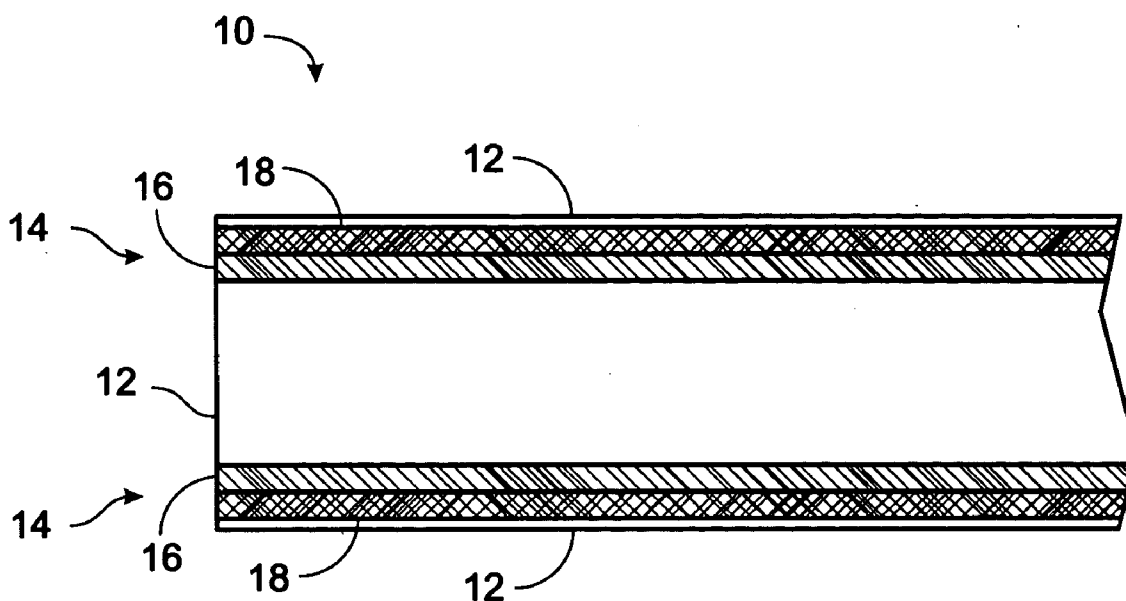


Fig. 1

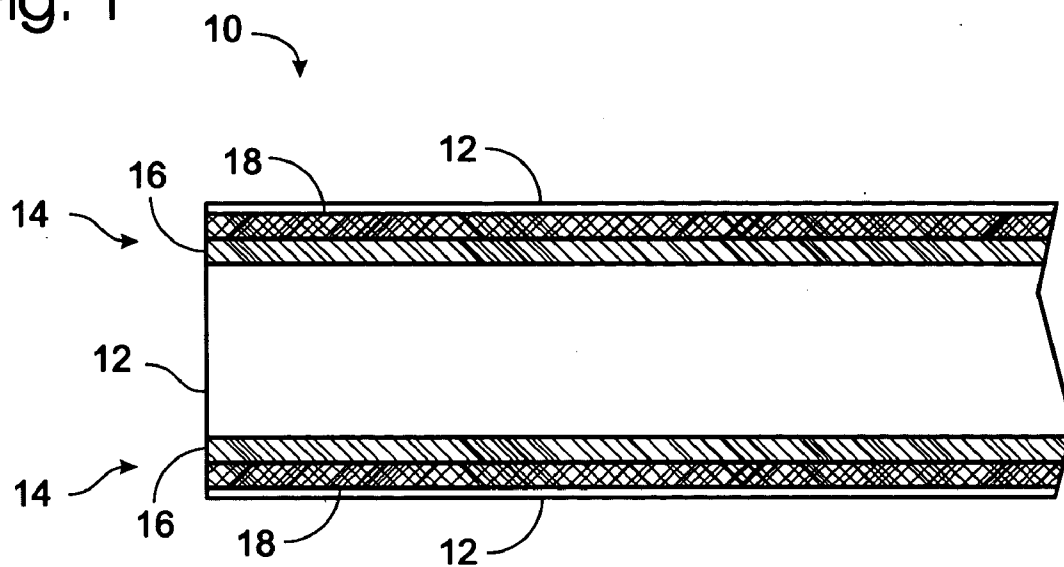


Fig. 3

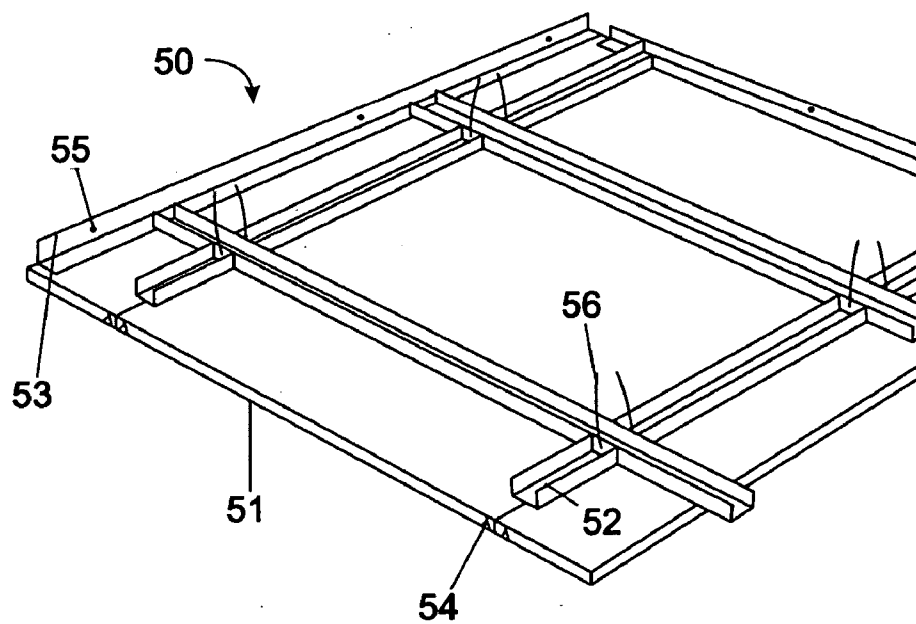


Fig. 2

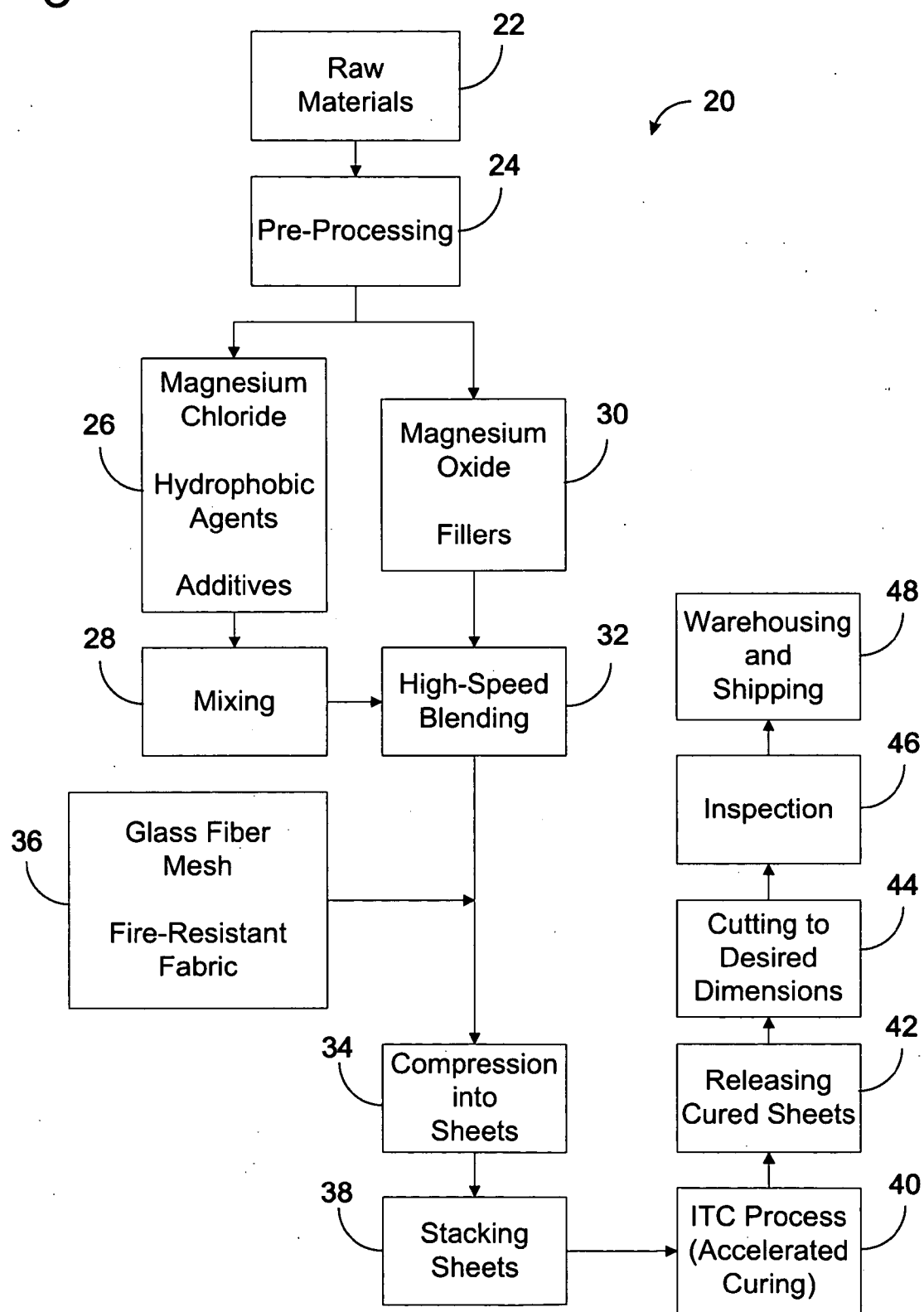


Fig. 4

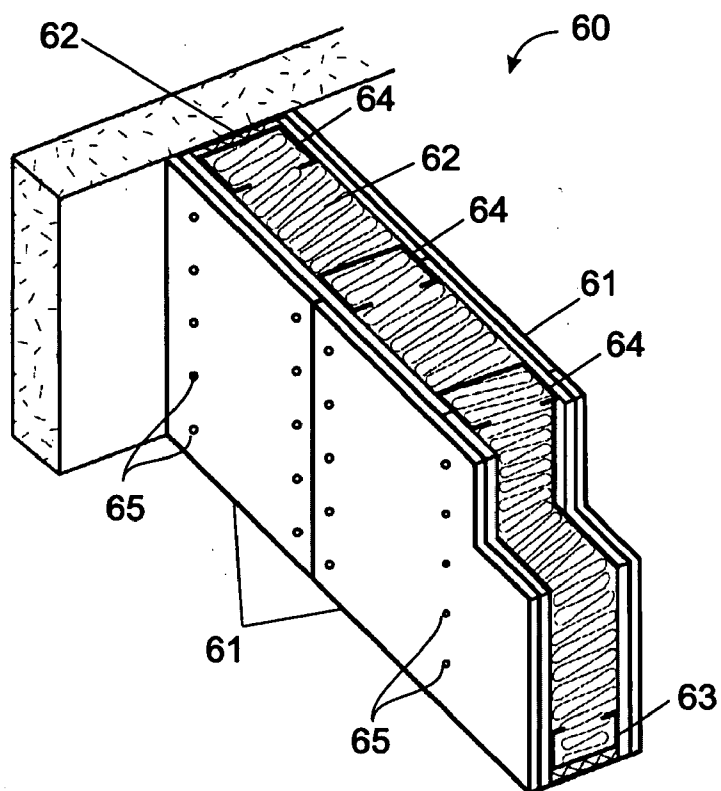


Fig. 5

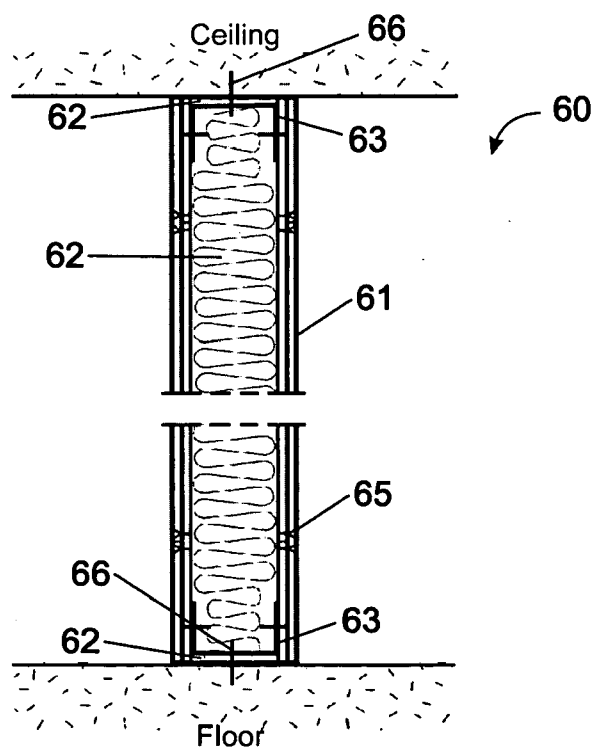


Fig. 6

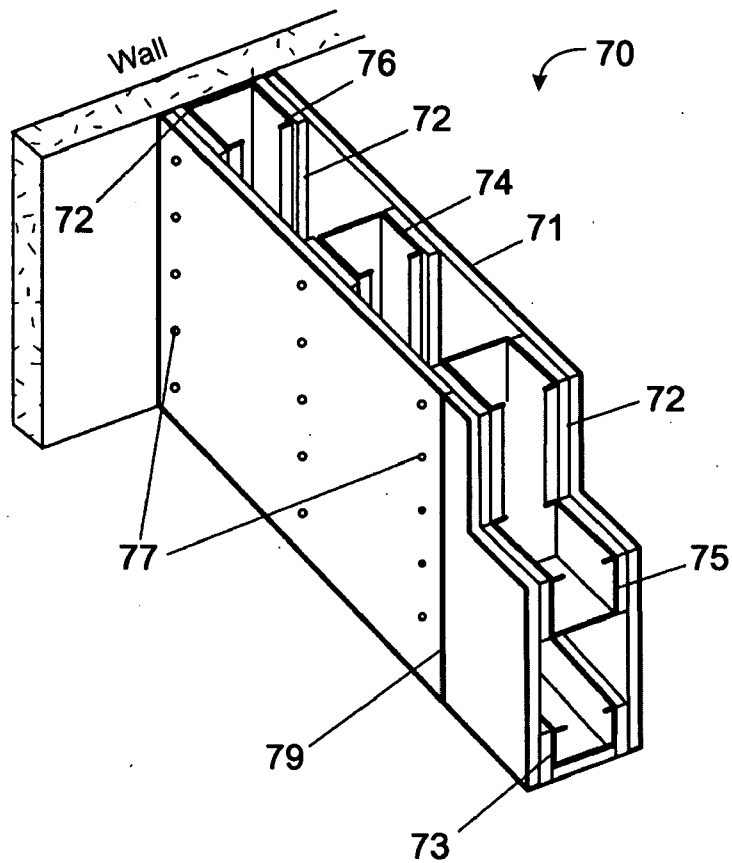


Fig. 7

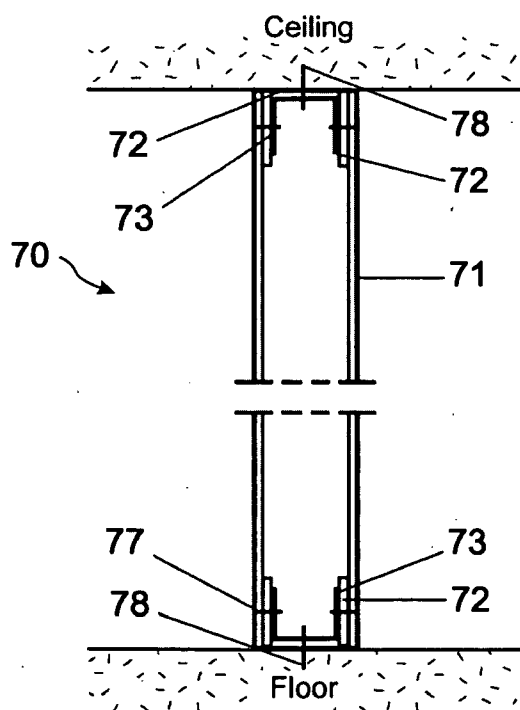


Fig. 8

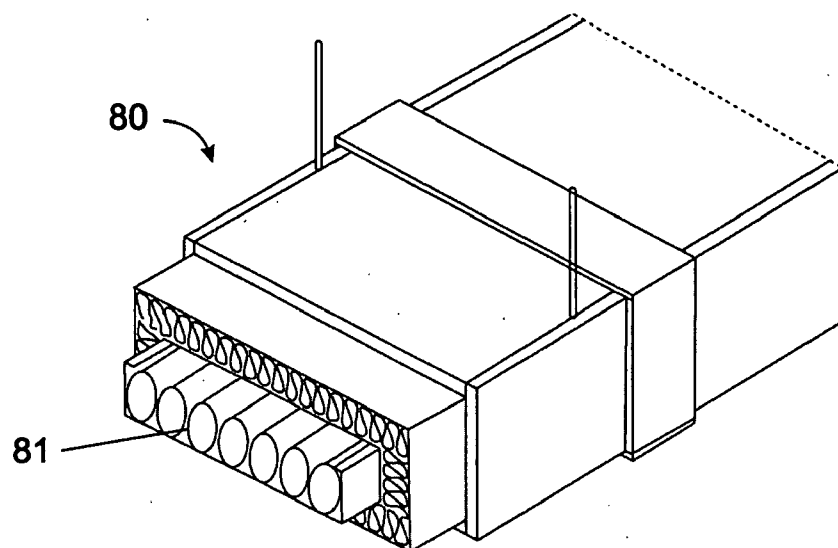


Fig. 9

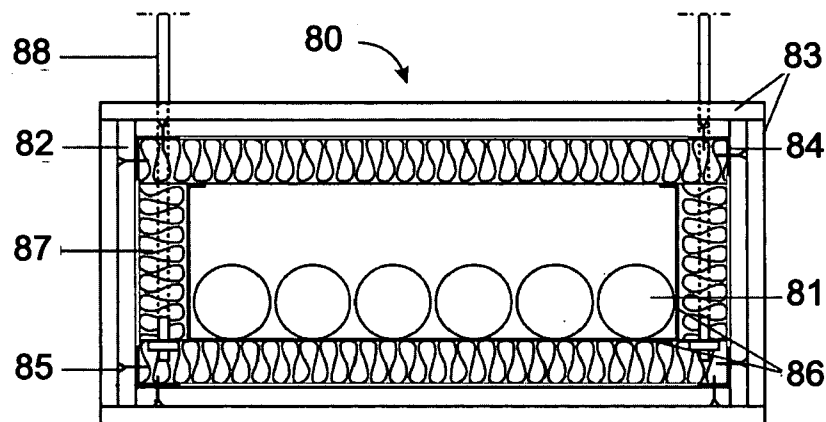
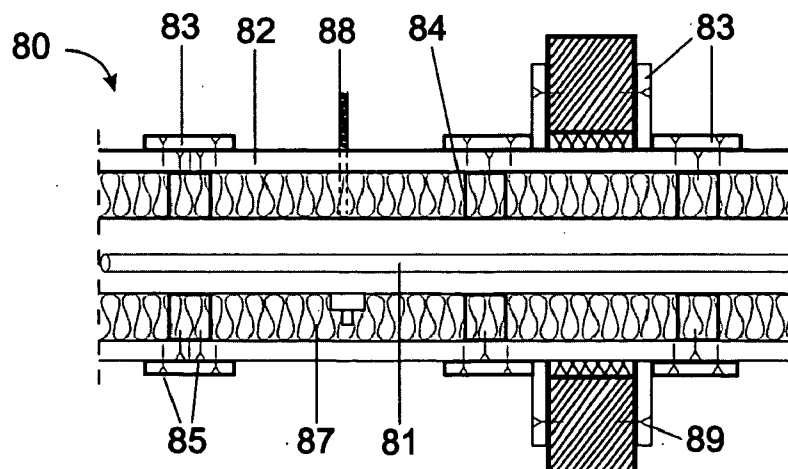


Fig. 10



FIRE-RESISTANT PANEL AND METHOD OF MANUFACTURE

TECHNICAL FIELD

[0001] The invention relates to the preparation of fire-resistant building materials. More particularly, the invention relates to fire-resistant panel materials that exhibit increased fire-resistance, and are lightweight, strong, and durable.

BACKGROUND

[0002] Government regulations now typically require that construction projects incorporate fire-resistant materials for purposes of enhancing fire safety. Building codes may even require the use of materials having established fire resistance ratings. Although a variety of non-combustible panel materials are commercially available, including gypsum boards, fiber-cement boards, calcium silicate boards, and the like, many demonstrate limited fire-resistance, and are environmentally-hazardous in their manufacture, use and disposal. Additionally, some non-combustible panel materials exhibit excessive weight, lack of strength and durability, and are susceptible to water damage.

[0003] In the manufacture of fire-resistant panel materials, it is therefore desirable to develop a product that is not only substantially fire-resistant, but is also water-resistant, light in weight, rigid, strong, and durable. For the protection of public health, such a product is preferably free of toxic materials such as formaldehyde and arsenic, and carcinogenic substances, such as asbestos and crystalline silica.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] **FIG. 1** is a partial cross-sectional view of a fire-resistant panel, according to an embodiment of the invention.

[0005] **FIG. 2** is a flowchart depicting a fire-resistant panel manufacturing process, according to an embodiment of the invention.

[0006] **FIG. 3** is a partial perspective view of a suspended ceiling system, according to an embodiment of the invention.

[0007] **FIG. 4** is a perspective sectional view of a partition system, according to an embodiment of the invention.

[0008] **FIG. 5** is a cross-sectional view of the partition system of **FIG. 4**.

[0009] **FIG. 6** is a perspective sectional view of a hoarding system, according to an embodiment of the invention.

[0010] **FIG. 7** is a cross-sectional view of the hoarding system of **FIG. 6**.

[0011] **FIG. 8** is a perspective sectional view of an electrical and mechanical services enclosure system according to an embodiment of the invention.

[0012] **FIG. 9** is a cross-sectional view of the enclosure system of **FIG. 8**.

[0013] **FIG. 10** is a longitudinal cross-sectional view of the enclosure system of **FIG. 8**.

DETAILED DESCRIPTION

[0014] Referring to **FIG. 1**, the present invention relates to a fireproof or fire-resistant panel material **10**, such as a

board, that offers a combination of a high degree of fire resistance, a low density, high flexural strength, and effective water resistance. These advantageous properties may be obtained by the preparation of a panel core **12** that includes magnesium compounds, sodium silicate, and kaolin, and may further include one or more fillers, and hydrophobic agents. The panel may further include one or more fire-resistant layers **14**.

[0015] As used herein, the terms “fireproof” and “fire-resistant” refer to a substance that is resistant to the effects of fire, that is, describing a material that is substantially or completely non-combustible and/or substantially insulating. By panel is meant a generally planar construction material. In one aspect of the invention, the panel is a fire-resistant board, dimensioned so as to be compatible with standard construction methods and materials.

[0016] The fire-resistant panel of the present invention may generally be prepared by first blending the above core materials with the desired fillers, hydrophobic agents and additives in appropriate proportions, followed by a process of strengthening the panel through the application of one or more layers of non-combustible fibrous glass mesh and fabric. The panels may then be cured by accelerating the exothermic chemical reactions of the ingredients, thereby generating heat and typically curing the panels within about 24 hours. As this process requires no applied energy or external heating, both the curing time and the associated energy costs may be dramatically reduced, in one example by about 90%. In one aspect of the invention, the panel is manufactured using recycled and/or waste materials, resulting in a construction material that is environmentally-friendly, as well as providing a reduction in overall waste production.

[0017] Referring to **FIG. 1**, the fire-resistant panel according to the present invention includes a core material **12**, including fire-resistant materials, fillers, hydrophobic agents and additives. Preferably, the core materials are non-toxic and non-carcinogenic. The core material typically includes a matrix formed by one or more magnesium compounds, a silicate, and kaolin clay. The magnesium compounds may be selected from magnesium chloride and magnesium oxide. The addition of silicates, preferably sodium silicate, and kaolin serve to enhance the fire-resistance and thermal resistance of the panel. The core material is generally formulated so that the resulting fire-resistant panel is composed of about 45% to about 60% by weight of the magnesium compounds, about 8% to about 15% by weight of sodium silicate, and about 10% to about 15% by weight of kaolin. The combination of these core matrix ingredients yield a panel core that contributes to the high flexural strength of the resulting cured panel.

[0018] The core material **12** may incorporate one or more fillers that serve to lower the weight of the panel. Appropriate filler materials may include organic fillers, such as sawdust, wood fibers, and agricultural waste materials such as rice hulls and wheat straw. Alternatively, or in addition, the filler material may be inorganic, such as perlite. The addition of perlite as a filler material may serve to reduce the weight of the resulting panel. Typically, the fire-resistant panel includes about 15% to about 20% by weight of such filler materials.

[0019] The core material may incorporate one or more hydrophobic agents. Such hydrophobic agents may be added

in order to increase the overall water-resistance of the fire-resistant panel. Any suitable hydrophobic agent may be used during panel manufacture, including for example oils and fatty acids. Alternatively, or in addition, boric acid may be used as a hydrophobic agent. Typically, the fire-resistant panel includes about 0.5% to about 1% by weight of hydrophobic agents.

[0020] Other additives may be selected to alter one or more performance characteristics of the fire-resistance panel. That is, characteristics such as flexibility, density, hardness, and the like may be tailored for a particular application. For example, aluminum oxide may be added in order to increase the hardness and compression strength of the resulting panel. Alternatively, or in addition, polyoxyethylene alkyl ether may be used as a defoaming agent to reduce the foaming of the ingredients during the manufacture of the panel. Typically, the fire-resistant panel includes about 2% to about 3% by weight of such additives.

[0021] The fire-resistant panel may be manufactured according to a process set out in flowchart 20 of FIG. 2. More specifically, the raw materials for the manufacturing process may be obtained at 22, and pre-processed for the manufacturing process at 24. Magnesium chloride, in aqueous form, is first blended with the appropriate fillers, hydrophobic agents, and additives in the desired proportions at 26, and thoroughly mixed in a mixer at 28. Magnesium oxide and fillers may be combined at 30, and the magnesium chloride mixture may then be added to the magnesium oxide mixture in a high-speed blender, and blended at high speed at 32. The mixture of core ingredients may then be placed in a panel form, or mold, and pressed into the desired thickness, such as by using a rolling mill, at 34.

[0022] In a selected aspect of the fire-resistant panel, one or more fire-resistant layers 14 may be applied to the panel during manufacture at 36. For example, one or more layer of fire-resistant glass fiber mesh 16 and/or fire-resistant fabric 18 may be applied to the panel to strengthen the panel, and to confer enhanced fire-resistance. An exemplary glass fiber mesh may have a density of 60 gram per square meter, and exhibit a fishnet mesh structure. An exemplary non-combustible fabric may have a density of 15 grams per square meter. Although any combination and arrangement of such layers may be used, typically, a single layer of glass fiber mesh and a single layer of fire-resistant fabric are applied to each side of the panel, so that the finished panel incorporates two layers each of glass fiber mesh and fabric.

[0023] Typically the fire-resistant glass fiber mesh 16 and fabric 18 are applied by placing them in the panel form before the mixture of core ingredients is added. After the core ingredient mixture is added to the form, additional layers may be applied to the upper surface of the core ingredients. The panel may then be compressed by a rolling mill to the desired thickness at 34. During this panel-forming process, the surface layers are typically encapsulated by the core material to at least some extent, and may be encapsulated entirely by the core material. Therefore, as shown in FIG. 1, the four layers of the reinforcing materials are enclosed within the core material, without additional adhesives.

[0024] The formed panel may then be cured using an Interactive Thermal Curing process (ITC process). The ITC process shortens conventional curing time by up to a factor

of 10, thereby providing a substantial saving of both energy and labor. In addition, the core material may be selected so that the curing process emits no greenhouse gases.

[0025] Typically, the curing process of fire-resistant boards such as gypsum boards, fiber-cement boards, calcium silicate boards, and the like, requires the use of heat, steam, pressure, or a combination of all of the above. In contrast, the ITC process accelerates the exothermic chemical reactions of the core ingredients in order to generate a sufficient amount of heat to cure the sheets without requiring any applied energy. In addition, curing time may be reduced considerably while the moisture content in the panel reaches an equilibrium value quickly and automatically.

[0026] The shaped 'green' (or uncured) panels are initially stacked up in racks and stored at room temperature for 24 hours, at 38 of FIG. 2. A plurality of panels are then released from the racks and stacked closely together. Preferably, the panels are stacked with little or no intervening space between panels. The closely stacked panels are then placed in a curing chamber, where the chemical reactions occurring among the core ingredients within the panels collectively generates sufficient heat to rapidly complete the curing process for the stacked panels, at 40 of FIG. 2. When panel temperatures reach about 100° C., excessive moisture inside the panel may be forced out as steam. Therefore the curing chamber may be so constructed as to permit the condensate to be collected for subsequent disposal.

[0027] As indicated, by using the ITC process, the chemical reactions occurring in the core materials are accelerated, and so the amount of the time required to complete the curing process for the panels may be drastically reduced. A conventional 10-day curing process may be reduced to one single day (24 hour period). Furthermore, as no external source of energy is required for the ITC process, the energy and labor costs for the production of the fire-resistant panels may be reduced by 90%, relative to a curing process that requires heating to effect curing.

[0028] After curing, the cured fire-resistant panels may be released and trimmed, at 42 of FIG. 2. As the panels may be manufactured in a wide range of sizes and thicknesses, the panels may then be cut into any desired size and shape, at 44. The fire-resistant panel is generally shaped to be fully compatible with standard construction methods and materials. The fire-resistant panel may be at least about 2 mm thick to about 28 mm thick. Preferably, panel is about 3 mm to about 18 mm thick. The fire-resistant panel is generally at least 1 foot wide, and preferably is about 4 feet wide. The fire-resistant panel may be up to 16 feet or any other suitable length. Typically the panel is at least 1 foot long, preferably at least 6 feet long, and more preferably at least 8 feet long.

[0029] After trimming and cutting, the panels may be inspected for flaws and to guarantee consistency and quality, at 46. The fire-resistant panels may then be warehoused and/or shipped, as needed, at 48.

[0030] The disclosed fire-resistant panel is particularly advantageous in that it is non-combustible, decay-resistant, water-resistant, weather-resistant, heat-insulating, sound-insulating, impact-resistant, termite-repellent, and fungi-repellent. The advantageous characteristics of the fire-resistant panel have been verified under stringent testing, as described in the following specific examples.

[0031] The disclosed fire-resistant panel passed the non-combustibility fire test in accordance with both the British Standard 476: Part 4 and Chinese GB 8624 (GB 5464-85) test standards. In one embodiment, the fire-resistant panel may withstand an intense heat of 1,200° C. for up to about 4-5 hours.

[0032] The disclosed panel is verified to be water-resistant in that it typically exhibits a water absorption rate of 0.23 g/m³ or less in accordance with the ASTM (American Society of Testing and Materials) C1185 test standard for water-resistance.

[0033] The heat-insulating qualities of the disclosed fire-resistant panel may be verified in that the disclosed panel typically exhibits a thermal conductivity between 0.089 W/m·K and 0.3096 W/m·K and an R Value of between 0.0577 m²·K/W and 0.143 m²·K/W in accordance with the ASTM C518 test standard for heat-insulation.

[0034] The sound-insulating qualities of the disclosed fire-resistant panel may be demonstrated using a partition constructed with 2 layers of 6 mm thick fire-resistant panel on each side of a common steel stud frame, providing an overall thickness of 124 mm, where the cavity is filled with 50 kg/m³ mineral wool. A partition constructed in this manner is capable of exhibiting a Sound Transmission Class (STC) of at least 51 according to the BS 2750: Part 3 test standard. An STC value represents a single number rating used to characterize the sound insulating value of a partition. The higher the STC rating, the less sound will be transmitted through the partition. An STC rating of 50 or higher is considered very good or excellent.

[0035] The disclosed fire-resistant panel may demonstrate an impact strength of greater than or equal to 4.04 m·kg, as determined in accordance with the ASTM D3029 test standard, and with a modulus of rupture greater than or equal to 31.42 MPa (Longitudinal); 30.84 MPa (Traverse) in accordance with the ASTM C120 test standard.

[0036] As the disclosed fire-resistant panel incorporates inorganic materials, as described above, the panel is substantially termite-repellent, and the ingredients further repel termites, woodworms and bugs. Additionally, the fungi-resistance of the disclosed fire-resistant panel may be verified in that the panel exhibits a rating of 0 (fungi free) in accordance with the ASTM G21 test standard.

[0037] The disclosed fire-resistant panel typically exhibits a density of about 690 kg/m³ as determined in accordance with the ASTM C1185 test standard, making the panel substantially lightweight in comparison with other non-combustible boards.

[0038] The disclosed fire-resistant panel typically exhibits a creep modulus that is greater than or equal to about 433 MPa/cm, and its load deflection is generally less than or equal to 2.59×10⁻³ of span, both in accordance with the ASTM D2990 test standard, making the disclosed panel highly dimensionally-stable. In addition, the disclosed fire-resistant panel is substantially non-deforming, exhibiting a modulus of elasticity greater than or equal to 7,820 MPa (Longitudinal); 6,347 MPa (Traverse) in accordance with the ASTM C120 test standard.

[0039] In addition to the above properties, the disclosed fire-resistant panel typically retains fasteners well, demon-

strating a fastener pull resistance between about 937.5 N and 1,160 N, as determined in accordance with the ASTM D473 test standard.

[0040] Due to the environmentally-friendly manufacturing process used to prepare the panels, the panels typically do not contain any environmentally-hazardous toxic glues, such as formaldehyde, arsenic, or carcinogenic substances such as asbestos or crystalline silica. More particularly, none of the ingredients typically used in preparing the disclosed fire-resistant panel are classified as hazardous by the Superfund Amendments and Reauthorization Act, the Toxic Substances Control Act, the Recommended Conservation and Recovery Act and Workplace Hazardous Materials Information System (Canada). Similarly, none of the ingredients used in preparing the disclosed panel are classified as carcinogenic by the International Agency for Research on Cancer, the Occupational Safety and Health Administration, or the National Toxicological Program. As a result, the disclosed fire-resistant panel may be considered substantially non-toxic and non-carcinogenic.

[0041] The disclosed fire-resistant panel is therefore lightweight, water resistant, durable, strong, and nail-holding, as well as exhibiting significant fire-resistance. However, in addition to the above desirable properties, the fire-resistant panel is versatile and may be readily handled like wood. The panel may be cut, sawn, drilled, nailed, screwed, stapled, wallpapered, painted and fabricated with veneer, laminate, or metal covering. The panel is highly dimensionally-stable, having a negligible expansion and contraction rate. Further, the panel will not delaminate or deteriorate even after prolonged exposure to moisture.

[0042] Due to these many advantageous properties, the fire-resistant panel of the disclosure may be particularly suited for use in partitions, ceilings, drywalls, hoarding, smoke barriers, fire doors, air-conditioning or cable ducts, electrical and mechanical services enclosures, raised floor cores, and the like. Where the panel is relatively thin, for example having a thickness of 6 mm or less, the panel may be bent to fit around, for example, round columns or other intricate architectural designs. The panel may serve as base for ceramic tiling even in wet environments. Additionally, the panel manufacture is environmentally-friendly, as it turns such waste materials as wood fibers, sawdust, rice hulls into a useful product that saves energy, emitting no greenhouse gases in the process.

[0043] A comparison between an embodiment of the fire-resistant panel according to the disclosure and other non-combustible panel materials is shown in Table 1.

TABLE 1

Feature	Gypsum Panel	Fiber-Cement Panel	Calcium Silicate Panel	Disclosed Panel
Non-Combustible	May be	Yes	Yes	Yes
Moisture-Resistant	No	Yes	Yes	Yes
Weather-Resistant	No	No	No	Yes
Impact-Resistant	No	Yes	No	Yes
Sound-Insulating	No	No	Yes	Yes
Heat-Insulating	No	No	Yes	Yes
Decay-Resistant	No	Yes	Yes	Yes
Termite-Resistant	No	Yes	Yes	Yes
Fungi-Repellent	No	Yes	Yes	Yes

TABLE 1-continued

Feature	Gypsum Panel	Fiber-Cement Panel	Calcium Silicate Panel	Disclosed Panel
Non-Deforming Safe to Use	No Fragile	No Carcinogenic*	Yes Carcinogenic*	Yes Non-toxic
Easy to Use:				
Sawing	Yes	Yes	Yes	Yes
Drilling	Yes	Yes	Yes	Yes
Stapling	No	No	No	Yes
Gluing	Yes	No	No	Yes
Nail-holding	No	No	No	Yes
Screw-holding	Insecure	Insecure	Insecure	Yes
Fabricating	No	No	No	Yes
Foiling	No	No	No	Yes
Veneering	No	No	No	Yes
Varnishing	No	No	No	Yes
Painting	Yes	Yes	Yes	Yes
Wallpapering	Yes	Yes	Yes	Yes
Tiling	No	Yes	Yes	Yes
Bendable (6 mm thick)	No	No	No	Yes
Fire Resistance (6 mm Integrity as per BS 476: Part 22)	15 min 700° C.	30 min 822° C.	60 min 925° C.	300 min 1200° C.
Density (kg/m ³)	700–950	1200–1450	900–950	690
Life Span (Indoors)	?	?	?	Up to 50 Years

*Carcinogenic due to the presence of respirable crystalline silica (CS). The International Agency for Research on Cancer (IARC) classifies CS as a carcinogenic substance.

[0044] Additional comparisons between an embodiment of the fire-resistant panel according to the disclosure and calcium silicate boards with respect to fire resistance, density, modulus of elasticity, modulus of rupture, water absorption rate, and toxicity are provided in Table 2.

TABLE 2

Test	Test Standard	Disclosed Panel	Calcium Silicate Board	Percentage Difference ¹
Density	ASTM C1185	690 kg/m ³	900 kg/m ³	–23%
Modulus of Elasticity	ASTM C120			
Longitudinal		7,820 N/mm ²	3,200 N/mm ²	+144%
Transverse		6,347 N/mm ²	2,500 N/mm ²	+154%
Modulus of Rupture	ASTM C120			
Longitudinal		31.4 N/mm ²	10.0 N/mm ²	+214%
Transverse		30.8 N/mm ²	5.5 N/mm ²	+460%
Water Absorption Rate ¹	ASTM C1185	approx. 0.23 g/cm ³	approx. 0.55 g/cm ³	–60%
Fastener Pull Resistance	ASTM D473	937.5N–1160N	550–620N	+70%–87%
Fire resistance ²	BS 476: Part 22	6 mm	9 mm	N/A
Toxicity		No	Yes ³	N/A

$$^1 \% \text{ Difference} = \frac{[\text{Data of Disclosed Panel}] - [\text{Data of Calcium Silicate Panel}]}{[\text{Data of Calcium Silicate Panel}]} \times 100\%$$

²Weight of water absorbed per unit volume of board

³Panel thickness required to achieve 4 hour integrity according to BS 476: Part 22

⁴Contains carcinogenic crystalline silica (CS). IARC classified crystalline silica as carcinogenic. Airborne dust of CS can cause silicosis, an incurable lung disease, and increase the risk of bronchitis, pulmonary fibrosis, tuberculosis, lung cancer, renal disease and scleroderma.

any type of construction that incorporates the panel, particular selected systems may demonstrate outstanding results, as set out below:

[0046] A section of a suspended ceiling system 50 that incorporates disclosed fire-resistant panels 51 is depicted in FIG. 3. The suspended ceiling system section may include a structural framework formed by U-channels 52, with steel angles 53 present along two edges. The fire-resistant panels may be attached to the U-channels for example with self-tapping screws 54 or other fasteners, while the angle braces may be attached to the concrete wall using, for example, 6 mm head diameter concrete nails 55. The suspended ceiling system is typically suspended via hangers 56. Although using fire-resistant panels having a thickness of only 6 mm, the resulting suspended ceiling system has achieved a fire-rating of 5 hours integrity at ~1,200° C. in accordance with the BS 476: Part 22: 1987.

[0047] A non-loadbearing partition system 60 incorporating the disclosed fire-resistant panel 61 is depicted in FIGS. 4 and 5. The partition system provides a nominal partition thickness of 111 mm, which may include two fire-resistant panels 61 on each side, each approximately 9 mm thick, enclosing mineral wool 62 having a density of approximately 100 kg/m³. The partition system may include an internal structural framework of upper and lower steel U-channels 63 and vertical steel U-channels 64, attached to the panels with suitable fasteners, such as self-tapping screws 65. The partition may be attached to the ceiling and floor using, for example, suitable anchor bolts 66. The resulting partition system is capable of achieving a fire-rating of 4 hours integrity and insulation at ~1,200° C. in accordance with BS 476: Part 22: 1987.

[0048] A steel stud hoarding (temporary fencing) system 70 that incorporates the disclosed fire-resistant panels is depicted in FIGS. 6 and 7. The hoarding system provides a

[0045] As detailed above, the fire-resistant panel disclosed herein exhibits superior performance, particularly in terms of fire-resistance and heat-insulation. While the use of the disclosed panel confers these advantageous properties onto

nominal partition thickness of 74 mm, which may include fire-resistant panels 71, each approximately 6 mm thick, and fire-resistant panel fillets 72, also approximately 6 mm thick. The hoarding system may include an internal structural

framework having upper and lower steel U-channels **73**, vertical steel U-channels **74**, horizontal steel U-channels **75**, and wall-mounted U-channels **76**. The framework may be attached to the panels and fillets with suitable fasteners, such as self-tapping screws **77**, while the hoarding system may be attached to the ceiling and floor using, for example, suitable anchor bolts **78**. Typically joints' between panels **71** would be sealed with a fire-rated sealant **79**. The resulting hoarding system is capable of achieving a fire-rating of 4 hours integrity at $\sim 1,200^{\circ}\text{C}$. in accordance with BS 476: Part 22: 1987.

[**0049**] An Electrical and Maintenance (E&M) services enclosure system **80** is depicted in **FIGS. 8, 9, and 10**. The enclosure system is particularly useful as a fire-resistant enclosure for electrical and mechanical services **81**, for example including one or more of electrical cables, communication cables, plumbing for water or other fluids, etc. The E&M services enclosure system may include fire-resistant panels **82**, each approximately 6 mm thick, with fire-resistant panel fillets **83**, also approximately 6 mm thick, enclosing joints between fire-resistant panels **82**. The joints are internally supported by steel angles **84** secured to the panels with self-tapping screws **85**. The fire-resistant panels define an interior space that includes a channel for the electrical and mechanical services **81** defined by a steel channel collar **86**, with the intervening space between the channel collar and the fire-resistant panel filled with mineral wool insulation, having a density of approximately 100 kg/m³ **87**. The E&M services enclosure system may be supported by threaded rod hangers **88**, with the hanger penetration openings typically sealed with an appropriate intumescent joint sealant. Fire-resistant panels and fillets may be secured to intervening walls using appropriate concrete nails **89** or other fasteners. **FIG. 10** shows a longitudinal section of an E&M services enclosure system, showing details of an intersection of the services enclosure duct with a wall. The depicted E&M services enclosure system is capable of achieving a fire-rating of 2 hours integrity and insulation in accordance with BS 476: Part 20: 1987, with respect to an external or internal fire.

Applications of the Fire-Resistant Panel

[**0050**] The disclosed fire-resistant panel may provide effective fire prevention and up to 5 hours of fire protection, and is particularly valuable when permitting the safe evacuation of human lives and assets, particularly in disasters like residential, commercial, or forest fires. The fire-resistant panel may therefore be used in numerous applications in the following industries:

a. Construction and Renovation

[**0051**] The panel offers advantageous properties wherever fire protection is required—including but not limited to offices, banks, shopping malls, department stores, supermarkets, restaurants, hotels, cinemas, theaters, opera houses, karaoke, night clubs, jewelry shops, convention centers, exhibition halls, schools, churches, hospitals, clinics, dormitories, gymnasiums, recreation and sports centers, car parks, hi-rise residential buildings, and the like. Non-combustible, strong and durable, the disclosed panel may be particularly suitable for partitions, ceilings, interior walls, drywalls, fire walls, hoarding, fire doors, soffits, air-conditioning duct liners, E&M services enclosures, electric conduit liners, plenum ceilings, cores for raised floors, lining

panels for elevators; wall coverings for elevator shafts, stairwells, garages; roof-decks, generator-covers, sound-insulating walls, thermal barriers and the like. The fire-resistant panel can also be used as ceramic tile underlayment in wet environments.

b. Air Transport

[**0052**] The disclosed panel with the highest fire-rating is most effective in fire protection for plane cabins and cargo holds; ceilings, partitions, wall coverings, fire doors, fire exits, fire separation barriers, air-conditioning duct coverings, E&M services enclosures for airports, air cargo terminals, air caterers, hangars, fuel storage, passengers waiting rooms, corridors, boarding gates, and the like.

c. Land Transport

[**0053**] The disclosed panel may be used in fire protective walls, flooring and body for all types of vehicles, including but not limited to cars, buses, trams, trucks, trailers, tourist coaches, mobile homes, school buses, ambulances, trains, cargo trains, MTR/light railcars, MTR/railway stations, terminals, multi-story car parks, gas stations, garages, cargo handling areas, and the like. The fire-resistant panel may offer particular utility in the transport of materials that exhibit a combustion hazard, such as oil trucks, flammable goods trucks, and the like.

d. Shipping

[**0054**] The disclosed panel is well-suited for lightweight and sound-insulating panels, partitions of cabins for all kinds of vessels, especially cruise ships, yachts, hydrofoils, ferries, oil tankers, LPG carriers and naval ships, among others.

e. Industry

[**0055**] The disclosed panel is well-suited for industrial wall coverings, partitions, ceilings, electric conduit liners, air conditioning duct covering; oil, flammable goods storage, fire doors, fire exits, fire separation barriers for factories, warehouses, electric sub-stations, noise silencers and the like. In particular, the disclosed fire-resistant panel offers advantages in the construction of fire protective walls, lift shafts, and stairwell liners for industrial buildings.

[**0056**] Although the present invention has been shown and described with reference to the foregoing operational principles and preferred embodiments, it will be apparent to those skilled in the art that various changes in form and detail may be made without departing from the spirit and scope of the invention. The present invention is intended to embrace all such alternatives, modifications and variances that fall within the scope of the appended claims.

What is claimed is:

1. A method of manufacturing a fire-resistant panel, comprising:

- (a) preparing a panel composition having an exothermic curing process;
- (b) forming the panel composition into a panel;
- (c) arranging a plurality of panels so that the heat released by the panels during the exothermic curing process is sufficient to cure the plurality of panels with no additional heating.

2. The method of claim 1, wherein the panels are cured within about 24 hours with no additional heating.

3. The method of claim 1, wherein forming the panel composition into a panel includes incorporating one or more layers selected from fire-resistant glass fiber and fire-resistant fabric within the panel.

4. The method of claim 1, wherein the panel composition includes magnesium oxide, magnesium chloride, and sodium silicate.

5. The method of claim 4, wherein the panel composition further includes kaolin, one or more fillers, one or more hydrophobic agents, and one or more additives.

6. A method of manufacturing a fire-resistant panel, comprising:

(a) blending an aqueous composition that includes magnesium compounds, sodium silicate, and kaolin;

(b) incorporating one or more layers selected from fire-resistant glass fiber and fire-resistant fabric within the composition and forming the composition into a panel;

(c) arranging a plurality of panels so that heat released by the panels collectively raises the temperature of the arranged panels sufficiently to cure the composition, with no external heating;

(d) shaping the sheets into fire-resistant panels.

7. The method of claim 6, wherein the composition further includes one or more of additional fillers, hydrophobic agents, and additives.

8. The method of claim 6, including incorporating one or more layers of glass fiber mesh and one or more layers of fire-resistant fabric within the composition on each side of the panel.

9. The method of claim 6, wherein the panels are arranged with substantially no intervening space between adjacent panels.

10. The method of claim 6, wherein the panels are held at a temperature sufficient to cure the panel composition, for a time sufficient to cure the composition.

11. The method of claim 10, wherein the time sufficient to cure the composition is about 24 hours.

12. The method of claim 6, wherein the temperature of the panels is raised to about 100° C.

13. The method of claim 6, wherein the composition is prepared from an aqueous solution of magnesium chloride and magnesium oxide.

14. The method of claim 7, wherein the fillers include perlite.

15. The method of claim 7, wherein the fillers include organic agricultural waste.

16. The method of claim 15, wherein fillers include at least one of sawdust, wood fibers, rice hulls, and wheat straw.

17. The method of claim 7, wherein the hydrophobic agents are selected from oils, fatty acids and boric acid.

18. The method of claim 7, wherein the additives include at least one of aluminum oxide and polyoxyethylene alkyl ether.

19. A fire-resistant panel, prepared according to the method of any of claims 1-18.

20. The fire-resistant panel of claim 19, having a composition that is

45%-60% by weight of magnesium compounds;

8%-15% by weight of sodium silicate;

10%-15% by weight of kaolin;

15%-20% by weight of fillers;

0.5%-1% of hydrophobic agents; and

2%-3% of additives.

21. The fire-resistant panel of claim 19, wherein the panel is capable of withstanding fire at a temperature of at least 1,000° C., and is configured for use in fire-resistant construction.

22. The fire-resistant panel of claim 20, wherein the fillers include organic agricultural waste materials.

23. The fire-resistant panel of claim 19, wherein the panel has a thickness of about 2 mm to about 28 mm, and a width of about 1 foot to about 4 feet, and a length of about 1 foot to about 16 feet.

24. An environmentally-friendly fire-resistant panel, comprising a core material that includes magnesium compounds, sodium silicate, kaolin, fillers, and additives, which is reinforced by 2 or more layers of fire-resistant glass fiber mesh and 2 or more layers of fire-resistant fabric; where the panel is cured by an internal exothermic process in about 24 hours without the application of external heating; and the panel exhibits high fire-resistance, low density, high flexural strength and effective water-resistance.

25. A suspended ceiling system comprising a fire-resistant panel of any of claims 19-24, characterized in that the suspended ceiling system is capable of achieving a fire rating of 5 hours integrity at a temperature of approximately 1,200° C. in accordance with the British Standard 476: Part 22: 1987.

26. A non-loadbearing partition system comprising a fire-resistant panel of any of claims 19-24, characterized in that the partition system is capable of achieving a fire-rating of 4 hours integrity and insulation at a temperature of approximately 1,200° C. in accordance with the British Standard 476: Part 22: 1987.

27. A steel stud hoarding system comprising a fire-resistant panel of any of claims 19-24, characterized in that the hoarding system is capable of achieving a fire-rating of 4 hours integrity at a temperature of approximately 1,200° C. in accordance with the British Standard 476: Part 22: 1987.

28. An electrical and mechanical services enclosure system comprising a fire-resistant panel of any of claims 19-24, characterized in that the enclosure system is capable of achieving a fire-rating of 2 hours integrity and insulation at a temperature of approximately 1,050° C. in accordance with the British Standard 476: Part 20: 1987.

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