MTR Survey of Plate Material Used in Structural Fabrication

Final Report – Part A
Yield-Tensile Properties

Submitted to

American Institute of Steel Construction, Inc.
One East Wacker Drive, Suite 3100
Chicago, IL 60601-2001

Submitted by

R. L. Brockenbrough & Associates, Inc.
17 Carleton Drive
Pittsburgh, PA 15243

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Summary

Introduction

Comprehensive mill test report data covering a year of recent plate production were provided by three steel producers. The data included information on tensile properties, Charpy impact toughness, and chemical composition. Preliminary analyses of the data from each producer were presented previously in progress reports. The present report (Final Report - Part A) presents the final analysis of the tensile data. Analyses of impact properties and chemical composition are presented in Part B and Part C, respectively.

The information from the three producers has been grouped wherever possible. Table 1 shows the data groupings and the source of the data in each group. Steels produced to the following ASTM steel designations are included: A36, A572 Gr. 50, A572 Gr. 60, A572 Gr. 65, A588, A852, and A514. A total of 38,575 lines of tensile data were analyzed.

Analysis of Tensile Data

The analysis of tensile data included yield point, tensile strength, yield-tensile ratio, and percent elongation. Table 2 lists the ASTM specified plate tensile properties for reference. The data as originally received from the producers contained some values that did not meet these specified tensile properties. However, in response to questions, each producer indicated that the data provided included all material produced, while their policy was to only ship products that met the specifications. Consequently, material that did not meet specified values was removed from the data before the final analyses reported herein were made.

The data were analyzed using the Excel spreadsheet software. A table of summary statistics (for yield point, tensile strength, yield-tensile ratio, and percent elongation) was generated for each data grouping. These tables are presented in Appendix A. The statistics tabulated include the following: mean, standard error, median, mode, standard deviation, sample variance, kurtosis, skewness, range, minimum, maximum, sum, count, confidence level (95%), coefficient of variation, mean plus two standard

deviations, and mean minus two standard deviations. Histograms for yield point, tensile strength, yield-tensile ratio, and percent elongation were also generated for the corresponding cases. These are presented in Appendix B.

Thickness Range Selection

One producer made all material in coil form for A36 steel 0.75 in. thick and less, and for A572 Gr. 50 steel 0.50 in. and less. Therefore, these thickness breaks were adopted in presenting the data for those steels. For A588 steel, the data were arbitrarily grouped into thicknesses through 2.00 in. and thicknesses over 2.00 in. For A514 steel, the data were grouped into thicknesses through 2.50 in. and thicknesses over 2.50 in. because specified minimum tensile properties change at that thickness.

Histograms

The histograms generally trend toward bell shaped distributions although there are exceptions, particular where the data cover a large thickness range. For example, the histogram for percent elongation in 2 in. for A36 steel 0.75 to 4.00 in., Figure B9, shows two distinct peaks. A review of the data shows that the right peak (greater elongation values) corresponds to thicknesses of 0.75 to 1.50 in., while the left peak (lesser elongation values) corresponds to thicknesses of 1.50 to 4.00 in. In some cases, the data are skewed to the left, such as in the histogram for percent elongation in 2 in. for A572 Grade 50 steel, 0.50 to 4.00 in., Figure B19, and the histogram for percent elongation in 2 in. for A588 steel, 0.312 to 2.00 in., Figure B34.

Mean Minus Two Standard Deviations

Table 3 shows cases where the "mean minus two standard deviations" was less than the specified minimum value for yield point, tensile strength, or percent elongation. This is presented only as an item of interest. As previously stated, only data that met specified values were used in the analysis.

Specified minimum values are shown in parentheses. It is assumed that all plates were over 24 in. wide so that the reduction in the elongation requirement applies (see footnote

to Table 2). It is apparent that where the values of mean minus two standard deviations fall below the specified minimums, they are generally very close to the specified minimums.

Yield-Tensile Ratio

Also summarized in Table 3 are the mean values of the yield-tensile ratio. This ratio is not a specified property and was calculated for information only. A simple un-weighted average value of these means for the various grades is as follows:

A36	0.65
A572-50	0.73
A572-60	0.74
A572-65	0.83
A588	0.70
A852	0.87
A514	0.92

These ratios follow the typical well-known trend of increasing yield-tensile ratio with increasing strength level.

Yield Point Statistics

Table 4 shows a summary of the key yield point statistics for all of the steels. This is generally the most important tensile property in design. As indicated, the ratio of mean to specified yield point varied from 1.11 to 1.30. The ratio decreased with thickness where two thickness ranges were shown, except for A514 steel, which had different specified properties for the two thickness ranges. The COV varied from 0.05 to 0.10. These statistics appear to be in line with assumptions made in the development of the AISC LRFD *Specification*, where the mean yield point for plate material was taken as 1.10 times the specified value and the COV was taken as 0.11.

Table 1

Summary of Yield-Tensile Analyses Conducted

Steel ASTM Designation	Thickness Range, in.	Producers	No. of Items	Summary Statistics Page No.*	Histogram Page No.**
A36	0.188-0.75	1, 2, 3	14,900	1	1-5
		1	13,862		
		2	241		
		3	797		
A36	Over 0.75-4.00	1, 2, 3	5871	1	6-10
		1	2506		
		2	1300		
		3	2065		
A572 Gr. 50	0.188-0.50	1, 2, 3	1161	2	11-15
		1	448		
		2	30		
		3	683		
A572 Gr. 50	Over 0.50-4.00	1, 2, 3	5646	2	16-20
		1	924		
		2	876		
		3	3846		
A572 Gr. 60	0.375-1.25	2, 3	42	3	21-25
		2	12		
		3	30		
A572 Gr. 65	0.312-1.25	3	128	3	26-30
A588	0.312-2.00	2, 3	1501	4	31-35
		2	358		
		3	1143		
A588	Over 2.00-4.00	2, 3	284	4	36-40
		2	168		
		3	124		
A852	0.50-3.25	3	28	5	41-45
A514	0.20-2.50	2, 3	8926	5	46-49
		2	35		
		3	8891		
A514	Over 2.50-4.00	2	270	5	50-53

* See Appendix A.
** See Appendix B.

Table 2

Specified Tensile Properties of Plates

Steel ASTM Designation	Thickness Range, in.	Yield Point, min., ksi	Tensile Strength, ksi	Elongation* in 2 in., %	Elongation* in 8 in., %
A36	Thru 8.00	36	58-80	23	20
A572-50	Thru 4.00	50	65 min.	21	18
A572-60	Thru 1.25	60	75 min.	18	16
A572-65	Thru 1.25	65	80 min.	17	15
A588	Thru 4.00	50	70 min.	21	18
A852	Thru 4.00	70	90-110	19	-
A514	Thru 2.50	100	110-130	18	-
A514	>2.50 – 6.0	90	100-130	16	-

* For plates wider than 24 in., the requirement is reduced by two percentage points (three for A572-60 and A572-65).

Table 3

Cases Where "Mean – 2SD" is Less Than Specified Minimum Values[+]

Producer No.	Steel	Nominal Thickness Range, in.	Yield Point, ksi*	Tensile Strength, ksi	Percent Elong. in 2 in.	Percent Elong. in 8 in.	Mean Yield-Tensile Ratio**
1, 2, 3	A36	0.188-0.75			19.3 (21)	16.2 (18)	0.69
1, 2, 3	A36	>0.75-4.00			20.4 (21)		0.61
1, 2, 3	A572-50	0.188-0.50					0.75
1, 2, 3	A572-50	>0.50-4.00	49.7 (50)				0.72
2, 3	A572-60	0.375-1.25	59 (60)				0.74
3	A572-65	0.312-1.25					0.83
2, 3	A588	0.312-2.00	48.4 (50)	69.3 (70)			0.74
2, 3	A588	>2.00-4.00	48.9 (50)				0.67
3	A852	0.50-3.25					0.87
2, 3	A514	0.188-2.50			15.4 (16)		0.94
2	A514	>2.50-4.00			13.9 (14)		0.90

+ Specified minimum values are shown in parenthesis.
* For A852 and A514 steel, replace Yield Point with Yield Strength.
** For information only, values are not specified.

Table 4

Summary of Key Yield Point Statistics

Steel ASTM Designation	Nominal Thickness Range, in.	Mean Yield Point, ksi*	Ratio of Mean to Specified Yield Stress	Coefficient of Variation, COV
A36	0.188-0.75	46.9	1.30	0.10
A36	>0.75-4.00	43.1	1.20	0.08
A572-50	0.188-0.50	58.3	1.17	0.05
A572-50	>0.50-4.00	56.8	1.14	0.06
A572-60	0.375-1.25	67.8	1.13	0.06
A572-65	0.312-1.25	74.3	1.14	0.06
A588	0.312-2.00	59.1	1.18	0.09
A588	>2.00-4.00	55.5	1.11	0.06
A852	0.50-3.25	88.2	1.26	0.09
A514	0.188-2.50	113.6	1.14	0.05
A514	>2.50-4.00	109.0	1.21	0.06

* For A852 and A514 steel, replace Yield Point with Yield Strength.

Appendix A

Summary Statistics for Yield-Tensile Data

Summary Statistics for A36, 0.188 – 0.75 in., Producers 1, 2, 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	46.8807	67.8976	0.6894	35.4978	22.9546
Standard Error	0.0395	0.0305	0.000376	0.1420	0.0303
Median	46.3	67.8	0.6833	33	22
Mode	46	68	0.6667	50	20
Standard Deviation	4.8265	3.7192	0.0459	8.0788	3.3761
Sample Variance	23.2954	13.8327	0.00211	65.2666	11.3977
Kurtosis	0.8129	0.4015	1.9787	-0.7248	1.8044
Skewness	0.6491	0.3941	0.8461	0.8048	0.9029
Range	35.6	28	0.4329	29	37
Minimum	36.0	58	0.5019	21	18
Maximum	71.6	86	0.9348	50	55
Sum	698522	1011674	10272	114835	285579
Count	14900	14900	14900	3235	12441
Confidence Level (95.0%)	0.0775	0.0597	0.000738	0.2785	0.0593
Coeff. of Variation	0.1030	0.0548	0.0666	0.2276	0.1471
Mean + 2SD	56.5337	75.3360	0.7813	51.6554	29.7067
Mean - 2SD	37.2276	60.4591	0.5976	19.3403	16.2025

Summary Statistics for A36, Over 0.75 – 4.00 in., Producers 1, 2, 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	43.1229	71.2091	0.6062	37.6538	27.1662
Standard Error	0.0449	0.0383	0.000634	0.1892	0.0522
Median	43.1	71	0.6081	33	28
Mode	45	70	0.6429	50	30
Standard Deviation	3.4386	2.9357	0.0486	8.5998	3.5829
Sample Variance	11.8238	8.6182	0.00236	73.9571	12.8370
Kurtosis	13.4702	9.5166	2.5200	-1.4796	-0.2252
Skewness	1.4900	0.6008	0.4808	0.3522	-0.4606
Range	60	56.2	0.5366	30	21
Minimum	36	59.1	0.4565	21	18
Maximum	96	115.3	0.9931	51	39
Sum	253175	418069	3559	77755	128089
Count	5871	5871	5871	2065	4715
Confidence Level (95.0%)	0.0880	0.0751	0.001243	0.3711	0.1023
Coeff. of Variation	0.0797	0.0412	0.0802	0.2284	0.1319
Mean + 2SD	50.0001	77.0805	0.7034	54.8534	34.3320
Mean - 2SD	36.2458	65.3378	0.5090	20.4541	20.0005

Summary Statistics for A572-50, 0.188 – 0.50 in., Producers 1, 2, 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	58.3183	77.4324	0.7531	42.7935	22.3059
Standard Error	0.0891	0.0784	0.000776	0.2353	0.0897
Median	58	77	0.7532	44	22
Mode	58	76	0.7500	43	20
Standard Deviation	3.0351	2.6726	0.0264	4.8844	3.0338
Sample Variance	9.2119	7.1426	0.000700	23.8573	9.2038
Kurtosis	1.5232	1.2110	1.4667	2.2353	2.3143
Skewness	0.6243	0.8059	-0.1070	-1.2937	0.7403
Range	23.2	21.4	0.2133	28	24
Minimum	51.0	67.0	0.6535	22	16
Maximum	74.2	88.4	0.8668	50	40
Sum	67708	89899	874	18444	25540
Count	1161	1161	1161	431	1145
Confidence Level (95.0%)	0.1748	0.1539	0.00152	0.4624	0.1759
Coeff. of Variation	0.0520	0.0345	0.0351	0.1141	0.1360
Mean + 2SD	64.3885	82.7775	0.8060	52.5623	28.3734
Mean - 2SD	52.2480	72.0873	0.7002	33.0247	16.2383

Summary Statistics for A572-50, Over 0.50 – 4.00 in., Producers 1, 2, 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	56.8405	79.4405	0.7165	42.1482	24.2337
Standard Error	0.0475	0.0637	0.000499	0.1610	0.0430
Median	56.4	78	0.7219	46	24
Mode	56	76	0.7368	50	24
Standard Deviation	3.5681	4.7901	0.0375	8.3923	3.0467
Sample Variance	12.7310	22.9455	0.0014	70.4309	9.2826
Kurtosis	56.8394	6.4651	2.3239	-0.5195	6.1252
Skewness	3.8606	1.4457	0.0817	-0.8034	0.8581
Range	75	64	0.3959	66	34
Minimum	50	65	0.5909	19	16
Maximum	125	129	0.9868	85	50
Sum	320921	448521	4045	114475	121774
Count	5646	5646	5646	2716	5025
Confidence Level (95.0%)	0.0931	0.1250	0.000978	0.3158	0.0843
Coeff. of Variation	0.0628	0.0603	0.0523	0.1991	0.1257
Mean + 2SD	63.9766	89.0208	0.7914	58.9329	30.3272
Mean - 2SD	49.7043	69.8602	0.6415	25.3636	18.1402

Summary Statistics for A572-60, 0.375 – 1.25 in., Producers 2, 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	67.8238	92.2024	0.7362	38.5172	20.0952
Standard Error	0.6212	0.7659	0.00550	0.7872	0.4030
Median	67	91	0.7430	38	20
Mode	67	89	0.7528	38	21
Standard Deviation	4.0260	4.9639	0.0356	4.2394	2.6115
Sample Variance	16.2087	24.6402	0.00127	17.9729	6.8200
Kurtosis	0.3802	0.3368	1.0478	-0.3480	-0.1848
Skewness	0.6627	0.7675	-0.9713	0.2981	0.1669
Range	18	23	0.1712	17	12
Minimum	60	81	0.625	30	15
Maximum	78	104	0.7962	47	27
Sum	2849	3873	30.9	1117	844
Count	42	42	42	29	42
Confidence Level (95.0%)	1.2546	1.5469	0.0111	1.6126	0.8138
Coeff. of Variation	0.0594	0.0538	0.0484	0.1101	0.1300
Mean + 2SD	75.8758	102.1302	0.8075	46.9961	25.3183
Mean - 2SD	59.7718	82.2746	0.6650	30.0383	14.8722

Summary Statistics for A572-65, 0.50 – 1.25 in., Producer 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	74.3438	89.6797	0.8290	40.3125	20.2188
Standard Error	0.4094	0.3817	0.0028	0.7744	0.3620
Median	73.5	89	0.8306	40.5	20
Mode	72	89	0.8523	40	20
Standard Deviation	4.6320	4.3179	0.0320	4.3806	4.0952
Sample Variance	21.4557	18.6446	0.0010	19.1895	16.7707
Kurtosis	1.6640	11.0871	3.6616	2.0226	12.5444
Skewness	0.8423	2.2756	-0.8199	-0.6937	2.9368
Range	25	35	0.2387	23	29
Minimum	65	81	0.6724	27	14
Maximum	90	116	0.9111	50	43
Sum	9516	11479	106	1290	2588
Count	128	128	128	32	128
Confidence Level (95.0%)	0.8102	0.7552	0.0056	1.5794	0.7163
Coeff. of Variation	0.0623	0.0481	0.0386	0.1087	0.2025
Mean + 2SD	83.6078	98.3156	0.8930	49.0737	28.4092
Mean - 2SD	65.0797	81.0438	0.7649	31.5513	12.0283

Summary Statistics for A588, 0.312 – 2.00 in., Producers 2, 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	59.1437	80.3327	0.7369	43.1403	24.7616
Standard Error	0.1381	0.1424	0.00126	0.2376	0.0784
Median	58	79	0.7436	46	24
Mode	58	76	0.750	50	24
Standard Deviation	5.3515	5.5162	0.0487	7.9489	2.8686
Sample Variance	28.6386	30.4289	0.00237	63.1853	8.2289
Kurtosis	19.1168	3.2138	1.8926	0.0780	4.3263
Skewness	3.5889	1.3979	0.2369	-1.1438	0.6367
Range	48.9	42	0.3976	32	34
Minimum	50	70	0.5730	19	16
Maximum	99	112	0.9706	51	50
Sum	88775	120579	1106.142	48274	33181
Count	1501	1501	1501	1119	1340
Confidence Level (95.0%)	0.2709	0.2793	0.0025	0.4662	0.1537
Coeff. of Variation	0.0905	0.0687	0.0661	0.1843	0.1158
Mean + 2SD	69.8467	91.3652	0.8344	59.0381	30.4988
Mean - 2SD	48.4407	69.3002	0.6395	27.2425	19.0244

Summary Statistics for A588, Over 2.00 – 4.00 in., Producers 2, 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	55.4599	82.5940	0.6714	30.6121	25.2976
Standard Error	0.1951	0.1959	0.00153	0.2424	0.2157
Median	55	82	0.6712	31	25
Mode	54	81	0.6667	30	24
Standard Deviation	3.2871	3.3013	0.0257	2.6103	2.7955
Sample Variance	10.8047	10.8983	0.000662	6.8134	7.8151
Kurtosis	21.9203	5.4848	4.8853	0.2000	-0.4756
Skewness	3.1494	1.1326	1.0411	-0.6101	-0.1725
Range	34	29	0.2063	13	13
Minimum	50	74	0.6092	23	19
Maximum	84	103	0.8155	36	32
Sum	15751	23457	191	3551	4250
Count	284	284	284	116	168
Confidence Level (95.0%)	0.3839	0.3856	0.0030	0.4801	0.4258
Coeff. of Variation	0.0593	0.0400	0.0383	0.0853	0.1105
Mean + 2SD	62.0340	89.1965	0.7229	35.8326	30.8887
Mean - 2SD	48.8857	75.9915	0.6199	25.3916	19.7065

Summary Statistics for A852, 0.50 – 3.25 in., Producer 3

Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	88.2222	100.7778	0.8746	24.3636	24.4375
Standard Error	1.5556	0.6822	0.0124	0.4106	0.9353
Median	91	102	0.8962	24	25.5
Mode	95	102	0.8247	26	27
Standard Deviation	8.0829	3.5446	0.0643	1.3618	3.7411
Sample Variance	65.3333	12.5641	0.00413	1.8545	13.9958
Kurtosis	-0.0584	-0.2098	-0.5742	-0.9674	1.2495
Skewness	-0.7418	0.0411	-0.5248	-0.2304	-1.2745
Range	29	15	0.2337	4	13
Minimum	70	94	0.7368	22	15
Maximum	99	109	0.9706	26	28
Sum	2382	2721	23.6	268	391
Count	27	27	27	11	16
Confidence Level (95.0%)	3.1975	1.4022	0.0254	0.9149	1.9935
Coeff. of Variation	0.0916	0.0352	0.0735	0.0559	0.1531
Mean + 2SD	104.3880	107.8670	1.0032	27.0873	31.9197
Mean - 2SD	72.0564	93.6886	0.7459	21.6400	16.9553

Summary Statistics for A514, 0.188 – 2.50 in., Producers 2, 3

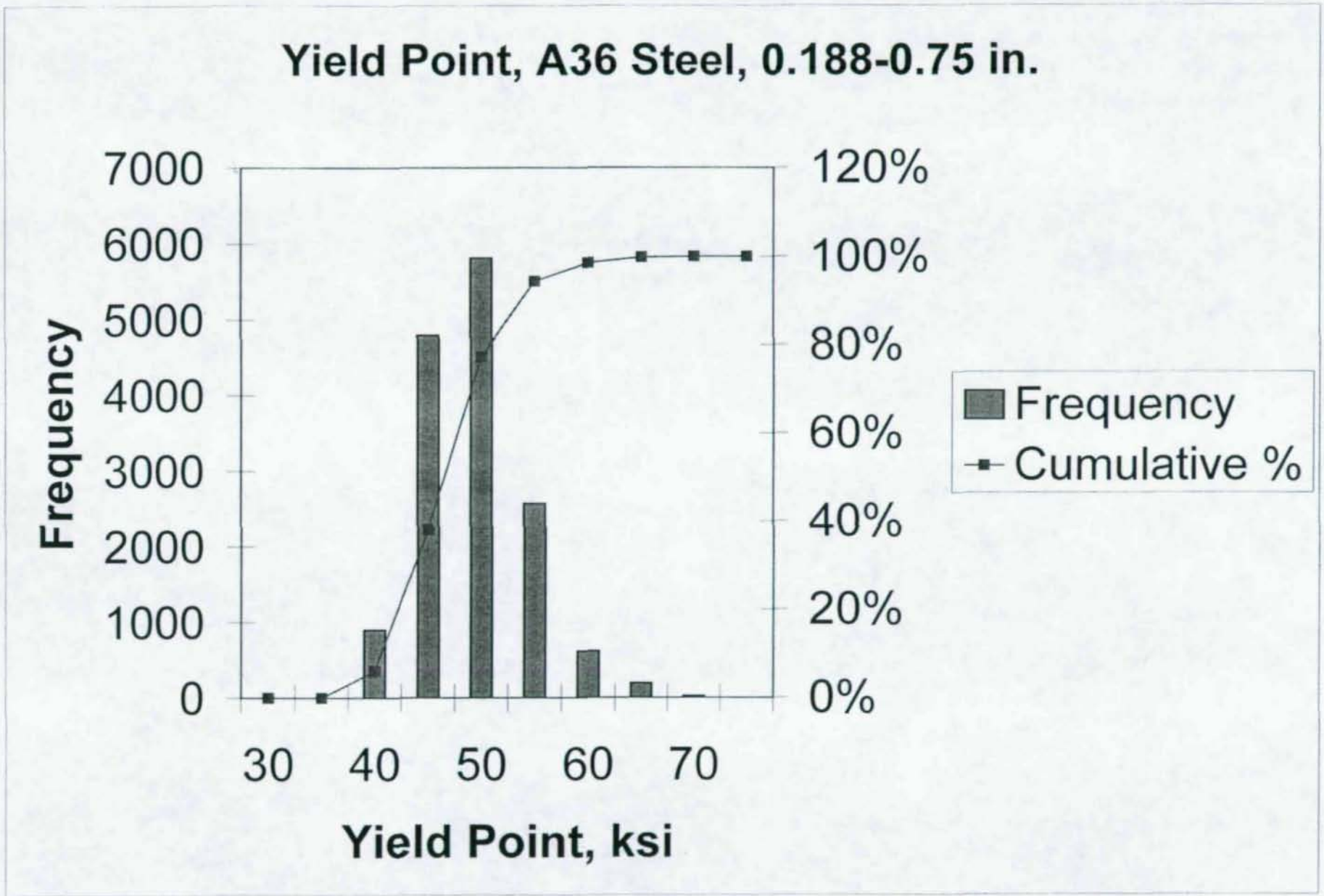
Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	113.5609	120.897	0.9391	26.7107	
Standard Error	0.0613	0.0543	0.000170	0.0596	
Median	114	121	0.9417	26	
Mode	115	121	0.9431	26	
Standard Deviation	5.7874	5.1271	0.0161	5.6312	
Sample Variance	33.4943	26.2876	0.000259	31.7105	
Kurtosis	-0.6368	-0.7681	6.2741	2.0284	
Skewness	-0.1820	-0.1753	-1.4223	1.1964	
Range	27	20	0.2308	34	
Minimum	100	110	0.7692	16	
Maximum	127	130	1.00	50	
Sum	1013644	1079127	8382	238420	
Count	8926	8926	8926	8926	
Confidence Level (95.0%)	0.1201	0.1064	0.000334	0.1168	
Coeff. of Variation	0.0510	0.0424	0.0172	0.2108	
Mean + 2SD	125.1357	131.1513	0.9713	37.9732	
Mean - 2SD	101.9860	110.6427	0.9069	15.4483	

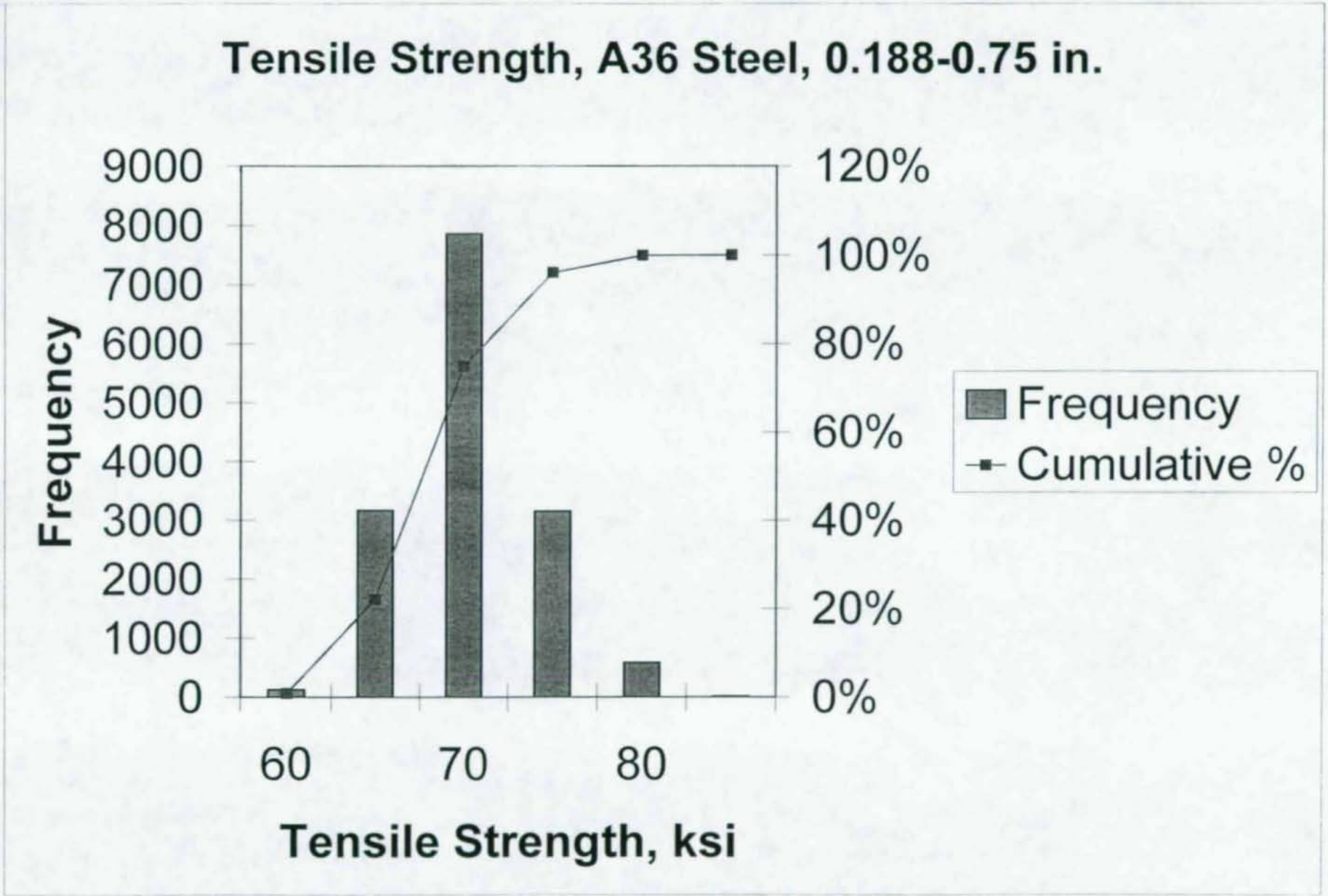
Summary Statistics for A514, Over 2.50 – 4.00 in., Producer 2

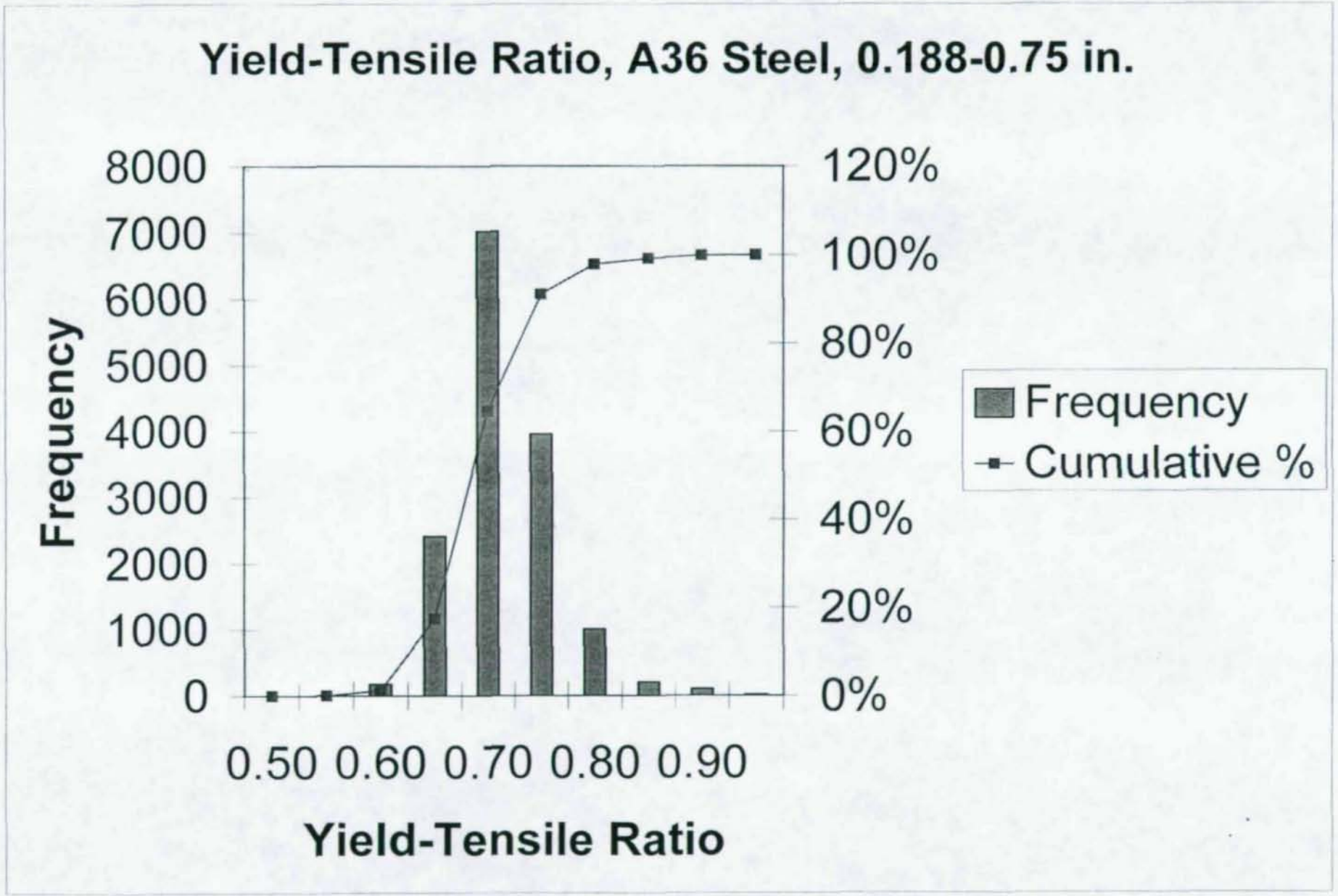
Statistic	Yield Point	Tensile Strength	Yield-Tensile Ratio	Percent Elongation in 2 in.	Percent Elongation in 8 in.
Mean	108.95	121.3859	0.8970	17.7	
Standard Error	0.3689	0.2745	0.00122	0.1149	
Median	109.7	122.0	0.8986	18	
Mode	109.5	123.5	0.8834	18	
Standard Deviation	6.0617	4.5110	0.0201	1.8878	
Sample Variance	36.7441	20.3492	0.000403	3.5639	
Kurtosis	0.1563	0.4832	0.2969	-0.3305	
Skewness	-0.6239	-0.7091	-0.6136	0.1621	
Range	29.7	23.7	0.1026	9	
Minimum	91.1	106.0	0.8292	14	
Maximum	120.8	129.7	0.9318	23	
Sum	29417	32774	242	4779	
Count	270	270	270	270	
Confidence Level (95.0%)	0.7263	0.5405	0.00240	0.2262	
Coeff. of Variation	0.0556	0.0372	0.0224	0.1067	
Mean + 2SD	121.0734	130.4080	0.9371	21.4757	
Mean - 2SD	96.8266	112.3639	0.8568	13.9243	

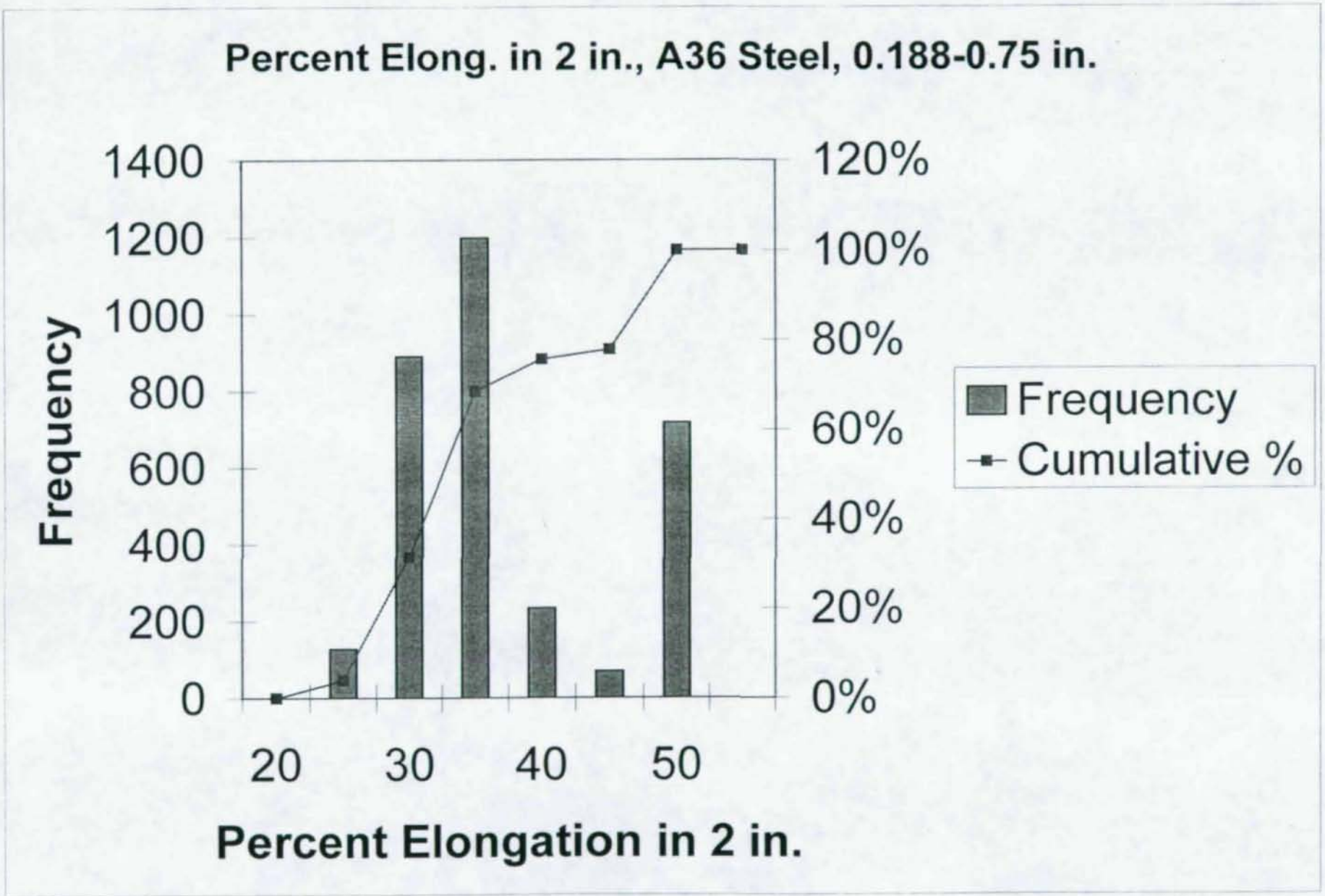
Appendix B

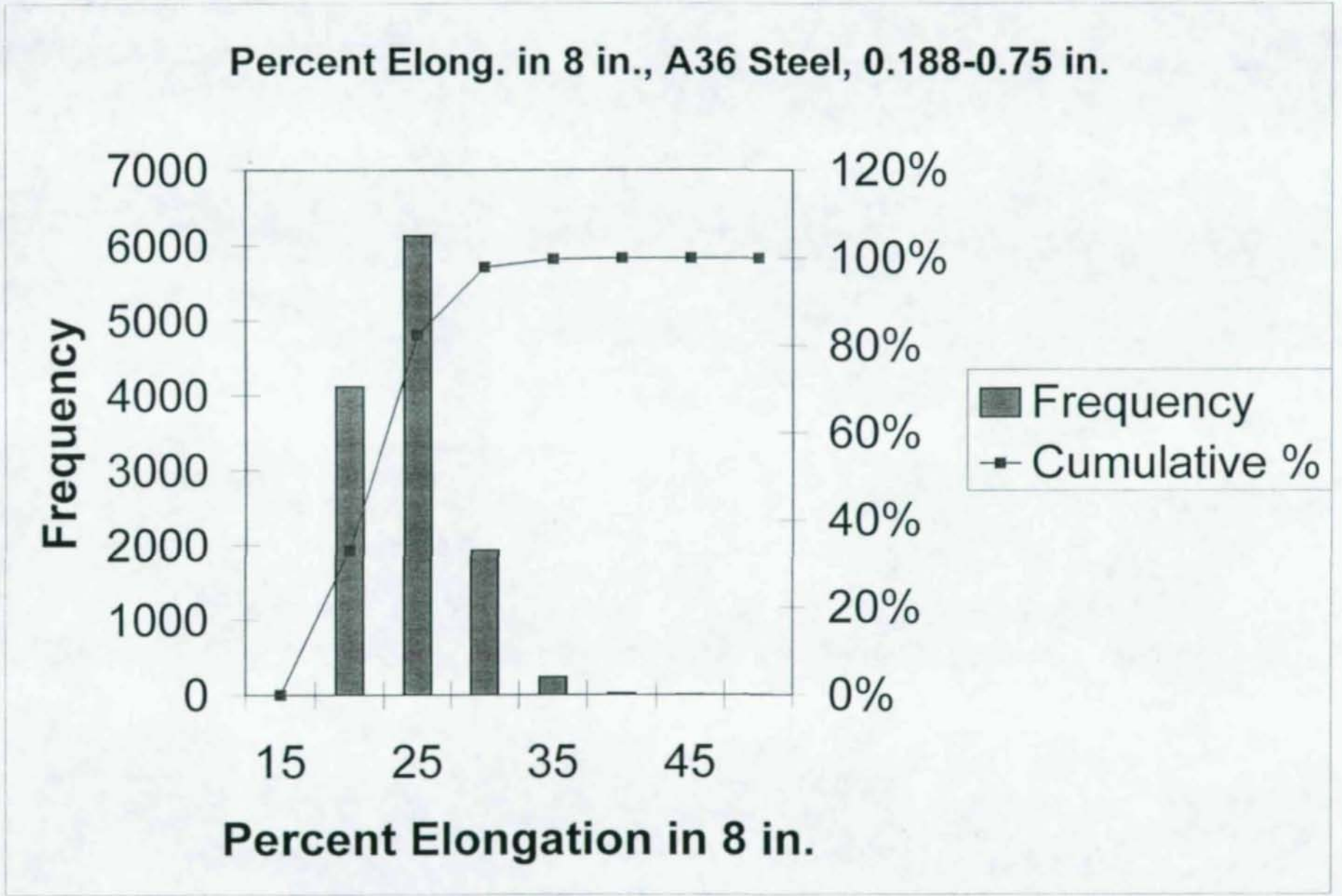
Histograms for Yield-Tensile Data

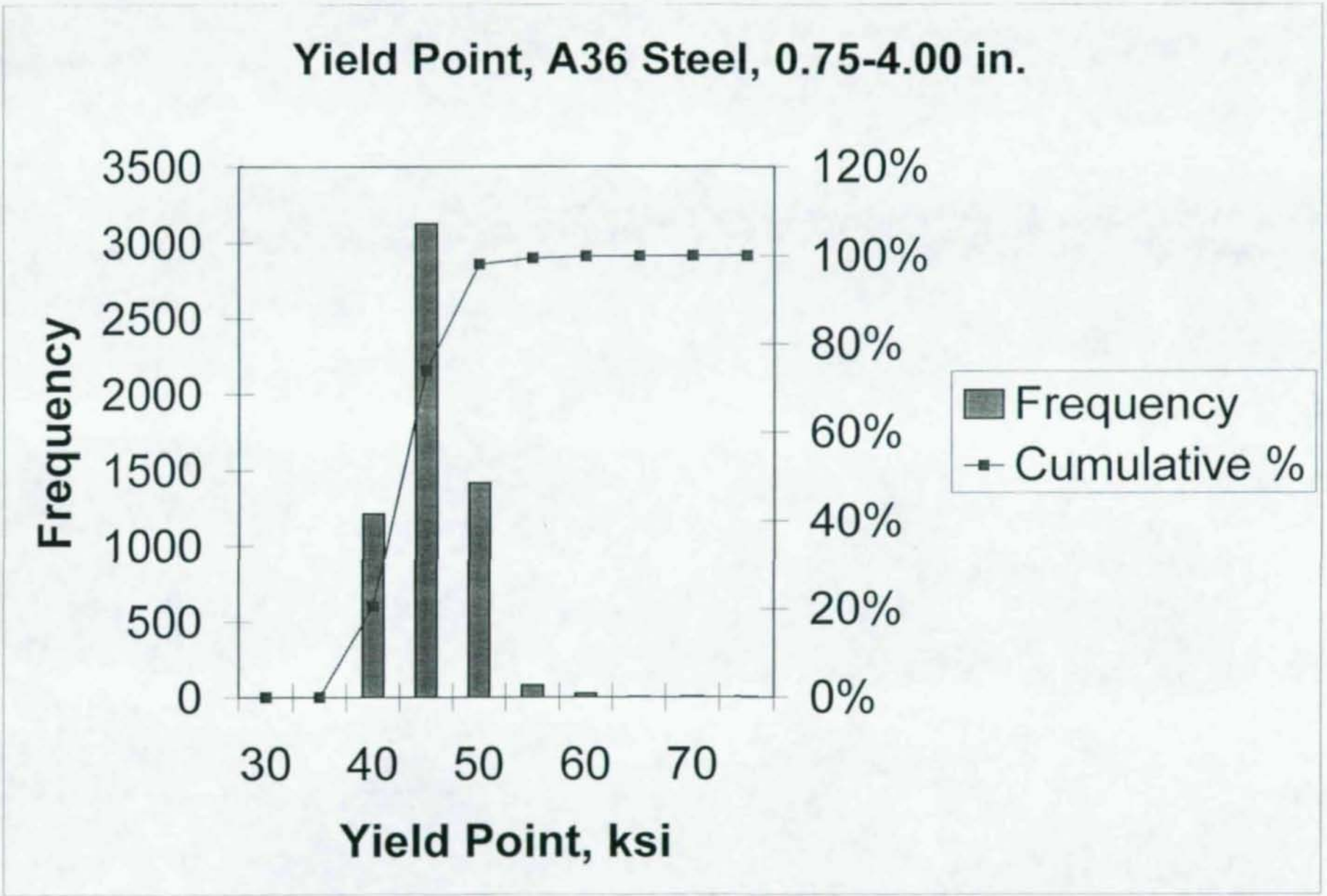

Yield Point, A36 Steel, 0.188-0.75 in.
Frequency
7000
6000
5000
4000
3000
2000
1000
0
120%
100%
80%
60%
40%
20%
0%
30
40
50
60
70
Yield Point, ksi
Frequency
Cumulative %

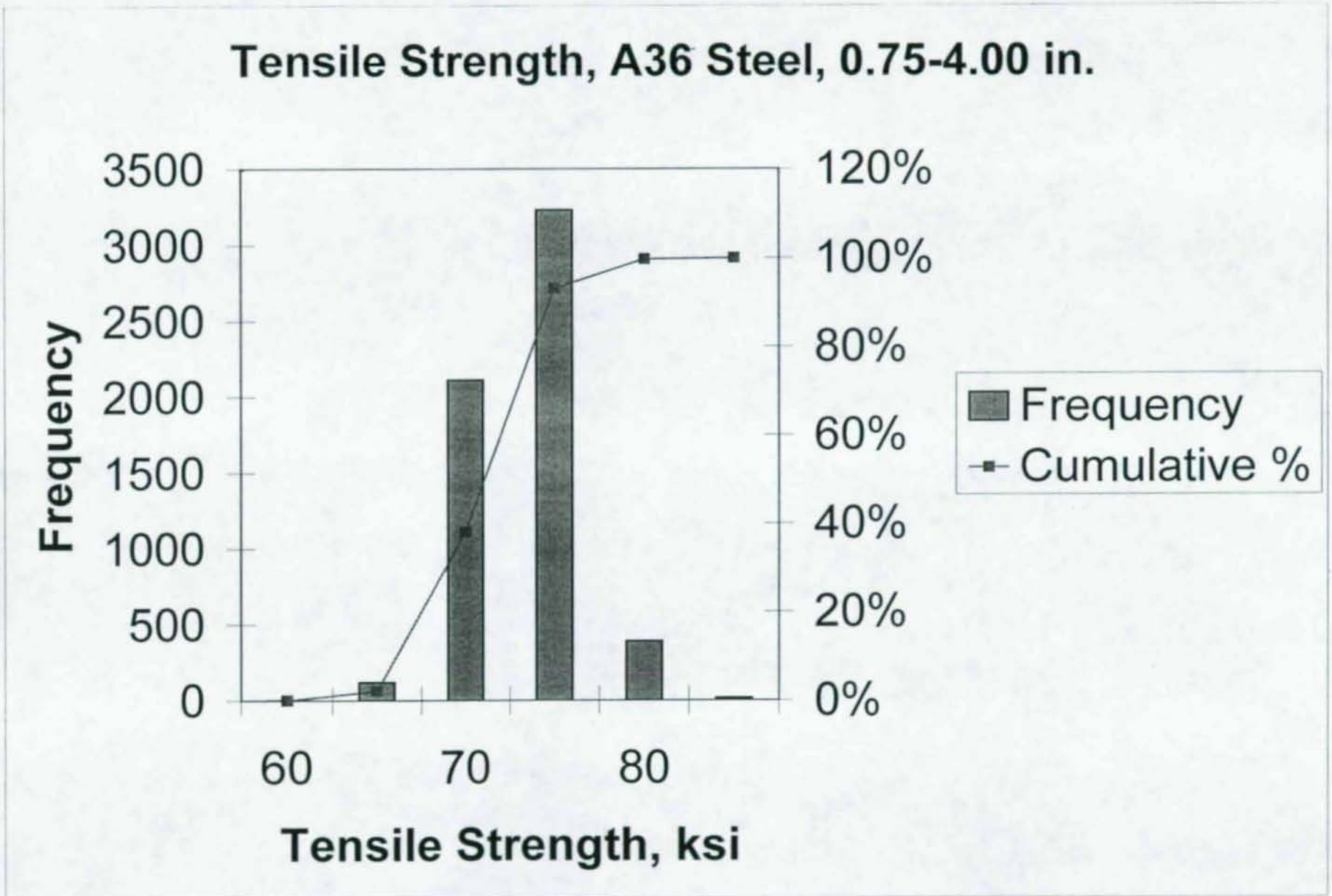

Tensile Strength, A36 Steel, 0.188-0.75 in.
Frequency
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
120%
100%
80%
60%
40%
20%
0%
60
70
80
Tensile Strength, ksi
Frequency
Cumulative %

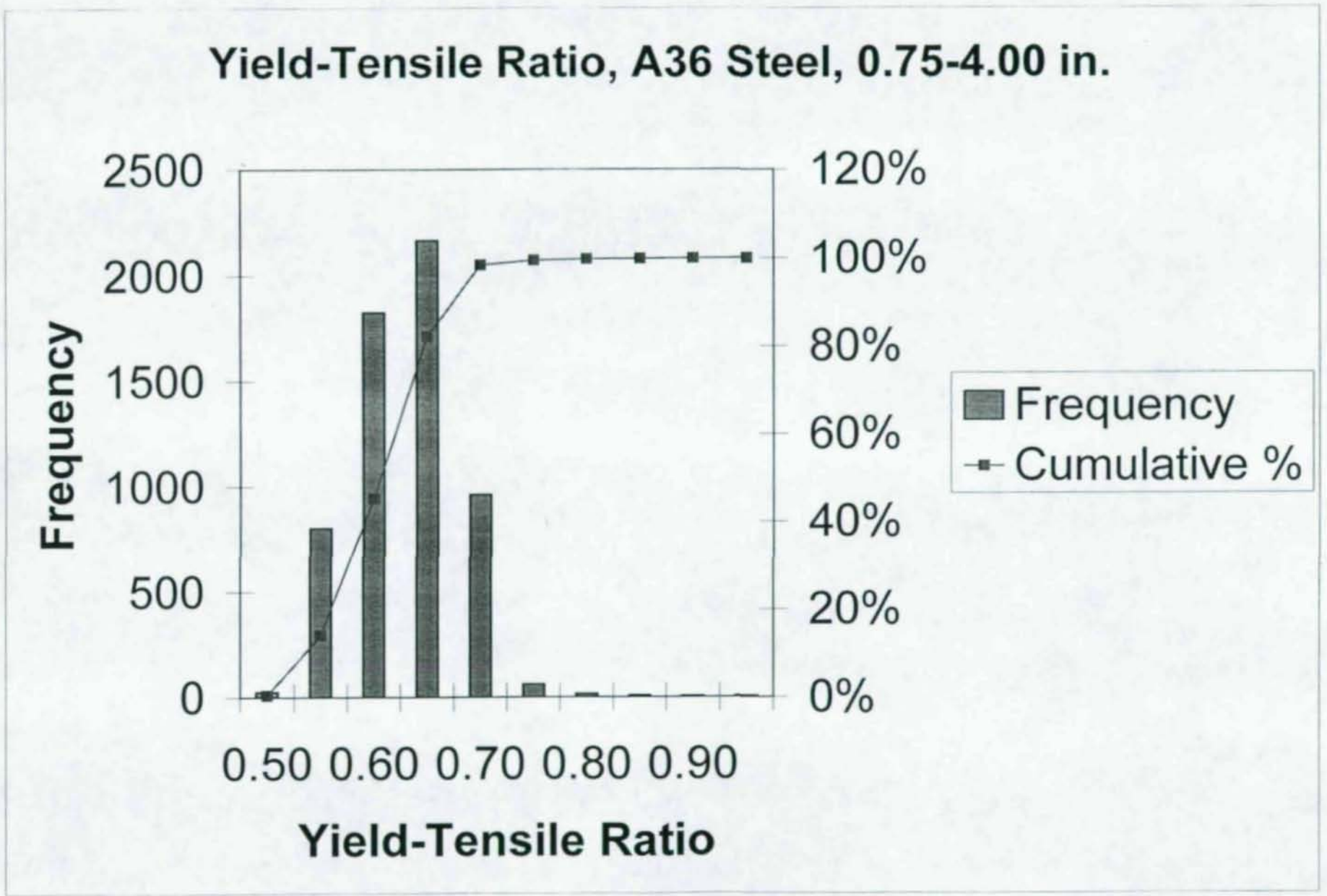

Yield-Tensile Ratio, A36 Steel, 0.188-0.75 in.
Frequency
8000
7000
6000
5000
4000
3000
2000
1000
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
0.50 0.60 0.70 0.80 0.90
Yield-Tensile Ratio

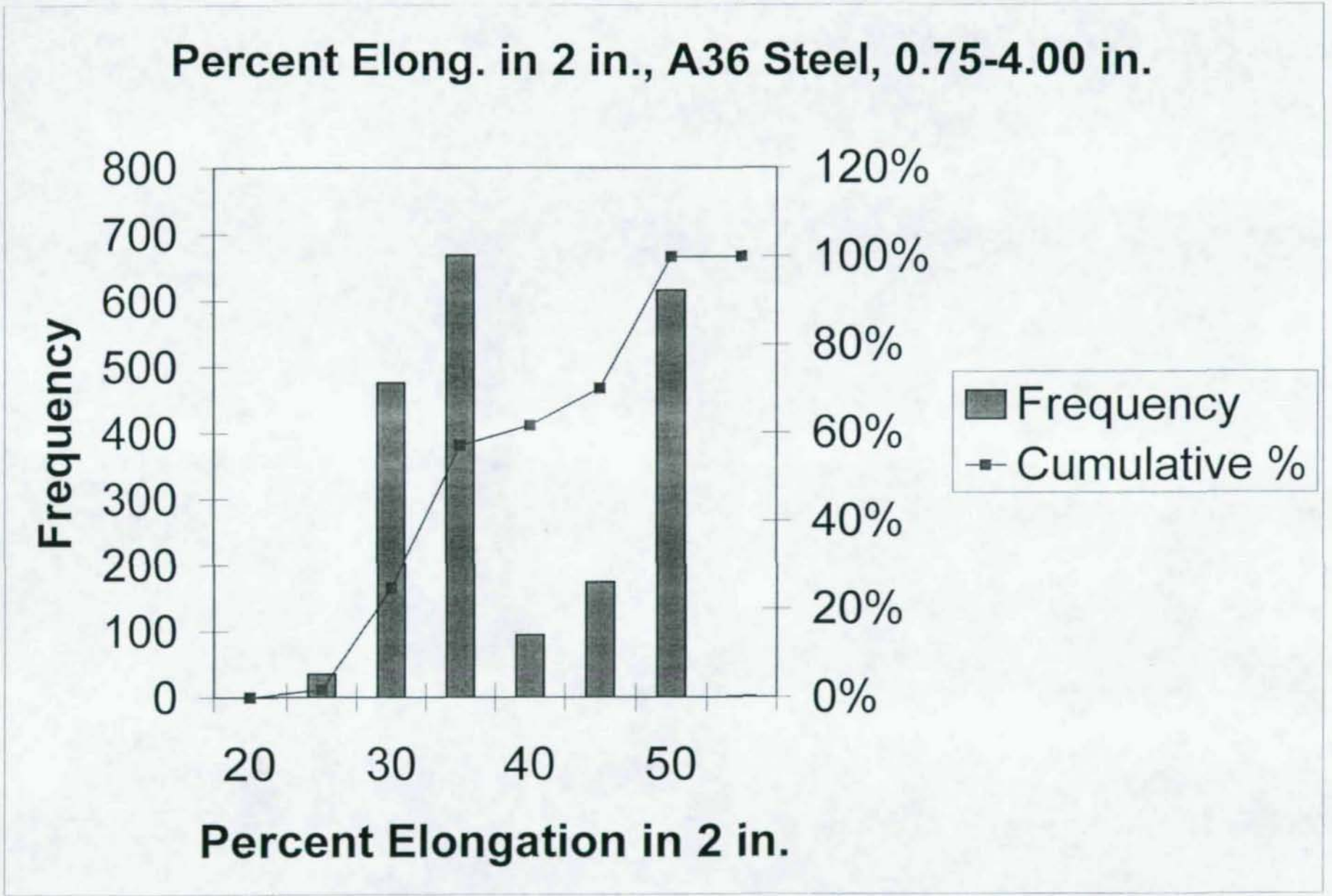

Percent Elong. in 2 in., A36 Steel, 0.188-0.75 in.
Frequency
1400
1200
1000
800
600
400
200
0
120%
100%
80%
60%
40%
20%
0%
20
30
40
50
Percent Elongation in 2 in.
Frequency
Cumulative %

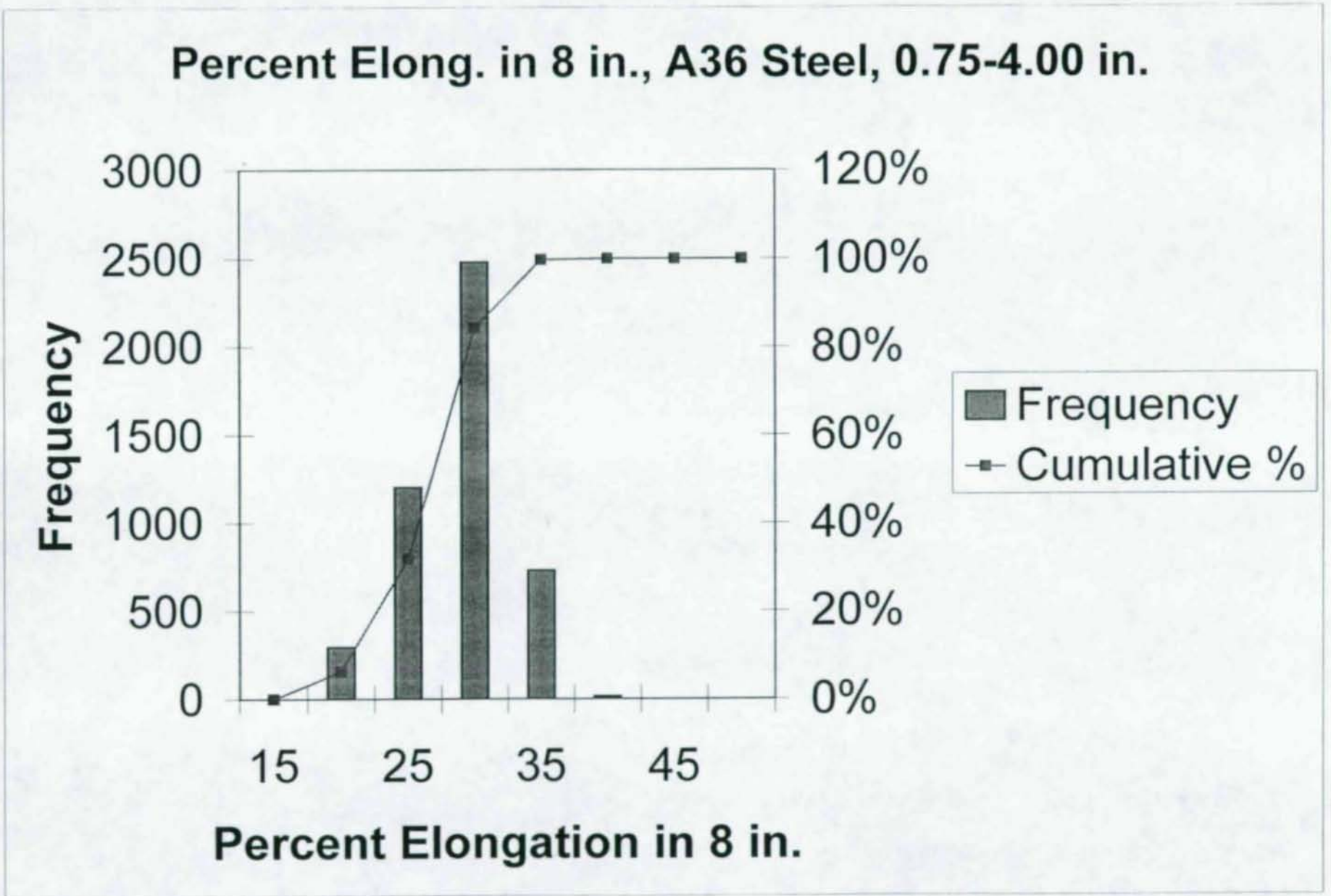

Percent Elong. in 8 in., A36 Steel, 0.188-0.75 in.
Frequency
7000
6000
5000
4000
3000
2000
1000
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
15
25
35
45
Percent Elongation in 8 in.

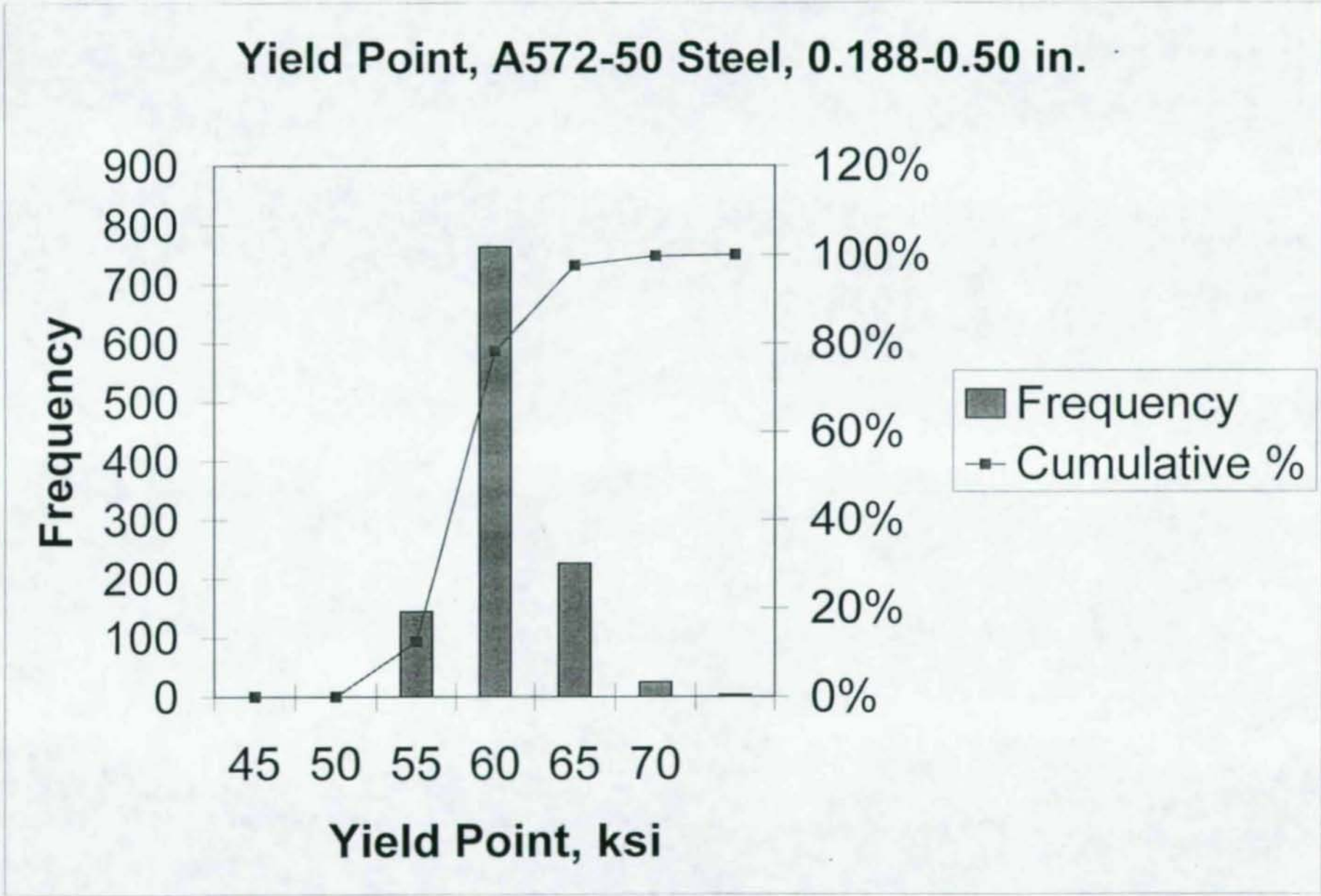

Yield Point, A36 Steel, 0.75-4.00 in.
Frequency
3500
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
30
40
50
60
70
Yield Point, ksi
Frequency
Cumulative %

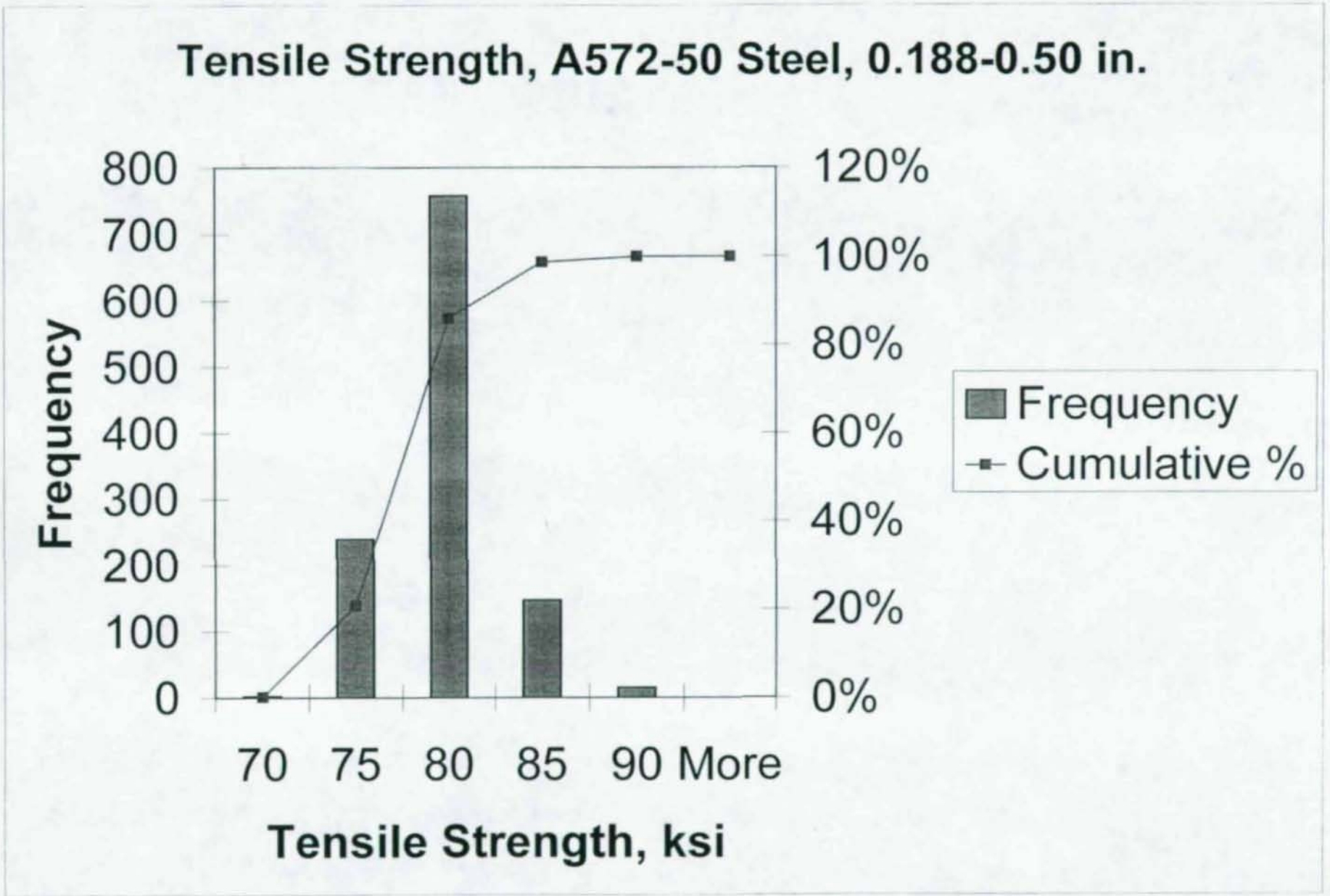

Tensile Strength, A36 Steel, 0.75-4.00 in.
Frequency
3500
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
60
70
80
Tensile Strength, ksi

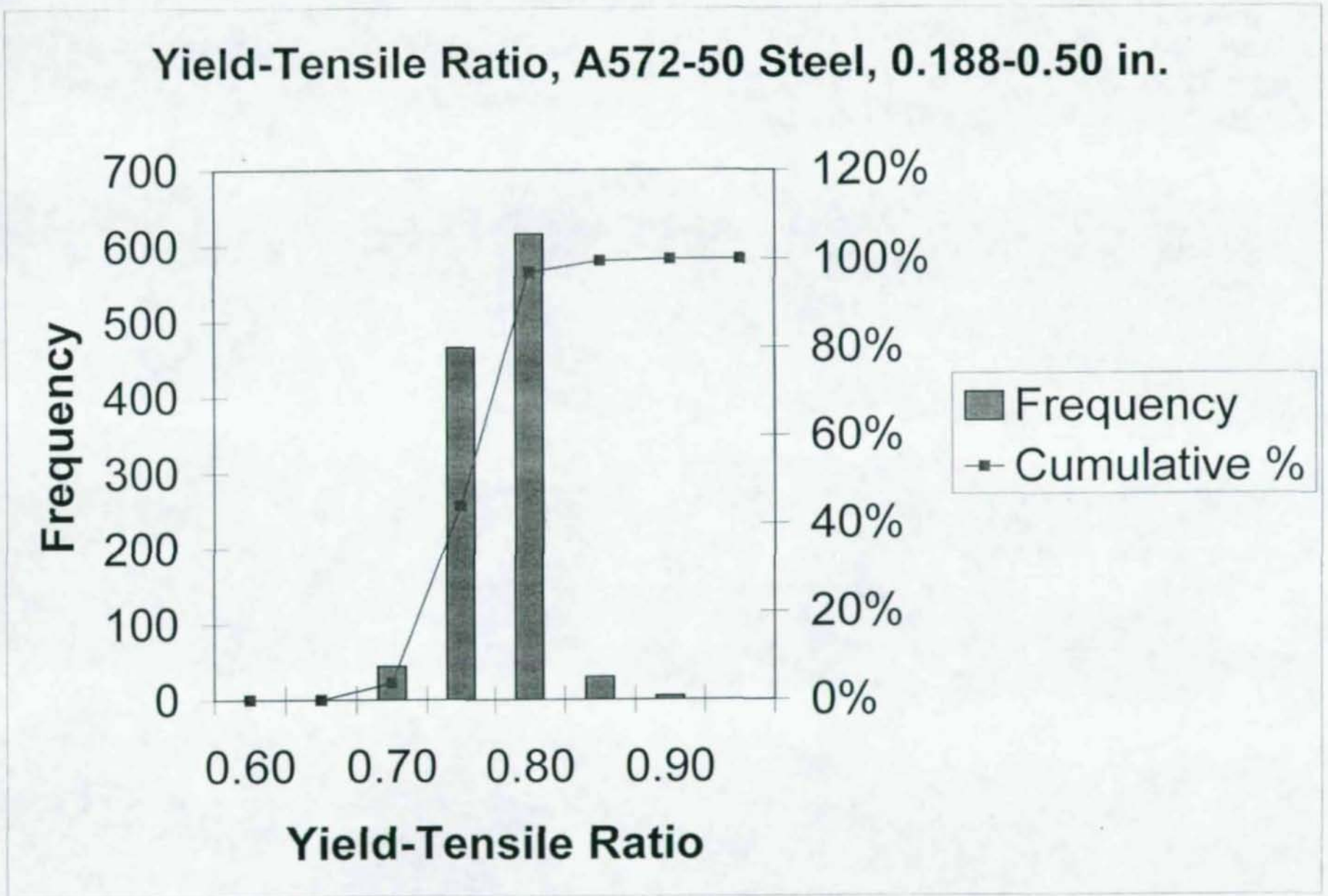

Yield-Tensile Ratio, A36 Steel, 0.75-4.00 in.
Frequency
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
0.50 0.60 0.70 0.80 0.90
Yield-Tensile Ratio

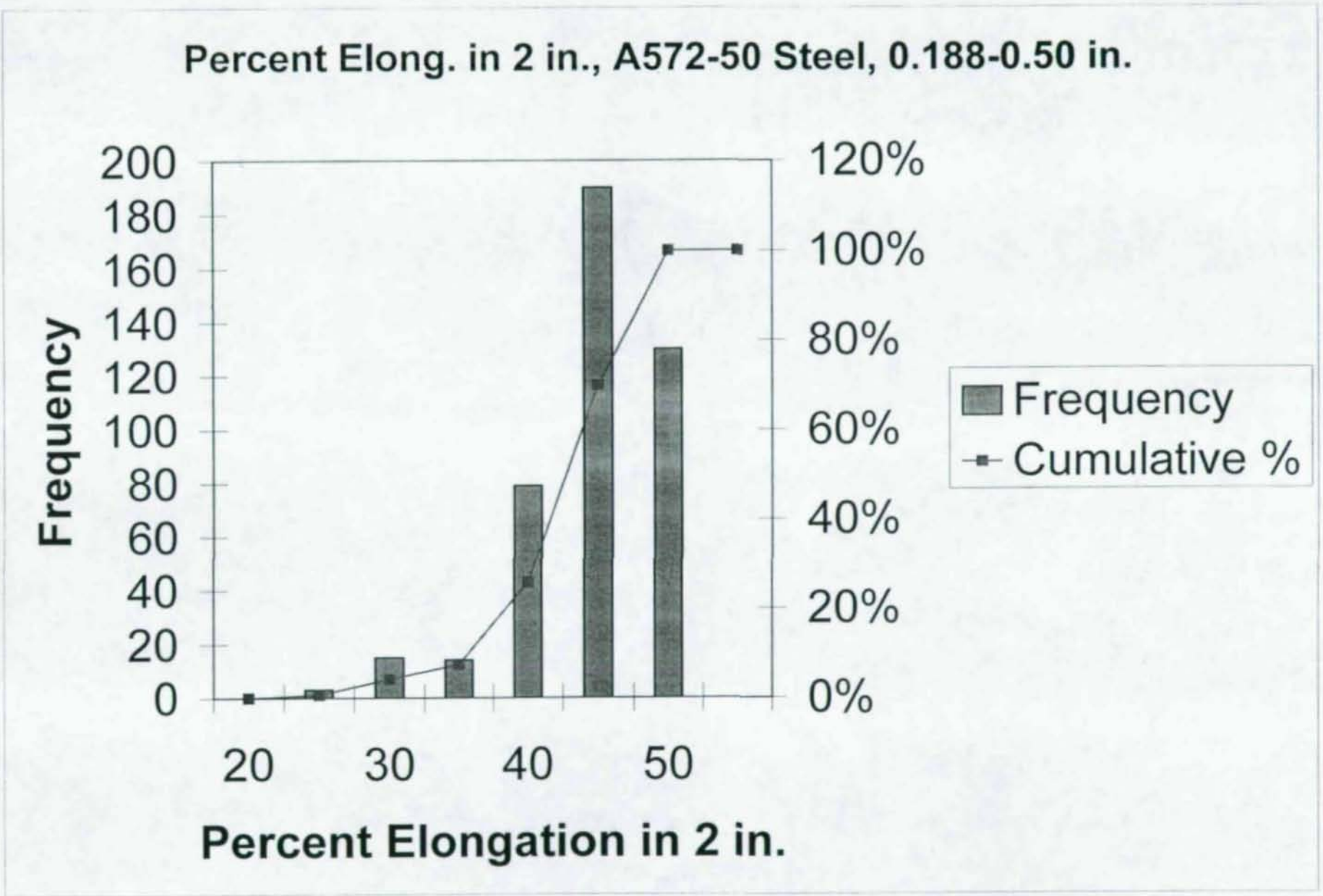

Percent Elong. in 2 in., A36 Steel, 0.75-4.00 in.
Frequency
800
700
600
500
400
300
200
100
0
120%
100%
80%
60%
40%
20%
0%
20
30
40
50
Percent Elongation in 2 in.
Frequency
Cumulative %

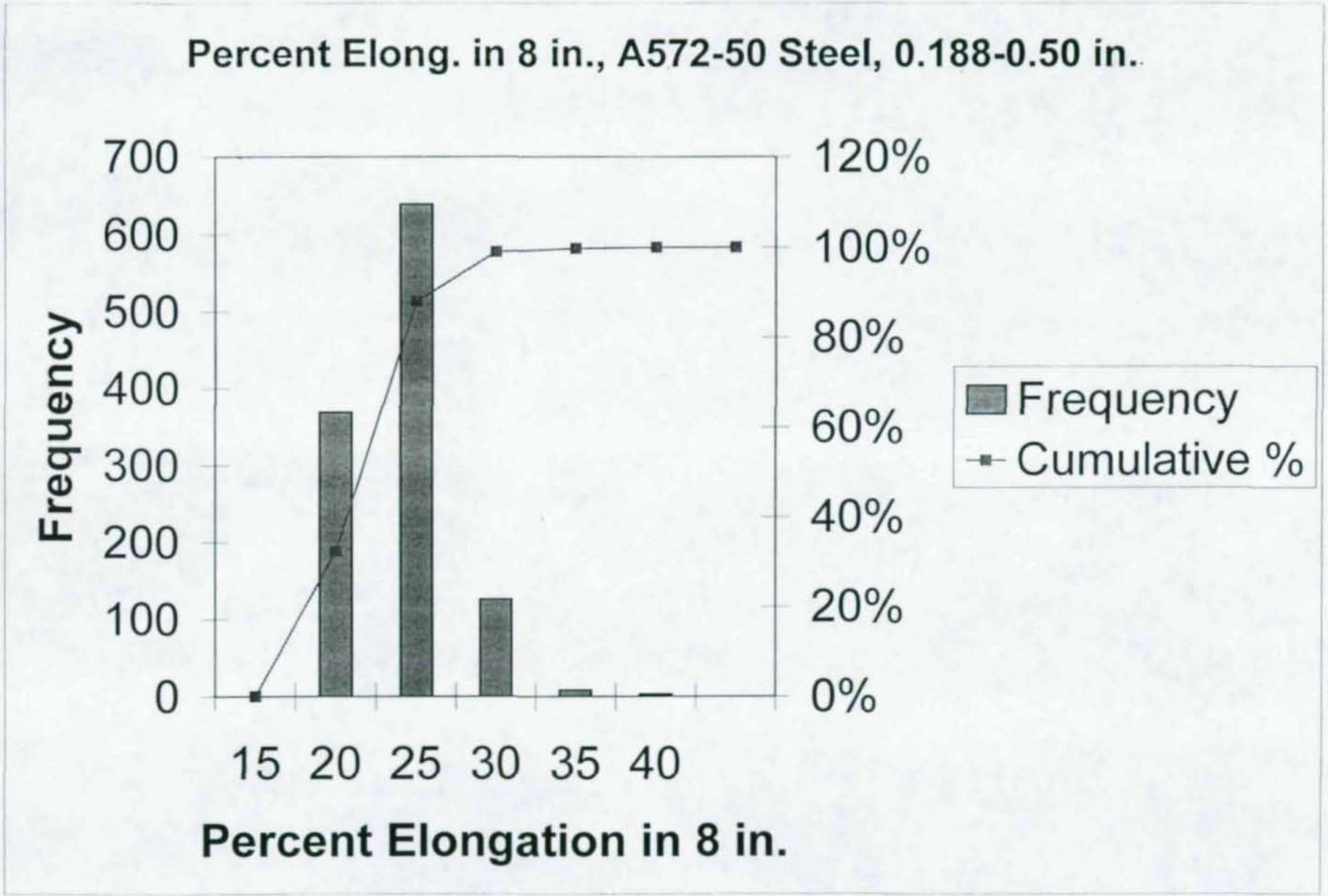

Percent Elong. in 8 in., A36 Steel, 0.75-4.00 in.
Frequency
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
15
25
35
45
Percent Elongation in 8 in.

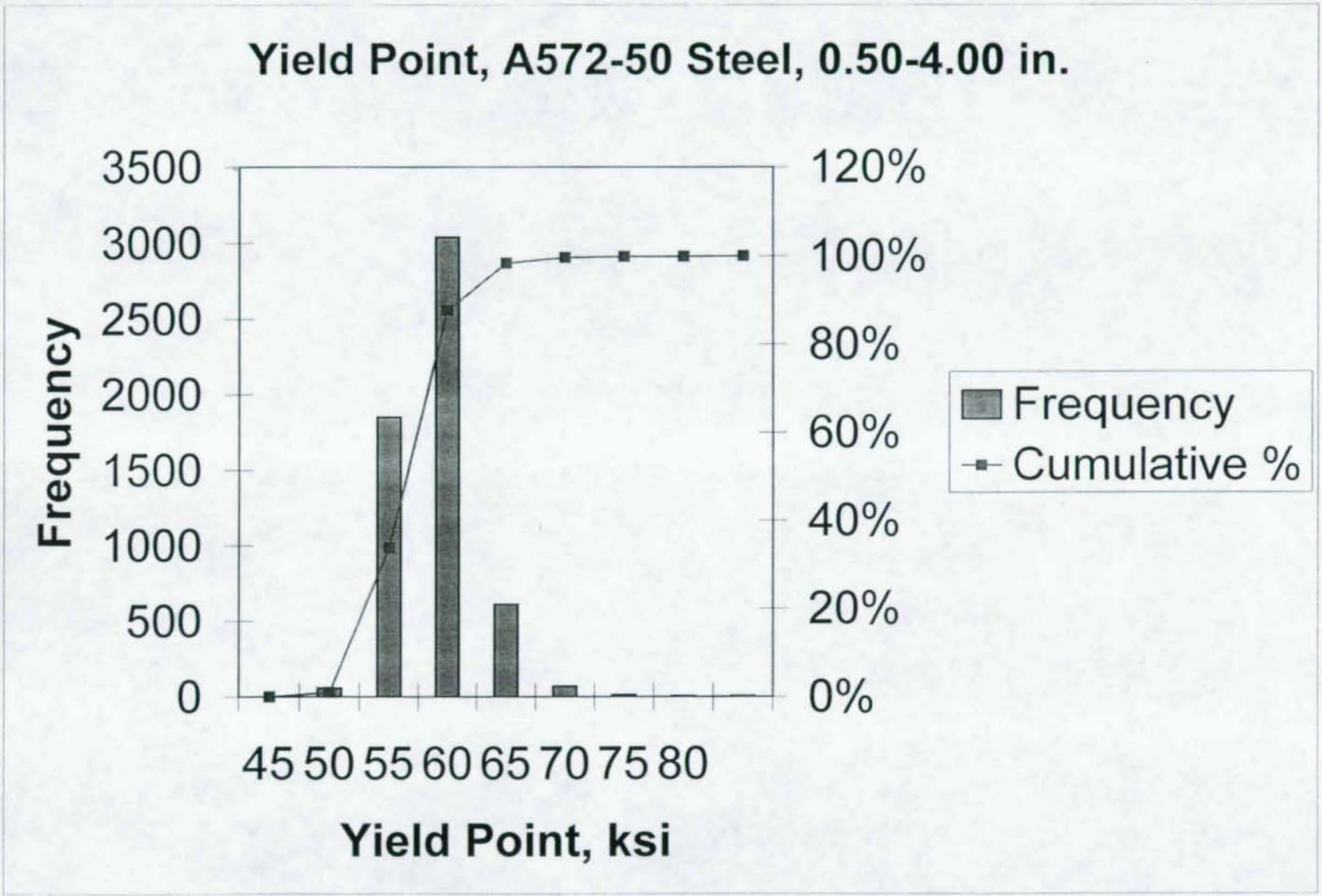

Yield Point, A572-50 Steel, 0.188-0.50 in.
Frequency
900
800
700
600
500
400
300
200
100
0
120%
100%
80%
60%
40%
20%
0%
45 50 55 60 65 70
Yield Point, ksi
Frequency
Cumulative %

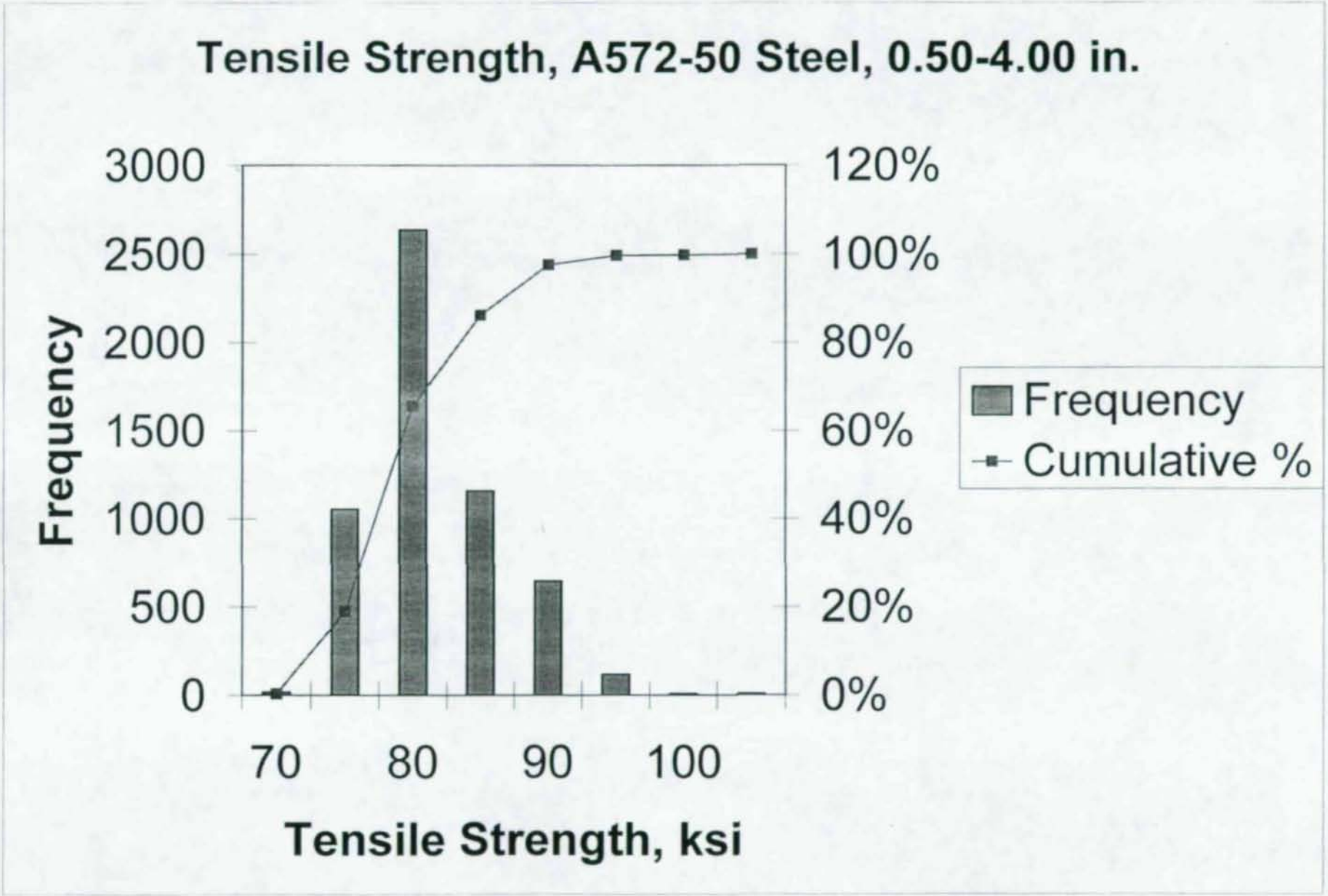

Tensile Strength, A572-50 Steel, 0.188-0.50 in.
800
700
600
500
400
300
200
100
0
Frequency
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
70
75
80
85
90 More
Tensile Strength, ksi

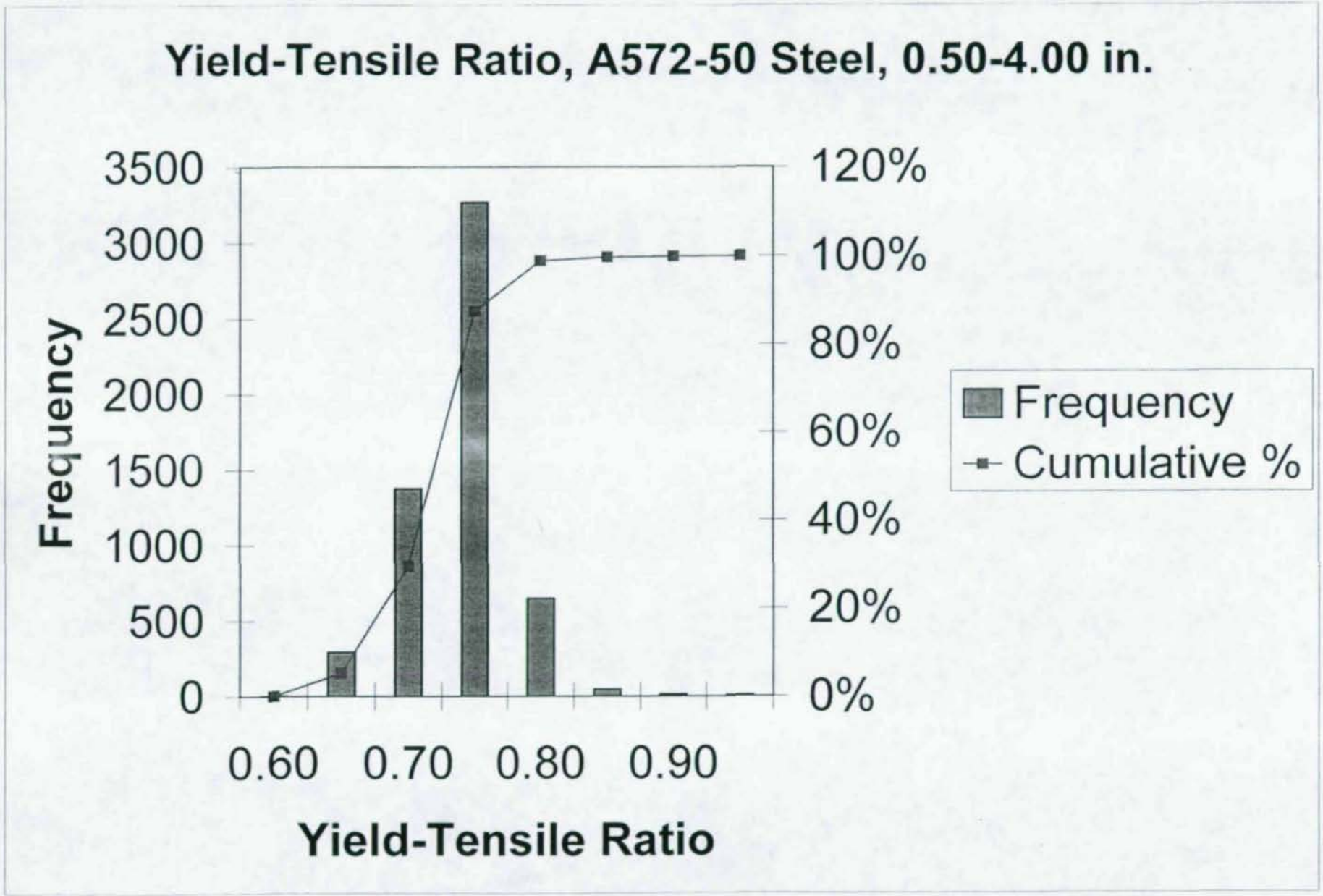

Yield-Tensile Ratio, A572-50 Steel, 0.188-0.50 in.
700
600
500
400
300
200
100
0
Frequency
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
0.60
0.70
0.80
0.90
Yield-Tensile Ratio

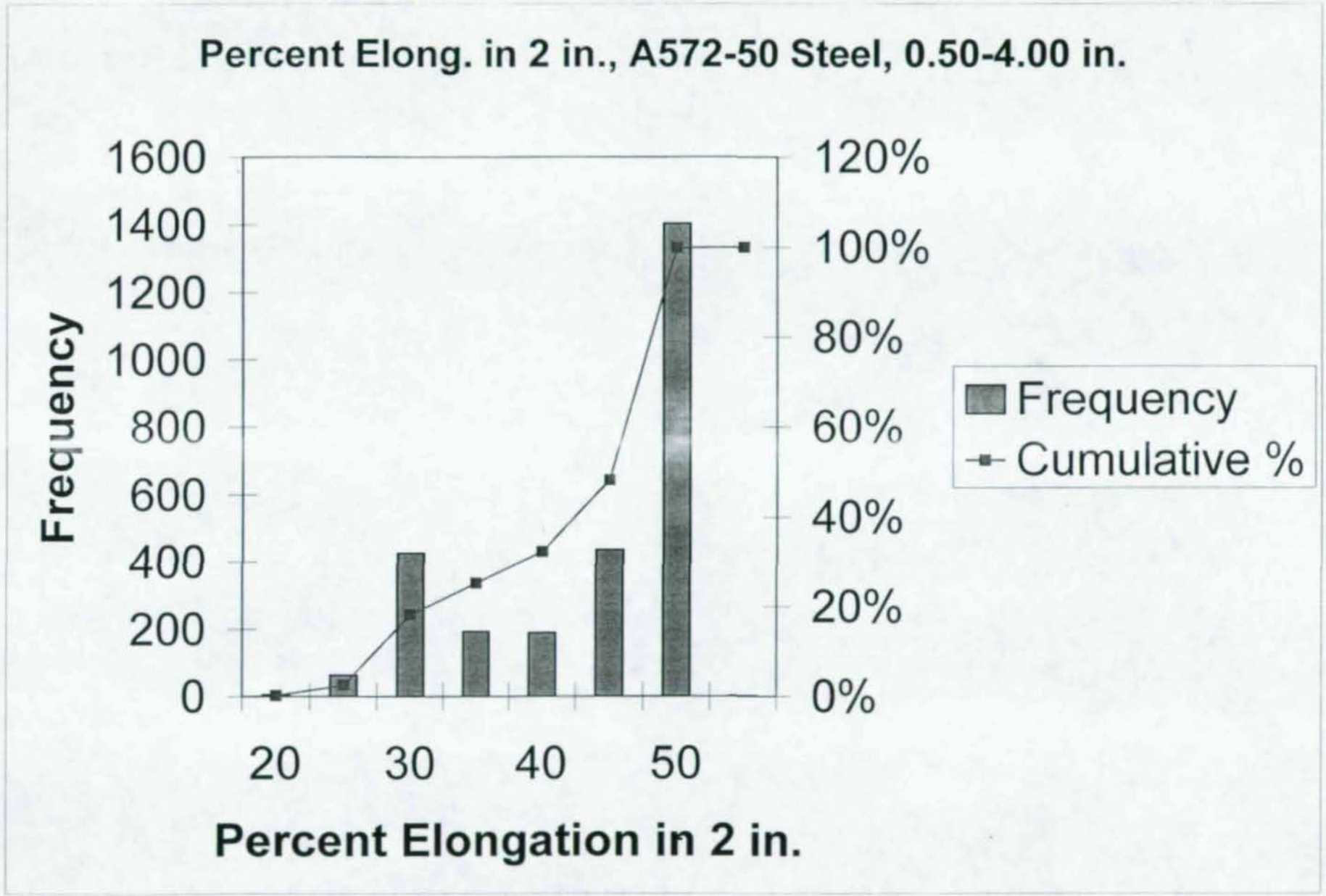

Percent Elong. in 2 in., A572-50 Steel, 0.188-0.50 in.
Frequency
200
180
160
140
120
100
80
60
40
20
0
120%
100%
80%
60%
40%
20%
0%
20
30
40
50
Frequency
Cumulative %
Percent Elongation in 2 in.

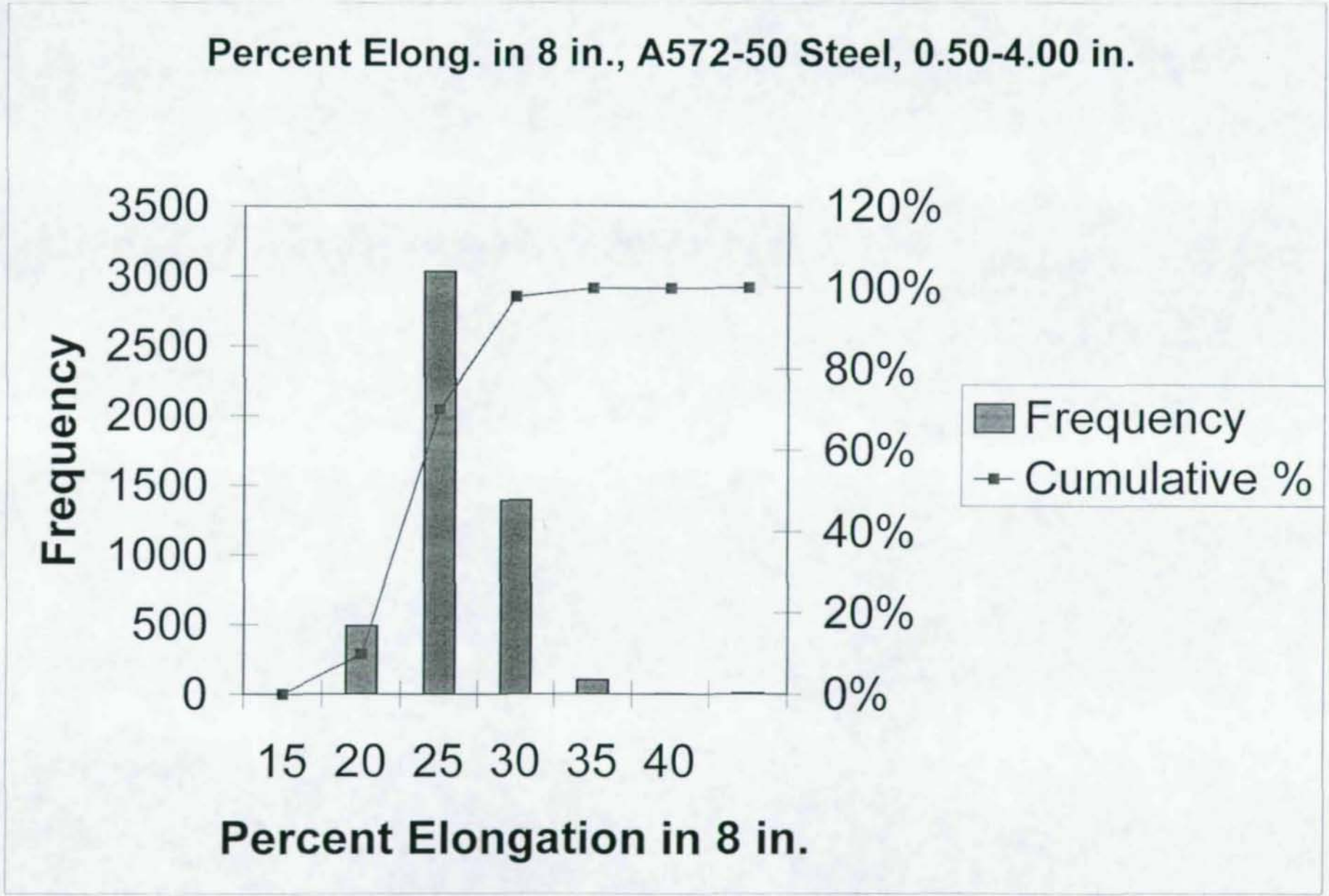

Percent Elong. in 8 in., A572-50 Steel, 0.188-0.50 in.
Frequency
700
600
500
400
300
200
100
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
15 20 25 30 35 40
Percent Elongation in 8 in.

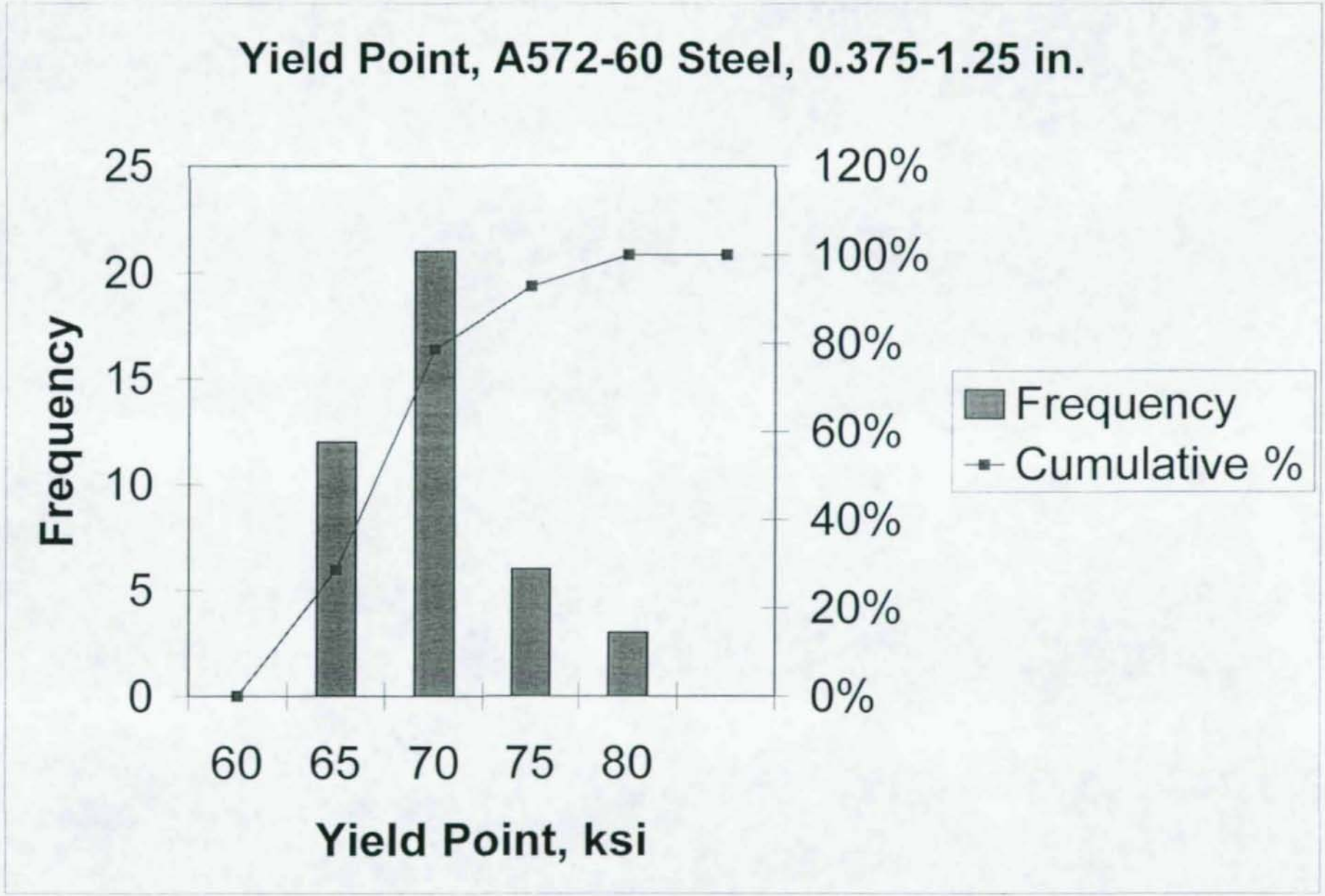

Yield Point, A572-50 Steel, 0.50-4.00 in.
Frequency
3500
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
45 50 55 60 65 70 75 80
Yield Point, ksi

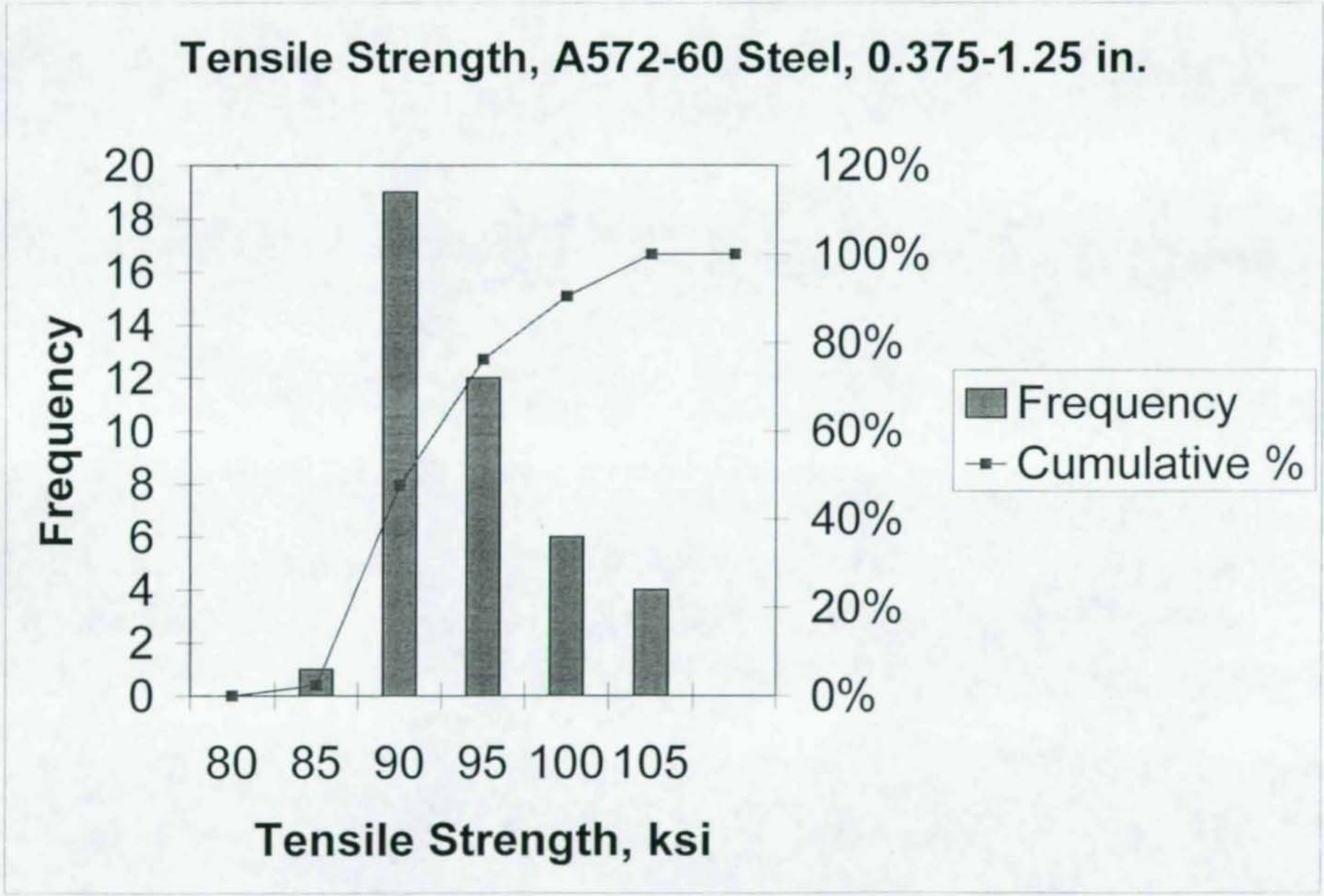

Tensile Strength, A572-50 Steel, 0.50-4.00 in.
Frequency
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
70
80
90
100
Tensile Strength, ksi
Frequency
Cumulative %

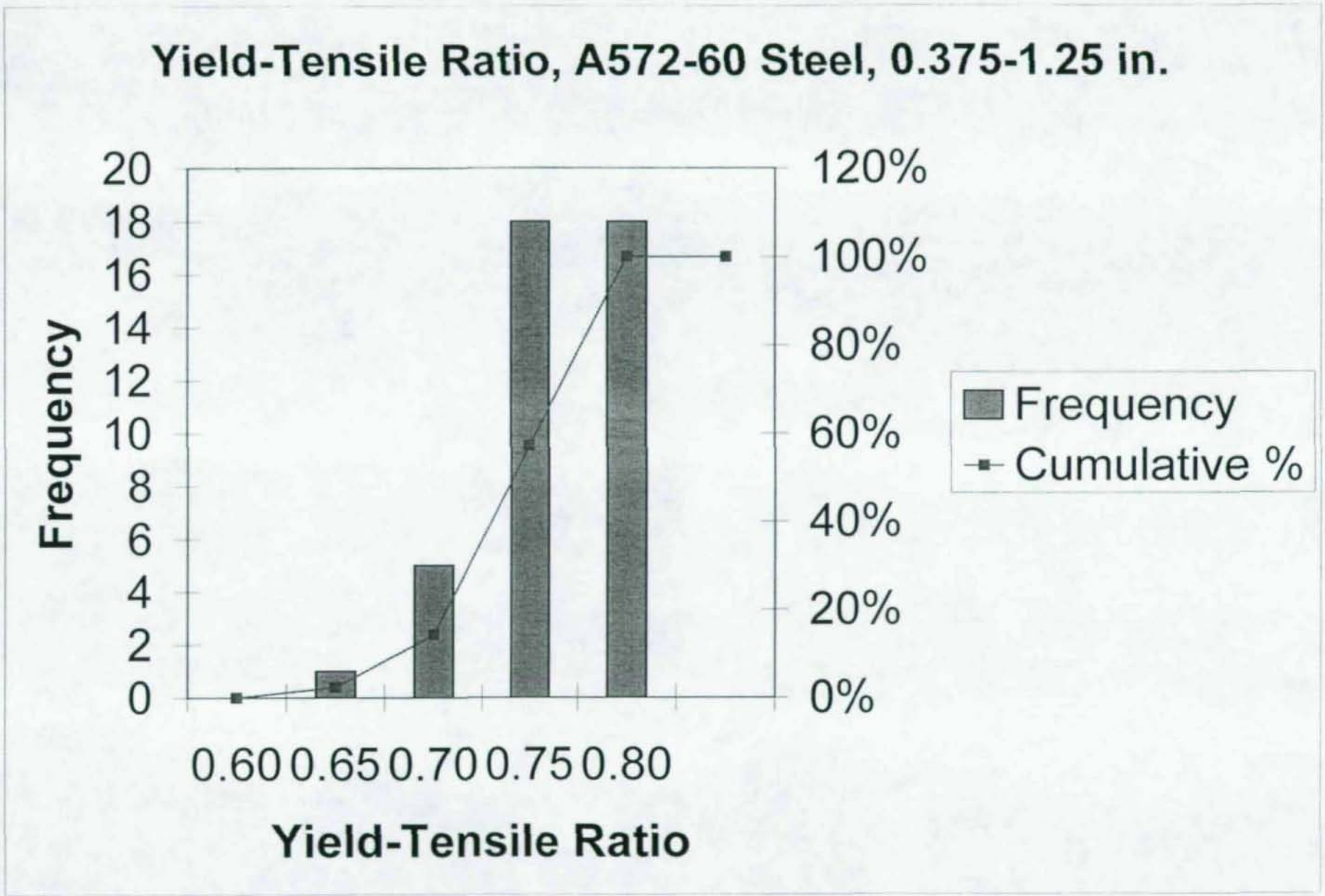

Yield-Tensile Ratio, A572-50 Steel, 0.50-4.00 in.
Frequency
3500
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
0.60
0.70
0.80
0.90
Yield-Tensile Ratio

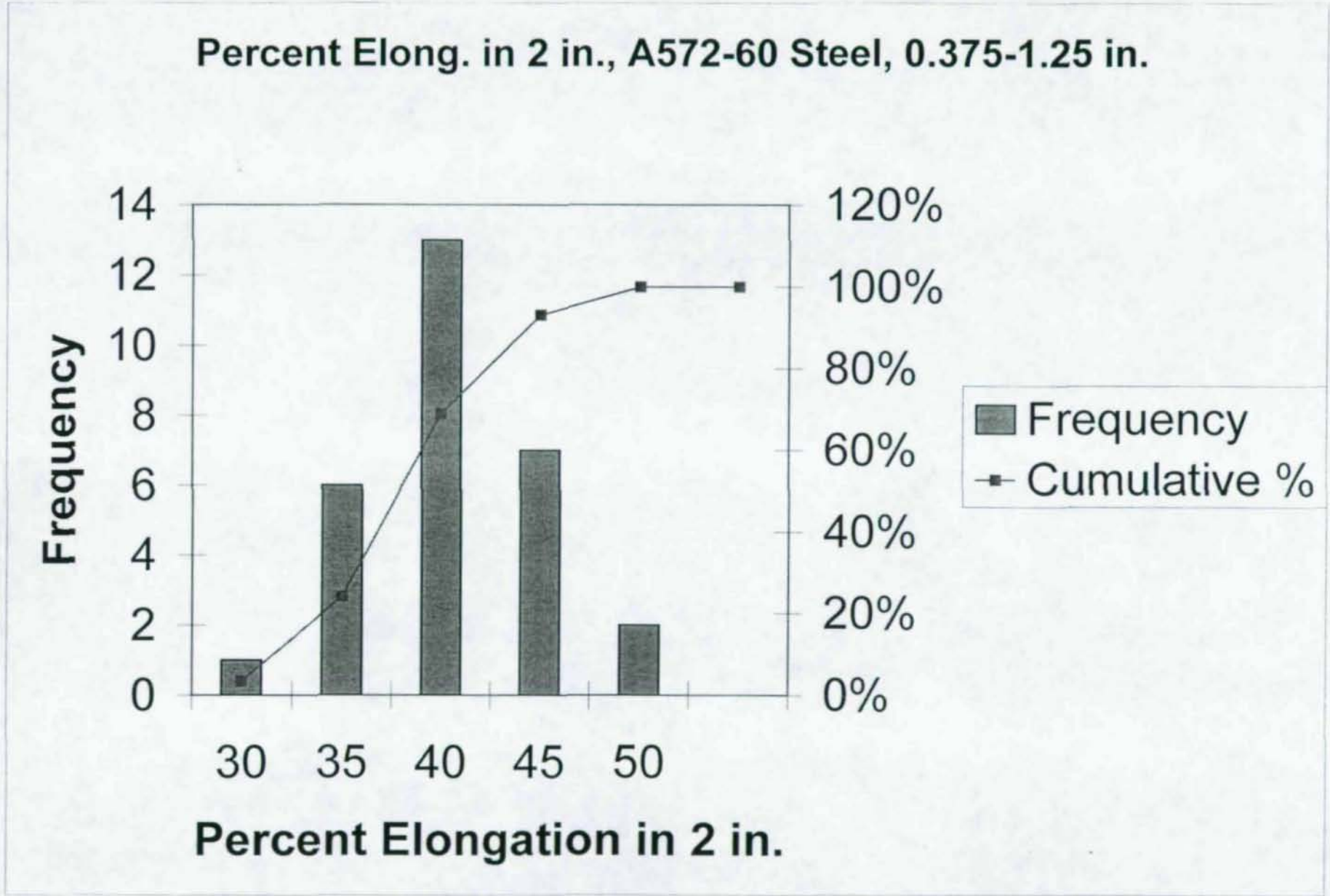

Percent Elong. in 2 in., A572-50 Steel, 0.50-4.00 in.
Frequency
1600
1400
1200
1000
800
600
400
200
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
20
30
40
50
Percent Elongation in 2 in.

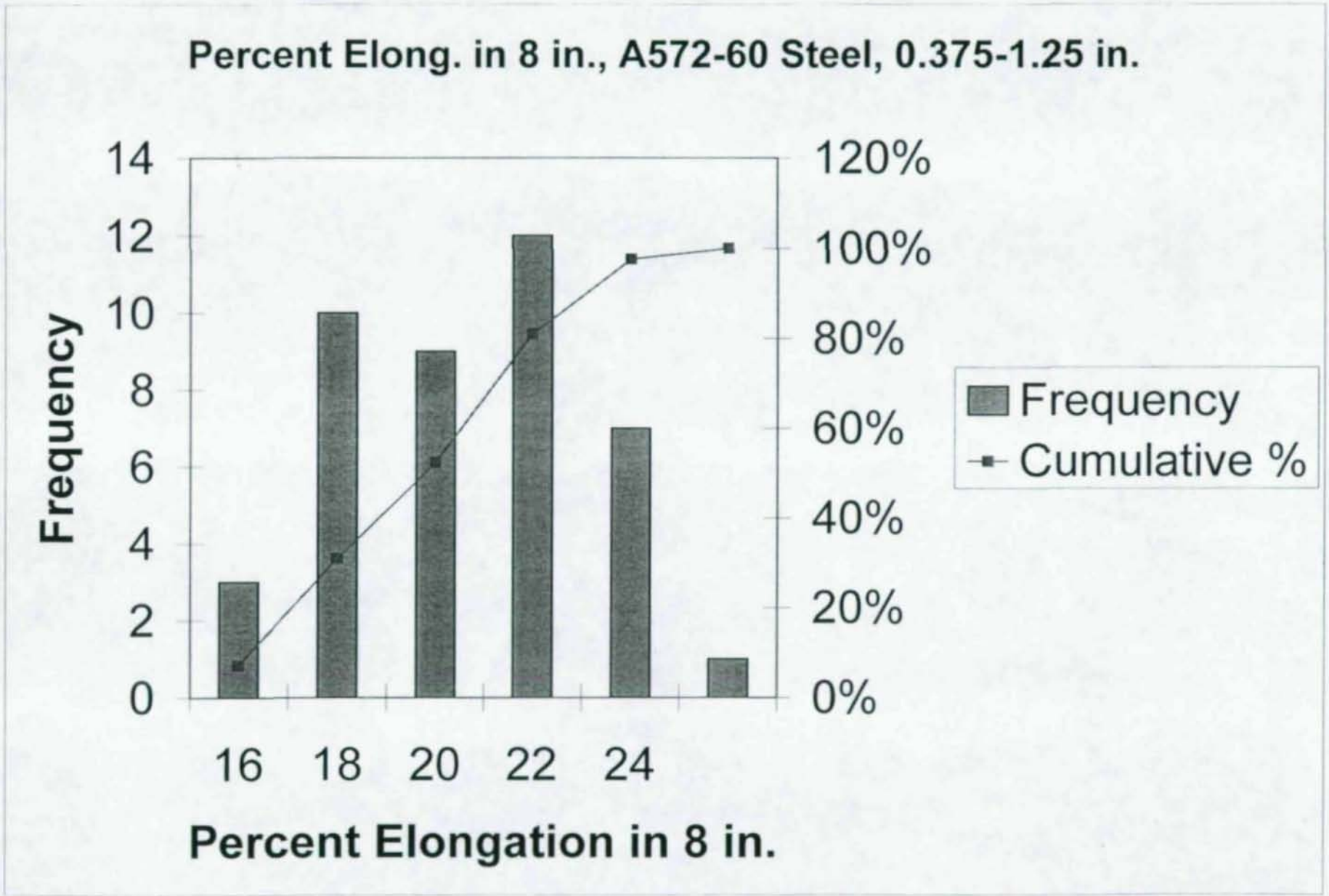

Percent Elong. in 8 in., A572-50 Steel, 0.50-4.00 in.
Frequency
3500
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
15 20 25 30 35 40
Percent Elongation in 8 in.
Frequency
Cumulative %

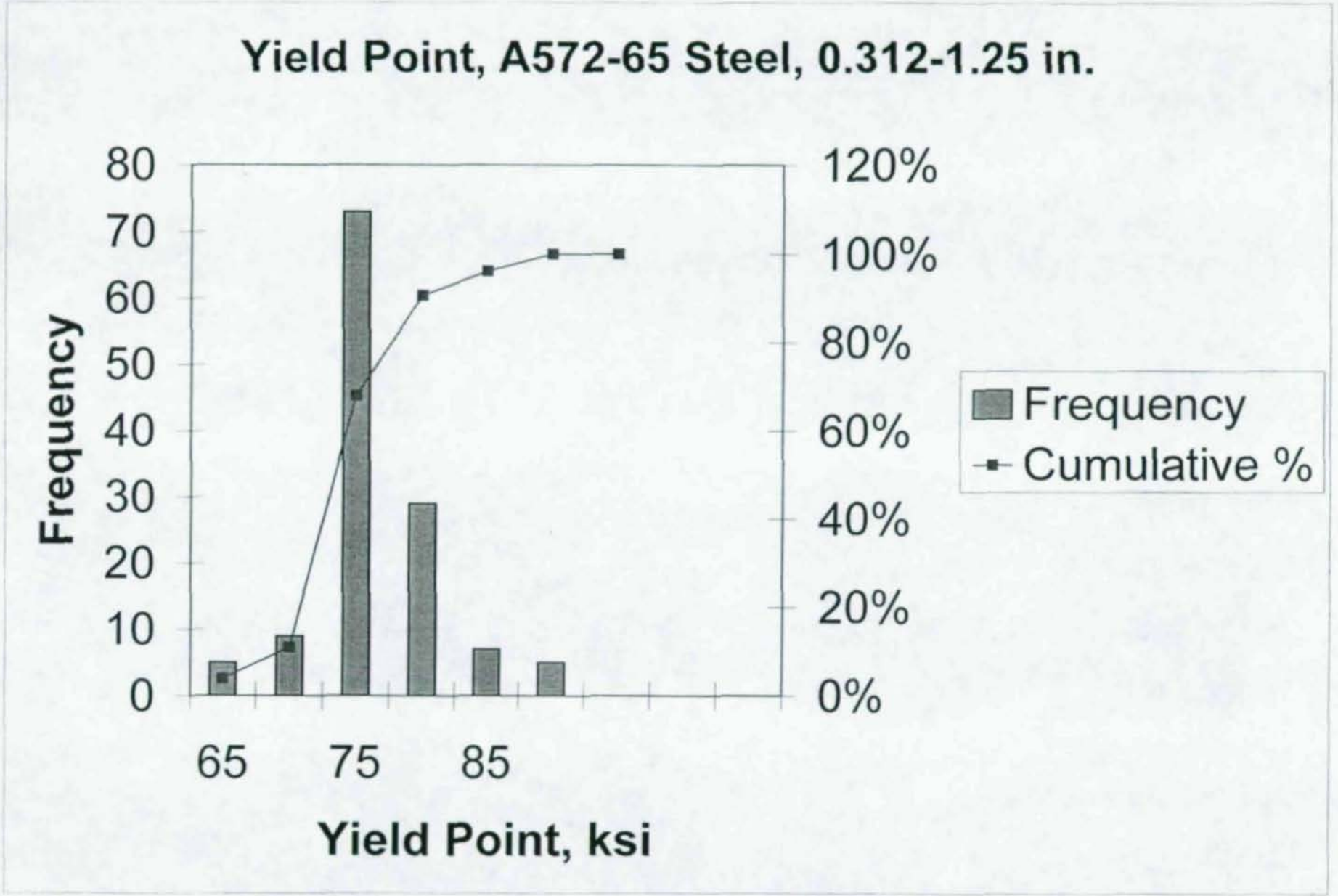

Yield Point, A572-60 Steel, 0.375-1.25 in.
Frequency
25
20
15
10
5
0
120%
100%
80%
60%
40%
20%
0%
60
65
70
75
80
Yield Point, ksi
Frequency
Cumulative %

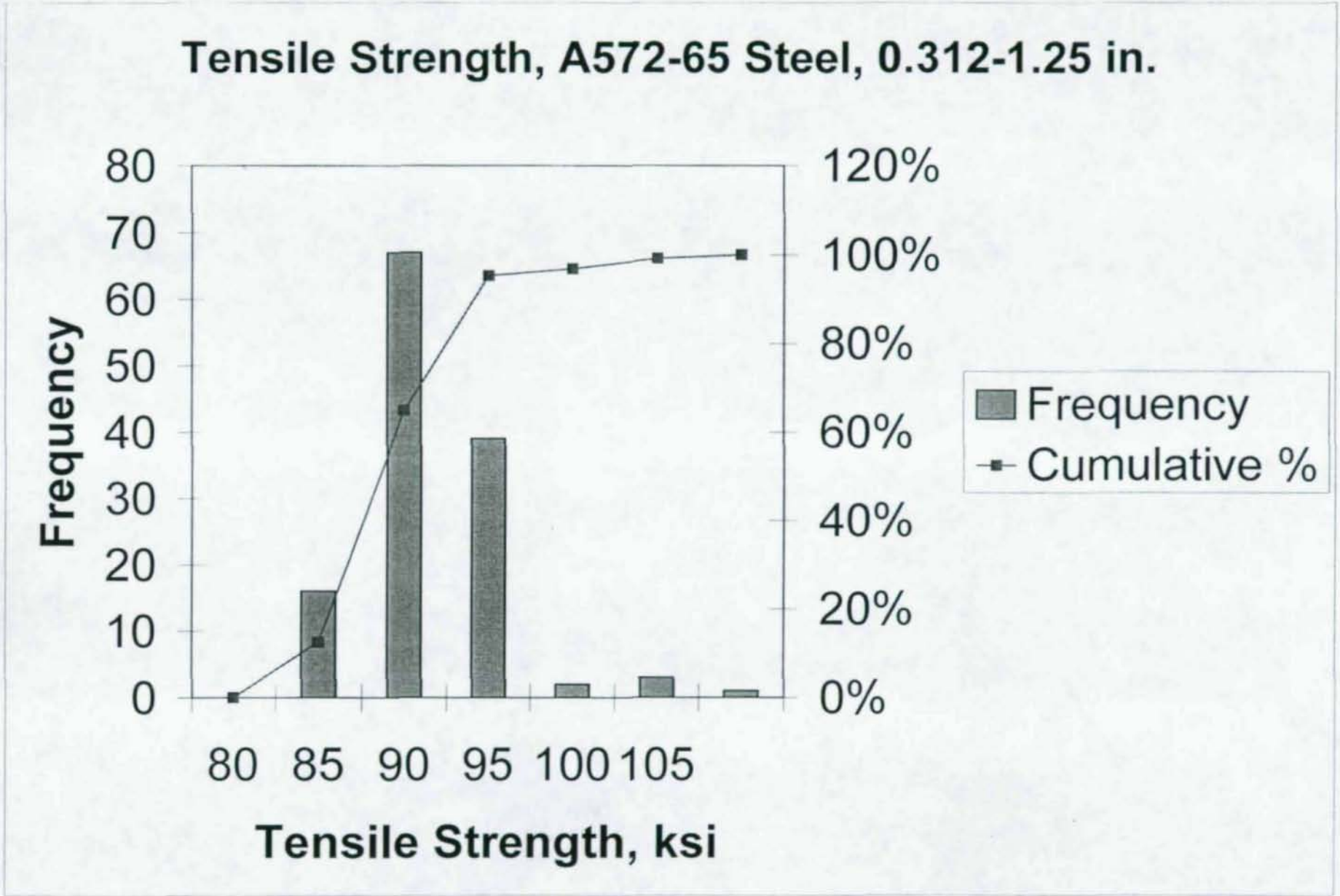

Tensile Strength, A572-60 Steel, 0.375-1.25 in.
Frequency
20
18
16
14
12
10
8
6
4
2
0
120%
100%
80%
60%
40%
20%
0%
80
85
90
95
100
105
Tensile Strength, ksi
Frequency
Cumulative %

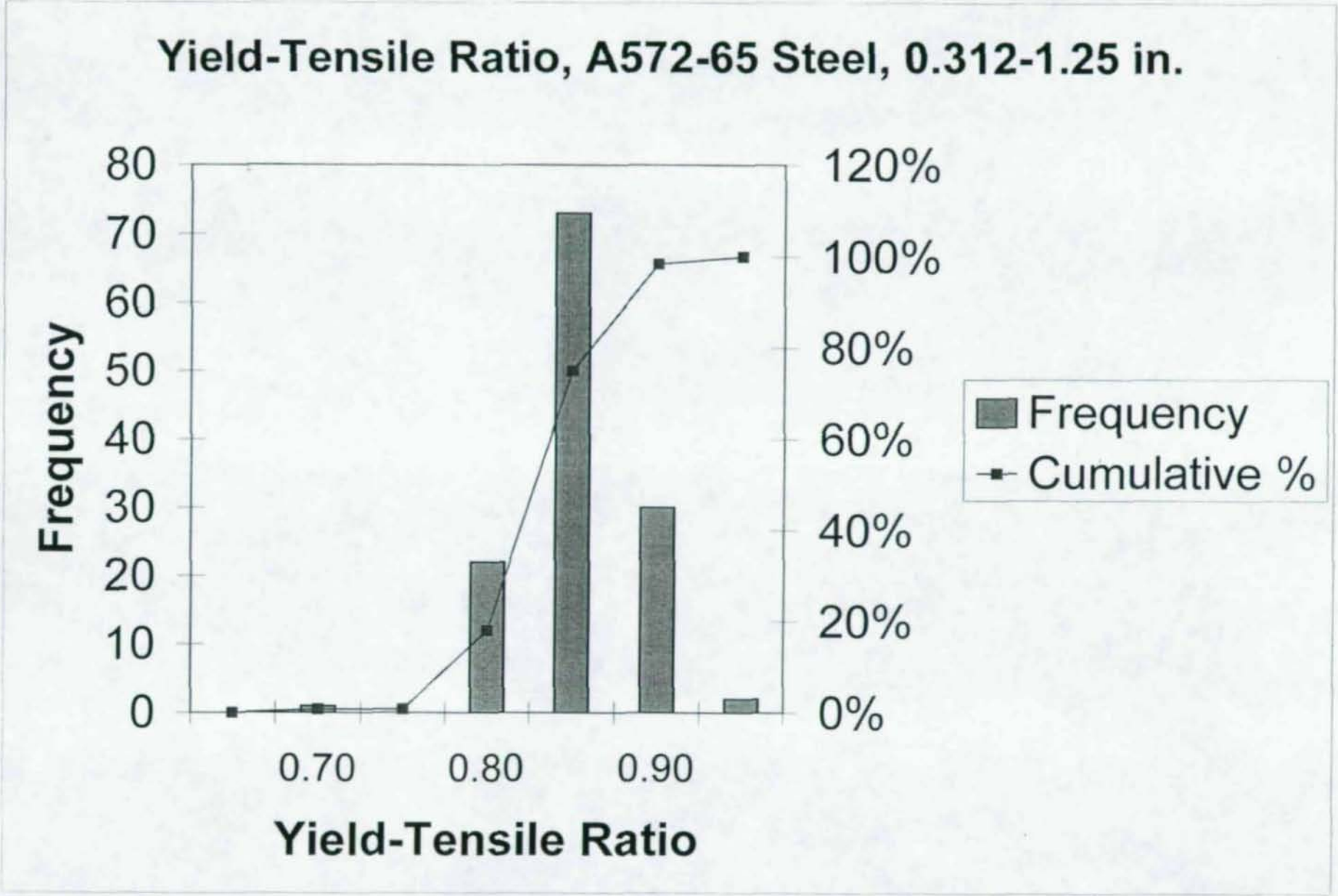

Yield-Tensile Ratio, A572-60 Steel, 0.375-1.25 in.
Frequency
20
18
16
14
12
10
8
6
4
2
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
0.60 0.65 0.70 0.75 0.80
Yield-Tensile Ratio

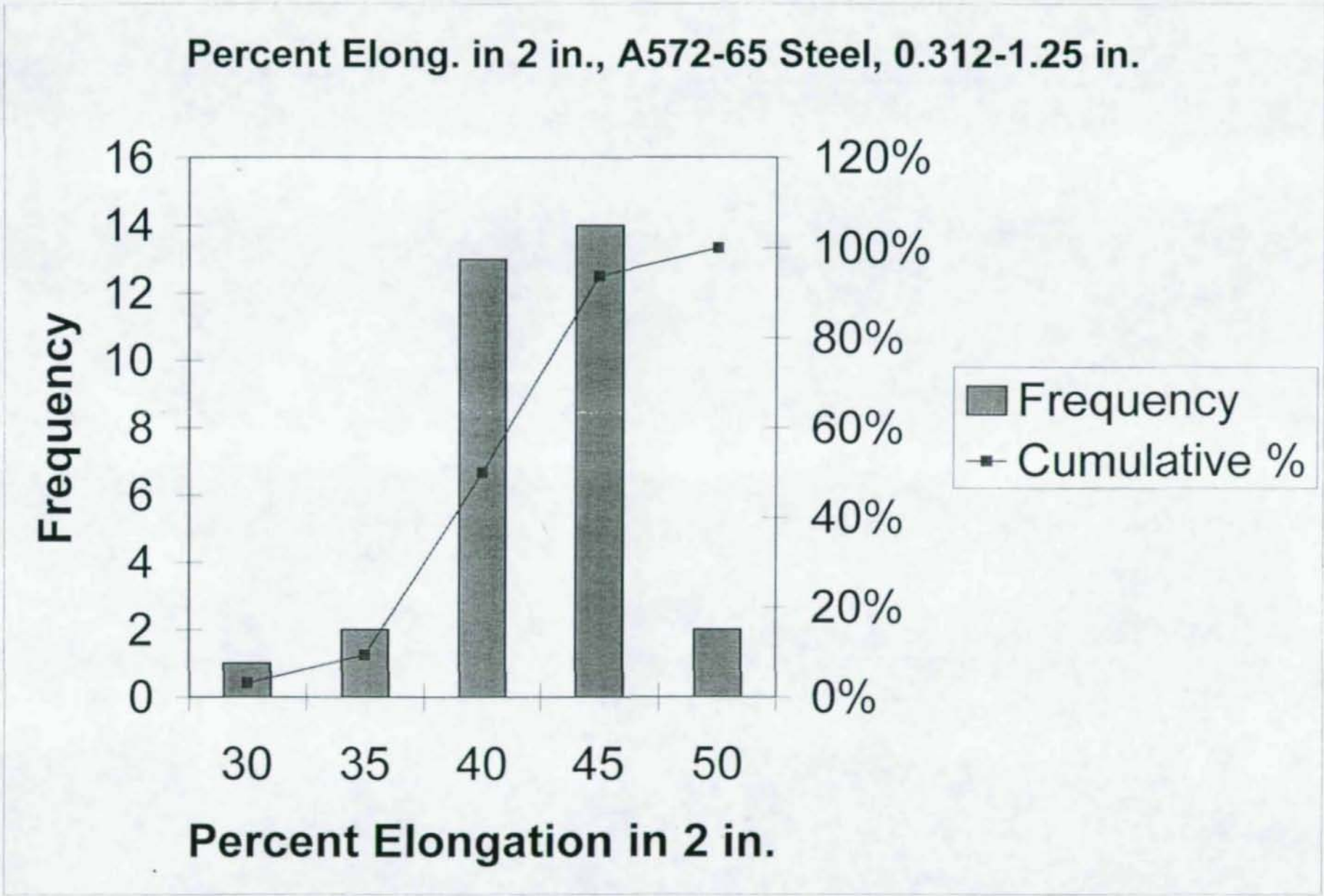

Percent Elong. in 2 in., A572-60 Steel, 0.375-1.25 in.
Frequency
14
12
10
8
6
4
2
0
120%
100%
80%
60%
40%
20%
0%
30
35
40
45
50
Frequency
Cumulative %
Percent Elongation in 2 in.

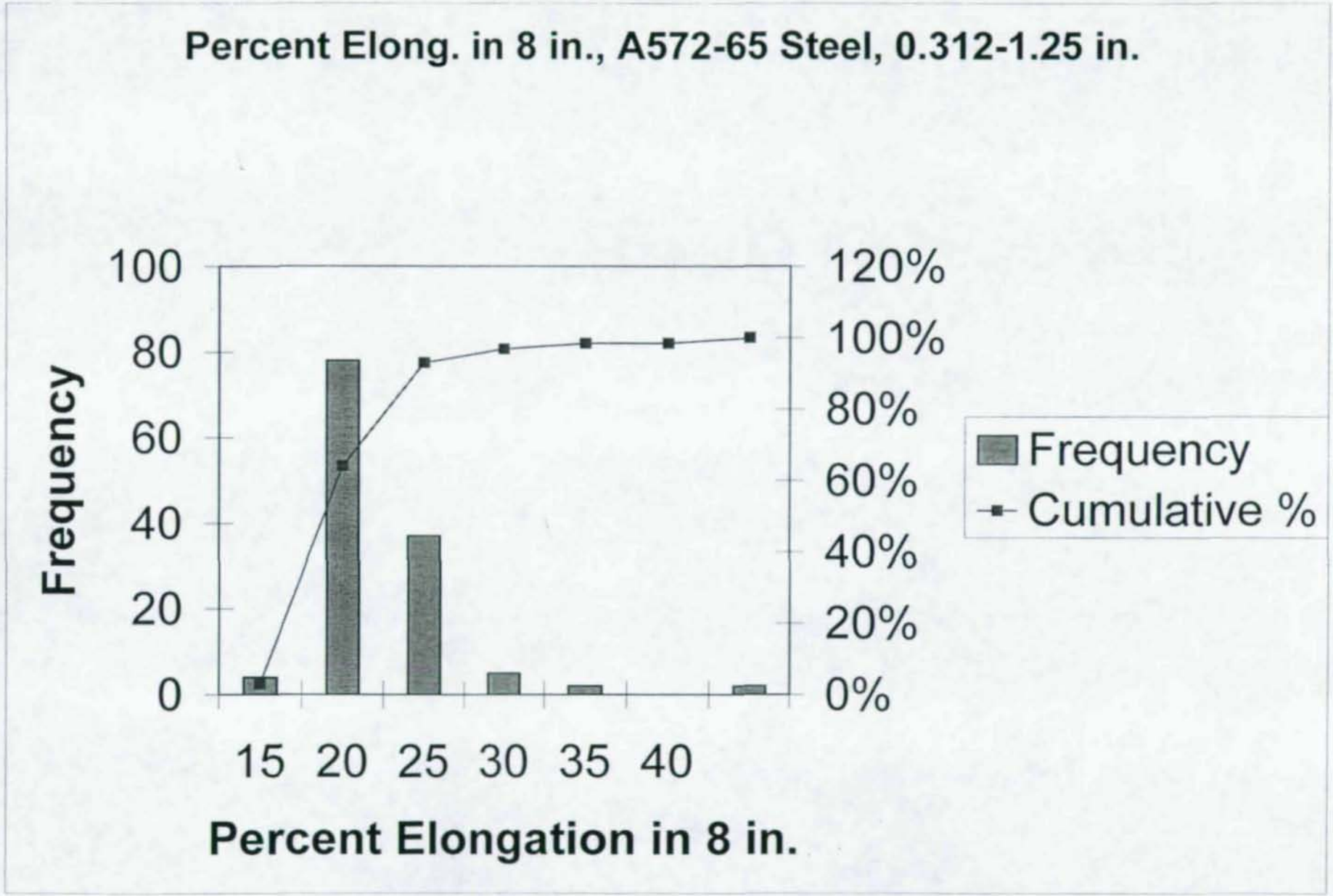

Percent Elong. in 8 in., A572-60 Steel, 0.375-1.25 in.
Frequency
14
12
10
8
6
4
2
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
16
18
20
22
24
Percent Elongation in 8 in.

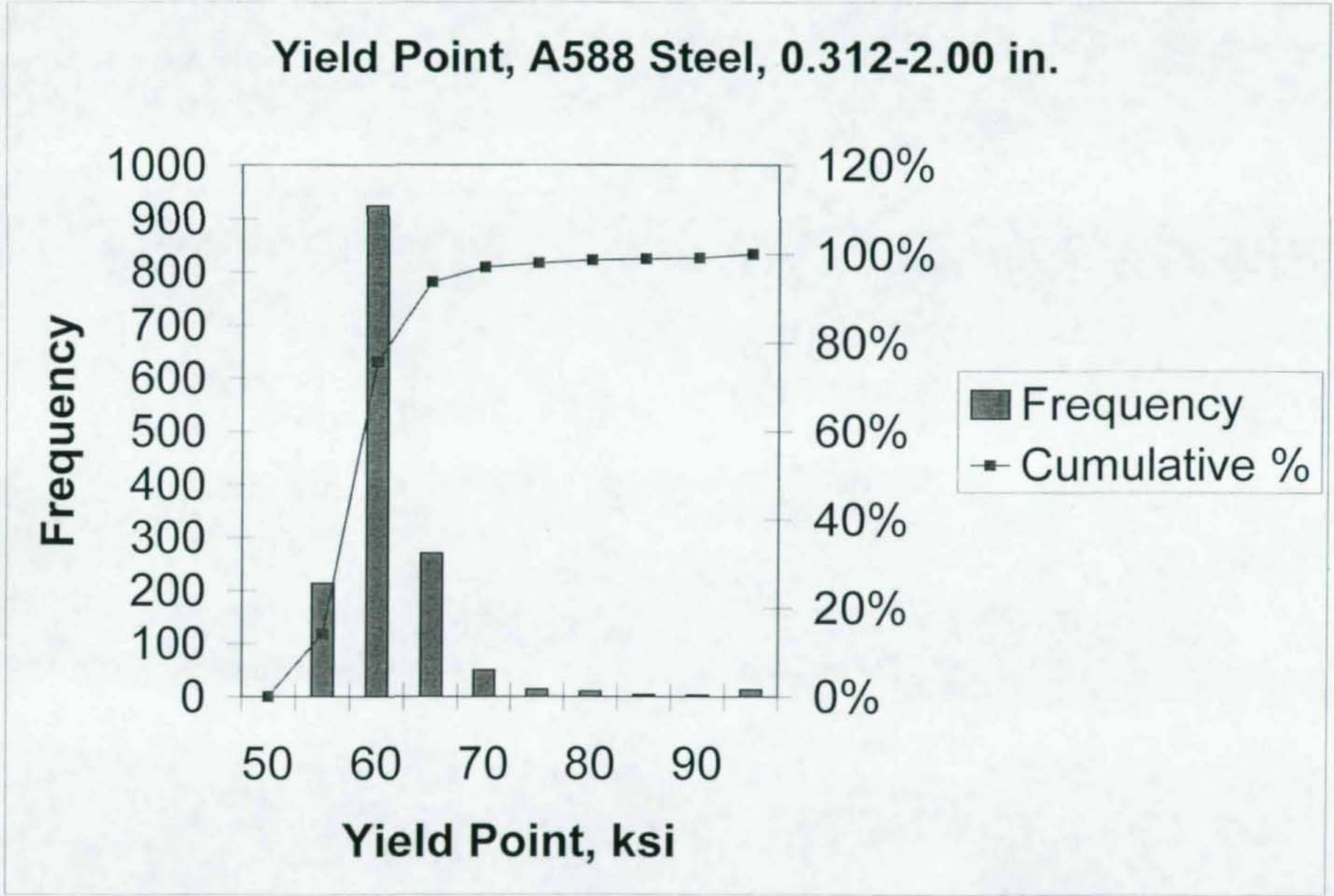

Yield Point, A572-65 Steel, 0.312-1.25 in.
Frequency
80
70
60
50
40
30
20
10
0
120%
100%
80%
60%
40%
20%
0%
65
75
85
Yield Point, ksi
Frequency
Cumulative %

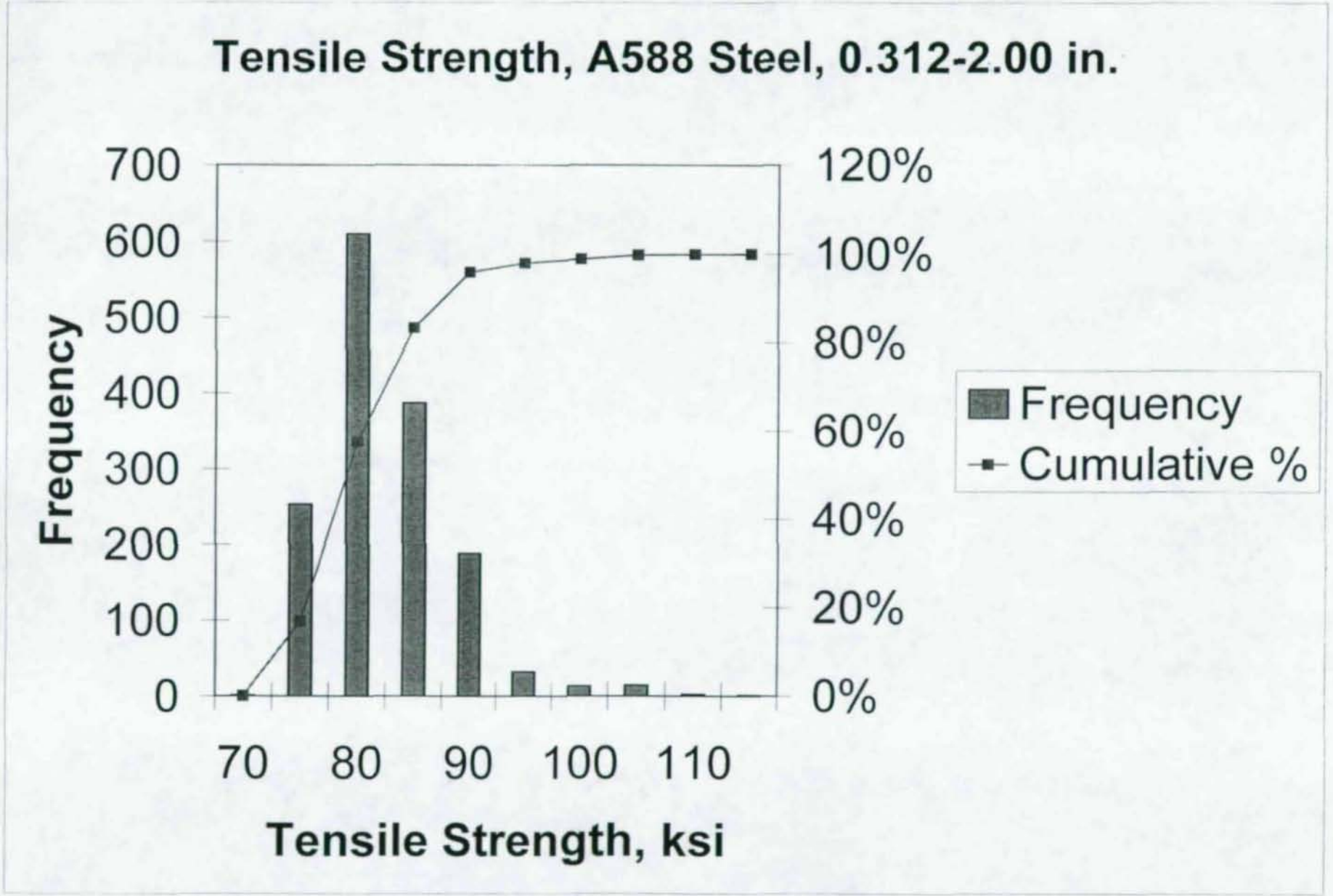

Tensile Strength, A572-65 Steel, 0.312-1.25 in.
Frequency
80
70
60
50
40
30
20
10
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
80
85
90
95
100
105
Tensile Strength, ksi

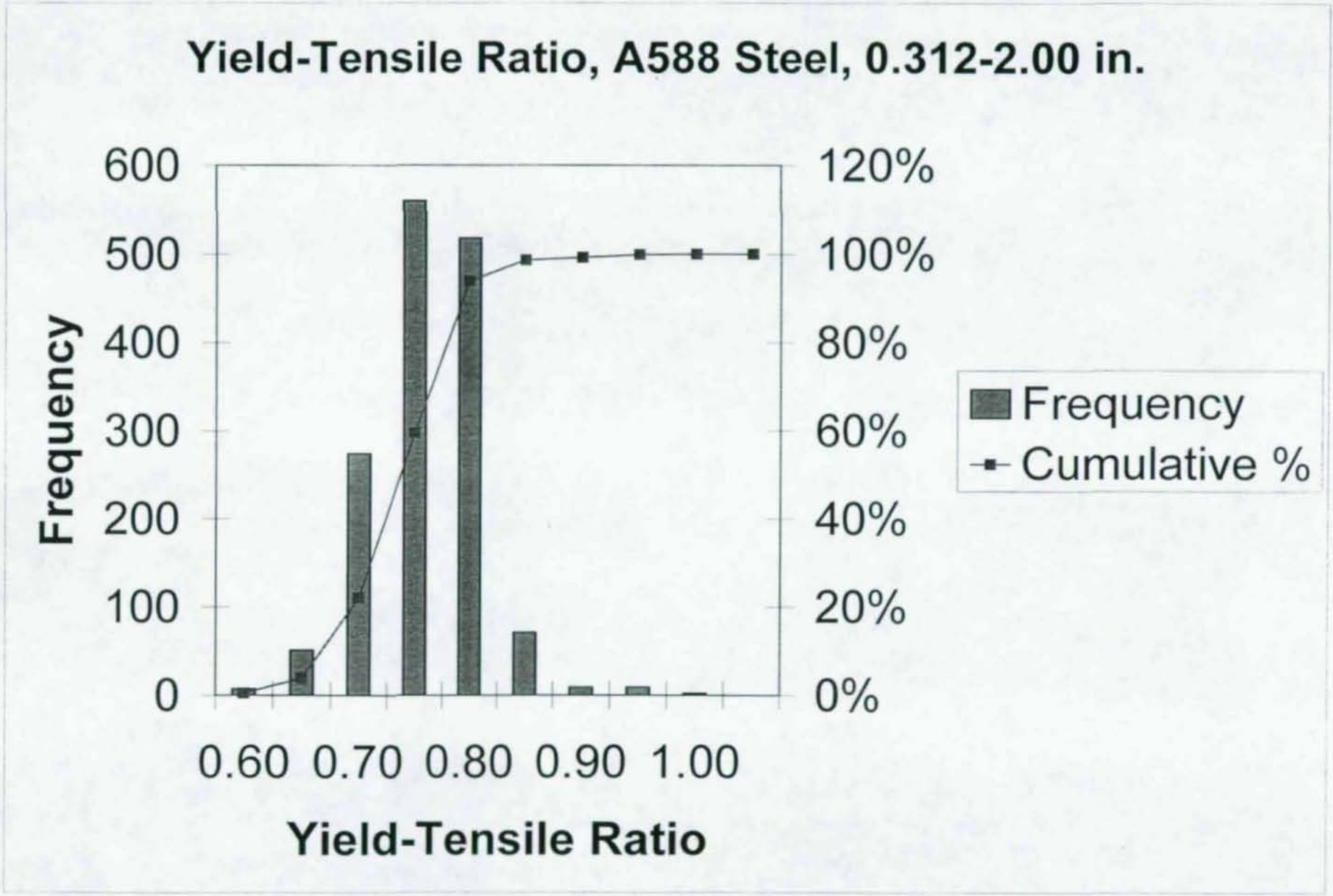

Yield-Tensile Ratio, A572-65 Steel, 0.312-1.25 in.
Frequency
80
70
60
50
40
30
20
10
0
120%
100%
80%
60%
40%
20%
0%
0.70
0.80
0.90
Yield-Tensile Ratio
Frequency
Cumulative %

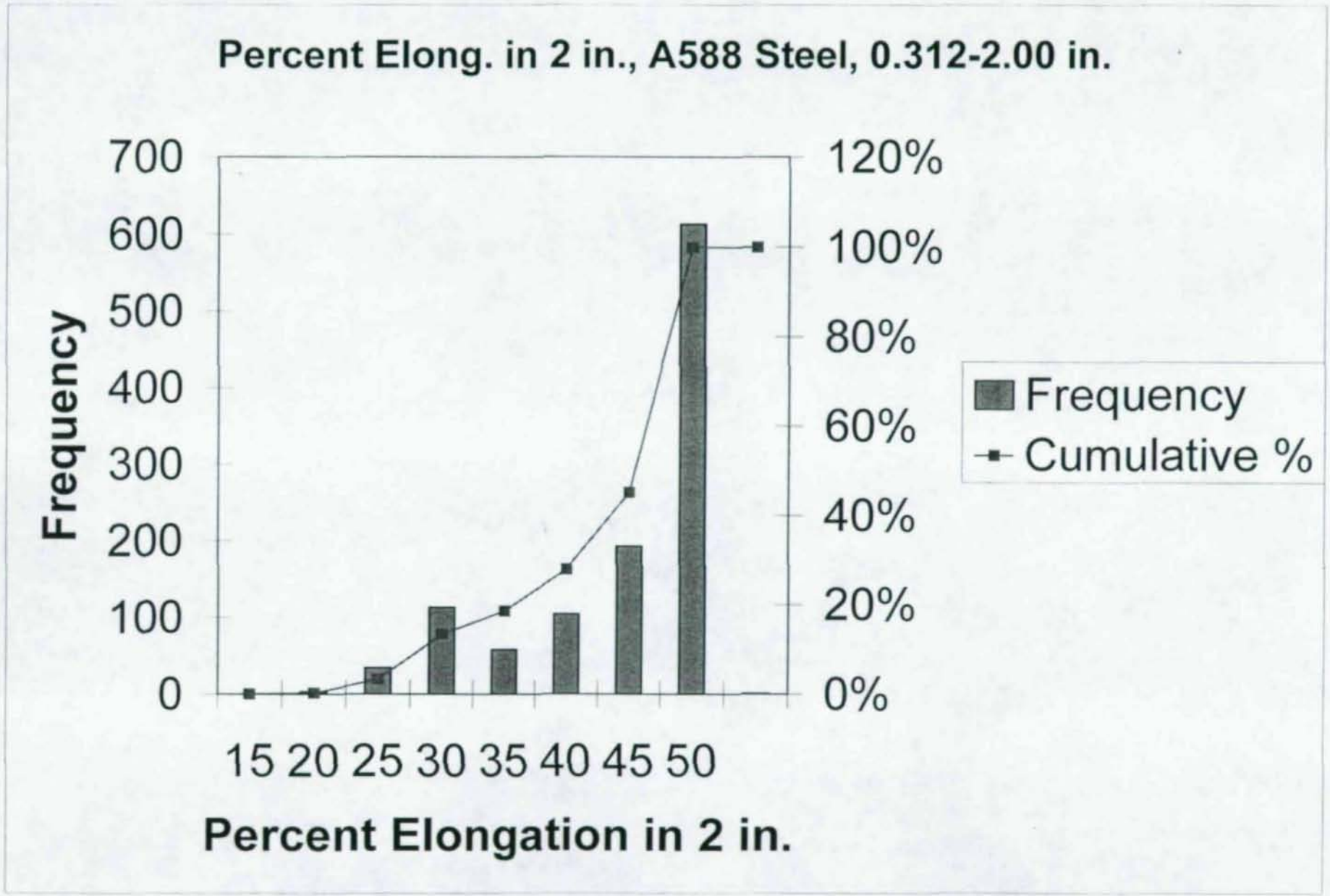

Percent Elong. in 2 in., A572-65 Steel, 0.312-1.25 in.
Frequency
16
14
12
10
8
6
4
2
0
120%
100%
80%
60%
40%
20%
0%
30
35
40
45
50
Percent Elongation in 2 in.
Frequency
Cumulative %

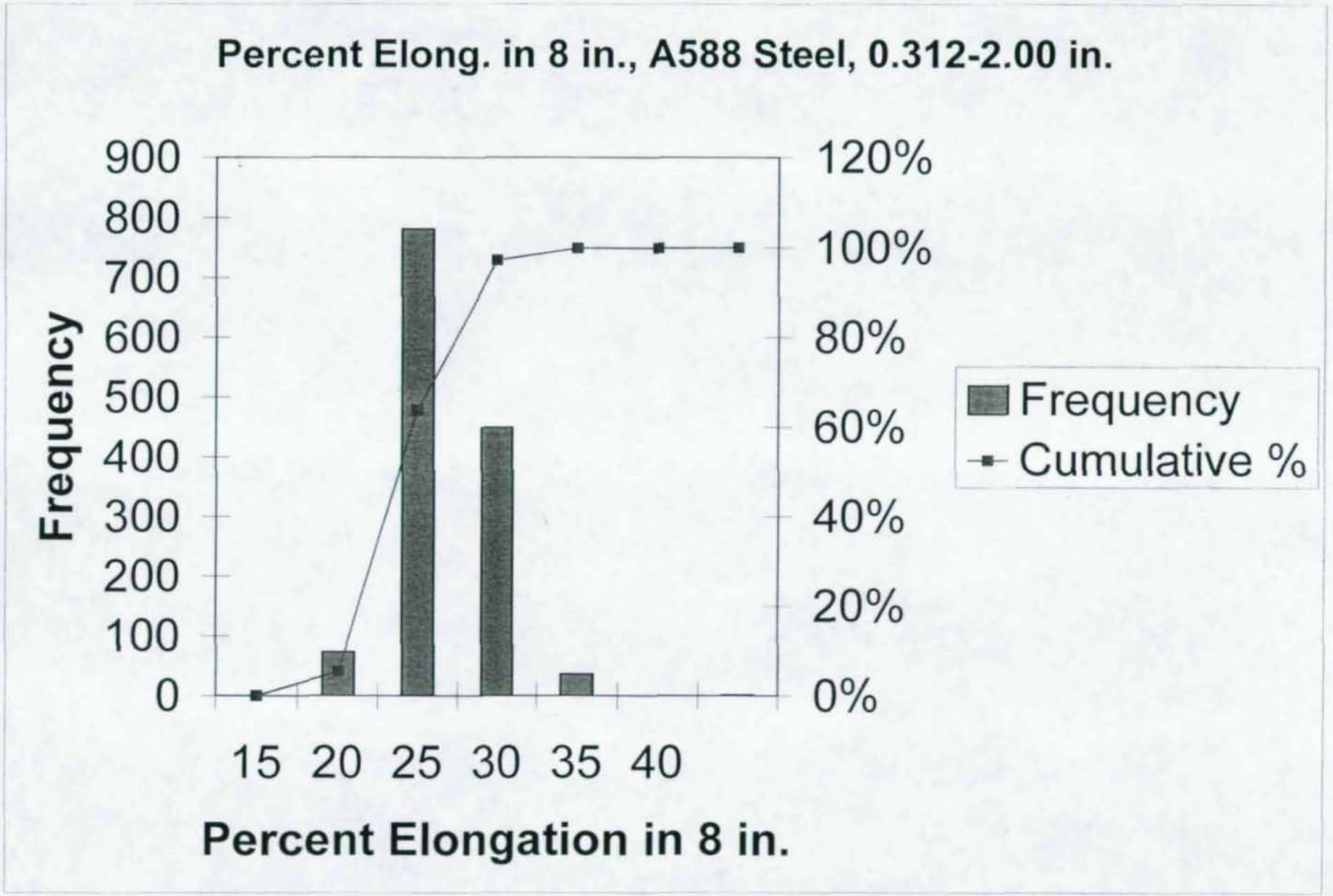

Percent Elong. in 8 in., A572-65 Steel, 0.312-1.25 in.
Frequency
100
80
60
40
20
0
120%
100%
80%
60%
40%
20%
0%
15 20 25 30 35 40
Percent Elongation in 8 in.
Frequency
Cumulative %

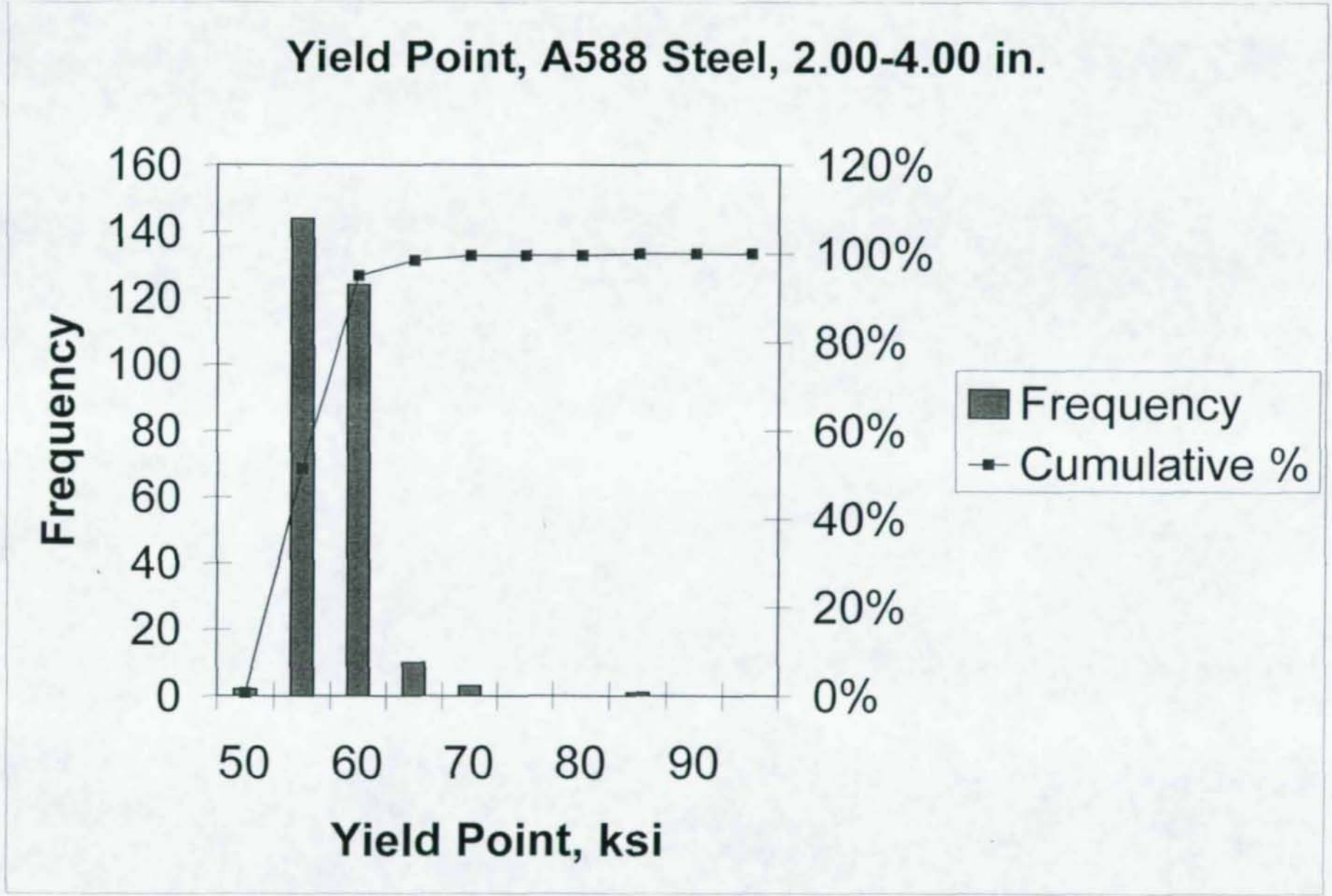

Yield Point, A588 Steel, 0.312-2.00 in.
Frequency
1000
900
800
700
600
500
400
300
200
100
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
50
60
70
80
90
Yield Point, ksi

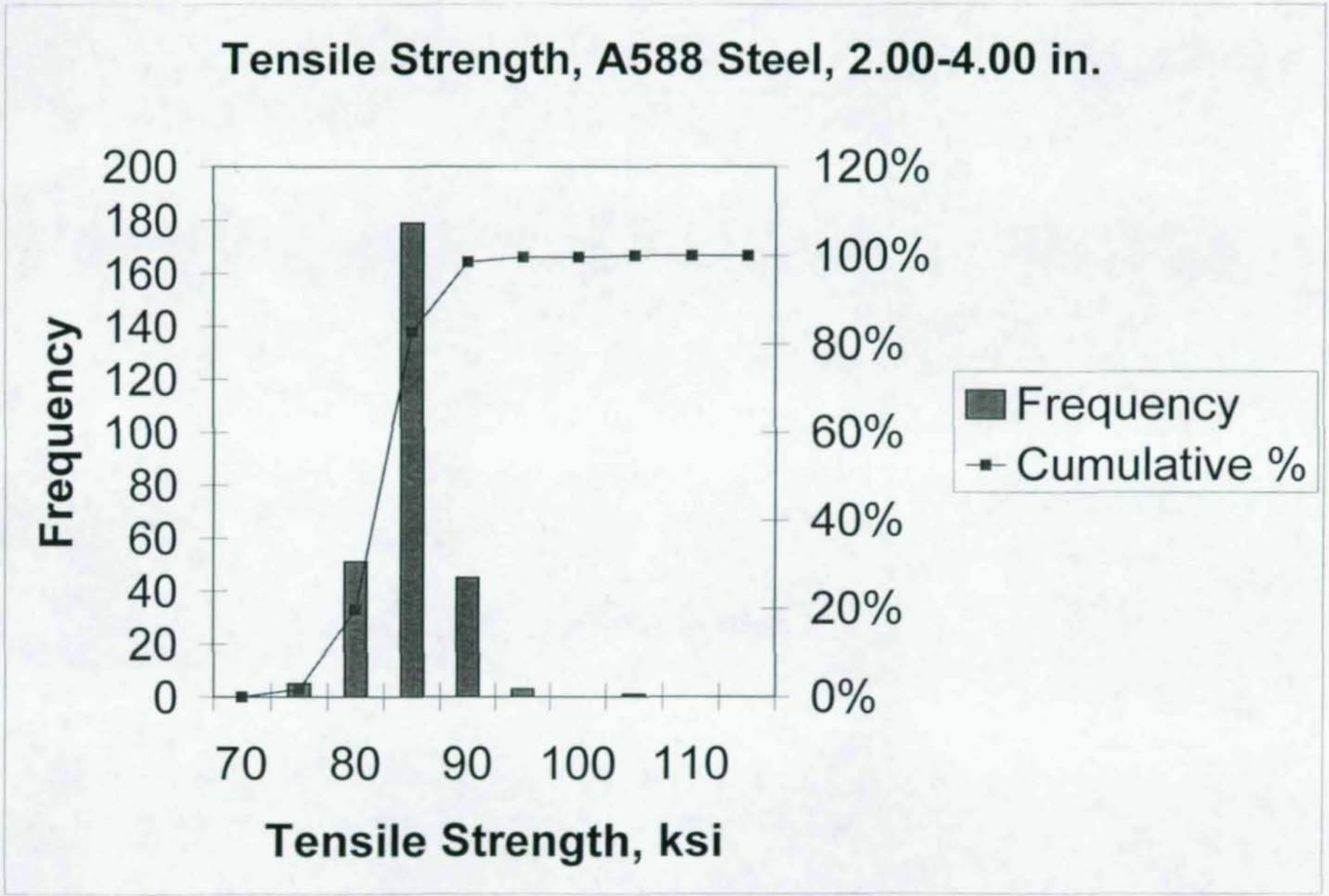

Tensile Strength, A588 Steel, 0.312-2.00 in.
Frequency
700
600
500
400
300
200
100
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
70
80
90
100
110
Tensile Strength, ksi

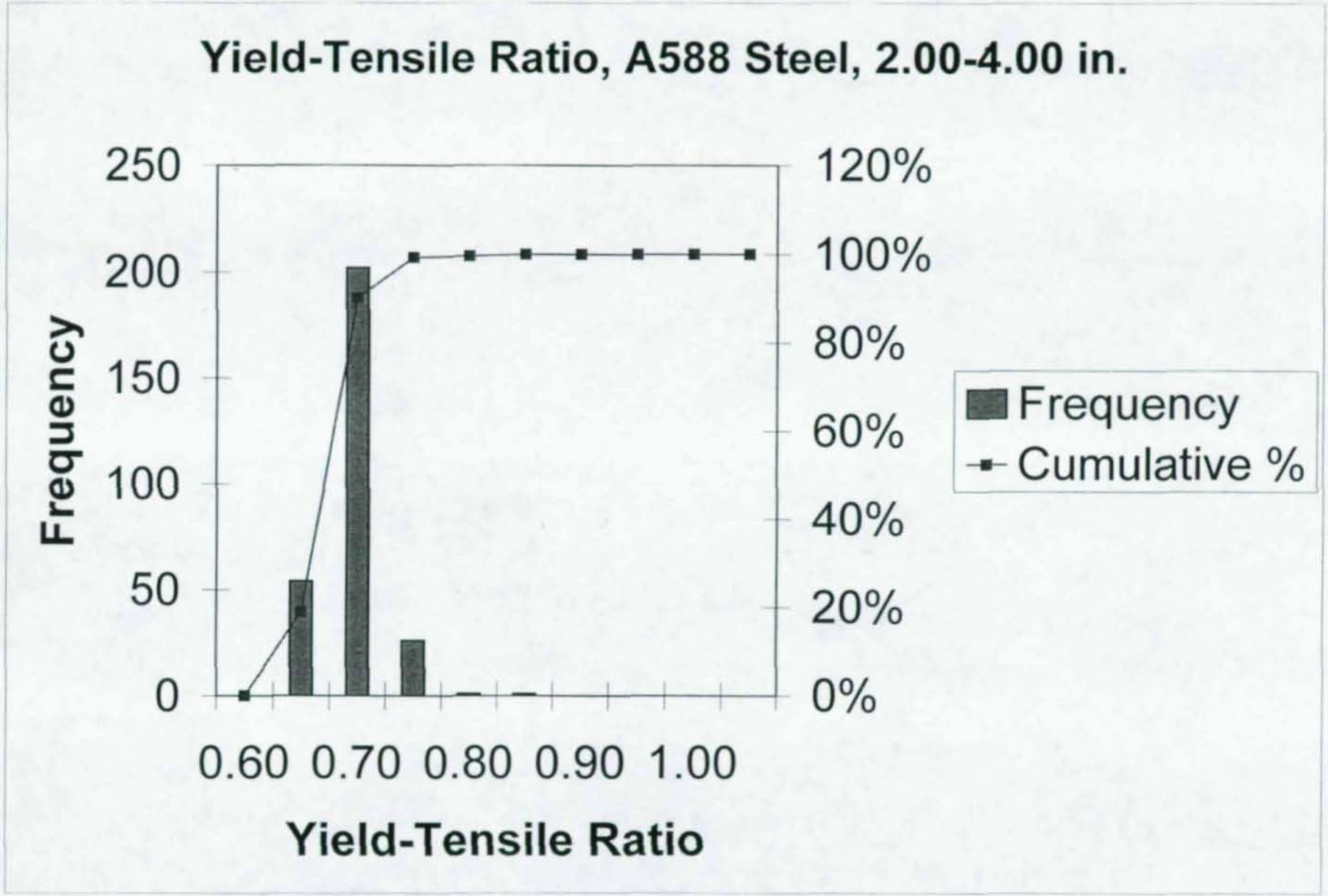

Yield-Tensile Ratio, A588 Steel, 0.312-2.00 in.
600
500
400
300
200
100
0
Frequency
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
0.60 0.70 0.80 0.90 1.00
Yield-Tensile Ratio

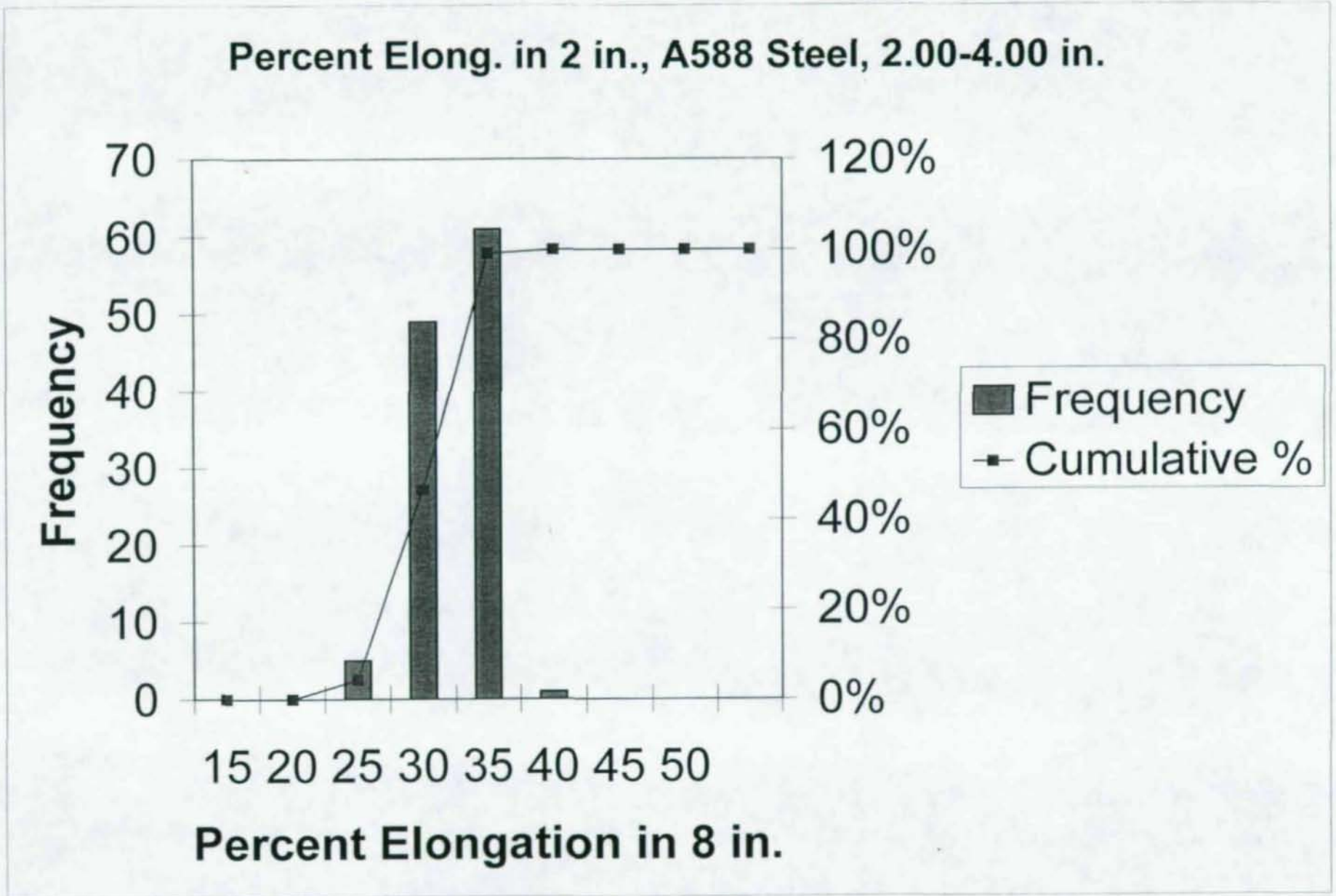

Percent Elong. in 2 in., A588 Steel, 0.312-2.00 in.
Frequency
700
600
500
400
300
200
100
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
15 20 25 30 35 40 45 50
Percent Elongation in 2 in.

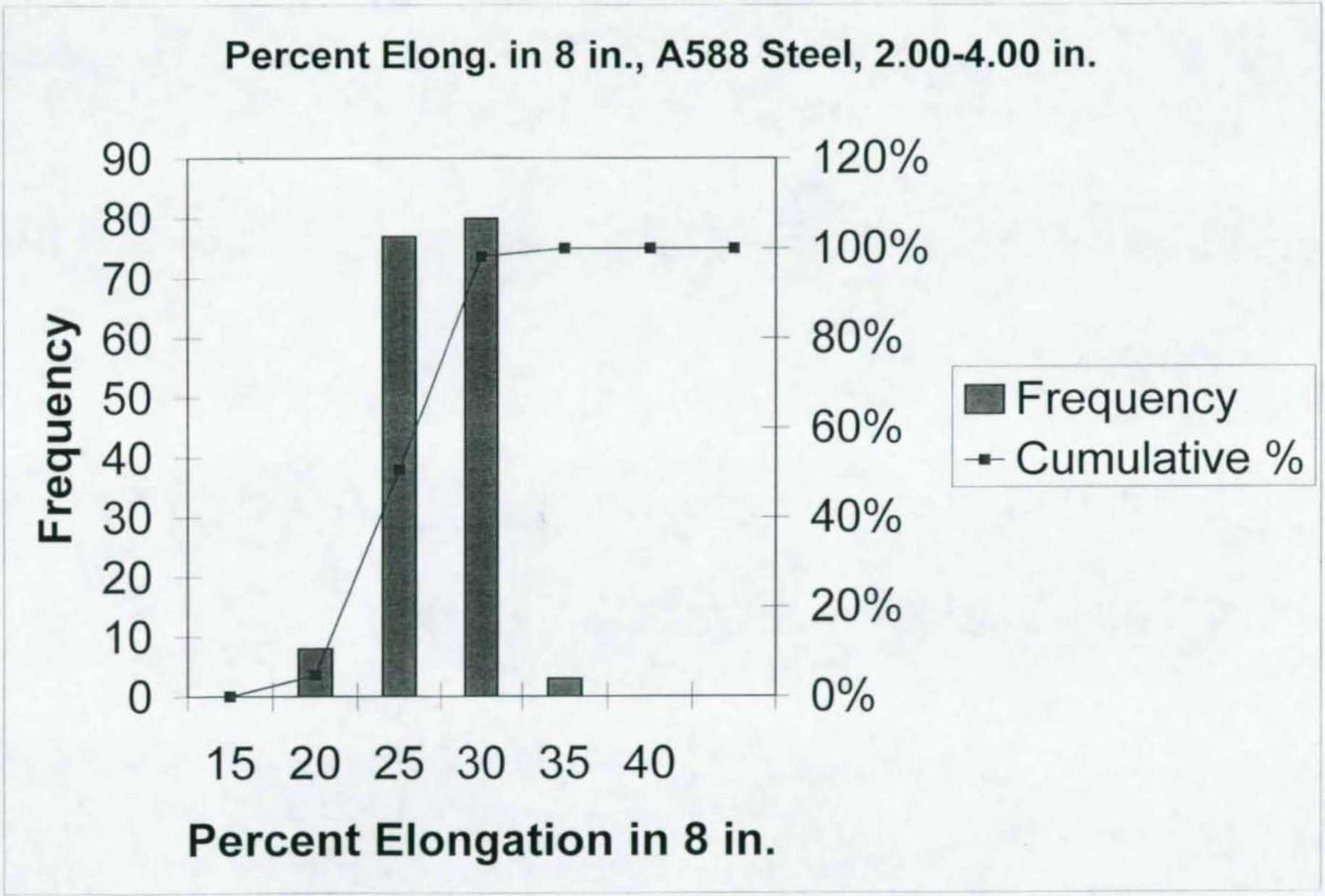

Percent Elong. in 8 in., A588 Steel, 0.312-2.00 in.
Frequency
900
800
700
600
500
400
300
200
100
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
15 20 25 30 35 40
Percent Elongation in 8 in.

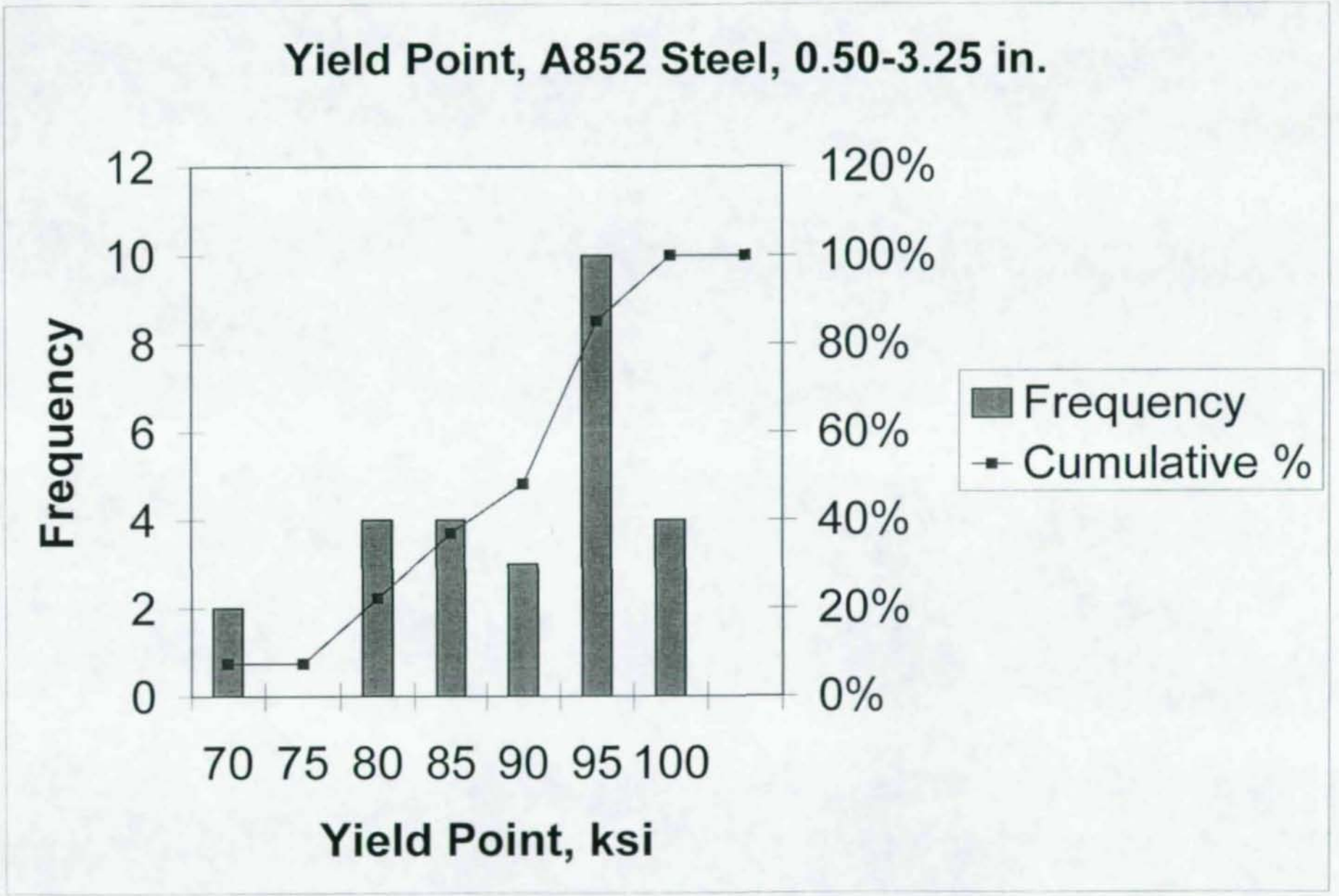

Yield Point, A588 Steel, 2.00-4.00 in.
Frequency
160
140
120
100
80
60
40
20
0
120%
100%
80%
60%
40%
20%
0%
50
60
70
80
90
Yield Point, ksi
Frequency
Cumulative %

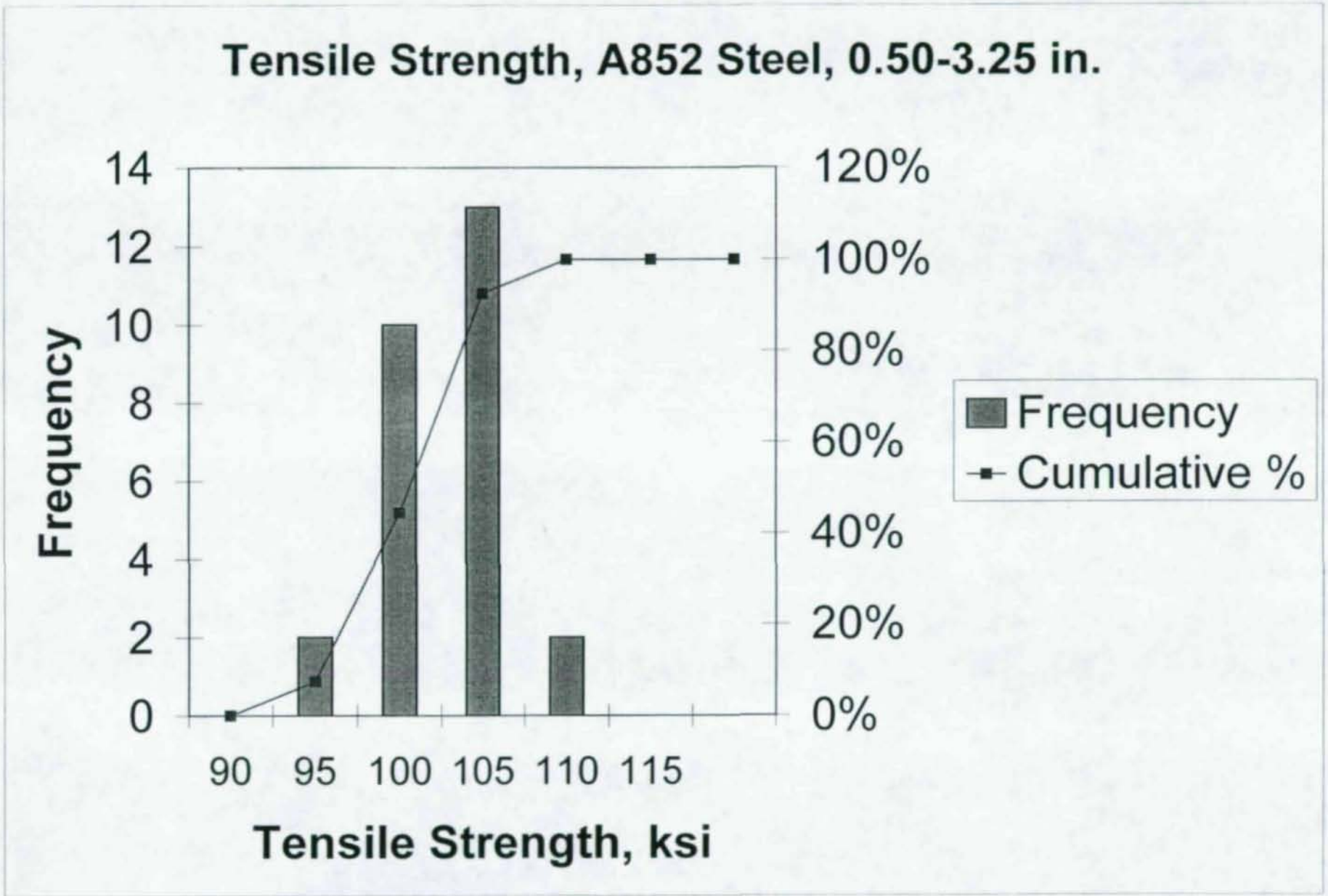

Tensile Strength, A588 Steel, 2.00-4.00 in.
Frequency
200
180
160
140
120
100
80
60
40
20
0
120%
100%
80%
60%
40%
20%
0%
70
80
90
100
110
Tensile Strength, ksi
Frequency
Cumulative %

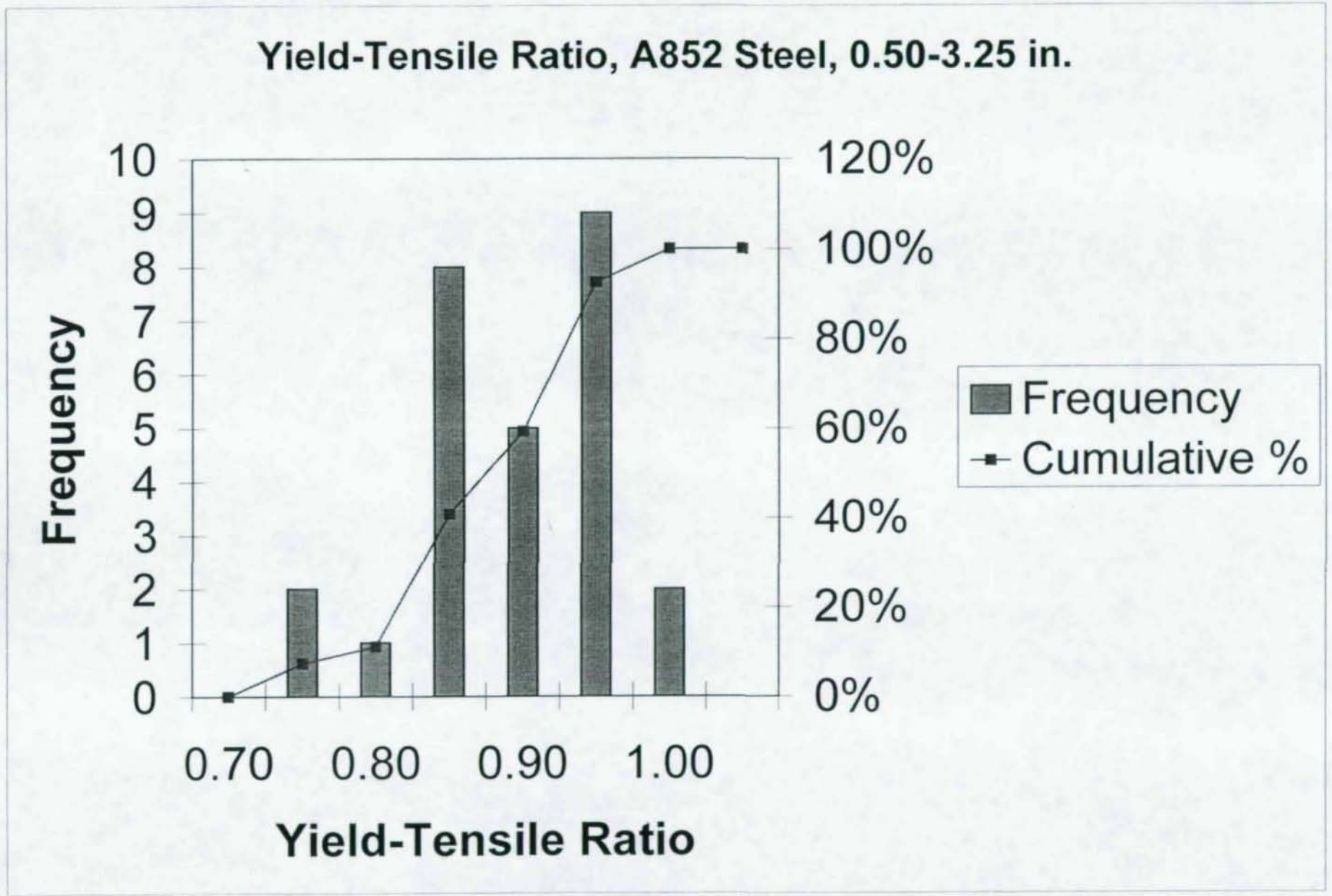

Yield-Tensile Ratio, A588 Steel, 2.00-4.00 in.
250
200
150
100
50
0
Frequency
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
0.60 0.70 0.80 0.90 1.00
Yield-Tensile Ratio

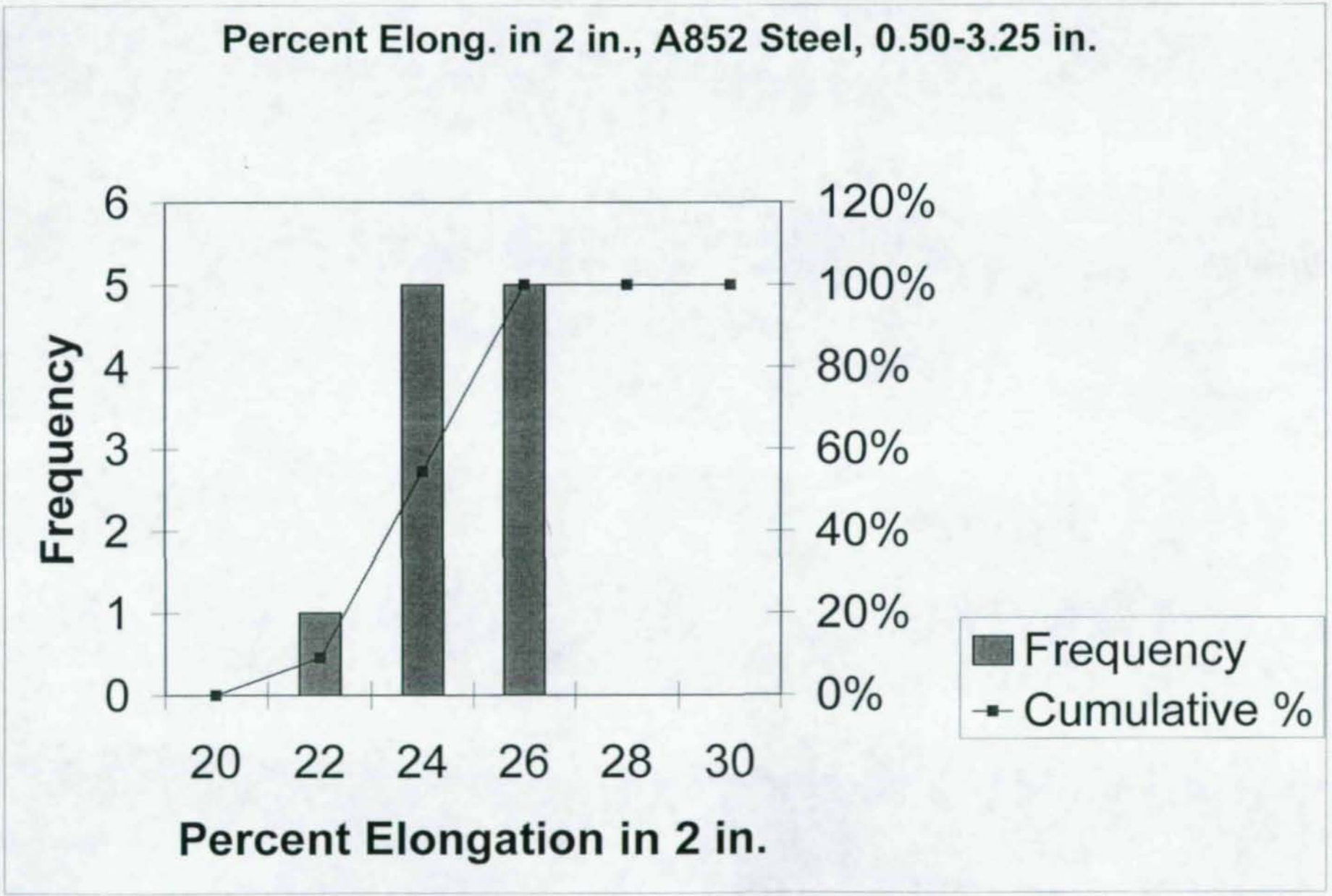

Percent Elong. in 2 in., A588 Steel, 2.00-4.00 in.
Frequency
70
60
50
40
30
20
10
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
15 20 25 30 35 40 45 50
Percent Elongation in 8 in.

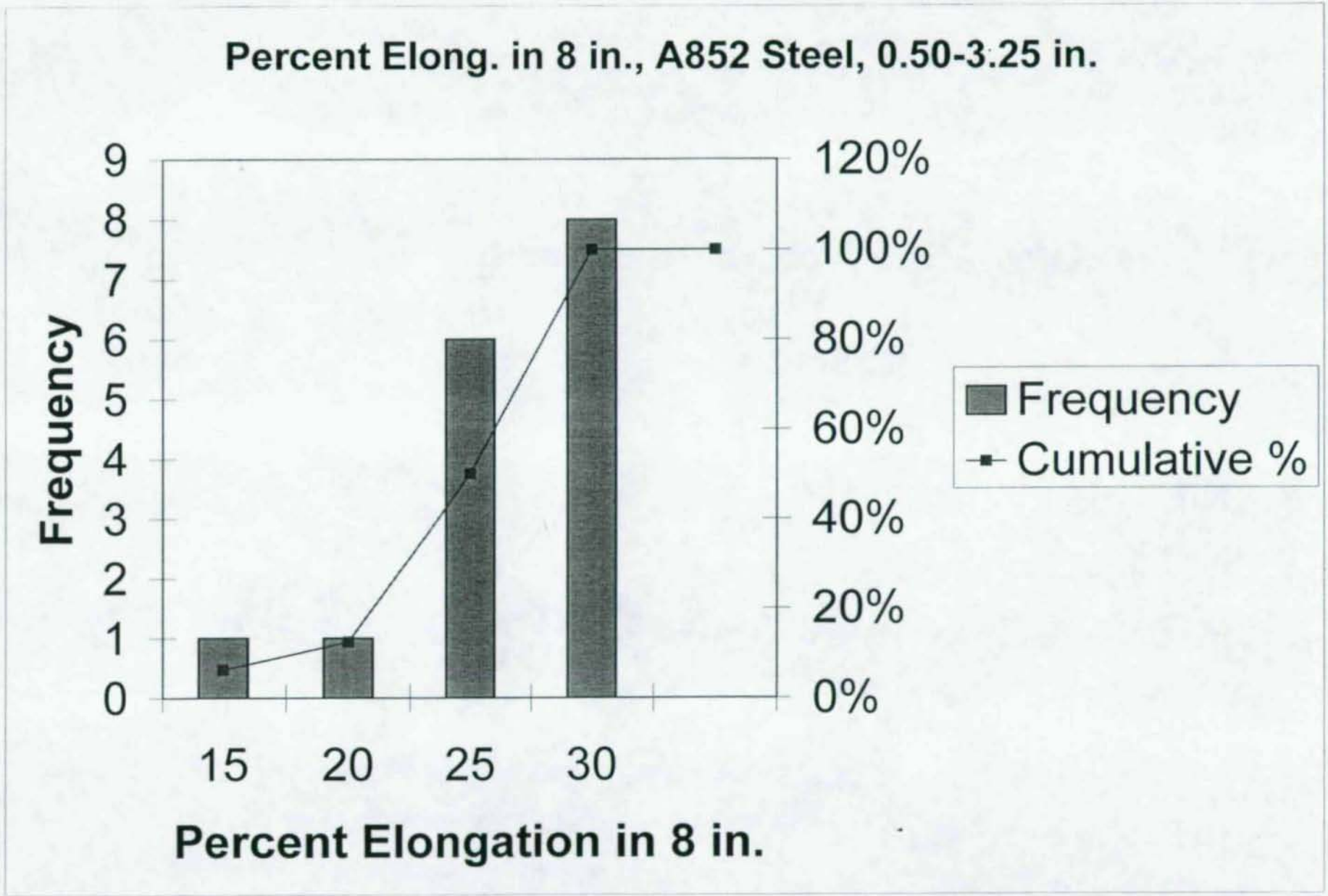

Percent Elong. in 8 in., A588 Steel, 2.00-4.00 in.
Frequency
90
80
70
60
50
40
30
20
10
0
120%
100%
80%
60%
40%
20%
0%
15
20
25
30
35
40
Percent Elongation in 8 in.
Frequency
Cumulative %

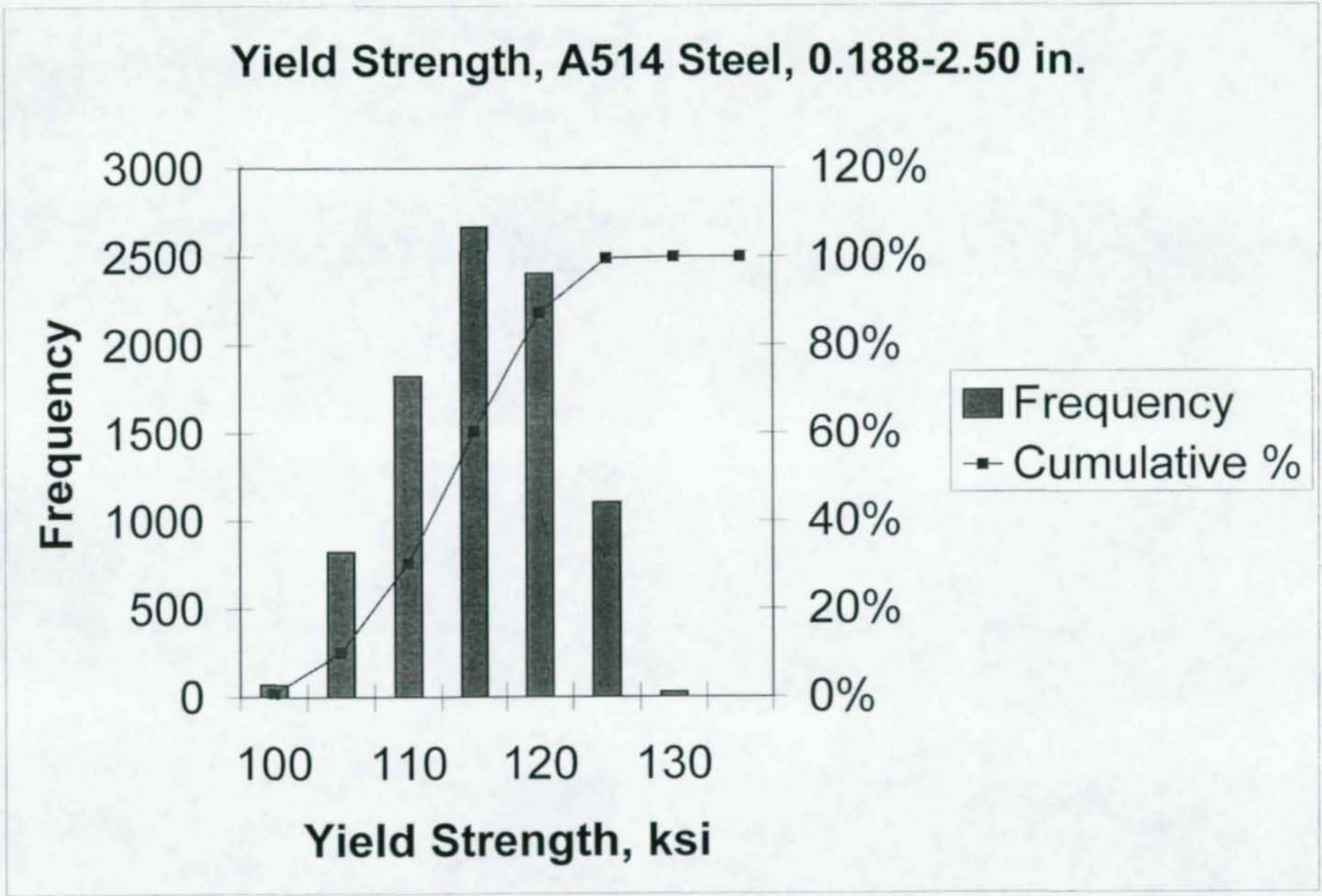

Yield Point, A852 Steel, 0.50-3.25 in.
Frequency
12
10
8
6
4
2
0
120%
100%
80%
60%
40%
20%
0%
70 75 80 85 90 95 100
Yield Point, ksi
Frequency
Cumulative %

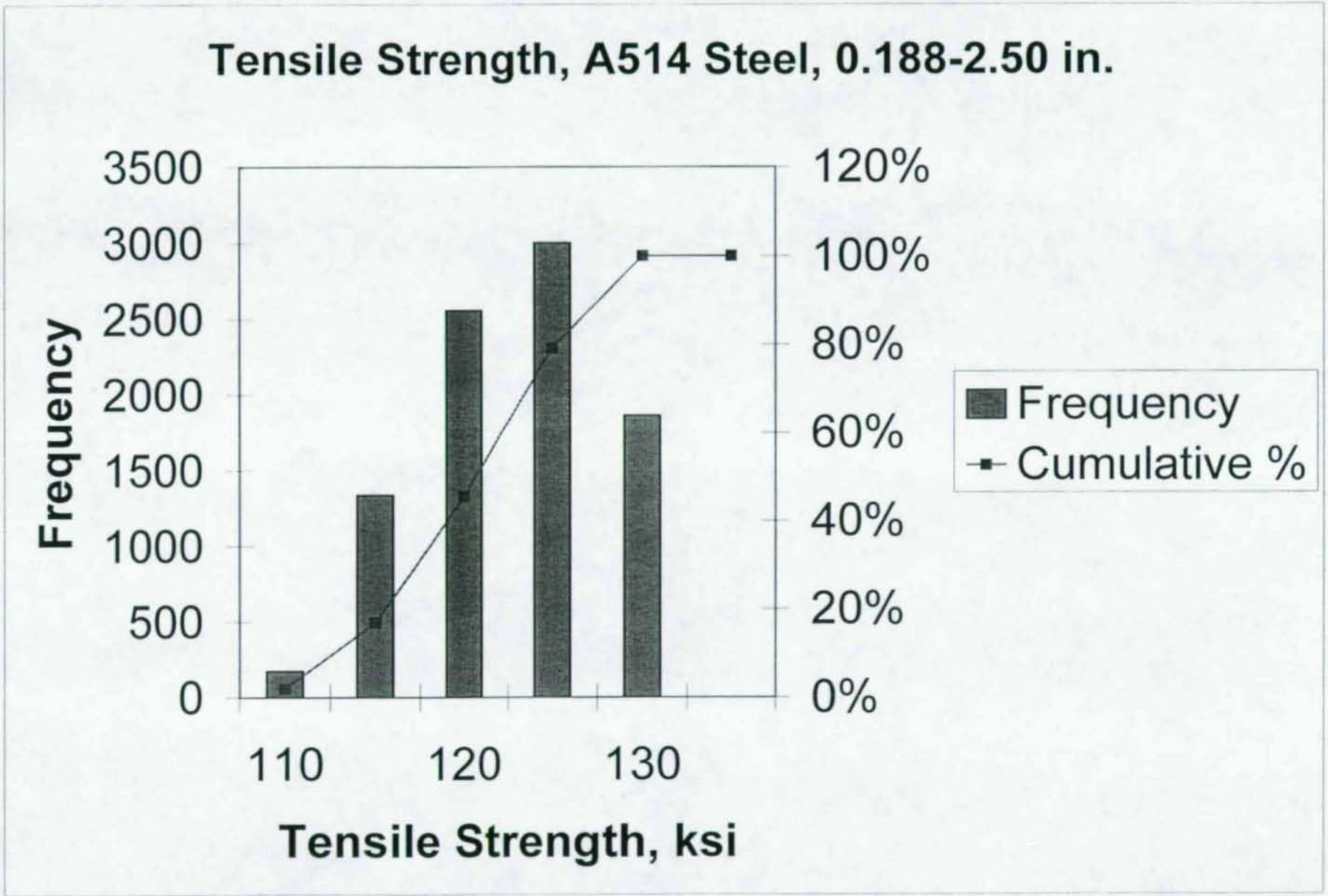

Tensile Strength, A852 Steel, 0.50-3.25 in.
Frequency
14
12
10
8
6
4
2
0
120%
100%
80%
60%
40%
20%
0%
90
95
100
105
110
115
Tensile Strength, ksi
Frequency
Cumulative %

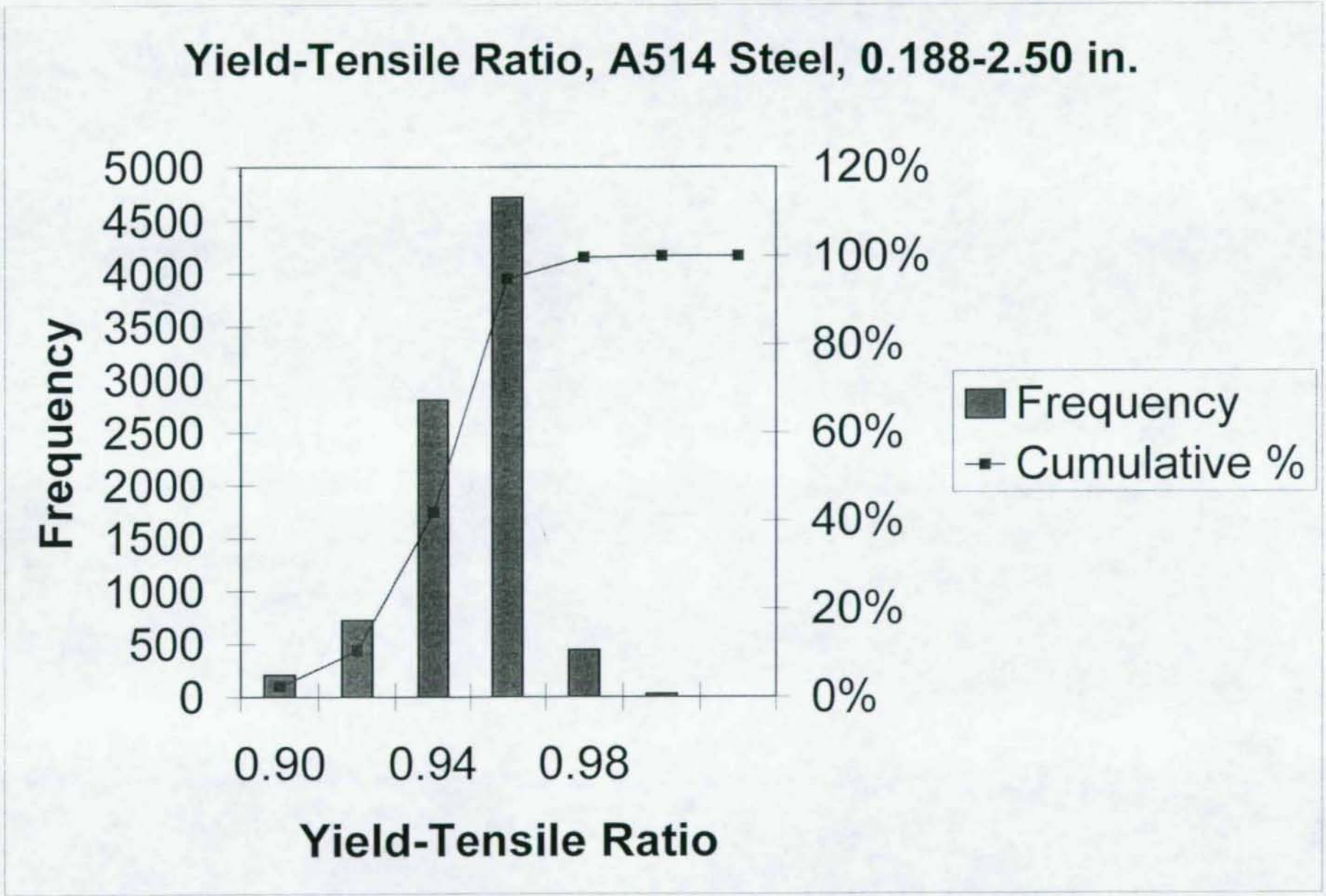

Yield-Tensile Ratio, A852 Steel, 0.50-3.25 in.
Frequency
10
9
8
7
6
5
4
3
2
1
0
120%
100%
80%
60%
40%
20%
0%
0.70
0.80
0.90
1.00
Yield-Tensile Ratio
Frequency
Cumulative %

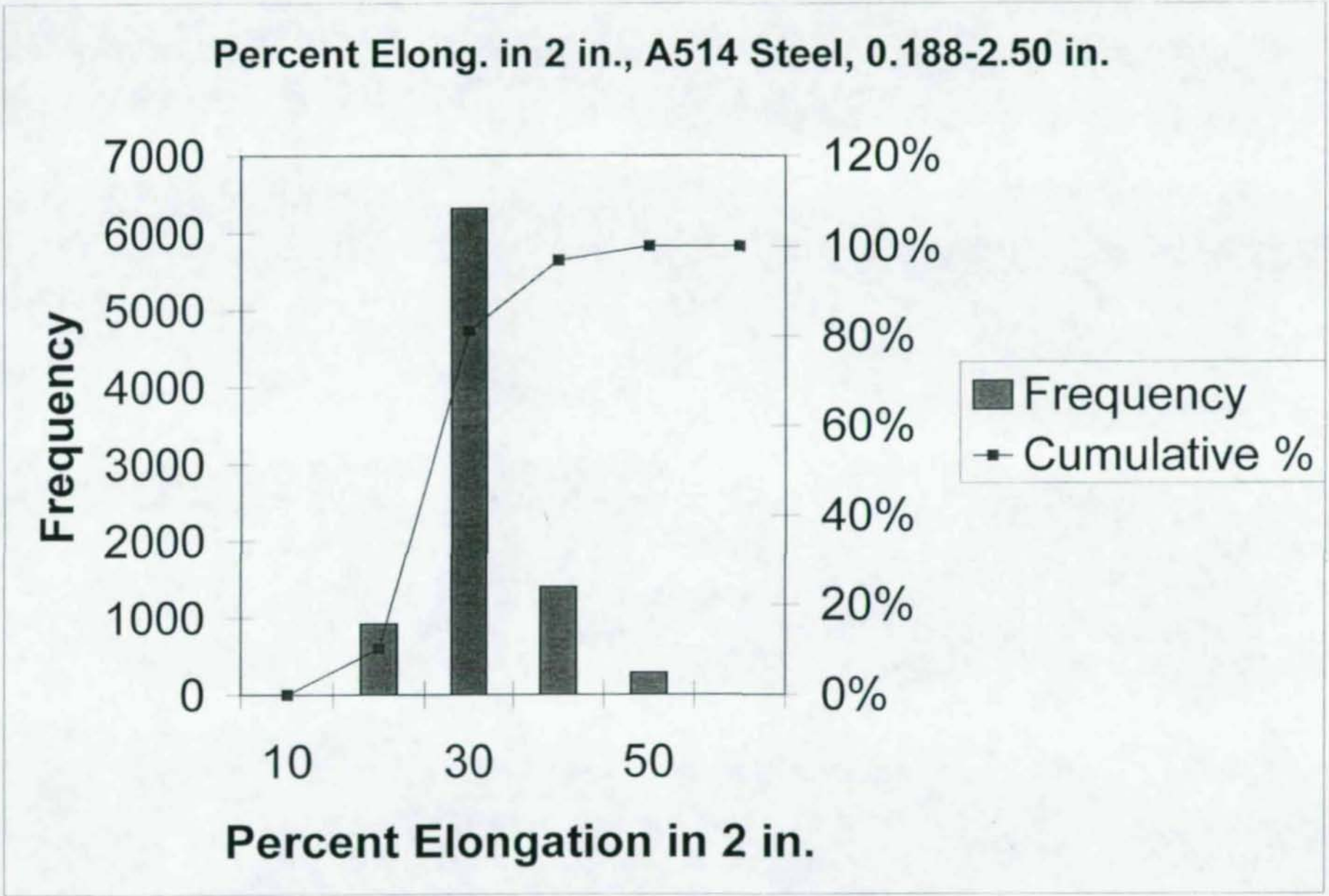

Percent Elong. in 2 in., A852 Steel, 0.50-3.25 in.
Frequency
0
1
2
3
4
5
6
120%
100%
80%
60%
40%
20%
0%
20
22
24
26
28
30
Percent Elongation in 2 in.
Frequency
Cumulative %

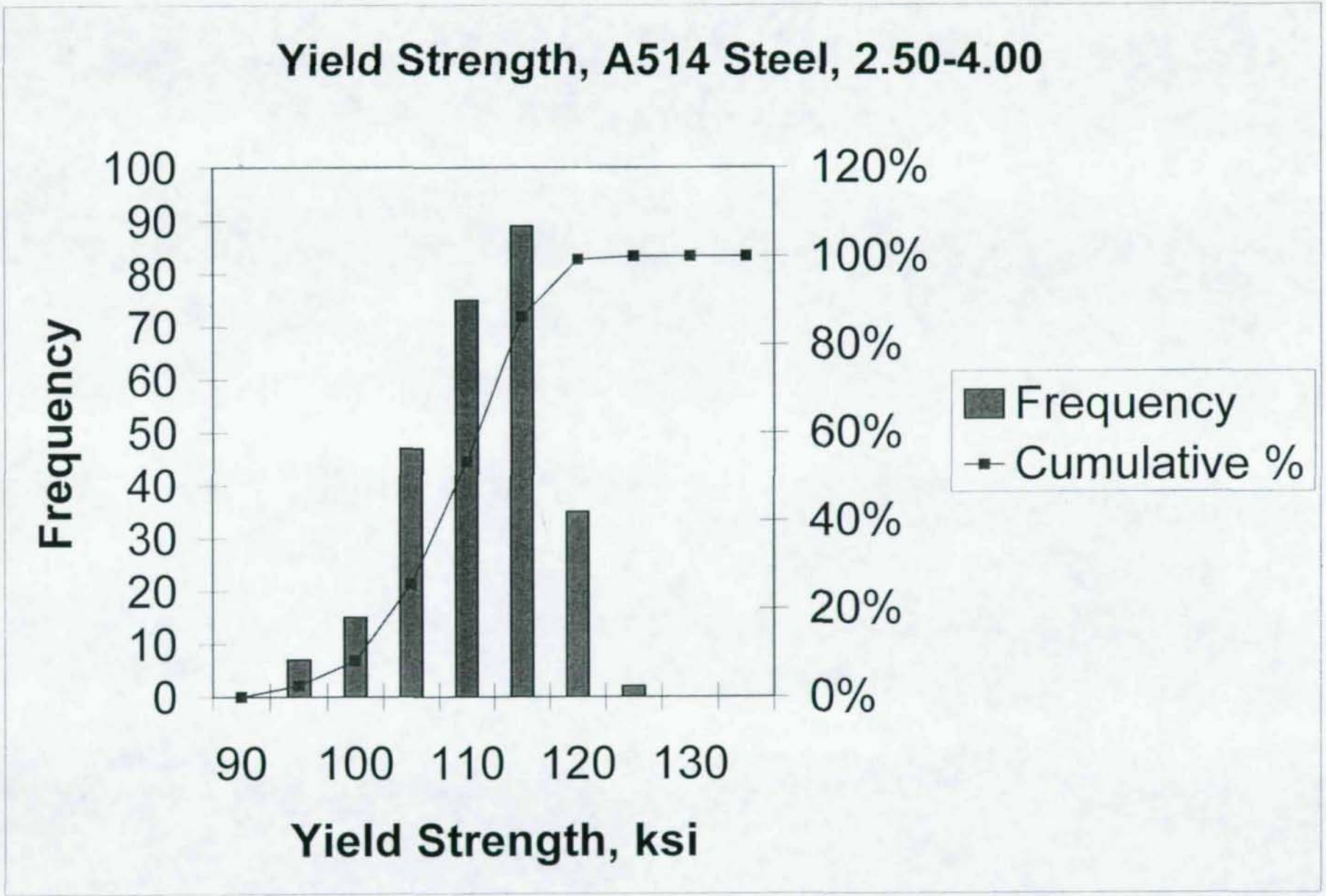

Percent Elong. in 8 in., A852 Steel, 0.50-3.25 in.
Frequency
0
1
2
3
4
5
6
7
8
9
120%
100%
80%
60%
40%
20%
0%
15
20
25
30
Percent Elongation in 8 in.
Frequency
Cumulative %

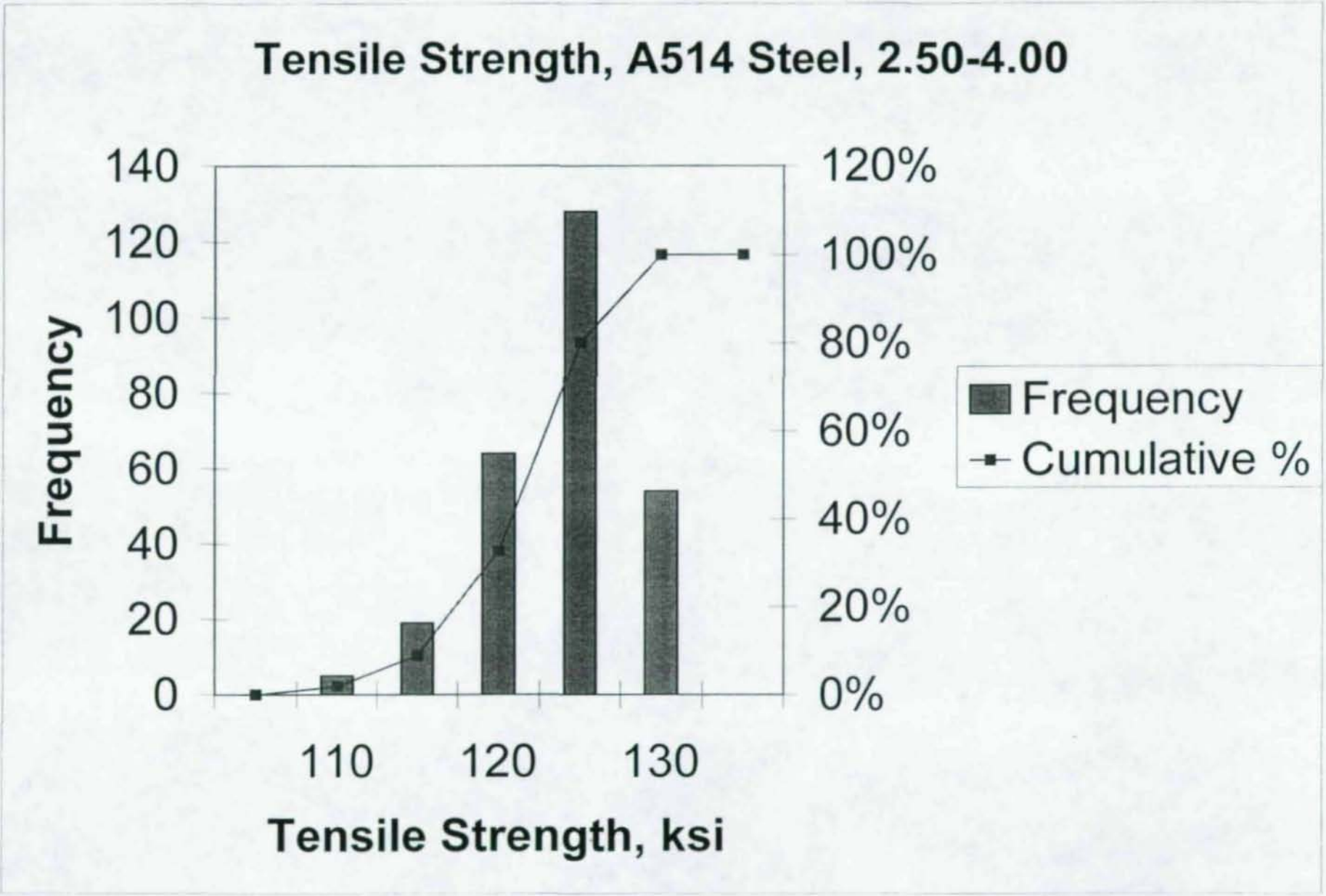

Yield Strength, A514 Steel, 0.188-2.50 in.
Frequency
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
100
110
120
130
Yield Strength, ksi
Frequency
Cumulative %

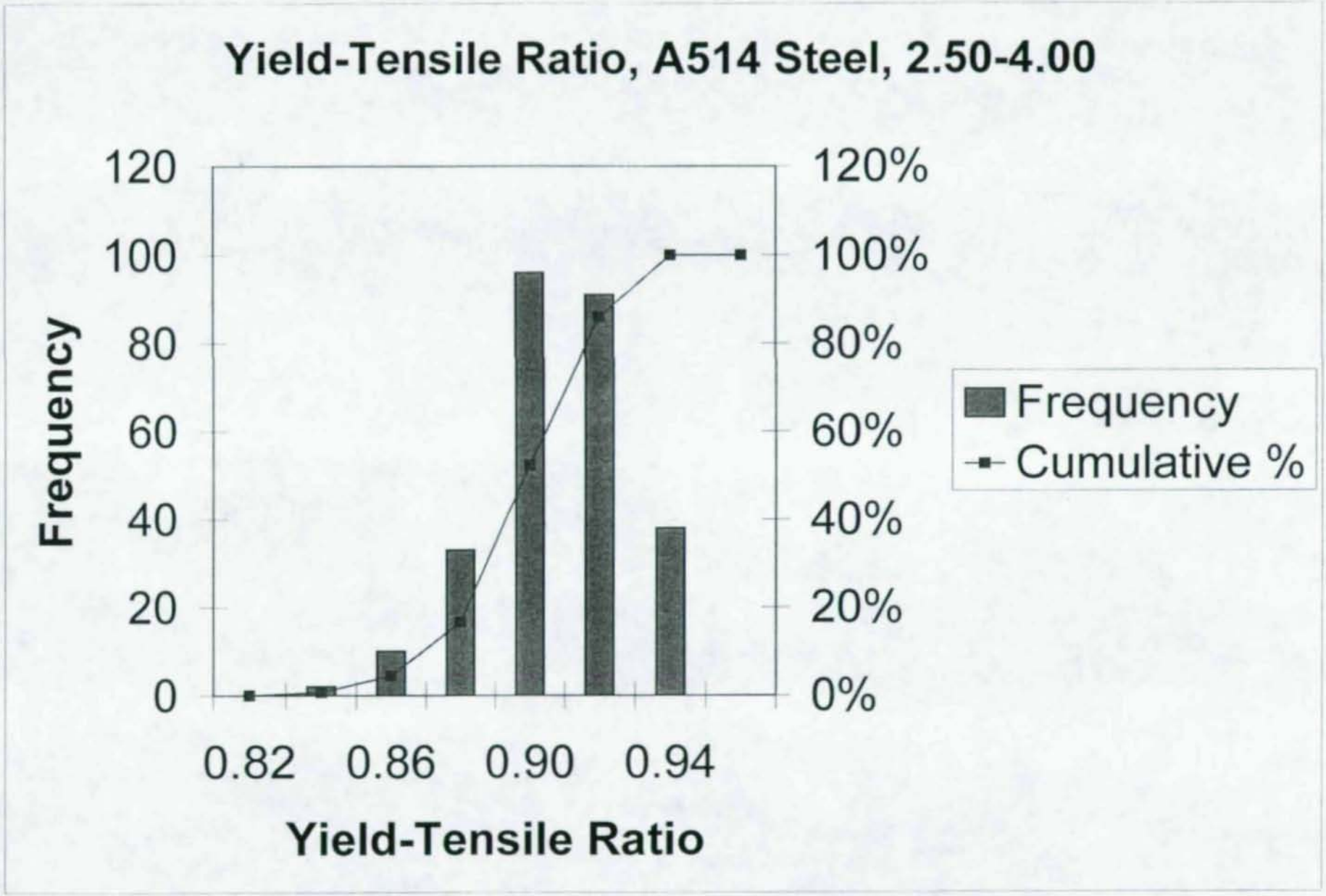

Tensile Strength, A514 Steel, 0.188-2.50 in.
Frequency
3500
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
110
120
130
Tensile Strength, ksi

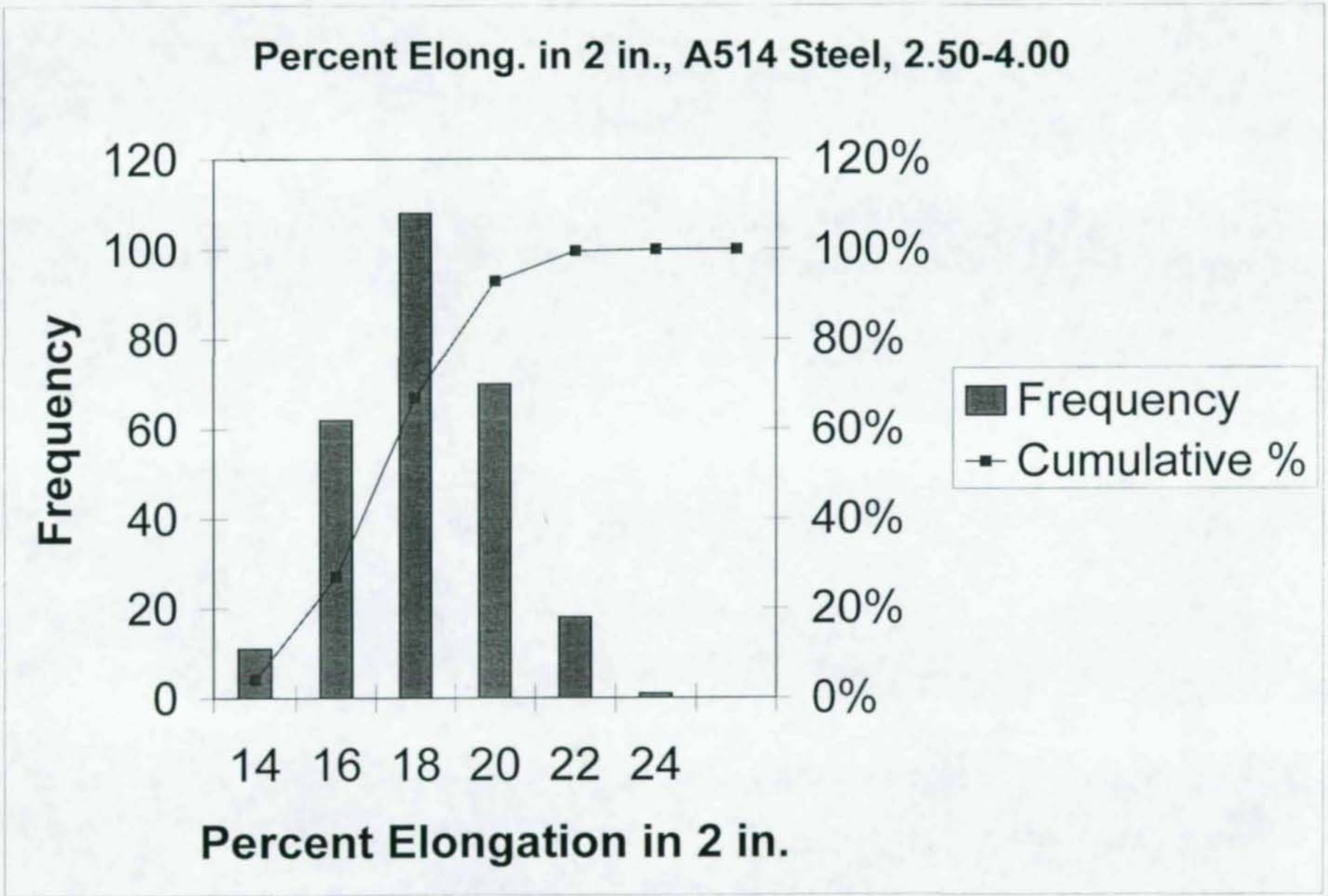

Yield-Tensile Ratio, A514 Steel, 0.188-2.50 in.
Frequency
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
120%
100%
80%
60%
40%
20%
0%
0.90
0.94
0.98
Yield-Tensile Ratio
Frequency
Cumulative %


Percent Elong. in 2 in., A514 Steel, 0.188-2.50 in.
Frequency
7000
6000
5000
4000
3000
2000
1000
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
10
30
50
Percent Elongation in 2 in.


Yield Strength, A514 Steel, 2.50-4.00
Frequency
100
90
80
70
60
50
40
30
20
10
0
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
90
100
110
120
130
Yield Strength, ksi


Tensile Strength, A514 Steel, 2.50-4.00
Frequency
140
120
100
80
60
40
20
0
120%
100%
80%
60%
40%
20%
0%
110
120
130
Tensile Strength, ksi
Frequency
Cumulative %


Yield-Tensile Ratio, A514 Steel, 2.50-4.00
120
100
80
60
40
20
0
Frequency
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
0.82
0.86
0.90
0.94
Yield-Tensile Ratio


Percent Elong. in 2 in., A514 Steel, 2.50-4.00
120
100
80
60
40
20
0
Frequency
120%
100%
80%
60%
40%
20%
0%
Frequency
Cumulative %
14
16
18
20
22
24
Percent Elongation in 2 in.