STP-NU-019-1

VERIFICATION OF ALLOWABLE STRESSES IN ASME SECTION III SUBSECTION NH FOR GRADE 91 STEEL

ASME STANDARDS TECHNOLOGY, LLC

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Prepared by:

R. W. Swindeman
Cromtech Inc

M. J. Swindeman
University of Dayton Research Institute

B. W. Roberts
BW Roberts Consultants

B. E. Thurgood
Bpva Engineering

D. L. Marriott
Stress Engineering Services

ASME STANDARDS TECHNOLOGY, LLC

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Summary of Changes
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The following changes have been made to the first revision of STP-NU-019.

Rev. 1 Page	*Location*	*Change*
v-vi	Table of Contents	Updated to reflect changes
6	paragraph 2, line 1	Corrected from reference [15] to [14]
6	figure 2	Replaced with correct figure
7	figure 3	Replaced with correct figure
8	paragraph 2, line 2	Corrected "if" to "of"
8	paragraph 4, line 3	Corrected "Fave" to "F_{ave}"
9	equation (3)	Improved formatting
9	equation (4)	Improved formatting
9	equation (5)	Improved formatting
9	equation (6)	Improved formatting
10	paragraph 1, line 4	Correct "Cave" to "C_{ave}"
11	paragraph 1, line 4	Corrected from reference [13] to [14]
11	figure 7	Replaced with correct figure
12	figure 9	Replaced with correct figure
13	figure 12	Replaced with correct figure
14	paragraph 1, line 7	Corrected figure number from 4 to 14.

Rev. 1 Page	*Location*	*Change*
19	figure 20	Replaced with correct figure
20	figure 22	Replaced with correct figure
24	figure 24	Replaced with correct figure
31	title	Deleted “**FISH**” and “**B**” from title.
45	title	Deleted “**FISH**” and “**B**” from title.
76	figure 26	Replaced with correct figure
77	equation (11)	Improved formatting
77	equation (12)	Improved formatting
79	figure 30	Replaced with correct figure
81	paragraph 3, line 6	Replaced “105” with “100,000”
81	paragraph 3, line 8	Replaced “104” with “10,000”
82	equation (13)	Improved formatting
83	figure 31	Replaced with correct figure
96	figure 41	Replaced with correct figure

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FOREWORD

This document is the result of work resulting from Cooperative Agreement DE-FC07-05ID14712 between the U.S. Department of Energy (DOE) and ASME Standards Technology, LLC (ASME ST-LLC) for the Generation IV (Gen IV) Reactor Materials Project. The objective of the project is to provide technical information necessary to update and expand appropriate ASME materials, construction and design codes for application in future Gen IV nuclear reactor systems that operate at elevated temperatures. The scope of work is divided into specific areas that are tied to the Generation IV Reactors Integrated Materials Technology Program Plan. This report is the result of work performed under Task 1 titled "Verification of Allowable Stresses in ASME Section III, Subsection NH with Emphasis on Alloy 800H and Grade 91 Steel (a.k.a., 9Cr-1Mo-V or 'Modified 9Cr-1Mo')."

ASME ST-LLC has introduced the results of the project into the ASME volunteer standards committees developing new code rules for Generation IV nuclear reactors. The project deliverables are expected to become vital references for the committees and serve as important technical bases for new rules. These new rules will be developed under ASME's voluntary consensus process, which requires balance of interest, openness, consensus and due process. Through the course of the project ASME ST-LLC has involved key stakeholders from industry and government to help ensure that the technical direction of the research supports the anticipated codes and standards needs. This directed approach and early stakeholder involvement is expected to result in consensus building that will ultimately expedite the standards development process as well as commercialization of the technology.

ASME has been involved in nuclear codes and standards since 1956. The Society created Section III of the Boiler and Pressure Vessel Code, which addresses nuclear reactor technology, in 1963. ASME Standards promote safety, reliability and component interchangeability in mechanical systems.

The American Society of Mechanical Engineers (ASME) is a not-for-profit professional organization promoting the art, science and practice of mechanical and multidisciplinary engineering and allied sciences. ASME develops codes and standards that enhance public safety and provides lifelong learning and technical exchange opportunities benefiting the engineering and technology community. Visit www.asme.org.

The ASME Standards Technology, LLC (ASME ST-LLC) is a not-for-profit Limited Liability Company, with ASME as the sole member, formed to carry out work related to newly commercialized technology. The ASME ST-LLC mission includes meeting the needs of industry and government by providing new standards-related products and services, which advance the application of emerging and newly commercialized science and technology and providing the research and technology development needed to establish and maintain the technical relevance of codes and standards. Visit www.stllc.asme.org for more information.

ABSTRACT

Part I Base Metal - The database for the creep-rupture of 9Cr-1Mo-V (Grade 91) steel was collected and reviewed to determine if it met the needs for recommending time-dependent strength values, St, for coverage in ASME Section III Subsection NH (ASME III-NH) to 650˚C (1200˚F) and 600,000 hours. The accumulated database included over 300 tests for 1% total strain, nearly 400 tests for tertiary creep and nearly 1700 tests to rupture. Procedures for analyzing creep and rupture data for ASME III-NH were reviewed and compared to the procedures used to develop the current allowable stress values for Gr 91 for ASME II-D. The criteria in ASME III-NH for estimating St included the average strength for 1% total strain for times to 600,000 hours, 80% of the minimum strength for tertiary creep for times to 600,000 hours and 67% of the minimum rupture strength values for times to 600,000 hours. Time-temperature-stress parametric formulations were selected to correlate the data and make predictions of the long-time strength. It was found that the stress corresponding to 1% total strain and the initiation of tertiary creep were not the controlling criteria over the temperature-time range of concern. It was found that small adjustments to the current values in III-NH could be introduced but that the existing values were conservative and could be retained. The existing database was found to be adequate to extend the coverage to 600,000 hours for temperatures below 650˚C (1200˚F).

Part II Weldments - A creep-rupture database that was used to develop stress rupture factors (SRFs) in ASME Section III Subsection NH (ASME III-NH) for weldments of 9Cr-1Mo-V (Gr 91) steel was reassembled. The intent was to review the original work, supplement the database with newer data and validate the applicability of the SRFs to longer time service to meet the needs for the Generation IV nuclear reactor materials program. After a review of the augmented database, approximately 85 of 200 data on weld metal and weldments were selected for the re-evaluation of SRFs. Data were processed using a lot-centered Larson Miller parametric analysis similar to the model used to correlate stress-rupture data for base metal. It was found that the weldments did not follow the same stress dependency in stress-rupture as base metal. As a result, the SRF values depended on both time and temperature. Some SRF values were estimated, but the long-time, low-stress SRF values were found to be lower than those values which formed a basis for the SRFs in 2007 ASME III-NH. Moreover, the lack of long-time data above 540˚C (1000˚F) made the database unsuitable for the estimation of SRFs for application to all the St values covered in ASME III-NH. The coverage needed for the Generation IV nuclear pressure vessels, however, was expected to be for temperatures below 540˚C (1000˚F). A review of European and Asian work on Gr 91 weldments provided helpful information in this respect. Although significant differences in behavior were reported from one research effort to another, special notice was taken of recent work in Japan to develop weld strength reduction factors (WSRFs) for use in the fossil and petrochemical industries. Here, the WSRFs were based on stress-rupture models applicable to welded components for long-time service to at least 600˚C (1110˚F). Further testing of Gr 91 weldments for long times and low stresses was recommended.

PART I - BASE METAL

1 INTRODUCTION

A three-year collaborative effort has been established between the Department of Energy (DOE) and the American Society of Mechanical Engineers (ASME) to address technical issues related to codes and standards applicable to the Generation IV Nuclear Energy Systems Program [1]. A number of tasks have been identified that are managed through the ASME Standards Technology, LLC (ASME ST-LLC) and involve significant industry, university and independent consultant activities. One of the tasks is the Verification of Allowable Stresses in ASME Section III, Subsection NH with Emphasis an Alloy 800H and Grade 91 Steel. The subtask on 9Cr-1Mo-V (Gr 91) steel involves both the verification of the current allowable stresses and the assessment of the data needed, if any, to extend the ASME Section III coverage of Gr 91 steel to 600,000 hours at 650˚C (1200˚F). To this end, a review and re-analysis is provided here that identifies data sources and analytical procedures that have been used in code-related work on Gr 91.

2 IDENTIFICATION OF MATERIALS

Grade 91 steel is one of several ferritic/martensitic and ferritic/bainitic steel of interest for the Generation IV pressure vessel. ASME III-NH identifies the permitted SA specifications and associated product forms for Gr 91 in Table I-14.1 (a). Included are forgings (SA-182), seamless tubing (SA-213), seamless pipe (SA-335) and plate products (SA-387). Specifications for similar products produced in Asia and Europe have similar chemistry requirements and are considered to be equivalent to the SA specifications. Thus, data produced on Gr 91 have been assembled into a single database without regard to country of origin.

Table 1 - Chemical Specifications for Grade 91 (wt %)

Element	SA-182*	SA-213*	SA-387*	EN 10216-2
C	0.08-0.12	0.08-0.12	0.08-0.12	.08-0.12
Mn	0.30-0.60	0.30-0.60	0.30-0.60	0.30-0.60
P	0.020max	0.020max	0.020max	0.020max
S	0.010max	0.010max	0.010max	0.010max
Si	0.20-0.50	0.20-0.50	0.20-0.50	0.20-0.50
Ni	0.40max	0.40max	0.40max	0.40max
Cr	8.0-9.50	8.0-9.50	8.0-9.50	8.0-9.5
Mo	0.85-1.05	0.85-1.05	0.85-1.05	0.85-1.05
Cb	0.06-0.10	0.06-0.10	0.06-0.10	0.06-0.10
N	0.03-0.070	0.03-0.070	0.03-0.070	0.03-0.07
Al	0.04max	0.04max	0.02max	0.04max
V	0.18-0.25	0.18-0.25	0.18-0.25	0.18-0.25
Ti			0.01max	
Zr			0.01max	

*Note: 2007 ASME Section II Part A for SA specifications

3 AVAILABLE SOURCES FOR CREEP-RUPTURE DATA

A development program on 9Cr-1Mo-V steel was undertaken by Combustion Engineering in 1975. The property goals for the material were outlined by Patriarca, et al. in 1976 [2], and a screening program was undertaken to reach these goals by optimizing carbide formers, identifying the best levels for nitrogen and nickel, minimizing δ-ferrite content and optimizing the "consolidation practice" on impact properties. Twenty-six experimental heats and one commercial heat were examined, and a report on these by Combustion Engineering in 1976 was the first to provide a significant listing of tensile and creep-rupture tests on both experimental and commercial lots of Gr 91 [3]. Here, Bodine, et al. provided data for time to 1% creep, tertiary creep and rupture life for three lots to approximately 6000 hours and temperatures to 650˚C (1200˚F) and Roberts produced a preliminary estimate of stress intensities S_m and St to 300,000 hours. From 1975 to the mid-1990s, the U.S. Department of Energy supported further mechanical testing of Gr 91, and the Oak Ridge National Laboratory (ORNL) assumed the management of the technology program. In parallel, intensive investigations were undertaken in Europe and Asia to qualify the material for usage in power-generating applications as a replacement for austenitic stainless steels in the temperature range from 550 to 650˚C (1020 to 1200˚F). In November 1981, an expanded data package was prepared by ORNL to meet the ASTM specification requirements and to qualify the material for insertion into power boilers on a trial basis. A data package for plate, bar and tube products was submitted for ASME Section I and Section VIII, Division 1 acceptance in June 1982. At that time there were seven commercial heats, two of which were re-melts, and fifteen lots of plate, bar and tubing. The creep-rupture database included over 80 rupture tests extending to as long as 20,000 hours. In November 1984, the data package was prepared for submission to ASME Section III with estimated stress intensities for Code Case N-47. Data for hot-extruded pipe and forgings were added along with data for commercial tubing produced in Japan. The expanded database included about 180 tests on fourteen heats and many lots. No data produced in Europe or Asia were included in the submission to ASME Section III. Material representations for the estimation of stress intensities for a draft CC for N-47 were produced by Sikka and Booker [4], [5]. Data were received from the Japan Atomic Power Co. for inclusion into the database [6].

In 1992, the allowable stresses in ASME II-D were challenged by the Europeans. A collection of stress-rupture data from U.S., European and Asian sources was undertaken by the Metal Properties Council (MPC) [7], [8], and a re-analysis of the data produced some changes in the allowable stresses in ASME Section II-D that were applicable for Section I and Section VII, Division I construction [9]. These allowable stresses were based on the criteria in ASME Section II, Appendix 1. In response, some changes were made to draft CC for N-47, although the criteria for setting stress intensities differed from Section II-D and the MPC database upon which the stresses were based was not provided. One notable item was that the stress lines in ASME II-D Table 1A for Gr 91 products ≥ 75 mm (3 in.) listed lower values than thinner products in the temperature range of 550 to 600˚C (1020 to 1100˚F). Except for Table I-14.2 (So values), the draft CC for N-47 was not changed to reflect the product thickness distinction. The database available for use in the evaluation of stress intensities for N-47 was expanded in 1993 by the addition of the German stress-rupture database [7] and the Japanese database [8]. However, no data for time to 1% creep or time to tertiary creep was accumulated. In 1995, the European developed a database, incorporating the U.S. and Japanese data as well as their own and set values for the average rupture strength that have not changed to this day [10]. More recently, additional data provided by the Japan Atomic Power Co. [11], the National Institute for Materials Science (NIMS) [12], [13], the Japan Nuclear Development Institute [13] and Europe [13] have become available.

4 GENERAL TRENDS IN THE CREEP BEHAVIOR OF GR 91 STEEL

A typical creep curve that forms the basis for the rules in Subsection NH is sketched in Figure 1 [15]. This curve is separated into three stages of creep, labeled "primary creep stage," "secondary creep stage" and "tertiary creep stage." The "components" of the total strain are assigned the identities illustrated in the figure: "elastic-plastic strain," "primary creep strain" and "secondary creep strain." The intercept strain shown in Figure 1 implies an exhaustion or limit to the primary creep component. The difference between this intercept strain and the elastic-plastic strain, identified as the primary creep strain in Figure 1, is often called the "transient strain limit." It should be noticed that the creep curve intercepts 1% total strain before transient creep is exhausted and the time to 1% strain ($t_{1\%}$) may be short relative to the rupture life (t_R) An important term not included in Figure 1 is the minimum creep rate (mcr). The product of the mcr and time has the same definition as the secondary creep component in Figure 1. This product is sometimes called the Monkman-Grant strain [16]. Another important term that is included in Figure 1 but not in reference 15 is the 0.2% offset tertiary creep strain and time. The strain and time (t_3) for tertiary creep are obtained from the creep curve at a point that is 0.2% above the extension of the secondary creep line [17]. Clearly, tertiary creep starts before the 0.2% offset limit is reached. A significant tertiary creep stage is shown in the Figure 1. However, the presence of necking and cracking beyond 5% strain complicates the interpretation of a tertiary creep component.

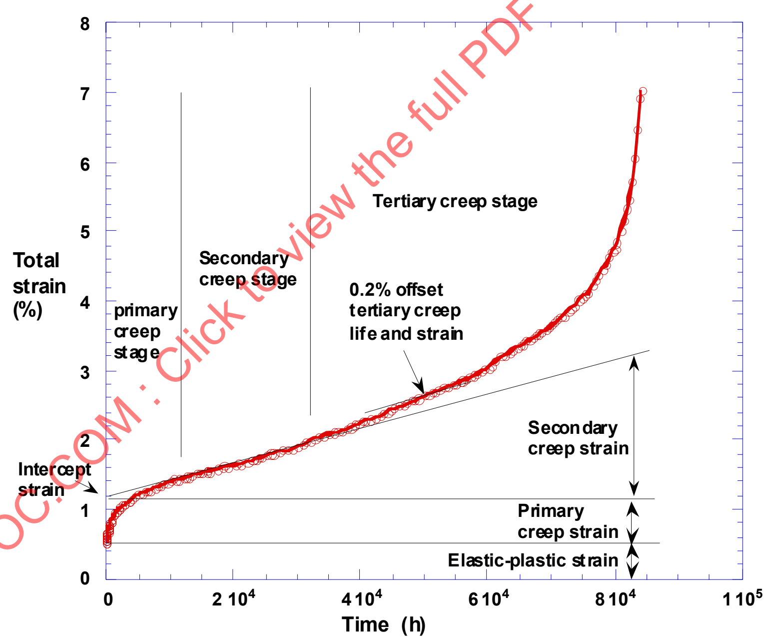

Figure 1 - Definitions for Components of Creep used in ASME Section III Subsection NH

5 CHARACTERISTICS OF THE CREEP DATABASE FOR ALLOY GR 91

The database assembled for the verification of allowable stresses in ASME III-NH provides information bearing on the three criteria in ASME III-NH that relate to time-dependent stress limits: time to 1% to strain ($t_{1\%}$); time to initiate tertiary creep (t_3); and time to rupture (t_R). With respect to the time to $t_{1\%}$, the bulk of the data were extracted from the U.S. database with additional data from the NIMS report [13]. The data in the U.S. database were entered as the time to 1% creep strain rather than time to 1% total strain. The NIMS database reported both time to 1% creep strain and time to 1% total strain. The ratio of these two times was found to be proportional to the applied stress. This ratio was used to convert the times in the U.S. database to times to 1% total strain. The distribution of data is shown in Figure 2. Altogether, a total of 312 values for $t_{1\%}$ creep were available. These were distributed from 450 to 780˚C (840 to 1435˚F) with times to 25,000 hours. Most data fell between 500 and 650˚C (930 and 1200˚F) at times below 5000 hours.

A substantial database for $t_{1\%}$ exists within the European database [14]. These were distributed more-or-less evenly at 550, 600 and 650˚C (1020, 1110 and 1200˚F) with a few short time data at 700˚C (1292˚F). The European data were not included in the database used to validate the ASME III-NH stress intensity values.

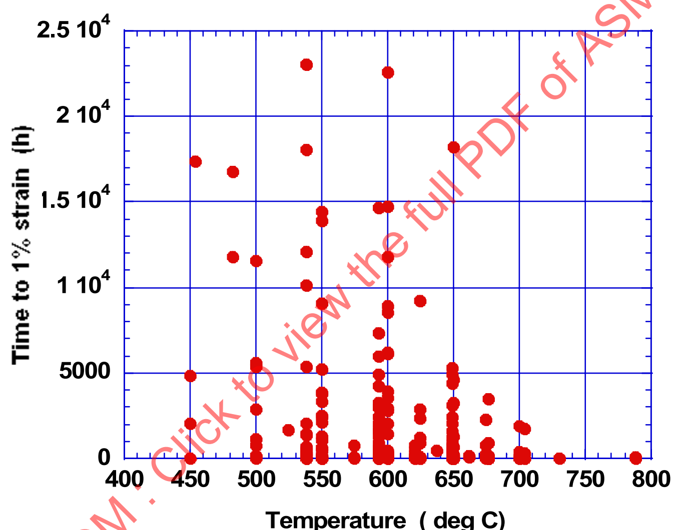

Figure 2 - Distribution of Time to 1% Strain ($t_{1\%}$) Data with Temperature

With respect to the time to t_3, the bulk of the data were extracted from the U.S. database and the Japanese institutions [6], [12], [13]. The distribution of data is shown in Figure 3. Altogether, a total of 398 values for t_3 creep were available. These were distributed from 450 to 780˚C (840 to 1435˚F) with times to 60,000 hours. Most data fell between 500 and 650˚C (930 and 1200˚F) at times less than 20,000 hours.

The database for rupture was large and included US, European, and Asian contributions. The distribution of data is shown in Figure 4. Over 1700 rupture data existed in the temperature of 450 to 780˚C (840 to 1735˚F) with most data between 450 and 700˚C (840 and 1292˚F). Products included tubes, pipes, plates, forging, and a billet. Product thicknesses ranged from 6 to 550 mm (1/4 to 21 in.).

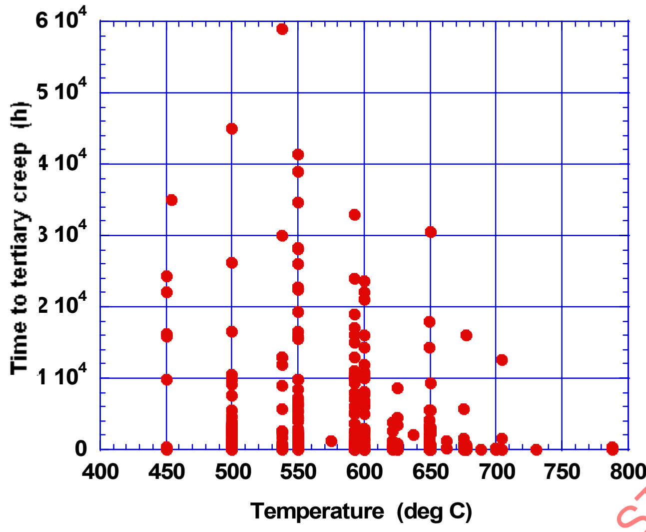

Figure 3 - The Distribution of the Time to T3 Data with Temperature

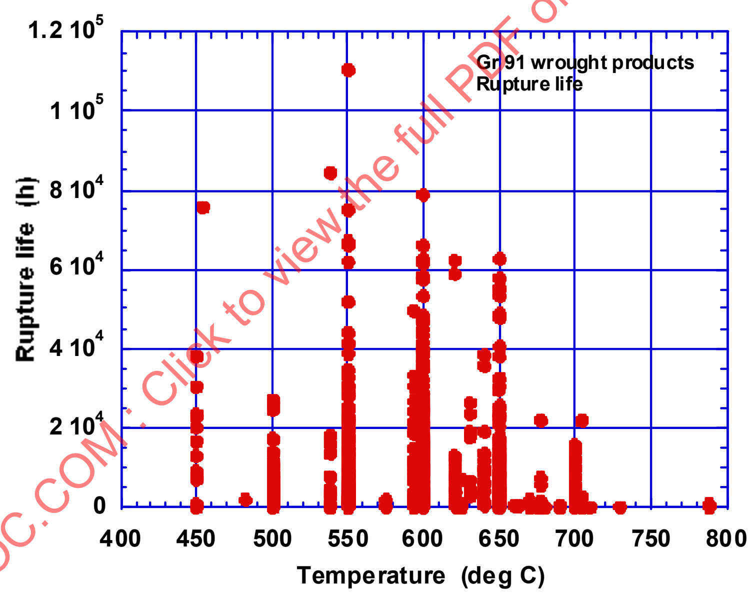

Figure 4 - The Distribution of the Time Rupture Data with Temperature

6 DATA ANALYSIS PROCEDURES

6.1 Criteria for Setting S_t Values

The criteria for setting allowable stresses for ASME Section I and Section II (identified in Appendix 1 in Section II-D) differ from the criteria for setting allowable stress intensities for ASME Section III Subsection NH (identified in paragraph NH-3221).

(a) Appendix 1 has a creep rate criterion which is 100% of the stress to produce a creep rate of 0.01%/1000h, while paragraph NH-3221 has a total (elastic, plastic, primary plus secondary creep) strain criterion which is 100% of the average stress to produce 1% total strain in a specific time, say 100,000 hours;

(b) Appendix 1 has a rupture strength criterion of F_{avg} times the average stress to produce rupture in 100,000 hours, while paragraph NH-3221 calls for 67% of the minimum stress to produce rupture in a specific time, say 100,000 hours;

(c) Appendix 1 has a second rupture strength criterion of 80% of the minimum stress to produce rupture in 100,000 hours, while NH-3221 calls for 80% of the minimum stress to cause initiation of tertiary creep in a specific time, say 100,000 hours. The factor F_{ave} used in Appendix 1 has the value 0.67 or less and depends on the slope of the stress-rupture curve around 100,000 hours [18]. Criteria (a) and (c) for III-NH require knowledge of the creep strain-time behavior.

6.2 Procedures for Estimating the Average Strength for 1% Strain and the Minimum Strength for the Onset of Tertiary Creep

There are no specific guidelines for estimating criteria (a) and (c) for ASME III-NH. Ideally, the development of material models for plasticity and creep as a function of time, temperature and stress for times to the limit set for III-NH could be used to determine the stress to produce 1% total strain and the "initiation" of tertiary creep. Knowledge of how the curves vary from lot to lot could be used to determine the minimum strength values. Attempts have been made to develop such models for producing the isochronous stress-strain curves in III-NH [19]-[21], but often the available data were judged to be insufficient to cover the range of products needed to fully develop the two criteria based on creep. The direct correlation of $t_{1\%}$ and t_3 permitted the use of a larger database for comparison of the criterion based on rupture strength. For this work on Gr 91, data analysis procedures for all three criteria were similar.

6.3 Selection of Analysis Methods

Several methods of analysis were selected. These were based on time-temperature parameters. In the first method, the Larson-Miller parameter (LMP) was selected in combination with a stress function f(S) that was a four-term ("third-order") polynomial in log stress. Thus, for the 1% total strain:

$$LMP = T_K\left(C + \log t_{1\%}\right) \tag{1}$$

Where C was the Larson-Miller parametric constant and TK was in Kelvin. The stress function was equated to the LMP:

$$LMP = f(s) = a_0 + a_1 \log S + a_2\left(\log S\right)^2 + a_3\left(\log S\right)^3 \tag{2}$$

where a_i was a series of four constants Using a least squares fitting method in which log $t_{1\%}$ was the dependent variable and T and log S were independent variables, the optimum values for C and a_i were determined. In this approach, all lots were processed together which produced a "global" or "single batch" analysis and one value for C that applied to all lots. Using the "best fit" values for f(S) and C, the log $t_{1\%}$ values calculated along with the residual, r_i, for each datum:

$$r_i = \log\left(\frac{t_{observed}}{t_{calculated}}\right) \tag{3}$$

The standard error of estimate (SEE) was obtained from the analysis in the customary way:

$$SEE = \left[\frac{\sum\left(\log t_{observed} - \log t_{calculated}\right)^2}{\left(N_d - D_f\right)}\right]^{1/2} \tag{4}$$

Where N_d was the number of data and D_f was the degrees of freedom.

A second analysis was undertaken that was essentially a Larson Miller parametric approach but employed a "lot-centered" procedure developed by Sjodahl that calculated a lot constant (C_{lot}) for each lot along with the Larson Miller constant, C, which represented the average lot constant (C_{ave}) for the lots [4], [23]. Only the average lot constant was used in estimating life, although the variation in the C_{lot} values was of interest in comparing lots.

The third method investigated was based on the Orr-Sherby-Dorn (OSD) parameter. Whereas the Larson-Miller parameter assumed that the activation energy for the process was stress dependent, the OSD parameter assumed that the activation energy for the process was not dependent on stress. Here:

$$t_{1\%} = A\exp\left(\frac{Q}{RT_k}\right)S^n\exp\left(\beta S\right) \tag{5}$$

where A, Q/R, n, and β are materials constants calculated by least squares regression analysis. R is the gas constant. The OSD parametric constant was written such that $t_{1\%}$ was expressed in the $\log_{10}$ form:

$$OSD = \frac{Q}{2.30258RT_k} - \log t_{1\%} \tag{6}$$

The stress function f(S) shown in equation (5) was written in $\log_{10}$ form:

$$f\left(S\right) = D + n\log S + \beta' S \tag{7}$$

Where D was ln A/2.30258 and β' was β/2.30258. Lot centering was not used in the fit of the OSD parameter.

The procedures for t_3 and t_R were the same as those used for $t_{1\%}$.

The underlying assumption in the regression analyses was that the residuals were normally distributed about zero. Also, it was expected that residuals would be more or less uniformly distributed with time, temperature and stress. These aspects of the parametric fits were examined graphically.

The minimum t_3 and minimum t_R for each temperature were based on a reduction in log life of 1.65 multiples of the standard error of estimate (SEE) produced by the model. The estimation of the minimum stress required that the appropriate root of the polynomial in log S be found.

7 RESULTS

7.1 Time to 1% Total Strain, $t_{1\%}$:

The fit of the Larson Miller parameter to the 1% total strain data is shown in Figure 5 (left). Data exhibited considerable scatter about the mean trend f(S) which curved downward with the increasing value of the LMP parameter. The optimum value of C for the global fit was 36.69157 which was one point lower than the C_{ave} value (37.67024) found for the lot-centered analysis. The distribution of residuals about the mean for the global analysis is shown in the histogram in Figure 6 (left). The SEE was 0.432 log cycle in time for the global analysis and 0.440 log cycle for the lot-centered analysis. The stress functions, f(S), for the two fits were similar, so the parametric curve for the lot-centered analysis closely resembled the curve shown in Figure 5 (left). The lot constants ranged from 36.865 for the strongest lot to 38.141 for the weakest lot. Both the weakest and strongest were tube products.

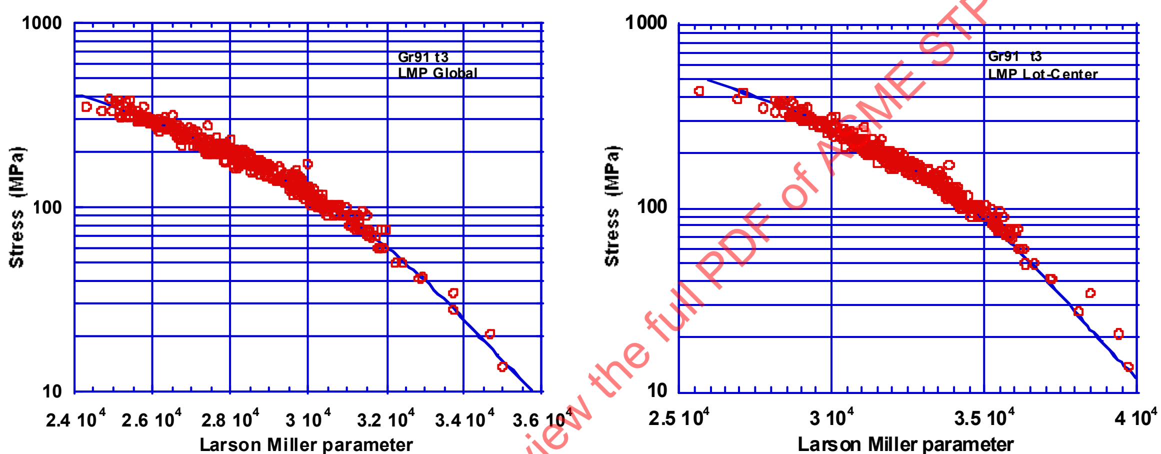

Figure 5 - Fit of the Larson Miller Parameter to the Time to Tertiary, t_3, for 27 Lots (left) Global; (right) Lot-Centered

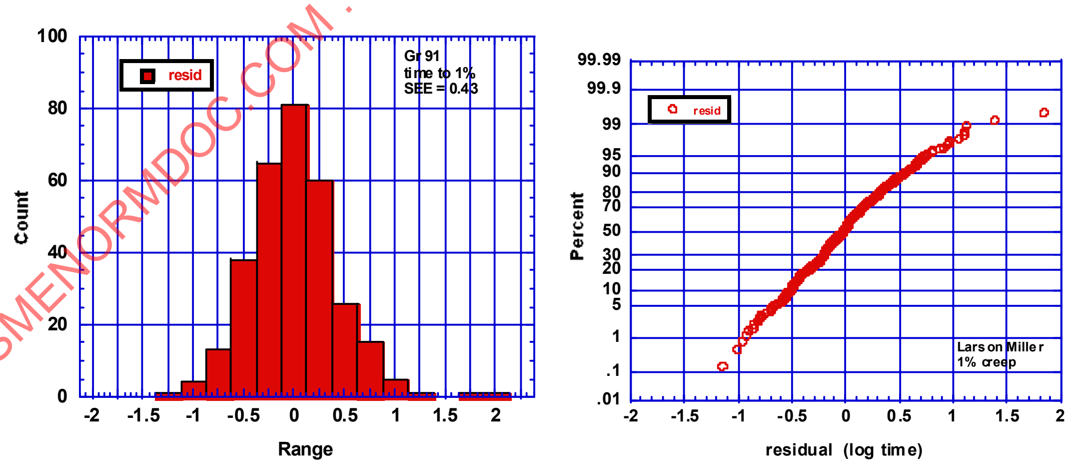

Figure 6 - Histogram of Residuals (left) and Frequency Graph for Residuals (right)

The global and lot-centered Larson Miller approaches produced very similar curves for stress versus $t_{1\%}$ and one such set of curves is shown in Figure 7 for temperatures from 450 to 650˚C (842 to 1202˚F). These curves were close to those developed by Caminada, et al. from the European database [14].

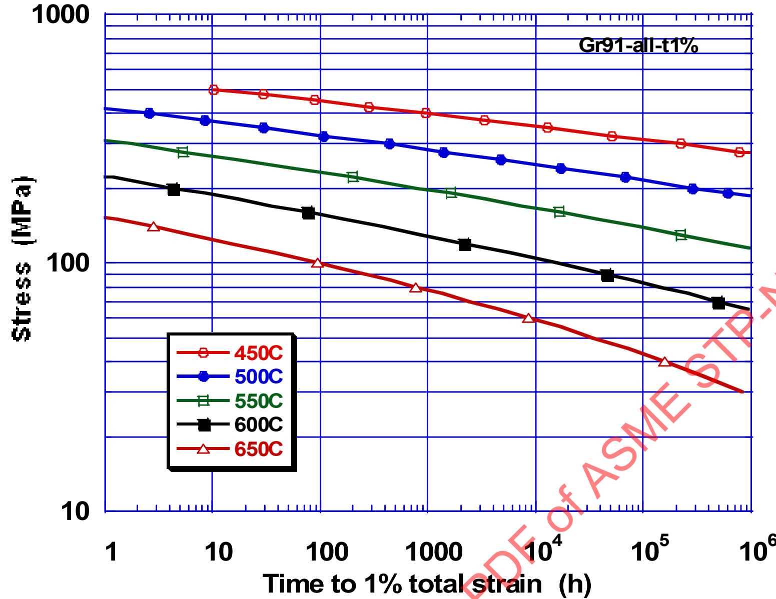

Figure 7 - Stress Versus $t_{1\%}$ Based on the Larson Miller Parameter

The fit of the OSD parameter to the $t_{1\%}$ data is shown in Figure 8. The general character of the curve was similar to the Larson Miller curves. The SEE for the OSD parameter was slightly greater (0.449 log time) than the Larson Miller fit but the OSD parameter contained one less parametric constant. The stress versus $t_{1\%}$ curves were very similar except at 650˚C (1202˚F), where the OSD predicted lower long-time strength.

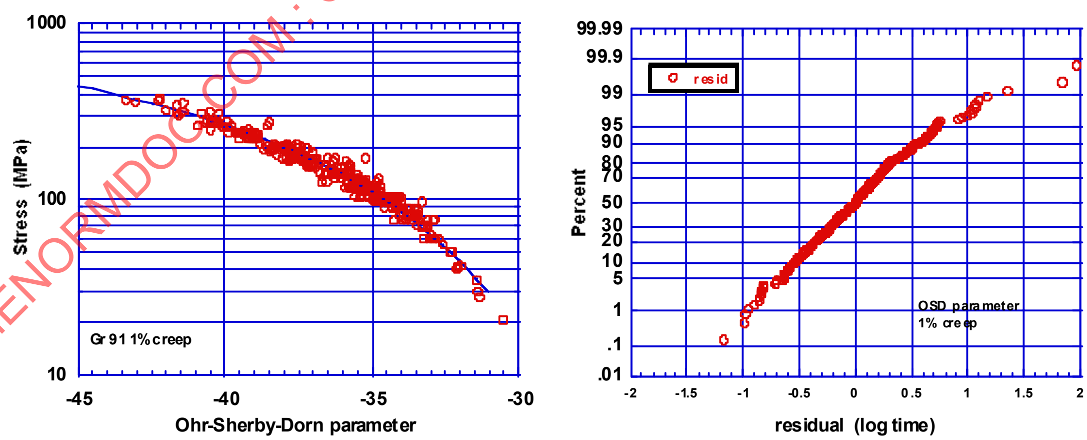

Figure 8 - The Fit of Data to the OSD Parameter (left) and Residual Frequency Graph (right)

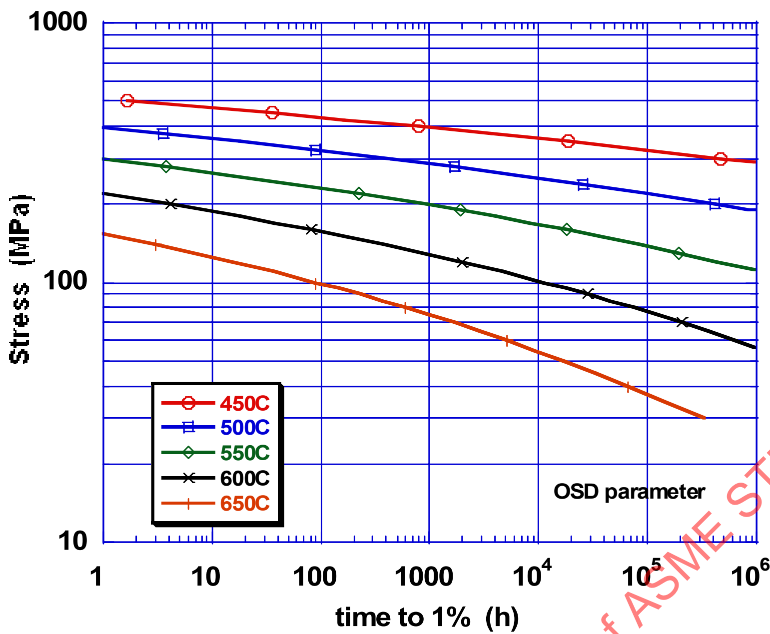

Figure 9 - Stress vs. $t_{1\%}$ Based on the Orr-Sherby-Dorn Parameter

7.2 Time to the Initiation of Tertiary Creep, t_3:

The database for t_3 included 392 data for 27 lots. The Larson Miller parameter fits produced parametric constants of 30.4198 and 34.8888 for the global and lot-centered fits, respectively. The stress versus parameter curves are shown in Figure 10. The SEE values were 0.381 and 0.419 in log time for the global and lot-centered fits, respectively.

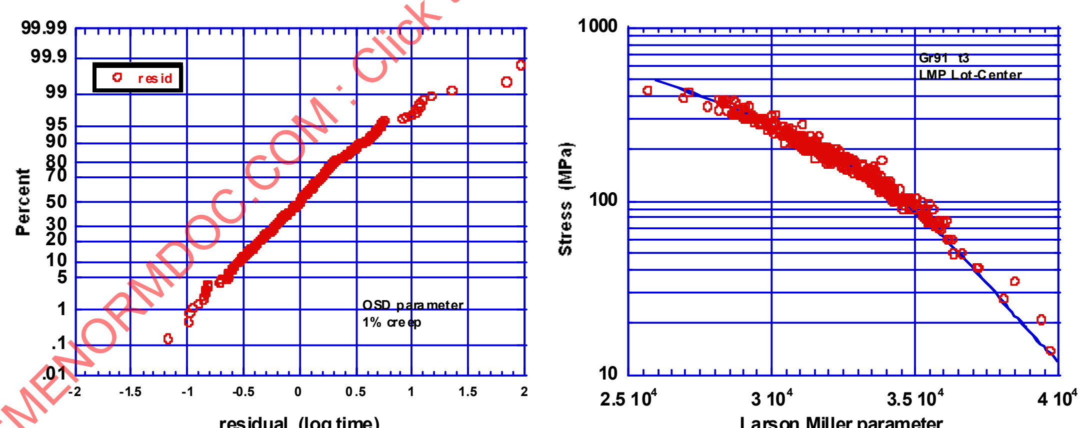

Figure 10 - Fit of the Larson Miller Parameter to the Time to Tertiary, t_3, for 27 Lots (left) Global; (right) Lot-Centered.

Plot of the histogram for the lot constants and frequency distribution of the residuals for the lot-centered analysis are shown in Figure 11. The histogram shows how the lot constants for three of the product forms were distributed. The 10 tube products averaged 34.907 with a standard deviation of 0.275, the 12 plate products averaged 34.788 with a standard deviation of 0.315 and 5 thick-section products averaged 35.163 with a standard deviation of 0.465. The frequency distribution curve indicated a small deviation from a normal distribution of residuals, as suggested in the plot shown in Figure 11 (right).

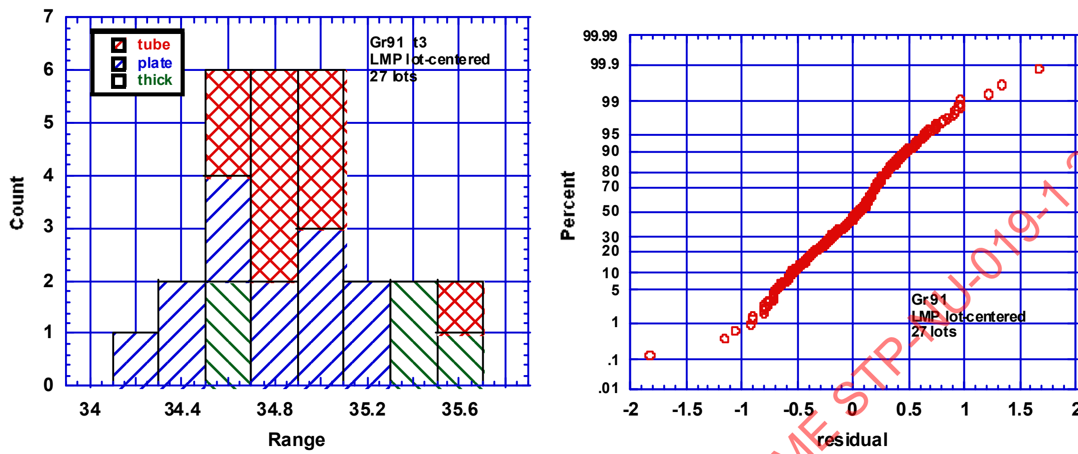

Figure 11 - Distribution of Larson Miller Parameter Lot Constants for Tertiary Creep with Product Form (left) and Percentage Distribution of Residuals for all Lots (right)

Figure 12 shows isothermal curves for the average stress to the initiate tertiary creep produced by the Larson Miller lot-centered model. These curves were similar to curves produced by the global fit. For long times, the global fit produced a lower SEE and slightly lower stresses than the lot-centered fit, but the difference was not judged to be significant.

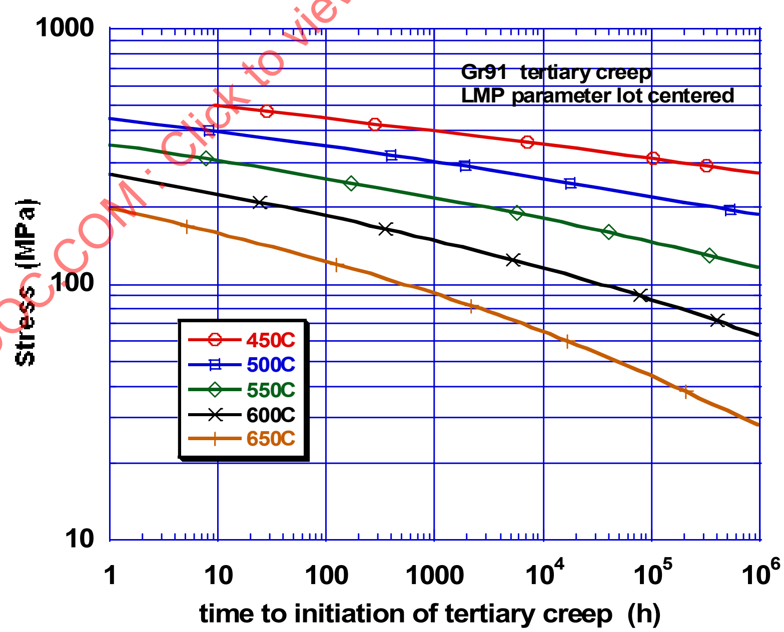

Figure 12 - Stress vs. the Time to the Initiation of Tertiary Creep for Several Temperatures Based on the Larson Miller Lot-Centered Model

A plot for the stress versus OSD parameter for t_3 data is shown in Figure 13 (left) and the frequency distribution of the residuals is shown in Figure 13 (right). The stress function approached a stress exponent of -2.7 as stress diminished. The OSD parameter captured the trend of the very low stress data better than the Larson Miller parameter. The SEE, however, was higher than that for the LMP and the percentage versus residual curve plotted in Figure 13 (right) departed somewhat from a normal trend at the tails. A family of curves for average stress to initiate tertiary creep as a function of time is plotted in Figure 14. Comparison of these curves with those in Figure 12 indicated that the OSD parameter produced similar stresses for short times and low temperatures but lower stresses for long times at high temperatures.

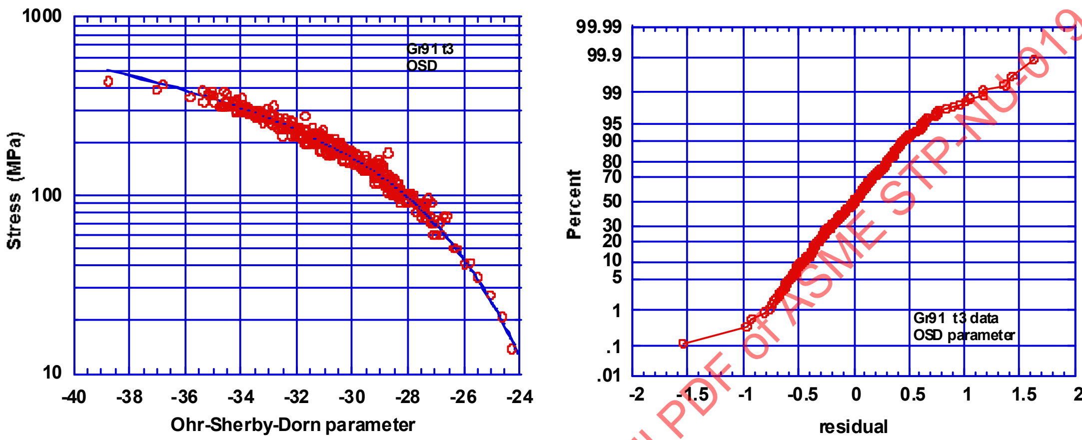

Figure 13 - Fit of the Orr-Sherby-Dorn Parameter to the Time to Tertiary Creep

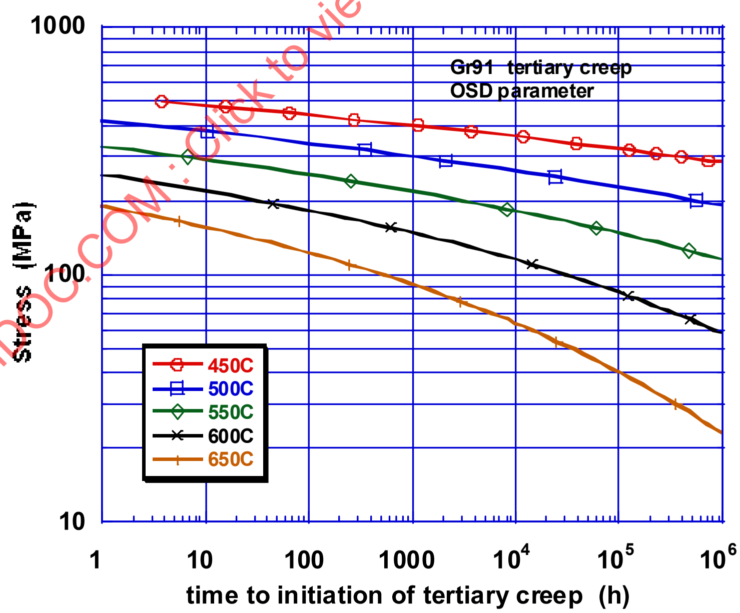

Figure 14 - Average Stress to Produce the Initiation of Tertiary Creep vs. Time for Several Temperatures Based on the Orr-Sherby-Dorn Parametric Model

As an alternative to developing a time-temperature-stress model directly from the t_3 data, the utilization of the correlation between tertiary creep life, t_3, and rupture life, t_R, was examined. This correlation, attributed to Leyda and Rowe [17], works very well for Gr 91, as may be seen in Figure 15 (left). To a first approximation, the ratio t_3/t_R was found to be 0.629 with a standard deviation of 0.089, as shown in Figure 15 (right). A least squares fit to the data in Figure 15 (left) found: $t_3 = 82.232 + 0.62271\ t_R$.

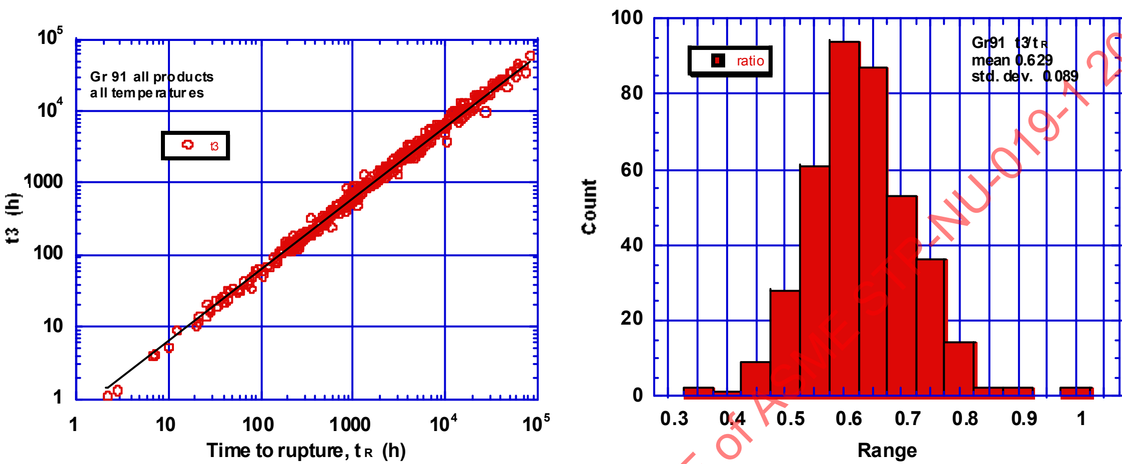

Figure 15 - The Leyda-Rowe Correlation Between t_3 and t_R (left) and Histogram of the t_3/t_R Ratio Values for 312 Data (right)

7.3 Stress-Rupture, t_R

As outlined in earlier section on available sources for creep-rupture data, the correlation of stress-rupture data to predict the long-time strength of Gr 91 steel has been an on-going activity at an international level for decades. The undertakings have been largely in support for the use of Gr 91 steel in ASME BPV Codes Section I and VIII, ASME Piping Codes B31.1 and B31.3 and corresponding overseas construction codes. The objective has been to estimate accurately the allowable stresses at the upper limit of the use temperature for Gr 91 steel. Many parametric procedures have been developed and compared but there remains no consensus as to which is best. Techniques to "improve" the accuracy of long time estimations include "censoring" data by not using data for times less than 3000 hours [24], region splitting by not using data produced at stresses above a fraction of the hot yield strength [25] and adding more parametric constants to the time-temperature-stress models [26]. However, it should be recognized that the criteria for setting S_t in III-NH are conservative relative to the criteria in ASME II-D Table 1-100, so the onus to produce accurate estimates from the same database is not as demanding.

Data corresponding to rupture lives less than 100 hours were not used in the analyses. This left nearly 1600 data covering temperatures from 450 to 780˚C (840 to 1435˚F). The Larson Miller global fit to these data is shown in Figure 16 (left) and lot-centered fit is shown in Figure 16 (right). One fit appeared to be as good as the other, although there was a four point difference in the optimized parametric constant: ~26 for the global fit and ~30 for the lot centered fit. The SEE values were similar: 0.333 in log time for the global fit and 0.345 in log time for the lot-centered fit. The distribution of residuals for the two fits was similar, and information is shown in Figure 17 for the lot centered model. The plots show how the residuals were distributed about zero. The distributions with temperature and stress are shown in Figure 18. These distributions show no strong bias (Figures 18a and 18b). When plotted against the observed rupture lives, the residuals tended to move from a negative bias to a positive bias with increasing life (Figure 18c). Also, the U.S. data tended to exhibit greater lives than the combined database (Figure 18d), while the long-time tests in the database tended to have shorter lives than predicted (Figure 18d). A few long-time tests in the U.S. data base were discontinued at times that placed them longer than predicted.

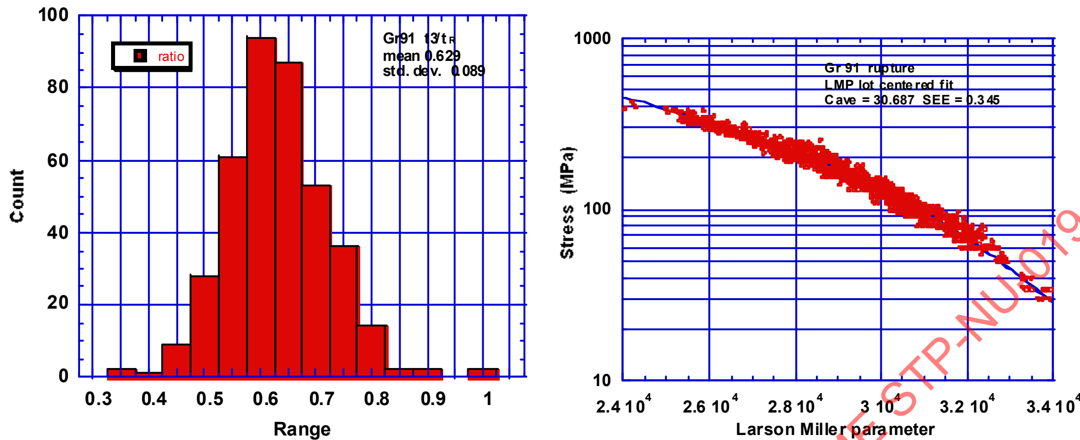

Figure 16 - Fit of the Larson Miller Parameter to Rupture Data: (left) Global Fit; (right) Lot-Centered Fit

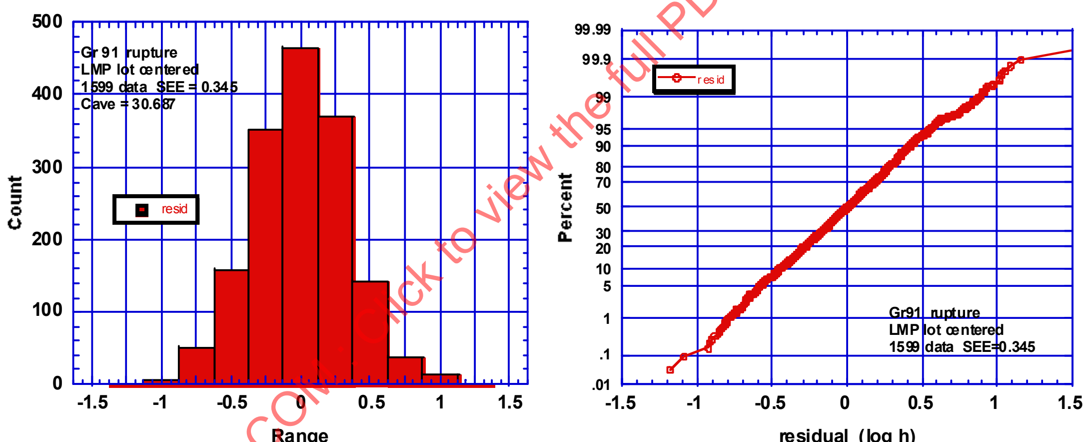

Figure 17 - The Distribution of Residuals for the Fit of the Larson Miller Parameter Lot-Centered Procedure to Rupture Data: Count vs. Range Histogram (left); Percent vs. Range Graph (right)

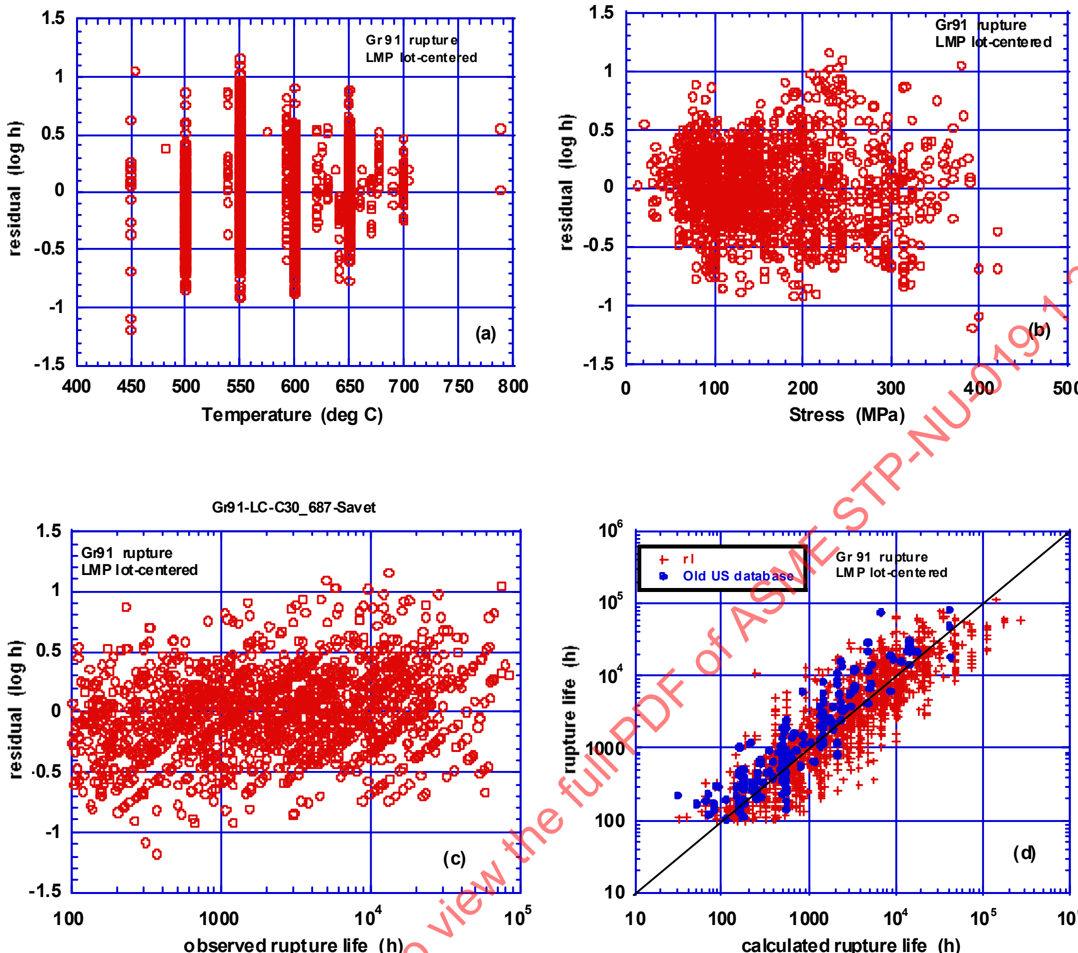

Figure 18 - Plots Showing the Characteristics of the Fit of the Larson Miller Lot-Center Model to Rupture Data: (a) Residuals vs. Temperature; (b) Residuals vs. Stress; (c) Residuals vs. Observed Rupture Life: and (d) Rupture Life vs. Calculated Rupture Life

An evaluation of the lot constants produced interesting results. These are shown in Table 2 below and in Figure 19. Since the log of the life for the LMP is given by $f(S)/T_k - C$, the lower C_{lot} values produced longer predicted lives for the same f(S) and T_k. As indicated in Table 2, the U.S. data manifested the lowest C_{lot} values and, correspondingly, the longest lives, as indicated in Figure 18d. The plates manifested the lowest C_{lot} values within the products and the forgings, the highest. As observed by Prager [9], the thicker products often had lower ultimate strength (UTS) and high C_{lot} values. This trend is shown in Figure 19. The decrease in C_{lot} with increasing UTS appeared to be the trend, more or less, for all products, as indicated in Figure 19 (left). The dependence of C_{lot} on thickness was less obvious as shown in Figure 19 (right). Products that were 75 mm (3/4 in.) or thicker consistently manifested higher C_{lot} values. ASME II-D lists lower stress values for these products at some temperatures.

Table 2 - Average Lot Constants for Different Products

Item	Number	Lot Constant	Std. Deviation
All	104	30.687	0.273
US	11	30.457	0.125
Others	93	30.714	0.272
Tubes	48	30.682	0.241
Plates	34	30.606	0.301
Pipes	13	30.824	0.176
Forgings	9	30.936	0.261
Thick Products	19	30.872	0.227

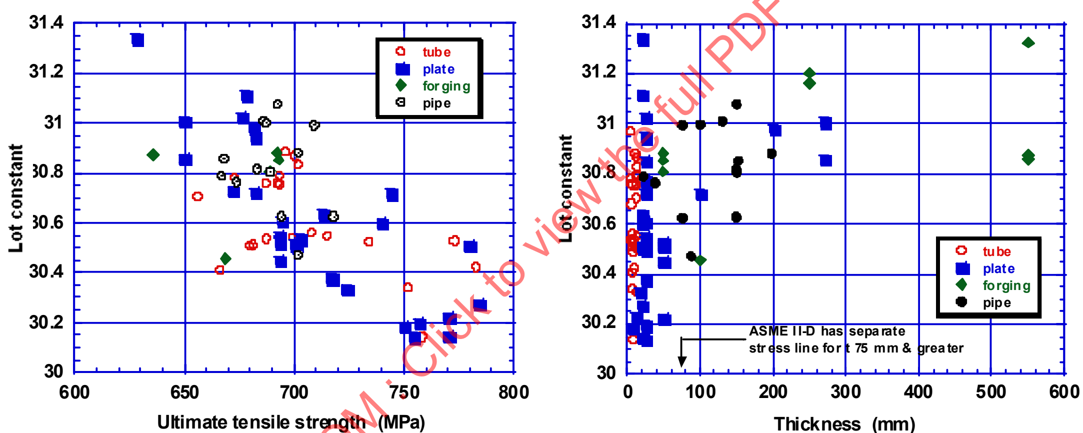

Figure 19 - Correlation of the Larson Miller Parameter Lot Constants with Ultimate Tensile Strength (left) and Product Thickness (right).

Finally, the average stress versus time-to-rupture curves are plotted in Figure 20 for values obtained from the Larson Miller lot-centered correlation. Temperatures cover 450 to 650˚C (840 to 1200˚F) and times cover 1 to 10^6 hours.

The form of the stress function, f(S), used in conjunction with the OSD parametric model, was the same as used by Sikka, Cowgill and Roberts in their early work on Gr 91 [4]. The exception was that a global procedure rather than a lot-centered procedure was introduced. The fit of the data to the parameter is shown in Figure 21 The SEE for the fit of the OSD parameter to the data was about the same as for the Larson Miller parameter with the SEE being 0.337 log cycle in time. The parametric constant was low (25681K) compared to the value found reported by Sikka, Cowgill and Roberts (31876K), but the stress exponent that dominates the very long-time behavior was about the same, about -2.54 for this fit and -2.49 for the Sikka, Cowgill and Roberts fit [3]. The average stress to produce rupture, calculated from the OSD parameter, is shown in Figure 22. Comparing these curves to the LMP isothermal curves in Figure 20 revealed that the OSD parameter predicted significantly lower stresses at high temperatures and long times.

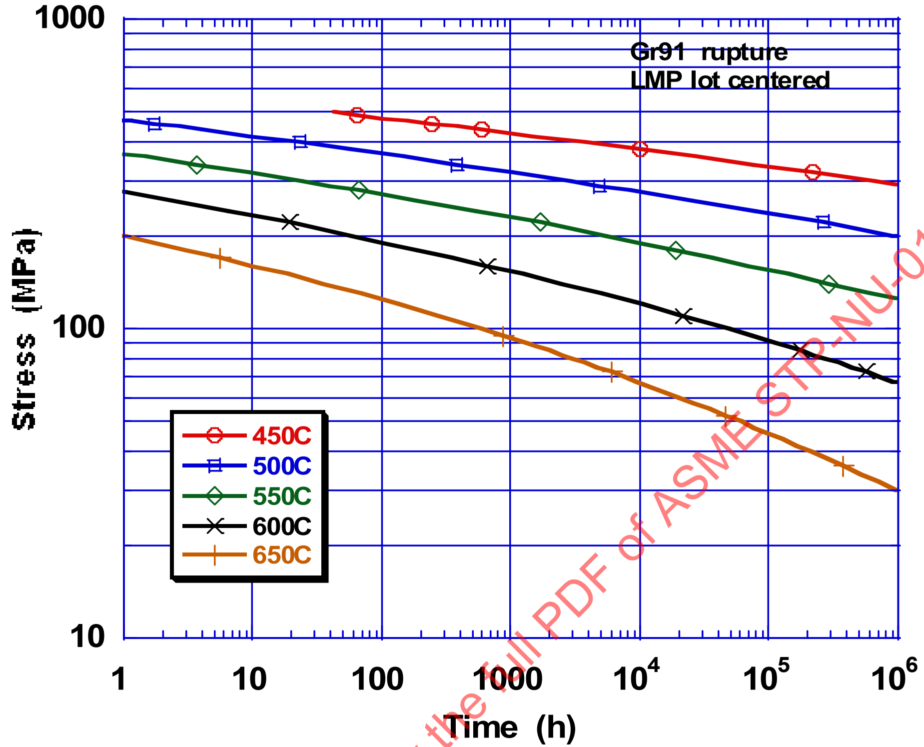

Figure 20 - Average Stress vs. Time to Rupture Based on the Larson Miller Lot-Centered Model

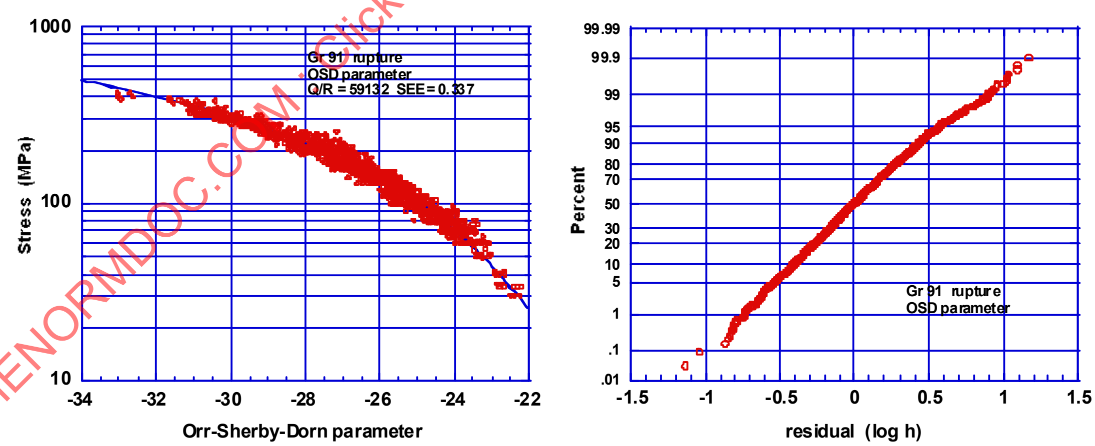

Figure 21 - Fit of the Orr-Sherby-Dorn Parameter to Rupture Data

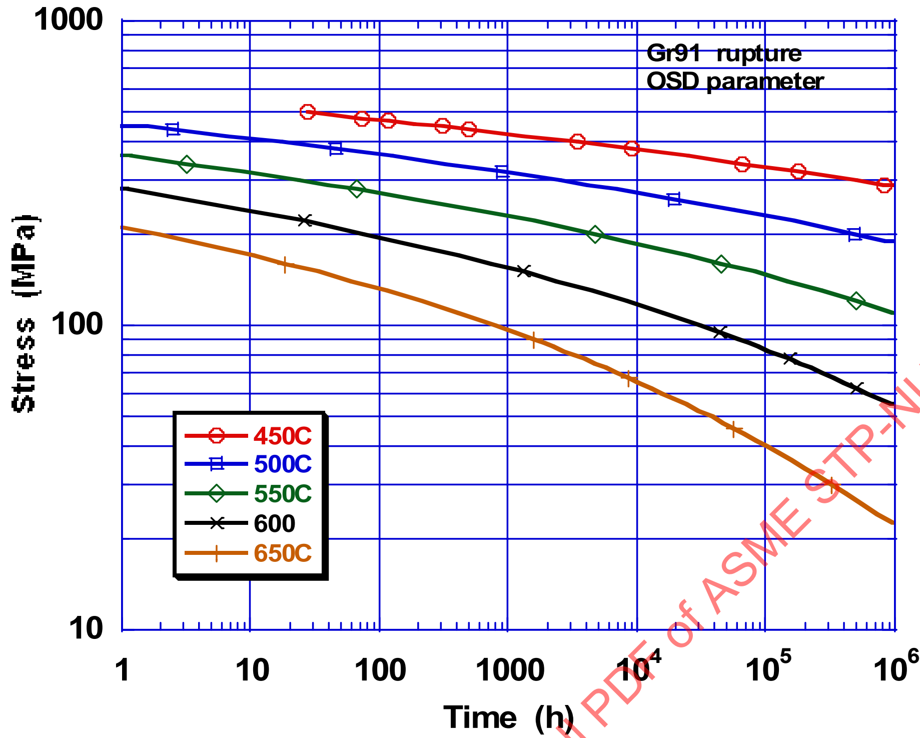

Figure 22 - Average Stress vs. Time to Rupture Based on the Orr-Sherby-Dorn Model

The average strength at 100,000 hours estimated from the LMP and OSD parameters are compared to other estimates in Table 3. These include the current values on which ASME II-D stresses are based. At 550˚C (1020˚F) and below, stress allowables are controlled by time-independent properties so rupture strengths in this temperatures range are often not reported. At 550˚C (1020˚F) and above, the rupture strength controls the allowables. The table shows that the original work of Sikka, Cowgill and Roberts produced stresses that were high and reflected the higher strength of the original U.S. lots. Subsequent analyses on the new larger database produced lower stresses, especially at 600 and 625˚C (595 and 1155˚F). Of all of the more recent analyses, the OSD global parametric analysis performed in this work produced the lowest stresses. The LM lot-centered parametric analysis, on the other hand, produced stresses that were more or less in the mid-range of the predicted values of the other parametric procedures. For this reason, it was judged to be a reasonable model on which to evaluate the validity of the current S_t values in ASME III-NH.

Table 3 - Comparison of the Strength for 100,000 Hour Estimate by Different Methods

Temp (°C)	Sikka, et al. 1984 OSD LC	LMP LC	OSD G	ASME II-D <75 mm	ASME II-D ≥75 mm	Kimura Pipe, Plate RS	Kimura Tube RS	Cipolla MRM-MC	Cipolla 2005 ECCC	ECCC 1995
450		335	332							
475		283	278							
500		236	229							258
525	208	193	185							210*
550	167	155	146			153	160	150	160	166
575	131	121	112	132	120	121	123	116	123	127*
600	98.6	91	83	97	91.9	94.2	92.5	85	93	94
625	71.8	66	59	67.9	68.2	71.1	66.1	62	67	69*
650	49.8	46	40	43.1	43.1	51.3	44.3	44	48	49

ODS LC - Orr-Sherby Dorn lot-centered
LMP LC - Larson Miller lot-centered
OSD G - Orr-Sherby Dorn global
RS - Region Splitting

MRM - Mendelson Roberts-Manson
MV - Minimum Commitment
ECCC - ECCC Recommendations 1999
*- Interpolated Value

8 EVALUATION OF THE CRITERIA CONTROLLING S_T

The various correlations developed in the previous section were used to plot strength versus time curves according to the criteria specified in NH-3221 for the selection of S_t. The first two plots in Figure 23 show the average stress for 1% strain against time as determined by either the Larson-Miller (left) or Orr-Sherby-Dorn (right) parameter. For most of the range of temperature and time, the two parameters produce similar results, but at the longer times and higher temperatures the OSD parameter produced slightly lower stress values. The second set of plots compares the tertiary creep criterion, namely 80% of the minimum stress for the initiation of tertiary creep. Again, the two parameters produced similar stresses for most conditions, while at the long time and low temperatures, the OSD parameter produced lower stresses. For all conditions, the tertiary creep criterion produced lower stresses than the 1% creep criterion. The third pair of plots compares the stress-rupture criterion for the two parameters. Again, the OSD parameter produced lower stresses for longer times at the higher temperatures. For all times and temperatures, the stress-rupture criterion produced equivalent or lower stresses than the 1% creep or tertiary creep criterion.

As mentioned in the previous section, the Larson Miller lot-centered parametric model was chosen for estimating the S_t values on a "trial basis." A plot of the recommended S_t values against time ("load duration" in ASME III-NH) is shown in Figure 24. The low-temperature, short-time values are not included in the plot. The current S_t values are included in the figure for comparison purposes. As may be seen, the new values are slightly higher for most conditions of stress and temperature. The selection of the OSD parameter would reduce the values by approximately 10% and drop the "new" S_t values to below those currently in ASME III-NH. This is a conservative option. It appears that the current values are conservative and close enough to the re-calculated values to be retained as they currently exist. The new model could serve to justify an extension of the values to 600,000 hours.

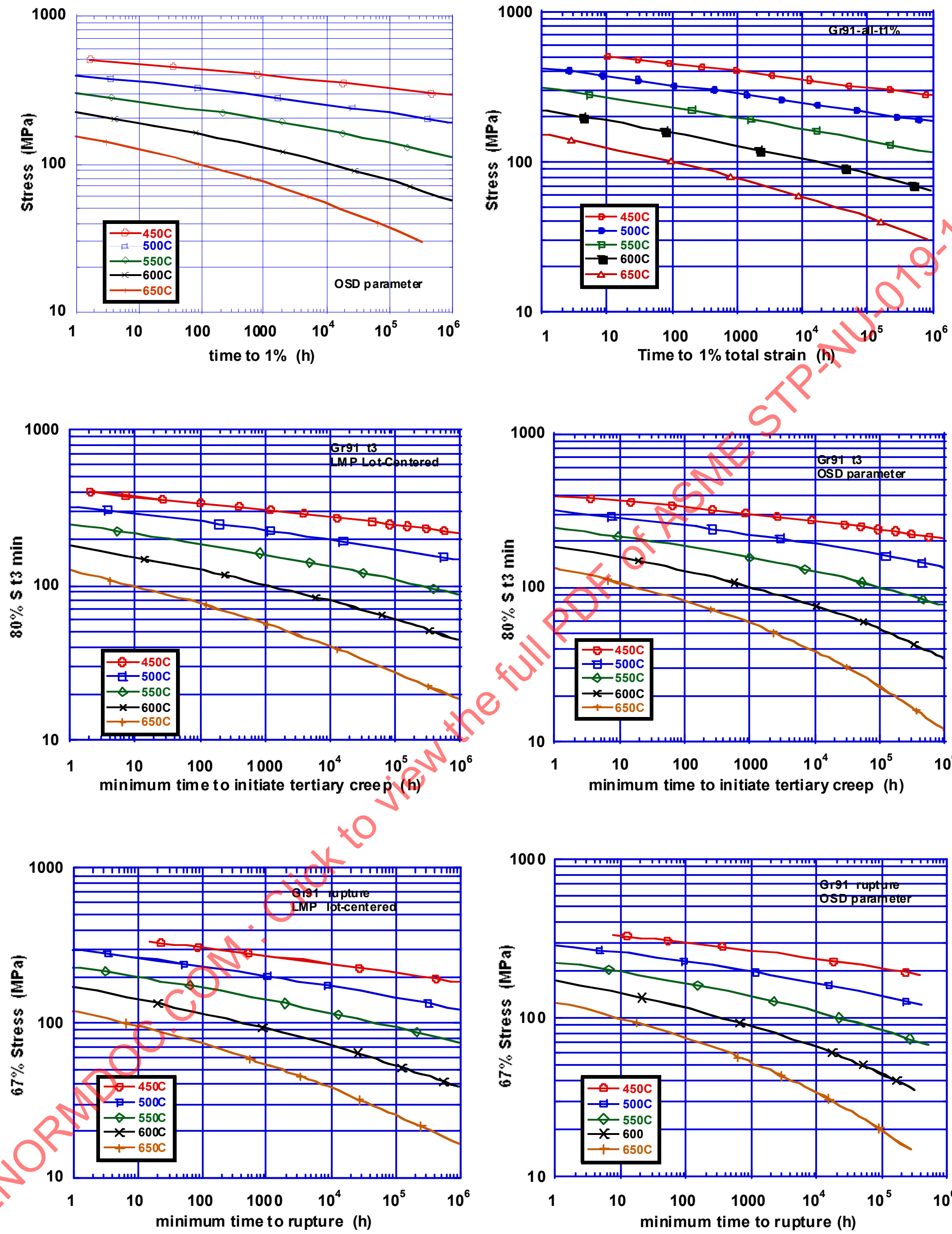

Figure 23 - Stress vs. Time Curves Plotted According to ASME III-NH Time-Dependent Criteria

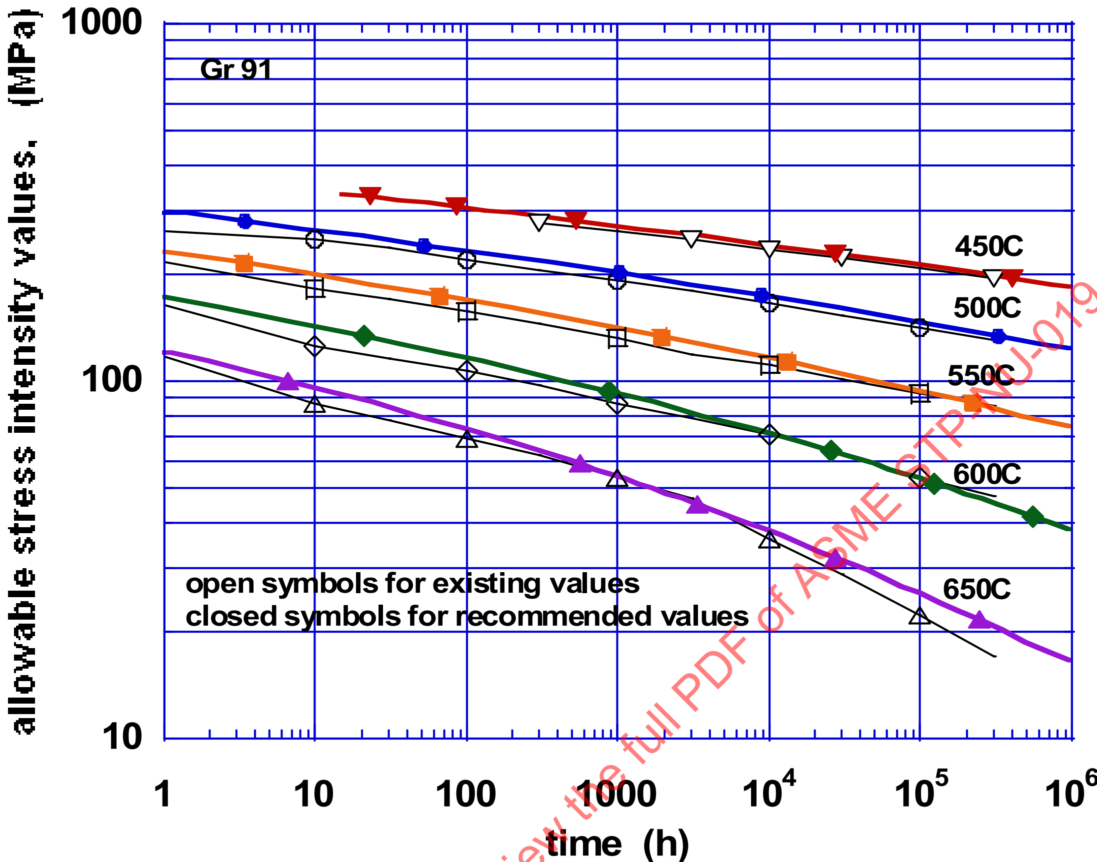

Figure 24 - Comparison of Current S_t Values with Values Based on the Larson Miller Parameter and New Database

9 SUMMARY AND RECOMMENDATIONS

The sources for high-temperature creep-rupture data for alloy Gr 91 were reviewed and the development of S_t values was traced for ASME Section III, Subsection-NH.

A database for time to 1% strain, time to the initiation of tertiary creep and rupture life was collected and characterized. Data for times equal to and greater than 100 hr. were correlated over the temperature range from 450 to 780˚C (840 to 1435˚F) by means of the Larson Miller and Orr-Sherby-Dorn time-temperature parameters.

Applying the Criteria set forth in ASME III-NH, it was found that the rupture strength controlled the allowable stress intensity values for all temperatures and times.

The S_t values estimated from the expanded database were found to be slightly greater than the values currently listed in ASME III-NH for some combinations of temperature and time. The new recommended values were based on the Larson Miller lot-centered parametric procedure. Since the current values in III-NH are conservative relative to these “recommended values,” there does not appear to be a strong justification for replacing current values.

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APPENDIX 1 – PARAMETRIC CONSTANTS

Values for the Parametric Constants

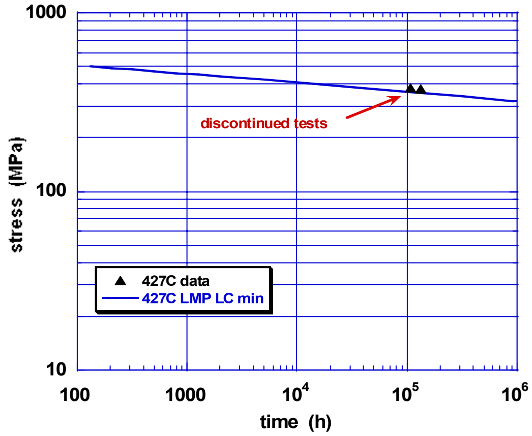
Criterion	Model	C	a0	a1	a2	a3	SEE	No. Data
1% Strain	LM Global	3.6691570E+01	3.9154320E+04	4.6794750E+03	-2.7401630E+03	-2.3222870E+03	0.43	312
1% Strain	LM Lot-centered	3.7670240E+01	3.7788110E+04	7.6310710E+03	-3.8617680E+03	-1.2336150E+02	0.44	312
Tertiary	LM Global	3.0419822E+01	4.4243387E+04	-1.3929863E+03	7.4038243E+03	-1.9273716E+03	0.38	392
Tertiary	LM Lot-centered	3.4888821E+01	5.3225365E+04	-2.1401406E+03	1.1292307E+04	-2.6329847E+03	0.42	392
Rupture	LM Global	2.6312710E+01	4.2101477E+04	-1.6437842E+03	8.2526912E+03	-1.9125831E+03	0.33	1599
Rupture	LM Lot-centered	3.0687250E+01	4.5487698E+04	-1.5228019E+03	7.8466260E+03	-1.9411510E+03	0.35	1599
	OSD	Q/R	A	n	b		SEE	No. Data
1% Strain	OSD Global	7.7764272E+04	-1.2824997E-25	-3.7117855E+00	-5.3309060E-02		0.45	312
Tertiary	OSD Global	6.5546769E+04	8.3458219E-22	-2.3948590E+00	-5.1796785E-02		0.39	392
Rupture	OSD Global	5.9132932E+04	9.8341800E-19	-2.5377686E+00	-4.2419449E-02		0.34	1599

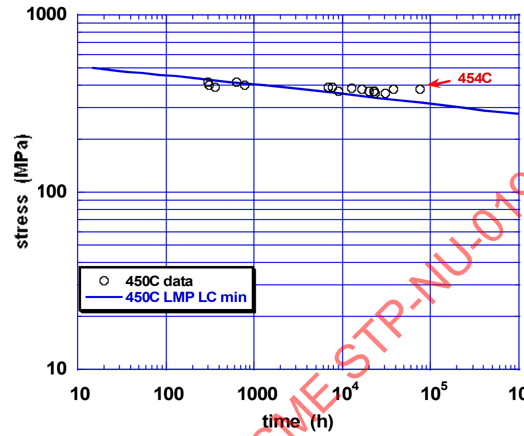
LMP f(S)=a0+a1 log(S)+a2[log(S)]^2-a3[log(S)]^3

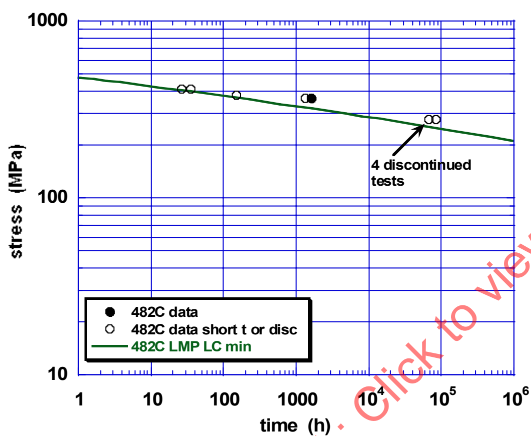
OSD f(s)=log[A S^n exp(bS)]

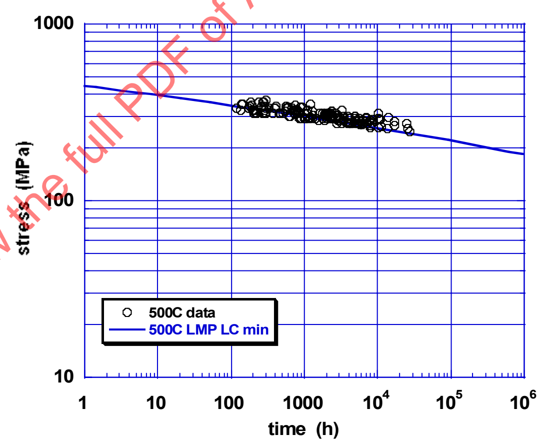
APPENDIX 2 – STRESS-TO-RUPTURE CURVES

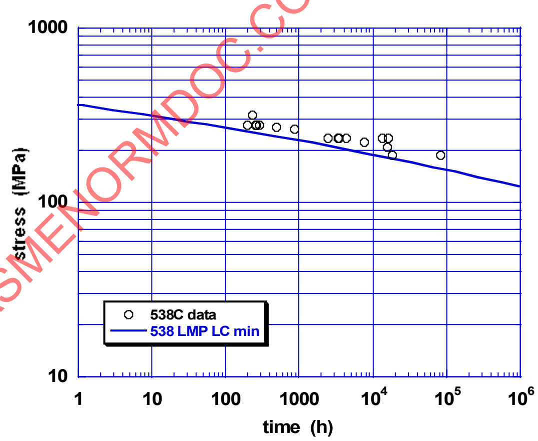
Comparison of Data to Minimum Stress-to-Rupture Curves Based On the Larson Miller Lot-Centered Procedure

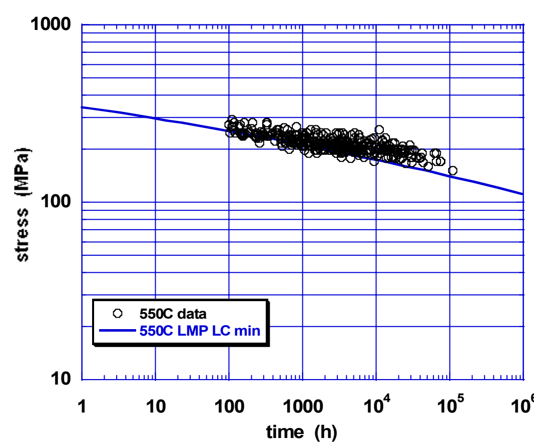


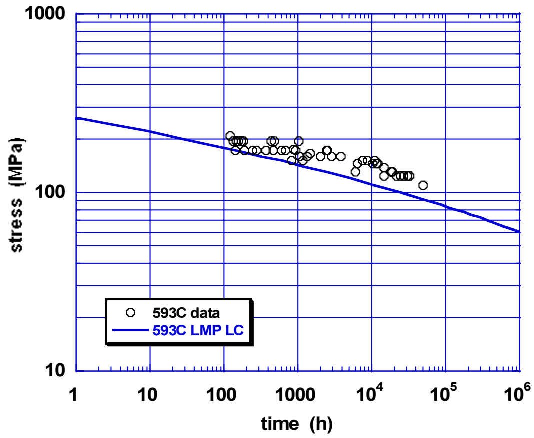




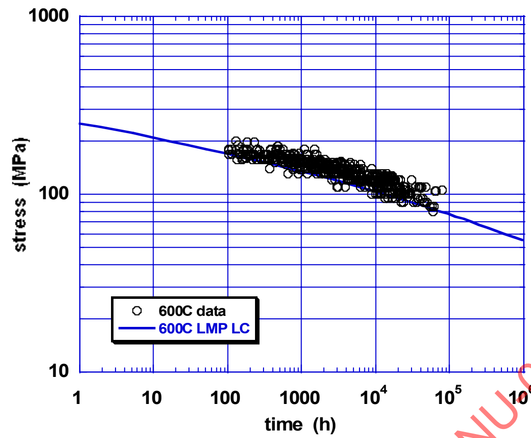




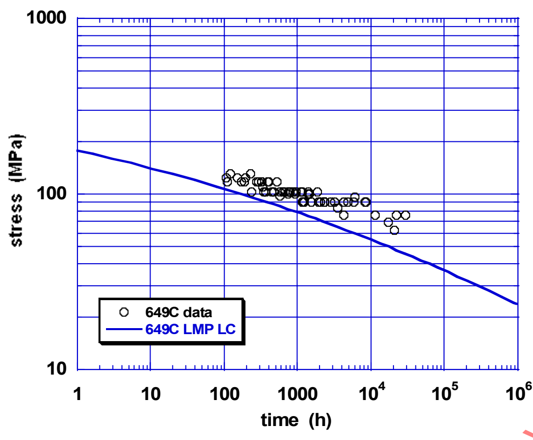




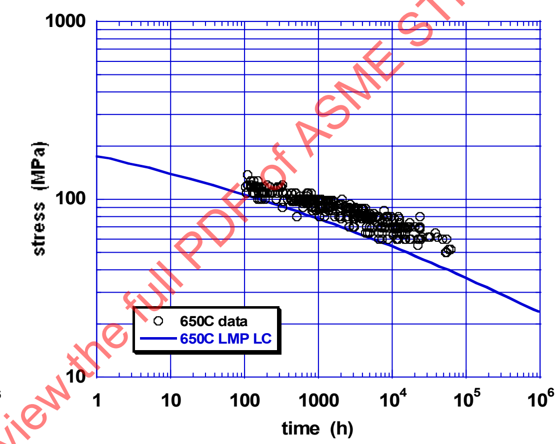
1000
100
10
stress (MPa)
1
10
100
1000
10^4
10^5
10^6
time (h)
593C data
593C LMP LC



1000
100
10
stress (MPa)
1
10
100
1000
10^4
10^5
10^6
time (h)
600C data
600C LMP LC



1000
100
10
stress (MPa)
1
10
100
1000
10^4
10^5
10^6
time (h)
649C data
649C LMP LC



1000
100
10
stress (MPa)
1
10
100
1000
10^4
10^5
10^6
time (h)
650C data
650C LMP LC

APPENDIX 3 - GRADE 91 DATA

ID	Heat	Temp	Temp	Stress	Rupture	Other
1	G1P	823	550	240	5775	GERM-2
2	G1P	823	550	220	12136	GERM-1
3	G1P	873	600	180	1095	GERM-5
4	G1P	873	600	150	3245	GERM-4
5	G1P	873	600	127	6218	
6	G1P	873	600	120	15264	GERM-3
7	G2P	823	550	280	330	GERM-7
8	G2P	823	550	240	1602	GERM-6
9	G2P	873	600	180	248	GERM-10
10	G2P	873	600	150	1936	GERM-9
11	G2P	873	600	120	6205	GERM-8
12	G2P	923	650	120	111	GERM-14
13	G2P	923	650	100	585	GERM-13
14	G2P	923	650	80	1196	GERM-11
15	G2P	923	650	80	3072	GERM-12
16	G3P	823	550	280	60	GERM-19
17	G3P	823	550	240	1008	GERM-18
18	G3P	823	550	220	3452	GERM-17
19	G3P	823	550	200	18017	GERM-16
20	G3P	823	550	180	29280	GERM-15
21	G3P	873	600	200	35	GERM-24
22	G3P	873	600	180	164	GERM-23
23	G3P	873	600	150	1415	GERM-22
24	G3P	873	600	120	10731	GERM-21
25	G3P	873	600	100	25161	GERM-20
26	G3P	923	650	150	13	GERM-29
27	G3P	923	650	120	121	GERM-28
28	G3P	923	650	100	435	GERM-27
29	G3P	923	650	80	2424	GERM-26
30	G3P	923	650	60	15225	GERM-25
31	G4P	823	550	280	160	GERM-31
32	G4P	823	550	220	3452	
33	G4P	823	550	240	5735	GERM-30
34	G4P	873	600	180	548	GERM-33
35	G4P	873	600	150	2648	GERM-32
36	G5P	823	550	280	116	GERM-37
37	G5P	823	550	220	4014	GERM-36
38	G5P	823	550	200	15768	GERM-35
39	G5P	823	550	180	30701	GERM-34
40	G5P	873	600	200	54	GERM-41
41	G5P	873	600	180	382	GERM-40
42	G5P	873	600	150	824	GERM-39
43	G5P	873	600	120	3600	GERM-38
44	G5P	923	650	150	11	GERM-46
45	G5P	923	650	120	123	GERM-45
46	G5P	923	650	100	696	GERM-44
47	G5P	923	650	80	23484	GERM-43
48	G5P	923	650	60	24784	GERM-42
49	G6P	823	550	280	211	GERM-48
50	G6P	823	550	240	4612	GERM-47
51	G6P	873	600	200	131	GERM-52
52	G6P	873	600	180	1500	GERM-51
53	G6P	873	600	150	3337	GERM-50
54	G6P	873	600	120	6000	GERM-49
55	G6P	923	650	120	331	GERM-55
56	G6P	923	650	100	708	GERM-54
57	G6P	923	650	80	6572	GERM-53
58	G7P	823	550	280	327	GERM-59
59	G7P	823	550	240	3000	GERM-58
60	G7P	823	550	220	5860	GERM-57
61	G7P	823	550	200	19408	GERM-56
62	G7P	873	600	180	505	GERM-62
63	G7P	873	600	150	2270	GERM-61
64	G7P	873	600	120	10840	GERM-60
65	G8t	823	550	240	3683	GERM-65
66	G8t	823	550	200	5968	GERM-63
67	G8t	823	550	220	7144	GERM-64
68	G8t	873	600	180	465	GERM-68
69	G8t	873	600	150	1759	GERM-67
70	G8t	873	600	120	7053	GERM-66
71	G8t	923	650	120	72	GERM-71
72	G8t	923	650	100	268	GERM-70
73	G8t	923	650	80	1672	GERM-69
74	G9P	823	550	240	830	GERM-75
75	G9P	823	550	220	2527	GERM-74
76	G9P	823	550	200	5693	GERM-73
77	G9P	823	550	180	16112	GERM-72
78	G9P	873	600	180	141	GERM-78
79	G9P	873	600	150	827	GERM-77
80	G9P	873	600	120	5911	GERM-76
81	G10B	823	550	280	18	GERM-81
82	G10B	823	550	240	291	GERM-80
83	G10B	823	550	200	4792	GERM-79
84	G10B	873	600	180	185	GERM-84
85	G10B	873	600	150	1348	GERM-83
86	G10B	873	600	120	4996	GERM-82
87	G11B	823	550	280	21	GERM-87
88	G11B	823	550	240	247	GERM-86
89	G11B	823	550	200	5208	GERM-85
90	G11B	873	600	180	102	GERM-90
91	G11B	873	600	150	928	GERM-89
92	G11B	873	600	120	8715	GERM-88
93	G12B	823	550	240	287	GERM-91
94	G12B	873	600	180	112	GERM-94
95	G12B	873	600	150	1019	GERM-93
96	G12B	873	600	120	6563	GERM-92
97	21774	823	550	220	1238.0	
98	21774	823	550	220	2595.0	
99	21774	823	550	210	2611.0	
100	21774	823	550	210	4317.0	
101	21774	823	550	200	5501.0	
102	21774	823	550	200	5813.0	
103	21774	823	550	190	7435.0	
104	21774	823	550	190	7436.0	
105	21774	873	600	1.40E+02	1111	
106	21774	873	600	1.40E+02	1340	
107	21774	873	600	1.30E+02	3432.0	
108	21774	873	600	1.30E+02	3675.0	
109	21774	873	600	1.20E+02	4091.0	
110	21774	873	600	1.20E+02	4277.0	
111	21774	873	600	1.10E+02	6275.0	
112	21774	873	600	1.10E+02	7133.0	
113	21774	873	600	1.00E+02	10615.0	
114	21774	873	600	1.00E+02	11779.0	
115	21774	923	650	90	843	
116	21774	923	650	90	920	
117	21774	923	650	80	1940	
118	21774	923	650	80	2045	

ID	Heat	Temp	Temp	Stress	Rupture	Other
119	21774	923	650	70	4445	
120	21774	923	650	70	4955	
121	21774	923	650	60	11545	
122	21774	923	650	60	12256	
123	21891	823	550	230	239.0	
124	21891	823	550	230	259.0	
125	21891	823	550	210	700.0	
126	21891	823	550	210	853.0	
127	21891	823	550	190	2888.0	
128	21891	823	550	190	3341.0	
129	21891	823	550	170	9501.0	
130	21891	873	600	150	843	
131	21891	873	600	150	1057	
132	21891	873	600	150	1178	
133	21891	873	600	150	1945	
134	21891	873	600	1.40E+02	2172	
135	21891	873	600	1.30E+02	2898.0	
136	21891	873	600	1.40E+02	2933	
137	21891	873	600	1.30E+02	3193.0	
138	21891	873	600	1.40E+02	3396	
139	21891	873	600	1.40E+02	3454	
140	21891	873	600	1.30E+02	3535.0	
141	21891	873	600	1.30E+02	3892.0	
142	21891	873	600	1.20E+02	5901.0	
143	21891	873	600	1.20E+02	6536.0	
144	21891	873	600	1.20E+02	8624.0	
145	21891	873	600	1.20E+02	9248.0	
146	21891	873	600	1.10E+02	10520.0	
147	21891	873	600	1.10E+02	10669.0	
148	21891	873	600	1.10E+02	10804.0	
149	21891	873	600	1.10E+02	10987.0	
150	21891	873	600	1.10E+02	12835.0	
151	21891	873	600	1.10E+02	13611.0	
152	21891	873	600	1.00E+02	16477.0	
153	21891	873	600	1.00E+02	19810.0	
154	21891	873	600	1.00E+02	21272.0	
155	21891	873	600	90	22164.0	
156	21891	873	600	90	23275.0	
157	21891	873	600	1.00E+02	23749.0	
158	21891	873	600	1.00E+02	25100.0	
159	21891	873	600	1.00E+02	29157.0	
160	21891	873	600	85	57463.0	
161	21891	873	600	85	61435.0	
162	21891	893	620	100	3885	
163	21891	893	620	100	4843	
164	21891	893	620	90	11257	
165	21891	893	620	90	12878	
166	21891	903	630	100	3603	
167	21891	903	630	100	3941	
168	21891	903	630	90	6552	
169	21891	903	630	90	6560	
170	21891	903	630	80	17619	
171	21891	903	630	80	19089	
172	21891	913	640	100	1184	
173	21891	913	640	100	1241	
174	21891	923	650	100	625	
175	21891	923	650	100	639	
176	21891	923	650	100	680	
177	21891	923	650	100	812	
178	21891	923	650	85	1241	
179	21891	923	650	85	1249	
180	21891	923	650	90	1257	
181	21891	923	650	90	1323	
182	21891	923	650	90	1377	
183	21891	923	650	90	1424	
184	21891	923	650	80	3368	
185	21891	923	650	80	3662	
186	21891	923	650	80	3736	
187	21891	923	650	80	3857	
188	21891	923	650	65	4423	
189	21891	923	650	65	4704	
190	21891	923	650	65	6689	
191	21891	923	650	70	7127	
192	21891	923	650	70	7140	
193	21891	923	650	65	7207	
194	21891	923	650	60	7333	
195	21891	923	650	70	11793	
196	21891	923	650	60	11817	
197	21891	923	650	70	12931	
198	21891	923	650	50	53255	
199	21891	923	650	50	53682	
200	21891	933	660	100	261	
201	21891	933	660	100	266	
202	21891	943	670	100	132	
203	21891	943	670	100	143	
204	21891	943	670	80	254	
205	21891	943	670	80	407	
206	21891	943	670	70	1418	
207	21891	943	670	70	1590	
208	21891	953	680	100	13	
209	21891	953	680	100	14	
210	21891	963	690	70	279	
211	21891	963	690	70	424	
212	21895	873	600	1.50E+02	583	
213	21895	873	600	150	727	
214	21895	873	600	1.40E+02	1478	
215	21895	873	600	1.40E+02	1726	
216	21895	873	600	1.30E+02	1777.0	
217	21895	873	600	1.30E+02	1990.0	
218	21895	873	600	1.20E+02	5346.0	
219	21895	873	600	1.20E+02	5617.0	
220	21895	873	600	1.10E+02	11064.0	
221	21895	873	600	1.10E+02	11566.0	
222	21895	873	600	1.00E+02	27182.0	
223	21895	873	600	1.00E+02	28811.0	
224	21895	893	620	100	8047	
225	21895	893	620	100	12372	
226	21895	903	630	100	2810	
227	21895	903	630	100	3699	
228	21895	913	640	100	242	
229	21895	913	640	100	286	
230	21895	923	650	100	192	
231	21895	923	650	100	424	
232	21895	923	650	100	440	
233	21895	933	660	100	191	
234	21895	943	670	100	86	
235	21895	943	670	100	93	
236	21895	953	680	100	11	
237	21895	953	680	100	13	
238	24423	873	600	1.40E+02	368	
239	24423	873	600	1.30E+02	643.0	
240	24423	873	600	150	803	
241	24423	873	600	150	1134	
242	24423	873	600	1.40E+02	1156	
243	24423	873	600	1.40E+02	1466	
244	24423	873	600	1.40E+02	1916	

ID	Heat	Temp	Temp	Stress	Rupture	Other
245	24423	873	600	1.30E+02	4021.0	
246	24423	873	600	1.20E+02	6750.0	
247	24423	873	600	1.20E+02	7705.0	
248	24423	873	600	1.10E+02	14250.0	
249	24423	873	600	1.10E+02	14842.0	
250	24423	873	600	1.00E+02	26455.0	
251	24423	873	600	1.00E+02	26689.0	
252	24423	923	650	100	82	
253	24423	923	650	100	173	
254	24423	923	650	90	1143	
255	24423	923	650	90	1156	
256	24931	873	600	1.40E+02	3627	
257	24931	873	600	1.40E+02	5575	
258	24931	873	600	1.30E+02	6279.0	
259	24931	873	600	1.30E+02	10551	
260	24931	923	650	100	775	
261	24931	923	650	100	2114	
262	24931	923	650	90	2294	
263	24931	923	650	90	2627	
264	24931	923	650	80	8845	
265	24931	923	650	80	9683	
266	28145	823	550	230	1075.0	
267	28145	823	550	230	2375.0	
268	28145	823	550	210	6683.0	
269	28145	823	550	210	28398.0	
270	28145	823	550	190	61894.0	
271	28145	823	550	170	65981.0	
272	28145	823	550	170	65981.0	
273	28145	823	550	190	66993.0	
274	28145	873	600	1.20E+02	14126.0	
275	28145	873	600	1.20E+02	20001.0	
276	28145	873	600	1.10E+02	41648.0	
277	28145	873	600	1.10E+02	46962.0	
278	28145	893	620	90	58974	
279	28145	893	620	90	62224	
280	28145	903	630	90	23396	
281	28145	903	630	90	26239	
282	28145	923	650	80	6349	
283	28145	923	650	80	8358	
284	28145	923	650	65	38079	
285	28145	923	650	60	47759	
286	28145	923	650	60	48657	
287	28145	923	650	60	54928	
288	28145	923	650	60	55318	
289	28524	823	550	200	21961.0	
290	28524	823	550	190	27823.0	
291	28524	823	550	180	41341.0	
292	28524	823	550	190	41643.0	
293	28524	873	600	1.40E+02	8936	
294	28524	873	600	1.30E+02	10366	
295	28524	873	600	1.30E+02	14106	
296	28524	873	600	1.20E+02	18381.0	
297	28524	873	600	1.20E+02	21727.0	
298	28524	873	600	1.10E+02	38504.0	
299	28524	873	600	1.10E+02	39267.0	
300	28524	923	650	100	1108	
301	28524	923	650	70	2955	
302	28524	923	650	90	3135	
303	28524	923	650	80	8547	
304	28524	923	650	80	12327	
305	28524	923	650	70	13606	
306	30865	893	620	100	7203	
307	30865	893	620	100	9865	

ID	Heat	Temp	Temp	Stress	Rupture	Other
308	30865	903	630	100	3841	
309	30865	903	630	100	4272	
310	30865	913	640	100	358	
311	30865	913	640	100	383	
312	30865	923	650	100	434	
313	30865	923	650	100	435	
314	30865	933	660	100	206	
315	30865	933	660	100	215	
316	30865	943	670	100	135	
317	30865	943	670	100	146	
318	30865	953	680	100	55	
319	30865	953	680	100	57	
320	31740	823	550	170	75042.0	
321	31740	873	600	1.20E+02	30648.0	
322	31740	873	600	1.10E+02	34490.0	
323	31740	873	600	1.05E+02	78714.0	
324	31740	923	650	78	4469	
325	31740	923	650	78	4599	
326	31740	923	650	75	7980	
327	31740	923	650	65	12410	
328	31740	923	650	60	22093	
329	31740	923	650	55	22137	
330	31740	943	670	78	531	
331	31740	943	670	78	873	
332	31740	963	690	78	106	
333	31740	963	690	78	155	
334	31740	983	710	78	30	
335	31740	983	710	78	32	
336	32648	923	650	78	2972	
337	32648	923	650	78	3093	
338	32648	943	670	78	326	
339	32648	943	670	78	354	
340	32648	963	690	78	76	
341	32648	963	690	78	88	
342	32648	983	710	78	17	
343	32648	983	710	78	23	
344	36198	873	600	1.10E+02	10284.0	
345	36198	873	600	1.15E+02	11048.0	
346	36198	873	600	1.10E+02	11111.0	
347	36198	873	600	1.15E+02	11229.0	
348	36198	873	600	1.05E+02	21515.0	
349	36198	913	640	80	5578	
350	36198	913	640	80	6625	
351	36198	913	640	75	8569	
352	36198	913	640	75	9466	
353	36198	913	640	70	13530	
354	37488	873	600	1.10E+02	9508.0	
355	37488	873	600	1.15E+02	9657.0	
356	37488	873	600	1.15E+02	9842.0	
357	37488	873	600	1.10E+02	10236.0	
358	37488	873	600	1.05E+02	17623.0	
359	37488	873	600	1.05E+02	17876.0	
360	37488	873	600	1.00E+02	23660.0	
361	37488	873	600	1.00E+02	24109.0	
362	37488	873	600	9.50E+01	37110.0	
363	37488	873	600	9.50E+01	39915.0	
364	37488	913	640	80	3767	
365	37488	913	640	80	4330	
366	37488	913	640	75	6371	
367	37488	913	640	75	6556	
368	37488	913	640	70	10178	
369	37488	913	640	70	11634	
370	37488	913	640	65	11652	

ID	Heat	Temp	Temp	Stress	Rupture	Other
371	37488	913	640	65	19131	
372	37488	913	640	60	35670	
373	37488	913	640	60	38534	
374	50315	823	550	200	658.0	
375	50315	823	550	190	1201.0	
376	50315	823	550	190	1550.0	
377	50315	823	550	200	1946.0	
378	50315	823	550	180	3406.0	
379	50315	823	550	180	6743.0	
380	50315	873	600	1.30E+02	886.0	
381	50315	873	600	1.30E+02	2322.0	
382	50315	873	600	1.20E+02	2812.0	
383	50315	873	600	1.10E+02	3087.0	
384	50315	873	600	1.10E+02	3827.0	
385	50315	873	600	1.00E+02	12050.0	
386	50315	873	600	1.00E+02	13377.0	
387	50315	923	650	100	64	
388	50315	923	650	100	86	
389	50315	923	650	90	323	
390	50315	923	650	80	510	
391	50315	923	650	90	809	
392	50315	923	650	80	1029	
393	63971	823	550	230	703.0	
394	63971	823	550	230	1253.0	
395	63971	823	550	215	2489.0	
396	63971	823	550	215	3079.0	
397	63971	873	600	160	537	
398	63971	873	600	160	572	
399	63971	873	600	150	1313	
400	63971	873	600	150	1423	
401	63971	923	650	100	538	
402	63971	923	650	90	1489	
403	69792	823	550	230	613.0	
404	69792	823	550	230	1047.0	
405	69792	823	550	200	5295.0	
406	69792	873	600	180	73	
407	69792	873	600	150	815	
408	69792	873	600	150	2581	
409	801141	823	550	280	40.0	
410	801141	823	550	275	50.0	
411	801141	823	550	280	50.0	
412	801141	823	550	270	60.0	
413	801141	823	550	260	100.0	
414	801141	823	550	250	189.0	
415	801141	823	550	250	271.0	
416	801141	823	550	235	531.0	
417	801141	823	550	230	985.0	
418	801141	823	550	235	1020.0	
419	801141	823	550	230	1144.0	
420	801141	823	550	220	1372.0	
421	801141	823	550	220	1464.0	
422	801141	823	550	220	1924.0	
423	801141	823	550	220	1980.0	
424	801141	823	550	210	4919.0	
425	801141	823	550	210	8480.0	
426	801141	823	550	205	9884.0	
427	801141	823	550	200	12662.0	
428	801141	823	550	195	14895.0	
429	801141	823	550	190	22239.0	
430	801141	823	550	180	34701.0	
431	801141	823	550	160	51929.0	
432	801141	823	550	170	75042.0	
433	801141	823	550	150	110301.0	
434	801141	873	600	160	356	
435	801141	873	600	160	406	
436	801141	873	600	160	499	
437	801141	873	600	160	635	
438	801141	873	600	150	929	
439	801141	873	600	150	1029	
440	801141	873	600	1.45E+02	1256	
441	801141	873	600	1.45E+02	1325	
442	801141	873	600	1.40E+02	2129	
443	801141	873	600	1.40E+02	2161	
444	801141	873	600	1.20E+02	2592.0	
445	801141	873	600	1.30E+02	3653.0	
446	801141	873	600	1.30E+02	4300.0	
447	801141	873	600	1.30E+02	4343.0	
448	801141	873	600	1.30E+02	4832.0	
449	801141	873	600	1.30E+02	5420.0	
450	801141	873	600	1.20E+02	8420.0	
451	801141	873	600	1.20E+02	9856.0	
452	801141	873	600	1.00E+02	9859.0	
453	801141	873	600	1.20E+02	9935.0	
454	801141	873	600	1.20E+02	10027.0	
455	801141	873	600	1.20E+02	11237.0	
456	801141	873	600	1.15E+02	11361.0	
457	801141	873	600	1.10E+02	12186.0	
458	801141	873	600	9.50E+01	13213.0	
459	801141	873	600	1.10E+02	14594.0	
460	801141	873	600	1.10E+02	16265.0	
461	801141	873	600	1.05E+02	17770.0	
462	801141	873	600	1.10E+02	19564.0	
463	801141	873	600	1.10E+02	20497.0	
464	801141	873	600	1.05E+02	24727.0	
465	801141	873	600	1.05E+02	25673.0	
466	801141	873	600	1.05E+02	28465.0	
467	801141	873	600	90	45049.0	
468	801141	873	600	85	53302.0	
469	801141	873	600	80	58439.0	
470	801141	923	650	120	59	
471	801141	923	650	120	84	
472	801141	923	650	110	159	
473	801141	923	650	110	179	
474	801141	923	650	97	340	
475	801141	923	650	100	387	
476	801141	923	650	97	442	
477	801141	923	650	100	497	
478	801141	923	650	95	614	
479	801141	923	650	95	693	
480	801141	923	650	86	826	
481	801141	923	650	86	926	
482	801141	923	650	90	1030	
483	801141	923	650	90	1464	
484	801141	923	650	80	2563	
485	801141	923	650	80	2973	
486	801141	923	650	65	4898	
487	801141	923	650	70	6492	
488	801141	923	650	70	8013	
489	801141	923	650	65	11280	
490	801141	923	650	60	14684	
491	801141	923	650	60	16981	
492	801450	873	600	200	95	
493	801450	873	600	200	99	
494	801450	873	600	170	490	
495	801450	873	600	170	760	
496	801450	873	600	150	2030	

ID	Heat	Temp	Temp	Stress	Rupture	Other
497	801450	873	600	150	2247	
498	801450	873	600	150	3016	
499	801450	873	600	150	3105	
500	801450	873	600	1.40E+02	5284	
501	801450	873	600	1.30E+02	5918.0	
502	801450	873	600	1.40E+02	6592	
503	801450	873	600	1.30E+02	8072.0	
504	801450	873	600	1.30E+02	9140	
505	801450	873	600	1.30E+02	10391	
506	801450	873	600	1.30E+02	10827	
507	801450	873	600	1.30E+02	12444	
508	801450	873	600	1.20E+02	17636.0	
509	801450	873	600	1.10E+02	18359.0	
510	801450	873	600	1.20E+02	18567.0	
511	801450	873	600	1.10E+02	24739.0	
512	801450	873	600	1.10E+02	25139.0	
513	801450	873	600	1.00E+02	35322.0	
514	801450	873	600	9.50E+01	37163.0	
515	801450	873	600	9.50E+01	43670.0	
516	801450	873	600	90	46652.0	
517	801450	873	600	9.00E+01	48358.0	
518	801450	923	650	130	78	
519	801450	923	650	110	131	
520	801450	923	650	115	141	
521	801450	923	650	115	158	
522	801450	923	650	100	575	
523	801450	923	650	100	631	
524	801450	923	650	80	2439	
525	801450	923	650	80	3515	
526	801450	973	700	70	146	
527	801450	973	700	70	157	
528	801450	973	700	50	927	
529	801450	973	700	50	968	
530	801450	973	700	35	3368	
531	801450	973	700	35	4591	
532	865767	873	600	1.50E+02	429	
533	865767	873	600	1.50E+02	553	
534	865767	873	600	150	677	
535	865767	873	600	150	845	
536	865767	873	600	1.30E+02	1192.0	
537	865767	873	600	150	1456	
538	865767	873	600	1.40E+02	1528	
539	865767	873	600	150	1530	
540	865767	873	600	1.30E+02	1593.0	
541	865767	873	600	1.40E+02	1644	
542	865767	873	600	1.30E+02	2645.0	
543	865767	873	600	1.10E+02	3001.0	
544	865767	873	600	1.30E+02	3771.0	
545	865767	873	600	1.30E+02	3872.0	
546	865767	873	600	1.30E+02	3950.0	
547	865767	873	600	1.20E+02	4676.0	
548	865767	873	600	1.00E+02	8778.0	
549	865767	873	600	1.10E+02	10666.0	
550	865767	873	600	1.00E+02	11457.0	
551	865767	873	600	1.10E+02	11632.0	
552	865767	873	600	1.20E+02	12234.0	
553	865767	873	600	9.50E+01	14772.0	
554	865767	873	600	9.50E+01	16412.0	
555	865767	873	600	9.50E+01	18158.0	
556	865767	873	600	1.00E+02	20450.0	
557	865767	873	600	1.00E+02	20739.0	
558	865767	873	600	9.50E+01	21508.0	
559	865767	873	600	90	32198.0	
560	865767	873	600	90	36240.0	
561	865935	873	600	150	3287	
562	865935	873	600	150	4568	
563	865935	873	600	1.30E+02	10697	
564	865935	873	600	1.30E+02	11690	
565	900637	873	600	1.30E+02	5238.0	
566	960637	873	600	150	805	
567	960637	873	600	150	907	
568	960637	873	600	1.30E+02	4775.0	
569	J1t	823	550	265	63.1	JP544
570	J1t	823	550	245	104	JP545
571	J1t	823	550	216	1193	JP546
572	J1t	823	550	196	6620	JP547
573	J1t	873	600	167	183.5	JP549
574	J1t	873	600	167	224.2	JP548
575	J1t	873	600	147	1392.9	JP550
576	J1t	873	600	128	4936.5	JP551
577	J1t	873	600	118	9129.8	JP552
578	J1t	923	650	118	121	JP553
579	J1t	923	650	108	155.2	JP554
580	J1t	923	650	98	476.3	JP555
581	J1t	923	650	78	2045.9	JP557
582	J1t	923	650	78	2530.7	JP556
583	J1t	923	650	69	5293.1	JP558
584	J1t	923	650	69	7308	JP559
585	J2t	873	600	152	1383.9	JP616
586	J2t	873	600	137	2236	JP617
587	J2t	873	600	123	11059	JP618
588	J2t	923	650	108	441	JP619
589	J2t	923	650	88	4115.6	JP620
590	J2t	923	650	74	8831	JP621
591	J3t	823	550	216	1193	JP234
592	J3t	823	550	216	1471	JP233
593	J3t	823	550	216	2089	JP232
594	J3t	823	550	196	8596	JP236
595	J3t	823	550	196	10913	JP235
596	J3t	873	600	167	665	JP238
597	J3t	873	600	167	682	JP237
598	J3t	873	600	147	1392	JP240
599	J3t	873	600	147	2164	JP239
600	J3t	873	600	118	8148	JP243
601	J3t	873	600	118	9624	JP241
602	J3t	873	600	118	13929	JP242
603	J3t	923	650	147	64.1	JP244
604	J3t	923	650	118	148.6	JP245
605	J3t	923	650	118	151.7	JP246
606	J3t	923	650	98	636.5	JP247
607	J3t	923	650	98	680.1	JP248
608	J3t	923	650	78	3802	JP250
609	J3t	923	650	78	4659	JP249
610	J3t	923	650	63	10285	JP251
611	J4t	823	550	265	51.1	JP127
612	J4t	823	550	245	155	JP128
613	J4t	823	550	216	1297	JP129
614	J4t	823	550	196	4990.6	JP130
615	J4t	873	600	166	206.1	JP131
616	J4t	873	600	167	682	JP132
617	J4t	873	600	147	1400.3	JP133
618	J4t	873	600	118	12030	JP134
619	J4t	923	650	118	126.3	JP135
620	J4t	923	650	118	151.7	JP136
621	J4t	923	650	98	591.2	JP137
622	J4t	923	650	78	4002.5	JP138

ID	Heat	Temp	Temp	Stress	Rupture	Other
623	J4t	923	650	69	10475	JP139
624	J4t	923	650	64	13365	JP140
625	J5P	823	550	245	119.9	JP2
626	J5P	823	550	265	138.4	JP1
627	J5P	823	550	216	593.2	JP3
628	J5P	823	550	196	6409	JP4
629	J5P	873	600	177	176	JP5
630	J5P	873	600	167	343.5	JP6
631	J5P	873	600	147	1324	JP7
632	J5P	873	600	128	5518	JP8
633	J5P	873	600	118	9056	JP9
634	J5P	923	650	118	139.8	JP10
635	J5P	923	650	108	280.5	JP11
636	J5P	923	650	98	637.7	JP12
637	J5P	923	650	78	3148.4	JP13
638	J5P	923	650	69	7962	JP15
639	J5P	923	650	69	9127	JP14
640	J5P	923	650	64	15174	JP16
641	J6P	773	500	343	56	JP17
642	J6P	773	500	324	210	JP18
643	J6P	773	500	278	3686	JP19
644	J6P	823	550	265	16	JP20
645	J6P	823	550	235	350	JP21
646	J6P	823	550	191	3724	JP22
647	J6P	873	600	186	40	JP23
648	J6P	873	600	167	147	JP24
649	J6P	873	600	156	760	JP25
650	J6P	923	650	127	47	JP27
651	J6P	923	650	118	121	JP26
652	J6P	923	650	108	221	JP28
653	J6P	923	650	87	3502	JP29
654	J6P	923	650	70	16296	JP30
655	J6P	923	650	61	40542	JP31
656	J6P	973	700	78	62	JP32
657	J6P	973	700	69	118	JP33
658	J6P	973	700	52	948	JP34
659	J6P	973	700	34	15730	JP35
660	J7P	773	500	323	136	JP37
661	J7P	773	500	323	197	JP36
662	J7P	773	500	277	3928	JP38
663	J7P	773	500	277	3966	JP39
664	J7P	823	550	265	27	JP40
665	J7P	823	550	265	39	JP41
666	J7P	823	550	235	159	JP42
667	J7P	823	550	191	3462	JP44
668	J7P	823	550	191	4968	JP43
669	J7P	873	600	186	25	JP45
670	J7P	873	600	186	28	JP46
671	J7P	873	600	156	318	JP47
672	J7P	873	600	156	324	JP48
673	J7P	873	600	138	760	JP51
674	J7P	873	600	138	964	JP49
675	J7P	873	600	138	1428	JP50
676	J7P	873	600	122	4266	JP52
677	J7P	873	600	122	7490	JP53
678	J7P	923	650	127	27	JP54
679	J7P	923	650	127	35	JP55
680	J7P	923	650	108	135	JP58
681	J7P	923	650	108	166	JP57
682	J7P	923	650	108	183	JP56
683	J7P	923	650	87	1376	JP61
684	J7P	923	650	87	1522	JP60
685	J7P	923	650	87	2042	JP59
686	J7P	923	650	70	10072	JP64
687	J7P	923	650	70	10968	JP62
688	J7P	923	650	70	11778	JP63
689	J7P	923	650	61	25560	JP66
690	J7P	923	650	61	30546	JP67
691	J7P	923	650	61	32532	JP65
692	J7P	973	700	69	125	JP69
693	J7P	973	700	69	128	JP70
694	J7P	973	700	69	164	JP68
695	J7P	973	700	34	9698	JP73
696	J7P	973	700	34	11830	JP72
697	J7P	973	700	34	12038	JP71
698	J9t	773	500	343	53	JP74
699	J9t	773	500	324	203	JP75
700	J9t	773	500	294	1050	JP76
701	J9t	773	500	278	3660	JP77
702	J9t	823	550	294	17	JP78
703	J9t	823	550	255	113	JP79
704	J9t	823	550	245	239	JP80
705	J9t	823	550	226	851	JP81
706	J9t	823	550	216	1676	JP82
707	J9t	823	550	196	3257	JP83
708	J9t	873	600	196	38	JP85
709	J9t	873	600	196	74	JP84
710	J9t	873	600	167	426	JP87
711	J9t	873	600	177	443	JP86
712	J9t	873	600	167	695	JP88
713	J9t	873	600	156	1012	JP89
714	J9t	873	600	147	1897	JP91
715	J9t	873	600	156	2076	JP90
716	J9t	873	600	138	4750	JP92
717	J9t	873	600	138	4864	JP93
718	J9t	873	600	122	12470	JP95
719	J9t	873	600	122	13200	JP94
720	J9t	873	600	104	62512	JP97
721	J9t	873	600	104	66234	JP96
722	J9t	923	650	137	57	JP98
723	J9t	923	650	127	88	JP99
724	J9t	923	650	127	150	JP100
725	J9t	923	650	118	313	JP101
726	J9t	923	650	104	566	JP105
727	J9t	923	650	104	696	JP104
728	J9t	923	650	108	703	JP103
729	J9t	923	650	108	736	JP102
730	J9t	923	650	98	991	JP106
731	J9t	923	650	88	4129	JP107
732	J9t	923	650	86	7668	JP108
733	J9t	923	650	78	7682	JP109
734	J9t	923	650	70	14880	JP112
735	J9t	923	650	70	17029	JP111
736	J9t	923	650	70	20304	JP110
737	J9t	923	650	70	23485	JP113
738	J9t	923	650	68	23613	JP114
739	J9t	923	650	52	57678	JP116
740	J9t	923	650	52	62532	JP115
741	J9t	973	700	88	60	JP117
742	J9t	973	700	78	98	JP118
743	J9t	973	700	69	302	JP120
744	J9t	973	700	69	400	JP119
745	J9t	973	700	59	587	JP121
746	J9t	973	700	52	960	JP122
747	J9t	973	700	52	1256	JP123
748	J9t	973	700	49	1462	JP124

ID	Heat	Temp	Temp	Stress	Rupture	Other
749	J9t	973	700	34	3924	JP125
750	J9t	973	700	34	5424	JP126
751	J12t	823	550	274.6	144	JP560
752	J12t	823	550	255	612.8	JP561
753	J12t	823	550	245.2	1142.6	JP563
754	J12t	823	550	245.2	1752.8	JP562
755	J12t	823	550	230.5	3462	JP564
756	J12t	823	550	230.5	5938	JP565
757	J12t	823	550	215.7	8037	JP566
758	J12t	823	550	205.9	14988	JP567
759	J12t	823	550	205.9	15094	JP568
760	J12t	823	550	196.1	21521	JP569
761	J12t	873	600	176.5	453.2	JP571
762	J12t	873	600	187.3	481.3	JP570
763	J12t	873	600	166.7	689	JP572
764	J12t	873	600	166.7	782.4	JP573
765	J12t	873	600	152	1394	JP574
766	J12t	873	600	147.1	3109	JP575
767	J12t	873	600	137.3	5250	JP577
768	J12t	873	600	137.3	6310	JP576
769	J12t	873	600	127.5	12715	JP578
770	J12t	873	600	118.7	16715	JP579
771	J12t	923	650	117.7	225.3	JP580
772	J12t	923	650	107.9	498.5	JP581
773	J12t	923	650	98.1	689	JP583
774	J12t	923	650	98.1	1037	JP582
775	J12t	923	650	98.1	1467	JP584
776	J12t	923	650	93.2	2088	JP585
777	J12t	923	650	93.2	2088	JP586
778	J12t	923	650	88.3	2532	JP588
779	J12t	923	650	88.3	3342	JP587
780	J12t	923	650	88.4	3532	JP589
781	J12t	923	650	88.4	3827	JP591
782	J12t	923	650	88.4	4331	JP590
783	J12t	923	650	68.6	11001	JP593
784	J12t	923	650	68.6	11808	JP592
785	J14t	823	550	274.6	100.7	JP506
786	J14t	823	550	255	484.6	JP507
787	J14t	823	550	245.2	1005.8	JP509
788	J14t	823	550	245	1152	JP508
789	J14t	823	550	245.2	1507.9	JP510
790	J14t	823	550	231.4	2606.6	JP511
791	J14t	823	550	230.5	5080	JP512
792	J14t	823	550	215.7	7405.8	JP513
793	J14t	823	550	206.9	11919	JP516
794	J14t	823	550	215.7	12732	JP514
795	J14t	823	550	205.9	13144	JP515
796	J14t	873	600	188.3	135.6	JP517
797	J14t	873	600	176.5	160.4	JP518
798	J14t	873	600	166.7	456.6	JP520
799	J14t	873	600	166.7	597.8	JP519
800	J14t	873	600	167.7	600.9	JP521
801	J14t	873	600	152	1222.4	JP522
802	J14t	873	600	152	1763.1	JP523
803	J14t	873	600	147.1	2310.1	JP526
804	J14t	873	600	147.1	2759	JP524
805	J14t	873	600	147.1	3776.8	JP525
806	J14t	873	600	137.3	4820.8	JP527
807	J14t	873	600	127.5	10276	JP528
808	J14t	873	600	118.7	17788	JP529
809	J14t	923	650	117.7	169.2	JP530
810	J14t	923	650	107.9	366.6	JP531
811	J14t	923	650	98.1	625	JP533
812	J14t	923	650	98.1	842.1	JP532
813	J14t	923	650	98.1	1255	JP534
814	J14t	923	650	93.2	1563.6	JP535
815	J14t	923	650	93.2	2660.6	JP536
816	J14t	923	650	88.3	2767.2	JP538
817	J14t	923	650	88.3	3177.1	JP537
818	J14t	923	650	83.4	3446.3	JP540
819	J14t	923	650	83.4	4013.6	JP539
820	J14t	923	650	83.4	4128.4	JP541
821	J14t	923	650	68.6	10882	JP543
822	J14t	923	650	68.6	16378	JP542
823	J16t	823	550	274.6	326.8	JP474
824	J16t	823	550	255	1298	JP475
825	J16t	823	550	245.2	2916	JP476
826	J16t	823	550	245.2	3507	JP477
827	J16t	823	550	245.2	5065	JP478
828	J16t	823	550	230.5	9512	JP479
829	J16t	823	550	230.5	13208	JP480
830	J16t	823	550	216.7	16700	JP481
831	J16t	823	550	215.7	17939	JP482
832	J16t	823	550	205.9	23329	JP483
833	J16t	873	600	187.3	470.9	JP484
834	J16t	873	600	166.7	1148	JP486
835	J16t	873	600	166.7	1499	JP487
836	J16t	873	600	166.7	1601	JP485
837	J16t	873	600	152	3404	JP488
838	J16t	873	600	152	3405	JP489
839	J16t	873	600	147.1	4330	JP490
840	J16t	873	600	147.1	5171	JP491
841	J16t	873	600	137.3	5404	JP492
842	J16t	873	600	127.5	14623	JP493
843	J16t	873	600	127.5	15317	JP494
844	J16t	923	650	117.7	276.4	JP495
845	J16t	923	650	107.9	490	JP496
846	J16t	923	650	99	1290	JP497
847	J16t	923	650	98.1	1327	JP498
848	J16t	923	650	98.1	1365	JP499
849	J16t	923	650	93.2	1874	JP501
850	J16t	923	650	93.2	1981	JP500
851	J16t	923	650	88.3	3030	JP503
852	J16t	923	650	88.3	4018	JP502
853	J16t	923	650	83.4	4266	JP505
854	J16t	923	650	83.4	4987	JP504
855	J18pl	773	500	392.3	67.8	JP454
856	J18pl	773	500	362.9	271.5	JP455
857	J18pl	773	500	345.2	746.3	JP456
858	J18pl	773	500	313.8	10296	JP457
859	J18pl	823	550	294.2	109.9	JP458
860	J18pl	823	550	264.8	814	JP459
861	J18pl	823	550	255	1538.9	JP460
862	J18pl	823	550	245.2	3174	JP461
863	J18pl	823	550	224.6	12167	JP462
864	J18pl	823	550	197.1	30726	JP463
865	J18pl	873	600	197.1	231.8	JP464
866	J18pl	873	600	167.7	1191	JP465
867	J18pl	873	600	146.1	6221.6	JP466
868	J18pl	873	600	127.5	13464	JP467
869	J18pl	873	600	127.5	16104	JP468
870	J18pl	923	650	138.3	110.6	JP469
871	J18pl	923	650	117.7	304.4	JP470
872	J18pl	923	650	98.1	1396	JP471
873	J18pl	923	650	88.3	3431	JP472
874	J18pl	923	650	73.6	12585	JP473

ID	Heat	Temp	Temp	Stress	Rupture	Other
875	J19pl	773	500	392.3	55	JP434
876	J19pl	773	500	362.9	186.6	JP435
877	J19pl	773	500	343.2	567.2	JP436
878	J19pl	773	500	323.6	3284	JP437
879	J19pl	823	550	294.2	63.1	JP438
880	J19pl	823	550	263.8	569	JP439
881	J19pl	823	550	245.2	2090	JP441
882	J19pl	823	550	225.6	8367	JP442
883	J19pl	823	550	255	11120	JP440
884	J19pl	823	550	197.1	24508	JP443
885	J19pl	873	600	196.1	181.8	JP444
886	J19pl	873	600	167.7	819	JP445
887	J19pl	873	600	146.1	3883	JP446
888	J19pl	873	600	127.5	14093	JP447
889	J19pl	873	600	127.5	15460	JP448
890	J19pl	923	650	137.3	98.5	JP449
891	J19pl	923	650	116.7	287.9	JP450
892	J19pl	923	650	98.1	1277	JP451
893	J19pl	923	650	88.3	2432	JP452
894	J19pl	923	650	73.6	12689	JP453
895	J20pl	773	500	343.3	180	JP393
896	J20pl	773	500	313	1765.8	JP394
897	J20pl	773	500	304	2437.7	JP395
898	J20pl	773	500	296.2	13981	JP396
899	J20pl	773	500	274.6	24565	JP397
900	J20pl	823	550	276.6	96.8	JP398
901	J20pl	823	550	230	995.3	JP399
902	J20pl	823	550	215.8	5001	JP400
903	J20pl	823	550	205.9	5053	JP401
904	J20pl	823	550	197.1	8282.5	JP402
905	J20pl	823	550	186.3	19316	JP403
906	J20pl	873	600	197	33.5	JP404
907	J20pl	873	600	167.7	337.3	JP405
908	J20pl	873	600	147.1	2723.1	JP406
909	J20pl	873	600	137.3	3584.9	JP407
910	J20pl	873	600	127.5	9324.5	JP408
911	J20pl	873	600	117.7	17037	JP409
912	J20pl	923	650	147.1	11.9	JP410
913	J20pl	923	650	118.7	140.5	JP411
914	J20pl	923	650	88.3	1915	JP412
915	J20pl	923	650	78.5	6107.2	JP413
916	J21pl	773	500	345.2	189.6	JP414
917	J21pl	773	500	305	1970	JP416
918	J21pl	773	500	313.8	2700	JP415
919	J21pl	773	500	297.1	3066	JP417
920	J21pl	823	550	276.6	21.1	JP418
921	J21pl	823	550	230.5	1111	JP419
922	J21pl	823	550	215.8	2711	JP420
923	J21pl	823	550	205.9	6367	JP421
924	J21pl	823	550	196.1	8337	JP422
925	J21pl	823	550	186.3	19976	JP423
926	J21pl	873	600	197.1	31.5	JP424
927	J21pl	873	600	165.7	382	JP425
928	J21pl	873	600	147.1	2267	JP426
929	J21pl	873	600	137.3	2982	JP427
930	J21pl	873	600	127.5	8754	JP428
931	J21pl	873	600	117.7	15577	JP429
932	J21pl	923	650	148.1	12.3	JP430
933	J21pl	923	650	117.7	132	JP431
934	J21pl	923	650	98.1	881	JP432
935	J21pl	923	650	78.5	5324	JP433
936	J22pl	773	500	342.3	409	JP329
937	J22pl	773	500	313.8	2145	JP330
938	J22pl	773	500	295.2	7054	JP331
939	J22pl	823	550	274.6	40.6	JP332
940	J22pl	823	550	246.2	461	JP333
941	J22pl	823	550	215.8	3997	JP334
942	J22pl	823	550	195.2	13404	JP335
943	J22pl	873	600	196.1	63.9	JP336
944	J22pl	873	600	166.7	618	JP337
945	J22pl	873	600	146.1	2772	JP338
946	J22pl	873	600	137.3	5158	JP339
947	J22pl	923	650	137.3	38.1	JP340
948	J22pl	923	650	117.7	155	JP341
949	J22pl	923	650	98.1	1460	JP342
950	J22pl	923	650	88.3	2114	JP343
951	J23pl	773	500	341.3	279	JP344
952	J23pl	773	500	313.8	2308	JP345
953	J23pl	773	500	294.2	5509	JP346
954	J23pl	823	550	274.6	37.8	JP347
955	J23pl	823	550	246.2	430	JP348
956	J23pl	823	550	214.8	3374	JP349
957	J23pl	823	550	196.1	15058	JP350
958	J23pl	873	600	196.1	39.5	JP351
959	J23pl	873	600	165.7	546	JP352
960	J23pl	873	600	147.1	2590	JP353
961	J23pl	873	600	137.3	3717	JP354
962	J23pl	923	650	137.3	40.4	JP355
963	J23pl	923	650	117.7	142	JP356
964	J23pl	923	650	98.1	1189	JP358
965	J23pl	923	650	98.1	1560	JP357
966	J23pl	923	650	88.3	3856	JP359
967	J24pl	773	500	344.2	267	JP360
968	J24pl	773	500	313.8	1638	JP361
969	J24pl	773	500	294.2	10365	JP362
970	J24pl	823	550	274.6	45.8	JP363
971	J24pl	823	550	244.2	377.8	JP364
972	J24pl	823	550	214.8	3959	JP365
973	J24pl	823	550	195.2	16843	JP366
974	J24pl	873	600	196.1	53.8	JP367
975	J24pl	873	600	166.7	510.8	JP368
976	J24pl	873	600	147.1	2904	JP369
977	J24pl	873	600	137.3	2971	JP370
978	J24pl	923	650	137.3	32.8	JP371
979	J24pl	923	650	117.7	181	JP372
980	J24pl	923	650	98.1	1291	JP373
981	J24pl	923	650	88.3	2593	JP374
982	J25pl	773	500	333.4	84.7	JP375
983	J25pl	773	500	295.2	1200	JP376
984	J25pl	773	500	274.6	4393	JP377
985	J25pl	773	500	263.8	11297	JP378
986	J25pl	823	550	245.2	162.3	JP379
987	J25pl	823	550	215.8	801	JP380
988	J25pl	823	550	196.1	4161	JP381
989	J25pl	823	550	176.5	22429	JP382
990	J25pl	823	550	165.7	25638	JP383
991	J25pl	873	600	167.7	105	JP384
992	J25pl	873	600	146.1	610.5	JP385
993	J25pl	873	600	152	1383.9	JP387
994	J25pl	873	600	137	2236	JP388
995	J25pl	873	600	117.7	6436	JP386
996	J25pl	873	600	123	11059	JP389
997	J25pl	923	650	108	441	JP390
998	J25pl	923	650	88	4115.6	JP391
999	J25pl	923	650	74	8831	JP392
1000	J26pl	773	500	332.5	86.9	JP279

ID	Heat	Temp	Temp	Stress	Rupture	Other
1001	J26pl	773	500	293.2	2223	JP280
1002	J26pl	773	500	274.6	4341	JP281
1003	J26pl	773	500	264.8	7959	JP282
1004	J26pl	823	550	243.2	150.8	JP283
1005	J26pl	823	550	215.8	885	JP284
1006	J26pl	823	550	195.2	3469	JP285
1007	J26pl	823	550	176.5	18215	JP286
1008	J26pl	873	600	167.7	89.6	JP287
1009	J26pl	873	600	146.1	1009	JP288
1010	J26pl	873	600	117.7	6092	JP289
1011	J27t	773	500	373	38.3	JP290
1012	J27t	773	500	353	138.7	JP291
1013	J27t	773	500	324	808.8	JP292
1014	J27t	773	500	294	4651.4	JP293
1015	J27t	823	550	294	17.4	JP294
1016	J27t	823	550	265	111.6	JP295
1017	J27t	823	550	245	340	JP296
1018	J27t	823	550	196	28375	JP297
1019	J27t	823	550	177	38595	JP298
1020	J27t	873	600	177	241	JP299
1021	J27t	873	600	157	1200	JP300
1022	J27t	873	600	147.1	2723.1	JP302
1023	J27t	873	600	127	16760	JP301
1024	J27t	923	650	127	120.8	JP303
1025	J27t	923	650	108	709.9	JP304
1026	J27t	923	650	78	10604	JP305
1027	J28t	773	500	373	44.5	JP306
1028	J28t	773	500	353	143	JP307
1029	J28t	773	500	324	749	JP308
1030	J28t	773	500	294	4875	JP309
1031	J28t	823	550	294	19.5	JP310
1032	J28t	823	550	265	114.3	JP311
1033	J28t	823	550	245	397.7	JP312
1034	J28t	823	550	196	32699	JP313
1035	J28t	873	600	177	270	JP314
1036	J28t	873	600	157	1466	JP315
1037	J28t	923	650	127	134.9	JP316
1038	J28t	923	650	108	793	JP317
1039	J28t	923	650	78	12358	JP318
1040	J29t	773	500	324	1113	JP319
1041	J29t	773	500	304	2789	JP320
1042	J29t	823	550	265	44.4	JP321
1043	J29t	823	550	235	341	JP322
1044	J29t	823	550	206	5512	JP323
1045	J29t	873	600	196	24.1	JP324
1046	J29t	873	600	167	187.7	JP325
1047	J29t	873	600	137	2605	JP326
1048	J29t	923	650	137	20.8	JP327
1049	J29t	923	650	108	238.8	JP328
1050	J30t	773	500	324	715	JP252
1051	J30t	773	500	304	2131	JP253
1052	J30t	823	550	265	46.8	JP254
1053	J30t	823	550	206	3877	JP255
1054	J30t	873	600	196	20	JP256
1055	J30t	873	600	167	161.9	JP257
1056	J30t	873	600	137	1441	JP258
1057	J30t	923	650	137	17.1	JP259
1058	J30t	923	650	108	177.7	JP260
1059	J30t	923	650	78	4377	JP261
1060	J31t	773	500	324	1085	JP262
1061	J31t	773	500	304	2846	JP263
1062	J31t	823	550	265	59.2	JP264
1063	J31t	823	550	235	305.3	JP265
1064	J31t	823	550	206	2498	JP266
1065	J31t	873	600	196	21.5	JP273
1066	J31t	873	600	196	30.1	JP267
1067	J31t	873	600	167	200	JP274
1068	J31t	873	600	167	228	JP268
1069	J31t	873	600	157	599	JP275
1070	J31t	873	600	137	2141	JP269
1071	J31t	923	650	137	24.9	JP270
1072	J31t	923	650	118	99.6	JP276
1073	J31t	923	650	108	190	JP277
1074	J31t	923	650	108	335.5	JP271
1075	J31t	923	650	98	645	JP278
1076	J31t	923	650	78	5294	JP272
1077	J32t	873	600	195	21.5	JP594
1078	J32t	873	600	167	200	JP595
1079	J32t	873	600	157	559.2	JP596
1080	J32t	923	650	118	99.6	JP598
1081	J32t	923	650	108	190	JP597
1082	J32t	923	650	98	645	JP599
1083	J33t	823	550	265	57.5	JP186
1084	J33t	823	550	245	178.3	JP187
1085	J33t	823	550	196	5931	JP188
1086	J33t	873	600	177	82.9	JP189
1087	J33t	873	600	157	460.5	JP190
1088	J33t	873	600	137	2661	JP191
1089	J33t	923	650	118	102.9	JP192
1090	J33t	923	650	78	5149	JP193
1091	J33t	923	650	69	15351	JP194
1092	J34pl	773	500	363	27.7	JP195
1093	J34pl	773	500	333	173.5	JP196
1094	J34pl	773	500	275	8525	JP197
1095	J34pl	823	550	265	44.1	JP198
1096	J34pl	823	550	235	350.5	JP199
1097	J34pl	823	550	226	875	JP200
1098	J34pl	823	550	196	8121	JP201
1099	J34pl	873	600	157	157.4	JP206
1100	J34pl	873	600	157	284.9	JP204
1101	J34pl	873	600	167	325	JP202
1102	J34pl	873	600	157	368.4	JP205
1103	J34pl	873	600	157	373	JP203
1104	J34pl	923	650	108	108.2	JP209
1105	J34pl	923	650	108	173.5	JP207
1106	J34pl	923	650	108	205.3	JP208
1107	J35P	873	600	157	157.4	JP612
1108	J35P	873	600	157	284.9	JP610
1109	J35P	873	600	157	368.4	JP611
1110	J35P	873	600	157	373.3	JP609
1111	J35P	923	650	108	108.2	JP615
1112	J35P	923	650	108	173.5	JP613
1113	J35P	923	650	108	205.3	JP614
1114	J36P	823	550	265	38.8	JP210
1115	J36P	823	550	245	141.8	JP211
1116	J36P	823	550	196	2397	JP212
1117	J36P	873	600	196	31.7	JP213
1118	J36P	873	600	137	1750	JP216
1119	J36P	873	600	157	1772	JP214
1120	J36P	873	600	137	2200	JP217
1121	J36P	873	600	137	3425	JP215
1122	J36P	923	650	127	28.2	JP218
1123	J36P	923	650	98	509	JP219
1124	J36P	923	650	78	4313	JP220
1125	J37P	823	550	196	8394.1	JP600
1126	J37P	873	600	157	350.4	JP601

ID	Heat	Temp	Temp	Stress	Rupture	Other
1127	J37P	873	600	147	742.4	JP602
1128	J37P	873	600	137	1725.1	JP603
1129	J37P	873	600	137	2192.3	JP604
1130	J38P	823	550	196	2730.4	JP606
1131	J38P	823	550	196	3988.6	JP605
1132	J38P	873	600	177	57.3	JP608
1133	J38P	873	600	177	77.5	JP607
1134	J39P	823	550	265	85.4	JP221
1135	J39P	823	550	216	1287	JP223
1136	J39P	823	550	216	4592	JP222
1137	J39P	873	600	196	60.3	JP224
1138	J39P	873	600	157	1164	JP225
1139	J39P	873	600	127	4248	JP227
1140	J39P	873	600	127	6218	JP226
1141	J39P	923	650	127	87.2	JP228
1142	J39P	923	650	98	754.6	JP229
1143	J39P	923	650	78	5074	JP231
1144	J39P	923	650	78	5153	JP230
1145	J40P	823	550	265	50.8	JP141
1146	J40P	823	550	245	145.4	JP142
1147	J40P	823	550	226	588	JP143
1148	J40P	873	600	186	52.4	JP144
1149	J40P	873	600	167	141.9	JP145
1150	J40P	873	600	147	799	JP146
1151	J40P	923	650	118	72.5	JP147
1152	J40P	923	650	98	441.6	JP148
1153	J40P	923	650	88	1041.2	JP149
1154	J41P	823	550	255	447.5	JP150
1155	J41P	823	550	226	8952	JP151
1156	J41P	873	600	177	377	JP152
1157	J41P	873	600	157	1729	JP153
1158	J41P	873	600	132	6343	JP154
1159	J41P	873	600	123	10901	JP155
1160	J41P	923	650	118	168.5	JP156
1161	J41P	923	650	98	460	JP157
1162	J41P	923	650	83	2830	JP158
1163	J41P	923	650	74	8410	JP159
1164	J41P	823	550	255	81.4	JP160
1165	J42P	823	550	226	708	JP161
1166	J42P	823	550	196	5389	JP162
1167	J42P	873	600	177	104.4	JP163
1168	J42P	873	600	157	643	JP164
1169	J42P	873	600	132	4371	JP165
1170	J42P	873	600	123	16749	JP166
1171	J42P	923	650	118	126.6	JP167
1172	J42P	923	650	98	1255	JP168
1173	J42P	923	650	83	5558	JP169
1174	J42P	923	650	74	17177	JP170
1175	J43P	873	600	177	59.9	JP622
1176	J43P	873	600	177	64.9	JP624
1177	J43P	873	600	177	75.1	JP623
1178	J43P	873	600	177	98.8	JP625
1179	J43P	873	600	157	243.3	JP628
1180	J43P	873	600	157	253.1	JP626
1181	J43P	873	600	157	395.1	JP627
1182	J43P	873	600	157	430.4	JP629
1183	J43P	873	600	132	1994.7	JP630
1184	J43P	873	600	132	2126.6	JP632
1185	J43P	873	600	132	2696	JP631
1186	J43P	873	600	132	3908.6	JP633
1187	J44P	773	500	363	12	JP171
1188	J44P	773	500	314	302.2	JP172
1189	J44P	773	500	275	3965.2	JP173
1190	J44P	823	550	275	22.9	JP174
1191	J44P	823	550	235	346.7	JP175
1192	J44P	823	550	216	1114.7	JP176
1193	J44P	823	550	196	3153.2	JP177
1194	J44P	873	600	186	36.4	JP178
1195	J44P	873	600	167	201.4	JP179
1196	J44P	873	600	147	1763.8	JP180
1197	J44P	873	600	108	40246	JP181
1198	J44P	923	650	127	40.6	JP182
1199	J44P	923	650	98	795.6	JP183
1200	J44P	923	650	78	5129.2	JP184
1201	J44P	923	650	69	22900	JP185
1202	JF10pl	823	550	216	2150	
1203	JF10pl	823	550	211	3093.5	
1204	JF10pl	823	550	211	2163.4	
1205	JF10pl	823	550	211	2045.6	
1206	JF10pl	823	550	211	1469.9	
1207	JF10pl	823	550	206	4049.8	
1208	JF10pl	873	600	142	1348.6	
1209	JF10pl	873	600	142	1949	
1210	JF10pl	873	600	142	2496.7	
1211	JF10pl	873	600	142	1555.7	
1212	JF11f	823	550	167	30507.8	
1213	JF11f	873	600	127	4011.9	
1214	JF2t	773	500	333	399.5	
1215	JF2t	773	500	314	1926.7	
1216	JF2t	773	500	304	1903.8	
1217	JF2t	773	500	304	1309.2	
1218	JF2t	773	500	284	5554	
1219	JF2t	773	500	284	4953.6	
1220	JF2t	773	500	275	7167.9	
1221	JF2t	773	500	265	17283.7	
1222	JF2t	773	500	255	25855.4	
1223	JF2t	823	550	245	286.4	
1224	JF2t	823	550	226	696.4	
1225	JF2t	823	550	216	1598.4	
1226	JF2t	823	550	211	1445.4	
1227	JF2t	823	550	206	2141	
1228	JF2t	823	550	201	3164.7	
1229	JF2t	823	550	191	9851.3	
1230	JF2t	823	550	191	8116.7	
1231	JF2t	823	550	177	22365.8	
1232	JF2t	873	600	177	128.1	
1233	JF2t	873	600	157	357.9	
1234	JF2t	873	600	137	3397.5	
1235	JF2t	873	600	127	7864.8	
1236	JF2t	873	600	118	15716.1	
1237	JF2t	873	600	113	10169.7	
1238	JF3t	773	500	343	97.3	
1239	JF3t	773	500	324	290.1	
1240	JF3t	773	500	314	1006.8	
1241	JF3t	773	500	314	1114.8	
1242	JF3t	773	500	309	760.1	
1243	JF3t	773	500	304	2034.3	
1244	JF3t	773	500	294	1423	
1245	JF3t	773	500	284	1890.9	
1246	JF3t	773	500	284	2881.9	
1247	JF3t	773	500	284	3068.1	
1248	JF3t	773	500	260	10109.1	
1249	JF3t	823	550	245	79.8	
1250	JF3t	823	550	230	240.5	
1251	JF3t	823	550	226	987.4	
1252	JF3t	823	550	216	762.1	

ID	Heat	Temp	Temp	Stress	Rupture	Other
1253	JF3t	823	550	211	997.6	
1254	JF3t	823	550	206	5398.2	
1255	JF3t	823	550	191	6327.8	
1256	JF3t	823	550	181	10306.1	
1257	JF3t	873	600	162	170.7	
1258	JF3t	873	600	152	538.5	
1259	JF3t	873	600	142	952.3	
1260	JF3t	873	600	137	2237.3	
1261	JF3t	873	600	132	2457.4	
1262	JF3t	873	600	123	6434.7	
1263	JF3t	873	600	113	14774.2	
1264	JF4f	773	500	333	59.1	
1265	JF4f	773	500	314	272.7	
1266	JF4f	773	500	314	223.7	
1267	JF4f	773	500	314	226.8	
1268	JF4f	773	500	314	201.3	
1269	JF4f	773	500	314	298.5	
1270	JF4f	773	500	294	1157	
1271	JF4f	773	500	294	906.7	
1272	JF4f	773	500	294	1129.2	
1273	JF4f	773	500	294	1010.8	
1274	JF4f	773	500	294	860.7	
1275	JF4f	773	500	294	1160.8	
1276	JF4f	773	500	294	1280.9	
1277	JF4f	773	500	294	871.2	
1278	JF4f	773	500	294	1047.7	
1279	JF4f	773	500	275	4288.8	
1280	JF4f	773	500	275	7156.8	
1281	JF4f	773	500	275	4068.6	
1282	JF4f	773	500	275	2803.4	
1283	JF4f	773	500	275	4020.2	
1284	JF4f	823	550	235	222.4	
1285	JF4f	823	550	235	228.1	
1286	JF4f	823	550	216	839.7	
1287	JF4f	823	550	216	907.2	
1288	JF4f	823	550	216	721.6	
1289	JF4f	823	550	216	720.1	
1290	JF4f	823	550	216	835.4	
1291	JF4f	823	550	201	1649.9	
1292	JF4f	873	600	146	746.2	
1293	JF4f	923	650	92	1080.2	
1294	JF5f	823	550	196	1803.4	
1295	JF5f	823	550	196	1563.4	
1296	JF5f	823	550	196	1463.9	
1297	JF6pl	723	450	436	7.4	
1298	JF6pl	723	450	392	364.7	
1299	JF6pl	723	450	387	12785	
1300	JF6pl	723	450	382	37992.7	
1301	JF6pl	723	450	373	22824.5	
1302	JF6pl	773	500	353	21	
1303	JF6pl	773	500	333	116.9	
1304	JF6pl	773	500	314	505.4	
1305	JF6pl	773	500	294	2435.7	
1306	JF6pl	773	500	294	3514.3	
1307	JF6pl	773	500	284	7812.4	
1308	JF6pl	773	500	275	4997	
1309	JF6pl	773	500	255	13553.4	
1310	JF6pl	773	500	245	27147.7	
1311	JF6pl	823	550	255	44.3	
1312	JF6pl	823	550	235	153.1	
1313	JF6pl	823	550	216	884.2	
1314	JF6pl	823	550	206	2282.1	
1315	JF6pl	823	550	196	3148.1	
1316	JF6pl	823	550	186	9348.6	
1317	JF6pl	823	550	177	13688.4	
1318	JF6pl	823	550	167	43918.4	
1319	JF6pl	873	600	177	59.9	
1320	JF6pl	873	600	157	301.7	
1321	JF6pl	873	600	137	2311.8	
1322	JF6pl	873	600	127	4477.7	
1323	JF6pl	873	600	118	11769.9	
1324	JF6pl	873	600	113	16109.7	
1325	JF6pl	923	650	118	75.6	
1326	JF6pl	923	650	98	523.8	
1327	JF6pl	923	650	93	1102.3	
1328	JF6pl	923	650	83	3328.4	
1329	JF6pl	923	650	78	4945.6	
1330	JF6pl	923	650	74	7614.2	
1331	JF7pl	773	500	333	329.7	
1332	JF7pl	773	500	333	687.8	
1333	JF7pl	773	500	333	560.6	
1334	JF7pl	773	500	294	4184.3	
1335	JF7pl	773	500	294	7074.1	
1336	JF7pl	773	500	294	4040.7	
1337	JF7pl	823	550	235	264.3	
1338	JF7pl	823	550	235	596.6	
1339	JF7pl	823	550	235	588.9	
1340	JF7pl	823	550	206	2342	
1341	JF7pl	823	550	206	6700.1	
1342	JF8f	773	500	314	376.9	
1343	JF8f	773	500	314	289.3	
1344	JF8f	773	500	314	841.1	
1345	JF8f	773	500	314	449.8	
1346	JF8f	773	500	294	2011.7	
1347	JF8f	773	500	294	1790.5	
1348	JF8f	773	500	294	2705.8	
1349	JF8f	773	500	294	2300.6	
1350	JF8f	773	500	275	5340	
1351	JF8f	773	500	275	5243	
1352	JF8f	773	500	275	6322.6	
1353	JF8f	773	500	275	5609.9	
1354	JF8f	823	550	216	262.9	
1355	JF8f	823	550	216	513	
1356	JF8f	823	550	216	584.6	
1357	JF8f	823	550	206	1044.7	
1358	JF8f	823	550	206	976.4	
1359	JF8f	823	550	196	1059.2	
1360	JF8f	823	550	196	1454.7	
1361	JF8f	823	550	196	2402.1	
1362	JF8f	823	550	177	4567.3	
1363	JF9pl	773	500	314	219.2	
1364	JF9pl	773	500	284	3485.6	
1365	JF9pl	823	550	235	830.1	
1366	JF9pl	823	550	216	2933.8	
1367	JF9pl	823	550	206	6831	
1368	JF9pl	823	550	206	1541.5	
1369	JF9pl	823	550	196	4744.1	
1370	JF9pl	823	550	183	5819.9	
1371	JF9pl	823	550	175	21042.1	
1372	JF9pl	873	600	177	167	
1373	JF9pl	873	600	157	812.3	
1374	JF9pl	873	600	147	2097.3	
1375	JF9pl	873	600	137	4736.1	
1376	JF9pl	873	600	127	9941	
1377	MgApl	723	450	400	309.5	
1378	MgApl	723	450	390	7711.2	

ID	Heat	Temp	Temp	Stress	Rupture	Other
1379	MgApl	723	450	370	19990.1	
1380	MgApl	723	450	360	30343.8	
1381	MgApl	773	500	300	631.8	
1382	MgApl	773	500	270	5857	
1383	MgApl	773	500	280	7691.3	
1384	MgApl	773	500	260	7979.5	
1385	MgApl	823	550	220	423.4	
1386	MgApl	823	550	200	2549	
1387	MgApl	823	550	190	6149.6	
1388	MgApl	823	550	180	17210	
1389	MgApl	873	600	160	162.6	
1390	MgApl	873	600	140	1722.4	
1391	MgApl	873	600	130	3756	
1392	MgApl	873	600	120	4358.4	
1393	MgApl	873	600	110	8378.1	
1394	MgApl	923	650	100	149.5	
1395	MgApl	923	650	80	1043	
1396	MgApl	923	650	70	3087.2	
1397	MgApl	923	650	60	8820.1	
1398	MGAt	773	500	360	277	NIMS-
1399	MGAt	773	500	340	875.4	NIMS-
1400	MGAt	773	500	320	2333.4	
1401	MGAt	773	500	300	4971.3	NIMS-
1402	MGAt	773	500	290	8840	NIMS-
1403	MGAt	823	550	240	498.8	NIMS-
1404	MGAt	823	550	220	2635.1	NIMS-
1405	MGAt	823	550	200	10778.3	NIMS-
1406	MGAt	873	600	160	696	NIMS-
1407	MGAt	873	600	140	2777.1	NIMS-
1408	MGAt	873	600	120	14286.8	NIMS-
1409	MGAt	873	600	110	24417.9	NIMS-
1410	MGAt	923	650	100	628.5	NIMS-
1411	MGAt	923	650	80	4472.3	NIMS-
1412	MGAt	923	650	70	12280.7	NIMS-
1413	MGAt	923	650	60	23231.1	NIMS-
1414	MGAt	973	700	60	430.6	NIMS-
1415	MGAt	973	700	50	1299	NIMS-
1416	MGAt	973	700	40	3354.4	NIMS-
1417	MGAt	973	700	30	9668.5	NIMS-
1418	MgBpl	723	450	450	11.4	
1419	MgBpl	723	450	420	302.1	
1420	MgBpl	723	450	400	779.6	
1421	MgBpl	723	450	390	7027.5	
1422	MgBpl	723	450	370	9158.9	
1423	MgBpl	723	450	380	16581.7	
1424	MgBpl	723	450	360	23403	
1425	MgBpl	773	500	320	551.6	
1426	MgBpl	773	500	310	2077	
1427	MgBpl	773	500	300	3452.6	
1428	MgBpl	773	500	270	6115.3	
1429	MgBpl	773	500	280	6951.4	
1430	MgBpl	823	550	240	158.7	
1431	MgBpl	823	550	220	1949.9	
1432	MgBpl	823	550	200	3574.4	
1433	MgBpl	823	550	190	11350.6	
1434	MgBpl	823	550	180	14814.3	
1435	MgBpl	873	600	160	177.6	
1436	MgBpl	873	600	140	842.7	
1437	MgBpl	873	600	130	2790.5	
1438	MgBpl	873	600	120	6473.7	
1439	MgBpl	873	600	110	10659.6	
1440	MgBpl	873	600	100	15740.1	
1441	MgBpl	923	650	100	163.4	
1442	MgBpl	923	650	90	626.8	
1443	MgBpl	923	650	80	1870.8	
1444	MgBpl	923	650	70	2639	
1445	MgBpl	923	650	60	6580	
1446	MGBt	773	500	360	239.2	NIMS-
1447	MGBt	773	500	300	615.8	
1448	MGBt	773	500	340	938.5	NIMS-
1449	MGBt	773	500	320	2334.1	NIMS-
1450	MGBt	773	500	290	10507.5	NIMS-
1451	MGBt	823	550	260	202	NIMS-
1452	MGBt	823	550	240	796.8	NIMS-
1453	MGBt	823	550	220	3487.6	NIMS-
1454	MGBt	823	550	200	13640.8	NIMS-
1455	MGBt	873	600	160	779.1	NIMS-
1456	MGBt	873	600	140	3773.9	NIMS-
1457	MGBt	923	650	110	325.7	NIMS-
1458	MGBt	923	650	100	831.1	NIMS-
1459	MGBt	923	650	80	6053.2	NIMS-
1460	MGBt	923	650	70	13031.9	NIMS-
1461	MGBt	923	650	60	17727.9	NIMS-
1462	MGBt	973	700	60	413	NIMS-
1463	MGBt	973	700	50	1255	NIMS-
1464	MGBt	973	700	40	3129.9	NIMS-
1465	MGBt	973	700	30	7681.4	NIMS-
1466	MgCpl	723	450	420	630.5	NIMS-
1467	MgCpl	723	450	370	22969.8	NIMS-
1468	MgCpl	773	500	320	815.7	NIMS-
1469	MgCpl	773	500	310	1918	NIMS-
1470	MgCpl	773	500	300	3989.7	NIMS-
1471	MgCpl	773	500	280	16832.5	NIMS-
1472	MgCpl	823	550	240	701.7	NIMS-
1473	MgCpl	823	550	220	3254.7	NIMS-
1474	MgCpl	823	550	200	14164.2	NIMS-
1475	MgCpl	823	550	190	23079.5	NIMS-
1476	MgCpl	873	600	160	895.3	NIMS-
1477	MgCpl	873	600	140	4451.5	NIMS-
1478	MgCpl	873	600	130	9728.3	NIMS-
1479	MgCpl	873	600	120	17356.9	NIMS-
1480	MgCpl	923	650	120	205.2	NIMS-
1481	MgCpl	923	650	100	969.9	NIMS-
1482	MgCpl	923	650	80	5304.9	NIMS-
1483	MgCpl	923	650	70	14188.9	NIMS-
1484	MGCt	773	500	340	600.3	NIMS-
1485	MGCt	773	500	320	1295.9	NIMS-
1486	MGCt	773	500	300	4864.1	NIMS-
1487	MGCt	773	500	290	10830.7	NIMS-
1488	MGCt	823	550	240	667.3	NIMS-
1489	MGCt	823	550	220	3724.3	NIMS-
1490	MGCt	823	550	200	14530	NIMS-
1491	MGCt	873	600	160	971.2	NIMS-
1492	MGCt	873	600	140	3414.7	NIMS-
1493	MGCt	873	600	110	21206.3	NIMS-
1494	MGCt	923	650	110	237.6	NIMS-
1495	MGCt	923	650	100	727.8	NIMS-
1496	MGCt	923	650	80	5409.5	NIMS-
1497	MGCt	923	650	70	13008.5	NIMS-
1498	MGCt	923	650	60	24807.4	NIMS-
1499	MGCt	973	700	60	447.5	NIMS-
1500	MGCt	973	700	50	1338.3	NIMS-
1501	MGCt	973	700	40	4065.3	NIMS-
1502	MGCt	973	700	30	14106.5	NIMS-
1503	JFA01pl	773.1	500	314	465	JCF-9
1504	JFA01pl	773.1	500	294	2312	JCF-10

ID	Heat	Temp	Temp	Stress	Rupture	Other
1505	JFA01pl	773.1	500	284	3333	JCF-11
1506	JFA01pl	823.1	550	226	507	JCF-13
1507	JFA01pl	823.1	550	206	1252	JCF-14
1508	JFA01pl	823.1	550	196	2935	JCF-15
1509	JFA01pl	873.1	600	167	112	JCF-17
1510	JFA01pl	873.1	600	157	213	JCF-18
1511	JFA01pl	873.1	600	137	1033	JCF-19
1512	JFA02pl	773.1	500	314	269.8	JCF-36
1513	JFA02pl	773.1	500	284	1587.6	JCF-37
1514	JFA02pl	773.1	500	275	3242.1	JCF-38
1515	JFA02pl	823.1	550	216	602.2	JCF-39
1516	JFA02pl	823.1	550	206	532.2	JCF-40
1517	JFA02pl	823.1	550	196	2031.7	JCF-41
1518	JFA02pl	873.1	600	167	64	JCF-42
1519	JFA02pl	873.1	600	157	133.2	JCF-43
1520	JFB03pl	773.1	500	333	400	JCF-68
1521	JFB03pl	773.1	500	304	2880	JCF-69
1522	JFB03pl	773.1	500	294	4152.6	JCF-70
1523	JFB03pl	773.1	500	294	4110.9	JCF-71
1524	JFB03pl	823.1	550	235	472	JCF-72
1525	JFB03pl	823.1	550	216	2000	JCF-73
1526	JFB03pl	823.1	550	201	5709	JCF-74
1527	JFB03pl	823.1	550	191	6251	JCF-75
1528	JFB03pl	873.1	600	167	279.8	JCF-76
1529	JFB03pl	873.1	600	147	1714.4	JCF-77
1530	JFB03pl	873.1	600	137	3456.5	JCF-78
1531	JF101t	773.1	500	333	300	JCF-128
1532	JF101t	773.1	500	314	734.6	JCF-129
1533	JF101t	773.1	500	304	2803.3	JCF-130
1534	JF101t	773.1	500	294	2989	JCF-131
1535	JF101t	773.1	500	284	6385.1	JCF-132
1536	JF101t	823.1	550	245	183.1	JCF-133
1537	JF101t	823.1	550	226	842	JCF-134
1538	JF101t	823.1	550	211	2980.8	JCF-135
1539	JF101t	823.1	550	206	3189.8	JCF-136
1540	JF101t	873.1	600	167	313.3	JCF-137
1541	JF101t	873.1	600	147	2355	JCF-138
1542	JF101t	873.1	600	137	2737.5	JCF-139
1543	JF202f	823.1	550	226	720.6	JCF-160
1544	JF202f	823.1	550	216	1650.7	JCF-161
1545	JF202f	823.1	550	201	4116.5	JCF-162
1546	JF202f	823.1	550	196	4873.5	JCF-163
1547	JF202f	823.1	550	235	286.8	JCF-164
1548	JF202f	823.1	550	226	504.8	JCF-165
1549	JF202f	823.1	550	206	1966.3	JCF-166
1550	JF202f	823.1	550	196	4831.8	JCF-167
1551	JF202f	873.1	600	157	389.1	JCF-168
1552	JF202f	873.1	600	147	776.7	JCF-169
1553	JF202f	873.1	600	137	2494.5	JCF-170
1554	JF202f	873.1	600	127	5465	JCF-171
1555	JF202f	873.1	600	137	3665.3	JCF-172
1556	91887	811.1	538	344.8	12.8	ORNL-13
1557	91887	811.1	538	317.2	28.5	ORNL-14
1558	91887	811.1	538	317.2	228.9	ORNL-15
1559	91887	811.1	538	268.9	486	ORNL-16
1560	91887	866.1	593	193.1	154.9	ORNL-8
1561	91887	866.1	593	193.1	485.2	ORNL-9
1562	91887	866.1	593	193.1	430.1	ORNL-10
1563	91887	922.1	649	131	120.7	ORNL-2
1564	91887	922.1	649	131	230.4	ORNL-3
1565	91887	922.1	649	117.2	409.2	ORNL-4
1566	91887	922.1	649	103.4	1888	ORNL-6
1567	91887	922.1	649	96.5	6073	ORNL-7

ID	Heat	Temp	Temp	Stress	Rupture	Other
1568	91887	950.1	677	103.4	171.9	ORNL-1
1569	982	866.1	593	193.1	175	ORNL-267
1570	982	866.1	593	172.4	931	ORNL-268
1571	982	866.1	593	151.7	10967	ORNL-269
1572	982	894.1	621	172.4	40	ORNL-266
1573	982	894.1	621	140	394.6	ORNL-265
1574	982	922.1	649	140	27.2	ORNL-260
1575	982	922.1	649	117.2	325	ORNL-261
1576	982	922.1	649	100	1408	ORNL-262
1577	982	922.1	649	89.6	5784	ORNL-263
1578	982	922.1	649	89.6	8368	ORNL-264
1579	982	950.1	677	117.2	21.6	ORNL-258
1580	982	950.1	677	89.6	294	ORNL-259
1581	982	977.1	704	89.6	31.1	ORNL-257
1582	3602	922.1	649	82.7	3515	ORNL-253
1583	3602	922.1	649	97.2	570	ORNL-252
1584	3602	922.1	649	117.2	387	ORNL-251
1585	3602	922.1	649	117.2	273	ORNL-250
1586	3602	922.1	649	117	173	ORNL-256
1587	3602	922.1	649	68.9	16997	ORNL-254
1588	3602	950.1	677	55.2	7185	ORNL-249
1589	3602	950.1	677	82.7	465	ORNL-248
1590	3602	950.1	677	97.2	164	ORNL-246
1591	3602	950.1	677	97.2	139	ORNL-255
1592	3602	950.1	677	97.2	177	ORNL-247
1593	231000	866.1	593	172.4	279	ORNL-291
1594	231000	866.1	593	172.4	465	ORNL-292
1595	231000	866.1	593	124.1	26787	ORNL-293
1596	231000	894.1	621	124.1	636	ORNL-289
1597	231000	922.1	649	117.2	96.2	ORNL-286
1598	231000	922.1	649	117.2	111	ORNL-294
1599	231000	922.1	649	103.4	344	ORNL-287
1600	231000	922.1	649	89.6	2306	ORNL-295
1601	231000	922.1	649	75.8	11491	ORNL-288
1602	231000	950.1	677	103.4	36.5	ORNL-285
1603	59020	866.1	593	193	186	ORNL-281
1604	59020	866.1	593	172.4	603	ORNL-283
1605	59020	866.1	593	173	676	ORNL-282
1606	59020	894.1	621	172.4	26.3	ORNL-278
1607	59020	894.1	621	140	655	ORNL-279
1608	59020	894.1	621	117.2	3741	ORNL-280
1609	59020	922.1	649	140	28.95	ORNL-274
1610	59020	922.1	649	117.2	298	ORNL-275
1611	59020	922.1	649	100	1439	ORNL-276
1612	59020	922.1	649	75.8	22134	ORNL-277
1613	59020	950.1	677	100	188.5	ORNL-272
1614	59020	950.1	677	75.8	1077	ORNL-273
1615	59020	977.1	704	100	10.3	ORNL-270
1616	59020	977.1	704	75.8	106	ORNL-271
1617	565160	866.1	593	172.4	2540	ORNL-218
1618	565160	866.1	593	144.8	10419	ORNL-219
1619	565160	866.1	593	124	33180	ORNL-220
1620	565160	894.1	621	124.1	1939	ORNL-217
1621	565160	922.1	649	124.1	152.3	ORNL-215
1622	565160	922.1	649	100	934.6	ORNL-216
1623	30394	811.1	538	186.2	84310	ORNL-22
1624	30394	866.1	593	158.6	2908	ORNL-21
1625	30394	922.1	649	103.4	756	ORNL-18
1626	30394	922.1	649	89.6	2340	ORNL-19
1627	30394	922.1	649	62.1	21028	ORNL-20
1628	30394	866.1	593	158.6	2040	ORNL-24
1629	30394	922.1	649	103.4	481	ORNL-25
1630	30394	866.1	593	151.7	7607	ORNL-32

ID	Heat	Temp	Temp	Stress	Rupture	Other
1631	30394	866.1	593	131	19179	ORNL-39
1632	30394	866.1	593	124.1	30544	ORNL-42
1633	30394	922.1	649	103.4	1155	ORNL-31
1634	30394	950.1	677	124.1	23	ORNL-30
1635	30394	977.1	704	27.6	21809	ORNL-29
1636	30394	1061.1	788	34.5	32.9	ORNL-26
1637	30394	1061.1	788	20.7	304.8	ORNL-27
1638	30394	1061.1	788	13.8	549.3	ORNL-28
1639	30394	727.1	454	379	75645	ORNL-46
1640	30394	866.1	593	137.9	14544	ORNL-37
1641	30394	922.1	649	103.4	777.2	ORNL-48
1642	30394	922.1	649	89.6	2785	ORNL-49
1643	30394	922.1	649	103.4	861.9	ORNL-50
1644	30394	922.1	649	103.4	962.6	ORNL-51
1645	30394	922.1	649	103.4	1383	ORNL-52
1646	30394	922.1	649	103.4	1118	ORNL-53
1647	30394	922.1	649	89.6	4856	ORNL-54
1648	30394	866.1	593	158.6	1084	ORNL-55
1649	30383	1003.1	730	60	34.8	ORNL-56
1650	30383	973.1	700	100	13.7	ORNL-57
1651	30383	973.1	700	100	11.5	ORNL-58
1652	30383	973.1	700	80	52	ORNL-59
1653	30383	973.1	700	60	451	ORNL-60
1654	30383	973.1	700	40	5533	ORNL-61
1655	30383	948.1	675	100	58.5	ORNL-63
1656	30383	948.1	675	100	88	ORNL-64
1657	30383	948.1	675	80	371.7	ORNL-65
1658	30383	935.1	662	100	344	ORNL-67
1659	30383	935.1	662	100	263	ORNL-68
1660	30383	923.1	650	140	29.1	ORNL-69
1661	30383	923.1	650	100	841	ORNL-71
1662	30383	923.1	650	100	710	ORNL-70
1663	30383	923.1	650	80	3818	ORNL-72
1664	30383	922.1	649	144.8	21	ORNL-74
1665	30383	922.1	649	131	57	ORNL-75
1666	30383	922.1	649	117.2	329	ORNL-77
1667	30383	922.1	649	117.2	191	ORNL-76
1668	30383	922.1	649	110	334	ORNL-78
1669	30383	910.1	637	100	2737	ORNL-79
1670	30383	898.1	625	170	44.2	ORNL-80
1671	30383	898.1	625	170	84.5	ORNL-81
1672	30383	898.1	625	140	683	ORNL-82
1673	30383	898.1	625	140	614	ORNL-83
1674	30383	898.1	625	120.6	1165	ORNL-84
1675	30383	898.1	625	100	6900	ORNL-86
1676	30383	873.1	600	200	96.5	ORNL-92
1677	30383	873.1	600	200	67.3	ORNL-91
1678	30383	873.1	600	170	939	ORNL-93
1679	30383	873.1	600	140	3359	ORNL-95
1680	30383	866.1	593	193.1	147	ORNL-100
1681	30383	866.1	593	165.6	1477	ORNL-101
1682	30383	866.1	593	124.1	21337	ORNL-102
1683	30383	866.1	593	110.3	49514	ORNL-103
1684	30383	848.1	575	245	44.7	ORNL-104
1685	30383	848.1	575	200	1754	ORNL-105
1686	30383	823.1	550	240	1896	ORNL-109
1687	30383	811.1	538	276	289	ORNL-118
1688	30383	811.1	538	262	860	ORNL-119
1689	30383	811.1	538	234	13513	ORNL-120
1690	30383	773.1	500	370	300	ORNL-127
1691	30383	773.1	500	352	1195	ORNL-128
1692	30182	755.1	482	365.4	1615	ORNL-180
1693	30182	811.1	538	234.4	4387	ORNL-179

ID	Heat	Temp	Temp	Stress	Rupture	Other
1694	30182	811.1	538	234.4	3468	ORNL-178
1695	30182	811.1	538	275.8	252	ORNL-177
1696	30182	811.1	538	275.8	259	ORNL-176
1697	30182	811.1	538	275.8	199	ORNL-175
1698	30182	866.1	593	206.7	38	ORNL-169
1699	30182	866.1	593	193.1	132	ORNL-170
1700	30182	866.1	593	172.4	368	ORNL-171
1701	30182	866.1	593	158.6	1332	ORNL-172
1702	30182	866.1	593	144.8	6369	ORNL-173
1703	30182	866.1	593	131	18505	ORNL-174
1704	30182	922.1	649	131	64	ORNL-160
1705	30182	922.1	649	103.4	373	ORNL-163
1706	30182	922.1	649	103.4	670	ORNL-162
1707	30182	922.1	649	103.4	567	ORNL-161
1708	30182	922.1	649	89.6	2058	ORNL-164
1709	30182	922.1	649	89.6	1555	ORNL-165
1710	30182	922.1	649	89.6	1139	ORNL-168
1711	30182	922.1	649	89.6	1242	ORNL-166
1712	30182	922.1	649	89.6	1188	ORNL-167
1713	30182	950.1	677	103.4	57	ORNL-155
1714	30182	950.1	677	89.6	222	ORNL-156
1715	30182	950.1	677	82.7	357	ORNL-157
1716	30182	950.1	677	68.9	1539	ORNL-158
1717	30182	950.1	677	59.3	5697	ORNL-159
1718	30182	977.1	704	89.6	21	ORNL-154
1719	30182	922.1	649	103.4	448	ORNL-181
1720	30182	922.1	649	103.4	236	ORNL-182
1721	30182	866.1	593	193.1	40.4	ORNL-183
1722	30182	866.1	593	193.1	73.6	ORNL-184
1723	30182	866.1	593	172.4	189.3	ORNL-185
1724	30182	866.1	593	172.4	247	ORNL-186
1725	30182	866.1	593	172.4	143	ORNL-187
1726	30182	866.1	593	151.7	1185	ORNL-188
1727	30182	866.1	593	151.7	824	ORNL-189
1728	30182	866.1	593	151.7	819	ORNL-190
1729	30182	866.1	593	131	6080	ORNL-191
1730	30182	811.1	538	186.1	18170	ORNL-192
1731	30176	811.1	538	234.4	3353	ORNL-146
1732	30176	866.1	593	124.1	14732	ORNL-145
1733	30176	866.1	593	206.9	122	ORNL-143
1734	30176	922.1	649	103.4	632	ORNL-142
1735	30176	922.1	649	124.1	193.8	ORNL-141
1736	30176	950.1	677	124.1	26	ORNL-139
1737	30176	950.1	677	103.4	46.8	ORNL-140
1738	14361	811.1	538	220.5	7688	ORNL-237
1739	14361	866.1	593	175.4	891	ORNL-234
1740	14361	866.1	593	144.7	12273	ORNL-235
1741	14361	894.1	621	144.7	210.8	ORNL-231
1742	14361	894.1	621	117.2	1859	ORNL-232
1743	14361	922.1	649	124.1	106	ORNL-226
1744	14361	922.1	649	117.2	521	ORNL-227
1745	14361	922.1	649	100	748	ORNL-228
1746	14361	922.1	649	89.6	4272	ORNL-229
1747	14361	922.1	649	75.8	29363	ORNL-230
1748	14361	950.1	677	75.8	510	ORNL-223
1749	14361	950.1	677	71	942	ORNL-224
1750	10148	811.1	538	234.4	16073	ORNL-197
1751	10148	866.1	593	158.9	3790	ORNL-194
1752	10148	866.1	593	144.8	11640	ORNL-195
1753	10148	866.1	593	124.1	24387	ORNL-196
1754	10148	922.1	649	89.6	3167	ORNL-193
1755	10148	866.1	593	193.1	1050	ORNL-207
1756	10148	866.1	593	172.4	2459	ORNL-208

ID	Heat	Temp	Temp	Stress	Rupture	Other
1757	10148	866.1	593	151.4	8918	ORNL-209
1758	10148	922.1	649	103.4	780	ORNL-204
1759	10148	922.1	649	89.6	1919	ORNL-205
1760	10148	950.1	677	68.9	1151	ORNL-202
1761	10148	950.1	677	41.6	21965	ORNL-203
1762	10148	977.1	704	41.4	2281	ORNL-201
1763	10148	922.1	649	75.8	4230	ORNL-211
1764	10148	811.1	538	234.4	2467	ORNL-212
1765	10148	811.1	538	206.8	15970	ORNL-213
1766	10148	922.1	649	89.6	8422	ORNL-214

Grade 91 Data Reference Flags

ID	Flag
47	3484
86	9496
1447	SOURCE?
1461	DISCREPANCY
1521	2880.5
1524	472.2
1528	276.8
1580	293.6
1590	165
1605	676.2
1607	655.1
1611	1439.6
1616	105.9
1623	84309
1639	75646
1651	11.15
1657	372
1671	84.9
1706	669
1707	566
1741	211
1742	1858.6

APPENDIX 4 - NIMS DATA

Table 4-1-1. Creep Data of 9Cr-1Mo-V-Nb Steel Tube, MGA

Temperature	Stress	Instantaneous strain, ε_I	Time to Specific Strain				Initiation of tertiary creep	Time to rupture	Minimum creep rate	Rupture elongation	Reduction of area
			0.2%ε_c	0.5%ε_c	1%ε_c	1%ε_I					
˚C	Mpa		h				h	h	1/h	%	%
500 °	360	-	-	-	-	-	-	277.00	-	22.6	84.2
	340	-	-	-	-	-	-	875.40	-	24.6	85.5
	320	-	-	-	-	-	-		-	26.9	86.2
	300	-	-	-	-	-	-	4,971.30	-	30.6	88.0
	290	-	-	-	-	-	-	8,840.00	-	27.2	89.0
	270	-	-	-	-	-	-	36,035.80	-	20.8	85.2
550	240	0.00159	1.5	12	47.7	34.5	307	498.80	8.1×10^{-5}	26.1	90.1
	220	0.00153	3.5	36.4	171	120	1650	2,635.10	1.6×10^{-5}	26.4	90.4
	200	0.00140	13.0	118	696	475	7250	10,778.30	2.8×10^{-6}	31.1	89
	180	0.00133	29.5	427	3940	2390	22700	35,101.80	5.8×10^{-7}	23.5	82.4
	170	0.00116	146.0	1690	12700	9030	34700	53,387.50	3.4×10^{-7}	21.4	80.2
600	160	0.00129	1.0	6.8	39	27.5	431	696.00	5.5×10^{-5}	30.4	92.9
	140	0.00119	1.9	24.5	173	125	1620	277.10	9.8×10^{-6}	31.2	90.8
	120	0.00095	11.3	250	2610	2070	6920	14,286.80	1.7×10^{-6}	25.3	83.0
	110	0.00088	45.9	1590	7320	6230	14400	24,417.90	8.4×10^{-7}	23.3	84.1
	100	0.00089	105.0	3010	13800	11800	23700	35,639.10	4.5×10^{-7}	18.7	80.2
650	100	-	-	-	-	-	-	628.50	-	35.8	93.3
	80	-	-	-	-	-	-	4,472.30	-	31.9	88.3
	70	-	-	-	-	-	-	12,280.70	-	36.1	84.4
	60	-	-	-	-	-	-	23,321.10	-	10.9	50.7
	50	-	-	-	-	-	-	59,498.10	-	11.4	14.7
700	60	-	-	-	-	-	-	430.60	-	39.2	91.9
	50	-	-	-	-	-	-	1,299.00	-	30.3	86.5
	40	-	-	-	-	-	-	3,354.40	-	31.7	75.0
	30	-	-	-	-	-	-	9,668.50	-	22.6	64.4

1) The test temperature was accidentally raised more than 10˚C above the specified temperature for a short time period during the test

Table 4-1-2. Creep Data of 9Cr-1Mo-V-Nb Steel Tube, MGB

Temperature	Stress	Instantaneous strain, $_{EI}$	Time to Specific Strain				Initiation of tertiary creep	Time to rupture	Minimum creep rate	Rupture elongation	Reduction of area
			$0.2\%_{Ec}$	$0.5\%_{Ec}$	$1\%_{Ec}$	$1\%_{EI}$					
˚C	Mpa		h				h	h	1/h	%	%
500	360	-	-	-	-	-	-	239.20	-	21.3	83.8
	340	-	-	-	-	-	-	938.50	-	24.4	85.8
	320	-	-	-	-	-	-	2,334.10	-	24.1	86.2
	300	-	-	-	-	-	-	6,165.80	-	24.6	86.6
	290	-	-	-	-	-	-	10,507.50	-	22.2	86.9
	270	-	-	-	-	-	-	40,858.80	-	21.6	85.9
550	260	0.00196	0.6	3.3	14.5	9.0	149	202.00	2.8×10^{-4}	25.6	88.6
	240	0.00163	0.3	3.3	21.2	14.2	539	796.80	6.0×10^{-5}	30.4	90.7
	220	0.00147	3.7	37	204	138	2310	3,487.60	1.1×10^{-5}	34.8	91.1
	200	0.00140	3.9	109	985	634	9910	13,640.80	1.9×10^{-6}	22.6	89.0
	180	0.00133	26.6	539	5340	3320	26100	40,142.30	4.6×10^{-7}	22.3	85.1
	170	0.00122	115	2640	18900	14400	41400	68,755.10	2.5×10^{-7}	26.2	83.0
600	160	0.00145	0.4	5.7	44.1	28.4	491	779.10	4.8×10^{-5}	34.6	90.8
	140	0.00117	3.4	71.5	604	441	2530	3,773.90	6.4×10^{-6}	23.9	90.4
	120	0.00095	28.5	824	4140	3530	10500	16,442.70	1.4×10^{-6}	20.6	83.0
	110	0.00087	54.4	2580	9730	8560	16000	26,545.20	6.4×10^{-7}	16.2	77.8
	100	0.00080	864	12300	23900	22600	21100	46,910.50	2.2×10^{-7}	23.3	84.8
650	110	-	-	-	-	-	-	325.70	-	35.3	95.0
	100	-	-	-	-	-	-	831.10	-	26.5	92.5
	80	-	-	-	-	-	-	6,053.20	-	24.5	86.2
	70	-	-	-	-	-	-	13,031.90	-	19.0	77.3
	60	-	-	-	-	-	-	27,727.90	-	13.0	36.0
	50	-	-	-	-	-	-	50,756.40	-	9.9	50.5
700	60	-	-	-	-	-	-	413.00	-	27.7	92.9
	50	-	-	-	-	-	-	1,255.00	-	37.6	88.3
	40	-	-	-	-	-	-	3,129.90	-	24.2	81.2
	30	-	-	-	-	-	-	7,681.40	-	44.8	84.8

Table 4-1-3. Creep Data of 9Cr-1Mo-V-Nb Steel Tube, MGC

Temperature	Stress	Instantaneous strain, $_{El}$	Time to Specific Strain				Initiation of tertiary creep	Time to rupture	Minimum creep rate	Rupture elongation	Reduction of area
			0.2%$_{Ec}$	0.5%$_{Ec}$	1%$_{Ec}$	1%$_{El}$					
°C	Mpa		h				h	h	1/h	%	%
500	340	-	-	-	-	-	-	600.30	-	26.5	84.8
	320	-	-	-	-	-	-	1,295.90	-	25.6	86.2
	300	-	-	-	-	-	-	4,864.10	-	26.5	86.6
	290	-	-	-	-	-	-	10,830.70	-	24.0	85.9
	270	-	-	-	-	-	-	62,475.00	-	21.0	83.0
550	240	0.00172	1.1	8.2	38.6	25.6	428	667.30	7.3×10^{-5}	28.2	89.0
	220	0.00165	2.7	23.6	135	90.2	2610	3,724.30	1.1×10^{-5}	29.5	89.0
	200	0.00138	12.9	138	960	622	9900	14,530.00	1.8×10^{-6}	28.0	88.7
	180	0.00133	45.5	843	8690	5250	28300	40,320.20	3.7×10^{-7}	19.5	84.8
	170	0.00114	91	1910	19900	13900	39000	61,209.20	2.2×10^{-7}	20.3	84.0
600	200	0.00195	0.1	0.5	2	1.3	21.9	40.40	1.4×10^{-3}	31.6	92.2
	160	0.00138	1.3	14.7	71.3	51.7	597	971.20	4.2×10^{-5}	41.1	92.9
	140	0.00116	4.3	60.2	388	284	2300	3,414.70	7.7×10^{-6}	27.6	89.7
	120	0.00096	31.2	621	3540	2930	7720	12,858.60	1.5×10^{-6}	30.0	88.3
	110	0.00088	47.4	1460	7150	6130	11900	21,206.30	8.1×10^{-7}	25.9	87.6
	100	0.00081	261	5010	16100	14700	21100	34,141.00	4.0×10^{-7}	21.7	86.2
625	140	0.00144	0.5	4.9	25.9	18.6	134	263.30	1.5×10^{-4}	38.6	92.9
	120	0.00116	1.6	21	123	93.8	577	1,040.80	3.5×10^{-5}	39.1	92.9
	100	0.00088	8.2	196	1050	881	3520	6,090.50	4.5×10^{-6}	36.8	91.4
	90	0.00079	31.4	646	3290	2850	8710	13,923.20	1.7×10^{-6}	34.4	90.7
650	110	0.00109	0.7	8.5	39.0	32.1	130	248.50	1.4×10^{-4}	34.7	94.0
	110	-	-	-	-	-	-	237.60	-	36.5	94.0
	100	-	-	-	-	-	-	727.80	-	37.7	93.9
	80	-	-	-	-	-	-	5,409.50	-	32.4	88.7
	70	-	-	-	-	-	-	13,008.50	-	25.6	80.9
	60	-	-	-	-	-	-	24,807.40	-	30.3	89.0
	50	-	-	-	-	-	-	41,425.20	-	15.5	45.0
675	80	0.00101	2.1	21.2	80.7	66.5	213	419.40	7.8×10^{-5}	59.4	96.8
	70	0.00085	13.3	98.3	303	266	684	1,251.90	2.3×10^{-5}	37.2	94.3
	60	0.00071	61.6	332	837	770	1640	3,045.20	9.8×10^{-6}	57.3	92.9
	50	0.00057	125	850	2440	2250	5740	10,081.80	3.1×10^{-6}	28.0	88.2
700	60	0.00081	2.9	22.9	76.3	67.3	185	364.60	8.7×10^{-5}	33.4	94.0
	60	-	-	-	-	-	-	447.50	-	34.7	92.6
	50	-	-	-	-	-	-	1,338.30	-	45.4	93.2
	40	-	-	-	-	-	-	4,065.30	-	35.4	92.2
	30	-	-	-	-	-	-	14,106.50	-	30.1	76.6

Table 4-1-4. Creep Data of 9Cr-1Mo-V-Nb Steel Plate, MgC

Temperature	Stress	Instantaneous strain, $_{El}$	Time to Specific Strain				Initiation of tertiary creep	Time to rupture	Minimum creep rate	Rupture elongation	Reduction of area
			0.2%$_{Ec}$	0.5%$_{Ec}$	1%$_{Ec}$	1%$_{El}$					
°C	Mpa		h				h	h	1/h	%	%
450	420	0.00350	2.0	18.2	86.5	32.8	365	630.50	4.8×10^{-5}	21.1	79.3
	370	0.00243	31.4	524	4040	2040	15800	22,629.80	1.1×10^{-6}	22.7	81.2
	360	0.00223	53.9	1310	8520	4840	24300	37,968.30	6.0×10^{-7}	21.9	82.0
500	320	0.00210	3.1	20.5	78.5	48.4	481	815.70	3.3×10^{-5}	27.6	84.3
	310	0.00203	5.5	35.8	183	109	1190	1,918.00	1.6×10^{-5}	24.8	84.3
	300	0.00200	3.9	36.1	222	121	2520	3,989.70	7.5×10^{-6}	24.7	84.6
	280	0.00180	16.8	248	1790	1100	10600	16,832.50	2.1×10^{-6}	28.3	85.6
	270		30.4	731	4270	2840	26300	38,156.50	9.3×10^{-7}	23.2	85.0
	260	0.00162	73.0	1470	7490	5400	45000	61,672.90	5.2×10^{-7}	21.7	85.5
550	240	0.00175	1.7	11.2	49.6	32.3	436	701.70	5.9×10^{-5}	30.0	88.2
	220	0.00165	2.2	29.2	172	103	2190	3,254.70	1.2×10^{-5}	27.1	88.0
	200	0.00142	21.1	284	1500	1040	9760	14,164.20	2.0×10^{-6}	27.6	86.9
	190	0.00131	21.4	508	2960	2130	15900	23,079.50	1.0×10^{-6}	22.2	85.2
	180	0.00122	49.5	947	5200	3810	22500	34,493.70	6.6×10^{-7}	29.4	87.6
600	160	0.00139	1.8	18.7	93.5	68.9	517	895.30	5.4×10^{-5}	30.8	90.5
	140	0.00113	6.5	91.3	457	348	2790	4,451.50	7.6×10^{-6}	30.4	88.5
	130	0.00112	21.4	334	1850	1420	6330	9,728.30	2.3×10^{-6}	29.7	88.6
	120	0.00098	63.1	848	4740	3920	10000	17,356.90	1.1×10^{-6}	28.2	86.5
	110	0.00091	120	2420	10400	8890	22000	35,420.00	6.1×10^{-7}	19.5	81.7
650	120	0.00149	0.5	4.4	21.5	16	124	205.20	2.0×10^{-4}	39.4	93.6
	100	0.00102	3.5	48.5	193	161	543	969.90	3.1×10^{-5}	37.8	91.3
	80	0.00078	78.9	564	1430	1290	2600	5,304.90	5.4×10^{-6}	27.0	89.8
	70	0.00073	200	1310	3530	3220	9260	14,188.90	2.2×10^{-6}	23.4	95.6
	50	0.00050	946	6340	19500	18200	30600	58,451.30	3.5×10^{-7}	19.5	72.2

APPENDIX 5 - ORNL DATA

Lot	TN	Temp (C)	Stress (MPa)	Life (h)	mcr (%/h)	t 1% (h)	tertiary	% El	% RA	in test (h)	Status	SN	Ann/Temp/h	Product
10148	22443	538	234.4	16073	0.00023	920	11900	28.3	80.39		R	A1T	1038/760/1	5/8-in pl
10148	22444	649	89.6	3167	0.0011	240	2450	26.25	79.75		R	A2T	1038/760/1	5/8-in pl
10148	22450	593	158.6	3790	0.0009	325	2550	24.68	79.75		R	A3T	1038/760/1	5/8-in pl
10148	22502	538	186.1		0.00001	60000				92000	D	A4T	1038/760/1	5/8-in pl
10148	22710	593	144.8	11640	0.00026	2000	9300	28.01	75.1		R	A6T	1038/760/1	5/8-in pl
10148	22874	593	193.1	1050	0.0036	90	73	24.75	86.4		R	B1T	1038/760/1	1/2-in pl
10148	22876	649	103.4	780	0.00425	200	470	32.62	88.48		R	B5T	1038/760/1	1/2-in pl
10148	22909	593	172.4	2459	0.00096	420	136	24.68	82.56		R	B2T	1038/760/1	1/2-in pl
10148	22913	593	151.7	8918	0.000325	2050	6100	24.75	86.4		R	B3T	1038/760/1	1/2-in pl
10148	22919	649	89.6	1919	0.002	450	1390	27.24	86.51		R	B4T	1038/760/1	1/2-in pl
10148	22975	677	68.9	1151	0.0039	200	760	31.49	87.2		R	B14T	1038/760/1	1/2-in pl
10148	23006	704	41.4	2281	0.00198	320	1600	25.65	84.46		R	B16T	1038/760/1	1/2-in pl
10148	23007	677	41.6	21965	0.00014	3700	16000	23.49	77.16		R	B15T	1038/760/1	1/2-in pl
10148	23174	649	75.8	4230	0.00068	1000	3300	26.11	88.42		R	D6T	1038/760/5	7 7/8-in oct
10148	23210	538	234.4	2467	0.0018	430	1700	25.87	83.9		R	E7T	1038/760/5	9 1/8-in bar
10148	23213	649	89.6	8464	0.00029	330	5500	18.6	76.24		R	B25T	1121/760/1	1/2-in pl
10148	23267	649	89.6	8422	0.00033	220	650	19.25	73.84		R	F1L	1038/760/1	9-in pipe
10148	23390	538	206.8	15970	0.00024	1000	12900	24.82	83.91		R	E8T	1038/760/5	9 1/8-in bar
10148	24772	482	275.8		0.000008	28500				69000	IT	A7T	1038/760/1	5/8-in pl
10148	24899	538	165.5		0.000003	30600				67000	IT	A8T	1038/760/1	5/8-in pl
10148	27786	621	124.1			100					IT	B92T	1038/760/1	1/2-in pl
10148	BCL	593	124.1	24387	0.000075	6000	16000	16.9	59.4		R	9T	1038/760/1	5/8-in pl
14361	24042	649	117.2	521	0.0067	35	320	31.39	92.56		R	1T	1038/760/6	forg
14361	24043	649	75.8	29363	0.00012	6000	18000	4.91	13		R	2T	1038/760/6	forg
14361	24060	593	175.4	891	0.0052	45	690	25.73	88.97		R	3T	1038/760/6	forg
14361	24081	649	89.6	4272	0.00098	760	3100	30.62	73.85		R	4T	1038/760/6	forg
14361	24083	593	144.7	12273	0.00081	746	10000	21.5	60		R	5T	1038/760/6	forg
14361	24101	593	124.1		0.000003					80000	IT	6T	1038/760/6	forg
14361	24161	538	220.5	7688	0.00061	400	5750	26.81	82.82		R	7T	1038/760/6	forg
14361	27703	649	100	748	0.0045	80	380	36.72	91.76		R	23T	1038/760/6	forg
14361	27706	649	124.1	106	0.062	1	52	39.2	93.91		R	14T	1038/760/6	forg
14361	27707	677	75.8	510	0.008	22	260	35.52	93.92		R	13T	1038/760/6	forg
14361	27715	621	144.7	211	0.025	12	115	34.32	92.85		R	24T	1038/760/6	forg
14361	27738	621	100		0.00033	900				7000	D	20T	1038/760/6	forg
14361	27752	621	117.2	1858.6	0.0021	150	1050	34.98	89.99		R	22T	1038/760/6	forg
14361	27760	677	71	942	0.005	130	580	50.68	93.93		R	21T	1038/760/6	forg
14361	27790	662	75.8	2027	0.0056	150	1200	38.96	91.12		R	19T	1038/760/6	forg
14361	Cam	593	193.1	65.7				40.3	92.1		R	T	1040/760/1	pipe
14361	Cam	593	193.1	63.6				37.7	92.1		R	T	1040/760/1	pipe
14361	Cam	593	193.1	82.4				37	90.5		R	L	1040/760/1	pipe
14361	Cam	593	193.1	67.6				43	90.7		R	L	1040/760/1	pipe
14361	Cam	649	131	52.7				43.7	74.4		R	T	1040/760/1	pipe
14361	Cam	649	131	58.9				43.7	71.3		R	T	1040/760/1	pipe

Lot	TN	Temp (C)	Stress (MPa)	Life (h)	mcr (%/h)	t 1% (h)	tertiary	% El	% RA	in test (h)	Status	SN	Ann/Temp/h	Product
14361	Cam	649	131	52.7				45.7	99.2		R	L	1040/760/1	pipe
14361	Cam	649	131	64.8				44.3	72.1		R	L	1040/760/1	pipe
30176	22092	649	103.4	632	0.0056	125	400	30.56	89.73		R	1T	1038/760/1	1-in pl
30176	22134	538	234.4	3353	0.0011	495	2500	22.48	84.32		R	2T	1038/760/1	1-in pl
30176	24357	538	206.8		0.000058					20000	D	346T	AGED	1-in pl
30176	24359	538	186.1		0.000017					20000	D	347T	AGED	1-in pl
30176	24752	482	275.8		0.000035	20000				70000	IT	7T	1038/760/1	1-in pl
30176	24847	538	165.5		0.00002	24000				69000	IT	8T	1038/760/1	1-in pl
30176	25624	600	220.6						60.15		R	TV4	1050/760/1	
30176	25663	500	496.4	53.7					69.67		R	TV7	1050/760/1	
30176	27792	677	103.4	46.8	0.11	3	30	33	93		R	327T	1038/760/1/P	1-in pl
30176	28028	593	172.4							1400	IT		1038/760/1	1-in pl
30176	28029	649	124.1	193.8	0.02		120	33.4	89.6		R	426	1038/760/1	1-in pl
30176	28036	593	206.9	122				27.84	86.16		R		1038/760/1	1-in pl
30176	BCL	593	124.1	14732	0.000089	2500	13000	22.3	83.8		R	9T	1038/760/1	1-in pl
30176	CE	677	124.1	26	0.15			24.46	92.1		R		1038/760/1	1-in pl
30182	21659	649	131	64	0.079	5		39.26	92.46		R	B6T	1038/760/1	5/8-in pl
30182	21669	649	103.4	566	0.0063	140		41.96	92.27		R	B7T	1038/760/1	5/8-in pl
30182	21670	538	275.8	199	0.02	25		29.53	83.38		R	B9T	1038/760/1	5/8-in pl
30182	21671	649	89.6	1555	0.0021	300		27.22	86.44		R	B10T	1038/760/1	5/8-in pl
30182	21672	538	234.4	4387	0.00095	450		24.16	84.42		R	B8T	1038/760/1	5/8-in pl
30182	21741	649	89.6	1242				31.77	88.78		R	B11T	1038/760/1	5/8-in pl
30182	21927	649	89.6	1188				35.05	90.85		R	B12T	1038/760/1	5/8-in pl
30182	21953	677	89.6	222	0.02	25		39.41	92.71		R	B13T	1038/760/1	5/8-in pl
30182	21977	704	86.9	21	0.28	15		41.72	95.09		R	B14T	1038/760/1	5/8-in pl
30182	22003	649	103.4	236	0.018	20	145	30.61	91.29		R	13T	1038/760/1	9 1/8-in bar
30182	22025	649	103.4	448	0.0095	55	270	34.82	92.24		R	14T	1038/760/1	9 1/8-in bar
30182	22137	649	103.4	669	0.0051	90	410	36.17	91.95		R	C2T	1038/760/1	5/8-in pl
30182	22146	649	103.4	373	0.01	100	210	36.94	93.94		R	D2T	1038/760/1	5/8-in pl
30182	22247	649	89.6	2058	0.0014	520	1420	21.16	84.76		R	C3T	1038/760/1	5/8-in pl
30182	22248	538	234.4	3468	0.0012	300	2650	22.36	83.9		R	D3T	1038/760/1	5/8-in pl
30182	22253	538	275.8	259	0.017	35	155	26.9	83.4		R	C4T	1038/760/1	5/8-in pl
30182	22273	649	89.6	1139	0.0028	220	660	32.15	90.93		R	D4T	1038/760/1	5/8-in pl
30182	22445	538	275.8	252	0.016	35	160	26.55	85.95		R	D5T	1038/760/1	5/8-in pl
30182	22857	593	193.1	73.6	0.099	7	40	29.25	88.63		R	31T-Q	1038/760/4	8-in pl
30182	22859	593	193.1	40.4	0.122	5.5	26	31.76	87.58		R	57T-C	1038/760/4	8-in pl
30182	22862	593	172.4	189.3	0.031	22	132	30.02	91.31		R	58T-C	1038/760/4	8-in pl
30182	22863	593	172.4	247	0.02	30	165	28.91	89.85		R	32T-Q	1038/760/4	8-in pl
30182	22864	593	172.4	143	0.038	20	92	30.72	88.92		R	14T-S	1038/760/4	8-in pl
30182	22870	593	151.7	819	0.0063	80	560	32.64	91.41		R	15T-S	1038/760/4	8-in pl
30182	22871	593	151.7	824	0.0065	80	590	30.15	92.19		R	59T-C	1038/760/4	8-in pl
30182	22873	593	151.7	1185	0.0043	110	900	27.79	91.59		R	33T-Q	1038/760/4	8-in pl
30182	22958	538	186.1	18170	0.0002	2000	12900	28.29	87.29		R	68T-C	1038/760/4	8-in pl
30182	23199	593	131	6080	0.00065	600	4950	33.21	88.72		R	70T-C	1038/760/4	8-in pl
30182	CE	677	103.4	57	0.08			27	93		R		1038/760/1	5/8-in pl

Lot	TN	Temp (C)	Stress (MPa)	Life (h)	mcr (%/h)	t 1% (h)	tertiary	% El	% RA	in test (h)	Status	SN	Ann/Temp/h	Product
30182	CE	677	82.7	357	0.0098			30	93		R		1038/760/1	5/8-in pl
30182	CE	677	68.9	1539	0.0019			29	91		R		1038/760/1	5/8-in pl
30182	CE	677	59.3	5697	0.00058			21	87		R		1038/760/1	5/8-in pl
30182	WARD	593	206.8	38	0.14			30.28	88.6		R		1038/760/1	5/8-in pl
30182	WARD	593	193.1	132	0.038			27.23	88		R		1038/760/1	5/8-in pl
30182	WARD	593	172.4	368	0.014			34.4	89.1		R		1038/760/1	5/8-in pl
30182	WARD	593	158.6	1332	0.0032			28.02	91.1		R		1038/760/1	5/8-in pl
30182	WARD	593	144.8	6369	0.00058			30.08	89.1		R		1038/760/1	5/8-in pl
30182	WARD	593	131	18505	0.00011			23.77	84.3		R		1038/760/1	5/8-in pl
30182		482	365.4	1615	0.00126			20.9	79.9		R		1038/760/1	5/8-in pl
30383	21243	538	234.4	13513	0.00023	850		21.47	80.01		R	16t	1038/760/1	2-in pl
30383	21409	538	275.8	289	0.0116	45		19.56	72		R	1t	1038/760/1	2-in pl
30383	21410	649	144.8	21	0.29	10		37.66	86.43		R	2t	1038/760/1	2-in pl
30383	21411	649	117.2	191	0.023	9		29.82	72.71		R	3t	1038/760/1	2-in pl
30383	21417	649	131	57	0.095	3		31.56	91.29		R	4t	1038/760/1	2-in pl
30383	21421	593	193.1	147	0.035	5		30.18	82.59		R	7t	1038/760/1	2-in pl
30383	21425	538	262	860	0.0047	110		24.08	76.22		R	8t	1038/760/1	2-in pl
30383	21427	649	110.3	334	0.012	20		31.8	73.92		R	10	1038/760/1	2-in pl
30383	21428	593	165.6	1477	0.0024	60		27.05	73.66		R	9t	1038/760/1	2-in pl
30383	21440	649	117.2	329	0.009			31.81	86.67		R	5t	1038/760/1	2-in pl
30383	22855	593	110.3	49514	0.000071	8800	33000	13	32		R	42t	1038/760/1	2-in pl
30383	23495	500	276		0.00006	9500				10336	VAR	13	1038/760/1	2-in pl
30383	23538	550	200		0.000018	3600				8178	D	14	1038/760/1	2-in pl
30383	23539	550	200							11919	VAR	e1	1038/760/1	2-in pl
30383	23550	550	276		0.045	10				90	VAR	16	1038/760/1	2-in pl
30383	23631	550	240		0.0025	145				2114	VAR	e2	1038/760/1	2-in pl
30383	23636	600	200	96.5	0.055	6	62	27	85.5		R	22	1038/760/1	2-in pl
30383	23645	500	240		0.00004	18000				14901	VAR	23	1038/760/1	2-in pl
30383	23646	600	170		0.0035	50	600			595	D	24	1038/760/1	2-in pl
30383	23671	650	100	841	0.004	160		35.4	89		R	27	1038/760/1	2-in pl
30383	23695	600	200	67.3	0.085	4	42				R	26	1038/760/1	2-in pl
30383	23706	550	200		0.000013	1800				10627	VAR	19	1038/760/1	2-in pl
30383	23711	550	170							5000	D	28	1038/760/1	2-in pl
30383	23719	550	140							5018	D	29	1038/760/1	2-in pl
30383	23735	650	140	29.1	0.18	2	16	37.5	88.2		R	32	1038/760/1	2-in pl
30383	23738	500	200		0.000032					5891	VAR	31	1038/760/1	2-in pl
30383	23739	550	240	1896	0.0022	170	1450	22.6	80.5		R	33	1038/760/1	2-in pl
30383	23740	500	200		0.000035					2062	VAR	e3	1038/760/1	2-in pl
30383	23763	600	140	3359	0.0008	410	2500				R	30	1038/760/1	2-in pl
30383	23787	550	100							8586	VAR	35	1038/760/1	2-in pl
30383	23789	500	170							6107	VAR	34	1038/760/1	2-in pl
30383	23858	500	200							9360	VAR	e4	1038/760/1	2-in pl
30383	23881	625	140	683	0.0045	80	500	24.6	84.7		R	38	1038/760/1	2-in pl
30383	23935	500	370	300	0.007	60	210	26	72.2		R	39	1038/760/1	2-in pl
30383	23936	575	200	1754	0.0016	130	1300	23.3	71.7		R	40	1038/760/1	2-in pl

Lot	TN	Temp (C)	Stress (MPa)	Life (h)	mcr (%/h)	t 1% (h)	tertiary	% El	% RA	in test (h)	Status	SN	Ann/Temp/h	Product
30383	23953	500	352	1195	0.0012	380	790	17	73.3		R	41	1038/760/1	2-in pl
30383	23972	600	100		0.0001					2221	VAR	42	1038/760/1	2-in pl
30383	23973	625	170	44.2	0.1	3	32	34.6	87.3		R	43	1038/760/1	2-in pl
30383	23976	550	200			5500				5800	D	e5	1038/760/1	2-in pl
30383	23980	625	120.6	1165	0.0021	130	840				D	44	1038/760/1	2-in pl
30383	23981	575	245	44.7	0.15	4.5		24.2	83.5		R	45	1038/760/1	2-in pl
30383	23982	575	170		0.00029	1000				5744	VAR	46	1038/760/1	2-in pl
30383	24290	500	310		0.00039	1400				2828	VAR	e6	1038/760/1	2-in pl
30383	24354	650	60		0.00013	5050				5657	VAR	e7	1038/760/1	2-in pl
30383	24355	650	80	3818	0.001	800	2600				R	47	1038/760/1	2-in pl
30383	24364	525	200							4318	D	48	1038/760/1	2-in pl
30383	24413	525	140							2610	V	50	1038/760/1	2-in pl
30383	24439	525	240		0.00024	2600				3859	VAR	51	1038/760/1	2-in pl
30383	24440	575	140							3907	VAR	e9	1038/760/1	2-in pl
30383	24565	600	170	939	0.0035	70	550				R	20	1038/760/1	2-in pl
30383	24615	625	100		0.00026	2800				2876	D	49	1038/760/1	2-in pl
30383	24616	600	120		0.00019					2876	D	52	1038/760/1	2-in pl
30383	24663	475	350							1916	D	15	1038/760/1	2-in pl
30383	24746	482	275.8							58000	IT	25t	1038/760/1	2-in pl
30383	24820	538	165.5			30594				69000	IT	26t	1038/760/1	2-in pl
30383	25424	450	427.5							2500	D	55	1038/760/1	2-in pl
30383	27386	538	206.8		0.000055	3400				22000	IT	88t	1038/760/1	2-in pl
30383	27403	538	206.8		0.000045	7800				22000	IT	90t	1038/760/1	2-in pl
30383	27434	600	80							12000	IT	e17	1038/760/1	2-in pl
30383	27556	700	100	13.7	0.25	1.1		30.3	93.04		R	e12	1038/760/1	2-in pl
30383	27557	675	100	58.5	0.08	7	30	39.15	94.04		R	e24	1038/760/1	2-in pl
30383	27562	625	50							6400	VAR	e26	1038/760/1	2-in pl
30383	27565	675	80	372	0.011	80		27.3	90.65		R	e16	1038/760/1	2-in pl
30383	27566	700	80	52	0.13	5	35	33.36	93.77		R	53	1038/760/1	2-in pl
30383	27572	730	60	34.8	0.2	3	19	27.3	90.65		R	e14	1038/760/1	2-in pl
30383	27584	675	75							1600	VAR	e18	1038/760/1	2-in pl
30383	27585	625	80		0.000055	10500				20000	IT	e20	1038/760/1	2-in pl
30383	27586	700	60	451	0.01	50	290	18	88.47		R	60	1038/760/1	2-in pl
30383	27587	700	40	5533	0.0011	400		23.76	67.49		R	61	1038/760/1	2-in pl
30383	27594	625	100	6900	0.00042	1400	4500	23.12	75.3		IT	62	1038/760/1	2-in pl
30383	27632	662	100	344	0.01	65	200	31.24	90.69		R	64	1038/760/1	2-in pl
30383	27633	637	100	2737	0.0012	550	2000	30.16	84.36		R	63	1038/760/1	2-in pl
30383	27640	650	100	710	0.0054	125	440	29.96	91.6		R	68	1038/760/1	2-in pl
30383	27642	700	100	11.15	0.53	1		46.52	93.04		R	66	1038/760/1	2-in pl
30383	27643	675	100	88	0.05	10	60	39.04	97.61		R	67	1038/760/1	2-in pl
30383	27645	662	100	263	0.013	50	155	32	90.1		R	65	1038/760/1	2-in pl
30383	27677	625	170	84.9	0.06	1.1	51	29.76	87.35		R	70	1038/760/1	2-in pl
30383	27683	625	140	614	0.0052	55	400	28.04	86.26		R	69	1038/760/1	2-in pl
30383	27758	600	100							17000	IT	e27	1038/760/1	2-in pl
30383	27893	688	100	22.1	0.29	1.2	14	37.92	92.68		R	334	1038/760/1	2-in pl

Lot	TN	Temp (C)	Stress (MPa)	Life (h)	mcr (%/h)	t 1% (h)	tertiary	% El	% RA	in test (h)	Status	SN	Ann/Temp/h	Product
30383	28026	625	80							2200	VAR	272	1038/760/1	2-in pl
30383	28027	600	220	6.7	1.1			55.47	87.34		R	F9-53	1038/760/1	2-in pl
30383	BCL	593	124.1	21337	0.00015	3000	11000	20	61.2		R	27T	1038/760/1	2-in pl
30394	21758	649	103.4	756	0.0055	100		27.81	89.74		R	3T	1038/760/1	5/8-in pl
30394	21769	538	186.2	84309	0.00002	14000	59000	12.14	46.04		R	4T	1038/760/1	5/8-in pl
30394	21774	593	158.6	2908	0.001	300		24.48	88.5		R	5T	1038/760/1	5/8-in pl
30394	21818	649	62.1	21028	0.00016	4800		19.53	68.63		R	9T	1038/760/1	5/8-in pl
30394	21822	427	413.7							120000	IT	6T	1038/760/1	5/8-in pl
30394	21894	649	89.6	2340	0.0018	350		30.06	84.71		R	8T	1038/760/1	5/8-in pl
30394	22002	649	103.4	481	0.0085	45	350	30.23	90.8		R	13T	1038/760/1	9 1/8-in bar
30394	22031	593	158.6	2040	0.0016	120	1500	25.16	85.41		R	15T	1038/760/1	9 1/8-in bar
30394	22090	649	103.4	1155	0.0031	210	580	27.61	84.09		R	1T	1038/760/2	1-in pl
30394	22770	454	379.2	75646	0.000008	40000	35000	20.07	75.8		R	16T	1038/760/0.5	1-in pl
30394	22973	538	186.2		0.000056					45000	?	225T	1038/760/2	1-in pl
30394	23039	649	103.4	777.2	0.0085	140	550	25.3	85.69		R	371T	1038/.5/760/1	1-in pl
30394	23047	649	103.4	861.9	0.0036	200	550	24.32	88.45		R	379T	1065/.3/760/1	1-in pl
30394	23050	649	103.4	962.6	0.0033	250	600	25.02	82.75		R	387T	1065/.5/760/1	1-in pl
30394	23051	649	103.4	1118	0.0027	325	740	27.76	86.03		R	403T	1093/.3/760/1	1-in pl
30394	23052	649	103.4	1383	0.0023	400	850	32.22	86.2		R	395T	1093/.2/760/1	1-in pl
30394	23111	649	89.6	2785	0.0017	550	1850	26.07	78.07		R	372T	1038/.5/760/1	1-in pl
30394	23200	649	89.6	4856	0.00091	850	3350	24.17	63.63		R	404T	1093/.3/760/1	1-in pl
30394	23506	593	158.6	1084	0.0034	80		23.07	80.04		R	458T	1038/760/PWHT	1-in pl
30394	23628	704	27.6	21809	0.00019	1800	12600	14.24	21.8		R	420T	1038/760/1	1-in pl
30394	23698	427	379.2		0.0000005					92000	IT	421T	1038/760/1	1-in pl
30394	23705	788	34.5	32.9	0.22	2.5	23	51.18	95.53		R	210T	1038/760/2	1-in pl
30394	23708	788	20.7	304.8	0.019	20	180	62.86	94.17		R	211T	1038/760/1	1-in pl
30394	23721	788	13.8	549.3	0.0066	100	360	53.97	93.57		R	212T	1038/760/0.5	1-in pl
30394	24577	538	165.5		0.000008					70000	IT	8T	1038/760/2	1-in pl
30394	24749	482	275.8		0.000003					69000	IT	7T	1038/760/1	1-in pl
30394	26533	593	151.7	7607	0.0003	1200	5200	21.45	74.96		R	435L	1038/760/1	1-in pl
30394	26534	593	137.9	14544	0.00018	3800	10300	14.75	61.52		R	436L	1038/760/0.5	1-in pl
30394	26535	593	131	19179	0.00012	4000	10000	17.37	53		R	437L	1038/760/2	1-in pl
30394	26537	593	131					17.1	43.3	8601	VAR	438L	1038/760/1	1-in pl
30394	26538	593	137.9					21.6	74.8	7695	VAR	439L	1038/760/1	1-in pl
30394	26541	593	131					19.7	63.9	13037	VAR	440L	1038/760/0.5	1-in pl
30394	26543	593	151.7					18.5	56.07	20903	VAR	441L	1038/760/0.5	1-in pl
30394	26545	593	151.7							15704	VAR	442L	1038/760/1	1-in pl
30394	26547	593	151.7					16.5	58.1	12292	VAR	443L	1038/760/2	1-in pl
30394	26548	593	151.7							26000	VAR	444L	1038/760/1	1-in pl
30394	BCL	593	124.1	30544	0.000098	5200	17000	12.8	39.4		R	9T	1038/760/1	1-in pl
30394		677	124.1	23	0.2			31.09	89.6		R		1038/760/1	1-in pl
59020	23189	593	193.1	186	0.039	6	135	31.17	88.74		R	1L	1038/760/1	tube
59020	23190	649	117.2	298	0.016	45	185	32.76	90.92		R	2L	1038/760/1	tube
59020	23191	593	172.4	603	0.01	20	410	29.22	85.64		R	3L	1038/760/1	tube
59020	23211	649	75.8	22134	0.000165	3500	14400	19.69	48.96		R	11L	1038/760/1	tube

Lot	TN	Temp (C)	Stress (MPa)	Life (h)	mcr (%/h)	t 1% (h)	tertiary	% El	% RA	in test (h)	Status	SN	Ann/Temp/h	Product
59020	27658	677	75.8	1077	0.004	150	600	35.24	95.66		R	14L	1038/760/1	tube
59020	27661	704	75.8	105.9	0.054	6	58	43.2	96.3		R	16L	1038/760/1	tube
59020	27666	649	100	1439.6	0.0025	160	920	29.08	88.86		R	24L	1038/760/1	tube
59020	27668	593	140	11513	0.00026	750		23.76	84.91		R	23L	1038/760/1	tube
59020	27669	593	173	676.2	0.007	20	480	27.12	90.03		R	21L	1038/760/1	tube
59020	27681	621	172.4	26.3	0.18	1	14	37.5	92.66		R	22L	1038/760/1	tube
59020	27688	621	140	655.1	0.012	25	420	26.64	89.82		R	15L	1038/760/1	tube
59020	27692	677	100	188.5	0.06		155	19.56	94.19		R	17L	1038/760/1	tube
59020	27694	704	100	10.3	0.7	0.5	5.2	41.4	95.47		R	18L	1038/760/1	tube
59020	27699	649	140	28.95	0.2	1.6	18	33.84	93.61		R	20L	1038/760/1	tube
59020	27705	621	117	3741	0.0009	120	2600	32.04	87.74		R	19L	1038/760/1	tube
91887	19373	649	117.2	409.2	0.0085			25.34	87.52		R	6T	1038/760/1	1/2-in pl
91887	19440	593	193.1	154.9	0.036			35.5	85.98		R	7T	1038/760/1	1/2-in pl
91887	20395	649	103.4	1888	0.0017			27.94	85.13		R	3T	1038/760/1	1/2-in pl
91887	20396	649	131	120.7	0.034			28.73	86.54		R	4T	1038/760/1	1/2-in pl
91887	CE	538	344.8	12.8	0.27	1.9	8.9	15	79		R	EXAT	1038/760/1	1/2-in pl
91887	CE	538	317.2	28.5	0.15	3.2	17.2	19	80		R	EXAU	1038/760/1	1/2-in pl
91887	CE	538	317.2	228.9	0.01	26.8	183	15	83		R	EXBG	1038/760/1	1/2-in pl
91887	CE	538	275.8	3444.6	0.000796	2371	2527	15	84		R	EXAL	1038/760/1	1/2-in pl
91887	CE	538	262			1880				3950		DP-TC	1038/760/1	1/2-in pl
91887	CE	593	193.1	485.2	0.0063	36.5	304	16	85		R	EXAJ	1038/760/1	1/2-in pl
91887	CE	593	193.1	430.1	0.007	41.7	282	31	97		R	EXAQ	1038/760/1	1/2-in pl
91887	CE	593	165.5		0.000083					5200	?	EXBH	1038/760/1	1/2-in pl
91887	CE	593	165.5	3132.8	0.000599	610	2320	15	85		R	EXAC-AR	1038/760/1	1/2-in pl
91887	CE	593	193	198.2	0.0201	15.6	117	27	69		R	EXAG	1038/760/1	1/2-in pl
91887	CE	649	131	230.4	0.0074	85.4	135		81		R	EXBK	1038/760/1	1/2-in pl
91887	CE	649	110.3		0.00038					3500	?	EXBH	1038/760/1	1/2-in pl
91887	CE	677	103.4	171.9	0.0146	40.2	103		84		R	EXAS	1038/760/1	1/2-in pl
91887	MTC	538	268.9	486	0.0088	31	320	35	80		R	WC-C	1038/760/1	1/2-in pl
91887	MTC	538	248.2		0.00003	415				7200	?	WC-E	1038/760/1	1/2-in pl
91887	MTC	593	158.6		0.00018	2100	7030			7700	?	WC-B	1038/760/1	1/2-in pl
91887	MTC	649	96.5	6073	0.0003	2400	4075	29	78		R	WC-A	1038/760/1	1/2-in pl
565163	24689	593	172.4	2540	0.00081	720		13.5	85		R	1	1038/760/1	10-in billet
565163	24721	593	144.8	10419	0.00024	2200	3700	16.93	83.49		R	2	1038/760/1	10-in billet
565163	24990	593	124.5	33180	0.000025	18000	24000	13.62	71.08		R	5	1038/760/1	10-in billet
565163	24995	593	76.8		0.000006					50000	D	4	1038/760/1	10-in billet
565163	25371	538	206.8		0.00002	17500				58000	D	6	1038/760/1	10-in billet
565163	27739	649	124.1	152.3	0.0225	25	80	26.44	90.54		R	9	1038/760/1	10-in billet
565163	27753	621	124.1	1939	0.0013	415	1150	14.93	83.65		R	10	1038/760/1	10-in billet
565163	27761	649	100	934.6	0.0021	330	530	16.8	88.03		R	8	1038/760/1	10-in billet
a231001	23227	593	172.4	279	0.02	12	205	28.84	90.16		R	1L	1040/780/1	pipe
a231001	23278	593	172.4	465	0.011	25	350	29.11	89.54		R	2L	1040/780/1	pipe
a231001	23392	649	117.2	96.2	0.067	6	65	35.96	90.93		R	3L	1040/780/1	pipe
a231001	23398	649	103.4	344	0.015	13		34.08	87.52		R	12L	1040/780/1	pipe
a231001	23790	593	124.1	26787	0.00011	3600	19000	20.54	77		R	4L	1040/780/1	pipe

Lot	TN	Temp (C)	Stress (MPa)	Life (h)	mcr (%/h)	t 1% (h)	tertiary	% El	% RA	in test (h)	Status	SN	Ann/Temp/h	Product
a231001	23796	649	75.8	11491	0.00011	5500		24.69	77.09		R	5L	1040/780/1	pipe
a231001	24289	649	117.2	111	0.033	16		32.66	93.3		R	4T	1040/780/1	pipe
a231001	24294	649	89.6	2306	0.0015	400		27.2	88.07		R	5T	1040/780/1	pipe
a231001	27716	621	124.1	636	0.006	22	400	30.88	91.41		R	11L	1040/780/1	pipe
a231001	27736	621	103.4	5107	0.00067	600	3750	21.92	85.79		R	10L	1040/780/1	pipe
a231001	27785	677	103.4	36.5	0.175	1.9	24	50.64	93.42		R	7L	1040/780/1	pipe
XA3177	CE	538	275.8	32	0.107				82		R	EXAY	1038/760/1	1/2-in pl
XA3177	CE	538	248.2	1123.7	0.00493	23	743	21	83		R	EXBE	1038/760/1	1/2-in pl
XA3177	CE	538	262	179.1	0.0415	8.5	109	25	77		R	EXBI	1038/760/1	1/2-in pl
XA3177	CE	593	193	164.8	0.0359	2.9	103	24	87		R	EXAV	1038/760/1	1/2-in pl
XA3177	CE	593	165.5	1320.9	0.00205	18.3	1290	19	77		R	EXAX	1038/760/1	1/2-in pl
XA3177	CE	593	179.3	963	0.00438	7.7	620	22	83		R	EXBF	1038/760/1	1/2-in pl
XA3177	CE	649	110.3	257.2	0.0105	46	146		53		R	EXAW	1038/760/1	1/2-in pl
XA3177	CE	649	95.5	840.6	0.00309	213	395	14	49		R	EXBC	1038/760/1	1/2-in pl
XA3177	MTC	538	220.6		0.000217	195						WB-A	1038/760/1	1/2-in pl
XA3177	MTC	593	151.7	5385.1	0.000433	375	3670	25	58		R	WB-B	1038/760/1	1/2-in pl
XA3177	MTC	649	82.7	5692.7	0.00018	1800	3110		22		R	WB-C	1038/760/1	1/2-in pl
XA3218	CE	593	165.5	1043.6	0.00394	613	98.7	17	79		R	EXAB	1038/760/1	1/2-in pl
XA3218	CE	593	193	143.9	0.0309	80.3	14.6	25	85		R	EXAD	1038/760/1	1/2-in pl
XA3218	CE	593	193	165.6	0.024		17.8	15	82		R	EXAE	1038/760/1	1/2-in pl
XA3218	CE	593	165.5	2254.2	0.0014	1691	136	15	70		R	EXBA	1038/760/1	1/2-in pl
XA3602	21504	649	117.2	387	0.0085	100		33.66	88.75		R	9T	1038/760/1	tube
XA3602	21514	677	97.2	165	0.022	42		30.88	91.4		R	10T	1038/760/1	tube
XA3602	21525	649	117.2	273	0.011	70		23.69	84.36		R	2L	1038/760/1	tube
XA3602	21526	677	97.2	139	0.026	30		28.02	91		R	3L	1177/760/1	tube
XA3602	21527	649	97.2	570	0.005	150		34.07	79.11		R	11T	1038/760/1	tube
XA3602	21536	677	82.7	465	0.0095	80		32.85	88.61		R	12T	1038/760/1	tube
XA3602	21541	649	117.2	173	0.021	35		32.12	90.78		R	14L	1177/760/1	tube
XA3602	21542	677	97.2	177	0.026	25		31.86	91.07		R	13L	1038/760/1	tube
XA3602	21546	649	82.7	3515	0.001	600		30.42	80.48		R	15L	1038/760/1	tube
XA3602	21628	649	69.9	16997	0.0002	2700		24.57	62.38		R	25L	1038/760/1	tube
XA3602	21640	677	55.2	7185	0.00061	1000		31.8	52.19		R	24L	1038/760/1	tube
YYC982C	23147	593	172.4	931	0.0055	55	690	31.87	90.34		R	8L	1040/780/1	tube
YYC982C	23153	593	193.1	175	0.034	17		29.87	86.23		R	9L	1040/780/1	tube
YYC982C	23157	649	89.6	5784	0.00049	125	400	16.8	74.32		R	11L	1040/780/1	tube
YYC982C	23158	649	117.2	325	0.0125	25	190	29.66	88.78		R	10L	1040/780/1	tube
YYC982C	23160	649	89.6	8368	0.00049	1400		21.71	72.2		R	12L	1040/780/1	tube
YYC982C	23163	593	151.7	10967	0.00029	800	8000	21.55	75.6		R	13L	1040/780/1	tube
YYC982C	27659	677	89.6	293.6	0.013	39	185	27.32	72.92		R	19L	1040/780/1	tube
YYC982C	27660	704	89.6	31.1	0.16	2		27.36	94.16		R	18L	1040/780/1	tube
YYC982C	27667	649	100	1408	0.0023	150	850	27.72	86.3		R	22L	1040/780/1	tube
YYC982C	27682	621	172.4	40	0.145	3	22	34.8	91.03		R	21L	1040/780/1	tube
YYC982C	27693	621	140	394.6	0.016	37	240	26.72	88.09		R	17L	1040/780/1	tube
YYC982C	27695	649	140	27.2	0.2	1	21	33.28	90.72		R	20L	1040/780/1	tube
YYC982C	27700	677	117.2	21.6	0.26	1.3	12	37.44	94.51		R	16L	1040/780/1	tube

APPENDIX 6 - JAPANESE GRADE 91 DATA (JP)

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
1	JP1	sht 5	sht 5	550	265	138.4
2	JP2	sht 5	pipe	550	245	119.9
3	JP3	sht 5	1050	550	216	593.2
4	JP4	sht 5	790	550	196	6409
5	JP5	sht 5	550 ys	600	177	176
6	JP6	sht 5	667 uts	600	167	343.5
7	JP7	sht 5		600	147	1324
8	JP8	sht 5		600	128	5518
9	JP9	sht 5		600	118	9056
10	JP10	sht 5		650	118	139.8
11	JP11	sht 5		650	108	280.5
12	JP12	sht 5		650	98	637.7
13	JP13	sht 5		650	78	3148.4
14	JP14	sht 5		650	69	9127
15	JP15	sht 5		650	69	7962
16	JP16	sht 5		650	64	15174
17	JP17	sht 6	sht 6	500	343	56
18	JP18	sht 6	pipe	500	324	210
19	JP19	sht 6	1040/760	500	278	3686
20	JP20	sht 6	508 ys	550	265	16
21	JP21	sht 6	647 uts	550	235	350
22	JP22	sht 6		550	191	3724
23	JP23	sht 6		600	186	40
24	JP24	sht 6		600	167	147
25	JP25	sht 6		600	156	760
26	JP26	sht 6		650	118	121
27	JP27	sht 6		650	127	47
28	JP28	sht 6		650	108	221
29	JP29	sht 6		650	87	3502
30	JP30	sht 6		650	70	16296
31	JP31	sht 6		650	61	40542
32	JP32	sht 6		700	78	62
33	JP33	sht 6		700	69	118
34	JP34	sht 6		700	52	948
35	JP35	sht 6		700	34	15730
36	JP36	sht 7	sht 7	500	323	197
37	JP37	sht 7	pipe	500	323	136
38	JP38	sht 7	1050/760	500	277	3928
39	JP39	sht 7	503 ys	500	277	3966
40	JP40	sht 7	668 uts	550	265	27
41	JP41	sht 7		550	265	39
42	JP42	sht 7		550	235	159
43	JP43	sht 7		550	191	4968
44	JP44	sht 7		550	191	3462
45	JP45	sht 7		600	186	25
46	JP46	sht 7		600	186	28
47	JP47	sht 7		600	156	318
48	JP48	sht 7		600	156	324
49	JP49	sht 7		600	138	964
50	JP50	sht 7		600	138	1428
51	JP51	sht 7		600	138	760
52	JP52	sht 7		600	122	4266
53	JP53	sht 7		600	122	7490
54	JP54	sht 7		650	127	27
55	JP55	sht 7		650	127	35
56	JP56	sht 7		650	108	183
57	JP57	sht 7		650	108	166
58	JP58	sht 7		650	108	135
59	JP59	sht 7		650	87	2042
60	JP60	sht 7		650	87	1522
61	JP61	sht 7		650	87	1376
62	JP62	sht 7		650	70	10968
63	JP63	sht 7		650	70	11778
64	JP64	sht 7		650	70	10072
65	JP65	sht 7		650	61	32532
66	JP66	sht 7		650	61	25560
67	JP67	sht 7		650	61	30546
68	JP68	sht 7		700	69	164
69	JP69	sht 7		700	69	125
70	JP70	sht 7		700	69	128
71	JP71	sht 7		700	34	12038
72	JP72	sht 7		700	34	11830
73	JP73	sht 7		700	34	9698
74	JP74	sht 9	sht 9	500	343	53
75	JP75	sht 9	tube	500	324	203
76	JP76	sht 9	1040/760	500	294	1050
77	JP77	sht 9	522 ys	500	278	3660
78	JP78	sht 9	715 uts	550	294	17
79	JP79	sht 9		550	255	113
80	JP80	sht 9		550	245	239
81	JP81	sht 9		550	226	851
82	JP82	sht 9		550	216	1676
83	JP83	sht 9		550	196	3257
84	JP84	sht 9		600	196	74
85	JP85	sht 9		600	196	38
86	JP86	sht 9		600	177	443
87	JP87	sht 9		600	167	426
88	JP88	sht 9		600	167	695
89	JP89	sht 9		600	156	1012
90	JP90	sht 9		600	156	2076
91	JP91	sht 9		600	147	1897
92	JP92	sht 9		600	138	4750
93	JP93	sht 9		600	138	4864
94	JP94	sht 9		600	122	13200
95	JP95	sht 9		600	122	12470
96	JP96	sht 9		600	104	66234

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
97	JP97	sht 9		600	104	62512
98	JP98	sht 9		650	137	57
99	JP99	sht 9		650	127	88
100	JP100	sht 9		650	127	150
101	JP101	sht 9		650	118	313
102	JP102	sht 9		650	108	736
103	JP103	sht 9		650	108	703
104	JP104	sht 9		650	104	696
105	JP105	sht 9		650	104	566
106	JP106	sht 9		650	98	991
107	JP107	sht 9		650	88	4129
108	JP108	sht 9		650	86	7668
109	JP109	sht 9		650	78	7682
110	JP110	sht 9		650	70	20304
111	JP111	sht 9		650	70	17029
112	JP112	sht 9		650	70	14880
113	JP113	sht 9		650	70	23485
114	JP114	sht 9		650	68	23613
115	JP115	sht 9		650	52	62532
116	JP116	sht 9		650	52	57678
117	JP117	sht 9		700	88	60
118	JP118	sht 9		700	78	98
119	JP119	sht 9		700	69	400
120	JP120	sht 9		700	69	302
121	JP121	sht 9		700	59	587
122	JP122	sht 9		700	52	960
123	JP123	sht 9		700	52	1256
124	JP124	sht 9		700	49	1462
125	JP125	sht 9		700	34	3924
126	JP126	sht 9		700	34	5424
127	JP127	sht 4	sht 4	550	265	51.1
128	JP128	sht 4	tube	550	245	155
129	JP129	sht 4	1050/790	550	216	1297
130	JP130	sht 4	510 ys	550	196	4990.6
131	JP131	sht 4	687 uts	600	166	206.1
132	JP132	sht 4		600	167	682
133	JP133	sht 4		600	147	1400.3
134	JP134	sht 4		600	118	12030
135	JP135	sht 4		650	118	126.3
136	JP136	sht 4		650	118	151.7
137	JP137	sht 4		650	98	591.2
138	JP138	sht 4		650	78	4002.5
139	JP139	sht 4		650	69	10475
140	JP140	sht 4		650	64	13365
141	JP141	sht 40	sht 40	550	265	50.8
142	JP142	sht 40	pipe	550	245	145.4
143	JP143	sht 40	1050/780	550	226	588
144	JP144	sht 40	502 ys	600	186	52.4
145	JP145	sht 40	687 uts	600	167	141.9
146	JP146	sht 40		600	147	799
147	JP147	sht 40		650	118	72.5
148	JP148	sht 40		650	98	441.6
149	JP149	sht 40		650	88	1041.2
150	JP150	sht 41	sht 41	550	255	447.5
151	JP151	sht 41	pipe	550	226	8952
152	JP152	sht 41	1050/780	600	177	377
153	JP153	sht 41	511 ys	600	157	1729
154	JP154	sht 41	702 uts	600	132	6343
155	JP155	sht 41		600	123	10901
156	JP156	sht 41		650	118	168.5
157	JP157	sht 41		650	98	460
158	JP158	sht 41		650	83	2830
159	JP159	sht 41		650	74	8410
160	JP160	sht 42	sht 42	550	255	81.4
161	JP161	sht 42	pipe	550	226	708
162	JP162	sht 42	1050/780	550	196	5389
163	JP163	sht 42	521 ys	600	177	104.4
164	JP164	sht 42	718 uts	600	157	643
165	JP165	sht 42		600	132	4371
166	JP166	sht 42		600	123	16749
167	JP167	sht 42		650	118	126.6
168	JP168	sht 42		650	98	1255
169	JP169	sht 42		650	83	5558
170	JP170	sht 42		650	74	17177
171	JP171	sht 44	sht 44	500	363	12
172	JP172	sht 44	pipe	500	314	302.2
173	JP173	sht 44	1040/760	500	275	3965.2
174	JP174	sht 44	517 ys	550	275	22.9
175	JP175	sht 44	683 uts	550	235	346.7
176	JP176	sht 44		550	216	1114.7
177	JP177	sht 44		550	196	3153.2
178	JP178	sht 44		600	186	36.4
179	JP179	sht 44		600	167	201.4
180	JP180	sht 44		600	147	1763.8
181	JP181	sht 44		600	108	40246
182	JP182	sht 44		650	127	40.6
183	JP183	sht 44		650	98	795.6
184	JP184	sht 44		650	78	5129.2
185	JP185	sht 44		650	69	22900
186	JP186	sht 33	sht 33	550	265	57.5
187	JP187	sht 33	tube	550	245	178.3
188	JP188	sht 33	1040/780	550	196	5931
189	JP189	sht 33	514 ys	600	177	82.9
190	JP190	sht 33	693 uts	600	157	460.5
191	JP191	sht 33		600	137	2661
192	JP192	sht 33		650	118	102.9
193	JP193	sht 33		650	78	5149
194	JP194	sht 33		650	69	15351
195	JP195	sht 34	sht 34	500	363	27.7
196	JP196	sht 34	plate	500	333	173.5

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
197	JP197	sht 34	1040/780/735	500	275	8525
198	JP198	sht 34	502 ys	550	265	44.1
199	JP199	sht 34	681 uts	550	235	350.5
200	JP200	sht 34		550	226	875
201	JP201	sht 34		550	196	8121
202	JP202	sht 34		600	167	325
203	JP203	sht 34		600	157	373
204	JP204	sht 34		600	157	284.9
205	JP205	sht 34		600	157	368.4
206	JP206	sht 34		600	157	157.4
207	JP207	sht 34		650	108	173.5
208	JP208	sht 34		650	108	205.3
209	JP209	sht 34		650	108	108.2
210	JP210	sht 36	sht 36	550	265	38.8
211	JP211	sht 36	pipe	550	245	141.8
212	JP212	sht 36	1040/760	550	196	2397
213	JP213	sht 36	509 ys	600	196	31.7
214	JP214	sht 36	689 uts	600	157	1772
215	JP215	sht 36		600	137	3425
216	JP216	sht 36		600	137	1750
217	JP217	sht 36		600	137	2200
218	JP218	sht 36		650	127	28.2
219	JP219	sht 36		650	98	509
220	JP220	sht 36		650	78	4313
221	JP221	sht 39	sht 39	550	265	85.4
222	JP222	sht 39	pipe	550	216	4592
223	JP223	sht 39	1040/780	550	216	1287
224	JP224	sht 39	512 ys	600	196	60.3
225	JP225	sht 39	694 uts	600	157	1164
226	JP226	sht 39		600	127	6218
227	JP227	sht 39		600	127	4248
228	JP228	sht 39		650	127	87.2
229	JP229	sht 39		650	98	754.6
230	JP230	sht 39		650	78	5153
231	JP231	sht 39		650	78	5074
232	JP232	sht 3	sht 3	550	216	2089
233	JP233	sht 3	cd tube	550	216	1471
234	JP234	sht 3	1050/790	550	216	1193
235	JP235	sht 3		550	196	10913
236	JP236	sht 3		550	196	8596
237	JP237	sht 3		600	167	682
238	JP238	sht 3		600	167	665
239	JP239	sht 3		600	147	2164
240	JP240	sht 3		600	147	1392
241	JP241	sht 3		600	118	9624
242	JP242	sht 3		600	118	13929
243	JP243	sht 3		600	118	8148
244	JP244	sht 3		650	147	64.1
245	JP245	sht 3		650	118	148.6
246	JP246	sht 3		650	118	151.7

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
247	JP247	sht 3		650	98	636.5
248	JP248	sht 3		650	98	680.1
249	JP249	sht 3		650	78	4659
250	JP250	sht 3		650	78	3802
251	JP251	sht 3		650	63	10285
252	JP252	sht 30	sht 30	500	324	715
253	JP253	sht 30	tube	500	304	2131
254	JP254	sht 30	1040/780	550	265	46.8
255	JP255	sht 30	517 ys	550	206	3877
256	JP256	sht 30	702 uts	600	196	20
257	JP257	sht 30		600	167	161.9
258	JP258	sht 30		600	137	1441
259	JP259	sht 30		650	137	17.1
260	JP260	sht 30		650	108	177.7
261	JP261	sht 30		650	78	4377
262	JP262	sht 31	sht 31	500	324	1085
263	JP263	sht 31	tube	500	304	2846
264	JP264	sht 31	1040/780	550	265	59.2
265	JP265	sht 31	507 ys	550	235	305.3
266	JP266	sht 31	693 uts	550	206	2498
267	JP267	sht 31		600	196	30.1
268	JP268	sht 31		600	167	228
269	JP269	sht 31		600	137	2141
270	JP270	sht 31		650	137	24.9
271	JP271	sht 31		650	108	335.5
272	JP272	sht 31		650	78	5294
273	JP273	sht 31		600	196	21.5
274	JP274	sht 31		600	167	200
275	JP275	sht 31		600	157	599
276	JP276	sht 31		650	118	99.6
277	JP277	sht 31		650	108	190
278	JP278	sht 31		650	98	645
279	JP279	sht 26	sht 26	500	332.5	86.9
280	JP280	sht 26	plate 270mm	500	293.2	2223
281	JP281	sht 26	1060/760/740	500	274.6	4341
282	JP282	sht 26	476 ys	500	264.8	7959
283	JP283	sht 26	650 uts	550	243.2	150.8
284	JP284	sht 26		550	215.8	885
285	JP285	sht 26		550	195.2	3469
286	JP286	sht 26		550	176.5	18215
287	JP287	sht 26		600	167.7	89.6
288	JP288	sht 26		600	146.1	1009
289	JP289	sht 26		600	117.7	6092
290	JP290	sht 27	sht 27	500	373	38.3
291	JP291	sht 27	tube	500	353	138.7
292	JP292	sht 27	1050/780	500	324	808.8
293	JP293	sht 27	502 ys	500	294	4651.4
294	JP294	sht 27	680 uts	550	294	17.4
295	JP295	sht 27		550	265	111.6
296	JP296	sht 27		550	245	340

Local ID	Designation ID	Heat Designation	Temp (C)	Stress (MPa)	Life (Hrs)
297	JP297	sht 27	550	196	28375
298	JP298	sht 27	550	177	38595
299	JP299	sht 27	600	177	241
300	JP300	sht 27	600	157	1200
301	JP301	sht 27	600	127	16760
302	JP302	sht 27	600	147.1	2723.1
303	JP303	sht 27	650	127	120.8
304	JP304	sht 27	650	108	709.9
305	JP305	sht 27	650	78	10604
306	JP306	sht 28 sht 28	500	373	44.5
307	JP307	sht 28 tube	500	353	143
308	JP308	sht 28 1050/780	500	324	749
309	JP309	sht 28 501 ys	500	294	4875
310	JP310	sht 28 681 uts	550	294	19.5
311	JP311	sht 28	550	265	114.3
312	JP312	sht 28	550	245	397.7
313	JP313	sht 28	550	196	32699
314	JP314	sht 28	600	177	270
315	JP315	sht 28	600	157	1466
316	JP316	sht 28	650	127	134.9
317	JP317	sht 28	650	108	793
318	JP318	sht 28	650	78	12358
319	JP319	sht 29 sht 29	500	324	1113
320	JP320	sht 29 tube	500	304	2789
321	JP321	sht 29 1040/780	550	265	44.4
322	JP322	sht 29 511 ys	550	235	341
323	JP323	sht 29 692 uts	550	206	5512
324	JP324	sht 29	600	196	24.1
325	JP325	sht 29	600	167	187.7
326	JP326	sht 29	600	137	2605
327	JP327	sht 29	650	137	20.8
328	JP328	sht 29	650	108	238.8
329	JP329	sht 22 sht 22	500	342.3	409
330	JP330	sht 22 plate	500	313.8	2145
331	JP331	sht 22 1060/760/740	500	295.2	7054
332	JP332	sht 22 526 ys	550	274.6	40.6
333	JP333	sht 22 701 uts	550	246.2	461
334	JP334	sht 22	550	215.8	3997
335	JP335	sht 22	550	195.2	13404
336	JP336	sht 22	600	196.1	63.9
337	JP337	sht 22	600	166.7	618
338	JP338	sht 22	600	146.1	2772
339	JP339	sht 22	600	137.3	5158
340	JP340	sht 22	650	137.3	38.1
341	JP341	sht 22	650	117.7	155
342	JP342	sht 22	650	98.1	1460
343	JP343	sht 22	650	88.3	2114
344	JP344	sht 23 sht 23	500	341.3	279
345	JP345	sht 23 plate 50 mm	500	313.8	2308
346	JP346	sht 23 1060/760/740	500	294.2	5509

Local ID	Designation ID	Heat Designation	Temp (C)	Stress (MPa)	Life (Hrs)
347	JP347	sht 23 528 ys	550	274.6	37.8
348	JP348	sht 23 693 uts	550	246.2	430
349	JP349	sht 23	550	214.8	3374
350	JP350	sht 23	550	196.1	15058
351	JP351	sht 23	600	196.1	39.5
352	JP352	sht 23	600	165.7	546
353	JP353	sht 23	600	147.1	2590
354	JP354	sht 23	600	137.3	3717
355	JP355	sht 23	650	137.3	40.4
356	JP356	sht 23	650	117.7	142
357	JP357	sht 23	650	98.1	1560
358	JP358	sht 23	650	98.1	1189
359	JP359	sht 23	650	88.3	3856
360	JP360	sht 24 sht 24	500	344.2	267
361	JP361	sht 24 plate 550 mm	500	313.8	1638
362	JP362	sht 24 1060/760/740	500	294.2	10365
363	JP363	sht 24 528 ys	550	274.6	45.8
364	JP364	sht 24 693 uts	550	244.2	377.8
365	JP365	sht 24	550	214.8	3959
366	JP366	sht 24	550	195.2	16843
367	JP367	sht 24	600	196.1	53.8
368	JP368	sht 24	600	166.7	510.8
369	JP369	sht 24	600	147.1	2904
370	JP370	sht 24	600	137.3	2971
371	JP371	sht 24	650	137.3	32.8
372	JP372	sht 24	650	117.7	181
373	JP373	sht 24	650	98.1	1291
374	JP374	sht 24	650	88.3	2593
375	JP375	sht 25 sht 25	500	333.4	84.7
376	JP376	sht 25 plate 270 mm	500	295.2	1200
377	JP377	sht 25 1060/760/740	500	274.6	4393
378	JP378	sht 25 476 ys	500	263.8	11297
379	JP379	sht 25 650 uts	550	245.2	162.3
380	JP380	sht 25 (12 h temper)	550	215.8	801
381	JP381	sht 25	550	196.1	4161
382	JP382	sht 25	550	176.5	22429
383	JP383	sht 25	550	165.7	25638
384	JP384	sht 25	600	167.7	105
385	JP385	sht 25	600	146.1	610.5
386	JP386	sht 25	600	117.7	6436
387	JP387	sht 25	600	152	1383.9
388	JP388	sht 25	600	137	2236
389	JP389	sht 25	600	123	11059
390	JP390	sht 25	650	108	441
391	JP391	sht 25	650	88	4115.6
392	JP392	sht 25	650	74	8831
393	JP393	sht 20 sht 20	500	343.3	180
394	JP394	sht 20 plate 25 mm	500	313	1765.8
395	JP395	sht 20 1060/760/740	500	304	2437.7
396	JP396	sht 20 535 ys	500	296.2	13981

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
397	JP397	sht 20	693 uts	500	274.6	24565
398	JP398	sht 20		550	276.6	96.8
399	JP399	sht 20		550	230	995.3
400	JP400	sht 20		550	215.8	5001
401	JP401	sht 20		550	205.9	5053
402	JP402	sht 20		550	197.1	8282.5
403	JP403	sht 20		550	186.3	19316
404	JP404	sht 20		600	197	33.5
405	JP405	sht 20		600	167.7	337.3
406	JP406	sht 20		600	147.1	2723.1
407	JP407	sht 20		600	137.3	3584.9
408	JP408	sht 20		600	127.5	9324.5
409	JP409	sht 20		600	117.7	17037
410	JP410	sht 20		650	147.1	11.9
411	JP411	sht 20		650	118.7	140.5
412	JP412	sht 20		650	88.3	1915
413	JP413	sht 20		650	78.5	6107.2
414	JP414	sht 21	sht 21	500	345.2	189.6
415	JP415	sht 21	plate 25 mm	500	313.8	2700
416	JP416	sht 21	1060/760/740	500	305	1970
417	JP417	sht 21	536 ys	500	297.1	3066
418	JP418	sht 21	694 uts	550	276.6	21.1
419	JP419	sht 21		550	230.5	1111
420	JP420	sht 21		550	215.8	2711
421	JP421	sht 21		550	205.9	6367
422	JP422	sht 21		550	196.1	8337
423	JP423	sht 21		550	186.3	19976
424	JP424	sht 21		600	197.1	31.5
425	JP425	sht 21		600	165.7	382
426	JP426	sht 21		600	147.1	2267
427	JP427	sht 21		600	137.3	2982
428	JP428	sht 21		600	127.5	8754
429	JP429	sht 21		600	117.7	15577
430	JP430	sht 21		650	148.1	12.3
431	JP431	sht 21		650	117.7	132
432	JP432	sht 21		650	98.1	881
433	JP433	sht 21		650	78.5	5324
434	JP434	sht 19	sht 19	500	392.3	55
435	JP435	sht 19	plate 25 mm	500	362.9	186.6
436	JP436	sht 19	1060/760	500	343.2	567.2
437	JP437	sht 19	613 ys	500	323.6	3284
438	JP438	sht 19	757 uts	550	294.2	63.1
439	JP439	sht 19		550	263.8	569
440	JP440	sht 19		550	255	11120
441	JP441	sht 19		550	245.2	2090
442	JP442	sht 19		550	225.6	8367
443	JP443	sht 19		550	197.1	24508
444	JP444	sht 19		600	196.1	181.8
445	JP445	sht 19		600	167.7	819
446	JP446	sht 19		600	146.1	3883

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
447	JP447	sht 19		600	127.5	14093
448	JP448	sht 19		600	127.5	15460
449	JP449	sht 19		650	137.3	98.5
450	JP450	sht 19		650	116.7	287.9
451	JP451	sht 19		650	98.1	1277
452	JP452	sht 19		650	88.3	2432
453	JP453	sht 19		650	73.6	12689
454	JP454	sht 18	sht 18	500	392.3	67.8
455	JP455	sht 18	plate 25 mm	500	362.9	271.5
456	JP456	sht 18	1060/760	500	345.2	746.3
457	JP457	sht 18	613 ys	500	313.8	10296
458	JP458	sht 18	754 uts	550	294.2	109.9
459	JP459	sht 18		550	264.8	814
460	JP460	sht 18		550	255	1538.9
461	JP461	sht 18		550	245.2	3174
462	JP462	sht 18		550	224.6	12167
463	JP463	sht 18		550	197.1	30726
464	JP464	sht 18		600	197.1	231.8
465	JP465	sht 18		600	167.7	1191
466	JP466	sht 18		600	146.1	6221.6
467	JP467	sht 18		600	127.5	13464
468	JP468	sht 18		600	127.5	16104
469	JP469	sht 18		650	138.3	110.6
470	JP470	sht 18		650	117.7	304.4
471	JP471	sht 18		650	98.1	1396
472	JP472	sht 18		650	88.3	3431
473	JP473	sht 18		650	73.6	12585
474	JP474	sht 16	sht 16	550	274.6	326.8
475	JP475	sht 16	tube	550	255	1298
476	JP476	sht 16	1050/765	550	245.2	2916
477	JP477	sht 16	655.6 ys	550	245.2	3507
478	JP478	sht 16	758.5 uts	550	245.2	5065
479	JP479	sht 16		550	230.5	9512
480	JP480	sht 16		550	230.5	13208
481	JP481	sht 16		550	216.7	16700
482	JP482	sht 16		550	215.7	17939
483	JP483	sht 16		550	205.9	23329
484	JP484	sht 16		600	187.3	470.9
485	JP485	sht 16		600	166.7	1601
486	JP486	sht 16		600	166.7	1148
487	JP487	sht 16		600	166.7	1499
488	JP488	sht 16		600	152	3404
489	JP489	sht 16		600	152	3405
490	JP490	sht 16		600	147.1	4330
491	JP491	sht 16		600	147.1	5171
492	JP492	sht 16		600	137.3	5404
493	JP493	sht 16		600	127.5	14623
494	JP494	sht 16		600	127.5	15317
495	JP495	sht 16		650	117.7	276.4
496	JP496	sht 16		650	107.9	490

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
497	JP497	sht 16		650	99	1290
498	JP498	sht 16		650	98.1	1327
499	JP499	sht 16		650	98.1	1365
500	JP500	sht 16		650	93.2	1981
501	JP501	sht 16		650	93.2	1874
502	JP502	sht 16		650	88.3	4018
503	JP503	sht 16		650	88.3	3030
504	JP504	sht 16		650	83.4	4987
505	JP505	sht 16		650	83.4	4266
506	JP506	sht 14	sht 14	550	274.6	100.7
507	JP507	sht 14	tube	550	255	484.6
508	JP508	sht 14	1050/765	550	245	1152
509	JP509	sht 14	651.7 ys	550	245.2	1005.8
510	JP510	sht 14	783.1 uts	550	245.2	1507.9
511	JP511	sht 14		550	231.4	2606.6
512	JP512	sht 14		550	230.5	5080
513	JP513	sht 14		550	215.7	7405.8
514	JP514	sht 14		550	215.7	12732
515	JP515	sht 14		550	205.9	13144
516	JP516	sht 14		550	206.9	11919
517	JP517	sht 14		600	188.3	135.6
518	JP518	sht 14		600	176.5	160.4
519	JP519	sht 14		600	166.7	597.8
520	JP520	sht 14		600	166.7	456.6
521	JP521	sht 14		600	167.7	600.9
522	JP522	sht 14		600	152	1222.4
523	JP523	sht 14		600	152	1763.1
524	JP524	sht 14		600	147.1	2759
525	JP525	sht 14		600	147.1	3776.8
526	JP526	sht 14		600	147.1	2310.1
527	JP527	sht 14		600	137.3	4820.8
528	JP528	sht 14		600	127.5	10276
529	JP529	sht 14		600	118.7	17788
530	JP530	sht 14		650	117.7	169.2
531	JP531	sht 14		650	107.9	366.6
532	JP532	sht 14		650	98.1	842.1
533	JP533	sht 14		650	98.1	625
534	JP534	sht 14		650	98.1	1255
535	JP535	sht 14		650	93.2	1563.6
536	JP536	sht 14		650	93.2	2660.6
537	JP537	sht 14		650	88.3	3177.1
538	JP538	sht 14		650	88.3	2767.2
539	JP539	sht 14		650	83.4	4013.6
540	JP540	sht 14		650	83.4	3446.3
541	JP541	sht 14		650	83.4	4128.4
542	JP542	sht 14		650	68.6	16378
543	JP543	sht 14		650	68.6	10882
544	JP544	sht 1	sht 1	550	265	63.1
545	JP545	sht 1	tube cd	550	245	104
546	JP546	sht 1	1050/790	550	216	1193

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
547	JP547	sht 1	539 ys	550	196	6620
548	JP548	sht 1	696 uts	600	167	224.2
549	JP549	sht 1		600	167	183.5
550	JP550	sht 1		600	147	1392.9
551	JP551	sht 1		600	128	4936.5
552	JP552	sht 1		600	118	9129.8
553	JP553	sht 1		650	118	121
554	JP554	sht 1		650	108	155.2
555	JP555	sht 1		650	98	476.3
556	JP556	sht 1		650	78	2530.7
557	JP557	sht 1		650	78	2045.9
558	JP558	sht 1		650	69	5293.1
559	JP559	sht 1		650	69	7308
560	JP560	sht 12	sht 12	550	274.6	144
561	JP561	sht 12	tube	550	255	612.8
562	JP562	sht 12	1050/765	550	245.2	1752.8
563	JP563	sht 12	668.3 ys	550	245.2	1142.6
564	JP564	sht 12	751.7 uts	550	230.5	3462
565	JP565	sht 12		550	230.5	5938
566	JP566	sht 12		550	215.7	8037
567	JP567	sht 12		550	205.9	14988
568	JP568	sht 12		550	205.9	15094
569	JP569	sht 12		550	196.1	21521
570	JP570	sht 12		600	187.3	481.3
571	JP571	sht 12		600	176.5	453.2
572	JP572	sht 12		600	166.7	689
573	JP573	sht 12		600	166.7	782.4
574	JP574	sht 12		600	152	1394
575	JP575	sht 12		600	147.1	3109
576	JP576	sht 12		600	137.3	6310
577	JP577	sht 12		600	137.3	5250
578	JP578	sht 12		600	127.5	12715
579	JP579	sht 12		600	118.7	16715
580	JP580	sht 12		650	117.7	225.3
581	JP581	sht 12		650	107.9	498.5
582	JP582	sht 12		650	98.1	1037
583	JP583	sht 12		650	98.1	689
584	JP584	sht 12		650	98.1	1467
585	JP585	sht 12		650	93.2	2088
586	JP586	sht 12		650	93.2	2088
587	JP587	sht 12		650	88.3	3342
588	JP588	sht 12		650	88.3	2532
589	JP589	sht 12		650	88.4	3532
590	JP590	sht 12		650	88.4	4331
591	JP591	sht 12		650	88.4	3827
592	JP592	sht 12		650	68.6	11808
593	JP593	sht 12		650	68.6	11001
594	JP594	sht 32	sht 32	600	195	21.5
595	JP595	sht 32	tube	600	167	200
596	JP596	sht 32	1050/780	600	157	559.2

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
597	JP597	sht 32	519 ys	650	108	190
598	JP598	sht 32	700 uts	650	118	99.6
599	JP599	sht 32		650	98	645
600	JP600	sht 37	sht 37	550	196	8394.1
601	JP601	sht 37	pipe 600x198	600	157	350.4
602	JP602	sht 37	1040/760	600	147	742.4
603	JP603	sht 37	511 ys	600	137	1725.1
604	JP604	sht 37	702 uts	600	137	2192.3
605	JP605	sht 38	sht 38	550	196	3988.6
606	JP606	sht 38	pipe 600x130	550	196	2730.4
607	JP607	sht 38	1040/780	600	177	77.5
608	JP608	sht 38	509ys/686uts	600	177	57.3
609	JP609	sht 35	sht 35	600	157	373.3
610	JP610	sht 35	pipe 470x150	600	157	284.9
611	JP611	sht 35	1050/780	600	157	368.4
612	JP612	sht 35	511 ys	600	157	157.4
613	JP613	sht 35	692 uts	650	108	173.5
614	JP614	sht 35		650	108	205.3
615	JP615	sht 35		650	108	108.2

Local ID	Designation ID	Heat Designation		Temp (C)	Stress (MPa)	Life (Hrs)
616	JP616	sht 2	sht 2	600	152	1383.9
617	JP617	sht 2	tube hf	600	137	2236
618	JP618	sht 2	1050/790	600	123	11059
619	JP619	sht 2	539 ys	650	108	441
620	JP620	sht 2	687 uts	650	88	4115.6
621	JP621	sht 2		650	74	8831
622	JP622	sht 43	sht 43	600	177	59.9
623	JP623	sht 43	pipe 432x75	600	177	75.1
624	JP624	sht 43	1050/780	600	177	64.9
625	JP625	sht 43	517 ys	600	177	98.8
626	JP626	sht 43	709 uts	600	157	253.1
627	JP627	sht 43		600	157	395.1
628	JP628	sht 43		600	157	243.3
629	JP629	sht 43		600	157	430.4
630	JP630	sht 43		600	132	1994.7
631	JP631	sht 43		600	132	2696
632	JP632	sht 43		600	132	2126.6
633	JP633	sht 43		600	132	3908.6

APPENDIX 7 - JAPANESE GRADE 91 DATA (JCF)

Specimen	Material	Heat Treatment	Temp (C)	Ultimate Tensile (kgf/mm^2)	Normal Stress (kgf/mm^2)	Rupture Time	Cycles to Failure
11-T-1	Plate A	NT	RT	51.8			
11-T-2	Plate A	NT	RT	52.2			
11-T-3	Plate A	NT	500	38.3			
11-T-4	Plate A	NT	500	38.7			
11-T-5	Plate A	NT	550	33.7			
11-T-6	Plate A	NT	550	33			
11-T-7	Plate A	NT	600	25.9			
11-T-8	Plate A	NT	600	25.7			
11-C-01	Plate A	NT	500		32	465	
11-C-09	Plate A	NT	500		30	2312	
11-C-02	Plate A	NT	500		29	3333	
11-C-03	Plate A	NT	500		27	3914 (STOPPED)	
11-C-10	Plate A	NT	550		23	507	
11-C-04	Plate A	NT	550		21	1252	
11-C-05	Plate A	NT	550		20	2935	
11-C-06	Plate A	NT	550		19	3891 (STOPPED)	
11-C-07	Plate A	NT	600		17	112	
11-C-08	Plate A	NT	600		16	213	
11-C-11	Plate A	NT	600		14	1033	
11-F-05	Plate A	NT	500				1146
11-F-06	Plate A	NT	500				2228
11-F-08	Plate A	NT	500				9380
11-F-02	Plate A	NT	550				1006
11-F-01	Plate A	NT	550				2233
11-F-03	Plate A	NT	550				7689
11-F-04	Plate A	NT	600				2248
11-F-07	Plate A	NT	600				6216
13-T-1	Plate A	NT+SR	RT	46			
13-T-2	Plate A	NT+SR	RT	46.3			
13-T-3	Plate A	NT+SR	500	34.1			
13-T-4	Plate A	NT+SR	500	34.1			
13-T-5	Plate A	NT+SR	550	29.8			
13-T-6	Plate A	NT+SR	550	30.4			
13-T-7	Plate A	NT+SR	600	25.5			
13-T-8	Plate A	NT+SR	600	24.2			
13-C-01	Plate A	NT+SR	500		32	269.8	
13-C-07	Plate A	NT+SR	500		29	1587.6	
13-C-10	Plate A	NT+SR	500		28	3242.1	
13-C-02	Plate A	NT+SR	550		22	602.2	
13-C-11	Plate A	NT+SR	550		21	532.2	
13-C-06	Plate A	NT+SR	550		20	2031.7	
13-C-04	Plate A	NT+SR	600		17	64	
13-C-05	Plate A	NT+SR	600		16	133.2	

Specimen	Material	Heat Treatment	Temp (C)	Ultimate Tensile (kgf/mm^2)	Normal Stress (kgf/mm^2)	Rupture Time	Cycles to Failure
13-F-02	Plate A	NT+SR	500				846
13-F-03	Plate A	NT+SR	500				1806
13-F-01	Plate A	NT+SR	500				9540
13-F-06	Plate A	NT+SR	550				875
13-F-05	Plate A	NT+SR	550				1771
13-F-04	Plate A	NT+SR	550				7169
13-F-08	Plate A	NT+SR	600				1600
13-F-07	Plate A	NT+SR	600				5410
36-T-1	Plate B	NT	RT	58.7			
36-T-2	Plate B	NT	RT	58			
36-T-3	Plate B	NT	500	44.8			
36-T-4	Plate B	NT	500	44.9			
36-T-5	Plate B	NT	550	38.5			
36-T-6	Plate B	NT	550	39.9			
36-T-7	Plate B	NT	600	30.1			
36-T-8	Plate B	NT	600	29.1			
34-T-1	Plate B	NT+SR	RT	51.9			
34-T-2	Plate B	NT+SR	RT	51.4			
34-T-3	Plate B	NT+SR	500	39.4			
34-T-4	Plate B	NT+SR	500	40.8			
34-T-5	Plate B	NT+SR	550	34.5			
34-T-6	Plate B	NT+SR	550	33.6			
34-T-7	Plate B	NT+SR	600	26.8			
34-T-8	Plate B	NT+SR	600	26.6			
34-C-01	Plate B	NT+SR	500		34	400	
34-C-03	Plate B	NT+SR	500		31	2880.5	
34-C-02	Plate B	NT+SR	500		30	4152.6	
34-C-04	Plate B	NT+SR	500		30	4110.9	
34-C-09	Plate B	NT+SR	550		24	472.2	
34-C-10	Plate B	NT+SR	550		22	2000	
34-C-11	Plate B	NT+SR	550		20.5	5709	
34-C-12	Plate B	NT+SR	550		19.5	6251	
34-C-17	Plate B	NT+SR	600		17	276.8	
34-C-18	Plate B	NT+SR	600		15	1714.4	
34-C-19	Plate B	NT+SR	600		14	3456.5	
34-C-20	Plate B	NT+SR	600		13	8174 (STOPPED)	
PN-T-01	Plate C	NT	RT	56.6			
PN-T-02	Plate C	NT	RT	53.5			
PN-T-03	Plate C	NT	100	51.9			
PN-T-04	Plate C	NT	100	53			
PN-T-05	Plate C	NT	150	51.8			
PN-T-06	Plate C	NT	150	52.6			
PN-T-07	Plate C	NT	200	50.8			
PN-T-08	Plate C	NT	200	50.6			
PN-T-09	Plate C	NT	250	50.5			
PN-T-10	Plate C	NT	250	50.9			

Specimen	Material	Heat Treatment	Temp (C)	Ultimate Tensile (kgf/mm^2)	Normal Stress (kgf/mm^2)	Rupture Time	Cycles to Failure
PN-T-11	Plate C	NT	300	49.7			
PN-T-12	Plate C	NT	300	49.3			
PN-T-13	Plate C	NT	350	48.3			
PN-T-14	Plate C	NT	350	48.8			
PN-T-15	Plate C	NT	400	48.6			
PN-T-16	Plate C	NT	400	49.2			
PN-T-17	Plate C	NT	450	45.1			
PN-T-18	Plate C	NT	450	45.5			
PN-T-19	Plate C	NT	500	41.7			
PN-T-20	Plate C	NT	500	41.7			
PN-T-21	Plate C	NT	550	37.1			
PN-T-22	Plate C	NT	550	36.4			
PN-T-23	Plate C	NT	600	28.3			
PN-T-34	Plate C	NT	600	28.3			
P-F-01	Plate C	NT+SR	550				1721
P-F-02	Plate C	NT+SR	550				2381
P-F-03	Plate C	NT+SR	550				4947
P-F-04	Plate C	NT+SR	550				6200
P-F-05	Plate C	NT+SR	600				1881
P-F-06	Plate C	NT+SR	600				2933
P-F-07	Plate C	NT+SR	600				4140
P-F-08	Plate C	NT+SR	600				10350
28-T-1	Tube A	NT	RT	56.2			
28-T-2	Tube A	NT	RT	50.7			
28-T-3	Tube A	NT	500	40.5			
28-T-4	Tube A	NT	500	36.6			
28-T-5	Tube A	NT	550	33.8			
28-T-6	Tube A	NT	550	35.2			
28-T-7	Tube A	NT	600	22.3			
28-T-8	Tube A	NT	600	24.4			
26-T-1	Tube A	NT+SR	RT	49.8			
26-T-2	Tube A	NT+SR	RT	47.7			
26-T-3	Tube A	NT+SR	500	38.4			
26-T-4	Tube A	NT+SR	500	38			
26-T-5	Tube A	NT+SR	550	30.2			
26-T-6	Tube A	NT+SR	550	30.7			
26-T-7	Tube A	NT+SR	600	21.7			
26-T-8	Tube A	NT+SR	600	21.8			
26-C-01	Tube A	NT+SR	500		34	300	
26-C-02	Tube A	NT+SR	500		32	734.6	
26-C-03	Tube A	NT+SR	500		31	2803.3	
26-C-04	Tube A	NT+SR	500		30	2989	
26-C-05	Tube A	NT+SR	500		29	6385.1	
26-C-09	Tube A	NT+SR	550		25	183.1	
26-C-10	Tube A	NT+SR	550		23	842	
26-C-11	Tube A	NT+SR	550		21.5	2980.8	

Specimen	Material	Heat Treatment	Temp (C)	Ultimate Tensile (kgf/mm^2)	Normal Stress (kgf/mm^2)	Rupture Time	Cycles to Failure
26-C-12	Tube A	NT+SR	550		21	3189.8	
26-C-17	Tube A	NT+SR	600		17	313.3	
26-C-20	Tube A	NT+SR	600		15	2355	
26-C-21	Tube A	NT+SR	600		14	2737.5	
TN-T-01	Tube B	NT	RT	54.9			
TN-T-02	Tube B	NT	RT	53.9			
TN-T-03	Tube B	NT	100	51.4			
TN-T-04	Tube B	NT	100	51.5			
TN-T-05	Tube B	NT	200	49.4			
TN-T-06	Tube B	NT	200	49.5			
TN-T-07	Tube B	NT	300	47.9			
TN-T-08	Tube B	NT	300	48.7			
TN-T-09	Tube B	NT	400	45.6			
TN-T-10	Tube B	NT	400	45.2			
TN-T-11	Tube B	NT	500	39.3			
TN-T-12	Tube B	NT	500	39.3			
FD-T-01	Forging	NT+SR	RT	46.3			
FD-T-02	Forging	NT+SR	RT	47.2			
FD-T-03	Forging	NT+SR	500	35.4			
FD-T-04	Forging	NT+SR	500	36			
FD-T-05	Forging	NT+SR	550	31.7			
FD-T-06	Forging	NT+SR	550	32.1			
FD-T-07	Forging	NT+SR	600	26.9			
FD-T-08	Forging	NT+SR	600	26.7			
F-C-01	Forging	NT+SR	550		23	720.6	
F-C-02	Forging	NT+SR	550		22	1650.7	
F-C-03	Forging	NT+SR	550		20.5	4116.5	
F-C-04	Forging	NT+SR	550		20	4873.5	
FD-C-01	Forging	NT+SR	550		24	286.8	
FD-C-02	Forging	NT+SR	550		23	504.8	
FD-C-03	Forging	NT+SR	550		21	1966.3	
FD-C-04	Forging	NT+SR	550		20	4831.8	
FD-C-06	Forging	NT+SR	600		16	389.1	
FD-3-07	Forging	NT+SR	600		15	776.7	
FD-C-08	Forging	NT+SR	600		14	2494.5	
FD-C-09	Forging	NT+SR	600		13	5465	
F-C-06	Forging	NT+SR	600		14	3665.3	
F-C-07	Forging	NT+SR	600		13	4203 (STOPPED)	
F-C-08	Forging	NT+SR	600		12	7228 (STOPPED)	
F-F-01	Forging	NT+SR	550				1860
F-F-02	Forging	NT+SR	550				2914
F-F-03	Forging	NT+SR	550				5223
F-F-04	Forging	NT+SR	550				17513

APPENDIX 8 - GERMAN GRADE 91 DATA

Designation ID	Lot	Temp (C)	Stress (MPa)	Tr (hrs)
GERM-1	G 105313-5	550	220	12136
GERM-2	G 105313-5	550	240	5775
GERM-3	G 105313-5	600	120	15264
GERM-4	G 105313-5	600	150	3245
GERM-5	G 105313-5	600	180	1095
GERM-6	G 105014-1	550	240	1602
GERM-7	G 105014-1	550	280	330
GERM-8	G 105014-1	600	120	6205
GERM-9	G 105014-1	600	150	1936
GERM-10	G 105014-1	600	180	248
GERM-11	G 105014-1	650	80	1196
GERM-12	G 105014-1	650	80	3072
GERM-13	G 105014-1	650	100	585
GERM-14	G 105014-1	650	120	111
GERM-15	G 105014-750	550	180	29280
GERM-16	G 105014-750	550	200	18017
GERM-17	G 105014-750	550	220	3452
GERM-18	G 105014-750	550	240	1008
GERM-19	G 105014-750	550	280	60
GERM-20	G 105014-750	600	100	25161
GERM-21	G 105014-750	600	120	10731
GERM-22	G 105014-750	600	150	1415
GERM-23	G 105014-750	600	180	164
GERM-24	G 105014-750	600	200	35
GERM-25	G 105014-750	650	60	15225
GERM-26	G 105014-750	650	80	2424
GERM-27	G 105014-750	650	100	435
GERM-28	G 105014-750	650	120	121
GERM-29	G 105014-750	650	150	13
GERM-30	G 105006 TZ	550	240	5735
GERM-31	G 105006 TZ	550	280	160
GERM-32	G 105006 TZ	600	150	2648
GERM-33	G 105006 TZ	600	180	548
GERM-34	G 105014-780	550	180	30701
GERM-35	G 105014-780	550	200	15768
GERM-36	G 105014-780	550	220	4014
GERM-37	G 105014-780	550	280	116
GERM-38	G 105014-780	600	120	3600
GERM-39	G 105014-780	600	150	824
GERM-40	G 105014-780	600	180	382
GERM-41	G 105014-780	600	200	54
GERM-42	G 105014-780	650	60	24784
GERM-43	G 105014-780	650	80	3484
GERM-44	G 105014-780	650	100	696
GERM-45	G 105014-780	650	120	123
GERM-46	G 105014-780	650	150	11
GERM-47	G 105014-3	550	240	4612
GERM-48	G 105014-3	550	280	211
GERM-49	G 105014-3	600	120	6000
GERM-50	G 105014-3	600	150	3337
GERM-51	G 105014-3	600	180	1500
GERM-52	G 105014-3	600	200	131
GERM-53	G 105014-3	650	80	6572
GERM-54	G 105014-3	650	100	708
GERM-55	G 105014-3	650	120	331
GERM-56	G 109311-30	550	200	19408
GERM-57	G 109311-30	550	220	5860
GERM-58	G 109311-30	550	240	3000
GERM-59	G 109311-30	550	280	327
GERM-60	G 109311-30	600	120	10840
GERM-61	G 109311-30	600	150	2270
GERM-62	G 109311-30	600	180	505
GERM-63	G 105313-T	550	200	5968
GERM-64	G 105313-T	550	220	7144
GERM-65	G 105313-T	550	240	3683
GERM-66	G 105313-T	600	120	7053
GERM-67	G 105313-T	600	150	1759
GERM-68	G 105313-T	600	180	465
GERM-69	G 105313-T	650	80	1672
GERM-70	G 105313-T	650	100	268
GERM-71	G 105313-T	650	120	72
GERM-72	G 105313-9	550	180	16112
GERM-73	G 105313-9	550	200	5693
GERM-74	G 105313-9	550	220	2527
GERM-75	G 105313-9	550	240	830
GERM-76	G 105313-9	600	120	5911
GERM-77	G 105313-9	600	150	827
GERM-78	G 105313-9	600	180	141
GERM-79	G 109811-OD	550	200	4792
GERM-80	G 109811-OD	550	240	291
GERM-81	G 109811-OD	550	280	18
GERM-82	G 109811-OD	600	120	9496
GERM-83	G 109811-OD	600	150	1348
GERM-84	G 109811-OD	600	180	185
GERM-85	G 109811-OZ	550	200	5208
GERM-86	G 109811-OZ	550	240	247
GERM-87	G 109811-OZ	550	280	21
GERM-88	G 109811-OZ	600	120	8715
GERM-89	G 109811-OZ	600	150	928
GERM-90	G 109811-OZ	600	180	102
GERM-91	G 109811-ON	550	240	287
GERM-92	G 109811-ON	600	120	6563
GERM-93	G 109811-ON	600	150	1019
GERM-94	G 109811-ON	600	180	112

PART II - WELDMENTS

1 INTRODUCTION

A three-year collaborative effort has been established between the Department of Energy (DOE) and the American Society of Mechanical Engineers (ASME) to address technical issues related to codes and standards applicable to the Generation IV Nuclear Energy Systems Program [1]. A number of tasks have been identified that are managed through the ASME Standards Technology, LLC (ASME ST-LLC) and involve significant industry, university and independent consultant activities. One of the tasks is the *Verification of Allowable Stresses in ASME Section III, Subsection NH With Emphasis an Alloy 800H and Grade 91 Steel*. A subtask on 9Cr-1Mo-V (Gr 91) steel involved both the verification of the current allowable stresses and the assessment of the data needed to extend the ASME Section III, Subsection NH (ASME III-NH) coverage of Gr 91 steel to 600,000 hours at 650˚C (1200˚F). A second subtask on Gr 91, reported here, undertook the review and re-evaluation of weld metal and weldment data to make a judgment as to the adequacy of the stress factors for weldments currently listed in ASME III-NH.

2 IDENTIFICATION OF FILLER METALS FOR GR 91

Gr 91 steel is one of several ferritic/martensitic and ferritic/bainitic steel of interest for the Generation IV pressure vessel. ASME III-NH identifies the permitted SA specifications and associated product forms for Gr 91 in Table I-14.1 (a). Included are forgings (SA-182), seamless tubing (SA-213), seamless pipe (SA-335) and plate products (SA-387). Specifications for similar products produced in Asia and Europe have similar chemistry requirements and are considered to the equivalent to the SA specifications. The permissible weld materials for Gr 91 listed in ASME III-NH are SFA 5.5 Class E90XX-B9, which applies to shielded metal arc (SMA) welding, SFA5.23 Class EB9, which applies to submerged arc (SA) welding and SFA5.28 Class ER90S-B9, which applies to gas shielded (GTA or GMA) welding. The chemistries for these deposited filler metals are provided in Table 4 where they may be compared to the specification for the Gr 91 wrought plate product. Of significance are the higher levels of Mn and Ni that are permitted in the filler metals. These elements suppress the martensite start and finish temperatures as well as the Ac1 critical temperature that limits the upper post weld heat treating (PWHT) temperature. Some specifications for filler metals limit the Mn plus Ni content to 1.5%. The increased Ni in the filler metal is desired for improved toughness. A PHWT temperature of 745˚C (1375˚F) is recommended in SFA-5.23 and 760˚C (1400˚F) in SFA-5.28. However, each construction code provides rules for PWHT, and in ASME III-NH, paragraph NH-3357 requires that the PWHT conform to NB-4620. The P number for Gr 91 is 5B (Group 2) and Table NB-4622.1-1 in ASME III-NB requires a PWHT in the temperature range of 730 to 775˚C (1350 to 1425˚F) for times that depend on the thickness of the product.

Table 4 - Chemistries for Grade 91 Steel and Filler Metals

Element	SA-387	SFA5.5 E9015-B9 Shielded Metal Arc	SFA5.23 EB9 Submerged Arc	SFA5.28 ER90S-B9 Gas Shielded Arc
C	0.08-0.12	0.08-0.13	0.07-0.13	0.07-0.13
Mn	0.30-0.60	1.2 max	1.25 max	1.2 max
P	0.020 max	0.01 max	0.010 max	0.010 max
S	0.010 max	0.01 max	0.010 max	0.01 max
Si	0.20-0.50	0.30 max	0.3 max	0.05-0.30
NI	0.40 max	0.8 max	1.00 max	0.8 max
Cr	8.0-9.50	8.0-10.50	8.0-10.00	8.0-10.50
Mo	0.85-1.05	0.85-1.20	0.80-1.10	0.85-1.2
Cb	0.06-0.10	0.02-0.07	0.02-0.10	0.02-0.10
N	0.03-0.070		0.03-0.070	0.03-0.07
Al	0.02 max	0.02-0.10	0.04 max	0.02 max
V	0.18-0.25	0.15-0.30	0.15-0.25	0.15-0.30
Ti	0.01 max			
Zr	0.01 max			
Cu		0.25 max	<0.1	<0.1

Note: 2007 ASME Section II Part A for SA-387 specification

Note: sum of Mn and Ni shall be less than or equal to 1.5%

3 BACKGROUND AND SOURCES FOR WELDMENT CREEP-RUPTURE DATA

A developmental program on 9Cr-1Mo-V steel was undertaken by Combustion Engineering, Inc in 1975 to meet the property goals identified by Patriarca, et. al. in 1976 [2]. A screening program was undertaken to reach these goals that included weld filler metal development [3]. The emphasis was on the Shielded Metal Arc (SMA) process, and batches were produced with 127 different compositions. The SMA wires with the best impact properties were selected for production of larger batches of wire to be used for both the SMA and Gas Tungsten Arc (GTA) welding processes. Creep-rupture testing at 538, 593 and 649˚C (100, 1100 and 1200˚F) was undertaken on two filler metals that were judged to be the best based on toughness. Of these, one proved to be superior in stress-rupture to the reference base metal and the other inferior. The chemistry of the undiluted weld pad for the best wire was 0.064% C; 0.64% Mn; 0.01% P; 0.011% S; 0.20% Si; 0.02% Ni; 9.15% Cr; 1.03% Mo; 0.04% Cb; 0.053% N; 0.001% Al; 0.16% V; and 0.03% Cu. Work on the poorly performing weld filler metal was discontinued.

From 1975 to the mid-1990s, the U.S. Department of Energy (DOE) supported further mechanical testing of weldments in Gr 91, and the Oak Ridge National Laboratory (ORNL) assumed the management of the technology program. By 1982, when data packages were prepared for submission to ASME Section I and Section VIII for code approval, the available creep-rupture data were from weldments fabricated using both standard 9Cr-1Mo filler and matching 9Cr-1Mo-V filler. Except for the developmental work of Bodine, et. al., all welds were produced by the gas tungsten arc (GTA) process. Further development by Sikka and coworkers produced weldments by the submerged arc (SA) and shielded metal arc (SMA) processes [4]-[7]. The filler metal most often used was the standard 9Cr-1Mo (Gr 9) steel. By 1987, it became clear that weldments in Gr 91 were significantly weaker than the base metal with the relative weakness increasing with increasing temperature [8], [9]. Various welding procedures and post weld heat treatments were examined but the lower strength associated with a weakness in the fine-grained region of the heat affected zone (HAZ) persisted [10]. These observations were confirmed by intensive investigations of weldment performance undertaken in Europe and Asia to qualify the material and components for usage in power-generating applications for the temperature range from 550 to 650˚C (1020 to 1200˚F) [11], [12], [13].

The DOE-sponsored programs produced virtually all of the information that led to the development of stress rupture factors for Gr 91 weldments similar to those in ASME III-NH Table 1-14.10 for other materials, and these factors were based on the ratio of the average strength of the weldment (for the ferritics) to the base metal [10]. In the subsequent revisions of ASME III Code Case N-47 that led to ASME III-NH, the material specifications for the Gr 91 filler metals that were addressed by the original code case submission were altered from SFA 5.4 (E505) to those mentioned earlier in this report, namely SFA-5.28 ER 90S-B9, SFA-5.5 E90XX and SFA-E.23 EB9. Since the heat affected zone (HAZ) in the base metal was thought to control the stress factor for weldments, the filler metal was not of primary concern and the stress rupture factors were not changed. The stress ruptures factors for Gr 91 were found to be relatively time independent but decreased with increasing temperatures. Since 1990, procedures and estimates of weld strength reduction factors were developed in Europe and Asia and several papers relating to their development have been published. These will be discusses later in the report.

4 CHARACTERISTICS OF THE CREEP-RUPTURE DATABASE FOR ALLOY GR 91 WELD METAL AND WELDMENTS

The database re-assembled for the evaluation of stress factors for Gr 91 weldments in ASME III-NH was focused on the stress-rupture behavior. Although some data on creep behavior and ductility were included, they will not be discussed or evaluated in this report. There were a number of significant factors that could be discussed and evaluated with respect to the stress-rupture for weldments. These included:

- base metal composition and product thickness,
- filler metal composition and flux or coating, if used,
- welding process and process variables,
- weld configuration and number of passes,
- preheat temperature, interpass temperature, and hold/drop preheat prior to PWHT,
- post weld heat treat temperature and time,
- test specimen location (all-weld or cross weld) and size, and,
- failure location (weld, fusion line, HAZ, base metal away from weld).

An effort was made to assemble or reference as much of the weldment information as practical. In Appendix 1, for example, there is a listing of information on approximately 75 weldments. Products included plates, tubes and pipes of Gr 91 with thicknesses in the range of 9 to 200 mm (3/8 to 8 in.). Filler metals included both standard 9Cr-1Mo steel and 9C-1Mo-V steel deposited by SMA, GTA, SA and flux core arc (FCA) welding processes. Not all 75 welded products were tested in creep. Some were used for toughness testing, bend testing, aging studies, tensile tests, fatigue tests, crack growth studies and the like. Some weldments were tested in the as-welded condition, but most were post weld heat treated (PWHT) in the temperature range of 705 to 785˚C (1300 to 1450˚F). Emphasis was placed on PWHT at 730 and 760˚C (1350 and 1400˚F) with times being one hour or longer for products of 25 mm (1-in.) or more thickness. Some weldments were re-normalized and tempered (NT).

Samples were extracted from the weldments in several locations and orientations, and the listing of weldments in Appendix 1 provides information on these topics. For example, "TW" indicates that samples were taken in the cross weld orientation with at least one HAZ in the test section while "all W" indicates that samples were taken from the weld metal and contained no base metal HAZ. A column is supplied that lists a drawing number "DWG XX" that is a sketch of the weldment showing the specimen locations. The sketches are provided in Appendix 2. The cross-weld specimens were typically uniform gage with 32- or 57-mm (1¼- or 2¼-in.) reduced sections and 6.3-mm (¼-in.) diameters. These specimens had either one or two weld fusion lines and associated HAZs. About half of the weldments were made with standard 9Cr-1Mo steel filler metal.

A search for the original records of the welding process details and deposit chemistries for the weldments listed in Appendix 1 was unsuccessful in many cases since many were more than 25 years old. Not including the developmental work performed by Bodine, et. al., only 18 weld deposit chemistries were found [3]. These chemistries were provided in Appendix 3.

Stress-rupture data for weld and weldment specimens are listed in Appendix 4. There are approximately 200 entries representing about 40 welds and weldments. The table includes temperature, stress, rupture life, elongation, reduction of area and some information on failure location. The failure location information was obtained by inspecting more than 150 specimens recovered from archival storage. Typically, failures identified as "shear" were in the fine-grained HAZ of the base metal. When the weld HAZ was more normal to the specimen axis, necking was sometimes observed.

The distribution of testing times with filler metals, weld process, PWHT temperature, and test temperatures are shown in Figure 25 through Figure 28. About the same number of tests were performed on weldments from standard Gr 9 and Gr 91 filler metals, but the testing times for the standard filler metal were longer. Several of the longer times represent discontinued creep-rupture tests, so most of the data pertain to times less than 10,000 hours. The longer time tests were mostly from the GTA weldment, although a few of the SA weld exceeded 10,000 hours. Most of the testing was performed at 538 and 593˚C (1000 and 1100˚F). There were no data below 538˚C (1000˚F). Finally, the number of tests on material with the 732˚C (1350˚F) PWHT was about the same as for the 760˚C (1400˚F) PWHT.

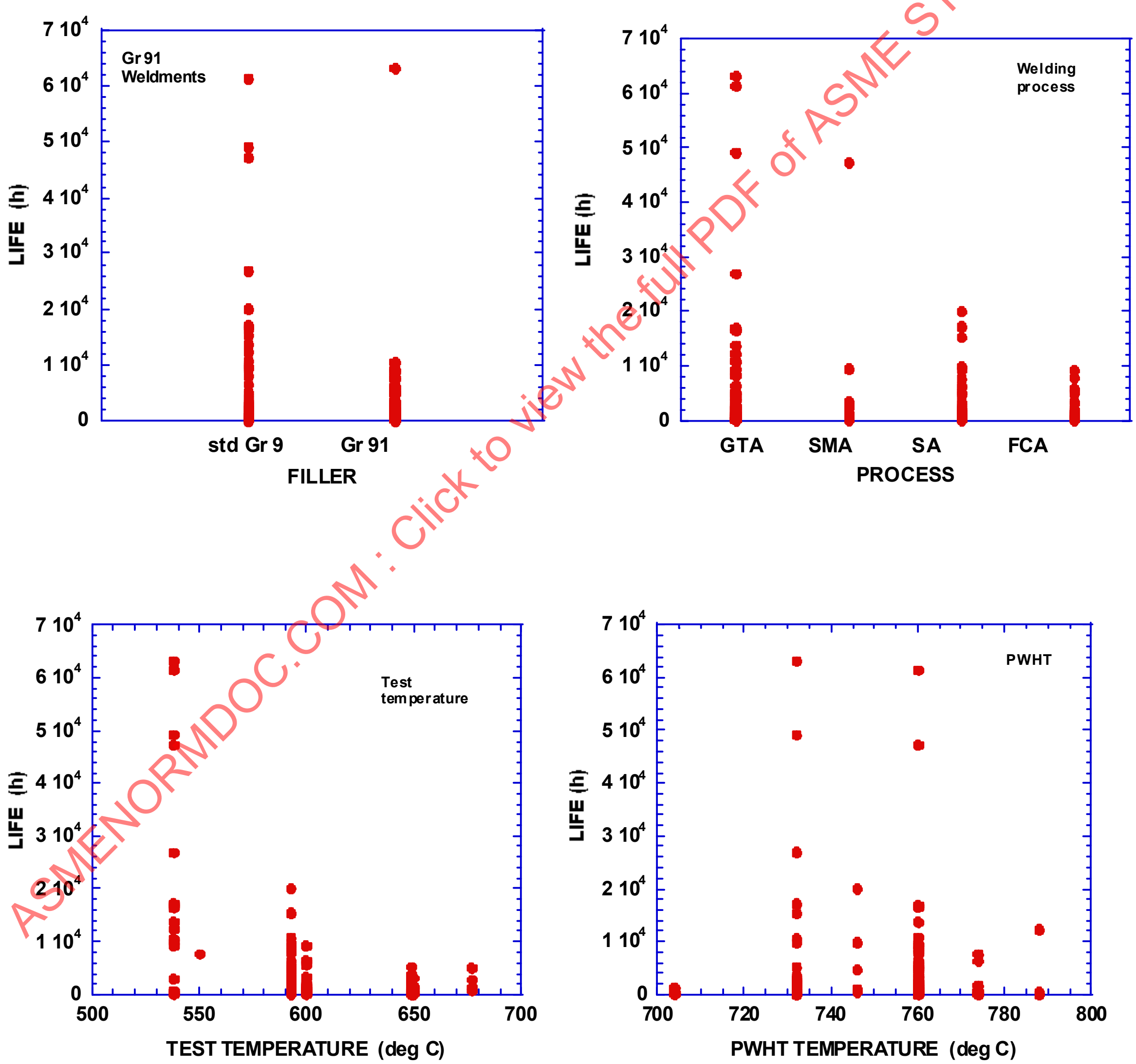


Figure 25 - The Distribution of the Rupture Data with Filler Metal, Weld Process, Test Temperature and PWHT Temperature

5 DATA EVALUATION

5.1 Criterion for Setting the Weldment Stress Rupture Factor Values

The criterion for setting the stress rupture factor (SRF) for Gr 91 weldments in ASME III-NH was the ratio of the average strength of the weldment to the average strength of the base metal. This criterion differs from the weld strength reduction factor (WSRF), which has been used to represent the ratio of the minimum weldment strength to the allowable design stress for the base metal. Typically, ruptures in Gr 91 weldments occurred in the fine-grained HAZ of the base metal at lower stresses and longer times.

5.2 Evaluation Methods

The weldment stress rupture factors currently in 2007 ASME III-NH were based on an evaluation of approximately 60 stress-rupture test data from GTA, SMA and SA weldments produced with both standard 9Cr-1Mo and 9Cr-1Mo-V steel filler metals [10]. These data were included in Appendix 4 and for tests at 538, 593 and 649˚C (1000, 1100 and 1200˚F) and times in the range of 17 to 17,200 hr. Brinkman, et. al. used a model developed for Gr 91 base metal and assumed the same temperature and stress dependency for weldments [10]. Thus:

$$\log t_r = C_h - 0.231S - 2.385\log S + 31080/T \tag{8}$$

where t_r is rupture life (h), S is stress (MPa), T is temperature (K) and C_h is the average “lot constant” obtained from a lot-center regression analysis. For base metal, C_h was -23.737 and for weldments C_h was -24.257. Solving the equation for S using the lot constants for base metal and weldments produced SRFs near 1.0 at high stresses and between 0.5 and 0.6 at very low stresses. These values were proposed in ASME III Code Case N-47, and the SRFs corresponding to 100,000 hr. were incorporated in ASME III-NH.

In the re-evaluation reported here, a modified database was correlated on the basis of equation (8). Mostly, the same data were used but rupture lives less than 100 hr. were deleted and some new data for SA weldments and FCA weldments were included. The database was expanded to approximately 85 points. A plot of the weldment rupture data against the “Orr-Sherby-Dorn” parameter (log t_r – 31080/T) from equation (8) is shown in Figure 26. Here, f(S) is the stress function from equation (8) using the lot constant for weldments [10]. The model was judged to be a reasonable fit but lacked data for stresses above 240 MPa and below 40 MPa. Also, the model tended to estimate higher strengths than observed in the 70 to 100 MPa stress range. One very short life datum at 593˚C (1100˚F) and 89 MPa appeared to be due to a weld metal failure at a defect. The isothermal data trend may be seen in Figure 27, which shows the stress-rupture data and estimated stress-rupture curves for several temperature. It is clear from Figure 27 that the estimation of the long-time rupture strengths for weldments would require significant extrapolation at all temperatures above 538˚C (1000˚F).

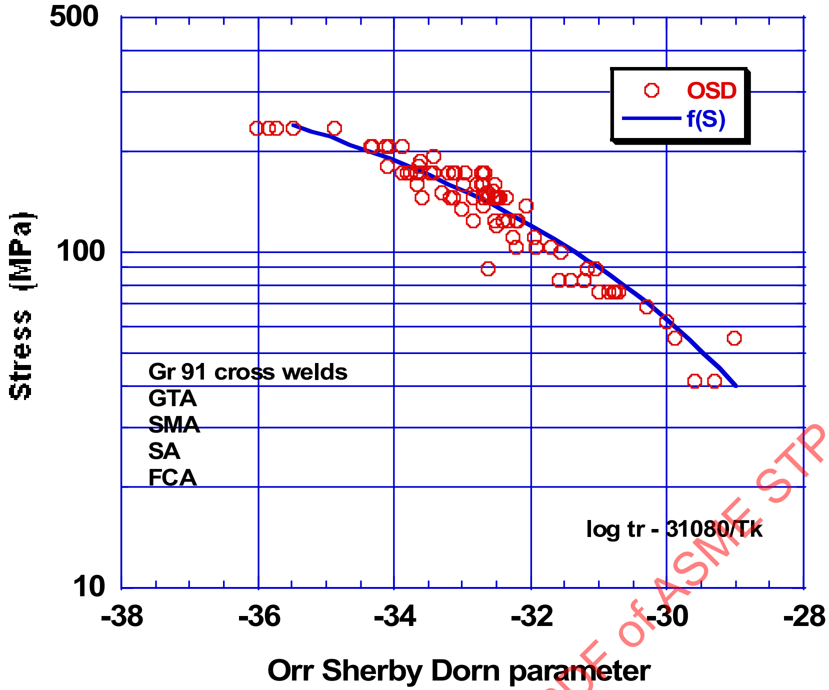


Figure 26 - Correlation of Gr 91 Cross Weld Rupture Data with the ASME III-NH Model

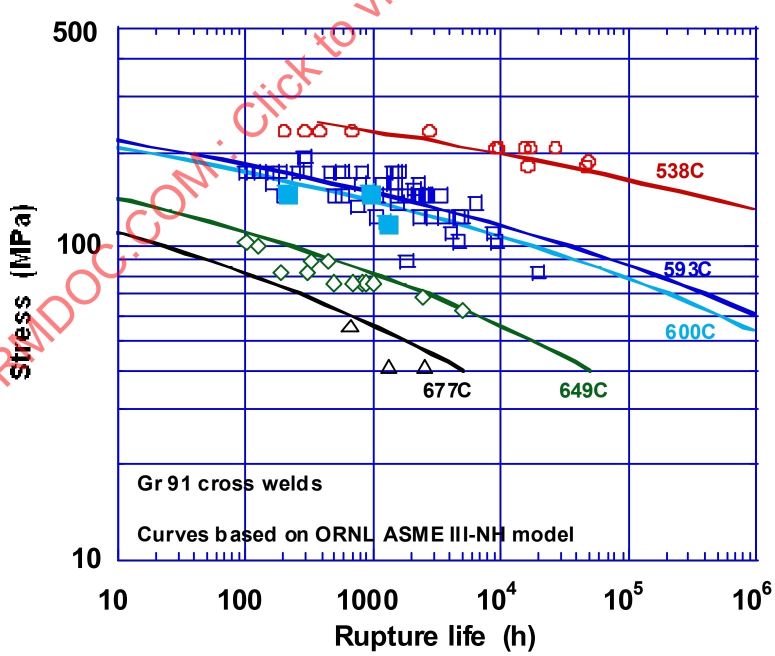


Figure 27 - Gr 91 Cross Weld Rupture Data and Calculated Isothermal Curves Based on OSD

An alternative evaluation consistent with ASME Section II procedures was performed in which a model based on the Larson-Miller parameter (LMP) was used. Here, the LMP was selected in combination with a stress function f(S) that was a four-term ("third-order") polynomial in log stress. This model was similar to the model developed for the base metal in Part 1. Thus:

$$LMP = T_K \left(C + \log t_k \right) \tag{9}$$

Where C was the average Larson-Miller parametric constant and T_K was in Kelvin.

The stress function was equated to the LMP:

$$LMP = f(s) = a_0 + a_1 \log S + a_2 \left(\log S \right)^2 + a_3 \left(\log S \right)^3 \tag{10}$$

where a_i was a series of four constants Using a least squares fitting method in which log tr was the dependent variable and T and log S were independent variables, the optimum values for C and a_i were determined. In this approach, lots were processed by the lot-centering procedure, described elsewhere [10], [14], and an average value for C that applied to all lots was found. Using the "best fit" values for f(S) and C, the log t_r values calculated along with the residual, r_i, for each datum:

$$r_i = \log \left(\frac{t_{observed}}{t_{calculated}} \right) \tag{11}$$

The standard error of estimate (SEE) was obtained from the analysis in the customary way:

$$SEE = \left[\frac{\sum \left(\log t_{observed} - \log t_{calculated} \right)^2}{\left(N_d - D_f \right)} \right]^{1/2} \tag{12}$$

Where N_d was the number of data and D_f was the degrees of freedom. The "best fit" values for the parameters were as follows:

C = 26.983991

a_0 = 92,750.65583

a_1 = -92,469.32172

a_2 = 45,383.25970

a_3 = -7807.12738

The standard error of estimate (SEE) for this model was near 0.385 in log time. The fit of f(S) to the data is shown in Figure 28. Compared to the stress function proposed for the ASME III-NH evaluation, the fit was better for stress in the range of 70 to 100 MPa but an inflection in the polynomial f(S) turned the curve toward the right at lower stresses. Extrapolation below 40 MPa was not possible. A comparison of data with the calculated isothermal curves is shown in Figure 29.

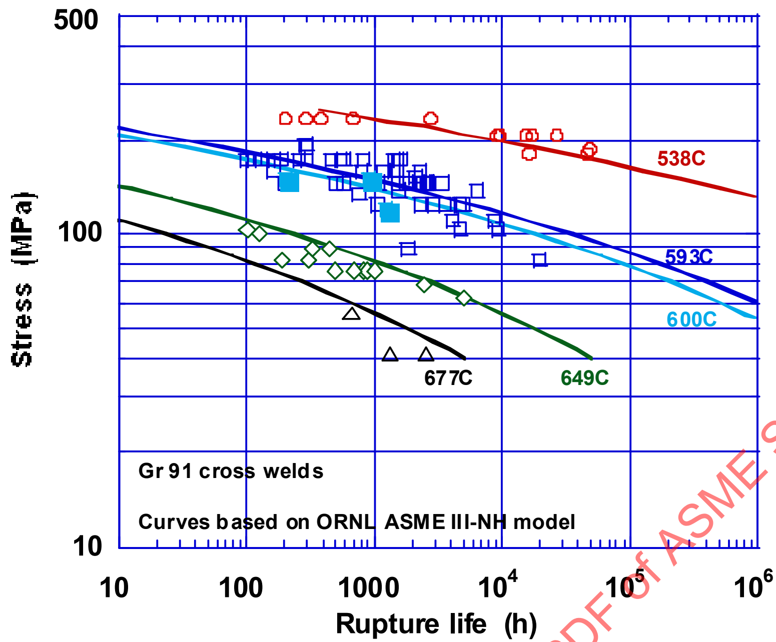


Figure 28 - Correlation of Gr-91 Cross WeldRupture Data with the Larson Miller Model

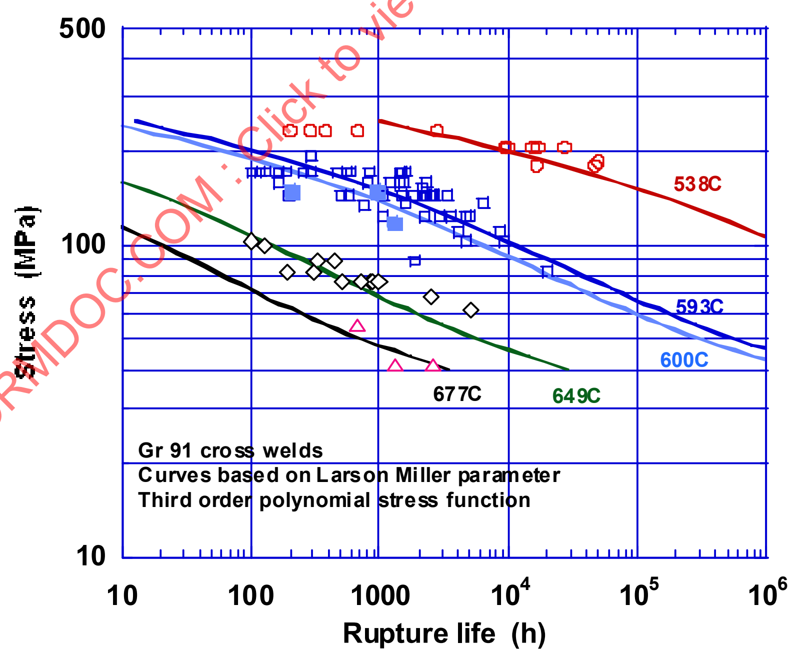


Figure 29 - Gr 91 Cross Weld Rupture Data and Calculated Isothermal Curves Based on LMP

The average lot constant and the stress function determined for the cross welds with the LMP model described above differed significantly from the base metal model described in Part 1. The average lot constant for the many lots of base metal was near 30.69 while the weldments averaged 26.97. The slope of the stress-rupture curve around 600˚C and 105 hr. was -8 for the base metal and -5 ½ for the weldments. However, the inflection in f(S) for the weldments at lower stresses was not established on the basis and any observed isothermal data trend. Most of the lots of weldments contained only one to three data and the trend of life with stress could not be established for such lots. The LMP values for lots with four or more data were adjusted for their specific lot constants and stress was re-plotted against f(S) and the lot LMPs. This construction is shown in Figure 30. Inspection on the trends revealed the f(S) was a reasonable representation of the data in the stress range of 70 to 220 MPa. These lots were not represented by data at stresses below 70 MPa.

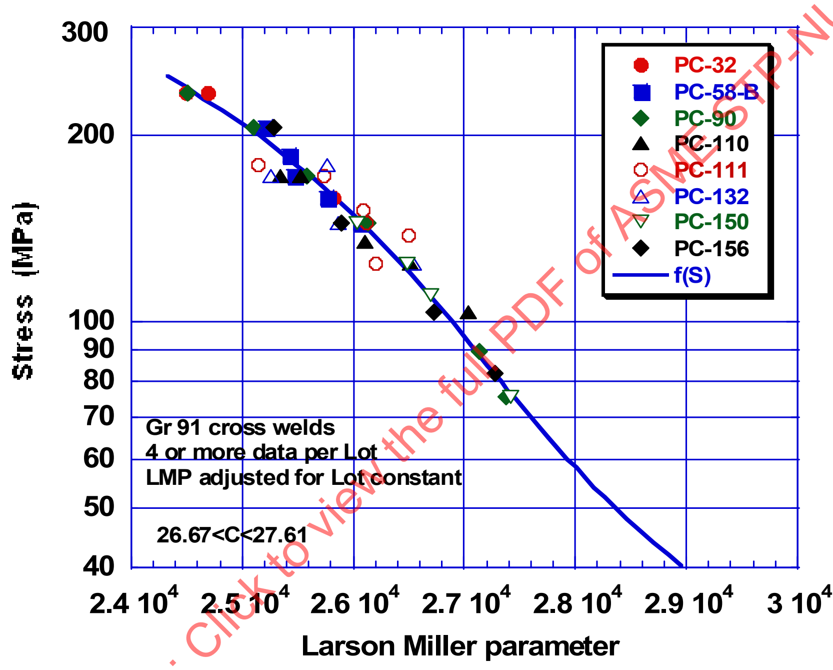


Figure 30 - Stress vs. the Larson Miller Parameter Adjusted for Lot Constant Differences

5.3 Estimation of Stress Rupture Factors

The lot-centered LMP stress-rupture model described in Part 1 was used for base metal and the lot-centered LMP stress-rupture model described above was used for weldments. Ratios for selected temperatures and times are provided in Table 5. Because of the lack of suitable data, SRFs are not entered for the shorter times at low temperatures and the longer times at high temperatures. For example, values for 300,000 and 600,000 hr. are not provided. At 10^5 hr., the SRF values differ significantly from the SRFs in ASME III-NH Table I-14.10 E-1. These values are also shown in Table 5.

Table 5 - Estimated Stress Rupture Factors for Gr 91 Weldments

Temperature (deg C)	10 h	100 h	1,000 h	10,000 h	100,000 h	ASME III-NH (2007)
425						1.00
450						0.95
475						0.93
500						0.92
525				0.97	0.92	0.91
550			1.00	0.94	0.84	0.89
575		1.00	0.97	0.80	0.73	0.87
600	1.00	1.00	0.91	0.77	0.66	0.84
625	1.00	0.95	0.81	0.68	0.66**	0.80
650	1.00	0.86	0.72	0.68**		0.76

** Note: very few data to support these values

5.4 Comparison of the Stress Rupture Factors with Other Assessments

Since the publication of the estimates SRFs for Gr 91 in the 1980s, there have been many assessments of Gr 91 and its weldments. Early work in Japan revealed low rupture strengths in the fine-grained region of the HAZ. Significant differences between base metal and weldments were observed by Sakaguchi for times to beyond 1000 hr. at 550, 600 and 650˚C (1020, 1110 and 1200˚F) with rupture strength ratios as low as 0.60 [15]. A recommendation was made by Sakaguchi to lower the tempering temperature of the base metal to below 700˚C (1290˚F) but increase the PWHT at 760˚C (1400˚F). This procedure improved the relative strength of the weldment. About the same time, Toyoda, et. al. performed stress-rupture tests on weldments with PWHT at 750˚C (1380˚F) and observed very little reduction in strength for times to 10,000 hr. [16]. The SRF at 600˚C (1100˚F) exceeded 0.9 and at 650˚C (1200˚F) it exceeded 0.85. Similar results were obtained by Taguchi, et. al. [17]. They provided stress-rupture curves to 10,000 hr. for welded joints in plates, forgings and tubes. At 500 and 550˚C (1020 and 1020˚F) the weldment strengths were close to base metal strengths while at 650˚C (1200˚F) the SRF was near 0.87.

Studies were undertaken of the all-weld metal properties and the re-normalized and tempered properties of weld metal and weldments [3], [18], [19], [20], [21]. These studies generally showed improved strength relative to the PWHT weldments, so SRFs below 1.0 were not an issue for "overmatched" filler metals and normalized and tempered weldments.

Middleton, et. al. performed extensive evaluations of data from laboratory weldment tests, HAZ simulated material tests and field in-service ruptures to establish the conditions that produced Type IV cracking in Gr 91 weldments [22]. They defined the temperature-life regions for parent metal failures and for Type IV HAZ failures and made estimates of a weld strength reduction factor (which is 1-SRF). Corresponding values for the long time SRFs at temperatures in the 550 to 600˚C (1020 to 1110˚F) range were 0.8 to 0.6. Masuyama and Askins published their test results of butt welds in tubes welded to headers and found significant early failures in Gr 91 weldments at 655˚C (1210˚F) due to Type IV cracking [23]. The SRFs were not provided but appeared to be low. Tanoue, et. al.

evaluated damage in thick-section Gr 91 weldments tested at 650˚C (1200˚F) [24]. They observed Type IV cracking and failure of the HAZ after 6000 hr. at 58.8 MPa. Based on the average strength of base metal determined in Part 1 of this report, the SRF from the work of Tanoue, et. al. would be around 0.81. This value is closer to the ASME III-NH SRF for 650˚C (1200˚F) than the estimates based on the new model presented here.

Nokada and coworkers examined stress-rupture behavior of welded P91 piping and elbows at 650˚C (1200˚F) [24], [25]. They tested full-thickness specimens extracted from the piping and elbows in addition to the pressurized pipes and elbows. Results showed similar failure modes and similar stress-rupture behavior in extracted sample and full section components when stress was based on the maximum principal stress. Although no SRFs were provided, it was clear that test data based on full-section, cross weld samples were a reliable indication of pressurized welded piping behavior.

Masuyama and Komai published results on continued testing in Japan of thick-section weldments and butt-welded tubes of Gr 91 [26]. They compared thick-section cross weld specimen data to base metal and included some results on pressurized vessels. One comparison was on the basis of the Larson Miller parameter in which they used a parametric constant of 36 for both the base metal and weldments. The stress functions were found to differ and the trends suggested that the SRFs decreased with increasing temperature and time. Interpolation of the LMP curves for 100,000 hr. at 500˚C (930˚F) indicated an SRF around 0.91 or 0.92. At the other extreme, it was possible to estimate the SRF for 10,000 hr. at 650˚C (1200˚F) to be around 0.77. These SRF values were consistent with values in ASME III-NH. In a later paper, Masuyama re-plotted the LMP curves using a parametric constant of 20 [27]. In this interpretation, the SRF at 650˚C (1200˚F) decreased to near 0.64. Comparison of the LMP curves for the two parametric constants, however, showed that the higher value for the parametric constant (C=36) was a better choice.

Cohn and Coleman reviewed work on the cross weld testing of Gr 91 and considered the effect of the PWHT temperature [28]. They found better strength when the PWHT was at 649˚C (1200˚F) rather than 704 or 760˚C (1300 to 1400˚F). They estimated some SRFs and observed that they decreased with decreasing stress and increasing time. They mentioned SRF values of 0.76 at 621˚C (1150˚F) and 0.8 at 607˚C (1125˚F). Most testing involved relatively short times, so decreases in the SRFs below the estimates provided by Cohn and Coleman were judged to be likely for longer times.

Brett and co-workers examined service failures in Gr 91 components and found that materials with high aluminum and low nitrogen were susceptible to premature rupture [29], [30], [31]. The HAZ of weldments in such lots exhibited low rupture strength relative to average strength material. Again, the relative strength decreased with increasing time and increasing temperature. The SRF values at 1000 hr. were around 0.75 for both 600 and 650˚C (1110 and 1200˚F). They suggested that SRFs could decrease to a “floor value” near 0.60.

Schubert, Klenk and Maile studied weldment behavior in several Cr-Mo-V steels for times to beyond 20,000 hr. [32]. They found that at high stresses and short time, failures occurred in the base metals away from the welds. With decreasing stresses and increasing time, HAZ ruptures were encountered, the stress-rupture curves for weldment data diverged from the base metal curves and life asymptotically approached stress-rupture curves representing 100% simulated HAZ materials. For the class of steels that includes Gr 91, they suggested the SRF should be around 0.95 at 550˚C (1020˚F) and 0.65 at 600˚C (1110˚F) for 100,000 hr. The value at 550˚C (1020˚F) is higher than that in ASME III-NH while the value at 650˚C (1200˚F) is much lower.

The SRFs in ASME III-NH formed the basis for the weld joint strength reduction factors (WSRFs) adopted for use with ASME B31.3 piping rules. The rationale for the WSRF values was provided by Becht [33] who recognized that the criteria for setting stress intensities in ASME III-NH differed from the criteria for setting allowable stresses for B31.1 Table A-1. For temperatures of 566˚C (1050˚F) and above, the WSRFs for Gr 91 were essentially identical to the SRFs in ASME III-NH.

Tabuchi and Takahashi provided a very comprehensive evaluation of WSRFs for Gr 91 based on a collection of 370 welded joint data [34]. Joining processes included SA, SMA, GTA and metal active gas (MAG) welds and testing times extended to well beyond 20,000 hr. at 550˚C (1020˚F). They used the Larson Miller parameter in combination with a second order polynomial log-stress function to represent the base metal and weldment data. Comparisons with the model used by Brinkman [equation (8)] to develop the SRFs for ASME III-NH revealed a very similar fit and prediction of stresses. Tabuchi and Takahashi also examined subsets of data that included (a) only tests that failed in the HAZ of the base metal and (b) only tests on thicker products that had specimen locations, groove angles and HAZs typical of components. The recommended model for weldments was as follows:

$$\log t_r = \frac{\left[34154 + 3494(\log S) - 2574(\log S)^2\right]}{T_k} - 31.4 \qquad (13)$$

where the SEE was 0.267 log cycle in life. This model was based on 141 data from specimens that qualified, with respect to HAZ width and groove angle, as typical of a structural component. The WSRFs recommended Tabuchi and Takahashi were based on 80% of the minimum strength of the weldment for 100,000 hr. life divided by the allowable stress for the base metal for that same life. The minimum strength corresponded to the stress for a rupture curve that was displaced to shorter times by 1.65 multiples of the SEE of the model [equation (12)]. This criterion for estimating the WSRF was different than the criterion used by Brinkman for estimating the SRFs for ASME III-NH, so a direct comparison of the SRFs and WSRFs was not possible. However, the Tubachi-Takahashi model was applicable to average strength and by substituting equation (13) for equations (9) and (10) above, the SRFs values could be calculated from the Japanese work. In Figure 31, the SRFs calculated from the Tabuchi and Takahashi equation are compared to the SRFs from the new fit provided above, the values in ASME III-NH for 100,000 hr., estimates from Schubert, Klenk and Maile [32] and the WSRF values proposed by Tabuchi and Takahashi [34].

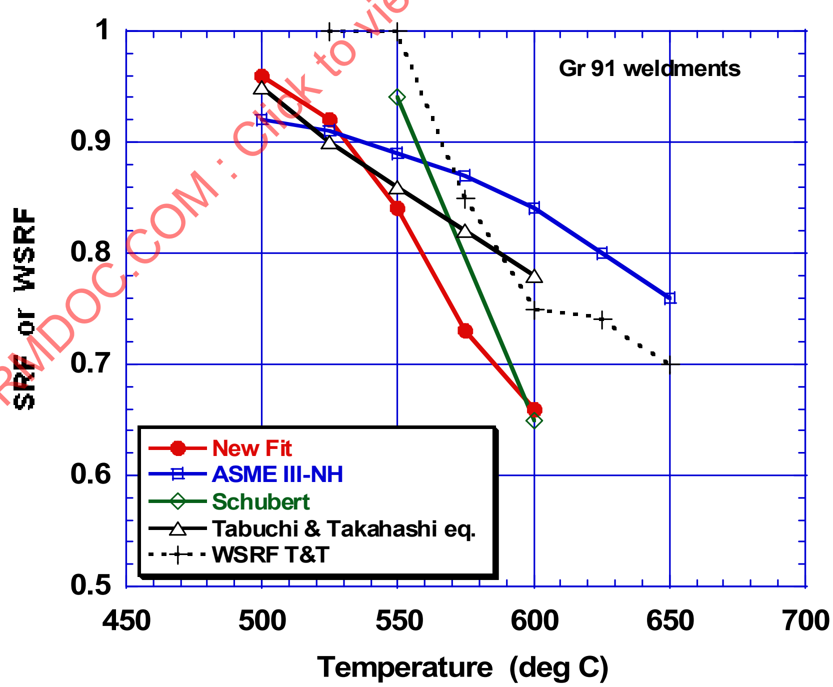


Figure 31 - Estimated Stress Rupture Factors and Weld Strength Reduction Factors for Gr 91 Weldments vs. Temperatures for 100,000 hr. Duration

In Figure 31, two trends are clear. First, at temperatures below 525˚C (975˚F), which are of interest for nuclear pressure vessels, the SRFs will exceed 0.9 by any estimation method. Second, at temperatures of 600˚C (1110˚F) and above, which are of primary interest to fossil and petrochemical applications, the SRFs and WSRFs will depend on the database, analysis method and criterion selected in the evaluation. The work of Tabuchi and Takahashi deserves special attention and appears to provide a conservative alternative to the new fit undertaken here and an improvement to the current SRF values in ASME III-NH.

Further work on Gr 91 weldments was published in 2007. Tabuchi, et. al. investigated GTA weldments with a "high" Ni filler metal for times to 10,000 hr. [35]. Again, Type IV failures occurred in the fine-grained HAZ of the base metal. At 600˚C (1110˚F), the slope of the log stress-log life curve for weldments between 1000 and 10,000 hr. was near -4, and behavior at both 600 and 650˚C (1110 and 1200˚F) was fairly close to the trend estimated from the "new fit" model presented here. The estimated SRFs for 10,000 hr. at 550, 600 and 650˚C (1020, 1110 and 1200˚F) were 0.83, 0.65 and 0.58, respectively. Yamazaki, Hongo and Watanabe examined the creep behavior of thick section Gr 91 GTA weldments for times to 10,000 hr. [36]. Their findings differed slightly from Tabuchi, et. al. [35] in that ruptures at 550˚C (1020˚F) and times to 1000 hr. at higher temperatures occurred in the weld metal. At 10,000 hr., the estimated SRFs at 550, 600 and 650˚C (1020, 1110 and 1200˚F) were 0.87, 0.67 and 0.67, respectively.

6 DISCUSSION OF EVALUATION

A number of factors that were important to the specification of SRFs for Gr 91 weldments were not considered in any detail. These factors were mentioned early in the report and will be discussed here, briefly.

The base metal composition could be important, as exemplified by the work of Brett and coworkers on materials with high Ni/Al ratios [29]-[31]. None of the base metal compositions included in this study fell into the high ratio category. Some base metal chemistries, however, could result in the weldment exceeding the Ac1 if high PWHT temperatures are used [37]. An effect on weldment behavior could be expected if the material exceeded the critical temperature. The highest PWHT used for this study was 788˚C (1450˚F) which is judged to be a safe temperature for the normal range of chemistries.

Product thickness could be important since the base metal properties are known to be sensitive to thickness. In ASME Section II Part D, products thicker than 75 mm (3 in.) have lower allowable stresses than thinner products for some temperatures. Thus, depending on the thickness, one might observe different SRFs for the same temperature-time conditions. The database considered here included only one thick product and only five data at 593˚C (1100˚F) were produced on the thick material. European and Asian researchers undertook more testing of weldments from thick products but no clear pattern emerged. However, it is significant that Tabuchi and Takahashi did not consider thin products in their development of WSRFs [34].

The filler metal composition could be important. Sometimes, Ni is added to filler metal for improved toughness. When the Ni + Mn exceed 1.2%, the Ac1, martensite start and martensite finish temperatures are lowered. The creep strength of the weld metal may be affected by untempered martensite produced from the retained austenite after tempering [38]. This will extend the region of failures in the weld metal, which normally occur at short times and high stresses. A few data from high Ni + Mn welds were included in the database used here. Half of the welds in the database were standard 9Cr-1Mo steel. This weld metal is expected to be weaker than 9Cr-1Mo-V. The deletion of rupture data short of 100 hr. eliminated some failures in the weld metal of the weldment. But not all of the specimens were available in the archives for inspection, so there is a possibility that some shorter time Gr 9 weld metal failures were retained in the processed database.

No detailed evaluation was undertaken to establish a relationship between the welding processes and the SRFs. The lot-centered analysis undertaken here produced Larson Miller parametric constants unique to each lot and it appeared that the SMA welds produced the strongest weldments (lowest lot constant) while the GTA welds produced the weakest weldments (highest lot constants). However, the SMA welds were most often made with the Gr 9 filler and the GTA welds were made with the Gr 91 filler metal. Other factors such as the base metal processing, weld configuration, number of passes and PWHT conditions were not examined.

Most of the test results included in database were produced on 0.6-mm (1/4-in.) diameter specimens. Some testing of full-thickness weldments is considered to be important to capture the effect of geometric restraint on the stress state in the HAZ. A few multiaxial tests were performed of the type described by Corum [39] and these generally supported the usefulness of the small specimen test results. Fortunately, testing of full-section weldments was undertaken by the Japanese [25], [26], [34], [35].

The selection of SRFs for inclusion in ASME III-NH Table 1.14.10 E-1 will require deliberation and action by the appropriate ASME Code committees. It is expected that when the factors are chosen they will apply to the Smt values rather than the So values in ASME III-NH. In this respect, no consideration has been given in this report to the development of minimum strength values for