— Fire Qual. Test 14980-97261
Rev. 0

FIRE ENDURANCE TEST OF A WALL ASSEMBLY CLAD WITH THERMO-LAG® 330-1

— Project No. 14980-97261

FIRE ENDURANCE TEST TO QUALIFY A WALL DESIGN
AS A 60 MINUTE FIRE RESISTANT ASSEMBLY

— November 7, 1994

Prepared For:

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ABSTRACT

A wall assembly consisting of a 3 in. x 3 in. x 3/8 in. steel angle structural frame supporting two layers of (5/8 in. nominal thickness) Thermo-Lag® 330-1 fire protective material (with Thermo-Lag 330-1 Trowel Grade over the steel elements) was tested (with the steel framework towards the fire) in accordance with ASTM E119-88 Fire Tests of Building Construction and Materials and met the requirements for a fire resistance rating of 60 minutes (1h).

The details, procedures and observations reported herein are correct and true within the limits of sound engineering practice. All specimens and test sample assemblies were produced, installed and tested under the surveillance of the testing laboratory's in-house Quality Assurance Program. This report describes the analysis of a distinct assembly and includes descriptions of the test procedure followed, the assembly tested, and all results obtained. All test data are on file and remain available for review by authorized persons.

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INTRODUCTION[1]

"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 43-1
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

[1] American Society for Testing and Materials, 1986 Annual Book of Standards, ASTM E119-88 Standard Methods of FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS.

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assemblies and structural units that constitute permanent integral parts of a finished building.

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."

OBJECTIVE

The objective of this project was to evaluate a specific Thermo-Lag wall construction for use as a 1-hour fire resistive barrier. The entire program was carried out in accordance with the TEST PLAN; *Fire Endurance Tests of a Wall Assembly Protected With The Thermo-Lag® 330-1 Fire Barrier System, Rev. 3*, which may be found in Appendix B of this document. For reasons of clarity and to reduce redundancy, many items discussed in the Test Plan have not been duplicated elsewhere in this document.

TEST PROCEDURE

FIRE 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 39 symmetrically-located natural gas burners designed to allow an even heat flux distribution across the

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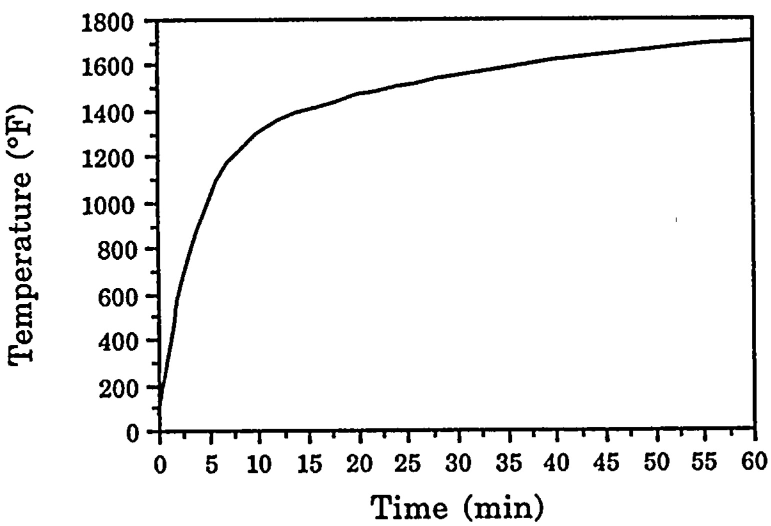
face of a test specimen. Furnace pressures may be maintained at any value from +0.04" W.C. to -0.20" W.C. It must be realized that any full-size vertical fire test furnace will have a pressure difference between the bottom and top of approximately 0.1 in. W.C. after operating temperatures are reached. 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. Many times the furnace pressure will be adjusted so that the "neutral pressure plane" (that where the pressure difference between the furnace interior and the laboratory 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. The neutral pressure plane was positioned at the top of the wall assembly in this test.

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 at least every 30 seconds and displayed for the furnace operator to allow control along the specified temperature curve.

The fire exposure is controlled to conform with the standard time-temperature curve shown in Figure 1, as determined by the table below:

ASTM E119 Time-Temperature Curve



Time (min)	Temperature (°F)
0	68
5	1000
10	1300
15	1399
20	1462
25	1510
30	1550
35	1584
40	1613
45	1638
50	1661
55	1681
60	1700

Figure 1

The fire test is controlled according to the standard time/temperature curve, as indicated by the average temperature obtained from the readings of the furnace interior thermocouples symmetrically located across the specimen, 6 in. away. The thermocouples are enclosed in protection tubes of such material and dimensions that the time constant of the thermocouple assembly lies between 5.0 and 7.2 minutes, as required by the E 119 standard. The furnace 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 the one hour test period.

The furnace pressure was controlled to be as nearly neutral with respect to the surrounding laboratory atmosphere as possible, measured at the top of the test specimen.

THERMOCOUPLES

Temperatures on the unexposed surface of the wall were measured with Type K, 24 GA, Chromel-Alumel electrically welded thermocouples formed from Chromel and Alumel wires of "special limits of error (±1.1°C)," and covered with Teflon® insulation. These thermocouples have a continuous operating capability of around 600°F. Temperatures of unexposed surfaces are monitored using thermocouples placed under 6 in. x 6 in. x 0.4 in. 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 1.0 minute. The temperature on the unexposed surface of a test specimen during the test is taken to be the average value of the qualification thermocouples.

DATA ACQUISITION SYSTEM

The outputs of the test article thermocouples and the furnace probes were monitored by a data acquisition system consisting of a John Fluke Mfg. Co., Model HELIOS 2289A Computer Front End and an Apple Computer Co., Macintosh Classic microcomputer and a 100 input thermocouple jack panel. The Computer Front End is connected to the RS422 Serial Interface Port of the Macintosh. The computer is programmed in Microsoft QuickBASIC to command the HELIOS units to sample the data input lines (from the thermocouple jack panel), receive and convert the data into a digital format, and to manipulate the raw data into usable units for display on screen and paper and for saving to magnetic hard disk.

HOSE STREAM TEST[1]

"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 $2\frac{1}{2}$-in. (64-mm) hose discharging through a National Standard Play pipe of corresponding size equipped with a $1\frac{1}{8}$-in. (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/100 ft^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 if less than 1-1/2 h	30 (207)	1
Less than 1 h, if desired	30 (207)	1

1 American Society for Testing and Materials, 1986 Annual Book of Standards, ASTM E119-88 Standard Methods of FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS.

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."

BARRIER INSPECTION

Following the fire exposure and each hose stream test, all barrier materials, joints and seams were visually inspected for burnthrough or openings in the barrier in accordance with the acceptance criteria outlined in the Test Plan.

TEST ASSEMBLY

TEST WALL

Structural Steel Elements

The framework for the test wall assembly consisted of a matrix of 3 in. x 3 in. x 3/8 in. steel angle including seismic bracing angles. Where two angle flanges met back to back, they were welded continuously along their flat sides (the unexposed face of the wall) with nominal 3/16 in. fillet welds. One section of the test wall contained a 24 in x 24 in. framed opening through which passed a 23-7/8 in. x 16 in. steel duct section (formed of 1/4 in. thick steel sections, continuously welded along the edges) at a 45° angle to the plane of the wall.

To allow for attachment of the Thermo-Lag® Board materials to the wall framework, 5/16 in. diameter holes were drilled through the flanges of the steel angle 12 in. o.c. along each run of angle. Bolts (1/4 in. diameter x 2-1/2 in. long) were placed through each hole with the threaded ends protruding on the unexposed face of the wall and the hex heads were tack-welded to the flange of the steel angle. Installed as such, the bolts provided a perimeter fastening means for each Thermo-Lag® panel. Exact locations of the fasteners and steel angle sections are contained in drawing in Appendix A. After assembly and welding, the steel was primed with Thermo-Lag® 351 Primer.

Thermo-Lag® 330-1 Materials

Thermo-Lag® materials were supplied by Florida Power & Light and were representative of materials installed in the field. Each one-hour rated Thermo-Lag® 330-1 V-ribbed panel is 5/8 in. thick nominal x 48 in. wide x 78 in. long, with stress skin monolithically adhered to the panel on one face. The stress skin was

installed on the V-ribbed surface of the panels. Thermo-Lag® 330-1 trowel grade subliming compound was also supplied to be used with 330-1 panels. All Thermo-Lag® panels were measured, saw cut and installed onto the respective test assembly by Peak Seals craft personnel. Installations were inspected by Peak Seals quality control inspectors. Details of the Thermo-Lag® installation are illustrated in Appendix J.

Other Materials

Materials used in conjunction with Thermo-Lag® components, or for penetration seals included: Silicone elastomer (Promatec 45B) seal material, Dow Corning 96081 caulk and Thermal Ceramic Kaowool M-Board (ceramic fiber damming board) and 1/2 in. wide x 0.020 in. thick type 304 stainless steel rolled-edge banding straps with wing seals. These materials were all supplied by Peak Seals, Inc., Houston, Texas.

THERMOCOUPLE PLACEMENT

For assessment of the performance of the wall system, only the following thermocouples (#1-18) will be considered:

> 24 gauge, Type K, Chromel-Alumel electrically welded thermocouples (Special Limits of Error: ± 1.1°C, purchased with lot traceability and calibration certifications) with Teflon® insulation were attached at not less than nine points on the unexposed surface of the test wall. Five of these were symmetrically disposed, with one at the approximate center of the specimen (TC #9), and four at the approximate centers of its quarter sections (TC #4-5, 13-14). None of the thermocouples were located within 12 in. of the edges of the test specimen or over fasteners. All nine thermocouples were placed under flexible pads (Ceraform 126, manufactured by Manville Specialty Products, 6±1/8 in. x 6±1/8 in. x 0.375±0.05 in. thick, all other details being as described in the E814 standard) held firmly against the surface and fit closely about the thermocouple. Additional thermocouples were located near the geometric center of each panel of Thermo-Lag® 330-1 and were covered with similar pads (TC #1-3, 6, 8, 10, 12, 15-18). Two thermocouples were located at a panel-to-panel interfaces and were covered with a pad as described above (TC #7, 11).

Additional thermocouples were installed for information only and designated as engineering thermocouples. The description of placement of these additional engineering thermocouples follows:

> Four thermocouples were attached to the unexposed face of the steel angle iron structure and were covered with Thermo-Lag® materials (TC #19-22). Five thermocouples were placed directly over panel-to-panel interfaces (TC #23-27)

and were covered with pads similar to those described above (note: the pads covering these thermocouples were notched into an hourglass shape to allow clearance for the mounds of Thermo-Lag® 330-1 Trowel Grade used to cover the material mounting studs). One thermocouple was placed on the unexposed face of the Thermo-Lag® board, 1" from the penetrating duct and was covered with a 2 in. x 2 in. pad of the construction noted previously (TC #28).

A drawing showing the exact placement of all thermocouples may be found in Appendix C.

THERMO-LAG® INSTALLATION HIGHLIGHTS

Application Methods

Thermo-Lag® 330-1, 5/8 in. nominal thickness panels were pre-cut to fit steel framing for the wall. The V-ribs on the panels were flattened prior to installation. Pieces were installed on the framing with two panels back to back, with stress skin facing out on both sides. Panels were fit over 1/4 in. diameter bolts which were welded to the 3 in. x 3 in. x 3/8 in. steel angles. Panels were attached with 1-1/2 in. o.d. and 1/4 in. i.d. washers and 1/4 in. nuts, tightened prior to post-buttering of joints. Following panel installation, trowel grade material was installed over bolts and washers and on structural steel on the exposed side of the fire wall. Several layers of trowel grade installation were required to develop the 0.786 in. dry film thickness. A double layer of 5/8 in. thick Thermo-Lag® 330-1 Panels were also installed on the outside of the duct penetration for a 9 in. distance from each wall face. The first layer was installed and post-buttered prior to the installation and post-buttering of the second layer. The panels were attached with stainless steel bands and tie-wire. For details and installation notes, see Appendix J "Thermo-Lag® Installation Details."

Duct Fireseal Installation

As part of the wall test, a penetration seal was installed internally in the duct. This seal performance and qualification was not part of this fire test. The penetration seal installation consisted of a 6 in. thick Promatec silicone elastomer seal (45B) centered in the duct at the wall location. The remaining duct internal volume was filled with Kaowool ceramic fiber and the ends of the duct were capped with M-board, held in place with Dow Corning 96081 Caulk and stainless steel tie-wire.

TEST RESULTS

The completed test specimen was installed against the Laboratory's vertical fire test furnace located on the Laboratory's grounds at 16015 Shady Falls Road, Elmendorf, Texas 78112, on September 14, 1994. The thermocouples were then connected to the data acquisition system and their outputs verified. The test was conducted by Herbert W. Stansberry II, with the following persons present:

Pat Madden	-	USNRC
Chuck Fisher	-	FP&L
Rick Dible	-	VECTRA
Cal Banning	-	VECTRA
Bud Auvil	-	VECTRA
Emmett Roan	-	Entergy
Biff Bradley	-	NEI
John Lenaghan	-	IES Utilities
Craig Narhi	-	IES Utilities
Roger Sims	-	CP&L
Steve Hardy	-	CP&L
Rich Lohman	-	TSI
Ralph Block	-	Promatec
Pat Mangan	-	AEP
Kent Brown	-	TVA
JJ Pierce	-	TVA
John Nicholas	-	Arcon
Randy Hemsley	-	Arcon
Randy Brown	-	Peak Seals
Deggary N. Priest	-	Omega Point Laboratories, Inc.
Kerry Hitchcock	-	Omega Point Laboratories, Inc.
Connie Humphry	-	Omega Point Laboratories, Inc.
Cleda Patton	-	Omega Point Laboratories, Inc.
Richard Beasley	-	Omega Point Laboratories, Inc.
Laudencio Castanon	-	Omega Point Laboratories, Inc.

The furnace was fired and the ASTM E119 standard 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 (placing the neutral pressure plane at the top of the furnace).

TIME (min:sec)	OBSERVATION
0:00	Furnace was fired at 9:11 a.m.
1:00	Discoloration of material along edges of penetrating duct and along edges of the steel angle flanges.
2:25	Ignition of the exposed face of the test wall.
12:00	Cracks forming on exposed face of wall at interfaces between angle flanges and wall panels.
36:31	Cracks forming in char layer across the exposed face of the test wall.
37:45	Cracks widening at angle flange to wall panel interfaces.
52:45	Cracks forming across stress skin on exposed face of test wall.
60:00	Furnace extinguished; sample prepared for hose stream tests.

After removal from the test furnace the condition of the test wall was noted as follows: All panels and trowel grade material were intact, several cracks existed in the outer char layer both along and across the steel angles, the stress skin on the exposed face of the test wall had separated from the panels, the damming material in the penetrating duct was discolored and some of the perimeter caulking had become dislodged.

The test wall was positioned for the hose stream test and was subjected to the cooling and erosion effects of the water stream for a period of 60 seconds. The water stream was delivered from a standard play pipe nozzle at a pressure of 30 psi from a distance of 20 feet. Following the hose stream test, slight traces of moisture leakage were noted at some panel to panel interfaces on the unexposed face of the test wall. Bare steel edges of angle flanges were exposed in several spots across the test wall. Trowel grade material was intact and secure on the steel angle (with the excepts noted previously). The stress skin on the exposed face of the panels was torn free of the sample in places. The layer of ceramic damming board exposed to the fire was dislodged by the hose stream and portions of the ceramic blanket within the duct also became dislodged. The elastomer seal had suffered no apparent damage.

After approximately one and one-half hours the decision was made to perform a second hose stream test for a time period of 90 seconds following the same parameters as the previous test. The condition of the test wall remained largely unchanged after the second hose stream test. Slight additional leakage was noted approximately 16 in. below thermocouple #25 on the unexposed face of the test wall. No holes or breeches in the barrier system were generated by either hose stream test and no projection of water through the test sample were discovered during the exposures.

During the post-test disassembly of the test wall the following observations were noted concerning the sample condition:

Approximately 3/16 in. to 1/4 in. of uncharred material remained in the exposed layer of Thermo-Lag® panels.

The second (unexposed side) layer of Thermo-Lag® remained completely uncharred throughout the surface of the test wall.

Material behind the steel angle flanges was completely intact and uncharred.

Approximately 1/4 in. of uncharred trowel grade material remained on the steel angle flange surfaces and approximately 3/8 in. of uncharred trowel grade material remained along the angle fillets.

During cross-section investigation of panel condition, several blisters within the Thermo-Lag® panels were noted in the area of thermocouple #14, which could be attributed to incomplete activation of the Thermo-Lag® material.

The significant temperatures for the test wall at the end of the fire exposure test are presented in the table below.

TC NO.	TEMP AT END OF TEST (°F)	TC NO.	TEMP AT END OF TEST (°F)
1	191	15	158
2	201	16	186
3	197	17	195
4	195	18	195
5	175	19*	230*
6	185	20*	220*
7	100	21*	229*
8	176	22*	213*
9	176	23*	119*
10	210	24*	120*
11	99	25*	101*
12	186	26*	102*
13	203	27*	125*
14	204	28*	100*
		Average	180

NOTE: Numbers with asterisks (*) indicate engineering-use-only thermocouples and are not considered in the average or in the performance evaluation of the test wall.

All data may be found in the Appendices attached to this document.

CONCLUSIONS

The test wall successfully withstood the fire endurance test without passage of flame or excessive heat and the barrier system was sufficient to prevent temperature rises on the unexposed face of the wall from exceeding 325°F on individual point and 250°F on average. The average temperature increase at the end of the 60 minute fire exposure period was 102°F and the largest individual temperature increase was 132°F. The wall system also maintained integrity after a solid stream hose stream test with a combined total exposure time of 2-1/2 minutes.