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REPORT NO. 46

STUDY OF PRESSURES RECORDED ON COPPER CRUSHER CYLINDERS WHEN USED FOR MORE THAN ONE ROUND

by

R. C. Gerdom

April 1936

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ABERDEEN PROVING GROUND, MARYLAND

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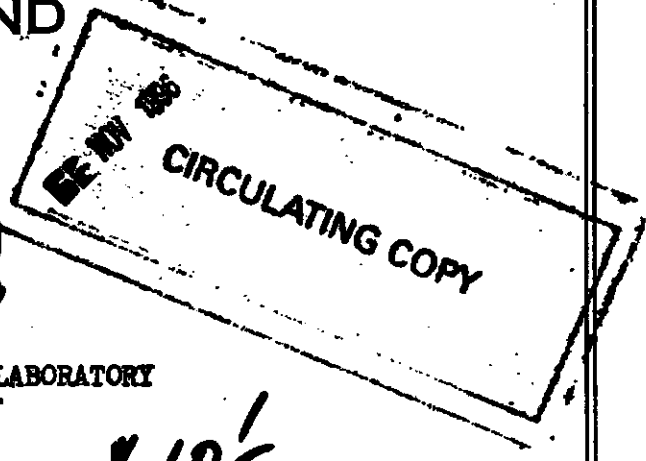
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ABERDEEN PROVING GROUND MARYLAND



BALLISTIC RESEARCH LABORATORY
REPORT

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STUDY OF PRESSURES RECORDED ON COPPER CRUSHER
CYLINDERS WHEN USED FOR MORE THAN ONE ROUND

BY

R. C. GERDOM

~~TECHNICAL BRANCH~~
~~ORDNANCE RESEARCH CENTER~~
~~ABERDEEN PROVING GROUND~~
~~MARYLAND~~

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REPORT NO. 46

7 APRIL 1936
ORDNANCE RESEARCH CENTER
PROJECT NO. _____

BRK

RCG/emh
Aberdeen Proving Ground, Md.
April 7, 1936

STUDY OF PRESSURES RECORDED ON COPPER CRUSHER
CYLINDERS WHEN USED FOR MORE THAN ONE ROUND

(In Connection with Project RB 116).

Abstract

Records of pressures were obtained by using the same copper crusher cylinders for several rounds. These were compared with the pressures obtained by the usual method during the firing of pressure rounds in the 105 mm, 12" and 14" guns.

Introduction

The Coast Artillery, when engaged in target practice, takes pressures on each trial shot. During the record series, however, time does not permit the removal and replacement of gauges each round. They, therefore, leave major caliber gauges containing copper crusher cylinders in the gun during the series and assume the pressure recorded on these coppers is the maximum pressure occurring during the series.

It is the purpose of this test to evaluate the errors resulting from this assumption.

Procedure

Additional gauges containing test coppers were inserted in pressure round as follows:

Gun	No. of Rds.	No. of Gauges	
		Med. Cal.	Major Cal.
12"	1	2	1
14"	17	9	1
105 mm A.A.	27	2	

With one exception, gauges containing test coppers were disassembled and the coppers measured each time they were subjected to a pressure. Gauge containing copper No. 19 was disassembled after being inserted in seventeen rounds of the 14" gun, at which time, it was found that gas had leaked by the obturating washer.

The lengths of the compressed coppers were measured to the nearest thousandth of an inch. Irregularities of the faces of compressed coppers and the lack of time between rounds made greater precision impossible.

Results

The results of the pressure measurements are given in Table I.

The results recorded during the firing of the 12 and 14" guns were quite different from those recorded during the firing of the 105 mm gun. Therefore two sets of plots were made: Plot No. 1 and Plot No. 2 cover the firing of the 12" and 14" gun and Plot 3 and 4 cover the firing of the 105 mm gun.

In plots Nos. 1, 2, 3 and 4

Δp_t vs $(p_{t1} - p_m)$ are plotted. The symbols are defined as follows:

<u>Symbol</u>	<u>Definition</u>
Δp_t	Increase in pressure for any one round as recorded on test copper.
p_{t1}	Pressure previously recorded on test copper.
p_m	Mean pressure recorded on uncompressed coppers.

In plots 2 and 4, only positive values of $p_{t1} - p_m$ are used.

Discussion

From plots No. 1 and No. 2 it appears that when loose medium caliber gauges, having the present prescribed piston clearances are used in 12" and 14" guns which have approximately 0.02 seconds pressure duration and subjecting them to a pressure not exceeding 34,000 lb/in²:

- a. Precompressed coppers may be subjected to any number of pressures, providing such pressures be at least 2500 lb/in² less than the previously applied pressure, without showing additional compression.
- b. That precompressed coppers, when subjected to pressures of from 0 - 2500 lb/in² less than the previously applied pressure may record pressures 1000 lb/in² greater than the maximum pressure to which they had been previously subjected.
- c. That precompressed coppers, when subjected to pressures greater than the previously applied pressure, may record pressures as great as 5000 lb/in² in excess of the pressures to which they have been subjected as measured by uncompressed coppers.

From plots No. 3 and No. 4 it appears that when loose medium caliber gauges, having the present prescribed piston clearances are used in 105 mm guns which have approximately .01 sec. pressure duration and exposing them to a pressure not exceeding 44,000 lb/in²;

- a. Additional compression of previously compressed coppers may take place even when the subsequent pressure is 7000 lb/in² less than the pressures previously recorded.

The difference of these results as compared with those recorded during the 12 and 14" gun firings may be explained by the difference in the time of exposure to pressure.

Attention is invited to the peculiar results obtained during the firing of the 105 mm gun as shown on plot 3. Here we find that when the pressure applied to the test coppers is greater than the pressure previously applied, the pressure recorded by the test coppers may be 4000 lb/in² less than the pressure recorded by uncompressed coppers.

The following explanation is offered for these results. When uncompressed coppers are used in guns such as the 105 mm in which a rapid rise in pressure takes place, the pistons in the gauge have a greater velocity than when partially compressed coppers are used. Likewise the friction of both the piston and obturating cups would be less with uncompressed coppers since they would start moving at a relatively low pressure. These conditions would tend to result in over shooting when uncompressed coppers are used. Under such conditions uncompressed coppers might record higher pressures than would partially compressed coppers.

Obviously the two records which show approximately double this amount of difference cannot be explained by the above conditions. It is thought these may be explained by pinching of the pistons.

It should be stated most emphatically that the pressure relations given in the preceding are only approximate. The probable error of the reading of the single gauge is of the order of magnitude of 1000 lb/in². Hence the values given in the preceding paragraph have large probable errors.

Major caliber gauges, only, are used for more than one round by the Coast Artillery. Since the results presented in this report were obtained principally by the use of medium caliber gauges, the dispersions are probably much greater than if major caliber gauges having adequate piston clearances had been used.

From report entitled "Report on Some Sources of Error in Piezo-Electric and Crusher Gauge Measurements" by R. H. Kent, it is evident that with the present piston clearances, pinching of the pistons should begin at relatively low pressures.

This inference is confirmed by recent tests during which comparative data of the effect of various piston clearances were obtained. See "Report on Investigation of the Cause Underlying Erratic Powder Pressures Obtained by Crusher Gauges" by Captain T. K. Vincent.

In view of these facts, it is thought probable that when gauges having properly designed clearances are obtainable, this test might be repeated and results having a much greater degree of accuracy obtained.

The undersigned is much indebted to Mr. R. H. Kent for advice and consultation.

H. H. Zornig
H. H. Zornig,
Lt. Col., Oro. Dept.,
Chief Research Division

R. C. Gerdon
R. C. Gerdon.

TABLE NO. I

REBULATION OF RESULTS OBTAINED DURING TEST

Date	Gun	Rd. No.	Mean Indicated Press, lb/in ²	Major Gauge Press, lb/in ²	Med. Gauge Press, lb/in ²	Med. Gauge Press, lb/in ²	Med. Gauge Press, lb/in ²	Test Copper No. 1 lb/in ²	Test Copper No. 2 lb/in ²
10/24/35	105 mm Tube No. 6222 P13	1	25,700		25,950	25,470		25,800	25,800
		2	36,800		37,600	36,000		34,500	34,700
		3	33,250		34,850	31,650		34,850	34,850
		4	44,000		44,750	43,250		40,400	35,500
		5	37,700		38,900	36,550		40,400	35,500
10/29/35	12" Gun 1888 M2 No. 29	1	21,400	21,300	21,450	21,450			
11/4/35	14" D.G. Mod. 1910 No. 18	1	11,950	11,150	12,250	12,450		40,400	35,500
		2	14,700	14,500	14,700	14,900		40,400	35,500
		3	19,950	20,100	20,450	19,250		40,400	Skid
		4	26,450	30,100	29,500	19,800		40,400	
		5	28,850	29,050	28,600	28,900		40,400	
		6	34,200	38,350	29,800	34,500		40,400	
		7	25,950	31,800	26,400	19,600		40,400	
11/11/35	14" D.G. Mod. 1910 No. 18	1	11,250	10,700	11,600	11,400		40,400	
		2	30,450	31,025	31,025	28,700	31,025	40,400	
		3	31,550	33,350	30,550	32,300	29,950	40,400	
		4	31,700	30,900	33,050	31,350	31,500	40,400	
		5	28,300	30,300	28,700	28,450	25,800	40,400	
		6	28,000	30,400	29,800	26,700	25,150	40,550	
		7	31,500	32,300	31,500	30,700	Skid	40,550	
		8	30,850	32,300	30,300	30,700	30,100	40,550	
		9	31,350	32,600	32,600	28,900	Skid	40,550	
		10	31,050	31,500	31,350	30,250		40,550	
11/14/35	105 mm M1 No. 1	1	37,800		37,250	38,350			
11/15/35	105 mm M3	3	38,300		38,100	38,500			
		4	37,700		40,400	35,000			
		5	38,600		35,650	41,500		41,300	
		6	39,700		39,250	40,200			
		7	39,350		39,250	39,450			
		8	41,300		40,950	41,700			
		9	41,200		41,900	40,550			
		10	41,700		41,300	42,100			
		11	40,600		40,200	40,950		41,300	
		12	40,800		40,550	40,950			
		13	41,100		40,950	41,300			
		14	40,100		39,800	40,400			
		15	37,500		38,500	36,550			
		16	38,900		38,700	39,050		41,900	
		17	38,200		37,450	36,900			
		18	40,000		39,050	40,950			
		19	34,100		37,100	31,050			
		20	36,050		37,250	34,350			
		21	35,950		32,100	39,800			
		22	37,550		37,100	38,000		42,300	
		23	38,100		38,000	38,150			

TABLE NO. I

TABULATION OF RESULTS OBTAINED DURING TEST

Date	Gun	Rd. No.	Mean Indicated Press, lb/in ²	Test Copper No. 3, lb/in ²	Test Copper No. 4, lb/in ²	Test Copper No. 5, lb/in ²	Test Copper No. 6, lb/in ²	Test Copper No. 7, lb/in ²	Test Copper No. 8, lb/in ²
10/24/35	105 mm Tube No. 6222 P13	1	25,700						
		2	36,800						
		3	33,250						
		4	44,000						
		5	37,700						
10/29/35	12" Gun 1868 No. 29	1	21,400	19,800	19,100	19,600			
11/4/35	14" D. J. Model 1910 No. 18	1	11,950		19,100	19,600	11,900		11,400
		2	14,700		19,100	19,600	14,500		14,500
		3	19,950		21,100	20,800	19,450		20,950
		4	26,450		31,050	30,250	31,650		31,200
		5	26,650	31,200	31,350	30,700	31,650		31,200
		6	34,200	37,250	35,500	37,100	33,350		31,200
		7	25,950	37,250	35,500				
11/11/35	"	1	11,250	37,250	35,500				
		2	30,450	37,450	35,500				
		3	31,550	37,450	35,500				
		4	31,700	37,450	35,500				
		5	28,300	37,450	35,500				
		6	28,000	37,450	35,500				
		7	31,500	37,450	35,500				
		8	20,350	37,450	35,500				
		9	31,350	37,450	35,700				
		10	31,050	37,450	35,700				
11/14/35	105 mm Tube No. 1	1	37,800						
11/15/35	105 mm P13	1	36,800						
		2	37,700						
		3	36,800						
		4	39,700	36,450				41,300	
		5	39,350		39,100				
		6	41,500						
		7	41,200						
		8	41,700		40,400				
		9	40,600						41,300
		10	40,800						
		11	41,100	39,400					
		12	40,100	40,400					
		13	37,500		40,950				
14	38,900						41,700		
15	38,200								
16	40,000								
17	34,100		41,100						
18	36,050								
19	35,950	41,500							
20	37,550						41,900		
21	38,100								

TABLE NO. I

TABULATION OF RESULTS OBTAINED DURING TEST

Date	Gun	Rd. No.	Mean Indicated Press, lb/in ²	Test Copper No. 15 lb/in ²	Test Copper No. 16 lb/in ²	Test Copper No. 17 lb/in ²	Test Copper No. 18 lb/in ²	Test Copper No. 19 lb/in ²	Test Copper No. 20 lb/in ²
10/24/35	105 mm Tube No. 6222 P13	1	25,700						
		2	36,800						
		3	33,250						
		4	44,000						
		5	37,700						
10/29/35	12" Gun 1888 M2 No. 29	1	21,400						
11/4/35	14" D.C. Mod. 1910 No. 18	1	11,950						
		2	14,700						
		3	19,950						
		4	26,450						
		5	28,850						
		6	34,200						
		7	25,950	30,900	29,950	30,700			
11/11/35	14" D.C. Model 1910 No. 18	1	11,250						10,700
		2	20,450	31,500	31,350		32,100		28,100
		3	31,550	34,700	31,350		32,400		33,050
		4	31,700	34,700	31,350		32,600		33,050
		5	28,300	34,700	31,350		32,600		33,050
		6	28,000	34,700	31,350		32,600		33,050
		7	31,500	34,700	31,500		33,050		33,200
		8	30,850	34,700	31,800		33,050	Leak Under Head	33,200
		9	31,350	34,700	32,250		34,000		33,400
		10	31,050	34,700	32,400		34,000		33,400
11/14/35	105 mm M1 No. 1	1	27,800	37,300			34,000		
11/15/35	105 mm M3	3	38,300	37,300			36,700		
		4	37,700	38,900			39,250		
		5	38,600						
		6	39,700						
		7	39,350						
		8	41,300		32,600				
		9	41,200	39,100			39,400		
		10	41,700						
		11	40,600						
		12	40,800		38,000				
		13	41,100						
		14	40,100						
		15	37,500						
16	38,900								
17	38,200	40,600			41,300				
18	40,000		38,300						
19	34,100								
20	36,050	40,800			41,300				
21	35,950								
22	37,550								
23	38,100			39,500					

Not disassembled between rounds

TABLE NO. I

TABULATION OF RESULTS OBTAINED DURING TEST

Date	Gun	Rd. No.	Mean Indicated Press, lb/in ²	Test Copper No. 9 ₂ lb/in ²	Test Copper No. 10 ₂ lb/in ²	Test Copper No. 11 ₂ lb/in ²	Test Copper No. 12 ₂ lb/in ²	Test Copper No. 13 ₂ lb/in ²	Test Copper No. 14 ₂ lb/in ²
10/24/35	105 mm Tube No. 6222 P13	1	25,700						
		2	36,800						
		3	33,250						
		4	44,000						
		5	37,700						
10/29/35	12" Gun 1888 M2 No. 29	1	21,400						
11/4/35	14" D.C. Model 1910 No. 18	1	11,950	11,850	12,250	11,800	13,100		
		2	14,700	15,100	14,900	15,100	16,050		
		3	19,950	21,100	19,600	20,800	22,300		
		4	26,450	31,350	31,950	30,900	30,250		
		5	28,850	31,650	31,950	31,650	Skid		
		6	34,200	37,600	36,400	38,150		38,900	
		7	25,950	37,600	36,400			38,900	30,100
11/11/35	14" D.C. Model 1910 No. 18	1	11,250	37,600					
		2	30,450	37,600	36,400				31,650
		3	31,550	37,600	36,400				33,050
		4	31,700	37,600	36,400				33,050
		5	28,300	37,600	36,400				33,050
		6	26,000	37,950	36,400				33,050
		7	31,500	37,950	36,400				33,050
		8	30,850	37,950	36,400				33,050
		9	31,350	37,950	36,400				33,050
		10	31,050	37,950	36,400				33,050
11/14/35	105 mm M1 No. 1	1	37,800						
11/15/35	M1 No. 7 105 mm M3	2	38,300						
		4	37,700						
		5	38,500						
		6	39,700		39,600				
		7	39,350	39,100					
		8	41,300						37,300
		9	41,200						
		10	41,700	39,800					
		11	40,600						
		12	40,800						37,300
		13	41,100		40,200				
		14	40,100		40,400				
		15	37,500	40,200					
		16	38,900						
		17	38,200						
18	40,000						39,600		
19	34,100	40,600							
20	36,050								
21	35,950		40,600						
22	37,550								
23	39,100						40,000		

PLOT I

ΔP_b VS $(P_{cb} - P_{m0})$
FOR 14" GUN

ΔP_b = INCREASE IN PRESSURE FOR ANY ONE
ROUND AS RECORDED ON TEST COPPER.

P_{cb} = PRESSURE PREVIOUSLY RECORDED
ON TEST COPPER.

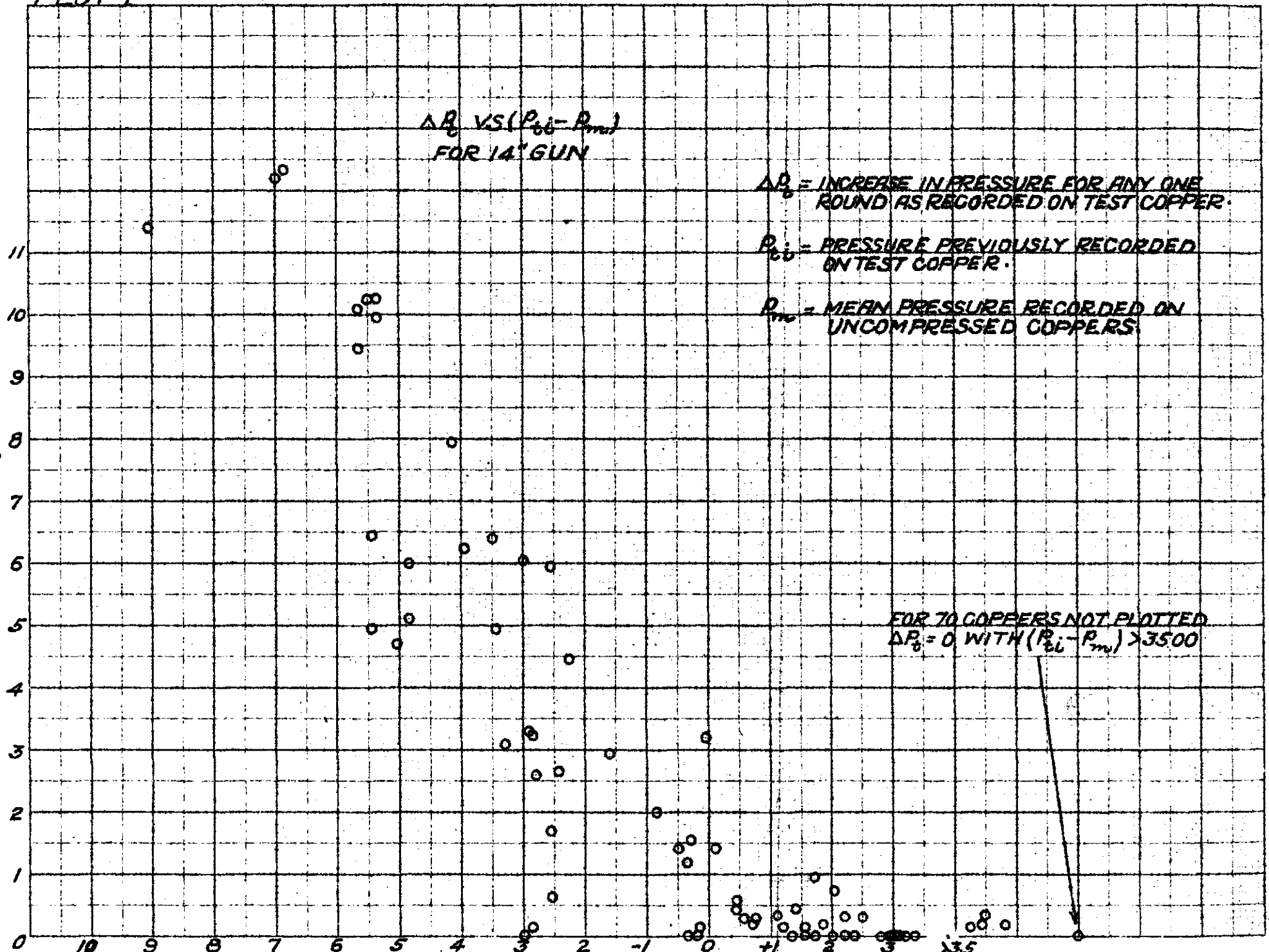
P_{m0} = MEAN PRESSURE RECORDED ON
UNCOMPRESSED COPPERS.

ΔP_b
1000 LBS/IN²

11
10
9
8
7
6
5
4
3
2
1
0

$P_{cb} - P_{m0}$ 1000 LBS/IN²

FOR 70 COPPERS NOT PLOTTED
 $\Delta P_b = 0$ WITH $(P_{cb} - P_{m0}) > 3500$



ΔP_b VS $(P_{bl} - P_{mc})$
FOR 14" GUN

ΔP_b = INCREASE IN PRESSURE FOR ANY ONE ROUND AS RECORDED ON TEST COPPER.

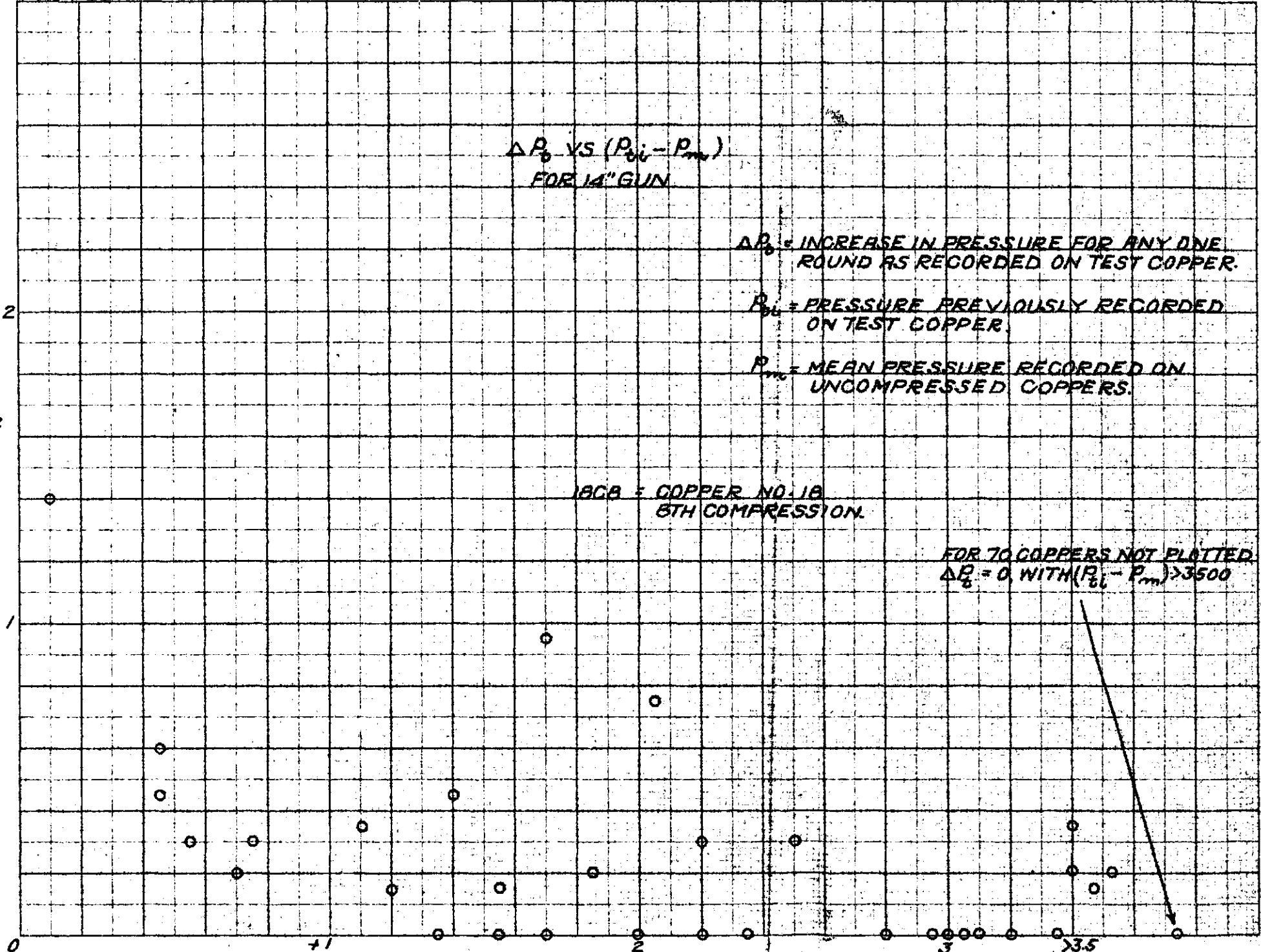
P_{bl} = PRESSURE PREVIOUSLY RECORDED ON TEST COPPER.

P_{mc} = MEAN PRESSURE RECORDED ON UNCOMPRESSED COPPERS.

ΔP_b
1000 LBS/IN²

18CB = COPPER NO. 18
8TH COMPRESSION.

FOR 70 COPPERS NOT PLOTTED
 $\Delta P_b = 0$ WITH $(P_{bl} - P_{mc}) > 3500$



PLOT III

ΔP_i VS ($P_{ti} - P_{mo}$)
FOR 105 MM GUN

ΔP_i = INCREASE IN PRESSURE FOR ANY ONE
ROUND AS RECORDED ON TEST COPPER.

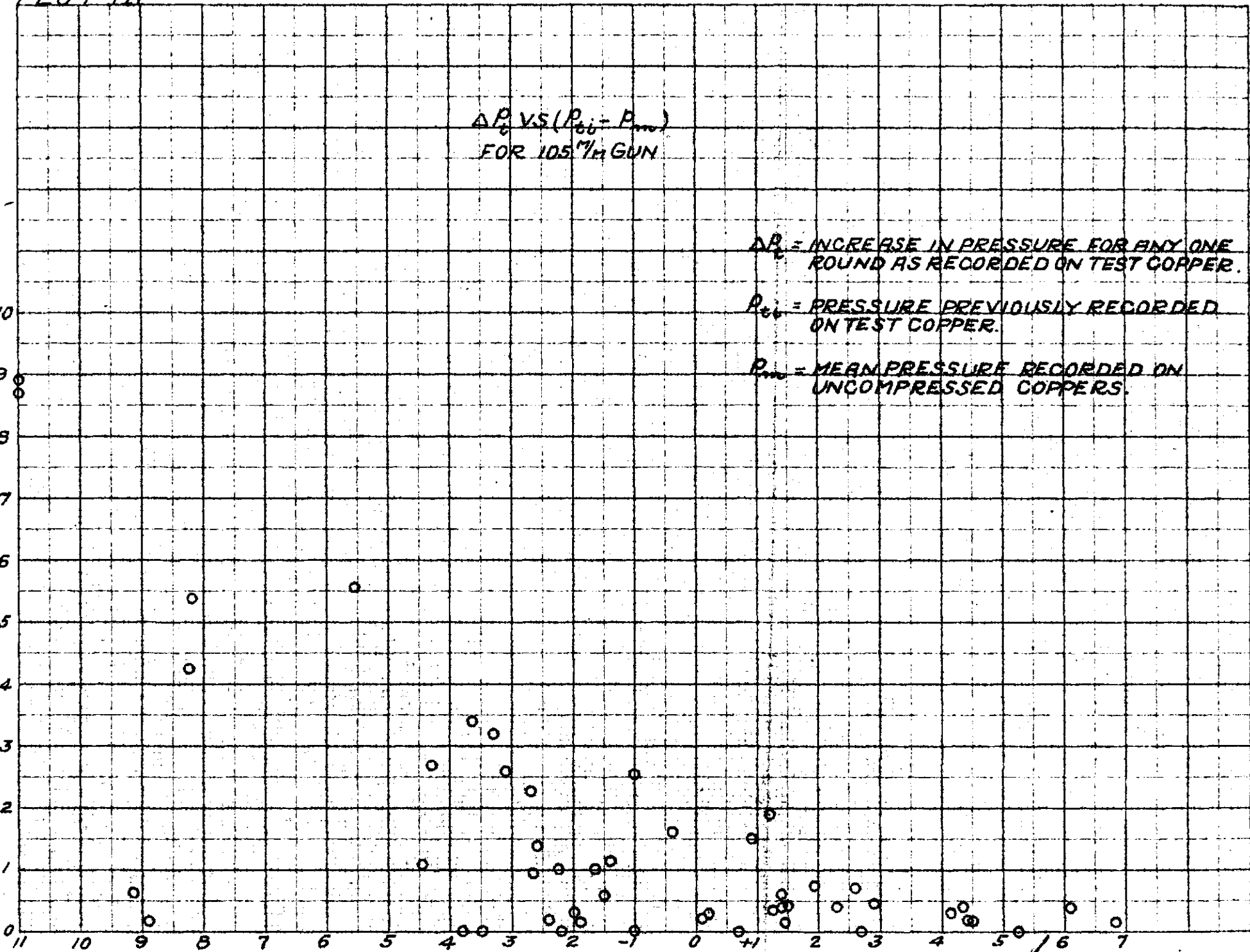
P_{ti} = PRESSURE PREVIOUSLY RECORDED
ON TEST COPPER.

P_{mo} = MEAN PRESSURE RECORDED ON
UNCOMPRESSED COPPERS.

ΔP_i
1000 LBS/IN²

10
9
8
7
6
5
4
3
2
1
0

$P_i - P_{mo}$ 1000 LBS/IN²



PLOT IV

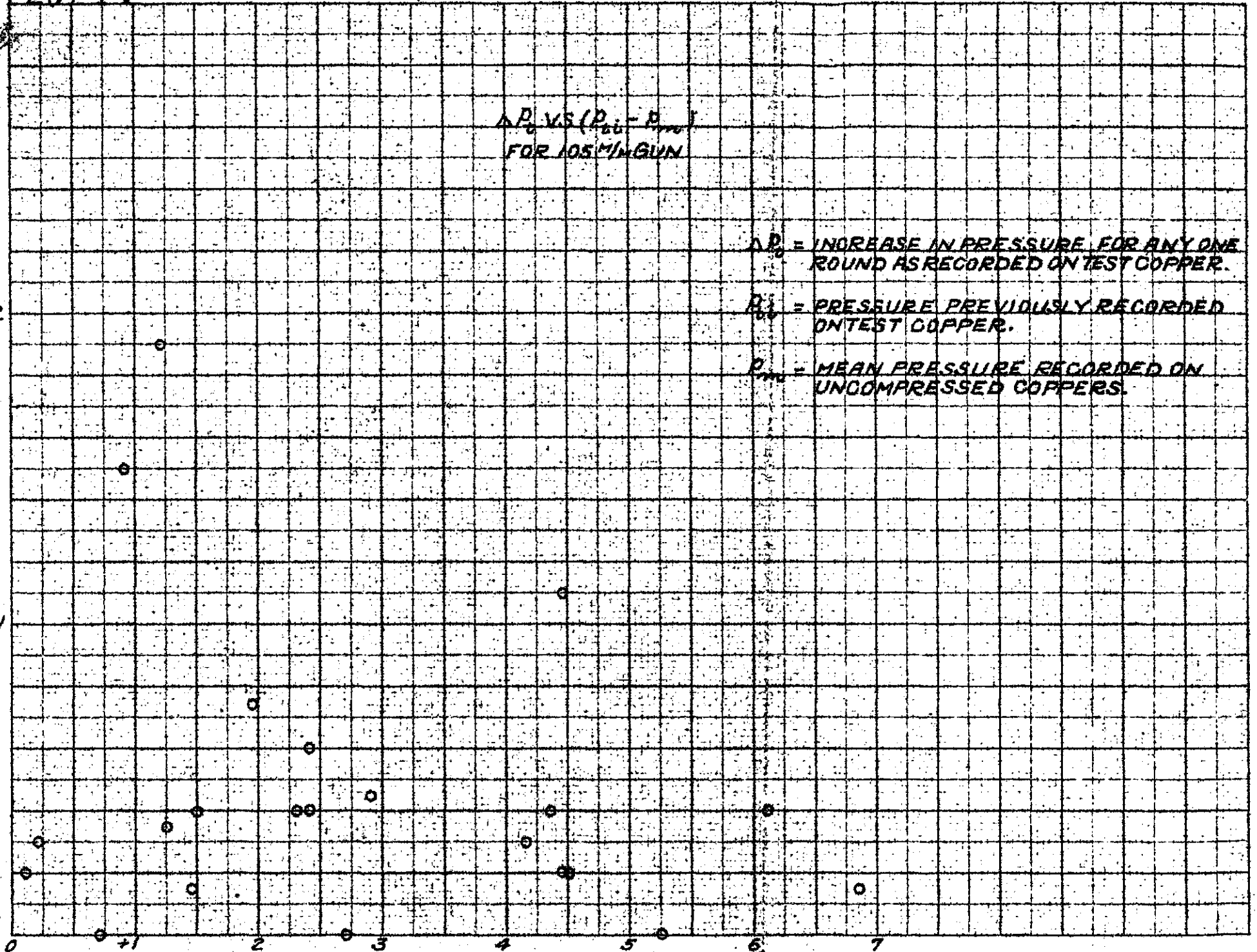
ΔP_0 VS $(P_{00} - P_{1000})$
FOR 105 M/IN GUN

ΔP_0 = INCREASE IN PRESSURE FOR ANY ONE ROUND AS RECORDED ON TEST COPPER.

P_{00} = PRESSURE PREVIOUSLY RECORDED ON TEST COPPER.

P_{1000} = MEAN PRESSURE RECORDED ON UNCOMPRESSED COPPERS.

2



1000 LBS/IN²

ΔP_0
1000 LBS/IN²

$P_{00} - P_{1000}$ 1000 LBS/IN²