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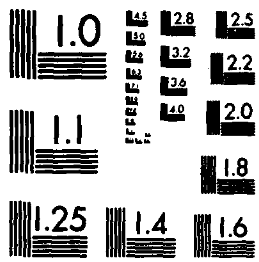

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THEORETICAL INVESTIGATION OF THE WAVE SHAPING PROCESS IN A SECTION OF LADDER FRACTURE TAPE

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THEORETICAL INVESTIGATION OF THE WAVE SHAPING PROCESS IN A SECTION OF LADDER FRACTURE TAPE

J.J. Masinskas and E.H. van Leeuwen

ABSTRACT

The presented paper describes the modelling of the detonation process in a section of Fracture Tape using the two-dimensional reactive Lagrangian Hydrodynamic code 2DL. The Forest Fire burn model of heterogeneous explosive shock initiation was used to model the explosive decomposition. The results show (i) the time dependent pressures (ii) detonation wave shaping and (iii) deformation of the tape.

Fracture tape is a channel-section neoprene moulding designed to be filled with plastic explosive. The moulding places barriers at regular intervals within the explosive which divide the detonation wave into two parts then focus both together to collide head on. Such a collision generates a narrow region of very high pressure, over 30 GPa in XTX-8003 compared with the normal detonation pressure of 19 GPa.

The calculations indicate that with the ladder geometry Fracture Tape, the detonation wave propagates around the barriers, as well as creating a shock wave which is transmitted through the barrier itself. The transmitted shock wave may detonate the explosive immediately behind the barrier before the propagated detonation reaches it, thereby reducing the pressure enhancement from the expected collision for some distance from the barrier.

The effects of changes in size or geometry can be modelled to assist in optimising tape performance.

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CONTENTS

THEORETICAL INVESTIGATION OF THE WAVE SHAPING PROCESS

IN A SECTION OF LADDER FRACTURE TAPE

1. INTRODUCTION

In recent years large hydrodynamic codes have been used to obtain a considerable amount of information concerning the structure of propagating detonation waves, Mader [1].

In this paper we report on the numerical modelling of the detonation process of a condensed explosive in a section of Fracture Tape [2]. The detonation process has been investigated using both a Eulerian and a Lagrangian hydrodynamic code to solve the compressible Navier-Stokes equations of fluid dynamics in two dimensions. In this study the reactive code 2DL [3] was used to model the detonation, whilst in a second study the code HELP (Hydrodynamic Elastic Plastic) was employed. In the latter case, the code is limited by the fact that it is non-reactive. This means that as detonation proceeds, the undetonated high explosive is not allowed to move or compress, leading to regions of unrealistically high pressure where inert materials in compression cannot relieve against undetonated high explosive. Useful results have been obtained [4], however.

The objective of the present study is to develop a numerical solution of the reactive fluid dynamics that occur in a section of Fracture Tape using the reactive Lagragian code 2DL. This provides a more realistic simulation than is possible with HELP.

Fracture Tape comprises a channel-section moulding made from a neoprene rubber compound filled with plastic or mouldable explosive. It comes in a number of geometric configurations as shown in Appendix A. It is particularly useful in fracturing metal plates e.g. for purposes of demolition, cutting up or destruction of or damage to a target. It has been used successfully for military purposes such as wall breaching, ordnance disposal and demolition. Other applications have been in industry where, for example, mineral exploration companies in the North Sea Oil fields have used Fracture Tape to fracture plates and pipes accurately.

Fracture Tape can be filled with either a sheet or plastic explosive. For example PE4 [5] and the sheet explosive Metabel [6] have been successfully used. (There seems little advantage in using sheet explosives if they must first be cut into pieces and cemented into place). A plastic explosive such as PE4 can simply be pressed into the cavity of the tape to the level of the transverse delay elements (barriers). The surface is then flattened and excess explosive removed. The filled tape is put in place with the explosive against the target, and held there using masking tape.

The tape may be initiated by any detonator capable of detonating the explosive used to fill the tape. A standard exploding bridge wire (EBW) detonator was used in experimental work at MRL. A small hole was cut into the neoprene backing at one end of the tape and filled with explosive, allowing the EBW to be placed in contact with the explosive.

The ideal behaviour of the detonation in a section of ladder Fracture Tape is shown in Fig (1). The incident detonation front at a typical barrier is shown in Fig 1(a). The barrier absorbs the shock, and allows the detonation to proceed through the gaps between it and the side walls of the tape. Provided the gap is larger than the critical diameter of the explosive, the detonation passes the corner of the barrier and proceeds towards the centre of the tape as well as along it, Fig 1(b). When the two fronts collide at the centreline of the tape, as shown in Fig 1(c), the resultant pressure is very much higher than the normal detonation pressure of the explosive. As the detonation proceeds, the point of collision moves along the centreline, see dotted line in Fig 1(d), and the collision angle is reduced, reducing the enhanced collision pressure. The next barrier in the tape is placed so as to repeat this process before the enhanced pressure decays too much.

The *2DL* calculations indicate the detonation behaviour shown in Fig 2. The incident detonation front at a typical barrier is shown in Fig 2(a). A shock wave is created within the barrier which proceeds through the barrier while the detonation propagates around the ends, Fig 2(b). The shock wave is delayed and attenuated by the barrier, but it can still reach the far side of the barrier before the detonation can propagate all the way to the centreline. The shock, even after attenuation in the barrier, can detonate the explosive, creating a third detonation front as shown in Fig 2(c), and preventing a full head-on collision. There is some interaction between the propagated and the induced detonations, but this occurs off the centreline, at a small collision angle and hence has only some enhancement. The dotted 'Y' in Fig 2(d) shows the paths of the two small enhanced areas until they merge at the centreline, and then proceed as in the ideal case.

The effect of the imperfect barrier is to reduce the pressure seen by the target immediately behind the barrier to the normal detonation pressure of the explosive, and hence reduce the cutting action.

The fracturing mechanism against metal targets can be understood as follows. When the tape is detonated against the surface of the target, the detonation front generates shock waves within the metal as it propagates along the tape. The shock waves propagate into the metal, interacting below the centreline of the tape to create a region with a very high pressure and large pressure gradients. The shock waves are also reflected from the rear surface of the metal as tension waves. Interaction of the incident and reflected waves creates a spall surface within the metal where its tensile strength has been exceeded. Fracture Tape therefore can cause spalling behind the metal plate, and can also cause a line of fracture through the metal under the centreline of the tape. Metallurgical aspects have been addressed in a separate study [17].

2. COMPUTATIONS

The two-dimensional Lagrangian hydrodynamic code, 2DL, described in Appendix B, was used to model numerically the reactive dynamics of neoprene Fracture Tape. The Forest Fire model of heterogeneous explosive shock initiation was used to achieve a realistic numerical simulation of the explosive burn. It is appropriate for this problem because it can model the heterogeneous detonation wave propagation in the explosive and the build-up to detonation in the explosive due to the transmission of the shock wave through the barrier. The HOM equations-of-state [1] are used in 2DL to describe the state of both the condensed and gaseous material. The detonation product parameters are calculated for the explosive products using the BKW code [10].

The explosive filling for the modelling of Fracture Tape in this study was chosen to be XTX-8003 [11,12,13] comprising 80% PETN (pentaerythritoltetranitrate) and 20% sylgard 182 (polydimethylsiloxane) silicone resin. XTX-8003 was chosen because it is widely known, well characterized and the data needed by 2DL was readily available. It is similar in composition and performance to the plastic explosive, Metabel, which has been used in some fracture tape firings by the Services. The plastic explosive PE4, 88% RDX, 11% grease and 1% PEDO (penta-erythritol di-oleate) is also used with Fracture Tape. The data needed by 2DL is not available for PE4, hence the modelling was done only with XTX-8003.The HOM equations-of-state and Forest Fire constants for XTX-8003 are given in Appendix C and the Pop plot and Forest Fire rates are shown in Figures C.1 and C.2.

The characterisation of the neoprene material was much simpler than that of the explosive composition. The neoprene is inert and remains solid, hence only solid data is needed. The shock properties were available from Ref [13], the others from Ref [15]. The data are shown in Appendix D.

The calculations were done with the Fracture Tape modelled in the plane of contact with the target. The explosive strip was bounded by neoprene walls, with rectangular barriers also of neoprene. The explosive XTX-8003 was initiated at one end of the tape from a square of 10 by 10 cells symmetrically on the longitudinal axis, Fig. 3, considered to contain fully decomposed XTX-8003 at an initial density of 2.6 Mg m^{-3} and initial pressure 33 GPa. This sends a diverging shock wave of approximately 20 GPa (1.5 GPa above the CJ pressure of XTX-8003) into the surrounding XTX-8003, see Fig. 4. Because of its small size, explosive within the initiation square needs to be compressed beyond the normal detonation state in order to detonate its surrounding cells. The propagating detonation settles to the normal state within a few cells. This is the required method of detonating explosives within 2DL, though it is not usually pointed out.

The computational cell size used in this calculation was 0.5 x 0.5 mm and the time step .01 μs. The computer time for calculating the 10,000 cells for 1200 cycles was 20 minutes on a Cyber 205 computer.

Figures 5-7 show the results of the calculation on the standard ladder tape. Only one half of the tape was modelled, with a reflective boundary along the centreline, because of symmetry. The diagrams show pressure contours within the body of the tape, as well as the pressure profile along the centreline.

Fig. 5 shows the computed detonation front passing around the end of the barrier and fanning out as a normal detonation wave. The centreline pressure profile shows the shock being transmitted into the undisturbed explosive, the pressure levels in the barrier and the reflected shock moving back into the detonation products. The pressure transmitted into the explosive is less than the normal detonation pressure, but it is sufficient to start a reaction. Reference to the Pop-Plot for the explosive, shown in Appendix C, indicates that the reaction will build up to full detonation within 1 mm from the barrier.

The detonation initiated by the transmitted shock is clearly shown in Fig. 6. It has built up to the full steady state detonation and is interacting with the detonation coming in from the side. The pressure in the colision region is nearly 30 GPa, compared with the normal detonation pressure of 19 GPa. The interaction is off-centre, but will move inwards as the detonation proceeds.

When the interaction regions reach the centreline, they merge, and the process continues, as in the ideal case. Fig. 7 shows the detonation just as it reaches the next barrier. A normal detonation propagates around the barrier. The very high pressure creates a very strong shock wave in the barrier, which propagates through the neoprene very quickly. The high pressure near the centreline is sustained for a very long time, shown by the plateau in the pressure profile.

3. CONCLUSION

This study of the operation of ladder Fracture Tape has shown that the tape barriers interfere with part of the detonation front in the explosive and focus the remaining parts of the detonation on the centreline of the tape. The resulting collision between the separate detonation fronts produces a narrow region of high pressure, greater than that of the normal detonation pressure of the explosive.

The calculations done using the 2DL code show that the barriers do not block the detonation completely, but that they transmit a shock which can initiate the explosive behind the barrier. The induced detonation interacts with the propagated detonation at some distance from the centreline, thereby preventing the expected head-on collision and hence reducing the peak pressure. The interaction moves inwards, eventually reaching the centreline some distance from the barrier.

The results of this study can be used to improve the design of Fracture Tape, e.g. by increasing the thickness of the barrier in order to further delay the transmitted shock. The numerical model can be used to assess the effect of the changes in design, and reduce the number of designs which need to be tested experimentally.

The ability of the 2DL code to model accurately the shock initiation of the explosive in 2-D was critical to this study. Other codes, without this detonation model, could only provide calculations related to the ideal case and did not show initiation behind the barrier at all.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

1. Mader, C.L., 1979, Numerical Modelling of Detonators, University of California press, Berkeley.

2. Alford, S.C., 1982, European Patent Application 81302787.7.

3. Washl, J.A., Masinskas, J.J. Numerical Modelling of Explosively - Produced Shock Loading, TTCP-WTP-1 27 Sep 1984.

4. Masinskas, J.J., Smith, D.L., Van Leeuwen, E. Numerical and Experimental Study of Fracture Tape at MRL. TTCP WTP-1 9 Oct 1985.

5. Chick, M.C., Learmonth, L.A. Determination of Shock Initiation and Detonation Characteristics of PE4 in Proof Test Geometries MRL-R-979 November 1985.

6. I.C.I. Technical Data - Explosives, METABEL Sep 1979.

7. Johnson, J.N., Mader, C.L., and Shaw, M.S., 1981, "2DL": A Lagrangian Two-Dimensional Finite Difference Code for Reactive Media LA-8922-M.

8. Forest, C.A., 1978, Burning and Detonation, LA-7245.

9. Walsh, J.M., Christian, R.H., Equation of State of Metals from Shock Wave Measurements. Physical Review 97, 1554 (1955).

10. Mader, C.L., 1967, Fortran BKW, A Code for Computing the Detonation Properties of Explosives LA-3704.

11. Skirpo, D., Johnson, J.O., Wodkerk, J.W., Shock Initiation of XTX-8003 and Pressed PETN, J. App. Phys. 41, 3884 (1970).

12. Gibbs, T.R., Popalato, A., editors, 1980, LASL Explosives Property Data; University of California Press.

13. Marsh, S.P., editor, 1980, LASL Shock Hugonist Data; University of California Press.

14. Mader, C.L., Gage, W.R., 1967, FORTRAN SIN LA-3720.

15. Brandrup, J., Immergut, E.H., editors, Polymer Handbook, 2nd edition.

16. Dobratz, B.M., Crawford, P.C., LLNL Explosives Handbook, 31 January 1985.

17. Reid, W.D., Walsh, B.E., Metallurgical Examination of the Effects of Fracture Tape on AISI 1020 Steel Plate, MRL Report in publication.

APPENDIX A

AVAILABLE TAPE GEOMETRIES

The ladder design comes in two widths of explosive, 25 mm and 60 mm, and each width can be obtained with either 6 mm or 3 mm depth for the explosive filling.

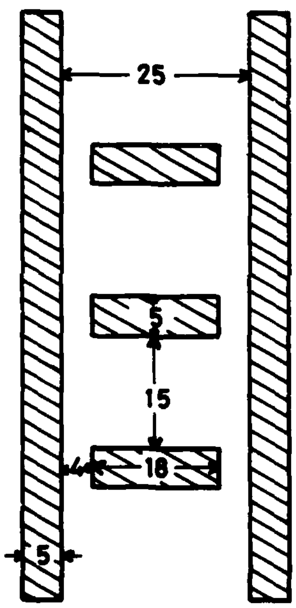


Fig A-1

25 mm Ladder

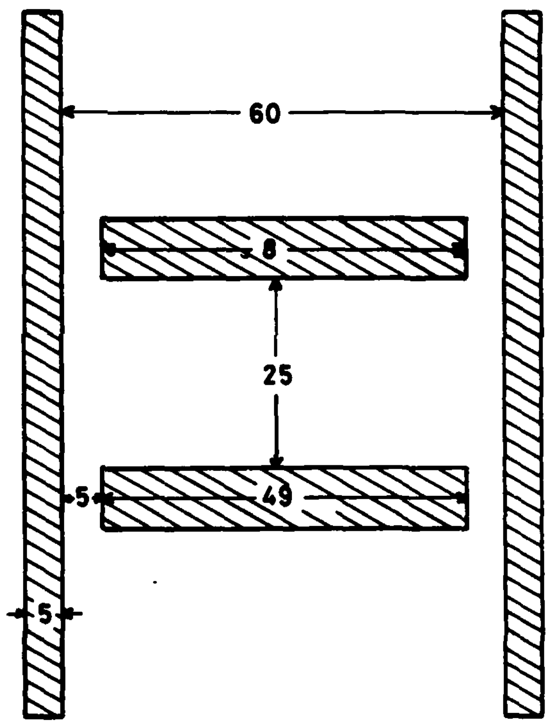


Fig A-2

60 mm Ladder

APPENDIX B

REACTIVE HYDRODYNAMIC CODE 2DL

The 2DL computer code, developed at Los Alamos National Laboratories [1], [7], uses a numerical finite difference scheme to solve the Lagrangian equations of motion for a compressible fluid in two dimensions. It is written in FORTRAN and can be used on most large computer systems with little change. The calculations described in this report were done on a CDC Cyber 205 computer.

The momentum and energy conservation equations used in 2DL are [7]:-

$$\rho \dot{U}_i = \frac{\partial S_{ij}}{\partial X_j} - \frac{\partial P}{\partial X_i} + \rho g_i \qquad (1)$$

$$\rho \dot{I} = P \rho \dot{V} + S_{ij} d_{ij} + \quad \nabla^2 T \qquad (2)$$

where

ρ - density

U_i - Cartesian velocity components

S_i - Eulerian position co-ordinates

S_{ij} - stress deviator components = $-(\sigma_{ij} - P\delta_{ij})$

σ_{ij} - total stress components

P - Pressure

g_i - gravitational field components

I - specific volume

λ - thermal conductivity

T - temperature

d_{ij} - rate of deformation tensor

$$d_{ij} = 1/2 \left(\frac{\partial U_i}{\partial X_j} + \frac{\partial U_j}{\partial S_i} \right) \qquad (3)$$

and a dot over a variables means the convective time derivative

$$\frac{d}{dt} = \frac{\partial}{\partial t}\Big|_{all\ X_i} + U_j \frac{\partial}{\partial X_i}\Big|_{t2} \qquad (4)$$

Conservation of mass is automatically satisfied in the Lagrangian finite difference scheme because each cell moves with the material, and no material can enter or leave a cell.

2DL solves the flow equations in either cylindrical (r,z) or Cartesian coordinate geometry. Thus U_x and U_z are the particle velocity in the X (or R) direction and the particle velocity in the Z direction respectively.

The thermodynamic state of each cell is calculated, using the HOM equations of state [1,7], from the specific volume and specific internal energy of the cell. Separate equations of state are used for condensed (solid or liquid) and gaseous components. The condensed component equation of state is derived from experimental Hugoniot data [13]. The gaseous equation of state is based on the isentrope, passing through the C-J state of the detonation products, calculated by another program, BKW [10]. A partially burnt explosive cell will have both condensed and gaseous components, and an iterative method is used to find the state of each component.

Several models of the explosive burn process are available in 2DL, each being suitable for a different type of problem. The Forest Fire model [8], in which the burn rate of the explosive is a function of the pressure, can predict the shock build up to detonation transition in an explosive and is the most suitable one for this study. Other models do not allow detonation to be induced behind the barrier and hence cannot be used. The function relating pressure to the burn rate is calculated by a program called FFIRE [8] from the shock Hugoniot data for the solid explosive, BKW calculated data for the detonation products and experimental Pop-Plot data for the run-to-detonation.

The problem is input to the 2DL code as a number of rectangular packages, which can be subdivided into cells. Each package is of one material, and may have other packages or some special conditions as boundaries. All packages must combine to form a grid with each column having the same number of cells. Several packages may be made from one material, allowing more complex geometries.

Output from 2DL is a sequence of memory dumps at designated intervals. Separate post-processing programs are then used to generate printed or graphical output. The 2DL code also creates a progress file where it lists any internal errors encountered and a record for every completed dump file. This is useful for analysing the progress of a calculation which did not finish as expected. The code can be restarted at any stage from the memory dump.

APPENDIX C

EXPLOSIVE DATA FOR XTX-8003

Three sets of data are needed to describe an explosive to the 2DL code. The first set of data describes the solid, unreacted explosive, the second set describes the detonation products and the third set covers the transition from unreacted explosive to detonation products.

For XTX 8003, the data used are presented in Table C1.

TABLE C1. PUBLISHED DATA FOR XTX-8003, AS USED IN 2DL

Composition	80% PETN 20% SYLGARD 182 (silicone rubber)
Density	1.53 Mg m^{-3}
Detonation Parameters	P_{CJ} = 18.8 GPa D_{CJ} = 7.30 km s^{-1}
Shock Hugoniot Data [16]	Us = C + SUp Us - shock velocity Up - particle velocity C - sound speed - 1.49 km s^{-1} S - 3.30
Run-to detonation Data [16]	$\ln (X) = A_o + A_1 \ln (P)$ X - run to detonation (mm) P - pressure detonation (GPa) A_o = 3.957 A_1 = -2.16

BKW Equation of state for detonation products

$$\ln(P) = A_p + B_p \ln(V) + C_p \ln^2(V) + D_p \ln^3(V) + E_p \ln^4(V)$$

$$\ln(I + Z) = K_I \ln(P) + M_I \ln^2(P) + N_I \ln^3(P) + O_I \ln^4(P)$$

$$\ln(T) = Q_T + R_T \ln(V) + S_T \ln^2(V) + T_T \ln^3(V) + U_T \ln^4(V)$$

A_p = − 3.572	K_I = −1.526	Q_T = 7.606
B_p = − 2.442	L_I = 4.991 E −01	R_T = − 4.604 E −01
C_p = + 2.811 E −01	M_I = 8.359 E −02	S_T = 1.054 E −01
D_p = + 5.493 E −03	N_I = 7.538 E −03	T_T = − 4.797 E −03
E_p = − 7.390 E −03	O_I = 2.745 E −04	U_T = − 1.829 E −03
	Z = 0.1	

P is pressure in Mbar

I is internal energy Mbar cm^3 g^{-1}

T is temperature

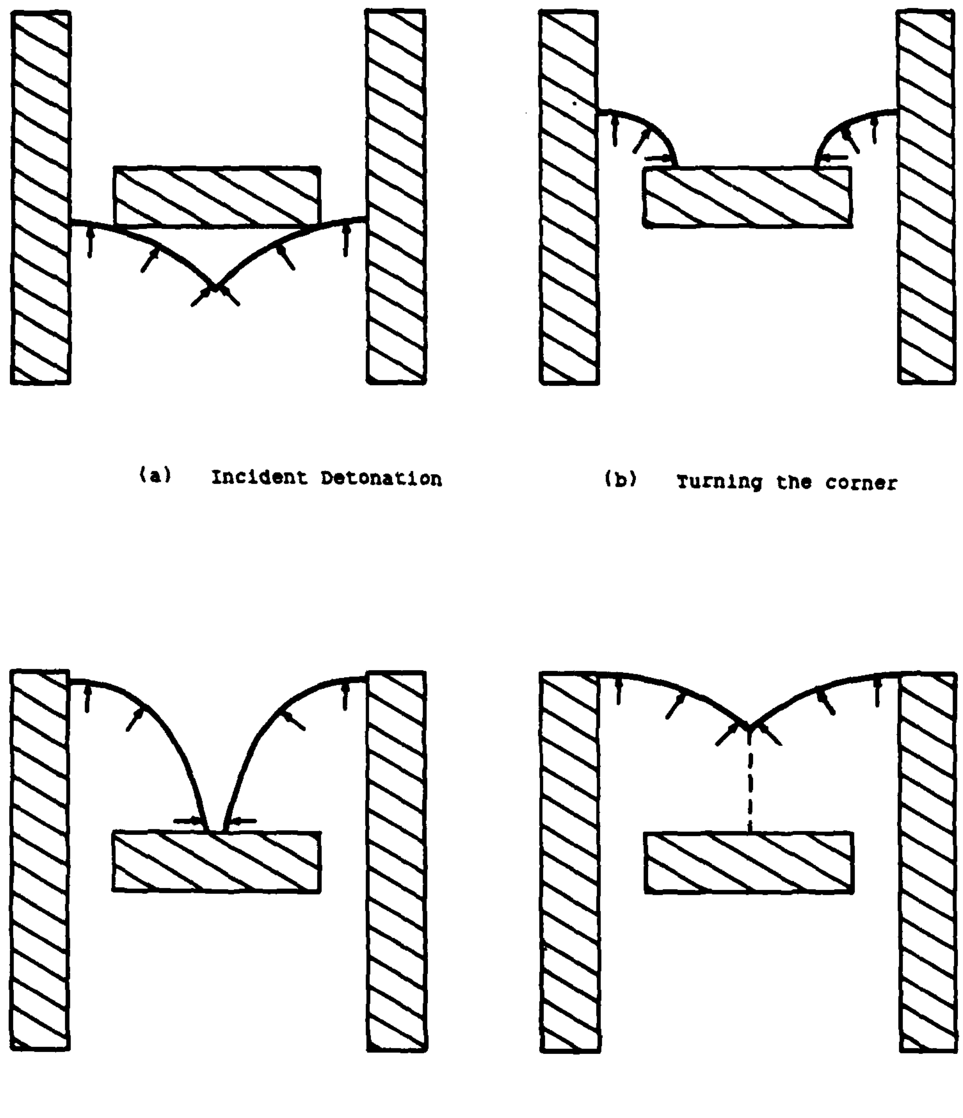
APPENDIX D

PUBLISHED DATA FOR NEOPRENE, AS USED IN 2DL

The neoprene used in Fracture Tape is an inert solid. It requires the same type of data as does the solid phase of the explosive. Shock Hugoniot data for the material is in ref [14], and other data was available in ref. [16]. The data used is shown in Table D1.

TABLE D1. PUBLISHED DATA FOR NEOPRENE, AS USED IN 2DL

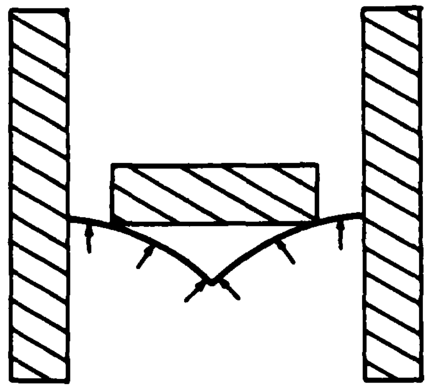
Density	$1.439\ \mathrm{Mg\ m^{-3}}$
Shock Hugoniot Data [13]	$C = 2.785\ \mathrm{km\ s^{-1}}$ $S = 1.419$
Gruneissen Coefficient	$\gamma = 1.39$
Specific Heat	$C_V = 1.63\ \mathrm{kJ\ kg^{-1}\ K^{-1}}$
Coefficient of linear thermal expansion	$\alpha = 2 \times 10^{-4}\ \mathrm{K^{-1}}$



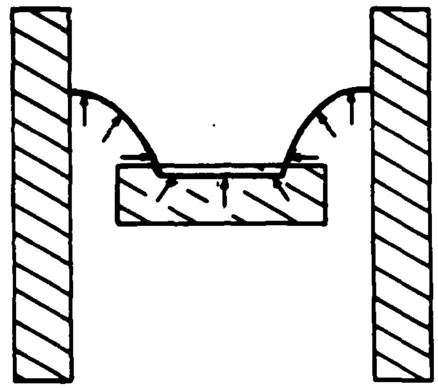
(a) Incident Detonation (b) Turning the corner

(c) Collision (d) Proceeding

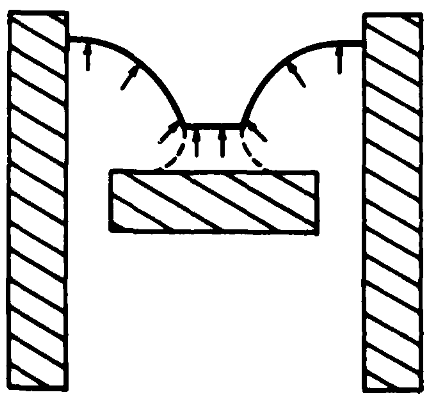
FIGURE 1 Ideal Propagation in Fracture Tape



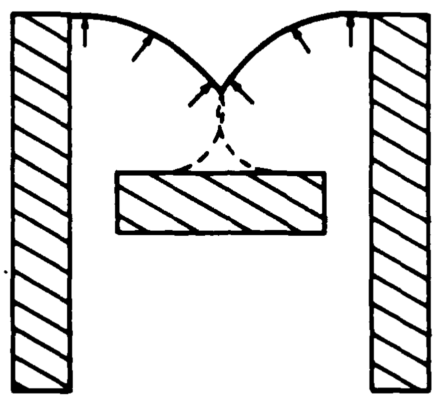
(a) Incident detonation



(b) Turning the corner and proceeding through the barrier



(c) Collisions



(d) Proceeding

FIGURE 2 Real Propagation in Fracture Tape

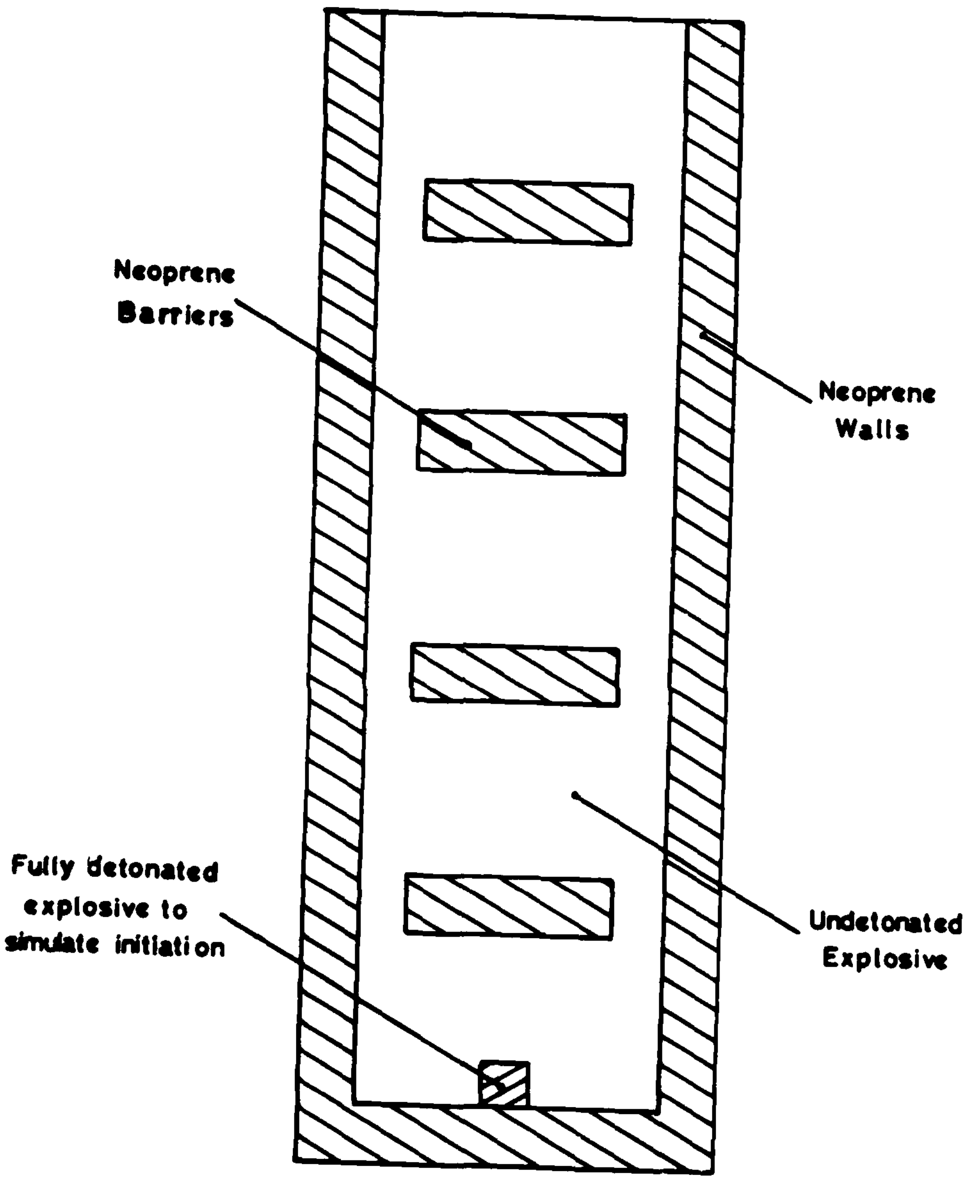

Neoprene
Barriers
Neoprene
Walls
Fully detonated
explosive to
simulate initiation
Undetonated
Explosive

FIGURE 3

CYCLE :100
TIME :.990

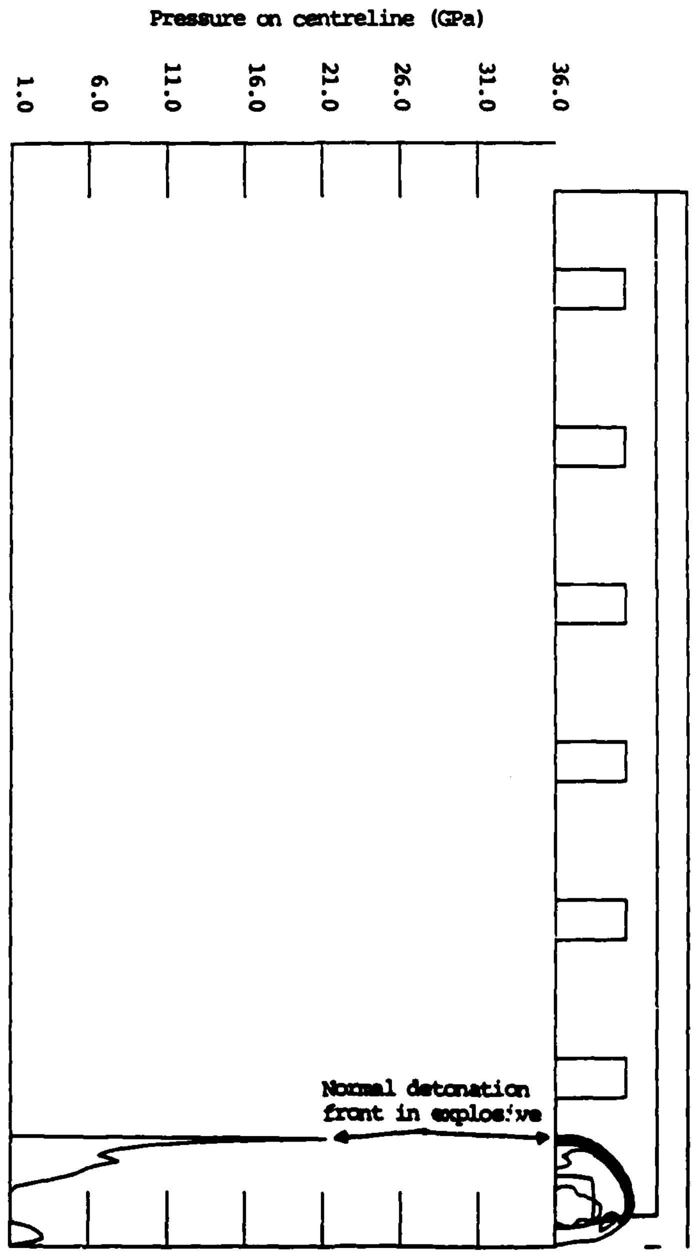


FIGURE 4

CYCLE :650
TIME :6.490

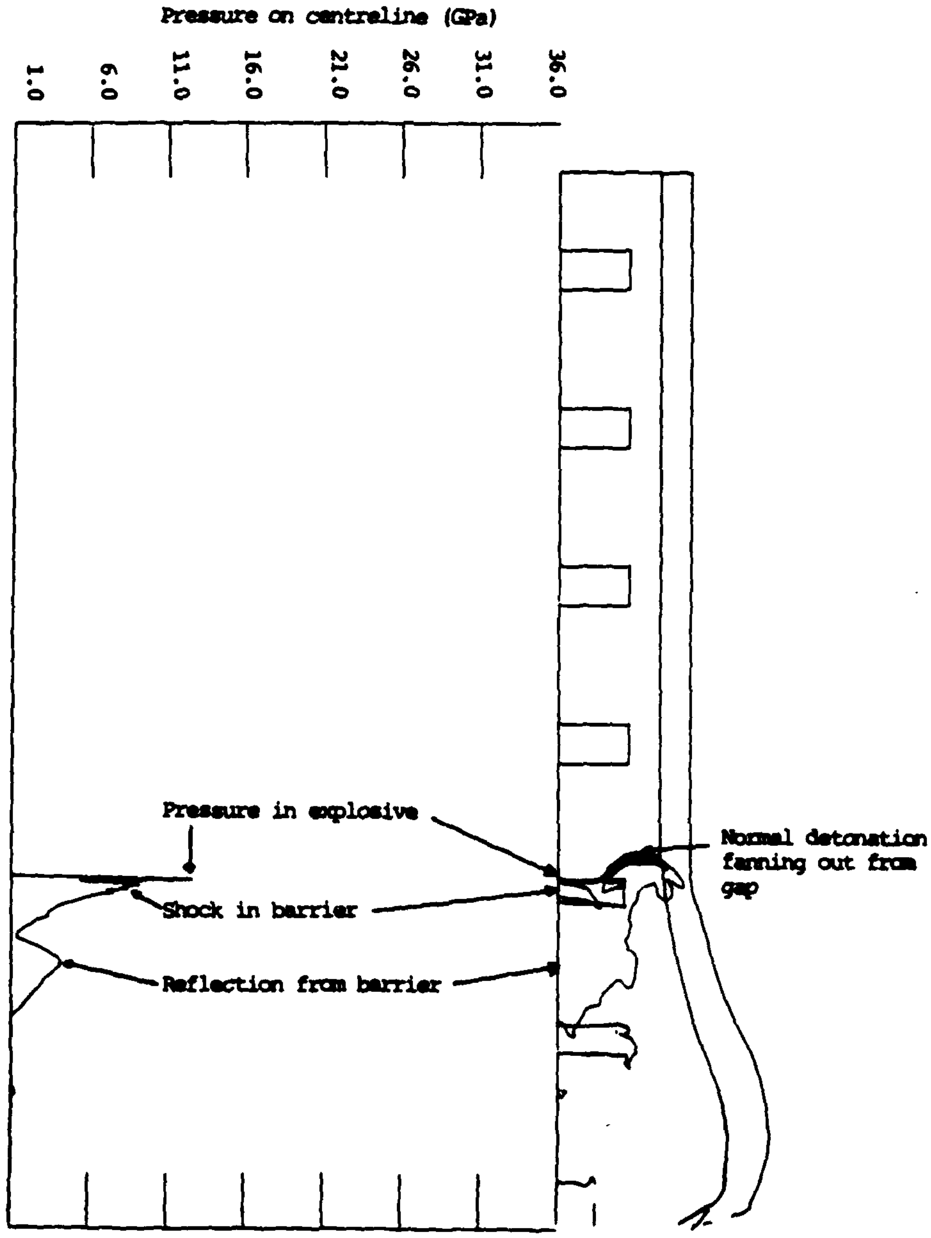


FIGURE 5

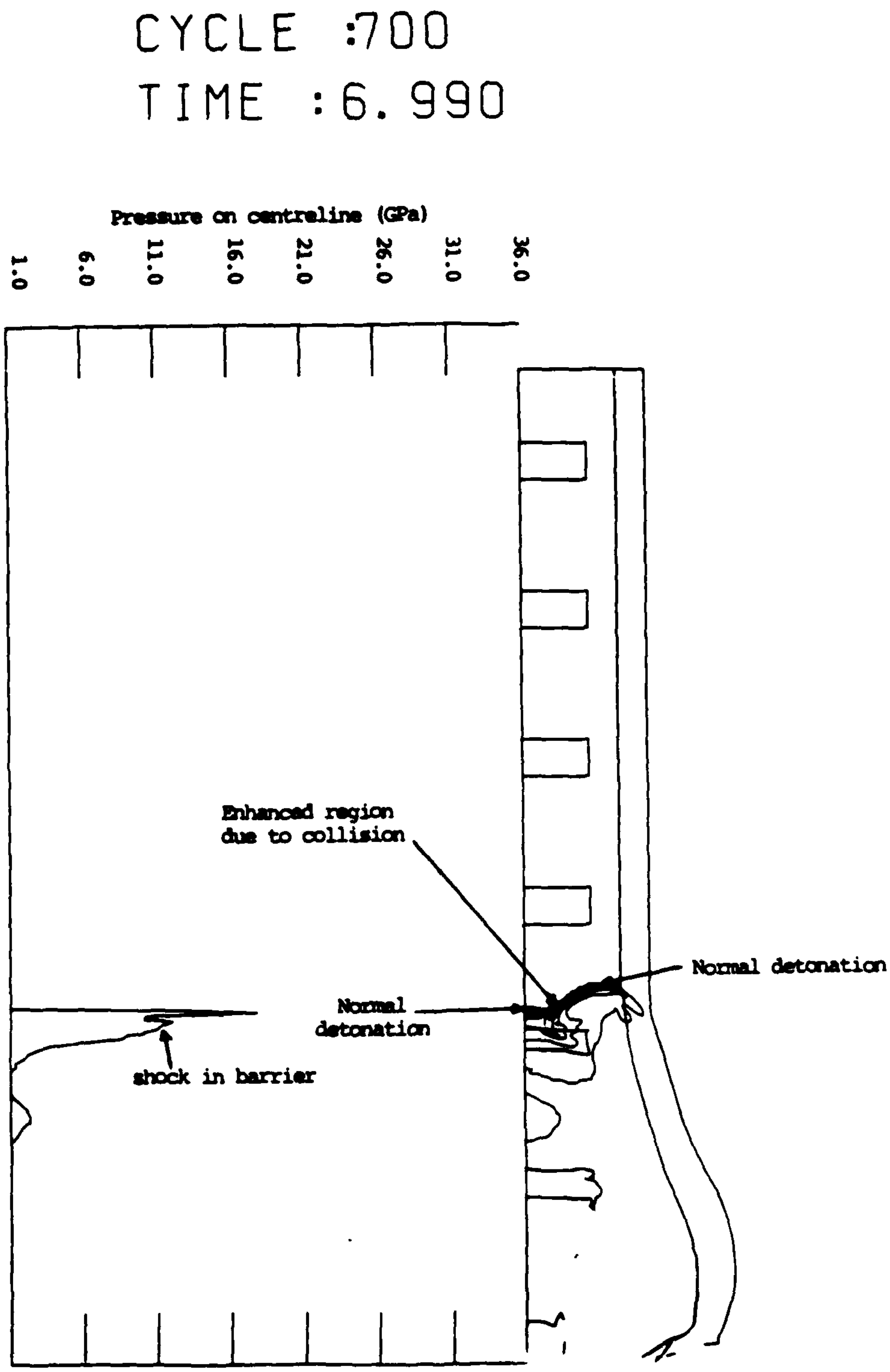

CYCLE :700
TIME :6.990
Pressure on centreline (GPa)
1.0
6.0
11.0
16.0
21.0
26.0
31.0
36.0
Enhanced region
due to collision
Normal detonation
Normal
detonation
shock in barrier

FIGURE 6

CYCLE :850

TIME :8.490

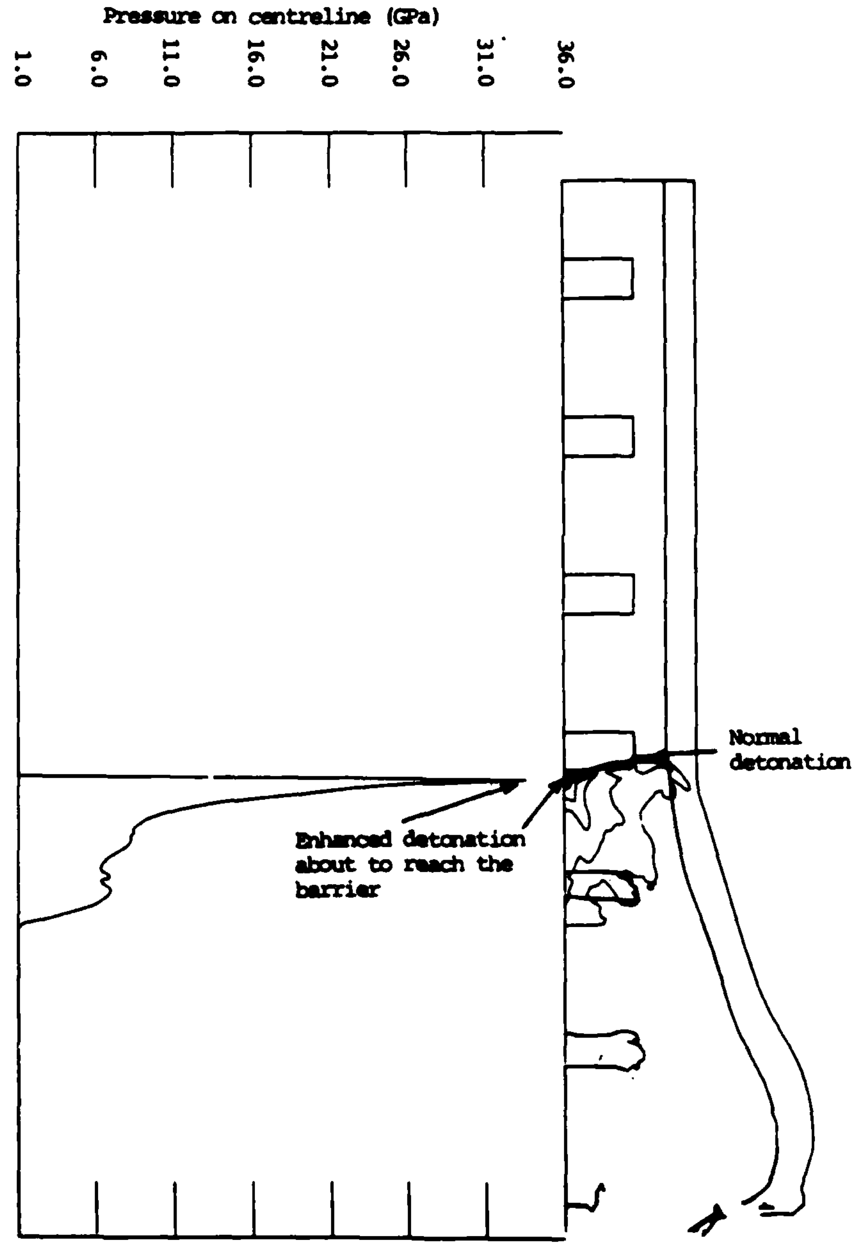


FIGURE 7

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KEYWORDS

Fracture tape	Wave shaping	Cutting charges
Shock waves	Hydrodynamic code	Detonation

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ABSTRACT

The presented paper describes the modelling of the detonation process in a section of Fracture Tape using the two-dimensional reactive Lagrangian Hydrodynamic code 2DL. The Forest Fire burn model of heterogeneous explosive shock initiation was used to model the explosive decomposition. The results show (i) the time dependent pressures (ii) detonation wave shaping and (iii) deformation of the tape.

Fracture tape is a channel-section neoprene moulding designed to be filled with plastic explosive. The moulding places barriers at regular intervals within the explosive which divide the detonation wave into two parts then focus both together to collide head on. Such a collision generates a narrow region of very high pressure, over 30 GPa in XTX-8003 compared with the normal detonation pressure of 19 GPa.

The calculations indicate that with the ladder geometry Fracture Tape, the detonation wave propagates around the barriers, as well as creating a shock wave which is transmitted through the barrier itself. The transmitted shock wave may detonate the explosive immediately behind the barrier before the propagated detonation reaches it, thereby reducing the pressure enhancement from the expected collision for some distance from the barrier.

The effects of changes in size or geometry can be modelled to assist in optimising tape performance.

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