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COMPARISON OF TWO QUENCHED STEEL BAR SAMPLES

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Metallurgical examination of two lengths of SAE 1038 carbon steel was done to compare the hardness gradient and microstructure obtained when bars were quenched from 1600°F into 10% brine or into a proprietary solution.

The hardness gradient of the two sectioned bars was similar except at the surface where prior decarburization affected the response to liquid-quenching.

The origin of the decarburization was not definitely established but this could have been present on the original hot-rolled bar stock or could have occurred during the long (3/4 hour) holding period in the austenitizing salt bath furnace at 1600°F.

For any future test, the neutrality of the salt bath should be checked; the holding time should be reduced to 10 minutes for 1 in. diameter sections and the test bars should be machined before hardening to eliminate any decarburization left by the hot rolling operation at the steel mill.

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INTRODUCTION

On June 15, 1966 two 6 inch lengths of 1 inch diameter, SAE 1038 steel were received for metallurgical examination. These samples had been heat treated as shown in Table 1 by Mr.G.Lussier at DOSCO Works, Montreal, P. Q., using a "neutral" salt bath.

The bars were identified as "SALT"-(10% brine quench) and "X"-(quenched in Mr. Lussier's proprietary solution). During a previous visit, April 1965, it was agreed that comparison would be made of the hardness and depth of hardening obtained by use of 10% brine (SALT) and X-solution quenches.

HEAT TREATMENT

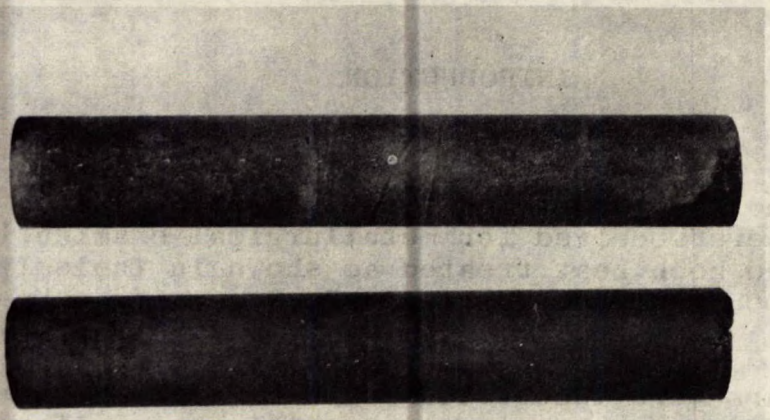
TABLE 1

Heat Treatment of Bar Material (As-Quenched Condition)

Salt (10% Brine Quench)	"X" Solution-Quench
(1) Rod was identified -"SALT"- (2) Rod was placed in neutral salt at 1600°F for 3/4 hr (3) Rod was taken out of furnace and was quenched in brine 10%(2lb salt in 2 gal water at 68°F). (4) After quenching the brine temperature rose to 93°F.	(1) Rod was identified -"X"- (2) Rod was placed in neutral salt bath at 1600°F for 3/4 hr. (3) Rod was taken out of furnace and was quenched in solution (2 gallons at 68°F). (4) After quenching the solution temperature rose to 87°F.

METALLURGICAL EXAMINATION

The heat treated bar samples are shown in Figure 1, as-received June 15, 1966 for metallurgical examination.



X½ approximately.

Figure 1. Illustrates 7 in. Lengths of 1 in. Diameter SAE 1038 Steel After Heat Treatment by Quenching from 1600°F in 10% Brine (SALT) or in Proprietary Solution (X).

Transverse sections were cut at the midpoint and ½ inch from each end of the bars. One of the remaining lengths of bar was cut longitudinally and polished for hardness testing.

Millings from a third length of this bar stock gave the results shown in Table 2.

Chemical Composition of Bar Stock

TABLE 2

Chemical Composition of Bar (cut from same length)

Element (%)	C	Mn	Cr	Ni	Mo	V
Bar Analysis	0.39	0.77	0.07	0.04	0.03	<0.01
SAE 1038	0.35 to 0.42	0.60 to 0.90	Tr	Tr	Tr	Tr

Tr - trace

Analysis confirmed that the bar stock was SAE 1038, having a low level of residual alloy constituent.

Transverse and Longitudinal Hardness Survey

Hardness results on wet-ground, polished disc sections cut at the centre position and $\frac{1}{2}$ in. from the end of each bar are listed in Table 3. The location of the Rockwell C hardness test on the disc surface is illustrated.

TABLE 3

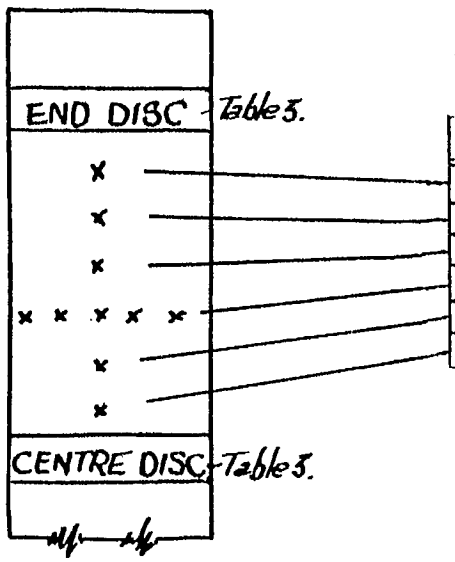
Hardness of Transverse Disc Sections

Location of Hardness Test	"SALT" (10% Brine) Disc 1	Centre	Disc 2	Proprietary Sol."X" Disc 1	Centre	Disc 2
surface	24	92RB	24	41	29	36
1/8 in.	44	25	44	46	43	44
1/4 in.	31	27	27	31	34	29
3/8 in.	23	25	27	22	26	22
1/2 in.	23	25	27	22	25	23
5/8 in.	25	25	27	18	25	22
3/4 in.	31	30	31	29	27	27
7/8 in.	24	28	45	46	43	45
surface	94RB	89RB	24	45	34	37

The results of Rockwell C tests made on a wet-ground and polished longitudinal section are listed in Table 4.

TABLE 4

Hardness-(Rockwell C)-Longitudinal Section



Salt	"X"
25	22
22	22
22	21
42, 22, 21, 21, 37	42, 22, 20, 20, 42
22	20
22	21

There is no significant difference in the "as-quenched" hardening pattern obtained by use of 10% brine or proprietary solution "X".

A Tukon hardness survey was made across the diameter of the two centre disc sections. The results of this survey are listed in Table 5. Figures 2 to 5 inclusive, illustrate the microstructure observed in this sample at the surface, 0.020 inch and 0.500 inch (centre) position.

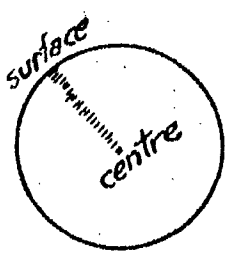
Microhardness Survey

TABLE 5

Hardness Rockwell C (converted from 500g Knoop)

Tukon Hardness Survey - Surface to Centre - Centre Disc Section

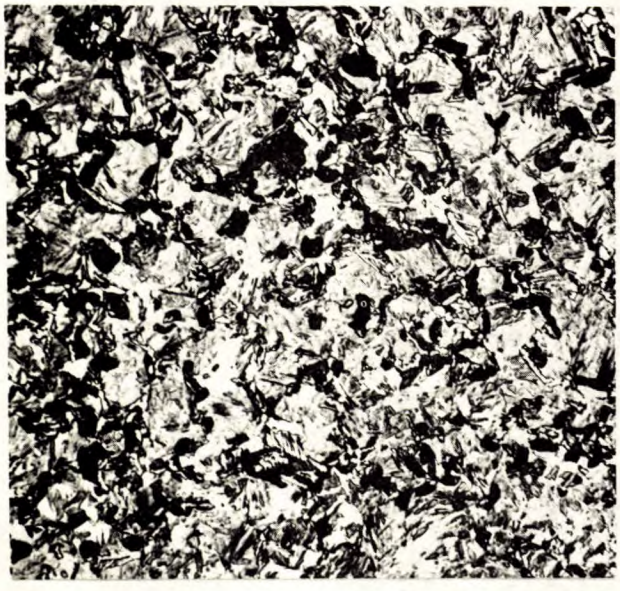
Distance from Surface (in)	SALT (10% Brine)	Solution (X)	Location of Photomicrographs
Surface	-	-	Fig.2a(salt); Fig.2b(X)
0.002 in.	82 Rockwell B	25 Rockwell C	
0.004 "	82 " "	35 " "	
0.006 "	26 Rockwell C	43 " "	
0.008 "	32 " "	45 " "	
0.010 "	34 " "	45 " "	
0.012 "	35 " "	48 " "	
0.014 "	38 " "	48 " "	
0.016 "	39 " "	48 " "	
0.018 "	49 " "	48 " "	
0.020 "	46 " "	50 "	Fig.3a(salt); Fig.3b(X)
0.030 "	46 " "	50 " "	
0.040 "	44 " "	50 " "	
0.050 "	48 " "	51 " "	
0.100 "	48 " "	51 " "	
0.200 "	38 " "	39 " "	
0.300 "	32 " "	25 " "	
0.400 "	29 " "	27 " "	
0.500 "	29 " "	27 " "	



(RB82) X500 2% nital etch
(a)
Figure 2. Brine - 0.003 in. from surface

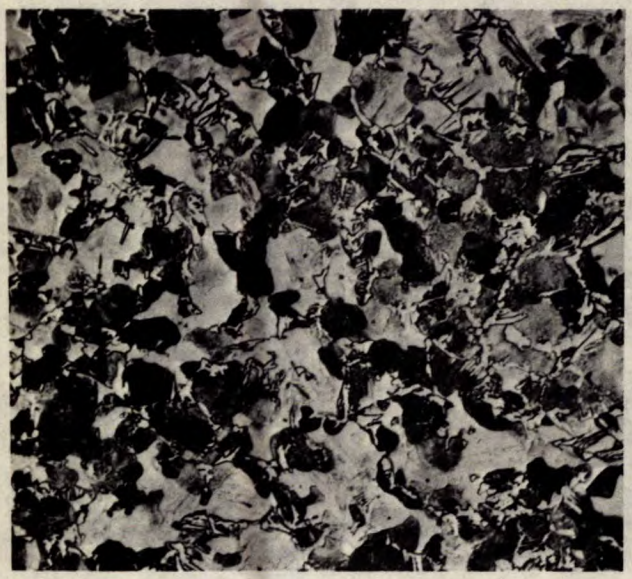
(RC25) X500 2% nital etch
(b)
Solution X-0.003 in. from surface.

Decarburization has occurred at the surface of tne salt sample during the 1600°F "neutral" salt holding period.



(RC46) X500 2% nital etch
(a)
Figure 3. Brine - 0.020 in. from surface.

(RC50) X500 2% nital etch
(b)
Solution X - 0.020 in. from surface.



(RC29) X500 2% nital etch
(a)
Brine - 0.50 in. from surface.

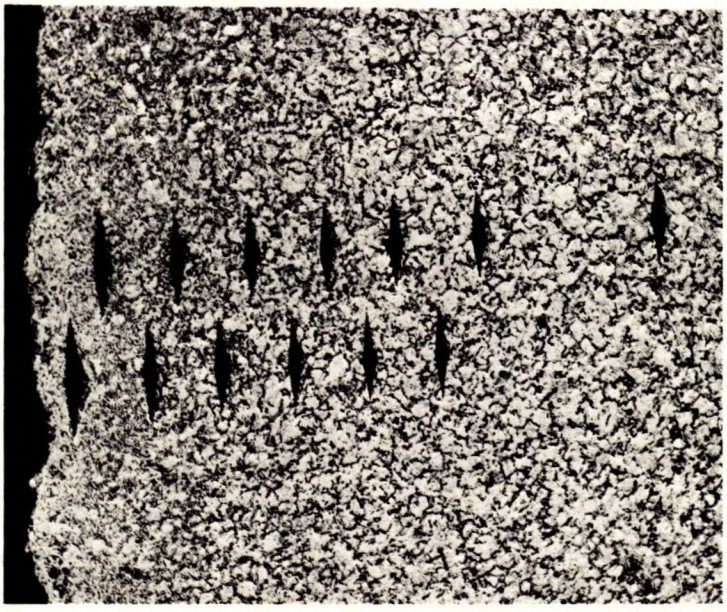
(RC27) X500 2% nital etch
(b)
Solution X - 0.50 in. from surface.

Figure 4.

The decarburized surface region of the centre disc section is illustrated in Figures 5 and 6. Except in the decarburized surface regions, up to 0.020 inch in depth, no significant hardness difference was observed in the sections tested.

X100 2% nital etch

Figure 5. Brine (Salt) Sample - As-Quenched.
The Rockwell C hardness gradient from the surface to 0.040 in. below the surface is shown.



X100 2% nital etch

Figure 6. Solution X - As-Quenched

The Rockwell C hardness gradient from tne surface to 0.040 in. below the surface is shown.

DISCUSSION OF RESULTS

Except for the presence of decarburization in the sample quenched in 10% brine no significant difference in hardness gradient was observed in comparison of the two samples.

It was observed that the "as-received" surface of sample X was less affected than that of the brine-quenched sample - this suggests that the neutral salt bath was decarburizing during the 3/4 hour holding period at 1600°F. Less decarburization occurred during the holding period for sample X.

Tables 3 and 4 indicate no effect due to difference of quench liquids. Figures 2 to 4 illustrate that, except for difference in the quantity of decarburized surface metal, the microstructure produced by the quenchants is similar at all positions in the test bar.

Figures 5 and 6 illustrate the extent to which the surface carbon content of each specimen has been reduced during the 3/4 hour holding period at 1600°F in the salt bath furnace. (A holding time of 10 minutes would have been more usual for this composition and section heated in a salt bath).

CONCLUSIONS

(1) There was no significant difference in the hardening pattern produced by the two quench liquids.

(2) Decarburization of surface metal occurred in the salt bath furnace while the samples were held at 1600°F for 3/4 hour. (Holding time should have been approximately 10 minutes).

(3) The salt sample was more severely decarburized in the furnace. Sample X was less severely decarburized. The surface appearance and hardness of both samples was affected by the presence of decarburization.

(4) The as-quenched surface quality and uniformity of hardness were slightly improved in the sample quenched in liquid X. This is attributed to differences in the amount of decarburization prior to quenching rather than to inherent difference in the quench liquids.

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