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DEVELOPMENT OF CHROME PLATING OF GUNS

by

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DEVELOPMENT OF CHROME PLATING OF GUNS

Abstract

Chromium plating of small arms barrels results in longer accuracy life. However, the cost of plating is excessive compared to the results obtained. The plating of 37 mm gun barrels to date has been unsatisfactory. The chromium plating of 3" A.A. gun tubes has been successful insofar as the technique of plating is concerned, but the expected increase in accuracy life has not materialized. The use of chromium plating generally for gun barrels is not economical.

Introduction

The following instructions were issued by the Chief of Ordnance concerning the investigation of the development of chrome plating of guns (O.O. 400.276/144; A.P.G. 472/312-Sept. 7, 1937):

"1. It is requested that a study be made of the development of plating of bores of guns.

2. In this study it is desired that the Proving Ground and other available records be examined and historical survey be prepared showing the steps taken by the Department in the development of plating of bores, both of small arms and of larger calibers.

3. It is desired that the sources of authority for all statements be given, either as a footnote or by reference to a bibliography appended. If technical reports are available concerning investigations at other establishments, or by other agencies, it is desired that they be considered and weighed in drawing conclusions.

4. It is desired that the study be presented in report form and be available, if practicable, by October 31.

By order of the Chief of Ordnance:

(G. F. Jenks)

G. F. Jenks,
Colonel, Ord. Dept.,
Assistant."

Procedure

The chromium plating investigations of the Ordnance Department were conducted on several types of guns concurrently. Also the application of the chromium plating process was done at three or more separate places. In view of these facts, the study has been divided into sections as follows, and the chronological order of occurrence has been followed, where possible:

I - Technique of chromium plating.

II - Investigation of chrome-plating applied to small arms barrels.

III - Investigation of chrome-plating applied to 37 mm gun barrels.

IV - Investigation of chrome-plating applied to antiaircraft gun liners.

V - Resumé and conclusions.

I - Technique of Chromium Plating

The principles underlying chromium plating are briefly as follows: (See "The electrodeposition of chromium", E. A. Ollard, A.R.C.S., May 17, 1935, Electrometallurgy, pp. 541-).

The solution used is chromic acid containing a small amount of sulphate. All commercial plating baths are of this composition. It is dense, brown, opaque, strongly acid and oxidising.

It is made by dissolving commercial chromic acid in water and adding sulphate as chromium sulphate or sulphuric acid. Commercial chromic acid is really chromic acid anhydride or chromium trioxide ($Cr\ O_3$). In water it forms chromic acid ($H_2\ Cr\ O_4$). It then probably forms bi-chromic acid ($H_2\ Cr_2\ O_7$) since it becomes red. Bi-chromates are red, whereas chromates are yellow.

When this solution works between two electrodes, it rapidly turns dark brown, and becomes opaque, due to the partial reduction of chromic acid and the formation of complexes. The effect at the anode is oxidising, at the cathode it is reducing.

When the current is on the following reactions occur:

$$2\ Cr\ O_3 \longrightarrow 2\ Cr + 3\ O_2$$

$$2\ H_2O \longrightarrow 2\ H_2 + O_2$$

The H_2 and Cr are at the cathode and the O_2 at the anode. The current efficiency is low with this set-up, because water breaks up at low voltage, and the current is mainly used in breaking up the water, leaving little available for the deposit of chromium.

The current densities vary directly with the temperature of the solution, its composition and the type of the object to be plated. Current densities vary from 80 - 100 amperes per square foot to 900 - 1000 amperes per square foot.

Although the solution is complex and its reactions are not understood completely, the solution is not difficult to control. The usual impurities in the solution are destroyed by oxidation due to the temperature of the solution. Three factors must be controlled, the chromic acid, trivalent chromium and the sulphate.

Frankford Arsenal Experiments.

The Frankford Arsenal initiated the development of chromium plating of gun barrels in the Ordnance Department in 1927. Majors A. B. Custis and George A. Woody, Ordnance Department, first conceived the idea of using this process for this purpose.

In the early experiments with small arms barrels, the barrels were held vertically with a long cylindrical anode placed centrally the entire length of the bore. Difficulties in eliminating gas in solution, obtaining flow of solution, keeping the anode centered, all led to uneven and unsatisfactory plating.

The early solution consisted of 40 ounces of chromic acid and .4 ounces of chromium sulphate to one gallon of water. Current densities of 100 amperes per square foot were used for steel, 200 amperes per square foot for nickel, copper, or brass. The temperature of the solution was maintained at 115° to 120° F.

The cost of chromium plating a small arms barrel was approximately $1.43. As this was 40% of the cost of the original barrel, the use of the process for small arms barrels suffered a set-back. Instead of entering into a production basis in the use of the process, the project remained one of limited experiment.

An improved method of plating was developed later in which the barrels were submerged vertically, breech end down in the solution. A movable anode was centered accurately in the bore. As this was withdrawn the thickness of plate in strategic places was controlled.

Plating was placed directly on the highly polished metal of the barrel, as the introduction of an intermediate plate to increase the anti-corrosive properties resulted in a composite plate which did not stand wear. With this new device, a .30 Cal. rifle barrel was chromium plated in about 2 hours.

The practice of plating with chromium finally developed two standard solutions. The so-called "Bureau of Standards" solution was used almost entirely in the East and consisted of 33 ounces of chromic acid and .3 ounces of sulphuric acid per gallon of water.

The so-called "Commercial" solution, used principally in the middle and far West consisted of 55 ounces of chromic acid and .3 ounces of sulphuric acid, per gallon of water.

The Bureau of Standards states that the plating range of the latter solution is limited at the high temperatures of solution.

The higher temperatures of solution which were adopted allowed higher current densities and formed the plate more rapidly. It was more dense and closely packed than where lower temperatures were used.

The above-mentioned procedure was used in chromium plating the small arms barrels, the 37 mm gun barrels, and 3" A.A. gun liners, M1, in guns No. 2 and No. 3. These liners were Forging Number 8301-1 and 8301-2, described later in this report.

The 3" A.A. gun liner, M3 - No. 1 (Forging 12862-6-55) was probably chromium plated at the Frankford Arsenal. There is no definite information available as to the history of its plating. However, the original directive provided for the plating of three (3) liners. Two were tested in 1928. The liner tested in 1928 may have been the third liner, plating of which may have been deferred until 1929, although there is no record available to substantiate this assumption.

The four 3" A.A. gun liners, M3, Nos. 7, 8, 9 and 10 were chromium plated by the Worthington Pump Company, Buffalo, New York in 1930. This was done by their personnel and ordnance inspectors were denied admittance to the plating plant. It can be assumed that the technique was representative of that period. It was apparent by inspection of the bore that a straight anode was used as relatively little chromium was deposited in the grooves and none on the chamber walls. The greater distance of the grooves and chamber walls from the straight anode and the relative weak "throw" of the plating solution caused this condition.

3" A.A. gun liner M3, No. 138 was plated at the Naval Gun Factory, Washington, D.C. using a technique which they have found successful in their own work. The "Bureau of Standards" solution was used. The temperature of the bath was maintained at 170° F. and a current of 1600 amperes was applied for 1 hour and 10 minutes. A plate .0005" to .0007" thick should result. (See U.S.N.G.F. chart - chromium plating 3" A.A. gun liner, M3, No. 138 - January 8, 1936).

The navy method of plating has been successfully applied to guns in their service up to 8-inch caliber. The tendency of projections on an object to be plated, such as the corners of the lands of rifling; to throw out radial projections, or stalactitic forms, known as "trees", (Wvt.

Ars. 472/444-Incl. 1) has been a problem to be solved in connection with thick plating. It is possible that the breakdown and tendency of the plating to peel in the early plated liners may be due to this phenomenon. It is possible that the navy method of plating, really a chrome "wash" of approximately .0005" thickness, may account for the success of their method.

II - Investigation of Chrome-Plating Applied to Small Arms Barrels

The Frankford Arsenal reported in Minutes of Conference on Chromium Plating, July 8, 1929 at that arsenal that chromium plated rifle barrels gave the following results in local tests.

No. rounds fired in each	-15,000
Muzzle velocity at 78 feet	
chromium plated barrel	- 2318 f.s.
non- " " barrel	- 2177 f.s.
Spread of pattern - plated barrel	- 4.05"
" " " - non-plated barrel	- 16"
Tipping and keyholing - plated barrel	- None
non-plated barrel	- Marked

They also noted an increase in velocity after several thousand rounds, in their opinion, due to lubricating and smoothing properties of chromium plating.

Based on these tests a 50% increase in accuracy life of barrels was indicated.

As a result of this and other tests, the Ordnance Office authorized the chromium plating of several rifle and machine gun barrels for Proving Ground and service tests.

Proving Ground Tests.

In October 16, 1929, the first Proving Ground tests were completed and reported upon in "First Partial Report" under the title of "Corrosion and Erosion in Small Arms with Chromium Plated Barrels".

Rifle and .30 Cal. Machine Gun Barrels

The materiel for this test included:

3 - barrels, .30 Cal. M1903 - Nos. 1296819; 1296755 and 1296696.
3 - barrels, .30 Cal. B.M.G. water-cooled, M1917, Nos. 01; 02; 03.

Procedure followed with rifle barrels

The tests of the rifle barrels included stargauging after each 1000 rounds, five round velocity and 2 - 10 round accuracy targets at 0 and after each 1000 rounds. The rounds to complete each 1000 rounds were fired for erosion at the rate of 1 per 6 seconds. Rifles were cooled after each 50 rounds. After each 1000 rounds the rifles were set aside for corrosion test for 72 hours.

The accuracy life was considered to be lost when the average mean radius of two consecutive targets at 600 yard measured 11 inches.

Procedure followed with machine gun barrels

The tests of the machine gun barrels included stargauging every 1000 rounds. Five round velocity targets were fired after each 2000 rounds. Targets consisted of 50 round bursts at 1000 inches, and were taken as the last firings in each 1000 rounds in order to be sure barrel was hot.

Rate of fire was 200 rounds per minute. After each 1000 rounds the barrel was laid aside for 72 hours to observe corrosion.

The accuracy life was considered to be lost when 4 or more keyholes or tips occur on 2 out of 3 consecutive targets.

Results of tests of rifle and machine gun barrels

In these tests the rifles lost their accuracy life at 6000 to 7000 rounds; 19-20,000 and 34-35,000 rounds respectively. It was believed that the first rifle barrel was bent.

The machine gun barrels after 20,000 rounds, 21,500 rounds and 31,500 rounds, respectively.

Conclusions reached in test of rifle and machine gun barrels

The conclusions reached in this test were that "chromium plating very materially increases the resistance of small

bores to both erosion and corrosion".

Pistol Barrels

The Third Partial Report under the above test shows that a number of chromium plated pistol barrels were tested. These were fired 10 rounds, then set aside for 72 hours until a total of 1000 rounds had been fired through each.

After 800 rounds, two of the barrels showed corrosion and erosion 1/2 to 3/4" from the breech ends.

It was concluded as a result of this test that chromium plating very materially increased the resistance of the barrels to corrosion and erosion.

.50 Cal. M.G. Barrels

In the Fourth Partial Report under the above test, 3 - .50 Cal. M.G. barrels, Nos. 521, 525 and 536 were tested.

The test of the .50 Cal. barrels consisted of erosion firing in 25 round bursts at the rate of 200 rounds/minute, taking 2 - 25 round targets as the last two bursts of 500 rounds, all firings at 1000 inches.

The accuracy life was considered at an end when 4 or more bullets keyholed or tipped on 2 out of 3 consecutive targets.

Tipping occurred after 500 rounds, the blame for which was laid to the use of light barrels instead of 11 lb. barrels.

.30 Cal. M.G. Barrels

The Fifth Partial Report under the above test reports the test on 2 - .30 Cal. M.G. barrels, Nos. M66 and M69.

These barrels were fired for velocity at 1000 inches and were then used on current work. The records are rather meager but at 12895 and 12720 rounds respectively, the barrels were reported to be still within their accuracy life insofar as muzzle velocity is concerned. They had each lost 250 f.s. in velocity and 132 yards in range at 1000 yards and 90 inches in elevation.

Resume.

The tests performed at Frankford Arsenal showed a 50% increase in accuracy life of plated barrels.

Several standards of accuracy life were established. These were based on the following factors, singly or in combination.

(a) Loss in muzzle velocity.

(b) Spread of pattern.

(c) Tipping and keyholing.

(d) Loss in range.

(e) Stargauge measurements.

The conclusions in each test were to the effect that erosion and corrosion were materially reduced in small arms barrels when they were plated.

The high cost of chromium plating undoubtedly caused the project to be suspended.

III - Investigation of Chromium Plating applied to 37 mm Gun Barrels

The Ordnance Committee in O.C.M. Item 6913, April 5, 1928, stated as follows:

> "Recent experiments with chromium plating of machine gun barrels indicates a marked increase in accuracy life".

It further recommended that two of the four 37 mm A.A. guns (barrels) M1 be chromium plated for use during the 1928 A.A. exercises. The "recent experiments" referred to were probably those conducted at the Frankford Arsenal.

Proving Ground Tests.

In the questionnaire sent to the Aberdeen Proving Ground in connection with the 1928 A.A. exercises, page 6, par. 28, the statement is made:

> "The bores of two (37 mm A.A.) guns have been chromium plated in an effort to increase the accuracy life. Compare the erosion and coppering with and without the plating".

The stargauge records at the Proving Ground indicate that 37 mm Browning Automatic 3000 f.s. guns, M1, Nos. 3 (C4558) and 4-(C4557) were chromium plated. The thickness

of plating or other information is not available. The firing records taken during the tests make no mention of the chromium plating or its behavior.

The star gauge records are as follows:

37 mm Gun, B.A., 3000 f.s.-Ml, No. 3 (C4553)

After 8 rounds.

Distance from origin	Lands change in dia.	Grooves change in dia.
12"	.000	.000
10.5	.0005	.000
10	.0010	.000

After 2283 rounds.

Distance from breech	Lands change in dia.	Grooves change in dia.
14"	-.002	-.002
12	.000	.000
10.5	.011	.003
10	.016	.004

At the muzzle the chromium plating was worn off of the lands. The plating in the grooves appeared to be satisfactory. The first third of the bore forward of the origin was entirely devoid of plating. The bore was moderately coppered between 14" and 32" from origin.

37 mm Gun, B.A., 3000 f.s.-Ml, No. 4 (C4557)

After 13 rounds.

Distance from breech	Lands change in dia.	Grooves change in dia.
12	.000	.000
10.5	.0005	.000
10	.0010	.000

After 2280 rounds.

Distance from breech	Lands change in dia.	Grooves change in dia.
16	-.003	-.005
14	.000	-.001
12	.001	.001
10.5	.010	.005
10	.015	.008

At the muzzle the chromium plating was mostly worn off of the lands and partly out of the grooves. The first third of the bore forward of the origin showed no evidence of plate remaining. Coppering in moderate amount was observed.

After 4133 rounds.

In 1937 this gun was again stargauged.

Distance from breech	Lands change in dia.	Grooves change in dia.
16	-.001	-.002
14	.002	.000
13	.005	.006
12	.011	.013
10.5	.022	.033
10	.028	.034
9.75	.033	.036

The report of the 1928 A.A. Exercises, page 108, par. 189, states:

> "The bores of two of the 37 mm guns (Full Automatic, M1 - Browning) were chromium plated. These barrels seem to be subject to erosion to the same extent as the two non-chromium barrels. As in the case of the 3-inch gun, this plating came off in flakes after firing a few rounds. The average rate of fire is 75 rounds per gun per minute, while the maximum rate is 105 rounds per gun per minute".

and page 144, par. 234:

> "That chromium plating for the bores of 37 mm guns is unsatisfactory in the present state of development".

Comparative Erosion.

No. Rounds	Not Plated				Plated			
	Gun No. 1		Gun No. 2		Gun No. 3		Gun No. 4	
	Erosion at Origin	Extent	Erosion at Origin	Extent	Erosion at Origin	Extent	Erosion at Origin	Extent
8					.001"	2"		
13							.001"	2"
222	.010	4"						
1276			.006	4"				
1866	.016	6"						
2280							.015	6"
2283					.016	4"		
4133							.033	6 1/4"

Resume.

The standard of comparison in these tests is based entirely on the stargauge records.

The peeling of the chromium plating is due to faulty technique of plating in all probability.

Based on comparative erosion of two plated with two unplated barrels, there is little difference in the erosion rate.

The conclusions of the Antiaircraft Board, 1928, are sound, based on the limited tests.

IV - Investigation of Chrome Plating Applied to Antiaircraft Liners

1928

In O.C.M. Item 6845, March 15, 1928, the Ordnance Department took the first official action with regard to chrome plating the bores of antiaircraft guns. The possibilities of this process as a means of prolonging the accuracy life of gun barrels had been informally considered prior to this time, and numerous experiments had been conducted at the Frankford Arsenal with chrome plated small arms barrels. Based on these experiments and the general adoption of chrome plating by industry in prolonging the life of dies, punches, etc., the recommendation was made by the Ordnance Committee, that the bores of three antiaircraft liners M1 be chromium plated. These were to be plated to a thickness of .0005".

The bore diameters were not to be increased to take care of this added thickness of plating, the liners to be machined to the same dimensions as the standard liners so that the chromium plating could be removed electrically in the event that it was not satisfactory; records at the Proving Ground show that two of these liners were completed and tested during the antiaircraft exercises at the Aberdeen Proving Ground and Fort Humphreys (now Fort Belvoir), Va., September to November, 1928. No record of the third liner can be found at the Proving Ground. It is probable that this third liner was tested in 1929, as no record can be found as to its origin.

Results of Test of Chrome Plated Liners during 1928 Antiaircraft Exercises

The two liners which were tested were assembled to 3" A.A. gun M1, Serial Nos. 2 and 3. These liners were designated as Forgings Nos. 8301-1 and 8301-2 respectively. The forgings were procured and cold worked at the Watertown Arsenal. They were finish machined at the Watervliet Arsenal. The chromium plating was done at the Frankford Arsenal, as described in Section I.

3" A.A. Gun M1 - No. 2 (Liner Forging No.8301-1)

The record of firings insofar as Proving Ground tests are concerned are contained in the following:

Rounds	Firing Record No.	Dates
1 - 11	3753	Aug. 20-22-1928
12 -139	3742	Sept. 5-14-1928
140- 591	3776	Sept. 17-Oct. 15-1928
592 -888	3795	Oct. 16-31-1928
889-1073	Fired by 62nd C.A.	April 1929
1074	--	May 8, 1929
1075 - 1083	4004	June 1-3-1929
1084 - 1630	Fired by 62nd C.A.	
1631 - 1649	4448	April 24, 1930

The behavior during firing was no different than was experienced with a standard liner.

The liner was stargauged periodically and extracts from these Proving Ground records are as follows:

Stargauge record after 11 Rounds.

No change in grooves or chamber diameter. Lands show .0005" and .0010" increase in diameter at 32.5 and 32.3" from the breech end respectively. No change in the plating was noted up to this time.

Stargauge record after 556 rounds.

Inches from Breech	Lands Change	Grooves Change
42	.000"	-.003"
40	.000	-.002
39	.001	-.002
38	.002	-.002
37	.003	-.001
36	.006	.000
35	.011	.001
34	.013	.003
33	.017	.008
32.5	.020	.012

No change was noted in chamber dimensions. The chromium plating was no longer visible to the eye in the bore of the gun, on lands or in grooves. The non-ferrous deposit of metal from the rotating bands obscured the surface somewhat and it was impossible to state whether or not the plating had flaked off.

After 888 rounds.

Inches from breech	Lands Change	Grooves Change
44	.000"	-.003"
42	.001	-.003
40	.002	-.004
39	.005	-.003
38	.008	-.002
37	.010	.000
36	.016	.001
35	.023	.003
34	.029	.006
33	.035	.013
32.5	.039	.018

No evidence of plating remains visible in bore.

After 1649 rounds.

Inches from breech	Lands Change	Grooves Change
60	-.001"	-.003"
55	.002	-.001
50	.004	.001
48	.006	.003
46	.010	.004
44	.014	.004
42	.017	.005
40	.022	.006
39	.025	.007
38	.031	.008
37	.037	.009
36	.047	.011
35	.058	.015
34	.065	.018
33	.073	.027
32.5	.078	.030

This concludes the stargauge records on this liner at the Proving Ground.

3" A.A. Gun, M1 - No. 3 (Liner Forging 8301-2)

The record of firings insofar as the Proving Ground tests are concerned are contained in the following:

Rounds	Firing Record No.	Date
1 - 10	3754	Aug. 23-1928
11 - 183	3743	Sept. 5-14-1928
184 - 741	3774	Sept.17-Oct. 15-1928
742 -1078	3796	Oct. 16-31-1928
1079 -1090	3994	May 21-22-1929
1091 -1132	3998	May 23-1929
1133 -1142	4047	June 18-25-1929
1143 -1145	4957	July 2, 1929
1146 -1161	4122	Aug. 1-5-1929
1162 -1173	4146	Aug. 9-1929
1174 -1190	4147	Aug. 15-16-1929
1191 -1202	4158	Sept. 3-1929
1203 -1212	4159	Sept. 3-1929

The liner has been in the possession of the 62nd Coast Artillery subsequent to the rounds shown and no record of its condition is available after these firings.

Prior to firing, inspection of the liner bore indicated an apparent absence of chromium plating near the breech midway of the bore, and also near the muzzle.

During the first firing test, a patch of chromium plating was removed from the bore by Round No. 8.

The liner was stargauged periodically with the following results:

Stargauge Records

After 10 Rounds.

No change in bore or chamber except .001" increase in land diameter 32.2" from breech end. The chromium plating was peeling off noticeably in spots throughout the bore. Midway of the bore at 9 to 12 o'clock, it had peeled for a distance of 18".

After 729 Rounds.

Distance from breech	Land Change	Grooves Change
40"	-.003"	-.003"
39	-.001	-.003
38	.000	-.002
37	.001	-.001
36	.005	.002
35	.010	.004
34	.015	.008
33	.022	.012
32.5	.027	.016

The chromium plating was no longer visible in the bore, but may have been obscured somewhat by the non-ferrous metal deposit from the rotating bands.

After 1078 Rounds.

Distance from breech	Land Change	Grooves Change
44	-.001"	-.003"
42	.001	-.003
40	.005	-.002
39	.008	-.001
38	.010	.000
37	.014	.001
36	.019	.002
35	.026	.005
34	.034	.010
33	.043	.016
32.5	.052	.023

The plating had apparently disappeared.

After 1322 Rounds.

(NOTE: This number of rounds furnished by 62nd C.A.C.)

Distance from breech	Land Change	Grooves Change
60	.000"	-.003"
55	.000	-.002
50	.002	-.001
48	.003	.000
46	.005	.001
44	.008	.003
42	.011	.004
40	.014	.006
39	.018	.007
38	.023	.008
37	.028	.010
36	.035	.012
35	.043	.015
34	.052	.018
33	.061	.026
32.5	.073	.031

The chromium plating appeared to be intact throughout the last third of the bore at the muzzle only.

Comparison of Erosion Behavior of Liners No. 2 (8301-1) and No. 3 (8301-2) with Unplated Liner

Round No.	Liner No.1 Unplated Erosion at origin of rifling. Inches	Liner No.1 Unplated Extent of erosion forward of origin. Inches	Liner No.2 Plated Erosion at origin of rifling. Inches	Liner No.2 Plated Extent of erosion forward of origin. Inches	Liner No.3 Plated Erosion at origin of rifling. Inches	Liner No.3 Plated Extent of erosion forward of origin. Inches
9	.000	.000				
10					.001	.000
11	.000		.0005	.000		
576	.025	11 1/2"				
586			.020	6 1/2		
729					.027	4 1/2
802	.035	13 1/2				
888			.039	9 1/2		
1078					.052	9 1/2

In evaluating these data it is noted that the chromium plating on Liner No. 3 was not satisfactory when received as noted on the original stargauge record. The plating had raised, appearing like small rust spots throughout the bore.

It appears from this comparison that chromium plating offered little advantage in decreasing erosion at the origin of rifling, but it indicates that the extent of the erosion through the bore was materially reduced when the liner was chromium plated.

Extract from Report of A.A. Exercises at Aberdeen Proving Ground and Ft. Humphries, Va. - Sept. to Nov. 1928

Page 75 - Par. 146.

" * * * Two of the removable liners were chromium plated on the interior of the bore and exterior surface. It was found that the chromium plating in the bore flakes off very rapidly and after several weeks of firing had entirely disappeared. The chromium plating for the inside of the gun apparently has no beneficial effect. The chromium plating on the outside of the liner gives the liner a smooth finish and prevents rusting. The other two liners not chromium plated functioned equally well and it is doubted whether the chromium plating on the outside of the gun is necessary".

Page 139 - Par. 218.

"Chromium plated liners: That further study be instituted with a view to improving the performance of chromium plating and that chromium plated liners be then retested".

Resume

This report was rendered after the 1928 tests and was prepared by officers who had carefully observed the behavior of the chromium plated liners. It is apparent that the board did not consider the noticeable increased resistance to erosion due to chromium plating shown by the stargauge records in drawing up their conclusions.

1929

In O.C.M. Item No. 7510, March 14, 1929, the manufacturing service, Office, Chief of Ordnance, requested authority to chromium plate one (1) 3" A.A. gun liner, M3, bore to a

depth of .001", which was approved by the Ordnance Committee.

The Removable Liner, M3, No. 1 (Forging No. 12962-6-55) was chromium plated in accordance with O.C.M. Item 7510. This liner was assembled to 3" A.A. Gun, M3 No. 1. It was procured and cold worked at the Watertown Arsenal, finish machined at the Watervliet Arsenal and probably chromium plated at the Frankford Arsenal.

This liner was tested at the Proving Ground during the Antiaircraft Exercises, 1929.

The firing records of this liner are contained in Proving Ground reports as follows:

Rounds	Firing Record No.	Dates
1 - 9	4170	Sept. 9-11, 1929
10 - 556	Fired by 62nd C.A.	Oct. 9-29, 1929

The firing records do not show any changes in the chromium plating during these firings.

Stargauge measurements were made at the Proving Ground as follows:

Star Gauge Records

After 6 Rounds.

No changes occurred in diameters across lands, grooves or in chamber. There was no evidence of the chromium plating having been affected by these rounds.

After 556 Rounds.

Inches from Breech	Lands diameter change	Grooves diameter change
40	-.002"	-.002
38	-.001	-.002
37	-.001	-.001
36	-.001	-.001
35	-.001	-.001
34	.003	.000
33	.024	.003
32.5	.033	.008

There was no evidence of the chrome plating leaving the bore.

Comparative Erosion Measurements between Liner No. 1 (Plated) and Liners 3 and 4 (Not Plated)

Distance from Breech Inches	Liner No.1 (12862-6-55) after 353 rds. Plated	Liner No.3 (12863-4-56) after 305 rds. Unplated	Liner No.4 (12868-6-58) after 260 rds. Unplated
50	-.002	-.002	-.002
48	-.002	-.001	-.001
46	-.002	.001	.000
44	-.003	.002	.000
42	-.003	.003	.001
40	-.002	.005	.001
38	-.002	.008	.003
37	-.002	.009	.004
36	-.001	.011	.005
35	-.001	.012	.006
34	+.001	.013	.007
33	.016	.015	.008
32.5	.025	.016	.009

Distance from Breech Inches	Liner No.1 after 556 rds. Plated	Liner No.3 after 775 rds. Unplated	Liner No.4 after 771 rds. Unplated
50	-.002	-.002	-.003
48	-.002	-.001	-.002
46	-.002	.002	.000
44	-.002	.004	.003
42	-.002	.010	.007
40	-.002	.015	.012
38	-.001	.021	.019
37	-.001	.025	.023
36	-.001	.029	.027
35	-.001	.034	.030
34	.003	.037	.032
33	.024	.039	.034
32.5	.033	.040	.037

These comparative measurements show that chromium plating has not reduced the erosion at the origin of rifling, but has materially increased the resistance of the bore of the liner to spread of erosion forward of the origin. In the plated liner the erosion extends forward 1 1/2 inches, whereas in

unplated liners with less rounds, it has extended 13 1/2 and 9 1/2 inches respectively.

After 556 rounds the extent of erosion in the plated liner is 1 1/2 inches, whereas after 775 and 771 rounds in unplated liners it is 13 1/2 and 11 1/2 inches respectively.

The Report of the Antiaircraft Exercises, 1929 - Aberdeen Proving Ground reports as follows:

Page 8 - " d - chromium plating -

The bore surface of one of the liners (No. 1) has been chromium plated. * * * * * *

There was no evidence of the chromium plating disappearing from the liner, as was noted in the chromium plated liner furnished for test last year. Due to the rapidity of firing and other causes, it was not possible to stargauge the liner as often as every 100 rounds. Continuing records were made and based on an equal number of rounds from each liner, the following facts were disclosed:

(1) For the first inch from the origin of rifling the erosion of the two types of liners is the same.

(2) From 1 to 1 1/2 inches from the origin of rifling the plated liner shows a gradual decrease in the amount of erosion, as compared to the unplated liner. Beyond 1 1/2 inches the plated liner shows practically no erosion whatever, whereas the erosion of the unplated liners extends to from 12 to 16" from the origin of rifling.

(3) There was slightly less copper deposit on the plated than on the unplated liners."

Page 74. " 38-e - chromium plated liners -

That the investigation of chromium plated liners be continued."

1930

The manufacturing service in a memorandum contained in O.C.M. Item 8108, February 20, 1930, recommended that 4 liners be chromium plated for test during the Antiaircraft

Exercises in 1930. The recommended thicknesses of plating were:

1 liner	-	.0015" thick
2 liners	-	.0020" "
1 liner	-	.0030" "

These recommendations were approved.

The following liners were chromium plated by the Worthington Pump Company, Buffalo, New York, and firing records at the Aberdeen Proving Ground for the same are:

3" A.A. Gun, M3 - No. 7 with Removable Liner

Liner chromium plated in bore .0015" thick.

Rounds	Firing Record No.	Date
1 - 7	4619	Aug. 9, 1930
8 - 167	4652	Aug. 19-26, 1930
168 - 908	4794	Aug. 27 - Nov. 7, 1930

3" A.A. Gun, M3 - No. 8 with Removable Liner

Liner chromium plated in bore .0020" thick.

Rounds	Firing Record No.	Date
1 - 7	4619	Aug. 9, 1930
8 - 53	4653	Aug. 9-26, 1930
54 - 977	4795	Aug. 27 - Nov. 7, 1930

3" A.A. Gun, M3 - No. 9 with Removable Liner

Liner chromium plated in bore .0020" thick.

Rounds	Firing Record No.	Date
1 - 7	4615	Aug. 8, 1930
8 -177	4654	Aug. 19-26, 1930
178 -734	4796	Aug. 27-Nov. 7, 1930

3" A.A. Gun, M3 - No. 10 with Removable Liner

Liner chromium plated in bore .0030" thick.

Round No.	Firing Record No.	Date
1 - 7	4620	Aug. 9, 1930
8 -126	4655	Aug. 19-26, 1930
127 -1033	4797	Aug. 27-Nov. 5, 1930

Stargauge records were taken periodically and are extracted as follows:

3" A.A. Gun, M3 - No. 7 .0015" thick plating

Star Gauge Records

After 7 rounds

No change in diameter in bore or chamber. No evidence of chromium plating leaving the bore.

After 176 rounds

No change in bore or chamber diameters. Slight coppering evident. No evidence of chromium plating leaving the bore.

After 409 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
34	.000	.000
33	.004	.001
32.5	.014	.006

No evidence of chromium plating leaving the bore.

After 674 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
37"	.000	-.001
36	.005	-.001
35	.009	.000
34	.010	.004
33	.019	.008
32.5	.033	.011

No evidence of the chrome plating leaving the bore except near the origin where the erosion has removed it.

After 801 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
39"	-.001	-.002
38	.000	-.002
37	.002	-.002
36	.007	-.001
35	.013	.002
34	.018	.006
33	.027	.010
32.5	.036	.013

No further evidence of removal of chromium plating.

After 905 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
39"	-.001	-.003
38	.001	-.002
37	.005	-.001
36	.009	.000
35	.015	.002
34	.020	.006
33	.031	.011
32.5	.041	.014

Three lands on the right hand side showed very slight flaking of chromium plating between 6 and 12 inches from muzzle.

3" A.A. Gun, M3 - No. 8 .002" thick

Stargauge Records

After 7 rounds

No change in bore or chamber diameters. No evidence of plating leaving the bore.

After 169 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
33	.000	.000
32.5	.004	.000

The chromium plating began to flake from the origin of rifling for a distance of 5 1/2 inches. Small spots on top of lands between 6 and 10 o'clock from midway of bore to within 12 inches of the muzzle flaked off.

After 425 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
38"	.000	-.002
37	.001	-.002
36	.003	-.001
35	.008	.000
34	.011	.000
33	.015	.001
32.5	.022	.003

The chromium plating flaked off the lands midway of the bore. Apparently the plating is entirely removed for a distance of 5 inches forward from the origin of rifling.

After 702 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
40	.000	-.002
39	.002	-.002
38	.004	-.002
37	.009	-.002
36	.012	-.002
35	.017	-.001
34	.022	.000
33	.027	.004
32.5	.036	.008

The flaking of the chromium plating extended to within 3" of the muzzle face and over more than half the lands.

There was no flaking in the grooves. The flaking at the origin extends forward 1/4" completely around the bore.

After 977 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
44	-.002	-.004
42	.001	-.004
40	.006	-.004
39	.010	-.003
38	.013	-.002
37	.019	-.001
36	.025	.000
35	.030	.002
34	.037	.004
33	.042	.010
32.5	.049	.012

No increase in flaking of chromium plating since last star-gauging.

3" A.A. Gun, M3 - No. 9 .0020" thick

Star Gauge Records

After 7 rounds

No change in bore or chamber diameters. The chromium plating showed slight evidence of leaving the bore approximately 44 1/2" from the breech face; also midway of the bore at 5 o'clock.

After 171 rounds

No change in bore or chamber diameters. The evidence of plating leaving the bore at a position 44 1/2" from the breech face did not develop further. The flaking midway of the bore increased, affecting seven lands at 5 o'clock, for a distance of 3 inches.

After 432 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
37	-.001	-.001
36	.001	-.001
35	.002	-.001
34	.003	.000
33	.007	.001
32.5	.017	.003

The chromium plating started flaking off the lands at about 35 inches from breech face.

After 615 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
37	-.001	-.002
36	.001	-.002
35	.004	-.001
34	.005	.000
33	.017	.006
32.5	.027	.010

Chromium plating showed flaking midway of the bore and for a space 6" from the forcing cone.

After 734 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
38	.000	-.003
37	.003	-.004
36	.004	-.003
35	.006	-.001
34	.009	.001
33	.021	.010
32.5	.032	.012

3" A.A. Gun, M3 - No. 10 .003" thick

Stargauge Records

After 7 rounds

No change in bore or chamber diameters. The chromium plating loosened up 48" from the breech face. It was greatest

on the lands and extended around the bore. Photograph A.P.G. 26990, shows an impression of this condition and it appears that the plating was not bonded to the base metal.

After 176 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
55	.000	.000
50	.001	.000
48.5	.001	.000
48	.004	.000
47.5	.001	.000
46	.000	.000
44	.000	.000
42	.001	.000
40	.001	.000
39	.001	.000
38	.000	.000
37	.000	.000
36	.000	.000
35	.000	.000
34	.000	.000

The flaking at a position 48" from the breech face did not increase. Flaking started at the muzzle on lands and grooves between one and 7 o'clock, and extended rearward for one inch.

After 405 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
55	.000	.000
50	.001	.000
48.5	.001	.000
48	.004	.000
47.5	.001	.000
46	.000	.000
44	.000	-.001
42	.001	-.001
40	.001	.000
39	.001	.000
38	.000	.000
37	.000	.000
36	.000	.000
35	.000	.000
34	.000	.000
33	.003	.004

The flaking of the chromium plating extended both around the bore and rearward from the muzzle.

After 626 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
55	.000	-.001
50	.001	-.001
48	.004	.000
46	.000	.000
44	.000	.000
42	.001	.000
40	.001	.000
39	.001	.000
38	.000	.000
37	.000	.000
36	.000	.000
35	.004	.000
34	.016	.002
33	.023	.017
32.5	.032	.011

Flaking at the muzzle increased slightly in depth.

After 745 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
55	-.003	.000
50	-.002	.000
48	.004	-.001
46	.000	-.001
44	-.001	-.001
42	.000	-.001
40	.000	-.001
39	-.001	-.001
38	-.002	-.001
37	-.002	-.001
36	-.001	.001
35	.003	.003
34	.022	.004
33	.033	.011
32.5	.042	.014

Slight increase in flaking was noted.

After 922 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
55	-.002	-.002
50	.001	-.002
48	.004	-.002
46	.000	-.002
44	-.001	-.002
42	.000	-.002
40	.000	-.002
39	.000	-.002
38	.000	-.001
37	.002	.001
36	.009	.004
35	.020	.006
34	.031	.008
33	.042	.017
32.5	.051	.019

No change in chromium plating was noted.

After 1033 rounds

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
55	-.001	-.001
50	.001	-.001
48	.004	-.001
46	.000	-.002
44	.000	-.002
42	.001	-.002
40	.001	-.001
39	.000	-.001
38	-.001	-.001
37	.002	.001
36	.010	.004
35	.022	.007
34	.033	.009
33	.045	.018
32.5	.054	.020

No change noted in chromium plating.

Comparison of 3" A.A. Guns, M3

Nos. 1, 7, 8, 9 and 10 Plated with Nos. 2, 3, and 4 Unplated

Rounds	PLATED						UNPLATED									
	No.2		No.3		No.4		No.1		No.7		No.8		No.9		No.10	
							Thickness .001"		Thickness .0015		Thickness .002		Thickness .002		Thickness .003	
	Erosion	Extent	Erosion	Extent	Erosion	Extent	Erosion	Extent	Erosion	Extent	Erosion	Extent	Erosion	Extent	Erosion	Extent
260					.009	11-1/2										
305			.016	15-1/2												
353							.025	2-1/2								
405															.018	1-1/2
409									.014	1-1/2						
425											.022	5-1/2				
432													.017	4-1/2		
556							.033	2-1/2								
615													.017	4-1/2		
626													.027	4-1/2		
674									.033	4-1/2						
703											.036	7-1/2				
734													.032	5-1/2		
739	.041	11-1/2														
748															.042	3-1/2
771					.037	11-1/2										
775			.040	15-1/2												
901									.036	5-1/2						
908									.041	6-1/2						
977											.049	7-1/2				
982													.051	5-1/2		
1033															.054	5-1/2

In each of these liners, flaking of the chromium plating started early. This flaking was not of the same degree in each, but there is no means of evaluating this failure.

Assuming that the liners were equally resistant to erosion insofar as chromium plating was concerned, an analysis of the comparative data shows:

(a) That chromium plating tends to reduce the erosion at the origin.

(b) That the erosion progresses faster and farther in non-plated liners.

(c) That the trend of erosion is to increase in amount and in area in direct proportion to the thickness of the plate. That is, a thin plating of chromium is better than a heavier one.

Extract from Report of Antiaircraft Exercises 1930

The report of the Antiaircraft Exercises held at the Aberdeen Proving Ground during 1930 comments as follows, regarding the chromium plated liners:

Page 6 - "3-d - chromium plating.

Comparison of the stargauge records of the guns used during the exercises last year and this year tends to show that the chromium plating of this gun is practical and that the chromium plated liner is superior to other types. From experience in the past two years it appears that plating to a thickness from .001" to .0015" is the most satisfactory. This opinion, however, is based on experience with one gun in each case. Further comparative test should be made with two groups of three or more guns plated to a thickness of .001" and .0015" and stargaugings made at regular intervals throughout the life of these guns.

One of the liners furnished this year was chromium plated on the exterior to a depth of .0005" while three others were untreated on the outside. When the liners were removed at the end of the exercises all liner exteriors and tube interiors were in excellent condition except the one which was chromium plated on the exterior. This liner had large burns and scores near the forward shoulder, and another burn and score on the underside about 2 feet from the muzzle. Corresponding scores were noted in the tube. It is concluded that chromium plating the exterior of the liners is unnecessary and undesirable."

That chromium plating be continued for these guns and that further experiments be carried out with .001" and .0015" plating.

1930 - 1935

Nothing was done in regard to chromium plating cannon during the period 1930-1935.

O.C.M. Item 12462, dated October 31, 1935, reviewed the previous experience with chromium plated liners, and carried approval to have one 3" A.A. liner, M3, chromium plated at the Naval Gun Factory, Washington Navy Yard, and then shipped to the Proving Ground for test. This was done and 3" A.A. gun liner, M3 - No. 138, was centrifugally cast and cold-worked at the Watertown Arsenal, finish machined at the Watervliet Arsenal to standard dimensions, except for bore and muzzle end. These latter dimensions were made as prescribed by the Navy Department. The Naval Gun Factory chromium plated the liner in accordance with their standard plating procedure to an approximate thickness of .0005".

The liner was received at the Proving Ground and tests were started in December, 1935. The test of the liner was made in conjunction with the test of pressure gauges.

Inspection of the bore of the liner prior to firing indicated that a copper colored area showed through the chromium from 5 to 7 o'clock from the origin of rifling to a point 1.58 feet from the muzzle. The description of the Naval Gun Factory process makes no mention of copper plating in conjunction with chromium plating.

Stargauge records were made at the conclusion of 7 rounds, then after each 5 rounds thereafter until 57 rounds had been fired. There was no change in bore or chamber dimensions, no evidence of erosion, and no evidence of peeling of the chromium plate.

(See First Partial Report on Test of 3" A.A. Gun Liner, M3 - No. 138, Chromium Plate, A.P.G., February 12, 1936).

The Second Partial Report on the above subject, dated August 27, 1936, contains complete data on the following:

After 112 rounds there was no evidence of erosion in the bore. Coppering was present as was to be expected.

After 182 rounds, no erosion occurred, although coppering increased.

After 247 rounds, erosion of .002" occurred on the lands at the origin of rifling and extended forward for .5 inch. The plating remained intact and coppering deposit increased.

After 333 rounds, the stargauge record shows:

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
26	-.001	-.002
25	.005	-.001
24.5	.015	.000

The chromium plating remained intact.

After 401 rounds -

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
26	-.001	-.001
25	+.014	.001
24.5	.023	.002

No evidence of chromium plating leaving the bore except that removed by erosion at origin.

After 495 rounds -

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
27	-.001	-.002
26	.006	.000
25	.022	.004
24.5	.032	.007

After 640 rounds -

Distance from Breech	Lands Change in Diameter	Grooves Change in Diameter
30	-.001	-.002
29	.001	-.002
28	.006	-.002
27	.012	-.001
26	.028	.002
25	.048	.014
24.5	.060	.019

The chromium plating is intact except for that removed by the erosion at the origin of rifling.

Comparing the erosion and extent of erosion in liner 138 with that observed in liners Nos. 1, 7, 8, 9 and 10, it was noted that the erosion is of greater magnitude in liner 138, but of no greater extent in area.

In these tests on liner 138 periodic firings with standard rounds were made in which velocities and pressures were taken. The results with the 12.7 lb. projectile are extracted as follows:

Round No.	M. V.	Pressure
136	2831	34100
184	2824	34200
294	2828	35200
642	2754	31800
662	2747	31200
677	2743	31600

In view of the increased erosion noted on the star-gauge records and the loss in M.V. and pressure, it was decided that the cost of chromium plating liners was not warranted inasmuch as increased accuracy life was not obtained.

O.C.M. Item 12705, March 12, 1936, approved the chromium plating of 8 additional liners for service test. In view of the results obtained in testing liner No. 138, this project was abandoned by O.C.M. Item 13208. This latter directive states:

"3-c - Recommendations.

That the development of chromium plating technique be closely followed by the Ordnance Department, with a view to its possible consideration for gun bore treatment when the progress of the art appears to warrant such consideration."

Chromium plated liners 1, 7, 8, 9 and 10 are in the hands of troops. Liner No. 133 is at the Proving Ground where it is used as a proof facility. It is being observed and reports on its behavior will be made when necessary.

V - Resume and Conclusions

a - Technique of chromium plating.

The Ordnance Department has not entered into an original field of development in its work with chromium plating. The private industries have covered the field of development. The Bureau of Standards has investigated these activities and reported upon them. The Navy Department has applied the process successfully to gun barrels.

From the tests it is noticeable that thin layers of properly applied plating are superior to heavy or thick layers. The application of a thin layer, such as is practiced by the Naval Gun Factory, may account for their success with chromium plating.

b - Application to small arms.

The results obtained were satisfactory.

The cost of plating is excessive when compared to the cost of replacement barrels and the value of added accuracy life.

c - Application to 37 mm Gun Barrels.

The limited tests with this caliber barrel are not conclusive.

It is probable that the application of the improved technique to barrels of this caliber, would prove successful.

The decision as to further investigation of plating gun barrels of this caliber depends upon costs of plating and value returned in accuracy life.

d - Application to 3" A.A. Gun Liners.

The early tests were made on liners experimentally plated using faulty technique.

The superiority of thin plating over thick plating was demonstrated in the tests of sample liners, one each of which was plated with various thicknesses of plate.

The first test in which loss in muzzle velocity was recorded occurred in the tests on the liner chromium plated at the Naval Gun Factory. While the loss in muzzle velocity is not serious, this fact together with the erosion of the bore indicates that chromium plating is not economically desirable for these guns.

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