STATISTICAL ANALYSIS OF CHARPY V-NOTCH TOUGHNESS FOR STEEL WIDE FLANGE STRUCTURAL SHAPES

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Prepared By

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INTRODUCTION

After the Northridge, California earthquake of January 17, 1994 questions have been raised about the notch toughness of rolled structural steel shapes. Material toughness is defined by Rolfe (Ref. 7) as "the resistance to unstable crack propagation in the presence of a notch". Notch toughness is defined in Salmon and Johnson (Ref. 8) as " the measure of the resistance of a metal to the start and propagation of a crack at the base of a standard notch, commonly using the Charpy V-Notch test". Several studies in the past have concentrated on investigating the variability of Charpy V-Notch toughness, or CVN toughness, within a steel plate or throughout the cross-section of a wide flange shape. References 1, 3 and 6 provide further information to the interested reader.

This report describes the variability of CVN toughness data as documented by six steel shape producers over the past 12 to 18 months at the standard ASTM A6/A6M flange location, and at the standard AISC Specification for Structural Steel Buildings Group 4 and 5 core area location. This report was prepared by Jacques Cattan of the American Institute of Steel Construction, and reviewed by Task Committee 115 on Materials of the AISC Committee on Specifications, with the support of the Structural Shapes Producers Council (SSPC) whose members graciously provided the survey data:

1. Bethlehem Steel Corporation, Bethlehem, Pennsylvania
2. British Steel, Houston, Texas
3. Chaparral Steel Company, Midlothian, Texas
4. Northwestern Steel & Wire, Sterling, Illinois
5. Nucor-Yamato Steel Company, Blytheville, Arkansas
6. TradeArbed, New York, New York

By Task Committee 115 on Materials of the AISC Committee on Specification;

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FRACTURE MECHANICS

Structural steels can reach a strength limit state in one of two manners: brittle or ductile. A ductile response is preferred, especially for high seismicity conditions, because it is gradual, provides energy dissipation and overload. Steel fracture is dependent on the rate of loading, the ambient temperature and any constraints applied to the material which would restrict plastic deformations. Slower loading rates, higher temperatures, and fewer constraints all increase material toughness. Additional factors affecting the fracture resistance of a component are geometry and surface conditions, the presence and size of existing discontinuities, or crack initiators. Bridge structures have long been identified as being susceptible to fatigue and fracture and hence, material toughness has been recognized as an important property for these exposed conditions. The toughness demands for enclosed buildings subject to wind and gravity loads, which are considered static, are relatively less severe than for bridges or for larger members in welded moment frames subject to high seismic loads.

To properly evaluate the toughness of a material the theory of fracture mechanics, which is widely covered in the literature, can be used. One common parameter is the energy absorbed by the material during fracture of a steel test specimen subject to a standard test. In a Charpy V-Notch test a small bar specimen with a milled notch is struck by a fast moving hammer, the energy that is absorbed in breaking the test sample is measured. Charpy V-Notch testing is documented in supplement (S5) of the ASTM A6/A6M specification and the test is performed according to the ASTM A370 specification on a sample collected according to the ASTM A673 specification. A minimum value of 15 ft-lbs at the test temperature taken to be +40°F is traditionally used for structural steel applications. This criteria was developed in the mid 1940s and the reader is referred to Chapter 13 of reference 7 for further information.

In addition to ASTM the AISC LRFD Specification (1993) Section A3.1.c requires testing for ASTM A6/A6M Group 4 and 5 shapes when used for certain applications. The testing is conducted in accordance with the ASTM A6/A6M, Supplement S5. Several additional requirements are set by the AISC Specification, including sampling from the core location and a required minimum average value of 20 ft-lbs absorbed energy at +70°F. AISC does not currently require any similar CVN properties for other shapes or other applications used for interior building construction under static conditions.

CVN values are a material qualification which are not directly used in AISC design equations. Engineers are advised that CVN values are to be used in conjunction with other properties of the material, its design and fabrication and should not be the only measure of the material adequacy.

SAMPLE DATA BASE

As mentioned previously six shape producers participated in the study. Data was submitted from heats produced in 1994 and 1995. The sample consisted of an unidentified mix of heats ordered with toughness requirements and heats tested for internal quality control purposes. The data for this study is considered representative of the present and future shape production as confirmed to AISC in writing by the six participating producers. The test samples were full size samples and are taken from the ASTM standard flange location or from the AISC core location, all in the longitudinal, or rolling direction. The tests were done at one of three temperatures: +32°F, +40°F and +70°F. Only wide flange structural shapes were considered and grouped by web thickness according to the ASTM A6/A6M. The steel grades evaluated are:

1. A36 HR (Hot Rolled)
2. A36 QST (Quenched and Self-Tempered)
3. A572 Gr50 HR
4. A572 Gr50 QST
5. A913 Gr65 QST
6. A588 HR
7. Dual grade (A36 and A572 Gr50)

ASTM A673 defines a test as the average of three specimens. Most data reported to AISC was the three required test values and the average of these three values. One producer did not provide the three separate test results but provided only the average. The total number of CVN values reported to AISC was 21,330. Also, the total number of average CVN values reported by the producers listed in the introduction to AISC was 8048. (Multiplying the number of average CVN values by three does not correspond to the total number of CVN values reported since one producer did not provide individual CVN values but provided only the average CVN).

Figure 1 shows the distribution of the average CVN values reported by ASTM steel grade designation. Figure 2 is the distribution of the average CVN values reported by ASTM group shape. Data that was provided with a known steel grade, a known test temperature and a known test location but which could not be classified in an ASTM group is shown in the not available (N/A) bin of the histogram. Figure 3 is the distribution of the average CVN values reported by test temperature. Figure 4 is the distribution of the average CVN values reported by test location. The N/A bin represents data for which producers did not specify a location. However, it is expected that the majority of the data for ASTM shape groups 1,2 and 3 was from the flange location while the majority of the data for ASTM shape groups 4 and 5 was from the AISC core location.

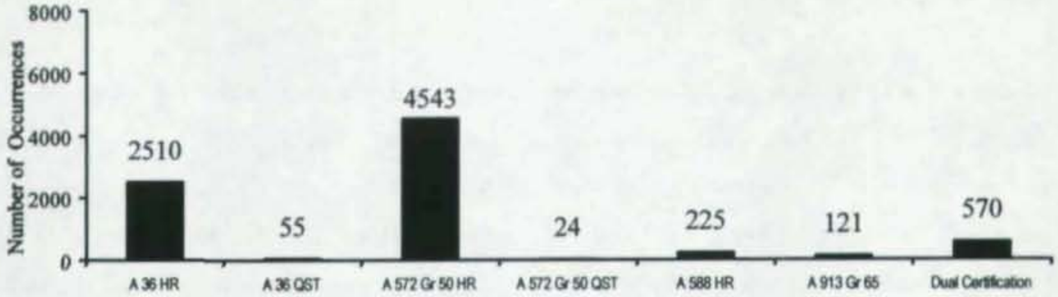

Figure 1. CVN Values Provided to AISC By ASTM Steel Grade

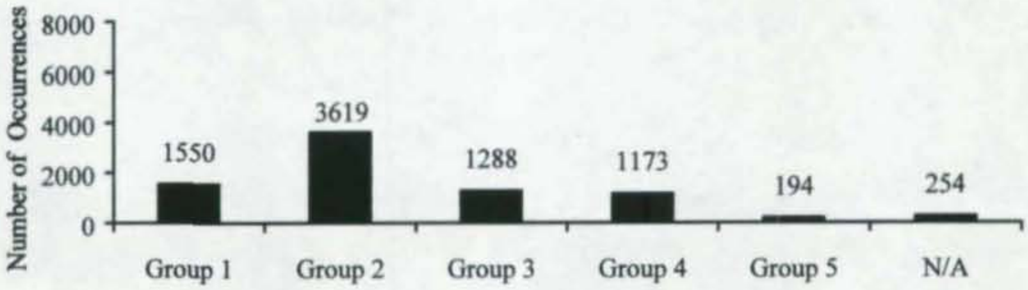

Figure 2. CVN Values Provided to AISC By ASTM Shape Group

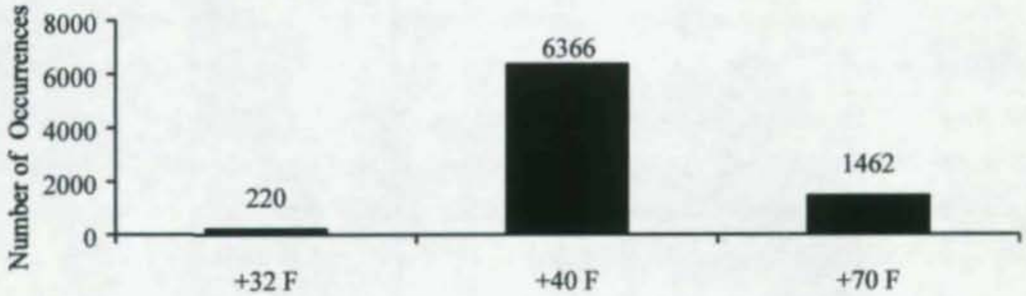

Figure 3. CVN Values Provided to AISC By Test Temperature

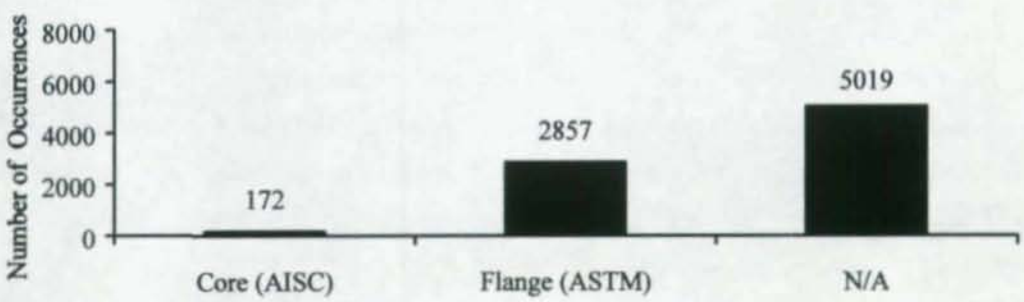

Figure 4. CVN Values Provided to AISC By Test Location

CVN STATISTICAL ANALYSIS

A set of data can be characterized by the following principle statistical parameters:

- Sample size
- Minimum value
- Mode (value that occurs most frequently)
- Mean (sum of all the values divided by the sample size)
- Maximum value
- The range of values (the difference between the maximum value and the minimum value)
- Standard deviation (measure of scatter).

A set of data can be further characterized by statistical information obtained from a cumulative distribution such as:

- The first quartile (value below which 25% of the data lies and above which 75% of the data is located)
- The median (value above and below which 50% of the sample is located)
- The third quartile (value below which 75% of the data lies and above which 25% of the data is located)

Finally, theoretical statistical distributions can be fit to the data and tested, but this was not done in this report. For further information the reader is directed to the references listed as well as numerous existing textbooks on statistical analysis.

For the statistical analysis the data was divided by steel grade, by temperature and by size group as shown in Table 1. Table 1 shows the steel grade, the test temperature, the sample size, and the statistical results obtained. Included in Table 1 are the following:

- The mode of the data
- The minimum value
- The mean
- The maximum value
- The range of the data
- The first quartile
- The median
- The third quartile

Table 1. Statistical Parameters

Steel Grade	Test Temp (°F)	ASTM Shape Group	Sample Size	Mode (ft lbs)	Minimum (ft lbs)	Mean (ft lbs)	Maximum (ft lbs)	First Quartile (ft lbs)	Median (ft lbs)	Third Quartile (ft lbs)
A36 QST	32	ALL	21	162	91	151	204	137	160	168
A36 HR	32	ALL	73	130	91	150	241	124	145	169
A36 HR	40	ALL	2011	66	16	112	286	65	98	147
		1	421	100	20	116	272	79	113	146
		2	1057	239	16	130	286	77	117	176
		3	315	36	19	86	240	63	77	98
		4	218	54	16	54	193	41	51	62
A36 HR	70	ALL	426	239	22	95	253	43	70	124
		1	262	43	25	59	177	36	50	75
		2	59	69	59	122	253	83	97	138
		3	24	239	25	200	240	235	239	239
		4	81	240	22	158	240	99	177	221
A572 Gr 50 QST	32	ALL	24	N/A	101	136	182	122	138	149
A572 Gr 50 HR	32	ALL	15	N/A	106	140	170	135	142	147
A572 Gr 50 HR	40	ALL	3930	79	16	91	288	64	80	97
		1	400	58	16	84	259	58	73	95
		2	2181	80	18	93	288	71	85	102
		3	813	86	16	83	280	65	82	96
		4	453	60	17	66	155	53	63	77
		5	83	49	29	62	155	47	59	71
A572 Gr 50 HR	70	ALL	598	47	15	61	241	31	51	74
		2	37	124	31	135	237	89	134	194
		3	90	74	31	76	202	56	68	91
		4	364	50	17	57	241	34	51	68
		5	104	26	15	33	116	23	27	32

NOTE: HR = Hot Rolled; QST = Quenched Self-Tempered

Table 1. (cont.) Statistical Parameters

Steel Grade	Test Temp (°F)	ASTM Shape Group	Sample Size	Mode (ft lbs)	Minimum (ft lbs)	Mean (ft lbs)	Maximum (ft lbs)	First Quartile (ft lbs)	Median (ft lbs)	Third Quartile (ft lbs)
A588 HR	40	ALL	223	21	16	140	290	71	129	204
		2	182	54	18	148	290	82	145	215
		3	41	N/A	16	103	249	58	75	155
A913 Gr65 OST	32	ALL	87	156	92	141	212	122	142	158
A913 Gr65 OST	70	ALL	34	48	33	61	108	45	57	79
Dual Certified	40	ALL	202	43	17	53	121	37	51	67
		1	142	38	17	51	121	35	48	63
		2	55	43	24	59	116	43	58	74
Dual Certified	70	ALL	368	65	15	59	131	41	55	74
		1	322	53	15	55	131	37	53	69
		2	46	65	60	86	123	67	91	99

NOTE: HR = Hot Rolled; QST = Quenched Self-Tempered

Figure 5 shows the distribution of the average CVN values used to determine the statistical parameters in Table 1. If the reader compares Figures 1 and 5 he/she will notice that 36 values were not used. *The 36 values not used came from shapes or heats which did not fit clearly an ASTM grade or group* studied here. In essence, the statistical analysis was performed on 8012 data points each representing the average of three CVN tests.

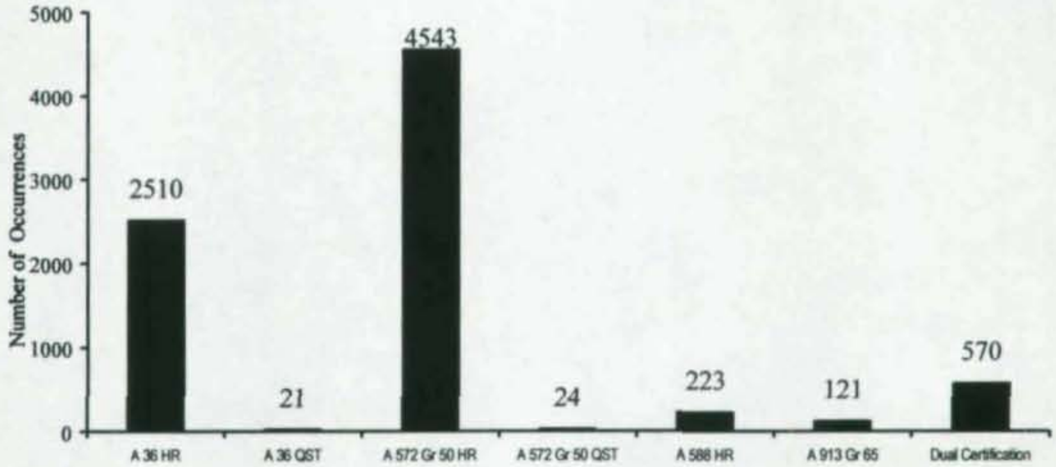

Figure 5. Data Used By ASTM Steel Grade

When possible the deviation of the individual test values from the reported average test value were computed and plotted in the charts provided in Appendix A. These values represent the scatter of each test with respect to the group average CVN value reported; the mean of these deviations vary from 3 to 17% and are usually of the order of 10 to 12% of the average. For each steel grade, test temperature, and ASTM Shape Group, a relative frequency distribution and a cumulative frequency distribution are plotted. For convenience, the cumulative frequency distributions are plotted on a larger sheet in Appendix B of this report. These charts allow the reader to directly read the probability of exceeding a given CVN value based on the data itself (not a theoretical fitted distribution). A certain steel grade, at a certain temperature and a certain ASTM Shape Group may not be presented due to the small sample of available data, which makes a statistical analysis not valid, or because it simply is not rolled. For instance: A572 Gr50 hot rolled group 1 shapes had only three data points at +70°F therefore, adding all present groups will give 595 values. However the All ASTM Groups graph contains 598 points, thus incorporating the group 1 shapes which alone are not statistically significant. Another instance is the dual certified hot rolled shapes at +40°F, in this case group 3 data was not statistically significant when examined alone.

RELATED COVERAGE IN THE AISC MANUALS

In order to put material toughness and the conditions that increase susceptibility to brittle fracture in an overall context, the following introductory sections from the AISC Manual of Steel Construction, pages 1-4 through 1-6 (the most recent 1989 ASD 9th Edition and the 1993 LRFD 2nd Edition, pages 1-6 through 1-9), are reproduced in their entirety. They are intended to overview the potential problems and provide some general and specific guidelines.

Brittle Fracture Considerations in Structural Design

As the temperature decreases, an increase is generally noted in the yield stress, tensile strength, modulus of elasticity, and fatigue strength of the structural steels. In contrast, the ductility of these steels, as measured by reduction in area or by elongation, and the toughness of these steels, as determined from a Charpy V-notch impact test, decrease with decreasing temperatures. Furthermore, there is a temperature below which a structural steel subjected to tensile stresses may fracture by cleavage, with little or no plastic deformation, rather than by shear, which is usually preceded by a considerable amount of plastic deformation or yielding.

Fracture that occurs by cleavage at a nominal tensile stress below the yield stress is commonly referred to as brittle fracture. Generally, a brittle fracture can occur in a structural steel when there is a sufficiently adverse combination of tensile stress, temperature, strain rate, and geometrical discontinuity (notch) present. Other design and fabrication factors may also have an important influence. Because of the interrelation of these effects, the exact combination of stress, temperature, notch, and other conditions that will cause brittle fracture in a given structure cannot be readily calculated. Consequently, designing against brittle fracture often consists mainly of (1) avoiding conditions that tend to cause brittle fracture and (2) selecting a steel appropriate for the application. A discussion of these factors is given in the following sections.

Conditions Causing Brittle Fracture

It has been established that plastic deformation can occur only in the presence of shear stresses. Shear stresses are always present in a uniaxial or biaxial state-of-stress. However, in a triaxial state of stress, the maximum shear stress approaches zero as the principal stresses approach a common value, and thus, under equal triaxial tensile stresses, failure occurs by cleavage rather than by shear. Consequently, triaxial tensile stresses tend to cause brittle fracture and should be avoided. A triaxial state-of-stress can result from a uniaxial loading when notches or geometrical discontinuities are present.

Increased strain rates tend to increase the possibility of brittle behavior. Thus, structures that are loaded at fast rates are more susceptible to brittle fracture. However, a rapid strain rate or impact load is not a required condition for a brittle fracture.

Cold work and the strain aging that normally follows generally increase the likelihood of brittle fracture. This behavior is usually attributed to the previously mentioned reduction in ductility. The effect of cold work that occurs in cold forming operations can be minimized by selecting a generous forming radius, and, thus, limiting the amount of strain. The amount of strain that can be tolerated depends on both the steel and the application.

The use of welding in construction increases the concerns relative to brittle fracture. In the as-welded condition, residual stresses will be present in any weldment. These stresses are considered to be at the yield point of the material. To avoid brittle fracture, it may be required to utilize steels with higher toughness than would be required for bolted construction. Welds may also introduce geometric conditions or discontinuities that are crack-like in nature. These stress risers will additionally increase the requirement for notch toughness in the weldment. Avoidance of the intersection of welds from multiple directions reduces the likelihood of triaxial stresses. Properly sized weld-access holes prohibit the intermittent weld layers. In most cases, weld metal notch toughness exceeds that of the base materials. However, for fracture-sensitive applications, notch-tough base and weld metal should be specified.

The residual stresses of welding can be greatly reduced through thermal stress relief. This reduces the driving force that causes brittle fracture, but if the toughness of the material is adversely affected by the thermal treatment, no increase in brittle fracture resistance will be experienced. Therefore, when weldments are to be stress relieved, investigation into the effects on the weld metal, heat-affected zone, and base material should be made.

Selecting a Steel To Avoid Brittle Fracture

The best guide in selecting a steel that is appropriate for a given application is experience with existing and past structures. A36 and Grade 50 (i.e., 50ksi yield stress) steels have been used successfully in a great number of applications, such as buildings, transmission towers, transportation equipment, and bridges, even at the lowest atmospheric temperatures encountered in the U.S. Therefore, it appears that any of the structural steels, when designed and fabricated in an appropriate manner, could be used for similar applications with little likelihood of brittle fracture. Consequently, brittle fracture is not usually experienced in such structures unless unusual temperature, notch, and stress conditions are present.

Nevertheless, it is always desirable to avoid or minimize the previously cited adverse conditions that increase the susceptibility of the steel to brittle fracture.

In applications where notch toughness is considered important, it usually is required that steels must absorb a certain amount of energy, 15 ft-lb or higher (Charpy V-notch test), at a given temperature. The test temperature may be higher than the lowest operating temperature depending on the rate of loading. See Rolfe and Barsom (1986) and Rolfe (1977).

Lamellar Tearing

The information on strength and ductility presented in the previous sections generally pertains to loadings applied in the planar direction (longitudinal or transverse orientation) of the steel plate or shape. It should be noted elongation and area reduction values may well be significantly lower in the through-thickness direction than in the planar direction. This inherent differentiality is of small consequence in many applications, but does become important in the design and fabrication of structures containing massive members with highly restrained welded joints.

With the increasing trend toward heavy welded-plate construction, there has been a broader recognition of the occurrence of lamellar tearing in some highly restrained joints of welded structures, especially those using thick plates and heavy structural shapes. The restraint induced by some joint designs in resisting weld deposit shrinkage can impose tensile strain sufficiently high to cause separation or tearing on planes parallel to the rolled surface of the structural member being joined. The incidence of this phenomenon can be reduced or eliminated through greater understanding by designers, detailers, and fabricators of (1) the inherent directionality of construction forms of steel, (2) the high restraint developed in certain types of connections, and (3) the need to adopt appropriate weld details and welding procedures with proper weld metal for through-thickness connections. Some guidelines in minimizing potential problems have been developed (AISC 1973). See also Part 8 in Volume II of the LRFD Manual and ASTM A770, Standard Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications.

Jumbo Shapes and Heavy Welded Built-up Sections

Although Group 4 and 5 W-Shapes, commonly referred to as jumbo shapes, generally are contemplated as columns or compression members, their use in non-column applications has been increasing. These heavy shapes have been know to exhibit segregation and a coarse grain structure in the mid-thickness region of the flange and the web. Because these areas may have low toughness, cracking might occur as a result of thermal cutting or welding (Fisher and Pense, 1987). Similar problems may also occur in welded built-up sections. To minimize the potential of brittle failure, the current LRFD Specification includes provisions for material toughness requirements, methods of splicing, and fabrication methods for Group 4 and 5 hot-rolled shapes and welded built-up cross sections with an element of the cross section more than two inches in thickness intended for tension applications.

CONCLUSIONS

The inherent statistical variability of steel production warrants higher target properties than the required minimum values, and this is reflected in the generally high CVN means, which range from 33 ft lbs at +70°F for A572 Gr50 hot rolled group 5 shapes to 200 ft lbs at +70°F for A36 hot rolled group 3 shapes. It is clear from the given data curves that, in general, the probability of obtaining adequate CVN values (15 ft-lbs at +40°F or 20 ft-lbs at +70°F in the longitudinal direction at the standard test location) when tested according to current codes and specifications is high. However, high material toughness values may not by themselves compensate for special conditions, poorly designed details, bad fabrication or inadequate inspection and usage. Table 2 contains the observed probability of exceeding a CVN value of 15 ft-lbs at +40°F or 20 ft-lbs at +70°F. These probabilities were obtained from the cumulative distribution curves. The values in Table 2 are given for each steel grade including all ASTM groups. The reader is encouraged to use the values in Table 2 in conjunction with the statistical parameters in Table 1 and the observed frequency charts of Appendix A and Appendix B.

Table 2. Observed Probabilities of Exceedance.

Steel Grade	Test Temp (°F)	ASTM Shape Group	Observed Probability of Exceedance 15 ft lbs (percent)	Observed Probability of Exceedance 20 ft lbs (percent)
A36 QST	32	ALL	100	100
A36 HR	32	ALL	100	100
A36 HR	40	ALL	99	97
		1	100	97
		2	100	99
		3	100	99
		4	96	95
A36 HR	70	ALL	100	95
		1	100	95
		2	100	100
		3	100	94
		4	100	97
A572 Gr 50 QST	32	ALL	100	100
A572 Gr 50 HR	32	ALL	100	100
A572 Gr 50 HR	40	ALL	100	99
		1	99	99
		2	100	99
		3	98	98
		4	100	99
		5	100	99
A572 Gr 50 HR	70	ALL	95	87
		2	100	100
		3	100	100
		4	96	89
		5	85	60
A588 HR	40	ALL	98	97
		2	99	98
		3	97	95
A913 Gr65 QST	32	ALL	100	100
A913 Gr65 QST	70	ALL	100	100
Dual Certified	40	ALL	99	94
		1	98	94
		2	100	99
Dual Certified	70	ALL	98	94
		1	98	93
		2	100	100

NOTE: HR = Hot Rolled; QST = Quenched Self-Tempered

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REFERENCES

1. American Iron and Steel Institute, "The variation of Charpy V-Notch Impact Test Properties in Steel Plates", Washington D. C., January 1979.

2. American Institute of Steel Construction, "LRFD Specification for Structural Steel", Chicago, IL, December 1993.

3. Barsom, J. M., "Material Considerations in Structural Steel Design", AISC Engineering Journal, 3rd Qtr. 1987.

4. Benjamin, J. R. and Cornell, C. A., "Probability, Statistics and Decision for Civil Engineers", McGraw-Hill, 1970.

5. Bevington, P. R., and Robinson, D. K., "Data Reduction and Error Analysis for the Physical Sciences", McGraw-Hill, Second Edition 1992.

6. Buragino, Gregory J.; Hansen, Steven S.; and Krouse, Dean C., "Metallurgical Characterization of Jumbo Shapes", AISC, National Steel Construction Conference, 1988.

7. Rolfe, S. T. and Barsom,. J. M., "Fracture and Fatigue Control in Structures. Application of fracture Mechanics", Prentice-Hall, 1977.

8. Salmon, C. G. and Johnson, J. E., "Steel Structures Design and Behavior", Harper Collins Publishers Inc., Third Edition 1990.

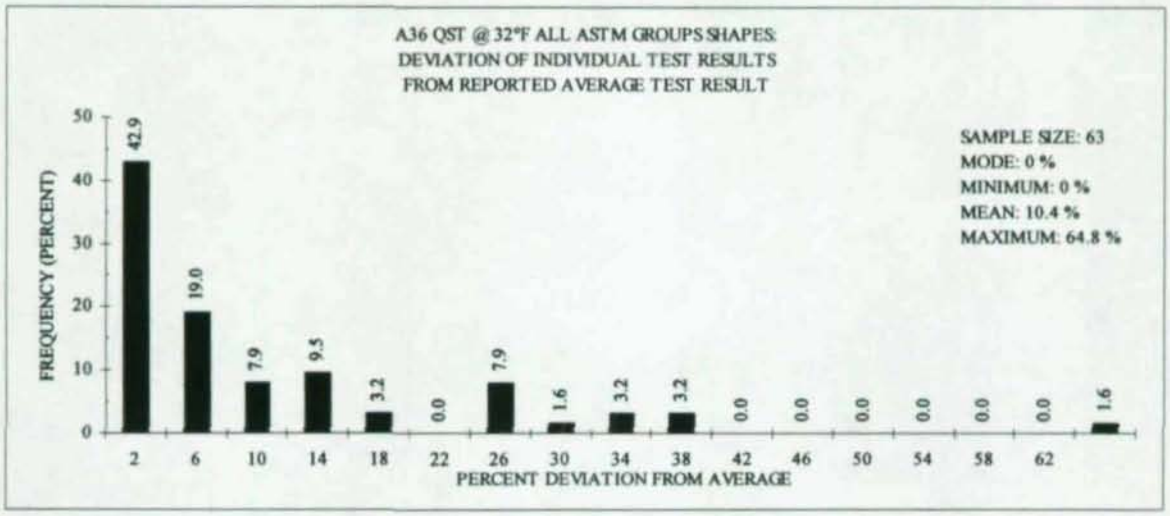
9. Vernon, J., "Introduction to Engineering Materials", Industrial Press Inc., Third Edition 1992.

APPENDIX A:

OBSERVED STATISTICAL DISTRIBUTIONS

NOTE: HR = Hot Rolled; QST = Quenched Self-Tempered

A36 STEEL


A36 QST @ 32°F ALL ASTM GROUPS SHAPES
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 63
MODE: 0 %
MINIMUM: 0 %
MEAN: 10.4 %
MAXIMUM: 64.8 %
FREQUENCY (PERCENT)
42.9
19.0
7.9
9.5
3.2
0.0
7.9
1.6
3.2
3.2
0.0
0.0
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1.6
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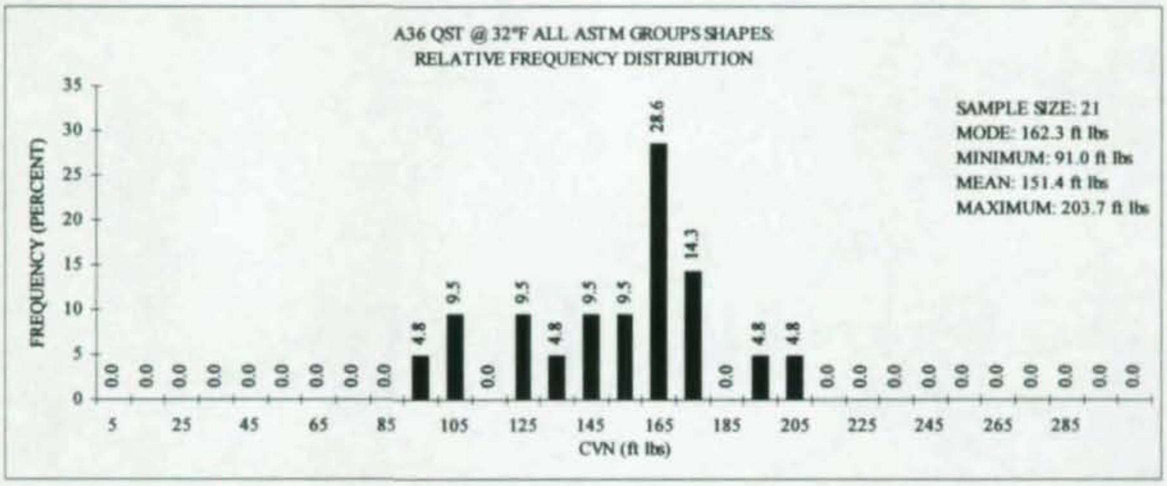
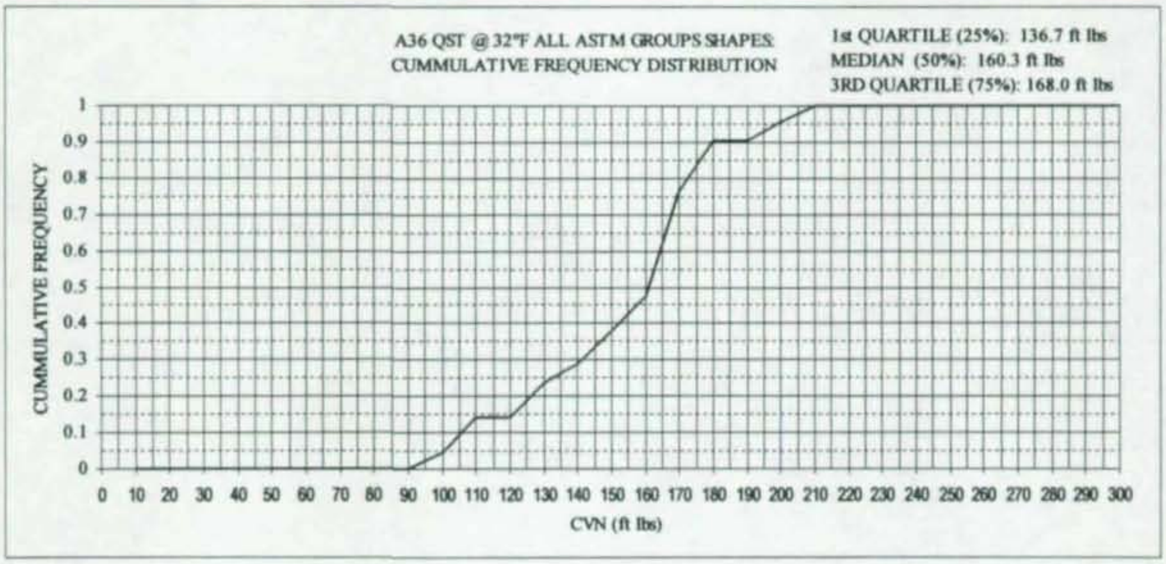
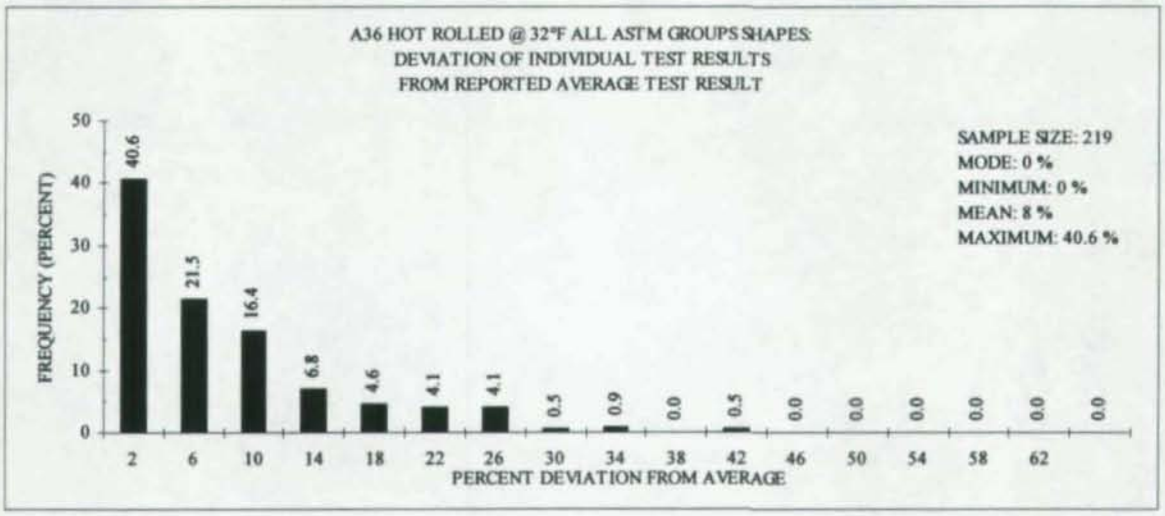
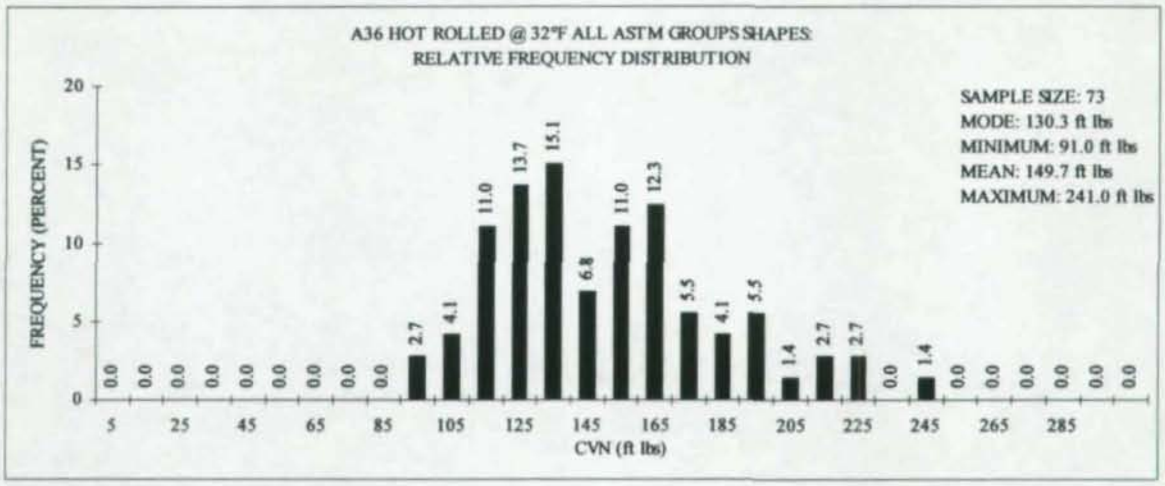
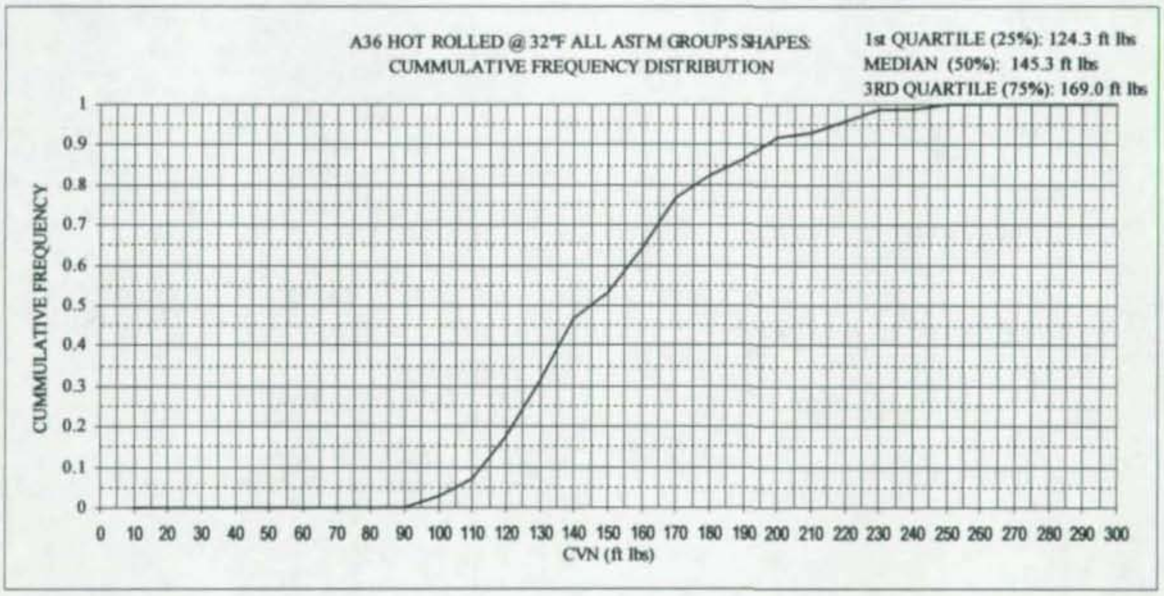
PERCENT DEVIATION FROM AVERAGE

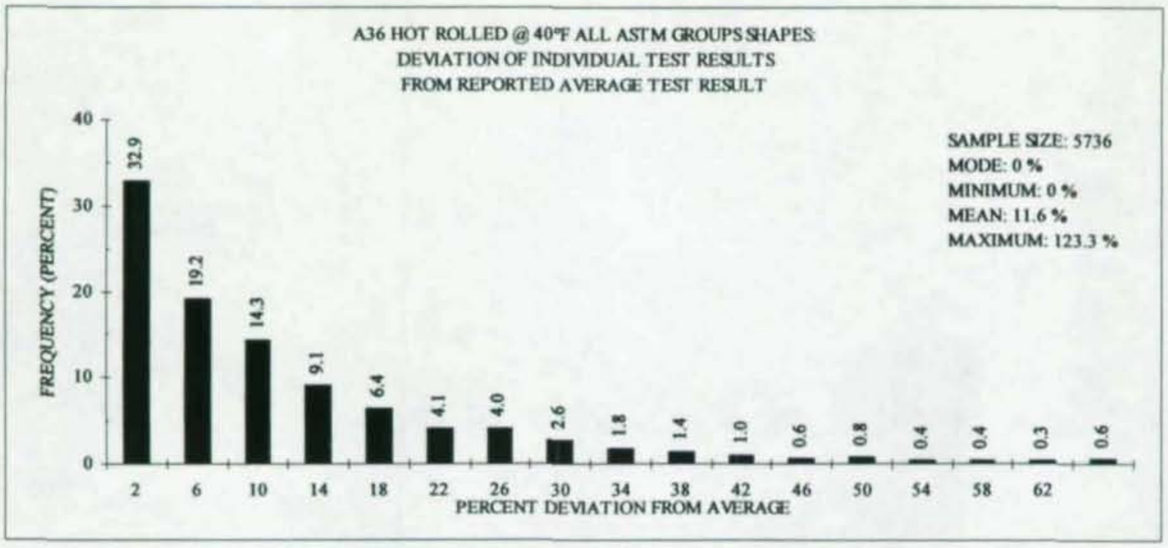

A36 QST @ 32°F ALL ASTM GROUPS SHAPES
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 21
MODE: 162.3 ft lbs
MINIMUM: 91.0 ft lbs
MEAN: 151.4 ft lbs
MAXIMUM: 203.7 ft lbs
FREQUENCY (PERCENT)
5 25 45 65 85 105 125 145 165 185 205 225 245 265 285
CVN (ft lbs)

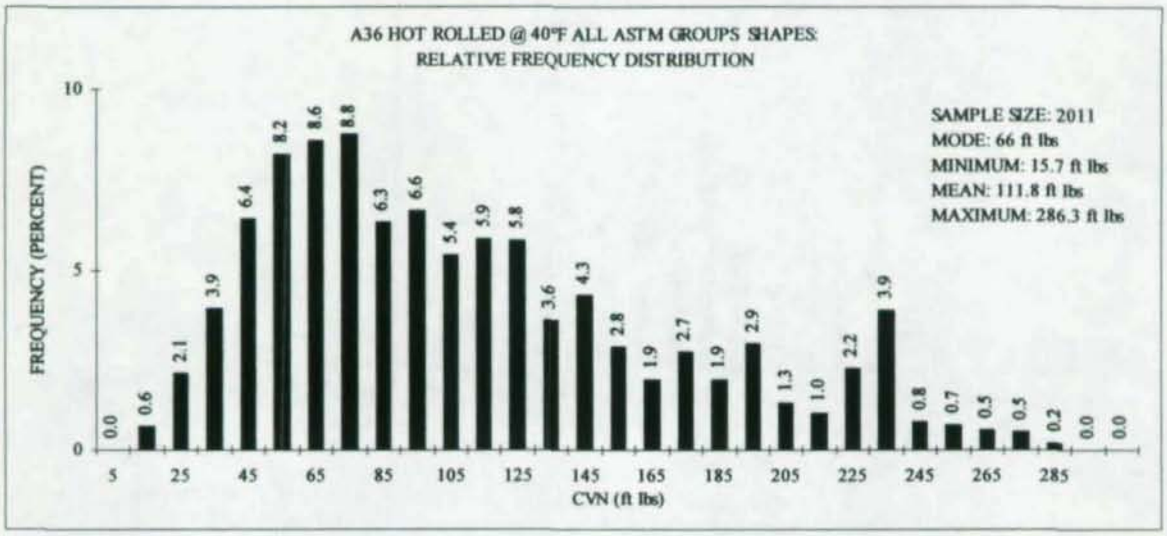

A36 QST @ 32°F ALL ASTM GROUPS SHAPES
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 136.7 ft lbs
MEDIAN (50%): 160.3 ft lbs
3RD QUARTILE (75%): 168.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

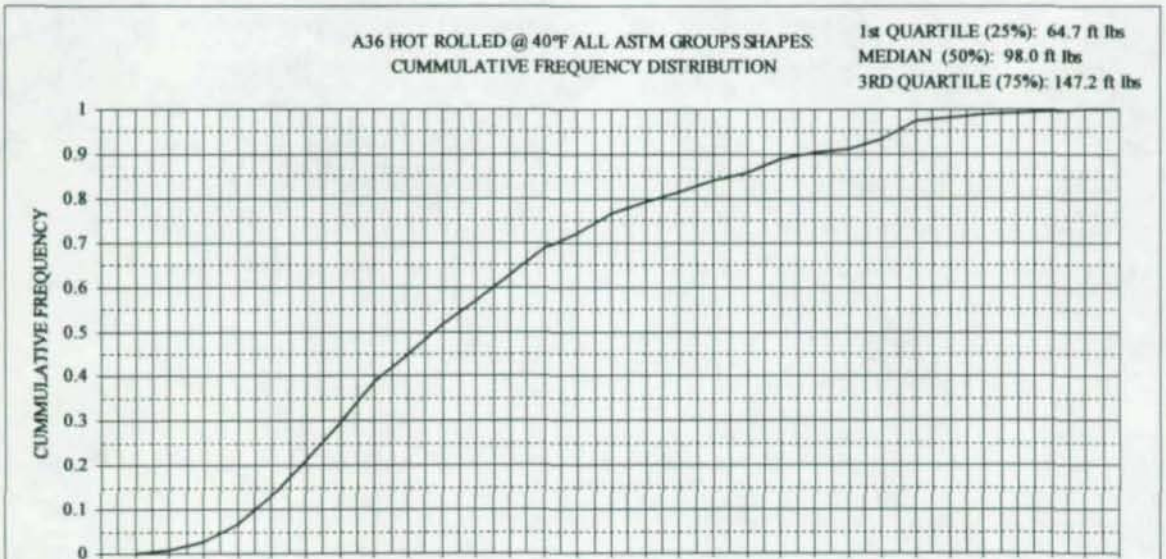

A36 HOT ROLLED @ 32°F ALL ASTM GROUPS SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 219
MODE: 0 %
MINIMUM: 0 %
MEAN: 8 %
MAXIMUM: 40.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE

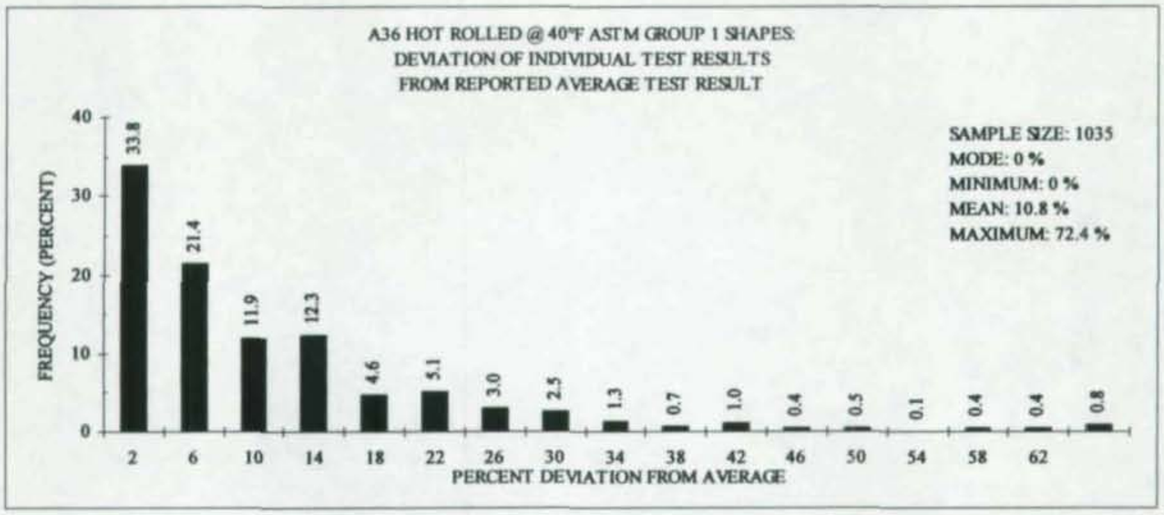

A36 HOT ROLLED @ 32°F ALL ASTM GROUPS SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 73
MODE: 130.3 ft lbs
MINIMUM: 91.0 ft lbs
MEAN: 149.7 ft lbs
MAXIMUM: 241.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

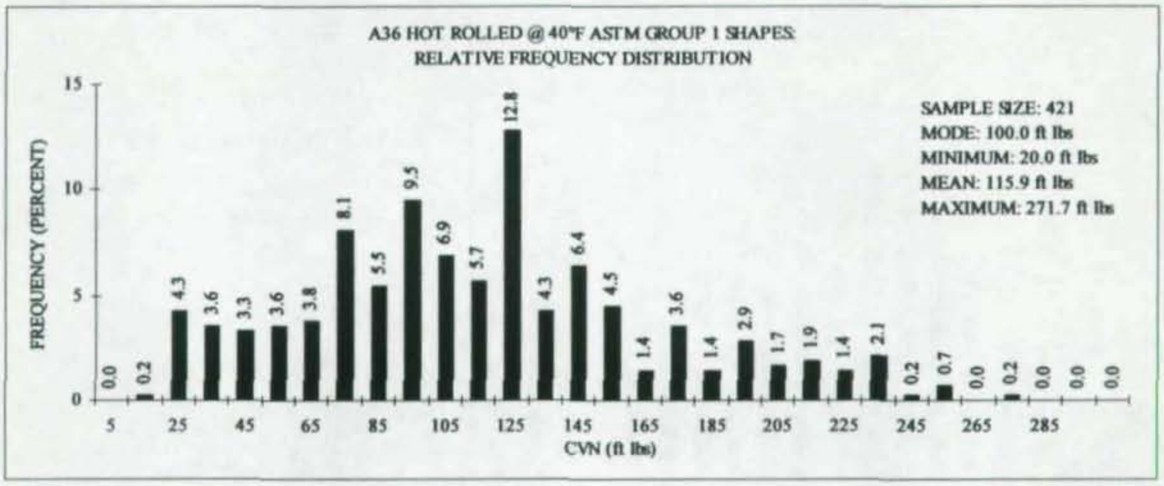

A36 HOT ROLLED @ 32°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 124.3 ft lbs
MEDIAN (50%): 145.3 ft lbs
3RD QUARTILE (75%): 169.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

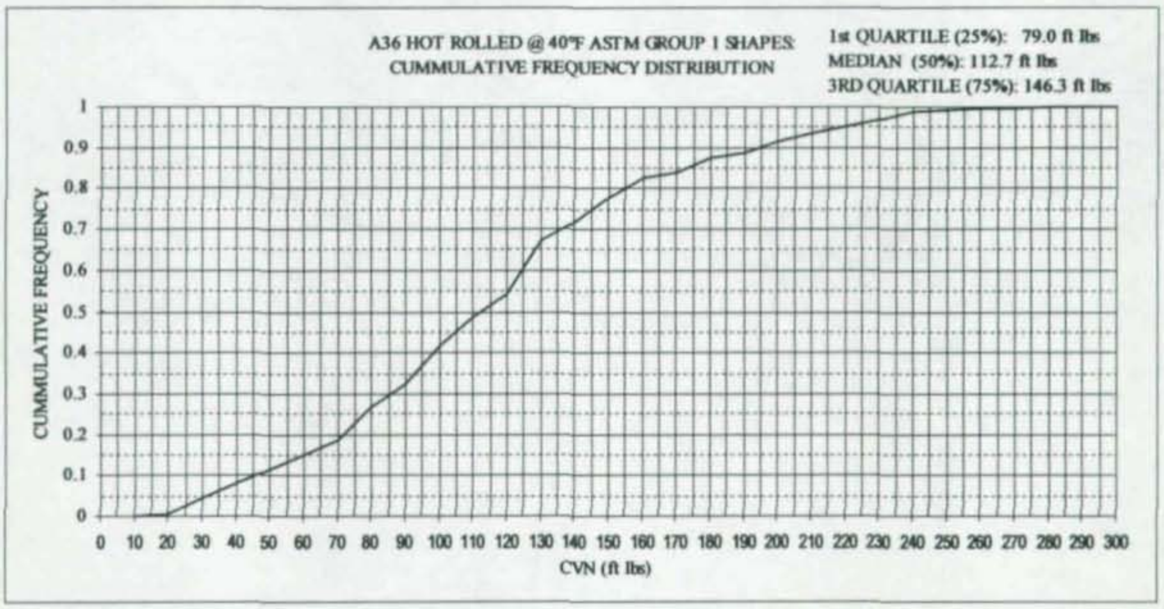

A36 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 5736
MODE: 0 %
MINIMUM: 0 %
MEAN: 11.6 %
MAXIMUM: 123.3 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
32.9
19.2
14.3
9.1
6.4
4.1
4.0
2.6
1.8
1.4
1.0
0.6
0.8
0.4
0.4
0.3
0.6

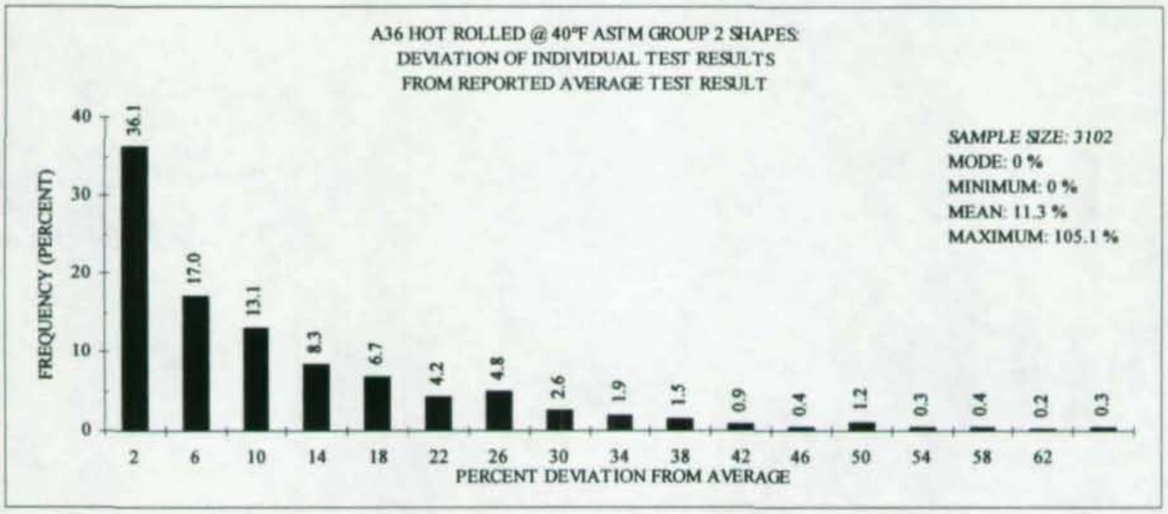

A36 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 2011
MODE: 66 ft lbs
MINIMUM: 15.7 ft lbs
MEAN: 111.8 ft lbs
MAXIMUM: 286.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

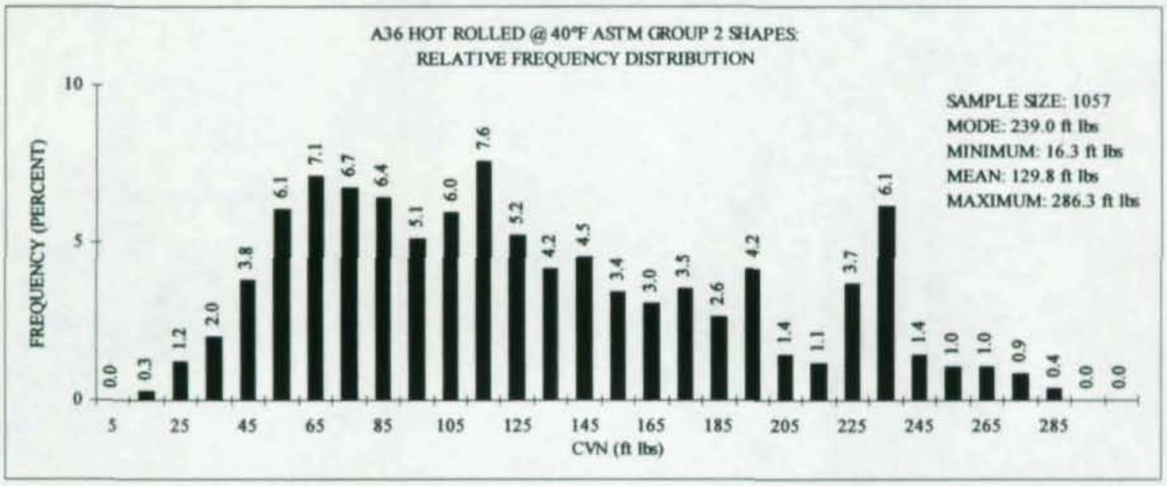

A36 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 64.7 ft lbs
MEDIAN (50%): 98.0 ft lbs
3RD QUARTILE (75%): 147.2 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

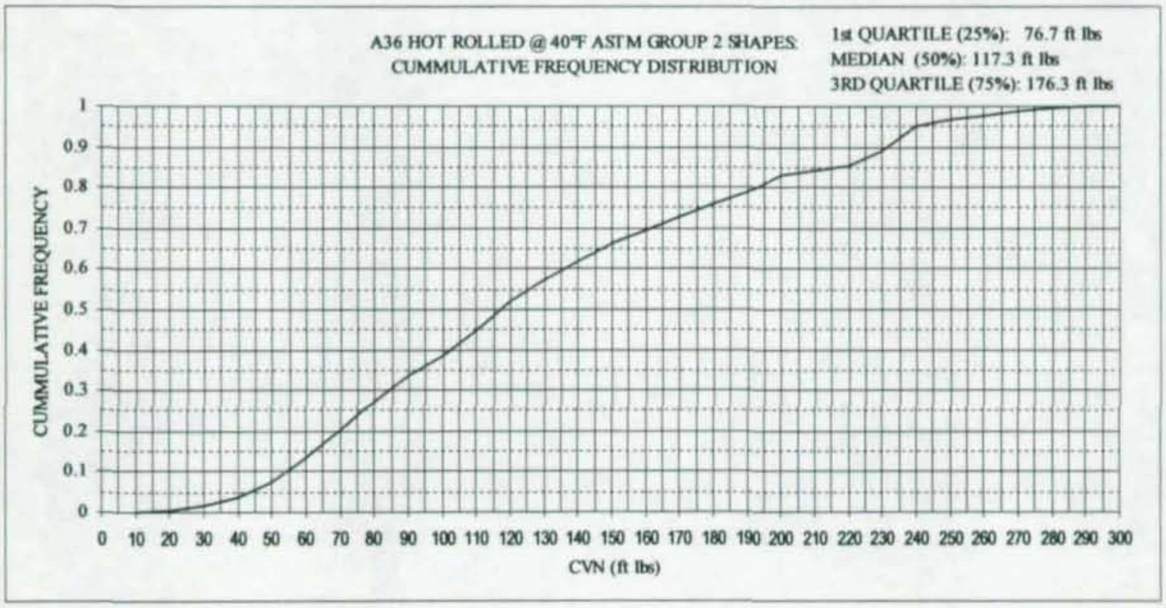

A36 HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 1035
MODE: 0 %
MINIMUM: 0 %
MEAN: 10.8 %
MAXIMUM: 72.4 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
33.8
21.4
11.9
12.3
4.6
5.1
3.0
2.5
1.3
0.7
1.0
0.4
0.5
0.1
0.4
0.4
0.8

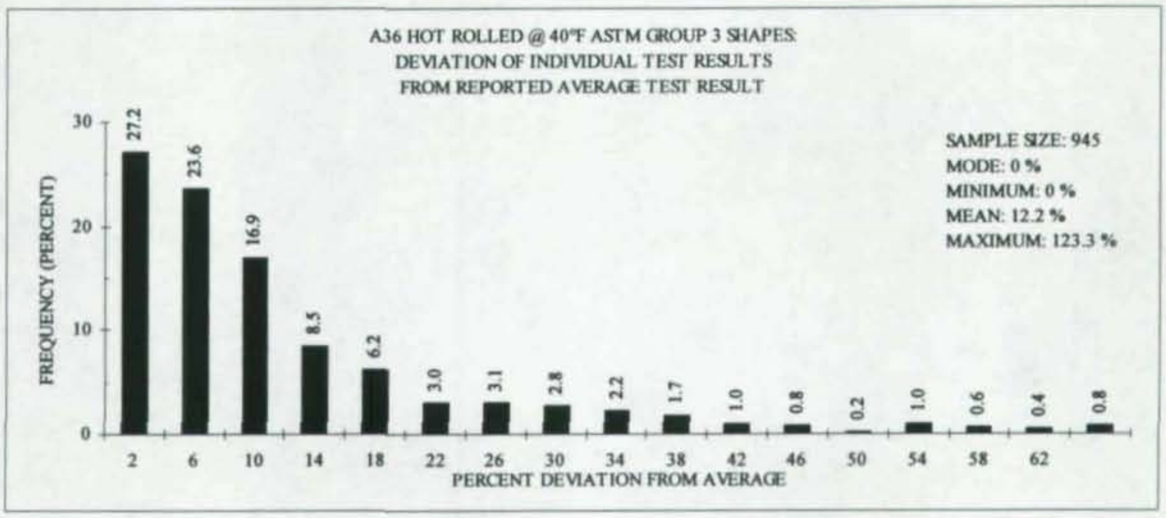

A36 HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 421
MODE: 100.0 ft lbs
MINIMUM: 20.0 ft lbs
MEAN: 115.9 ft lbs
MAXIMUM: 271.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)
0.0
0.2
4.3
3.6
3.3
3.6
3.8
8.1
5.5
9.5
6.9
5.7
12.8
4.3
6.4
4.5
1.4
3.6
1.4
2.9
1.7
1.9
1.4
2.1
0.2
0.7
0.0
0.2
0.0
0.0
0.0

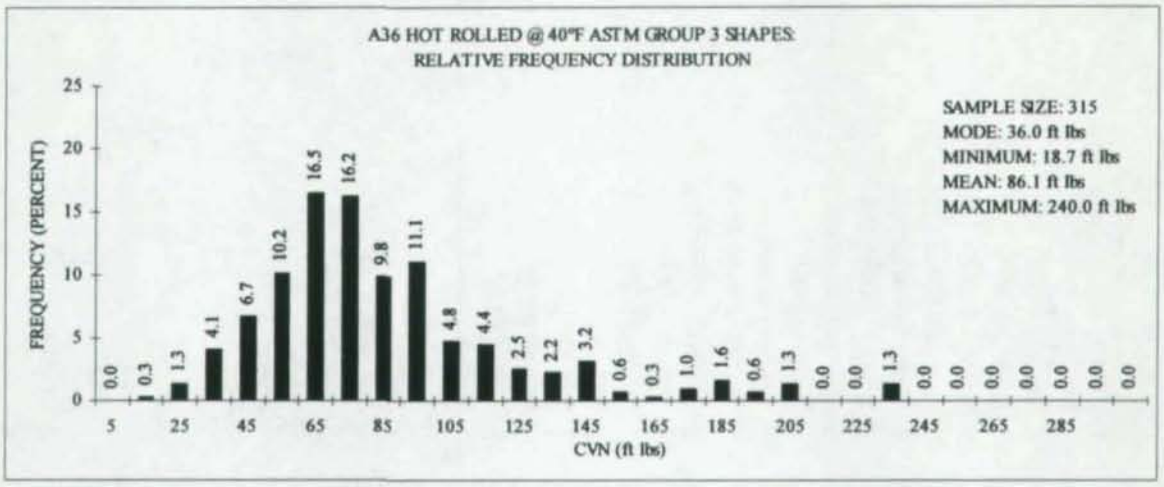

A36 HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 79.0 ft lbs
MEDIAN (50%): 112.7 ft lbs
3RD QUARTILE (75%): 146.3 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

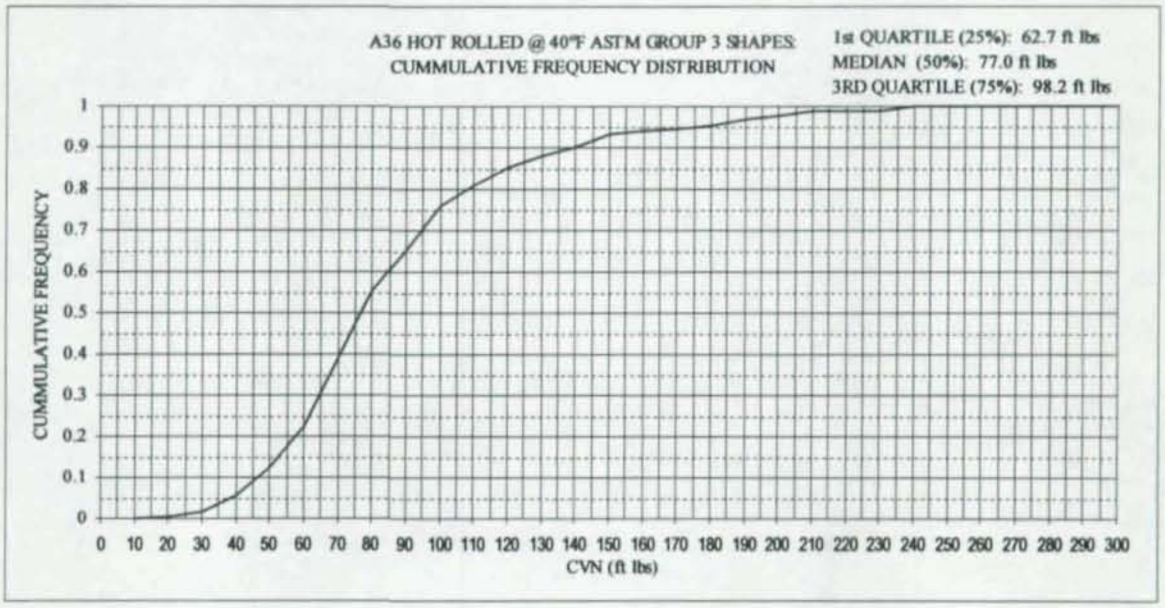

A36 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 3102
MODE: 0 %
MINIMUM: 0 %
MEAN: 11.3 %
MAXIMUM: 105.1 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
36.1
17.0
13.1
8.3
6.7
4.2
4.8
2.6
1.9
1.5
0.9
0.4
1.2
0.3
0.4
0.2
0.3

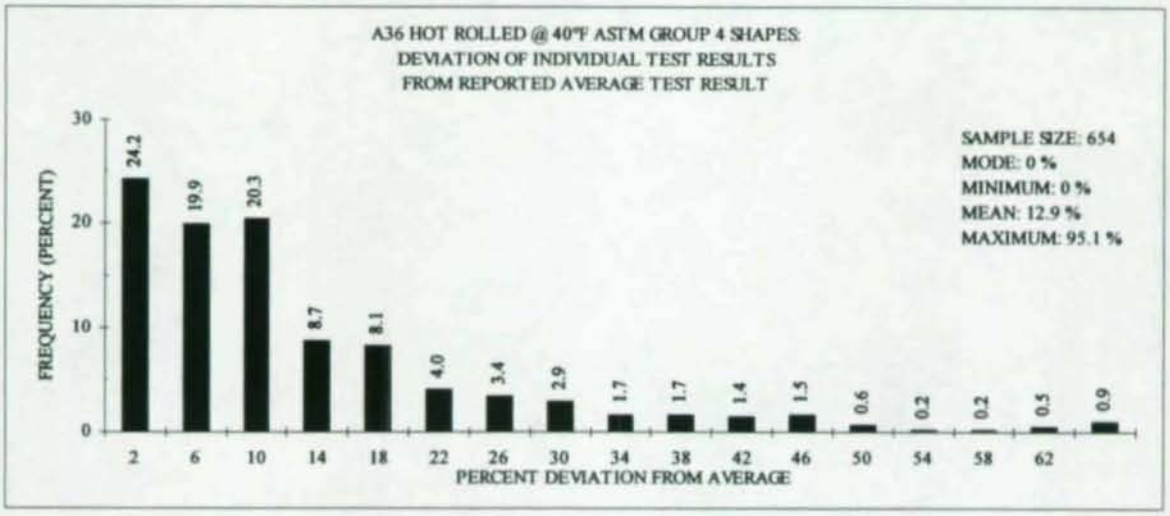

A36 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 1057
MODE: 239.0 ft lbs
MINIMUM: 16.3 ft lbs
MEAN: 129.8 ft lbs
MAXIMUM: 286.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)
0.0
0.3
1.2
2.0
3.8
6.1
7.1
6.7
6.4
5.1
6.0
7.6
5.2
4.2
4.5
3.4
3.0
3.5
2.6
4.2
1.4
1.1
3.7
6.1
1.4
1.0
1.0
0.9
0.4
0.0
0.0

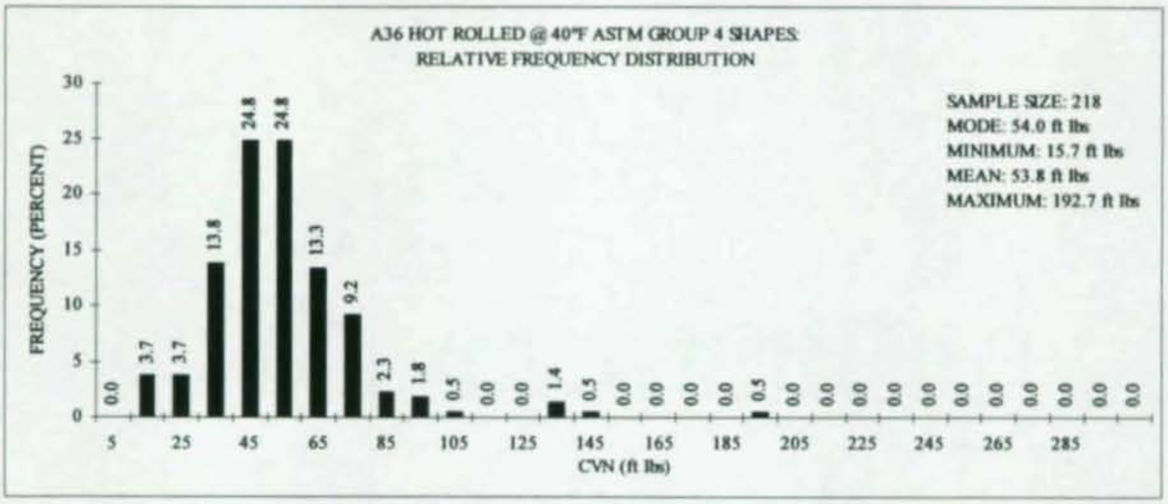

A36 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 76.7 ft lbs
MEDIAN (50%): 117.3 ft lbs
3RD QUARTILE (75%): 176.3 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

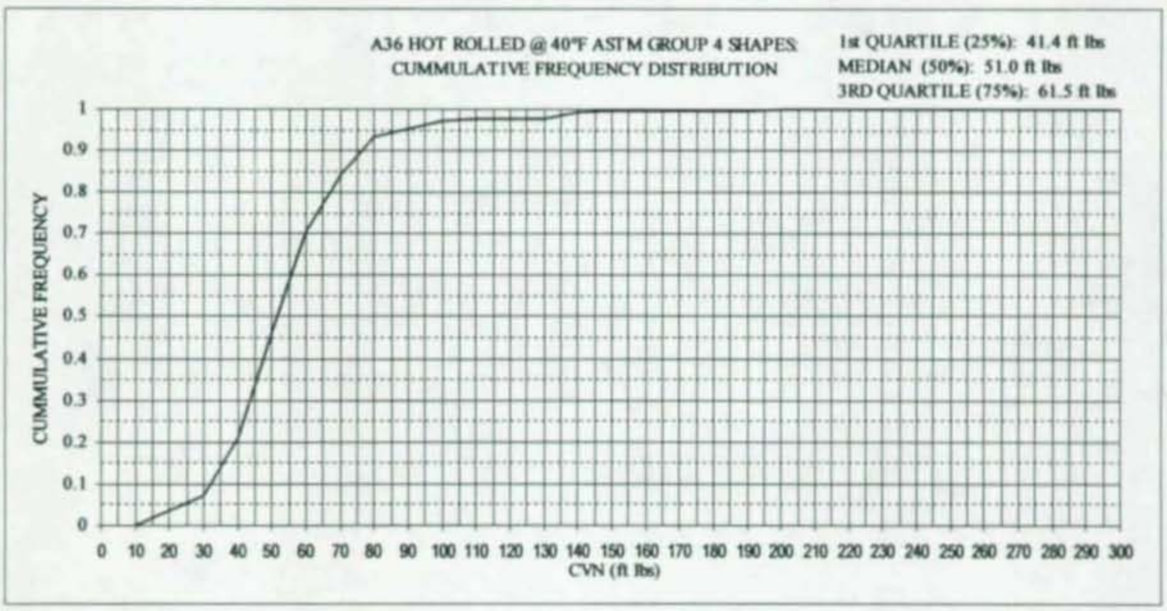

A36 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 945
MODE: 0 %
MINIMUM: 0 %
MEAN: 12.2 %
MAXIMUM: 123.3 %
FREQUENCY (PERCENT)
27.2
23.6
16.9
8.5
6.2
3.0
3.1
2.8
2.2
1.7
1.0
0.8
0.2
1.0
0.6
0.4
0.8
PERCENT DEVIATION FROM AVERAGE

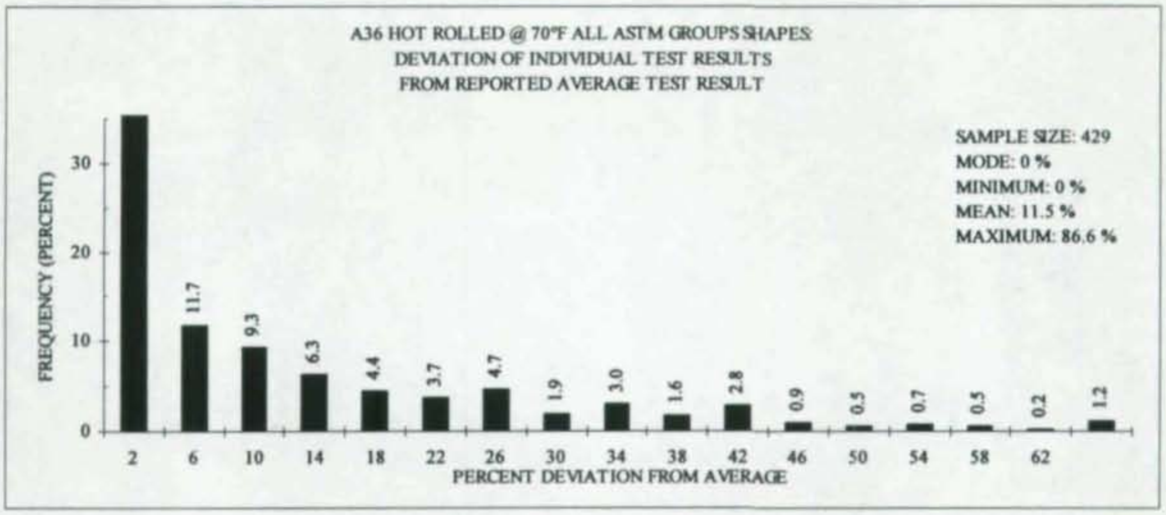

A36 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 315
MODE: 36.0 ft lbs
MINIMUM: 18.7 ft lbs
MEAN: 86.1 ft lbs
MAXIMUM: 240.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

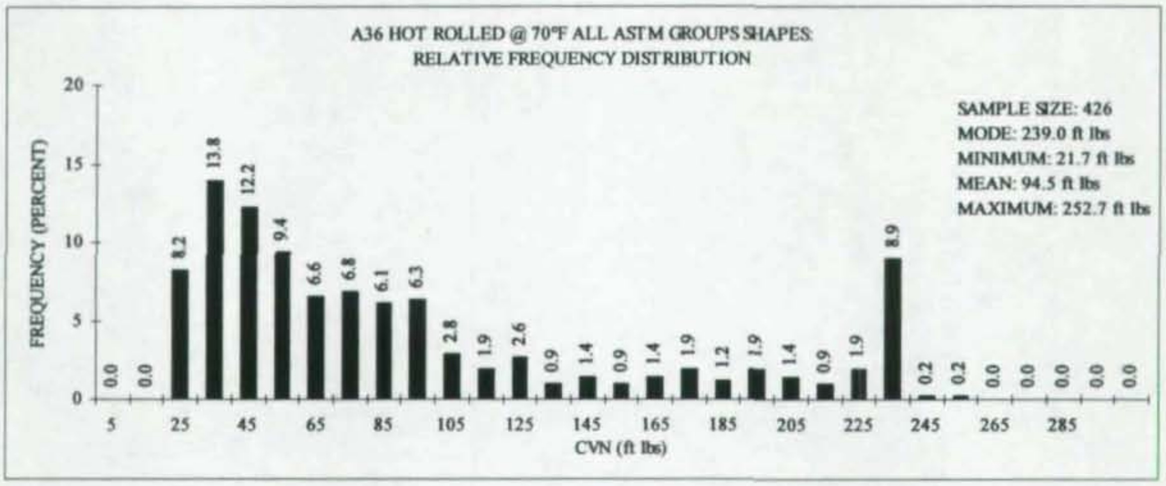

A36 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 62.7 ft lbs
MEDIAN (50%): 77.0 ft lbs
3RD QUARTILE (75%): 98.2 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

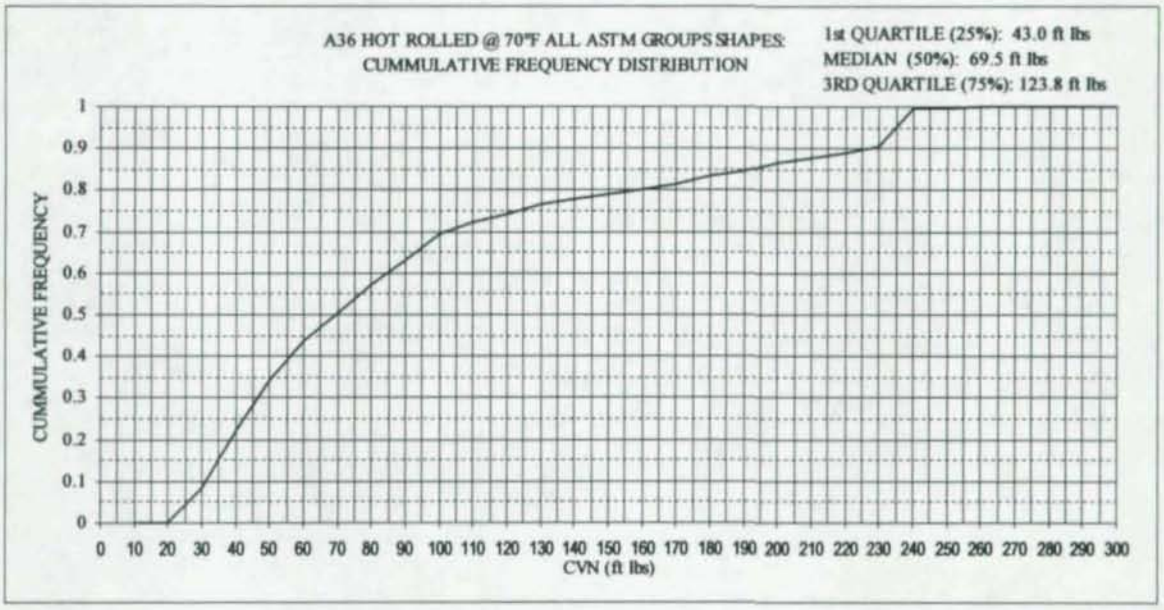

A36 HOT ROLLED @ 40°F ASTM GROUP 4 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 654
MODE: 0 %
MINIMUM: 0 %
MEAN: 12.9 %
MAXIMUM: 95.1 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE

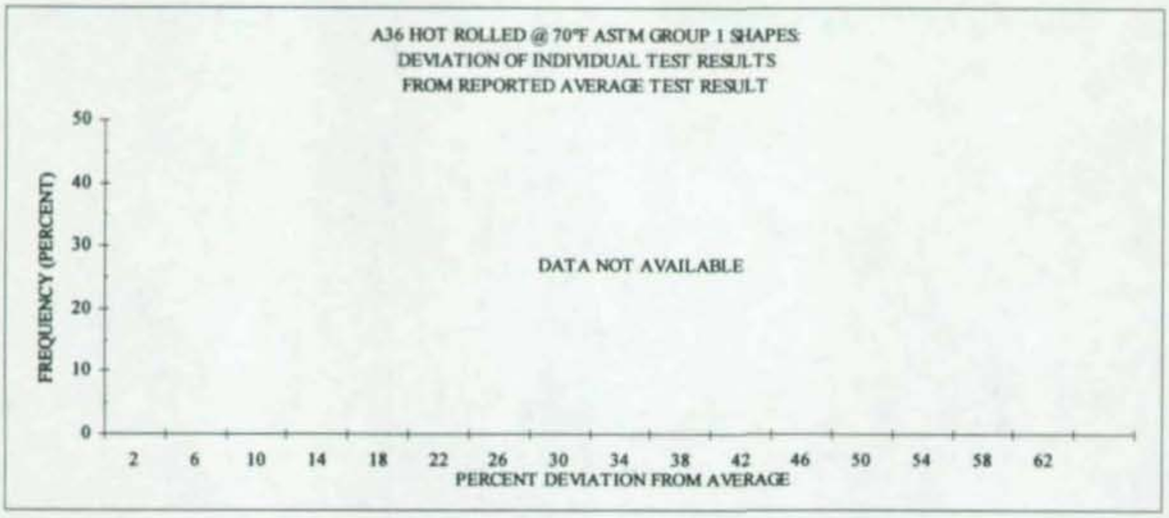

A36 HOT ROLLED @ 40°F ASTM GROUP 4 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 218
MODE: 54.0 ft lbs
MINIMUM: 15.7 ft lbs
MEAN: 53.8 ft lbs
MAXIMUM: 192.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

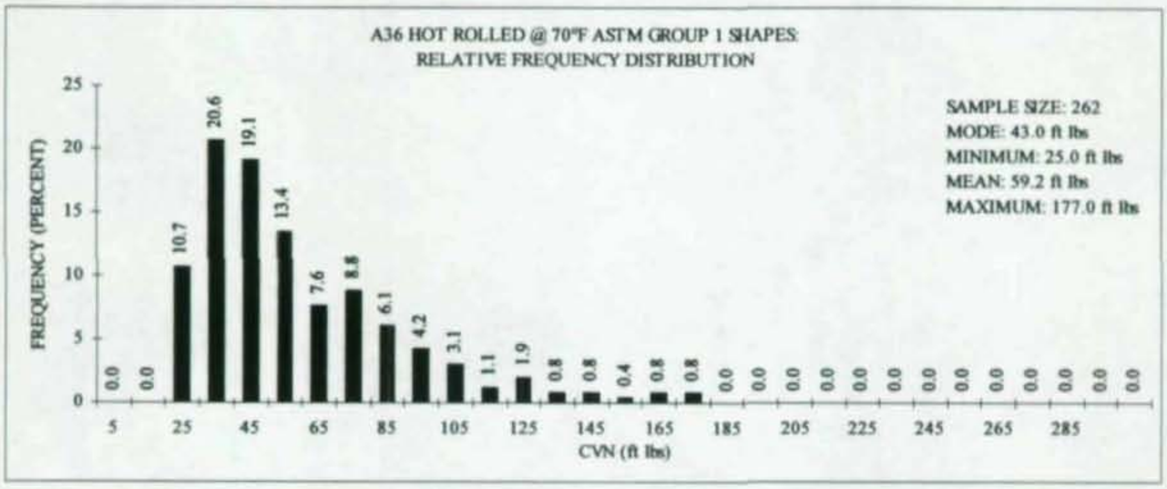

A36 HOT ROLLED @ 40°F ASTM GROUP 4 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 41.4 ft lbs
MEDIAN (50%): 51.0 ft lbs
3RD QUARTILE (75%): 61.5 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

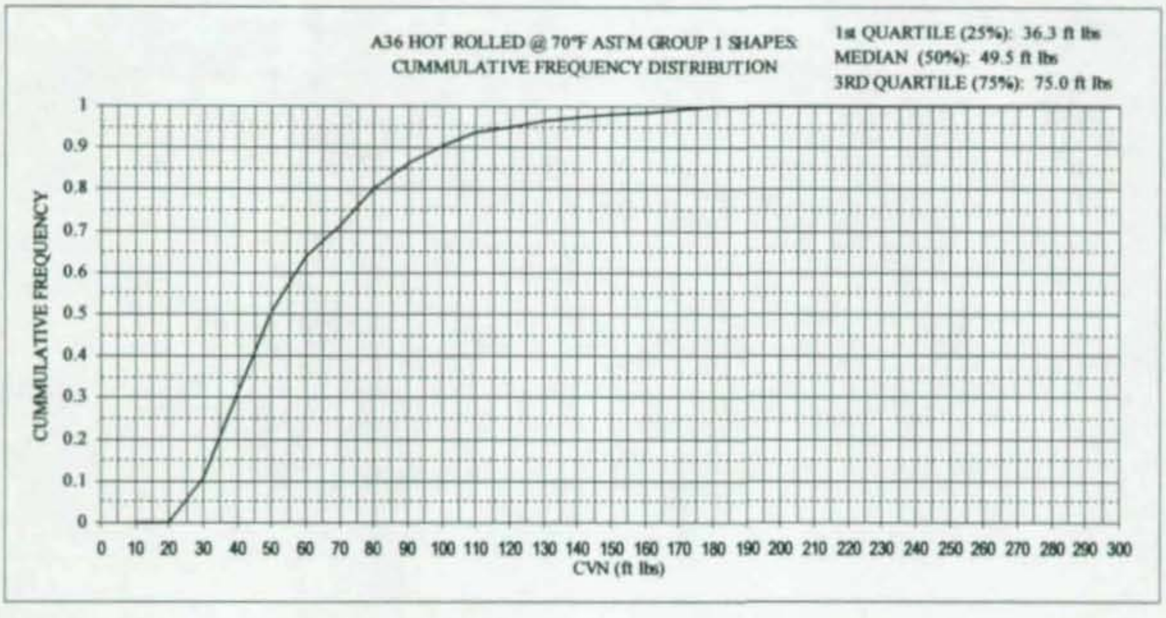

A36 HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 429
MODE: 0 %
MINIMUM: 0 %
MEAN: 11.5 %
MAXIMUM: 86.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE

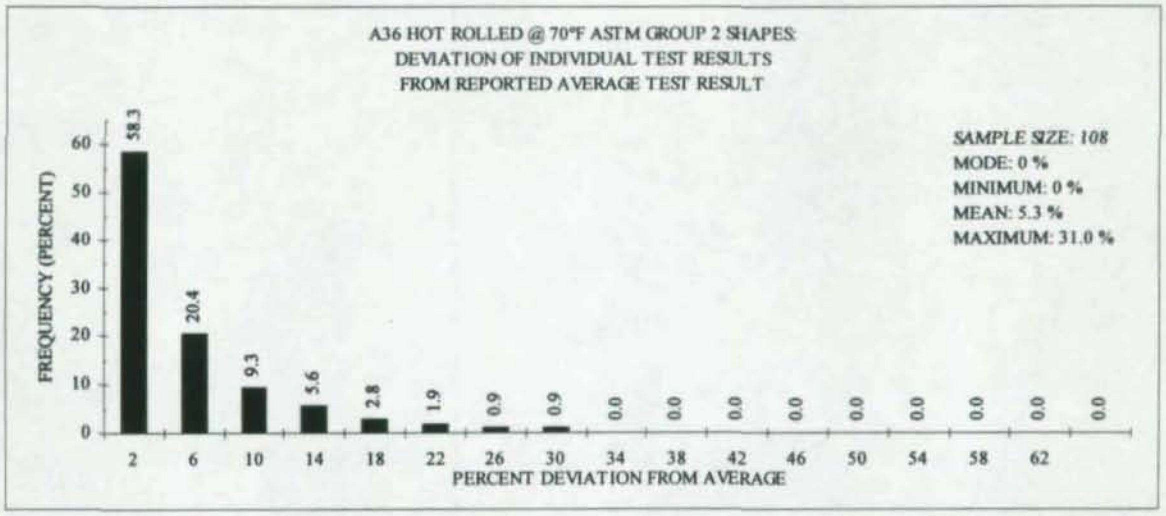

A36 HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 426
MODE: 239.0 ft lbs
MINIMUM: 21.7 ft lbs
MEAN: 94.5 ft lbs
MAXIMUM: 252.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

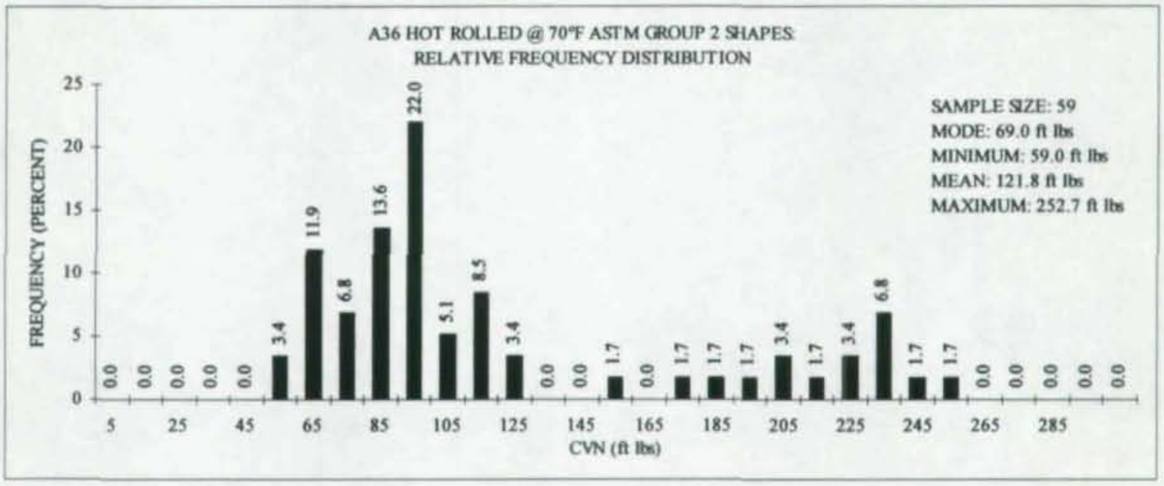

A36 HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 43.0 ft lbs
MEDIAN (50%): 69.5 ft lbs
3RD QUARTILE (75%): 123.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

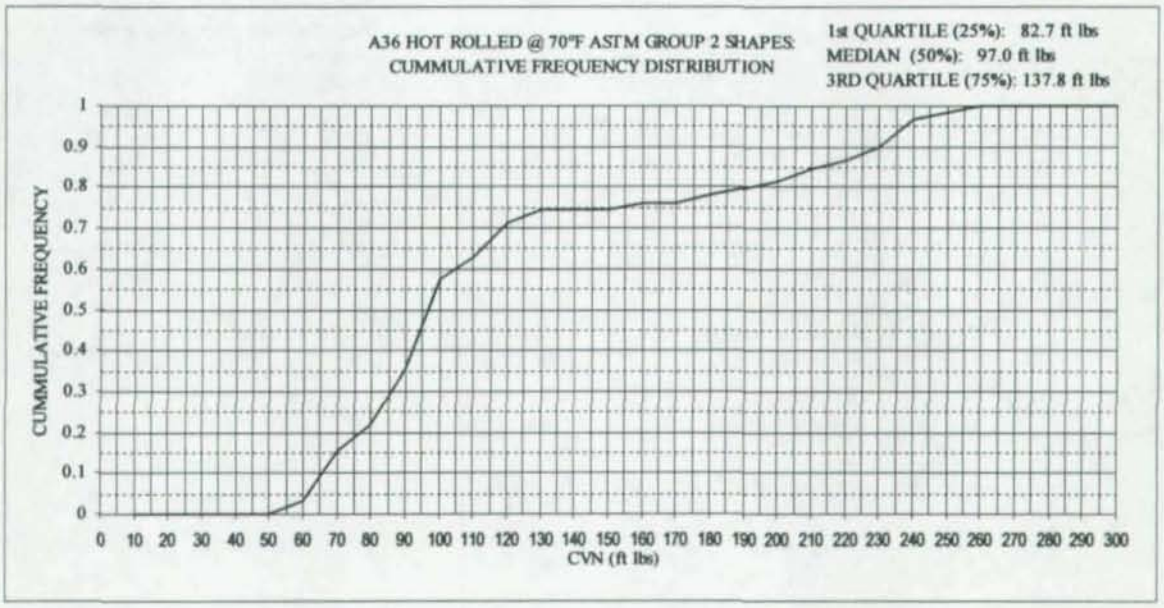

A36 HOT ROLLED @ 70°F ASTM GROUP 1 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
FREQUENCY (PERCENT)
DATA NOT AVAILABLE
PERCENT DEVIATION FROM AVERAGE

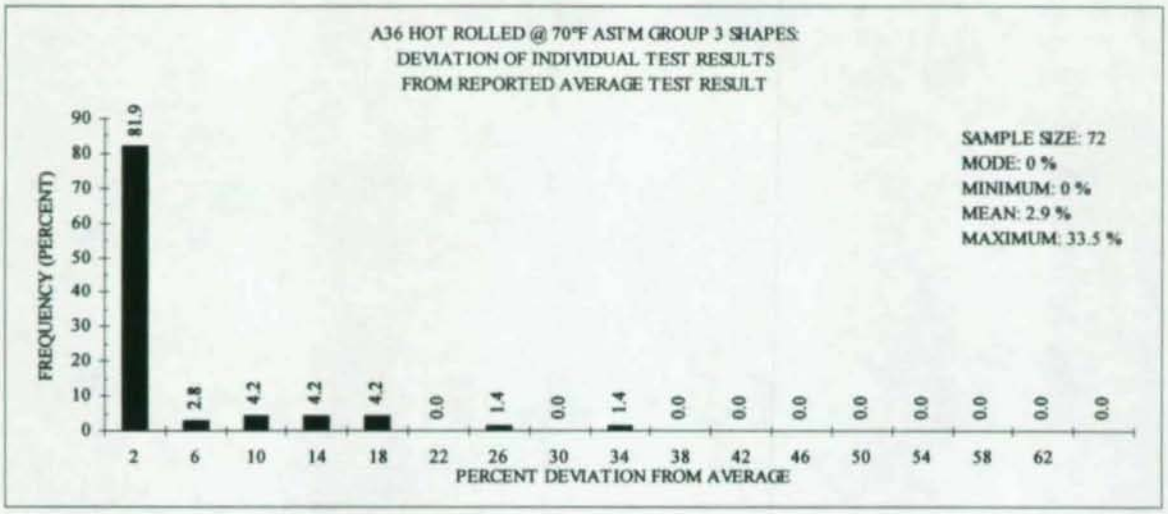

A36 HOT ROLLED @ 70°F ASTM GROUP 1 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 262
MODE: 43.0 ft lbs
MINIMUM: 25.0 ft lbs
MEAN: 59.2 ft lbs
MAXIMUM: 177.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

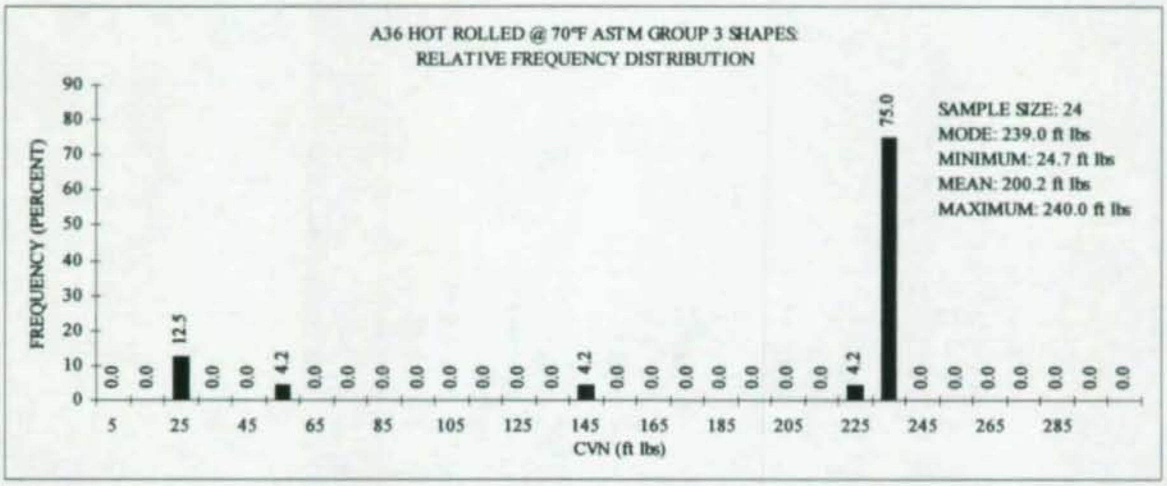

A36 HOT ROLLED @ 70°F ASTM GROUP 1 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 36.3 ft lbs
MEDIAN (50%): 49.5 ft lbs
3RD QUARTILE (75%): 75.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

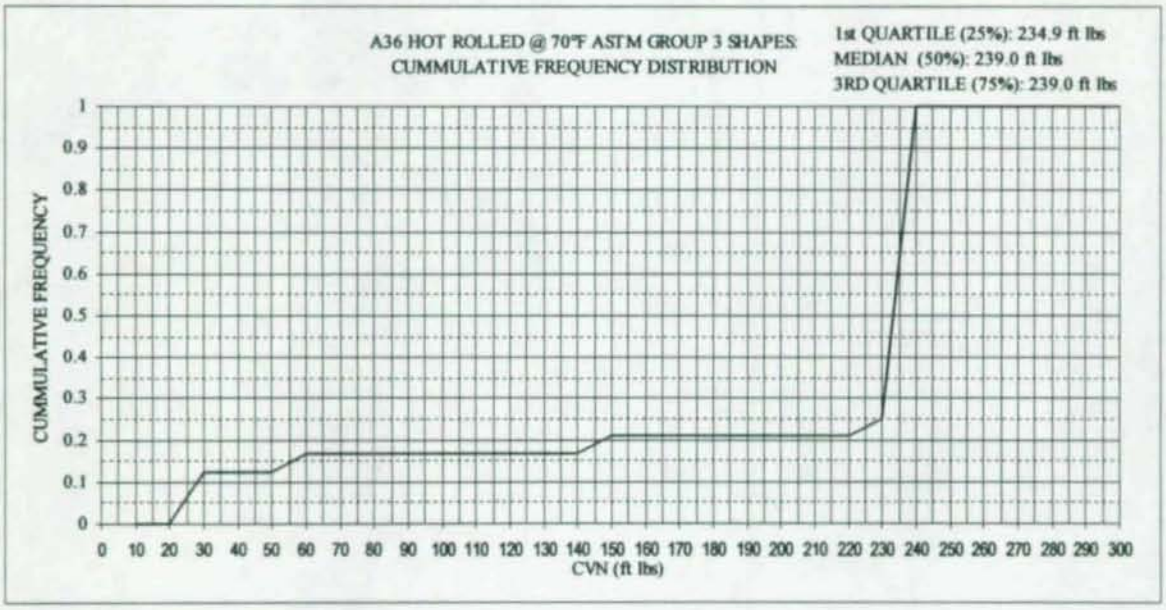

A36 HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 108
MODE: 0 %
MINIMUM: 0 %
MEAN: 5.3 %
MAXIMUM: 31.0 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
58.3
20.4
9.3
5.6
2.8
1.9
0.9
0.9
0.0

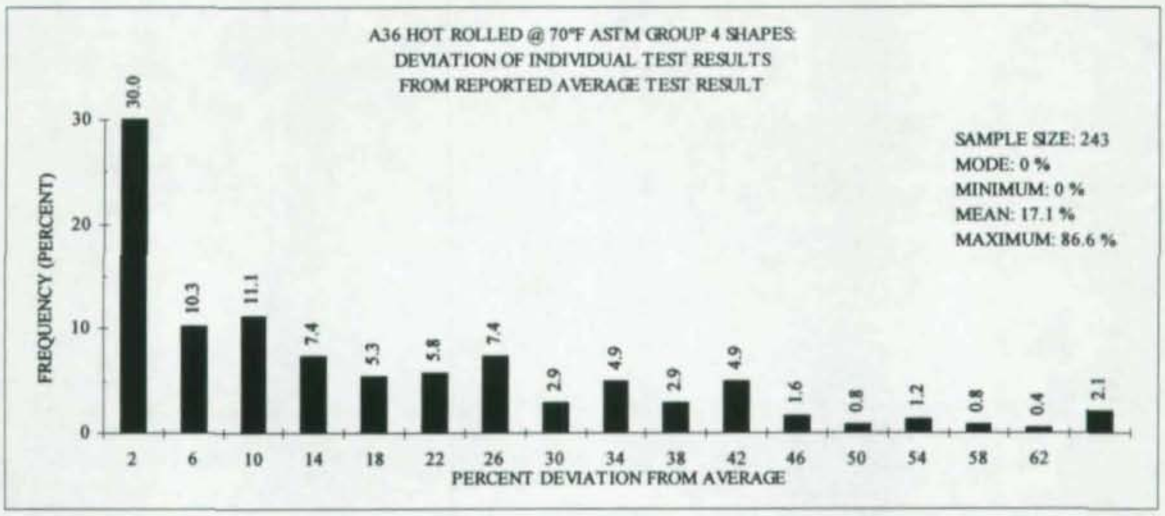

A36 HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 59
MODE: 69.0 ft lbs
MINIMUM: 59.0 ft lbs
MEAN: 121.8 ft lbs
MAXIMUM: 252.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

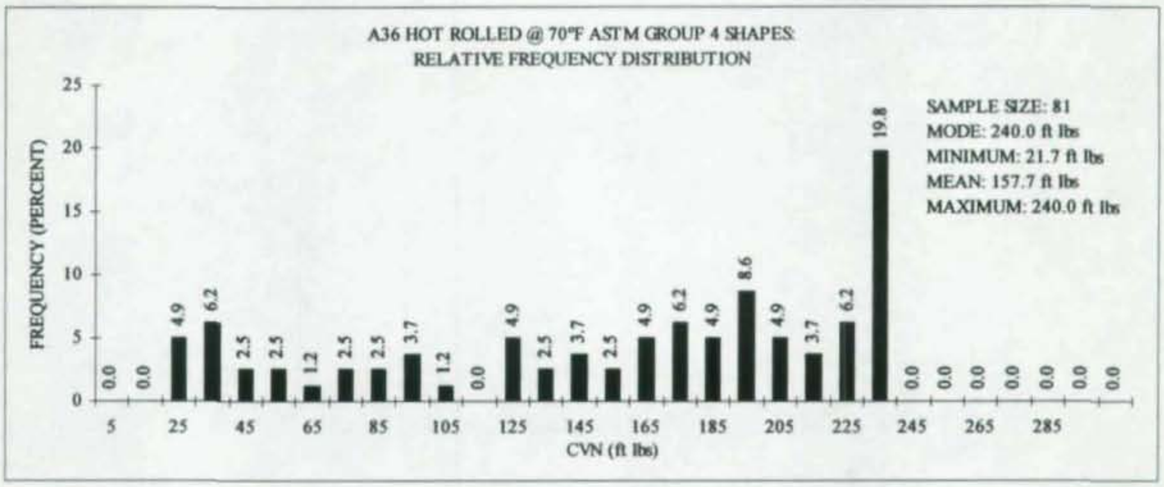

A36 HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 82.7 ft lbs
MEDIAN (50%): 97.0 ft lbs
3RD QUARTILE (75%): 137.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

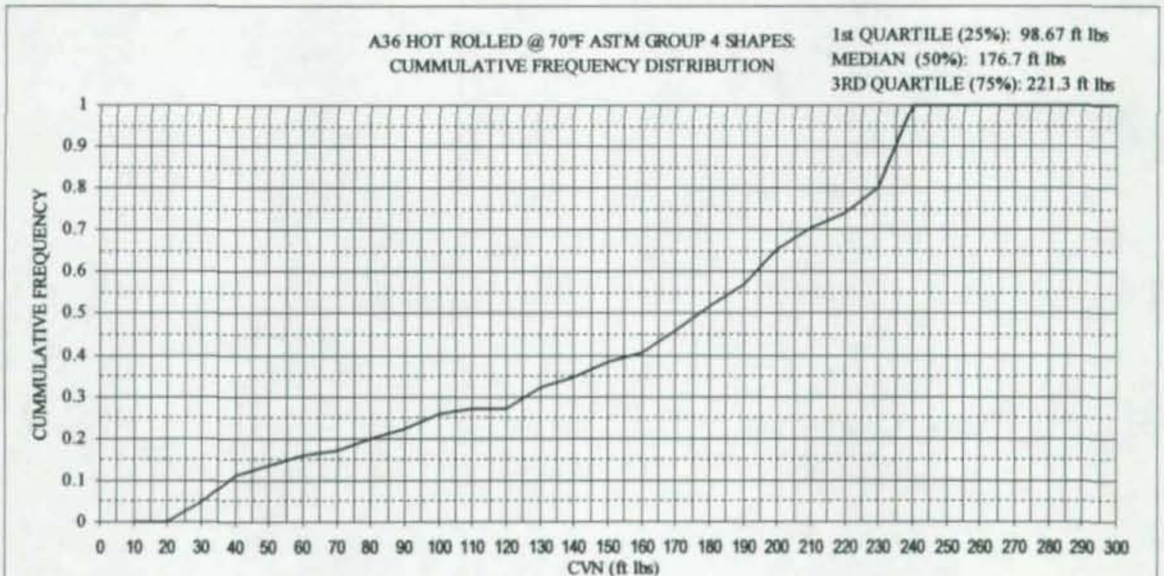

A36 HOT ROLLED @ 70°F ASTM GROUP 3 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 72
MODE: 0 %
MINIMUM: 0 %
MEAN: 2.9 %
MAXIMUM: 33.5 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE


A36 HOT ROLLED @ 70°F ASTM GROUP 3 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 24
MODE: 239.0 ft lbs
MINIMUM: 24.7 ft lbs
MEAN: 200.2 ft lbs
MAXIMUM: 240.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

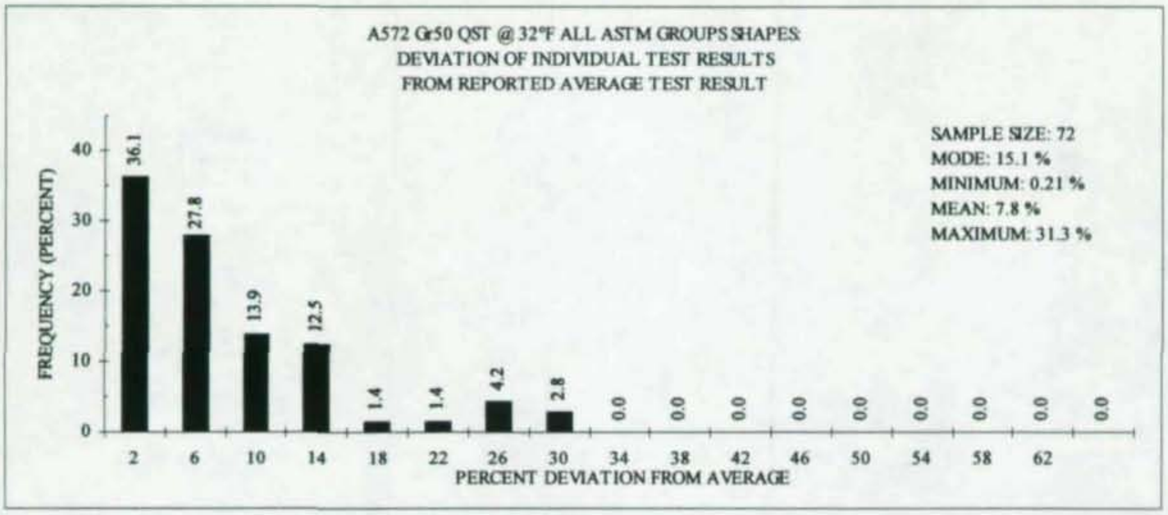

A36 HOT ROLLED @ 70°F ASTM GROUP 3 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 234.9 ft lbs
MEDIAN (50%): 239.0 ft lbs
3RD QUARTILE (75%): 239.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

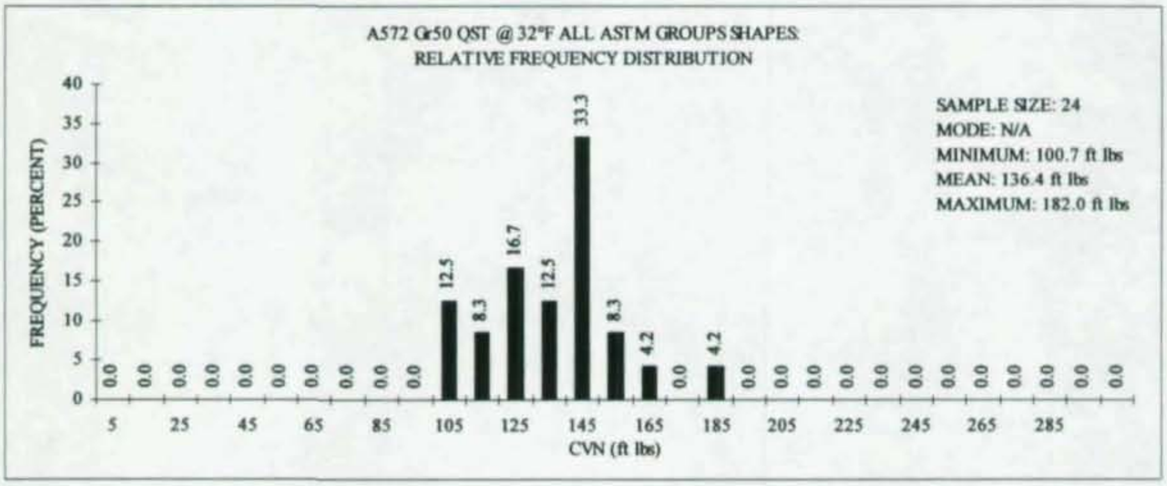

A36 HOT ROLLED @ 70°F ASTM GROUP 4 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 243
MODE: 0 %
MINIMUM: 0 %
MEAN: 17.1 %
MAXIMUM: 86.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
30.0
10.3
11.1
7.4
5.3
5.8
7.4
2.9
4.9
2.9
4.9
1.6
0.8
1.2
0.8
0.4
2.1
2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62
0 10 20 30

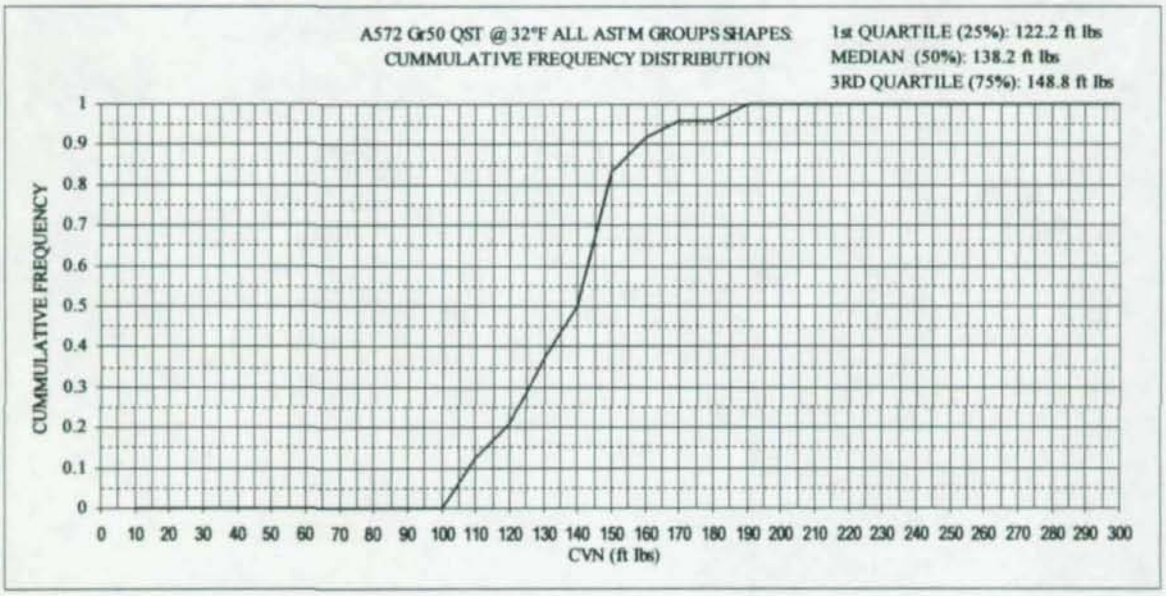

A36 HOT ROLLED @ 70°F ASTM GROUP 4 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 81
MODE: 240.0 ft lbs
MINIMUM: 21.7 ft lbs
MEAN: 157.7 ft lbs
MAXIMUM: 240.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)
0.0 0.0 4.9 6.2 2.5 2.5 1.2 2.5 2.5 3.7 1.2 0.0 4.9 2.5 3.7 2.5 4.9 6.2 4.9 8.6 4.9 3.7 6.2 19.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0
5 25 45 65 85 105 125 145 165 185 205 225 245 265 285
0 5 10 15 20 25

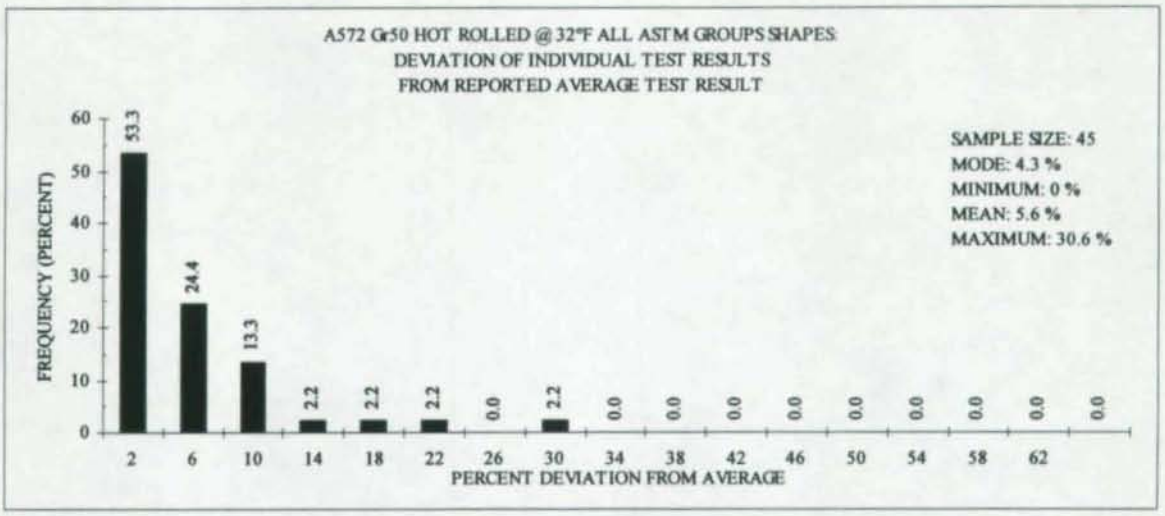

A36 HOT ROLLED @ 70°F ASTM GROUP 4 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 98.67 ft lbs
MEDIAN (50%): 176.7 ft lbs
3RD QUARTILE (75%): 221.3 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300

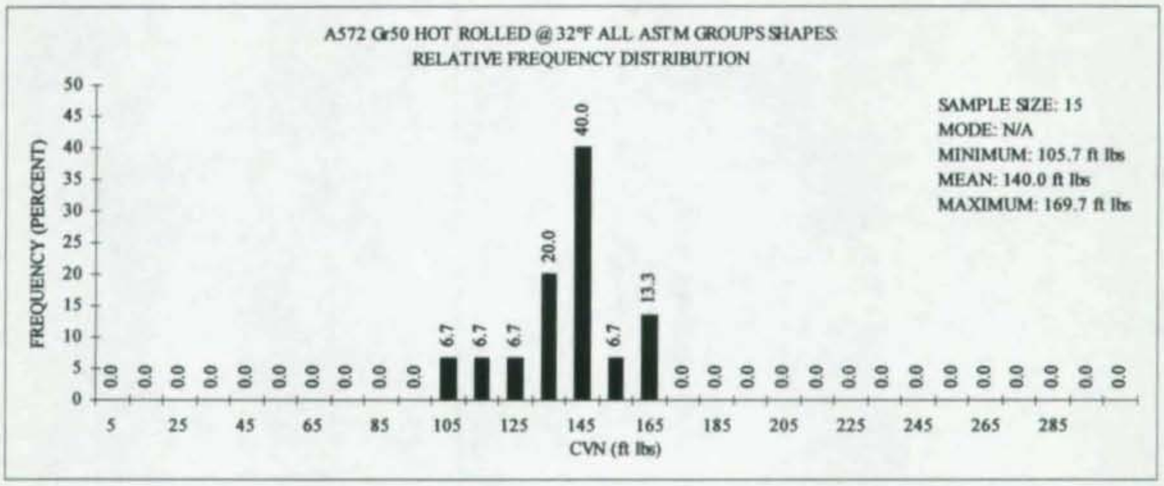
A572 Gr50 STEEL

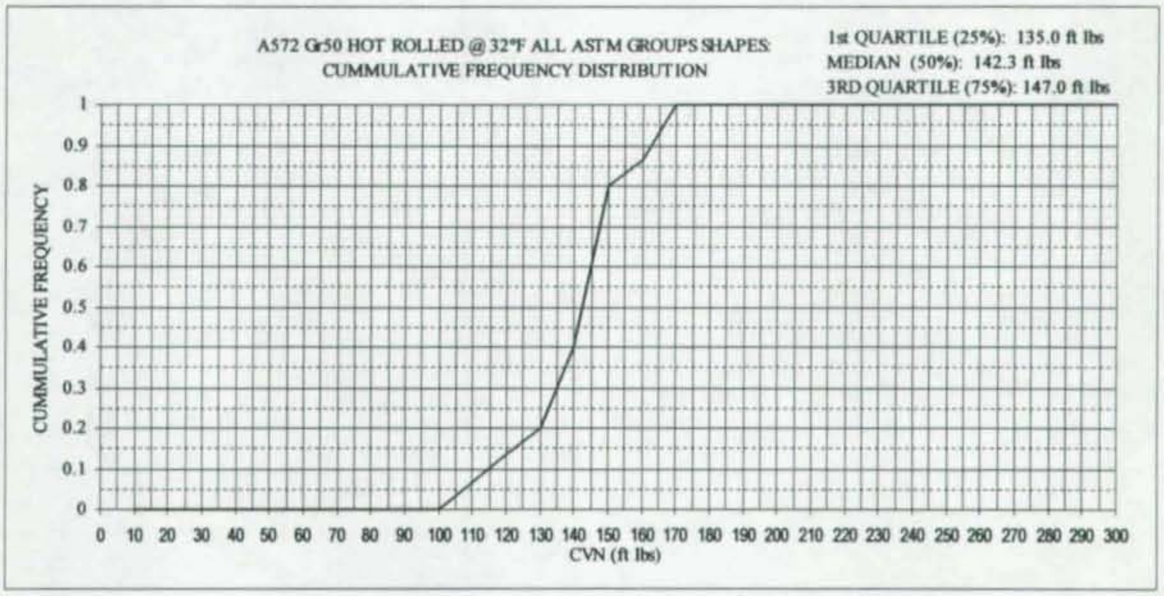

A572 Gr50 QST @ 32°F ALL ASTM GROUPS SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 72
MODE: 15.1 %
MINIMUM: 0.21 %
MEAN: 7.8 %
MAXIMUM: 31.3 %
FREQUENCY (PERCENT)
36.1
27.8
13.9
12.5
1.4
1.4
4.2
2.8
0.0
PERCENT DEVIATION FROM AVERAGE

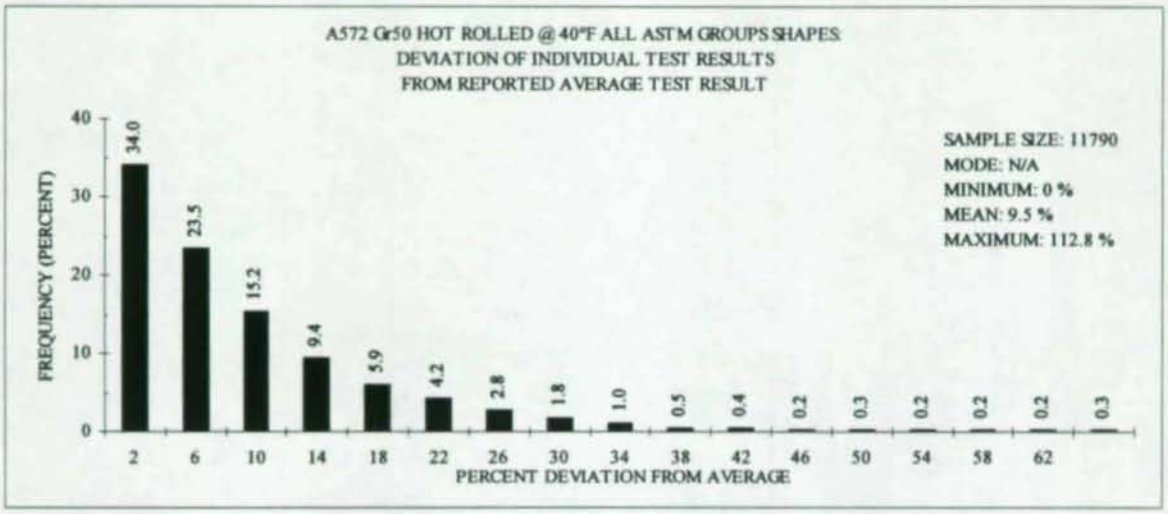

A572 Gr50 QST @ 32°F ALL ASTM GROUPS SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 24
MODE: N/A
MINIMUM: 100.7 ft lbs
MEAN: 136.4 ft lbs
MAXIMUM: 182.0 ft lbs
FREQUENCY (PERCENT)
12.5
8.3
16.7
12.5
33.3
8.3
4.2
4.2
0.0
CVN (ft lbs)

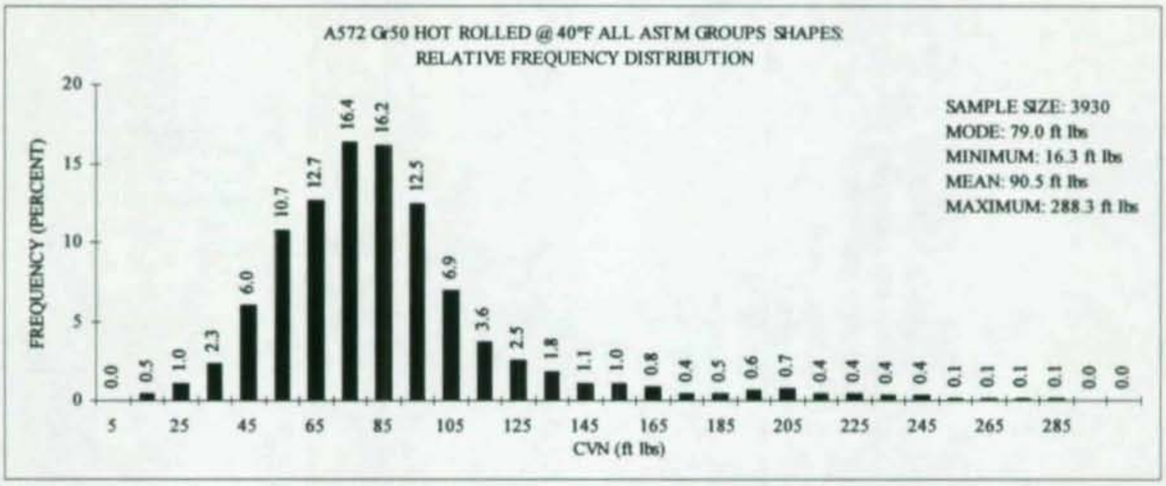

A572 Gr50 QST @ 32°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 122.2 ft lbs
MEDIAN (50%): 138.2 ft lbs
3RD QUARTILE (75%): 148.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

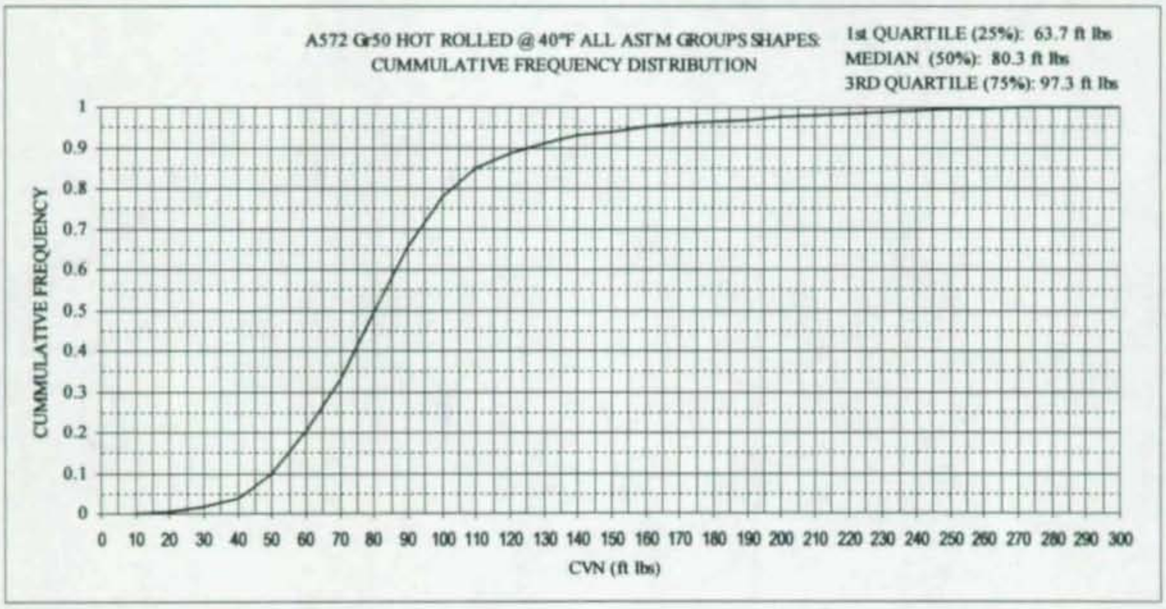

A572 Gr50 HOT ROLLED @ 32°F ALL ASTM GROUPS SHAPES
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 45
MODE: 4.3 %
MINIMUM: 0 %
MEAN: 5.6 %
MAXIMUM: 30.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE

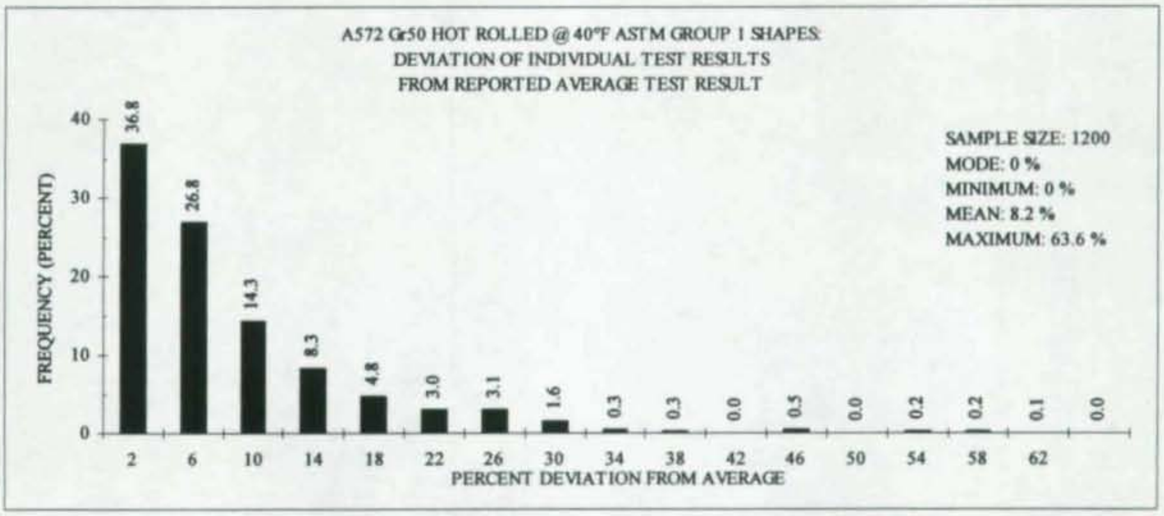

A572 Gr50 HOT ROLLED @ 32°F ALL ASTM GROUPS SHAPES
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 15
MODE: N/A
MINIMUM: 105.7 ft lbs
MEAN: 140.0 ft lbs
MAXIMUM: 169.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

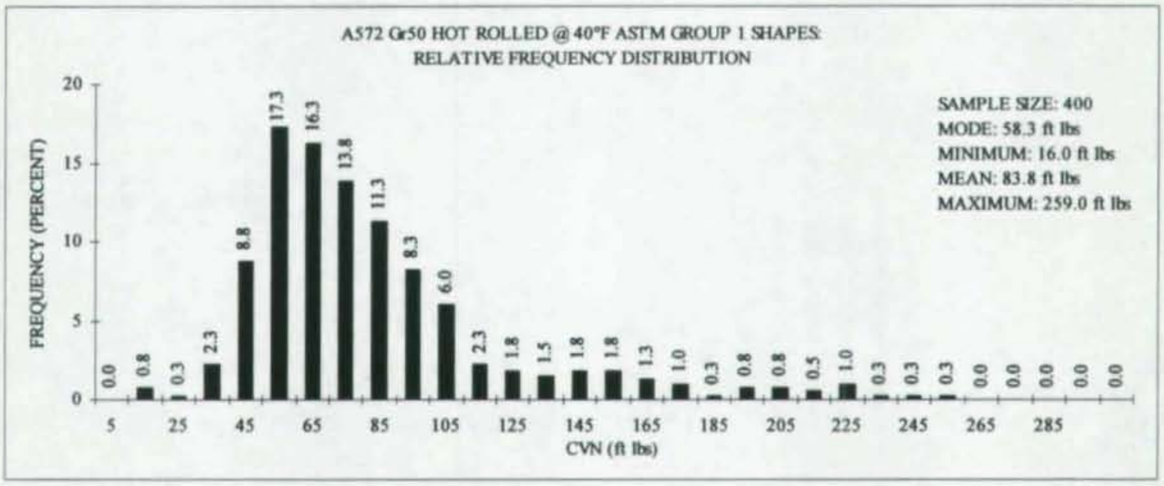

A572 Gr50 HOT ROLLED @ 32°F ALL ASTM GROUPS SHAPES
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 135.0 ft lbs
MEDIAN (50%): 142.3 ft lbs
3RD QUARTILE (75%): 147.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

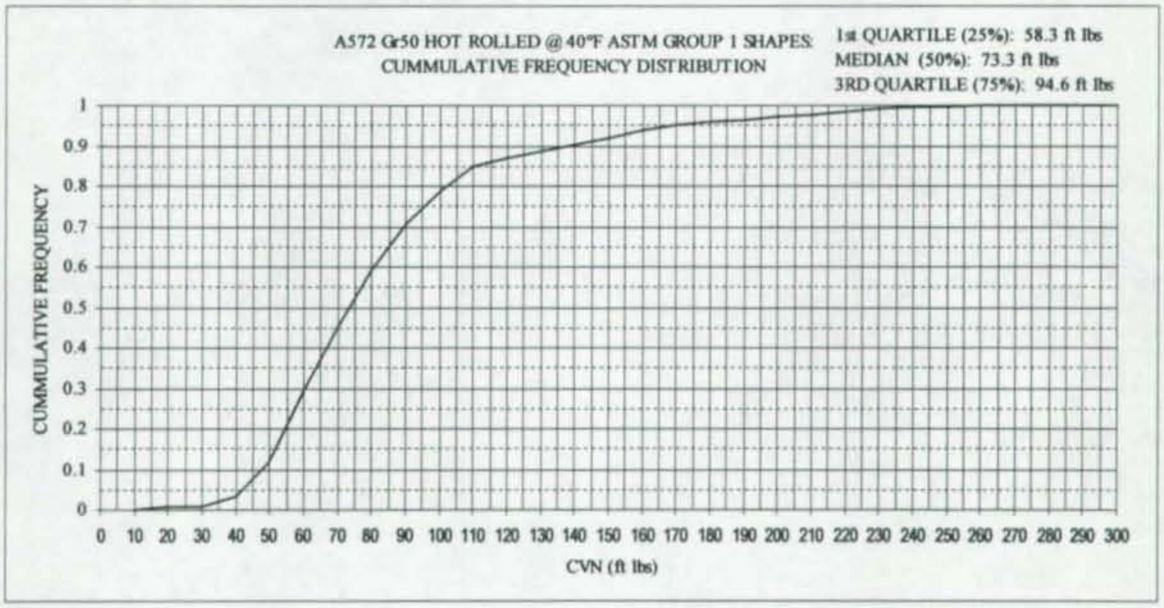

A572 Gr50 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 11790
MODE: N/A
MINIMUM: 0 %
MEAN: 9.5 %
MAXIMUM: 112.8 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
34.0
23.5
15.2
9.4
5.9
4.2
2.8
1.8
1.0
0.5
0.4
0.2
0.3
0.2
0.2
0.2
0.3

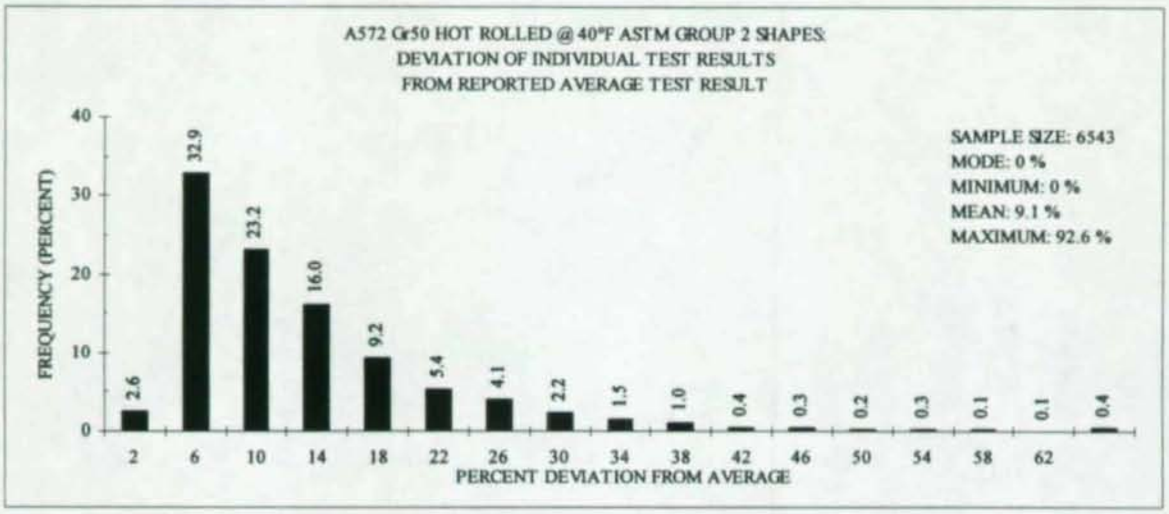

A572 Gr50 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 3930
MODE: 79.0 ft lbs
MINIMUM: 16.3 ft lbs
MEAN: 90.5 ft lbs
MAXIMUM: 288.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)
0.0
0.5
1.0
2.3
6.0
10.7
12.7
16.4
16.2
12.5
6.9
3.6
2.5
1.8
1.1
1.0
0.8
0.4
0.5
0.6
0.7
0.4
0.4
0.4
0.4
0.1
0.1
0.1
0.1
0.0
0.0

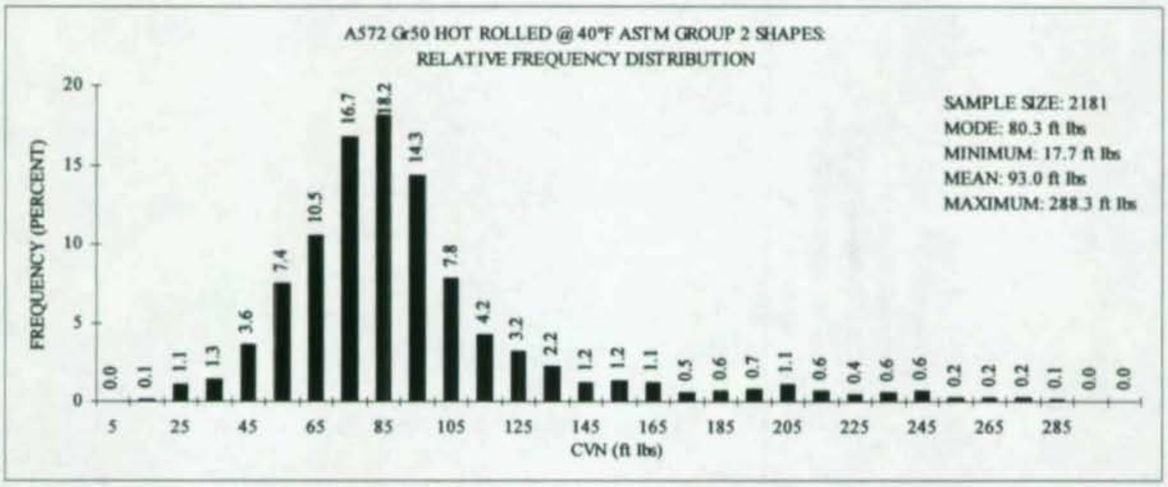

A572 Gr50 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 63.7 ft lbs
MEDIAN (50%): 80.3 ft lbs
3RD QUARTILE (75%): 97.3 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

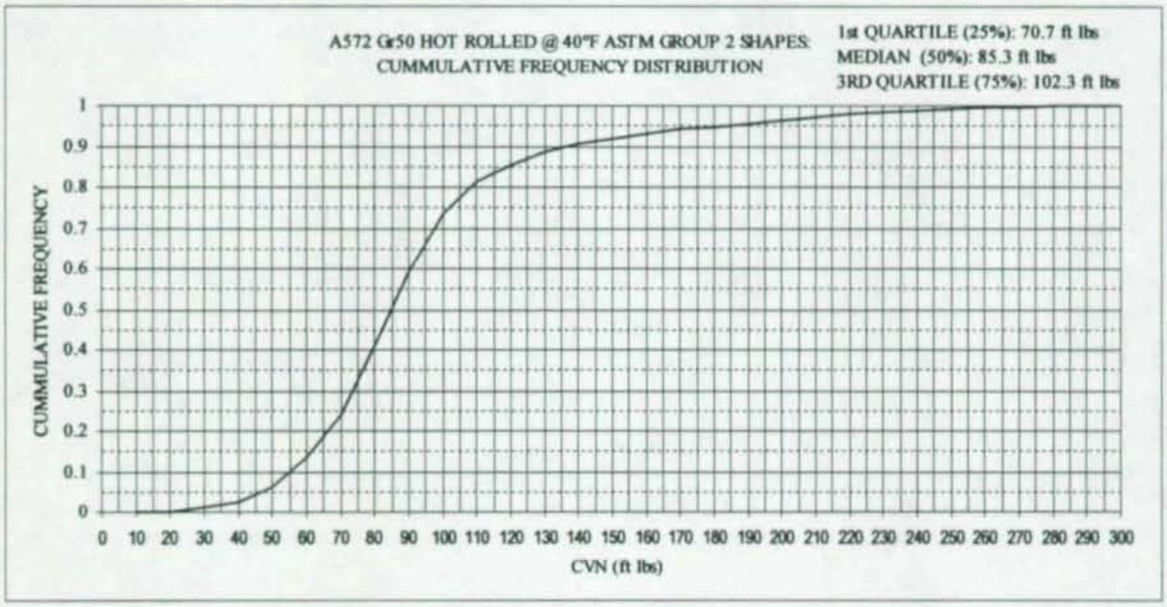

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 1200
MODE: 0 %
MINIMUM: 0 %
MEAN: 8.2 %
MAXIMUM: 63.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
36.8
26.8
14.3
8.3
4.8
3.0
3.1
1.6
0.3
0.3
0.0
0.5
0.0
0.2
0.2
0.1
0.0

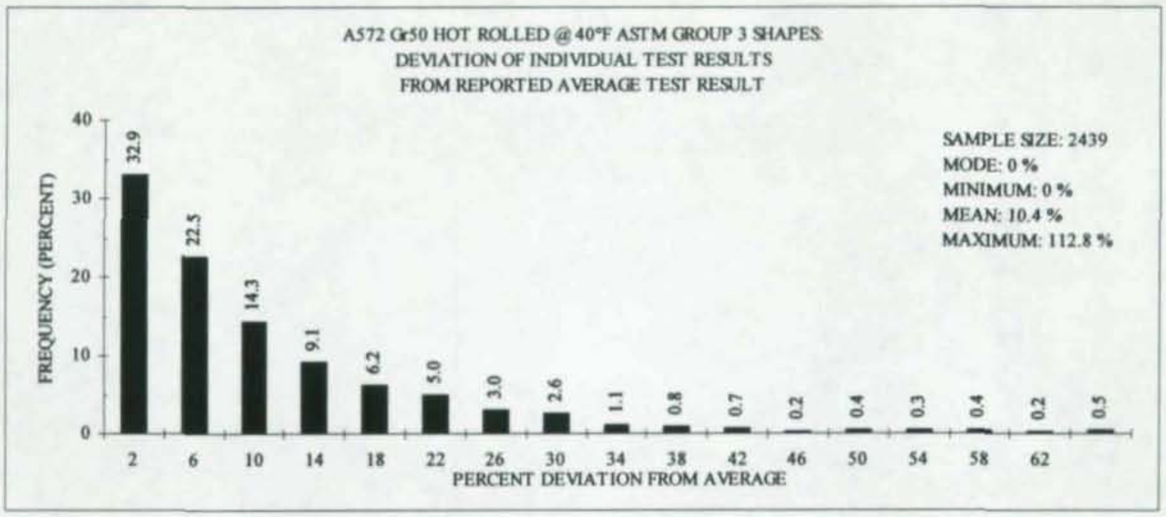

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 400
MODE: 58.3 ft lbs
MINIMUM: 16.0 ft lbs
MEAN: 83.8 ft lbs
MAXIMUM: 259.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)
0.0
0.8
0.3
2.3
8.8
17.3
16.3
13.8
11.3
8.3
6.0
2.3
1.8
1.5
1.8
1.8
1.3
1.0
0.3
0.8
0.8
0.5
1.0
0.3
0.3
0.3
0.0
0.0
0.0
0.0
0.0


A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 58.3 ft lbs
MEDIAN (50%): 73.3 ft lbs
3RD QUARTILE (75%): 94.6 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

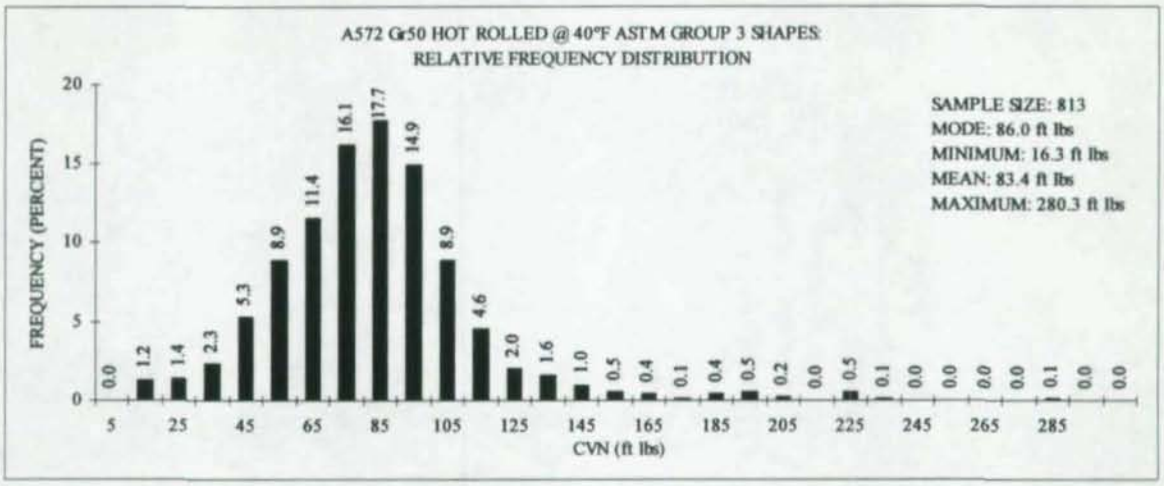

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 6543
MODE: 0 %
MINIMUM: 0 %
MEAN: 9.1 %
MAXIMUM: 92.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE


A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 2181
MODE: 80.3 ft lbs
MINIMUM: 17.7 ft lbs
MEAN: 93.0 ft lbs
MAXIMUM: 288.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

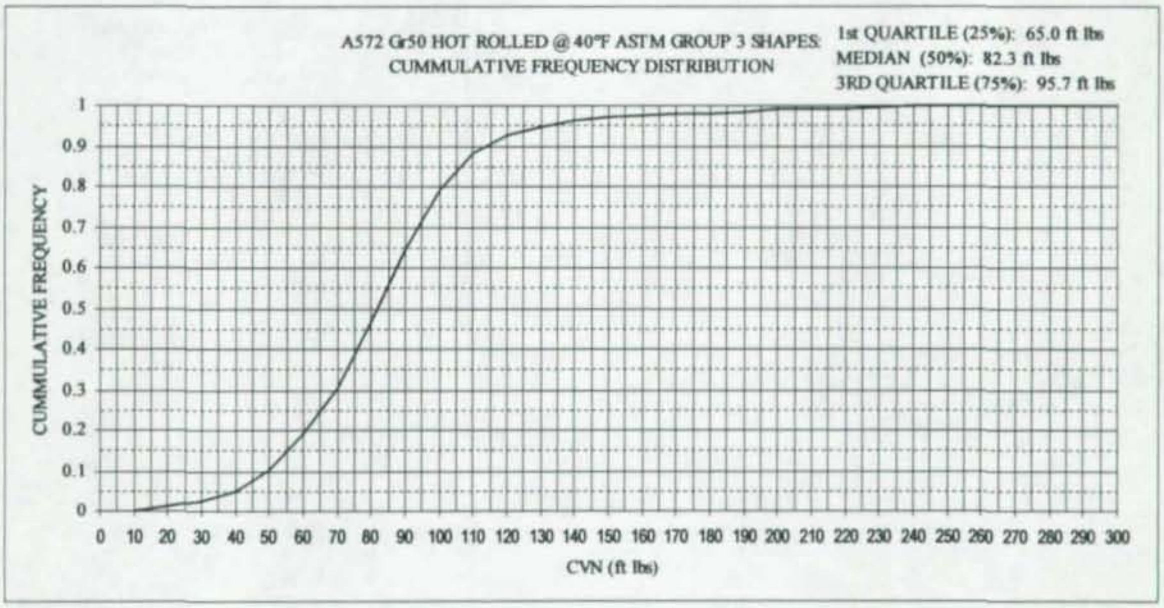

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 70.7 ft lbs
MEDIAN (50%): 85.3 ft lbs
3RD QUARTILE (75%): 102.3 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)



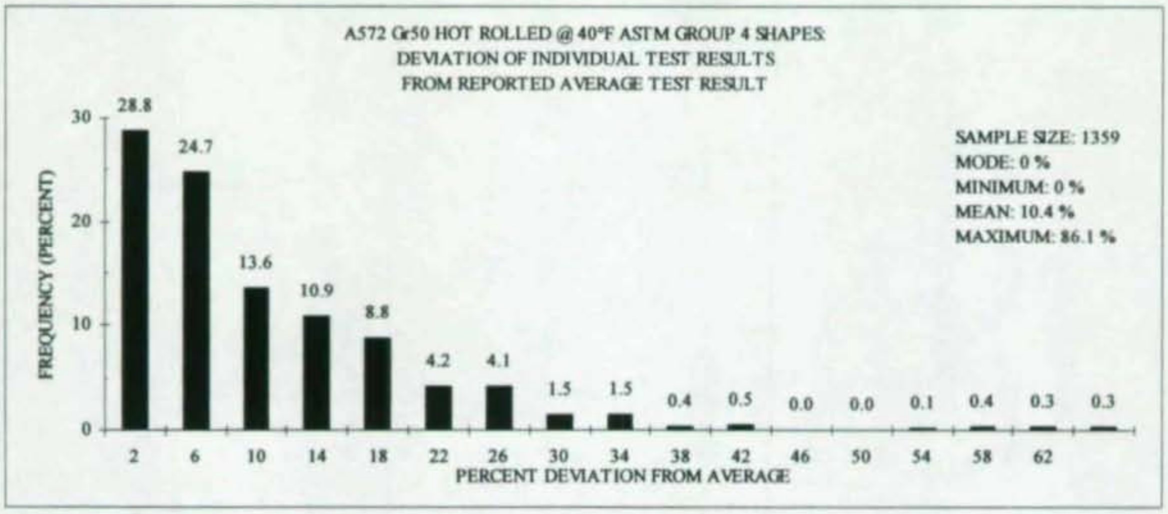
A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 2439
MODE: 0 %
MINIMUM: 0 %
MEAN: 10.4 %
MAXIMUM: 112.8 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE

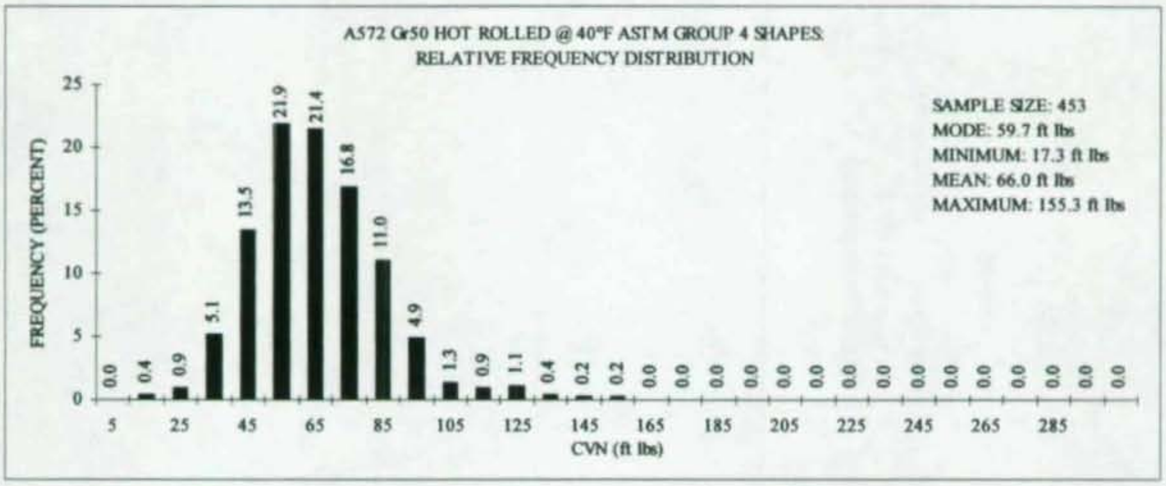


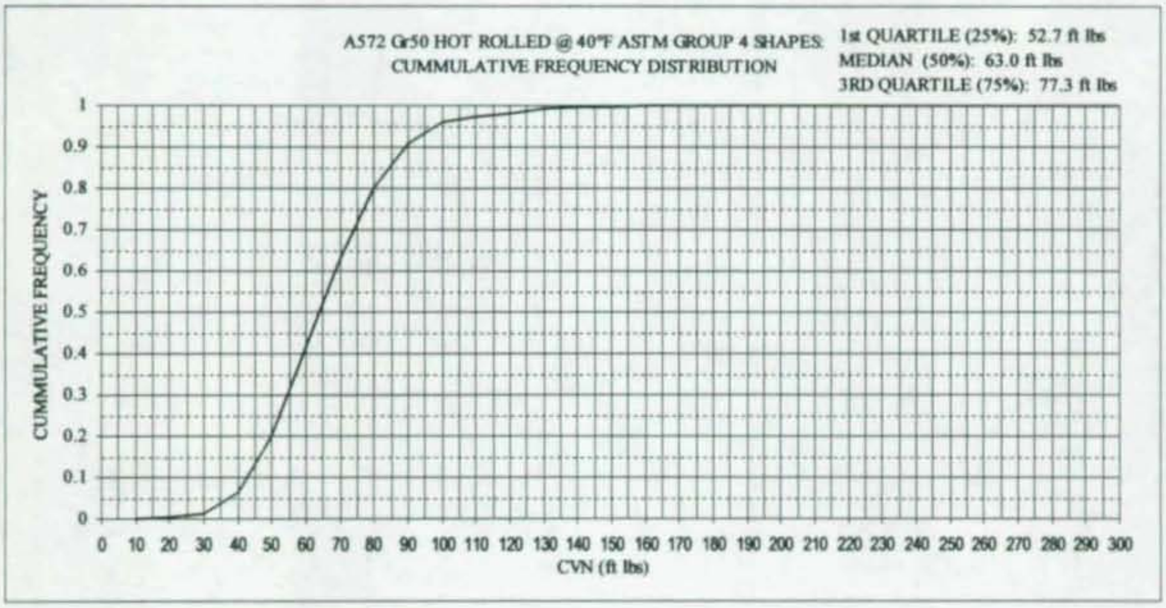
A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 813
MODE: 86.0 ft lbs
MINIMUM: 16.3 ft lbs
MEAN: 83.4 ft lbs
MAXIMUM: 280.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

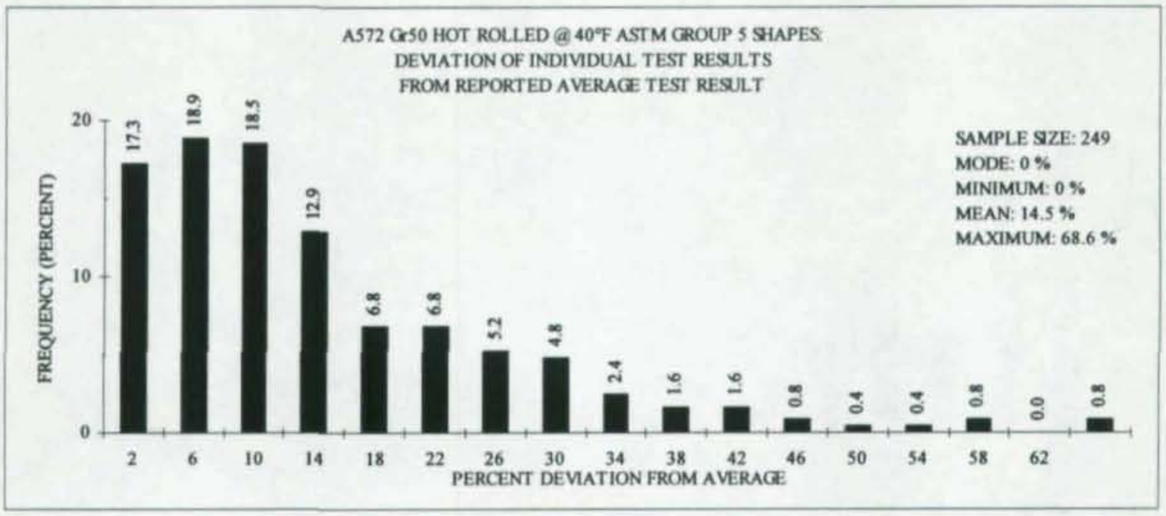


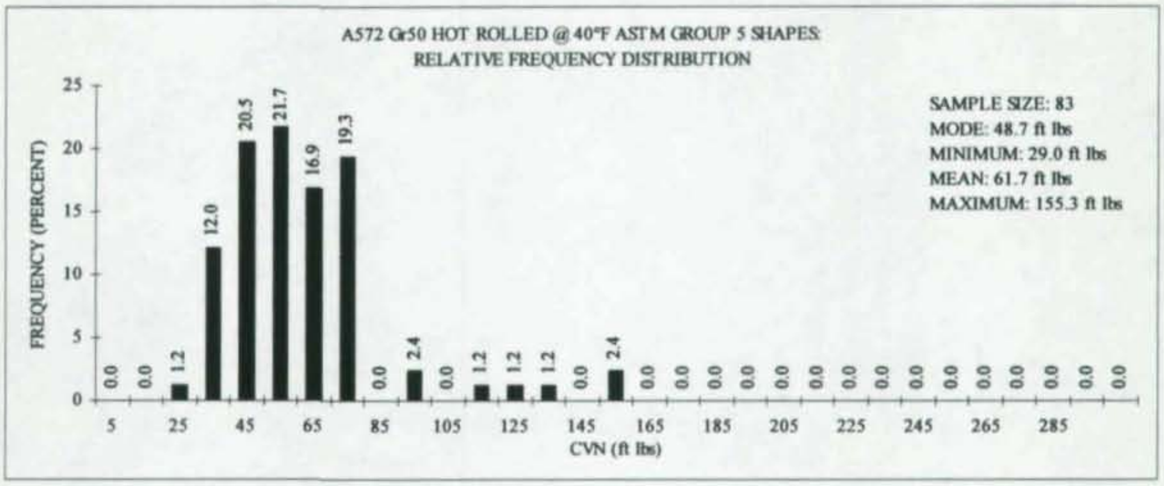
A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 65.0 ft lbs
MEDIAN (50%): 82.3 ft lbs
3RD QUARTILE (75%): 95.7 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

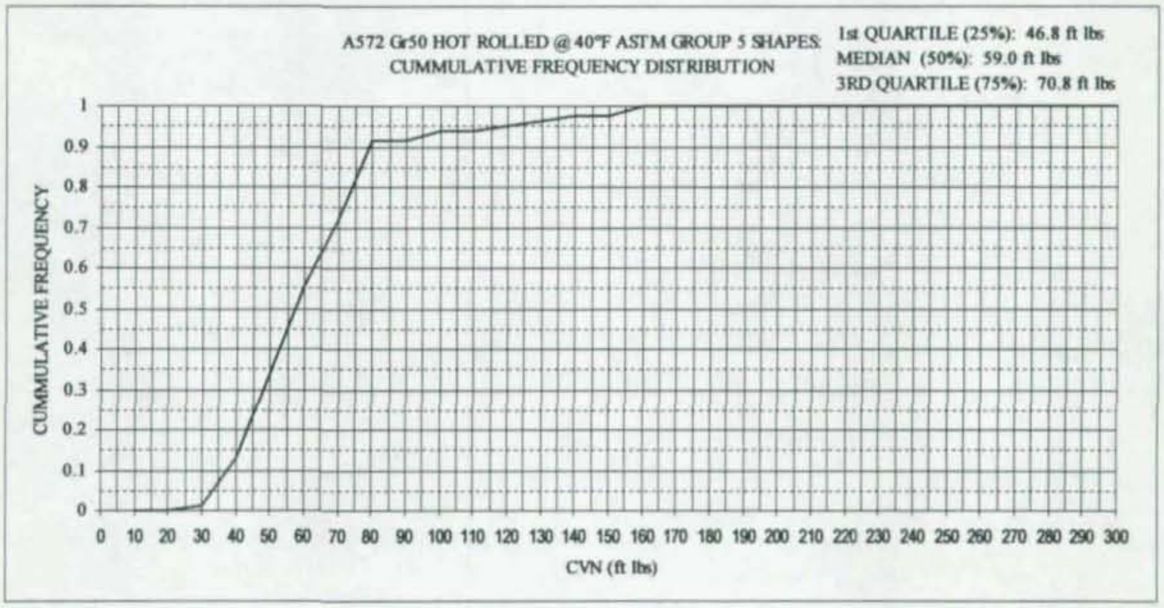

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 4 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 1359
MODE: 0 %
MINIMUM: 0 %
MEAN: 10.4 %
MAXIMUM: 86.1 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
28.8
24.7
13.6
10.9
8.8
4.2
4.1
1.5
1.5
0.4
0.5
0.0
0.0
0.1
0.4
0.3
0.3

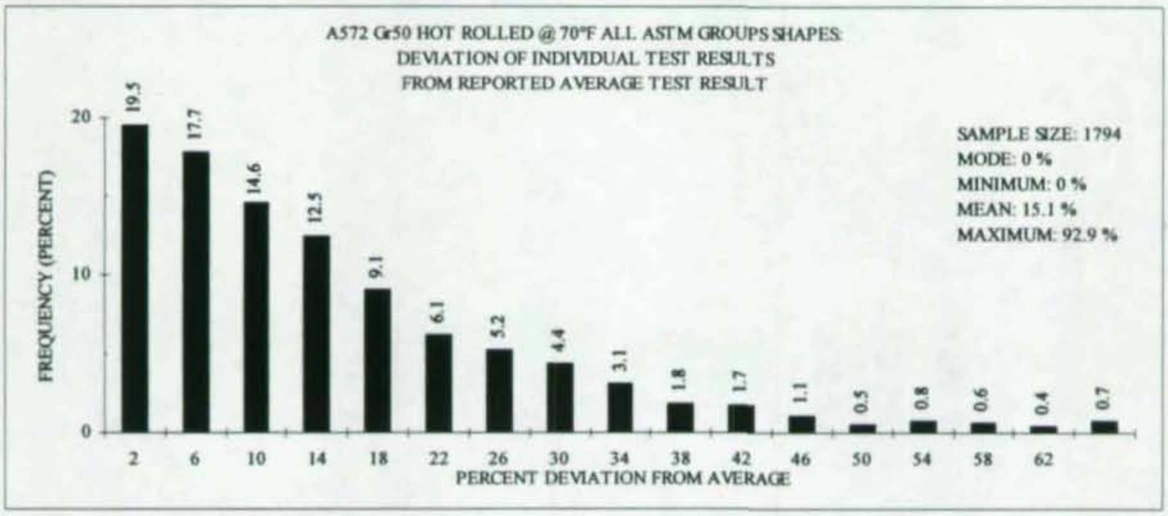

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 4 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 453
MODE: 59.7 ft lbs
MINIMUM: 17.3 ft lbs
MEAN: 66.0 ft lbs
MAXIMUM: 155.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

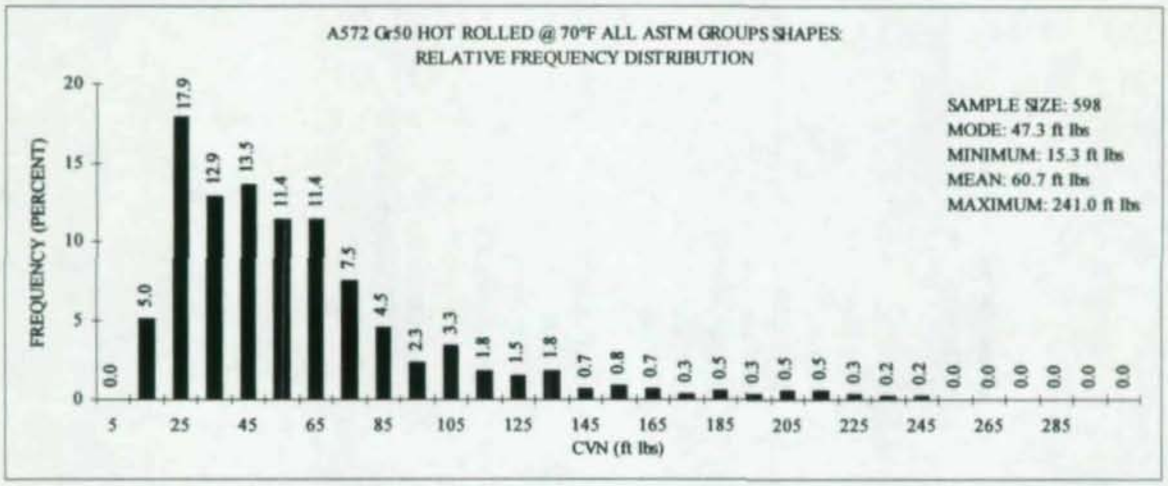

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 4 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 52.7 ft lbs
MEDIAN (50%): 63.0 ft lbs
3RD QUARTILE (75%): 77.3 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

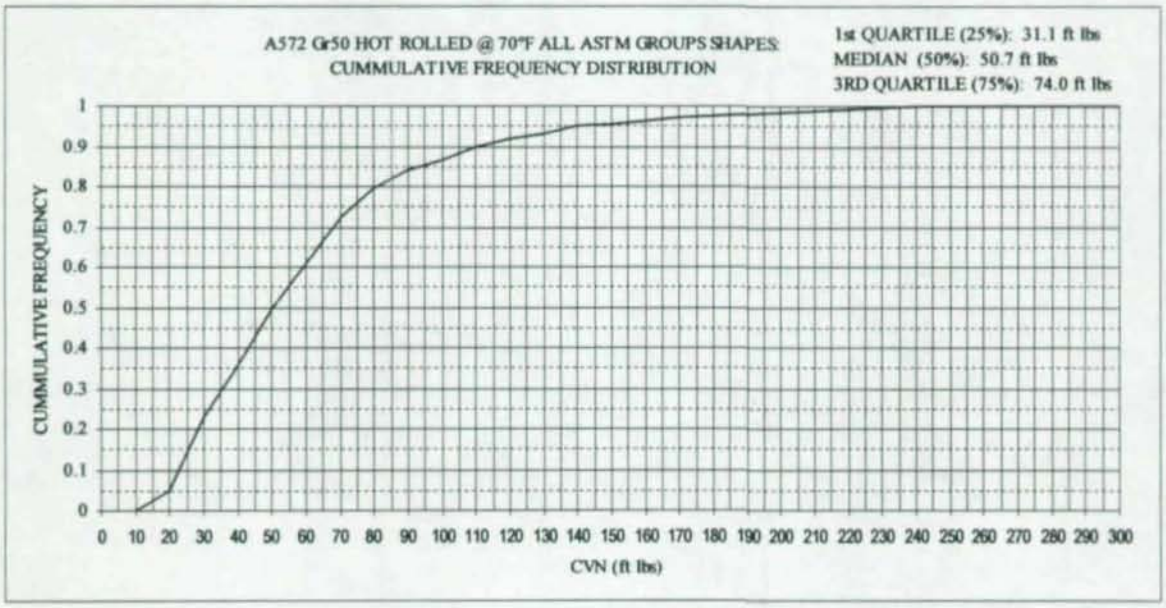

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 5 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 249
MODE: 0 %
MINIMUM: 0 %
MEAN: 14.5 %
MAXIMUM: 68.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE

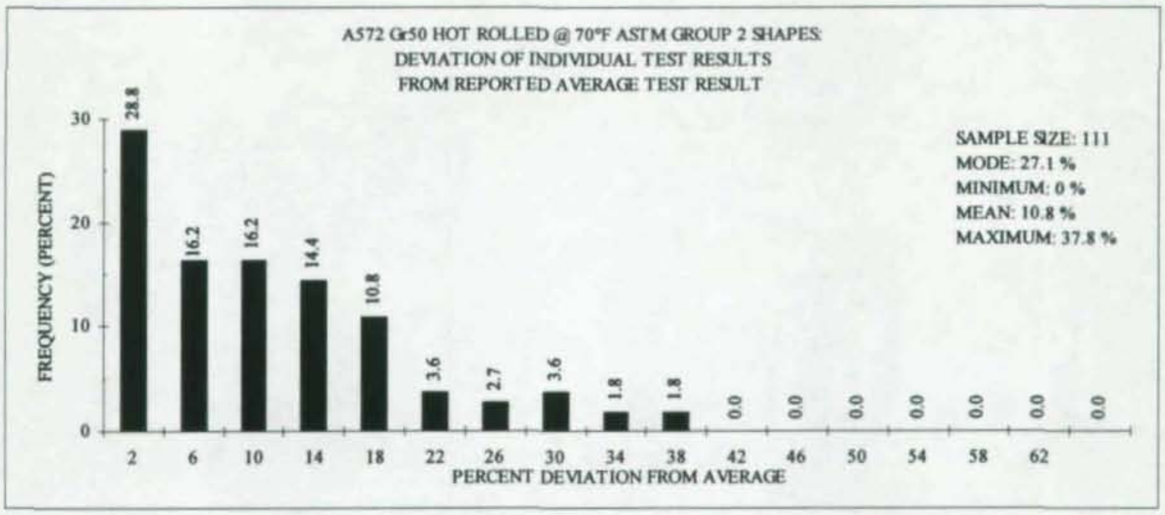

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 5 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 83
MODE: 48.7 ft lbs
MINIMUM: 29.0 ft lbs
MEAN: 61.7 ft lbs
MAXIMUM: 155.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

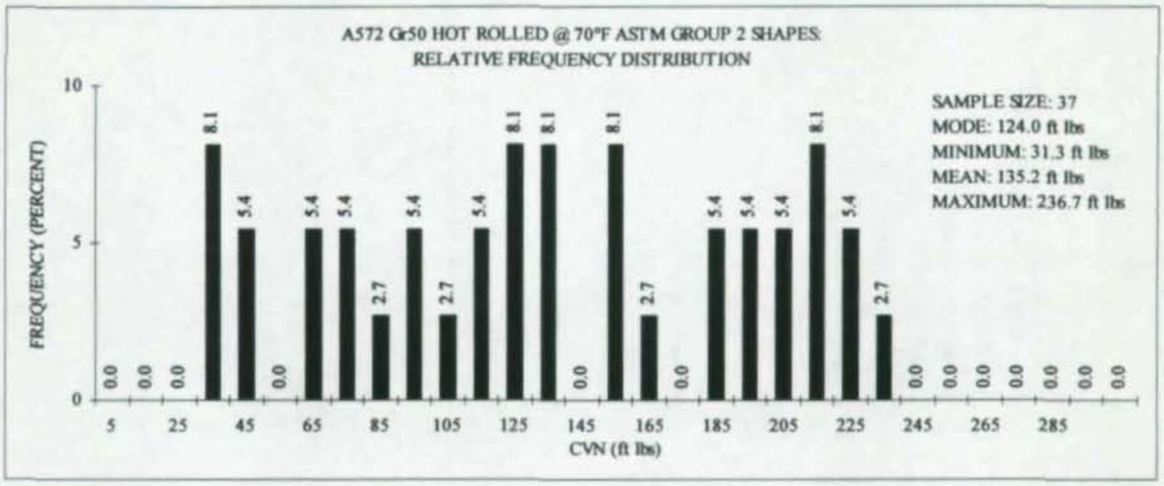

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 5 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 46.8 ft lbs
MEDIAN (50%): 59.0 ft lbs
3RD QUARTILE (75%): 70.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

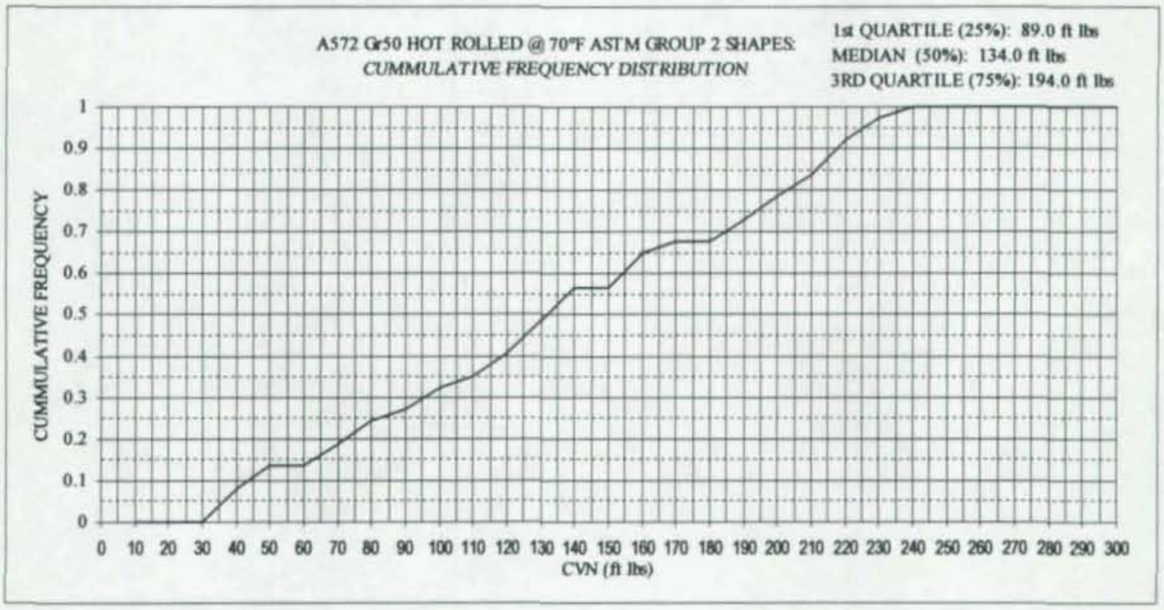

A572 Gr50 HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 1794
MODE: 0 %
MINIMUM: 0 %
MEAN: 15.1 %
MAXIMUM: 92.9 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
19.5
17.7
14.6
12.5
9.1
6.1
5.2
4.4
3.1
1.8
1.7
1.1
0.5
0.8
0.6
0.4
0.7

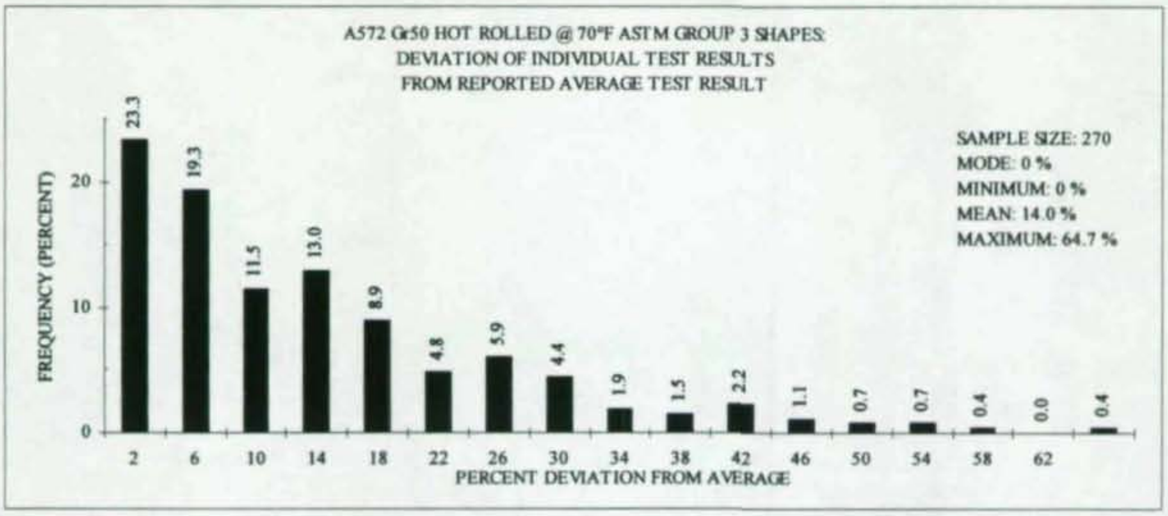

A572 Gr50 HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 598
MODE: 47.3 ft lbs
MINIMUM: 15.3 ft lbs
MEAN: 60.7 ft lbs
MAXIMUM: 241.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

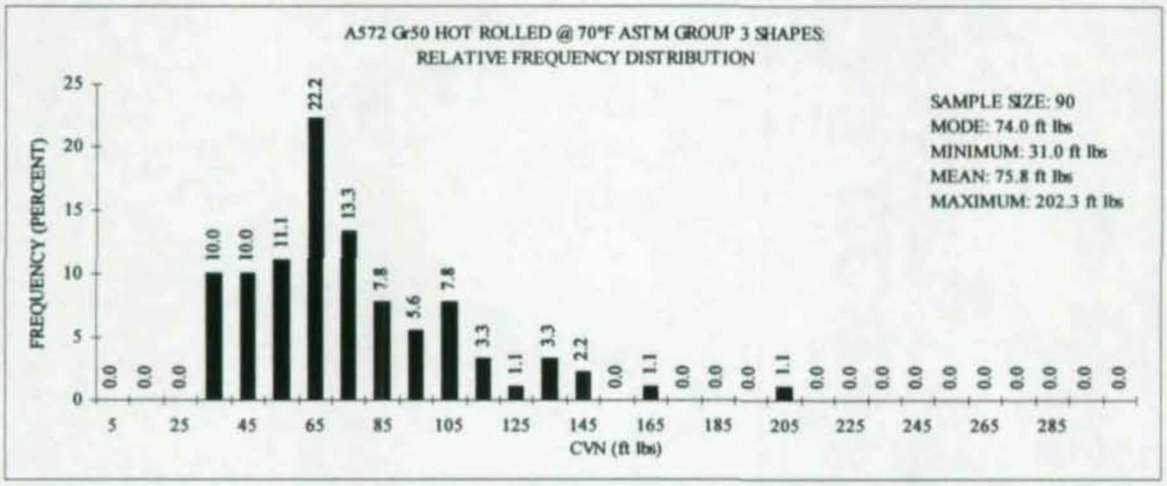

A572 Gr50 HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 31.1 ft lbs
MEDIAN (50%): 50.7 ft lbs
3RD QUARTILE (75%): 74.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

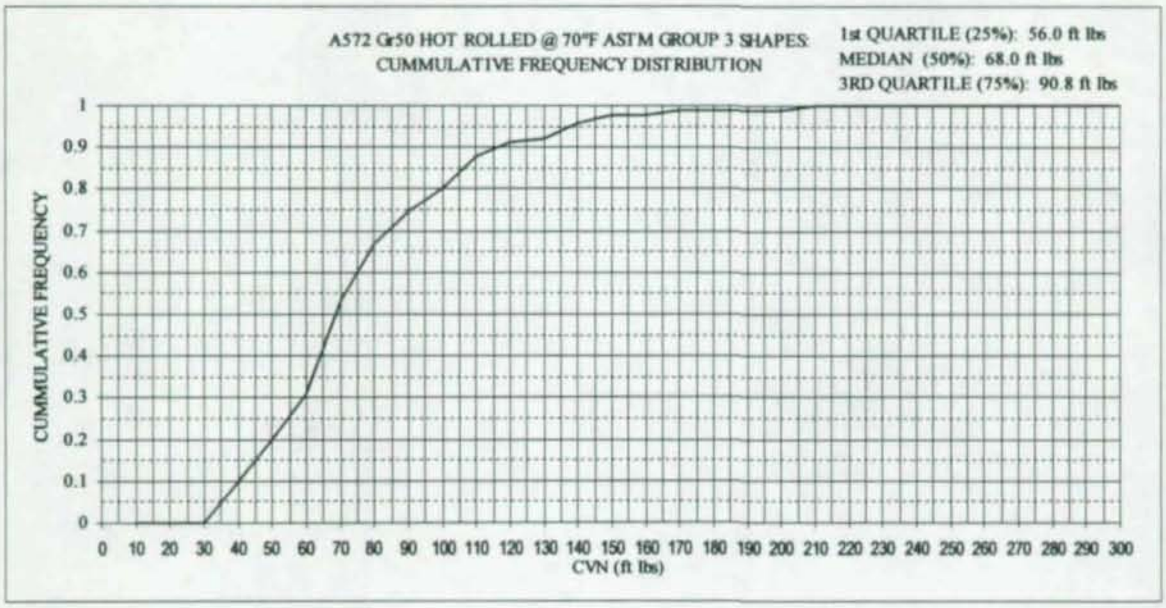

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 111
MODE: 27.1 %
MINIMUM: 0 %
MEAN: 10.8 %
MAXIMUM: 37.8 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE

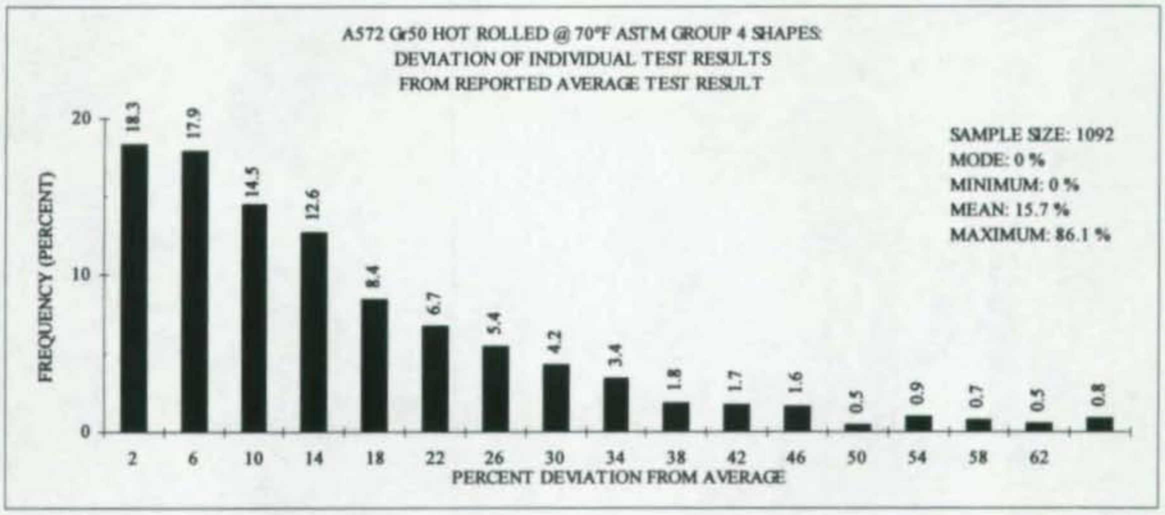

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 37
MODE: 124.0 ft lbs
MINIMUM: 31.3 ft lbs
MEAN: 135.2 ft lbs
MAXIMUM: 236.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

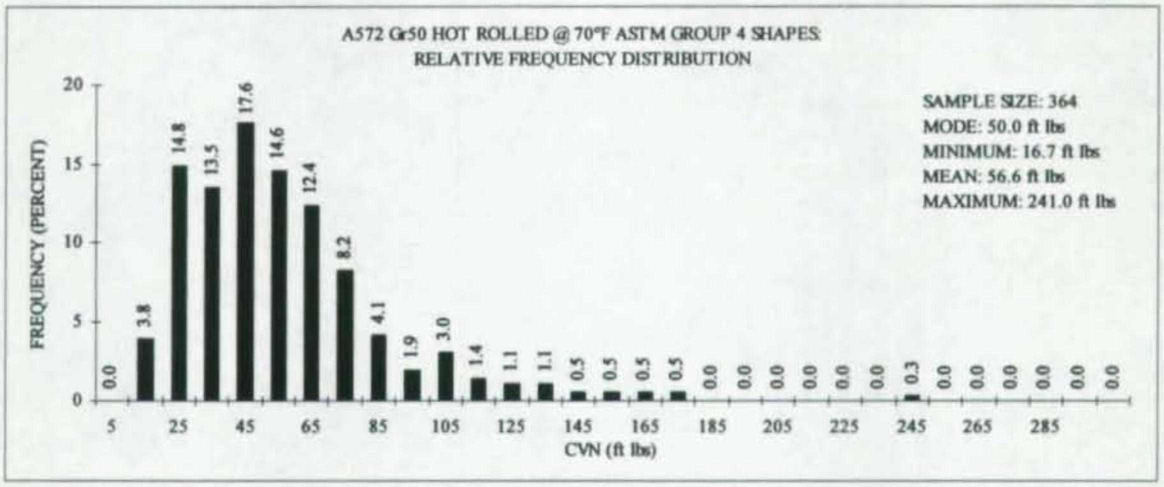

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 89.0 ft lbs
MEDIAN (50%): 134.0 ft lbs
3RD QUARTILE (75%): 194.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

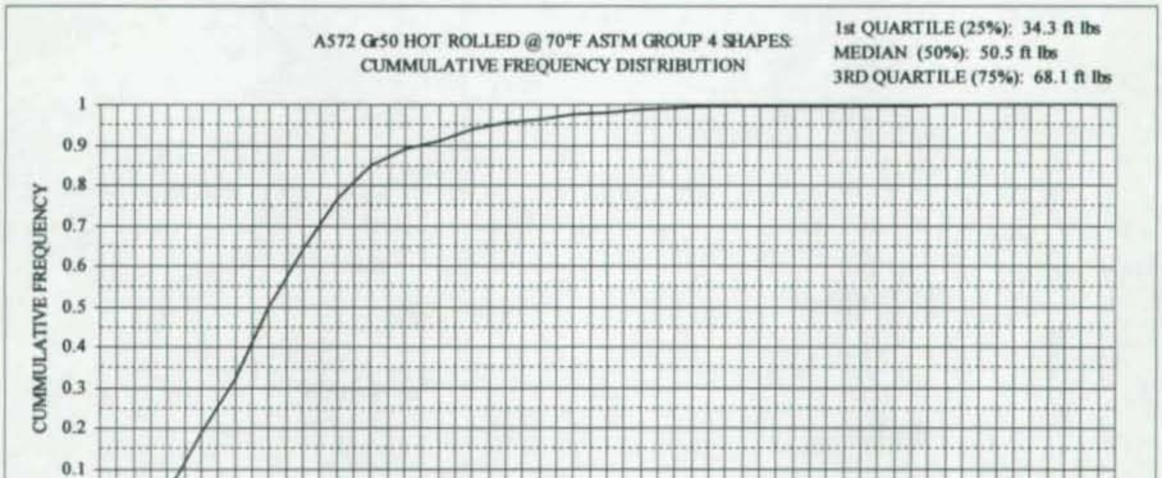

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 3 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 270
MODE: 0 %
MINIMUM: 0 %
MEAN: 14.0 %
MAXIMUM: 64.7 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
23.3
19.3
11.5
13.0
8.9
4.8
5.9
4.4
1.9
1.5
2.2
1.1
0.7
0.7
0.4
0.0
0.4

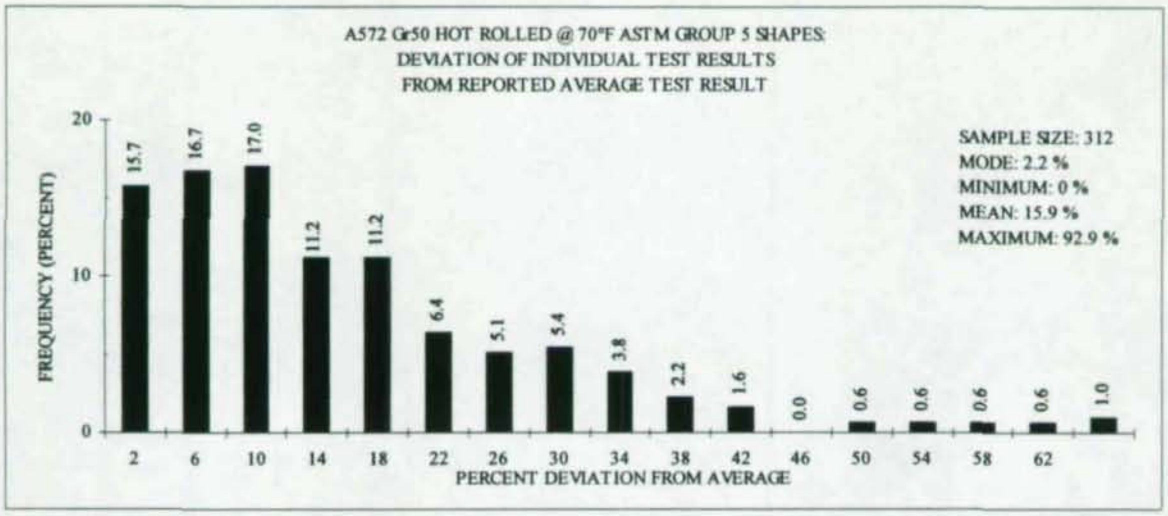

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 3 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 90
MODE: 74.0 ft lbs
MINIMUM: 31.0 ft lbs
MEAN: 75.8 ft lbs
MAXIMUM: 202.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

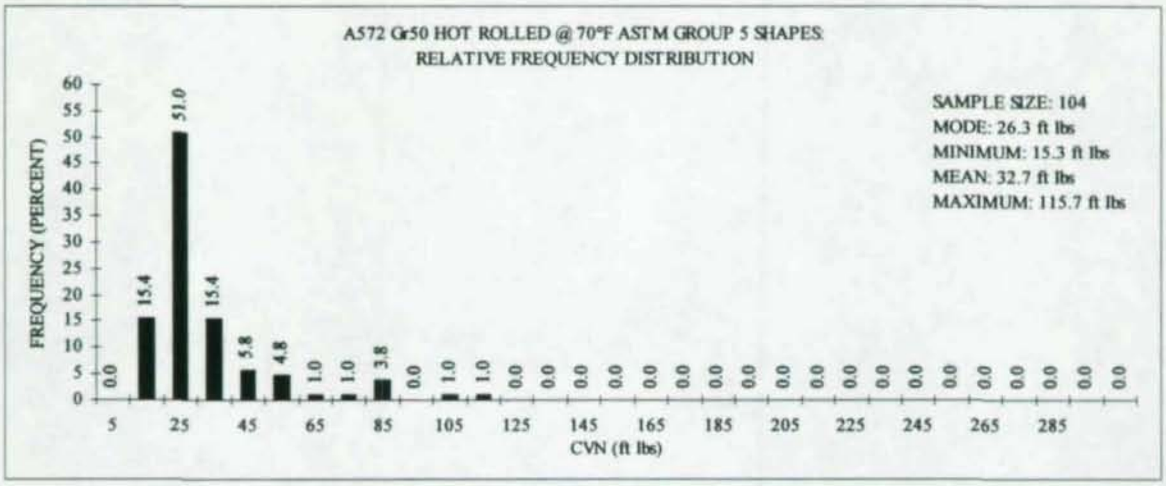

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 3 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 56.0 ft lbs
MEDIAN (50%): 68.0 ft lbs
3RD QUARTILE (75%): 90.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

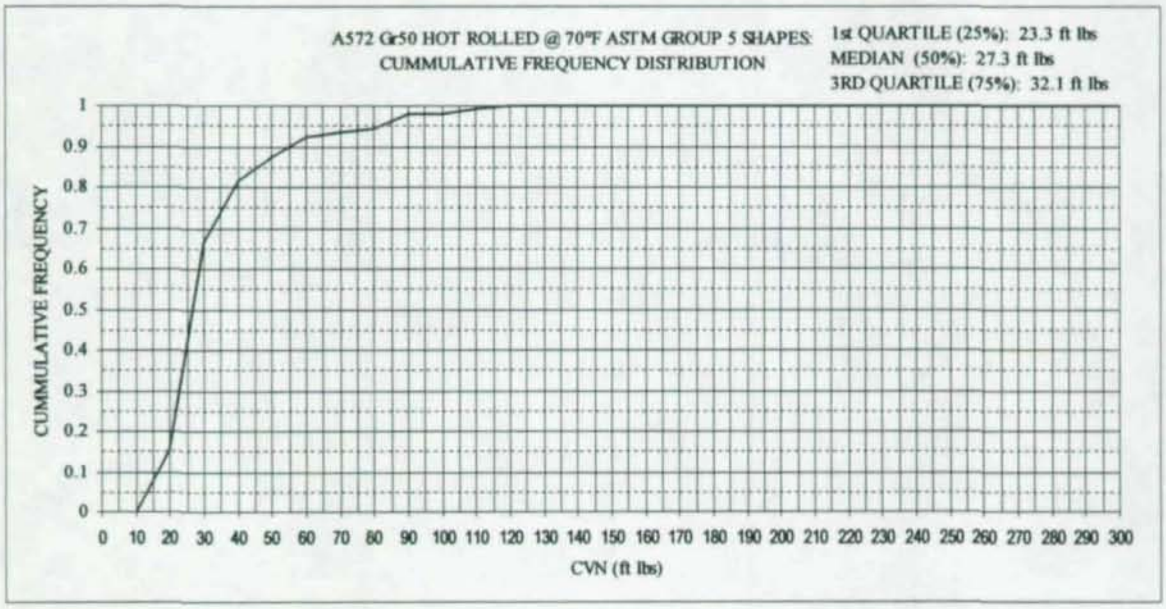

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 4 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 1092
MODE: 0 %
MINIMUM: 0 %
MEAN: 15.7 %
MAXIMUM: 86.1 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
18.3
17.9
14.5
12.6
8.4
6.7
5.4
4.2
3.4
1.8
1.7
1.6
0.5
0.9
0.7
0.5
0.8


A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 4 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 364
MODE: 50.0 ft lbs
MINIMUM: 16.7 ft lbs
MEAN: 56.6 ft lbs
MAXIMUM: 241.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)
0.0
3.8
14.8
13.5
17.6
14.6
12.4
8.2
4.1
1.9
3.0
1.4
1.1
1.1
0.5
0.5
0.5
0.5
0.3

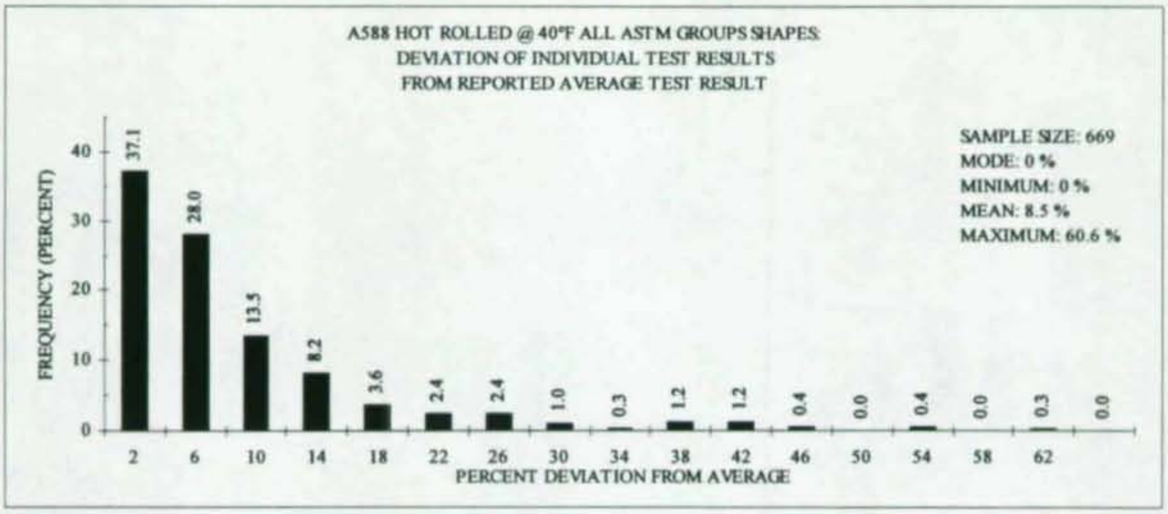

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 4 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 34.3 ft lbs
MEDIAN (50%): 50.5 ft lbs
3RD QUARTILE (75%): 68.1 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

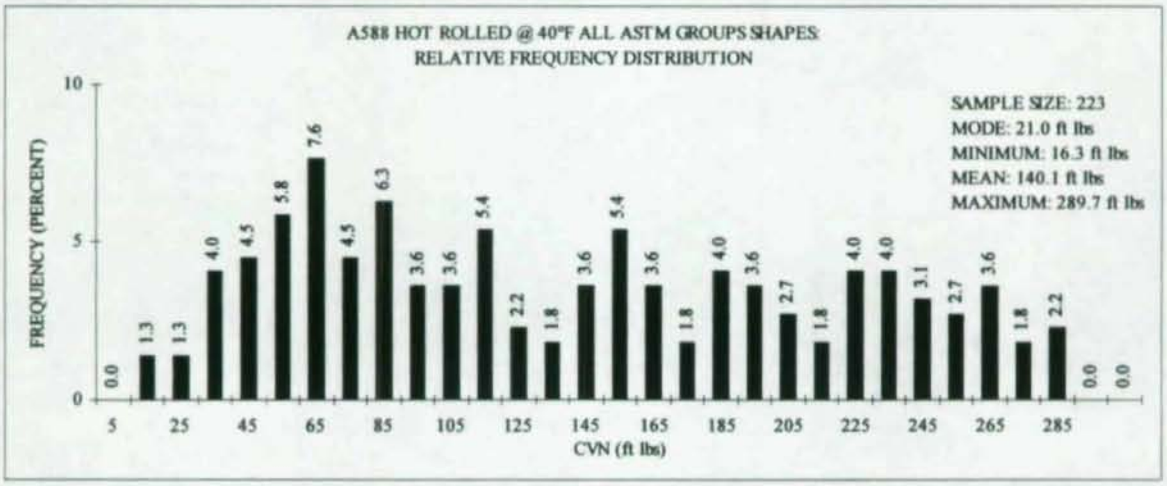

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 5 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 312
MODE: 2.2 %
MINIMUM: 0 %
MEAN: 15.9 %
MAXIMUM: 92.9 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
15.7 16.7 17.0 11.2 11.2 6.4 5.1 5.4 3.8 2.2 1.6 0.0 0.6 0.6 0.6 0.6 1.0
2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62

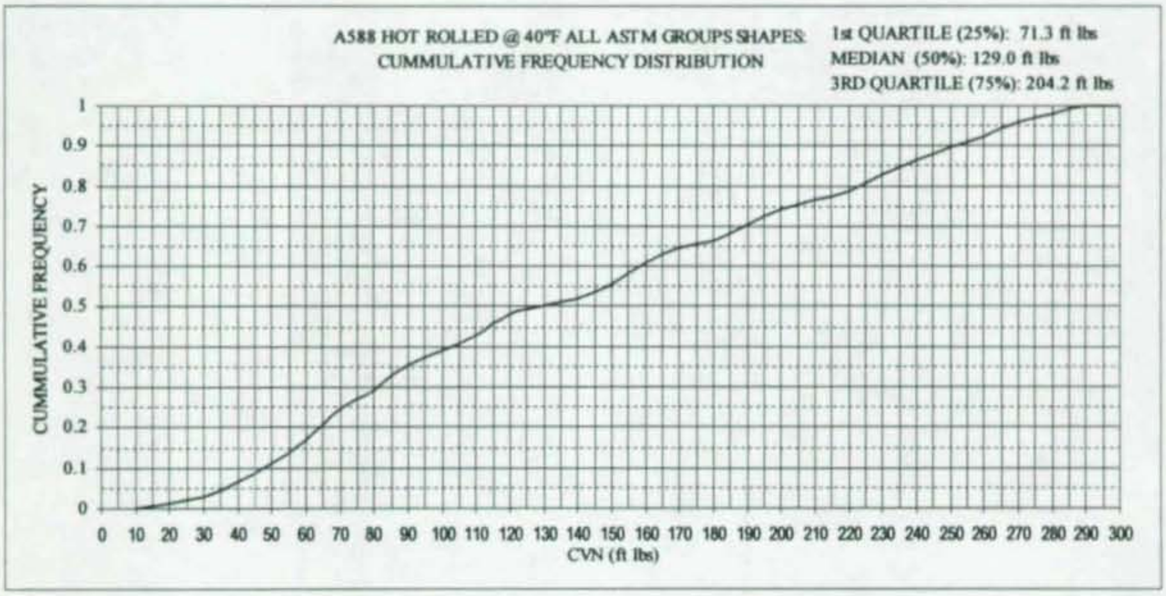

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 5 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 104
MODE: 26.3 ft lbs
MINIMUM: 15.3 ft lbs
MEAN: 32.7 ft lbs
MAXIMUM: 115.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)
0.0 15.4 51.0 15.4 5.8 4.8 1.0 1.0 3.8 0.0 1.0 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
5 25 45 65 85 105 125 145 165 185 205 225 245 265 285

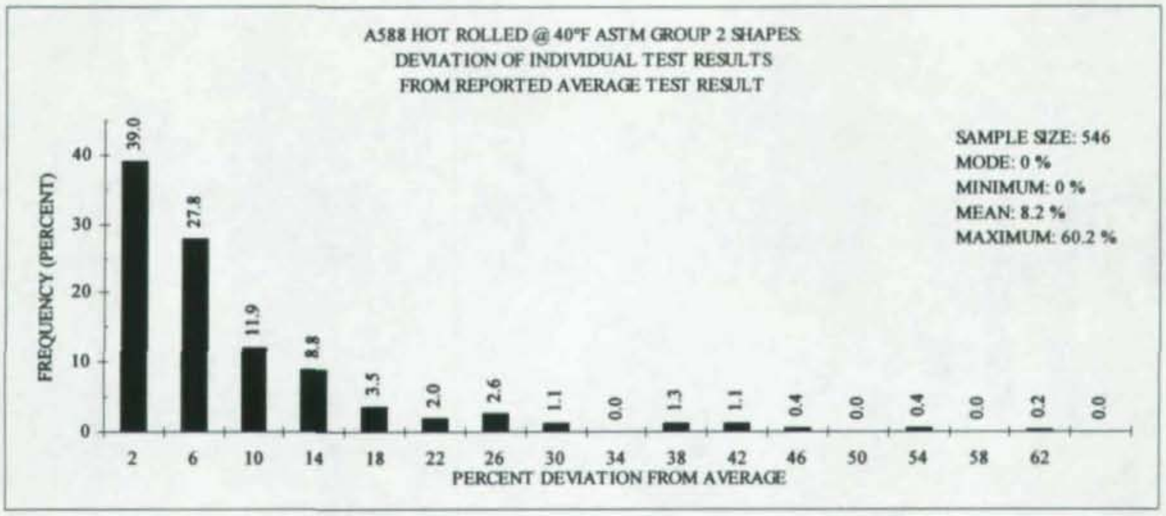

A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 5 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 23.3 ft lbs
MEDIAN (50%): 27.3 ft lbs
3RD QUARTILE (75%): 32.1 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

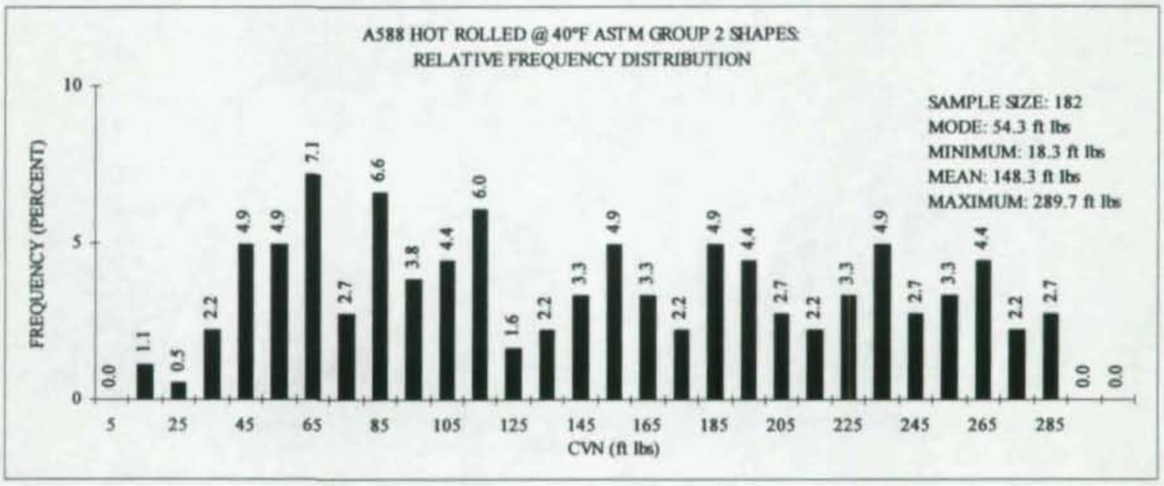
A588 STEEL

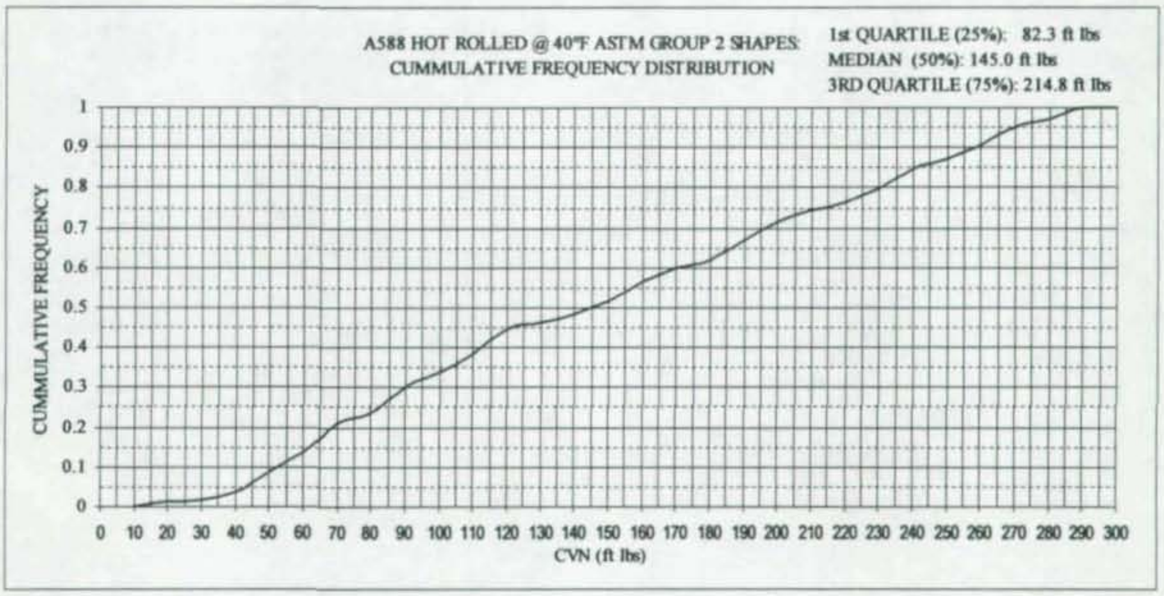

A588 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 669
MODE: 0 %
MINIMUM: 0 %
MEAN: 8.5 %
MAXIMUM: 60.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
37.1
28.0
13.5
8.2
3.6
2.4
2.4
1.0
0.3
1.2
1.2
0.4
0.0
0.4
0.0
0.3
0.0

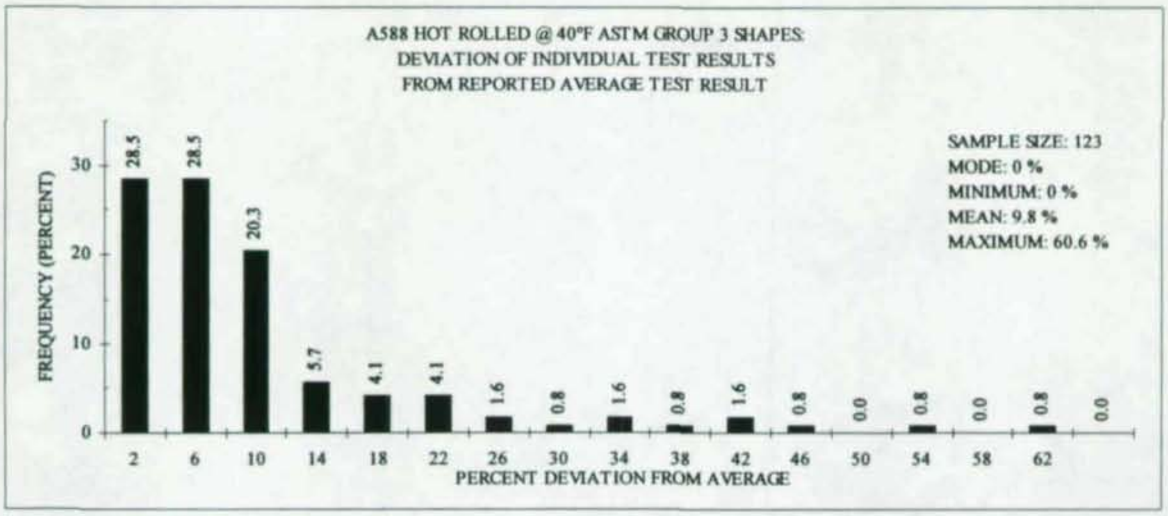

A588 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 223
MODE: 21.0 ft lbs
MINIMUM: 16.3 ft lbs
MEAN: 140.1 ft lbs
MAXIMUM: 289.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)
0.0
1.3
1.3
4.0
4.5
5.8
7.6
4.5
6.3
3.6
3.6
5.4
2.2
1.8
3.6
5.4
3.6
1.8
4.0
3.6
2.7
1.8
4.0
4.0
3.1
2.7
3.6
1.8
2.2
0.0
0.0

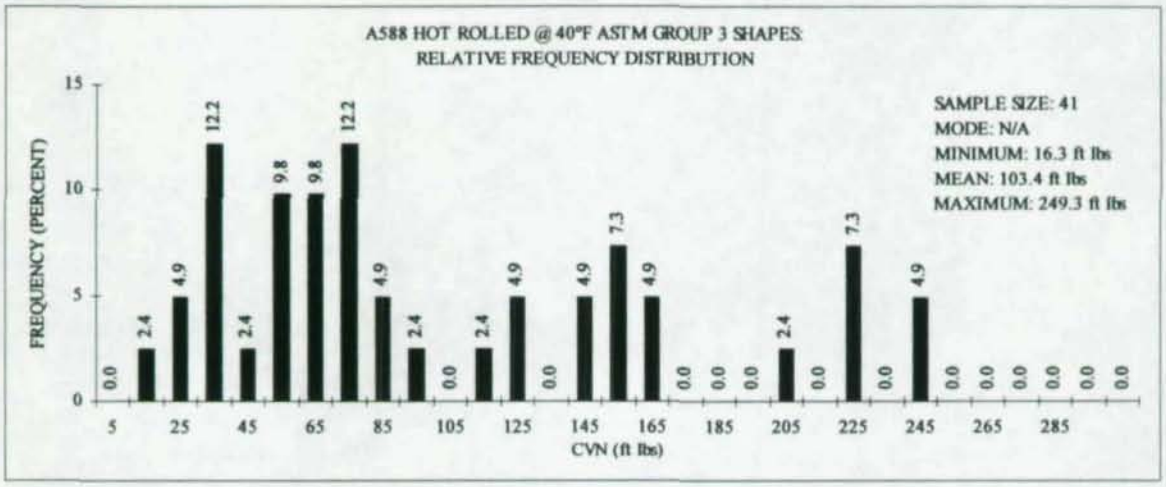

A588 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 71.3 ft lbs
MEDIAN (50%): 129.0 ft lbs
3RD QUARTILE (75%): 204.2 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

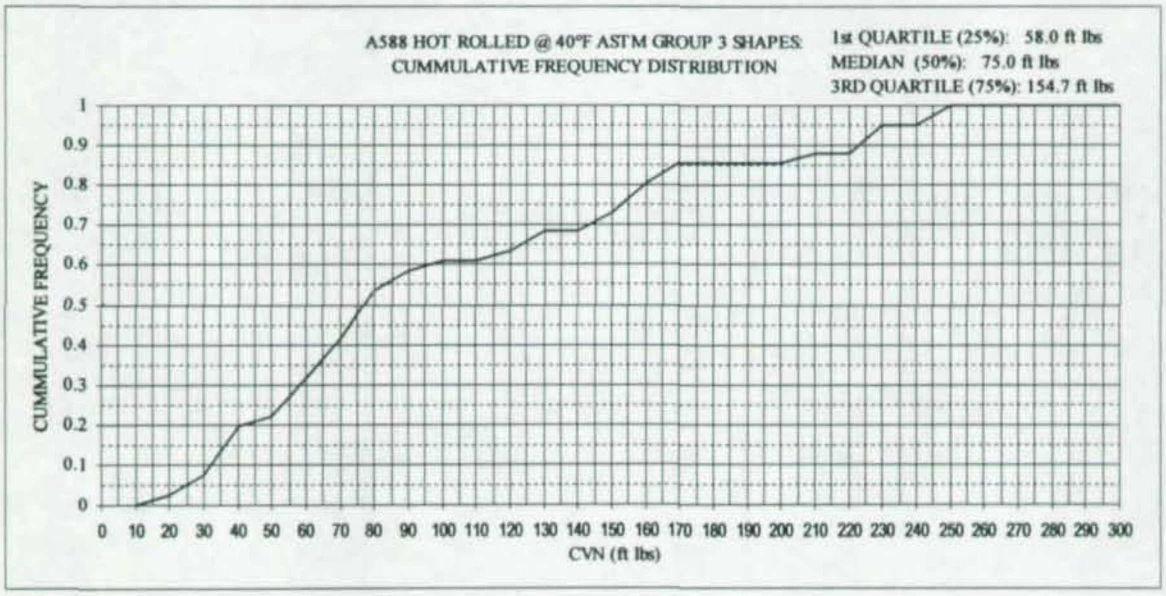

A588 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 546
MODE: 0 %
MINIMUM: 0 %
MEAN: 8.2 %
MAXIMUM: 60.2 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
39.0
27.8
11.9
8.8
3.5
2.0
2.6
1.1
0.0
1.3
1.1
0.4
0.0
0.4
0.0
0.2
0.0


A588 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 182
MODE: 54.3 ft lbs
MINIMUM: 18.3 ft lbs
MEAN: 148.3 ft lbs
MAXIMUM: 289.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

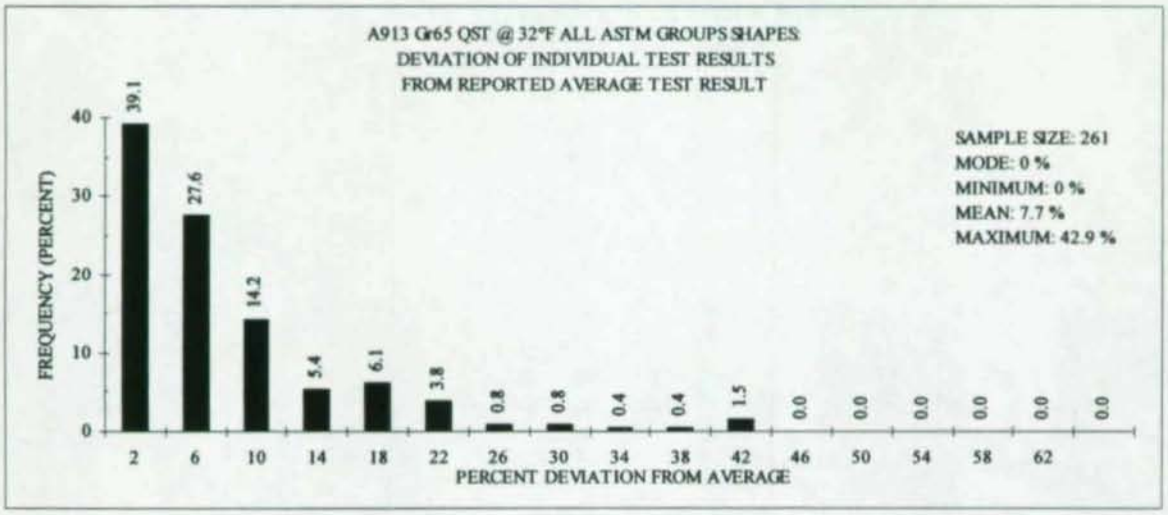

A588 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 82.3 ft lbs
MEDIAN (50%): 145.0 ft lbs
3RD QUARTILE (75%): 214.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

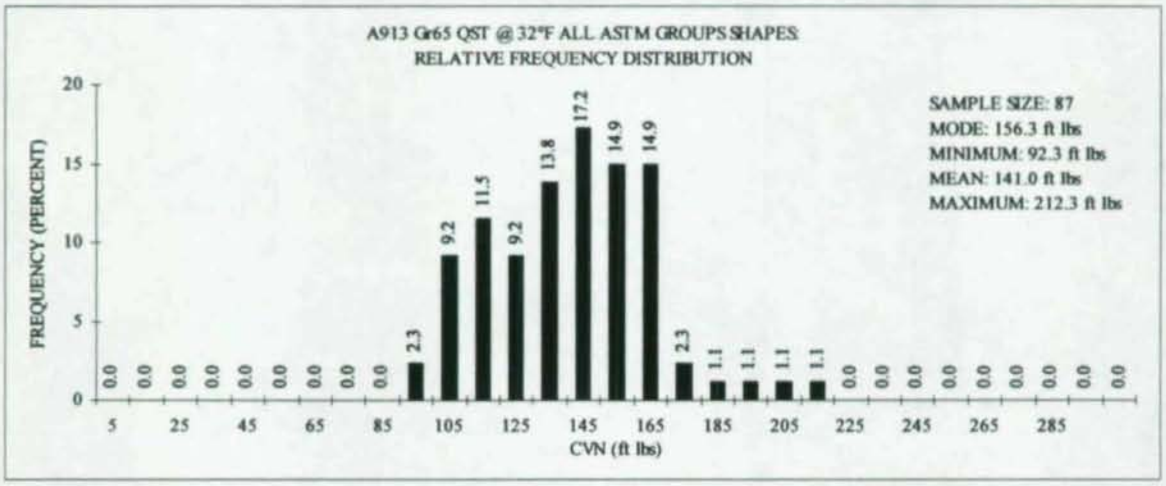

A588 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 123
MODE: 0 %
MINIMUM: 0 %
MEAN: 9.8 %
MAXIMUM: 60.6 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE

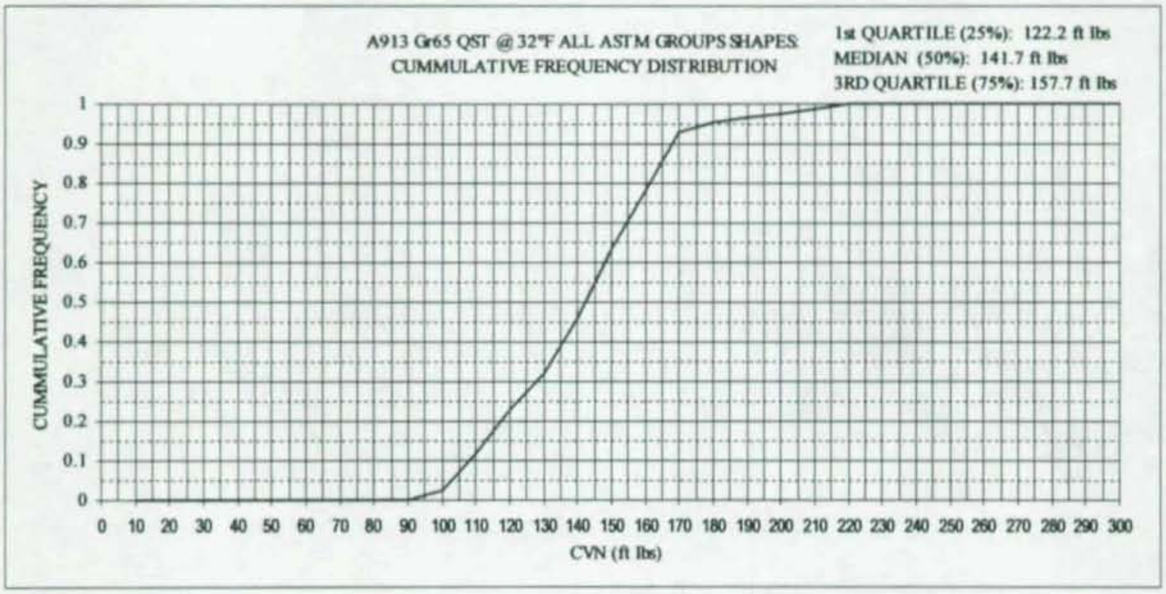

A588 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 41
MODE: N/A
MINIMUM: 16.3 ft lbs
MEAN: 103.4 ft lbs
MAXIMUM: 249.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

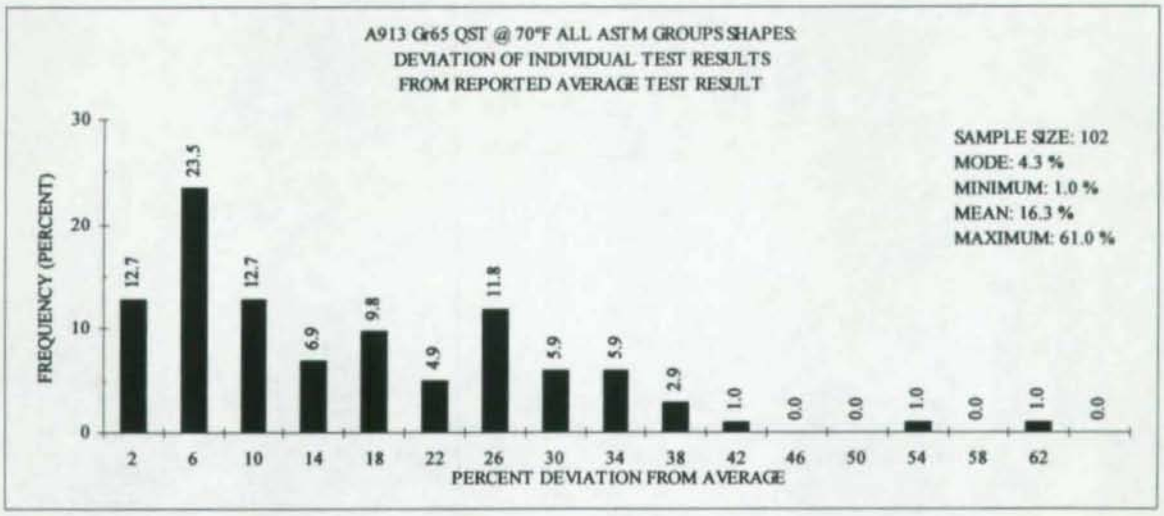

A588 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 58.0 ft lbs
MEDIAN (50%): 75.0 ft lbs
3RD QUARTILE (75%): 154.7 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

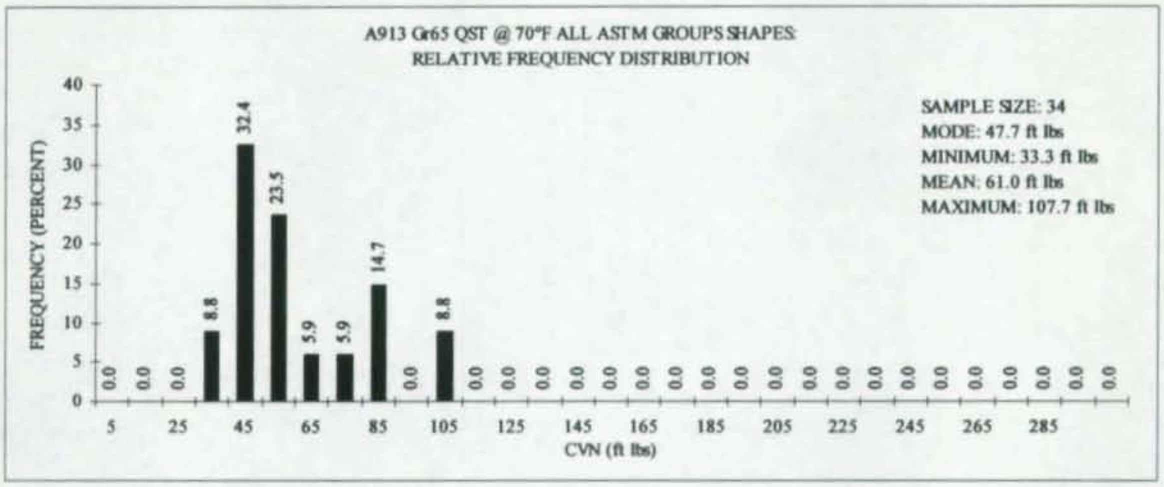
A913 Gr65 STEEL

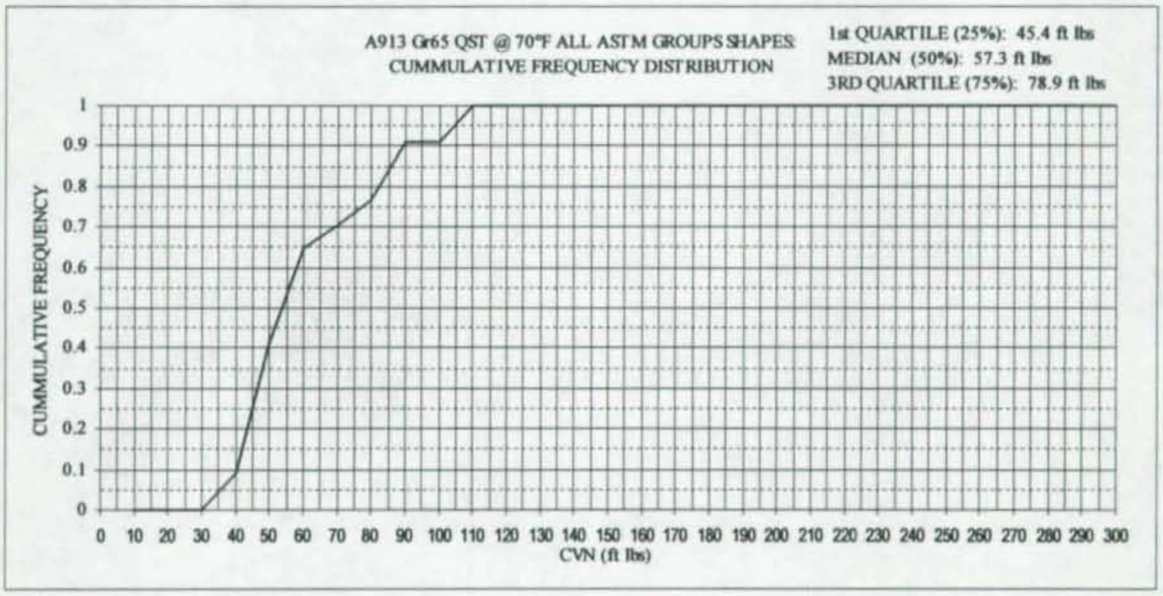

A913 Gr65 QST @ 32°F ALL ASTM GROUPS SHAPES
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 261
MODE: 0 %
MINIMUM: 0 %
MEAN: 7.7 %
MAXIMUM: 42.9 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
39.1
27.6
14.2
5.4
6.1
3.8
0.8
0.8
0.4
0.4
1.5
0.0
0.0
0.0
0.0
0.0
0.0


A913 Gr65 QST @ 32°F ALL ASTM GROUPS SHAPES
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 87
MODE: 156.3 ft lbs
MINIMUM: 92.3 ft lbs
MEAN: 141.0 ft lbs
MAXIMUM: 212.3 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

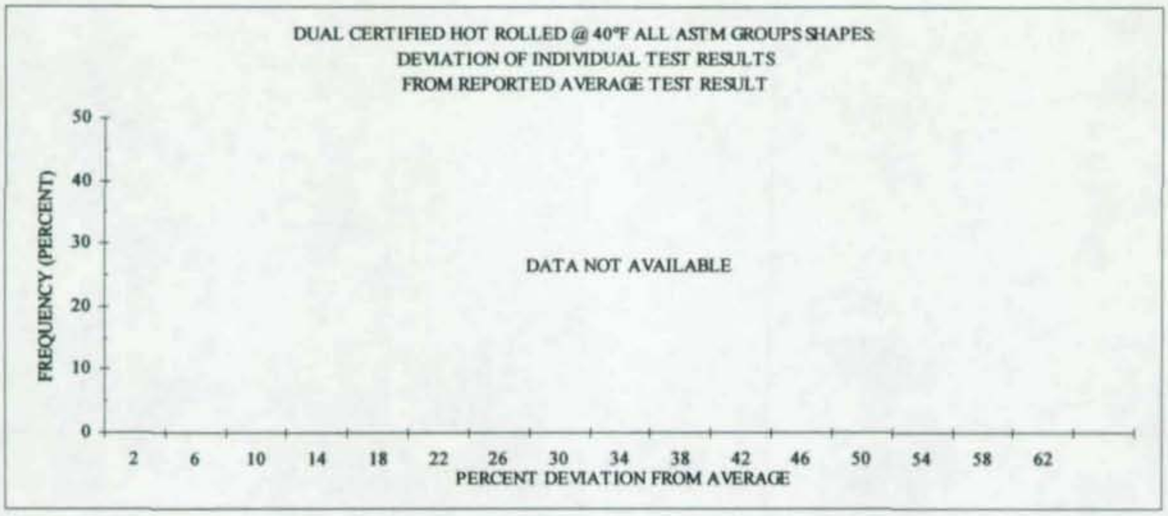

A913 Gr65 QST @ 32°F ALL ASTM GROUPS SHAPES
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 122.2 ft lbs
MEDIAN (50%): 141.7 ft lbs
3RD QUARTILE (75%): 157.7 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

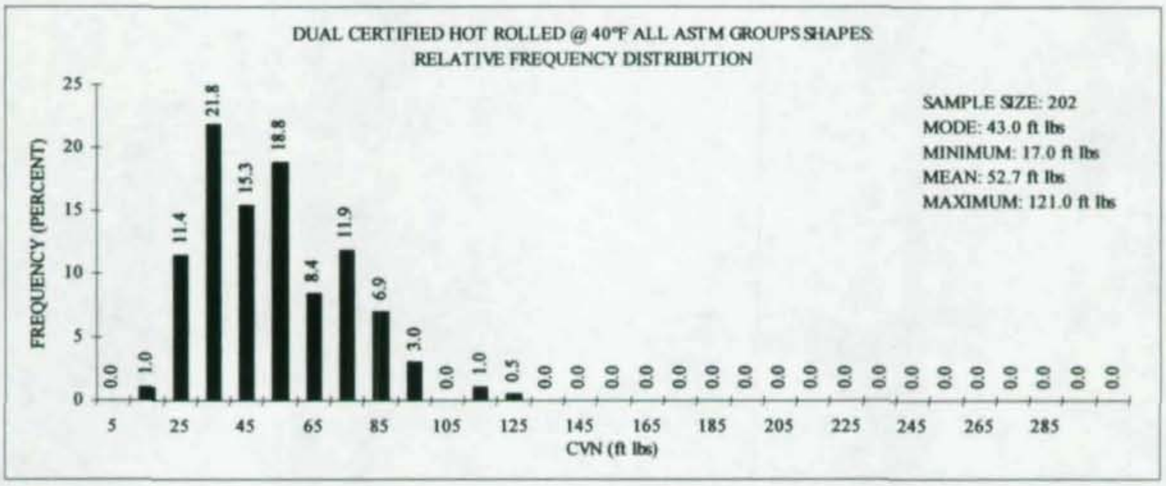

A913 Gr65 QST @ 70°F ALL ASTM GROUPS SHAPES
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
SAMPLE SIZE: 102
MODE: 4.3 %
MINIMUM: 1.0 %
MEAN: 16.3 %
MAXIMUM: 61.0 %
FREQUENCY (PERCENT)
PERCENT DEVIATION FROM AVERAGE
12.7
23.5
12.7
6.9
9.8
4.9
11.8
5.9
5.9
2.9
1.0
0.0
0.0
1.0
0.0
1.0
0.0

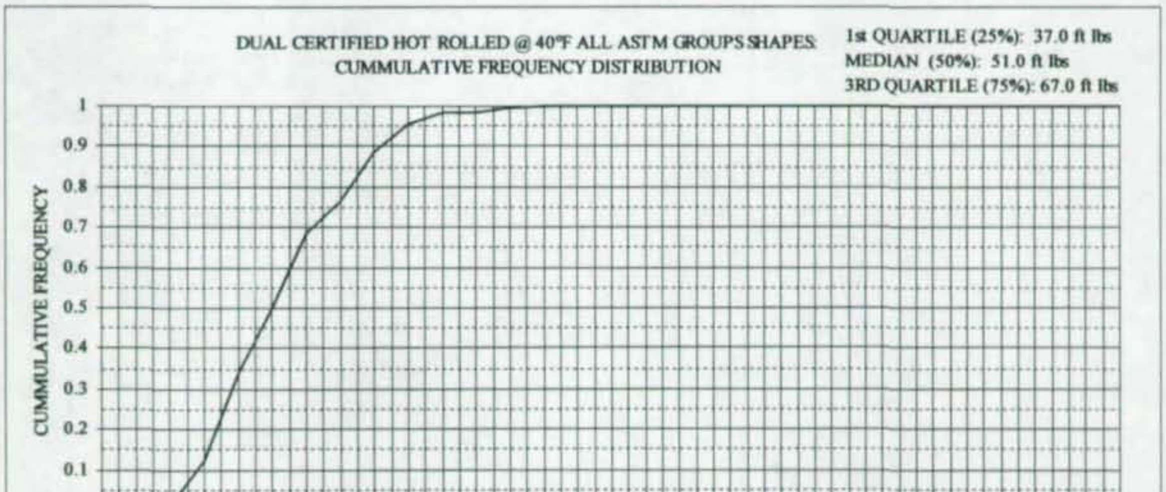

A913 Gr65 QST @ 70°F ALL ASTM GROUPS SHAPES
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 34
MODE: 47.7 ft lbs
MINIMUM: 33.3 ft lbs
MEAN: 61.0 ft lbs
MAXIMUM: 107.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

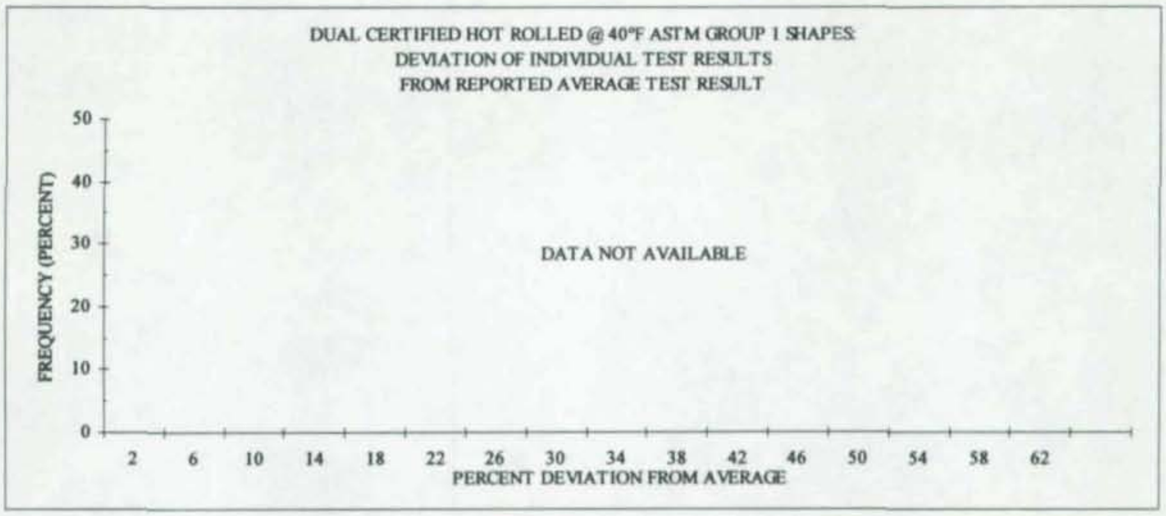

A913 Gr65 QST @ 70°F ALL ASTM GROUPS SHAPES
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 45.4 ft lbs
MEDIAN (50%): 57.3 ft lbs
3RD QUARTILE (75%): 78.9 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

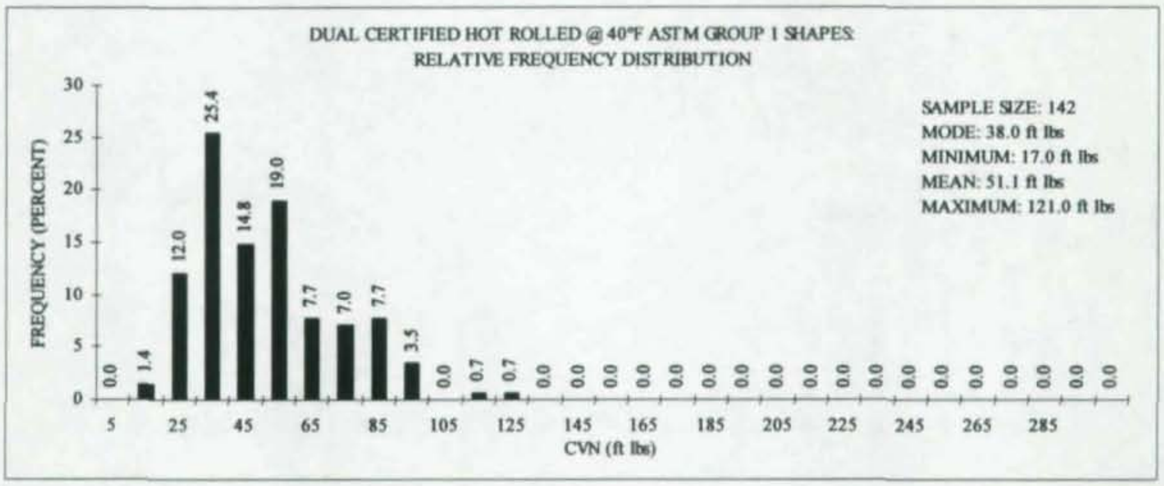
DUAL CERTIFIED STEEL

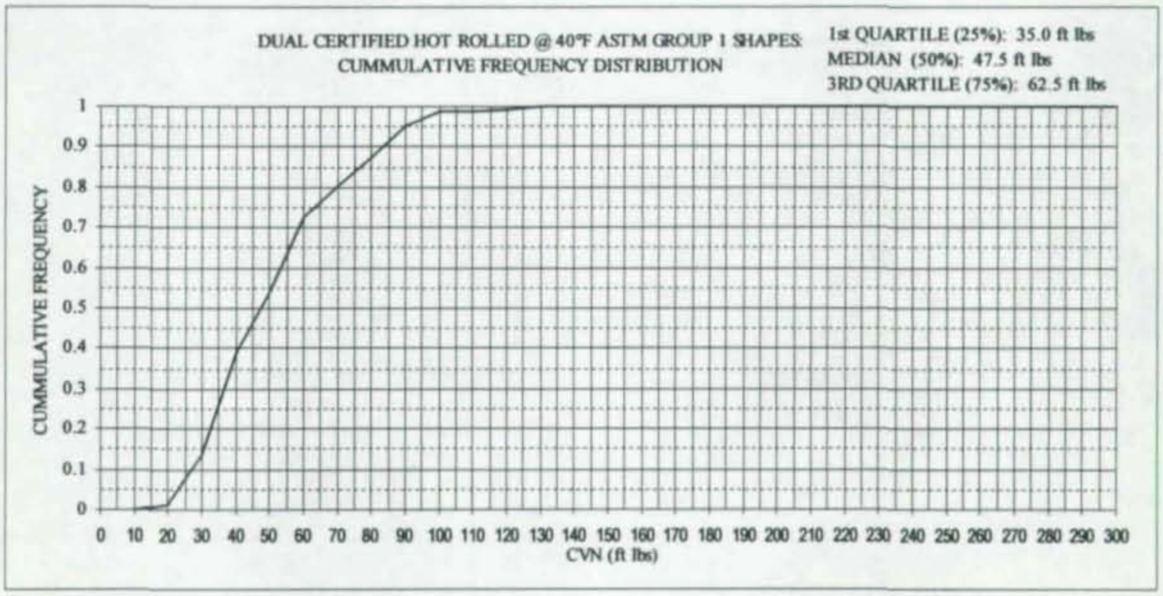

DUAL CERTIFIED HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
FREQUENCY (PERCENT)
DATA NOT AVAILABLE
PERCENT DEVIATION FROM AVERAGE

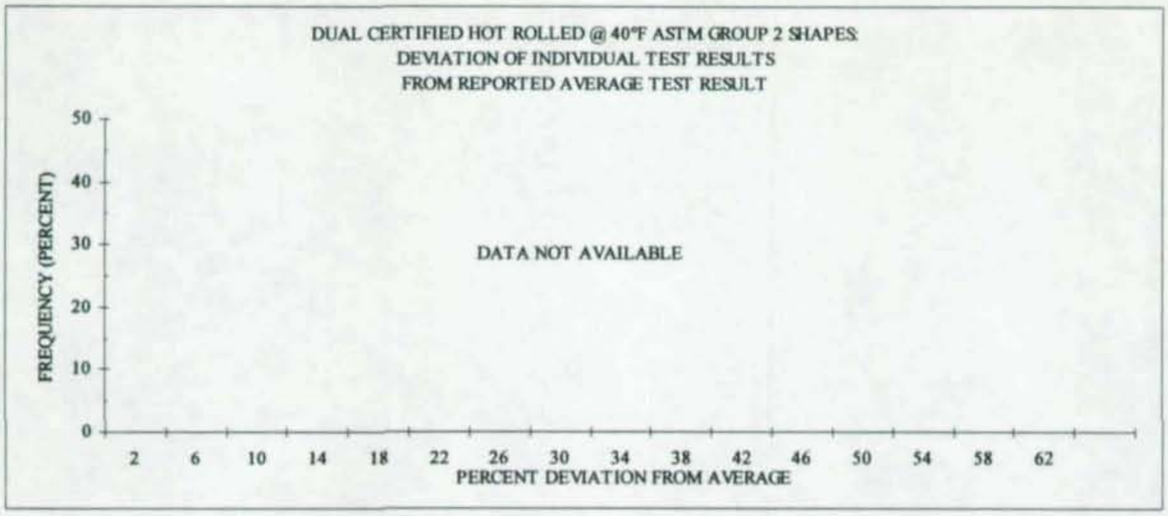

DUAL CERTIFIED HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 202
MODE: 43.0 ft lbs
MINIMUM: 17.0 ft lbs
MEAN: 52.7 ft lbs
MAXIMUM: 121.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

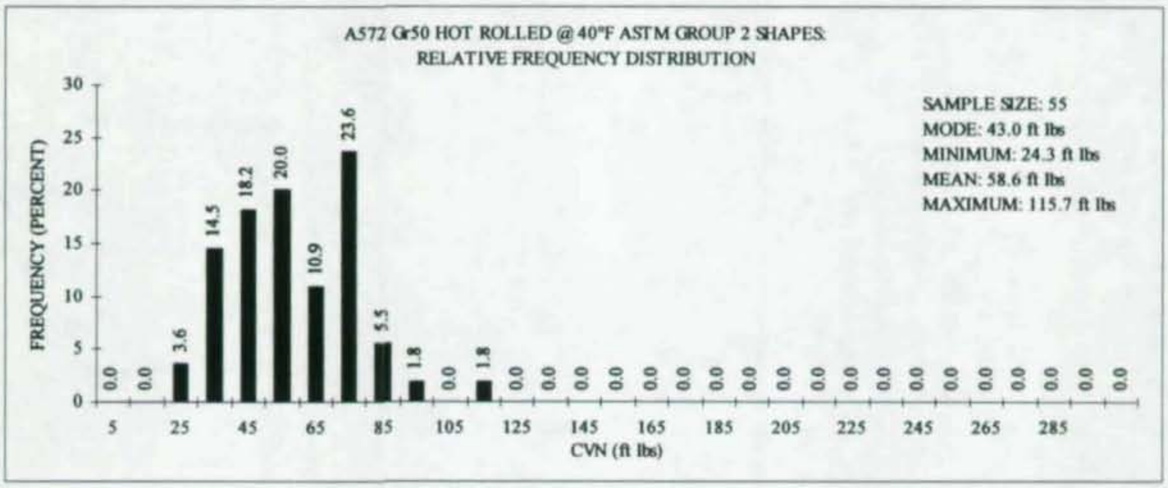

DUAL CERTIFIED HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 37.0 ft lbs
MEDIAN (50%): 51.0 ft lbs
3RD QUARTILE (75%): 67.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

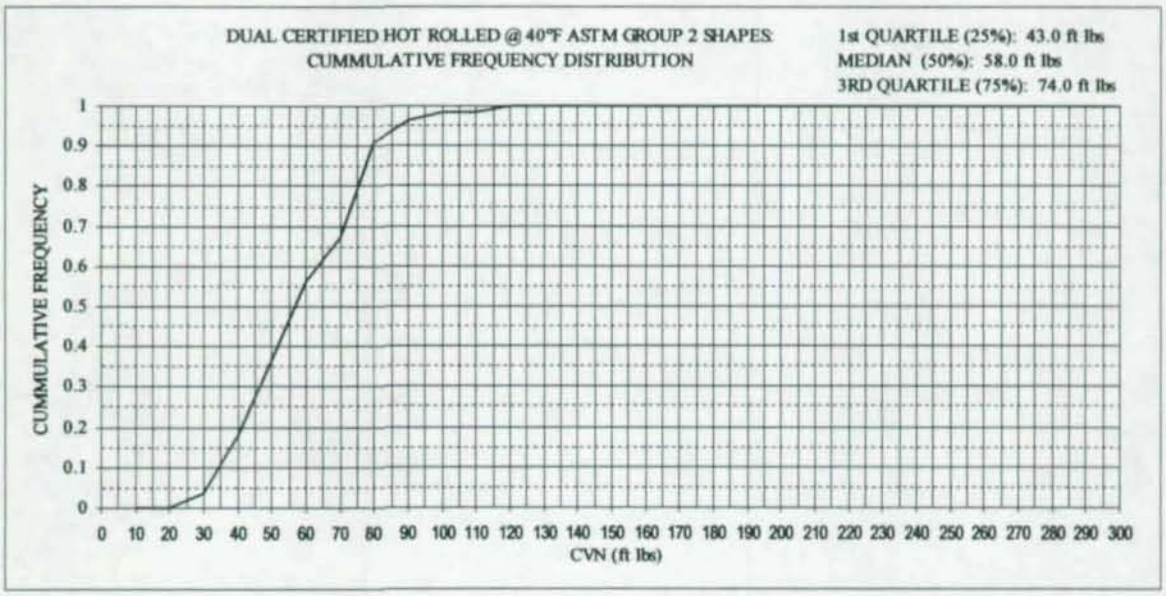

DUAL CERTIFIED HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
FREQUENCY (PERCENT)
DATA NOT AVAILABLE
PERCENT DEVIATION FROM AVERAGE

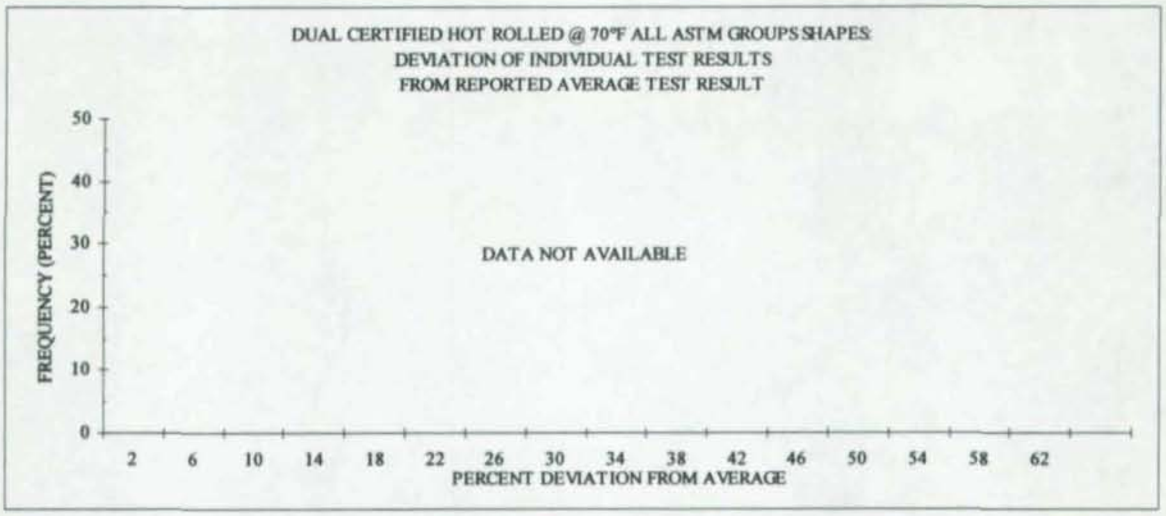

DUAL CERTIFIED HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 142
MODE: 38.0 ft lbs
MINIMUM: 17.0 ft lbs
MEAN: 51.1 ft lbs
MAXIMUM: 121.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

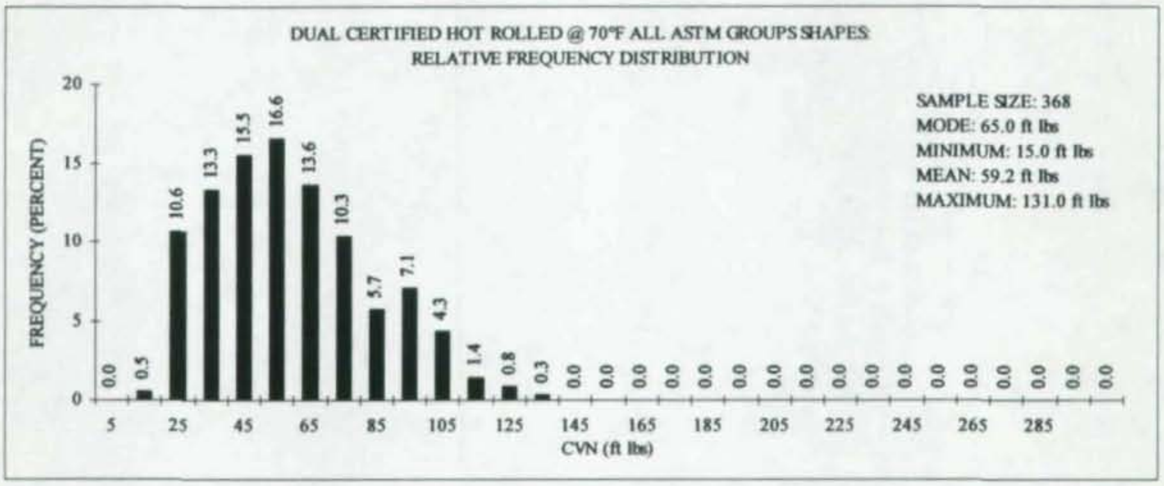

DUAL CERTIFIED HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 35.0 ft lbs
MEDIAN (50%): 47.5 ft lbs
3RD QUARTILE (75%): 62.5 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

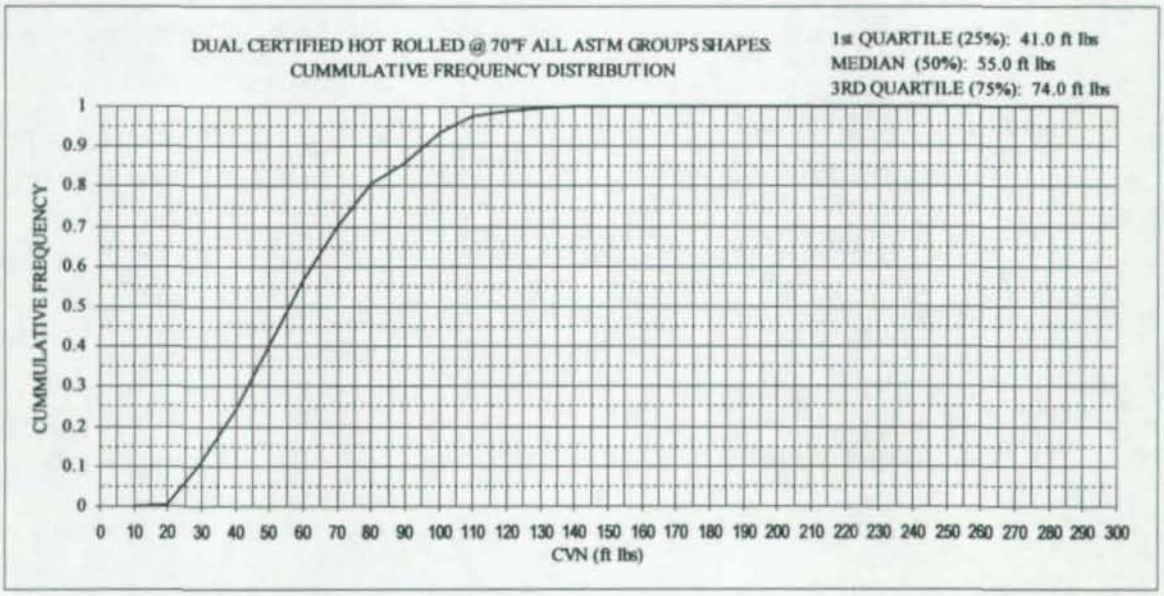

DUAL CERTIFIED HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
FREQUENCY (PERCENT)
DATA NOT AVAILABLE
PERCENT DEVIATION FROM AVERAGE

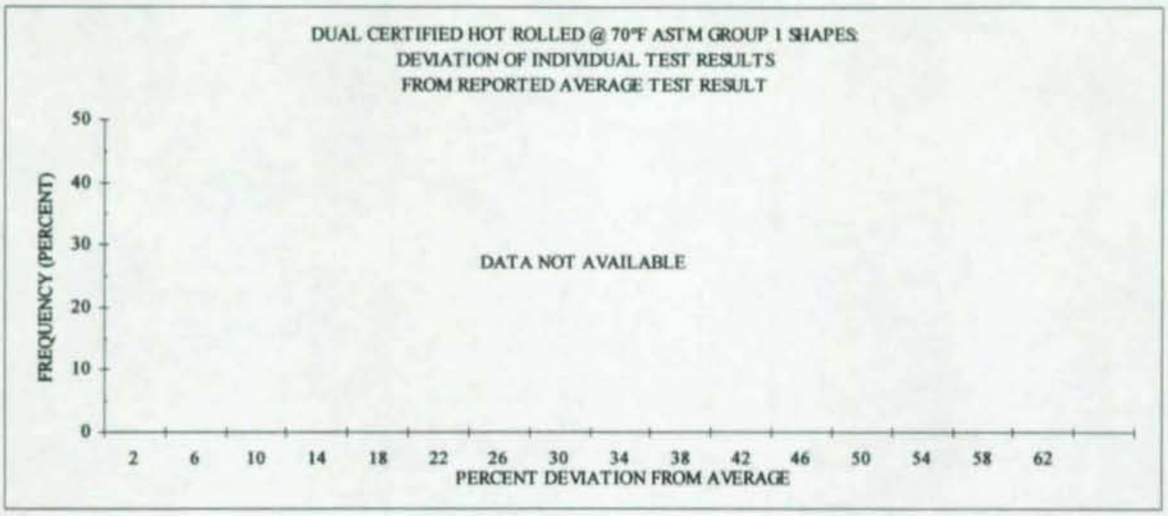

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 55
MODE: 43.0 ft lbs
MINIMUM: 24.3 ft lbs
MEAN: 58.6 ft lbs
MAXIMUM: 115.7 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

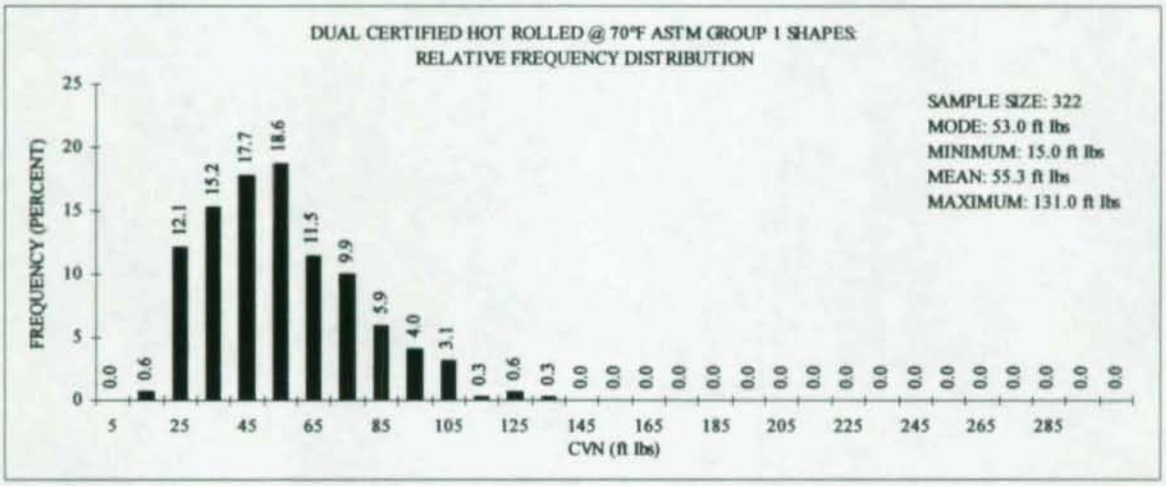

DUAL CERTIFIED HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 43.0 ft lbs
MEDIAN (50%): 58.0 ft lbs
3RD QUARTILE (75%): 74.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

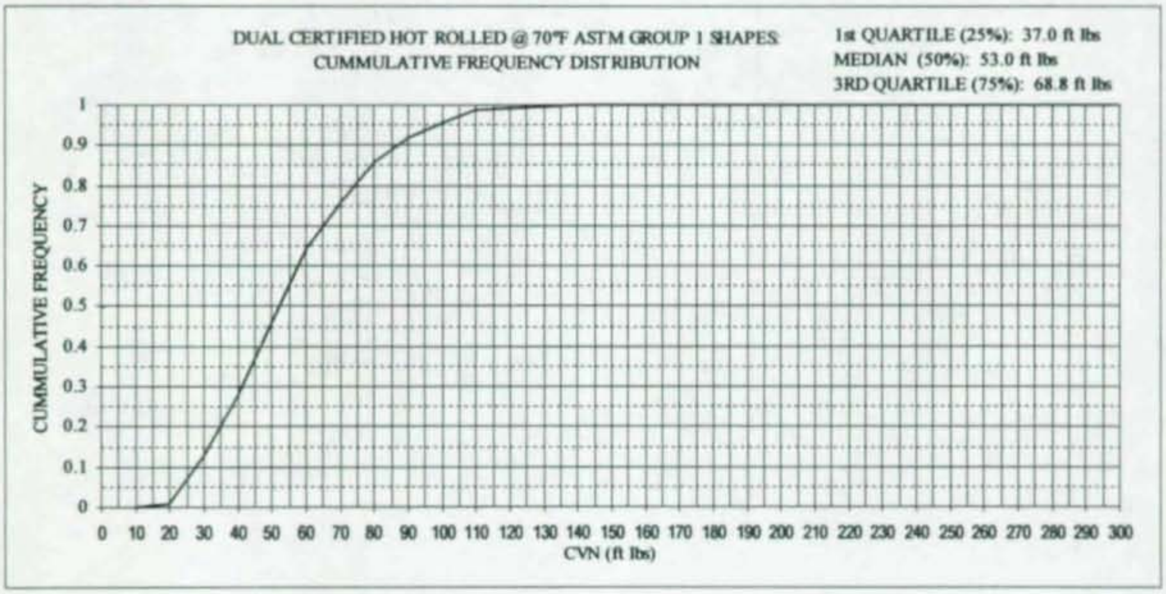

DUAL CERTIFIED HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
FREQUENCY (PERCENT)
DATA NOT AVAILABLE
PERCENT DEVIATION FROM AVERAGE

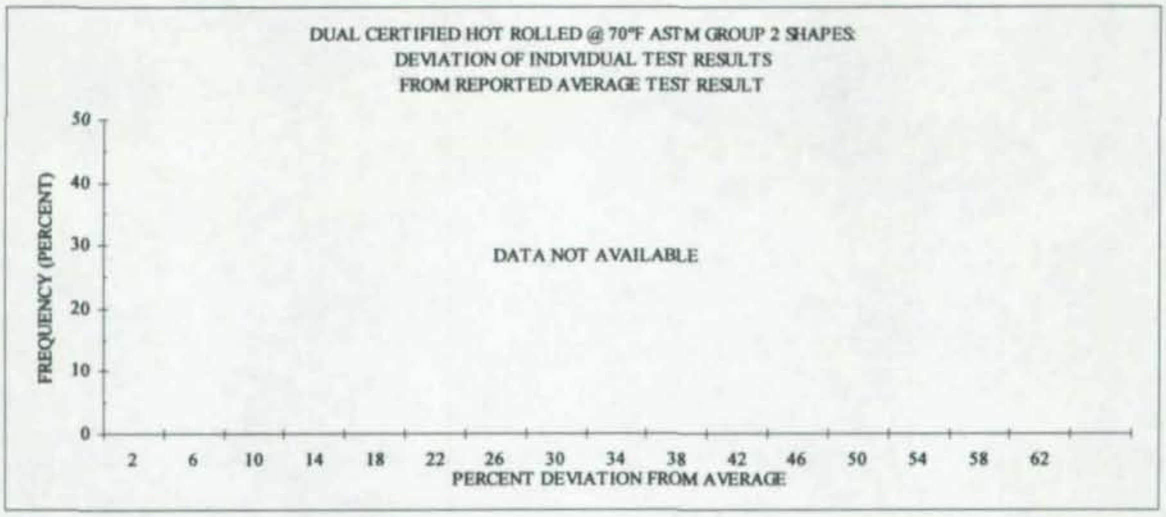

DUAL CERTIFIED HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 368
MODE: 65.0 ft lbs
MINIMUM: 15.0 ft lbs
MEAN: 59.2 ft lbs
MAXIMUM: 131.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

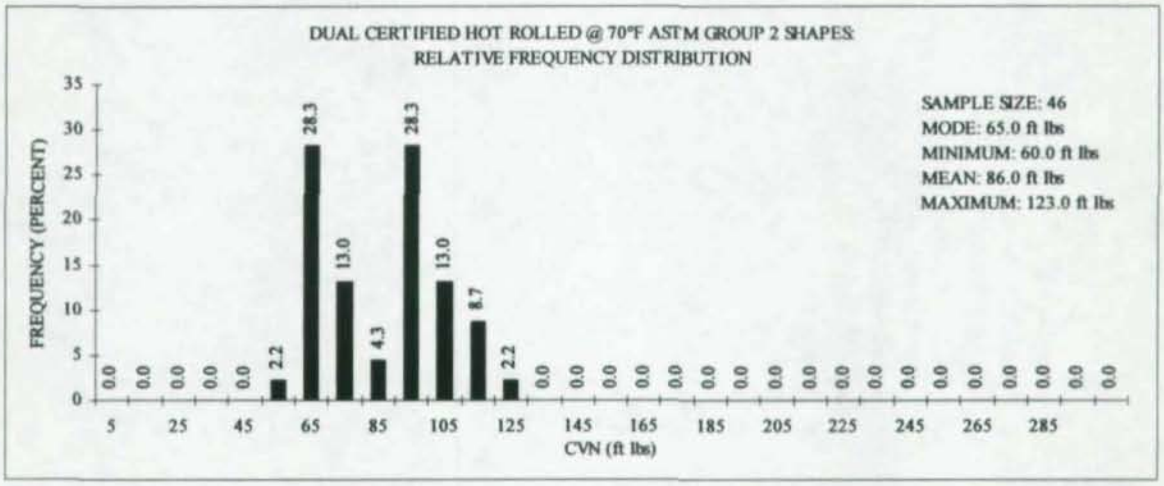

DUAL CERTIFIED HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 41.0 ft lbs
MEDIAN (50%): 55.0 ft lbs
3RD QUARTILE (75%): 74.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

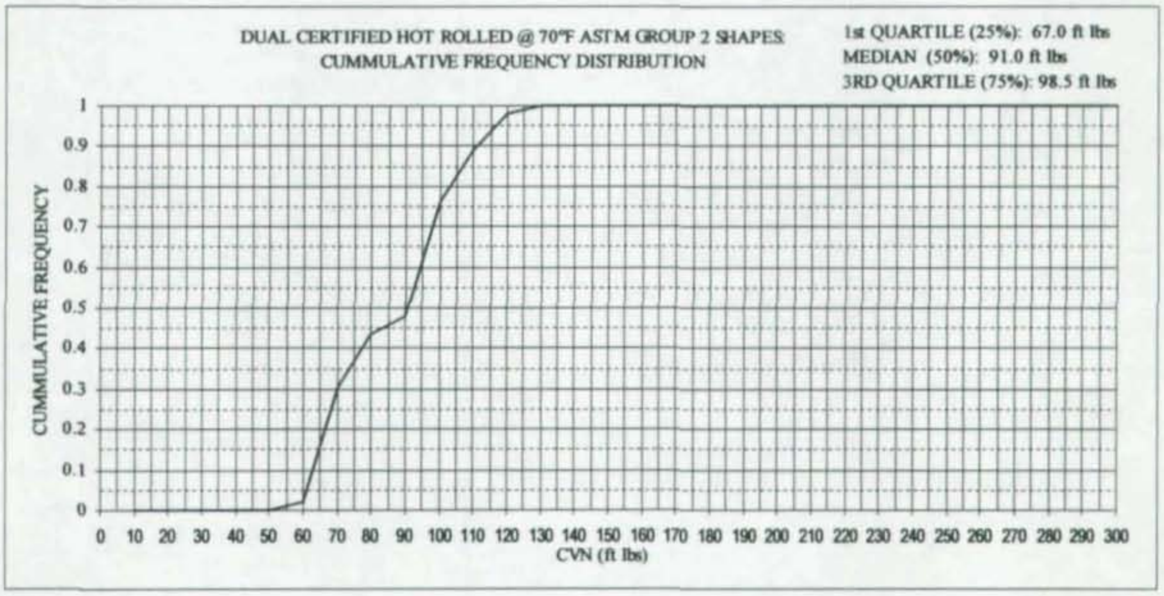

DUAL CERTIFIED HOT ROLLED @ 70°F ASTM GROUP 1 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
FREQUENCY (PERCENT)
DATA NOT AVAILABLE
PERCENT DEVIATION FROM AVERAGE


DUAL CERTIFIED HOT ROLLED @ 70°F ASTM GROUP 1 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 322
MODE: 53.0 ft lbs
MINIMUM: 15.0 ft lbs
MEAN: 55.3 ft lbs
MAXIMUM: 131.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)


DUAL CERTIFIED HOT ROLLED @ 70°F ASTM GROUP 1 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 37.0 ft lbs
MEDIAN (50%): 53.0 ft lbs
3RD QUARTILE (75%): 68.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)


DUAL CERTIFIED HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
DEVIATION OF INDIVIDUAL TEST RESULTS
FROM REPORTED AVERAGE TEST RESULT
FREQUENCY (PERCENT)
DATA NOT AVAILABLE
PERCENT DEVIATION FROM AVERAGE


DUAL CERTIFIED HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
RELATIVE FREQUENCY DISTRIBUTION
SAMPLE SIZE: 46
MODE: 65.0 ft lbs
MINIMUM: 60.0 ft lbs
MEAN: 86.0 ft lbs
MAXIMUM: 123.0 ft lbs
FREQUENCY (PERCENT)
CVN (ft lbs)

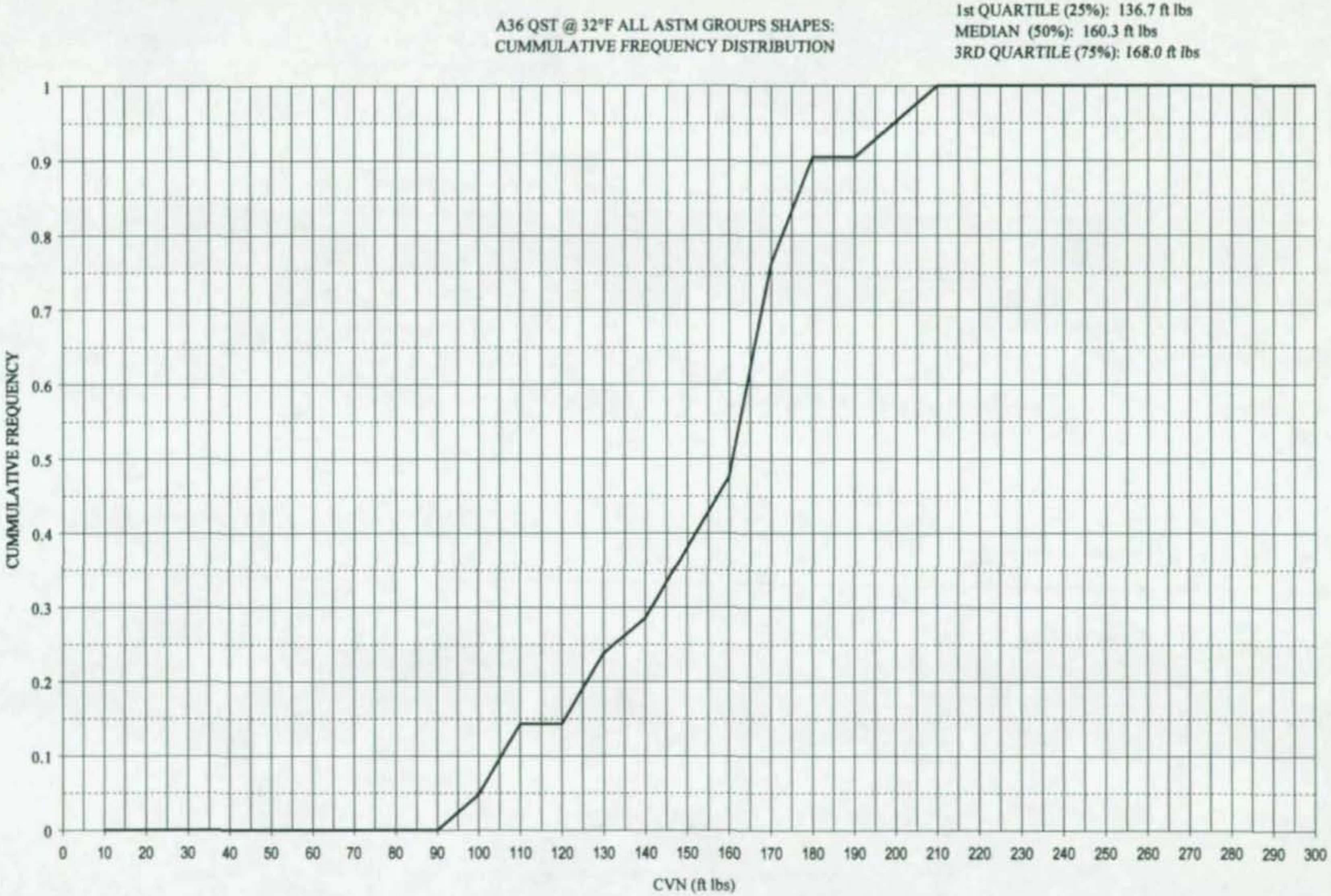

DUAL CERTIFIED HOT ROLLED @ 70°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 67.0 ft lbs
MEDIAN (50%): 91.0 ft lbs
3RD QUARTILE (75%): 98.5 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

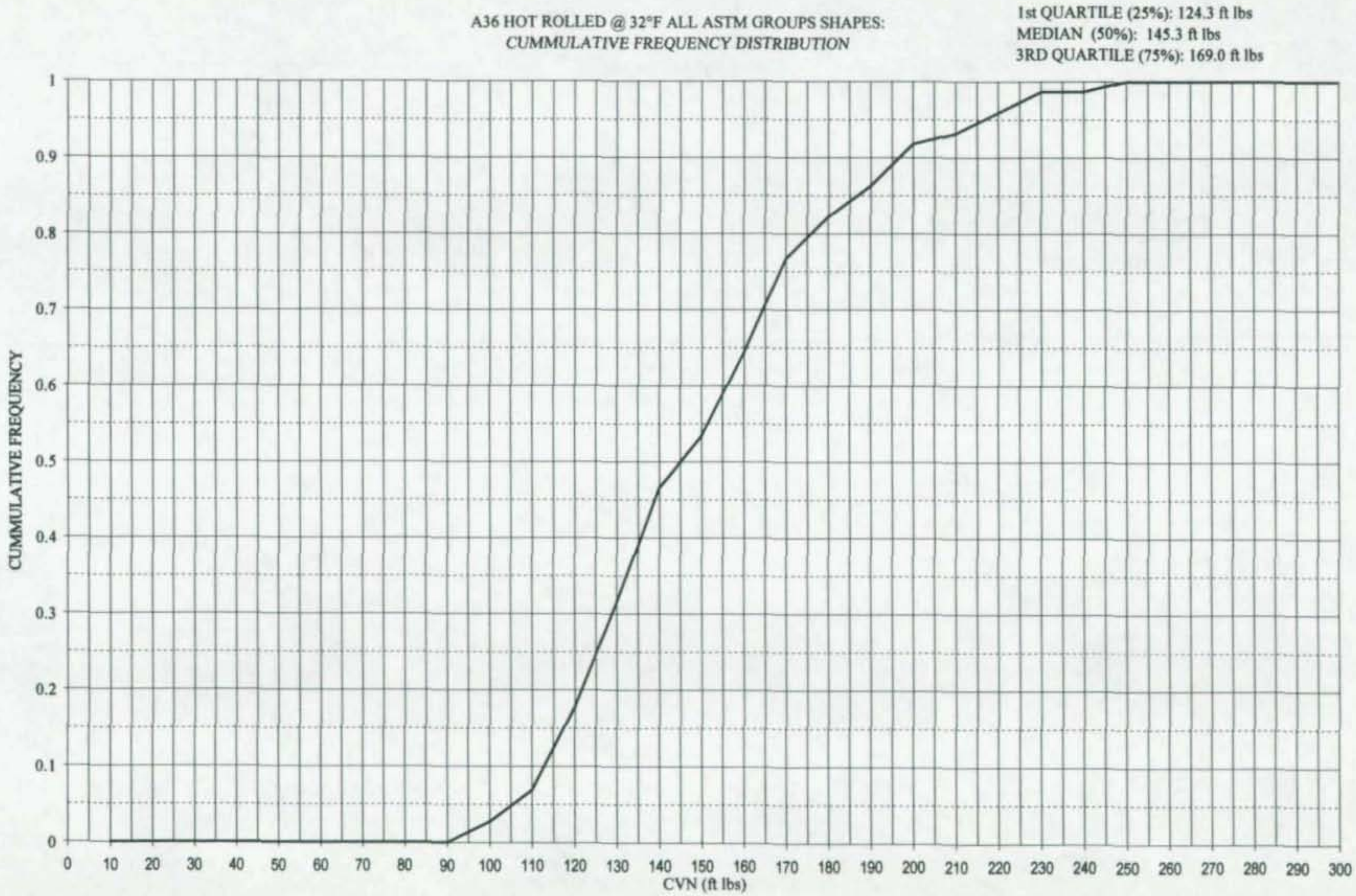
APPENDIX B:

OBSERVED CUMMULATIVE DISTRIBUTIONS

NOTE: HR = Hot Rolled; QST = Quenched Self-Tempered

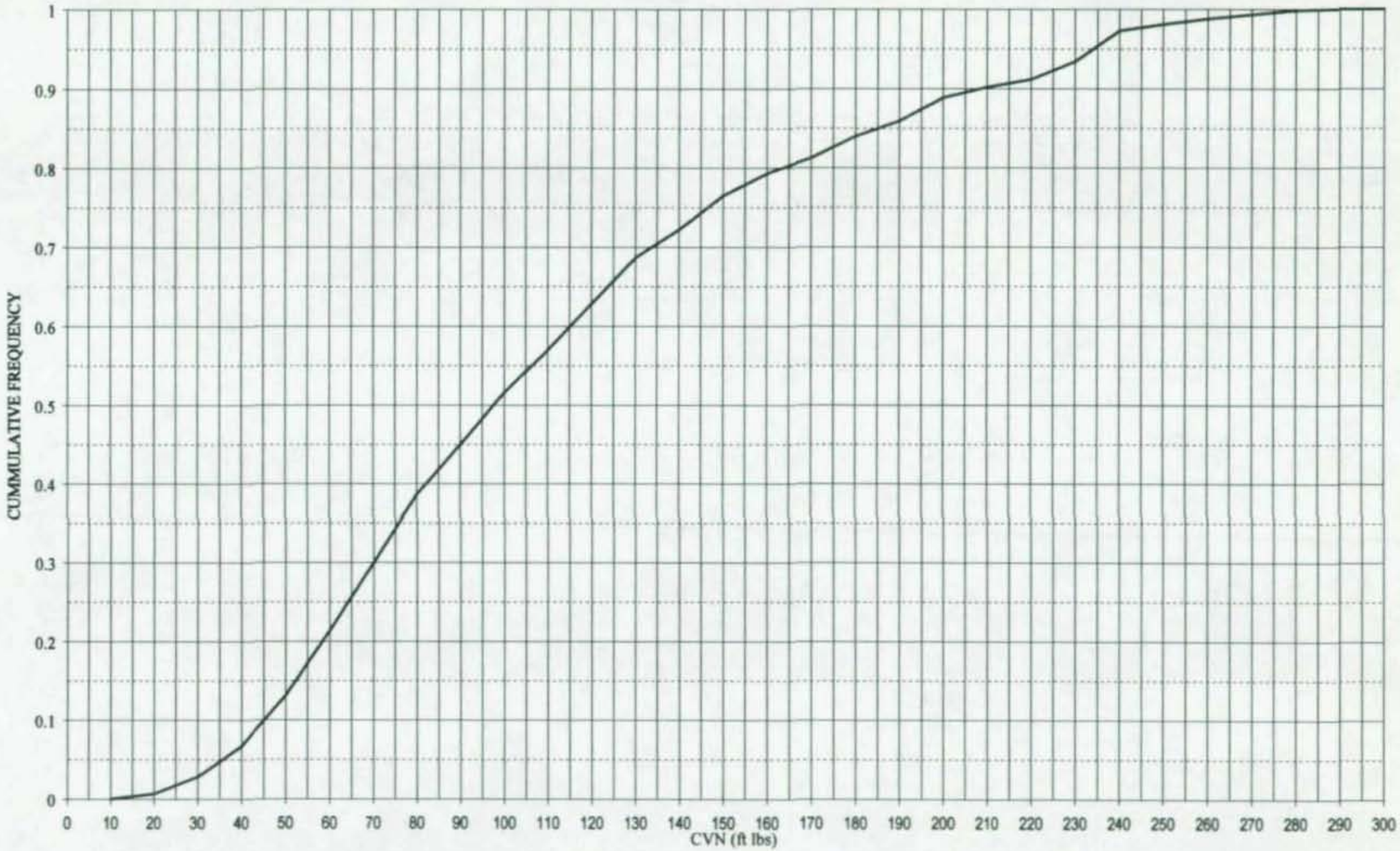
A36 STEEL

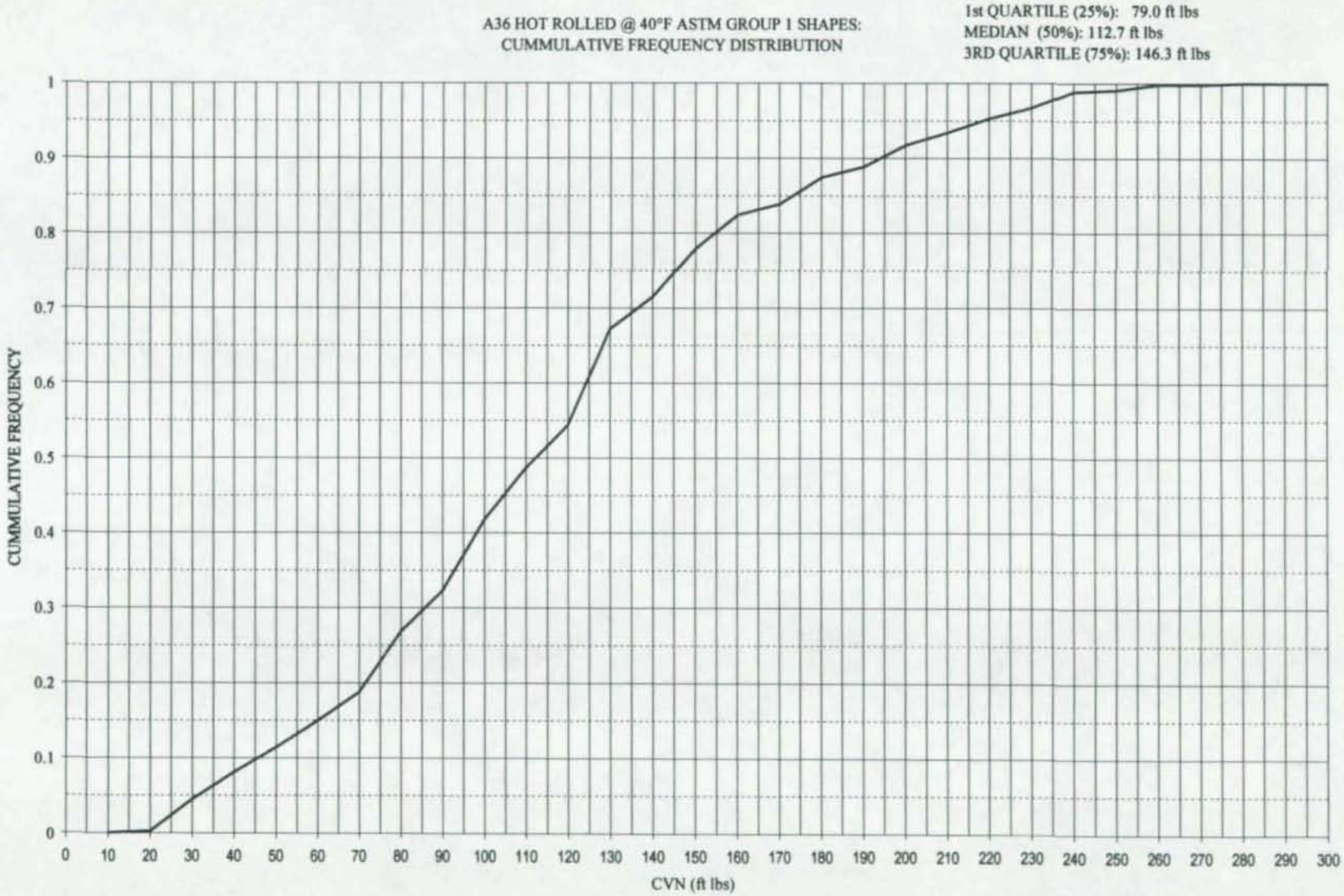

A36 QST @ 32°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 136.7 ft lbs
MEDIAN (50%): 160.3 ft lbs
3RD QUARTILE (75%): 168.0 ft lbs
CUMMULATIVE FREQUENCY
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
CVN (ft lbs)

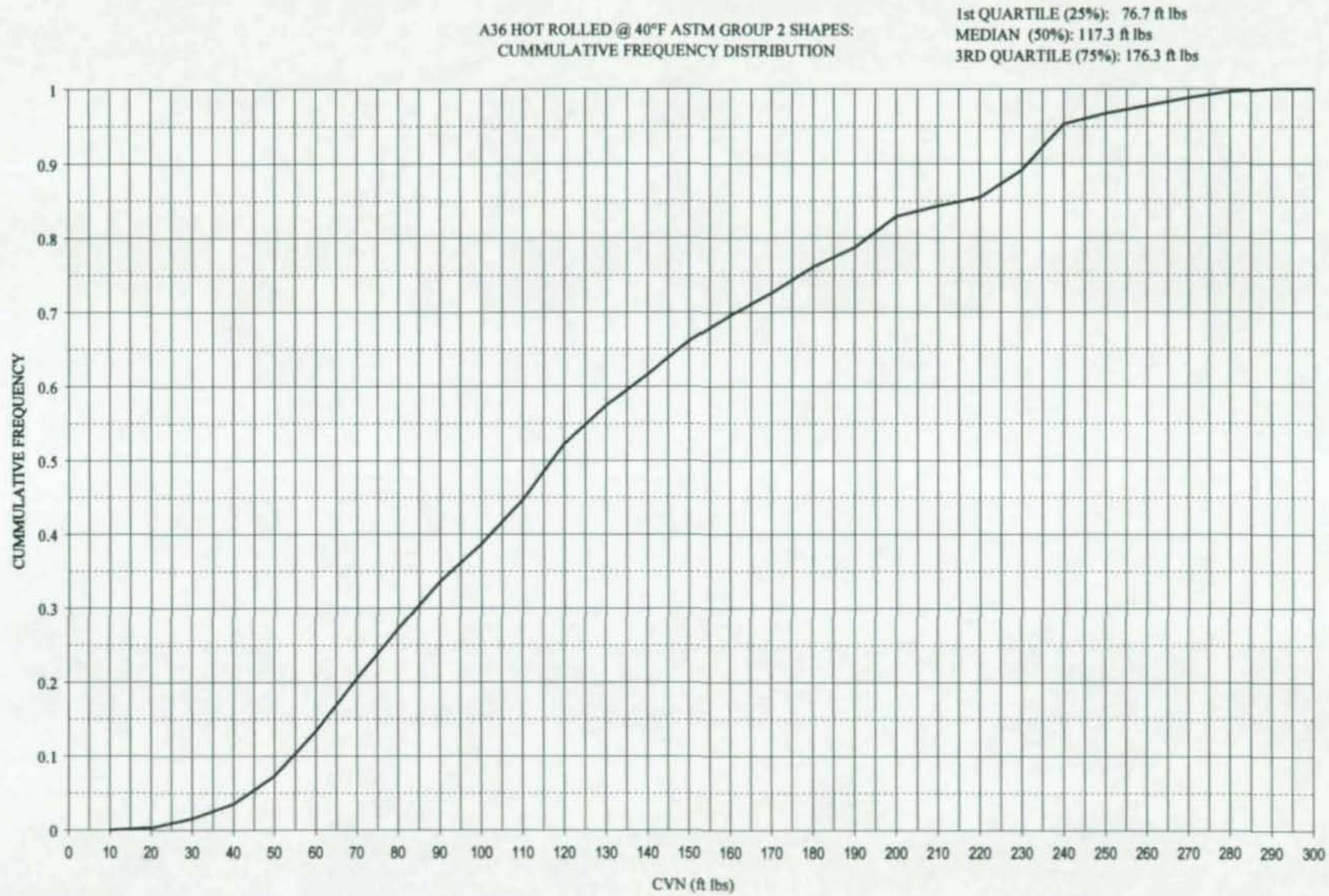

A36 HOT ROLLED @ 32°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 124.3 ft lbs
MEDIAN (50%): 145.3 ft lbs
3RD QUARTILE (75%): 169.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

A36 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION

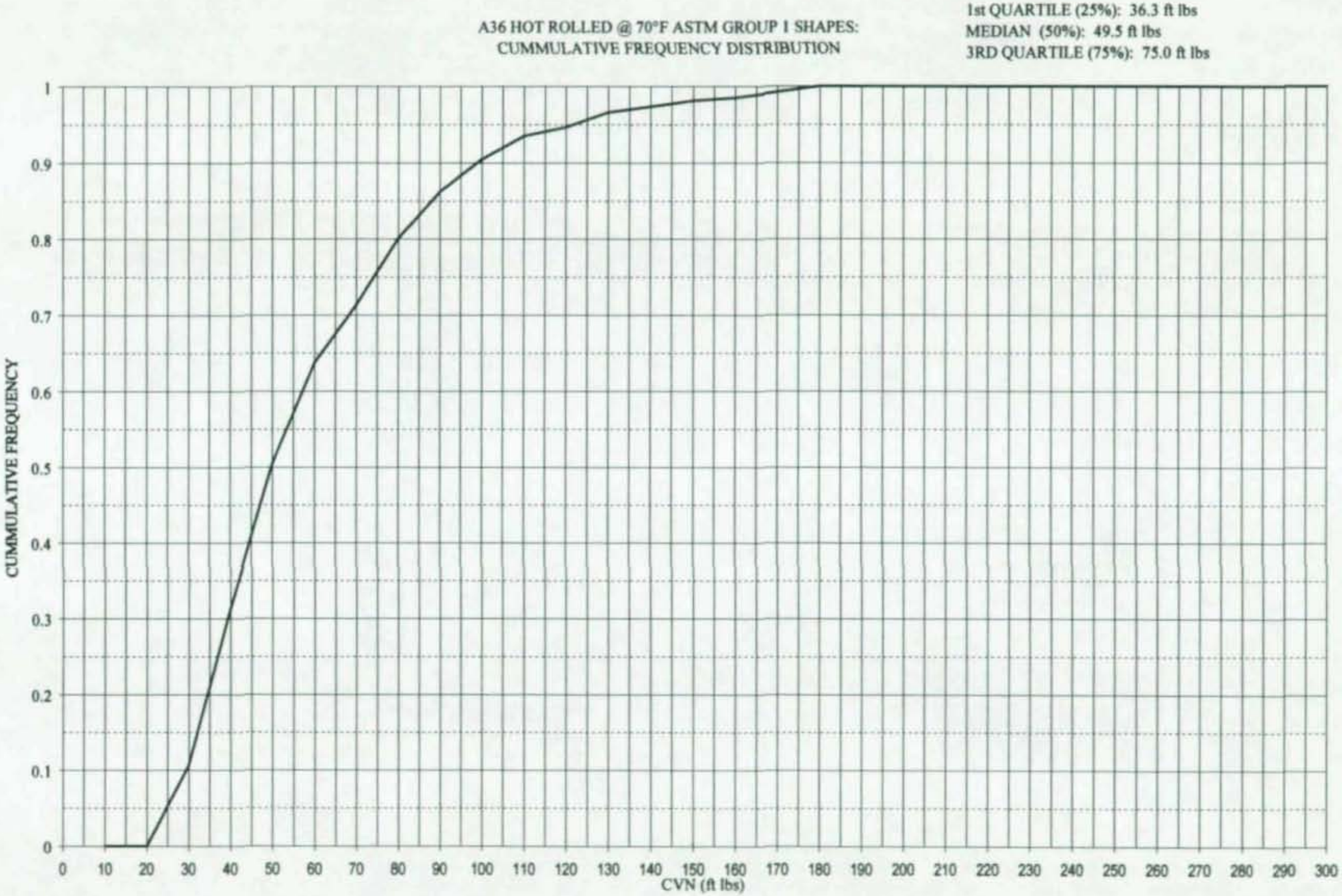
1st QUARTILE (25%): 64.7 ft lbs
MEDIAN (50%): 98.0 ft lbs
3RD QUARTILE (75%): 147.2 ft lbs

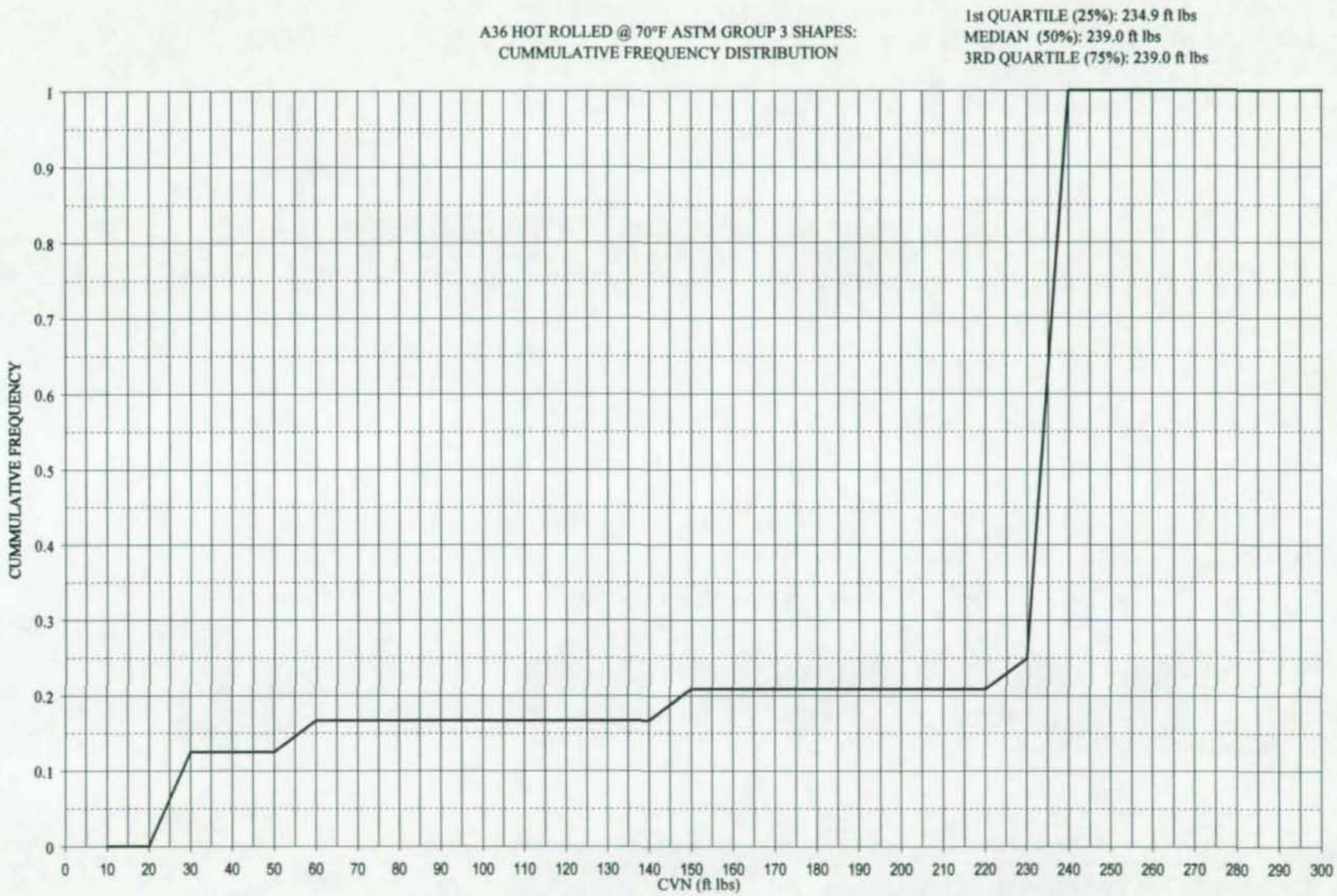



A36 HOT ROLLED @ 40°F ASTM GROUP 1 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 79.0 ft lbs
MEDIAN (50%): 112.7 ft lbs
3RD QUARTILE (75%): 146.3 ft lbs
CUMMULATIVE FREQUENCY
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
CVN (ft lbs)

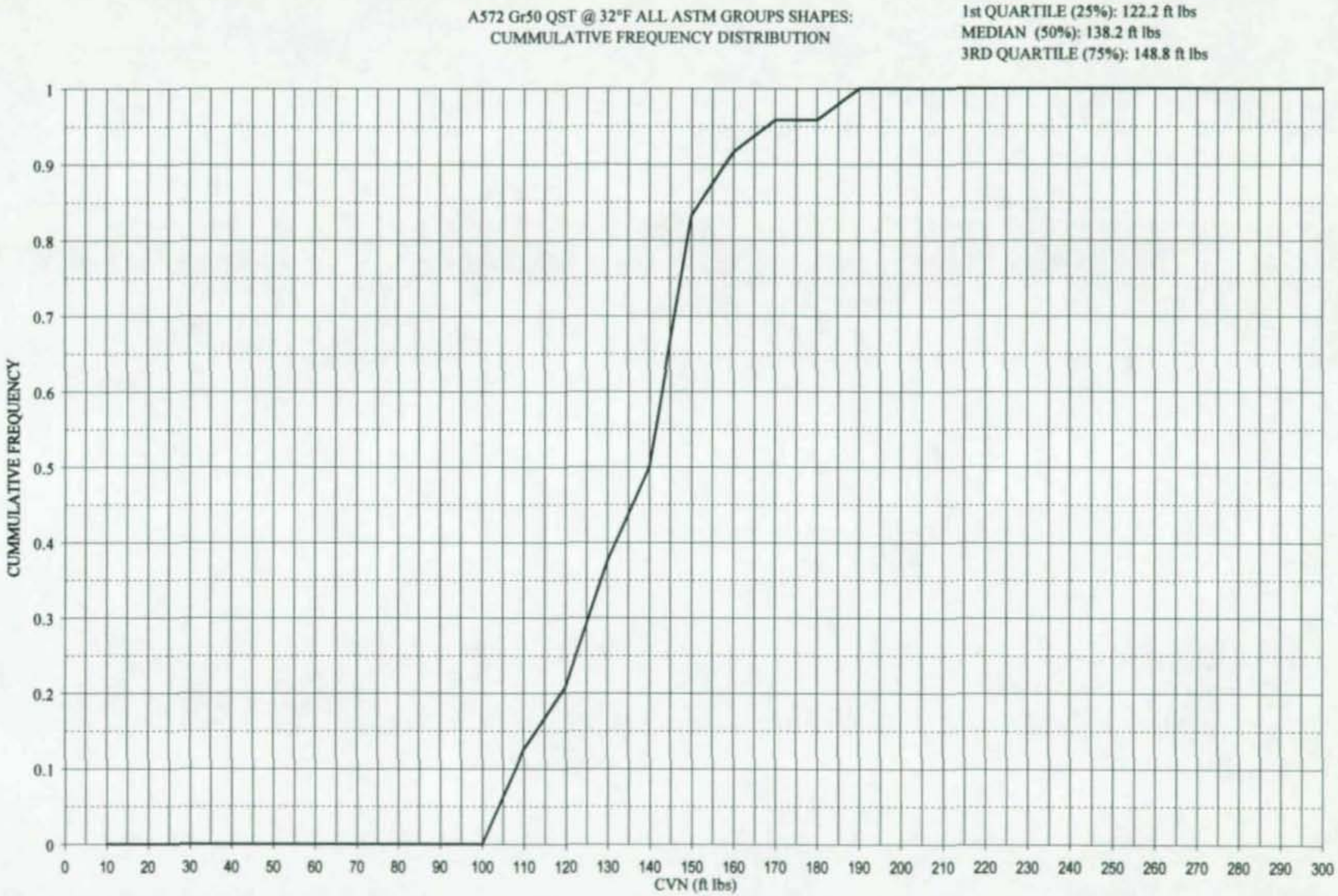

A36 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 76.7 ft lbs
MEDIAN (50%): 117.3 ft lbs
3RD QUARTILE (75%): 176.3 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)


A36 HOT ROLLED @ 40°F ASTM GROUP 4 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 41.4 ft lbs
MEDIAN (50%): 51.0 ft lbs
3RD QUARTILE (75%): 61.5 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300


A36 HOT ROLLED @ 70°F ASTM GROUP 1 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 36.3 ft lbs
MEDIAN (50%): 49.5 ft lbs
3RD QUARTILE (75%): 75.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

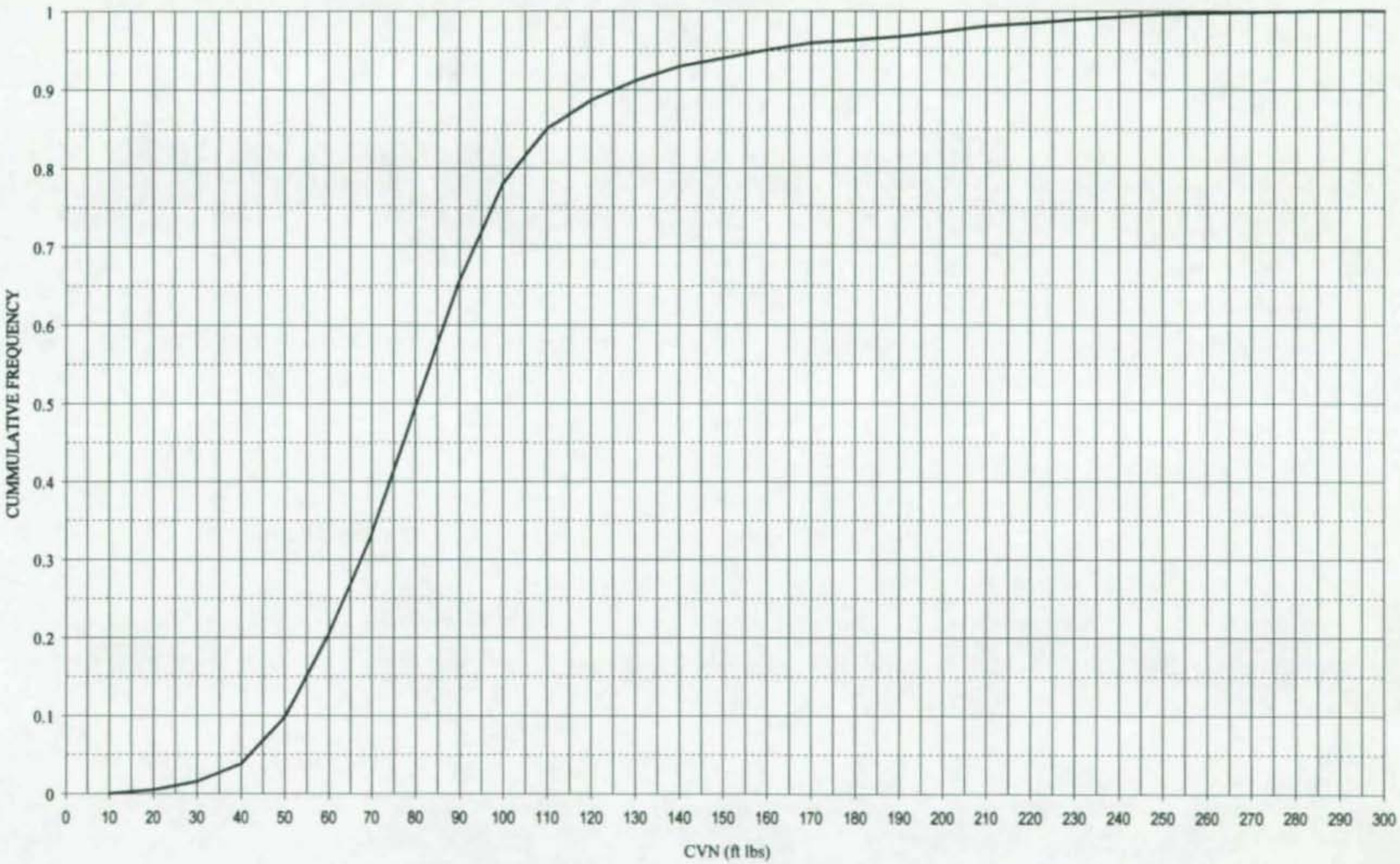

A36 HOT ROLLED @ 70°F ASTM GROUP 3 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 234.9 ft lbs
MEDIAN (50%): 239.0 ft lbs
3RD QUARTILE (75%): 239.0 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300

A572 Gr50 STEEL


A572 Gr50 QST @ 32°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 122.2 ft lbs
MEDIAN (50%): 138.2 ft lbs
3RD QUARTILE (75%): 148.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)

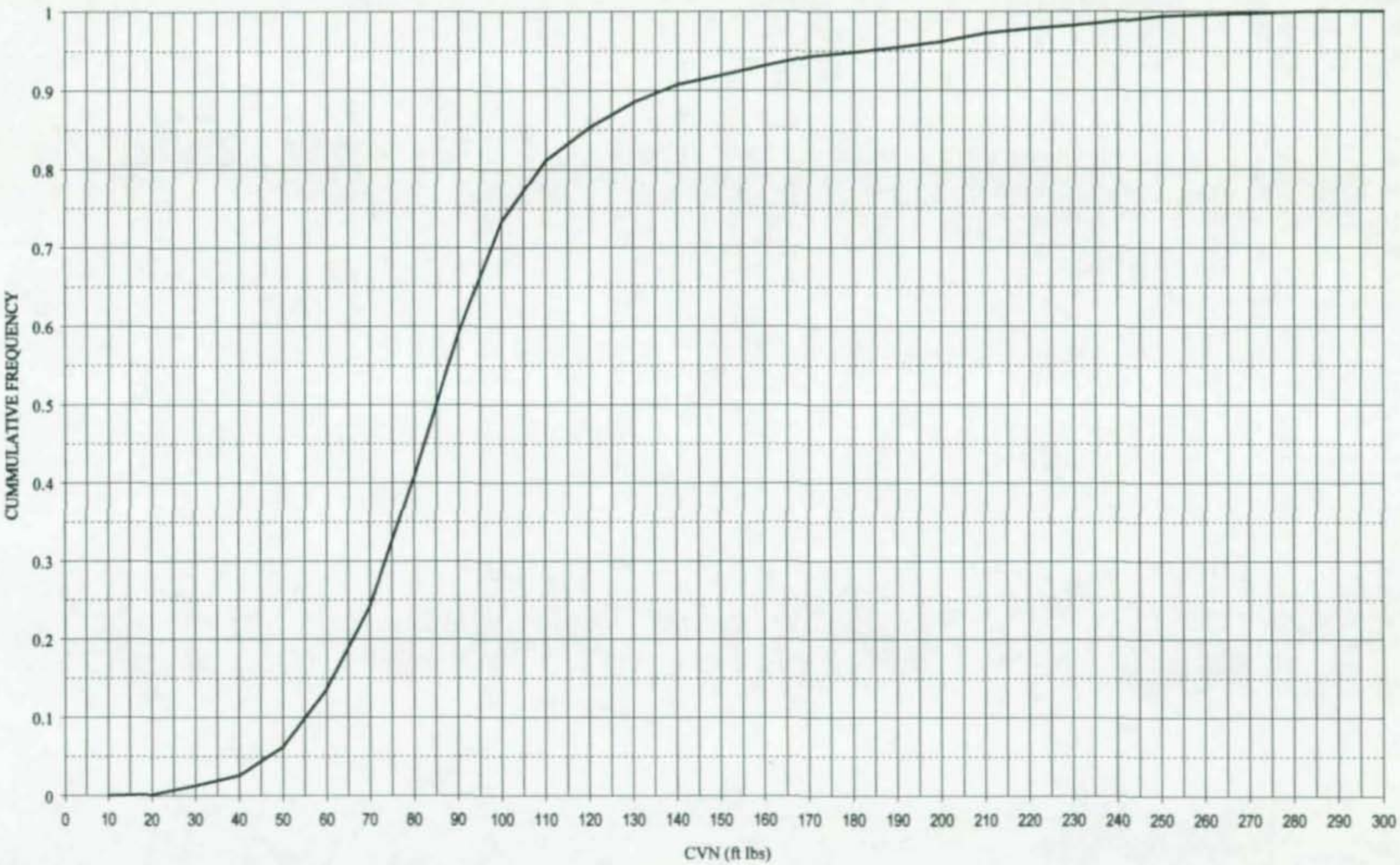
A572 Gr50 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION

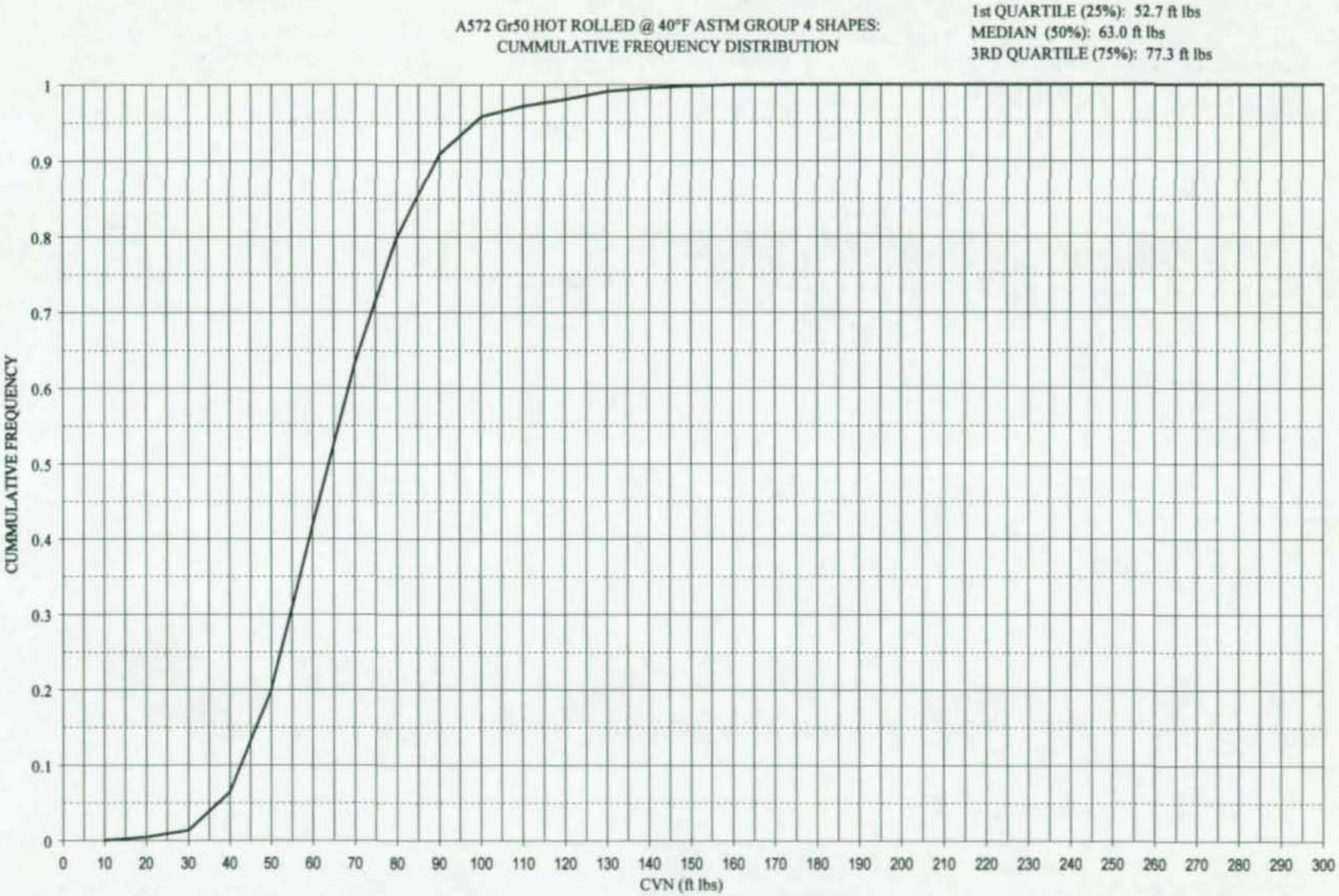
1st QUARTILE (25%): 63.7 ft lbs
MEDIAN (50%): 80.3 ft lbs
3RD QUARTILE (75%): 97.3 ft lbs

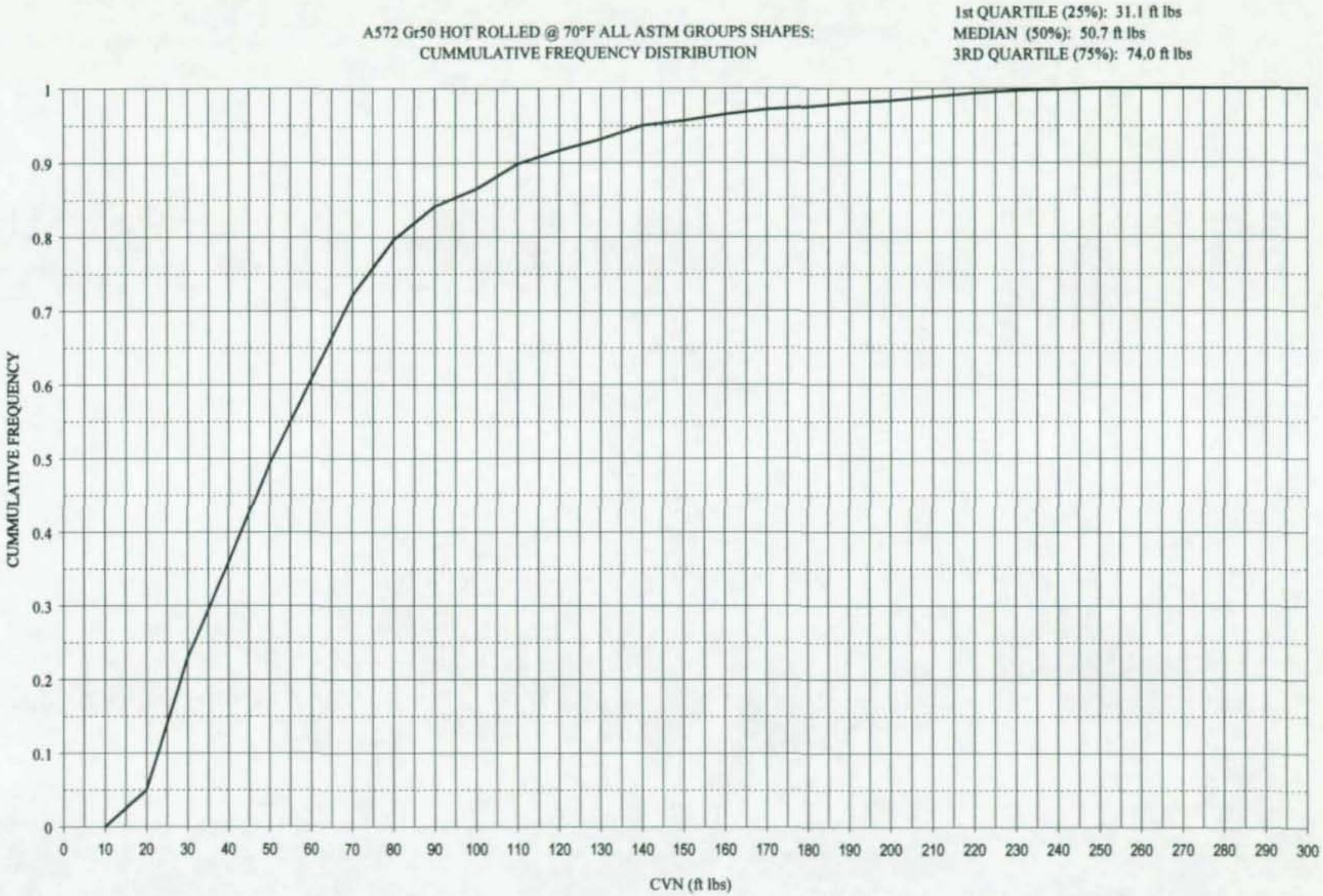


A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 2 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION

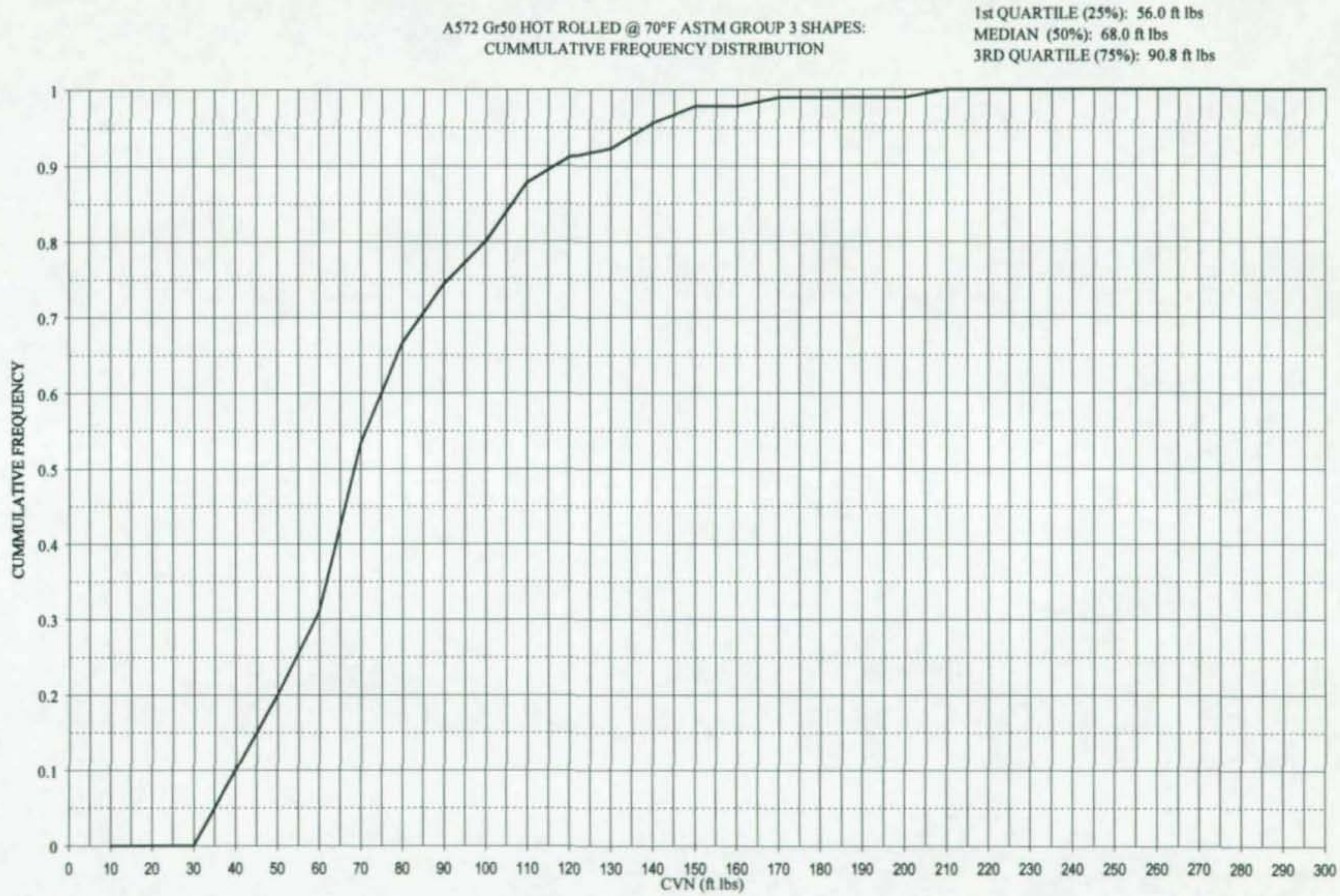
1st QUARTILE (25%): 70.7 ft lbs
MEDIAN (50%): 85.3 ft lbs
3RD QUARTILE (75%): 102.3 ft lbs



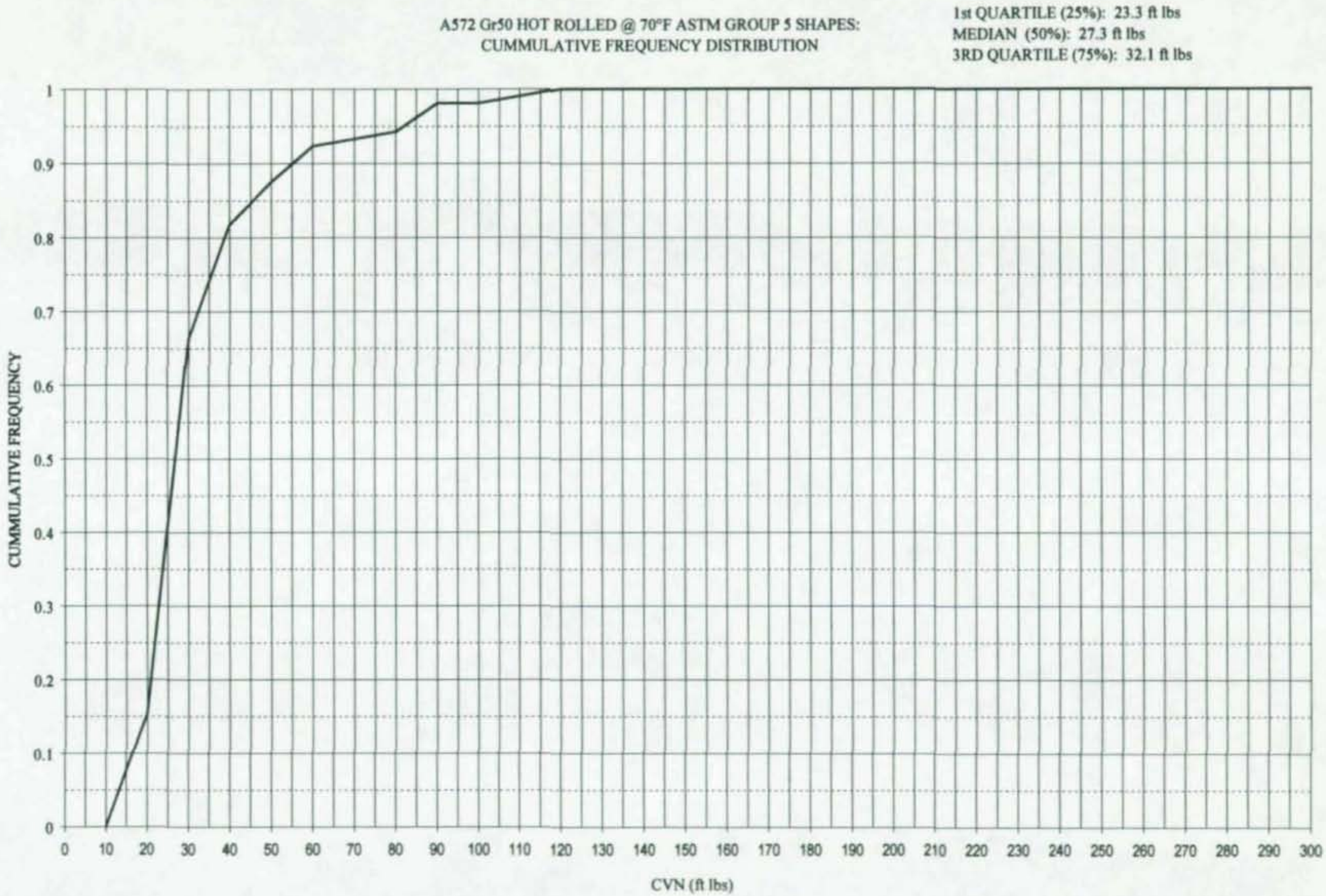

A572 Gr50 HOT ROLLED @ 40°F ASTM GROUP 4 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 52.7 ft lbs
MEDIAN (50%): 63.0 ft lbs
3RD QUARTILE (75%): 77.3 ft lbs
CUMMULATIVE FREQUENCY
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
CVN (ft lbs)



A572 Gr50 HOT ROLLED @ 70°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 31.1 ft lbs
MEDIAN (50%): 50.7 ft lbs
3RD QUARTILE (75%): 74.0 ft lbs
CUMMULATIVE FREQUENCY
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
CVN (ft lbs)


A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 3 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 56.0 ft lbs
MEDIAN (50%): 68.0 ft lbs
3RD QUARTILE (75%): 90.8 ft lbs
CUMMULATIVE FREQUENCY
CVN (ft lbs)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300

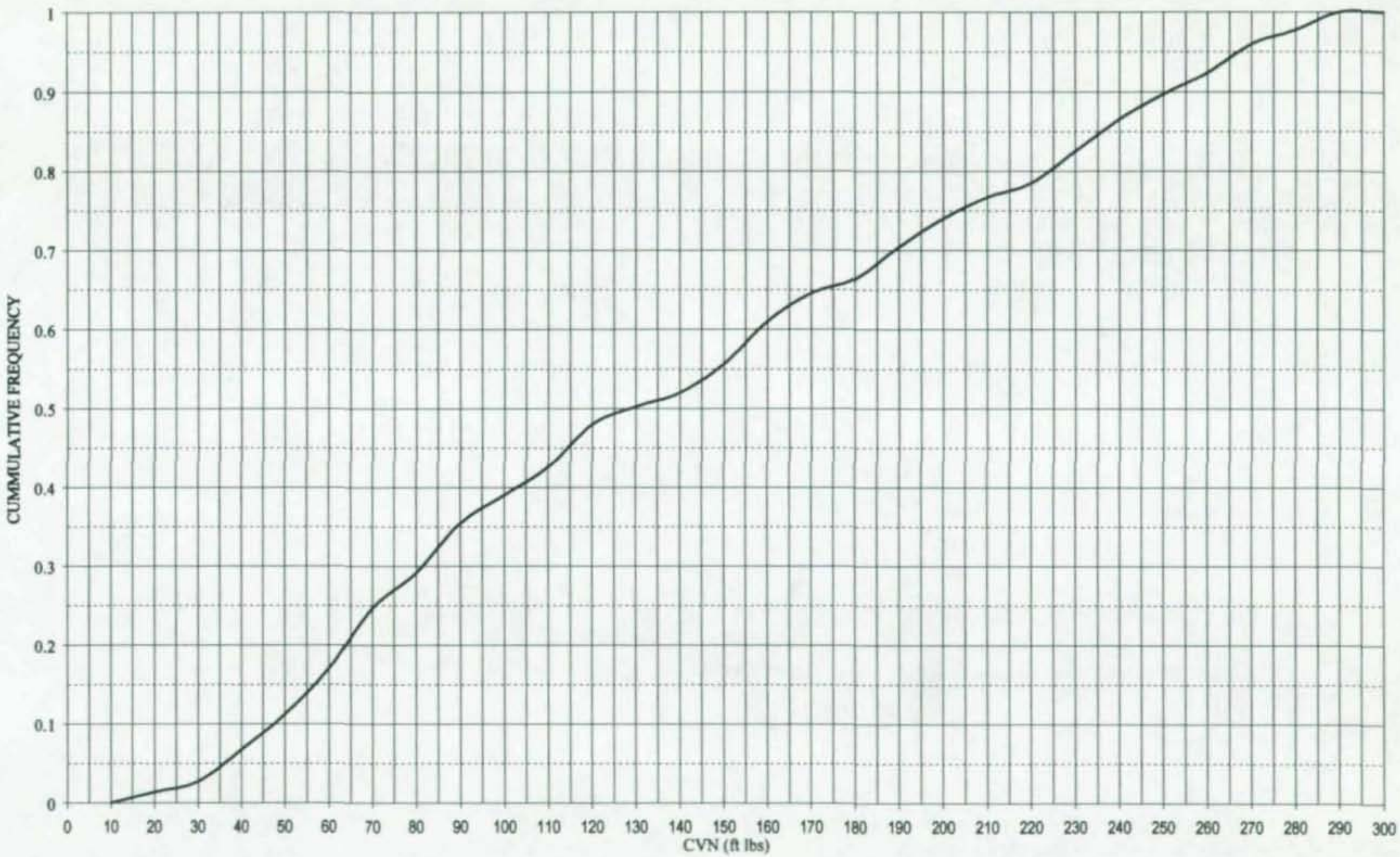
00500


A572 Gr50 HOT ROLLED @ 70°F ASTM GROUP 5 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 23.3 ft lbs
MEDIAN (50%): 27.3 ft lbs
3RD QUARTILE (75%): 32.1 ft lbs
CUMMULATIVE FREQUENCY
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
CVN (ft lbs)

A588 STEEL

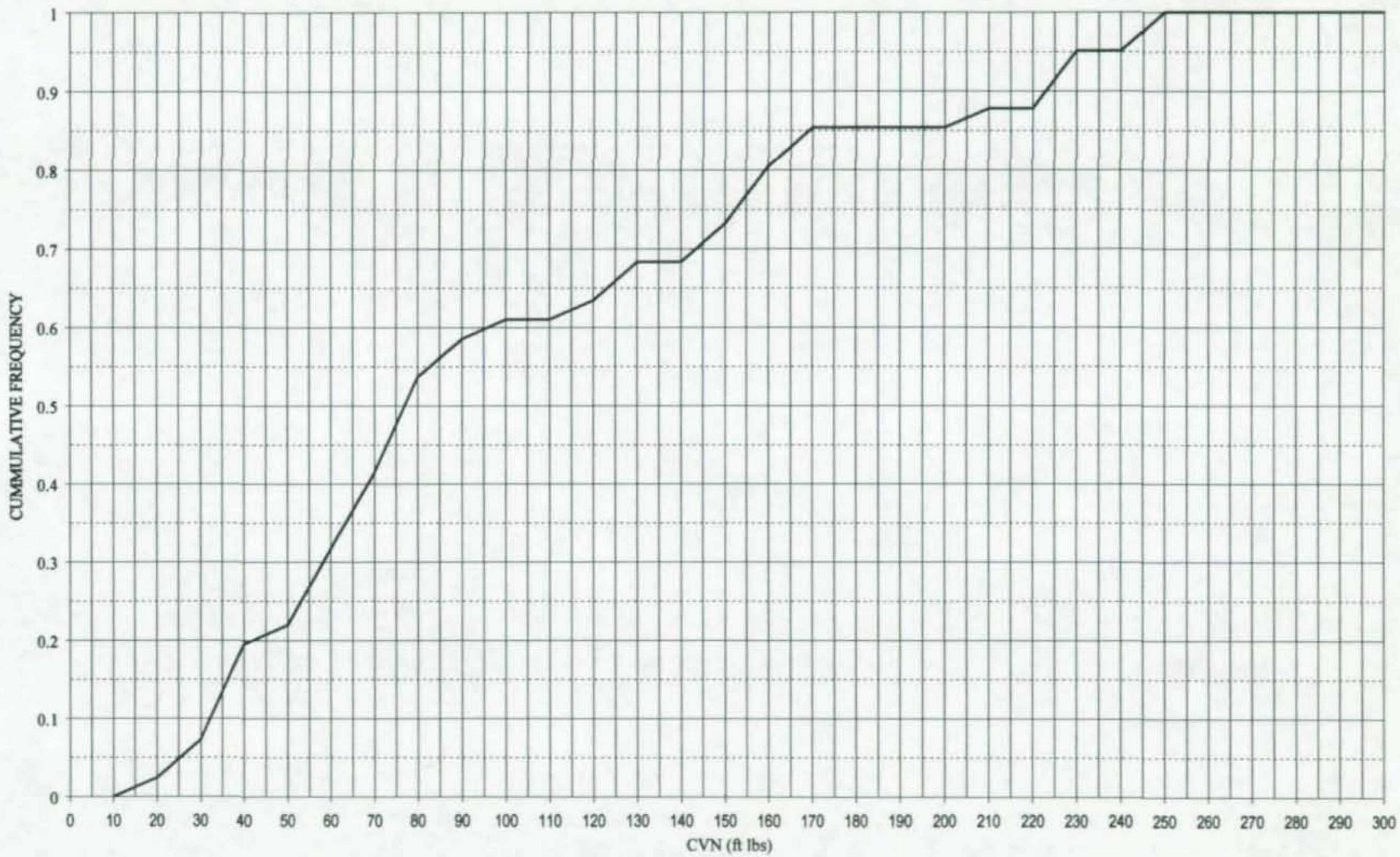
A588 HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION

1st QUARTILE (25%): 71.3 ft lbs
MEDIAN (50%): 129.0 ft lbs
3RD QUARTILE (75%): 204.2 ft lbs



A588 HOT ROLLED @ 40°F ASTM GROUP 3 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION

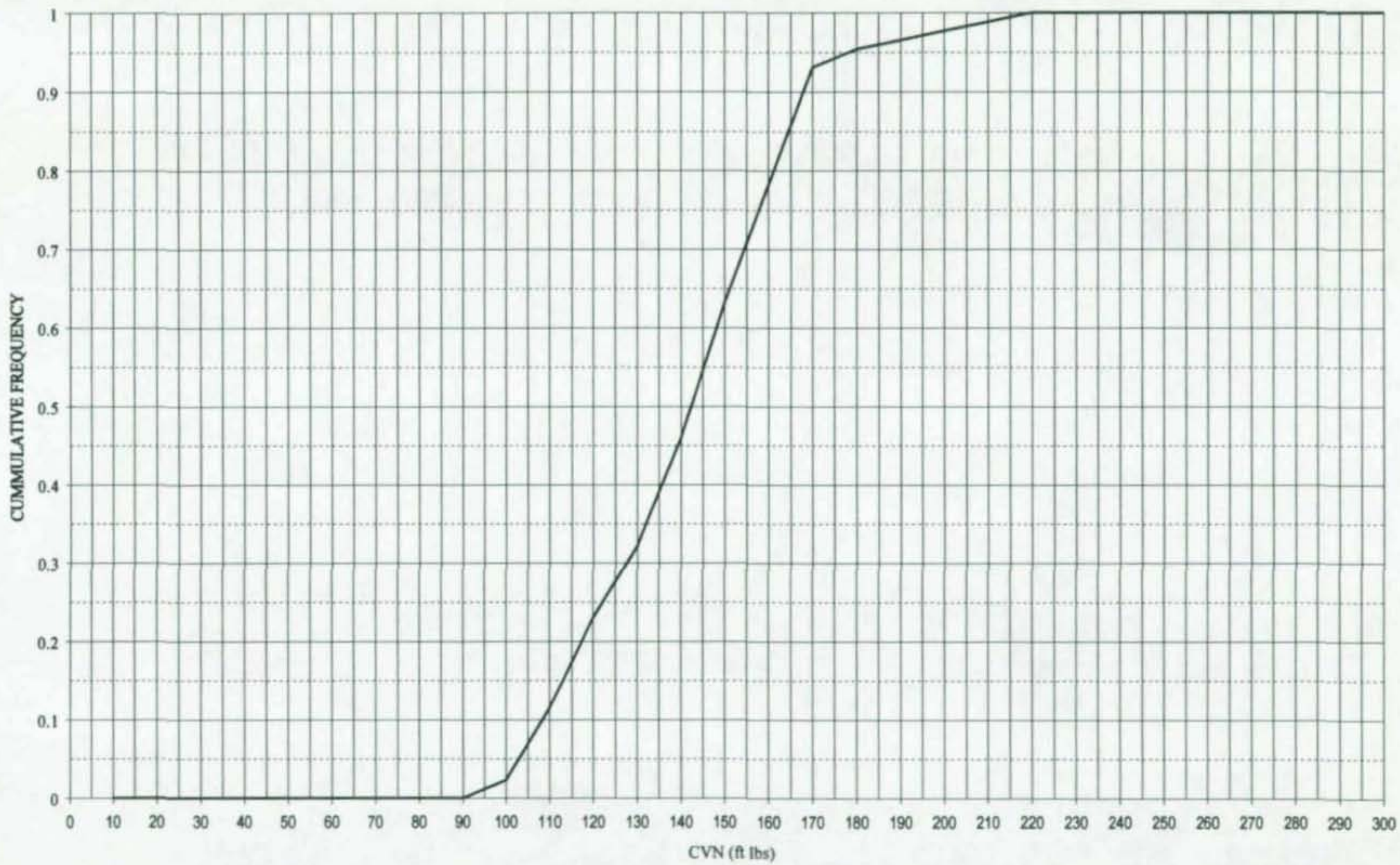
1st QUARTILE (25%): 58.0 ft lbs
MEDIAN (50%): 75.0 ft lbs
3RD QUARTILE (75%): 154.7 ft lbs



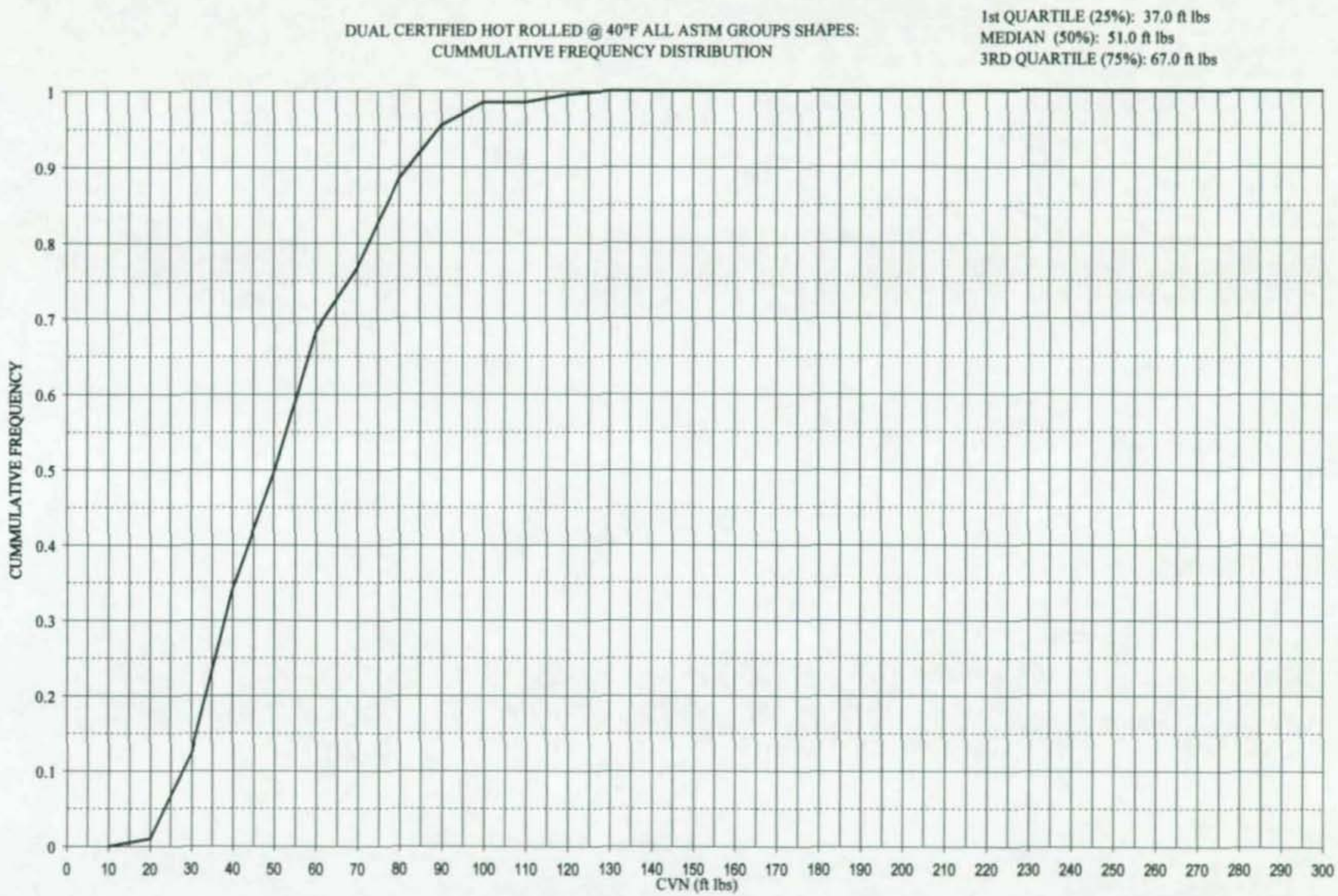
A913 Gr65 STEEL

A913 Gr65 QST @ 32°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION

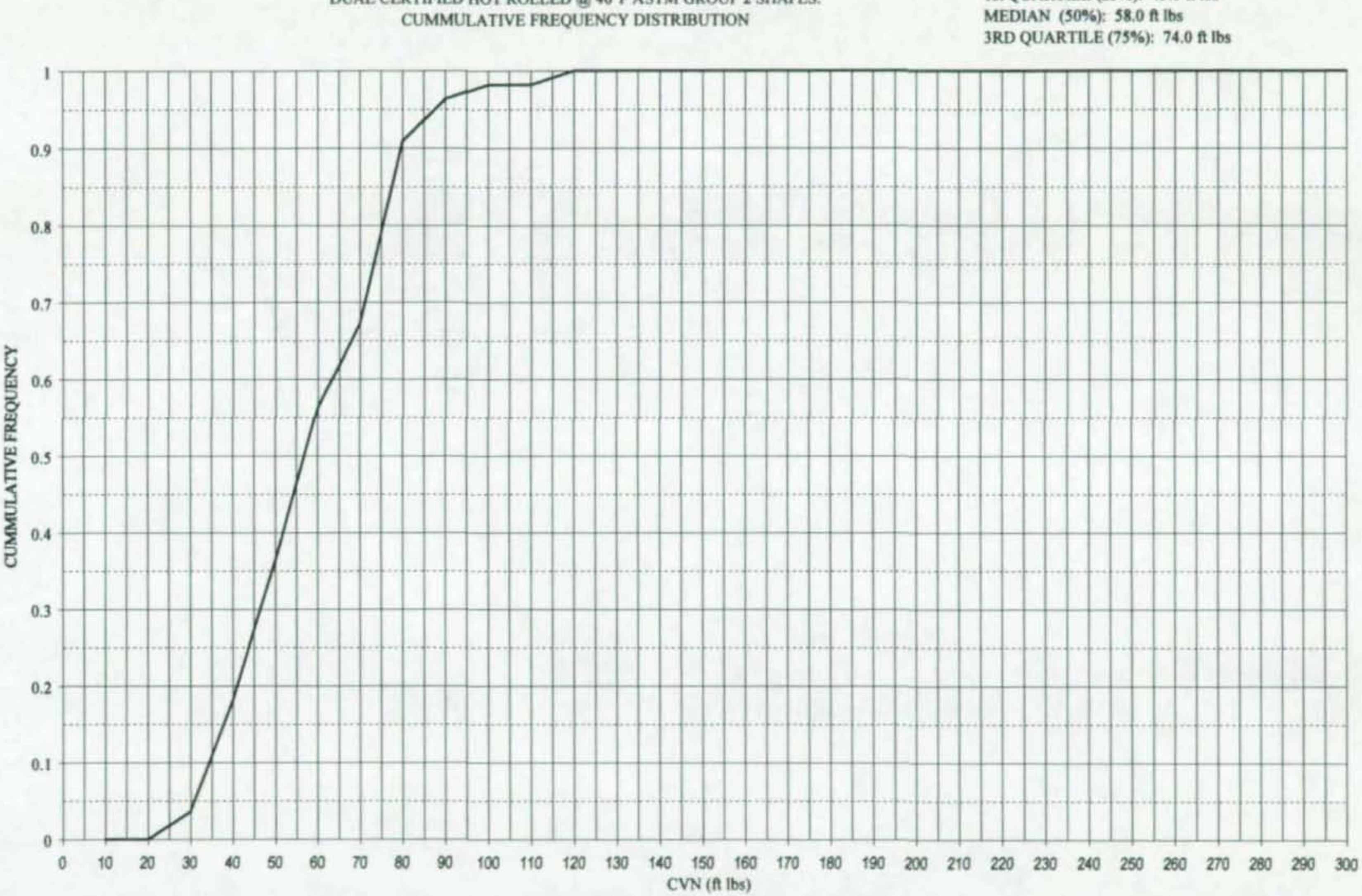
1st QUARTILE (25%): 122.2 ft lbs
MEDIAN (50%): 141.7 ft lbs
3RD QUARTILE (75%): 157.7 ft lbs



DUAL CERTIFIED STEEL

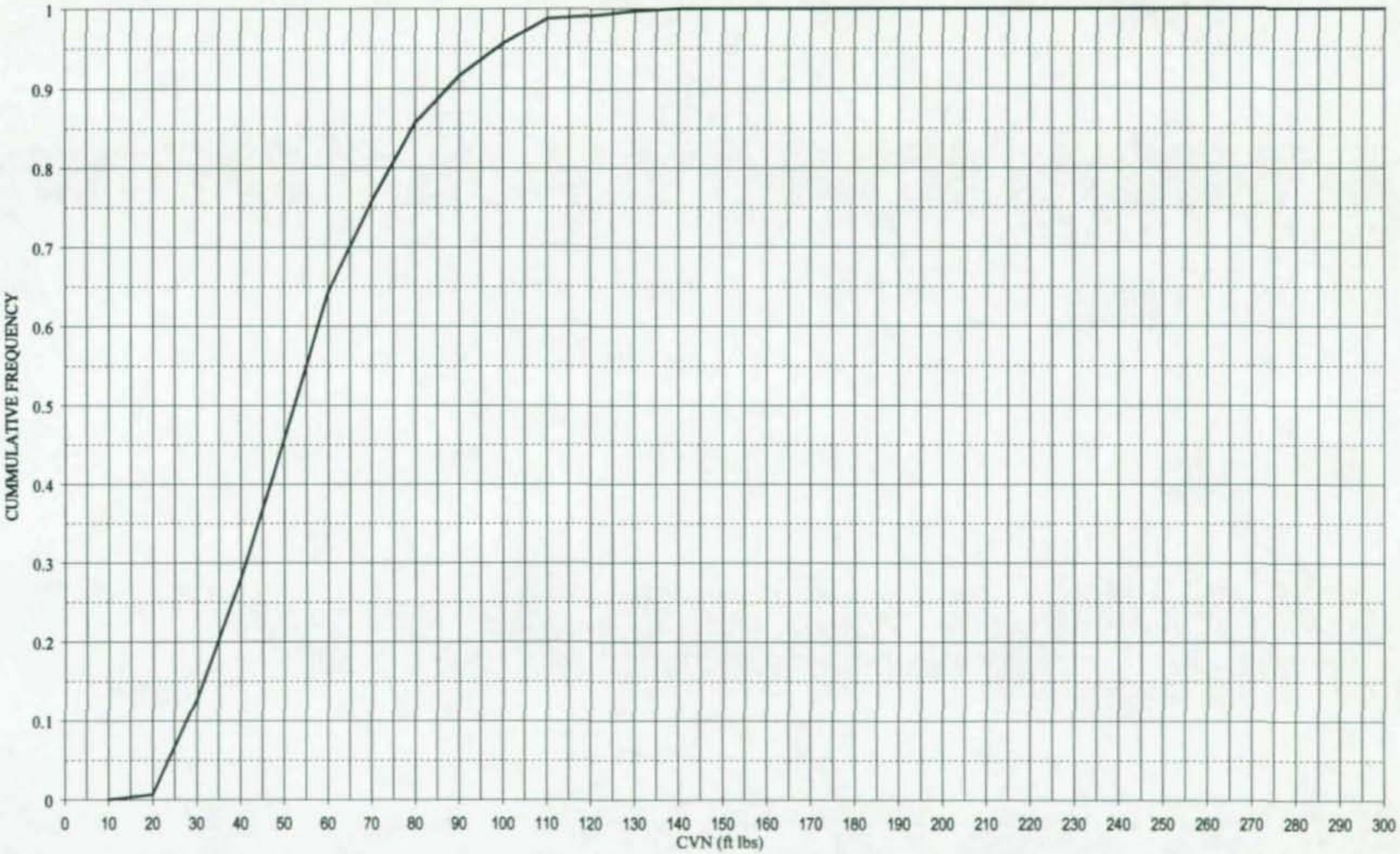

DUAL CERTIFIED HOT ROLLED @ 40°F ALL ASTM GROUPS SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION
1st QUARTILE (25%): 37.0 ft lbs
MEDIAN (50%): 51.0 ft lbs
3RD QUARTILE (75%): 67.0 ft lbs
CUMMULATIVE FREQUENCY
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
CVN (ft lbs)

1st QUARTILE (25%): 43.0 ft lbs
MEDIAN (50%): 58.0 ft lbs
3RD QUARTILE (75%): 74.0 ft lbs



DUAL CERTIFIED HOT ROLLED @ 70°F ASTM GROUP 1 SHAPES:
CUMMULATIVE FREQUENCY DISTRIBUTION

1st QUARTILE (25%): 37.0 ft lbs
MEDIAN (50%): 53.0 ft lbs
3RD QUARTILE (75%): 68.8 ft lbs



00510

APPENDIX C:

STEEL PRODUCERS SUPPORTING LETTERS

Bethlehem Structural Products Corporation

A Subsidiary of Bethlehem Steel Corporation
501 E. Third Street, Bethlehem, PA 18016-7599

June 2, 1995

Mr. Neil Zundel, President
American Institute of Steel Construction
One East Wacker Drive, Suite 3100
Chicago, IL 60601-2001

Subject: Structural Shape Charpy Statistics

Dear Neil:

We have reviewed your 5/24/95 memorandum requesting written certification of the listed data interpretations. Our responses to each individual item are as follows:

1. **Data is representative of all your current and future shape production. No production data below 15 ft-lbs @ 40 or 20 ft-lbs. @ 70° has been omitted.**

   As noted in our data transmittal letter, the submitted data represents the full range of structural wide flange sections currently produced primarily from basic oxygen furnace melted and ingot cast steel. Beginning in December, 1995, most of our structural wide flange production will be restricted to ASTM Group 1 Sections sourced from electric furnace melted continuous cast steel. This is expected to change our data profiles, but we are confident that all of the wide flange structural sections we will produce for building applications will easily meet the minimum toughness criteria stated above.

   With regard to omission of data, we have eliminated results where there was a clear indication of flawed specimens, testing irregularities, or operator error. In such cases, results of retests confirmed the true toughness characteristics of the material, and are included in the data. The omitted data may have been above or below the stated minimums.

2. **Data submitted is expected to be representative of material produced to the proposed 50 ksi specification.**

   The same provisions noted above apply here as well. Notwithstanding our change in material sourcing after November, 1995, it is probable that we would have modified existing chemistries, or introduced new chemistries into our process. In either case, all chemistries would be designed to be capable of meeting the stated toughness criteria.

3. **Chemistry and production practices do not vary between the material tested and other shape material provided.**

   The data submitted is representative of the full spectrum of chemistries and production practices we utilize. However, within the submitted data are a number of different chemistries, some of which are designed to meet more stringent toughness requirements. This results in some scatter in the data.

4. **Tests were performed in accordance with ASTM/AISC standards.**

   As noted in our data transmittal letter, most of the data is taken from the standard flange test location per ASTM A673. However, approximately 90% of the +70 F Group 4 and 5 test data was taken from the AISC specified "core" location.

5. **Any other review comments on the draft report and statistical tabulations.**

   As a general comment, toughness properties are typically dependent upon chemistry, rolling parameters, and material thickness. Producers design their processes so that the most "difficult" sections they roll will achieve the minimum requirements, and the "easier" sections will exceed minimum requirements without difficulty. Thus, we would expect to see the data skewing and scatter that was experienced on this study. This scatter and skewing can be even more pronounced when the data from all of the producers is concatenated.

If you have any further questions, please do not hesitate to contact my office.

Sincerely,

BETHLEHEM STRUCTURAL PRODUCTS CORPORATION

RERoll

R. E. Roll
Vice President, Sales and Marketing

RCA:bd

cc: D C Krouse
R C Atkinson

British Steel Inc
5410 Havenwoods
Houston, Texas 77066
Telephone (713) 440-4494
Facsimile (713) 440-3004

FACSIMILE TRANSMISSION

FROM: M. E. McKnight

TO: Neil Zundel AISC FAX NUMBER CHICAGO

DATE: 2 June 1995 PAGES One

REFERENCE Structural Shape Charpy Statistics

* *

With reference to your letter of 5/24/95 on the above referenced subject, the results of Charpy Impact Tests we reported to you are accurate and fully reflect the results which we would expect to achieve on material whether or not impact tests are specified.

Regards,

M.E.McKnight

CHAPARRAL STEEL

300 Ward Road • Midlothian, Texas 76065-9651 • (214) 775-8241

Mr. Jacques Cattan
American Institute of Steel Construction
One East Wacker Dr.
Suite 3100
Chicago, IL. 60601-2001

June 6, 1995

Dear Mr. Cattan:

Re: Data provided for Structural Shape Charpy Statistics.

The data provided by Chaparral for analysis, was taken from records of internal quality control testing, which we perform on a periodic basis to establish and monitor material characteristics. The tests were performed in accordance with ASTM A673 and ASTM A370 and the data contains a mixture of full and sub-size test specimens as appropriate for the shape thickness being tested. No data points were omitted from the average values and all data points regardless of specimen size were in excess of 15 ft/lbs @ 40F and 20 ft/lbs @ 70F. All test samples were taken from standard production material, no special chemistry or production practices are included. The values obtained would be representative of our past, current and future shape production and would be applicable to the proposed 50 ksi specification should it be approved by ASTM.

Respectfully,

Tom L. Harrington
Manager - Quality Assurance

TLH/lj

NEIL ZUNDEL
PRESIDENT AISC

6/1/95

THE CHARPY IMPACT DATA SUPPLIED TO JAQUES CATTAN REPRESENTS OUR 1994 TESTS AND IS REPRESENTATIVE OF OUR CURRENT AND FUTURE MATERIAL FOR SHAPES TO THE BEST OF MY KNOWLEDGE. ALL OF THE DATA SUPPLIED WAS A RESULT OF TESTS RUN FOR CUSTOMER REQUIREMENTS IN ACCORDANCE WITH ASTM STANDARDS. NO DATA BELOW 15 FT-LBS @40F OR 20 FT-LBS @70F WAS OMITTED. THE CHEMISTRY AND PRODUCTION PRACTICES DO NOT VARY SIGNIFICANTLY BETWEEN MATERIAL TESTED AND OTHER MATERIAL. ALTHOUGH I DO NOT ANTICIPATE A DRASTIC CHANGE IN IMPACT PROPERTIES FOR MATERIAL PRODUCED TO THE PROPOSED 50 KSI SPEC, THERE COULD BE SLIGHT CHANGES, DEPENDING ON THE SIZE OF THE FINISHED PRODUCT AND THE FINAL FORM OF THE NEW 50 KSI SPEC.

BOB OLSON
Bob Olson
MANAGER OF METALLURGY
NORTHWESTERN STEEL AND WIRE CO.

1995 Recipient of the
SHINGO PRIZE
for EXCELLENCE in MANUFACTURING

NYS

Nucor - Yamato Steel

POB 1228 · Blytheville, Arkansas · 72316

Friday, June 02, 1995.

Mr Neil Zundel
President
American Institute of Steel Construction, Inc.
One East Wacker Drive
Suite 3100
Chicago, Il. 60601-2001

Re: Structural Shape Charpy Statistics

Dear Mr Zundel

Pleased be advised the following regarding the Nucor-Yamato Steel data provided for the AISC'c Structural Shape Charpy Statistic Survey:

- The Charpy data provided at 40°F and 70°F is representative of our routine manufacturing processes. All measured impact strengths have been reported for materials produced by Nucor-Yamato Steel during the study period (1 Jan - 31 Dec 1994). The data has not been filtered in any manner prior to presentation to the AISC.

- The samples tested for Chapry impact were selected by customer request and represent a true random sampling from our regular production. Chemistries and production practices used were not varied from normal for the production of this material.

- Chemistry and production methods have not varied (to date) from the sampling period. Hence the data presented is representative of current material characteristics. It is expected that the data reported will be representative of material to be produced to the proposed 50ksi grade specifications (as presented to ASTM in Denver, May 1995).

- All testing was performed according to ASTM specifications. Sample location for group 1 through 3 products were as per ASTM. Group 4 sample location corresponds to AISC requirements.

Should you require any further information or clarification please contact me as below.

Yours

Douglas A Rees-Evans
Plant Metallurgist
Nucor-Yamato Steel
POB 1228
Blytheville, AR. 72316
501-762-5500 x145.

00517

PROFILARBED 45d2

Société anonyme

G.D.
V.M.
R.B.
S.C.
J.C.G.

ProfilARBED. Site de Differdange. L - 4533 Differdange

TradeARBED Inc.
Attention Mr. J.-C. Gerardy
825 Third Avenue (at 50th Street)
NEW YORK N.Y. 10022
U.S.A.

Site de Differdange

DIRECTION /lam365DI

L - 4503 Differdange
Téléphone 5820 - 2' 10
Téléfax 5820 - 2111

Differdange (G.D. de Luxembourg) June 1st 1995

Re.: CVN statistics

Dear Sir,

- Data is representative of all our current and future shape production. No data below 15 ft-lbs at 32 or 20 ft-lbs at 70°F has been omitted.

- Data submitted is expected to be representative of material produced to the proposed 50 KSI specification.

- Chemistry and production practices do not vary between the material tested and other shape material provided.

- Test were performed in accordance with ASTM AISC standards for all wide flange beams.

Best regards,

PROFILARBED s.a.
Site de Differdange
Le Directeur d'Usine

Carlo PANUNZI

Siège social à Esch-sur-Alzette 66 route de Luxembourg R.C. Luxembourg No 41983 IBLC 15406203 No Id LU 15406203 TVA 1992 - 22 - 13449