AN EVALUATION OF THE YIELD, TENSILE, CREEP, AND RUPTURE STRENGTHS OF WROUGHT 304, 316, 321, AND 347 STAINLESS STEELS AT ELEVATED TEMPERATURES

Prepared for the
METALS PROPERTIES COUNCIL
by G. V. Smith

ASTM Data Series DS 5S2
(Supplement to Publication DS5, formerly STP 124)

List price $6.00

Published by the
AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia, Pa. 19103

AN EVALUATION OF THE YIELD, TENSILE, CREEP, AND RUPTURE STRENGTHS OF WROUGHT 304, 316, 321, AND 347 STAINLESS STEELS AT ELEVATED TEMPERATURES

Prepared for the
METALS PROPERTIES COUNCIL
by G. V. Smith

ASTM Data Series DS 5S2
(Supplement to Publication DS5, formerly STP 124)

Published by the
AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia, Pa. 19103

Related Publications

Report on the Elevated-Temperature Properties of Stainless Steels, DS 5
Supplement (to the above report), DS 5S1

Reports on the Elevated-Temperature Properties of:
Chromium-Molybdenum Steels, DS 6
Carbon Steels, DS 11
Copper and Copper Base Alloys, DS 12
Wrought Phosphor Bronze Alloys, DS 13
Steel and Super Strength Alloys, DS 14
Wrought Medium-Carbon Alloy Steels, DS 15
Weld-Deposited Metal and Weldments, DS 16
Chromium Steels, DS 18
Cast Iron, DS 19
Aluminum Alloys, DS 20
Metals and Alloys from Cryogenic to
Elevated Temperatures, DS 22

Library of Congress Catalog Card Number: 78-77331
SBN 8031-2000-1

Note

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

Printed in Alpha, New Jersey
February 1969

Data Series DS 5 S2
The American Society for Testing and Materials

Contents

Summary

This report offers evaluations of elevated temperature strength data for a number of wrought austenitic stainless steels, types 304, 304L, 316, 316L, 321, and 347. The data were previously published in ASTM Special Technical Publication No. 124, "The Elevated Temperature Properties of Stainless Steels" (1952), and in a supplement to that report, ASTM Data Series Publication DS5-S1 (1965). The evaluations have been made for the Metal Properties Council under a subcommittee, of which Dr. M. Semchyshen is Chairman. They seek to offer best current assessments of the various properties that commonly form the basis for the setting of allowable stresses, and are presented in a form readily usable by Code groups for such a purpose.

The body of the report provides, in text, figures and tables, details concerning the materials, the evaluation procedures that were employed, and the results that were achieved. On the pages immediately following this abstract are provided for each of the individual grades of steel, in turn, graphical summaries of the different properties evaluated, Figures 1-7; these are followed by graphical comparisons of the different grades with one another, Figures 8-11.

Introduction

One of the most important functions for which the Metal Properties Council was organized is that of gathering, evaluating, and publishing available data on the engineering properties of metals. In this activity, the Council will continue and extend similar work carried on by the Joint Committee on Effect of Temperature on Properties of Metals sponsored since its organization in 1925 by ASME and ASTM, and now also by the Metal Properties Council.

The data that are evaluated in this report were originally gathered by the Joint Committee or by the ASME Boiler and Pressure Vessel Committee, which in turn made them available to the Joint Committee. The data were obtained from many different industrial and governmental test laboratories in the United States, and, in general, do not represent coordinated test programs. The data are included in an ASTM report, Special Technical Publication No. 124, Elevated Temperature Properties of Stainless Steels published in 1952 and in a supplement to that report, ASTM Data Series Publication DS5-S1, published in 1965. However, not all of the previously published data are considered in the present evaluation. Data representing material not conforming with current ASTM specifications in respect to chemical composition, mechanical properties, and processing practices have been excluded.

Since the original data were included in ASTM STP No. 124 or ASTM DS5-S1, they are not tabulated in the present report. However, all of the data considered in the present evaluation appear as individual points on the plots of yield and tensile strength vs temperature, or of stress vs creep rate or rupture time.

A distinction has been made amongst the regular grades, the H grades, and the L grades where possible, and where it has seemed appropriate. The L grades, 304L and 316L, can be distinguished straight forwardly by the limitation of carbon content; furthermore, this is an appropriate distinction that recognizes a well-defined effect of carbon on strength of types 304 and 316. The H grades of certain specifications prescribe heat treatments ostensibly optimal for material intended for high-temperature service. However, for types 321 and 347, material meeting the "H" grade requirements, that is 321H and 347H, annealing must be performed at a higher temperature than for the regular grades, the exact temperature depending upon whether the prior processing has involved hot or cold working; in contrast, types 304H and 316H may be annealed at a lower temperature than for the regular grades, and independently of whether the material had been previously hot or cold worked. Moreover, in both 304H and 316H, the carbon content is permitted to range between 0.04 and 0.10 per cent, whereas the carbon content of the regular grade is limited to 0.08 per cent maximum. Although there is no lower limit on carbon specifications for the regular grades of 304 and 316, the ASME Code stress tables impose, by means of a footnote, an effective minimum of 0.04 per cent for service temperatures over 1000°F. Thus, it appears that the specifications for types 304H and 316H are less restrictive

than those for the regular grades in that all material meeting the requirements of the regular grades also meet the H grade requirements. For these reasons, a distinction between the regular and H grades has been attempted in the present evaluations only for types 321 and 347. When it was uncertain whether processing had involved cold vs hot working, a lot was arbitrarily categorized as regular grade unless the solution temperature exceeded the minimum level (2000°F) specified for material that had been cold worked.
The type designations 304L and 316L have been assigned to all materials having carbon contents less than 0.04 per cent.

At one time, it was not uncommon to reheat annealed austenitic stainless steels to the temperature range of about 1500-1600°F for purposes of "stabilizing" against intergranular corrosion sensitization. Some of the data in ASTM STP No. 124 and its supplement DS5-S1 represent material so treated. Such heat treatment is less commonly used now, certainly for applications at elevated temperature, and, in fact, specifications for H-grades would appear to prohibit the stabilizing treatment by stating: "All H grades shall be furnished in the solution-treated condition." Moreover, there is evidence that material receiving the stabilizing heat treatment may have different properties than solution-treated material. [See ASTM STP 124 and ASTM DS5-S1 and also Krebs and Soltys (Joint International Conference on Creep, 1963)] Presumably the differences in properties reflect a difference in the character of the precipitates formed under different treatments. For these reasons, the data representing material that had received the stabilizing heat treatment has been excluded from the present evaluation.

Most all of the available data represent wrought material and the relatively few data for material in the form of castings have not been included in the evaluations. With some exceptions, data for bar and plate have been distinguished from data for pipe and tube in the plots of this report. Data identified by donors only as "wrought" have been arbitrarily put in the bar-plate category. However, in the final evaluations for determining trend curves for the variation of strength with temperature, it has seemed inappropriate to distinguish amongst the different wrought product forms.

Evaluation Procedures

The evaluations of this report are directed primarily to providing information readily useful for establishing the effects of temperature on the different strength properties of interest to Code groups for the setting of allowable working stresses. (Fracture ductility data are not evaluated in this report, but are included in STP 124 and DS5-S1, previously cited.) The specific strength properties of interest include the yield strength (as defined in the material specification), ultimate tensile strength, rupture strength and creep strength. In this report, creep strength and rupture strength are each evaluated at two levels: as the stresses to produce a secondary creep rate of 0.01% per 1000 hours or 0.1% per 1000 hours, and to cause rupture in 100,000 hours or 10,000 hours. All of these properties are required over the range of temperature for which allowable stresses are set (generally up to 1500°F for the austenitic stainless steels considered in this report) and are best depicted in terms of "trend curves" (or tabulations) of strength versus temperature.

The evaluation methods employed herein are essentially those that have evolved over the years in evaluating data for the ASME Boiler and Pressure Vessel Committee. The basic approach is one of seeking to establish, by the best possible means, characteristic trend curves, which depict the variation with temperature of the several basic strength properties. The procedures used will be described and illustrated, but their merits relative to other possible procedures will not be argued in detail in the present report.

Yield Strength and Tensile Strength

The available data are plotted as dependent upon temperature in Figures 12a-12h (yield strength) and Figs. 13a-13h (tensile strength). For Grade 304-304H, there were sufficient data available to make possible a distinction between bar, plate and pipe-tube product forms, and separate plots are provided. However, there were too few data available for the remaining grades to warrant an effort to distinguish between product forms. In fact, for Grades 316-316H and 321-321H, no data for any product form exist for temperatures between 75° and 500°F. The data for grade 347-347H were examined in the ratio plots to be described later to determine whether the H grade might be distinguished from the regular grade; the two scatter bands overlapped indistinguishably.

With the exception of 304 plate and 304 pipe, the data were not generated by systematic test programs (with common test temperatures, for example), and it is not usually feasible to develop the trend curve for variation of strength with temperature by simply passing a curve through the averages of the data at different temperatures. Such a curve would be subject to local distortion by limited data representing lots differing from the average. The procedure that has been used to develop trend curves involves normalizing the data in terms of the ratio of strength at temperature to the strength at room temperature, on the premise that a lot of material which exhibits relatively high strength at room temperature may reasonably be expected also to exhibit high strength at elevated temperatures (below the range in which creep becomes important). If the premise is accepted, it then becomes possible to utilize all of the available elevated temperature data for which there are corresponding test results at room temperature, and to develop the characteristic trend curve by the method of least squares.

Plots of strength ratio versus temperature for the available data are given in Figs. 14a-h (yield strength) and Figs. 15 a-h (tensile strength). Excluding a few data, identified on the plots, which appeared to lie outside the general scatter band, trend curves were developed for the data in Figs. 14 and 15 by polynomial regression analysis. The computer program that was employed terminated the analysis at the polynomial degree for which there was no further reduction in the sum of the squares of the residuals. The excluded data were invariably on the high side; possible reasons for deviations on the high side include testing at relatively fast strain rate and residual straightening stresses. Except for Grade 304L, the excluded data represent test temperatures greater than 1050°F, and hence lie above the range in which allowable stresses would ordinarily be expected to be governed by the short-time tensile properties.

The normalizing (ratioing) procedure depends upon the validity of the room temperature test result, but this result is the least subject to lack of control over test conditions.

In any event, the advantages of the ratio approach outweigh any disadvantage, as will become evident.

The best fit curves developed by the computer regression analyses are drawn on the ratio plots of Figs. 14 and 15; the results are also presented in tabular form in Tables 1 and 2. The trend curves developed for grade 316-316H and for 321-321H, for which there were no data between room temperature and 500°F, seem not unreasonable in that range, except for the tensile strength curve of grade 321-321H, which exhibits a minimum at 400-400°F that seems unreasonable. Visual inspection of the latter data, and comparison with the other trend curves suggest that a more reasonable trend curve would be that given by the dashed line in Fig. 15g. Clearly, a need exists for tests of 316-316H and 321-321H at temperatures up to 500°F. For all other grades, the trend curves seem reasonably well defined, and although additional data would be helpful, the need is not urgent.

Expressing the characteristic trend curves in terms of strength ratios has the advantage that various stress levels, e.g. mean and minimum, may be computed directly for any temperature within the range of the available test data. Similarly, the ratios of the trend curves are applicable to different strength specifications, within the range of the available test data. Thus, for a specification having a minimum tensile strength requirement of 75,000 psi at room temperature, the minimum tensile strength to be expected at a given elevated temperature would be derived directly by multiplying 75,000 psi by the appropriate ratio. Or, the mean value to be expected at that same elevated temperature would be derivable by applying the same ratio to the mean of the test data at room temperature. For their possible interest,

Table 1

Ratio of Yield Strength at Temperature To Yield Strength
At Room Temperature
(0.2% Offset)

Wrought Austenitic Stainless Steels*

Temp. °F	304 Bar	304 Plate	304 Pipetube	304	304L	316	316L	321	347	321-347
					No distinction as to product form					
75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
100	.96	.96	.96	.96	.97	.97	.97	.97	.98	
200	.83	.84	.84	.83	.85	.86	.85	.85	.92	
300	.75	.75	.75	.75	.77	.78	.76	.76	.85	
400	.69	.68	.69	.69	.70	.70	.70	.69	.80	
500	.65	.64	.65	.65	.65	.66	.64	.64	.75	
600	.61	.61	.62	.61	.62	.63	.61	.61	.72	
700	.58	.58	.59	.59	.60	.60	.58	.59	.69	
800	.55	.57	.57	.56	.58	.59	.55	.57	.68	
900	.53	.55	.54	.54	.56	.58	.53	.57	.67	
1000	.51	.52	.52	.52	.53	.57	.50	.56	.67	
1100	.48	.49	.51	.49	.50	.55	.47	.55	.66	
1200	.46	--	.51	.47	.45	.54	.42	.53	.65	
1300	.42	--	--	.44	--	.51	--	.50	.61	
1400	.38	--	--	.39	--	.48	--	.47	.54	
1500	.31	--	--	.31	--	.43	--	.40	.43	
1600	.20	--	--	.20	--	--	--	--	--	

* No distinction is made between "regular" and "H" grades.

Table 2

Ratio of Tensile Strength at Temperature to Tensile Strength at Room Temperature
Wrought Austenitic Stainless Steels*

Temp °F	304 Bar	304 Plate	304 Pipetube	304	304L	316	316L	321**	347
				No distinction as to product form					
75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100	.96	.97	.97	.97	.97	.97	.97	.95	.97
200	.84	.87	.88	.86	.86	.91	.88	.82	.87
300	.78	.81	.83	.80	.79	.89	.83	.77	.80
400	.76	.77	.80	.78	.76	.87	.81	.76	.75
500	.76	.75	.79	.77	.75	.87	.80	.79	.73
600	.76	.75	.79	.77	.74	.88	.80	.82	.72
700	.77	.74	.79	.77	.73	.87	.80	.84	.71
800	.76	.74	.78	.76	.72	.86	.79	.85	.71
900	.74	.73	.76	.74	.70	.83	.76	.83	.71
1000	.70	.69	.71	.70	.66	.78	.72	.79	.70
1100	.63	.63	.64	.63	.60	.71	.66	.71	.67
1200	.55	.55	.52	.55	.53	.62	.59	.61	.62
1300	.46			.46	.45	.52	.50	.49	.54
1400	.36			.35	.36	.41	.41	.37	.43
1500	.26			.25	.26	.30	.31	.25	.28

* No distinction is made between regular and H grades

** Values between 75 and 500, for which there were no data, seem unreasonable. Visual inspection suggests the following values: 100F - .97; 200F - .89; 300F - .84; 400F - 83; 500F - .83; 600F -.83; 700F - .83; 800F - .83

the means and also the standard deviations of the data at room temperature have be-n computed and are given in Table 3. In this connection, it should be emphasized that the room-temperature test data of the present evaluation are those gathered in soliciting data for elevated temperature. No separate effort was made to gather room temperature data, of which there must be vast quantities.

A comparison of the trend curves for the different product forms of Grade 304-304H is of interest. As shown in Table 1, the yield strength ratios of bar, pipe-tube and plate material are within 0.01 of their average to temperatures exceeding 1100°F, well up into the creep range, and beyond which there are no data for plate. For tensile strength, Table 2, the deviations of individual product forms from the average are only very slightly greater. Unfortunately, for the other grades, there were too few data available for different product forms to attempt comparisons. However, the absence of significant differences for the different product forms of grade 304-304H provides a measure of confidence to stress-setting agencies which have generally had to assume similarity of trend curves for different product forms. Whether or not trend curves for forgings and particularly castings might safely be assumed to be similar to that for bar, pipe-tube and plate, however, is uncertain, and to an extent depending upon differences in specified chemical composition, and processing history. Inspection of the ratio plots revealed no distinction between grades 347 and 347H, and the data were therefore treated as a single population. No effort was made to distinguish between grades 321 and 321H in view of the paucity of data, and as described in the Introduction, in view of the overlapping of specification requirements for grades

Table 3

Mean Yield and Tensile Strengths and Standard Deviations of Available Room Temperature Data

	Yield Strength-1000 psi			Tensile Strength-1000 psi		
Grade	No. of Data	Mean	Std. Dev.	No. of Data	Mean	Std. Dev.
304 Bar	12	35.0	6.0	12	83.8	3.6
304 Pipe	14	37.7	6.4	14	84.0	5.3
304 Plate	5	38.9	5.7	5	83.4	2.7
304 (all)	31	36.9	6.4	31	83.9	4.3
304L	13	33.8	3.6	14	79.2	2.7
316	14	38.0	6.4	14	83.3	6.4
316L	6	33.7	6.4	9	78.9	2.9
321*	4	29.7	0.8	5	81.8	7.3
347	18	38.2	5.2	18	87.0	5.0

Note: No distinction is made between the regular and H grades.

* One yield strength value at 67,700 psi was excluded as being unreasonable. The computed standard deviation of the sample also seems unreasonable.

304 and 304H and grades 316 and 316H, it has not seemed appropriate to attempt a distinction for these grades.

Not only are the trend curves similar for different product forms of grade 304-304H, but for yield strengths, they are surprisingly similar throughout the intermediate temperature range for all of the different grades excepting 347-347H; this latter grade exhibits ratios as much as 15 per cent higher than those for the other grades. For the tensile strength trend ratios differences exist amongst the grades. Grade 347 now exhibits the least ratio of all the grades, at intermediate temperatures, and grade 316 the highest. The L grades of 304 and 316 exhibit slightly lower ratios than the corresponding regular grades.

The trend curves are shown together for ready comparison in Figure 8 (yield Strength) and Figure 9 (tensile strength).

Creep and Rupture Strengths

The available time-for-rupture and secondary creep-rate data for all lots of a given grade are plotted as dependent upon stress in Figures 16-22. The data for grades 347 and 347H are shown in common plots, Fig. 22, treating the data as though from a common population. This seemed appropriate after discovering by the F and t tests of statistics, applied to the rupture data at 1200°F, at which the greatest number of data were available, that the differences in the variances and the means were not significant. The available data are relatively meager and it is possible that greater quantities of data would reveal that there are significant differences. Similarly, visual inspection of the even more meager creep data did not suggest significant differences between types 347 and 347H. Bar-plate data are differentiated from pipe-tube data by the symbols used in the plots, but in the evaluations, no distinction as to product form is made.

In analyzing rupture-time and creep-rate data at a specific temperature two broad types of evaluation procedure have been employed by analysts, one treating all of the data for a given grade as from a common population, the other treating data from different heats individually. Both involve the need to extrapolate data representing tests of relatively short duration (e.g. up to 10,000 hours) to obtain estimates of the stress for rupture in relatively long times (e.g. in 100,000 hours). Not infrequently, there is also a need to extrapolate creep-rate data from faster to slower rates, but interpolations are sometimes possible, as e.g. to obtain the stress for a secondary creep rate of 0.01% per 1000 hours, which is one of the criteria of the ASME Boiler and Pressure Vessel Codes. (If, however, the creep strain after some long interval such as 100,000 hours, is required, as in certain foreign Codes, then an extrapolation is almost always required, as with the rupture-time data.)

For either approach, the data are commonly plotted on log-log coordinates, as in Figs. 16-22. For many materials, such plotting tends to linearize the relation between the variables, whereas in other instances, a degree of curvilinearity may exist, particularly when the data are viewed in a common scatter band.

The extrapolations may also be carried out indirectly with the aid of one or another of several time-compensated temperature parameters. In brief, the parameter techniques make possible an estimate of the stress for rupture (or stress for a particular creep strain or creep rate) in a relatively long time at relatively low temperature from tests of relatively short duration at higher temperature. Such an approach is facilitated if the test program is planned in advance with such an objective. Since this has only infrequently been true of the data available for analysis in this report, the parameter approach is inherently incapable of providing, in the present instance, estimates of long-time strength at temperatures approaching the upper limits of practical interest. Other practical limitations also exist, too involved to consider here. However, the Metal Properties Council is exploring in a separate program the feasibility of applying time-temperature parameters, to the evaluation of the type of data generally available. The results of thisprogram will be published separately, and the parameter techniques will not be further considered in the present report.

As for extrapolation of isothermal data by a scatter-band approach or by individual treatment of different lots, arguments both pro and con may be advanced. (see, for example, Joint International Conference on Creep , 1963, published by Institution of Mechanical Engineers, London, or "High Temperature Properties of Steels," British Iron and Steel Institute Report, P- 97, 1966). In the present evaluation, principal emphasis has been put on the individual treatment of separate lots, for reasons which will be discussed in a separate report. However, in some instances, the scatter bands have been evaluated and the results incorporated into this report for purposes of comparison. Moreover, a least squares analysis of the scatter band has been used in this report at a further stage of evaluation in which the results of the tests at different temperatures are considered together in arriving at the characteristic trend curve for the variation of strength with temperature.

In extrapolating the isothermal plots of stress vs time-for-rupture (or of stress vs secondary creep rate), a crucial question is that of whether the variables are related linearly (on the log-log plots) or by an equation of second degree or even higher order. Particularly for rupture time, an abrupt change in slope, corresponding to a change in fracture mode, is frequently noted. One of the advantages of treating individual results (in the case, for example, of stress vs rupture times) is that changes in slope are detected, and when they occur, extrapolation can be made on the slope representing the longer-time test results, whereas, such changes in slope tend to give the scatter band a curvilinear appearance. In point of fact, however, in the present instance, visual inspection of the scatter plots of Figs. 16-22 give little reason to believe that the relationship is other than linear. An important reason for not assuming a higher degree for the relationship, unless the evidence clearly supports such an assumption, is that the curve defined by least-squares analysis is importantly weighted by the power terms for the long time tests. This weighting can give an exaggerated curvilinearity.

As for the log-log plots of stress vs secondary creep rate, the data of the present report not infrequently showed curvilinearity at low creep rates, and consequently the individual interpolations or extrapolations were made from the curve which was judged visually to offer the best fit.

The individual extrapolations were carried out on plots, too numerous to be included herein, in which the individual lots of data were differentiated. With few exceptions, the rupture-time data were not extrapolated unless data were available for three levels of stress, with at least one rupture time exceeding 1000 hours. Also, with few exceptions, the creep-rate data were not extrapolated by more than 1 log cycle. In performing the least-squares analyses of the scatter bands of the stress vs rupture-time plots, the evaluations were weighted to the longer-time results by arbitrarily excluding rupture-times less than about 50 hours.

Linear least-squares analyses were carried out for the time-to-rupture test results at 1200°F for all except the L grades, and extended to a rupture time of 100,000 hours. Significant differences in the extrapolated values exist depending upon whether stress or time-to-rupture is chosen as the independent variable, and the proper distinction between these in the present instance is controversial. Accordingly, regression was carried out in both ways for each grade, and the two results are included, for comparison with the results of the individual visual extrapolations, in Table 4 (rupture in 10,000 hours) and Table 5 (rupture in 100,000 hours).

The results of the individual isothermal extrapolations or interpolations are plotted as dependent upon temperature in Figs. 23 a-g, stress for rupture in 10,000 hours and stress for a secondary creep rate of 0.1% per 1000 hours, and in Figs. 24 a-g, stress for rupture in 100,000 hours and stress for a secondary creep rate of 0.01% per 1000 hours. Semilogarithmic coordinates have been chosen for these plots because this frequently tends to

Table 4

Stress for Rupture in 10,000 Hours at 1200 F--1000 psi

Type	Number of Lots	Mean of Visual Extrap. $\bar{x}$	Regression Anal. Time Independ.	Regression Anal. Stress Independ.	Stand. Deviation S	* $\bar{x}$-1.65S	Min. of Visual Extrap.
304-304H	24	15.32	15.0	13.1	2.19	11.70	9.3
316-316H	15	16.40	17.3	15.9	1.23	14.37	13.6
321	19	13.09	13.3	11.2	2.35	9.21	8.9
321H	25	15.20	16.0	14.1	2.31	11.39	11.9
347-347H	21	17.13	17.3	16.0	1.50	14.66	14.0

Table 5

Stress for Rupture in 100,000 Hours at 1200 F--1000 psi

Type	Number of Lots	Mean of Visual Extrap. $\bar{x}$	Regression Anal. Time Independ.	Regression Anal. Stress Independ.	Stand. Deviation S	* $\bar{x}$-1.65S	Min. of Visual Extrap.
304-304H	23	11.04	11.6	8.52	2.11	7.56	6.9
316-316H	12	11.61	12.9	10.4	1.41	9.29	9.4
321	16	8.59	9.26	6.8	2.46	4.53	5.5
321H	20	10.27	11.9	9.3	2.19	6.65	7.6
347-347H	16	12.22	12.8	10.8	1.44	9.84	10.0

*95% of all values should be greater than value in this column linearize the variation. The means and standard deviations of the stresses to cause rupture in 10,000 hours and 100,000 hours at 1200°F for the grades for which there were more than 10 sets of data have been computed and included in Tables 4 and 5, previously mentioned.

It is of interest that a choice of time as the independent variable leads to a greater strength at long times for rupture and since the two regression lines diverge from the centroid, the difference becomes greater as the reference time increases. Interestingly, the averages of the values obtained by individual extrapolation, fall between the two regression lines, but approximate more closely to the time-independent choice of variable.

The data in the plots of strength vs temperature, Figs. 23 and 24, were analyzed by the method of least squares, choosing temperature as the independent variable. As indicated previously, semilog plotting tends to linearize the relation between the variables, but it might be argued that a polynomial relation should be assumed. On the basis of prior experience reported in the literature (e.g. by Smith, Dulis and Houston, Trans. ASM 42, 1950 p. 935), on the basis of the behavior of individual lots in the present evaluation, and from inspection of the plots of Figs. 23 and 24 of this report, a linear relation was assumed for present purpose. An additional consideration was that there were relatively few data available at either end of the temperature range of interest, with the consequent possibility of a distortion of the true relation. In several instances, data were lacking at the higher temperatures, and the regression lines were extrapolated to provide a best estimate. The linear regression lines are shown on the data plots, and the results are tabulated in Tables 6-9. The various regression lines for rupture in 100,000 hours and for a secondary creep

Table 6

Average Stress for Rupture in 10,000 Hours - 1000 psi

Temp °F	304 L	304-304 H	(1) 304 - 304 H Adj.	316 L	316 - 316 H	(1) 316 - 316 H Adj.	321	(1) 321 Adj.	321 H	347 - 347 H	(1) 347 - 347 H Adj.
950											
1000	25.0*	36.0	40.0	39.0*	43.0*	43.5			40.0*	48.0	52.7
1050	20.0	28.0	31.1	30.5	34.0	34.4	31.0*	31.5	31.5	36.0	39.5
1100	15.6	22.2	24.6	23.5	26.5	26.8	23.5	23.8	24.8	27.5	30.2
1150	12.2	17.3	19.2	18.2	20.8	21.0	17.3	17.6	19.3	20.5	22.5
1200	9.7	13.8	15.32	14.2	16.2	16.4	12.9	13.1	15.2	15.6	17.13
1250	7.6	10.8	12.0	11.0	12.7	12.9	9.7	9.85	11.8	11.9	13.1
1300	6.0	8.5	9.45	8.5	9.9	10.0	7.2	7.3	9.2	9.0	9.9
1350	4.7	6.7	7.45	6.6	7.7	7.8	5.4	5.5	7.2	6.8	7.5
1400	3.7	5.3	5.9	5.1	6.0	6.06	4.0	4.05	5.6*	5.1	5.6
1450	2.9	4.15	4.6	3.95	4.7	4.75	3.05	3.10	4.4*	3.85	4.23
1500	2.3	3.25	3.61	3.05	3.7	3.74	2.28	2.32	3.4*	2.90	3.18
1550	1.8										
1600	1.41										

(1) Adjusted by displacement of the regression line by the amount required to effect coincidence with the mean of the visual extrapolation results at 1200 F.

Table 7

Average Stress for Rupture in 100,000 hours - 1000 psi

(by linear regression of log strength vs temperature)

Temp °F	304L	304-304H	(1) 304-304H Adjust.	316L	316-316H	(1) 316-316H Adjust.	321	(1) 321 Adjust.	321H	347-347H	(1) 347-347H Adjust.
900											
950											
1000	19.5*	25.8	29.0	34.5*	37.0*				29.0*	37.5	40.0
1050	15.0	20.0	22.6	25.0	28.0	28.5	23.0*	22.7	22.5	28.0	29.8
1100	11.6	15.8	17.8	18.5	20.8	21.2	16.5	16.3	17.4	20.8	22.2
1150	8.9	12.5	14.1	13.7	15.1	15.35	12.0	11.9	13.3	15.3	16.3
1200	6.9	9.8	11.04	10.1	11.4	11.6	8.7	8.6	10.3	11.5	12.25
1250	5.3	7.6	8.6	7.4	8.4	8.55	6.3	6.23	7.9	8.6	9.15
1300	4.1	6.0	6.8	5.5	6.3	6.4	4.6	4.55	6.1	6.4	6.8
1350	3.15	4.7	5.3	4.0	4.7	4.8	3.3	3.26	4.7	4.7	5.0
1400	2.4	3.7	4.17	3.0	3.45	3.51	2.45	2.42	3.6*	3.55*	3.78
1450	1.87	2.9	3.27	2.2	2.6	2.64	1.75	1.73	2.8*	2.64*	2.81
1500	1.45	2.3	2.59	1.6	1.95	1.98	1.27	1.26	2.12*	1.95*	2.08

1 - By the percentage required to adjust the value at 1200F, from regression analysis, to equal the average of the values at 1200F developed by visual extrapolation of individual lots. No adjustment was required for 321H, and in view of the small number of data, none was attempted for 304L and 316L.

* - By extrapolation to temperatures outside of test range.

Table 8

Average Stress for Secondary Creep Rate of 0.1% per 1000 hours - 1000 psi

Temp. °F	304L	304-304H	316L	316-316H	321	321H	347-347H
950							
1000		25.5	23.5	35.5			53.0
1050	9.7*	20.5	18.0	28.0	30.0*	26.5*	38.0
1100	7.7	16.5	14.0	22.5	20.0	20.3	27.5
1150	6.2	13.3	10.8	18.0	13.1	15.6	20.0
1200	4.95	10.8	8.3	14.2	8.8	12.0	14.8
1250	4.00	8.7	6.4	11.2	5.8	9.2	10.7
1300	3.2	7.0	4.9	8.9	3.85	7.1	7.8
1350	2.55	5.7	3.8	7.1	2.55	5.4	5.6
1400	2.05	4.6	2.9	5.6	1.70	4.2	4.1
1450	1.63	3.7	2.28	4.4	1.13	3.2	3.0
1500	1.30	2.95	1.75	3.55	0.75	2.5	2.15

* By extrapolation beyond test range

Table 9

Average Stress for Secondary Creep Rate of 0.01% per 1000 hours - 1000 psi

(by linear regression of log strength vs temperature)

Temp °F	304L	304-304H	316L	316-316H	321	321H	347-347H
900							
950							
1000	7.8*	17.9	22.5	20.1			30.5
1050	6.3*	14.0	16.2	15.8	13.6*	16.6*	22.4
1100	5.1	11.1	12.0	12.4	9.2	12.4	16.2
1150	4.0	8.9	8.8	9.9	5.9	9.3	12.0
1200	3.25	7.2	6.4	7.9	3.9	7.0	8.7
1250	2.6	5.7	4.7	6.1	2.55	5.25	6.4
1300	2.1	4.5	3.5	4.8	1.7	4.00	4.7
1350	1.7	3.6	2.5	3.8	1.1	2.95	3.4
1400	1.34	2.9	1.85	3.0	0.74	2.25	2.5
1450	1.09	2.3	1.35	2.4	0.48	1.70	1.8
1500	0.88	1.8	1.00	1.9	0.32	1.28	1.3

* By extrapolation to temperatures outside test range

rate of 0.01% per 1000 hours are compared with one another in Figs. 10 and 11.

In a number of instances, the regression line failed to pass exactly through the average of the values of 1200°F, and for those materials an adjusted average involving displacement of the regression line by the amount that would effect coincidence at 1200°F, was computed. These values are also tabulated in Table 7, and form the basis for the computation of minimum rupture strengths to be discussed below. The observed disparities may reflect in some instances differences between product forms. For example, there were relatively few data for the pipe-tube product form of type 304-304H at temperatures other than 1200°F, and the regression line may have been weighted downward from the average at 1200°F by the force of the data for bar-plate. Presumably, with a greater quantity of data at temperatures other than 1200°F, and data more representative of different product forms, the regression lines would tend to pass closer to the averages at 1200°F.

A number of agencies setting allowable stresses provide for a factor to be applied against the minimum stress for rupture in 100,000 hours. Accordingly, the data of the present report have been evaluated in an effort to provide minimum trend curves. Two methods delineating a minimum have been used, one based upon the minimum observed values developed by visual extrapolation of the individual log-log plots of stress vs rupture time, the other by a statistical procedure involving the subtraction of a multiple of the standard deviation from the mean of the observed values developed by visual extrapolation of the individual log-log plots. This latter technique involves an assumption of a normal distribution of strength values; available evidence indicates that this assumption is reasonably valid.

The minimum values observed at any temperature may be expected to depend sensitively upon the number of tests, until the number becomes relatively large, and since there were so relatively few data available for temperatures other than 1200°F, it appeared expedient to compute the minimum values at other than 1200°F by multiplying the average values by the ratio of minimum value at 1200°F, developed by either of the two procedures described in the preceding paragraph, to the average value at 1200°F. An alternative statistical method based upon the confidence limits of the regression lines of Fig. 24 was not adopted because of the flaring to be expected of the confidence band at the extremes of the temperature range, a flaring which would be agravated by the sparsity of data.

Minimum stresses for rupture in 100,000 hours, computed by the two procedures, are tabulated in Table 10. The particular statistical basis chosen defines a value which should be exceeded by 95% of all test values. It is of interest that in a number of instances this statistically defined minimum value approximates reasonably well the observed minimum. Since the observed minimum value depends upon the subjective judgement of the analyst and implicitly assumes that the minimum value derives from valid tests of a representative material, the greater objectivity of the statistically defined minimum would seem to commend itself.

The trend curves for rupture strength and creep strength developed in this report are offered as representing a best current assessment. The confidence that can be placed in the curves is limited, owing to the relatively limited quantity of data available.

Table 10

Minimum Stress for Rupture in 100,000 hours - 1000 psi

Temp °F	304-304H		316-316H		321		321H		347-347H	
	1	2	1	2	1	2	1	2	1	2
950										
1000	18.1	19.9					21.5	18.8	32.7	32.2
1050	14.1	15.5	23.1	22.8	14.52	12.0	16.7	14.6	24.3	23.9
1100	11.1	12.2	17.15	16.9	10.43	8.6	12.9	11.3	18.1	17.8
1150	8.8	9.65	12.4	12.25	7.62	6.28	9.85	8.62	13.3	13.1
1200	6.9	7.55	9.4	9.28	5.5	4.53	7.63	6.68	10.0	9.85
1250	5.37	5.9	6.91	6.82	3.99	3.29	5.85	5.12	7.47	7.35
1300	4.25	4.65	5.18	5.11	2.91	2.40	4.52	3.96	5.55	5.45
1350	3.31	3.63	3.88	3.84	2.09	1.72	3.48	3.05	4.08	4.02
1400	2.61	2.86	2.84	2.80	1.55	1.28	2.67	2.33	3.09	3.04
1450	2.04	2.24	2.14	2.11	1.11	.91	2.08	1.82	2.29	2.26
1500	1.62	1.77	1.60	1.58	0.81	.66	1.57	1.37	1.70	1.68

1. Computed by multiplying average trend curve (adjusted when necessary) by ratio of observed individual minimum value at 1200°F to average at 1200°F. Refer to Tables 5 and 7.

2. Computed by multiplying average trend curve (adjusted when necessary) by ratio of statistically defined minimum (average less 1.65 times the standard deviation) at 1200°F to the average at 1200°F. Refer to Tables 5 and 7.

Rupture strength data (100,000 hours) are particularly meager for test temperatures other than 1200°F, at which these materials find their greatest commercial interest, and, for type 347-347H,and for type 321H are completely lacking at temperatures above 1350°F. Creep strength data are meager at all temperatures.

Acknowledgment

Grateful acknowledment is made to the Chairman, Dr. M. Semchyshen, and members of Subcommittee No. 1 of the Metal Properties Council and to Mr. P. M. Brister, Chairman of the Technical Advisory Committee of the Council for helpful adive. Credit is also to be given to the Boiler and Pressure Vessel of the American Society of Mechanical Engineers for making available the results of prior data evaluations that facilitated the preparation of the present report.

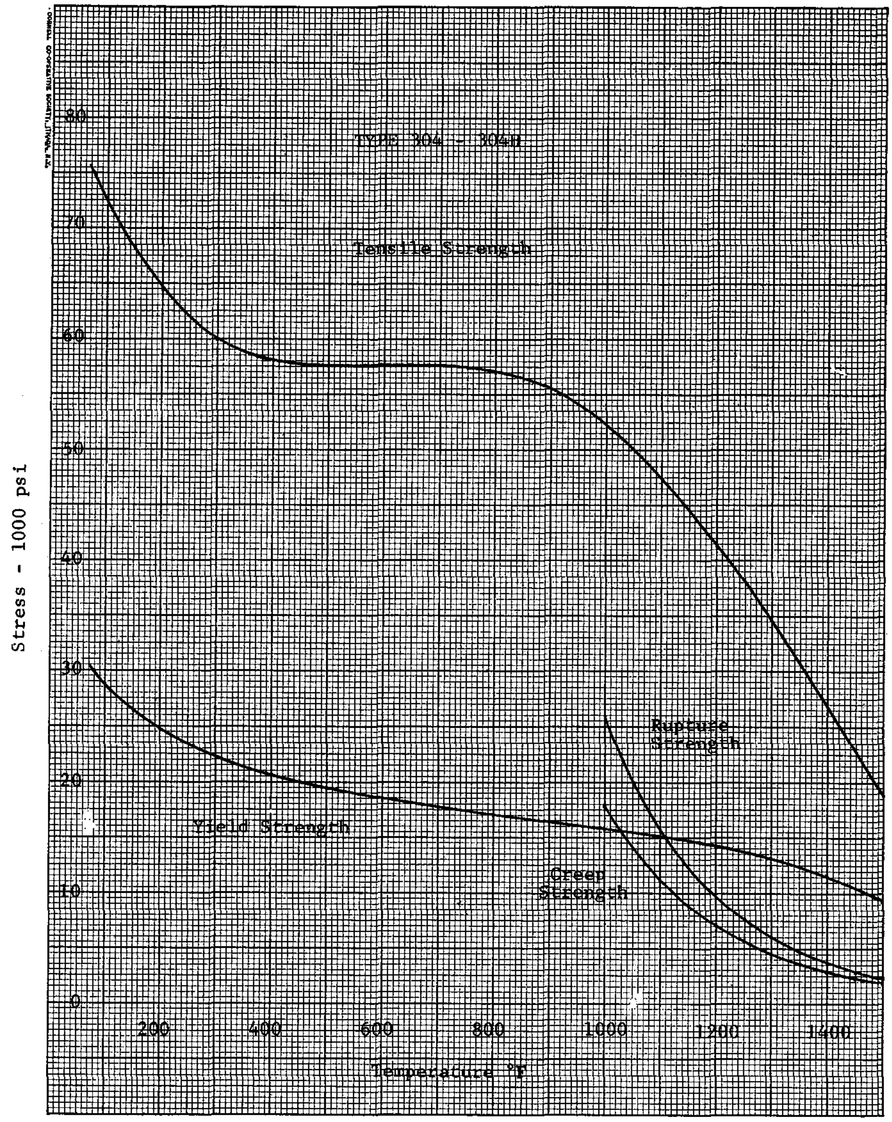

Fig. 1 - Type 304-304H. Effect of temperature on yield strength (0.2% offset), tensile strength, average creep strength (0.01% per 1000 hours) and average rupture strength (100,000 hours). Yield and tensile strengths have been adjusted to 30,000 and 75,000 psi at 75°C.

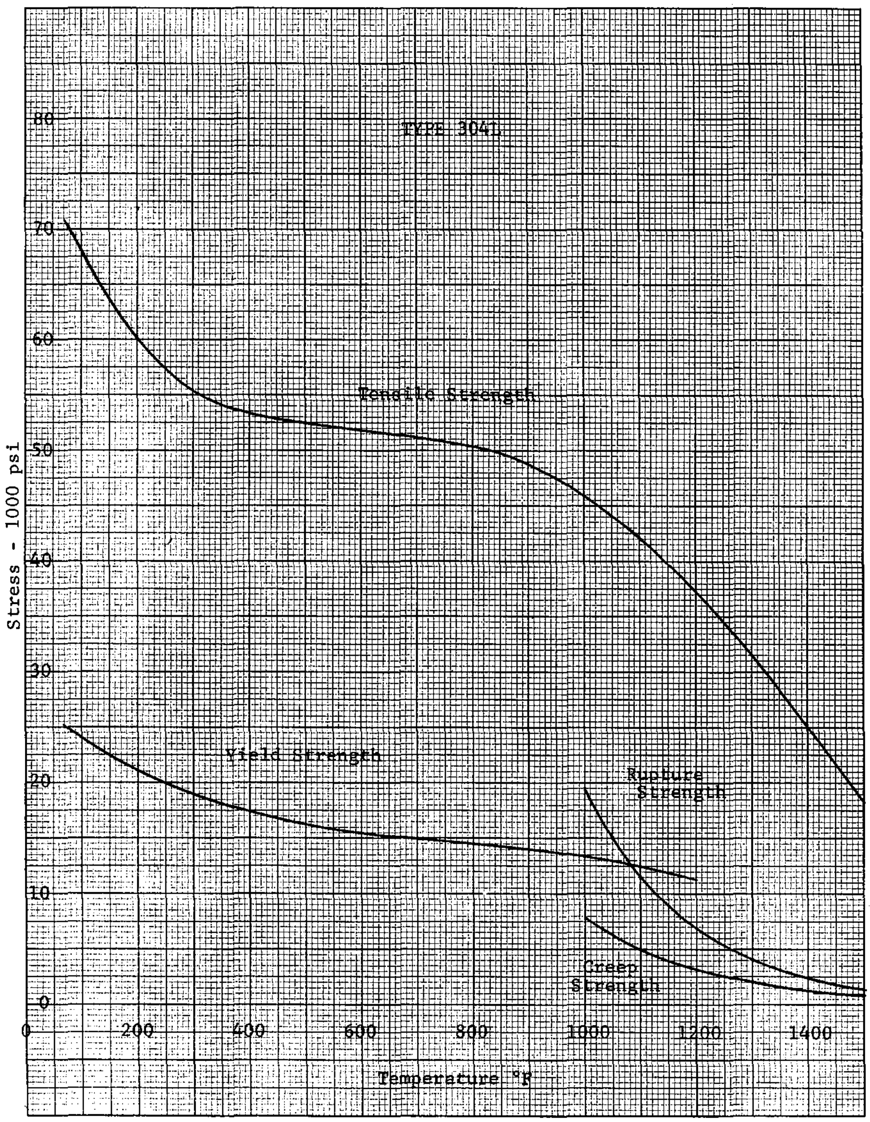

Fig. 2 - Type 304L. Effect of temperature on yield strength (0.2% offset), tensile strength, average creep strength (0.01% per 1000 hours) and average rupture strength (100,000 hours). Yield and tensile strengths have been adjusted to 25,000 and 70,000 psi at 75°C.

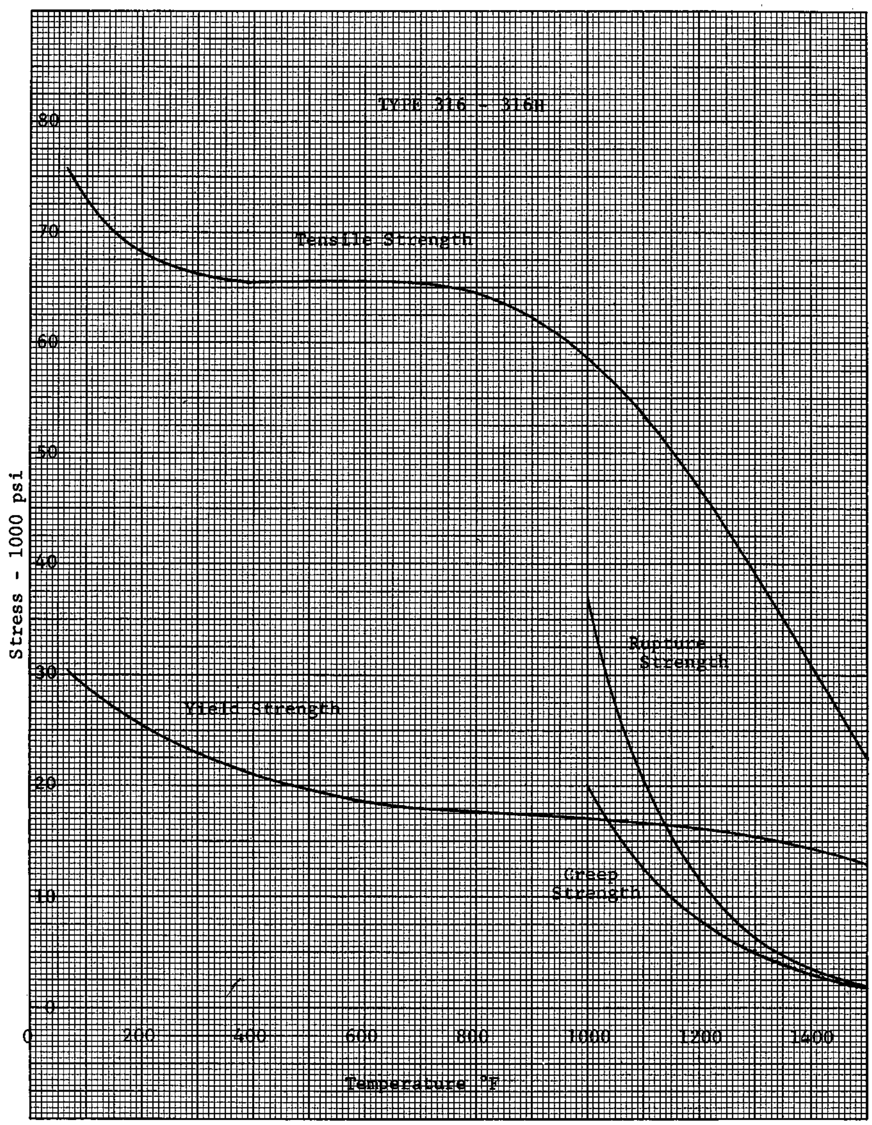

Fig. 3 - Type 316-316H. Effect of temperature on yield strength (0.2% offset), tensile strength, average creep strength (0.01% per 1000 hours) and average rupture strength (100,000 hours). Yield and tensile strengths have been adjusted to 30,000 and 75,000 psi at 75°C.

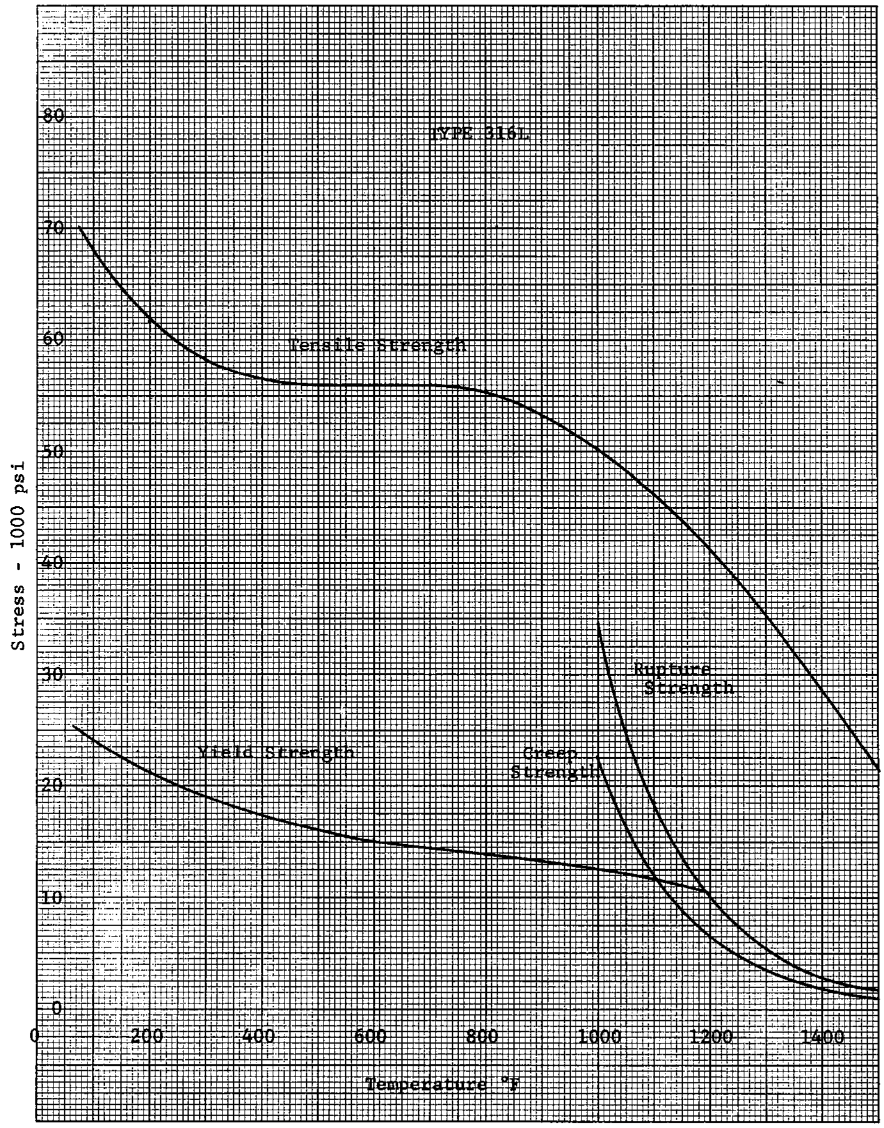

Fig. 4 - Type 316L. Effect of temperature on yield strength (0.2% offset), tensile strength, average creep strength (0.01% per 1000 hours) and average rupture strength (100,000 hours). Yield and tensile strengths have been adjusted to 25,000 and 70,000 psi at 75°C.

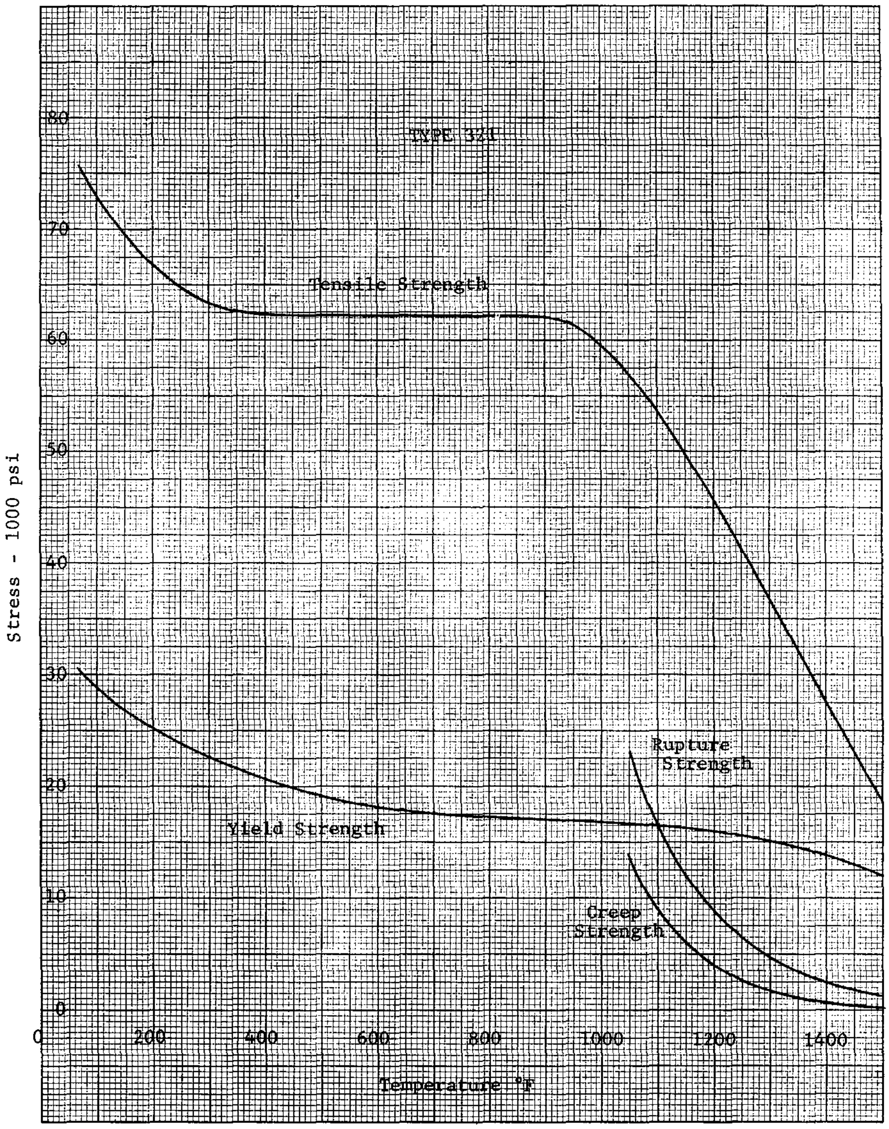

Fig. 5 - Type 321. Effect of temperature on yield strength (0.2% offset), tensile strength, average creep strength (0.01% per 1000 hours) and average rupture strength (100,000 hours). Yield and tensile strengths have been adjusted to 30,000 and 75,000 psi at 75°C.

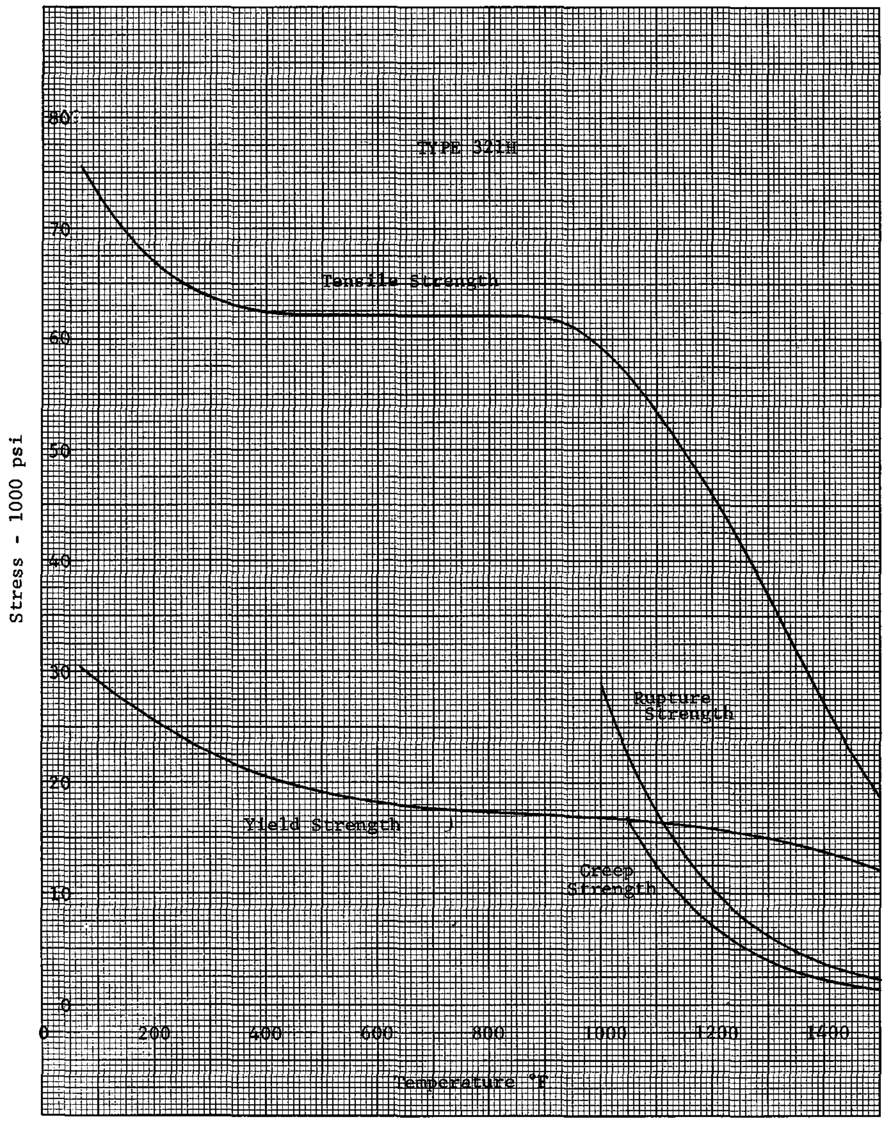

Fig. 6 - Type 321H. Effect of temperature on yield strength (0.2% offset), tensile strength, average creep strength (0.01% per 1000 hours) and average rupture strength (100,000 hours). Yield and tensile strengths have been adjusted to 30,000 and 75,000 psi at 75°C.

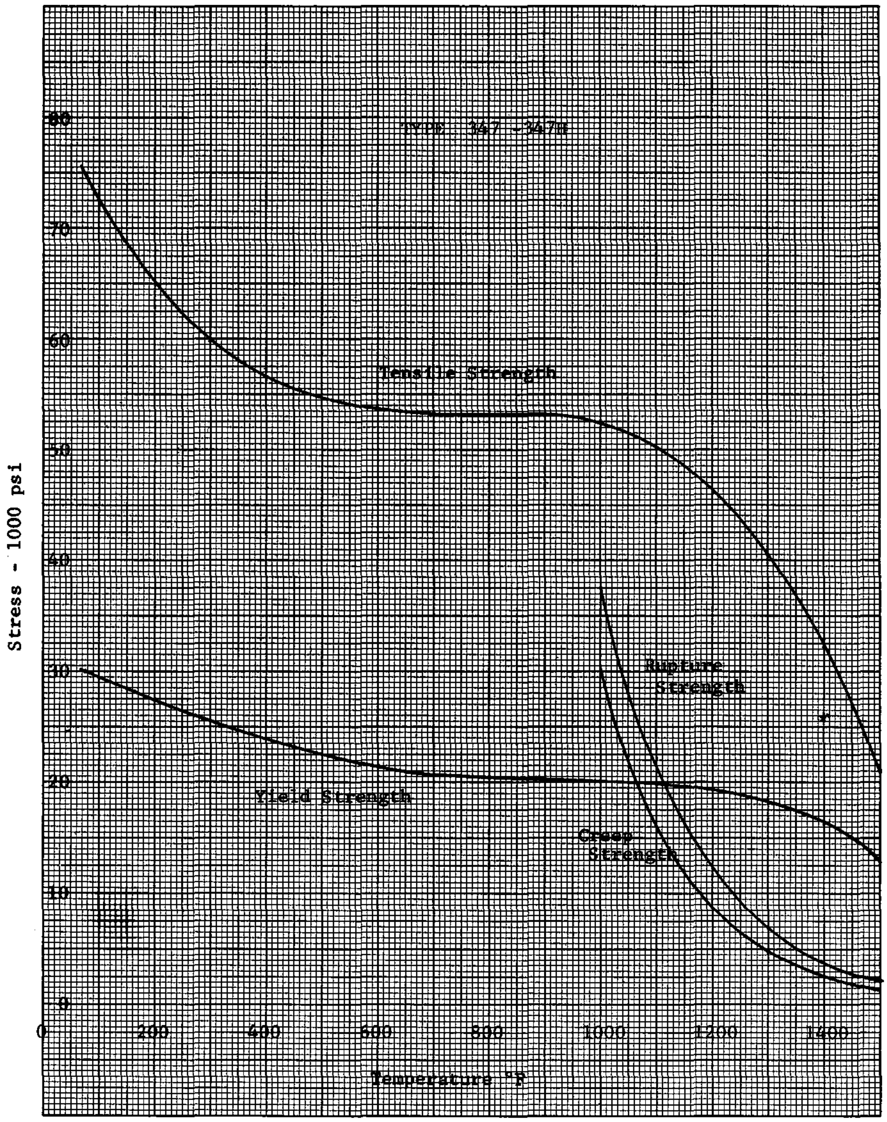

Fig. 7 - Type 347-347H. Effect of temperature on yield strength (0.2% offset), tensile strength, average creep strength (0.01% per 1000 hours) and average rupture strength (100,000). Yield and tensile strengths have been adjusted to 30,000 and 75,000 psi at 75°C.

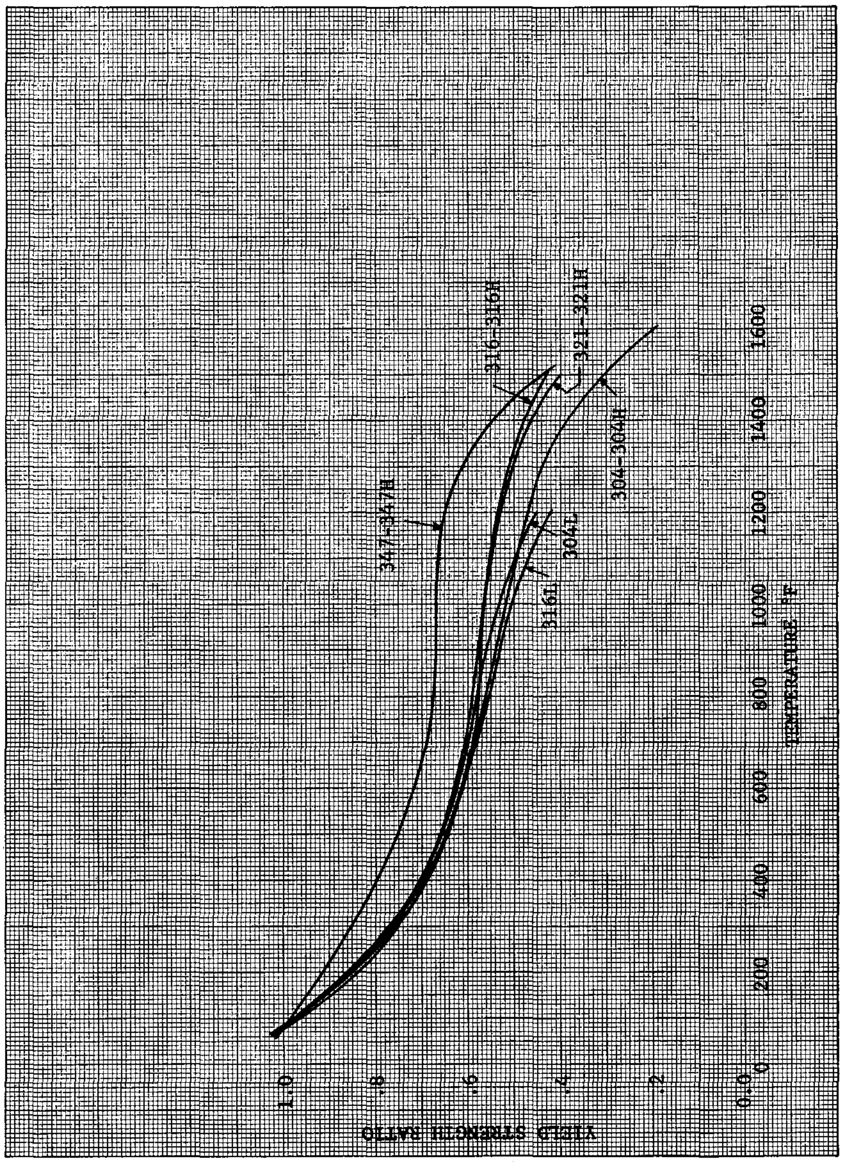

Fig. 8 - Comparison of yield strength (0.2% offset) trend curves for wrought austenitic stainless steel.

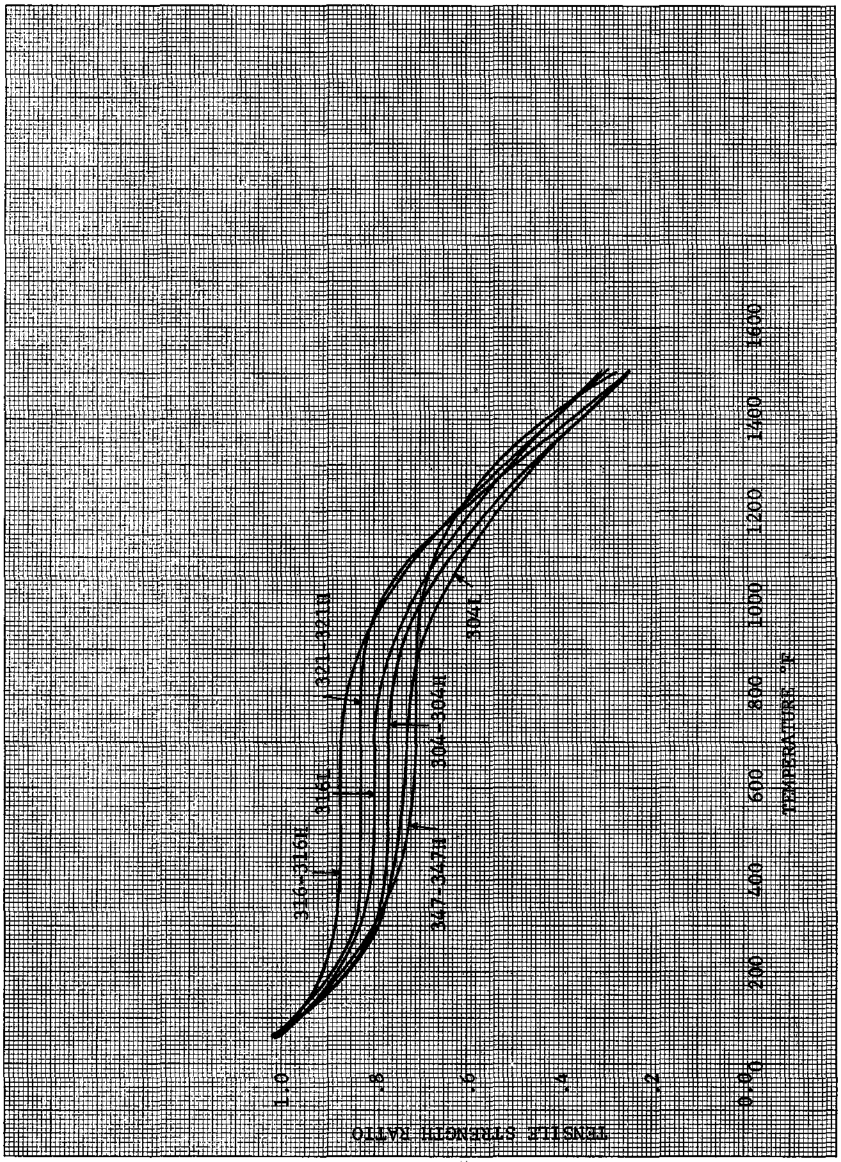

Fig. 9 - Comparison of tensile strength trend curves for wrought austenitic stainless steel.

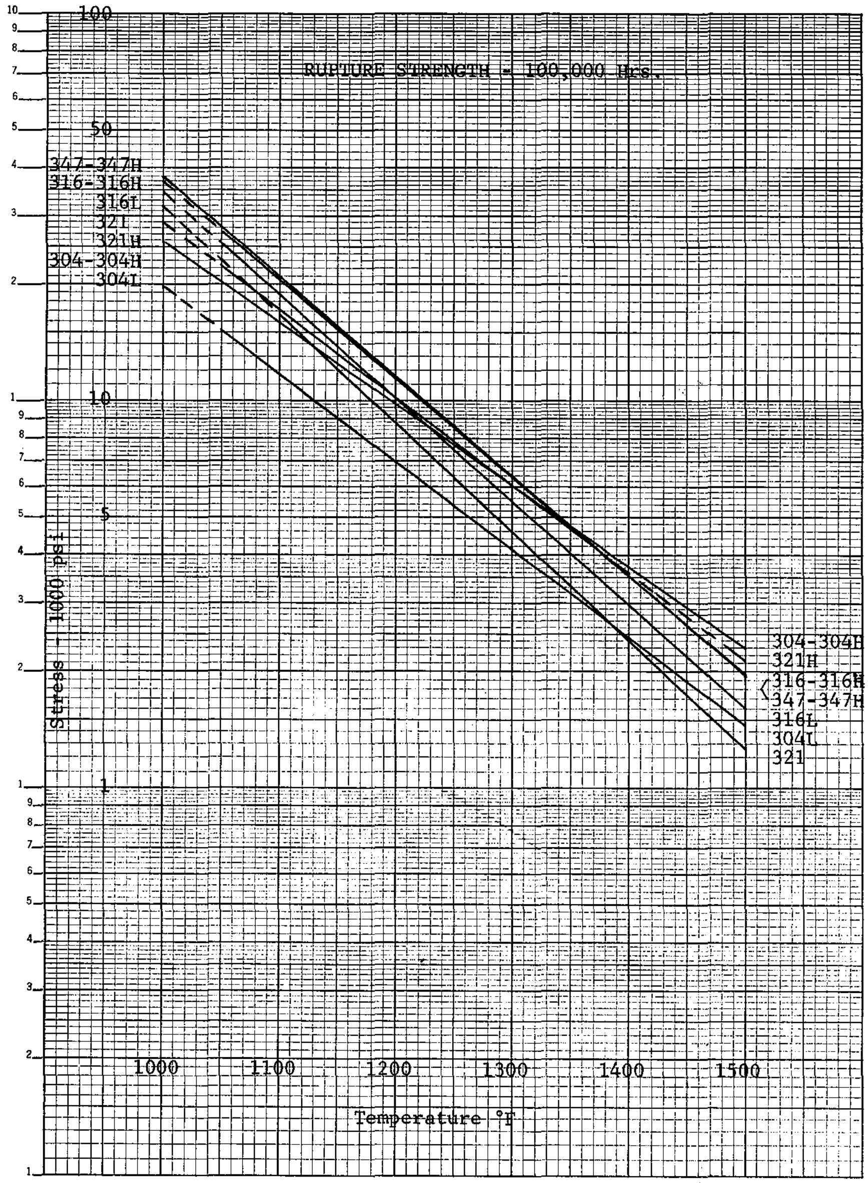

Fig. 10 - Comparison of average rupture strength (100,000 hours) trend curves.

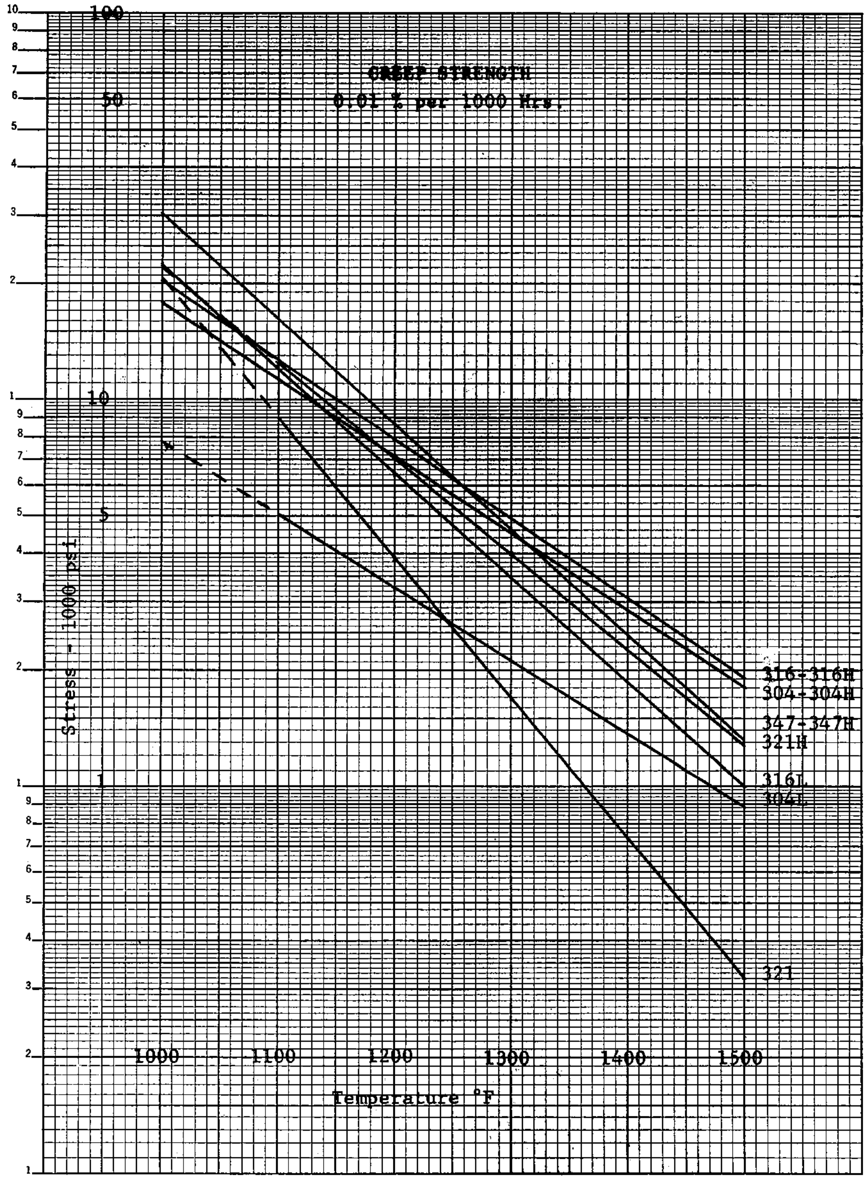

Fig. 11 - Comparison of average creep strength (0.01%/1000 hours) trend curves.

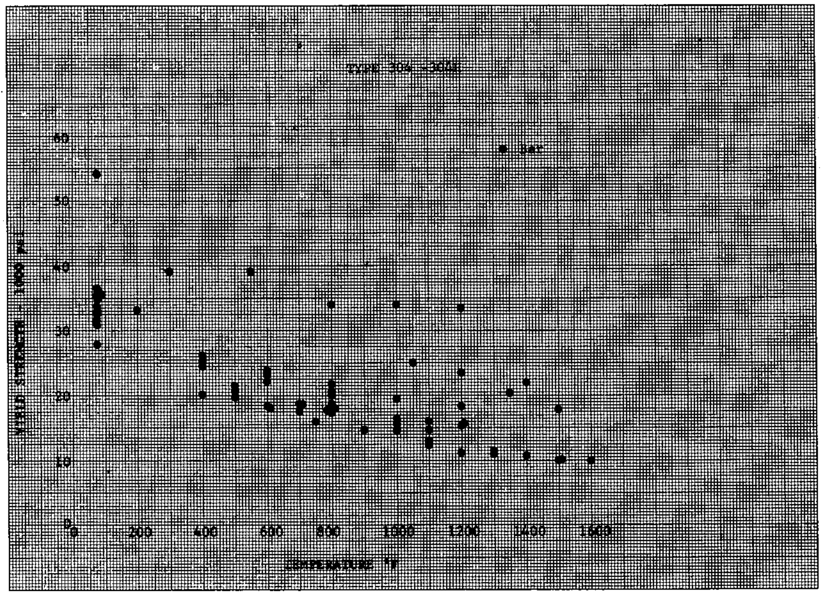

Fig. 12 - Variation of yield strength (0.2% offset) with temperature.
a. Type 304-304H bar

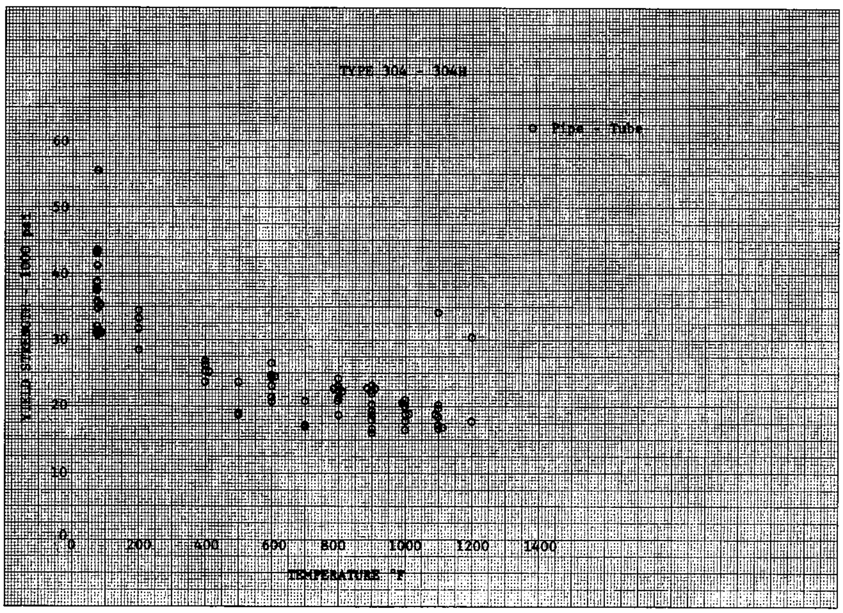

Fig. 12 - Variation of yield strength (0.2% offset) with temperature.
b. Type 304-304H pipe-tube

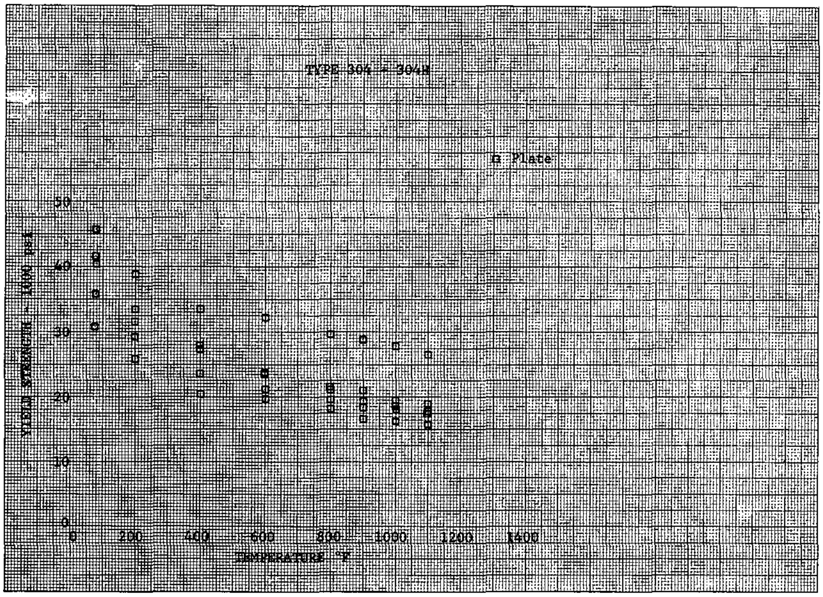

Fig. 12 - Variation of yield strength (0.2% offset) with temperature.
c. Type 304-304H plate

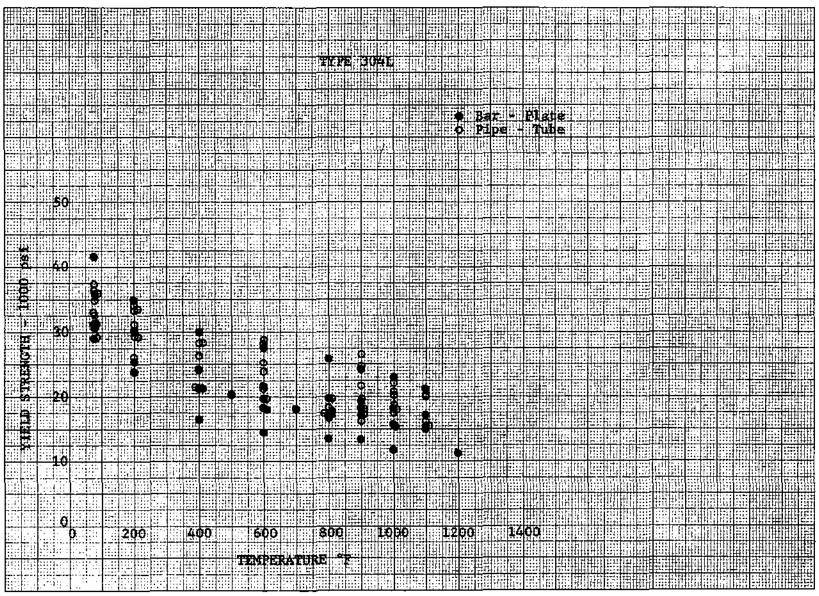

Fig. 12 - Variation of yield strength (0.2% offset) with temperature.
d. Type 304L

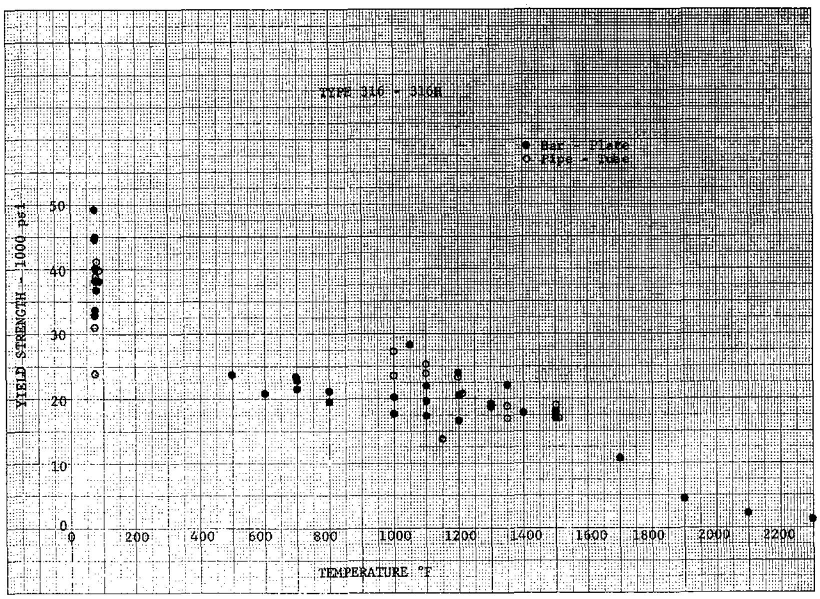

Fig. 12 - Variation of yield strength (0.2% offset) with temperature.
e. Type 316

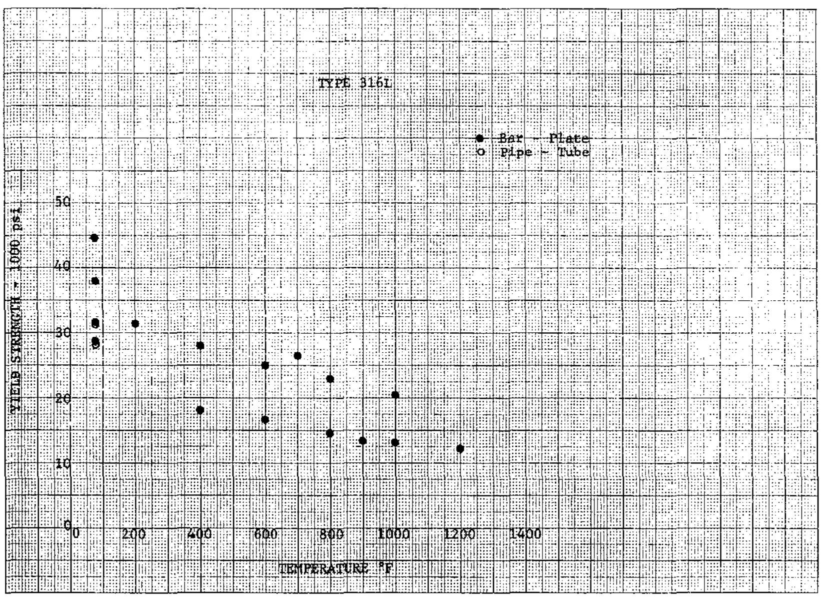

Fig. 12 - Variation of yield strength (0.2% offset) with temperature.
f. Type 316L

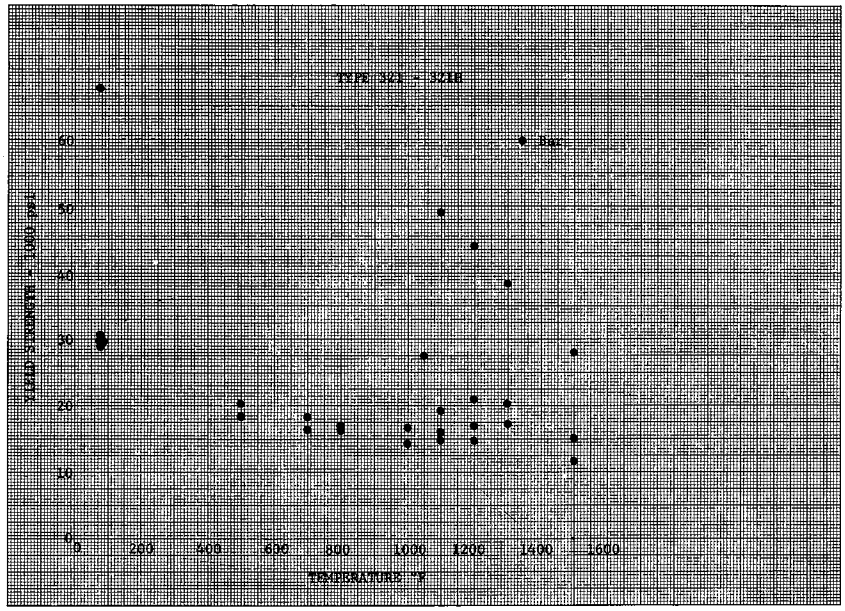

Fig. 12 - Variation of yield strength (0.2% offset) with temperature.
g. Type 321-321H

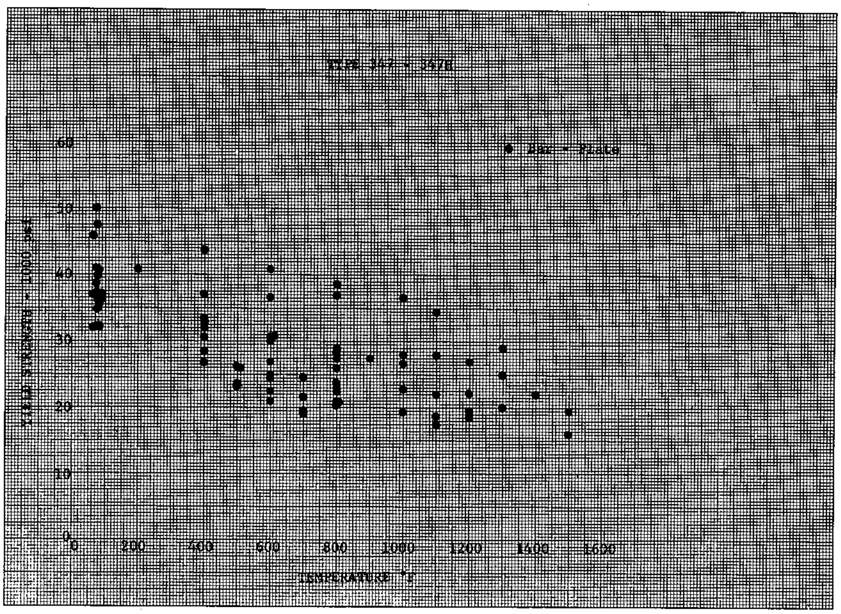

Fig. 12 - Variation of yield strength (0.2% offset) with temperature.
h. Type 347-347H

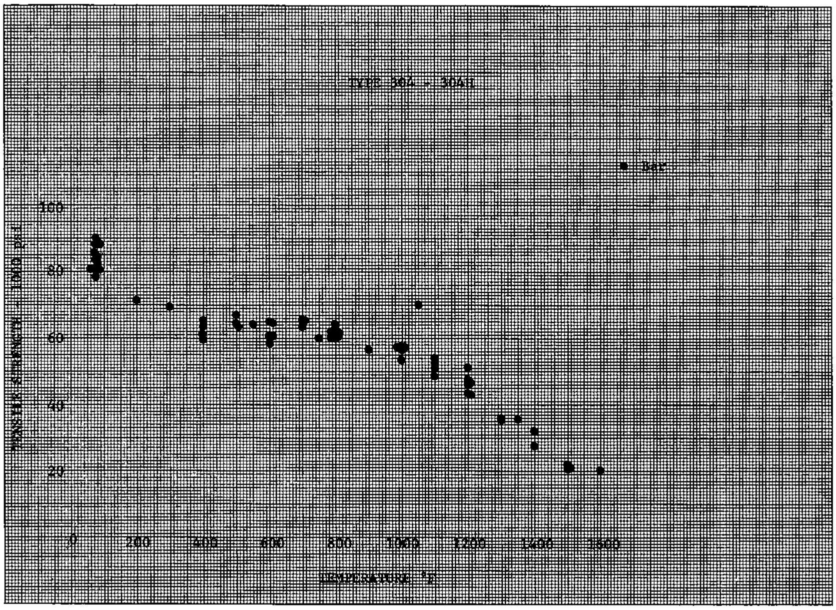

Fig. 13 - Variation of tensile strength with temperature.
a. Type 304-304H bar

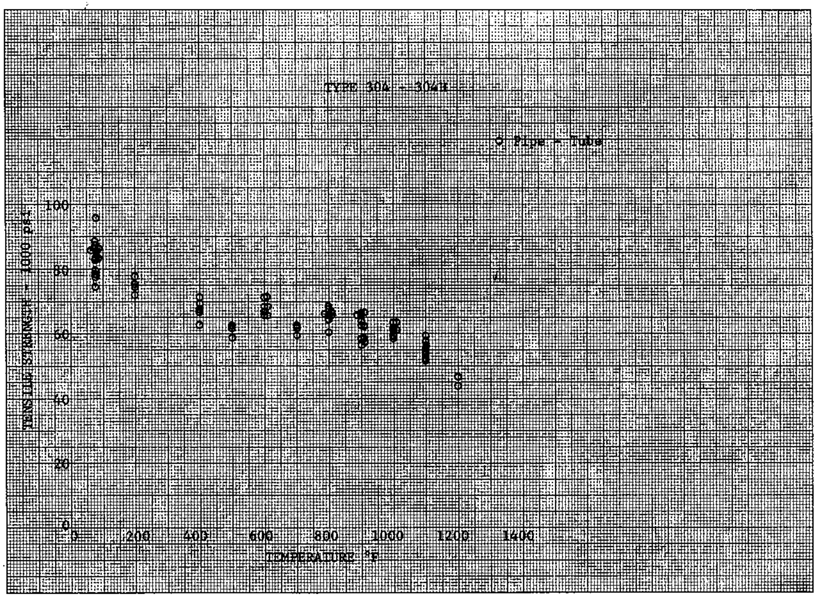

Fig. 13 - Variation of tensile strength with temperature.
b. Type 304-304H pipe-tube

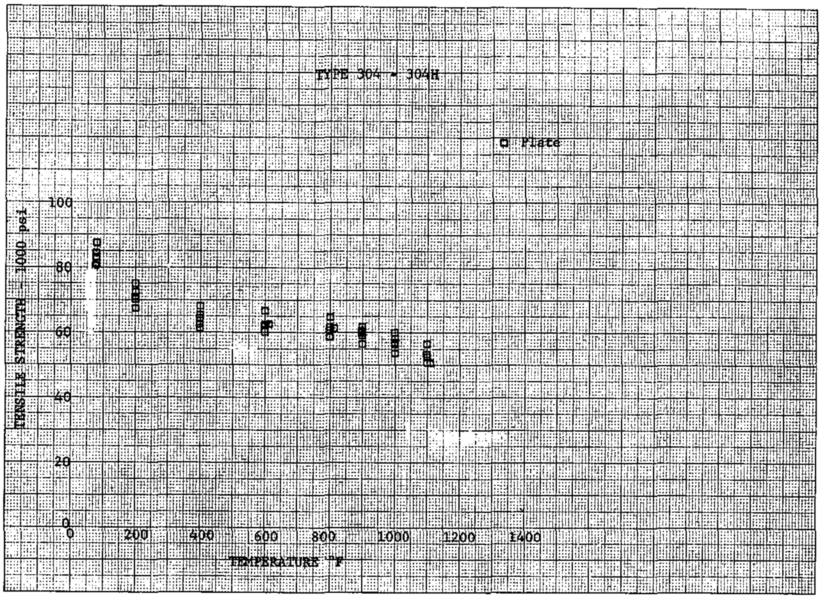

Fig. 13 - Variation of tensile strength with temperature.
c. Type 304-304H plate

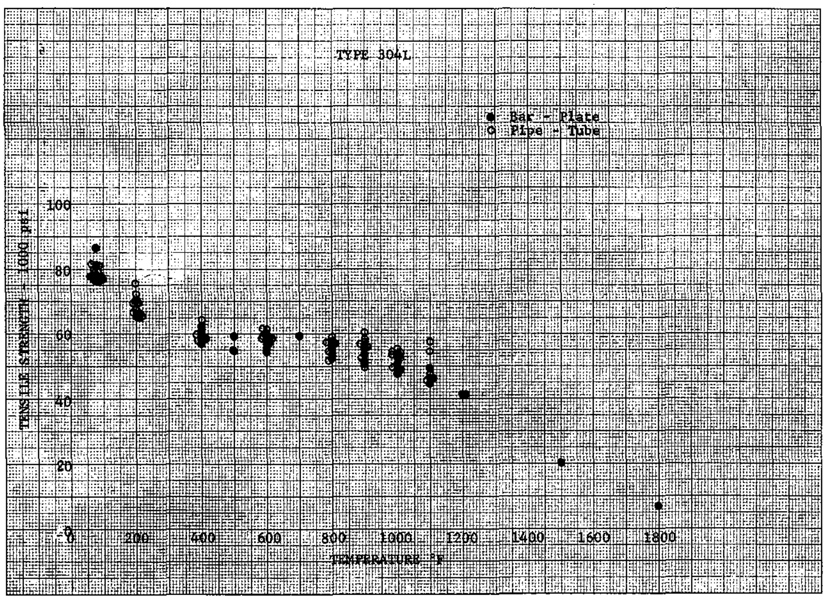

Fig. 13 - Variation of tensile strength with temperature.
d. Type 304L

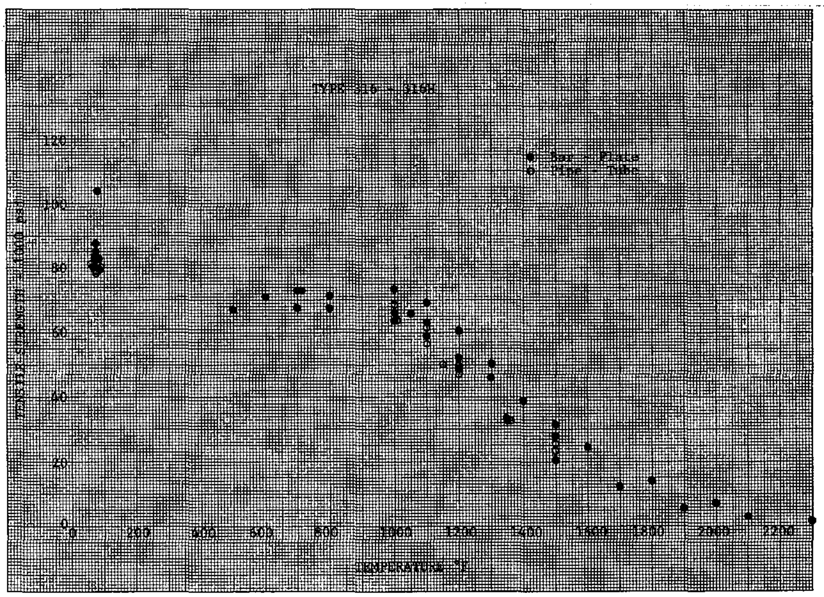

Fig. 13 - Variation of tensile strength with temperature.
e. Type 316

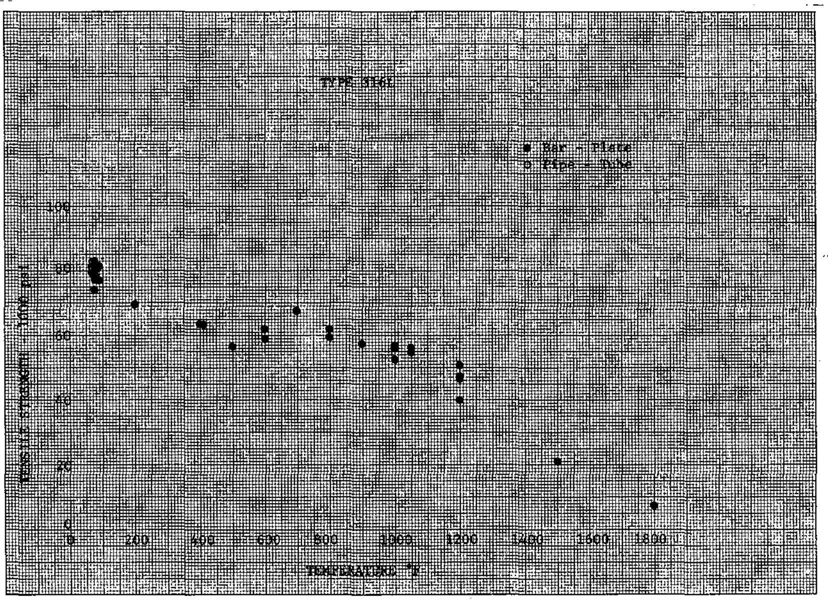

Fig. 13 - Variation of tensile strength with temperature.
f. Type 316L

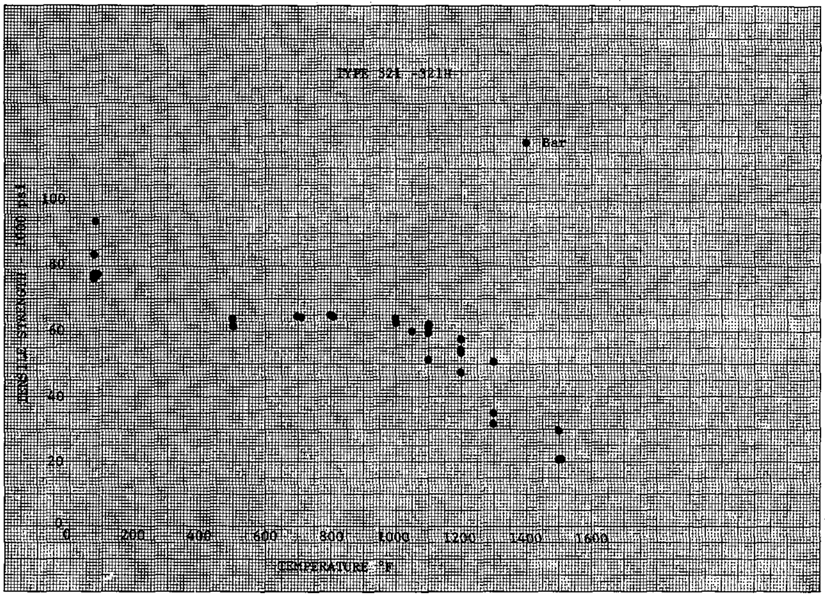

Fig. 13 - Variation of tensile strength with temperature.
g. Type 321-321H

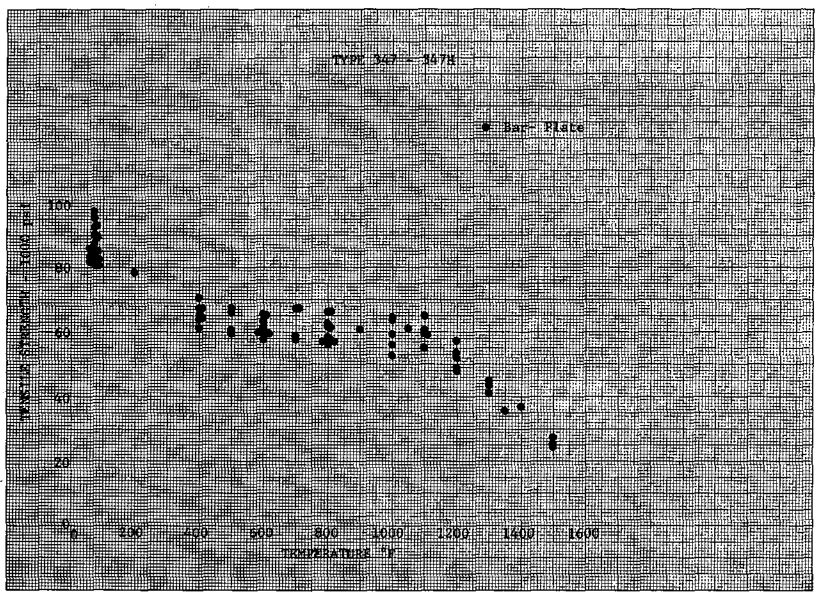

Fig. 13 - Variation of tensile strength with temperature.
h. Type 347-347H

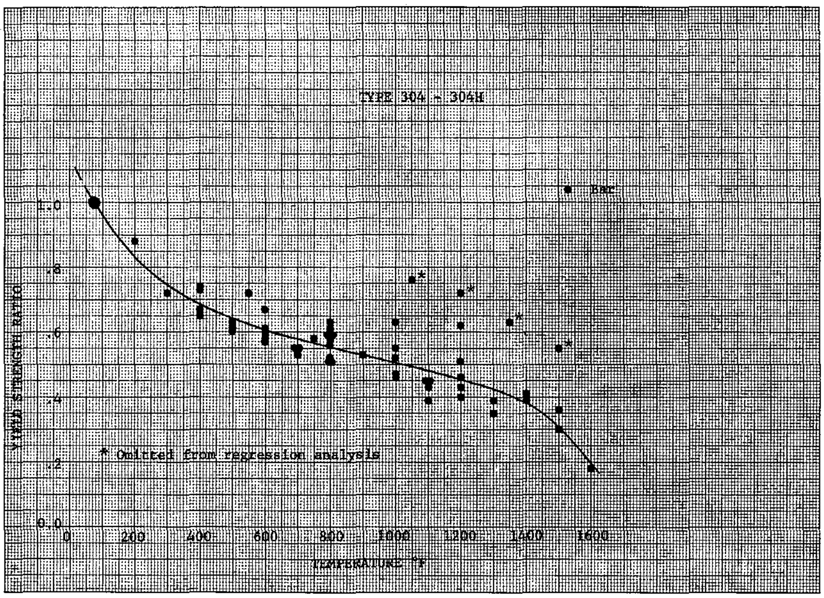

Fig. 14 - Variation of yield strength ratio with temperature
a. Type 304-304H bar

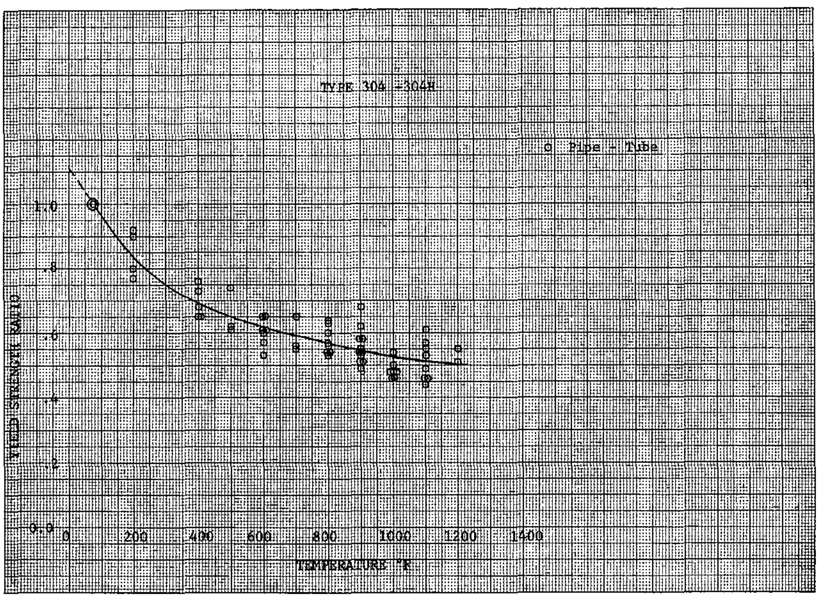

Fig. 14 - Variation of yield strength ratio with temperature
b. Type 304-304H pipe-tube

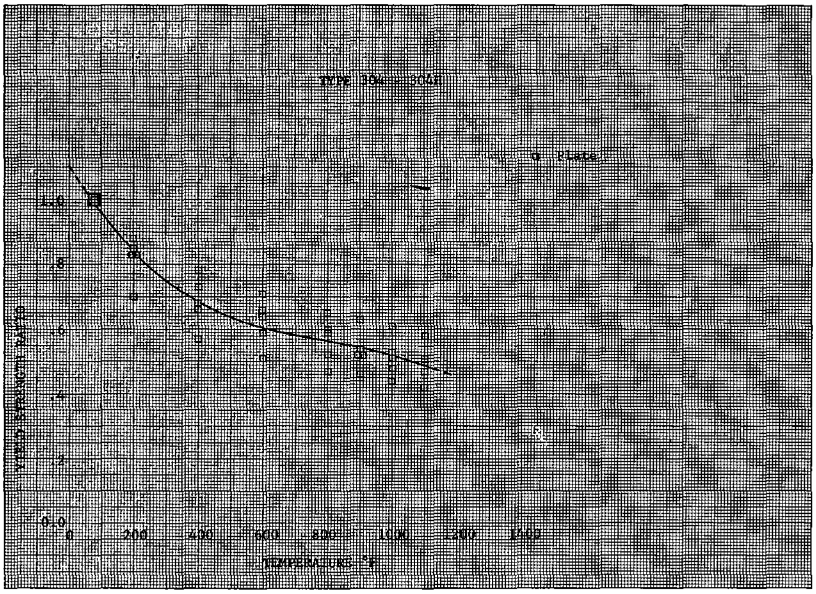

Fig. 14 - Variation of yield strength ratio with temperature
c. Type 304-304H plate

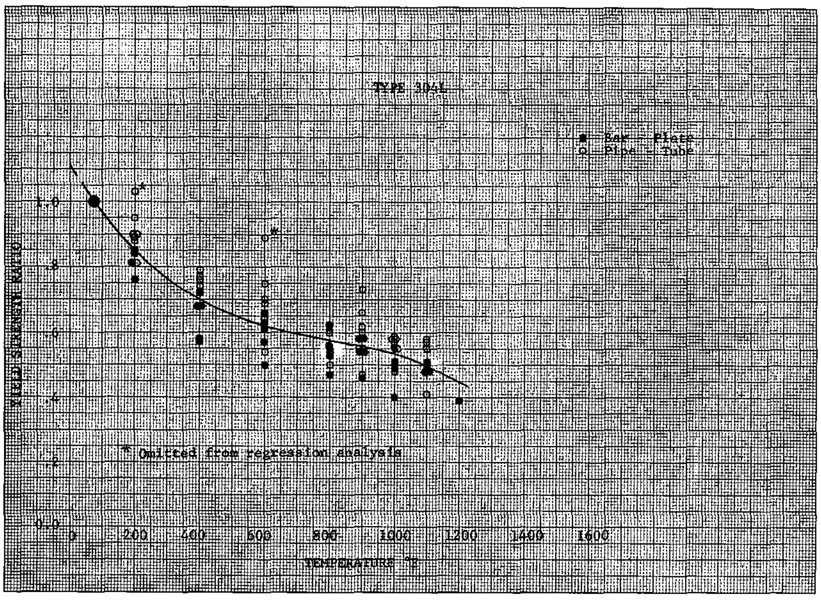

Fig. 14 - Variation of yield strength ratio with temperature
d. Type 304L

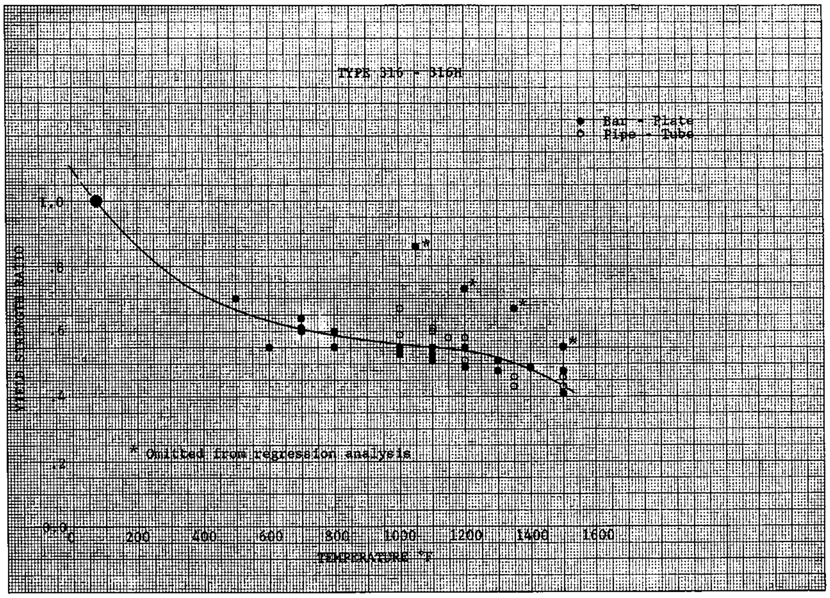

Fig. 14 - Variation of yield strength ratio with temperature
e. Type 316

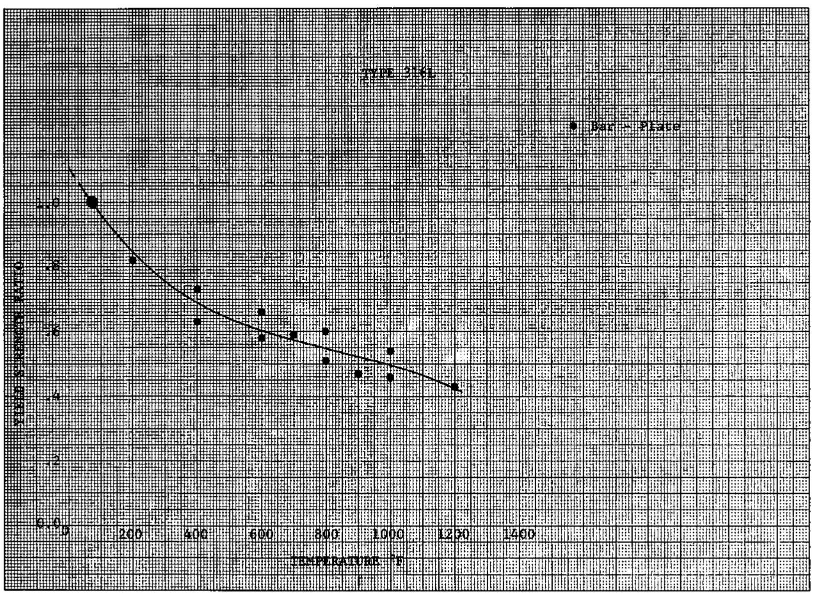

Fig. 14 - Variation of yield strength ratio with temperature
f. Type 316L

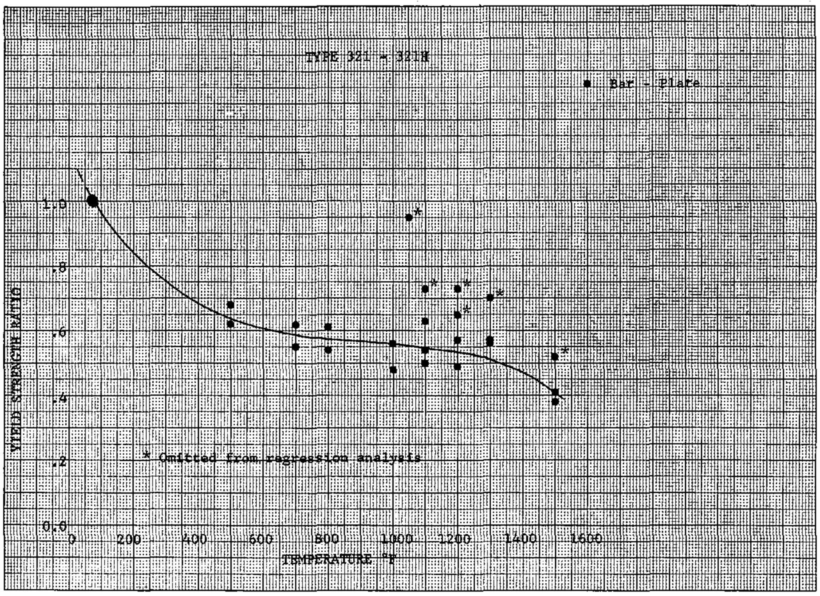

Fig. 14 - Variation of yield strength ratio with temperature
g. Type 321-321H

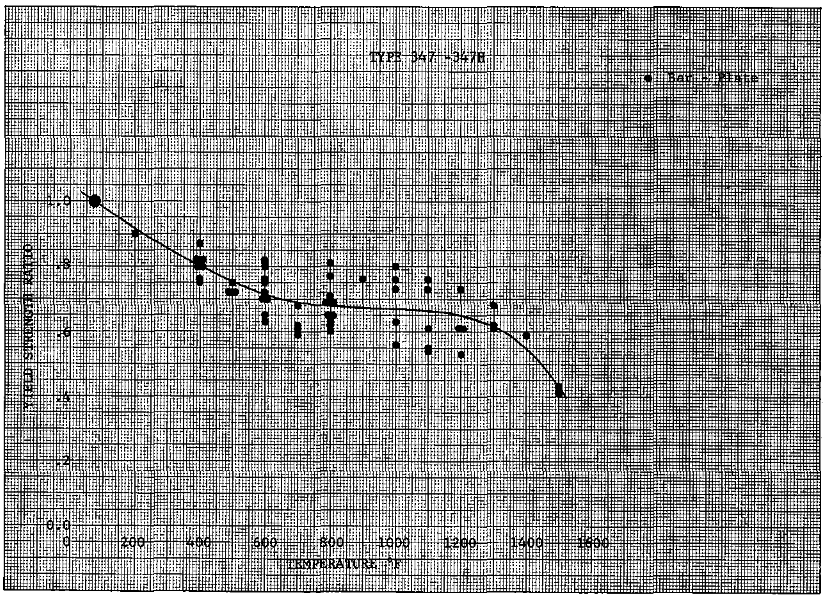

Fig. 14 - Variation of yield strength ratio with temperature
h. Type 347-347H

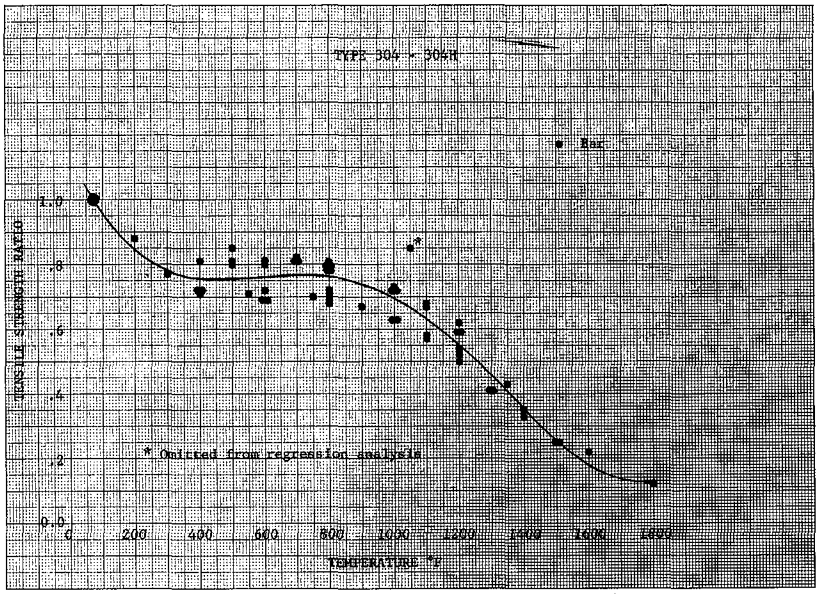

Fig. 15 - Variation of tensile strength ratio with temperature.
a. Type 304-304H bar

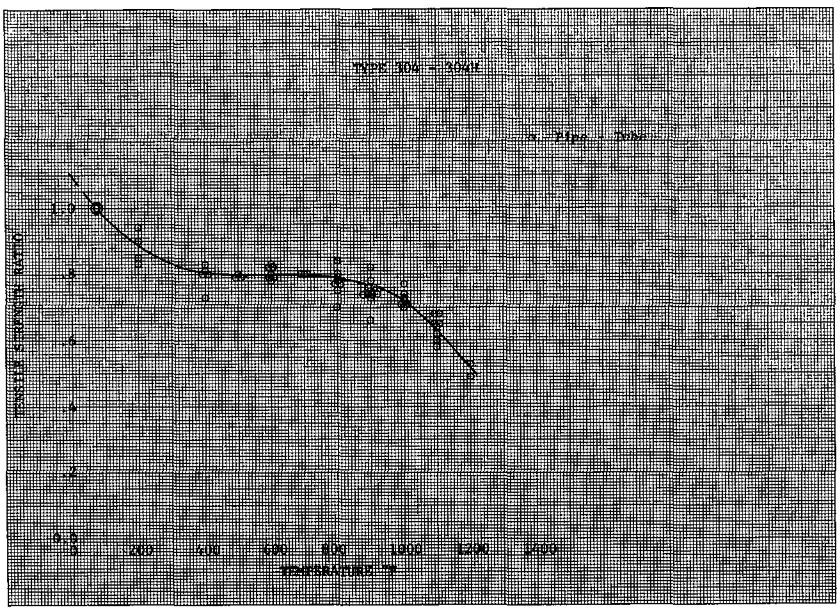

Fig. 15 - Variation of tensile strength ratio with temperature.
b. Type 304-304H pipe tube

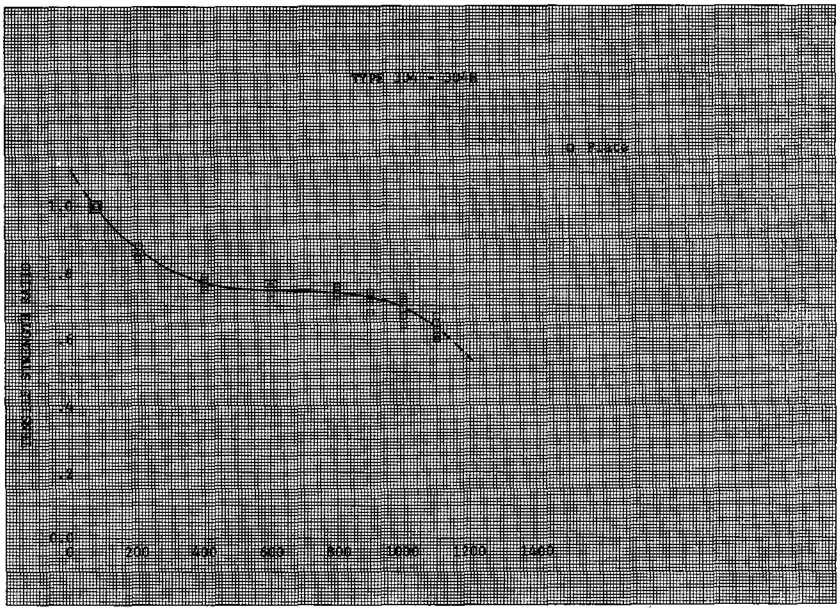

Fig. 15 - Variation of tensile strength ratio with temperature.
c. Type 304-304H plate

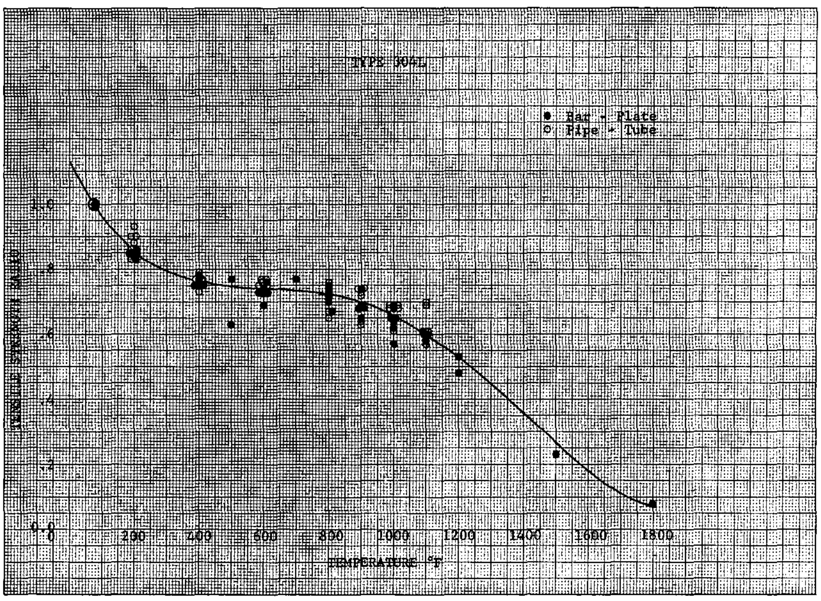

Fig. 15 - Variation of tensile strength ratio with temperature.
d. Type 304L

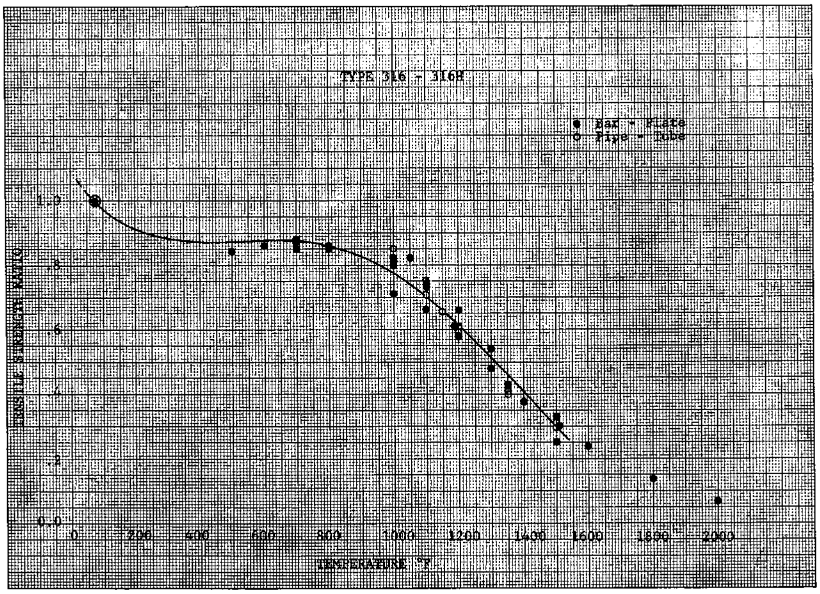

Fig. 15 - Variation of tensile strength ratio with temperature.
e. Type 316

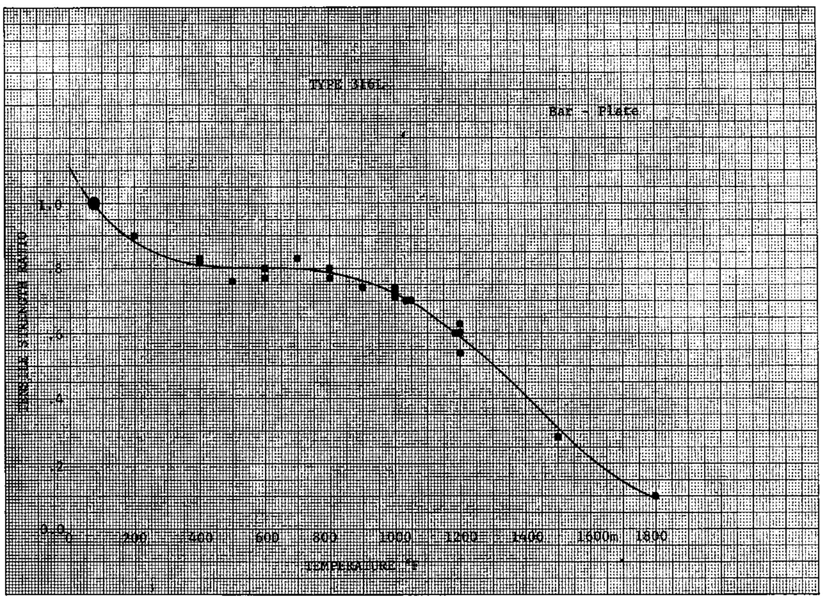

Fig. 15 - Variation of tensile strength ratio with temperature.
f. Type 316L

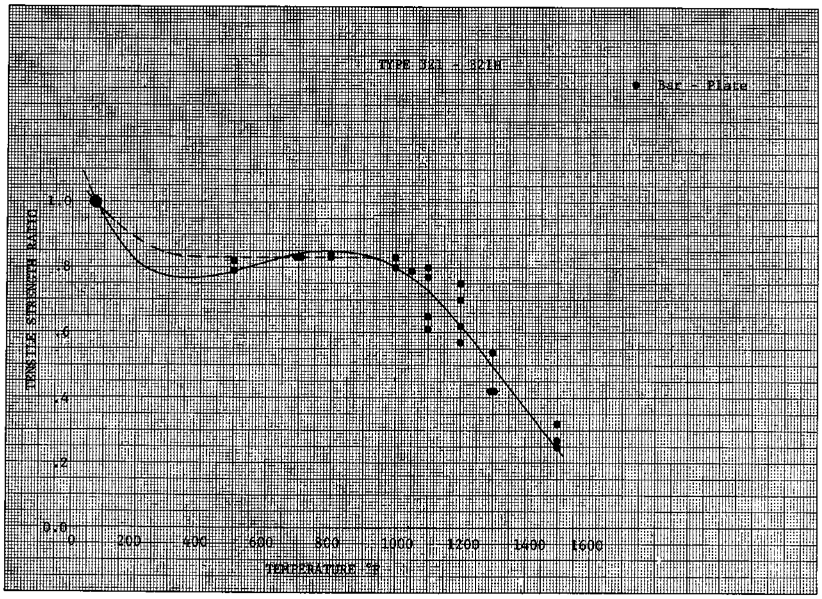

Fig. 15 - Variation of tensile strength ratio with temperature.
g. Type 321-321H

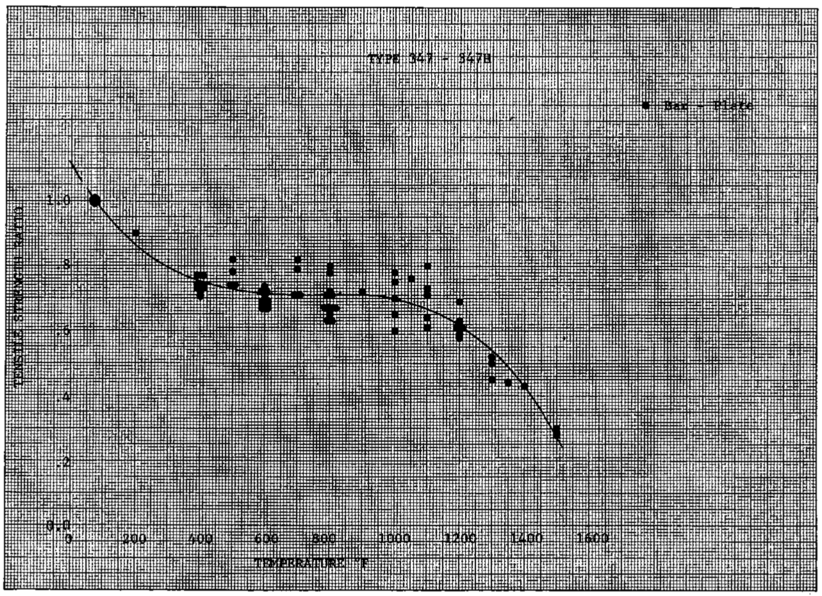

Fig. 15 - Variation of tensile strength ratio with temperature.
h. Type 347-347H

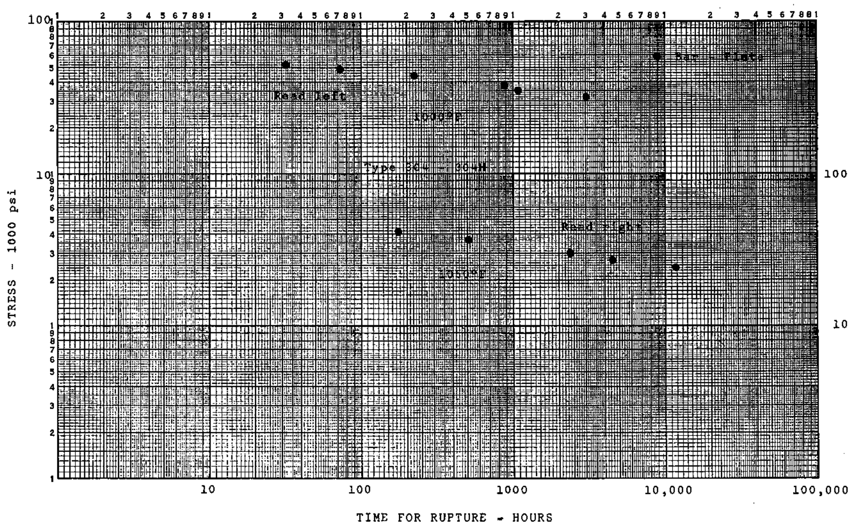

Fig. 16 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304-304H.

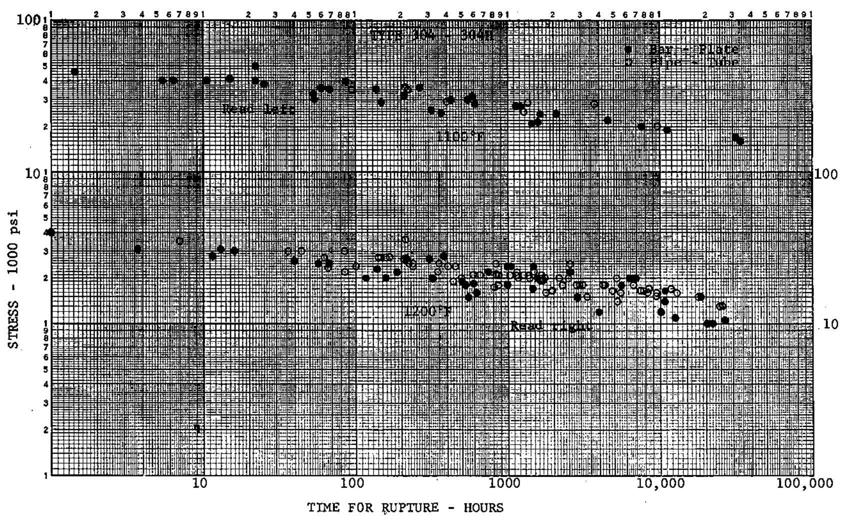

Fig. 16 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304-304H. (Continued)

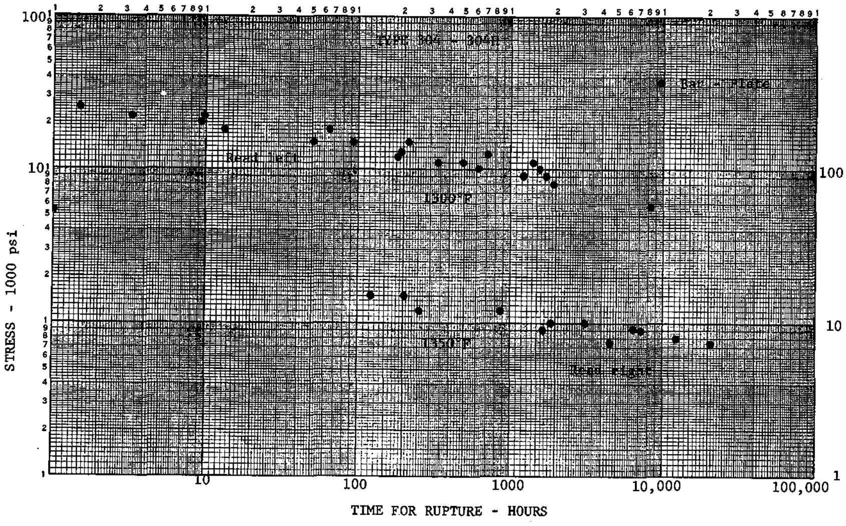

Fig. 16 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304-304H.

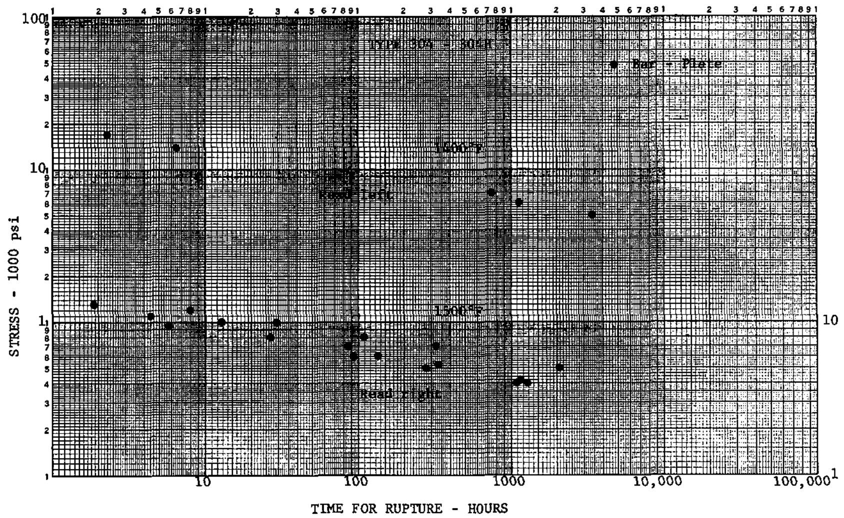

Fig. 16 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304-304H. (Continued)

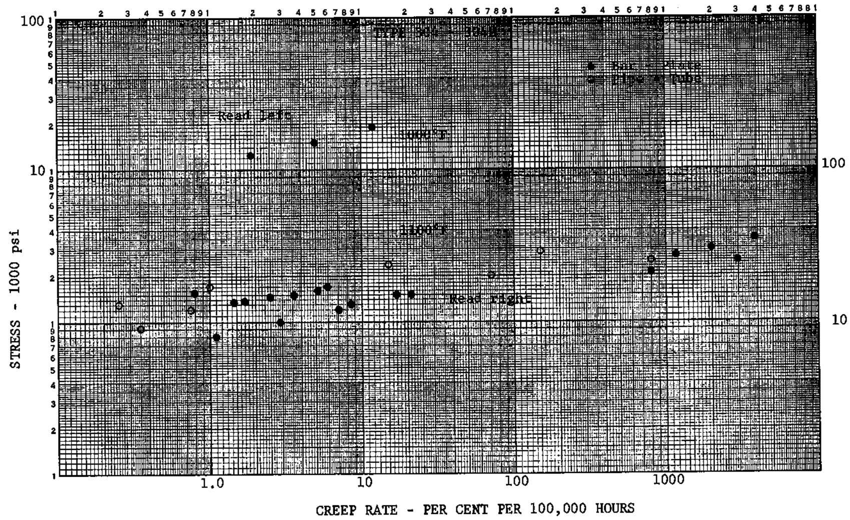

Fig. 16 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304-304H.

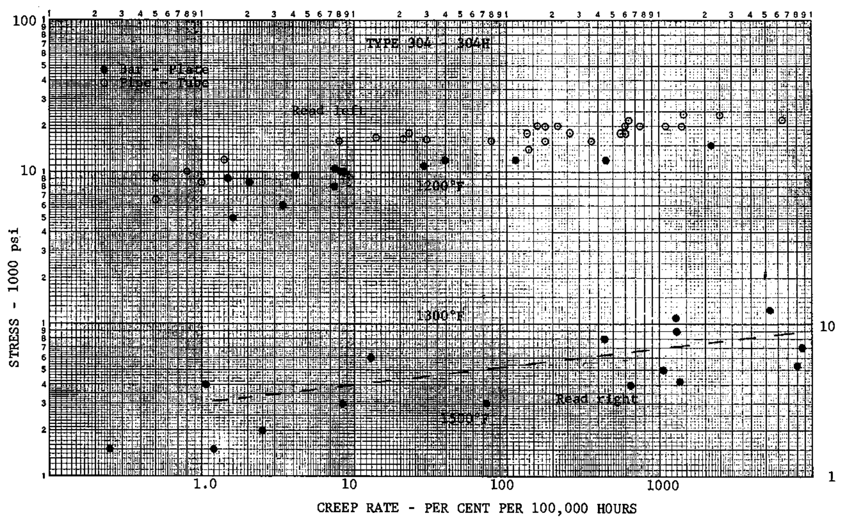

Fig. 16 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304-304H. (Continued)

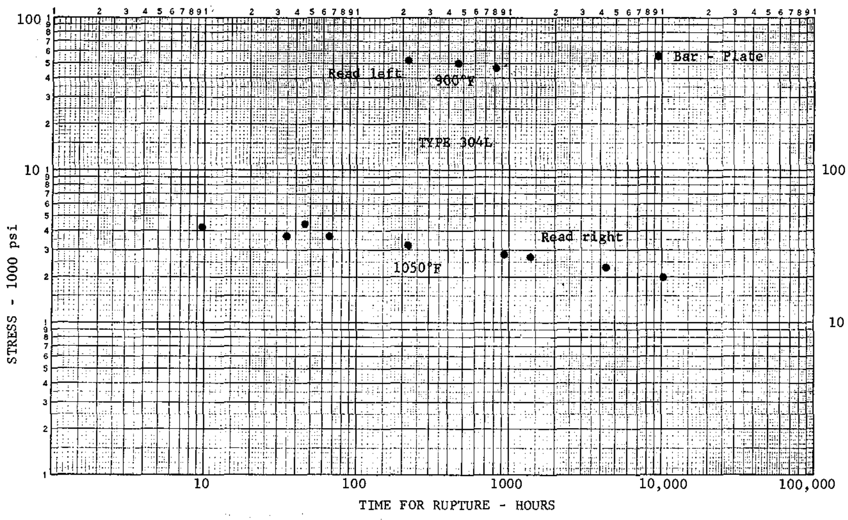

Fig. 17 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304L

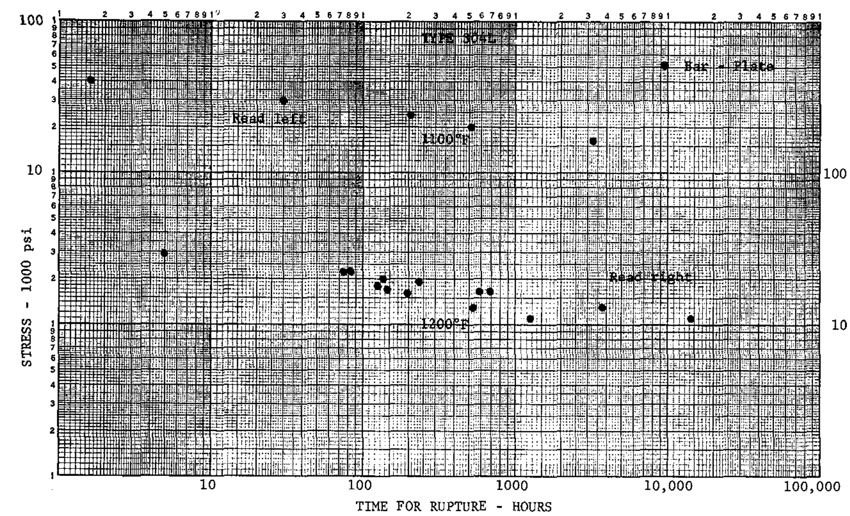

Fig. 17 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304L (Continued)

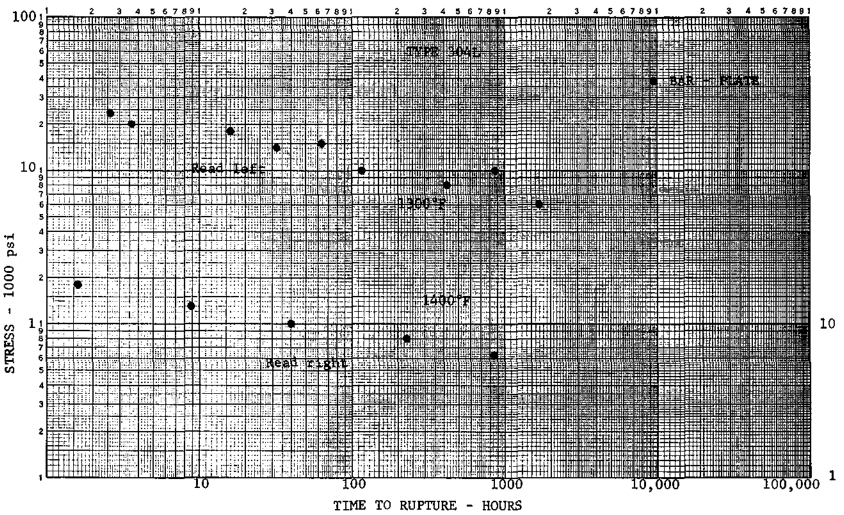

Fig. 17 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304L

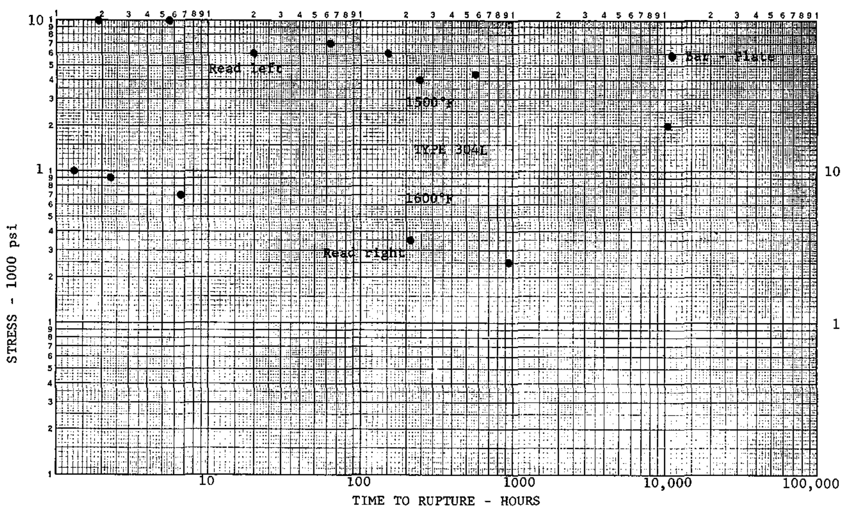

Fig. 17 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304L (Continued)

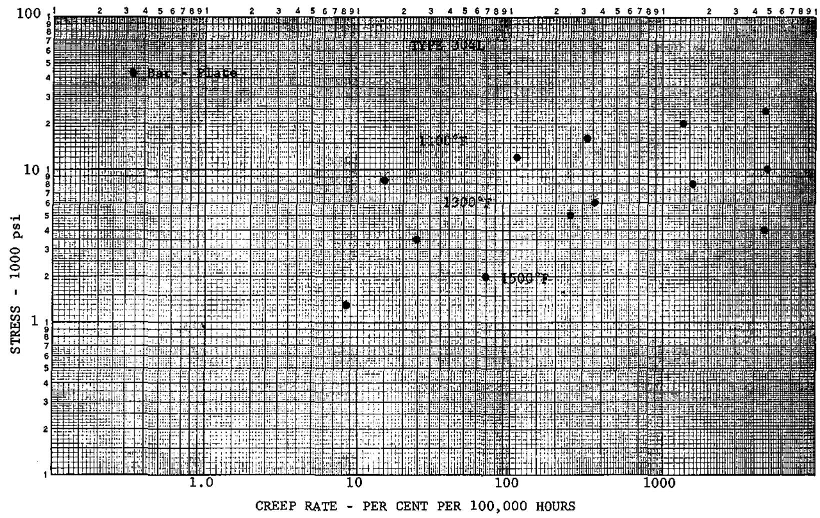

Fig. 17 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 304L

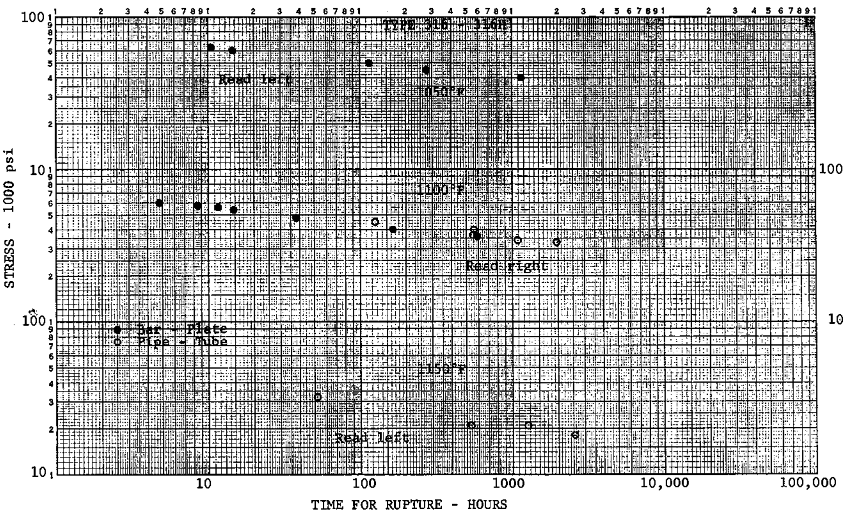

Fig. 18 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316-316H

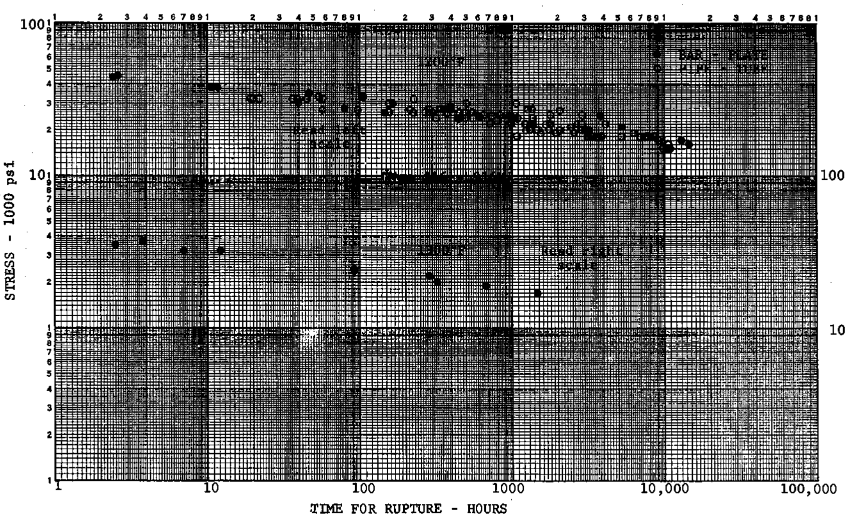

Fig. 18 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316-316H (Continued)

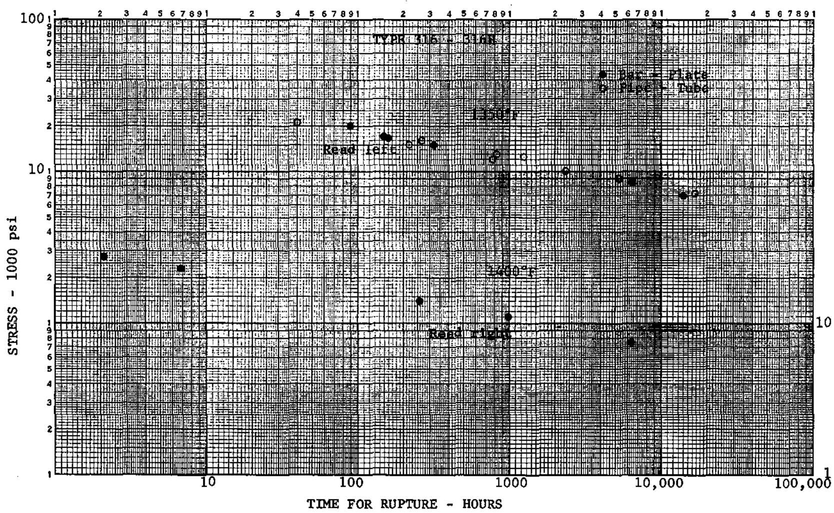

Fig. 18 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316-316H

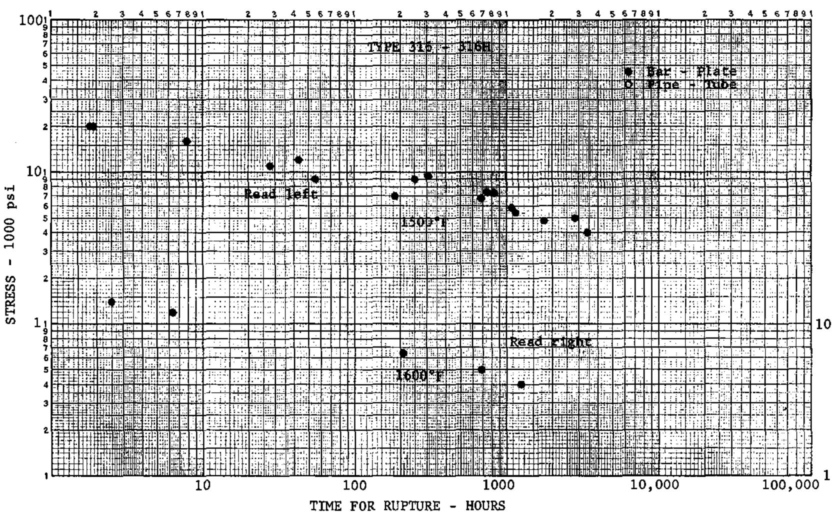

Fig. 18 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316-316H (Continued)

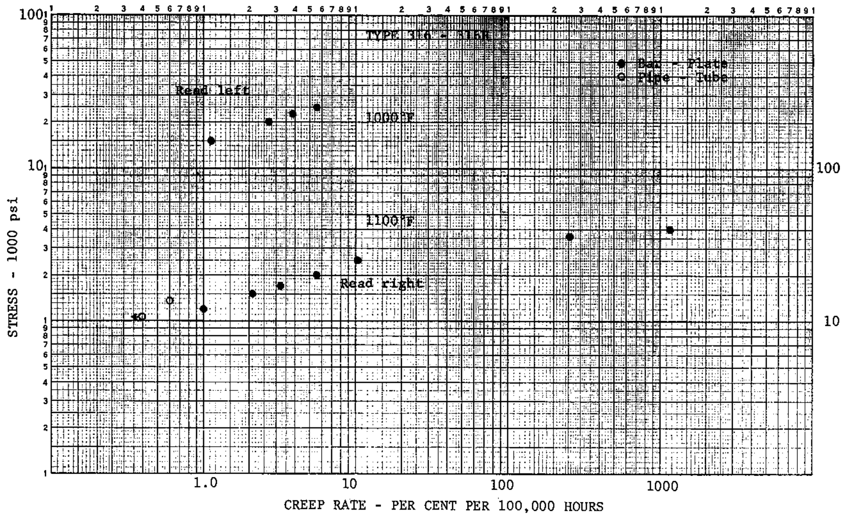

Fig. 18 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316-316H

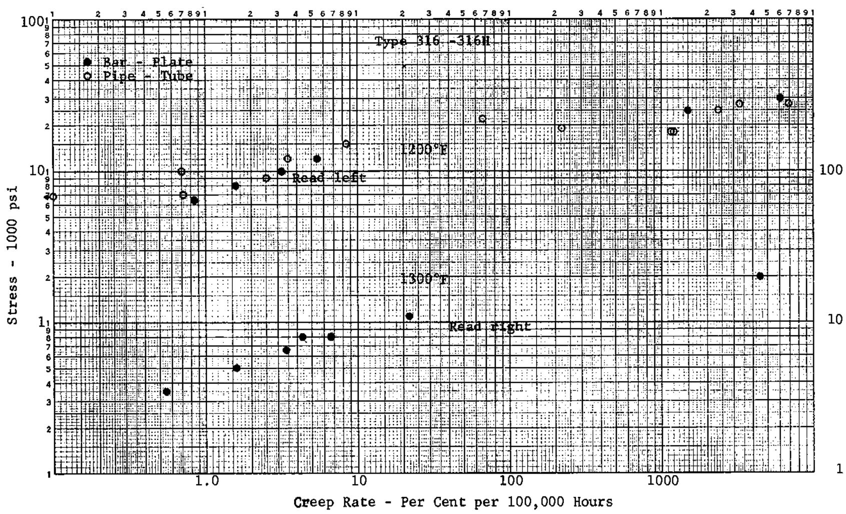

Fig. 18 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316-316H (Continued)

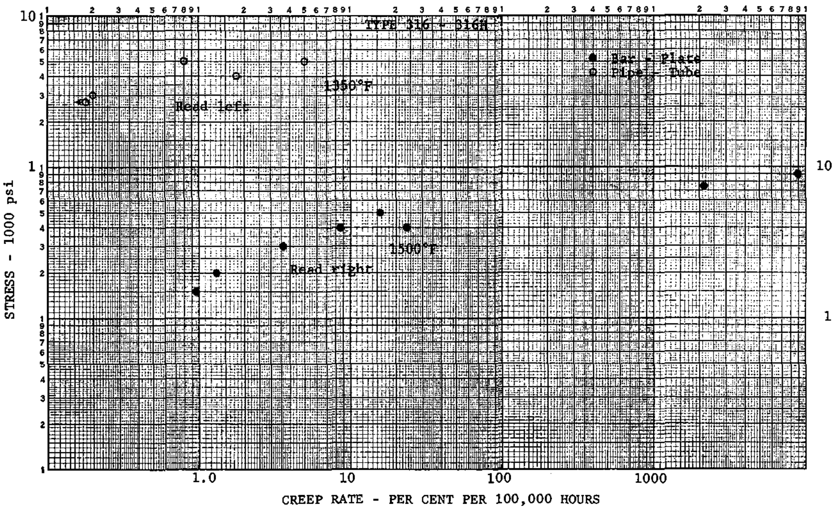

Fig. 18 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316-316H

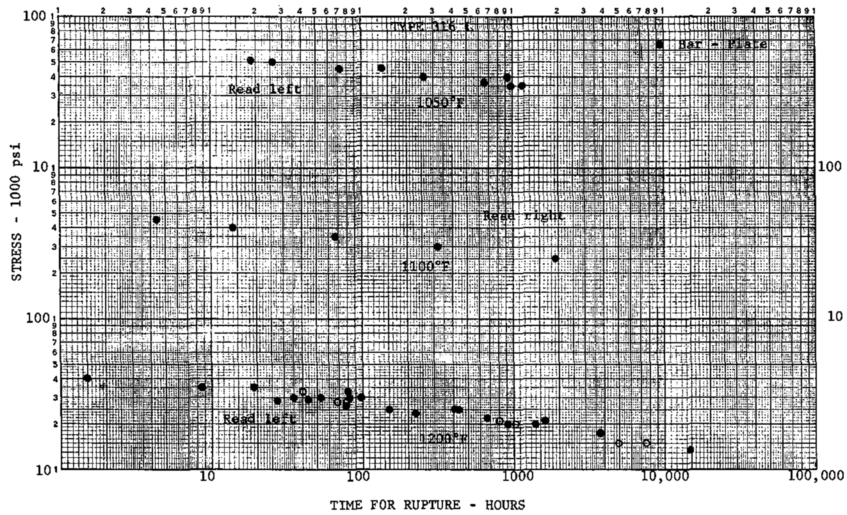

Fig. 19 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316L

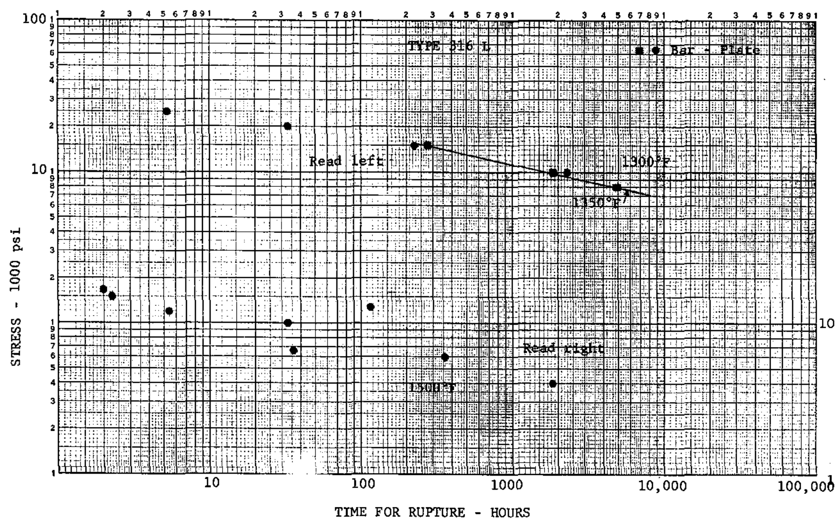

Fig. 19 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316L (Continued)

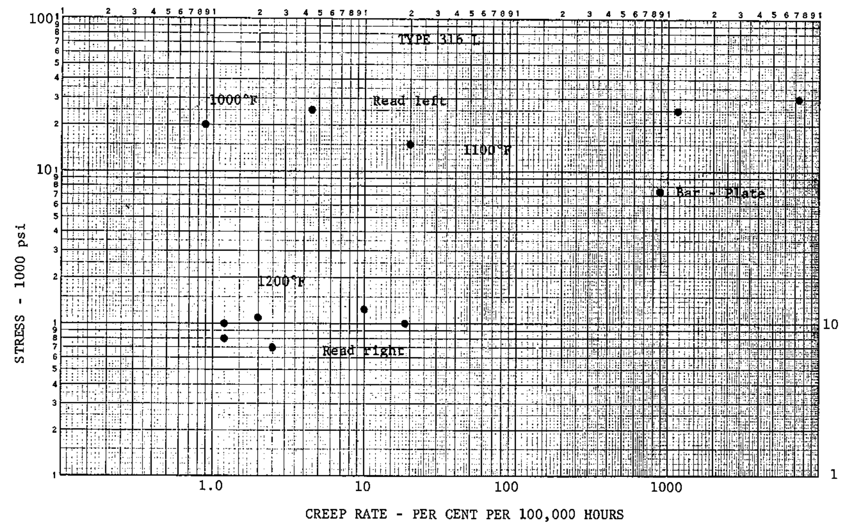

Fig. 19 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316L

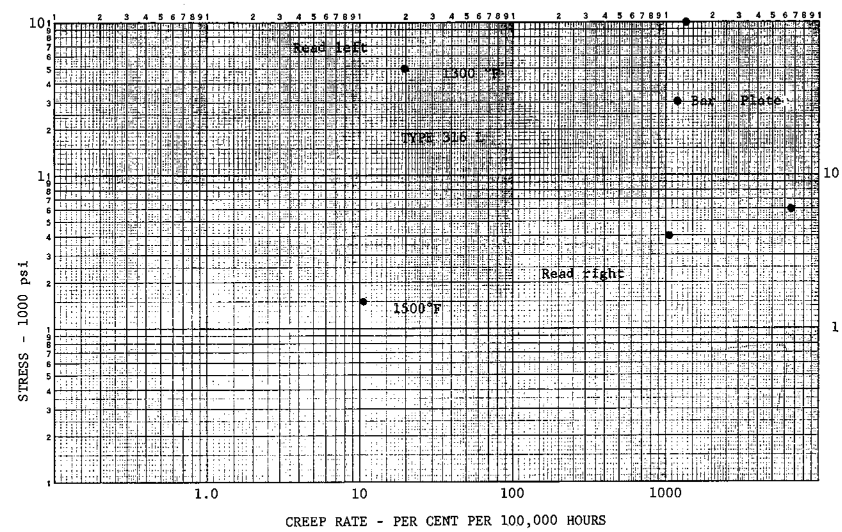

Fig. 19 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 316L

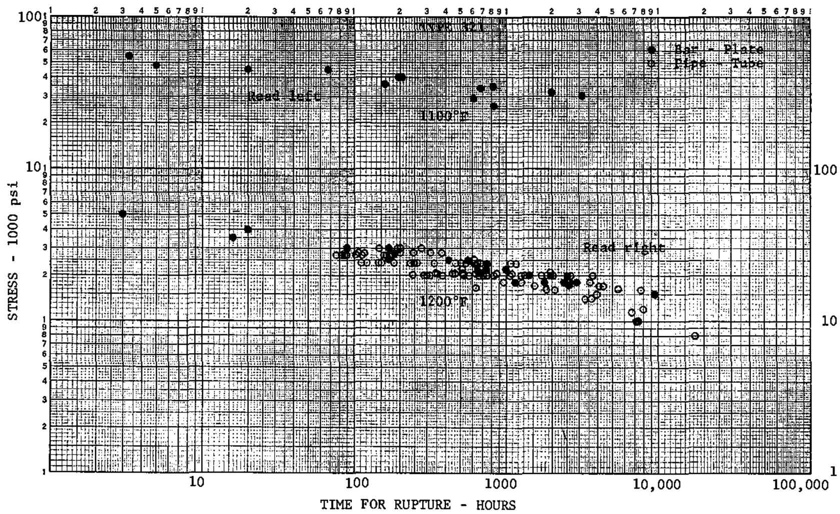

Fig. 20 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321

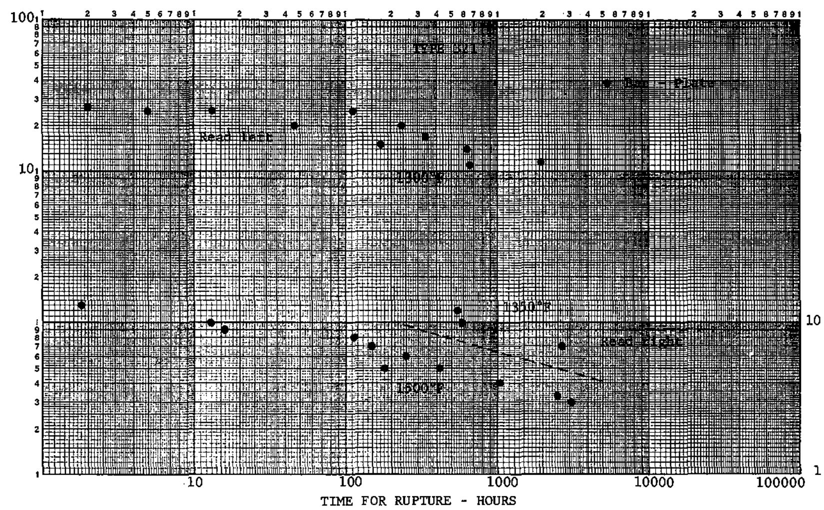

Fig. 20 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321 (Continued)

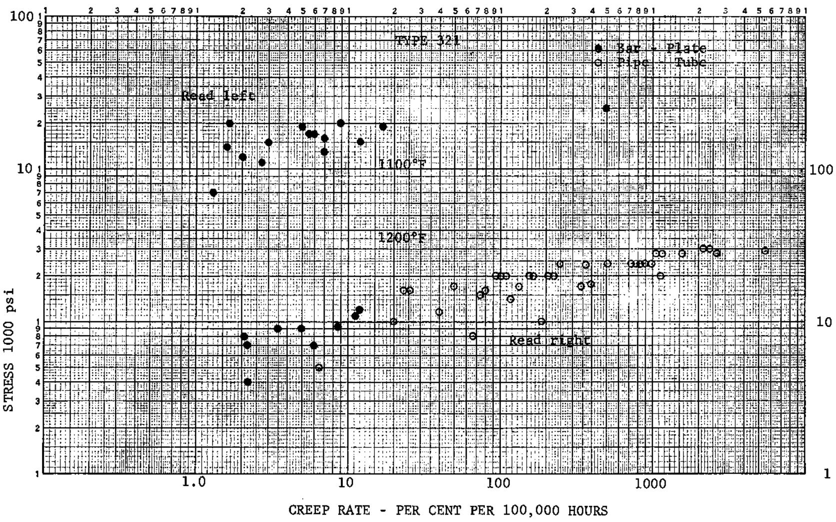

Fig. 20 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321

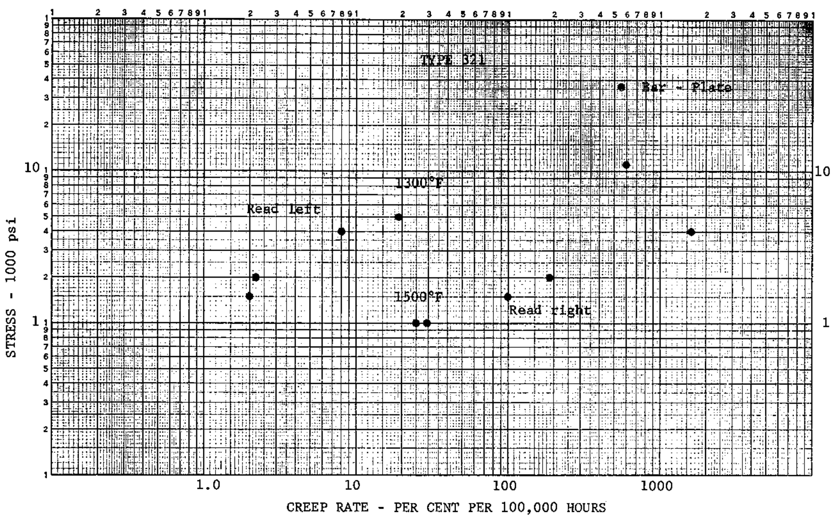

Fig. 20 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321

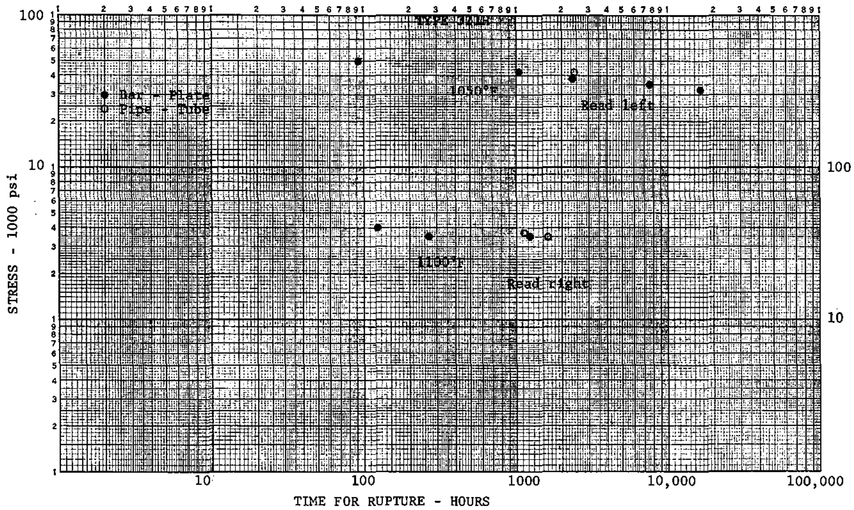

Fig. 21 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321H

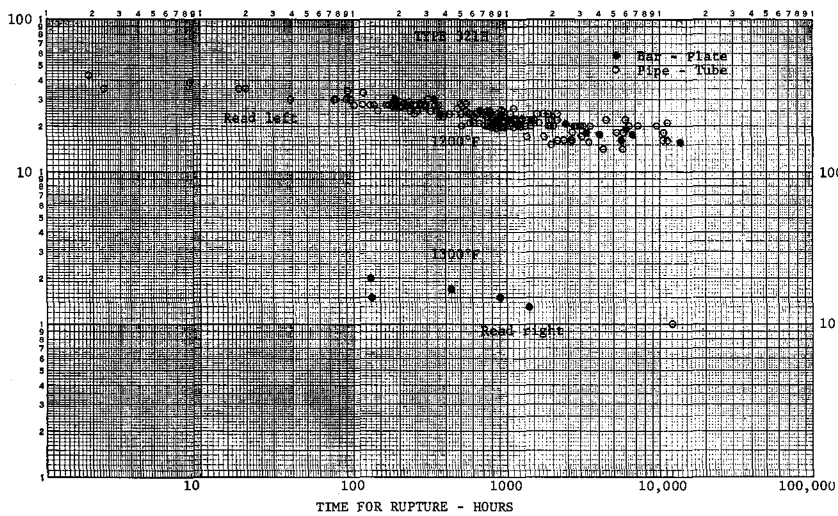

Fig. 21 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321H (Continued)

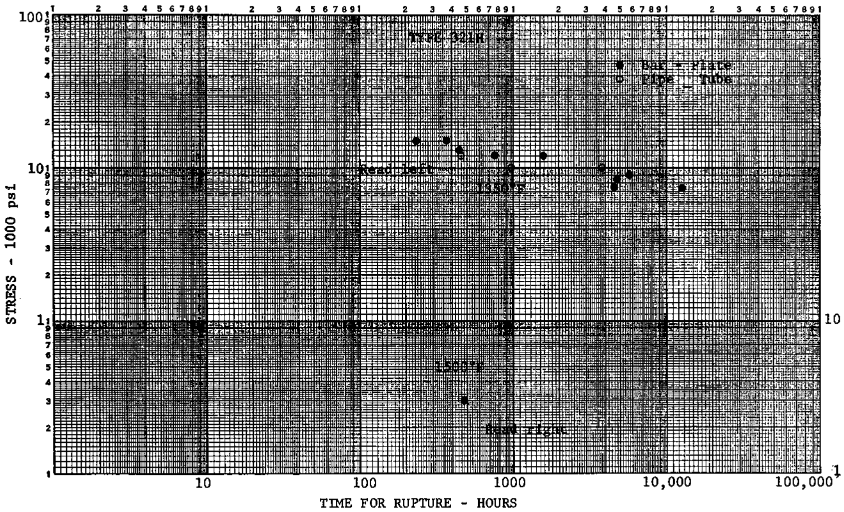

Fig. 21 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321H

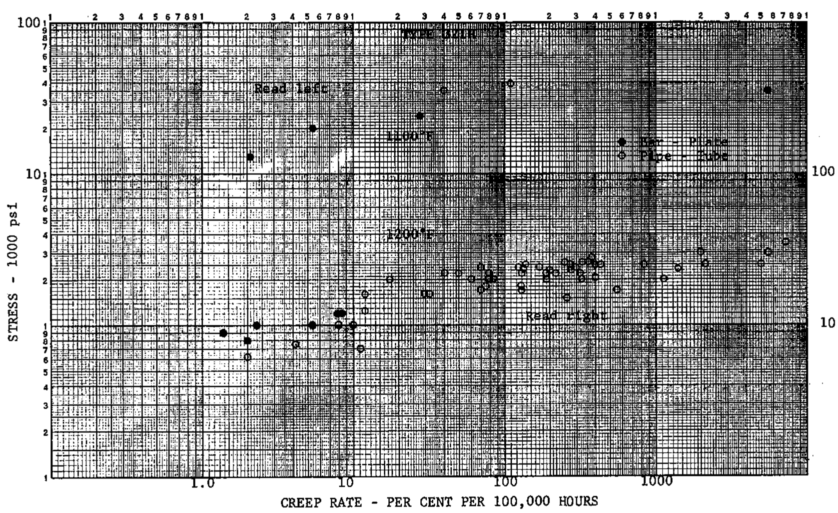

Fig. 21 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321H (Continued)

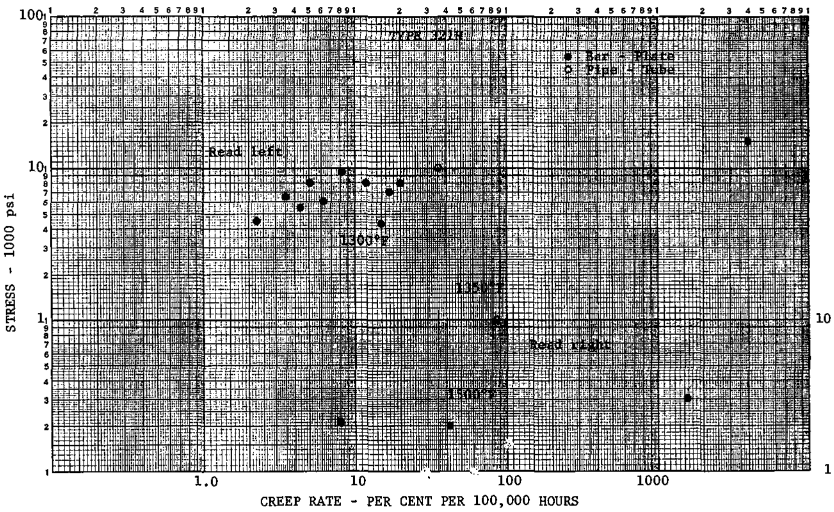

Fig. 21 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 321H

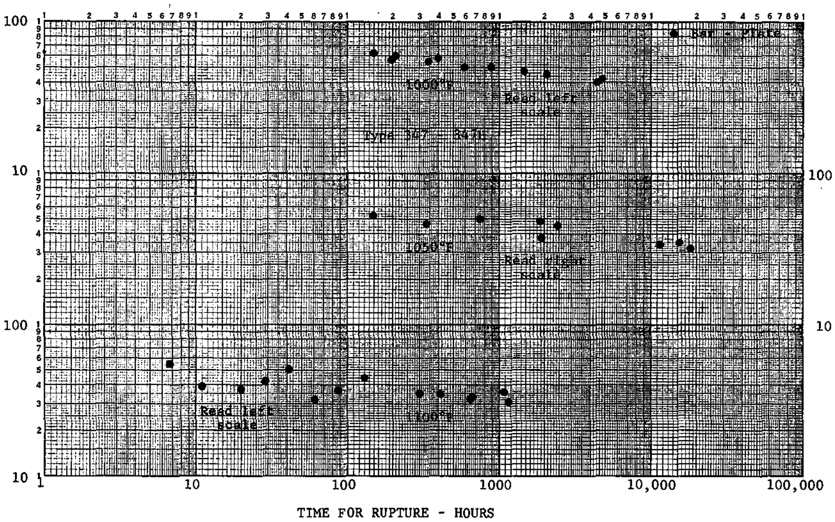

Fig. 22 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 347-347H

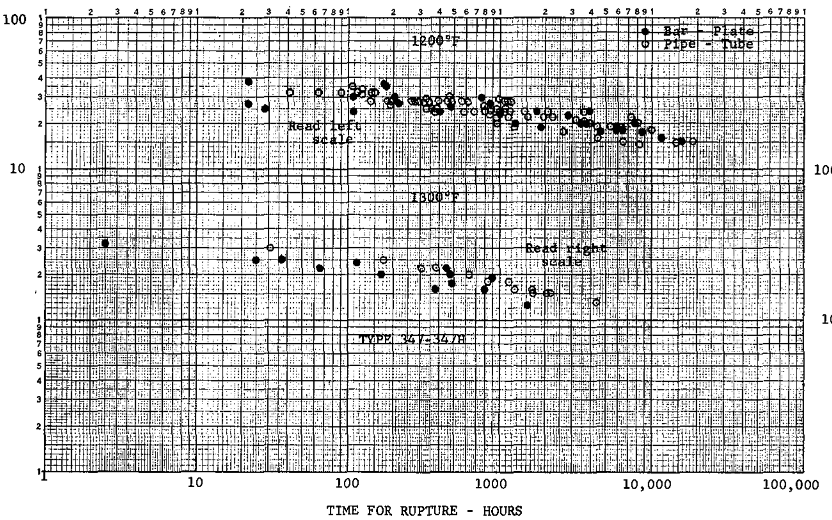

Fig. 22 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 347-347H (Continued)

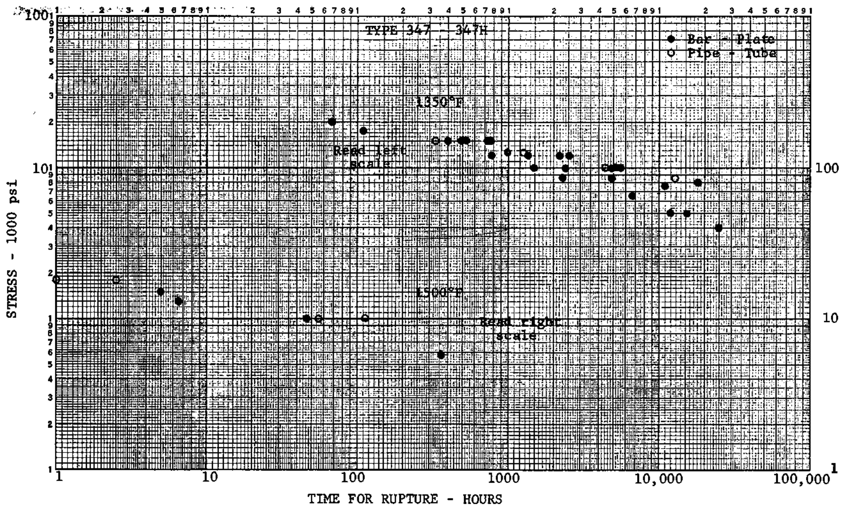

Fig. 22 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 347-347H

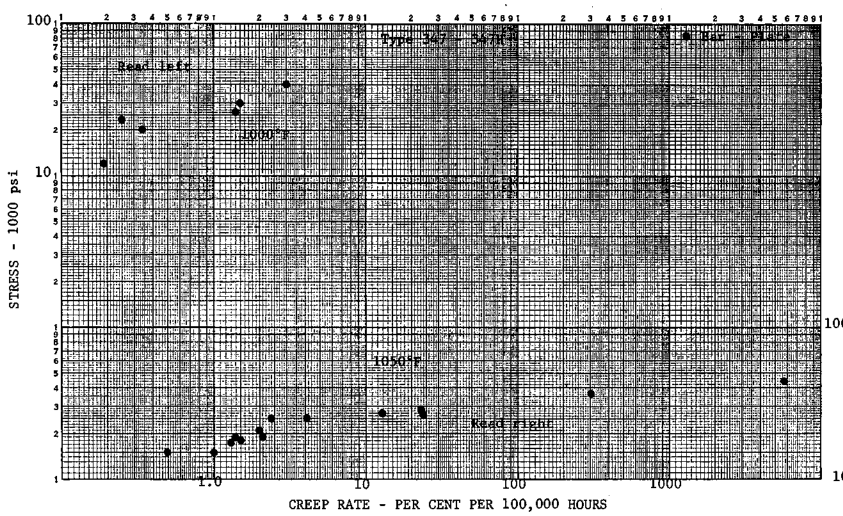

Fig. 22 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 347-347H (Continued)

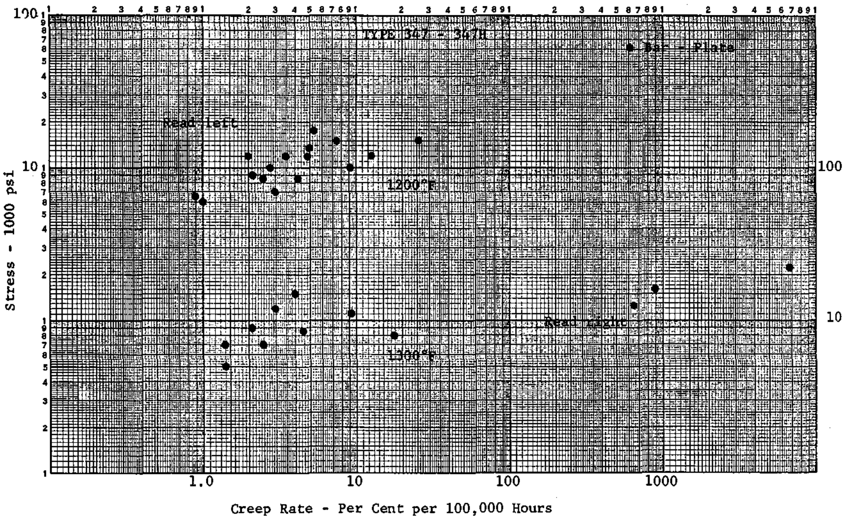

Fig. 22 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 347-347H

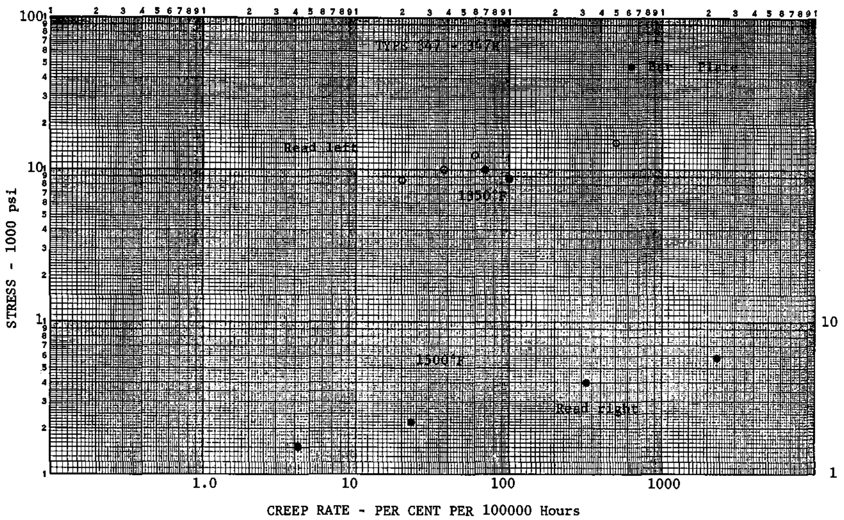

Fig. 22 - Log-log plots of stress vs time for rupture and stress vs secondary creep rate. Type 347-347H

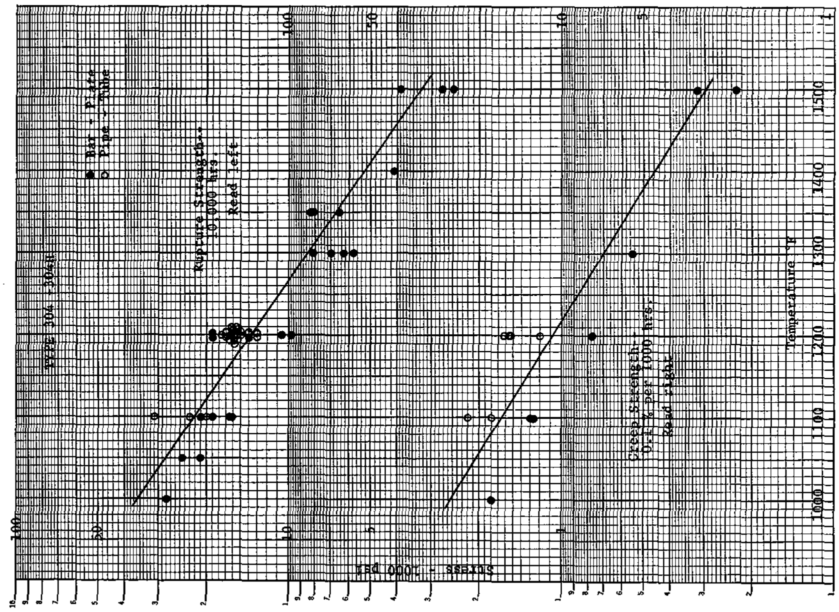

Fig. 23 - Variation of rupture strength (10,000 hours) and creep strength (0.1% per 1000 hours) with temperature.

a. Type 304-304H

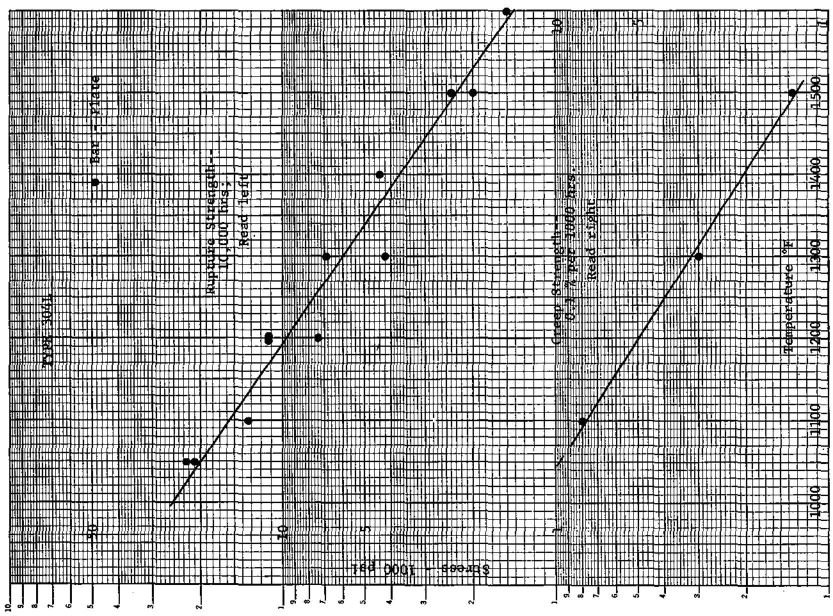

Fig. 23 - Variation of rupture strength (10,000 hours) and creep strength (0.1% per 1000 hours) with temperature.

b. Type 304L

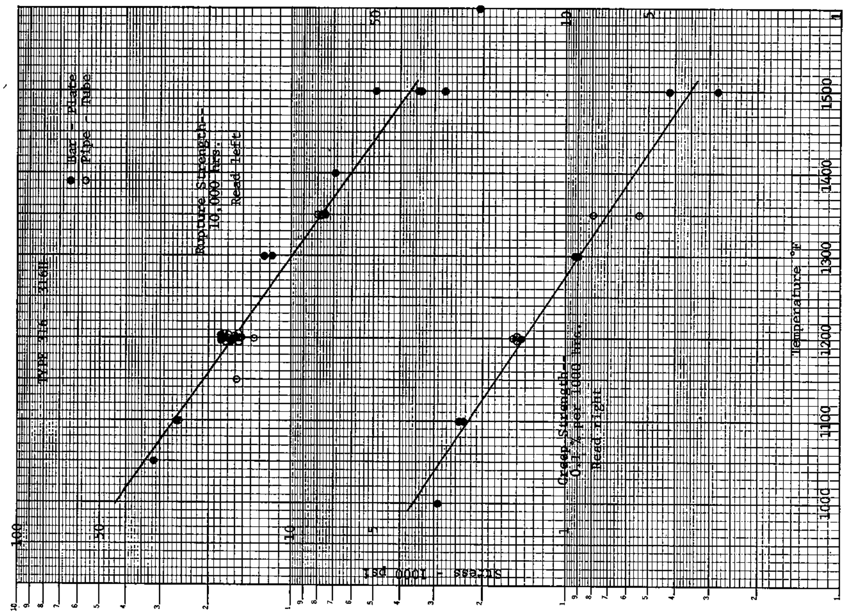

Fig. 23 - Variation of rupture strength (10,000 hours) and creep strength (0.1% per 1000 hours) with temperature.
c. Type 316-316H

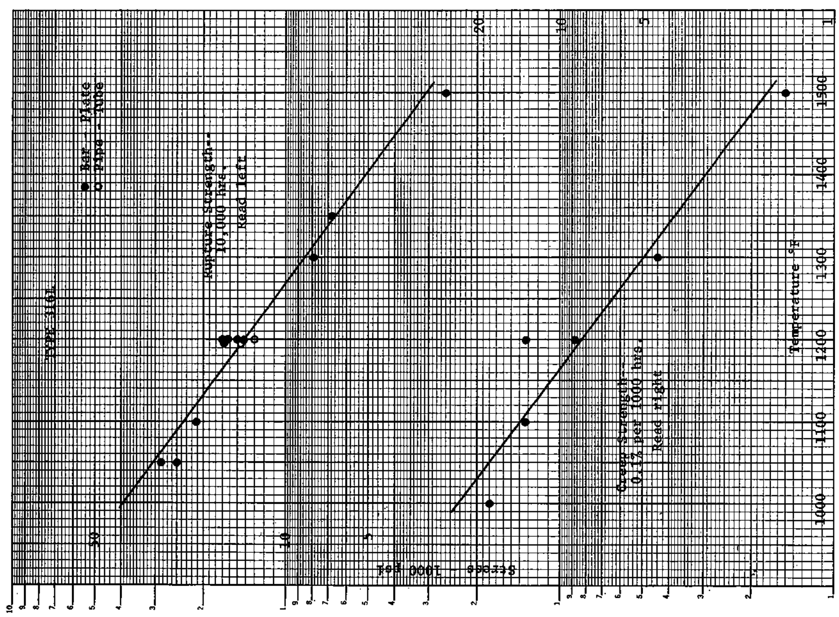

Fig. 23 - Variation of rupture strength (10,000 hours) and creep strength (0.1% per 1000 hours) with temperature.
d. Type 316L

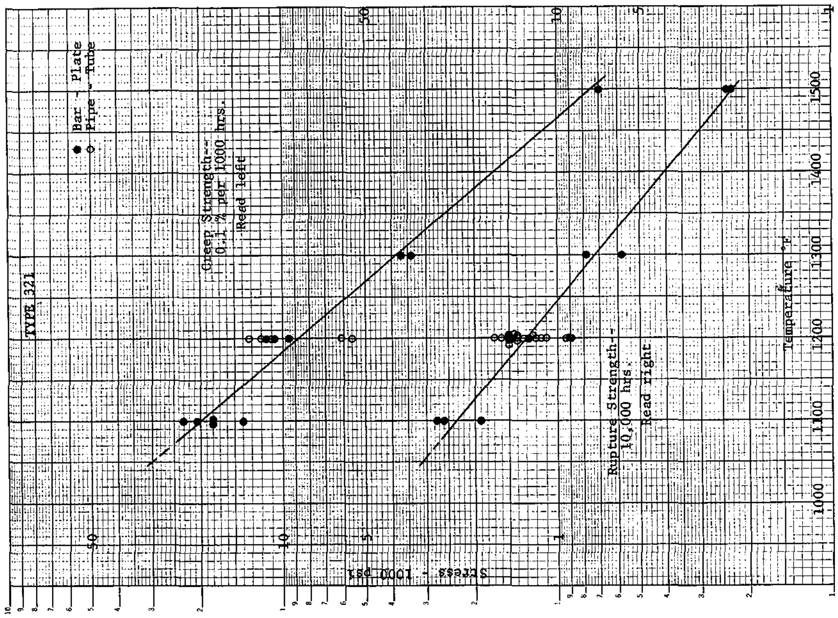

Fig. 23 - Variation of rupture strength (10,000 hours) and creep strength (0.1% per 1000 hours) with temperature.
e. Type 321

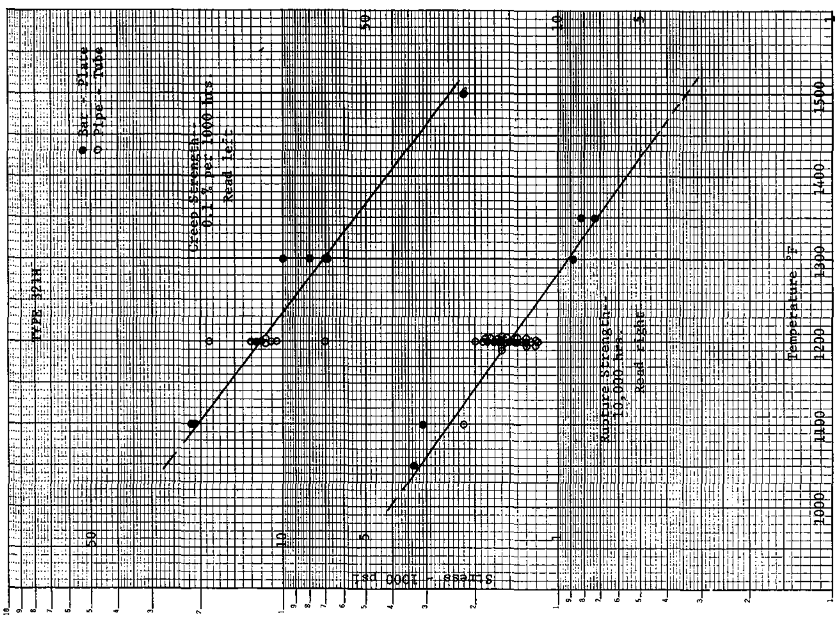

Fig. 23 - Variation of rupture strength (10,000 hours) and creep strength (0.1% per 1000 hours) with temperature.
f. Type 321H

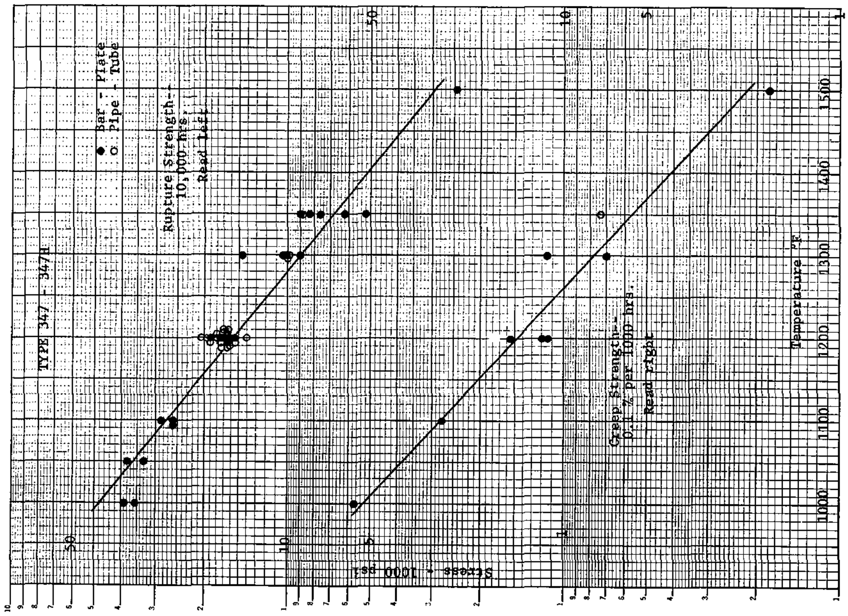

Fig. 23 - Variation of rupture strength (10,000 hours) and creep strength (0.1% per 1000 hours) with temperature.

g. Type 347-347H

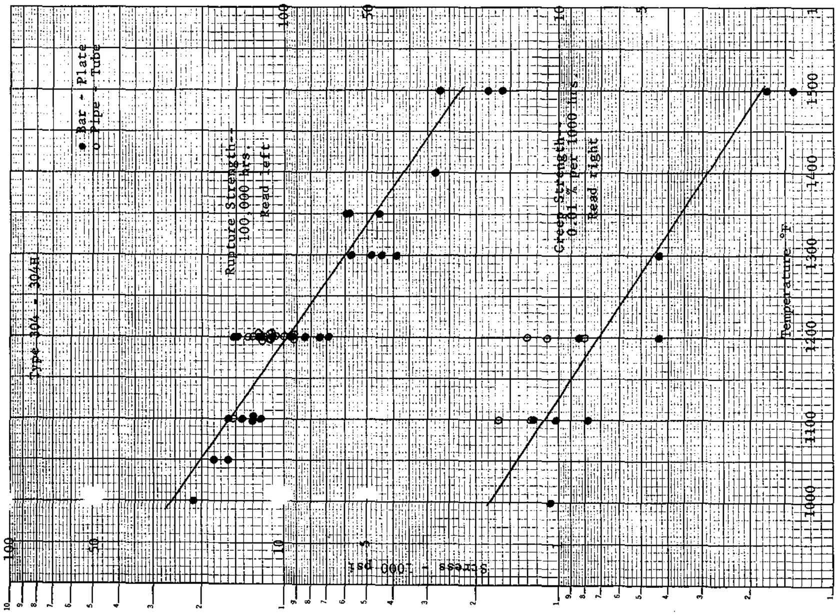

Fig. 24 - Variation of rupture strength (100,000 hours) and creep strength (0.01% per 1000 hours) with temperature.

a. Type 304-304H

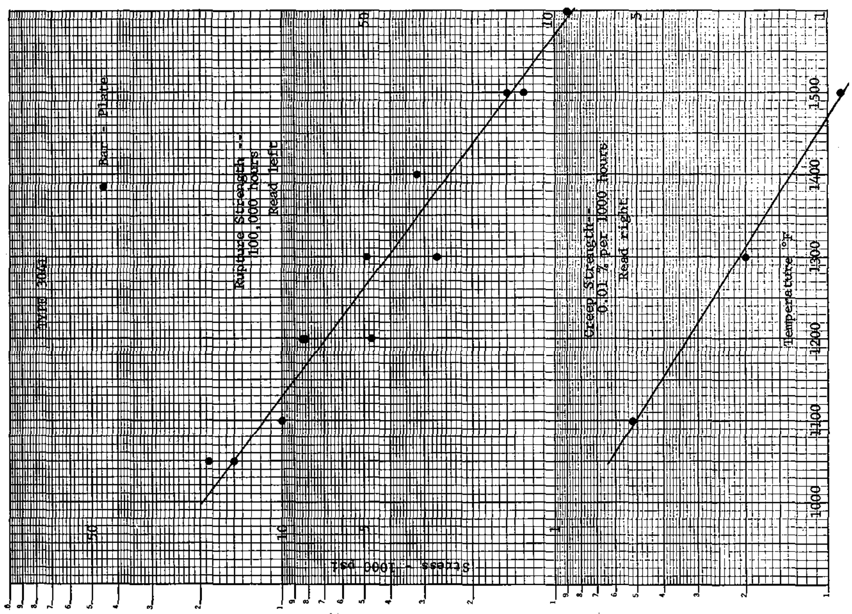

Fig. 24 - Variation of rupture strength (100,000 hours) and creep strength (0.01% per 1000 hours) with temperature.

b. Type 304L

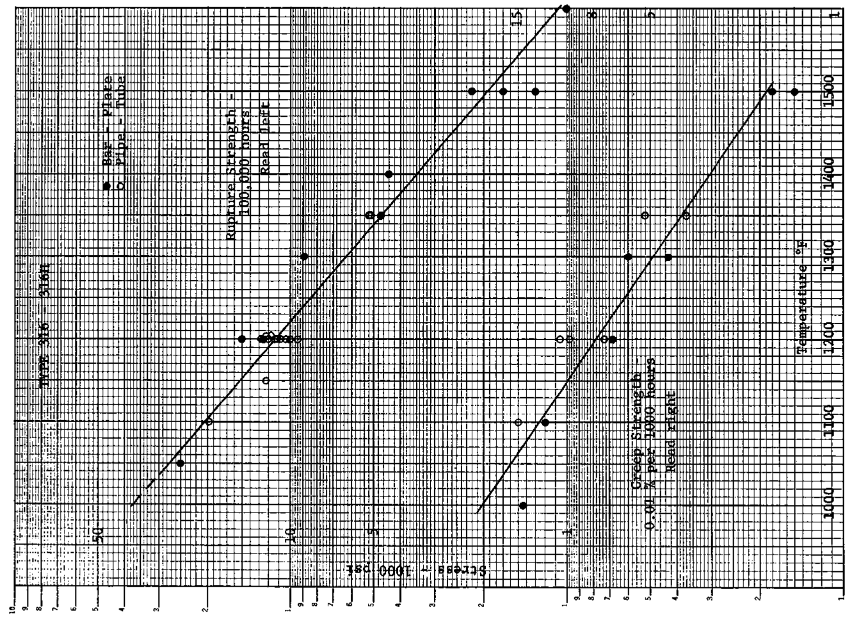

Fig. 24 - Variation of rupture strength (100,000 hours) and creep strength (0.01% per 1000 hours) with temperature.
c. Type 316-316H

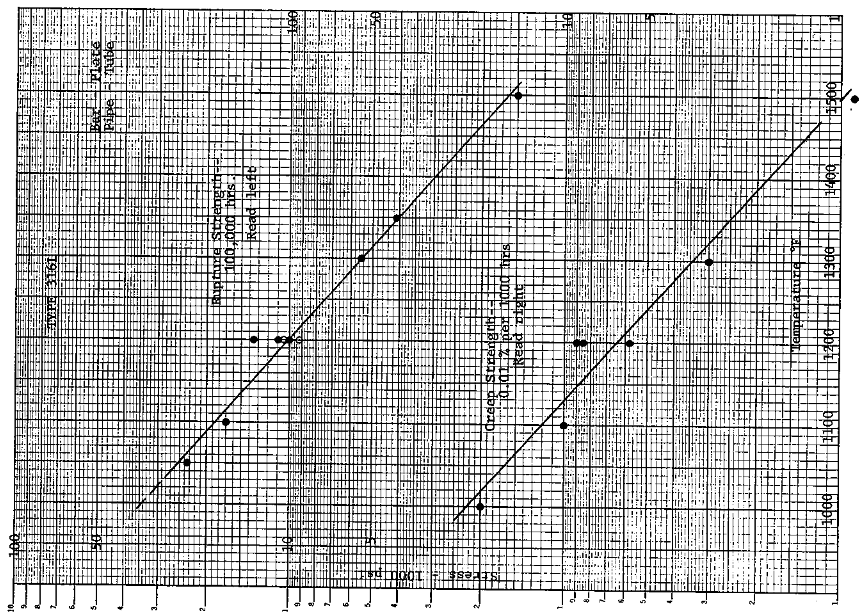

Fig. 24 - Variation of rupture strength (100,000 hours) and creep strength (0.01% per 1000 hours) with temperature.
d. Type 316L

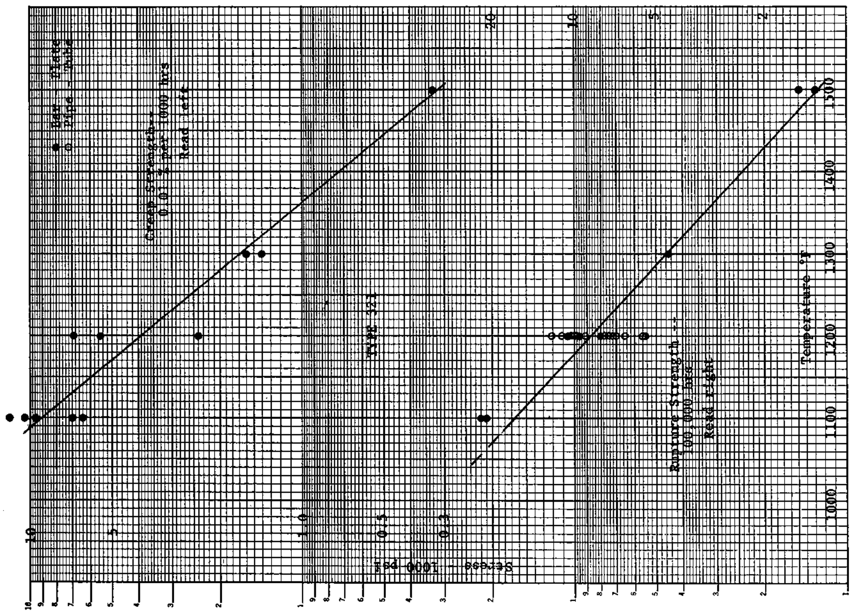

Fig. 24 - Variation of rupture strength (100,000 hours) and creep strength (0.01% per 1000 hours) with temperature.
e. Type 321

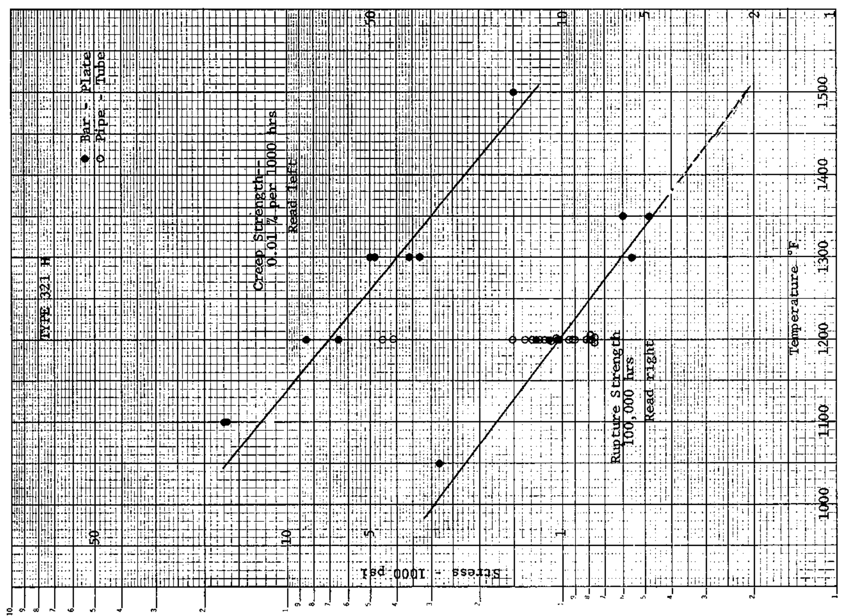

Fig. 24 - Variation of rupture strength (100,000 hours) and creep strength (0.01% per 1000 hours) with temperature.
f. Type 321H

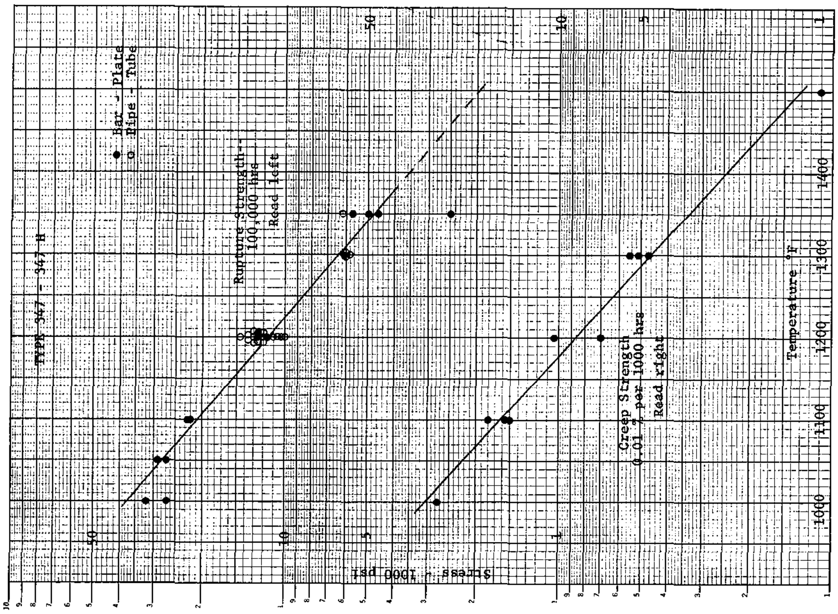

Fig. 24 - Variation of rupture strength (100,000 hours) and creep strength (0.01% per 1000 hours) with temperature.
g. Type 347-347H