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Ballistic Research Laboratories

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BALLISTIC LABORATORY

REPORT

REPORT ON INVESTIGATION OF THE CAUSES UNDERLYING ERRATIC POWDER PRESSURES OBTAINED FROM CRUSHER GAUGES

(IN CONNECTION WITH PROJECT RB 116)
(O.O. 413.6/12432 - APG 413.6/487)

BY

CAPT. T. K. VINCENT

[redacted]

February 18, 1936

Report No. 34

ABERDEEN PROVING GROUND
ABERDEEN, MD.

Report No. 34

TKV/cvp
ABERDEEN PROVING GROUND, MD.,
FEBRUARY 18, 1936.

REPORT ON INVESTIGATION OF THE CAUSES UNDERLYING ERRATIC POWDER PRESSURES OBTAINED FROM CRUSHER GAUGES

(IN CONNECTION WITH PROJECT RB 116)
(O.O. 413.6/12432 - APG 413.6/487)

OBJECT OF TEST

To obtain comparative data regarding the behavior of crusher gauges, assembled under different conditions and with different tolerances, from controlled firings in the 3" A.A. Gun Liner M3, No. 138, chromium plated.

DISCUSSION

OCM Item 12462 directed certain tests to be performed on 3" A.A. Gun Liner M3, #138, which was chromium plated in the bore at the Naval Gun Factory, Washington Navy Yard. This test provided for proof firing to be followed by 50 rounds in 5-round series, with taking of periodic bore measurements and bore impressions. The results of this test, insofar as effect on the liner is concerned, are reported in Firing Record 8807, (O.P. 4987; O.O. 472.93/4449; A.P.G. 472.91/362), and in First Partial Report on test of 3" A.A. Gun Liner M3, No. 138, chromium plated, and Fifth Report on O.P. No. 4987, Ordnance Program 4987, OCM Item 12462, dated February 12, 1936.

The Proving Ground has experienced erratic results in powder pressure readings obtained from crusher gauges for some time. Prior to the adoption of the new standard firing record forms, which provide for recording individual pressures obtained as well as mean pressures, these erratic results were not so apparent. The old firing record forms reported the mean pressures only, and wide variance in individual readings were often

absorbed in the mean result. In cases where standard firings were made under these conditions of pressure taking or where established charge-pressure curves for a lot of powder were used to obtain data for firings, and the firings made from the curves gave contrary results, the effects of erratic individual pressures were forcefully brought to view.

The cannon crusher gauges in use today are of the Noble type, an outgrowth of the Rodman knife gauge. Those used at the Aberdeen Proving Ground have been in service for many years, many having been formerly used at Sandy Hook Proving Ground. The specifications for these gauges provide for pistons to be made of hardened tool steel, ground to size and the gauge bodies to be made of forged No. 3 steel. This latter steel corresponds to W.D. 1055, a medium carbon steel. In the absence of specified physical requirements and heat treatment of the bodies and pistons, it can be seen that there should be great variance in their ability to withstand scoring, distortion and permanent deformation. The clearance between the piston and the body is 0.0002" with tolerances of +.004" in cylinder diameter, and -.0004" in piston diameter.

The regulations at the Proving Ground provide for the selection of cannon pressure gauges for standardization firings having clearances of .0002" between piston and cylinder with tolerances of +.0002" on the cylinder diameter and -.0002" on the piston diameter. For other than standardization firings the clearance is .0002" between piston and cylinder, with tolerances of +.0004" on cylinder diameter and -.0004" on piston diameter.

Mr. R. H. Kent in a paper entitled "Report on Some Sources of Error in Piezo-electric and Crusher Gauge Measurements (In Connection with Project RB 117)", dated Aberdeen Proving Ground, Dec. 2, 1935, concludes that the pinching effect observed in the case of the piezo-electric gauges should also affect the measurements made with the copper crusher gauges. This pinching effect is caused by the pressure of the powder gases applied to the exterior cylindrical surface of the gauge body, distorting the inner cylinder wall and binding the piston, so as to prohibit free movement.

From all of the foregoing it was concluded that the firings to be conducted in the 3" A.A. Gun Liner M3, No. 138, presented an excellent opportunity to schedule some tests of crusher gauges in which their behavior under certain variables of assembly and selection could be observed.

In O.O. 471.91/2052; A.P.G. 472.91/362-2, the Ordnance Office authorized tests to be conducted in this gun along the following lines:

(a) Select 16 medium caliber crusher gauges which are in good condition, assemble pistons to 8 of these gauges to give total clearance in each case of .0005" between cylinder wall and piston. Assemble pistons to the other 8 crusher gauges to give a total clearance of .0010" between cylinder wall and piston.

(b) Assemble all gauges with the cylinder wall and piston wiped dry, no lubricant to be used about the gauges except on closing cap threads and body washer.

(c) All gauges to be assembled, disassembled, measured, etc., by the Gauge Section, using the same procedure at all times.

(d) Copper cylinders to be of the same lot and anneal with zero initial compression.

(e) Four gauges of each lot of 8 described in (a) above, to be assembled with standard copper obturator cups, the remaining gauges to have the copper cup replaced with a wax seal consisting of 2 parts cup grease, 2 parts beeswax and 1 part resin.

(f) The 16 gauges will be divided into four sets of four gauges each, each set to consist of:

1 gauge - .0005" clearance; copper cup
1 gauge - .0005" clearance; wax obturator
1 gauge - .0010" clearance; copper cup
1 gauge - .0010" clearance; wax obturator

These gauges are all numbered and sets will remain intact throughout the whole test.

(g) Forty rounds to be fired at five different pressures:

8 at 20,000 lbs. per sq. in.
8 at 27,000 " " " "
8 at 31,500 " " " "
8 at 36,000 " " " "
8 at 41,200 " " " "

(h) Each round to have a set of four gauges, assembled as described in (f) above, inserted in the case.

(i) In half of the rounds at each pressure, the set of gauges is to be fixed in the bottom of the case. In the other half of the rounds, the gauges are to be placed in the case in accordance with current procedure at the Proving Ground.

Procedure

A lot of powder was selected from that available at the Proving Ground for use in this test. The powder selected was DuPont 1492 - 1918 - for 6" Gun M1900-03-05. It is a pyro powder, multiperforated grain having a web thickness of 0.0360". This powder is suitable for use in the 3" A.A. Gun M3.

Standard 3" cast iron proof slugs, weighing 15 lbs. each, were used in all firings. Cartridge cases, 3" A.A. Mk. II A1, drawing 71-5-3, unmodified, were used with M21 Primers, Lot 1355-15, in all rounds.

Firings were conducted in groups of five rounds each, the first round of each group being a warming round, the remaining four having gauges assembled as prescribed. This was necessary due to the limited number of gauges used, 16 in all or sufficient for 4 rounds, and the requirements of the original directive (OCM Item 12462) which called for five-round groups between stargauging, etc. Two groups were fired at each pressure, each group being fired on a different day usually since the gauges had to be disassembled and reassembled by the Gauge Section between groups and the necessary stargauging of the liner performed. Boulenge muzzle velocities were taken on all rounds.

The description of assembly of each group of five rounds follows:

Round	Fixed or Loose in Case	Gauge No.	Piston Clearance	Obturator Seal
Warming	-	No gauges	-	
1	Fixed	5942	.0010	Wax
		4525	.0010	Copper
		4734	.0005	Wax
		4190	.0005	Copper
2	Fixed	4970	.0010	Wax
		2422	.0010	Copper
		4748	.0005	Wax
		2834	.0005	Copper
3	Loose	5908	.0010	Wax
		3640	.0010	Copper
		4744	.0005	Wax
		4329	.0005	Copper
4	Loose	4774	.0010	Wax
		1728	.0010	Copper
		4875	.0005	Wax
		3259	.0005	Copper

The problem of fixing the four gauges in rounds 1 and 2 of each series presented difficulties. Various metal holders were devised and tried out in an effort to hold the four gauges upright in the case and against the case wall in order that there would be no interference with the action of the primer. The MII Al case is rather long, and the mouth opening is only 3" in diameter. With the facilities available at the Proving Ground there appeared to be no simple and inexpensive method of accomplishing this. The Research Division at the Proving Ground suggested that the four gauges be held together with strong rubber bands, each gauge in contact with the primer body and resting on the bottom of the inside of the case. It was believed that no interference with the primer action would occur. A simple fixture was devised for assembling the gauges in position in this manner, and this method was used for fixing the gauges in rounds 1 and 2 of each series.

The data obtained in the firings are shown on the attached sheets, Exhibits "A" to "F". The data shown on Exhibit "F" was obtained by firing 2 additional groups using a powder charge to give pressures lower than those used for the initial test shown on Exhibit "A". This was done to obtain additional data in the lower pressure range and to see if the high pressures shown on Exhibit "E" had permanently affected the gauges.

Pressures obtained were not corrected in any way for erosion, etc.

Analysis of Data

Exhibit "A"

It will be noted that the results obtained in the firings of the first series, Rounds 14, 15, 16 and 17, showed very little difference between gauges with different characteristics. When these firings were repeated three days later (Rounds 18, 20, 21 and 22) under as near identical conditions as possible, it is noted that the gauges having pistons with .0005" clearance and wax obturators in Rounds 19, 20 and 22, showed considerable dispersion from the other gauges assembled with them in the rounds.

The dispersions from the mean values for all combinations of variables as shown in columns 13 to 16, inclusive, indicate that the gauges having large piston clearance (.0010") and assembled with copper cup obturators show very much less dispersion in pressure than any other combination tested.

Attention is invited to gauge No. 4744 assembled in the 3rd round of each series. This gauge has a piston with

.0005" clearance and was always assembled with a wax obturator. Its behavior, however, is unlike that of other gauges with similar characteristics, and the results obtained from it are more like those obtained with the .0010" clearance gauges. This gauge was carefully checked and rechecked several times to find out the cause for this paradoxical behavior. No explanation is offered.

Exhibit "B"

The results shown for these series continue to follow the trend indicated in Exhibit "A". The mean dispersions are of greater magnitude due to the greater effect of the low reading gauges. The dispersion in columns 11 and 12 indicate that fixing the gauges in the round is not an advantage, but contributes to greater deviations.

Gauge No. 4744 continues to behave at variance with similar gauges. Gauges having large piston clearance and copper obturator cups have the least dispersion.

Exhibit "C"

The results of previous firings are unchanged by these series. Through a misunderstanding one gauge in each series, Rounds 35 and 42 were assembled with copper cups instead of wax. This change was considered in arriving at the mean values.

Exhibits "D" and "E"

The results of these firings are consistent with previous results.

Exhibit "F"

These series were fired to see what effect, if any, the repeated firings had on the gauges.

It was expected that the results would be consistent with those shown on Exhibit "A". Such was not the case, and it appears that some of the gauges have been permanently deformed, or otherwise changed so that they no longer behave normally.

CONCLUSIONS

From the data obtained in these tests it appears that gauges with tight pistons will give consistently lower pressures and greater dispersions than will be given by gauges having pistons with greater clearance.

That these tests do not give sufficient data on which to base the limits of clearance between pistons and cylinders in gauges.

That definite conclusions cannot be drawn from this data regarding the effects of fixation of gauges, or use of wax compounds in lieu of copper obturator cups; due to the confusing effects of the variables introduced into the tests.

RECOMMENDATIONS

That further tests be made to determine the maximum piston clearance which can be allowed.

That no further tests be made at this time having reference to fixation of gauges in the round.

That further investigation of lubrication of the gauge parts be conducted.

That the search for a substitute for copper obturating cups be continued.

T. K. Vincent,
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Proof Officer.

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RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3"A.A. GUN, M3, WITH CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES (MEDICAL); 4 PER ROUND, ALL ASSEMBLING, MEASURING ETC BY GAUGE SECTION

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/SQ IN.	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ IN. (.075" mic Spindle)	MEAN OF GAUGES WITH .0005" PISTON CL.	MEAN OF GAUGES WITH .0010" PISTON CL.	MEAN OF GAUGES WITH COPPER OBT. CUPS	MEAN OF GAUGES WITH WAX OBTURATOR	MEAN OF GAUGES ASSEMBLED TO ROUND	INDIV MEAN DISPERSION PRESSURE	MAX DISPERSION GAUGES FIXED IN ROUND	MAX DISPERSION GAUGES LOOSE IN ROUND	INDIV DISPERSION .0005" PISTON CLEARANCE	INDIV DISPERSION .0010" PISTON CLEARANCE	INDIV DISPERSION COPPER OBT. CUPS	INDIV DISPERSION WAX OBT	FIRING DATE	REMARKS
2	14	20,000	5942	✓19,550						+350	600			+275	+300			
3			4525	✓19,000						-200				-275	-150			
4		(3"-20 / X1492)	4734	✓18,950	19,125	19,275	19,150	19,250	19,200	-250			-175			-300		
5			4190	✓19,300						+100			+175		+150			
6	15	PYRO POWDER	4970	✓18,900						- 25	450			-100		- 75		
7			2422	✓19,100						+175				+100	-225			
8			4748	✓19.050	18,850	19,000	18,875	18,975	18,925	+125			+200			+75		
9			2834	✓18,650						-275			-200		+225			
10	16		5908	✓19,550						+175		550		- 50		+175		
11			3640	✓19,650		19,600				+275				+ 50	+275			
12			4744	✓19,200	19,150		19,075	19,375	19,375	-175			+50			-175		
13			4329	✓19,100						-275			-50		-275			
14	17		4774	✓19,240		19,270				-270		1000		+120		+75		
15			1728	✓19,500						- 10				-170	-325			
16			4875	✓19,150	19,650		19,875	19,195	19,510	-360			-500			-45		TIGHT PISTON - WAX - Low pressure
17			3259	✓20,150						+640			+500		+325			GREATEST DISP - TIGHT PISTON, COPPER CUP
18	19	20,000	5942	✓18,975		19,040				+ 825	4,250			-60		+1,910		
19			4525	✓19,100						+950				+60	-180			
20			4734	✓15,150	17,275		19,250	17,065	18,150	-3,000			- 2,125			-1,910		TIGHT PISTON, WAX. Low pressure
21			4190	✓19,400						+ 1,250			+ 2,125		+150			
22	20		4970	✓19.000		19.000				+1540	5,500			0		+ 2,750		
23			2422	✓19.000						+1540				0	+325			
24			4748	✓13.500	15,925		18,675	16,250	17,460	-3960			- 2,925			-2,750		TIGHT PISTON WAX - Low pressure
25			2834	✓18,250						+ 890			+ 2,925		- 325			
26	21		5908	✓19.400		19.200				+ 575		1950		+100		+975		
27			3640	✓19.200						+ 375				-100	- 30			
28			4744	✓17.450	18,350		19,230	18,425	18,825	-1375			- 900			- 975		TIGHT PISTON, WAX - Low pressure
29			4329	✓19.250						+425			+ 900		+ 30			
30	22		4774	✓19.025		19,090				+1345		6950		-45		+3,115		
31			1728	✓19,150						+1470				+45	- 300			
32			4875	✓12.800	16,275		19,450	15,915	17,680	-4880			- 3,415			- 3,115		TIGHT PISTON, WAX - Low pressure
33			3259	✓19.750						+2070			+ 3,415		+ 300			
34	MEAN																	
35	VALUES.	20000		18,640	18,075	19,210	19,230	18,860	18,640	—	3,700	2,610	2460	197	445	2340		

FIRED JAN 10, 1936 A.M.

FIRED JAN 13, 1936 P.M.

EXHIBIT "A"

RECAPITULATION · PRESSURE DATA - SPECIAL GAUGES IN 3" HAGGON, M3 CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES (INED. CAL), 4 per round, All assembling measuring etc By GAUGE SECTION

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/SQ.IN.	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ IN (.075 MER SPINDLE)	MEAN OF GAUGES WITH 0.0005" PISTON CL	MEAN OF GAUGES WITH 0.0010" PISTON CL	MEAN OF GAUGES WITH COPPER OBT CUPS	MEAN OF GAUGES WITH WAX OBTURATOR	MEAN OF ALL GAUGES ASSEMBLED TO ROUND	INDIV MEAN DISPERSION PRESSURE	MAX. DISPERSION GAUGES FIXED IN ROUND	MAX. DISPERSION GAUGES LOOSE IN ROUND	INDIV DISPERSION WITH 0.0005" PISTON CLEARANCE	INDIV DISPERSION WITH 0.0010" PISTON CLEARANCE	INDIV DISPERSION COPPER OBT. CUPS	INDIV DISPERSION WAX OBTURATOR	FIRING DATE	REMARKS
2	24	27,000	5942	26.400		25.790				+2.620	9.350			+ 610		+4650		
3			4525	25,175						+ 1,395				- 610	-640			
4		3"-129	4734	17.100	21.775		25.815		23780	-6,680			-4 675			-4650		
5		1492	4190	26,450						+2670			+4675		+640			
6	25	PYRO	4970	25.050		25.800				+2.885	13850			- 750		+6175		
7		POWDER	2422	26.550						+ 4,385				- 750	+1100			
8			4748	12.700	18.525		25450		22165	-9.465			-5.825			-6175		
9			2834	24.350						+2.185			+5.825		-1100			
10	26		5908	26.000		25.075				+2.210		5.300		+ 925		+2650		
11			3640	24.150						+ 860				- 925	+925			
12			4744	20.700	21.500		23225		23.290	-2.590			- 800			-2650		
13			4329	22 300						- 910			+ 800		-925			
14	29		4774	25.750		26.300				+4.210		14400		- 550		+6.650		
15			1728	26.850						+5.310				+ 550	+2875			
16			4875	12.450	16.775		23.975		21.580	-9.040			-4325			-6650		
17			3259	21.100						- 440			+4325		-2875			
18	29	27000	5942	26.000		25.650				+1960	7.950			+350		+3775		
19			4525	25,300						+1,260				- 350	- 550			
20			4734	18.450	22.425		25850		22225	-5.590			-3975			-3775		
21			4190	26400						+2.360			+3975		+ 550			
22	30		4970	25,700		25,850				+2,190	8.400			-150		+4050		
23			2422	26.000						+2.440				+ 150	+525			
24			4748	17.600	21.275		25475		23.560	-5.960			-3675			-4.050		
25			2834	24.950						+1.390			+3675		-525			
26	31		5908	26.500		27.175				-540		1350		-675		- 50		
27			3640	27.850						- 810				+675	+325			
28			4744	26.600	26.900		27.525		27.040	- 440			- 800			+ 50		
29			4329	27.200						+ 160			+ 800		-325			
30	32		4774	25.150		25.425				+1,310		7.700		-275		+3375		
31			1728	25,700						+1.860				+275	- 200			
32			4875	18 400	22.250		25900		23.840	-5.440			-3.850			-3.375		
33			3259	26.100						+2.160			+3.850		+ 200			
34	MEAN																	
35	VALUES	27.000		23,660	21.430	25.880	25,400	21.900	23,660		9.890	7,190	3.430	535	890	3920		

JAN. 14, 1936 P.M.

JAN. 16, 1936 A.M.

EXHIBIT "B"

RECAPITULATION PRESSURE DATA – SPECIAL GAUGES IN 3" AA GUN M3 CHROMIUM PLATED LINER #13 (3)

SELECTED PRESSURE GAUGES (MED. CAL.) 4 per round. All assembling, measuring etc. by GAUGE SECTION

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/sq in	MEDIUM CALIBER GAUGE NO	PRESSURE #/SQ IN (.075" MICK SPINDLE)	MEAN OF GAUGES WITH 0.0005" PISTON CL.	MEAN OF GAUGES WITH 0.0010" PISTON CL.	MEAN OF GAUGES WITH COPPER OBT CUPS	MEAN OF GAUGES WITH WAX OBTURATOR	MEAN OF ALL GAUGES ASSEMBLED TO ROUND	INDIV. MEAN DISPERSION PRESSURE	MAX DISPERSION GAUGES FIXED IN ROUND	MAX DISPERSION GAUGES LOOSE IN ROUND	INDIV DISPERSION WITH 0.0005" PISTON CLEARANCE	INDIV DISPERSION WITH 0.0010" PISTON CLEARANCE	INDIV DISPERSION COPPER OBT CUPS	INDIV DISPERSION WAX OBTURATOR	FIRING DATE	REMARKS
2	34	31,500	5442	29,500		30.200				+2,225	13,100			-700		+5,850	JAN. 17. 1936 P.M.	
3			4525	30,900				23.650	27.275	+3,625				+700	0			
4		(4th Lay 1442 PYRO POWDER)	4734	17.800	24.350		30,900			-9,415			-6,550			-5,850		
5			4190	30,900						+2,625			+6,550		0			
6	35		4970	28.275		29.410		*28.275		+2,605	17.150			-1,140		* 0		
7			2422	30,550			*		25,670	+4,880				+1,140	*+5750			
8			4748	13.400	21,925		24.800			-12,270			-8,525		*-11,400			This gauge assembled with copper cup
9			2834	30.450						+4,780			+8,525		*+5,650			
10	36		5908	30.225		30,910		28.360		+395		5,100		-690		+1,860		
11			3640	31,600					29.830	+1,770				+690	+300			
12			4744	26.500	28.750		31.300			-3,330			-2,250			-1,860		
13			4329	31.000						+1,170			+2,250		-300			
14	37		4774	27,900		29450		20900		+6,375		17,700		-1550		+7000		
15			1728	31.000			22.150		21.525	+9,475				+1550	+8,850			
16			4875	13,900	13,600					-7,625			+300			-7000		
17			3259	13,300						-8,225			-300		-8,850			
18	39	31,500	5942	30,350		30,700		24.175		+2,760	13.050			+350		+6,175	JAN. 21. 1936 A.M.	
19			4525	31.050					27.590	+3,460				-350	+50			
20			4734	18,000	24.475		31,000			-9,590			-6,475			-6,175		
21			4190	30,950						+2,360			+6,475		-50			
22	40		4970	28.200		29.050		22450		+2,160	13,200			-850		+5,750		
23			2422	29.900			29.625		26,040	+3,860				+850	+275			
24			4748	16,100	23,025					-9,340			-6,925			-5,750		
25			2834	29.350						+3,310			+6,925		-275			
26	41		5908	30,100		29.075		28.325		+1,880		3,550		+1,025		+1,775		
27			3640	28,050			28,125		28,220	-170				-1025	-75			
28			4744	26.550	27.375					-1,670			-825			-1,775		
29			4329	28.200						-20			+825		+75			
30	42		4774	29.900		30.050		*29.900		+4,290		14,700		-150		* 0		
31			1728	30.200			*24,180		25,610	+4,590				+150	*+6,020			
32			4875	15,500	21.175					-10,110			-5,675		*-8,680			This gauge assembled with copper cup
33			3254	26.850						+1,240			+5,675		*+2,670			
34 35	MEAN VALUES			26.470	23.085	29.860	*28,850	×24.640	26.470		14125	10.263	4490	807	*1590	×4735		

* NOT CONSIDERED IN AVERAGES IN LINES 34 35

× MEAN OF 6 VALUES ONLY

EXHIBIT "C"

RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3" A.A. GUN IN 3 CHROMIUM PLATED LINER #139

SELECTED PRESSURE GAUGES (MEDICAL); 4 per round, All assembling measuring etc by Gauge Section

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	SERIAL NUMBER OF ROUND	EXPECTED PRESSURE — #/SQ IN	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ IN (.075" MICR SPINDLE)	MEAN OF GAUGES WITH 0.0005" PISTON CL	0.0010" PISTON CL.	COPPER OBT. CUPS	WAX OBTURATORS	MEAN OF ALL GAUGES IN ROUND	INDIV MEAN DISPERSION PRESSURE	MAX. DISPERSION GAUGES FIXED	MAX DISPERSION GAUGES LOOSE	INDIVIDUAL DISPERSION WITH 0.0005" PISTON CL	0.0010" PISTON CL	COPPER OBT CUPS	WAX OBT	DATE OF FIRING	REMARKS
2	49	36,000	5942	34,000		33,975		27,400	31,930	+2070	18,175			+ 25		+6,600	JAN 27, 1936 A.M.	
3			4525	33,950						+2020				- 25	-2515			
4		(4#-9#,20 1492)	4734	20,800	29,890		36,460			-11,130			-9,185			-6,600		
5			4190	38,975						+7,045			+9,185		+2515			
6	50	(4#-9#,20 1492)	4970	34,300		35,675		27,410	31,870	+2,430	16,525			- 1375		+6,890		
7			2422	37,050						+5,180				+1375	+ 725			
8			4748	20,525	28,060		36,325			-11,245			-7,540			-6,890		
9			2834	35,600						+3,730			+7,540		- 725			
10	51		5908	34,675		36,390		34,120	36,300	- 1,625		5,175		- 1,715		+ 555		
11			3640	38,100						+ 1,800				+1,715	- 325			
12			4744	33,600	36,190		38,450			- 2,700			-2,585			- 555		
13			4329	38,775						+2,475			+2,585		+ 325			
14	52		4774	29,450		33,400		22,200	29,700	- 250		22,400		- 3,950		+ 7,250		
15			1728	37,350						+7,650				+ 3,950	+ 190			
16			4875	14,950	26,960		37,160			-14,750			-10,015			- 7,250		
17			3259	36,975						+ 7,275			+10,015		- 190			
18	54	36,000	5942	39,550		40,350		31,075	36,500	+3,050	20,100			- 800		+8,475		
19			4525	41,150						+4,650				+ 800	- 775			
20			4734	22,600	32,650		41,925			-13,900			-10,050			- 8,475		
21			4190	42,700						+ 6,200			+10,050		+ 775			
22	55		4970	38,100		38,600		30,350	34,300	+3,800	16,500			- 500		+7,750		
23			2422	39,100						+4,800				+ 500	+ 850			
24			4748	22,600	30,000		38,250			-11,700			- 7,400			-7,750		
25			2834	37,400						+ 3,100			+ 7,400		- 850			
26	56		5908	40,800		39,470		39,700	39,150	+1,650		2,675		+1,330		-1,100	JAN 28, 1936 P.M.	
27			3640	38,125						- 1,025				- 1,330	- 485			
28			4744	38,600	38,850		38,610			- 550			- 250			-1,100		
29			4329	39,100						- 50			+ 250		+ 485			
30	57		4774	30,900		34,850		25,950	29,975	+ 925		17,800		- 3950		+4950		
31			1728	38,800						+8,825				+ 3950	+4400			
32			4875	21,000	25,100		34000			- 8975			- 4100			- 4950		
33			3259	29,200						- 775			+ 4,100		- 4400			
34																		
35		36000		33700	30,960	36,600	37645	29,800	33,715		17,825	12,000	6,400	1700	1285	5450		

EXHIBIT "D"

RECAPITULATION - PRESSURE DATA SPECIAL GAUGES IN 3" A A GUN, M 3 - CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES - (MED. CAL.); 4 per round, All assembling, measuring etc by GAUGE SECTION

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/SQ.IN	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ.IN. (.075 MICR SPINDLE)	← MEAN OF GAUGES WITH 0.0005" PISTON CL	0.0010" PISTON CL.	COPPER OBT. CUPS	WAX OBTURATED →	MEAN OF ALL GAUGES IN ROUND	INDIV MEAN DISPERSION PRESSURE	MAX DISPERSION GAUGES FIXED	MAX DISPERSION GAUGES LOOSE	← INDIVIDUAL DISPERSION WITH 0.0005" PISTON CL	0.0010" PISTON CL	COPPER OBT. CUPS	WAX OBT →	DATE OF FIRING	REMARKS
2	59	41,200	5942	38100		40,400				+ 290	15,985			-2,300		+5,430		
3			4525	42700			42,950	32670	37,810	+4,890				+2,300	- 250			
4		(4#-13oz)	4734	27225	35215					- 10,595			- 7,990			-5,430		
5		X1492	4190	43200						+ 5,340			+ 7,990		+ 250			
6	60	POWDER PYRO	4970	42600		42,775				+4,185	16,850			- 175		+ 8,100	JAN. 30. 1936 P.M.	
7			2422	42950			42,475	34,500	38,415	+4,535				+ 175	+ 475			
8			4748	26100	34,050					-12,315			- 7,950			- 8,100		
9			2834	42000						+3,585			+7,950		- 475			
10	61		5908	41050		41,025		40,850		- 100		1,250		+ 25		+ 200		
11			3640	41000					41,150	- 150				- 25	- 450			
12			4744	40650	41,125		41,450			- 500			- 775			- 200		
13			4329	41900						+ 750			+ 775		+ 450			
14	62		4774	33050		38,200		30,275		-3,290		15,850		- 5,150		+2,775		
15			1728	43350					36,340	+7,010				+ 5,150	+ 950			
16			4875	27500	34,475		42,400			- 8,840			-6,925			-2,775		
17			3259	41450						+ 5,110			+6,925		- 950			
18	64	41,200	5942	39,200		41,300		30,450		+3,850	21,700			- 2,100		+ 8,750		
19			4525	43,400					35,450	+7,950				+2,100	+2,950			
20			4734	21,700	29,600		40,450			-13,750			- 7,900			- 8,750		
21			4190	37,500						+ 2,050			+ 7,900		- 2,950			
22	65		4970	42,350		41,600		32,700		+ 8,075	19,300			+ 750		+ 9,650	JAN. 30. 1936 P.M.	
23			2422	40,850			35,850		34,275	+ 6,575				- 750	+5,000			
24			4748	23,050	26,950					-11,225			- 3,900			- 9,650		
25			2834	30,850						- 3,425			+ 3,900		- 5,000			
26	66		5908	42,950		43,600		41,515		+ 750		4,175		-650		+1,435		
27			3640	44,250			42,875		42,200	+2,050				+650	+1,375			
28			4744	40,075	40785					- 2,125			- 710			- 1,435		
29			4329	41,500						- 700			+ 710		-1,375			
30	67		4774	32,500		33,325		28,900		+ 210		11,900		- 825		+ 3,600		
31			1728	34,150					32,290	+1,860				+ 825	-1,525			
32			4875	25,300	31,250		35,675			- 6,990			- 5,950			-3,600		
33			3259	37,200						+ 4,910			+ 5,950		+1,525			
34																		
35				37,240	34,180	40,550	40,510	34,000	37,240		18,460	8,300	5260	1498	1622	4993		

EXHIBIT "E"

(6)

RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3"AA GUN NO. CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES (MEDIAL) 4 PER ROUND: ALL ASSEMBLING, MEASURING ETC BY GAUGE SECTION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
				← MEAN OF GAUGES WITH				MEAN OF ALL GAUGES IN ROUND	INDIV MEAN DISPERSION PRESS	MAX DISPERSION GAUGES FIXED	MAX DISPERSION GAUGES BOOST	← INDIVIDUAL DISPERSION WITH				→ DATE OF FIRING	REMARKS
SERIAL NO. OF ROUND	EXPECTED PRESSURE #/SQ.IN	MEDIUM CALIBER GAUGE NO.	PRESSURE #/SQ.IN (.075" MICR SPINDLE)	.0005" PISTON CL	.001" PISTON CL.	COPPER OBT CUPS	MAX OBTURATOR					.0005" PISTON CL	.001" PISTON CL.	COPPER OBT CUPS	MAX OBT		
69	16,500	5942	✓16,900		17,000		15,900		+ 560	2,200			-100		+1000		
		4525	✓17,100						+ 760				+100	+225			
	(2*-140)	4734	14,900	15,675		16,875		16,340	- 1,440			-775			-1000		
	X1492	4190	16,450						+ 110			+775		-225			
70	PYRO POWDER	4970	✓17,950		17,900		15,825		+2,210	4,500			+50		+2,125		
		2422	✓17,850						+2,110				- 50	+2,025			
		4748	✓13,700	13,575		15,825		15,740	- 2,040			+125			-2,125		
		2834	✓13,450						- 2,290			-125		-2,025			
71		5908	✓17,575		17,540		17,225		+ 935		2,975		+35		+350		
		3640	✓17,500						+ 860				- 35	+ 275			
		4744	✓16,875	15,740		17,225		16,640	+ 235			+1,140			-350		
		4329	✓17,600						- 2,070			-1,140		- 275			
72		4774	✓16,150		16,175		13,675		+1,550		5,000		-25		+2,475		
		1728	✓16,200						+1,580				+25	1250			
		4875	✓11,200	13,070		13,675		14,620	-3,420			-1,855			-2,475		
		3259	✓14,925						+ 305			+1,855		+1250			
75	16,500	5942	✓17,300		17,225		16,050		+1,000	2,350			+75		+1,250		
		4525	✓17,150						+ 850				- 75	+1,100			
		4734	✓14,800	15,375		16,050		16,300	-1,500			-575			-1,250		
		4190	✓15,950						- 350			+575		-1,100			
76		4970	✓18,700		18,590		16,775		+2,955	7,750			+110		+1,925		
		2422	✓18,475						+2,730				-110	+3,765			
		4748	✓14,850	12,900		14,715		15,745	- ,895			+1,950			-1,925		
		2834	✓10,950						-4,795			-1,950		-3,765			
77		5908	✓18,000		17,675		17,575		+1,060		2,750		+325		+ 425		
		3640	✓17,350						+ 410				-325	+1,050			
		4744	✓17,150	16,200		16,300		16,490	+ 210			+950			- 425		
		4329	✓15,250						- 1,690			- 950		-1,050			
78		4774	✓17,025		16,870		14,940		+1,300		4,175		+170		+2,090		
		1728	✓16,700						+ 975				-170	+185			
		4875	✓12,850	14,590		16,515		15,725	-2,875			-1,740			-2,090		
		3259	✓16,325						+ 600			+1,740		-185			
			16,050	14,640	17,370	16,000	16,000	16,000		4200	3725	1140	111	1235	2690		

JAN. 31.1936 A.M.

JAN. 31.1936 P.M.

EXHIBIT "F"