



## **USE OF INSULATING MATERIAL OFF-CUTS FOR FIRE RATED DOOR AND STRUCTURES**

### **Field of the Invention**

[0001] The present invention relates to fire resistant doors, panels, walls and similar partition-type structures.

[0002] In particular, the present invention is a fire resistant structure and a new method of arranging insulating material in fire resistant structures like doors, panels, walls and partitions such that the amount of insulating material needed to meet any fire rating is reduced.

### **Background of the Invention**

[0003] Fire resistant doors, also commonly referred to as fire check doors or simply as fire doors, are installed to prevent the spread of a fire from one part of a building or enclosure to another part. Fire doors are designed by manufacturers to meet certain national or international standards and fire doors are commonly specified in building codes for critical areas of buildings.

[0004] The duration for which a fire door can withstand a fire of standardized intensity is its fire resistance rating and doors are designated by this rating. The term fire resistance rating is also known as the fire rating.

[0005] Fire doors may be of the swinging or sliding types. Fire doors may also be made of wood or metal, usually steel or stainless steel.

[0006] For wood or wood composite fire doors, they are usually constructed with a frame which contributes to defining the outline of the door. Depending on the construction, doors may also have an inner frame. Panels or "skins" are mounted on both faces of the door. These skins may



be made of hardboard, plywood or medium density fiberboard (MDF). Such doors may also have structural solid timber or plywood members to support any ironmongery fixtures such as hinges, knobs, handles, lock sets, automatic door closers, louvers, vision panels and viewers.

[0007] Within the frame thus defined, fire doors may have insulating layers of solid timber, plywood or other insulating material forming part of an insulating core. Depending on the fire rating desired, the construction of the insulating cores may range from simple solid timber pieces to more complex arrangements with multiple layers of insulating material. What is conventional and common amongst these arrangements, is that the insulating layers are essentially continuous or are in complete sheets of material, without any joints.

[0008] The choice of insulating material for the cores may be selected from any one or more of the range of insulating, non-combustible material such as fiber glass, vermiculite, mineral wool ("rock" wool), medium density fiber board (MDF), chip board, cement board, gypsum board or gypsum fiber board.

[0009] The insulating material may be made solely of one material or may comprise a mixture or composite of other insulating materials. The insulating layers may also be arranged in layers, mounted on and sandwiching, a lightweight support inner layer or frame to form the insulating core. This is the general construction of a conventional fire door.

[0010] In a fire, the function of the insulating core of the fire door is to present a barrier to high temperatures or the direct flames of the fire on the side of the exposed face of the door from spreading to other unexposed face of the door.

[0011] To obtain a 30-minute fire rating under the Singapore Standard 332: 2000: clause 4 (equivalent to British Standard BS 476, Part 22, 1987), a fire door must maintain its structural integrity and its insulation must not allow the mean temperature on its unexposed face to increase by more than 140°C or the temperature at any position on the unexposed face to increase by more than 180°C. Over the duration of this test, the temperature of the

test furnace typically rises from ambient to 440°C in five minutes and thence to 820°C in 30 minutes.

[0012] A good material for use in the insulating core for fire doors is gypsum, which is hydrated calcium sulfate. When gypsum compressed and bonded with fillers such as glass fiber, it becomes gypsum board. The two main surfaces of the board may be faced with paper or cellulose fiber for ease of handling and for added strength. Gypsum boards typically come in 4' x 8' (1,200 mm x 2,400 mm) sheets, and are available in various densities and thickness, with thicker and denser gypsum boards being more fire resistant than thinner and lighter boards.

[0013] As an illustration of the kind of insulation necessary for fire doors, the American Gypsum Association's publication, GA-600-2000 Fire Resistance Design Manual, states that a 5/8" (15.9 mm) thick sheet of the fire resistant "Type X" gypsum board can provide up to one hour of fire resistance.

[0014] Gypsum makes a good fire insulation material as it is about 21 percent by weight chemically combined with water. When exposed to fire, this water is slowly released as steam in the process called calcination, insulating the board from heat. Even after all the water is released, the calcinated gypsum board continues to act as a barrier against heat.

[0015] One invention, Bernt et al, US 5,558,707, uses alternating bands of hydrated gypsum and styrene bubbles in a door core to provide increased fire resistance. However, that invention will conceivably increase the weight of the door as the core contains added water. In addition, the method of fabrication taught by that invention is complicated and is likely to increase the cost manufacture. The cost of a fire door is also contributed by the high cost of the insulating materials used.

[0016] Thus, an invention that is simple to manufacture, uses less insulating material and does not compromise the fire resistance rating will be welcome in the industry.

### **Summary of the Invention**

[0017] In one aspect, the present invention provides a method of fabricating a fire protective structure. The method comprises arranging at least one discontinuous layer of fire insulating material to apposed at least one other layer of fire insulating material for the insulating core of said fire protective structure such that any joint in said at least one discontinuous layer of fire insulating material is overlapped by the at least one other layer of fire insulating material such that there is no contiguous path is present between any joint of the at least one discontinuous layer and the at least one other layer of insulating material for heat or flame to breach the insulating core.

[0018] In another aspect, the present invention is a fire door comprising at least one insulating core, at least one supporting frame, at least one panel skin and at least one ironmongery fixture wherein the insulating core comprises at least one discontinuous layer of at least one type of insulating material.

### **Brief Description of the Drawings**

[0019] A preferred embodiment of the present invention will now be more fully described, by way of example, with reference to the drawings of which:

[0020] FIG. 1 is an exploded perspective view illustrating the typical construction of a conventional fire door with continuous sheets or layers of insulation;

[0021] FIGS. 2A, 2C and 2D are exploded perspective views while FIG. 2B is a cross-sectional view showing the arrangement and construction of an insulating core for a fire door under one method by which the present invention may be practiced;

[0022] FIGS. 3A and 3B are end elevation views of insulating cores with different arrangements of discontinuous sheets or layers of insulating material laid with substantial voids for fire doors under the present invention; and

[0023] FIGS. 4A, 4B and 4C are end elevation views of insulating cores showing examples of different arrangements of the outer layers of insulating material for the insulating core under the present invention.

### **Detailed Description of the Drawings**

[0024] The present invention teaches fabrication of a fire resistant structure and a new method of arranging insulating material in fire resistant structures such as doors, panels, walls and partitions such that the amount of insulating material needed for any particular fire rating is reduced.

[0025] In this application, the present invention may be used in fire doors, fixed or movable panels, ceilings and other similar structures that partition one part of a building or enclosure from another. The invention may also be applied in vehicles or temporary shelters as well.

[0026] While the present invention teaches the use of gypsum board as the preferred embodiment, it can also be applied to similar products made of other materials by various manufacturers for identical or similar applications, provided that they meet the requirements of an insulating material.

[0027] One aspect of the invention is the method of mounting such insulating materials in the core of fire protective structures in such an arrangement as to confer a desired fire rating to the fire resistant structure.

[0028] In another aspect, the present invention provides a wood fire door fabricated with an insulating core taught by the method described.

[0029] In this application, the orientation of the door to the directions of up, down, top and bottom are used in the conventional sense, as when the door is finished and mounted in a door frame for use. When used in a door, the flat sheet components of the door such as the skins and insulating material have "faces" which are their flat surfaces. When attached or mounted to the door, these faces may be facing the interior of the door (interior faces) or to the exterior (exterior faces).

[0030] FIG. 1 shows a conventional fire door. The construction is that of an insulating core of single sheets of regular gypsum board **110** of density 694 kg/m<sup>3</sup> and with a thickness of at least 3/8" (9.5 mm) each mounted on either side of an inner timber frame or layer **112** with a gap of 19.5 mm and used in a fire door with a suitable outer frame formed by a top rail **116** and a bottom rail **118** with plywood facings or skins **114** of 3.0 mm thickness, Tests by the inventors have shown that a fire door with such an insulating core can exceed the 30-minute rating for the Singapore Standard cited in the background of this application (SS 332: 2000: clause 4; results not shown).

[0031] These two gypsum boards **110** form the outer layer and together with the inner timber layer **112**, the entire sandwich construction forms the insulating core of the fire door.

[0032] For such applications, the gypsum boards used are in whole, continuous sheets, cut to size. Manufacturers of fire doors usually generate a lot of "off-cuts": pieces of insulating material in odd dimensions that are generally unusable as insulation in the prior art as they are not whole sheets.

[0033] The present invention recites a method of advantageously using such off-cuts of suitable fire insulating materials such as gypsum board in the core of fire doors to be used.

[0034] The present invention also recites arrangements of insulating material in the core of fire doors that allow less insulating material to be used while not compromising the desired fire resistance rating of the door.

[0035] In the prior art, with regard to insulating material of a fixed density, fire door ratings are increased by increasing the thickness of the insulating layers or materials used.

[0036] Unlike the techniques taught in the prior art, the present invention maintains the distance, thickness or space between the faces of the outer layers of the core by stacking pieces of insulating material in the inner layer of the core of the door in lieu of a conventional supporting timber inner frame. When sandwiched by the gypsum boards of the outer layer, the

discontinuous inner layers of the insulating material form substantial voids filled with air are created in the insulating core. In other words, the pieces of insulating material now form the inner frame, obviating the need for a conventional supporting timber inner frame. This is shown more clearly in FIGS. 2A-D.

[0037] FIGS. 2A-D show one method by which a fire door of nominal size 1,250 mm wide x 2,448 mm high x 46 mm thick incorporating the novel insulating core of the present invention may be fabricated will now be described as an example (not to scale). FIGS. 2A and 2B show details on the construction of the inner layer of the insulating core while FIGS. 2C and 2D show how the outer layers of insulating material are apposed to the inner layers of the insulating core.

[0038] Referring to FIG. 2A, a top rail **212**, a bottom rail **214** rails and two side rails or stiles **216** of a supporting outer frame are first prepared. These rails are 40 mm high x 140 mm thick with a slot **216** of 20mm x 10 mm running centrally along them. These four rails define the outline of the door are as long as appropriate. These are then placed loosely together relative to each other horizontally, either on the floor or on a work bench.

[0039] Pieces of insulating material **218** of regular (694 kg/m<sup>3</sup> density) gypsum board (1,120 mm wide x 400 mm high x 9.5 mm thick) are then slotted into the grooves of the rails and secured in place with adhesive. The pieces are arranged in a vertically staggered arrangement, overlapping their neighboring pieces above and below them by at least 25 mm **220**, leaving a gap **222** of 350 mm between the pieces of insulating material **218** to form the inner insulating layer (FIG. 2A).

[0040] To further reinforce the gypsum pieces, supporting spacers **224**, as long as the gap is high and preferably of gypsum board cut-offs, may be glued or affixed in the gaps between adjacent pieces to support the pieces. These supporting spacers are usually positioned at the long ends of the pieces and slotted into the grooves of the rails. For wide doors, another supporting spacer at the center of the pieces may be appropriate.

[0041] When using pieces of other types of insulating materials that are sufficiently stiff, these supporting spacers may not be needed.

[0042] Again in FIG. 2A, the rails **212**, **214** and **216** of the outer frame are then forced into their final positions, engaging their shallow mortise and tenon joints **232**. Other joinery methods such as dovetail joints and miter joints may also be used. The central slots **226** of the rails allow the pieces of gypsum of the inner layer in contact with them to be seated securely and held in position. Mechanical fasteners may be used to supplement the adhesive. The mounted inner layer is then set aside until the adhesive has cured.

[0043] FIG. 2B shows the side elevation of the overlapping arrangement of the pieces of insulating materials **218** placed into the central slot of the top rail **212** and the side rail **216**. Supporting spacers **224** are placed between pieces of insulating material to help keep them in position.

[0044] While a central slot **226** in the profile of the outer frame rails is described, other similar profiles for the rails, such as rabbets or tongue and groove woodworking joinery means or arrangements, may be used to hold the gypsum strips in place.

[0045] The subsequent steps are shown in FIGS. 2C and 2D. Another sheet each of gypsum board trimmed to sufficient size (1,100 mm wide x 2,263 mm high x 9.5 mm thick) to form the outer layer **228** of the core is then secured by adhesive and mechanical fasteners to either face of the inner layer of the core and to the supporting outer frame. The profile of the outer frame is also cut to accept the gypsum sheets of the outer layer such that the insulating sheets of both the inner and outer cores are tightly apposed to each other and to the outer frame.

[0046] With the outer layers of gypsum sheets **228** applied, the gaps **222** between the gypsum pieces form substantial voids in the insulating core. Such substantial voids **314** may be clearly seen in the cross-sectional drawings of the insulating cores in FIGS. 3A and 3B. Thus the insulation formed by the inner layers of the core is discontinuous, with large gaps or voids.

[0047] Thereafter, skins **232** of plywood 3 mm thick are glued and fastened over the outer layer of the core, wholly or partially covering the outer frame. This set-up is then clamped in a press until the adhesive has cured (FIG. 2C). Subsequently, the door is then trimmed if necessary.

[0048] To finish the door, "lipping" material **234** of hardwood may be fastened to the exposed top, bottom and side edges of the door (FIG. 2D). The door may then be finished (sanded, painted or laminated) as desired. Any ironmongery fixtures such as hinges, knobs, handles **236**, lock sets or locks **238**, automatic door closers, louvers, vision panels and viewers may then be added.

[0049] This arrangement of the insulating layers is one embodiment of the present invention. While a (final) horizontal arrangement of the alternating pieces is shown, the pieces may also be arranged in a (final) vertical arrangement without departing from the scope of the present invention.

[0050] While a diagonal arrangement of staggering the pieces may conceivably be used under the present invention, it will be hard to ensure that the gaps or joints between the pieces are overlapped and secured properly in such an arrangement.

[0051] The heart of the present invention lies in the tightly apposed, staggered arrangement of the pieces of insulating material to maintain the thickness of the core of the door (and hence, the distance between the skins of the door) so as to prevent heat and fire from breaching the core, and consequently the fire door.

[0052] Even with the substantial voids present in the insulating cores, there is no contiguous path for heat or flame through the gaps or joints between the pieces of insulating material throughout the thickness of the core.

[0053] That is, the gaps or joints in one layer of the core is not in such close proximity to other gaps or joints in adjacent layers. The overlapping staggered arrangement of the joints are such that flame or heat do not have a direct, contiguous path through the insulating core. As such, fire protection offered by the insulating material is maintained. The preferred amount of overlapping in the present invention is at least 25 mm or 1".

[0054] To ensure that the protection offered by these pieces of insulation of the present invention is preserved, the gypsum pieces are preferably to remain securely fixed in their positions. This is ensured by slotting them into the rails of the outer frame, augmenting the gaps with supporting spacers, and fastening with adhesive supplemented by mechanical fasteners such as nails and staples as necessary.

[0055] Tests conducted by the present inventors have borne out this inventive concept. With the staggered pieces of gypsum replacing the plywood inner frame in a conventional fire door (FIG. 1) and maintaining the same gap (6/8" or 19.5 mm) between the outer layers of the core, a fire rating equal to that achieved by the conventional fire door is obtainable. A novel door constructed as described (FIGS. 2A-D) earned a 30-minute rating under the Singapore Standard (SS 332: 2000: clause 4) in confidential developmental tests.

[0056] In other embodiments of the present invention, one or more staggered rows of insulating material may be used as both the inner and outer layers of insulation. FIGS. 3 and 4 show only end elevation views of other embodiments of the insulating cores of the fire door or fire resistant structure without the other elements such as the rails of the outer frame or the skins so as not to obscure the invention.

[0057] FIG. 3A shows an insulating core with an inner insulating layer made of a single staggered vertical row of gypsum pieces **310** with a continuous sheet of insulation for the outer layer **318**. The layers of the insulating core are shown creating substantial voids **314** when they are apposed to one another.

[0058] FIG. 3B shows an insulating core with an inner insulating layer with three staggered vertical rows of gypsum pieces **312**. These embodiments of the present invention contain substantial voids **314** in their insulating cores.

[0059] With the overlapping of the gaps or joints **316** between the different layers of the insulating material, there is no contiguous path for heat or

flame from one side of the door or structure to penetrate or breach the insulating core.

[0060] To increase the fire rating of doors or structures with insulating cores of the present invention, the gaps between the gypsum pieces may be reduced or even eliminated in the insulating core (FIG. 4A), thus producing no substantial voids in the cores. The pieces of insulating material **416** forming the inner layers of the insulating core are placed in close approximation to each other, abutting without any substantial gaps other than the joints **414** between the pieces of insulating material. Such embodiments, while not reducing the overall weight of the fire door nor the amount of materials required, will nevertheless still advantageously allow off-cuts to be used in their fabrication.

[0061] The staggered arrangement may also extend to the insulating material forming the outer layer of the insulating core. In the cross-section shown in FIG. 4B, the gypsum boards available are of insufficient size to allow continuous sheets to be used. A smaller piece of board **410** is then used to supplement it, with the joint or gap **414** between the sheets arranged such that no contiguous gap is available as a conduit through the thickness of the door for flame or heat to breach. FIG. 4C shows both the inner and outer layers of the insulating core as being discontinuous, comprised pieces of insulating pieces. The inner layers' insulating pieces **416** and outer layers' insulating pieces **418** of the insulating core are arranged with the joints **414** in an overlapping fashion to maintain the fire rating of the door or structure.

[0062] Under the present invention, multiple pieces of insulating material may be used for both the outer and inner layers of the insulating core as long as the overlapping arrangements of the pieces do not allow breaching of the door by fire and heat for the duration required by the desired fire rating. The number of layers of insulation may also be varied within the scope of the present invention.

[0063] While the intended purpose is to make use of off-cuts to reduce waste, an additional advantage is that, as less material is used, the fire door

is also lighter. If the advantage of a lighter door is desired, whole sheets of gypsum board may be cut into suitable sizes for use under this invention if cut-offs are not available.

[0064] In addition, while the pieces of gypsum used are shown to be of the same width and height, pieces of gypsum of different heights but of the same thickness and width may be used as long as the gaps or joints do not present a contiguous path for fire to breach the core. This minimizes waste and labor required to fabricate the door.

[0065] By combining through mixing and matching, insulating materials with different fire resistant properties, various fire door cores and hence fire doors may be fabricated under the present invention to meet different requirements.

[0066] While the present invention is illustrated by example of substantially rigid material such as gypsum board, other insulating material such as more flexible mineral or "rock" wool may be used. The batting of such flexible materials may be laid in strips but care must be taken the material is securely fasten to prevent shifting due to handling and gravity so as to have less insulation in certain parts of the core than others. The such materials must also be evenly laid and the thickness maintained

[0067] It will be appreciated by anyone of ordinary skill in the art that the method taught regarding the staggered arrangement of the pieces of insulating material is advantageous, particularly the emphasis of not allowing any contiguous gaps through the thickness of the core.

[0068] The present invention will allow fabrication of fire doors from the large amounts of cut-offs generated in the fire door fabrication industry, so as to minimized wastage while reducing cost and not compromising on the protection offered by required of fire doors.

[0069] Fire protection is not sacrificed with the overlapping of the materials preventing any contiguous gaps for flame or heat to breach the insulation. At the same time, the weight of the door is reduced as less material is used.

[0070] Rearrangement, substitution or omission of other components of the structures such as the supporting outer and inner frames, panel "skins",

edging ("lipping") or lamination, as well as equivalent methods of joinery and fastening of these components together, may be varied without departing from the scope of the present invention. Application of the invention to different materials other than those mentioned here but which serve the same function remains within the scope of the present invention.

[0071] In accordance with the figures, a preferred embodiment of the invention was described. In the above description, details were provided to describe the preferred embodiment. It shall be apparent to one skilled in the art that the invention may be practiced without such details. Some of these details may not been described at length so as not to obscure the invention.

[0072] While the fabrication of a fire door with components of certain dimensions is described, the description should not be taken to be limited to the door described.

[0073] It will be appreciated that although one preferred embodiment has been described in detail, various modifications and improvements can be made by a person skilled in the art without departing from the scope of the present invention.

[0074] An example of such a variation is that the present invention may also be similarly applied to partition structures such as walls and ceiling panels to retard the spread fire in a burning building or enclosure. The invention may also be applied to temporary structures and vehicles such as ships and boats. While the insulating material is primarily for fire, the present invention can conceivably be used for sound insulation as well,

**CLAIMS**

What is claimed is:

1. A method of fabricating a fire protective structure, said method comprising:  
arranging at least one discontinuous layer of fire insulating material  
to apposed at least one other layer of fire insulating material  
for an insulating core of said fire protective structure  
such that  
any joint in said at least one discontinuous layer of fire insulating  
material is overlapped by said at least one other layer of fire  
insulating material  
and where  
no contiguous path is present between any joint of said at least one  
discontinuous layer and said at least one other layer of  
insulating material for heat or flame to breach said insulating  
core.
2. The method of Claim 1, wherein said at least one other layer of fire  
insulating material may be continuous or discontinuous.
3. The method of Claim 1, wherein upon fabrication, said insulating core  
contains at least one substantial void formed by the arrangement of said at  
least one discontinuous layer of fire insulating material with said at least  
one other layer of fire insulating material.
4. The method according to Claim 1, wherein upon fabrication, said insulating  
core does not contain substantial voids formed by the arrangement of said  
discontinuous layers of insulating materials.
5. A method according to Claim 1, said method further comprising:

arranging and fastening said pieces of insulating material in said at least one discontinuous layer;  
fastening and supporting said at least one discontinuous layer of insulating material in at least one frame;  
fastening of at least one panel skin over said at least one discontinuous layer of insulating material; and  
finishing said fire protective structure with optional finishes and fixtures.

6. The method of Claim 5, said fastening and supporting further comprises preparing said at least one frame with at least one slot, rabbet, tongue or groove, to accept said at least one discontinuous insulating layer.
7. The method of Claim 5, said optional finishing with optional finishes comprises edging, sanding, painting and laminating.
8. The method of Claim 5, said finishing with fixtures comprises installing of ironmongery fixtures appropriate for function of said fire protective structure.
9. A fire door comprising:
  - at least one insulating core;
  - at least one supporting frame; and
  - at least one panel skin,wherein said insulating core comprises at least one discontinuous layer of at least one type of insulating material.
10. The fire door of Claim 9, said insulating core further comprising at least one inner insulating layer and at least one insulating outer layer, said insulating core further containing substantial voids.

11. The fire door of Claim 9, said insulating core further comprising at least one inner layer and at least one outer layer, said insulating core further not containing substantial voids.
12. The fire door of Claim 9, said insulating core being fire protective by an arrangement of at least one discontinuous layer of insulating material not having a contiguous path for heat or flame between joints of said at least one insulating core.
13. The fire door of Claim 9, said at least one panel skin comprises hardboard, plywood or medium density fiberboard (MDF).
14. The fire door of Claim 9, said at least one type of insulating material comprises fiber glass, vermiculite, mineral wool ("rock" wool), medium density fiber board (MDF), chip board, cement board, gypsum board or gypsum fiber board.
15. The fire door of Claim 9, said at least one discontinuous layer of insulating material fastened to said at least one supporting frame by at least one woodworking joinery means.
16. The fire door of Claim 10, said substantial voids formed by gaps between said at least one discontinuous layer of insulating material and at least another insulating layer.
17. The fire door of Claim 12, said not having a contiguous path for heat and flame achieved by arranging overlapping of pieces of insulating material and ensuring said arrangement is kept in position.
18. The fire door of Claim 15, said woodworking joinery means comprises at least one slot, rabbet, or tongue and groove arrangement.

19. A fire protective structure comprising:
  - at least one insulating core;
  - at least one supporting frame; and
  - at least one panel skin;said insulating core comprising at least one discontinuous layer of at least one type of insulating material.
20. The fire protective structure of Claim 19, said structure comprising doors, panels, walls and partitions.