SESSION VII

BLAST (MODELING AND SIMULATION)

DIRECT COURSE INDUSTRIAL HARDENING EXPERIMENT AND PREDICTIONS

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ABSTRACT

The report describes the background for a practical approach to prepare industry (equipment) to survive a nuclear attack. The status of efforts to assess technical options so far conceived at a forthcoming simulation of a 1 kt weapon are discussed and results predicted.

INTRODUCTION

The Federal Emergency Management Agency (FEMA) has established a continuing program to develop procedures for industry to apply to reduce its vulnerability to nuclear attack. Under the austere civil defense budget, the only practical approach open to FEMA to develop this is through a self-help program that can be implemented effectively by industry upon warning of an impending disaster. To be effective, extremely simple methods will be required that have a significant impact on vulnerability at a minimum expenditure of critical resources (manpower, materials, available time). There are three aspects to developing a truly effective solution: conception, testing of technical effectiveness, and testing of practical feasibility. Field tests such as those scheduled for September 1983 at White Sands Missile Range (WSMR) provide the opportunity to test the technical effectiveness of industrial options that have been conceived. This paper describes the status of the technical assessment of a relatively recently conceived option, the tests planned, and predicted results.

BACKGROUND

Studies conducted by Boeing Corp. at Misers Bluff have demonstrated that industrial equipment can survive drag forces and overpressures at ground ranges where the latter are 300 psi and more, if the equipment is simply buried. However, a realistic assessment of industry options for protecting industrial equipment has shown many plants will have little opportunity to bury equipment as most plants are surrounded by asphalt and concrete surfaces of parking lots, paved loading areas, streets, etc. Moreover, construction equipment to do ground breaking, and dirt moving and hauling, will be in short supply for industrial hardening because this equipment will be needed for creating shelter space. Out of a practical necessity, therefore, some kind of hardening option appeared necessary that could improve equipment survivability using the meager resources most likely to be available.

Other than to collapse under the sudden application of an overpressure, equipment is likely to be damaged principally as a result of impacts that are due to sliding, overturning, building collapse, or missiles. Considerable data already exist on missile velocities as a function of drag forces and missile geometry, and debris studies on wall and building failures can be used in conjunction with this and with material properties to assess the impact damage via the mechanisms of missiles and building collapse. Little information has been developed, however, on sliding and overturning of industrial equipment and related damage. To rectify this, exploratory studies were initiated at the MILL RACE 1 kt weapon simulation event conducted at WSMR, in New Mexico in 1981, to examine overturning and to assess the potential for harnessing the static overpressure to reduce sliding, both under drag forces and at a single ground range (i.e., where the static overpressure from this surface burst was 20 psi). These studies used artifacts (drums) to simulate industrial equipment and showed that both overturning and sliding under drag forces could be affected rather significantly by simple expedients - for example, clustering items in a group and banding them tightly so that they would act as a unit. Hence, the basic concepts were confirmed through the exploratory tests; additional data are needed now to develop information that can be applied by industry with confidence.

EXPERIMENTAL OBJECTIVES:

The major thrust of the DIRECT COURSE experimental program on industrial hardening is to further verify the clustering concept by:

1. Testing actual equipment clusters under conditions similar to the simulated clusters tested at MILL RACE where 55-gallon drums were used;
2. Testing of an actual equipment cluster inside a frangible structure;
3. Testing of simulated equipment clusters under a wider range of conditions than those used at MILL RACE including:
   a. higher overpressures
   b. larger clusters
   c. materials other than seat belt webbing for securing the cluster
   d. effects of static overpressure on anchoring equipment packages (on dirt and, possibly, water surfaces) against the horizontal dynamic pressure impulse

A secondary objective is to further study the behavior of unhardened equipment under blast loading to help assess vulnerability.

EXPERIMENTAL ARRANGEMENT FOR EQUIPMENT CLUSTER TESTS

Cluster Details

Each cluster will consist of 9 individual items of equipment arranged as illustrated in Figure 1.

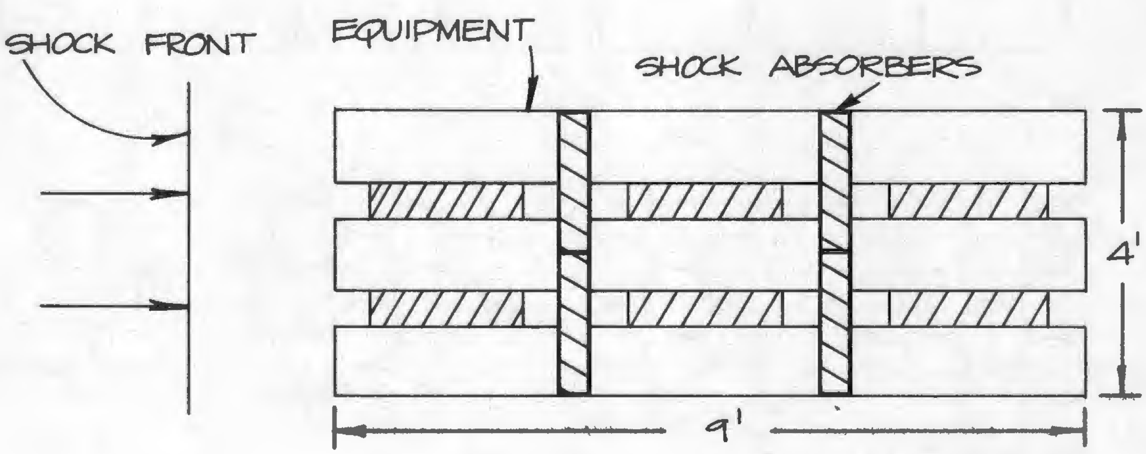

FIG. 1. SKETCH OF ACTUAL EQUIPMENT CLUSTER.

Overall dimensions of a cluster will be 4 ft x 9 ft, and the package will be oriented so that the blast front will impinge on the narrower (4 ft) side; the overall density will be about 16 lb/ft^3. This particular array was selected to model the behavior of a heavy equipment cluster exposed to a 1 Mt weapon. The heavy equipment cluster modeled (one assembled in an earlier demonstration experiment) had a maximum dimension of 20 ft and a density of 50 lb/ft^3 (1). A discussion of the basis of this modeling is given here, in Appendix A.

Cluster Layout

Three of the clusters described will be tested; two of them will be in the open at the 20 psi static overpressure level (Item 1, above), and one will be inside a structure (Item 2, above) at a static overpressure somewhere between 15 psi and 25 psi. The two clusters in the open will be on different surfaces, one on a prepared surface of concrete or asphalt and the other on dirt. The cluster inside the structure will be on a concrete surface and will be slightly modified from those in the open as it will also be exposed to missiles from breakup of the wall, and possibly to structural collapse. The modification will consist of adding shock absorbing material around and on top of the cluster when it is assembled.

Both still and high speed photography will be used to record response.

EXPERIMENTAL ARRANGEMENTS FOR SIMULATED EQUIPMENT CLUSTERS

Cluster Details

For these tests 55-gallon drums will be used to simulate equipment items and clustered in various arrays similar to what was done at MILL RACE (2). Sketches of the arrays that will be tested are shown in Figure 2.

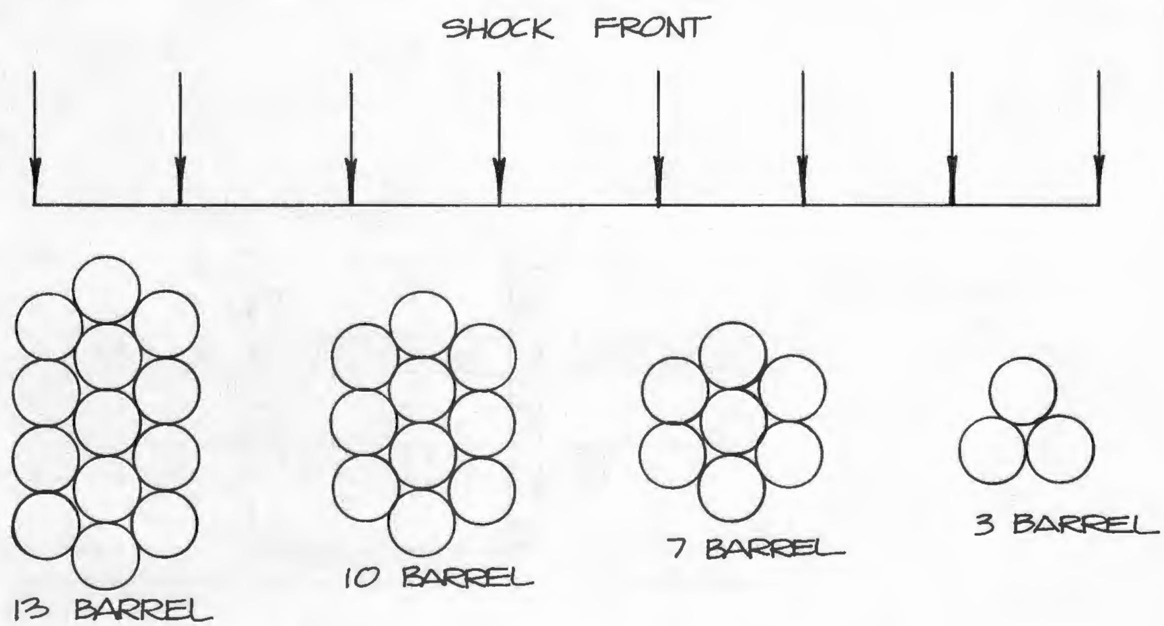

FIG. 2. SKETCHES OF BARREL CLUSTERS.

Cluster Layout

The planned cluster tests are divided into three groups depending on the particular overpressure levels where the cluster is to be located.

Group I - Tests at 30 psi

At three different locations, 7 and 10 barrel arrays will be placed with at least one array being on a stabilized surface so that high speed photographs may be taken. These tests will help to evaluate the overturning and sliding response and the securability of items into larger arrays and at higher overpressures than tested at MILL RACE.

Group II - Tests at 20 psi

A. At one location, three 7-barrel arrays will be secured with more commonly available strapping material than the seat belt webbing used at MILL RACE.

B. At two locations having different types of surfaces, two 3-barrel arrays having half the normal weight will be placed. One of the arrays will be anchored with the expedient soil anchor used at MILL RACE. The objective here will be to determine if the cluster size can be reduced by using soil anchors.

Group III - Tests at 40 psi

At two locations having different surfaces, one 7-barrel and one 13-barrel array will be placed with one surface sufficiently stabilized to permit high speed photographs of the cluster motions. The purpose of these tests is to extend the Group I tests to still higher overpressures and larger clusters.

EQUIPMENT REFERENCE TESTS

To provide reference data on the equipment, individual items will be exposed to static overpressures at the 20 psi ground range.

TEST SUMMARY

Table I provides a summary of the expected test results.

TABLE 1: PREDICTED VELOCITIES AND DISPLACEMENTS OF ARTIFACTS

Test Array	P_o (psi)	I_q (psi-s)	D (ft)	F (ft/s)	V_a (ft/s)	V_o	V_a/V_o	Overturn	Displacement in D
Full scale 1 Mt Heavy Equip.	20	3	20	0.1	14	22	0.64	NO	(D/3)
Direct Course 1 kt Light Equip. Package	20	0.3	9	0.033	9.3	15	0.63	NO	(D/3)
3 Drums	20	0.3	3.7	0.07	10.7	9.5	1.13	probably	(D)
7 Drums	30	0.6	5.4	0.10	10	10	1.0	marginal	(D/2)
10 Drums	30	0.6	6.7	0.10	8.4	13	0.65	NO	(D/4)
7 Drums	40	0.87	5.4	0.10	15	10	1.5	YES	(1.1D)
13 Drums	40	0.87	8.7	0.10	10	15	0.67	NO	(0.3D)

REFERENCES

1. J.V. Zaccor, R.D. Bernard, and R.E. Peterson, Industrial Hardening: 1981 Technical Status-Report, Scientific Service, Inc., Redwood City, California, SSI 8145-7 (September 1982).

2. R.S. Tansley and J.V. Zaccor, Testing of Shelter Design and Industrial Hardening Concepts at the MILL RACE Event, Scientific Service, Inc., Redwood City, California, SSI 8115-4 (January 1982).

APPENDIX A

SCALING OF EQUIPMENT CLUSTERS

Calculations given in Reference 1 show that, for truly impulsive loads, the cluster will not overturn nor will it slide more than a distance, D, providing that:

$$D > 1.5[I_q/F]^{2/3}$$

where D = the minimum horizontal dimension of the cluster (ft)
I_q = the dynamic pressure impulse (psi-s)
F = the ratio of the density of the cluster to that of steel
and it is assumed that the height of the cluster is less than 1/3D.

To illustrate the scaling involved, assume it is desired to model in a 1 kt test using real equipment a full scale cluster having a D = 20 and an F = 0.1 exposed to a 1 Mt weapon burst. This means that D and/or F have to be reduced so that the above equation holds for a reduction in I_q of a factor of 10. This could be accomplished, for example, by reducing F by a factor of 10 to a value of 0.01. However, this is an impractically low value of F, as even very lightweight home shop tools have F values ranging from 0.19 to 0.044. On the other hand, the total change could be made in the D factor, which would reduce it by almost a factor of 5 down to slightly more than 4 ft. This would make it virtually impossible to meet the required height-to-depth ratio as well as to include very many items of real equipment.

The most practical approach is to change both the D and the F values; i.e., to reduce both. For example, to simulate the 1 Mt condition in Table 1 on real equipment at 1 kt, the recommended cluster has a D = 9 and an F = 0.033 (see item 2 on Table 1). This combination avoids the problems discussed previously and is convenient to work with. Note that what this type of scaling means is that the model scale case will have the same likelihood of overturning as the full scale case and that in both cases the cluster will slide less than a distance D. Likelihood of overturning means that the model scale cluster will be accelerated to the same fraction of the velocity needed for overturning as the full scale case, which for the clusters selected is about 2/3.