BLAST/FIRE INTERACTION EXPERIMENTS

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ABSTRACT

Los Alamos Technical Associates, Inc. (LATA), under contract to the Federal Emergency Management Agency (FEMA), is fielding three categories of experiments at the DIRECT COURSE H.E. Event. The three categories consist of: 1) constrained debris, 2) unconstrained debris, and 3) room fires.

The overall goal of these experiments is to reduce the present uncertainties in estimates of fire effects of nuclear explosions caused by airblast effects, notably extinction of fires by airblast. More specifically, the experimental objectives are to explore mechanisms of air blast extinction, to test conclusions drawn from shocktube experiments.

The objectives of the three categories of experiment enumerated above are as follows:

1. The objectives of the experiments with constrained debris will be to validate the use of the SRI Blast/Fire Facility as a bona fide source of practical-situation data, and to extend the data base to test conditions that are not readily provided in shocktubes. These variables include: 1) larger areas of exposed debris and, 2) orientation, with respect to both the advanced shock and earth's gravitational field.

2. The addition of "real world" debris in unconstrained configuration provides for data to extend the data base to include more realistic debris mixes, establish blowout criteria for debris that is free to move with the airblast, observe any firebrand production and trajectories, and to observe conditions for rekindling of blast-supressed debris fires.

3. The objective of the room fire experiments is to determine susceptibility of such fires to blowout as a function of fire intensity. The DIRECT COURSE tests may serve to strengthen the conclusion of the Ft. Cronkhite shock tunnel tests. As a bonus, these room fire tests, even without including blast effects, will extend the range of fire dynamics experience to help verify the general validity of room-scaling rules.

Background

1. Debris Fires

The MILL RACE event in September 1981 was initially viewed as an opportunity to verify data taken by direct simulation in the SRI shocktube facility. Unfortunately, the SAI developed thermal pulse accessory was not delivered to SRI in time to allow full simulation prior to MILL RACE. Fires started by brief exposure to a propane burner (used in lieu of the thermal radiation source) in a shredded-filter-paper representation (or idealization) of debris were extinguished in the SRI facility by blast waves that approximated MILL RACE loadings, but definitive data were not obtained. This was compounded by the failure at MILL RACE to acheive unambiguous ignition in the debris specimens exposed to the thermal radiation source (TRS).

Debris fires have been experimentally studied by various investigators. The data most relevant to questions of airblast interaction, prior to the pre-MILL RACE tests by SRI, date from the 1950s; studies conducted at UCLA on wildland fuels and newspaper employed a combined shocktube (actually a blowdown system) and thermal source. The resulting data show a regular, and fairly strong, dependence of extinction thresholds on both preburn time and positive-phase duration.

2. Room Fires

The currently accepted models of the incendiary effects of nuclear explosions in urban areas focus on fire starts in rooms, the underlying assumption being that fires in rooms will dominate the outcome. Unquestionably, fires in rooms comprise a category of special interest in fire growth dynamics. The enclosure not only serves to limit air supply to the fire, but it conserves a portion of the heat released by the fire to intensify it, often leading to a relatively abrupt involvement of the entire room and its contents in an event called "flashover". Viewed operationally, as well as in straight forward damage assessment terms, flashover is a critical end point to the development of the incipient fire. The mathematical models customarily treat the incipient fire, prior to flashover, as a feeble, and therefore blast-sensitive stage in the growth of the fire, and full scale test of incipient room fires that were conducted in the Ft. Cronkhite blast tunnel consistently resulted in blowout thresholds at peak overpressures only slightly higher than 2 psi. Even when the airblast fails to extinguish it, the conventionally modeled fire is perceived to be still quite easily extinguished by prompt action of the first-aid fire-fighting type to the occurence of flashover. The conventional wisdom may, however, be wrong.

During the ENCORE event of operation UPSHOT/KNOTHOLE in 1953, a furnished room, its window facing the fireball, flashed over in less than a minute after exposure to a thermal fluence of about 25 cal/cm^2.

The building was rapidly destroyed by a fire that did not blow out despite an incident airblast of about 6-to-9-psi peak overpressure. A conclusion that the ENCORE response, rather than being an anomally, is the common situation to expect--as opposed to the slow buildup of fire from a feeble, airblast-vulnerable start--could go a long way toward explaining some of the puzzling experimental-results vis-a-vis historical-experience inconsistencies concerning incendiary consequences of nuclear explosions in or near urban complexes. If such a conclusion is borne out by further experimental work, it will significantly impact current perceptions of the dynamics and threat potential of fires caused by nuclear explosions. In turn it will effect civil defense planning, such as crisis relocation, key worker shelter locations, preattack fire-defense preparations, and both trans-attack and post-attack fire-fighting strategy.

Objectives

The overall goal of this program is to reduce the present uncertainties in estimates of fire effects of nuclear explosions caused by airblast effects, notably extinction of fires by airblast. More specifically, the experimental objectives are to explore mechanisms of airblast extinction, to test conclusions drawn from historical and research experience, and to verify data derived from shocktube experiments.

The experiments to be fielded at WSMR consist of the following types:

1. constrained (idealized) debris,
2. unconstrained (real-world) debris, and
3. room fires.

The objectives of the three categories of experiments are as follows:

1. The objectives of the experiments with constrained, idealized debris will be, as they were at MILL RACE, to validate the use of the SRI Blast/Fire Facility as a bona fide source of practical-situation data, and to extend the data base to test conditions that are not readily provided in shocktubes. These variables include (1) larger areas of exposed debris and (2) orientation with respect to both the advancing shock and the earth's gravitational field.

2. The addition of "real world" debris in unconstrained configuration provides for data to extend the data base to include more realistic debris mixes, establish blowout criteria for debris that is free to move with the airblast, observe any firebrand production and trajectories, and to observe conditions for rekindling of blast-suppressed debris fires.

3. The objective of the room fire experiments is to determine susceptibility of such fires to blowout as a function of fire intensity. The DIRECT COURSE tests may serve to strengthen the conclusions of the Ft. Cronkite shock tunnel tests, though that appears less likely today than it would have a decade ago. As a bonus, these room fire tests, even without including blast effects, will extend the range of fire dynamics experience to help verify the general validity of room fire scaling rules.

1. Technical Approach

Debris

Each experiment will consist of five debris pans (1' × 2' × 3"). Four of the units will be located 1.5 m above grade at various angles relative to ground zero. The remaining unit will be located at grade normal to ground zero. Two each of these experiments will be located at the overpressure levels (1, 3, and 7 psi). The two experiments will contain the same fuel but at two different densities. Propane will be used to ignite the debris in each pan. The ignition system will be activated using a spark ignitor or pilot flame and will be terminated prior to shock arrival.

Test Variables

The test variables to be monitored in these six experiments are (1) shock orientation, (2) position in shock wave, at grade and 1.5 m above ground, (3) peak overpressure, (4) preshock burn time, and (5) fire extinguishment threshold.

Instrumentation

The instrumentation will consist of a free field pressure measurement at each station--total of three. Two camera's running at 2,000 f/s and two time lapse (1 f/s) at each station will provide the necessary visual coverage.

Preliminary Tests

Tests will be conducted prior to the September event to determine the desired fuel densities and the preshot burn times needed to obtain the desired fuel burning rates at shock arrival.

2. Unconstrained (Real World) Debris

Each experiment will consist of a 6' × 12' × 6" test bed located at grade at the 1, 3, and 7 psi overpressure levels. The fuel beds will be normal to ground zero and will contain a mixture of various cellulosic materials. As in the Task 1 experiments, ignition will be achieved utilizing a propane system and will be terminated prior to shock arrival.

Test Variables

The test variables to be monitored in these three experiments are (1) peak overpressure, (2) firebrand production and translation, (3) fire extinguishment threshold, and (4) late-time fire rekindling.

Instrumentation

The uncontrained debris experiment utilizes the same free field pressure measurement and camera coverage, since both experiments are located at the same locations.

Preliminary Tests

Tests will be conducted prior to the September event to determine fuel mixture and the preshot burn times needed to obtain the desired burning rates at shock arrival.

3. Room Fires

This experiment is composed of four separate blockhouses (of the ENCORE model), furnished as a representative urban occupancy, with fire initiated by propane gas supply. Two distinct variations are planned: (1) a room fully flashed over prior to shock arrival; and (2) a room experiencing rapid heat buildup (comparable to the ENCORE situation) at the time of shock arrival, but not yet flashed over. Two blockhouses, one of each of these variations, will be located together in the DIRECT COURSE test bed at a distance expected to experience a peak overpressure of 7 psi. An additional variation (1) blockhouse will be located to experience a 9 psi overpressure and an additional variation (2) blockhouse, to receive 3 psi. The room furnishings will be ignited prior to shock arrival utilizing a propane ignition system similar to one used in Tasks I and II.

Test Variables

In addition to blast wave loading, the only intentional variable in this experiment is the intensity of the fire as represented by the two test variations described above. It should be noted that large rates of heat release such as proposed for this experiment, to represent exposures to the high radiation fluxes of a nuclear fireball capable of initiating primary fires in urban interiors, are expected to cause flashover conditions in relatively short times, such as a minute or two.* The development of convective flow of air into the room, in the lower portion of the ventilating opening (e.g., with window), and flow of combustion products and other hot

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* Contrast this with the 15 to 20 minute growth periods predicted by current analytical models for initial room fires resulting from nuclear explosions.

gases out of the upper part is a much slower process. Therefore, the flashed over room continues to undergo changing conditions with time, and time elapsed between flashover and shock arrival is a variable that must be controlled by experimental design. In the case of the room fire that has not reached a flashover state prior to shock arrival, the rate of approach must be controlled (by controlling the supply of propane), and the time elapsed between the start of heating and shock arrival will be an even more critical experimental control variable than the counterpart delay in the flashed over rooms. The dynamics of fire growth are fairly predictable and appropriate scaling rules can be derived from full-scale tests and modeling studies.

Instrumentation

For each of the four stations, the instrumentation requirements will consist of: (1) one free field and three internal building pressure measurements (front, side, and back wall); (2) two thermal radiation measurements, one externally mounted viewing the building window and one internally mounted at floor level with a vertical field of view; (3) three temperature measurements, the first located at the ceiling, the second 6 inches below the ceiling, and the third at 2 inches below the window soffit; and (4) one flowrate measurement to monitor propane flow to the burner inside the building. The camera coverage will consist of two cameras one camera will be directed at the window with the remaining camera mounted in the wall for internal coverage.

Preliminary Tests

Tests will be conducted to determine the preburn times needed to obtain the desired burning conditions (flashover and preflashover) at shock arrival.

Results and Conclusions:

None at this time.