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ROYAL ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

MATERIALS EXPLOSIVES DIVISION

R.A.R.D.E. MEMORANDUM (MX) 34/62

The manufacture of an R.D.X. based explosive sheet

V. Jamieson
J. Wilby

Fort Halstead
Kent.

August 1962

R.A.R.D.E.
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The manufacture of an R.D.X. based explosive sheet

V. Jamieson } (X2)
J. Wilby }

Summary

The manufacture of several explosive sheets is described. The most satisfactory, was a sheet containing 88% RDX with the remaining 12% essentially polyisobutylene of molecular weight approximately 15,000. This sheet was a pliable material which detonated satisfactorily at a thickness of 0.1".

Another RDX based sheet in which the binder was a mixture of depolymerised rubber and polyurethane was unsatisfactory as the rubber aged.

Approved for issue:

L. Northcott, Principal Superintendent 'MX' Division

CONTENTS

		Page
1.	Introduction	1
2.	Experimental	1
	2.1 Unmodified Polyurethanes as binder	1
	2.2 Depolymerised Rubber (D.P.R.) binder	1
	2.3 Polyurethane-modified D.P.R. binder	2
	2.4 Polyisobutylene (P.I.B.) binder	2
3.	Manufacture of SX1.	2
	3.1 The Binder	2
	3.2 Incorporation of RDX	3
	3.3 Preparation of Sheet	3
4.	Assessment of Physical Properties	3
	4.1 Handling Tests	3
	4.2 Stability	5
	4.3 Density and Viscosity	6
	4.4 Impact Sensitiveness	6
5.	Assessment of Initiation and Propagation	6
	5.1 Comparative tests on Du Pont, SX1, and RDX/DPR 90/10 Sheets	6
	5.2 Additional experience with SX1	7
6.	Cutting Power	8
7.	Discussion	9
8.	Conclusions	10
9.	Acknowledgments	10
	Reference	10
	Appendix 1. Nemul 1291	11
	Appendix 2. Notes on the use of SX1	12
	Table I	13
	Table II	14

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1. INTRODUCTION

The Applied Explosives Branch was asked to develop a sheet explosive for use in explosive-forming(1) and to introduce the manufacturing procedure into an R.O.F. at an early stage, in view of anticipated requirements from industrial firms engaged on this work. Subsequently, interest was also expressed in the application of this explosive to certain ordnance demolition techniques.

The requirements were for a sheet with the following properties:

(a) It must be capable of manufacture with uniform thickness, as low as 0.08 inch.

(b) It must be pliable and capable of being bent through an acute angle without cracking.

(c) It must be capable of initiation from a detonator, without a CE pellet; for use in explosive forming, the detonator should be as small as possible.

(d) It should propagate reliably.

Two sheet explosives fulfilling most of these requirements are commercially available. One is marketed by the U.S. firm of Du Pont (EL-506) and the other is manufactured in this country by Messrs. I.C.I. under the trade name of "Metabel". Both of these explosive sheets are based on PETN whereas the R.A.R.D.E. work has been directed towards a sheet based on RDX. RDX is a less sensitive explosive than PETN and for general handling purposes it is considered preferable to use RDX.

2. EXPERIMENTAL

2.1 Unmodified Polyurethanes as binder.

A series of preliminary mixes based on castor oil, and Daltocell SF (a modified polyethylene adipate) indicated that a flexible sheet could not be produced with a relatively highly cross-linked binder of the polyurethane type without reducing the explosive content of the composition below 75 per cent. At this level of loading the sheets did not propagate when made from grade 1A RDX.

It was thought that a higher percentage explosive content could be obtained using a less densely cross-linked polyurethane and therefore experiments were carried out in which part of the castor oil in the castor oil/tolylene di-isocyanate (T.D.I.)/RDX composition was replaced by polypropylene glycols of various molecular weights.

The lower molecular weight polypropylene glycols however did not give a flexible sheet but with P.P.G.2025 a plastic, although very sticky sheet, was obtained.

Work therefore was discontinued on this line of attack and the use of depolymerised rubber as a binder was considered. Table I summarises the mixes which were examined in this phase of work.

2.2 Depolymerised Rubber (D.P.R.) as a binder.

From previous experiences it was considered that depolymerised rubber could be a suitable binder in preparing flexible sheet and experiments were carried out using two types of different viscosity. Using D.P.R. of viscosity 25000 poises an 87/13 RDX/DPR compound was made which gave a flexible sheet but which was of poor tensile strength.

By using D.P.R. of viscosity 5000 poises in the same manner compositions of higher plasticity were obtained and flexible sheets containing 9% and 10% of D.P.R. were made. The 90/10 composition was extremely flexible but the sheet had a poor tensile strength so that its uniform thickness was not maintained on handling and could easily be thinned. The 91/9 composition was slightly less flexible and more resistant to thinning. Both compositions were however, quite sticky to the touch and it was suggested that the application of a surface coating would overcome this. Accordingly a sheet of polyethylene 0.004" thick was bonded to the surface of the 90/10 composition explosive sheet. This gave a non-sticky surface and the sheet remained flexible with some improvement in tensile strength. However it was still soft and, short of producing a laminated material, coatings of this kind do little to overcome the ease with which a sheet may be thinned.

The introduction of a small percentage of polyurethane into the composition effected a considerable improvement in this direction because the plastic formed a matrix throughout the whole sheet and gave a stiffening effect.

2.3 Polyurethane-modified D.P.R. binder.

Polyurethanes were initially examined as modifiers for the RDX/DPR 90/10 composition. The method employed required the addition of the requisite amount of castor oil/T.D.I. mixture to the RDX/DPR, rolling the product to a thin sheet and curing in a steam heated cabinet for 16 hours.

The product obtained was of good flexibility, of improved tensile strength and resistance to thinning. Further sheets were produced using different percentages of polyurethane and alternative polyester bases for the polyurethane; also, because of the success of this technique polyurethanes were added to other plastic compositions. Table II summarises the compositions which were examined in this phase of the work.

Two more promising lines were compositions 18 and 19 (Table 2.) The penta-erythitol tetra-ricinoleate (P.E.T.R.) modified sheet was less flexible that the comparable castor oil sheet, and it was thought that a satisfactory sheet could probably be made using less P.E.T.R. than would be possible with castor oil. However this would mean that the limits on the amount of P.E.T.R. to be added would need to be extremely small. It was decided that a greater error could be tolerated if castor oil were used. The final composition based on DPR to be studied was RDX/DPR 90/10 plus 2.5 (+ 0.5) per cent castor oil/ T.D.I.4/1 (Comp.20).

2.4 Polyisobutylene (P.I.B.) binder.

An alternative approach to the polyurethane based binder was to examine the possibility of a binder with little or no cross-linking, as it was felt that cross-linking increased the tendency to crack on handling. Polyisobutylene of molecular weight 3000 was investigated but, in proportion of 80/20 RDX/PIB, gave a very sticky soft sheet. When the molecular weight was increased to approximately 15000 the resultant sheet made from RDX/PIB, 80/20, had good flexibility and appeared satisfactory. The development of this sheet has proceeded and it has already been used in an ordnance demolition techniques trial under the name SX1 (Sheet Explosive 1). The manufacture and properties of SX1 are described in the following sections. Its composition was finalised as 88 parts RDX and 12 parts binder.

3. MANUFACTURE OF SX1

3.1 The Binder

The polyisobutylene used was "B15" material made by Oppanol with molecular weight approximately 15,000.

This PIB was too viscous for incorporation with RDX directly and the PIB was therefore diluted with diethyl hexyl sebacate to reduce the overall viscosity of the binder. 80 parts of the PIB were mixed with 20 parts of the diethyl hexyl sebacate, and the mixture was stirred at 90-100°C until the sebacate was uniformly dispersed throughout the PIB.

3.2 Incorporation of RDX.

272 gms of the binder, were added to 2000 gms of Grade 1A RDX in a water slurry 1/6 RDX/Water, and the mixture heated to 95°C and stirred for 1 hour, at 200 revs. a minute, by which time the RDX was uniformly coated with the binder. The RDX/binder was filtered through Cambric and rolled wet; a total of ten passes through Torrence Laboratory Rolls was given with a 3/1000" gap. The mix was finally dried in a 10 lb. Werner Pfleiderer Incorporator for 4 hours at about 95°C.

3.3 Preparation of Sheet.

A pair of motor driven cordite rolls were used to form the material into sheets. Various thicknesses were made ranging from 0.084" to 0.34" in thickness.

The sheet at this stage had some stickiness due to the PIB; this was found undesirable on storage. To overcome this the sheets were painted with an emulsion paint Nemul 1291 (see Appendix 1) which is an internally plasticised vinyl acetate copolymer dispersion. This coats the sheet with a thin film of polyvinyl acetate and removes the stickiness.

4. ASSESSMENT OF PHYSICAL PROPERTIES

4.1 Handling Tests.

It was considered desirable to compare the general handling characteristics of the Du Pont and I.C.I. sheets with both SX1 and one of the RDX/DPR compositions.

The tests carried out and the performance ratings are given below; all the tests were carried out on sheets 0.1" thick.

Rigidity Test, 1.

A piece of the explosive sheet was placed over the edge of a table. The results were evaluated as follows:-

(a) remained rigid

(b) remained fairly rigid with a slight drop

(c) slowly folded over the edge

(d) fairly quickly folded over the edge

Flexibility Test, 2.

A piece of the sheet was folded around a wooden pin, either 0.7" diameter or 1" diameter. The results were evaluated as:-

(a) folded round and recovered fairly well on release

(b) folded round and recovered slightly on release

(c) folded round and did not recover elastically

(d) too rigid to fold round

(e) tore

Folding Test, Test 3.

A piece of the material was folded over on itself and brought into firm contact over a fairly sharp fold by finger pressure. The results were evaluated as:-

(a) Folded and recovered elastically without rupture and without leaving a permanent wrinkle when flattened back by hand to original shape.

(b) Folded but did not recover elastically: could be unfolded without rupture or leaving a permanent wrinkle.

(c) As (a) but left a permanent wrinkle.

(d) As (b) but left a permanent wrinkle.

(e) As (c) but ruptured.

Squeezing Test, Test 4.

A piece of the material was measured for thickness and was then pressed between finger and thumb with moderate pressure. After the pressure was released the thickness was again measured. The results were evaluated as:-

(a) no thinning occurred - material rigid

(b) yielded slightly followed by elastic recovery

(c) fair yielding occurred followed by elastic recovery

(d) permanent yielding occurred, exceeding 10% of original thickness

(e) considerable permanent thinning occurred (beyond about 20% of thickness).

Tearing Test, Test 5.

A piece of the material was pulled back between finger and thumb. The ease of tearing was assessed:-

(a) material stretched elastically before tearing

(b) material tore with fairly strong pull

(c) brittle cracks appeared

(d) material tore easily

(e) material parted very easily - no resistance.

Ability to retain a shape, Test 6.

A piece of the material was folded length wise to form an approximate angle of 120°. The round wedgeshape so formed was supported at the base. The ability to retain the shape formed was judged:-

(a) retained shape for 15 minutes with no sign of slumping or springing

(b) retained shape but with some springing

(c) retained shape but with some slumping

(d) slumped.

The results of all these tests are summarised below:

	Test Number					
	1	2	3	4	5	6
Du Pont Sheet	b	a	a	b	a	a
Metabel	d	c	b	e	e	d
RDX/D.P.R., 90/10	c	b	c	c	b	c
SX1	a	b	d	d	a	a

Two additional measurements were carried out relating to handling properties:

The requirement that the sheet should have a uniform thickness implies that it should not "thin" easily under an applied stress. The ease with which various sheets could be thinned was estimated by measuring the force required to reduce the thickness by 0.005".

The tensile strength was also measured using dumb-bell shaped specimens with a $\frac{1}{4}$" neck. Results are given below, expressed as a percentage of the strength of the Du Pont Sheet.

Material	Tensile Strength	Compressive Strength (Force to cause indentation of 0.005")
Du Pont Sheet	100	100
SX1 (with PVA films)	36	-
SX1 (without PVA films)	36	38
RDX/DPR 90/10	28	-
RDX/Polyurethane (No. 6. Table 1)	175	133
RDX/DPR/Polyurethane (No. 20. Table 2)	80	100

4.2 Stability.

A climatic trial was carried out in which both SX1 and RDX/DPR/Polyurethane (No. 20 Table 2) were subjected to 80°C for one week. SX1 was unaffected but the RDX/DPR/Polyurethane had hardened and become brittle. This hardening was ascribed to oxidation of the depolymerised rubber component of the binder.

Additional evidence for satisfactory stability of SX1 was given by the results of a vacuum stability test on 5 gms of the material at 120°C; 0.9 ml of gas was evolved in 40 hours.

Owing to oxidation of the DPR work on sheets containing this ingredient has ceased, while evaluation of SX1 has proved reasonably satisfactory.

4.3 Density and Viscosity.

The density of SX1 was 1.52 gms/cc; or for an $\frac{1}{8}$" thick sheet approximately 3 gms/sq.in. or 15 ozs/sq.ft. The density of the RDX/DPR/Polyurethane sheet (No. 20 Table 2) was 1.59 gms/cc or for a sheet 0.09" thick, 12 ozs per sq.ft. or 2.4 gms/sq.in. These figures enable the amount of explosive to be calculated for sheets of various thickness.

Similar values are quoted for the Du Pont sheet of 2 gms/sq.in. for a 0.084" thick sheet and 3 gms/sq.in. for a 0.125" thick sheet.

The "viscosity" of SX1 and the RDX/DPR sheets were determined on the Hounsfield Tensometer and the results are given below together with the figure for PE4, for comparison:-

Material	Viscosity (poises)
SX1 (without PVA film)	4.7×10^6
RDX/DPR	3.0×10^6
PE4	2×10^4

The viscosity of SX1 and the RDX/DPR compositions will depend very much on the efficiency of the incorporation and the final particle size of the RDX.

4.4 Impact Sensitiveness.

The impact sensitiveness of SX1, the RDX/DPR/Polyurethane sheet and the Du Pont sheet have been determined on the Rotter Machine. The results are as follows:-

Material	F. of I.
SX1	107
RDX/DPR/Polyurethane (No. 20 Table 2)	85
Du Pont Sheet	43

5. ASSESSMENT OF INITIATION AND PROPAGATION

5.1 Comparative tests on Du Pont, SX1 and RDX/DPR 90/10 Sheets.

The following eight initiation tests were carried out on sheets 0.1" thick. In tests 1-5 and 8, the sheet explosive was laid on a 1" thick witness plate of aluminium; detonation gave a deep crater on the witness plate. No booster pellets were used.

Test Number	Detonator	Details
1	Briska No. 8	The detonator was supported vertically by means of a wooden holder 1" dia. x 1" long, drilled to take the detonator, which rested on one thickness if the explosive sheet 3" long by 1" wide.
2	I.C.I. No. 3	As for 1.
3	Briska No. 8	The detonator was laid on one thickness of the explosive sheet 3" long by 1" wide to which it was strapped by adhesive P.V.C. tape .004" (thick).
4	Briska No. 8	As for 1 but using only a ¼" wide strip of explosive sheet.
5	Briska No. 8	As for 1 but using a 1/10" wide strip of explosive sheet.
6	Briska No. 8	As for 1 but using 1" thick hard wood as the backing plate; 2 inches of the explosive sheet were sandwiched between 1" thick aluminium plates.
7	Briska No. 8	As for 1. The sheet explosive was made into a wedge shaped hollow charge, contained angle 120°.
8	Cordtex	Cordtex was strapped across a 1" wide by 3" long strip of explosive sheet backed by a 1" thick aluminium plate. The Cordtex was initiated 8" away from the test piece.

The results were:-

Material	Test Number							
	1	2	3	4	5	6	7	8
Du Pont	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Metabel	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
SX1	Yes	No	Yes	*	No	Yes	Yes	No
RDX/DPR/90/10	Yes	No	No	Yes	No	-	-	-

* Detonator in centre of strip. Detonation proceeded in one direction only.

5.2 Additional Experience with SX1

Additional experiments, to those mentioned in para. 5.1, have been carried out on SX1, both at R.A.R.D.E. and also at a Joint Services Project at Lydd Camp to assess the use of this material for bomb disposal purposes. In these experiments no booster pellets were used and the detonator was held perpendicular to the sheet and as near the centre of the sheet as possible. The detonator was held in place with plasticine.

Notes on the use of SX1 were prepared for the trial at Lydd and are reproduced as Appendix 2.

The following thicknesses of sheet have been made and tested with No.8 Briska detonators.

0.084", 0.105", 0.125", 0.146", 0.165", 0.247", 0.34".

Several firings have now been carried out on all thicknesses and only in the 0.084" thick sheet did detonation failures occur on strips wider than $\frac{1}{2}$". The details of the seven successful firings of the 0.105" thick sheet are as follows:-

Test Type	Width of strip of SX1, inches	No. of successful firings (No failures)	Witness Plate
1	0.5	3	$\frac{1}{4}$" mild steel
2	0.75	1	$\frac{1}{4}$" mild steel
3	1.0	1	$\frac{1}{4}$" mild steel
4	1.0	1	$\frac{1}{2}$" aluminium
5	1.5*	1	$\frac{1}{4}$" mild steel

* 1.5" diameter disc initiated at centre.

For the 0.084" thick sheet, with the PVA film peeled off at the point where the No. 8 Briska detonator was placed, a successful firing was obtained from test types 2, 3, and 5 but no detonation from test type 1. When the PVA film was left intact a successful firing was obtained from test type 4 but from a repeat of test type 1 detonation only travelled in one direction from the detonator and not in the other.

The results from paras. 5.1 and 5.2 suggest that there is no difficulty in initiating sheets down to 0.105" thick with a No.8 Briska detonator. Failure may occur with sheets 0.084" thick but the chance of a success may be improved if the PVA film is removed where the detonator is placed.

An experiment has shown that a detonation will propagate along 20 ft. of SX1, 0.125" thick and $\frac{3}{4}$" wide.

6. CUTTING POWER

The results below indicate the general cutting ability of SX1 on mild steel and aluminium. Only one result was obtained in each condition, except in the cases mentioned. The results are recorded as either "cut" or "no cut" although in the "no cut" case there may have been some scabbing but no actual cut. The firing set-up was identical to the system described in para. 5.2.

<u>$\frac{1}{4}$" Mild Steel</u>

Thickness of SX1 (inches)	Width of explosive strip			Circle $1\frac{1}{2}$" dia.
	$\frac{1}{2}$"	$\frac{3}{4}$"	1"	
0.084"	*	No Cut	Cut	Hole Cut
0.105	Cut	Cut	Cut	Hole Cut
0.125	Cut≠	Cut	Cut	Hole Cut

*The explosive did not detonate.

≠Two successful experiments.

$\frac{1}{2}$" Mild Steel

Thickness of SX1 (inches)	Width of Explosive	
	$\frac{3}{4}$"	1"
0.125	-	No Cut
0.146	-	No Cut
0.165	-	No Cut
0.247	Cut	Cut

$\frac{1}{2}$" Aluminium

Thickness of SX1 (inches)	Width of Explosive 1"
0.084	No Cut
0.105	No Cut
0.125	No Cut
0.146	Cut

It was found in many of these experiments that the plate would be almost cut, i.e. considerable scabbing and extensive splitting of the sheet, but the plate would be still held together just below where the detonator was placed. Only about $\frac{1}{2}$" or so from the detonator did the event build up to a full detonation. In these cases a slightly thicker sheet was needed for effective cutting.

This effect can be reduced by placing an extra thickness of sheet, approximately 1" by 1" square, below the detonator. If this technique is employed the cutting power is improved and the plates in the tables above may be cut with explosive sheet one thickness less than those quoted.

7. DISCUSSION

This discussion is confined to comments on SX1, RDX/DPR, and the RDX/DPR/Polyurethane (No. 20 Table 2) compositions for which most experience is available.

Despite quite reasonable handling properties the RDX/DPR and RDX/DPR/Polyurethane sheets both suffered from a serious drawback. They became hard and brittle on climatic storage at 80°C, see para. 4.2. This was attributed to oxidation of the DPR in the binder and it is for this reason that only SX1 is still being actively examined for explosive forming and bomb disposal applications.

SX1 is a stable sheet, para. 4.2, and sufficiently insensitive, para. 4.4, for general handling purposes.

Its handling properties, particularly without the PVA film, are satisfactory except for its slight stickiness which is the only reason the PVA is applied. However this film reduced the pliability of the sheet although in this condition the properties described in para. 4.1 are fairly satisfactory.

An objection to the PVA film is that it has a tendency to crack or wrinkle on bending the sheet, especially if the sheet is at a temperature approaching 0°C. The PVA film can therefore be regarded as a weak feature of SX1.

It is proposed to investigate the possibility of developing an improved sheet, even though SX1 is satisfactory in its present form for many purposes. There are clearly two lines of profitable investigation:

(a) To use a different surface coating from PVA so that the handling properties of the RDX/PIB binder will be modified as little as possible.

(b) To investigate a modification to the PIB binder which will eliminate the stickiness of the sheet and consequently remove the need for a surface coating.

It is not proposed to alter the proportion of RDX in the final mix. 88% of RDX gives sufficient power for most purposes, e.g. it contains as much RDX as PE4, and there has been no difficulty in the experiments performed so far to initiate the sheet, of thicknesses of 0.105" and above, from a No.8 Briska detonator.

8. CONCLUSIONS

A pliable explosive sheet can be made containing 88% RDX with the remaining 12% being essentially polyisobutylene with a high molecular weight of 15,000. The slight stickiness of the material, which might be a disadvantage on storage can be overcome by coating it with a thin film of polyvinyl acetate.

The stability of the sheet, from vacuum stability results is good; and its figure of insensitiveness is 107, a figure which is sufficiently high for there to be no serious sensitiveness problems during manufacture and use.

It has been found that sheets 0.105" thick and greater will detonate from a No.8 Briska detonator; but for 0.084" thick sheets initiation may be more successful if the PVA film is peeled back where the detonator is placed.

9. ACKNOWLEDGMENTS

Acknowledgment is made of the assistance given by Mr. L. J. Coleman, Paint Laboratory, D.C.I., Woolwich, towards the choice of the PVA Emulsion Paint for use with SX1.

The authors also wish to acknowledge the initiation tests and handling tests carried out by Messrs. Costello and Finnie, X.1 (Paras. 4.1 and 5.1).

Messrs. R. S. Dawson, W.T. Jones, R. Sexton and B. D. Titcomb, X.2, carried out most of the practical work.

Reference

1) Unpublished War Office Memorandum 1961

T.M. Finnie and J. W. Whent.

APPENDIX 1

N E M U L 1291

Description	Internally plasticised vinyl acetate copolymer dispersion.
Soldis Content	55% ± 1%
pH	4 - 5
Viscosity	2000/2500 c.p.s. thixotropic
Particle Size	Mainly under 1 micron
Mechanical Stability	Excellent
Freeze/thaw stability	Withstands 5 cycles - 10°C to 20°C
Odour	Slight, free monomer content below 0.5%
Specific gravity	1.09 - 1.1 (11 lbs. per gl.)
FILM	
Colour	Air dries clear colourless Stores clear yellow.
Hardness	Approximately equivalent to externally plasticised p.v.a. 16% D.B.P. content.
Gloss	Good
Water resistance	Excellent-high scrubbing resistance
Adhesion	Excellent
Ageing	Excellent, suitable for exterior use
Sole Manufacturers	KEINER & CO. LTD., CHURCH PATH, MITCHAM, SURREY.
Without Liability	550207

APPENDIX 2 (see para. 5.2)

Notes on the use of RARDE Explosive Sheet, SX1

1. Composition

The composition is 88% RDX with a binder which is essentially PIB (polyisobutylene) of high molecular weight. The sheets have been painted with a polyvinyl acetate (PVA) emulsion paint which gives them a thin coating of PVA to eliminate sticking on storage.

2. Storage

It is recommended that the sheets be stored in a warm magazine, approximately 60-70°F. This is because the surface film of PVA tends to crack at lower temperatures. Other materials are being investigated as improved surface coatings and will be used on future sheets.

3. Preparation of Charges for firing

The sheet should be cut to the desired shape in a warm room with a sharp steel knife; while cutting the material should be placed on a non-sparking surface preferably wood or hardboard.

Bostik 692 is a suitable adhesive for attaching the sheet to the surface to be cut or formed. A thin film of Bostik 692 is spread on the surface and the piece of explosive sheet pressed gently onto it. This will set in a few minutes to give good contact. This good contact will be maintained if the system is subsequently surrounded by water.

If the sheet has to be attached under water, Bostik 692 can still be used, although in this case the Bostik will not set to give firm contact. However the "stickiness" of the Bostik is usually sufficient to hold the sheet in place for a short time before it is fired.

N.B. The compatibility of Bostik 692 with SX1 is satisfactory for the short periods needed for most firing experiments, but the compatibility for long periods of contact is still to be investigated. It is suggested that the explosive sheet should only be attached with Bostik just before firing and should not be stored in this condition. Service adhesives for which satisfactory compatibility has been established are being investigated as a replacement for Bostik 692.

4. Initiation

Initiation is satisfactory from an electric No.8 Briska detonator; no intermediate, e.g. CE or RDX pellet, is then necessary. The detonator should be placed perpendicular to the sheet and as near the centre as possible, and can be held in this position with a small piece of plasticine around the sides of the detonator but not underneath the detonator. Good contact must be ensured between the sheet and the detonator, but the detonator should not be pushed into the sheet.

In the case of the thinnest sheets, 0.084" thick, the thin film of PVA should be peeled back with a sharp knife where the detonator is to be placed, but for the other sheets the PVA film can be left intact.

5. Examples of cutting power on Mild Steel

(a) ¼" thick Mild Steel plate can be cut with a strip of explosive sheet ½" wide. The thickness recommended is 0.125". This thickness of steel has been cut with sheet 0.105" thick and ½" wide but 0.125" thick is more reliable.

(b) ½" thick Mild Steel plate can be cut with a strip of explosive ¾" wide and 0.247" thick.

TABLE I

Compositions using unmodified Polyurethane Binders

Comp. No.	Polyester	% Polyester	Polyether	% Polyether	% T.D.I.	% R.D.X.	Remarks
1.	HPE239c	18.0	-	-	2.0	80	) Very poor flexibility -
2.	Daltocell SF	17.6	-	-	2.4	80	) did not
3.	Castor Oil	16.0	-	-	4.0	80	) propagate.
4.	Castor Oil	11.2	-	-	2.8	86	Rigid, fired from No.8 det.
5.	Castor Oil	20.0	-	-	5.0	75	Improved Flexibility.
6.	Castor Oil	24.0	-	-	6.0	70	Good Flexibility.
7.	Castor Oil	7.6	P.P.G. 2025	15.0	2.4	75	Plastic very sticky.
8.	Castor Oil	12.2	P.P.G. 2025	4.0	3.8	80	Rigid.
9.	Castor Oil	7.4	P.P.G. 425	5.0	3.6	84	Rigid.
10.	Castor Oil	7.0	P.P.G. 750	9.0	4.0	80	Very poor flexibility.
11.	Castor Oil	7.0	P.P.G. 1500	10.0	3.0	80	Very poor flexibility.
12.	Castor Oil	5.0	(P.P.G. 1500 (P.P.G. 2025	5.0) 6.0)	2.0	84	Plastic, slightly sticky.

TABLE II

The use of Polyurethanes as modifiers for plastic compositions

Composition No.	Basis	Polyester	% Polyurethane added	Remarks
13.	RDX/DPR 90/10	Castor Oil	1.0	Flexible - not sticky
14.		Castor Oil	3.0	" " "
15.		Castor Oil	6.0	Poor Flexibility
16.		Daltocell SF	3.2	" "
17.		HPE 239c	3.0	Rigid
18.		Castor Oil	3.2	Flexible
19.		Penta Erythritol	3.0	Poor Flexibility
20.		Castor Oil	2.5	Flexible
21.	PE4		2.0	Sticky
22.	RDX/P.I.B. sheet		1.0	Rigid.

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