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EXTRAPOLATION OF RUPTURE DATA FOR TYPE 304 (18Cr-10Ni), GRADE 22(2-1/4Cr-1Mo) AND GRADE 11(1-1/4Cr-1/2Mo-3/4Si) STEELS

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Report 34006-2P

July, 1971

Progress Report to:
The Metal Properties Council
New York City, New York

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INTRODUCTION

Rupture strengths at prolonged times are a major factor in the determination of the design stresses of alloys for service in the temperature range where creep governs the strength. In establishing Code stresses, The Boiler and Pressure Vessel Committee of the American Society for Mechanical Engineers considers the minimum and average 100,000 hour strengths. Straight line extrapolation of shorter time tests has been used to determine the 100,000 hour values. (In many cases, the longest tests have been of the order of 1000 hours although tests of the order of 10,000 hours are preferred.)

In an earlier study, extrapolated strengths were determined from available data for Type 304, Grade 22 and Grade 11 steels using parameter techniques (ref. 1). The Larson-Miller and the Manson-Haferd parameters were used with the Mendelson, Roberts and Manson computer program to optimize constants. The Larson-Miller parameter was also included with the commonly used constant C of 20. The 100,000 hour strengths obtained were, in some cases, considerably different to those determined by straight line extrapolation. This occured when the parameters indicated that there were changes in slope of the rupture curves at times greater than the longest test data. The strengths also differed somewhat depending on the particular parameter technique used. This must have been accompanied by variations in the degree to which the mathematics of the parameters were consistent with the stress-rupture time data. The analysis carried out did not, however, allow selection of the most appropriate parameter method or the best estimates of the long time strengths.

In the presently reported study, methods for determining the best possible estimates of the 100,000 hour strengths for setting code stresses were explored. This included extrapolation of rupture data and the calculation of minimum and average strengths as a function of temperature. The data analysed were the same as previously utilized (ref. 1-4) together with newly generated data for Type 304 and Grade 22 steels (ref. 5, 6).

PROCEDURES

Extrapolation to 100,000 Hours

Two general procedures have been used to extrapolate rupture data. One involves treatment of all the data from a grade as a common population while for the other each data set is individually evaluated. Stress-rupture time characteristics of individual sets of data may not be evident from plots of many data sets. The first method can therefore result in large errors in the predicted strengths. Consequently, for the present investigation the data sets were extrapolated individually.

Initially, very entensive analysis was carried out for the sets for which there was considerable data. The trends or correlations evident were then used to provide greater control of extrapolations of the sets of more limited data. The analysis involved the following steps:

(1) The rupture curves within the range of test data were drawn by eye. Consideration was given to the family of curves concept (consistent changes of slope with time and temperature) and also the nature of the stress-rupture time characteristics evident for other data sets of similar material.

(2) Where sufficient data was available a special "parameter" technique (ref. 7) was used for extrapolation. The method involves graphical extension of iso-stress lines on plots of log rupture time versus a function of temperature. This technique was selected as the "base method" of the study because it was considered to be the best method currently available for accurate extrapolation of rupture data. This is because it utilizes the stress-time-temperature characteristics of the short time data to predict the long time strengths without forcing any preconceived mathematical behavior on the extrapolation. The iso-stress lines used in the method are also basic to most parameter methods. However, in these cases, the lines are forced to fit particular mathematical models. For instance, the Larson-Miller parameter dictates that the iso-stress lines are linear on plots of log time versus reciprocal absolute temperature (1/Tabs) and converge to a single point on 1/Tabs=0.

Extrapolations by the "iso-stress" method were carried out starting with the sets with the most extensive data. For each of several times, stress levels were read off the rupture curves for each test temperature. Iso-time curves were constructed by plotting these values on coordinates of log stress versus temperature (fig. 3). Temperature-time values were picked off these curves for a number of constant stress levels and plotted on graphs of log time versus temperature (T) and log time versus reciprocal absolute temperature (1/Tabs) (fig. 5, 6). These iso-stress lines were then extrapolated to 100,000 hours as a family of curves. Temperature and stress values for 100,000 hour rupture were read from the iso-stress curves and plotted on the previously utilized log stress versus temperature graphs (fig. 3). An iso-time line (i.e. a stress-temperature trend curve) for 100,000 hours was drawn through these points.

(3) As the extent of the data became more limited, typical characteristics were used to aid establishment of curves in the "iso-stress" analysis technique. Some of the features utilized were: (i) relationships between tensile and rupture strengths (ii) characteristic shapes of iso-time and iso-stress lines.

(4) Many sets, particularly those of very limited data, could not be analysed by the above methods. Consequently, alternative techniques were utilized. The most appropriate method was selected from straight line extrapolation of log stress-log rupture time curves, the Larson-Miller parameter with a constant C of 20 and the Manson Compromise method (ref. 8) (for Grade 22 steel). In addition, were available from the previous investigation (ref. 1) results were included which were obtained using the Larson-Miller and Manson-Haferd parameter with optimized constants.

Weighting of Data

In the previous analysis (ref. 5) using straight line extrapolation of rupture curves, only the 100,000 hour strengths derived from data sets which met certain minimum requirements were used to determine Code stresses. For example, values were not included from sets for which only parameter data was available or when there were not iso-temperature points at three levels of stress with at least one rupture time exceeding 1000 hours.

In the present study, it was clearly evident that for the various data sets of each steel the confidence that could be placed in the 100,000 hour strengths varied considerably. Consequently, in order to provide data suitable for determination of minimum and average values, strengths (taken at 50°F intervals) were weighted from 0-5 according to the author's confidence in the accuracy of the extrapolation. In the mental process of establishing the weights, the confidence in the extrapolations were considered to increase with the following:

(1) Number of test points.

(2) Time of the longest test.

(3) Decreasing data scatter.

(4) Number of test temperatures and consistency of rupture characteristics evident between adjacent curves.

(5) The degree to which the mathematics of the extrapolation method was consistent with the data.

(6) Decreasing number of assumptions (or externally applied controls) utilized in the extrapolation.

Thus the weighting system permitted strengths from almost every data set and also from different extrapolation techniques to be included in the analysis for minimum and average trend curves.

Average and Minimum Strengths

In establishing design stresses the ASME Boiler and Pressure Vessel Committee considers the average and minimum 100,000 hour strengths. These are determined as trend curves from plots of stress versus temperature.

Trend curves were developed using the 100,000 hour strengths derived in the present investigation. The data used were those weighted according to the confidence in the accuracy of the prediction. The curves were established for selected heat treatments, compositions and product forms of each steel. The evaluations were primarily carried out to further characterize the trends in the strengths determined in the investigation. Further analysis is recommended if values developed are to be considered in terms of Code stresses.

Semi-log plotting tends to linearize the relationship between strength and temperature. Consequently, to determine average values the regression analysis were carried out using log stress as the dependent variable. Results were obtained using polynominal degrees from 1-4. The curve of best fit was selected by consideration of the standard deviations.

Minimum trend curves were determined by the following techniques, the first two of which were computerized:

Method 1: At each test temperature a minimum strength was obtained by subtraction of a multiple of the standard deviation from the mean of the log stress values. (Basic to these calculations, is the assumption of a normal distribution of log strength values; available evidence indicates that this assumption is reasonably valid.) Trend curves were obtained by regressing the minimum values as a function of temperature using log stress as the dependent variable.

Minimum values at each temperature were calculated using 1.282, 1.645 and 2.326 times the standard deviations. These correspond to ensuring statistically, that 90.0, 95.0 and 99.0 percent of the data respectively lie above the minimum. In order to limit the scope of the analysis, trend curves were established using only the 95.0 percent values. The minimum values at each temperature were expected to be sensitive to the number of data points. Consequently, in computing the trend curves, it was considered desirable to bias the results so that the curve was most dependent on the minimum values at the temperature with the greatest number of test points. Therefore, the strengths at each temperature were weighted according to the number of data points. The weights, ranged from 0 for one data point to about 10 for the temperature with the maximum number of strength values. The degree (from 1-4) of the trend curve polynomial was selected by minimizing the standard deviation.

Method 2: Minimum trend curves were computed by multiplying the average curve by the following factors determined at the temperature with the "greatest" number of weighted 100,000 hour strengths.

(A) The ratio of the statistically defined minimum (average less 1.645 times the standard deviation) to the average.

(B) The ratio of the observed minimum to average.

These methods, which have been used previously (ref. 5) result in minimum curves parallel the average trend curves.

Method 3: The minimum trend curve was drawn by eye. Special consideration was given to the minimum strength at each test temperature derived by subtraction of 1.645 standard deviations from the mean of the log stress values.

RESULTS

The 100,000 hour rupture strengths for the three alloys are presented in Tables I, II, and III. The strengths reported under "iso-stress" include: (i) values determined by iso-stress line extrapolation for the sets for which considerable data was available and (ii) values for the sets of more limited data obtained utilizing typical time-temperature-stress characteristics to aid extrapolation. Strengths derived by application of the Larson-Miller parameter with C of 20 are also presented. Where available from the previous investigation (ref. 1) values are included which were determined using the Larson-Miller and Manson-Haferd parameters with optimized constants. The strengths derived by straight line extrapolation of log stress-log rupture time curves are those reported in references 2 through 6. The results for Grade 22 steel (table III) include strengths determined by the Manson compromise parameter and values selected for determination of average and minimum trend curves.

The weights assigned to the best estimates of the 100,000 hour strengths are included in the Tables. Only the strengths rated 1 through 5 were used to determine the minimum and average values (tables IV, V and VI).

The results of the analysis for each of the three steels considered in this investigation follows.

Type 304 (18Cr-10Ni) Stainless Steel

Extrapolation of Rupture Data

The majority of the test data available were at temperatures from 1050° to 1350°F. Typically, at these temperatures the data could be fitted by linear log stress-log rupture time curves (fig. 1). These curves often diverged slightly. For one data set ("AR-2") there was an increase in steepness with time (fig. 2). The curves at 1100° and 1200°F are drawn to include a slope change at about 1000 hours. It would, however, be equally possible to draw a curvilinear rupture curve. In either case, the steeper curves at prolonged times are not reflected in the shorter time higher temperature data. Under these circumstances, extrapolation of short time data by parameter techniques on straight line log-log curves can lead to erroneous strengths. Similar behavior was not clearly evident in other sets of data even though in some cases tests were to as long as 10,000 hours. If however, other lots of material were susceptible to a breakdown in strength at long times this would lower average and possibly minimum strengths for these materials. It is strongly recommended that further consideration be given to this aspect.

The more significant features of the extrapolation of the data to 100,000 hours were as follows:

(1) Where available, tensile strengths were plotted on the log stress versus temperature plots (fig. 3). These defined lines of "maximum rupture strength" (a tensile test can be considered to be equivalent to a rupture test of about 0.1 hours). The curves for rupture were drawn below this line so that a given temperature the strength decreased with increasing time. The iso-time lines merged with the tensile curve at lower temperatures. The inclusion of the tensile data improved the reliability of extension of the curves to temperatures lower than the test data. In some cases, it even influenced the iso-time characteristics within the range of test data.

In cases where sufficient tensile data was not available, use was made of scatter bands and average values reported for similar material (ref. 5).

(2) In many cases, the iso-time curves on plots of log stress versus temperature were reasonably linear (fig. 4). This was particularly apparent for temperatures above 1000°F. For some data sets a slight curvature occurred (fig. 3). However, in all cases, interpolation and extrapolation of the curves could be made over limited temperature ranges with reasonable confidence.

(3) The similarity of the slopes of the rupture curves at adjacent temperatures (fig. 1) suggests by the "family of curves" concept, that straight line extrapolation of the log stress-log rupture time curves probably leads to reasonably accurate predictions of the 100,000 hour strength levels.

Where possible, for the sets of extensive data, the strengths determined by straight line extrapolation were compared with those derived by "iso-stress line extrapolation" (fig. 7). The maximum difference in the predicted strengths was about 10 percent. This excellent agreement supports the applicability of straight line extrapolation for this particular material. The significance of this comparison for the higher test temperatures (low stresses) is somewhat questionable. Extrapolations using the "iso-stress" technique necessitated extending the iso-time lines beyond the temperature range of the test data. (Equivalent to extending a parameter master curve outside the range of test stresses.) It is contended, however, that this is likely to lead to as good if not better predictions than obtained by extrapolation of rupture curves.

(4) A principle difficulty encountered in the study was the development of methods for analysing data sets for which tests were available at only one test temperature. For Type 304 stainless steel, however, the preceeding observation showed that the 100, 000 hour strengths could be determined by straight line extrapolation.

The use of parameter techniques permits the determinations of strengths at temperatures lower than the test data. For iso-temperature data this requires pre-selection of the parameter method and parameter constants. For the purposes of the present analysis, the Larson-Miller parameter with C=20 was utilized. This parameter indicated strengths that differed by up to 20 percent from those determined by iso-stress line extrapolation (or straight line extrapolation) (fig. 8). The method must, however, be expected to provide reasonable accurate strength predictions for temperatures differing only 50° or 100°F from that of the test data. These extrapolations presumably could be improved by utilization of another constant or parameter. Ideally, the technique should be selected on the basis of comparisons of strengths predicted by various extrapolation methods with strengths determined by actual tests. Such an approach was beyond the limitations of the analysis carried out.

Evaluation of 100,000 hour strengths

The distinctions made between grades in the data analysis were the same as previously utilized (ref. 5). The H grade ("optimum heat treatment") is less restrictive than the regular grade. Consequently, the data for these materials were combined. The L grade which requires lower carbon content was treated separately. The two sets of data for material which had received a stabilizing heat treatment (S-grade) were excluded from the evaluation.

The data available for the regular and H grades (fig. 9) being fairly extensive provided a reasonable basis for establishing minimum and average strengths. The following observations were made:

(1) The average trend curve selected was a degree 2 polynomial of log stress versus temperature (table 4) (fig. 9). The curve exhibits slight curvature and is similar in nature to many of the iso-time curves for 100,000 hours established for individual data sets (figs. 3, 4).

(2) Considerable variation in minimum strengths occurred at each temperature depending on the standard deviation used to lower the average strengths (table 4).

The trend curves derived by the methods used indicated similar minimum strength levels. For this material, Method 2 which forces the minimum curve to be parallel the average trend curve is probably an acceptable analysis technique. This is because (i) the width of the scatter band is fairly uniform and (ii) materials with strengths on the high side of the range at low temperatures are also high in the scatter band at high temperatures (characteristic of metallurigically stable materials).

The data available for low carbon material (L grade) was very limited (table 4) (fig. 10). The data does indicate, however, that the strengths are lower than for the regular grade.

Grade 22 (2-1/4Cr-1Mo) steel

Extrapolation of Rupture Data

The rupture curves for the Grade 22 materials exhibited marked slope changes. Consequently, accurate prediction of the 100,000 hour strengths is dependent on correcly incorporating these changes in slope of the rupture curves into the analysis.

Initially, the data were studied in order to establish typical stress-rupture time characteristics. The majority of the data sets (fig. 11) were found to be consistent with the following:

(1) At the lower test temperatures (around 900°F) the rupture curves undergo a slight increase in steepness.

(2) At intermediate temperatures (about 1000°F) an increase followed by a decrease in steepness occurs, i.e. the rupture curves exhibit "  " type behavior.

(3) A drastic increase in steepness occurs at the highest test temperatures (around 1200°F).

The severity of the instabilities varied. Most evident, at the lower test temperatures, the changes in slope tended to be less severe the lower the short time strength. Presumably, the instabilities are due to thermally induced microstructural changes. Consequently, it might be expected that the rupture characteristics vary with heat treatment and composition. The study was not, however, directed at obtaining correlations of this nature.

Most important, in each regime of behavior, the rupture curves form a "family". In other words, there are consistent changes in slope with temperature variation. Thus, the behavior at long times is reflected at shorter times at higher temperatures, i.e. the data is consistent with parameter concepts. Correctly used, parameter techniques can therefore provide accurate estimates of the long time strengths. On the other hand, predictions using straight line extrapolation of the log-log curves can lead to erroneous results. Accurate extrapolations will result from this method only if test data is available beyond the time periods where no further instabilities occur before 100,000 hours.

The following comments on the extrapolations to 100,000 hours have been abbreviated where similar to those previously presented for Type 304 steel:

(1) Where sufficient data was available, extrapolations were carried out using the "iso-stress" method. Tensile data was included to aid in establishing the nature of the iso-time curves (fig. 12). For the annealed materials, a maximum in tensile strength (ref. 6) occurred at temperatures around 700°F (characteristic of materials which exhibit dynamic strain aging). Utilization of this tensile data to improve determination of rupture characterisitics could be questioned. This did not arise, however, because the rupture data for the annealed materials were concentrated at the higher test temperatures so that little or no use was made of the tensile strengths.

(2) Because of the instabilities in the rupture curves the iso-time curves had complex shapes (fig. 12, 13). This result is in marked contrast to Type 304 steel for which the curves were almost linear. Most important, curves for 100,000 hours increased in steepness at about 1000°F (fig. 13). This reflects the instabilities in the rupture curves at higher test temperatures (fig. 11). Thus, in order to extrapolate the rupture curves at temperatures above 1000°F this downward break must be correctly incorporated into the analysis. For this reason, there is considerable question as to the 100,000 hour strengths determined at 1200°F. In the majority of cases, insufficient data existed either at prolonged times at 1200°F or at higher test temperatures to permit accurate extrapolation.

The shape of the iso-time lines for 100,000 hours were most predictable at temperatures below about 1000°F (fig. 12). Interpolations and extrapolations could be made over small temperature ranges with reasonable confidence.

(3) The 100,000 hour strengths determined by the "iso-stress" method (data sets with three or more test temperatures) were compared with those derived by rupture curve extrapolation (refs. 3,6) and by the Larson-Miller parameter with C=20. Straight line extrapolation generally resulted in lower strengths than determined by the "iso-stress" technique (fig. 14). The reasonably good agreement shown reflects to a great extent the nature of the data sets used in the com-

parison. These were the sets of extensive data, often with test times beyond where further instabilities were expected. Analysis of shorter time data by straight line extrapolation could result in much larger errors in predicted strength.

The Larson-Miller parameter with C=20 provided strengths very similar to those determined by the "iso-stress" method (fig. 15). Consequently, this method was used to extrapolate the sets of limited data particularly those for which there was only one test temperature. Predictions by this method were expected to be reasonably accurate. Again, however, presumably other standard parameter methods could be developed to improve these determinations.

Evaluation of 100,000 hour strengths

Plots of the 100,000 hour strengths for a number of product forms and heat treatments are included as Figures 16 through 20. Average and minimum strengths are presented in Table V. The following features are evident:

(1) The non-linear iso-time behavior (on plots of log stress versus temperature) previously discussed for individual data sets (figs. 12, 13) is apparent. Consequently, it is inappropriate to force a linear relationship on the regression analysis in the determination of minimum and average values.

(2) For wrought Grade 22 steel in various heat treated conditions (fig. 16) the range of strengths decreased with increasing temperature. Presumably this results from thermally induced structural changes. It is possible that at long times at high temperatures, all of the original materials tend towards similar equillibrium structures. Obviously under such circumstances, Method 2 which lowers the average trend curve should not be used to determine the minimum curve.

(3) For the annealed materials (fig. 17) the strengths are on the low side of the range at the low test temperatures. This probably reflects a relatively stable structure introduced by heat treatment, which is not affected to any great extent by subsequent test exposures. (Grade 22 is thermally weakened by thermal exposure - ref. 9). It is probable

that under these circumstances, (a stable structure) Method 2 can be used to determine the minimum trend curve.

(4) For materials tempered after quenching or normalizing, the strength range decreased with increasing temperature (fig 18). The rupture strengths at the lower test temperatures can be correlated with the room temperature tensile strengths. Smith (ref. 6) adjusted the rupture strengths to selected levels of specified minimum tensile strength in order to determine average trend curves. This type of approach was considered desirable but was outside the scope of the investigation. Probably, this analysis technique adequately copes with the observed decrease in scatter band width with increasing temperatures.

(5) The data for weld metal (table 5) (fig. 19) were high in the scatter band for Grade 22 steel while the cast materials (fig. 20) had strengths on the low side of the range.

Grade 11 (1-1/4Cr-1/2Mo-3/4Si) Steel

Extrapolation of Rupture Data

The rupture characteristics evident for Grade 11 steels (fig 21, 22) were similar in nature to those previously described for Grade 22 materials (fig. 11). All of the sets of data were consistent with the following:

(1) At the lowest test temperatures (around 900°F) the rupture curves increased in steepness at prolonged test times.

(2) At intermediate temperatures (1000° and 1050°F) the curves exhibited "" type behavior.

(3) At the highest test temperatures (1200°, 1300°F and to a limited extent at 1100°F) the rupture curves showed an increase in steepness.

From the sets for which data was available at more than one temperature it was evident that the rupture characteristics were consistent with parameter concepts. (The behavior at long times at low temperatures were reflected at shorter times at higher temperatures.)

The parameter master curves exhibited changes in slope (fig. 23) that were directly reflective of the instabilities in the rupture curves. Consideration was given to this characteristic shape of the master curve in drawing parameter curves for the sets of more limited data. The curves for minimum and average strengths (log stress as a function of temperature) should also have this shape.

Unlike Grade 22 steel, there was almost no sets for which sufficient data was available to adequately establish iso-stress characteristics (especially because of their complex nature. Thus long time strengths could not be determined by the "iso-stress" technique. It was also impossible to use the iso-stress characteristics to indicate which of the parameter methods used was most consistent with the data and hence could be expected to result in the best estimates of the 100,000 hour strengths.

Due to limited data and the complexity of the stress-rupture characteristics in many instances optimization of parameter constants by computer techniques (ref. 1) led to highly questionable strength estimates. Under these circumstances parameters with predetermined constants provide superior results. Because of this the data were analysed using the Larson-Miller parameter with C=20 and the Manson-compromise method. These two techniques resulted in similar 100,000 hour strengths (fig. 25). In many cases, these results were markedly different from those determined by straight line extrapolation of rupture curves (fig. 24). Compared to straight line extrapolation, parameters indicated lower strengths at the lower temperatures (about 900°F) and higher values at the higher temperatures (1000° and 1050°F). Parameters and straight line extrapolations gave similar strengths only in the cases where data was available to test times beyond where no further instabilities were expected (prior to 100,000 hours). Thus straight line extrapolations result in accurate 100,000 predictions only when all instabilities are correctly incorporated into the analysis. (It should be noted that in the analysis previously carried out to determine Code stresses (ref. 4) apparantly the rupture curves were drawn only to include the downward breaks at the intermediate and the highest test temperatures.

In order to establish minimum and average strengths it was necesssary to select 100,000 hour stresses from those determined in the study. To accomplish this, the following basis was used:

(1) Where data was available at more than one temperature, consideration was given to the degree to which the mathematics of the parameters were consistent with the data. The principle factor utilized was the extent of the mismatch between parameter curves drawn for each individual test temperature. Where more than one method appeared equally applicable, the strengths selected were the most conservative.

(2) For the iso-temperature data, master curves could only be derived by parameter methods with fixed constants. Consequently, the strengths selected were the most conservative of those derived by the Larson-Miller parameter with a C of 20 and the Manson compromise method.

(3) Where it was believed that testing had been carried out to longer times than where instabilities could be expected, weight was given to the results of straight line extrapolation. This was necessarily the case for the tests at the highest test temperature (1100°F or greater) where the strengths could not directly be determined by parameter methods. However, values determined by extrapolation of parameter master curves were also considered.

Prior to carrying out analysis for minimum and average values, the selected strengths (table 3) were weighted according to the confidence in the accuracy of the prediction.

Evaluation of 100,000 Hour Strengths

Reflecting the complex shape of the parameter curves (fig. 23) (or iso-time curves) for Grade 11 steels the average and minimum trend curves (figs. 26 through 29) were not linear.

At the lower temperatures, the materials annealed below the critical range gave lower strengths than the materials annealed above or near the top of the critical range or those normalized and tempered. The latter two heat treatments resulted in similar strengths.

As was the case for Grade 22 steel, there was a tendency for the range in strengths to be greatest at the lower test temperatures. Again, this negates Method 2 as the most appropriate technique for determining the minimum curve.

SUMMARY AND CONCLUSIONS

Methods were explored for determining the best possible estimates of the 100,000 hour rupture strengths for setting code stresses. The study used data available for Type 304 (18Cr-10Ni), Grade 22 (2-1/4Cr-1Mo) and Grade 11 (1-1/4Cr-1/2Mo-3/4Si) steels. The data sets had a range in the number of test points, times, temperatures and stress-rupture time characteristics. Analysis techniques were derived by extrapolating the test data. Minimum and average trend curves were determined from the 100,000 hour strengths obtained.

The nature of the study did not permit irrevocable experimental demonstration of many of the concepts developed. These should be considered only as the authors opinion.

It was apparent that extrapolations to 100,000 hours should not be achieved by a particular preconceived technique. For each data set, the extrapolation method should be dictated by both the extent of the test data and the nature of the stress-rupture time characteristics. It may be desirable to utilize more than one extrapolation method to determine strengths for different data sets of a given steel or even for different temperatures of a single set of data.

It is recommended that trends or characteristics evident from detailed analysis of the sets of extensive data be used to aid extrapolation of sets of more limited data. Effort should be made to extract as much information as possible from the avilable data. Data sets should not be excluded due to too limited data or large amounts of scatter, etc.

The "flexible" analysis system used provided 100,000 hour strengths determined by several extrapolation techniques from data sets which varied in nature. The strengths were weighted (from 1-5) according to the confidence in the accuracy of the extrapolation. This was found to be an effective method of providing data suitable for the determination of minimum and average trend curves.

Limited study indicated that the minimum trend curves varied considerably depending on the analysis technique used. In selecting an appropriate method consideration should be given to the extent of the data available, the metallurgical characteristics of the material and the nature of typical 100,000 iso-time curves for individual data sets. Although plotting of log stress versus temperature tended to linearize the trend curves, such a relationship should not be forced on the data. Further development of techniques for determining minimum and average trend curves should be undertaken.

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TABLE 1

THE 100,000 HOUR STRENGTH LEVELS FOR TYPE 304 AUSTENTIC STEEL

Extrapolation Methods: I-S = Iso-stress Line Extrapolation; L-L = Straight Line Extrapolation of Log Stress - Log Rupture Time Curves (refs. 2, 5); LM-20 = Larson-Miller Parameter with C = 20; L-M = Larson-Miller Parameter with an Optimized Constant; M-H = Manson Haferd Parameter with Optimized Constants;
Data Weights: Values in brackets from 1 - 5

STRESSES (1000 psi) FOR RUPTURE IN 100,000 HOURS

Data* Sheet	Extrapola-tion Method	Temperature °F 850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600
Type 304, 304S and 304H																	
1	I-S	45.7	38.7(1)	31.2(2)	23.3(3)	17.0(4)	12.4(5)	9.2(5)	7.1(5)	5.6(5)	4.4(5)	3.5(4)	2.8(4)	2.2(3)	1.8(3)	1.4(2)	1.1(1)
	L-L						13.0				4.4				1.8		
	LM-20	37.4	30.9	25.4	20.8	16.9	13.7	11.0	8.8	7.0	5.5	4.1					
	LM			21.8	17.8	14.4	11.7	9.4	7.5	6.0	4.8						
	MH			17.6	13.8	10.9	8.5	6.7	5.3	4.2							
15	I-S	44.9	36.0(1)	27.7(2)	20.7(4)	15.7(5)	12.1(5)	9.3(5)	7.3(5)	5.7(4)	4.5(3)	3.6(2)	2.8(1)	2.2			
	L-L					16.0			7.4								
	LM-20	38.5	31.1	25.8	20.5	15.0	12.0	(9.0)	(6.8)								
	LM	35.4	29.0	23.8	18.5	13.8	12.0										
	MH	30.9	26.0	21.6	17.6	14.4											
19	I-S		35.5	28.2(2)	22.7(4)	18.7(5)	15.7(5)	13.4(5)	11.3(5)	9.4(5)	7.7(5)	6.0(5)	4.7(3)	3.6(1)	2.8		
	L-L					18.0			12.3			5.8					
	LM-20		37.4	29.9	25.7	22.3	19.0	15.5	12.2	9.6	(7.4)						
	LM			27.7	23.4	19.5	16.1	13.2	10.7	8.6							
	MH			24.0	21.7	19.5	17.4	15.3	13.3	11.3	8.8						
20	I-S	49.6	43.8(1)	37.3(2)	30.7(4)	24.7(5)	19.0(5)	14.6(5)	11.2(5)	8.5(5)	6.3(5)	4.7(5)	3.5(4)	2.5(2)	1.8(1)	1.3	
	L-L					24.0			11.5			4.7					
	LM-20	(49.0)	42.1	34.4	27.9	22.3	17.6	13.8	10.7	8.2	6.2	(4.6)					
	LM			36.2	29.4	23.5	18.6	14.5	11.2	8.5	6.4						
	MH			37.2	29.5	22.9	17.2	12.8	9.6	7.4							
21S	I-S	46.3	39.3(1)	32.0(2)	25.3(3)	19.3(4)	15.4(4)	12.8(4)	10.8(5)	8.6(5)	6.6(5)	5.0(5)	3.7(3)	2.8(2)	2.1(1)	1.6	
	L-L					16.5			11.7			4.8					
	LM-20		40.4	30.7	24.5	20.3	16.9	13.9	11.0	8.2	(5.9)						
	LM			29.0	23.4	19.3	16.0	13.1	10.4	7.8							
	MH			24.7	21.7	19.0	16.8	14.9	13.3	11.4	8.1						
22	L-L											5.9					
	LM-20						(17.3)	14.1	11.3	9.2(1)	7.5(3)	(6.0)(5)	(4.9)(2)				
23	I-S		43.2	36.8	30.2(1)	24.2(1)	19.0(2)	14.6(3)	11.0(5)	8.1(5)	6.1(5)	4.6(5)	3.4(3)	2.6(2)	1.9(1)	1.3	
	L-L								11.0			4.5					
	LM-20				(23.0)	19.5	16.0	12.9	10.0	7.7	(5.7)						
	LM					20.1	16.4	13.4	10.6	8.0							
	MH			19.7	18.2	16.5	14.8	13.0	11.2	9.3							
24A	L-L								14.9								
	LM-20				(32.8)	27.0	21.9(1)	(17.8)(2)	(14.7)(4)	(11.9)(1)							
24B	L-L								15.1								
	LM-20					(25.3)	21.6(1)	(18.3)(2)	(15.5)(4)	(12.4)(1)							
29	L-L								11.3								
	LM-20						18.1	(15.4)(1)	(13.2)(2)	(11.2)							
30	L-L								12.4								
	LM-20						18.4(1)	(15.2)(1)	(12.5)(3)	(10.2)							
31A	L-L								12.2								
	LM-20					(21.2)	17.7(1)	(15.0)(1)	(12.7)(3)	(10.7)							
31B	L-L								9.2								
	LM-20						17.7(1)	(12.7)(1)	(9.5)(3)	(7.0)							
31C	L-L								11.3								
	LM-20						17.8	(14.5)(1)	(11.3)(2)	(9.1)							
32	L-L								13.0								
	LM-20				(28.3)	23.2	19.3(1)	16.0(2)	(13.2)(4)	(10.9)(1)							
33	LL								13.5								
	LM-20				(27.5)	23.1	19.4(1)	(16.3)(1)	(13.7)(3)	(11.4)							
34	LM-20					23.3	(18.5)	(14.8)	(11.7)(1)	(9.3)							
35A	LM-20					22.3	(17.7)	(13.8)	(10.8)(1)	(8.6)							
35B	LM-20					23.1	(18.1)	(14.1)	(11.1)(1)	(8.7)							
36A	L-L								11.9								
	LM-20			(33.7)	27.5	22.3	(18.2)	(14.7)(1)	(12.0)(2)	(9.7)							
36B	L-L								11.1								
	LM-20				26.9	21.7	(17.4)	(14.0)	(11.2)(1)	(9.0)							
38	L-L								11.2								
	LM-20				29.5	23.3	(18.5)	(14.6)(1)	(11.5)(2)	(9.0)							
40	I-S	47.0(4)	39.2(5)	32.0(5)	25.1(5)	19.7(5)	15.1(5)	11.7(5)	9.1(5)	7.2(5)	5.8(5)	4.8(5)	3.9(4)	3.3(3)	2.7(3)	2.2(2)	1.8(1)
	L-L						16.0				5.7				2.7		
	LM-20	45.1	37.6	30.6	24.6	19.6	15.7	12.8	10.5	8.7	7.1	5.6	(4.3)	(3.4)			
	LM			29.5	23.6	18.8	15.1	12.3	10.1	8.4	6.8	5.3					
	MH			29.0	21.7	16.2	12.3	9.4	7.3	5.8							
43-2	L-L								12.0								
	LM-20					(21.9)	18.5	(15.6)	(13.2)(1)	(11.1)							
44H	L-L								9.5								
	LM-20					19.2	15.3	(12.1)(1)	(9.6)(2)	(7.6)							
46-1	L-L								13.3								
	LM-20						21.5	(17.7)(1)	(14.7)(3)	(12.1)							

*Data Source: Reference 2 - Sheets 1 through 1H and 2L through AL
Reference 5 - Sheets 9 - 12 through 9-109 and 9-21 through 9-27

TABLE 1 (cont.)

STRESSES (1000 psi) FOR RUPTURE IN 100,000 HOURS

Data* Sheet	Extrapolation Method	Temperature °F															
		850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	1550	1600
A	I-S	46.7	37.4(1)	28.3(2)	22.3(3)	19.4(4)	12.8(5)	9.9(5)	7.5(5)	5.9(5)	4.6(5)	3.6(4)	2.8(4)	2.2(3)	1.7(2)	1.3(1)	1.0
	L-L						12.1				4.8						
	LM-20		32.2	25.3	20.6	16.8	13.6	10.7	8.3	6.3	4.9	4.0	(3.1)				
	LM			23.6	19.3	15.7	12.5	9.8	7.5	5.8	4.5						
	MH			19.4	16.4	13.8	11.5	9.5	7.8	6.4	5.2	4.1					
B	I-S			26.3	20.7(1)	15.7(2)	11.7(3)	8.8(4)	6.9(4)	5.3(4)	4.2(4)	3.4(4)	2.7(4)	2.1(3)	1.7(2)	1.4(1)	1.1
	L-L								6.9		3.9		2.8		1.6		
	LM-20		32.7	25.9	20.4	16.2	12.8	10.1	8.0	6.3	5.0	(3.8)					
	LM			21.3	17.0	13.6	10.9	8.8	7.0	5.6	4.5						
	MH			18.3	14.5	11.5	9.1	7.2	5.8	4.6							
C-1	I-S	45.7	37.0	29.7(1)	23.6(2)	18.8(4)	15.0(5)	11.9(5)	9.5(5)	7.5(4)	6.0(3)	4.8(1)	3.8				
	L-L						15.2		9.4								
	LM-20		(37.0)	29.3	23.4	18.7	14.9	(11.7)									
	LM			28.7	23.0	18.4	14.7										
	MH			25.2	21.9	18.7	15.6										
D	I-S	47.7	41.2	34.2(1)	27.8(2)	22.5(3)	18.0(4)	14.4(5)	11.5(5)	9.1(4)	7.2(3)	5.7(1)	4.5				
	L-L						18.3		10.8								
	LM-20		(39.0)	33.1	26.9	21.8	17.7	(13.7)									
	LM			33.0	26.8	21.8	17.7										
	MH			30.2	25.8	21.8	18.1										
E	I-S		44.6	37.7	30.9(1)	24.7(2)	19.6(3)	15.3(3)	11.8(3)	9.1(2)	7.0(1)	5.4					
	L-L								12.1								
	LM-20		(38.0)	34.4	29.3	23.8	(18.4)										
	LM			34.4	29.3	23.8											
G	LM-20				26.1	21.3	(17.2)	(13.9)	(11.3)(1)	(9.2)							
IH	I-S	44.2(1)	35.5(2)	27.8(3)	21.8(5)	17.6(4)	14.0(4)	11.5(4)	9.5(4)	7.7(3)	6.3(1)	5.2	4.2				
	L-L				21.5		13.0										
	LM-20	44.8	37.7	30.7	24.0												
	LM			20.8													
	MH			23.8	20.3												
9-12	I-S+		40.5(1)	27.9(2)	19.2(3)	15.2(4)	12.3(4)	10.1(4)	8.2(4)	6.6(3)	5.4(1)	4.4					
	L-L+		49.5			14.8			8.6								
	LM-20	42.6	35.0	28.8	23.2	18.3	(14.0)	(11.1)									
AR-2	I-S+	44.5	37.0(1)	30.1(2)	23.4(3)	17.8(4)	13.5(5)	10.3(5)	8.0(5)	6.3(4)	5.0(3)	3.9(2)	3.1(1)	2.4			
	L-L+						13.5		8.0								
	LM-20		35.3	29.3	24.0	19.7	16.2	13.3	11.1	9.1	7.5	6.0	4.7	(3.7)			
9-184	I-S+		40.4	34.2	28.3	21.7(1)	18.0(2)	14.2(3)	11.2(4)	8.8(4)	7.1(4)	6.0(3)	5.0(3)	4.2(2)	3.6(2)	3.0(1)	2.5
	L-L+								10.5		6.9						
	LM-20				(29.0)	20.8	15.9	13.1	11.2	9.7	(8.5)						
9-102	I-S+		49.6	43.5(1)	36.1(2)	28.7(3)	21.6(4)	15.7(4)	11.3(5)	8.2(3)	6.1(1)	4.4					
	L-L+						23.5		11.3								
	LM-20		(43.4)	34.6	27.7	22.0	17.6	(14.1)									
9-104	L-L+						20.1(2)										
	LM-20		38.0	32.3	(27.8)	(23.8)(1)	(20.1)	(17.3)									
9-105	I-S+		44.2	36.8	31.4(1)	25.2(2)	19.7(3)	14.8(3)	11.0(3)	8.3(2)	6.2(1)	4.6					
	L-L+						20.2		11.0								
	LM-20	(42.2)	37.3	32.1	25.9	21.0	(16.9)	(13.7)									
9-109	L-L+								11.9(3)								
	LM-20				28.7	23.0	18.4(1)	(14.8)(1)	(11.9)	(9.6)							
Type 304L																	
2L	L-L								4.7								
	LM-20				18.6	13.1	(9.2)	(6.5)(1)	(4.6)(2)	(3.2)							
3L	I-S		33.4	26.3(1)	19.8(2)	14.2(3)	10.0(5)	7.0(5)	5.0(5)	3.8(5)	2.9(5)	2.4(5)	1.9(5)	1.6(5)	1.3(4)	1.1(2)	0.9(1)
							10.0				2.7				1.3		
	LM-20	33.7	27.6	22.1	17.3	13.4	10.2	7.8	5.9	4.5	3.5	2.8	2.2				
	LM			19.2	14.7	11.0	8.2	6.3	5.0	4.1	3.5	2.9	2.2				
	MH	27.3	20.6	15.3	11.3	8.5	6.4	5.0	3.9	3.1	2.6	2.1					
4L	I-S	45.0(3)	36.5(4)	29.3(5)	23.2(5)	18.5(5)	14.3(5)	11.2(5)	8.7(5)	6.6(5)	5.0(5)	3.9(5)	2.9(5)	2.3(5)	1.7(5)	1.3(4)	0.9(3)
	L-L					18.6			8.2		4.9		3.2		1.5		0.9
	LM-20	37.1	31.3	25.9	21.2	17.2	13.8	11.0	8.7	6.9	5.3	4.1	3.1				
	LM	36.7	30.9	25.6	20.9	16.9	13.6	10.8	8.6	6.7	5.2	4.0	3.0				
	MH	37.2	29.2	22.0	16.1	11.6	8.4	6.0	4.4	3.3							
AL	I-S		34.0	25.9(1)	19.8(3)	15.7(4)	12.8(4)	10.4(4)	8.6(5)	7.0(3)	5.7(1)						
	L-L					15.0			8.4								
	LM-20	(43.2)	33.0	25.5	20.5	16.7	13.2	(10.7)	(8.5)								
	LM			23.4	18.5	14.9	12.8										
	MH			21.6	17.7	14.6	12.1										
9-21b	I-S+	51.5	44.2(2)	34.8(3)	26.7(3)	20.3(4)	15.6(4)	12.0(4)	9.2(4)	7.0(3)	5.3(2)	4.1(1)					
	L-L+		48.0			20.5			9.2								
	LM-20	40.6	34.8	27.3	21.9	17.6	(14.2)	(11.5)									
9-22	L-L+					13.2(4)											
	LM-20	38.2	29.3	(22.3)(1)	(17.2)(2)	(13.2)											
9-27	I-S+	42.0	33.7	26.1(1)	20.3(2)	16.6(3)	14.1(2)	12.3(2)	10.8(2)	9.4(1)	8.2						
	L-L+					16.6			10.8								
	LM-20	41.1	34.0	28.1	23.8	20.3											

\+ Values derived by the author

( ) Strengths predicted outside the range of test stresses

TABLE 2

THE 100,000 HOUR STRENGTH LEVELS (1000 psi) FOR GRADE 22 STEEL

Extrapolation Methods: I-S = Iso-stress Line Extrapolation; L-L = Straight Line Extrapolation of Log Stress - Log Rupture Time Curves (refs. 3,6); LM-20 - Larson-Miller Parameter with C=20; L-M = Larson-Miller Parameter with an Optimized Constant; M-H = Manson-Haferd Parameter with Optimized Constants;
Data Weights: Values in brackets from 1-5

Data* Sheet	Extrapolation Methods	TEMPERATURE °F 750	800	850	900	950	1000	1050	1100	1150	1200
Wrought Products (Pipe Tube and Bar)											
1	I-S			23.0(3)	18.3(4)	13.8(5)	10.6(5)	7.7(3)	5.3		
	L-L						11.0	8.0	6.1		
	LM-20	34.5(1)	28.0(1)	22.5	17.7	13.6	10.4				
	LM		27.3		17.3	13.5	10.4				
	MH		26.4		15.8	12.2	9.5				
2	L-L						14.1				
	LM-20		(39.5)	28.0(1)	23.5(1)	(19.5)(1)	(15.7)				
3	I-S				22.5(2)	17.8(3)	14.0(5)	10.7(3)	7.2		
	L-L						12.8		8.2		
	LM-20		30.0	24.0(1)	19.6	16.0	(12.7)	(9.3)			
	LM			24.3	19.6	15.8					
	MH			22.1	18.6	15.5					
4	L-L						12.2				
	LM-20	34.5	29.5(1)	24.0(1)	(19.2)	(14.8)					
5	I-S				18.7(2)	14.9(3)	11.9(5)	9.6(3)	6.5		
	L-L						11.3		8.0		
	LM-20		31.5	24.5(1)	19.4	15.6	(12.5)	(9.8)			
	LM		29.2		18.1	14.6					
	MH		27.7		17.3	14.0					
6	I-S				18.5(2)	15.2(3)	12.5(4)	10.0(3)	7.1		
	L-L						12.5		8.4		
	LM-20		31.5	25.0(1)	19.9	15.9	12.9	(10.7)			
	LM				19.2	15.6	12.7				
	MH		25.9		17.5	14.5	12.0				
7	I-S				18.5(1)	14.0(1)	10.5(2)	8.0			
	LM-20		(31.5)	24.0	17.9	13.6	10.3	(7.6)			
	LM				18.2	13.8					
8	I-S				16.9(1)	12.8(1)	9.7(2)	7.3			
	LM-20			(25.0)	17.6	13.2	9.7	(7.1)			
	LM				16.7	12.4					
9	I-S				21.0(1)	15.9(1)	11.9(2)	8.9			
	LM-20			(24.5)	19.5	15.8	12.7	(9.3)			
	LM				18.4	14.8					
10	LM-20		(42.0)	29.5(1)	(21.5)						
11	LM-20				19.9(1)	15.0(1)					
12	LM-20					(16.8)					
13	LM-20				(21.0)	15.5(1)					
14	LM-20				19.3(1)	16.2(1)					
15	L-L								8.0		
	LM-20				(21.5)	17.0(1)	13.3(1)				
16	L-L								9.3		
	LM-20			(26.0)	19.8(1)	16.0(1)	13.7(1)	(11.7)			
17	L-L								9.1		
	LM-20			(18.8)	(15.9)	13.8(1)	12.0(1)	(9.8)			
18	I-S			23.5(2)	17.9(3)	13.5(4)	10.2(5)	7.4(5)	4.7(4)	2.6(1)	1.2
	L-L						10.0		6.7		2.5
	LM-20			(24.0)	17.8	13.9	11.0	8.4	6.0	(3.2)	
	LM				17.0	13.7	10.7	8.1	5.8		
	MH				16.0	13.1	10.7	8.5	6.0		
19	L-L								6.4		
	LM-20					(17.3)	12.0(1)	(8.3)			
20	I-S				20.0(2)	15.8(3)	12.5(4)	9.6(2)			
	L-L						10.1				
	LM-20			(31.0)	20.0	15.2	12.0	(9.3)			
	LM				20.2	15.1	12.2				
	MH				18.5	13.3					
21	LM-20				22.0(1)						
25	I-S			28.0(2)	21.5(3)	16.1(4)	12.0(5)	8.2(4)	4.8		
	L-L						11.8	8.7	4.8		
	LM-20	(40.5)	34.0(1)	27.5	21.0	15.7	11.0	(6.8)			
	LM		29.4		19.5	14.4	11.4				
	MH		26.5		18.9	15.1	11.3				
26	I-S			28.0(2)	21.0(3)	15.4(4)	11.5(5)	8.6(2)	5.7		
	L-L							9.3	7.2		
	LM-20		37.5(1)	28.5	22.0	16.7	13.4				
	LM		32.5		19.6	16.1					
	MH		32.5		15.6						

* Data Source: Reference 3 -- Sheets 1 through STP - 5
Reference 6 -- Sheets P-8a through W-25

TABLE 2 (cont.)

THE 100,000 HOUR STRENGTH LEVELS FOR GRADE 22 STEEL

Data Sheet	Extrapola-Methods	750	800	850	900	950	1000	1050	1100	1150	1200
		TEMPERATURE °F									
27	I-S					17.6(1)	11.4(3)	8.4			
	L-L							8.5			
	LM-20	(41.0)	33.0	25.5(1)	19.0(1)	14.3	(11.2)	(8.3)			
	LM		28.0		16.8						
	MH				16.7						
28	I-S			25.0(1)	19.2(2)	14.3(3)	10.5(5)	7.5(5)	5.0(5)	3.2(5)	1.9(1)
	L-L						10.1		5.7		1.9
	LM-20		(29.5)	23.5	18.2	13.4	10.2	7.7	5.2	(3.1)	
	LM		18.3		17.4	12.8	9.9	7.4	4.9		
	MH				17.4	12.8	9.1	6.0	3.8		
29	I-S			22.8(1)	17.9(3)	14.9(5)	12.3(5)	9.4(5)	6.6(5)	4.2(4)	2.2(1)
	L-L						12.0				2.6
	LM-20		(28.0)	22.0	17.3	14.7	11.6	8.3	5.8	(3.7)	
	LM				17.9	14.2	10.8	7.9	5.6		
	MH		20.9		16.2	13.8	11.4	9.1	6.9		
30	I-S			25.0(1)	19.7(3)	15.3(5)	11.6(5)	7.9(5)	4.9(4)	2.9(3)	1.5
	L-L						11.0				2.5
	LM-20			27.5	19.2	14.7	12.0	9.6	6.4	(3.3)	
	LM				18.8	14.7	12.2	9.5			
	MH				17.8	14.2	11.4	8.4			
31	I-S			30.5(1)	24.0(3)	18.4(5)	14.0(5)	9.9(5)	5.9(5)	3.1(3)	1.5(1)
	L-L						13.4				2.1
	LM-20		(31.0)	(27.5)	23.0	17.3	12.7	9.4	6.2	(3.2)	
	LM					19.2	14.1	11.3	8.7		
	MH				24.8	18.2	14.3	10.8	7.3		
32	I-S			24.5(1)	20.5(3)	17.0(5)	13.0(5)	8.9(5)	5.1(5)	2.6(3)	1.2(1)
	L-L						13.1		6.5		2.0
	LM-20			(28.5)	21.0	16.5	13.6	10.7	6.9	(2.8)	
	LM				23.5	17.3	13.9	11.9	8.4		
	MH					17.3	14.3	10.5	6.5		
33	LM-20			(29.0)	(23.0)	18.3(1)	14.3(1)	10.8(1)	7.1(1)		
	LM					19.6	14.3	11.1	7.6		
	MH					17.4	14.1	10.7	6.6		
34	LM-20			(24.5)	17.3(1)	13.5(1)	11.2(1)	8.0(1)	5.5(1)		
	LM				18.0	14.2	11.7	9.5	7.1		
	MH					14.2	11.3	8.4			
35A	LM-20				(22.0)	16.7(1)	13.3(1)	10.3(1)	7.0(1)	(3.8)	
	LM				20.6	16.2	13.3	9.5			
	MH				19.9	16.2	12.4	9.0			
35B	LM-20				18.0(1)	14.2(1)	11.5(1)	9.1(1)	6.7(1)	(4.3)	
	LM					14.9	12.1	9.7	7.2		
	MH					14.3	11.1	8.0			
36A	LM-20				18.7(1)	14.7(1)	12.5(1)	10.0(1)	(6.4)	(2.9)	
36B	LM-20				21.5(1)	14.8(1)	12.0(1)	9.5(1)	(6.4)	(3.5)	
	LM				16.1	13.1	10.7	8.1			
	MH				15.9	12.9	9.9				
37A	LM-20				(20.0)	15.4(1)	12.0(1)	9.3(1)	6.2(1)	(3.2)	
	LM					17.5	13.9	11.0	8.4		
	MH					16.0	12.3	8.5	5.0		
37B	LM-20			(24.5)	19.0(1)	15.4(1)	12.8(1)	10.0(1)	6.7(1)	(3.5)	
	LM					18.8	15.2	12.5	6.5		
	MH					17.4	14.6	11.3			
38A	LM-20			(25.5)	(20.0)	15.7(1)	12.3(1)	9.6(1)	(7.2)		
	MH					15.6	12.0	8.1			
38B	LM-20			(24.0)	18.7(1)	14.6(1)	11.6(1)	9.1(1)	(6.4)		
	LM				16.3	12.2	9.1				
	MH				14.5	11.0	8.4				
39	LM-20			24.5(1)	18.4(1)	14.6(1)	11.8(1)	9.3(1)	6.7(1)	(4.2)	
	LM					16.1	13.4	11.2	8.6		
	MH				16.9	14.1	12.1	10.2	8.1		
A	I-S				26.5(1)	19.3(3)	13.3(5)	8.9(4)	5.6		
	L-L						12.0		7.0		
	LM-20			47.0	30.0	19.3	13.8	9.9	(6.6)		
	LM		42.2		29.3	19.2	14.0				
	MH		38.3		23.3	14.5					
B	LM-20			(33.5)	24.5(1)	20.5(1)	16.5(1)	11.7(1)	(7.4)		
	LM					26.6	21.9	17.4	13.3		
	MH				29.4	25.3	21.4	17.9	14.6	11.7	
40	L-L							9.1			
	LM-20	36.5	30.5(1)	24.5(1)	19.2(1)	(14.8)	(11.3)				
41	LM-20	75.5	69.0(1)	49.5(1)	31.5(1)	(20.5)					

TABLE 2 (cont.)

THE 100,000 HOUR STRENGTH LEVELS FOR GRADE 22 STEEL

Data Sheet	Extrapola-tion Method	TEMPERATURE °F 750	800	850	900	950	1000	1050	1100	1150	1200
42	I-S			24.5(2)	20.5(3)	17.0(4)	13.4(5)	9.7(5)	6.6(5)	4.2(5)	2.5(1)
	L-L						13.4		6.9		2.8
	LM-20		31.5(1)	24.5	20.0	15.9	12.0	8.9	6.2	3.8	(2.3)
	LM		21.1		19.9	15.8	11.6	8.3	5.8		
	MH				17.2	13.5	11.8	9.1	6.6	4.4	
43	L-L								7.8		
	LM-20					(17.2)	14.0(1)	10.0(1)	(6.5)(1)		
44	L-L								8.0		
	LM-20					(16.6)	13.4(1)	9.4(1)	(5.8)(1)		
45	L-L								5.6		
	LM-20					(22.0)	15.2(1)	(8.3)(1)	(4.4)(1)		
46A	LM-20			(46.0)	(34.5)(1)						
46B	L-L								7.2		
	LM-20					(17.2)	12.7(1)	9.6(1)	(7.2)(1)		
46C	L-L								6.4		
	LM-20					(20.0)	15.1(1)	(9.3)(1)	(5.8)(1)		
47A	L-L							9.1			
	LM-20				31.0(1)	21.5(1)	(13.6)				
47B	L-L							12.0			
	LM-20				28.0(1)	21.5(1)	(13.7)				
48	I-S		44.5(2)	36.0(2)	29.0(4)	22.0(4)	16.0(4)	11.7(4)	6.2(4)	3.3(4)	1.6(3)
	L-L							13.2			2.1
	LM-20	54.0(1)	44.5	37.5	30.0	22.0	14.0	8.7	5.5	3.3	1.6
	LM		46.6		32.8	25.9	18.1	11.3	6.9	4.4	2.7
	MH		46.8		29.0	21.1	14.3	8.9	5.2	2.7	1.4
49	L-L								5.3		
	LM-20					(16.8)	11.4(1)	8.1(1)	(5.1)(1)		
	LM						10.7	7.6			
	MH					13.0	9.9	7.3			
STP-5	I-S				20.5(1)	16.2(3)	12.7(3)	10.2(2)	6.8		
	S						12.6				
	LM-20		(36.0)	27.5(1)	21.0	17.2	(14.2)				
	LM				16.7						
	MH				17.1						
P8a	I-S	53.5(3)	46.5(5)	38.0(5)	31.0(5)	25.0(4)	20.0(1)				
	L-L		50.0		33.0		24.0				
	LM-20	52.5	45.5	39.5	33.5	27.5	(20.2)				
P8b	I-S	81.5(2)	69.0(4)	51.0(4)	37.0(4)	27.0(2)	19.5				
	L-L		78.0		40.0						
	LM-20	77.0	64.0	51.5	38.5						
P12	I-S	53.0(2)	45.0(3)	37.0(5)	30.5(2)	24.5(1)					
	L-L			35.0	31.0						
	LM-20	Inconsistent Data									
P15a	I-S		59.5(3)	49.0(4)	38.0(2)						
	L-L			55.0							
	LM-20	67.0(1)	58.0	49.5	(41.0)						
P15b	I-S		62.5(1)	50.5(2)	38.5(3)	26.5(2)					
	L-L				44.0						
	LM-20	67.5	58.0	49.0	39.5	(27.0)	(16.4)				
P15c	I-S		61.0(2)	51.0(4)	39.5(5)	26.0(3)	18.0(2)	12.5(1)			
	L-L				46.0		20.0		10.2		
	LM-20	64.5	56.0	48.0	40.0	29.5	20.0	(13.1)			
P15d	I-S			42.5(2)	35.0(5)	25.0(3)	14.2(1)				
	L-L				37.0		24.0				
	LM-20	56.5	49.5(1)	42.0	34.5	27.0	19.8				
P15e	I-S		36.5(1)	31.0(1)	26.5(1)						
	L-L			31.5	27.5						
	LM-20	53.0	42.5	(36.0)							
P21	I-S	73.5(1)	57.3(3)	53.5(1)	45.0(1)						
	L-L		65.0	49.0	41.0						
	LM-20	72.5	58.0	(46.0)							
P23	I-S	109.0(1)	92.0(2)	62.0(1)							
	L-L		100.0	68.0							
	LM-20	107.0	83.0	(61.0)							
P24a	L-L		110								
	LM-20	122.0(1)	94.0(1)								
P24b	I-S	87.5(3)	68.0(5)	51.0(5)							
	L-L		78.0	50.0							
	LM-20	90.0	67.5	(50.0)							
P33	LM-20	64.0(1)	(51.0)(1)								
P34	I-S			62.0(1)	43.5(2)	25.5(2)	14.0(3)	7.7(3)	4.3(3)	2.5(1)	1.4
	LM-20	97.0	80.5	48.5	30.0	19.5	13.5	7.9	4.3		

TABLE 2 (cont.)

THE 100.000 HOUR STRENGTH LEVELS FOR GRADE 22 STEEL

Data Sheet	Extrapolation Methods	750	800	850	900	950	1000	1050	1100	1150	1200
		TEMPERATURE °F									
P40	I-S	78.0(3)	68.5(5)	55.5(5)	41.0(5)	28.0(4)	17.0(1)				
	L-L		67.0		39.0		20.0				
	LM-20	76.5	65.5	51.0	38.0	(23.5)					
P41	I-S	69.5(3)	59.5(5)	50.5(5)	39.0(5)	28.0(4)	19.6(1)				
	L-L		57.0		40.0		20.5				
	LM-20	67.5	57.5	48.0	38.0	(24.0)					
P42	I-S	51.0(3)	41.0(4)	34.5(4)	29.0(4)	24.0(3)	19.2(1)				
	L-L		40.0		26.5		20.0				
	LM-20	47.5	39.0	32.5	27.5	24.0	(21.0)				
P45	L-L		50.0								
	LM-20	(54.0)(1)									
P52a	LM-20			55.0(1)	(33.5)(1)	(20.0)					
P52b	I-S	68.5(2)	56.5(3)	48.0(5)							
	L-L			48.0	30.5						
	LM-20	51.5	(43.0)	(36.5)							
P52c	I-S	48.0(1)	41.5(2)	35.5(4)							
	L-L			35.0	30.5						
	LM-20	51.5	43.0	(36.5)							
T-2	I-S	58.0(2)	52.0(3)	45.0(4)	37.0(4)	27.0(4)	17.7(4)	11.0(2)	6.4	3.6	
	L-L					34.0			7.4		
	LM-20	58.0	50.5	42.5	30.0	21.5	15.2				
T-5	LM-20			20.5(1)	18.3(1)	16.1(1)	12.7(1)				
T-48	I-S					20.0(2)	14.8(3)	10.4(4)	6.5		
	L-L							10.1	7.2		
	LM-20		(37.0)	29.5(1)	23.0(1)	17.2	12.6	(9.1)			
T49	I-S					14.7(2)	10.3(3)	7.5(4)	5.4		
	L-L							7.0	5.8		
	LM-20	(36.0)	29.5(1)	23.5(1)	17.6(1)	12.8	9.7				
T50	I-S					16.9(2)	12.2(3)	8.7(4)	5.8		
	L-L							8.1	6.1		
	LM-20	(49.0)	38.5(1)	29.5(1)	22.0(1)	15.8	11.2				
T-51	I-S					16.7(2)	11.9(3)	8.3(4)	5.6		
	L-L							7.5	5.6		
	LM-20			31.5(1)	21.5(1)	15.6	11.4				
T-52	I-S				22.5(2)	16.5(3)	12.2(4)	8.9(5)	5.9		
	L-L							7.9	6.0		
	LM-20		42.0(1)	31.0(1)	22.0	15.9	11.5				
T-53	I-S					18.6(1)	14.6(2)	10.9(2)	7.2		
	LM-20				26.0(1)	14.7	(11.9)				
T-54	I-S					12.7(1)	9.4(3)	7.0(4)	5.1		
	L-L							5.9	4.8		
	LM-20			(33.0)	23.5(1)	14.3	10.4	(7.3)			
T-55	I-S						11.7(2)	8.5(2)	6.1		
	LM-20			(34.0)	24.0(1)	15.3(1)					
T-56	I-S					15.7(2)	11.4(4)	8.3(4)	5.5(1)		
	L-L							6.8	5.9		
	LM-20				25.5(1)	16.0	11.2	(8.0)			
T-57	I-S						10.6(1)	6.8(1)	4.4		
	LM-20				26.0(1)	14.9(1)	(11.0)				
T-58	I-S					14.5(2)	10.8(4)	8.0(4)	5.7		
	L-L							5.5	5.7		
	LM-20		(47.5)	40.5(1)	28.0(1)	15.8	11.3	(8.4)			

T-63 through T-108 45 data sets each of which consist of 2 tests at 1100°F
Analysis using LM-20 indicated 100,000 hour strengths at 950°F from 12.9 to 16.6 ksi.
The average 14.1 ksi was weighted 15

Data Sheet	Extrapolation Methods	750	800	850	900	950	1000	1050	1100	1150	1200
T-109	I-S			27.5(2)	21.5(4)	16.6(5)	13.0(5)	9.6(4)	6.4		
	L-L					16.0	13.0	10.4			
	LM-20	39.0(1)	33.0(1)	26.5	20.5	16.5	13.5	10.3	(7.0)		
Castings											
C-1	I-S				18.6(1)	14.5(2)	11.4(4)	8.9(4)	6.1		
	L-L							6.1			
	LM-20				19.3	14.3	(11.4)				
C-2	I-S			31.0(1)	24.5(1)	19.1(2)	14.5(2)	10.3(1)	6.6		
	L-L						14.1				
	LM-20		39.0(1)	31.0	23.0	(15.1)					
C-3	I-S			25.2(1)	19.2(1)	14.7(2)	11.3(2)	8.3(1)	5.7		
	L-L						9.8		5.6		
	LM-20		34.5(1)	25.0	18.8	14.4					
C-14	I-S		30.5(1)	23.5(2)	18.3(3)	14.2(4)	11.0(5)	8.4(4)	5.9		
	L-L					16.0					
	LM-20		34.0	27.0	20.5	15.8	12.0	(8.0)			
C-15	I-S		33.5(1)	26.0(2)	20.5(3)	15.8(4)	12.2(5)	9.2(4)	6.4		
	LM-20		33.0	26.0	20.0	15.7	12.0	(8.7)			

TABLE 2 (cont.)

THE 100,000 HOUR STRENGTH LEVELS FOR GRADE 22 STEEL

Data Sheet	Extrapolation Methods	750	800	850	900	950	1000	1050	1100	1150	1200
		TEMPERATURE °F									
Weld Metal											
W-16	I-S		50.0(2)	44.0(4)	35.5						
	L-L			50.0	41.0						
	LM-20	62.0(1)	54.0								
W-21	I-S		71.0(1)	48.0(2)	22.0						
	L-L			56.0	28.0						
	LM-20	90.5(1)	70.0	(36.0)							
W-22	I-S	76.0(1)	60.5(4)	45.0(5)	31.5(1)	21.5					
	L-L		70.0	45.0	36.0						
	LM-20	73.0	58.0	45.0							
W-23	I-S	72.0(3)	58.0(5)	44.0(5)	32.0(4)	23.0(1)					
	L-L		66.0	52.0	33.0						
	LM-20	71.5	61.0	45.5	(32.5)						
W-24	I-S	99.0(1)	79.0(3)	54.0(5)	29.0(1)						
	L-L		80.0	59.0							
	LM-20	102.0	73.0	(43.5)							
W-25	I-S	67.5(1)	56.0(2)	45.0(2)	35.5						
	L-L		54.0		41.0						
	LM-20	67.5	56.5	(47.0)							

( ) Strengths predicted outside the range of test stresses

TABLE 3

THE 100,000 HOUR STRENGTH LEVELS (1000 psi) FOR GRADE 11 STEEL

Extrapolation Methods: L-L=Straight Line Extrapolation of Log Stress-Log Rupture Time Curve (Data from Ref. 4); LM-20 = Larson-Miller Parameter with C=20; MC = Manson Compromise Parameter; L-M = Larson - Miller Parameter with Optimized Constant; M-H = Manson-Haferd Parameter with Optimized Constants.
S-S: Extrapolated Strength Selected for Determination of Average and Minimum Values
Data Weights = Values in brackets from 1 - 5

Data* Sheet	Extrapola-tion Methods	TEMPERATURE°F 750	800	850	900	950	1000	1050	1100	1150	1200
1	S-S		45.0(1)	38.1(2)	27.0(1)						
	LM-20		45.0	38.1	(27.3)						
	MC		(46.5)	39.2	(27.0)						
2	S-S		40.8(1)	36.3(2)	25.3(2)	17.7(1)					
	L-L						13.0				
	LM-20		41.5	36.3	26.3	(18.5)					
	MC		(40.8)	37.5	25.3	(17.7)					
3	S-S		45.0(1)	40.0(2)	29.3(2)	19.8(1)					
	L-L						15.0				
	LM-20		45.0	40.0	29.3	(20.2)					
	MC		(46.8)	40.6	29.8	(19.8)					
4	S-S		35.8(1)	31.4(2)	25.0(3)	17.0(4)	11.2(5)	7.5(1)			
	L-L						11.0	7.0			
	LM-20		36.2	30.3	22.5	15.8	11.3	(8.3)			
	MC		38.3	31.0	22.0	15.2	10.8	(7.7)			
	LM		(41.0)	35.2	26.8	17.0	10.7				
	MH		35.8	31.4	25.0	17.0	11.2	(7.5)			
5	S-S				23.2(1)						
	LM-20				(23.7)						
	MC				(23.2)						
6	S-S				27.5(1)						
	LM-20				(28.0)						
	MC				(27.5)						
7	S-S				27.4(2)						
	LM-20				27.4						
	MC				27.5						
8	S-S				27.0(2)						
	LM-20				27.0						
	MC				27.0						
9	S-S				26.4(2)	20.7(1)					
	LM-20				26.5	(20.8)					
	MC				26.4	(20.7)					
10	S-S				23.1(1)	15.3(2)	10.6(3)	6.3(2)	4.0(2)		
	L-L						8.8		4.3		
	LM-20			(34.0)	23.5	14.9	10.5	(6.3)			
	MC				23.1	13.6	8.9	(6.1)			
	LM				27.4	15.9	10.6	(6.3)			
	MH			(31.8)	22.2	15.3	10.8	(7.0)			
11	S-S				28.1(1)	19.2(2)					
	L-L						7.7				
	LM-20				(28.1)	20.0					
	MC				(29.0)	19.2					
12	S-S			40.5(1)	25.7(2)	14.9(3)	10.2(5)	6.2(3)	3.3(3)		
	L-L						9.7		4.3		
	LM-20			40.5	26.5	15.5	10.2	(6.2)			
	MC			(42.0)	25.7	14.9	9.4	(5.8)			
	LM				27.1	15.4	10.4				
	MH			31.9	22.6	15.7	10.7	7.3			
13	S-S				28.7(1)	15.6(2)	11.4(2)	8.2(1)			
	L-L						10.0				
	LM-20			(43.0)	28.7	17.0	12.1	(8.2)			
	MC				28.9	15.6	11.4	(8.3)			
	LM				16.9	12.4					
	MH				28.6	16.1					
14	S-S		34.4(1)	28.2(1)	20.0(2)	12.6(2)	9.8(1)				
	L-L							5.8			
	LM-20	39.3	34.4	28.2	20.3	13.2	(10.0)				
	MC		38.0	29.8	20.0	12.6	(9.8)				
15	S-S			31.8(1)	22.4(2)	13.9(2)					
	L-L							5.4			
	LM-20			31.8	23.2	14.2					
	MC			33.7	22.4	13.9					
16	S-S			41.8(1)	25.8(2)	14.3(2)	10.1(1)	6.2(1)			
	L-L							5.8			
	LM-20			41.8	27.6	14.9	(10.6)				
	MC			43.1	25.8	14.3	(10.1)				
17	S-S		39.8(1)	32.0(1)	20.2(2)						
	LM-20		39.8	32.0	20.7						
	MC		(43.0)	33.8	20.2						
18	S-S		36.5(1)	28.9(1)	20.9(2)						
	LM-20		36.5	28.9	20.9						
	MC		(41.5)	30.3	21.0						

* Data Source: Reference 4

TABLE 3 (cont.)

THE 100,000 HOUR STRENGTH LEVELS FOR GRADE 11 STEEL

Data Sheet	Extrapolation Methods	TEMPERATURE°F 750	800	850	900	950	1000	1050	1100	1150	1200
19	S-S		35.1(1)	29.8(2)	21.6(2)	13.9(1)					
	LM-20	40.0	35.1	29.8	21.9	(15.1)					
	MC		38.8	31.2	21.6	(13.9)					
20	S-S		39.5(1)	32.9(2)	22.9(2)	14.9(1)					
	LM-20		39.5	32.9	23.3	(16.1)					
	MC		(42.4)	34.0	22.9	(14.9)					
21	S-S			34.1(2)	23.5(2)	14.6(1)					
	LM-20		(44.0)	34.1	23.5	(16.1)					
	MC			36.8	23.7	(14.6)					
22	S-S			36.0(2)	24.1(2)	14.6(1)					
	LM-20		(44.0)	36.0	24.4	(15.0)					
	MC			37.3	24.1	(14.6)					
23	S-S		37.8(1)	30.2(2)	21.3(2)	14.2(1)					
	LM-20		37.8	30.2	21.4	(14.2)					
	MC		(41.8)	32.0	21.3	(14.2)					
24	S-S			38.2(1)	27.5(3)	13.7(3)	8.8(1)	5.5(1)	2.9(1)		
	L-L						9.0	5.5	3.1		
	LM-20		(44.0)	38.2	28.2	14.7	(9.3)				
	MC			39.0	27.5	13.7	(8.8)				
	LM			39.0	29.5	16.0					
	MH			37.2	28.4	13.7					
25	S-S				24.7(2)						
	LM-20				25.0						
	MC				24.7						
26	S-S				24.7(2)						
	LM-20				25.0						
	MC				24.7						
27	S-S			33.0(1)	25.0(2)						
	LM-20			(33.0)	25.4						
	MC			(35.7)	25.0						
28	S-S				20.0(1)						
	LM-20			(35.0)	(21.3)						
	MC			(39.0)	(20.0)						
29	S-S				23.9(1)						
	LM-20				(24.2)						
	MC				(23.9)						
30	S-S				26.5(2)						
	LM-20				26.8						
	MC				26.5						
31	S-S				21.9(1)						
	LM-20				(22.6)						
	MC				(21.9)						
32	S-S				24.2(1)						
	LM-20			(32.3)	(24.3)						
	MC			(34.2)	(24.2)						
33	S-S			32.7(1)	22.7(1)						
	LM-20			(32.7)	(22.7)						
	MC			(35.0)	(22.8)						
34	S-S			36.2(1)	27.2(2)	15.9(2)					
	LM-20			36.2	27.2	15.9					
	MC			36.2	28.9	15.1					
	LM				23.8	13.4					
35	S-S				22.3(1)						
	LM-20			(33.8)	(23.5)						
	MC			(34.0)	(22.3)						
36	S-S				26.3(1)	13.9(3)	10.0(3)	7.2(1)			
	L-L						10.5		4.4		
	LM-20				30.2	16.0	10.6	(8.1)			
	MC				29.8	14.8	10.0	(7.2)			
	LM				26.3	13.9					
	MH				21.7	14.2	10.3				
37	S-S		34.1(1)	28.2(1)	20.7(2)	13.1(2)	9.7(1)				
	L-L							6.4			
	LM-20	40.0	34.1	28.2	20.9	13.8	(10.0)				
	MC		37.9	29.3	20.7	13.1	(9.7)				
38	S-S		38.8(1)	33.1(1)	23.7(2)	13.1(2)	10.2(1)				
	L-L							5.2			
	LM-20	(44.0)	38.8	33.1	23.9	13.8	(10.2)				
	MC		(41.0)	35.3	23.7	13.1	(10.2)				
39	S-S		49.5(1)	41.2(1)	30.0(2)	13.7(2)					
	L-L							4.2			
	LM-20		(49.5)	41.2	30.5	13.8	(10.9)				
	MC		(50.2)	43.2	30.0	13.7					

TABLE 3 (cont.)

THE 100,000 HOUR STRENGTH LEVELS FOR GRADE 11 STEEL

Data Sheet	Extrapolation Methods	TEMPERATURE°F 750	800	850	900	950	1000	1050	1100	1150	1200
40	S-S	38.1(1)	34.0(1)	29.1(1)	20.7(2)	11.9(2)	9.7(2)	6.8(2)			
	L-L							5.0			
	LM-20	38.1	34.0	29.1	21.0	12.3	(10.0)				
	MC		36.9	30.0	20.7	11.9	(9.7)				
41	S-S			36.9(1)	25.3(2)	13.3(2)	9.9(1)				
	L-L							4.7			
	LM-20		(45.8)	36.9	26.0	14.1	(9.9)				
	MC		(49.8)	39.0	25.3	13.3	(10.2)				
42	S-S			43.5(1)	29.4(2)	14.0(2)	10.0(1)				
	L-L							4.0			
	LM-20			43.5	29.8	15.0	(10.5)				
	MC			44.3	29.4	14.0	(10.0)				
43	S-S		36.0(1)	29.8(1)	22.0(2)	13.4(2)					
	L-L							6.0			
	LM-20	40.0	36.0	29.8	22.0	14.0					
	MC		38.8	31.7	22.3	13.4					
44	S-S		37.8(1)	32.0(1)	23.2(2)	16.1(2)					
	LM-20	41.2	37.8	32.0	23.3	17.7					
	MC		40.0	33.3	23.2	16.1					
45	S-S		38.1(1)	33.8(1)	25.6(2)	17.0(1)					
	LM-20	(42.2)	38.1	33.8	25.8	(18.4)					
	MC		40.0	35.0	25.6	(17.0)					
46	S-S		38.0(1)	33.2(1)	21.8(2)						
	LM-20	(41.5)	38.0	33.2	22.5						
	MC		40.0	35.2	21.8						
47	S-S			32.8(1)	21.8(2)						
	LM-20			32.8	22.7						
	MC			34.7	21.8						
48	S-S		37.8(1)	33.6(1)	22.8(2)	15.0(1)					
	LM-20	(40.7)	37.8	33.6	22.8	(16.3)					
	MC		39.8	34.7	23.5	(15.0)					
49	S-S		36.1(1)	31.0(1)	24.3(2)	18.3(1)					
	L-L							8.4			
	LM-20	39.8	36.1	31.0	24.6	19.0					
	MC		38.3	32.4	24.3	(18.3)					
50	S-S		34.0(1)	27.6(1)	21.7(2)	14.3(2)	10.8(1)				
	L-L							6.8			
	LM-20	39.0	34.0	27.6	21.7	15.2	(10.9)				
	MC		37.0	29.4	21.8	14.3	(10.8)				
51	S-S		35.0(1)	29.7(1)	22.8(2)	13.8(2)	9.9(1)				
	L-L							6.0			
	LM-20	41.5	35.0	29.7	23.0	14.4	(10.1)				
	MC		39.1	31.2	22.8	13.8	(9.9)				
52	S-S		42.0(1)	37.7(1)	27.2(2)	15.1(2)					
	L-L						14.5	4.8			
	LM-20		(42.0)	37.7	28.0	16.0					
	MC		(43.4)	38.7	27.2	(15.1)					
	LM				35.7	25.0					
	MH				34.8	22.6					
53	S-S		41.0(1)	37.3(2)	24.9(1)						
	L-L						14.5				
	LM-20		(41.0)	37.5	(26.4)						
	MC		(42.8)	37.3	(24.9)						
54	S-S			28.8(1)	21.0(2)	14.8(3)	11.1(5)	7.6(3)	5.7(3)		
	L-L						10.4		5.8		
	LM-20			28.8	21.0	14.8	11.1	(7.8)			
	MC			29.8	20.7	14.2	10.4	(7.6)			
	LM			31.2	22.9	15.7	11.7	(8.2)			
	MH				22.6	14.8	10.3				
55	S-S			29.1(1)	21.9(2)	15.2(2)	11.0(1)				
	L-L						10.4		6.4		
	LM-20			29.1	22.0	15.2	(12.2)				
	MC			29.8	21.9	15.2	(11.0)				
	LM			(32.0)	23.9	17.5	(12.7)				
56	S-S			29.0(1)	21.2(2)	13.8(2)	10.8(1)				
	L-L						10.4		5.8		
	LM-20		(35.5)	29.0	21.7	14.5	(11.3)				
	MC			29.8	21.2	13.8	(10.8)				
	LM				25.7	18.4	12.9				
57	S-S			29.2(1)	21.2(2)						
	L-L						10.4				
	LM-20			29.2	21.8						
	MC			30.2	21.2						
58	S-S		36.4(1)	29.8(1)	22.7(2)	14.4(2)					
	L-L							5.6			
	LM-20	(41.5)	36.4	29.8	22.8	15.2					
	MC		39.7	31.7	22.7	14.4					
59	S-S		39.6(1)	32.3(1)	21.8(2)	14.5(2)	10.8(1)				
	L-L						10.8				
	LM-20		39.5	32.3	21.8	15.7					
	MC		40.6	34.8	22.0	14.5					
	LM				31.3	18.3	11.1				
	MH				31.6	16.6					

TABLE 3 (cont.)

THE 100,000 HOUR STRENGTH LEVELS FOR GRADE 11 STEEL

Data Sheet	Extrapolation Methods	TEMPERATURE°F 750	800	850	900	950	1000	1050	1100	1150	1200
60	S-S			35.5(1)	20.0(2)	12.6(3)	9.9(5)	7.1(4)	5.2(4)		
	L-L						9.2		5.2		
	LM-20			(35.5)	21.5	13.3	10.2	7.6			
	MC			(35.6)	20.0	12.6	9.7	7.1			
	LM				22.9	14.6	10.2				
	MH				21.6	12.6	9.0				
61	S-S			26.6(1)	16.2(2)	11.1(1)					
	L-L						7.0				
	LM-20			26.6	16.5	(11.3)	(9.7)				
	MC			27.9	16.2	(11.1)	(9.4)				
62	S-S		41.2(1)	33.8(1)	23.2(2)	13.0(1)					
	LM-20		(41.2)	33.8	23.8	(13.5)					
	MC		(43.8)	35.9	23.2	(13.0)					
63	S-S		30.5(1)	27.3(1)	20.4(2)	13.3(2)					
	L-L							6.7			
	LM-20		30.5	27.3	21.0	13.9	(11.0)				
	MC		(32.0)	28.3	20.4	13.3	(10.4)				
64	S-S		31.5(1)	26.1(2)	16.2(2)	11.3(2)	9.5(1)				
	L-L							5.3			
	LM-20	36.7	33.0	26.1	16.2	11.8	(9.8)				
	MC		31.5	26.1	16.5	11.3	(9.5)				
68	S-S			38.2(1)	27.0(2)	14.1(2)	9.4(3)				
	L-L						7.7		3.1		
	LM-20			38.2	27.9	14.9	10.0				
	MC			39.9	27.0	14.1	9.4				
	LM			39.5	28.9	15.3	10.4				
	MH				30.0	15.5	9.1				
69	S-S				20.4(2)	13.9(2)	10.6(2)	7.2(2)	4.2(1)		
	LM-20			31.9	21.1	14.3	11.3	8.2	(5.2)		
	MC				20.4	13.9	10.6	7.2	(4.2)		
	LM				24.2	17.0	12.0	8.6	6.2		
	MH					22.7	16.2	11.6	8.4	6.1	
70	S-S				22.1(2)	13.2(2)	10.0(2)	6.6(2)	4.5(1)		
	LM-20				22.1	14.0	10.7	7.5	(5.2)		
	MC				22.7	13.2	10.0	6.6	(4.5)		
	LM					20.3	13.4	9.3	6.8		
	MH				24.7	16.5	12.0	9.2	7.3		
71	S-S			28.0(2)	18.1(2)	12.3(2)	9.6(2)	6.5(2)	4.5(1)		
	LM-20			28.0	20.4	14.5	10.3	7.5	(5.4)		
	MC			29.0	18.1	12.3	9.6	6.5	(4.5)		
	MH				14.2	11.7	9.9	8.3	6.8		
72	S-S		33.0(2)	25.3(2)	18.9(2)	14.2(2)	10.5(2)	7.0(2)	4.5(1)		
	LM-20		33.0	25.3	19.7	15.2	11.5	8.0	(5.1)		
	MC		35.0	26.9	18.9	14.2	10.5	7.0	(4.5)		
	LM				28.7	21.6	15.9	11.4	7.9		
	MH				28.0	19.0	13.5	9.2	5.6		
73	S-S				22.6(1)	14.4(2)	10.7(2)	7.1(2)	4.1(1)		
	LM-20				22.7	14.8	11.5	8.3	(5.3)		
	MC				22.6	14.4	10.7	7.1	(4.1)		
74	S-S	47.5(1)	44.5(1)	40.0(2)	22.0(2)	13.7(2)	9.5(2)	6.6(2)	4.3(1)		
	L-L						8.3		4.3		
	LM-20	47.5	44.5	40.0	22.2	14.2	10.1				
	MC	(48.5)	46.2	39.0	22.0	13.7	9.5	(6.6)			
	LM		43.7	31.0	18.4	11.8	(8.7)				
	MH				17.0	12.0	9.1				
75	S-S		51.0(1)	47.2(2)	32.3(2)	16.8(2)	9.8(2)	6.9(1)	4.3(1)		
	L-L				40.0		11.0		4.3		
	LM-20		51.0	47.2	33.2	17.0	10.2	(8.0)			
	MC	(52.5)	52.0	48.0	32.3	16.8	9.8	(6.9)			
	LM		51.2	46.5	29.8	17.3	10.5				
	MH		46.1	36.0	28.9	16.1					
76	S-S		54.0(1)	44.8(1)	28.2(2)	15.3(2)	9.0(2)	6.1(1)	4.2(1)		
	L-L				40.0		8.4		3.8		
	LM-20		54.0	45.6	29.8	15.9	9.8	(6.7)			
	MC		(55.8)	44.8	28.2	15.3	9.0	(6.1)			
	LM				38.6	25.7	15.5	8.4			
	MH			50.7	38.4	27.0	17.3	9.9			
77	S-S					16.0(2)	12.8(2)				
	LM-20					(16.5)	13.4				
	MC					16.0	12.8				
78	S-S				21.9(1)	15.1(2)	10.1(2)	7.0(2)	4.1(1)		
	LM-20				24.0	15.7	10.1	7.7	(5.2)		
	MC				21.9	15.1	10.5	7.0	(4.1)		
	LM					23.3	15.9	11.1	7.9		
	MH					21.7	15.2	10.7	7.6		
79	S-S		43.7(1)	31.0(1)	20.0(2)	12.8(3)	9.4(3)	6.6(2)	4.7(2)		
	L-L				24.0		9.6		4.7		
	LM-20		43.7	31.2	20.0	12.8	9.4	(6.6)			
	MC		44.2	31.0	19.7	12.6	8.9	(6.4)			
	LM		44.9	26.2	20.5	14.1	9.6				
	MH			32.0	19.1	12.0	8.2				

TABLE 3 (cont.)

THE 100,000 HOUR STRENGTH LEVELS FOR GRADE 11 STEEL

Data Sheet	Extrapolation Methods	TEMPERATURE °F 750	800	850	900	950	1000	1050	1100	1150	1200
80	S-S			45.0(1)	26.0(2)	13.5(2)	9.2(2)	6.9(2)	4.7(3)		
	L-L				33.0		7.1		4.7		
	LM-20			45.0	27.3	14.2	9.8	6.9			
	MC			45.0	26.0	13.5	9.2	(6.6)			
	LM				28.5	15.3	10.1	7.2			
	MH			41.5	25.0	15.2	9.9	7.3			
81	S-S		47.5(1)	43.0(2)	26.0(2)	12.2(2)	8.3(2)	5.5(1)	4.0(1)		
	L-L				37.0		7.1		4.0		
	LM-20		47.9	43.1	26.2	13.1	9.0	(5.8)			
	MC		47.5	43.0	26.0	12.2	8.3	(5.5)			
	LM			37.0	28.3	16.7	10.8				
	MH			45.5	28.3	15.4	9.2				
82	S-S			31.6(1)	26.5(1)	18.9(1)					
	L-L					22.0		7.4			
	LM-20	36.0	32.8	29.0							
	MC		34.5	28.2							
	LM				28.5	19.5					
	MH			31.6	26.5	18.9					
83	S-S			29.8(1)							
	L-L				25.0						
	LM-20			29.8							
	MC			31.0							
84	S-S				27.5(1)	17.0(2)	11.6(3)	6.2(2)	3.0(2)		
	L-L						11.4		5.4		
	LM-20				27.5	17.0	11.6	(6.2)			
	MC				27.8	16.3	10.7	(6.1)			
	LM					21.3	15.3				
	MH					20.9	14.8				
85	S-S				23.0(2)						
	L-L						10.9				
	LM-20				23.5						
	MC				23.0						
86	S-S				20.5(1)						
	LM-20				(22.0)						
	MC				(20.5)						
87	S-S			30.8(1)	19.3(2)						
	L-L						9.4				
	LM-20			30.8	19.7						
	MC			32.0	19.3						
88	S-S			34.2(1)	21.1(2)	12.5(3)	9.5(3)	7.7(3)	5.1(4)		
	L-L						7.8		5.5		
	LM-20			34.2	22.7	13.7	10.2	7.7	(5.1)		
	MC				22.0	12.9	9.8	7.4	(4.9)		
	LM				21.1	12.5	9.5	8.8			
	MH			26.3	18.5	13.7	10.5	8.0			
89	S-S			36.5(1)	20.2(2)	13.8(3)	10.0(5)	6.6(3)	5.4(3)		
	L-L						8.7		5.5		
	LM-20			36.5	21.4	14.2	10.5	(7.4)			
	MC				20.2	13.8	10.0	6.6			
	LM				20.1	13.7	10.4				
	MH			26.3	17.8	13.3	10.3				
90	S-S				24.7(2)	13.5(1)					
	L-L						7.8				
	LM-20				25.8	(13.8)					
	MC				24.7	(13.5)					
91	S-S				21.7(1)	14.4(2)	9.6(2)	6.7(2)	4.6(2)		
	L-L						6.5		3.4		
	LM-20				21.5	15.0	10.7	(6.9)			
	MC				21.7	14.4	9.6	(6.7)			
	LM				23.1	15.2	11.0				
	MH				21.0	13.4	8.9				
92	S-S			28.0(1)	20.8(2)	14.0(2)	11.3(1)				
	L-L										
	LM-20			(28.0)	21.3	14.4	(11.7)				
	MC			(30.0)	20.8	14.0	(11.3)				
93	S-S	58.0(2)	51.0(3)	39.9(2)	26.0(2)	15.3(2)	9.6(2)	5.8(2)	3.6(2)	2.0(2)	.9(2)
	LM-20	58.0	52.5	42.1	27.2	15.7	10.2	7.1	4.8	2.9	1.6
	MC	62.0	51.5	39.9	26.0	15.3	9.6	5.8	3.6	2.0	.9
	LM		54.8		32.5	22.7	15.4	10.3	6.9	4.6	2.9
	MH		58.9		35.7	24.4	15.3	9.1	5.2	2.9	1.6

( ) Strengths predicted outside of the range of test stresses

TABLE IV

AVERAGE AND MINIMUM STRESSES FOR RUPTURE IN 100,000 HOURS FOR TYPE 304 AUSTENTIC STEEL

Temperature (°F)	No. of Data Points	No. of Weighted Points	Stress Range of Data (ksi) Minimum	Stress Range of Data (ksi) Maximum	Weighted Average Stress (ksi)	Weighted Average Lowered by 1.282SD (ksi)	Weighted Average Lowered by 1.645SD (ksi)	Weighted Average Lowered by 2.326SD (ksi)	Average Strength (ksi)	Minimum Strengths (ksi) Method 1	Minimum Strengths (ksi) Method 2 A	Minimum Strengths (ksi) Method 2 B	Minimum Strengths (ksi) Visual
Type 304 and 304H													
850	2	5	44.2	47.0	46.4	44.8	44.4	43.6	45.7	42.6	31.4	32.5	35.0
900	7	12	35.5	40.5	38.1	35.9	35.3	34.2	37.3	32.7	25.6	26.5	28.8
950	11	23	27.7	43.5	30.3	26.4	25.5	23.7	30.2	25.2	20.7	21.5	23.3
1000	15	40	19.2	36.1	24.0	19.5	18.5	16.6	24.3	19.3	16.7	17.4	18.9
1050	17	54	15.2	28.7	19.4	15.3	14.4	12.8	19.5	14.9	13.4	13.9	14.8
1100	25	74	11.7	21.9	15.8	12.0	11.2	9.7	15.6	11.4	10.7	11.1	11.5
1150	31	89	8.8	18.3	12.5	9.3	8.6	7.4	12.3	8.8	8.5	8.8	8.9
1200	35	113	6.9	15.5	10.7	7.8	7.2	6.1	9.7	6.7	6.7	6.9	6.9
1250	20	66	5.3	12.4	7.6	5.6	5.2	4.5	7.6	5.2	5.2	5.4	5.4
1300	17	53	4.2	7.7	5.8	4.4	4.1	3.5	6.0	4.0	4.1	4.3	4.2
1350	12	41	3.4	6.0	4.7	3.4	3.2	2.7	4.6	3.1	3.2	3.3	3.3
1400	10	29	2.7	5.0	3.6	2.5	2.3	2.0	3.6	2.3	2.5	2.6	2.6
1450	7	17	2.1	4.2	2.7	1.9	1.7	1.5	2.8	1.8	1.9	2.0	2.0
1500	6	13	1.7	3.6	2.3	1.5	1.3	1.1	2.1	1.4	1.4	1.5	1.5
1550	5	7	1.3	3.0	1.8	1.2	1.0	0.83	1.6	1.1	1.1	1.1	1.2
1600	2	2	1.1	1.8	1.4	0.90	0.79	0.63	1.2	0.82	0.83	0.85	
						Polynomial Degree			2	1	2	2	
Type 304L													
850	1	3	45.0	45.0	45.0				48.9	36.0	30.0	30.3	32.8
900	2	6	36.5	44.2	39.1	34.3	33.1	30.9	37.3	27.4	22.9	23.1	25.0
950	6	12	22.3	34.8	29.3	24.4	23.2	21.2	28.5	20.9	17.5	17.7	19.2
1000	6	17	17.2	26.7	21.8	18.0	17.2	15.6	21.8	15.9	13.4	13.5	14.7
1050	6	23	13.2	20.3	16.6	13.5	12.8	11.5	16.6	12.1	10.2	10.3	11.2
1100	5	20	10.0	15.6	13.2	10.5	9.9	8.8	12.7	9.2	7.8	7.8	8.5
1150	6	21	6.5	12.3	10.1	7.3	6.7	5.7	9.7	7.0	6.0	6.0	6.5
1200	6	23	4.6	10.8	7.8	5.1	4.6	3.8	7.4	5.4	4.6	4.6	4.9
1250	5	17	3.8	9.4	6.1	4.0	3.6	2.9	5.7	4.1	3.5	3.5	3.8
1300	4	13	2.9	5.7	4.3	2.8	2.5	2.1	4.3	3.1	2.7	2.7	2.9
1350	3	11	2.4	4.1	3.2	2.3	2.1	1.7	3.3	2.4	2.0	2.0	2.2
1400	2	10	1.9	2.9	2.4	1.8	1.6	1.4	2.5	1.8	1.6	1.6	1.7
1450	2	10	1.6	2.3	1.9	1.5	1.4	1.2	1.9	1.4	1.2	1.2	1.3
1500	2	9	1.3	1.7	1.5	1.3	1.2	1.1	1.5	1.0	0.91	0.91	0.98
1550	2	6	1.1	1.3	1.2	1.1	1.1	1.0	1.1	0.80	0.69	0.69	0.75
1600	2	4	0.9	0.9	0.9	0.9	0.9	0.9	0.86	0.61	0.53	0.53	0.57
						Polynomial Degree			1	1	1	1	

Average Strengths: By regression of log stress versus temperature

Minimum Strengths: Method 1: Regression of log stress versus temperature of minimum values (determined by lowering weighted averages by 1.645SD); Method 2: Multiplying average curve by the following factors determined at the temperature with the greatest number of weighted points: A--The ratio of the statistically defined minimum to the average, B--The ratio of the observed minimum to the average; Method 3--Visual

TABLE V

AVERAGE AND MINIMUM STRESSES FOR RUPTURE IN 100,000 HOURS FOR GRADE 22 STEEL

Temperature (°F)	No. of Data Points	No. of Weighted Points	Stress Range of Data (ksi) Minimum	Stress Range of Data (ksi) Maximum	Weighted Average Stress (ksi)	Weighted Average Lowered by 1.282SD (ksi)	Weighted Average Lowered by 1.645SD (ksi)	Weighted Average Lowered by 2.326SD (ksi)	Average Strength (ksi)	Minimum Strengths (ksi) Method 1	Minimum Strengths (ksi) Method 2 2A	Minimum Strengths (ksi) Method 2 2B	Minimum Strengths (ksi) Visual
Wrought Material													
750	19	33	34.5	122.0	66.8	45.4	41.1	34.1	65.1	45.4	50.9	49.2	42.0
800	30	66	28.0	94.0	54.7	37.1	33.6	27.8	52.2	30.5	40.9	39.4	32.5
850	48	100	20.5	62.0	39.4	25.5	22.8	18.5	37.5	22.2	29.3	28.3	22.8
900	66	131	16.9	45.0	27.1	17.8	16.0	13.1	25.9	16.8	20.2	19.5	16.2
950	69	163	12.7	28.0	18.0	13.1	12.0	10.3	17.9	12.9	14.0	13.5	12.3
1000	64	163	9.4	20.0	12.7	10.4	9.8	8.9	12.5	9.6	9.8	9.4	9.6
1050	50	131	6.8	12.5	9.0	7.5	7.2	6.6	8.7	6.8	6.8	6.6	6.9
1100	23	54	4.3	7.2	5.7	4.7	4.4	4.0	5.8	4.4	4.5	4.4	4.4
1150	9	29	2.5	4.2	3.4	2.6	2.5	2.2	3.4	2.7	2.7	2.6	2.5
1200	6	8	1.2	2.5	1.8	1.3	1.2	1.0	1.6	1.3	1.3	1.2	1.2
							Polynomial Degree		4	3	4	4	
Wrought Material, Annealed Above or Near Top of Critical Range													
750	2	2	34.5	39.0	36.7	32.8	31.8	30.0	32.5	25.6	27.1	24.9	26.0
800	6	6	28.0	42.0	33.7	27.3	25.8	23.2	29.6	24.4	24.6	22.7	23.7
850	21	26	22.8	40.5	26.6	22.2	21.1	19.3	25.6	21.6	21.3	19.6	20.5
900	40	63	16.9	28.0	20.8	17.7	16.9	15.6	21.0	17.9	17.5	16.1	16.8
950	50	112	12.7	20.5	15.7	13.6	13.9	12.2	16.4	13.9	13.6	12.5	12.9
1000	46	122	9.4	16.5	12.3	10.6	10.1	9.4	12.1	10.0	10.1	9.3	9.3
1050	39	106	6.8	11.7	9.0	7.6	7.3	6.7	8.5	6.8	7.1	6.5	6.4
1100	16	38	4.7	7.1	5.8	4.9	4.6	4.2	5.7	4.3	4.7	4.4	4.2
1150	6	19	2.6	4.2	3.5	2.6	2.4	2.1	3.6	2.5	3.0	2.8	
1200	4	4	1.2	2.5	1.9	1.1	1.0	0.81	2.2	1.4	1.8	1.7	
							Polynomial Degree		2	2	2	2	
Wrought Material, Normalized and Tempered and Quenched and Tempered													
750	17	31	48.0	122.0	68.8	49.2	45.2	38.4	65.2	42.8	46.3	29.5	44.1
800	22	58	30.5	94.0	57.5	41.7	38.4	32.8	56.3	39.3	40.0	25.5	38.2
850	23	68	20.5	62.0	45.3	34.0	31.5	27.3	45.5	33.3	32.3	20.6	31.5
900	22	59	18.3	45.0	35.0	27.5	25.8	22.9	34.4	26.0	24.4	15.5	24.4
950	15	39	16.1	28.0	25.3	21.9	21.0	19.5	24.3	18.8	17.2	11.0	17.8
1000	13	22	12.7	20.0	16.3	13.6	13.0	11.8	16.1	12.5	11.4	7.3	11.6
1050	7	13	7.7	12.5	10.1	7.9	7.3	6.5	9.9	7.7	7.0	4.5	7.0
1100	5	10	4.3	7.2	5.5	4.2	3.9	3.4	5.7	4.4	4.1	2.6	4.0
1150	2	5	2.5	3.3	3.1	2.7	2.5	2.3	3.1	2.3	2.2	1.4	2.2
1200	1	3	1.6	1.6	1.6				1.6	1.1	1.1	0.71	1.1
							Polynomial Degree		2	2	2	2	
Weld Metal													
750	6	8	62.0	99.0	76.4	62.1	58.7	52.9	75.7	57.6	66.2	72.2	
800	6	17	50.0	79.0	61.9	51.0	48.4	43.9	61.4	49.8	53.6	58.5	
850	6	23	44.0	54.0	46.8	42.0	40.8	38.6	46.3	40.0	40.5	44.0	
900	3	6	29.0	32.0	31.4	29.9	29.4	28.6	32.5	30.0	28.4	31.0	
950	1	1	23.0	23.0	23.0				21.3	20.9	18.6	20.3	
							Polynomial Degree		2	2	2	2	
Castings													
800	4	4	30.5	39.0	34.4	30.1	29.0	27.0	33.7	28.9	29.3	31.6	
850	4	6	23.5	31.0	25.9	22.6	21.8	20.3	26.0	21.9	22.6	24.4	
900	5	9	18.3	24.5	19.9	17.5	16.9	15.8	20.0	16.8	17.4	18.7	
950	5	14	14.2	19.1	15.5	13.5	13.0	12.2	15.3	13.1	13.3	14.4	
1000	5	18	11.0	14.5	11.8	10.6	10.3	9.7	11.7	10.2	10.2	11.0	
1050	5	14	8.3	10.3	8.9	8.2	8.1	7.8	8.3	8.1	7.8	8.4	
							Polynomial Degree		2	2	2	2	

Average Strengths: By regression of log stress versus temperature

Minimum Strengths: Method 1: Regression of log stress versus temperature of minimum values (determined by lowering weighted average by 1.645SD); Method 2: Multiplying average curve by the following factors determined at the temperature with the greatest number of weighted points: A--The ratio of the statistically defined minimum to the average, B--The ratio of the observed minimum to the average; Method 3: Visual

TABLE VI

AVERAGE AND MINIMUM STRESSES FOR RUPTURE IN 100,000 HOURS FOR GRADE 11 STEEL

Temperature (°F)	No. of Data Points	No. of Weighted Points	Stress Range of Data (ksi)		Weighted Average Stress (ksi)	Weighted Average Lowered by			Average Strength (ksi)	Minimum Strengths (ksi)			
			Minimum	Maximum		1.282SD (ksi)	1.645SD (ksi)	2.326SD (ksi)		Method 1	Method 2 2A	Method 2 2B	Visual
Wrought Material													
750	3	4	38.1	58.0	50.4	38.4	35.7	31.2		38.3			35.8
800	36	39	30.5	54.0	40.0	32.6	30.9	27.9	42.3	31.6	33.9	30.2	31.8
850	63	80	25.3	47.2	34.0	27.5	26.0	23.4	33.2	24.7	26.6	23.8	25.7
900	88	158	16.2	32.3	23.5	19.6	18.7	17.0	22.7	18.4	18.2	16.2	18.0
950	65	125	11.1	20.7	14.4	12.4	11.9	11.0	14.9	13.0	12.0	10.7	11.9
1000	41	89	8.3	12.8	10.2	9.2	8.9	8.4	10.0	8.7	8.0	7.2	8.2
1050	27	52	5.5	8.2	6.8	6.0	5.9	5.5	6.8	5.5	5.4	4.8	5.5
1100	22	41	2.9	5.7	4.5	3.5	3.2	2.9	4.3	3.3	3.5	3.1	3.3
1150	1	2	2.0	2.0	2.0				2.4	1.9	1.9	1.7	
1200	1	2	0.9	0.9	0.9				0.90	1.0	0.72	0.64	
						Polynomial Degree			4	2	4	4	
Wrought Material Annealed Above or Near Top of Critical Range													
750	2	2	38.1	47.5	42.8	34.8	32.9	29.6		36.3			
800	18	19	33.0	54.0	40.1	32.7	30.8	27.7	41.9	31.1	33.6	32.5	31.2
850	35	48	25.3	47.2	34.8	28.1	26.6	23.9	34.2	24.9	27.4	25.7	26.0
900	57	100	18.1	32.3	24.2	20.1	19.2	17.5	23.4	18.7	18.7	18.1	17.8
950	38	75	11.9	20.7	14.6	12.5	12.0	11.0	15.2	13.2	12.2	11.8	12.0
1000	26	59	8.8	12.8	10.3	9.3	9.0	8.5	10.0	8.7	8.0	7.8	8.0
1050	19	34	5.5	8.2	6.8	6.0	5.9	5.5	6.7	5.4	5.4	5.2	5.3
1100	14	23	2.9	5.4	4.3	3.2	3.0	2.6	4.2	3.1	3.4	3.3	3.3
						Polynomial Degree			4	3	4	4	
Wrought Material Annealed Below Critical Range													
800	5	5	30.5	41.2	35.8	30.0	28.5	26.0	35.7	30.8	29.4	28.5	27.8
850	11	12	26.1	35.5	29.5	25.8	24.9	23.3	29.3	22.7	24.1	23.4	22.0
900	11	22	16.2	23.2	20.5	17.5	16.8	15.5	20.2	16.8	16.6	16.2	16.0
950	10	20	11.1	15.2	13.6	11.9	11.4	10.7	13.8	12.4	11.4	11.1	11.5
1000	6	14	9.5	11.1	10.5	9.7	9.5	9.1	10.1	9.1	8.3	8.1	8.5
1050	2	7	7.1	7.6	7.3	7.0	6.9	6.7	7.6	6.7	6.3	6.1	6.2
1100	2	7	5.2	5.7	5.4	5.1	5.0	4.8	5.4	5.0	4.4	4.3	4.3
						Polynomial Degree			4	1	4	4	
Wrought Material Normalized and Tempered													
750	1	2	58.0	58.0	58.0								
800	11	13	34.0	51.0	41.3	33.5	31.7	28.5	44.4	31.9	38.6	39.6	32.8
850	15	17	27.6	45.0	34.4	27.9	26.3	23.7	33.1	26.6	28.8	29.6	25.4
900	18	33	20.0	26.5	23.3	20.8	20.2	19.0	22.4	19.4	19.5	20.0	18.0
950	16	28	12.2	18.9	14.5	12.5	12.0	11.2	14.8	12.9	12.8	13.2	12.0
1000	9	16	8.3	11.3	9.6	8.7	8.4	8.0	9.8	8.3	8.5	8.8	7.8
1050	6	11	5.5	7.0	6.5	5.8	5.6	5.3	6.5	5.4	5.7	5.8	5.2
1100	6	11	3.6	4.7	4.4	3.8	3.6	3.4	4.1	3.7	3.6	3.7	3.2
1150	1	2	2.0	2.0	2.0				2.2		1.9	2.0	
1200	1	2	0.9	0.9	0.9				0.91		0.79	0.81	
						Polynomial Degree			4	3	4	4	

Average Strengths: By regression of log stress versus temperature

Minimum Strengths: Method 1: Regression of log stress versus temperature of minimum values (determined by lowering weighted average by 1.645SD); Method 2: Multiplying average curve by the following factors determined at the temperature with the greatest number of weighted points, A--The ratio of the statistically defined minimum to the average, B--The ratio of the observed minimum to the average; Method 3: Visual

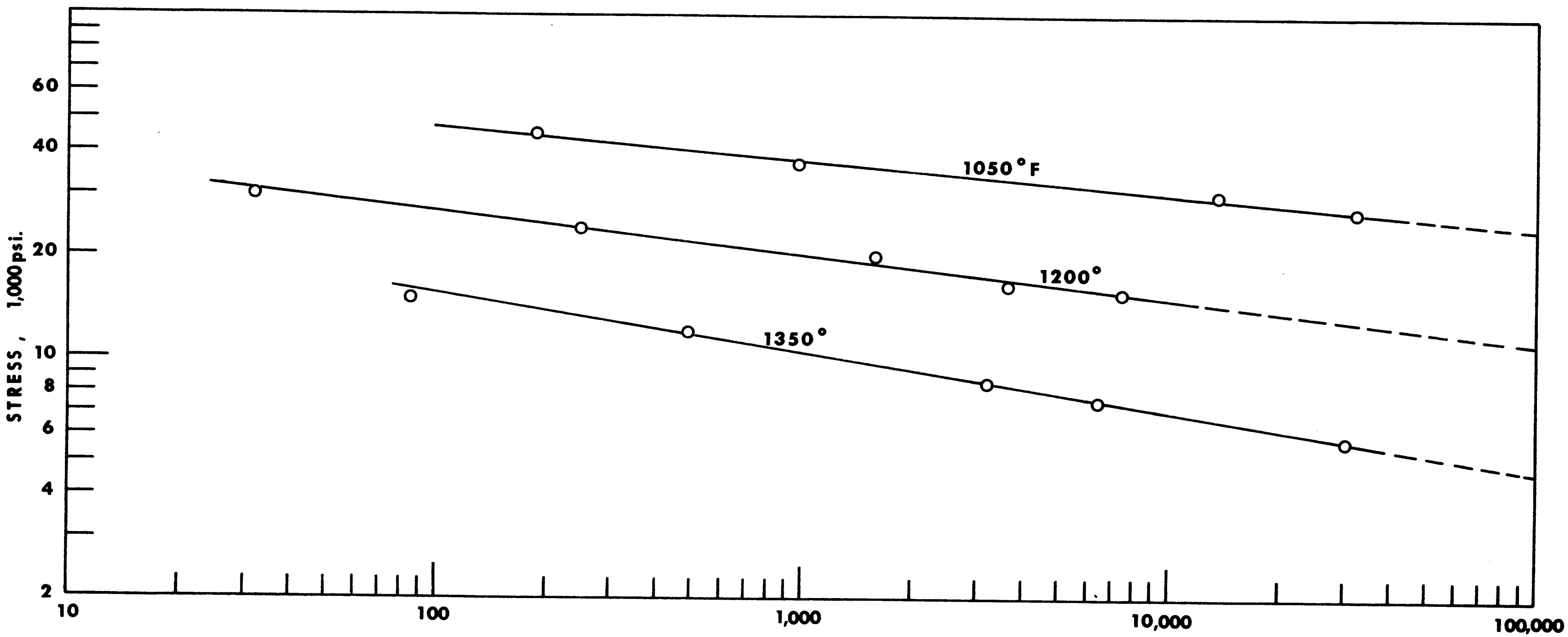

Figure 1. Stress versus Rupture Time Data Typical for Type 304 Austenitic Stainless Steel

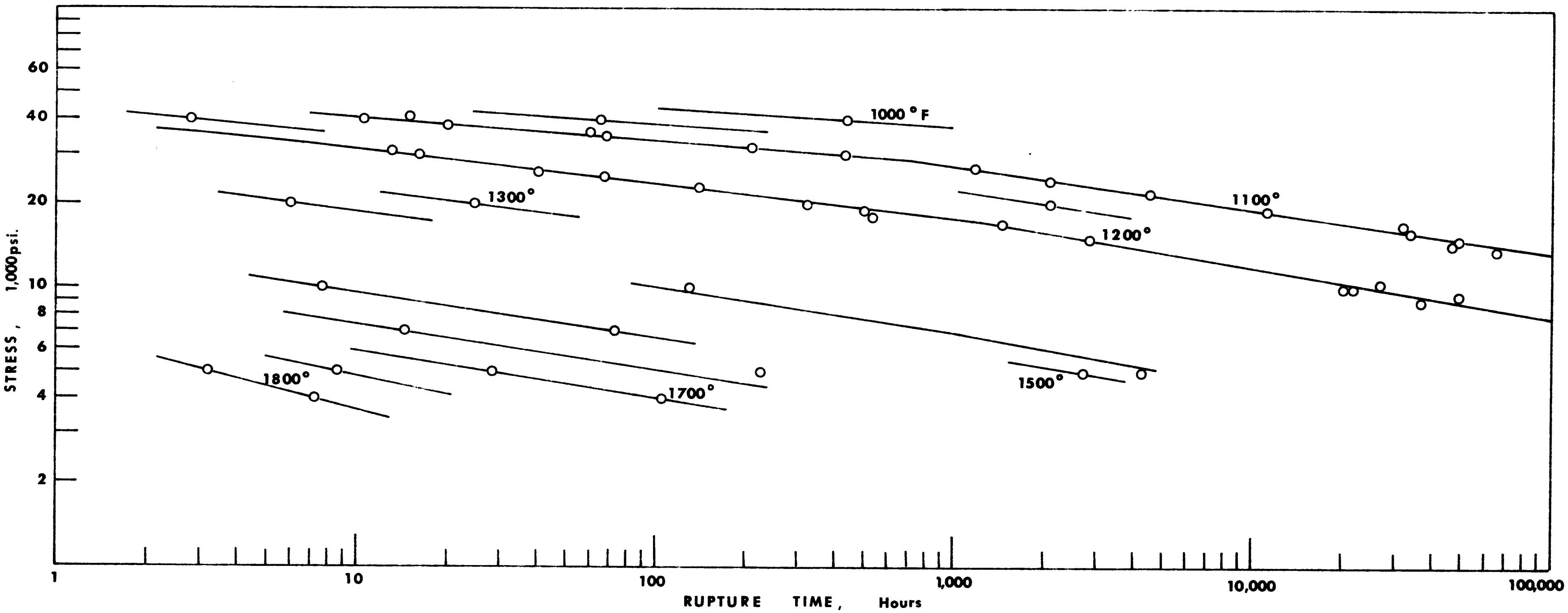

Figure 2. Stress versus Rupture Time Data for the "AR-2", Type 304 Stainless Steel.

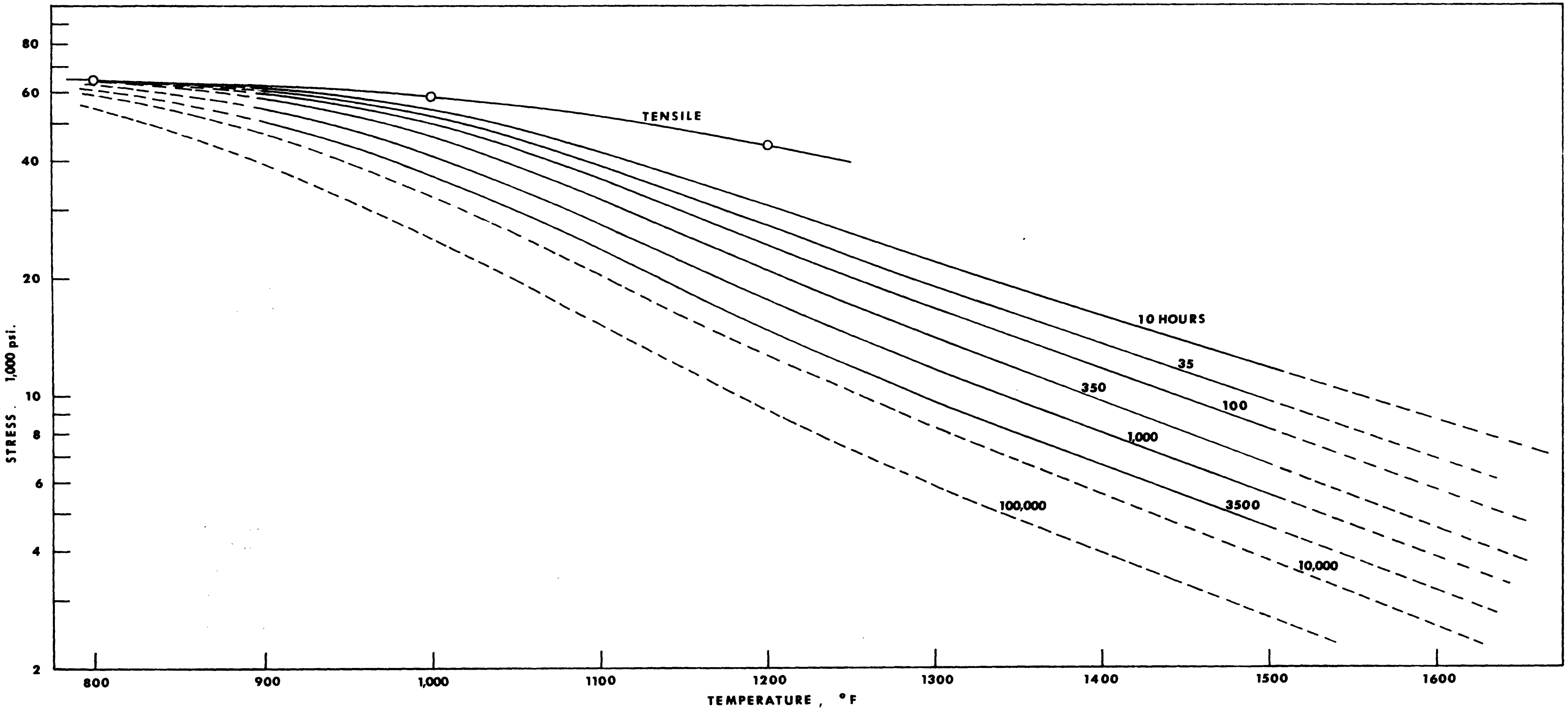

Figure 3. Curves of Stress versus Temperature for Selected Rupture Times ("Iso Time" Curves) Typical for Type 304 Austenitic Stainless Steel. The Curves for 10,000 and 100,000 Hours Were Derived by Extrapolating the Iso-Stress Lines of Figures 5 and 6.

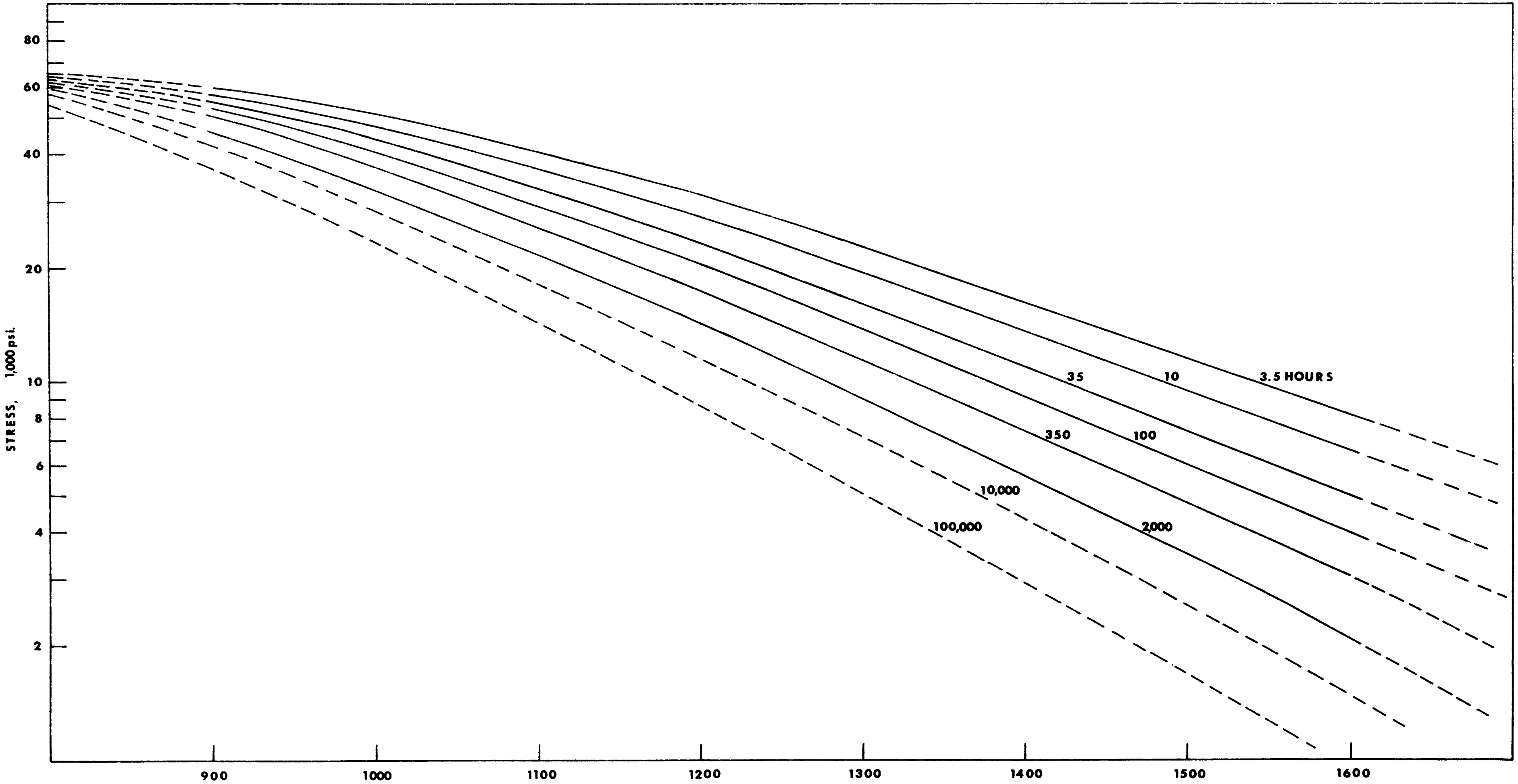

Figure 4. Iso-Time Curves Typical for Type 304 Austenitic Stainless Steel

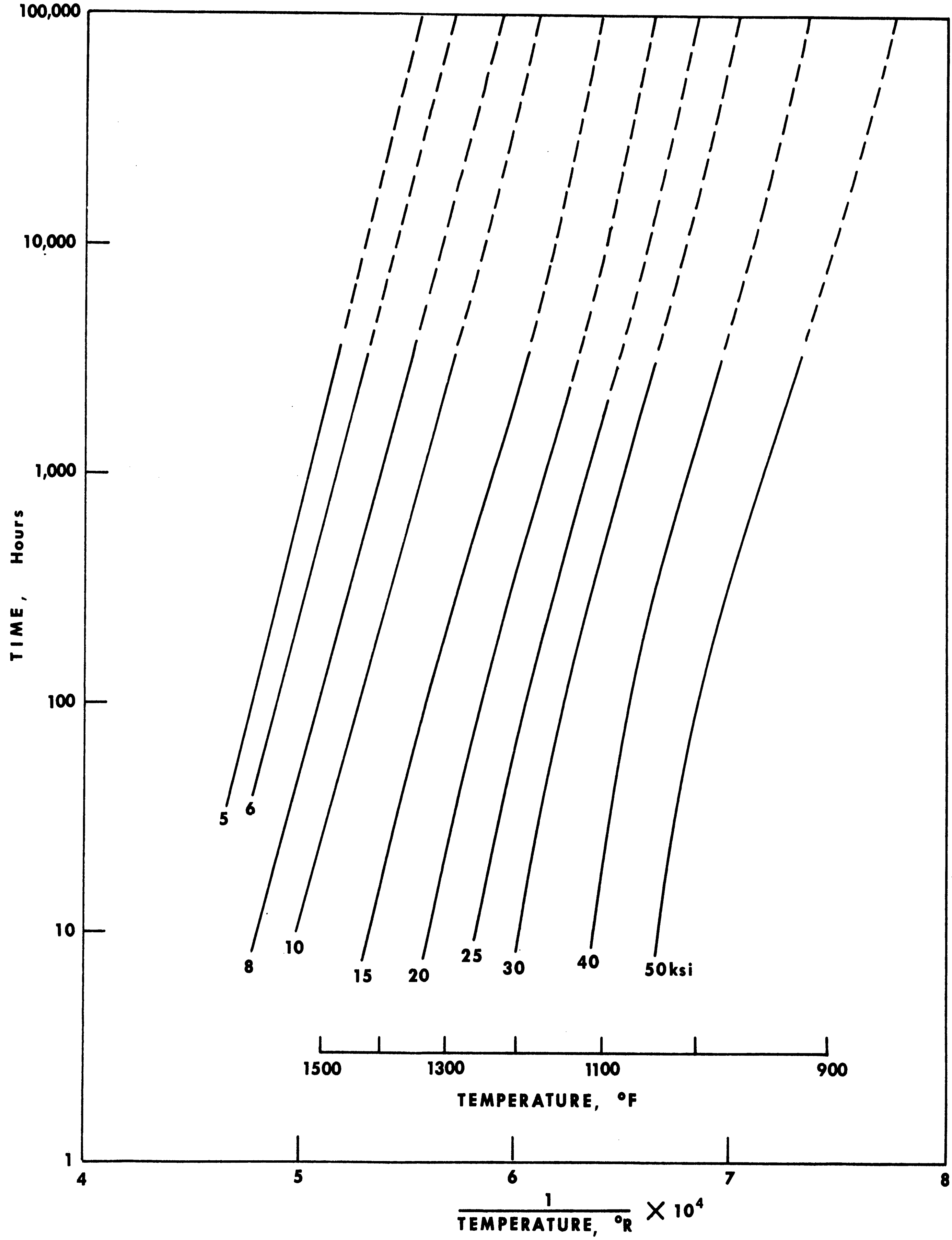

Figure 5. Iso-Stress Curves of Rupture Time versus Reciprocal Absolute Temperature Typical for Type 304 Austenitic Stainless Steel.

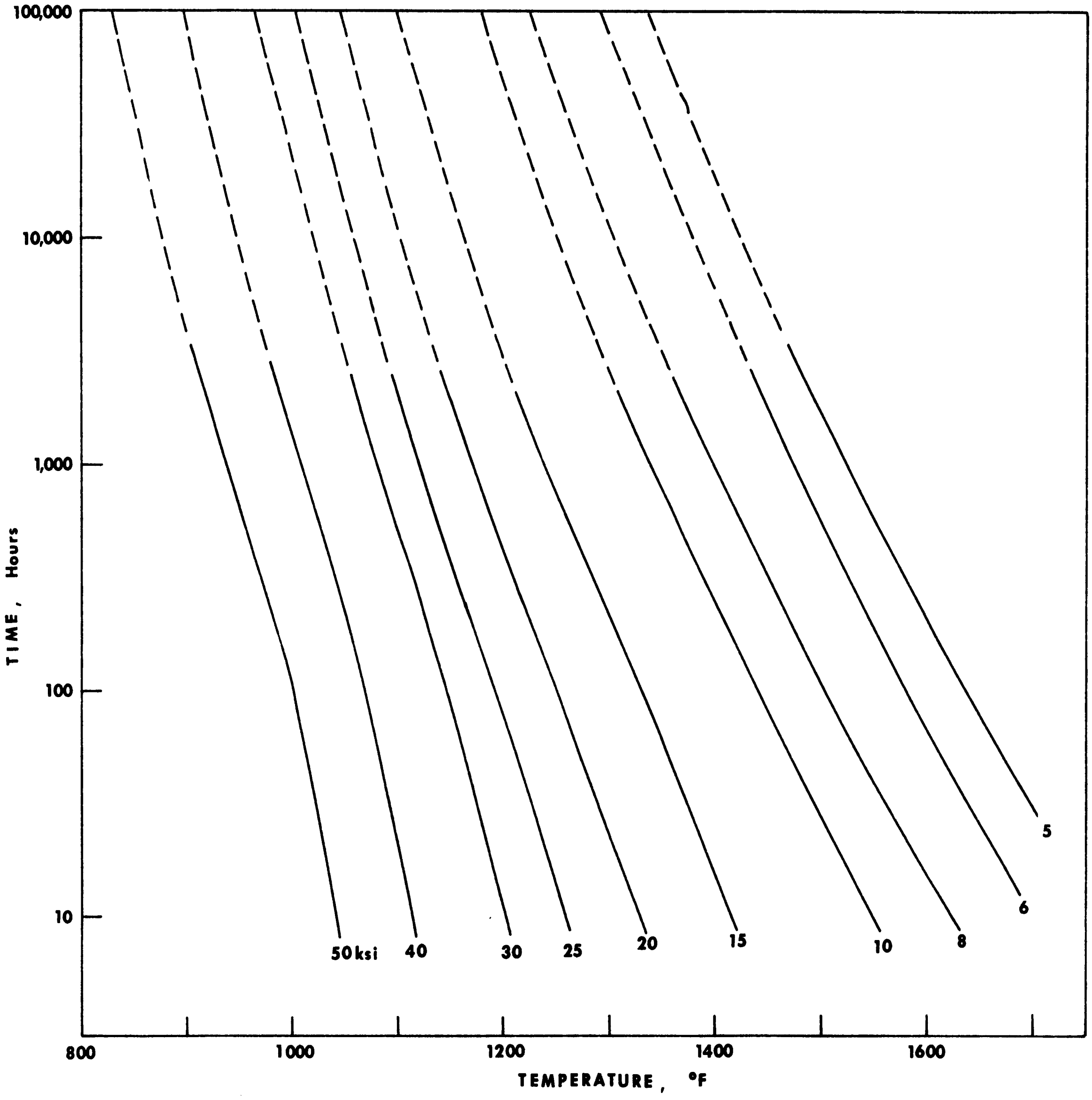

Figure 6. Iso-Stress Curves of Rupture Time versus Temperature Typical for Type 304 Austenitic Stainless Steel.

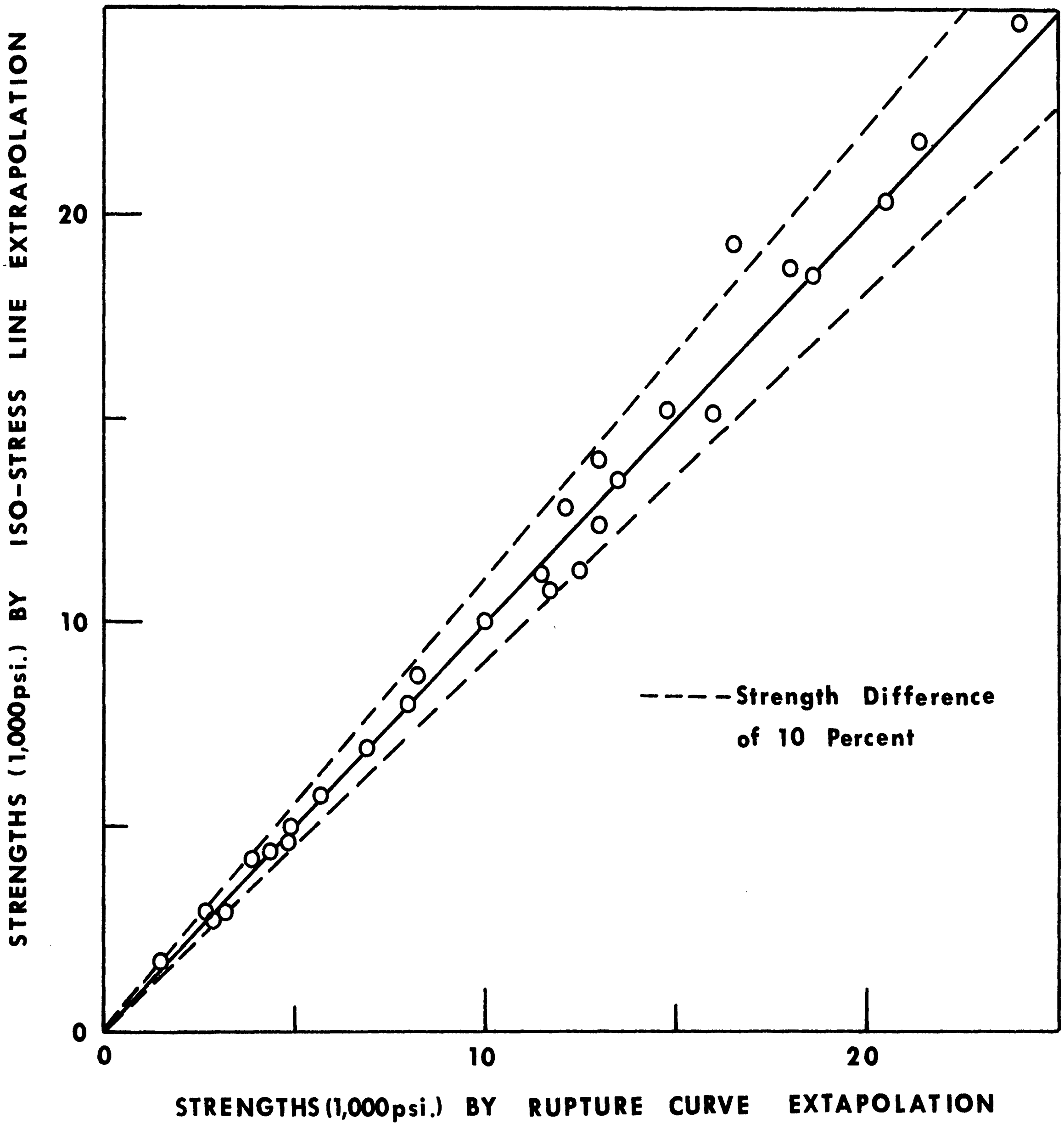

Figure 7. Comparison of the Stresses for Rupture of Type 304 Austenitic Stainless Steel in 100,000 Hours Obtained by the Indicated Extrapolation Methods.

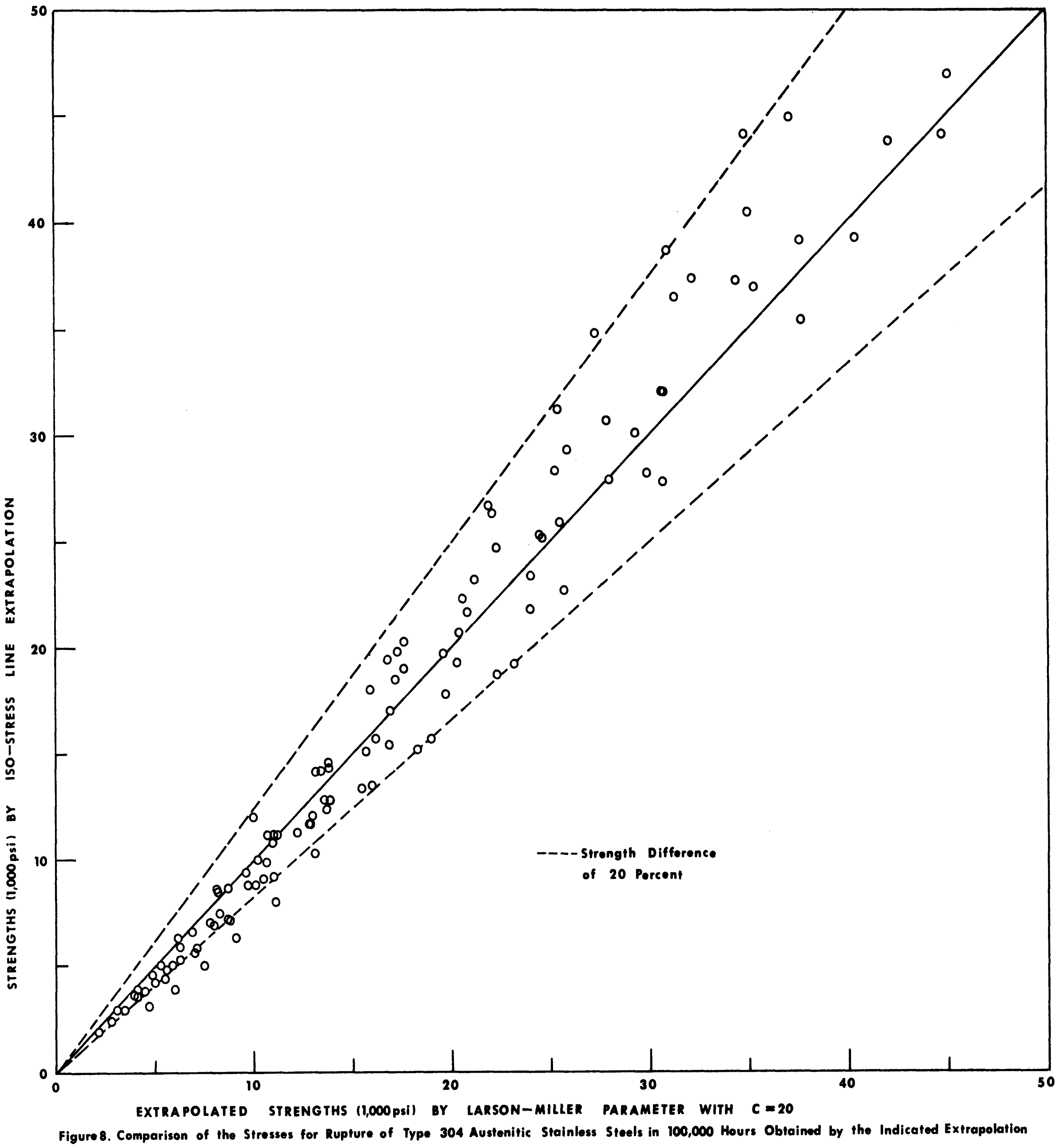

Figure 8. Comparison of the Stresses for Rupture of Type 304 Austenitic Stainless Steels in 100,000 Hours Obtained by the Indicated Extrapolation Methods.

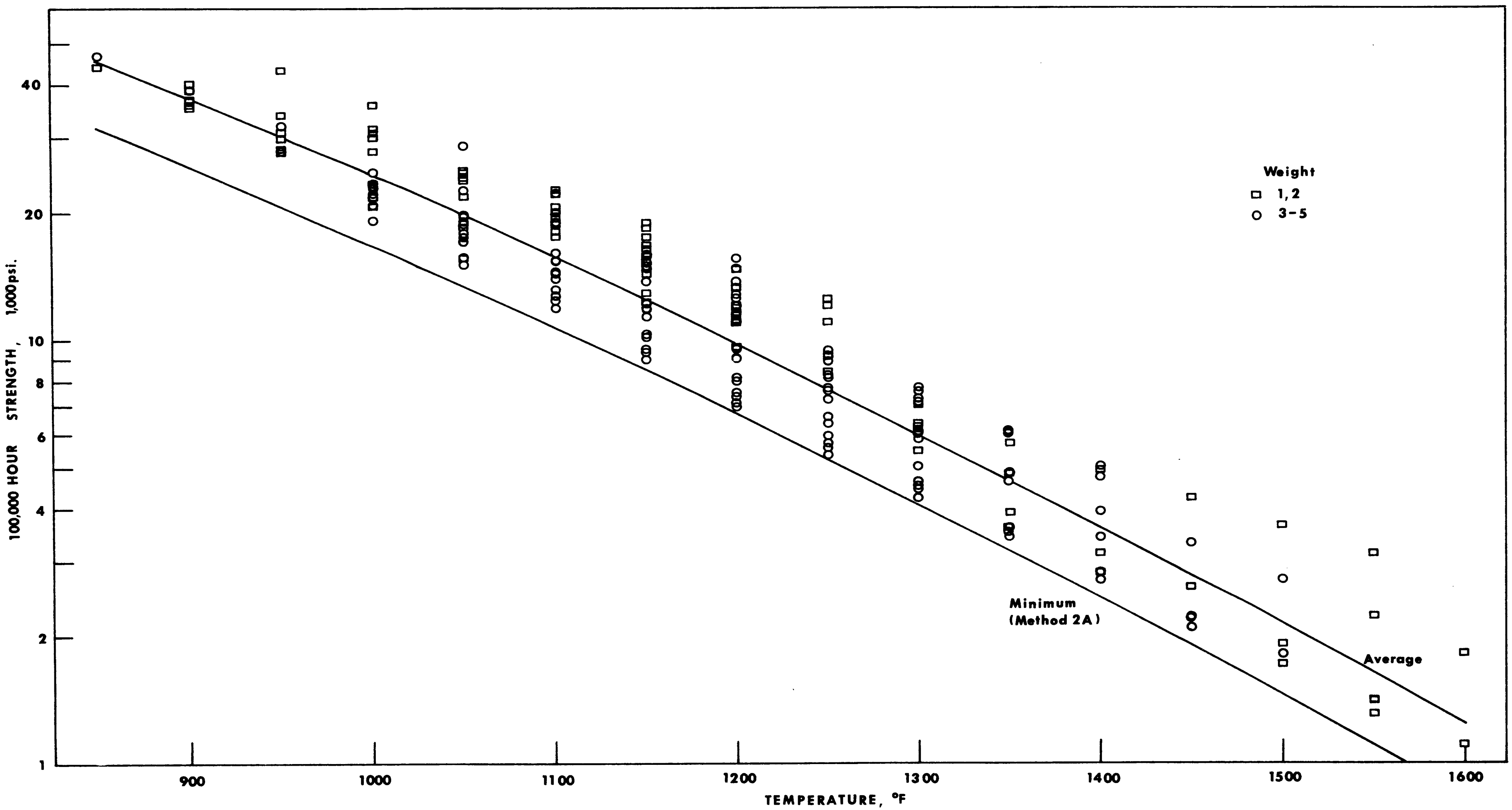

Figure 9 : Variation of the 100,000 Hour Rupture Strength with Temperature for Type 304 and 304H Stainless Steel.

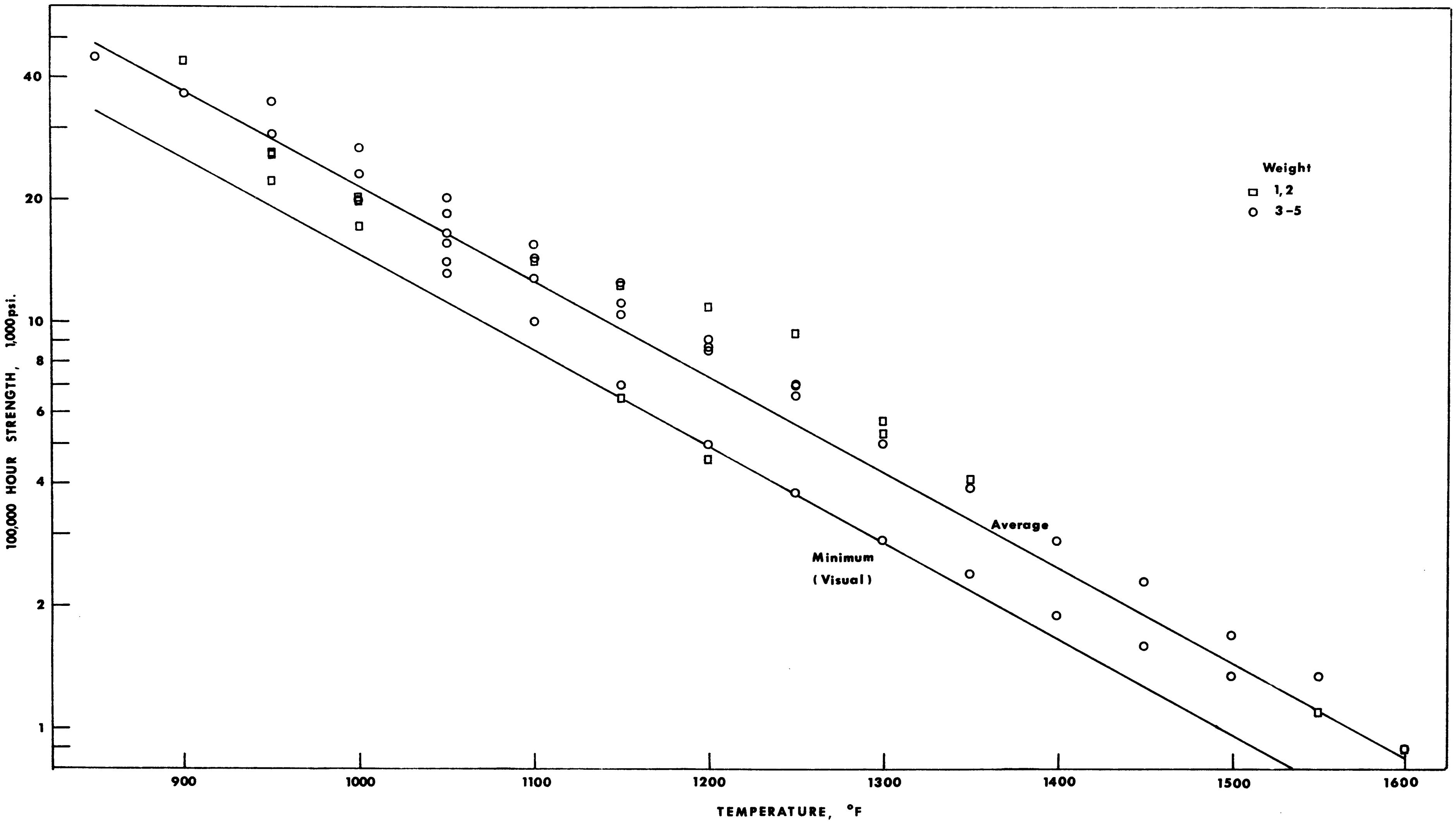

Figure10 : Variation of the 100,000 Hour Rupture Strength with Temperature for Type 304L Austenitic Stainless Steel.

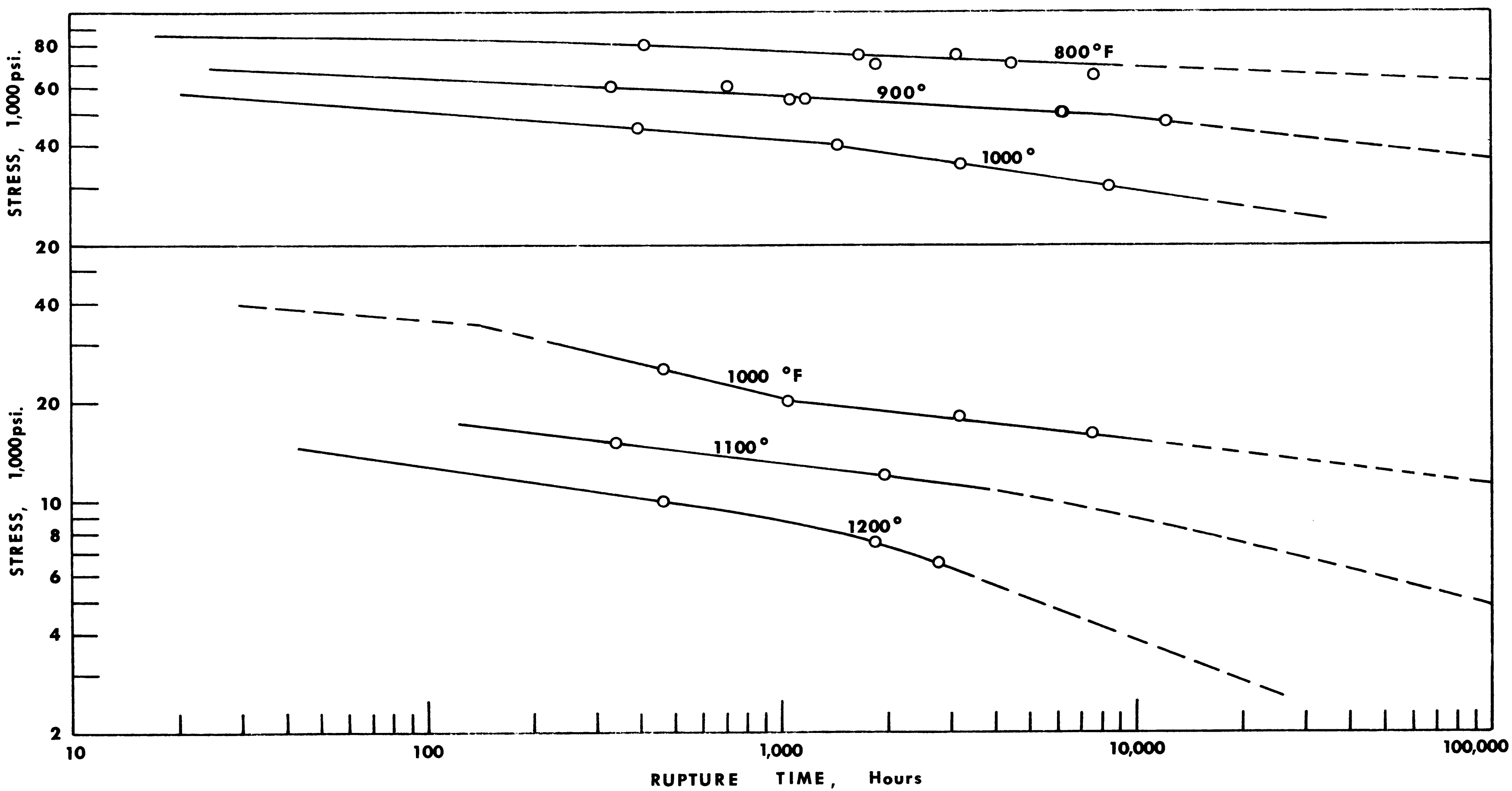

Figure 11. Stress versus Rupture Time Data Typical for Grade 22 Steel.

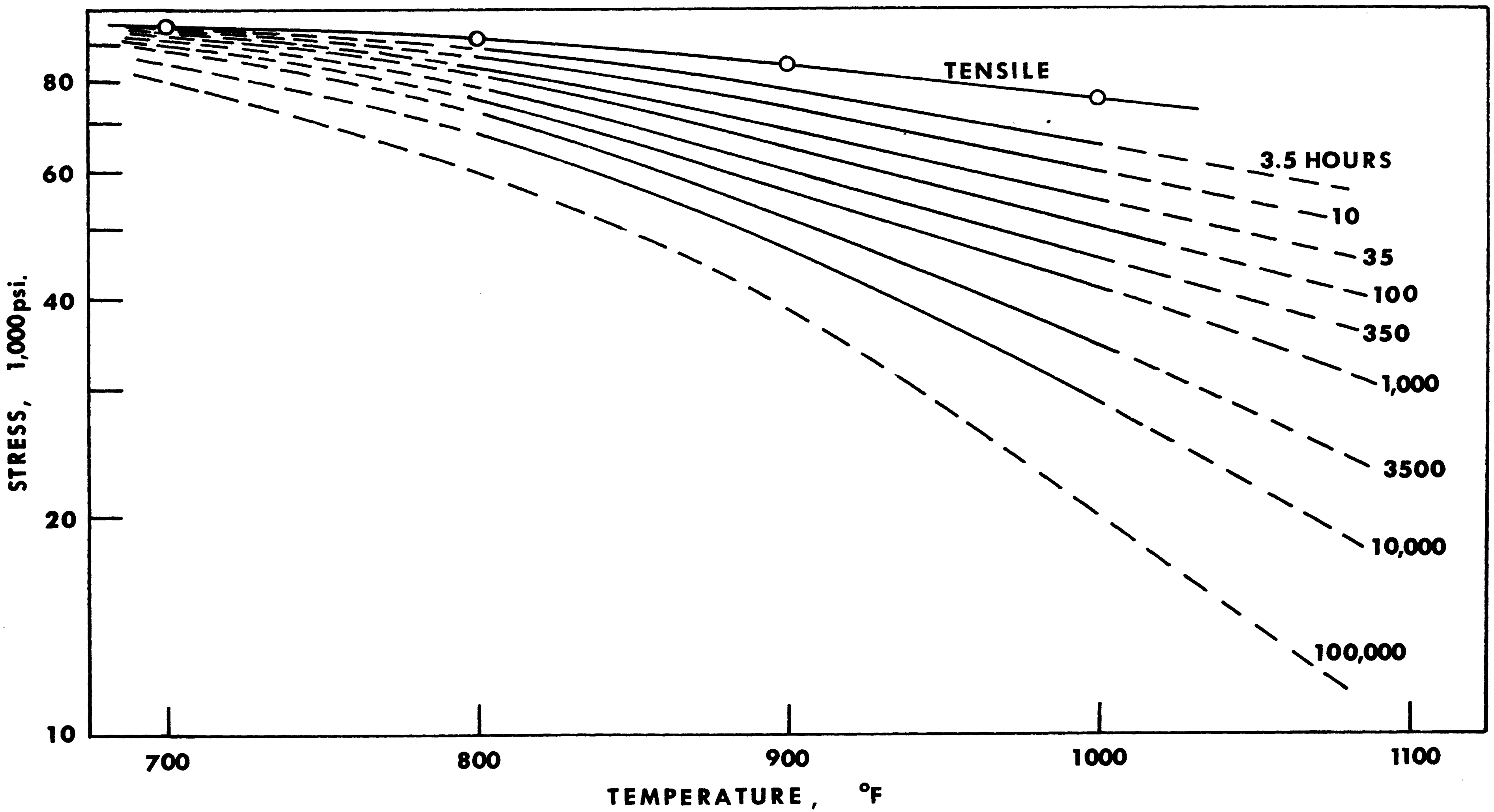

Figure 12. Curves of Stress versus Temperature for Selected Rupture Times (Iso-Time Curves) for Grade 22 Steel. The Curve for 100,000 Hours was Derived by Extrapolating Iso-Stress Lines.

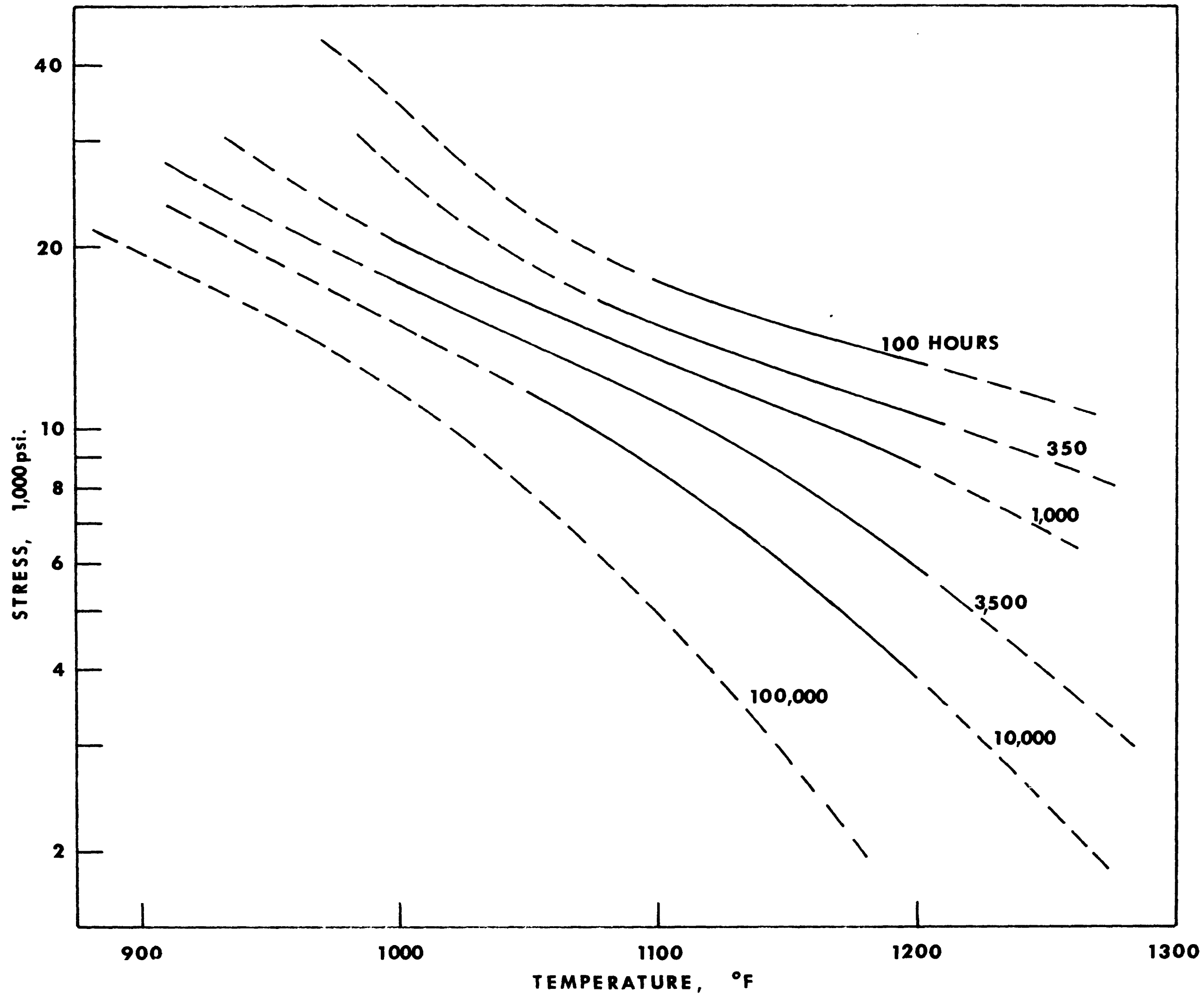

Figure 13. Iso-Time Curves Typical for Grade 22 Steel.

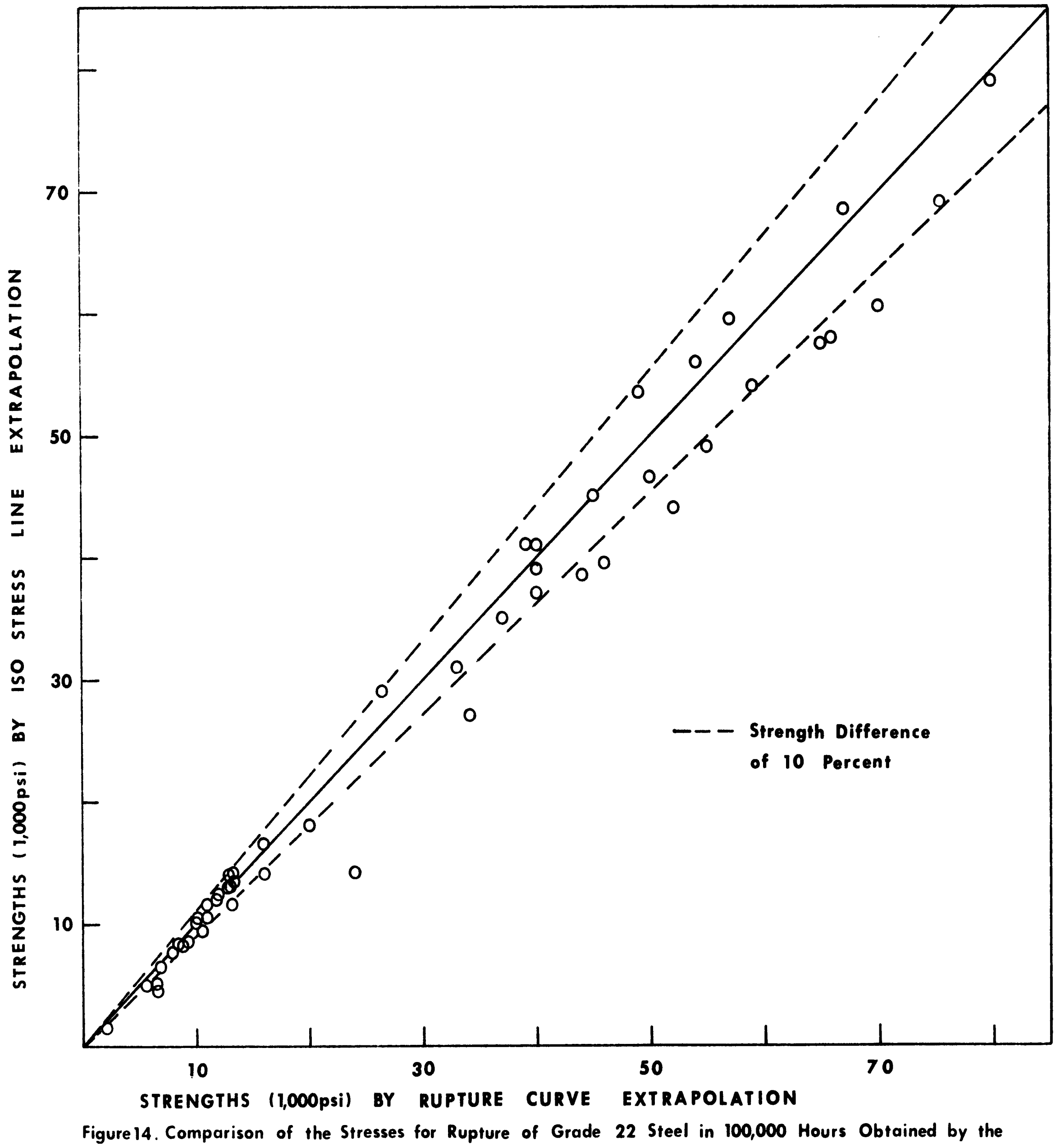

Figure 14. Comparison of the Stresses for Rupture of Grade 22 Steel in 100,000 Hours Obtained by the Indicated Extrapolation Methods.

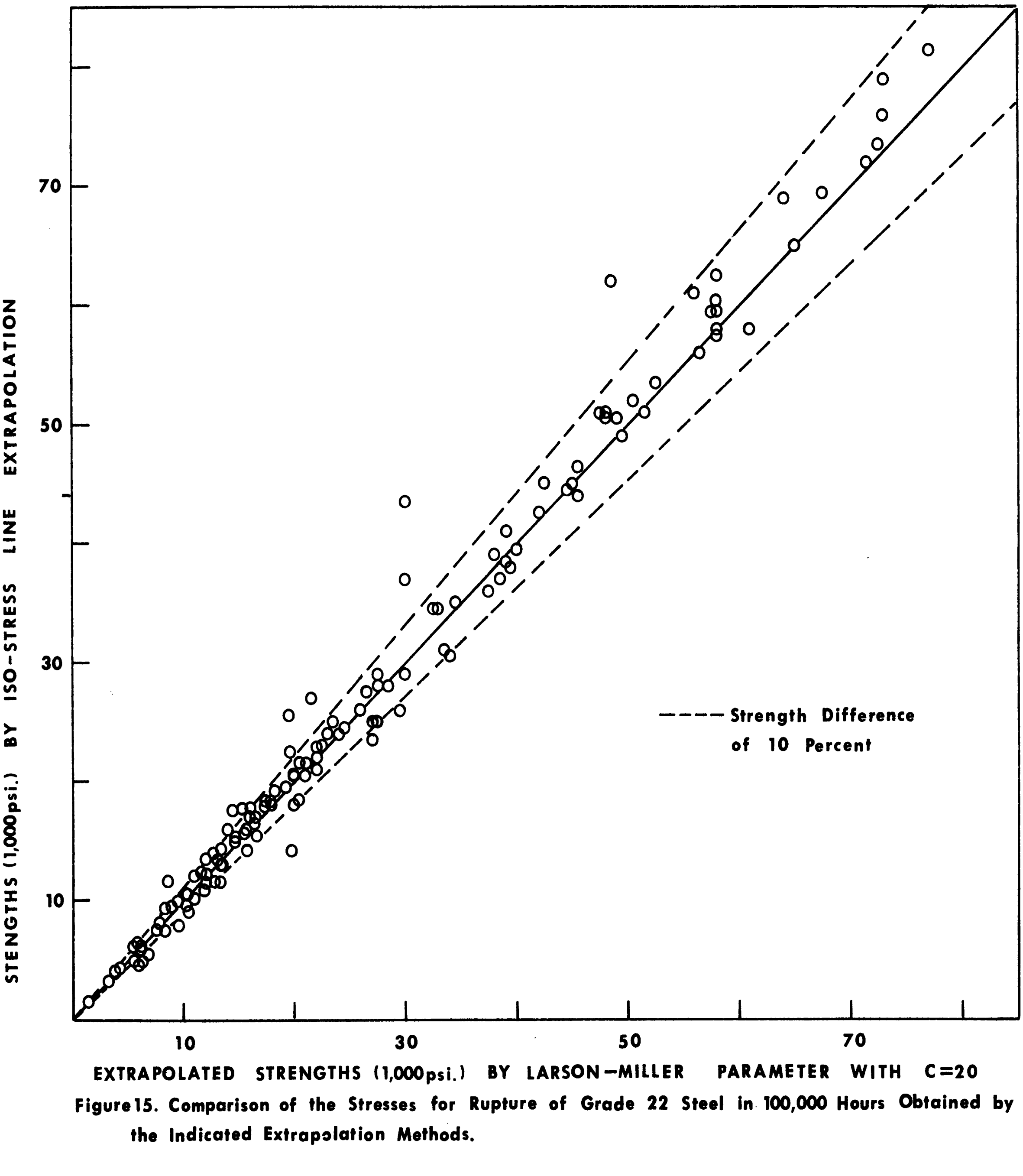

Figure 15. Comparison of the Stresses for Rupture of Grade 22 Steel in 100,000 Hours Obtained by the Indicated Extrapolation Methods.

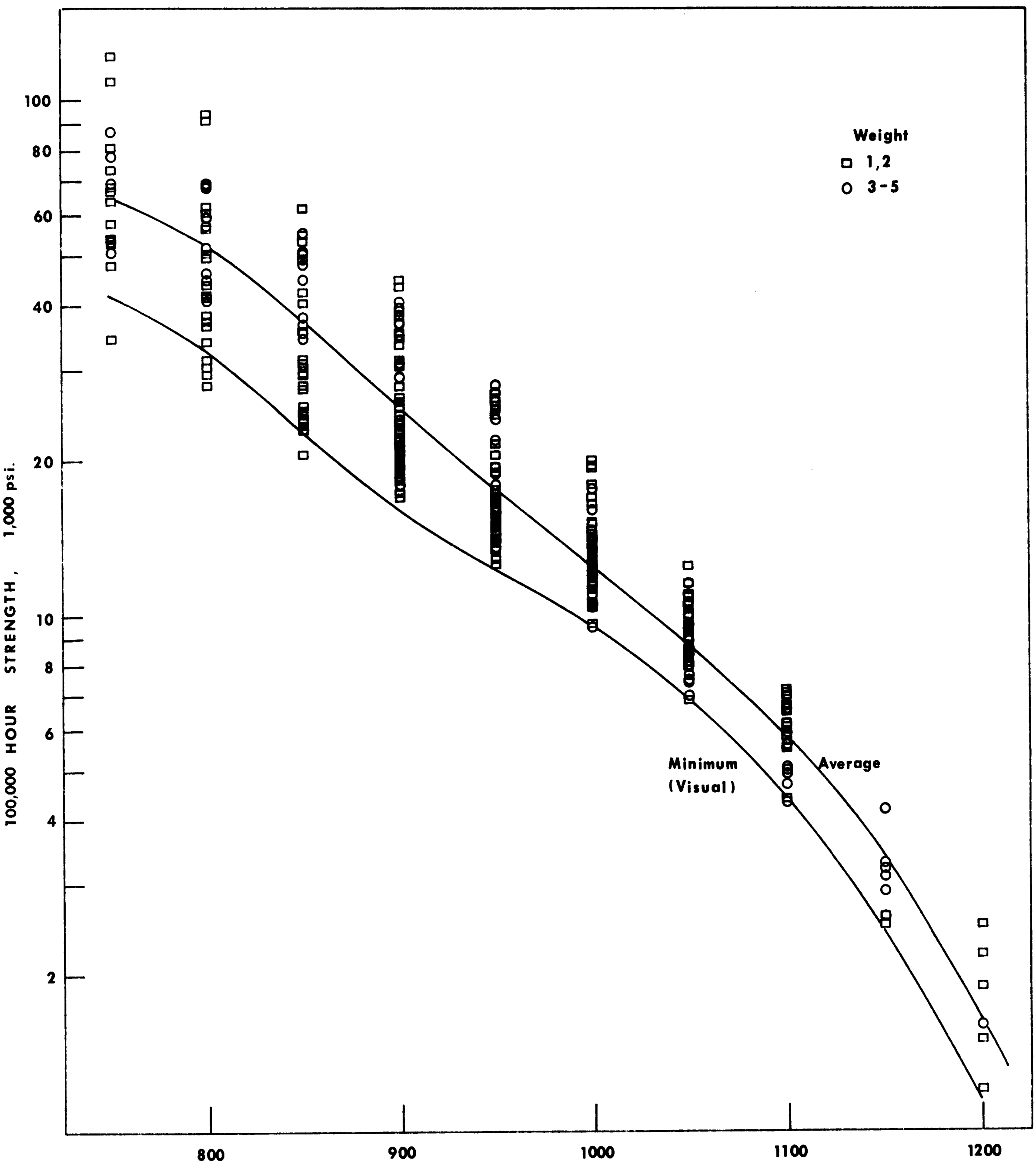

Figure16. Variation of the 100,000 Hour Rupture Strength with Temperature for Wrought Grade 22 Steel.

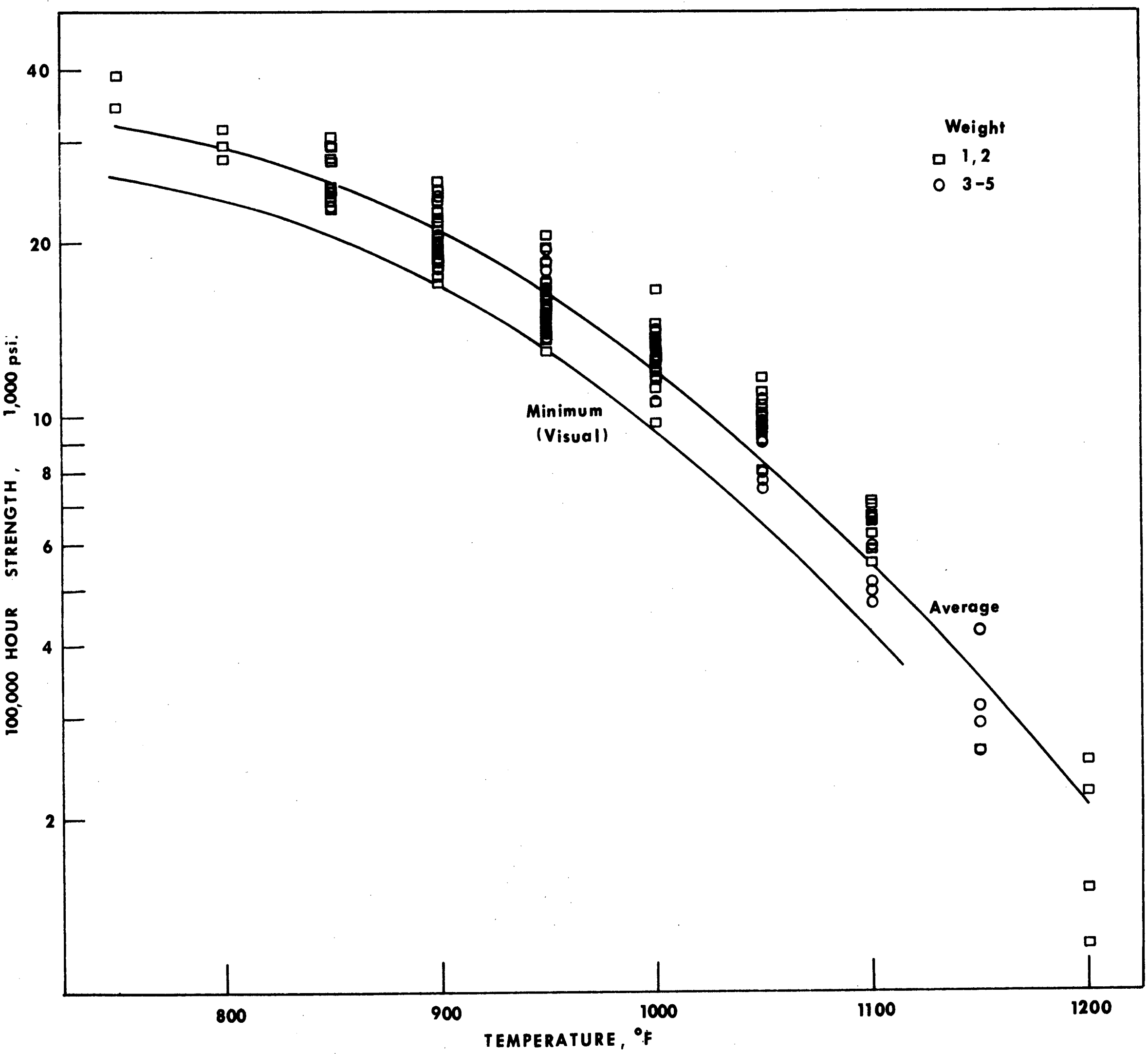

Figure17. Variation of the 100,000 Hour Rupture Strength with Temperature for Grade 22 Steel Annealed Above or Near Top of Critical Range.

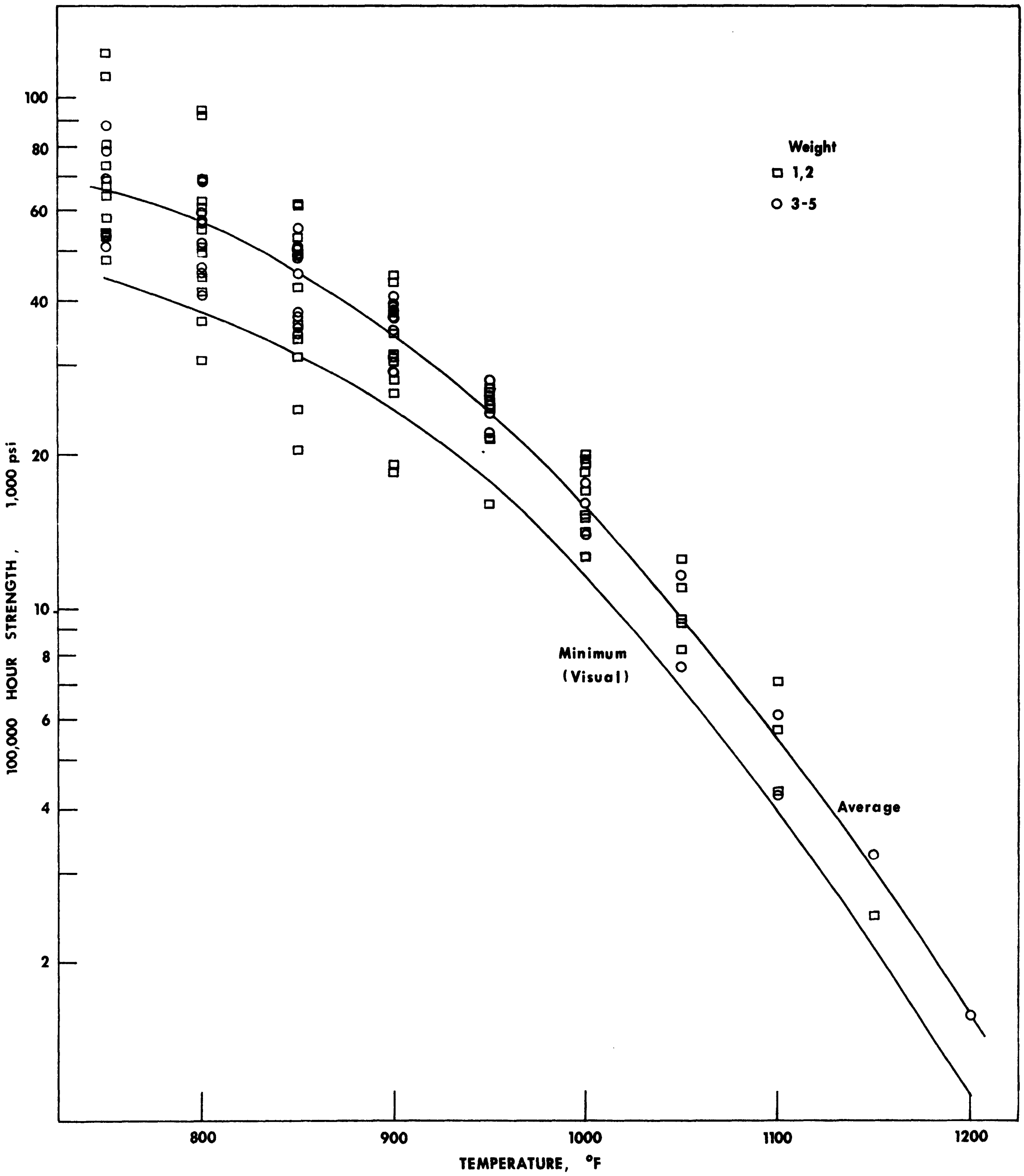

Figure 18: Variation of the 100,000 Hour Rupture Strength with Temperature for Grade 22 Steel Normalized and Tempered and Quenched and Tempered.

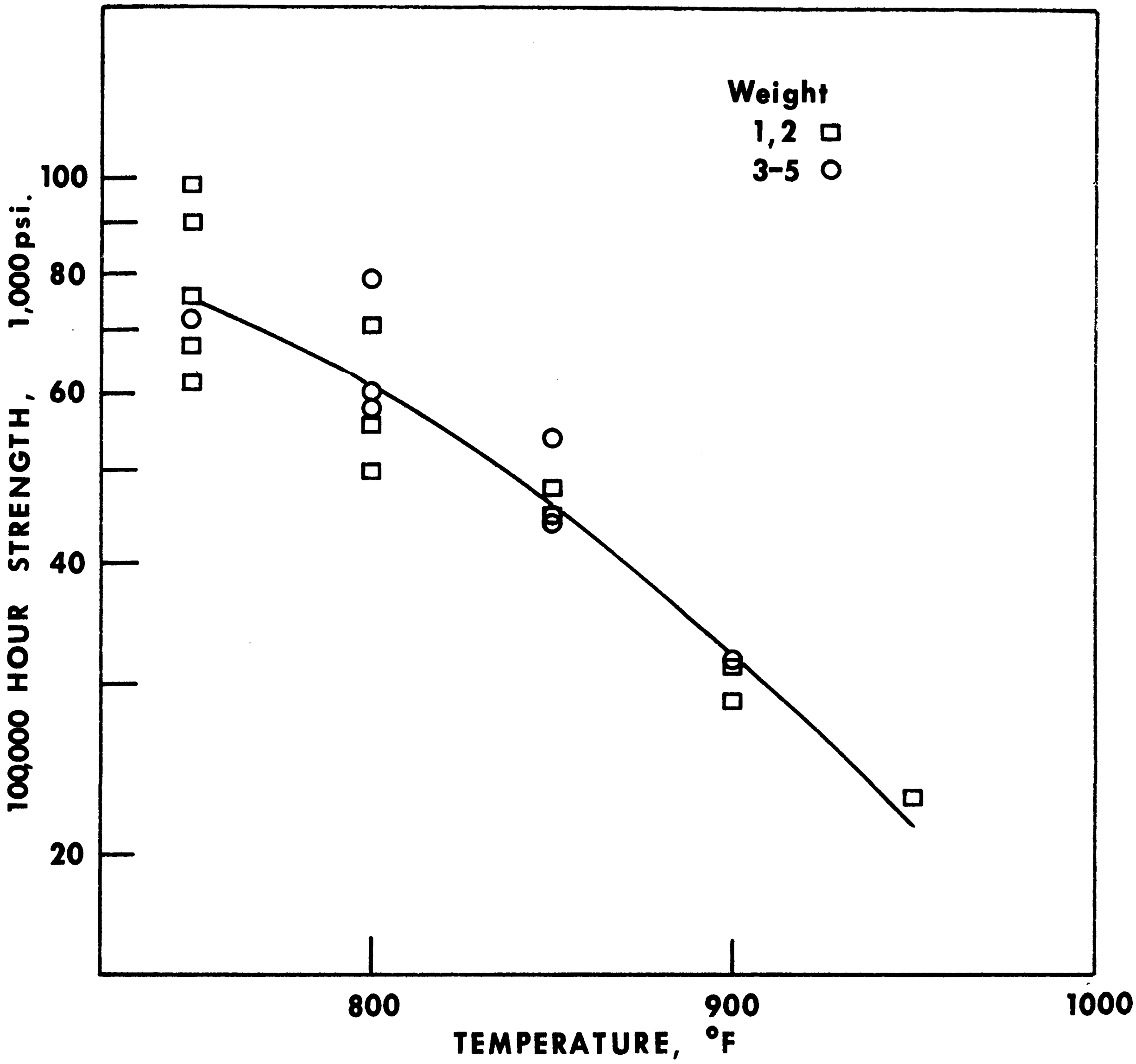

Figure 19. Variation of the 100,000 Hour Rupture Strength with Temperature for Grade 22 Weld Metal.

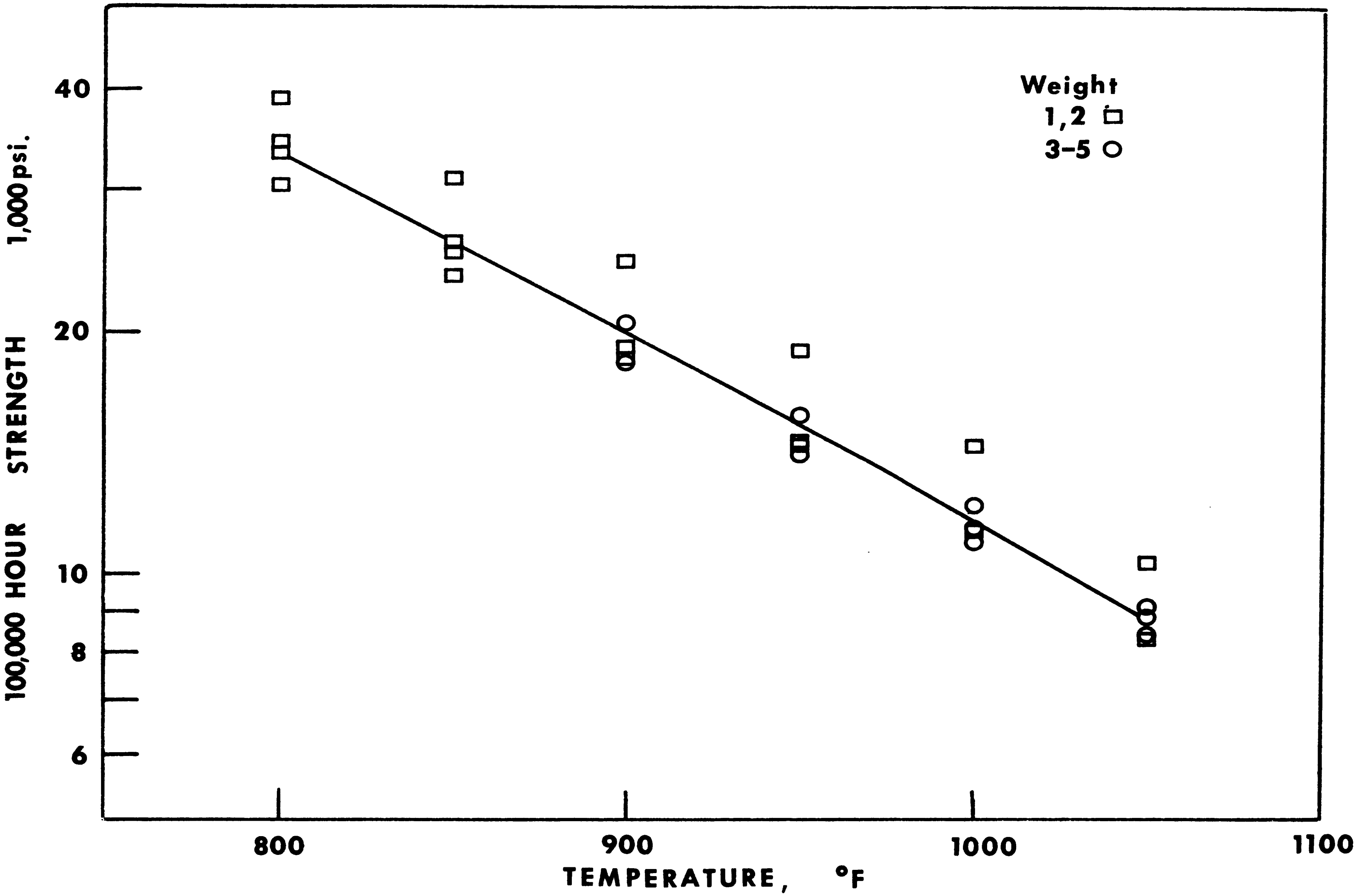

FIGURE 20: Rupture Strength Variation of Grade 22 Castings with Temperature.

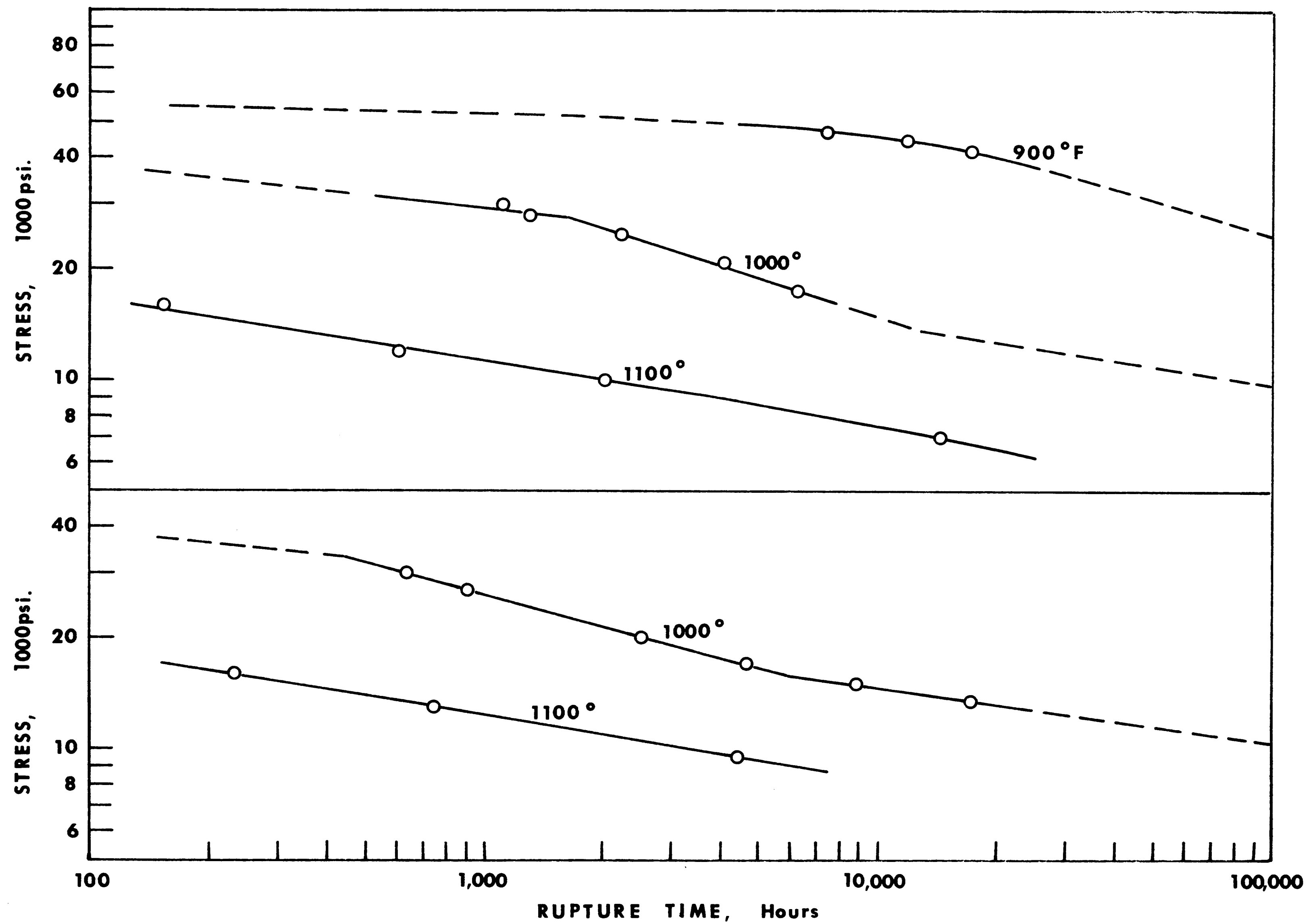

Figure 21. Stress versus Rupture Time Data Typical for Grade 11 Steel.

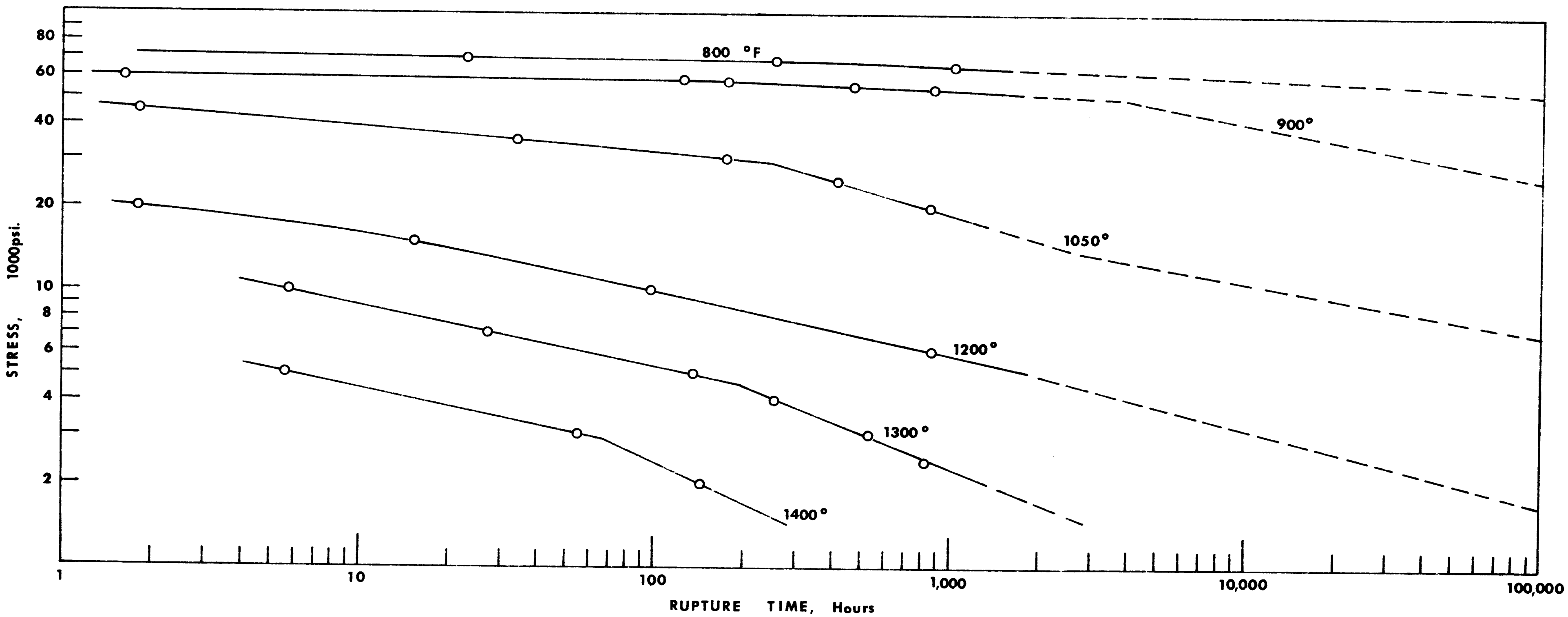

Figure 22. Stress versus Rupture Time Data Typical for Grade 11 Steel.

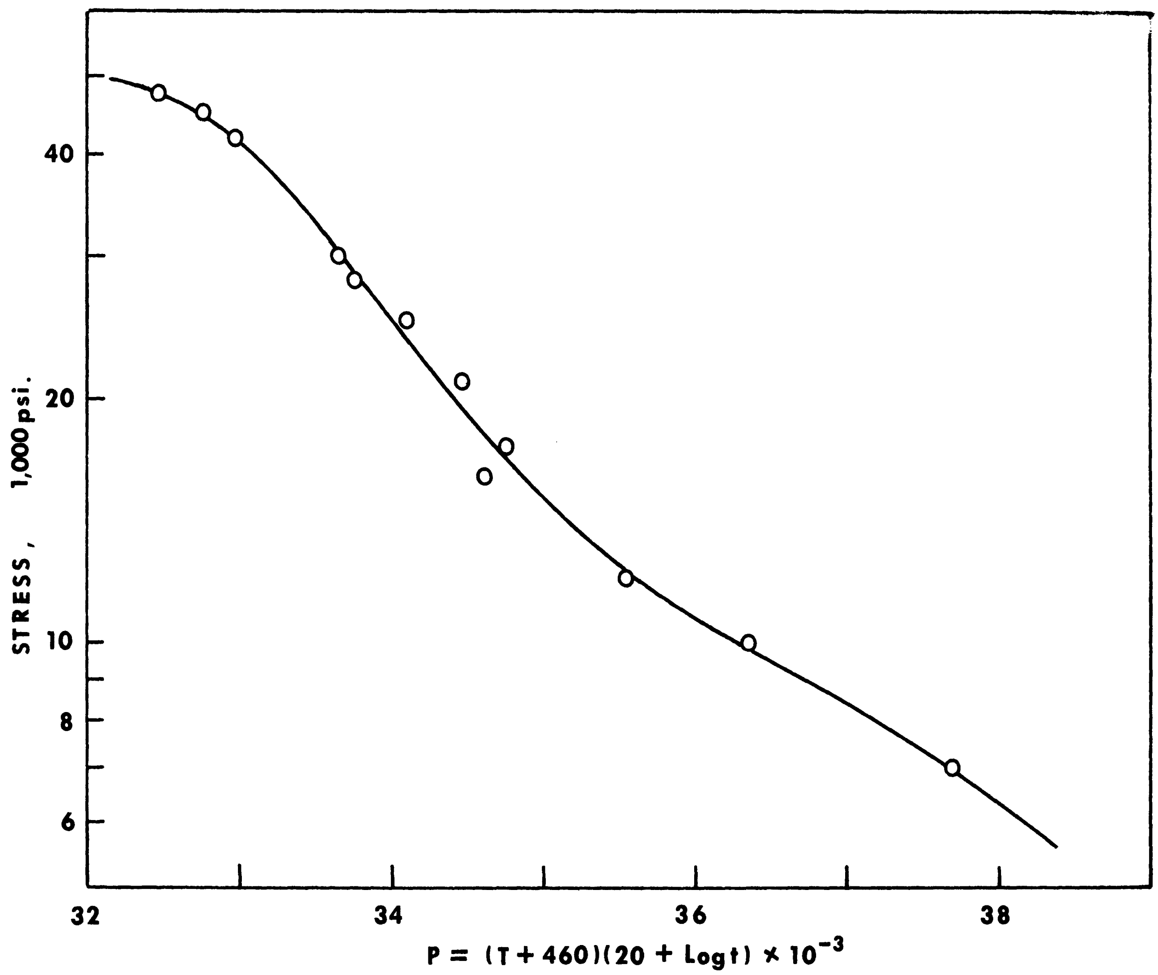

Figure 23. Stress versus Larson-Miller Parameter with C=20 Typical of Grade 11 Steel

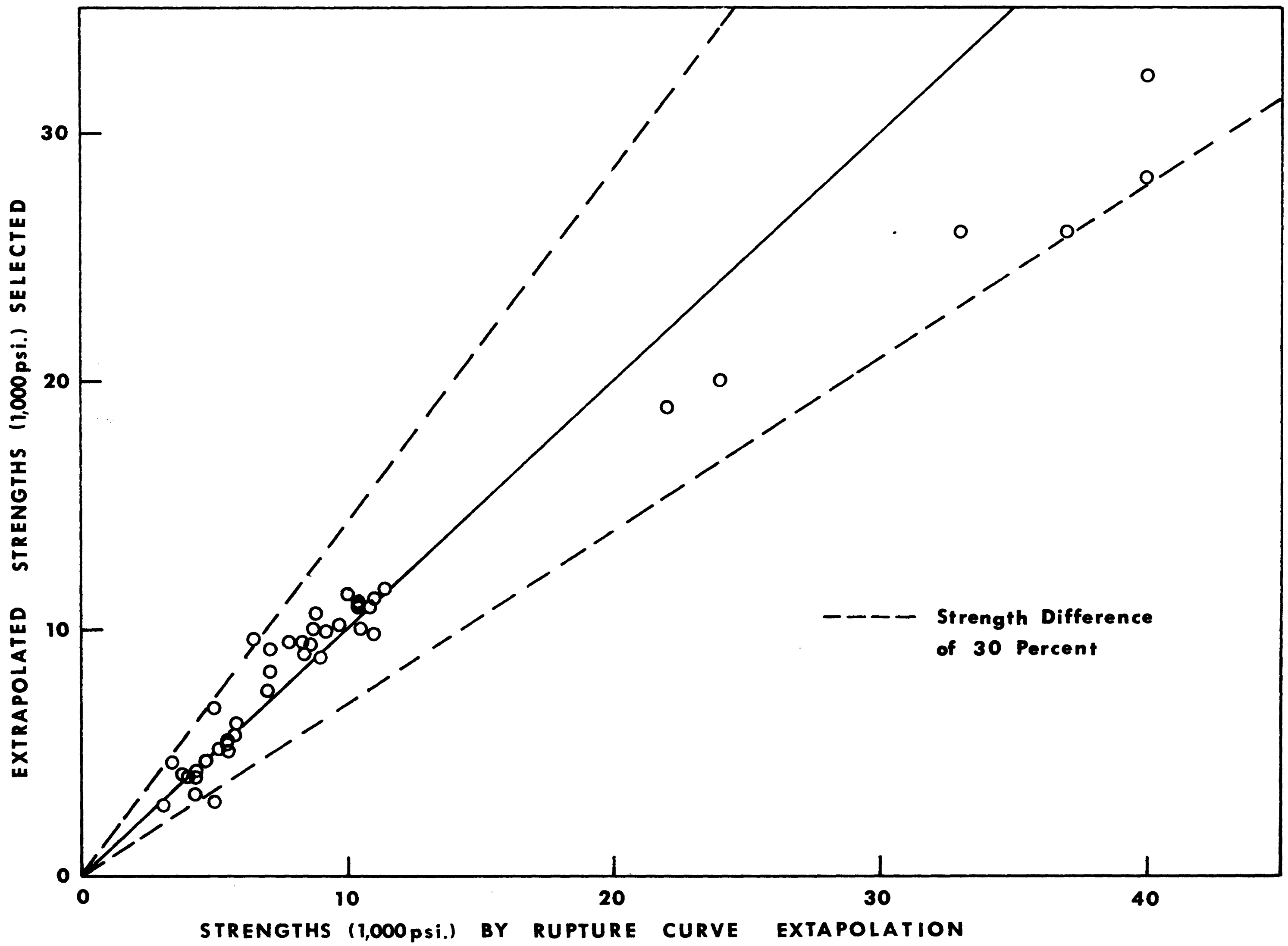

Figure 24 : Comparison of the Stresses for Rupture of Grade 11 Steel in 100,000 Hours Obtained by the Indicated Extrapolation Methods.

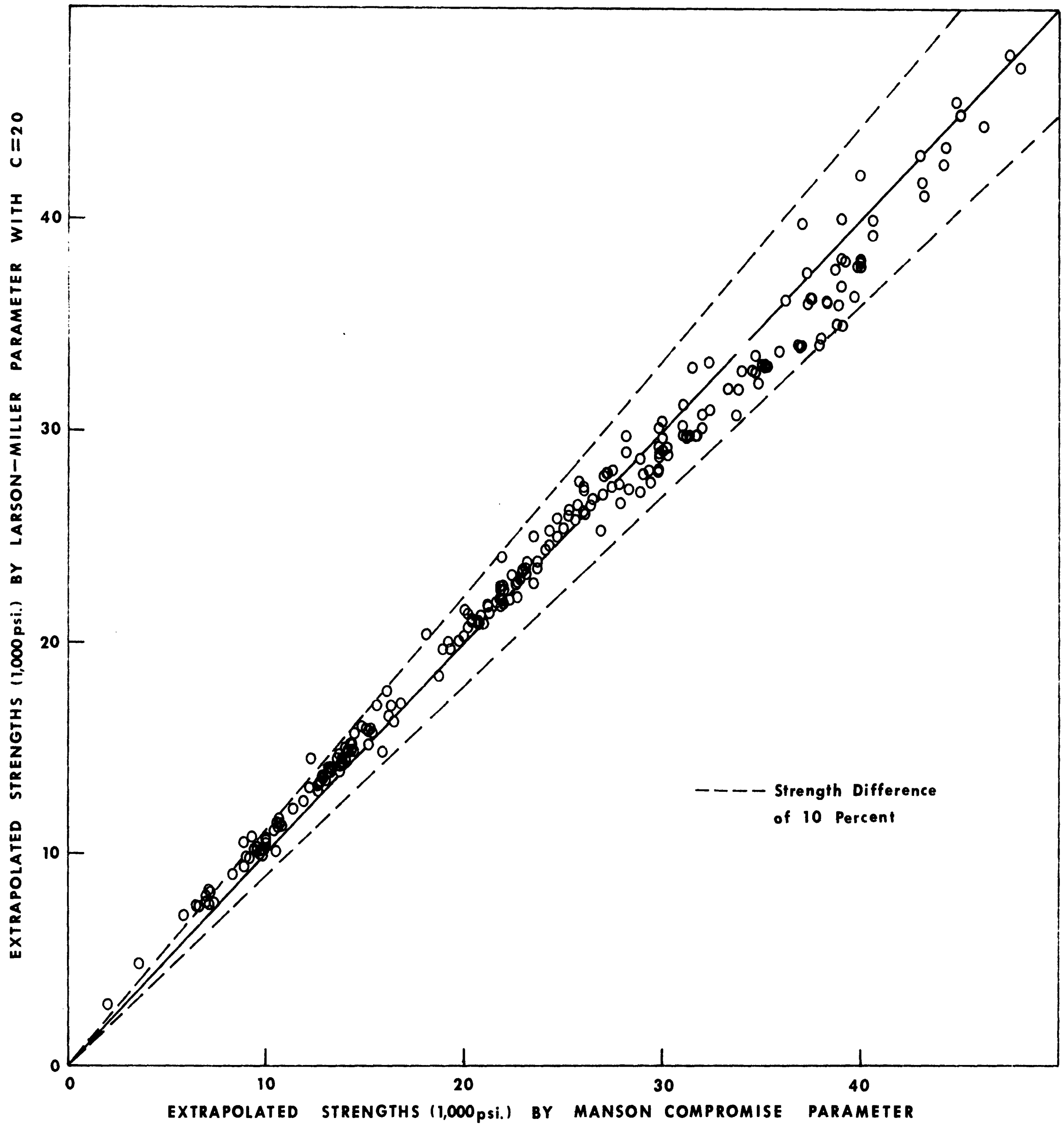

Figure 25 : Comparison of the Stresses for Rupture of Grade 11 Steel in 100,000 Hours Obtained by the Indicated Extrapolation Methods.

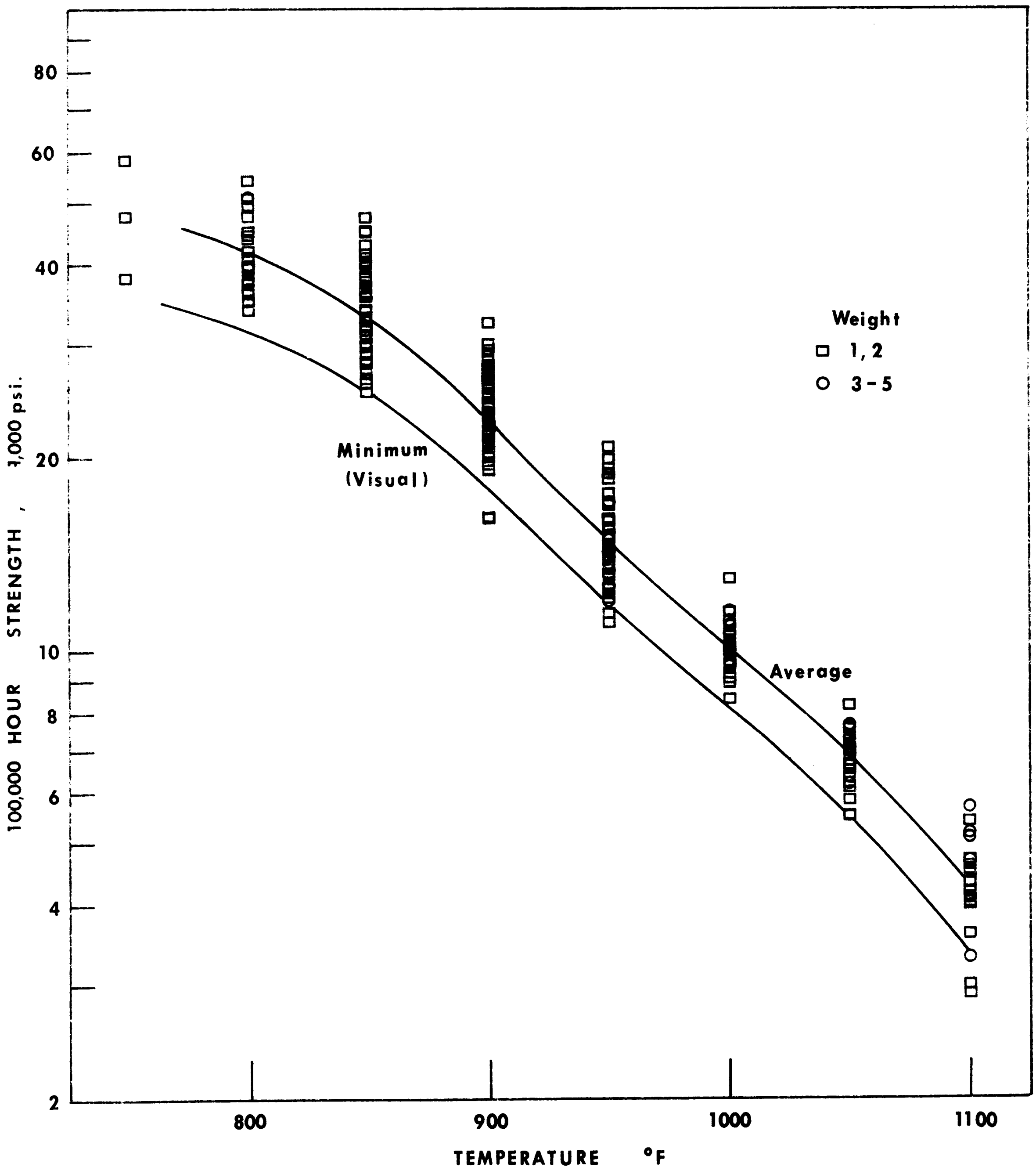

Figure 26 : Variation of the 100,000 Hour Strength with Temperature for Grade 11 Steel.

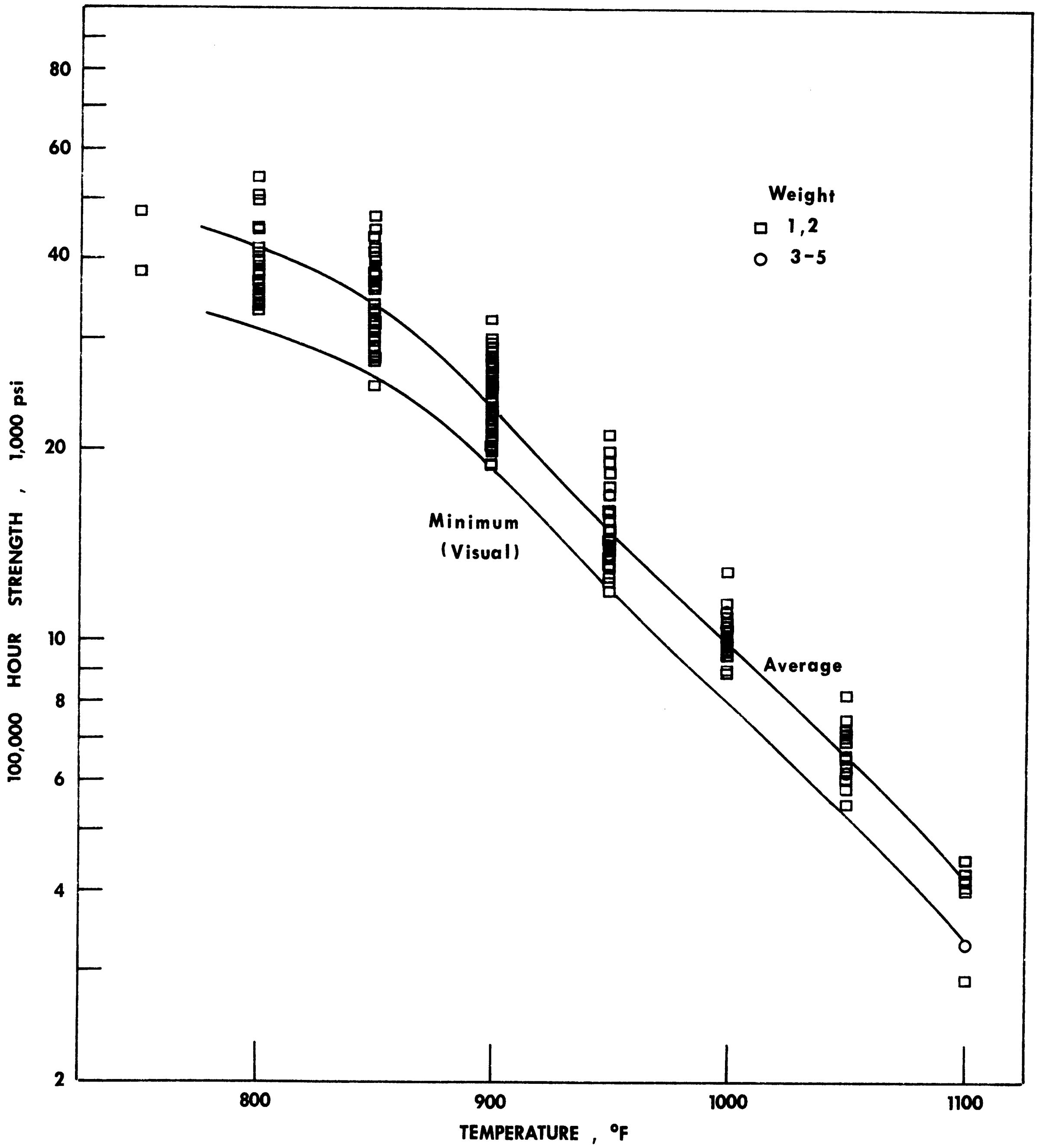

Figure 27 : Variation of the 100,000 Hour Strength with Temperature for Grade 11 Steels Annealed Above or Near the Top of the Critical Range.

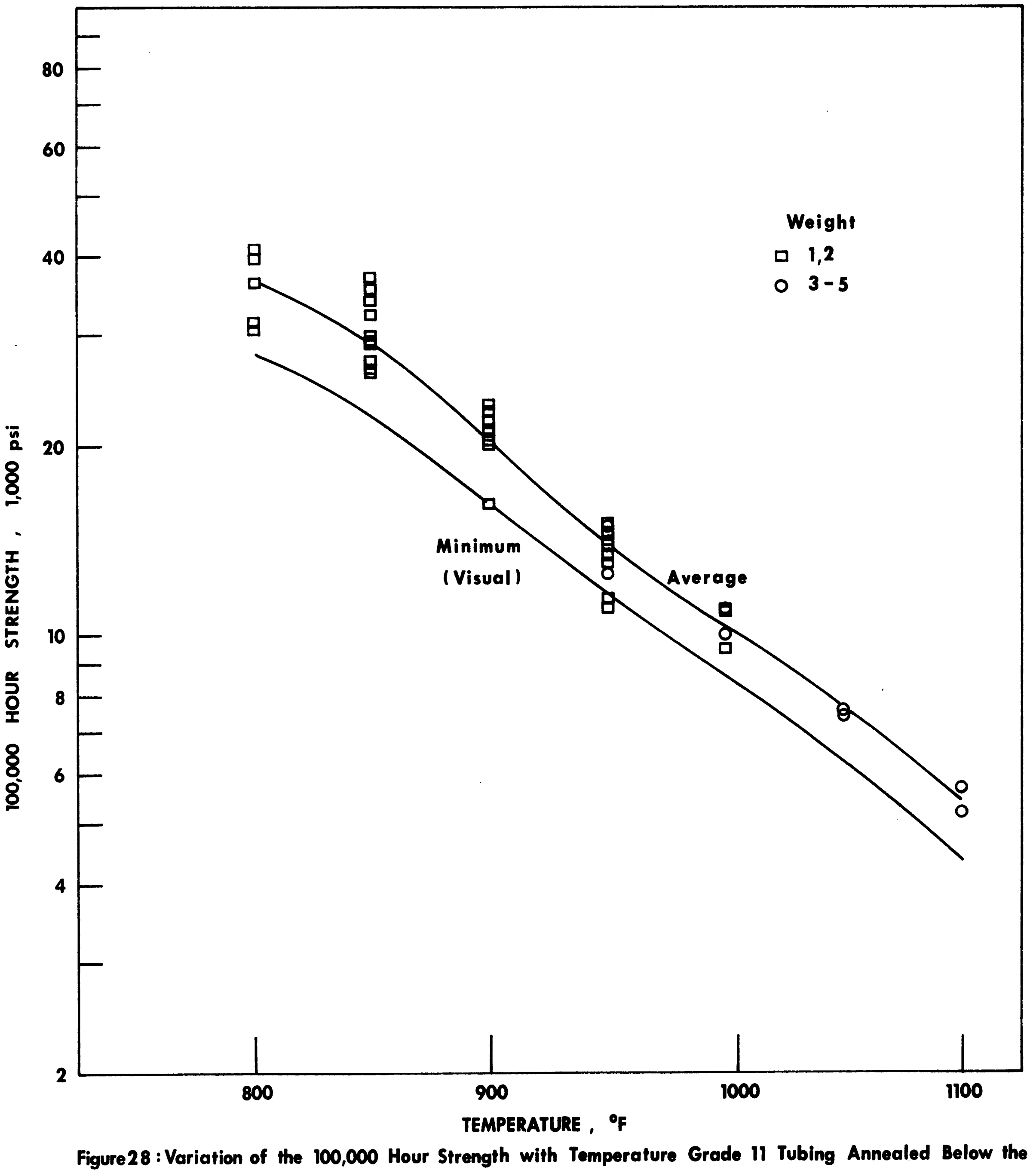

Figure 28 : Variation of the 100,000 Hour Strength with Temperature Grade 11 Tubing Annealed Below the Critical Range.

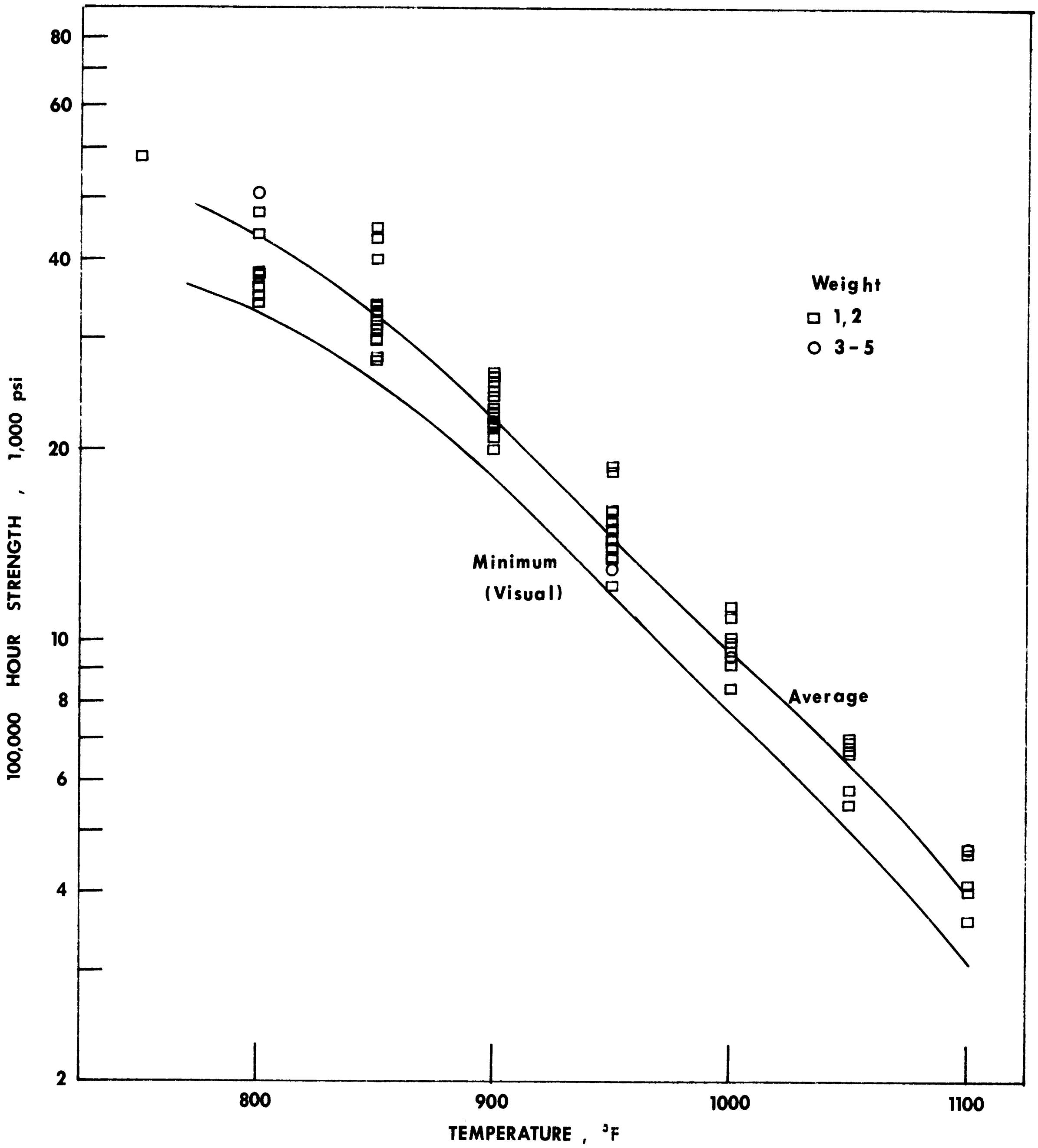

Figure 29 : Variation of the 100,000 Hour Strength with Temperature for Grade 11 Steels Normalized and Tempered.