

ANNEALED, HOT ROLLED AND NORMALIZED NICKEL ALLOY STEELS

A PRACTICAL GUIDE TO THE USE
OF NICKEL-CONTAINING ALLOYS
N° 388

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The Nickel Institute republished the handbook in 2022. Despite the age of this publication the information herein is considered to be generally valid.

Material presented in the handbook has been prepared for the general information of the reader and should not be used or relied on for specific applications without first securing competent advice.

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Location of Tensile Property Data

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Normalized Nickel Steels	8
Annealed Nickel Steels	9
1000 ^b	11
2300	11
2500	12
3100	12
3200	13
3300	13
4300 ^b	6
4600 ^b	6
4626 ^b	4
4718 ^b	4
4720 ^b	4
4800 ^b	7
SAE EX-1 (5 Ni-0.25 Mo)	4
8600 ^b and 8700 ^b	7
9400	14

^a The AISI-SAE system for numbering steels is used if applicable.

^b AISI-SAE Standard Steel, "1965 SAE Handbook."

Annealed, Hot Rolled, and Normalized Nickel Alloy Steels

This bulletin provides information on the mechanical properties of nickel alloy steels in the unhardened condition used for fabricating operations. Fabrication is carried out normally on material in the soft, unhardened condition and is followed often, but not always as discussed in the next paragraph, by liquid quenching and tempering to secure an optimum combination of mechanical properties.

Normalized steels are used, without further heat treatment, where improvement over carbon steel is desired but liquid quenching is either impractical or not required. These applications include (1) some large forgings,* (2) some plate steels** for low-temperature service and other uses, and (3) structures fabricated from flat products, bars and structural shapes, all of such character that liquid quenching is not feasible. For the latter classification some of the

standard AISI-SAE steels are employed occasionally but the field has been taken over largely by steels with compositions and treatments developed specifically for the purpose.†

Representative tensile properties of as-rolled, annealed, and normalized nickel-containing steels are presented in graphical form on the following pages. The graphs are based on data assembled from many sources covering section sizes from ½ to 1½ inches in diameter or thickness. Data on unhardened 4626, 4718, 4720 and SAE EX-1 (5 per cent nickel-0.25 per cent molybdenum) steels are given in Table I.

* Bulletin 3-A, "Nickel Alloy Steels for Heavy Forgings".

** Bulletin 3-B, "Nickel Alloy Steel Plates".

† Bulletin 4-E, "Nickel-Copper High Strength Low Alloy Steels".

TABLE I
Unhardened 4626, 4718, 4720 and SAE EX-1 Steels

Steel Type ^a	Size, ^b in.	Condition	Brinell Hardness Number	Tensile Properties			
				Tensile Strength, psi	Yield Point, psi	Elong (2 in.), %	Red. of Area, %
4626	1	N ^c	165	83,000	56,000 ^f	29	60
4718	¾	N ^c	220	110,000	71,000 ^f	24	57
	¾	AR ^d	218	108,000	68,000 ^f	23	52
	¾	A ^e	170	85,000	54,000	29	60
4720	1	N ^c	165	83,000	52,000	31	67
	2 ¹ / ₆	AR ^d	146	80,000	45,000	29	60
	1	A ^e	144	75,000	53,000	32	64
SAE EX-1	1¼	N ^c	220	108,000	74,000 ^f	25	56

^a Composition, %:

Steel	Carbon	Manganese	Nickel	Chromium	Molybdenum
4626	0.24-0.29	0.45-0.65	0.70-1.00	—	0.15-0.25
4718	0.16-0.21	0.70-0.90	0.90-1.20	0.35-0.55	0.30-0.40
4720	0.17-0.22	0.50-0.70	0.90-1.20	0.35-0.55	0.15-0.25
SAE EX-1	0.15-0.21	0.35-0.60	4.80-5.30	—	0.20-0.30

^b Diameter or thickness.

^c Normalized 1650-1700 F.

^d As Rolled.

^e Annealed, cooled in laboratory furnace from 1700 F.

^f 0.2% offset yield strength.

TENSILE PROPERTY CHARTS

STANDARD NICKEL ALLOY STEELS

This section presents data on the following types of nickel alloy steels which are listed as AISI-SAE Standard Alloy Steels in the "1965 SAE Handbook"

Steel Type	Page No.
4300	6
4600	6
4800	7
8600 and 8700	7

Note: See page 8 for Normalized Nickel Steels and page 9 for Annealed Nickel Steels.

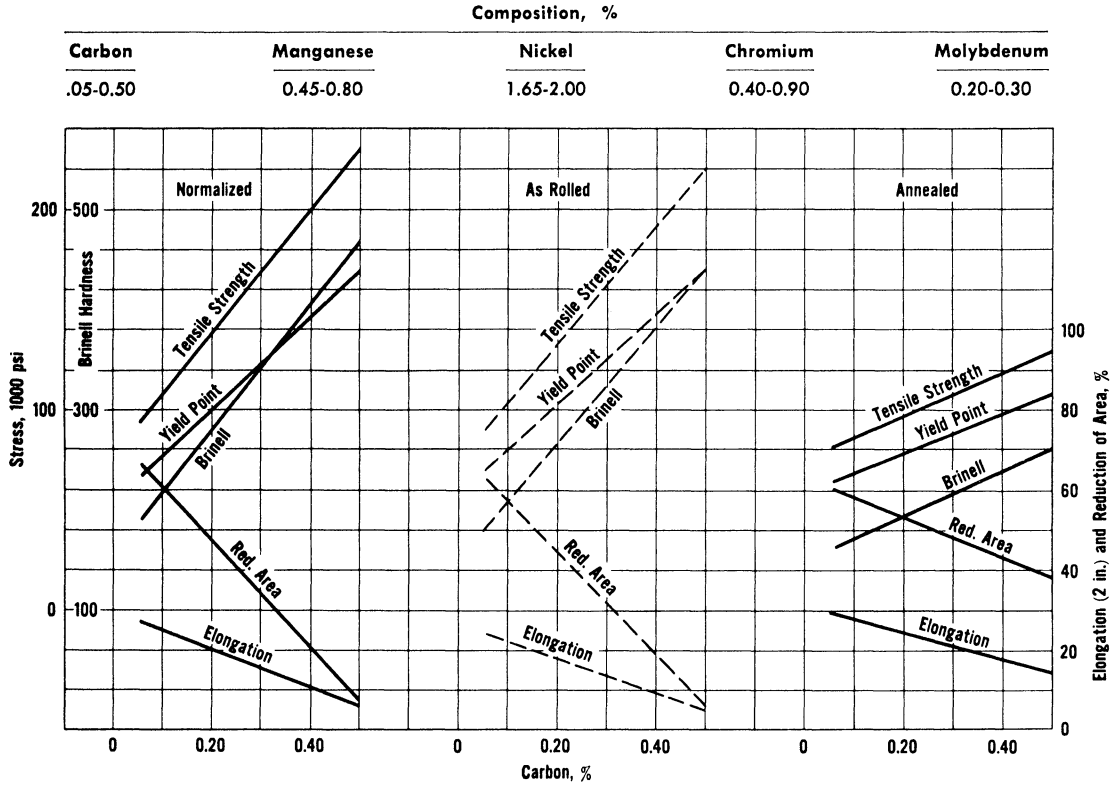
IMPORTANT—The following tensile property charts, covering normalized, as-rolled, and annealed nickel alloy steels, show values believed to be representative. However, the variables affecting the tensile properties of unhardened steels are so many that the strictly approximate nature of the charts must be clearly recognized. *The chart values should never be used to establish minimum requirements.*

Properties vary depending on how the steels were melted, processed and cooled. Variations in composition within the specification limits also affect the properties. The uncertainty is greatest in the as-rolled properties which depend largely on the temperature at which rolling was finished. Therefore, the as-rolled data are shown as broken lines on the graphs.

The annealed properties are the result of simple furnace cooling from temperatures above the critical range. Hardnesses and structures resulting from more specialized conditioning treatments are discussed in Bulletin 6-C, "Annealing Characteristics of Nickel Alloy Steels."

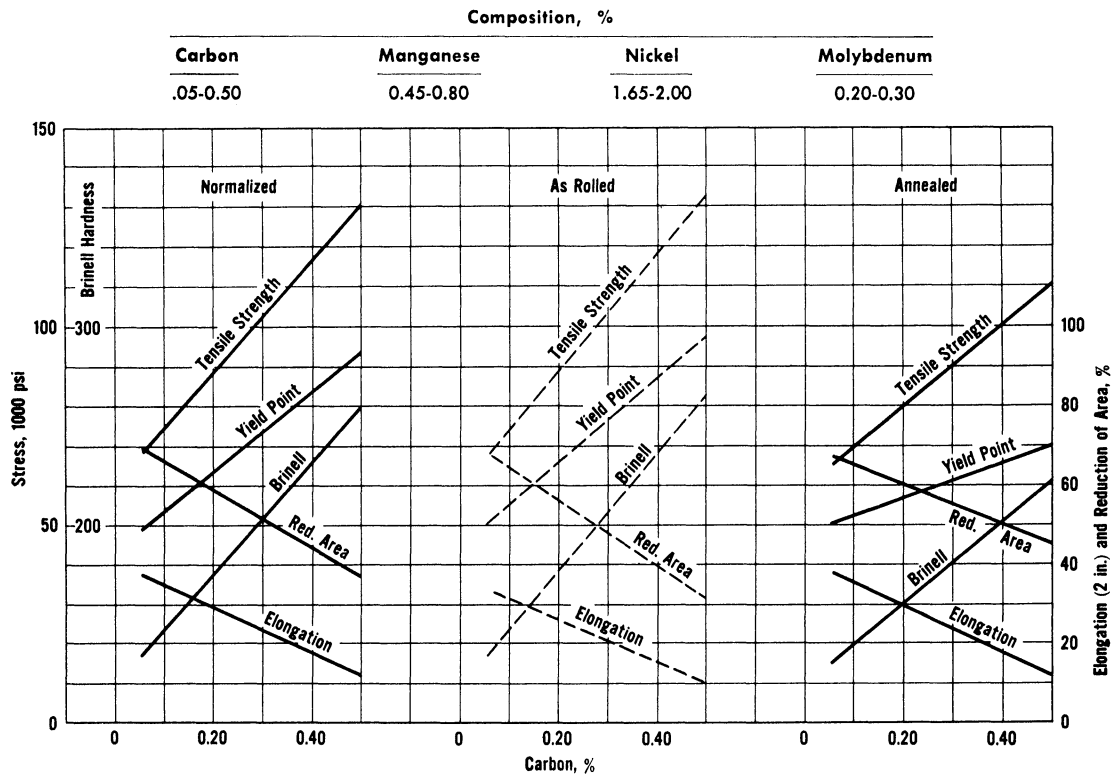
Nickel-Chromium-Molybdenum Steels, 4300 Series

(In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

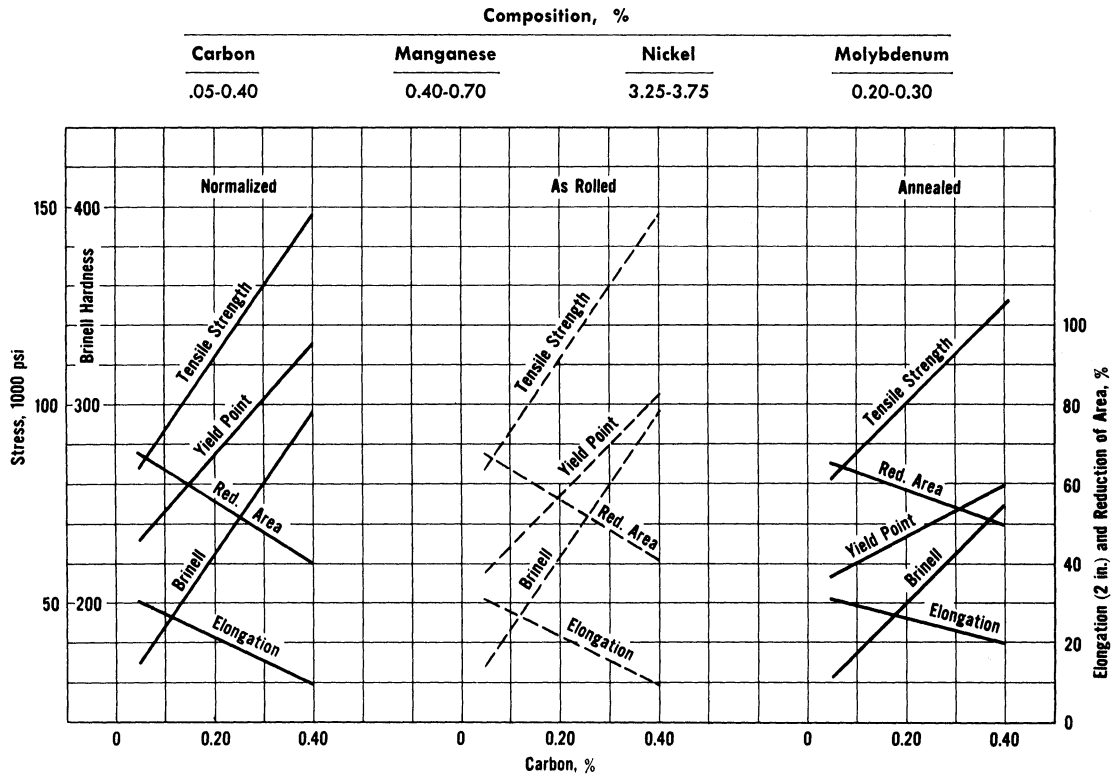


Nickel-Molybdenum Steels, 4600 Series

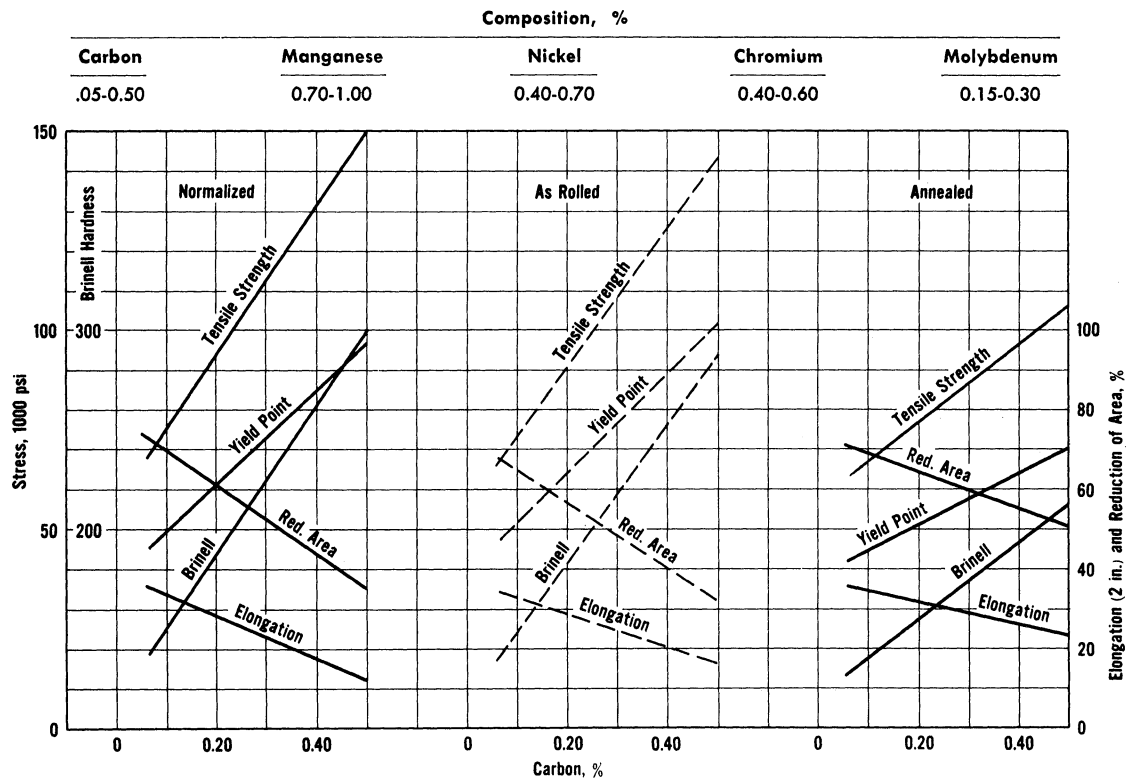
(In small sizes, 1/2 to 1 1/2-in. diameter or thickness)



Nickel-Molybdenum Steels, 4800 Series (In small sizes, 1/2 to 1 1/2-in. diameter or thickness)



Nickel-Chromium-Molybdenum Steels, 8600 and 8700 Series (In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

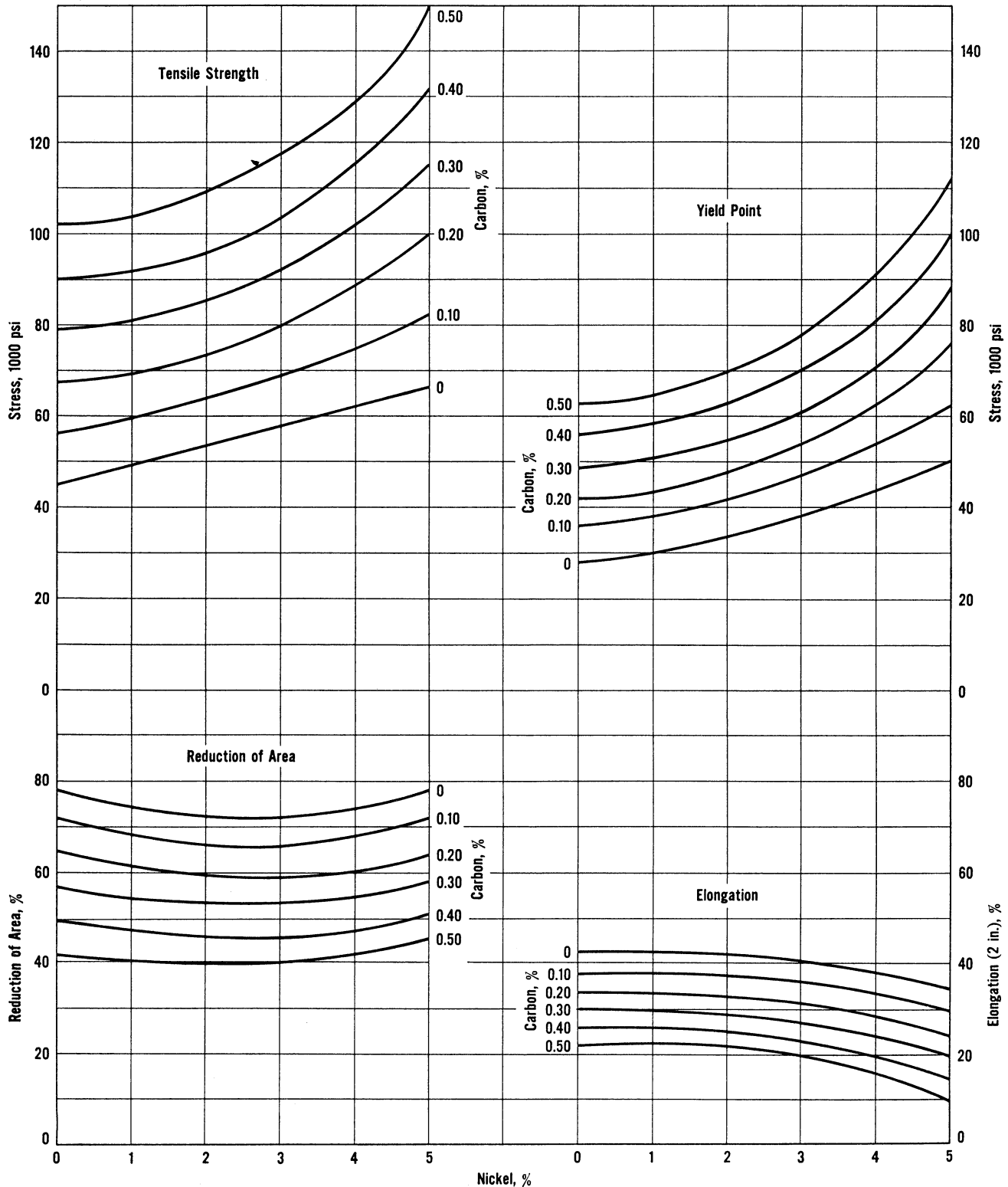


Normalized Nickel Steels

(In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, %

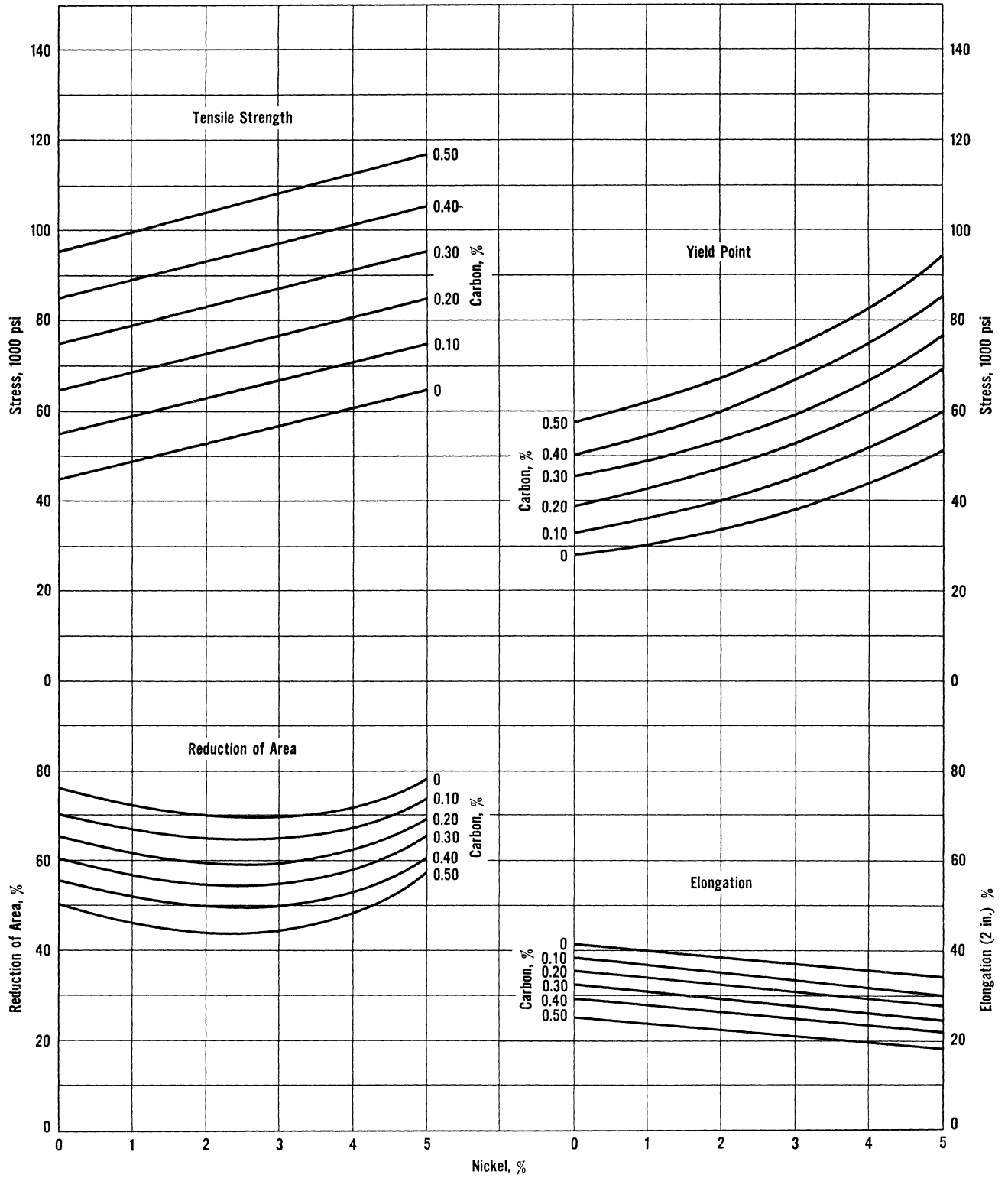
Carbon	Manganese	Nickel
0-0.50	0.40-0.90	0-5.00



Annealed Nickel Steels

(In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, %		
Carbon	Manganese	Nickel
0-0.50	0.40-0.90	0-5.00



TENSILE PROPERTY CHARTS

CARBON STEELS AND NONSTANDARD NICKEL ALLOY STEELS

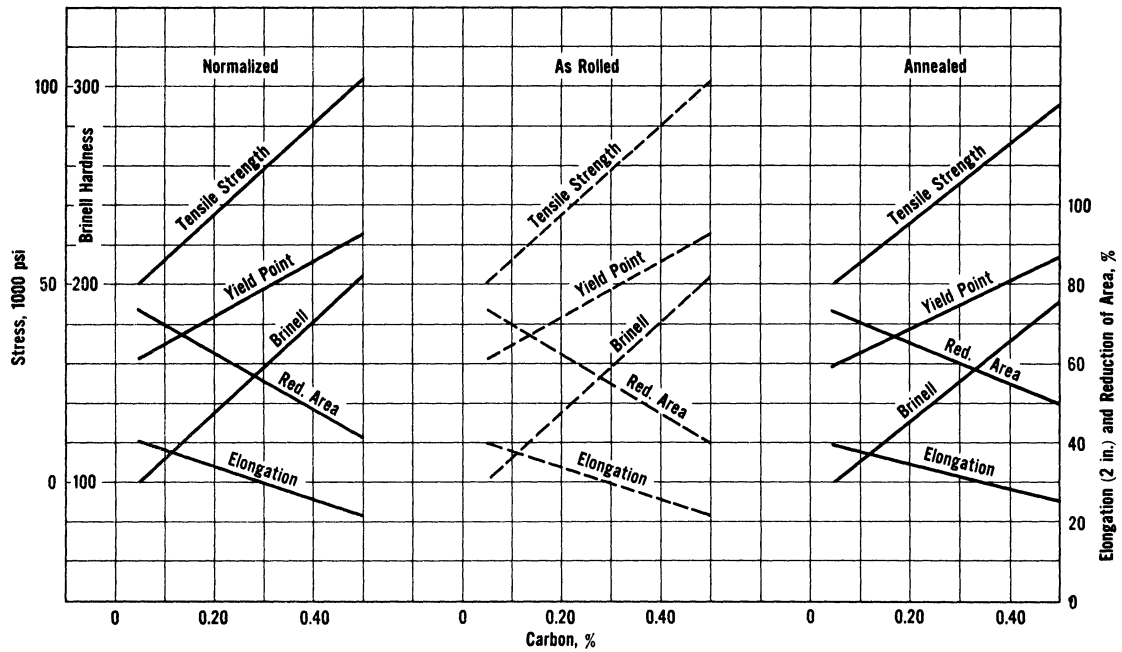
This section presents data on AISI-SAE Standard Carbon Steels and on Nickel Alloy Steels which formerly were AISI-SAE designations but do not appear as standard compositions in the "1965 SAE Handbook".

Steel Type	Page No.
1000	11
2300	11
2500	12
3100	12
3200	13
3300	13
9400	14

Carbon Steels, 1000 Series (In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, %

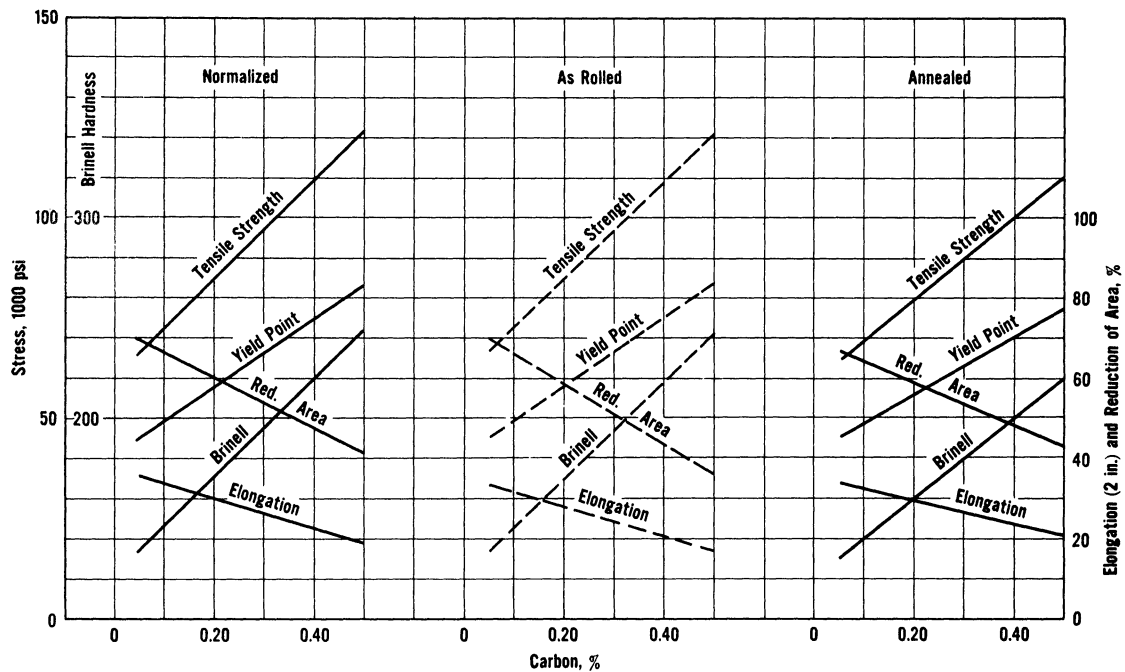
Carbon	Manganese
.05-0.50	0.30-0.90



3 1/2 % Nickel Steels, 2300 Series (In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, %

Carbon	Manganese	Nickel
.05-0.50	0.40-0.90	3.25-3.75

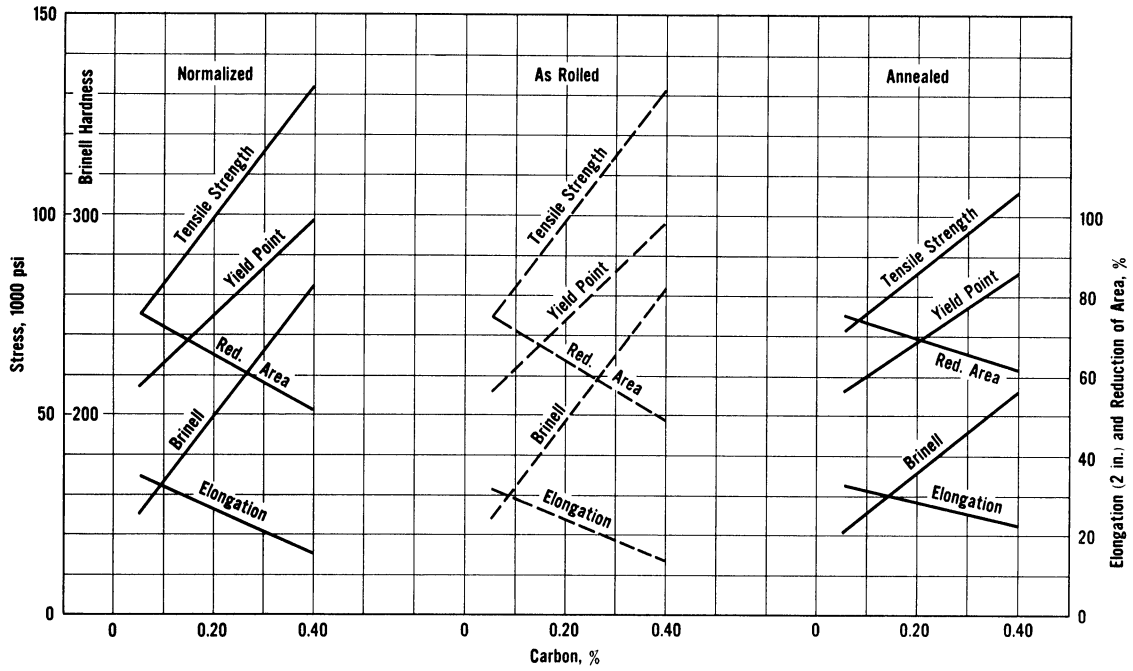


5% Nickel Steels, 2500 Series

(In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, %

Carbon	Manganese	Nickel
.05-0.40	0.45-0.60	4.75-5.25



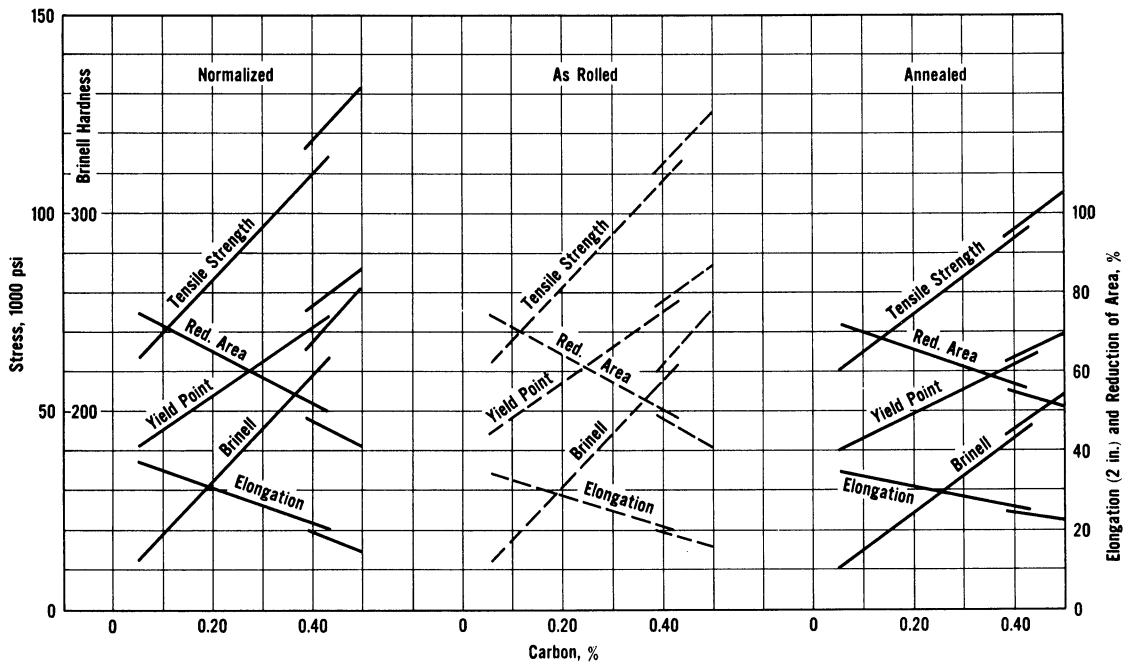
Nickel-Chromium Steels, 3100 Series

(In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, % *

Carbon	Manganese	Nickel	Chromium
.05-0.43	0.40-0.90	1.10-1.40	0.55-0.75
0.38-0.50	0.70-0.90	1.10-1.40	0.70-0.90

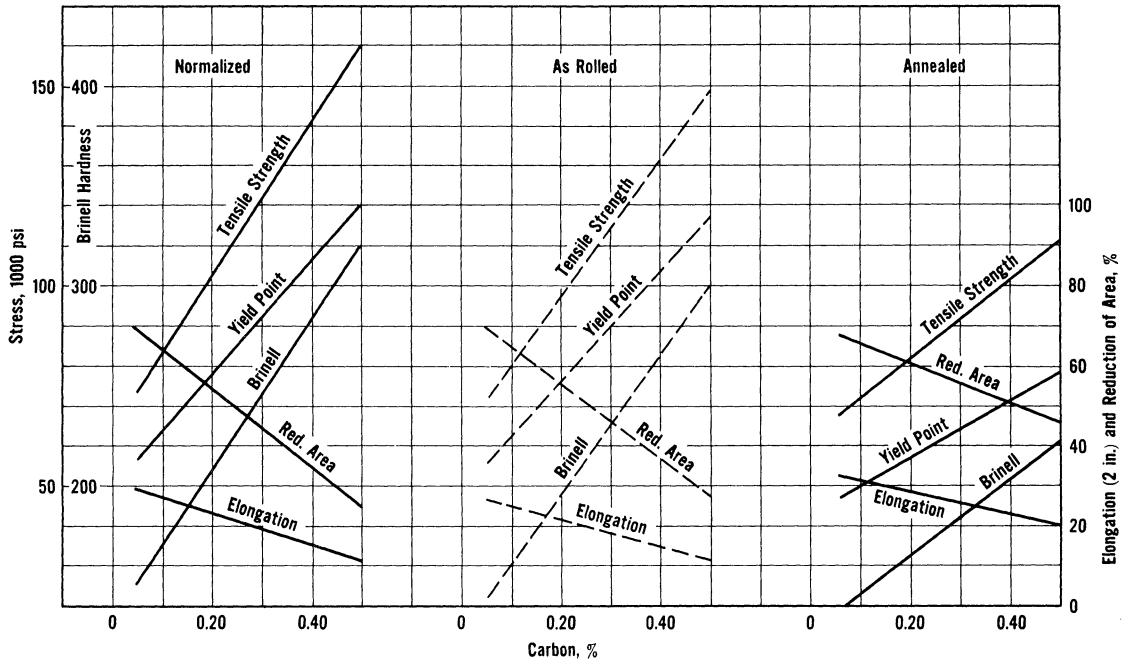
* Note increase in alloy content in the higher carbon range.



Nickel-Chromium Steels, 3200 Series (In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, %

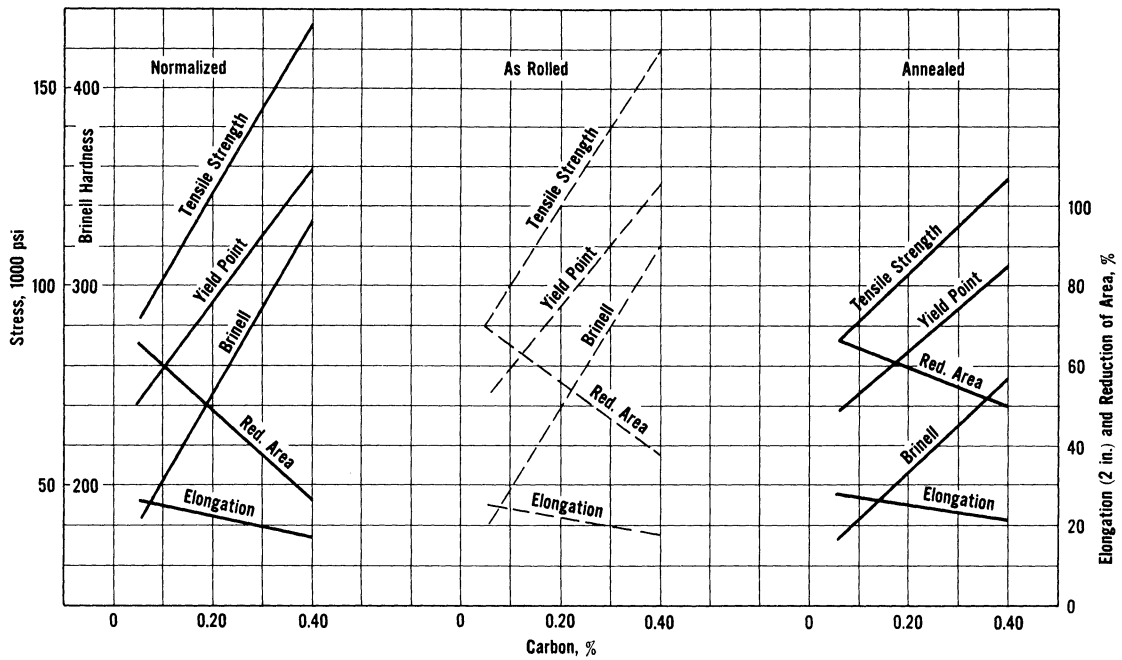
Carbon	Manganese	Nickel	Chromium
.05-0.50	0.40-0.60	1.65-2.00	0.90-1.20



Nickel-Chromium Steels, 3300 Series (In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, %

Carbon	Manganese	Nickel	Chromium
.05-0.40	0.45-0.60	3.25-3.75	1.40-1.75



Nickel-Chromium-Molybdenum Steels, 9400 Series

(In small sizes, 1/2 to 1 1/2-in. diameter or thickness)

Composition, %

Carbon	Manganese	Nickel	Chromium	Molybdenum
.05-0.50	0.90-1.30	0.30-0.60	0.30-0.50	.08-0.15

