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U.S. Naval Proving Ground, Dahlgren, Va. (NPG Report No. 940)

First Partial Report on Ballistic Test of Experimental Propellants in the 5"/38 Caliber Blowout Gun - and Appendixes A thru D

Feistman, M.L. 14 May'52 31pp. tables, graphs, drwgs

Powder, Propellant - Performance
Powder, Propellant - Ballistics
Picrite

Ordnance and Armament (22)
Explosives (6)

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Ballistic Test of Experimental Propellants in the 5"/38 Caliber Blowout Gun

PART A

SYNOPSIS

1. The preliminary results of an investigation of the ignition and primary stages of burning of some standard and experimental propellants in a 5"/38 Blowout Gun are given in this report. Information as to time of primer venting and rupture of the chamber sealing disk, and pressure-time curves recorded at the front, middle, and rear of the chamber have been obtained. Oscillograph records illustrating typical performance and tables of values, averaged for the rounds fired, of time intervals and pressures are included.

2. Five powders have been fired in the Naval Proving Ground blowout gun, each through a charge temperature range of 45°F to 120°F. All charges were service loaded and used the Mk. 13-1 primer which had been modified to fire electrically only. The powders consisted of NH propellant, NPFB-234; Cordite "N" propellant, EX 6381; and three cool picrite propellants, EX 6659, EX 6688 and EX 6696.

3. As the charge temperatures were decreased from 120°F to 45°F, all the curves obtained became smoother. At a charge temperature of 45°F, two of three rounds with EX 6696 misfired. When the charges were broken down, it was found that scorching and partial ignition of the grains around the primer had occurred. At all charge temperatures the curves for the middle and front of the chamber generally exhibited more oscillations than those for the rear of the chamber.

4. The intervals from primer blowout to start of pressure and start of pressure to maximum pressure became progressively smaller as the charge temperature increased. For all of the propellants at each charge temperature the average time interval from start of pressure to maximum pressure decreased progressively from the rear to the front of the chamber.

Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blowout Gun

TABLE OF CONTENTS

	Page
SYNOPSIS	1
TABLE OF CONTENTS	2
AUTHORITY	3
REFERENCES	3
BACKGROUND	3
OBJECT OF TEST	4
PERIOD OF TEST	4
DESCRIPTION OF ITEMS TESTED	4
DESCRIPTION OF TEST EQUIPMENT	4
PROCEDURE	4
RESULTS AND DISCUSSION	5
CONCLUSIONS	8
APPENDIX A - COMPOSITION OF PROPELLANTS	TABLE I
GEOMETRY OF PROPELLANTS	TABLE II
TABULATED DATA	TABLE III 1-2 (Incl)
APPENDIX B - DRAWINGS	FIGURES 1-4 (Incl)
APPENDIX C - PRESSURE-TIME RECORDS	FIGURES 5-22 (Incl)
APPENDIX D - DISTRIBUTION	1-5 (Incl)

Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blowout Gun

PART B

INTRODUCTION

1. AUTHORITY:

BUORD Conf ltr NP9 Re2d-EM:df Ser 22675 of 11 July 1951 to NAVPROV.

2. REFERENCES:

a. BUORD ltr S78-1(51)(Re2a) of 28 March 1946 to NAVPROV
b. BUORD Restr ltr S74-1(5")(Re2a) EM:blm of 6 January 1948 to NAVPROV
c. UMN/S21 Conf - University of Minnesota Monthly Progress Report of March - April 1948
d. ABL/P13 Conf - Strand Rate Ballistic Studies of Plateau Type Propellants by S. Zmachinski and R. F. Preckel - December 1948
e. BUORD Conf ltr NP9 (Re2d) EM:ltm of 17 June 1949 to NAVPROV
f. NAVPROV Conf ltr S78-1(45)(X91731) of 2 September 1949 to BUORD
g. NPG Report No. 829 Conf - Construction and Calibration of a 5"/38 Caliber Blowout Gun - of 20 August 1951

3. BACKGROUND:

Reference (a) requested that the Naval Proving Ground set up a 5" blowout chamber to investigate the action of Albanite type powders since damage had occurred to a 5"/38 gun and mount during one phase of test firing with this type powder. Reference (b) authorized the modification of a 5"/38 barrel to function as a blowout chamber with instrumentation to obtain pressure-time curves and other interior ballistic measurements. It was requested that this blowout chamber be used to conduct studies of the ignition and behavior of new types of compositions and granulations during the early stages of burning. Reference (g) was the final report on the construction and calibration of this chamber. Under reference (e), the Naval Proving Ground was requested to set up a continuing program for the investigation of ignition and early burning characteristics of experimental and production type propellants in the 5"/38 blowout gun. Reference (f) was written in compliance with the request that the Naval Proving Ground briefly outline its proposed research program for the coming year.

Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blowout Gun

4. OBJECT OF TEST:

To investigate the ignition and behavior of propellants during early stages of burning. This report discusses the first series of firings conducted.

5. PERIOD OF TEST:

a.	Date of Receipt of Directive	20 June 1949
b.	Date Phase Begun	1 December 1949
c.	Date Phase Completed	13 October 1950

PART C

DETAILS OF TEST

6. DESCRIPTION OF ITEMS TESTED:

Five powders have been fired in the Naval Proving Ground blowout gun, each through a charge temperature range of 45°F to 120°F. All charges were service loaded and used the Mk. 13-1 primer which had been modified to fire electrically only. The powders consisted of NH propellant, NPFB-234; Cordite "N" propellant, EX 6381; and cool picrite propellants, EX 6659, EX 6686 and EX 6696. The composition and geometry of the propellant grains under discussion will be found in Appendix (A), Tables I and II.

7. DESCRIPTION OF TEST EQUIPMENT:

The pressure gages, gage and calibration circuits, temperature control and recording units, and blowout gun are completely described in reference (g).

8. PROCEDURE:

Five rounds of each powder were fired at each charge temperature, making a total of 75 rounds (excluding some misfires and repeat rounds). The blowout gun was conditioned to the charge temperature with the cooling and heating equipment described in reference (g).

9. RESULTS AND DISCUSSION:

a. The three gage channels have been designated as A, B, and C, A being the gage channel 3 inches from the base of the cartridge case, B the middle gage channel 14 inches from the base, and C the channel nearest the muzzle end of the chamber and 25 inches from the base. The position of the gage channels and the primer are shown in Figure 2, Appendix (B). The seating of the case in the blowout gun is indicated in Figure 4, Appendix (B). The primer Mk. 13-1 is shown in Figure 3, Appendix (B).

b. The channel A curves for EX 6659 and EX 6696 at 120°F, Figures 13 and 18, Appendix (C), were the smoothest of all the curves obtained for the powders fired at this charge temperature. They are almost completely free of oscillations. EX 6659 shows a step just prior to maximum pressure. The NH and Cordite "NW" powders, NPFB-234 and EX 6381, (Figures 7 and 10, Appendix (C)), also exhibit the same type of step, although more pronounced. The curve of channel A for EX 6688 (Figure 16, Appendix (C)) indicates a sudden increase in the rate of change of pressure from 0.5 to 1.0 milliseconds after indicated rupture of the disc. The curve also is not as smooth as those for the other two cool propellants. Channels B and C curves are similar for all powders at 120°F and exhibit more oscillations than those for Channel A. In this respect, EX 6688 showed the largest amplitude of oscillations.

c. All the curves showed improvement at a charge temperature of 90°F over those for 120°F. The irregularities mentioned above were still in evidence for NPFB-234 and EX 6688 (Figures 6 and 15, Appendix (C)). However, the step just prior to maximum pressure presented in the channel A curves for EX 6381 and EX 6659 at 120°F disappeared at 90°F (Figures 9 and 12, Appendix (C)). In addition, the channel A curves for EX 6381, EX 6659, and EX 6696 exhibited a step in the low pressure region 500 to 1500 lbs/in^2 (Figures 9, 12, and 17, Appendix (C)) at this temperature.

d. At a charge temperature of 45°F, the curves were superior in smoothness to those for the higher temperatures, and the irregularities on the channel A curves specifically mentioned in paragraphs (a) and (b) are not in evidence. It was found that two of three rounds with EX 6696 misfired. In these two rounds, the powder grains around the primer had been partially ignited and scorched.

Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blowout Gun

e. The intervals from primer blowout to start of pressure and from start of pressure to maximum pressure became progressively smaller as the charge temperature increased (Table III, Appendix (A)). The greatest variation of these intervals with temperature was found with the Cordite "N" propellant EX 6381. The variation in the time interval from primer blowout to maximum pressure over the charge temperature range is the smallest for NPFB-234. Considering only the events at the rear of the chamber, the time intervals for the other four propellants increase from an average value of 7.34 milliseconds at 120°F to 19.12 milliseconds at 45°F, while the increase for NPFB-234 is 6.82 to 9.11 milliseconds respectively. For all of the propellants at each charge temperature the interval from start of pressure to maximum pressure became progressively smaller from the rear to the front of the chamber.

f. A plot of the maximum pressures, averaged over the three channels, versus charge temperature for the powders fired is shown in Figure 1, Appendix (B). The curve for NPFB-234 indicates a linear relationship over the charge temperature range fired.

g. As previously outlined, propellants EX 6381, EX 6696 and EX 6659 show steps in their channel A curves in the low pressure region 500 to 1500 lbs/in^2 (Figures 9, 12, and 17, Appendix (C)). In reference (c), it was reported "Lead and certain other heavy metals, free or in certain of their compounds, when added to a relatively cool double base powder can cause that powder to show plateaus in its burning rate curve at pressure of 500 to 1500 lbs/in^2, depending upon the percentage content of the metal". The above statement is substantiated in more detail in reference (d), in which the effects of adding small amounts of lead compounds from 0.5% to 16.0% are discussed. Although EX 6381 and EX 6696 contain 0.51% $PbCO_3$ and 0.96% $PbCO_3$ respectively, this cannot be solely responsible for the step formation since EX 6659 does not contain any lead or other metallic compound.

From Figure 2, Appendix (B), it is apparent that the powder grains at the channel A position will be the first affected by the primer venting and the first indication of pressure should be on the channel A curve. Initial irregularities in this curve in the low pressure region are probably due to a change in the burning rate of the powder itself or some gas phase reaction. The oscillations on the channel B and C curves may be caused by the above conditions and/or the passing of pressure waves initiated by events

occurring in the vicinity of the primer. From the time the primer vents to the first indication of pressure there is an average time of 3.12 milliseconds during which the propellant grains around the primer are burning and giving off gaseous products. Upon reaching a certain energy level these gases undergo a rapid transformation causing an increase in pressure. The energy released may ignite surrounding grains, which will burn rapidly, due to the higher pressure at which they are ignited. However, there will be a delay from the time of reaction of the gases to the ignition of the additional grains, so that the pressure-time curve will tend to level off until these grains commence burning. The absence of the steps at low pressure at charge temperatures of 45°F and 120°F may be explained as follows. At 45°, the gases are being evolved at a slow enough rate so that they can distribute themselves over a greater volume of the charge. They may not reach the energy level necessary for the transformation until after most of the grains in the area have commenced burning. At 120°F, the grains are at an initially higher potential energy level before ignition. Upon ignition, the grains burn more rapidly and the gases serve to ignite other grains more readily, which generates sufficient energy to prevent combustible gases from accumulating and remaining confined to some configuration as is possibly the case for the 90°F charge.

h. The step on the curve just prior to maximum pressure, as previously noted for NPFB-234 at 90°F and 120°F and EX 6381 and EX 6659 at 120°F, and the sharp rise in pressure just prior to maximum pressure, for EX 6688 at 90°F and 120°F, occur from about 0.5 to 1.0 millisecond after disc blowout, so that these effects may be associated with the rupture of the disc. However, they may also be due to the above described phenomena of gas reaction at some energy level.

i. Further investigations will be carried out to determine the effect of charge assembly and ignition system variations on these steps. The effects of this phenomenon upon the entire ballistic cycle will also be studied.

j. Four additional sets of curves are included in this report to indicate the order of deviations from the average values of pressures and times for rounds fired under the same ballistic conditions (Figures 19 to 22, Appendix (C)). These curves were obtained with EX 6381 at a charge temperature of 90°F. Maximum differences of pressures from the tabulated average values are about ±5%. The time intervals are generally of the same order for any given powder under similar conditions.

k. The firings upon which this report is based were in the nature of an exploratory investigation to determine the manner in which the weapon would act and what information could be obtained. The instrumentation is undergoing further refinements as tests are continued.

PART D

CONCLUSIONS

10. a. As the charge temperatures decreased from 120°F to 45°F, the curves became smoother. At all charge temperatures, the curves for the middle and front of the chamber generally exhibited more oscillations than those for the rear of the chamber.

b. The intervals from primer blowout to start of pressure and start of pressure to maximum pressure became progressively smaller as the charge temperature increased. For all of the propellants at each charge temperature the average time interval from start of pressure to maximum pressure decreased progressively from the rear to the front of the chamber.

Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blowout Gun

The tests upon which this report is based were conducted by:
M. L. FEISTMAN, Interior Ballistics Division,
Armament Department

This report was prepared by:
M. L. FEISTMAN, Interior Ballistics Division,
Armament Department

This report was reviewed by:
L. D. WEBER, Interior Ballistics Division,
Armament Department
D. C. CAIN, Head, Interior Ballistics Division,
Armament Department
L. C. KLINGAMAN, Commander, USN, Armament Officer,
Armament Department
C. C. BRAMBLE, Director of Research, Ordnance Group

APPROVED: IRVING T. DUKE
Rear Admiral, USN
Commander, Naval Proving Ground

C. T. Mauro

C. T. MAURO
Captain, USN
Ordnance Officer
By direction

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NPG REPORT NO. 940

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

First Partial Report

on

Ballistic Test of Experimental Propellants

in the 5"/38 Caliber Blowout Gun

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Date: MAY 14 1952

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TABLE I

COMPOSITION (%) OF PROPELLANTS

Powder	Type	NC	NG	Picrite	DNT/DBP	Diphenylamine	DBP	Centralite	$PbCO_3$	Total Volatiles	Ash
NPFR-234	NH	85.08 13.16%N			12.33	0.97				1.62	
EX-6381	Cordite N	19.13 13.0%N	18.18	54.50				7.50	0.51	0.18	
EX-6659	2150°K NG	20.04 13.20%N	10.56	59.97			7.50	1.93		0.23	
EX-6688	1950°K NG	19.50 13.20%N	8.97	60.49			9.50	1.59			
EX-6696	1950°K+ 1% $PbCO_3$	20.07 13.20%N	10.97	57.86			9.47	1.63	0.96	0.49	0.10

NC - Nitrocellulose
% N - % Nitrogen
NG - Nitroglycerin
DNT - Dinitrotoluene
DBP Dibutylphthalate

TABLE II

GEOMETRY OF PROPELLANTS

Powder	Length Inches	Diam. Inches	Perforation Diam. Inches	Outer Web Inches	Inner Web Inches	Average Web Inches	Charge Weight Fired Lbs.	P.P.D. Inches
NPFB-234	0.7060	0.3060	0.0310	0.0550		0.0530	15.53	4.7
EX-6381	0.7200	0.2850	0.0290	0.0530		0.0500	15.56	5.8
EX-6659	0.4780	0.2094	0.0244	0.0388	0.0344	0.0341	16.00	5.1
EX-6688	0.3860	0.1635	0.0172	0.0291	0.0269	0.0280	16.00	4.5
EX-6696	0.4735	0.1960	0.0220	0.0304	0.0345	0.0324	16.00	4.3

TABLE III

TABULATED DATA

t of Pressure ax. Pressure lliseconds B	C	Disc Blowout Time Milliseconds	Start of Press. (a) to D.B.O. Milliseconds	Max. Pressure P.S.I. A	B	C	Pressure at Disc Blowout P.S.I. A	B	C
9 5.53	4.17	4.97	2.95	10800	11650	11275	3300	3825	1475
4 4.81	4.22	3.28	1.91	11600	13125	12575	5525	5375	1500
7 4.70	4.10	3.27	2.72	12850	13051	13900	6175	6275	2400
9 9.85	8.61	15.27	4.04	7750	8300	8275	825	1125	1150
57 7.38	5.84	4.89	2.43	9950	10450	10800	1500	1450	1250
53 6.24	4.79	3.84	3.17	10875	11025	11600	3125	3125	975
71 11.68	8.88	12.33	9.94	9600	10025	9675	2700	3250	3075
90 5.35	3.94	4.38	2.30	9675	10925	9850	3175	3750	825
85 4.55	3.04	3.90	3.27	11100	11675	11000	5075	6750	2975

TABLE III

TABULATED DATA

Temp. of Powder °F	Primer B. O. to Start of Pressure Milliseconds A	B	C	Primer B. O. to Max. Pressure Milliseconds A	B	C	Start of Pressure to Max. Pressure Milliseconds A	B	C	Disc Blowout Time Milliseconds	Start of Pres. (a) to D.B.O. Milliseconds	Max. Pressure P.S.I. A	B	C	Pressure at Disc Blowout P.S.I. A	B	C
Powder: NPFB-234																	
45	2.02	3.74	4.86	9.11	9.27	9.03	7.09	5.53	4.17	4.97	2.95	10800	11650	11275	3300	3825	1475
90	1.81	2.22	2.73	7.15	7.03	6.95	5.34	4.81	4.22	3.28	1.91	11600	13125	12575	5525	5375	1500
120	0.55	2.05	2.86	6.82	6.75	6.96	6.27	4.70	4.10	3.27	2.72	12850	13051	13900	6175	6275	2400
Powder: EX-6381																	
45	11.67	9.20	12.99	21.76	19.05	21.60	10.09	9.85	8.61	15.27	4.04	7750	8300	8275	825	1125	1150
90	3.13	3.69	5.37	10.80	11.07	11.21	7.67	7.38	5.84	4.89	2.43	9950	10450	10600	1500	1450	1250
120	0.62	1.80	3.16	8.15	8.04	7.95	7.53	6.24	4.79	3.84	3.17	10875	11025	11600	3125	3125	975
Powder: EX-6659																	
45	3.86	4.68	7.69	16.57	16.36	16.57	12.71	11.68	8.88	12.33	9.94	9600	10025	9675	2700	3250	3075
90	2.08	2.83	4.24	7.98	8.18	8.18	5.90	5.35	3.94	4.38	2.30	9675	10925	9850	3175	3750	825
120	0.88	2.26	3.31	6.73	6.81	6.35	5.85	4.55	3.04	3.90	3.27	11100	11675	11000	5075	6750	2975

TABLE III (Continued)

Temp. of Powder °F	Primer B. O. to Start of Pressure Milliseconds A	B	C	Primer B. O. to Max. Pressure Milliseconds A	B	C	Start of Pressure to Max. Pressure Milliseconds A	B	C	Disc Blowout Time Milliseconds	Start of Pres. (a) to D.B.O. Milliseconds	Max. Pressure P.S.I. A	B	C	Pressure at Disc Blowout P.S.I. A	B	C
Powder: EX-6688																	
45	3.10	7.38	6.50	17.44	17.01	16.00	14.34	9.64	9.50	-	-	12325	12750	10500	-	-	-
90	1.52	2.40	4.85	7.62	7.12	7.92	6.10	4.72	3.07	5.06	3.74	12775	13925	13825	4075	5075	3950
120	0.49	1.97	3.72	6.52	6.42	6.65	6.03	4.45	2.93	4.19	3.71	15300	15325	14775	8250	8525	6775
Powder: EX-6696																	
45	Charge would not ignite at this temperature -																
90	0.92	2.11	4.24	7.87	7.91	8.12	6.95	5.80	3.73	4.19	3.25	10275	10950	10825	2225	2975	175
120	0.59	2.37	4.26	7.79	7.96	7.77	7.20	5.59	3.51	4.16	3.65	11500	11625	10950	6200	5700	3075

Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blow-out Gun

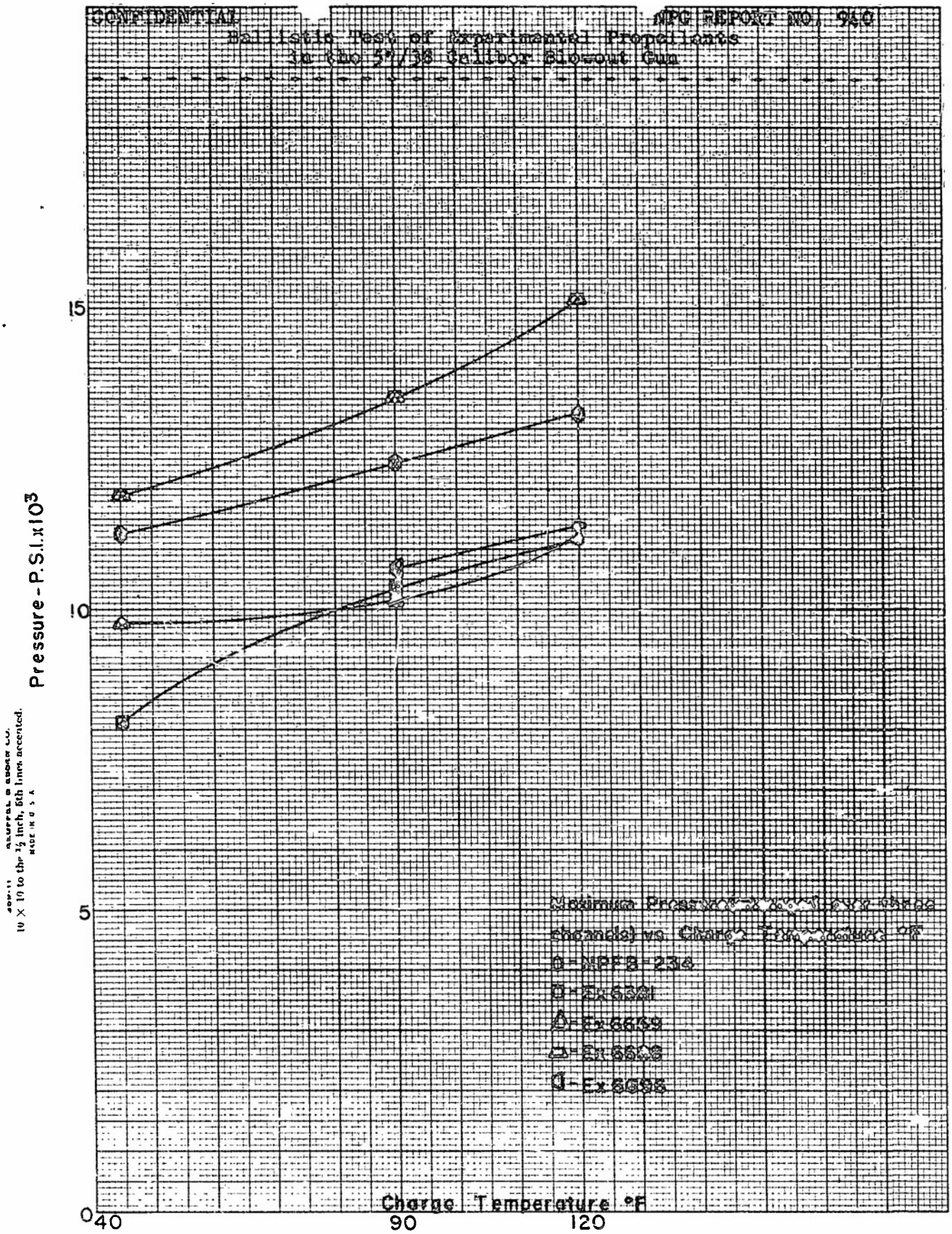
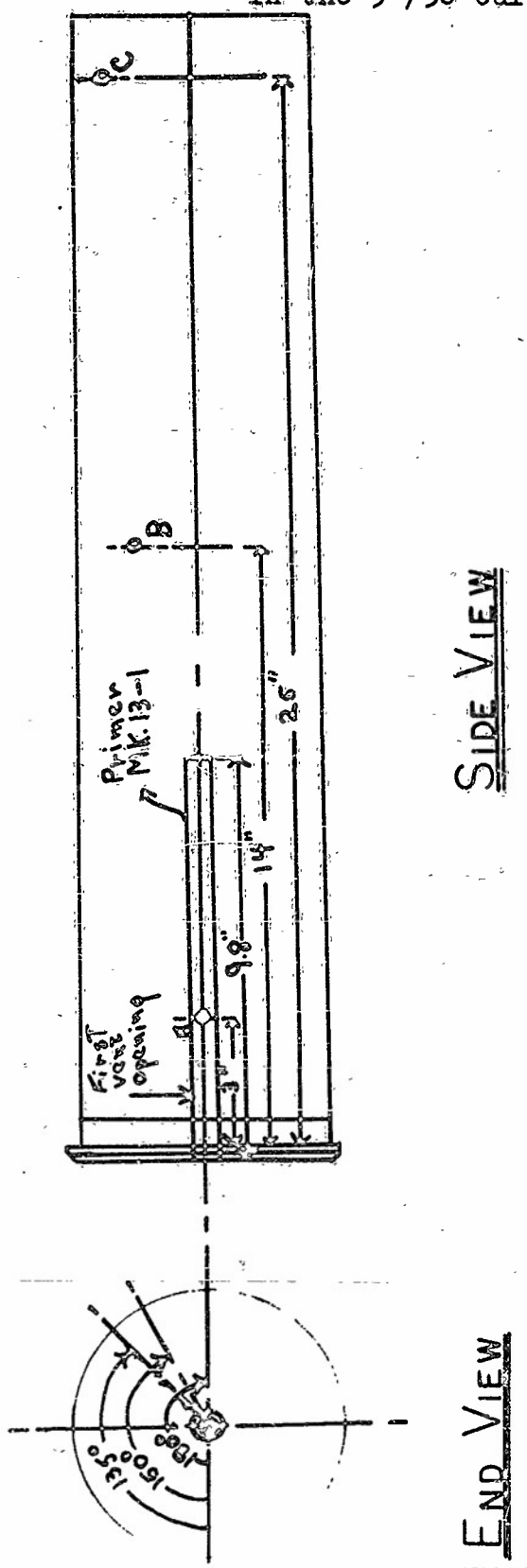


Figure 1



SIDE VIEW

END VIEW

GAGE HOLES AND PRIMER POSITION
IN BLOWOUT GUN CASE

NP9-17817 Ballistic Test of Experimental Propellants in the 5"/38 Caliber Blowout Gun.

FIGURE 3

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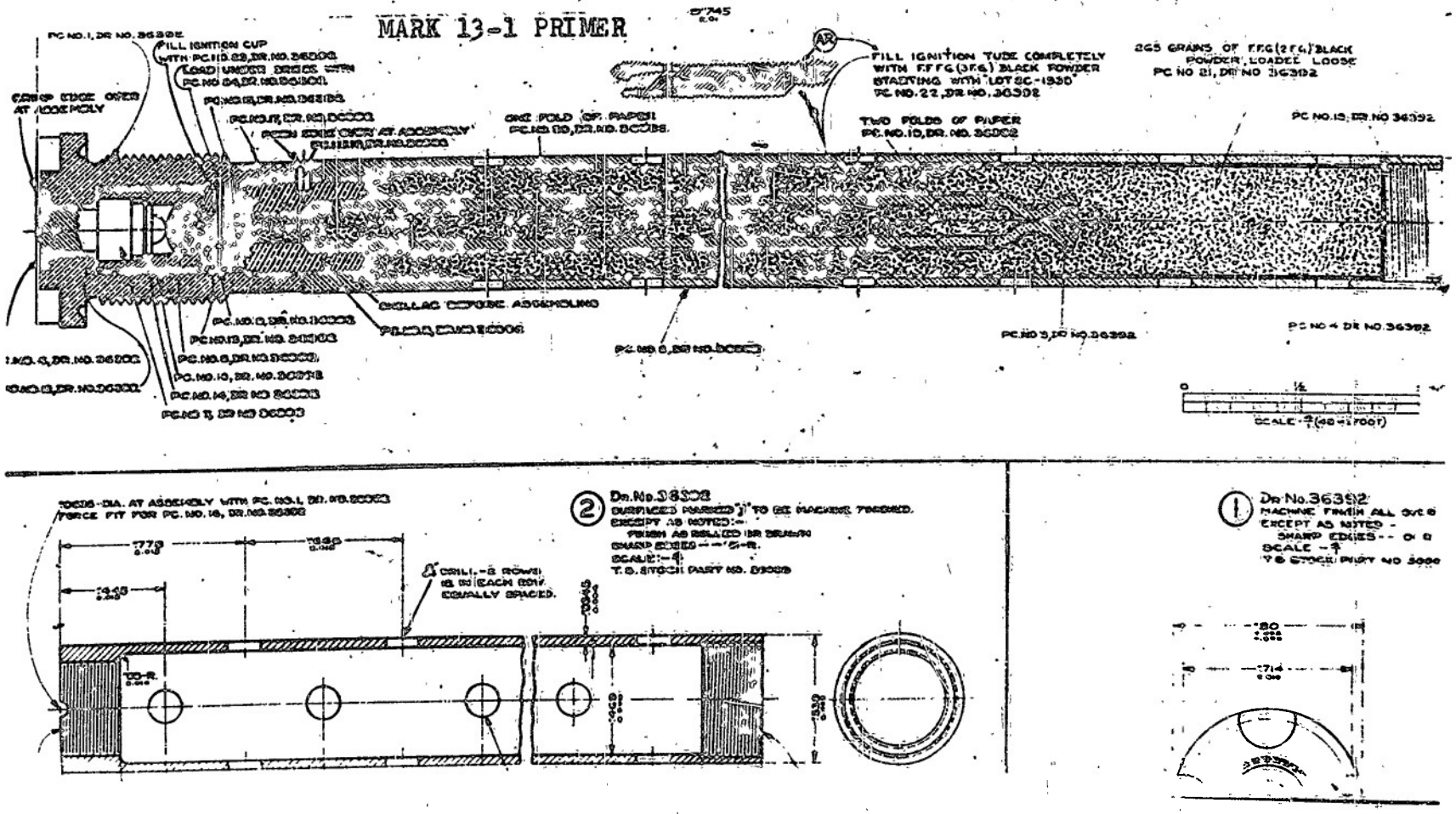
MARK 13-1 PRIMER



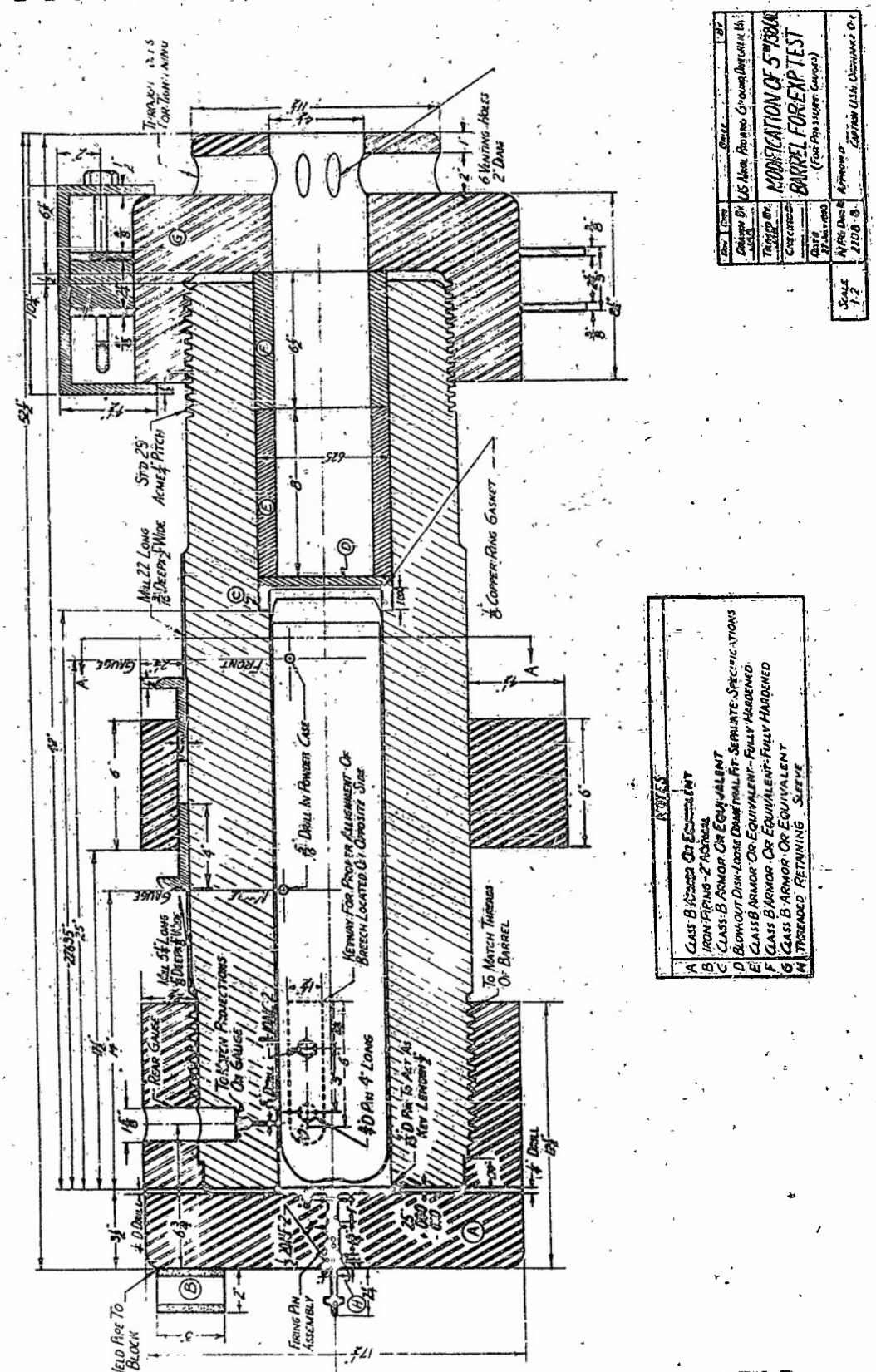


FIGURE 4

APPENDIX B

Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blowout Gun

NPFB-234 at 45°F

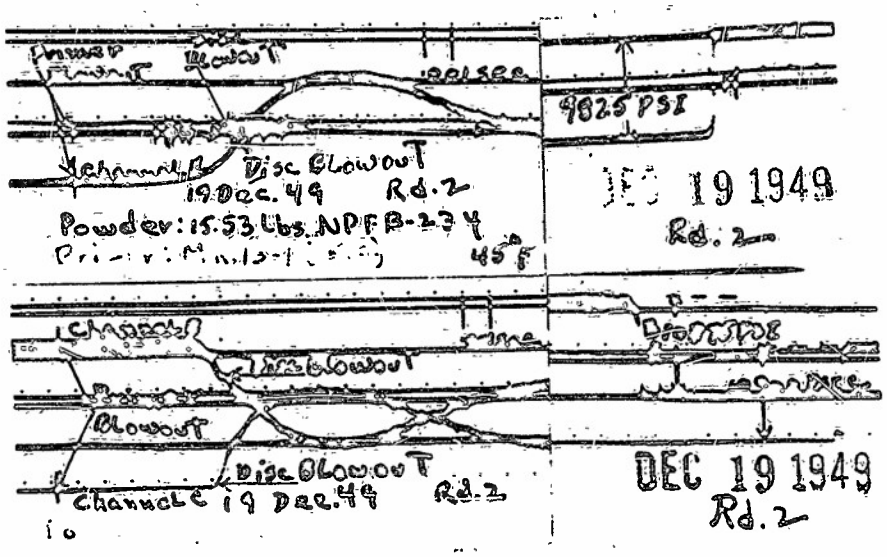
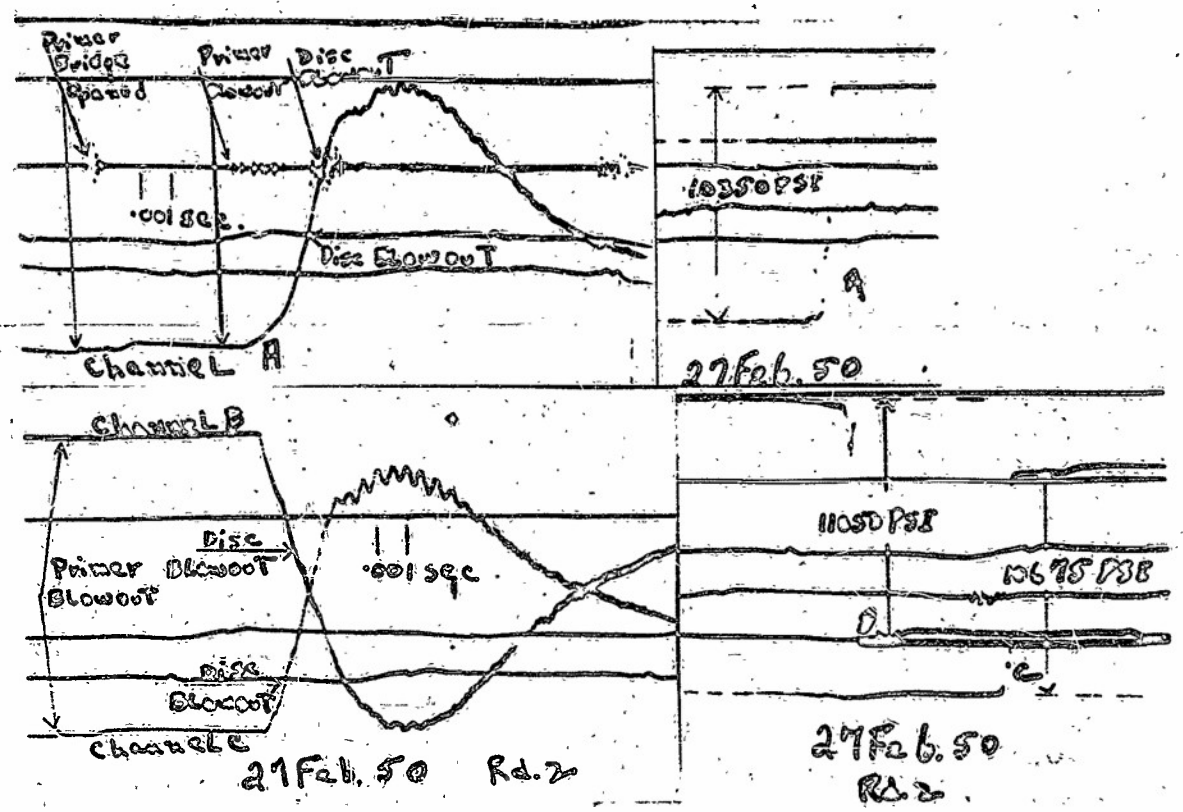


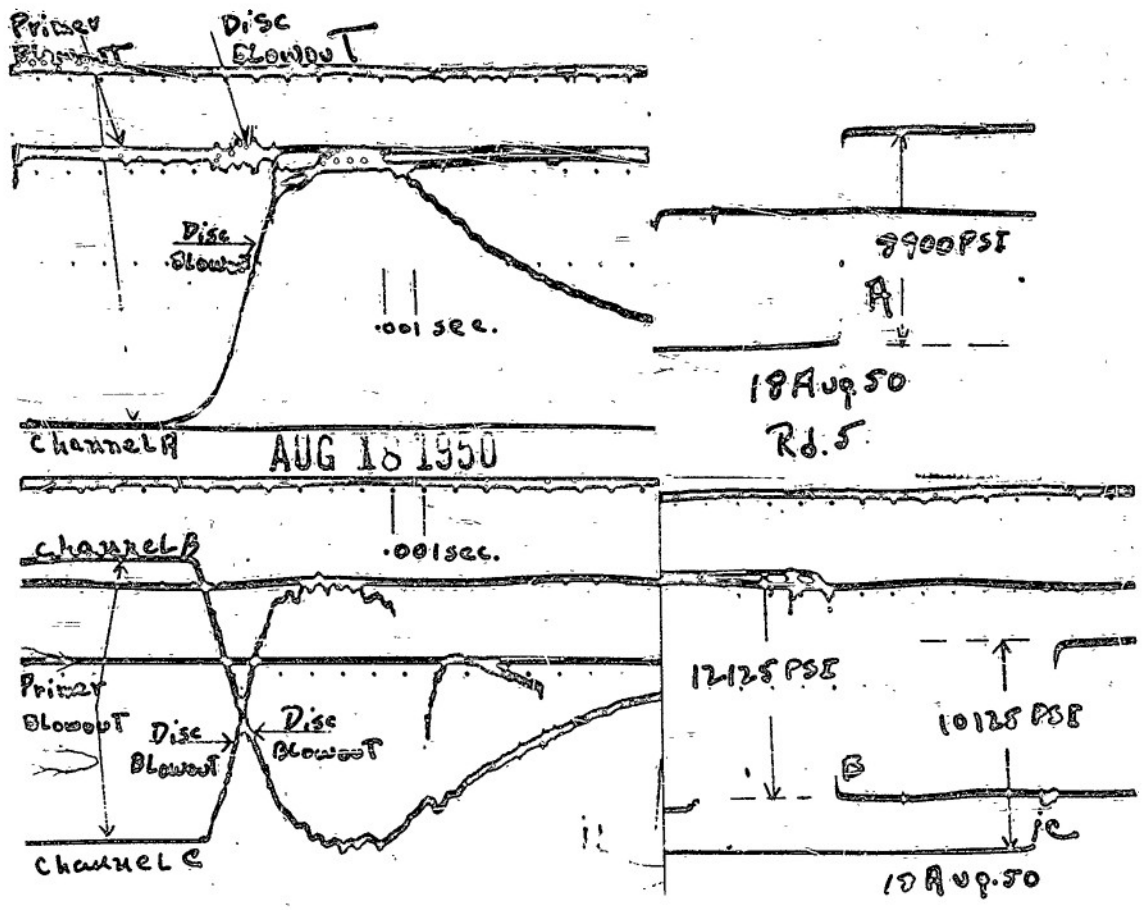
FIGURE 5

APPENDIX C

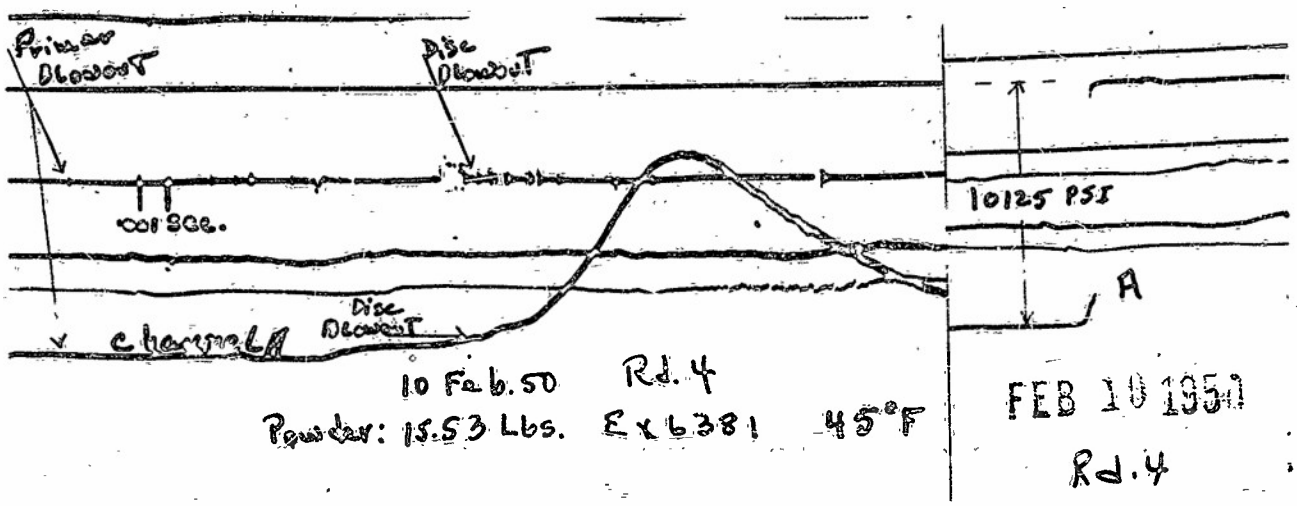
NPFB-234 at 90°F

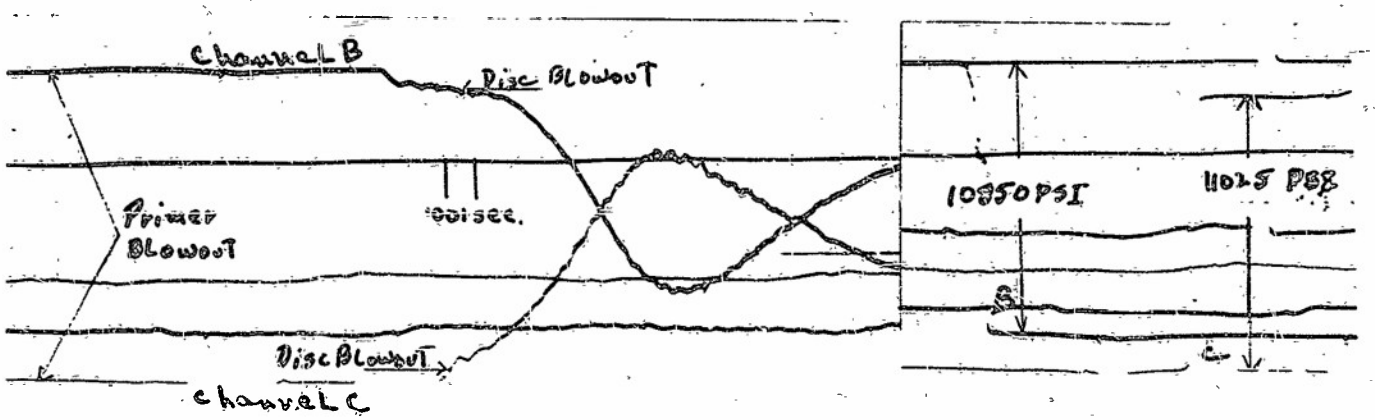


NPFB-234 at 120°F



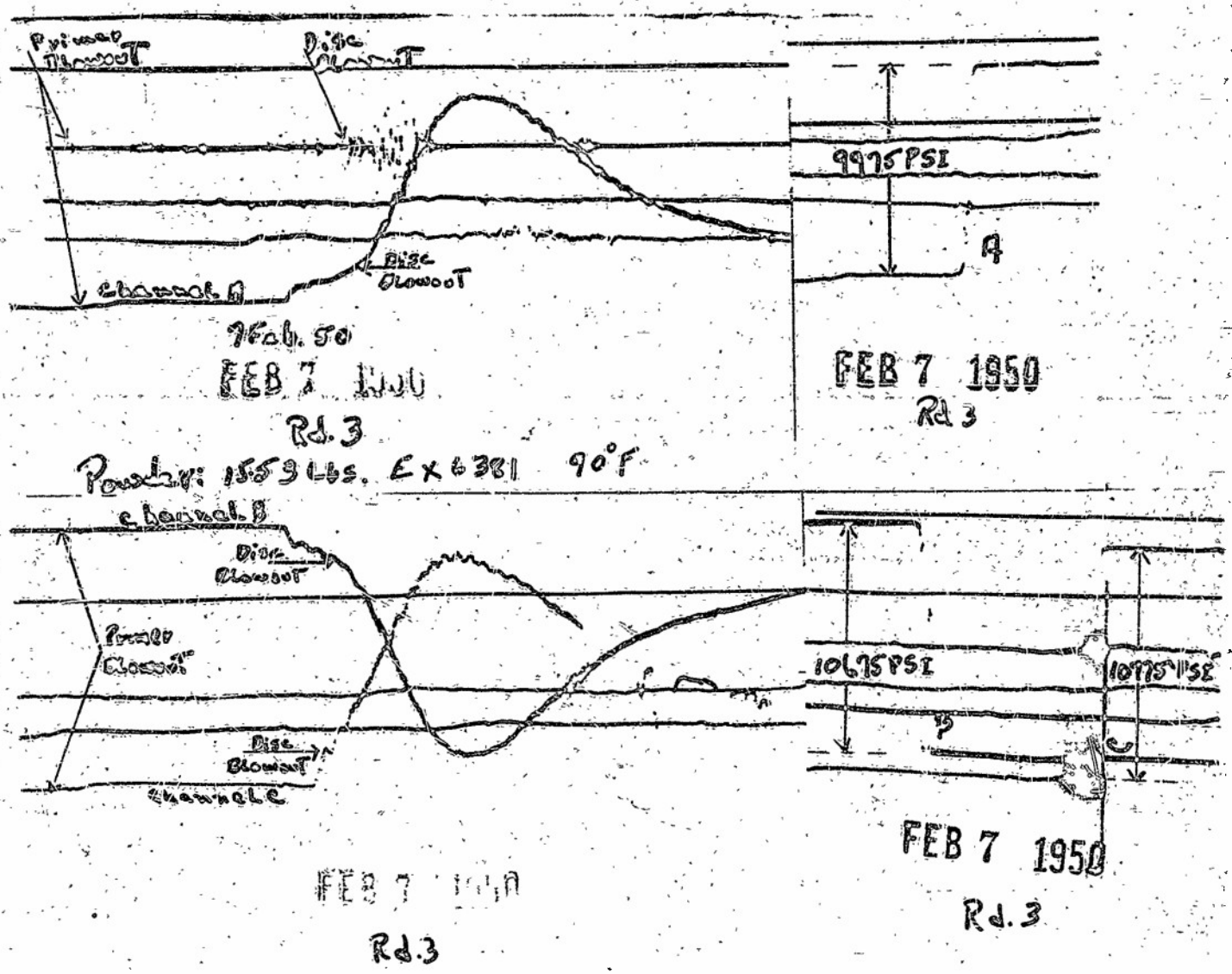
EX-6381 at 45°F



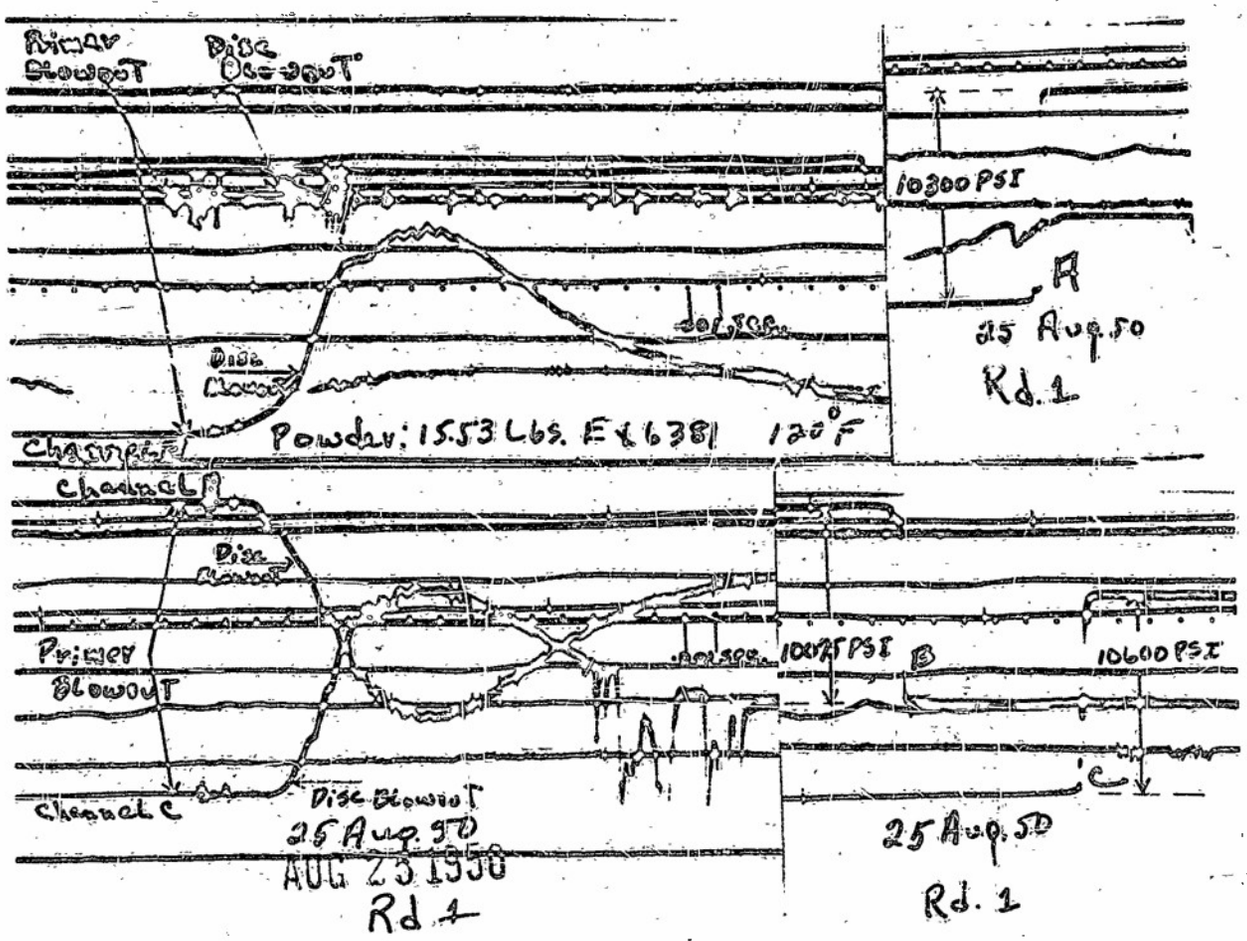


FE 10 1950 10 Feb. 50 FEB 10 1950
Rd. 4 Rd. 4

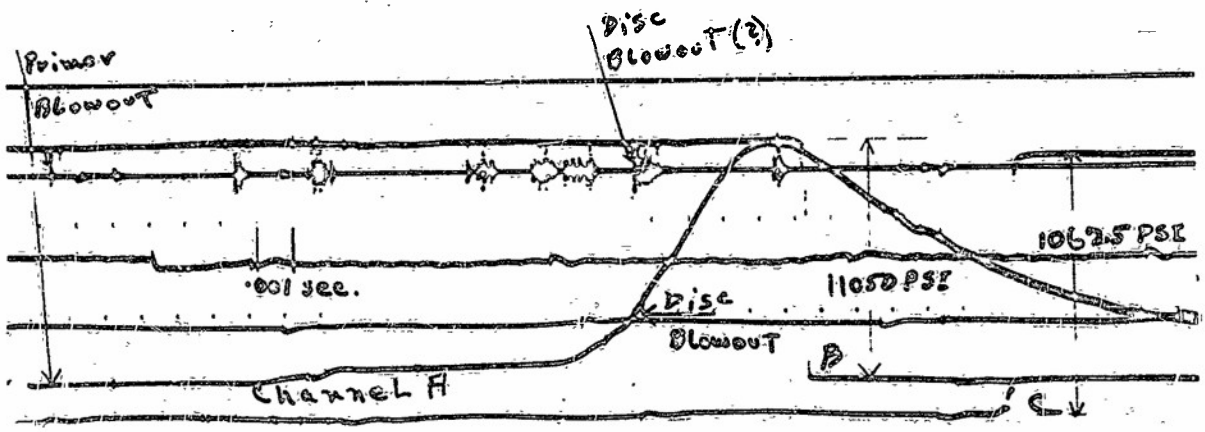
EX-6381 at 90°F



EX-6381 at 120°F



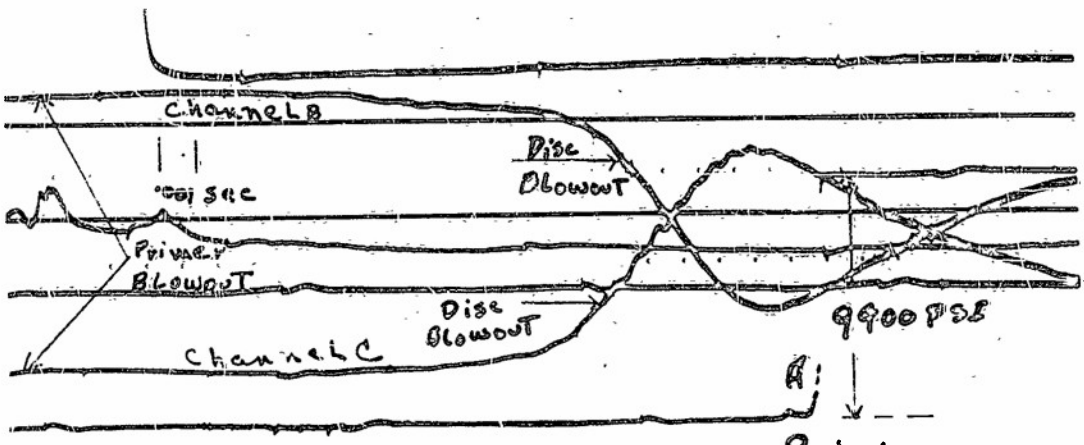
EX-6659 at 45°F



5i

21 April 50 Rd.4

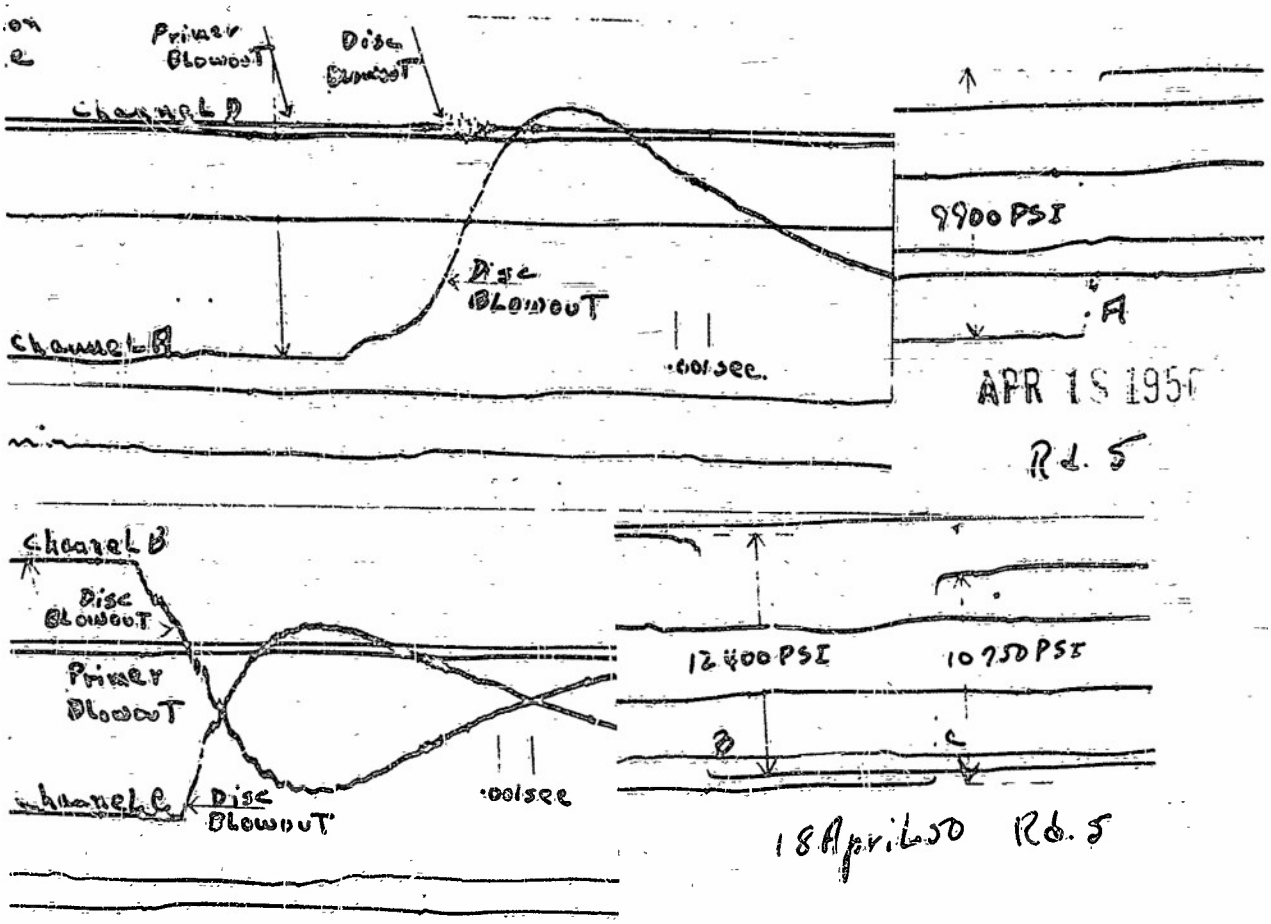
Powder: 16.0 Lbs Ex.6659 45°F



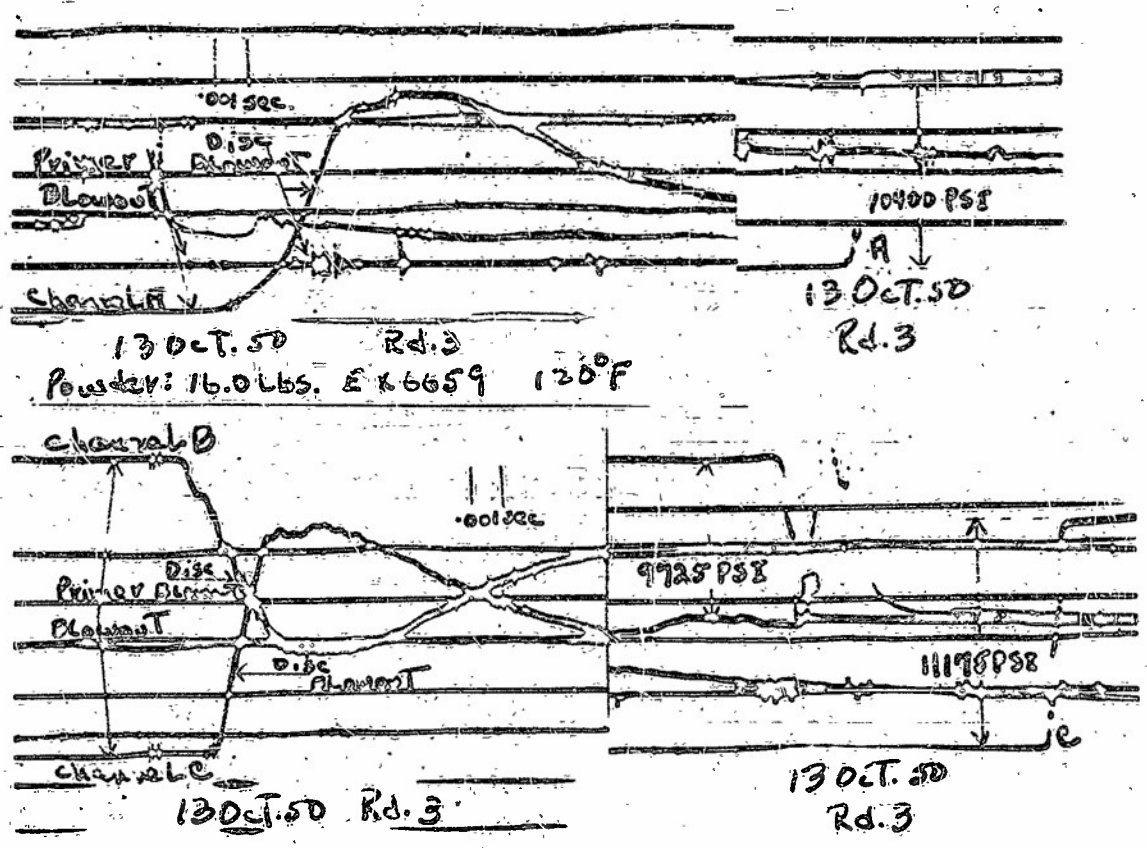
21 April 50 Rd.4

Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blowout Gun

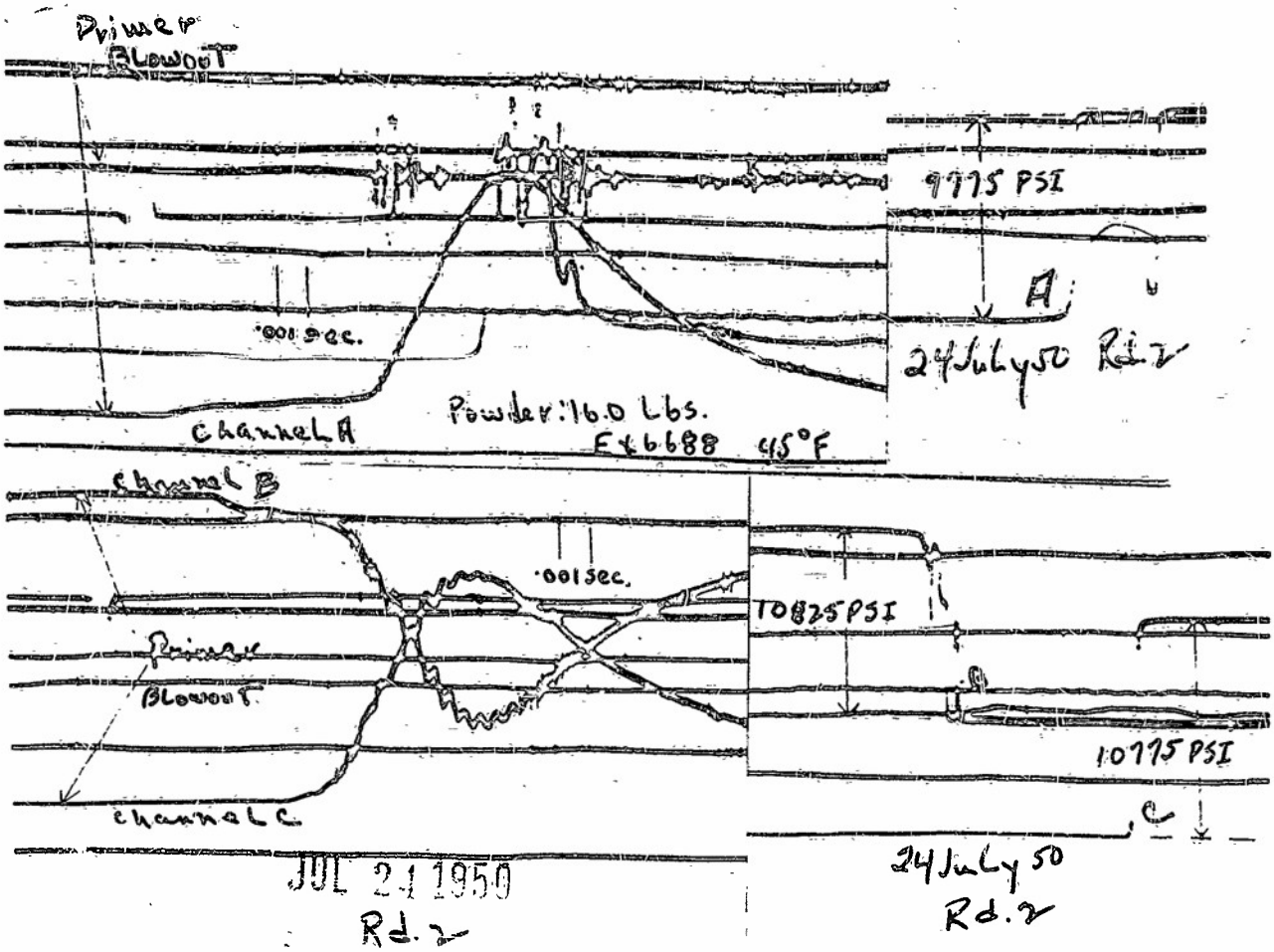
EX-6659 at 90°F



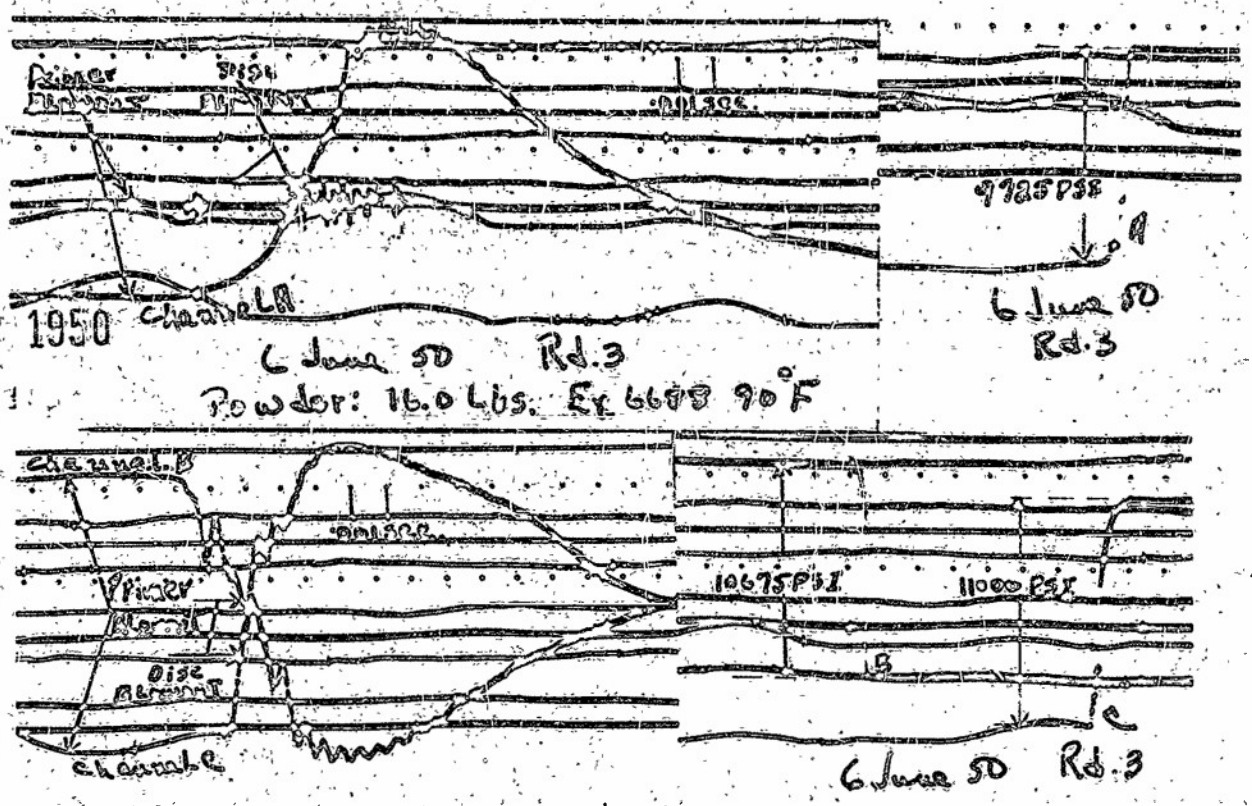
EX-6659 at 120°F



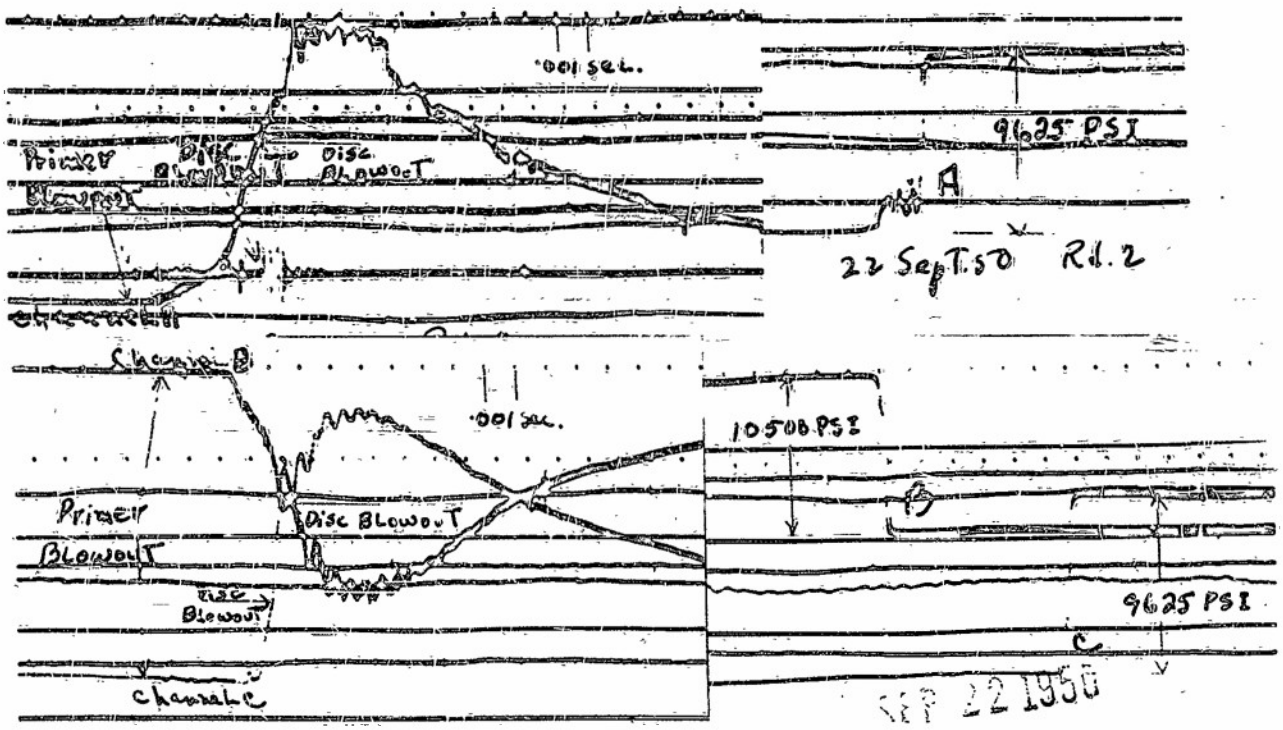
EX-6688 at 45°F



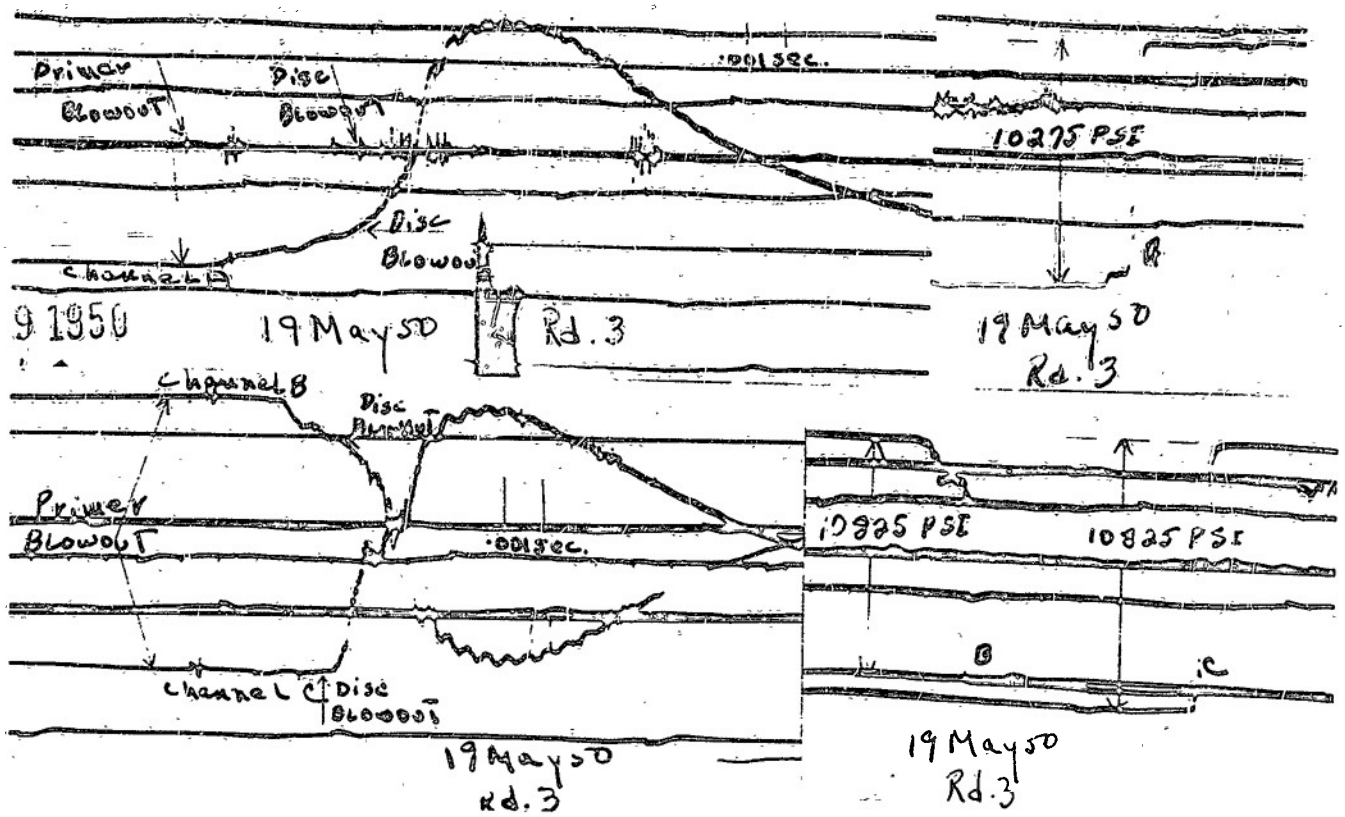
EX-6688 at 90°F



EX-6688 at 120°F

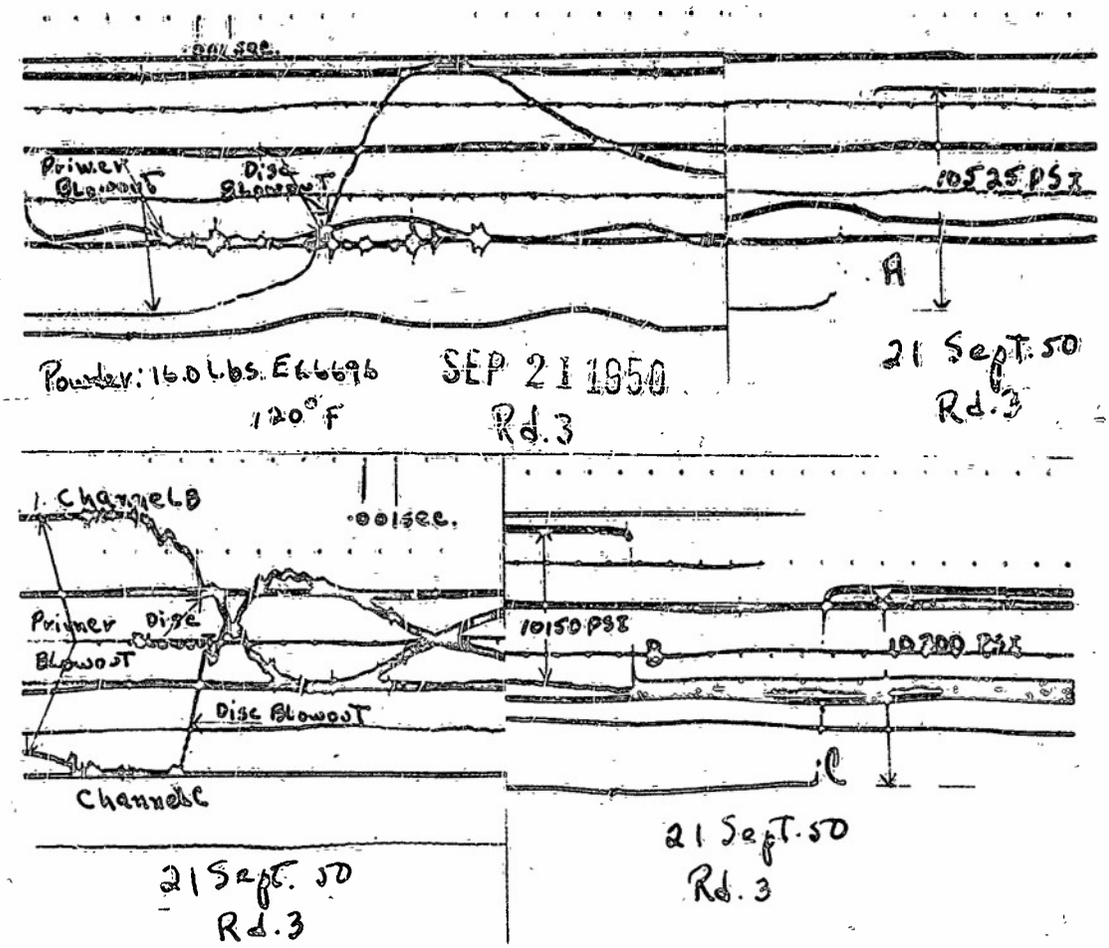


EX-6696 at 90°F



Ballistic Test of Experimental Propellants
in the 5"/38 Caliber Blowout Gun

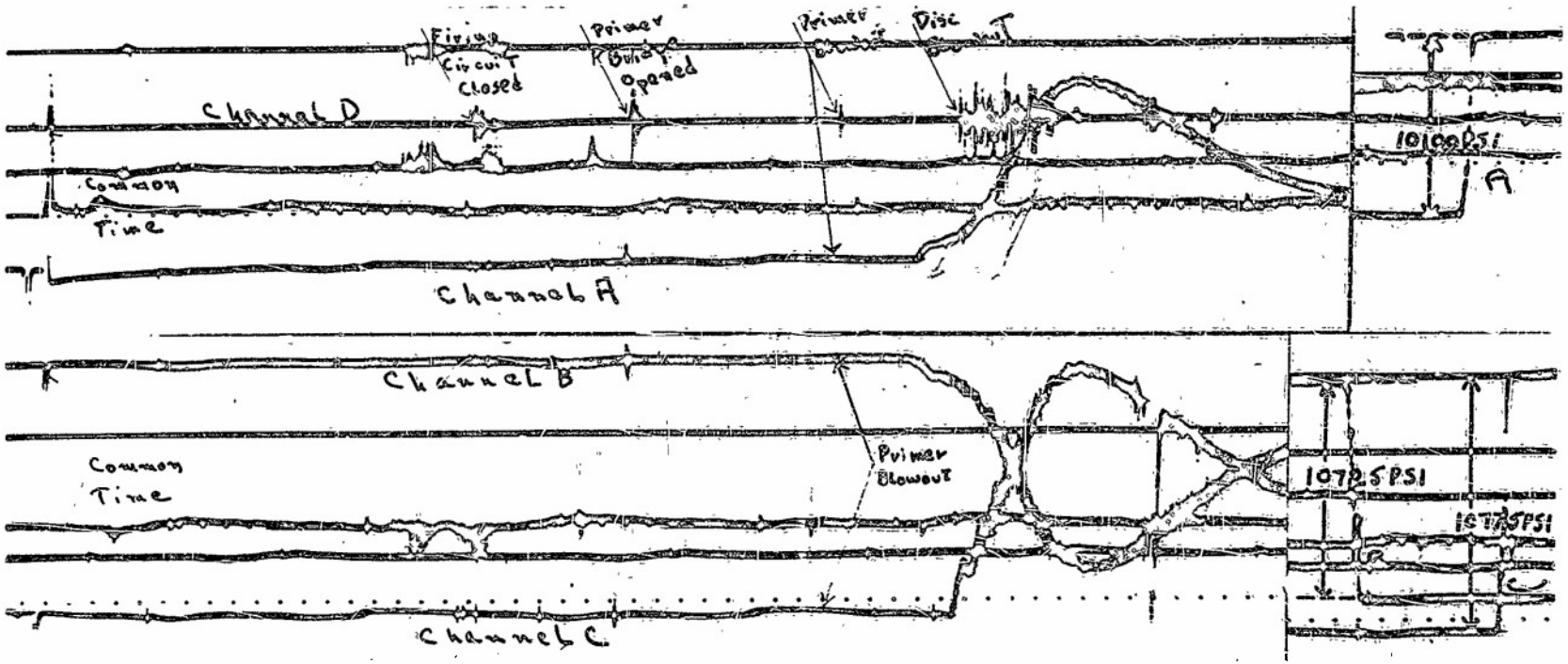
EX-6696 at 120°F



NP 9 -45090 FIGURE 19 DATE 6 Feb. 50 ROUND 2	5"/38 BLOWOUT CHAMBER DATA POWDER EX 6391 90°F 15.56 Lbs. P.P.D. = 5.8" PRIMER MK. 13-1 [E.O.]	PRESSURES (POUNDS PER SQUARE INCH):					
		MAXIMUM			AT DISC BLOWOUT		
		A	B	C	A	B	C
		10400	10275	10550	1350	1175	—

TIMES (MILLISECONDS):

PRIMER BLOWOUT TO START OF PRESSURE			PRIMER BLOWOUT TO MAXIMUM PRESSURE			START OF PRESSURE TO MAXIMUM PRESSURE			PRIMER BLOWOUT TO DISC BLOWOUT	START OF PRESSURE AT A TO DISC BLOWOUT
A	B	C	A	B	C	A	B	C		
3.50	3.24	5.41	10.79	10.57	10.99	7.29	7.33	5.58	5.10	1.60

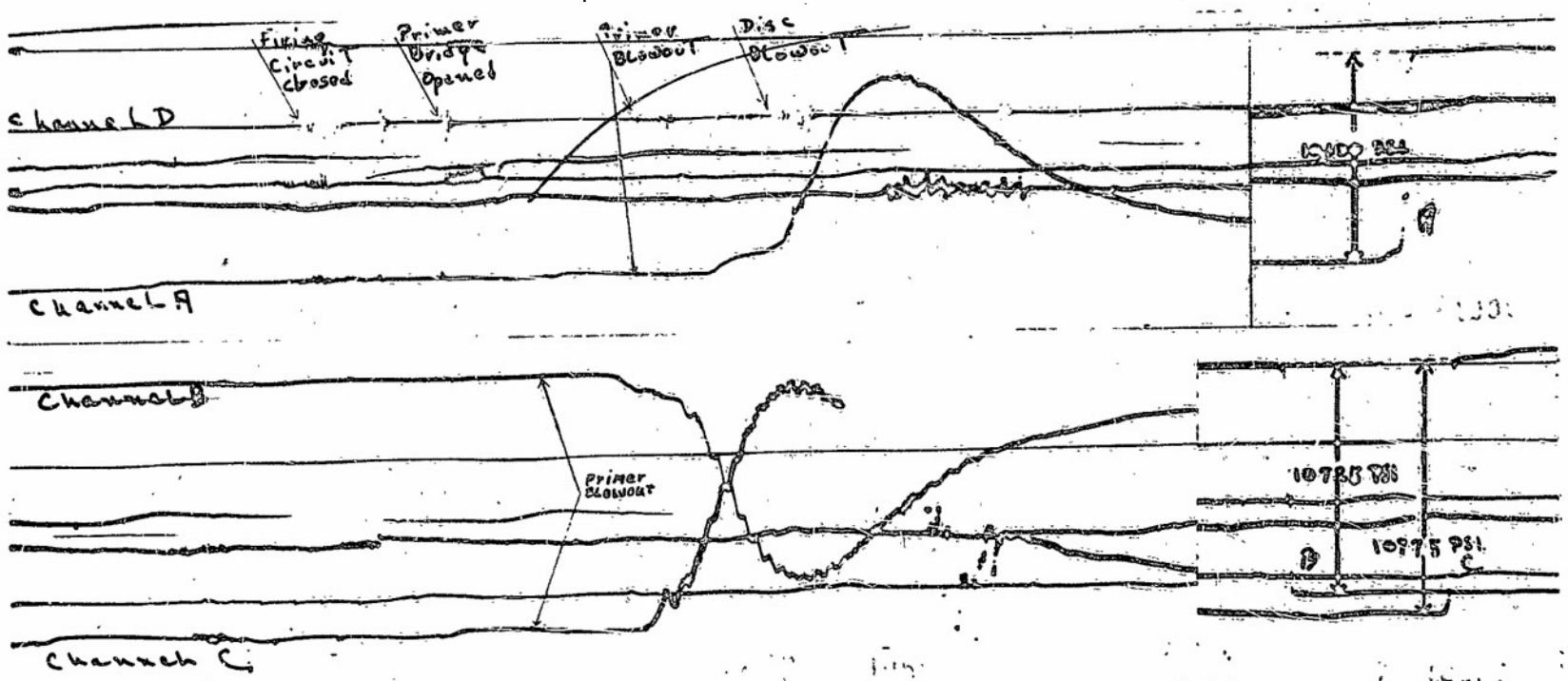


APPENDIX C

NP 9– 45091 FIGURE 20 DATE 7 Feb. 50 ROUND 1	5"/38 BLOWOUT CHAMBER DATA POWDER Ex 6391 15.56 Lbs. 90°F P.P.D. = 5.8" PRIMER Mk. 19-1 [5.0]	PRESSURES (POUNDS PER SQUARE INCH):					
		MAXIMUM			AT DISC BLOWOUT		
		A	B	C	A	B	C
		9600	9600	10250	1100	1125	1600

TIMES (MILLISECONDS):

PRIMER BLOWOUT TO START OF PRESSURE			PRIMER BLOWOUT TO MAXIMUM PRESSURE			START OF PRESSURE TO MAXIMUM PRESSURE			PRIMER BLOWOUT TO DISC BLOWOUT	START OF PRESSURE AT A TO DISC BLOWOUT
A	B	C	A	B	C	A	B	C		
3.15	2.76	4.76	11.08	11.39	10.96	7.93	8.63	6.20	5.60	2.45

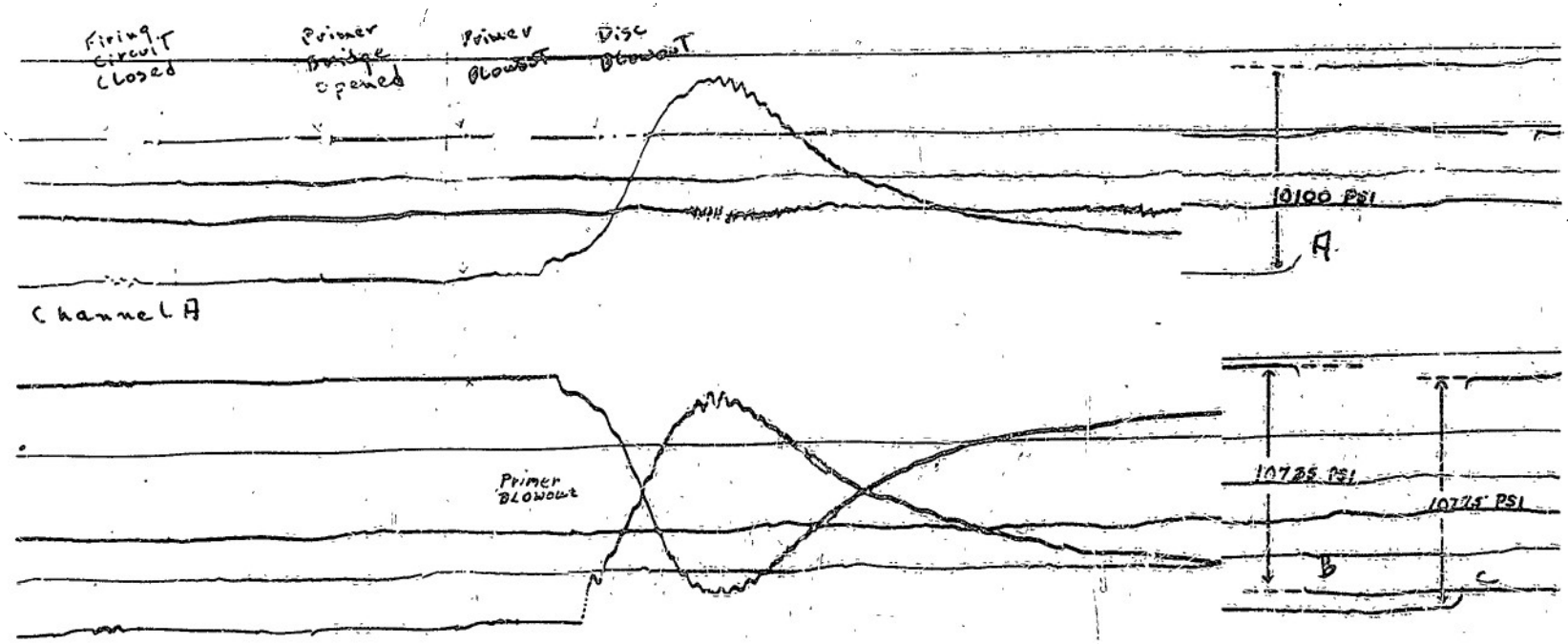


APPENDIX C

NP9 -45092	5"/38 BLOWOUT CHAMBER DATA	PRESSURES (POUNDS PER SQUARE INCH)					
FIGURE 21	POWDER EX 6381 15.56 Lbs.	MAXIMUM			AT DISC BLOWOUT		
DATE 7 Feb.50	90°F P.P.D.: 5.8"	A	B	C	A	B	C
ROUND 2	PRIMER MK.13-1 [E.O.]	9525	10275	10900	1900	1750	2150

TIMES (MILLISECONDS):

PRIMER BLOWOUT TO START OF PRESSURE			PRIMER BLOWOUT TO MAXIMUM PRESSURE			START OF PRESSURE TO MAXIMUM PRESSURE			PRIMER BLOWOUT TO DISC BLOWOUT	START OF PRESSURE AT A TO DISC BLOWOUT
A	B	C	A	B	C	A	B	C		
3.00	3.57	5.05	10.62	10.58	11.07	7.62	7.01	6.02	5.53	2.53

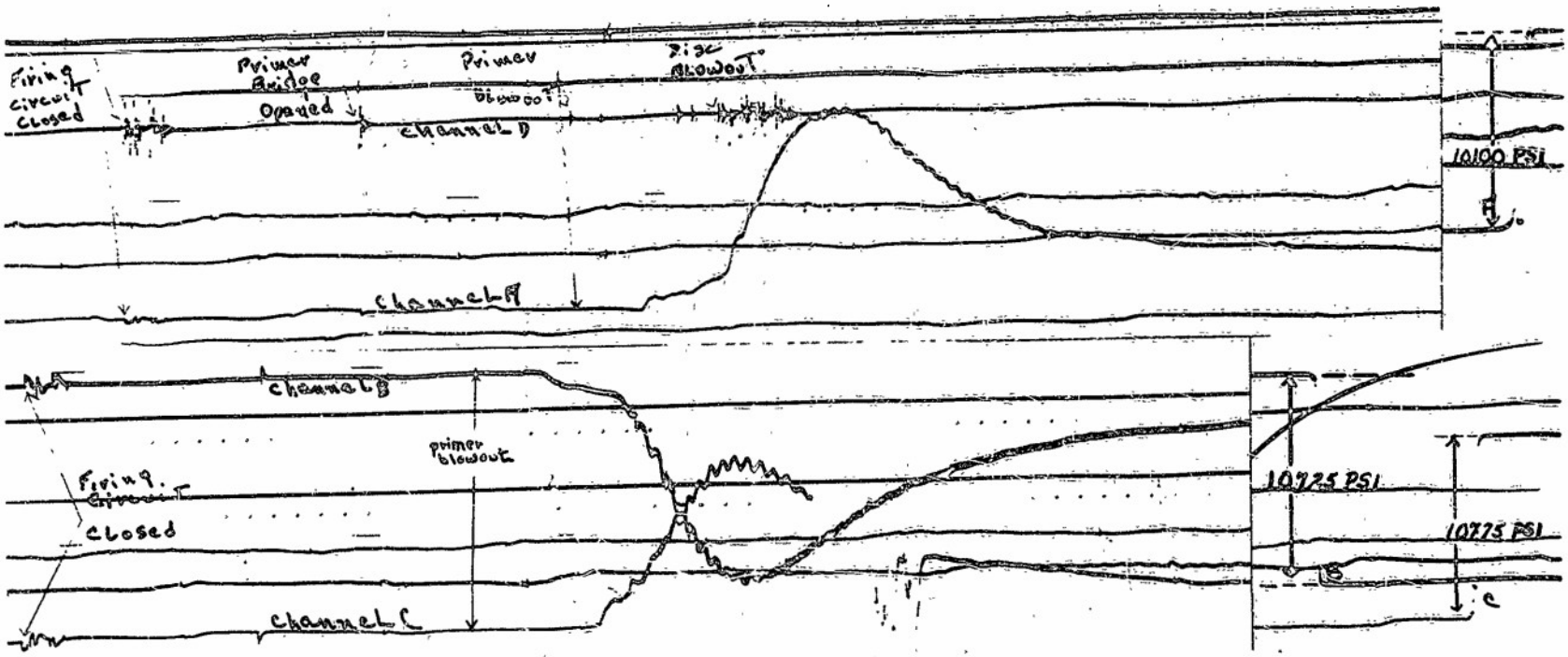


APPENDIX C

NP9 45093 FIGURE 22 DATE 21 March 50 ROUND 3	5"/38 BLOWOUT CHAMBER DATA POWDER EX 6391 90°F 15.56 Lbs. P.P.D. = 5.8" PRIMER MK. 13-1 [E.O.]	PRESSURES (POUNDS PER SQUARE INCH):					
		MAXIMUM			AT DISC BLOWOUT		
		A	B	C	A	B	C
		10025	10700	9900	1550	1425	900

TIMES (MILLISECONDS):

PRIMER BLOWOUT TO START OF PRESSURE			PRIMER BLOWOUT TO MAXIMUM PRESSURE			START OF PRESSURE TO MAXIMUM PRESSURE			PRIMER BLOWOUT TO DISC BLOWOUT	START OF PRESSURE AT A TO DISC BLOWOUT
A	B	C	A	B	C	A	B	C		
2.91	2.80	5.47	11.14	11.42	11.13	8.23	8.62	5.66	6.18	3.27



APPENDIX C

Ballistic Test of Experimental Propellants
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