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ADVISORY COUNCIL ON SCIENTIFIC RESEARCH
AND TECHNICAL DEVELOPMENT

U.P. PROPELLANTS SUB-COMMITTEE

Plastic Propellant

Interim Report for the period September - December 1942.

Work carried out at P.D.E., Aberporth and Chemical Section, Fort Halstead.

by

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SUMMARY

Cone & Cylinder Charge.

Smooth burning has been obtained between -20° and +140°F, for two modifications of the 2 inch diameter cone and cylinder charge. A more satisfactory inert plastic composition, based on ammonium sulphate, has been developed.

End Burning Charge.

Limited success over the service temperature limit has been obtained with 5 inch lengths of the 2 inch diameter charge; the chief difficulty is undoubtedly due to the presence of air in the plastic composition, giving rise to a large bulk expansion of the charge.

Plastic Compositions.

A study has been made of the preparation of compositions containing nitrocellulose - triacetin as binder by plastic milling. Excessively long times of milling are required, particularly with the larger capacity incorporators. With dispolene as binder, a satisfactory composition is produced by simple mixing, without plastic milling, and the time required is considerably shorter. Owing to the inadequate supplies of dispolene and triacetin, attention has been turned to binders in larger potential supply. Preliminary experiments with oxidised castor and rape-seed oil binders show that although plastic milling takes place, satisfactory compositions may be obtained in a reasonable time with 12-13% binder.

(A). CONE & CYLINDER CHARGE

1. Functioning over service temperature range.

With the faster burning type of plastic propellant (P.372, N.C.-triacetin binder) it was reported previously (P.D.E. Report 1942/77) that the modified or "open" cone and cylinder charge failed at high temperatures. This has been found to be due to the very soft nature of the inert plastic composition (IP5, ZnO - N.C.-triacetin) which was used to prevent burning at the head end surface of the charge. At 140°F. this composition flowed appreciably, leaving the surface unprotected; earlier results had established that if burning was allowed on this surface, bursts occurred at high temperatures with the faster-burning propellants. The inert plastic was replaced by one consisting of 70% sodium nitrate, 13% ammonium picrate, and 17% binder B.140 (IP6). A number of rounds have been filled with composition P372, using the "open" cone and cylinder charge, which has the cylindrical hole extended to the end, and a 0.5 inch space between the end of the charge and the head, the end surface being protected by a 0.2 inch layer of inert plastic IP6. A diagram of this charge shape, hereinafter referred to as Type "A" is given in fig.1. These rounds burnt smoothly at 140°F; details of these firings are given in Table I. It was also found that the original, or "blind" cone and cylinder charge functioned correctly at high temperatures when the layer of luting between the charge and the head closure was replaced by IP6. (Table I - rounds 1044-5).

The cone and cylinder charge has been further modified by dispensing with the space at the head end. The cylindrical hole is, as in Type "A", extended to the end of the charge, which is covered with a 0.2 inch layer of inert plastic. The inert plastic is pressed tightly against the perforated head obturator and head closure. The complete charge is thus supported at all points in the rocket tube. A diagram of this charge, Type "B", is given in fig.1. The results of firing a number of rounds, filled with P.372 in this shape, at the extremes of temperature are given in Table I. Smooth burning was obtained in all cases.

Before the development of the Type "B" charge, a few full length (22.5") rounds were filled with P.295 using the Type "A" charge. The inert plastic (IP4) consisted of zinc oxide and dispolene 75. No bursts occurred at the upper and lower temperature limits. Details of these firings are given in Table II; the pressure-time and thrust-time curves of these rounds are reproduced in figs.2 - 8. The curves of the rounds fired at 140°F. are very rounded and similar to those given by the original "blind" cylinder charges. No explanation of this has yet been advanced, but it is thought to be connected with a possible distortion of the charge by the pressure difference along the tube.

It has not been found possible to measure this pressure difference, as electrical pressure gauges placed at the head and choke end of a 22.5 inch charge record substantially the same pressure. Four such pressure-time curves of 22½" rounds at air temperature and at 140°F. are reproduced in figs. 9 and 10.

2. Development of an inert plastic composition.

The inert plastic composition, IP6, used for protecting the end surface of P.372 in the above trials, was composed mainly of sodium nitrate and was relatively hard. It also cracked at small percentage compressions so that it is probable that it would not form a satisfactory protective covering for the end surface of the charge after prolonged climatic storage.

Further work has been done on producing a composition which is incombustible, but has similar plastic properties to the propellant itself. The same binder (B.140) was used as in the propellant. The solids were chosen so as to give an inert and neutral composition, which would not form sensitive picrates in contact with the ammonium picrate at the surface of the propellant. The compositions were prepared by mixing for 15-30 minutes in a small (150 gm.) incorporator. A number of compositions were examined. Their plastic properties are given in Table III. P.384 is also included in the Table for comparison; this composition is similar to P.372, but has a lower sodium nitrate content, and a correspondingly lesser chemical action on the rocket tube during firing (c.f. P.D.E. Report 1942/77 page 5.)

It was observed that sodium chloride gave a good plastic when mixed with an equal amount of ammonium picrate, but failed to do so when used alone. This is also probably true of sodium nitrate. Calcium sulphate (anhydrous) and calcium carbonate gave soft plastics with a marked work hardening.

The most satisfactory plastic compositions were obtained with ammonium oxalate and ammonium sulphate. From the supply position ammonium sulphate is to be preferred. pH measurements of dilute (1%) solutions of ammonium sulphate and of the plastic composition (IP14) derived from it gave values of 5.72 and 5.88 respectively. By adding a trace of calcium carbonate (0.5% of the solid content) the pH could be brought back to 6.92. The addition of a small amount of ammonium picrate shortened the time required for complete incorporation. A small number of rounds have been filled, with P.384, Type "B" cone and cylinder charge 6 x 2.14 inch diameter, using IP.14 (ammonium sulphate - N.C.-triacetin) as the inert plastic. These fired satisfactorily at -5 and at 140°F.

(B). END-BURNING CHARGE

1. Functioning over service temperature range.

Where a long time of burning is required the propellant may be loaded into a tube and burnt at its end surface. Experiments have been carried out to test the suitability of the plastic propellant in this form of charge. A shortened 2 inch rocket tube was used, giving a charge-space length of 6.5 inches, 500 gm. of propellant was loaded into the tube by hand-stemming. This gave a charge length of about 5 inches, which burnt under pressure for about 10-20 seconds, depending upon the composition that was used. Preliminary trials at the upper and lower temperature limits were made with compositions P.295 and P.372, the former containing dispolene as binder and the latter, N.C.-triacetin. The results of these firings are given in Tables IV - VI. It is seen that there is a very high incidence of failures, the bursts occurring almost immediately after ignition. Examination of the fragments of the bursts indicated clearly that the composition had burnt down the side of the tube, owing to the charge separating from the tube at the low temperature.

If separation from the tube took place only for a short distance at the top or free end of the charge, it was thought that a number of perforated obturators inserted in the charge and fitting tightly against the tube might prevent the flame travelling down the whole length of the tube. Four rounds were filled in this manner, two with P.295 and two with P.372. Service 2 inch rocket head obturators, perforated with a 1 inch diameter hole, were used, and inserted at 1 inch intervals in the charge. The results of firing at -20°F. are shown in Tables IV and V (Rounds 1085-6 and 1088-9). With P.372 the rounds burst after 0.5 and 2 seconds, instead of immediately after ignition; with P.295 one round burst immediately but the other burnt successfully. The thrust of this latter round, however, varied periodically from 3 to 7 lbs., corresponding approximately with the spacing of the obturators in the charge. This would appear to show that

the composition had separated from the tube for the greater part of its length and that the spacing of the obturators had prevented the flame from travelling down the side of the tube far enough in advance of the normal burning front for the thrust to rise above 7 lbs., compared with the normal value of 3-4 lbs.

Measurements have shown that the plastic compositions as prepared at present contain an appreciable amount of air (P.295 approximately 6%), P.361, similar to P.372, approximately 2% - P.D.E. Report 1942/62). On pressing the cylindrical block of composition in the end-burning charge at 0.25 tons per sq.inch using a flat plunger, the subsequent expansion of the included air produces a "reassertion" of the composition and the free end of the charge forms a convex surface. In a long charge the movement is sufficient to break up the surface and produce an initial peak during burning. Round 1053 (Table VI), with an eleven inch charge, gave over double the normal thrust during the first second of burning. It was usual, therefore, to fill the round by hand-stemming the composition, so that the pressure would not be high enough to produce any movement after filling. An appreciable movement may still however, be produced by changes in temperature. On cooling, the ideal plastic charge would remain adhering to the walls of the tube and sink in, forming a concave surface at the free end of the charge. From the firing results with P.372 and P.295 it is apparent that these compositions are not sufficiently plastic at low temperatures to behave in this way, and to accommodate the shrinkage without separating from the tube.

Further trials have **therefore been** carried out with a much softer composition - P.388. This contains 20% N.C.-triacetin binder instead of 15%, as in P.372. The plastic properties of this composition at air temperature are compared with P.372, P.295 and P.384, in Table VII. It was found that when incorporating an N.C.-triacetin binder in an amount above that required to make a composition of normal plasticity, (e.g. P.372, P.384), it is difficult to control the plasticity accurately; values are therefore given for the plastic properties of individual batches of P.388 used in the firing trials. P.388 flows under the conditions of test for the normal plastic compositions (load of 130 gm./cm.^{2}) No flow was observed, however, when 2 inch diameter charges were stored horizontally at 140°F, but it is probable that with larger diameter charges the free end surface might have to be supported. This would not be so difficult as with the internal burning shapes. It follows that if it should prove necessary, a much lower yield value could be accepted for the end-burning charge compositions.

The results of firing rounds filled with P.388 are given in Table VIII. For charges stemmed in the tube at air temperature smooth burning was obtained down to -5 F. No firings have yet been made below this temperature. For satisfactory functioning at the upper temperature limit it was found necessary to load in the charge at an elevated temperature, (see page 5.) Rounds thus filled at 140°F. gave an appreciable incidence of bursts at -5° F; subsequent examination showed evidence of burning at the wall. In cooling from 140°F. to -5°F. there will be a considerable contraction of the charge, and it is evident that P.388 is still not sufficiently soft to take up the large movement at the end of the charge without separating from the tube.

This large movement of the charge with temperature could be most satisfactorily overcome by reducing the amount of air included in the plastic composition. If this is not found possible without great difficulty, a still softer composition may be used, and filling temperatures lower than 140°F. may be tried. The use of an adhesive to prevent the charge separating from the wall at low temperatures has yet to be investigated.

The behaviour of the end-burning charge at the upper temperature limit has also been examined. The normal method of filling by hand-stemming at air temperature gave immediate bursts at 140°F. (Table VI). Examination of a hot round showed clearly the cause of the bursts; the charge had expanded, forming a convex end-surface containing innumerable cracks. A number of rounds were then filled by hand-stemming the composition at 140°F, so that there would be no further movement of the charge before firing. These rounds, however, also burst when fired at 140°F. (Table IX, Rounds 1119, 1129, 1165-6). In order to ascertain whether the cause of the bursts was related to the soft nature of P.388, similar rounds were filled with P.384 and fired at -5 and 140°F. These all burst. (Table X). One possible cause was that the burning of the igniter might displace violently the surface of the hot composition and cause irregular burning. This was suggested by the appearance of some fragments of composition recovered from a burst at 140°F; there were indications that burning had proceeded from a point in the centre of the end surface down into the charge. A comparatively mild igniter was used in the above firings - an electric fuze with 1.5 gm. of S.R.252 (sulphurless gunpowder, potassium nitrate, silicon), but in most cases the free volume above the surface of the charge was small. The free volume for each round is given in Table IX. On increasing this volume from 170 to 1080 c.c. smooth burning at 140°F. was obtained, although with the same igniter (1.5 gm. S.R.252) ignitions, intervals of 1-2 seconds were observed. One round was also fired successfully at 140°F. with a free volume of 170 c.c. using an electric fuze and 0.5 gm. S.R.252 sprinkled on the surface of the charge. Two similar rounds, however, failed to ignite.

(C). PLASTIC COMPOSITIONS

1. Nitrocellulose-triacetin binder.

Previous experiments have shown (P.D.E. Report 1942/47, page 2) that the satisfactory incorporation of N.C.-triacetin or N.C.-nitrobenzene binders into ammonium picrate-sodium nitrate mixtures can only be carried out by prolonged milling, during which time there is a very considerable reduction in particle size. This plastic milling, as it is termed, enables the percentage of binder to be reduced below that required for a simple mixing, as in the dispolene binder compositions. For example, while 20% dispolene gives a composition of satisfactory plastic properties, a similar amount of an N.C.-triacetin binder, plastic milled, gives a very soft composition of low yield value (see page 4); in order to produce a normal plastic composition the binder must be reduced to 15 or 16 per cent.

These preliminary results were obtained in a Werner-Pfleiderer mill of 5 lb. capacity. A number of incorporations have now been carried out in mills of similar type, but of different capacities. The usual method of charging the mill consists of adding first the sodium nitrate (120 b.s.s.) and binder, followed after mixing for a few minutes by the correct amount of ammonium picrate (120 b.s.s.) After the ingredients have been completely mixed the charge appears as a wet powder, which gradually aggregates during the milling. During the last stages of aggregation, the large lumps of plastic appear to "ride" on top of the blades, and then finally settle down round the blades forming one coherent mass. Measurements on samples withdrawn from the mill during the incorporation show that the plastic properties of the composition change fairly rapidly during this last stage, and milling is usually continued for a further 25-50 per cent of the time taken to form the coherent mass. At the end of this time there is a long period during which the softness of the composition remains approximately constant, while the percentage compression for crack formation slowly increases. After very prolonged milling the composition gradually hardens. During the milling the colour of the mixture changes from an orange-red (red ammonium picrate has been used) to a light yellow, indicating a continuous decrease in particle size.

The temperature also rises progressively. The time taken to reach th coherent plastic mass, described above, forms an approximate standard for comparing the times of incorporation necessary for different compositions and for various size batches. These times are given in Table XI.

It is seen that with the N.C.-triacetin binder a considerable time for milling is needed to produce a composition of normal plastic properties (e.g. P.384), and that the time of milling increases rapidly with the size of charge. P.388, a soft composition, of low yield value, requires a shorter time but the difference in time is not so marked in the larger batches. Doubling the speed of the blades approximately halves the time (Table XI, bottom half); these latter speeds are those recommended by the makers of the incorporators, and it is doubtful whether the speed could be further increased. By adding the solids gradually to the mill a reduction in milling time of approximately 25% was obtained. For comparison, the approximate times of incorporation are given for dispolene binders. These show the great advantage, for time of incorporation, of the simple mixing over the plastic milling. Plastic-milled compositions, however, have better plastic properties, e.g. a high percentage compression for crack formation, and as far as present evidence shows, behave more satisfactorily under climatic storage in a filled round. Dispolene, in any case, has the disadvantages of low performance and short supply. It would seem desirable to obtain a binder which can produce a satisfactory plastic composition either by simple mixing or by considerably shorter times of plastic milling.

2. Oxidised vegetable oil binders.

Blown castor and blown rape-seed oils have been investigated as possible binders for plastic compositions. The samples examined include oils of different viscosities. The properties of plastic compositions prepared from these oils are given in Tables XII and XIII.

A striking feature of the results is the small amount (13%) of oil necessary to produce a satisfactory plastic composition. The lowest viscosity oil examined, blown castor oil, nominally 30 poises, gave a very "short" and friable composition, but for the higher viscosity oils, it was noticeable that the same percentage (13%) of binders, but with widely differing viscosity, all gave compositions of approximately similar plastic properties. Two of the oils, viz. gelled rape oil and heavy blown castor oil, were examined on a larger scale of incorporation. It is apparent that plastic milling, and not simple mixing, is necessary to produce a plastic composition, but the times of milling are considerably shorter than with the N.C.-triacetin binder. For comparison, times for incorporation of extra heavy blown castor oil in batches up to 30 lb. are included in Table XI.

The gelled oils appeared to be markedly thixotropic, and the viscosity figures, measured in a falling sphere viscometer, can only be very approximate. Two samples of blown and gelled rape oil, B150/1 and B150/2, gave considerably different times of incorporation.

A 5 lb. batch of composition prepared with heavy blown castor oil was milled for a time considerably greater than that required to produce a satisfactory plastic composition. Samples were withdrawn from the mill at intervals, and their plastic properties examined. The results are tabulated in Table XIV, and given graphically in fig.11. The time taken for the composition to reach a coherent mass was 25 minutes; the composition softened noticeably during the next 30 minutes. No change in softness occurred, within the limits of experimental error, for the next hour, after which a progressive hardening took place. The rate of temperature rise of the composition in the mill decreased after the

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It is propos
composition P.39

3. Combustible r

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binder.

composition had attained its maximum softness. There was a very marked change of colour from orange-red to pale yellow during the milling, the particle size distribution evidently being most favourable for close packing of the crystals and filling of the voids when the composition attained its maximum softness. The subsequent hardening and resulting slow temperature rise shows that further reduction in particle size, resulting in a less favourable distribution, takes place.

It is proposed to carry out a small-scale firing trial with composition P.399, containing 13% of extra heavy blown castor oil.

3. Combustible resin binders.

A small amount of plastic composition (P.385) containing a combustible resin binder has been prepared and examined for performance on firing. 15% of combustible resin was used; plastic milling took place, but the time of milling for a 5 lb. charge was somewhat shorter than that necessary for preparing a similar charge containing an N.C.-triacetin binder. The plastic properties of the composition, together with results of firing, are given in Table XV. The performance index, 135, compares favourably with the value of approximately 125 obtained on the same scale of firing with a composition containing an N.C.-triacetin binder.

TABLE I

Charge. Shape: 6 x 2.14 inch diam., cone and cylinder.

Area: Approximately 18 sq.in., depending on design of charge.

Composition: P.372

Weight: 365-70 gm.

Choke: 0.328 inch

Serial No. of round.	Batch No. of Compn.	Design of head end of charge.	Charge temp. °F	Thrust lb.	Remarks
1044	11	Original charge design - Cylindrical hole blind at end, covered with 0.2 inch layer of IP6.	130	105	N
1045	11		130	115	N
		Type A.			
1047	11	Cylindrical hole open at end, with 0.5 inch space between charge and head closure; head end of charge covered with 0.2 inch layer of IP6.	130	150	initial peak
1079	13		140	165	N
1080	17		140	125	N
1081	14		140	140	N
1082	14		140	120	N
1083	14		140	115	N
1084	13		140	170	N
		Type B.			
1046	11	Cylindrical hole open at end; no space between charge and head closure. Head end of charge covered with 0.2 inch layer of IP6.	130	135	N
1052	12		130	85	N
1058	12		140	130	N
1059	12		140	125	N
1060	11		140	135	N
1061	12		140	120	N
1062	11		140	115	N
1063	11		140	140	N
1068	14		-23	-	N
1069	14		-23	-	N
1070	14		-23	-	N

N = normal behaviour.

Charge

Choke:

Serial No. of Round.	Batc No. c comp
1006	28
1030	29
1031	"
1032	"
1033	"
1034	"
1035	"

TABLE II

Charge. Shape: 22.7 x 2.14 inch diam., cone and cylinder.

Area: 66 sq.in.

Composition: P.295

Weight: 1500 gm.

Choke: 0.438 inch.

Serial No. of Round.	Batch No. of comp.	Design of head end of charge.	Charge temp. F.	Max. pressure lb./sq.in.	Max. thrust lb.
		Type A.			
1006	28	Cylindrical hole open at end,	air	750	74
1030	29	with 0.5 inch space between	130	-	155
1031	"	charge and head closure; head	130	950	140
1032	"	end ofcharge covered with	130	-	150
1033	"	0.2 inch layer of IP4.	-20	720	100
1034	"		-20	680	98
1035	"		-20	700	110

Pressure-time and thrust-time curves of these rounds are reproduced **in figures** 2-8

TABLE III

Inert Plastic Compositions

Comp. No.	Composition of solids.	% binder B.140	Percentage compression (68°F) * At 212 gm/cm²	At 530 gm/cm²	For crack formation
P384	Ammonium picrate 50 Sodium nitrate 14	16	8	28	66
IP5	Zinc oxide (300 b.s.s.)	20	very	soft	
IP6	Ammonium picrate 13 Sodium nitrate 70	17	6	10	19
IP7	Ammonium picrate 42.5 Sodium bicarbonate 42.5	15	plastic	but	not inert
IP8	Sodium chloride (coarse) 80	20	not	plastic	
IP9	Sodium chloride 80	20	not	plastic	
IP10	Sodium chloride 42 Ammonium picrate 42	16	plastic,	but not inert	
IP11	Ammonium sulphate (coarse) 80	20	not	plastic	
IP12	Gypsum 80	20	"	"	
IP13	Calcium carbonate 80	20	very	hard	
IP14	Ammonium sulphate 80	20	21	36	71
IP15	Calcium sulphate (anhyd.) 80	20	very	hard	
IP16	Calcium sulphate (anhyd.) 75	25		plastic	
IP17	Calcium sulphate (anhyd.) 70	30	very	soft	
IP18	Ammonium oxalate 80	20	3	5	72
IP19	Ammonium oxalate 75	25	20	36	75
IP20	Ammonium sulphate 80 Lubrol W. 1	19	24	-	25
IP21	Ammonium picrate 10 Ammonium sulphate 70	20	31	50	70
IP22	Ammonium picrate 13 Ammonium sulphate 70	17	12	27	45

Unless otherwise stated, all solids are 120 b.s.s. or less.

* In all compression measurements, initial diameter of pellet was 15 mm.

Charge.

Choke:

Filling:

Serial No. of Round.	Batch No. of comp.	Cha ler (i
870	26	
924	26	
921	26	
922	26	
923	26	
898	26	
899	26	
1085	30	
1086	30	

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Chok

Fill

Serial No. of round.	Batch No. of Comp.
932	5
1071	15
1072	15
1073	15
1074	15
1088	14
1089	14

TABLE IV

Charge. Shape: 2.14 inch diam., end burning.

Area: 3.6 sq.in.

Composition: P.295

Weight: 3-500 gm.

Choke: 0.110 inch

Filling: Hand stemmed.

Serial No. of Round.	Batch No. of comp.	Charge length (in.)	Charge temp. °F	Pressure lb./in.^{2}	Thrust lb.	Remarks
870	26	5.2	Air	750	5	Control
924	26	3.1	-10	350	-	N
921	26	3.1	-10	-	-	N
922	26	3.1	-10	-	-	N
923	26	3.1	-10	2800	-	initial peak
898	26	5.2	-11	-	-	burst
899	26	5.2	-5	-	4	N
1085	30	5.2	-20	-	3 - 7	*
1086	30	5.2	-20	-	-	* burst

N = normal behaviour

* obturators inserted in the charge. (see page 3.)

TABLE V

Charge. Shape: 2.14 inch diameter, end burning.

Area: 3.6 sq.in.

Composition: P.372

Weight: 350-500 gm.

Choke: 0.125 inch

Filling: Hand stemmed

Serial No. of round.	Batch No. of Comp.	Charge length (in.)	Charge temp. (°F.)	Pressure lb./sq.in.	Thrust lb.	Remarks
932	5	4.7	Air	900	17	Control
1071	15	3.6	-23	-	-	burst
1072	15	3.6	-23	-	-	burst
1073	15	3.6	-23	-	-	burst
1074	15	3.6	-23	-	-	burst
1088	14	5.5	-20	-	-	* burst at 2 sec.
1089	14	5.5	-20	-	-	* burst at 0.5 sec.

* obturators inserted in the charge (see page 3.)

TABLE VI

Charge.

Shape: 3.08 inch diameter, end burning.

Area: 7.5 sq.in.

Composition: P.372
P.295

Weight: 300 - 2200 gm.

Choke: P.372 - 0.194 inch
P.295 - 0.125 inch

Serial No. of round.	Comp.	Batch No. of Comp.	Charge length (in.)	Charge temp. °F.	Pressure lb./sq.in.	Thrust lb.	Remarks.
1053	P.295	30	11	air	- 1800 (peak)	15 35	peak for 1st sec.
1054	"	30	11	140	-	-	burst
1055	"	30	11	-5	-	-	burst
1041	P.372	13	1.5	air	750	20	
1067	"	13	3.0	150	-	-	burst

TABLE VII

Plastic properties of propellants used in end burning charges

Serial No. of Comp.	Percentage composition		Percentage Compression at 68°F. At 212 gm/cm²	At 530 gm/cm²	For crack formation
P295	Sodium dinitrophenate 40 Sodium nitrate 40 Dispolene (68°F = 7000 p.) 20		24	31	44
P372	Ammonium picrate 42.5 Sodium nitrate 42.5 N.C.(30%) in triacetin 15		14	30	53
P384	Ammonium picrate 50 Sodium nitrate 34 N.C.(30%) in triacetin 16		8	28	66
P388	Ammonium picrate 50 Sodium nitrate 30 N.C.(30%) in triacetin 20	Batch 1 " 2 " 3 " 4 " 5	48 31 23 34 30	- 49 46 - 49	72 75 59 57 72

Charge

Shap
Area
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Choke: 0.12

Filling: Hand

Serial No. of round.	Batch No. of comp.	Charge length (in.)
1105	1	2.6
1107	1	2.6
1108	1	2.6
1109	1	2.6
1113	2	6.0
1114	2	6.0
1126	3	5.5
1127	3	5.5
1134	3	5.5
1138	4	5.5
1140	4	5.5
1141	4	5.5
1142	4	5.5
1116	2	6.0
1123	2	6.0
1128	3	5.5
1135	4	5.5
1136	4	5.5
1137	4	5.5
1139	4	5.5
1174	5	5.5
1175	5	5.5

Charge.

Choke:

Filling:

Igniter:

Serial No. of round.	Batch No. of comp.	L a c
1119	2	
1129	3	
1165	5	
1166	5	
1132	3	
1133	3	
1130	3	
1131	3	
1154	5	
1155	5	
1156	5	
1157	5	
1143	4	

N =

TABLE VIII

Charge — Shape: 2.14 inch diam., end burning
Area: 3.6 sq.in.
Composition: P388
Weight: 250-550 gm.

Choke: 0.125 inch

Filling: Hand-stemmed

Serial No. of round.	Batch No. of comp.	Charge length (in.)	Charge temp. (°F) on filling.	Charge temp. (°F) on firing.	Remarks
1105	1	2.6	air	air	pressure 680 lb./sq.in.
1107	1	2.6	air	-5	N
1108	1	2.6	air	-5	N
1109	1	2.6	air	-5	N
1113	2	6.0	air	-5	N
1114	2	6.0	air	-5	N
1126	3	5.5	air	-5	N
1127	3	5.5	air	-5	N, 18 sec. burning
1134	3	5.5	air	-5	N, 19 " "
1138	4	5.5	air	-5	N, 19 " "
1140	4	5.5	air	-5	N, 18 " "
1141	4	5.5	air	-5	N, 19.5 " "
1142	4	5.5	air	-5	N, 17 " "
1116	2	6.0	140	-5	burst
1123	2	6.0	140	-5	burst at 0.3 sec.
1128	3	5.5	140	-5	burst at 10 sec.
1135	4	5.5	140	-5	N, 19.5 sec. burning
1136	4	5.5	140	-5	N, 20 " "
1137	4	5.5	140	-5	N, 16 " "
1139	4	5.5	140	-5	N, 19 " "
1174	5	5.5	140	-7	N, 20 " "
1175	5	5.5	140	-7	burst at 9 sec.

N = normal behaviour.

TABLE IX

Charge. — Shape: 2.14 inch diam., end burning
Area: 3.6 sq.in.
Composition: P388
Weight: 175-500 gm.

Choke: 0.125 inch

Filling: Hand-stemmed at 140°F.

Igniter: 1.5 gm. SR.252

Serial No. of round.	Batch No. of comp.	Length of available charge space (in.)	Charge Length (in.)	Free vol. above charge. (c.c.)	Charge temp. on firing.	Remarks.
1119	2	8.5	6.0	80	140	burst at 0.3 sec.
1129	3	8.5	6.0	80	140	* burst at 1 sec.
1165	5	8.5	4.4	170	140	burst
1166	5	8.5	4.4	170	140	burst
1132	3	4.9	3.6	80	100	N
1133	3	4.9	3.6	80	100	burst
1130	3	4.9	1.8	180	100	N
1131	3	4.9	1.8	180	100	N
1154	5	25	5.5	1080	140	N
1155	5	25	5.5	1080	140	N
1156	5	25	5.5	1080	140	N
1157	5	25	5.5	1080	140	N
1143	4	8.5	5.5	110	140	N. ignited with electric fuze and 0.5 gm. SR.252

N = normal behaviour

* charge pressed $\frac{1}{4}$ ton/sq.in. after filling. perforated obturator on surface of charge.

TABLE X

Charge. Shape: 2.14 inch diam., end burning
Area: 3.6 sq.in.
Composition: P384
Weight: 500 gm.
Length: 5.5 inches

Choke: 0.125 inch

Filling: Hand-stemmed at 140°F.

Igniter: 1.5 gm. SR.252

Free vol. above charge = 110 c.c.

Serial No. of round.	Batch No. of comp.	Charge temp. °F	Remarks
1124	7	-5	burst at 2 sec.
1125	7	-5	burst immediately
1117	7	140	" "
1118	7	140	" "
1151	8	140	burst at 1 sec.
1152	8	140	burst immediately
1153	8	140	" "

TABLE XI

Incorporation of plastic compositions containing different types of binders.

Incorporator.		Time to attain plastic state			
Capacity (lb.)	Peripheral speed of fast blade (ft./min.)	16% N.C.-triacetin P.384	20% N.C.-triacetin P.388	20% Dispolene P.295	13% Blown Castor Oil. P.399
0.3	27.6	50 min.	10 min.	2 min.	-
5	20.6	6 hrs.	4 hrs.	-	-
10	26.2	15 hrs.	12 hrs.	30 min.	-
0.3	47.6	20 min.	7 min.	1 min.	8 min.
5	35.4	3½ hrs.	-	-	30 min.
10	45.0	8 hrs.	-	20 min.	3 hrs. ✱
30	47	-	-	-	4 hrs. +

✱ Solids added over interval of 25 minutes
+ " " " " " 2 hrs.

TABLE XII

Compositions containing Oxidised Rape-seed Oil Binder

TABLE XII

Compositions containing Oxidised Rape-seed Oil Binder

BINDER.				PLASTIC COMPOSITION.						
Description.	Serial and Batch No.	Viscosity 68° F. poises	Viscosity 135°F poises	% binder	Serial & Batch No.	Wt. of charge (lb)	Hrs. to attain plastic state	% Compression (68 °F) At 212 gm/cm²	At 530 gm/cm²	For Crack Formation
Gelled Rape-seed	B150/1	33,000 *	104 *	13	P396/1	0.3	-	19	41	72
				13	P396/2	0.3	-	17	31	52
				13	P396/3	5	0.5	35	51	72
Oil	B150/2	12,000 *	292 *	13	P396/4	5	3.5	not plastic		
				12	P404/1	5	6	14	33	65

: * values only approx: oil markedly thixotropic

TABLE XIII

Compositions containing oxidised Castor Oil Binders.

BINDER.				PLASTIC COMPOSITION.					
Description.	Serial and Batch No.	Viscosity 68 F. poises	Viscosity 135 F poises	% binder	Serial & Batch No.	Wt. of charge (lb.)	Hrs. to attain plastic state.	% Compression (80°F)	
								At 212 gm/cm^2	At 530 gm/cm^2	For Crack Formation.
Blown castor oil 60 p.	B155/1	50.5	3.8	13	P400/1	0.3	-	5	14	26
Heavy blown castor oil, 900 p.	B154/1	1400	59.2	13	P399/1	0.3	-	9	23	42
				13	P399/2	0.3	-	5	15	48
Extra heavy blown castor oil.	B154/2	13,400	322	13	P399/6	0.3	0.13	-		
				13	P399/3	5	0.5	12	38	62
				13	P399/4	10	3	-	40	68
				13	P399/5	30	4	-	25	68
				12.5	P406/1	5	1.2	22	39	70
Gelled castor oil	B153/1	28,500 *	204 *	13	P398/1	0.3	-	10	-	53
				13	P398/2	0.3	-	9	35	50

* values only approx: oil markedly thixotropic.

TABLE XIII

Compositions containing oxidised Castor Oil Binders.

BINDER.				PLASTIC COMPOSITION.						
Description.	Serial and Batch No.	Viscosity 68 F. poises	Viscosity 135 F poises	% binder	Serial & Batch No.	Wt. of charge (lb.)	Hrs. to attain plastic state.	% Compression (80°F)		
								At 212 gm/cm^2	At 530 gm/cm^2	For Crack Formation.
Blown castor oil 60 p.	B155/1	50.5	3.8	13	P400/1	0.3	-	5	14	26
Heavy blown castor oil, 900 p.	B154/1	1400	59.2	13	P399/1	0.3	-	9	23	42
				13	P399/2	0.3	-	5	15	48
Extra heavy blown castor oil.	B154/2	13,400	322	13	P399/6	0.3	0.13	-		
				13	P399/3	5	0.5	12	38	62
				13	P399/4	10	3	-	40	68
				13	P399/5	30	4	-	25	68
				12.5	P406/1	5	1.2	22	39	70
Gelled castor oil	B153/1	28,500 *	204 *	13	P398/1	0.3	-	10	-	53
				13	P398/2	0.3	-	9	35	50

* values only approx: oil markedly thixotropic.

TABLE XIV

Plastic milling of composition containing blown castor oil binder.

Composition P.399/3 - 13% blown castor oil, B.154/2
Weight of charge - 5 lb.
Peripheral speed of fast blade - 35.4 ft./min.
Room temperature 70°F.

Time of Incorporation.	Temp. of charge (°F)	% Compression (68°F)	
		At 530 gm/cm^2	For crack formation.
25 min.	106	25	50
1 hr.	120	38	62
1.5	129	39	57
2	136	35	68
2.5	137	31	66
3	140	26	65
4.5	151	15	67

TABLE XV

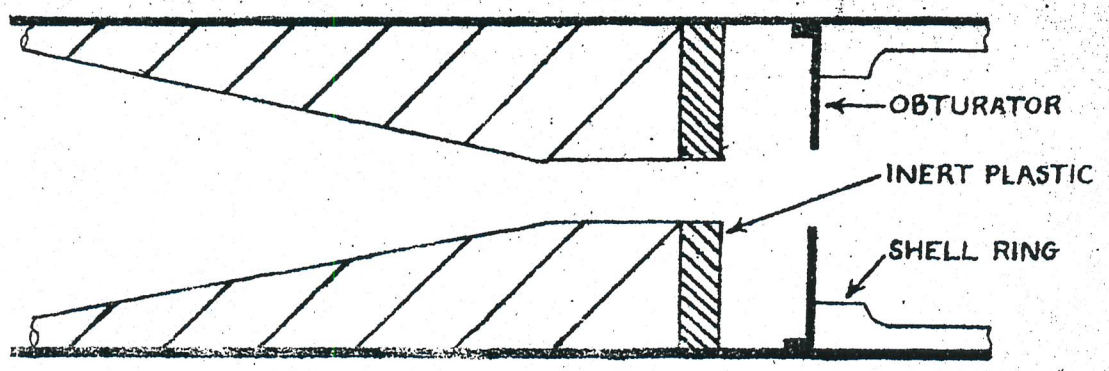
Plastic composition containing combustible resin

Composition: Ammonium picrate 42.5%) P.385
Sodium nitrate 42.5%)
Combustible resin 15%)

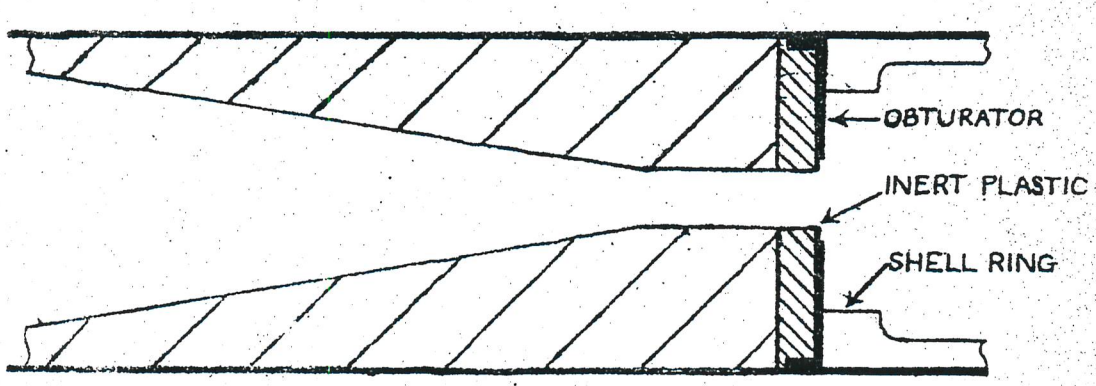
Charge: 5 lb.
Time of incorporation: 4 hrs.
Peripheral speed of blade 20.6 ft./min.
Maximum temperature attained: 131°F.
Compression (68°F) at 500 gm/cm^2 2.1%
(c.f.P295 = 30%)
" " for crack formation 48%

Serial No. of round.	Charge Shape	Charge Wt. (gm)	Choke diam. (in.)	Pressure lb./in.^{2}	Thrust lb.	Rate of burning sec/in.	Perf. Index
1095	6 x 2.14 inch cone & cylinder area 18.5 in.^{2}	400	0.400	800	65	2.0	134
1094		400	0.350	1450	80	1.65	135

MODIFIED CONE & CYLINDER CHARGE DESIGNS



TYPE "A" CHARGE



TYPE "B" CHARGE

FIG. 1.

PRESSURE-TIME & THRUST TIME CURVES FOR 2-INCH ROCKET FILLED PLASTIC PROPELLANT

CHARGE

SHAPE { CONE & CYLINDER, 22·7×2·14 INCH; HOLE OPEN TO END OF ROUND, WITH ½-INCH GAP & PROTECTED END SURFACE. TYPE 'A'.

SURFACE 66 □"
COMPOSITION P285/29
WEIGHT 1500 gm
TEMPERATURE AIR (CONTROL)

NOZZLE CHOKE 0·438"

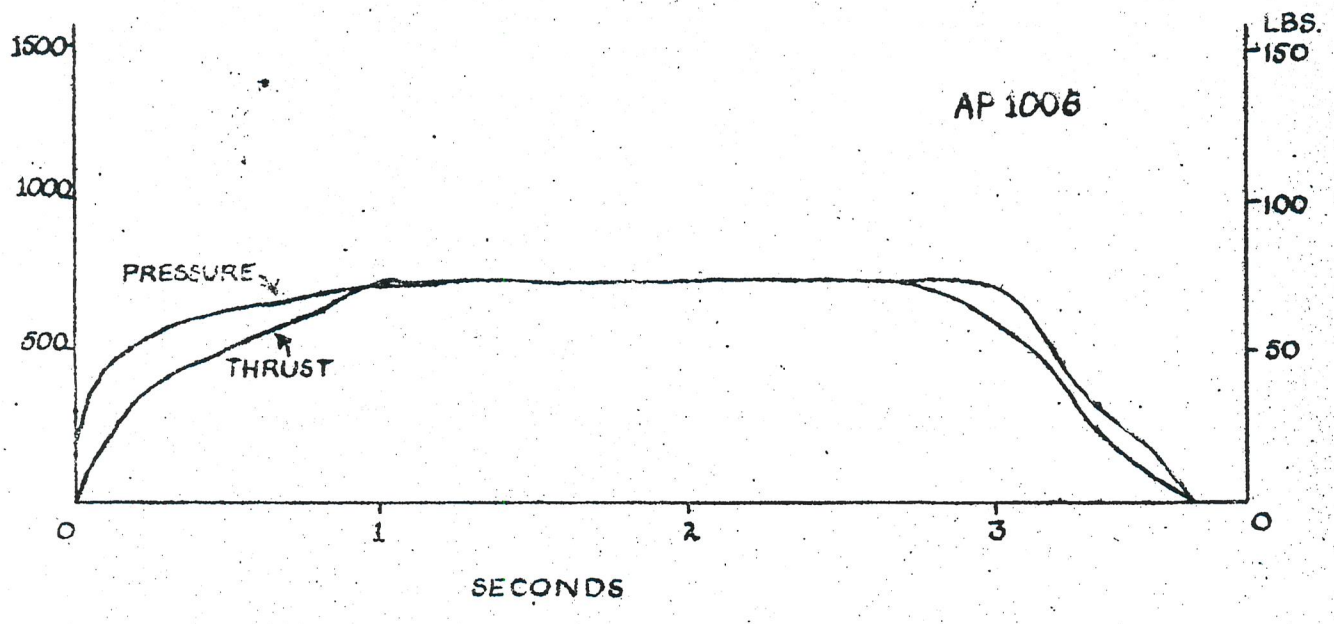


FIG. 2.

PRESSURE-TIME & THRUST-TIME CURVES FOR 2-INCH ROCKET
FILLED PLASTIC PROPELLANT

CHARGE

SHAPE { CONE & CYLINDER, 22·7 × 2·14 INCHES; HOLE OPEN TO END OF ROUND, WITH ½ INCH GAP AND PROTECTED END SURFACE. TYPE "A".

SURFACE 66 □"
COMPOSITION P295/29
WEIGHT 1500 gr.
TEMPERATURE 130°F.

NOZZLE CHOKE 0·438"

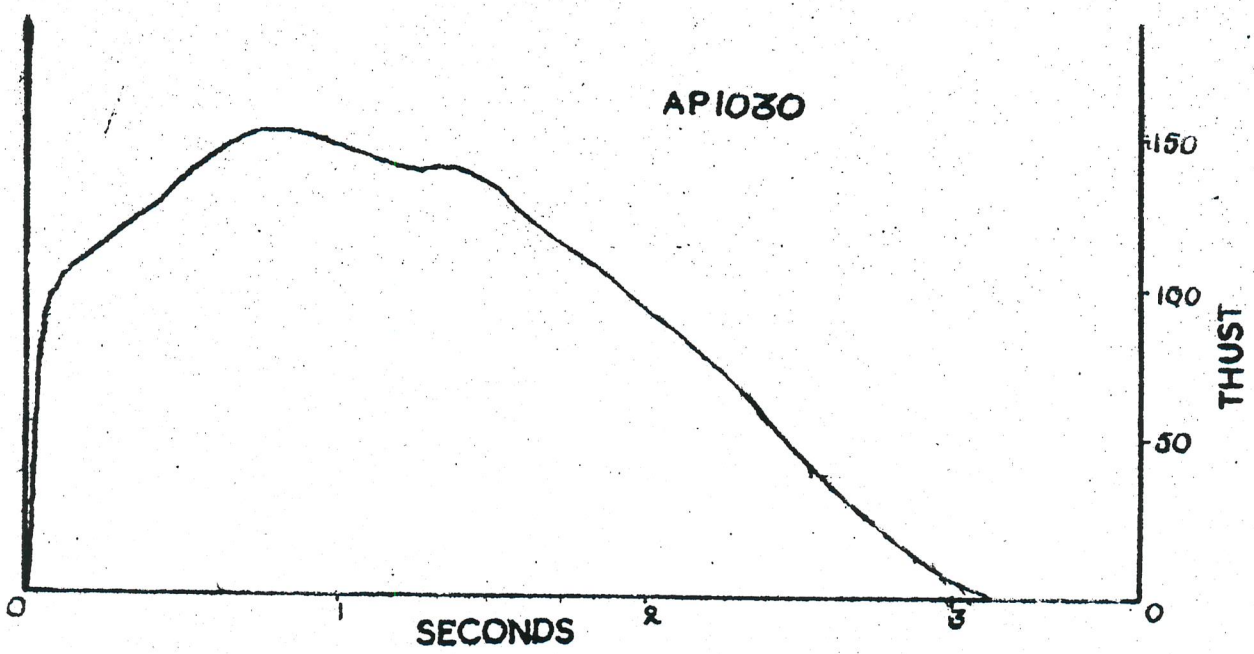


FIG.3.

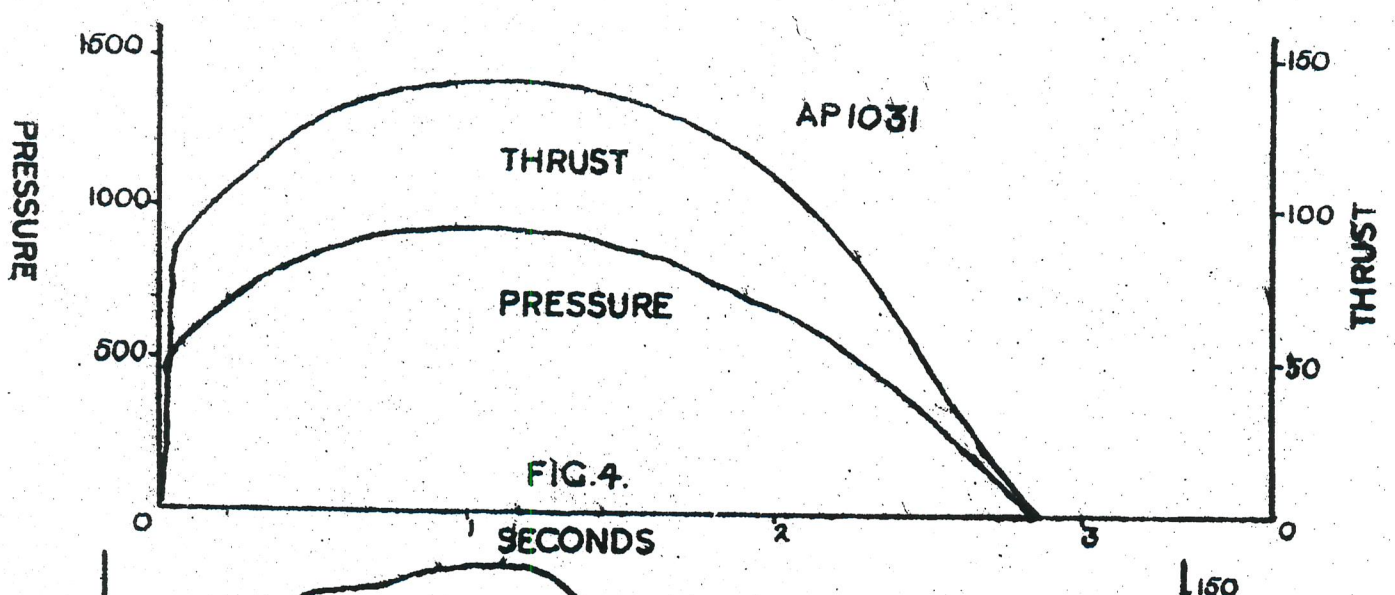


FIG.4.

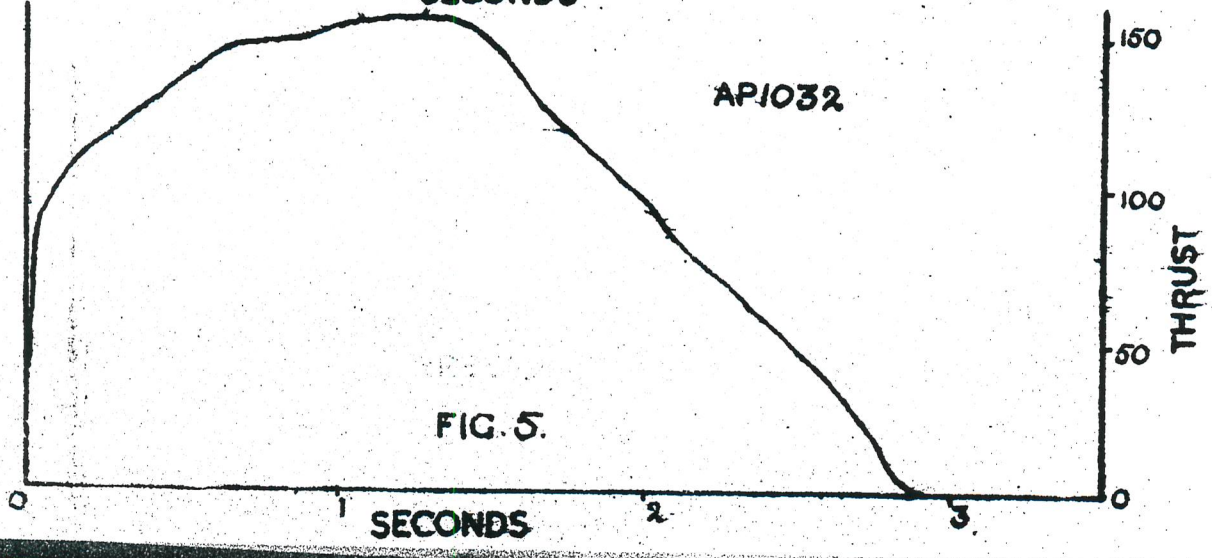


FIG.5.

PRESSURE-TIME & THRUST-TIME CURVES FOR 2-INCH ROCKET FILLED PLASTIC PROPELLANT

CHARGE

SHAPE { CONE & CYLINDER, 2.27 · 2.14 INCHES, HOLE OPEN TO END OF ROUND, WITH ½-INCH GAP AND PROTECTED END SURFACE. TYPE "A".

SURFACE 66 □"
COMPOSITION P295/28
WEIGHT 1500 GM.
TEMPERATURE -20°F.

NOZZLE CHOKE 0.438"

FIG.6. AP1033

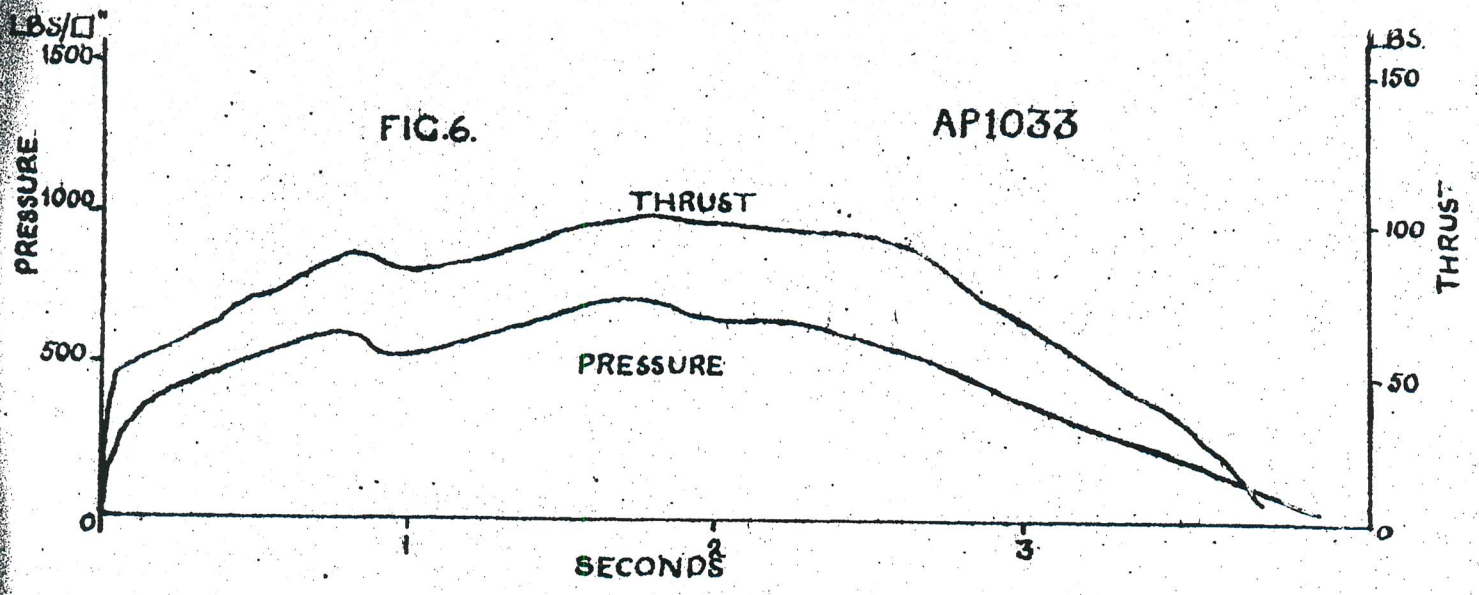


FIG.7. AP1034

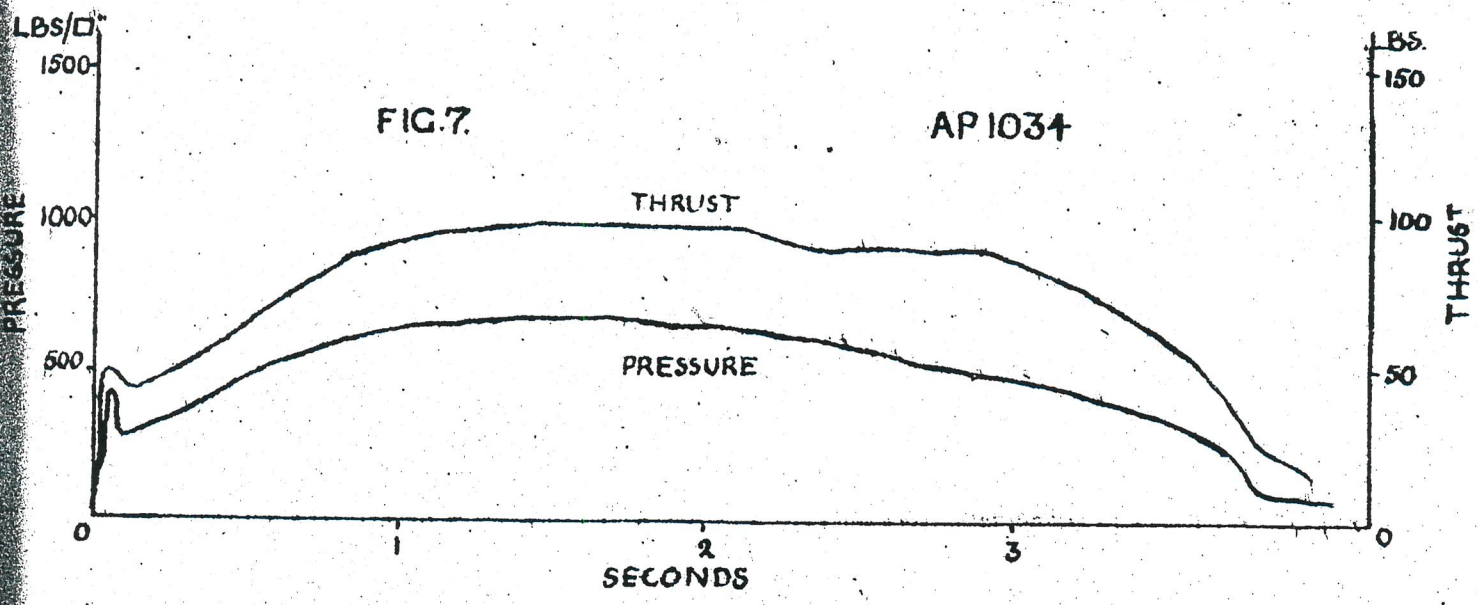
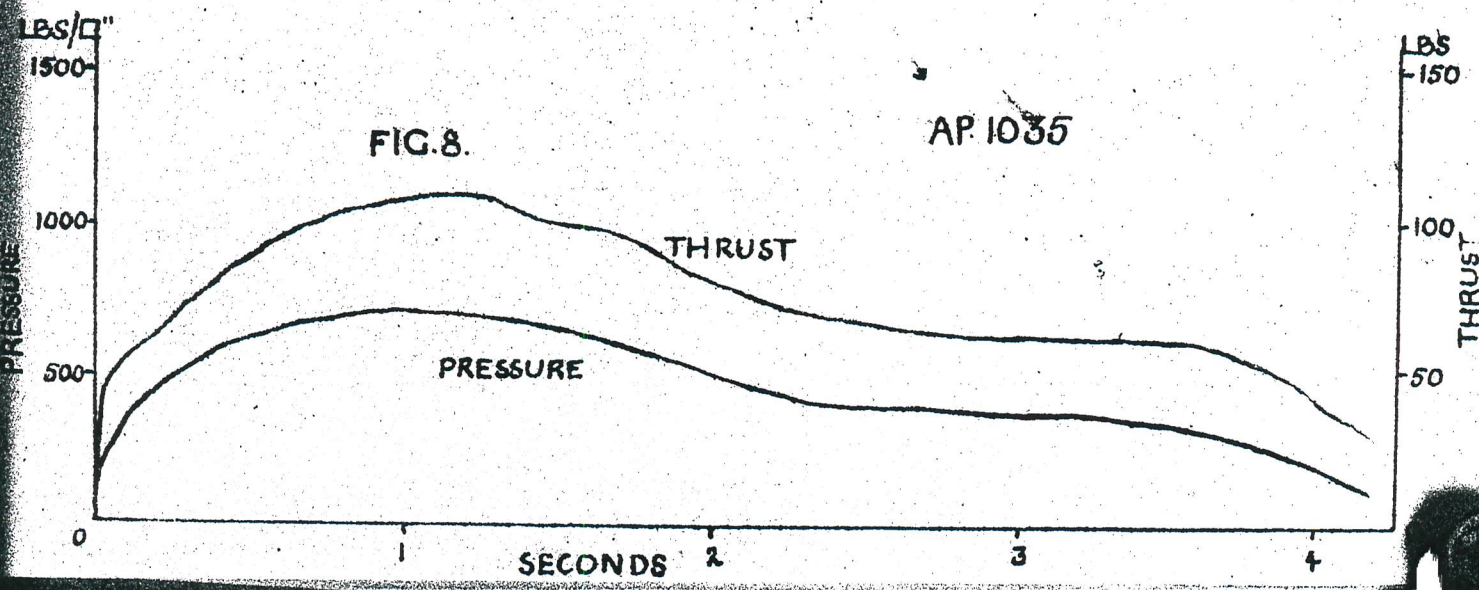


FIG.8. AP 1035



PRESSURE-TIME CURVES FOR 2" ROCKET FILLED PLASTIC PROPELLANT

CHARGE:

SHAPE { CONE & CYLINDER, 22·7 × 2·14 INCH;
HOLE OPEN TO END OF ROUND, WITH
½-INCH GAP & PROTECTED END SURFACE TYPE "A".

SURFACE 66 □"
COMPOSITION P295/29
WEIGHT 1500 GM.
TEMPERATURE AP995: 140°F, 1044: AIR.

NOZZLE:

CHOKE 0·438".

PRESSURES RECORDED AT HEAD & CHOKE END OF ROUND.

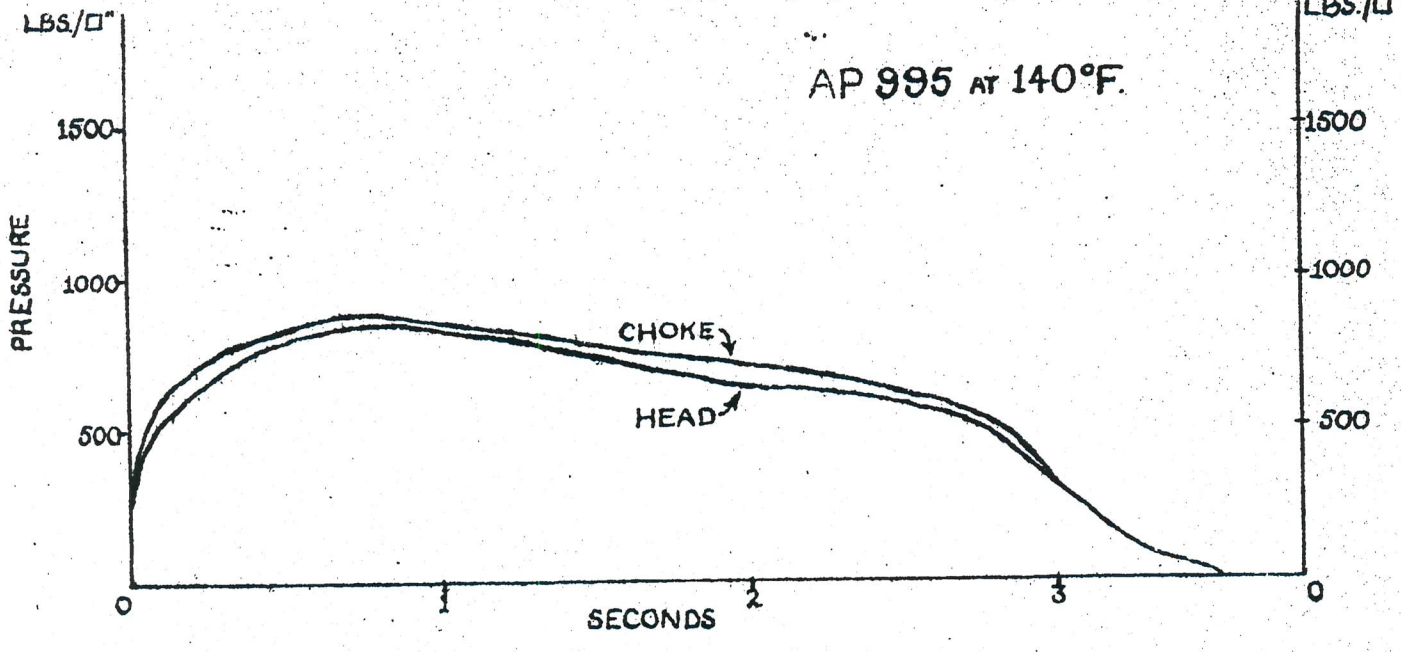


FIG.9.

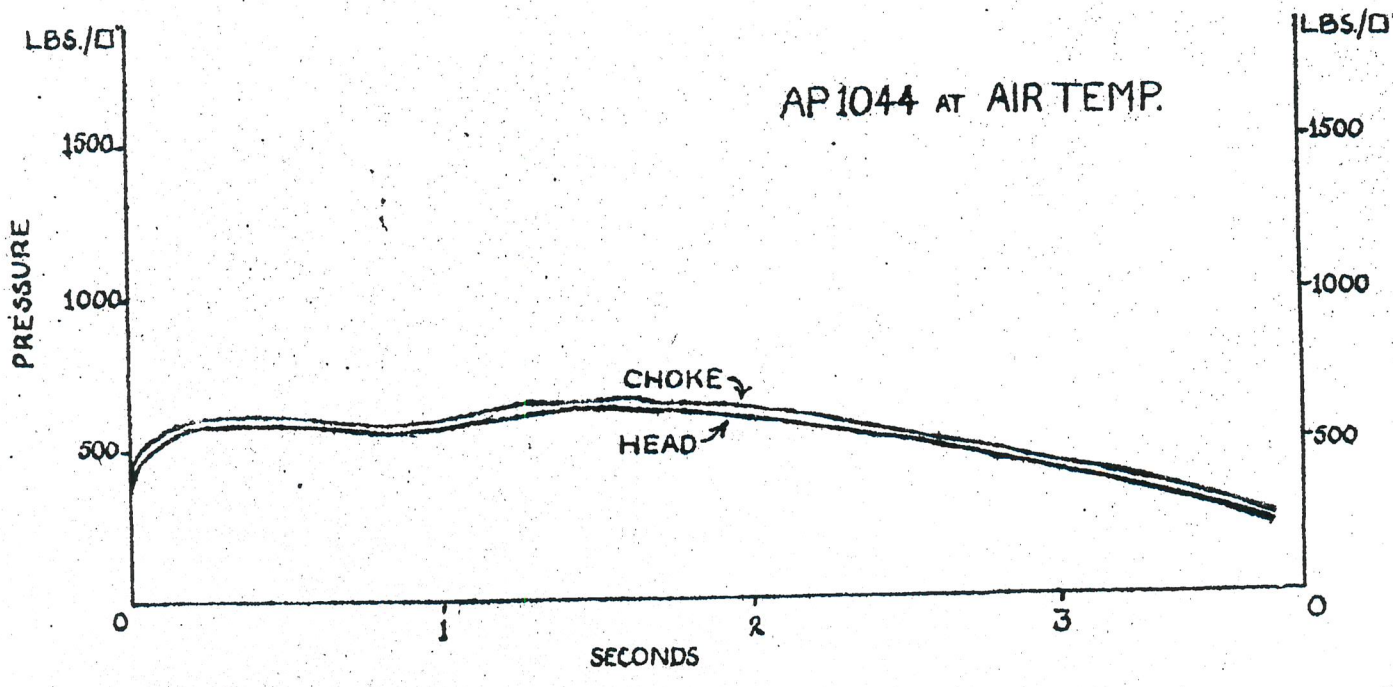


FIG.10.

PLASTIC MILLING OF COMPOSITION CONTAINING BLOWN CASTOR OIL BINDER

P389/3

AMM. PICRATE	43·5
SOD. NITRATE	43·5
HEAVY BLOWN CASTOR	13

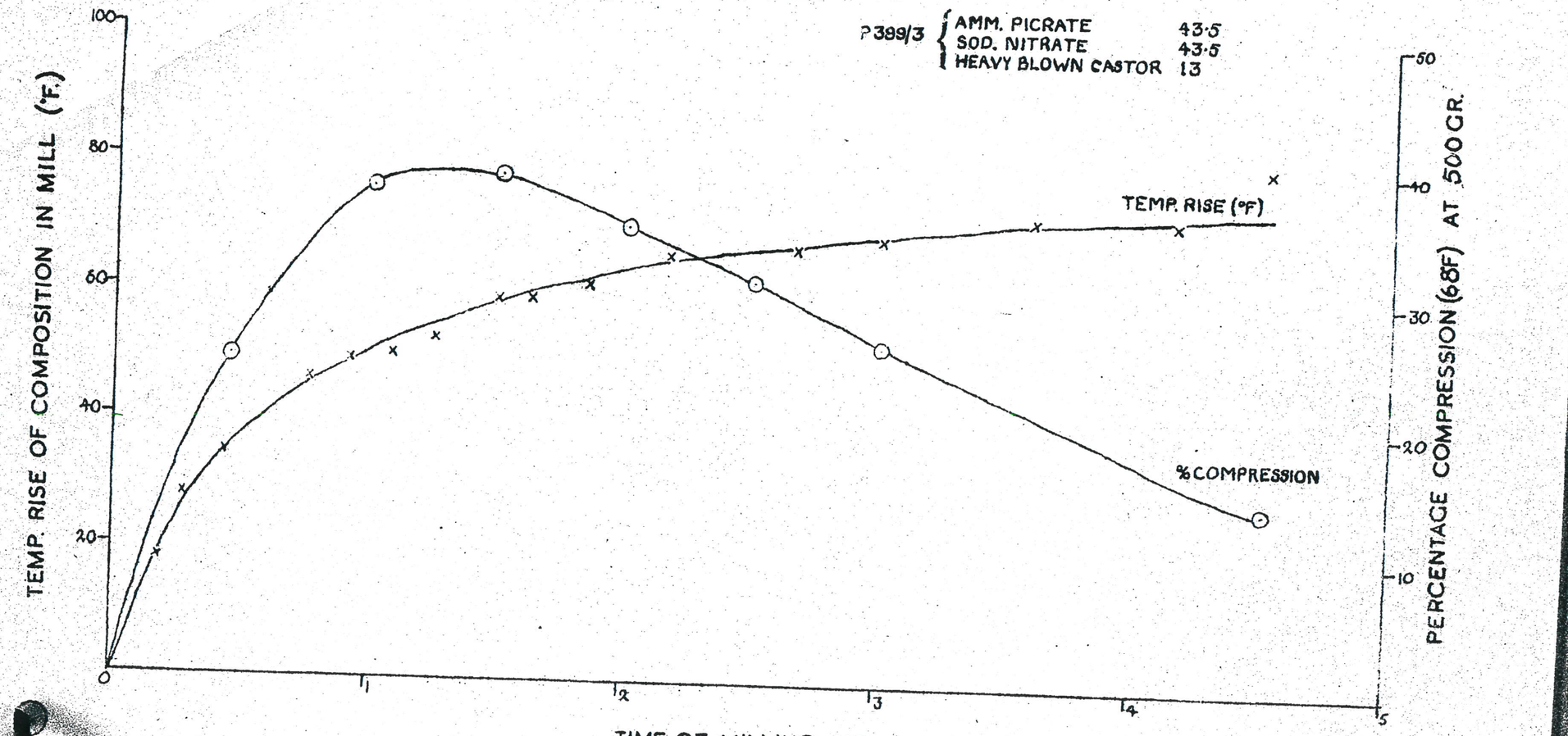


FIG. II.