



**EARLE M. JORGENSEN
COMPANY**

REFERENCE BOOK

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MECHANICAL PROPERTIES AND HARDENABILITY

INTRODUCTION

The following pages contain pertinent data on the properties of certain of the more frequently used carbon and alloy steels. Much of the information is based on laboratory tests. However, results of tests of steels of similar composition may differ to some extent due to residual alloy content, agitation of the quenching medium and other variable factors.

Therefore, the tables and charts on the following pages are offered **only as a guide** to (1) those properties that may normally be expected from a particular grade of steel and (2) the treatment to use in order to obtain the desired properties.

MECHANICAL PROPERTIES

The mechanical properties (tensile strength, yield point, etc.) shown herein are the results of actual tests performed as follows:

Carbon Steels. Properties shown are the averages of three heats, selected so that the significant elements are in the middle of the chemical composition limits and incidental elements are at a minimum. Quenched-and-tempered properties are based on treating a 1" round, which is machined down to .505" for the tensile test. All steels tested are fine grain, except the free-machining grades (1117 and 1137), which are coarse grain.

Alloy Steels. Properties shown are based on a single heat, selected so that the significant elements are in the middle of the chemical composition limits and incidental elements are at a minimum. Quenched-and-tempered properties are based on treating a .530" round for the hardening grades and a .565" round for the carburizing grades. These sizes are small enough to insure a thoroughly effective quench. Thus, the charts reflect typical values that may be expected of fully-hardened steels. For the tensile test, the pieces are machined down to .505". All alloy steels tested are fine grain.

IZOD IMPACT

Izod impact values are often difficult to duplicate, and the data shown should be considered only as reasonable expectation. Fine-grain steels normally show higher impact values than coarse-grain steels, and this should be considered when reviewing the Izod results.

CRITICAL RANGES

Critical ranges are shown for each grade and are based on a heating and cooling rate of 400° per hour. The Ac₁ and Ac₃ points represent the critical range for heating and the Ar₃ and Ar₁ points represent the range for cooling.

MASS EFFECT

In order to illustrate the variance in properties occurring among quenched and tempered bars of different sizes, values are shown for 1/2", 1", 2", and 4" rounds. All these values are based on the results of a single heat, which has been selected to represent an average for the grade. Tensile and hardness values are higher on the surface and decrease toward the center.

Tensile specimens for 1/2" and 1" rounds are taken from the centers of the bars. Specimens for 2" and 4" rounds are taken from the half-radius position, as is conventionally required by most specifications. Sizes larger than 4" round will not show materially lower properties. Sections other than rounds will show approximately the same mass effect relationship as long as the section width is not more than twice the thickness.

END-QUENCH HARDENABILITY

Since alloy steels are ordinarily used for their deep-hardening characteristics, End-Quench Hardenability (Jominy) charts are given for the alloy grades. These charts show "hardenability bands"; that is, the maximum band minimum values that may normally be expected. The broken line within each and represents the hardenability characteristics of an actual heat, whose mass effect properties are shown under Mass Effect Data.

The scale at the bottom of the hardenability charts represents distances from the quenched end of the test specimen. The scale at the top of the charts is for convenience in converting the results of the end-quench test to the results that may be expected at the **centers** of round bars of various diameters when quenched in water or oil. (This correlation between end-quench test results and the centers of round bars is also illustrated in the table on Page 29 of this section. In addition, that table gives similar information for the **surface** and **half-radius** positions of rounds bars.)

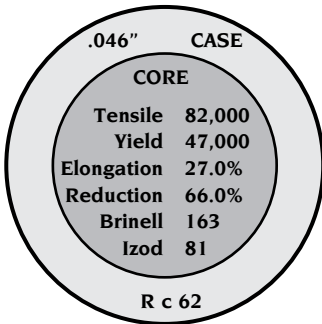
1018

Analysis		Critical Range		Thermal Treatment	
Carbon	.15/.20	Ac ₁	1360°F	Forge	2150° - 2250°F
Manganese	.60/.90	Ac ₃	1530°F	Normalize	1650° - 1750°F
Phosphorus	.04 Max.	Ar ₃	1440°F	Anneal	1550° - 1650°F
Sulphur	.05 Max	Ar ₁	1300°F		

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	67,000	45,000	36	58	137	60
Normalized	66,000	43,000	37	60	137	86
Annealed	60,000	40,000	38	62	121	90

Size Treated, 1" Rd.



Single Quench and Temper

1. Carburized at 1675°F for 8 hours.
2. Pot Cooled.
3. Reheated to 1425°F.
4. Water Quenched.
5. Tempered at 350°F.

MASS EFFECT DATA

Mock-carburized at 1675°F for 8 hours; reheated to 1425°F; quenched in water; tempered at 350°F.

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
1/2" Rd.	135,000	67,000	13.6	24.3	262	14.3
1" Rd.	87,000	55,000	25.5	57.3	179	70.3
2" Rd.	82,000	50,250	30.0	69.6	163	105.5
4" Rd.	74,000	40,250	32.5	71.6	149	97.8

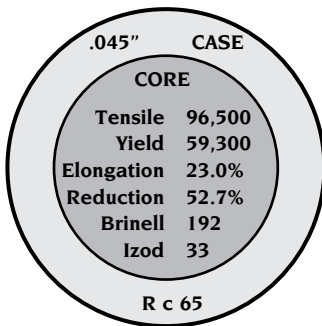
1117

Analysis		Critical Range		Thermal Treatment	
Carbon	.14/.20	Ac ₁	1345°F	Forge	2150° - 2250°F
Manganese	1.00/1.30	Ac ₃	1540°F	Normalize	1650° - 1750°F
Phosphorus	.040 Max.	Ar ₃	1450°F	Anneal	1550° - 1650°F
Sulphur	.08/13	Ar ₁	1340°F		

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	71,000	44,000	33	63	143	60
Normalized	70,000	42,000	33	63	137	66
Annealed	66,000	41,000	32	58	121	65

Size Treated, 1" Rd.



Single Quench and Temper

1. Carburized at 1700°F for 8 hours.
2. Pot Cooled.
3. Reheated to 1450°F.
4. Water Quenched.
5. Tempered at 350°F.

MASS EFFECT DATA

Mock-carburized at 1700°F for 8 hours; reheated to 1450°F; quenched in water; tempered at 350°F.

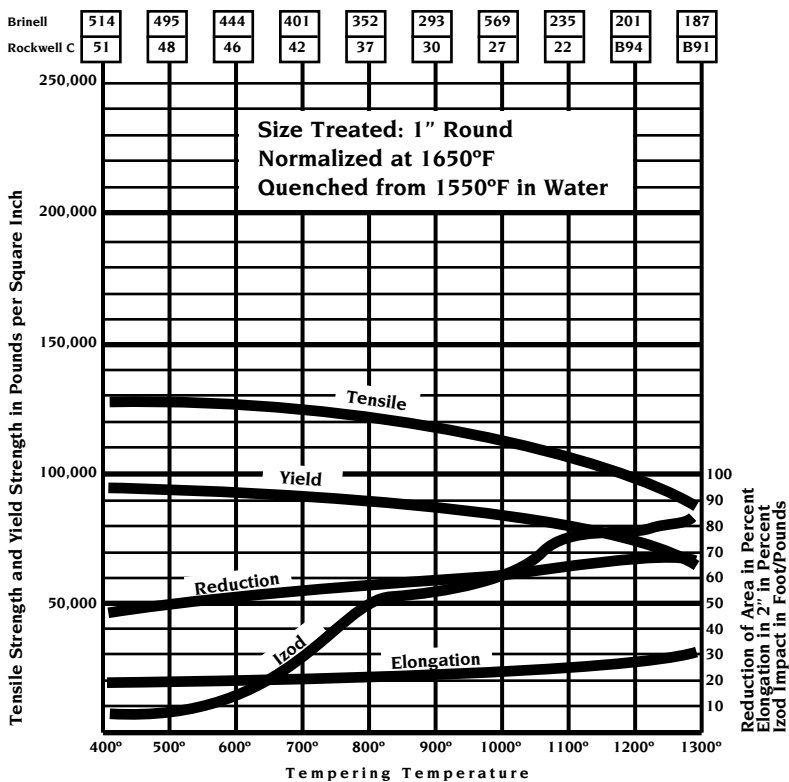
	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
1/2" Rd.	124,700	66,500	9.7	18.4	235	12.5
1" Rd.	89,500	50,500	22.3	48.8	183	37.3
2" Rd.	78,000	47,750	26.3	65.7	156	61.5
4" Rd.	77,000	45,000	27.3	62.6	156	85.8

1040

Analysis	Critical Range	Thermal Treatment
Carbon .37/.44	Ac ₁ 1340°F	Forge 2100° - 2200°F
Manganese .60/.90	Ac ₃ 1445°F	Normalize 1600° - 1750°F
Phosphorus .04 Max.	Ar ₃ 1350°F	Anneal 1450° - 1550°F
Sulphur .05 Max.	Ar ₁ 1250°F	Harden 1525° - 1575°F oil or water

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	90,000	59,000	26	50	201	36
Normalized	87,000	58,000	28	52	192	38
Annealed	80,000	48,000	30	54	159	40



1040 (Continued)

AS-QUENCHED ROCKWELL C HARDNESS

	1/2" Rd.		1" Rd.		2" Rd.		4" Rd.	
	Water	Oil	Water	Oil	Water	Oil	Water	Oil
Surface	54	28	50	23	50	B93	B98	B91
1/2 Radius	53	22	22	21	B97	B92	B96`	B91
Center	53	21	18	18	B95	B91	B95	B89

MASS EFFECT DATA

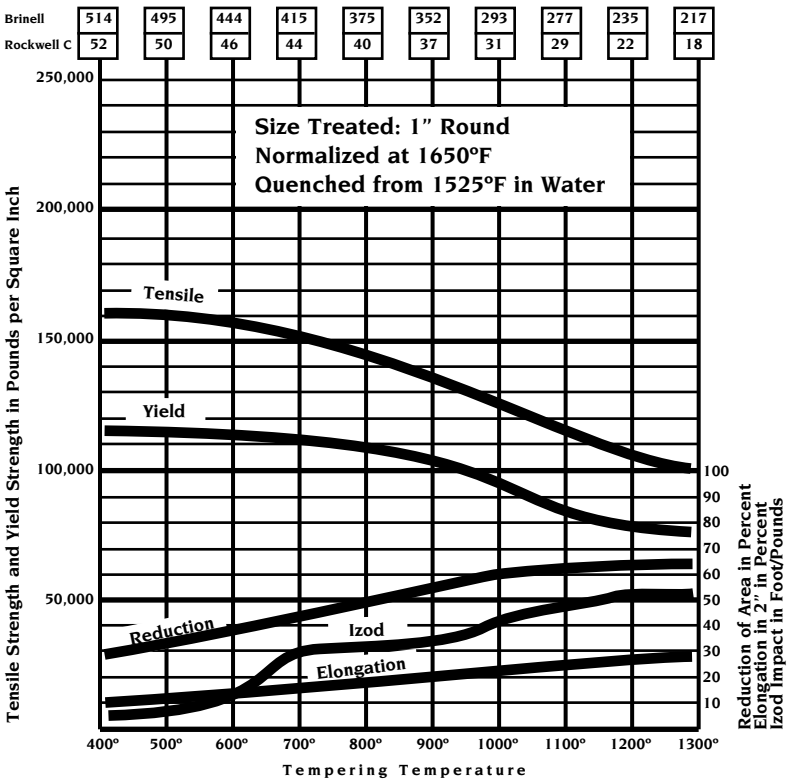
	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Water-quenched from 1550°F; tempered at 1000°F						
1/2" Rd.	109,000	81,500	23.8	61.5	223	75.0
1" Rd.	107,750	78,500	23.2	62.6	217	72.0
2" Rd.	101,750	69,500	24.7	63.6	207	85.5
4" Rd.	99,000	63,825	24.7	60.2	201	62.0
Water-quenched from 1550°F; tempered at 1100°F						
1/2" Rd.	101,250	71,000	26.4	65.2	212	79.2
1" Rd.	100,000	69,500	26.0	65.0	207	75.0
2" Rd.	95,000	68,000	29.0	69.2	197	100.0
4" Rd.	94,250	59,125	27.0	63.4	192	73.5
Water-quenched from 1550°F; tempered at 1200°F						
1/2" Rd.	96,000	69,000	27.7	66.6	201	91.5
1" Rd.	93,500	68,000	27.0	67.9	197	83.0
2" Rd.	89,000	59,875	28.7	69.0	183	107.5
4" Rd.	85,000	54,750	30.2	67.2	170	93.5
Oil-quenched from 1575°F; tempered at 1000°F						
1/2" Rd.	104,750	72,500	27.0	62.0	217	66.5
1" Rd.	96,250	68,000	26.5	61.1	197	68.0
2" Rd.	92,250	59,750	27.0	59.7	187	75.2
4" Rd.	90,000	57,500	27.0	60.3	179	61.0
Oil-quenched from 1575°F; tempered at 1100°F						
1/2" Rd.	100,500	69,500	27.0	65.2	207	76.0
1" Rd.	91,500	64,250	28.2	63.5	187	80.7
2" Rd.	86,750	56,875	28.0	62.5	174	91.5
4" Rd.	82,750	52,250	30.0	61.6	170	81.0
Oil-quenched from 1575°F; tempered at 1200°F						
1/2" Rd.	95,000	66,625	28.9	65.4	197	86.0
1" Rd.	85,250	60,250	30.0	67.4	170	88.2
2" Rd.	82,500	54,500	31.0	66.4	167	93.7
4" Rd.	78,750	50,000	31.2	64.5	156	85.5

1055

Analysis	Critical Range	Thermal Treatment
Carbon .50/.60	Ac ₁ 1340°F	Forge 2100° - 2200°F
Manganese .60/.90	Ac ₃ 1420°F	Normalize 1550° - 1650°F
Phosphorus .04 Max.	Ar ₃ 1320°F	Anneal 1450° - 1550°F
Sulphur .05 Max.	Ar ₁ 1250°F	Harden 1450° - 1550°F oil or water

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	110,000	65,000	18	37	235	18
Normalized	109,000	62,000	19	39	212	20
Annealed	97,000	52,000	23	47	187	23



1055 (Continued)

AS-QUENCHED ROCKWELL C HARDNESS

	1/2" Rd.		1" Rd.		2" Rd.		4" Rd.	
	Water	Oil	Water	Oil	Water	Oil	Water	Oil
Surface	64	57	60	33	50	27	33	B98
1/2 Radius	59	37	35	30	32	25	27	B95
Center	57	34	33	26	26	21	20	B91

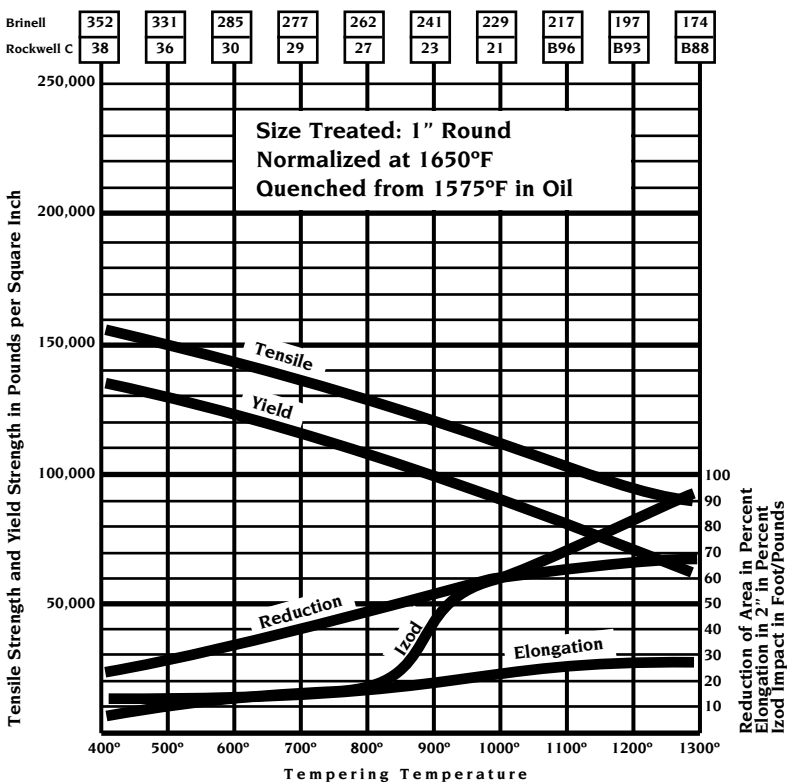
MASS EFFECT DATA

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Water-quenched from 1525°F; tempered at 1000°F						
1/2" Rd.	134,000	99,000	20.0	54.4	269	42.2
1" Rd.	131,250	92,250	20.0	55.2	262	21.1
2" Rd.	129,500	84,125	20.7	56.6	255	23.5
4" Rd.	122,750	78,250	21.5	55.3	248	15.0
Water-quenched from 1525°F; tempered at 1100°F						
1/2" Rd.	119,000	88,000	21.7	59.9	241	51.2
1" Rd.	118,000	80,000	22.5	59.9	241	23.5
2" Rd.	117,250	78,750	23.0	61.0	235	24.5
4" Rd.	112,250	68,250	23.7	55.5	229	15.5
Water-quenched from 1525°F; tempered at 1200°F						
1/2" Rd.	110,000	86,000	24.8	60.6	229	65.7
1" Rd.	109,000	76,500	23.7	61.2	229	24.0
2" Rd.	107,750	68,500	24.7	61.0	223	25.2
4" Rd.	104,500	65,250	25.2	60.8	217	16.7
Oil-quenched from 1550°F; tempered at 1000°F						
1/2" Rd.	132,500	87,500	20.7	52.9	262	21.7
1" Rd.	123,500	76,000	20.2	53.3	248	21.7
2" Rd.	122,500	74,875	19.7	51.4	248	19.7
4" Rd.	121,000	69,000	19.7	48.0	241	22.0
Oil-quenched from 1550°F; tempered at 1100°F						
1/2" Rd.	122,000	81,000	22.8	58.1	248	22.0
1" Rd.	114,000	70,500	23.5	57.6	223	22.5
2" Rd.	112,000	68,000	23.0	55.6	223	20.2
4" Rd.	101,000	58,750	25.2	54.5	207	21.7
Oil-quenched from 1550°F; tempered at 1200°F						
1/2" Rd.	112,500	74,000	24.6	61.8	229	32.0
1" Rd.	106,000	64,250	24.7	60.5	217	22.2
2" Rd.	105,000	64,000	25.0	59.1	217	19.5
4" Rd.	96,750	55,750	25.5	56.6	197	28.0

Analysis		Critical Range		Thermal Treatment	
Carbon	.32/.39	Ac ₁	1330°F	Forge	2100° - 2200°F
Manganese	1.35/1.69	Ac ₃	1450°F	Normalize	1600° - 1700°F
Phosphorus	.04 Max.	Ar ₃	1310°F	Anneal	1450° - 1500°F
Sulphur	.08/.13	Ar ₁	1180°F	Harden	1500° - 1600°F
					oil or water

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	92,000	56,000	27	62	192	61
Normalized	96,000	57,000	26	62	183	50
Annealed	85,000	50,000	30	60	170	54



1137 (Continued)

AS-QUENCHED ROCKWELL C HARDNESS

	1/2" Rd.		1" Rd.		2" Rd.		4" Rd.	
	Water	Oil	Water	Oil	Water	Oil	Water	Oil
Surface	57	48	56	34	52	28	48	21
1/2 Radius	53	43	50	28	35	22	23	18
Center	50	42	45	23	24	18	20	16

MASS EFFECT DATA

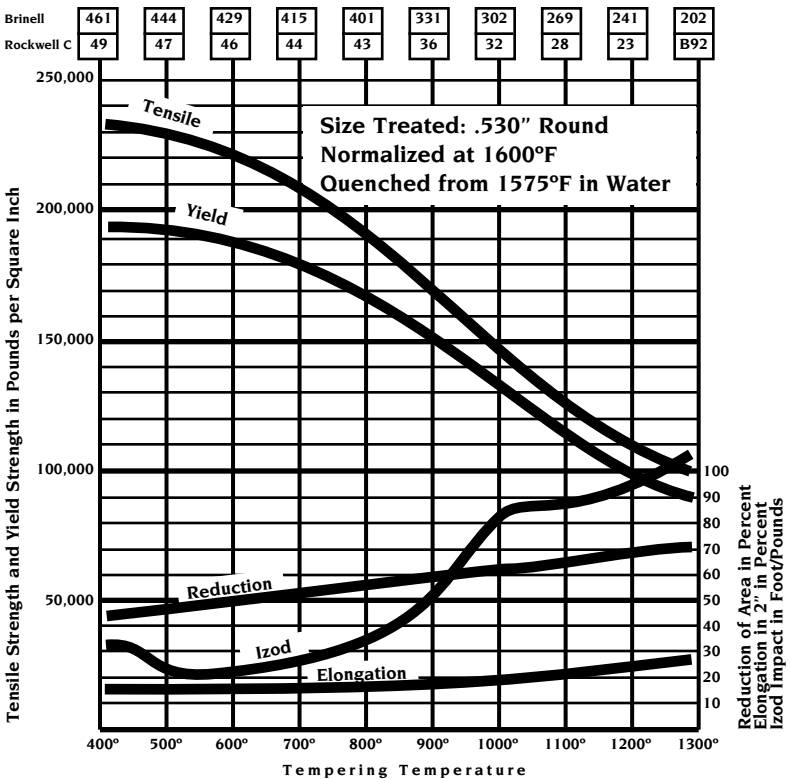
	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Water-quenched from 1550°F; tempered at 1000°F						
1/2" Rd.	129,500	112,000	17.1	51.3	262	40.5
1" Rd.	122,000	98,000	16.9	51.2	248	37.5
2" Rd.	110,000	71,250	20.8	56.1	229	46.0
4" Rd.	108,000	69,000	20.3	52.1	223	22.5
Water-quenched from 1550°F; tempered at 1100°F						
1/2" Rd.	112,500	95,000	21.4	57.6	229	44.0
1" Rd.	107,750	87,750	21.0	59.2	223	49.5
2" Rd.	105,250	76,000	22.0	61.7	217	61.0
4" Rd.	97,750	61,250	23.5	60.9	201	29.0
Water-quenched from 1550°F; tempered at 1200°F						
1/2" Rd.	105,000	89,000	23.9	61.2	223	74.3
1" Rd.	102,500	81,750	22.3	58.8	217	60.0
2" Rd.	97,500	67,000	24.0	64.1	201	61.5
4" Rd.	95,500	60,000	24.0	63.5	197	37.8
Oil-quenched from 1575°F; tempered at 1000°F						
1/2" Rd.	127,500	100,000	18.2	55.8	223	44.3
1" Rd.	108,000	75,750	21.3	56.0	223	50.3
2" Rd.	105,000	63,000	23.0	56.2	217	30.8
4" Rd.	100,500	58,750	22.3	55.5	201	31.5
Oil-quenched from 1575°F; tempered at 1100°F						
1/2" Rd.	112,500	90,000	21.8	61.0	229	58.3
1" Rd.	100,750	68,750	23.5	60.1	207	56.0
2" Rd.	98,000	61,500	23.0	57.8	207	40.3
4" Rd.	95,250	57,000	24.5	59.5	192	32.0
Oil-quenched from 1575°F; tempered at 1200°F						
1/2" Rd.	104,000	80,500	24.6	63.6	217	67.8
1" Rd.	97,750	68,750	23.5	60.8	201	59.5
2" Rd.	97,000	57,250	25.0	64.1	197	46.0
4" Rd.	94,500	56,000	24.0	61.1	192	40.5

4130

Analysis	Critical Range	Thermal Treatment
Carbon .28/.33	Ac ₁ 1400°F	Forge 2150° - 2250°F
Manganese .40/.60	Ac ₃ 1510°F	Normalize 1600° - 1700°F
Phosphorus .035 Max.	Ar ₃ 1400°F	Anneal 1500° - 1600°F
Sulphur .04 Max.	Ar ₁ 1305°F	Harden 1500° - 1650°F
Silicon .15/.35		oil or water
Chromium .80/1.10		
Molybdenum .15/.25		

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	100,000	60,000	25	60	212	—
Annealed	80,000	56,000	28	57	149	53



4130 (Continued)
MASS EFFECT DATA

The following are actual values from a single heat, the hardenability curve of which is indicated by the broken line in the End-Quench Hardenability chart below.

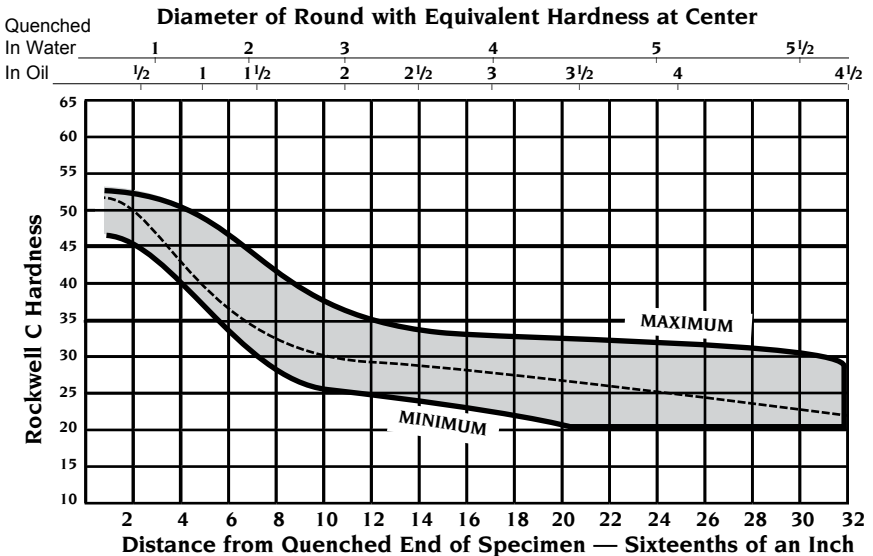
	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Normalized at 1600°F; air cooled						
1/2" Rd.	106,500	67,000	25.1	59.6	217	51.7
1" Rd.	97,000	63,250	25.5	59.5	197	63.7
2" Rd.	89,000	61,750	28.2	65.4	167	78.7
4" Rd.	88,750	57,750	27.0	61.2	163	77.8

Water-quenched from 1575°F; tempered at 900°F						
1/2" Rd.	166,500	161,000	16.4	61.0	331	50.7
1" Rd.	161,000	137,500	14.7	54.4	321	41.2
2" Rd.	132,750	110,000	19.0	63.0	269	76.5
4" Rd.	121,500	95,000	20.5	63.6	241	69.7

Water-quenched from 1575°F; tempered at 1000°F						
1/2" Rd.	151,000	142,500	18.1	63.9	302	71.7
1" Rd.	144,500	129,500	18.5	61.8	293	66.2
2" Rd.	121,750	98,750	21.2	66.3	241	88.0
4" Rd.	116,000	91,500	21.5	63.5	235	86.2

Water-quenched from 1575°F; tempered at 1100°F						
1/2" Rd.	133,000	122,500	20.7	69.0	269	79.2
1" Rd.	128,000	113,250	21.2	67.5	262	86.0
2" Rd.	114,500	91,500	21.7	67.7	229	90.5
4" Rd.	101,500	77,500	24.5	69.2	197	90.5

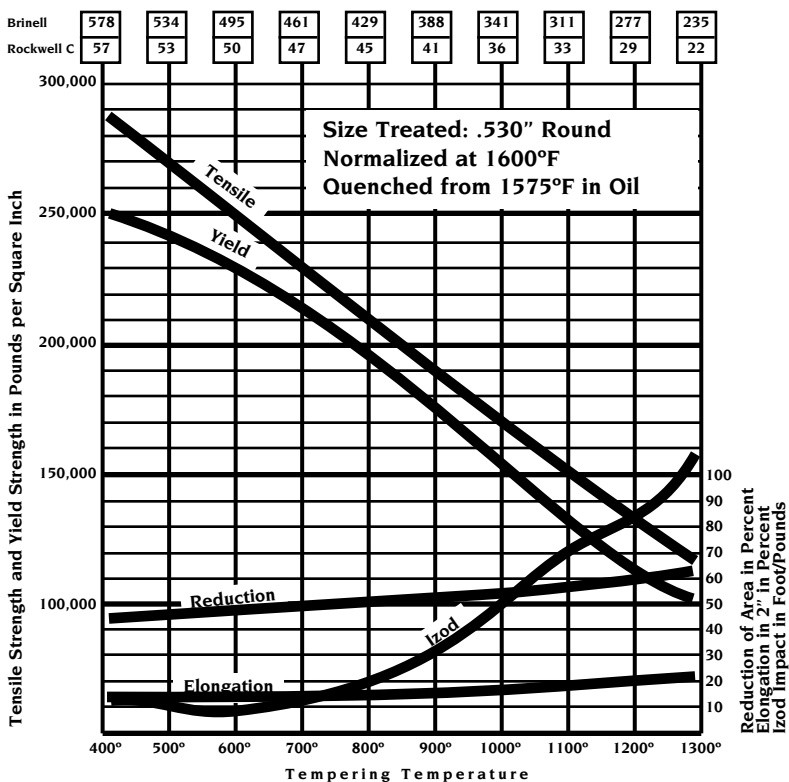
END-QUENCH HARDENABILITY



Analysis	Critical Range	Thermal Treatment
Carbon .40/.45	Ac ₁ 1395°F	Forge 2100° - 2200°F
Manganese .75/1.00	Ac ₃ 1450°F	Normalize 1600° - 1700°F
Phosphorus .035 Max.	Ar ₃ 1330°F	Anneal 1450° - 1550°F
Sulphur .04 Max.	Ar ₁ 1280°F	Harden 1525° - 1625°F, oil
Silicon .15/.38		
Chromium .80/1.10		
Molybdenum .15/.25		

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	140,000	90,000	20	45	285	—
Annealed	95,000	60,000	26	60	187	67



4142 (Continued)

MASS EFFECT DATA

The following are actual values from a single heat, the hardenability curve of which is indicated by the broken line in the End-Quench Hardenability chart below.

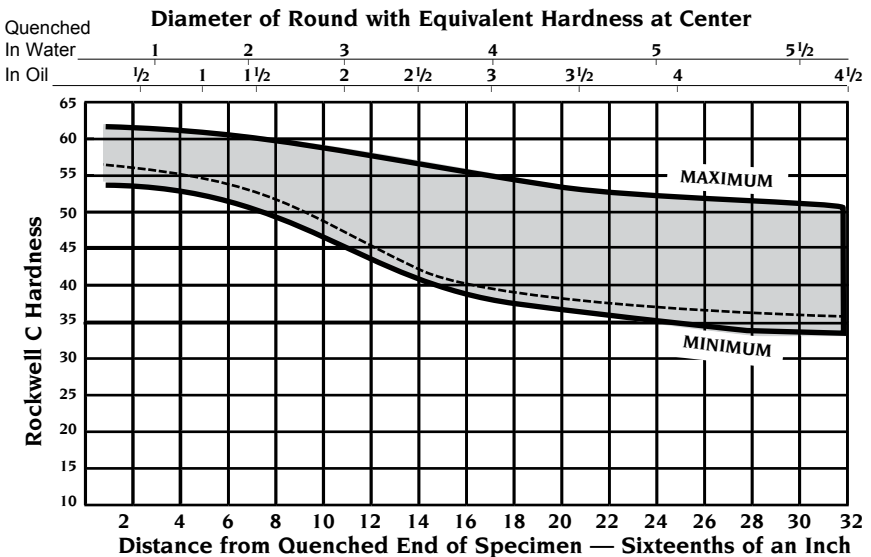
	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Normalized at 1600°F;						
air cooled						
1/2" Rd.	148,500	98,500	17.8	48.2	302	21.5
1" Rd.	148,000	95,000	17.7	46.8	302	16.7
2" Rd.	140,750	91,750	16.5	48.1	285	13.0
4" Rd.	117,500	69,500	22.2	57.4	241	29.0

Oil-quenched from 1550°F;						
tempered at 1000°F						
1/2" Rd.	171,500	161,000	15.4	55.7	341	43.5
1" Rd.	156,000	143,250	15.5	56.9	311	54.5
2" Rd.	139,750	115,750	17.5	59.8	285	66.7
4" Rd.	127,750	99,250	19.2	60.4	277	37.7

Oil-quenched from 1550°F;						
tempered at 1100°F						
1/2" Rd.	157,500	148,750	18.1	59.4	321	66.0
1" Rd.	140,250	135,000	19.5	62.3	285	70.5
2" Rd.	127,500	102,750	21.7	65.0	262	84.0
4" Rd.	116,750	87,000	21.5	62.1	235	82.5

Oil-quenched from 1550°F;						
tempered at 1200°F						
1/2" Rd.	136,500	128,750	19.9	62.3	277	73.6
1" Rd.	132,750	122,500	21.0	65.0	269	84.5
2" Rd.	121,500	98,250	23.2	65.8	241	91.2
4" Rd.	112,500	83,500	23.2	64.9	229	86.7

END-QUENCH HARDENABILITY

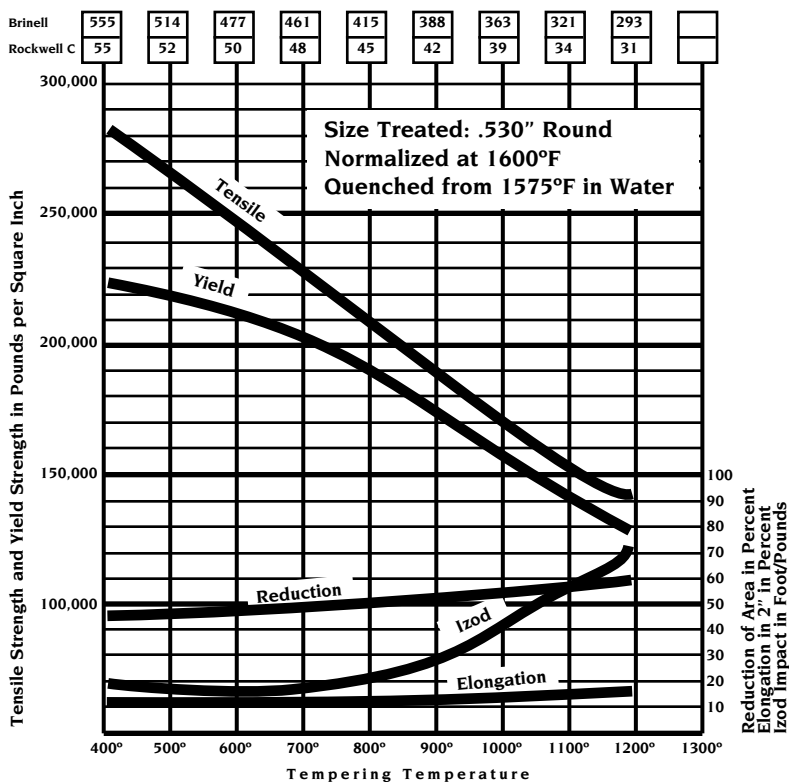


4340

Analysis	Critical Range	Thermal Treatment
Carbon	.38/.43	Ac ₁ 1350°F Forge 2200° - 2300°F
Manganese	.60/.80	Ac ₃ 1415°F Normalize 1600° - 1700°F
Phosphorus	.035 Max.	Ar ₃ 890°F Anneal 1500° - 1600°F
Sulphur	.04 Max.	Ar ₁ 720°F Harden 1475° - 1575°F, oil
Silicon	.15/.35	
Chromium	.70/.90	
Nickel	1.65/2.00	
Molybdenum	.20/.30	

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	178,000	100,000	10	30	363	—
Annealed	110,000	66,000	23	49	197	25



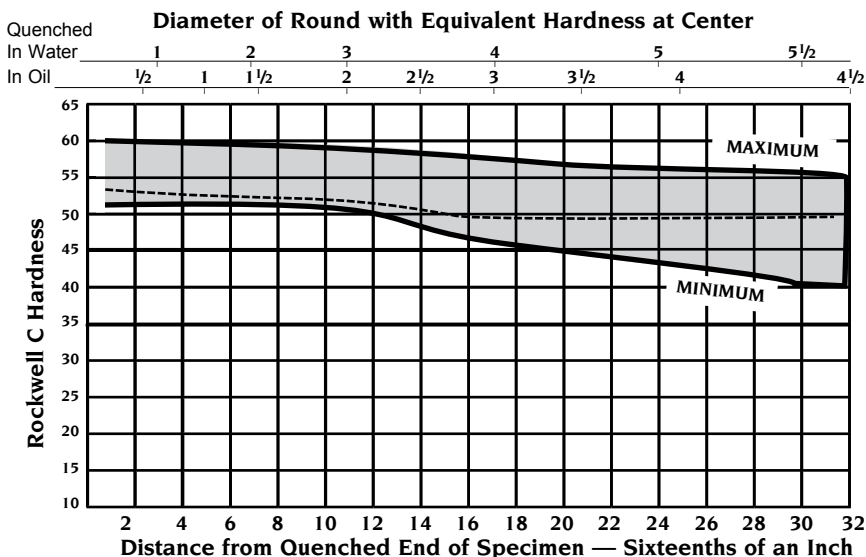
4340 (Continued)

MASS EFFECT DATA

The following are actual values from a single heat, the hardenability curve of which is indicated by the broken line in the End-Quench Hardenability chart below.

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Normalized at 1600°F;						
air cooled						
1/2" Rd.	209,500	141,000	12.1	35.3	388	11.5
1" Rd.	185,500	125,000	12.2	36.3	363	11.7
2" Rd.	176,750	114,500	13.5	37.3	341	10.5
4" Rd.	161,000	103,000	13.2	36.0	321	8.0
Oil-quenched from 1475°F;						
tempered at 1000°F						
1/2" Rd.	182,000	169,000	13.7	45.0	363	37.5
1" Rd.	175,000	166,000	14.2	45.9	352	39.0
2" Rd.	170,000	159,500	16.0	54.8	341	53.0
4" Rd.	164,750	145,250	15.5	53.4	331	46.0
Oil-quenched from 1475°F;						
tempered at 1100°F						
1/2" Rd.	165,750	162,000	17.1	57.0	331	55.5
1" Rd.	164,750	159,000	16.5	54.1	331	50.5
2" Rd.	147,250	139,250	19.0	60.4	293	75.5
4" Rd.	133,750	114,500	19.7	60.7	269	61.7
Oil-quenched from 1475°F;						
tempered at 1200°F						
1/2" Rd.	145,000	135,500	20.0	59.3	285	67.5
1" Rd.	139,000	128,000	20.0	59.7	277	72.7
2" Rd.	134,750	121,000	20.5	62.5	269	86.2
4" Rd.	124,000	105,750	21.7	63.0	255	91.0

END-QUENCH HARDENABILITY

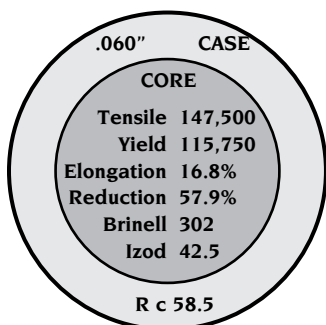


Analysis		Critical Range		Thermal Treatment	
Carbon	.17/.22	Ac ₁	1300°F	Forge	2150° - 2250°F
Manganese	.45/.65	Ac ₃	1490°F	Normalize	1650° - 1750°F
Phosphorus	.035 Max.	Ar ₃	1335°F	Anneal	1550° - 1600°F
Sulphur	.040 Max	Ar ₁	1220°F		
Silicon	.15/.35				
Nickel	1.65/2.00				
Molybdenum	.20/.30				

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	90,000	68,000	27	56	187	—
Annealed	74,000	54,000	31	60	149	70

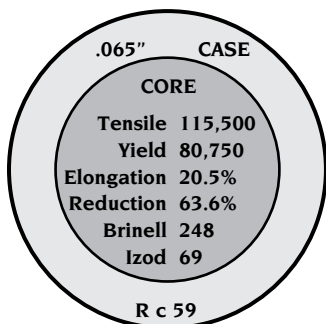
Size Treated, .565" Rd.



FOR MAXIMUM CORE TOUGHNESS

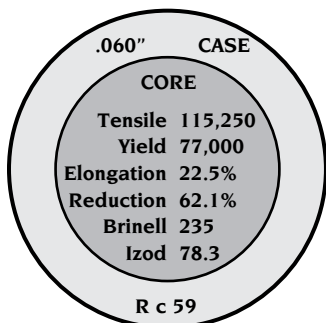
Direct Quench from Pot

1. Carburized at 1700°F for 8 hours.
 2. Quenched in oil.
 3. Tempered at 450°F.
- For maximum case hardness, temper at 300°F for Rc 60.5.



Single Quench and Temper

1. Carburized at 1700°F for 8 hours.
 2. Pot Cooled.
 3. Reheated to 1500°F.
 4. Quenched in oil.
 5. Tempered at 450°F.
- For maximum case hardness, temper at 300°F for Rc 62.5.



Double Quench and Temper

1. Carburized at 1700°F for 8 hours.
 2. Pot Cooled.
 3. Reheated to 1525°F and quenched in oil.
 4. Reheated to 1475°F and quenched in oil.
 5. Tempered at 450°F.
- For maximum case hardness, temper at 300°F for Rc 62.

4620 (Continued)

MASS EFFECT DATA

The following are actual values from a single heat, the hardenability curve of which is indicated by the broken line in the End-Quench Hardenability chart below.

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Normalized at 1650°F; air cooled						
1/2" Rd.	87,250	54,750	30.7	68.0	192	92.3
1" Rd.	83,250	53,125	29.0	66.7	174	98.0
2" Rd.	80,500	53,000	29.5	67.1	167	99.3
4" Rd.	77,000	51,750	30.5	65.2	163	91.8

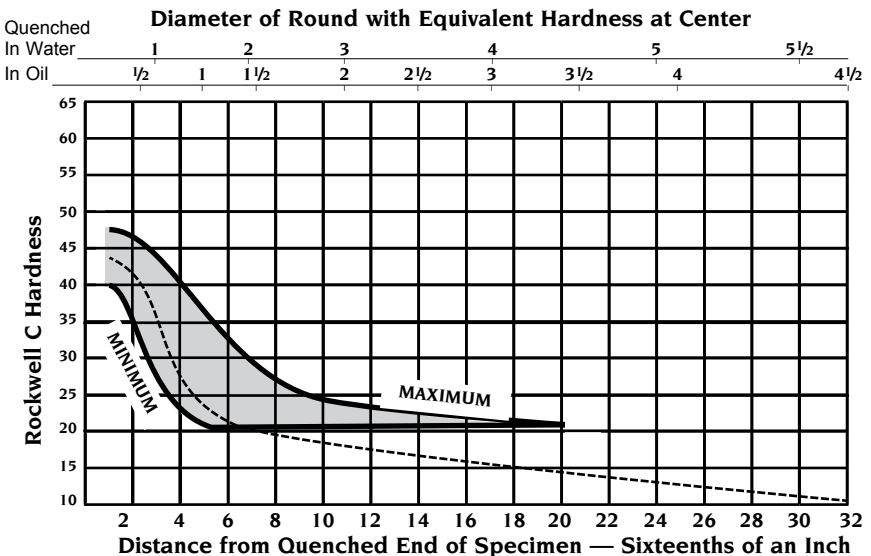
Mock-carburized at 1700°F for 8 hours; reheated to 1500°F; Quenched in oil; tempered at 300°F

1/2" Rd.	127,000	89,500	20.0	59.8	255	43.3
1" Rd.	98,000	67,000	25.8	70.0	197	98.0
2" Rd.	96,500	65,250	27.0	69.7	192	101.8
4" Rd.	84,750	52,500	29.5	69.2	170	100.5

Mock-carburized at 1700°F for 8 hours; reheated to 1500°F; Quenched in oil; tempered at 450°F

1/2" Rd.	117,500	81,000	21.4	65.3	241	73.8
1" Rd.	98,000	66,250	27.5	68.9	192	94.8
2" Rd.	95,750	62,000	26.8	69.2	187	100.5
4" Rd.	84,500	52,750	29.8	70.3	170	103.8

END-QUENCH HARDENABILITY

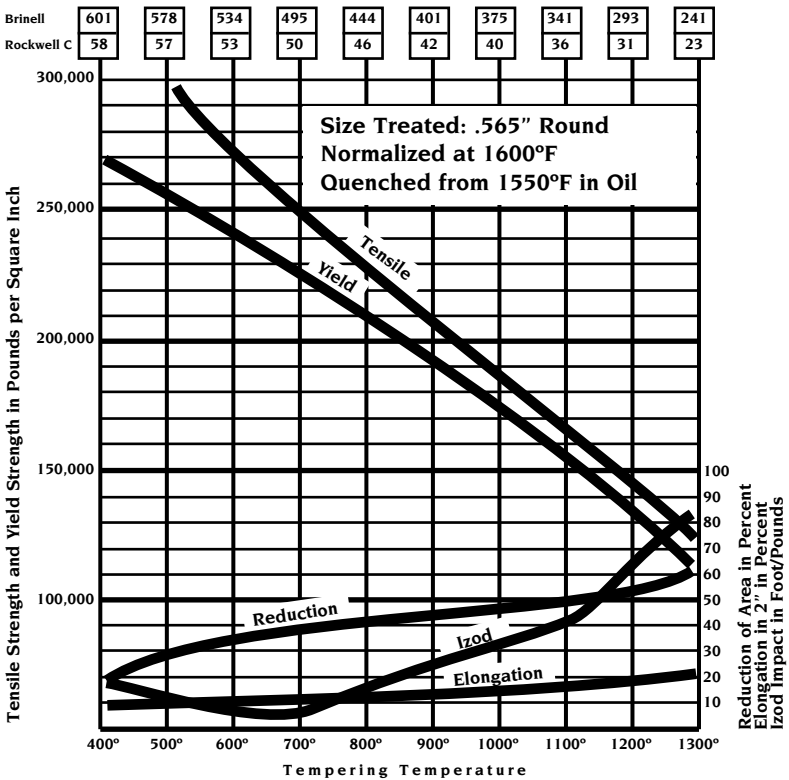


6150

Analysis	Critical Range	Thermal Treatment
Carbon	.48/.53	Ac ₁ 1395°F Forge 2150° - 2300°F
Manganese	.70/.90	Ac ₃ 1445°F Normalize 1600° - 1700°F
Phosphorus	.035 Max.	Ar ₃ 1315°F Anneal 1500° - 1600°F
Sulphur	.040 Max.	Ar ₁ 1290°F Harden 1550° - 1625°F, oil
Silicon	.15/.35	
Chromium	.80/1.10	
Vanadium	.15 Min.	

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	130,000	75,000	20.5	56.0	269	21
Annealed	96,000	59,000	23.0	48.5	197	20



6150 (Continued)

MASS EFFECT DATA

The following are actual values from a single heat, the hardenability curve of which is indicated by the broken line in the End-Quench Hardenability chart below.

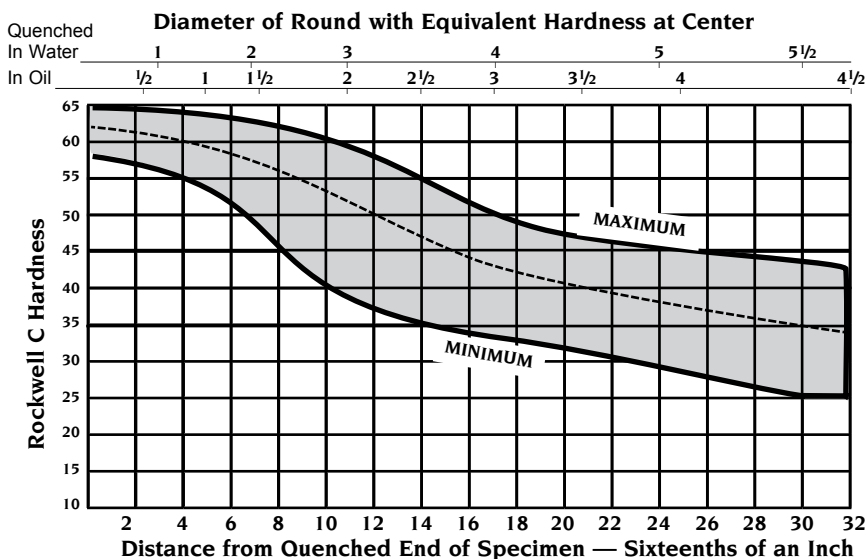
	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Normalized at 1600°F; air cooled						
1/2" Rd.	141,250	93,000	20.6	63.0	285	27.0
1" Rd.	136,250	89,250	21.8	61.0	269	26.2
2" Rd.	129,750	75,250	20.7	56.5	262	20.5
4" Rd.	128,000	67,000	18.2	49.6	255	17.0

Oil-quenched from 1550°F; tempered at 1000°F						
1/2" Rd.	179,000	177,750	14.6	49.4	363	26.0
1" Rd.	173,500	167,750	14.5	48.2	352	24.7
2" Rd.	166,000	145,250	14.5	46.7	331	19.5
4" Rd.	151,500	127,000	16.0	48.7	302	17.5

Oil-quenched from 1550°F; tempered at 1100°F						
1/2" Rd.	160,000	158,500	16.4	52.3	321	39.2
1" Rd.	158,250	150,500	16.0	53.2	311	34.0
2" Rd.	148,250	131,750	17.7	55.2	293	33.7
4" Rd.	130,000	108,500	19.0	55.4	262	38.5

Oil-quenched from 1550°F; tempered at 1200°F						
1/2" Rd.	147,000	141,500	17.8	53.9	293	43.7
1" Rd.	141,250	129,500	18.7	56.3	293	56.7
2" Rd.	133,750	116,500	19.5	57.4	269	51.7
4" Rd.	121,500	94,500	21.0	59.7	241	45.2

END-QUENCH HARDENABILITY



8620

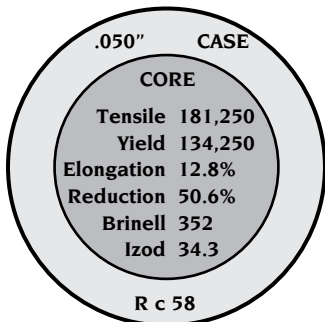
Analysis	Critical Range	Thermal Treatment
Carbon .18/.23	Ac ₁ 1380°F	Forge 2150° - 2250°F
Manganese .70/.90	Ac ₃ 1520°F	Normalize 1650° - 1750°F
Phosphorus .035 Max.	Ar ₃ 1400°F	Anneal 1550° - 1600°F
Sulphur .040 Max	Ar ₁ 1200°F	
Silicon .15/.35		
Chromium .40/.60		
Nickel .40/.70		
Molybdenum .15/.25		

MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
As Rolled	97,000	57,000	25	58	201	—
Annealed	78,000	56,000	31	62	156	82

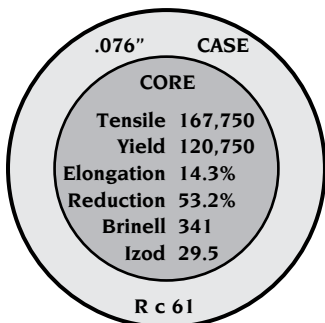
FOR MAXIMUM CORE TOUGHNESS

Size Treated, .565" Rd.



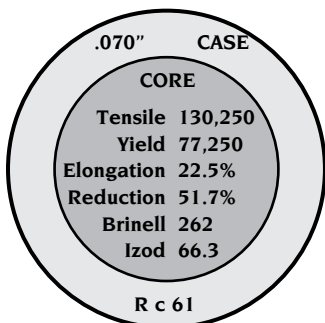
Direct Quench from Pot

1. Carburized at 1700°F for 8 hours.
 2. Quenched in oil.
 3. Tempered at 450°F.
- For maximum case hardness, temper at 300°F for Rc 63.



Single Quench and Temper

1. Carburized at 1700°F for 8 hours.
 2. Pot Cooled.
 3. Reheated to 1550°F.
 4. Quenched in oil.
 5. Tempered at 450°F.
- For maximum case hardness, temper at 300°F for Rc 64.



Double Quench and Temper

1. Carburized at 1700°F for 8 hours.
 2. Pot Cooled.
 3. Reheated to 1550°F and quenched in oil.
 4. Reheated to 1475°F and quenched in oil.
 5. Tempered at 450°F.
- For maximum case hardness, temper at 300°F for Rc 64.

8620 (Continued)

MASS EFFECT DATA

The following are actual values from a single heat, the hardenability curve of which is indicated by the broken line in the End-Quench Hardenability chart below.

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Izod
Normalized at 1675°F; air cooled						
1/2" Rd.	96,500	54,250	26.3	62.5	197	62.5
1" Rd.	91,750	51,750	26.3	59.7	183	73.5
2" Rd.	87,250	51,500	27.8	62.1	179	81.3
4" Rd.	81,750	51,500	28.5	62.3	163	74.0

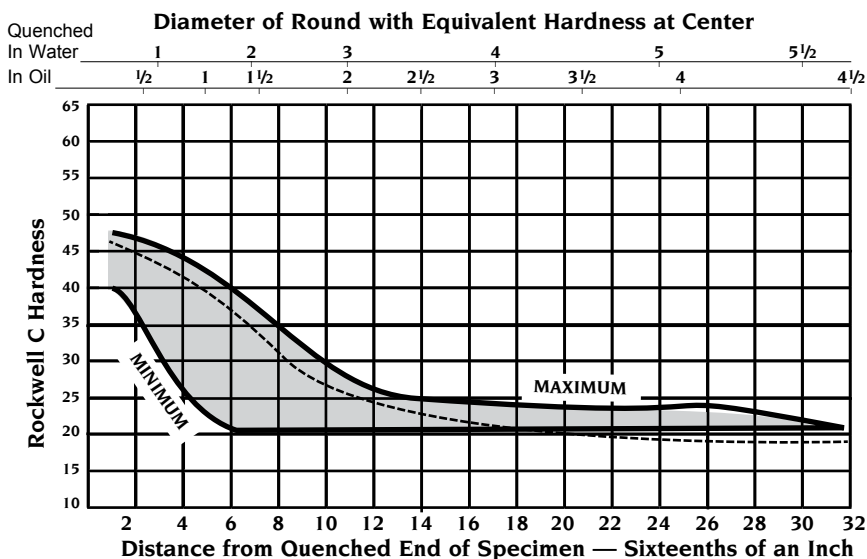
Mock-carburized at 1700°F for 8 hours; reheated to 1550°F; quenched in oil; tempered at 300°F

1/2" Rd.	199,500	157,000	13.2	49.4	388	13.5
1" Rd.	126,750	83,750	20.8	52.7	255	42.3
2" Rd.	117,250	73,000	23.0	57.8	235	48.8
4" Rd.	98,500	57,750	24.3	57.6	207	49.5

Mock-carburized at 1700°F for 8 hours; reheated to 1550°F; quenched in oil; tempered at 450°F

1/2" Rd.	178,500	139,500	14.6	53.9	352	11.5
1" Rd.	124,250	80,750	19.5	54.2	248	23.0
2" Rd.	114,500	72,250	22.0	59.0	229	38.0
4" Rd.	98,000	55,500	25.5	57.8	201	43.4

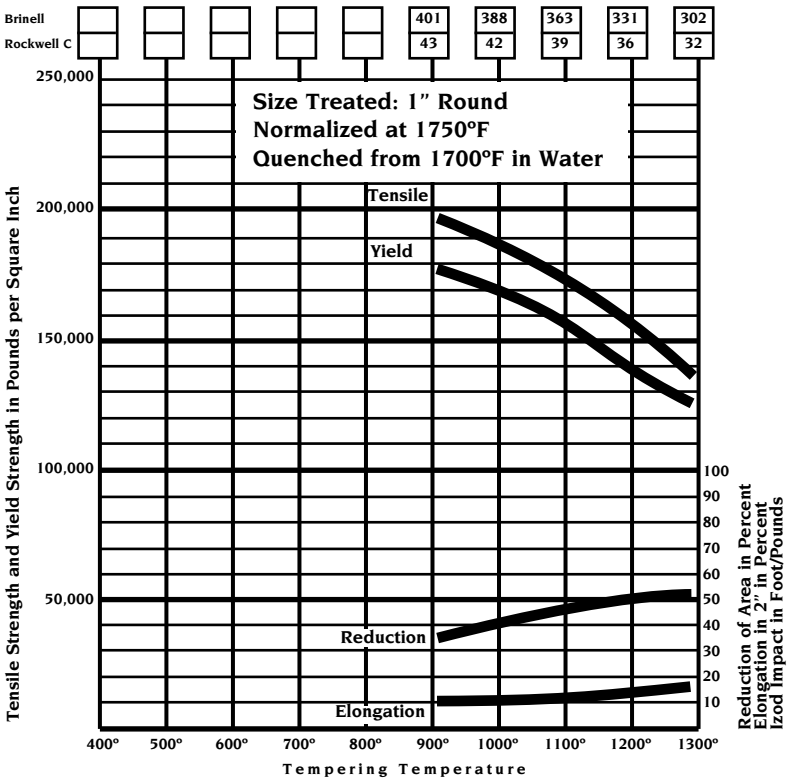
END-QUENCH HARDENABILITY



NITRIDING #3

(135 Modified)

Analysis	Critical Range	Thermal Treatment
Carbon .38/.43	Ac ₁ 1450°F	Forge 1950° - 2250°F
Manganese .50/.70	Ac ₃ 1580°F	Normalize 1750° - 1800°F
Phosphorus .025 Max.	Ar ₃ 1310°F	Anneal 1700°F
Sulphur .025 Max.		Quench 1700° - 1725°F, water
Silicon .20/.40		
Chromium 1.40/1.80		
Molybdenum .30/.40		
Aluminum .95/1.30		

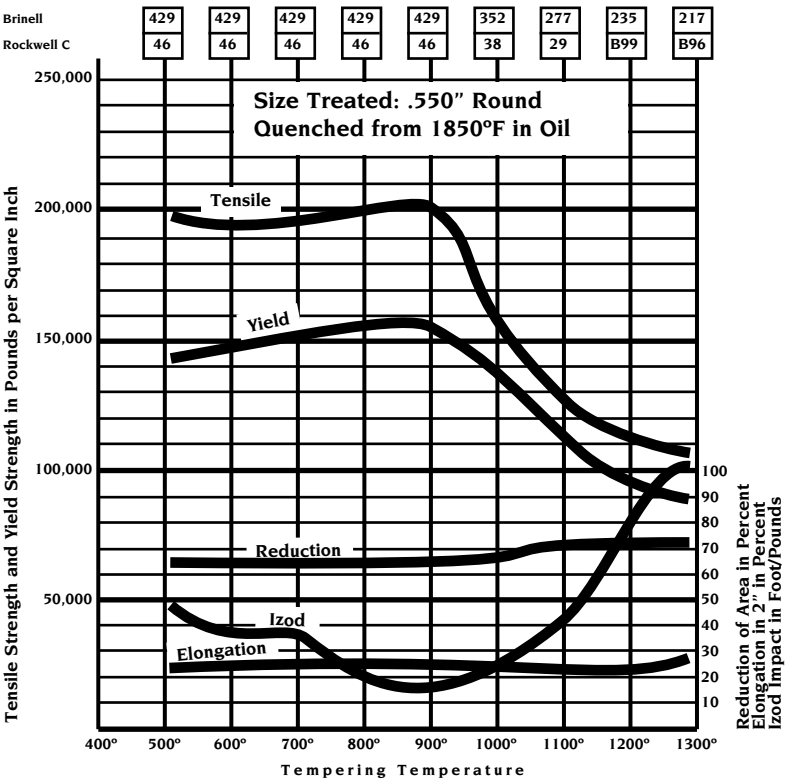


TYPE 410

Analysis		Thermal Treatment	
Carbon	.15 Max.	Forge	2000° - 2200°F. Cool slowly.
Manganese	1.00 Max.	Process Anneal	1250° - 1450°F. (Brinell 170-197.)
Phosphorus	.04 Max.	Full Anneal	1500° - 1600°F. Furnace cool. (Brinell 137-167.)
Sulphur	.04 Max.	Harden	1700° - 1850°F. Cool rapidly.
Silicon	1.00 Max.	Temper	400° - 1400°F. (tempering between 700° and 1050°F is not recommended.)
Chromium	11.50/13.50		

TYPICAL MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red. Area	Brinell	Rockwell B	Izod
Annealed Bars	75,000	40,000	35	70	155	—	90
Annealed Sheets	65,000	35,000	25	—	—	70	—

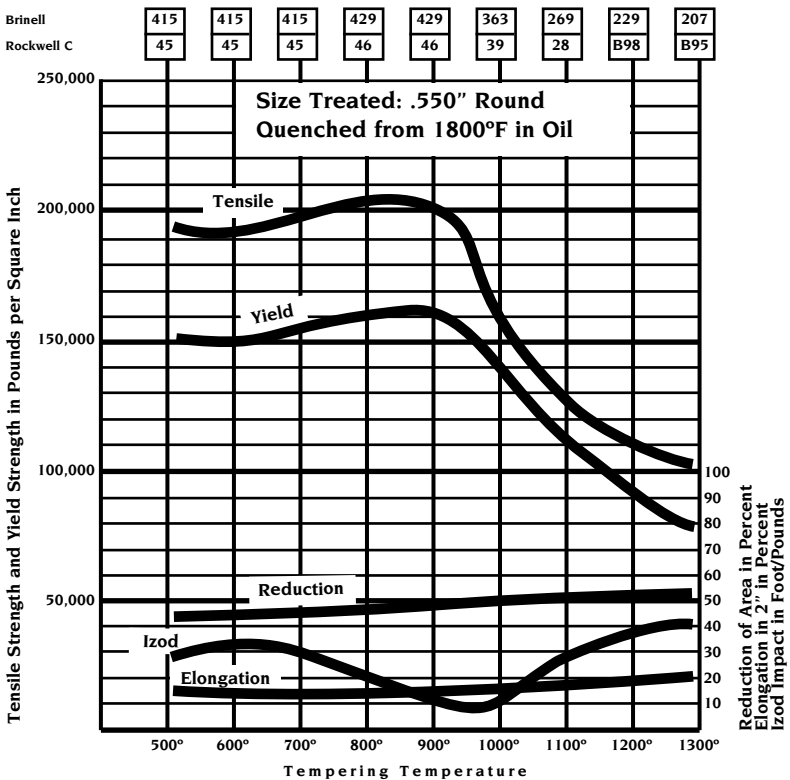


TYPE 416

Analysis		Thermal Treatment	
Carbon	.15 Max.	Forge	2100° - 2300°F. Cool slowly.
Manganese	1.25 Max.	Process Anneal	1200° - 1400°F. (Brinell 170-207.)
Phosphorus	.06 Max.	Full Anneal	1550° - 1650°F. Furnace cool. (Brinell 137-167.)
Sulphur	.15/.40	Harden	1700° - 1850°F. Cool rapidly.
Silicon	1.00 Max.	Temper	400° - 1400°F. (Tempering between 700° and 1050°F is not recommended.)
Chromium	12.00/13.50		

TYPICAL MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red.Area	Brinell	Izod
Annealed Bars	75,000	40,000	30	60	155	70

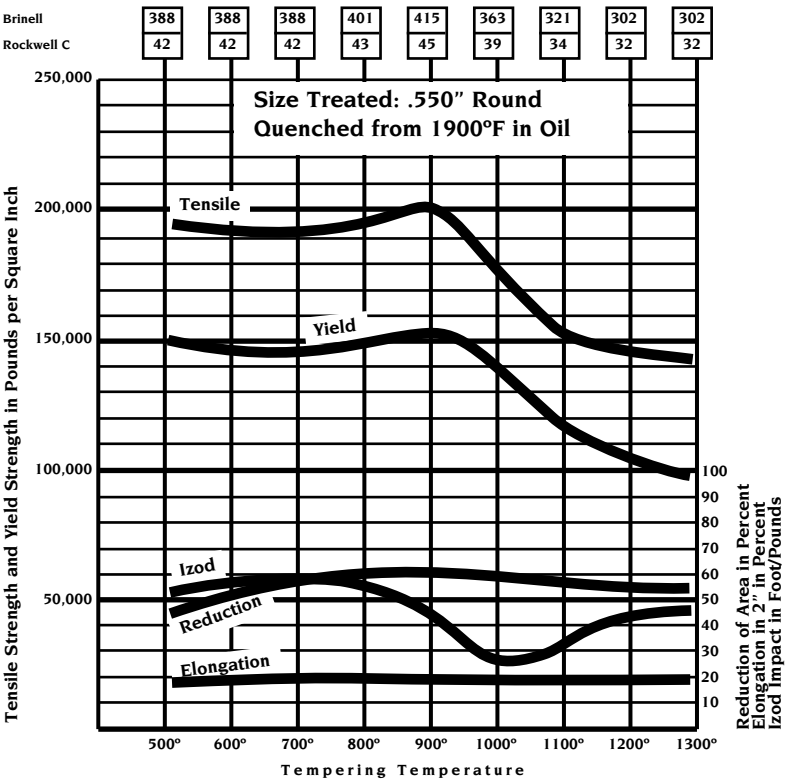


TYPE 431

Analysis		Thermal Treatment
Carbon	.13/.17	Forge 2100° - 2200°F. Cool slowly.
Manganese	.30/.80	Process Anneal 1150° - 1225°F. (Brinell 241-293.)
Phosphorus	.040 Max.	Full Anneal Not practical.
Sulphur	.030 Max.	Harden 1850° - 1950°F. Cool rapidly.
Silicon	.20/.60	Temper 400° - 1200°F. (Tempering between 650° and 1100°F is not recommended.)
Chromium	15.50/16.50	
Nickel	2.00/3.00	

TYPICAL MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red.Area	Brinell	Izod
Annealed Bars	125,000	95,000	20	55	262	50

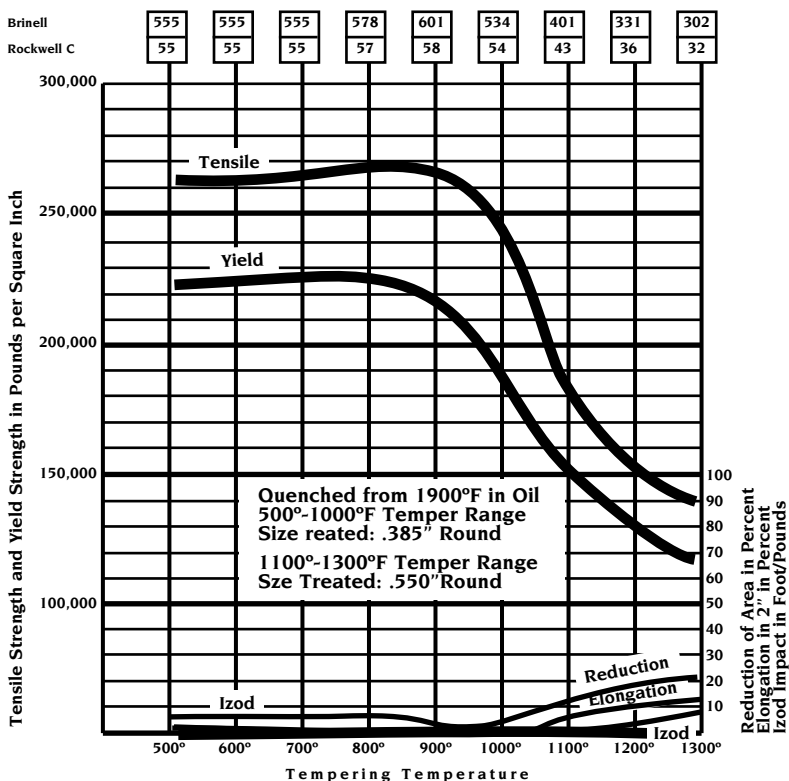


TYPE 440 C

Analysis		Thermal Treatment	
Carbon	.95/1.20	Forge	1900° - 2100°F. Cool slowly.
Manganese	1.00 Max.	Process Anneal	1350° - 1450°F. (Brinell 255-285.)
Phosphorus	.04 Max.	Full Anneal	1550° - 1650°F. Furnace cool. (Brinell 229-255.)
Sulphur	.03 Max.	Harden	1850° - 1950°F. Cool rapidly.
Silicon	1.00 Max.	Temper	300° - 800°F.
Chromium	16.00/18.00		
Molybdenum	.65 Max.		

TYPICAL MECHANICAL PROPERTIES

	Tensile Strength	Yield Strength	Elongation in 2"	Red.Area	Brinell	Izod
Annealed Bars	110,000	65,000	14	25	235	2



**CORRELATION BETWEEN
END-QUENCH HARDENABILITY TEST
AND ROUND BARS**

Distance from Quenched End of Specimen Where Hardness Reading Is Taken	Diameter in Inches of Round Bar Having Equivalent Hardness					
	At Center		At Half-Radius		At Surface	
	When Quenched in Oil	When Quenched in Water	When Quenched in Oil	When Quenched in Water	When Quenched in Oil	When Quenched in Water
1	.2	.3	.2	.6	.2	.1
2	.4	.6	.5	1.0	.5	1.6
3	.6	1.0	.7	1.3	.8	2.6
4	.8	1.3	.9	1.6	1.0	4.0
5	1.0	1.6	1.1	2.0	1.3	5.0
6	1.2	1.8	1.3	2.2	1.8	6.0
7	1.4	2.0	1.5	2.4	2.2	7.0
8	1.6	2.3	1.8	2.7	2.5	
9	1.8	2.5	2.0	3.0	3.0	
10	1.9	2.8	2.2	3.3	3.5	
11	2.0	3.0	2.5	3.5	4.0	
12	2.3	3.2	2.7	3.8	4.7	
13	2.4	3.5	2.8	4.0	5.3	
14	2.5	3.6	3.0	4.3	5.8	
15	2.7	3.7	3.2	4.5	6.5	
16	2.9	3.9	3.4	4.7		
17	3.0	4.0	3.6	4.9		
18	3.1	4.2	3.8	5.0		
19	3.3	4.4	4.0	5.3		
20	3.4	4.5	4.2	5.4		
21	3.5	4.6	4.3	5.6		
22	3.6	4.7	4.5	5.7		
23	3.7	4.8	4.7	5.9		
24	3.9	5.0	4.8	6.0		
25	4.0	5.1	4.9			
26	4.2	5.2	5.0			
28	4.3	5.4	5.1			
30	4.4	5.5	5.3			
32	4.5	5.6	5.4			



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