RELEASED: JUNE 1972
AUTHOR: W. W. DYRKACZ

FERROUS ALLOYS

	Fe
Low	C
12	Cr
+	Cb

410 Cb

1. GENERAL

410Cb is an improved version of the standard Type 410 stainless steel. By the addition of about 0.15 percent Cb, certain properties are improved without altering any of the desirable characteristics of Type 410. The 410Cb stainless grade offers these major advantages over Type 410:

a. higher strength, ductility, and toughness at room, elevated and sub-zero temperatures
b. refinement in grain size
c. easier control of tempered hardness thru decreased sensitivity to time and temperature variations

It is used as an alternate to Type 410 in applications requiring uniformly high properties, uniform response to tempering and where the control of ferrite content is necessary (1)(2).

1.01 Commercial Designation

410Cb

1.02 Alternate Designations

AMS 5609; SAE 51410 Cb modified.

1.03 Specifications

Table 1.03.

1.04 Composition

Table 1.04.

1.05 Heat Treatment

(see also 1.09).

1.051 Fully anneal for maximum formability at 1450 to 1650F, usually 1550-1650F, followed by furnace cooling at 50F per hour maximum to 1100F. Hardness should be about Rockwell C 20.

1.052 Austenitize at 1700 to 1850F followed by an air cool or oil quench depending on section size and shape. As-quenched hardness should be about 42 to 44 Rockwell C (3).

1.0521 Effect of austenitizing temperature on grain size. The small addition of .10 to .15 columbium to Type 410 produces a marked refinement in its grain structure as shown by grain size measurements conducted on 1 1/2 inch diameter bars held one hour at various heating temperatures (3). Effect of columbium on grain size of Type 410 when austenitized at various temperatures, Table 1.0521.

1.053 Temper at 400 to 1400F for 1 to 12 hours, generally 4 hours. Tempering at temperatures between 700 and 1050F is not generally recommended, because of reduced resistance to corrosion and stress corrosion, and reduction of impact strength. However, 410Cb displays reduced susceptibility to temper embrittlement compared to regular Type 410 stainless steel (3).

1.0531 Effect of tempering temperature on hardness, Master tempering curves for 410Cb and regular Type 410, Figure 1.0531.

1.06 Hardness

This steel is air hardening. Also, sections up to 10 inches x 10 inches can be hardened to Rockwell C 42 to 44 by oil quenching from 1800F (3)(5).

1.061 Since 410Cb is more resistant to tempering than regular Type 410, a higher hardness is obtained with the 410Cb steel at any specified temperature when tempered between 950 and 1400F, Figure 1.061.

1.062 Hardness versus tempering temperature with constant tempering time for 410Cb versus regular Type 410, Table 1.062.

1.07 Forms and Conditions Available

410Cb is available as forging billets, bars, wire, forgings, and mechanical tubing in a wide range of commercial sizes in the annealed condition or heat treated to a broad range of mechanical properties (1)(2).

1.08 Melting and Casting Practice

Electric furnace air melt.

1.09 Special Considerations

1.091 Avoid tempering at 700 to 1050F because of reduced corrosion resistance, stress corrosion resistance, and impact strength. However, 410Cb exhibits a significantly higher level of notch impact strength than Type 410 when tempered between 700 and 1050F, and 410Cb shows a faster recovery of toughness in the trough region with tempering temperatures above 950F, as well (see Figure 3.0234).

1.092 Variation in tempering time and temperature are considerably less critical for 410Cb than for regular Type 410 stainless steel in the range of 950 to 1150F as shown by the early development of hardness plateaus (see Figure 1.061). These tempering characteristics of 410Cb can be used to advantage to enable close control of hardness and to produce uniformity of hardness within a furnace load when working to narrow specified hardness levels particularly within the broad range of Rockwell C 25 to 35. Substitution of 410Cb for Type 410 in such situations results in virtual elimination of re-heat treatments, permits larger furnace loads, and allows the mixing of parts with dissimilar and varying cross sections within the same furnace load (1)(3)(7).

1.093 The applicability of a comparatively high tempering temperature for hardness levels within the range of Rockwell C 20 to 32 is beneficial from the standpoint of additional relief of internal mechanical stresses and for dimensional stability in parts made from 410Cb (3).

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range. Same as for Type 410 stainless steel(4). (see also Code 1401)

2.012 Phase changes. Same as for Type 410 (4).

2.013 Thermal conductivity. Same as for Type 410 (4).

2.014 Thermal expansion. Same as for Type 410 (4).

2.015 Specific heat. Same as for Type 410 (4).

2.016 Thermal diffusivity.

2.02 Other Physical Properties

2.021 Density. Same as for Type 410 stainless steel (4) (see also Code 1401).

2.022 Electrical properties. Same as for Type 410 (4).

2.023 Magnetic properties. Same as for Type 410 (4).

2.024 Emittance.

2.025 Damping capacity.

2.03 Chemical Properties

2.031 Corrosion resistance.

2.0311 410Cb is resistant to atmospheric and fresh water corrosion and to a variety of mild acids and alkalines. It is inferior to the Type 300 stainless steels and may require corrosion protection. Maximum corrosion resistance is developed in the hardened condition, but the corrosion resistance is reduced by tempering between 700 and 1050F. The surface must be free from scale and foreign particles to prevent galvanic corrosion. The results of laboratory and actual service tests indicate that the minor addition of columbium is neutral insofar as affecting the general corrosion resistance of Type 410 stainless steel (3).

2.0312 410Cb is susceptible to both stress corrosion and to hydrogen embrittlement, if heat treated to high strength levels. In certain accelerated stress corrosion cracking tests conducted in the laboratory, the small addition of columbium to Type 410 indicates a slight trend toward improved resistance to stress corrosion cracking (3). The higher tempering temperature required for 410Cb to develop tensile strengths equivalent to those of regular Type 410 results in more effective relief of residual internal stresses that, in some environments, promote stress corrosion cracking (1).

2.032 Oxidation resistance of 410Cb is good up to 1200F for continuous service and up to 1400F for intermittent service (4).

2.04 Nuclear Properties

	Fe
Low	C
12	Cr
+	Cb

410 Cb

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

3.011 AMS specified mechanical properties, Table 3.011.

3.02 Mechanical Properties at Room Temperature

3.021 Typical mechanical properties, Table 3.021.

3.0212 Typical tensile properties of 410Cb compared with regular Type 410 at various tempering temperatures, Figure 3.0212.

3.0213 Effect of size of cross section,. Table 3.0213.

3.0214 Effect of austenitizing and tempering temperatures, Table 3.0214.

3.0215 Tensile strength versus elongation of 410Cb compared with regular Type 410, Figure 3.0215.

3.0216 Effect of exposure at elevated temperature on room temperature properties, Table 3.0216.

3.022 Compression.

3.023 Impact.

3.0231 Effect of tempering temperature on impact strength (see Table 3.021).

3.0232 Effect of austenitizing temperature on impact strength (see Table 3.0214).

3.0233 Effect of size of cross section on impact strength (see Table 3.0213).

3.0234 Charpy V-notch impact strength of 410Cb compared with regular Type 410 after various tempering treatments, Figure 3.0234.

3.024 Bending.

3.025 Torsion and shear.

3.026 Bearing.

3.027 Stress concentration.

3.0271 Notch properties (see Table 3.0216).

3.0272 Fracture toughness.

3.028 Combined properties.

3.03 Mechanical Properties at Various Temperatures

3.031 Typical short time, elevated temperature tensile properties using two different tempering temperatures, Table 3.031.

3.0312 Elevated temperature tensile properties of 410Cb compared with regular type 410 stainless steel (typical), Figure 3.0312.

3.032 Compression.

3.033 Impact.

3.0331 Charpy V-notch impact strength of 410Cb at room and sub-zero temperatures versus Type 410, Figure 3.0331.

3.0332 Effect of tempering temperature on impact strength of 410Cb and Type 410 bar at room and sub-zero temperatures, Figure 3.0332.

3.034 Bending.

3.035 Torsion and shear.

3.036 Bearing.

3.037 Stress concentration.

3.038 Combined properties.

3.04 Creep and Creep Rupture Properties

3.041 Creep rupture curves at 900 to 1100F for bar tempered at 1200F for 410Cb versus Type 410, Figure 3.041.

3.042 Creep rupture curves at 900 to 1100F for 410Cb tempered bar using 1850F and 2000F austenitizing temperatures, Figure 3.042.

3.05 Fatigue Properties

3.051 S-N curves for heat treated bar, Figure 3.051.

3.06 Elastic Properties

3.061 Poisson's ratio. Same as Type 410 (4).

3.062 Modulus of elasticity. Same as Type 410 (4).

3.063 Modulus of rigidity. Same as Type 410 (4).

4. FABRICATION

4.01 Formability

4.011 410Cb is generally formed in the fully annealed condition utilizing the same practice used for Type 410.

4.012 Forgeability and forging procedures. Same as Type 410.

4.02 Machining and Grinding

4.021 Machinability and machining practice. Same as for Type 410.

4.03 Welding

4.031 Weldability and welding procedures. Same as for Type 410.

4.04 Surface Treatment

AMS	Form	Military
5609	Bars, Forgings, Forging Stock and Mechanical Tubing	-

TABLE 1.03 SPECIFICATIONS.

Source	AMS 5609 (2)		(3)
	Percent		
	Minimum	Maximum	Typical
Carbon	.12	.15	.13
Manganese	-	.60	.50
Silicon	-	.50	.25
Phosphorus	-	.025	.012
Sulfur	-	.025	.018
Chromium	11.50	12.50	11.95
Nickel	-	.75	.20
Molybdenum	-	.20	-
Aluminum	-	.05	-
Copper	-	.50	-
Columbium	.05	.25	.12
Tin	-	.05	-
Nitrogen	-	.08	-
Iron	Balance		Balance

TABLE 1.04 COMPOSITION.

Heating Temperature F - 1 hr	ASTM Grain Size (avg at 100x)	
	Type 410	410Cb
1700	6	8 to 9
1800	5	8
1900	4 to 5	8
2000	4	7 to 8

TABLE 1.0521 EFFECT OF COLUMBIUM ON GRAIN SIZE OF TYPE 410 WHEN AUSTENITIZED AT VARIOUS TEMPERATURES.

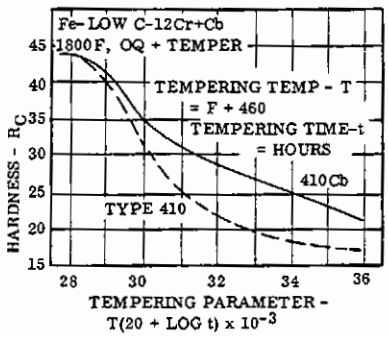

FIG. 1.0531 MASTER TEMPERING CURVES FOR 410Cb AND TYPE 410. (3, p. 81)

Fe
Low C
12 Cr
+ Cb

410 Cb

Source	AMS 5609 (2)
Alloy	Fe-low C-12Cr + Cb
Form	Bar, Forgings, Mechanical Tubing, and Forging Stock
Condition	1700F, 1 hr, AC + 600F, 2 hr (double temper)
F_{tu} - min - ksi	185*
F_{ty} - min - ksi	152
e(2 in or 4D) min - percent	10
RA - min - percent	30
Hardness - R_C	40-45

* Capability requirement of material 0.500 in or less in diameter, wall thickness, or distance between parallel sides or 0.500 in diameter specimens cut from larger bars, forgings, or tubing and given heat treatment specified above.

TABLE 3.011 AMS SPECIFIED MECHANICAL PROPERTIES.

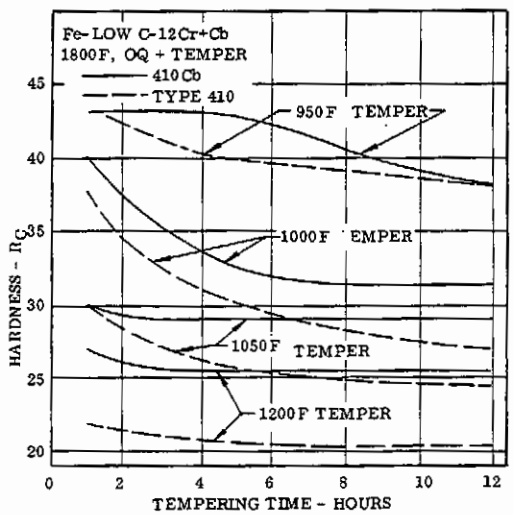

FIG. 1.061 TEMPERING CHARACTERISTICS OF 410Cb AND TYPE 410. (3, p. 81)

Source	(3)(4)								
Alloy	Fe-Low C-12Cr + Cb								
Form	Bar - 1 inch diameter								
Condition	1850F, oil quench +(F) Temper, 4 hr, AC								Ann
Temper - F	500	700	900	1000	1100	1200	1300	1400	-
F_{tu} - ksi	195	194	199	157	137	125	114	101	100
F_{ty} - ksi	161	162	156	138	121	109	94	79	75
e(2 in)-percent	16	16	18	18	19	20	22	26	25
RA - percent	61	61	60	64	64	65	69	72	70
Hardness-R_C	43	43	43	34	28	25	22	-	-
-R_B	-	-	-	-	-	-	-	99	99
Charpy V-Notch Impact - ft lb	50	55	30	37	68	95	110	110	-

TABLE 3.021 TYPICAL MECHANICAL PROPERTIES.

Source	(3)	
Form	Bar - 1 in diameter	
Condition	1850F, oil quench +(F) temper, 4 hr, AC	
Tempering Temperature - F	Rockwell Hardness	
	410Cb	Type 410
500	C43	C43
700	C43	C41
900	C43	C42
1000	C34	C28
1100	C28	C24
1200	C25	C20
1300	C22	B97
1400	B99	B92

TABLE 1.062 HARDNESS VERSUS TEMPERING TEMPERATURE WITH CONSTANT TEMPERING TIME FOR 410Cb VERSUS REGULAR TYPE 410.

	Fe
Low	C
12	Cr
+	Cb

410 Cb

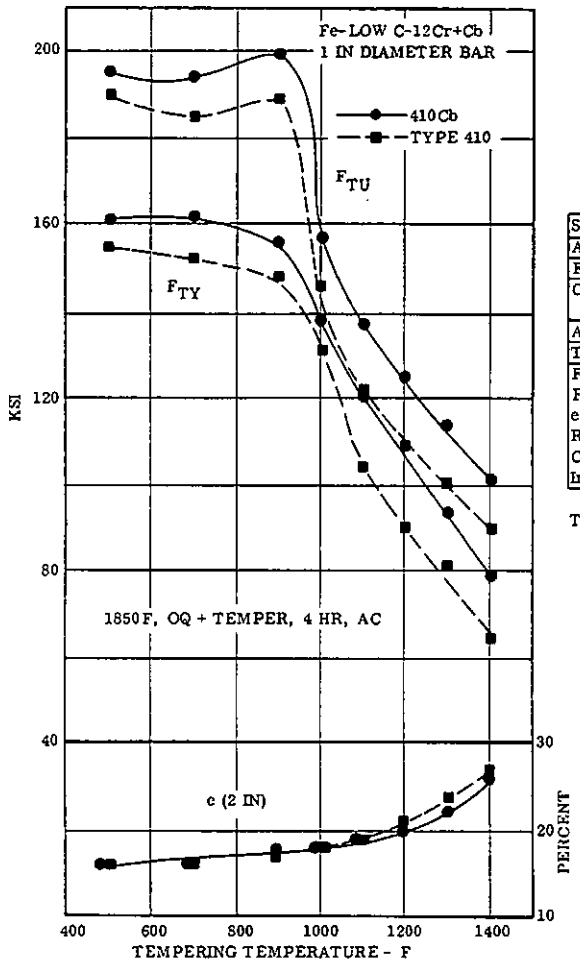

FIG. 3.0212 EFFECT OF TEMPERING TEMPERATURE ON ROOM TEMPERATURE TENSILE PROPERTIES OF 410Cb AND TYPE 410 BAR. (3, p. 82)

Source	(6)									
Alloy	Fe-Low C-12Cr + Cb									
Form	Bar - 1 inch diameter									
Condition	Austenitize (F), 0.5 hr, oil quench + Temper (F), 4 hr, AC									
Austenitize - F	1700	1850	1700	1850	1700	1850	1700	1850	1700	1850
Temper - F	700		1000		1100		1200		1300	
F_{tu} - ksi	193	194	146	157	129	137	120	125	111	114
F_{ty} - ksi	166	162	130	138	115	121	103	109	95	99
e(2 in)-percent	16	16	20	18	20	19	21	20	22	22
RA - percent	50	51	67	64	67	64	67	65	70	69
Charpy V-Notch Impact - ft lb	54	56	64	37	64	68	110	96	117	110

TABLE 3.0214 EFFECT OF AUSTENITIZING AND TEMPERING TEMPERATURES.

Source	(5)		
Alloy	Fe-Low C-12Cr + Cb		
Condition	1850 F, oil quench + 1200 F, 4 hr, AC		
Form - Bar	2 5/8 inch diameter	4 5/8 inch diameter	5 1/4 inch diameter
F_{tu} - ksi	125	124	126
F_{ty} - ksi	112	112	110
e(2 in) - percent	20	21	20
RA - percent	65	64	61
Hardness - R_C	26	26	26
Charpy V-Notch Impact - ft lb	90 to 96	40 to 46	55 to 65
Longitudinal tests at mid-radius location.			

TABLE 3.0213 EFFECT OF SIZE OF CROSS SECTION.

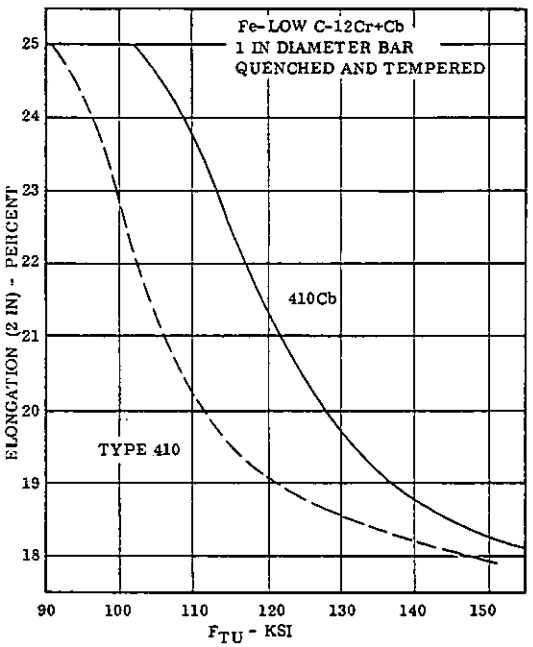

FIG. 3.0215 TENSILE STRENGTH VERSUS ELONGATION OF 410Cb AND TYPE 410. (1, p. 4)

Source	(5)			
Alloy	Fe-Low C-12Cr + Cb			
Form	1 inch diameter bar			
Condition	1850F, 0.5 hr, oil quench + 1200F temper + exposure			
Exposure Temp and Stress	None	900F-50 ksi	None	900F-55 ksi
Exposure Time - hours	None	17,229	None	16,818
F_{tu} - smooth - ksi	127	128	-	-
notched - ksi	-	-	208	223
e(4D) - percent	20	18	-	-
Hardness - R_C	26	27	26	27
Notch specimen: K_t = 3.0, 60° notch with .005 R, .375 inch diameter smooth section.				

TABLE 3.0216 EFFECT OF EXPOSURE AT ELEVATED TEMPERATURE ON ROOM TEMPERATURE PROPERTIES.

	Fe
Low	C
12	Cr
+	Cb

410 Cb

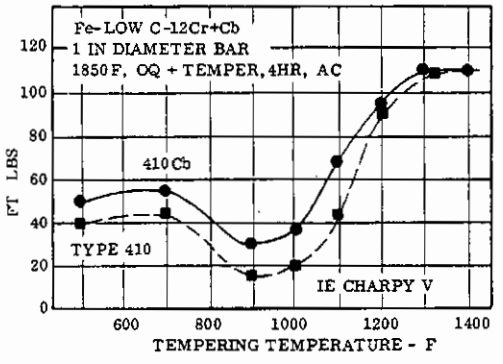

FIG. 3.0234 EFFECT OF TEMPERING TEMPERATURE ON ROOM TEMPERATURE IMPACT STRENGTH OF 410Cb AND TYPE 410 BAR. (3, pp. 82, 83)

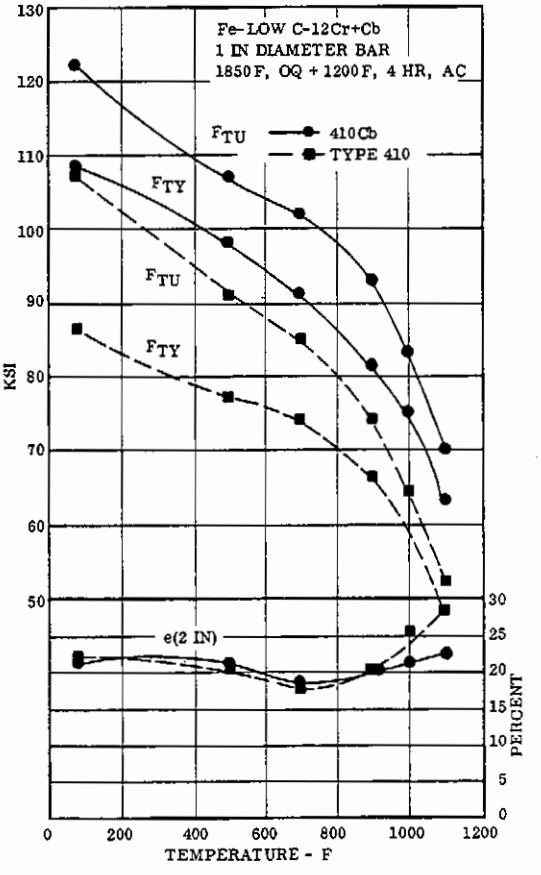

FIG. 3.0312 EFFECT OF TEST TEMPERATURE ON TENSILE PROPERTIES OF 410Cb AND TYPE 410 BAR. (3, p. 86)

Source	(1)(3)(6)									
Alloy	Fe-low C-12Cr + Cb									
Form	Bar - 1 inch diameter									
Condition	1850F, oil quench + (F) Temper, 4 hr, AC									
Tempering Temp - F	1200					1100				
Test Temp F	500	700	900	1000	1100	500	700	900	1000	1100
F_{tu} - ksi	107	102	93	83	70	117	110	97	-	74
F_{ty} - ksi	98	91	81	75	63	107	101	92	-	71
e(2 in)-percent	21	18	20	21	22	17	15	18	-	21
RA - percent	67	65	67	-	80	70	68	72	-	81

TABLE 3.031 TYPICAL SHORT TIME, ELEVATED TEMPERATURE TENSILE PROPERTIES USING TWO DIFFERENT TEMPERING TEMPERATURES.

	Fe
Low	C
12	Cr
+	Cb

410 Cb

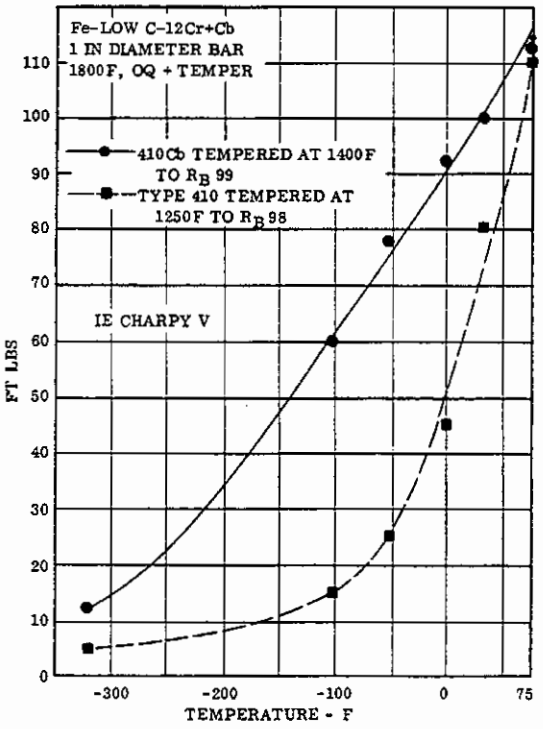

FIG. 3.0331 EFFECT OF TEST TEMPERATURE ON IMPACT STRENGTH OF 410Cb AND TYPE 410 TEMPERED BAR. (5)

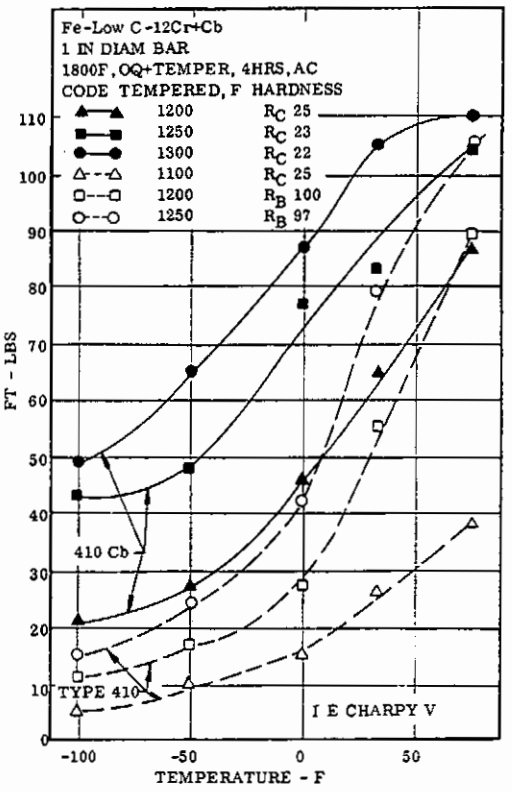

FIG. 3.0332 EFFECT OF TEMPERING TEMPERATURE ON IMPACT STRENGTH OF 410 Cb AND TYPE 410 BAR AT ROOM AND SUB-ZERO TEMPERATURES.

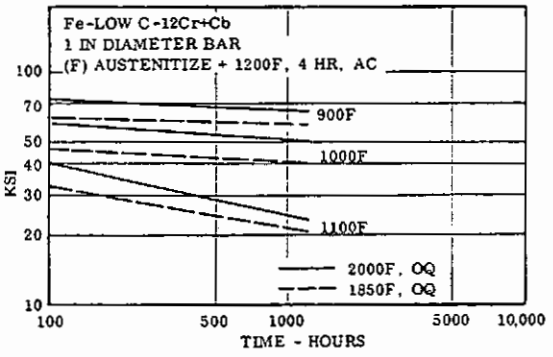

FIG. 3.042 CREEP RUPTURE CURVES AT 900 TO 1100F FOR 410 Cb TEMPERED BAR USING TWO AUSTENITIZING TEMPERATURES. (1, p. 6)

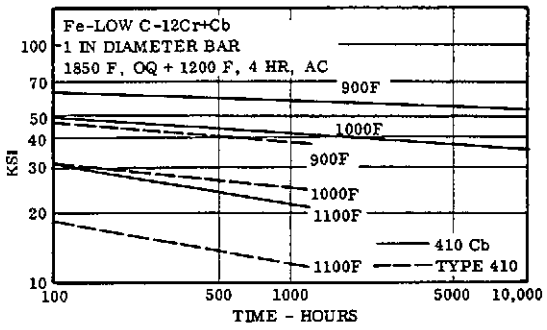

FIG. 3.041 CREEP RUPTURE CURVES AT 900 TO 1100F FOR 410Cb AND TYPE 410 TEMPERED BAR. (1,p.6)(5)

	Fe
Low	C
12	Cr
+	Cb

410 Cb

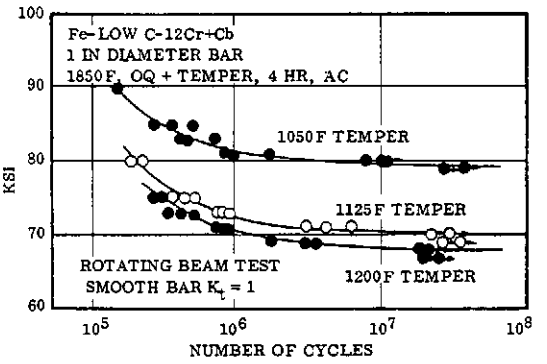

FIG. 3.051 S-N CURVES AT ROOM TEMPERATURE FOR 410Cb BAR. (8)

REFERENCES

1. Armco Steel Corporation, Product Data Bulletin S-32, "Armco 410Cb Stainless Steel" (September 1966).
2. AMS 5609 (January 31, 1964).
3. Tanczyn, H., "Properties of 12 Percent Chromium Alloys Modified with Small Columbium Additions," ASTM Special Technical Publication No. 369 (1965).
4. Private communication with A. C. Burton, Research Engineer, Armco Steel Corporation, Baltimore, Maryland (February 1971).
5. Tanczyn, H., "What Columbium Does to Type 410 Stainless Steel," Metal Progress (November 1966).
6. "Stainless Steel Properties Bettered with Columbium," STEEL (September 3, 1962).
7. "Columbium Addition Toughens Type 410 Stainless Steel" IRON AGE (August 30, 1962).
8. Private communication with H. Tanczyn, Senior Research Engineer, Armco Steel Corporation, Baltimore, Maryland (July 1971).