AD NUMBER
AD516318
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Distribution authorized to DoD and DoD contractors only; Foreign Government Information; DEC 1969. Other requests shall be referred to British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.
AUTHORITY
DSTL, AVIA 37/1210, 1 Aug 2008; DSTL, AVIA 37/1210, 1 Aug 2008

ERDE TR 4 CONFIDENTIAL ERDE TR 4

MINISTRY OF TECHNOLOGY

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

TECHNICAL REPORT No. 4

Very Fast Burning Cordites (U)

E.A. Baker

FOR OVERSEAS RELEASE CONDITIONS SEE INSIDE COVER

WALTHAM ABBEY
ESSEX

December
1969

CONFIDENTIAL

RELEASE CONDITIONS FOR OVERSEAS DISTRIBUTION

A

1. THIS INFORMATION IS RELEASED BY THE UK GOVERNMENT TO THE RECIPIENT GOVERNMENT FOR DEFENCE PURPOSES ONLY.
2. THIS INFORMATION MUST BE ACCORDED THE SAME DEGREE OF SECURITY PROTECTION AS THAT ACCORDED THERETO BY THE UK GOVERNMENT.
3. THIS INFORMATION MAY BE DISCLOSED ONLY WITHIN THE DEFENCE DEPARTMENTS OF THE RECIPIENT GOVERNMENT AND TO ITS DEFENCE CONTRACTORS WITHIN ITS OWN TERRITORY, EXCEPT AS OTHERWISE AUTHORISED BY THE MINISTRY OF TECHNOLOGY REPORTS CENTRE. SUCH RECIPIENTS SHALL BE REQUIRED TO ACCEPT THE INFORMATION ON THE SAME CONDITIONS AS THE RECIPIENT GOVERNMENT.
4. THIS INFORMATION MAY BE SUBJECT TO PRIVATELY-OWNED RIGHTS.

B

1. THIS INFORMATION IS RELEASED BY THE UK GOVERNMENT TO THE RECIPIENT GOVERNMENT FOR DEFENCE PURPOSES ONLY.
2. THIS INFORMATION MUST BE ACCORDED THE SAME DEGREE OF SECURITY PROTECTION AS THAT ACCORDED THERETO BY THE UK GOVERNMENT.
3. THIS INFORMATION MAY BE DISCLOSED ONLY WITHIN THE DEFENCE DEPARTMENTS OF THE RECIPIENT GOVERNMENT AND TO THOSE NOTED IN THE ATTACHED LIST, EXCEPT AS OTHERWISE AUTHORISED BY THE MINISTRY OF TECHNOLOGY REPORTS CENTRE. SUCH RECIPIENTS SHALL BE REQUIRED TO ACCEPT THE INFORMATION ON THE SAME CONDITIONS AS THE RECIPIENT GOVERNMENT.
4. THIS INFORMATION MAY BE SUBJECT TO PRIVATELY-OWNED RIGHTS.

C

1. THIS INFORMATION IS RELEASED BY THE UK GOVERNMENT TO THE RECIPIENT GOVERNMENT FOR DEFENCE PURPOSES ONLY.
2. THIS INFORMATION MUST BE ACCORDED THE SAME DEGREE OF SECURITY PROTECTION AS THAT ACCORDED THERETO BY THE UK GOVERNMENT.
3. THIS INFORMATION MAY BE DISCLOSED ONLY WITHIN THE DEFENCE DEPARTMENTS OF THE RECIPIENT GOVERNMENT, EXCEPT AS OTHERWISE AUTHORISED BY THE MINISTRY OF TECHNOLOGY REPORTS CENTRE.
4. THIS INFORMATION MAY BE SUBJECT TO PRIVATELY-OWNED RIGHTS.

D

5. THIS INFORMATION IS RELEASED FOR INFORMATION ONLY AND IS TO BE TREATED AS DISCLOSED IN CONFIDENCE. THE RECIPIENT GOVERNMENT SHALL USE ITS BEST ENDEAVOURS TO ENSURE THAT THIS INFORMATION IS NOT DEALT WITH IN ANY MANNER LIKELY TO PREJUDICE THE RIGHTS OF ANY OWNER THEREOF TO OBTAIN PATENT OR OTHER STATUTORY PROTECTION THEREFOR.
6. BEFORE ANY USE IS MADE OF THIS INFORMATION FOR THE PURPOSE OF MANUFACTURE, THE AUTHORISATION OF THE MINISTRY OF TECHNOLOGY REPORTS CENTRE MUST BE OBTAINED.

MINISTRY OF TECHNOLOGY

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

Technical Report No. 4

December 1969

Very Fast Burning Cordites (U)

by

E.A. Baker

SUMMARY

Work has been carried out at ERDE on double-base propellants containing lead beta-resorcylate and basic cupric salicylate to which carbon blacks have been added. For most of the work the standard solventless process was used. The highest platonised burning rates were obtained with Dixigloss carbon black and one formulation, F488/1827, burning at 41 mm/s at pressures between 17 and 34 MN/m^2 has been the subject for development trials which will be reported separately. At lower calorimetric values, slower burning rates were obtained, but platonisation could be extended to pressures of at least 45 MN/m^2 or to 51 MN/m^2 by changing to low nitrogen content nitrocellulose.

Replacement of some nitrodiphenylamine by resorcinol gave further increases in burning rate. Attempts to increase burning rates by activation of Dixigloss and charcoal were not successful and similar burning rates were obtained with somewhat larger amounts of untreated Dixigloss.

Solvent processed versions of some promising fast burning formulations for use in thin web sizes were satisfactorily tested.

Further copies of this report can be obtained from Mintech. Reports Centre, Station Square House, St. Mary Cray, Orpington, Kent. BR5 3RE

CONTENTS

Reference: WAC/204/04

1. INTRODUCTION

The use of combinations of compounds of lead and copper to give fast burning rates in double-base propellants was published in American Patent 3,138,499. Using British methods and ingredients, propellants containing lead beta-resorcylate and cupric salicylate gave slower burning rates than expected. To increase the burning rates of British versions, carbon black has been added. The work has involved ballistic assessment to decide the most suitable type of carbon black and to explore the possibility of improving ballistics by activation of carbon blacks.

The two carbon blacks tested initially were:

(i) Ukarb 340, a British produced furnace black with average particle size of about 50 millimicrons.

(ii) Dixigloss, an American channel black with average particle size of about 5 - 10 millimicrons.

Experiments were also carried out to optimise the proportions of the two ballistic modifiers and one selected formulation, F488/1827, has been the subject of full scale development trials.

Attempts have been made to raise burning rates by the addition of resorcinol and to extend the pressure range of platonisation by examining the effects of calorimetric level and of the nitrogen level of the nitrocellulose.

In view of the possibility of safer extrusion and production of thinner web thicknesses in complex shapes such as multi-tube, a few promising compositions have been processed by the solvent-type procedure and their ballistics determined.

During the early stages of the work, efflorescence on the surface of a propellant containing lead beta-resorcylate and normal cupric salicylate was observed. This was first thought to be salicylic acid and in order to improve propellant storage properties a change was made from normal cupric salicylate to the basic salt, which appeared to give a slight increase in burning rates. The efflorescence has not been obtained with this type of composition since the change but it should be noted that later chemical analyses showed the deposit was beta-resorcylic acid.

Most of the propellants contain 2-nitrodiphenylamine as stabiliser since this is known to give higher burning rates in general than carbamite, besides a reduced tendency to formation of traces of nitrogen on prolonged hot storage.

/2. .....

2. FAST BURNING RATES

2.1 Effect of Carbon Black on Burning Rates

2.1.1 Ukarb 340

Comparison of strand burning rates from first experiments with the UK composition F488/1225 with data in US Patent 3,138,499, indicated that the presence of Ukarb 340 carbon black, which should have increased burning rates, was having little effect. This was confirmed in a later series of small scale experiments in which 0.1, 0.2 and 0.3 parts of Ukarb 340 was added to a propellant similar to F488/1225 but with basic cupric salicylate replacing the normal salt:

Composition No.	Ukarb 340, parts	Strand Burning Rates (mm/s) at MN/m^2				
		14	17	21	24	27.5
F488/1889	Nil	31.3	32.7	33.2	32.8	33.8
F488/1890	0.1	31.8	33.4	33.4	33.0	33.5
F488/1891	0.2	32.6	33.7	33.7	33.3	33.7
F488/1892	0.3	33.3	34.7	34.2	33.3	33.3

Thus the addition of 0.3 parts of Ukarb 340 increased the burning rate by, at most, 6 per cent at the lower pressures and only 2 per cent at 24 MN/m^2 with consequent improvement of the plateau. (Table 1, Group 1.)

2.1.2 Dixigloss

In a series of small scale experiments, each mix containing the same batches of nitrocellulose, lead beta-resorcylate, and normal cupric salicylate, 0.4 parts of Ukarb 340 in the F488/1225 formulation was successively replaced by 0.15, 0.4, 0.6 and 0.8 parts of the more active carbon black, Dixigloss. Strand burning rates for these lots (F488/1761, F488/1762, F488/1783, F488/1798) are summarised in Table 1, Group 2 and illustrated in Fig. 1. Calorimetric values of the final propellants are about 4450 kJ/kg (1060 cal/g)*. The curves

/show .....

*Table 1 includes calculated calorimetric values for propellant matrices (i.e. not including lead beta-resorcylate, cupric salicylate, carbon black) rounded up to 100 parts. Since the three ballistic modifiers have negative values - large ones in the cases of basic cupric salicylate and carbon black - the real value for the final propellant may be on average as much as 500 - 600 kJ/kg lower than these calculated values. Fired values for complete propellant are additionally listed in the Table where available and quoted in the text whenever possible.

show steady increases in burning rates for each increment of carbon black up to 0.6 parts over the whole pressure range measured. Plateau burning rates are increased from 30 mm/s up to about 40 mm/s. There is a tendency for the plateaux to extend into a higher pressure range as the amount of carbon black increases. With the addition of 0.8 parts Dixigloss, the further increases in burning rates are confined to the higher pressures and there is a tendency to reduce the "mesa" character of the curves.

These effects are confirmed in a later single experiment (not illustrated) using a different batch of cupric salicylate in which the addition of 0.7 parts Dixigloss gave burning rates intermediate between those obtained for 0.6 and 0.8 parts Dixigloss (F488/1826 - Table 1, Group 2). The general effects noted with increasing amounts of up to 0.3 per cent Dixigloss have been confirmed in a hotter matrix incorporating basic cupric salicylate instead of the normal salt (F488/1886, F488/1887, F488/1888 - Table 1, Group 2). Larger amounts of Dixigloss, up to 1.3 parts, have been added to cooler compounds without loss of platonisation (e.g. F488/1905 - Table 1, Group 2). Similar large amounts have been added to hotter compositions, again without loss of platonisation (Section 2.4).

2.1.3 Activated Carbon Blacks

Samples of Dixigloss carbon black were activated by heating shallow layers in a furnace in air at 650°C for thirty minutes. Some granular 'activated wood charcoal' purchased from British Drug Houses Ltd., was re-activated in the same manner and, since such charcoal would be expected to contain potassium compounds which might be detrimental to platonisation, the experiments were extended to include sugar charcoal activated in the same way.

Dixigloss was activated on two separate occasions and was tested at 0.15 and 0.3 parts respectively, in comparison with 0.6 and 0.8 parts of the untreated black.

Composition No.	Dixigloss, parts		Strand Burning Rates (mm/s) at MN/m^2				
	Normal	Activated	17	21	24	27.5	31
F488/1783	0.6		39.3	39.1	38.9	37.6	37.9
F488/1784		0.15	39.2	41.0	41.9	41.9	42.8
F488/1798	0.8		39.1	39.8	39.9	40.4	40.5
F488/1799		0.3	36.0	36.3	36.1	36.4	37.9

/The .....

The different behaviour may be due to uncontrolled stages during activation but it is indicated that the first treatment of the carbon black was effective and that an appreciable increase in strand burning rates of the propellant was achieved. However similar rates can be achieved by using larger amounts of untreated carbon black and there was insufficient effort to justify further investigation of activation at the time.

Addition of 0.2 and 0.4 parts of treated activated sugar charcoal gave slower strand burning rates than those obtained with 0.6 parts Dixigloss. (F488/1851, F488/1852, F488/1827 - Table 1, Groups 3 and 5.) The behaviour approximated to Ukarb 340 and it was indicated that further increases in the charcoal level would not give significantly faster burning rates.

Replacement of 0.6 parts of Dixigloss by 0.3 and 0.6 parts of activated sugar charcoal gave considerably slower strand burning rates with no indication that additional amounts of the sugar charcoal would increase the burning rates (F488/1873, F488/1874, F488/1827 - Table 1, Groups 3 and 5). The results suggest that only a slight catalysis was being obtained.

Following a suggestion that fine carbon blacks may be aggregated, comparative tests were made in F488/1827 of "uncompressed" and "compressed" grades of Dixigloss N1, with a negative result. Tests in ATN cast double-base propellant of an ultrasonically-milled Dixigloss slurry also gave no difference from normal ballistics.

2.2 Modifier Levels and Ratios

2.2.1 In Absence of Carbon Black

The effects of changes in ballistic modifier ratios and levels were studied in a group of four mixes using the same basic paste (F488/1896, 1897, 1898, 1899) followed later by a separate single mix (F488/1907). In these experiments the basic cupric salicylate varied from 1 to 3 parts per 96 parts matrix and the lead beta-resorcylate from 1 to 2 parts. Strand burning rates are summarised in Table 1, Group 4 and illustrated in Fig. 2.

The two compositions containing only one part of basic cupric salicylate have appreciable burning rate exponents and are not truly platonised. The remaining formulations with 2 parts or more of basic cuprric salt are well platonised with mesa characteristics. The plateau burning rate is raised from 24 mm/s to 30 mm/s as the lead beta-resorcylate is increased from 1 part to 2 parts. In compositions F488/1896 and F488/1897, each with peak burning rates of about 30 mm/s, the presence of 3 parts of the basic cupric salt displaces the peak rate and mesa trough to pressures about 4 MN/m^2 lower. It is apparent that even without carbon black, burning rates in excess of 30 mm/s may be obtained by using larger amounts of lead beta-resorcylate.

/Two .....

Two potentially useful compositions at about 5050 kJ/kg have emerged from this work and the results of this series indicate the possibilities for quality control using adjustments on the proportions of ballistic modifiers:

Composition No.	Lead beta-resorcylate	Basic cupric salicylate	Peak rate, mm/s	Pressure, MN/m^2	Trough rate, mm/s	Pressure, MN/m^2
F488/1896	2	3	29.8	13.7	26.4	20.7
F488/1897	2	2	30.0	17.2	28.7	24.1

Composition F488/1896 has found application in the composited Snifter IV motor.

2.2.2 Carbon Black Present

On the basis of work described in Section 2.1.2 a Dixigloss level of 0.6 parts was selected as giving the most effective platonisation at high rates. Strand burning rates for a series of experiments in which the amounts of basic cupric salicylate was varied from 1 to 3 parts and the lead beta-resorcylate from 2 to 3 parts are summarised below:

Composition No.	Lead Beta-Resorcylate, parts	Basic Cupric Salicylate, parts	Strand Rates of Burning (mm/s) at MN/m^2					
			17	21	24	27.5	31	34.5
F488/1827	3	2	40.6	41.4	41.4	40.9	41.1	42.4
F488/1854	3	3	39.2	41.0	41.0	40.4	40.4	40.6
F488/1855	2	3	37.2	38.7	38.9	38.9	38.9	39.6
F488/1856	3	1	40.8	41.7	41.4	40.7	40.6	41.7

It will be noted that with 3 parts of lead beta-resorcylate the strand burning rates over the mesa are not much affected as the amount of basic cupric salicylate is reduced from 3 parts to 1 part. This perhaps is rather surprising in the light of results discussed in Section 2.2.1 where, with no carbon black but only 2 parts of lead beta-resorcylate, the burning rates were quite sensitive to similar variations in the basic cupric salicylate content.

/The .....

The increases in burning rates with larger amounts of lead beta-resorcylate noted in the formulations without carbon black occur also to some extent in the presence of carbon black but without any shift to a higher pressure range. (F488/1854, F488/1855 as shown above.)

In a pair of strictly comparable formulations it was found that the burning rates for a formulation containing 4 parts of lead beta-resorcylate were marginally faster at the lower pressures than rates for the formulation containing 3 parts (F488/1902, F488/1903 - Table 1, Group 8).

2.2.3 Basic Cupric Salicylate

Early work on the system of ballistic modifiers under discussion in this report involving all lots of propellant F488/1225 and some of the early lots of F488/1827 contained normal cupric salicylate. The slight efflorescence of resorcylic acid led to doubts about ballistic and chemical stability of this type of propellant and all later work has been based on basic cupric salicylate. Storage trials of propellant F488/1827 containing the basic salt have been completed satisfactorily and will be discussed, together with other development work on this propellant, in a separate report. Strand burning rates for the first six lots of F488/1827 containing the basic salt and for six lots of the same propellant containing the normal salt are compared below:

		MN/m^2					
		17.2	20.7	24.1	27.6	31.0	34.5
Normal cupric salicylate	Mean rate (mm/s)	36.6	37.1	36.6	36.3	37.6	38.9
	s.d.	1.40	1.32	1.24	0.94	0.66	0.51
Basic cupric salicylate	Mean rate (mm/s)	39.9	40.6	40.9	40.4	40.1	41.1
	s.d.	0.56	0.36	0.38	0.48	0.56	0.46

Although these results suggest that basic compound will give faster burning rates and slightly better platonisation than the normal salt it must be borne in mind that each set of figures relates to only a single batch. Three further consignments of basic cupric salicylate have since been tested and have given rates close to the mean rates for the basic salt quoted above, and alternative sources of the material are currently being explored, as well.

/2.3 .....

2.3 Variations in Basic Matrix

2.3.1 Nitrocellulose Level

Differences in strand burning rates of F488/1798 with 54 parts of nitrocellulose and F488/1828 with 49 parts of nitrocellulose are very small (see below). This small effect is also confirmed by a comparison between an early batch of F488/1827 containing normal cupric salicylate and F488/1783.

Composition No.	NC (12.2% N), parts	Strand Rates of Burning (mm/s) at MN/m^2					
		17	21	24	27.5	31	34.5
F488/1798	54	39.1	39.8	39.9	40.4	40.5	41.4
F488/1828	49	39.3	40.2	40.4	39.9	39.6	40.9
F488/1783	54	39.3	39.1	38.9	37.6	37.9	39.9
F488/1827	49	38.3	38.9	38.4	37.9	38.6	-

2.3.2 Low Nitrogen Nitrocellulose

In the relatively fast-burning propellant KU containing cupric oxide and lead stannate, replacement of the 12.2% N wood nitrocellulose by 11.7% N wood nitrocellulose was found to give faster burning rates. The lower nitrogen nitrocellulose was therefore tested in the present work at two levels. In a matrix containing 54 parts of nitrocellulose and with normal cupric salicylate, 11.7% N nitrocellulose gave an incipient plateau at about 17 MN/m^2 (F488/1834 - Table 1, Group 6). No firings were carried out at pressures above 21 MN/m^2 but, from a study of the curves, it is unlikely that there is any plateau above that pressure as found with the comparable propellant containing 12.2% N nitrocellulose (F488/1783 - Table 1, Group 7).

In a matrix with 49 parts of 11.7% N nitrocellulose, with basic cupric salicylate, and with the formulation adjusted to compensate for the lower calorimetric value of the nitrocellulose, a good plateau was obtained (F488/1857 - Table 1, Group 6) at slightly faster rates and at higher pressures than with the similar formulation containing 12.2% N wood nitrocellulose:

/Table .....

Propellant No.	NC, % N	Strand Rates of Burning (mm/s) at MN/m^2							
		14	17	21	24.5	27	31	34.5	38
F488/1857	11.7	37.7	39.8	41.5	42.0	42.2	42.7	41.9	42.5
F488/1827	12.2	38.9	40.6	41.4	41.4	40.9	41.1	42.4	-

The use of low nitrogen nitrocellulose to obtain plateaux at the highest possible pressures, as distinct from fastest possible burning rates, is discussed in Section 3.2.

2.4 Resorcinol

Resorcinol has given faster burning rates in a number of formulations. Its effect on burning rates of propellants containing basic cupric salicylate and lead beta-resorcylate has been tested in variants of the F488/1827 formulation and the results for these experiments are summarised in Table 1, Group 8.

Straight replacement of 2 parts of nitrodiphenylamine by 2 parts of resorcinol in the F488/1827 formulation gave burning rates no faster than rates for comparable batches of F488/1827 itself (see F488/1871). However, when the amount of Dixigloss was increased from 0.6 to 0.8 parts, the peak burning rate rose by 2.5 mm/s with, if anything, some improvement in platonisation (F488/1872). This contrasts favourably with the tendency (noted in Section 2.1.2) for similar formulations not containing resorcinol to be less well platonised when the Dixigloss level is increased to 0.8 parts. In subsequent experiments involving resorcinol and including only a little nitrodiphenylamine (to avoid excessive cooling) and with 4 parts of lead beta-resorcylate the addition of 1.0 part of Dixigloss gave burning rates of 46.5 mm/s between 21 MN/m^2 and 34 MN/m^2, but a further increase to 1.2 parts Dixigloss gave a less well platonised curve with no further increase in burning rates:

Composition No.	Resorcinol, parts	Dixigloss, parts	Strand Burning Rates (mm/s) at MN/m^2						
			17	21	24.5	27	31	34.5	38
F488/1903	1.5	0.8	44.4	45.5	45.5	45.0	44.2	44.7	46.1
F488/1912	"	1.0	45.1	46.5	46.5	46.2	46.5	46.5	48.1
F488/1913	"	1.2	43.6	45.3	46.3	46.5	46.5	46.5	47.6

/This .....

This series includes F488/1977, the fastest burning double-base propellant yet made at ERDE. This propellant has a calorimetric value of 4800 kJ/kg and burns at about 50 mm/s with a pressure exponent only marginally above zero between 24 and 31 MN/m^2. Intended as a feasibility study for a case-bondable cast propellant, the formulation has a very low nitrocellulose content, 42 per cent, and would be too soft for the normal extrusion process.

2.5 Alternative Ballistic Modifiers

None of the other ballistic modifiers tested have given faster strand burning rates than obtained from the basic cupric salicylate-lead beta-resorcylate-Dixigloss system.

Work on cupric oxide in combination with lead beta-resorcylate and Dixigloss has been reported already.[1] At calorimetric values of 4500 kJ/kg or more the burning rates are slightly slower and less well platonised than for corresponding propellants containing basic cupric salicylate with lead beta-resorcylate and Dixigloss. Basic copper beta-resorcylate also gave slightly lower burning rates but with a good mesa and, with Dixigloss increased from 0.6 to 1.0 parts, the rates matched those for F488/1827 containing basic cupric salicylate. Similarly tested, copper phthalate gave slower rates and a less well platonised curve even with the larger amount of Dixigloss.

Combinations of basic cupric salicylate with lead stannate, lead salicylate, lead phthalate and lead stearate, together with Dixigloss, at calorimetric values of about 4500 kJ/kg, have given plateaux or very low pressure exponents in the range 21 to 28 MN/m^2 at burning rates between 33 mm/s and 39 mm/s but in none of the propellants have burning rates reached those obtained with lead beta-resorcylate. In a hotter matrix lead stannate with basic cupric salicylate gave similar fast rates in this pressure range but with no platonisation.

In a cooler matrix with low nitrogen nitrocellulose, lead stannate, basic cupric salicylate and Dixigloss gave good platonisation in the relatively high pressure range 31 MN/m^2 to 42 MN/m^2 but again the burning rates are slower and the pressure range of platonisation is no more extensive than for F488/1906, the corresponding propellant containing lead beta-resorcylate (Section 3.2 of this Report).

2.6 Solvent Processing

For recoilless gun and other applications requiring extremely short burning times three formulations, including F488/1827, have been made by the solvent process with ether/alcohol and extruded in a number of shapes including hexagonal multi-tubular 37 hole charges. Strand burning rates for each of the three formulations prepared by the solvent process are summarised in Table 1, Group 9. Both F488/1827 itself and the harder version, F488/1838, give slightly slower burning rates than the corresponding lots prepared by the solventless process and, in each case, the curve is less well platonised. The cooler formation, F488/1853, with its high nitrocellulose content has no equivalent solventless version but again is poorly platonised.

/Since .....

Since extra rolling develops the lower end of the F488/1827 plateau, these results are consistent with the need for doing work on the propellant (by shearing) to develop the full plateau. Besides making smaller extruded webs feasible and the propellant much tougher, solvent processing is also regarded as a potentially safer process, since fires during rolling appear to be more serious and more frequent with these hot, fast burning compositions than with the general run of solventless propellants. In some applications involving composited sheet, e.g. Snifter IV motors, propellants such as F488/1827 tend to be too brittle particularly at low temperatures. Work is continuing on semi-solventless processing of these propellants to obtain the tougher physical properties always associated with solvent working, whilst retaining the fully platonised ballistics developed by rolling. Experience to date is that rolling of solvent dough does not fully develop the plateau or mesa burning rate characteristics (Table 1, Group 9). An additional solvent treatment of material produced to the final shape by the normal solventless process is another possibility currently being investigated.

3. EXTENSION OF PLATONISATION TO HIGHER PRESSURES

3.1 Lower Calorimetric Values

The experimental work discussed in earlier sections of this report, in general, was aimed at obtaining the fastest possible burning rates consistent with satisfactory platonisation. None of the formulations tested is platonised above 34 MN/m^2. However, in addition some effort has been directed towards obtaining plateaux or mesas extending into a higher pressure range for possible application in mortars or cross-section-limited rockets or launchers. Following the KU cordite development it was thought that lower calorimetric values would be helpful, and this has been found to be correct.

Strand burning rates for these batches are summarised in Table 1, Group 10 and some of the curves are illustrated in Fig. 3. It will be seen that a drop in calorimetric value of 850 - 1250 kJ/kg using dibutyl phthalate as a coolant results in little change in the pressure of the peak burning rate but that the mesa troughs, in general, are pushed to pressures above 40 MN/m^2. Burning rates, with mesa peaks at about 32 mm/s, are much lower than rates for similar but hotter formulations.

Replacement of dibutyl phthalate by the alternative plasticiser/coolant triacetin has, for its calorimetric value, given a more extended mesa than might be expected (F488/1926 - Table 1, Group 2; Fig. 3). This variant together with changes in modifier levels, use of resorcinol, further reductions in calorimetric value, etc. may be tested further. Work to test ultra-violet radiation absorbers such as 2,4-dihydroxybenzophenone as alternatives to Dixigloss carbon black has so far given negative results.

/3.2 .....

3.2 Low Nitrogen Nitrocellulose

Replacement of 12.2% N wood nitrocellulose by 11.7% N wood nitrocellulose in the hotter, faster, formulations is discussed in Section 2.3.2 above. The same lower nitrogen nitrocellulose has been assessed at two levels in cooler formulations F488/1906 and F488/1948 (Table 1, Group 6). The strand burning curves for these two lots are compared with curves for a similar formulation based on normal 12.2% N nitrocellulose in Fig. 4. This comparison suggests that low nitrogen nitrocellulose gives peak burning rates about 2.5 mm/s higher at about 31 MN/m^2 and mesa troughs at 48 MN/m^2 - about 7 MN/m^2 higher than normal 12.2% N nitrocellulose.

4. QUALITY OF INGREDIENTS

4.1 General

The ingredients used in the work described have, in general, complied with the following specifications:

Wood nitrocellulose (12.2% N)	CS 5377A
Wood nitrocellulose (11.7% N)	CS 1777
Dibutyl phthalate	CS 1969
Triacetin	BS 1997
Nitrodiphenylamine	DEF 4509
Carbamite	DEF 4508
Resorcinol	TS 570

The wood nitrocellulose (12.2% N) used for most of the work was made from Blend V paper. The use of nitrocellulose made from Blend VI paper has resulted in changes in burning rates of some platonised propellants in production at ROF Bishopton, but experience with propellant F488/1827 both at Bishopton and at ERDE and with other relevant formulations at ERDE indicates that this change is not a significant factor with the propellants containing lead beta-resorcylate and cupric salicylate with which this report deals.

4.2 Ballistic Modifiers

No formal specification for lead beta-resorcylate existed when the two batches used in the work covered by this report were manufactured but, in each case, the lead content of the material is below the minimum required of the current specification TS 556.

/Four .....

Four batches of basic cupric salicylate were ordered to National Lead Company Specification P957/55. The first of the batches, used for the bulk of the work, was marginally below the specification limit in respect of salicylic acid determination. More recently a method of manufacture has been developed at ERDE; the strand burning rates of propellant F488/1827 containing several batches of basic cupric salicylate made at ERDE are very close to the rates obtained with the commercial product.

5. CONCLUSIONS

5.1 Lead beta-resorcylate and cupric salicylate in combination can give platonised burning rates of up to 33 mm/s in the range 14 - 21 MN/m^2 without the addition of carbon black.

5.2 The addition of carbon blacks moved the plateaux to faster rates and higher pressures. In particular, with Dixigloss carbon black, good plateaux were obtained up to 43 mm/s in the range 21 - 31 MN/m^2 at a propellant calorimetric value of about 4600 kJ/kg.

5.3 The replacement of some nitrodiphenylamine by resorcinol contributed towards faster burning rates and a full plateau burning rate of 46.5 mm/s was achieved.

At lower calorimetric values, of the order of 3400 kJ/kg, with lead beta-resorcylate, cupric salicylate and Dixigloss, platonisation was extended to at least 45 MN/m^2 with burning rates of 28 - 30 mm/s. A slight increase in rate and extension of the plateau limits to 51 MN/m^2 resulted from the use of 11.7% N wood nitrocellulose.

5.4 Small-scale tests of activated charcoals and activated Dixigloss did not give rates faster than could be obtained with larger amounts of untreated Dixigloss.

6. REFERENCE

1. Baker, E.A. ERDE Report No. 10/R/67

/TABLE 1 .....

TABLE 1

Table Group	F488/	Formulation, parts									Other Ingredients, parts		Calorimetric Value (kJ/kg)		Strand Rates of Burning (mm/s) at MN/m^2										
		Wood NC	% N	NG	DBP	2-NDPA	Lead Beta -Resorcylate	Cupric Salicylate	Basic Cupric Salicylate	Dixigloss			Matrix* (Calc.)	Propellant (Fired)	14	17	21	24	27.5	31	34.5	38	41.5	45	48
1	1225	54.0	12.2	40.0	-	2.0	3.0	2.0	-		Ukarb	0.4	5040	4540	31.8	32.5	32.3	31.8	33.0	-	-	-	-	-	-
	1889	"	"	"	-	"	"	-	2.0				"		31.3	32.7	33.2	32.8	33.8	35.6	-	-	-	-	-
	1890	"	"	"	-	"	"	-	"		Ukarb	0.1	"		31.8	33.4	33.4	33.0	33.5	-	-	-	-	-	-
	1891	"	"	"	-	"	"	-	"		Ukarb	0.2	"		32.6	33.7	33.7	33.3	33.7	-	-	-	-	-	-
	1892	"	"	"	-	"	"	-	"		Ukarb	0.3	"		33.3	34.7	34.2	33.3	33.3	-	-	-	-	-	-
	1897	49.0	"	44.0	1.0	"	2.0	-	"				5060		28.8	29.7	29.2	28.9	30.0	-	-	-	-	-	-
2	1761	54.0	12.2	40.0	-	2.0	3.0	2.0	-	0.15			5040		31.1	31.5	30.7	30.5	32.3	-	-	-	-	-	-
	1762	"	"	"	-	"	"	"	-	0.4			"		34.6	35.5	35.8	35.3	35.1	36.6	-	-	-	-	-
	1783	"	"	"	-	"	"	"	-	0.6			"	4448	37.9	39.3	39.1	38.9	37.6	37.9	39.9	42.0	-	-	-
	1798	"	"	"	-	"	"	"	-	0.8			"		37.1	39.1	39.8	39.9	40.4	40.5	41.4	-	-	-	-
	1826	"	"	"	-	"	"	"	-	0.7			"		-	39.6	40.1	39.6	38.9	38.9	-	-	-	-	-
	1838	"	"	38.4	-	"	"	-	2.0	0.6			5020	4470	38.5	40.0	40.0	39.2	38.0	38.0	38.6	40.2	42.0	-	-
	1886	50.0	"	44.0	-	"	"	-	"	0.1			5190		-	34.5	34.8	34.5	35.6	37.6	40.4	-	-	-	-
	1887	"	"	"	-	"	"	-	"	0.2			"		34.2	35.7	36.3	35.6	35.8	37.9	39.9	-	-	-	-
	1888	"	"	"	-	"	"	-	"	0.3			"	4690	35.7	37.3	37.8	37.5	37.4	38.6	40.6	-	-	-	-
	1905	53.0	"	38.0	7.0	"	"	-	"	1.3			4040		-	-	29.8	31.2	32.7	32.3	31.2	29.9	29.0	29.0	30.1
3	1784	54.0	12.2	40.0	-	2.0	3.0	2.0	-		Activated Dixigloss	0.15	5040		-	39.2	41.0	41.9	41.9	42.8	-	-	-	-	-
	1799	"	"	"	-	"	"	"	-		Activated Dixigloss	0.3	"		33.9	36.0	36.3	36.1	36.4	37.9	39.1	-	-	-	-
	1851	49.0	"	44.0	1.0	"	"	-	2.0		Activated Charcoal	0.2	5060		31.3	32.4	32.2	31.5	32.7	34.8	37.1	40.0	42.7	-	-
	1852	"	"	"	"	"	"	-	"		Activated Charcoal	0.4	"		31.6	32.7	32.9	31.5	32.7	34.8	37.1	-	40.9	-	-
	1873	"	"	"	"	"	"	-	"		Sugar Charcoal	0.3	"		30.1	31.7	31.7	30.9	31.7	33.8	35.6	-	-	-	-
	1874	"	"	"	"	"	"	-	"		Sugar Charcoal	0.6	"		30.1	31.4	31.7	31.0	31.9	34.0	36.3	-	-	-	-
4	1896	49.0	12.2	44.0	1.0	2.0	2.0	-	3.0				5060	4586	29.8	28.5	26.5	27.5	29.6	-	-	-	-	-	-
	1897	"	"	"	"	"	"	-	2.0				"		28.8	30.0	28.6	28.6	30.4	32.8	34.8	-	-	-	-
	1898	"	"	"	"	"	"	-	1.0				"		26.6	27.6	27.6	28.9	31.4	34.5	37.3	-	-	-	-
	1899	"	"	"	"	"	1.0	-	"						22.9	23.8	25.5	27.9	30.9	34.5	37.3	-	-	-	-
	1900	"	"	"	"	-	2.0	-	3.0		Carbamite	2.0	5040		28.3	28.4	27.3	27.1	28.6	30.7	33.0	-	-	-	-
	1907	"	"	"	"	2.0	1.0	-	2.0				"	4682	23.7	23.6	24.7	26.8	29.6	-	-	-	-	-	-
5	1827	49.0	12.2	44.0	1.0	2.0	3.0	-	2.0	0.6			5060	4498	38.9	40.6	41.4	41.4	40.9	41.1	42.4	(Typical rates)			
	1854	"	"	"	"	"	"	-	3.0	0.6			5040	4393	37.2	39.2	41.0	41.0	40.4	40.4	40.6	42.0	-	-	-
	1855	"	"	"	"	"	2.0	-	"	0.6			"		35.4	37.2	38.7	38.9	38.9	38.9	39.6	-	-	-	-
	1856	"	"	"	"	"	3.0	-	1.0	0.6			"		38.8	40.8	41.7	41.4	40.7	40.6	41.7	-	-	-	-
	1894	"	"	"	"	"	4.0	-	2.0	0.8			"		39.0	41.1	42.5	42.7	42.5	41.7	41.4	42.2	43.7	-	-
	1902	"	"	45.0	-	0.5	3.0	-	"	0.8	Resorcinol	1.5	5210		40.0	42.0	44.0	44.8	45.0	45.0	45.5	-	-	-	-
	1903	"	"	"	-	"	4.0	-	"	0.8	Resorcinol	1.5	"		42.3	44.4	45.5	45.5	45.0	44.2	44.7	46.1	48.3	-	-

*Matrix Cal. Val. Calculated Per 100 Parts Matrix

/continued .....

TABLE 1 (continued)

Table Group	F488/	Formulation, parts: Wood NC	% N	NG	DBP	2-NDPA	Lead Beta -Resor-cylate	Cupric Sali-cylate	Basic Cupric Sali-cylate	Dixi-gloss	Other Ingredients, parts	Calorimetric Value (kJ/kg): Matrix (Calc.)*	Propellant (Fired)	Strand Rates of Burning (mm/s) at MN/m^2: 14	17	21	24	27.5	31	34.5	38	41.5	45	48
6	1834	54.0	11.7	40.0	-	2.0	3.0	2.0	-	0.6		4870	4263	35.7	37.3	38.5	-	-	-	-	-	-	-	-
	1857	49.0	"	45.0	-	"	"	-	2.0	0.6		5060	4460	37.7	39.8	41.5	42.0	42.2	42.7	41.9	42.5	43.8	-	-
	1906	53.0	"	39.2	5.8	"	"	-	"	1.0		3930	3473	-	-	32.7	33.2	33.7	33.5	33.3	32.1	30.5	30.0	30.7
	1948	55.0	"	36.5	6.5	"	"	-	"	1.0		3810	3251	-	-	28.3	30.4	31.2	31.5	30.7	29.9	29.1	28.6	28.6
7	1783	54.0	12.2	40.0	-	2.0	3.0	2.0	-	0.6		5040		38.0	39.3	39.1	38.9	37.6	37.9	39.9	42.0	-	-	-
	1798	"	"	"	-	"	"	"	-	0.8		"		37.1	39.1	39.8	39.9	40.4	40.5	41.4	-	-	-	-
	1827M	49.0	"	44.0	1.0	"	"	-	2.0	0.8		5060		38.7	39.8	41.2	41.2	40.9	40.9	41.2	42.8	44.0	-	-
	1828	"	"	"	"	"	"	2.0	-	0.8		"		-	39.3	40.2	40.4	39.9	39.6	40.9	-	-	-	-
	1901	"	"	45.0	-	"	"	-	2.0	0.8		5210	4657	39.2	41.8	43.5	43.7	43.7	43.7	45.0	-	-	-	-
8	1871	49.0	12.2	44.0	1.0	-	3.0	-	2.0	0.6	Resorcinol 2.0	5060	4548	38.3	40.3	41.5	41.7	41.7	41.4	41.7	43.0	45.1	-	-
	1872	"	"	"	1.0	-	"	-	"	0.8	Resorcinol 2.0	"		39.0	41.1	43.0	43.1	43.2	43.2	42.9	44.0	45.5	-	-
	1902	"	"	45.0	-	0.5	"	-	"	0.8	Resorcinol 1.5	5210		40.0	42.0	44.0	44.8	45.0	45.0	45.5	-	-	-	-
	1903	"	"	"	-	"	4.0	-	"	0.8	Resorcinol 1.5	"		42.3	44.4	45.5	45.5	45.0	44.2	44.7	46.1	48.3	-	-
	1912	"	"	"	-	"	"	-	"	1.0	Resorcinol 1.5	"	4619	43.0	45.1	46.5	46.5	46.2	46.5	46.5	48.1	49.6	-	-
	1913	"	"	"	-	"	"	-	"	1.2	Resorcinol 1.5	"		41.0	43.6	45.3	46.3	46.5	46.5	46.5	47.6	49.1	-	-
	1914	53.0	"	41.0	-	"	"	-	"	0.8	Resorcinol 1.5	5100	4435	40.5	42.6	43.5	43.7	43.5	42.4	42.4	43.5	45.1	-	-
	1915	"	"	"	-	"	"	-	"	1.0	Resorcinol 1.5	"		39.5	42.1	44.0	44.7	45.0	44.7	44.0	45.5	47.1	-	-
	1977	42.0	"	50.0	-	"	"	-	"	1.0	Resorcinol 1.5	-	4800	44.2	47.7	49.1	50.3	50.6	50.8	51.4	52.8	55.5	-	-
9	1827S	49.0	12.2	44.0	1.0	2.0	3.0	-	2.0	0.6	Solvent Processing	5060		39.0	-	40.2	40.6	40.7	-	40.9	-	44.3	-	49.4
	1838	54.0	"	38.4	-	"	"	-	"	0.6	" "	5020		35.2	37.0	38.5	38.8	39.1	39.1	39.4	42.0	44.6	-	-
	1853	65.0	"	27.4	-	"	"	-	"	0.6	" "	4620		29.3	31.2	33.4	35.5	36.3	36.8	37.6	38.2	-	-	-
	1838	54.0	"	38.4	-	"	"	-	"	0.6	Semi-solvent	5020		33.0	34.5	36.0	37.0	38.0	38.8	40.0	-	-	-	-
10	1884	53.0	12.2	38.0	7.0	2.0	3.0	-	2.0	0.6		4040	3531	29.1	30.4	31.3	31.7	31.2	30.5	29.2	28.7	29.3	-	-
	1895	"	"	"	"	"	"	-	"	1.0		"	3590	29.3	31.4	32.9	33.2	33.0	32.5	31.0	29.9	29.7	30.0	31.3
	1904	"	"	36.5	8.5	"	"	-	"	1.0		3810		-	-	30.5	30.7	30.5	29.5	27.9	26.9	26.4	26.2	27.3
	1905	"	"	38.0	7.0	"	"	-	"	1.3		4040		-	-	29.8	31.2	32.7	32.3	31.2	29.9	29.0	29.0	30.3
	1926	55.0	"	35.5	-	"	"	-	"	1.0	Triacetin 7.5	4180	3636	27.5	30.4	32.3	32.3	32.2	31.5	30.2	28.9	28.7	29.0	30.1

*Matrix Cal. Val. Calculated Per 100 Parts Matrix

CONFIDENTIAL

ERDE TR4

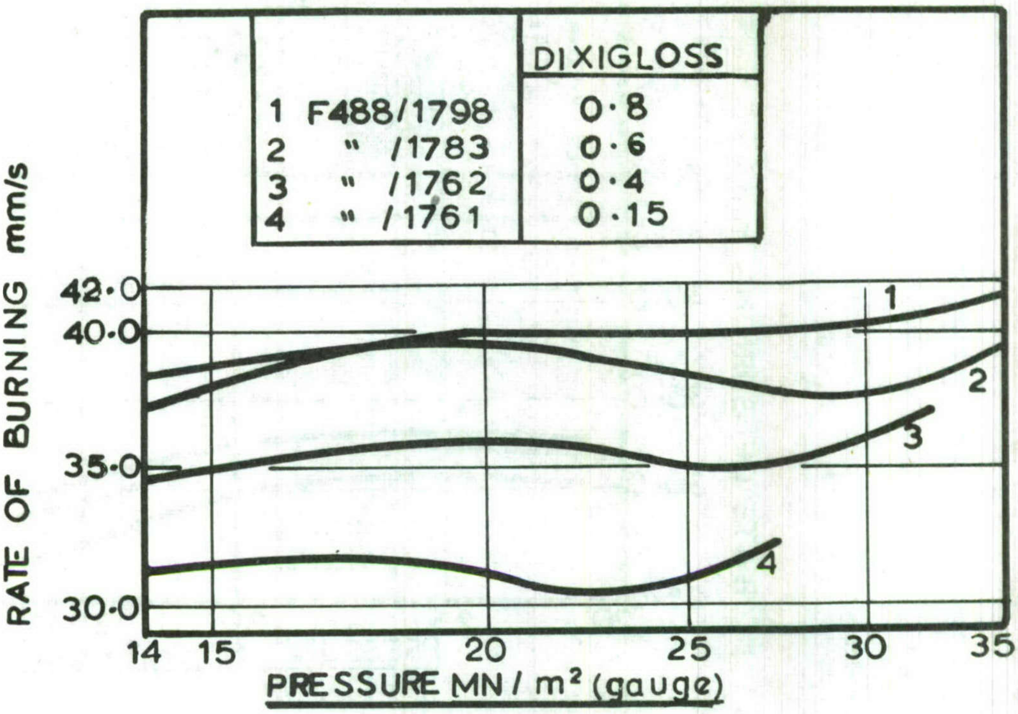
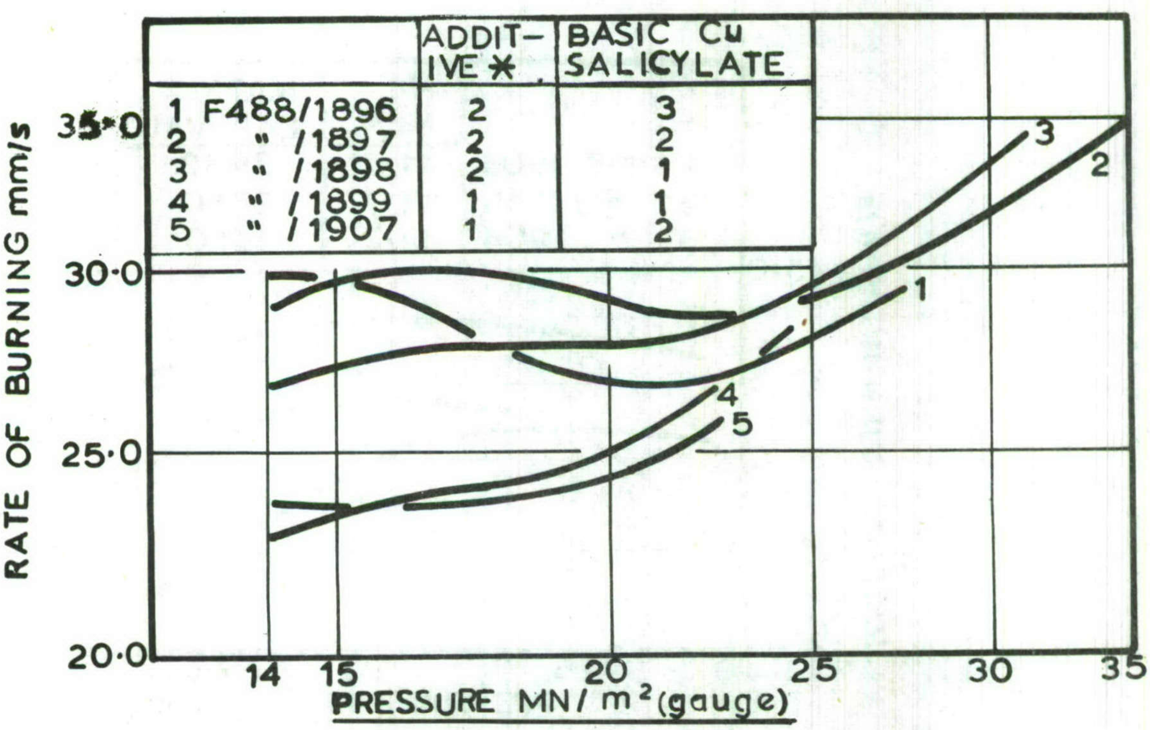


FIG 1



* Pb BETA-RESORCYLATE

FIG 2

CONFIDENTIAL

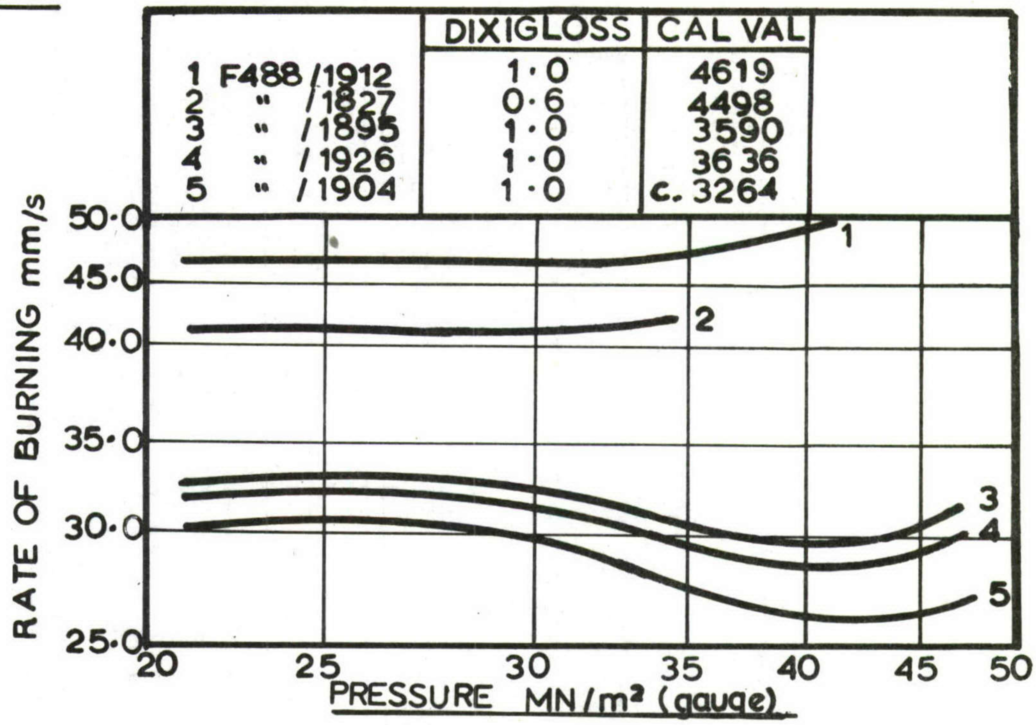

DIXIGLOSS
CAL VAL
1 F488/1912 1·0 4619
2 " /1827 0·6 4498
3 " /1895 1·0 3590
4 " /1926 1·0 3636
5 " /1904 1·0 c. 3264
RATE OF BURNING mm/s
50·0
45·0
40·0
35·0
30·0
25·0
20
25
30
35
40
45
50
PRESSURE MN/m² (gauge)
1
2
3
4
5

FIG 3

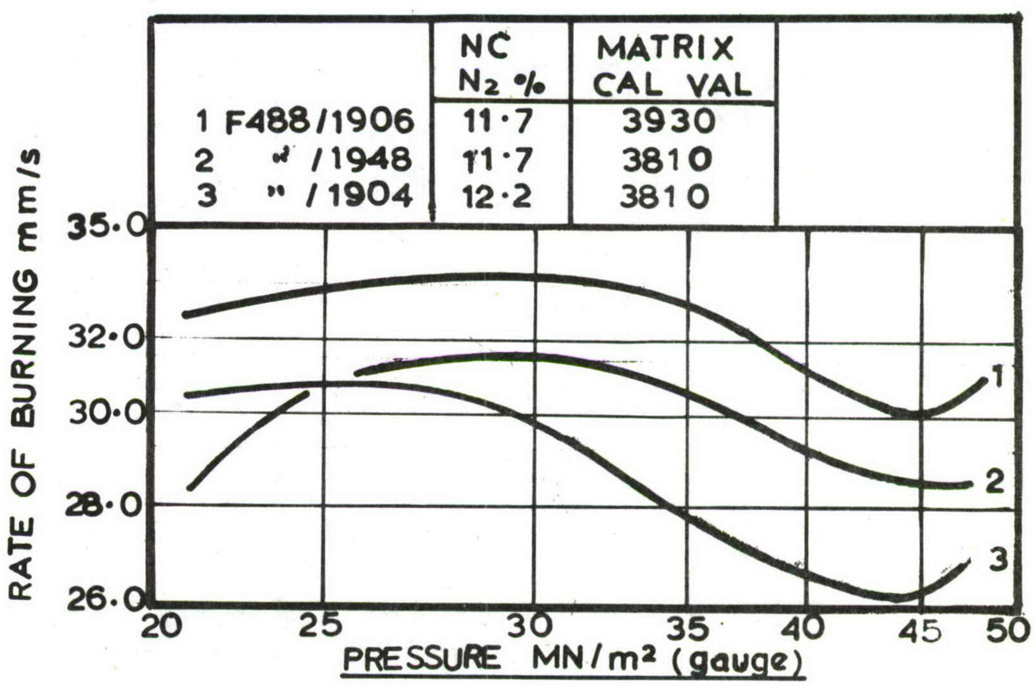

NC N₂ %
MATRIX CAL VAL
1 F488/1906 11·7 3930
2 " /1948 11·7 3810
3 " /1904 12·2 3810
RATE OF BURNING mm/s
35·0
32·0
30·0
28·0
26·0
20
25
30
35
40
45
50
PRESSURE MN/m² (gauge)
1
2
3

FIG 4

DETACHABLE ABSTRACT CARDS

The Abstract Cards detached from this document are located as follows:

1. Section .... Signature .... Date ....

2. Section .... Signature .... Date ....

3. Section .... Signature .... Date ....

4. Section .... Signature .... Date ....

CONFIDENTIAL

CONFIDENTIAL

[dstl]

Information Centre
Knowledge Services
[dstl] Porton Down,
Salisbury
Wilts
SP4 0JQ
22060-6218
Tel: 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD516318

Date of Search: 1 August 2008

Record Summary: AVIA 37/1210
Title: Very fast burning cordites
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) ERDE TR 4
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.