MASTER

SENSITIVITY AND PERFORMANCE TESTING OF HE

P. E. Kramer

DEVELOPMENT DIVISION

JULY - SEPTEMBER 1975

Normal Process Development
Endeavor No. 231

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operated for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
under
U. S. GOVERNMENT Contract DA-11-173-AMC-487(A)

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ABSTRACT

The effort to establish a simple, accurate, and inexpensive method for measuring detonation pressures (C-J pressure) of explosives was reactivated, with attention being focused on a technique previously investigated at LLL. Acceptable results were obtained with PBX 9404, LX-04, and CB-3, but not with TNT.

INTRODUCTION

Most accepted detonation pressure data have been generated with the flyer plate method which involves observing the free surface velocities of plates placed in contact with the detonating explosive. Despite the success of this method it has several drawbacks. It is expensive, time consuming, and reduction of the data involves considerable subjectivity.

Most pressure measurements at Pantex have been made using the aquarium technique, which has proven to be inexpensive and simple to perform, but also has the drawback that reduction of the data (streak camera film) requires subjective judgment. The reports in this series for January - December 1974 reported efforts to acquire aquarium test data via the detonation electric effect (DEE) rather than with a streak camera. This approach was expected to retain all the advantages of the standard aquarium technique while avoiding subjectivity in treatment of the data. This still appears feasible but progress has been hindered by experimental difficulties. It was decided to lay this approach aside temporarily and investigate a method which has received some attention at LLL.

DISCUSSION

Investigators at LLL have reported^a a method by which detonation pressure is determined using DEE to monitor the shock velocity induced in a stack of Plexiglas discs. Their procedure involved a stack of five Plexiglas discs (25 mm diameter x 1.25 mm thick) placed in contact with a plane wave initiated explosive sample (25 - 50 mm diameter x various thicknesses). DEE was employed to monitor the shock arrival times at the disc interfaces. The resulting distance-time data were used to calculate the detonation pressure. Private communication has indicated that several algorithms for data reduction have been investigated.

Since it appears that this method could easily meet our goals of simplicity and economy, it was decided to evaluate it for possible use at Pantex.

Plexiglas stacks of the same geometry employed at LLL were used. The discs were separated by 0.006 mm of Mylar for signal enhancement. In treating the data it was assumed that the shock velocity in the Mylar

^aH. L. Hornig, E. L. Lee, M. Finger, J. E. Kurrie, "Equation of State of Detonation Products," *Proceedings of Fifth Symposium on Detonation*, Office of Naval Research, ACR-184.

was the same as in the Plexiglas. Since the Mylar constituted only 0.5% of the total stack length, the error from this assumption should be negligible. The slow rate of shock deceleration in the downstream discs also indicates that the impedance mismatch at the interfaces was of little significance. DEE was used to monitor shock arrival at interfaces and produced six distance-time pairs [including the point (0,0)] for each stack. The oscilloscope records produced clear, sharp records and multiple tests showed the data to be quite reproducible with averaging of 2 or 3 shots being sufficient to yield an excellent representative result for a given test set-up.

The plane wave initiated explosive samples were 50 mm in diameter and varied in length from 50 to 100 mm. It was now evident that this method was economical, simple, and capable of providing consistent results. One question remained; could one algorithm for data reduction be found which yielded accurate pressure values for familiar explosives? The above mentioned flyer plate method was selected as the standard of accuracy. A single universal algorithm was demanded so that the method could be confidently applied to unfamiliar explosives.

Tests were conducted with four explosives; PBX 9404, LX-04, CB-3, and TNT. The data are listed in Table I. The distance and time values represent averages of several shots.

TREATMENT OF DATA

In any detonation pressure test which employs an inert monitor, (in this case, the Plexiglas) the data for the monitor must be treated by some algorithm to yield an "initial" shock velocity. Combining this velocity with the inert Hugoniot and some form of isentrope for the explosive detonation products yields a figure for the detonation pressure. Assumption of an ideal gas isentrope has been shown to yield excellent results and was used in this work. In liquid monitors, the initial shock velocity is found by estimating the initial slope of a distance-time curve or measuring the incremental velocity through a short length of the monitor. But in most solids, the Von Neumann spike manifests itself for a finite distance into the monitor, resulting in initial shock velocities too large to be representative of the detonation (Chapman-Jouguet) pressure. Thus, unless the shock is observed in sufficient detail to delineate the Von Neumann spike, some algorithm must be applied to the data to produce an "initial" value for the shock velocity following the spike. To illustrate this point, incremental shock velocities for the first disc (~ 1.25 mm) in each stack were used to calculate detonation pressures. Table II clearly illustrates the excessive calculated pressures which result from this approach.

It is thus seen that the shock velocity for the first disc is too large in each case and inclusion of the transit time for that disc in any treatment of the data would bias the results toward excessive pressure. For that reason all further manipulation of the data excludes the point (0,0).

The data simply do not contain sufficient information to calculate the actual "initial" shock velocity, but it might so happen that there exists an algorithm which consistently yields accurate calculated pressures for known explosives. If such were the case, then it might reasonably be assumed that this would work for unfamiliar explosives also. That is, we might have a nonrigorous but effective method for determining detonation pressures. To this end, several promising approaches were tested. The results are summarized in Table III.

The most notable feature of Table III is that no method of data treatment yielded a good value of pressure for TNT. The only algorithm which came within 1 GPa was No. 3, which consistently yielded low pressures for the other explosives and was one of the poorer techniques overall, even including the TNT results. It thus seems that we cannot satisfy our requirement that a single method of data treatment yield good pressure values for the familiar explosives. This implies that this experimental technique cannot be considered as a universally applicable method for measuring the detonation pressure of explosives. A clue to the problem lies in algorithm 3, the one which yielded the best result for TNT. In this algorithm, the Plexiglas shock velocity is simply equated to the incremental velocity for the second disc, with no attempt at any sort of extrapolation to shorter distance (which would yield a higher velocity). Since the pressures from algorithm 3 for the other three explosives are all too low, it is indicated that some extrapolation was needed. On the other hand, even without extrapolation the velocity was too high for TNT. This implies that, with TNT, the Von Neumann spike effect persists for more than 1.25 mm into the Plexiglas, whereas the persistence is less than 1.25 mm for the other explosives.

It appears that this experimental technique, combined with algorithm 1 (clearly the best of those tried), can yield detonation pressures accurate to well within 1 GPa for explosives with sufficiently short reaction zones. For explosives with longer reaction zones, calculated pressures will be too large. Just what a "sufficiently short" reaction zone is has not been determined, and besides, it is not likely that the reaction zone length of an unfamiliar explosive would be known.

CONCLUSIONS

The detonation pressure measurement technique discussed in this report has proven to be both economical and simple to use. However, no single method of data reduction has been found which yields accurate results for all the tested explosives. It does appear that the experimental technique combined with algorithm 1 can be used to determine the detonation pressure (within 1 GPa) of explosives with reaction zones no longer than that of CB-3.

Table I. Distance-Time Data for Plexiglas Stacks

Plexiglas Density = 1.186 Mg/m^3
 Plexiglas Hugoniot: $U_s = 2.598 + 1.516 U_p \text{ (km/s)}$

	Explosive							
	PBX 9404		LX-04		CB-3		TNT	
Density (Mg/m^3)	1.840		1.865		1.715		1.628	
Detonation Velocity (km/s)	8.80		8.47		7.91		6.93	
Distance(mm)-Time(μs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1.270	0.175	1.267	0.177	1.263	0.179	1.260	0.196
	2.541	0.356	2.539	0.361	2.532	0.369	2.530	0.410
	3.820	0.541	3.813	0.549	3.799	0.564	3.804	0.628
	5.100	0.728	5.087	0.739	5.073	0.760	5.074	0.848
	6.373	0.915	6.358	0.929	6.341	0.959	6.348	1.072

Table II. Pressures Calculated Using Velocity in First Disc

Explosive	Pressure (GPa)	
	Calculated	Accepted
PBX 9404	37.4	36.6
LX-04	35.9	34.2
CB-3	31.9	29.5
TNT	23.6	19.1

Table III. Pressures Calculated from Table I
Data by Several Algorithms^a

	Pressure (GPa) with Algorithm							Accepted Value
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	
PBX 9404	36.0	35.6	35.0	36.4	36.0	37.0	36.3	36.6
LX-04	34.1	33.7	33.7	36.2	35.3	37.5	35.8	34.2
CB-3	29.5	29.1	28.5	30.6	29.9	30.7	29.6	29.5
TNT	20.9	20.6	20.0	21.0	20.7	21.5	20.9	19.1
Accuracy Ranking Including TNT	1	2	5	6	3	7	4	
Accuracy Ranking Excluding TNT	1	2	5	6	4	7	3	

^aPoint (0,0) omitted in all cases

Algorithm:

- 1: Time fitted as quadratic in distance, velocity extrapolated to zero distance
- 2: Same as 1 except velocity extrapolated to center of first disc
- 3: Incremental velocity for second disc
- 4: Velocities for second and third discs fitted as linear function of distance, extrapolated to zero distance
- 5: Same as 4 except extrapolated to center of first disc
- 6: Velocity of discs 2 - 5 fitted as quadratic in distance, extrapolated to zero distance
- 7: Same as 6, except extrapolated to center of first disc