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PROPERTIES OF TWO STAINLESS HOT WORK TOOL STEELS

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Suitable austenitizing temperatures, grain size and hardness, tempering curves and some tensile properties were investigated for Atlas HW-28, a modified stainless 420 type steel, and for Uddeholm Calmax (HW-33-C), a Swedish die steel of the 12% Cr type but with high tungsten and cobalt contents.

Both steels have good resistance to softening on tempering up to 1050°F. Some improvement over the straight stainless 420 grade can be seen. Values similar to 5% Cr non-stainless grades were obtained.

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(14 pages, 4 figures, 5 tables)

INTRODUCTION

Material from two types of hot work steels was submitted by Atlas Steels Ltd., Welland, Ontario, for hardness and tensile testing. One steel, designated HW-28, is a modification of Stainless 420, melted in a 500-lb induction furnace at Atlas Steels. The primary use for that material would be in the light metal extrusion die field. A possible additional use would be in aircraft parts which require high strength combined with corrosion resistance, such as under-carriages, etc. The other steel, Calmax, was produced in Sweden by Uddeholm Ahtiebolag and came to use as a pipe extrusion die in Canada. After a fatigue failure, this die was sectioned and forged to small test bars for an evaluation of mechanical properties. The test designation for this material is HW-33-C.

Three tests were carried out to get a general idea for comparison purposes with existent Atlas grades. First, a grain size and hardness determination as a function of austenitizing temperatures, second, full range tempering and hardness tests after the most favourable austenitizing treatment, and, third, some tensile tests, were included. In comparison with other steels, of lower alloy contents, a definite improvement of tempered hardness could be observed with the modified stainless 420 type, and the highly alloyed die steel showed even better properties.

However, no improvement over values obtained with non-stainless, five percent chromium tool steels, such as Crovan or Avrocan (H13, H11) could be seen. Also, no improvement over other modern stainless steels such as USS 12 Mo V, etc., could be shown. In this respect, the very highly alloyed HW-33 (Calmax) grade is somewhat disappointing. It must be said, that for very specialized purposes, for instance extrusion dies, other characteristics not investigated here, eg hot wear resistance, oxidation resistance, etc., might prove substantial advantages of this alloy. Actual comparative performance tests would give the best indication of these benefits.

CHEMICAL ANALYSES

In Table 1, the analyses of both steels are shown as established by Atlas Steels Limited.

TABLE 1

Chemical Analyses of HW-28 and HW-33-C in %

	C	Mn	Si	P	S	Cr	Mo	V	W	Co	Ni
HW-28	.38	.51	.41	.014	.020	13.43	1.30	.59	-	-	.16
HW-33-C	.23	.48	.42	-	-	12.62	.08	.47	7.74	9.11	-

The heat No. of HW-28 was G588; HW-33-C originated from an extrusion die.

TEST RESULTS

Hardness and Grain Size vs Austenitizing Temperatures

Ten samples of each steel were heated to ten different austenitizing temperatures and air cooled after 10 minutes soak, without preheating. The $\frac{3}{4}$ in. round samples were $1\frac{1}{2}$ in. long and were cut half way through near the middle. After breaking the cooled bars in two with a sledge hammer, the fracture grain size was estimated by comparison with the scale of the Shepherd fracture series. One fragment of each bar was ground flat with precaution against overheating so as to prevent a tempering effect. Table 2 gives the hardness values measured on the samples. Included are data obtained by the metallurgical laboratory at Atlas on material from the same heat of HW-28, and values given in the heat treatment instructions by Uddeholm Ahtiebolag. In general, good agreement was obtained with these data. Figures 1 and 2 are graphical presentations of the same data.

Grain coarsening occurred at about 1950°F with HW-28, whereas HW-33-C resisted grain growth up to 2050°F. Subsequently, 1850°F and 1900°F were chosen as safe austenitizing temperatures for HW-28, and 1875°F and 2000°F were chosen for HW-33-C, the lower temperature resulting in nearly the same hardness as with the maximum safe temperature of 2000°F for the latter steel.

Tempering Data

Several pieces of $\frac{3}{4}$ in. diameter, $\frac{1}{2}$ in. thick from each alloy were austenitized at the two temperatures established above. After soaking for ten minutes and air cooling, single test pieces were tempered twice for one hour at various temperatures up to 1300°F. Tables 3 and 4 list the hardness values obtained and also values already established for HW-28 by Atlas Steels and other values for Calmax presented in the heat treatment instructions by Uddeholm Ahtiebolag.

TABLE 2

Hardness and Grain Size vs Austenitizing Temperatures of HW-28 and HW-33-C

Austenitizing Temperature °F	HW-28 PM results 1) Hardness R_c	HW-28 PM results 1) Grain Size Shepherd	HW-28 Atlas results 2) Hardness R_c	HW-28 Atlas results 2) Grain Size Shepherd	HW-33-C PM results 3) Hardness R_c	HW-33-C PM results 3) Grain Size Shepherd	Uddeholm Calmax 4) Hardness R_c
1700	-	-	29	7	-	-	46
1750	$41\frac{3}{4}$	8	42	7-8	$51\frac{1}{2}$	9	48
1800	$47\frac{1}{2}$	8-9	$44\frac{1}{2}$	8	$53\frac{1}{4}$	9	50
1850	$54\frac{1}{4}$	8-9	51	9	54	9	52
1900	57	8-9	52	9-10	$54\frac{3}{4}$	9	53
1950	59	7-8	57	7-8	55	9	54
2000	$58\frac{1}{2}$	6	$57\frac{1}{2}$	6	55	9	$54\frac{1}{2}$
2050	$57\frac{3}{4}$	4-5	-	-	$54\frac{1}{2}$	9	$54\frac{1}{2}$
2100	57	4	-	-	$53\frac{1}{2}$	6	$54\frac{1}{4}$
2150	$56\frac{3}{4}$	3	-	-	$52\frac{3}{4}$	3-4	$53\frac{3}{4}$
2200	$56\frac{1}{2}$	3	-	-	52	3	53

1) No preheat, 10 min soak.

2) No preheat, 30 min soak.

3) No preheat, 10 min soak.

4) Preheated at 1250, 15 min soak.

All air cooled.

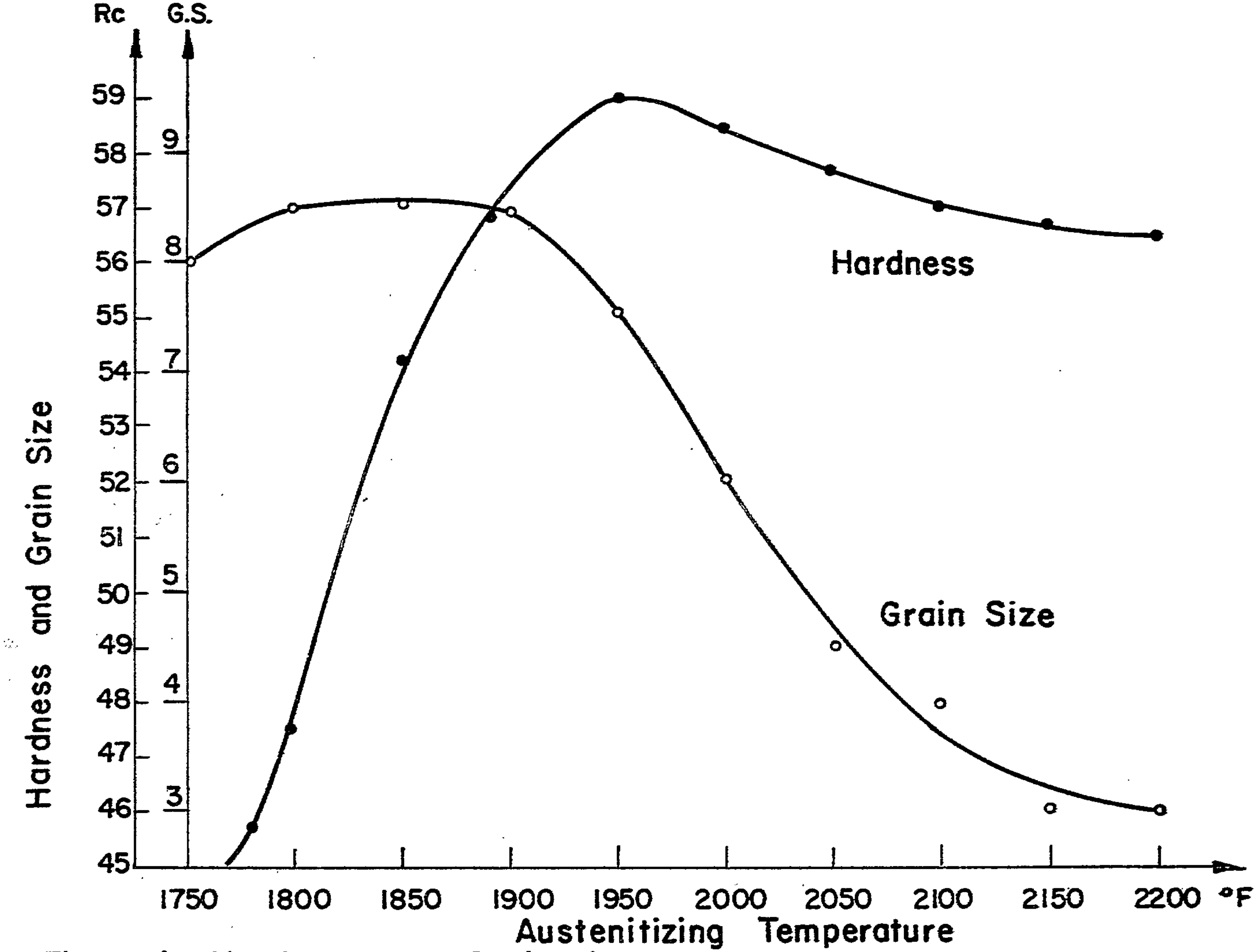

Figure I: Hardness and Grain Size vs. Austenitizing Temperature of HW-28.

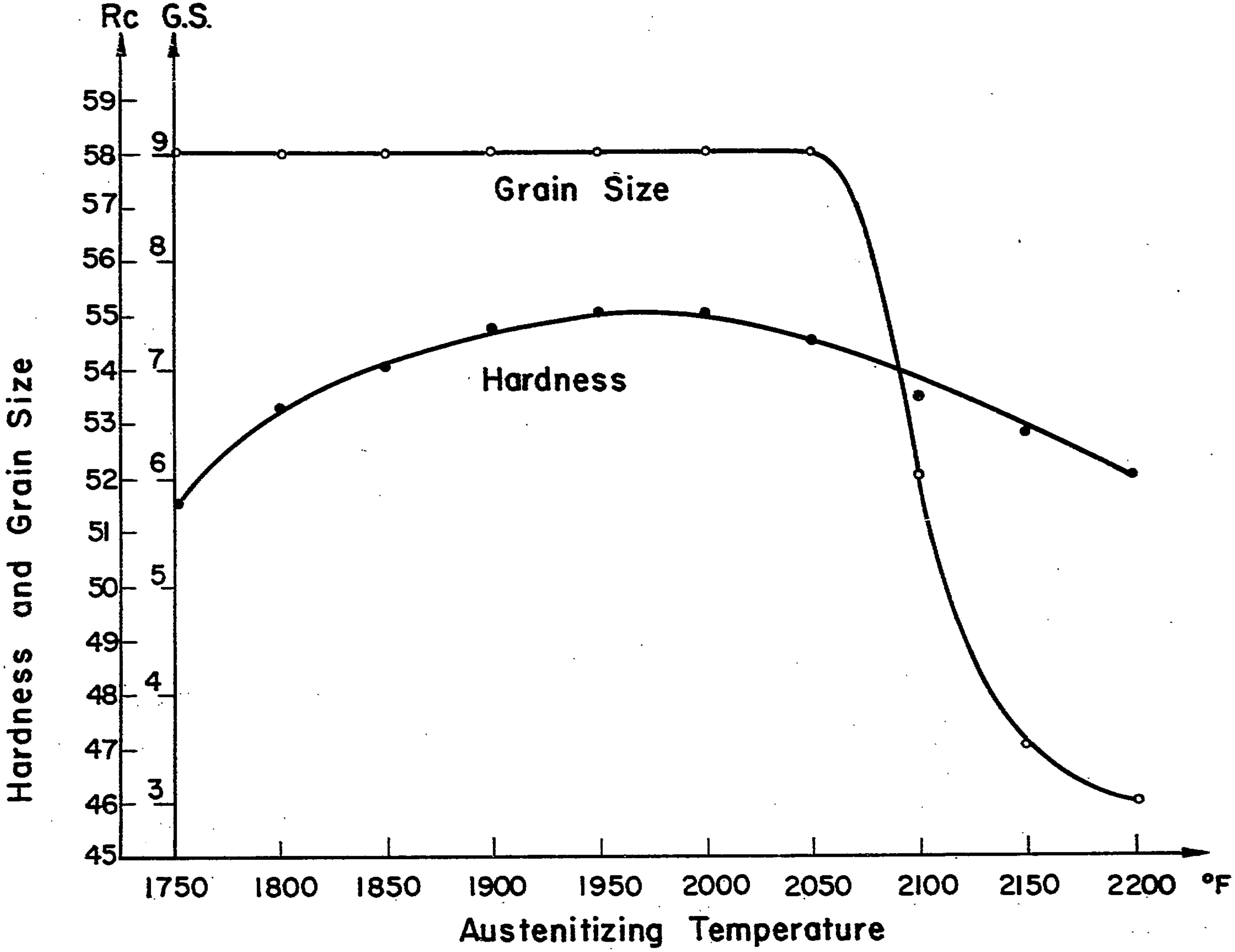

Figure 2 : Hardness and Grain Size vs. Austenitizing Temperature of HW-33-C

TABLE 3

Hardness of HW-28 after Austenitizing for 10 Minutes at 1850°F and 1900°F, Followed by Air Cooling and Double Tempering for 1 hr + 1 hr

Tempering Temperature °F	Hardness R_c after 1850°F Austenitizing	Hardness R_c after 1900°F Austenitizing	Hardness R_c Atlas Steels 1850°F 1)	Hardness R_c Atlas Steels 1900 1)
as air cooled	54¼	57	51	52
500	51	52½	-	-
800	53	53¾	49½	51½
900	53½	54¾	50½	53½
950	53	54½	48	51½
1000	49	51	44½	50
1050	44	44½	40	45½
1100	41¼	42½	35	36½
1200	37½	37¾	32½	32½
1300	29¾	31½	26	26

1) ½ hr soak at austenitizing temperature, double temper 2 hr + 1 hr

TABLE 4

Hardness of HW-33 after Austenitizing for 10 Minutes at 1875°F and 2000°F, Followed by Air Cooling and Double Tempering for 1 hr + 1 hr

Tempering Temperature °F	Hardness, R_c after 1875°F Austenitizing	Hardness, R_c after 2000°F Austenitizing	Hardness, R_c Uddeholm, after 2000°F Austenitizing, 1)
as air cooled	54½	54¾	54½
500	51	51¼	51
800	53	53¼	52
900	54½	54¼	53¼
950	54	54¾	53½
1000	51	54	53¾
1050	49½	51¾	53¼
1100	48	51½	53
1200	46	48¼	49½
1300	41¼	42¾	43½

1) austenitized for 15 minutes after proceeding
preheat at 1250°F
tempered 3 hr + 3 hr

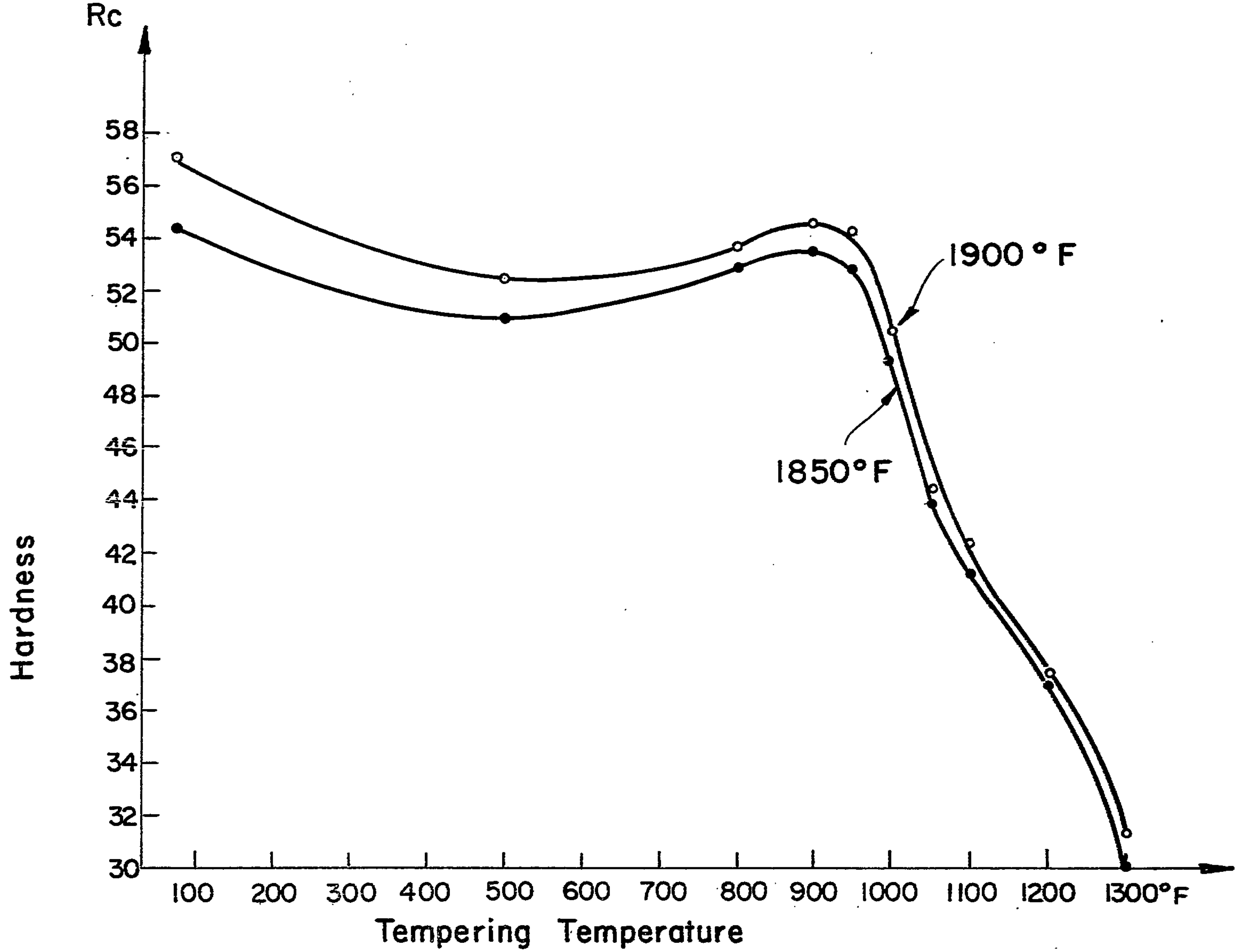

Figure 3: Tempering Curves for HW-28, Austenitized at 1850 & 1900° F Double Tempered for 1 hr + 1 hr at Different Temperatures.

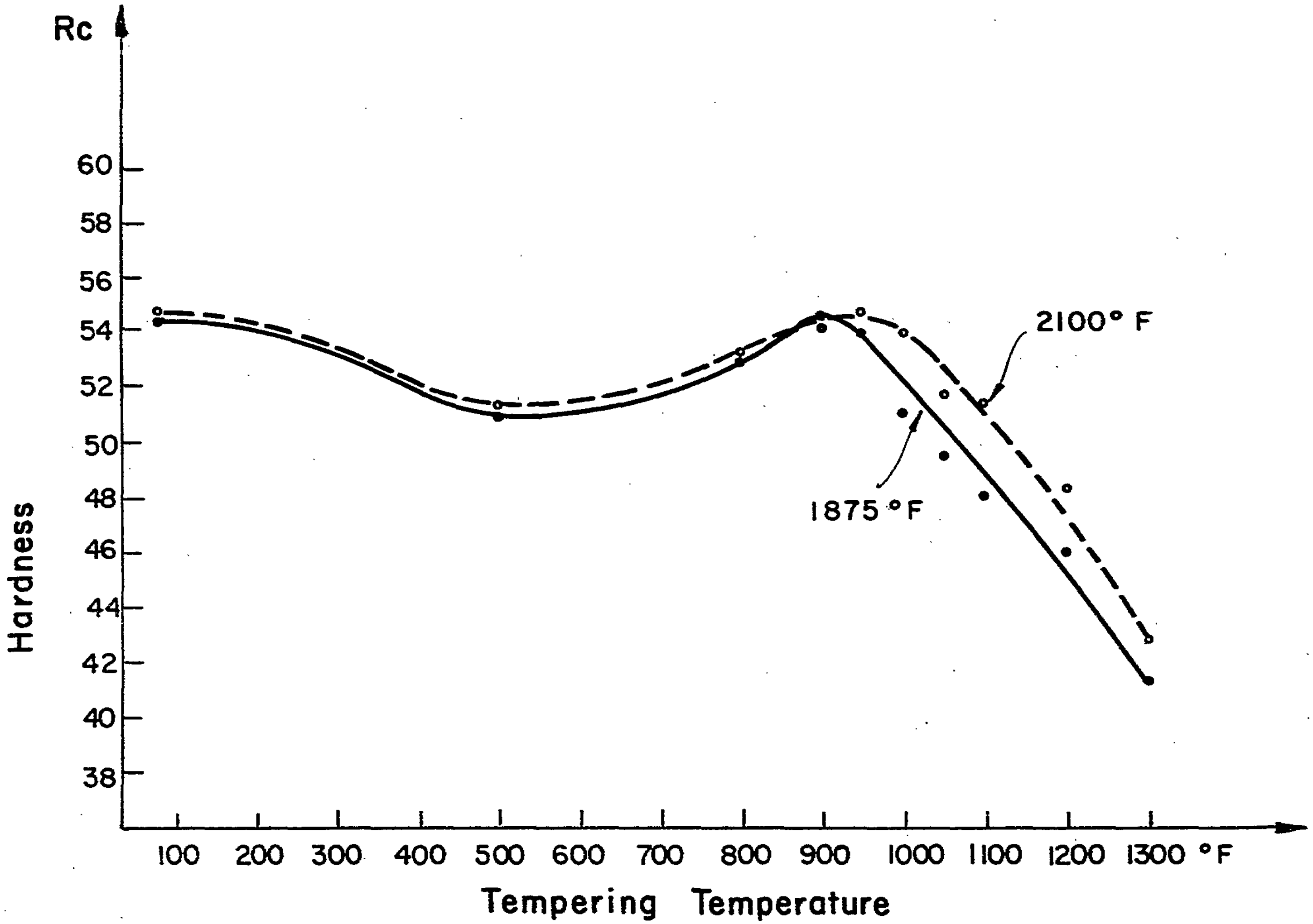

Figure 4 : Tempering Curves for HW-33, Austenitized at 1875 & 2000°F, Double Tempered at Different Temperatures 1hr + 1 hr.

Figures 3 and 4 are graphical presentations of the tempering data. HW-28 has its peak of secondary hardening between 900 and 925°F. Beyond this temperature, the hardness falls off rapidly and almost linearly. The 50°F higher austenitizing temperature of 1900°F results in a slightly higher hardness of about one R_c unit throughout the tempering range.

HW-33-C shows its peak of secondary hardness at the same tempering temperature as HW-28, namely at 925°F. However, due to the much higher alloy contents, and the addition of tungsten and cobalt, the hardness does not drop very rapidly after the peak. Even after tempering at 1300°F, the hardness is better than 40 R_c. The lower austenitizing temperature of 1875°F results in a slightly lower hardness beyond the peak than the recommended austenitizing temperature of 2000°F. If salt bath facilities are not available it appears that a lower than recommended austenitizing temperature can be used in order to minimize surface decarburization.

Tensile Properties of HW-33-C

Five tensile bars of this grade only were heat treated as follows: 10 minutes soak at 2000°F, air cooling, double tempering at 1050°F for 1 hr + 1 hr. Austenitizing was carried out in a carbon block muffle. A very thin layer of decarburized metal was ground off the bars, achieving a small taper along the 1½ in. gauge length of the 0.375 in. diameter bars. Table 5 lists the tensile properties at room and elevated temperatures as obtained with these bars. The ductility values at room temperature are satisfactory for the strength level of 270,000 psi ultimate tensile strength. The strength at 1000°F (185,000 psi ultimate tensile strength) is also quite satisfactory but no higher than that attainable with other stainless

TABLE 5

Tensile Properties of HW-33 at Room and at Elevated Temperatures

Bar No. 1)	Test Temperature °F	U.T.S. kpsi	0.2% Yield kpsi	$\frac{\text{Yield}}{\text{U.T.S.}} \cdot 100$ %	Elongation in 4D %	Reduction of Area %	Remarks
1	72	270.0	196.7	72.8	10.0	33.1	
2	72	264.5	199.5	75.4	8.9	33.9	
3	900	199.5	155.3	77.8	12.7	48.7	
4	1000	185.1	-	-	14.7	49.6	curve not reliable
5	1000	188.1	141.7	75.1	13.3	45.0	

1) All bars had same heat treatment of 10 minutes soak at 2000°F, air cooling, double tempering at 1050°F for 1 hr + 1 hr, resulting in a hardness of R_c 52.

Bar dimensions: D = 0.375, L = 1.5 in.

as well as non-stainless steels (such as several modified stainless 420 grades or H11 and H13 die steels).

CONCLUSIONS

HW-28, the modified stainless 420 grade, offers some advantage over the common grade. Test results obtained at the Physical Metallurgy Division laboratory confirm closely the results established by Atlas Steels Limited. The main advantage of this grade is its tensile strength at elevated temperatures, eg at 1000°F 200,000 psi compared with only 150,000 psi for stainless 420. However, no tensile tests were conducted at the Physical Metallurgy Division laboratory on this grade. The most favourable heat treatment consists of austenitizing at 1900°F and air cooling, followed by tempering at 1000°F for twice one hour. The resulting hardness is R_c 51 with a very fine grain size.

HW-33-C, the highly alloyed Swedish stainless die steel will offer the best mechanical properties when austenitized at 2000°F, air cooled, and tempered at 1050°F for twice one hour. The hardness in this condition is R_c 52 with a very fine grain size. Tensile tests show an ultimate tensile strength of 270,000 psi at room temperature and of 185,000 psi at 1000°F. These values can be obtained with HW-28 and many other modified stainless high strength steels. Also, non-stainless five percent chromium die steels offer equal elevated temperature strengths. A justification of the high alloy content of HW-33-C might be the higher wear, oxidation and surface penetration resistance in die applications. It is recommended that these factors should be investigated in actual service tests. For high strength applications in aircraft, this steel offers no advantage over lighter alloys because the high tungsten content reduces the strength to weight ratio. Also, usually no additional wear resistance will be required in aircraft parts.

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