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EFFECTS OF COMBUSTIBLES ON INTERNAL QUASI-STATIC LOADS

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ABSTRACT

The effects of placing solid and liquid combustible materials near detonating explosives on internal blast loading was measured during tests conducted in a one-eighth scale model of a containment structure. In many cases, dramatic increases in gas pressures resulted. The paper will summarize data and present conclusions regarding the effects of combustibles on internal blast loads.

INTRODUCTION

For explosions in enclosures involving high explosives or combustible materials in contact with high explosives, the long-duration gas pressures caused by confinement of the products of the explosives can be the dominant loads causing structural failure. These quasi-static pressures are determined by the total heat energy in the explosive and/or combustible source, the volume of the enclosure, the vent area and vent panel configuration, the mass per unit area of vent covers, the amount of oxygen in the enclosure, and the initial ambient conditions.

Previous analytic work, similitude analysis, and numerous experiments have addressed several aspects of this problem and provided a good data base for more general predictions. Reference 1 collates much of this information for gas pressure parameters from bare high explosive detonations in enclosures with open vents, while Reference 2 includes analytic predictions of these parameters for similar explosions with covered vents with various masses per unit area.

More recently, test data for gas pressures in sealed structures from high explosives surrounded by combustible liquids and solids has been obtained (Reference 3). This series of experiments was conducted with combustible materials placed in varying degrees of contact with high explosive charges. The explosion tests were conducted in a one-eighth scale model of the Pantex Damaged Weapons Facility. The program, conducted by SwRI, was sponsored by DOE and monitored by Mason & Hanger, Silas-Mason Co., Inc., Pantex Plant. The object of the tests was to determine whether the combustible materials could contribute to the quasi-static pressure development, within a sealed enclosure. In this paper, the authors will summarize conclusions of these experiments regarding the effects of combustibles on internal blast loads.

EXPERIMENTAL PROGRAM

The combustible materials of interest to the sponsor which were investigated in this effort are listed in Table 1. Six series of tests were conducted with each series having a different combustible configuration. In every case, the high explosive was 0.992 lb of PBX-9404. The only parameter not held constant was the combustible configuration. Figures 1 through 6 illustrate each of the test configurations described in Table 1.

Series 1 and 2 tests, conducted in an earlier phase of this experimental program, (Reference 5) used bare and cased cylindrical explosive charges. These tests produced higher quasi-static pressures than expected, based on previous tests (See Reference 4 and 5) with equal weight, bare spherical charges of the same PBX-9404 explosive. To explain this discrepancy, it was noted that the cylindrical charges had combustible solids in intimate contact, while the spherical charges did not. It was postulated that rapid burning of all or part of those materials caused greater pressure rises than for explosives alone. This phenomenon can be quite important in predicting quasi-static pressures in blast containment structures when solid or liquid combustible materials are in intimate contact with or are near detonating high explosives. The Phase IV tests, Series 3 through 6 were intended to obtain more data on the effects of such combustibles on blast and gas pressure loads in containment structures.

Figure 7 shows the one-eighth scale model of the Damaged Weapons Facility used to determine the effects of the combustible materials in contact with or near explosive charges. The enclosed volume of the structure remained constant throughout the experiments at 145.3 ft^3. Six blast and six gas pressure transducers were located at various points throughout the model. Figure 8 shows a floor plan of the model indicating the position of the explosive charge throughout the experiments. The floor plan also shows the transducer positions at which pressure measurements were recorded.

EXPERIMENTAL RESULTS

Results of the experimental program are presented in this section. Table 2 shows the peak quasi-static pressure associated with each of the six configurations. From previous tests with bare PBX-9404 charges, the quasi-static pressure value is known to be 48.7 psi. It is this value which was used as a baseline to compare measurements for all combustible configurations. The excess quasi-static pressure column contains the difference between the measured pressure and the baseline. In every case, the addition of combustible materials in near contact with the HE charge increased the quasi-static pressure, in some cases dramatically.

To illustrate the pressure enhancement caused by the different combustible materials actual data records will be examined. Figures 9 -11 show the pressure histories measured at location 26 with three different combustible configurations. Figure 9 represents a pressure history resulting from a bare, spherical PBX-9404 charge. This figure shows a maximum pressure amplitude just under 50 psi. Figure 10 shows a pressure history obtained when a spherical charge is in contact with two polycarbonate lenses, Series 4. The quasi-static pressure is now read about 58 psi, indicating an increase in pressure over the bare charge. Figure 11 represents a pressure history measured in Series 6, where the four-sided polyethylene box surrounded the charge. The quasi-static pressure of 85 psi shows a dramatic increase over the bare charge configuration.

The degree of quasi-static pressure enhancement produced by a combustible is related to the heat energy content of the material. This is shown in Figure 12 where the excess P_{qs} (the P_{qs} produced by the combustible plus the HE, less the P_{qs} produced by the HE alone) is plotted as a function of the combustible energy content (See Table 2). The combustible energy content is defined as the mass of combustible times the appropriate heat of combustion from Table 3. As seen in Figure 12, the enhancement in the quasi-static pressure increases uniformly with increasing combustible energy, as long as the combustible is in intimate contact with the charge. The only point not following the general trend of the data corresponds to the series of tests in which the combustible fluid was dispersed a large distance from the charge (Series 5).

SUMMARY

The phenomenon of quasi-static pressure enhancement produced when combustible materials are placed near HE sources has only been recently discovered. The principal conclusions of this study are:

- Combustible materials near explosives can markedly increase gas pressures in enclosed structures,
- There is a lack of data on HE-combustible combinations,
- Quasi-static loading calculations should include estimates of contributions from the burning of combustible materials whenever such materials are expected to be in intimate contact with HE sources,
- Effects of combustibles should be investigated further to determine methods for prediction. Variations in charge to combustible mass, charge type, structure volume, degree of venting and degree of contact between HE and combustible should be studied.

FIGURES AND TABLES

Table 1. Combustible Materials and Configurations Tested*

Series	Material	Configuration
1	Polycarbonate	A 67.7 gm polycarbonate disk was attached to the end of a cylindrical ($\ell/d=1$) charge.
2	Polycarbonate and Aluminum	A 135 gm aluminum casing surrounding the side of a cylindrical charge. A polycarbonate disk covered one end of the charge.
3	50/50 Mix of DMF** and Acetone	A spherical charge was submerged in 5 oz of the fluid.
4	Polycarbonate	Two polycarbonate hemispheres were attached to opposite poles of the charge. The total polycarbonate weight was 48.25 gm.
5	50/50 Mix of DMF and Acetone	Five 1 oz containers of the fluid were equally spaced on a circle 36 in. in diameter around the charge.
6	Low density Polyethylene	Polyethylene beads suspended in an epoxy base, and formed into a four-sided box, centered on the charge. The weight of the box was 273 gm.

*The explosive was 0.992 lb of PBX-9404. Test Series 1 and 2 utilized cylindrical charges, while the remaining tests utilized spherical charges. The charge location was the same in all experiments.

**Dimethyl Formamide

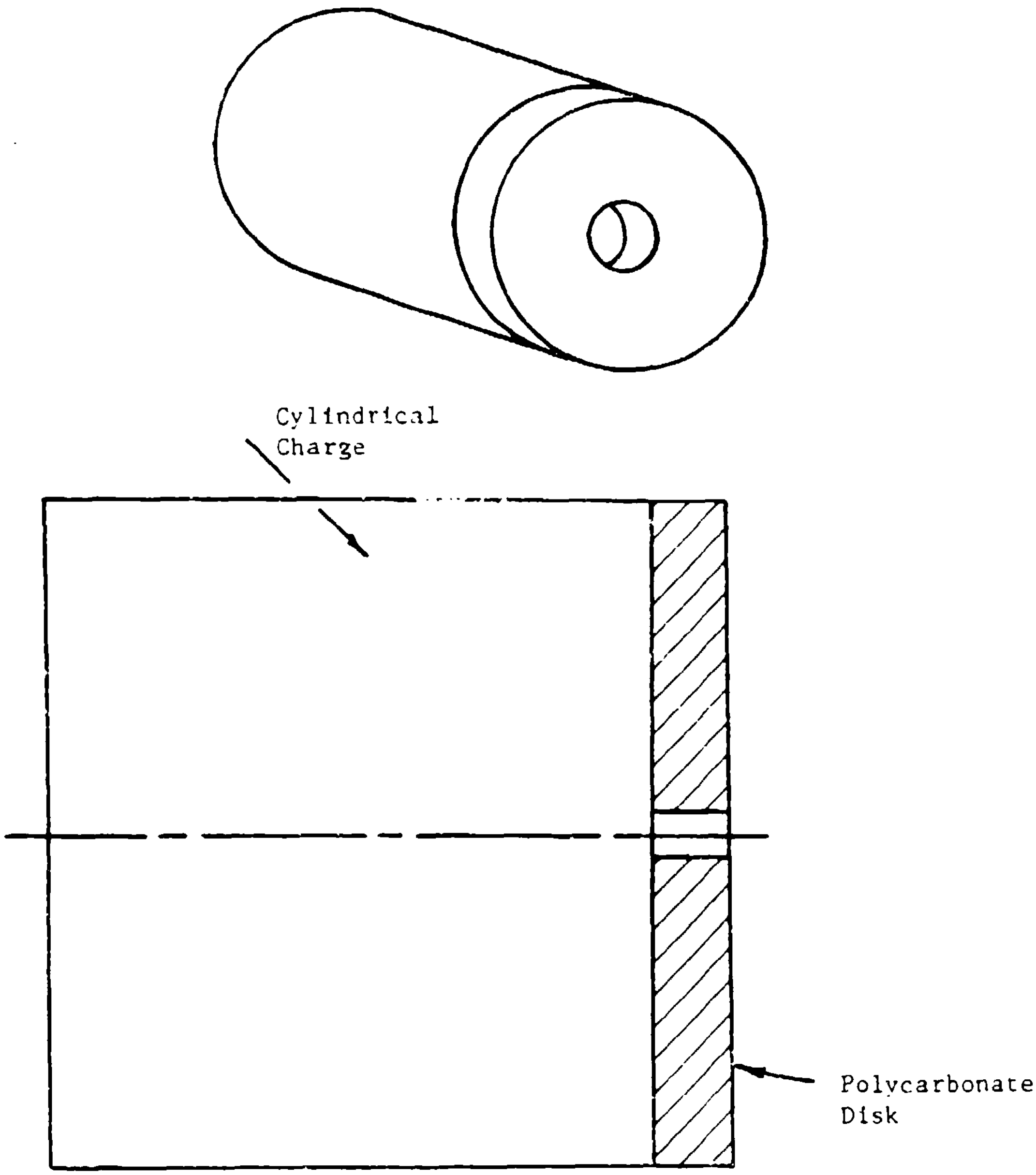


Figure 1. Series 1 Configuration

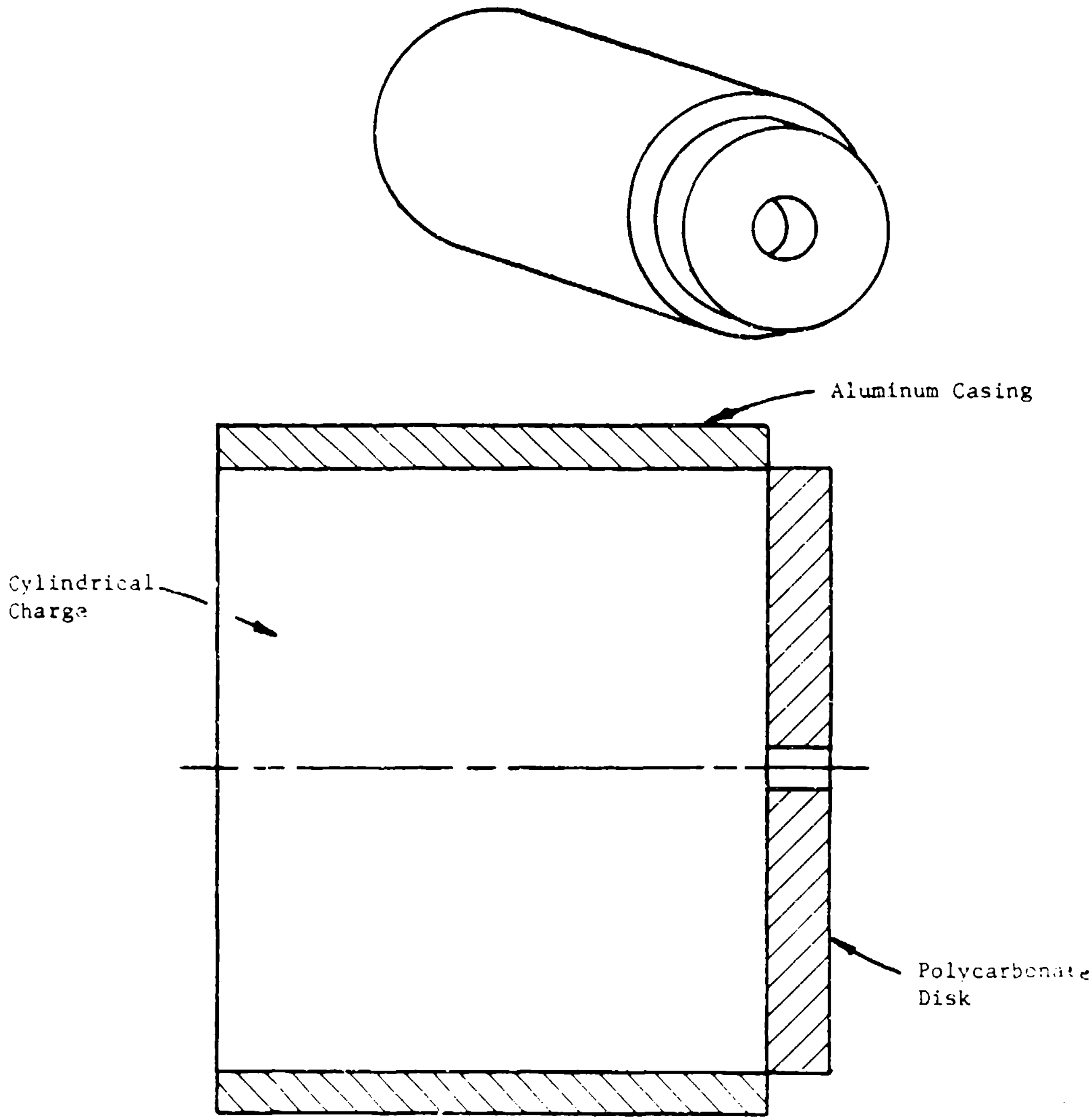


Figure 2. Series 2 Configuration

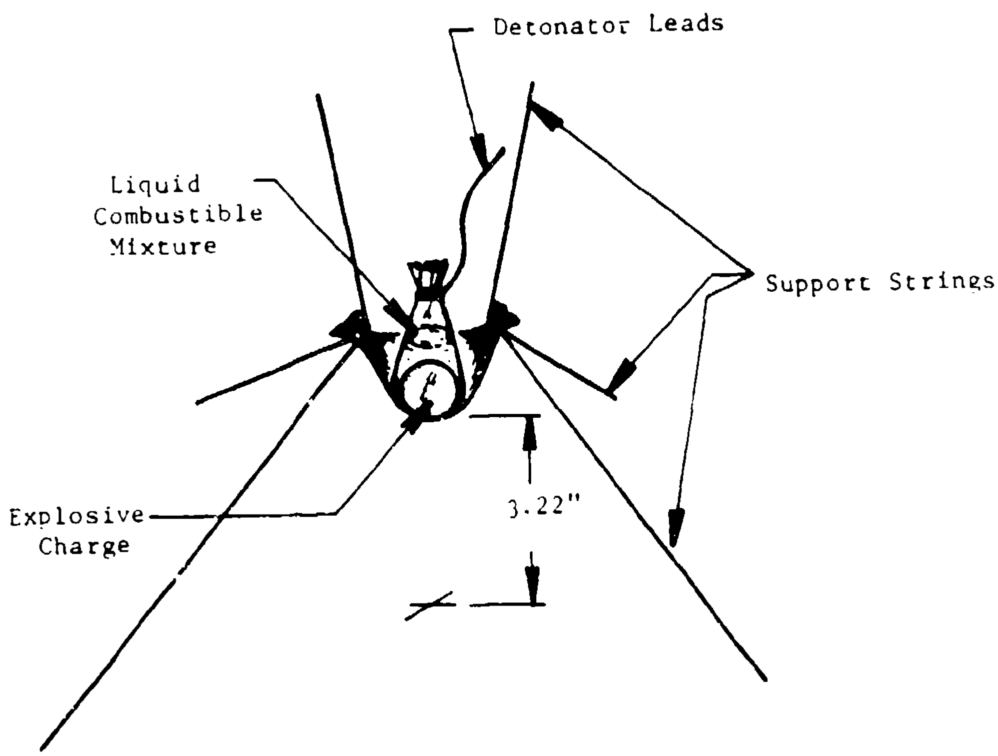


Figure 3. Series 3 Configuration

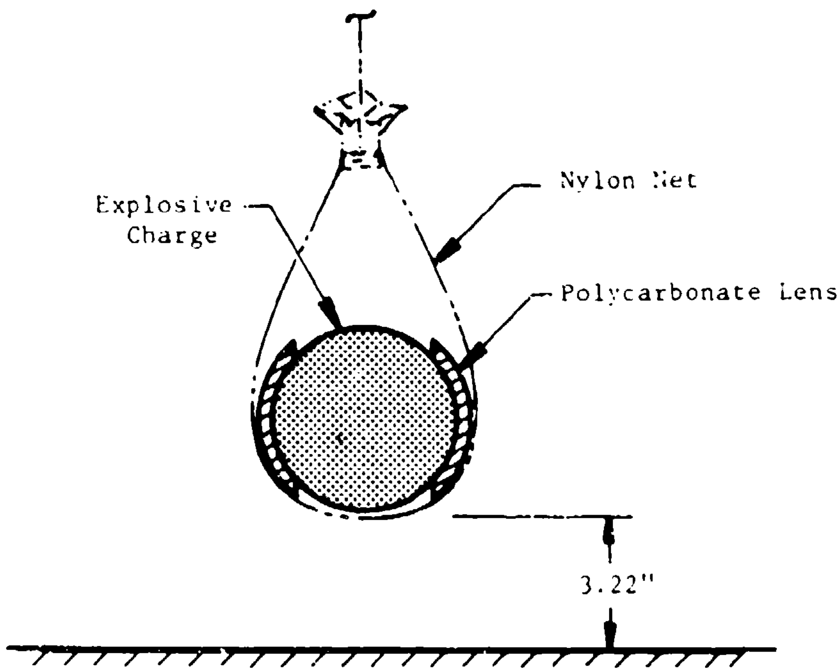


Figure 4. Series 4 Configuration

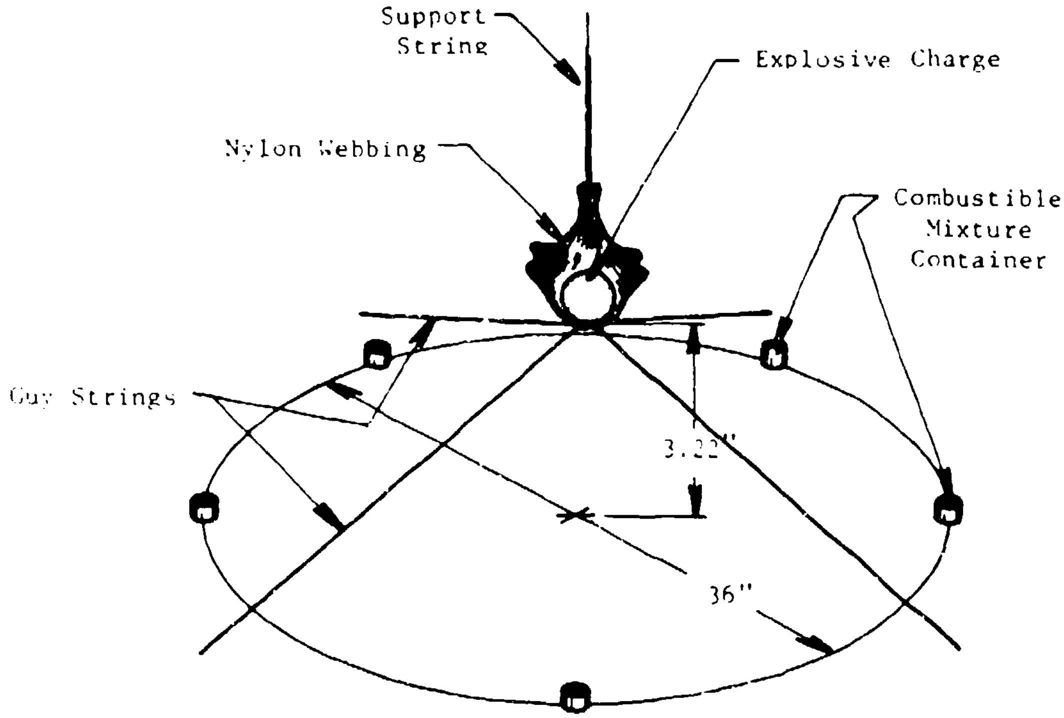


Figure 5. Series 5 Configuration

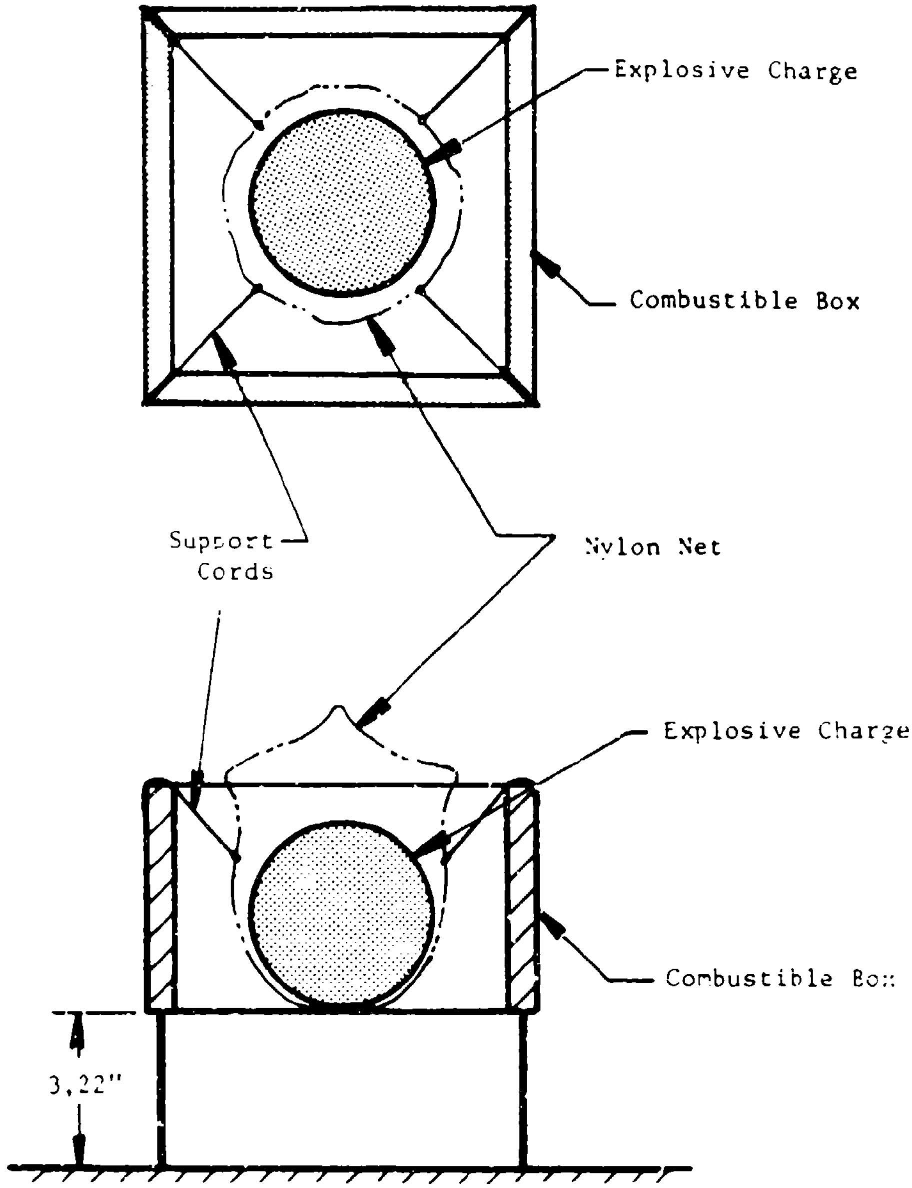


Figure 6. Series 6 Configuration

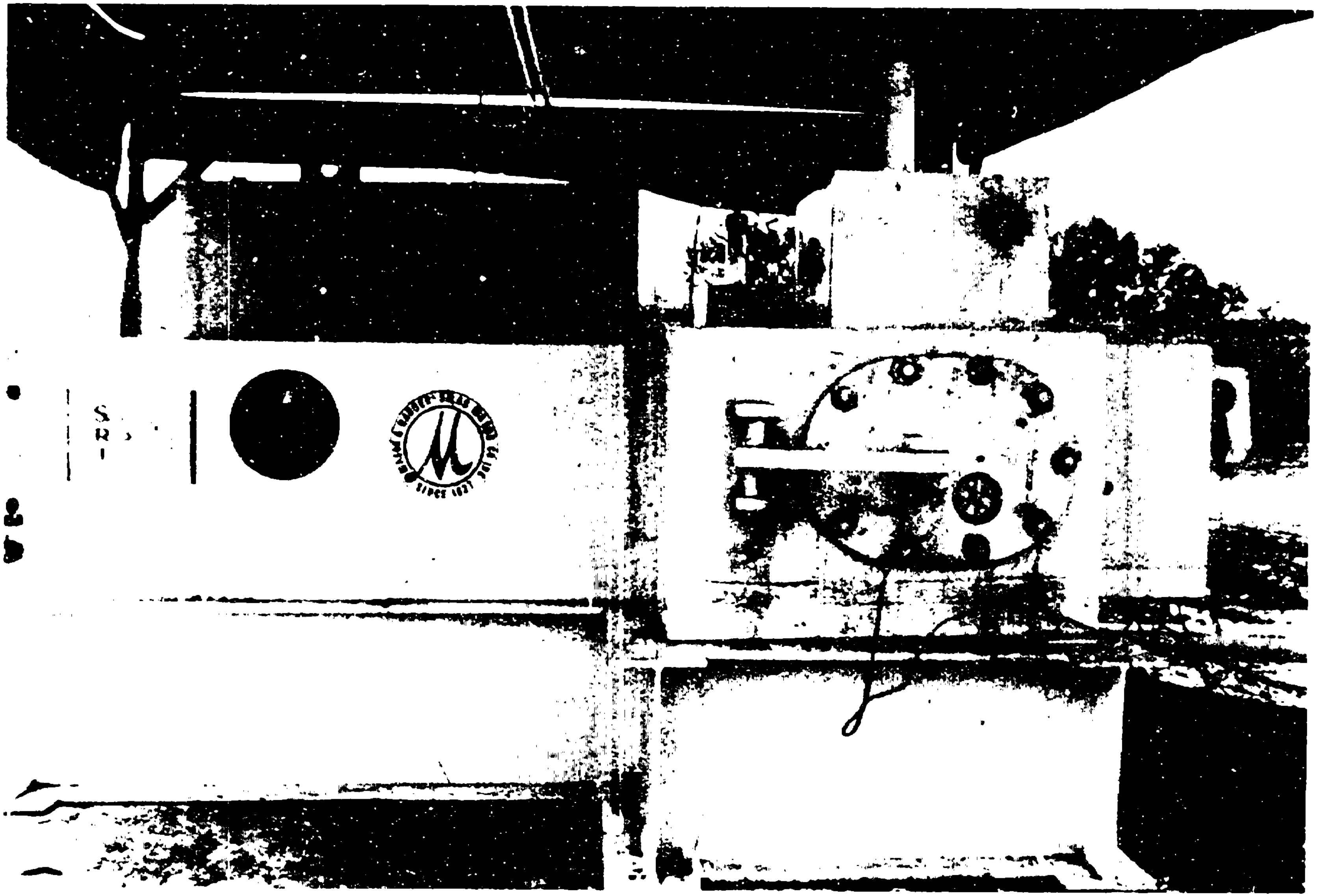
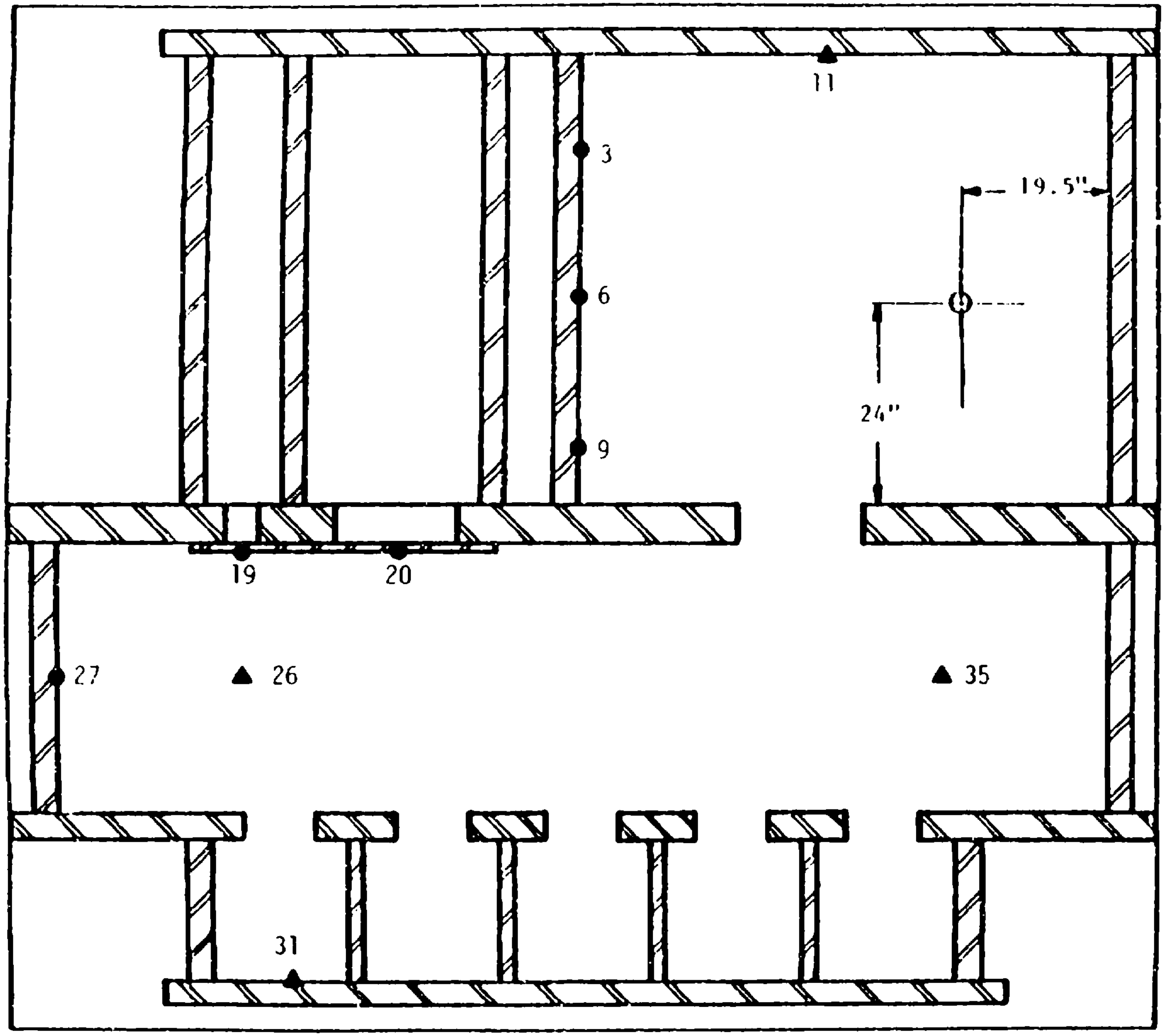


Figure 7. Scale Model Of The Pantex Damaged Weapons Facility



● Blast pressure

▲ Gas Pressure

Figure 8. Charge and Transducer Locations

Table 2
Summary of P_{QS} Enhancement

Series	Combustible	P_{QS} (psi)	ΔP_{QS} Excess Quasi-Static Pressure (psi)	Combustible Energy (Mcal)
Previous tests	HE only	48.7	0	0
1	Polycarbonate (cylindrical)	62.1	13.4	0.488
2	Polycarbonate + Aluminum (cased cylindrical)	76.0	27.3	1.487
3	DMF/Acetone in contact	68.6	19.9	0.267
4	Polycarbonate Hemispheres	56.4	7.7	0.348
5	DMF/Acetone at Distance	60.3	11.6	0.274
6	Polyethylene	85.4	36.7	4.37

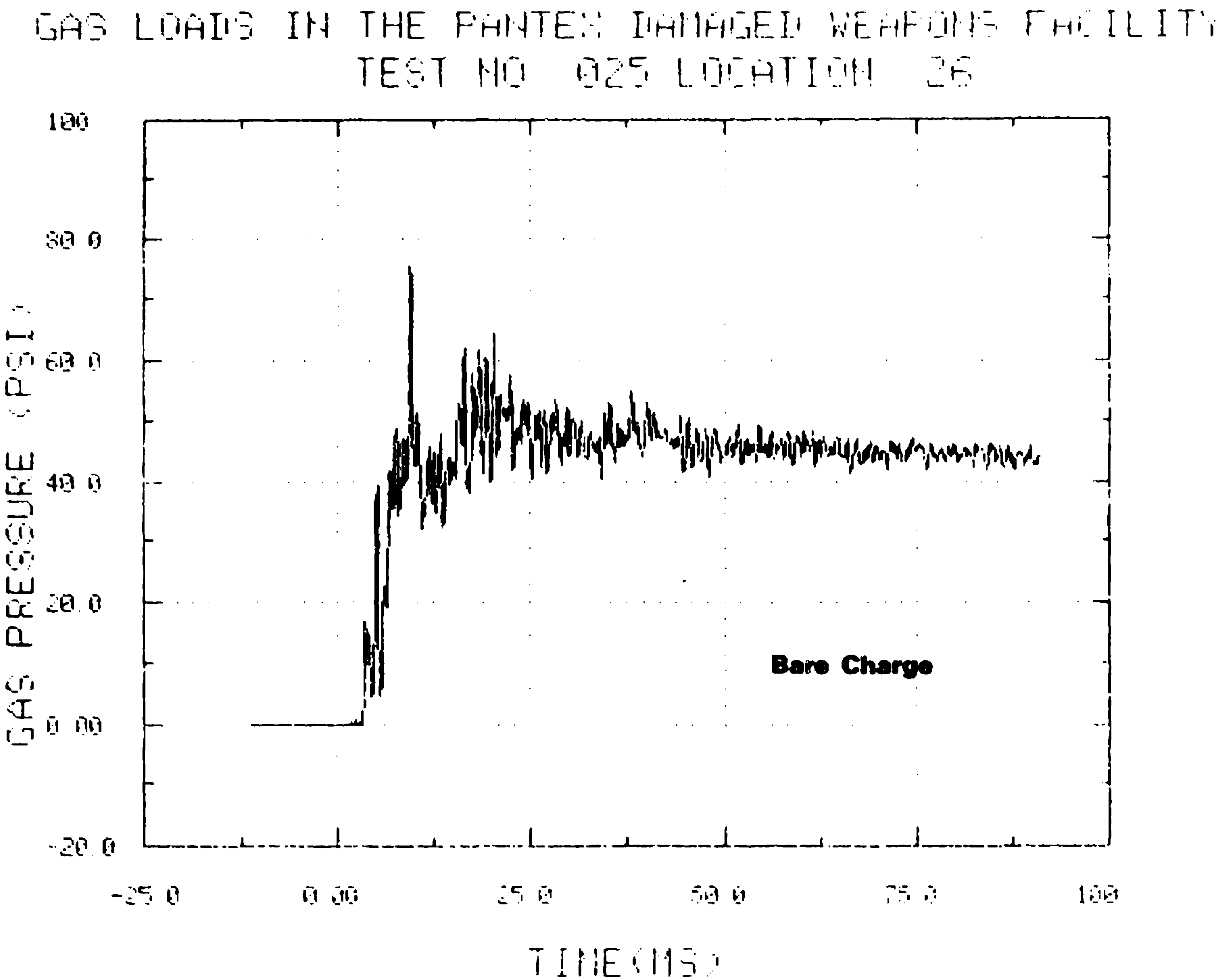


Figure 9. Pressure History From Bare PBX-9404 Charge

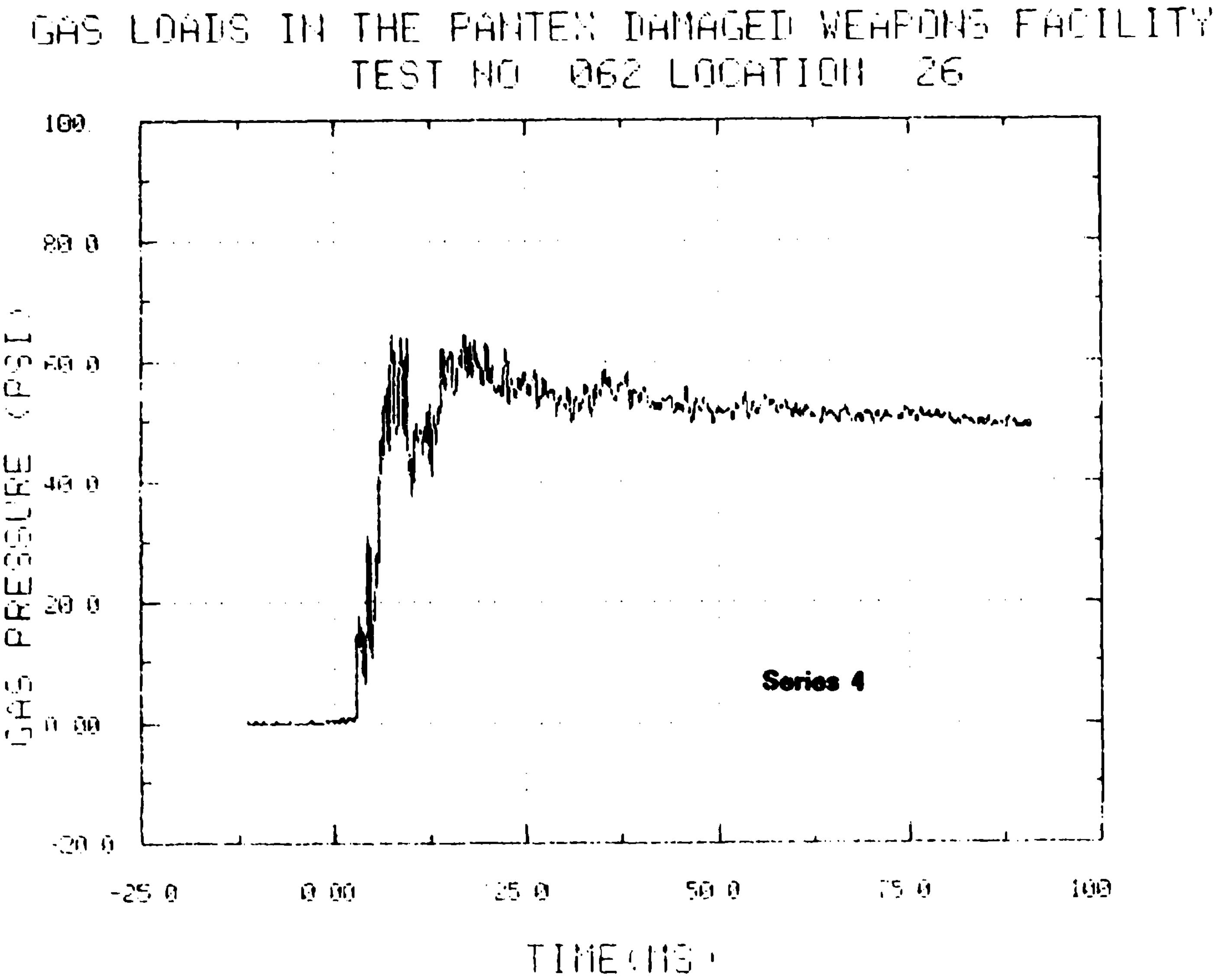


Figure 10. Pressure History From Charge With Attached Polycarbonate Lenses

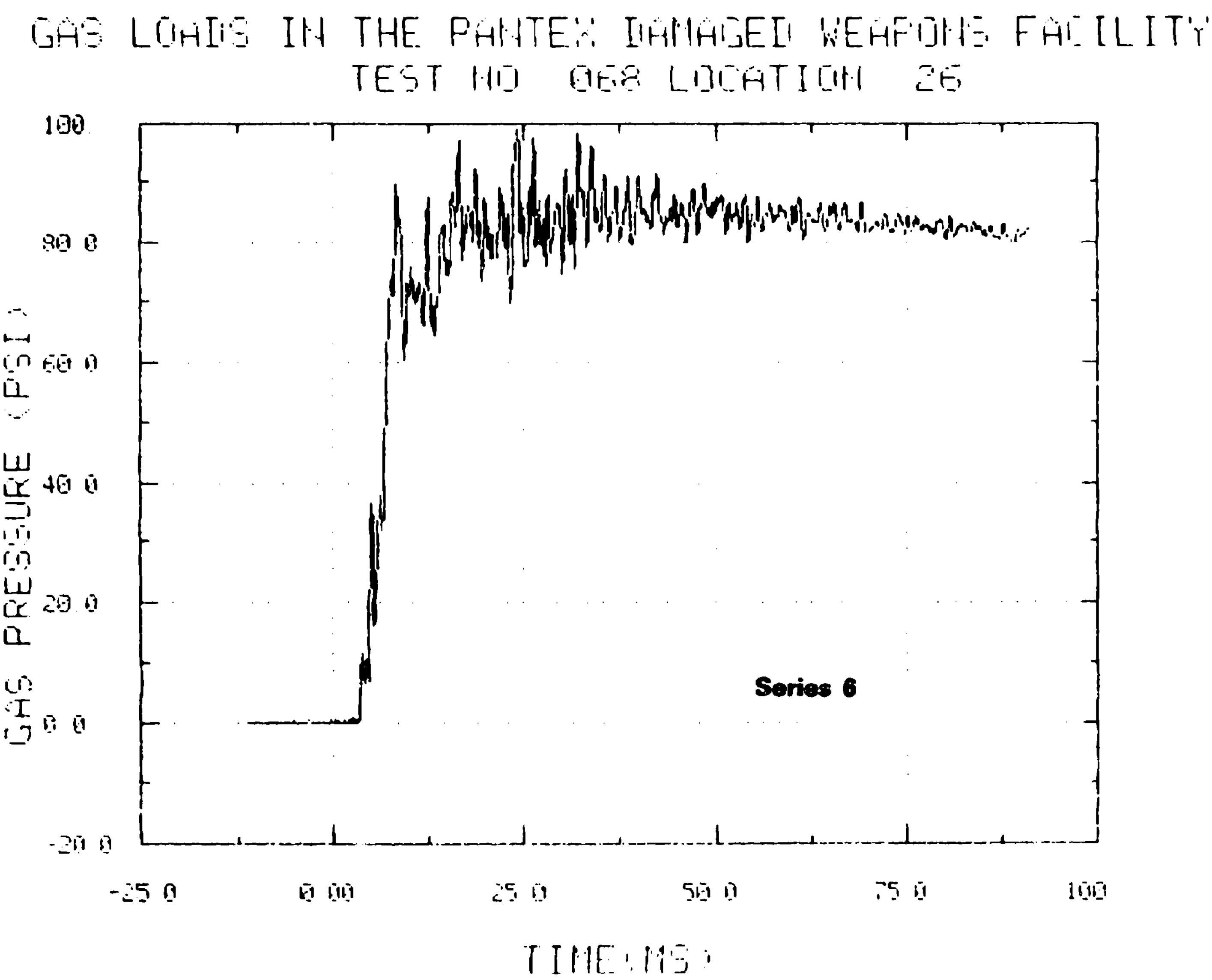


Figure 11. Pressure History From Charge Surrounded By Polyethylene Box

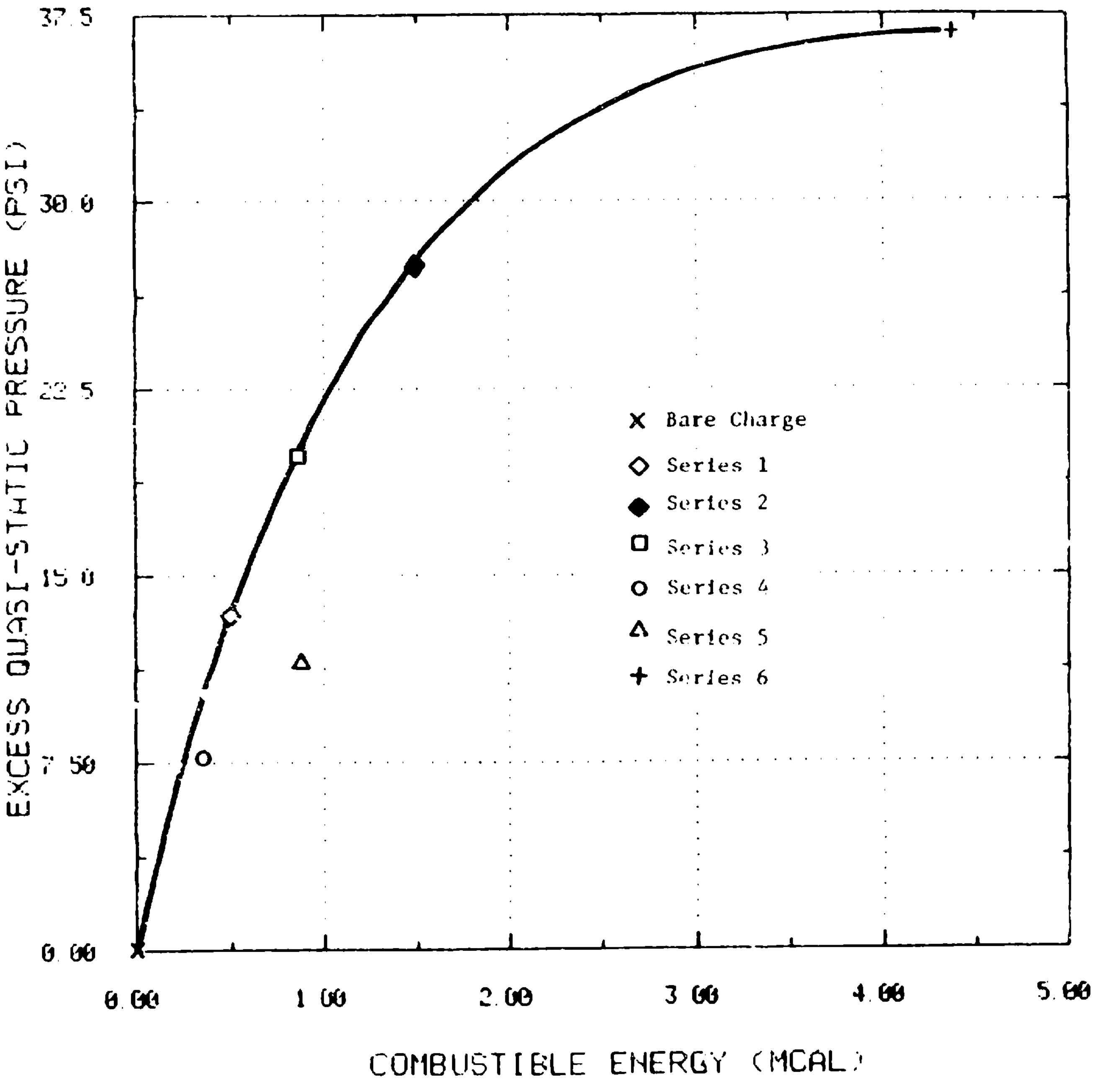


Figure 12. Excess Quasi-Static Pressure

Table 3. Heat of Combustion for the Various Combustible Test Materials

Material	Heat of Combustion (cal/gm)
PBX-9404	2369
Polycarbonate	7223
Acetone	7363
DMF	6259
Polyethylene	9400
Aluminum	7400

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