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INFLUENCE OF BURST POSITION ON AIRBLAST, GROUND SHOCK, AND CRATERING IN SANDSTONE

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by

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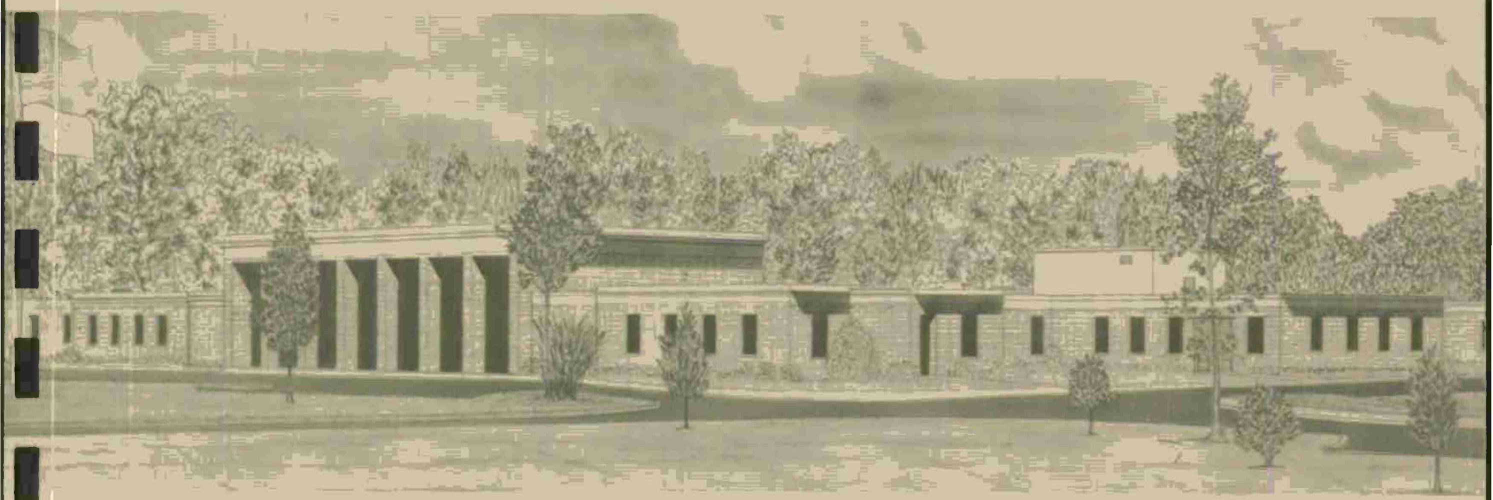

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Seven 1000-lb nitromethane spheres were detonated at different height/depths of burst with respect to the surface of a sandstone rock mass near Grand Junction, Colorado. The purpose of the tests was to study the effects of burst position on airblast, ground shock (the primary interest), and cratering phenomena. Ground motions were measured directly beneath the charges to maximum depths of 60 ft and at several locations near the ground surface within horizontal distances of 100 ft. Airblast pressure-time histories were determined along the rock surface at five stations extending to the 10-psi level. (Continued)

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20. ABSTRACT (Continued).

"Postshot surveys were made to determine apparent and true crater dimensions. Test results showed crater dimensions, horizontal motions near the surface, and peak airblast pressure were strongly dependent on burst position." The most influential charge elevations ranged from two charge radii above the surface to two charge radii below the surface. Airblast, crater, and ground motion parameters were normalized and plotted as functions of normalized charge elevation to provide a direct and simple assessment of charge position effects.

Preface

This paper was prepared for presentation at the 16th Annual Explosives Safety Seminar sponsored by the Department of Defense Explosive Safety Board and held at Hollywood, Florida, 24-26 September 1974. Costs attendant to this presentation were borne by Office, Chief of Engineers, funds allotted to the U. S. Army Engineer Waterways Experiment Station (WES) for Project CENSE.

Field work for this project (CENSE) was conducted in the fall of 1973 near Grand Junction, Colorado, under the direction of Mr. J. K. Ingram, Project Scientist.

The presentation was prepared by Messrs. J. K. Ingram, J. L. Drake, and L. F. Ingram in the Weapons Effects Laboratory, WES, under the general direction of Mr. W. J. Flathau, Laboratory Chief. COL G. H. Hilt, CE, was Director of WES; Mr. F. R. Brown was Technical Director.

Contents

Conversion Factors, U. S. Customary to Metric (SI) Units of Measurement

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
feet per second	0.3048	meters per second
pounds	0.4535924	kilograms
pounds per square inch	6894.757	pascals

INFLUENCE OF BURST POSITION ON AIRBLAST, GROUND SHOCK, AND CRATERING IN SANDSTONE

Introduction

Purpose

1. This paper presents an analysis of the results of the CENSE I experiments in terms of the relative enhancement (or suppression) of the primary explosion effects resulting from the degree of explosive containment.

Background

2. Effects of ground shock, cratering, and airblast are very sensitive to charge position for near-surface bursts. Results of previous high explosive tests indicate large increases in motion magnitudes and crater dimensions occurring as the height of burst is varied from slightly elevated to buried configurations. This strong correlation is caused partly by the increase in contact area between the explosive and the ground.

3. Project CENSE (Coupling Efficiency of Near Surface Explosions) is a high explosive test program sponsored by the Office, Chief of Engineers, to study systematically the effects of burst position on ground shock, cratering, and airblast in varying geologies. Primary interest is the ground motion directly beneath the charge and the strong surface motions near the explosion.

Approach

4. In autumn of 1973, the first series of tests, consisting of detonations of seven 1000-lb* nitromethane spheres, was conducted in a nearly homogeneous sandstone near Grand Junction, Colorado. Burst positions relative to the center of the charge, in units of charge radii, were $-4R_c$, $-R_c$, $-0.5R_c$, 0 , $+0.5R_c$, $+R_c$, and $+7R_c$

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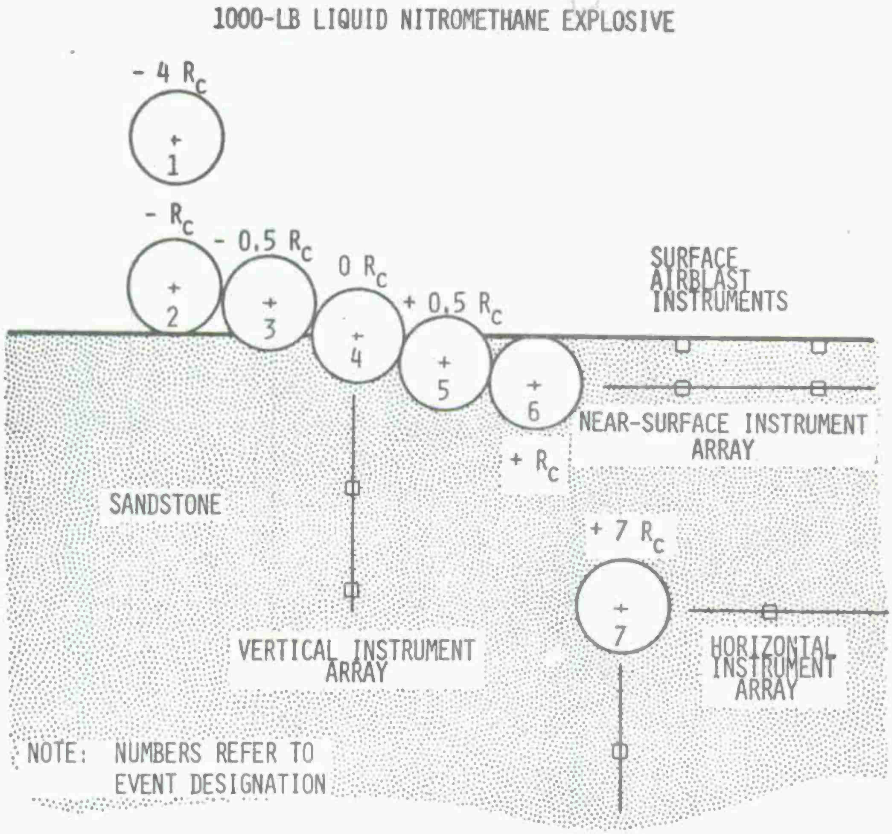
* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.



CENSE-I GEOMETRY

Figure 1. CENSE I experimental plan

(R_c = 1.5 ft). Figure 1 shows the experimental geometry and event number designations for the various tests. Vertical motion gages were placed on-axis directly beneath each charge. Radial arrays of two-component vertical and horizontal motion sensors were placed near the ground surface at fixed ranges from ground zero, depending on expected surface airblast overpressures of 150, 70, 30, 15, and 10 psi for the elevated bursts. Airblast gages were placed along the rock surface directly over the near-surface motion instruments, except on the deeply buried configuration (for which airblast levels were trivial).

Scope

5. Coupling factors, defined as the ratio of an effect magnitude to that for a standard containment condition, were introduced to measure this enhancement and to simplify the data presentation. Specific coupling factors for the various effects were:

$$\text{Airblast factor, } F_a = \frac{\text{surface overpressure}}{\text{standard free-air pressure}}$$

$$\text{Ground shock factor, } F_u = \frac{\text{peak horizontal particle velocity}}{\text{peak radial velocity for full containment } (\text{DoB} = 7R_c)}$$

$$\text{Cratering factors, } F_r, F_d, F_v = \frac{\text{true crater dimensions}}{\text{true crater dimension for full containment } (\text{DoB} = 7R_c)}$$

6. The analysis of the data from CENSE I is in terms of these coupling factors and is limited to measurements made along the near-surface instrument radial. Data from measurements directly beneath the explosive are not included.

Data Presentation

Near-surface ground motion

7. Particle velocities were measured with vertical and horizontal sensors near the rock surface at fixed ranges from ground zero (36, 48, 65, 85, and 100 ft) for all tests. The gages were 2 ft deep for all tests except the fully contained burst (shot 7), for which they were at shot depth.

8. The most consistent motion parameter best illustrating containment effects was the horizontal particle velocity. A composite plot of the horizontal particle velocity wave forms at the 48-ft range for all burst positions is shown in Figure 2. These normalized wave forms, which are typical of those at other ranges, show a slight increase in the characteristic pulse width (duration) with increased containment. The most dramatic increase occurred when the blast was fully contained. This figure clearly demonstrates that burst position does not change the characteristic horizontal particle velocity wave form; however, large increases in peak amplitude were noted with increasing containment.

9. A parametric plot of peak horizontal particle velocity versus

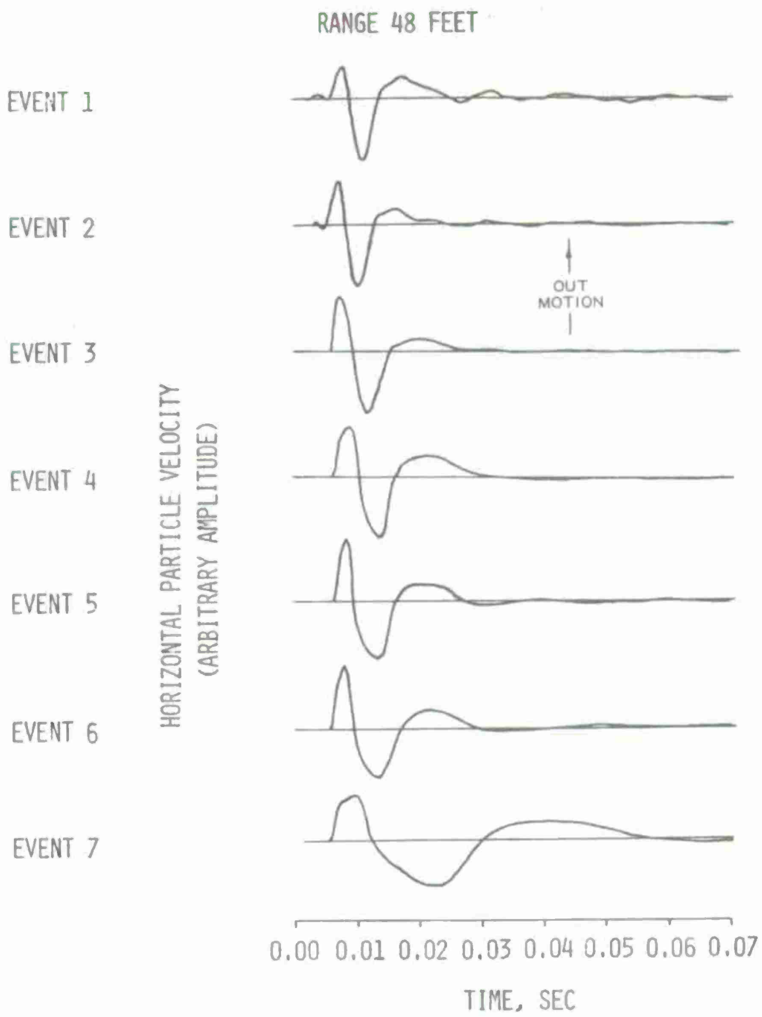


Figure 2. Near-surface horizontal particle velocity wave forms at 48-ft range

scaled range for the various charge containments is shown in Figure 3. Scaled range is defined as the actual range divided by the cube root of the charge weight and is expressed in units of $ft/lb^{1/3}$. This scaling law allows for data correlation and extrapolation for different explosive weights.

10. Data trends, shown as lines of approximately equal slope in Figure 3, show a tenfold increase in peak horizontal velocity when the charge containment was varied from slightly elevated (Event 1, $-4R_c$) to fully buried (Event 7, $+7R_c$). This marked increase is best described by the ground coupling factor F_u as shown in Figure 4. This plot shows

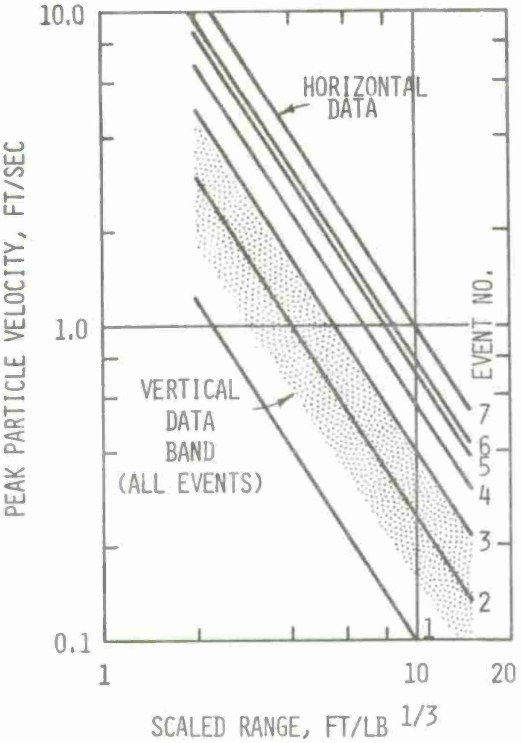


Figure 3. Peak particle velocity versus scaled range as a function of charge containment

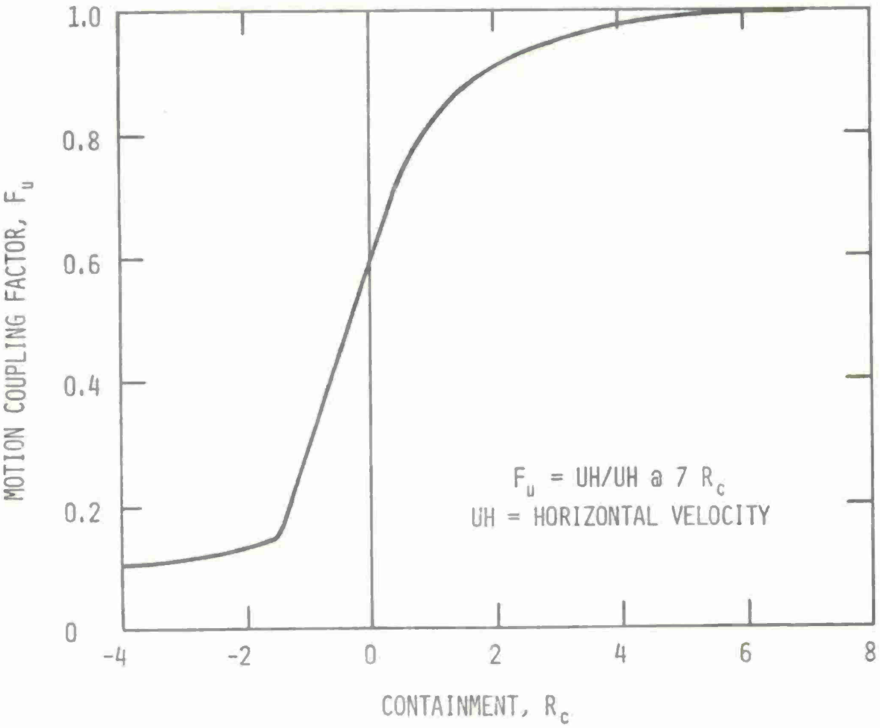


Figure 4. Motion coupling factor F_u as a function of charge containment

that the greatest sensitivity of coupling occurs for the near-surface charge positions, that is, slightly elevated to slightly buried ($-2R_c$ to $+2R_c$). In this region, F_u is proportional to the containment parameter. The coupling factor becomes asymptotic to its maximum value of unity for greater containment and approaches a lower limit of about 0.1 for the elevated burst positions.

11. In contrast to the strong sensitivity of the horizontal peak motions to burst position, the peak vertical particle velocities were found to be virtually independent of the degree of containment. Data spread (shown as hatched area in Figure 3) was ±50 percent of the mean with no pronounced trend associated with explosion containment. Phasing of the local airblast loading, which dominated the vertical motions, and the surface wave was believed to be the principal source of scatter in the vertical velocity data.

Surface airblast

12. Surface airblast measurements were made at five ranges (36, 48, 65, 85, and 100 ft) from ground zero, corresponding to a general overpressure range of 150 to 10 psi. Airblast gages were flush-mounted in a concrete pad to minimize effects of surface roughness on the measurements. An average coupling factor for each shot was determined from the mean of the coupling factors determined by the five measurements on each shot. In all cases the overpressure was reduced to standard temperature and pressure before being compared with the standard free-air curve.

13. Average airblast coupling factors F_a as a function of charge containment are shown in Figure 5. Similar to the effects noted for ground motion, the airblast suppression (enhancement) was strongly influenced by the burst position in the containment region from $-2R_c$ to $+R_c$. For bursts higher than $-2R_c$ the enhancement asymptotically approached a maximum value of twice the free-air condition. Suppression was substantial for burst positions within the rock where containment was greater than unity. F_a was about 1.3 for the surface burst (containment equal to zero).

14. The airblast coupling factor was independent of range for the

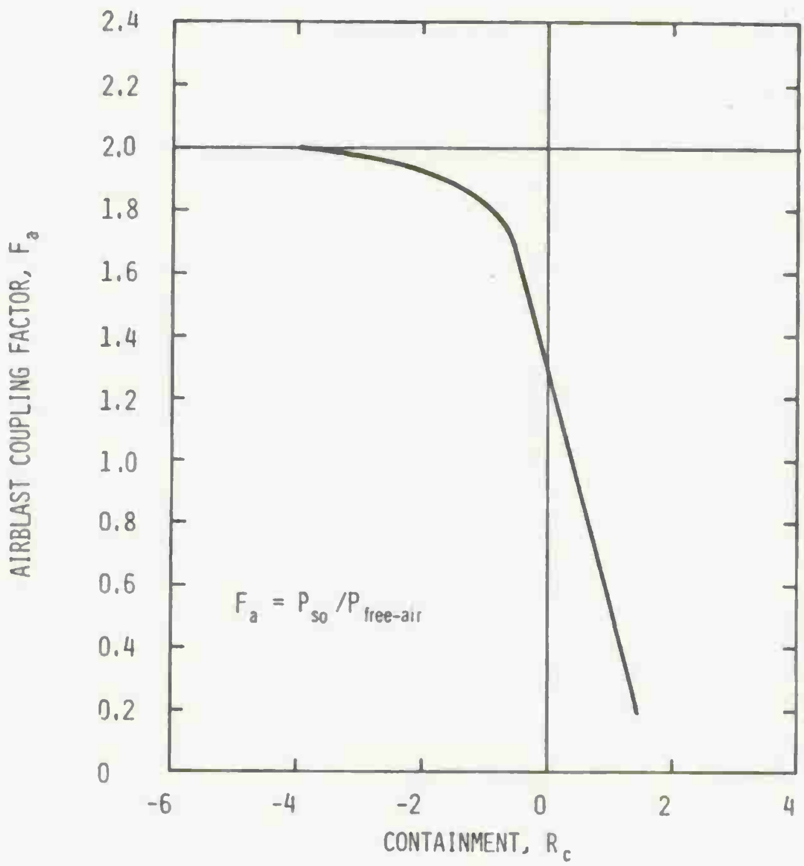


Figure 5. Airblast coupling factor F_a as a function of charge containment

relatively small spread of above-surface positions investigated; however, as the containment increased, F_a became more dependent upon the specific range. Increasing containment caused a progressive flattening of the peak pressure attenuation with range, limiting the conclusion about airblast suppression to shallow-buried bursts (containment about $1R_c$ or less). Extrapolation to greater depths of burst and ranges is not warranted with this data base.

Crater parameters

15. The true crater formed by an explosion is defined as the boundary of the crater representing the limit of dissociation of the medium by the explosion (the crater prior to debris fallback). True radius, true depth, and true volume are parameters used to define the true crater. As with motion and airblast, coupling factors best illustrate

influence of burst position on crater formation. Crater parameter coupling factors as a function of charge containment are shown in Figure 6. Simple ratios were used to derive coupling factors for radius F_r and depth F_d ; however, $F_v^{1/3}$, a cube root ratio used for volume, allowed convenient plotting and showed more clearly the relationship between volume and radius. As seen in Figure 6, the region of greatest crater parameter sensitivity to charge containment (burst position) was within the same bounds as that of both airblast suppression and ground motion enhancement, i.e., $-2R_c$ to $+2R_c$. The depth coupling factor was somewhat of a surprising exception to this observation. The depth factor followed the F_r and $F_v^{1/3}$ response for charge containments less than $-0.5R_c$, but was relatively independent of containment between $-0.5R_c$ and $+1.5R_c$. For containment greater than $+1.5R_c$ the crater depth factor followed a similar, but lower-valued, curve. This result can perhaps be restated as follows: the true crater depth remained essentially

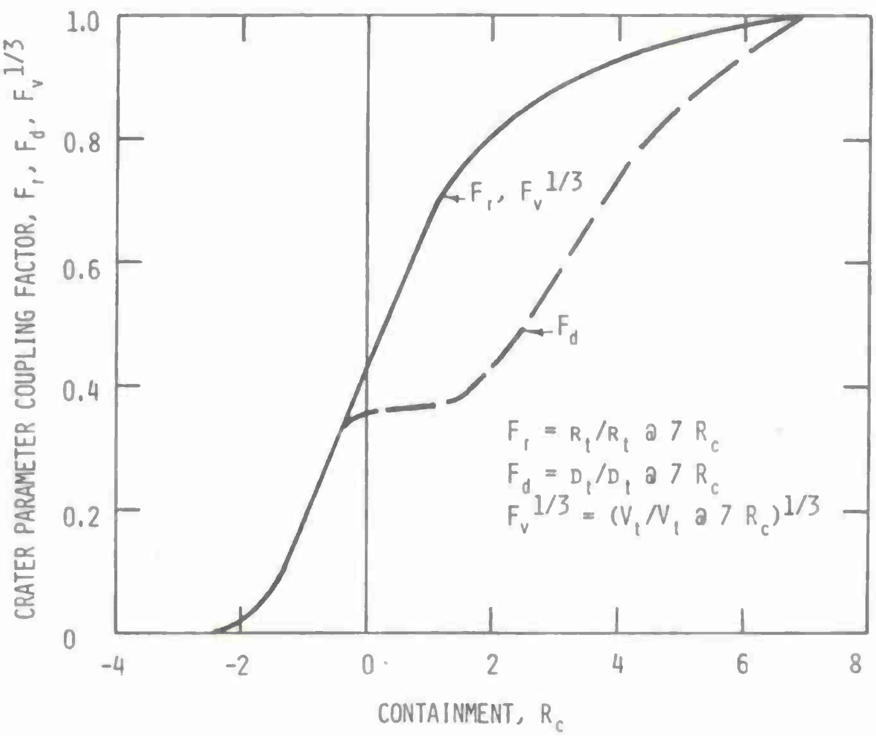


Figure 6. Crater parameter coupling factors F_r , F_d , $F_v^{1/3}$ as a function of charge containment

constant for charge burials from $-0.5R_c$ to $+1.5R_c$; the increase in true crater volume resulted from increasing crater radius with depth of burst.

Conclusions

16. The CENSE I experiments clearly demonstrated a strong influence of burst position on horizontal ground motion, airblast pressures, and crater dimensions for near-surface explosions in or over sandstone. The strongest influence was observed for burst positions ranging from two charge radii above the surface to two charge radii below the surface ($-2R_c$ to $+2R_c$). Within this interval, tenfold changes were noted in the horizontal particle motion amplitudes, airblast suppression, and true crater radius. True crater volumes increased on the order of a hundredfold in this range. Outside this containment interval, coupling factors slowly approached their respective asymptotic limits.

17. Two explosion effects, the peak vertical particle velocity and the true crater depth, were not as strongly dependent on the near-surface burst position. Peak vertical particle velocities were determined to be independent of burst containment over the broad range of burst positions tested. True crater depth was found to be essentially constant for the containment interval $-0.5R_c$ to $+1.5R_c$.

Future Plans

18. Phase II of this study, using similar weights and experimental procedures in a uniform soil, is now being conducted. Effects of geological layering will be studied later.

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