(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 February 2008 (21.02.2008)

PCT

(10) International Publication Number
WO 2008/021206 A2

(51) International Patent Classification:
B29C 33/38 (2006.01) *B32B 5/00* (2006.01)
B32B 17/00 (2006.01) *C09K 21/00* (2006.01)

(21) International Application Number:
PCT/US2007/017747

(22) International Filing Date: 9 August 2007 (09.08.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/836,794 10 August 2006 (10.08.2006) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, 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, LV, MC, MT, 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).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:
— *without international search report and to be republished upon receipt of that report*

WO 2008/021206 A2

(54) Title: LAYERED FIRE RETARDANT BARRIER PANEL

(57) Abstract: A fire retardant barrier panel (16) comprising a first protective layer (18) of a first material and a fire resistant phenolic-based resin layer (19) bonded to the protective layer. The first material may be selected from the group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials. The resin may be a phenol or phenolic resin. The fire retardant barrier panel may further comprise a second protective layer (20) bonded to the resin layer (19) such that the resin layer is between the first and second protective layers. The second protective layer (20) may be selected from the group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials.

LAYERED FIRE RETARDANT BARRIER PANEL

Cross-Reference to Related Applications

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 60/836,794, filed August 10, 2006. The entire content of such application is incorporated by reference herein.

Technical Field

[0002] The present invention relates generally to fire retardant materials, and more particularly to a layered phenolic-resin-based fire retardant panel.

Background Art

[0003] The use of phenolic resins for fire resistance is known in the prior art. For example, U.S. Patent No. 5,079,078 discloses a fire resistant panel of woven glass preimpregnated with a phenolic resin. The panel is formed as a single layer by a compression molding technique that utilizes pressure of 50-100psi at a temperature of 350 degrees for 20-30 minutes. U.S. Patent No. 5,320,870 discloses a method of spraying phenolic resin compositions to form an outer fire protective coating.

[0004] Phenolic-based resin panels are known in the prior art for uses other than fire prevention. U.S. Patent No. 4,503,115 teaches a decorative molded panel made with thermoplastic resin, such as a phenolic-based resin.

[0005] Although phenolic resin is known for its fire-resistant properties, the methods of creating fire retardant panels and enclosures in the prior art are complicated and time consuming. There is a need, therefore, for an improved fire retardant panel with improved thermal properties that can be fabricated cost-efficiently.

Brief Summary of the Invention

[0006] With parenthetical reference to the corresponding parts, portions or surfaces of the disclosed embodiment, merely for purposes of illustration and not by way of limitation, the present invention provides an improved fire retardant barrier panel (16) comprising a first protective layer (18) of a first material and a fire resistant phenolic-based resin layer (19) bonded to said protective layer. The first material may be selected from the group consisting

of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials. The resin may be a phenol or phenolic resin.

[0007] The fire retardant barrier panel may further comprise a second protective layer (20) bonded to the resin layer (19) such that the resin layer is between the first and second protective layers. The second protective layer (20) may be selected from the group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials.

[0008] In another aspect, the invention includes a method of creating a fire retardant barrier panel comprising the steps of mixing water, resin, and surfactant with boric acid and expandable filler, adding a catalyst, providing a mold (23), pouring the mixture into the mold (23), and allowing the mixture to harden. The mold (23) may be lined on at least one side with a first protective material. The first protective material may be selected from the group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials. The method may include coating at least one side of the hardened mixture with a first protective layer selected from the group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials. The coating may form a layer (18) that bonds to the hardened mixture (19) without adhesive.

[0009] Accordingly, the general object of the invention is to provide an improved fire retardant panel.

[0010] Another object is to provide an improved fire retardant panel that withstands high temperatures.

[0011] Another object is to provide an improved fire retardant panel for use in a fireproof safe or fireproof cabinet that can protect items inside the safe or cabinet from thermal damage.

[0012] Another object is to provide an improved fire retardant panel having a phenol resin layer or a phenol resin inner core.

[0013] Another object is to provide an improved fire retardant panel that effectively delays heat transfer from one side to the other.

[0014] Another object is to provide an improved fire retardant panel that does not utilize adhesives to bind layers together.

[0015] Another object is to provide a simple method for manufacturing an improved fire retardant panel.

[0016] These and other objects and advantages will become apparent from the foregoing and ongoing written specification, the accompanying drawings and the appended claims.

Brief Description of the Drawings

[0017] Fig. 1 is a perspective view of a first embodiment of a fire retardant panel.

[0018] Fig. 2 is a sectional view of the embodiment shown in Fig. 1, taken generally on line 2-2 of Fig. 1.

[0019] Fig. 3 is a perspective view of a heat source applied to the fire retardant panel shown in Fig. 1.

[0020] Fig. 4 is a table of 60-minute test results for the panel shown in Fig. 3.

[0021] Fig. 5 is a graph of 60-minute test results for the panel shown in Fig. 3.

[0022] Fig. 6 is a perspective view of a second embodiment of a fire retardant panel.

[0023] Fig. 7 is a perspective view of the panel shown in Fig. 6 together with a backing plate and a heat source applied to the panel.

[0024] Fig. 8 is a table of 60-minute test results for the panel shown in Fig. 7.

[0025] Fig. 9 is a graph of the 60-minute test results for the panel shown in Fig. 7.

[0026] Fig. 10 is a perspective view of a third embodiment of a fire retardant panel.

[0027] Fig. 11 is a sectional view of the embodiment shown in Fig. 10, taken generally on line 11-11 of Fig. 10.

[0028] Figs. 12a-f is a table of ASTM E119 3-hour test results for the panel shown in Fig. 10.

[0029] Fig. 13 is a graph of ASTM E119 3-hour test results for the panel shown in Fig. 10.

[0030] Fig. 14 is a perspective view of the mold used in the process by which the fire resistant panel shown in Figs. 1 and 6 is made.

[0031] Fig. 15 is a perspective view of the mold used in the process by which the fire resistant panel shown in Fig. 10 is made.

Description of the Preferred Embodiments

[0032] At the outset, it should be clearly understood that like reference numerals are intended to identify the same structural elements, portions or surfaces consistently throughout the several drawing figures, as such elements, portions or surfaces may be further described or explained by the entire written specification, of which this detailed description is an integral part. Unless otherwise indicated, the drawings are intended to be read (e.g., cross-

hatching, arrangement of parts, proportion, degree, etc.) together with the specification, and are to be considered a portion of the entire written description of this invention. As used in the following description, the terms "horizontal", "vertical", "left", "right", "up" and "down", as well as adjectival and adverbial derivatives thereof (e.g., "horizontally", "rightwardly", "upwardly", etc.), simply refer to the orientation of the illustrated structure as the particular drawing figure faces the reader. Similarly, the terms "inwardly" and "outwardly" generally refer to the orientation of a surface relative to its axis of elongation, or axis of rotation, as appropriate.

[0033] Referring now to the drawings, and, more particularly, to Fig. 1 thereof, the present invention provides a layered composite panel thermal management system, the preferred embodiment of which is generally indicated at 16. As shown in Fig. 1, panel 16 generally comprises a resin layer 19 laminated between two protective layers 18 and 20, respectively.

[0034] In this first preferred embodiment, fire retardant panel 16 has a total thickness of 2 1/4 inches. Protective layer 18 is 5/8 inch thick and made of gypsum. It is contemplated, however, that both the material used and thickness of layer 18 may vary depending on the application. For example, protective layer 18 may be formed of other materials such as ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool or intumescent materials. Although protective layer 18 in this embodiment is a thermal barrier material, alternatively, layer 18 may be a coating. As shown in Fig. 3, protective layer 18 is adapted to be placed between the anticipated heat source 21 and resin layer 19. It has been found that the thermal properties of the core resin layer are improved with the use of this protective outside layer.

[0035] Resin layer 19 is a phenolic resin composition. In the preferred embodiment, resin layer 19 is made with water, phenolic resin, surfactant, boric acid, a lightweight expandable filler, and a catalyst. Resin layer 19 is 1 1/8 inches thick. The thickness of layer 19, however, may vary depending on the application.

[0036] Protective layer 20 is adapted to be the furthest layer from heat source 21. Protective layer 20 therefore serves as the final barrier layer between heat source 21 and the items panel 16 means to protect. The exterior face of protective layer 20, which is on the side opposite heat source 21 is referred to as the cold face of panel 16. The cold face is the outer surface of panel 16 that is the greatest distance from heat source 21, and closest to the protected items. Protective layer 20 is 1/2 inch thick and made of foam. However, it is contemplated that both the material and thickness of layer 20 may vary depending on the

application. For example, protective layer 20 may be formed of other materials such as gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, phenolic resin, mineral wool or intumescent material.

[0037] Testing was performed to demonstrate the efficacy of panel 16. As shown in Fig. 3, panel 16 was exposed to a 1400 degree Fahrenheit heat source 21. Protective layer 18 faced heat source 21, while protective layer 20 was furthest from heat source 21. The ambient starting temperature was 75F. Heat source 21 was applied directly to panel 16 for 60 minutes. Temperature readings were taken at intervals of 1 minute at the cold face of the test panel.

[0038] Under these conditions, protective layer 18 reached 1416F on the hot face. The highest temperature on the cold face of protective layer 20, or the side furthest from heat source 21, only reached 81F. Fig 4 is a tabular display of the 60-minute test results for the panel shown in Fig. 2. Fig. 5 displays the results graphically.

[0039] Fig. 6 shows a second embodiment 26. Panel 26 also has three layers 15, 16, and 17. Panel 26 has a total thickness of 62mm and a weight of 24 pounds per cubic foot. As in the first embodiment, protective layer 15 is adapted to be placed between anticipated heat source 21, and inner resin layer 16. Protective layer 15 is 25mm thick and made of ceramic board. It is contemplated, however, that both material and thickness of layer 15 may vary depending on the application. For example, protective layer 15 may be formed of other materials such as gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, phenolic resin, mineral wool or intumescent material.

[0040] Resin layer 16 is a phenolic resin composition. Again, resin layer 16 is made with water, phenolic resin, surfactant, boric acid, a lightweight expandable filler, and a catalyst. Resin layer 16 is 25 mm thick, although it is contemplated that thickness may vary depending on the application.

[0041] Protective layer 17 is 12 mm thick and made of phenolic foam. Protective layer 17, however, may be formed of other materials such as ceramic fiber, basalt, fiberglass, carbon fiber, phenolic resin, mineral wool or intumescent material.

[0042] Testing was performed to demonstrate the efficacy of panel 26. To simulate the performance of the fire retardant panel in a fireproof safe or cabinet, the panel was covered with a 1.6mm stainless steel plate 25, as shown in Fig. 7. Panel 26 was exposed to a 1700F heat source 21. Protective layer 15 faced heat source 21, while stainless steel plate 25 was furthest from heat source 21. The ambient starting temperature was 75F. As seen in Fig. 7,

the heat source 21 was a torch applied directly to panel 26 shown in Fig. 6. Heat source 21 was applied for 60 minutes. The ambient starting temperature was 84F. Temperature readings were taken at intervals of 1 minute on the steel plate cold face with thermal couples.

[0043] Under these conditions, panel 26 withstood temperatures of up to 1720F during a 60-minute test and the highest temperature on the cold face of steel plate 25 only reached 104F. Fig 8 is a tabular display of the 60-minute test results for panel 26. Fig. 9 displays the results graphically.

[0044] Following the 60-minute test, very little of resin layer 16 was consumed during the 60-minute test, and the chemical bonds between layers 15 and 16, and layers 16 and 17 were still intact. It is believed that the addition of both protective layers 15 and 17 increased the thermal barrier and protective value of the panel as it provided a physical layer of protection to the resin core. The use of layer 15 provided insulating value that increased the efficacy of the panel.

[0045] Panels 16 and 26 are both formed by the same method. First, resin layer 16/19 is created by mixing wet components and dry components at room temperature until the dry components are completely moistened. Wet components include water, a surfactant and a phenolic resin. In a preferred embodiment, the phenolic resin is a low viscosity unmodified liquid phenolic resole resin. The Cellobond 2027L resin manufactured by Borden Chemical, Inc. of South Glamorgan, UK, may be used. Dry components include boric acid and a lightweight expandable or preexpanded filler. In a preferred embodiment the expandable filler is Expancel (need more detail as there are several different products in the Expancel line). A catalyst is then added to the moistened mixture. In a preferred embodiment, the catalyst is Phencat 10 or Phencat 15, both manufactured by Borden Chemical, Inc. of South Glamorgan, UK.

[0046] Next, as seen in Fig. 14, mold 23 is provided. Protective layer 15/18 is applied on one side of the interior cavity of mold 23, and protective layer 17/20 is applied on the opposite side of the interior cavity of mold 23. Although this embodiment includes two protective layers 15/18, 17/20, it is contemplated that the mixture may be molded with just one protective layer, or with more than two protective layers as an alternative. Thus, resulting mold 23 is lined with two protective layers, 15/18, 17/20, with a space provided between the two protective layers. The activated resin-based mixture is then poured into mold 23, filling the space between protective layers 15/18 and 17/20. The resin-based mixture must be poured while still in liquid form, before solidification.

[0047] Mold 23 is then covered and clamped. The resin-based mixture will chemically expand for 6-8 minutes, and the resultant gas is discharged through vents 24 in mold 23. The expansion time will vary with the temperature of the reagents. Panel 16 or 26 is then allowed to cure at room temperature, although it is contemplated that an oven may be used to accelerate the curing process. Resultant panel 16/26 is a layered composite of two protective layers 15/18, 17/20 and inner resin layer 16/19 sandwiched therebetween. The layers are chemically bonded together so use of an adhesive is not necessary.

[0048] Alternatively, for some applications, the phenolic resin-based mixture could be poured into an unlined mold 23 so the resultant hardened resin layer 16/19 is not flanked by protective layers 15/18 and 17/20. This molded resin layer 16/19 can then be coated using a brush or spray with a fire resistant material to create the layered fire retardant barrier panel. The coating may be gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool or intumescent materials. With this method, resin layer 19 will then have a thin outer coating as a protective layer.

[0049] Figs. 10-13 show a third embodiment 36. Panel 36 is formed from just two laminated layers 28 and 29. Protective layer 28 is adapted to be placed between the anticipated heat source 21, and resin layer 29. In this third embodiment, protective layer 28 is formed of a 1 inch thick ceramic board. It is, however, contemplated that both material and thickness of layer 28 may vary depending on the application. For example, protective layer 28 may be formed of other materials such as gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool or intumescent materials.

[0050] Like resin layer 19 in the other embodiments, resin layer 29 is a phenolic resin composition. In this embodiment, resin layer 29 is made with water, phenolic resin, surfactant, boric acid, a lightweight expandable filler, and a catalyst. Resin layer 29 is 1 1/2 inches thick, although the thickness of layer 29 may vary. Since panel 36 does not have a second protective layer like the first two embodiments, the surface of resin layer 29 is adapted to be the cold face. Resin layer 29 therefore serves as the final barrier layer between the heat source 21 and the items panel 36 means to protect.

[0051] An ASTM E119 3-hour test was performed to demonstrate the efficacy of panel 36. Panel 36 was exposed to heat source 21. Protective layer 28 faced heat source 21, while resin layer 29 was furthest from the heat source 21. The ambient starting temperature was 83F. Heat source 21 was applied to protective layer 29 of panel 26 for three (3) hours.

[0052] Temperature was measured at intervals of 1 minute in heat source 21, at the interface of protective layer 28 and resin layer 29, 1/2 inch into resin layer 29 behind the interface of protective layer 28 and resin layer 29, and on two locations on the cold face of resin layer 29. Panel 36 withstood up to 1925F for 3 hours with no signs of degradation. Figs. 12a-f are a tabular display of the 3-hour test results for this embodiment. Fig. 13 displays the results graphically. The ceramic of protective layer 28 separated and the heat radiates from inside. This separation demonstrates the importance of an effective chemical bond between the layers of a fire retardant panel. The cold face of resin layer 29 was not heat damaged during testing, with white marks resulting from moisture. The chemical bond between protective layer 28 and resin layer 29 withstood the 3-hour test. Very little of resin layer 29 was consumed during the 3-hour test.

[0053] Panel 36 is formed in a series of steps. First, resin layer 29 is created by mixing wet components and dry components at room temperature until the dry components are completely moistened. Wet components include water, a surfactant and a phenolic resin. In a preferred embodiment, the phenolic resin is a low viscosity unmodified liquid phenolic resole resin. The Cellobond 2027L resin manufactured by Borden Chemical, Inc. of South Glamorgan, UK, may be used. Dry components include boric acid and a lightweight expandable filler. In a preferred embodiment the expandable filler is Expancel, Grade 551 WE 40 D 36. A catalyst is then added to the moistened mixture. In a preferred embodiment, the catalyst is Phencat 10 or Phencat 15, both manufactured by Borden Chemical, Inc. of South Glamorgan, UK.

[0054] Next, as seen in Fig.15, mold 23 is provided. Protective layer 28 is applied on one side of the interior cavity of mold 23. Although this embodiment includes one protective layer 28, it is contemplated that the mixture may be molded with more than one protective layer as an alternative. Thus, resulting mold 23 is lined with one protective layer, 28, with a space provided between protective layer 28 and the opposite face of the interior cavity of the mold. The activated resin-based mixture is then poured into mold 23, filling the space between protective layer 28 and the side of mold 23. The resin-based mixture must be poured while still in liquid form, before solidification.

[0055] Mold 23 is then covered and clamped. The resin-based mixture will chemically expand for 6-8 minutes, and the resultant gas is discharged through vents 24 in mold 23. The expansion time will vary with the temperature of the reagents. Panel 36 is then allowed to cure at room temperature, although it is contemplated that an oven may be used to accelerate

the curing process. Resultant panel 36 is a layered composite of protective layer 28 and resin layer 29 chemically bonded thereto. The layers are chemically bonded together so use of an adhesive is not necessary.

[0056] Alternatively, for some applications, the phenolic resin-based mixture could be poured into an unlined mold 23 so the resultant resin layer 29 is not bonded to protective layer 28 during molding. This molded resin layer 29 can then be coated using a brush or spray with a fire resistant material to create the layered fire retardant barrier panel 36. The coating may be gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool, intumescent materials or some other protective layer that is applied. With this method, resin layer 29 will then have a thin outer coating as protective layer 28.

[0057] The present invention contemplates that many changes and modifications may be made. Therefore, while the presently-preferred forms of the fire resistant barrier panel have been shown and described, and a number of alternatives discussed, persons skilled in this art will readily appreciate that various additional changes and modifications may be made without departing from the spirit of the invention, as defined and differentiated by the following claims.

Claims

What is claimed is:

1. A fire retardant barrier panel comprising:

a first protective layer of a first material;

a fire-resistant phenolic-based resin layer bonded to said first protective layer; and

a second protective layer bonded to said resin layer such that said resin layer is between said first and second protective layers.

2. The panel set forth in claim 1, wherein said first material is selected from a group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials.

3. The panel set forth in claim 1, wherein said resin layer is a phenol or phenolic resin.

4. The panel set forth in claim 1, wherein said second protective layer is selected from a group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials.

5. A method of forming a fire retardant barrier panel comprising the steps of:

providing water, a resin, a surfactant, boric acid, and an expandable filler;

mixing said water, resin, surfactant, boric acid and expandable filler;

adding a catalyst;

providing a mold;

pouring said mixture of water, resin, surfactant, boric acid and expandable filler and said catalyst into said mold; and

allowing said mixture to harden.

6. The method set forth in claim 5, wherein said mold is lined on at least one side with a first protective material.

7. The method set forth in claim 6, wherein said first protective material is selected from a group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials.

8. The method set forth in claim 5, and further comprising the step of coating at least one surface of said hardened material with a first protective layer selected from a group consisting of gypsum, ceramic fiber, phenolic foam, basalt, fiberglass, carbon fiber, mineral wool and intumescent materials.

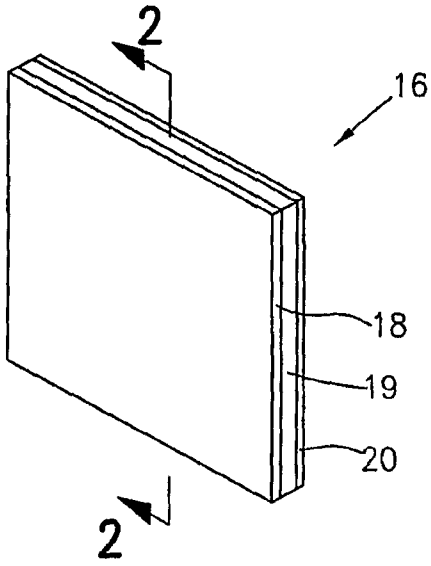

FIG. 1

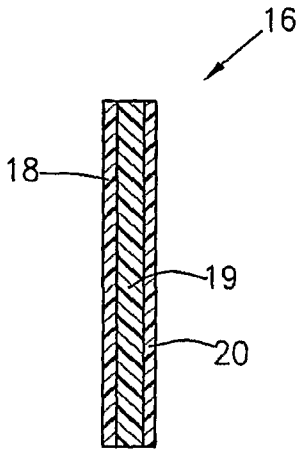

FIG. 2

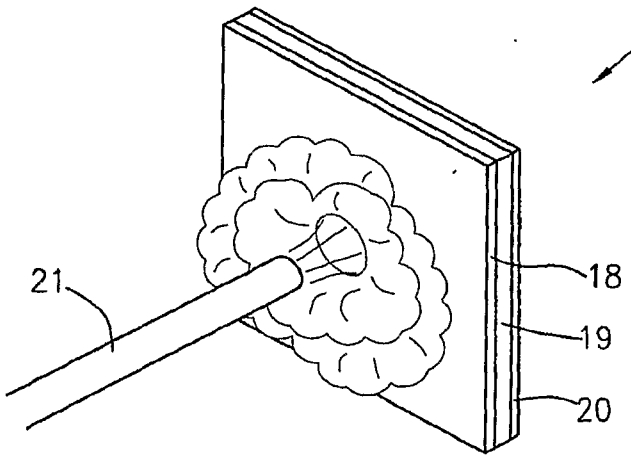

FIG. 3

Test Results

Time	Fire-face	PYRO-FOAM	GYM-Pyro	BACK-FACE
1	432	77	73	76
2	830	77	73	76
3	1378	77	75	76
4	1370	77	77	76
5	1320	77	82	76
6	1350	77	85	76
7	1362	77	89	76
8	1376	77	97	76
9	1380	77	100	76
10	1394	77	107	76
11	1405	77	111	76
12	1414	79	120	77
13	1349	79	124	77
14	1318	80	126	77
15	1315	81	133	76
16	1317	82	138	77
17	1347	84	145	77
18	1348	84	147	77
19	1354	86	156	77
20	1360	87	162	77
21	1358	91	178	77
22	1360	92	186	77
23	1355	96	199	77
24	1357	98	205	77
25	1351	105	212	77
26	1346	111	213	78
27	1349	119	215	77
28	1360	127	216	78
29	1358	135	216	78
30	1352	147	217	78
31	1389	154	218	78
32	1397	162	218	78

Test Results

Time	Fire-face	PYRO-FOAM	GYM-Pyro	BACK-FACE
33	1403	167	218	78
34	1397	173	218	78
35	1405	177	219	78
36	1409	183	220	78
37	1409	185	221	78
38	1402	192	225	79
39	1409	193	227	78
40	1406	197	232	79
41	1403	199	235	78
42	1406	202	239	79
43	1410	202	240	79
44	1413	204	245	79
45	1409	204	248	79
46	1424	206	253	79
47	1397	206	254	79
48	1389	207	259	79
49	1385	207	262	79
50	1387	206	265	79
51	1388	207	272	79
52	1390	207	275	80
53	1390	207	280	80
54	1390	207	283	80
55	1401	208	288	80
56	1394	208	292	80
57	1400	208	296	80
58	1408	208	298	80
59	1407	209	302	80
60	1407	209	303	80
61	1409	209	306	80
62	1404	209	310	80
63	1412	210	318	81
64	1416	210	321	81

FIG. 4

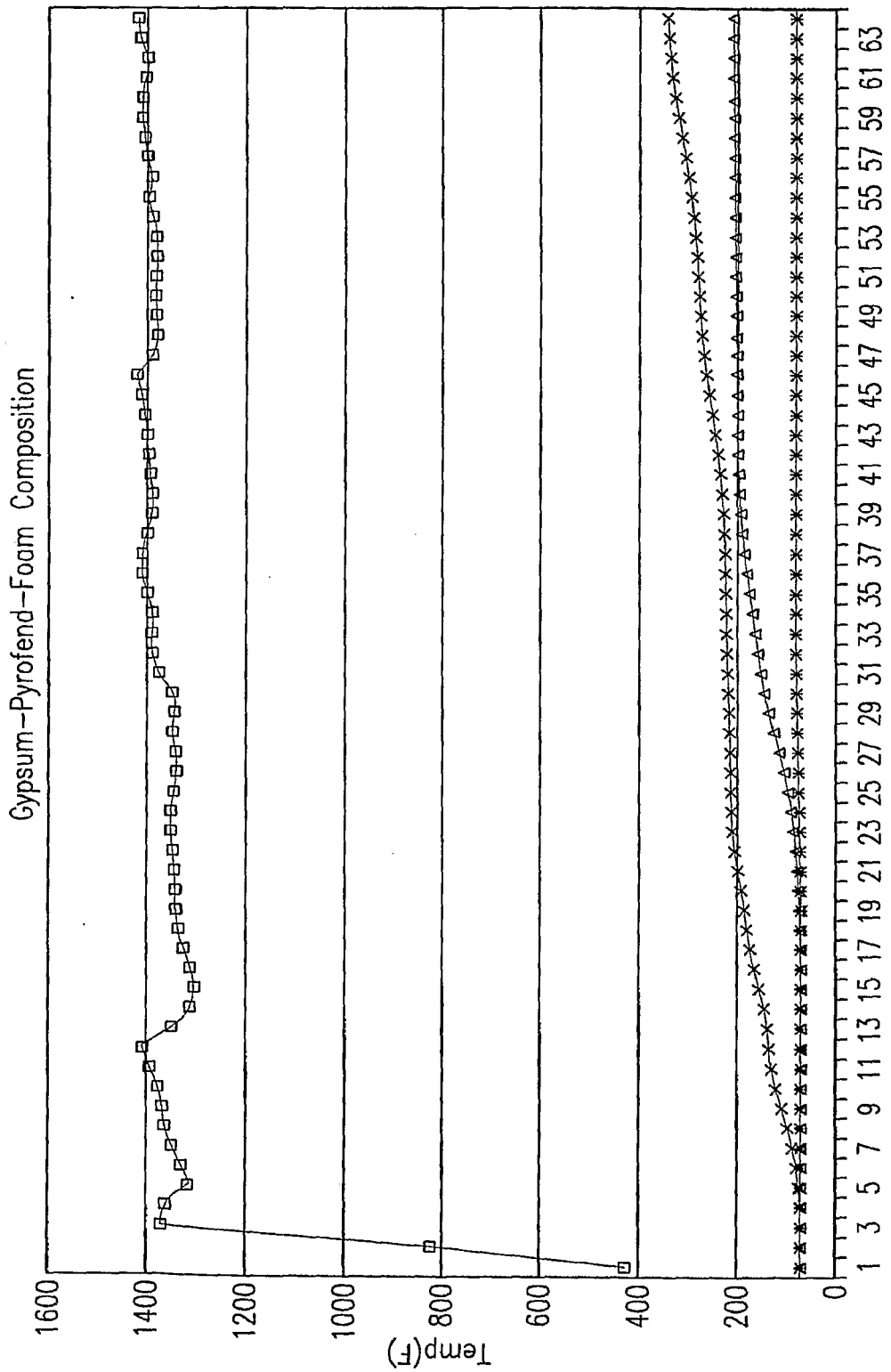
Gypsum-Pyrofend-Foam Composition
Temp(F)
1600
1400
1200
1000
800
600
400
200
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63
Time
Fireface
Pyro-FOAM
GYM_Pyro
BACKFACE

FIG. 5

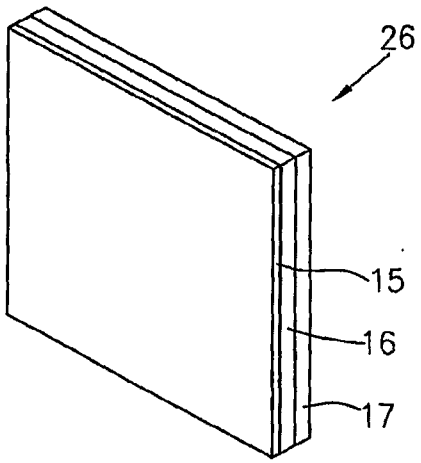

FIG. 6

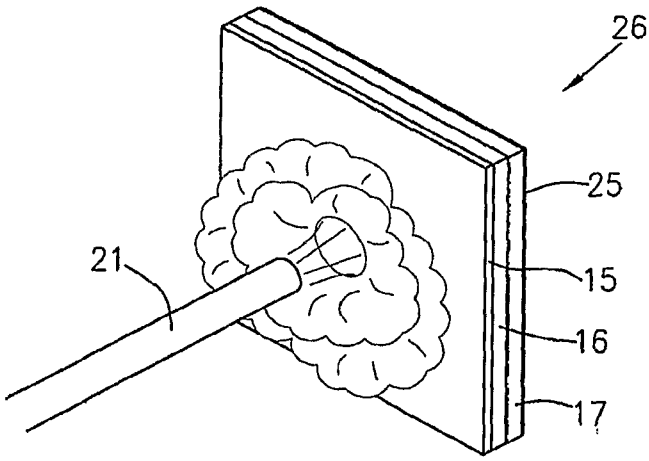

FIG. 7

Test Results

Time	Fire Face	Fiber/ Pyro	Pyro/ Foam	Cold Face
1	81	76	83	86
2	635	76	82	86
3	1276	80	82	86
4	1376	80	82	86
5	1426	82	82	86
6	1481	84	82	87
7	1525	87	82	87
8	1541	92	82	87
9	1559	96	82	87
10	1566	102	82	87
11	1573	110	82	87
12	1577	116	82	87
13	1581	123	83	88
14	1593	130	83	87
15	1600	139	83	88
16	1609	146	84	88
17	1618	155	84	88
18	1624	166	85	88
19	1629	176	85	89
20	1631	190	87	89
21	1635	196	87	89
22	1640	199	89	89
23	1643	205	90	89
24	1643	207	89	89
25	1644	211	89	89
26	1645	216	90	89
27	1647	221	90	89
28	1647	225	92	89
29	1647	229	92	90
30	1649	234	93	89
31	1649	240	94	90
32	1652	245	96	90
33	1653	250	96	90
34	1693	255	98	90

Test Results

Time	Fire Face	Fiber/ Pyro	Pyro/ Foam	Cold Face
35	1694	261	99	90
36	1699	264	103	90
37	1700	267	103	91
38	1702	269	106	90
39	1699	273	107	91
40	1703	276	111	91
41	1701	276	112	92
42	1706	284	115	91
43	1705	288	117	91
44	1706	291	119	91
45	1706	296	120	92
46	1706	296	120	92
47	1706	296	120	92
48	1711	305	128	94
49	1711	306	136	94
50	1711	301	138	95
51	1711	301	141	95
52	1710	300	142	96
53	1709	303	144	96
54	1708	306	146	96
55	1711	307	147	97
56	1713	309	149	98
57	1712	310	151	98
58	1710	312	152	99
59	1709	313	154	100
60	1710	315	155	100
61	1708	316	157	100
62	1710	319	158	101
63	1712	319	159	101
64	1712	321	160	102
65	1712	321	161	102
66	1711	324	162	102
67	1713	325	163	103
68	1714	327	164	104

FIG. 8

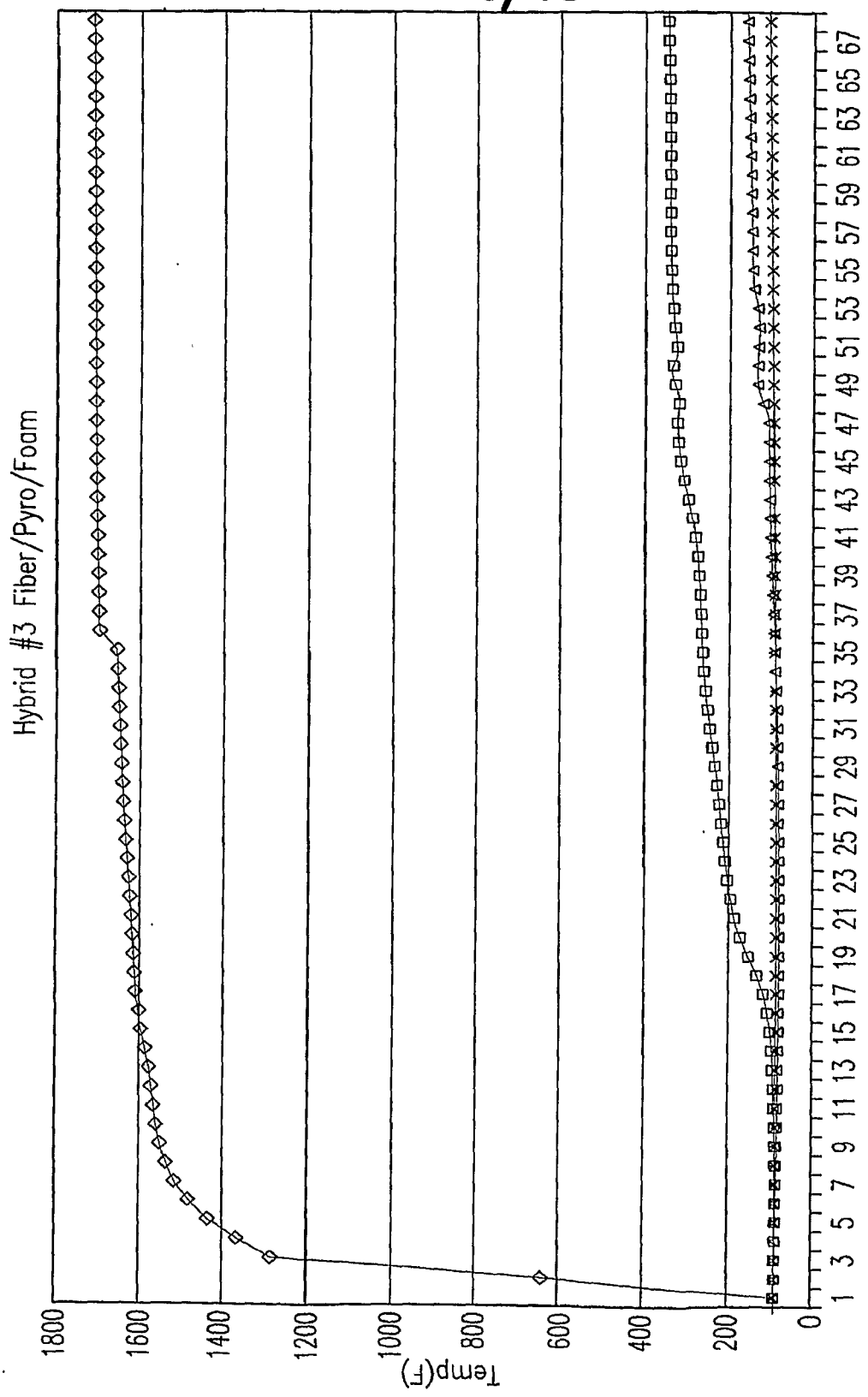
Hybrid #3 Fiber/Pyro/Foam
Temp(F)
1800
1600
1400
1200
1000
800
600
400
200
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67
Time (minutes)
Fireface
Fiber/Pyro
Pyro/Foam
Cold Face

FIG. 9

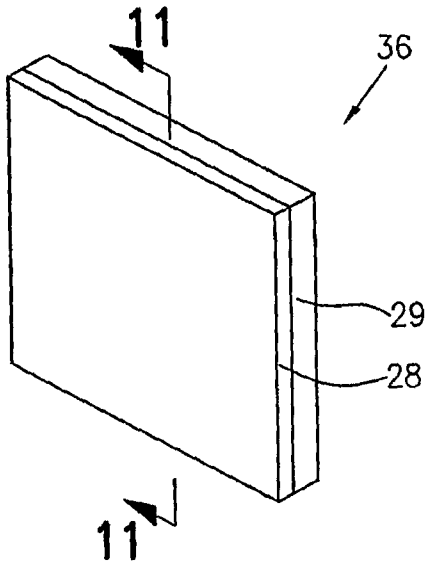

FIG. 10

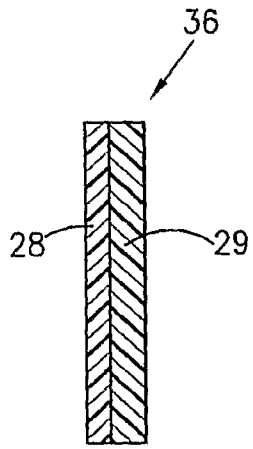

FIG. 11

FtNum	TestDate	TestTime	Mins	E119	tc97	tc98	tc99	tc100	'Furnace'	tc101	tc102	'2 inch depth'	tc103	tc104	'1 inch depth'
050168	6/23/2005	6:13:10	0	74	99	99	98	100	99	82	82	82	83	83	83
050168	6/23/2005	6:14:10	1	261	269	254	259	277	265	83	83	83	83	83	83
050168	6/23/2005	6:15:10	2	447	569	510	529	545	538	84	82	83	83	83	83
050168	6/23/2005	6:16:10	3	633	722	656	674	678	683	92	83	88	83	83	83
050168	6/23/2005	6:17:10	4	820	916	837	854	853	865	114	83	98	83	83	83
050168	6/23/2005	6:18:10	5	1002	1003	938	952	947	960	135	83	109	83	83	83
050168	6/23/2005	6:19:10	6	1062	1086	1016	1035	1028	1041	147	83	115	83	83	83
050168	6/23/2005	6:20:10	7	1122	1127	1073	1091	1086	1094	154	83	119	83	83	83
050168	6/23/2005	6:21:10	8	1182	1171	1115	1134	1127	1137	166	83	125	83	83	83
050168	6/23/2005	6:22:10	9	1242	1208	1153	1170	1163	1173	199	84	142	83	83	83
050168	6/23/2005	6:23:10	10	1301	1263	1199	1225	1221	1227	236	85	161	84	83	83
050168	6/23/2005	6:24:10	11	1321	1357	1293	1328	1318	1324	273	86	179	84	83	83
050168	6/23/2005	6:25:10	12	1340	1376	1320	1348	1335	1345	313	87	200	84	84	84
050168	6/23/2005	6:26:10	13	1360	1384	1335	1359	1350	1357	355	89	222	84	84	84
050168	6/23/2005	6:27:10	14	1380	1403	1357	1379	1370	1377	394	91	242	85	84	84
050168	6/23/2005	6:28:10	15	1399	1413	1364	1384	1374	1384	430	93	262	85	85	85
050168	6/23/2005	6:29:10	16	1412	1421	1379	1398	1390	1397	461	95	278	86	85	85
050168	6/23/2005	6:30:10	17	1425	1441	1398	1417	1407	1416	487	98	293	87	86	86
050168	6/23/2005	6:31:10	18	1437	1462	1415	1433	1423	1433	510	101	306	87	86	87
050168	6/23/2005	6:32:10	19	1450	1476	1431	1449	1438	1448	534	105	319	88	87	87
050168	6/23/2005	6:33:10	20	1462	1485	1446	1462	1454	1462	557	109	333	88	88	88
050168	6/23/2005	6:34:10	21	1472	1498	1461	1478	1468	1476	580	113	346	89	88	89
050168	6/23/2005	6:35:10	22	1482	1514	1478	1492	1482	1491	600	119	360	90	89	90
050168	6/23/2005	6:36:10	23	1491	1521	1482	1496	1486	1496	618	126	372	91	90	90
050168	6/23/2005	6:37:10	24	1501	1524	1487	1501	1492	1501	631	134	382	92	91	92
050168	6/23/2005	6:38:10	25	1510	1527	1492	1504	1495	1504	642	143	392	94	93	94
050168	6/23/2005	6:39:10	26	1518	1517	1484	1495	1487	1496	649	153	401	96	94	95
050168	6/23/2005	6:40:10	27	1526	1519	1484	1496	1488	1497	655	162	408	98	96	97
050168	6/23/2005	6:41:10	28	1534	1523	1486	1500	1493	1500	659	171	415	100	98	99
050168	6/23/2005	6:42:10	29	1542	1527	1493	1504	1497	1505	663	179	421	103	100	102
050168	6/23/2005	6:43:10	30	1550	1531	1495	1508	1501	1509	667	186	427	106	103	104
050168	6/23/2005	6:44:10	31	1557	1539	1501	1514	1507	1515	672	193	432	109	107	108
050168	6/23/2005	6:45:10	32	1564	1544	1504	1519	1511	1519	677	199	438	113	110	112
050168	6/23/2005	6:46:10	33	1571	1551	1513	1526	1518	1527	683	204	443	116	114	115

FIG. 12a

FtNum	TestDate	TestTime	Mins	E119	tc97	tc98	tc99	tc100	'Furnace'	tc101	tc102	'2 inch depth'	tc103	tc104	'1 inch depth'
050168	6/23/2005	6:47:10	34	1577	1553	1517	1531	1524	1531	689	208	448	120	119	119
050168	6/23/2005	6:48:10	35	1584	1561	1525	1537	1530	1538	695	211	453	124	123	124
050168	6/23/2005	6:49:10	36	1590	1562	1528	1540	1533	1541	701	214	457	129	128	129
050168	6/23/2005	6:50:10	37	1596	1571	1534	1547	1541	1548	707	215	461	134	134	134
050168	6/23/2005	6:51:10	38	1602	1575	1541	1553	1546	1554	713	217	465	139	139	139
050168	6/23/2005	6:52:10	39	1607	1582	1545	1558	1551	1559	718	217	468	144	145	144
050168	6/23/2005	6:53:10	40	1613	1580	1552	1564	1557	1563	723	218	470	147	151	149
050168	6/23/2005	6:54:10	41	1618	1611	1575	1588	1583	1589	728	218	473	153	156	155
050168	6/23/2005	6:55:10	42	1623	1643	1612	1627	1616	1625	735	218	476	156	161	159
050168	6/23/2005	6:56:10	43	1628	1663	1632	1644	1633	1643	745	218	482	162	166	164
050168	6/23/2005	6:57:10	44	1633	1658	1628	1637	1628	1638	756	219	488	166	171	168
050168	6/23/2005	6:58:10	45	1638	1658	1628	1641	1631	1640	765	221	493	170	175	172
050168	6/23/2005	6:59:10	46	1643	1664	1635	1645	1636	1645	772	222	497	179	178	179
050168	6/23/2005	7:00:10	47	1647	1672	1639	1651	1642	1651	779	223	501	177	181	179
050168	6/23/2005	7:01:10	48	1652	1673	1643	1657	1646	1655	785	225	505	181	184	182
050168	6/23/2005	7:02:10	49	1657	1679	1649	1662	1652	1660	791	226	508	180	186	183
050168	6/23/2005	7:03:10	50	1661	1685	1655	1667	1658	1666	797	226	512	181	188	185
050168	6/23/2005	7:04:10	51	1665	1691	1660	1674	1663	1672	805	228	516	185	190	188
050168	6/23/2005	7:05:10	52	1669	1693	1669	1680	1669	1678	813	229	521	186	191	188
050168	6/23/2005	7:06:10	53	1673	1700	1671	1684	1674	1682	822	231	526	187	192	189
050168	6/23/2005	7:07:10	54	1677	1708	1674	1688	1678	1687	830	233	532	189	193	191
050168	6/23/2005	7:08:10	55	1681	1711	1680	1692	1681	1691	839	234	537	188	194	191
050168	6/23/2005	7:09:10	56	1685	1716	1683	1696	1686	1695	848	236	542	189	195	192
050168	6/23/2005	7:10:10	57	1689	1718	1687	1701	1690	1699	859	238	548	194	196	195
050168	6/23/2005	7:11:10	58	1693	1721	1688	1704	1694	1702	869	239	554	193	196	195
050168	6/23/2005	7:12:10	59	1696	1724	1697	1710	1699	1708	878	241	559	192	197	195
050168	6/23/2005	7:13:10	60	1700	1732	1699	1713	1703	1712	886	243	564	193	197	195
050168	6/23/2005	7:14:10	61	1704	1734	1703	1718	1706	1715	895	244	569	194	198	196
050168	6/23/2005	7:15:10	62	1707	1736	1705	1718	1707	1717	902	247	574	195	198	197
050168	6/23/2005	7:16:10	63	1711	1724	1694	1705	1696	1704	909	248	578	195	198	197
050168	6/23/2005	7:17:10	64	1715	1721	1691	1702	1694	1702	914	250	582	193	199	196
050168	6/23/2005	7:18:10	65	1718	1730	1699	1714	1703	1711	919	252	585	195	199	197
050168	6/23/2005	7:19:10	66	1722	1769	1734	1755	1743	1750	926	254	590	193	199	196
050168	6/23/2005	7:20:10	67	1725	1759	1730	1743	1731	1740	937	257	597	193	199	196
050168	6/23/2005	7:21:10	68	1728	1754	1728	1739	1729	1738	947	260	603	192	200	196

FIG. 12b

FtNum	TestDate	TestTime	Mins	E119	tc97	tc98	tc99	tc100	'Furnace'	tc101	tc102	'2 inch depth'	tc103	tc104	'1 inch depth'
050168	6/23/2005	7:22:10	69	1732	1754	1727	1739	1729	1737	954	262	608	193	200	196
050168	6/23/2005	7:23:10	70	1735	1753	1729	1741	1730	1738	962	266	614	192	200	196
050168	6/23/2005	7:24:10	71	1738	1755	1730	1742	1731	1740	968	269	619	195	200	197
050168	6/23/2005	7:25:10	72	1741	1757	1731	1743	1732	1741	975	273	624	193	200	197
050168	6/23/2005	7:26:10	73	1744	1759	1733	1746	1735	1743	981	277	629	192	200	196
050168	6/23/2005	7:27:10	74	1747	1762	1733	1747	1736	1744	988	282	635	194	201	198
050168	6/23/2005	7:28:10	75	1750	1762	1736	1750	1739	1747	995	286	641	194	201	197
050168	6/23/2005	7:29:10	76	1753	1766	1740	1752	1741	1750	1001	291	646	193	201	197
050168	6/23/2005	7:30:10	77	1756	1768	1741	1754	1743	1752	1009	296	653	194	201	197
050168	6/23/2005	7:31:10	78	1759	1770	1744	1756	1745	1754	1017	300	659	193	201	197
050168	6/23/2005	7:32:10	79	1762	1774	1745	1759	1748	1756	1025	305	665	194	202	198
050168	6/23/2005	7:33:10	80	1765	1775	1750	1762	1750	1759	1034	313	673	194	202	198
050168	6/23/2005	7:34:10	81	1768	1777	1749	1763	1752	1760	1042	322	682	194	202	198
050168	6/23/2005	7:35:10	82	1771	1780	1753	1765	1755	1763	1051	331	691	194	202	198
050168	6/23/2005	7:36:10	83	1774	1780	1753	1766	1755	1764	1060	339	699	195	202	199
050168	6/23/2005	7:37:10	84	1776	1785	1755	1768	1757	1766	1071	347	709	195	202	199
050168	6/23/2005	7:38:10	85	1779	1785	1757	1770	1760	1768	1081	358	720	195	202	198
050168	6/23/2005	7:39:10	86	1782	1784	1760	1772	1761	1769	1093	368	731	195	202	199
050168	6/23/2005	7:40:10	87	1784	1790	1760	1774	1763	1772	1105	377	741	195	202	199
050168	6/23/2005	7:41:10	88	1787	1790	1763	1775	1765	1773	1117	387	752	194	202	198
050168	6/23/2005	7:42:10	89	1790	1789	1764	1777	1766	1774	1130	396	763	195	202	199
050168	6/23/2005	7:43:10	90	1792	1799	1772	1786	1774	1783	1142	405	773	195	202	199
050168	6/23/2005	7:44:10	91	1795	1806	1776	1789	1778	1787	1155	413	784	198	202	200
050168	6/23/2005	7:45:10	92	1797	1808	1779	1793	1782	1791	1168	422	795	196	202	199
050168	6/23/2005	7:46:10	93	1799	1809	1783	1797	1785	1793	1182	430	806	195	202	198
050168	6/23/2005	7:47:10	94	1802	1813	1788	1800	1788	1797	1195	439	817	195	202	199
050168	6/23/2005	7:48:10	95	1804	1815	1789	1802	1790	1799	1208	447	827	196	202	199
050168	6/23/2005	7:49:10	96	1806	1816	1791	1805	1792	1801	1221	455	838	197	202	200
050168	6/23/2005	7:50:10	97	1809	1821	1796	1808	1796	1805	1234	463	849	196	202	199
050168	6/23/2005	7:51:10	98	1811	1821	1795	1809	1797	1805	1246	471	859	197	202	199
050168	6/23/2005	7:52:10	99	1813	1822	1795	1810	1798	1806	1257	478	868	199	202	200
050168	6/23/2005	7:53:10	100	1815	1826	1799	1813	1802	1810	1268	487	877	198	202	200
050168	6/23/2005	7:54:10	101	1817	1828	1802	1814	1804	1812	1280	495	888	200	203	201
050168	6/23/2005	7:55:10	102	1820	1828	1805	1818	1806	1814	1292	503	898	199	203	201
050168	6/23/2005	7:56:10	103	1822	1832	1803	1817	1805	1814	1303	511	907	199	203	201

FIG. 12c

FtNum	TestDate	TestTime	Mins	E119	tc97	tc98	tc99	tc100	'Furnace'	tc101	tc102	'2 inch depth'	tc103	tc104	'1 inch depth'
050168	6/23/2005	7:57:10	104	1824	1830	1805	1820	1807	1816	1313	519	916	200	204	202
050168	6/23/2005	7:58:10	105	1826	1832	1805	1820	1808	1816	1321	527	924	202	204	203
050168	6/23/2005	7:59:10	106	1828	1834	1807	1822	1811	1818	1329	535	932	199	204	202
050168	6/23/2005	8:00:10	107	1830	1836	1811	1826	1812	1821	1336	543	940	199	205	202
050168	6/23/2005	8:01:10	108	1832	1839	1813	1827	1815	1823	1343	552	947	202	205	203
050168	6/23/2005	8:02:10	109	1833	1836	1815	1828	1815	1823	1349	559	954	200	205	203
050168	6/23/2005	8:03:10	110	1835	1840	1814	1828	1816	1825	1352	566	959	200	206	203
050168	6/23/2005	8:04:10	111	1837	1844	1817	1830	1819	1827	1356	573	965	201	206	203
050168	6/23/2005	8:05:10	112	1838	1843	1817	1830	1819	1827	1360	580	970	203	203	203
050168	6/23/2005	8:06:10	113	1840	1843	1817	1832	1821	1828	1365	588	976	202	202	202
050168	6/23/2005	8:07:10	114	1842	1848	1822	1836	1823	1832	1369	595	982	203	204	203
050168	6/23/2005	8:08:10	115	1843	1848	1823	1837	1825	1833	1372	601	987	204	208	206
050168	6/23/2005	8:09:10	116	1844	1848	1824	1837	1825	1833	1374	607	991	204	211	207
050168	6/23/2005	8:10:10	117	1846	1850	1825	1839	1826	1835	1377	614	995	205	212	208
050168	6/23/2005	8:11:10	118	1847	1848	1825	1839	1826	1834	1379	619	999	205	213	209
050168	6/23/2005	8:12:10	119	1849	1850	1827	1840	1828	1836	1381	625	1003	206	214	210
050168	6/23/2005	8:13:10	120	1850	1849	1826	1840	1828	1836	1383	628	1005	206	215	210
050168	6/23/2005	8:14:10	121	1851	1853	1830	1842	1831	1839	1385	632	1009	206	216	211
050168	6/23/2005	8:15:10	122	1852	1853	1827	1842	1830	1838	1387	636	1011	207	217	212
050168	6/23/2005	8:16:10	123	1854	1858	1828	1843	1832	1840	1389	640	1015	208	218	213
050168	6/23/2005	8:17:10	124	1855	1856	1831	1845	1834	1842	1392	643	1018	209	219	214
050168	6/23/2005	8:18:10	125	1856	1859	1830	1846	1833	1842	1395	647	1021	209	220	215
050168	6/23/2005	8:19:10	126	1857	1859	1833	1847	1835	1844	1399	651	1025	210	222	216
050168	6/23/2005	8:20:10	127	1858	1858	1833	1847	1835	1843	1402	655	1029	211	223	217
050168	6/23/2005	8:21:10	128	1860	1864	1834	1848	1836	1846	1405	659	1032	212	224	218
050168	6/23/2005	8:22:10	129	1861	1857	1835	1849	1837	1844	1408	663	1036	213	225	219
050168	6/23/2005	8:23:10	130	1862	1862	1837	1851	1839	1847	1411	667	1039	213	226	220
050168	6/23/2005	8:24:10	131	1863	1864	1839	1851	1840	1848	1414	672	1043	214	227	221
050168	6/23/2005	8:25:10	132	1865	1860	1838	1852	1840	1848	1417	676	1047	215	229	222
050168	6/23/2005	8:26:10	133	1866	1859	1839	1852	1840	1848	1420	682	1051	217	231	224
050168	6/23/2005	8:27:10	134	1867	1863	1840	1854	1842	1850	1422	689	1056	218	232	225
050168	6/23/2005	8:28:10	135	1869	1865	1840	1854	1842	1850	1425	695	1060	219	233	226
050168	6/23/2005	8:29:10	136	1870	1864	1843	1855	1844	1851	1428	700	1064	220	234	227
050168	6/23/2005	8:30:10	137	1871	1866	1841	1855	1843	1851	1431	704	1067	222	236	229
050168	6/23/2005	8:31:10	138	1872	1868	1842	1856	1845	1853	1433	709	1071	224	238	231

FIG. 12d

FtNum	TestDate	TestTime	Mins	E119	tc97	tc98	tc99	tc100	'Furnace'	tc101	tc102	'2 inch depth'	tc103	tc104	'1 inch depth'
050168	6/23/2005	8:32:10	139	1874	1868	1844	1857	1845	1853	1435	713	1074	225	240	232
050168	6/23/2005	8:33:10	140	1875	1871	1846	1860	1848	1856	1437	717	1077	226	241	234
050168	6/23/2005	8:34:10	141	1876	1867	1845	1859	1847	1855	1440	720	1080	227	241	234
050168	6/23/2005	8:35:10	142	1878	1872	1847	1862	1849	1857	1443	724	1084	228	243	235
050168	6/23/2005	8:36:10	143	1879	1876	1852	1867	1855	1862	1445	728	1086	230	244	237
050168	6/23/2005	8:37:10	144	1880	1885	1862	1876	1863	1872	1448	732	1090	231	246	239
050168	6/23/2005	8:38:10	145	1882	1888	1866	1879	1866	1875	1453	736	1094	233	248	241
050168	6/23/2005	8:39:10	146	1883	1891	1869	1883	1870	1878	1457	739	1098	234	250	242
050168	6/23/2005	8:40:10	147	1884	1895	1871	1886	1873	1881	1462	743	1102	237	252	245
050168	6/23/2005	8:41:10	148	1885	1897	1874	1888	1875	1884	1464	747	1106	239	254	246
050168	6/23/2005	8:42:10	149	1887	1898	1876	1889	1877	1885	1469	751	1110	241	256	249
050168	6/23/2005	8:43:10	150	1888	1903	1877	1892	1879	1888	1472	755	1114	244	257	251
050168	6/23/2005	8:44:10	151	1889	1902	1878	1894	1880	1889	1475	759	1117	246	260	253
050168	6/23/2005	8:45:10	152	1890	1904	1882	1896	1883	1891	1479	764	1122	249	262	255
050168	6/23/2005	8:46:10	153	1892	1905	1884	1898	1884	1893	1482	768	1125	251	264	257
050168	6/23/2005	8:47:10	154	1893	1907	1885	1898	1886	1894	1485	772	1128	253	266	259
050168	6/23/2005	8:48:10	155	1894	1908	1884	1900	1886	1895	1487	776	1132	254	268	261
050168	6/23/2005	8:49:10	156	1895	1910	1887	1901	1888	1896	1490	780	1135	257	270	264
050168	6/23/2005	8:50:10	157	1896	1911	1888	1903	1890	1898	1492	784	1138	260	273	266
050168	6/23/2005	8:51:10	158	1898	1911	1892	1904	1891	1899	1495	789	1142	262	275	268
050168	6/23/2005	8:52:10	159	1899	1917	1891	1906	1893	1902	1497	793	1145	264	278	271
050168	6/23/2005	8:53:10	160	1900	1915	1892	1906	1895	1902	1501	797	1149	267	280	273
050168	6/23/2005	8:54:10	161	1901	1914	1892	1907	1894	1902	1502	801	1151	269	283	276
050168	6/23/2005	8:55:10	162	1902	1916	1895	1909	1896	1904	1504	805	1155	271	285	278
050168	6/23/2005	8:56:10	163	1904	1920	1895	1910	1897	1906	1507	810	1158	274	289	281
050168	6/23/2005	8:57:10	164	1905	1920	1896	1911	1898	1906	1507	814	1161	277	292	284
050168	6/23/2005	8:58:10	165	1906	1922	1897	1912	1899	1908	1510	818	1164	279	294	286
050168	6/23/2005	8:59:10	166	1907	1920	1897	1911	1898	1906	1512	822	1167	280	296	288
050168	6/23/2005	9:00:10	167	1908	1921	1898	1912	1900	1908	1514	826	1170	283	300	292
050168	6/23/2005	9:01:10	168	1910	1921	1900	1914	1901	1909	1516	829	1173	286	301	294
050168	6/23/2005	9:02:10	169	1911	1921	1900	1913	1901	1909	1518	834	1176	288	305	297
050168	6/23/2005	9:03:10	170	1912	1921	1901	1915	1901	1910	1520	837	1179	290	307	299
050168	6/23/2005	9:04:10	171	1913	1924	1901	1915	1902	1910	1523	841	1182	293	309	301
050168	6/23/2005	9:05:10	172	1915	1922	1901	1915	1902	1910	1524	845	1184	295	312	304
050168	6/23/2005	9:06:10	173	1916	1923	1900	1915	1903	1910	1524	848	1186	296	314	305

FIG. 12e

FtNum	TestDate	TestTime	Mins	E119	tc97	tc98	tc99	tc100	'Furnace'	tc101	tc102	'2 inch depth'	tc103	tc104	'1 inch depth'
050168	6/23/2005	9:07:10	174	1917	1918	1903	1916	1903	1910	1527	851	1189	298	317	308
050168	6/23/2005	9:08:10	175	1919	1922	1900	1915	1903	1910	1527	855	1191	302	321	312
050168	6/23/2005	9:09:10	176	1920	1921	1901	1915	1901	1910	1528	858	1193	305	326	316
050168	6/23/2005	9:10:10	177	1921	1926	1903	1917	1905	1913	1529	862	1195	310	333	321
050168	6/23/2005	9:11:10	178	1922	1927	1904	1919	1905	1914	1532	865	1198	315	339	327
050168	6/23/2005	9:12:10	179	1924	1926	1906	1919	1906	1915	1533	869	1201	320	345	333
050168	6/23/2005	9:13:10	180	1925	1926	1907	1921	1908	1916	1535	872	1203	326	352	339

FIG. 12f

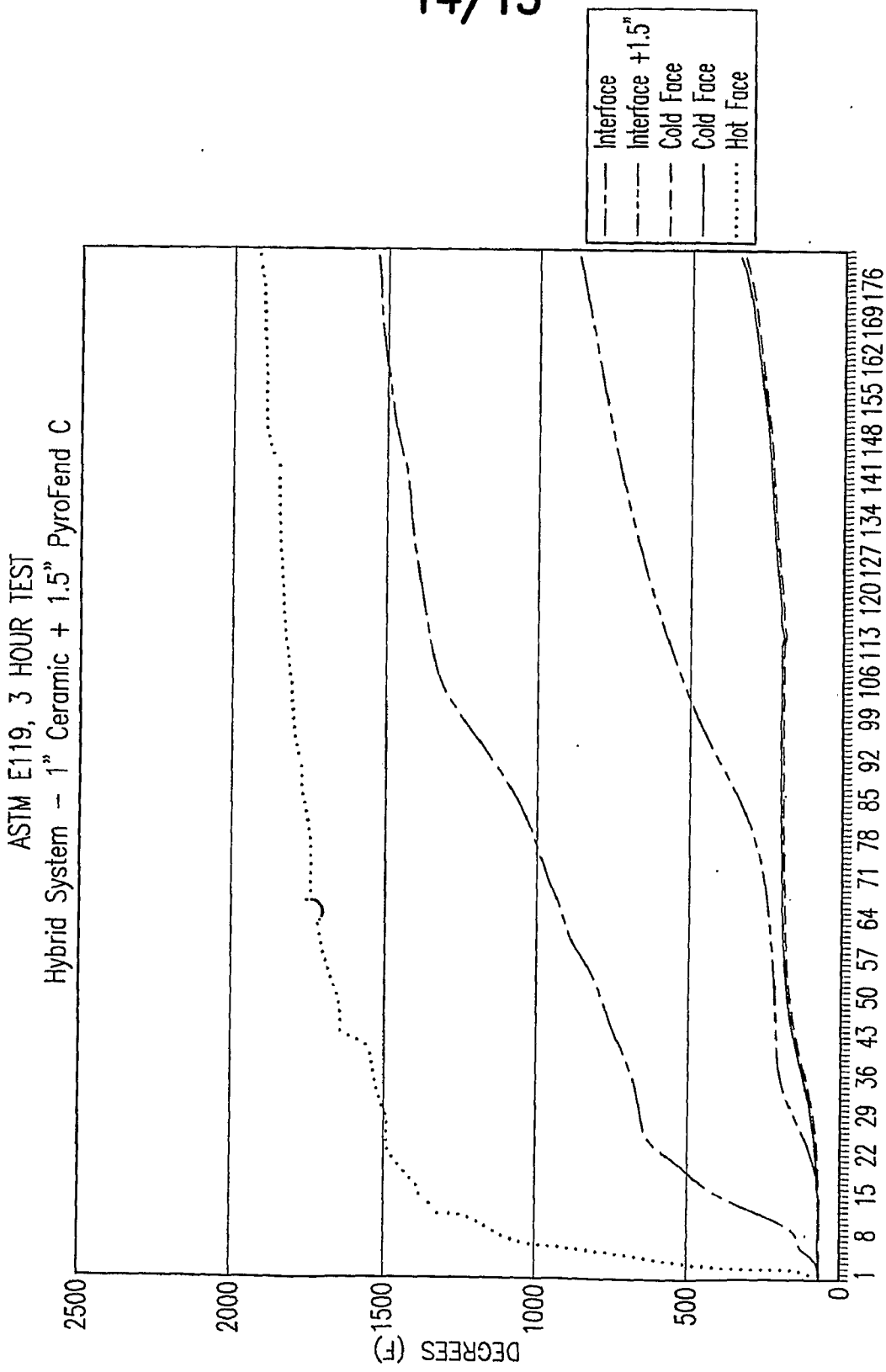
ASTM E119, 3 HOUR TEST
Hybrid System – 1" Ceramic + 1.5" PyroFend C
Interface
Interface +1.5"
Cold Face
Cold Face
Hot Face
DEGREES (F)
2500
2000
1500
1000
500
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141 148 155 162 169 176
MINUTES

FIG. 13

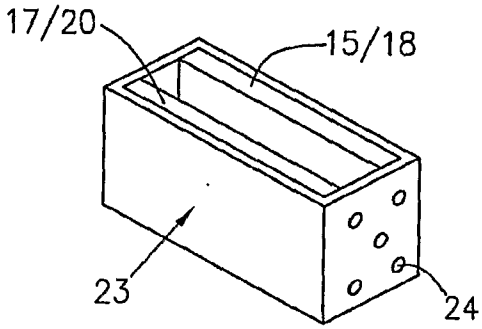

FIG. 14

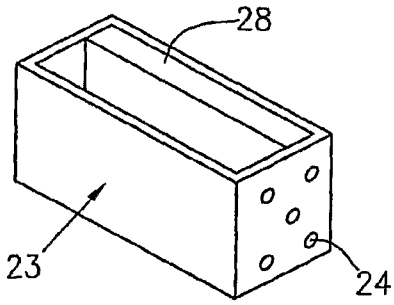

FIG. 15