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1946/14

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Interim Report 1946/14

Propellants Plastic

Use with Light Alloy Motor

P.D.E.
Aberporth

September, 1946.

Summary

The report describes experiments carried out to date on the filling, static firing and projection of a light alloy rocket using both high and low energy binder plastic propellants. The main defects fall roughly into two classes and some progress has been made in overcoming them.

Contents

I. Introduction

The original object of making rocket propellants with plastic properties was to enable the propellant to be loaded against the wall of the motor, with the gas conduit centrally placed. One of the main objects of this is to protect the wall of the motor from the hot propellant gases, so that the motor may be made lighter than would otherwise be necessary, and the performance of the weapon thereby improved.

In using light alloys as a means of lightening the motor, it is particularly important that the propellant shall in fact provide the protection intended, in a reliable manner, because the mechanical properties of light alloys fall off badly under a moderate rise of temperature. It was scarcely to be hoped that an assembly reliable enough for Service use would be developed without considerable experiment and experience. The present report describes the work so far carried out; which though very incomplete should, it is thought, be set out at this stage because it indicates fairly clearly the direction of the next advance.

Effective inhibition over the ends as well as the walls of the charge is necessary in the charge design used (P.D.882/1 and 2) since if recession is permitted to take place, the motor wall will overheat at the exposed parts. The method at first used was to provide end plates of an annular width equal to the web thickness of the charge. As the results show this method has not proved adequate and proposals for its improvement are discussed.

II. Filling Technique

1. General

No serious difficulties have been encountered in the filling operation and the majority of the charges have been exceptionally well formed and free from air inclusions or other visible defects. A tendency has been noticed for the charges to be slightly pulled away from the shell rings by the withdrawal of the former after pressing. The behaviour is somewhat erratic in this respect and so far it has not been possible to correlate this observation with any other variable.

Drawings for vacuum filling attachments have been prepared and part of the equipment manufactured but this work has not been given high priority as no large air inclusions have been encountered in over sixty pressings and it is thought improbable that the adhesion of the propellant to the wall of the motor can be improved by the use of vacuum filling in this particular charge design. (As produced by filling tools to P.D.882/1 and 2).

A considerable variation in the plasticity of different batches of R.D.2633 propellant has been noticed which has necessitated frequent changes in pressing temperature in order to get reproducible results. It is felt that attempts should be made during manufacture to improve the uniformity of the physical properties of the propellant.

2. Tube Lacquers and Finishes

At present a kaolin-filled "Alvar" lacquer is being applied over the anodised surface by C.S.A.R. It is considered that both the adhesion and mechanical strength of this lacquer require improvement before it could be recommended for Service use (See however C.S.A.R.'s Report No. A.R.D. Explosives 211/46).

No information is at present available on the precise type of anodising process used for these tubes and it is possible that the adhesion of the lacquers varies with the method of anodising.

A supply of specially roughened tubes for large-scale adhesion experiments is awaited from C.E.A.D.

III. Static Firings

1. High Energy Binder Propellant

A total of 58 rounds has been fired statically. Temperatures of -5°, Air and 140°F. have been covered. The full results are given in Table I, while Table II gives details of the behaviour and results of examination of all bursts. Table III gives a brief summary of all static and projection firing to date.

Considering the work in chronological order the following results have been obtained. The first twelve rounds were pressed in unlacquered tubes and on firing at air temperature two practically instantaneous bursts were obtained. A further seven rounds with unlacquered tubes in which the pressure during the forming of the charge had been maintained for five minutes were then fired at air temperature quite successfully. Ten rounds which had been coated with a filled lacquer by C.S.A.R. were pressed and then stored in a vertical position for three days at 120°F. in order to ascertain that no charge-slip was induced by the lacquer and then fired statically. Of the five fired at 140°F. three burst late in burning while the others functioned correctly. The remaining five all burnt correctly at -5°F. with the exception of one round which gave a tube perforation just before the end of burning.

The failures at 140°F. may have been due in part to deterioration of the propellant brought about by the three days storage at 120°F. The storage undoubtedly caused the high initial peaks which were recorded but the fact that they were late bursts and the correct behaviour of the stored rounds at -5°F. suggests that there may have been some additional cause (See Table II).

A further four unstored rounds were next fired successfully at 140°F. but of ten rounds supplied pressed by C.S.A.R. two burst late in burning at 140°F. while three similar bursts were obtained at -5°F.

It seemed clear at this stage that late bursts were in general caused by tube failures at a point immediately to the rear of the venturi plate indicating that the walls had become exposed to the hot gases by detachment of the propellant at this point. (See Figs. 17, 19 and 20). In order to overcome this defect a lengthened venturi-plate has been evolved (P.D. drawing 820/7; Fig.25). Ten rounds fitted with such a plate have been filled and fired statically at -5°F. Of these, four burst almost instantaneously while the remainder functioned correctly, there being no sign of tube perforation or overheating in the neighbourhood of the venturi entry. Subject to further confirmation it appears likely that this modification will eliminate the majority of late-bursts. It is noteworthy that the lot of propellant involved in these ten rounds was the hardest so far supplied, the softness figure being 10. (See Table II). Abnormal behaviour at -5°F. is not therefore surprising.

A selection of pressure and thrust-time curves for firing temperatures of -5°, air and 140°F. is attached (Figs. 3 to 11).

2. <u>Low Energy Binder Propellant</u>

Sixteen rounds have been filled using propellant R.D.2049 in tubes coated with "Hycar" lacquer. Of these, five fired at air temperature functioned correctly (See Table I and curves Figs. 12 to 14); but of the same number fired at -5°F. two failed about half way through burning due to the use of light alloy venturi plates which were almost completely eroded away. The remaining three were quite satisfactory.

The times of burning were naturally longer than those obtained with the high energy binder propellant R.D.2633, the thrusts being correspondingly lower.

3. <u>Venturi Erosion and Defects</u>

It was noticed that a number of venturi were swollen at a point just outside the throat after firing with propellant R.D.2633 (See Fig. 24 showing sectioned venturi). In the case of rounds 5.P.344 and 5.P.282 the venturi were completely split open just before all-burnt as illustrated in Figs. 26 and 27. These components were examined by C.E.A.D. and stated to be below the specified wall thickness.

The high energy binder propellant causes considerable erosion of the venturi entry. This is shown in Fig. 24 while Fig. 25 shows the appearance of the venturi, fitted with modified venturi plate, before and after firing. In general the throat diameter using R.D.2633 does not alter appreciably, being sometimes slightly reduced and sometimes slightly enlarged on firing. On the other hand the low energy binder propellant R.D.2049 causes appreciable reduction in throat diameter. This may be due to the fact that there is a greater area of metal exposed to the gas stream in the latter case due to the use of a smaller venturi throat.

4. <u>Functioning of Thermal Fuze</u>

Seven of the firings at air temperature already mentioned were made in conjunction with tests of the thermal fuze. In all cases correct arming was observed while four records were obtained showing satisfactorily functioning of fuze to P.D.786/2.

IV. Discussion of Causes of Bursts

A description of the type and probable cause of each burst appears in Table II which should be studied in conjunction with the photographs (Figs. 15 to 23) and miniature pressure or thrust time curves (Figs. 1 and 2).

It will be noticed that in general bursts have occurred very early, i.e. at not more than 0.2 sec. after the commencement of burning or late, i.e. after 0.6 sec. burning. Examination of fragments of tubes and propellant from the former type has generally indicated that they were due to detachment of the propellant from the walls of the motors leading to excessive burning surfaces, the high pressures then developed were clearly established by the pressure recording. This type of burst is portrayed in Fig. 1 rounds Q.818, 823, 819, 824, 701, 744 and Fig. 2 round Q.788.

The late bursts, or merely tube perforations as they are in some cases, occur without any marked rise in pressure and in a mild case as shown in Fig. 1 round Q.774 and Fig. 2 round Q.784, there is nothing in the pressure-time curve to suggest any fault. Measurement of the performance indices shows that this figure is slightly below normal in these two cases, indicating that the perforation occurred almost at the end of burning. The majority of the remaining failures of this type were clearly due to the same phenomenon i.e. overheating of the exposed wall at the venturi end because of detachment of the propellant at this point. The only doubtful late bursts appear to be rounds Q.768 Fig.16 in which the tube burst only at the head end and 5.P.351 Fig.18 which was fired without recording the pressure-time curve and again failure appears to have started at the head end. The pressure at which the latter burst occurred is unfortunately not known.

V. Projection Trials

Six rounds filled H.E.B. propellant R.D.2633 have been projected at air temperature at a low Q.E. All rounds functioned correctly with the exception of one which became unstable near the end of burning and ranged short. Because of the smoke cloud it was impossible to observe the behaviour fully but it is thought probable that the tube perforated, as in several of the static firings, and the venturi and fin assembly became detached.

Of six similar rounds employing the L.E.B. propellant R.D.2049, all the motors functioned correctly but some small objects, probably fins, were observed to fall off one round near the end of burning.

The gravity drop was noticeably greater with R.D.2049 propellant and the ranging, at the low Q.E. considerably less than with R.D.2633. (See Report to Trial 155 F(1)).

The projection trial established that the fin assembly will require strengthening for Service use.

VI. Conclusions

1. The nature of the failures is now fairly well understood. They are of two kinds (a) the propellant burns at the wall soon after ignition, developing a high pressure in consequence, and so bursting the motor, (b) the propellant gases reach the motor wall comparatively late in the burning period and the wall gives way at the working pressure owing to loss of strength.

2. Both kinds of failure are thus ultimately due to insufficient adhesion between the propellant and the light alloy wall. The effect '(a)' is accentuated in the less soft batches of propellant. Improvement in adhesion would appear to be the most profitable line of attack in the immediate future.

3. A closer correlation between firing trials and rheological and adhesion tests, for a given batch of propellant should be instituted. A variety of laboratory adhesion measurements including a "peeling" test is desirable.

4. An investigation with the object of securing less batch-to-batch variation in the rheological properties of the propellant should be instituted.

VII. Future Development at P.D.E.

1. It is proposed to carry out further trials to obtain conclusive evidence that the lengthened venturi end-ring to P.D.820/7 is essential. Propellant R.D.2633 (H.E.B.) will be used since it is more likely to fail than R.D.2049 (L.E.B.)

2. Experiments will be continued in order to prove that it is necessary to maintain pressure during filling for about five minutes. The system being completely closed during this period.

3. Demonstration that, having cleared 1. and 2. above, and ignoring for the time being, the effects of climatic storage and rough usage, the L.E.B. propellant will give reliable results when fired statically or projected.

Table I

Static Firing Results for LAP/R.P. R.D.2633 and R.D.2049 propellants

Serial Numbers		Charge temp. °F.	Ignition Interval (sec.)	Time of burning (sec.)		Initial Peak		Max. Pressure lb./sq.in.	Max. Thrust (lb.)	Performance Index	Charge Weight lb. oz.	Igniter	Venturi diam. (in.)		Date of Firing	Batch No.	Remarks
Filling	Firing			Total	To half thrust	Pressure (lb./sq.in.)	Thrust (lb.)						Before firing	After firing			
SP-267	Q.696	50	0.04	1.53	1.07	1465	6410	1453	6445	-	41 - 5	Standard 3" carton	-	2.17	6.11.45.	WA.8	
274	697	78	0.03	1.58	1.00	1638	7300	-	-	-	41 - 14	"	2.155	2.12	9.11.45.	"	
265	698	54	0.04	1.48	1.01	1450	7000	-	-	-	41 - 5	"	2.164	2.19	"	"	
266	699	"	0.04	1.56	1.01	1547	7400	-	-	171	41 - 6	"	2.155	2.18	"	"	
264	700	58	0.04	1.54	1.04	1527	7440	-	-	179	41 - 14	"	2.153	2.18	14.11.45.	"	
275	701	"	N.R.	0.06	-	>2300	>10000	-	-	-	41 - 10	"	2.148	N.R.	"	WA.7	Burst
283	744	40	0.05	0.21	-	>2500	>12000	-	-	-	41 - 4	"	2.152	N.R.	14.12.45.	WA.8	Burst
282	745	"	0.03	1.61	1.06	N.R.	7160	N.R.	-	173	41 - 5	"	2.149	2.16	"	"	Venturi split open near end of burning.
287	746	"	0.03	1.54	1.03	N.R.	7160	N.R.	-	176	41 - 4	"	2.147	2.10	"	"	
285	747	"	0.03	1.58	1.04	N.R.	7080	N.R.	7160	178	41 - 6	"	2.151	2.20	"	"	
284	748	"	0.04	1.56	1.04	N.R.	7560	N.R.	-	178	41 - 6	"	2.151	2.17	"	"	
288	749	"	0.03	1.60	1.06	N.R.	7052	N.R.	7244	178	41 - 6	"	2.149	2.12	"	"	
297	760	45	0.05	1.56	1.03	N.R.	7240	N.R.	7280	178	41 - 6	"	2.156	2.11	15. 1.46.	"	Filling technique modified for this and all subsequent rounds.
301	761	"	0.03	1.46	1.03	N.R.	7532	N.R.	7500	178	41 - 12	"	2.148	2.10	"	WA.7	
299	762	"	0.03	1.50	1.04	N.R.	7312	N.R.	7320	179	41 - 8	"	2.152	2.11	"	WA.8	
296	763	"	0.03	1.48	1.03	N.R.	7320	N.R.	-	176	41 - 9	"	2.156	2.12	"	"	
300	764	"	0.04	1.44	0.998	N.R.	7392	N.R.	7396	176	41 - 7	"	2.142	2.10	"	WA.7	
298	765	"	0.03	1.48	1.02	N.R.	7468	N.R.	7400	176	41 - 7	"	2.162	2.10	"	"	
295	766	"	0.03	1.52	1.03	N.R.	7120	N.R.	7000	176	41 - 1	"	2.145	2.13	"	WA.8	
347	767	140	0.03	1.26	0.87	2535	14350	-	-	177	41 - 0	LAP/RP filled SR.371C 16 gm.	2.140	2.13	13. 3.46.	W.34-35	This round and all the following in Lacquered tube ∤
348	768	"	0.03	0.45	-	3155	17130	-	-	-	41 - 0	"	-	N.R.	"	"	Burst ∤
349	769	"	0.03	0.72	-	2540	13340	-	-	-	40 - 8	"	-	N.R.	"	"	Burst ∤
350	-	"	-	-	-	Not Recorded		-	-	-	40 - 14	"	2.148	2.14	"	"	Functioned correctly ∤
351	-	"	-	-	-	Not Recorded		-	-	-	40 - 4	"	-	N.R.	"	"	Burst ∤
341	770	-5	0.03	1.68	1.09	1241	6268	1340	6884	176	40 - 9	"	2.152	2.12	"	"	∤
342	771	"	0.04	1.64	1.10	1271	6552	1280	6832	176	40 - 12	"	2.151	2.12	"	"	∤
343	772	"	0.04	1.61	1.11	1240	6160	1340	6920	176	41 - 0	"	2.146	2.14	"	"	∤
344	773	"	0.05	1.62	1.10	1288	6500	1280	6552	174	39 - 11	"	-	N.R.	"	"	Venturi split open ∤
345	774	"	0.04	1.53	1.11	1268	6432	1237	6440	171	40 - 11	"	-	"	"	"	Burst ∤
358	778	140	0.02	1.13	0.84	N.R.	9680	N.R.	-	176	40 - 10	LAP/RP filled 22 gm. G.12	2.16 (nominal)	"	16. 4.46.	W.10	
359	779	"	0.02	1.16	0.85	N.R.	10600	N.R.	-	180	40 - 10	"	"	"	"	"	
360	780	"	0.02	1.17	0.84	N.R.	9912	N.R.	-	179	41 - 0	"	"	"	"	"	
361	781	"	0.02	1.15	0.84	N.R.	9860	N.R.	-	178	41 - 0	"	"	"	"	"	
362	782	"	0.02	0.60	-	N.R.	11660	N.R.	-	-	41 - 2	"	"	"	24. 4.46.	Lot 10	Pressed by C.S.A.R. Burst
363	783	"	0.01	1.11	0.65	N.R.	12040	N.R.	-	176	41 - 0	"	"	"	"	"	" " "
364	784	"	0.02	1.13	0.83	N.R.	11960	N.R.	-	175	41 - 5	"	"	"	"	"	" " " Burst
365	785	"	0.02	1.17	0.84	N.R.	12230	N.R.	-	176	41 - 3	"	"	"	"	"	" " "
366	786	"	0.02	1.13	0.84	N.R.	11480	N.R.	-	177	40 - 13	"	"	"	"	"	" " "
367	787	-5	0.03	1.39	1.07	N.R.	6400	N.R.	7288	175	40 - 15	"	"	"	26. 4.46.	"	" " "
368	788	"	0.02	0.08	-	N.R.	-	N.R.	7048	-	41 - 1	"	"	"	"	"	" " " Burst
369	789	"	0.03	1.40	1.05	N.R.	6640	N.R.	7348	177	41 - 2	"	"	"	"	"	" " "
370	790	"	0.02	0.66	-	N.R.	-	N.R.	7720	-	41 - 4	"	"	"	"	"	" " " Burst
371	791	"	0.02	1.45	-	N.R.	-	N.R.	[illegible]620	-	41 - 2	"	"	"	"	"	" " " Burst
455	804	59	0.05	1.81	1.57	-	-	1420	4340	[illegible]	40 - 7	SR.371C 3" Carton ≠	1.66 (nominal)	1.55	1.[illegible].46.	WA.11 & 12	RD.2049
456	805	"	0.03	1.96	1.58	-	-	1448	4322	159	40 - 0	"	"	1.55	"	"	"
457	806	"	0.03	1.98	1.59	-	-	1396	4304	159	40 - 0	"	"	1.54	"	"	"
458	807	"	0.06	2.01	1.58	-	-	1440	4440	157	40 - 0	"	"	1.54	"	"	"
459	808	"	0.03	1.94	1.60	-	-	1459	4390	158	40 - 8	"	"	1.54	"	"	"
460	815	-5	0.02	1.32	0.97	-	-	1340	7980	177	40 - 10	"	2.16 (nominal)	N.R.	5. 8.46.	44 & 45	R.D.2633. Modified end rings.
461	816	"	0.02	1.19	N.R.	-	-	1470	-	-	40 - 10	"	"	"	"	"	"
462	817	"	0.04	1.32	0.95	-	-	1462	8200	174	41 - 8	"	"	"	"	"	" " " "
463	818	"	0.02	0.06	-	-	-	>2000	10000	-	40 - 13	"	"	"	"	"	" " " " Burst
464	819	"	0.02	0.07	-	-	-	>2000	10300	-	40 - 14	"	"	"	"	"	" " " " Burst
465	820	"	0.03	1.34	0.98	-	N.R.	1478	N.R.	N.R.	40 - 9	"	"	"	16.8.46.	"	" " " "
466	821	"	0.03	1.19	0.82	-	"	1680	"	"	40 - 11	"	"	"	"	"	" " " "
473	822	"	0.03	1.24	0.86	-	"	1560	"	"	40 - 11	"	"	"	"	"	" " " "
474	823	"	0.03	0.06	-	-	"	>2400	"	"	40 - 6	"	"	"	"	"	" " " " Burst
475	824	"	0.03	0.14	-	-	"	>2600	"	"	40 - 9	"	"	"	"	"	" " " " Burst
476	831	"	0.02	2.39	2.02	-	-	1126	3560	146	40 - 5	"	1.66 (nominal)	"	28.8.46.	13/14/20	R.D.2049
477	832	"	0.03	1.43	-	-	-	1152	3778	-	40 - 3	"	"	"	"	"	" Light alloy end-ring failed
479	833	"	Hang-fire	1.51	-	850	3000	1141	3790	-	40 - 6	"	"	"	"	"	" " " " "
480	834	"	0.03	2.18	1.87	-	-	1158	3790	151	40 - 9	"	"	"	10.9.46.	"	R.D.2049
482	835	"	0.03	2.23	1.91	-	-	1130	3670	148	40 - 9	"	"	"	"	"	"

∤ Stored for 3 days at 120°F.
≠ Standard LAP/RP igniters could not be used as they failed to fit the shell rings.
N.R. Not recorded.

Note: The word "Burst" in the above table implies some form of motor tube failure.

Table II

Examination of Burst Rounds

Round number		Firing Temp. °F.	Propellant Lot No.	C.S.A.R.'s Softness Figure	Time of burning to point of burst (sec.)	Maximum pressure recorded (lb./sq.in.)	Nature of Burst	Probable Cause of Burst	Pressure or Thrust-Time Curve Fig. No.	Photograph Fig. No.
Filling	Firing									
5F.275	Q.701	Air	WA.7	22	0.06	Off scale at 2,300	Tube fragmented	Detachment of propellant from wall of tube over considerable area.	1	None
283	744	"	WA.8	16	0.21	Off scale at 2,500	"	"	1	15
348	768	140	34-35	33	0.45	Off scale at 3,200	Tube fragmented over half length starting at head.	Not certain	1	16
349	769	140	"	33	0.72	2,500	Venturi ejected together with small (threaded) portion of tube.	Overheating of tube behind venturi plate	1	17
351	-	140	"	33	N.R. but about same as two previous rounds.	N.R.	Tube split from end to end, a few fragments.	Not certain	-	18
345	774	-5	"	33	Near end of burning	1,237	Hole in tube to rear of venturi plate.	Overheating of tube behind venturi plate	1	19
362	782 *	140	W.10	49	0.6	N.R.	Venturi and extreme end of tube ejected.	" " " " " "	2	20
364	784 *	140	"	"	Near end of burning	N.R.	Small hole to rear of venturi plate.	" " " " " "	2	20
368	788 *	-5	"	"	0.10	N.R.	Tube split into large fragments.	General detachment of propellant from wall of tube.	2	21
370	790 *	-5	"	"	0.86	N.R.	Venturi and extreme end of tube ejected.	Overheating of tube behind venturi plate.	2	20
371	791 *	-5	"	"	0.50	N.R.	" " "	" " " " " "	2	20
463	818	-5	44 & 45	10	0.06	Off scale at 2,000	Tube fragmented	General detachment of propellant from wall of tube.	1	22
464	819	-5	"	"	0.07	Off scale at 2,000	Shell ring ejected, tube only slightly damaged.	" " " " " "	1	None
474	823	-5	"	"	0.06	Off scale at 2,400	Tube split and fragmented at one end only.	" " " " " "	1	23
475	824	-5	"	"	0.14	Off scale at 2,600	Venturi and extreme end of tube ejected.	" " " " " "	1	20

* Rounds pressed by C.S.A.R.

Table III

Summary of Results of both static and projection firings

Firing Temperature °F.	Propellant	Number of rounds		
		Functioned correctly	Early Burst	Tube Failure
-5	R.D. 2633	12	5	3
Air	R.D. 2633	22	2	1
140	R.D. 2633	9	0	5
-5	R.D. 2049	3	0	0
Air	R.D. 2049	11	0	0

FIG.1.

PRESSURE TIME CURVES FOR L.A.P/R.P. BURST ROUNDS.

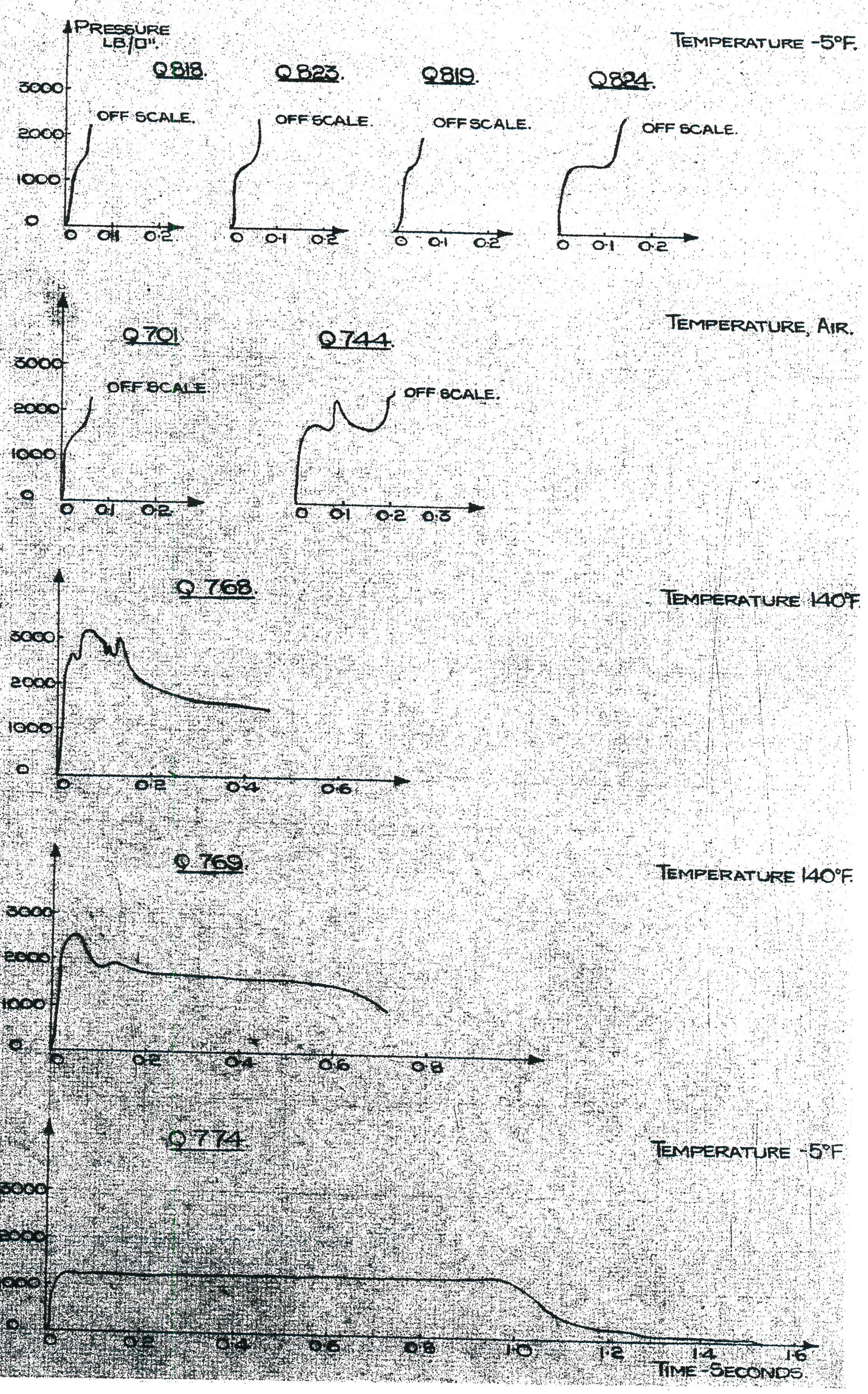

Fig. 2.

Thrust Time Curves for L.A.P/R.P. Burst Rounds.

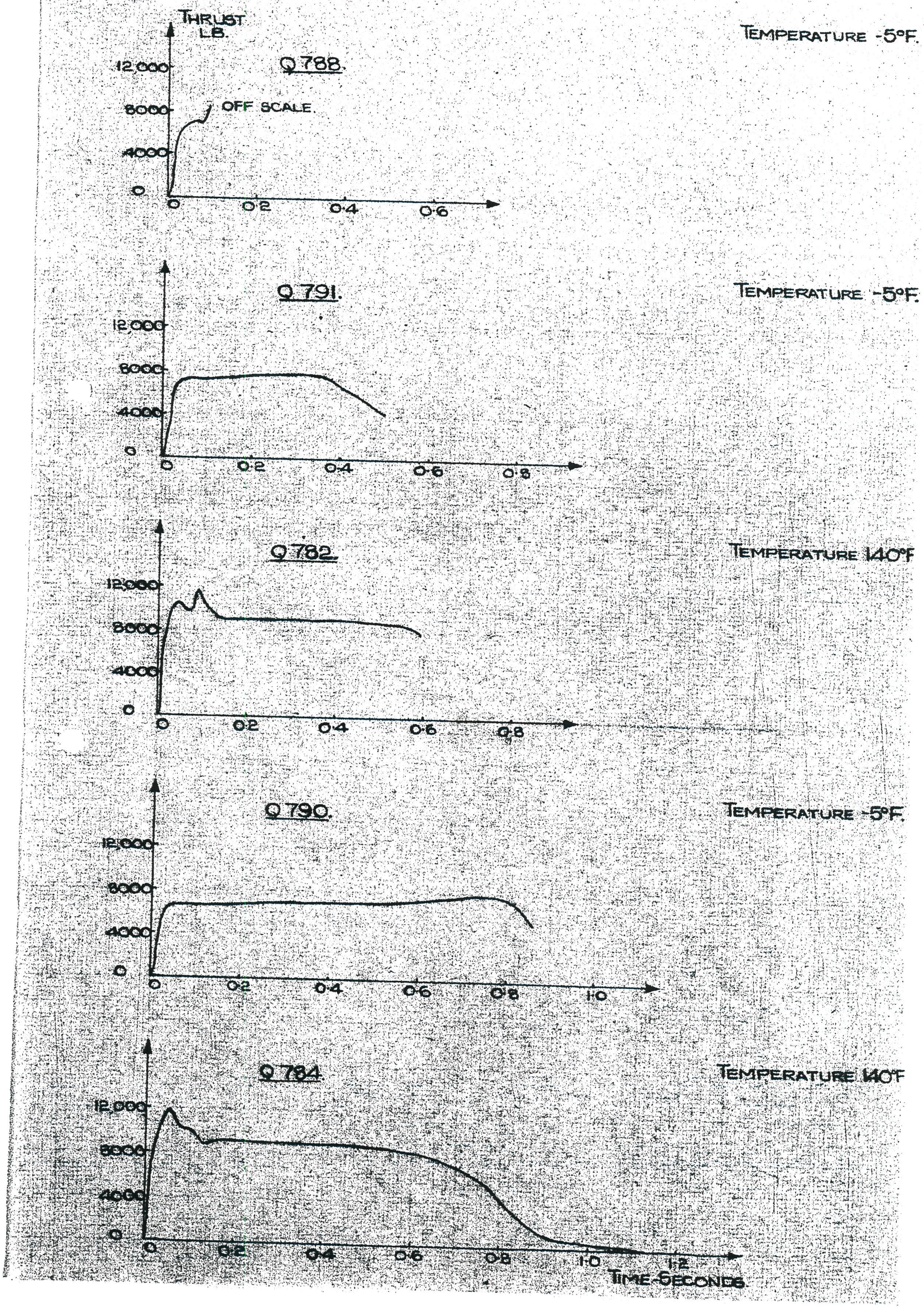

FIG. 3.

PRESSURE AND THRUST TIME CURVES FOR 5" L.A.P./R.P. AT -5°F.

PROPELLANT :- RD 2653.	ROUND NO:- Q-772.
CHARGE WEIGHT :- 41 LBS.	SERIAL NO:- 5P-343.
IGNITER :- 16GMS. GR 371G.	DATE FIRED :- 13-3-46.
VENTURI :- 2·16" DIA.	IGNITION INTERVAL :- 0·038 SECS.

PERFORMANCE INDEX :- 175·5.

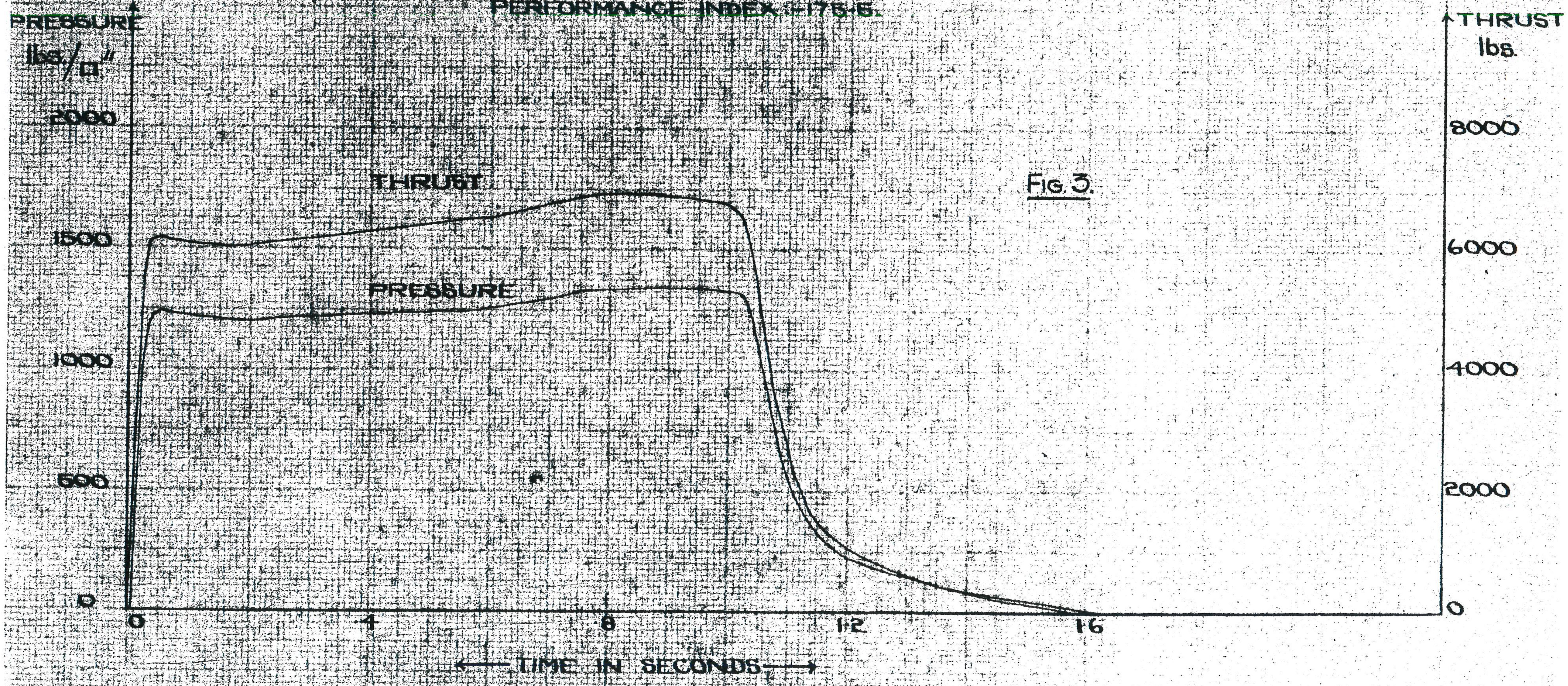

Fig. 3.

FIG 4.

PRESSURE AND THRUST TIME CURVES FOR 5" LAP/RP AT +5°F

PROPELLANT :- RD 2633. ROUND NO :- Q - 773.
CHARGE WEIGHT :- 39 LBS 10½ OZS SERIAL NO :- 5P - 344
IGNITER :- 16 GMS SR 371C. DATE FIRED :- 13 - 3 - 46
VENTURI :- 2·18" DIA. IGNITION INTERVAL :- 0·047 SEC
PERFORMANCE INDEX :- 173·5

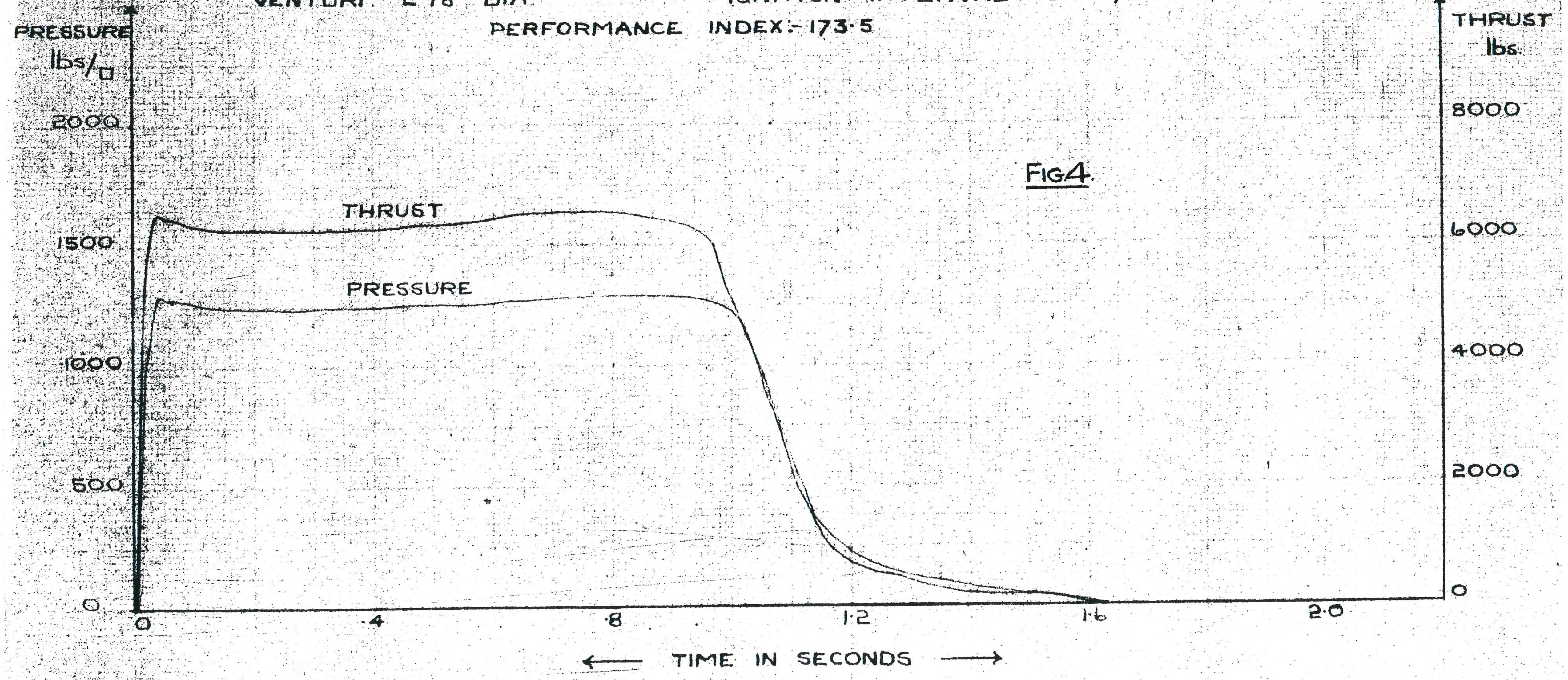

FIG 5.

PRESSURE AND THRUST TIME CURVES FOR 5" LAP/RP AT -5°F

PROPELLANT - RD 2633. ROUND NO :- Q-774.
CHARGE WEIGHT :- 40LBS 11OZS. SERIAL NO :- SP-345.
IGNITER :- 16GMS SR 371c DATE FIRED :- 13 - 3 - 46.
VENTURI :- 2·18" DIA. IGNITION INTERVAL :- 0·035 SEC

PERFORMANCE INDEX :- 171

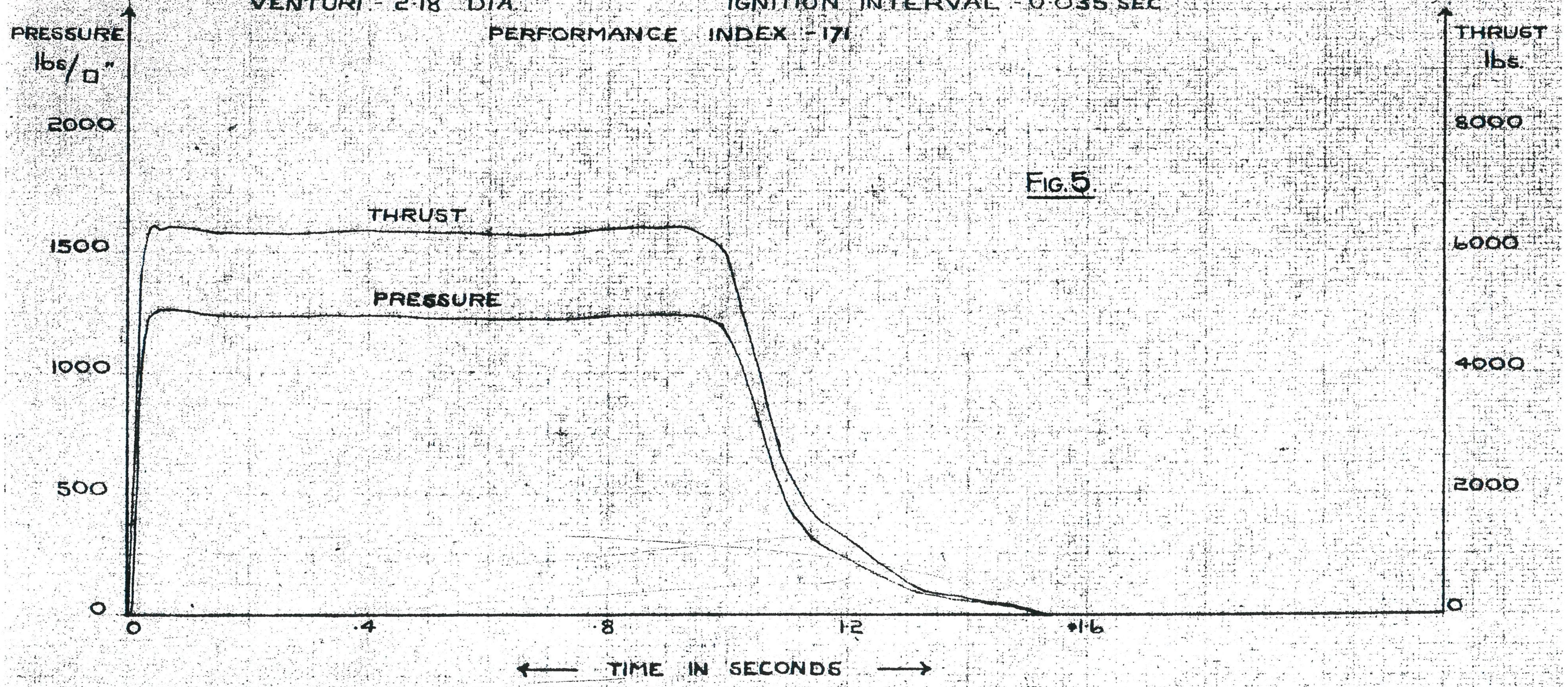

FIG. 5.

FIG. 6.

PRESSURE AND THRUST TIME CURVES FOR 5" L.A.P/R.P AT 58°F

PROPELLANT R.D. 2633 | ROUND NO. Q 700
CHARGE WEIGHT 41 LBS 15½ OZS | SERIAL NO. SP 264
IGNITER STANDARD 3" CARTON | DATE FIRED 14-11-45
VENTURI 2.15" DIA | IGNITION INTERVAL 0.040 SEC

PERFORMANCE INDEX 178.5.

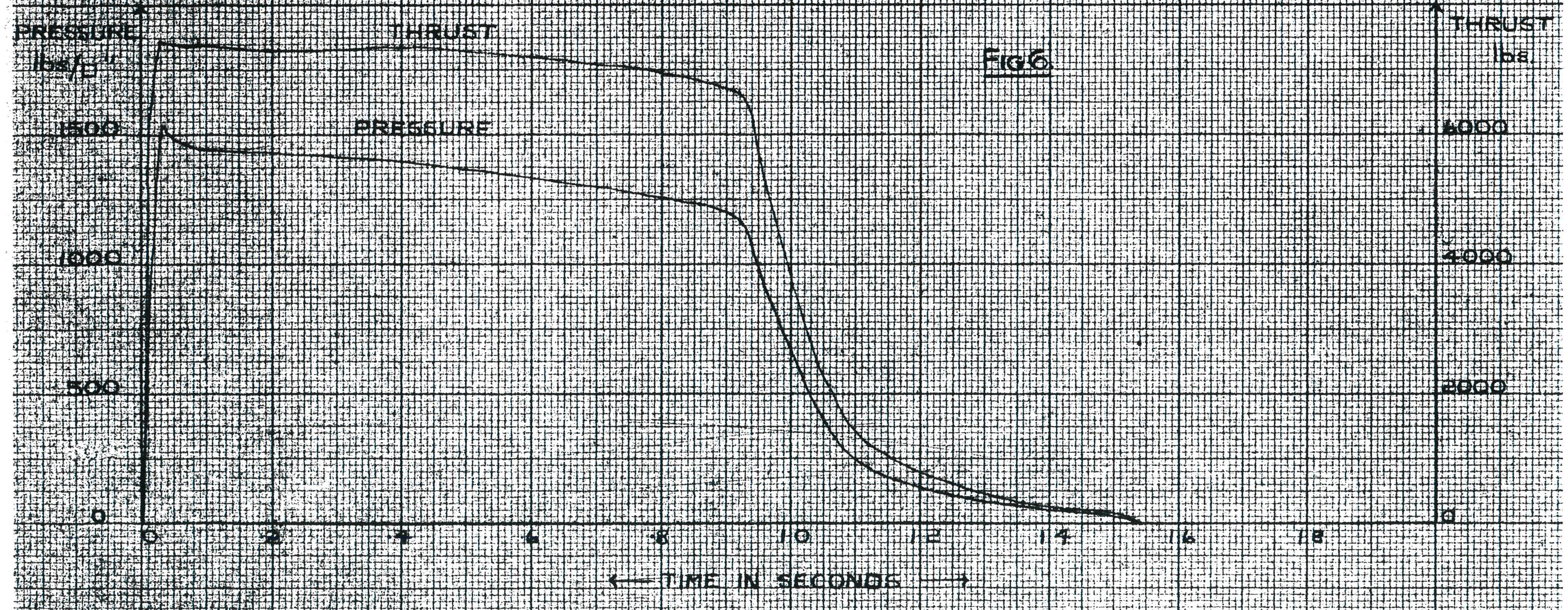

FIG. 7.

THRUST TIME CURVE FOR 5" L.A.P./R.P. AT 46°F.

PROPELLANT:- RD 2653
CHARGE WEIGHT:- 41 LBS. 6¾ OZS.
IGNITER:- STD. 5" CARTON.
VENTURI:- 2.16" DIA.

ROUND NO. Q-765.
SERIAL NO. SP 296.
DATE FIRED:- 15-1-46.
IGNITION INTERVAL:- 0.034 SEC.

PERFORMANCE INDEX:- 176.

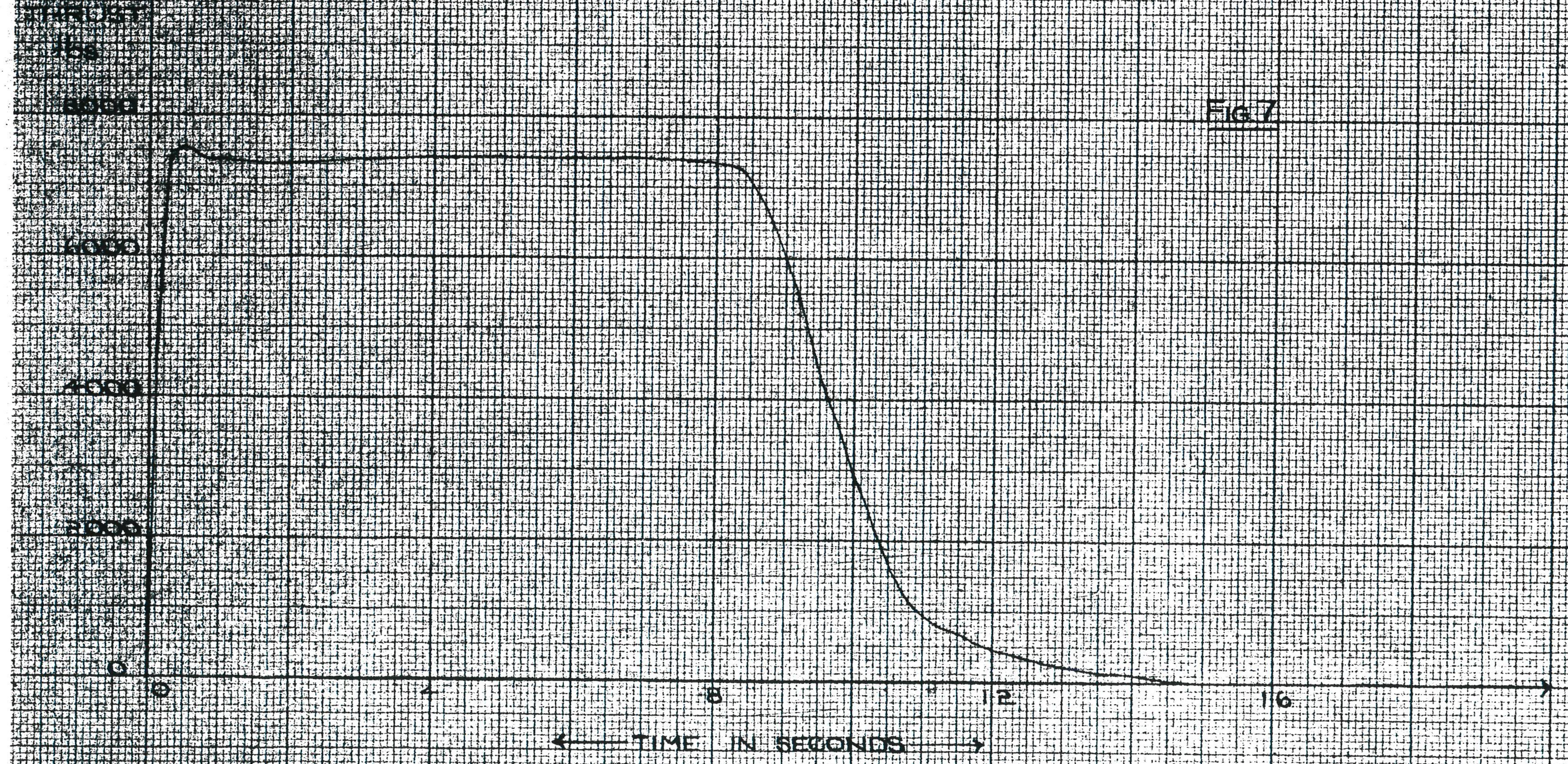

FIG 8

THRUST TIME CURVE FOR 5" L.A.P./R.P. AT 46°F

PROPELLANT - RD 2633.
CHARGE WEIGHT - 41 LBS. 1OZ.
IGNITER - STD. 3" CARTON
VENTURI - 2.16" DIA.

ROUND NO. Q - 766
SERIAL NO. - 5P - 295.
DATE FIRED - 15 - 1 - 46.
IGNITION INTERVAL 0.034 SEC.

PERFORMANCE INDEX - 176.

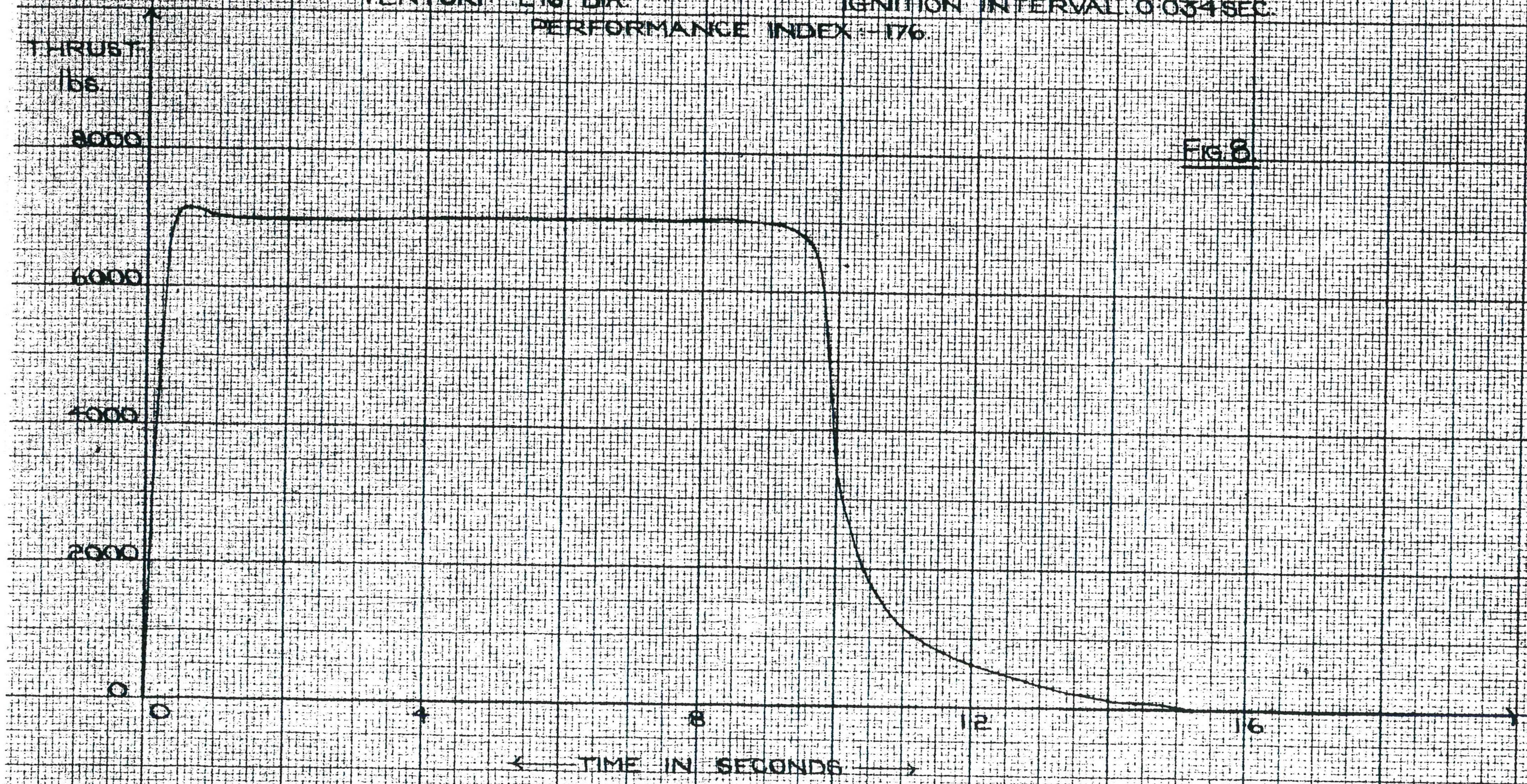

Fig 8.

FIG 9.

THRUST TIME CURVE FOR 5" LAP/RP AT 140°F

PROPELLANT - RD 2633
CHARGE WEIGHT - 41 LBS
IGNITER - 22 GMS G12
VENTURI - 2·16" DIA

ROUND NO - Q - 783
SERIAL NO - 5P - 363
DATE FIRED - 24 - 4 - 46
IGNITION INTERVAL - 0·012 SEC

PERFORMANCE INDEX - 175·5

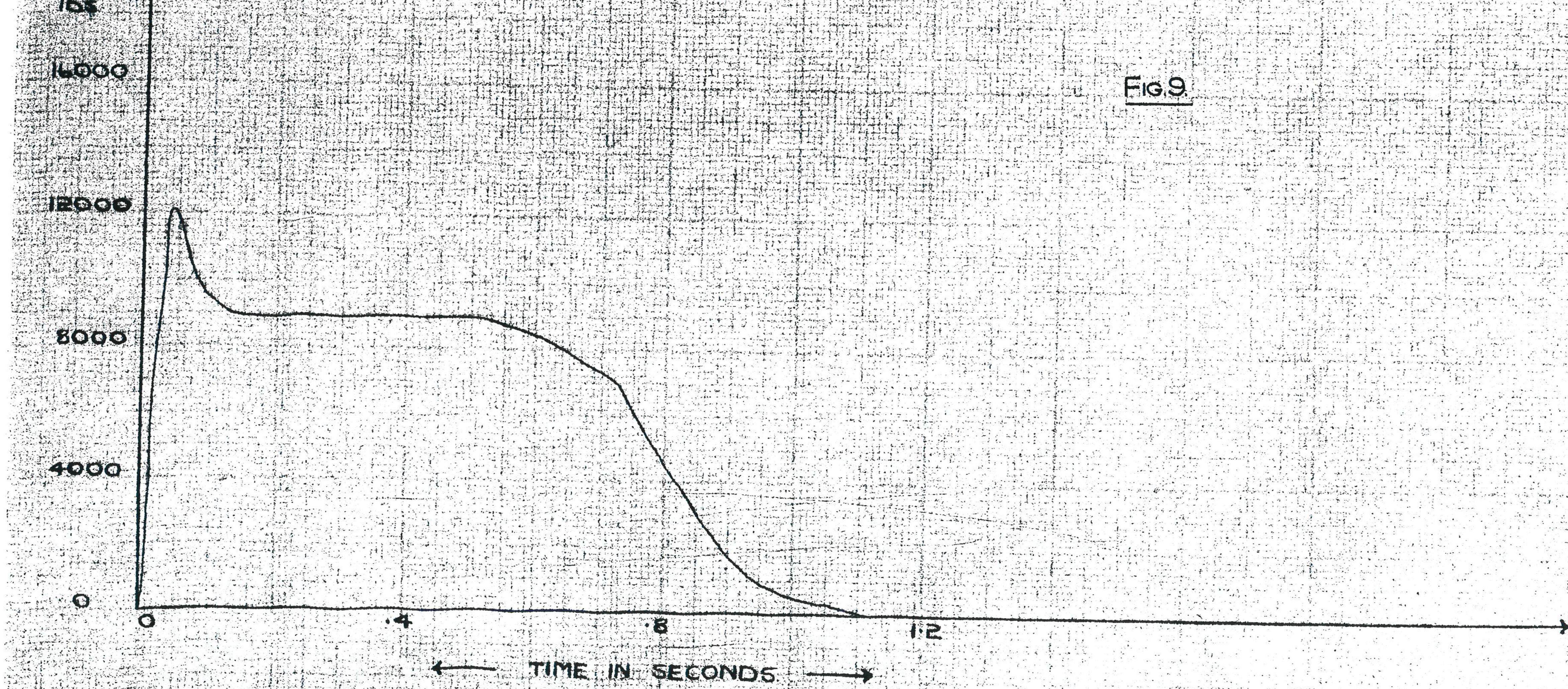

FIG 10.

THRUST TIME CURVES FOR 5" L.A.P./R.P. AT 140°F.

PROPELLANT :- RD 2633.
CHARGE WEIGHT :- 40LBS. 9½OZS.
IGNITER :- 22 GMS. G12.
VENTURI :- 2·16" DIA.

ROUND NO :- Q-779.
SERIAL NO :- 5P-359.
DATE FIRED :- 16-4-46.
IGNITION INTERVAL :- 0·021 SEC.

PERFORMANCE INDEX :- 179·5.

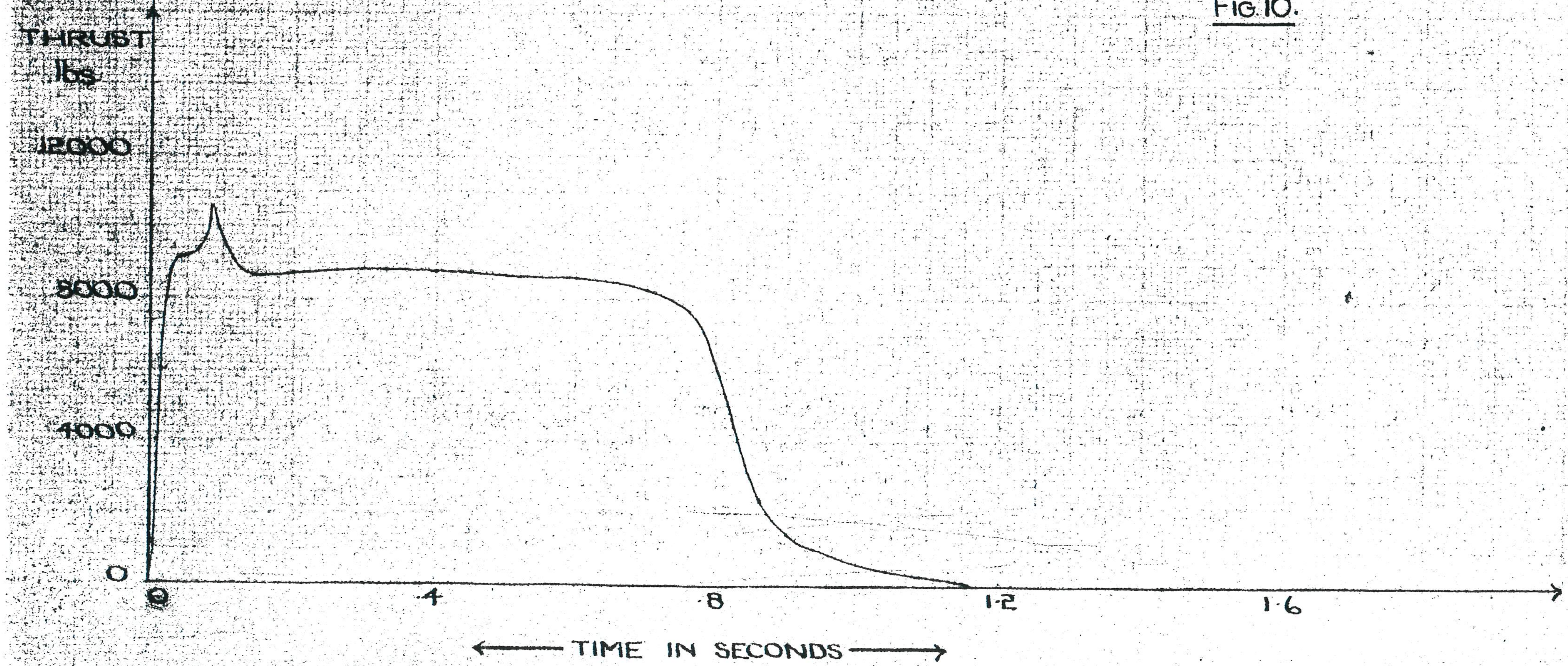

Fig.10.

FIG. 11

THRUST TIME CURVE FOR 5" LAP/BP AT 140°F

PROPELLANT - RD 2633
CHARGE WEIGHT - 40 LBS 15 OZS
IGNITER - 22 GMS G 12
VENTURI - 2·16" DIA.

ROUND NO - Q-786
SERIAL NO - SP-366
DATE FIRED - 24-4-46
IGNITION INTERVAL - 0·016 SEC

PERFORMANCE INDEX 176·5

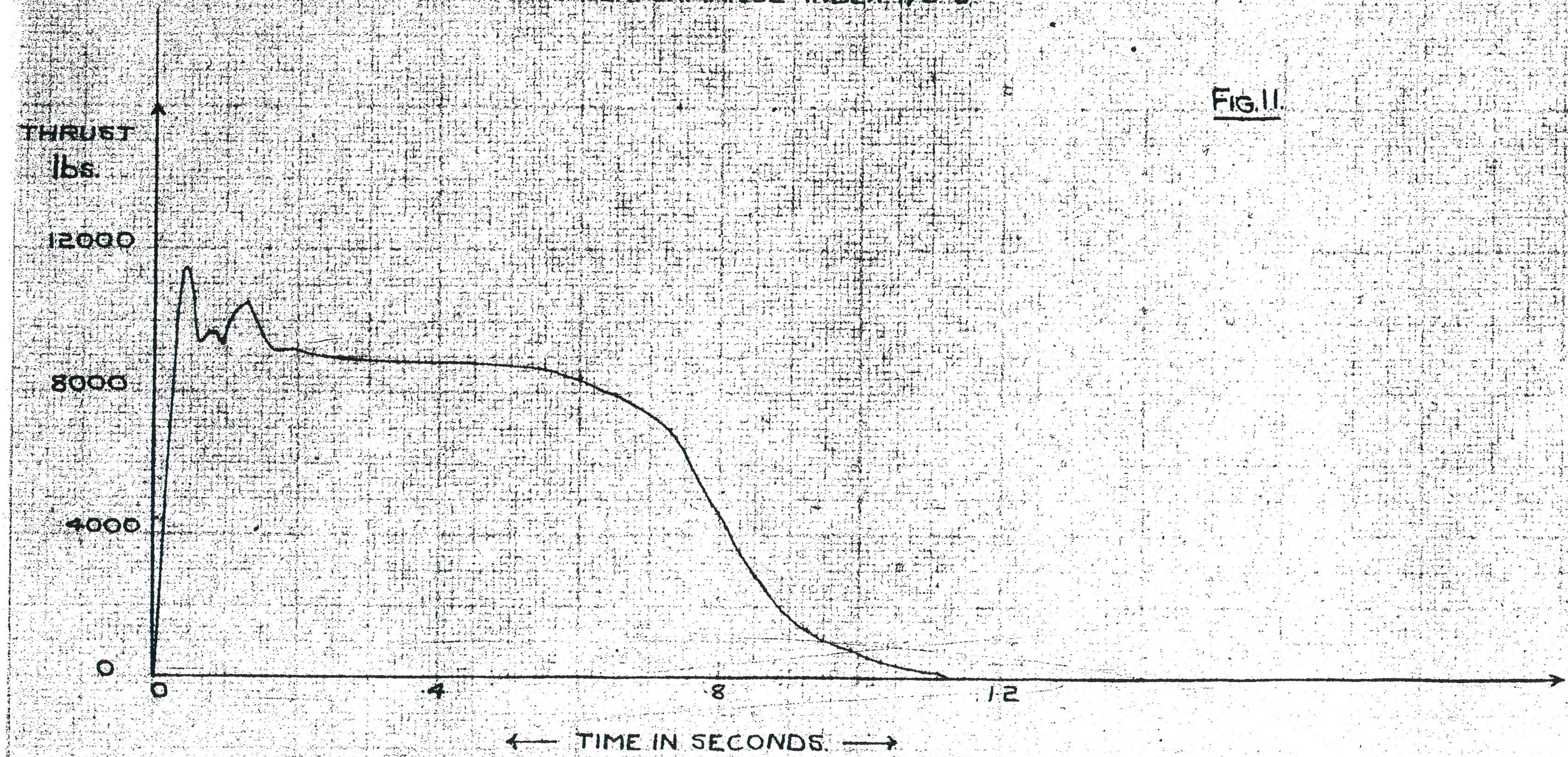

FIG. 11

FIG. 12.

PRESSURE AND THRUST TIME CURVES FOR 5" L.A.P./R.P. AT 59°F

PROPELLANT - RD 2049
CHARGE WEIGHT - 40 LBS
IGNITER - STANDARD 3" CARTON
VENTURI - 1.66" DIA

ROUND NO. - Q - 80L
SERIAL NO. - SP 457
DATE FIRED - 1. 8. 46
IGNITION INTERVAL - 0.027 SEC.

PERFORMANCE INDEX - 158.5

FIG. 12.

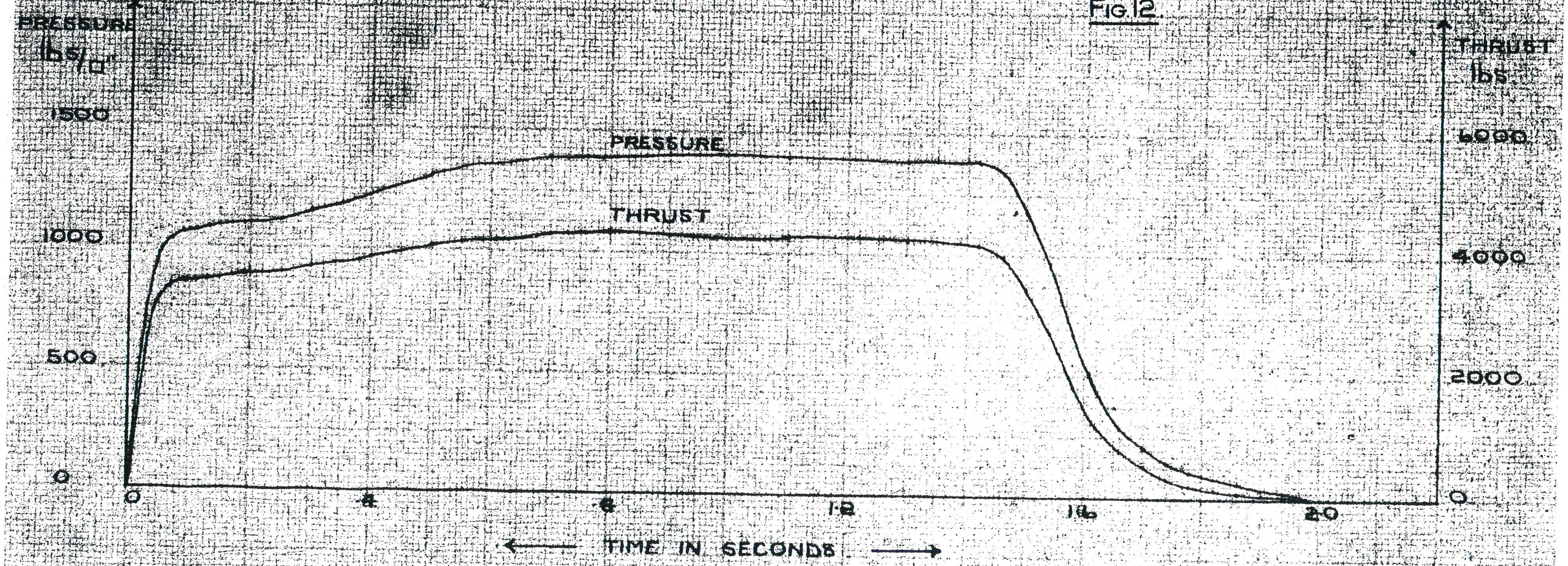

FIG 13.

PRESSURE AND THRUST TIME CURVES FOR 5" L.A.P/R.P. AT 59°F

PROPELLANT - RD 2049.
CHARGE WEIGHT - 40 LBS.
IGNITER - STD. 3" CARTON.
VENTURI - 1·66" DIA.

ROUND NO :- Q - 807.
SERIAL NO :- SP - 458.
DATE FIRED :- 1-8-46.
IGNITION INTERVAL :- 0·058 SEC.

PERFORMANCE INDEX - 156·5.

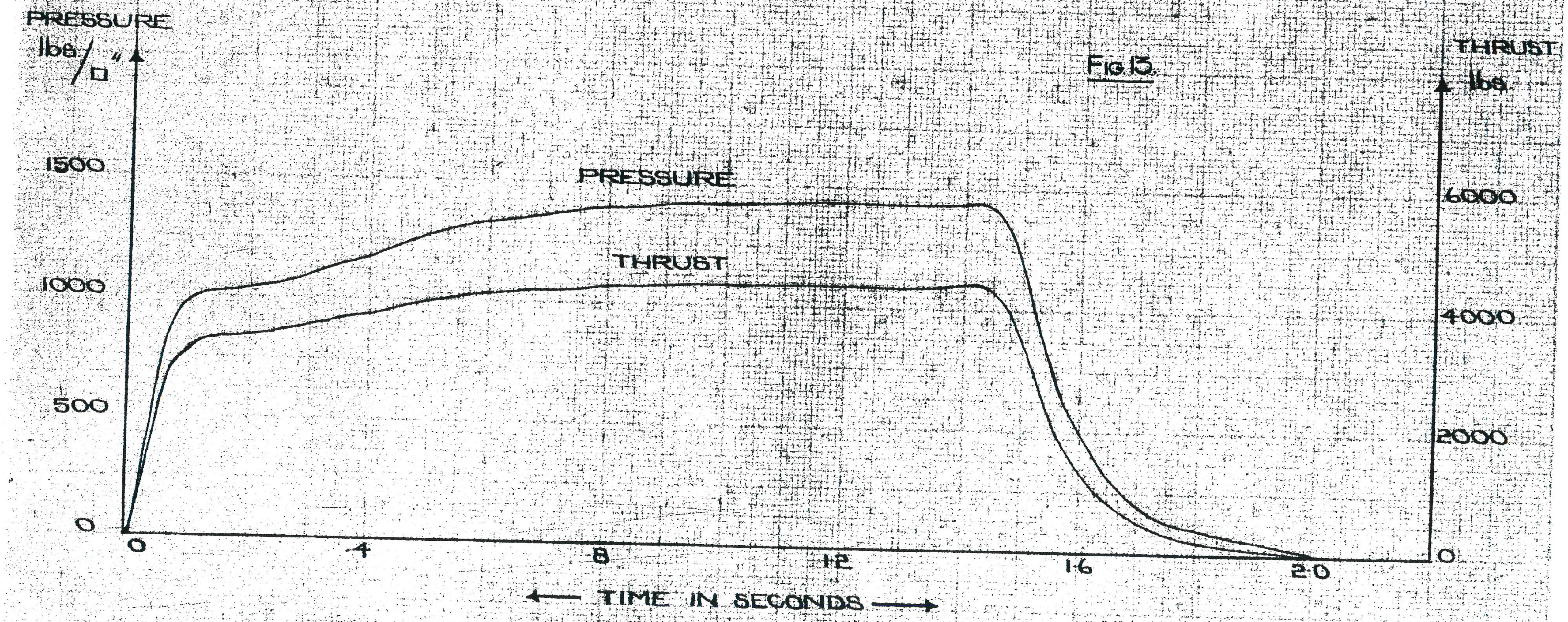

FIG. 14.

PRESSURE AND THRUST TIME CURVES FOR 5" L.A.P./R.P. AT 59°F

PROPELLANT :- RD 2049.
CHARGE WEIGHT :- 40 LBS. 8OZS.
IGNITER :- STD. 3" CARTON.
VENTURI :- 1·66" DIA.

ROUND NO :- Q-808.
SERIAL NO :- 5P-459.
DATE FIRED :- 1-8-46.
IGNITION INTERVAL :- 0·030 SEC.

PERFORMANCE INDEX :- 158.

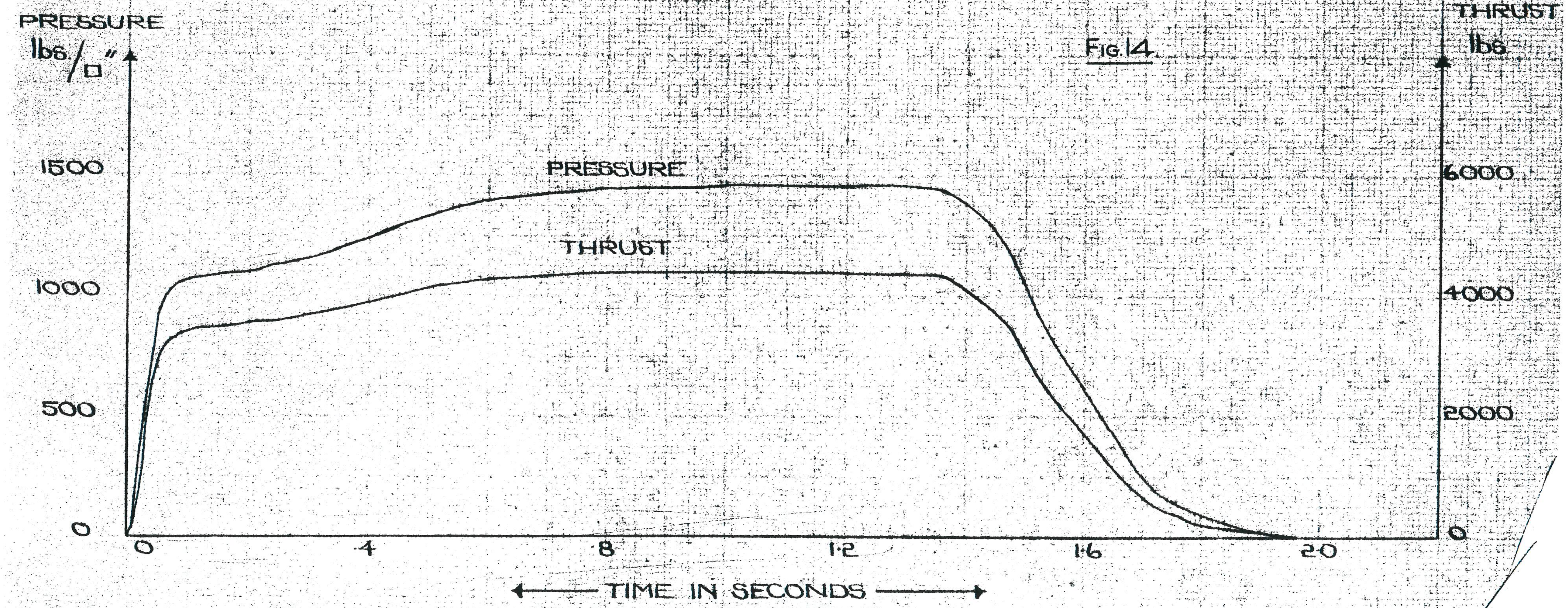

Fig. 15. 5.P.283.
Q. 744.

Fig. 16. 5.P.348
Q. 768

Fig. 17. 5.P.349
Q. 769

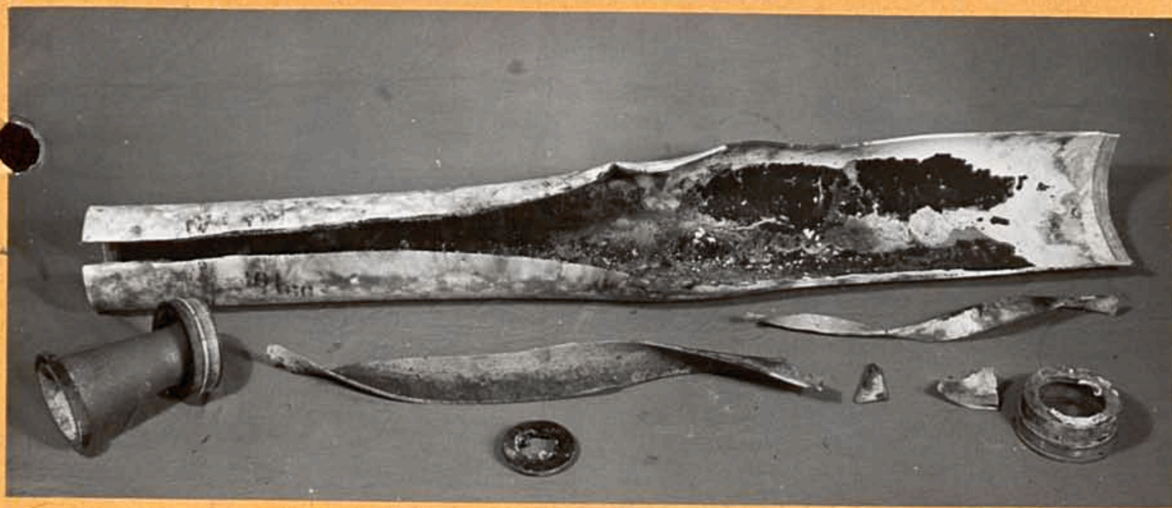

Fig. 18. 5.P.351
Q. -

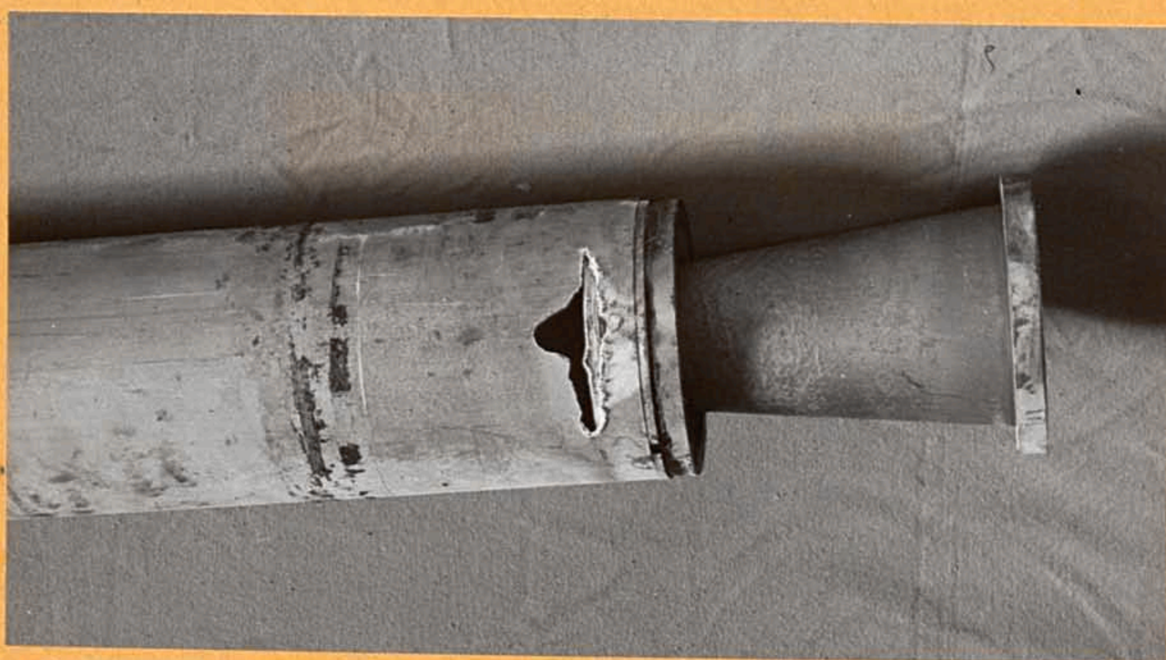

Fig. 19. 5.P.345
Q. 774

5.P.475 Q. 824 | 5.P.371 Q. 791 | 5.P.370 Q. 790 | 5.P.364 Q. 784 | 5.P.362 Q. 782

Fig. 20

Fig. 21. 5.P.368
Q. 788

Fig. 22. 5.P.463
Q. 818

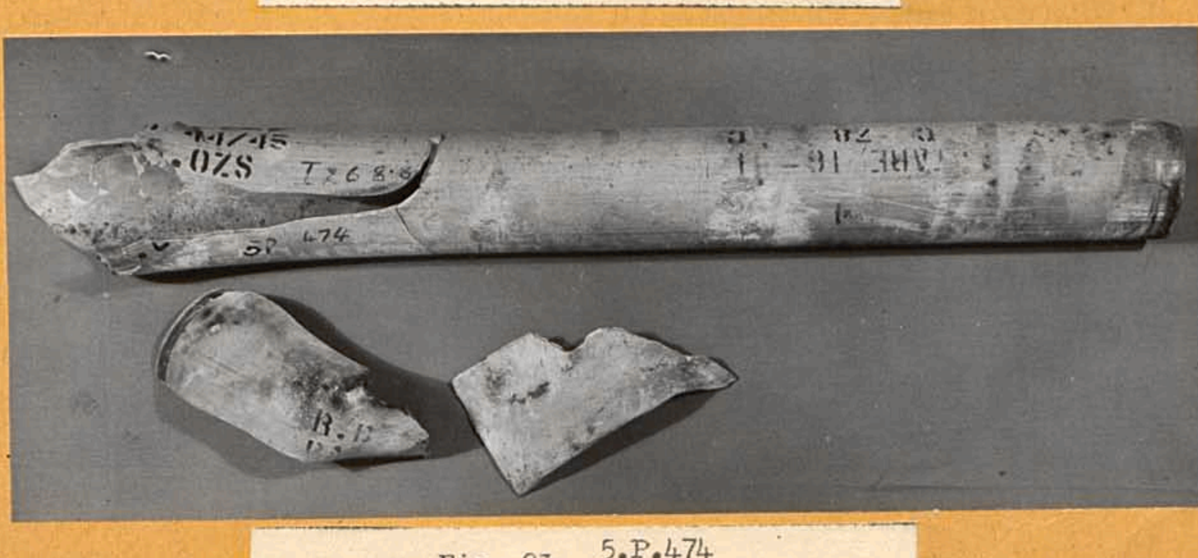

Fig. 23. 5.P.474
Q. 823

Fig. 24.

Fig. 25.

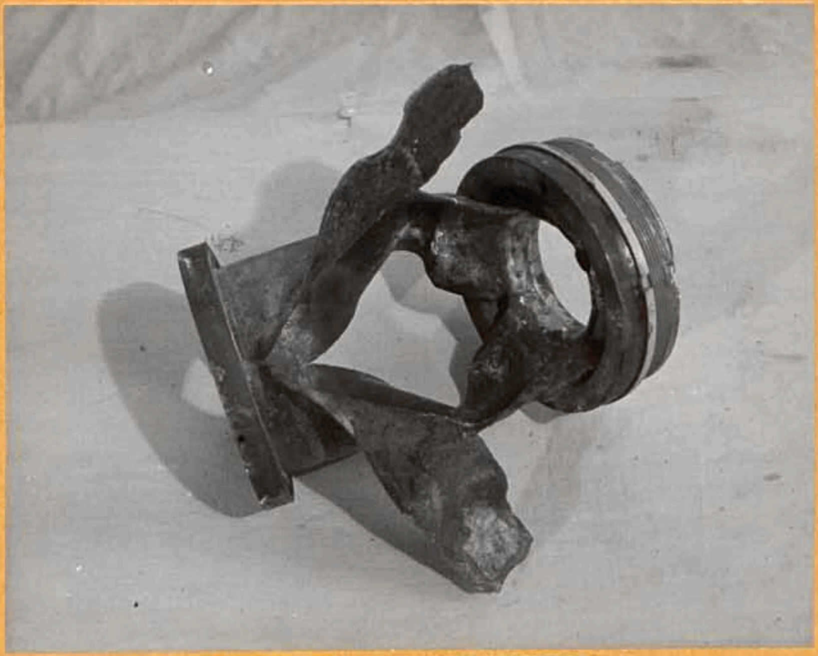

Fig. 26.

Fig. 27.