UNCLASSIFIED

Record of Army Ordnance Research and Development

VOLUME 2

SMALL ARMS AND SMALL ARMS AMMUNITION

BOOK 2

Small Arms Ammunition

Regraded to Uncl, by authority of OTCM 37706 2/15/61
by Am 9/18/64

OFFICE OF THE CHIEF OF ORDNANCE, WASHINGTON, D.C.

TX 10, 37

~~CONFIDENTIAL~~

UNCLASSIFIED

CHAPTER 15 — STEEL CARTRIDGE CASES

Before and during World War II, extended development of steel cartridge cases was carried out by the major world powers because of an insufficient quantity of copper to meet anticipated military needs. Extended use of steel cartridge cases was made by the Germans and Russians. The use of the steel case by these countries was a result of military necessity.

So far as the United States was concerned, the caliber .45 steel cartridge case was the only item approved for unrestricted military use. In contrast to foreign steel cartridge cases, which caused frequent gun malfunctions and stoppages, the caliber .45 steel case gave generally satisfactory performance.

In August 1942 an anticipated copper shortage made it appear that it might be necessary to initiate production of steel cartridge cases at an early date. Agreement was reached between the Research and Development Service and the Industrial Service whereby the over-all responsibility for the program was vested in the latter. The former performed the following functions:

a. Placing and supervising such research and development contracts as the Industrial Service believed desirable.

b. Arranging and directing the conduct of Aberdeen Proving Ground tests of steel cartridge cases to evaluate military characteristics.

c. Arranging with the using services for Service Board tests.

As a result of Service Board tests, the carbine and caliber .50 steel cartridge cases were approved for use by the Army Ground Forces in the event that brass cases were not available.

Protective finishes for steel cartridge cases were extensively investigated. The most satisfactory coating, phenol-formaldehyde resin lacquer, was unsatisfactory from the point of view of application to mass production methods for small-arms ammunition. The finish adopted was commercially known as Zinc-Cronak, and consisted of zinc plating followed by dipping in chromic acid solution.

The scope of the steel cartridge case program may be realized by a capitulation of the quantities of ammunition produced. During the peak production months in 1943—1944 an average of 300,000,000 caliber .45 steel-cased cartridges were produced per month by the Evansville Ordnance Plant. By November 1943 more than 75,000,000 caliber .30 steel cartridge cases had been manufactured by the Denver Ordnance Plant alone. By November 1943 more than 70,000,000 caliber .50 steel cartridge cases had been made by the Lowell Ordnance Plant. Frankford Arsenal production figures for the period October 1942 to June 1944 are given below:

Caliber .30: 17,200,000 rounds
Caliber .45: 57,100,000 rounds
Caliber .50: 9,000,000 rounds

During the 2 years from August 1942 to August 1944 the United States accomplished more in steel cartridge case development than did the Germans during the period from World War I through World War II. The success of the U. S. steel cartridge case program is due in no small measure to the cooperation extended to the Ordnance Department by industry. While the caliber .45 was the only case released without restriction, service tests of the caliber .30 carbine and caliber .50 ball cartridge cases demonstrated excellent quality in all respects except under extreme weathering conditions. It was only an abrupt reduction in ammunition requirements which prevented the manufacture and issue of carbine and cal. .50 steel cartridge cases for combat use.

CALIBER .22 LONG RIFLE CARTRIDGE.

Caliber .22 long rifle cartridges are used by the armed forces principally for training purposes. There are no government-owned establishments manufacturing this ammunition and purchase is made from the following commercial organizations: Western Cartridge Company, Remington Arms Company, Federal Cartridge Corporation, and Winchester Repeating Arms Company.

When it appeared in 1942 that a shortage of copper was imminent, all manufacturers of caliber .22 long rifle cartridges were requested to convert to steel cases at the earliest possible date. Because of equipment, neither the Federal Cartridge Corporation nor the Winchester Repeating Arms Company was in a position to supply ammunition assembled with steel cases.

By April 1943 the Western Cartridge Company had produced a total of 1,012,000 rounds. In acceptance tests, 29 misfires, caused by light blows occurred in 1,800 rounds fired. By the same date the Remington Arms Company had manufactured 8,000,000 rounds. In acceptance tests a total of 27,600 rounds of the Remington production were fired with the following casualties:

757 split cases
19 misfires
8 failures to extract
1 failure to feed
1 split body

As a protective finish the Western Cartridge Company used parkerizing followed by a coating of oil; Remington used zinc plating.

Since caliber .22 ammunition was to be used almost entirely for training purposes under controlled conditions, the Ordnance Committee on 24 June 1943[1] recommended limited procurement of ammunition assembled with steel cartridge cases. However, because of manufacturing difficulties as well as the limited amount of copper which would be saved, the commercial organizations made no extensive production of the caliber .22 cartridge assembled with steel cases during World War II.

CALIBER .30 CARBINE AMMUNITION.

The Evansville Ordnance Plant found that the process developed for the caliber .45 steel cartridge case could be readily adapted to the production of caliber .30 carbine ammunition.

In September 1943 a pilot production lot of caliber .30 steel-cased carbine ammunition (Lot ES-25607 X) was submitted to Aberdeen Proving Center for extended tests. The test program included normal functioning under conditions of dust, weathering, low temperature, combined weathering and dust, salt water, distilled water corrosion, and flash tests. A total of 24,000 rounds each of brass and steel was fired. The steel-cased ammunition gave 1.7 percent malfunctions and .096 percent case casualties. The brass-cased cartridges used as a control gave 1.4 percent malfunctions and .029 percent case casualties. In the flash test the number of sparklers emerging from the muzzle when steel-cased cartridges were fired was 50 percent greater than that noted with brass.[2]

So far as the Ordnance Department tests could ascertain, the caliber .30 steel-cased carbine ammunition compared favorably with brass-cased ammunition. On 25 November 1943 the Ordnance Committee[3] recommended that samples be furnished service boards to determine the behavior of the ammunition under service conditions in order that complete information might be available in the event copper became critical.

By 22 March 1944[4] results of tests by the Cavalry Board and Infantry Board had been furnished the Ordnance Department. The Cavalry Board concluded that steel-cased ammunition compared favorably with brass-cased ammunition and recommended that it be considered suitable as a Substitute Standard for service use.

The Infantry Board concluded that:

a. The functioning of the steel-cased ammunition compared favorably to that of the standard brass-cased ammunition.

b. The muzzle flash of the subject ammunition, although objectionable, should not constitute cause for rejection if it cannot be remedied without undue complications.

c. Due to inherently lower corrosion resistance of steel as compared with brass which constitutes a latent weakness in the subject ammunition, specific instructions should be issued covering storage care and handling after removal from packing container.

d. Ammunition assembled with brass cases is preferable to the subject ammunition.

As the result of the Cavalry and Infantry Board tests, the Commanding General, Army Ground Forces, recommended that "Although the subject ammunition was found to be generally satisfactory, it is recommended that brass cartridge cases be used for carbine ammunition as long as brass is obtainable."[5]

After extended tests of 500,000 rounds of steel-cased carbine ammunition at Marine Corps training stations, that organization concluded that the steel-cased carbine cartridge was a suitable Substitute Standard for the brass-cased carbine cartridge. On 11 October 1945 the issue of steel-cased carbine ammunition for training purposes was approved by the Ordnance Committee.[6]

CALIBER .30 CARTRIDGE.

Because of the wide variety of weapons in which caliber .30 ammunition is fired, as well as the physical dimensions of the cartridge case, the substitution of steel presented more difficulty with this cartridge than any other. The project was conducted principally at Frankford Arsenal and the Denver Ordnance Plant, although limited quantities of steel-cased caliber .30 ammunition were manufactured at the Lake City, Utah, and Twin Cities Ordnance Plants.

Principal production effort was concentrated upon WD-1020 steel spheroidized annealed, fully killed with aluminum (silicon maximum .05%). In order to use available machinery, development was concentrated upon a process which would avoid anneals between drawing, trimming, or heading operations.

The Frankford Arsenal process, adopted at that station 17 November 1942, provided the basis of operations for other ordnance plants. The sequence of operations in the Frankford Arsenal process is given below:[7]

1. First draw. Vertical duplex crank press.
2. Wash and dry to remove drawing compound.
3. Cuprodine and rinse to apply copper flash coating.
4. Wash and dry to prevent rusting.
5. Second draw. Vertical single crank press.
   (If too many splits are obtained in second draw, bake the unprocessed first draw pieces at 475° F for 40 min., wash clean and continue with operation 3).
6. Wash and dry to remove drawing compound.
7. Cuprodine and rinse to apply copper coating.
8. Wash and dry to prevent rusting.
9. Pocket bump (regular bumping machine)—horizontal toggle and crank machine.
10. Wash and dry to remove oil.
11. Cuprodine and rinse to apply copper coating.
12. Wash and dry to prevent rusting.
13. Third draw. Vertical single crank press.
14. Wash and dry to remove drawing compound.
15. First trim. Regular trimming machine.
16. Wash and dry to remove oil.
17. Cuprodine and rinse to apply copper coating.
18. Wash and dry to prevent rusting.
19. Fourth draw. Vertical single crank press.
20. Wash and dry to remove drawing compound.
21. Second trim. Regular trimming machine.
22. Wash and dry to prevent rusting.
23. Cuprodine and rinse to apply copper coating.
24. Wash and dry to prevent rusting.
25. Head. Horizontal toggle and crank machine, regular tools.
26. Wash and dry to remove oil and prevent rust.
27. Head turn. Regular head turning machine, using a little lard oil on the tool and an air blast for cooling the tool and the work.
28. Vent. Horizontal toggle and crank machine (pocketing machine converted to venting machine).
29. Wash and dry to remove oil.
30. Body anneal. Twin screw, gas-flame, annealing machine, operating at 96 cases per minute, using 13 large burners (.50 cal. burners). Iris to be 1⅛—1¼ inch from head of case.
31. Pickle. Continuous scoop type pickle unit—5 to 10 percent sulphuric acid and rinse. (Rinse and wash in rumbling barrel, if necessary.)

32. Cuprodine and rinse to apply copper coating.
33. Wash and dry to prevent rusting.
34. Taper. Regular tapering machine.
35. Wash and dry to remove oil.
36. Inspect to remove defective pieces to save tool on end trim machine.
37. Finish and trim. Regular machine.
38. Inspect.
39. Pack for shipping to plating department.
40. Zinc plate .0001-inch to .0002-inch thickness.
41. Bake at 250° F for 1 hour (to eliminate hydrogen).
42. Cronak treat and dry.
43. Inspect.
44. Prime.
45. Load.
46. Gage and weigh.
47. Proof test firing.
48. Pack.

Split bodies, split necks, failures to extract, ruptures, and ruptured heads were common in the acceptance tests and frequently reached a total as great as 10 percent. However, toward the end of the caliber .30 program the total casualties seldom exceeded .5 percent.

The Frankford Arsenal Ordnance Laboratory concentrated its efforts upon the development of a method of manufacture of caliber .30 heat-treated steel cartridge cases. The most satisfactory results were obtained with WD-1030 steel. The method of manufacture is given below:[8]

Operation	Description
1. Blank and cup	Double acting crank press operating at 72 r.p.m. The die was continually flooded with a 1 to 1 mixture of Gilron No. 155 and water. No plating or film of any type was used on the strip stock before cupping.
2. Wash and dry	Continuous screw conveyor type washing and drying machine. Pieces were washed in a solution of 25 lb. of Apex Pic-kleen in 225 gal. of water at 180° F, rinsed in water at 180° F, and dried in a hot air blast.
3. Anneal	The cups were annealed at 1,250° F for 2 hr. in a recirculating air type electric furnace. Furnace cooled to 1,000° F and then air-cooled to room temperature.
4. Pickle	The cups were pickled in a rotary tumbling barrel to remove the scale. The pickling solution was 10% by vol. sulphuric acid heated to approximately 180° F. The cups were tumbled long enough to remove all the scale (Approx. 10 min.).
5. Wash and dry	Same as 2
6. Cuprodine plate	The cups were immersed in a cuprodine solution (3 to 4 oz. of cuprodine powder per gal. of 2% by vol. sulphuric acid) for approximately 30 sec. Excess cuprodine solution was drained off.
7. Wash and dry	Same as 2
8. First draw	Crank press operating at 110 r.p.m. The dies and draw pieces were flooded with Gilron No. 155 lubricant diluted with an equal volume of water.
9. Wash and dry	Same as 2
10. Anneal	Same as 3
11. Pickle	Same as 4
12. Wash and dry	Same as 2
13. Cuprodine plate	Same as 6
14. Wash and dry	Same as 2
15. Second draw	Crank press operating at 95 r.p.m. The dies and draw pieces were flooded with Gilron No. 155 lubricant diluted with an equal volume of water.
16. Wash and dry	Same as 2
17. Bump	Horizontal toggle and crank press operating at 110 r.p.m. Prime No. 1 lard oil was used as a lubricant and was applied to the pieces as they tumbled in the hopper of the machine.
18. Wash and dry	Same as 2
19. Cuprodine plate	Same as 6
20. Wash and dry	Same as 2
21. Third draw	Same as 15
22. Wash and dry	Same as 2
23. First trim	Rotary cutter trimming machine operating at 80 r.p.m. The tools used for this operation are standard tools used for brass cases.
24. Wash and dry	Same as 2
25. Cuprodine plate	Same as 6
26. Wash and dry	Same as 2
27. Fourth draw	Same as 15
28. Wash and dry	Same as 2
29. Second trim	Same as 23 except speed is 110 r.p.m.
30. Wash and dry	Same as 2
31. Cuprodine plate	Same as 6
32. Wash and dry	Same as 2
33. Head	Same as 17
34. Wash and dry	Same as 2
35. Cuprodine plate	Same as 6
36. Wash and dry	Same as 2

Operation	Description
37. Head turn	Horizontal spindle machine operating at 45 r.p.m. with spindle speed of 1,925 r.p.m. The cases were fed automatically into a collet which gripped the case and held it in position. The cutting tool then moved forward and machined the head of the case. After machining, the tool moved away and the case was spring ejected from the collet.
38. Heat treat	The cases were heat-treated in controlled atmosphere electric furnace. They passed through the furnace on a conveyor belt at a speed such that they were in the furnace for approximately 15 min. The furnace temperature was set for 1,550° F and it is estimated that the cases were at this temperature for approximately 5 to 7 minutes. At the rear of the furnace the cases dropped into a 6 percent brine solution. They were then tempered at 750° F for 1 hr. in an electric recirculating air furnace.
39. Body anneal	Gas flame annealing machine. The heads of the cases were submerged in water as they passed through the gas flame. The temperature at the mouth of the cases was slightly above 1,600° F (checked with an optical pyrometer) and gradually decreased until there was no discoloration of the case at a distance of 1⅛ in. to 1¼ in. from the mouth.
40. Pickle	Same as 4
41. Wash and dry	Same as 2
42. Cuprodine plate	Same as 6
43. Wash and dry	Same as 2
44. Taper and plug	Vertical double action crank press operating at 85 r.p.m. Tapering was done in two stages and the mouth of the case was sized with a chromium plated plugging stem. Prime No. 1 lard oil was used as a lubricant and was wiped on the cases by an automatic wiping mechanism.
45. Wash and dry	Same as 2
46. Final trim	Automatic trimming machine operating at 80 r.p.m. The case was trimmed with an ordinary 15/32 in. twist drill ground and mounted in a spindle turning at 1,740 r.p.m. The case was held stationary while the drill advanced on the mouth of the case, trimming it to the required length.
47. Primer vent	The cases were vented on a standard primer inserting machine with only the vent station and the vent-detect station in operation.
48. Zinc plate	The cases were zinc plated according to the following procedure: A. Strip cuprodine plate from cases in an alkaline cyanide solution in a tumbling barrel. B. Water rinse. C. Light pickle in 1 to 1 solution of hydrochloric acid, if necessary. D. Water rinse. E. Electrolytic cyanide zinc plating bath in tumbling barrel. Plated to a thickness of .0002 in. F. Water rinse. G. Centrifugal air dry. H. Bake at 400° F for 1 hr. I. Water dip. J. Cronak dip for 10 to 20 sec. K. Water rinse. L. Air dry.

The caliber .30 heat-treated steel cartridge case was superior to the cold-drawn steel case. Approximately 100,000 rounds were manufactured at the Frankford Arsenal laboratory of which 32,000 were fired at the Aberdeen Proving Ground between September 1942 and February 1943, under conditions of normal firing, dust, cold, protected and unprotected weathering, and corrosion (salt water and distilled water). The following is a summary of the case casualties recorded under these stringent firing conditions:[9]

Casualty	No.	Percentage
Body splits	3	.009%
Neck splits	34	.10 %
Shoulder splits	4	.013%
Primer leaks	1	.003%
Ruptures	2	.006%
Faulty extraction	78	.24 %

In February 1942, a Research and Development contract was placed with the General Electric Company, Cleveland, Ohio, for the development of a continuous die process for the manufacture of caliber .30 steel cartridge cases.[10] The contract covered the design and fabrication of a two-line multistage progressive die; the design of a cartridge case trimming and head turning machine; cartridge case neck annealing furnace; and cartridge case tapering and neck sizing machine. In addition, the procurement of one 250- to 350-ton automatic press with an 8-inch stroke was authorized (fig. 137).

Upon completion of this contract, the procurement from the General Electric Company of a head turning machine, a trimming machine, a tapering and neck sizing machine, a batch type furnace, as well as blanking, cupping and shaving dies, was approved. Authorization was also granted for the manufacture of 2,000,000 caliber .30 steel draw pieces (fig. 138). Prior to curtailment of the steel cartridge case program, the General Electric Company submitted 28,000 fourth draw pieces to Frankford Arsenal to be fabricated into finished cases and test fired. Results of the tests are summarized below:[11]

Lot No.	Rounds Fired	Weapon	Pressure	Case Casualties
				WD-1030 Cold-worked Steel, Unplated Cases
1	75	M2 AC MG	113%	None
3	8	Springfield 1903	113%	None
S-1514	178	M2 AC MG	113%	1 neck split, 15 partial ruptures (head)
5	76	Springfield 1903	113%	1 primer leak
S-1515	39	M2 AC MG	113%	1 partial rupture (head)
S-1516	96	M2 AC MG	113%	6 partial ruptures (head)
S-1517	67	M2 AC MG	113%	1 partial rupture (head)
				WD-1030 Cold-worked Steel, Zinc-plated Cases
S-1519	1,390	M2 AC MG	113%	7 complete ruptures (head) 115 partial ruptures (head)
				WD-1020 Cold-worked Steel, Unplated Cases
2	175	M2 AC MG	113%	3 body splits
4	11	Springfield 1903	113%	None
S-1518	179	M2 AC MG	113%	5 partial ruptures (head)
				WD-1030 Heat-treated Steel, Zinc-plated Cases
S-1026	1,606	M2 AC MG	113%	None
S-1026	104	M1 rifle	113%	None
S-1033	11,434	M2 AC MG	113%	9 neck splits
S-1033	300	BAR	113%	None
S-1033	312	M1 rifle	113%	None
S-1033	120	Springfield 1903	113%	None
S-1033	45	Springfield 1903	150%	1 failed to extract
				WD-1020 Heat-treated Steel, Zinc-plated Cases
S-1035	605	M2 AC MG	113%	47 neck splits, 36 primer leaks, 4 failures to extract
S-1035	200	M1 rifle	113%	4 neck splits, 26 failures to extract
S-1035	9	BAR	113%	9 failures to extract
S-1035	1,469	Springfield 1903	113%	77 neck splits, 11 primer leaks, 69 failures to extract
S-1035	20	Springfield 1903	150%	10 failures to extract

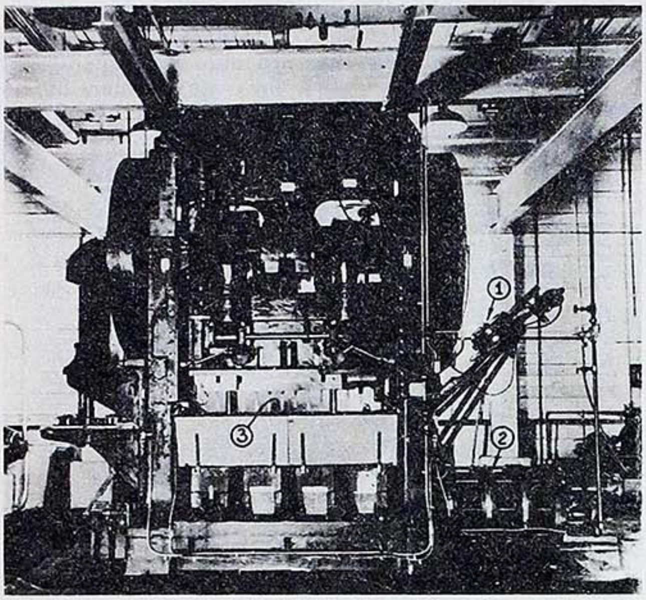


FIGURE 137—CALIBER .30 CARTRIDGE CASE PROGRESSIVE DIE PRESS

1. AUTOMATIC HOPPER
2. AIR CUSHION
3. DIE

The above results indicated that heat treatment of WD-1030 steel leads to satisfactory firing results.

A limited number of brass cases were manufactured by the progressive die method, and in firing tests compared favorably with brass cases made by the present standard process.

Before the continuous die process developed by the General Electric Company can be fully evaluated, it is essential that a large number of caliber .30 brass cases be manufactured. The progressive die equipment has been transferred to Frankford Arsenal where further operational tests are under way.

CALIBER .45 CARTRIDGE.

In August 1942 development work was initiated at Frankford Arsenal and the Evansville Ordnance Plant on caliber .45 steel cartridge cases. By October 1942 the Evansville Ordnance Plant had achieved a satisfactory process for the mass production of the caliber .45 steel cartridge cases.[12] The process employed WD-1020 steel and consisted of the following operations:

1. Blank and Cup
2. Wash—Rinse—Dry
3. Cup Anneal
4. Pickle—Rinse—Rinse—Rinse—Dry
5. Cuprodine
6. First Draw
7. Cuprodine
8. Second Draw
9. Remove Copper Wash—Rinse—Dry
10. Normalize
11. Pickle—Rinse—Rinse—Rinse—Dry
12. Cuprodine
13. Third Draw
14. Wash—Rinse—Dry
15. First Trim
16. Pocket
17. Head and Identify
18. Wash—Rinse—Dry
19. Head Turn
20. Finish Trim
21. Pierce Vent Hole
22. Zinc Plate
23. Hydrogen Embrittlement Relief
24. Dichromate Coating

In Aberdeen Proving Ground tests difficulty was encountered with feeding in the Reising, M1928A1, and M1 submachine guns in the presence of dust or corrosion. Otherwise the ammunition functioned satisfactorily in all weapons at normal, excessive, and low temperatures.

Corrosion resistance was obtained by plating the exterior of the case with a coating of zinc of thickness .00015 inch to .0002 inch. The plating was followed by a dip in chromic acid which minimized the formations of

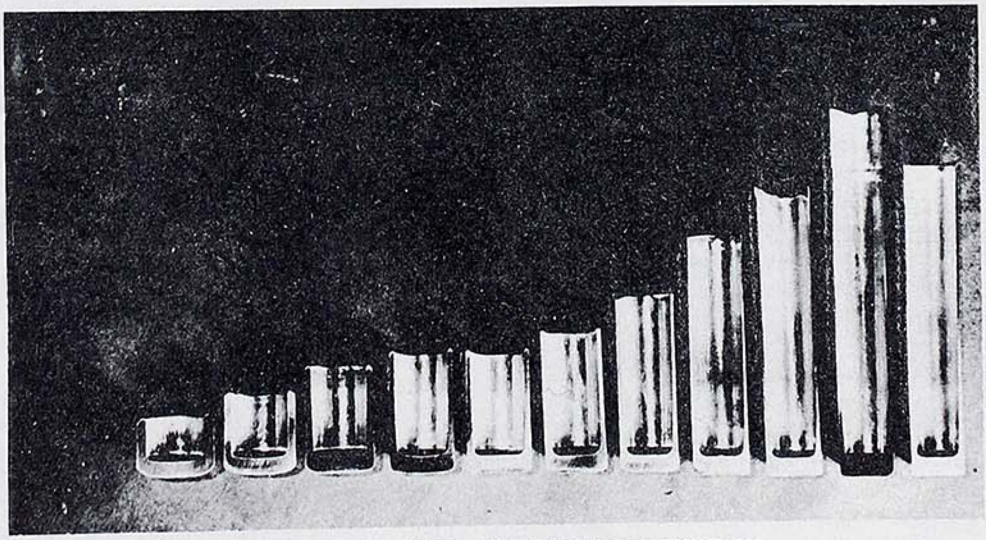


FIGURE 138—DRAW STAGES OF CASE IN PROGRESSIVE DIE

the usual bulky corrosion products of zinc when exposed to air. The complete round, with the exception of the case head, was again dipped in chromic acid after assembly to minimize couple corrosion between the case and bullet.

Samples of the caliber .45 cartridge were furnished the Tank Destroyer Board, Infantry Board, and Marine Corps Equipment Board for tests. The Tank Destroyer Board recommended that an improved finish be developed for the steel case.[13] The Infantry Board recommended that the caliber .45 steel cartridge case be adopted as Substitute Standard.[14] The Marine Corps Equipment Board found that the subject ammunition was satisfactory as a substitute for brass-cased ammunition for training purposes.

On 12 November 1942 the Ordnance Committee recommended that the Evansville process be released for production, and that the ammunition so manufactured be limited to service within the continental limits of the United States until further information could be attained on corrosion resistance, the effect of aging, and behavior under conditions normally encountered in service.[15]

By 11 January 1943 approximately 100,000,000 Cartridges, Pistol, Ball, Caliber .45, with steel cartridge cases (fig. 139), had been manufactured. All lots had successfully passed the inspection tests conducted in accordance with U. S. Army specifications. In addition 5,000 rounds of each production lot manufactured had been tested at the Aberdeen Proving Ground under conditions of low temperature, dust, weathering, etc. It was the opinion of the Ordnance Department that the ammunition was satisfactory for service use. Accordingly, on 14 January 1943 the Ordnance Committee recommended that the restrictions on the issue of Cartridge, Pistol, Ball, Caliber .45, M1911 assembled with steel cartridge cases be removed.[16]

Steel cartridge cases were also extensively used for the caliber .45 dummy, high-pressure test, blank, and tracer cartridges.

The caliber .45 steel cartridge case was generally satisfactory for service use, although complaints were received from several theaters which indicated that the protective finish was not completely adequate under extreme conditions of high humidity and temperature.

CALIBER .50 BALL CARTRIDGE.

The principal facilities engaged in the development of the caliber .50 steel cartridge cases were the Remington Arms Company and Frankford Arsenal. The Milwaukee and St. Louis Ordnance Plants also conducted research programs on caliber .50 steel cases. The Remington Arms Company worked under Research and Development contracts at Bridgeport, Connecticut, and under production contract at the Lowell Ordnance Plant. The basic objectives of the Remington development contract were:

1. Initiate the development of a process to manufacture caliber .50 steel cases with chief emphasis on:
    a. Blank-cup-and-draw as the basis of the process;
    b. Cold work only to develop the necessary physical properties;
    c. As few intermediate anneals as possible and preferably none;
    d. Utilization of as much existing brass case equipment with as few changes as possible.
2. Set up a pilot production line at Bridgeport on which to evaluate the process developed. As insurance against the failure of the cold-work process, a hardening furnace was supplied.
3. Subsidiary to the foregoing goal, evaluate alternative draw pieces.
4. Develop a satisfactory corrosion-resistant finish.
5. Supply, by means of detailed monthly reports circulated to the caliber .50 industry, prompt and full information on all caliber .50 steel case developments worked on by Remington.

The following points summarized the results accomplished:

1. The blank-cup-and-draw work outlined in the contract was successfully carried out.
2. An alternative process, using hot extrusion instead of blanking and cupping, was found to merit further investigation.
3. The corrosion resistance study developed several promising possibilities but up to the time when work was suspended, none had been developed to the point where it could justifiably supplant the standard Zinc-Cronak finish. The most promising finishes evaluated were:
    a. Phenolic lacquer on Bonderite or steel.
    b. Duplex copper-lead electroplate, possibly with a final phenolic lacquer applied in an integrated plating unit from a water dispersion.

    The hot-extrusion supplement to the contract covers the evaluating of these optimum finishes further.

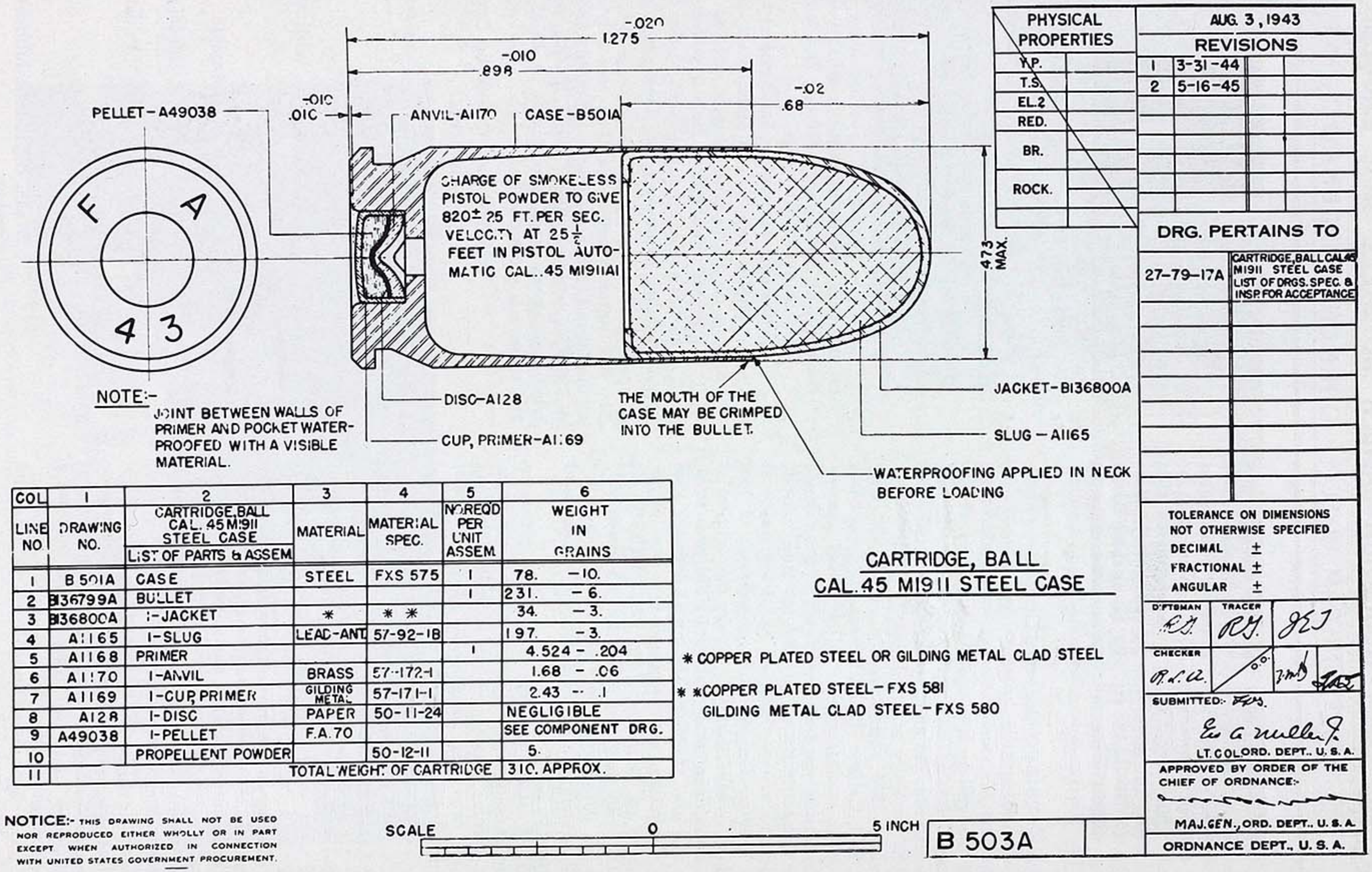
The Remington process (fig. 140) was successfully used at the Lowell Ordnance Plant, a monthly production rate of 750,000 Cartridges, Ball, Caliber .50, T25, being reached when operations were terminated. A brief summary of the process is presented below:

Noninverted, Coined-lip Cup

Strip inspection
Blank
Wash, cuprodine, lubricate
Cup
Wash and dry
Inspect
Anneal
Pickle, cuprodine, lubricate
Inspect

Cartridge Case

Cup wash and lubricate
First draw
Wash, cuprodine, lubricate
Second draw
Wash, cuprodine, lubricate
Third (final) draw
Wash and dry
Trim
Belt inspect
Wash, cuprodine, lubricate
Pocket



NOTE:- JOINT BETWEEN WALLS OF PRIMER AND POCKET WATERPROOFED WITH A VISIBLE MATERIAL.

COL	1	2	3	4	5	6
LINE NO.	DRAWING NO.	CARTRIDGE, BALL CAL. .45 M1911 STEEL CASE LIST OF PARTS & ASSEM	MATERIAL	MATERIAL SPEC.	NO. REQD PER UNIT ASSEM.	WEIGHT IN GRAINS
1	B 501A	CASE	STEEL	FXS 575	1	78. −10.
2	B136799A	BULLET			1	231. − 6.
3	B136800A	1-JACKET	*	* *		34. − 3.
4	A1165	1-SLUG	LEAD-ANT	57-92-1B		197. − 3.
5	A1168	PRIMER			1	4.524 − .204
6	A1170	1-ANVIL	BRASS	57-172-1		1.68 − .06
7	A1169	1-CUP, PRIMER	GILDING METAL	57-171-1		2.43 − .1
8	A128	1-DISC	PAPER	50-11-24		NEGLIGIBLE
9	A49038	1-PELLET	F.A.70			SEE COMPONENT DRG.
10		PROPELLENT POWDER		50-12-11		5.
11		TOTAL WEIGHT OF CARTRIDGE				310. APPROX.

NOTICE:- THIS DRAWING SHALL NOT BE USED NOR REPRODUCED EITHER WHOLLY OR IN PART EXCEPT WHEN AUTHORIZED IN CONNECTION WITH UNITED STATES GOVERNMENT PROCUREMENT.

CARTRIDGE, BALL
CAL. .45 M1911 STEEL CASE

* COPPER PLATED STEEL OR GILDING METAL CLAD STEEL

* *COPPER PLATED STEEL-FXS 581
GILDING METAL CLAD STEEL-FXS 580

PHYSICAL PROPERTIES	
Y.P.	
T.S.	
EL.2	
RED.	
BR.	
ROCK.	

AUG. 3, 1943

REVISIONS	
1	3-31-44
2	5-16-45

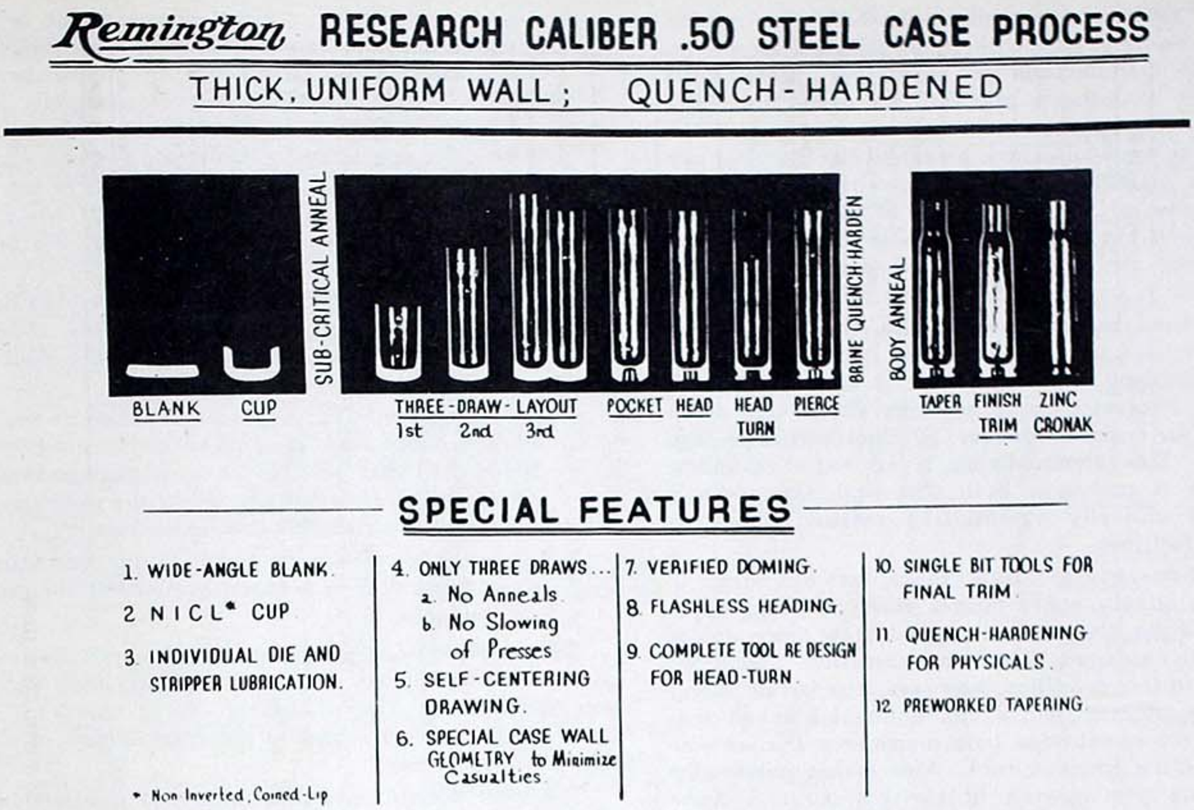
DRG. PERTAINS TO	
27-79-17A	CARTRIDGE, BALL CAL. .45 M1911 STEEL CASE LIST OF DRGS. SPEC. & INSP. FOR ACCEPTANCE

TOLERANCE ON DIMENSIONS NOT OTHERWISE SPECIFIED
DECIMAL ±
FRACTIONAL ±
ANGULAR ±

D'FTSMAN E.J.
TRACER R.J. JEJ
CHECKER R.L.C.
SUBMITTED:
E. A. Muller Jr.
LT. COL. ORD. DEPT., U. S. A.
APPROVED BY ORDER OF THE CHIEF OF ORDNANCE:-
MAJ. GEN., ORD. DEPT., U. S. A.
ORDNANCE DEPT., U. S. A.

B 503A

FIGURE 139—CARTRIDGE, BALL, CALIBER .45, M1911, STEEL CASE



Remington RESEARCH CALIBER .50 STEEL CASE PROCESS

THICK, UNIFORM WALL; QUENCH-HARDENED

SPECIAL FEATURES

1. WIDE-ANGLE BLANK.
2. N I C L* CUP
3. INDIVIDUAL DIE AND STRIPPER LUBRICATION.

* Non Inverted, Coined-Lip

4. ONLY THREE DRAWS...
   a. No Anneals.
   b. No Slowing of Presses
5. SELF-CENTERING DRAWING.
6. SPECIAL CASE WALL GEOMETRY to Minimize Casualties.
7. VERIFIED DOMING.
8. FLASHLESS HEADING.
9. COMPLETE TOOL RE DESIGN FOR HEAD-TURN.
10. SINGLE BIT TOOLS FOR FINAL TRIM.
11. QUENCH-HARDENING FOR PHYSICALS.
12. PREWORKED TAPERING.

FIGURE 140—REMINGTON RESEARCH CALIBER .50 STEEL CASE PROCESS

Cartridge Case (Contd.)

Head
Wash and dry
Head turn
Separate chips
Vent
Wash and dry
Quench harden
Body anneal
Pickle, cuprodine, lubricate
Taper
Wash and dry
Finish face and bur
Separate chips
First unprimed inspection
Zinc plate and Cronak
Second unprimed inspection

Remington conducted an investigation of cold-headed draw pieces and hot-extruded draw pieces. The cold-headed draw piece investigation was conducted in conjunction with the Waterbury Farrel Tool and Machine Company and was terminated after a preliminary investigation in view of the following:

1. Cold-heading requires a very considerable force (in the neighborhood of 75 tons) which in turn requires a rather large cold-heading machine. The availability of the latter is quite limited and no appreciable production on existing equipment could be obtained. This was sufficient reason for dropping further consideration of the cold-heading process.
2. Cold-heading does not appear capable of producing a draw piece which is farther along in the process than a point which is perhaps equivalent to the conventional cup or first draw. This is in contrast to the hot-extruded draw piece.
3. Unlike the hot-extruded draw piece, the cold-headed cup can be made only from spheroidized steel.

Hot-extruded draw pieces were investigated as the result of the experiments of Biginelli in France, who conducted extensive studies of the application of hot extrusion to steel artillery case manufacture. The advantages of the hot-extruded draw pieces included:

1. The slugs from which the draw pieces are made are sheared from a round rather than blanked from a flat bar. This is an important consideration because:
   a. An immediate saving of 35 to 40 percent in the total tonnage of steel fabrication required is effected since; in shearing a slug from a round bar, there is no scrap webbing. In the case of the flat bar the scrap webbing constitutes 35 to 40 percent of the bar.
   b. There is more rolling capacity in the United States of the type required for caliber .50 round bar than for flat bar stock. Moreover, the cost

of round is less than for flat bar. This reflects the greater ease with which the steel companies can manufacture the round bar. Thus, costs per 100 pounds are $3.27 for round and $4.17 for flat bars.

   c. Less rigid tolerances on round bar diameter can be permitted than are allowable on the thicknesses of flat bars. Thus at the present time round bar diameter tolerances for hot-extrusion stock are ± .008 inch, whereas only ± .004 inch is permitted on flat bar thickness.

2. The round bars from which the slugs are sheared can be used in the as-hot-rolled condition. This is an important advantage since to date it has been found necessary to spheroidize all flat bar stock used for cupping caliber .50 steel cartridge case cups. This spheroidizing is an extra operation which is costly in both time and expense and which critically overburdens existing spheroidizing facilities.
3. The hot-extruded draw piece, as extruded, is comparatively softer farther along in the process than is the blanked-and-cupped draw piece unless quench-hardened from the extrusion operation. Even in this condition, however, it is farther along in the process than a conventional blanked cup since the as-extruded base diameter is the same as that of the finished case. This makes potentially possible the drawing of the hot-extruded draw piece with only a single pass whereas at least three passes are necessary with the blanked-and-cupped draw piece.
4. The flow structure of a hot-extruded case is markedly superior to that found in a case made with the blank-cup-and-draw piece. Whereas the latter has a definite orientation of inclusions, etc., in the rolling direction so that in the finished case the flow structure is symmetrical only about a single plane passing through the central axis of the case, the hot-extruded case on the contrary has a flow structure which is symmetrical about the central axis.
5. The primer pocket can readily be indented during the hot-extrusion operation. By this means it is hoped to eliminate completely the pocketing operation.
6. It is possible to vary the cross-section of the head of a hot-extruded case over considerably wider limits than that possible on a blanked-and-cupped draw piece. Thus one can select the optimum base geometry for strength and extraction.
7. There is no "fracture line" in the hot-extruded draw piece such as is found in blanked-and-cupped draw pieces.

Before the investigation of the hot-extruded draw pieces was completed, the steel cartridge case program was terminated. The equipment to be used for steel draw pieces was converted to the manufacture of aluminum cartridge cases.

The most difficult and only unsolved program in the caliber .50 steel case development was that of corrosion resistance. The following table presents a summary of the finishes studied:

FINISH	CORROSION RESISTANCE	ABUSE RESISTANCE	DUST TEST
Bonderite			
1. Alone	Poor	No data	No data
2. Plus oil, wax or inhibitor	Poor	No data	No data
3. Plus resin film	Good	Good	Good
Copper Electroplate			
1. Alone	Poor	No data	No data
2. Plus oil, wax or inhibitor	Poor	No data	No data
3. Surface oxidized to CuO—			
a. Alone	Poor	Poor	Equivalent to Zinc-Cronak
b. Plus oil	Good	Poor	Stoppages
c. Plus wax	Fair	Poor	Chamber build-up
d. Plus resin film	Fair	Fair	Good
Lead Electroplate			
1. Alone	Fair	Fair	No data
2. Pb-Cu duplex plate	Poor	No data	No data
3. Cu-Pb duplex plate	Good	Good	No data
4. Cu-Pb-Cu triplex plate	Poor	No data	No data
5. Pb-Cu codeposit plate	Poor	No data	No data
6. Pb-Sb codeposit plate	Good	No data	No data
Parkerite			
1. Alone	Fair	Good	Equivalent to Zinc-Cronak
2. Plus oil	Good	Good	Stoppages
3. Plus wax	Good	Good	Chamber build-up
4. Plus organic inhibitors	Good	Poor	No data

FINISH	CORROSION RESISTANCE	ABUSE RESISTANCE	DUST TEST
Resin Film			
1. Straight phenolic	Good	Good	O.K. (limited testing)
2. DV-phenolic	Good	Fair	O.K. (limited testing)
3. Oil-phenolic	Fair	Fair	O.K. (limited testing)
4. Linseed oil	Fair	Poor	No data
5. Linseed oil plus alkyd	Good	Poor	No data
6. Alkyd (Glyptal)	Good	Good	No data
7. Formex	Good	Good	No data
8. Silicone vapor	Fair	Fair	No data
9. Silicone varnish	Good	Good	No data
10. Polyvinyl acetate	Good	Fair	No data
11. "F" resin	Good	Fair	No data
Zinc Electroplate			
1. Alone	Poor	No data	No data
2. Cronak			
a. Alone	Fair, especially poor after 150° F storage	Fair	Occasional rim shears
b. Plus oil	No significant improvement	Fair	More frequent rim shears
c. Plus wax	No significant improvement	Fair	Chamber build-up
d. Plus graphite	Fair, especially poor after 150° F storage	Fair	O.K. (limited testing)
3. Phosphated (Bonderite)	Same as Zinc-Cronak	No data	No data
4. Westinghouse Predip	Same as Zinc-Cronak	Same as Zinc-Cronak	No data
5. Anodic black	Same as Zinc-Cronak	Same as Zinc-Cronak	No data
6. Schulein	Same as Zinc-Cronak	Same as Zinc-Cronak	No data
7. Iridite	Slightly better than Zinc-Cronak	Same as Zinc-Cronak	No data
8. Lum	Same as Zinc-Cronak	Same as Zinc-Cronak	No data

A brief description of the finishes is presented below:

Alkyd (Glyptal)—A resin film made by reacting a polyhydric alcohol with phthalic anhydride.

Bonderite—The Bonderizing process is patented by the Parker Rust Proof Company, Detroit, Michigan. It produces, by chemical action on steel, a thin crystalline, inert, water-insoluble, somewhat absorbent phosphate coating. The coating has little corrosion resistance in itself or in combination with oil. It is generally used as a base for paint or lacquer.

Copper—This electroplate was applied from a DuPont high-speed copper bath; i.e., from an alkaline cyanide solution. The copper-copper oxide finish is applied by first plating on the steel a minimum of .0002 inch of copper. The surface of the copper is then converted to copper oxide (CuO) by immersing in a hot alkaline oxidizing solution. The copper oxide film is black, inert, adherent and has the ability to absorb and retain added rust-inhibiting oils or waxes.

"F" Resin—A resin film made by resinifying a furan such as furfuryl alcohol or furfural with an acid catalyst.

Formex—A resin film made by General Electric. It is a mixture of phenol formaldehyde and polyvinyl formal.

Inhibitor—For the purpose of this discussion an inhibitor can be defined as an organic compound characterized by a relatively long chain molecule with one end tending to be attracted to metal and the other end being water repellent.

Iridite—Iridite is a chemically produced protective film on zinc which in method of application, appearance and corrosion resistance is very similar to Cronak. The process was developed by the Rheem Manufacturing Company, Baltimore, Maryland. Zinc-plated articles are immersed for 15 seconds in an aqueous solution containing—

Zinc chloride	1.4%
Chromic acid	14.0%

at 95° F, rinsed and then dried in warm air (about 130° F). No details as to the chemical composition of the film are available.

Lead—Lead electroplate was applied from a DuPont lead sulfamate bath.

Linseed Oil—Bodied oil applied from a water emulsion.

Lum—A process which claims to improve the corrosion resistance and heat stability of chromate coatings, e.g., Cronak, on zinc or cadmium metals or alloys. After the article has been treated in an acid chromate bath, e.g., Cronak solution, it is immersed for 15 seconds to 5 minutes in a boiling aqueous solution of (1) 10 percent sodium dichromate; (2) 1 percent sodium hydroxide; or (3) 10 percent sodium dichromate, 1 percent sodium hydroxide. The stabilized coating is then rinsed in hot water and dried in hot air. (From U.S. Patent 2,288,007, June 30, 1942; John C. Lum assignor to Westinghouse, Pittsburgh.)

Oil—Hydrocarbons from petroleum. In this work inhibitors were sometimes added to the oil.

Parkerite—The Parkerizing process is patented by the Parker Rust Proof Company, Detroit, Michigan. The process produces on steel by chemical action an inert, water-insoluble, absorbent phosphate coating which in itself has little corrosion resistance, but in combination with oils or waxes produces excellent corrosion resistance. Chemically, the Parkerite and Bonderite coatings are apparently similar. However, Parkerizing requires a reaction time of 30 to 60 minutes and produces a coating .002 inch —.0005 inch thick, while Bonderizing requires only a 2- to 5-minute reaction time and produces a thinner, less corrosion-resistant finish.

Phenolic Varnish—A resin film made by reacting a phenol with formaldehyde.

Polyvinyl Acetate—A water emulsion of high viscosity polyvinyl acetate obtained from the DuPont Electrochemicals Department, Niagara Falls.

Schulein—An electrolytic process for producing on zinc plate a jet black surface finish using alternating current through an aqueous solution containing chromic acid and sulphuric acid.

Silicone—A resin film-forming material made from alkyl or aryl silicone halides. These halogen compounds are generally liquids possessing high vapor pressure. They react with water to form hydroxy derivatives capable, upon the application of heat or the presence of a catalyst, of forming polymeric condensation products known as silicone compounds. These compounds are generally clear, hard solids with excellent water repellency and high electrical resistance.

Silicone Wax—A silicone precipitate formed from the reaction of silicone chlorides with water.

Wax—Materials having a waxy texture including "true" waxes (esters of high molecular weight, fatty acids with high molecular weight, monohydric alcohols) such as Carnauba as well as such petroleum hydrocarbons as paraffin and microcrystalline wax.

Westinghouse Predip—A method of improving the corrosion resistance of a phosphate; e.g., Bonderized, surface by predipping or spraying the metal surface for a few seconds with a disodium phosphate solution containing a small amount of a titanium colloid.

Zinc Electroplate—This plate was applied from a DuPont Zin-O-Lite solution.

Zinc-Cronak—The Cronak process was developed and is patented by the New Jersey Zinc Company. It is a surface treatment for zinc, designed to reduce the tendency of zinc to build up white basic zinc carbonate corrosion products—"flower"—in corrosive atmospheres, especially those containing salt; e.g., marine atmospheres. The process consists in immersing the zinc-plated article for 5 to 15 seconds at room temperature in a solution containing:

Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)	200 grams
Sulphuric acid (94%, specific gravity 1.84)	6-9 ml
Water	1 liter

followed by a water-rinse and warm air-dry (about 130° F). This produces on the surface of the zinc a thin, iridescent, varicolored film.

Zinc Anodic Black—A process developed by United Chromium Corporation for producing on zinc a gray-black anodized surface. Details of the process were not revealed.

SERVICE BOARD TESTS

The following quantities of caliber .50 ball ammunition assembled with steel cartridge cases manufactured by the Lowell Ordnance Plant were furnished Ground Force Service Boards for tests to determine the suitability of subject ammunition for Ground Force use as a substitute for brass-cased ammunition:[17]

Quantity	Service Board
10,000 rounds	Tank Destroyer Board, Camp Hood, Texas
10,000 rounds	Cavalry Board, Fort Riley, Kansas
20,000 rounds	Infantry Board, Fort Benning, Georgia

The tests have been completed and results received.

Facts determined by the Infantry Board[18] are presented:

a. There is no appreciable difference in the weight of brass- and steel-cased ammunition.

b. There is no apparent difference in the accuracy of the brass- and steel-cased ammunition.

c. The functioning of brass- and steel-cased ammunition after exposure to normal weather conditions is about equal.

d. Ten days exposure to weathering has no apparent corrosive effect on the steel cartridge case of the subject ammunition.

e. Brass-cased ammunition is superior to steel-cased ammunition in resistance to corrosion when subjected to salt water spray.

f. When the protective coating of the subject ammunition is removed by abrasive wear of belting and unbelting, the rate of corrosion is increased when exposed to salt spray.

g. No difference in the muzzle flash of the gun could be detected between brass- and steel-cased ammunition.

h. The functioning of brass- and steel-cased ammunition when subjected to rough handling is about equal.

i. The functioning of new ammunition, both brass and steel, is about equal.

The Infantry Board concluded:

a. That the subject ammunition is less resistant to corrosion than brass-cased ammunition.

b. That under normal conditions the functioning of the subject ammunition is substantially equal to that of standard brass-cased ammunition.

c. That steel-cased ammunition is an acceptable substitute for brass-cased ammunition, in the event that brass is not available.

d. That specific instructions should be issued relative to maintenance in storage of steel-cased ammunition and its care by troops in the field.

The Infantry Board recommended:

a. That subject ammunition as submitted be considered an acceptable substitute for brass-cased ammunition in the event brass is not available.

b. That specific instructions be formulated and issued regarding care of subject ammunition in storage and care after removal from packing containers.

The advantages and disadvantages of steel-cased ammunition over brass-cased ammunition as determined by the Tank Destroyer Board[19] are presented:

a. Withstands rough handling to a greater degree than cartridges caliber .50 assembled with brass cases in the following respects:

(1) Steel cases are less easily dented.

(2) Bullet gripped more firmly by mouth of case results in fewer short rounds.

(3) More rigid neck of case results in fewer bent rounds.

(4) More rigid lips of case result in fewer loose projectiles.

b. The steel-cased round offers greater resistance to moisture in the following respects:

(1) Tighter fit of bullet in neck of case affords better protection against penetration of moisture at that point.

(2) Exterior surface treatment protects steel surface from mild weathering.

c. Steel-cased ammunition functions in machine gun better in the following respects:

(1) More rigid mouth of case produces fewer damages to neck as a result of failures to load.

(2) Less likely to malfunction due to rusted metallic belt links as occurs with metallic belt link used in conjunction with brass cases.

d. The steel-cased ammunition offers greater resistance to marring by sharp edges of metallic belt links during operation of belt loading machine.

The following two disadvantages of steel-cased ammunition were noted by the Tank Destroyer Board:

a. Offers less resistance to oxidation than brass-cased ammunition.

b. On firing in burst of 50 rounds through warm to hot barrels, the steel-cased ammunition tends to produce stoppages due to difficulty in extracting empty shell cases from chamber.

The following conclusions were drawn by the Tank Destroyer Board:

a. The subject round offers an accuracy comparable to standard ammunition.

b. Steel-cased ammunition offers greater resistance to rough handling than brass-cased ammunition.

c. Subject ammunition produces fewer malfunctions except under sustained full-automatic fire of 50-round bursts.

d. Subject ammunition offers satisfactory resistance to mild short term weathering tests and to immersion in both salt and fresh water.

e. Steel-cased ammunition requires a long term subtropical weathering test for final determination of durability in tropics.

f. Steel-cased ammunition should be modified for experimental purposes by applying a light brass surfacing to the exterior surface of the shell case.

The Tank Destroyer Board recommended that subject round be considered suitable for use by Tank Destroyer units in the event brass was not available, subject to a favorable supplementary report on subtropical weathering.

Caliber .50 ball ammunition assembled with steel cartridge cases was tested by the Cavalry Board under normal and adverse service conditions. Brass-cased ammunition was used as control. Program of tests together with results are presented:[20]

a. **Normal Functioning Test:**

475 rounds of each type of ammunition were fired as issued. Firing results: No malfunctions with steel-cased; 1 failure to chamber and 5 misfires encountered in brass-cased.

b. **Weathering Test:**

100 cartridges of each type were exposed on the ground to the elements for 15 days. Firing results: No malfunctions.

c. **Corrosion Test:**

100 cartridges of each type were immersed in water and dried in alternate 24-hour periods of 15 days. Firing results: No steel-cased malfunctions; 2 misfires with brass-cased ammunition. 100 cartridges of each type were immersed in salt water for 15 days. Firing results: 2 failures to extract with steel-cased rounds. 11 failures to extract and 7 misfires with brass-cased ammunition.

d. **Battering Test:**

25 rounds of each type were shaken in a box with rocks prior to firing. Firing results: No malfunctions.

e. **Dust Test:**

Dust and dirt were poured on 25 belted cartridges. Firing results: No malfunctions with steel-cased ammunition; 1 failure to chamber with brass-cased ammunition.

f. **Mud Test:**

25 rounds of each type of belted cartridges were immersed in mud bath. Firing results: 100 percent failure to chamber for both types.

g. **Fast Functioning Test:**

Cartridges as issued fired full automatic in a 100-round belt. Firing results: No malfunctions.

h. **Flash Test:**

100-round burst of each type was observed for sparklers and muzzle cones. Firing results: Sparklers were infrequently observed in ejection of steel cases, none with brass cases. Muzzle cones were barely visible and comparable in daylight firing. No night firing was conducted.

i. **Accuracy Test:**

No. Rds. Fired	Cartridge	Range	Average Mean Radii (Inches)
10	Steel	1,000 in.	0.9
10	Brass	1,000 in.	1.0
10	Steel	100 yd.	3.5
10	Brass	100 yd.	4.1
10	Steel	300 yd.	9.7
10	Brass	300 yd.	10.8

The Cavalry Board concluded that the steel-cased cartridges compared favorably with brass-cased ammunition under normal and adverse service conditions and were suitable for combat use.

The Cavalry Board recommended that the caliber .50 ball cartridge assembled with steel case be considered suitable as Substitute Standard for service use.

In view of the noncritical status of brass the following was the recommendation of the Headquarters, Army Ground Forces:[21]

> "a. Caliber .50 ammunition assembled with steel cartridge cases be given no further consideration for adoption at this time, but be considered satisfactory for service use in the event that brass becomes so critical that the situation would preclude the manufacture of brass cases. In the event steel cases are employed, specific instructions be formulated regarding care in storage and care after issue and these instructions be disseminated to those concerned."

STEEL CARTRIDGE CASES — REFERENCES

1. OCM 20823, dated 24 June 1943
2. 1st through 8th Memorandum Reports on Lot EC-25607-X, Aberdeen Proving Center, concluded 25 September 1943
3. OCM 22160
4. OCM 23368
5. O.O. 471.4/1876 (C)
6. OCM 29368
7. Frankford Arsenal Small Arms Ammunition Division Report No. 87A
8. Frankford Arsenal Ordnance Laboratory Report No. R-277
9. Frankford Arsenal Ordnance Laboratory Report No. R-481
10. Contract W-314-ORD-15742
11. Frankford Arsenal Ordnance Laboratory Report No. R-389
12. Weekly Report, Evansville Ordnance Plant, 26 October 1942
13. Report of Tank Destroyer Board, "Report of Test to Caliber .45 Steel Cartridge Case Ammunition and Experimental Packaging, dated 16 January 1943"
14. Report of the Infantry Board, No. 1431, dated 22 December 1942
15. OCM 19150
16. OCM 19493
17. O.O. 471.4/12523, dated 12 March 1945
18. Report of the Infantry Board No. 1860 "Caliber .50 Ammunition Assembled with Steel Cartridge Cases," dated 29 August 1945
19. Report of Tank Destroyer Board—"Report of Test of Caliber .50 Ball Ammunition Assembled with Steel Cartridge Cases," Project No. 308, dated 28 April 1945
20. Report of the Cavalry Board, dated 19 May 1945, "Service Test Cartridge Caliber .50 Ball Assembled with Steel Case"
21. O.O. 471.4/129, dated 10 September 1945

GENERAL REFERENCES ON STEEL CARTRIDGE CASES

CALIBER .30 STEEL CARTRIDGE CASES

1. Frankford Arsenal Laboratory Report No. R-134, "Steel Cartridge Cases, Caliber .30," December 1941
2. Frankford Arsenal Laboratory Report No. R-159, "Manufacturing of Caliber .30 Steel Cartridge Cases from .17% Carbon Steel," February 1942
3. Frankford Arsenal Laboratory Report No. R-160, "Steel Cartridge Cases, Caliber .30 Fabricated from .26% Carbon 2.00% Manganese Copper Clad Steel," February 1942
4. Frankford Arsenal Laboratory Report No. R-161, "Steel Cartridge Cases, Caliber .30 Fabricated from .35% Carbon Steel," February 1942
5. Frankford Arsenal Laboratory Report No. R-171, "Steel Cartridge Cases, Caliber .30," June 1942
6. Frankford Arsenal Laboratory Report No. R-213, "Steel Cartridge Cases, Caliber .30," July 1942
7. Frankford Arsenal Laboratory Report No. R-214, "Steel Cartridge Cases, Caliber .30," August 1942
8. Frankford Arsenal Laboratory Report No. R-277, "Heat Treated Steel Cartridge Case, Caliber .30," February 1943
9. Frankford Arsenal Laboratory Report No. R-388, "Manufacture of Caliber .30 Steel Cartridge Cases Using the Progressive Die," August 1943

10. Frankford Arsenal Laboratory Report No. R-389, "Steel Cartridge Cases, Caliber .30 General Electric Draw Pieces," August 1943
11. Frankford Arsenal Laboratory Report No. R-481, "Heat Treated Steel Cartridge Cases, Caliber .30," May 1944
12. Small Arms Ammunition Division, Report No. 87A, Caliber .30, Steel Cartridge Case Development

CALIBER .45 STEEL CARTRIDGE CASES

1. Frankford Arsenal Laboratory Report No. R-232, "Steel Cartridge Cases, Caliber .45," July 1942
2. Frankford Arsenal Laboratory Report No. R-309, "Steel Cartridge Case, Caliber .45," April 1943

CALIBER .50 STEEL CARTRIDGE CASES

REMINGTON ARMS COMPANY

1. RDR 42-18—Development of Caliber .50 Steel Cases, September 1942
2. RDR 42-21—Development of Caliber .50 Steel Cases, October 1942

   Ballistic Supplement of October 1942 Report, November 1942
3. RDR 42-24—Development of Caliber .50 Steel Cases, November 1942
4. RDR 43-4—Development of Caliber .50 Steel Cases, March 1943

   Ballistic Supplement to March 1943 Report
5. RDR 43-11—Development of Caliber .50 Steel Cases—Preliminary Report on a Non-Inverted Cup, 1 April—12 June 1943
6. RDR 43-12—Development of Caliber .50 Steel Cases, May 1943
7. RDR 43-17—Development of Caliber .50 Steel Cases, June 1943
8. RDR 43-18—Caliber .50 High Pressure at Low Temperature, August 1943
9. RDR 43-23—Caliber .50 Steel Cases, Progress Report on Finishes, September 1943
10. RDR 43-30—Caliber .50 Steel Case—Supplementary Report on Ordnance Department Inspectors Firing Test, November 1943
11. RDR 44-14—Caliber .50 Steel Case—Hot Extrusion, April 1944

    Caliber .50 Steel Case—Blank-Cup-and-Draw Process, March 1944
12. Frankford Arsenal Laboratory Report No. R-432, "Cold Worked Steel Cartridge Case, Caliber .50," November 1943

SPARKLET DEVICES, INC.

1. Progress Report No. 1—Development Contract—Caliber .50 Steel Cartridge Cases, 15 July 1942
2. Progress Report No. 2—Development of Caliber .50 Steel Cartridge Cases
3. Progress Report No. 3—Development of Caliber .50 Steel Cartridge Cases
4. Progress Report No. 4—Development of Caliber .50 Steel Cartridge Cases
5. Progress Report No. 5—Development of Caliber .50 Steel Cartridge Cases
6. Progress Report No. 6—Development of Caliber .50 Steel Cartridge Cases

STANT MANUFACTURING COMPANY

1. Progress Report No. 1—Development of Caliber .50 Steel Cartridge Cases, 1 June 1942
2. Progress Report No. 2—Development of Caliber .50 Steel Cartridge Cases, 1 July 1942
3. Progress Report No. 3—Development of Caliber .50 Steel Cartridge Cases, 1 August 1942
4. Progress Reports Nos. 4 & 5—Development of Caliber .50 Steel Cartridge Cases, 1 August 1942, 30 September 1942
5. Progress Report No. 6—Method of Manufacture of Firing test samples for Caliber .50 Steel Cartridge Cases, 15 February 1943

MISCELLANEOUS

1. R-352 Galvanic Attach of Zinc Plate on Steel Cartridge Case
2. R-457 Protective Finishes for Small Arms Steel Cartridge Cases, February 1944
3. R-463 Supplemental Finishes for Zinc Plated Steel Cartridge Cases, February 1944
4. R-260 Lubricants for Drawing Steel Cartridge Cases, September 1943
5. R-292 Lubricants for Drawing Steel Cartridge Cases, April 1943
6. R-293 Lubricants for Drawing Steel Cartridge Cases, April 1943
7. R-318 Abrasive Silica in Filler-Bearing Draw Lubricants, April 1943
8. R-394 Development of Lubricants for Use in Drawing Steel Cartridge Cases, February 1944
9. R-243 Investigation of Tool Life for Caliber .30 Steel Case Tools, August 1942

10. R-422 Hydrogen Embrittlement of Small Arms Steel Cartridge Cases, October 1943

11. R-335 Research Covering the Factors Influencing the Deep Drawing of Steel Cartridge Cases, May 1943

12. R-410 Research Covering the Factors Influencing the Deep Drawing of Steel Cartridge Cases, September 1943. Progress Report No. 17

13. R-439 Research Covering the Factors Influencing the Deep Drawing of Steel Cartridge Cases, December 1943. Progress Report No. 18

14. R-467 Research Covering the Factors Influencing the Deep Drawing of Steel Cartridge Cases. Progress Report No. 19, March 1944

15. R-468 Research Covering the Factors Influencing the Deep Drawing of Steel Cartridge Cases. Progress Report No. 20, January 1944

16. Small Arms Ammunition—A History of an Industry, 1918-1944, Vol. I

17. Aberdeen Proving Ground Reports Conducted Under Ordnance Program—5374