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"17-22-A"V STEEL MODIFIED WITH COLUMBIUM OR ALUMINUM

by

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"17-22-A"V STEEL MODIFIED WITH COLUMBIUM OR ALUMINUM

Timken "17-22-A"V steel has excellent creep-rupture properties at temperatures up to 1100°F. Higher creep-rupture strengths, retention of strength to higher temperatures, increased ductility and wider latitudes in heat treatment could, however, be useful enhancements of the properties of this steel.

In this investigation Timken supplied specimens from a heat with an addition of 0.44 percent Cb and from three heats with Al contents varying from 0.21 to 0.63 percent. These materials in a number of different conditions of heat treatment were evaluated by rupture tests at 1100°F and for the Cb bearing heat at 1200°F as well. Experimental induction furnace heats rolled to barstock were used in this investigation. Some bars were heat treated in massive blocks to simulate the heat treatment of rotor forgings for gas turbines.

The base "17-22-A"V composition used was the nominal 0.3 percent C and 0.8 percent Mn adopted by Timken for adequate hardenability when rotor forgings are normalized and tempered.

SUMMARY AND CONCLUSIONS

The addition of 0.44 percent Cb to "17-22-A"V steel resulted in rupture strengths at 1100° and 1200°F which were on the high side of the range for the steel when normalized from 1850° to 1950°F. The ductility of the alloy was low, however. The results from adding Cb were difficult to understand and as a consequence additional research might be warranted.

Adding Al in the range of 0.21 to 0.63 percent was of no benefit except to increase ductility when the temperature of heat treatment was 1750° or 1800°F. Even then one heat did not show the improved ductility.

The data again demonstrate the lower strength and ductility which seem to be associated with C contents of 0.30 percent and Mn levels at about 0.8 percent. These levels were used to obtain hardenability adequate for forged discs.

MATERIAL

Tensile specimens were supplied from four heats of "17-22-A"V steel. Columbium had been added to one heat while the other three contained varying amounts of Al. Two of the heats, Heats 2759 and 2760, were 30 pound induction heats. The other two were 300 pound laboratory induction furnace heats. The composition (Weight percent) of the heats as reported by The Timken Roller Bearing Company were as follows:

Heat No.	C	Mn	P	S	Si	Cr	Ni	Mo	V	Cb	Al
A165	.295	.65	.018	.036	.79	1.31	.18	.51	.80	.44	-
A173	.32	.85	.015	.018	.70	1.30	.07	.49	.87	-	.21
2759	.32	.85	.013	.041	.78	1.33	.19*	.72	.73	-	.32
2760	.31	.83	.016	.039	.78	1.37	.19*	.70	.75	-	.63

* - Ni + Cu

The specimens supplied were machines from heat treated 7/8-inch diameter barstock. The bars for Heat A165 and for one treatment of Heat A173 were enclosed in 9-inch by 9 1/2-inch by 4-inch thick blocks to simulate the heat treatment of forgings. Specimens were also supplied from directly heat treated barstock from Heat A173. The treatments and hardness were as follows:

Heat No.	Heat Treatment	BHN
	7/8-inch diameter bars sealed in blocks	
A165	Normalized from 1850°F and tempered for 6 hours at 1250°F	302/311
A165	Normalized from 1900°F and tempered for 6 hours at 1250°F	302/321
A165	Normalized from 1950°F and tempered for 6 hours at 1250°F	311/321
A173	Normalized from 1850°F and tempered for 6 hours at 1250°F	311/321

Heat No.	Heat Treatment	
	7/8-inch diameter barstock	
A173	Normalized from 1750°F and tempered for 6 hours at 1225°F	293/302
A173	Normalized from 1800°F and tempered for 6 hours at 1225°F	311/321
A173	Normalized from 1850°F and tempered for 6 hours at 1225°F	321/331

Barstock from the other two heats, Heat 2759 and 2760, was normalized from 1800°F followed by a 6 hour temper at 1225°F, resulting in Brinell hardness values of 311 and 285, respectively.

RESULTS

The rupture properties were surveyed using two tests (Table I) for all but Heat A173 which was more completely evaluated. These tests defined the rupture strengths (Figure 1 and Table II) for 100 and 500 hours. Table II does, however, include estimated values for 1000 hours because rupture strengths for 1000 hours are widely used for evaluating alloys of the type under consideration.

Columbium Modification

The stresses for rupture in 100 hours at 1100°F were similar to those characteristic of experimental heats of "17-22-A"V steel. The estimated strengths at 1000 hours were within the range for "17-22-A"V steel. Ductility values in the rupture tests were low.

Increasing the normalizing temperature from 1850°F to 1950°F only slightly increased the stress at 1100°F for rupture in 100 hours. Lower strengths at longer time periods were indicated since the slope of the stress-rupture time curve was somewhat steeper.

The indicated rupture strengths at 1200°F would apparently be somewhat higher than those for "17-22-A"V steel at the longer time periods. Ductilities were again very low.

The microstructure (Plate 1) appeared to be a mixture of very fine and quite coarse "grained" tempered bainite when normalized at 1850°F. Normalizing at 1900°F removed all fine grains (Plate 2) and 1950°F resulted in marked coarsening (Plate 3).

The comparisons based on experimental heats may not be correctly evaluating the effect of Cb. The barstock was heat treated by being placed in holes in blocks 9-inch by 9 1/2-inch by 4-inch thick to simulate forgings. The comparative data for experimental heats of "17-22-A"V steel were obtained from barstock heat treated directly. The difference in cooling rate then could be altering comparative properties. Data previously obtained has generally indicated lower properties for "17-22-A"V steel when the C was about 0.3 percent and the Mn about 0.8 percent. These levels of C and Mn were needed to obtain hardenability sufficient for disc forgings. The Cb may therefore have helped to raise the strength since the values are slightly higher than the range for production material. The poor rupture ductility, however, would handicap the Cb modification as a potentially useful alloy.

It is difficult to understand the microstructures. Columbium would be expected to be a grain growth restrainer. Secondly, it should require higher than usual temperatures of heat treatment to dissolve CbC and obtain effective increases in strength. The slight increase in strength accompanying the upper temperature of normalizing (1950°F) is therefore not surprising. However, the apparently coarse grained austenite, adequate hardening and low ductility are surprising. Titanium (Report 243) had the expected effects and was very effective in increasing strength and ductility when heat treated at 1950°F and higher. Possibly the Cb only reduced the effective C content of the alloy and thus raised strengths.

There would seem to be sufficient reason to investigate the role of Cb more than was done for this investigation with emphasis on solution of CbC and avoiding the apparent coarsening of the austenite during heat treatment.

Aluminum Additions

Heat A173 with 0.21 percent Al had rupture strengths on the low side of the range for production heats of "17-22-A"V steel when normalized from 1750° and 1800°F (See Tables I and II and Figure 1). Ductility was high after these treatments. Raising the normalizing temperature from 1800° to 1850°F, however, reduced ductility to very low values with some increase in strength. This emphasized the sensitivity of the alloy to small changes in temperature of heat treatment in that temperature range.

To simulate the heat treatment of disc forgings, barstock from this heat was also normalized from 1850°F and tempered at 1250°F while sealed in a block which measured 9 by 9 1/2 by 4 inches. There appeared to be little difference in rupture strength and ductility between the barstock heat treated in the block and the barstock heat treated directly.

Plates 4, 5 and 6 show a fine tempered bainitic structure when the normalizing temperature was 1750°, 1800° or 1850°F. Considerable coarsening occurred during heat treatment in a block at 1850°F, although it may not have been uniform (Plate 7).

Heat 2759 with 0.32 percent Al had slightly higher 100-hour strengths than Heat A173 when normalized from 1800°F. Ductility was, however, lower. The 0.63 percent level of Heat 2760 resulted in ductilities similar to Heat A173, but with lower long time strengths. There were no observed differences in microstructure (Plates 8 and 9). There does not appear to be an obvious reason for the low ductility and somewhat higher strength of Heat 2759 with 0.30 percent Al.

The data suggest that Al additions might be useful for improving ductility in rupture tests when temperatures of normalizing are kept at 1800°F or lower.

TABLE I

Stress-Rupture Time Data at 1100° and 1200°F for Columbium and Aluminum Modified "17-22-A"V Steel

Heat Treatment Austenitized (°F)	Tempered (°F)	BHN	Stress (psi)	Rupture Time (Hours)	Elongation (% in 2 in.)	Reduction of Area (%)
Rupture Tests at 1100°F						
"17-22-A"V + 0.44% Cb (Heat A165)						
(A) 1850	1250	302/311	55,000	61	5.0	14.5
			45,000	217	2.0	7.0
(A) 1900	1250	302/321	55,000	118	2.5	4.5
			48,000	210	1.5	5.0
(A) 1950	1250	311/321	55,000	85	2.0	4.0
"17-22-A"V + 0.21% Al (Heat A173)						
(B) 1750	1225	293/302	45,000	21	19.0	61.5
			37,000	129	17.5	39.0
			29,000	398	20.0	28.5
(B) 1800	1225	311/321	45,000	42	11.5	35.5
			37,000	170	18.5	30.0
			29,000	526	14.0	22.5
(B) 1850	1225	321/331	32,000	544	2.0	(c)
(A) 1850	1250	311/321	50,000	28.5	4.5	12.5
			37,000	233	1.5	1.5
			32,000	330	2.0	(c)
"17-22-A"V + 0.32% Al (Heat 2759)						
(B) 1800	1225		36,000	231	2.5	7.0
			30,000	522	4.0	5.0
"17-22-A"V + 0.63% Al (Heat 2760)						
(B) 1800	1225		40,000	144	10.0	13.0
			30,000	322	13.0	15.0
Rupture Tests at 1200°F						
"17-22-A"V + 0.44% Cb (Heat A165)						
(A) 1850	1250	302/311	30,000	120	2.5	8.0
			22,000	361	1.5	6.0
(A) 1900	1250	302/321	30,000	88.5	3.0	5.0
			22,000	434	3.0	3.5

(A) Barstock sealed in a block (B) Barstock (C) Broke in fillet.

TABLE II

Rupture-Test Properties at 1100° and 1200°F of Columbium and Aluminum Modified "17-22-A"V Steel

Heat Treatment Austenitized (°F)	Heat Treatment Tempered (°F)	Material Treated	BHN	Rupture Strength (psi) and Elongation (%) 100 hours	500 hours	1000 hours
Rupture Properties at 1100°F						
"17-22-A"V + 0.44% Cb (Heat A165)						
1850	1250	Barstock sealed in a block	302/311	50,000(5)	39,000(2)	(35,000)
1900	1250	Barstock sealed in a block	302/321	57,000(2.5)	38,500(1.5)	(32,000)
1950	1250	Barstock sealed in a block	311/321	53,000(2)	-	-
"17-22-A"V + 0.21% Al (Heat A173)						
1750	1225	Barstock	293/302	38,000(18)	27,500(20)	(23,500)
1800	1225	Barstock	311/321	39,500(18)	(29,000(14)	(25,000)
1850	1225	Barstock	321/331	-	32,500(2)	(29,000)
1850	1250	Barstock sealed in a block	311/321	41,500(<4)	37,500(2)	(29,000)
"17-22-A"V + 0.32% Al (Heat 2759)						
1800	1225	Barstock	311	44,000(3)	30,500(4)	(25,500)
"17-22-A"V + 0.63% Al (Heat 2760)						
1800	1225	Barstock	285	46,000(10)	26,000(13)	(20,500)
Typical Values for "17-22-A"V						
Experimental induction heats				45,000-52,000(8)	-	30,000-36,000(5)
Production heats (High C and Mn for Hardenability)				40,000-50,000(5)	-	24,000-33,000(4)
Rupture Properties at 1200°F						
"17-22-A"V + 0.44% Cb (Heat A165)						
1850	1250	Barstock sealed in a block	302/311	31,500(2.5)	20,000(1.5)	(16,500)
1900	1250	Barstock sealed in a block	302/321	29,000(3)	21,500(3)	(19,000)
Typical Values for "17-22-A"V Steel						
Production heats (High C and Mn for Hardenability)				25,000-30,000(10)	-	13,000-15,000(3.5)

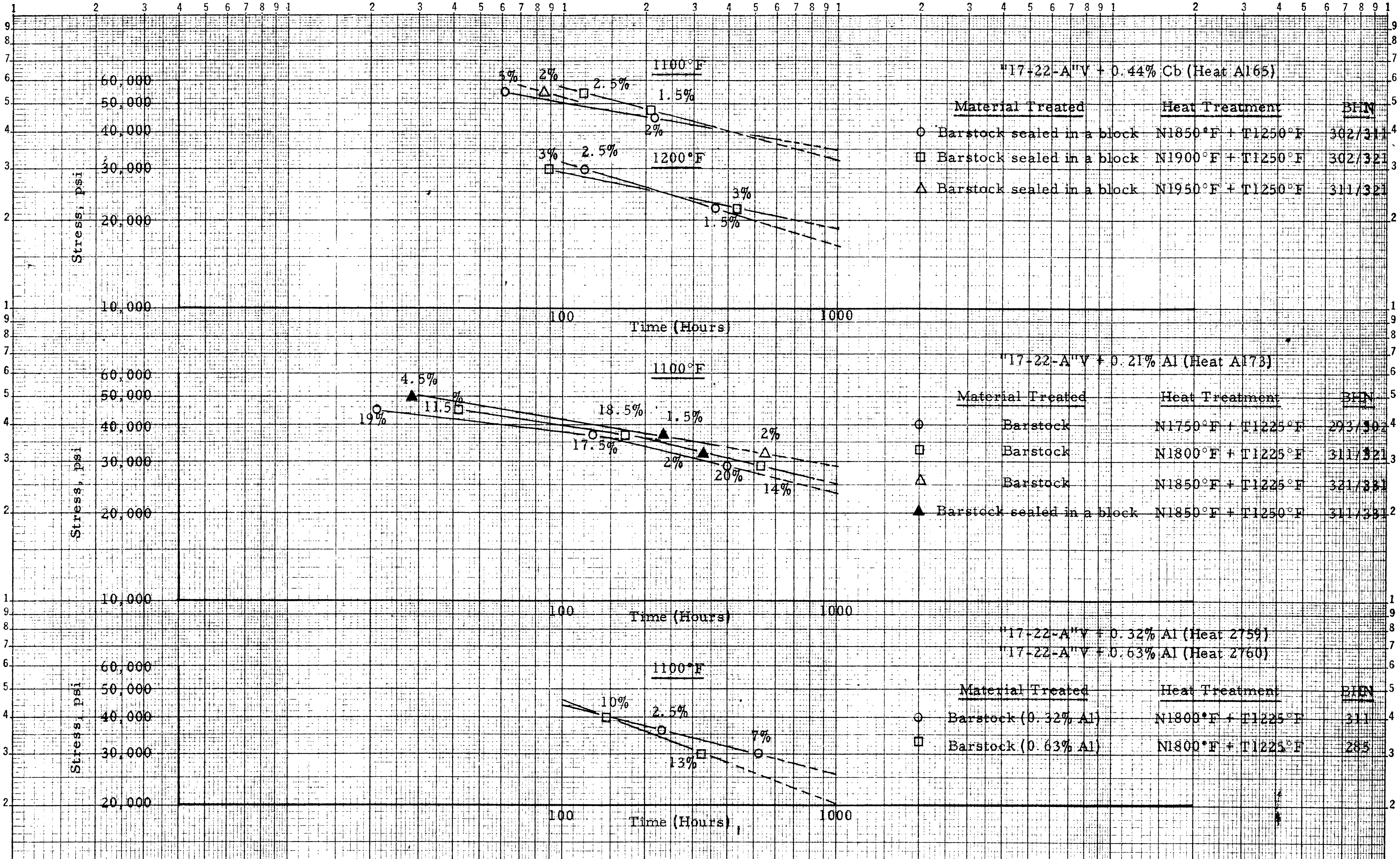

Figure 1. Stress-Rupture Time Curves at 1100° and 1200°F for Columbium and Aluminum Modified "17-22-A"V Steel