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DREV SETBACK SIMULATOR: DESIGN AND PERFORMANCE

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by

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ABSTRACT

4D// A laboratory machine has been designed, fabricated and put into operation at DREV to simulate the collapsing of a base cavity as the filling of a shell is setback under the high axial acceleration of gun launch. The simulator design followed the recommendations made in a theoretical study by Pasman. Its overall construction is described, including a specimen mounting assembly developed to prevent all leakage of the composition under test.

Initial tests simulated a 105-mm shell with accelerations up to 25,000 times the normal acceleration of gravity, loaded with Composition A-3, cast TNT, Composition B and a castable plastic-bonded explosive, with air cavities of 2.5, 1.5 or 1.0 mm height. The explosive was ignited in each instance even though pressures never exceeded about one-third of that found necessary to achieve ignition of Composition B in Picatinny-type simulators. Some tests were also conducted using inert specimens for comparison purposes and to evaluate the simulator and its instrumentation. //

RÉSUMÉ

Un simulateur d'effet de recul de conception originale a été mis au point au CRDV. Sa conception repose sur les recommandations d'une étude théorique faite afin de reproduire, de façon réelle en laboratoire, la compression par effet de recul d'un espace d'air situé à la base d'un obus lors du lancement de ce dernier dans un canon. On présente une description détaillée du simulateur y compris celle du montage de l'échantillon conçu de façon à prévenir toute fuite d'air ou de la composition testée.

Les performances du simulateur du CRDV ont été évaluées à l'aide d'une série d'essais simulant des accélérations jusqu'à 25,000 g_n pour un obus de 105 mm. Ces premiers tests ont porté sur une composition inerte et sur des explosifs dont le TNT coulé, la Composition B, la Composition A-3 et un explosif coulable à liant plastique. Ces explosifs réagirent tous à la compression dite adiabatique d'espaces d'air, soit de 2.5, 1.5 ou 1.0 mm, et ce à des pressions de l'ordre du tiers de celle nécessaire pour initier une réaction de la Composition B sur un simulateur de type Picatinny.

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NOMENCLATURE

b	clear space between any two outer (or inner) rings
C	constants
OD	outside diameter (of outer ring of the ring spring)
ID	inside diameter (of inner ring of the ring spring)
g_n	free fall acceleration
R	radius of the piston
t	thickness of the piston head
x	calculated specimen pressure
y	recorded specimen pressure
Θ	taper angle of the conical surfaces
σ	standard deviation

Subscripts

o	outside
c	cylindrical portion

1.0 INTRODUCTION

Gun prematures have been studied in the U.S. by Schimmel (Ref. 1) who devised a laboratory machine to simulate the collapse of a shell-filling cavity as a result of setback forces while being fired from a gun. Similar machines with added refinements were also used later in the U.K. and Australia. In all these machines, a propellant-actuated force on a movable piston compressed an air gap adjacent to an explosive specimen. In these tests, the specimen was restrained at the opposite end by a fixed piston and both pistons and the specimen were enclosed in a tight-fitting robust cylindrical sleeve. The adequacy of this first generation of setback simulators was explored by Pasman (Ref. 2) in a theoretical study that compared them with the DREV simulator, which was then being designed.

Pasman's study examined the closure of the air gap in these early setback simulators and compared it with a highly idealized collapse of a shell-filling cavity wherein the filling fails because of shear at a cylindrical surface whose cross section is equal to that of the cavity. This sheared-off explosive column would be accelerated toward the rear of the shell by setback, in a manner which it is hoped would be simulated accurately by the movable metal piston of a laboratory machine. Pasman showed that the inertia of this accelerating piston will, at the moment when the cavity becomes quite small, cause the gas pressure in the collapsing cavity to greatly exceed the steady-state pressure associated with that acceleration. He also showed that the magnitude of this excess in a simulator will be comparable to that occurring in a shell only if the inertia of the piston is similar to that of the explosive column. That is, the moving piston of a simulator should have a mass per unit cross-sectional area equal to the mass of explosive per unit cross-sectional area of the shell.

Furthermore, Pasman's study examined the interval of this pressure surge above the steady-state value associated with a shell's momentary acceleration; that is, the interval of piston deceleration during which the cavity size changes little and the explosive itself is compressed. He assumed that the cavity is at or near the base of the shell and that there is no leakage of air from the cavity, either laterally along the shell wall or along the surface of the sheared-away column. The pressure release wave spreads from the cavity throughout the shell filling which is already precompressed by the shell's forward acceleration. Since precompression in a simulator is not readily accomplished, specimen length should be limited so that the rate of pressure release by explosive compression does not greatly exceed that of a shell. On the other hand the specimen must not be too short, otherwise its smaller compression would increase the pressure too much above that produced in a shell. A length of about 25 mm was considered to be a suitable compromise. (For a discussion of these points see Ref. 2, especially p. 61 and supplementary note 'e' on p. 65.)

Pasman's study found that a typical shell-filling cavity collapses in less than 0.25 ms, which is short compared with the total duration of substantial shell acceleration. This duration is defined somewhat arbitrarily as the time during which shell acceleration exceeds one-half of its peak value. During cavity collapse, the explosive column will be largely unsupported from the moment when shearing failure of the explosive occurs. Thus it will accelerate toward the base of the shell with only the shell's forward acceleration, which is considered to be constant because of the shortness of this time interval. Subsequently, cavity pressure will be maintained at a high level for several milliseconds while the shell continues to go through substantial forward acceleration. Therefore a simulator should feature a movable piston to which a force is applied suddenly and then maintained for an appropriate duration. Pasman concluded that a force with an adequately short rise time could be produced by our proposed crushing of metallic honeycomb under a moving hammer.

Pasman found that the critical interval for possible ignition does not exceed 0.5 ms and usually is considerably shorter. On p. 58 of Ref. 2 we find: "The critical moment for possible ignition is just after pressure and cavity height start to level off, at which time the gas temperature passes a peak value and the heat flux is maximum", and then on p.61: "Our calculations show that equilibrium pressure is much less important than velocity of the piston; rapidity of heat generation is crucial in attaining high temperatures at the explosive surface". From these considerations, Pasman concluded that our proposed use of metallic honeycomb for applying a constant force on the piston would adequately simulate setback conditions, the crushing strength of honeycomb being constant for most of its initial height.

Pasman drew attention to the need for the hammer velocity to exceed the velocity that would be acquired by a free falling explosive column during projectile acceleration. It was proposed that adequate hammer velocities could be conveniently obtained by the use of a compressed air gun.

During the final design stages of the setback simulator and while it was being fabricated, experiments were conducted on an interim machine (Ref. 3). This was mainly to complete the design of the specimen mounting, including polyethylene seals, and to check a measurements system which would be an integral part of the simulator.

Finally, the DREV setback simulator was put into operation and tested on inert and explosive specimens which simulated the launching of shells up to 25,000 g_n. These initial results are described here.

The work was performed at DREV between 1974 and 1980 under PCN 21A06 Detonation Processes, formerly Project No. 10-28-48 Explosives Research Engineering.

2.0 DREV SETBACK SIMULATOR: DESIGN AND OPERATION

The DREV setback simulator was designed to realistically reproduce, in a laboratory, the launching conditions in guns. It was designed at DREV and manufactured in the Establishment's machine shop.

The DREV simulator consists of an air gun that drives a hammer vertically downward, so that a piece of metallic honeycomb mounted on its underside strikes a movable piston. The motion of this piston collapses an air gap above a closely confined explosive specimen. The downward motion of the hammer is arrested by a ring spring before the honeycomb is compressed to a point where its compressive strength exceeds the desired steady-state value. The working parts of the simulator are shown schematically in Fig. 1.

The movable piston, hereafter simply called the piston, has an enlarged end face upon which the honeycomb impacts. This piston fits snugly into a heavy confinement cylinder whose lower end is closed by a fixed piston, hereafter called the anvil, on which the explosive specimen rests. These components, along with sealing discs described in the following subsection, are referred to as the specimen mounting.

An overall view of the simulator is presented in Fig. 2. The main framework consists of two square steel plates held apart by four pillars, one at each corner, to provide a working space for accommodating the mounted explosive specimen. The lower plate rests on a massive pedestal which in turn rests on a heavy steel plate located in a floor well. This plate is supported by four caissons (not shown). The hammer, with its honeycomb affixed, passes freely through an oversize hole in the uppermost plate to impact the piston.

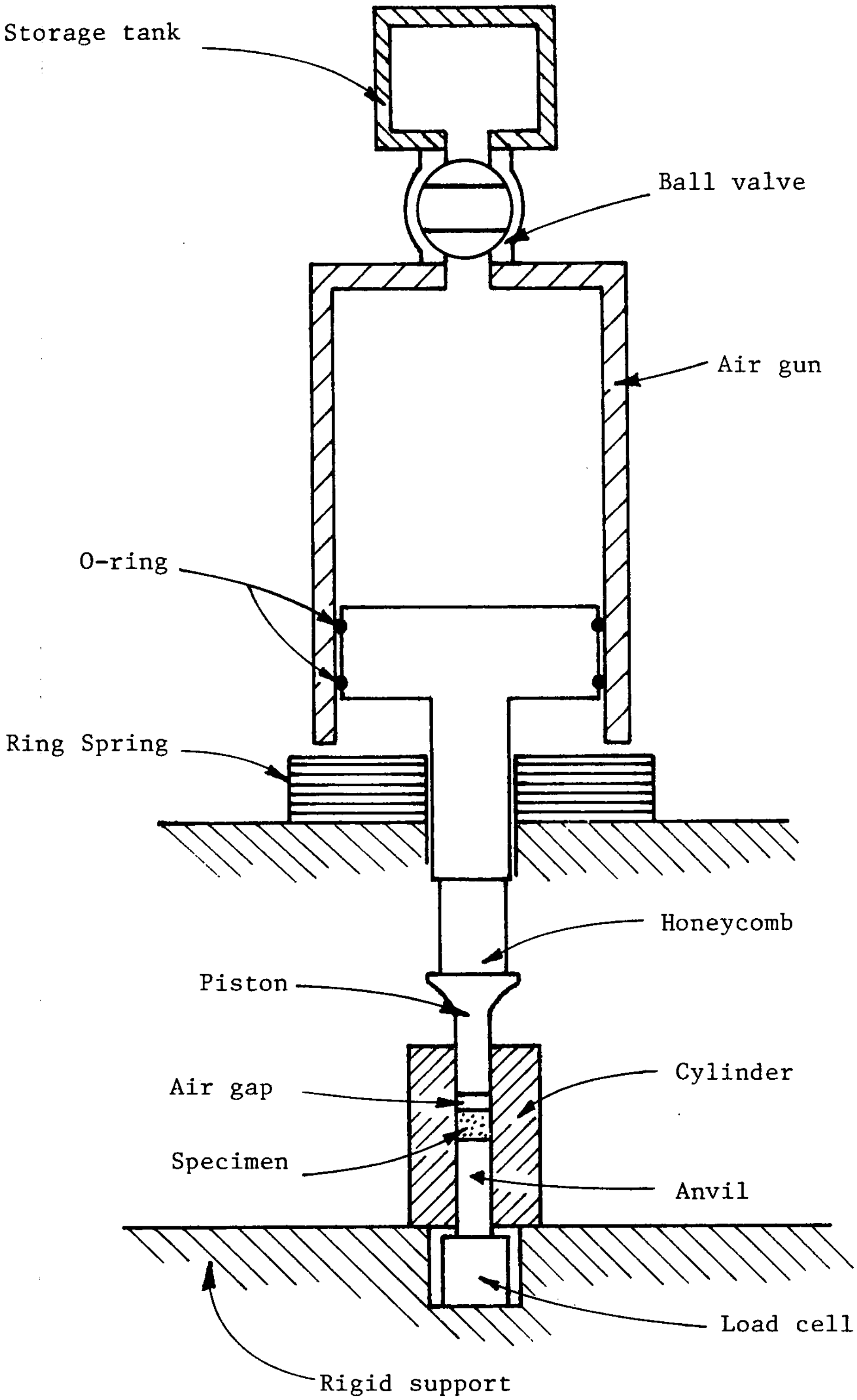

FIGURE 1 - Schema of the DREV setback simulator

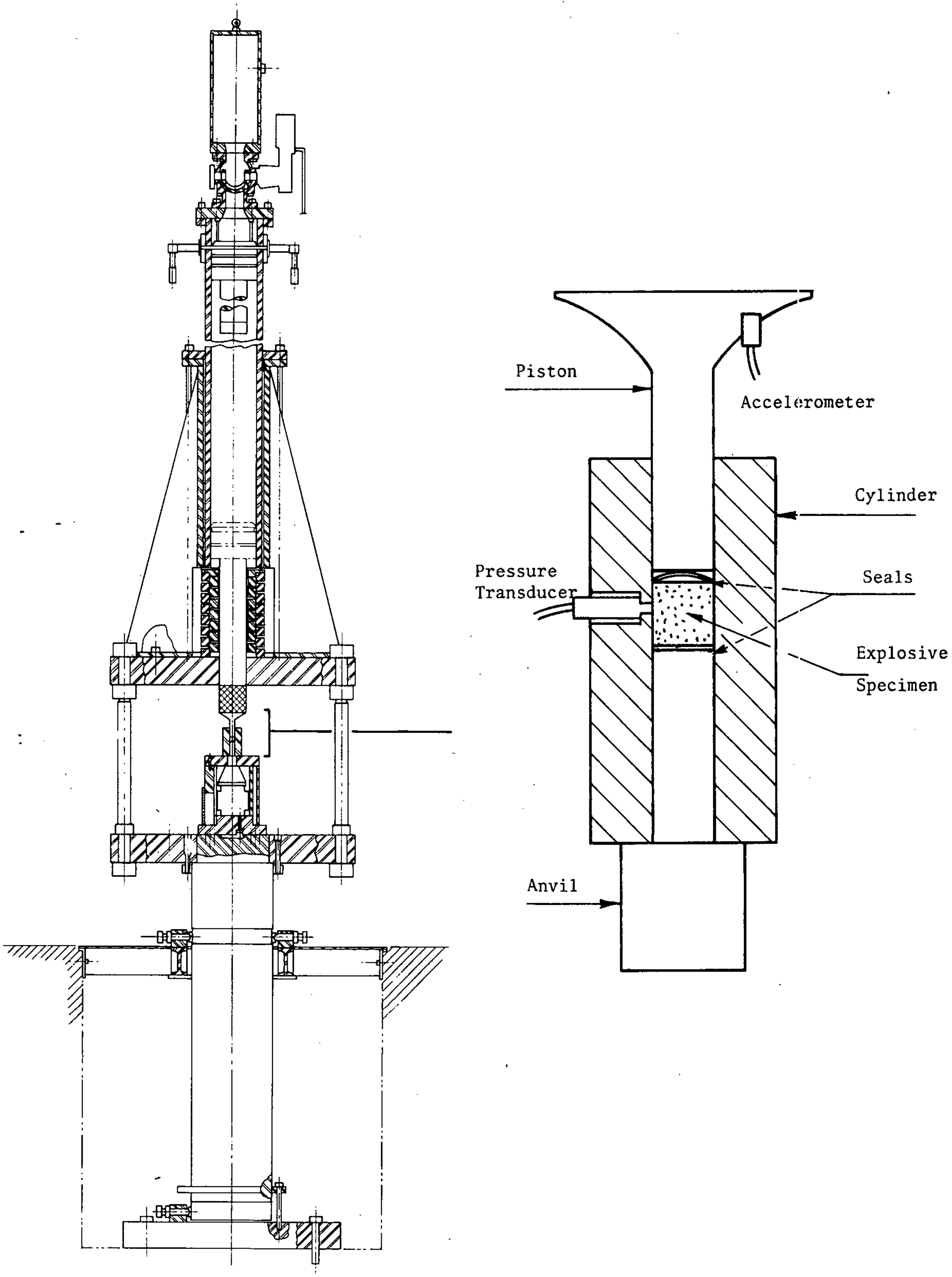

FIGURE 2 - The DREV setback simulator with an enlarged view of the specimen mounting

The simulator is equipped with instruments to monitor the hammer velocity, piston acceleration, explosive pressure and anvil loading. Each can be recorded and reproduced on graphs for convenience in analyzing each test result.

2.1 Specimen Mounting

The piston, whose enlarged uppermost end is impacted by the honeycomb, is machined on a lathe from 7075-T6 aluminum hot-rolled rod stock. Steel would have been unsuitable as its greater density would have produced a piston whose mass per unit cross-sectional area was too large, unless the piston diameter was inconveniently small. The actual mass of the aluminum piston is 424 g to simulate a Comp B filling of 1.675 Mg/m^3 density and 0.5 m height. The piston nominal diameter was fixed at 25.4 mm. This is a compromise between a larger diameter, which would have led to an excessive mass per unit cross-sectional area, and a smaller diameter with insufficient resistance to buckling under impact loading.

The surface finish of the cylindrical surface is 0.4 μm. The length-to-diameter ratio of the sliding surface is held at approximately 2.

The enlarged head of the piston must exceed that of the honeycomb and be sufficiently robust that it does not deform during the test interval. The design shown in Fig. 3 was found to be satisfactory, where the contour shown has the form of the parabola

$$t = C_1R^2 + C_2R + C_3 \qquad [1]$$

where

$t_c = 31.75$ mm at $R = R_c = 12.70$ mm,
$t_o = 1.58$ mm at $R = R_o = 50.80$ mm,
$C_1 = 2.065 \cdot 10^{-2}$
$C_2 = -2.103$, and
$C_3 = 55.122$.

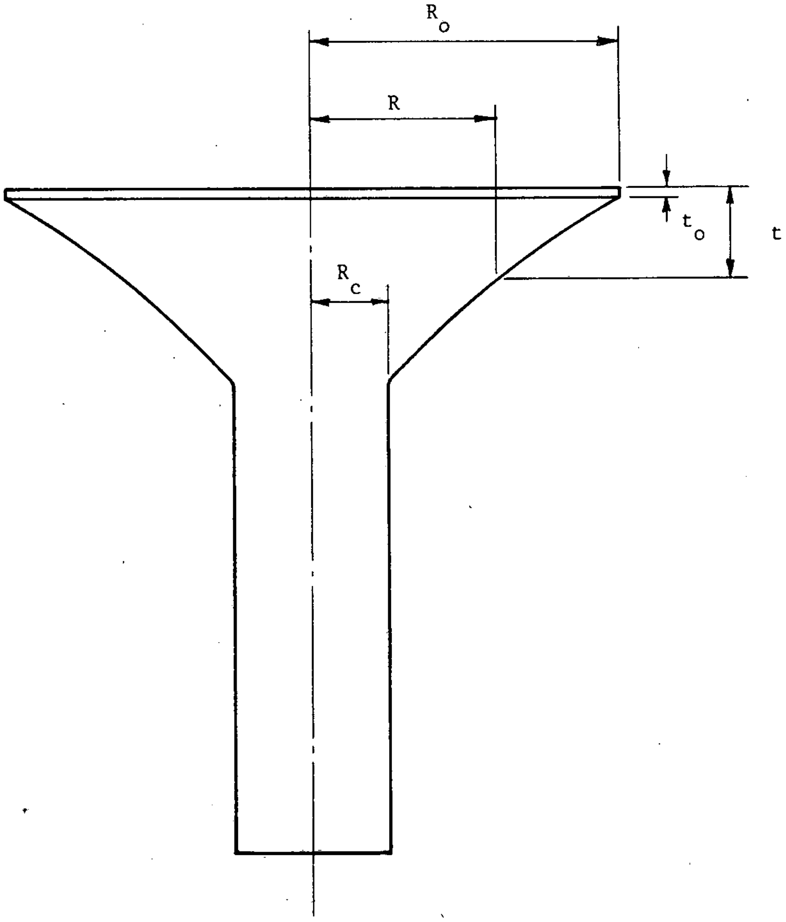

FIGURE 3 - A piston for the specimen mounting

Close tolerances are maintained inside the heavy confinement cylinder. Its bore is 25.40 + 0.013 mm, while both piston and anvil have a diameter of 25.39 - 0.018 mm. The explosive specimen is machined to a diameter of 25.38 + 0.015 mm. The inside surface of the cylinder is honed to a surface finish of 0.4 µm.

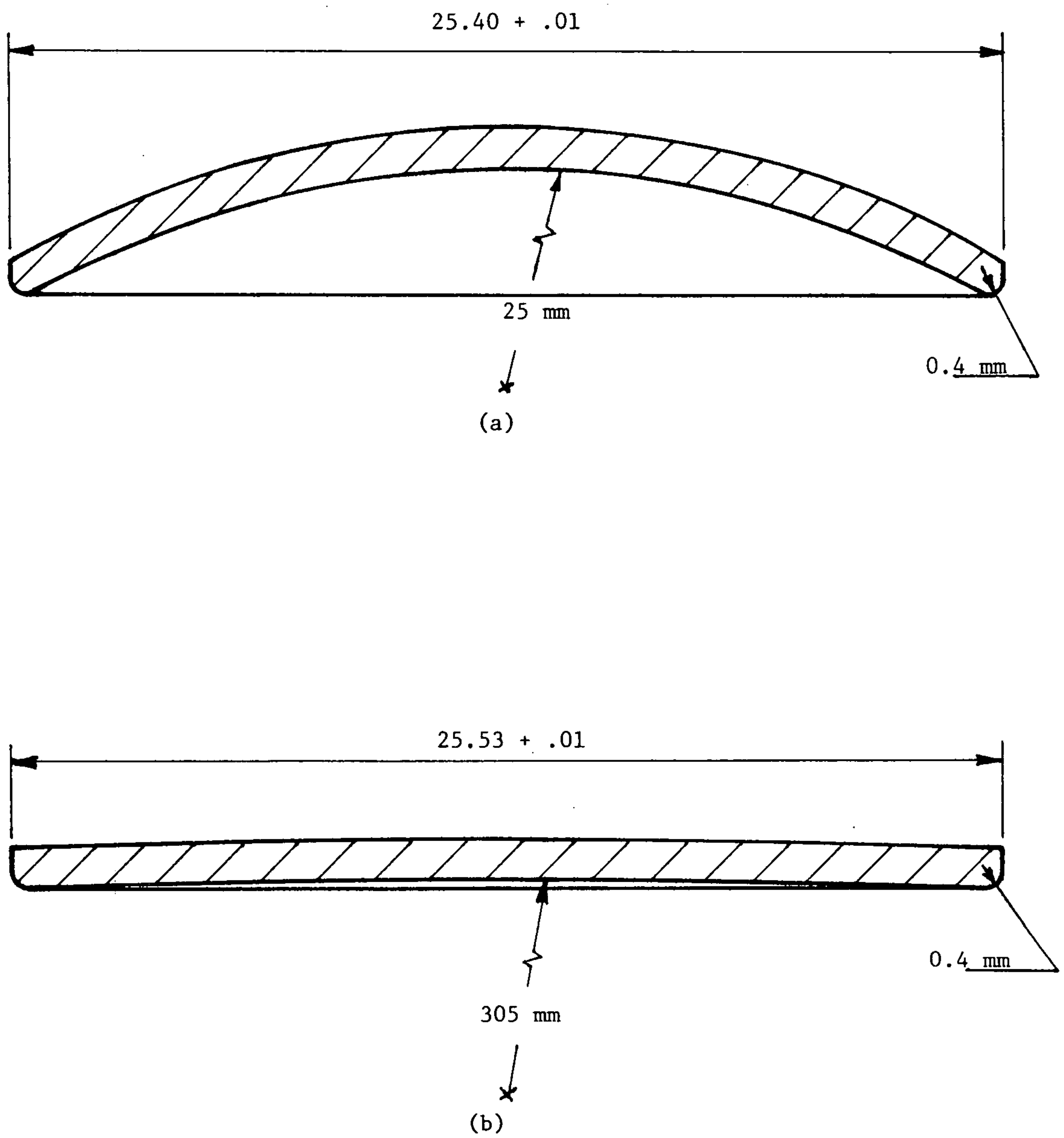

FIGURE 4 - Polyethylene seals for the specimen mounting: (a) for a 2.5-mm air gap and (b) for the zero air gap and lower seal

Seals of polyethylene were designed for use at both the top and bottom of the explosive specimen, as it was found that some air leakage would otherwise occur and oftentimes explosive would also be extruded into the clearance gap around the piston. These seals are 1 mm thick and are produced by injection molding. The upper seal, which is in contact with the piston, has a spherical shape, with models of different radii each designed to assure the desired air gap adjacent to the explosive. A typical radius of 25 mm gives an air gap of 2.5 mm, reproducible to about ± 2 percent. The lower seal is nearly flat (actually it has a radius of 30 cm which gives an air gap adjacent to the explosive of 0.08 mm). Upper and lower seals are shown in Fig. 4.

It should be noted that the design of these seals changes the conditions envisaged by Pasman, who assumed that the air gap would have the form of a cylinder. With our cavity of a somewhat different shape, it is to be expected that absolute values of the explosive surface temperature would differ somewhat from those computed by Pasman.

2.2 Honeycomb

Pieces of honeycomb are cut in the shape of a cylinder with a serrated circle cutter from flat stock panels obtained from Hexcel Corporation, Casa Grande, Arizona. Only one design of panel has been used in the present work. It is a corrugated type with a panel thickness of 133 mm, manufactured from aluminum alloy 5052 sheet of thickness 0.08 mm to a comb size of 3.2 mm. Its dynamic crushing strength is nominally 15 MPa.

Cut pieces with a diameter of 98 mm performed adequately when the piece was fitted with a narrow band of thin plastic in the form of a sleeve to prevent outward deformation by buckling of individual combs. Normally such a sleeve was unnecessary as this function was performed by the plastic sleeve which holds the honeycomb centered on and in contact with the face of the hammer. Pieces were also cut with

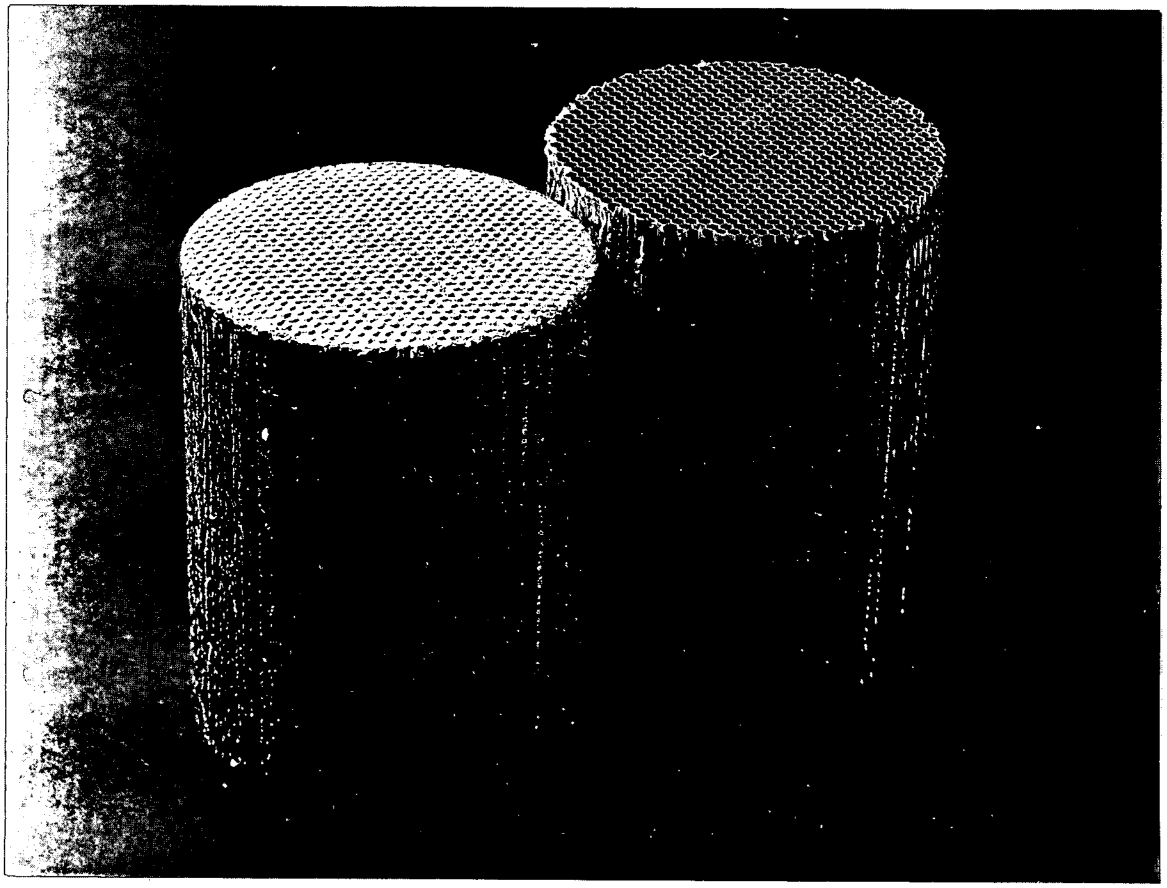

FIGURE 5 - Two pieces of honeycomb: left foreground, precrushed in the usual manner; at right, as cut from stock plate

a smaller diameter for simulating a lower projectile acceleration, but those with diameters too small failed by massive buckling. It was found feasible to reduce considerably the cross-sectional area of the honeycomb by cutting pieces in the shape of an annulus.

Each piece of cut honeycomb is statically compressed to crush one end to about 3 mm before using it on the simulator (Fig. 5). This precrushing eliminates the well-known sharp excess or spike in the crushing force just at the start of the crushing interval.

2.3 Air Gun

The smooth-bore air gun, mounted at the top of the simulator to shoot vertically downward, accelerates its 'shot' when a fast-opening valve allows compressed air to pass from a storage tank into the breech of the gun. The shot is actually the simulator's hammer in the shape of a piston which is fitted into the bore of 266.7 mm diameter and made gas tight by two O-rings of Viton lubricated with a high-vacuum silicone grease by Dow Corning. The bottom of the hammer has a long protrusion, to which the honeycomb is attached, that passes freely through the upper plate of the main frame. The main body of the hammer is shaped for impacting the ring spring. The hammer weighs 75 kg and its total stroke is about 2.5 m.

The breech of the air gun is connected to a storage tank only by a gas-tight valve which features the rapid opening of a modified V-port ball valve of size 101.6 mm. (The valve and its actuator were originally supplied by De Zurick Co., Minnesota.) The volume of the breech when the hammer occupies its uppermost position, including that of the valve in the open position, is 0.042 m^3. The tank volume is 0.035 m^3 where an operating pressure of 1.5 MPa gives a 75-kg hammer a velocity of about 35 m/s.

In an operational cycle the hammer is lifted to its starting position in less than 45 s by a vacuum pump, Ingersol-Rand model V23A, with 1.5 m^3/s capacity at atmospheric pressure. As the hammer approaches the top, its conical leading edge displaces radially outward a set of four spring-loaded pins. These pins then reverse direction as the hammer is lifted further, moving inward to engage a groove around the hammer. This groove has a conical upper face so that the pins will later be pushed outward as the compressed air pushes the hammer downward, and a flat lower edge to avoid any further upward motion of the hammer. By means of these pins, referred to as locating pins, the volume of the gun breech is controlled precisely. Each locating pin can be secured in its innermost position by a pneumatically operated safety pin. Each safety pin can only be removed by air pressure in a double acting cylinder, thereby ensuring safety for the operator of the machine.

2.4 Ring Spring

The moving hammer is stopped at the end of each simulator test by the use of a ring spring to avoid crushing the honeycomb beyond the point of constant crushing strength. In this way, the test is not invalidated and the specimen mounting can be preserved for further examination. The ring spring, illustrated in Fig. 6, consists of a stack of separate rings. Each of these rings makes contact with its immediate neighbor only at a conical interface along which sliding occurs when an axial load is applied. Energy is absorbed as alternate rings are subjected to tension and compressive loads. Also, energy is dissipated by friction during both the compression and subsequent expansion of the ring spring to the extent that the rebound of the hammer is virtually zero. This high energy dissipation, along with its inherent high energy absorption for a given available space, make the ring spring highly suitable for this function since crushing honeycomb uses only a small fraction of the total kinetic energy of the hammer.

The ring spring was designed so that it would stop the hammer in a relatively short distance, within the maximum design loading of the main frame and with no sticking of a ring to each another. The general procedures described in Ref. 4 were followed. It was machined from steel AISI 01 alloy with a taper angle of 0.349 rad. Its OD is 403 mm, its ID is 152 mm and its overall height is 460 mm. There are 17 rings, each 50.8 mm high. The maximum travel between two outer (or two inner) rings is 3.18 mm. Each outer ring has a cross-sectional area 20% greater than that of each inner ring. The ring spring stops a 75-kg hammer moving at 35 m/s in a distance of about 20 mm.

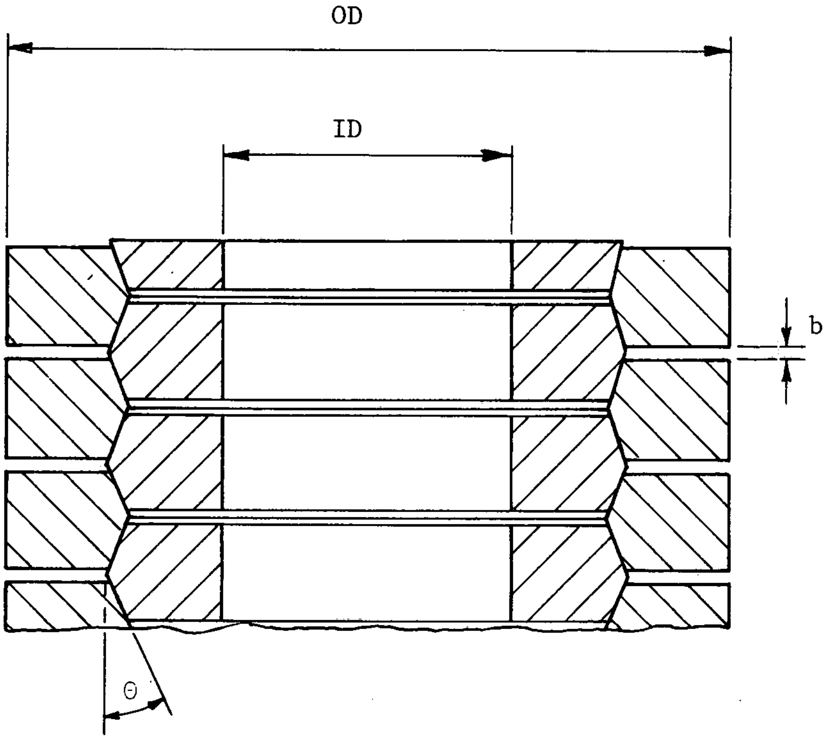

FIGURE 6 - Section of a typical ring spring

2.5 Main Framework and Foundation

The main structural members and their supporting foundation were designed to resist a load at the specimen mounting and/or at the ring spring of 200 Mg dynamically applied force. The actual loading by the ring spring exceeds this value somewhat but, since the load rises gradually to its peak value, it is understandable that the structure has shown no dimensional change.

The working frame consists of two steel plates, each 138 x 138 x 15 cm, which are held 84 cm apart by four 7.6-cm pillars, one at each corner. The upper plate supports the gun and the ring spring. This frame and the specimen mounting rest directly on a steel pedestal, 46 cm in diameter, 213 cm in length, which in turn rests on a 122 x 122 x 15 cm steel plate supported by four concrete-filled steel caissons. The bottom end of the pedestal has a spherical end face of 40 m radius. This facilitates leveling the machine by means of two sets of screws which engage the pedestal at floor level and at the level of the foundation plate.

2.6 Instrumentation

The setback simulator is equipped with sensors to detect and measure several features of each test experiment in order to ascertain the projectile acceleration being simulated and to monitor conditions at the explosive specimen. The hammer velocity, the crushing force of the honeycomb, the piston acceleration and the pressure at the explosive can be recorded.

The velocity of the hammer is monitored for each test by measuring the time interval between the interruption of two transverse laser beams by the hammer immediately prior to crushing the honeycomb. The photocell's signals are timed by Hewlett-Packard model 5328A counters. Hammer velocity is preselected by setting the initial pressure in the air tank of the gun. This pressure is measured by a Wallace and Tierman series 1500 absolute pressure gauge.

The force delivered to the explosive specimen during a test is monitored continuously by a load cell mounted between the anvil and the rigid support, as illustrated in Fig. 1. It should be noted that any friction between the piston and the heavy confinement cylinder will not contribute to the recorded value, as this cylinder bears directly on the rigid support. The load cell registers only the force applied to the specimen and includes the reaction peak, if there is any. The load cell used is a Lebow model 3156-101 with dual bridge.

The pressure applied to the specimen is monitored directly by a pressure transducer fitted into a lateral bleed hole in the cylinder. This transducer is used when a low-level reaction or none at all is expected. The pressure transducer is a Kistler model 607-C4.

An accelerometer monitors the motion of the piston to which it is attached when the level of reaction is expected to be low or zero. The accelerometer used is a Kistler model 805A.

The signals from the load cell, the pressure transducer and the accelerometer are all recorded by Biomation model 805 transient waveform recorders whose signals are reproduced on paper by a Y-T recorder. The experimental values were obtained by visually fitting a horizontal line onto each recorded trace.

3.0 EXPERIMENTAL TESTS

In order to evaluate the performance of the simulator and its instrumentation and to provide a suitable basis for the comparison of later results from explosive specimens, a series of 14 tests was carried out on inert specimens. In these tests the air gap was set at 2.5 mm and the honeycomb was designed to give the 424-g piston an acceleration of 25,000 g_n while simulating that of a shell. The inert specimens were machined from cured castings of ammonium chloride in a binder based on polybutadiene in the weight proportions of 84/16.

Tests on explosives were also conducted using specimens of Composition A-3 pressed to 1.59 Mg/m^3 and specimens machined from castings of TNT, Composition B and CX-84A. CX-84A is a castable plastic-bonded explosive consisting of RDX in a binder based on polybutadiene in the weight proportions of 84/16. Each was tested with an air gap of 2.5, 1.5 or 1.0 mm, and also with no gap using identical top and bottom seals.

4.0 RESULTS AND DISCUSSION

4.1 Inert Specimens

Arbitrarily chosen instrumentation recordings from one test are reproduced here as Figs. 7 to 9. These show the force on the load cell, the specimen pressure, and the piston acceleration respectively. Each is superimposed on a calibration curve to establish its measurement scale. Each recorded trace has superimposed signals, some of which have yet to be identified.

The load cell record (Fig. 7) shows a constant force of 116 kN during the initial interval of 3.5 ms, whereupon it falls off gradually. The violent oscillations near the end of the record are attributed to shock impact upon and within the ring spring.

The specimen pressure record (Fig. 8) shows a constant force of 250 MPa during the initial interval of 3.2 ms, after which it falls off gradually. The initial rise time of this pressure appears to be about 0.1 ms.

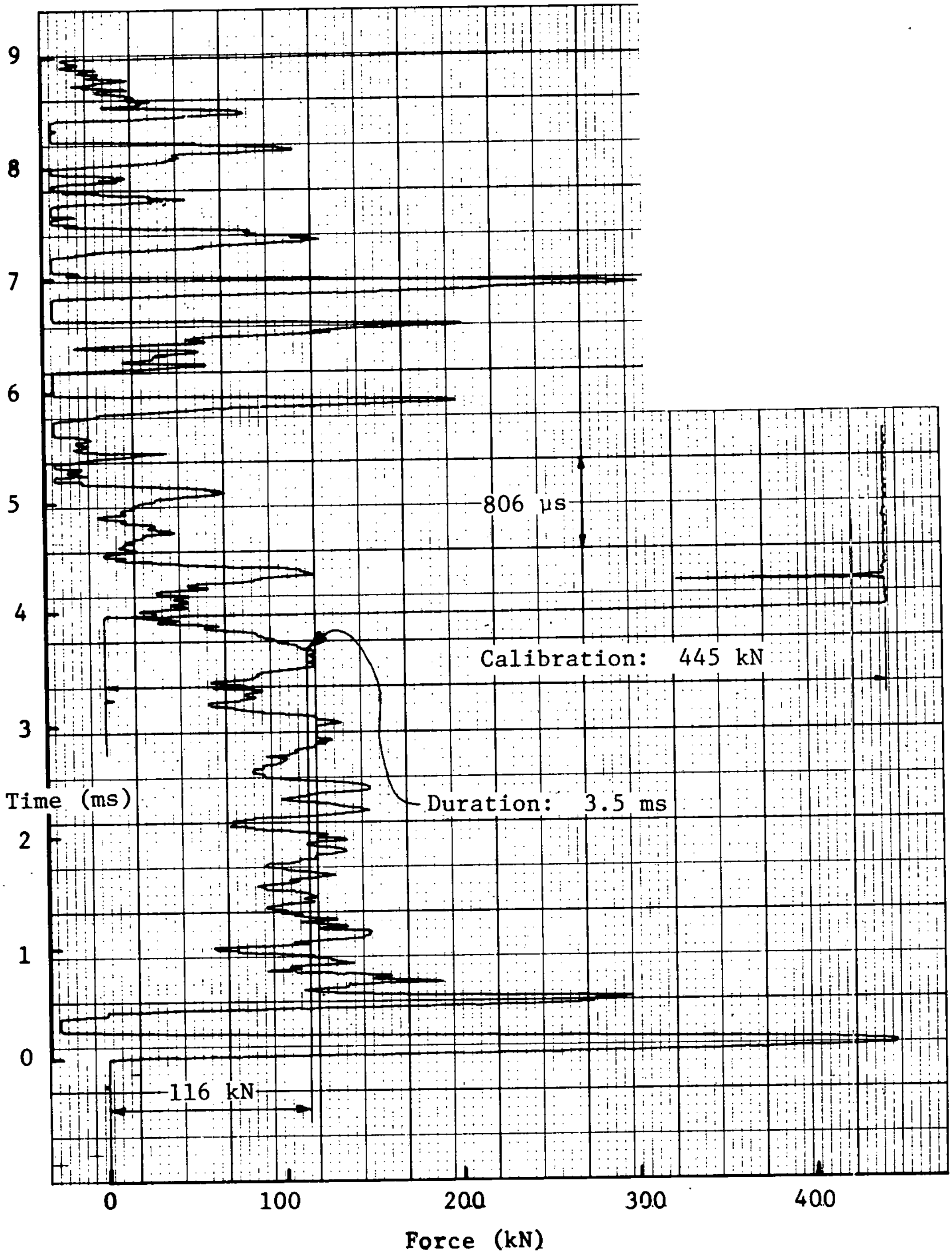

FIGURE 7 - Typical load versus time recording for inert specimen, 2.5-mm air gap and 25,000 g_n acceleration

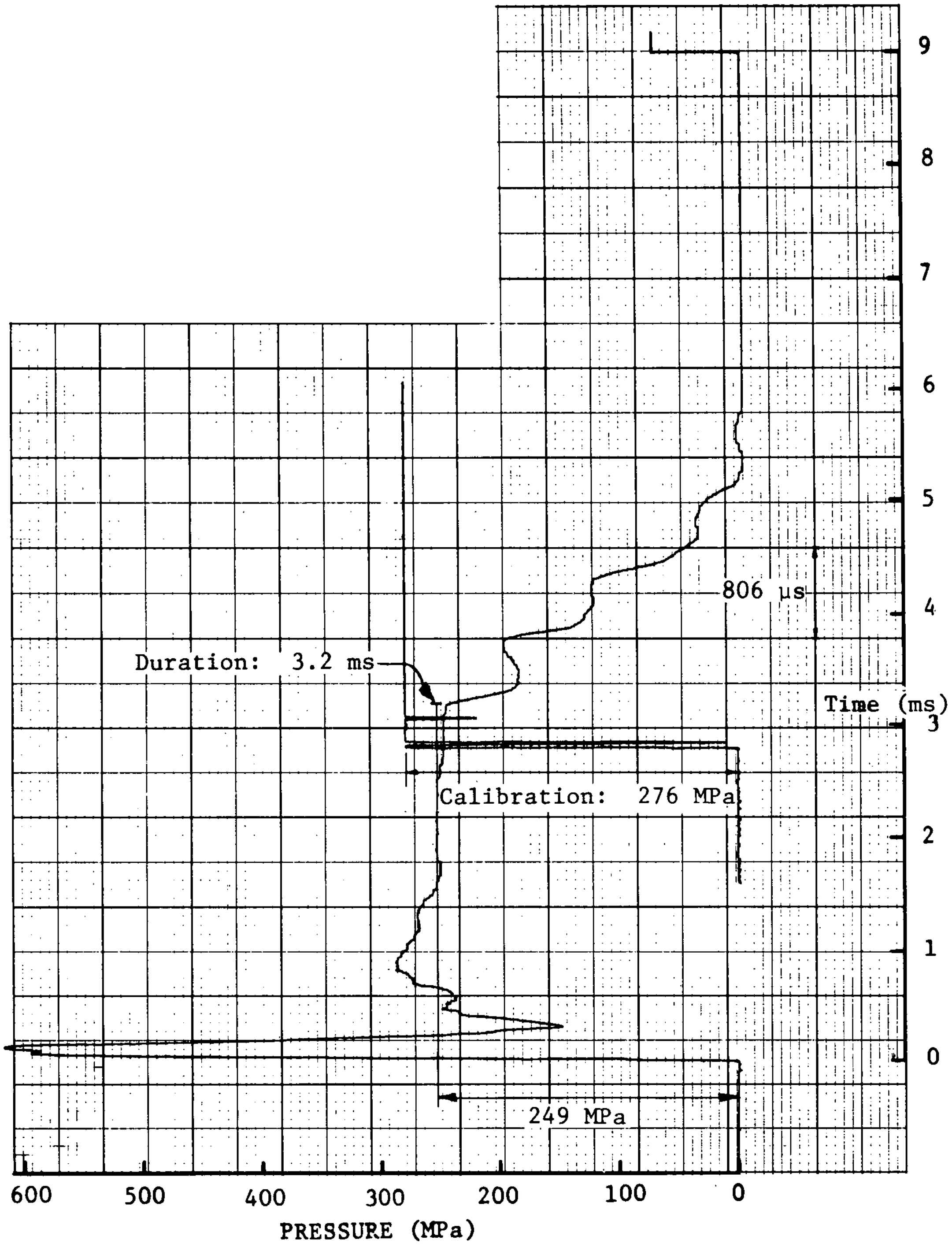

FIGURE 8 - Typical specimen pressure versus time recording for inert specimen, 2.5-mm air gap and 25,000 g_n acceleration

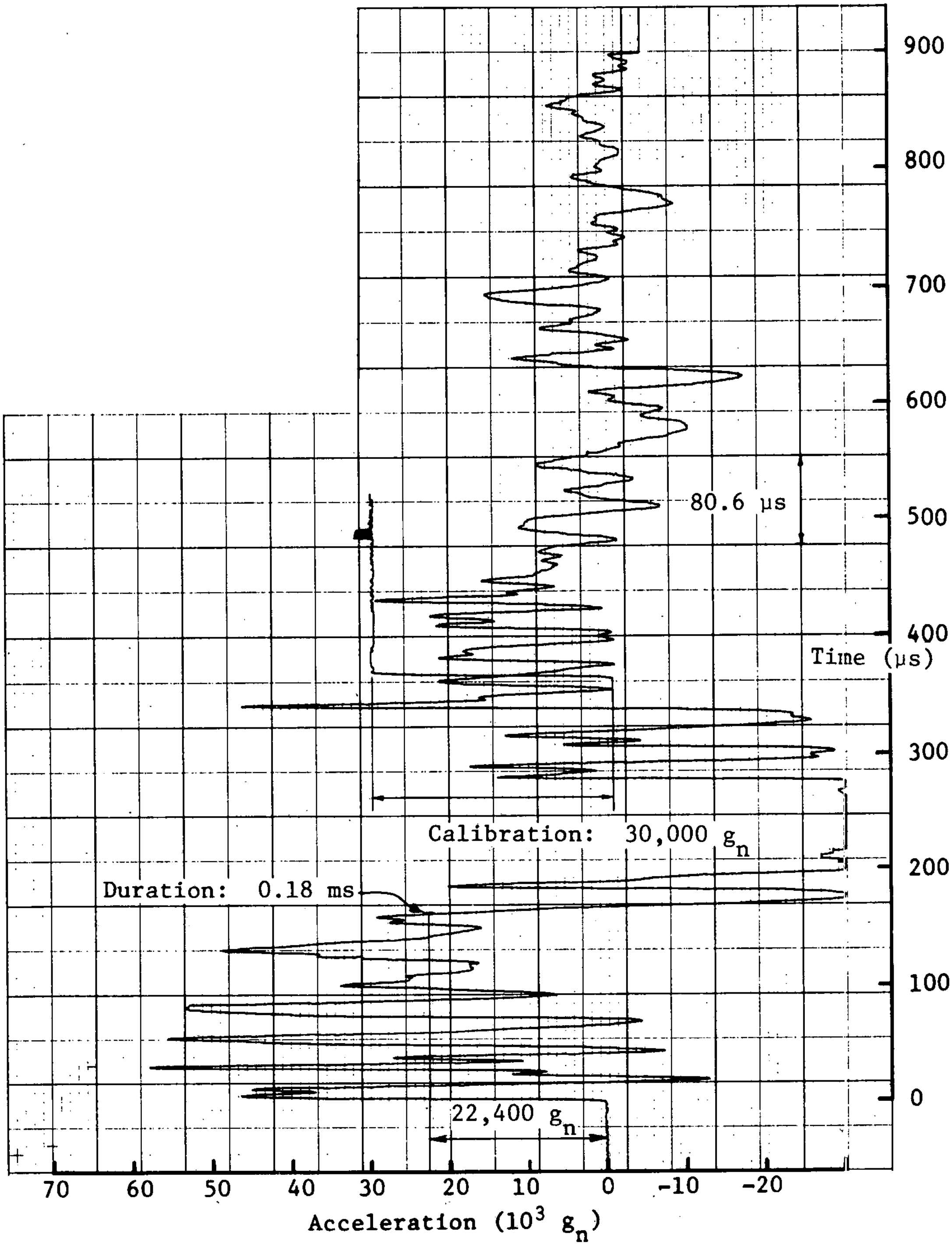

FIGURE 9 - Typical piston acceleration versus time recording for inert specimen with 2.5-mm air gap

The piston acceleration record (Fig. 9) shows a constant acceleration of 22,400 g_n during the initial interval of about 0.18 ms. It then falls off suddenly to negative values, where the peaks are deliberately clipped because we recorded only the accelerations that were of interest.

The usefulness of our instrumentation is illustrated by the manner in which the final design of the piece of honeycomb was influenced by the recordings of the accelerometer. When the honeycomb was precrushed in the standard manner to a uniform depth of about 3 mm, to eliminate a major initial peak in the crushing force, it was found that piston acceleration still initially rose somewhat above its steady-state value (Fig. 10a). Overshoot was completely avoided, however, when the flat face of the crushed honeycomb extended only over the central half of its cross-sectional area, with the depth of precrushing increasing progressively thereafter at larger radii. In this manner, by reducing the effective cross-sectional area of the honeycomb during the initial stages of its collapse, it was found possible to attain a square-wave acceleration (Fig. 10b). Precrushing the honeycomb to a spherical end shape gave an acceleration which initially undershot the final steady-state value (Fig. 10c).

Instrumentation recordings from all 14 inert specimen tests are summarized in Table I. It is to be noted that piston acceleration is reasonably constant ($\sigma = 2.50\%$), while the force on the load cell and the specimen pressure are somewhat less so ($\sigma = 4.46\%$ and 5.70%).

The recorded specimen pressure might have been expected to be equal to that calculated by dividing the force measured by the load cell by the cross-sectional area of the specimen. But when the specimen pressure was plotted as ordinate (Fig. 11) against this calculated pressure as abscissa, the numerical values in Table I were found to give the equation

$$y = 1.189\ x\ . \qquad [2]$$

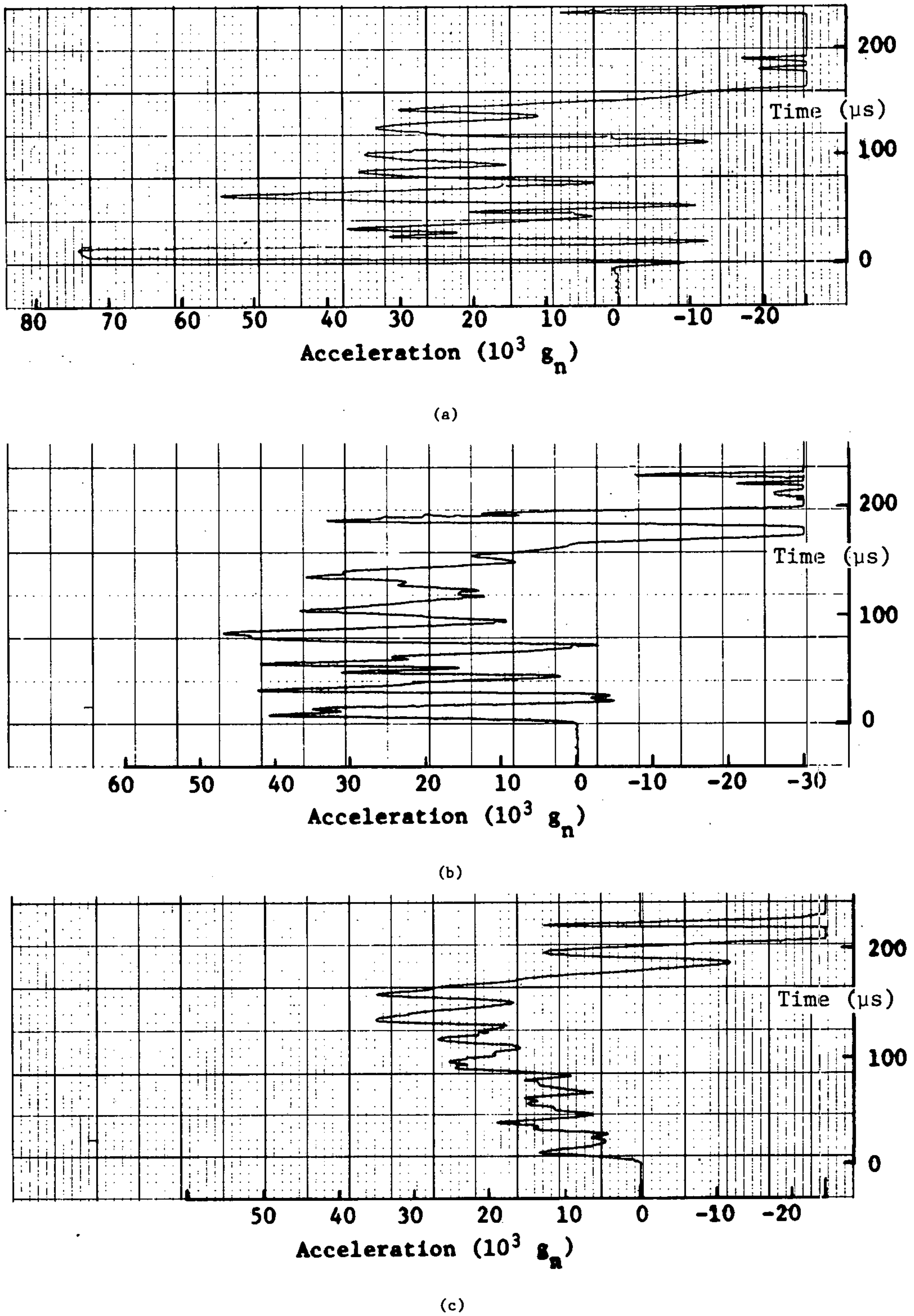

FIGURE 10 - Piston acceleration curves with honeycomb precrushed (a) with a flat end face, (b) with central area flat and peripheral area curved, radius 0.38 m and (c) with a spherical end face

TABLE I

The DREV setback simulator* with an inert specimen and a 2.5-mm air gap

Test No.	Tank Pressure (kPa)	Hammer Velocity (m/s)	Piston Acceleration (g_n)	Specimen Pressure (MPa)	Load Cell Force (kN)
1	1100	20.2	†	269	114
2	1035	Not recorded	†	276	120
3	1100	26.9	§	255	114
4	1275	29.7	§	273	118
5	1450	31.9	§	258	114
6	1275	29.1	§	266	108
7	1380	31.2	§	268	112
8	1475	34.3	22800	284	117
9	1500	37.5	22600	251	107
10	1455	35.3	Not recorded	223	101
11	1425	35.2	22650	253	108
12	1425	36.1	22400	256	108
13	1410	35.7	23850	283	114
14	1375	34.5	Not recorded	273	116
Mean	--	--	22860	263	112
σ	--	--	572	15	5

* As an exception, the piston weighed 453 g for each of these tests.

† Acceleration was not recorded because an adequate design for the interconnecting cable had not yet been worked out.

§ Acceleration is not measurable because of incorrect honeycomb shape.

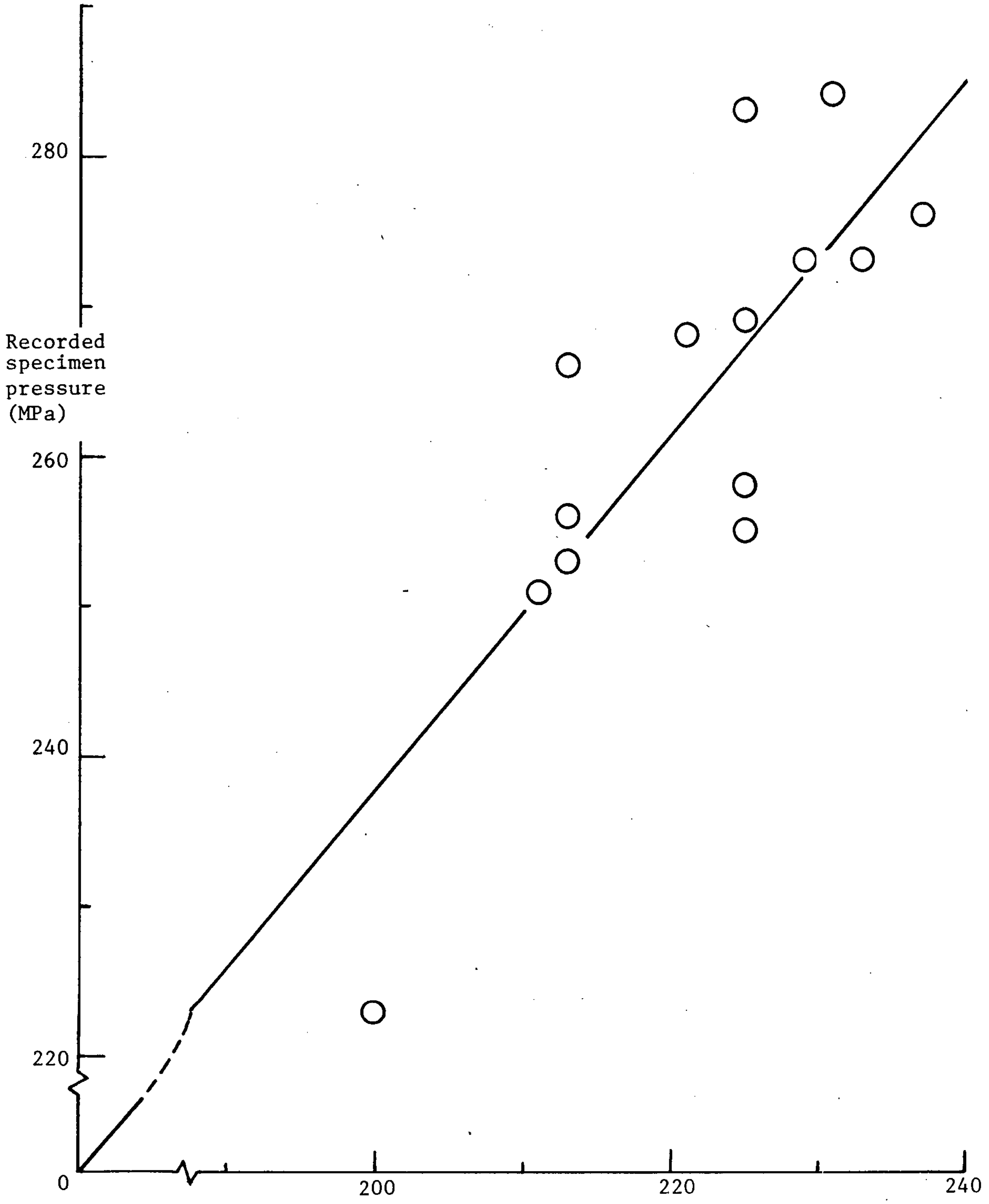

FIGURE 11 - The recorded specimen pressure versus the pressure calculated from the load cell recording

The points were fitted to a straight line through the origin with the criterion of best fit that the sum of the squares of the error in y be a minimum. That is, the recorded specimen pressure is about 18.9% greater than that calculated from the load cell force. This excess is attributed to friction at the interface between the heavy confining cylinder and the specimen, and possibly also the anvil. Friction with the specimen is not unexpected since most recovered specimens have an increased diameter and require a press to remove them. The anvil and piston are usually easy to remove.

In a similar fashion, the recorded piston acceleration values were smaller than expected for a nonstandard piston of 453 g. This deficiency will be due in part to the pressure buildup in the air cavity but is likely to be attributed mainly to an inaccurate calibration of our accelerometer. The latter was purchased about eight years ago and its calibration has never been checked.

Each specimen mounting was dismantled and examined following every test. It was found that the polyethylene seals worked well in that none of the specimen residue could be found beyond the seals.

4.2 Explosive Specimens

All tests conducted on explosive specimens are summarized in Table II, where the outcome of each test is also described. The test outcome is assessed by examining the components upon dismantling the specimen mountings.

The tests conducted with a zero air gap confirm the results obtained using inert specimens, as no trace of the explosive specimen was extruded beyond the polyethylene seals. This is important in that it enables us to rule out explosive extrusion as the mode of ignition in all later tests of this design.

Those conducted with an air gap all gave ignition. The time delay, from the start of gap closure to ignition, as indicated by the load cell recording, is less than 0.1 ms for Comp B (Fig. 12), about 0.12 ms for Comp A-3 (Fig. 13) and about 0.3 ms for TNT (Fig. 14). It should be noted that a delay of about 0.1 ms or less cannot be measured with any accuracy because the ignition peak is superimposed on the initial rapid increase in signal strength.

For CX-84A it is difficult to identify the point at which ignition begins. About 3 ms after the start of gap closure the recorded force should have started to fall off, but in Fig. 15 it starts rising at about 2.8 ms and subsequently falls only about 3 ms later, long after the hammer has come to rest. Perhaps ignition occurred much earlier than 2.8 ms, as the reaction has a slow rate of explosive consumption and may initially lack the vigor to register on the load cell.

Explosive ignition was obtained in these tests at a specimen pressure of about 250 MPa, approximately one-third of that needed in Picatinny-type simulators. Hubbard et al (Ref. 5) discussed such results and pointed out that the pressure level required for the ignition of RDX/TNT-60/40 type A was about three times greater than the typical peak pressure found in modern guns. Also, Taylor and Ervin (Ref. 6) reported only one ignition from 28 tests on Comp B under an applied pressure of 830 MPa with a 3.2-mm air gap.

TABLE II

Explosive response to the DREV setback test simulating the launch of shells under an acceleration of 25,000 g_n

Explosive	Air Gap (mm)	Ignitions	Reaction*
TNT	0	0/5	N
"	2.5	5/5	L
Comp A-3	0	0/5	N
"	1.0	3/3	E
Comp B	0	0/5	N
"	1.5	5/5	E
CX-84A	0	0/5	N
"	2.5	5/5	S

* The reaction, if any, is described by the use of four damage levels as follows:

E : Explosion (metal parts disrupted or extensively deformed, no explosive recovered).

L : Large partial (some metal parts show evidence of explosive deformation, some explosive recovered).

S : Small partial (metal parts show no evidence of explosive deformation, most of the explosive recovered).

N : No reaction (explosive shows no evidence of reaction).

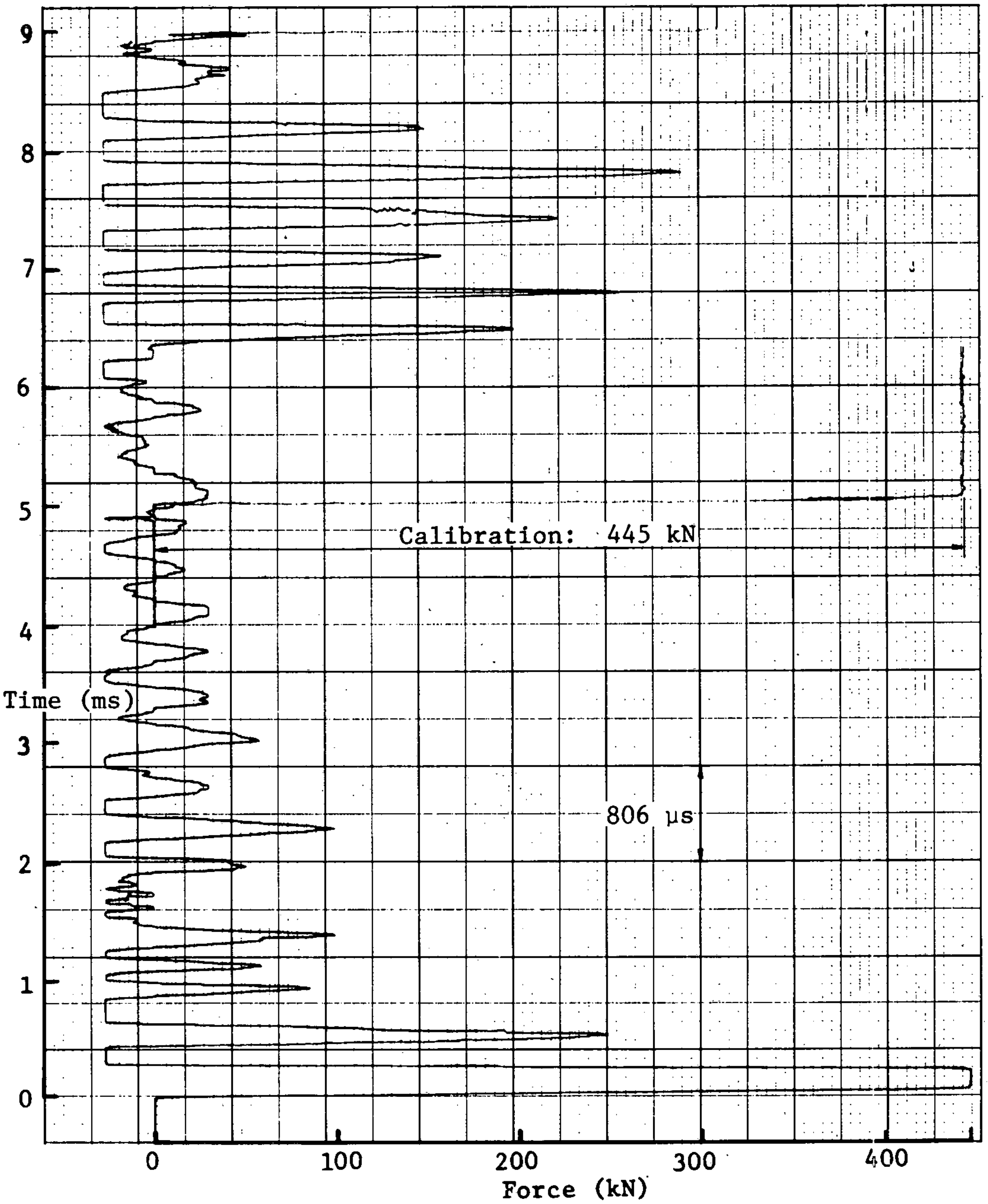

FIGURE 12 - Typical load versus time recording for a Comp B specimen initiated under a 1.5-mm air gap

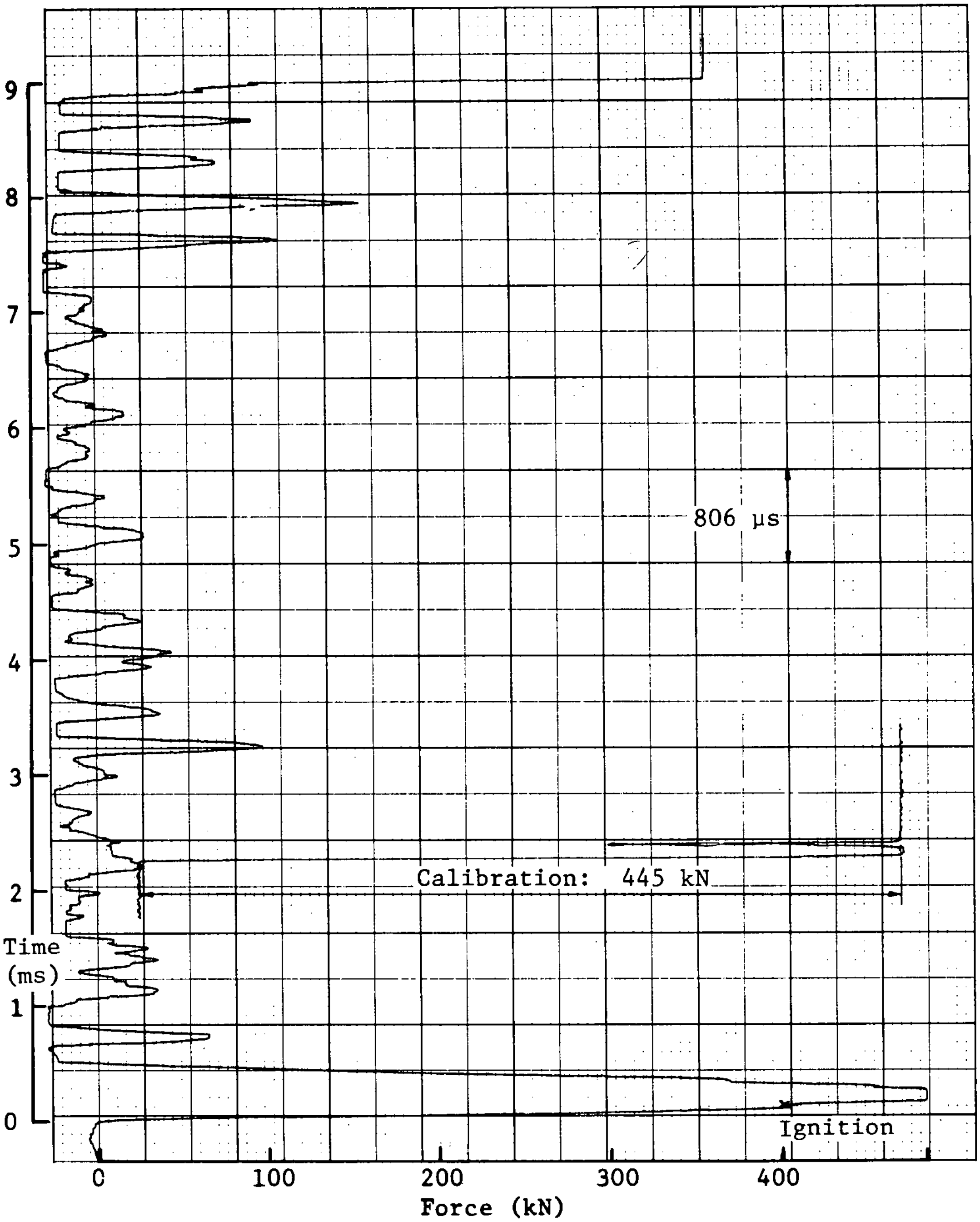

FIGURE 13 - Typical load versus time recording for a Composition A-3 specimen initiated under a 1.0-mm air gap

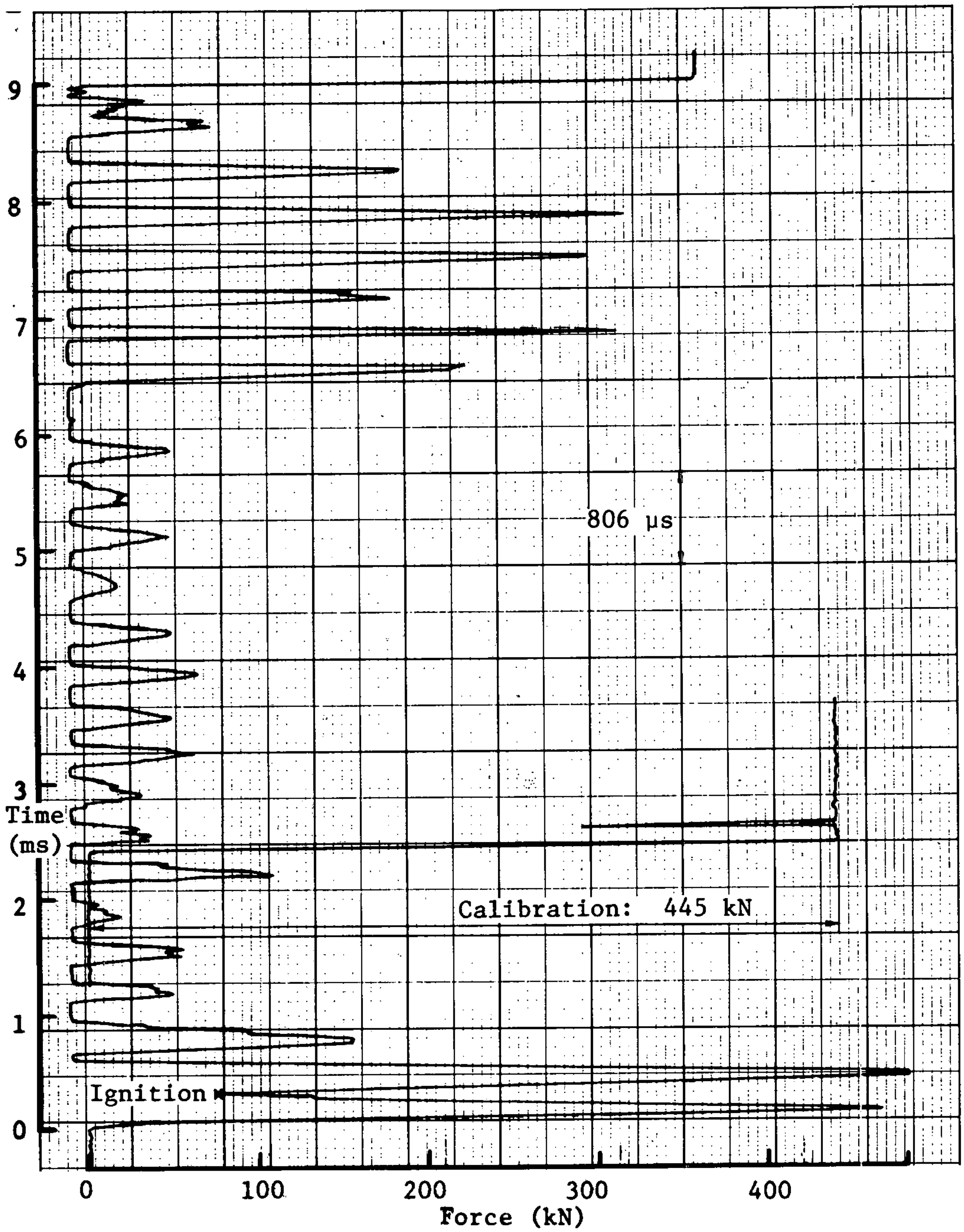

FIGURE 14 - Typical load versus time recording for a TNT specimen initiated under a 2.5-mm air gap

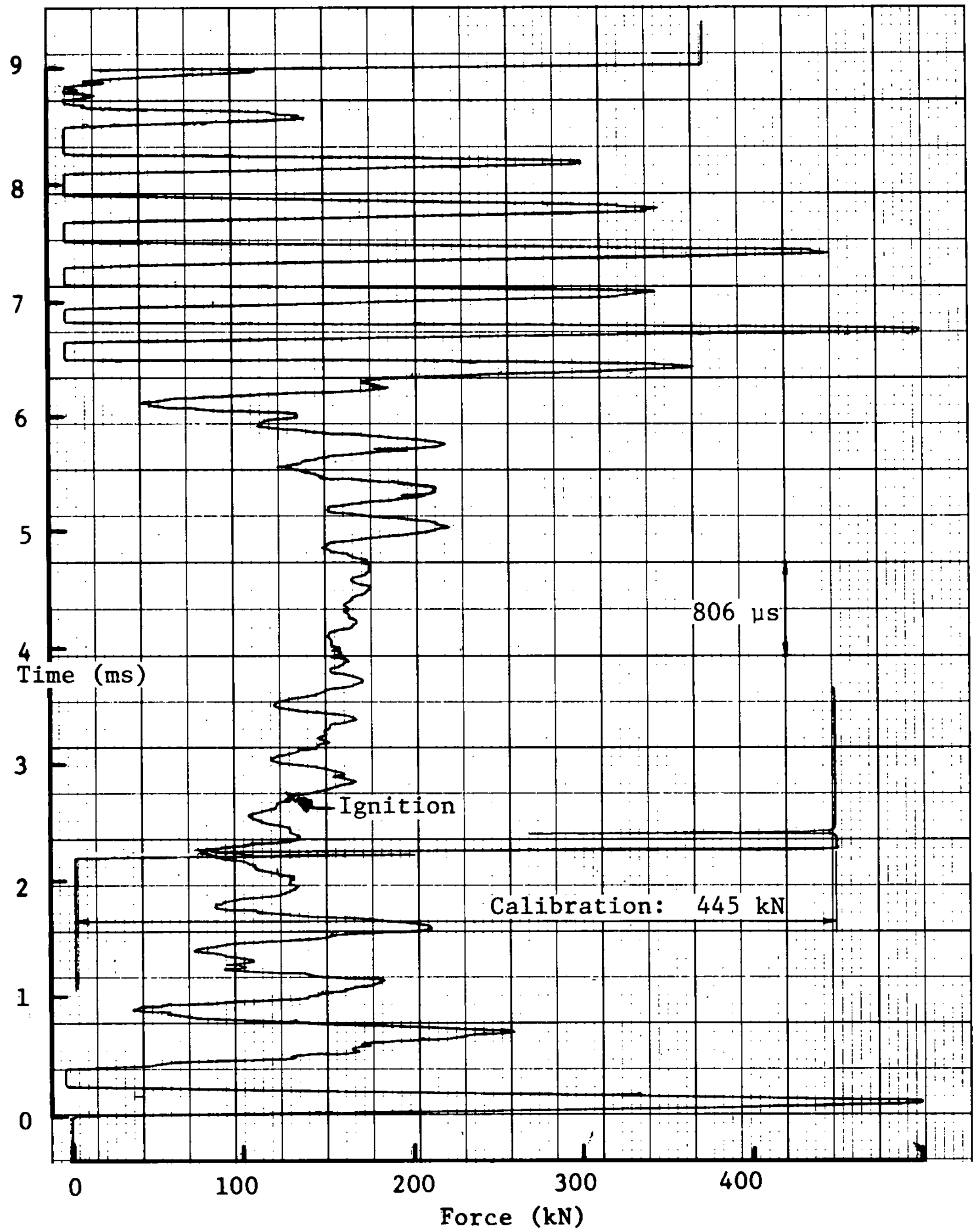

FIGURE 15 - Typical load versus time recording for a CX-84A specimen initiated under a 2.5-mm air gap

5.0 CONCLUSIONS

A setback simulator has been designed, manufactured and operated successfully. Its features include those recommended by Pasman in order to realistically simulate cavity collapse in a shell launched with an acceleration up to 25,000 times the normal acceleration of gravity. With its realistic rate of closure of an air gap, ignition is repeatedly obtained at a pressure of about one-third that needed for ignition in a Picatinny-type simulator.

An advanced design for closure, where the moving piston compresses an air gap adjacent to the explosive specimen, has eliminated the extrusion of explosive into the clearance around the piston. This removes all doubt as to whether any given ignition may have been due to such extruded explosive.

6.0 ACKNOWLEDGEMENTS

All internal ballistic calculations for the design of the air gun were carried out by Dr. Mario Cloutier (deceased). Many individuals in our Mechanical Workshop and Drafting Section contributed much to the solution of design and construction problems; the contributions made by Messrs. Raymond Beaulieu and Pierre Lemay are especially worthy of note. Mr. Claude Demers participated in putting the simulator into operation and in conducting most of the tests.

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CRDV R-4274/82 (NON CLASSIFIE)

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"Simulateur d'effet de recul du CRDV: conception et performance" par C. Bélanger et G.R. Walker

Un simulateur d'effet de recul de conception originale a été mis au point au CRDV. Sa conception repose sur les recommandations d'une étude théorique faite afin de reproduire, de façon réelle en laboratoire, la compression par effet de recul d'un espace d'air situé à la base d'un obus lors du lancement de ce dernier dans un canon. On présente une description détaillée du simulateur y compris celle du montage de l'échantillon conçu de façon à prévenir toute fuite d'air ou de la composition testée.

Les performances du simulateur du CRDV ont été évaluées à l'aide d'une série d'essais simulant des accélérations jusqu'à 25,000 g_n pour un obus de 105 mm. Ces premiers tests ont porté sur une composition inerte et sur des explosifs dont le TNT coulé, la Composition B, la Composition A-3 et un explosif coulable à liant plastique. Ces explosifs réagirent tous à la compression dite adiabatique d'espaces d'air, soit de 2.5, 1.5 ou 1.0 mm, et ce à des pressions de l'ordre du tiers de celle nécessaire pour initier une réaction de la Composition B sur un simulateur de type Picatinny.

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"DREV Setback Simulator: Design and Performance" by C. Bélanger and G.R. Walker

A laboratory machine has been designed, fabricated and put into operation at DREV to simulate the collapsing of a base cavity as the filling of a shell is setback under the high axial acceleration of gun launch. The simulator design followed the recommendations made in a theoretical study by Pasman. Its overall construction is described, including a specimen mounting assembly developed to prevent all leakage of the composition under test.

Initial tests simulated a 105-mm shell with accelerations up to 25,000 times the normal acceleration of gravity, loaded with Composition A-3, cast TNT, Composition B and a castable plastic-bonded explosive, with air cavities of 2.5, 1.5 or 1.0 mm height. The explosive was ignited in each instance even though pressures never exceeded about one-third of that found necessary to achieve ignition of Composition B in Picatinny-type simulators. Some tests were also conducted using inert specimens for comparison purposes and to evaluate the simulator and its instrumentation.

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