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Will the Second Item Ignite?

Vytenis Babrauskas

Center for Fire Research
National Engineering Laboratory
U.S. Department of Commerce
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Final Report

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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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Vytenis Babrauskas

Abstract

The problems of characterizing the burning of more than a single fuel item in a room fire are considered, and one specific area is explored experimentally. The first step in describing multiple item burning is to determine if, in fact, it will occur, given the assumed ignition of the first item. This question has been experimentally explored from two aspects. (1) Irradiances have been measured at various distances from burning objects, along with their mass loss rates. (2) The ignitability of exposed objects has been determined using a bench-scale uniform flux ignitability test. It is then suggested that whether the second item will ignite can best be determined analytically from considering these two sets of results.

Key words: Burning rate, case goods, chairs, fire tests, flammability, furniture fires, ignitability, room fires, upholstered furniture.

1. INTRODUCTION

The burning rates of combustible items in building fires has been a matter of long-standing concern. The problem has typically been studied from two approaches. On the one hand, room fire burning has often been considered to be uniquely described by the fuel load (fire load), with the fuel load, expressed as the equivalent weight of wood fuel per unit floor area, being the primary variable characterizing a fire. The fuel load comprises both movable furnishings and any combustible interior finish and trim. Ingberg originally developed these concepts in the 1920's [1][1]. Ingberg's basic intent was to determine the effect of the burnout of all combustibles on fire penetration of barriers and on structural stability. More recently, interest has turned to the details of the transient nature of fire growth in a room, and significant advances have been made in measuring and describing the burning behavior of a single, isolated fuel item, commonly a piece of furniture [e.g., 2]. Missing, however, is knowledge of any interactions. Two types of interactions in general can be seen. First fuel/room interactions will occur whenever the presence of a room fire around the fuel item modifies its burning rate. This happens primarily in the later, post-flashover stage of a fire and involves two burning rate effects, augmentation due to increased radiation, and diminution due to vitiation of the air from combustion product contamination. Second, significant fuel/fuel interactions can occur whenever the first burning item can ignite a second one. In this study we are concerned primarily with fuel/fuel interactions where the fuel objects are pieces of furniture. A similar approach can be taken for wall linings or other different types of combustibles. We will assume that an initial item is on fire and will examine the possibilities for involvement of additional items. Burning of the initial and any subsequent items will be assumed not to lead to significant fuel/room interactions.

2. TESTING FOR FUEL/FUEL INTERACTIONS

The interaction between two pieces of fuel becomes a moot question if the items are placed one against the other, since then continuous flame spread can occur. Ignition can also occur for slightly separated items if the flames and hot gases from the first impinge directly on the

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[1] Numbers in brackets refer to the literature references listed at the end of this report.

second. Conversely, if the second item is placed in the opposite corner of a room, far from the first ignited item, no involvement is expected until room flashover (at flashover the previously unignited items are assumed to ignite nearly simultaneously). For items that are nearby yet not directly contiguous, however, it becomes appropriate to determine if the second item can ignite by radiation from the first, with the two then burning as one "fuel packet." If this is likely, we would then want to predict this combined burning rate, which can be higher than burning rates measured for the two items separately. Such investigation has not yet been made.

Since significant interaction is possible only if the second item ignites from the first, it becomes of interest to determine this potential for ignition. Given a set of n test specimens, one would wish to conduct tests with each item paired with each other, with alternately the one or the other being viewed as the ignitor, and all done at various separation distances. On the order of n^2 tests at each separation distance would be required. Additional tests may further be required to determine repeatability. A program of this nature is unrealistic.

The problem can, however, be separated into its elements analytically. A given combustible item is presumed to be ignited and burning. It is possible to determine first the irradiance, as a function of distance, from this burning item No. 1, then to test some item No. 2 with different irradiances to determine the minimum for ignition. The actual determination of ignition can then be done analytically, by comparing the results. A testing program now becomes practical since instead of n^2 tests at several separation distances only n irradiance mapping tests have to be run, the irradiances being measured at several separation distances in a single test. Separately, 2n ignitability tests can yield sufficient data on the ignitability item No. 2. In this procedure, any separate combustible in a room can be item No. 1 or item No. 2 -- appropriate choices can only be made based on a plausible fire scenario.

Once the ignition or non-ignition of subsequent items is established, the effects on burning rates would have to be considered. Once two or more items are burning their individual burning rates need no longer be what they would have been for a sole item, but can be modified both by radiation and by the convective flow fields. The magnitude of this effect has not been studied.

3. IRRADIANCE MAPPING TESTS

In the present study experimental work was conducted to address one specific problem in the area of fuel interactions -- will the second item ignite by radiation? This was to be characterized by separate tests for irradiance (radiant heat flux) and for ignitability.

A very limited amount of irradiance mapping work has been reported in the literature for common furnishings items. Theobald [3] burned several types of common furniture in an open area, placing small targets of cotton cloth, wood blocks and plywood sheet at various separation distances. Maximum distances for target ignition were recorded. Fang [4] and Klein [5] used heat flux gages to measure the irradiance at different distances from burning upholstered chairs.

The present test series utilized the following set-up. A load platform, 0.91 m by 1.88 m in size, was suspended from a water-cooled load cell above. The load cell had a live load capacity of about 150 kg. Load cell output was recorded with a digital data logger. The rms load fluctuation level was measured as the equivalent of $\pm$ 6 g under ambient temperature conditions. The primary cause for fluctuations in experiments of this type, however, is not due to the limit of resolution within the load cell itself, but rather due to the turbulence of the fire. Fire turbulence manifests itself as buoyancy fluctuations acting upon the load platform. These were not studied in detail but are in the order of 100 or 200 g. The test load cell data were taken every 20 s and smoothed numerically with a 6 point averaging technique. In the case of tall specimens, material loss from the platform was prevented by erecting a wire mesh screen around the specimen. No significant losses occurred from the platform in any test.

To measure the irradiances at multiple locations in two dimensions a movable trolley was constructed. Gardon-type gages were mounted at 0.41, 0.86, 1.32, and 1.78 m height above the platform. The trolley was moved along a track having detents at 0.05, 0.20, 0.50, 1.12, and 1.73 m from the leading edge of the specimen (See Figure 1). The convective heat flux component from the fire was not desired since only the problem of igniting objects at a distance is considered here. Therefore, the gages were used with wide-angle (150°) Irtran 2* windows, which block convective effects but transmit radiant energy over the desired wave length range of 0.8 to 13.0 μm. Fang's data [4] suggest that at short distances from the source a convective component on the order of 10 to 20% of the radiant heat flux should be considered likely while in the immediate vicinity of the source, convective heating can even dominate. Conversely, away from the source plume region a modest convective cooling effect can be found. The trolley was moved back one space at each data scan so that a complete record as a function of distance was obtained every five scans.

The test rig was located in a large experimental area, with free access to fresh air. The products of combustion were collected in a large hood overhead. The collection rate was sufficient to avoid the backing down of combustion products into the experimental space.

Specimens were ignited by lighting off a small polyethylene waste basket filled with 12 polyethylene-covered paper milk cartons. Six cartons were placed upright in the waste basket, while six were torn into small pieces and dropped inside. The total weight of a waste basket was 285 g, while the 12 cartons together weighed 390 g, for a total weight of 675 g. The gross heat of combustion was measured to be

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* Trademark, Eastman Kodak Co. This identification does not constitute a recommendation nor does it imply that other devices could not be used.

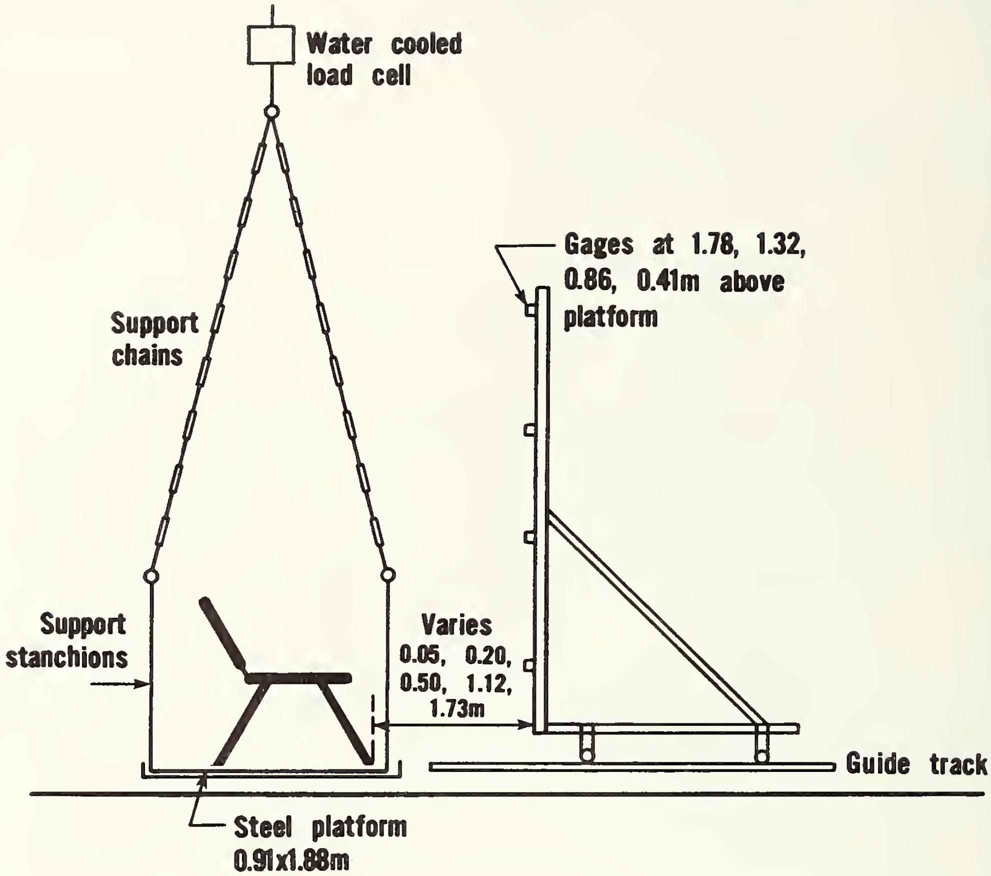

Figure 1. General view of irradiance mapping apparatus and weighing platform

46.32 kJ/g for the waste basket and 20.26 kJ/g for the cartons, representing 21.10 MJ in all. Using an estimated correction, this gives a heat content of 19.7 MJ, based on the net heat of combustion. The waste baskets and milk cartons were essentially identical to ones used in tests at the University of California, Berkeley [6]. Figure 2 shows the mass loss rates for three specimens from the present series, along with two from Berkeley. It is seen that there is no systematic difference between the burning rates (one specimen from the present series, however, showed a delayed early fire development). For purposes of characterizing this ignition source, it seems appropriate to consider a constant mass loss rate $\dot{m}$ = 1.8 g/s (equivalent to 52.5 kW based on the heat content as determined above) for the first 200 s and negligible thereafter. At the cessation of all burning an average of 61% of the initial mass is consumed. If we define the active burning period to extend for the first 200 s, then by subtraction, during the remaining 2200 s or so of slower or smoldering type burning an additional 51 g of mass is lost. (By actual measurement at 200 s an average of 66 g still remains to be burnt.) In testing furniture items, the igniting waste basket was placed flush against the side or back of the specimen in each case. Flux measurements were then taken at 90° away, to the front or side, respectively. (Ignition is generally not possible without direct contact of waste basket against the test specimen at a height of 0.41 m and 0.05 m away from the burning waste basket an irradiance of only 8 kW/m^2 was measured. This is appropriate since the waste basket is used only to provide ignition of item No. 1 and should otherwise produce a small fire.)

4. IGNITION TESTS

Ignition of furniture items has most commonly been tested with small non-uniform flame sources, e.g. [7]. This is intended to simulate the actual ignition conditions of the first item. In the present case, however, the ignition potential of the second item is of concern. In such case, the second item receives an irradiance from the first item

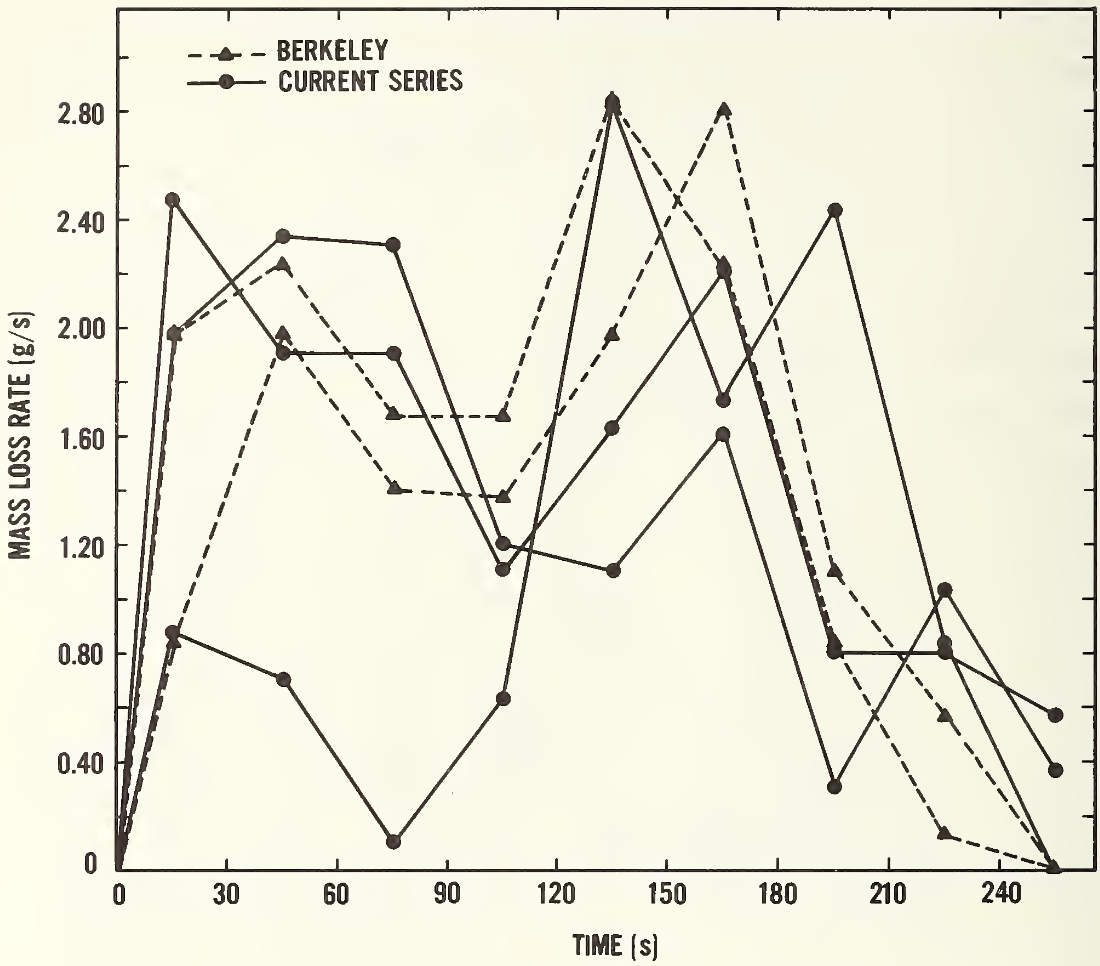

Figure 2. Wastebasket mass loss rates

which is only slowly varying over its surfaces. Thus a test is needed where a uniformly distributed irradiance rather than a concentrated source is used. A piloted ignition condition is to be preferred for two reasons: flying brands can be realistically expected, and piloted ignition results typically show less scatter than autoignition. The ignition testing was done in an apparatus adapted from a proposed International Organization for Standardization (ISO) test [8]. The apparatus was modified (Figure 3) primarily by substituting an electric spark ignition (which is more repeatable and less affects specimen irradiance) instead of the prescribed gas pilot, and by modifying the specimen holder. All specimens are tested in the horizontal orientation in this test. While there are differences in ignition characteristics that depend on orientation, these were considered small compared to other sources of variability. The specimens were 150 x 150 mm in surface area. The existing thickness, up to 50 mm was used. Samples were cut from large, flat furniture areas, such as backs, seats, or side panels. No attempt was made to test edges or small members. Two irradiance values were used, 20 and 40 kW/m^2, as measured by a Gardon gage mounted in place of the sample. The 20 kW/m^2 value was chosen since it represents a value near the minimum ignition flux for many common combustibles. Those combustibles which require as much as 40 kW/m^2 for ignition would be considered difficult-to-ignite; conversely, some data exist [9] to show that for certain especially easily ignitable combinations of materials, even 10 kW/m^2 may be sufficient for ignition. The apparatus was used in a draft shielded area. Power was turned on to the heater and stabilized at the desired irradiance. The specimen in its specimen holder was then quickly slid in and a stopwatch started. Ignition was considered to occur at the first evidence of flaming. An exception was taken for melamine-laminate clad particle board type products. These "exploded" at a certain point in heating when a violent delamination took place. Further testing was not practical after such delamination and this event was tabulated as tantamount to ignition.

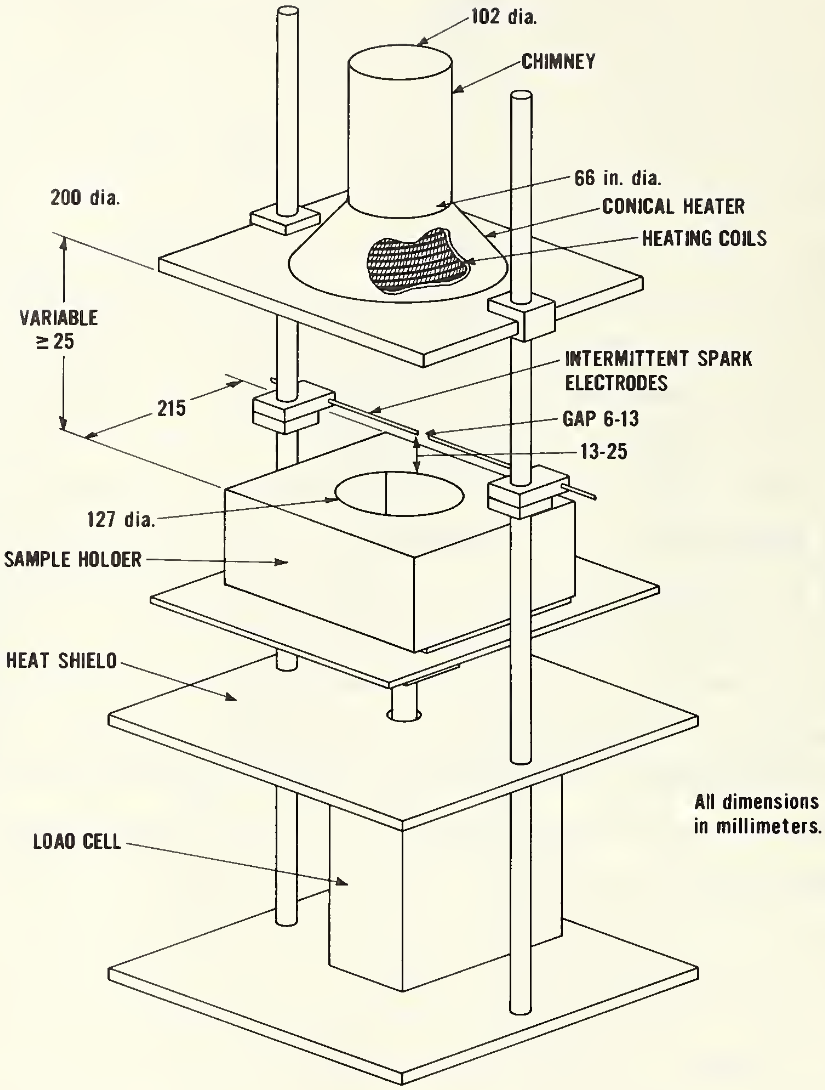

Figure 3. View of ignition test apparatus

5. RESULTS OF TESTS

Tests were conducted on some eighteen types of specimens, predominantly modern office furniture (Table 1). Exceptions included F16 a traditional residential type easy chair, F19 a couch associated with a fire in a local hospital sitting room, and F18 a prototype low-flammability prison chair. Illustrations of typical pieces are shown in Figures 4 through 8. Irradiance mapping data for the fastest burning upholstered specimen, wicker couch F19, are illustrated in Figures 9 and 10. From Figure 10 it can be seen that the burning item does not act as a point source and that a $1/r^2$ flux representation would not be appropriate in the near region (far away, of course, there is no significant hazard needing to be addressed). A summary of the principal results is given in Table 2.

Two specimens, F04 and F11, were run in identical replicate tests. Chair F04 burned very similarly in both tests. Storage cabinet F11, however, showed different fire development rates in the two tests. Most major surfaces of this unit were covered with a melamine type plastic laminate which is hard to ignite and does not readily spread fire. Flame spread, and therefore, burning rate were consequently determined by successive ignitions of the more ignition prone components, i.e., paper fuel, drawer insides, and shelf edges, all of this taking place somewhat randomly. Even though F11 and a similar but smaller cabinet, F10, showed substantial weight loss rates, neither of them indicated much radiant heat flux. This is because the measurements were taken from the side position; the only surfaces facing to the side in these specimens were fully laminate covered and did not readily burn. The side measurement position was considered preferable here since nearby combustibles would more likely be found close to the sides, rather than at the front.

Chair F17 was tested both from the sides and from the front. The results confirmed earlier exploratory findings that with upholstered

TABLE 1

Specimens Tested

SPECIMEN	TOTAL WEIGHT (kg)	TYPE [a]
F01	27.8	Acoustical office screen, fiberglass padding, nytril fabric (2 screens in corner)
F02	8.5	Molded frame "tulip" chair, cotton fabric
F03	13.2	Chrome frame armchair, vinyl cover
F04	27.8	Oak armchair, vinyl cover
F05	45.9	Oak two-seater, vinyl cover
F08	9.4	Chrome frame Breuer chair, nylon fabric
F09	43.4	Plywood/laminate desk (1.21 x 0.44 x 0.78 m high)
F10	27.7	Plywood/laminate storage cabinet
	(+ 7.7	added weight of paper load)
F11	79.1	Large vertical plywood/laminate storage cabinet (0.79 x 0.38 x 1.93 m high)
	(+ 19.1	added weight of paper load)
F12	17.1	Chrome frame armchair, vinyl cover
F13	7.3	Oak side chair, vinyl cover
F14	6.1	Fiberglass molded chair, no padding
F15	18.5	Oak armchair, vinyl cover
F16	23.4	Traditional style easy chair, polypropylene fabric
F17	18.0	Molded polyethylene pedestal chair, vinyl cover
F18	35.6	Prototype prison chair, polyethylene frame, neoprene foam, Nomex fabric
F19	19.9	Hospital couch, wicker frame polypropylene fabric
F20	7.7	Padded stacking sidechair, vinyl cover
WB	0.675	Polyethylene waste basket, filled with 12 milk cartons

a - all upholstered furniture had polyurethane foam padding, unless otherwise specified.

TABLE 2

Results of Irradiance Mapping Tests

SPECIMEN	FLUX GAGES	MAXIMUM IRRADIANCE (kW/m^2)	HEIGHT FOR PEAK IRRADIANCE (m)	MAXIMUM RADIAL DISTANCE WHERE 10 kW/m^2 REACHED[d] (m)	MAXIMUM RADIAL DISTANCE WHERE 20 kW/m^2 REACHED[d] (m)	MAXIMUM RADIAL DISTANCE WHERE 40 kW/m^2 REACHED[d] (m)	PEAK $\dot{m}$ (g/s)	TIME AT PEAK (s)
F01	45°	6.3	0.41	--	--	--	1.9	780
F02	Side	22	0.86	0.39	0.11	--	6.8	640
F03	Side	37	0.86	0.87	0.16	--	6.2	760
F04	Side	61	0.41	0.50	0.29	0.14	27	480
F04[a]	Side	56	0.41	0.50	0.34	0.13	23	320
F05	Side	63	0.41	0.93	0.54	0.44	36	660
F08	Side	7.8	0.41	--	--	--	3.8	120
F09	Side	21	0.41	0.45	0.16	--	17	2420
F10	Side	18	0.41	0.35	--	--	28	2300
F11	Side	14	0.41	0.41	--	--	52	1440
F11[a]	Side	6.3	0.41	--	--	--	28	620
F12	Front	32	0.41	0.26	0.16	--	12	360
F13	Side	25	0.41	0.30	0.13	--	6.7	780
F14	Side	4.8	0.41	--	--	--	< 2	200
F15	Side	57	0.41	0.84	0.29	0.12	12	820
F16	Side	59	0.86	1.33	0.79	0.20	22	900
F17	Side	69	0.41	1.37	0.44	0.20	20	1940
F17	Front	48	0.41	0.74	0.43	0.10	18	880
F18	Side	< 1	--	--	--	--	< 2	
F19	Front	79	0.41	1.38	0.88	0.40	47	640
F20	Side	5.4	0.41	--	--	--	2.3	2600
F20[b]	Side	15	0.86	0.14	--	--	6.3	180

a -- replicate test
b -- three stacked specimens
c -- gages located at heights of 0.41, 0.86, 1.32, 1.78
d -- measurement locations at 0.05, 0.20, 0.50, 1.12, 1.73, values are interpolated

(a) Before test

(b) Near peak burning

Figure 4. Storage unit F11

(a) Before test

(b) Near peak burning

Figure 5. Easy chair F16

(a) Before test

(b) Near peak burning

Figure 6. Pedestal chair F17

(a) Before test

(b) Near peak burning

Figure 7. Wicker couch F19

(a) Before test

(b) Near peak burning

Figure 8. Stacking auditorium chairs F20

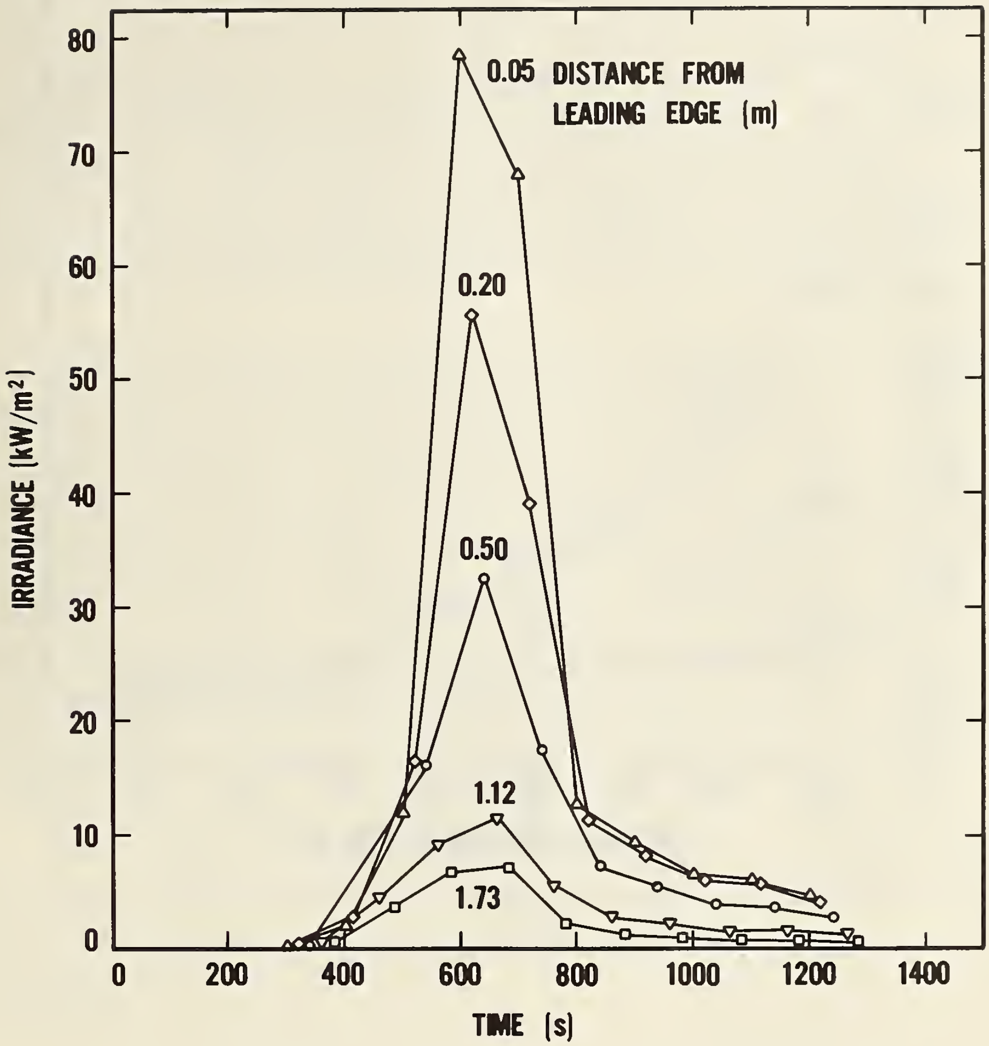

Figure 9. Irradiances for specimen F19, measured at 0.41 m height

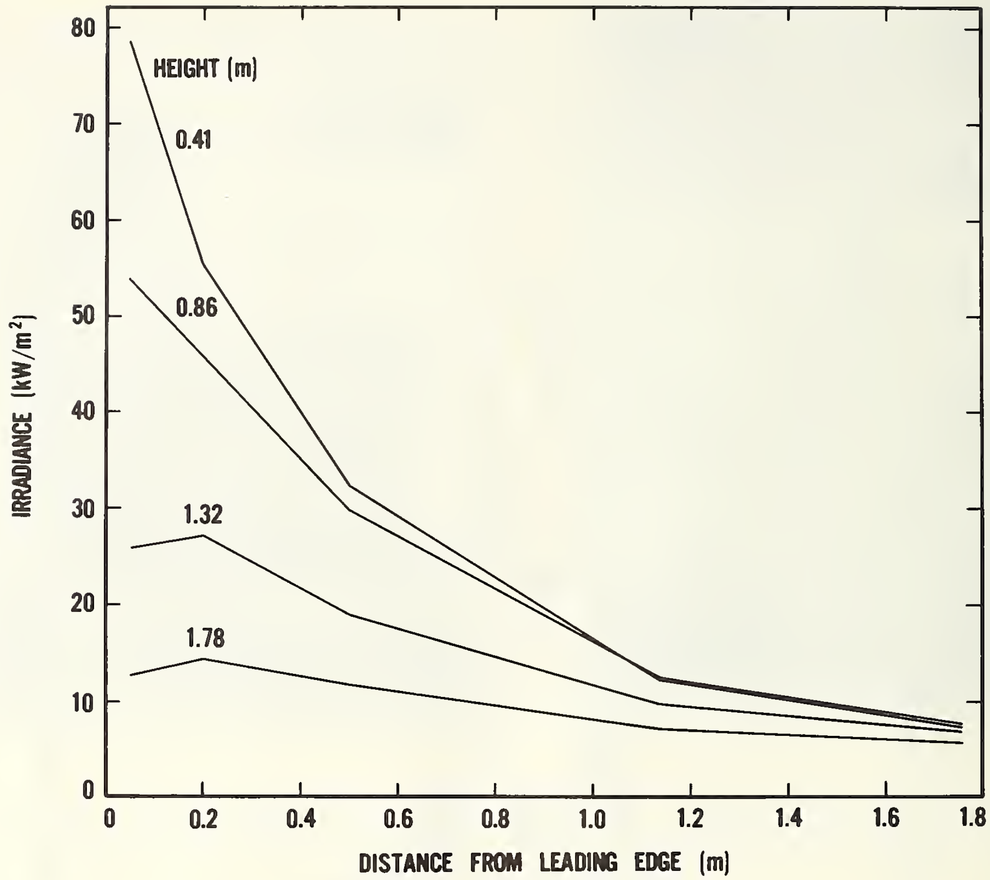

Figure 10. Irradiance distribution for specimen F19 at peak burning time

chairs, the side and front positions tend to give quite similar results, with slightly worse behavior being observed at the side position.

One specimen, F20, was an auditorium chair made to be stacked. Two tests were conducted with this type chair, a single unit and three stacked chairs. The single unit did not show significant burning; the three stacked chairs, however, burned vigorously and showed peak fluxes and mass loss rates some ten times that of the single chair.

Results of ignition tests are given in Table 3. All specimens tested ignited at the higher, 40 kW/m^2 irradiance with the exception of the prison chair F18.* A number of specimens failed to ignite at the lower, 20 kW/m^2 irradiance. Figure 11 suggests that if more than about 40 s is required for ignition at 40 kW/m^2 irradiance, then ignition at 20 kW/m^2 is unlikely. For homogeneous, thermally-thick materials, both theory and experiments [10] indicate that the ignition time is expected to vary inversely with the second power of the irradiance. The data in Figure 11 show a dependence closer to the first power of irradiance.

The ignitability results can also be useful in evaluating certain other fire possibilities, e.g., ignition from a fireplace rather than from a burning furniture item if irradiances from such a source are determined.

6. ANALYSIS

The specimens tested here are seen to cover a broad spectrum of burning behaviors, ranging from those which would not ignite from a wastebasket source at all, to ones which were readily ignitable and led

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* Testing at higher irradiances was not done in this program and a minimum value for this special prototype chair was not determined. It is interesting to note, however, that results from other tests show that a good readily available construction consisting of wool upholstery fabric over neoprene foam requires approximately 65 kW/m^2 for ignition.

TABLE 3

Results of Ignition Tests

SPECIMEN	IGNITION TIME AT 20 kW/m^2 IRRADIANCE (s)	IGNITION TIME AT 40 kW/m^2 IRRADIANCE (s)
F01	43	24
F02	29	14
F03	25	14
F04 Seat	18	11
Back	31	9.3
F05	29	11
F08	∞	41
F09	∞	110
F10	∞	236
F11	∞	191
F12	24	11.4
F13	41	18.5
F14	∞	455
F15	22	15.3
F16	38	14.5
F17 Seat	20	12.0
Back	31	17.3
F18	∞	∞
F19	N.A.	N.A.
F20 Seat	32	12.4
Back	32	11.3

∞ - Did not ignite
N.A. - Not available

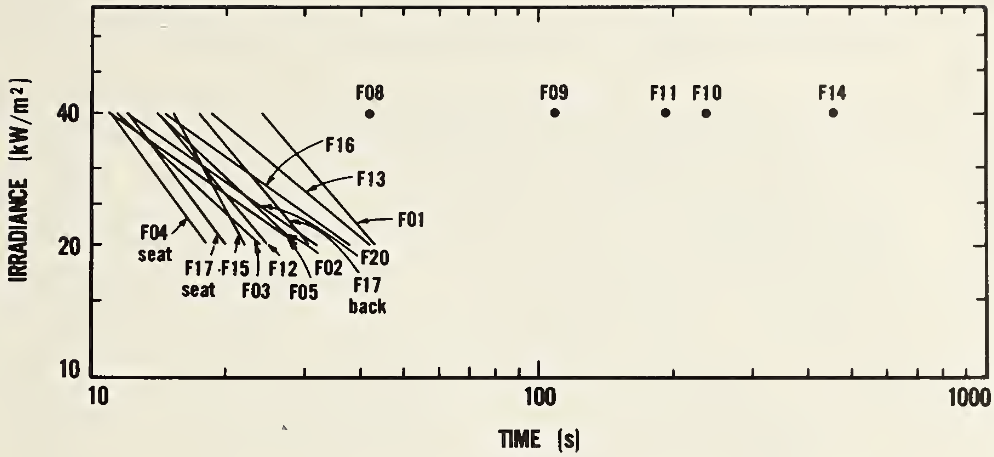

Figure 11. Irradiance-time relationship for ignitability tests

to large fires. A fiberglass molded chair, F14, and a highly retardant treated prison chair, F18, failed to ignite and burn from a direct contact wastebasket fire. Thus, they would not likely act as ignition sources for other objects in a real fire. (Both specimens also did not ignite at 40 kW/m^2 in the ignition apparatus.) Several specimens burned vigorously, producing maximum irradiances in the vicinity of 40-80 kW/m^2. These included F04, an oak armchair; F05, a similar styled two-seater; F15, another oak armchair; F16, a traditional easy chair; F17, a molded polyethylene pedestal chair; and F19, a wicker couch. The corresponding peak mass loss rates here were primarily in the range of 20-47 g/s. Assuming, very roughly, an effective heat of combustion of 21 kJ/g [11], suggests these to be fires in the range of 0.4 to 1.0 MW. For point of reference, such fire output can be expected to flash over [11] rooms with ventilation factors $A\sqrt{h} \leq 0.5$ to 1.3 $m^{5/2}$, (where A = area of door/window, h = height). This rule holds for rooms of moderate wall area; additional considerations apply [11] for small-ventilation, large wall area rooms. A common doorway size can yield a ventilation factor ≃ 2.2 $m^{5/2}$; thus these specimens, burning alone, would not likely be sufficient for room flashover if doorway flows are the ventilation source. Windows, however, can commonly be found with $A\sqrt{h} \simeq 1.0$ $m^{5/2}$, so flashover would be possible in that case.

Storage cabinets F10 and F11 represented a special case since they showed mass loss rates in the same range as the fast-burning specimens above, yet showed low irradiances to the side (6 to 8 kW/m^2). Thus, these would - short of flashover - not likely involve any additional fuel items to the side, although they could readily involve items placed in front or overhead and could also, given sufficiently small ventilation $A\sqrt{h}$, lead to flashover.

The remaining fuel items were all active fire sources but somewhat less serious than the sources mentioned above. Since 20 kW/m^2 is not reached, second item involvement would not be expected with F01, F08, or F20 (single) at any separation adequate to prevent direct flame contact. Specimens F02, F03, F09, F12, F13, and F19 did exceed irradiances of 20

kW/m^2 and thus might lead to ignition with an appropriate second item placed close enough.

The majority of furniture pieces using fabric/polyurethane foam constructions ignited within 45 s at an irradiance of 20 kW/m^2. This length of time is short in comparison to peak burning durations, typically several minutes (Figure 9); thus any No. 1 items showing irradiances > 20 kW/m^2 would presumably ignite any of these No. 2 items. The pieces that required 40 kW/m^2 or more for ignition generally took a long time to ignite. The analysis would then require an examination of the complete item No. 1 irradiance-time curve, which is probably not warranted.

While a detailed irradiance mapping, as in the present study, is a fairly time-consuming operation, a record of the mass loss rate is likely to be available from most testing programs. Thus, it would be useful if mass loss rate values could be used to approximately deduce the expected maximum irradiance. Data from the present test series have been plotted to seek this relationship in Figure 12. The irradiances are the maximum at 0.05 m away and at the heights as indicated in Table 2. There is no simple correlation to be seen, primarily because some of the specimens burn in an open manner while others are -- at least from some directions -- self-shielded. For making conservative irradiance estimates, then, it would be appropriate to use an envelope curve; such a curve has been indicated in Figure 12 and can be useful in making estimations.

One further rough simplification can be made. By combining those points on the envelope curve in Figure 12 with the irradiance values given in Table 2, a relationship between the mass loss rate for item No. 1 and distance-to-given-irradiance can be obtained. This is shown in Figure 13 for 10, 20, and 40 kW/m^2 levels and can be used to evaluate candidate items No. 2.

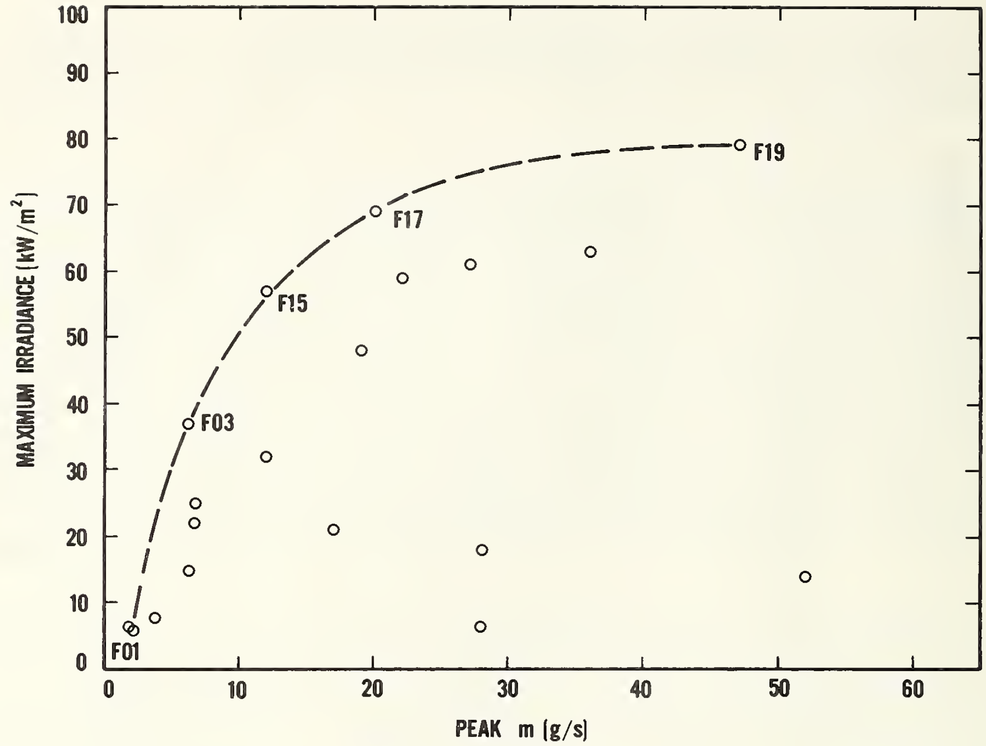

Figure 12. Dependence of maximum irradiance on peak mass loss rate

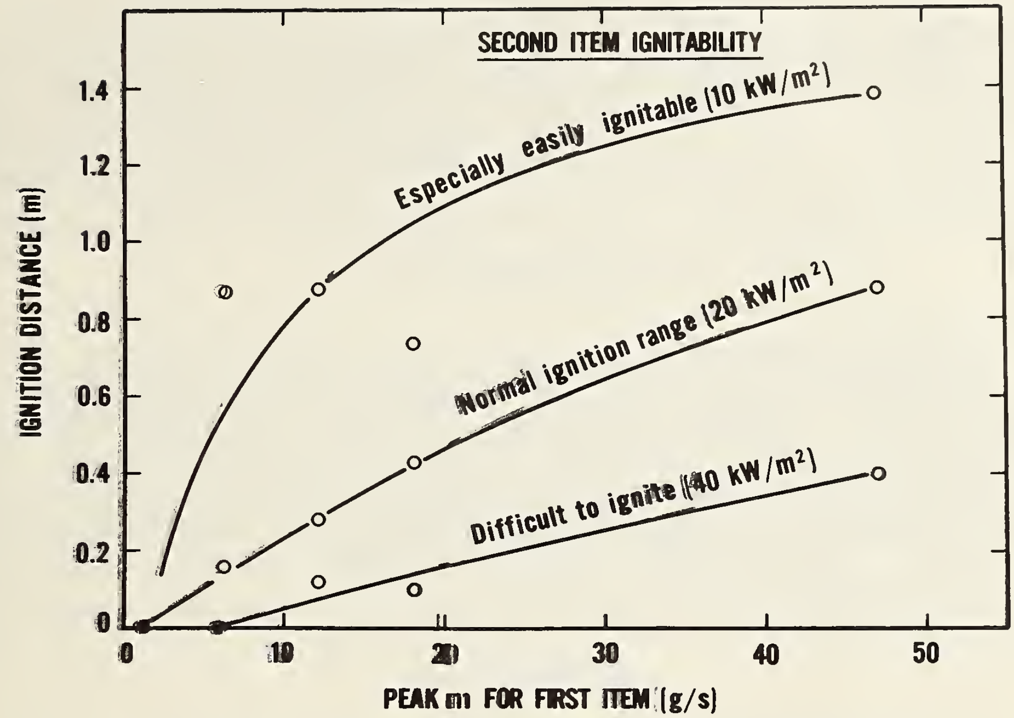

Figure 13. Relationship between peak mass loss rate and ignition distance for various ignitability levels

7. CONCLUSIONS

A method has been developed for assessing the likelihood of ignition of additional, non-contiguous fuel objects when an initial object has been set afire. The procedure involves making irradiance measurements during the burning of the first item and conducting a bench-scale ignitability test on specimens of the second object.

Irradiances measured 0.05 m away range to near 80 kW/m^2 for the fastest burning specimens; however, 40 kW/m^2 was not recorded farther than 0.44 m away and 20 kW/m^2 was not found beyond 0.88 m distant. The implication is that common furnishings items, which normally require a minimum irradiance approaching 20 kW/m^2 for ignition, would stand little hazard of fire involvement if placed at least 1 m away from the initial source.

The above conclusion is only applicable for fires short of flashover. Once flashover is reached, most combustibles can be presumed to ignite and burn regardless of where they are in the room. Potential for flashover can be evaluated using the techniques described in [11].

A modified version of the ISO ignitability test was found useful for performing the required ignition tests. This method is superior to most other common ignitability tests since, by virtue of a controlled flux and one-dimensional heat conduction, it permits analytical use in describing room fire behaviors. Greater use should be made of a test of this type for systematic characterization of product performance.

An empirical relationship between peak mass loss rate and limiting maximum irradiance has been obtained. Also, a similar relationship was derived relating critical distances for ignition to peak mass loss rates. These relationships could be refined with additional test data and with more detailed considerations of shielded fires.

Peak irradiances of 40 kW/m^2 and 57 kW/m^2 measured at 0.05 m from the burning No. 1 item produce irradiances $\geq$ 20 kW/m^2 at up to 0.20 m and 0.50 m away, respectively, from the item. Additional values could usefully be derived from further studies.

8. ACKNOWLEDGEMENTS

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15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The burning of more than a single fuel item in a room fire has not been well characterized. The first step in describing multiple item burning is to determine if, in fact, it will occur. This question has been experimentally explored from two aspects. (1) The radiant heat fluxes from burning first-to-ignite objects have been measured, along with their mass loss rates. (2) The ignitability of exposed objects has been determined using a bench-scale uniform flux ignitability test. It is then suggested that whether the second item will ignite can best be determined analytically from considering these two sets of results.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Burning rate, case goods, chairs, furniture fires, ignitability, room fires, upholstered furniture.

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