December 1971 URS 7030-6

Summary Report

AN ATTEMPT TO EXPLORE THE EFFECT of HIGH BLAST OVERPRESSURE ON THE PERSISTENCE of SMOULDERING COMBUSTION IN DEBRIS

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

urs research company

UNCLASSIFIED

Security Classification

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 Co., San Mateo, Calif.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

AN ATTEMPT TO EXPLORE THE EFFECT OF HIGH BLAST OVERPRESSURE ON THE PERSISTENCE OF SMOULDERING COMBUSTION IN DEBRIS

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	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1971	8	0

8a. CONTRACT OR GRANT NO. DAHC20-71-C-0223 b. PROJECT NO. c. Modification P616-1 d.	9a. ORIGINATOR'S REPORT NUMBER(S) 7030-6 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Civil Defense Office of the Secretary of the Army Washington, D.C.

13. ABSTRACT

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.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

Security Classification

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SUMMARY

Recent research (OCD Work Unit 25341) has shown that fires, simulating those that would occur in urban interiors due to thermal radiation from a nuclear weapon explosion, are extinguished by the blast wave from the explosion in areas in which the peak incident overpressure equals or exceeds about 2.5 psi. Smouldering combustion remained, in fuels capable of supporting it, in these experiments, commonly reigniting the fuels within periods ranging from minutes to hours.

The present series of experiments were devoted to exploring the effects of higher shock overpressures, up to about 9 psi, on the persistence of smouldering combustion. It was found that no difference appeared in the persistence of smouldering combustion in cotton-filled mattresses between overpressures of 5 psi and 9 psi. Other fuels tested, i.e., polyurethane foam cushions, and kapok-filled cushions, failed to support smouldering combustions after extinguishment of flaming combustion by blast.

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INTRODUCTION

Recent research (OCD Work Unit 25341) has shown that fires, simulating those that would occur in urban interiors due to ignition of their furnishings by thermal radiation from a nuclear explosion, are extinguished by blast waves with nominal incident overpressures of about 2.5 psi and higher propagating into the rooms through windows. The results of this investigation indicate that the debris of interior kindling fuels, that were capable of supporting smouldering combustion, such as sofa and chair cushions, and mattresses, continued to smoulder in many cases after extinguishment of flame by propagation of the blast wave into the room. The smouldering debris commonly reignited itself to flaming combustion within a period of time ranging from minutes to hours.

One result of the tests that was insufficiently documented to support a firm conclusion, was that smouldering of debris was reduced or eliminated in tests in which the debris was subjected to higher overpressures and to high velocity flows of longer duration. Analysis of the test data indicated that the probability of sustained fire starts at overpressures above about 5 psi would be primarily dependent on the existence of a mechanism, operative at higher overpressures, which would be capable of extinguishing smouldering combustion in fuels capable of supporting it.

EXPERIMENTAL PROCEDURE

A limited investigation was undertaken with the purpose of revealing any effect by which smouldering combustion is suppressed or extinguished by blast waves of higher overpressure. In addition, some tests were conducted in which the possible effect of dust, due to fragmented plasterboard, in extinguishing smouldering combustions, was explored. The dust produced in fragmentation of plasterboard contains hydrated calcium sulfate as a major ingredient. This material would serve as an especially effective heat sink when impinged onto the surface of smouldering fuels, since the water of hydration is removed at 163°C with absorption of heat in the process.

The experimental procedure was limited to exposing elements of burning interior fuels to a blast wave within the $8\frac{1}{2}$-ft x 12-ft test selection of the URS Shock Tunnel, without attempting to simulate the geometry or furnishings of complete rooms.

A total of 8 tests was conducted, two tests at each of two overpressures and in each of two conditions. In one of the two conditions, the samples were exposed in the open tunnel. In the other condition, plasterboard sheets were mounted transversely in the tunnel upstream of the samples. The two test overpressures were at nominal 5 psi and 9 psi levels

Kindling fuels, commonly encountered in urban interiors, that were capable of smouldering combustion, were arranged in a row transverse to the tunnel axis. The fuel samples were ignited by propane-oxygen flames arranged in a row above them. Fuels were exposed to ignition for 7 seconds, in the experiments at 5 psi overpressure level, followed by a 14 second interval between the end of ignition and blast arrival. In the experiments at 9 psi overpressure, a 14 second ignition period was followed by a 7 second delay before blast arrival. This arrangement had the advantage that the interval between the end of ignition and blast arrival approximated the intervals that would obtain between the second peak of the thermal radiation pulse, and the arrival of the blast wave at ranges from a 1 MT low airburst corresponding to the 5 and 9 psi overpressure levels. Also, the periods of time during which the fuels were exposed to ignition were approximately in proportion to the total radiant thermal energy that the fuels would receive at their respective ranges.

Fuels included in each test that occur commonly in urban interiors were polyurethane foam sofa cushions (without cotton or dacron batting), a kapok chair cushion, and an innerspring mattress having cotton batting as its principal fuel component.

RESULTS

The results of the tests were not distinguishable on the basis of the overpressure of the blast wave, or the presence of plasterboard upstream from the sample, although the presence of plasterboard did, indeed, result in dissemination of plaster dust over the remains of the samples. The results were substantially the same for all the tests.

- Flame was extinguished in all the samples upon passage of the blast wave.
- Smouldering ignition persisted in the mattress in every test.
- Mattresses reignited themselves to flaming combustion with 30 minutes to one hour after each test.
- Kapok cushions and polyurethane foam cushions failed to support smouldering combustion in any of the tests.

The failure of polyurethane foam cushions to support smouldering combustion appeared, at first, to be contrary to results reported for OCD Work Unit 25341, in which smouldering of such cushions was observed after passage of the blast wave over them. It was recalled, however, that, in the previous work, cotton batting had been inserted between the cushion cover and the foam plastic on the side exposed to ignition. When cotton batting was added to some of the cushions in the present test series, they supported smouldering combustion for periods as long as 2 hours, eventually extinguishing themselves.

CONCLUSIONS AND RECOMMENDATIONS

Of three types of kindling fuels, commonly found in urban interiors, that were employed in the present tests (i.e., polyurethane foam cushions, kapok-filled cushions, and mattresses containing cotton batting as a major component), only the cotton-filled mattresses consistently supported smouldering combustion by passage of the blast wave. Furthermore, when cotton batting was inserted between the cover and the foam plastic of polyurethane foam cushions, on the side exposed to ignition, these cushions became capable of supporting smouldering combustion for a period of about 2 hours. These results would indicate objects containing cotton batting to represent a special hazard with respect to persistence of smouldering combustion in debris after passage of the blast wave.

In view of the importance of smouldering combustion as an ignition source in areas where flame has been extinguished by blast, further research appears to be warranted in identifying kindling fuels in urban interiors that support smouldering combustion, and the conditions under which such combustion developes into fire. An understanding of the mechanism of smouldering combustion might lead to methods of chemical pretreatment or other means to inhibit the smouldering of these fuels, or prevent their rekindling into flame.

The present investigation must be considered only a preliminary attempt to explore the effect of higher blast overpressures on the persistence of smouldering combustion. Only 8 tests were conducted, and owing to limitations of the test facility, these were confined to a maximum overpressure of only 9 psi. The positive phase duration of the blast wave could not be made to exceed about 60 - 80 milliseconds, so that the effects on smouldering combustion of long duration positive pressure pulses, characteristic of nuclear blast waves, could not be explored.

Since the mechanism of the interaction of fire and blast is not presently understood, no assertions can be made as to the possible effect on the fire-blast interaction of such variables as shock overpressure, the particle velocity and temperature of the flow behind the shock, or the duration of flow and positive pressure. These variables are capable of manifesting themselves in a wide variety of combinations in the diffraction of blast waves around and through urban complexes.

Since the basic physical processes involved in such flows are well understood, it is possible to compute the conditions of pressure and flow, as a function of time, that will obtain in any specific case. Estimation of the effect of the flow regime on the persistence of smouldering combustion or of flame, however, will require a more thorough understanding of the specific dependence of these phenomena on various flow variables.

It appears that the next step in elucidation of fire-blast interaction in civil defense will be to determine the specific flow parameters upon which the extinguishment of flame, and, perhaps, of smouldering combustion is principally dependent.