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Armor Plate

The Effect Of Normalizing Armor Plate Ingots For Homogeneous Plate

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The Effect of Normalizing Armor Plate Ingots For Homogeneous Plate

Object

To determine the effect of the standard centrifugal casting normalizing treatment (28 hrs. at 1150°C., air cool; 9 hrs. at 950°C., air cool; 9 hrs. at 850°C., furnace cool) upon the quality of homogeneous armor resulting therefrom.

Abstract

The normalizing treatment did not increase the ballistic limit of the plates. Plates drawn at 1150°F. (620°C) were more ductile and "buttoned" less than similar plates that did not receive the normalizing treatment, but at a ballistic limit, approximately 100 f.s. less than the plates that were not normalized. Reheat treatment, consisting esentially in a lower draw (1000°F), (about 535°C) did not increase the ballistic limits of the normalized plate but did result in considerable "buttoning" of the plates under fire.

References:

(a) 95th Partial Report of Test, Light Armor Plate, A.P.G., 3 Jan. 1935.

(b) 9th Partial Report of Test, Light Armor Plate, A. P. G., 8 Jan., 1935.

(c) Heat Records, Watertown Arsenal, Ingots 12-600 and 12-614.

(d) Expenditure Orders 67-A21 and 67-A22, Watertown Arsenal.

The excellent ductility produced in gun castings by means of long-time high temperature normalizing treatments made it seem advisable to investigate the possibilities of the method as applied to armor plate. It was felt that if the ductility of plate could be increased without loss of ballistic resistance plates might be obtained with greatly increased resistance to spalling, buttoning, and cracking.

Two ingots were made with the same foundry practice, particular effort being made to reduce variations in foundry practice to a minimum. Top and bottom discs were taken for macro-etching and the chips for chemical analysis were taken from the bottom surface of the top disc midway between the center and the outside wall of each ingot. The macro-etched discs of ingot 12-600 before and after normalizing, and of 12-614, are shown in figs. 1 to 6 inclusive. The chemical analyses of the ingots is as follows:

Ingot	C	Mn	P	S	Si	Cr	Mo	V	Ni
Watertown Arsenal									
12-600	.54	.55	.008	.015	.21	1.29	.67	.23	--
12-614	.53	.50	.015	.019	.17	1.25	.54	.23	--
Henry Disston & Sons, Inc.									
12-600	.52	.56	.016	.016	.18	1.20	.86	.26	.07
12-614	.51	.42	.013	.016	.14	1.21	.56	.29	.09

Ingot 12-600, after top and bottom discards had been taken, was subjected to the following homogenizing treatment:

Temp	Time at Temp	Cooling
1150°C	28 hrs.	Air
950°C	9 "	"
850°C	9 "	Furnace

Ingot 12-614 was not treated.

Both ingots were rolled into plates 1/4", 3/8", and 1/2" thick by Henry Disston & Sons, Inc., under W.A. Purchase Orders 7091 and 8542 and the plates were heat treated as follows: (a) Oil quench from 1650°F (896°C); (b) Draw at 1150°F (620°C) for 2 hrs., followed by air cooling.

The plates were then shipped to the Aberdeen Proving Ground for ballistic test under Spec. 31 and Spec. AXS54. The results obtained were as follows:

Ballistic Limit - F.S.-Striking Velocity

	Spec.31	Spec.AXS-54	Increase in B.L. Shown by Non-Homogenized Ingot
1/4" Plate			
7091C2(12-600)	---	1135	
12-614-1	1631	1247	
12-614-2	1545	1229	43F.S.
3/8" Plate			
7091B2(12-600)	---	1762	
12-614-3	2234	1877	
12-614-4	2178	1854	104F.S.
1/2" Plate			
7091-A2(12-600)	---	2304	
12-614-5	2685	2451	
12-614-6	2678	2445	144F.S.

Ingot 614 (not normalized) showed better ballistic resistance. However, buttons were started or thrown from all the plates of ingot 614, whereas ingot 600 showed unusual ductility and toughness.

It was, therefore, concluded that the plates of ingot 600 might be made harder, sacrificing some ductil... but with a gain in ballistic resistance. These plates were returned to Disston & Sons, where they were re-quenched from 1650°F (896°C) and redrawn for two hours at 1000°F (536°C). They were then returned to the Aberdeen Proving Ground for ballistic test, where the following results were obtained:

Ballistic Limit - F. S. Striking Velocity

	Spec.31	AXS54	Change From Previous Test Under AXS54
1/4" Plate			
7091C2(12-600)	1557	1176	-19F.S.
*7091C2 "	1529	1173	(-22) "
3/8" Plate			
7091B2 (12-600)	2107	1844	+82 "
*7091B2 "	2082	1755	(- 7) "
1/2" Plate			
7091A2	2776	2370	+66 "
*7091A2	2721	2326	(+22) "

* - B.L. on rear surface of plate

It is apparent that the lower draw temperature decreased the resistance of the 1/4" plate and slightly increased the resistance of the 3/8" and 1/2" plate. However, during this test all plates threw buttons from both sides.

A draw temperature between 1000°F and 1150°F might have prevented the spalling that developed with the 1000°F draw but would not have increased the ballistic resistance.

As a result of these tests it seems logical to conclude that the extra expense and time required to normalize homogeneous armor plate ingots is not justified. While it is quite true that increased ductility was obtained when both steels were drawn at 1150°F (618°C), the decrease in ballistic limit offset this advantage. It must be assumed that the time and temperature of soaking for forging and rolling is, at present, sufficient to accomplish all practical homogenizing that is necessary. However, the increased ductility afforded by this procedure might be sufficient to prevent spalling and buttoning from the core of face hardened plates. It is felt, therefore, that the use of such treatment for face-hardened plates should be investigated.

Respectfully submitted,

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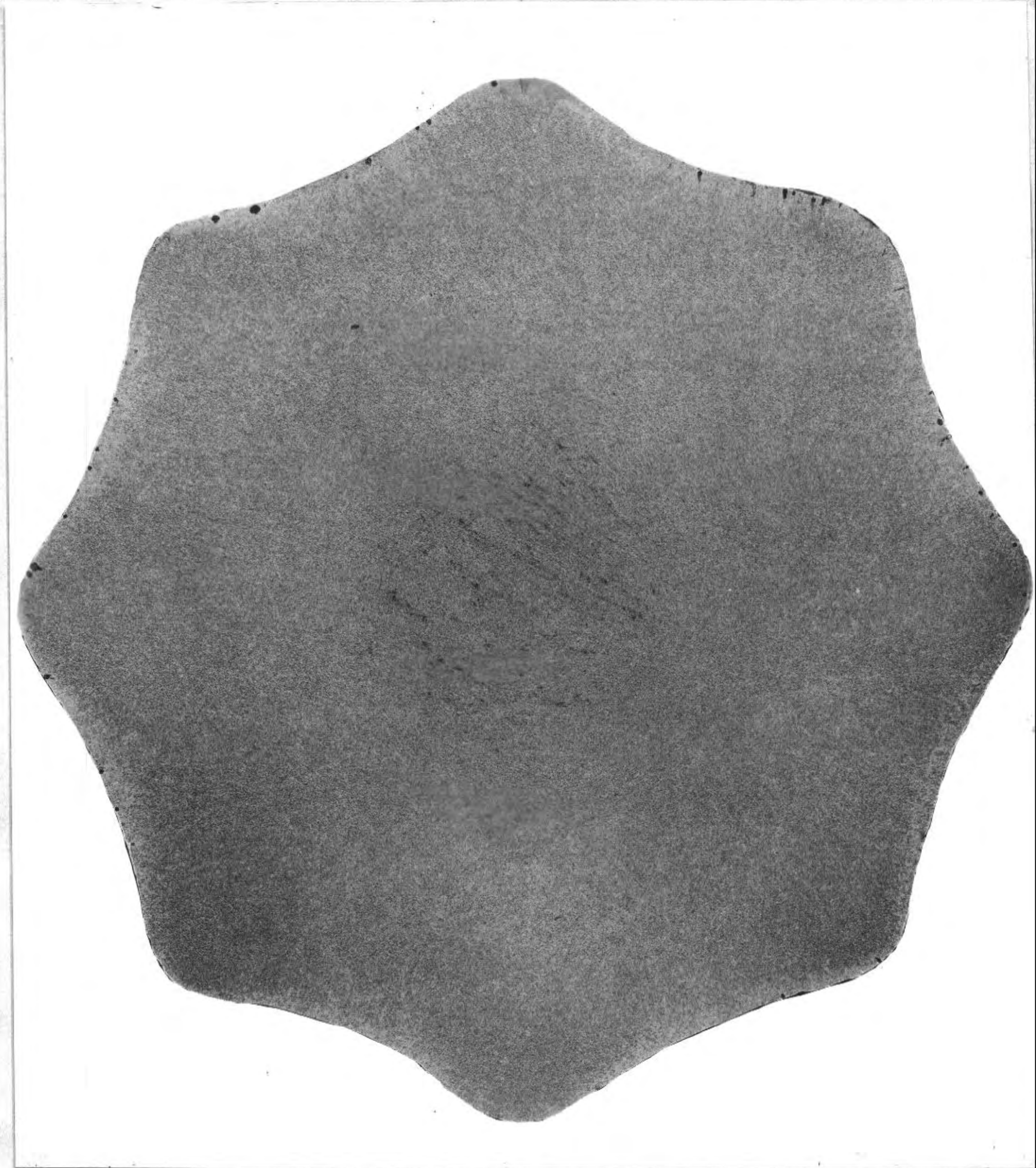

FIG. 1
HT. 600T. 226-208
AS CAST

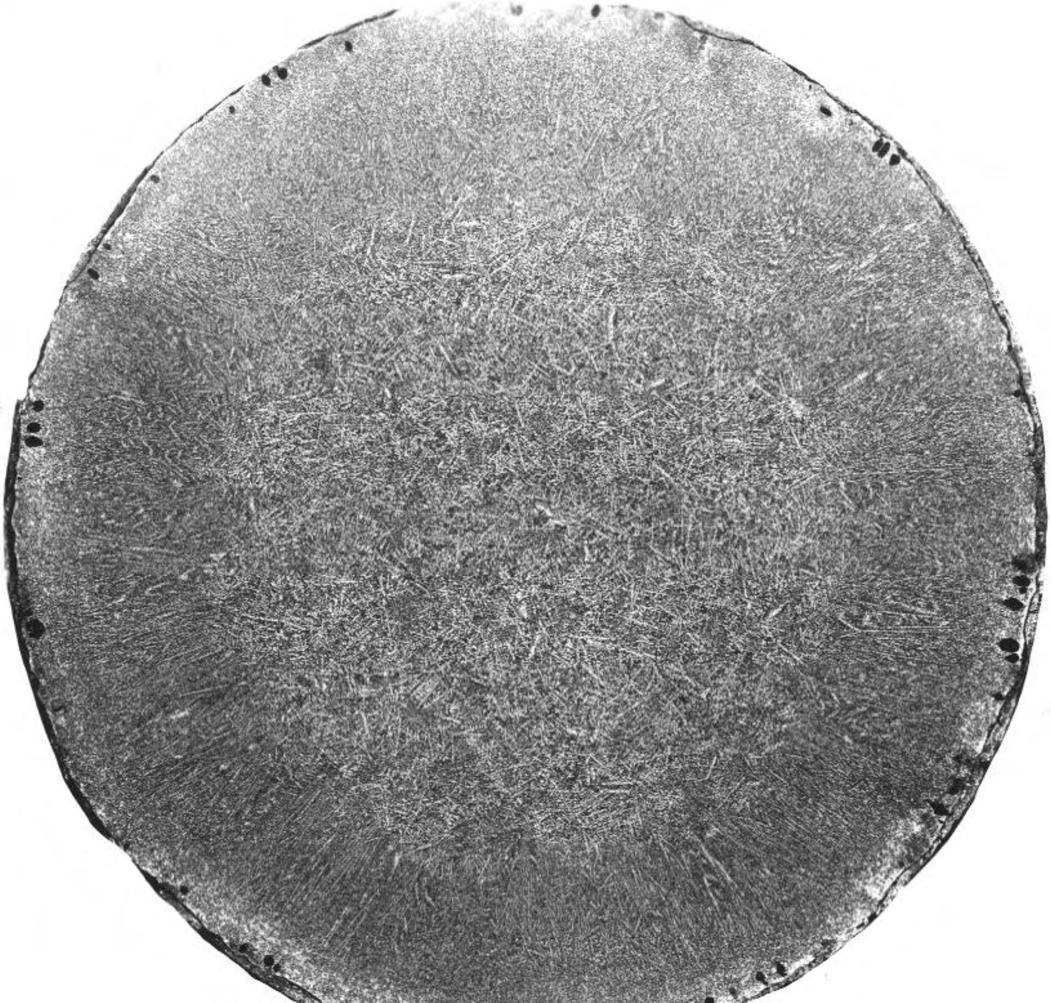

FIG. 2

HT. 600B 226-209

AS CAST

3

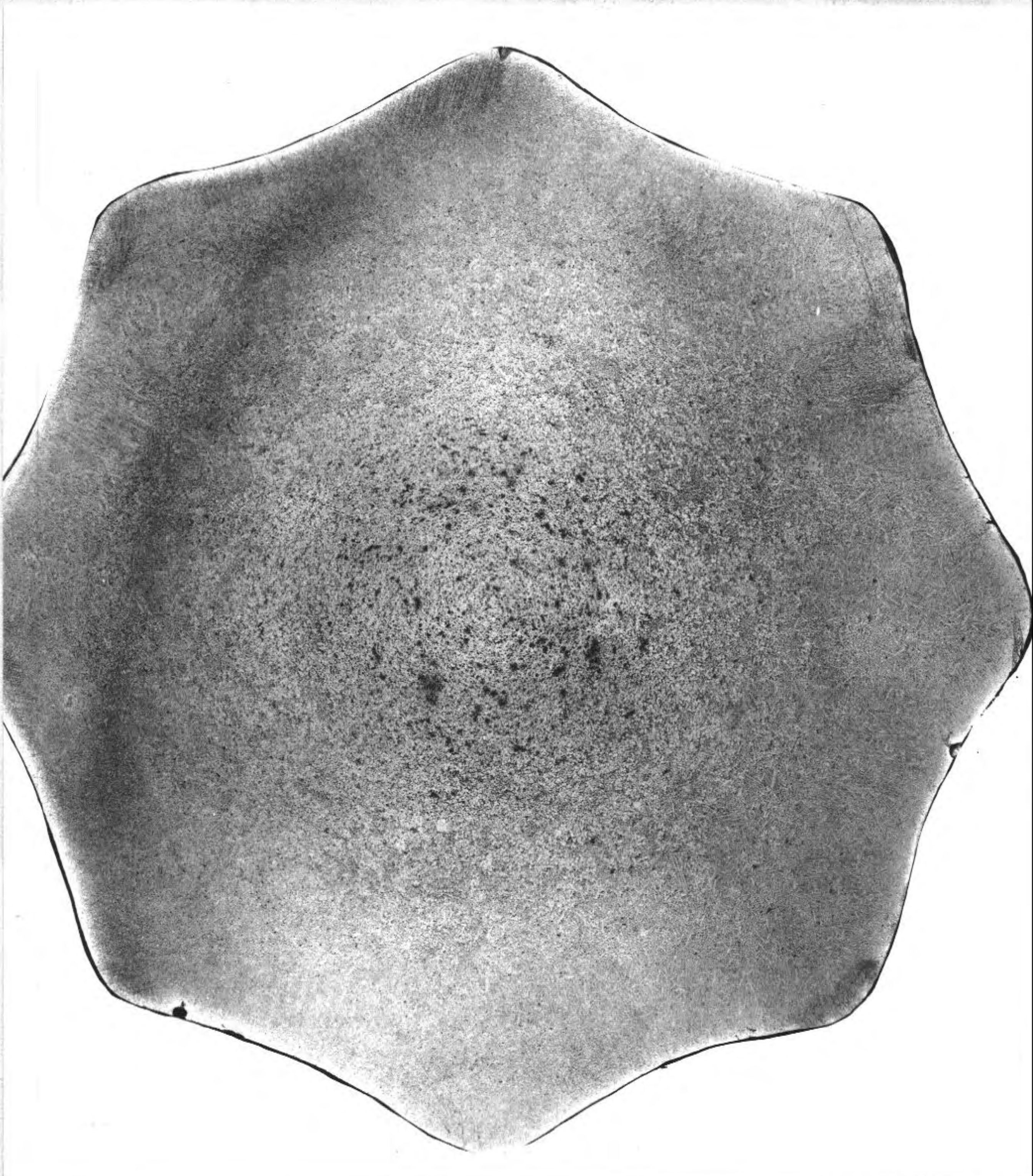

FIG. 3

HT. 600T. 226-218

AFTER HEAT TREATMENT

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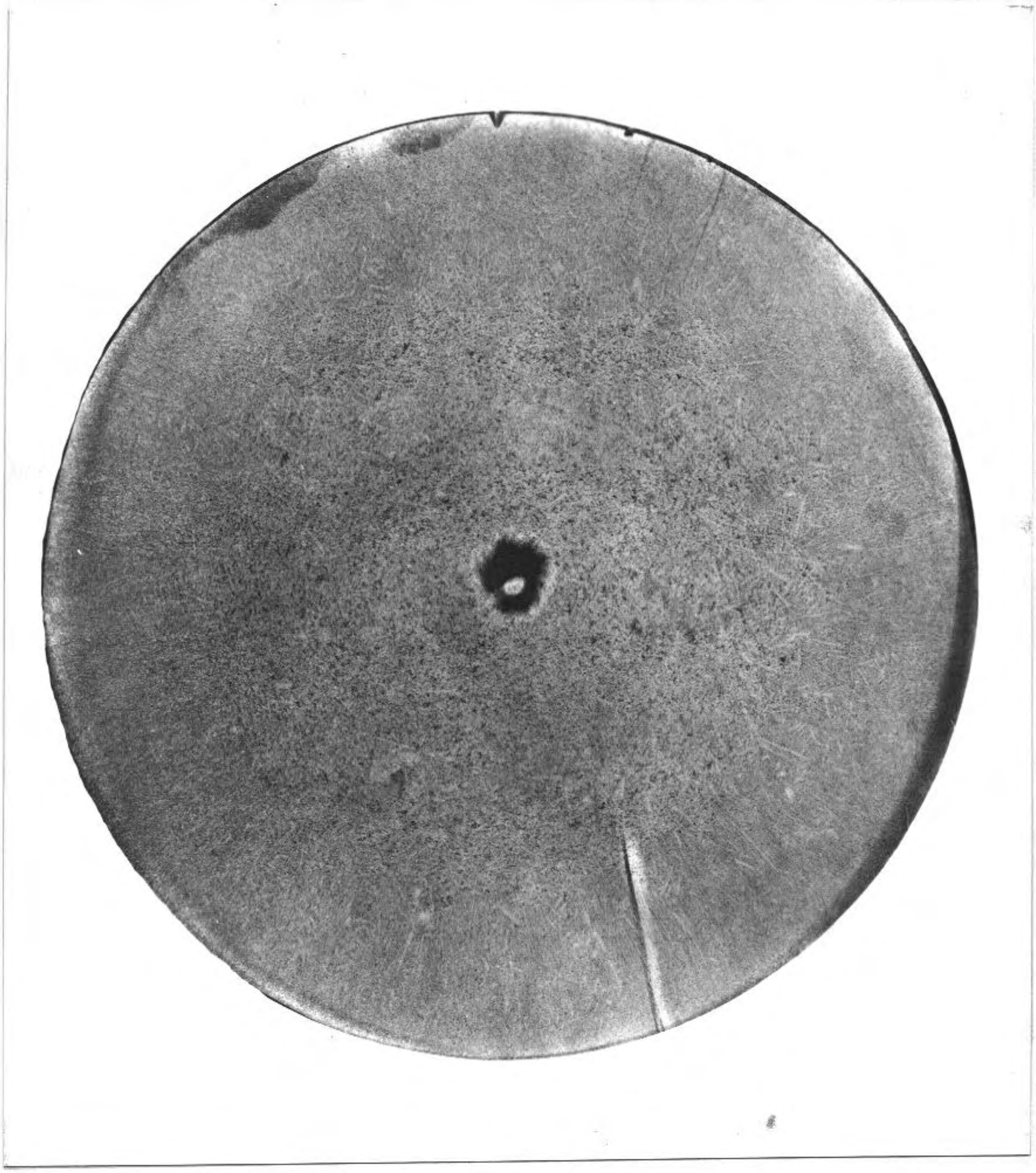

FIG. 4

HT. 600B 226-217

AFTER HEAT TREATMENT

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5

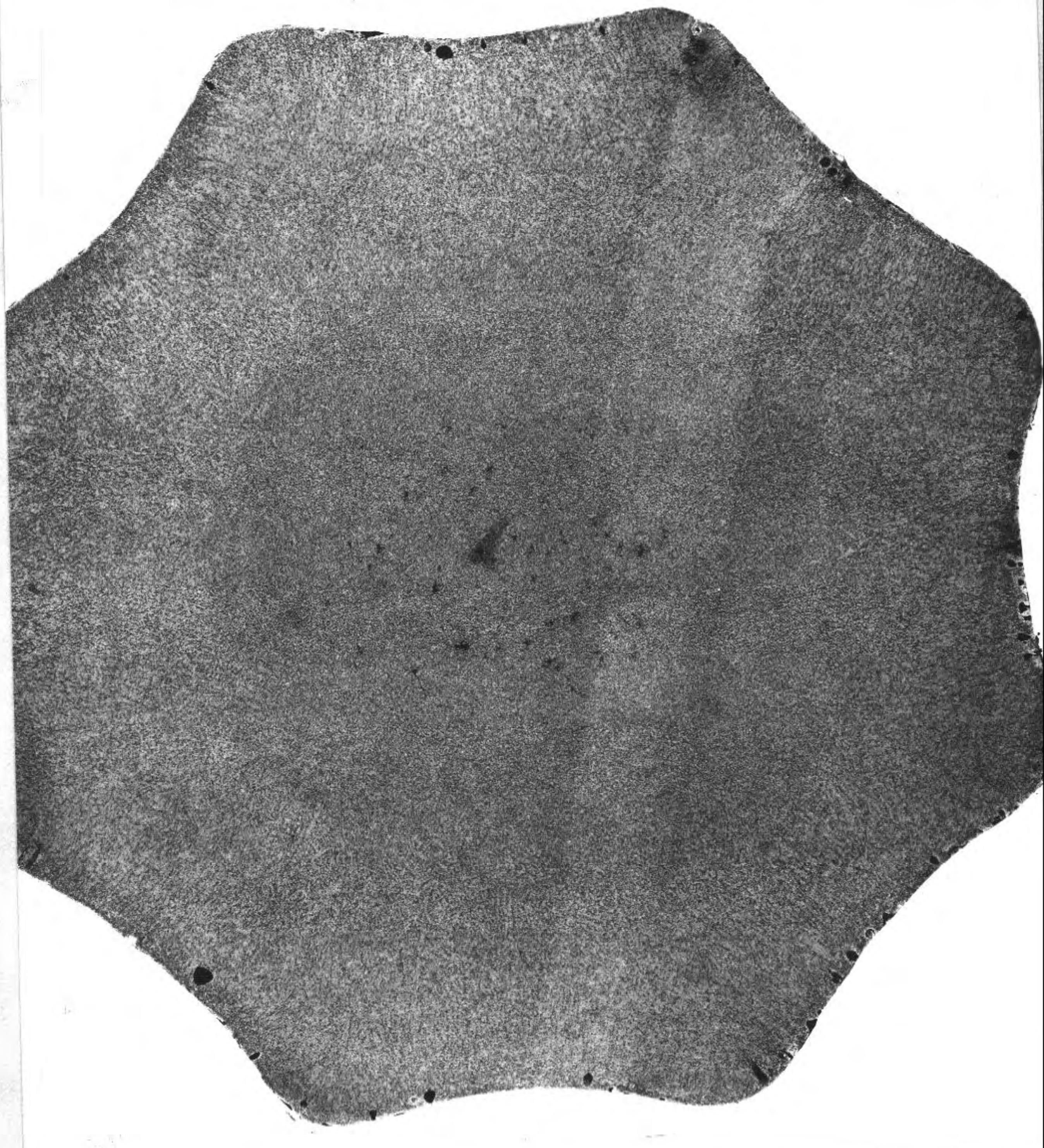

FIG. 5

HT. 614T. 226-286

AS CAST

6

FIG. 6

HT. 614B 226-285

AS CAST