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RECENT STUDIES OF BURIED CHARGES OF SINGLE, MULTIPLE, AND PLATE EXPLOSIVES, WITH DETAILS OF ATMOSPHERIC PROPAGATION EFFECTS, APPLIED TO HUMAN AND PHYSICAL IMPACT.

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INTRODUCTION

Characteristics of blast waves from explosions in simple geometries and containment media have been well defined by hydrodynamic models and verified by experiment [1-3]. A large class of useful explosions, those only partially contained by the close surrounding medium, are less adequately understood. This report addresses the problem of airblast emitted into the atmosphere from explosions buried in the ground at less than containment depth. Examples of such explosions have arisen in cratering excavation, mining and quarrying, ordnance disposal, and military High Explosives Simulation Tests (HEST). Some recent HEST data have been assembled here to help define an empirical approach to airblast predictions, for operational safety as well as for controlling environmental impact on neighboring communities.

BACKGROUND

The simplest case, of a single buried explosion charge, was subject to extensive cratering experimentation during Project Plowshare - the peaceful use of nuclear explosions [4]. It was found that emitted airblast could be reasonably well predicted because the overpressure attenuation (compared to an airburst) depended primarily on the depth of burst divided by the cube root of the yield or high explosives (HE) weight, and characteristics of the geologic medium, (i.e., rock, alluvium, dry, saturated, etc.). Limited tests were also conducted with linear and planar arrays of multiple charges, although there were not enough data collected for high confidence analyses.

With early HEST projects, however, it was not clear that there should be any relationship to crater test results. Only recently have there been results available from a sufficient variety of HESTs, so that an airblast model could be empirically established. It turned out, as will be shown, that this empirical model also works for cratering explosions.

HEST CONFIGURATION

The general configuration of HESTs consists of a sheet of HE laid in an excavated cavity, of either rectangular or circular plan form, covered by some depth of overburden. Construction usually provides an open cavity above the explosive and beneath a roof that carries this overburden. The objective of such tests has been to create an explosion blast compression wave of long duration, extended by containment under the overburden, and simulating the shock wave from a much larger (even megatons) explosion.

Following detonation, a vertically moving plane wave is formed and reflected by the overburden cover; eventually the cavity is filled with high-pressure explosion products. In time, this pressure lifts and ruptures the overburden, allowing the gas to vent into the atmosphere. This venting gas generates an atmospheric blast wave that is usually not strong by close-in explosion standards, but may reach to tens of kilopascals overpressure. In result, test personnel and equipment must be kept at safe distances. Furthermore, in some larger tests, involving over 100 Mg HE, airblast may propagate to neighboring communities with sufficient force to cause nuisance damage to windows and wall plaster, and hazard from flying or falling glass. When this is a possibility, a weather-watch is needed to determine that shot-time atmospheric conditions of winds and temperatures will attenuate, rather than enhance, wave overpressures.

HEST AIRBLAST MODEL

The strength of a vented wave should depend on the amount of HE, the area over which it is spread, the overburden, and the time to venting. But the time and character of venting, that is the failure of the overburden containment seal, would seem to depend on the texture of its material - usually soil, gravel, or sand. Any physical assessment of that characteristic would be artificial.

On the other hand, the fractional amount of energy expended, in lifting an overburden to its venting failure point, depends on the overburden mass per unit of planform area. Vented overpressure should thus have some relationship to the overburden mass per unit of HE mass. Also, at large distances compared to cavity dimensions, the airblast wave approaches hemispherical shape so that equal overpressures would be expected at distances scaled in proportion to the cube root of the total yield, just as for point explosions.

Experience with HESTs and cratering tests has shown that the vented airblast compression was relatively slow compared to shocked waves from airbursts, so that propagation was nearly acoustic. Thus overpressure decayed inversely with the first power of distance.

Applying this concept to crater test measurements [5-9], and using true crater volume divided by explosion yield (weight) for the overburden factor, produced a promising condensation of measurements into a curved belt shown by open symbols in Fig. 1. Three points fell parallel and below this belt, but on the safe side so their explanation and understanding is not critical. The evaluation distance, 914 m (3000 ft) from 18 Mg (20-ton) HE, was selected as representative of intermediate and distant "acoustic" propagations. This falls beyond the range of diffractive distortions caused by the crater lip.

HEST data, shown by solid symbols, when taken alone, do not give as clear a pattern of response. Included with the crater data, however, they seem to reinforce the model.

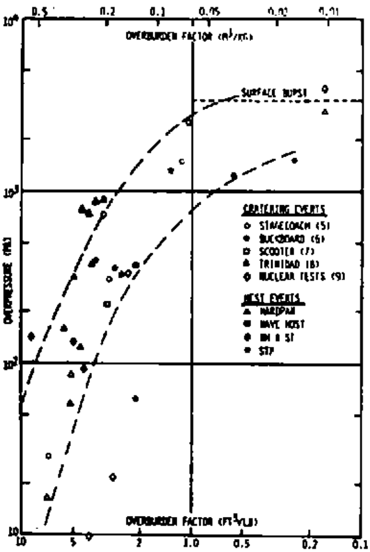

Fig. 1. Reference Overpressure Vs. Overburden Factor for Buried Explosions.

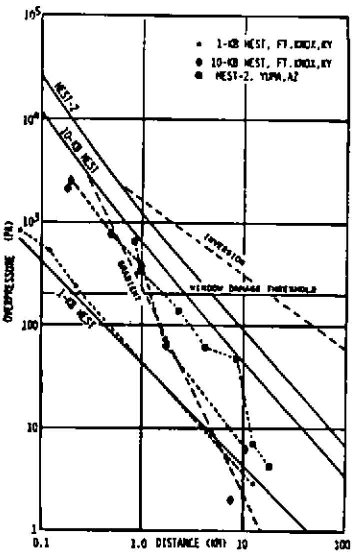

Fig. 2. Overpressure Predictions and Measurements for HEST Examples.

BLAST PREDICTION EXAMPLES

This prediction model was used for three test events in this past year. Predicted overpressures at appropriate yield-scaled distances established the acoustic propagation curves in Fig. 2, for two tests at Ft. Knox, KY, and for one test at Yuma, AZ. Measured overpressure results, shown by the data points, are in reasonable agreement with predictions at intermediate ranges (to 1 km), before atmospheric refraction effects take precedence. At longer ranges, these curves take different slopes depending on local shot-time weather conditions.

REMARKS

Our test plans changed several times since the abstract for this presentation was submitted. In consequence, the 50 Mg test within 50 km of a one-million population has not yet been fired. It may come later this year.

This work was jointly supported by the U.S. Department of Energy and the U.S. Department of Defense Nuclear Agency.

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