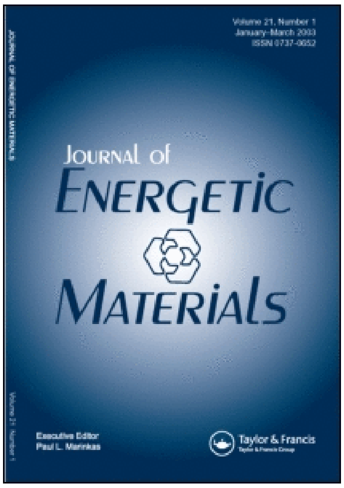

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Cartridge case deformation test

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CARTRIDGE CASE DEFORMATION TEST

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ABSTRACT

This paper describes a re-evaluation of a very small-scale explosives performance test which was first developed in the 1960's. The test uses a .303" brass cartridge case both as charge container and witness piece, and has continued in intermittent use at the UK Forensic Explosives Laboratory to the present day. In the test a small quantity of the test material is loaded into the cartridge case and initiated by a No 6 detonator. A broad performance classification is obtained by inspection of the recovered cartridge case base, and more detailed comparisons of particular explosives may be obtained by weighing the recovered bases.

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31 materials were tested, ranging from high explosives to non-explosives. 10 shots were fired with each of four explosives and 5 shots were fired with each of the other materials. The base weights obtained ranged from about 2g for military high explosives to about 9g for non-explosives.

The test offers a rapid and simple method for assessing the performance of explosive materials. It enables a clear distinction to be made between those explosives which detonate and those which deflagrate under the conditions of the test.

INTRODUCTION

A forensic laboratory specialising in explosives work often receives improvised explosive mixtures of unknown composition for examination. Chemical analysis of such mixtures is valuable and often essential, but a direct measurement of explosive potential can be particularly useful and may provide compelling evidence in court. In the 1960's Lidstone[1], working at this laboratory, described a test which he had developed to meet this requirement for a very small-scale forensic test of explosive behaviour. The test uses a .303" brass cartridge case both as charge container and witness piece, and can be carried out (with suitable facilities) in a normal laboratory building. There is no doubt that full assessment of explosive performance is best carried out at or close to the intended scale of use, but such tests are time-consuming, expensive and require large amounts of explosive. In many forensic cases there is little sample available and the costs of full-scale testing would not be justifiable, but tests on a laboratory scale are well worthwhile.

The brass .303" cartridge case was chosen for the test because it possesses walls of tapering thickness and has a thick base portion which corresponds in function to a small witness plate. Figure 1 is a cross sectional view of a case. It is a suitable container for liquid and solid materials and automatically standardises the geometry of the charge making the cartridge case test a simple and rapid method for assessing the effectiveness of a wide range of explosive compositions.

Although the test has been in intermittent use since its development a re-evaluation was recently required in preparation for external accreditation by the United Kingdom Accreditation Service (UKAS). In addition the large supply of cases originally obtained and used in the initial standardisation was nearly exhausted. Thus a programme of firings was undertaken both to re-evaluate the test and to standardise the new supply of cases.

MATERIALS AND APPARATUS

Cartridge cases

Brass .303" cartridge cases were obtained from Value Bullet Company, Pudsey, West Yorkshire, UK. Pilot batches from two differing supplies, identified as `Remington' and `Greek', were obtained from this source. The previous supply of cases had two fire holes and an anvil suitable for Berdan caps, but the new supplies had the single larger hole for Boxer caps.

Physical measurements, which are reproduced below, were made of 20 cases from both the `Greek' and `Remington' pilot batches to evaluate the precision of manufacture.

TABLE 1.

Dimensions of Cases

	Remington cases			Greek cases		
	Mean	Standard Deviation	Coeff. of Variation (%)	Mean	Standard Deviation	Coeff. of Variation (%)
Weight (g)	10.45	0.12	1.15	11.25	0.10	0.88
Length	56.23	0.03	0.05	56.20	0.07	0.12
O.D. at base	11.51	0.07	0.61	11.57	0.12	1.01
I.D. at base	9.41	0.12	1.27	9.26	0.11	1.18
Thickness of wall at base	1.06	0.08	7.10	1.16	0.09	8.38
O.D. at point of taper	10.25	0.10	0.96	10.25	0.10	1.02
I.D. at point of taper	9.34	0.13	1.35	9.29	0.14	1.52
Thickness of wall at point of taper	0.46	0.09	18.79	0.48	0.07	14.72

<u>Hardness testing of the cartridge cases</u>

Vickers hardness tests were carried out on .303" brass cartridge cases from the two different sources. The load, 2.5kg, was applied at positions 8mm, 23mm and 38mm from the base of the case. Each of the measurements, which are reproduced below, represents the mean hardness of two diametrically opposite parts of the case.

TABLE 2.

Vickers Hardness Test Results, 2.5 kg Load

	Remington cases			Greek cases		
Distance from the base (mm)	Mean	Standard Deviation	Coeff. of Variation (%)	Mean	Standard Deviation	Coeff. of Variation (%)
8	200.4	3.0	1.5	180.4	13.8	7.7
23	161.7	18.6	11.5	171.0	7.2	4.2
38	139.4	7.3	5.2	169.9	5.6	3.3

From the physical measurements there appeared to be no significant differences in the precision of manufacture. However, the hardness tests showed different hardness profiles, one with hardness decreasing from base to mouth and the other with fairly uniform values along the length of the case. The cases of Greek origin were selected.

Explosives and other test materials

Explosives and other test materials were obtained from the sources shown in Table 3 below.

TABLE 3.

Sources of Materials

Test material	Source
C4 plastic explosive	Expro Chemical Products Inc, Quebec, Canada
PE4 plastic explosive, HMX, TNT, PETN	Royal Ordnance, Bridgwater, UK
Tetryl (CE), Gunpowder G40, Gunpowder G20	Laboratory standard collection
Semtex-H	Forensic material
OE7135 (booster), Delta 100	Exchem Explosives
Special Gelatine 80%, E80, E900, Powergel 700, Powergel 1000	Nobels Explosives, UK
Energel 400, Energel 450, Energel 600	Ulster Industrial Explosives, UK
Nitrocellulose (12.2% and 13.1% Nitrogen)	Royal Ordnance, Bishopton, Renfrewshire
m-Dinitrobenzene, Sodium Chlorate, Boric Acid	BDH Chemicals, Poole, Dorset, UK
Calcium ammonium nitrate fertiliser.	Sheppey fertilisers, Isle of Sheppey, UK
Ammonium nitrate fertiliser/sugar mixture	Laboratory test material
Yellow soft paraffin	Esso Petroleum, UK
Icing sugar	Silver spoon, British Sugar PLC, UK

During firings the cartridge cases were contained in a welded steel cylinder of 300mm height and 190mm internal diameter, having walls 10mm thick. A solid cylindrical steel block of diameter 220mm and thickness 70mm, having a weight of approximately 20kg, was used as a lid. To absorb the explosive energy and decelerate case fragments the steel cylinder was about two thirds filled with case fragments the steel cylinder was about two thirds filled with softwood pellets (Pampuss Pellets, Pettex Ltd Essex, UK). During normal operation no significant explosive effects escape the cylinder, but for additional safety it is placed within an armoured glass and steel fume cabinet.

Choice of detonators

The test to date has employed a No 6 detonator, but these are becoming difficult to obtain in the UK. A limited comparison of Nobels No6 strength and No8 strength electric instantaneous aluminium PETN detonators was therefore carried out, giving the results shown in Table 4 below.

TABLE 4.

Detonator Comparison Results

Test material	No 6 detonator Mean base weight (g)	No 8 detonator Mean base weight (g)
$CaCO_3$ (inert)	8.58 (2 tests)	9.12 (2 tests)
Ammonium nitrate fertiliser/sugar mixture	4.81 (3 tests)	4.17 (4 tests)
Semtex-H	1.73 (2 tests)	1.07 (4 tests)

After these tests had been completed a substantial supply of No 6 detonators was fortunately located, and it was decided to continue with this type. The comparison tests indicate that No 8 detonators could probably be used with little effect upon the results, but a more extensive study would be necessary to confirm this conclusion.

PROCEDURE

Range of materials tested

31 materials were tested, ranging from high explosive through low explosive to non-explosive. The classes of explosives were as follows:

(i) Military high explosives

(ii) Commercial blasting explosives including gel and emulsion explosives

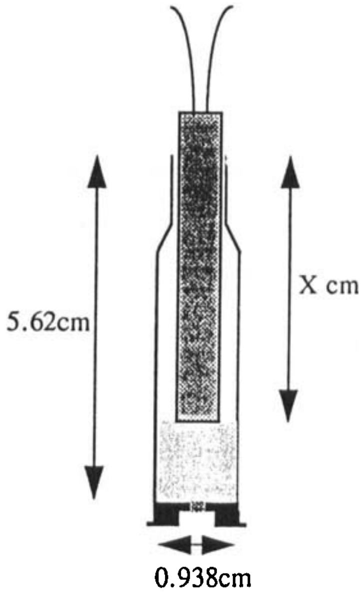
(iii) Common improvised explosives

(iv) Low explosives and non-explosives

10 shots were fired with four of the explosives, PETN, Semtex-H, TNT and gunpowder as these straddle the whole range of explosive performance. 5 shots were fired with each of the other materials.

Charge loading

The fire hole in the base of a case was plugged with a small piece of plasticine. 2g of the test material was accurately weighed into the case and gently pressed, using a simple brass hand-stemming tool, to remove any air pockets. The free space above the charge was then measured and the loading density calculated as shown.



Assuming the inside of the cartridge is a perfect cylinder

Radius of cartridge case = $\frac{0.938}{2}$ cm

Depth of explosive inside cartridge case = 5.62 - X cm

Volume occupied by explosive charge = $\pi \times \frac{0.938^2}{4} \times (5.62 - X)\ cm^3$

Loading density = $\frac{\text{Mass of explosive (g)}}{\text{Volume occupied by explosive charge } (cm^3)}$

Finally the detonator was placed into the cartridge so that it touched the test material and positioned centrally using a small piece of adhesive tape as shown above and in Figure 2.

Firing

The prepared cartridge case was inserted vertically into the wood pellets in the centre of the steel cylinder. The detonator lead wires were passed through a small slot in the steel wall and the cylinder was closed with the weighted lid. Electrical connection to a firing unit was made via terminals set into the armoured fume cabinet wall and the charge fired.

Retrieval of case fragments and evaluation of result

The weighted lid was removed and the base of the cartridge case was retrieved by passing the contents of the steel vessel through a coarse sieve (area $4500mm^2$ with 6mm diameter holes). The base remains as a single piece and can readily be picked out unless the test material is an explosive of very high performance. Such explosives shatter the base, but with care it is normally possible to retrieve most of the fragments of a shattered base.

Any plasticine which remained, any of the test charge which had failed to fire, and any pieces of wood pellet which had become attached were removed from the recovered base and it was weighed to the nearest milligram. When the base was shattered, all recovered base fragments were weighed. In addition to weighing the base was allocated to one of the following categories:

Category 4: All the case walls were detached and the base was shattered into a central ring and detached outer ring, or entirely into pieces.

Category 3: Any case walls remaining attached were less than 5mm length and the base ring was intact. Vernier callipers were used to measure the distance from the tip of the longest piece of attached wall to the point of attachment to the base.

Category 2: Some or all of the case walls remained but splitting of the walls (petalling) extended to within 10mm of case base. Vernier callipers were used to measure the distance from the flat base to the lowest point of splitting.

Category 1: The case walls were intact and splitting did not extend to within 10mm of the base.

RESULTS AND DISCUSSION

Figures 3 to 6 are photographs of case bases illustrating the full range of performance.

Military and commercial explosives

Results for military high explosives and commercial explosives are shown in Table 5. The two forms of TNT, cast pellet and flake, gave different base weights and categories, indicating that cast TNT was not brought to detonation under the conditions of the test. Similarly several of the commercial gel/emulsion explosives failed to detonate under the test conditions.

TABLE 5.

Results for Military and Commercial Explosives

Explosive	No of firings	Mean loading density (g/cm^3)	Mean base weight (g)	Standard deviation	Coefficient of variation (%)	Category
C4	5	1.370	1.630	0.479	29.38	4,4,4,4,4
Semtex-H	10	1.402	1.825	0.456	25.00	4,4,4,4,4,4,4,4,4,4
PE4	5	1.420	2.110	0.154	7.32	4,4,4,4,4
HMX	5	1.064	2.207	0.288	13.06	4,4,4,4,4
CE (Tetryl)	5	0.778	2.966	0.320	10.79	4,4,3,3,3
PETN	10	0.800	2.989	0.138	4.62	3,3,3,3,3
m-dinitrobenzene	5	1.008	3.290	0.313	9.51	3,3,3,3,3
Nitrocellulose (12.2% N)	5	0.134	3.429	0.134	3.91	3,3,3,3,3
Nitrocellulose (13.3% N)	5	0.658	3.566	0.217	6.09	3,3,3,3,3
Special gelatine 80%	5	1.365	3.660	0.060	1.65	3,3,3,3,3
TNT (flake)	10	0.862	3.998	0.328	8.20	3,3,2,3,2,3,2,3,3,3
TNT (pellet)	5	1.650	7.190	0.872	12.14	2,2,2,2,2
OE7135 (booster)	5	0.719	3.251	0.273	8.39	3,3,3,3,3
Powergel 700	5	1.304	3.312	0.183	5.54	3,3,3,3,3
Powergel 1000	5	1.196	3.335	0.145	4.35	3,3,3,3,3
Energel 450	5	1.365	3.492	0.136	3.90	3,3,3,3,3
Delta100	5	0.724	3.749	0.227	6.05	3,3,3,3,3
E900	5	0.958	5.129	1.697	33.13	2,3,2,2,3
Energel 400	5	1.304	5.500	1.514	27.54	2,2,3,3,2
Energel 600	5	1.304	5.788	1.231	21.26	2,2,2,2,2
E80	5	0.928	7.836	0.888	11.33	2,2,2,2,1

Improvised, lower performance and non-explosives

Table 6 gives the results obtained from improvised explosives, low performance explosives and non-explosives. Calcium ammonium nitrate/sugar and pure ammonium nitrate/sugar both underwent detonation and gave similar base weights of 3.920g and 4.068g respectively. Ammonium nitrate/fuel oil and ammonium/nitrate mineral jelly both failed to detonate. The sodium chlorate/sugar mixtures illustrate the effects of different ratios of the two materials; the 70/30 mixture gave a consistent category 2 result, whilst the 50/50 mixture gave three category 1 results.

TABLE 6.

Results for Common Improvised Explosives, Low Explosives and Non-explosives

Explosive	No of firings	Mean loading density (g/cm^3)	Mean base weight (g)	Standard deviation	Coefficient of variation (%)	Category
Calcium ammonium nitrate/icing sugar (90/10)	5	1.510	3.920	0.264	6.73	3,3,3,3,3
Ammonium nitrate/icing sugar (90/10)	5	1.320	4.068	0.186	1.32	3,3,3,3,3
Sodium chlorate/icing sugar (70/30)	5	1.741	6.725	1.175	17.48	2,2,2,2,2
Sodium chlorate/icing sugar (50/50)	5	1.603	8.179	0.312	3.82	1,1,1,2,2
Ammonium nitrate/fuel oil (94/6)	5	0.927	8.522	0.216	2.54	1,1,1,1,1
Ammonium nitrate/mineral jelly	5	0.899	8.663	0.335	3.87	2,2,2,2,1
Gunpowder-G40	10	1.035	8.207	0.352	4.29	2,2,2,2,2,2,2
Gunpowder-G20	5	1.204	9.124	0.137	1.507	1,1,1
Calcium carbonate	5	1.014	8.590	0.224	2.60	1,1,1,1,1
Boric acid	5	1.141	8.860	0.182	2.05	1,1,1,1,1

Repeatability of the test

In most cases all of the firings for a particular explosive gave the same category. Some lay on the borderline between two categories and gave results in either, but in no case were results obtained which spanned three categories. The coefficients of variation of the mean base weights varied from 4.29% at the low performance end of the scale to 25.0% for the highest performance explosives. The poor repeatability for very high performance is due to the difficulty encountered in recovering all the fragments from a very high order detonation. Some small fragments are missed (having passed through the sieve).

Interpretation of results

The test results can be used for two purposes. If a basic assessment of explosive performance is required without direct comparison Table 7 below can be used to interpret the category:

TABLE 7.

Interpretations of Categories

Category	Explosive performance rating
4	High. Detonation has occurred.
3	Moderate to high. Detonation has occurred.
2	Some explosive effect. Deflagration or partial detonation.
1	Inert or failed to initiate under the test conditions

If a more precise comparison of the performance of two or more explosives is required the base ring fragment weights can be used. A higher performance is indicated by a lower base ring weight.

Failure to detonate

A significant number of undoubtedly detonable explosives failed to detonate under the conditions of the test and in these cases the explosive performance was seriously underestimated. The explosives were those which in normal use require a booster for satisfactory initiation. Further work will address this drawback to the current test procedure. It may be that the use of No 8 detonators would reduce the extent of the problem, but it is unlikely that, given the very small scale of the test, all insensitive explosives can be brought to detonation.

CONCLUSIONS

The test offers a rapid and simple method for assessing the performance of explosive materials, or for making more precise performance comparisons. The small sample quantities, relative simplicity of the procedure and the lack of dependence on specialist equipment are all considerable advantages. The ranking of explosive performance of the materials tested was found to be similar to that obtained when the test was first reported. Some detonable explosives failed to detonate under the test conditions, which is a significant disadvantage of the method.

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1. D.P. Lidstone, Explosivstoffe, 1969, No. 9, pp193-201

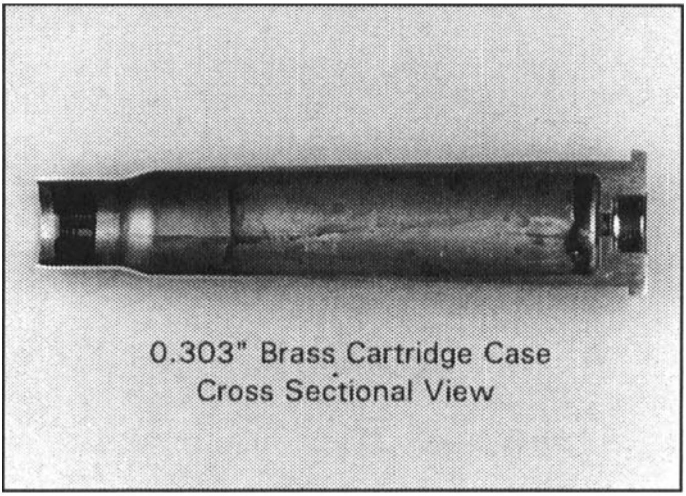

FIGURE 1
Cross Sectional View of Cartridge Case

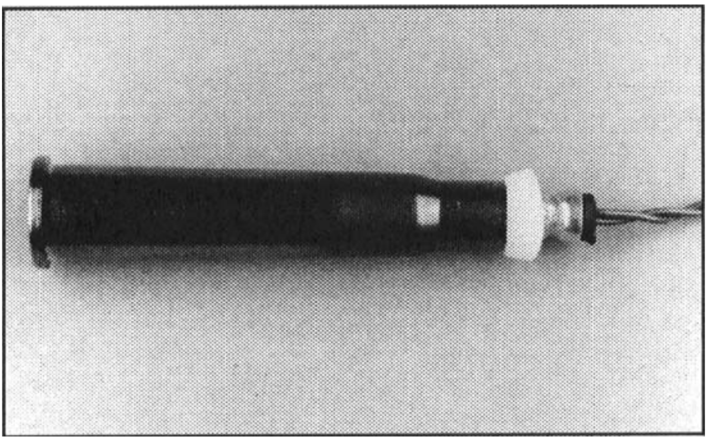

FIGURE 2
Prepared Case Ready for Firing

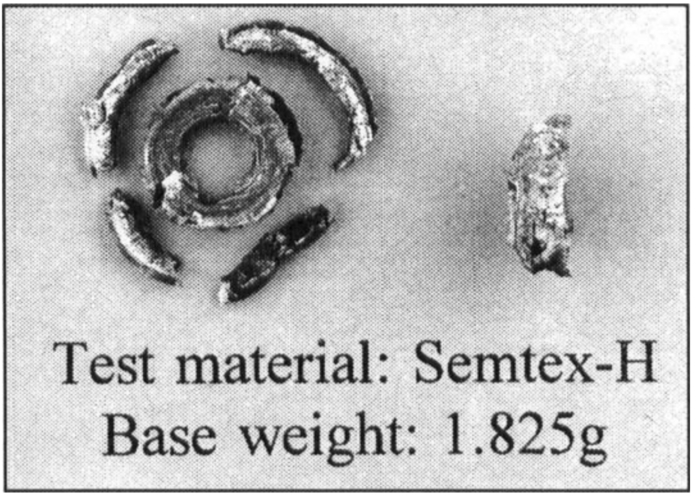

FIGURE 3
Example of a Category 4 Result; Semtex-H.

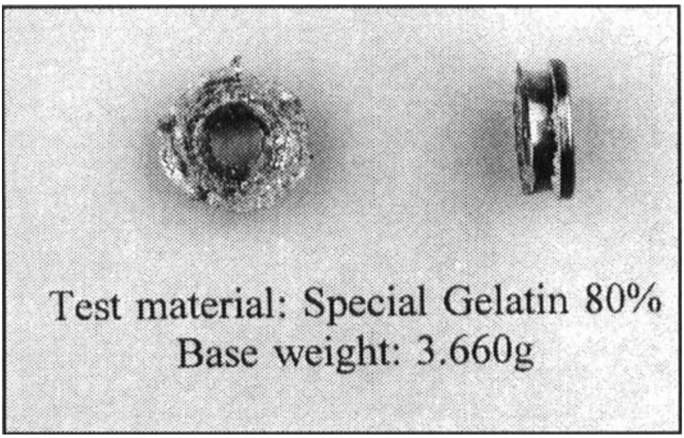

FIGURE 4
Example of a Category 3 Result; Special Gelatin 80%.

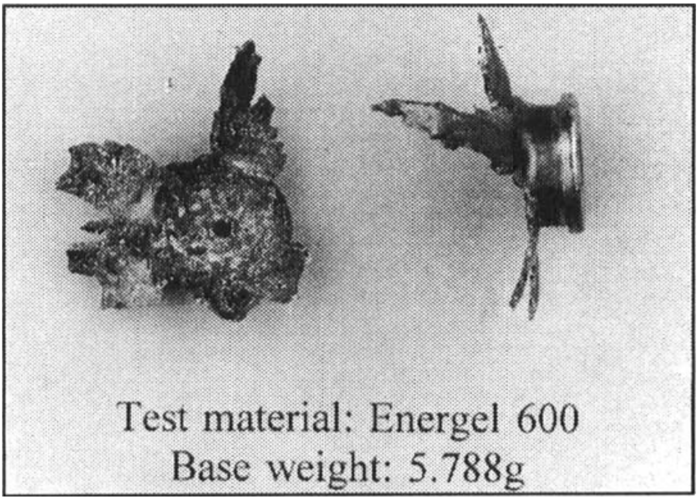

FIGURE 5
Example of a Category 2 Result; Energel 600.

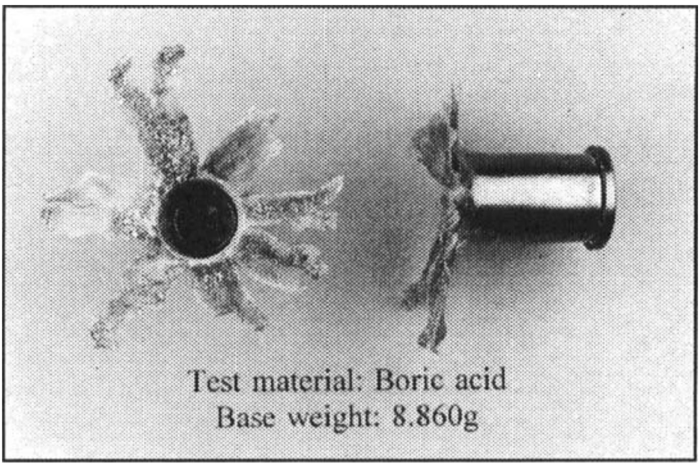

FIGURE 6
Example of a Category 1 Result; Boric acid.