Fire Qual Test 14980-97668
Rev. C

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

Project No. 14980-97668

FIRE ENDURANCE TEST TO QUALIFY A CP&L CEILING DESIGN AS A 180 MINUTE FIRE RESISTANT ASSEMBLY

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Prepared For:

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ABSTRACT

A ceiling assembly consisting of a 3 in. x 3 in. x 1/4 in. steel angle structural frame supporting expanded metal panels, protected with Thermo-Lag 330-1 fire protective material, was tested in accordance with ASTM E119-88 Fire Tests of Building Construction and Materials and met the requirements for a fire resistance rating of 180 minutes (3h).

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 QC surveillance of either Peak Seals, Inc. or 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.

Herbert W. Stansberry II, Fire Test Technologist	5/30/95 Date
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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.

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 ceiling construction for use as a 3-hour fire resistive barrier. The entire program was carried out in accordance with the TEST PLAN; *IES Utilities Fire Endurance Tests of Thermo-Lag® of Steel Beams & Ceiling Assemblies, Rev. 5,* 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

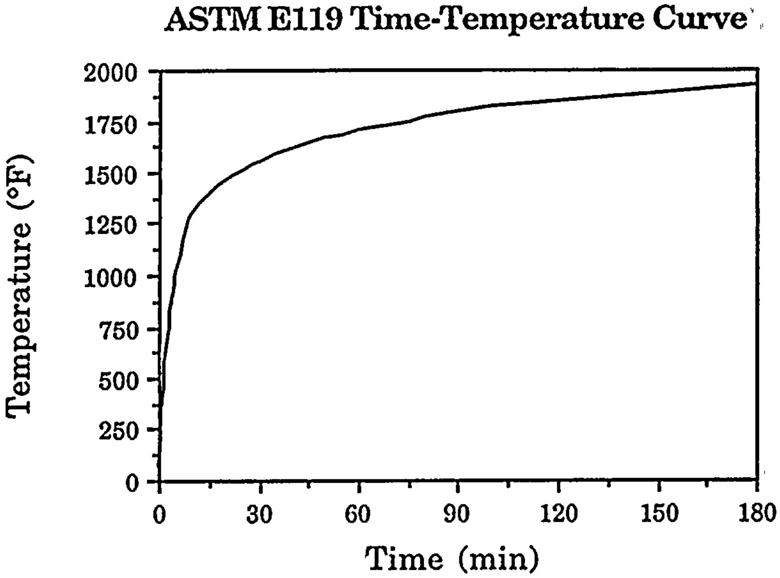
This entire test program was performed in accordance with VECTRA Technologies' TEST PLAN, Rev. 5, which has been included in Appendix B. Many of the specific details of this project will be found in that document.

FIRE TEST FURNACE

The 12' x 18' x 7' deep horizontal test furnace is designed to allow the test specimen to be uniformly exposed to the specified time-temperature conditions. It is fitted with 12 symmetrically-located premixed propane/air gas burners, located 6 feet below the top ledge of the furnace, and designed to allow an even heat flux distribution across the under surface of a horizontal test specimen. Furnace pressures may be maintained at any value from +0.5" W.C. to -0.05" W.C. at the exposed surface of the test article. The burners, when fully fired, will deliver 20 MBtu/hr total heat input. The furnace consists of a structural steel frame, lined with sheet metal and insulated with a six inch thick layer of ceramic fiber. One wall of the furnace contains a personnel door to allow access to the inside with the test article in place.

The temperature within the furnace is determined to be the mathematical average of thermocouples located symmetrically within the furnace and positioned twelve inches away from the exposed 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 monitored at least every 15 seconds and displayed for the furnace operator to allow control along the specified temperature curve. A paper printout of the data is produced every 30 seconds, and all data is saved to hard disk at intervals of once per minute unless more often is requested.

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



Time (min)	Temperature (°F)
0	68
5	1000
10	1300
20	1462
30	1550
45	1638
60	1700
90	1792
120	1850
180	1925

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.

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

THERMOCOUPLES

Temperatures on the unexposed surface of the ceiling 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 all nine thermocouples.

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

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, a 100 input thermocouple jack panel and voltage input terminal strips. 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.

TEST ASSEMBLY

CAROLINA POWER & LIGHT TEST CEILING

Structural Steel Elements

The framework for the test ceiling assembly consisted of a welded matrix of 3 in. x 3 in. x 1/4 in. steel angle. On the perimeter angle, the flats faced toward the furnace with the flanges facing upwards. The end angle were cut to 69 in. and the flanges were oriented toward the center of the ceiling assembly. The long side angles were cut to 156 in. and the flanges were both oriented toward the rear of the ceiling assembly. Cross angles were then cut to 67 in. and welded across the short dimension of the ceiling (between the front and rear long angles). The cross angles did not extend the full width of the assembly, but were set in 1 in. from the front and the rear of the ceiling. The flanges of the cross angles were all oriented toward the right side of the ceiling and all faced toward the furnace. Sections of expanded metal (ASTM A-36, 1.14 lb. per sq. ft., Diamond Pattern, MIL-M-17194C, 1/4 in. thick, #18) were cut and welded on top of the perimeter angle and between each pair of cross angles. Lengths of steel angle (12 in. long) were then welded to the short ends of the ceiling assembly to facilitate transporting the assembly and supporting it on the furnace. The entire framework was then cleaned and primed with Thermo-Lag® 351 solvent based Steel Primer.

Drawings showing the details of the steel framing may be found in Appendix A.

Thermo-Lag® 330-1 Materials

Thermo-Lag® materials were supplied by Thermal Science, Inc. (TSI), St. Louis, MO. The Thermo-Lag® materials were representative of materials installed in the field. Materials supplied by TSI were 330-69 Stress Skin sheets 4 ft. x 7 ft., 330-1 Subliming Trowel Grade Material and 351 Steel Primer. All Thermo-Lag® panels were field fabricated from trowel grade material and stress skin, and installed onto the respective test assembly by Peak Seals craft personnel using approved VECTRA drawings, procedures and specifications. Installations were inspected by Peak Seals, Inc. certified quality control inspectors.

Other Materials

Other commercial grade products used were: 1/4 in. diameter x 2 in. long A-307 Bolts, 1/4 in. diameter A-307 nuts and 1/4 in. id x 1-1/2 in. o.d. oversized steel washers. These materials, and the steel framework materials, were purchased by Omega Point Laboratories, Inc.

THERMOCOUPLE PLACEMENT

For assessment of the ceiling assembly, 24 gauge, Type K, Chromel-Alumel electrically welded thermocouples (Special Limits of Error: ± 1.1°C, purchased with lot traceability and calibration certifications) were attached at not less than nine points (TC #1-9) on the unexposed surface of the test ceiling. Five of these were located along the longitudinal centerline of the ceiling assembly. 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 ASTM E119 standard) held firmly against the surface and fixed closely about the thermocouple.

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

THERMO-LAG® INSTALLATION HIGHLIGHTS

Application Methods

The Thermo-Lag panels used to protect the ceiling assembly were field fabricated using 330-69 Stress Skin and 330-1 Trowel Grade Material. Three panels 30 in. wide x 69 in. long and two panels 27 in. wide x 69 in. long were fabricated by troweling a total dry film thickness of 1/2+1/8,-0 in. of Trowel Grade material onto pre-cut sheet of Stress Skin in several layers, each not exceeding 1/4 in. thickness. The panels were allowed to dry overnight between layers.

Trowel Grade material was applied to the stress skin side of the fabricated panels in a layer 3/8 in. thick and to the expanded metal in a layer 1/8 in. thick prior to installation of the panels. The panels were secured to the ceiling assembly with bolts washers and nuts. Bolt locations may be found on drawings in Appendix A and J. After installation of the panels on the bottom (exposed) side of the ceiling assembly, a 1/2 in. thick layer of trowel grade material was applied to the top of the expanded metal surface and allowed to dry. The bolts, washers and nuts on the exposed side of the panels were covered with a minimum thickness of 1 in. of trowel grade material. Once the top 1/2 in. layer above the expanded metal was allowed to dry, a skim coat of trowel grade material, to compensate for shrinkage, and stress skin was applied above the top 1/2 in. thick layer.

The exposed steel was covered with a 0.75±0.06 in. layer of trowel grade material. The final thickness was achieved with several thinner layers of material, with drying time allowed between layers.

TEST RESULTS

The completed test specimen was placed on the Laboratory's large horizontal fire test furnace, located on the Laboratory's grounds at 16015 Shady Falls Road, Elmendorf, Texas 78112, on January 26, 1995. Two other test articles were simultaneous evaluated but will but reported on under separate cover. The thermocouples were connected to the data acquisition system and their outputs verified. The test was conducted by Herbert W. Stansberry II, project manager, with the following persons present:

Cal Banning	-	VECTRA
Tom Lenaghan	-	IES
Craig Narshi	-	IES
Bruce Gerwie	-	AEP
Roger Sims	-	CP&L

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Steve Hardy	-	CP&L
Rich Lohman	-	TSI
Randy Brown	-	Peak Seals
Alex Ringel	-	Promat
Todd Griesemer	-	Promat
Deggary N. Priest	-	Omega Point Laboratories, Inc.
Kerry Hitchcock	-	Omega Point Laboratories, Inc.
Connie Humphrey	-	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 180 minutes. The pressure differential between the laboratory surrounding the furnace and the exposed portion of the specimen was maintained at approximately 0.00 in. water column throughout the test.

TIME (min:sec)	OBSERVATION
0:00	Furnace was fired at 11:38 a.m.
0:33	The exposed side of the test item was beginning to turn brown.
0:55	The ceiling assembly had ignited fairly uniformly across the exposed surfaces.
27:09	The exposed side of the ceiling assembly began sagging.
87:33	The sagging had worsened and cracks began appearing around the perimeter.
130:00	The ceiling assembly was sagging approximately 4 in. in the center of the exposed side.
173:05	The seams between panels on the unexposed side began opening and the exposed face sagging had increased to approximately 6 in. Cotton waste was applied to the opening seams, but did not ignite or char due to migration of hot gases.
180:00	Test completed; furnace extinguished. Test sample was removed from furnace for inspection.

Due to the order of removal of the three test specimens, the assembly remained on the furnace for approximately 15 minutes following the test. A small hose was used to extinguish any small amount of flaming that was present upon removal of the specimen from the furnace. The exposed surface of the test item was covered with a layer of black ash.

During the post-test disassembly of the ceiling assembly, the following observations were noted concerning the sample condition:

> The unexposed side of the ceiling was discolored and darkened at the locations of the cross angles. The seams between panels on the unexposed face of the sample were separated, but did not constitute through openings to the exposed side. Between 1/4 in. and 3/8 in. of uncharred material was in place on the unexposed face of the sample, with the top 1/4 in. of material still pliable. Approximately 1/4 in. depth of char existed below this (above the expanded metal). At bolt locations, no difference was noted in the barrier condition as compared to the field. Material was fully charred under the pad covering thermocouple No. 2 and at the cross angle locations. No material remained uncharred on the exposed face of the ceiling assembly. Char depths of approximately 2 in. were measured on the exposed face of the assembly.

The significant temperatures on the unexposed surface of the ceiling assembly 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	183	6	184
2	355	7	190
3	287	8	187
4	204	9	191
5	208	Avg.	221

The average initial temperature for all thermocouples at the start of the test was 64°F, yielding an allowable temperature increase of 250°F, or 314°F actual for the average temperatures. (A 325°F increase above the 64°F initial temperature yields a maximum allowable individual temperature of 389°F, in accordance with ASTM E119-88.) All of the thermocouples on the unexposed face of the test ceiling met the stated acceptance criteria for a fire endurance rating of three hours (180 minutes).

During the course of the fire exposure, a computer error necessitated changing the data acquisition system. The thermocouple inputs were removed from the original system and connected to the replacement system one at a time to reduce the chance of lost data. After completion of the test, the cause of the computer error was traced, allowing the original data to be recovered. The data presented in Appendix D is the amalgamation of these two data files (no data was lost during the conversion).

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CONCLUSIONS

The horizontal ceiling assembly clad in Thermo-Lag® 330-1 material as described herein, met the requirements of the TEST PLAN for a fire resistance rating of three hours. The acceptance criteria required is that described in ASTM E119. The fire barrier system installed onto the ceiling assembly met these criteria as the following conditions were met: The ceiling withstood the fire endurance test without passage of flame or gases hot enough the ignite cotton waste, for a period of three hours; the average temperature of all nine unexposed surface thermocouples did not exceed 250°F above the average initial temperature; and the maximum reading for any single thermocouple did not exceed a temperature rise of 325°F above its initial temperature.