



Standard Test Method of Small-Scale Evaluation of Fire-Retardant Paints (2-Foot Tunnel Method)¹

This standard is issued under the fixed designation D3806; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method determines the protection a coating affords its substrate, and the comparative burning characteristics of coatings by evaluating the flame spread over the surface when ignited under controlled conditions in a small tunnel. This establishes a basis for comparing surface-burning characteristics of different coatings without specific consideration of all the end-use parameters that might affect surface-burning characteristics under actual fire conditions.

1.2 In addition to the experimental flame spread rate, the weight of panel consumed, time of afterflaming and afterglow, char dimensions and index, and height of intumescence may be measured in this test. However, a relationship should not be presumed among these measurements.

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.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

¹ This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.21 on Chemical Analysis of Paints and Paint Materials.

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2. Referenced Documents

2.1 *ASTM Standards:*²

C220 Specification for Flat Asbestos-Cement Sheets
D344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts
D1475 Test Method For Density of Liquid Coatings, Inks, and Related Products
D2196 Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer
E84 Test Method for Surface Burning Characteristics of Building Materials

2.2 *Federal Standard:*

Fed. Spec. TT-V-119 Varnish, Spar, Phenolic Resin³

3. Significance and Use

3.1 A number of laboratory procedures are used to evaluate the effectiveness of fire-retardant and fire-resistant treatments and coatings. In general, these methods measure the three stages of fire development: (1) ignition; (2) flame spread (rate of growth of the fire); and (3) conflagration extent. While all three are of extreme importance, flame spread has been recognized as the main factor associated with testing fire-retardant coatings.

3.2 Flame spread ratings based upon Test Method E84 have acquired common acceptance by regulatory agencies, but such large-scale tests are seldom practical during the development or modification of a fire-retardant coating.

3.3 This test method provides the relative flame spread of experimental coatings using small test specimens. By calibrating the 2-foot tunnel with Test Method E84-rated fire-retardant paint, results obtained by this test method should be indicative of those obtained with a large specimen in the Test Method E84 tunnel.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, <http://quicksearch.dla.mil>.

4. Apparatus

4.1 *Flame Tunnel*⁴ (see Fig. 1A)—610-mm (two-foot) flame tunnel consisting of asbestos-cement board mounted on an iron framework and supplied with natural gas fuel of uniform quality.

4.1.1 The framework is constructed of 3 by 25 by 25-mm ($\frac{1}{8}$ by 1 by 1-in.) angle iron, the top of which provides a 610 by 100-mm (24 by 4-in.) specimen holder inclined at 28° to the horizontal. The framework is mounted on a 250 by 610 by 13-mm (10 by 24 by $\frac{1}{2}$ -in.) steel base. The specimen holder is elevated 185 mm ($7\frac{3}{8}$ in.) above the base at the lower (fire) end and 480 mm ($18\frac{7}{8}$ in.) at the upper (flue) end.

4.1.2 The fire end and sides of the tunnel are covered to the extent shown in Fig. 1, with 6-mm ($\frac{1}{4}$ -in.) asbestos-cement board⁵ or 6-mm ($\frac{1}{4}$ -in.) inorganic reinforced-cement board⁶ attached to the inside of the angle iron framework. The open flue end and the cut-out sides allow a natural draft through the tunnel. Additional air access is provided by a 25-mm (1-in.) hole drilled in the cover at the fire end, centered and 115 mm ($4\frac{1}{2}$ in.) above the base.

4.1.3 An observation window made of a 50-mm (2-in.) wide strip of 3-mm ($\frac{1}{8}$ -in.) polished heat-resistant sheet glass⁷ is located just below the specimen holder, extending the full length of the tunnel, 610 mm (24 in.). This glass is marked by any appropriate method at 1-in. intervals from 4 to 22 in. A 560 by 55 by 2-mm (22 by $2\frac{1}{4}$ by $\frac{1}{16}$ -in.) sheet metal shield is attached above the window, slanting downwards at an angle of 60° to shield the observation window. The angle iron panel holder is notched along the bottom or supporting lip of the angle at 25-mm (1-in.) intervals to assist in the measurements of the flame advance.

NOTE 1—A rule may also be mounted outside the observation window to help measure the flame advancement.

4.1.4 A 2.5-mm ($\frac{3}{32}$ -in.) hole is drilled in the side of the specimen holder immediately above the center of the burner to allow insertion of a thermocouple.

4.1.5 The tunnel should be placed in an area as free from drafts as possible with facilities for removal or escape of combustion products. (Standard laboratory hood with forced draft off during test.)

⁴ The sole source of supply of a suitable cabinet and assembly known to the committee at this time is Dek-Tron Scientific, 244 East 3rd St., Plainfield, NJ 07060. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

⁵ The sole source of supply of an asbestos-cement board, transite, known to the committee at this time is Manville Corp., Denver CO 80217. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

⁶ The sole source of supply of inorganic reinforced-cement board, #100S and 100H, nominal 1600 to 1760 kg/m³ (100 to 110 lb/ft³), known to the committee at this time is Shameful Corp., 100 Spence Lane, Nashville, TN 37210. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

⁷ Quartz or high-silica glass has been found satisfactory for this purpose.

4.2 *Burner*,⁸ 215 mm (8.5 in.) high with 40-mm diameter, 10-mm thick grid for use with natural gas. The burner is placed 57 mm ($2\frac{1}{4}$ in.) in from the fire end of the tunnel and 25 mm (1 in.) below the bottom side of the sample holder, that is, 30 mm ($1\frac{1}{8}$ in.) from the bottom of the specimen. See Fig. 1.

NOTE 2—Artificial gas or liquid petroleum (LP) gas may be used, but burners designed for these types of gases must be used.

4.3 *Ignition Transformer*, or other suitable ignition source, to generate a spark through a 2-mm ($\frac{1}{16}$ -in.) Nichrome wire to the burner barrel. The transformer is activated by a push-button type spark switch.

4.4 *Gas Supply*, of uniform quality controlled by a positive-flow pressure regulatory valve (0 to 152 mm (0 to 6 in.) water) and a gas flowmeter (0.6 to 5.0 SCFH).

4.5 *Insulating and Fire Resistant Backing for Test Panels*, consisting of 100 by 605-mm ($3\frac{7}{8}$ by $23\frac{7}{8}$ -in.) pieces of 13-mm ($\frac{1}{2}$ -in.) asbestos-cement board or inorganic reinforced cement board and $\frac{1}{2}$ -in. steel plate applied one above the other with asbestos cement or the inorganic reinforced cement board placed directly on top of the test panel.

4.6 *Thermocouple*⁹ totally shielded (see Note 3), installed through the hole in the side of the specimen holder so that its tip rests on the back, cool side, of the test panel.

NOTE 3—Some commercial tunnels are supplied with more than one thermocouple.

4.7 *Recording Potentiometer*, 0 to 300°C range.

4.8 *Audible Timer*, set to sound at 15-s intervals to indicate the time for flame-front measurements.

4.9 *Constant Temperature and Humidity Room or Cabinet*, maintained at 50 ± 5 % relative humidity and $23 \pm 2^\circ\text{C}$ ($73.5 \pm 3.5^\circ\text{F}$).

5. Test Panels

5.1 *Test Panels*—See Table 1 for a list of various woods and their densities. Wood, 6 by 100 by 605-mm ($\frac{1}{4}$ by $3\frac{7}{8}$ by $23\frac{7}{8}$ -in.) close grained, as nearly edge grain as possible and free from knots and imperfections. The panels should be solid wood with surfaces planed and sanded (see Note 4). Kiln-dry test panels to contain not more than 10 weight % of moisture on an oven dry basis.

NOTE 4—Douglas fir, 6.3-mm ($\frac{1}{4}$ -in.) 3-ply, marine-grade plywood may be used upon agreement between manufacturer and user. Asbestos-cement board, steel, or concrete may be used upon agreement between manufacturer and user.

5.1.1 Prior to coating, condition test panels for 14 days in the controlled atmosphere of 50 ± 5 % relative humidity and

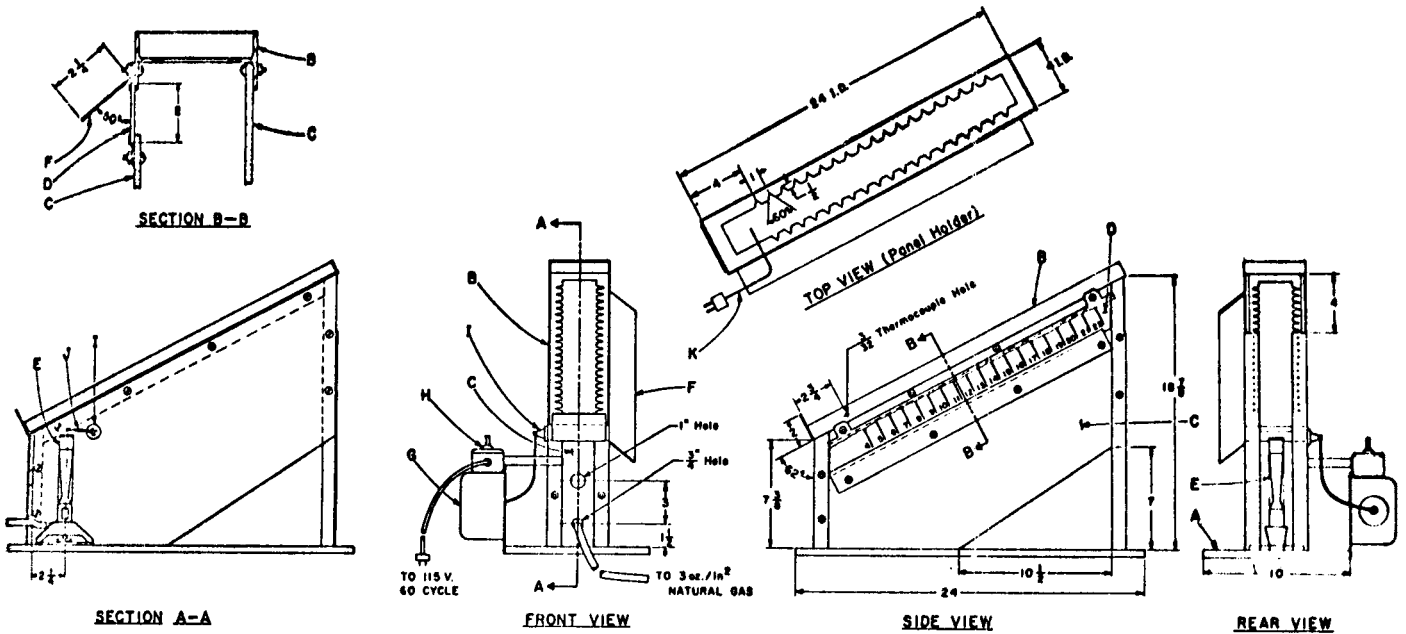
⁸ The sole source of supply of a burner, Catalog No. 3-902 for artificial gas, or Catalog No. 3-900 and 3-902 for natural gas and LP gas, respectively, known to the committee at this time is Fisher Scientific Co. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

⁹ The sole source of supply of a thermocouple, Megopak Type J, known to the committee at this time is Megopak Co. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

Materials of Construction and Equipment List

Item No	Item	Description	Item No	Item	Description
A	Base Plate	1/2 x 10 x 24 Steel plate	F	Glare Shield	1/16 x 2 1/4 x 22 Metal sheeting
B	Framework	1/8 x 1 x Angle iron throughout	G	Ignition Transformer	115 V, 60 Hz, 5000 V, 20 A secondary
C	Side and Front Panels	1/4 Transite or Chem-Fil 100S or 100 H ⁸ cut to specifications	H	Spark Switch	Push button type
D	Side Glass	1/8 x 2 x 24 Polished Vycor cut as shown	I	Ceramic Insulator	
E	Burner	Artificial Gas Model	J	Spark Wire	1/16 OD Nichrome
	Gas Control Valve (not shown)	1/8 Orifice, 1" Pipe size, outlet 3 oz/in ²	K	Thermocouple	Megopak Type J, totally shielded
	Gage, Gas (not shown)	0-30 oz/in ² Dial		Recording Potentiometer	115 V, 60 Hz, 0-300°C, Type J cond

Note: All Dimensions Expressed in Inches Unless Otherwise Noted.



METRIC EQUIVALENTS

in.	mm	in.	mm
1/16	1.6	3	76
3/32	2.4	4	102
1/8	3.2	7	178
1/4	6.4	7 3/8	187
1/2	12.7	10	254
1	25.4	10 1/2	267
1 1/2	38	18 3/8	480
2 1/4	57	22	560
2 3/4	70	24	610

FIG. 1 Flame Tunnel

TABLE 1 Densities and Panel Weights of Various Woods (Conditioned at Relative Humidity 50 ± 5 % and 23± 2°C (73.5 ± 3.5°F) for 14 days)

Type of Wood	Density (9 to 10 % Moisture), kg/m ³ (lb/ft ³)	Weight of 3 ⁷ / ₈ by 23 ⁷ / ₈ by 1/4 in. Panel, g
Red cedar	345 to 360 (21.4 to 22.4)	130 to 140
Douglas fir	465 to 560 (29 to 35)	180 to 215
White pine-Ponderosa pine	360 to 420 (22.4 to 26.4)	140 to 160
Southern yellow pine	495 to 590 (31 to 37)	190 to 225
Redwood	435 to 450 (27.2 to 28.2)	165 to 175

23 ± 2°C (73.5 ± 3.5°F) to a 9 to 10 % moisture content. Refer to **Table 1** for the density and weight per panel of each listed wood.

5.1.2 Seal the ends of the panels with two coats of varnish conforming to Fed. Spec. TT-V-119 after conditioning. Allow each coat of varnish to air-dry 18 to 24 h.

6. Calibration Standards

6.1 *Zero-Flame Spread*—Asbestos-cement board, Type F conforming to Specification **C220**, 13 by 100 by 605 mm (1/2 by 3⁷/₈ by 23⁷/₈ in.), conditioned as in **5.1.1**.

NOTE 5—Inorganic reinforced cement board, 6.3-mm (1/4-in.) thick may be substituted for asbestos cement.

6.2 *Fire-Rated Standard*—A test panel, similar to that used with test coatings, coated with Test Method **E84** rated paint at the manufacturer's recommended spreading rate and conditioned as in Section **7**.

NOTE 6—Do not use paint beyond manufacturer's stated shelf life.

7. Preparation of Test Panels

7.1 Thoroughly mix the coating under test by a suitable means until it is uniform in composition and consistency. Test Methods **D2196** describes a suitable preparation procedure.

7.2 Determine the density of the coating in accordance with Test Method **D1475** in grams per millilitre (or pounds per gallon) for calculating the weight of the coating to be applied to the panel to comply with the specified spreading rate.

7.3 Brush apply the coating to conditioned test panels in as uniform a manner as possible to obtain the specified spreading rate. A suitable procedure appears in Test Method **D344**. Application may be by other conventional means and in as many coats as required to obtain the necessary weight of coating, or desired wet- or dry-film thickness.

7.4 Calculate the weight of coating to be applied using the following equation:

$$W = \frac{\left(3 \frac{7}{8} \times 23 \frac{7}{8}\right) D}{144 S_R} \times 454 \quad (1)$$

where:

W = weight of applied wet coating, g,
 D = coating density, lb/gal, and
 S_R = spreading rate, ft²/gal.

7.4.1 Use the following equation when metric units are employed:

$$W = \frac{60.5 D}{S_R} \quad (2)$$

where:

W = weight of applied wet coating, g,
 D = coating density, g/mL, and
 S_R = spreading rate in m²/L.

7.5 Dry the coated panels under standard conditions (**4.9**) until equilibrium weight is obtained, allowing sufficient time for the complete evaporation of solvents, any curing that might be required by the material, and for the attainment of equilibrium moisture content. Forty-eight hours are normally sufficient except for certain coatings that may require longer periods because they trap solvent or contain solvents that evaporate very slowly.

7.6 Apply and cure non-air-drying coatings as recommended by the supplier and condition as specified in **7.5**.

8. Calibration of the Tunnel

8.1 Calibrate the tunnel prior to each day's operation with the calibration standards described in Section **6**.

8.1.1 Place the zero flame-spread standard in the holder, smooth side down, and back it with the backing plate (**4.5**).

8.1.2 Open the gas valve and adjust to a pressure of 1.3 kPa (3 oz/in.²) and a constant flow of 38 mL/s (4.8 ft³/h), and actuate the interval timer.

NOTE 7—These conditions are specified for a natural gas supply providing 40 MJ/m³ (1055 BTU/ft³). For any other gas supply, adjust flow to provide 1490 J/s (5085 BTU/h).

8.1.2.1 When the timer sounds, ignite the burner using the ignition transformer. Observe the flame front, measure in inches and record at 15-s intervals the flame position by aligning the notches in the bottom of the specimen holder with the markings on the observation window.

8.1.3 Record the extreme tip of the flame advance (flame front) on the panel surface, disregarding flame extending up the tunnel but completely on the angle iron support. After a total test period of 4 min, extinguish the burner.

8.1.4 Calculate the mean of the three highest consecutive readings of the flame advance of the zero-flame spread standard L_a .

8.2 Repeat the calibration procedure using a fire-rated standard (**6.2**). Designate the mean of the three highest consecutive readings of the flame advanced as L_R . The difference between the mean readings for the zero flame-spread

standard and the fire-rated standard ($L_R - L_a$) is directly related to the Test Method E84 flame-spread rating of the rated standard (F_{SR}).

9. Procedure for Determination of Flame-Spread Rating

9.1 Remove a test panel (Section 7) from the controlled atmosphere, weigh immediately, and then mount in the specimen holder, coated-side down. Insert the thermocouple through the hole in the holder (4.6) so that its tip is directly above the center of the burner and resting on the back, or uncoated side, of the test panel. Back the panel with the asbestos-cement board and steel backing.

9.2 Apply the flame and determine the advance of the flame front in the same manner as the calibration procedure (Section 8), except allow the burner to operate for an additional 60 s after making the last of the 15-s readings before extinguishing the burner. Designate the mean of the three highest consecutive readings of the flame advance of the specimen during the 4-min test period as L_s .

9.3 Repeat the determination with at least five panels.

10. Calculation

10.1 Calculate the experimental flame-spread rating using the following equation:

$$F_{SE} = \frac{(L_s - L_a)}{L_R - L_a} \times F_{SR} \quad (3)$$

where:

- F_{SE} = flame spread of specimen,
- L_s = mean of three flame advance readings of specimen, in. (mm),
- L_a = mean of three flame advance readings of zero flame-spread standard, in. (mm),
- L_R = mean of three flame advance readings of rated standard, in. (mm), and
- F_{SR} = flame-spread rating of rated standard.

10.2 Calculate the mean of the replicate panels, rounding off to the nearest five units.

11. Optional Measurements

11.1 *Afterflaming Time*—Observe and record the time in seconds that flaming continues on the face of the test specimen after the burner has been extinguished. Report as afterflaming time.

11.2 *Afterglow Time*—Observe in subdued light and record the additional time in seconds that the surface of the test specimen continues to emit light (glows) after the flame has gone out. Report as afterglow time.

11.3 *Panel Consumption*—After the completion of the flame-spread test (Section 9), replace the specimen in the constant atmosphere (see 5.1.1) for not less than 72 h. Reweigh the panel and determine the weight loss in grams. Report loss as panel consumption.

11.4 *Degree of Intumescence*—Measure the height of intumescence (foam formation) in millimetres at the point on the specimen that was directly above the burner. Report the height as intumescence.

11.5 *Insulation Value*—Measure the initial panel temperature in degrees Celsius or Fahrenheit and subtract it from the maximum temperature observed during the flame-spread test (Section 9). Report the difference as ΔT .

11.6 *Char Dimensions and Index*—Cut the panel into four rectangular pieces using a fine-toothed saw so that the cuts intersect at the point of flame impingement (directly over the burner). Measure in centimetres the maximum width of charring of the wood found below the paint film on the lateral cut. Likewise, measure the maximum length of charring found on the longitudinal cut. Measure the maximum depth to which charring has penetrated as evidenced on either cut. Determine the char index by multiplying the maximum char width, length, and depth.

12. Report

12.1 *Experimental Flame Spread*—Report the following information:

- 12.1.1 The calibration values of L_R and L_a (Section 8),
- 12.1.2 Type of substrate used,
- 12.1.3 Number of test panels,
- 12.1.4 Mean spreading rate,
- 12.1.5 Pressure, flow rate, and type of gas fuel,
- 12.1.6 Mean L_s value for each panel (Section 9), and
- 12.1.7 Mean flame-spread value (F_{SE}) for each material under test (Section 9).

12.2 *Optional Measurements*—Report may contain the following information:

- 12.2.1 *Panel Consumption*—Mean initial and final weight of coated specimens and mean weight loss in grams (11.3),
- 12.2.2 Afterflaming time in seconds (11.1),
- 12.2.3 Afterglow time in seconds (11.2),
- 12.2.4 Height of intumescence in millimetres (11.4),
- 12.2.5 *Insulation Value*—Initial and maximum temperatures, and temperature difference (ΔT) (11.5), and
- 12.2.6 *Char Depth and Volume*—Maximum width, length, and depth of charring of wood in centimetres and the char index in cubic centimetres (11.6).

13. Precision and Bias

13.1 *Precision*:

13.1.1 Nonuniformity of test panels (both in the wood and in the coating), variations in fuel supply and rate, and operator error are the chief sources of error in operation of the 610-mm (2-foot) tunnel.

13.1.2 The degree of repeatability is dependent on the level of flame-spread ratings. Table 2 shows that while the standard

TABLE 2 Repeatability^A

Flame-Spread Ratings	Standard Deviation	Coefficient of Variation
0 to 25	1.2	9.6
25 to 75	3.1	6.2
75 to 135	3.65	3.5
0 to 135	2.85	4.6

^A This information was derived from *Journal of Paint Technology*, Vol. 39, No. 511, 1967, p. 495.

deviation of duplicate results increases with an increase in ratings, the coefficient of variation decreases by a factor of more than 2.0.

13.1.3 The standard deviation in **Table 2** relates to the maximum difference that would be expected between duplicate panels; that is, a second result in the flame-spread range from 0 to 25 should fall within 4.8 units ($\pm 2.8 \times 1.2$) at the 95 % confidence level.

13.2 *Bias*—The procedure in this test method for measuring flame spread has no bias because the value of flame spread can be defined only in terms of a test method.

14. Keywords

14.1 fire-retardant; flame spread; paints; tunnel method

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