TEST REPORT

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ASTM E119-00a Fire Tests of Building Construction and Materials

Sandwich Panels For Modular Construction

Project No. 16235-117482

ONE-HOUR FIRE RESISTANCE TEST OF
A NON-BEARING WALL ASSEMBLY

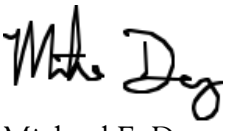
February 25, 2004

Prepared for:

Panel Built Inc.
P.O. Box 2658
Blairsville, GA 30514

Abstract

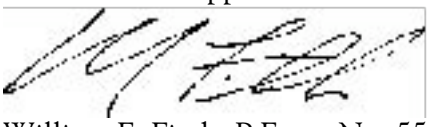
A 3" thick non-loadbearing wall assembly consisting of a sandwich panel wall clad on each side with one layer of 5/8" Type X gypsum drywall and insulated with 3 pcf mineral wool insulation, produced, assembled and tested as described herein, successfully met the conditions of acceptance as outlined in **ASTM Method E119-00a Fire Tests of Building Construction and Materials** for a fire endurance rating of 60 minutes (1-h).



Michael E. Dey
Manager, Fire Resistance

Date: February 25, 2004

Reviewed and approved:



William E. Fitch, P.E. No. 55296

Date: February 25, 2004

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ACCREDITED
No. 0689-01

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INTRODUCTION[1]

The test specimen identification is as provided by the client and Omega Point Laboratories, Inc. accepts no responsibility for any inaccuracies therein. Omega Point did not select the specimen and has not verified the composition, manufacturing techniques or quality assurance procedures

"The performance of walls, columns, floors, and other building members under fire exposure conditions is an item of major importance in securing constructions that are safe, and that are not a menace to neighboring structures nor to the public. Recognition of this is registered in the codes of many authorities, municipal and other. It is important to secure balance of the many units in a single building, and of buildings of like character and use in a community; and also to promote uniformity in requirements of various authorities throughout the country. To do this it is necessary that the fire-resistive properties of materials and assemblies be measured and specified according to a common standard expressed in terms that are applicable alike to a wide variety of materials, situations, and conditions of exposure.

Such a standard is found in the methods that follow. They prescribe a standard exposing fire of controlled extent and severity. Performance is defined as the period of resistance to standard exposure elapsing before the first critical point in behavior is observed. Results are reported in units in which field exposures can be judged and expressed.

The methods may be cited as the "Standard Fire Tests," and the performance or exposure shall be expressed as"2-h,""6-h,""1/2-h," etc.

When a factor of safety exceeding that inherent in the test conditions is desired, a proportional increase should be made in the specified time-classification period.

The ASTM E119 test procedure is identical or very similar to the following standard test methods:

UL 263
UBC 7-1
NFPA 251
ANSI A2.1

1. Scope

1.1 These methods are applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. They are also applicable to other assemblies and structural units that constitute permanent integral parts of a finished building.

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[1] American Society for Testing and Materials, 2000 Annual Book of Standards, ASTM E119-00a Standard Methods of FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS.

1.2 It is the intent that classifications shall register performance during the period of exposure and shall not be construed as having determined suitability for use after fire exposure.

1.3 *This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.*

Note 1 - A method of fire hazard classification based on rate of flame spread is covered in ASTM Method E84, Test for Surface Burning Characteristics of Building Materials.

1.4 The results of these tests are one factor in assessing fire performance of building construction and assemblies. These methods prescribe a standard fire exposure for comparing the performance of building construction assemblies. Application of these test results to predict the performance of actual building construction requires careful evaluation of test conditions.

2. Significance

2.1 This standard is intended to evaluate the duration for which the types of assemblies noted in 1.1 will contain a fire, or retain their structural integrity or exhibit both properties dependent upon the type of assembly involved during a predetermined test exposure.

2.2 The test exposes a specimen to a *standard* fire *exposure* controlled to achieve specified temperatures throughout a specified time period. In some instance, the *fire exposure* may be followed by the application of a *specified standard* fire hose stream. The exposure, however, may not be representative of all fire conditions which may vary with changes in the amount, nature and distribution of fire loading, ventilation, compartment size and configuration, and heat sink characteristics of the compartment. It does, however, provide a relative measure of fire performance of comparable assemblies under these specified fire exposure conditions. Any variation from the construction or conditions (that is, size, method of assembly, and materials) that are tested may substantially change the performance characteristics of the assembly.

2.3 The test standard provides for the following:

2.3.1 In walls, partitions and floor or roof assemblies:

2.3.1.1 Measurement of the transmission of heat.

2.3.1.2 Measurement of the transmission of hot gases through the assembly, sufficient to ignite cotton waste.

2.3.1.3 For load bearing elements, measurement of the load carrying ability of the *test specimen* during the test exposure.

2.3.2 For individual load bearing assemblies such as beams and columns: Measurement of the load carrying ability under the test exposure with some consideration for the end support conditions (that is, restrained or not restrained).

2.4 The test standard does not provide the following:

2.4.1 Full information as to performance of assemblies constructed with components or lengths other than those tested.

2.4.2 Evaluation of the degree by which the assembly contributes to the fire hazard by generation of smoke, toxic gases, or other products of combustion.

2.4.3 Measurement of the degree of control or limitation of *the passage of* smoke or products of combustion through the assembly.

2.4.4 Simulation of the fire behavior of joints between building elements such as floor-wall or wall-wall, etc., connections.

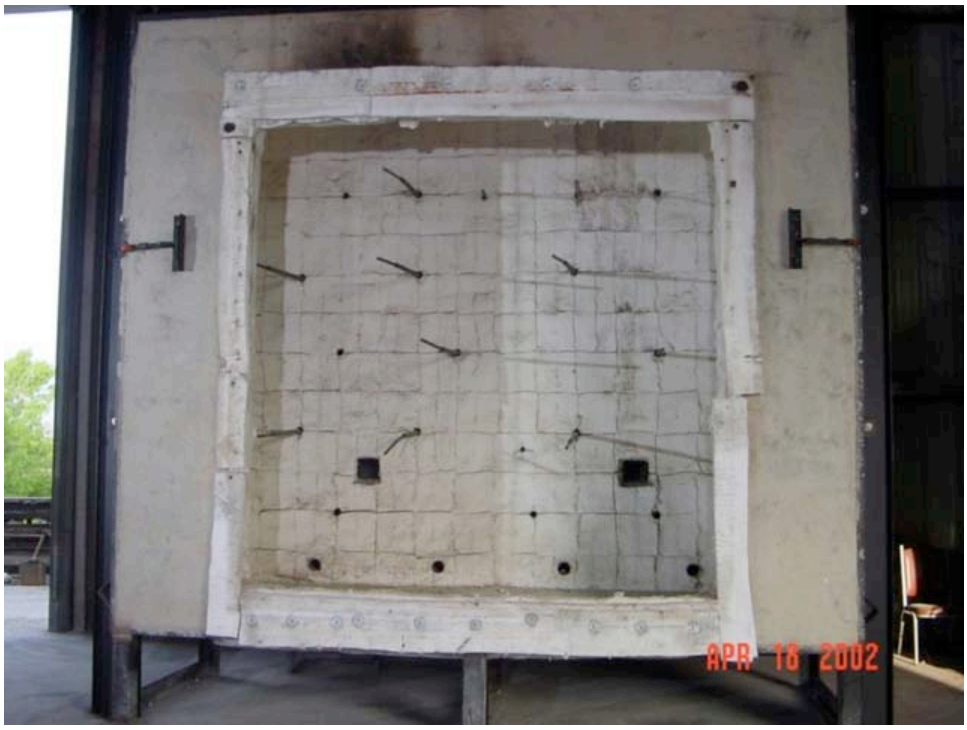
2.4.5 Measurement of flame spread over surface of tested element.

2.4.6 The effect of fire endurance of conventional openings in the assembly, that is electrical receptacle outlets, plumbing pipe, etc., unless specifically provided for in the construction tested."

TEST PROCEDURE

Test Furnace

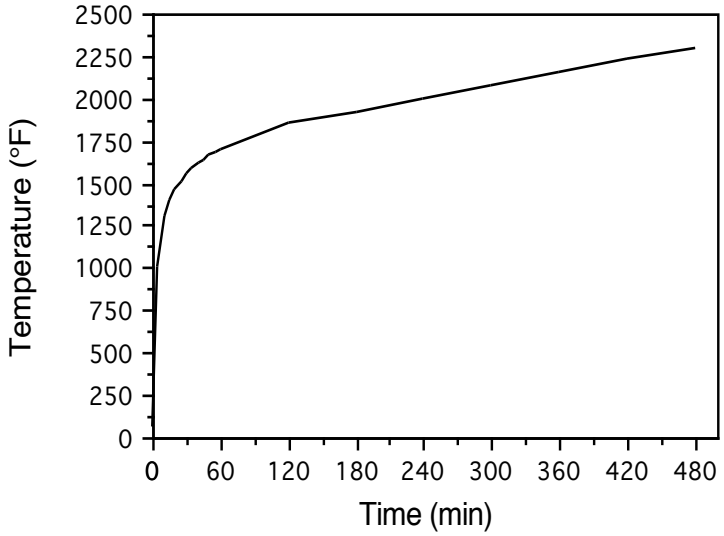
The test furnace is designed to allow the specimen to be uniformly exposed to the specified time-temperature conditions. It is fitted with 6 propane/air burners positioned on the left and right side walls, designed to allow an even heat flux distribution across the face of a test specimen while allowing no direct flame impingement. The maximum energy input into the furnace is 15 Mbtu/hr. The furnace operator has controls which allow the following items to be varied during the test: the overall energy input into the furnace; the air/gas ratio to the burners; and, the input of additional air beyond that passing through the burners. The furnace opening is 14 ft wide, 12 ft tall and 4 ft deep. It may be fitted with a collar that reduces the front opening to 10 ft x 10 ft, if desired. Furnace pressures may be maintained at any value from +0.15" W.C. to -0.15" W.C. Any full-size vertical fire test furnace will have a pressure difference between the bottom and top of approximately 0.01 in. W.C. per vertical foot after operating temperatures are reached. For this reason, the furnace is operated by controlling the pressure within the furnace (with respect to the laboratory ambient pressure) by regulating the pressure at a specific horizontal plane in the furnace. The furnace pressure will often be adjusted so that the "neutral pressure plane" (that where the pressure difference between the furnace interior and the laboratory ambient is zero) is at a desired location: for instance; at the top, at a point $^{1}/3$ of the way down from the top, or at the bottom of the specimen.



This photograph of the vertical furnace shows it with a concrete adapter in place which reduces its opening to 120" x 120". Without the adapter the furnace will accept test specimens 144" tall x 168" wide. The furnace is 48" deep, with burners on the sides, so that no flame impingement on the specimen occurs.

The temperature within the furnace is determined to be the mathematical average of thermocouples located symmetrically within the furnace and positioned six inches away from the vertical face of the test specimen. The materials used in the construction of these thermocouples are those suggested in the test standard. During the performance of a fire exposure test, the furnace temperatures are recorded every 15 seconds and displayed for the furnace operator to allow control along the specified temperature curve. For report presentation purposes, the data is saved once per minute.

The fire exposure is controlled to conform with the standard time-temperature curve shown in Figure 1, as determined by the table on the following page.



Time (min)	Temperature (°F)
0	68
5	1000
10	1300
20	1462
30	1550
60	1700
90	1792
120	1850
180	1925
240	2000
300	2075
360	2150
420	2225
480	2300

Figure 1

The furnace interior temperature during a test is controlled such that the area under the time•temperature curve is within 10% of the corresponding area under the standard time•temperature curve for 1 hour or less tests, 7.5% for those less than 2 hours and 5% for those tests of 2 hours or more duration.

Temperatures of Unexposed Surfaces

Temperatures of unexposed surfaces are monitored using 24 gage, type K thermocouples placed under 6" x 6" x 0.4" thick dry, felted pads as described in the standard. Temperature readings are taken at not less than nine points on the surface, at intervals not exceeding one minute. A drawing of the thermocouple locations can be found in Appendix B.

Applied Load

If required, this test method may be used to expose a wall to fire and hose stream tests while maintaining a compressive load on the wall. Unlike a non-load bearing test (in which the specimen is typically constructed within the bounds of a masonry/structural steel frame, and is effectively restrained on all four perimeter sides), a load bearing test is performed by "pinching" the test wall from top to bottom, while leaving the vertical sides unrestrained. This is accomplished at this laboratory, by the use of a load-bearing frame which has a movable bottom section. The test wall is placed (or constructed in place) between the top and bottom beams of the load frame, and hydraulic actuators press upwards on the bottom beam until the desired load is applied to the wall assembly. The entire frame, while maintaining the desired load, is moved into position in front of the vertical fire resistance furnace and the fire exposure and subsequent hose stream tests are performed.

Fire Endurance Test

The fire exposure is continued on the specimen with its applied load if applicable, until failure occurs, or until the specimen has withstood the test conditions for the desired fire endurance rating.

Hose Stream Test

"10.1 Where required by the conditions of acceptance, subject a duplicate specimen to a fire exposure test for a period equal to one half of that indicated as the resistance period in the fire endurance test, but not for more than 1 h, immediately after which subject the specimen to the impact, erosion, and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, changes in direction being made slowly.

10.2 *Exemption -* The hose stream test shall not be required in the case of constructions having a resistance period, indicated in the fire endurance test, of less than 1 h.

10.3 *Optional Program -* The submitter may elect, with the advice and consent of the testing body, to have the hose stream test made on the specimen subjected to the fire endurance test and immediately following the expiration of the fire endurance test.

10.4 *Stream Equipment and Details -* The stream shall be delivered through a 2 1/2-" (64-mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a 1 1/8-" (28.5-mm) discharge tip of the standard-taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of the application shall be as prescribed [in the table below]:

Conditions For Hose Stream Test		
Resistance Period	Water Pressure at Base of Nozzle, psi (kPa)	Duration of Application, min/100ft^2 (9 m^2) exposed area
8 h and over	45 (310)	6
4 h and over if less than 8 h	45 (310)	5
2 h and over if less than 4 h	30 (207)	2-1/2
1-1/2 h and over if less than 2 h	30 (207)	1-1/2
1 h and over is less than 1-1/2 h	30 (207)	1
Less than 1 h, if desired	30 (207)	1

10.5 *Nozzle Distance -* The nozzle orifice shall be 20 ft (6-m) from the center of the exposed surface of the test specimen if the nozzle is so located that when directed at the center its axis is normal to the surface of the test specimen. If otherwise located, its distance from the center shall be less than 20 ft by an amount equal to 1 ft (305-mm) for each 10 deg of deviation from the normal."

Correction Factor

When the indicated resistance period is 1/2 h or over, determined by the failure criteria of the standard, a correction shall be applied for variation of the furnace exposure from that prescribed, where it will affect the classification. This is to be done by multiplying the indicated period by two thirds of the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period and dividing the product by the area between the standard curve and a base line of 68°F (20°C) for the same part of the indicated period, the latter area increased by 3240°F•min to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For a fire exposure in the test higher than standard, the indicated resistance period shall be increased by the amount of the correction. For a fire exposure in the test lower than standard, the indicated resistance period shall be similarly decreased for fire exposure below standard. The correction is accomplished by mathematically adding the correction factor, C, to the indicated resistance period.

The correction can be expressed by the following equation:

$$C = \frac{2\,I\,(A - A_s)}{3\,(A_s + L)}$$

where:

C = correction in the same units as I,
I = indicated fire-resistance period,
A = area under the curve of indicated average furnace temperature for the first three fourths of the indicated period,
A_s = area under the standard furnace curve for the same part of the indicated period, and
L = lag correction in the same units as A and A_s (54°F•h or 30°C•h (3240°F•min or 1800°C•min))

CONDITIONS OF ACCEPTANCE

16. Conditions of Acceptance – [Loadbearing Walls]

16.1 Regard the test as successful if the following conditions are met:

16.1.1 The wall or partition shall have sustained the applied load during the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

16.1.2 The wall or partition shall have sustained the applied load during the fire and hose stream test as specified in Section 11, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.

16.1.3 Transmission of heat through the wall or partition during the fire endurance test shall

not have been such as to raise the [average] temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

18. Conditions of Acceptance – [Nonloadbearing Walls]

18.1 Regard the test as successful when the following conditions are met:
18.1.1 The wall or partition has withstood the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.
18.1.2 The wall or partition shall has [sic] withstood the fire and hose stream test as specified in Section 10, without passage of flame, of gases hot enough to ignite cotton waste, or of passage of water from the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.
18.1.3 Transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the [average] temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

[The E119 standard further states:]

7.4 Where the conditions of acceptance place a limitation on the rise of temperature of the unexposed surface, the temperature end point of the fire endurance period shall be determined by the average of the measurements taken at individual points; except that if a temperature rise of 30% [325°F above initial temperature] in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire endurance period judged as ended.

TEST SPECIMEN CONSTRUCTION

The test specimen identification is as provided by the client and Omega Point Laboratories, Inc. accepts no responsibility for any inaccuracies therein. Omega Point did not select the specimen and has not verified the composition, manufacturing techniques or quality assurance procedures

Two identical wall assemblies were constructed to complete this testing; one for the full-scale fire test and one for the hose stream retest. The construction of the two walls consisted of the following:

The 3" thick modular panels were shipped to the Laboratory and consisted of 26 GA., 1-3/4" galvanized steel studs (the stud spacing depends on panel size and is shown for this test in Appendix A), covered on each side with a single layer of 5/8" thick Type X gypsum wallboard (National Gypsum, Gold Bond Fire Shield) fastened using 1-1/4" long drywall screws spaced nominally 8" o.c. The panels were assembled on the floor, and then the entire wall capped around the perimeter with 3" wide, 20 GA galvanized steel channel, which was fastened to the top and bottom at each stud location, and on the vertical sides through pre-drilled holes spaced nominally 16" o.c., using 1-1/2" long steel laminating screws. The stud cavities in each panel

were packed with nominal 2.5 pcf, 2" thick mineral wool batt insulation (Roxul). After assembling the wall on the floor and attaching the perimeter channel, the entire wall assembly was tilted into place into one of the laboratory's nonbearing test frames. The wall was supported in the frame using 3" x 3" x 1/4" steel angle on each side. The studs in each vertical panel end were positioned so that when the panels were placed together, a 1-1/2" wide by 1-3/4" deep space was created for the insertion of a gypsum filler. The gypsum filler consisted of a 1/2" thick piece of standard gypsum drywall (National, Gold Bond) sandwiched between layers of 5/8" thick Type X gypsum drywall (National, Gold Bond Fire Shield), laminated together with a neoprene contact adhesive. The gypsum filler sections were each 10 ft. long to completely fill the air space between each panel connection. The joints were then covered with 24 GA joint covers fastened with #10 x 1-1/2" PHPN spaced 8" o.c. See Appendix A for drawings of the entire assembly.

TEST RESULTS AND OBSERVATIONS

The test specimen, contained in a non-loadbearing test frame, was placed in front of the Laboratory's vertical wall furnace on February 12, 2004. The thermocouple leads were then connected to the data acquisition system and their outputs verified. The laboratory air temperature was 51°F, with a relative humidity of 70%. At 3:20 p.m., the furnace was fired and the standard E119 time-temperature curve followed for a period of 60 minutes. The pressure difference between the inside of the furnace (measured by a pressure tap located approximately 1/3 of the way down from the top of the specimen, on the horizontal centerline of the furnace) and the laboratory ambient air, was maintained at –0.03 in. of water column throughout the entire test, following the first five minutes of the test, which resulted in the neutral pressure plane being positioned at the top of the test assembly.

Observations made during the test are as follows:

Time (min:sec)	Observation
0:00	Start of test
0:33	Ignition of the paper on the exposed face
0:56	Paper consumed; joint covers beginning to deflect between screws
5:00	Exposed surface turning gray, paper ash flaking away
7:30	Light flames are issuing from the exposed side wall joints
20:00	Vertical cracks are forming in the exposed gypsum wallboard
54:00	Steam from the unexposed joint covers in the top 1/3 of the wall
55:15	Horizontal cracks are forming near the center of the exposed surface
60:00	End of fire exposure
63:03	Hose stream test begun from a perpendicular distance of 20 feet at a nozzle pressure of 30 psi. The stream was played across the wall panel in both horizontal and vertical directions.
63:51	Hose stream penetrated the unexposed surface by knocking the gypsum loose at two locations.

The wall withstood the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for the 60-minute fire test. Transmission of heat through the wall during the fire endurance test did not raise the average temperature on the unexposed surface more than 250°F, nor any individual temperature more than 325°F.

Following the 60-minute fire exposure test, the test wall was removed from the furnace, and exposed, against the heated surface, to the impact, cooling and erosion effects of the standard hose stream test. The nozzle pressure was 30 psi, the distance between the nozzle and the wall surface was 20 feet and the water was applied for a total period of 1 minute. The hose stream penetrated the wall after 48 seconds.

The table below shows the maximum temperatures measured at each location during the 60-minute fire endurance test.

TC #	MAX. TEMP (°F)	TC #	MAX. TEMP (°F)
1	217	7	217
2	217	8	215
3	229	9	215
4	224	10	178
5	217	11	152
6	212	**Average**	**208**

During the fire test, the wall was measured for deflection at three points along it's vertical centerline: at 30" (position #1), 60" (position #2) and 90" (position #3) from the left side of the wall. Measurements were made from a taut string to the wall surface at each location.

TIME (min)	Position #1 (in.)	Position #2 (in.)	Position #3 (in.)
0	6-3/8	6-3/8	6-3/8
17	7	7	7
34	9-1/4	9-1/2	9
45	9-5/8	10-1/4	9-1/2
55	10	10-1/2	9-5/8

In accordance with the E119 test standard, a calculation for any correction to the indicated fire resistance period was done. The correction factor was then mathematically added to the

indicated fire resistance period, yielding the fire resistance period achieved by this specimen:

ITEM	DESCRIPTION	TEST VALUE
C	correction factor	-0.01 min (-1 second)
I	indicated fire-resistance period	60 min
A	area under the curve of indicated average furnace temperature for the first three fourths of the indicated period	56 688°F•min
As	area under the standard furnace curve for the same part of the indicated period	56 702°F•min
L	lag correction	3240°F•min
	FIRE RESISTANCE PERIOD ACHIEVED BY THIS SPECIMEN ==>	60

Note: The standard specifies that the fire resistance be determined to the nearest integral minute. Consequently, if the correction factor is less than 30 seconds, and the test specimen met the criteria for the full indicated fire resistance period, no correction is deemed necessary. That was the case for this project.

Listings and plots of the furnace control temperatures and specimen unexposed surface temperatures may be found in Appendix C1. A photographic documentation of the test has been included in Appendix D1.

Hose Stream Retest

The wall assembly was placed in the Laboratory's non-loadbearing test frame and placed in front of the test furnace on February 13, 2004. The ambient temperature at the start of the test was 50°F, with a relative humidity of 60%. The same procedure was followed as the previous test with regards to fire exposure. The wall assembly was placed against the furnace and exposed to the ASTM E 119 time/ temperature curve for a period of 30 minutes. There are no thermocouples required on the unexposed surface for this test. After the fire exposure, the wall was subjected to the effects of the standard hose stream test for a period of 60 seconds without developing any openings or allowing passage of water.

Observations made during the test are as follows:

Time (min:sec)	Observation
0:00	Furnace fired at 10:55 a.m.
0:40	Ignition of gypsum paper
1:05	Paper fully consumed; joint covers deflecting between screws
4:45	Exposed surface turning gray; paper ash flaking away
10:00	Wall beginning to bow inward
12:50	Hairline vertical cracks are forming in the exposed gypsum
30:00	Furnace extinguished
32:16	The wall was exposed to the standard hose stream test for a period of 60 seconds at a pressure of 30 psi from 20 feet away from the exposed surface. The water knocked all of the exposed gypsum and insulation loose from the wall, but did not penetrate the layer of 5/8" gypsum wallboard on the unexposed surface, which remained firmly attached to the studs with no openings.

The wall withstood the fire and hose stream tests without passage of flame, of gases hot enough to ignite cotton waste, or of the passage of water from the hose stream. No openings developed that permitted a projection of water from the stream beyond the unexposed surface during the time of the hose stream test. Listings and plots of the furnace control temperatures may be found in Appendix C2. A photographic documentation of the test has been included in Appendix D2.

CONCLUSIONS

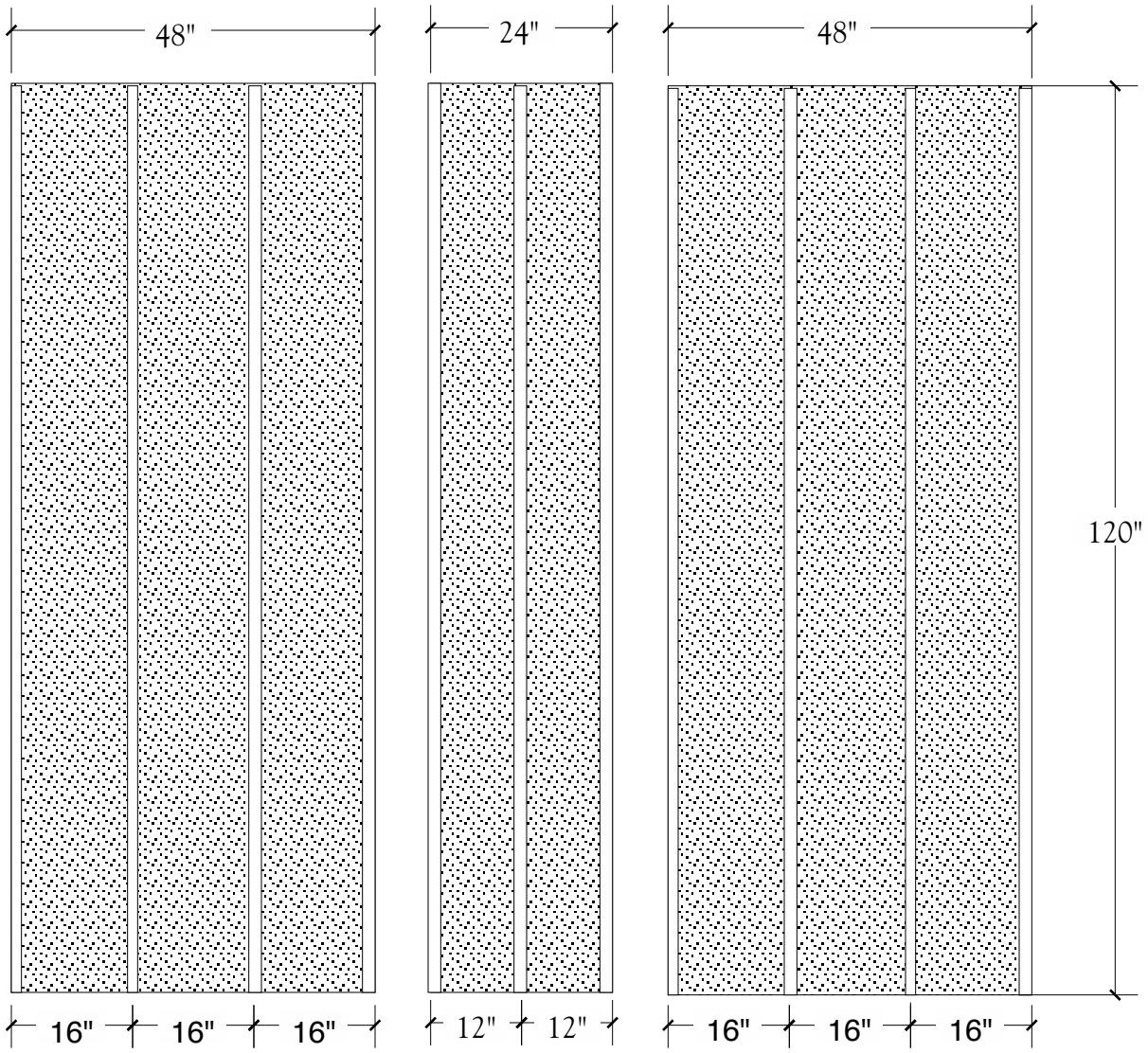
The test specimen identification is as provided by the client and Omega Point Laboratories, Inc. accepts no responsibility for any inaccuracies therein. Omega Point did not select the specimen and has not verified the composition, manufacturing techniques or quality assurance procedures.

The Panel Built modular panels tested as described in this report achieved a fire endurance of 60 minutes (non-loadbearing wall) in accordance with ASTM E 119-00a Standard Fire Tests for Building Construction and Materials. Although the 3" wide wall panel system was tested with nothing covering the 5/8" Type X gypsum on either side, it is commonly accepted that the addition of any wall coverings would only enhance the wall's fire endurance rating.

OMEGA POINT LABORATORIES

APPENDIX A

CONSTRUCTION DRAWINGS

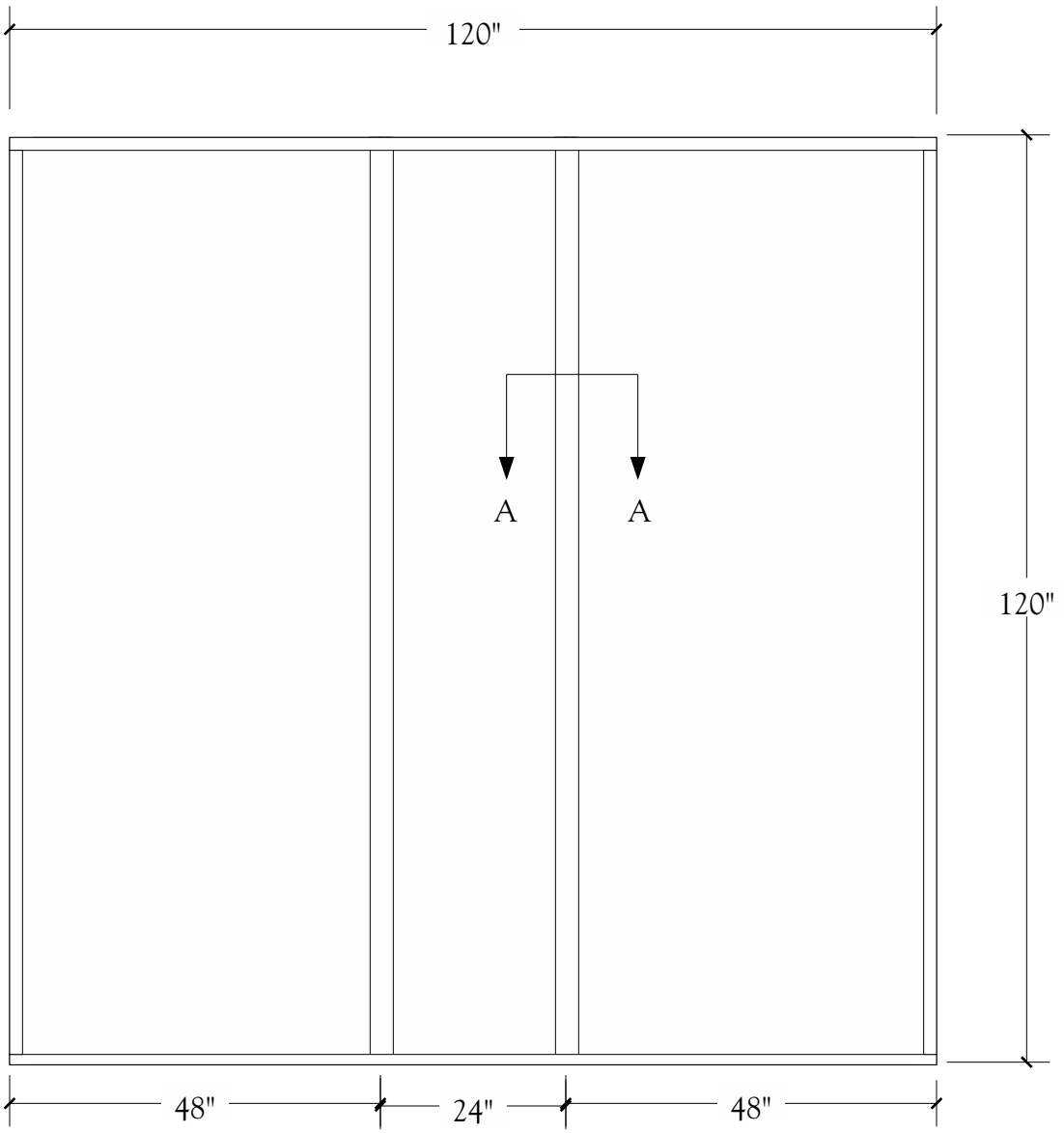


ELEVATION VIEW (one side of gypsum removed to show stud details)

The wall assembly consisted of three modular panels as shown above. The studs were 1-3/4" C-channel with 1-1/2" leg length, 26 GA. galvanized steel. The stud cavities were insulated with 2" thick, 2.5 pcf Roxul mineral wool insulation. The studs were covered on both sides with a single layer of 5/8" thick Type X gypsum wallboard fastened with 1-1/4" drywall screws spaced nominally 8" o.c.

OMEGA POINT LABORATORIES, INC. Project No. 16235-117482
Panel Built, Inc.
Fig. 1 Stud Layout

Scale: 1/2"=1'



ELEVATION VIEW

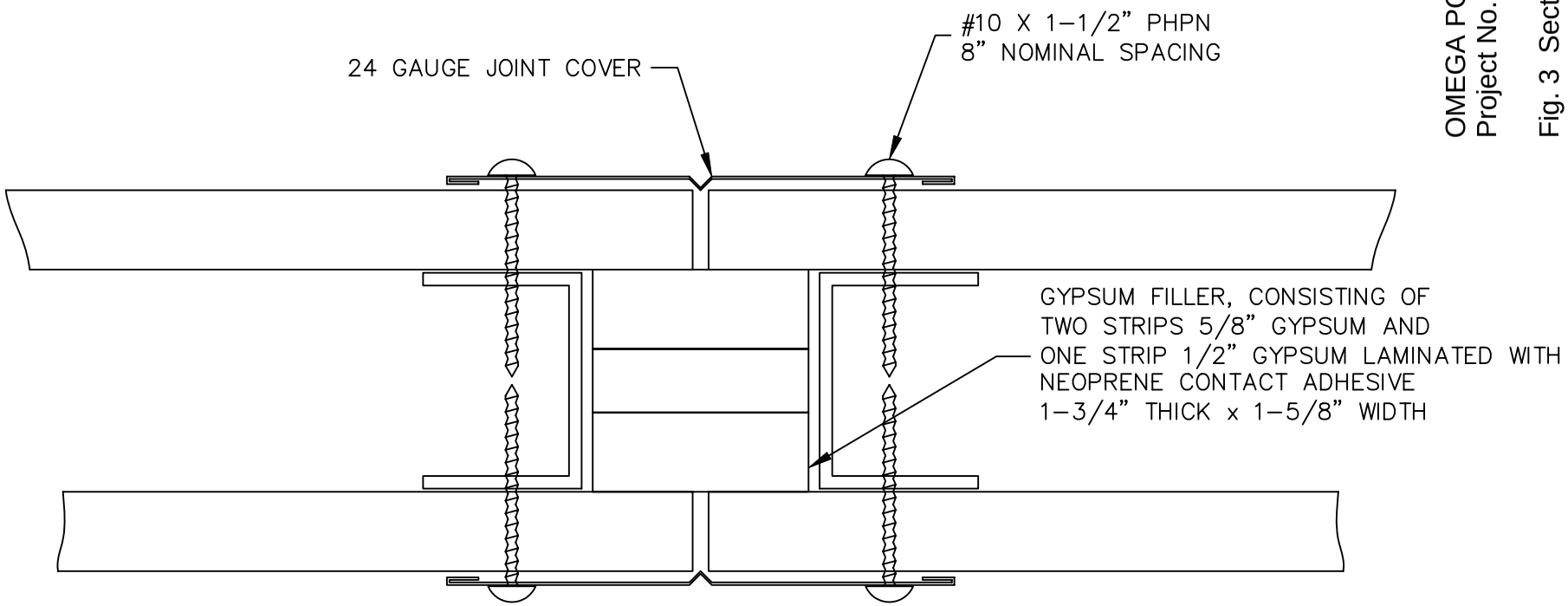
Once assembled, the panels were capped around the perimeter with 3" wide, 20 GA galvanized steel channel, fastened to the channel with 1-1/2" long steel laminating screws at each stud location. The joint detail is shown in Figure 3.

OMEGA POINT LABORATORIES, INC. Project No. 16235-117482
Panel Built, Inc.
Fig. 2 Panel Layout

Scale: 1/2"=1'

OMEGA POINT LABS
Project No. 16235-117482

Fig. 3 Section A-A

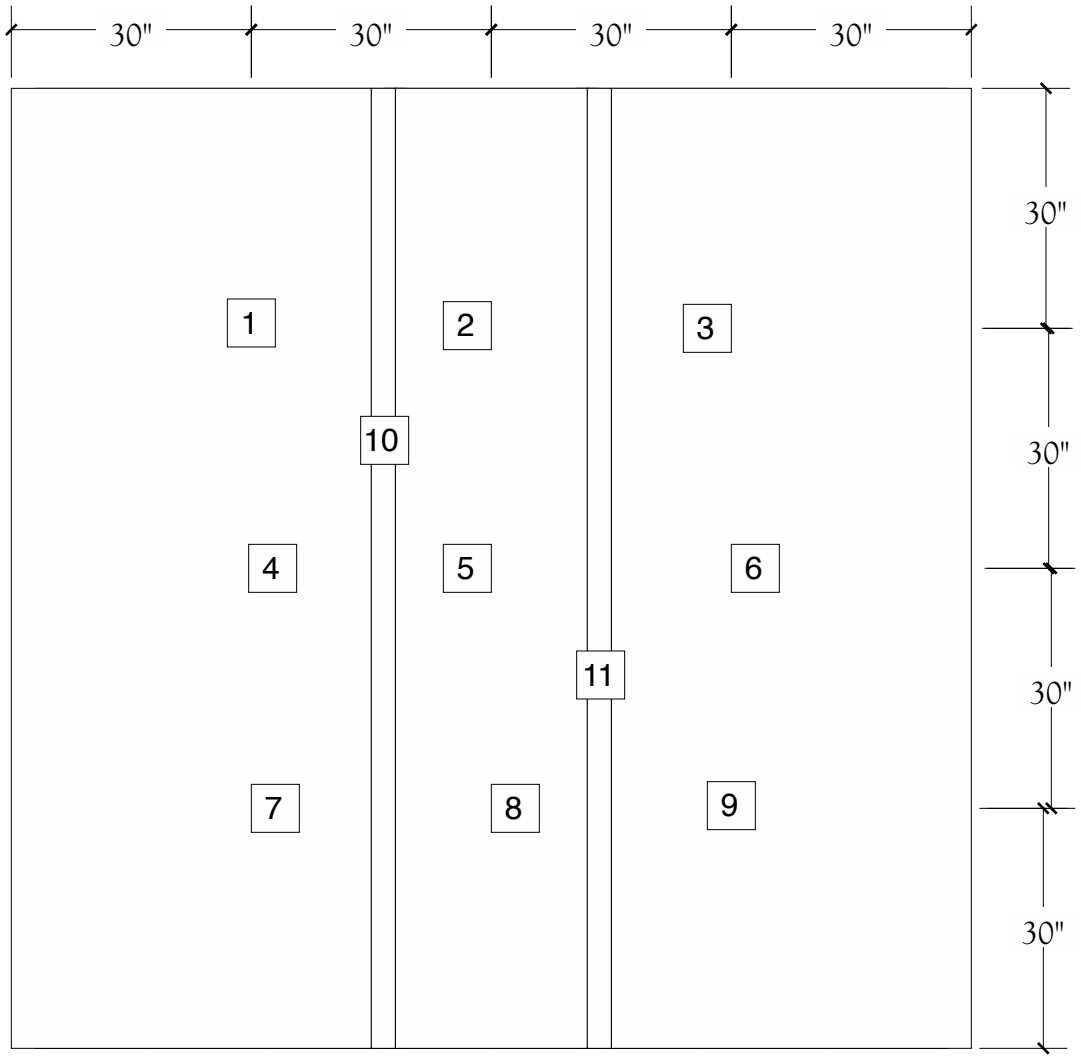


SECTION A-A

ONE HOUR JOINT

APPENDIX B

THERMOCOUPLE LOCATIONS



ELEVATION VIEW

NOTE:
The unexposed surface was instrumented with eleven 24 ga., type K thermocouples (Special Limits of Error: ±1.1°C) arranged in a symmetric pattern as shown. Each thermocouple was then covered with a standard E119 TC Pad, held in place with a small daub of silicone adhesive on each corner.

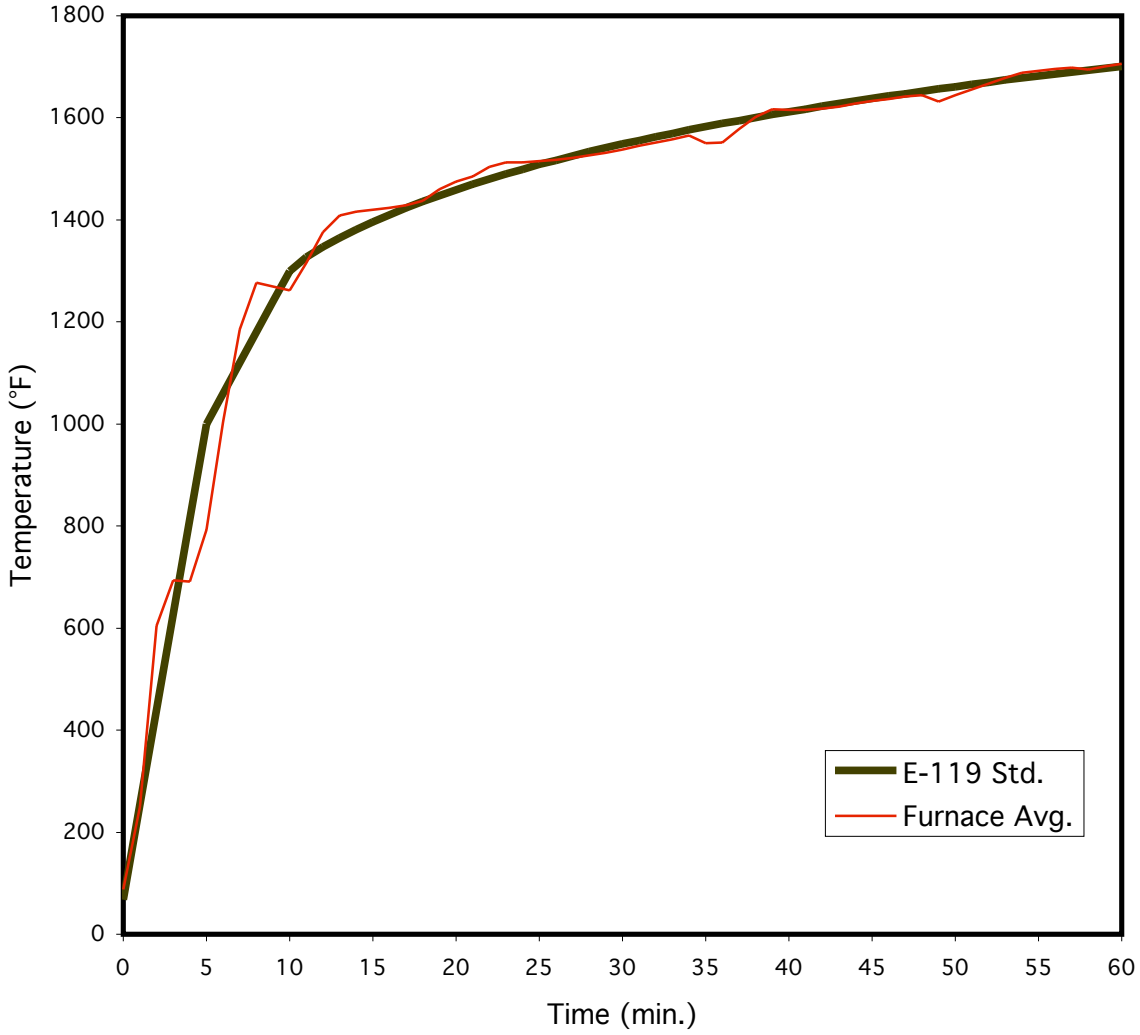
OMEGA POINT LABORATORIES, INC. Project No. 16235-117482
Panel Built, Inc.
Fig. 4 TC Locations

Scale: 1/2"=1'

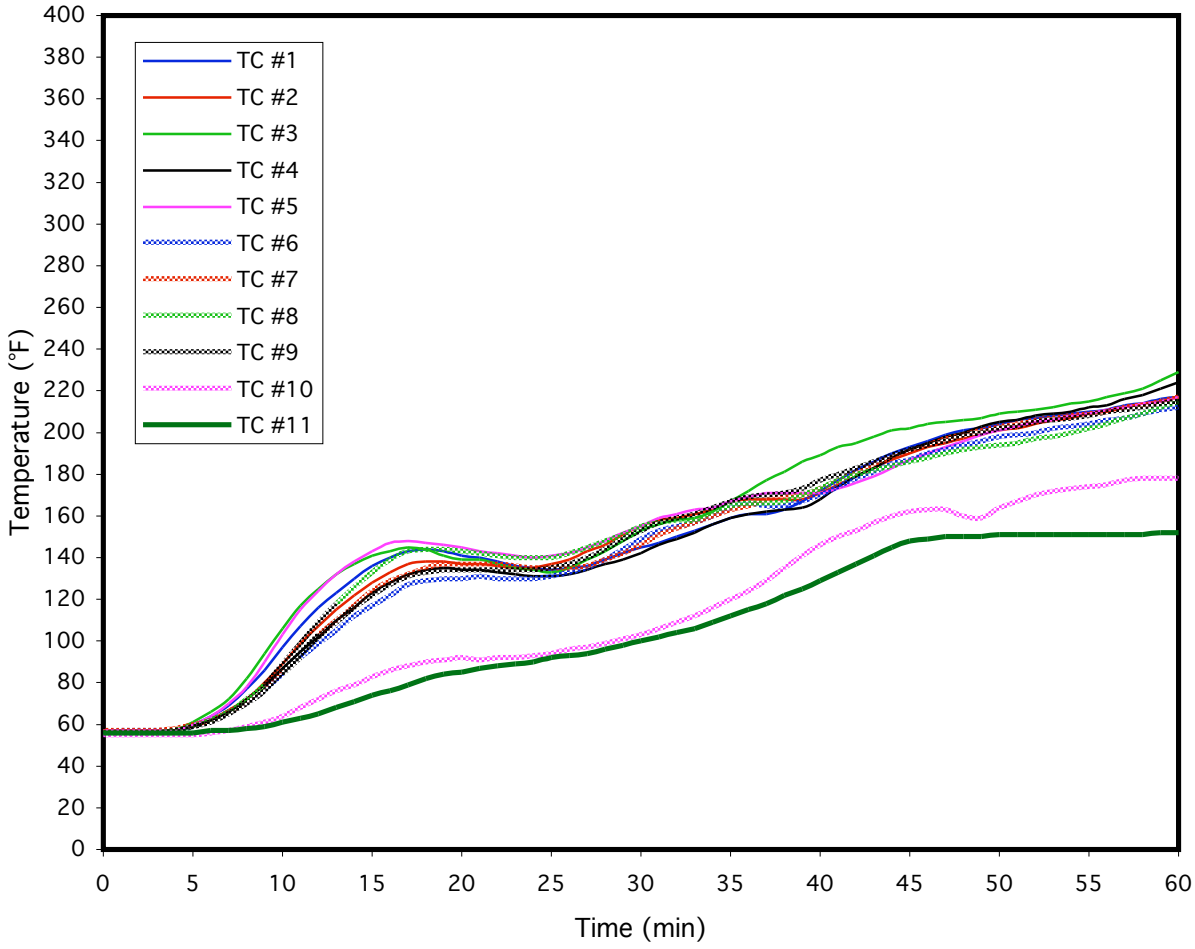
APPENDIX C1

THERMOCOUPLE DATA

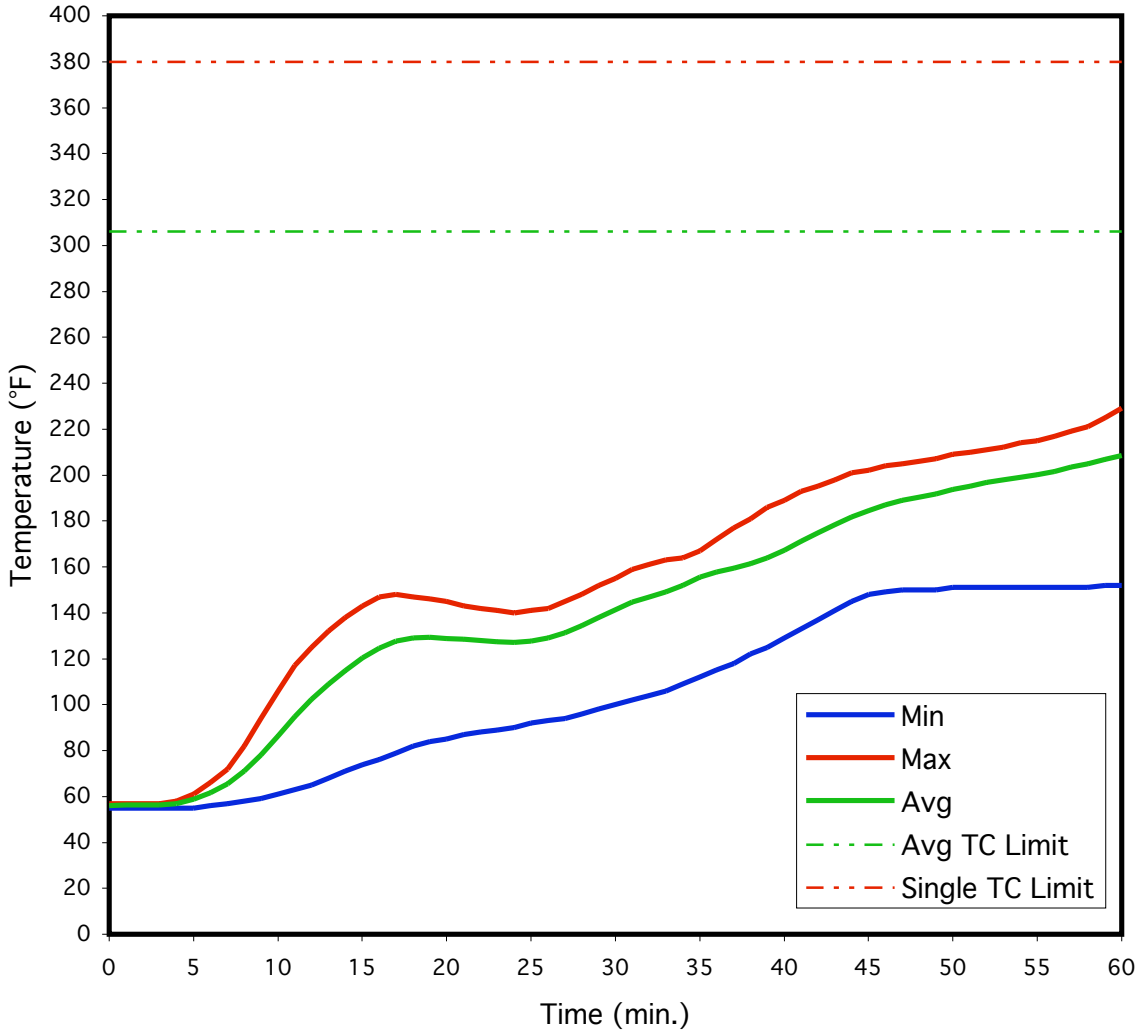
Panel Built Inc.
Project No. 16235-117482
Furnace Interior Temperatures



Panel Built Inc.
Project No. 16235-117482
Individual Cold Side Temperatures



Panel Built Inc.
Project No. 16235-117482
Min, Avg, Max Cold Side Temperatures



Time (min)	E119 Std Average (°F)	Furnace Average (°F)	Integration of Furnace Average (°F•min)	Integration of E119 Std Average (°F•min)	Error (%)	Furnace Probe #1 (°F)	Furnace Probe #2 (°F)
0	68	88	0	0	0.00	91	91
1	254	250	101	93	8.74	340	301
2	441	604	460	372	23.72	727	648
3	627	693	1041	838	24.29	770	724
4	814	691	1665	1490	11.79	744	719
5	1000	793	2339	2328	0.49	879	826
6	1060	1004	3170	3290	-3.64	1106	1029
7	1120	1186	4197	4312	-2.66	1269	1206
8	1180	1277	5361	5394	-0.62	1333	1299
9	1240	1269	6565	6536	0.45	1306	1296
10	1300	1262	7763	7738	0.32	1296	1291
11	1328	1316	8984	8984	0.00	1354	1343
12	1347	1376	10261	10252	0.09	1406	1392
13	1364	1409	11586	11539	0.40	1436	1424
14	1381	1417	12930	12843	0.68	1440	1434
15	1396	1420	14281	14163	0.83	1441	1439
16	1410	1424	15635	15497	0.89	1446	1444
17	1424	1428	16993	16846	0.87	1451	1450
18	1436	1437	18357	18207	0.83	1461	1460
19	1448	1460	19738	19581	0.80	1484	1479
20	1459	1475	21137	20967	0.81	1497	1496
21	1470	1485	22549	22363	0.83	1506	1504
22	1480	1504	23975	23770	0.86	1524	1518
23	1490	1513	25416	25187	0.91	1530	1524
24	1499	1513	26860	26614	0.93	1529	1523
25	1508	1515	28306	28049	0.92	1531	1524
26	1517	1518	29755	29494	0.89	1533	1527
27	1525	1522	31207	30947	0.84	1536	1530
28	1533	1526	32663	32408	0.79	1542	1535
29	1541	1531	34124	33877	0.73	1545	1540
30	1549	1538	35590	35353	0.67	1550	1543
31	1556	1545	37064	36837	0.62	1558	1551
32	1552	1552	38544	38327	0.57	1563	1555
33	1558	1558	40030	39825	0.52	1569	1559
34	1565	1565	41524	41329	0.47	1576	1566
35	1551	1428	42952	42840	0.26	1564	1563
36	1552	1552	44374	44357	0.04	1565	1559
37	1578	1578	45871	45880	-0.02	1592	1579
38	1602	1602	47393	47409	-0.03	1613	1601
39	1617	1617	48934	48944	-0.02	1626	1615
40	1616	1616	50482	50485	-0.01	1624	1615
41	1615	1615	52030	52032	0.00	1623	1616
42	1618	1618	53579	53583	-0.01	1623	1619
43	1628	1623	55131	55140	-0.02	1628	1620

Time (min)	E119 Std Average (°F)	Furnace Average (°F)	Integration of Furnace Average (°F•min)	Integration of E119 Std Average (°F•min)	Error (%)	Furnace Probe #1 (°F)	Furnace Probe #2 (°F)
44	1633	1629	56688	56702	-0.02	1634	1627
45	1638	1634	58251	58269	-0.03	1639	1634
46	1643	1637	59819	59841	-0.04	1642	1636
47	1648	1643	61390	61418	-0.04	1648	1644
48	1652	1645	62966	62999	-0.05	1648	1641
49	1657	1632	64536	64585	-0.08	1637	1635
50	1661	1645	66107	66176	-0.10	1651	1645
51	1666	1656	67689	67771	-0.12	1662	1657
52	1670	1667	69283	69370	-0.13	1674	1668
53	1674	1678	70888	70973	-0.12	1683	1677
54	1678	1689	72503	72581	-0.11	1691	1687
55	1682	1692	74125	74193	-0.09	1694	1691
56	1686	1696	75751	75809	-0.08	1697	1693
57	1690	1698	77380	77429	-0.06	1700	1695
58	1694	1695	79008	79053	-0.06	1697	1692
59	1698	1700	80638	80680	-0.05	1704	1697
60	1701	1706	82273	82311	-0.05	1708	1702
Max Temp							
Max Allowed							

Time (min)	Furnace Probe #3 (°F)	Furnace Probe #4 (°F)	Furnace Probe #5 (°F)	Furnace Probe #6 (°F)	Furnace Probe #7 (°F)	Furnace Probe #8 (°F)	Furnace Probe #9 (°F)	Furnace Probe #10 (°F)
0	90	87	90	84	89	89	87	89
1	233	253	313	215	234	240	283	214
2	502	593	717	588	592	632	662	548
3	584	674	773	678	694	756	723	661
4	605	676	751	666	700	750	700	678
5	708	787	878	743	794	859	805	762
6	891	1014	1101	940	993	1109	1029	958
7	1062	1197	1275	1131	1176	1287	1201	1145
8	1175	1278	1345	1230	1268	1360	1273	1243
9	1197	1262	1320	1222	1260	1339	1246	1241
10	1212	1255	1309	1210	1251	1325	1233	1232
11	1267	1312	1364	1268	1302	1377	1289	1275
12	1328	1366	1421	1343	1358	1442	1350	1334
13	1360	1396	1455	1386	1386	1477	1376	1364
14	1377	1402	1456	1393	1394	1477	1383	1376
15	1389	1405	1454	1398	1398	1476	1384	1380
16	1399	1410	1460	1399	1404	1471	1390	1378
17	1410	1417	1465	1401	1407	1468	1396	1378
18	1422	1428	1477	1410	1415	1472	1406	1383
19	1442	1453	1495	1434	1441	1494	1430	1404
20	1460	1468	1503	1453	1456	1506	1449	1422
21	1471	1480	1514	1457	1470	1518	1460	1439
22	1489	1497	1532	1476	1489	1539	1481	1461
23	1501	1504	1537	1488	1499	1545	1490	1475
24	1504	1504	1537	1484	1500	1541	1488	1476
25	1508	1507	1539	1486	1504	1544	1492	1479
26	1511	1510	1542	1490	1507	1547	1494	1483
27	1514	1513	1544	1494	1513	1548	1498	1488
28	1519	1518	1549	1499	1516	1553	1503	1492
29	1523	1523	1554	1504	1522	1559	1508	1498
30	1528	1530	1560	1509	1530	1566	1514	1505
31	1535	1537	1567	1516	1538	1573	1522	1513
32	1542	1542	1572	1526	1543	1582	1529	1519
33	1548	1549	1579	1530	1551	1588	1535	1528
34	1555	1557	1588	1536	1560	1596	1543	1536
35	1551	1545	1565	1529	1542	1573	1529	1517
36	1549	1545	1570	1526	1545	1578	1531	1520
37	1567	1571	1601	1547	1573	1609	1559	1547
38	1587	1592	1627	1574	1599	1640	1581	1570
39	1601	1607	1641	1588	1614	1655	1594	1585
40	1604	1606	1637	1588	1613	1650	1593	1586
41	1605	1606	1635	1588	1611	1648	1592	1586
42	1608	1607	1638	1592	1613	1651	1595	1588
43	1613	1612	1642	1597	1618	1656	1600	1594

Time (min)	Furnace Probe #3 (°F)	Furnace Probe #4 (°F)	Furnace Probe #5 (°F)	Furnace Probe #6 (°F)	Furnace Probe #7 (°F)	Furnace Probe #8 (°F)	Furnace Probe #9 (°F)	Furnace Probe #10 (°F)
44	1619	1618	1649	1604	1623	1662	1606	1600
45	1624	1623	1655	1608	1627	1668	1612	1605
46	1628	1626	1655	1611	1632	1670	1616	1609
47	1635	1631	1663	1617	1635	1676	1620	1613
48	1636	1633	1664	1617	1641	1677	1623	1620
49	1629	1622	1645	1609	1627	1660	1609	1604
50	1637	1637	1664	1620	1640	1676	1626	1616
51	1646	1648	1674	1631	1651	1686	1636	1628
52	1657	1659	1688	1643	1661	1700	1649	1638
53	1668	1669	1699	1653	1673	1713	1659	1650
54	1677	1680	1712	1662	1683	1724	1669	1659
55	1681	1683	1713	1667	1687	1725	1671	1663
56	1686	1688	1719	1671	1690	1730	1675	1666
57	1690	1689	1719	1674	1694	1732	1677	1669
58	1688	1685	1717	1669	1690	1728	1672	1666
59	1693	1693	1721	1673	1697	1734	1679	1672
60	1698	1697	1727	1678	1702	1738	1685	1679
Max Temp								
Max Allowed								

Time (min)	Furnace Probe #11 (°F)	Furnace Probe #12 (°F)	Cold Side Min (°F)	Cold Side Avg (°F)	Cold Side Max (°F)	Cold Side TC #1 (°F)	Cold Side TC #2 (°F)	Cold Side TC #3 (°F)	Cold Side TC #4 (°F)	Cold Side TC #5 (°F)
0	87	85	55	56	57	56	56	56	56	57
1	201	173	55	56	57	56	56	56	56	57
2	592	450	55	56	57	56	56	56	56	57
3	716	565	55	56	57	56	56	56	56	57
4	724	581	55	57	58	57	57	57	57	57
5	814	663	55	59	61	60	59	61	59	60
6	1022	861	56	62	66	64	62	66	62	64
7	1209	1073	57	66	72	69	67	72	66	70
8	1307	1208	58	71	82	77	72	82	72	78
9	1303	1234	59	78	94	86	80	94	79	90
10	1293	1241	61	86	106	97	89	106	87	103
11	1336	1301	63	95	117	107	99	117	95	115
12	1388	1378	65	102	125	116	107	125	102	124
13	1424	1423	68	109	132	123	115	132	110	132
14	1433	1433	71	115	138	130	122	137	116	138
15	1437	1440	74	120	143	136	128	141	123	143
16	1441	1444	76	125	147	140	133	143	128	147
17	1446	1450	79	128	148	143	137	145	132	148
18	1453	1458	82	129	147	144	138	144	134	147
19	1477	1483	84	129	146	143	138	141	135	146
20	1492	1493	85	129	145	141	137	139	134	145
21	1502	1501	87	129	143	140	137	139	134	143
22	1518	1521	88	128	142	138	136	137	133	142
23	1530	1534	89	127	141	136	135	135	132	141
24	1531	1534	90	127	140	135	135	134	131	140
25	1533	1536	92	128	141	134	137	133	131	141
26	1535	1540	93	129	142	135	139	135	132	142
27	1539	1544	94	131	145	136	143	139	134	145
28	1542	1548	96	134	148	139	146	143	137	148
29	1547	1553	98	138	152	142	151	148	139	152
30	1555	1560	100	141	155	145	155	153	142	155
31	1562	1568	102	145	159	147	158	156	146	159
32	1569	1576	104	147	161	150	159	158	149	161
33	1575	1581	106	149	163	153	161	159	152	163
34	1583	1587	109	152	164	156	163	162	156	164
35	1565	1567	112	155	167	159	167	167	159	167
36	1567	1569	115	158	172	161	168	172	161	169
37	1591	1595	118	160	177	161	168	177	162	171
38	1617	1620	122	161	181	163	168	181	163	171
39	1636	1638	125	164	186	167	168	186	164	171
40	1637	1639	129	167	189	172	171	189	168	171
41	1636	1638	133	171	193	177	175	193	174	173
42	1638	1641	137	175	195	182	179	195	179	176
43	1644	1646	141	178	198	186	183	198	183	179

Time (min)	Furnace Probe #11 (°F)	Furnace Probe #12 (°F)	Cold Side Min (°F)	Cold Side Avg (°F)	Cold Side Max (°F)	Cold Side TC #1 (°F)	Cold Side TC #2 (°F)	Cold Side TC #3 (°F)	Cold Side TC #4 (°F)	Cold Side TC #5 (°F)
44	1649	1651	145	182	201	190	187	201	188	183
45	1652	1658	148	185	202	193	190	202	192	187
46	1657	1661	149	187	204	196	193	204	195	190
47	1661	1667	150	189	205	199	195	205	198	193
48	1667	1668	150	190	206	201	197	206	200	196
49	1652	1654	150	192	207	202	199	207	203	199
50	1662	1667	151	194	209	204	201	209	205	201
51	1674	1677	151	195	210	206	202	210	206	203
52	1683	1689	151	197	211	207	204	211	208	205
53	1696	1701	151	198	212	208	206	212	209	206
54	1707	1711	151	199	214	209	207	214	210	208
55	1711	1715	151	200	215	210	209	215	212	209
56	1713	1719	151	202	217	211	210	217	213	211
57	1718	1723	151	203	219	213	212	219	216	212
58	1715	1719	151	205	221	214	214	221	218	214
59	1720	1722	152	207	225	216	215	225	221	215
60	1725	1728	152	208	229	217	217	229	224	217
Max Temp			152	208	229	217	217	229	224	217
Max Allowed			380	306	382	381	381	381	381	382

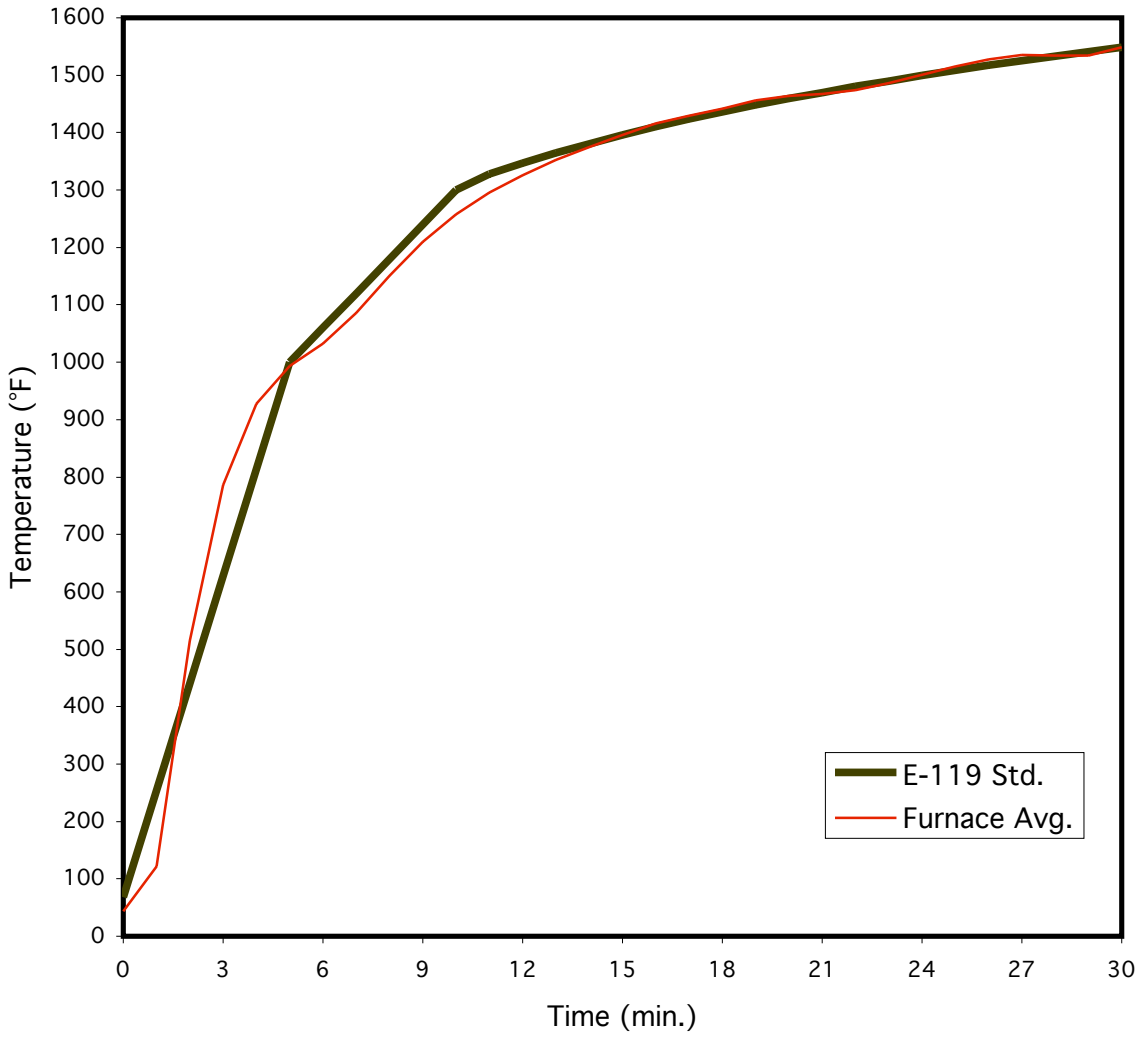
Time (min)	Cold Side TC #6 (°F)	Cold Side TC #7 (°F)	Cold Side TC #8 (°F)	Cold Side TC #9 (°F)	Cold Side TC #10 (°F)	Cold Side TC #11 (°F)	Lab Ambient (°F)
0	56	57	56	56	55	56	51
1	57	57	56	56	55	56	51
2	57	57	56	56	55	56	51
3	57	57	56	56	55	56	51
4	57	58	57	57	55	56	51
5	59	60	59	59	55	56	51
6	62	62	62	61	56	57	51
7	66	66	66	65	57	57	52
8	71	71	72	70	59	58	52
9	77	78	79	76	61	59	52
10	84	86	89	85	64	61	52
11	92	95	99	93	68	63	52
12	99	103	109	102	72	65	52
13	105	110	118	109	76	68	52
14	112	117	126	116	79	71	52
15	117	124	133	122	83	74	52
16	122	129	139	127	86	76	53
17	127	132	143	131	88	79	52
18	129	135	144	133	90	82	53
19	130	137	144	134	91	84	53
20	130	137	143	134	92	85	53
21	131	137	142	134	91	87	53
22	130	137	141	134	92	88	53
23	130	136	140	134	92	89	53
24	130	135	140	134	93	90	53
25	131	135	140	135	94	92	53
26	133	135	142	137	96	93	53
27	135	136	145	140	97	94	53
28	139	139	148	144	99	96	53
29	144	142	151	149	101	98	53
30	149	146	155	153	103	100	53
31	153	151	157	157	106	102	53
32	155	154	158	159	109	104	53
33	157	157	158	161	112	106	53
34	160	160	162	164	116	109	53
35	164	163	165	167	120	112	53
36	166	165	166	169	124	115	53
37	165	168	166	170	129	118	53
38	165	169	167	171	135	122	54
39	167	170	170	173	141	125	53
40	170	173	173	177	146	129	53
41	174	177	177	180	150	133	53
42	178	181	180	183	153	137	53
43	181	185	182	186	157	141	53

Time (min)	Cold Side TC #6 (°F)	Cold Side TC #7 (°F)	Cold Side TC #8 (°F)	Cold Side TC #9 (°F)	Cold Side TC #10 (°F)	Cold Side TC #11 (°F)	Lab Ambient (°F)
44	185	188	184	189	160	145	53
45	187	191	186	192	162	148	53
46	190	194	188	194	163	149	53
47	192	197	190	196	163	150	53
48	194	199	192	199	160	150	53
49	196	201	193	200	159	150	54
50	198	203	194	202	164	151	54
51	199	204	195	203	167	151	54
52	200	206	197	205	170	151	54
53	202	207	198	206	172	151	54
54	203	208	200	207	173	151	54
55	204	209	202	208	174	151	54
56	206	210	204	210	175	151	54
57	207	212	207	211	177	151	54
58	209	213	209	212	178	151	55
59	211	215	212	214	178	152	54
60	212	217	215	215	178	152	53
Max Temp	212	217	215	215	178	152	
Max Allowed	381	382	381	381	380	381	

APPENDIX C2

THERMOCOUPLE DATA – HOSE RETEST

Panel Built Inc.
Project No. 16235-117482A
Furnace Interior Temperatures



Time (min)	E119 Std Average (°F)	Furnace Average (°F)	Furnace Probe #1 (°F)	Furnace Probe #2 (°F)	Furnace Probe #3 (°F)	Furnace Probe #4 (°F)	Furnace Probe #5 (°F)	Furnace Probe #6 (°F)
0	68	43	43	43	43	43	43	43
1	254	121	142	178	118	111	150	93
2	441	515	579	647	398	503	721	474
3	627	786	861	878	636	773	917	757
4	814	928	988	1000	799	926	1031	889
5	1000	994	1038	1052	895	999	1079	952
6	1060	1032	1065	1086	959	1039	1106	987
7	1120	1086	1115	1138	1026	1094	1158	1034
8	1180	1151	1174	1201	1100	1158	1220	1102
9	1240	1210	1227	1255	1167	1214	1274	1163
10	1300	1257	1270	1300	1224	1259	1317	1215
11	1328	1295	1305	1335	1269	1295	1349	1257
12	1347	1326	1334	1361	1309	1327	1374	1288
13	1364	1352	1357	1384	1341	1352	1400	1315
14	1381	1375	1377	1406	1362	1374	1424	1341
15	1396	1396	1397	1426	1386	1395	1446	1363
16	1410	1416	1414	1444	1409	1415	1465	1382
17	1424	1429	1428	1457	1427	1427	1476	1398
18	1436	1442	1442	1468	1443	1442	1488	1411
19	1448	1456	1456	1480	1458	1456	1502	1424
20	1459	1464	1465	1485	1468	1466	1504	1431
21	1470	1467	1468	1484	1474	1469	1504	1432
22	1480	1474	1475	1488	1481	1476	1509	1438
23	1490	1486	1486	1501	1492	1488	1523	1451
24	1499	1501	1501	1517	1505	1502	1539	1466
25	1508	1515	1514	1530	1518	1516	1553	1482
26	1517	1528	1525	1543	1530	1530	1566	1490
27	1525	1535	1531	1551	1539	1537	1574	1496
28	1533	1534	1529	1551	1540	1535	1571	1495
29	1541	1535	1528	1552	1542	1535	1571	1496
30	1549	1548	1542	1567	1552	1549	1588	1510

Time (min)	Furnace Probe #7 (°F)	Furnace Probe #8 (°F)	Furnace Probe #9 (°F)	Furnace Probe #10 (°F)	Furnace Probe #11 (°F)	Furnace Probe #12 (°F)	TC #40 (°F)
0	43	43	43	44	42	43	50
1	106	104	165	103	101	83	50
2	498	433	620	466	490	353	51
3	775	791	851	745	814	629	51
4	925	975	955	896	966	785	51
5	998	1046	998	964	1040	864	52
6	1038	1080	1027	1000	1077	922	51
7	1088	1133	1076	1047	1126	996	52
8	1150	1194	1141	1109	1186	1079	52
9	1207	1248	1199	1165	1242	1154	52
10	1253	1292	1244	1213	1286	1215	52
11	1291	1328	1277	1251	1323	1263	52
12	1323	1353	1307	1283	1352	1303	53
13	1350	1372	1334	1312	1372	1338	53
14	1367	1394	1355	1335	1395	1371	53
15	1388	1415	1368	1353	1420	1399	53
16	1408	1435	1386	1367	1442	1422	53
17	1423	1445	1398	1377	1453	1438	53
18	1438	1457	1409	1391	1465	1452	53
19	1453	1472	1423	1404	1480	1468	53
20	1462	1479	1431	1416	1487	1478	53
21	1467	1480	1435	1426	1489	1480	53
22	1475	1486	1443	1436	1495	1487	53
23	1487	1496	1457	1449	1505	1499	53
24	1501	1510	1473	1465	1520	1514	54
25	1515	1522	1487	1480	1533	1528	54
26	1529	1537	1500	1493	1547	1540	54
27	1537	1544	1509	1501	1555	1548	54
28	1536	1543	1508	1502	1554	1549	54
29	1536	1541	1509	1503	1552	1549	54
30	1549	1558	1524	1516	1564	1562	54

APPENDIX D1

PHOTOGRAPHS

The panels were assembled on the ground prior to mounting in the test frame

The panel core was insulated with 2" thick Roxul mineral wool

Close up of panel corner

Intermediate stud within a panel

Gypsum filler installed at a panel connection

Gypsum filler installed at a panel connection

3", 20 GA channel installed around the perimeter

The channel was attached at each stud location with 1-1/2" laminating screws

Panel joint prior to installing cover

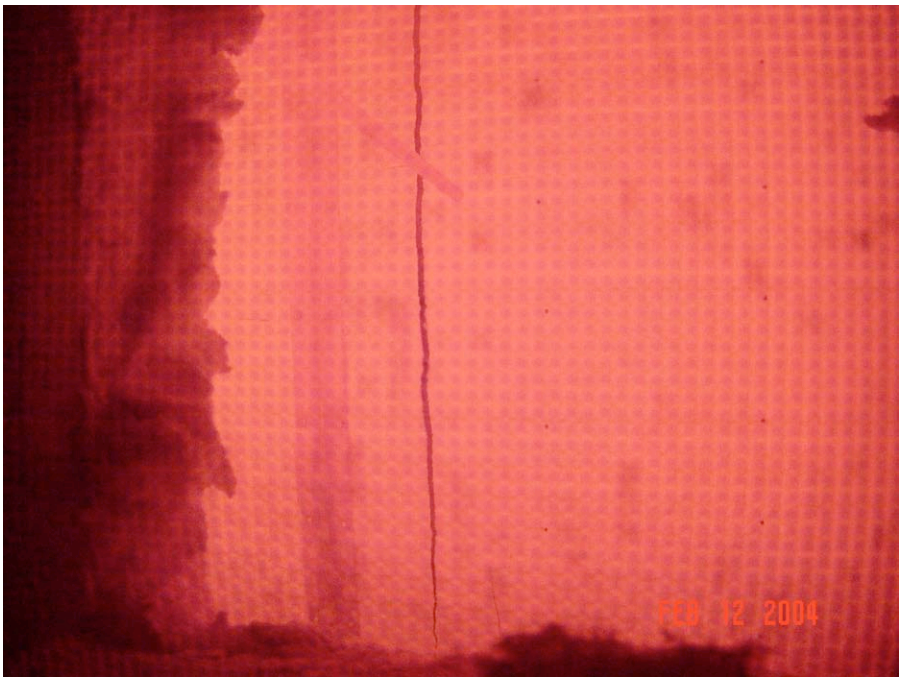
Joint covers installed

The completed wall was then tipped into place in a nonbearing test frame

Exposed surface prior to mounting against the furnace

Start of test

Exposed surface (right side)



Crack formed in the exposed gypsum wallboard

Wall beginning to bow inward

Furnace extinguished after 60 minutes

End of test

Moving the assembly into position for the hose stream test

The hose stream penetrated the wall after 48 seconds, indicating a failure

Exposed face after the hose stream test

Unexposed face after the hose stream test

Unexposed face after the hose stream test

The water stream penetrated the wall in two locations, as shown

APPENDIX D2

PHOTOGRAPHS – HOSE RETEST

Exposed face prior to mounting against the furnace

Start of test

Furnace interior

Furnace interior

Furnace extinguished after 30 minutes

Moving the assembly into position for the hose stream retest

Moving the assembly into position for the hose stream retest

Hose stream retest

Exposed face after the hose stream retest

Unexposed face after the hose stream retest