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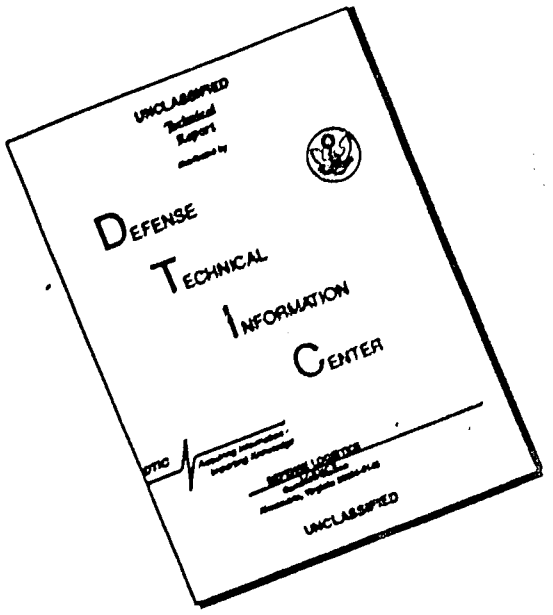

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REPORT NO. 327/2

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RIFLE BARREL STEEL - SPRINGFIELD ARMORY

JULY 26, 1937

WATERTOWN ARSENAL
WATERTOWN, MASS.

[redacted]

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[redacted] Report No. 327/2 July 2, 1937

SUMMARY OF INVESTIGATION OF RIFLE BARREL STEEL

1. The best material investigated was the Colt stock identified as #1 and #2. This material was superior to any of the other samples examined and much superior to the material covered by Watertown Arsenal Report No. 327/1.

2. All barrels showed a degree of nonuniformity in the heat treated state indicative of improper mill practices. Even the best material examined could have been improved by proper heat treatment at the mill.

3. While most of the steels examined came within the SAE 4155 classification, they are not considered a commercial product. SAE 4150 would produce the desired properties and still have the advantage of being a normal mill product if proper mill practice could be secured.

4. A study of both macro and micro structure does not indicate the necessity for lower limits of sulphur and phosphorus provided the uniformity of distribution and dissemination are satisfactory.

5. Longitudinal and transverse physical tests indicate too low a ductility value in the transverse test. This could be predicted from the macro structure and points to

the necessity for elimination of banding.

6. Erosion studies show that heat checking starts at the bottom of tool or chatter marks. Cracks progress perpendicular to the bore and when crossing bands branch in a direction along the band parallel to the bore. Hence, excessive banding points toward a shorter accuracy life of the barrel.

7. It is believed that better stock could be obtained by purchasing uniform material untreated (preferably hot-rolled or annealed) with subsequent heat treatment at the Armory under proper supervision and unified control.

8. The following basic requirements are recommended for inclusion in the specification.

1. Material to be purchased hot-rolled or annealed to a maximum hardness of 260 Brinell.

2. The chemical composition to be as follows: (Steel 4150)

C	Mn	P	S	Cr	Mo
.47/.53	.60/.90	.040 max.	.040 max.	.80/1.10	.15/.25

3. Require that the material furnished shall be of such quality that it can be heat treated to produce the following physical properties.

	P. L.	T. S.	Elon.	Red.	Test Bar Position
Longitudinal	130,000	150,000	17.0	50.0	50% Radius
Transverse	125,000	150,000	16.0	40.0	" "

4. Require macro-etch test and Baumann print from each end of each bar furnished. Test to be in both transverse and longitudinal directions using specimen 1-1/2" long, split through middle. These tests to show uniformity of structure from center to surface.

9. The recommendation in the preceding paragraph is for the purpose of securing better material in the near future. However, since basic cause of poor material appears to be in mill practice, it is recommended that answers to the attached questionnaire be required by the purchase order. This questionnaire has been used and required by this arsenal as well as Watervliet in the purchase of gun forgings and breech block. It has lead to definite improvement in the material secured as well as a basis for prescribing mill practice. After a period of two or three years combined with information now being correlated at this arsenal, the Ordnance Department should be able to prescribe a definite procedure for rifle barrel stock.

Confidential
Report No. 327/2
Watertown Arsenal

June 21, 1937

RIFLE BARREL STEEL - SPRINGFIELD ARMORY

Six specimens of rifle barrel steels obtained from various sources were submitted by Springfield Armory for comparison.

Conclusions

1. Fabrique Nationale - This steel was moderately dirty, comprised of small short inclusions. Long stringers of non-metallics were absent. The structure was decidedly banded, segregated, fairly fine grained, but poorly heat treated. It probably was in the hot worked condition. The carbon content around the bore was somewhat higher than that elsewhere.

2. Colt Barrel A after 10,000 Rounds - This steel was moderately dirty, comprised of small short inclusions. The inclusions formed both long and short chains. The structure was banded, fairly fine grained and in its final heat treated condition. More careful control of the heat treatment would have improved its micro-structure considerably.

3. Midvale Bar 1, Heat 6705 1 15/16" Dia. - This steel was moderately dirty, comprised of small short inclusions. The tendency to form chains was present but few chains were actually formed. The structure was decidedly banded, somewhat segregated, #6 grain size and in the hot worked condition.

4. Colt Stock #1, As Received from Mill 1 3/16" Dia. This steel was fairly clean. The inclusions were small, short, but tended to form short, fairly widely separated chains. The structure was decidedly banded, slightly segregated and in the hot worked condition.

5. Colt Stock #2, Colt Heat Treatment - This steel was fairly clean. The inclusions were small, short and more or less separated with a few short chains. The structure was decidedly banded, slightly segregated and very fine grained. A little more care in the heat treatment would have improved the structure somewhat.

6. Cal. .30 M1903 Rifle #286901, Mfg. by Avis - This steel was dirty. The inclusions were small, fairly short with a tendency to form chains. The structure was banded, segregated #6 grain size and showed that the steel had been BURNT during the heating for hot forming. The rupture was undoubtedly due to fatigue of burnt steel. No heat treatment short of remelting would have made this barrel safe.

TABLE A

Identification of Specimens

FNA - Fabrique Nationale Cal. .50 Rifle.

AA - Colt Barrel A after 10,000 Rounds.

M1A - Midvale Steel, Heat 6705, Bar 1, 1 15/16" Dia.

C1A - Colt Stock #1, As Received from Mill 1 3/16" Dia.

TABLE A Cont'd

C2A - Colt Stock #2, Heat Treated by Colt.

AVA - Ruptured Cal. .30 M1903, Rifle #286901, Mfg. by AVIS.

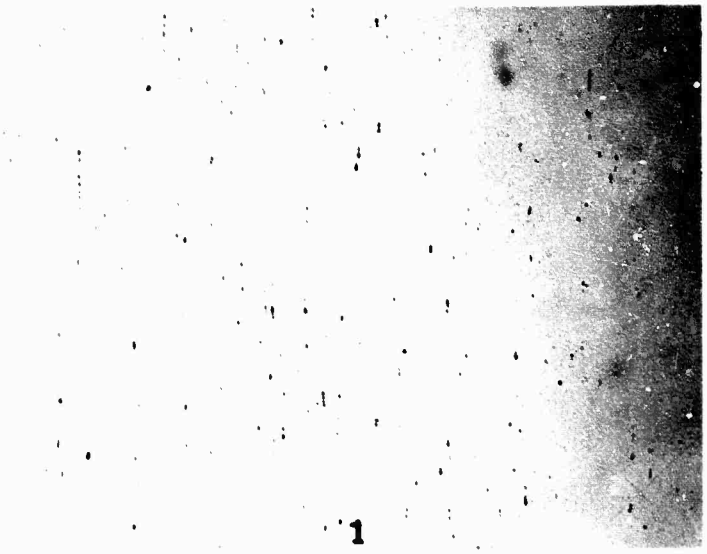
Respectfully submitted,

H. G. Carter

H. G. Carter,
Assoc. Metallurgist.

Fig. 1, X25, Unetched, FNA Showing the dirt condition, Inclusions were small & short. No chains.
MG-276

Fig. 2, X3, $CuCl_2$ etched, FNA. Showing the steel to be decidedly banded.
MG-277
Plate WA639-701



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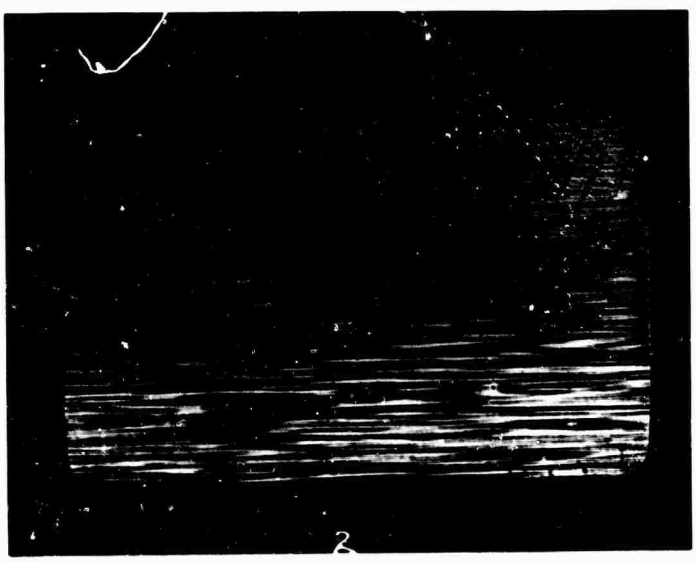

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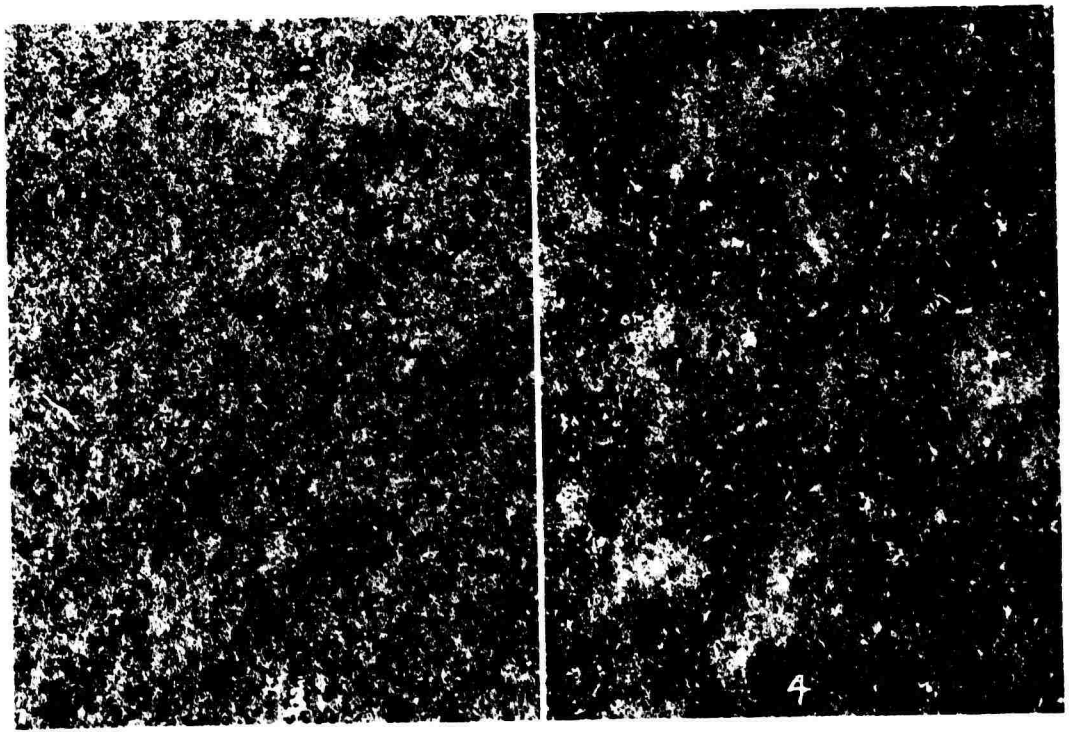
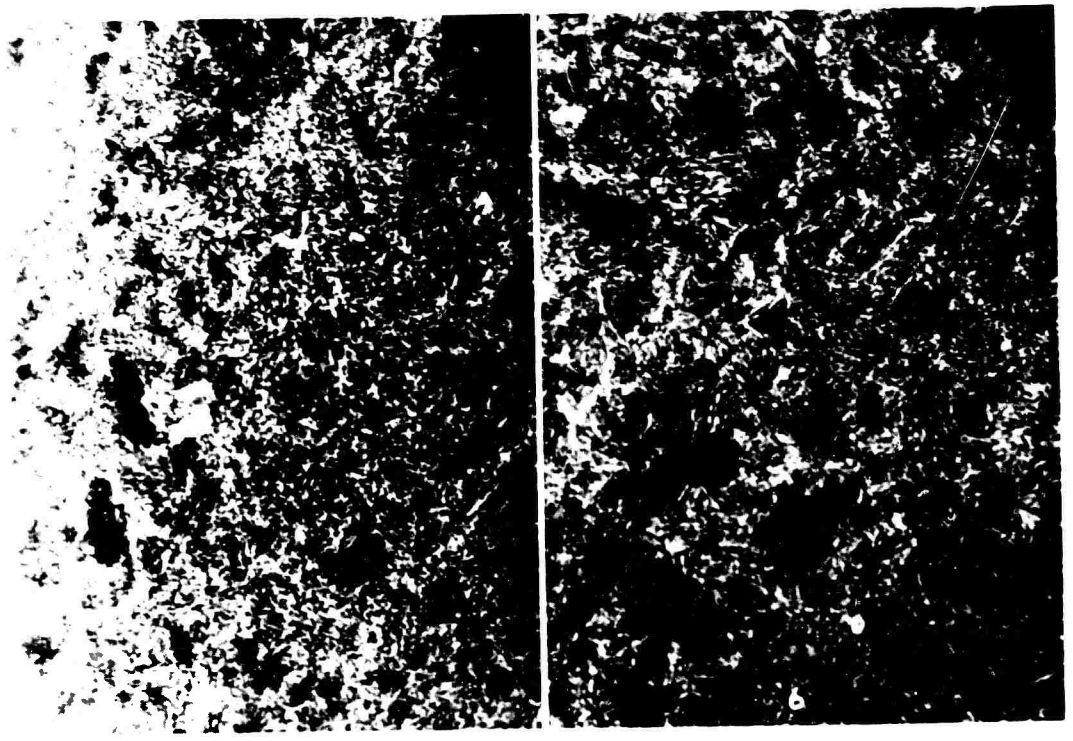
W.A. 639-701

Figs.3 & 4, X100 1% Nital etched, FNA, Midwall and bore sections. The structure was fairly fine grained but segregated. Bore section was somewhat higher in carbon than the midwall.
MG-259 & 260

Figs. 5 & 6, X1000, Same as Figs. 3 & 4. The structure was in a hot worked condition.
MG-269 & 270
Plate WA639-702



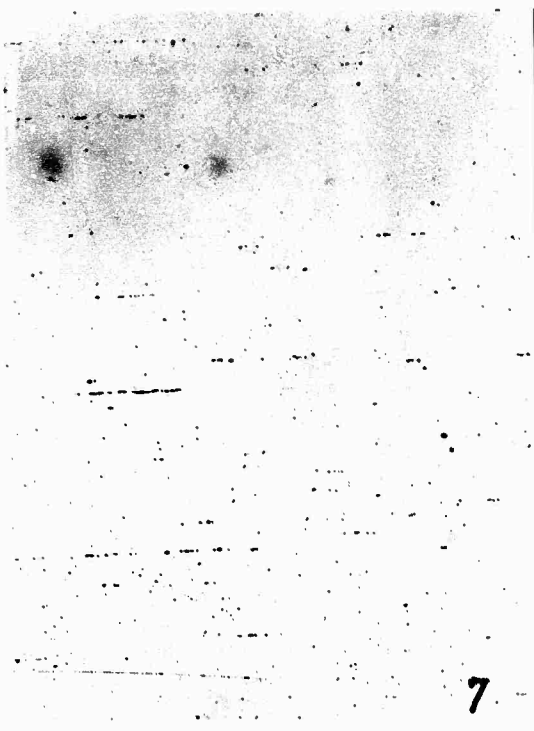


W.A. 639-702

Fig. 7, X25, Unetched AA. Moderately dirty. Small & short inclusions, forming both long & short chains. MG-278

Fig. 8, X3, $CuCl_2$ etched AA. Steel was banded. MG-279

Figs. 9 & 10, X100 & X1000 1% Nital etched AA. Fairly fine grained sorbite with pseudo martensitic tendency. MG-261 & 271
Plate WA 639-703



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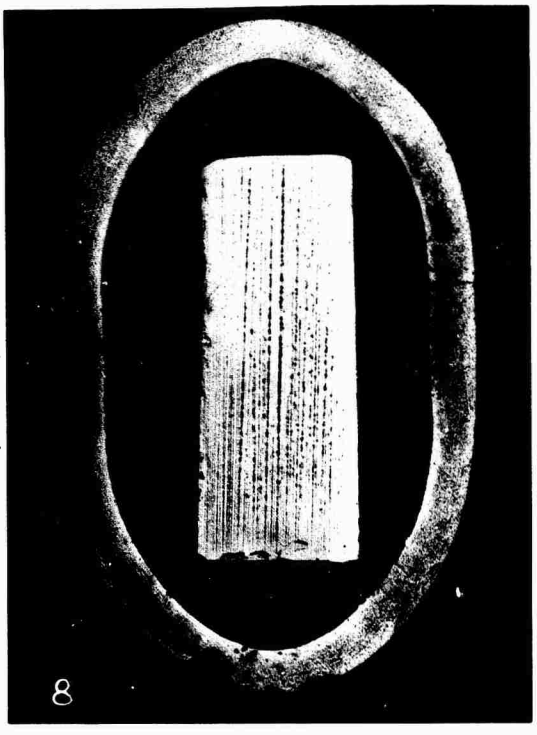

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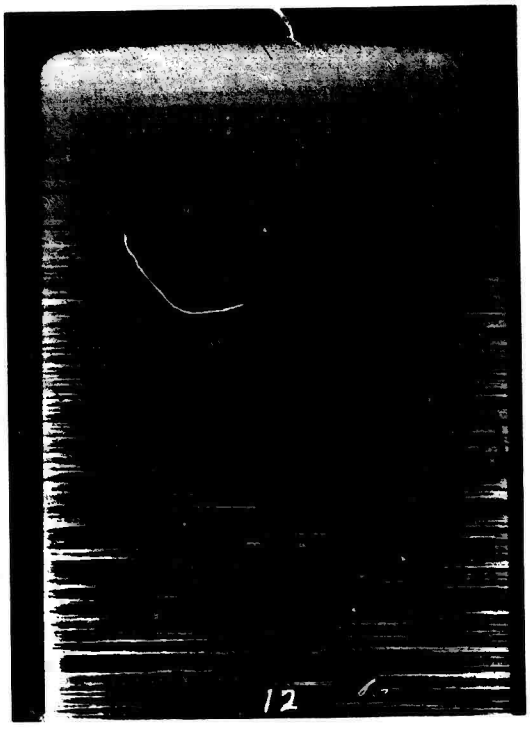
WA 639-703

Fig. 11, X25, Unetched, M1A. Moderately dirty. Small, short inclusions with a tendency to form chains, however, only a few chains actually formed.
MG-280

Fig. 12, X3, $CuCl_2$ etched, M1A. Steel was banded.
MG-281

Figs. 13 & 14, X100 & X1000 1% Nital etched. M1A. Somewhat segregated, grain size #6, Hot worked condition.
MG-262 & 272

Plate WA639-704



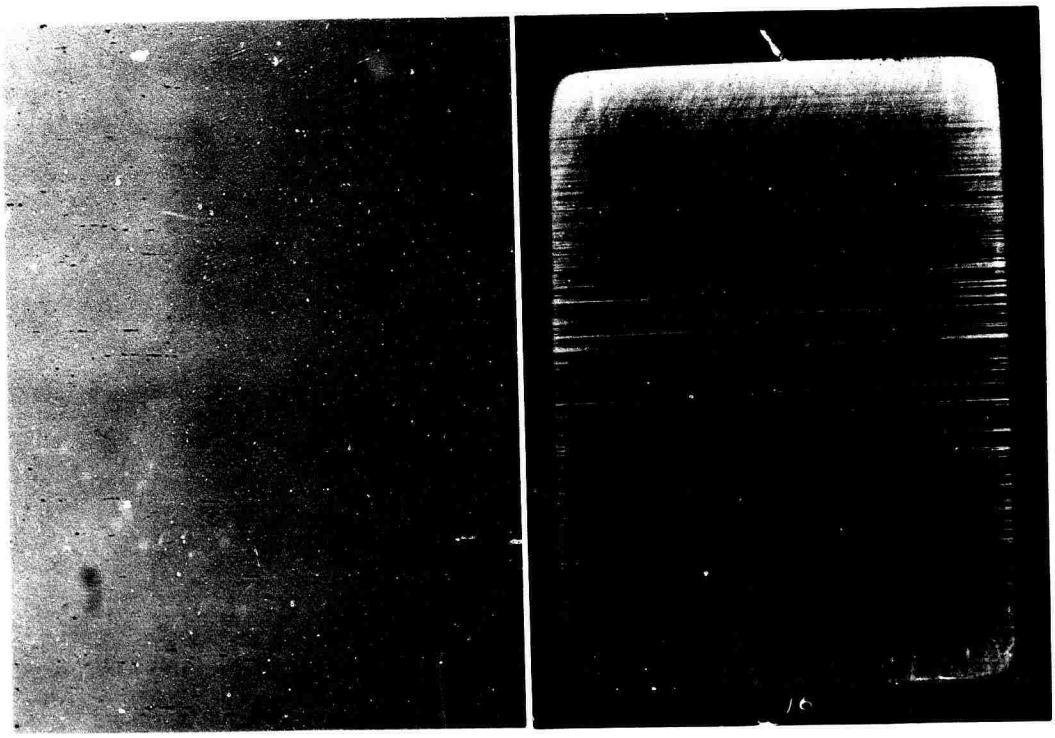
W.A. 639-704

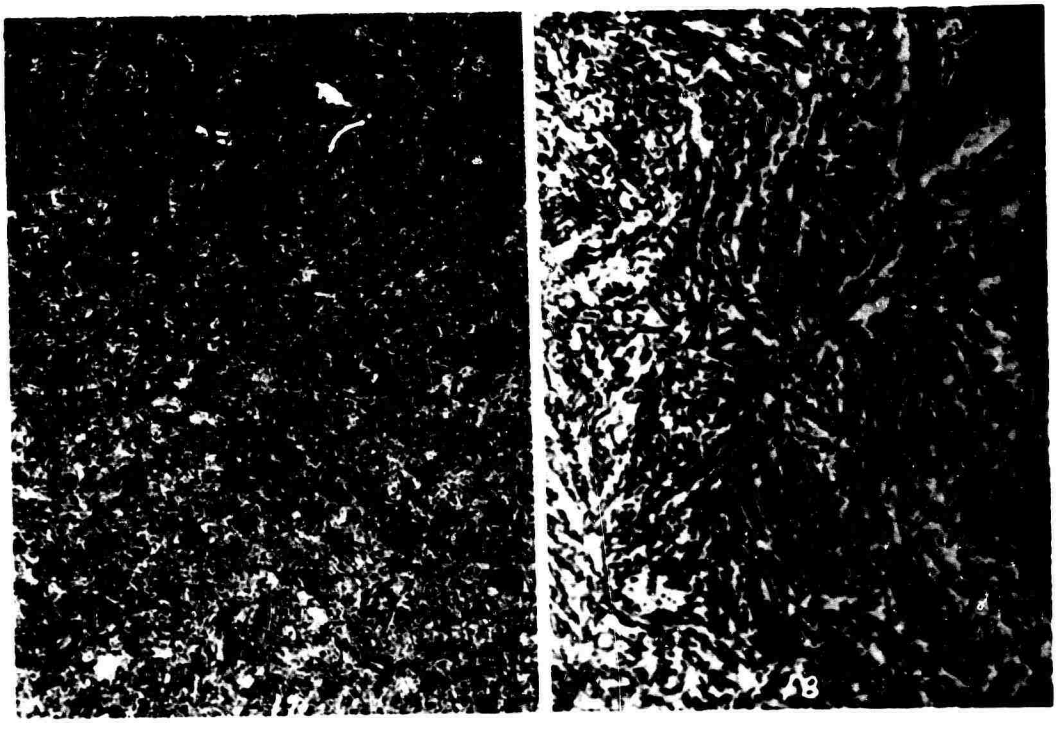
Fig. 15, X25, Unetched, C1A. Fairly clean. Inclusion small and short. Tend to form short fairly widely separated chains.
MG-282

Fig. 16, X3, $CuCl_2$ etched, C1A. Steel was decidedly banded. MG-283

Figs. 17 & 18, X100 & X1000, 1% Nital etched, C1A. Slightly segregated grain size #7. Hot worked condition. MG-263-273

Plate WA639-705





W.A.639-705

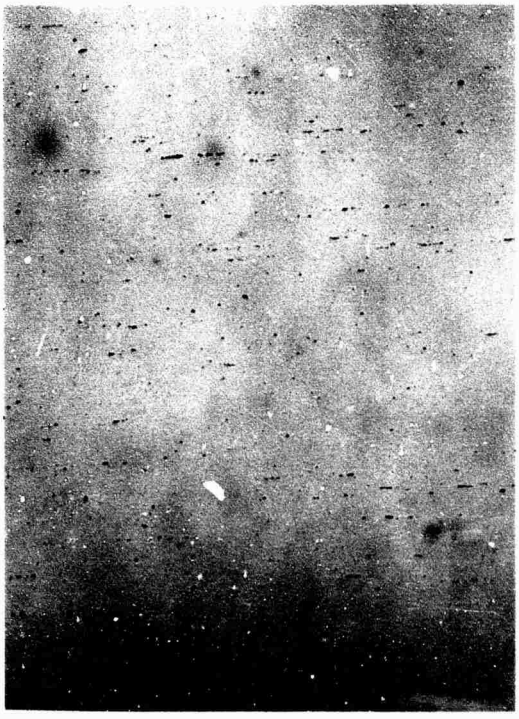
Fig. 19, X25, Unetched C2A. Fairly clean. Inclusions small, more or less separated short chains. MG-284

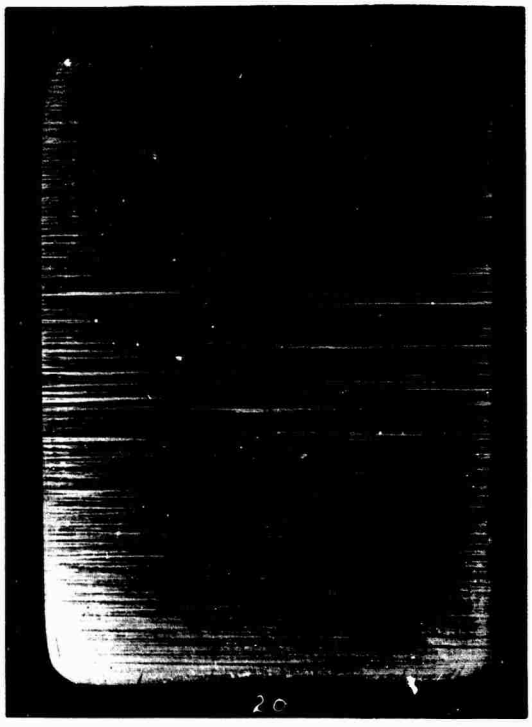
Fig. 20, X3, $CuCl_2$ etched, C2A. The steel was decidedly banded. MG-285

Figs. 21 & 22, X100 & X1000, 1% Nital etched, C2A. Slightly segregated fine grained troostite sorbite with some free ferrite.

MG-264 & 274

Plate WA 659/706



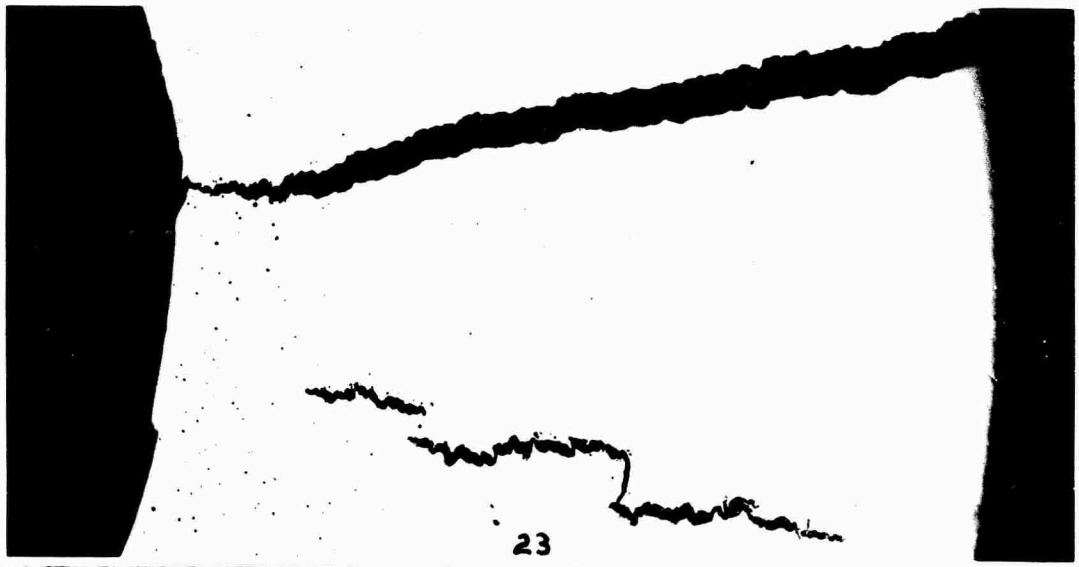


W.A.639-706

Fig. 23, X25, Unetched AVA. Trans. showing rupture cracks. MG-257

Figs. 24 & 25, X100 & X1000, AVA. Trans. near crack. Segregations due to burnt condition. MG-265 & 275

Plate WA639-707



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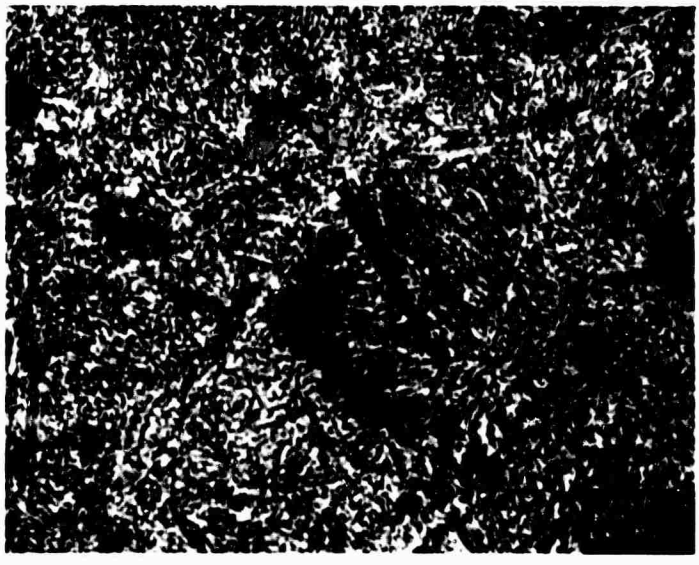


WA.635-707

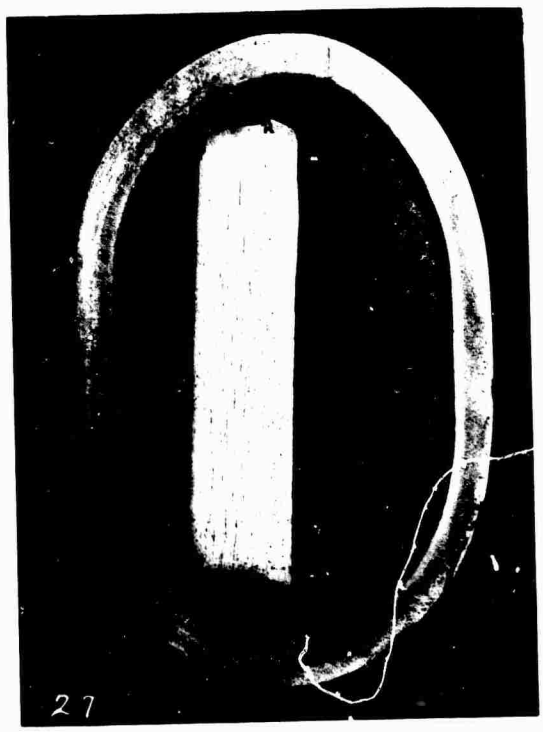
Fig. 26, X25, Unetched, Long. Sect. AVA. Steel is dirty. Inclusions were fairly small with a tendency to form chains. MG-286

Fig. 27, X3, $CuCl_2$ etched, AVA. Steel is banded. MG-287

Fig. 28, X25, $CuCl_2$ etched, AVA. Crack area. Badly segregated & burnt.
A - phosphorus segregates
B - ferrite segregates
Indicates insipient fusion - ie. Burnt metal
MG-266

Fig. 29, X25, $CuCl_2$ etched AVA. Area opposite crack. Condition similar to Fig. 28.
MG-267

Plate WA639-708



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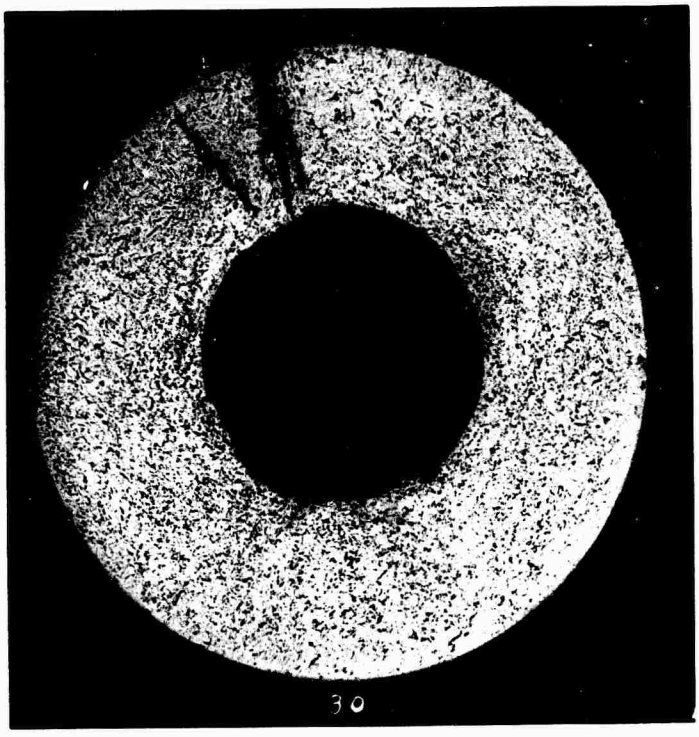
WA 639-708

Fig. 30, X5 $CuCl_2$ etched Trans. Sect. AVA. Steel showed general partial reversion to cast condition.

MG-268A

Fig. 31, X500, $CuCl_2$ etched AVA. Near crack. Showing reversion to cast segregated condition.
A Phosphorus segregates.
B - Ferrite segregates.
Indicates insipient fusion - ie. Burnt metal.

MG-268
Plate WA639-709



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310/1790

May 4, 1937 193

REPORT OF STEEL ANALYSIS

SAMPLE	C.	Mn.	Si.	S.	P.	Ni.	Cr.	Cu.	Mo.	Va.
Samples from Mr. N.L.Reed										
Ex.O. 47-A19, marked:										
Colt Stock #1	.565	.51	.280	.018	.022	.15	.92	.18	.20	Nil
Colt Stock #2	.565	.50	.275	.017	.020	.14	1.01	.18	.23	Nil
Colt Stock A	.585	.51	.290	.017	.021	.10	.95	.18	.18	Nil
Midvale Heat 6705	.455	.56	.270	.018	.022	.06	1.04	.28	.20	Nil
Fabrique Nationale	.655	.60	.325	.022	.007	.17	.92	.14	.11	.19

A. Sloan
Chemist

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WATERTOWN ARSENAL
310/1789

May 3, 1937 193

REPORT OF STEEL ANALYSIS

SAMPLE	C.	Mn.	Si.	S.	P.	Ni.	Cr.	Cu.	
Sample from Mr. N.L. Reed									
Ex.O. 47-A19 - Ruptured									
Rifle Barrel, Avis Mfg. Co.									
(thru Springfield Armory)	.60	1.03	.235	.072	.088	.42	.28	.15	
	Mo	Va							
	Nil	Nil							

A. Sloan
Chemist

copy

gmm

Report No. 122/36

May 4, 1937

Spectrographic analysis of 6 Rifle Barrel Stocks,
Ex. O. 47-A19

	AS	C1S	C2S	M1S	FNS	AVIS
Sn	Trace	Trace	Trace	Trace	Trace	Trace
Al	"	Present (low)	Present (low)	"	"	"
Co	Nil	Nil	Nil	Nil	Nil	Nil
Cb	"	"	"	"	"	"
Ta	"	"	"	"	"	"
Ti	"	"	"	"	"	"
W	"	"	"	"	"	"
Zr	"	"	"	"	"	"

For Mo, V, Cu, Si, Ni, Mn, Cr, see Chemical Report.

Reference: Plates #526, 527

S. Vigo

S. Vigo
Analyst

gmm

Report No. 327/2

May 4, 1937

Springfield Armory Rifle Barrel Steel, Ex. O. 47-A19
Partially finished .50 Cal. Rifle - Steel from Fabrique Nationale

Specimen Mark		Dia.In.	P.L.	Y.S.P.	T.S.	Elon.	Red.of Area	Break	Appearance of Fracture
FN6-L	Longitudinal	.357"	126,000	127,000	152,500	16.4	50.6	Middle third	3/4 cup, star fracture.
12-1	"	"	126,000	128,000	153,000	15.0	50.6	"	Cupped, star fracture.
3-2	"	.113"	126,000	130,000	157,000	17.5	48.5	"	3/4 cup, star fracture.
9-2	"	"	128,000	131,000	154,000	17.5	49.8	"	Full cup, star fracture.
6-T	Transverse	"	124,000	127,000	154,000	15.0	36.4	"	Cupped, laminated, non-metallic streaks between laminations.
12-T	"	"	120,000	125,000	154,500	15.0	39.2	Outer third	" " " "

Charpy Values-Round

Specimen Mark	Ft. Lbs.	Appearance of Fracture
FN-3	47.5	3/4 cup, fine granular structure.
FN-9	45.6	Cupped, fine granular structure.

Springfield Armory Rifle Barrel Steel - Rifle Barrel Steel from Midvale
Heat 6705-1 15/16" Dia. Ex. O. 47-A19

Specimen Mark		Dia.In.	P.L.	Y.S.P.	T.S.	Elon.	Red.of Area	Break	Appearance of Fracture
M1-6-1	Longitudinal	.357"	102,000	105,000	145,000	17.5	57.8	Middle third	Cupped, star fracture.
12-1	"	"	100,000	104,000	142,000	17.1	56.3	"	3/4 cup, star fracture.
6-2	"	.113"	Curved		140,500	17.5	52.2	Outer third	3/4 cup, pitted.
6-3	"	"	98,000	101,000	140,000	22.5	49.7	Middle third	Full cup, pitted.
6-T	Transverse	"	95,000	99,000	136,500	16.3	34.0	"	Cupped, laminated, non-metallic streaks between laminations.
12-T	"	"	80,000	96,000	136,500	17.5	27.6	"	" " "

Charpy Values-Round

Specimen Mark	Ft. Lbs.	Appearance of Fracture
M1-12-2	41.0	Cupped, crystalline, fan structure radiating from non-metallic area near outer edge of fracture.
M1-12-3	35.5	Break at corner of notch, crystalline, fan structure radiating from non-metallic area near outer edge of fracture.

Springfield Armory Rifle Barrel Stock - Colt Stock #1, As received from mill - 1 3/16" (Dia. Ex. O. 47-A19 (O.D.

Specimen Mark		Dia.In.	P.L.	Y.S.P.	T.S.	Elon.	Red.of Area	Break	Appearance of Fracture
C1-6-1	Longitudinal	.357"	52,000	59,000	115,000	20.7	54.8	Middle third	3/4 cup, fine grain structure.
12-1	"	"	54,000	65,000	115,500	21.0	53.7	"	Cupped, fine grain structure.
6-2	"	.113"	60,000	70,000	115,500	25.0	53.0	"	Cupped, pitted structure.
6-3	"	"	64,000	76,000	117,500	26.3	52.2	"	" " "
6-T	Transverse	"	68,000	76,000	116,000	21.3	42.0	"	Partially cupped, laminated, non-metallic streaks between laminations.
12-T	"	"	66,000	75,000	116,000	18.8	39.2	"	" " " "

Charpy Values-Round

Specimen Mark	Ft. Lbs.	Appearance of Fracture
C1-12-2	36.4	Break at corner of notch, crystalline structure.
C1-12-3	33.9	" " " " " " "

Springfield Armory Rifle Barrel Steel - Colt Stock #2, Heat Treated,
1 3/16" O.D. Ex. O. 47-A19

Specimen Mark		Dia. In.	P.L.	Y.S.P.	T.S.	Elon.	Red. of Area	Break	Appearance of Fracture
C2-6-1	Longitudinal	.357"	134,000	138,000	156,000	18.0	57.4	Middle third	3/4 cup, star fracture.
12-1	"	"	130,000	136,000	156,000	18.0	57.8	"	Cupped, star fracture.
6-2	"	.113"	136,000	139,000	159,000	20.0	51.0	Outer third	Cupped star fracture.
6-3	"	"	134,000	137,000	156,500	20.0	54.6	"	" " "
6-T	Transverse	"	122,000	128,000	154,000	16.3	40.6	"	45° break, laminated non-metallic streaks between laminations.
12-T	"	"	126,000	132,000	156,500	15.0	39.2	"	" " "

Charpy Values-Round

Specimen Mark	Ft. Lbs.	Appearance of Fracture
C2-12-2	50.5	Full cup, fine granular structure.
C2-12-3	48.9	" " " " "

Springfield Armory Rifle Barrel Steel, Colt Barrel A, after 10,000 Rounds.
Ex. O. 47-A19

Specimen Mark		Dia. In.	P.L.	Y.S.P.	T.S.	Elon.	Red. of Area	Break	Appearance of Fracture.
A6-1	Longitudinal	.252"	128,000	129,000	159,000	16.5	56.2	Middle third	Cupped, star fracture.
12-1	"	"	126,000	132,000	162,000	18.0	55.2	"	" " "
3-2	"	.113	128,000	133,000	162,000	17.5	53.5	"	Cupped, star fracture.
9-2	"	"	132,000	137,000	165,000	20.0	51.0	Outer third	" " "
Ruptured Cal. .30 M1903 Rifle #286901, Muzzle Section									
AV-8-1		.113"	92,000	98,000	125,000	17.5	53.5	Middle third	Cupped, star fracture.
-8-2		"	104,000	104,000	127,500	18.8	52.2	"	" " "

D. E. Driscoll,
Assoc, Inspector.

EROSION OF COLT MACHINE GUN BARREL A-2

Peter R. Kosting

Object

To observe effects of erosion of Colt machine gun barrel A, piece 2.

Reference - Ex.O. 47-A19

Conclusion

1. After 10,000 rounds, lands at origin of rifling were eroded smooth but accuracy was evidently higher than for other Colt barrels.

2. Metal was very uniformly sorbitic, extremely banded and very dirty.

3. Most, but not all, radial cracks when they branch follow a path initially parallel to bore and to banding, and in a direction toward the breech; the intersection of radial cracks with nonmetallics which are strung out normal to them, may be a point of weakness and may be the initial starting point of longitudinal cracks.

4. "White" layer was apparently normal; a duplex structure could be discerned.

Material

Colt Machine Gun Barrel A, piece 2, section including portion for neck of cartridge case and beginning of rifling, 1" long.

Analysis - Report No. 310/1790 - SAE 4150 Steel

C	Mn	Si	P	S	Ni	Cr	Cu	Mo
.585	.51	.29	.021	.017	.10	.95	.18	.18

Properties - Report No. 327/2

Long.	P. L.	Y.S.P.	T. S.	El.	R.A.
" 0.252	127,000	130,500	160,500	17.2	55.7
" 0.113	130,000	135,000	163,500	18.8	52.3

Heat Treatment - Colt's

Barrel fired 10,000 rounds

Velocity after 10,000 rounds: 2393 ft/sec.

Accuracy:

Keyholing: not reported assume none observed
Target pattern:

Range	100 yards Observed	(1000 in. Calculated) W. A.
E.V.	28.0 in.	7.8 in.
E.H.	16.8 in.	4.7 in.
E.S.	29.7 in.	8.2 in.

Study

Metallographic study of bore area.

Results

The condition of the bore is shown in Figure 1. The lands were eroded smooth with grooves; checking and spalling were noticeable. Figure 2 shows the extent of cracking at a cross-section of the bore. Figures 3 and 4 show the intersections of radial cracks with non-metallics strung out normal to them.

Figures 5 and 6 show the banding of this steel and the crack system where radial cracks started to spread longitudinally in a direction toward the breech. Due to the Wood's metal used for mounting the specimen, difficulty was encountered in etching the very edge. Oberhoffer's etch was used. Figures 7 and 8 show the microstructure, the former just a little distance from bore, and the latter at bore. Nital etch was used.

Discussion

This particular gun barrel stock was exceedingly banded. There exists a general but not perfect parallelism between bands and streaks of nonmetallics. The radial cracks tend to split longitudinally in one direction, and

most, but not all, branches seem to be parallel to bands and to bore. The intersection of radial cracks with nonmetallics may be a point of weakness facilitating the origin of a longitudinal crack.

The sorbitic structure is very uniform, being particularly free from large areas and streaks of ferrite.

The "white" layer is shown to be duplex.

Respectfully submitted,

Peter R Kosting

Peter R. Kosting
Chemical Engineer

Fig. 1

Both Halves of Colt Machine Gun Barrel A
(X.O. 47-A19) X3.

Section at origin of rifling.

Fired 10,000 rounds.

FIG. I

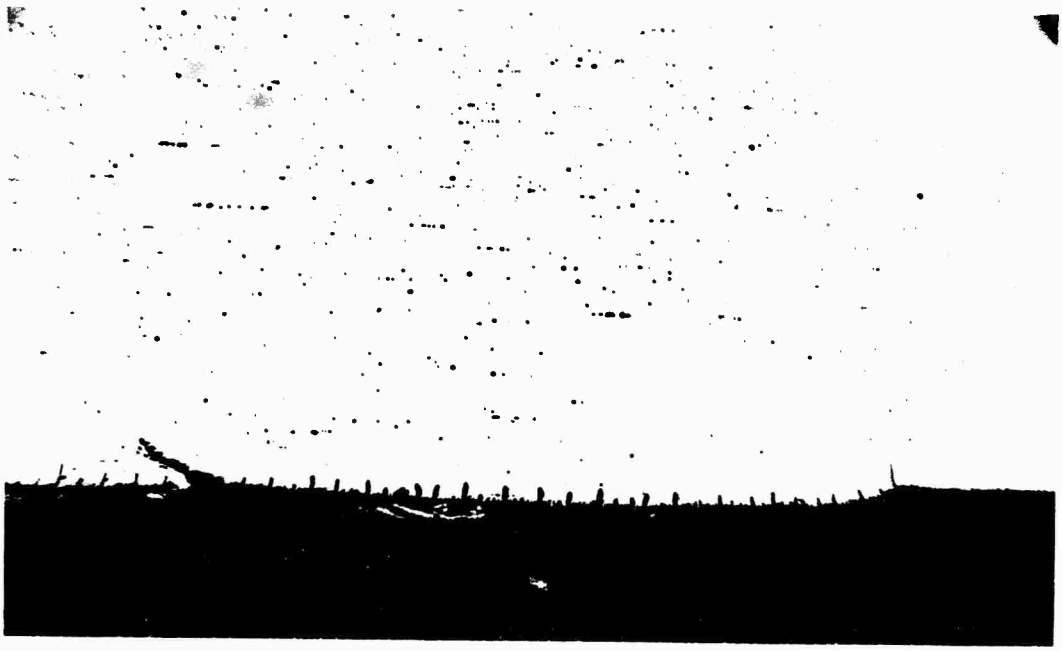


Fig.2 x15

Fig.3 x250

Fig.4 WA.639-734 x250

CRACK SYSTEM IN COLT MACHINE GUN BARREL #A 2 (X.O. 47 A 19)

Fig.5 x25
Banding

Fig.6 x25
Crack System

Fig.7 x1000
Near Bore

W.A.635-735

Fig.8 x1000
Bore

gmm

Report No. 513/76

June 10, 1937

Macrographic Test

Springfield Armory Rifle Barrel Steel

Ex.O. 47-A19

Material: Six types of Rifle Barrel Steels

These steels were submitted for macro-examination with the following objects in view:

a. determination of the quality of foreign and commercial steels used for rifle barrels in comparison with Springfield Armory standard grades.
b. development of the proper specification for the material.

The six steels considered are:

1. Partially finished .50 Cal. Rifle Steel from Fabrique Nationale - Stamped FN

2. Colt .30 Cal. Rifle Barrel after ten thousand rounds - Stamped A

3. Rifle Barrel Steel from Midvale Steel Company, Bar #1, Ht. 6705R, Dia. 1 15/16" per specification SXS 16 (Springfield Armory) - Stamped M1

4. " " " Bar #2 - Stamped M2

5. Colt Rifle Barrel Stock #1, as received from mill, O.D. 1 3/16" - Stamped C1

" " " Stock #2, Heat treated - Stamped C2

6. Ruptured .30 Cal. M1903 Rifle #286901 muzzle section, manufactured by Avis, (see W.A. 474.6/145 and Springfield Armory report of accident No. 206) - Stamped AV

Results of short time etch (10 minutes) in Standard Watertown Arsenal Solution

HCL	-	38%
H_2SO_4	-	12%
water	-	50%

FN Steel

Transverse Section Stamped FN-B - The section shows a fairly prominent dendritic structure from the outside to the bore with very little interdendritic non-metallics and no heavy pitting from the acid reaction.
Longitudinal Section Stamped FN-C - The metal shows very fine longitudinal streaks at the outer portion gradually changing to a slightly more prominent similar structure near the bore. The partially finished smooth bore shows no defects.

A Steel

Transverse Section Stamped A-B - The metal shows a very well worked dendritic structure with slightly more prominent interdendritic material than the FN Steel. Very short radial cracks extend from the bore surface (after firing) for one, two hundredths of an inch.
Longitudinal Section Stamped A-C - The longitudinal streaking is fairly prominent, some of the sulphide and phosphide segregations extending for 1/4". The heat checking in the bore is only found on the lands.

M1 Steel

Transverse Section Stamped M1-B - The steel has been well forged and heat treated. The material at the outer portion of the disc shows a very homogeneous and fine macrostructure. The amount of segregation in the center is greater than any of the other steels.
Longitudinal Section Stamped M1-C - As noted in the transverse disc the structure at the outside is clean and uniform but it changes quite suddenly to a heavier streaked section (sulphide and phosphide streak) that is very prominent at the extreme center. Some of the elongated sulphides appear to be about 1" long.

M2 Steel

Transverse Section Stamped M2-B - This disc was taken from part 2 of the lot described above and shows practically the same macrostructure. It does, however, show a slight amount of decarburization at the extreme outside.

C1 Steel

Transverse Section Stamped C1-B - The metal appears to be very fine, clean and uniform near the outside with relatively little change in amount of non-metallics near the center. The extreme center has a small amount of non-metallics which will be completely removed in forming the bore.
Longitudinal Section Stamped C1-C - The metal has quite uniform characteristics at the outside with a tendency toward streaks near the center. The streaks are not as prominent as in Steel M1.

C2 Steel

Transverse Section Stamped C2-B - The metal of this disc has the same

general characteristics as disc C1 but the ferrite bodies, "stems of the dendrites", and the interdendritic material are more in contrast because of the heat treatment given the steel. The small amount of segregation in the center will be removed in forming the bore of the rifle.
Longitudinal Section Stamped C2-C - This section shows a very fine and very uniform macrostructure at the outside gradually changing to a somewhat streaky formation with dark areas but fairly high in sulphur and phosphorus.

AV Steel

Transverse Section Stamped AV-B - This section was etched the same length of time as the other pieces, but is very much over-etched. The sulphur and phosphorus are very high, correspondingly the rate of solubility in acid is high. This section shows a rather coarse dendritic structure with very heavy interdendritic sulphide and phosphide areas.
Longitudinal Section Stamped AV-C - The amount of segregation in the longitudinal streaks is quite heavy. The general dark color of the piece after etching is the result of higher than the average sulphur and phosphorus.

All of the above sections were macroetched further to give a total of twenty-five minutes in the etching bath in order to make a more suitable surface for photomacrographing and to study the possible changes occurring. The results of this etching did not in any way change the characteristics described after light etch.

Baumann Prints

FN Steel Baumann Prints - The transverse print shows a uniform pale color throughout with no concentration at the center. The longitudinal print indicates very little streaking of sulphide segregations.

A Steel Baumann Print - The cross section shows very fine and uniform distribution of sulphur and phosphorus with very little tendency for streaks in the longitudinal band.

M1 Steel Baumann Prints - The print is somewhat darker and has a coarser distribution. The longitudinal section shows very prominent and pronounced sulphur and phosphorus streaks in the central portion.

M2 Steel Baumann Print - Equivalent to M1 Steel.

C1 Steel Baumann Prints - The print from the transverse section is very uniform throughout with a fine dissemination of sulphur and phosphorus. The longitudinal print shows a slight amount of streaks at the extreme center.

C2 Steel Baumann Prints - The prints are the same as C1.

AV Steel Baumann Prints - The transverse print is very dark with some quite coarse spots near the bore. The longitudinal print shows large sulphide and phosphide areas and wide streaks throughout.

Macrostructure:

Steel	FN	-	Satisfactory
"	A	-	"
"	C1	-	"
"	C2	-	"
"	M1	-	Barely passable
"	M2	-	" "
"	AV	-	Unsatisfactory

Reference: See Photomacrographs 740-8 and 740-9, and reproductions of Baumann Prints 740-8B and 740-9B.

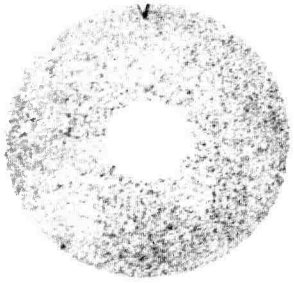
Recommendations:

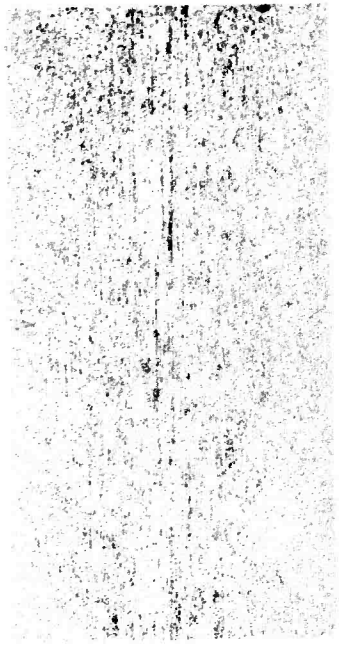
If the steel used at Springfield Armory is to be considered the equal of commercial or foreign steels, a change in specification is apparently necessary. The sulphur and phosphorus limit should be somewhat lower (unless its dissemination is satisfactory) and the standard for macro-etching should be of a grade that will not allow segregations, especially in the part of the bar that will form the bore of the rifle.

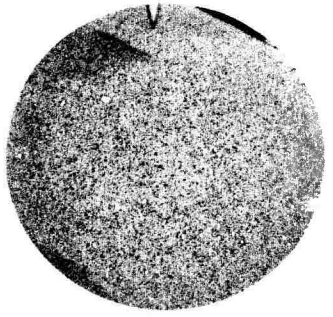
N. L. Reed

N. L. Reed

ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL.
RIFLE BARREL STEEL 6-15-37
740-8







FN-C FN-B A-C A-B MI-C MI-B

RIFLE BARREL STEEL

W.A. 740-88

ORDNANCE DEPT. U.S.A.
WATERTOWN ARSENAL
RIFLE BARREL STEEL
6-15-37 740-9

M2-B C1-C C1-B C2-C C2-B AV-C AV-B

RIFLE BARREL STEEL

W.A. 740-98

ORDNANCE FORGINGS

Information Requested for Each Forging

1. - Mark of identification and heat number.

2. - Chemical composition.- Process - Basic | Open Hearth
Acid | Electric Furnace

3. - Mold - Shape and dimensions in detail, accompanied by drawing.

4. - Method of Casting

Cast from (a) top of ladle
(b) bottom of ladle

into (a) top of mold
(b) bottom of mold.

5. - Hot Top - Data for the cast metal:

Shape and size
(a) cross section
(b) length
(c) weight

If the steel was bottom poured, please give weight and dimensions of sinkhead.

6. - Ingot

-Weight
(a) with hot top
(b) without hot top

-Shape - corrugated, square, fluted, etc.

-Dimensions
(a) Maximum diameter at top
(b) Minimum " " "
(c) Maximum diameter at bottom
(d) Minimum " " "
(e) Nominal length of ingot
(f) Effective length of ingot (length excluding hot top or sinkhead)

A sketch is very desirable; if available, it will simplify the description.

7. - Discards

I. Dimensions and weight

(a) from top (indicate whether or not hot top is included in figures)
(b) from bottom
(c) other discards

II. Indicate clearly at what stage of manufacture each discard was made.

8. - What was the approximate temperature of the ingot

(a) at time of stripping?

(b) at time of placing in heating furnace?

9. - Indicate approximately the period of time from the moment of stripping to the moment of placing the ingot into the heating furnace.

10. - At the time of placing the ingot in the heating furnace, was the ingot considered to have a uniform temperature throughout, or was the center considered to be at a higher temperature? If so, indicate the approximate difference in temperatures between the central part and the outside.

11. - Indicate for each heating operation approximate temperature of heating furnace at the time of charging the metal.

12. - Indicate for each heating operation

(a) time for bringing up to temperature

(b) time held at temperature

13. - Indicate for each heating operation temperature of metal leaving the furnace to be hot-worked.

14. - Hot-working operations and their sequence: Was hot-working carried out

(a) only under press
(b) " " hammer
(c) " " rolls
(d) first under press and then under hammer
(e) " " hammer " " " press
(f) " " rolls " " " press or hammer

15. - Number of heats required for working:

(a) under rolls
(b) " press
(c) " hammer

16. - Description of the method of hot-working (character of die used, etc.)

17. - Type (and name of manufacturer), capacity and other essential characteristics of the rolls, presses or hammers used.

18. - Was forging upset during manufacture? If so, at what stage and to what dimensions (cross section and length)?

19. - Indicate the actual dimension of the metal piece to which the reduction was effected in each of the successive operations mentioned above in (14):

(a) cross sectional dimensions
(b) length

20. - Indicate approximate temperature of the metal at the time each hot-working operation was stopped.

21. - Manner of cooling (or heating) after the last hot-working operation, including data on:

(a) cooling medium
(b) initial temperature of the cooling operation
(c) final temperature of the cooling operation
(d) period of time required for cooling to the final temperature

22. - Heat treatment:

Give for each step of heat treatment the following information, stating also the treatment that preceded or followed the machining operation (turning outside, boring, etc.) on the forging:

(a) furnace temperature at time of placing forging in furnace
(b) time for bringing up to treatment temperature
(c) treatment temperature
(d) time of hold (soaking) at the temperature in (c)
(e) cooling: (1) manner
(2) medium
(3) time
(f) temperature to which forging was cooled.

23. - Indicate number of forgings or billets made from the same ingot.

24. - If several billets or forgings are made from the same ingot, indicate:

(a) The relative position of each billet in the ingot

(b) The relative position of each forging in the ingot.

25. - If several forgings are made from the billet indicate their relative position in it.

26. - For each of the billets and forgings indicate the mark showing which of its ends was the nearest to the bottom of the ingot. (A sketch may assist the description).

27. - Indicate the position of every test metal slab or disc by giving <u>their distance</u> from the extreme end of the rough forging, which is nearest to the bottom of the ingot. (Sufficient data are desired to determine approximate location of the test metal slab in the ingot from which it originated).

ISSUE OF 7-1-36

5TH REVISION