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NATIONAL BUREAU OF STANDARDS REPORT

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FIRE PERFORMANCE CHARACTERISTICS OF A GLASS FIBER SANDWICH PANEL

by

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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
421 5627	March 22, 1967	9505

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For

General Services Administration
Reference: Letter dated August 22, 1966

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ABSTRACT

Evaluation of the fire performance characteristics of a glass fiber-reinforced plastic sandwich panel was made on the basis of surface flammability, furnace exposure, smoke and potential heat tests, for both uncoated panels and those coated with an intumescent-type fire-retardant paint. The test methods used are described and the test results tabulated.

1. Introduction

A letter dated August 22, 1966 from the General Services Administration authorized the performance of tests to determine the fire characteristics of a glass fiber-reinforced plastic sandwich panel. Evaluation of the panel was to be on the basis of surface flammability, furnace exposure, smoke and potential heat tests, for both uncoated panels and those coated with an intumescent-type fire-retardant paint.

2. Materials

The panel consisted of polyester sheets reinforced with a mat of woven glass fiber, and separated by glass fiber ribs and a core of rigid urethane foam. The sheets were 0.040 in. thick and the ribs were spaced 2 in. apart to form a rigid 1-5/8 in. thick (1-3/4 in. nominal) sandwich panel intended for load-bearing applications. The plastic components were reported to be treated for fire-retardancy.

The latex intumescent fire-retardant paint was applied by the paint manufacturer. This paint is listed by Underwriters' Laboratories, Inc., and at the prescribed coverage rate of 100 sq ft per gallon, has a U. L. flame spread classification of 25 (on unprimed Douglas Fir).

The uncoated panels were received on September 6, 1966 and the coated panels on November 2, 1966, all prepared in the required test sizes. All specimens were conditioned to equilibrium with an ambient temperature of 73 ± 5 F and 50 ± 5 percent relative humidity prior to t test.

3. Test Methods

3.1 Surface Flammability

These measurements were made using the radiant panel flame-spread test apparatus (see Figure 1.) The detailed test procedure is outlined elsewhere [1, 2]. In brief, the test requires a 6 by 18 in. specimen, facing and inclined 30 degrees to a vertically-mounted, gas-fired radiant panel. The energy output of the panel was controlled to be the same as that from a blackbody of the same dimensions operating at a temperature of 670 C (1238 F). Ignition was initiated at the upper edge of the test specimen and observations were made of the progress of the flame front down the specimen surface, as well as the temperature rise of the thermocouples in a stack supported above the test specimen. The test duration was 15 min., or until sustained flame propagated down the entire 18 in. length of specimen, whichever time was less. The flame-spread index, I_s, was computed as the product of the flamespread factor F_s and the heat evolution Q, or $I_s = F_sQ$, where

$$F_s = 1 + \frac{1}{t_3} + \frac{1}{t_6-t_3} + \frac{1}{t_9-t_6} + \frac{1}{t_{12}-t_9} + \frac{1}{t_{15}-t_{12}} .$$

The symbols t_3 to t_{15} correspond to times in minutes from specimen exposure until arrival of the flame front at a position 3 to 15 in., respectively, along the length of the specimen. The heat evolution Q is proportional to the observed maximum temperature rise of the stack thermocouples.

In cases where flames flash across all or a significant portion of the surface without immediately establishing sustained flaming, a "Flash Potential" designation is also applied.

3.2 Furnace Exposure

Each test specimen measuring 30 in. square was placed so as to form the horizontal cover of a gas-fired furnace containing an opening approximately 22 in. square. The bottom surface of the specimen was subjected to heat and flame impingement controlled to duplicate the prescribed time-temperature exposure in standard fire endurance tests [3]. The temperatures (1000 F at 5 min, 1300 F at 10 min, 1550 F at 30 min) were

indicated by No. 18 B&S gage chromel-alumel thermocouples placed in wrought iron pipes 4 in. below the exposed surface of the specimen. One 24-gage chromel-alumel thermocouple was placed at the center of the unexposed upper surface of the specimen and covered with an asbestos pad conforming to the specifications prescribed in the standard fire endurance test. Another 24-gage thermocouple was centrally located within the foamed plastic core. This test is not equivalent to, but may be considered a scale or pilot model of the standard fire-endurance test, which requires a fire-exposed area of 100 sq ft for walls and 180 sq ft for floors. Tests are continued until there is a passage of flame through the panel, or until the transmission of heat through the panel raises the temperature of the thermocouple under the asbestos pad more than 250 deg F above its initial temperature.

3.3 Smoke Accumulation and Toxic Gas Concentration

The smoke produced during the burning of the test specimen was collected and measured photometrically, employing a laboratory test method developed for the purpose [4]. As shown in Figure 2, the test utilizes a closed chamber of 18 cu. ft volume containing an electrically-heated furnace which provides an irradiance of 2.2 Btu/sec sq ft (2.5 w per sq cm) on the surface of a nominal 3-in. square specimen (actual exposed area 2-9/16 in. square). Tests were performed under both flaming and nonflaming (smoldering) conditions, representing two typical fire exposure situations.

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 of the chamber 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.

Indications of the concentrations of the toxic gases CO, HCl, and HCN were obtained by drawing a measured volume of the gas mixture in the test chamber through commercial colorimetric gas detector tubes [5], using a small syringe or bellows pump. Concentration was indicated by a color change or by the length of color stain along pre-calibrated detector tubes, using the manufacturers' calibration sheets. However, no verification has been made by this laboratory of the manufacturers' claims for the accuracy of the indicators. The gas mixture was sampled at or

near the time when the optical density reached its peak, since experience has shown that this generally corresponded to the period of peak concentration for these gases.

3.4 Potential Heat

Quantitative measurements were made of the total heat released under simulated fire exposure conditions using the potential heat test method [6]. The method makes use of standard calorimetric techniques in which the burning of small quantities of combustible in an otherwise inert material is assured by use of a combustion promoter which is added prior to test. By measuring heat of combustion in an oxygen bomb calorimeter both before and after exposure to a "standardized fire" (2 hr in air at 750 C), the difference may be considered as the potential heat of the material. See Figure 3.

4. Test Results

4.1 Surface Flammability

Individual and average flame spread index values are listed in Table 1. The flame spread index of the unpainted panels was 115, based on the average of four test specimens. Flames propagated slightly beyond 12 in. in approximately 2-1/2 to 3-1/2 minutes, but eventually died out. The painted panels generally ignited and propagated flames past the 3 in. mark in about 1/2 min. approximately the same as the unpainted panels. The paint intumesced after 1 min. or so, and the maximum sustained flame travel was limited to about 8 to 10 in. However, flames occasionally flashed over a significant portion of the surface, both before and after intumescence occurred, due to ignition of combustible vapors which were intermittently released through the paint layer. Therefore, a "Flash Potential" designation is appended to the average flame spread index (I_s = 10) for the painted panels.

4.2 Furnace Exposure

Duplicate tests were performed for both the unpainted and painted specimens. The test results are summarized in Table 2.

The unpainted specimens evolved an appreciable amount of heavy weight, light yellow smoke, during the first 5 minutes of test. After 15 minutes, smoke was observed coming directly out of the upper surface. The painted specimens evolved a lesser amount of smoke. Intumescence of the paint film due to fire exposure, extended approximately 1 in. from the surface, and remained at the conclusion of the tests.

The time to reach a 250 deg F temperature rise on the unexposed surface was approximately 9 min. for the unpainted panels and 16 min. for the painted panels. In no case was there any flamethrough for the test duration, which ranged up to 30 min. A photograph of the specimens after test is shown in Fig. 4.

4.3 Smoke Accumulation and Indicated Concentrations of Toxic Gases

Duplicate tests were performed for both the unpainted and painted specimens, and under flaming and nonflaming exposure. The test results are summarized in Table 3. It may be noted that the unpainted specimens produced more smoke and at a faster rate than the painted specimens, under both exposure conditions. The maximum specific optical density levels recorded are comparable to those obtained for certain cellulosic and plastic materials, but considerably above levels measured for inorganic materials and certain coated cellulosic materials [4].

The toxic gas concentration indications for CO and HCℓ were also consistently higher for the unpainted specimens. The indicated concentration of 400 ppm HCℓ for the unpainted specimens under flaming exposure was considerably above the M.A.C.[a/] value of 5 ppm. The M.A.C. value for CO is 100 ppm. All indicated HCN values were below the M.A.C. value of 10 ppm. Interpretation of the indicated concentrations in terms of true concentrations and with respect to toxicological limits is discussed in Section 5.

HCℓ indications were also obtained when the fiberglass-reinforced polyester sheet was tested separately, and when the cellular plastic core was tested separately. These measurements reflect the presence of chlorinated compounds in both the polyester sheet and the urethane foam core.

4.4 Potential Heat

Duplicate tests were performed for both the unpainted and painted specimens, and the results are summarized in Table 4.

The average potential heat was 6690 Btu/lb for the unpainted panels and 6520 Btu/lb for the painted panels. On the basis of the measured weights of the panels, and the percent residue values, it appears that the glass mat weighed about 0.57 lb/ft^2, approximately 50 percent of the panel weight, and the paint weighed about 0.28 lb/ft^2 (2 surfaces), approximately 20 percent of the painted panel weight.

On an area basis, the potential heat was 7900 Btu/ft^2 for the unpainted panel and 9520 Btu/ft^2 for the painted panel. The potential heat of the paint alone, was by difference, 1620 Btu/ft^2 or 5800 Btu/lb.

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a/ M.A.C. = Maximum average atmospheric concentration for 8-hr day adopted by American Conference of Gov't Industrial Hygienists, 1963

5. Discussion

Based on the fire tests performed on the sandwich panel as well as other tests and measurements made in this laboratory, certain differences were noted in the "rated" or "nominal" description of the components. These were with regard to (1) panel thickness, 1-5/8 in., rather than 1-3/4 in., and (2) paint layer thickness in excess of the prescribed amount.

Measurements were made of the (dry) paint coat thickness on a number of the specimens, and these were generally in excess of the prescribed 5-1/2 mil thickness (corresponding to 100 sq ft per gallon). On the basis of 25 measurements of radiant panel specimens, the average dry paint thickness was 10 mils (range 4 to 15 mils), and for the 30 in. square slab specimens, the average dry paint thickness was 15 mils (range 9 to 24 mils).

The test results indicate that the application of the intumescent paint, in the thicknesses tested, provides a measurable improvement in certain fire characteristics. For surface flammability, the flame spread index was decreased from 115 to 10. However, the delayed or intermittent release of combustible vapors from the painted panel indicates that very rapid (flash) flame propagation may possibly occur in enclosed spaces under certain conditions. Since the exposed surface is the most critical in surface flammability, small changes in the composition and thickness of the surface layer could have a large effect upon flame spread behavior.

For the relatively severe conditions of the furnace exposure test, failure by thermal transmission was increased from approximately 9 minutes to 16 minutes due to the paint layer. No flames penetrated through any of the panels tested for the test duration, which ranged up to 30 minutes. For comparison, it is estimated that the fire endurance of a gypsum wallboard and stud partition would be approximately 40 to 60 minutes.

For smoke and toxic gas concentrations, the painted panels produced lower levels compared to the unpainted panels. However, the smoke levels for the painted panel were considerably in excess of those for inorganic materials, or even certain coated cellulosic materials [4]. A discussion of the significance and limitations of the maximum specific optical density (D_m) value in terms of visual obscuration is given in Ref [4]. Also included is a discussion of the technique and suitability for extrapolating the smoke chamber test results to surface areas and to chamber volumes of other size.

As noted previously, no verification was made by this laboratory of the manufacturers' claims for the accuracy of the colorimetric gas indicator tubes. The use of the recorded values as true concentration values with any high degree of confidence may be limited by a number of factors, including the time and location of sampling, the effects of relative humidity and

elevated temperatures, the absorption of gas on the surfaces of the chamber and on smoke particles, interpretation of the color change, and interfering reactions by other gases. The error in reading the color stain length may be up to ±15 percent in some cases. No correction was made for the temperature of the gas sample. Even if true gas concentrations were known, their use in terms of toxicological limits, such as illustrated in Table 5, would still be open to some question. An approximate relationship between the toxic gas concentration measured in the smoke chamber and the projected concentration within a much larger room, is given by

$$C_{room} = C_{test} \frac{V_t}{A_t} \frac{A_r}{V_r} .$$

This simply scales concentration, C, in direct proportion to the area, A, of specimen involved and in inverse proportion to the chamber volume, V. As an example, the gas concentration in rooms of 1000 and 10,000 ft^3 volume is shown in Figure 5 for a series of lines corresponding to surface areas of 10, 100 and 1000 sq ft.

For potential heat, the painted panels yielded a slightly lower value than the unpainted panels on a weight basis. However, taking the difference in weight into account, the potential heat on an area basis was actually greater for the painted panel and amounted to 9520 Btu/ft^2. This is due to the contribution from the combustible content of the paint. For comparison, the potential heat of a conventional gypsum wallboard and stud partition would be of approximately the same magnitude, due principally to the wood studs. It should be noted that potential heat measurements give no indication of the rate at which heat may be released, but only the total available regardless of position, and under severe fire exposure conditions.

6. References

[1] Interim Federal Standard 00136b (COM-NBS), December 26, 1962.

[2] "Method of Test for Surface Flammability of Materials Using a Radiant Heat Energy Source," ASTM Designation E162-66T, 1966.

[3] "Standard Methods of Fire Tests of Building Construction and Materials," ASTM Designation E119-61, 1961.

[4] Gross, D., Loftus, J. J., and Robertson, A. F., "A Method for Measuring Smoke from Burning Materials," ASTM STP 422, 1967.

[5] a. Scott Draeger Multi-Gas Detector, distributed by Scott Aviation Corporation, Lancaster, N. Y.

b. MSA Colorimetric Carbon Monoxide Tester, Mine Safety Appliances Co., Pittsburgh, Pa.

[6] Loftus, J. J., Gross, D., and Robertson, A. F., "Potential Heat--A Method for Measuring the Heat Release of Materials in Building Fires," ASTM Proc. 61, 1336-48, 1961.

USCOMM-NBS-DC
TG10210-2143:FR3680

Table I. Surface Flammability Test Results

Specimen	Flame Spread Index, I_s†	
	Individual	Average
Painted Panel	6* 8* 4* 22*	10*
Unpainted Panel	110 99 112 138	115

*Flash Potential

† For comparison, I_s = 0 for asbestos-cement board
I_s = 5 to 20 for gypsum board
I_s = 80 to 160 for red oak
I_s = 120 to 200 for exterior grade Douglas fir plywood

Table 2. Furnace Exposure Test Results

Specimen	Test No.	Time to 250 deg F Temp Rise	Test Duration	Notes
		min:sec	min	
Unpainted	1	8:50	30	No flaming through panel
	2	9:00	11	No flame through
Painted	3	16:30	25	Surface intumescence no flame through
	4	15:10	16	Surface intumescence No flame through

Table 3. Smoke and Indicated Concentrations of Toxic Gases

Average of Two Tests

Specimen	Exposure	Smoke*			Toxic Gas Indicated Concentration		
		Dm	Time to D_s = 16	Rm	CO	HCℓ	HCN
			min	min^{-1}	ppm	ppm	ppm
Painted Panel	Flaming	290	1.18	71	400	40	7
	Non-flaming	150	1.72	31	100	5	2
Unpainted Panel	Flaming	400	0.53	198	900	400	4
	Non-flaming	210	1.53	57	200	70	1

*D_m : maximum specific optical density (maximum smoke accumulation from a given area of material under the prescribed exposure).

R_m : maximum smoke accumulation rate (maximum rate of increase in specific optical density averaged over a 2 min period)

Time to D_s = 16: time period prior to attaining a "critical" smoke level (D_s = 16 is an arbitrarily selected level, corresponding to T = 16 percent and V/LA = 20).

See reference [4] for more detailed discussion

Table 4. Potential Heat Test Results

Specimen	Weight	Residue*	Heat of Combustion*		Potential Heat*	
			Direct	Residue	Weight Basis†	Area Basis
	psf	percent	Btu/lb	Btu/lb	Btu/lb	Btu/ft^2
Painted Panel	1.46	41.8	6530	40	6520	9520
Unpainted Panel	1.18	47.7	6740	100	6690	7900

* Average of two tests

† For comparison, potential heat of asbestos, concrete = 0 Btu/lb
gypsum board = 500 to 1000 Btu/lb
wood = 8000 Btu/lb

Table 5. Measuring Range of Colorimetric Indicator Tubes and Toxicological Data for Selected Gases

		GAS		
		CO	HCℓ	HCN
Indicator Tube Data				
Measuring Range, lower, ppm		10	2	2
upper, ppm		1000	1000	150
Toxicological Data				
M.A.C.[a/]	ppm	100	5	10
Irritation on Brief Exposure [b/]	ppm	-	35	
Immediate Danger to Life[b/] (2 to 5 min)	ppm	10,000	1000-2000	200-300

a/ Maximum average atmospheric concentration for 8-hr day adopted by American Conference of Gov't Industrial Hygienists, 1963

b/ Draeger Information Sheets (includes toxicological references)

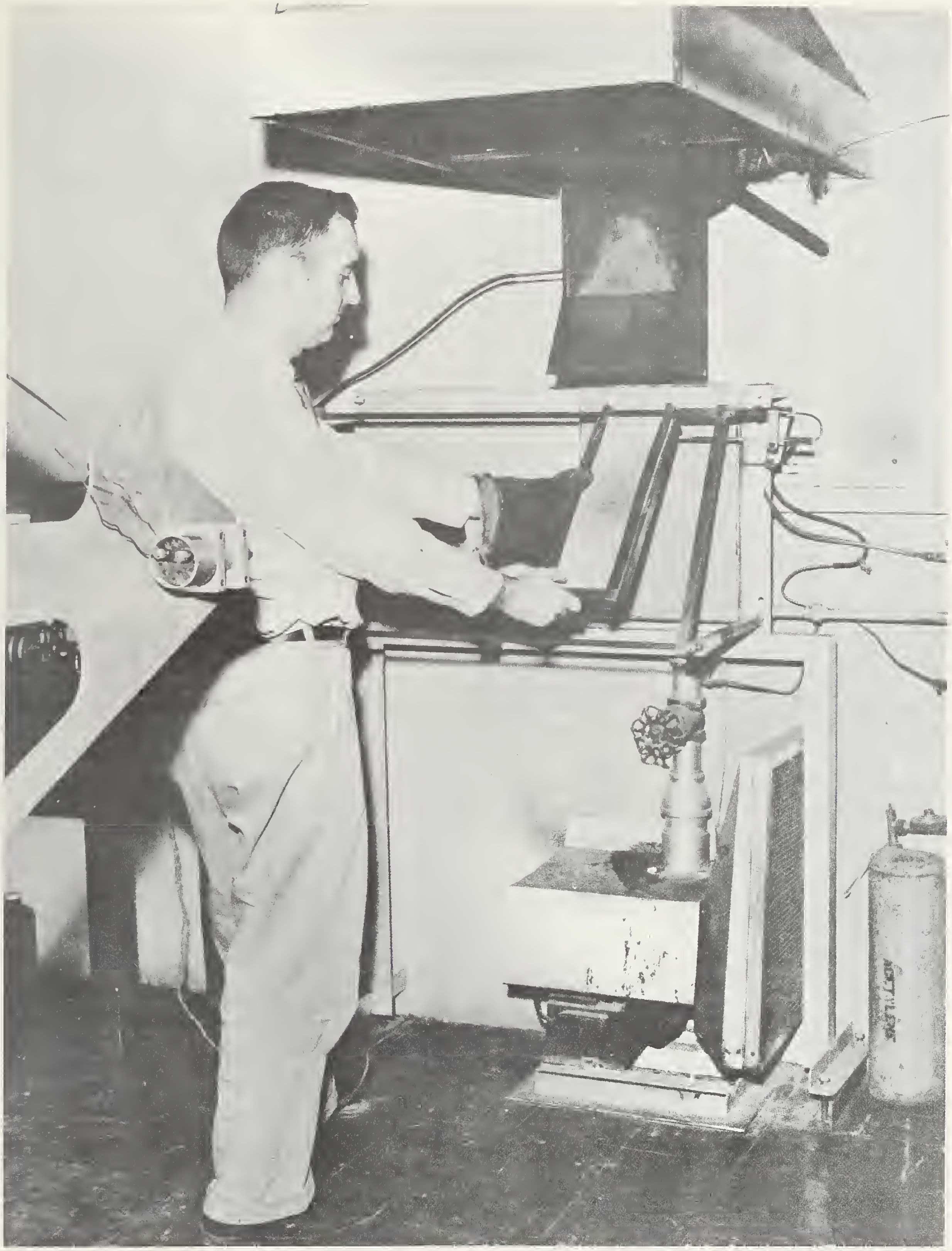

Fig. 1. Radiant Panel Flame-Spread Test Apparatus

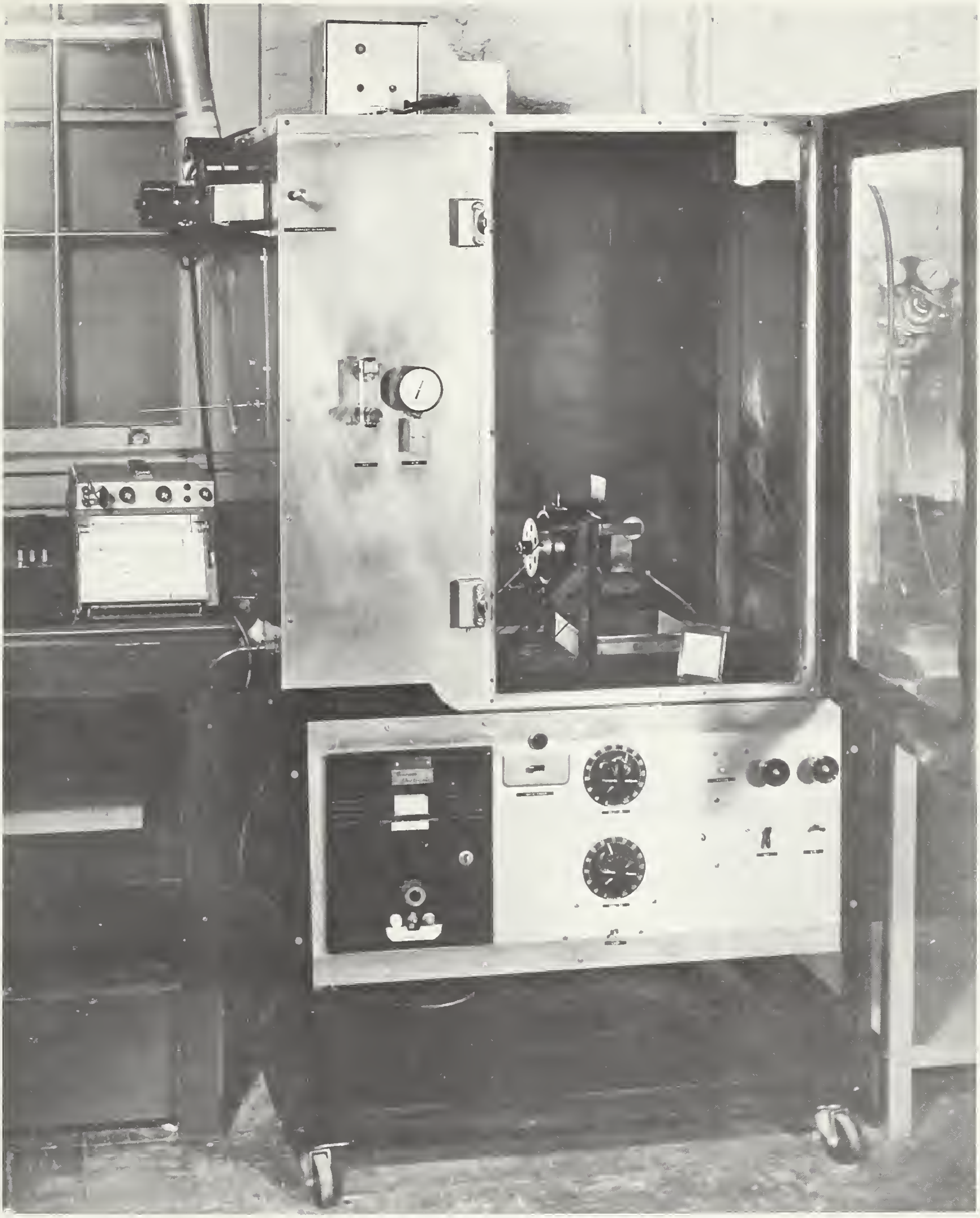

Fig. 2. Smoke Test Chamber

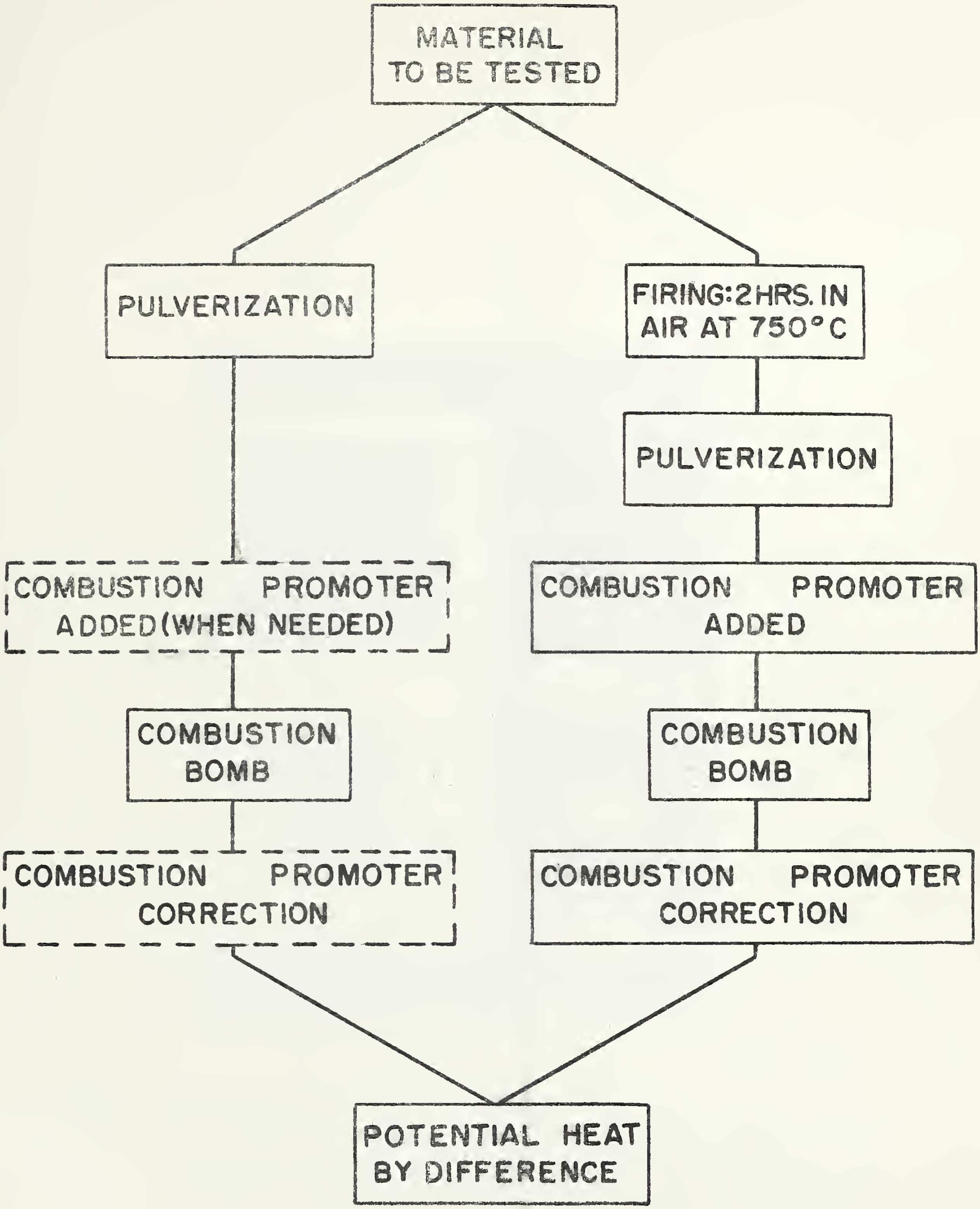

Fig. 3. Schematic Diagram of Test Procedure for Potential Heat Measurements

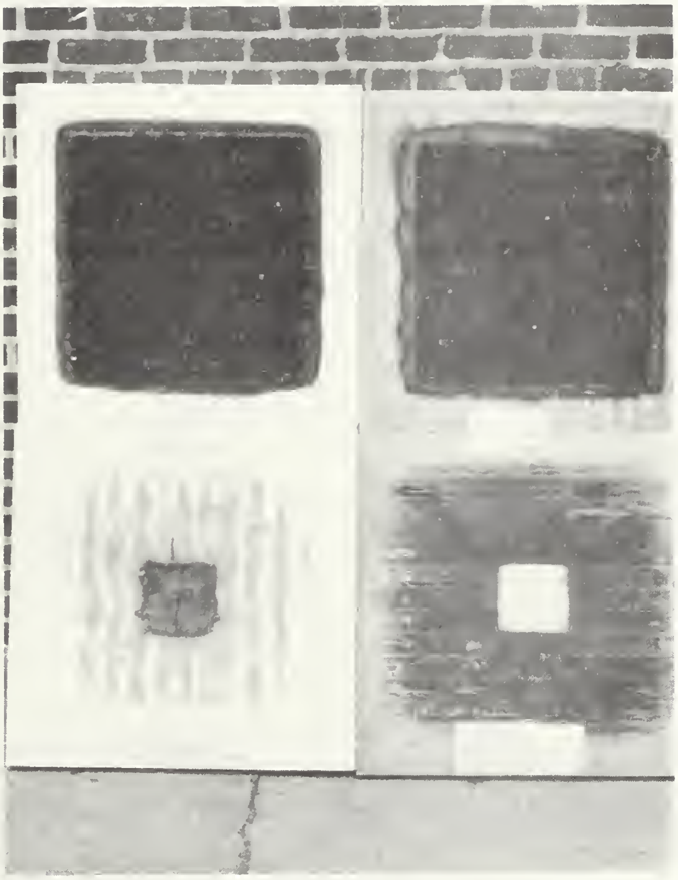

Fig. 4. Sandwich Panels After Furnace Exposure
Upper Left: Fire-exposed painted surface;16 min exposure
Upper Right: Fire-exposed unpainted surface; 11 min exposure
Lower Left: Unexposed painted surface; 25 min exposure
Lower Right: Unexposed unpainted surface; 30 min exposure

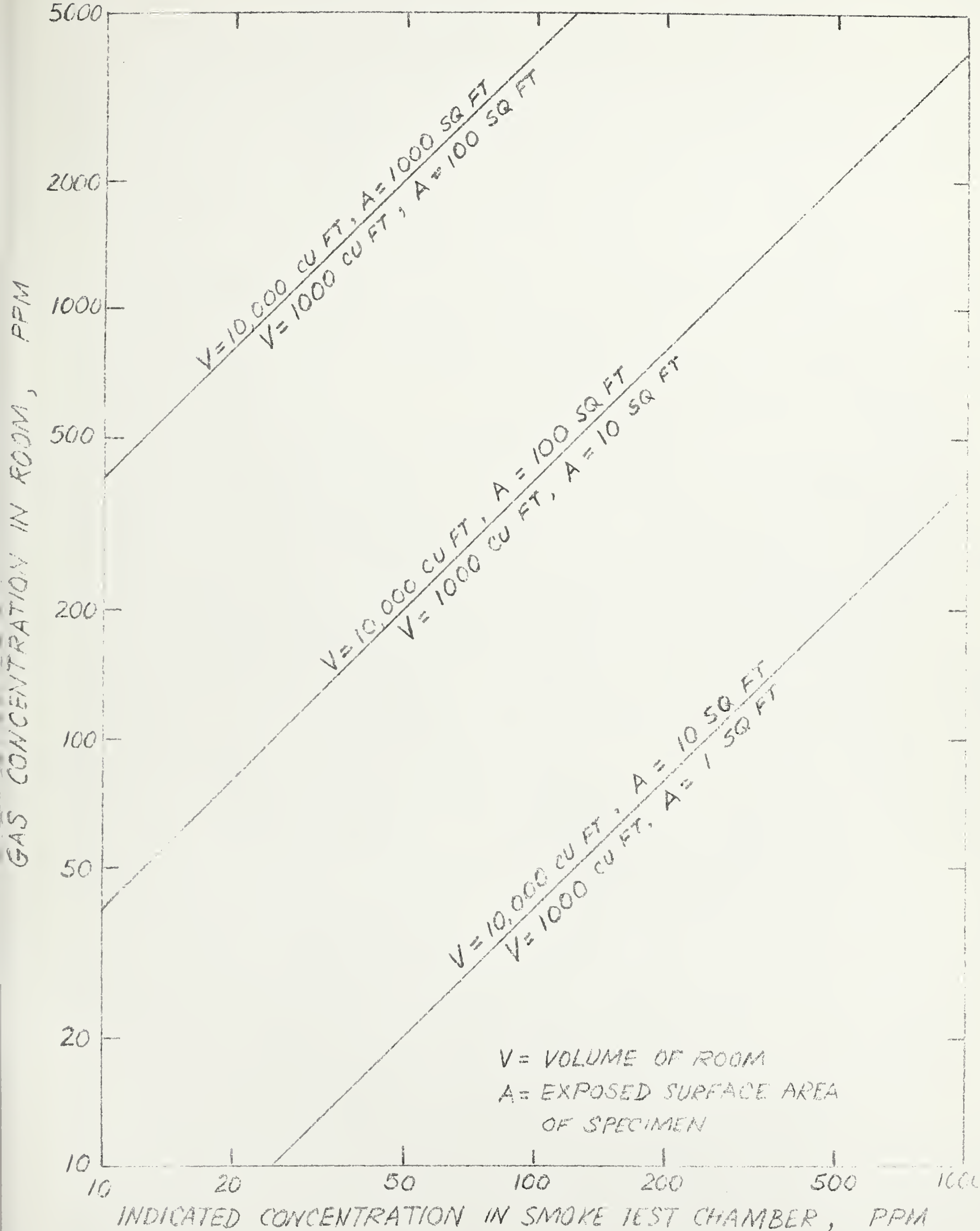

Fig. 5. Gas Concentration in 1000 cu ft and 10,000 cu ft Rooms Based on Indicated Concentration in Smoke Chamber