NATIONAL BUREAU OF STANDARDS REPORT

10 469

EVALUATION OF THE FIRE PERFORMANCE OF SANDWICH PANEL USED IN THE MARK III PREFABRICATED LEWIS BUILDING

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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EVALUATION OF THE FIRE PERFORMANCE OF SANDWICH PANEL USED IN THE MARK III PREFABRICATED LEWIS BUILDING

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ABSTRACT

Results of laboratory tests to evaluate the fire performance of an aluminum/paper honeycomb structural sandwich panel building are presented. Smoke generation, surface flammability and flame penetration measurements are summarized. It is concluded that the panel may be limited in its ability to prevent flamethrough under severe fire exposure, but is considered safe from the standpoint of spread of flame along exposed surfaces.

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1.0 INTRODUCTION

At the request of the Naval Civil Engineering Laboratories, Port Hueneme, California, an evaluation was undertaken of a structural sandwich panel building, designated as a "Relocatable Lewis Building." The work was performed under contract and NCEL Project No. PO-9003 dated 27 March 1969 and this report covers fire studies on the Mark III panels.

In the evaluation of the fire performance of exterior walls, consideration is usually given to both life safety and property damage. From the standpoint of life safety alone, the most important characteristics are:

Smoke and Toxic Products
Surface Flammability
Structural Stability
Flame Penetration

While it is not possible to relate any of these characteristics directly and quantitatively to a life hazard under all use conditions, comparative test methods now exist or can be adapted for the measurement of these properties. Smoke generation, surface flammability and flame penetration can be determined with relative ease using small-scale specimens. The properties of joints, fasteners or other critical elements, can sometimes also be evaluated on laboratory-size samples. However, a complete evaluation of the structural stability of a building element under fire exposure, usually requires testing on full-size panels or assemblies.

The most common test method for evaluating the fire performance of large-size walls (also floors, roofs, bemas, columns) is the standard fire endurance test, ASTM E119. This test measures the time period during which the test construction continues to act as a fire barrier and during which a structural member when subjected to the full design load, will continue to function. The fire exposure represents the complete burnout of combustibles within the enclosing room, and the purpose of the test is to provide a time rating for officials concerned primarily with protection of property.

In some cases, there is little justification for evaluating constructions according to the standard fire endurance test. In one or two-room, single-story buildings provided with suitable exits, and other life safety controls, and where the occupancy or combustible fire load is unusually light, the fire endurance test may not be appropriate. On the other hand, where light-weight panels are to serve as structural members, it is important to ensure that structural failure and/or flame penetration will not occur from a relatively small fire, where the life safety of occupants is not otherwise threatened.

Metal-skin sandwich panels with paper or plastic cores may be particularly susceptible to the effects of relatively minor or incidental fires. With light gage steel, or aluminum (melting point 660°C, 1220°F), serving as the structural skin, a localized failure could result with fairly moderate temperatures (700 to 1200°F). Knowledge of the characteristics and effects of incidental (e.g. wastebasket or trash) fires on light-weight sandwich panels represents an important aspect of this evaluation.

Several ad hoc fire tests have been performed on light-weight insulated panels in the past. Approximately 6 to 8 years ago, the Factory Mutual laboratories employed a "corner test" to evaluate the performance of polyurethane insulated corrugated steel panels typical of those used in industrial steel-framed buildings. The fire exposure consisted of burning wood pallets placed 1 foot away from each wall, and observations were made of the spread of flames and the burning of the unprotected polyurethane foam insulation.

Two years ago, Underwriters' Laboratories, Inc. performed an investigation on insulated wall panels, also based on a large-scale corner test with wood crib fire exposure. The objective of the test was to measure the ability of the panels to resist the spread of flame and to limit damage of the panels sufficient to require replacement. The ability of the panels to withstand structural failure while loaded, and to ensure life safety under relatively light fire exposure conditions, were not considerations in these tests.

In the present study, measurements were made of surface flammability, smoke generation, and the effects of flame on the aluminum skin surface, on the paper honeycomb core and on the extruded joints of the prefabricated building panels. A full-scale fire endurance test was performed to indicate the maximum limit of such panels in conventional fire endurance terms. Tests planned to examine the structural sensitivity of the panels to incidental fires, could not be accomplished within the project budget.

The results of the tests performed are comparative, although no parallel study was made of alternate systems, e.g. Quonset hut, "Butler" building, etc. In addition, no judgments were made (or should be inferred) with regard to building separation, exit provisions, compartmentation, or other fire-safe features of buildings constructed from these panels.

2.0 MATERIALS

The sandwich panels for the Mark III Prefabricated Relocatable Lewis Building were composed of adhesive-laminated aluminum skins with a paper honeycomb core. The aluminum skins were 0.024 inch thick, stucco embossed and prefinished in white paint. The core was compressed phenolic-impregnated (nominal 11 percent), kraft paper honeycomb (cell size 3/4 inch), with the paper "ribbons" parallel to the panel width.

The adhesive was synthetic rubber.

The unit weight of a panel, normally 4 feet by 8 feet or 4 feet by 14 feet, was 1.18 lb/ft^2. The paper honeycomb was exposed along the panel edges. For assembly of the panels into a wall, extruded rigid vinyl "locking cleats" were used.

3.0 TEST METHODS

3.1 Flame Spread (ASTM E162)

Flame spread was measured using the radiant panel apparatus [1]. In this test, a 6" x 18" specimen is mounted in a holder which is placed at an angle of 30° with respect to the vertically mounted radiant panel. The energy output of the panel was controlled so that it was equal to the output of a blackbody of the same dimensions operating at 670°C.

A small pilot flame impinges near the top of the specimen and the times for the flame front to travel in three inch increments (t_3, t_6, t_9, t_{12}, t_{15}) is recorded. In all cases the test ended when the flame front traversed the whole length of the specimen, or after 15 minutes exposure time, whichever was shorter. The temperature rise is measured by thermocouples placed in the stack above the specimen.

The flame spread index, I_s, is calculated using the equation $I_s = F_sQ$, where Q is the heat evolved and F_s is the flame spread factor: $F_s = 1 + 1/(t_6 - t_3) + 1/(t_9 - t_6) + 1/(t_{12} - t_9) + 1/(t_{15} - t_{12})$. The heat evolved is proportional to the observed maximum temperature rise of the stack thermocouples.

3.2 Smoke Accumulation

The smoke produced during the burning of test specimens was collected and measured photometrically, employing a laboratory test method developed for the purpose [2]. The test utilizes a closed chamber of 18 cu. ft. volume containing an electrically heated furnace which provides an irradiance of 2.5 watts per sq. cm. (2.2 Btu/sec. sq. ft.) on the surface of a nominal 3 inch square specimen. The method assumes the applicability of Bouguer's law to the attenuation of light by smoke, and smoke quantity is therefore reported in terms of optical density rather than light absorptance. Optical density is the single measurement most characteristic of a "quantity of smoke" with regard to visual obscuration.

To take into account the optical path length, L the volume, V, and the specimen surface area producing smoke, A, a specific optical density is defined as $D_s = V/LA(\log_{10} 100/T)$, where T is the percent light transmittance. Thus, for a selected exposure in the test chamber, and within certain limitations, a single test permits rough extrapolation to surface areas and to chamber volumes of other size.

3.3 Flame Penetration

Each test specimen measuring 36" x 36" was subjected to heat and flame impingement from a vertically oriented gas burner centrally located below the horizontally mounted specimen. The test apparatus is fully described in paragraph 4.3.3 "Flame-Resistance Tests" of Federal Specification SS-A-118b, "Acoustical Units, Prefabricated." The flame was controlled to duplicate the prescribed time-temperature exposure in standard fire endurance tests (1000°F at 5 min., 1300°F at 10 min., 1550°F at 30 min.), as indicated by a thermocouple located 1 inch below the lower surface of the specimen. The available equipment was utilized as a convenient and economical means for evaluating resistance to flame penetration from a fairly severe but localized flame. It is not to be considered as equivalent or comparable to the standard fire endurance test in which the exposing fire is applied to an entire wall surface measuring not less than 100 sq. ft. in area.

Thermocouples were placed at several locations within the wall structure and on the unexposed upper surface to indicate the progressive temperature increase. The unexposed surface thermocouple was placed centrally and covered with an asbestos pad conforming to the specifications prescribed in the standard fire endurance test. Visual observations were also made, such as the time of occurrence and extent of flaming in the core.

3.4 Full Scale Test (ASTM E119)

In the full scale test, a wall of at least 100 sq. ft. area is placed in front of a furnace and exposed to the standard time-temperature curve [3]. The wall was assembled from four 4 ft. by 8 ft. panels, making a 16 ft. wall, 8 ft. high.

The controlled time-temperature curve is determined by the following points:

1000° F (538° C)........at 5 min.
1300° F (704° C)........at 10 min.
1550° F (843° C)........at 30 min.
1700° F (927° C)........at 1 hr.
1850° F (1010° C).......at 2 hrs.
2000° F (1093° C).......at 4 hrs.
2300° F (1260° C).......at 8 or more hrs.

The furnace temperature was measured by 12 thermocouples protected by heavy steel pipes and placed 6 inches from the exposed side of the wall so that they did not touch the wall during the test.

The panel fails (a) when it can no longer support the load, (b) when the unexposed surface temperature rises more than 250 degrees F (139 degrees C) average or 325 degrees F (181 degrees C) single point, or (c) when flames or gases hot enough to ignite cotton waste pass through the wall within the specified time of acceptance (i.e. -- the rating of the panel -- 1/2 hr., 1 hr., etc.).

The furnace temperatures should be read at intervals of 5 minutes or less for any test that does not exceed 2 hours. The accuracy of the furnace control should be such that the area under the time-temperature curve is within 10 percent of the corresponding area under the standard curve.

The temperature of the unexposed surface of the panel was measured by 12 thermocouples under asbestos pads arranged as shown in Fig. 1.

4.0 TEST RESULTS

4.1 Flame Spread

Charring, blistering, and peeling occurred on the aluminum exterior surface and the core behind the exposed area was severely burned. However, no flaming occurred either with or without the joint. The paper honeycomb ignited readily and flames travelled the full 18" length in less than 1 1/2 minutes. The results are given in Table I.

TABLE I

Test Results

Material	Flame Spread Index, I_s	Maximum Smoke, D_m
Aluminum surface, without joint	0	73
Aluminum surface, with joint	0	198
Paper Honeycomb core	174	55
Core/joint section		706

4.2 Smoke Accumulation

The smoke was measured under flaming exposure conditions and the results are given in Table I.

4.3 Flame Penetration

As previously mentioned, it did not take long for the aluminum skin to melt. By the very nature of the test, the exposing flame temperature is required to surpass the melting point within 10 minutes. The observations of the test were as follows:

Event	Panel Without Joint #1	#3	Panel with Joint #2	#4
Test duration, min.	20	18	29	30
Flamethrough exposed surface, min.	16	16	27	28
250°F temp rise in core, min.	6	5	8	6
250°F temp rise, unexposed surface, min.	13	13	11	11

4.4 Full Scale Test

Even more than in the flame penetration test, melting of the aluminum played an important part in the early failure in this test, in which a structural load of 200 lb/ft was applied.

After only one minute, the exposed face of the panel had melted. Flames penetrated to the unexposed side at 3 min. 15 sec. and the panel could not support the load after 4 minutes. Surface temperature failure occurred shortly after 3 minutes. The panel also gave off very dense smoke, starting at 1 1/4 minutes. The test observations were as follows:

Time	Observation
0 min. 30 sec.	Panel beginning to darken
0 min. 45 sec.	Increased separation between joints
1 min. 10 sec.	Deflection 1 1/16 in.
1 min. 15 sec.	Dense smoke from upper joints - much decreased visibility
2 min.	Vibration of the panel. Deflection 1 15/16 in.
3 min. 15 sec.	Deflection 3 1/16 in.
3 min. 30 sec.	Flames visible through center joint
3 min. 35 sec.	Flamethrough - upper part of center joint
4 min.	Load failure
4 min. 45 sec.	Gas off - flames extending several feet beyond panel face
10 min.	Continued smoldering and charring on exposed surface
15 min.	Panel removed - honeycomb still glowing in several places

See Fig. 2 for the graph of the furnace time-temperature curve and Fig. 3 for graphs of the average and maximum temperatures on the unexposed surface. Figures 4 and 5 show the panel prior to and after tests, respectively.

5.0 DISCUSSION

Table II lists flame spread, smoke generation, and flame (heat) penetration data on other types of walls for comparison.

The Mark III structural sandwich panel is considered safe from the standpoint of the spread of flame along its exposed aluminum surfaces. However, the combustible paper honeycomb and the extruded vinyl cleats represent potential sources of heavy smoke development under fire exposure.

In addition, the panel is limited in its ability to prevent flame-through under severe fire exposure. A localized severe fire may be expected to flame through in approximately 15 minutes, while an extended area severe fire would result in flame through in about 3 1/2 minutes and in catastrophic failure of a loaded wall in less than 5 minutes.

The effect on a loaded wall of a small incidental fire, representing a more limited accidental fire exposure, was not examined.

6.0 REFERENCES

[1] 1970 Annual Book of ASTM Standards, Part 14, pp. 500-511, "Standard Method of Test for Surface Flammability of Materials Using a Radiant Heat Energy Source," ASTM E162-67.

[2] Gross, D., Loftus, J. J., and Robertson, A. F., "Method for Measuring Smoke from Burning Materials," ASTM Special Technical Publication STP 422, pp. 166-204, 1967.

[3] 1970 Book of ASTM Standards, Part 14, pp. 397-408, "Standard Methods of Fire Tests of Building Construction and Materials," ASTM E119-69.

TABLE II

Comparative Data on Representative Wall Surfaces

Wall Surface or Assembly	Flame Spread Index Is	Maximum Smoke Dm (Flaming)	Penetration (250° F rise, unexposed surfac min
Aluminum/Paper Honeycomb, Mark III	0	73	13
Do, joint	0	198	11
Asbestos Cement Board	0	0	
Gypsum Board, painted	8	15	
Plywood, painted	105	86	
Plywood, unpainted	155	94	
Aluminum Lap Siding/Urethane Foam/ Wood Studs/ Gypsum Wallboard			35
Wood Drop Siding/ Fiberboard Sheathing/ Wood Studs/ Gypsum Wallboard			65

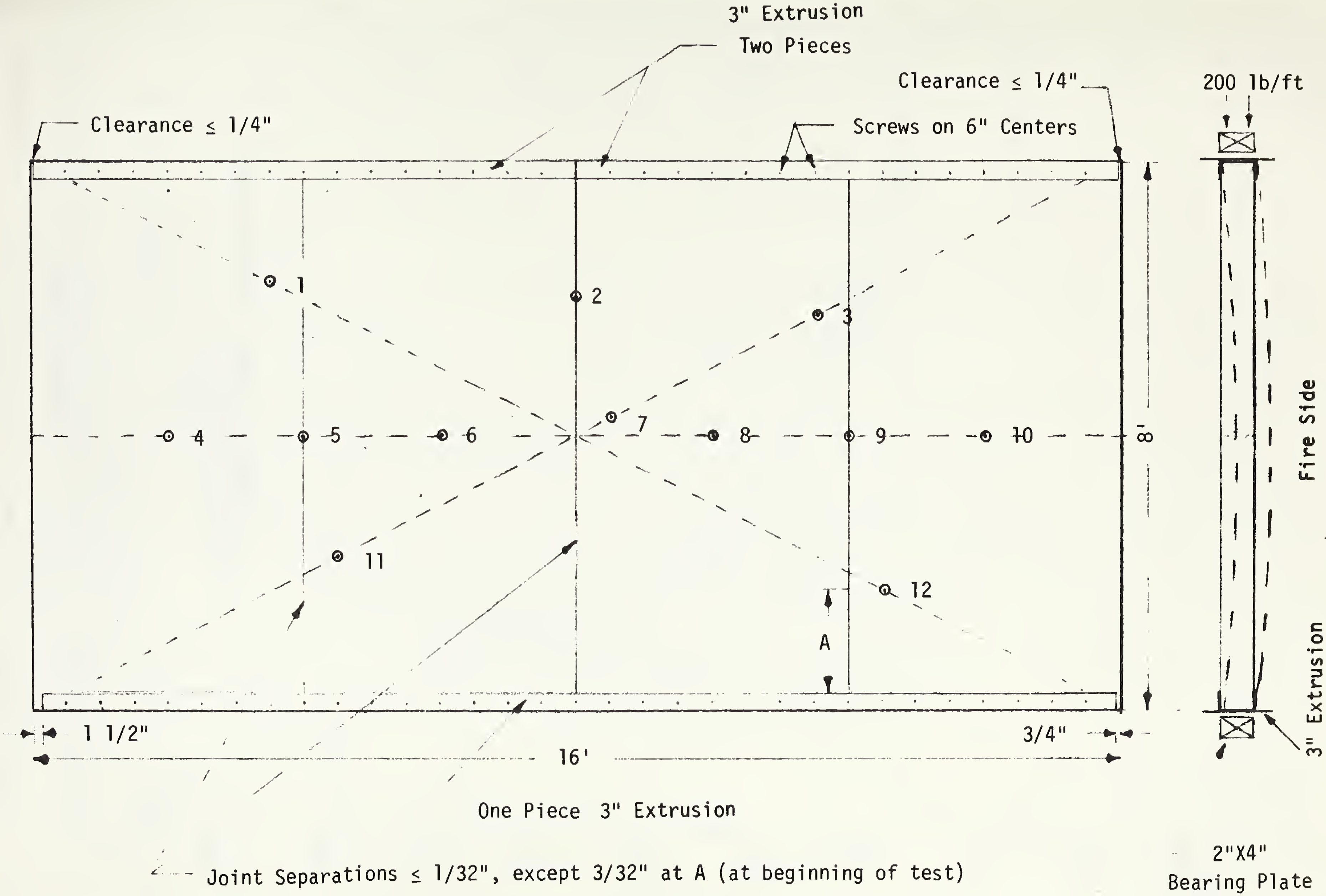

Fig. 1 Arrangement of Panels and Thermocouples for ASTM E-119 Fire Endurance Test

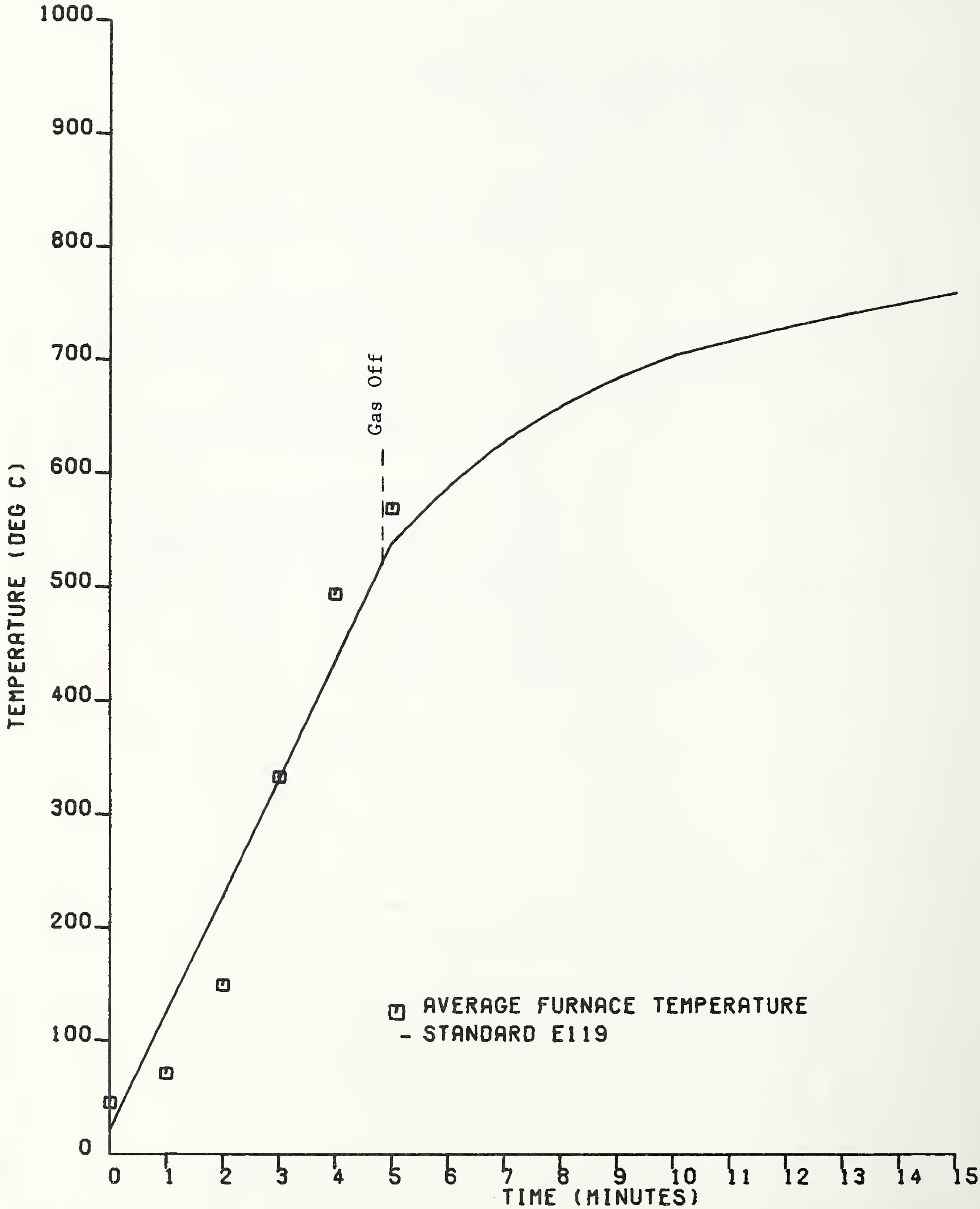

Fig. 2 AVERAGE FURNACE TEMPERATURE FOR TEST 476 COMPARED WITH STANDARD E119

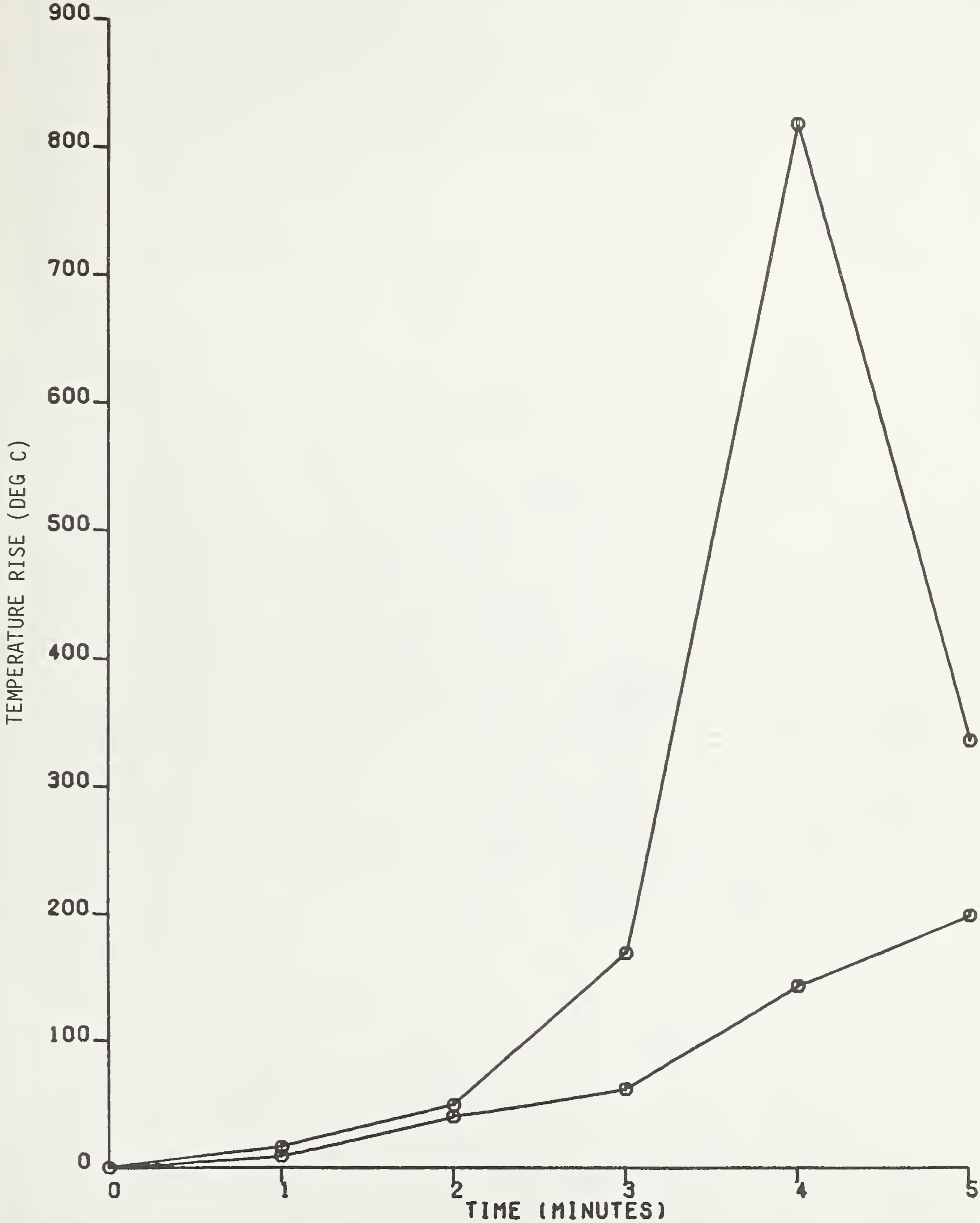

Fig. 3 MAXIMUM AND AVERAGE SURFACE TEMPERATURE RISE FOR TEST 476

Fig. 4 The honeycomb sandwich panel and positions of the twelve thermocouples prior to ASTM E-119 full-scale test.

Fig. 5 Wall panel after test. Notice charring and hole at center joint where flamethrough occurred.