DATA SHEET

LATROBE SPECIALTY STEEL COMPANY
Latrobe, PA 15650-0031 USA

CSS-42L™ VIM-VAR

PRELIMINARY

(U.S. Patent Number 5,424,028)

HIGH PERFORMANCE CARBURIZING STAINLESS STEEL
BEARING AND GEAR STEEL

Typical	C	Cr	V	Ni	Mo	Co	Cb
Composition	**0.12**	**14.0**	**0.60**	**2.00**	**4.75**	**12.5**	**0.02**

CSS-42L™ is a case carburizable stainless steel alloy intended to be used at operating temperatures up to 800°F (427°C). The alloy is able to achieve and maintain a high surface hardness when carburized and heat treated that combines high fracture toughness, hot hardness, metal-to-metal wear resistance and corrosion resistance while retaining core ductility and strength. The alloy is particularly suited for use in bearing applications and also in cams, shafts, gears, bolts and like articles exposed to elevated temperature and corrosive atmospheres. This material is covered by U.S. Patent No. 5,424,028.

FIGURES AND TABLES

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CSS-42L™ VIM-VAR

TABLE 1-- Suggested Guidelines for Carburizing and Heat Treating CSS-42L™

CSS-42L™
(U.S. Patent No. 5,424,028)

Carburizing Cycle:

- Preoxidize at 954°C (1750°F) (not required when vacuum carburizing)
- Carburize at 954°C (1750°F)
- Slow cool to 204°C - 260°C (400°F - 500°F) (or directly harden in vacuum)
- Condition at 593°C (1100°F) for 4 hours (not required when direct hardening in vacuum)

Hardening Cycle:

- Austenitize at 1093°C - 1121°C (2000°F - 2050°F)
- Oil quench (or gas/fan quench to 66°C (150°F) and cool to room temperature if vacuum furnace)
- Subzero cool to -79°C (-110°F) (or lower, whatever is convenient)
- Temper at 496°C (925°F) for 2 hours
- Deep cryogenically treat for 1 hour (minimum)
- Temper at 496°C (925°F) for 2 hours

Reference: Burrier, H. I.; Tomasello, C. M.; Balliett, S. A.; Maloney, J. L.; Milam, D. L.; Ogden, W. P.; "Development of CSS-42L™, A High Performance Carburizing Stainless Steel for High Temperature Aerospace Applications." Reprinted from the paper presented at the Fifth International Symposium on Bearing Steels; November 19-21, 1996; New Orleans, Louisiana.

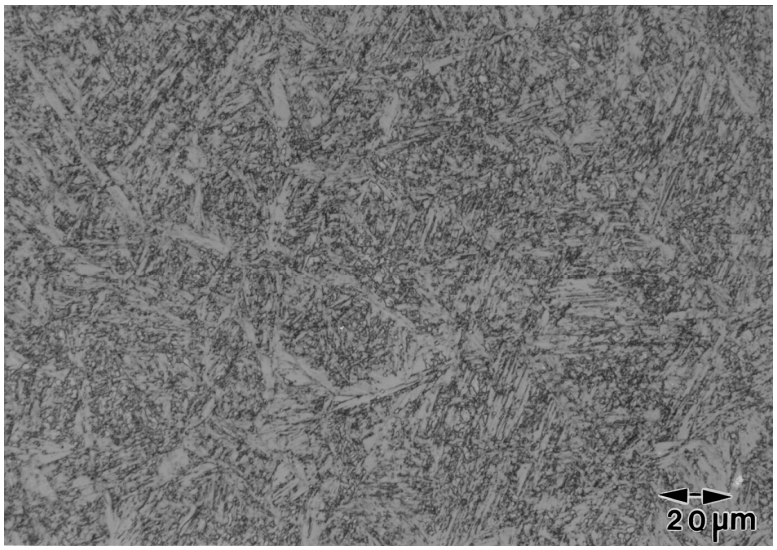
CSS-42L™ VIM-VAR

FIGURE 1. CSS-42L™ MICROSTRUCTURE

(U. S. Patent Number 5,424,028)

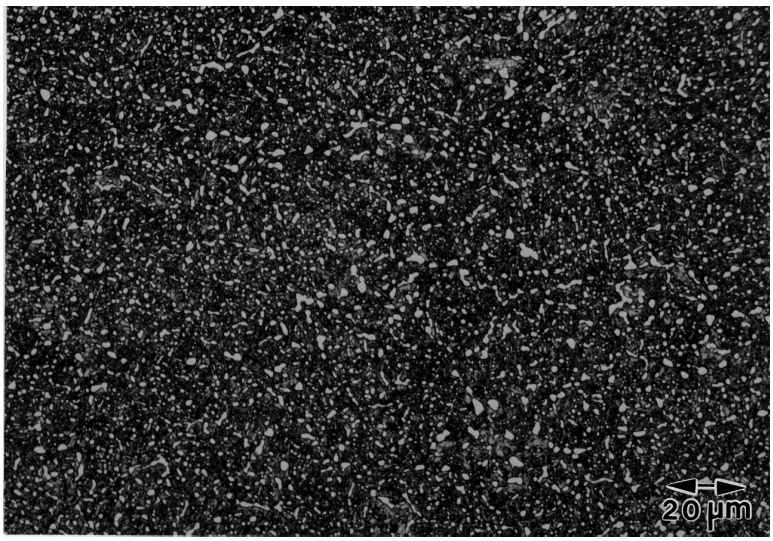
CORE MICROSTRUCTURE

Condition: Heat Treated
Etchant: Marble's etch
Magnification: 500x



CASE MICROSTRUCTURE

Condition: Gas Carburized and Heat Treated
Etchant: Marble's Etch
Magnification: 500x



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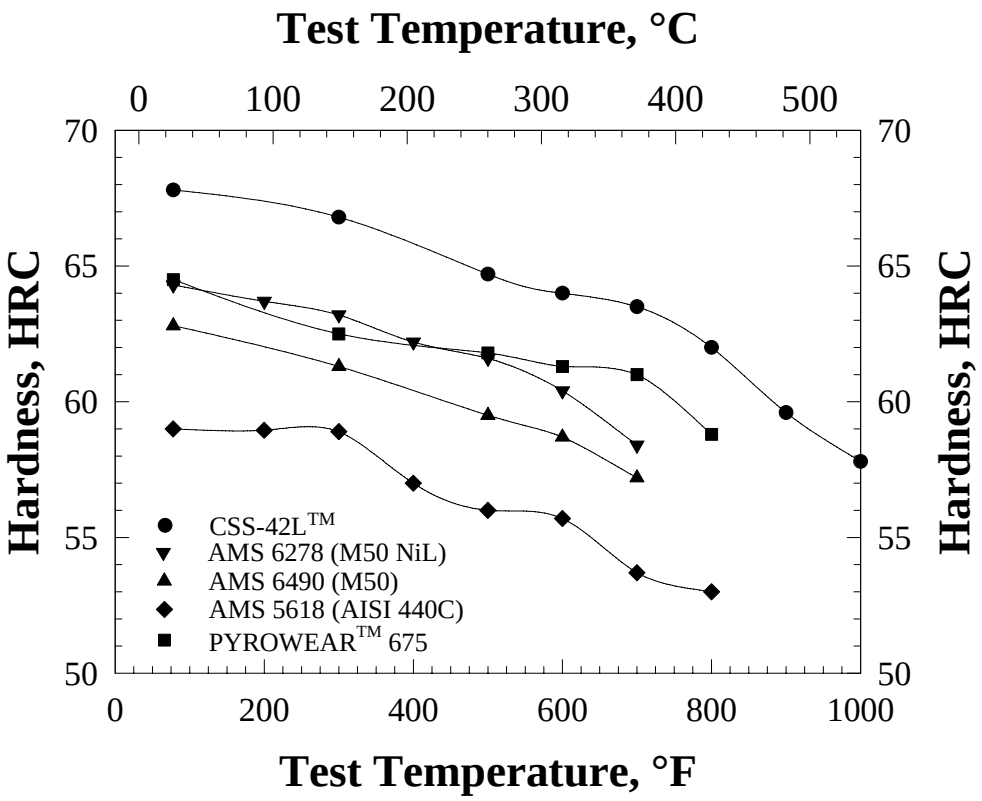


FIGURE 2. Hot hardness of case carburized CSS-42L™ and comparative alloys (direct Rockwell C hardness measurements).

TABLE 2-- Average Core Mechanical Property Data from Longitudinal Samples

Tempering Temperature		UTS		YS		R.A.	elongation	Young's modulus x 10^6	
°C	(°F)	MPa	(ksi)	MPa	(ksi)	%	%	GPa	(Msi)
496	(925)[1]	1760	(255.2)	1336	(193.7)	56.2	18.5	207.9	(30.16)
524	(975)[1]	1841	(267.0)	1340	(194.4)	54.6	16.0	211.3	(30.65)
496	(925)[2]	1764	(255.8)	1200	(174.1)	59.4	21.0	--	--

[1] Solution treated at 1052°C (1925°F), austenitized at 1038°C (1900°F), and tempered at the indicated temperature.
[2] Heat treated per Table 1.

TABLE 3-- ASTM E399 Fracture Toughness Data of Core Material (Pseudo Carburized)

Alloy	Tempering Temperature		Hardness	Orientation	K_q		K_{Ic}	
	°C	(°F)	HRC		MPa√m	(ksi√in)	MPa√m	(ksi√in)
9310 [1]	149	(300)	39	TL	--	--	115	105
CSS-42L™ [2]	316	(600)	44	TL	--	--	119.7	108.9
	316	(600)	43	TL	--	--	112.4	102.3
	496	(925)	50	TL	50.1	(45.6)	--	--
	496	(925)	49	TL	50.7	(46.1)	--	--
CSS-42L™ [3]	496	(925)	47	TL	112.6	(102.4)	--	--
	496	(925)	46	TL	113.9	(103.6)	--	--
M50-NiL [4]	524	(975)	44	CR	--	--	52	57.1
M50 [4]	538	(1000)	63	CR	--	--	17.6	16

[1] Jatczak, C. F., "Specialty Carburizing Steels for Elevated Temperature Service," Metal Progress, 1978, pp. 70-78.
[2] Pseudo carburization included 1052°C (1925°F) solution treat followed by 1038°C (1900°F) austenitize and tempering at the indicated temperature.
[3] Heat treated per Table 1.
[4] Bamberger, E. N., Averbach, B. L. and Pearson, P. K., "AFWAL-TR-84-2103 Final Report - Improved Fracture Toughness Bearings," Air Force Aero Propulsion Laboratory - W. P. A. F. B., Ohio, January, 1985.

TABLE 4-- ASTM E1304 (Short Rod) Fracture Toughness Data of Core Material (Pseudo Carburized)

Alloy	Tempering Temperature		Hardness	Orientation	K_{Ivj}		K_{IvM}	
	°C	(°F)	HRC		MPa√m	(ksi√in)	MPa√m	(ksi√in)
CSS-42L™ [1]	496	(925)	51	LT	62.6	(57.0)	64.8	(59.0)
	524	(975)	51	LT	--	--	77.1	(70.2)
	524	(975)	51	TS	--	--	81.9	(74.5)
	524	(975)	51	TS	91.8	(83.5)	--	--
CSS-2L™ [2]	496	(925)	47	LT	--	--	125.1	(113.7)
	496	(925)	47	LT	--	--	125.3	(113.9)
M50-NiL [3]	538	(1000)	44	LT	63.1	(57.4)	--	--

[1] Solution treated at 1052°C (1925°F), austenitized at 1038°C (1900°F), and tempered at the indicated temperature.
[2] Heat treated per Table 1.
[3] Commercially reported data from Latrobe Steel Company.

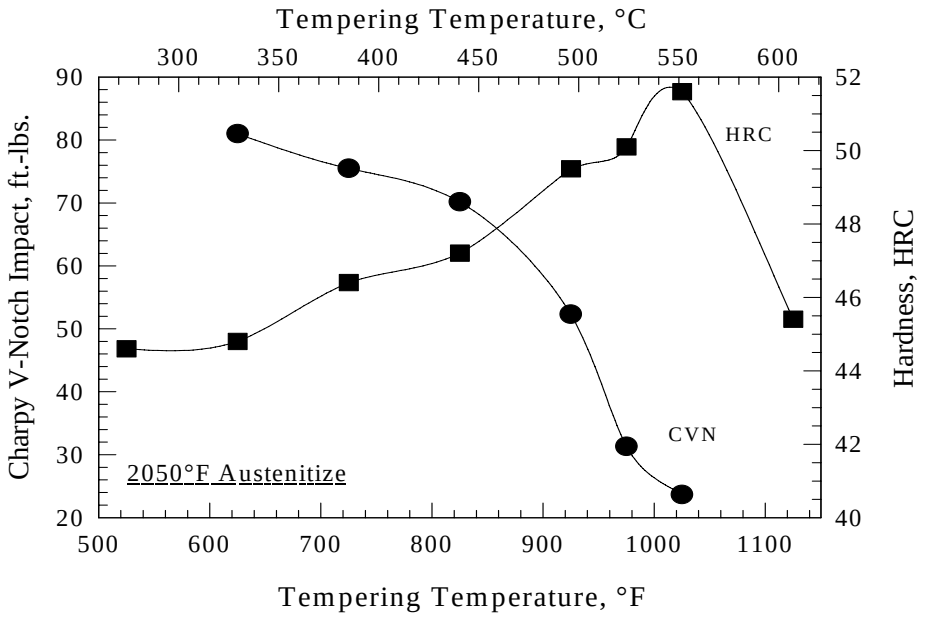


FIGURE 3. Core impact and hardness measurements versus tempering temperature for CSS-42L™. CVN samples were taken from the LT orientation (hardness measurements were direct Rockwell C).

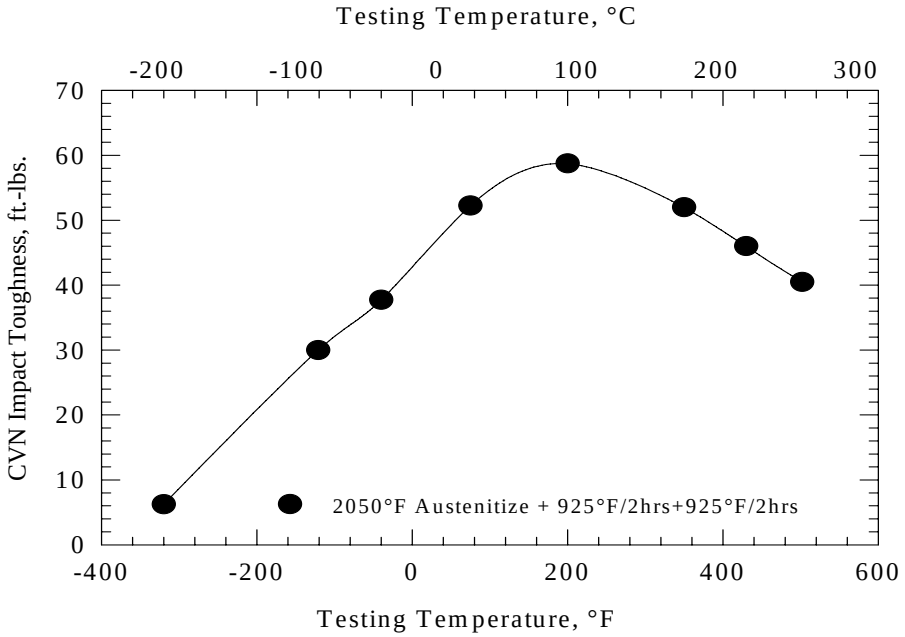


FIGURE 4. Core impact transition temperature diagram for CSS-42L™. (CVN samples were taken from the LT orientation)

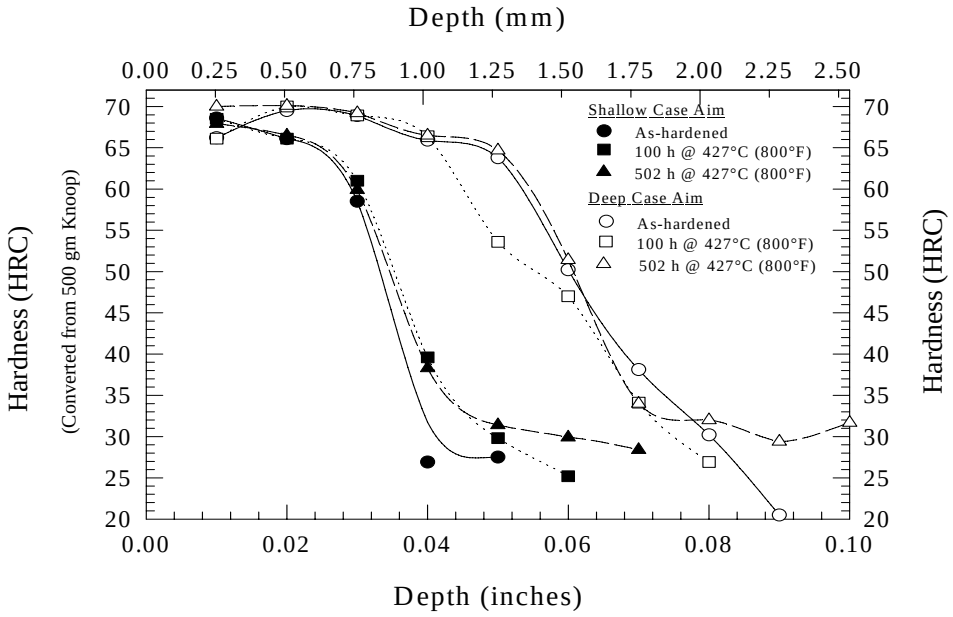


FIGURE 5. Vacuum carburizing results illustrate shallow and deep case aims and the effects of exposure at 427°C (800°F) (hardened from 1121°C (2050°F)).

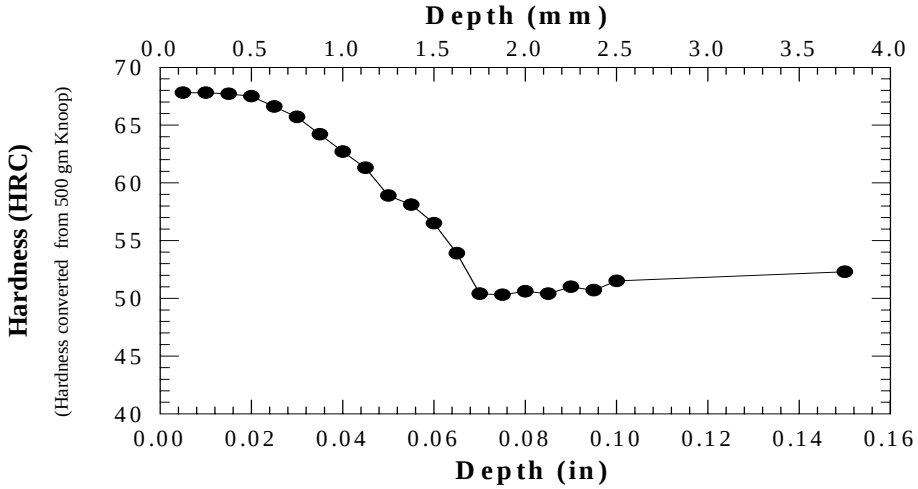


FIGURE 6. Hardness profiles after gas carburizing at 1.3% carbon potential (hardened from 1038°C (1900°F)).

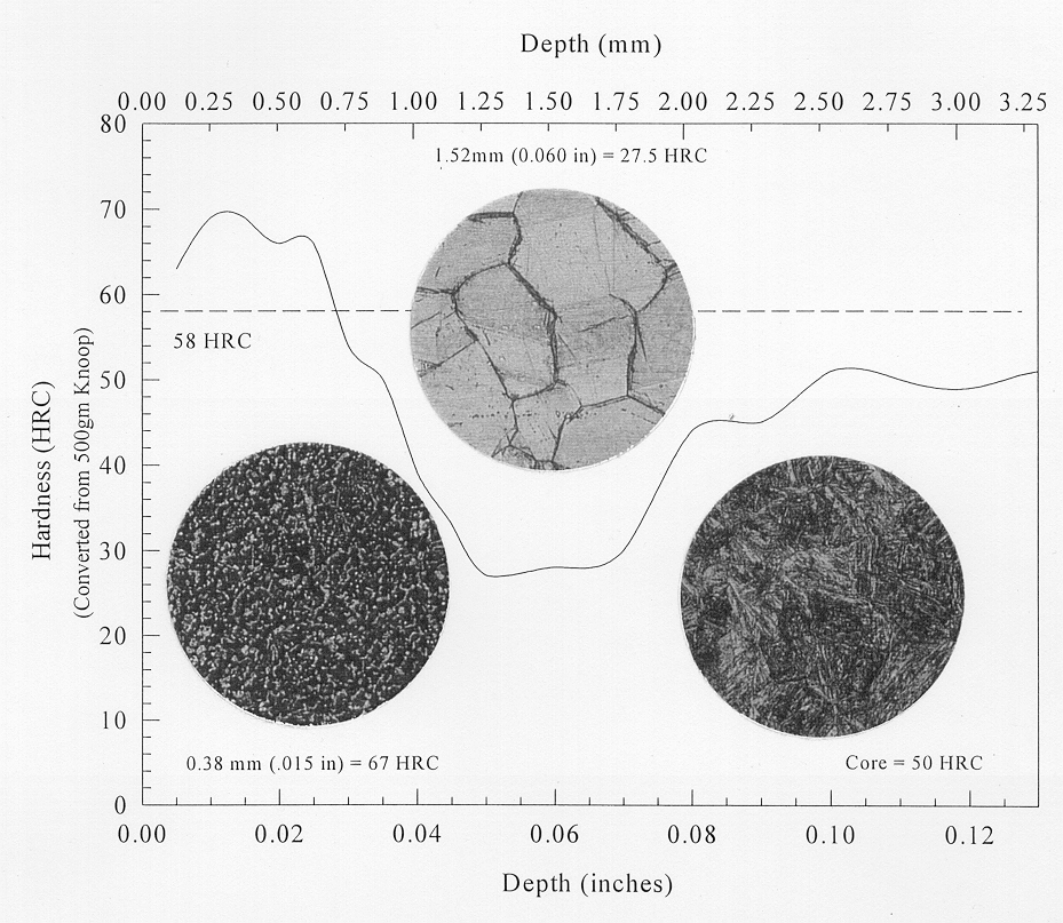


FIGURE 7. Hardness and microstructure of CSS-42L™ after carburizing and heat treating according to Table 1 (hardened at 1121°C (2050°F)). (original magnification 500x)

TABLE 5-- Effect of Austenitizing Temperature on Case Hardness and Residual Stress

Austentitizing Temperature		Residual Stress Average from indicated depth		Effective Case Depth to 58 HRC	
°C	(°F)	0.25-0.50mm	(0.01-0.02 in)	mm	(in)
1038	(1900)	514.4 MPa	(74.6 ksi)	0.864	(0.034)
1093	(2000)	-44 MPa	(-6.4 ksi)	0.711	(0.028)
1121	(2050)	-249 MPa	(-36.1 ksi)	0.305	(0.012)

Note: All samples come from the same experimental carburizing cycle to illustrate the effects of austenitizing temperature.

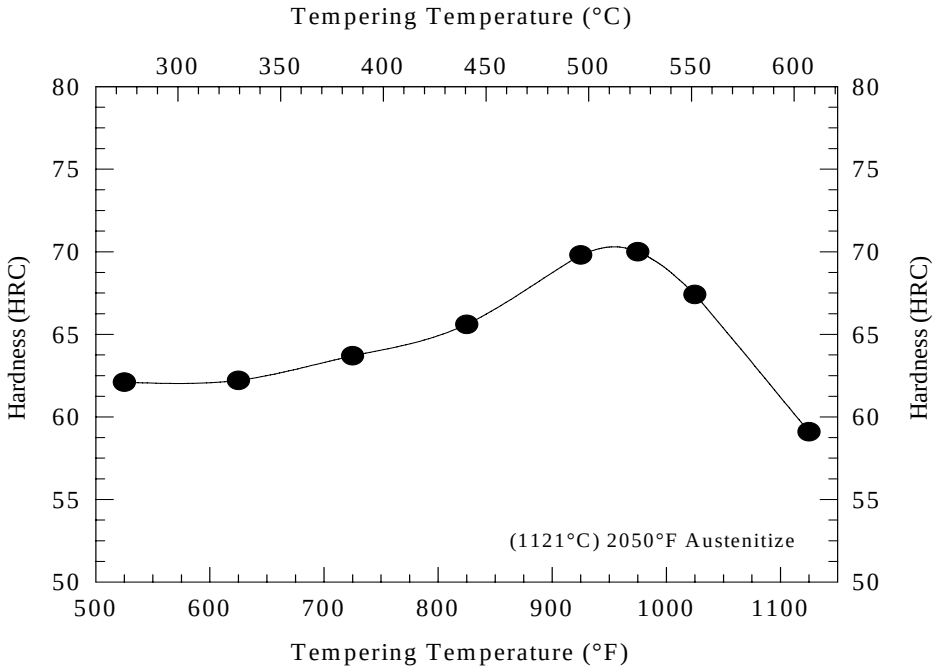


FIGURE 8. CSS-42L™ carburized case tempering curve (direct Rockwell C hardness measurements).

TABLE 6-- Ball-on-Rod Fatigue Results of CSS-42L™

Carburized Specimen #1			Carburized Specimen #2		
Hours	Cycles[1] (Million)	Reason[2]	Hours	Cycles[1] (Million)	Reason[2]
294.4	151.9	Ball spall	95.4	49.2	Machine
212.4	109.6	Ball spall	188.7	97.4	Cup spall
438.0	226.0	Ball spall	149.7	77.2	Ball spall
853.7	440.5	Ball spall	360.9	186.2	Cup spall

[1] Accumulated cycles is obtained by multiplying the accumulated test hours by 516,024 cycles/hour.
[2] Reason test was discontinued.

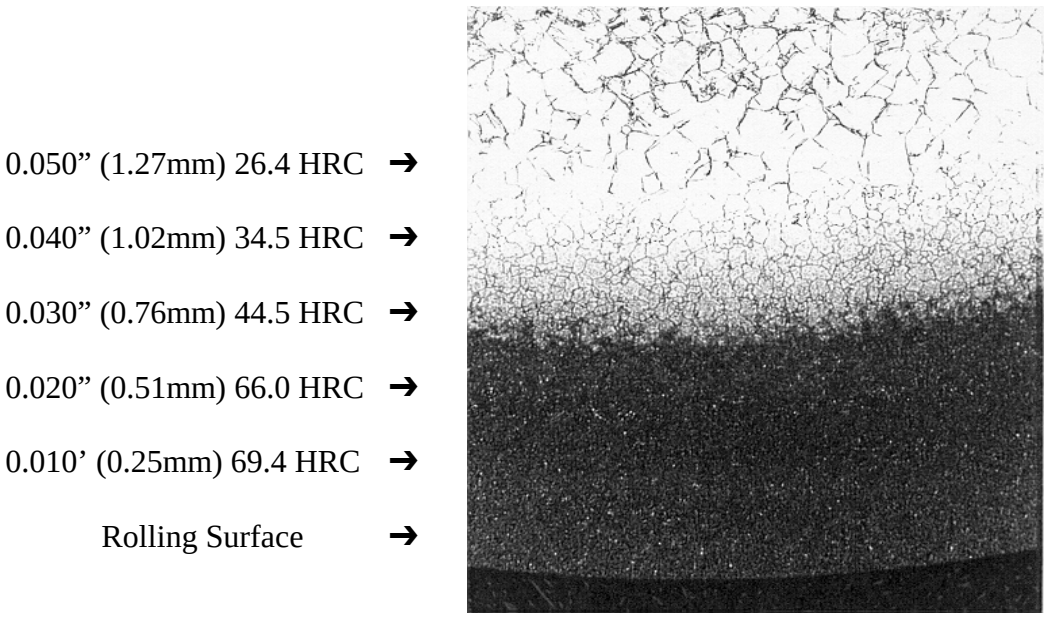


FIGURE 9. Carburized case microstructure of rolling contact fatigue CSS-42L™ test rod (original magnification 50X).

Corrosion Resistance

The potentiodynamic scanning curves shown below were generated according to the Standard Practice for Conducting Potentiodynamic Polarization Resistance Measurements (ASTM G59) and the Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements (ASTM G102). The passive current density of the case is higher than 440C, while the core current density is significantly lower. Therefore, the corrosion rate for the case may be slightly higher than 440C while the core corrosion rate is predicted to be superior to 440C. The corrosion rate of the case is improved by lowering the tempering temperature.

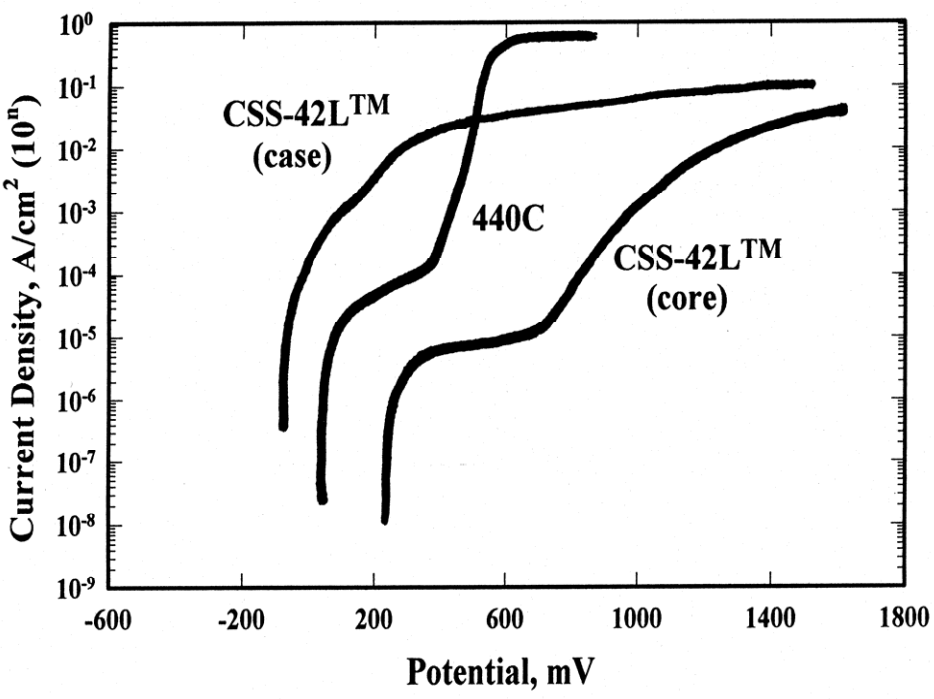
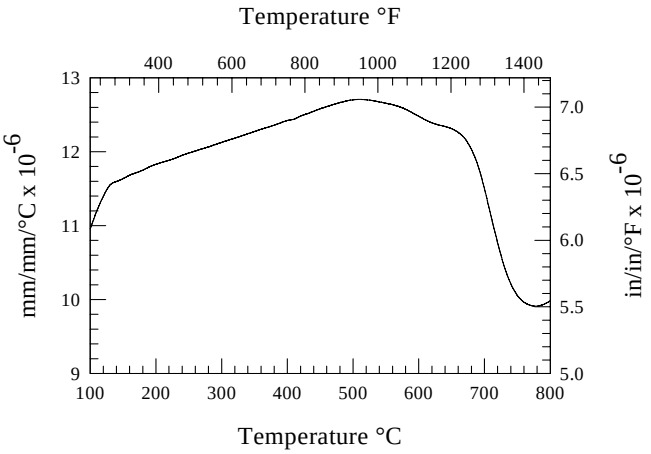


FIGURE 10. Current density - potential curves for CSS-42L™ case and core and 440C steels in 3.5% NaCl solution using an Ag/AgCl Reference electrode. The CSS-42L™ samples were tempered at 925°F. The 440C was tempered at 350°F.

FIGURE 11. PHYSICAL PROPERTIES OF CSS-42L™

Coefficient of Thermal Expansion:



°F	(°C)	10^{-6} in/in/°F (10^{-6} mm/mm/°C)
70 - 400	(20 - 205)	6.4 (11.6)
70 - 600	(20 - 315)	6.5 (11.8)
70 - 800	(20 - 425)	6.7 (12.0)

Density: 7.89 g/cm^3 (0.28 lb/in^3)

Thermal Conductivity: