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O T T A W A

December 2, 1946.

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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2146.

(Subsequent to Investigation Reports)  
(Nos. 1991, 2002, 2014, 2015, 2105 )  
(and 2035, January-October, 1946. )

Research on Optimum Thread Form for Proposed  
Anglo-American-Canadian Screw Thread.

PART VII. - Investigation of Heat Treatment to be  
Used for Threaded Studs.

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(This research is performed in )  
( collaboration with the National )  
( Bureau of Standards, Washington, )  
( U. S. A., the National Physical )  
( Laboratory, Teddington, England, )  
( and the National Research Council, )  
( Ottawa, Canada. )

(Copy No. 8.)

### Abstract

In order to determine the minimum hardness variation attainable in the quenching treatment for steel to be used in the screw-thread research program, a hardness analysis has been carried out on a number of quenched bars of Atlas steel S.P.S. 245. This steel is comparable, as regards hardenability, to steel S.A.E. 6150, the type which is to be used in the screw-thread research.

Two quenching methods have been compared: in the first, bars of 1-inch diam. x 26 inches length were quenched in a vertical position without a shield; in the second, bars of identical size were quenched with a thin cylindrical shield in order to obtain uniform cooling effect in transferring specimens from the furnace to quenching tank.

CANADA

Bureau of Mines

Mineral Dressing and  
Metallurgy Division

Physical Metallurgy  
Research Laboratories

DEPARTMENT  
OF  
MINES AND RESOURCES

Mines and Geology Branch

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Origin and Purpose of Investigation:

At a Screw Thread Research Committee Conference held in the Physical Metallurgy Research Laboratories, Ottawa, on August 22-23, 1946, it was agreed that for comparison tests of different thread forms in fatigue a homogeneous steel is required in order to eliminate the effect of undesirable variables. In order to obtain the requisite heat-treated homogeneous steel, it was decided that a series of experiments would be performed at the P.M.R.L. to establish

(Origin and Purpose of Investigation, cont'd) -

the conditions of satisfactory laboratory heat treatment.

Due to the fact that a supply of the high-tensile material (steel S.A.E. 6150) which is to be used for Canadian studs was not readily available at the time these experiments were initiated, it was decided to proceed with this work, using an alternate material. A steel favourably comparable with steel S.A.E. 6150 as regards hardenability, Atlas steel S.P.S. 245, was selected for this purpose. Bar stock of this Atlas steel was received in the annealed condition.

#### PROCEDURE:

##### 1. Preparation of Bars.

The 1-inch-diameter bar stock was cut into 26-inch lengths, so as to allow adequate material for the fixing of bars in the quenching fixture and for the cutting of 24-inch test specimens from the heat-treated bar. To facilitate the fastening of bars in the quenching fixture, two  $\frac{1}{4}$ -inch-diameter holes were drilled approximately  $\frac{3}{8}$  inch from either end of each bar. Prior to heat treatment, the bars were cleaned by means of sand blasting, also checked for alignment. A total of thirty-two bars were prepared in this manner and numbered.

##### 2. Heat Treating Experiments.

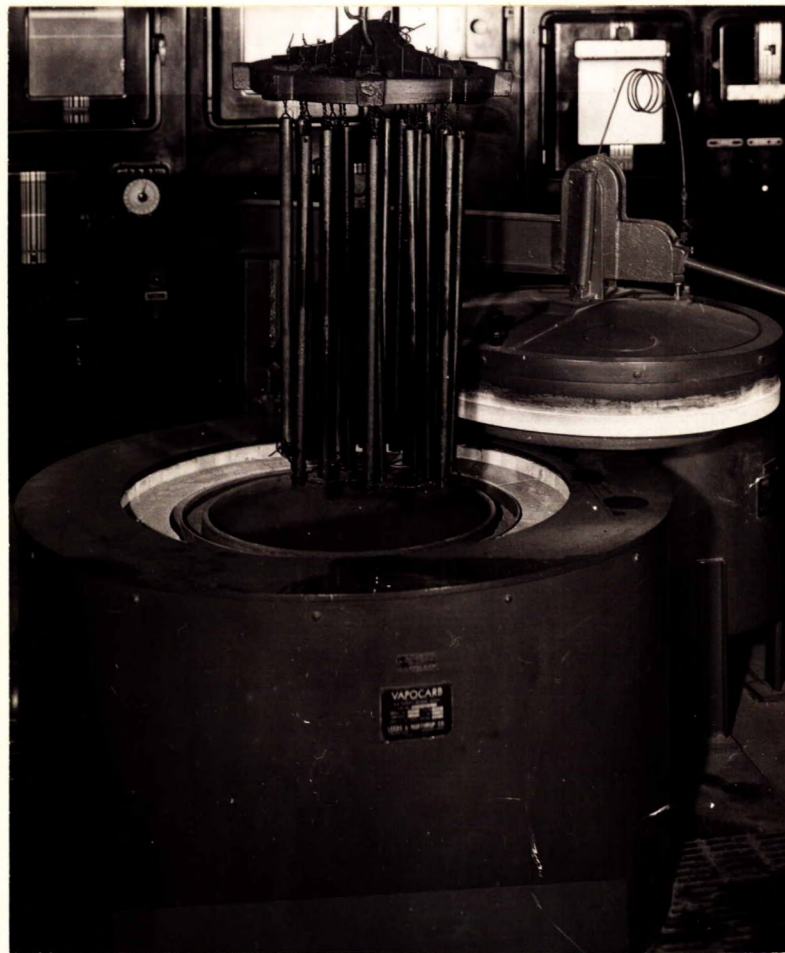
###### (a) Quenching Treatments -

Using these bars, two quenching methods were compared: in the first, twenty-two of the bars were held securely in a vertical position by means of a fixture during the heat treating operation (Figure 1); in the second, fourteen of the bars were held in a similar manner during the heat treating operation, in addition to which specimens

(Heat Treating Experiments, cont'd) -

were enclosed in a thin cylindrical shield (Figure 2) in order to obtain a uniform cooling effect in transferring specimens from the heating furnace to the quenching oil. In both experiments, the bars were arranged in the fixture as illustrated in Figure 1, with a space of approximately 2 inches between each bar. In the second experiment, a space of about 2 inches was also left between the bars and the cylindrical shield.

Figure 1.



35 K.W. VAPOCARB-HUMP FURNACE, SHOWING FIXTURE  
USED TO HOLD SPECIMENS IN POSITION DURING  
HEAT TREATMENT OPERATION.

(Figure 2 follows,  
( on Page 4.

(Heat Treating Experiments, cont'd) -

Figure 2.



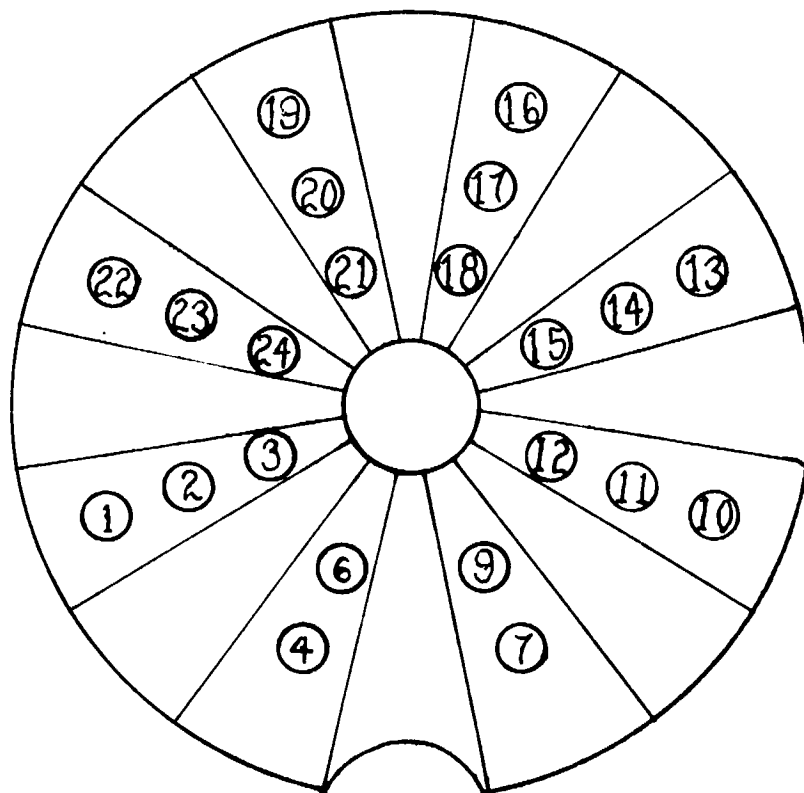
SHIELD USED TO ENCLOSE VERTICALLY HELD BAR  
SPECIMENS DURING HEAT TREATING OPERATION.

In Figure 3 is illustrated the positioning of the bars quenched without a shield, while Figure 4 illustrates the positions occupied by the bars quenched with the protective shield.

(Figures 3 and 4 follow,  
( on Page 5. )

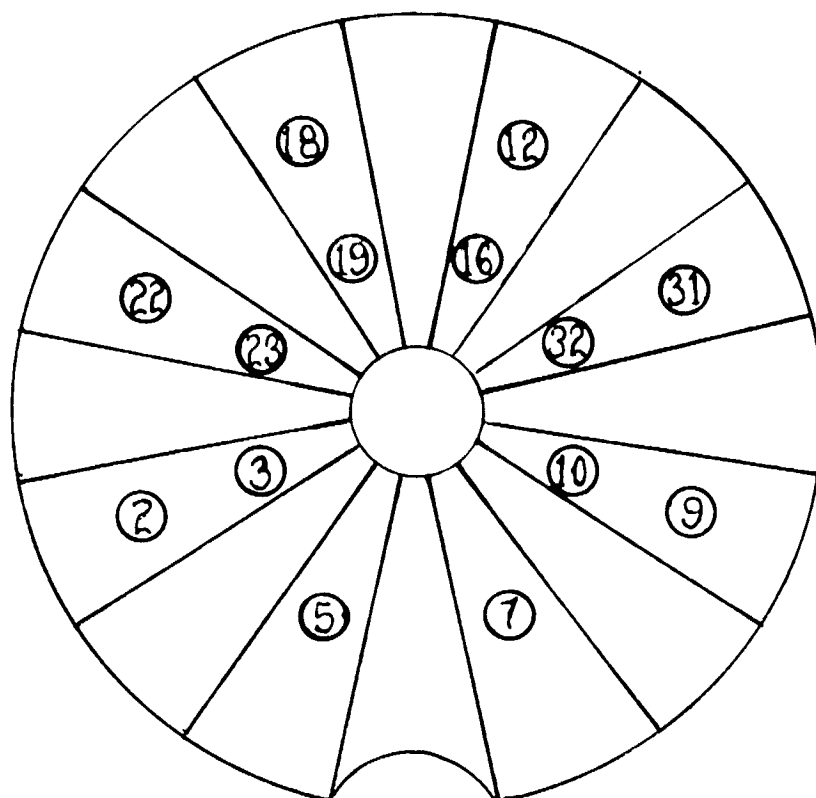
(Heat Treating Experiments, cont'd) -

Figure 3.



Position of Bars Quenched  
Without Shield

Figure 4.



Position of Bars Quenched  
With Shield

(Heat Treating Experiments, cont'd) -

In both experiments, the bars were austenitized at 1550° F. for 1½ hours in a Vapocarb furnace, then quenched in oil at approximately 120° F.

To determine the minimum hardness variation obtained, as well as to check the relative uniformity of these two quenching treatments and to ascertain whether or not the quenching treatments had afforded sufficiently rapid cooling rates to result in the production of completely martensitic structures, a number of quenched bars were subjected to hardness analysis. Procedures followed in and results of hardness testing are dealt with below.

#### (b) Tempering -

After all necessary hardness tests had been made on test specimens cut from the quenched bars, the entire lot was drawn in a Leeds & Northrup Homo furnace at 1200° F. for a period of two hours, then cooled in still air.

Hardness tests were then carried out on specimens cut from the drawn bars. Procedures followed in hardness testing, as well as the results obtained, are presented below.

### 3. Hardness Tests.

#### (a) Bars Quenched Without Shield -

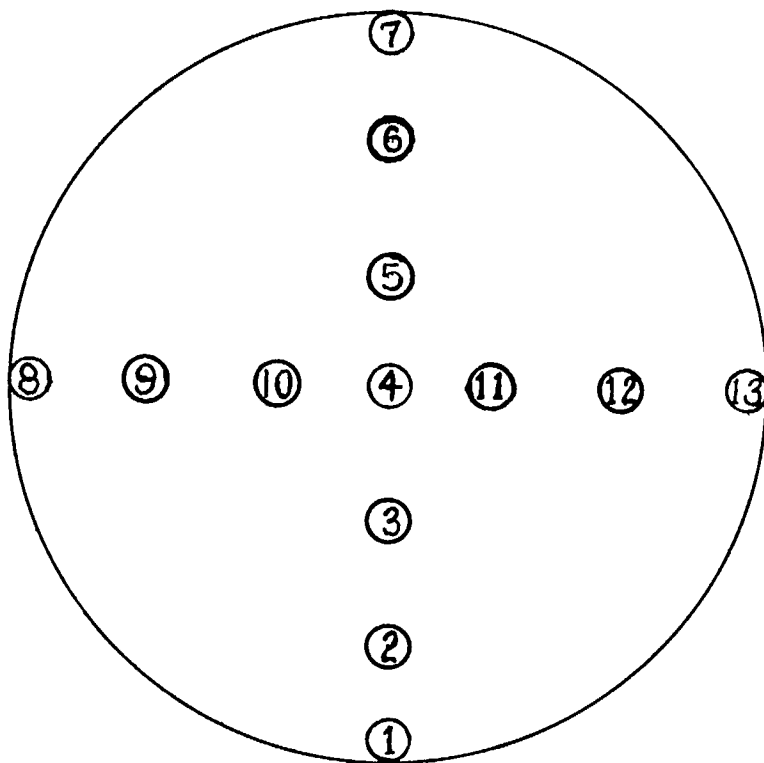
Three of the bars which had been quenched without the shield, Bars Nos. 13, 14 and 15, were selected for hardness testing. As seen from Figure 3, these three bars, because of the relative positions which they occupied during heat treatment, are representative of the quenched lot. Hardness tests were made on each bar at both ends, that is at both top and bottom, using both the Rockwell and Brinell instruments. It should be noted that, prior to hardness

(Hardness Tests, cont'd) -

testing, about 1 inch of material was cut off each end of of each bar, thus removing the drilled portions which of course cooled differently than the central portions of the bars. Results of these hardness tests are recorded in Table I.

Discs,  $\frac{3}{8}$  inch in thickness, were then cut from the centres of each of these three bars for transverse hardness tests. The hardness of these discs was checked by means of Rockwell "C" and Vickers measurements taken in two directions across the face of the disc, as indicated in Figure 5. Results are tabulated in Table II.

Figure 5.



SKETCH INDICATING RELATIVE POSITIONS OF HARDNESS TESTS MADE ON FLAT SURFACE OF  $\frac{1}{8}$ -INCH DISCS.

(Hardness Tests, cont'd) -

(b) Bars Quenched Without Shield and Tempered -

Using the same three bars, hardness tests were carried out on each after tempering, a procedure somewhat similar to that employed on the quenched bars being followed. That is, hardness tests were performed on the outside surfaces of the bars as well as on  $\frac{1}{2}$ -inch discs cut from the top, centre and bottom of each bar. The results of these tests are recorded in Tables III and IV.

(c) Bars Quenched With Shield -

Eight of the bars which had been quenched with the shield, Bars Nos. 2, 3, 9, 10, 22, 23, 31 and 32, were selected for hardness testing. As illustrated in Figure 4, these eight bars, because of the relative positions occupied by them during the heat treating operation, constitute a representative cross-section of the quenched lot. Three  $\frac{1}{2}$ -inch discs, similar to those previously described, were cut from each bar, one from each of the top, bottom and centre positions, then subjected to hardness tests. Results are given in Table V.

(d) Bars Quenched With Shield and Tempered -

The 1-inch discs referred to above were tested for hardness after tempering, readings being taken by means of both Vickers and Rockwell instruments. Hardness test results are tabulated in Table VI.

CONCLUSIONS:

1. In quenching without a shield, the maximum overall variation in surface hardness of the bars after quenching was determined to be Rockwell C-15 (Brinell 87), while the maximum overall variation in hardness of discs cut from the centres of these bars was found to be Rockwell C-3 (Vickers 41).

(Hardness Tests, cont'd) -

The same bars, after tempering, exhibited an overall maximum surface hardness variation of Rockwell C-7.5 (Brinell 40), and an overall maximum hardness variation between centres and both ends of Rockwell C-3.5 (Vickers 11).

2. In quenching with a shield, the maximum overall hardness variation between the centres and ends of quenched bars was found to be Rockwell C-8 (Vickers 115). After drawing, the maximum overall hardness variation between the centre, top and bottom portions was determined to be Rockwell C-2 (Vickers 10). From results obtained in hardness testing the quenched specimens, it is apparent that the cooling rate in quenching by this method was sufficiently rapid to result in a satisfactory martensitic structure.

3. It is concluded that, using the quenching treatment in which the shield is employed, the minimum hardness variation consistently attainable with 1-inch-diameter bars of Atlas steel S.P.S. 245 is Rockwell C-2. Inasmuch as steel S.A.E. 6150 is favourably comparable as regards hardenability to Atlas steel S.P.S. 245, it should be possible to obtain a similarly small hardness deviation with the former steel using the heat treating equipment and technique described in the foregoing.

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Ottawa, Canada,  
December 2, 1946.  
TWW:CHB:LB.

(Tables I to VI follow,  
( on Pages 10 to 31. )

TABLE I. - Surface Hardness of Quenched Bars (Without Shield).

	BAR NO. 13				BAR NO. 14				BAR NO. 15			
	H A R D N E S S				H A R D N E S S				H A R D N E S S			
	T o p		B o t t o m		T o p		B o t t o m		T o p		B o t t o m	
	R."C"	Brinell	R."C"	Brinell	R."C"	Brinell	R."C"	Brinell	R."C"	Brinell	R."C"	Brinell
	50	51.4	45	53.4	57.5	55.5	48	60.1	59.5	53.4	49.5	55.5
	51	55.5	45.5	51.4	59	55.5	48	55.5	58.5	55.5	50.5	57.8
	50	53.4	48		57.5	57.8	46.5		59.5	53.4	49	55.5
	51.5		46		60		49		54.5		49.5	
	50.5		48		58.5		50		56		49	
	55		47		60		47		53.5		48	
	58.5		46.5		60		50.5		57			
	57.5		49									
	59.5		50									
	56.5		46.5									
Maximum Hardness Variation	9.5	41	5	20	2.5	23	4	46	6	21	2.5	23
Overall Maximum Hardness Variation	Brinell 41 Rockwell C-14.5				Brinell 46 Rockwell C-13.5				Brinell 44 Rockwell C-11.5			
Maximum overall hardness variation for <u>all</u> bars)	Brinell 87. Rockwell C-15.											

TABLE II. - Hardness of  $\frac{1}{8}$ " Discs from Quenched Bars (Without Shield).

Position on Disc	B A R N O. 13		B A R N O. 14		B A R N O. 15	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers	Rockwell "C"	Vickers	Rockwell "C"	Vickers	Rockwell "C"
	10-kg. load	150-kg. load	10-kg. load	150-kg. load	10-kg. load	150-kg. load
1	599	55.5	606	56	579	54
2	592	55.5	606	56	572	54.5
3	592	55.5	606	57	585	56.5
4	585	55	585	56	572	55
5	585	55	585	57	606	56.5
6	585	55	606	56	592	55.5
7	592	54	585	56	606	56
8	599	55	585	56	592	56
9	592	55.5	592	56	585	56
10	579	55	572	56.5	599	57
11	585	55.5	592	57	613	56
12	585	55.5	599	56	613	56
13	590	54	606	56	606	55
Maximum Hardness Variation	20	1.5	34	1	41	3
Overall Maximum Hardness Variation	) Rockwell C-3 ) Vickers 41					

TABLE III. - Surface Hardness of Quenched and Drawn Bars (Without Shield).

	BAR NO. 13				BAR NO. 14				BAR NO. 15			
	H A R D N E S S				H A R D N E S S				H A R D N E S S			
	T o p		B o t t o m		T o p		B o t t o m		T o p		B o t t o m	
	R. "C"	Brinell	R. "C"	Brinell	R. "C"	Brinell	R. "C"	Brinell	R. "C"	Brinell	R. "C"	Brinell
	24	269	19	269	25	269	21	248	20	269	21	262
	21.5	248	21.5	248	25.5	241	20.5	229	21	269	22.5	241
	22		19		25		22.5		24		22.5	
	22		18.5		25		20		23.5		25	
	21.5		18.5		22		22.5		20.5		21.5	
	26		22.5		23		21		21.5		22	
	23.5		18.5		26		22.5		22.5		21	
	26		22				23		23.5		21.5	
	23		23						21			
	23		20									
Maximum Hardness Variation	4.5	21	4.5	21	4	28	3	19	3.5	0	4	21
Overall Maximum Hardness Variation	Brinell 21 Rockwell C-7.5				Brinell 40 Rockwell C-6				Brinell 28 Rockwell C-5			
Maximum overall hardness variation for all bars) Brinell 40. ) Rockwell C-7.5.												

TABLE IV. - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (Without Shield)

Position on Disc	BAR NO. 13 TOP		BAR NO. 13 CENTRE		BAR NO. 13 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10 kg. load	Rockwell "C"	Vickers 10 kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	272	26	274	25.5	274	24
2	272	26.5	274	25	274	24.5
3	270	26	270	25	274	26
4	272	26	270	25	274	25.5
5	270	26	272	25.5	270	26
6	272	27	276	26	274	26.5
7	272	26.5	272	26	274	25.5
8	270	25	270	24	274	25
9	279	27	272	26	274	26.5
10	272	26.5	272	26	274	26
11	274	26	272	25	274	26
12	274	26.5	270	25	274	25.5
13	274	27	274	24	274	25
Maximum Hardness Variation	9	2	6	2	4	2.5
Overall Maximum Hardness Variation	Rockwell C-3 Vickers 9					

TABLE IV (cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (Without Shield).

Position on Disc	BAR NO. 14 TOP		BAR NO. 14 CENTRE		BAR NO. 14 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10 kg. load	Rockwell "C"	Vickers 10 kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	272	26	274	25.5	274	25.5
2	272	26.5	274	25	274	25.5
3	274	27	⊕270	25	274	26
4	⊕272	26	270	25	274	26
5	274	⊕⊕27.5	272	25.5	⊕276	25.5
6	276	27	⊕276	26	270	⊕24.5
7	274	26.5	272	26	270	25
8	272	⊕24	270	⊕⊕24	270	26.5
9	⊕⊕279	26.5	272	⊕26	⊕⊕268	26
10	276	27	272	26	274	26
11	272	25	272	25	274	⊕26.5
12	272	25	270	25	274	25.5
13	279	24.5	274	24	274	24.5
⊕Maximum Hardness Variation	7	3.5	6	2	8	2
⊕⊕Overall Maximum Hardness Variation	Rockwell C-3.5 Vickers 11					

TABLE IV (cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (Without Shield).

Position on Disc	BAR NO. 15 TOP		BAR NO. 15 CENTRE		BAR NO. 15 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10 kg. load	Rockwell "C"	Vickers 10 kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	274	224	268	24	274	25.5
2	274	26.5	270	25.5	274	25.5
3	274	26.5	272	25	274	26.5
4	274	25	272	25	272	25.5
5	272	26.5	272	25	274	26
6	272	26	274	25.5	274	26
7	276	25.5	270	24	272	25
8	270	26	272	25	272	25
9	272	25	274	24	272	25
10	276	26	274	25	274	25
11	276	26.5	272	24.5	276	26
12	276	26.5	272	25	274	25.5
13	270	27	274	25	276	26
Maximum Hardness Variation	6	3	6	1.5	4	1.5
Overall Maximum Hardness Variation	Rockwell C-3 Vickers 8					

TABLE V. - Hardness of  $\frac{1}{2}$ " Discs from Quenched Bars (With Shield).

Position on Disc	BAR NO. 2 TOP		BAR NO. 2 CENTRE		BAR NO. 2 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10 kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	592	55	585	54	560	55
2	585	55	585	55	592	55
3	592	56	579	53	572	54
4	572	55.5	566	55	554	53
5	579	56	554	54.5	585	54
6	592	55.5	566	53	572	54
7	579	55	530	53	572	54
8	572	55	606	54	613	55
9	554	54.5	599	55.5	599	56
10	585	56	599	56	548	55.5
11	554	56.5	572	55	542	52
12	554	56	572	55.5	542	52
13	542	54	592	54	530	51
Maximum Hardness Variation	50	2.5	76	3	83	5
Overall Maximum Hardness Variation	Rockwell C-5.5 Vickers 83					

TABLE V (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched Bars (With Shield).

Position on Disc	BAR NO. 3 TOP		BAR NO. 3 CENTRE		BAR NO. 3 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	572	53	498	53	585	53
2	579	53	572	55	579	54.5
3	592	53	579	54	566	52
4	566	53.5	528	54	560	52.5
5	579	55	572	55	548	52
6	572	55.5	572	56	579	52
7	606	56	572	56	585	52
8	579	56	572	53	606	48
9	592	55	572	53	572	49
10	572	59	579	53	579	49
11	579	53	579	56	566	54
12	579	53	572	56	585	55
13	566	53.5	566	56	585	56
Maximum Hardness Variation	40	6	81	3	58	4
Overall Maximum Hardness Variation	Rockwell C-7 Vickers 108					

TABLE V (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched Bars (With Shield).

Position on Disc	BAR NO. 9 TOP		BAR NO. 9 CENTRE		BAR NO. 9 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	585	53.5	613	56	572	55
2	572	54	606	56	579	55
3	599	55	585	56	585	54.3
4	585	54	572	55	606	54
5	606	55	579	54	572	55
6	572	56	585	54	585	56
7	592	54	536	54	606	55
8	606	54	572	54	Soft spot. "	53
9	572	54	572	53		53
10	585	54.5	579	54	562	53
11	606	55	585	55.5	572	54
12	599	56	579	55.5	579	56
13	579	55.5	585	54	599	56
Maximum Hardness Variation	34	2.5	77	3	44	3
Overall Maximum Hardness Variation	Rockwell C-3 Vickers 77					

TABLE V (CONT'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched Bars (With Shield).

Position on Disc	B A R N O. 10 T O P		B A R N O. 10 C E N T R E		B A R N O. 10 B O T T O M	
	H A R D N E S S		H A R D N E S S		H A R D N E S S	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	585	54	548	53	554	55
2	536	54	585	53.5	572	54
3	548	54.5	572	52.5	579	55
4	572	54.5	579	55.5	579	54.5
5	579	55.5	585	54.5	566	54.5
6	585	55.5	606	55	585	53.5
7	572	55	606	55.5	548	53
8	548	53.5	606	56	548	53.5
9	566	55.5	579	55	572	55
10	599	54.5	572	56	566	55.5
11	606	55.5	548	53	579	54.5
12	599	54	585	53	585	53
13	572	54	585	54	606	53
Maximum Hardness Variation	70	2	58	3.5	58	2.5
Overall Maximum Hardness Variation	Rockwell C-3.5 Vickers 70					

TABLE V (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched Bars (With Shield).

Position on Disc	B A R N O. 22 T O P		B A R N O. 22 C E N T R E		B A R N O. 22 B O T T O M	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	585	54.5	579	56	585	55
2	579	55.5	585	56	606	55.5
3	566	55.5	599	55.5	579	55.5
4	599	54.5	606	55	572	54
5	585	55	585	56	606	56
6	579	55	572	56	599	56.5
7	572	55	579	55.5	599	56
8	606	53	579	56	592	56
9	592	54	606	56	592	56.5
10	572	54.5	585	56	572	55
11	585	55	572	55	579	54
12	579	55.5	579	56	585	54
13	599	54.5	579	55.5	579	54
Maximum Hardness Variation	40	2.5	34	1	34	2.5
Overall Maximum Hardness Variation	Rockwell C-3.5 Vickers 40					

TABLE V (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched Bars (With Shield).

Position on Disc	BAR NO. 23 TOP		BAR NO. 23 CENTRE		BAR NO. 23 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	VICKERS 10-kg. load	Rockwell "C"
1	572	52	579	54	599	55
2	579	53	536	53	599	55.5
3	536	53	542	52.5	585	55.5
4	566	54.5	529	54.5	572	55
5	542	55	585	53.5	536	56
6	585	54.5	606	54	548	54
7	579	54	536	54.5	542	54
8	566	53	579	54	572	54
9	585	52	572	53.5	579	53.5
10	599	55	579	54.5	606	56
11	606	55	606	55.5	585	54.5
12	572	55	585	55.5	606	54
13	579	55	599	55	599	54
Maximum Hardness Variation	70	3	70	3	70	2.5
Overall Maximum Hardness Variation	Rockwell C-4 Vickers 70					

TABLE V (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched Bars (With Shield).

Position on Disc	B A R N O. 31 T O P		B A R N O. 31 C E N T R E		B A R N O. 31 B O T T O M	
	H A R D N E S S		H A R D N E S S		H A R D N E S S	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	572	52	572	53	572	53
2	585	52	585	53.5	585	53.5
3	579	53.5	599	53.5	579	54
4	585	53.5	585	54	566	53.5
5	572	55	572	55	572	56
6	606	55.5	606	56	606	56
7	579	55	585	55	592	55
8	572	55.5	579	55.5	566	53
9	606	53	572	55.5	579	54
10	585	55	606	56	585	55
11	572	54	572	55	572	54.5
12	579	54	579	55	579	55
13	566	53	572	54	599	56
Maximum Hardness Variation	40	3.5	34	3	40	3
Overall Maximum Hardness Variation	Rockwell C-4 Vickers 40					

TABLE V (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched Bars (With Shield).

Position on Disc	BAR NO. 32 TOP		BAR NO. 32 CENTRE		BAR NO. 32 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	585	54	585	54	599	55.5
2	572	54.5	579	56	572	56
3	579	56	572	57	566	57
4	599	56	606	55.5	606	55
5	572	55	599	56	572	57
6	606	54	599	56	579	56.5
7	599	54	592	54	585	54
8	579	55.5	585	56	572	56
9	576	56	572	56.5	599	56
10	606	57	579	57	572	57
11	585	55	599	56.5	566	55.5
12	599	54	606	56.5	572	54.5
13	572	54	572	56	579	54
Maximum Hardness Variation	34	3	34	3	40	3
Overall Maximum Hardness Variation	Rockwell C-3 Vickers 40					
Maximum overall hardness variation for all bars ) Vickers 115. 						

TABLE VI - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (With Shield).

Position on Disc	BAR NO. 2 TOP		BAR NO. 2 CENTRE		BAR NO. 2 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rowckell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	262	27	266	26.5	264	26.5
2	262	26.5	264	26.5	262	27
3	260	27	264	27	260	27
4	264	26.5	264	26	266	26
5	262	27.5	262	26.5	264	27
6	260	27.5	258	27	264	27.5
7	258	26	260	26.5	262	27.5
8	262	27	264	26	264	26.5
9	266	27	262	27	258	27.5
10	262	27.5	262	27	262	27.5
11	266	28	264	27	262	27
12	262	27.5	266	27	266	27.5
13	262	26.5	258	26	264	27.5
Maximum Hardness Variation	8	2	8	1	8	1
Overall Maximum Hardness Variation	Rockwell C-2 Vickers 8					

TABLE VI (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (With Shield).

Position on Discs	BAR NO. 3 TOP		BAR NO. 3 CENTRE		BAR NO. 3 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	264	27.5	262	27	262	27
2	264	27.5	260	27.5	268	27
3	266	26.5	268	27.5	262	27
4	268	26.5	264	28	264	26
5	262	27.5	258	28	260	26.5
6	260	27.5	260	27.5	264	27
7	264	26.5	262	27	262	27
8	260	27.5	262	27	262	27
9	262	27.5	264	28	264	27.5
10	262	27	268	28	260	27.5
11	266	27	262	28	264	27
12	264	27.5	260	27.5	262	27
13	262	27	264	27.5	262	27
Maximum Hardness Variation	8	1	10	1	8	1.5
Overall Maximum Hardness Variation	Rockwell C-2 Vickers 10					

TABLE VI (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (With Shield).

Position on Disc	BAR NO. 9 TOP		BAR NO. 9 CENTRE		BAR NO. 9 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	264	⊕⊕26	264	⊕27	262	⊕26
2	262	27	262	27	262	27
3	262	26.5	264	⊕27.5	⊕264	27.5
4	⊕260	26.5	262	27	⊕⊕258	27
5	262	27	262	27.5	262	⊕28
6	260	27.5	⊕260	27	262	27.5
7	⊕⊕268	27	262	27	262	27.5
8	260	26.5	260	27	260	26.5
9	262	⊕⊕28	264	27.5	264	27.5
10	262	27.5	⊕268	27.5	262	27.5
11	264	27	264	27.5	262	28
12	264	27.5	264	27	260	27.5
13	268	26	264	27	262	27
⊕Maximum Hardness Variation	8	2	8	0.5	6	2
⊕⊕Overall Maximum Hardness Variation	Rockwell C-2 Vickers 10					

TABLE VI (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (With Shield).

Position on Disc	B A R N O. 10 T O P		B A R N O. 10 C E N T R E		B A R N O. 10 B O T T O M	
	H A R D N E S S		H A R D N E S S		H A R D N E S S	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	260	26.5	262	26.5	262	26
2	262	27	264	27	264	26.5
3	268	27	262	27	266	27
4	258	26.5	262	26.5	268	26.5
5	264	27	268	27	266	26.5
6	268	27.5	262	27	268	27.5
7	262	27	262	27	260	26.5
8	260	26.5	264	26.5	262	26.5
9	264	27	262	27	262	27.5
10	266	27.5	262	27.5	262	28
11	264	27	264	27	264	27
12	262	27	264	27.5	264	27
13	264	26	264	27	266	27
Maximum Hardness Variation	10	1.5	6	1	6	2
Overall Maximum Hardness Variation	Rockwell C-2 Vickers 10					

TABLE VI (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (With Shield).

Position on Disc	B A R N O. 22 T O P		B A R N O. 22 C E N T R E		B A R N O. 22 B O T T O M	
	H A R D N E S S		H A R D N E S S		H A R D N E S S	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	266	27	264	27	268	27
2	264	26.5	264	27	264	27.5
3	266	27.5	262	27	262	27.5
4	262	27	262	26.5	262	27.5
5	264	28	264	27	262	27.5
6	260	28	262	27.5	264	27.5
7	264	27.5	266	26.5	262	27.5
8	264	27.5	264	27	262	27
9	262	27.5	264	27.5	264	27
10	262	28	264	27.5	264	27.5
11	266	28	266	27	262	27.5
12	268	27.5	266	27.5	262	27.5
13	262	27	258	27	262	27
Maximum Hardness Variation	8	1.5	8	1	6	0.5
Overall Maximum Hardness Variation	Rockwell C-1.5 Vickers 10					

TABLE VI (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (With Shield).

Position on Disc	B A R N O. 23 T O P		B A R N O. 23 C E N T R E		B A R N O. 23 B O T T O M	
	H A R D N E S S		H A R D N E S S		H A R D N E S S	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	266	26	262	26.5	268	26
2	262	27	262	27	264	27.5
3	262	27	260	27	264	28
4	264	27	266	26.5	266	27
5	266	27	264	27	262	28
6	260	27	268	27.5	262	27.5
7	258	27	260	27	262	27
8	260	27	262	27	262	27
9	266	27	262	27	264	27
10	264	27.5	264	27	266	27.5
11	264	27.5	264	27	262	27.5
12	264	27.5	266	28	264	27
13	262	26	268	27	264	26.5
Maximum Hardness Variation	8	1.5	8	1.5	6	2
Overall Maximum Hardness Variation	Rockwell C-2 Vickers 10					

TABLE VI (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (With Shield).

Position on Disc	BAR NO. 31 TOP		BAR NO. 31 CENTRE		BAR NO. 31 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	262	27	264	27	260	27
2	266	26.5	266	27	266	27
3	264	27	260	27	266	28
4	266	27	266	27	260	27.5
5	264	27.5	264	27	262	27.5
6	266	27.5	262	27.5	262	28
7	260	27	262	26.5	260	27
8	262	27	262	26.5	262	26.5
9	264	27.5	260	27.5	262	27.5
10	266	27.5	264	27.5	266	27.5
11	260	27.5	264	26	260	27
12	262	27.5	264	27.5	264	27.5
13	262	27.5	262	26.5	264	27
Maximum Hardness Variation	6	1	6	1.5	6	1
Overall Maximum Hardness Variation	Rockwell C-2 Vickers 6					

TABLE VI (Cont'd) - Hardness of  $\frac{1}{2}$ " Discs from Quenched and Drawn Bars (With Shield).

Position on Disc	BAR NO. 32 TOP		BAR NO. 32 CENTRE		BAR NO. 32 BOTTOM	
	HARDNESS		HARDNESS		HARDNESS	
	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"	Vickers 10-kg. load	Rockwell "C"
1	264	26.5	264	27.5	264	27
2	266	27	262	27.5	266	27
3	266	27.5	264	28	262	28
4	264	27	262	27	266	27
5	262	27.5	262	27.5	262	28
6	262	28	262	27.5	262	28
7	262	27.5	264	27	264	27
8	262	27.5	262	27.5	262	27
9	262	27	266	27.5	262	27.5
10	262	27	266	28	262	28
11	264	27	264	28	264	28
12	262	27.5	264	27.5	264	27.5
13	262	27	266	27.5	264	27
Maximum Hardness Variation	4	1.5	4	1	4	1
Overall Maximum Hardness Variation	Rockwell C-1.5 Vickers 4					