December 1971

URS 7030-5

Summary Report

THE IGNITION HAZARD to URBAN INTERIORS DURING NUCLEAR ATTACK due to BURNING CURTAIN FRAGMENTS TRANSPORTED by BLAST

Contract No. DAHC 20-71-C-0223 Modification P616-1

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Prepared for:

OFFICE of CIVIL DEFENSE
Office of the Secretary of the Army, Washington, D.C. 20310

Prepared by Thomas Goodale

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SUMMARY

THE PROBLEM

There exists some uncertainty at present, in the formulation of civil defense doctrine, as to whether it is advisable for window curtains to be closed or open during nuclear attack. Closed curtains would be in position to intercept some major portion, or all, of the thermal radiation pulse that would otherwise enter through the window and ignite kindling fuels within the room. But because they did so they would probably ignite and the flaming curtains, propelled into the room by the blast wave, could represent an even more serious ignition hazard than would occur if the window remained uncovered, and the curtains uninvolved. Because of this uncertainty, limited investigation, was undertaken to gain information concerning the ignition hazard represented by burning curtain fragments carried on a blast wave into typical urban interiors.

The specific objective of the research described in this report was to investigate the propensity of burning curtains, carried into typical urban interiors by blast waves, to cause ignitions within the interiors capable of leading to flashover. The situation simulated in the experiments was one in which the closed curtains, having been ignited by thermal radiation from a nuclear weapon explosion, were carried, still burning, into a room in which none of the kindling fuels had been ignited owing to interception of most of the thermal pulse by the curtains. The blast wave, transporting the burning curtain fragments, was assumed to originate from the same weapon producing the thermal pulse, so that an appropriate delay time intervened, in each experiment, between curtain ignition and blast arrival.

THE METHOD

The effect of blast-transported burning curtain remnants in causing interior ignition was investigated in two widely different kinds of urban interiors, a living room, and an office.

The experimental program was conducted in a full-scale test room constructed in the test section of the URS Shock Tunnel Facility. All tests were conducted at a nominal incident blast overpressure of 1 psi since it had been found in previous work that incident overpressures much higher than this, e.g., 2.4 psi, and higher, invariably extinguish fire in burning curtains, a result that would annul the purpose of the tests proposed here.

Curtains were ignited by propane gas jet manifolds arranged on the upstream side of the curtains with the jets directed toward the curtains.

The interval of time delay between the end of the ignition period, that is, the extinguishment of the propane gas flames, and the initiation of the blast wave in the experiments was chosen to be that which would occur between the peak of the second thermal pulse of 1 Mt and 5 Mt low airbursts and blast arrival times for such bursts at ranges corresponding to an incident overpressure of 1 psi. These delay times were 32 seconds and 54 seconds for 1 Mt and 5 Mt airbursts, respectively.

Three different weights of curtain material, having different burning times, were used in the experiments. Curtains were simulated in all the experiments by sheets of 100% cotton fabric, of appropriate weight, hung from a steel rod by drapery hooks.

Events within the rooms following blast arrival were documented by means of high-speed (Fastax) photography and pre- and post-shot still photography, supplemented by written notes.

Fires initiated by burning curtain fragments were [illegible] until they could be definitely characterized as flaming combustion or as smouldering combustion, capable of leading to flaming combustion. The probability of flashover of the room due to such ignitions was inferred from the size of the items in which fires occurred, and the number of such ignitions.

FINDINGS

Ignited window curtains pass through a phase of flaming combustion during which the fabric is charred and weakened sufficiently that the remnants drop to the floor under the window, where they are further consumed by smouldering combustion, usually accompanied by flame. Since transportation of the burning curtains by a blast wave entering the window is much more effective for hanging curtains then for curtains that have dropped to the floor under the window, the likelihood of burning curtain fragments being carried into the room by the blast wave will depend to a major degree on whether the curtains remain hanging at the time of blast arrival.

When a heavier fabric was lined with a lighter fabric and the lighter fabric received [illegible] from the propane ignition manifold, it was found that the burning times of the combinations were much lower than those of the heavier fabrics alone. The lining (muslin was used) ignited and reached full flaming combustion in a few seconds, and served as kindling to accelerate the ignition and combustion of the heavier fabric adjacent to it. Although addition of the muslin liner increased the weight of the panel per unit of its area, the burning time of the combination was typically only half that of the unlined fabric or less. Thus, the rate of energy release in combustion of the lined curtains was usually more than twice that of the unlined curtains.

It was found that the burning times of fabrics, of various weights per unit area, could be conveniently controlled and adjusted by partial lining of the material with muslin. By this means, the burning times of curtains could be made substantially independent of the weight of the fabric composing them. The liklihood of room ignition, or flashover, resulting from the burning curtain remnants being transported into the room by the blast, was inferred from the size of the items in which fires occurred, and their number, and by how well the fires were established. The hazard of room ignition in each test was characterized as follows; "No hazard of room ignition" applied to cases in which no fires remained burning after a test; "Small hazard of room ignition" applied to cases in which fire was in a poorly established, or smouldering stage in the room contents; and "Severe hazard of room ignition" was applied to cases in which fire was well established and building up in major items of furniture.

Seventeen tests were conducted. Severe hazard of room ignition resulted from 7 of the 17 experiments, while a small hazard of room ignition occurred in 4 cases.

Tests resulting in severe hazard of room ignition corresponded closely to cases in which the blast wave arrived at an optimum stage in combustion of the curtains (when they were fully aflame but only partially consumed). The evidence for this optimum condition was the absence of major portions of unburned curtain material in the room, or of charred curtain remains under the windows. In these cases,large, fully ignited fragments of the curtains were deposited on fuel items in the room, and these fragments continued to burn briskly, thus serving to induce fully developed fires in the room.

In cases in which curtains were not fully ignited at blast arrival, the curtain fragments tended to smoulder, and to induce smouldering fires in the test room. Where curtains had passed the optimum stage of flaming combustion, charred remnants distributed throughout the test room lacked sufficient remaining fuel value to serve as efficient secondary ignition sources. Characteristically, these charred fragments would produce charred holes through several layers of paper, or in the nap of the rug, without any ignition of these items to flaming or smouldering combustion.

Although no quantitative data were obtained regarding the duration of the period in which burning curtains remained in a near-optimum condition for inducing secondary ignitions in interior fuels, it appears that this condition prevailed for only about 20% of the burning time in our experiments, and that it occurred near the near the center of that time interval.

The hazard of secondary ignitions due to blast-transported burning curtain fragments appears to depend critically, in each case, on the burning time of the curtains relative to the time to blast arrival. Owing to the relatively brief period, in the burning of curtains, during which they constitute very effective secondary ignition sources when transported by blast, approximate or unrealistic data on burning times could result in unrealistic analysis of the overall urban fire hazard from this source.

CONTENTS

ILLUSTRATIONS

TABLES

INTRODUCTION

There exists some uncertainty at present, in the formulation of Civil Defense doctrine, as to whether it is advisable for window curtains to be closed or open during nuclear attack. Closed curtains would be in position to incercept some major portion, or all, of the thermal radiation pulse that would otherwise enter through the window and ignite kindling fuels within the room. But, because they did so, they would probably ignite and the flaming curtains, propelled into the room by the blast wave, could represent an even more serious ignition hazard than would occur if the window remained uncovered, and the curtains uninvolved. Because of this uncertainty, limited investigation, reported in this document, was undertaken to gain information concerning the ignition hazard represented by burning curtain fragments carried on a blast wave into typical urban interiors.

OBJECTIVE AND SCOPE

OBJECTIVE

The objective of the present research described in this report was to investigate the propensity of burning curtains, carried into typical urban interiors by blast waves, to cause ignitions within the interiors capable of leading to flashover. The situation simulated in the experiments was one in which the closed curtains, having been ignited by thermal radiation from a nuclear weapon explosion, were carried, still burning, into a room in which none of the kindling fuels had been ignited owing to interception of most of the thermal pulse by the curtains. The blast wave, transporting the burning curtain fragments, was assumed to originate from the same weapon producing the thermal pulse, so that an appropriate delay time intervened, in each experiment, between curtain ignition and blast arrival.

SCOPE

The effect of burning curtain remnants in causing ignition was investigated in two widely different kinds of urban interiors, a living room and an office. A nominal incident blast wave overpressure of 1 psi was propagated into the rooms in all experiments. Two different delay times between ignition and blast arrival were investigated. These were the delay times that would occur at ranges corresponding to the 1 psi peak blast overpressure level surrounding a 1 Mt and a 5 Mt low airburst of a nuclear weapon.

APPROACH

The experimental program was conducted in a full-scale test room constructed in the test section of the URS Shock Tunnel Facility. Blast waves were produced in the tunnel by gas rapidly pressurized in an upstream compression section through the detonation of primacord arranged parallel to the axis of that section. The blast waves so produced travelled down the expansion chamber finally reaching the $8\frac{1}{2}$-ft x 12-ft test section. The layout and operating details of the Shock Tunnel Facility have been presented in a previous report (Ref. 1, page 4-10).

All tests were conducted at a nominal incident blast overpressure of 1 psi, since it had been found in previous work (Ref. 2) that incident overpressures much higher than this, (viz, 2.4 psi and higher) invariably extinguish fire in burning curtains, a result that would annul the purpose of the tests proposed here.

Curtains were ignited by propane gas jet manifolds arranged on the upstream side of the curtains with the jets directed toward the curtains.

The interval of time delay between the end of the ignition period, that is, the extinguishment of the propane gas flames, and the initiation of the blast wave in the experiments was chosen to be that which would occur between the peak of the second thermal pulse of 1 Mt and 5 Mt low airbursts and blast arrival times for such bursts at ranges corresponding to an incident overpressure of 1 psi.

Three different weights of curtain material were used in the experiments, having different burning times.

Events within the rooms following blast arrival were documented by means of high-speed (Fastax) photography and pre- and post-shot still photography, supplemented by written notes.

Fires initiated by burning curtain fragments were allowed to develop until they could be definitely characterized as flaming combustion or as smouldering combustion, capable of leading to flaming combustion. The probability of flashover of the room due to such ignitions was inferred from the size of the items which fires occurred, and the number of such ignitions.

DESIGN OF THE EXPERIMENT

Ignited window curtains pass through a phase of flaming combustion during which the fabric is charred and weakened sufficiently that the remnants drop to the floor under the window, where they are further consumed by smouldering combustion, usually accompanied by flame. Since transportation of the burning curtains by a blast wave entering the window is much more effective for hanging curtains than for curtains that have dropped to the floor under the window, the likelihood of burning curtain fragments being carried into the room by the blast wave will depend to a major degree on whether the curtains remain hanging at the time of blast arrival.

The time required for ignited curtains to be consumed in combustion has been shown experimentally (Ref. 3) to be greater for curtains composed of heavy fabric than for those composed of lighter fabric, in accordance with predictions based on theory (Ref. 4). Heavier fabrics also release more energy in combustion than do lighter materials, so that both the total energy release available for secondary ignitions by the burning curtains, and the time available during which ignitions can occur, can be expected to change as the weight of fabric in curtains increases.

Surveys of urban interior furnishings (Ref. 4 and 5) have shown that the weight per unit of fabric contained in window curtains, varies over a wide range, and that cotton is the material of which window curtains are most commonly composed.

In any actual nuclear weapon attack on an urban target, the burning times* of curtains, ignited by the thermal pulse, would be determined by the properties of individual curtains, and would be independent of the time required for arrival of the blast wave at the windows in which the curtains

* Burning times are here defined as the time elapsed between the second peak of thermal radiation (or, in our experiments, the time at which the gas jets igniting the curtains were turned off) and the time at which curtain remnants dropped to the floor.

in question were hanging. Thus, in any actual attack, arrival of the blast wave would find some curtains consumed to the point that they had already dropped to the floor, while, in other cases, ignition of heavy, slow-burning curtains might not be fully developed at the time of blast arrival. In either case, the probability of room ignition due to burning curtain fragments would be reduced,* either owing to failure of the fragments to be distributed within the room, in the former case, or because the curtains were not fully ignited in the latter case.

If curtains having a statistical distribution of properties, corresponding to those found to occur in urban interiors, had been used in our tests, many of the curtains would have either been fully consumed, or would have been incompletely ignited at the time of blast arrival, so that these tests would have been individually inconclusive regarding the existence of a secondary ignition hazard. Furthermore, the scope of the present program did not allow a sufficient number of tests to be conducted that statistically significant results would be possible over the entire distribution of curtain properties for each blast delay time of interest.

It was decided at the outset, therefore, to concentrate our attention on interactions in which curtains were in full flaming combustion but still hanging at the windows, at the time of blast arrival in each experiment. It was felt intuitively that this general area of interaction would post the greatest hazard of room ignition by burning curtain fragments, and that its study would be most productive of useful insight to the problem.

The interval of time delay between the end of the ignition period, that is, the extinguishment of the propane gas flames, and the initiation of the

* Exceptions to this rule are possible, e.g., if a sofa, or other large item of kindling fuel was located directly under the window, the hazard of room ignition due to burning curtains dropping from the window could be high. We consider such hazards to be outside the scope of the present investigation which is concerned only with the ignition hazard to room contents due to blast-transported burning curtain fragments.

blast wave in the experiments was chosen to be that which would occur between the peak of the second thermal pulse of 1 Mt and 5 Mt low airbursts and blast arrival times for such bursts at ranges corresponding to an incident overpressure of 1 psi. These delay times were 32 seconds and 54 seconds for 1 Mt and 5 Mt airbursts, respectively.

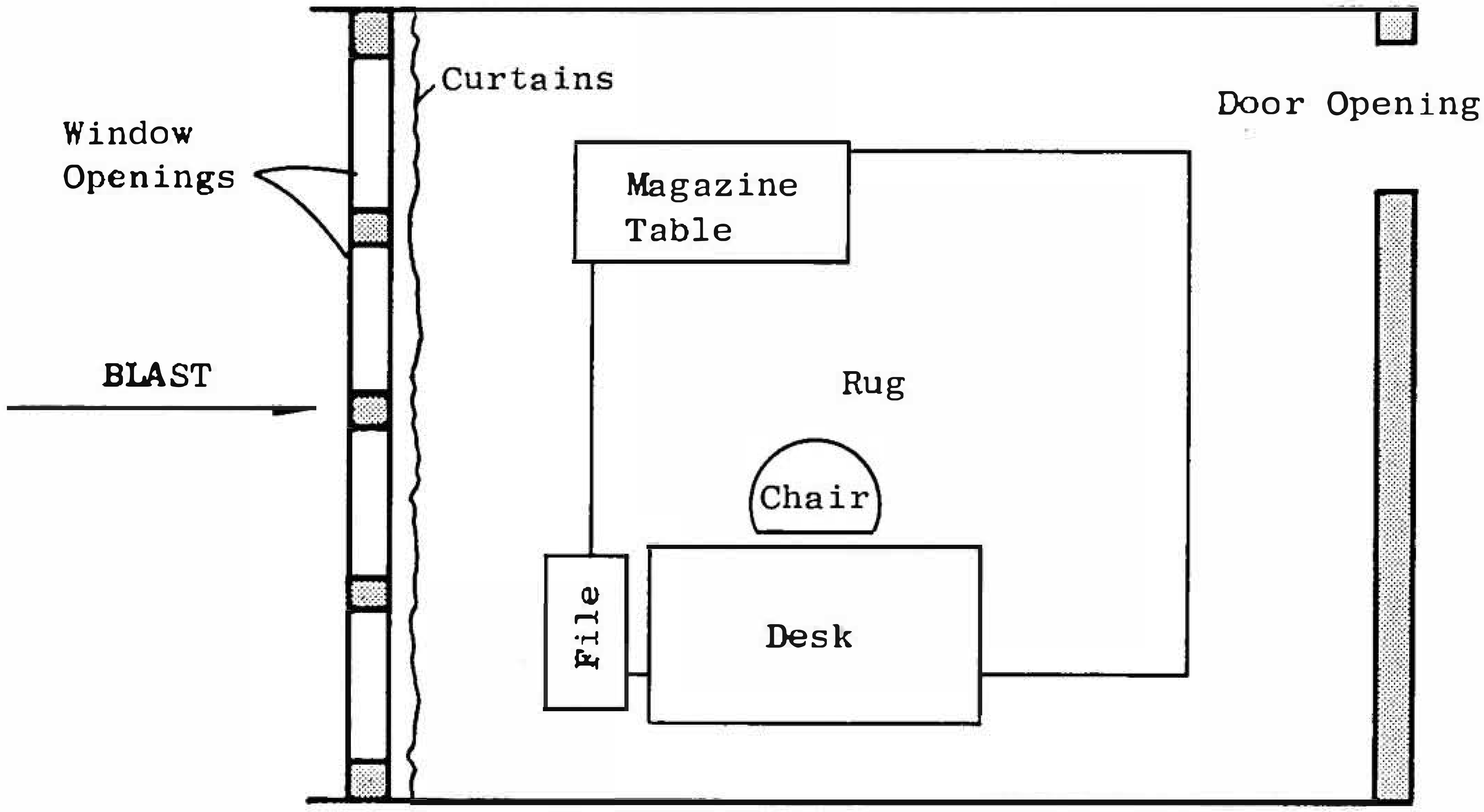
A minimum of 2 experiments were planned at the delay time of 32 secs, corresponding to the 1 Mt weapon yield, and for each of the two specified occupancy types, i.e., living room and office, in which a light curtain having a burning time of approximately 40 to 50 secs would be employed. A minimum of two experiments were planned at each of the two delay times between ignition and blast arrival corresponding to 1 and 5 Mt airbursts, and for each of the occupancy types specified, i.e., living room and office, for which a curtain would be selected having a total burning time greater than 54 secs, and preferably between 60 and 70 secs. Finally, a minimum of two experiments were planned at a single delay time of 54 secs, in each of the two specified occupancy types. A heavy curtain material having a burning time of about 100 secs was to be used in these experiments. It was decided that all curtains should be composed of 100% cotton fabric.

EXPERIMENTAL PROCEDURE

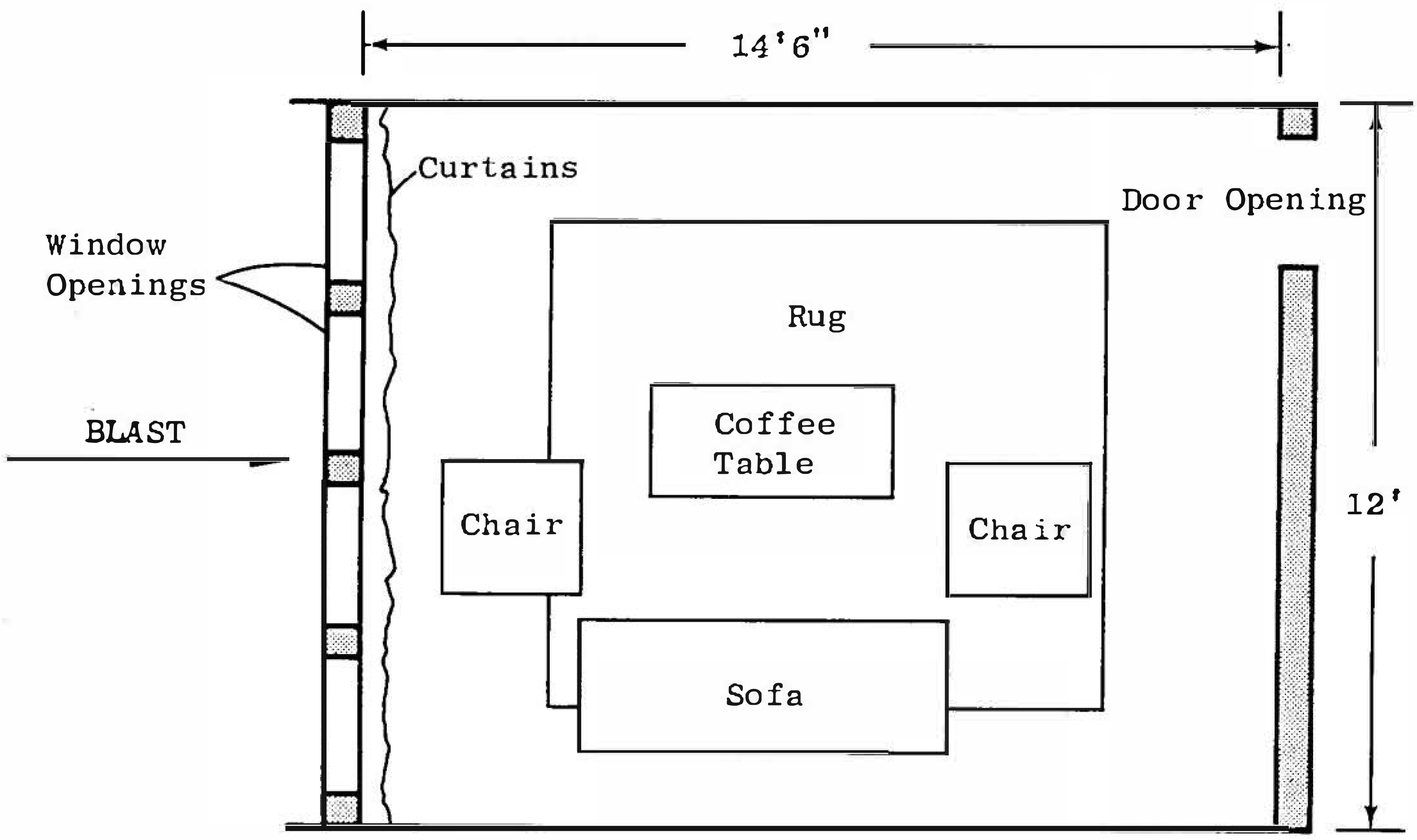
Curtains were simulated in all the experiments by sheets of fabric, of appropriate weight, hung from a steel rod by drapery hooks. The rod was mounted horizontally 3 inches above the window opening in the upstream wall of the test room. Material direct from the bolt was used for curtains (without hemming, pleating, or other fabrication) with consequent economy of time in their preparation.

The dimensions of the test room, and locations of the windows, and the layout of furniture, in the two kinds of occupancies simulated in the tests, as shown in Fig. 1. Four window openings were provided in the upstream wall, each 52 inches high and 27 inches wide.

Curtains were ignited by propane gas jets arranged in two horizontal rows, the gas jets issued from holdes, each 0.5 0 in. in diameter, drilled in 3/4 inch steel pipes. The holes were spaced 8½ inches apart across the width of the window wall. One of the two steel pipes, from which the gas jets issued, was mounted horizontally at the bottom edge of the windows, the other was mounted horizontally 24 inches above the bottom of the window openings. The pipes, from which the gas jets issued, were mounted at about 4 inches distance from the curtains, on their upstream side, with the jets directed nearly horizontally toward the curtains. After hanging the curtains, in each experiment, and completing other preparations, small pilot lights were ignited at each gas jet. These flames ascended vertically from each of the holes in the manifold, and were too small to reach the curtain material. A steel rod mounted across the window wall between the curtains and the gas manifold prevented the curtains from being blown against the pilot lights by transient air drafts. During ignition of the curtains, the propane to the gas manifold was turned up to full volume, which caused each of the gas jets to flow nearly horizontally at high velocity, and to impinge against the curtain. The bouyancy of the burning propane jets caused them to flow upward over the fabric so that curtains were ignited over a major proportion of their surface.



OFFICE OCCUPANCY



LIVING ROOM OCCUPANCY

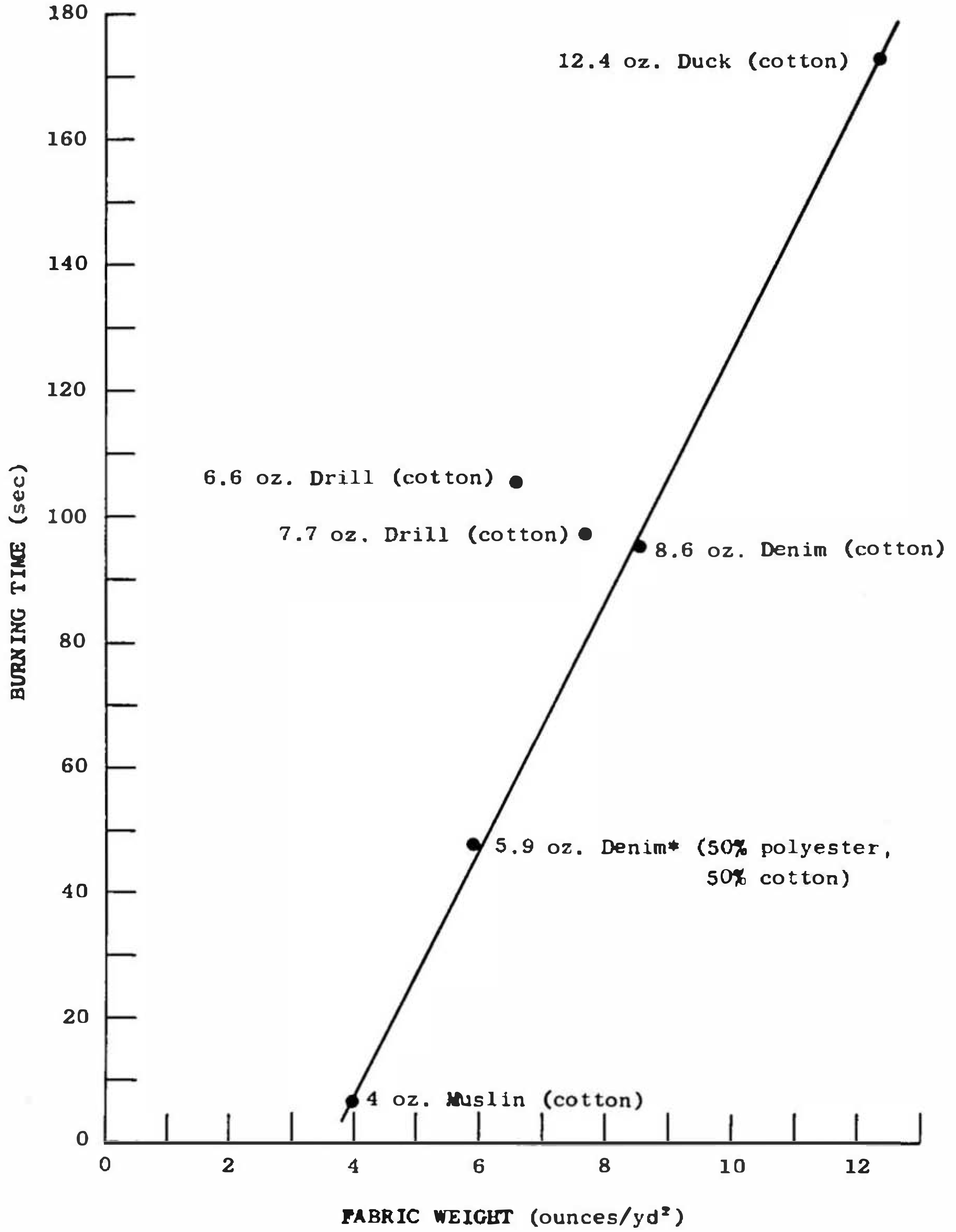
Fig. 1. Dimensions of Test Rooms, and Layout of Furniture in Them

A ten-second application of the gas jet manifold was employed, in the majority of cases, for curtain ignition. After turning off the propane to the manifold, a period of time was allowed to elapse before firing of the primacord in the compression chamber of the shock tunnel. This time corresponded, in each experiment, to the time between the second thermal maximum and blast arrival time, at a range corresponding to 1 psi overpressure, for the nuclear explosion the effects of which were being simulated.

As indicated earlier, it was decided to concentrate our attention on interactions in which the curtains were in flaming combustion but still hanging at the windows at the time of blast arrival. Further, it was desired to conduct tests with curtains composed of fabric of different weights per unit area having specific burning times between approximately 40 and 100 secs. Some preliminary experiments were undertaken to determine the kinds and weights of cotton fabric and the experimental conditions necessary to achieve these requirements.

Fabric panels of various weights per unit area were hung as curtains in the test room in the URS Shock Tunnel and ignited by a 10 sec application of the propane flame manifold. The time required for combustion of the curtain to proceed to the point that the curtain remnants dropped to the floor was measured in each case.

As indicated in Fig. 2, the burning times thus measured for various fabrics were approximately proportional to the weight per unit area of the fabrics, except for two samples of cotton drill which had notably greater burning times than would have been expected from their weight. The fabrics used in the experiments were obtained from various retail commercial sources and were employed in the tests without any attempt to determine the effects on the burning times of any sizing, flame retardants, or other treatment to which the fabrics may have been subjected in the course of their manufacture.



*This fabric was not used in the main test program because it was not 100% cotton.

Fig. 2. Burning Time as a Function of Fabric Weight of Unlined Curtain Materials

If a heavier fabric was lined with a lighter fabric, e.g., 8.6 oz/yd^2 denim lined with 4.0 oz/yd^2 muslin or 12.4 oz/yd^2 duck lined with 4.0 oz/yd^2 muslin, the lighter fabric receiving the heat from the propane ignition manifold, it was found that the burning times of the combinations were much lower than those of the heavier fabrics alone. The muslin lining ignited and reached full flaming combustion in a few seconds, and served as kindling to accelerate the ignition and combustion of the heavier fabric adjacent to it. Although addition of the muslin liner increased the weight of the panel per unit of its area, the burning time of the combination was typically only half that of the unlined fabric or less. Thus, the rate of energy release in combustion of the lined curtains was usually more than twice that of the unlined curtains.

It was found that the burning times of fabrics, of various weights per unit area, could be conveniently controlled and adjusted by partial lining of the material with muslin. By this means, the burning times of curtains could be made substantially independent of the weight of the fabric composing them. This effect is illustrated in Fig. 3, in which the ratio, burning time of partially lined curtain to burning time of the same material, un-unlined, is plotted against the weight of 4.0 ounce muslin lining per unit weight of curtain material. The characteristics of curtains used in experiments at the two blast delay times selected are given in Table 1.

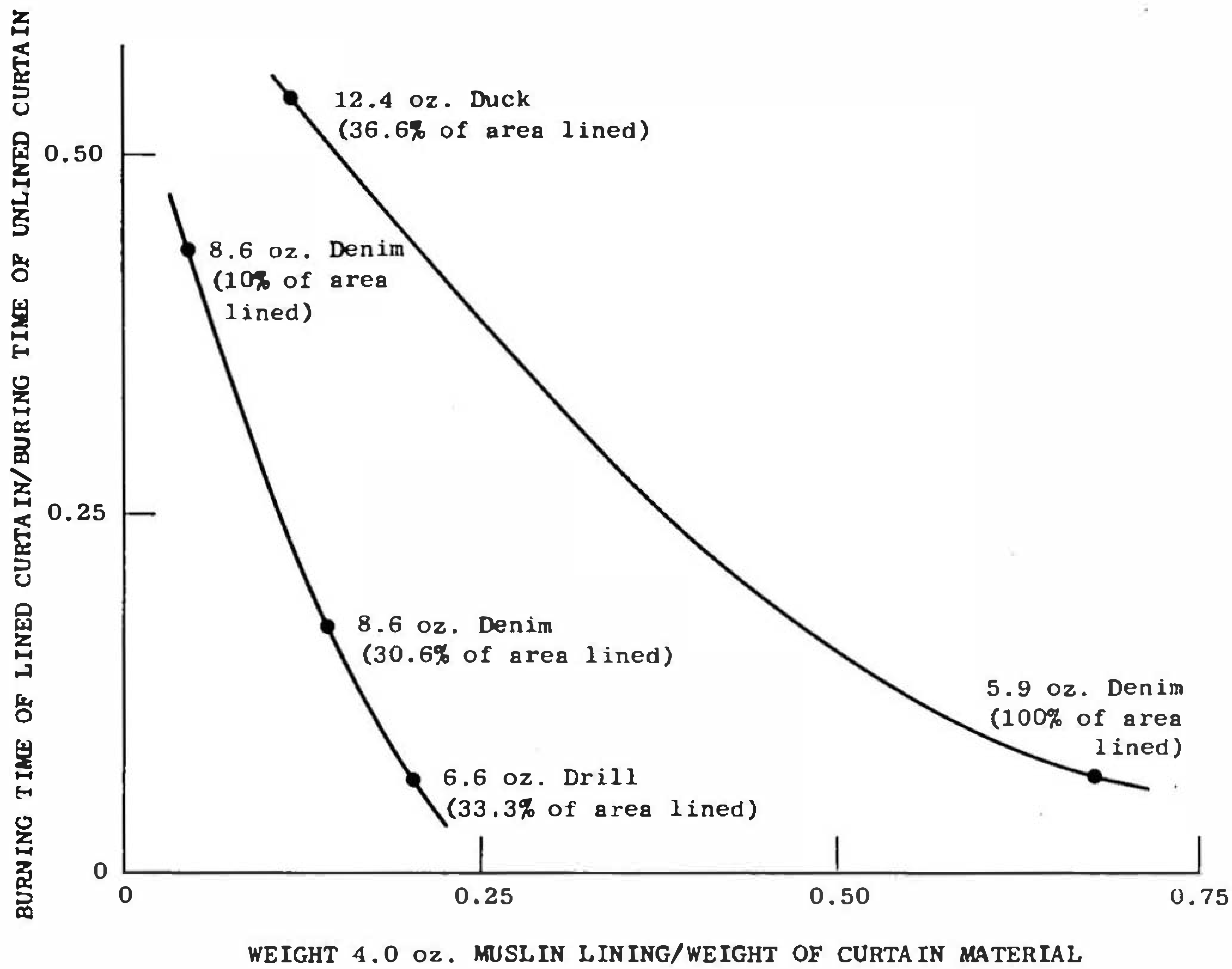


Fig. 3. The Effect of Partial Lining of Curtains on Their Burning Times. The ratio of burning time of lined curtain to burning time of the same curtain material, unlined, plotted against the weight of 4.0 oz. muslin lining per unit weight of curtain material.

Table 1

CURTAIN PROPERTIES AND TEST CONDITIONS
IN STUDY OF INTERIOR IGNITIONS
BY BLAST-TRANSPORTED BURNING CURTAINS

Fabric Weight (oz/yd^2) and	Amount and Location of 4 oz muslin partial lining	Approximate Burning Time of Curtain with partial lining	Blast Delay Time	Occupancy Type	No. of Tests
6.6 oz drill	Horizontal Strip 6" wide on up-stream side of panel 18" from bottom edge	50 sec	32 sec	Office Living room	2 2
8.6 oz demin	ditto	75 sec	32 sec	Office Living room	2 2
8.6 oz demin	ditto	75 sec	54 sec	Office Living room	2 2
12.4 oz duck	Horizontal strip 11" wide on up-stream side; 5" wide strip on downstream side	about 120 sec	54 sec	Office Living room	2 2

RESULTS

Seventeen tests were conducted. The results are summarized in Table II. The likelihood of room ignition, or flashover, resulting from the burning curtain remanants being transported into the room by the blast, was inferred from the size of the items in which fires occurred, and their number, and by how well the fires were established. The hazard of room ignition in each test was chacterized as follows: "No hazard of room ignition" applied to cases in which no fires remained burning after a test; "Small hazard of room ignition" applied to cases in which fire was in a poorly established, or smouldering stage in the room contents; and "Severe hazard of room ignition" applied to cases in which fire was well established and building up in major items of furniture.

As indicated in Table II, severe hazard of room ignition resulted from 7 of the 17 experiments, while a small hazard of room ignition occurred in 4 cases.

Table 2

RECAPITULATION OF TEST RESULTS

Test No	Occupancy Type	Fabric Wt	Blast Delay Time	Remarks
1	Office	6.6 oz	32 sec	3 fires which extinguished themselves No hazard of room ignition
2	Office	6.6 oz	32 sec	Fire on desk; in newspaper near downstream end of table. Rug ignited two places. Severe hazard of room ignition.
3	Office	8.6 oz	32 sec	No ignitions. Curtains only partially burned, more than half remained unburned. No hazard of room ignition.
4	Office	8.6 oz	32 sec	One ignition in a file folder. More than half of curtains unburned. Small hazard of room ignition.
5	Office	8.6 oz	54 sec	No ignitions. Charred curtain remnants profusely scattered over room. These charred the nap of the rug but not the base. Newspapers charred thru several layers, but no ignition. No hazard of room ignition.
6	Office	12.4 oz	54 sec	Fires in desk file drawer, on table, and in rug. Severe hazard of room ignition.
7	Office	12.4	54 sec	No ignitions. No hazard of room ignition.
8	Office	8.6 oz	54 sec	Small fires on floor, in desk file drawer and in waste basket. All fires extinguished themselves. No hazard of room ignition.
9	Office	12.4 oz	54 sec	Fires in chair, papers on desk top, papers and table cloth on table, and in rug near chair and table. Very severe hazard of room ignition.

Table 2 cont.

RECAPITULATION OF TEST RESULTS

Test No.	Occupancy Type	Fabric Wt	Blast Delay Time	Remarks
10	Living Room	8.6 oz	54 sec	One fire in newspaper on floor. Small hazard of room ignition.
11	Living Room	8.6 oz	54 sec	One fire in newpaper on floor. Small hazard of room ignition.
12	Living Room	8.6 oz	32 sec	Fire in edge of rug and in chair. Severe hazard of room ignition.
13	Living Room	8.6 oz	32 sec	Fire in papers on table, and in rug. Smouldering fire in two sofa cushions. Severe hazard of room ignition.
14	Living Room	6.6 oz	32 sec	Fire in cloth and paper on table. Smouldering fire in rug and sofa which extinguished itself. Small hazard of room ignition.
15	Living Room	6.6 oz	32 sec	Small fire in paper on floor and on table. Smouldering fire in chair. Small hazard of room ignition.
16	Living Room	12.4 oz	54 sec	Smouldering fire on floor and table and in sofa and chair cushion. Much smoke. Severe hazard of room ignition.
17	Living Room	12.4 oz	54 sec	Three major fires; one in chair, one on coffee table, one on floor. Severe hazard of room ignition.

CONCLUSIONS AND RECOMMENDATIONS

Experimental conditions had been arranged with a view to having the blast wave arrive after the curtains were fully ignited and in flaming combustion, but before they had been consumed to the point that they were ready to fall. In the course of the experimental program, it was found that a considerable variation in the burning characteristics of curtains frequently occurred from one test to the next, even though the experimental conditions of the tests appeared to be identical. In some tests, the recovery of major portions of the curtains unburned indicated that the blast wave had arrived before the curtains were fully ignited, whereas, in other cases, charred curtain remains found on the floor under the window indicated combustion of the curtains to be so far advanced at the time of blast arrival that portions of them had fallen.

Tests resulting in severe hazard of room ignition corresponded closely to cases in which the blast wave arrived at an optimum stage in combustion of the curtains, when they were fully aflame, but only partially consumed. The evidence for this optimum condition was the absence of major portions of unburned curtain material in the room, or of charred curtain remains under the windows. In these cases, large, fully ignited fragments of the curtains were deposited on fuel items in the room, or of charred curtain remains under the windows. In these cases, large, fully ignited fragments continued to burn briskly, thus serving to induce fully developed fires in the room.

In cases in which curtains were not fully ignited at blast arrival, the curtain fragments tended to smoulder, and to induce smouldering fires in the test room. Where curtains had passed the optimum stage of flaming combustion, charred remnants, distributed throughout the test room, lacked sufficient remaining fuel value to serve as efficient secondary ignition sources. Characteristically, these charred fragments would produce charred holes through several layers of paper, or in the nap of the rug, without any ignition of these items to flaming or smouldering combustion.

Although no quantitative data were obtained regarding the duration of the period in which burning curtains remained in a near-optimum condition for inducing secondary ignitions in interior fuels, it appears that this condition prevailed for only about 20% of the burning time in our experiments, and it occurred near the center of that time interval.

Our experiments were planned with a view to having each curtain near the stage of flaming combustion that would be optimum for generation of secondary ignitions by blast-transported fragments. In any actual nuclear attack, the stage of combustion of curtains, ignited by the thermal pulse, will be independent of blast arrival time, so that the hazard of room ignition due to burning curtain fragments should be very much less than in our experiments.

The hazard of secondary ignitions due to blast-transported burning curtain fragments appears to depend critically, in each case, on the burning time of the curtains relative to the time to blast arrival. Owing to the relatively brief period, in the burning of curtains, during which they constitute very effective secondary ignition sources when transported by blast, approximate or unrealistic data on burning times could result in seriously erroneous analysis of the overall urban fire hazard from this source.

It is recommended that further investigation of the mechanism by which fire progresses in various kinds of curtains be undertaken, with a view to development of a capability for more accurate prediction of their burning times under various conditions. This predictive capability, together with statistical data on the distribution and frequency of various kinds of curtains in urban occupancies, would allow computation of realistic frequencies for secondary ignitions in urban interiors due to transport of burning curtain fragments by blast from nuclear weapons.

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
URS RESEARCH COMPANY, San Mateo, Calif.

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
THE IGNITION HAZARD TO URBAN INTERIORS DURING NUCLEAR ATTACK DUE TO BURNING CURTAIN FRAGMENTS TRANSPORTED BY BLAST

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Summary Report

5. AUTHOR(S) (First name, middle initial, last name)
Thomas Goodale

6. REPORT DATE
December 1971

7a. TOTAL NO. OF PAGES
25

7b. NO. OF REFS
5

8a. CONTRACT OR GRANT NO.
DAHC20-71-C-0223

b. PROJECT NO.

c. Modification P616-1

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
URS 7030-5

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
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11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

The specific objective of the research described in this report was to investigate the propensity of burning curtains, carried into typical urban interiors by blast waves, to cause ignitions within the interiors capable of leading to flashover.

The experimental program was conducted in a full-scale test room constructed in the test section of the URS Shock Tunnel Facility. Three different weights of curtain material, having different burning times, were used in the experiments. Curtains were ignited by propane gas jet manifolds arranged on the upstream side of the curtains with the jets directed toward the curtains. All tests were conducted at a nominal incident blast overpressure of 1 psi since it had been found that incident overpressures much higher than this invariably extinguish fire in burning curtains.

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THE IGNITION HAZARD TO URBAN INTERIORS DURING NUCLEAR ATTACK DUE TO BURNING CURTAIN FRAGMENTS TRANSPORTED BY BLAST
URS 7030-5
URS Research Company, San Mateo, California
December 1971 25 pp. Contract DAHC20-71-C-0223 Modificatien P616-1

Unclassified

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