REPORT

ON

INFLUENCE OF MOLYBDENUM AND MANGANESE MODIFICATIONS ON THE HIGH TEMPERATURE PROPERTIES OF TYPE 410 STEEL

By

R. Jackowski

J. W. Freeman

PROJECT 842
REPORT 201

May 20, 1954

THE TIMKEN ROLLER BEARING COMPANY
STEEL AND TUBE DIVISION
CANTON, OHIO

INTRODUCTION

There are wide applications for 12 Cr type steels with improved strength at high temperatures. This report covers an investigation of the possibility of adding molybdenum for this purpose. Manganese was increased to nearly three percent to balance the gamma loop closing tendency of molybdenum and thereby reduce the amount of weak delta ferrite.

The 300-pound induction furnace heat tested was rather low in carbon, 0.033 percent. Nitrogen was 0.13 percent.

SUMMARY

The modified 12 Cr - 3 Mo - 3 Mn steel had 100-hour and 1000-hour rupture strengths at 1100°F of 34,000 psi and 23,000 psi respectively, together with elongations for both time periods of approximately 45 percent.

The addition of Mn to 12 Cr - 3 Mo steel did result in as high or higher rupture strength at 1100°F as had been previously obtained for 12 Cr - 3 Mo - 2 Ni steel in the oil quenched condition, although the strength was still below that of 12 Cr - 3 Mo steel.

The 12 Cr - 3 Mo - 3 Mn steel had a rather large amount of delta ferrite in the microstructure. The 3 percent of manganese was not able to offset the combined effects of low carbon and the molybdenum in promoting ferrite in the structure.

TEST MATERIALS

Machined 0.505-inch diameter specimens were supplied from a 300-pound induction heat having the following chemical composition:

Heat No.	C	Mn	P	S	Si	Cr	Mo	N_2
A203	0.033	2.82	0.010	0.020	1.20	10.95	3.20	0.130

The specimens were normalized from 2250°F (20 minutes at heat) and tempered for six hours at 1200°F to 293 - 302 Brinell. The reported results of a short-time tensile test at room temperature are as follows:

Tensile Strength (psi)	Yield Strength(psi)		Elongation (%)	Reduction of Area (%)
	0.02%	0.2%		
138,000	77,500	96,250	17.0	37.9

RESULTS

The individual stress-rupture test data obtained at 1100°F are listed in Table I and the established stress - rupture time curve shown in Figure 1. The 100-hour and 1000-hour rupture strengths as shown by this curve are 34,000 psi and 23,000 psi respectively. The elongation was approximately 45 percent at both time periods.

The microstructure of the original material and of the longest time stress-rupture test was examined microscopically. The original microstructure is shown in Plate No. 1 at magnifications of 100 and 1000 diameters. The appearance of the fracture and the side of the longest time rupture specimen are shown in Plate 2 at 100 diameters.

DISCUSSION

The rupture strength and elongation of the 12 Cr - 3 Mo - 3 Mn steel are compared in Figure 2 and in the following tabulations with those of 12 Cr - 3 Mo and 12 Cr- 3 Mo - 2 Ni steel previously investigated (Report 197).

Steel	Heat No.	Heat Treatment	BHN	Rupture Strength (psi)		Elongation (%)	
				100-hr	1000-hr	100-hr	1000-hr
12 Cr - 3 Mo - 3 Mn	A203	N. 2250°F + 6 hrs at 1200°F	293/ 302	34,000	23,000	45	45
12 Cr - 3 Mo - 2 Ni	02287	O.Q. 2115°F + 6 hrs at 1200°F	288/ 304	29,000	(23,000)*	35	--
12 Cr - 3 Mo	02718	O.Q. 2115°F + 6 hrs at 1200°F	286/ 302	37,500	(31,000)	24	--

* Figures enclosed in brackets indicate straight line extrapolation of the stress-rupture time curves.
Note: Data for 12 Cr - 3 Mo - 2 Ni and 12 Cr - 3 Mo steels from Report 197.

The rupture strength of the normalized 12 Cr - 3 Mo - 3 Mn steel, Heat A203, is higher at 100 hours and equal at 1000 hours to that of the oil quenched 12 Cr - 3 Mo - 2 Ni steel from Heat 02287 at 1100°F. However, the strengths of the 12 Cr - 3 Mo - 3 Mn steel are lower than those of the oil quenched 12 Cr - 3 Mo steel from Heat 02178.

The ductility of the 12 Cr- 3 Mo - 3 Mn steel at 100 hours is higher than for either of the other two alloys.

Microscopic examination of the fractured specimen indicated a transgranular type of fracture. The surface adjacent to the fracture showed no signs of intergranular oxidation of cracking. The only change observed in the structure after rupture testing was increased tempering of the martensite.

The original structure consisted of tempered martensite and delta ferrite. The added manganese did not appear to be very effective in counteracting the gamma loop closing tendency of the chromium and molybdenum combined with the low carbon content, as may be seen from the amount of delta ferrite present in the original structure. The rather high nitrogen content in the 12 Cr - 3 Mo - 3 Mn alloy apparently was not sufficient to offset the low carbon content. The rather high normalizing temperature did not unduly coarsen the structure.

Delta ferrite content is evidently not a good indicator of strength at high temperatures. The 12 Cr - 3 Mo had at least as much ferrite as the 12 Cr - 3 Mo - 3 Mn steel. Yet both had higher strength than the 12 Cr - 3 Mo - 2 Ni modifications, which was practically free from delta ferrite.

Such experience as has been obtained in this laboratory would not indicate that normalizing would result in much difference in rupture properties, as compared to the oil quench for the other two alloys. Thus, the effects observed were probably due to other factors.

TABLE I

Rupture Data at 1100°F for 12 Cr - 3 Mo - 3 Mn Modified 410 Steel (Heat A203)

(Normalized 2250°F + Tempered 1200°F)

Stress (psi)	Time to Rupture (hours)	Elongation (% in 2 in.)	Reduction of Area (%)
37,500	64	39.0	82.0
32,000	139	48.0	81.0
22,000	1318	44.0	78.5

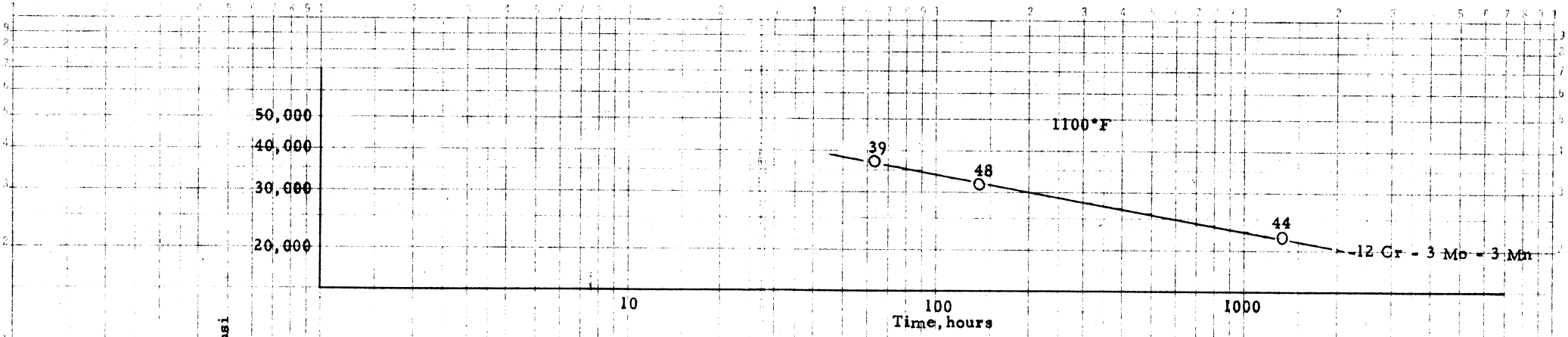
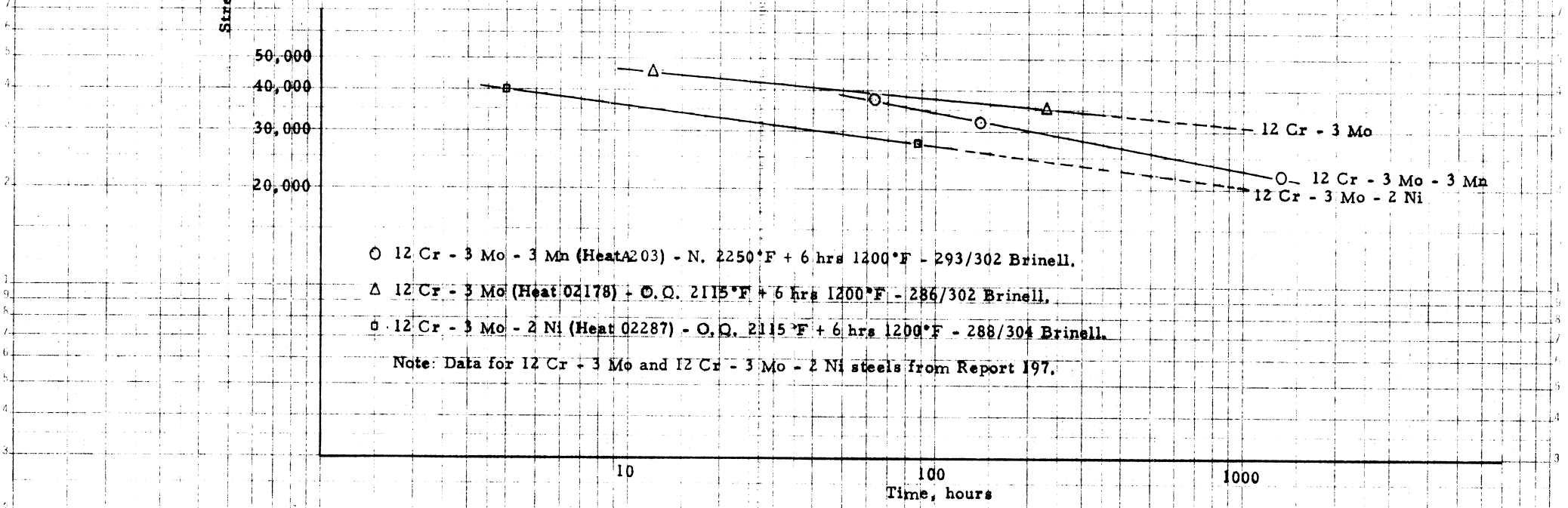


Figure 1. - Stress - Rupture Time Curve for 12 Cr - 3 Mo - 3 Mn Modified Type 410 Steel (Heat A203), Normalized 2250°F + Tempered 6 Hours at 1200°F to 193 - 302 Brinell Hardness.



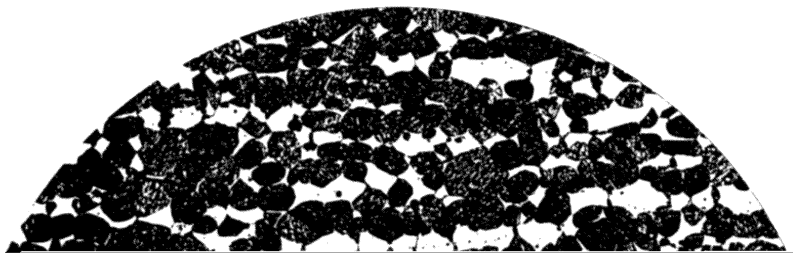
○ 12 Cr - 3 Mo - 3 Mn (Heat A203) - N. 2250°F + 6 hrs 1200°F - 293/302 Brinell.

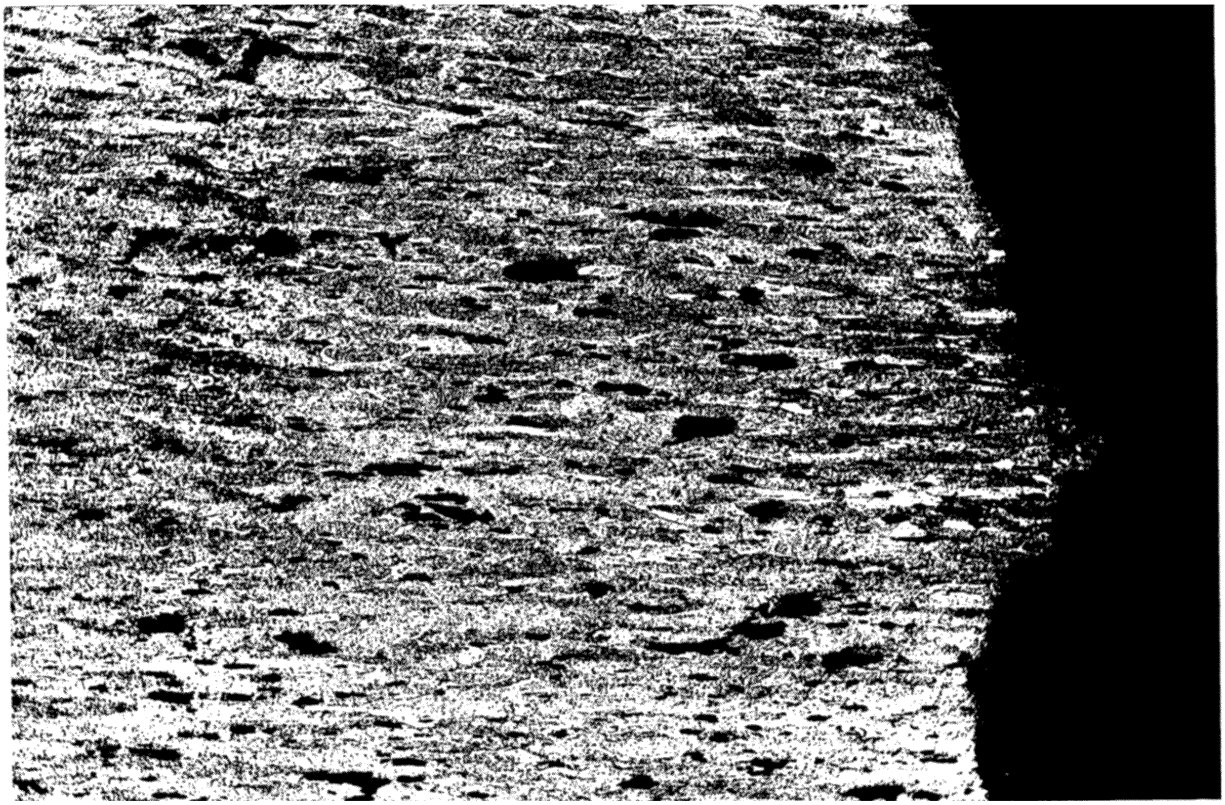
△ 12 Cr - 3 Mo (Heat 02178) - O.Q. 2115°F + 6 hrs 1200°F - 286/302 Brinell.

□ 12 Cr - 3 Mo - 2 Ni (Heat 02287) - O.Q. 2115°F + 6 hrs 1200°F - 288/304 Brinell.

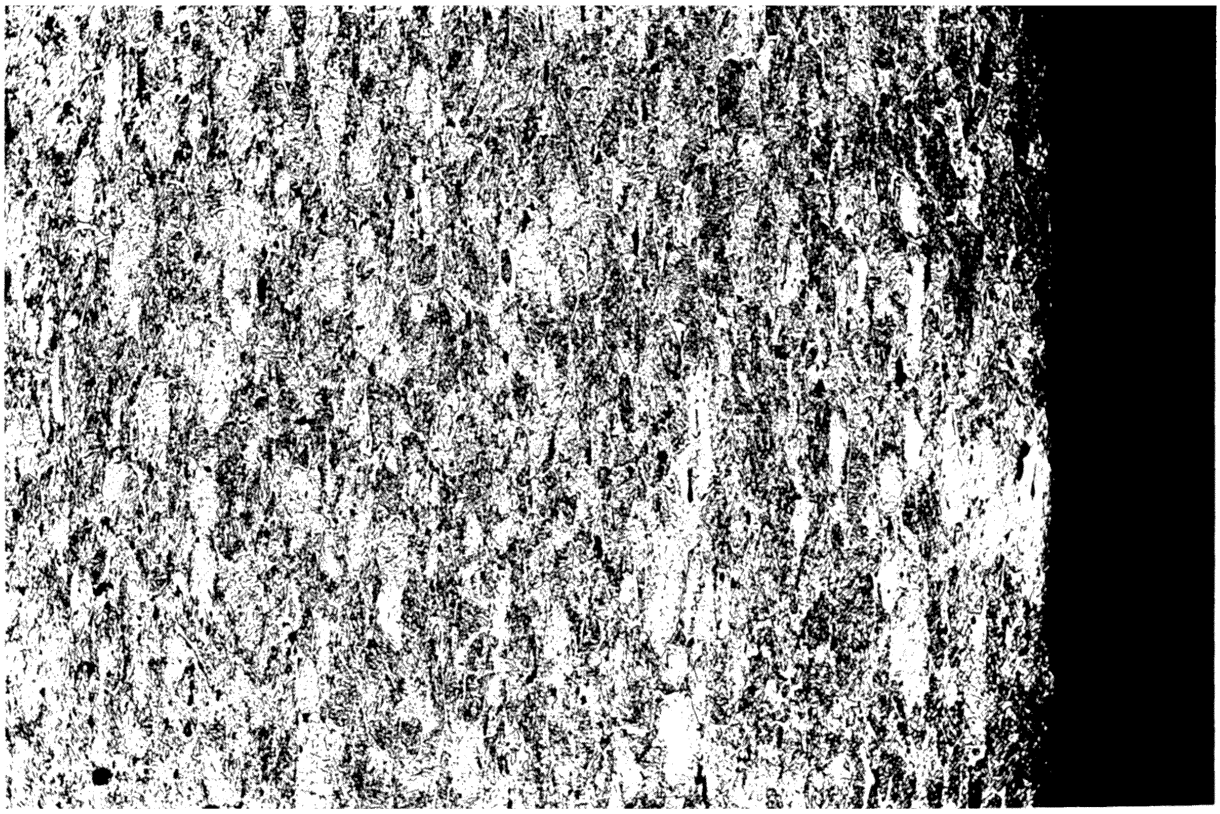
Note: Data for 12 Cr - 3 Mo and 12 Cr - 3 Mo - 2 Ni steels from Report 197.

Figure 2. - Comparative Stress - Rupture Time Curves for 12 Cr - 3 Mo - 3 Mn, 12 Cr - 3 Mo, and 12 Cr - 3 Mo - 2 Ni Steels at 1100°F.





Fracture X100D



Edge X100D

Plate No. 2. Microstructure of 12 Cr - 3 Mo - 3 Mn Modified Type 410 Steel, Normalized from 2250°F and Tempered for 6 Hours at 1200°F to 293/302 Brinell. Fractured after 1318 Hours at 1100°F and 22,000 psi.