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# Addendum 2

## Introduction

This addendum contains updated elastic and rupture stress data for materials based on WRC Bulletin 541, 3rd Edition, Addendum 1. Updated data is provided in SI and USC units for Low-Carbon Steel, 1.25Cr-0.5Mo, 9Cr-1Mo (Rupture Exponent), 9Cr-1Mo-V, TP304L, TP316L, TP317L, TP321, TP321H, Alloy 800HT, and HK-40. New data is provided in SI and USC units for TP115 and Advanced 347AP, and 9Cr-2Si-1Cu (Grade 921).

This addendum also incorporates corrections to errors found in the 7th Edition of API Standard 530, Addendum 1. Updated data is provided in SI and USC units for 1.25Cr-0.5Mo, 9Cr-1Mo, 9Cr-1Mo-V, 316/316H, 317L, 321H, and 800HT. Tables 4, 5, and 6 have been revised to provide the corrected Larson-Miller Constants, figure numbers, and limiting design metal temperature for the heater-tube alloys noted above.

*Front matter: The following notice shall be added to the front matter because this standard is now revised under continuous maintenance (as opposed to periodic maintenance).*

## Notice

### Instructions for Submitting a Proposed Revision to this Standard Under Continuous Maintenance

The American Petroleum Institute maintains this standard under continuous maintenance procedures. These procedures establish a document program for regular publication of addenda or revisions, including timely and documented consensus action on requests for revisions to any part of the standard. Proposed revisions shall be submitted to the Director, Standards Department, American Petroleum Institute, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

*Changes Made in Addendum 2:*

This 2nd Addendum to API 530, 7th Edition, contains changes and updates that are substantively the same as those made in WRC Bulletin 541, 3rd Edition, Addendum 1 (WRC 541). These changes include:

— The introduction of a creep rupture design factor, similar to the existing elastic design factor, which ensures appropriate conservatism in the allowable stresses for materials with only limited data. In this 2nd Addendum to the 7th Edition, factors other than 1.0 are applied to the L-grade 300 series stainless steels, and in one case, to a newly recognized material. The creep rupture design factor is only required for design of new tubes, consistent with the scope of this standard. Fitness-for-service (FFS) practitioners evaluating the creep damage or remaining life of existing heater tubes need not apply this factor.

— Second-order polynomial regressions for Larson-Miller Parameter (LMP) as a function of stress have been eliminated and replaced with either 1st order (linear) or 3rd order (cubic) regressions. By their nature, quadratic regressions cannot be monotonic. Physical constraints require that rupture time (and therefore LMP) always increases with decreasing stress. However, there will always exist some range of stresses over which a 2nd order polynomial of LMP vs. stress will actually decrease with decreasing stress. This would indicate that rupture time would also decrease with decreasing stress, which defies the physical rules of creep behavior. Although prior 2nd order regressions generally behaved appropriately over the range of stresses reflected in the base dataset, application of LMP properties to stresses outside of this range (for example, in computerized finite element simulations or numerical method calculations) resulted in errors. WRC 541 has eliminated 2nd order LMP vs. stress regressions and has instituted constraints on the coefficients of the 3rd order polynomials to ensure physical behavior is predicted over all stress ranges.

— Three new materials have been recognized, including two low-alloy steels and one austenitic stainless steel.

  — Grade 921 (9Cr-2Si-1Cu) is a coking-resistant variation of conventional 9Cr-1Mo.

  — Alloy 115 is a creep strength enhanced ferritic steel intended to provide improved oxidation, sulfidation, and $H_2/H_2S$ corrosion resistance over 9Cr-1Mo-V (Grade 91) steel.

  — Advanced 347AP stainless steel (18Cr-10Ni-3Cu-Nb) is an austenitic stainless steel intended to provide comparable or superior creep properties compared to type 347H, while resisting sensitization and stress corrosion cracking even without a stabilizing heat treatment.

— Appendix H has been updated to reflect recent and ongoing efforts to improve the API Standard 530 and WRC 541 material database. New paragraphs in Section H.9 have been added to reflect the new materials recognized in this addendum.

Corrections to errors found in API 530, 7th Edition, Addendum 1 include:

— Corrected calculations for the rupture exponent values for 1.25Cr-0.5Mo, 9Cr-1Mo, 9Cr-1Mo-V. The polynomial expressions for the rupture exponent, as presented in WRC 541, were verified using the definition of rupture exponent in Appendix H.

— Tensile and yield strength trend curves and/or room temperature values for 316/316H, 317L, 321H, and 800HT have been corrected to reflect material specifications, resulting in revisions to the stress curves for these materials.

— An error was found in Material Constant *A* (Table 3) for C-0.5Mo steel of the 6th Edition. They should be $7.45 \times 10^7$ MPa and $4.69 \times 10^{10}$ psi, instead of $2.01 \times 10^7$ MPa and $2.91 \times 10^9$ psi.

— The rupture exponent *n* versus temperature curves were all originally drawn using the 5th order polynomial curve fit coefficients given in Table 4 of WRC 541, 3rd Edition. However, when plotting the curve for Advanced 347AP SS, it was found that the curve did not coincide exactly with the curve drawn based on the definition in Equation (H.5). It was found that this difference was due to having rounded the coefficients to fewer digits than required. When expressed in the scientific format, these coefficients should have at least seven decimal points.

— Based on the above information, all the rupture exponent *n* versus temperature curves for steels with new stress curves in this addendum, including the new steels that were incorporated, were verified for correctness. It was found that there is discrepancy between the curve plotted using the curve fit coefficients from Table 4 of WRC 541, 3rd Edition and the definition in Equation (H.5) for 1.25Cr-0.5Mo steel, USC units. There is still a small discrepancy in 9Cr-1Mo steel curve, SI units; a large difference was found in Alloy 115, SI units. All the rest of the steels reviewed in this addendum were found to be correct. For those curves where a discrepancy was found, the rupture exponent *n* versus temperature curves were re-plotted using the definition in Equation (H.5).

— In the case of Type 317L stainless steel, correction of the room temperature yield and tensile strengths to specified values resulted in a separate set of curves for this alloy. Previously, 316L and 317L were plotted on the same set of strength and rupture curves; in this addendum, they are presented in separate curves. The rupture allowable stresses are identical between the two materials, while the yield, tensile, and elastic allowable curves differ.

NOTE 1 Updated and new materials addressed in this addendum are distinguished in tables with ***bold italics*** text.

NOTE 2 Annex E and Annex F contain stress curves and data tables for updated and new materials addressed in this addendum. Refer to Addendum 1 for information on materials not revised in Addendum 2.

NOTE 3 Refer to Table 6 and Table 7 for the applicable figure and table designations relevant to Addendum 1 and Addendum 2.

*Section 3: The following new terms shall be added:*

**3.4**
**creep rupture design factor**
$F_{cr}$
A factor applied to determine the rupture allowable stress.

NOTE The materials that have $F_{cr}$ < 1.0 are 304L, 316L, 317L, and Advanced 347AP; refer to Table 4, and WRC 541, 3rd Edition, Addendum 1.

**3.18**
**rupture stress based on minimum LM-parameter and with $F_{cr}$ = 1.0**
$\sigma_{r*}$
The minimum rupture strength for a specified design life within the limiting design metal temperatures shown in Table 5.

*Section 6.3: This section shall be replaced with the following:*

## 6.3 Rupture Allowable Stress

The rupture allowable stress, $\sigma_r$, is defined as:

$$\sigma_r = F_{cr} \times \sigma_{r*}$$

where:

$F_{cr}$ is the creep-rupture design factor for the specific material as shown in Table 4.

$F_{cr}$ equals 1.0 for most materials, except for L-grade austenitic stainless steels where $F_{cr}$ equals 0.8; for Advanced SS 347AP, $F_{cr}$ equals 1.0 below a temperature of 704 °C (1300 °F), and $F_{cr}$ equals 0.8 for temperatures above 704 °C (1300 °F).

$\sigma_{r*}$ is the minimum rupture strength for a specific design life within the limiting design metal temperature shown in Table 5.

Section H.6 defines rupture strength and provides the data sources. The 20,000-hour, 40,000-hour, 60,000-hour, and 100,000-hour rupture allowable stresses were developed from the Larson-Miller Parameter curves for the minimum rupture strength. All rupture allowable stress curves and data tables shown in API Standard 530 already include the appropriate $F_{cr}$.

For a design life other than those shown, the corresponding rupture allowable stress shall be developed from the Larson-Miller Parameter curves for the minimum rupture strength (see 6.6) and the appropriate $F_{cr}$. The Larson-Miller curves used are based on curves published in WRC 541 and reflect the mechanical property data obtained from tubes manufactured using modern techniques.

*Table 3: This table shall be replaced with the following:*

**Table 3--Material Constant for Temperature Fraction**

| Material | Type or Grade | Constant $A$ | |
|---|---|---|---|
| | | MPa | (psi) |
| ***Low-carbon Steel*** | **—** | ***1.14 × 10^6^*** | ***(2.72 × 10^7^)*** |
| Medium-carbon Steel | B | $3.55 \times 10^5$ | $(5.15 \times 10^7)$ |
| C-½Mo Steel | T1 or P1 | $4.73 \times 10^8$ | $(6.86 \times 10^{10})$ |
| ***1-¼Cr-½Mo Steel*** | ***T11 or P11*** | ***1.31 × 10^7^*** | ***(1.29 × 10^9^)*** |
| 2-¼Cr-1Mo Steel | T22 or P22 | $3.30 \times 10^5$ | $(4.79 \times 10^7)$ |
| 3Cr-1Mo Steel | T21 or P21 | $3.38 \times 10^5$ | $(4.91 \times 10^7)$ |
| 5Cr-½Mo Steel | T5 or P5 | $3.38 \times 10^5$ | $(4.91 \times 10^7)$ |
| 5Cr-½Mo-Si Steel | T5b or P5b | $3.38 \times 10^5$ | $(4.91 \times 10^7)$ |
| ***9Cr-1Mo Steel*** | ***T9 or P9*** | ***8.15 × 10^5^*** | ***(8.64 × 10^7^)*** |
| ***9Cr-1Mo V Steel*** | ***T91 or P91*** | ***9.65 × 10^5^*** | ***(3.41 × 10^8^)*** |
| ***9Cr-2Si-1Cu Steel*** | ***T921 or P921*** | ***2.02 × 10^6^*** | ***(8.64 × 10^7^)*** |
| ***10.5Cr-V (Alloy 115)*** | ***T115 or P115*** | ***8.65 × 10^6^*** | ***(4.02 × 10^8^)*** |
| 18Cr-8Ni Steel | 304 or 304H | $2.05 \times 10^5$ | $(2.98 \times 10^7)$ |
| ***18Cr-8Ni Steel*** | ***304L*** | ***1.09 × 10^5^*** | ***(1.68 × 10^7^)*** |
| ***16Cr-12Ni-2Mo Steel*** | ***316 or 316H*** | ***4.02 × 10^5^*** | ***(5.83 × 10^7^)*** |
| ***16Cr-12Ni-2Mo Steel*** | ***316L*** | ***2.15 × 10^5^*** | ***(3.47 × 10^7^)*** |
| ***16Cr-12Ni-3Mo Steel*** | ***317L*** | ***2.15 × 10^5^*** | ***(3.47 × 10^7^)*** |
| ***18Cr-10Ni-Ti Steel*** | ***321*** | ***1.07 × 10^6^*** | ***(1.31 × 10^8^)*** |
| ***18Cr-10Ni-Ti Steel*** | ***321H*** | ***7.10 × 10^5^*** | ***(8.68 × 10^7^)*** |
| 18Cr-10Ni-Nb [a] Steel | 347 | $3.74 \times 10^5$ | $(5.43 \times 10^7)$ |
| 18Cr-10Ni-Nb [a] Steel | 347H | $5.05 \times 10^5$ | $(7.33 \times 10^7)$ |
| ***18Cr-10Ni-Nb Steel*** | ***347LN*** | ***4.43 × 10^6^*** | ***(6.21 × 10^8^)*** |
| ***18Cr-10Ni-3Cu-Nb Steel*** | ***Advanced 347AP*** | ***3.26 × 10^6^*** | ***(3.72 × 10^8^)*** |
| Ni-Fe-Cr | Alloy 800 | $1.37 \times 10^6$ | $(1.99 \times 10^8)$ |
| ***Ni-Fe-Cr*** | ***Alloy 800H*** | ***1.35 × 10^5^*** | ***(1.87 × 10^7^)*** |
| ***Ni-Fe-Cr*** | ***Alloy 800HT*** | ***1.80 × 10^5^*** | ***(2.61 × 10^7^)*** |
| ***25Cr-20Ni*** | ***HK-40*** | ***2.04 × 10^4^*** | ***(4.65 × 10^6^)*** |

[a] Formerly called columbium (Cb)

*Table 4: This table shall be replaced with the following*

**Table 4—Larson-Miller Constants[4]**

| Material | Type or Grade | Larson-Miller Constants $C_{LM}$ | | Creep-Rupture Design Factor |
|---|---|---|---|---|
| | | minimum properties | average properties | $F_{cr}$ |
| ***Low-carbon Steel*** | **—** | ***18.15*** | ***17.70*** | ***1.0*** |
| Medium-carbon Steel | B | 15.6 | 15.15 | 1.0 |
| C-½Mo Steel | T1 or P1 | 19.007756 | 18.72537 | 1.0 |
| ***1-¼Cr-½Mo Steel*** | ***T11 or P11*** | ***22.05480*** | ***21.55*** | ***1.0*** |
| 2-¼Cr-1Mo Steel | T22 or P22 | 19.565607 | 18.9181 | 1.0 |
| 3Cr-1Mo Steel | T21 or P21 | 15.785226 | 15.38106 | 1.0 |
| 5Cr-½Mo Steel | T5 or P5 | 16.025829 | 15.58928 | 1.0 |
| 5Cr-½Mo-Si Steel | T5b or P5b | 16.025829 | 15.58928 | 1.0 |
| ***9Cr-1Mo Steel*** | ***T9 or P9*** | ***20.946*** | ***20.5*** | ***1.0*** |
| ***9Cr-1Mo V Steel*** | ***T91 or P91*** | ***23.45*** | ***23.11*** | ***1.0*** |
| ***9Cr-2Si-1Cu Steel*** | ***T921 or P921*** | ***20.946*** | ***20.5*** | ***1.0*** |
| ***10.5Cr-V (Alloy 115)*** | ***T115 or P115*** | ***25.95*** | ***25.66*** | ***1.0*** |
| 18Cr-8Ni Steel | 304 or 304H | 16.145903 | 15.52195 | 1.0 |
| ***18Cr-8Ni Steel*** | ***304L*** | ***18.287902*** | ***17.55*** | ***0.8*** |
| ***16Cr-12Ni-2Mo Steel*** | ***316 or 316H*** | ***16.764145*** | ***16.30987*** | ***1.0*** |
| ***16Cr-12Ni-2Mo Steel*** | ***316L*** | ***15.740107*** | ***15.2*** | ***0.8*** |
| ***16Cr-12Ni-3Mo Steel*** | ***317L*** | ***15.740107*** | ***15.2*** | ***0.8*** |
| ***18Cr-10Ni-Ti Steel*** | ***321*** | ***13.325*** | ***12.8*** | ***1.0*** |
| ***18Cr-10Ni-Ti Steel*** | ***321H*** | ***15.293986*** | ***14.75958*** | ***1.0*** |
| 18Cr-10Ni-Nb[a] Steel | 347 | 14.889042 | 14.25 | 1.0 |
| 18Cr-10Ni-Nb[a] Steel | 347H | 14.17 | 13.65 | 1.0 |
| ***18Cr-10Ni-Nb[a] Steel*** | ***347LN*** | ***16.6233*** | ***16.4067*** | ***1.0*** |
| ***18Cr-10Ni-3Cu-Nb[a] Steel*** | ***Advanced 347AP*** | ***17.99*** | ***16.67*** | ***[b]*** |
| Ni-Fe-Cr | Alloy 800 | 17.005384 | 16.50878 | 1.0 |
| ***Ni-Fe-Cr*** | ***Alloy 800H*** | ***16.564046*** | ***16.04227*** | ***1.0*** |
| ***Ni-Fe-Cr*** | ***Alloy 800HT*** | ***13.606722*** | ***13.2341*** | ***1.0*** |
| ***25Cr-20Ni*** | ***HK-40*** | ***10.856489*** | ***10.4899*** | ***1.0*** |

[a] Formerly called columbium (Cb).

[b] 1.0 up to and below 704 °C (1300 °F), 0.8 above 704 °C (1300 °F)

[4] WRC Bulletin 541, 3rd Edition.

*Table 5: This table shall be replaced with the following:*

**Table 5—Limiting Design Metal Temperature for Heater-tube Alloys[5]**

| Materials | Type or Grade | Limiting Design Metal Temperature | | Lower Critical Temperature | |
|---|---|---|---|---|---|
| | | °C | (°F) | °C | (°F) |
| ***Low-carbon Steel*** | ***—*** | ***540*** | ***(1000)*** | ***720*** | ***(1325)*** |
| Medium-carbon Steel | B | 540 | (1000) | 720 | (1325) |
| C-½Mo Steel | T1 or P1 | 566 | (1150) | 720 | (1325) |
| ***1¼Cr-½Mo Steel*** | ***T11 or P11*** | ***650*** | ***(1100)*** | ***775*** | ***(1427)*** |
| 2¼Cr-1Mo Steel | T22 or P22 | 650 | (1200) | 805 | (1480) |
| 3Cr-1Mo Steel | T21 or P21 | 650 | (1200) | 815 | (1500) |
| 5Cr-½Mo Steel | T5 or P5 | 650 | (1200) | 820 | (1510) |
| 5Cr-½Mo-Si Steel | T5b or P5b | 650 | (1200) | 845 | (1550) |
| ***9Cr-1Mo Steel*** | ***T9 or P9*** | ***705*** | ***(1300)*** | ***825*** | ***(1515)*** |
| ***9Cr-1Mo-V Steel*** | ***T91 or P91*** | ***705*** | ***(1300)*** | ***830*** | ***(1525)*** |
| ***9Cr-2Si-1Cu Steel*** | ***T921 or P921*** | ***705*** | ***(1300)*** | ***785*** | ***(1445)*** |
| ***10.5Cr-V (Alloy 115)*** | ***T115 or P115*** | ***677*** | ***(1250)*** | ***830*** | ***(1525)*** |
| 18Cr-8Ni Steel | 304 or 304H | 815 | (1500) | — | — |
| ***18Cr-8Ni Steel*** | ***304L*** | ***815*** | ***(1500)*** | ***—*** | ***—*** |
| ***16Cr-12Ni-2Mo Steel*** | ***316 or 316H*** | ***815*** | ***(1500)*** | ***—*** | ***—*** |
| ***16Cr-12Ni-2Mo Steel*** | ***316L*** | ***815*** | ***(1500)*** | ***—*** | ***—*** |
| ***18Cr-12Ni-3Mo Steel*** | ***317L*** | ***815*** | ***(1500)*** | ***—*** | ***—*** |
| ***18Cr-10Ni-Ti Steel*** | ***321*** | ***815*** | ***(1500)*** | ***—*** | ***—*** |
| ***18Cr-10Ni-Ti Steel*** | ***321H*** | ***815*** | ***(1500)*** | ***—*** | ***—*** |
| 18Cr-10Ni-Nb Steel | 347 | 815 | (1500) | — | — |
| 18Cr-10Ni-Nb Steel | 347H | 815 | (1500) | — | — |
| ***18Cr-10Ni-Nb Steel*** | ***347LN*** | ***694*** | ***(1282)*** | ***—*** | ***—*** |
| ***18Cr-10Ni-3Cu-Nb[a]*** | ***Advanced 347AP*** | ***815*** | ***(1500)*** | ***—*** | ***—*** |
| Ni-Fe-Cr | Alloy 800 | 815 | (1500) | — | — |
| ***Ni-Fe-Cr*** | ***Alloy 800H*** | ***900*** | ***(1650)*** | ***—*** | ***—*** |
| ***Ni-Fe-Cr*** | ***Alloy 800HT*** | ***1010*** | ***(1850)*** | ***—*** | ***—*** |
| ***25Cr-20Ni*** | ***HK40*** | ***1010*** | ***(1850)*** | ***—*** | ***—*** |

[a] Formerly called columbium (Cb).

[5] WRC Bulletin 541, 3rd Edition.

*Table 6: This table shall be replaced with the following:*

**Table 6—Index to Allowable Stress Curves (SI Units)**

| Steel Type | Figures & Table Number, Addendum 1 | Figures & Table Number, Addendum 2 | Alloy |
|---|---|---|---|
| Ferritic | E.1, 2, 3 (Table E.1) | ***E.1, 2, 3 (Table E.1)*** | ***Low-carbon steel (A 192)*** |
| | E.4, 5, 6 (Table E.2) | E.4, 5, 6 (Table E.2) | Medium-carbon steel (A 106B, A 210A1) |
| | E.7, 8, 9 (Table E.3) | E.7, 8, 9 (Table E.3) | C-½ Mo Steel |
| | E.10, 11, 12 (Table E.4) | ***E.10, 11, 12 (Table E.4)*** | ***1¼ Cr-½ Mo Steel*** |
| | E.13, 14, 15 (Table E.5) | E.13, 14, 15 (Table E.5) | 2¼ Cr-1 Mo Steel |
| | E.16, 17, 18 (Table E.6) | E.16, 17, 18 (Table E.6) | 3Cr-1 Mo Steel |
| | E.19, 20, 21 (Table E.7) | E.19, 20, 21 (Table E.7) | 5Cr-½ Mo Steel |
| | E.22, 23, 24 (Table E.8) | E.22, 23, 24 (Table E.8) | 5Cr-½ Mo-Si Steel |
| | E.25, 26, 27 (Table E.9) | ***E.25, 26, 27 (Table E.9)*** | ***9Cr-1Mo Steel*** |
| | E.28, 29, 30 (Table E.10) | ***E.28, 29, 30 (Table E.10*** | ***9Cr-1Mo-V Steel*** |
| | N/A | ***E.31, 32, 33 (Table E.11)*** | ***9Cr-2Si-1Cu Steel*** |
| | N/A | ***E.34, 35, 36 (Table E.12)*** | ***10.5Cr-V (Alloy 115)*** |
| Austenitic | E.31, 32, 33 (Table E.11) | E.37, 38, 39 (Table E.13) | 18Cr-8Ni (304 and 304H) Stainless Steel |
| | E.34, 36, 37 (Table E.12) | ***E.40, 41, 42 (Table E.14)*** | ***18Cr-8Ni (304L) Stainless Steel*** |
| | E.37, 38, 39 (Table E.13) | ***E.43, 44, 45 (Table E.15)*** | ***16Cr-12Ni-2Mo (316 and 316H) Stainless Steel*** |
| | E.40, 41, 42 (Table E.14) | ***E.46, 47, 48 (Table E.16)*** | ***16Cr-12Ni-2Mo (316L) Stainless Steel*** |
| | E.40, 41, 42 (Table E.14) | ***E.49, 50, 51 (Table E.17)*** | ***16Cr-12Ni-3Mo (317L) Stainless Steel*** |
| | E.43, 43, 44 (Table E.15) | ***E.52, 53, 54 (Table E.18)*** | ***18Cr-10Ni-Ti (321) Stainless Steel*** |
| | E.46, 47, 48 (Table E.16) | ***E.55, 56, 57 (Table E.19)*** | ***18Cr-10Ni-Ti (321H) Stainless Steel*** |
| | E.49, 50, 51 (Table E.17) | E.58, 59, 60 (Table E.20) | 18Cr-10Ni-Nb (347) Stainless Steel |
| | E.52, 53, 54 (Table E.18) | E.61, 62, 63 (Table E.21) | 18Cr-10Ni-Nb (347H) Stainless Steel |
| | E.67, 68, 69 (Table E.23) | ***E.64, 64, 65 (Table E.22)*** | ***18Cr-10Ni-Nb (347LN) Stainless Steel*** |
| | N/A | ***E.67, 68, 69 (Table E.23)*** | ***18Cr-10Ni-3Cu-Nb (Adv. 347AP) Stainless Steel*** |
| | E.55, 56, 57 (F.19) | E.70, 71, 72 (Table E.24) | Ni-Fe-Cr (Alloy 800) |
| | E.58, 59, 60 (F.20) | ***E.73, 74, 75 (Table E.25)*** | ***Ni-Fe-Cr (Alloy 800H)*** |
| | E.61, 62, 63 (F.21) | ***E.76, 77, 78 (Table E.26)*** | ***Ni-Fe-Cr (Alloy 800HT)*** |
| | E.64, 65, 66 (F.22) | ***E.79, 80, 81 (Table E.27)*** | ***25Cr-20Ni (HK-40)*** |

*Table 7: This table shall be replaced with the following:*

**Table 7— Index to Allowable Stress Curves (USC Units)**

| Steel Type | Figures & Table Number, Addendum 1 | Figures & Table Number, Addendum 2 | Alloy |
|---|---|---|---|
| Ferritic | F.1, 2, 3 (Table F.1) | ***F.1, 2, 3 (Table E.1)*** | ***Low-carbon steel (A192)*** |
| | F.4, 5, 6 (Table F.2) | F.4, 5, 6 (Table E.2) | Medium-carbon steel (A106B, A210A1) |
| | F.7, 8, 9 (Table F.3) | F.7, 8, 9 (Table E.3) | C-½ Mo Steel |
| | F.10, 11, 12 (Table F.4) | ***F.10, 11, 12 (Table E.4)*** | ***1¼ Cr-½ Mo Steel*** |
| | F.13, 14, 15 (Table F.5) | F.13, 14, 15 (Table E.5) | 2¼ Cr-1 Mo Steel |
| | F.16, 17, 18 (Table F.6) | F.16, 17, 18 (Table E.6) | 3Cr-1 Mo Steel |
| | F.19, 20, 21 (Table F.7) | F.19, 20, 21 (Table E.7) | 5Cr-½ Mo Steel |
| | F.22, 23, 24 (Table F.8) | F.22, 23, 24 (Table E.8) | 5Cr-½ Mo-Si Steel |
| | F.25, 26, 27 (Table F.9) | ***F.25, 26, 27 (Table E.9)*** | ***9Cr-1Mo Steel*** |
| | F.28, 29, 30 (Table F.10) | ***F.28, 29, 30 (Table E.9)*** | ***9Cr-1Mo-V Steel*** |
| | N/A | ***F.31, 32, 33 (Table E.11)*** | ***9Cr-2Si-1Cu Steel*** |
| | N/A | ***F.34, 35, 36 (Table E.12)*** | ***10.5Cr-V (Alloy 115)*** |
| Austenitic | F.31, 32, 33 (Table F.11) | F.37, 38, 39 (Table E.13) | 18Cr-8Ni (304 and 304H) Stainless Steel |
| | F.34, 36, 37 (Table F.12) | ***F.40, 41, 42 (Table E.14)*** | ***18Cr-8Ni (304L) Stainless Steel*** |
| | F.37, 38, 39 (Table F.13) | ***F.43, 44, 45 (Table E.15)*** | ***16Cr-12Ni-2Mo (316 and 316H) Stainless Steel*** |
| | F.40, 41, 42 (Table F.14) | ***F.46, 47, 48 (Table E.16)*** | ***16Cr-12Ni-2Mo (316L) Stainless Steel*** |
| | F.40, 41, 42 (Table F.14) | ***F.49, 50, 51 (Table E.17)*** | ***16Cr-12Ni-3Mo (317L) Stainless Steel*** |
| | F.43, 43, 44 (Table F.15) | ***F.52, 53, 54 (Table E.18)*** | ***18Cr-10Ni-Ti (321) Stainless Steel*** |
| | F.46, 47, 48 (Table F.16) | ***F.55, 56, 57 (Table E.19)*** | ***18Cr-10Ni-Ti (321H) Stainless Steel*** |
| | F.49, 50, 51 (Table F.17) | F.58, 59, 60 (Table E.20) | 18Cr-10Ni-Nb (347) Stainless Steel |
| | F.52, 53, 54 (Table F.18) | F.61, 62, 63 (Table E.21) | 18Cr-10Ni-Nb (347H) Stainless Steel |
| | F.67, 68, 69 (Table F.23) | ***F.64, 65, 66 (Table E.22)*** | ***18Cr-10Ni-Nb (347LN) Stainless Steel*** |
| | N/A | ***F.67, 68, 69 (Table E.23)*** | ***18Cr-10Ni-3Cu-Nb (Adv. 347AP) Stainless Steel*** |
| | F.55, 56, 57 (F.19) | F.70, 71, 72 (Table E.24) | Ni-Fe-Cr (Alloy 800) |
| | F.58, 59, 60 (F.20) | ***F.73, 74, 75 (Table E.25)*** | ***Ni-Fe-Cr (Alloy 800H)*** |
| | F.61, 62, 63 (F.21) | ***F.76, 77, 78 (Table E.26)*** | ***Ni-Fe-Cr (Alloy 800HT)*** |
| | F.64, 65, 66 (F.22) | ***F.79, 80, 81 (Table E.27)*** | ***25Cr-20Ni (HK-40)*** |

*Annex E, List of Stress Curves and Data Tables (SI Units): The titles of the indicated figures and tables shall be changed to align with updated and new materials in Table 6 as follows:*

**List of Figures and Tables (SI Units)**

**Low-carbon Steels**



**1-1/4Cr-1/2Moly Steels**



**9Cr-1Moly Steels**



**9Cr-1Mo-V Steels**



**9Cr-2Si-1Cu Steels (Grade 921)**

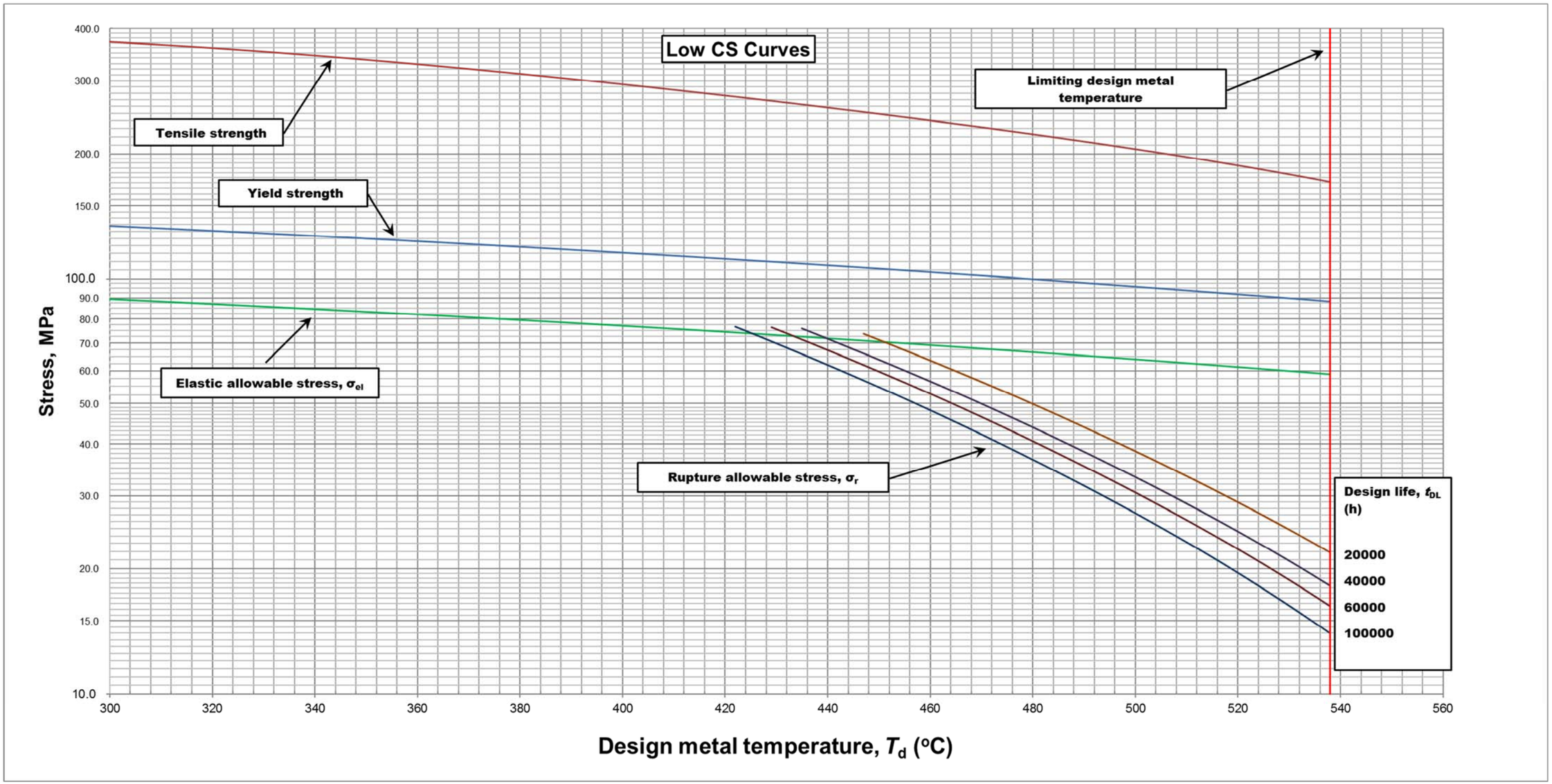



**Figure E.1—Stress Curves (SI Units) for ASTM A192 Low-carbon Steels**

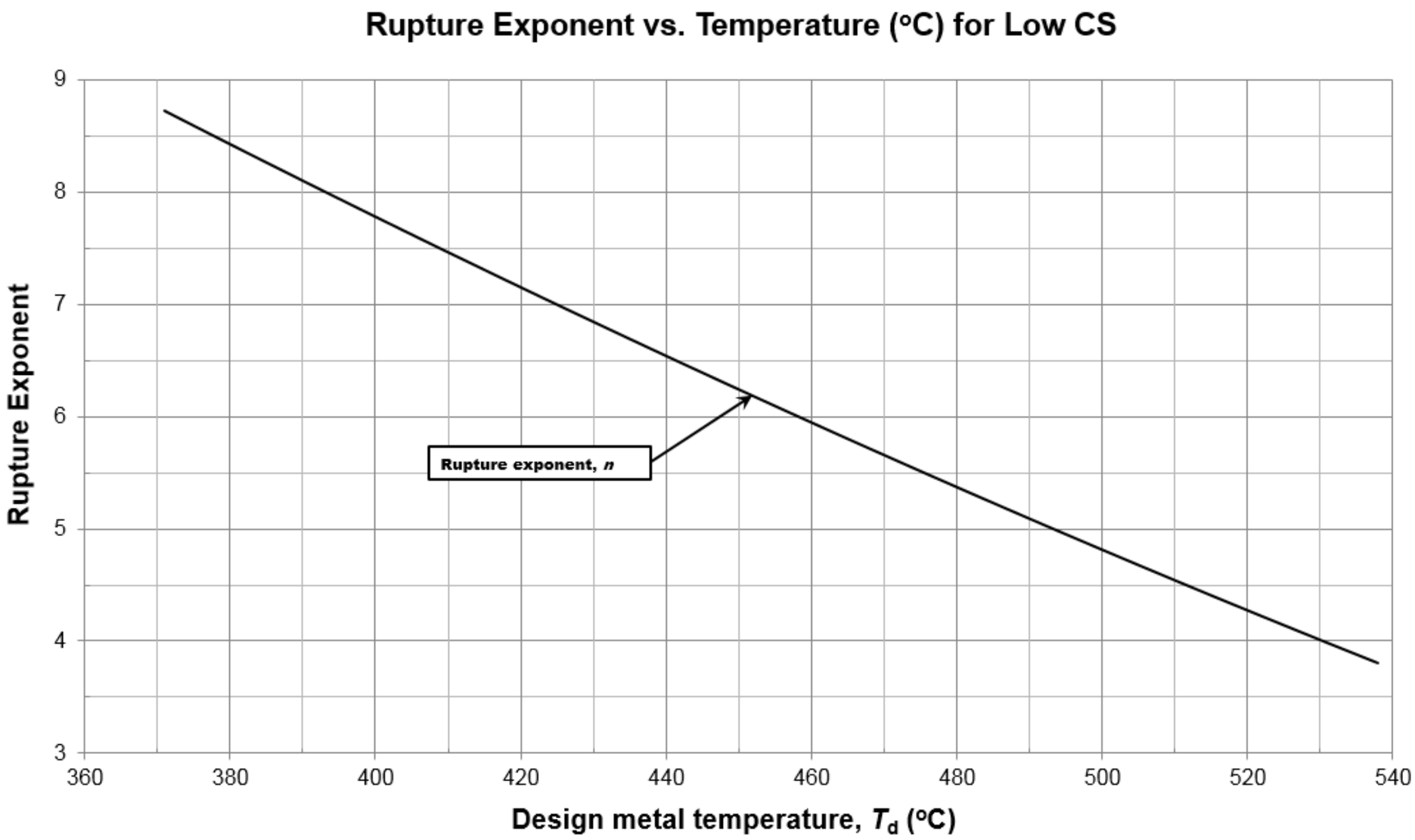



**Figure E.2—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A192 Low-carbon Steels**

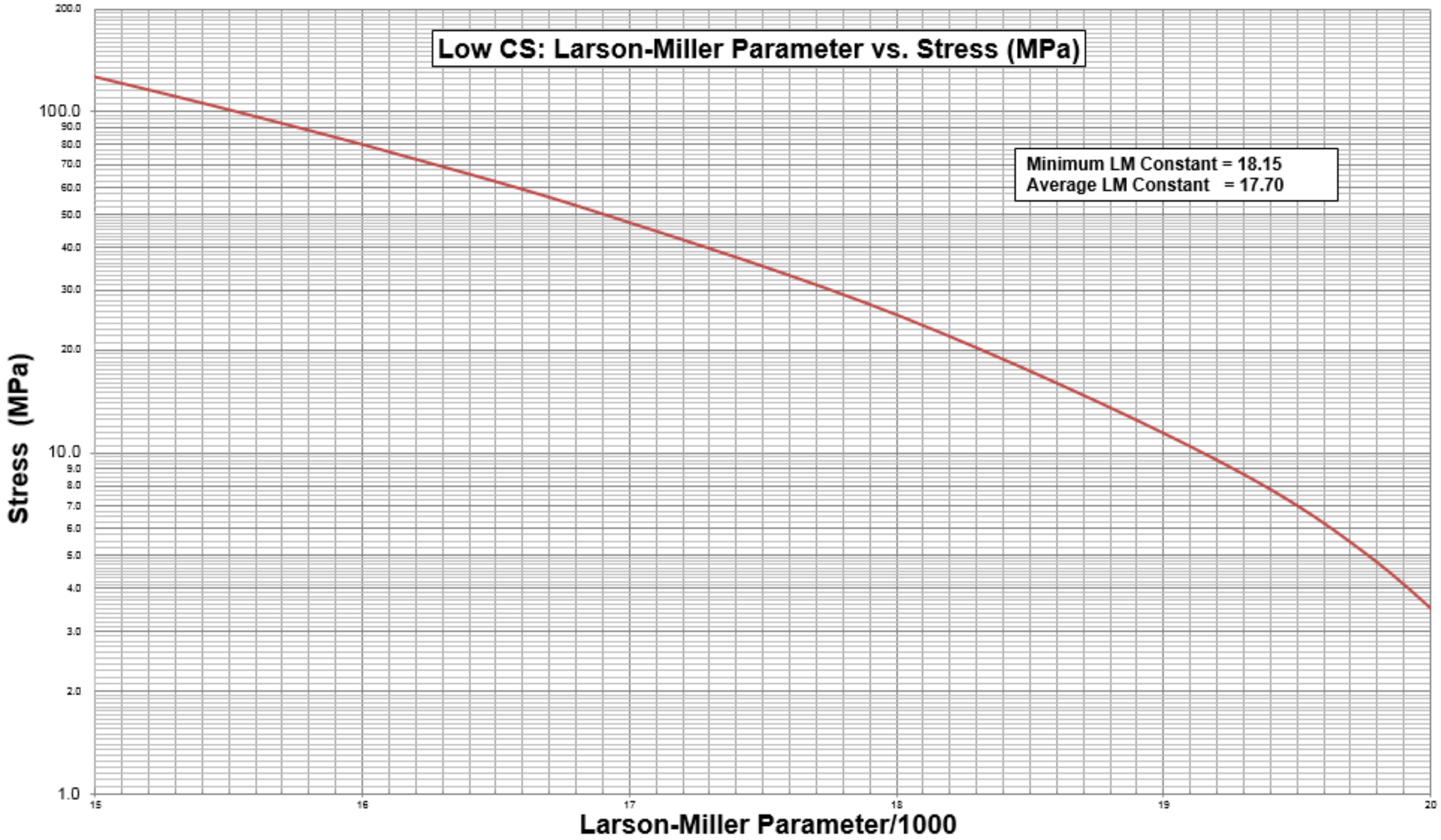



**Figure E.3—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A192 Low-carbon Steels**

**Table E.1—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A192 Low-carbon Steels**

| Low CS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 300 | 89.4 | | | | | |
| 310 | 88.2 | | | | | |
| 320 | 87.0 | | | | | |
| 330 | 85.8 | | | | | |
| 340 | 84.6 | | | | | |
| 350 | 83.3 | | | | | |
| 360 | 82.1 | | | | | |
| 370 | 80.8 | | | | | |
| 380 | 79.6 | | | | | 8.4 |
| 390 | 78.3 | | | | | 8.1 |
| 400 | 77.0 | | | | | 7.8 |
| 410 | 75.8 | 87.5 | 94.0 | 99.4 | 109.1 | 7.5 |
| 420 | 74.5 | 78.3 | 84.4 | 89.4 | 98.5 | 7.2 |
| 430 | 73.2 | 69.8 | 75.4 | 80.2 | 88.7 | 6.8 |
| 440 | 71.9 | 61.9 | 67.2 | 71.6 | 79.7 | 6.5 |
| 450 | 70.6 | 54.8 | 59.7 | 63.8 | 71.3 | 6.2 |
| 460 | 69.3 | 48.2 | 52.7 | 56.6 | 63.6 | 5.9 |
| 470 | 67.9 | 42.2 | 46.4 | 49.9 | 56.5 | 5.7 |
| 480 | 66.6 | 36.7 | 40.6 | 43.9 | 49.9 | 5.4 |
| 490 | 65.3 | 31.7 | 35.3 | 38.3 | 43.9 | 5.1 |
| 500 | 64.0 | 27.2 | 30.5 | 33.3 | 38.5 | 4.8 |
| 510 | 62.7 | 23.2 | 26.2 | 28.7 | 33.5 | 4.5 |
| 520 | 61.3 | 19.6 | 22.3 | 24.6 | 29.0 | 4.3 |
| 530 | 60.0 | 16.3 | 18.8 | 20.9 | 24.9 | 4.0 |
| 538 | 58.9 | 14.0 | 16.3 | 18.2 | 21.9 | 3.8 |

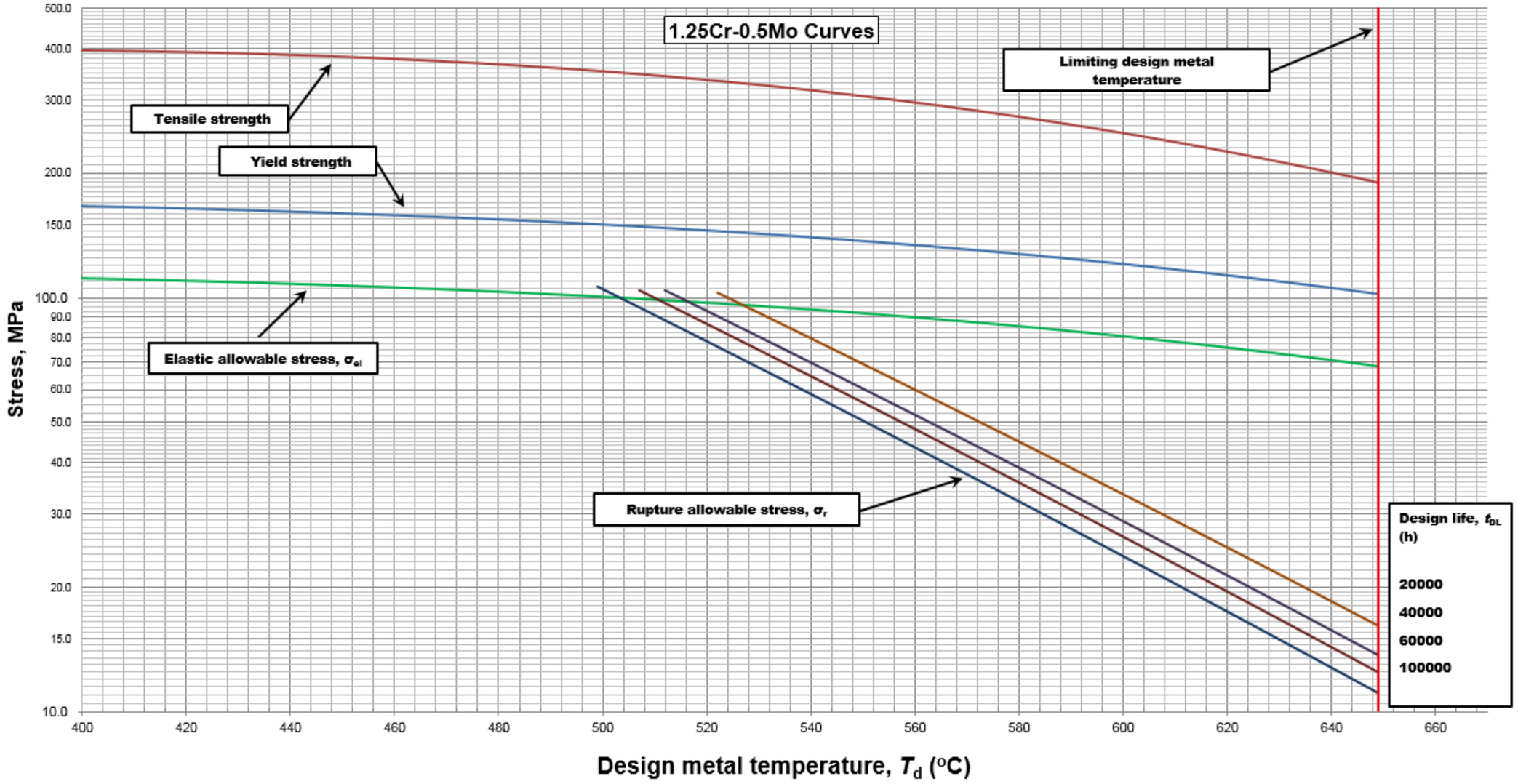



**Figure E.10—Stress Curves (SI Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels**

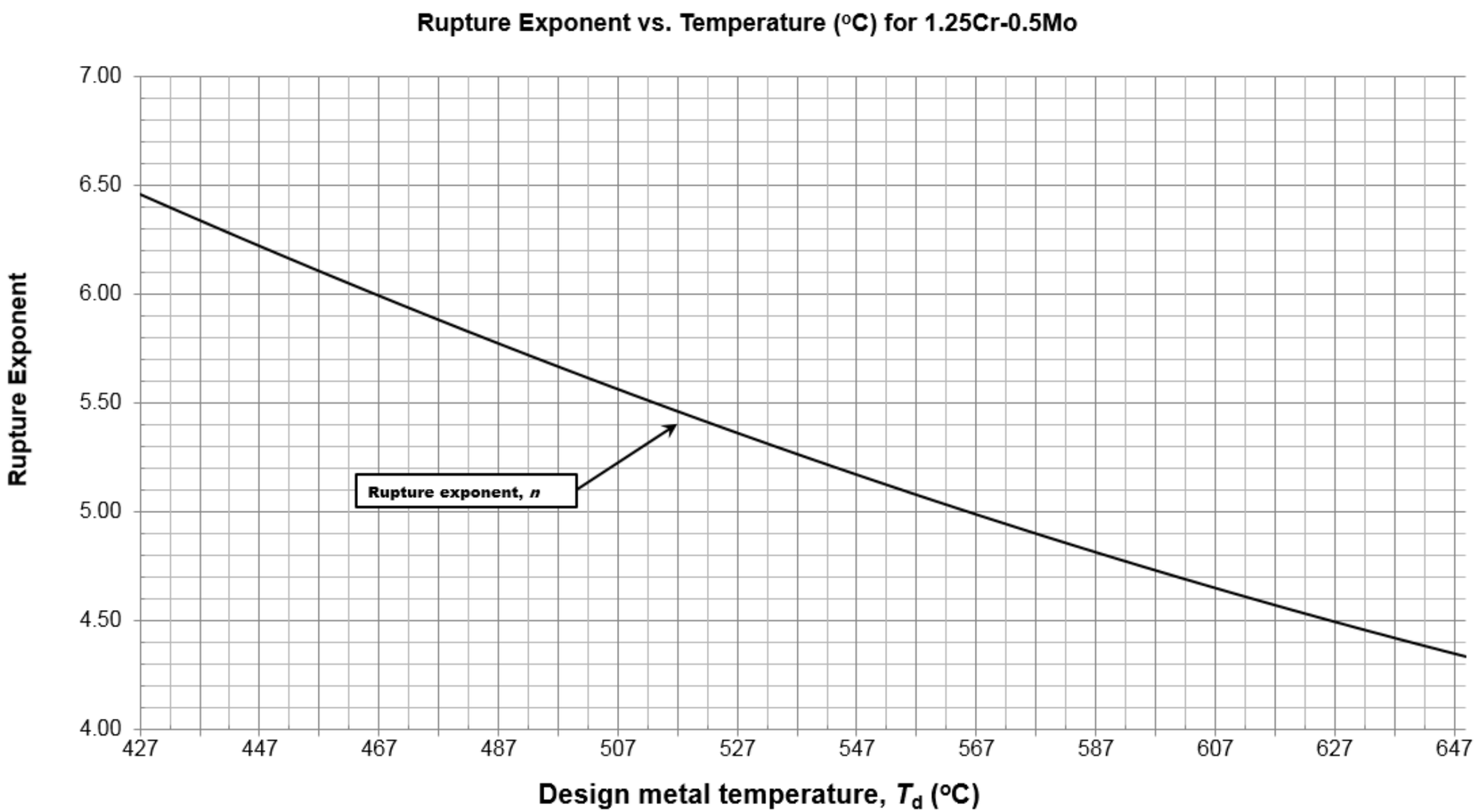



**Figure E.11—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels**

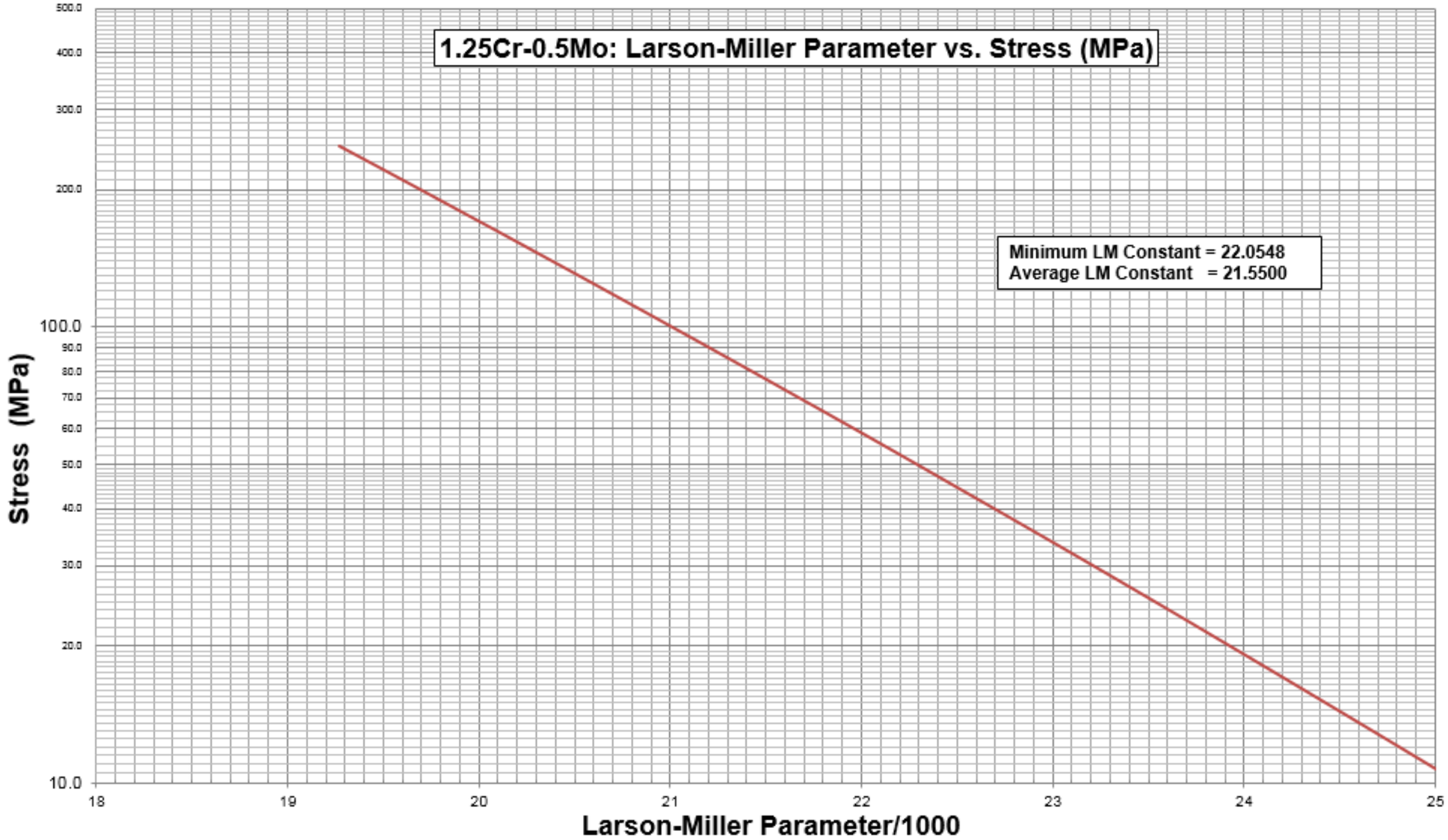



**Figure E.12—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels**

**Table E.4—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels**

| 1.25Cr-0.5Mo | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 300 | 116.2 | | | | | |
| 310 | 115.8 | | | | | |
| 320 | 115.5 | | | | | |
| 330 | 115.1 | | | | | |
| 340 | 114.7 | | | | | |
| 350 | 114.3 | | | | | |
| 360 | 113.8 | | | | | |
| 370 | 113.3 | | | | | |
| 380 | 112.7 | | | | | |
| 390 | 112.1 | | | | | |
| 400 | 111.4 | | | | | |
| 410 | 110.7 | | | | | |
| 420 | 109.9 | | | | | |
| 430 | 109.0 | | | | | 6.4 |
| 440 | 108.0 | | | | | 6.3 |
| 450 | 107.0 | | | | | 6.2 |
| 460 | 105.9 | | | | | 6.1 |
| 470 | 104.7 | | | | | 6.0 |
| 480 | 103.4 | 140.2 | 153.1 | 186.9 | 164.2 | 5.8 |
| 490 | 102.0 | 121.5 | 132.9 | 162.9 | 142.7 | 5.7 |
| 500 | 100.5 | 105.2 | 115.3 | 141.8 | 123.9 | 5.6 |
| 510 | 98.9 | 91.0 | 99.9 | 123.3 | 107.5 | 5.5 |
| 520 | 97.3 | 78.7 | 86.5 | 107.2 | 93.3 | 5.4 |
| 530 | 95.5 | 68.0 | 74.8 | 93.1 | 80.8 | 5.3 |
| 540 | 93.6 | 58.6 | 64.7 | 80.8 | 69.9 | 5.2 |
| 550 | 91.7 | 50.6 | 55.9 | 70.1 | 60.5 | 5.1 |
| 560 | 89.6 | 43.6 | 48.2 | 60.7 | 52.3 | 5.1 |
| 570 | 87.5 | 37.5 | 41.6 | 52.6 | 45.1 | 5.0 |
| 580 | 85.3 | 32.2 | 35.8 | 45.5 | 38.9 | 4.9 |
| 590 | 83.0 | 27.7 | 30.8 | 39.3 | 33.6 | 4.8 |
| 600 | 80.7 | 23.8 | 26.5 | 34.0 | 28.9 | 4.7 |
| 610 | 78.2 | 20.4 | 22.8 | 29.3 | 24.9 | 4.6 |
| 620 | 75.8 | 17.5 | 19.6 | 25.3 | 21.4 | 4.5 |
| 630 | 73.2 | 14.9 | 16.8 | 21.8 | 18.4 | 4.5 |
| 640 | 70.6 | 12.8 | 14.4 | 18.7 | 15.8 | 4.4 |
| 649 | 68.3 | 11.1 | 12.5 | 16.3 | 13.7 | 4.3 |

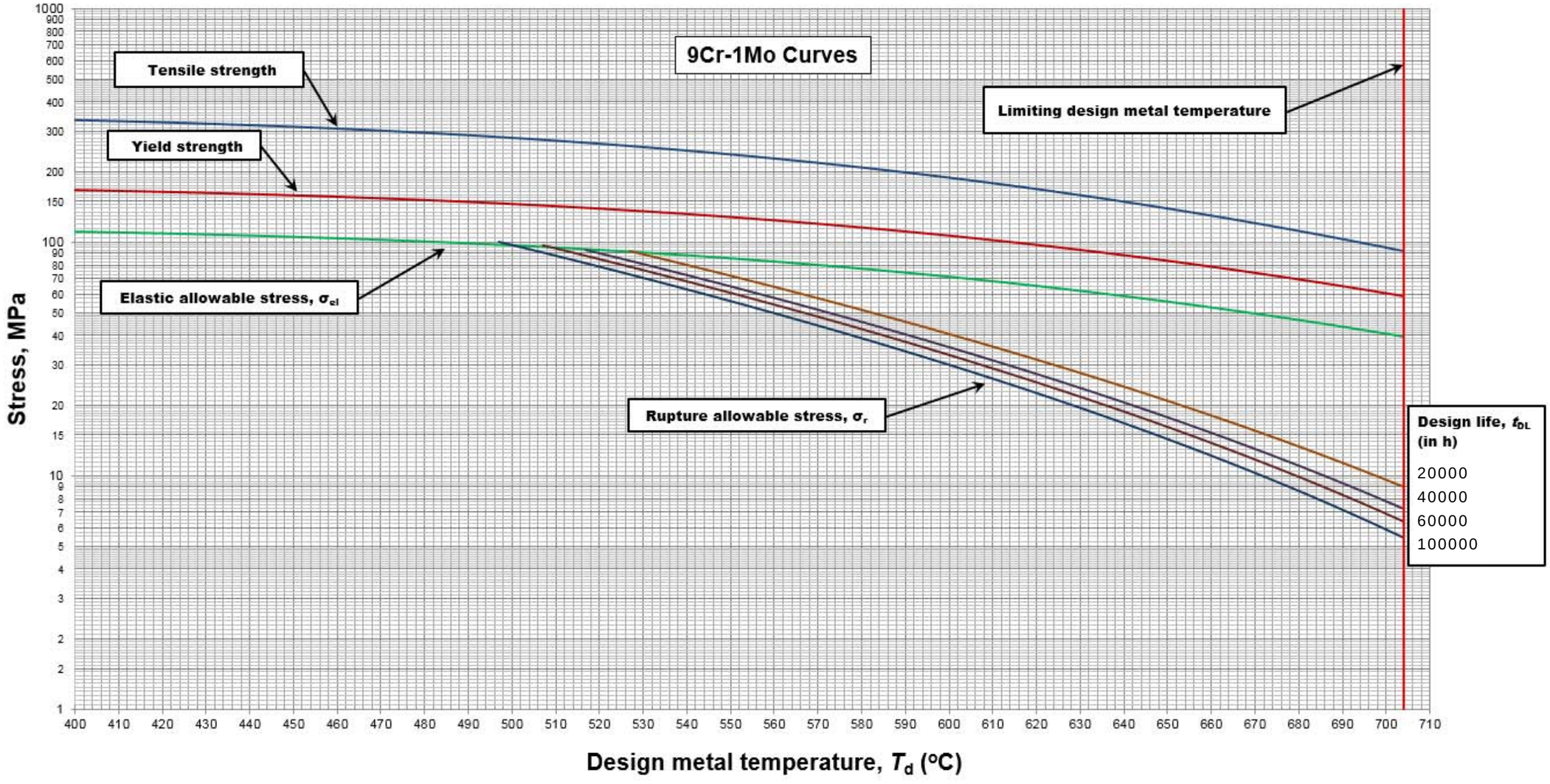



**Figure E.25—Stress Curves (SI Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels**

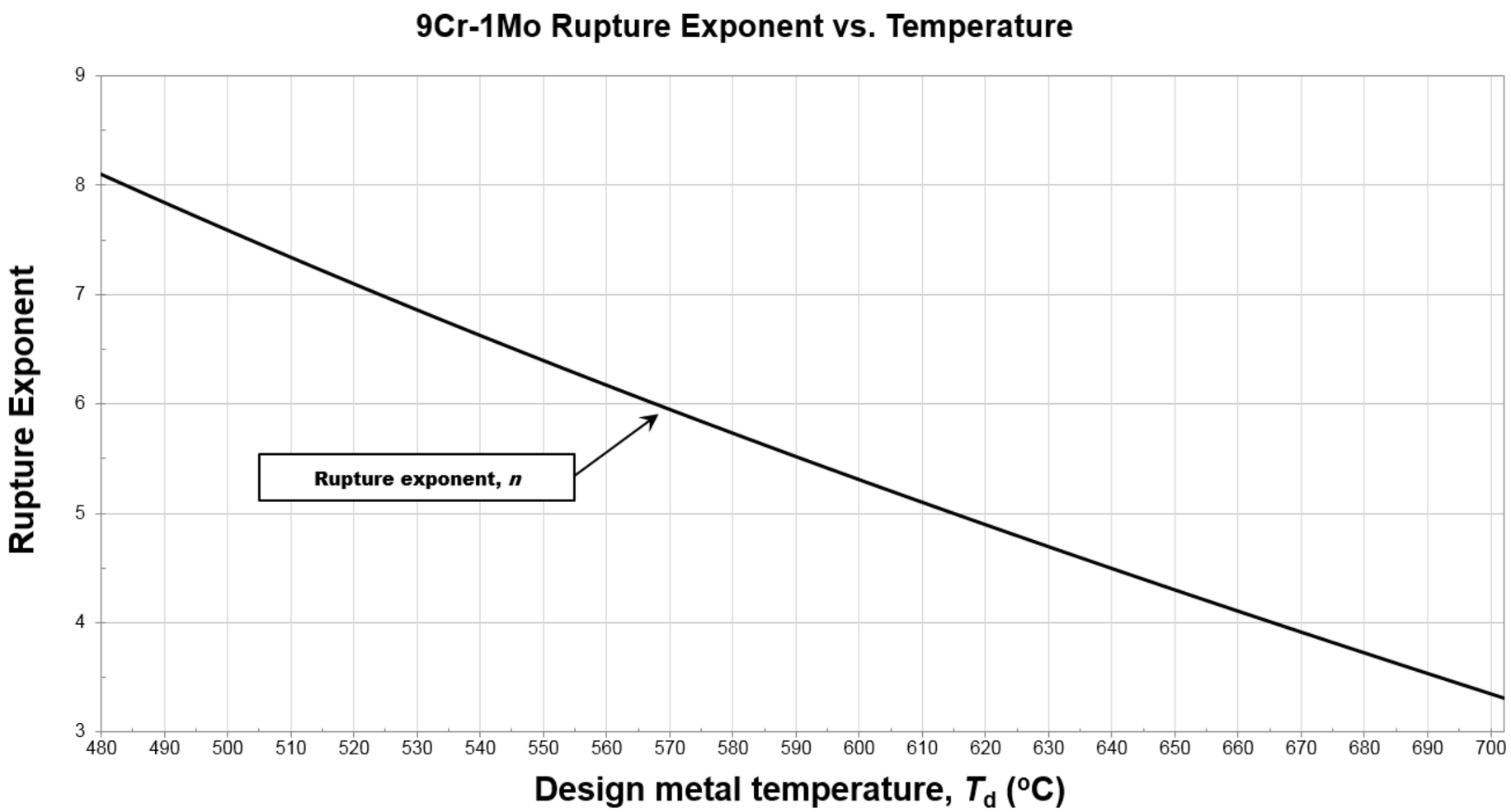



**Figure E.26—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels**

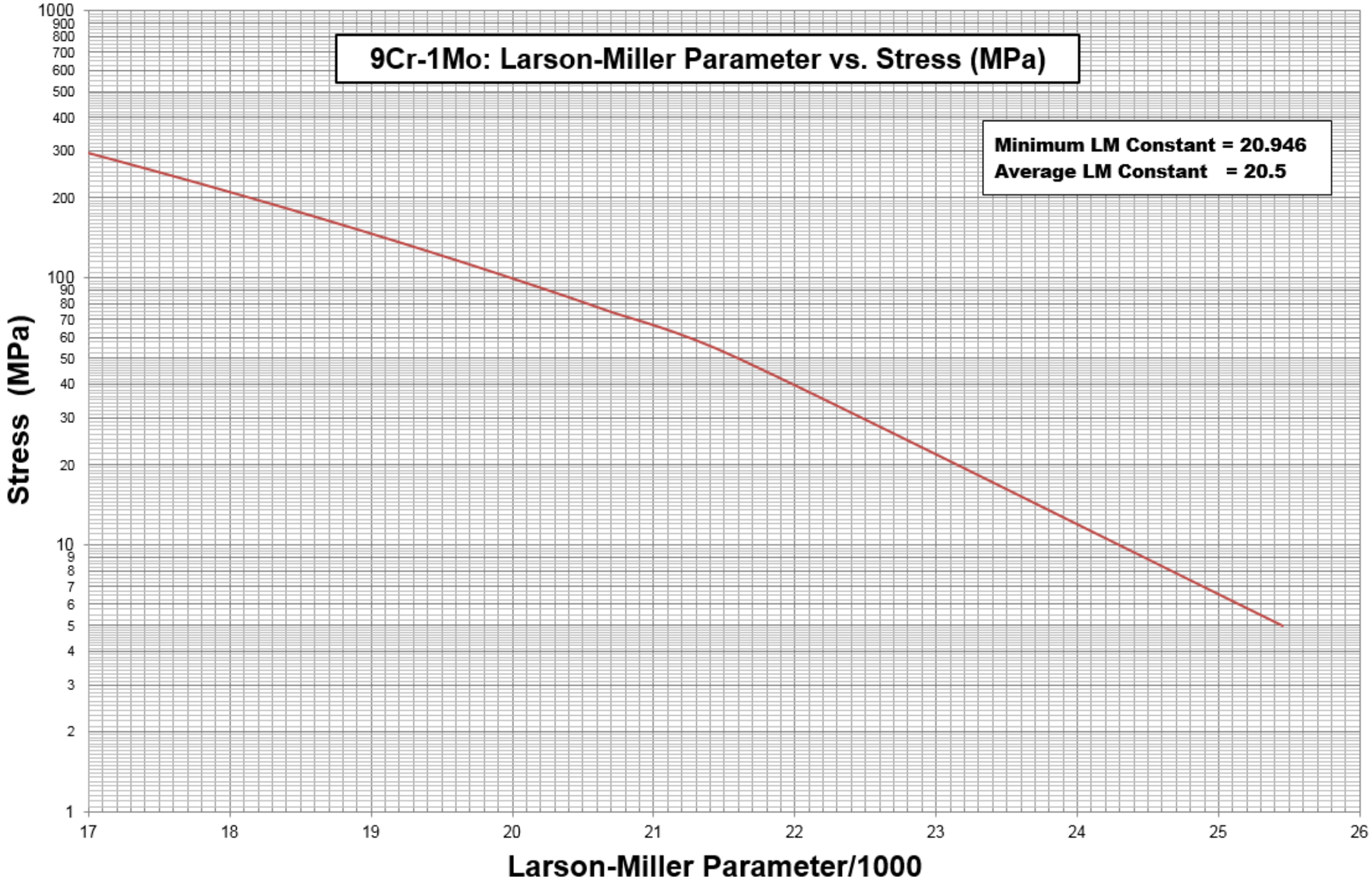



**Figure E.27—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels**

**Table E.9—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels**

| 9Cr-1Mo Steel | | | | | | |
|---|---|---|---|---|---|---|
| **Design Metal Temperature, $T_d$** (Centigrade) | **Elastic Allowable Stress, $\sigma_{el}$** (MPa) | **Rupture Allowable Stress, $\sigma_r$** | | | | **Rupture Exponent, *n*** |
| | | **$t_{DL}$ = 100,000 h** (MPa) | **$t_{DL}$ = 60,000 h** (MPa) | **$t_{DL}$ = 40,000 h** (MPa) | **$t_{DL}$ = 20,000 h** (MPa) | |
| 300 | 117.0 | | | | | |
| 310 | 116.7 | | | | | |
| 320 | 116.3 | | | | | |
| 330 | 115.9 | | | | | |
| 340 | 115.4 | | | | | |
| 350 | 115.0 | | | | | |
| 360 | 114.4 | | | | | |
| 370 | 113.8 | | | | | |
| 380 | 113.2 | | | | | |
| 390 | 112.4 | | | | | |
| 400 | 111.6 | | | | | |
| 410 | 110.7 | | | | | |
| 420 | 109.7 | | | | | |
| 430 | 108.5 | | | | | |
| 440 | 107.3 | | | | | |
| 450 | 106.0 | | | | | |
| 460 | 104.5 | | | | | |
| 470 | 102.9 | | | | | |
| 480 | 101.2 | | | | | |
| 490 | 99.3 | 107.8 | 115.2 | 121.3 | 132.5 | 7.9 |
| 500 | 97.4 | 97.2 | 104.1 | 109.9 | 120.3 | 7.6 |
| 510 | 95.3 | 87.4 | 93.9 | 99.3 | 109.0 | 7.4 |
| 520 | 93.0 | 78.5 | 84.5 | 89.5 | 98.6 | 7.2 |
| 530 | 90.7 | 70.3 | 75.8 | 80.5 | 89.0 | 6.9 |
| 540 | 88.2 | 62.7 | 67.9 | 72.2 | 80.1 | 6.7 |
| 550 | 85.6 | 55.9 | 60.6 | 64.6 | 72.0 | 6.4 |
| 560 | 82.9 | 49.6 | 54.0 | 57.7 | 64.5 | 6.2 |
| 570 | 80.2 | 43.9 | 48.0 | 51.4 | 57.7 | 6.0 |
| 580 | 77.3 | 38.7 | 42.4 | 45.6 | 51.4 | 5.8 |
| 590 | 74.3 | 34.0 | 37.4 | 40.3 | 45.7 | 5.6 |
| 600 | 71.3 | 29.8 | 32.9 | 35.6 | 40.5 | 5.4 |
| 610 | 68.3 | 26.0 | 28.8 | 31.2 | 35.8 | 5.1 |
| 620 | 65.2 | 22.5 | 25.1 | 27.3 | 31.5 | 4.9 |
| 630 | 62.0 | 19.5 | 21.8 | 23.8 | 27.6 | 4.7 |
| 640 | 58.9 | 16.7 | 18.9 | 20.7 | 24.1 | 4.5 |
| 650 | 55.7 | 14.3 | 16.2 | 17.8 | 20.9 | 4.3 |
| 660 | 52.6 | 12.2 | 13.8 | 15.3 | 18.1 | 4.1 |
| 670 | 49.5 | 10.2 | 11.8 | 13.1 | 15.6 | 4.0 |
| 680 | 46.5 | 8.6 | 9.9 | 11.1 | 13.3 | 3.8 |
| 690 | 43.5 | 7.1 | 8.3 | 9.3 | 11.4 | 3.6 |
| 700 | 40.6 | 5.9 | 6.9 | 7.8 | 9.6 | 3.4 |
| 704 | 39.4 | 5.4 | 6.4 | 7.3 | 8.9 | 3.3 |

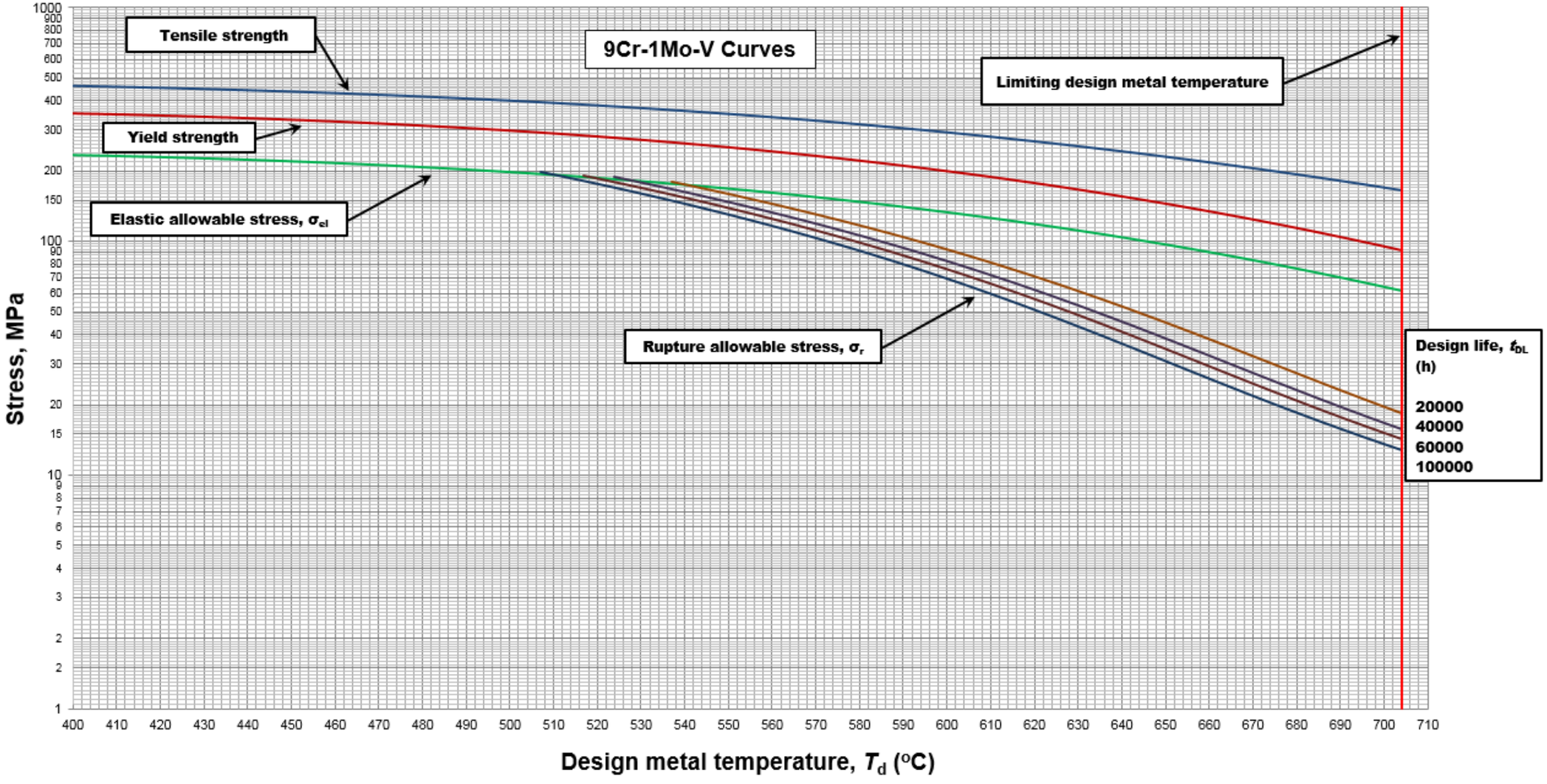



**Figure E.28—Stress Curves (SI Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels**

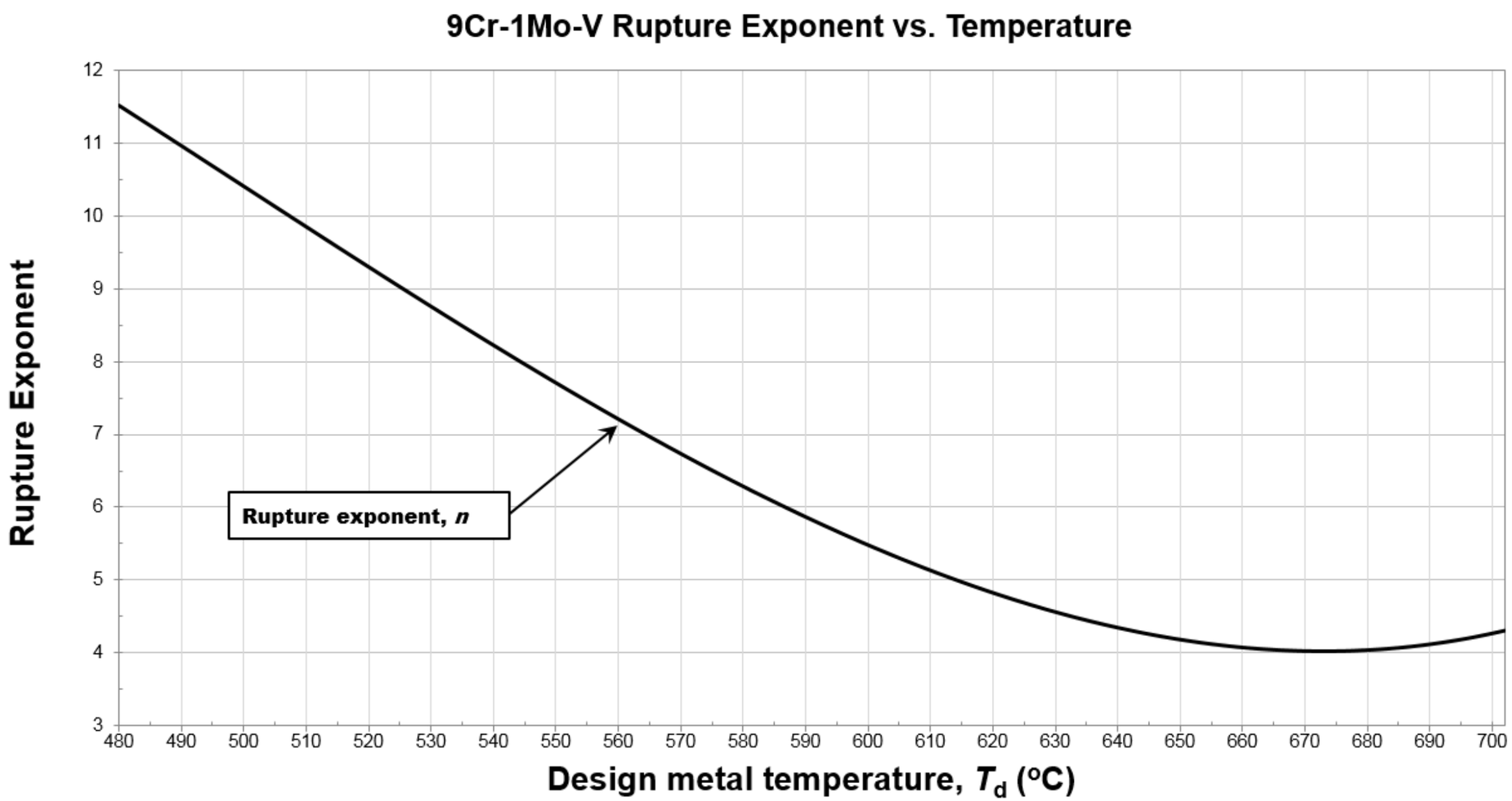



**Figure E.29—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels**

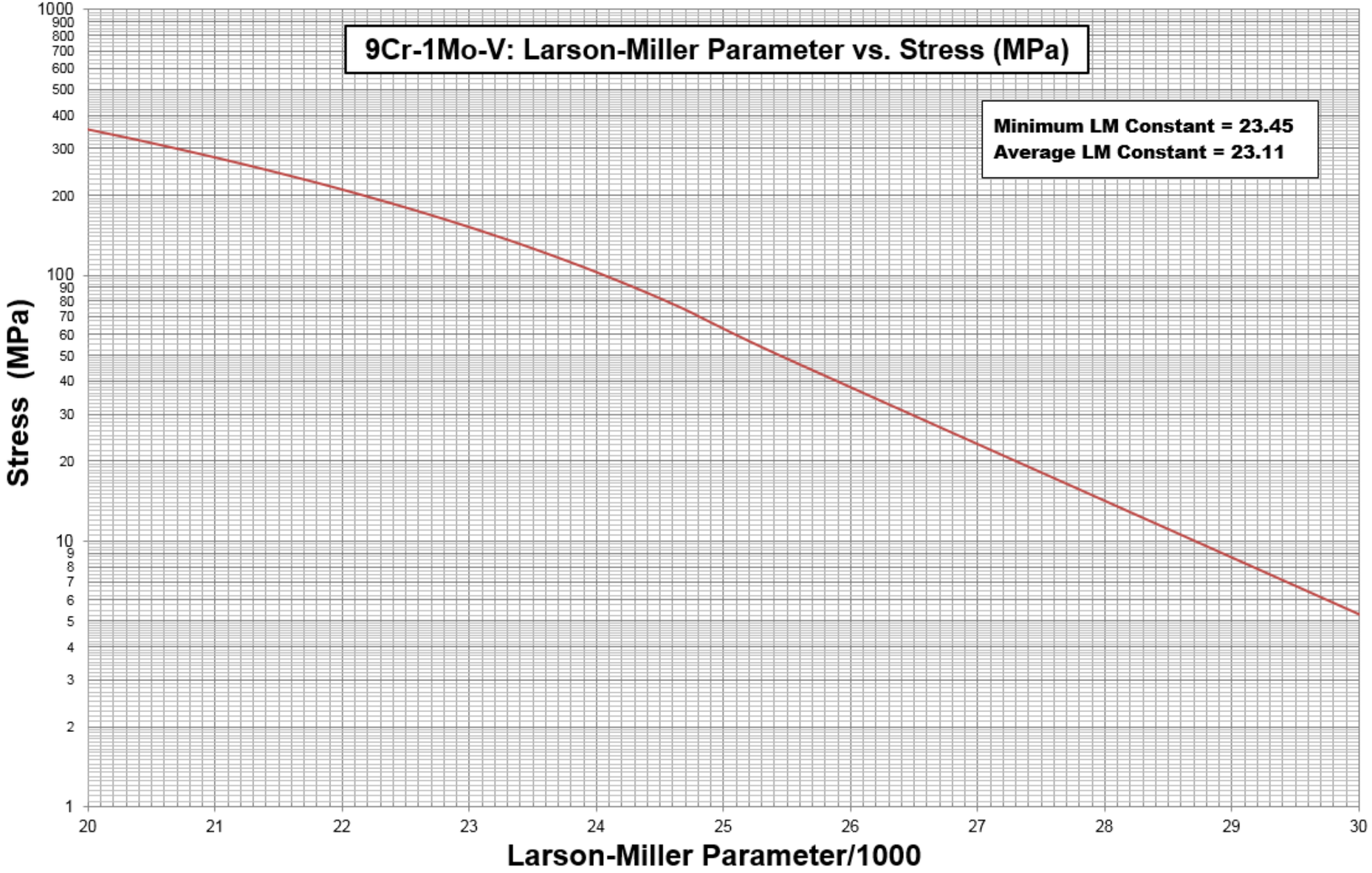



**Figure E.30—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels**

**Table E.10—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels**

| 9Cr-1Mo-V Steel | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 300 | 244.1 | | | | | |
| 310 | 244.0 | | | | | |
| 320 | 243.7 | | | | | |
| 330 | 243.3 | | | | | |
| 340 | 242.7 | | | | | |
| 350 | 241.9 | | | | | |
| 360 | 241.0 | | | | | |
| 370 | 239.8 | | | | | |
| 380 | 238.4 | | | | | |
| 390 | 236.8 | | | | | |
| 400 | 234.8 | | | | | |
| 410 | 232.6 | | | | | |
| 420 | 230.1 | | | | | |
| 430 | 227.3 | | | | | |
| 440 | 224.2 | | | | | |
| 450 | 220.7 | | | | | |
| 460 | 216.9 | | | | | |
| 470 | 212.8 | | | | | |
| 480 | 208.3 | | | | | |
| 490 | 203.6 | 228.3 | 239.4 | 248.5 | 264.3 | 11.1 |
| 500 | 198.4 | 210.0 | 220.9 | 229.8 | 245.3 | 10.5 |
| 510 | 193.0 | 192.6 | 203.2 | 211.8 | 226.8 | 10.0 |
| 520 | 187.3 | 175.8 | 186.1 | 194.4 | 209.1 | 9.4 |
| 530 | 181.3 | 159.8 | 169.7 | 177.8 | 192.1 | 8.9 |
| 540 | 175.0 | 144.5 | 154.1 | 161.9 | 175.8 | 8.3 |
| 550 | 168.5 | 129.9 | 139.2 | 146.7 | 160.1 | 7.8 |
| 560 | 161.8 | 116.1 | 125.0 | 132.3 | 145.2 | 7.3 |
| 570 | 154.9 | 103.1 | 111.6 | 118.5 | 130.9 | 6.8 |
| 580 | 147.8 | 90.9 | 99.0 | 105.6 | 117.4 | 6.4 |
| 590 | 140.6 | 79.6 | 87.1 | 93.4 | 104.7 | 5.9 |
| 600 | 133.3 | 69.1 | 76.1 | 82.0 | 92.7 | 5.6 |
| 610 | 126.0 | 59.5 | 66.0 | 71.5 | 81.4 | 5.2 |
| 620 | 118.7 | 50.8 | 56.7 | 61.8 | 71.0 | 4.9 |
| 630 | 111.3 | 43.1 | 48.4 | 53.0 | 61.5 | 4.6 |
| 640 | 104.1 | 36.4 | 41.1 | 45.2 | 52.8 | 4.4 |
| 650 | 96.9 | 30.6 | 34.7 | 38.3 | 45.1 | 4.2 |
| 660 | 89.9 | 25.8 | 29.2 | 32.3 | 38.3 | 4.1 |
| 670 | 83.0 | 21.8 | 24.6 | 27.2 | 32.4 | 4.0 |
| 680 | 76.4 | 18.4 | 20.8 | 23.0 | 27.3 | 4.0 |
| 690 | 69.9 | 15.7 | 17.7 | 19.5 | 23.1 | 4.1 |
| 700 | 63.7 | 13.5 | 15.2 | 16.7 | 19.7 | 4.2 |
| 704 | 61.3 | 12.8 | 14.3 | 15.7 | 18.4 | 4.3 |

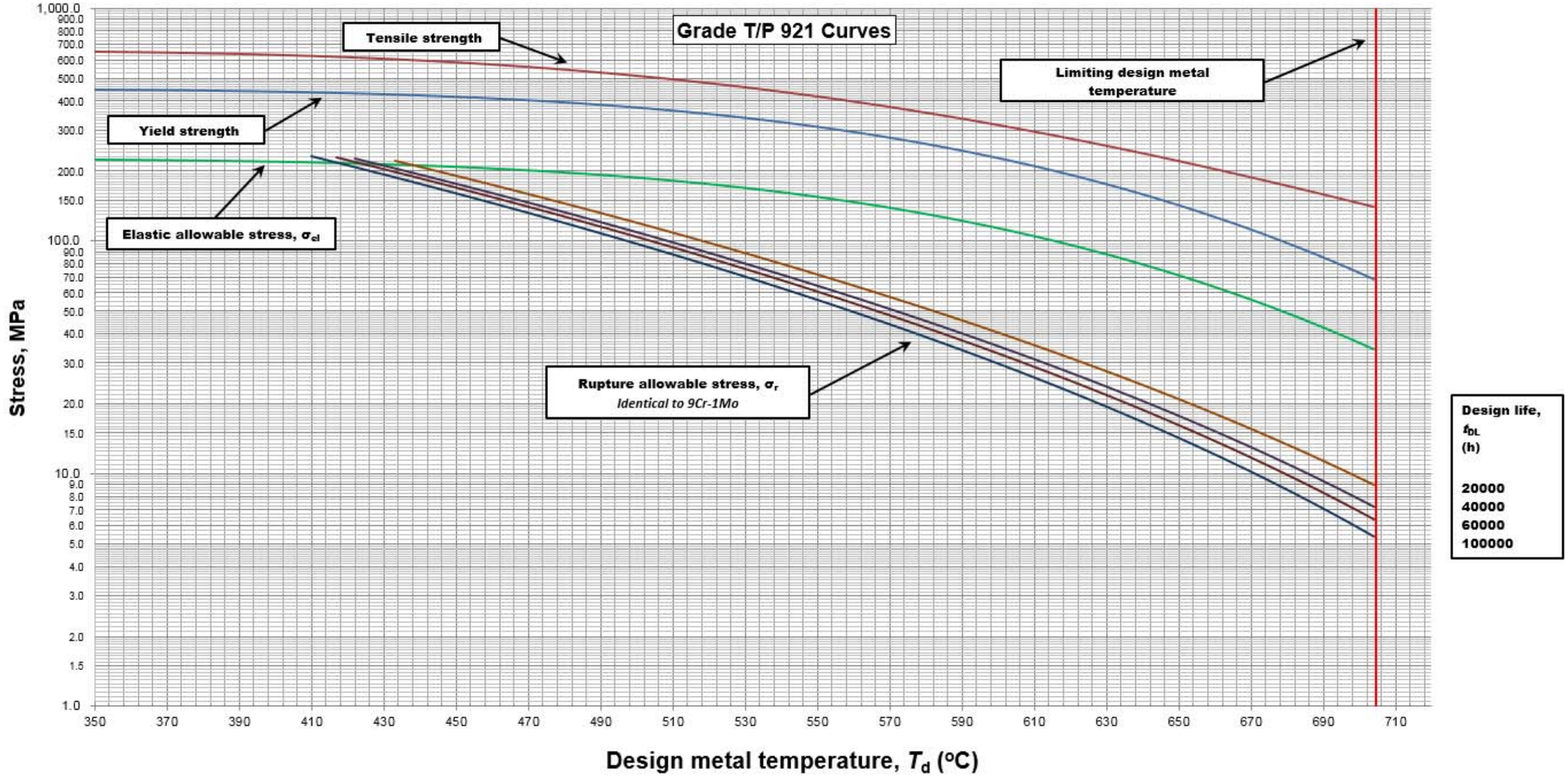



**Figure E.31—Stress Curves (SI Units) for ferritic steel ASTM A213-T921 and A335-P921 9Cr-2Si-1Cu Steels (Grade 921)**

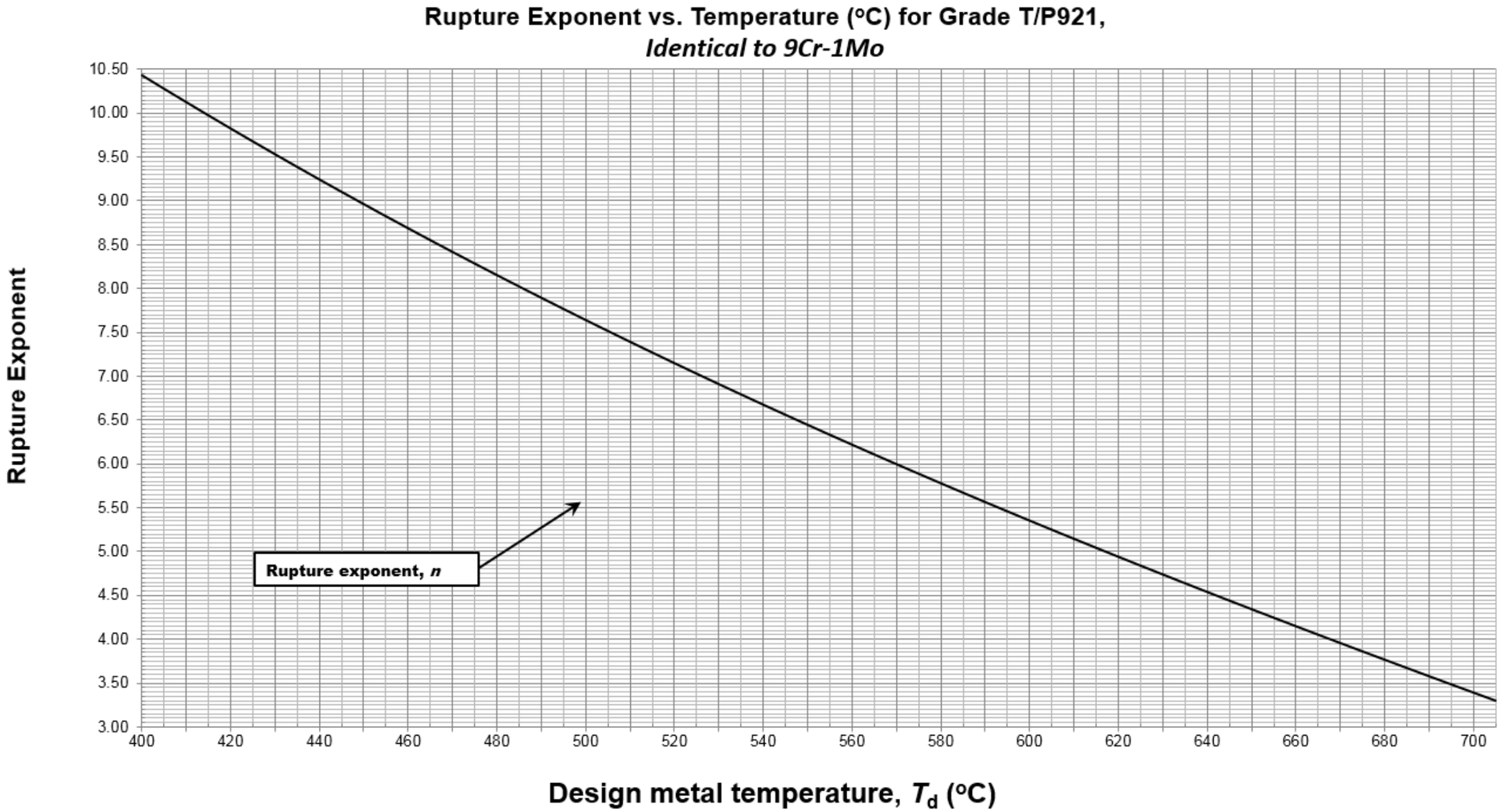



**Figure E.32—Rupture Exponent vs. Temperature Curve (SI Units) for ferritic steel ASTM A213-T921 and A335-P921 9Cr-2Si-1Cu Steels (Grade 921)**

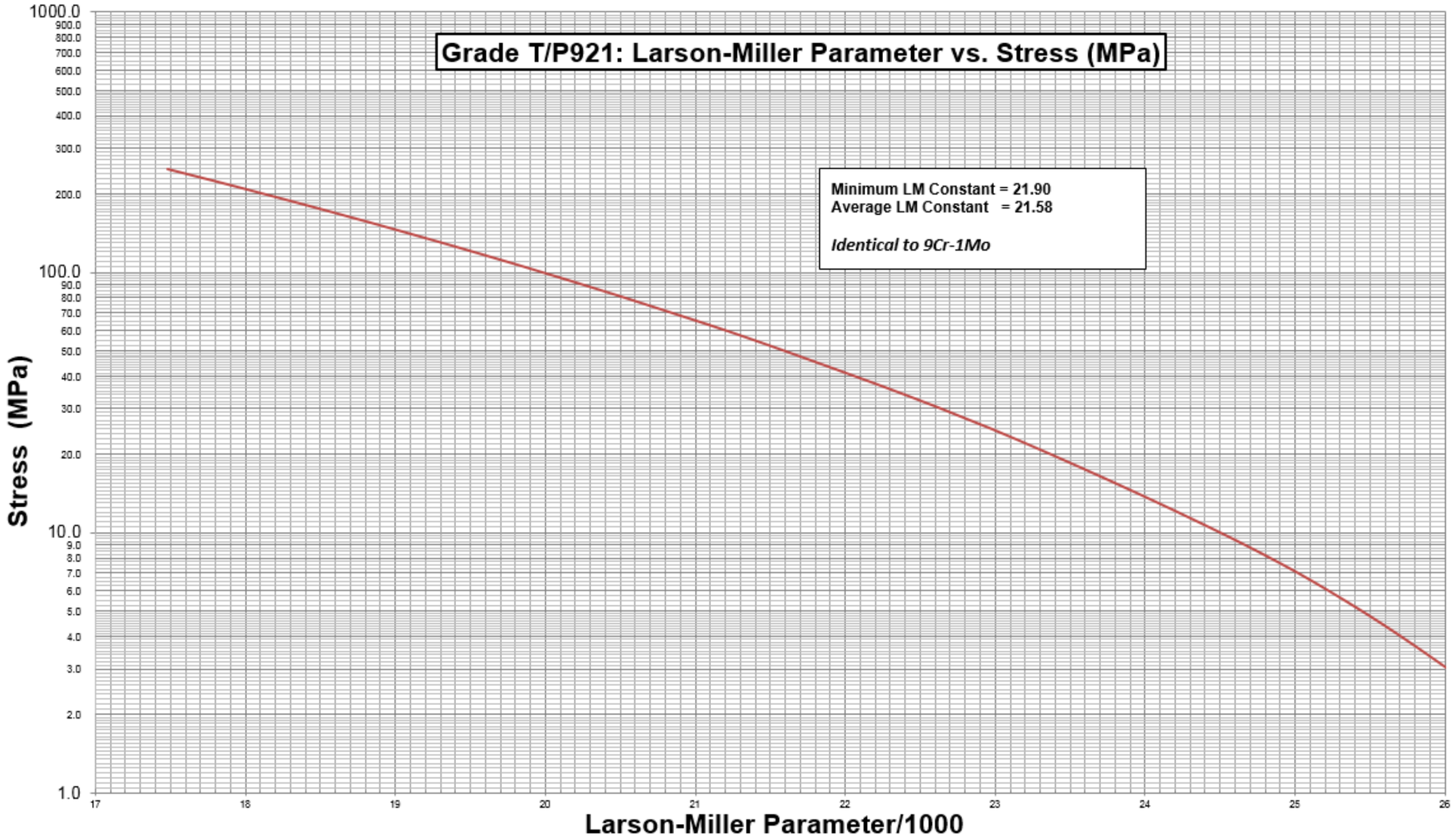



**Figure E.33—Larson-Miller Parameter vs. Stress Curve (SI Units) for ferritic steel ASTM A213-T921 and A335-P921 9Cr-2Si-1Cu Steels (Grade 921)**

**Table E.11—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for Ferritic Steel ASTM A213-T921 and A335-P921 9Cr-2Si-1Cu Steel (Grade 921)**

| Grade T/P921 | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{al}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ (Identical to 9Cr-1Mo) | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 350 | 223.1 | | | | | |
| 360 | 222.6 | | | | | |
| 370 | 221.9 | | | | | |
| 380 | 221.0 | | | | | |
| 390 | 220.0 | | | | | |
| 400 | 218.7 | 251.4 | 264.2 | 291.5 | 274.7 | 10.4 |
| 410 | 217.2 | 230.3 | 242.4 | 268.4 | 252.4 | 10.1 |
| 420 | 215.4 | 210.7 | 222.1 | 246.7 | 231.6 | 9.8 |
| 430 | 213.2 | 192.5 | 203.3 | 226.5 | 212.2 | 9.5 |
| 440 | 210.8 | 175.5 | 185.7 | 207.6 | 194.1 | 9.2 |
| 450 | 207.9 | 159.8 | 169.4 | 190.0 | 177.3 | 9.0 |
| 460 | 204.6 | 145.2 | 154.2 | 173.7 | 161.7 | 8.7 |
| 470 | 200.9 | 131.8 | 140.2 | 158.5 | 147.2 | 8.4 |
| 480 | 196.7 | 119.3 | 127.2 | 144.4 | 133.8 | 8.2 |
| 490 | 192.1 | 107.8 | 115.2 | 131.3 | 121.3 | 7.9 |
| 500 | 187.0 | 97.2 | 104.1 | 119.2 | 109.9 | 7.6 |
| 510 | 181.4 | 87.4 | 93.9 | 108.0 | 99.3 | 7.4 |
| 520 | 175.3 | 78.5 | 84.5 | 97.6 | 89.5 | 7.2 |
| 530 | 168.8 | 70.3 | 75.8 | 88.1 | 80.5 | 6.9 |
| 540 | 161.9 | 62.7 | 67.9 | 79.3 | 72.2 | 6.7 |
| 550 | 154.6 | 55.9 | 60.6 | 71.2 | 64.6 | 6.4 |
| 560 | 146.9 | 49.6 | 54.0 | 63.8 | 57.7 | 6.2 |
| 570 | 138.9 | 43.9 | 48.0 | 57.0 | 51.4 | 6.0 |
| 580 | 130.6 | 38.7 | 42.4 | 50.8 | 45.6 | 5.8 |
| 590 | 122.1 | 34.0 | 37.4 | 45.1 | 40.3 | 5.6 |
| 600 | 113.5 | 29.8 | 32.9 | 40.0 | 35.6 | 5.4 |
| 610 | 104.9 | 26.0 | 28.8 | 35.3 | 31.2 | 5.1 |
| 620 | 96.2 | 22.5 | 25.1 | 31.0 | 27.3 | 4.9 |
| 630 | 87.7 | 19.5 | 21.8 | 27.2 | 23.8 | 4.7 |
| 640 | 79.4 | 16.7 | 18.9 | 23.7 | 20.7 | 4.5 |
| 650 | 71.2 | 14.3 | 16.2 | 20.6 | 17.8 | 4.3 |
| 660 | 63.5 | 12.2 | 13.8 | 17.8 | 15.3 | 4.1 |
| 670 | 56.0 | 10.2 | 11.8 | 15.3 | 13.1 | 4.0 |
| 680 | 49.1 | 8.6 | 9.9 | 13.1 | 11.1 | 3.8 |
| 690 | 42.6 | 7.1 | 8.3 | 11.1 | 9.3 | 3.6 |
| 700 | 36.6 | 5.9 | 6.9 | 9.4 | 7.8 | 3.4 |
| 704 | 34.3 | 5.4 | 6.4 | 8.8 | 7.3 | 3.3 |

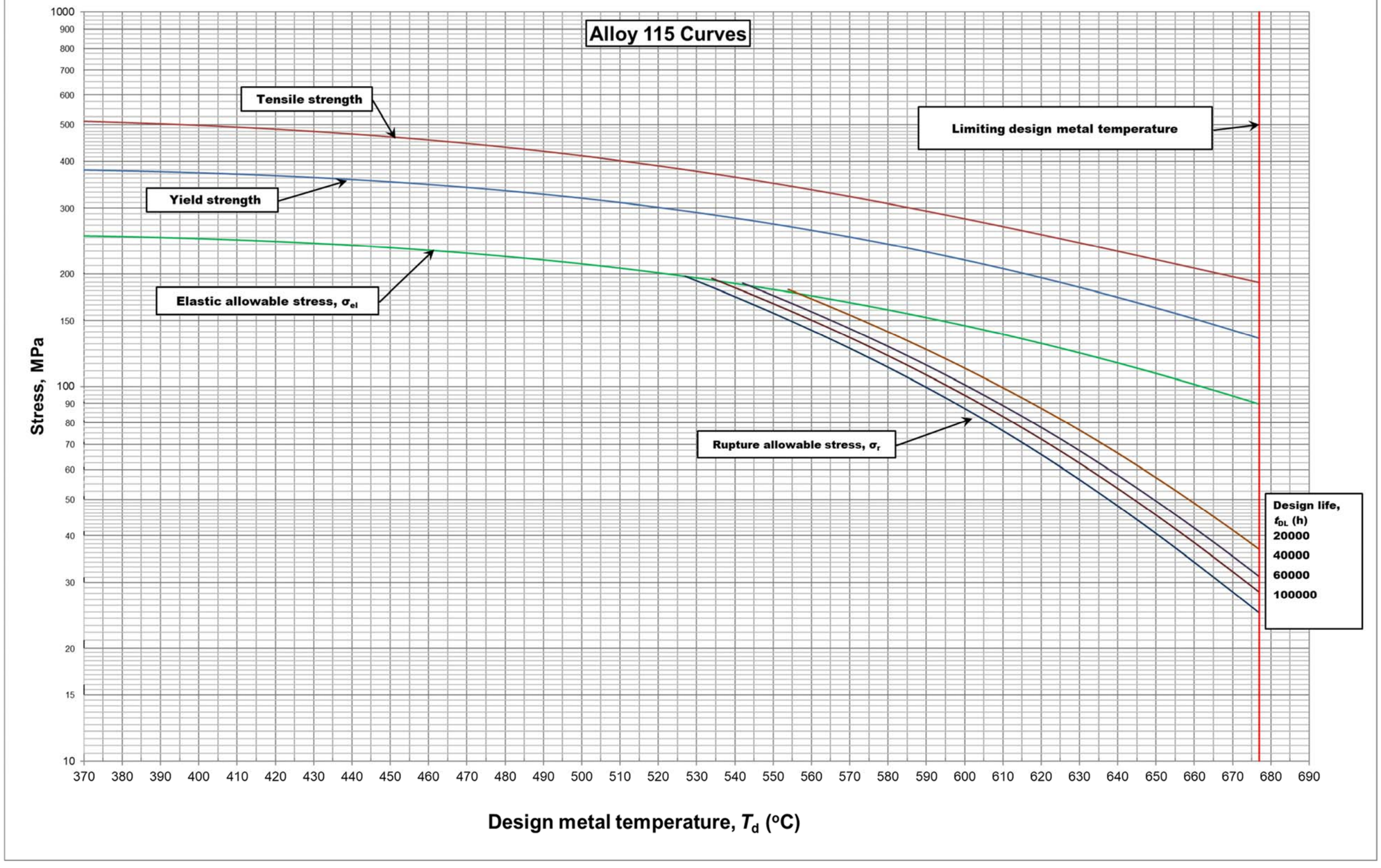



**Figure E.34—Stress Curves (SI Units) for ferritic steel ASTM A213-T115 and A335-P115 10.5Cr-V Steels (Alloy 115)**

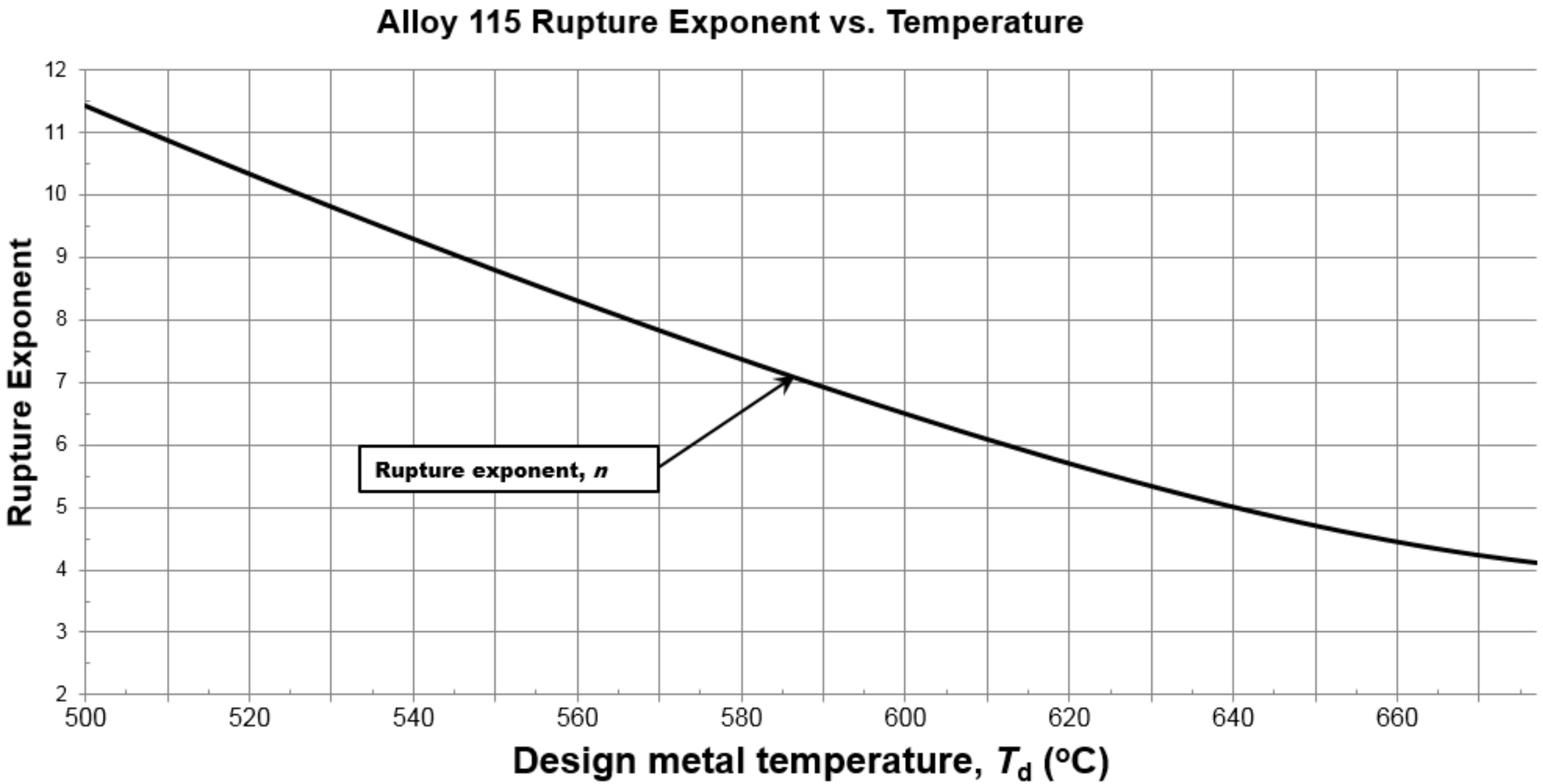



**Figure E.35—Rupture Exponent vs. Temperature Curve (SI Units) for ferritic steel ASTM A213-T115 and A335-P115 10.5Cr-V Steels (Alloy 115)**


**Figure E.36—Larson-Miller Parameter vs. Stress Curve (SI Units) for Ferritic Steel ASTM A213-T115 and A335-P115 10.5Cr-V Steels (Alloy 115)**

**Table E.12—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for Ferritic Steel ASTM A213-T115 and A335-P115 10.5Cr-V Steels (Alloy 115)**

| Alloy 115 | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Celsius) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 370 | 252.5 | | | | | |
| 380 | 251.3 | | | | | |
| 390 | 249.8 | | | | | |
| 400 | 248.1 | | | | | |
| 410 | 246.1 | | | | | |
| 420 | 243.7 | | | | | |
| 430 | 241.1 | | | | | |
| 440 | 238.1 | | | | | |
| 450 | 234.7 | | | | | |
| 460 | 230.9 | | | | | |
| 470 | 226.8 | | | | | |
| 480 | 222.3 | | | | | |
| 490 | 217.5 | | | | | |
| 500 | 212.3 | | | | | 13.3 |
| 510 | 206.7 | | | | | 12.8 |
| 520 | 200.8 | 209.9 | 220.9 | 229.8 | 245.5 | 12.2 |
| 530 | 194.6 | 191.3 | 201.9 | 210.5 | 225.7 | 11.7 |
| 540 | 188.1 | 173.7 | 183.9 | 192.2 | 206.8 | 11.1 |
| 550 | 181.4 | 157.0 | 166.8 | 174.7 | 188.8 | 10.6 |
| 560 | 174.4 | 141.3 | 150.6 | 158.2 | 171.7 | 10.0 |
| 570 | 167.3 | 126.4 | 135.3 | 142.5 | 155.5 | 9.5 |
| 580 | 160.0 | 112.4 | 120.9 | 127.8 | 140.1 | 9.0 |
| 590 | 152.6 | 99.4 | 107.4 | 113.9 | 125.7 | 8.4 |
| 600 | 145.1 | 87.3 | 94.8 | 101.0 | 112.1 | 7.9 |
| 610 | 137.6 | 76.1 | 83.1 | 88.9 | 99.3 | 7.3 |
| 620 | 130.1 | 65.8 | 72.3 | 77.7 | 87.5 | 6.8 |
| 630 | 122.7 | 56.5 | 62.4 | 67.4 | 76.5 | 6.2 |
| 640 | 115.4 | 48.0 | 53.4 | 58.0 | 66.4 | 5.7 |
| 650 | 108.1 | 40.5 | 45.4 | 49.5 | 57.2 | 5.1 |
| 660 | 101.1 | 34.0 | 38.3 | 42.0 | 48.9 | 4.6 |
| 670 | 94.2 | 28.3 | 32.0 | 35.3 | 41.5 | 4.0 |

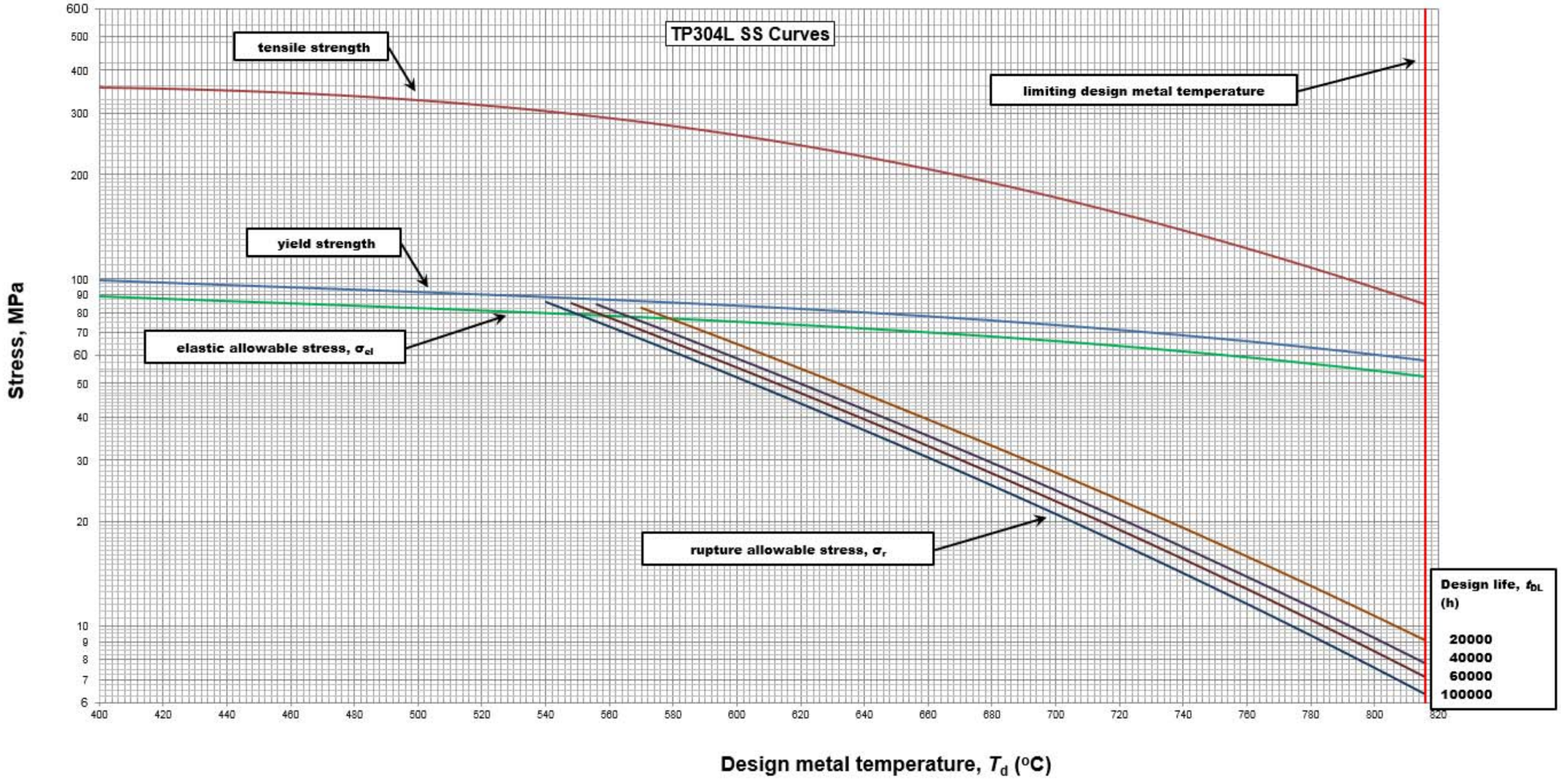



**Figure E.40—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP304L (18Cr-8Ni) Stainless Steels**

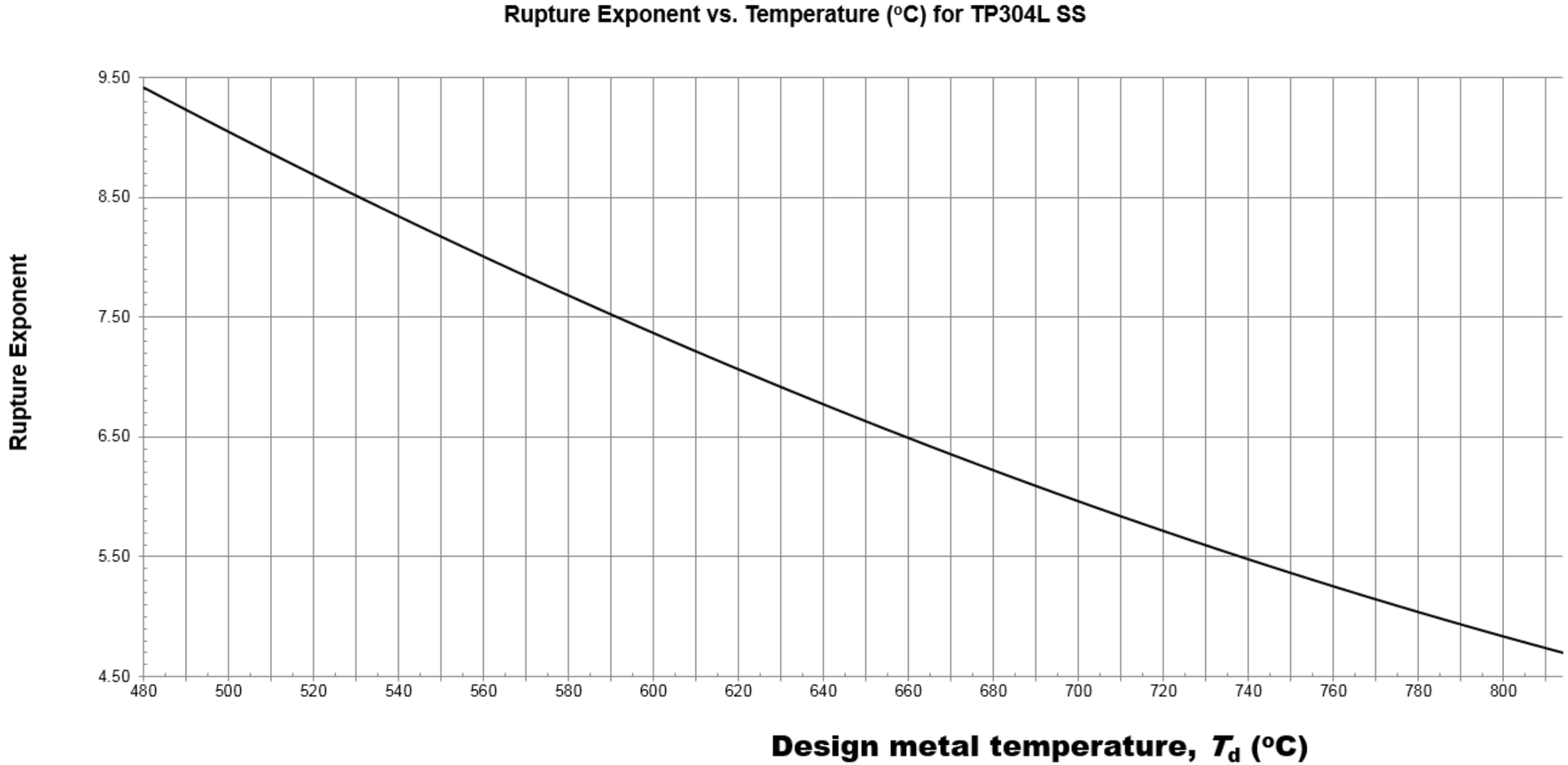



**Figure E.41—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP304L (18Cr-8Ni) Stainless Steels**

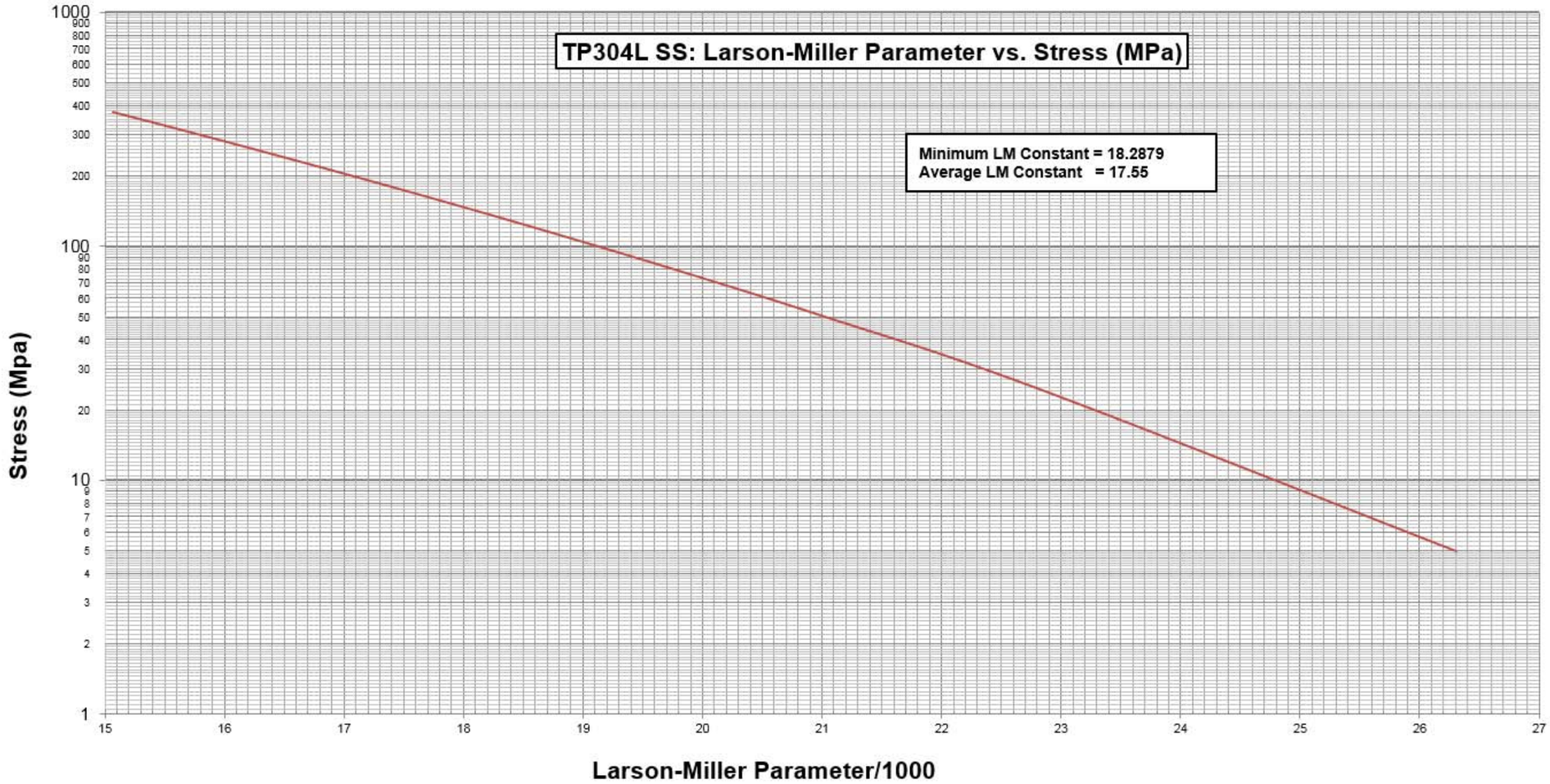



**Figure E.42—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP304L (18Cr-8Ni) Stainless Steels**

**Table E.14—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312 and ASTM A376 TP304L (18Cr-8Ni) Stainless Steels**

| TP304L SS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 400 | 89.1 | | | | | |
| 410 | 88.4 | | | | | |
| 420 | 87.7 | | | | | |
| 430 | 87.0 | | | | | |
| 440 | 86.3 | | | | | |
| 450 | 85.7 | | | | | |
| 460 | 85.0 | | | | | |
| 470 | 84.3 | | | | | |
| 480 | 83.7 | | | | | |
| 490 | 83.0 | | | | | 9.3 |
| 500 | 82.4 | | | | | 9.1 |
| 510 | 81.7 | | | | | 8.9 |
| 520 | 81.0 | | | | | 8.7 |
| 530 | 80.4 | | | | | 8.5 |
| 540 | 79.7 | 85.5 | 91.0 | 95.6 | 103.9 | 8.4 |
| 550 | 79.0 | 78.8 | 84.0 | 88.3 | 96.2 | 8.2 |
| 560 | 78.3 | 72.6 | 77.5 | 81.6 | 89.0 | 8.0 |
| 570 | 77.5 | 66.8 | 71.4 | 75.3 | 82.3 | 7.9 |
| 580 | 76.8 | 61.4 | 65.8 | 69.4 | 76.0 | 7.7 |
| 590 | 76.0 | 56.5 | 60.5 | 63.9 | 70.2 | 7.6 |
| 600 | 75.2 | 51.8 | 55.7 | 58.9 | 64.7 | 7.4 |
| 610 | 74.4 | 47.6 | 51.1 | 54.1 | 59.7 | 7.2 |
| 620 | 73.6 | 43.6 | 46.9 | 49.8 | 54.9 | 7.1 |
| 630 | 72.8 | 39.9 | 43.1 | 45.7 | 50.6 | 6.9 |
| 640 | 71.9 | 36.5 | 39.5 | 41.9 | 46.5 | 6.8 |
| 650 | 71.0 | 33.4 | 36.1 | 38.5 | 42.7 | 6.7 |
| 660 | 70.1 | 30.5 | 33.1 | 35.2 | 39.2 | 6.5 |
| 670 | 69.2 | 27.8 | 30.2 | 32.2 | 36.0 | 6.4 |
| 680 | 68.2 | 25.3 | 27.6 | 29.5 | 33.0 | 6.2 |
| 690 | 67.2 | 23.1 | 25.1 | 26.9 | 30.2 | 6.1 |
| 700 | 66.2 | 21.0 | 22.9 | 24.6 | 27.6 | 6.0 |
| 710 | 65.1 | 19.1 | 20.9 | 22.4 | 25.2 | 5.9 |
| 720 | 64.0 | 17.3 | 19.0 | 20.4 | 23.0 | 5.7 |
| 730 | 62.9 | 15.7 | 17.2 | 18.5 | 21.0 | 5.6 |
| 740 | 61.8 | 14.2 | 15.6 | 16.8 | 19.1 | 5.5 |
| 750 | 60.6 | 12.8 | 14.1 | 15.3 | 17.4 | 5.4 |
| 760 | 59.4 | 11.6 | 12.8 | 13.9 | 15.8 | 5.3 |
| 770 | 58.2 | 10.4 | 11.6 | 12.5 | 14.4 | 5.2 |
| 780 | 57.0 | 9.4 | 10.4 | 11.3 | 13.0 | 5.1 |
| 790 | 55.7 | 8.4 | 9.4 | 10.2 | 11.8 | 5.0 |
| 800 | 54.4 | 7.6 | 8.5 | 9.2 | 10.7 | 4.9 |
| 810 | 53.1 | 6.8 | 7.6 | 8.3 | 9.6 | 4.8 |
| 816 | 52.3 | 6.4 | 7.1 | 7.8 | 9.1 | 4.7 |

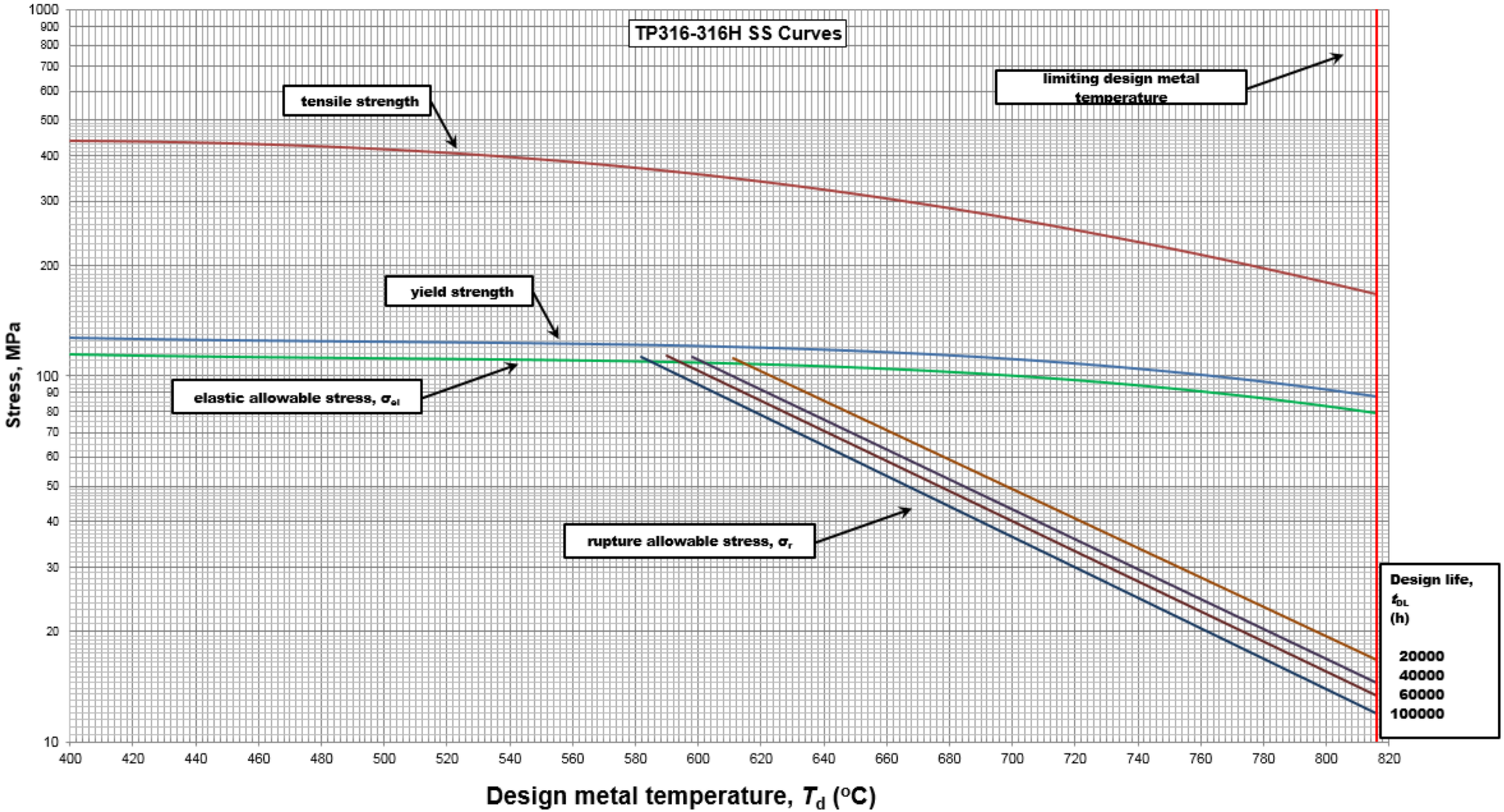



**Figure E.43—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels**

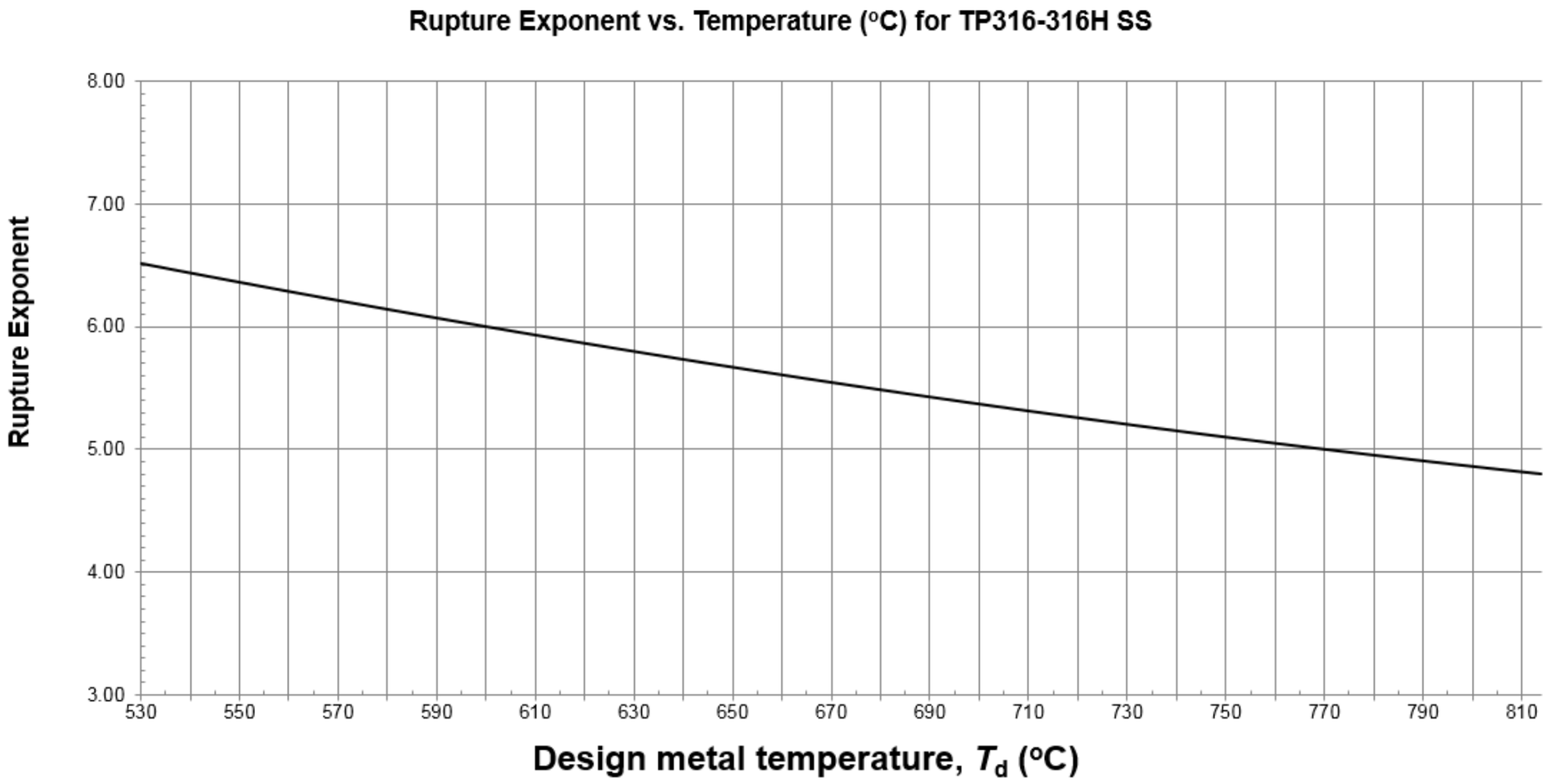



**Figure E.44—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP316 and 316H (16Cr-12Ni-2Mo) Stainless Steels**

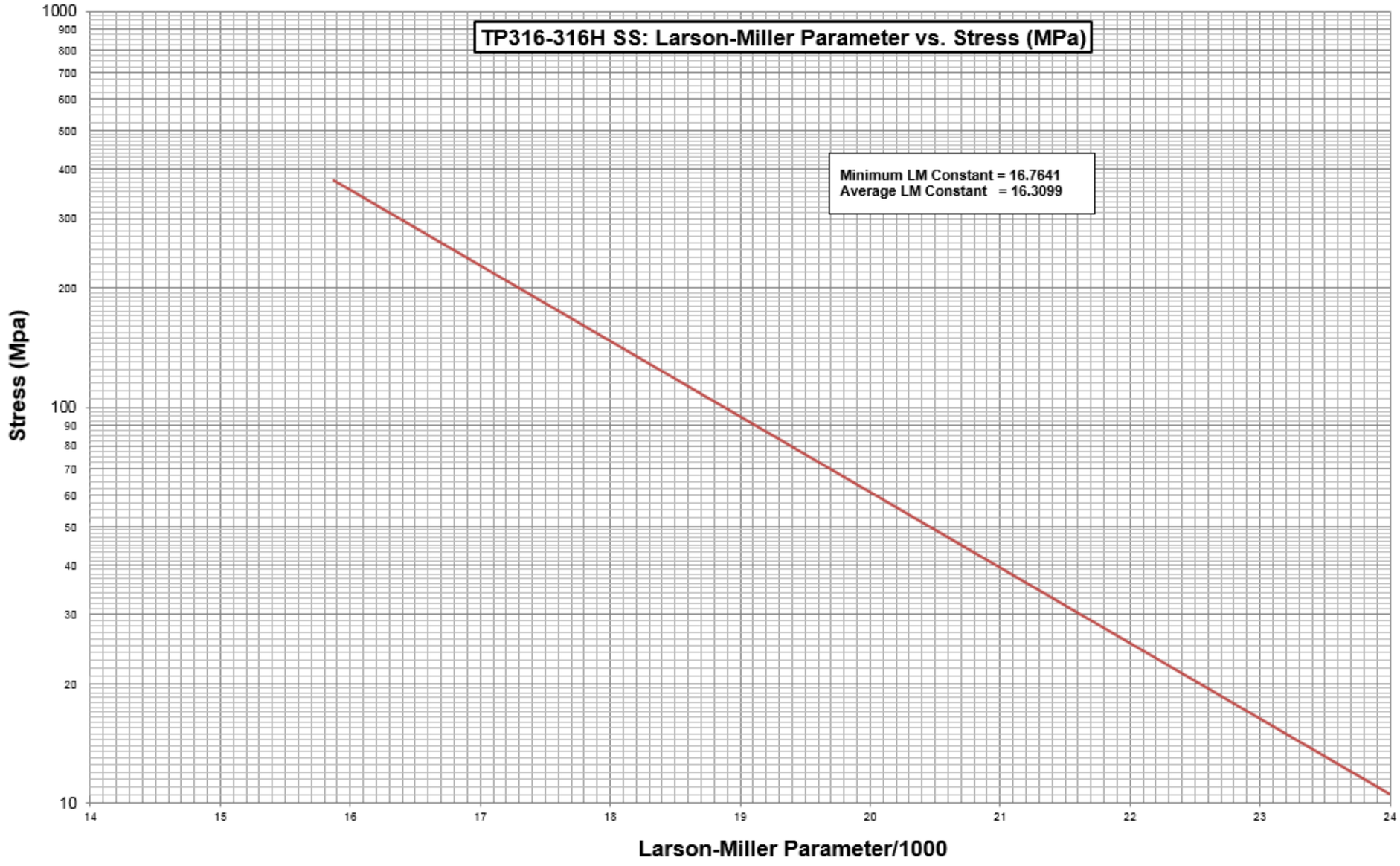



**Figure E.45—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP316 and 316H (16Cr-12Ni-2Mo) Stainless Steels**

**Table E.15—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP316 and 316H (16Cr-12Ni-2Mo) Stainless Steels**

| TP 316-316H SS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 400 | 114.7 | | | | | |
| 410 | 114.3 | | | | | |
| 420 | 113.9 | | | | | |
| 430 | 113.5 | | | | | |
| 440 | 113.2 | | | | | |
| 450 | 112.9 | | | | | |
| 460 | 112.7 | | | | | |
| 470 | 112.4 | | | | | |
| 480 | 112.2 | | | | | |
| 490 | 112.0 | | | | | |
| 500 | 111.8 | | | | | |
| 510 | 111.6 | | | | | |
| 520 | 111.4 | | | | | 6.6 |
| 530 | 111.2 | | | | | 6.5 |
| 540 | 111.0 | | | | | 6.4 |
| 550 | 110.7 | | | | | 6.4 |
| 560 | 110.4 | | | | | 6.3 |
| 570 | 110.1 | | | | | 6.2 |
| 580 | 109.7 | 114.7 | 124.6 | 133.1 | 149.0 | 6.2 |
| 590 | 109.3 | 104.2 | 113.3 | 121.2 | 135.8 | 6.1 |
| 600 | 108.8 | 94.7 | 103.1 | 110.3 | 123.8 | 6.0 |
| 610 | 108.3 | 86.1 | 93.8 | 100.4 | 112.9 | 5.9 |
| 620 | 107.7 | 78.2 | 85.3 | 91.4 | 102.9 | 5.9 |
| 630 | 107.1 | 71.1 | 77.6 | 83.2 | 93.8 | 5.8 |
| 640 | 106.3 | 64.6 | 70.6 | 75.8 | 85.5 | 5.7 |
| 650 | 105.5 | 58.7 | 64.2 | 69.0 | 77.9 | 5.7 |
| 660 | 104.6 | 53.3 | 58.4 | 62.8 | 71.0 | 5.6 |
| 670 | 103.6 | 48.5 | 53.1 | 57.2 | 64.8 | 5.6 |
| 680 | 102.6 | 44.0 | 48.3 | 52.0 | 59.0 | 5.5 |
| 690 | 101.4 | 40.0 | 44.0 | 47.4 | 53.8 | 5.4 |
| 700 | 100.1 | 36.4 | 40.0 | 43.1 | 49.1 | 5.4 |
| 710 | 98.8 | 33.1 | 36.4 | 39.3 | 44.7 | 5.3 |
| 720 | 97.3 | 30.0 | 33.1 | 35.7 | 40.8 | 5.3 |
| 730 | 95.8 | 27.3 | 30.1 | 32.5 | 37.2 | 5.2 |
| 740 | 94.2 | 24.8 | 27.4 | 29.6 | 33.9 | 5.2 |
| 750 | 92.4 | 22.5 | 24.9 | 27.0 | 30.9 | 5.1 |
| 760 | 90.6 | 20.5 | 22.7 | 24.5 | 28.1 | 5.1 |
| 770 | 88.7 | 18.6 | 20.6 | 22.3 | 25.7 | 5.0 |
| 780 | 86.7 | 16.9 | 18.8 | 20.3 | 23.4 | 5.0 |
| 790 | 84.6 | 15.4 | 17.1 | 18.5 | 21.3 | 4.9 |
| 800 | 82.5 | 14.0 | 15.5 | 16.9 | 19.4 | 4.9 |
| 810 | 80.2 | 12.7 | 14.1 | 15.3 | 17.7 | 4.8 |
| 816 | 78.9 | 12.0 | 13.3 | 14.5 | 16.8 | 4.8 |

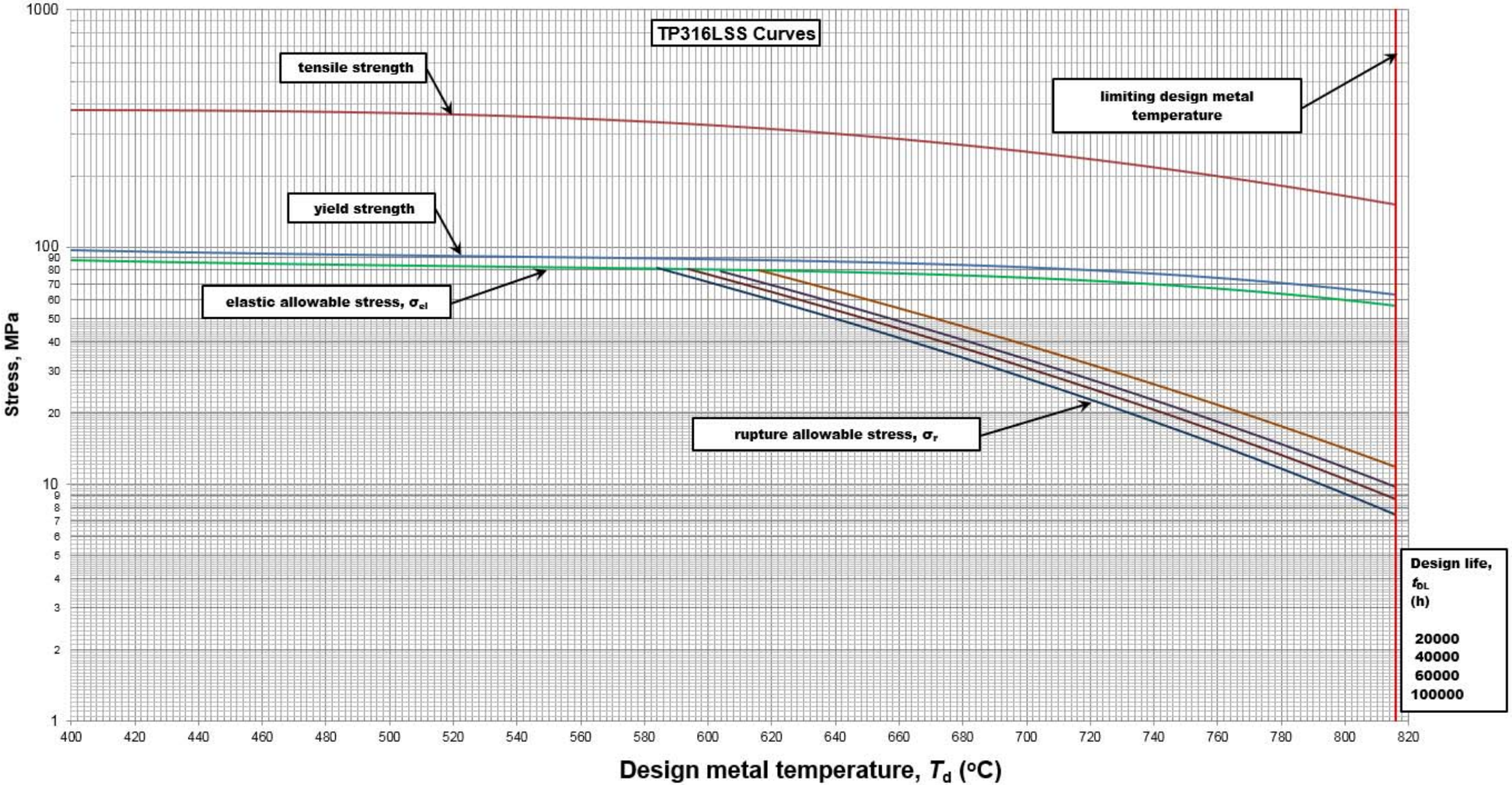



**Figure E.46—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASMT A379 TP316L (18Cr-8Ni-2Mo) Stainless Steels**

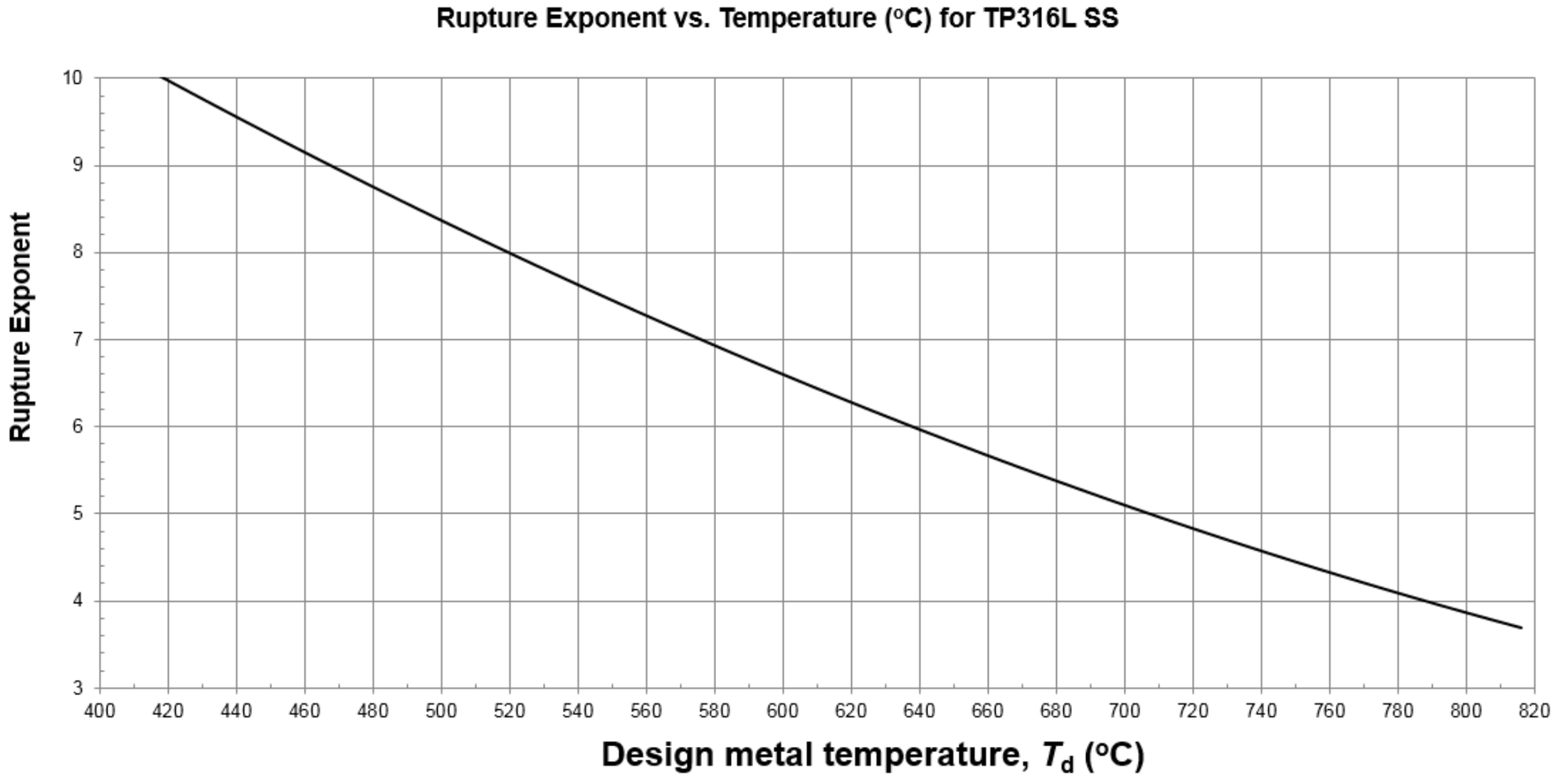



**Figure E.47—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L Stainless Steels**

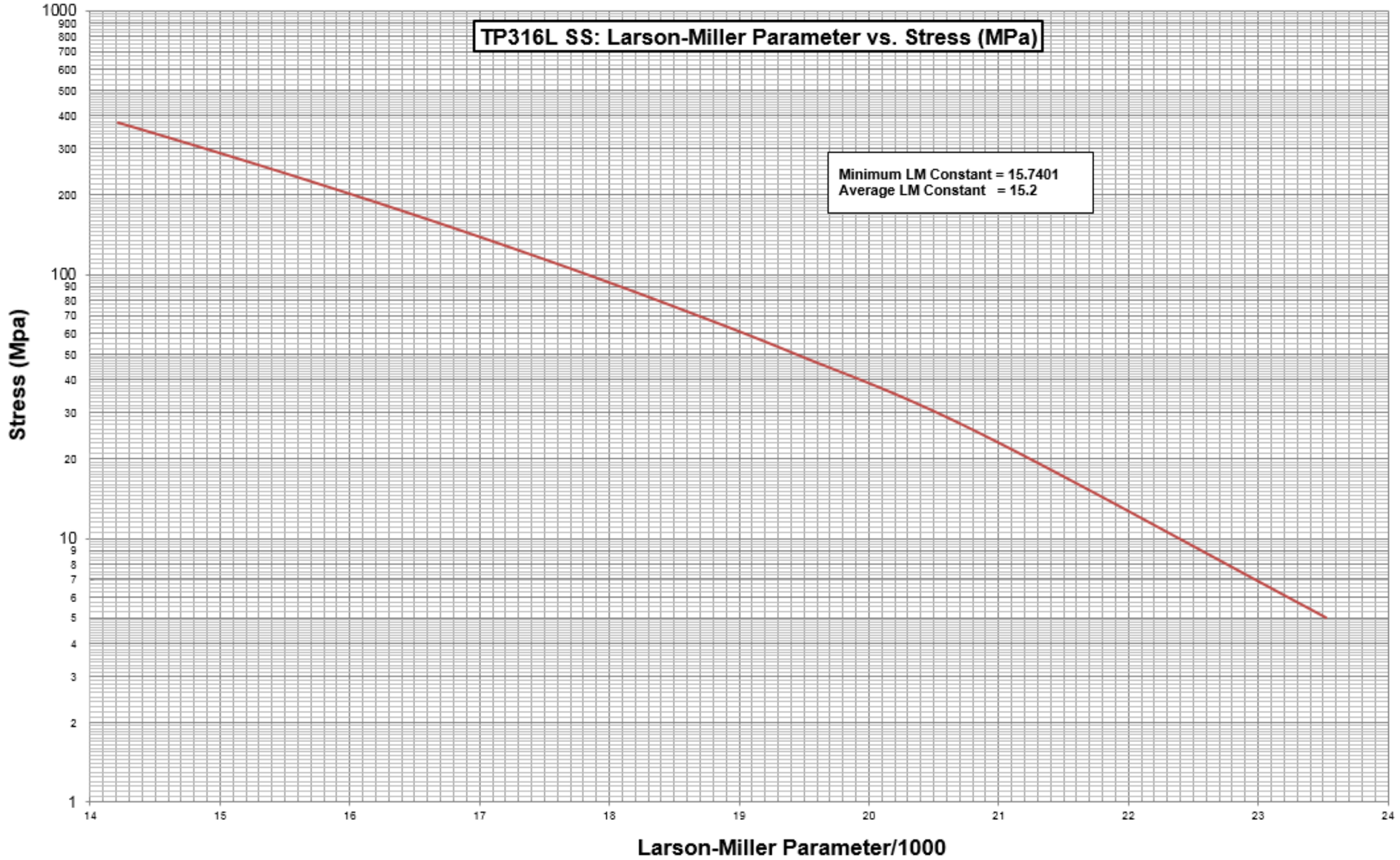



**Figure E.48—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L Stainless Steels**

**Table E.16—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L Stainless Steels**

| TP316L SS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 400 | 87.6 | | | | | |
| 410 | 87.0 | | | | | |
| 420 | 86.5 | | | | | |
| 430 | 86.0 | | | | | |
| 440 | 85.6 | | | | | |
| 450 | 85.2 | | | | | |
| 460 | 84.8 | | | | | |
| 470 | 84.4 | | | | | |
| 480 | 84.0 | | | | | |
| 490 | 83.7 | | | | | 8.6 |
| 500 | 83.4 | | | | | 8.4 |
| 510 | 83.1 | | | | | 8.2 |
| 520 | 82.8 | | | | | 8.0 |
| 530 | 82.5 | | | | | 7.8 |
| 540 | 82.2 | | | | | 7.6 |
| 550 | 81.9 | | | | | 7.5 |
| 560 | 81.6 | | | | | 7.3 |
| 570 | 81.2 | | | | | 7.1 |
| 580 | 80.9 | 84.1 | 90.8 | 96.4 | 106.6 | 6.9 |
| 590 | 80.6 | 77.3 | 83.6 | 88.9 | 98.5 | 6.8 |
| 600 | 80.2 | 71.0 | 76.9 | 81.9 | 91.0 | 6.6 |
| 610 | 79.8 | 65.1 | 70.7 | 75.4 | 84.0 | 6.4 |
| 620 | 79.4 | 59.6 | 64.8 | 69.3 | 77.4 | 6.3 |
| 630 | 78.9 | 54.5 | 59.4 | 63.6 | 71.3 | 6.1 |
| 640 | 78.4 | 49.8 | 54.4 | 58.3 | 65.5 | 6.0 |
| 650 | 77.8 | 45.4 | 49.7 | 53.4 | 60.2 | 5.8 |
| 660 | 77.2 | 41.4 | 45.4 | 48.8 | 55.2 | 5.7 |
| 670 | 76.6 | 37.6 | 41.4 | 44.6 | 50.6 | 5.5 |
| 680 | 75.8 | 34.1 | 37.7 | 40.7 | 46.3 | 5.4 |
| 690 | 75.0 | 30.9 | 34.2 | 37.1 | 42.3 | 5.2 |
| 700 | 74.1 | 28.0 | 31.1 | 33.7 | 38.6 | 5.1 |
| 710 | 73.1 | 25.3 | 28.1 | 30.6 | 35.2 | 5.0 |
| 720 | 72.1 | 22.8 | 25.4 | 27.7 | 32.0 | 4.8 |
| 730 | 70.9 | 20.5 | 23.0 | 25.1 | 29.1 | 4.7 |
| 740 | 69.7 | 18.4 | 20.7 | 22.6 | 26.4 | 4.6 |
| 750 | 68.3 | 16.5 | 18.6 | 20.4 | 23.9 | 4.5 |
| 760 | 66.9 | 14.7 | 16.7 | 18.4 | 21.6 | 4.3 |
| 770 | 65.3 | 13.1 | 14.9 | 16.5 | 19.5 | 4.2 |
| 780 | 63.6 | 11.7 | 13.3 | 14.8 | 17.5 | 4.1 |
| 790 | 61.9 | 10.3 | 11.9 | 13.2 | 15.7 | 4.0 |
| 800 | 60.0 | 9.1 | 10.5 | 11.8 | 14.1 | 3.9 |
| 810 | 58.0 | 8.1 | 9.3 | 10.4 | 12.6 | 3.8 |
| 816 | 56.8 | 7.5 | 8.7 | 9.7 | 11.8 | 3.7 |

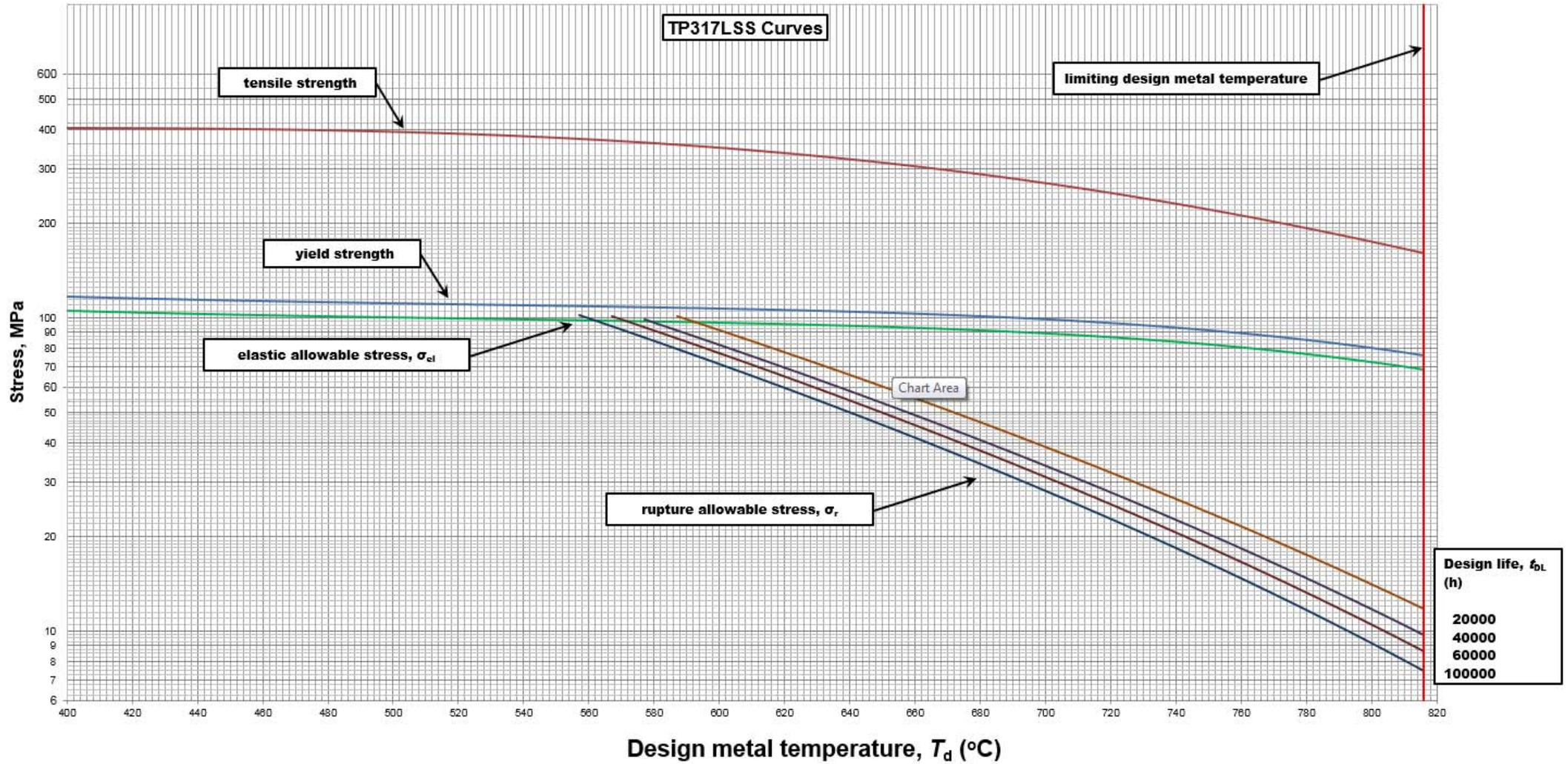



**Figure E.49—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM A379 TP317L (18Cr-8Ni-3Mo) Stainless Steels**

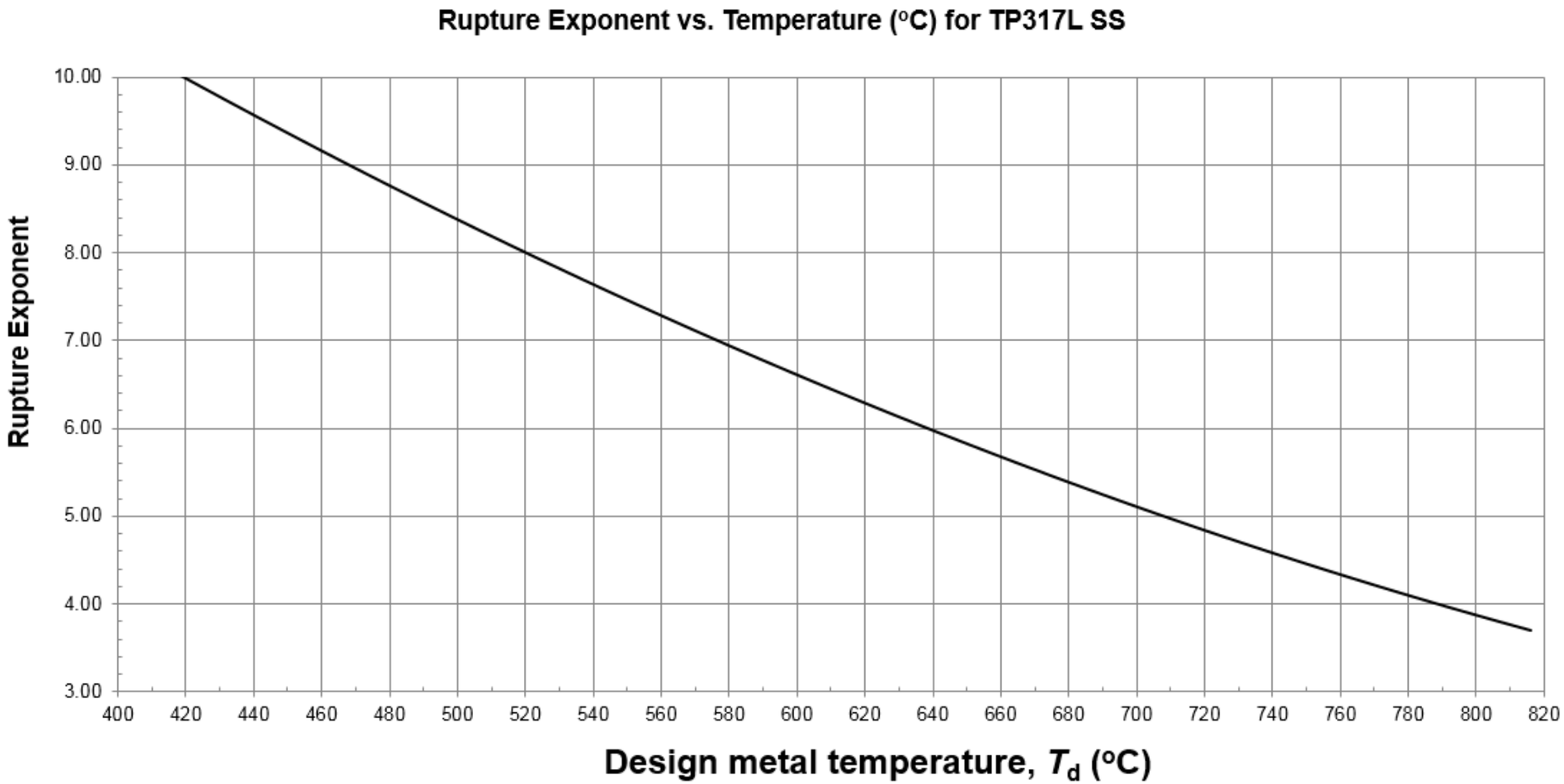



**Figure E.50—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP317L Stainless Steels**

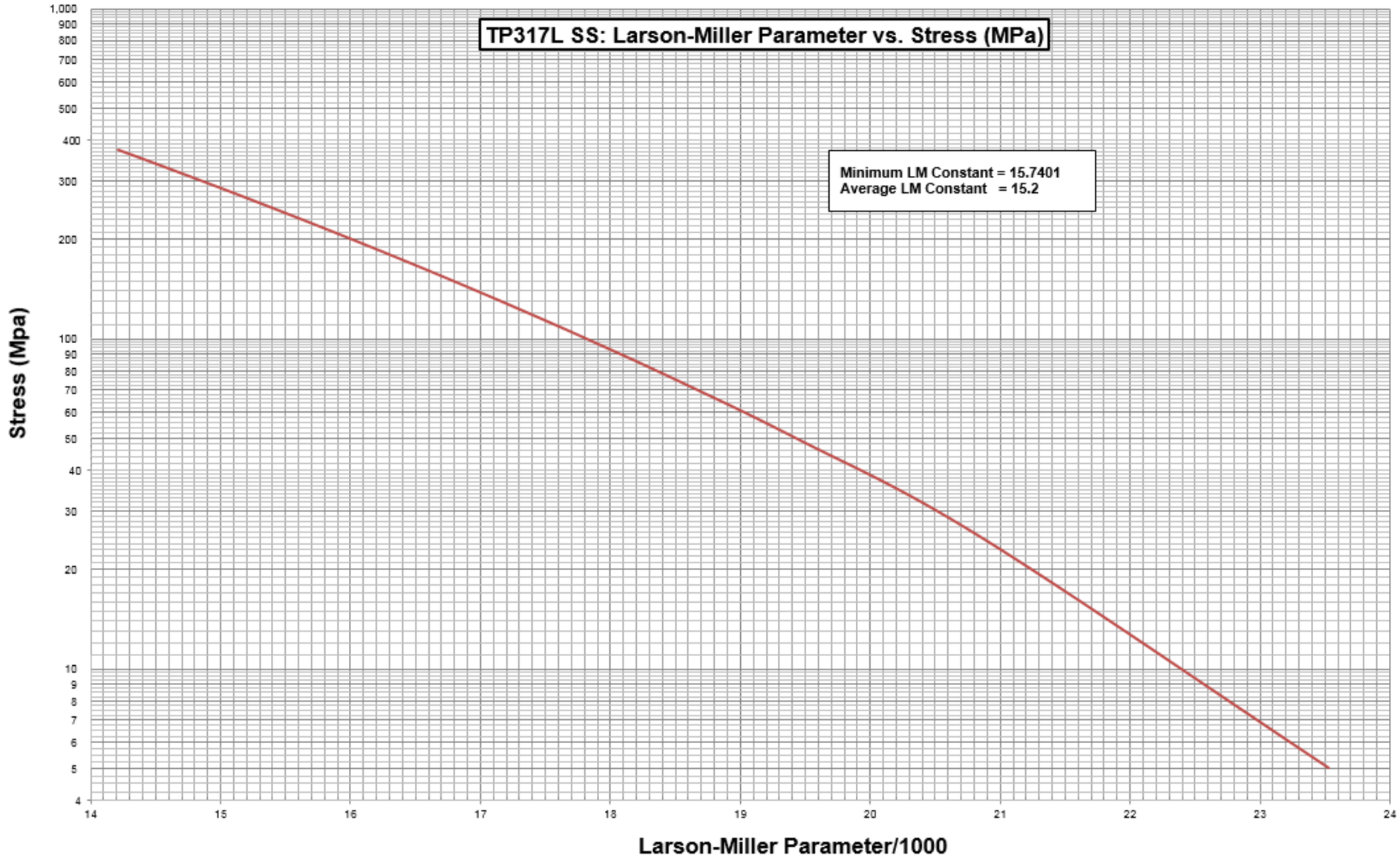



**Figure E.51—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP317L Stainless Steels**

**Table E.17—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP317L Stainless Steels**

| TP317L SS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 400 | 105.3 | | | | | |
| 410 | 104.7 | | | | | |
| 420 | 104.1 | | | | | |
| 430 | 103.5 | | | | | |
| 440 | 102.9 | | | | | |
| 450 | 102.4 | | | | | |
| 460 | 102.0 | | | | | |
| 470 | 101.5 | | | | | |
| 480 | 101.1 | | | | | |
| 490 | 100.7 | | | | | 8.6 |
| 500 | 100.3 | | | | | 8.4 |
| 510 | 99.9 | | | | | 8.2 |
| 520 | 99.5 | | | | | 8.0 |
| 530 | 99.2 | | | | | 7.8 |
| 540 | 98.8 | | | | | 7.6 |
| 550 | 98.4 | | | | | 7.5 |
| 560 | 98.1 | 99.3 | 106.7 | 113.0 | 124.3 | 7.3 |
| 570 | 97.7 | 91.5 | 98.5 | 104.4 | 115.2 | 7.1 |
| 580 | 97.3 | 84.2 | 90.8 | 96.4 | 106.6 | 6.9 |
| 590 | 96.9 | 77.3 | 83.6 | 88.9 | 98.5 | 6.8 |
| 600 | 96.4 | 71.0 | 76.9 | 81.9 | 91.0 | 6.6 |
| 610 | 96.0 | 65.1 | 70.7 | 75.4 | 84.0 | 6.4 |
| 620 | 95.5 | 59.6 | 64.9 | 69.3 | 77.4 | 6.3 |
| 630 | 94.9 | 54.5 | 59.4 | 63.6 | 71.3 | 6.1 |
| 640 | 94.3 | 49.8 | 54.4 | 58.3 | 65.5 | 6.0 |
| 650 | 93.6 | 45.4 | 49.7 | 53.4 | 60.2 | 5.8 |
| 660 | 92.9 | 41.4 | 45.4 | 48.9 | 55.2 | 5.7 |
| 670 | 92.1 | 37.6 | 41.4 | 44.6 | 50.6 | 5.5 |
| 680 | 91.2 | 34.1 | 37.7 | 40.7 | 46.3 | 5.4 |
| 690 | 90.2 | 30.9 | 34.2 | 37.1 | 42.3 | 5.2 |
| 700 | 89.1 | 28.0 | 31.1 | 33.7 | 38.6 | 5.1 |
| 710 | 88.0 | 25.3 | 28.1 | 30.6 | 35.2 | 5.0 |
| 720 | 86.7 | 22.8 | 25.4 | 27.7 | 32.0 | 4.8 |
| 730 | 85.3 | 20.5 | 23.0 | 25.1 | 29.1 | 4.7 |
| 740 | 83.8 | 18.4 | 20.7 | 22.7 | 26.4 | 4.6 |
| 750 | 82.2 | 16.5 | 18.6 | 20.4 | 23.9 | 4.5 |
| 760 | 80.4 | 14.7 | 16.7 | 18.4 | 21.6 | 4.3 |
| 770 | 78.5 | 13.1 | 14.9 | 16.5 | 19.5 | 4.2 |
| 780 | 76.5 | 11.7 | 13.3 | 14.8 | 17.5 | 4.1 |
| 790 | 74.4 | 10.3 | 11.9 | 13.2 | 15.7 | 4.0 |
| 800 | 72.2 | 9.2 | 10.5 | 11.8 | 14.1 | 3.9 |
| 810 | 69.8 | 8.1 | 9.3 | 10.4 | 12.6 | 3.8 |
| 816 | 68.3 | 7.5 | 8.7 | 9.7 | 11.8 | 3.7 |

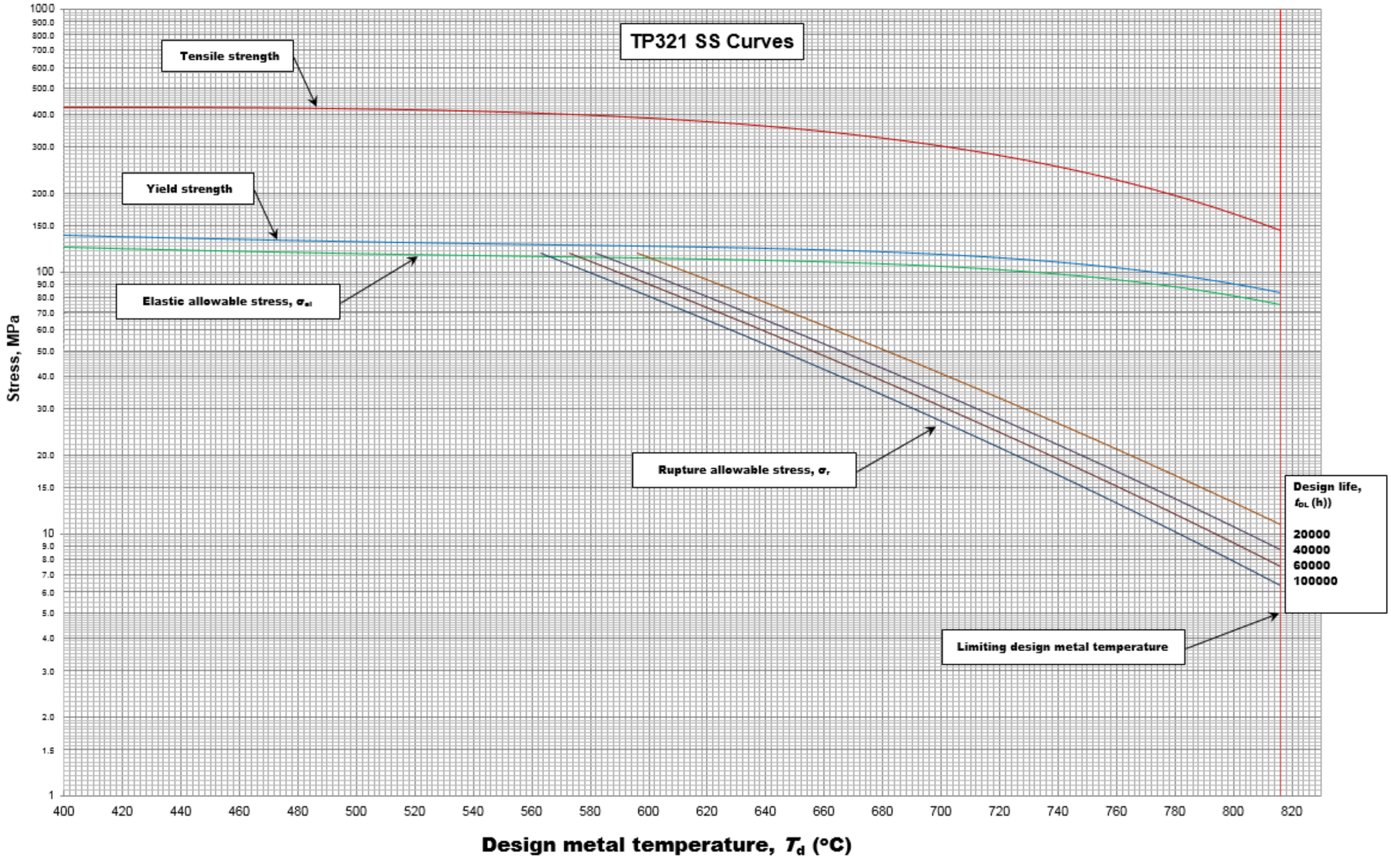



**Figure E.52—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP321 (18Cr-10Ni-Ti) Stainless Steels**

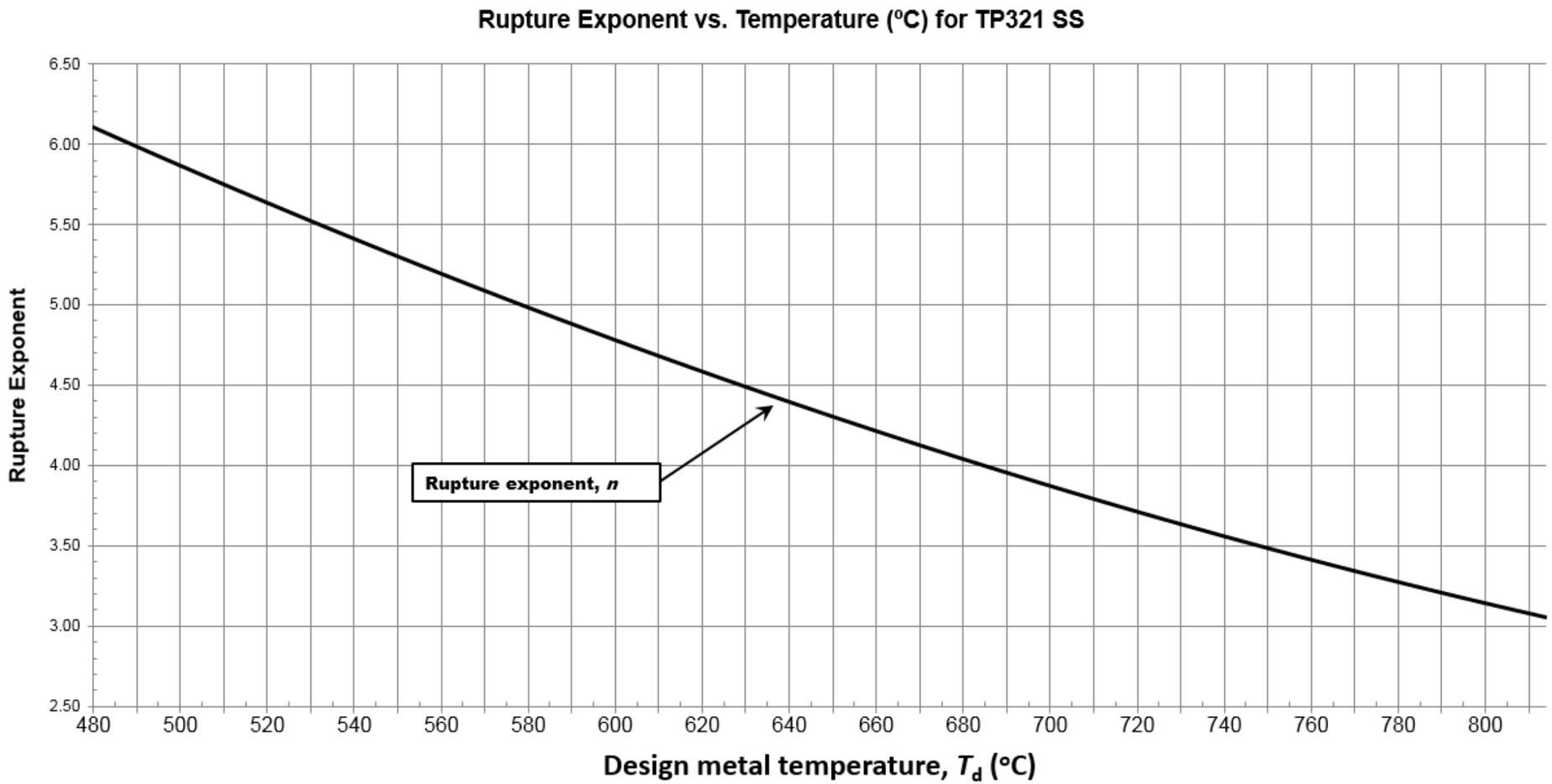



**Figure E.53—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP321 (18Cr-10Ni-Ti) Stainless Steels**

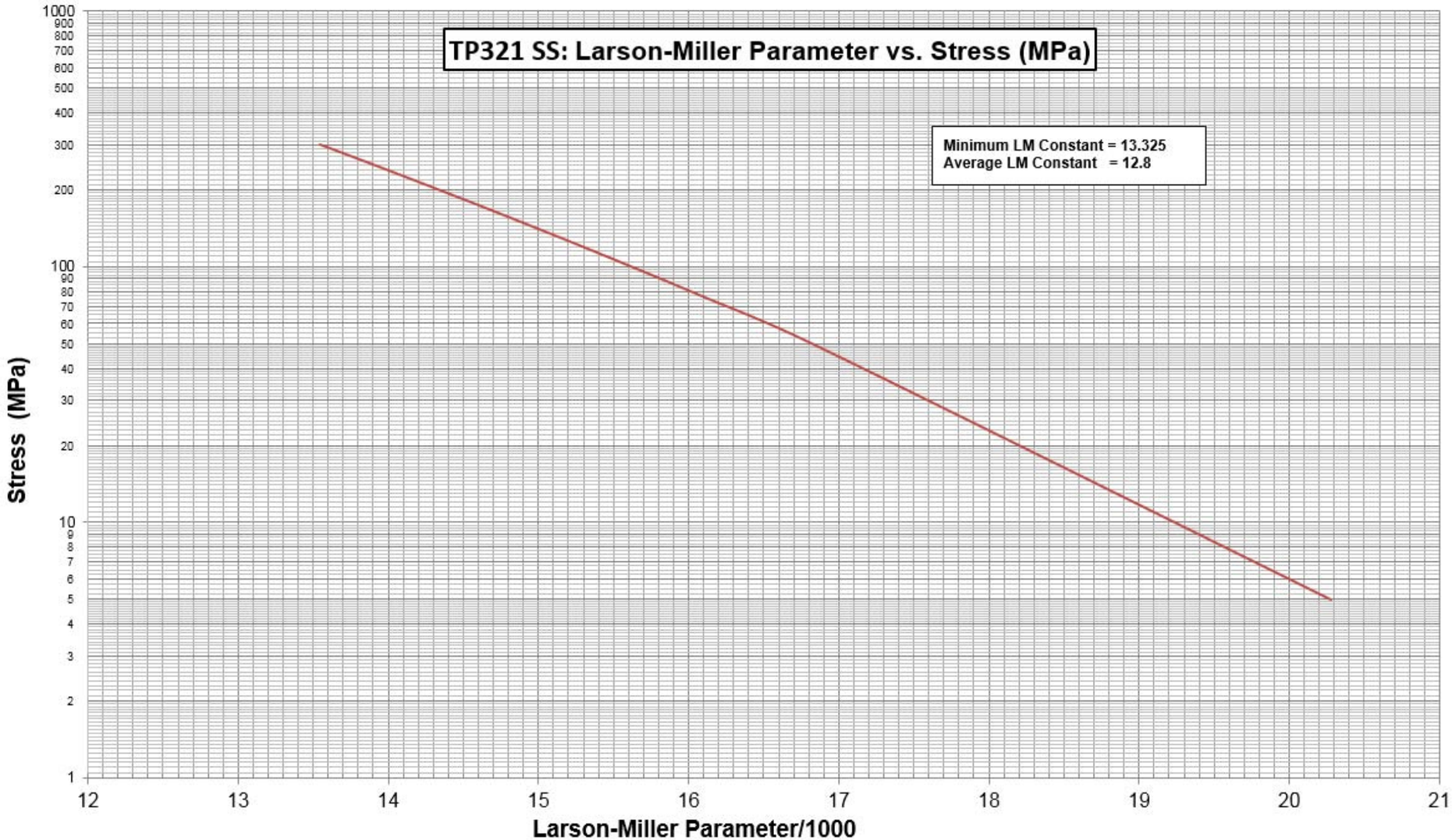



**Figure E.54—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP321 (18Cr-10Ni-Ti) Stainless Steels**

**Table E.18—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP321 (18Cr-10Ni-Ti) Stainless Steels**

| TP321 SS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 400 | 124.5 | | | | | |
| 410 | 123.7 | | | | | |
| 420 | 122.9 | | | | | |
| 430 | 122.1 | | | | | |
| 440 | 121.4 | | | | | |
| 450 | 120.7 | | | | | |
| 460 | 120.0 | | | | | |
| 470 | 119.4 | | | | | |
| 480 | 118.8 | | | | | |
| 490 | 118.2 | | | | | 6.0 |
| 500 | 117.6 | | | | | 5.9 |
| 510 | 117.1 | | | | | 5.7 |
| 520 | 116.6 | | | | | 5.6 |
| 530 | 116.1 | | | | | 5.5 |
| 540 | 115.6 | | | | | 5.4 |
| 550 | 115.2 | 134.3 | 148.2 | 160.1 | 182.6 | 5.3 |
| 560 | 114.7 | 121.5 | 134.4 | 145.5 | 166.4 | 5.2 |
| 570 | 114.3 | 109.9 | 121.8 | 132.0 | 151.4 | 5.1 |
| 580 | 113.9 | 99.2 | 110.2 | 119.7 | 137.7 | 5.0 |
| 590 | 113.4 | 89.5 | 99.7 | 108.5 | 125.1 | 4.9 |
| 600 | 113.0 | 80.7 | 90.1 | 98.2 | 113.6 | 4.8 |
| 610 | 112.5 | 72.7 | 81.3 | 88.8 | 103.0 | 4.7 |
| 620 | 112.0 | 65.4 | 73.3 | 80.2 | 93.4 | 4.6 |
| 630 | 111.4 | 58.8 | 66.1 | 72.4 | 84.5 | 4.5 |
| 640 | 110.8 | 52.8 | 59.4 | 65.3 | 76.5 | 4.4 |
| 650 | 110.1 | 47.3 | 53.4 | 58.8 | 69.1 | 4.3 |
| 660 | 109.3 | 42.4 | 48.0 | 52.9 | 62.4 | 4.2 |
| 670 | 108.4 | 37.9 | 43.0 | 47.6 | 56.3 | 4.1 |
| 680 | 107.4 | 33.9 | 38.6 | 42.7 | 50.7 | 4.0 |
| 690 | 106.3 | 30.2 | 34.5 | 38.3 | 45.6 | 4.0 |
| 700 | 105.0 | 26.9 | 30.8 | 34.3 | 41.0 | 3.9 |
| 710 | 103.6 | 24.0 | 27.5 | 30.7 | 36.8 | 3.8 |
| 720 | 102.0 | 21.3 | 24.5 | 27.4 | 33.1 | 3.7 |
| 730 | 100.1 | 18.9 | 21.8 | 24.5 | 29.6 | 3.6 |
| 740 | 98.1 | 16.7 | 19.4 | 21.8 | 26.5 | 3.6 |
| 750 | 95.8 | 14.8 | 17.2 | 19.4 | 23.7 | 3.5 |
| 760 | 93.3 | 13.1 | 15.3 | 17.2 | 21.1 | 3.4 |
| 770 | 90.6 | 11.5 | 13.5 | 15.3 | 18.8 | 3.3 |
| 780 | 87.6 | 10.2 | 12.0 | 13.6 | 16.8 | 3.3 |
| 790 | 84.4 | 8.9 | 10.5 | 12.0 | 14.9 | 3.2 |
| 800 | 80.9 | 7.8 | 9.3 | 10.6 | 13.2 | 3.1 |
| 810 | 77.2 | 6.9 | 8.2 | 9.4 | 11.7 | 3.1 |
| 816 | 74.9 | 6.3 | 7.6 | 8.7 | 10.9 | 3.0 |

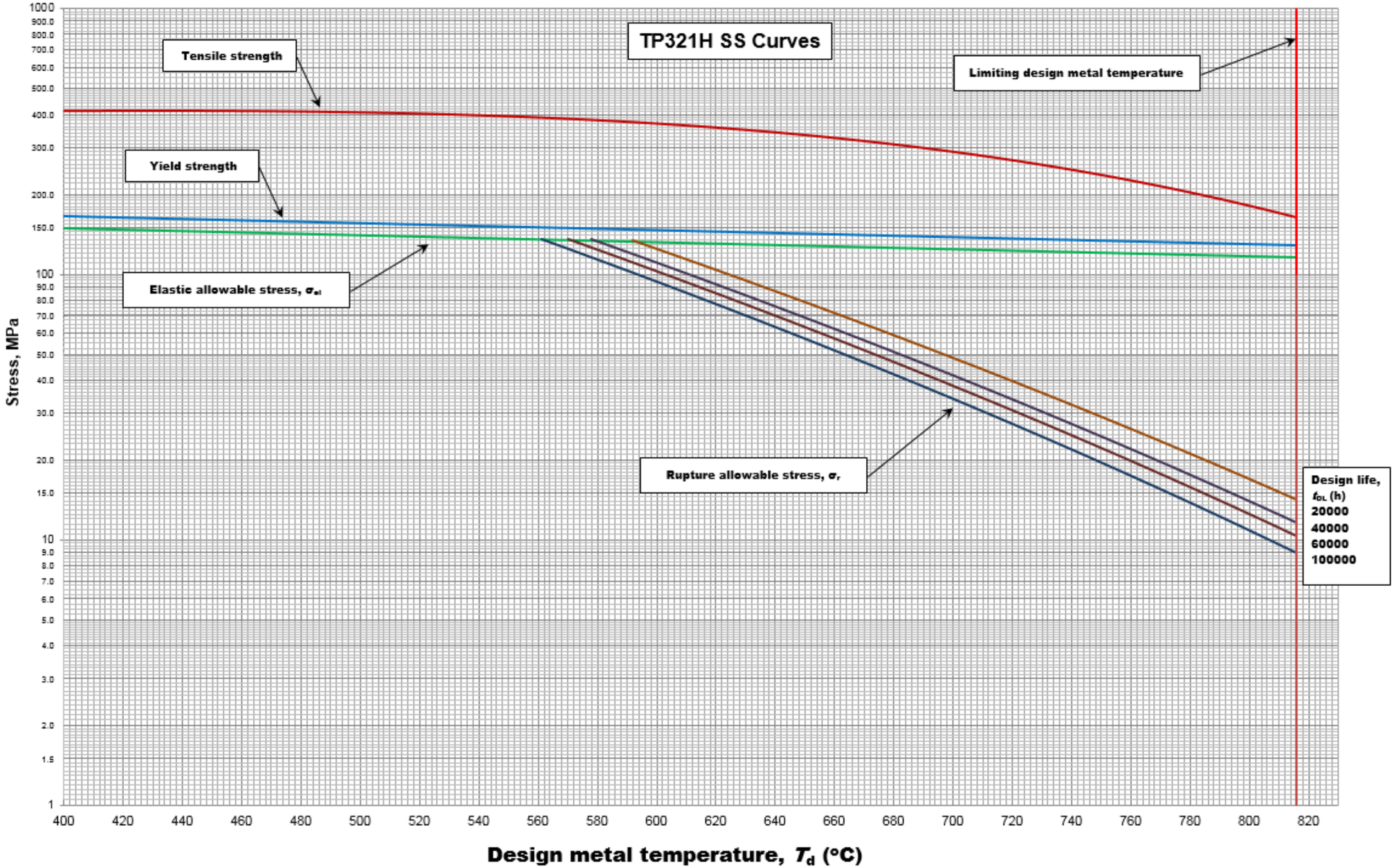



**Figure E.55—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels**

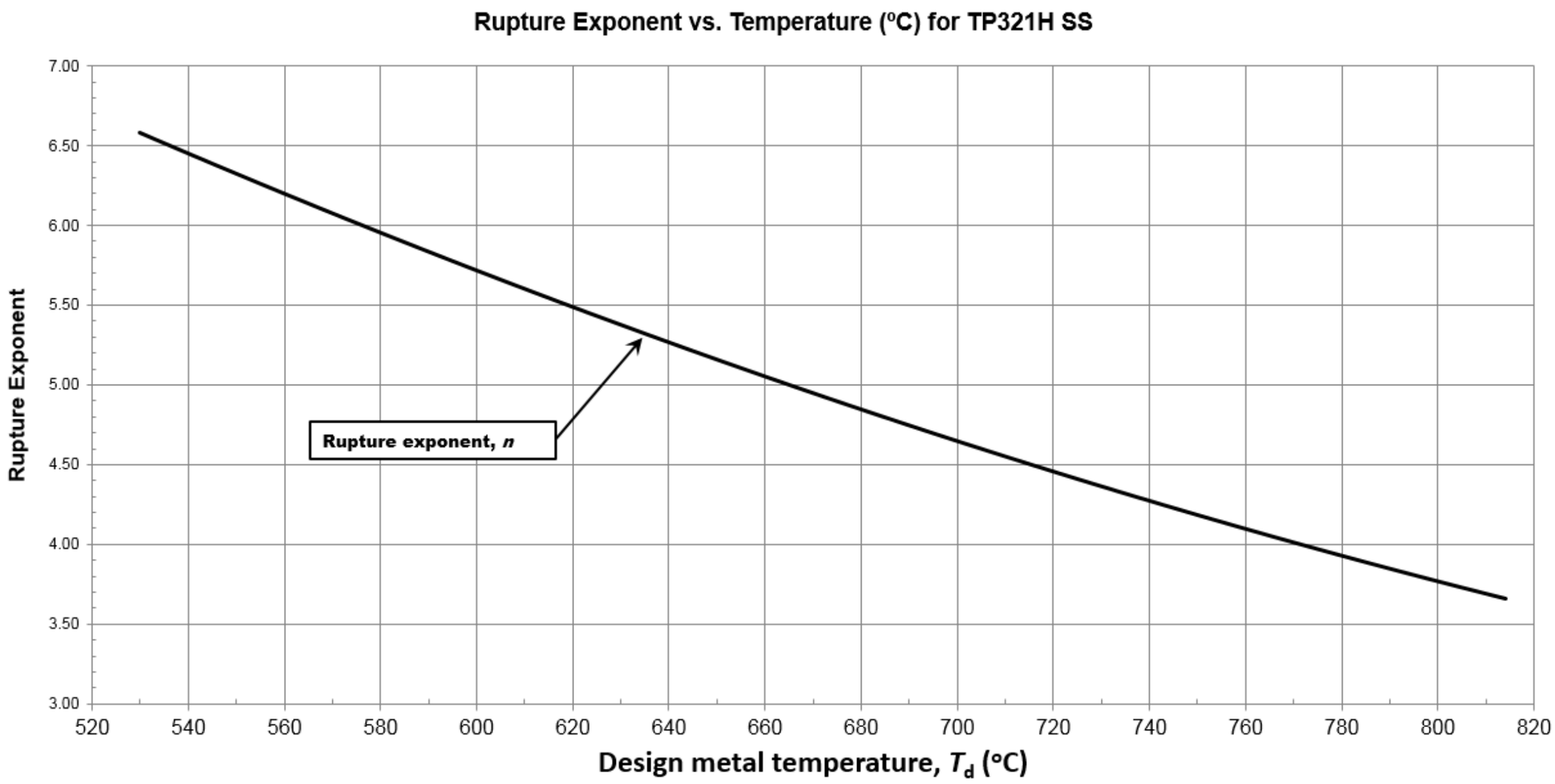



**Figure E.56—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP321H (18Cr-10Ni-Ti) Stainless Steels**

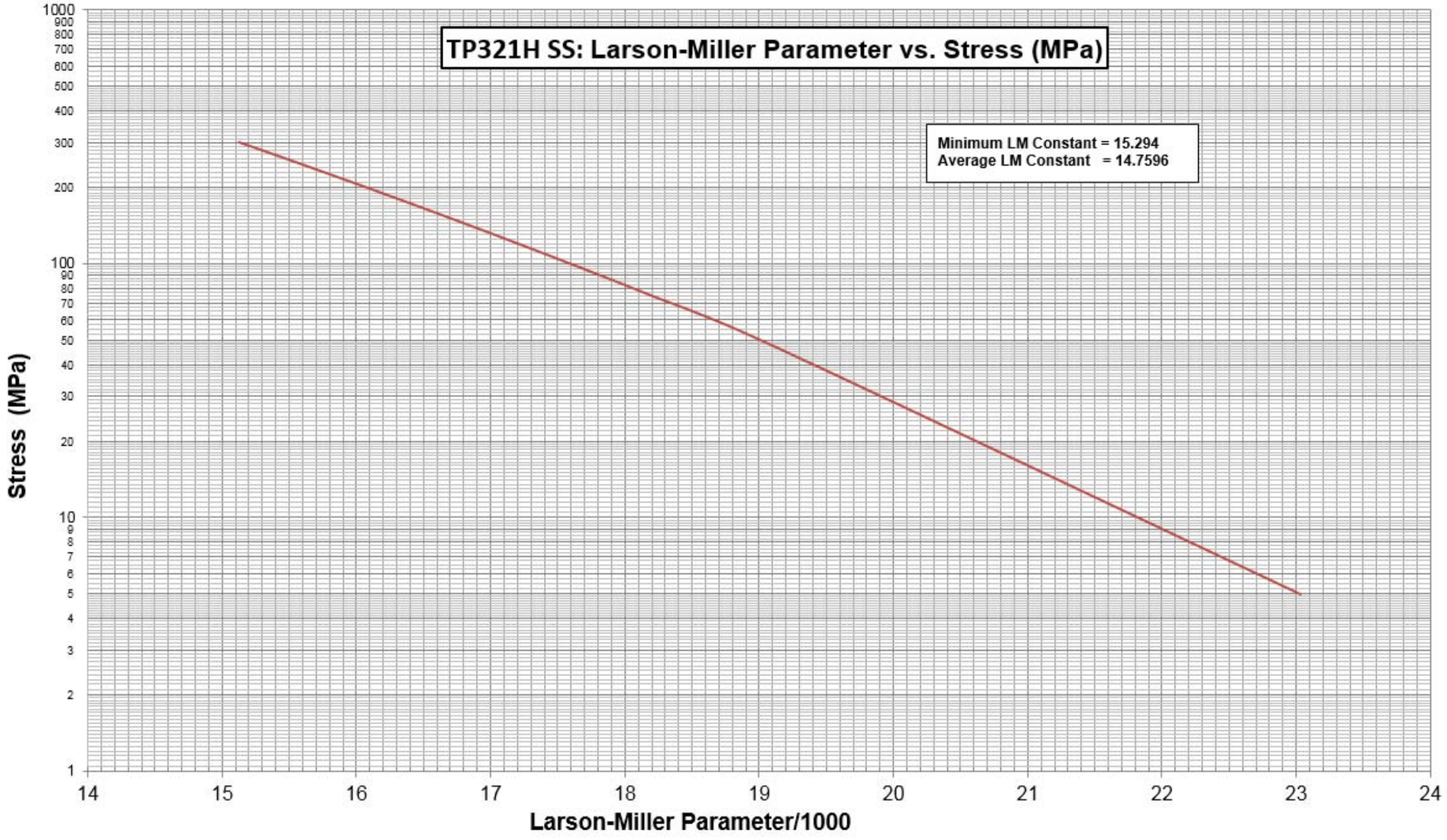



**Figure E.57—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP321H (18Cr-10Ni-Ti) Stainless Steels**

**Table E.19—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM 376 TP321H (18Cr-10Ni-Ti) Stainless Steels**

| TP321H SS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 400 | 148.5 | | | | | |
| 410 | 147.6 | | | | | |
| 420 | 146.7 | | | | | |
| 430 | 145.8 | | | | | |
| 440 | 145.0 | | | | | |
| 450 | 144.1 | | | | | |
| 460 | 143.2 | | | | | |
| 470 | 142.4 | | | | | |
| 480 | 141.5 | | | | | |
| 490 | 140.7 | | | | | |
| 500 | 139.9 | | | | | |
| 510 | 139.0 | | | | | |
| 520 | 138.2 | | | | | |
| 530 | 137.4 | | | | | |
| 540 | 136.5 | | | | | 6.5 |
| 550 | 135.7 | 150.2 | 163.0 | 174.0 | 194.2 | 6.3 |
| 560 | 134.9 | 136.9 | 148.9 | 159.1 | 178.0 | 6.2 |
| 570 | 134.1 | 124.8 | 135.9 | 145.4 | 163.1 | 6.1 |
| 580 | 133.3 | 113.6 | 124.0 | 132.8 | 149.3 | 6.0 |
| 590 | 132.5 | 103.3 | 113.0 | 121.2 | 136.6 | 5.8 |
| 600 | 131.7 | 93.9 | 102.8 | 110.5 | 124.8 | 5.7 |
| 610 | 130.9 | 85.2 | 93.5 | 100.7 | 114.0 | 5.6 |
| 620 | 130.2 | 77.3 | 85.0 | 91.6 | 104.0 | 5.5 |
| 630 | 129.4 | 70.0 | 77.2 | 83.3 | 94.9 | 5.4 |
| 640 | 128.6 | 63.4 | 70.0 | 75.7 | 86.4 | 5.3 |
| 650 | 127.8 | 57.3 | 63.4 | 68.7 | 78.6 | 5.2 |
| 660 | 127.1 | 51.7 | 57.4 | 62.3 | 71.5 | 5.1 |
| 670 | 126.3 | 46.7 | 51.9 | 56.4 | 65.0 | 4.9 |
| 680 | 125.6 | 42.1 | 46.9 | 51.1 | 59.0 | 4.8 |
| 690 | 124.8 | 37.9 | 42.3 | 46.2 | 53.5 | 4.7 |
| 700 | 124.1 | 34.1 | 38.1 | 41.7 | 48.4 | 4.6 |
| 710 | 123.3 | 30.6 | 34.3 | 37.6 | 43.8 | 4.5 |
| 720 | 122.6 | 27.4 | 30.9 | 33.9 | 39.6 | 4.5 |
| 730 | 121.9 | 24.6 | 27.7 | 30.5 | 35.7 | 4.4 |
| 740 | 121.1 | 22.0 | 24.9 | 27.4 | 32.2 | 4.3 |
| 750 | 120.4 | 19.6 | 22.3 | 24.6 | 29.0 | 4.2 |
| 760 | 119.7 | 17.5 | 19.9 | 22.0 | 26.1 | 4.1 |
| 770 | 119.0 | 15.6 | 17.8 | 19.7 | 23.5 | 4.0 |
| 780 | 118.3 | 13.9 | 15.9 | 17.6 | 21.1 | 3.9 |
| 790 | 117.6 | 12.3 | 14.1 | 15.7 | 18.9 | 3.8 |
| 800 | 116.9 | 10.9 | 12.6 | 14.0 | 16.9 | 3.8 |
| 810 | 116.2 | 9.7 | 11.2 | 12.5 | 15.1 | 3.7 |
| 816 | 115.7 | 9.0 | 10.4 | 11.6 | 14.1 | 3.6 |

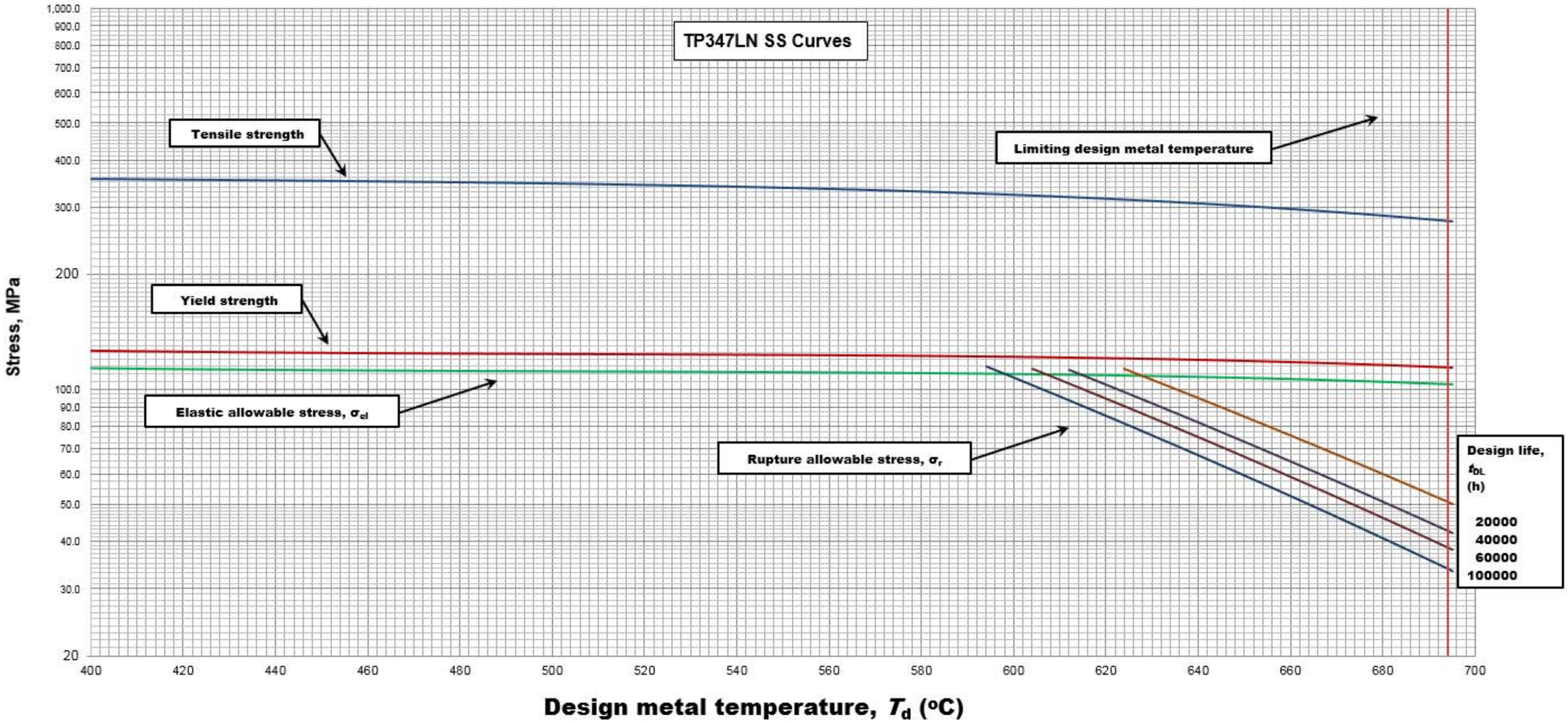



**Figure E.64—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP347LN (18Cr-10Ni-Nb) Stainless Steels**

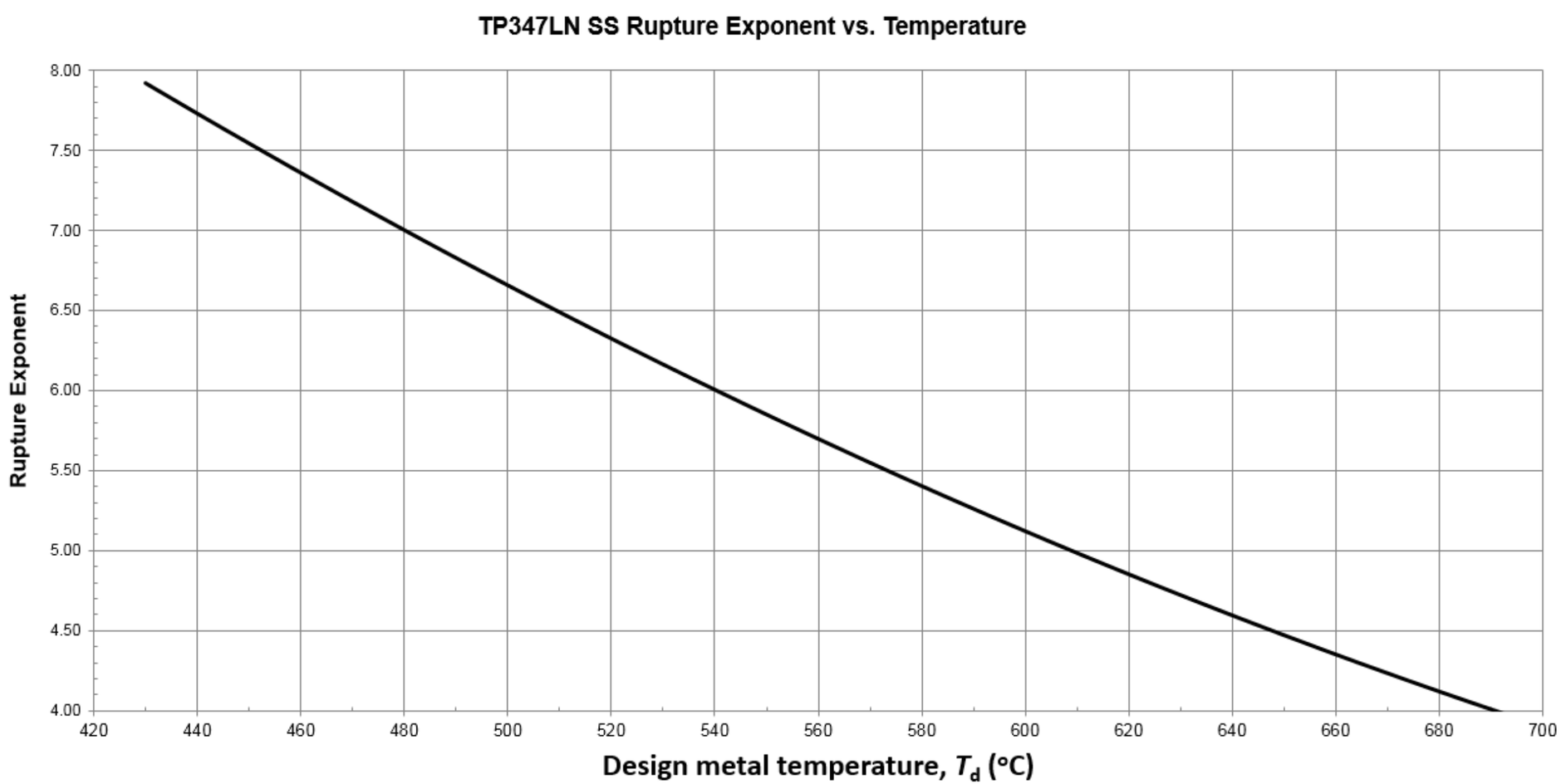



**Figure E.65—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP347LN (18Cr-10Ni-Nb) Stainless Steels**

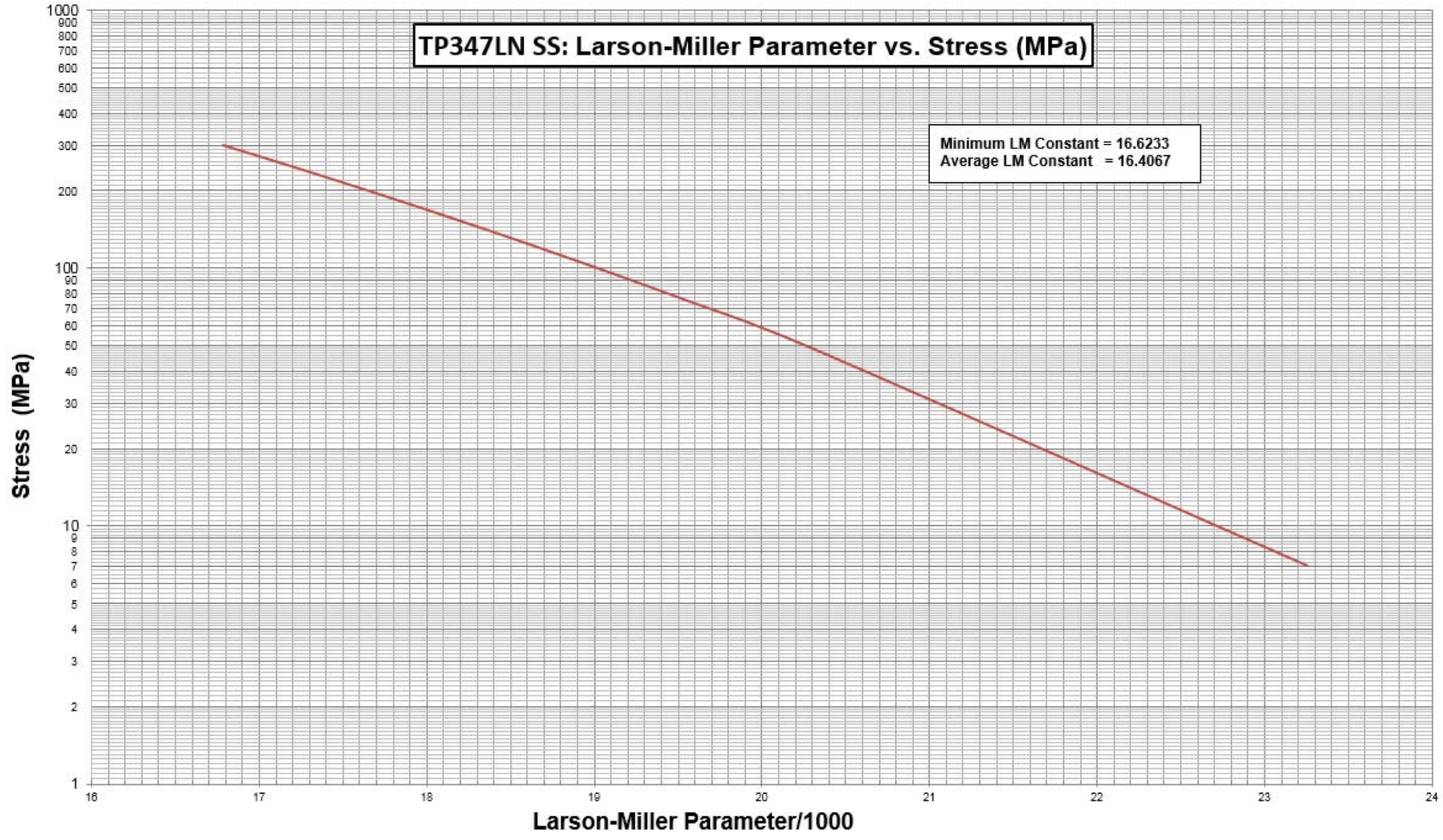



**Figure E.66—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP347LN (18Cr-10Ni-Nb) Stainless Steels**

**Table E.22—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP347LN (18Cr-10Ni-Nb) Stainless Steels**

| TP347LN SS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 400 | 113.8 | | | | | |
| 410 | 113.4 | | | | | |
| 420 | 113.1 | | | | | |
| 430 | 112.8 | | | | | |
| 440 | 112.5 | | | | | |
| 450 | 112.3 | | | | | |
| 460 | 112.1 | | | | | |
| 470 | 111.9 | | | | | |
| 480 | 111.8 | | | | | |
| 490 | 111.7 | | | | | 6.8 |
| 500 | 111.5 | | | | | 6.7 |
| 510 | 111.4 | | | | | 6.5 |
| 520 | 111.3 | | | | | 6.3 |
| 530 | 111.2 | | | | | 6.2 |
| 540 | 111.1 | | | | | 6.0 |
| 550 | 110.9 | | | | | 5.9 |
| 560 | 110.7 | | | | | 5.7 |
| 570 | 110.5 | | | | | 5.6 |
| 580 | 110.3 | | | | | 5.4 |
| 590 | 110.0 | 120.2 | 132.6 | 143.3 | 163.2 | 5.3 |
| 600 | 109.7 | 107.4 | 118.8 | 128.6 | 147.0 | 5.1 |
| 610 | 109.3 | 95.7 | 106.2 | 115.2 | 132.2 | 5.0 |
| 620 | 108.9 | 85.2 | 94.8 | 103.1 | 118.7 | 4.9 |
| 630 | 108.3 | 75.7 | 84.5 | 92.0 | 106.4 | 4.7 |
| 640 | 107.7 | 67.1 | 75.1 | 82.1 | 95.2 | 4.6 |
| 650 | 107.1 | 59.4 | 66.7 | 73.0 | 85.0 | 4.5 |
| 660 | 106.3 | 52.4 | 59.1 | 64.8 | 75.8 | 4.4 |
| 670 | 105.4 | 46.2 | 52.2 | 57.5 | 67.5 | 4.2 |
| 680 | 104.5 | 40.6 | 46.1 | 50.8 | 60.0 | 4.1 |
| 694 | 103.4 | 33.8 | 38.5 | 42.7 | 50.7 | 4.0 |

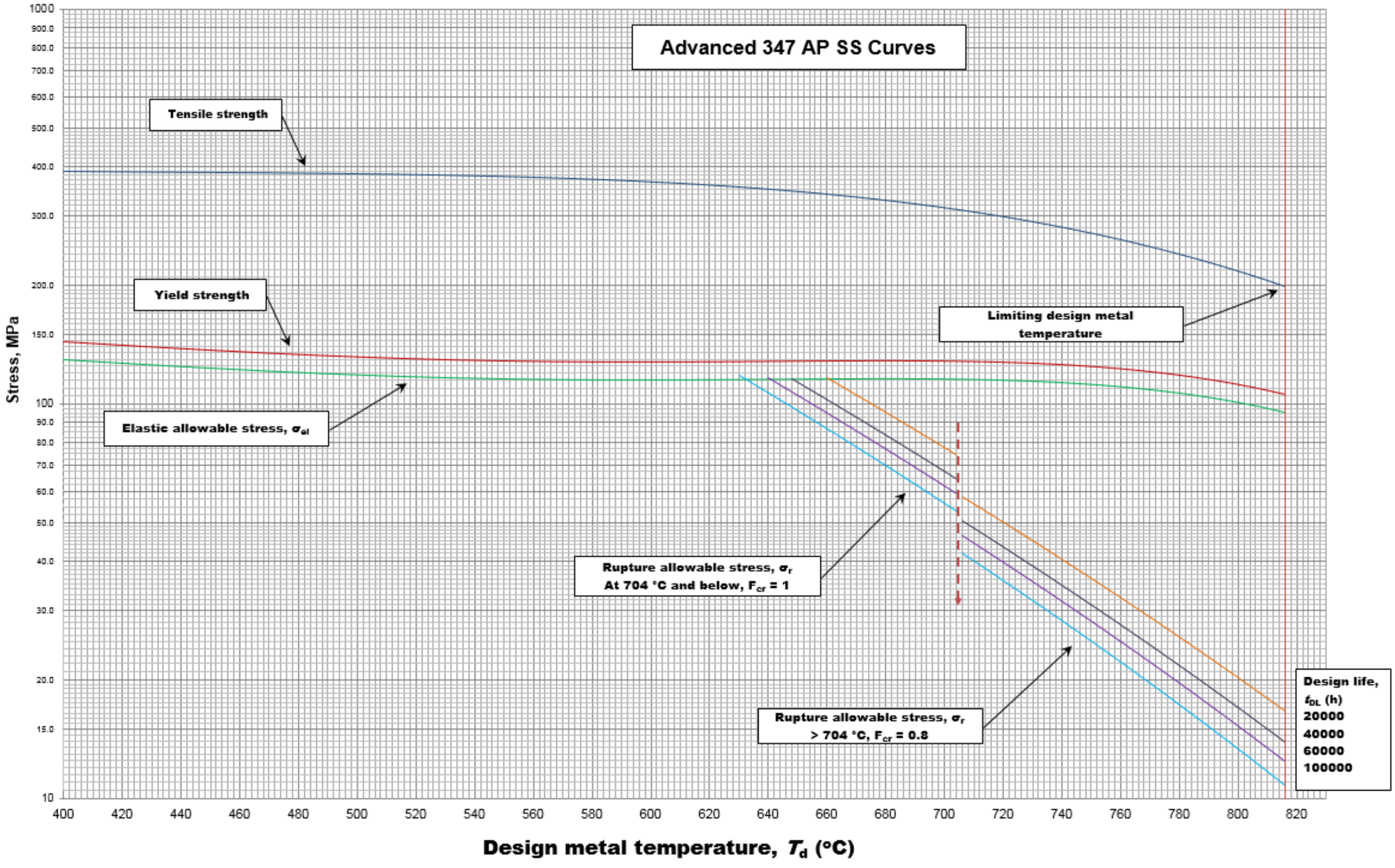



**Figure E.67—Stress Curves (SI Units) for ASTM A213 and ASTM A312 Advanced 347AP Stainless Steels**

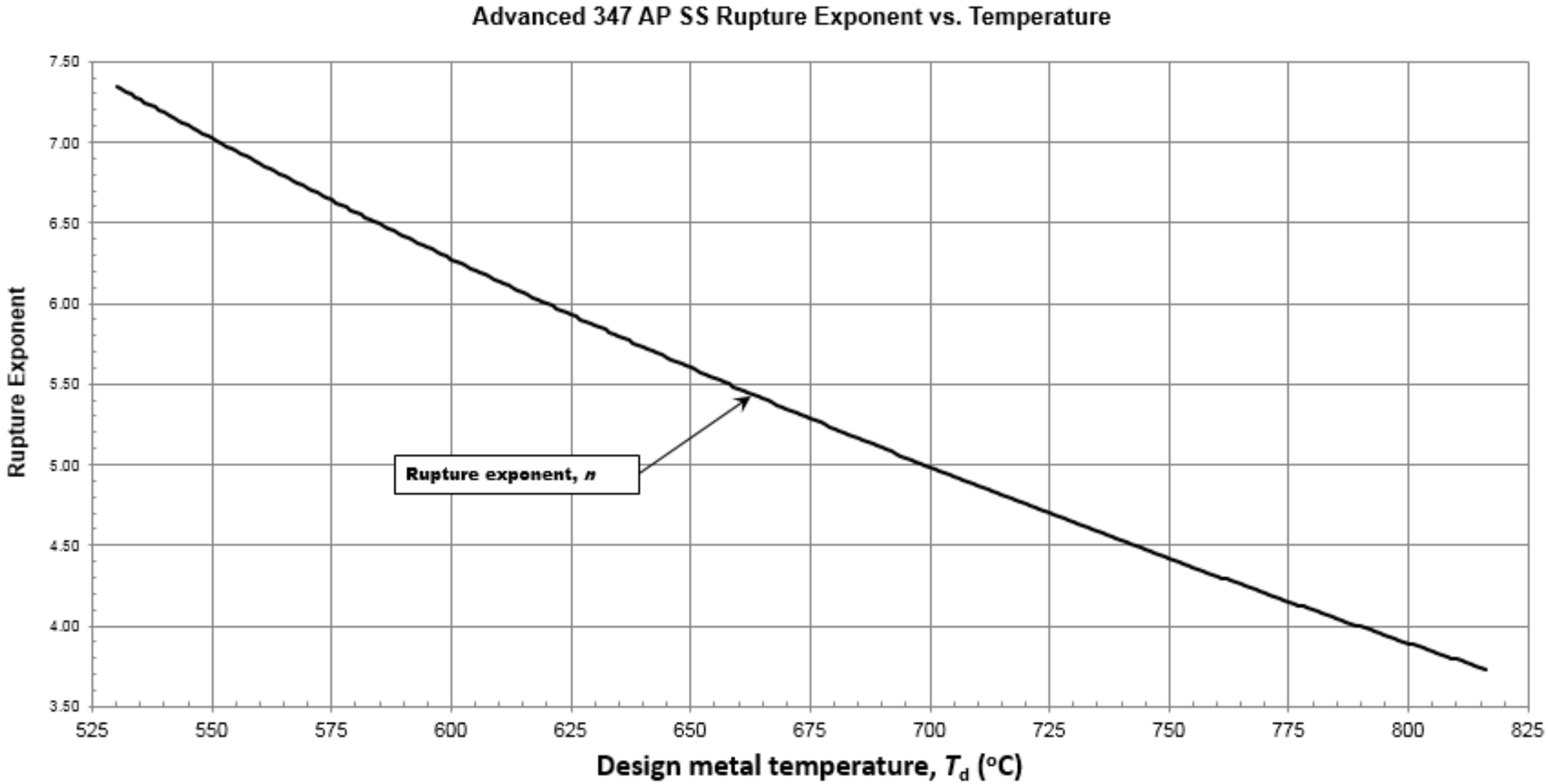



**Figure E.68—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213 and ASTM A312 Advanced 347AP Stainless Steels**

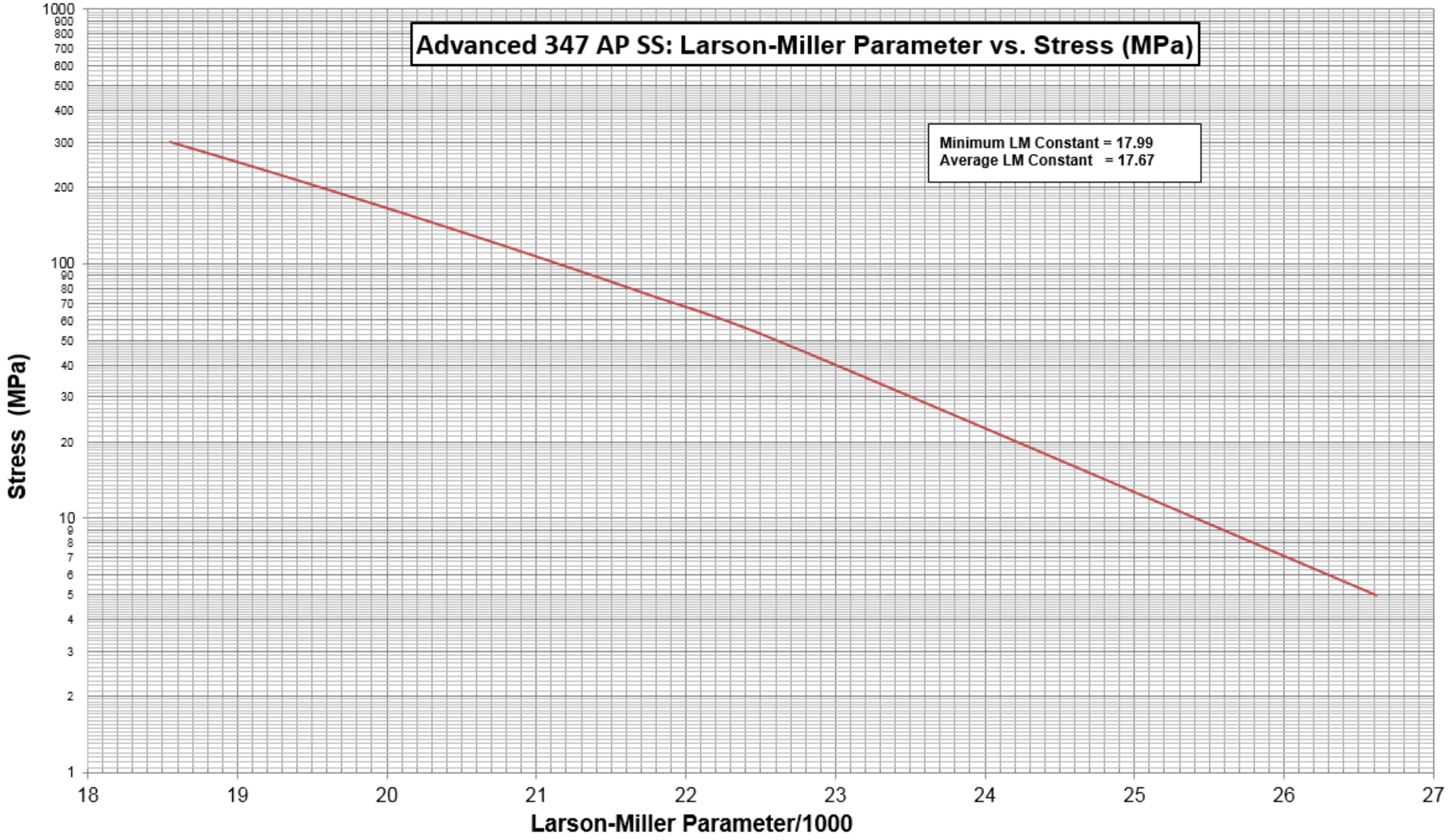



**Figure E.69—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213 and ASTM A312 Advanced 347AP Stainless Steels**

**Table E.23—Elastic, Rupture and Allowable Stresses for ASTM A213 and ASTM A312 Advanced 347AP Stainless Steels**

| Advanced 347 AP SS | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 400 | 129.8 | | | | | |
| 410 | 128.4 | | | | | |
| 420 | 127.1 | | | | | |
| 430 | 125.9 | | | | | |
| 440 | 124.7 | | | | | |
| 450 | 123.5 | | | | | |
| 460 | 122.4 | | | | | |
| 470 | 121.4 | | | | | |
| 480 | 120.5 | | | | | |
| 490 | 119.6 | | | | | |
| 500 | 118.8 | | | | | |
| 510 | 118.0 | | | | | |
| 520 | 117.4 | | | | | |
| 530 | 116.9 | | | | | 7.3 |
| 540 | 116.4 | 283.4 | 304.5 | 322.3 | 354.8 | 7.2 |
| 550 | 116.0 | 258.3 | 278.1 | 294.7 | 325.1 | 7.0 |
| 560 | 115.7 | 235.3 | 253.7 | 269.2 | 297.6 | 6.9 |
| 570 | 115.5 | 214.0 | 231.2 | 245.6 | 272.2 | 6.7 |
| 580 | 115.4 | 194.5 | 210.5 | 223.9 | 248.7 | 6.6 |
| 590 | 115.3 | 176.6 | 191.4 | 203.9 | 227.1 | 6.4 |
| 600 | 115.3 | 160.1 | 173.9 | 185.6 | 207.1 | 6.3 |
| 610 | 115.3 | 145.0 | 157.8 | 168.6 | 188.7 | 6.1 |
| 620 | 115.4 | 131.2 | 143.0 | 153.1 | 171.7 | 6.0 |
| 630 | 115.5 | 118.5 | 129.5 | 138.8 | 156.2 | 5.9 |
| 640 | 115.7 | 107.0 | 117.1 | 125.7 | 141.8 | 5.7 |
| 650 | 115.8 | 96.4 | 105.8 | 113.8 | 128.7 | 5.6 |
| 660 | 116.0 | 86.8 | 95.4 | 102.8 | 116.6 | 5.5 |
| 670 | 116.1 | 78.0 | 85.9 | 92.8 | 105.5 | 5.3 |
| 680 | 116.1 | 70.0 | 77.3 | 83.6 | 95.4 | 5.2 |
| 690 | 116.0 | 62.7 | 69.5 | 75.2 | 86.1 | 5.1 |
| 700 | 115.9 | 56.1 | 62.3 | 67.6 | 77.6 | 5.0 |
| 710 | 115.6 | 40.1 | 44.6 | 48.6 | 55.9 | 4.9 |
| 720 | 115.1 | 35.8 | 39.9 | 43.5 | 50.3 | 4.8 |
| 730 | 114.4 | 31.9 | 35.7 | 38.9 | 45.2 | 4.6 |
| 740 | 113.5 | 28.3 | 31.8 | 34.8 | 40.5 | 4.5 |
| 750 | 112.3 | 25.1 | 28.3 | 31.0 | 36.2 | 4.4 |
| 760 | 110.8 | 22.2 | 25.1 | 27.6 | 32.4 | 4.3 |
| 770 | 109.0 | 19.7 | 22.3 | 24.5 | 28.9 | 4.2 |
| 780 | 106.7 | 17.3 | 19.7 | 21.8 | 25.7 | 4.1 |
| 790 | 104.1 | 15.3 | 17.4 | 19.3 | 22.9 | 4.0 |
| 800 | 101.1 | 13.4 | 15.3 | 17.0 | 20.3 | 3.9 |
| 810 | 97.7 | 11.7 | 13.5 | 15.0 | 18.0 | 3.8 |
| 816 | 95.4 | 10.8 | 12.5 | 13.9 | 16.7 | 3.7 |

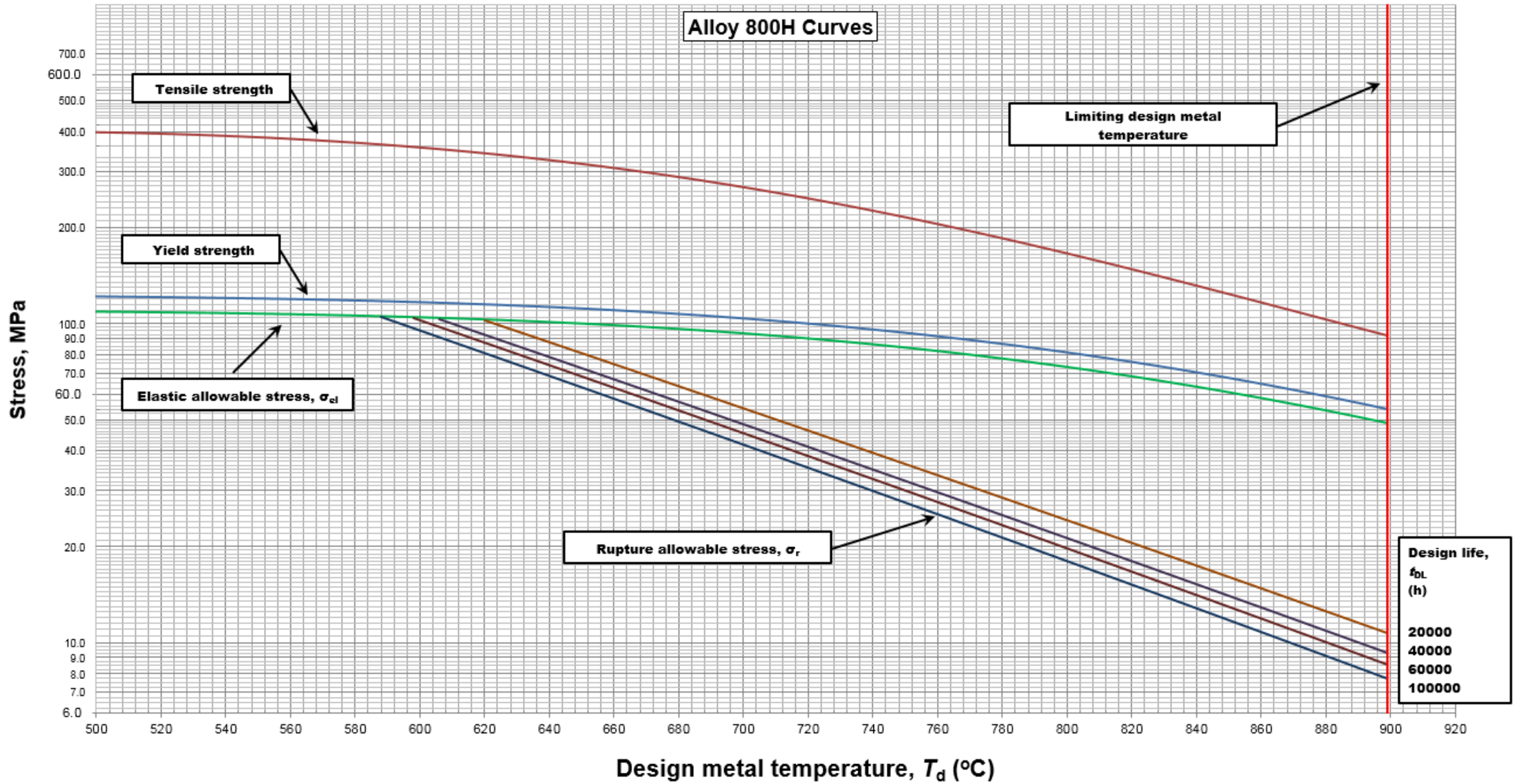



**Figure E.73—Stress Curves (SI Units) for ASTM B407 Alloy 800H Steels**

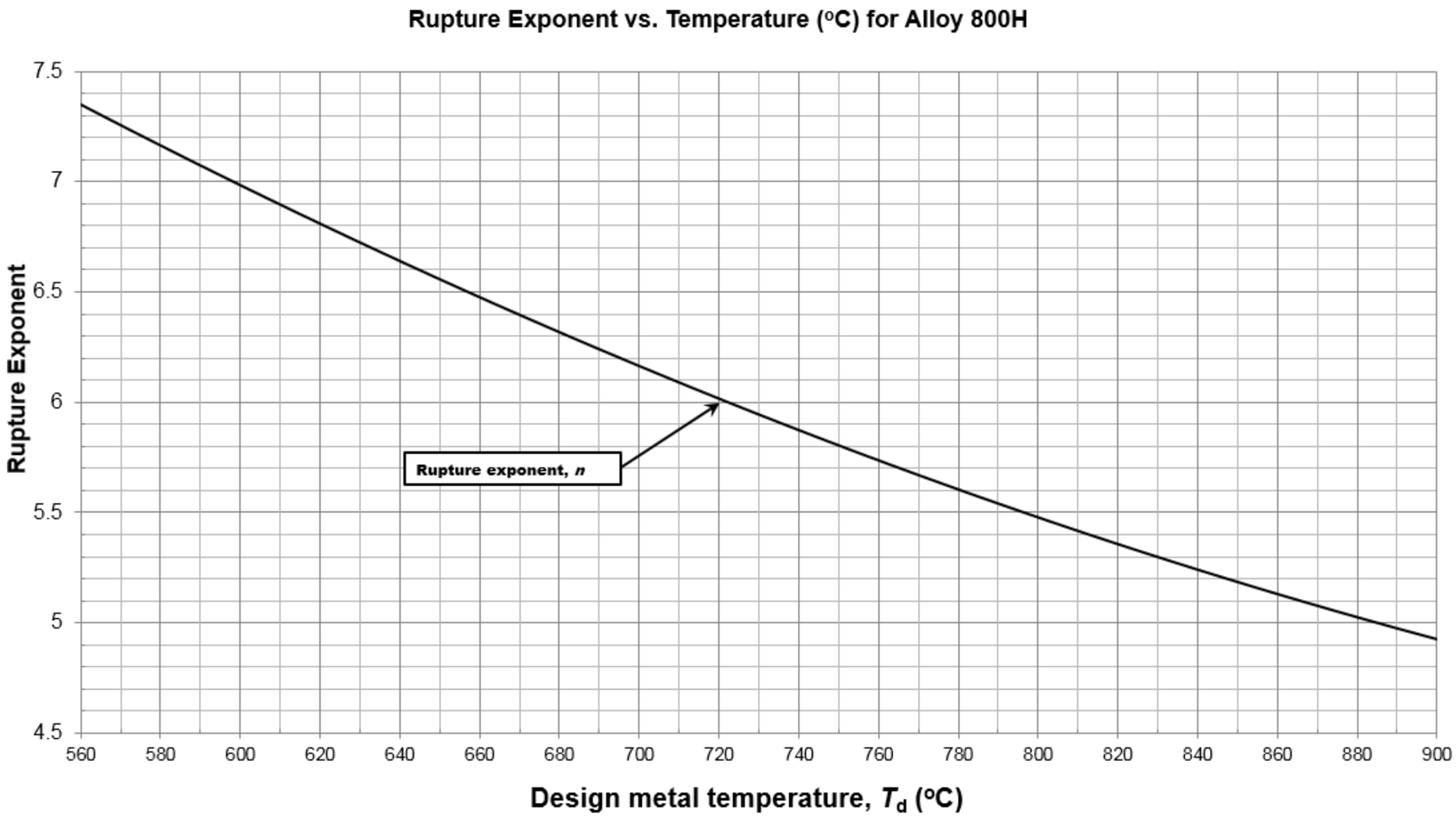



**Figure E.74—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM B407 Alloy 800H 5teels**

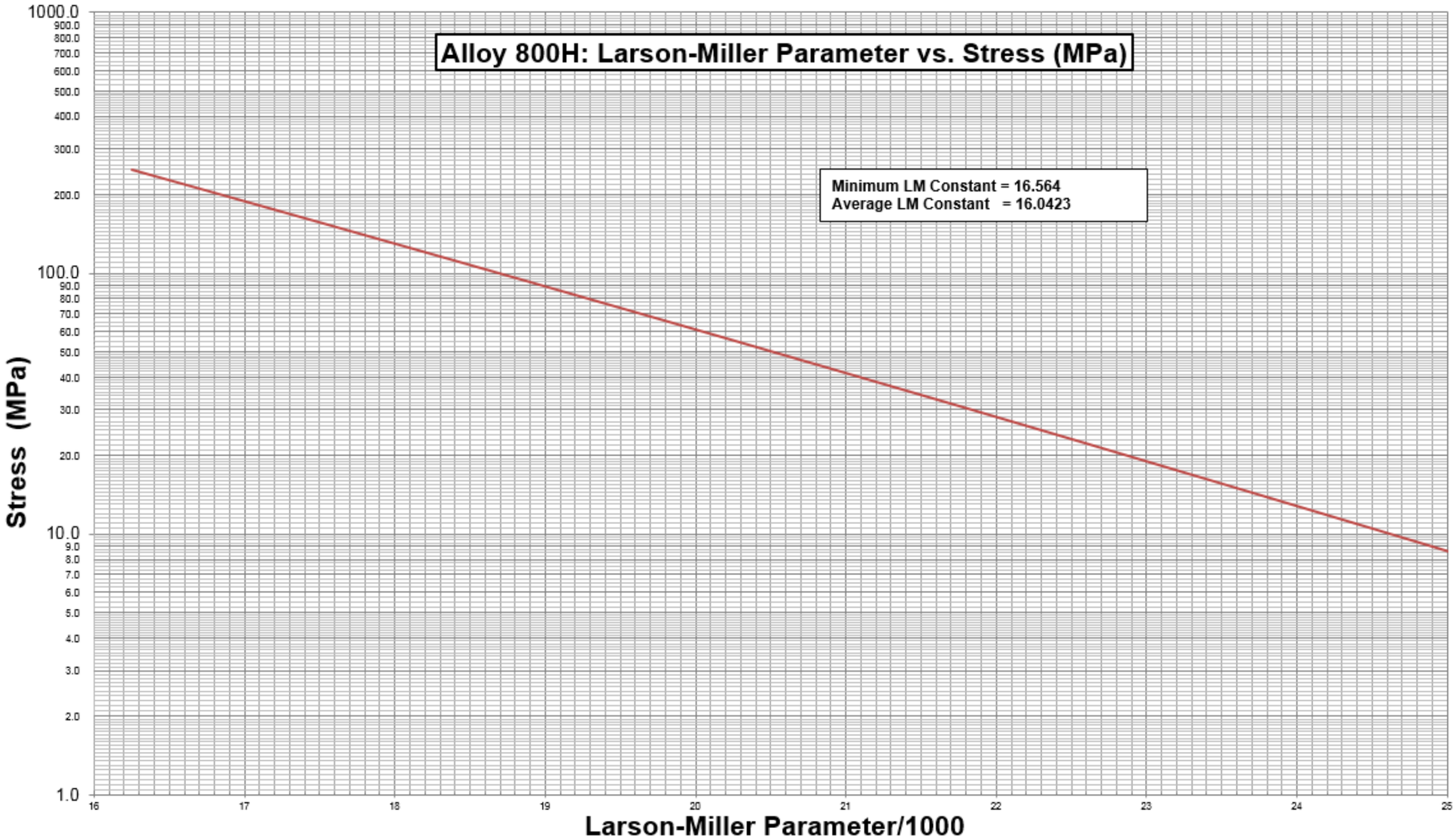



**Figure E.75—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM B407 Alloy 800H Steels**

**Table E.25—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM B407 Alloy 800H Steels**

| Alloy 800H | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 480 | 110.0 | | | | | |
| 490 | 109.8 | | | | | |
| 500 | 109.5 | | | | | |
| 510 | 109.3 | | | | | |
| 520 | 109.0 | | | | | |
| 530 | 108.7 | | | | | |
| 540 | 108.3 | | | | | 7.5 |
| 550 | 107.9 | | | | | 7.4 |
| 560 | 107.5 | | | | | 7.4 |
| 570 | 107.0 | | | | | 7.3 |
| 580 | 106.4 | 112.2 | 120.5 | 127.5 | 140.4 | 7.2 |
| 590 | 105.8 | 103.4 | 111.2 | 117.7 | 129.8 | 7.1 |
| 600 | 105.1 | 95.3 | 102.5 | 108.7 | 120.0 | 7.0 |
| 610 | 104.4 | 87.8 | 94.6 | 100.3 | 110.9 | 6.9 |
| 620 | 103.5 | 80.9 | 87.2 | 92.6 | 102.5 | 6.8 |
| 630 | 102.6 | 74.5 | 80.4 | 85.4 | 94.7 | 6.7 |
| 640 | 101.6 | 68.6 | 74.2 | 78.8 | 87.5 | 6.6 |
| 650 | 100.5 | 63.2 | 68.4 | 72.7 | 80.9 | 6.6 |
| 660 | 99.3 | 58.2 | 63.0 | 67.1 | 74.7 | 6.5 |
| 670 | 98.0 | 53.6 | 58.1 | 61.9 | 69.0 | 6.4 |
| 680 | 96.6 | 49.3 | 53.5 | 57.1 | 63.7 | 6.3 |
| 690 | 95.1 | 45.4 | 49.3 | 52.6 | 58.8 | 6.2 |
| 700 | 93.6 | 41.8 | 45.4 | 48.5 | 54.3 | 6.2 |
| 710 | 91.9 | 38.4 | 41.8 | 44.7 | 50.1 | 6.1 |
| 720 | 90.2 | 35.3 | 38.5 | 41.2 | 46.2 | 6.0 |
| 730 | 88.3 | 32.5 | 35.4 | 38.0 | 42.7 | 5.9 |
| 740 | 86.4 | 29.9 | 32.6 | 35.0 | 39.3 | 5.9 |
| 750 | 84.4 | 27.5 | 30.0 | 32.2 | 36.3 | 5.8 |
| 760 | 82.3 | 25.3 | 27.6 | 29.7 | 33.5 | 5.7 |
| 770 | 80.1 | 23.2 | 25.4 | 27.3 | 30.9 | 5.7 |
| 780 | 77.9 | 21.3 | 23.4 | 25.2 | 28.5 | 5.6 |
| 790 | 75.6 | 19.6 | 21.5 | 23.2 | 26.2 | 5.5 |
| 800 | 73.3 | 18.0 | 19.8 | 21.3 | 24.2 | 5.5 |
| 810 | 70.9 | 16.5 | 18.2 | 19.6 | 22.3 | 5.4 |
| 820 | 68.5 | 15.2 | 16.7 | 18.0 | 20.5 | 5.4 |
| 830 | 66.0 | 14.0 | 15.4 | 16.6 | 18.9 | 5.3 |
| 840 | 63.5 | 12.8 | 14.1 | 15.3 | 17.4 | 5.2 |
| 850 | 61.0 | 11.8 | 13.0 | 14.0 | 16.1 | 5.2 |
| 860 | 58.5 | 10.8 | 11.9 | 12.9 | 14.8 | 5.1 |
| 870 | 56.0 | 9.9 | 11.0 | 11.9 | 13.6 | 5.1 |
| 880 | 53.5 | 9.1 | 10.1 | 10.9 | 12.5 | 5.0 |
| 890 | 51.0 | 8.3 | 9.2 | 10.0 | 11.5 | 5.0 |
| 899 | 48.5 | 7.7 | 8.6 | 9.3 | 10.7 | 4.9 |

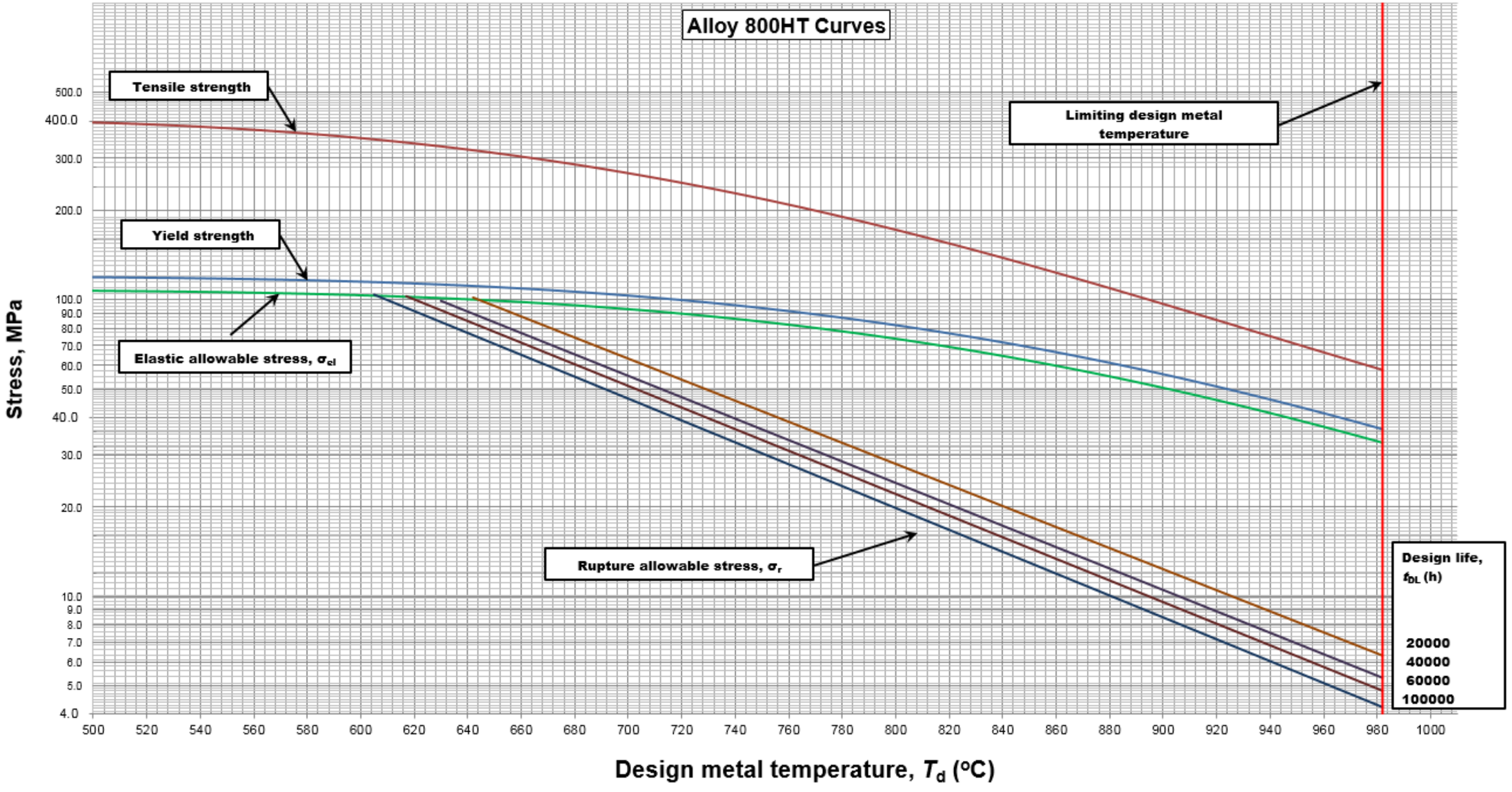



**Figure E.76—Stress Curves (SI Units) for ASTM B407, Alloy 800HT Steels**

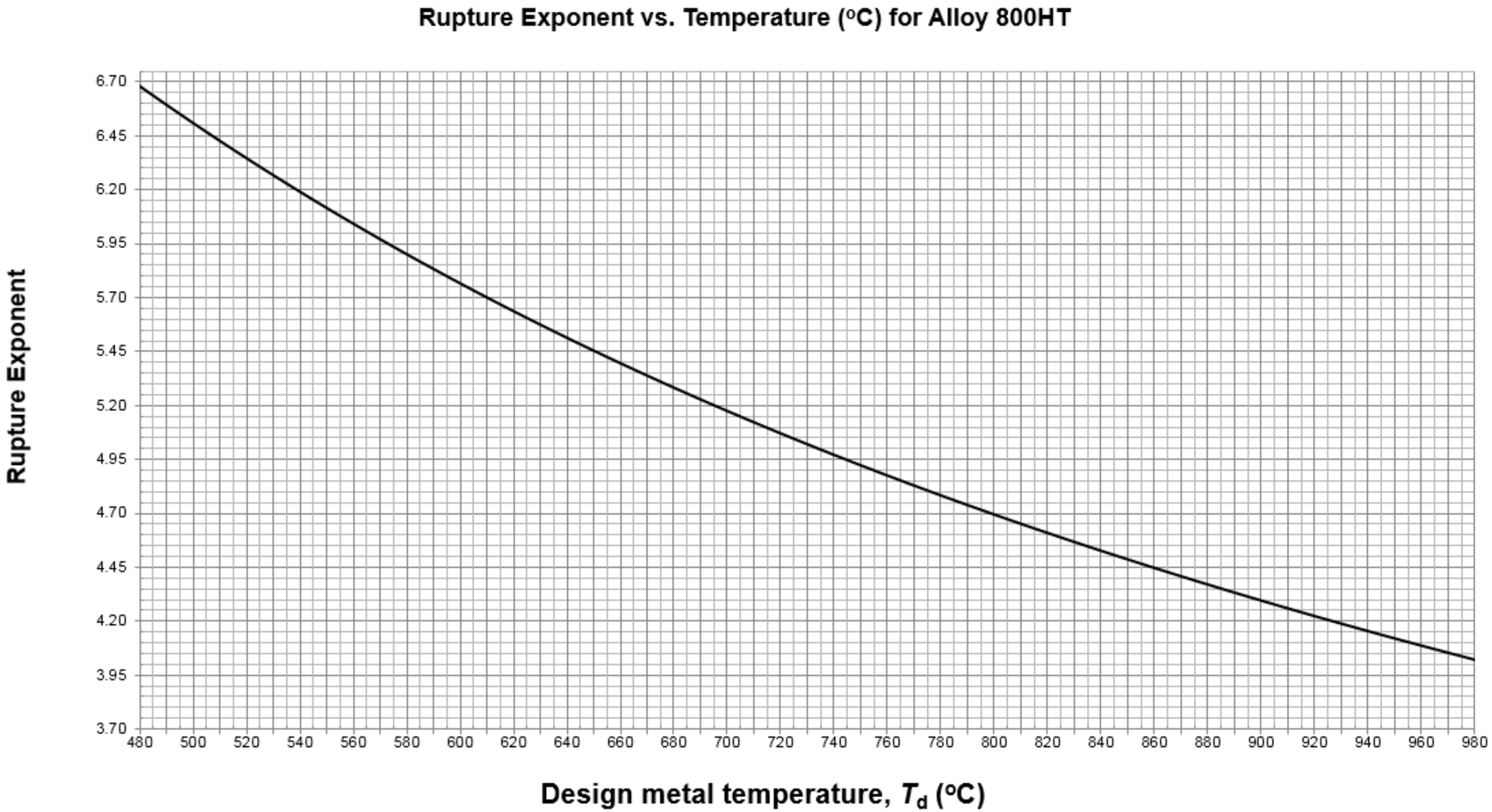



**Figure E.77—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM B407 Alloy 800HT Steels**

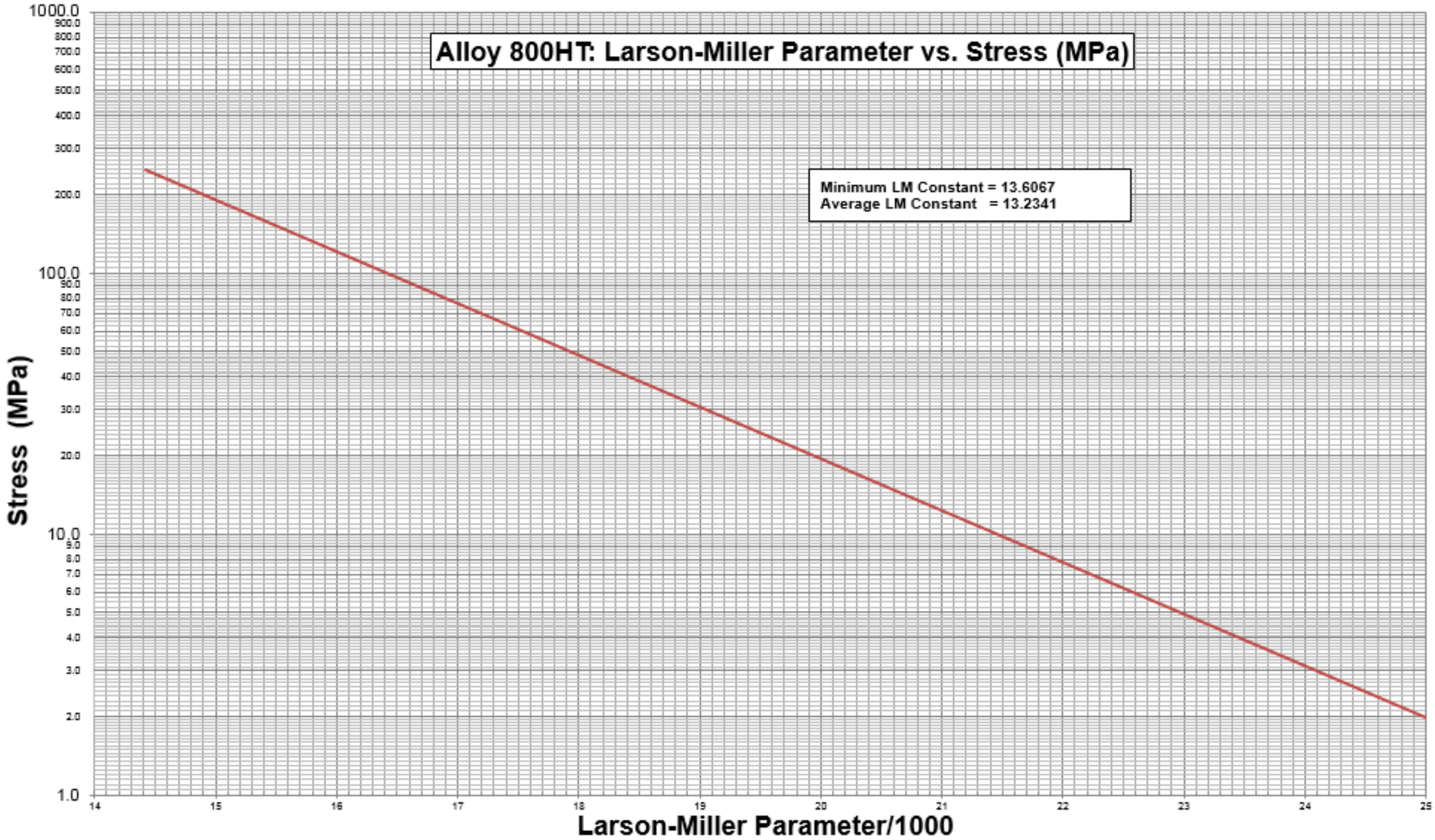



**Figure E.78—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM B407 Alloy 800HT Steels**

**Table E.26—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM B407 Alloy 800HT Steels**

| Alloy 800HT | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 480 | 107.4 | | | | | |
| 490 | 107.3 | | | | | 6.6 |
| 500 | 107.1 | | | | | 6.5 |
| 510 | 106.9 | | | | | 6.4 |
| 520 | 106.7 | | | | | 6.4 |
| 530 | 106.5 | | | | | 6.3 |
| 540 | 106.2 | | | | | 6.2 |
| 550 | 105.9 | | | | | 6.1 |
| 560 | 105.5 | | | | | 6.1 |
| 570 | 105.1 | | | | | 6.0 |
| 580 | 104.6 | | | | | 5.9 |
| 590 | 104.1 | | | | | 5.8 |
| 600 | 103.5 | 108.5 | 118.5 | 127.1 | 143.3 | 5.8 |
| 610 | 102.8 | 99.6 | 109.0 | 117.0 | 132.1 | 5.7 |
| 620 | 102.1 | 91.5 | 100.2 | 107.7 | 121.7 | 5.6 |
| 630 | 101.2 | 84.1 | 92.1 | 99.1 | 112.2 | 5.6 |
| 640 | 100.3 | 77.2 | 84.7 | 91.2 | 103.4 | 5.5 |
| 650 | 99.3 | 70.9 | 77.9 | 83.9 | 95.2 | 5.5 |
| 660 | 98.2 | 65.2 | 71.6 | 77.2 | 87.8 | 5.4 |
| 670 | 97.0 | 59.9 | 65.9 | 71.1 | 80.9 | 5.3 |
| 680 | 95.7 | 55.0 | 60.6 | 65.4 | 74.5 | 5.3 |
| 690 | 94.4 | 50.5 | 55.7 | 60.2 | 68.7 | 5.2 |
| 700 | 92.9 | 46.4 | 51.2 | 55.4 | 63.3 | 5.2 |
| 710 | 91.4 | 42.6 | 47.1 | 51.0 | 58.3 | 5.1 |
| 720 | 89.7 | 39.2 | 43.3 | 46.9 | 53.8 | 5.1 |
| 730 | 88.0 | 36.0 | 39.8 | 43.2 | 49.5 | 5.0 |
| 740 | 86.2 | 33.0 | 36.6 | 39.7 | 45.6 | 5.0 |
| 750 | 84.3 | 30.3 | 33.7 | 36.5 | 42.1 | 4.9 |
| 760 | 82.3 | 27.9 | 31.0 | 33.6 | 38.8 | 4.9 |
| 770 | 80.3 | 25.6 | 28.5 | 31.0 | 35.7 | 4.8 |
| 780 | 78.2 | 23.5 | 26.2 | 28.5 | 32.9 | 4.8 |
| 790 | 76.1 | 21.6 | 24.1 | 26.2 | 30.3 | 4.7 |
| 800 | 73.8 | 19.9 | 22.1 | 24.1 | 28.0 | 4.7 |
| 810 | 71.6 | 18.2 | 20.3 | 22.2 | 25.8 | 4.7 |
| 820 | 69.3 | 16.7 | 18.7 | 20.4 | 23.7 | 4.6 |
| 830 | 67.0 | 15.4 | 17.2 | 18.8 | 21.9 | 4.6 |
| 840 | 64.6 | 14.1 | 15.8 | 17.3 | 20.2 | 4.5 |
| 850 | 62.2 | 13.0 | 14.5 | 15.9 | 18.6 | 4.5 |
| 860 | 59.9 | 11.9 | 13.4 | 14.7 | 17.1 | 4.5 |
| 870 | 57.5 | 11.0 | 12.3 | 13.5 | 15.8 | 4.4 |
| 880 | 55.1 | 10.1 | 11.3 | 12.4 | 14.5 | 4.4 |
| 890 | 52.8 | 9.2 | 10.4 | 11.4 | 13.4 | 4.3 |
| 900 | 50.4 | 8.5 | 9.6 | 10.5 | 12.3 | 4.3 |
| 910 | 48.1 | 7.8 | 8.8 | 9.7 | 11.4 | 4.3 |
| 920 | 45.9 | 7.2 | 8.1 | 8.9 | 10.5 | 4.2 |
| 930 | 43.6 | 6.6 | 7.4 | 8.2 | 9.7 | 4.2 |
| 940 | 41.5 | 6.0 | 6.8 | 7.5 | 8.9 | 4.2 |
| 950 | 39.3 | 5.6 | 6.3 | 6.9 | 8.2 | 4.1 |
| 960 | 37.3 | 5.1 | 5.8 | 6.4 | 7.6 | 4.1 |
| 970 | 35.3 | 4.7 | 5.3 | 5.9 | 7.0 | 4.1 |
| 980 | 33.3 | 4.3 | 4.9 | 5.4 | 6.4 | 4.0 |

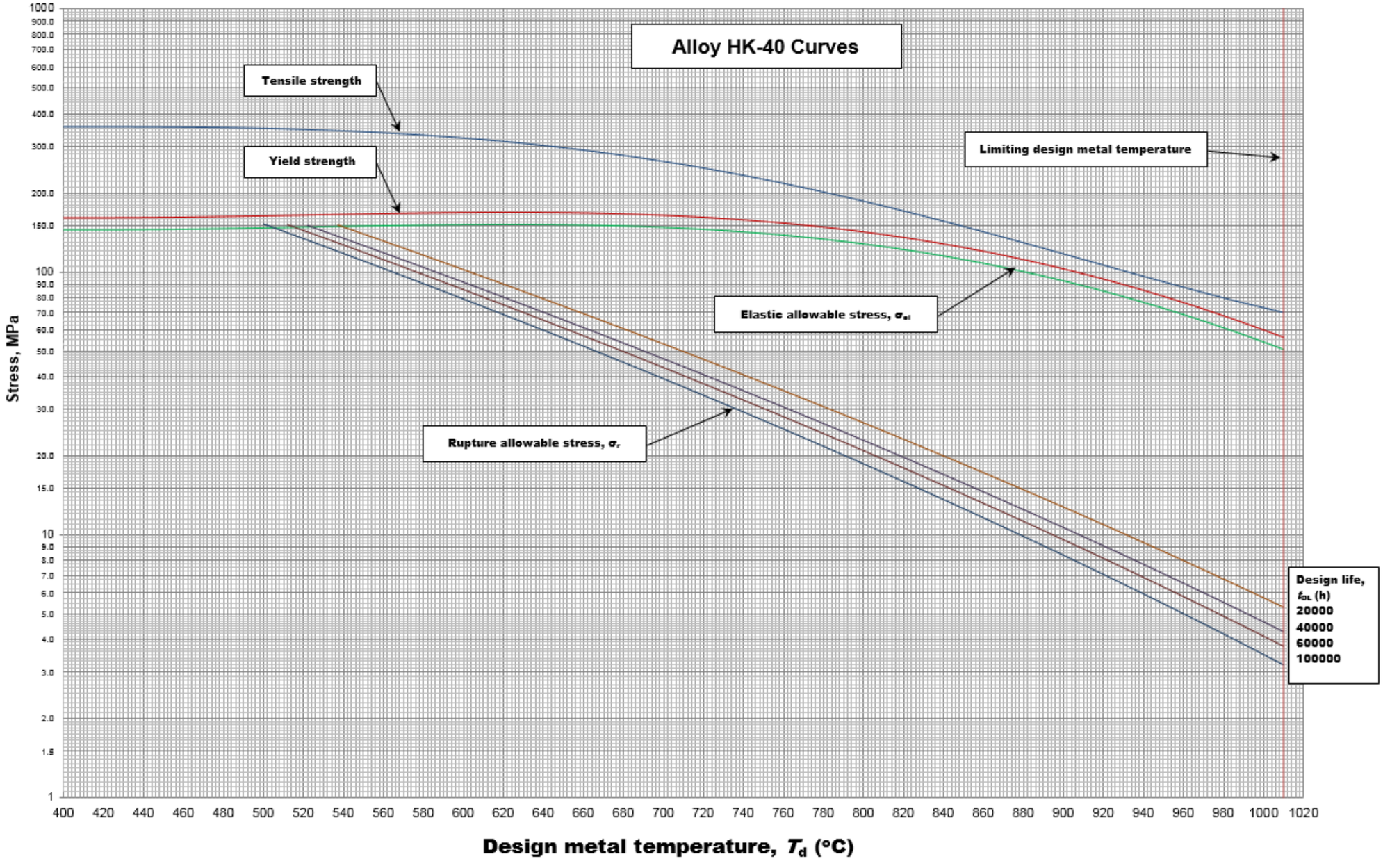



**Figure E.79 – Stress Curves (SI Units) for ASTM A608 Grade HK-40 Steels**

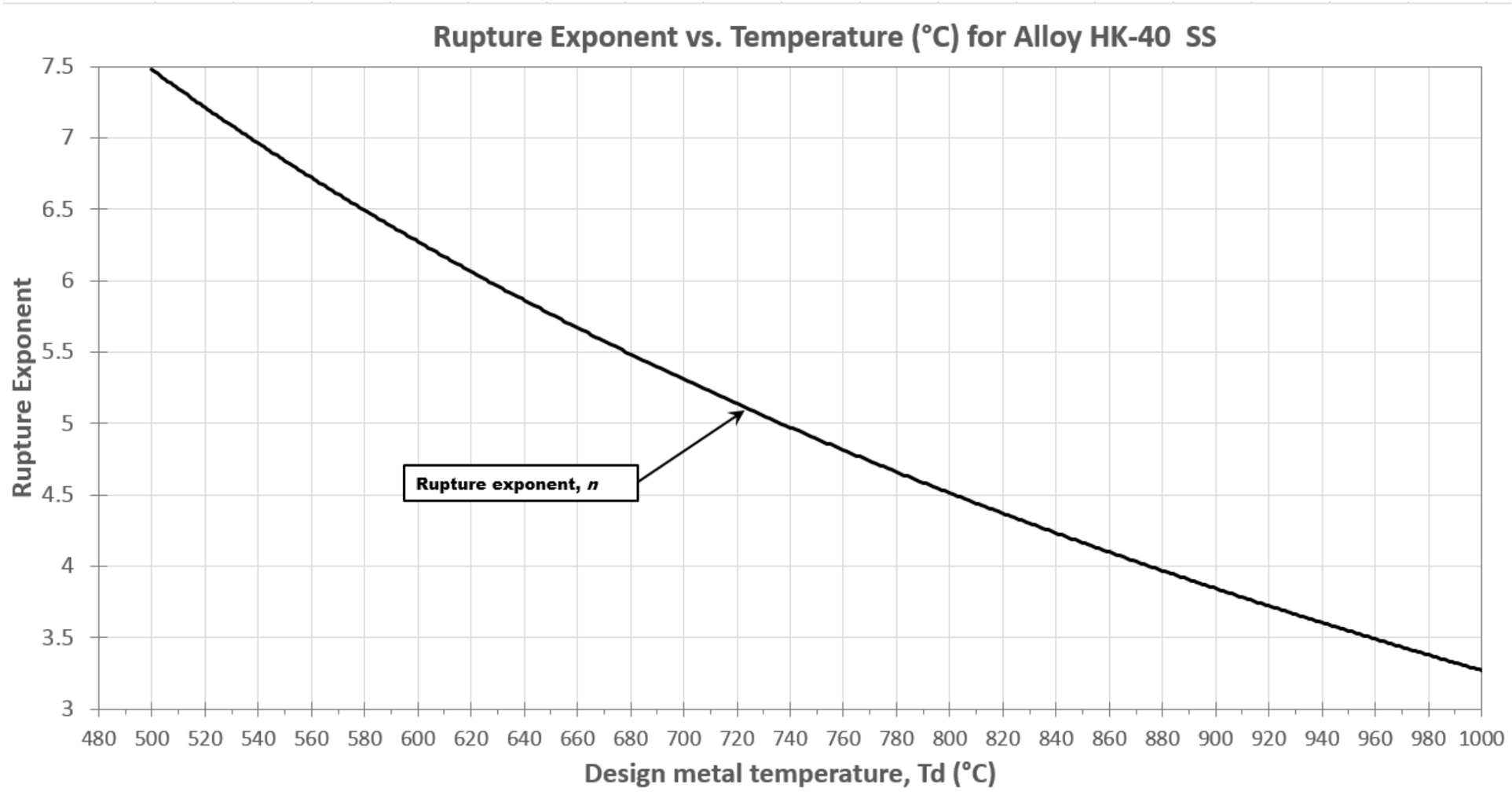



**Figure E.80 – Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A608 Grade HK-40 Steels**

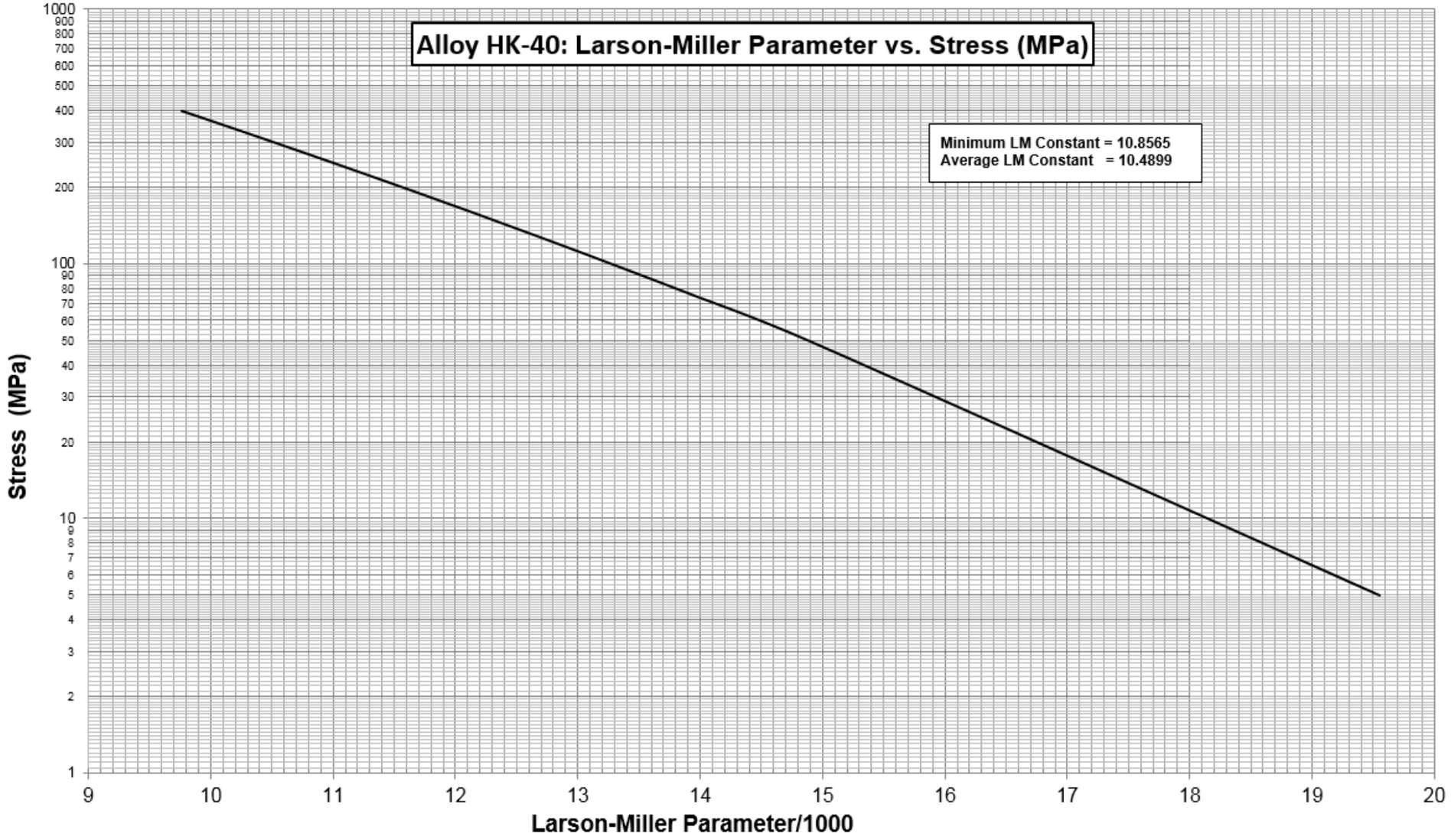



**Figure E.81 – Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A608 Grade HK-40 Steels**

**Table E.27 – Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A608 Grade HK-40 Steels**

| Alloy HK-40 | | | | | | |
|---|---|---|---|---|---|---|
| Design Metal Temperature, $T_d$ (Centigrade) | Elastic Allowable Stress, $\sigma_{el}$ (MPa) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (MPa) | $t_{DL}$ = 60,000 h (MPa) | $t_{DL}$ = 40,000 h (MPa) | $t_{DL}$ = 20,000 h (MPa) | |
| 500 | 146.9 | 152.1 | 162.9 | 172.1 | 188.7 | 7.12 |
| 510 | 147.4 | 142.6 | 153.0 | 161.7 | 177.7 | 7.02 |
| 520 | 147.9 | 133.7 | 143.6 | 152.0 | 167.3 | 6.92 |
| 530 | 148.4 | 125.3 | 134.8 | 142.8 | 157.4 | 6.82 |
| 540 | 148.9 | 117.4 | 126.5 | 134.1 | 148.1 | 6.72 |
| 550 | 149.4 | 110.0 | 118.6 | 125.9 | 139.3 | 6.62 |
| 560 | 149.8 | 103.0 | 111.2 | 118.1 | 130.9 | 6.53 |
| 570 | 150.2 | 96.4 | 104.2 | 110.8 | 123.1 | 6.43 |
| 580 | 150.6 | 90.1 | 97.6 | 103.9 | 115.6 | 6.34 |
| 590 | 150.9 | 84.3 | 91.4 | 97.4 | 108.6 | 6.24 |
| 600 | 151.2 | 78.8 | 85.6 | 91.3 | 101.9 | 6.2 |
| 610 | 151.4 | 73.6 | 80.1 | 85.5 | 95.7 | 6.1 |
| 620 | 151.4 | 68.8 | 74.9 | 80.1 | 89.8 | 6.0 |
| 630 | 151.4 | 64.2 | 70.0 | 75.0 | 84.2 | 5.9 |
| 640 | 151.3 | 59.9 | 65.4 | 70.1 | 78.9 | 5.8 |
| 650 | 151.0 | 55.9 | 61.1 | 65.6 | 74.0 | 5.7 |
| 660 | 150.7 | 52.1 | 57.1 | 61.3 | 69.3 | 5.6 |
| 670 | 150.1 | 48.6 | 53.3 | 57.3 | 64.9 | 5.5 |
| 680 | 149.5 | 45.2 | 49.7 | 53.6 | 60.7 | 5.4 |
| 690 | 148.6 | 42.1 | 46.4 | 50.0 | 56.8 | 5.4 |
| 700 | 147.6 | 39.2 | 43.2 | 46.7 | 53.2 | 5.3 |
| 710 | 146.5 | 36.5 | 40.3 | 43.6 | 49.7 | 5.2 |
| 720 | 145.1 | 33.9 | 37.5 | 40.6 | 46.5 | 5.1 |
| 730 | 143.6 | 31.5 | 34.9 | 37.9 | 43.4 | 5.0 |
| 740 | 141.9 | 29.3 | 32.5 | 35.3 | 40.5 | 5.0 |
| 750 | 140.0 | 27.2 | 30.2 | 32.9 | 37.8 | 4.9 |
| 760 | 137.9 | 25.2 | 28.1 | 30.6 | 35.3 | 4.8 |
| 770 | 135.6 | 23.4 | 26.1 | 28.5 | 32.9 | 4.7 |
| 780 | 133.1 | 21.7 | 24.3 | 26.5 | 30.7 | 4.7 |
| 790 | 130.5 | 20.1 | 22.5 | 24.6 | 28.6 | 4.6 |
| 800 | 127.7 | 18.6 | 20.9 | 22.9 | 26.6 | 4.5 |
| 810 | 124.7 | 17.2 | 19.4 | 21.2 | 24.8 | 4.4 |
| 820 | 121.6 | 15.9 | 17.9 | 19.7 | 23.1 | 4.4 |
| 830 | 118.3 | 14.7 | 16.6 | 18.3 | 21.5 | 4.3 |
| 840 | 114.9 | 13.6 | 15.4 | 17.0 | 20.0 | 4.2 |
| 850 | 111.4 | 12.6 | 14.2 | 15.7 | 18.5 | 4.2 |
| 860 | 107.7 | 11.6 | 13.2 | 14.5 | 17.2 | 4.1 |
| 870 | 104.0 | 10.7 | 12.2 | 13.5 | 16.0 | 4.0 |
| 880 | 100.2 | 9.9 | 11.2 | 12.5 | 14.8 | 4.0 |
| 890 | 96.3 | 9.1 | 10.4 | 11.5 | 13.7 | 3.9 |
| 900 | 92.4 | 8.4 | 9.6 | 10.6 | 12.7 | 3.8 |
| 910 | 88.4 | 7.7 | 8.8 | 9.8 | 11.8 | 3.8 |
| 920 | 84.5 | 7.1 | 8.1 | 9.1 | 10.9 | 3.7 |
| 930 | 80.5 | 6.5 | 7.5 | 8.4 | 10.1 | 3.7 |
| 940 | 76.5 | 6.0 | 6.9 | 7.7 | 9.3 | 3.6 |
| 950 | 72.6 | 5.5 | 6.3 | 7.1 | 8.6 | 3.5 |
| 960 | 68.8 | 5.0 | 5.8 | 6.5 | 8.0 | 3.5 |
| 970 | 65.0 | 4.6 | 5.3 | 6.0 | 7.4 | 3.4 |
| 980 | 61.3 | 4.2 | 4.9 | 5.5 | 6.8 | 3.4 |
| 990 | 57.6 | 3.8 | 4.5 | 5.1 | 6.3 | 3.3 |
| 1000 | 54.1 | 3.5 | 4.1 | 4.7 | 5.8 | 3.3 |
| 1010 | 50.7 | 3.2 | 3.8 | 4.3 | 5.3 | 3.2 |

*Annex F, List of Stress Curves and Data Tables (USC Units): The titles of the indicated figures and tables shall be changed to align with updated and new materials in Table 6 as follows:*

## List of Figures and Tables (USC Units)

### Low-carbon Steels



**1-1/4Cr-1/2Moly Steels**



**9Cr-1Moly Steels**



**9Cr-1Moly-V Steels**



**9Cr-2Si-1Cu Steels (Grade 921)**

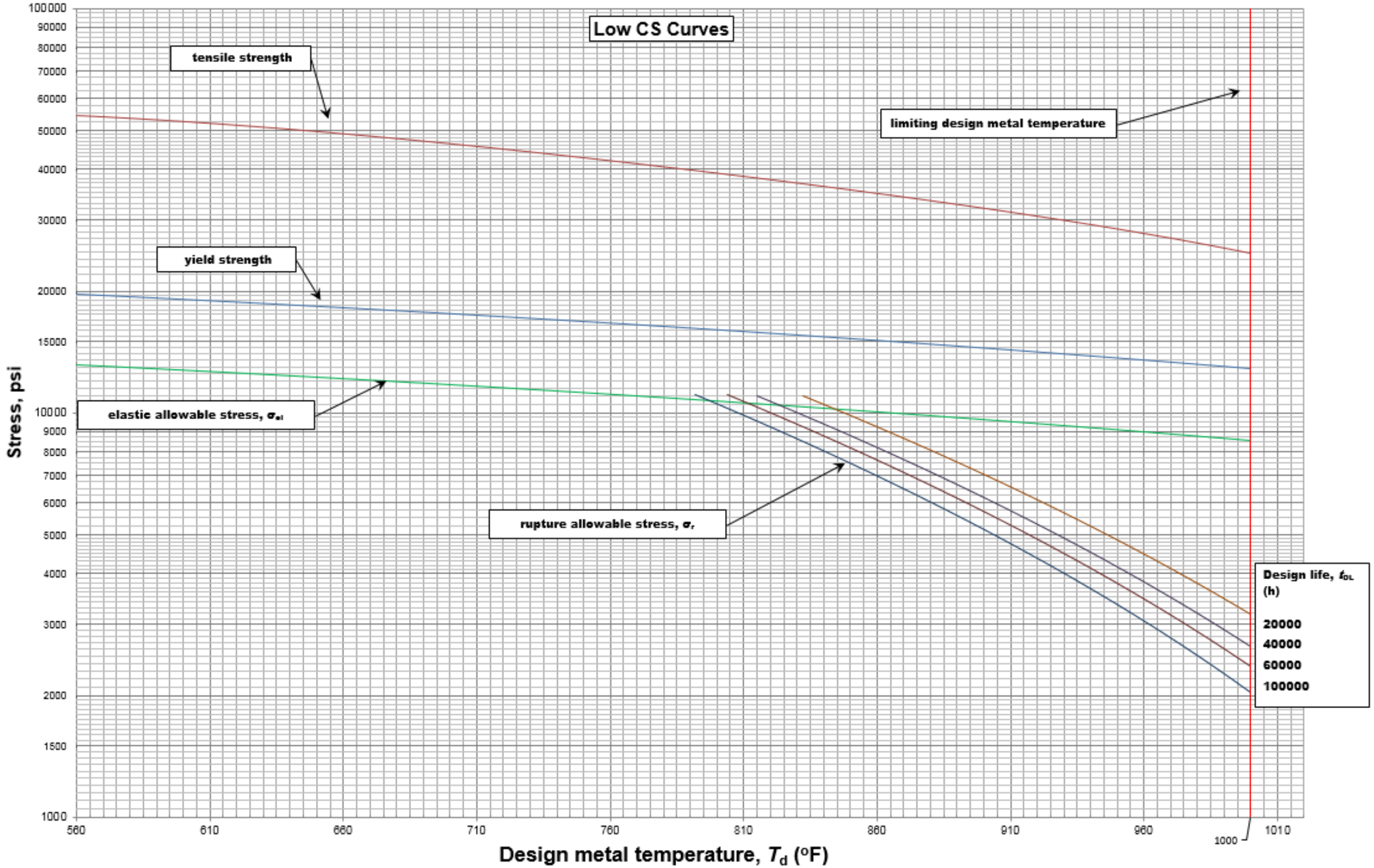



**Figure F.1—Stress Curves (USC Units) for ASTM A192 Low-carbon Steels**

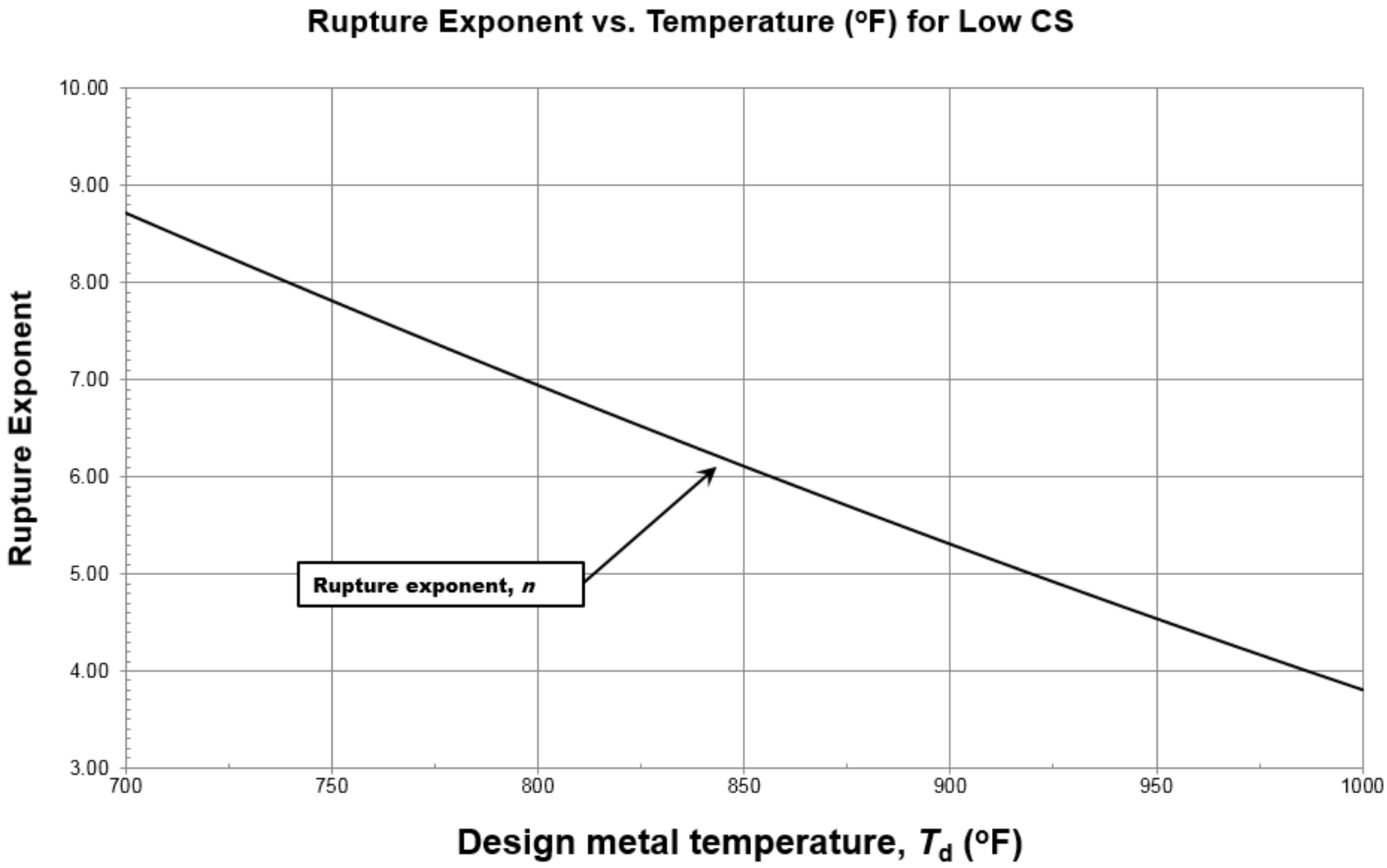



**Figure F.2—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A192 Low-carbon Steels**

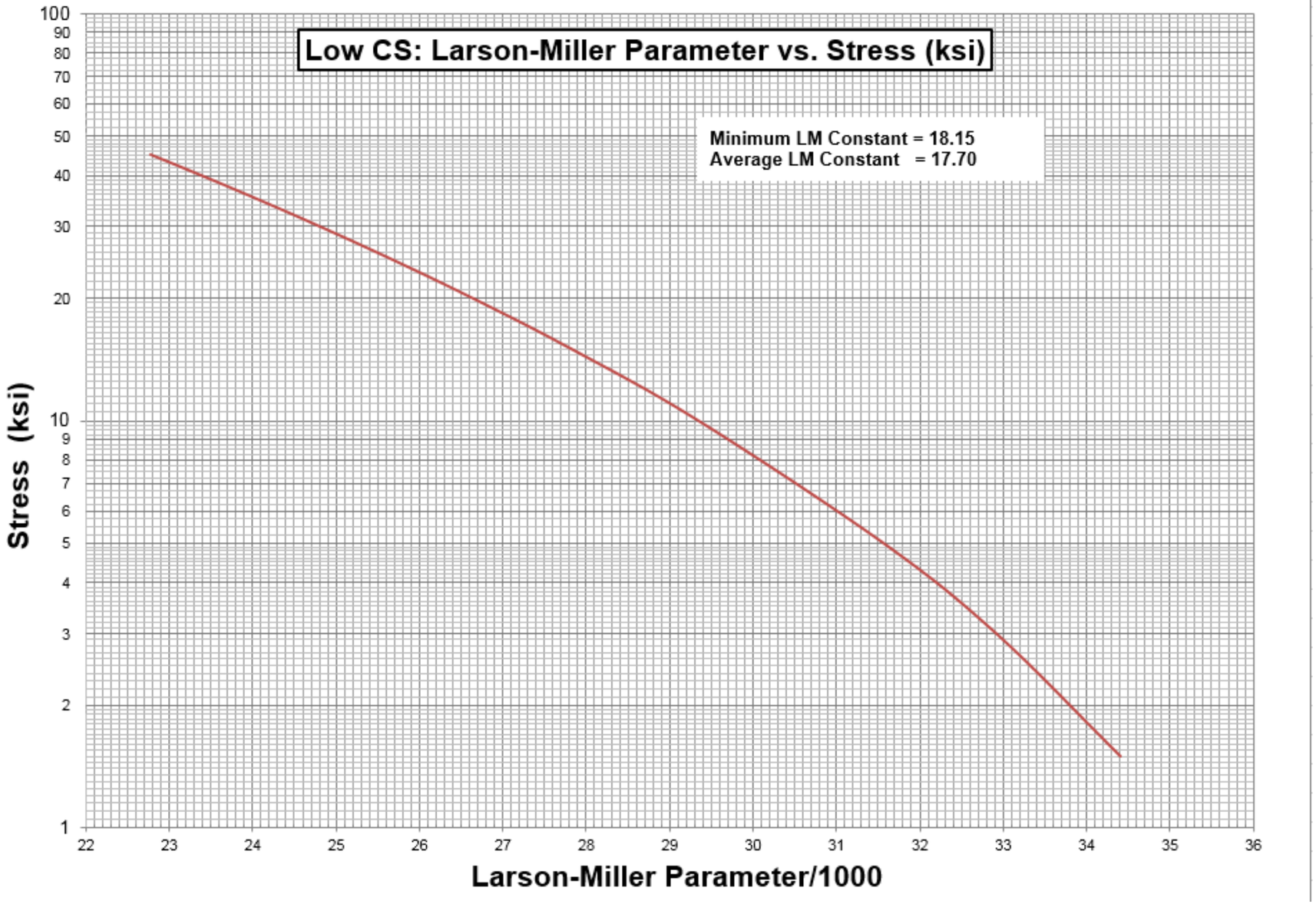



**Figure F.3—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A192 Low-carbon Steels**

**Table F.1—Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A192 Low-carbon Steels**

| Low CS | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 640 | 12.3 | | | | | |
| 650 | 12.2 | | | | | |
| 660 | 12.1 | | | | | |
| 670 | 12.0 | | | | | |
| 680 | 11.9 | | | | | |
| 690 | 11.8 | | | | | |
| 700 | 11.7 | | | | | |
| 710 | 11.6 | | | | | |
| 720 | 11.5 | | | | | |
| 730 | 11.4 | | | | | |
| 740 | 11.3 | | | | | 8.0 |
| 750 | 11.2 | 14.3 | | | | 7.8 |
| 760 | 11.1 | 13.5 | | | | 7.6 |
| 770 | 11.0 | 12.7 | 13.6 | | | 7.5 |
| 780 | 10.9 | 11.9 | 12.8 | | | 7.3 |
| 790 | 10.8 | 11.2 | 12.1 | 12.8 | | 7.1 |
| 800 | 10.7 | 10.5 | 11.4 | 12.1 | | 6.9 |
| 810 | 10.6 | 9.9 | 10.7 | 11.3 | 12.6 | 6.8 |
| 820 | 10.5 | 9.2 | 10.0 | 0.0 | 11.8 | 6.6 |
| 830 | 10.4 | 8.6 | 9.4 | 10.0 | 11.1 | 6.4 |
| 840 | 10.3 | 8.1 | 8.8 | 9.4 | 10.5 | 6.3 |
| 850 | 10.2 | 7.5 | 8.2 | 8.8 | 9.8 | 6.1 |
| 860 | 10.1 | 7.0 | 7.6 | 8.2 | 9.2 | 5.9 |
| 870 | 10.0 | 6.5 | 7.1 | 7.7 | 8.6 | 5.8 |
| 880 | 9.8 | 6.0 | 6.6 | 7.1 | 8.1 | 5.6 |
| 890 | 9.7 | 5.6 | 6.2 | 6.6 | 7.5 | 5.5 |
| 900 | 9.6 | 5.2 | 5.7 | 6.2 | 7.0 | 5.3 |
| 910 | 9.5 | 4.8 | 5.3 | 5.7 | 6.6 | 5.2 |
| 920 | 0.0 | 4.4 | 4.9 | 5.3 | 6.1 | 5.0 |
| 930 | 9.3 | 4.0 | 4.5 | 4.9 | 5.7 | 4.8 |
| 940 | 9.2 | 3.7 | 4.1 | 4.5 | 5.2 | 4.7 |
| 950 | 9.1 | 3.4 | 3.8 | 4.2 | 4.9 | 4.5 |
| 960 | 9.0 | 3.1 | 3.5 | 3.8 | 4.5 | 4.4 |
| 970 | 8.9 | 2.8 | 3.2 | 3.5 | 4.1 | 4.2 |
| 980 | 8.8 | 2.5 | 2.9 | 3.2 | 3.8 | 4.1 |
| 990 | 8.7 | 2.3 | 2.6 | 2.9 | 3.5 | 3.9 |
| 1000 | 8.6 | 2.0 | 2.4 | 2.7 | 7.0 | 3.8 |

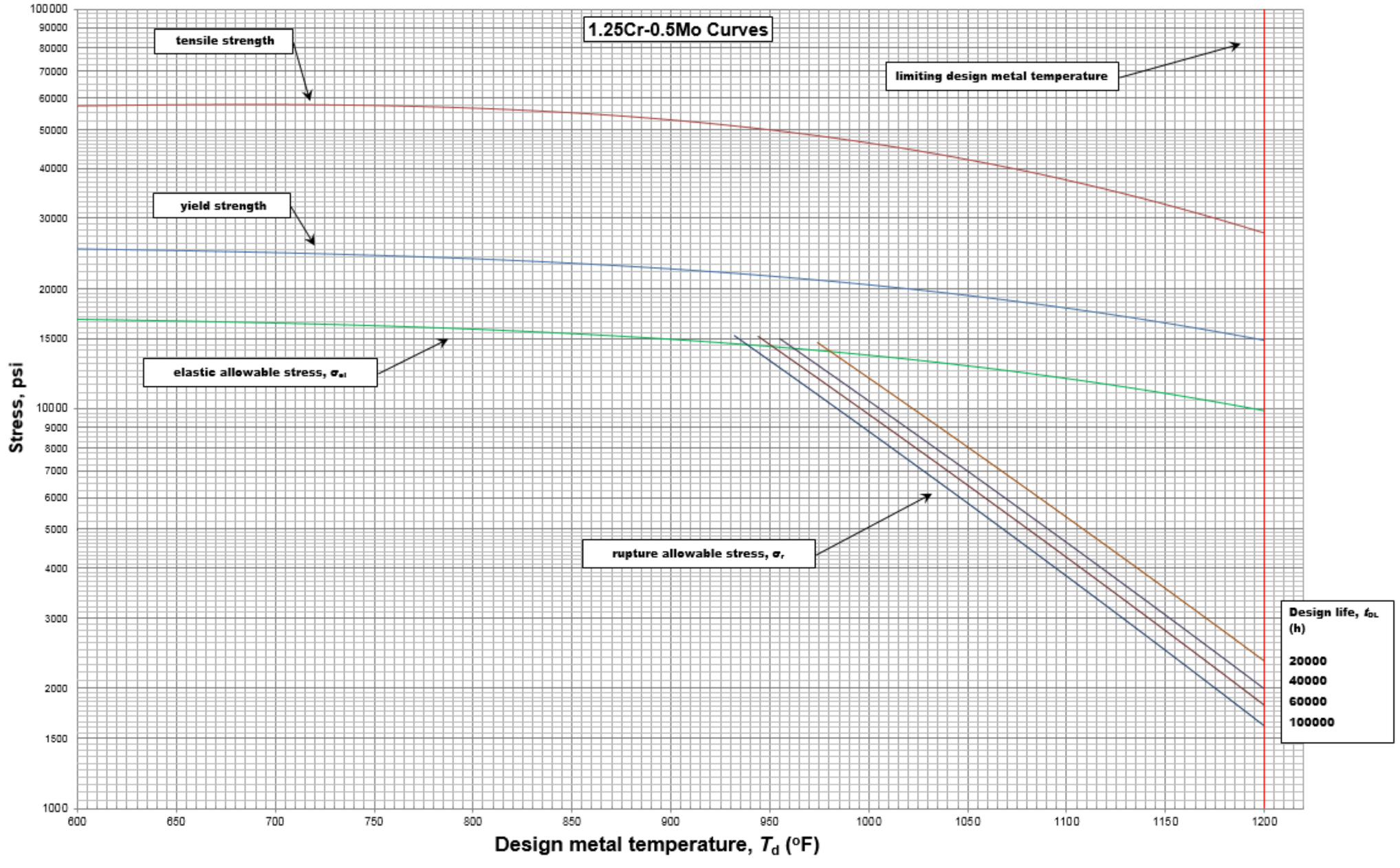



**Figure F.10—Stress Curves (USC Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels**

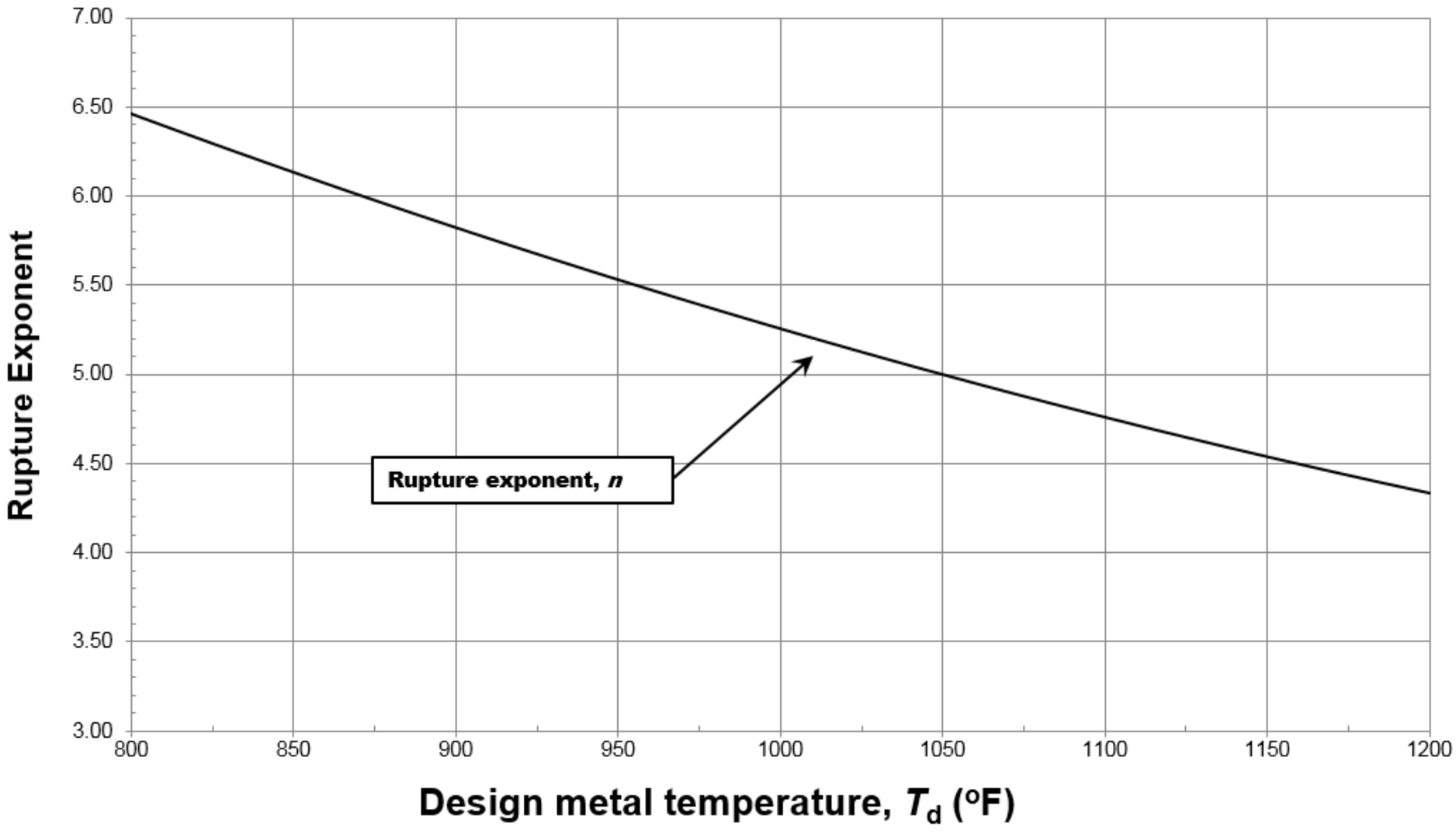



**Figure F.11—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels**

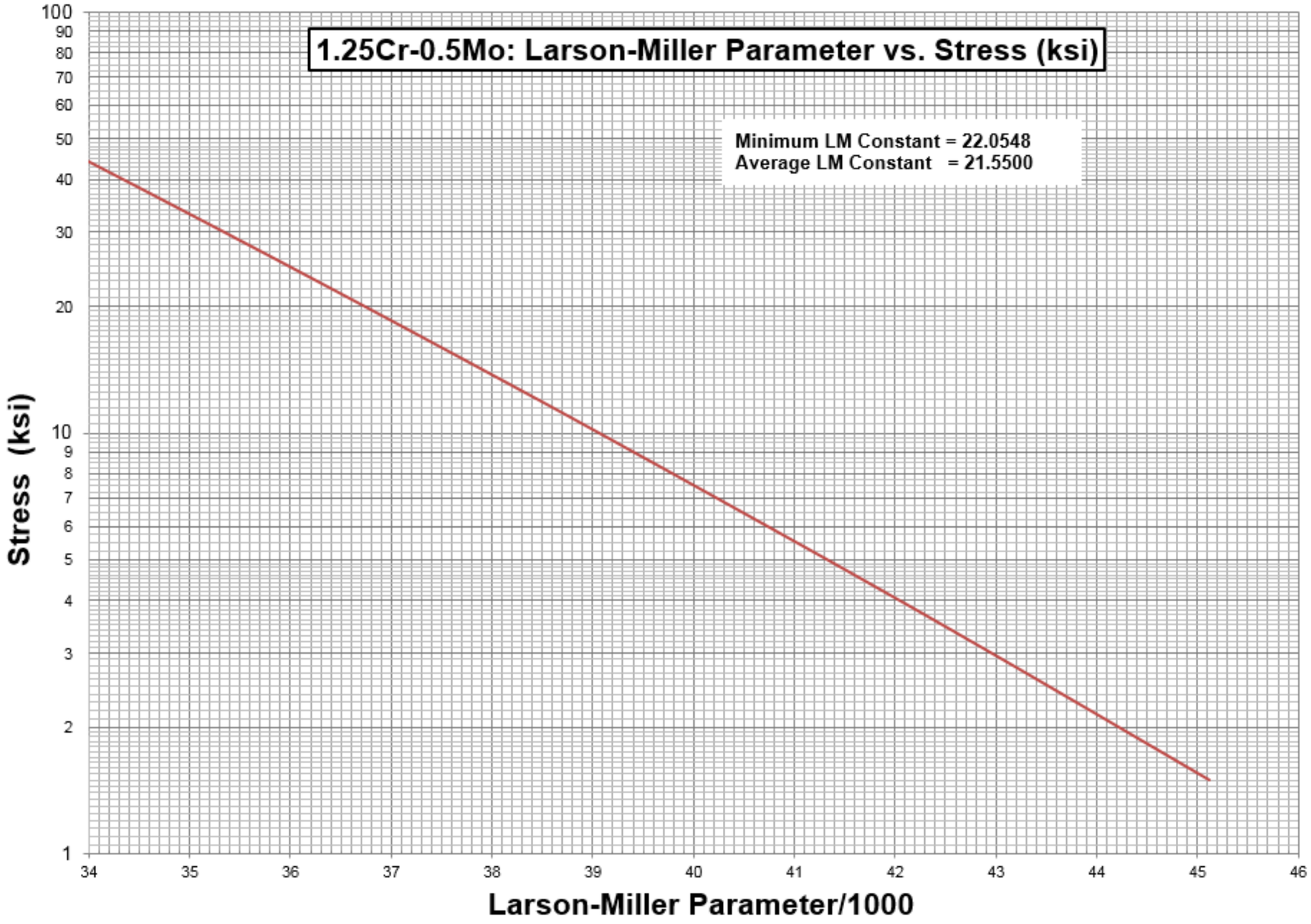



**Figure F.12—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels**

**Table F.4—Elastic, Rupture Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213 T11 and ASTM A335 P11 1-1/4Cr-1/2Mo Steels**

| 1.25Cr-0.5Mo | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 600 | 16.8 | | | | | |
| 620 | 16.7 | | | | | |
| 640 | 16.6 | | | | | |
| 660 | 16.6 | | | | | |
| 680 | 16.5 | | | | | |
| 700 | 16.4 | | | | | |
| 720 | 16.3 | | | | | |
| 740 | 16.2 | | | | | |
| 760 | 16.1 | | | | | |
| 780 | 16.0 | | | | | |
| 800 | 15.8 | | | | | 6.46 |
| 820 | 15.7 | | | | | 6.33 |
| 840 | 15.5 | | | | | 6.20 |
| 860 | 15.3 | | | | | 6.07 |
| 880 | 15.2 | 23.1 | 25.2 | 27.0 | 30.3 | 5.94 |
| 900 | 14.9 | 19.7 | 21.5 | 23.1 | 26.0 | 5.82 |
| 920 | 14.7 | 16.8 | 18.4 | 19.7 | 22.3 | 5.70 |
| 940 | 14.5 | 14.3 | 15.7 | 16.9 | 19.1 | 5.59 |
| 960 | 14.2 | 12.2 | 13.4 | 14.4 | 16.4 | 5.47 |
| 980 | 13.9 | 10.4 | 11.4 | 12.3 | 14.0 | 5.36 |
| 1000 | 13.6 | 8.8 | 9.7 | 10.5 | 12.0 | 5.26 |
| 1020 | 13.3 | 7.5 | 8.2 | 8.9 | 10.2 | 5.15 |
| 1040 | 13.0 | 6.3 | 7.0 | 7.6 | 8.7 | 5.05 |
| 1060 | 12.6 | 5.3 | 5.9 | 6.4 | 7.4 | 4.95 |
| 1080 | 12.3 | 4.5 | 5.0 | 5.5 | 6.3 | 4.85 |
| 1100 | 11.9 | 3.8 | 4.3 | 4.6 | 5.4 | 4.76 |
| 1120 | 11.5 | 3.2 | 3.6 | 3.9 | 4.6 | 4.67 |
| 1140 | 11.1 | 2.7 | 3.0 | 3.3 | 3.9 | 4.58 |
| 1160 | 10.7 | 2.3 | 2.6 | 2.8 | 3.3 | 4.50 |
| 1180 | 10.3 | 1.9 | 2.2 | 2.4 | 2.8 | 4.41 |
| 1200 | 9.9 | 1.6 | 1.8 | 2.0 | 2.3 | 4.33 |

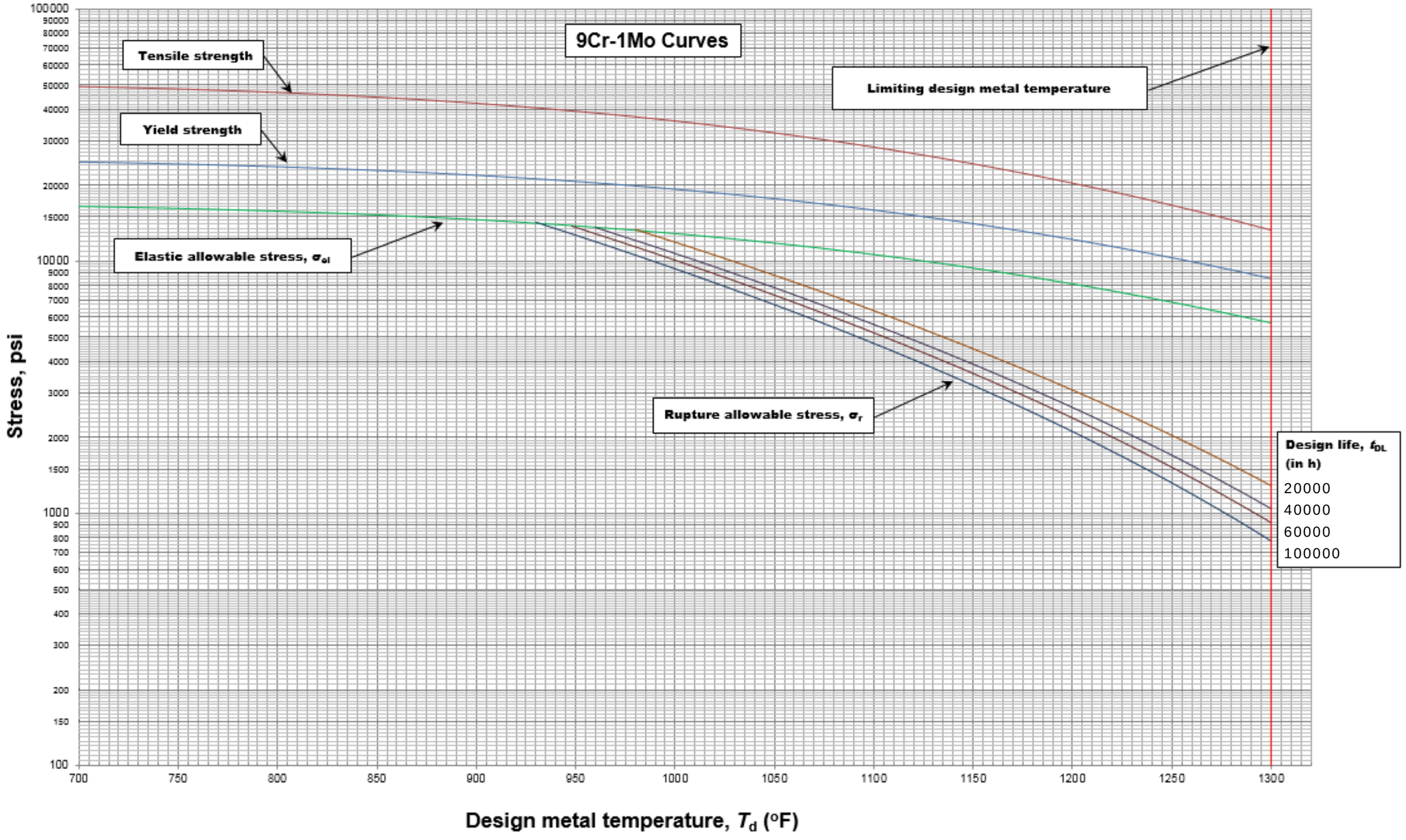



**Figure F.25—Stress Curves (USC Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels**

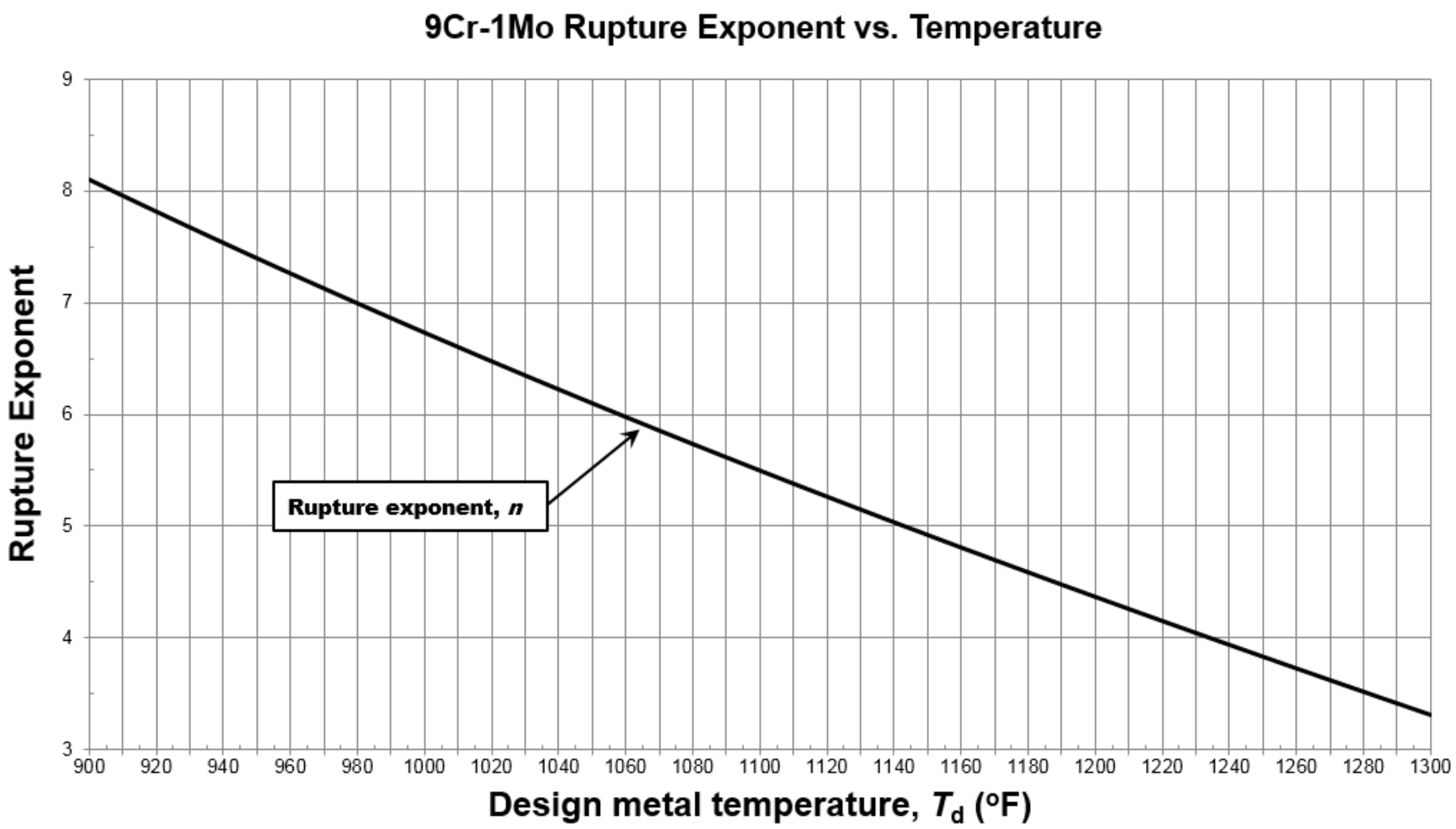



**Figure F.26—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels**

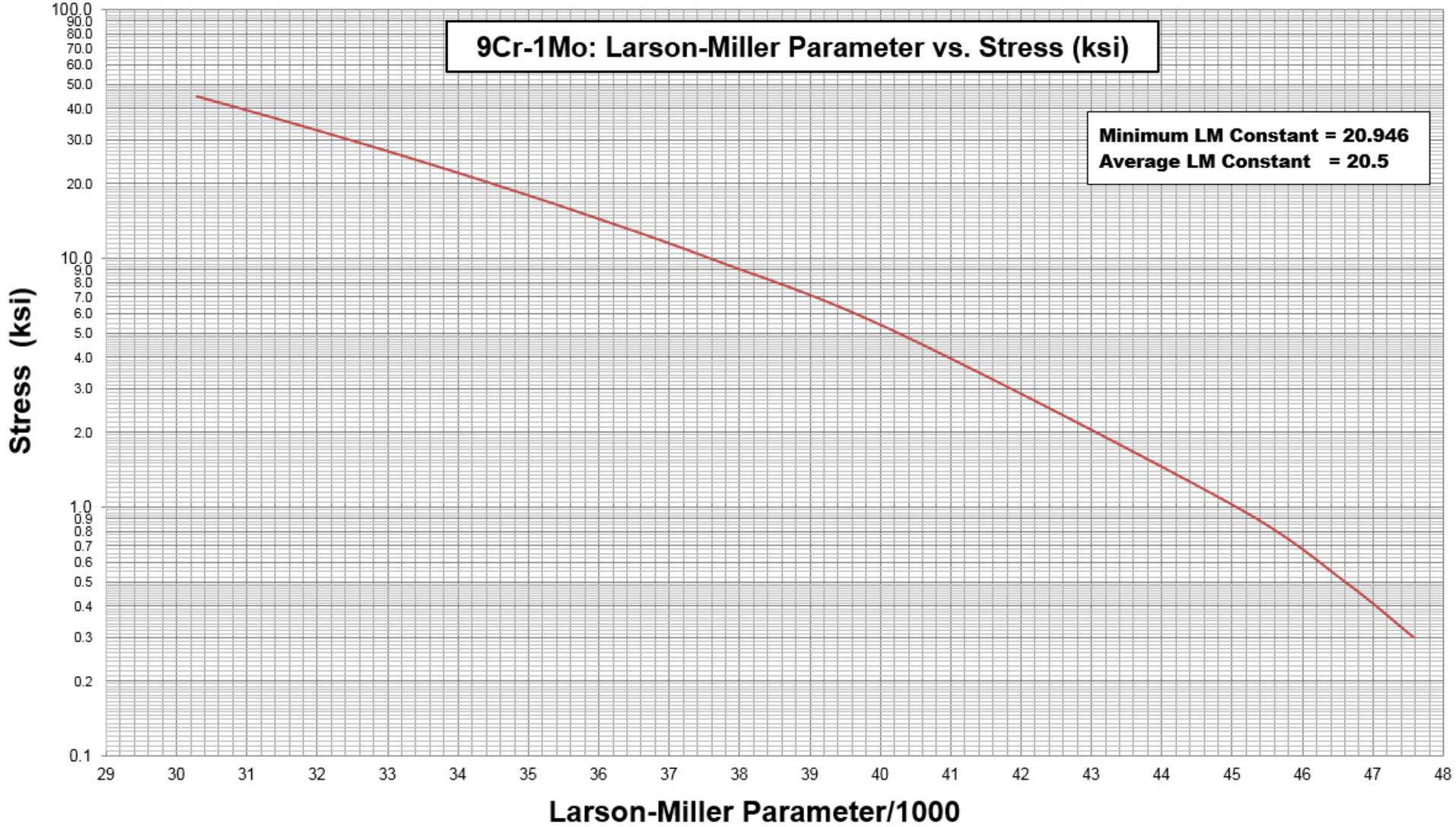



**Figure F.27—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels**

**Table F.9—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213 T9 and ASTM A335 P9 9Cr-1Mo Steels**

| 9Cr-1Mo Steel | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 700 | 16.5 | | | | | |
| 720 | 16.4 | | | | | |
| 740 | 16.3 | | | | | |
| 760 | 16.1 | | | | | |
| 780 | 16.0 | | | | | |
| 800 | 15.8 | | | | | |
| 820 | 15.6 | | | | | |
| 840 | 15.4 | | | | | |
| 860 | 15.1 | | | | | |
| 880 | 14.9 | | | | | |
| 900 | 14.6 | | | | | 8.1 |
| 920 | 14.3 | 15.1 | 16.2 | 17.0 | 18.6 | 7.8 |
| 940 | 14.0 | 13.5 | 14.4 | 15.2 | 16.7 | 7.5 |
| 960 | 13.6 | 11.9 | 12.8 | 13.6 | 15.0 | 7.3 |
| 980 | 13.3 | 10.6 | 11.4 | 12.1 | 13.4 | 7.0 |
| 1000 | 12.9 | 9.3 | 10.1 | 10.7 | 11.9 | 6.7 |
| 1020 | 12.5 | 8.2 | 8.9 | 9.5 | 10.6 | 6.5 |
| 1040 | 12.0 | 7.2 | 7.8 | 8.4 | 9.4 | 6.2 |
| 1060 | 11.6 | 6.3 | 6.9 | 7.4 | 8.3 | 6.0 |
| 1080 | 11.1 | 5.5 | 6.0 | 6.4 | 7.3 | 5.7 |
| 1100 | 10.6 | 4.7 | 5.2 | 5.6 | 6.4 | 5.5 |
| 1120 | 10.1 | 4.1 | 4.5 | 4.9 | 5.6 | 5.3 |
| 1140 | 9.6 | 3.5 | 3.9 | 4.2 | 4.8 | 5.0 |
| 1160 | 9.1 | 3.0 | 3.3 | 3.6 | 4.2 | 4.8 |
| 1180 | 8.6 | 2.5 | 2.8 | 3.1 | 3.6 | 4.6 |
| 1200 | 8.1 | 2.1 | 2.4 | 2.6 | 3.1 | 4.4 |
| 1220 | 7.6 | 1.8 | 2.0 | 2.2 | 2.6 | 4.1 |
| 1240 | 7.1 | 1.5 | 1.7 | 1.9 | 2.2 | 3.9 |
| 1260 | 6.6 | 1.2 | 1.4 | 1.6 | 1.9 | 3.7 |
| 1280 | 6.2 | 1.0 | 1.1 | 1.3 | 1.6 | 3.5 |
| 1300 | 5.7 | 0.8 | 0.9 | 1.0 | 1.3 | 3.3 |

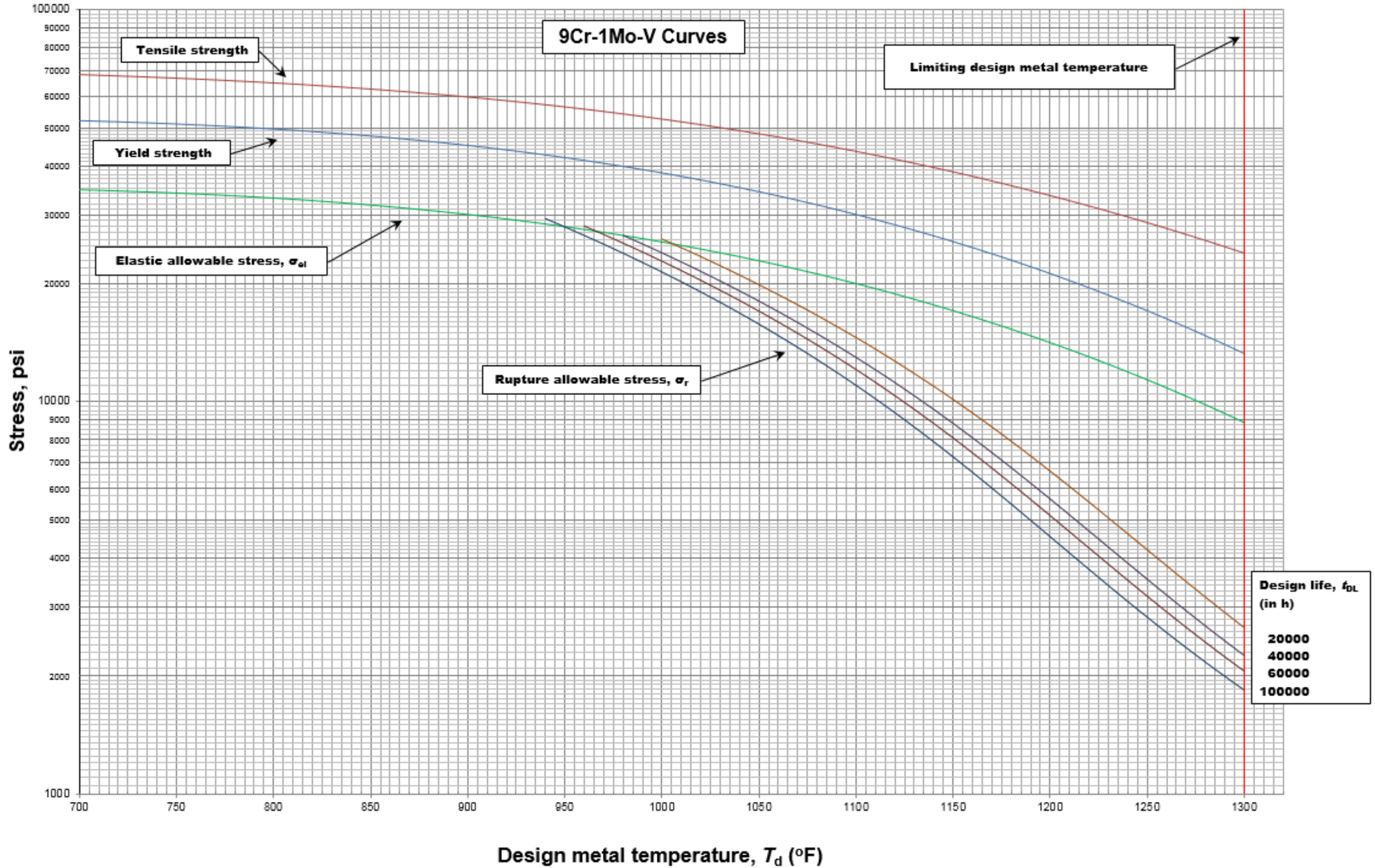



**Figure F.28—Stress Curves (USC Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels**

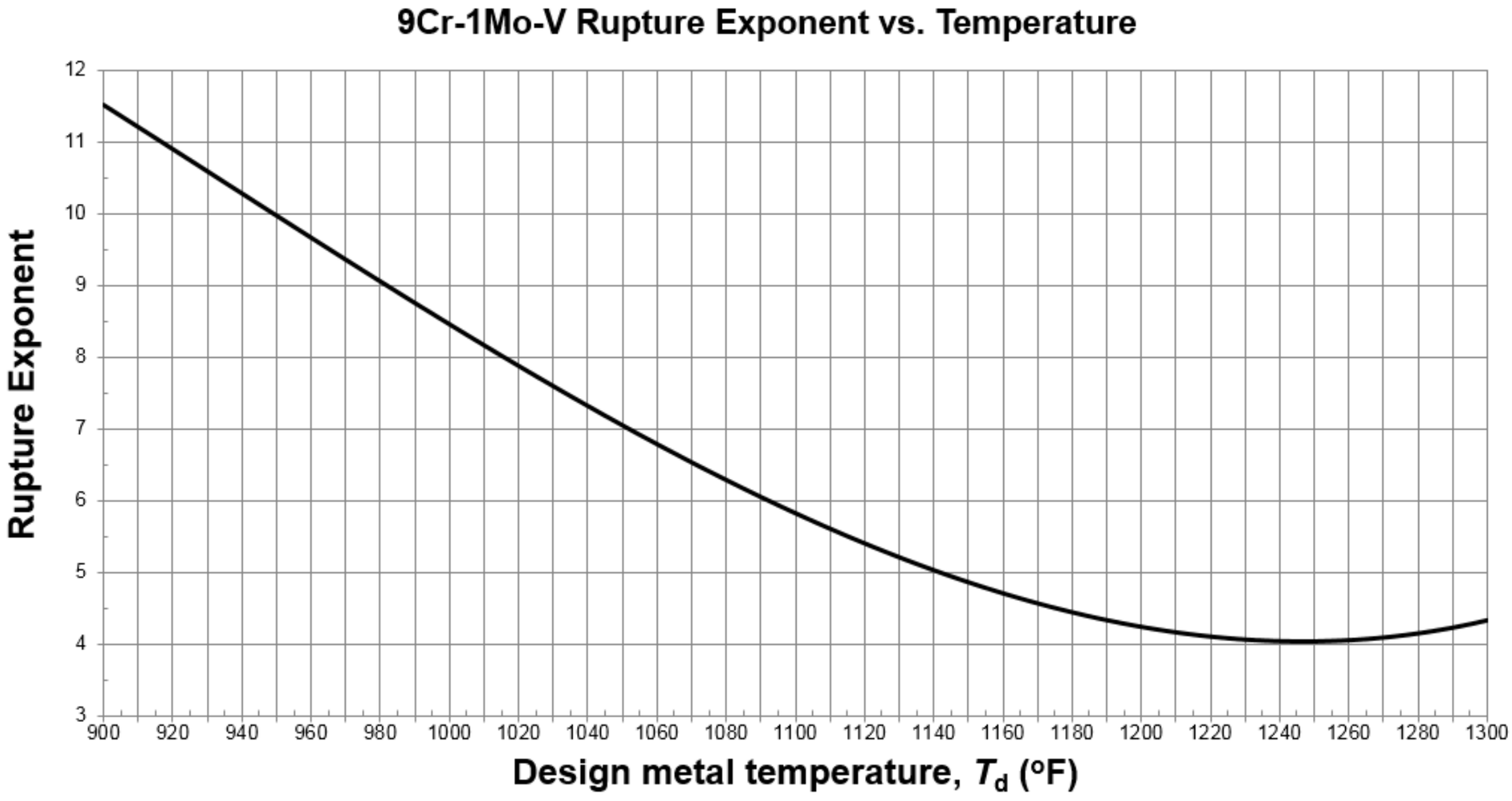



**Figure F.29—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels**

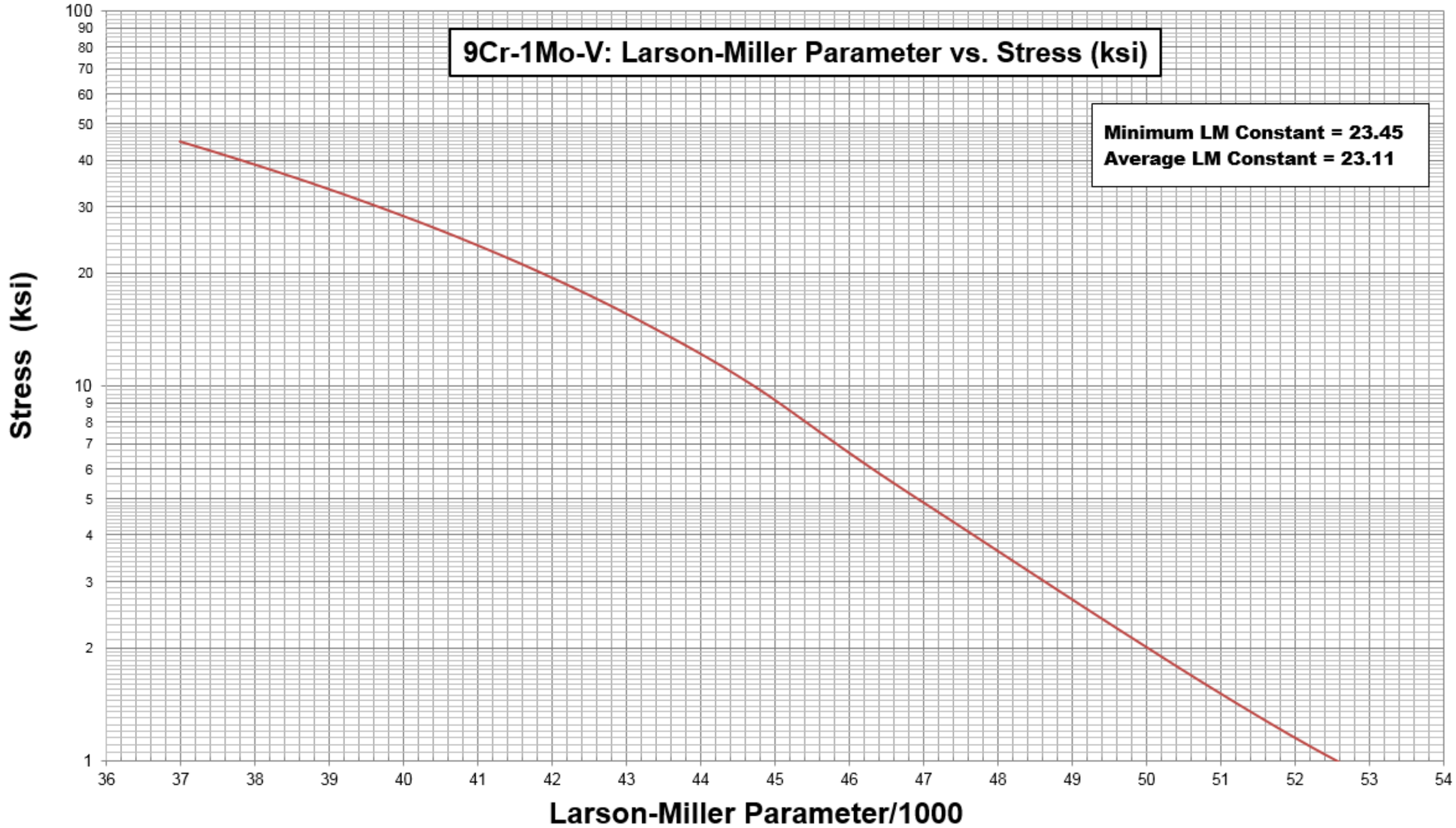



**Figure F.30—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels**

**Table F.10—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) ASTM A213 T91 and ASTM A335 P91 9Cr-1Mo-V Steels**

| 9Cr-1Mo-V Steel | | | | | | |
|---|---|---|---|---|---|---|
| **Temperature** (Fahrenheit) | **Elastic Allowable Stress, $\sigma_{el}$** (ksi) | **Rupture Allowable Stress, $\sigma_r$** | | | | **Rupture Exponent, *n*** |
| | | **$t_{DL}$ = 100,000 h** (ksi) | **$t_{DL}$ = 60,000 h** (ksi) | **$t_{DL}$ = 40,000 h** (ksi) | **$t_{DL}$ = 20,000 h** (ksi) | |
| 700 | 34.7 | | | | | |
| 720 | 34.5 | | | | | |
| 740 | 34.2 | | | | | |
| 760 | 33.9 | | | | | |
| 780 | 33.5 | | | | | |
| 800 | 33.1 | | | | | |
| 820 | 32.6 | | | | | |
| 840 | 32.0 | | | | | |
| 860 | 31.4 | | | | | |
| 880 | 30.8 | | | | | |
| 900 | 30.0 | | | | | |
| 920 | 29.3 | 32.2 | 33.8 | 35.1 | 37.4 | 10.9 |
| 940 | 28.4 | 29.3 | 30.9 | 32.2 | 34.4 | 10.3 |
| 960 | 27.5 | 26.6 | 28.1 | 29.3 | 31.5 | 9.6 |
| 980 | 26.6 | 23.9 | 25.4 | 26.6 | 28.7 | 9.0 |
| 1000 | 25.6 | 21.4 | 22.8 | 24.0 | 26.0 | 8.5 |
| 1020 | 24.5 | 19.1 | 20.4 | 21.5 | 23.5 | 7.9 |
| 1040 | 23.4 | 16.8 | 18.1 | 19.2 | 21.1 | 7.3 |
| 1060 | 22.3 | 14.8 | 16.0 | 17.0 | 18.8 | 6.8 |
| 1080 | 21.2 | 12.8 | 14.0 | 14.9 | 16.6 | 6.3 |
| 1100 | 20.0 | 11.0 | 12.1 | 13.0 | 14.6 | 5.8 |
| 1120 | 18.9 | 9.4 | 10.4 | 11.2 | 12.7 | 5.4 |
| 1140 | 17.7 | 7.9 | 8.8 | 9.6 | 11.0 | 5.0 |
| 1160 | 16.5 | 6.6 | 7.4 | 8.1 | 9.4 | 4.7 |
| 1180 | 15.3 | 5.5 | 6.2 | 6.8 | 7.9 | 4.4 |
| 1200 | 14.2 | 4.5 | 5.1 | 5.7 | 6.7 | 4.2 |
| 1220 | 13.0 | 3.7 | 4.2 | 4.7 | 5.6 | 4.1 |
| 1240 | 11.9 | 3.1 | 3.5 | 3.9 | 4.6 | 4.0 |
| 1260 | 10.9 | 2.6 | 2.9 | 3.2 | 3.8 | 4.1 |
| 1280 | 9.8 | 2.2 | 2.4 | 2.7 | 3.2 | 4.2 |
| 1300 | 8.9 | 1.8 | 2.1 | 2.3 | 2.7 | 4.3 |

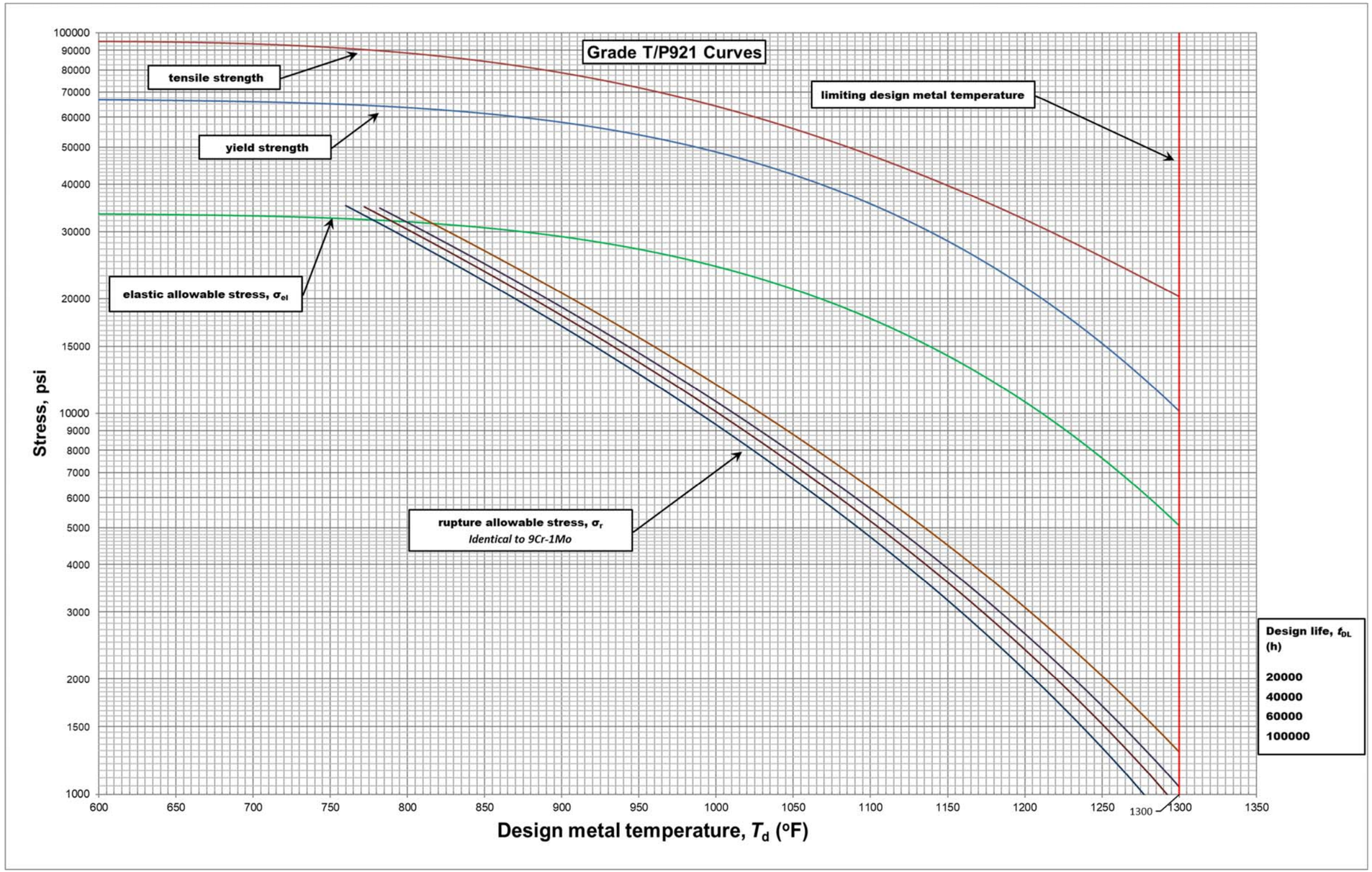



**Figure F.31—Stress Curves (USC Units) for ferritic steel ASTM A213-T921 and A335-P921 9Cr-2Si-1Cu Steels (Grade 921)**

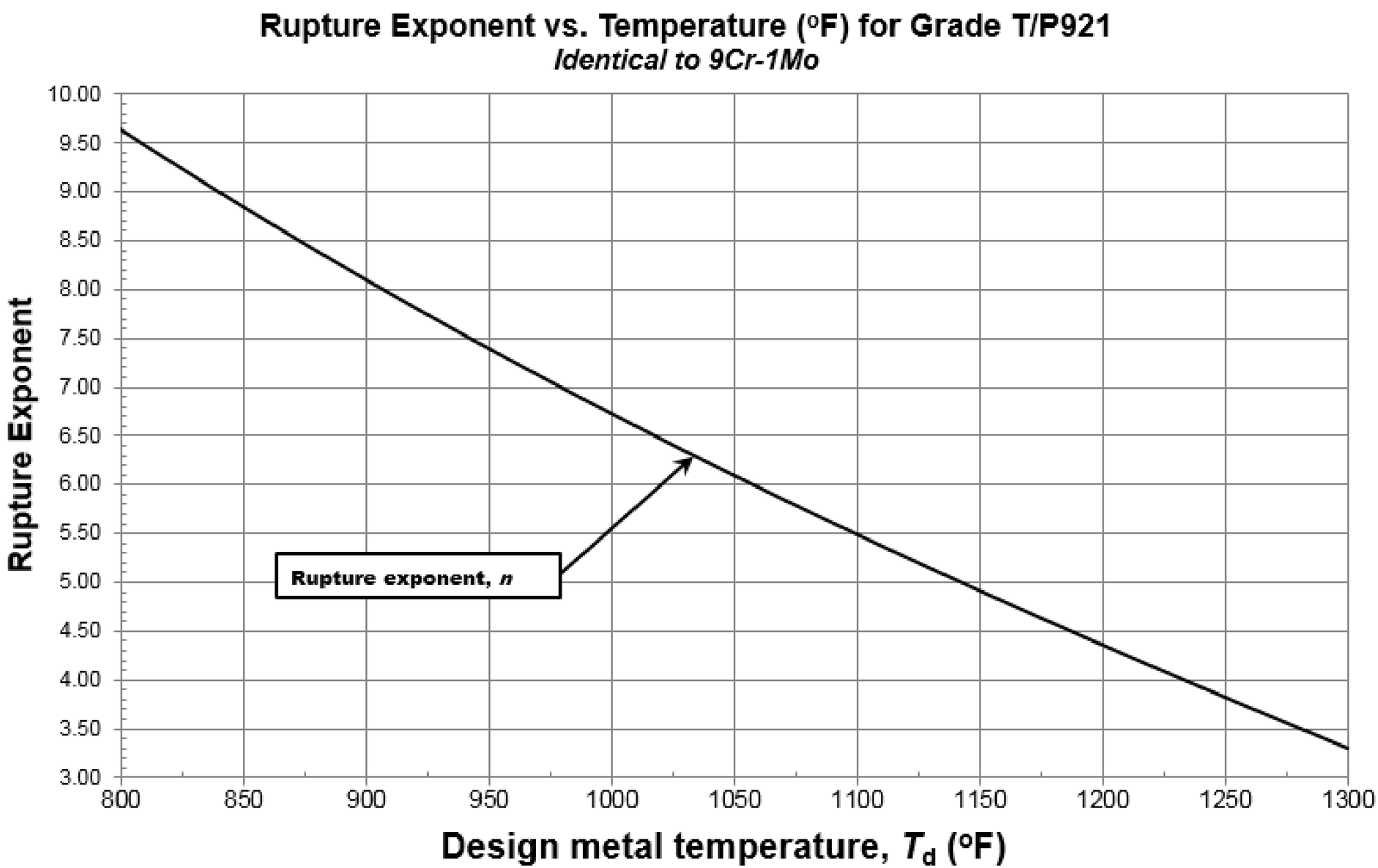



**Figure F.32—Rupture Exponent vs. Temperature Curve (USC Units) for ferritic steel ASTM A213-T921 and A335-P921 9Cr-2Si-1Cu Steels (Grade 921)**

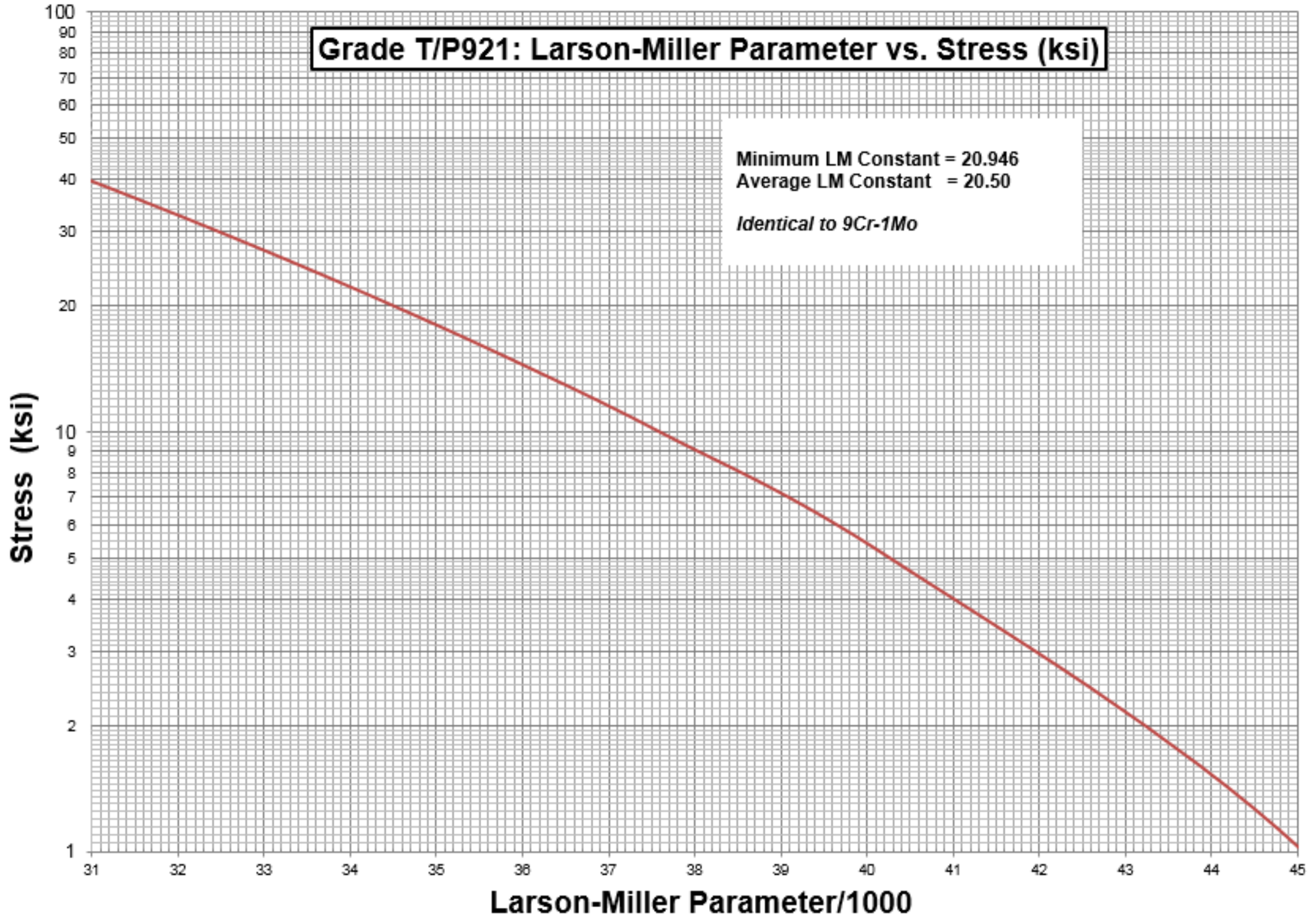
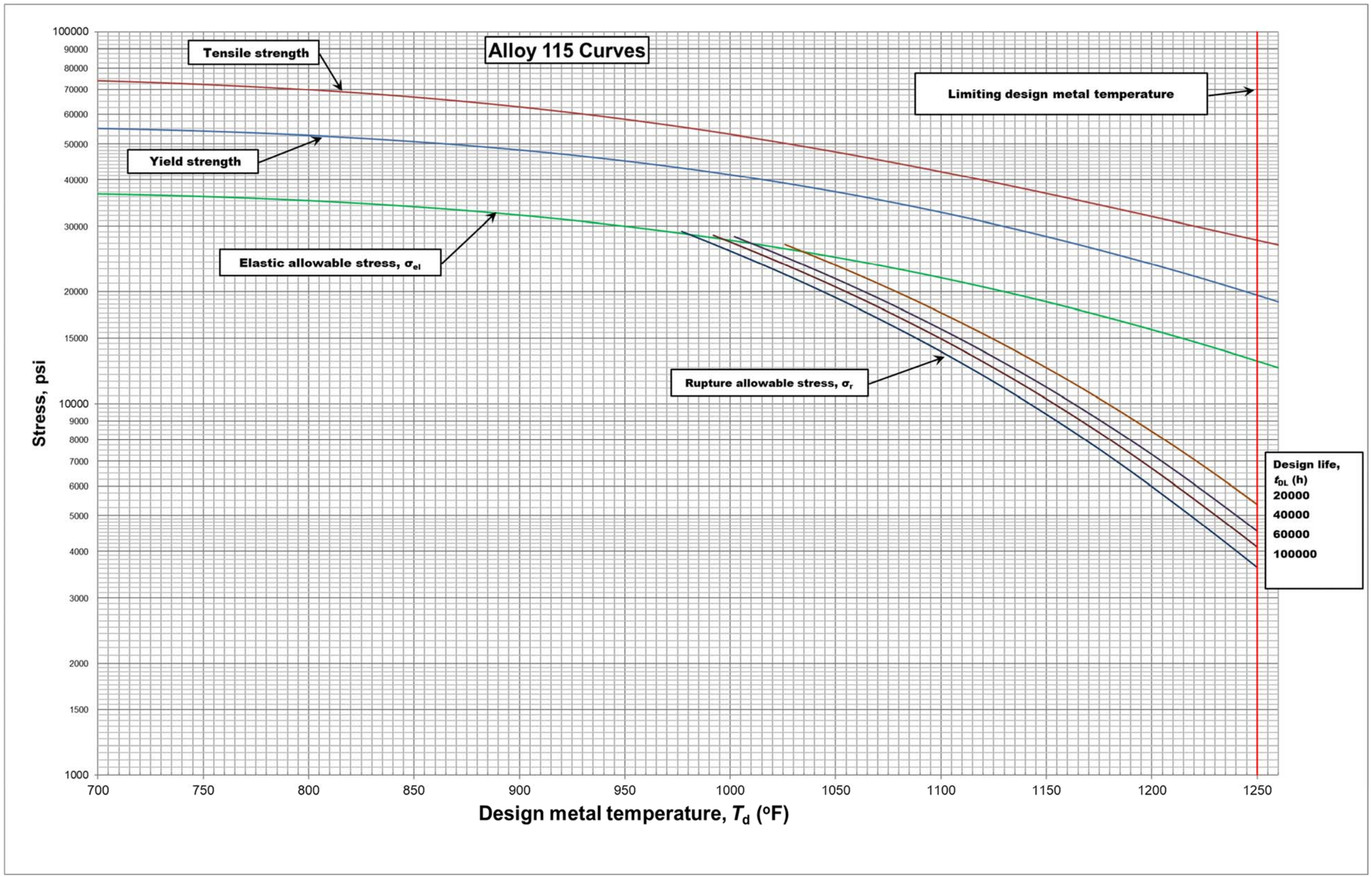



**Figure F.33—Larson-Miller Parameter vs. Stress Curve (USC Units) for ferritic steel ASTM A213-T921 and A335-P921 9Cr-2Si-1Cu Steels (Grade 921)**

**Table F.11—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ferritic steel ASTM A213-T921 and A335-P921 9Cr-2Si-1Cu Steels (Grade 921)**

| Grade T/P921 | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ (Identical to 9Cr-1Mo) | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 600 | 33.4 | | | | | |
| 620 | 33.3 | | | | | |
| 640 | 33.2 | | | | | |
| 660 | 33.2 | | | | | |
| 680 | 33.1 | | | | | |
| 700 | 33.0 | | | | | |
| 720 | 32.8 | | | | | |
| 740 | 32.6 | | | | | |
| 760 | 32.4 | 35.1 | 36.9 | 40.8 | 38.4 | 10.3 |
| 780 | 32.1 | 31.8 | 33.5 | 37.1 | 34.9 | 10.0 |
| 800 | 31.8 | 28.8 | 30.4 | 33.8 | 31.7 | 9.6 |
| 820 | 31.4 | 26.0 | 27.5 | 30.7 | 28.7 | 9.3 |
| 840 | 31.0 | 23.4 | 24.8 | 27.8 | 26.0 | 9.0 |
| 860 | 30.4 | 21.1 | 22.4 | 25.2 | 23.5 | 8.7 |
| 880 | 29.8 | 18.9 | 20.1 | 22.8 | 21.1 | 8.4 |
| 900 | 29.1 | 16.9 | 18.1 | 20.5 | 19.0 | 8.1 |
| 920 | 28.3 | 15.1 | 16.2 | 18.4 | 17.0 | 7.8 |
| 940 | 27.4 | 13.5 | 14.4 | 16.5 | 15.2 | 7.5 |
| 960 | 26.5 | 11.9 | 12.8 | 14.8 | 13.6 | 7.3 |
| 980 | 25.4 | 10.6 | 11.4 | 13.2 | 12.1 | 7.0 |
| 1000 | 24.3 | 9.3 | 10.1 | 11.8 | 10.7 | 6.7 |
| 1020 | 23.1 | 8.2 | 8.9 | 10.5 | 9.5 | 6.5 |
| 1040 | 21.8 | 7.2 | 7.8 | 9.3 | 8.4 | 6.2 |
| 1060 | 20.5 | 6.3 | 6.9 | 8.2 | 7.4 | 6.0 |
| 1080 | 19.1 | 5.5 | 6.0 | 7.2 | 6.4 | 5.7 |
| 1100 | 17.7 | 4.7 | 5.2 | 6.3 | 5.6 | 5.5 |
| 1120 | 16.3 | 4.1 | 4.5 | 5.5 | 4.9 | 5.3 |
| 1140 | 14.9 | 3.5 | 3.9 | 4.8 | 4.2 | 5.0 |
| 1160 | 13.5 | 3.0 | 3.3 | 4.1 | 3.6 | 4.8 |
| 1180 | 12.1 | 2.5 | 2.8 | 3.5 | 3.1 | 4.6 |
| 1200 | 10.7 | 2.1 | 2.4 | 3.0 | 2.6 | 4.4 |
| 1220 | 9.4 | 1.8 | 2.0 | 2.6 | 2.2 | 4.1 |
| 1240 | 8.2 | 1.5 | 1.7 | 2.2 | 1.9 | 3.9 |
| 1260 | 7.1 | 1.2 | 1.4 | 1.8 | 1.6 | 3.7 |
| 1280 | 6.0 | 1.0 | 1.1 | 1.5 | 1.3 | 3.5 |
| 1300 | 5.1 | 0.8 | 0.9 | 1.3 | 1.0 | 3.3 |


Alloy 115 Curves
Tensile strength
Yield strength
Elastic allowable stress, $\sigma_{el}$
Rupture allowable stress, $\sigma_r$
Limiting design metal temperature
Design life, $t_{DL}$ (h)
20000
40000
60000
100000
Stress, psi
100000
90000
80000
70000
60000
50000
40000
30000
20000
15000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1500
1000
700
750
800
850
900
950
1000
1050
1100
1150
1200
1250
Design metal temperature, $T_d$ (°F)

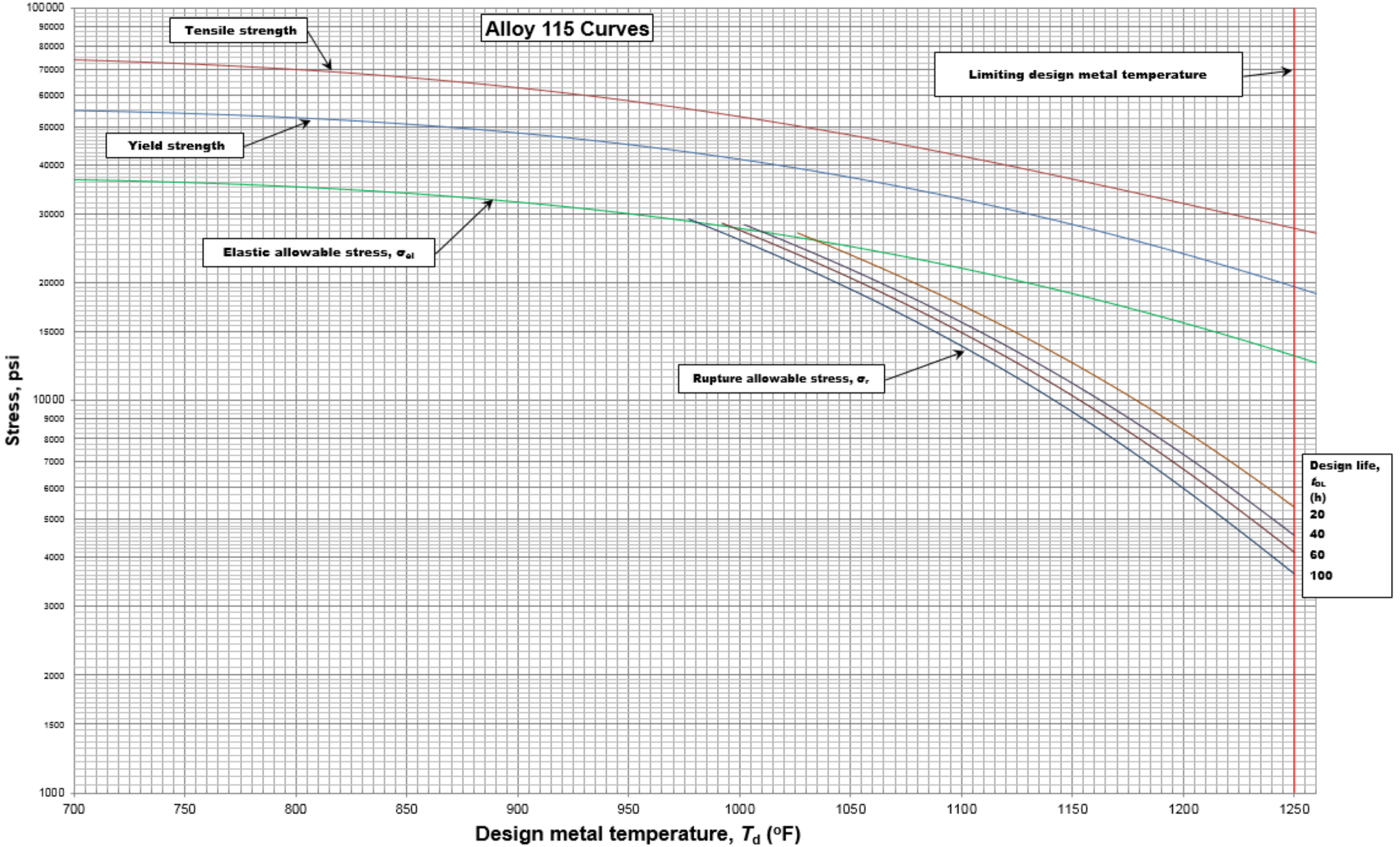



**Figure F.34—Stress Curves (USC Units) for ferritic steel ASTM A213-T115 and A335-P115 10.5Cr-V Steels (Alloy 115)**

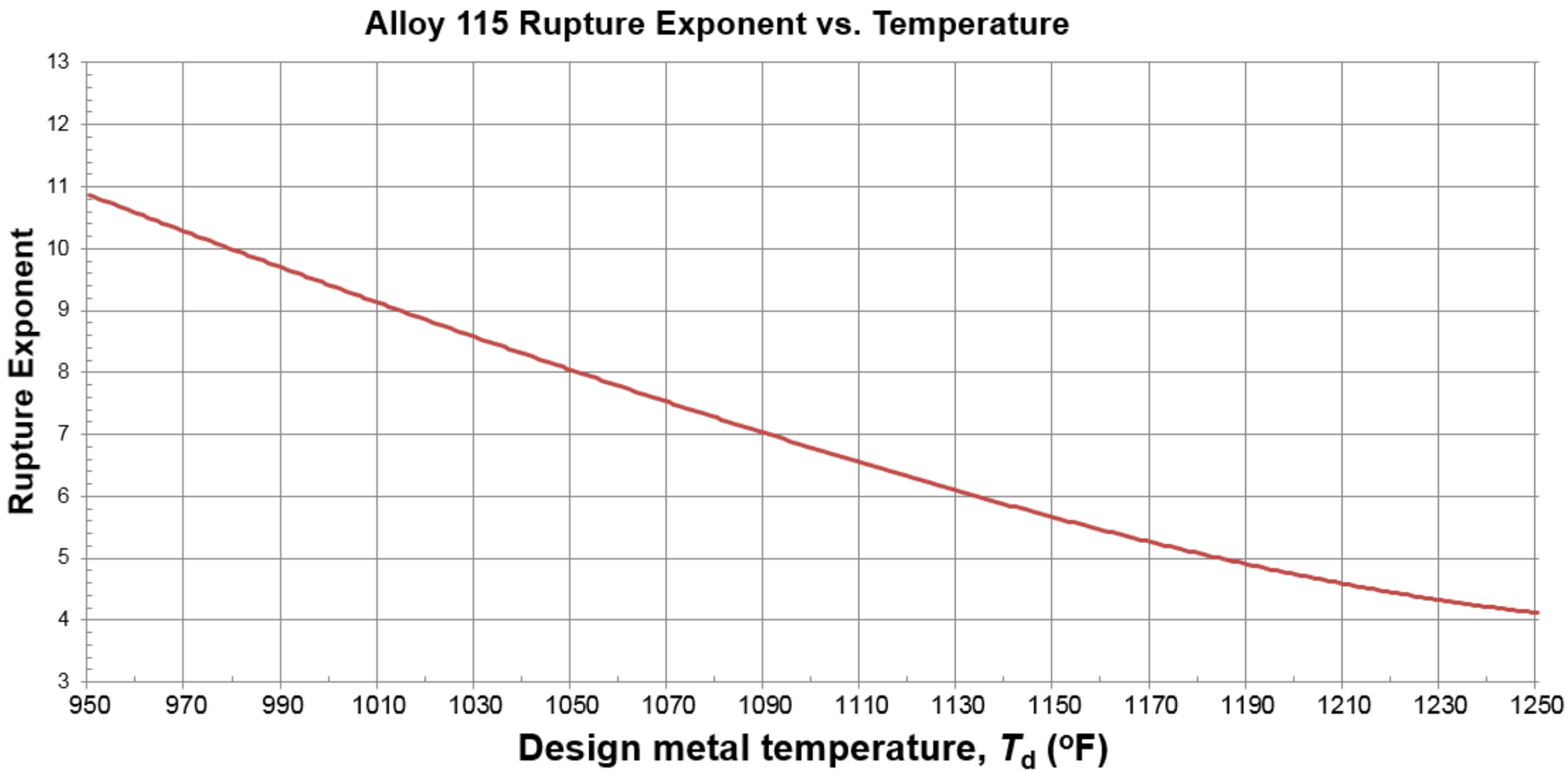



**Figure F.35—Rupture Exponent vs. Temperature Curve (USC Units) for ferritic steel ASTM A213-T115 and A335-P115 10.5Cr-V Steels (Alloy 115)**

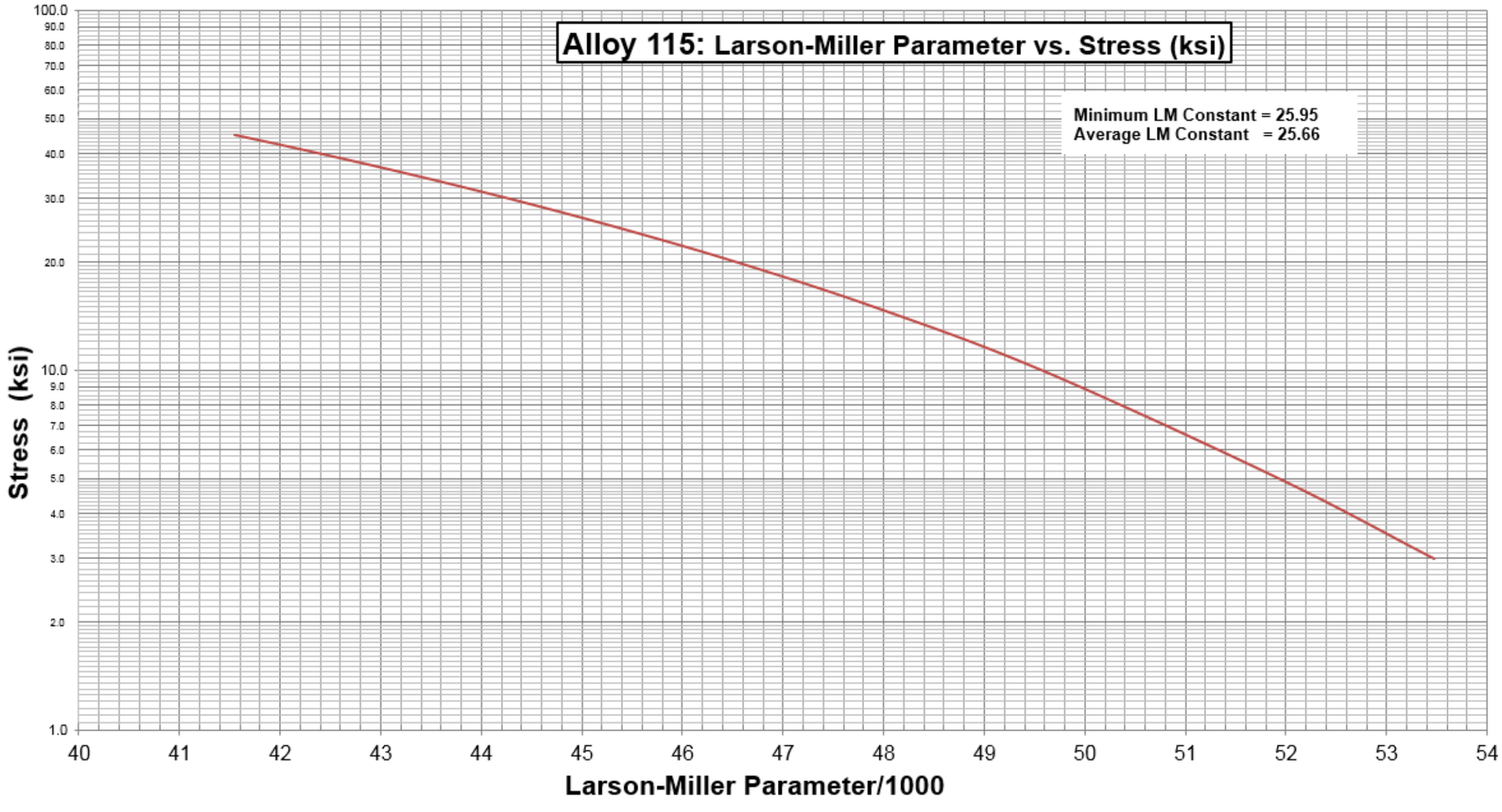



**Figure F.36—Larson-Miller Parameter vs. Stress Curve (USC Units) for ferritic steel ASTM A213-T115 and A335-P115 10.5Cr-V Steels (Alloy 115)**

**Table F.12—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ferritic steel ASTM A213-T115 and A335-P115 10.5Cr-V Steels (Alloy 115)**

| Alloy 115 | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 700 | 36.6 | | | | | |
| 720 | 36.4 | | | | | |
| 740 | 36.2 | | | | | |
| 760 | 35.9 | | | | | |
| 780 | 35.5 | | | | | |
| 800 | 35.1 | | | | | |
| 820 | 34.6 | | | | | |
| 840 | 34.1 | | | | | |
| 860 | 33.5 | | | | | |
| 880 | 32.8 | | | | | |
| 900 | 32.1 | | | | | 12.4 |
| 920 | 31.3 | 38.2 | 40.0 | 41.4 | 43.9 | 11.8 |
| 940 | 30.4 | 34.9 | 36.5 | 37.9 | 40.3 | 11.2 |
| 960 | 29.5 | 31.6 | 33.3 | 34.6 | 36.9 | 10.6 |
| 980 | 28.5 | 28.6 | 30.1 | 31.4 | 33.6 | 10.0 |
| 1000 | 27.5 | 25.7 | 27.2 | 28.4 | 30.5 | 9.4 |
| 1020 | 26.4 | 23.0 | 24.4 | 25.6 | 27.6 | 8.8 |
| 1040 | 25.3 | 20.5 | 21.8 | 22.9 | 24.9 | 8.3 |
| 1060 | 24.1 | 18.1 | 19.3 | 20.4 | 22.3 | 7.8 |
| 1080 | 23.0 | 15.9 | 17.1 | 18.0 | 19.8 | 7.3 |
| 1100 | 21.8 | 13.8 | 14.9 | 15.9 | 17.5 | 6.8 |
| 1120 | 20.6 | 11.9 | 13.0 | 13.8 | 15.4 | 6.3 |
| 1140 | 19.4 | 10.2 | 11.1 | 12.0 | 13.4 | 5.9 |
| 1160 | 18.2 | 8.6 | 9.5 | 10.2 | 11.6 | 5.5 |
| 1180 | 17.0 | 7.2 | 8.0 | 8.7 | 9.9 | 5.1 |
| 1200 | 15.8 | 6.0 | 6.7 | 7.3 | 8.4 | 4.7 |
| 1220 | 14.7 | 4.9 | 5.5 | 6.1 | 7.1 | 4.4 |
| 1240 | 13.6 | 4.0 | 4.5 | 5.0 | 5.9 | 4.2 |
| 1250 | 12.5 | 3.6 | 4.1 | 4.5 | 5.4 | 4.1 |

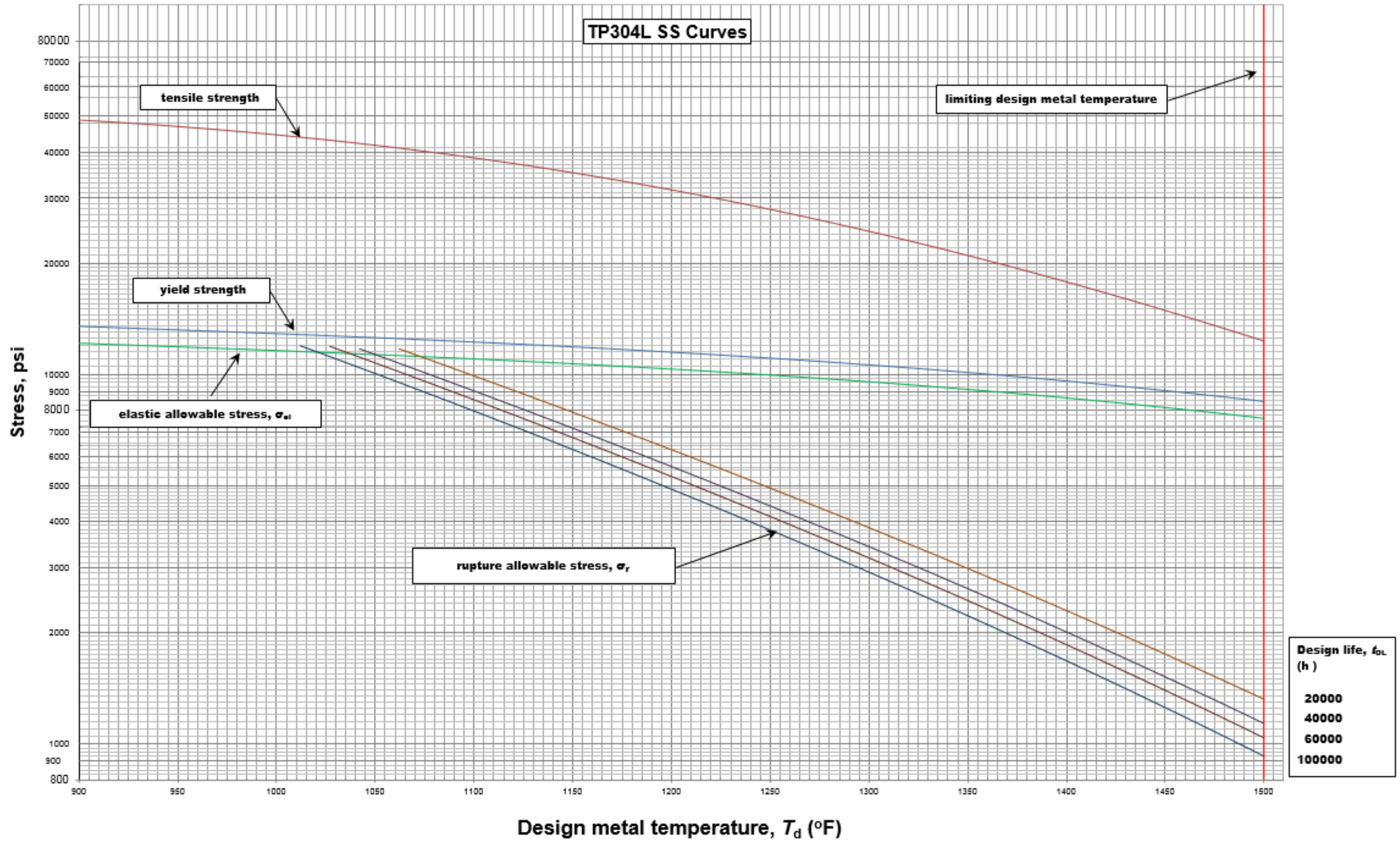



**Figure F.40—Stress Curves (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP304L (18Cr-8Ni) Stainless Steels**

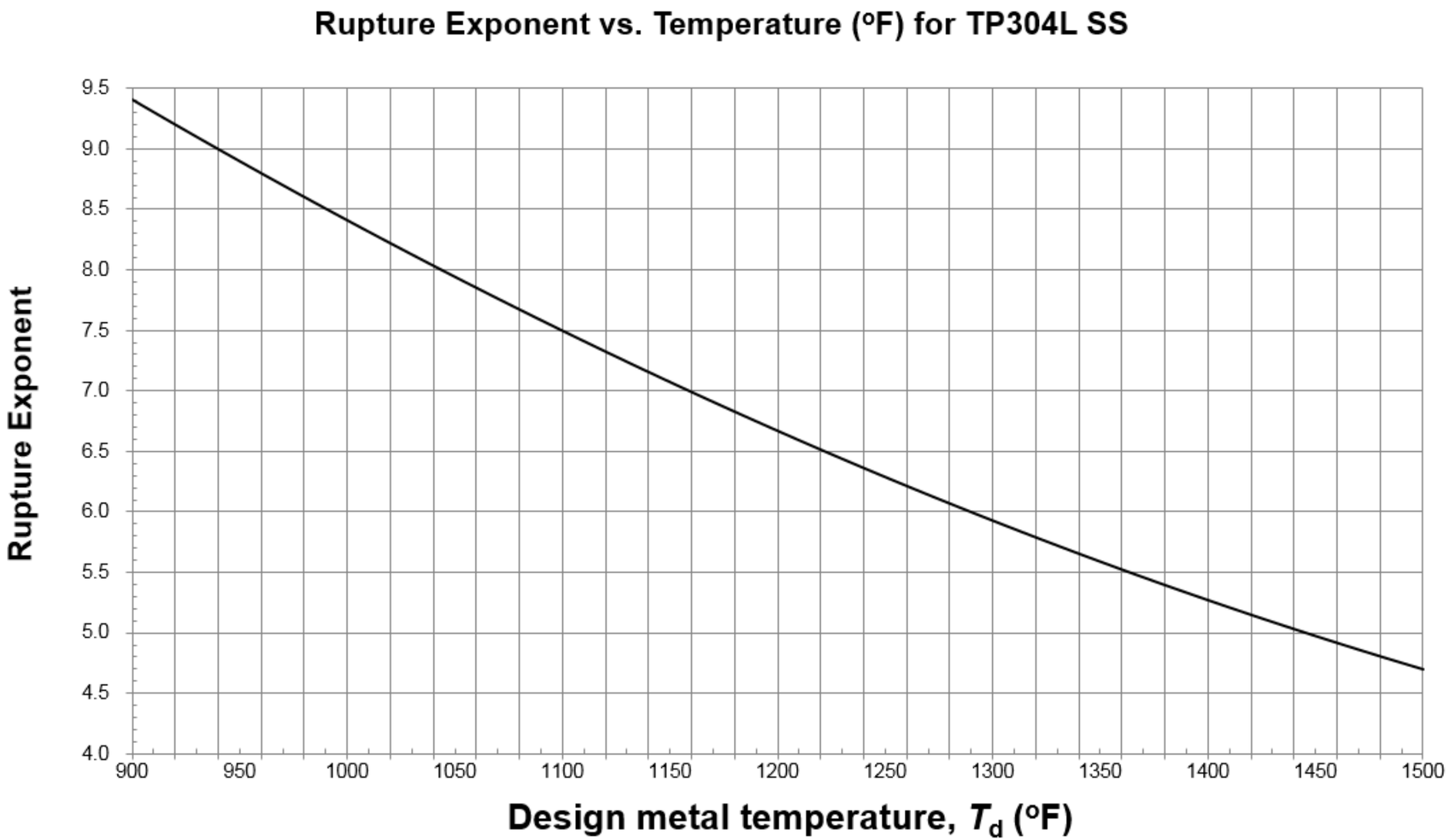



**Figure F.41—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP304L (18Cr-8Ni) Stainless Steels**

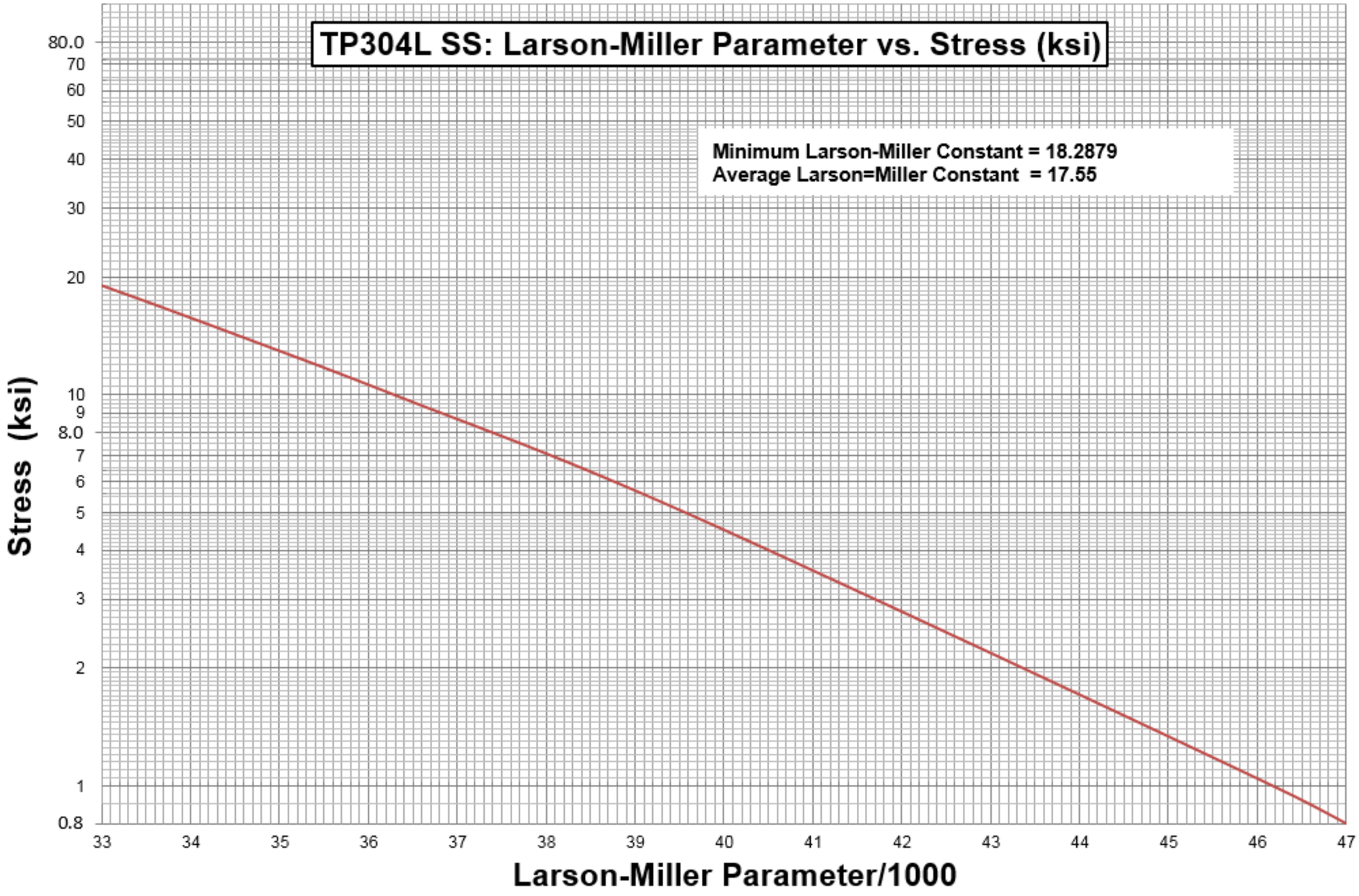



**Figure F.42—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP304L (18Cr-8Ni) Stainless Steels**

**Table F.14—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A312 and ASTM A376 TP304L (18Cr-8Ni) Stainless Steels**

| TP304L SS | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 800 | 12.7 | | | | | |
| 820 | 12.6 | | | | | |
| 840 | 12.5 | | | | | |
| 860 | 12.4 | | | | | |
| 880 | 12.2 | | | | | |
| 900 | 12.1 | | | | | 9.4 |
| 920 | 12.0 | | | | | 9.2 |
| 940 | 11.9 | | | | | 9.0 |
| 960 | 11.8 | | | | | 8.8 |
| 980 | 11.7 | | | | | 8.6 |
| 1000 | 11.6 | | | | | 8.4 |
| 1020 | 11.5 | 11.5 | 12.3 | 12.9 | 14.1 | 8.2 |
| 1040 | 11.4 | 10.5 | 11.2 | 11.8 | 12.9 | 8.0 |
| 1060 | 11.3 | 9.6 | 10.3 | 10.8 | 11.8 | 7.9 |
| 1080 | 11.1 | 8.7 | 9.4 | 9.9 | 10.8 | 7.7 |
| 1100 | 11.0 | 8.0 | 8.5 | 9.0 | 9.9 | 7.5 |
| 1120 | 10.9 | 7.2 | 7.8 | 8.2 | 9.1 | 7.3 |
| 1140 | 10.8 | 6.6 | 7.1 | 7.5 | 8.3 | 7.2 |
| 1160 | 10.6 | 6.0 | 6.4 | 6.8 | 7.5 | 7.0 |
| 1180 | 10.5 | 5.4 | 5.8 | 6.2 | 6.9 | 6.8 |
| 1200 | 10.3 | 4.9 | 5.3 | 5.6 | 6.3 | 6.7 |
| 1220 | 10.2 | 4.4 | 4.8 | 5.1 | 5.7 | 6.5 |
| 1240 | 10.0 | 4.0 | 4.3 | 4.6 | 5.2 | 6.4 |
| 1260 | 9.9 | 3.6 | 3.9 | 4.2 | 4.7 | 6.2 |
| 1280 | 9.7 | 3.2 | 3.5 | 3.8 | 4.2 | 6.1 |
| 1300 | 9.5 | 2.9 | 3.2 | 3.4 | 3.8 | 5.9 |
| 1320 | 9.4 | 2.6 | 2.9 | 3.1 | 3.5 | 5.8 |
| 1340 | 9.2 | 2.3 | 2.6 | 2.8 | 3.1 | 5.7 |
| 1360 | 9.0 | 2.1 | 2.3 | 2.5 | 2.8 | 5.5 |
| 1380 | 8.8 | 1.9 | 2.1 | 2.2 | 2.6 | 5.4 |
| 1400 | 8.6 | 1.7 | 1.9 | 2.0 | 2.3 | 5.3 |
| 1420 | 8.4 | 1.5 | 1.7 | 1.8 | 2.1 | 5.2 |
| 1440 | 8.2 | 1.3 | 1.5 | 1.6 | 1.8 | 5.0 |
| 1460 | 8.0 | 1.2 | 1.3 | 1.4 | 1.7 | 4.9 |
| 1480 | 7.8 | 1.0 | 1.2 | 1.3 | 1.5 | 4.8 |
| 1500 | 7.6 | 0.9 | 1.0 | 1.1 | 1.3 | 4.7 |

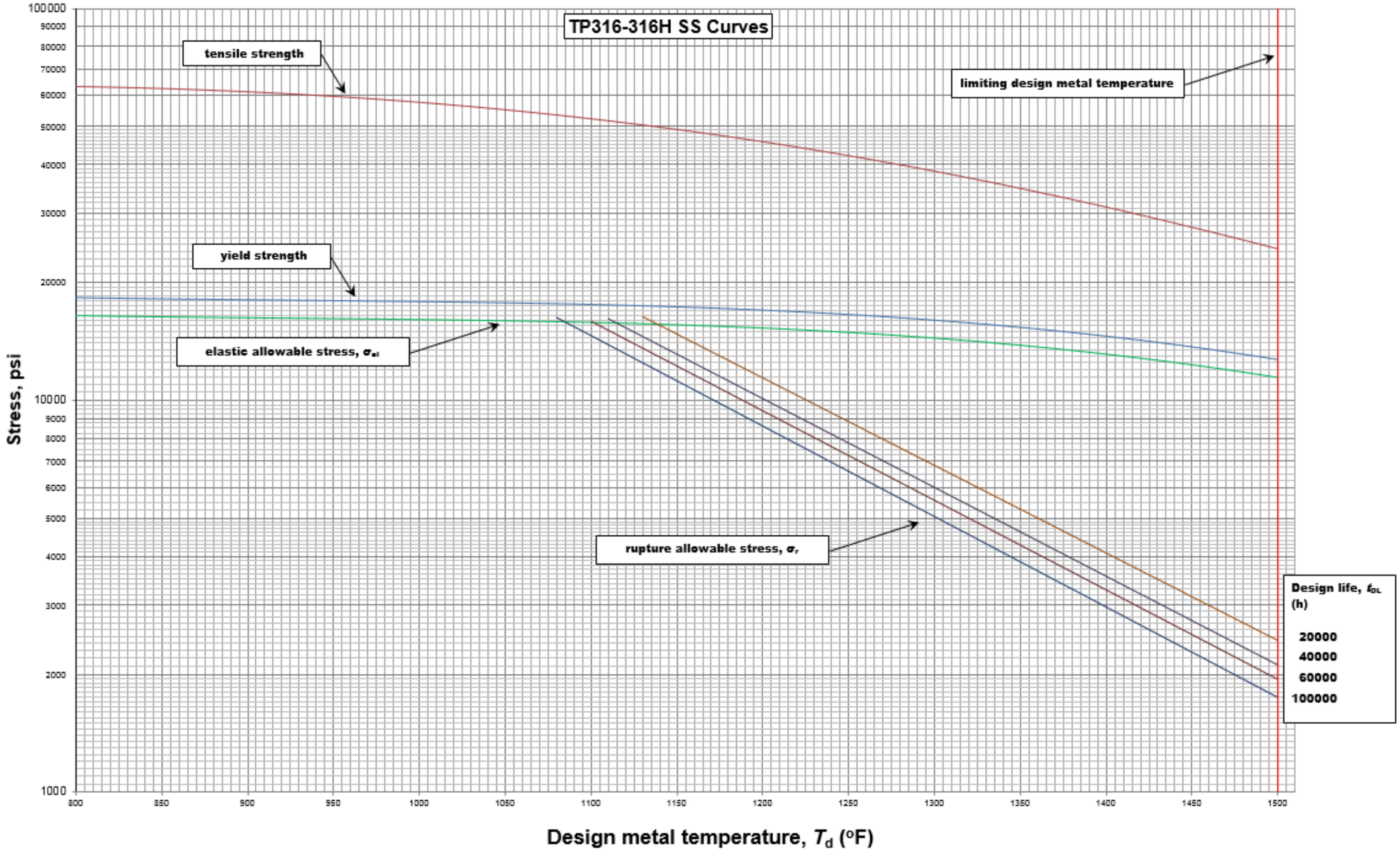



**Figure F.43—Stress Curves (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP 316 and 316H (16Cr-12Ni-2Mo) Stainless Steels**

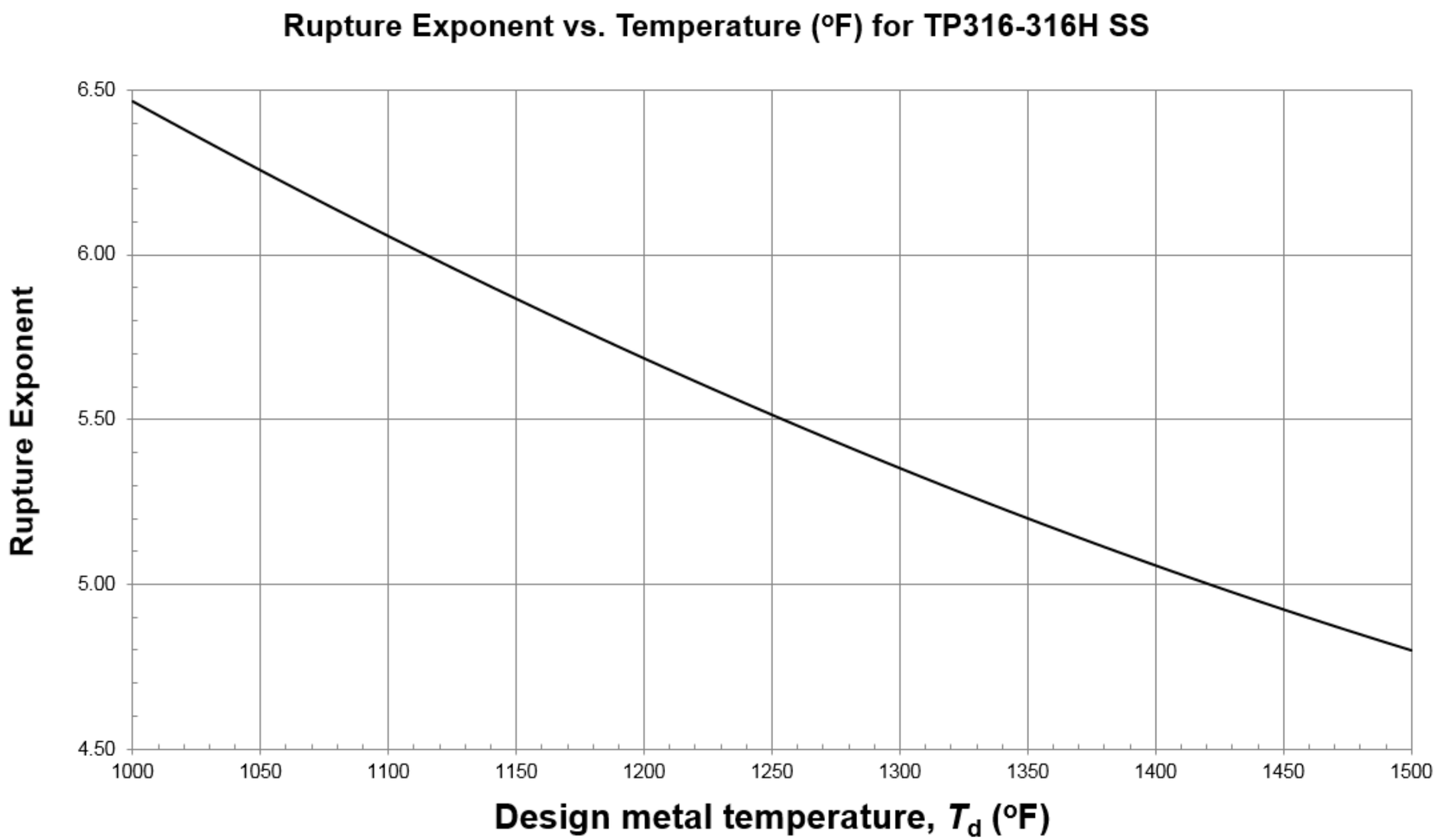



**Figure F.44—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP316 and 316H (16Cr-12Ni-2Mo) Stainless Steels**

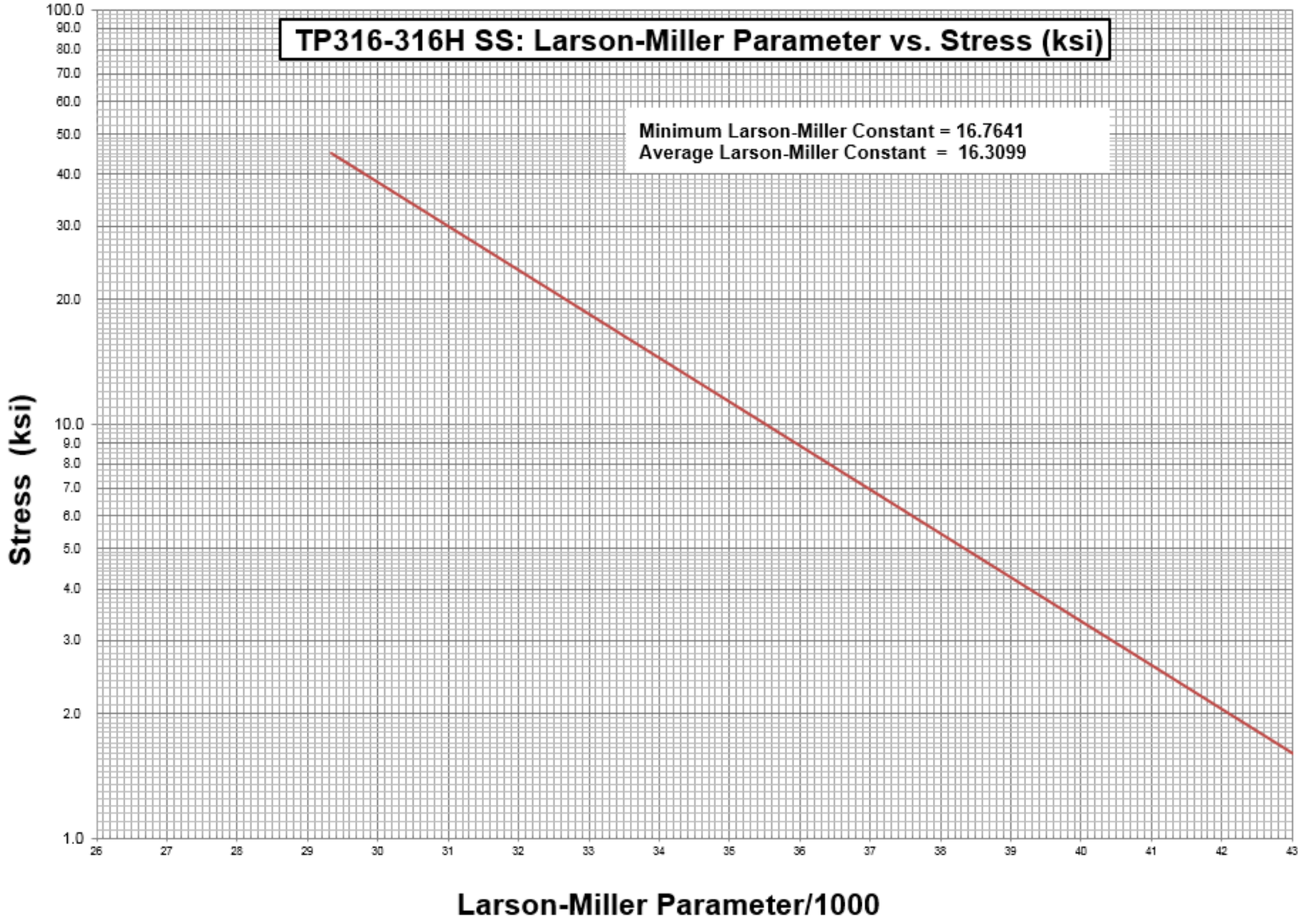



**Figure F.45—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP316 and 316H (16Cr-12Ni-2Mo) Stainless Steels**

**Table F.15—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP316 and 316H (16Cr-12Ni-2Mo) Stainless Steels**

| TP 316-316H SS | | | | | | |
|---|---|---|---|---|---|---|
| **Temperature** (Fahrenheit) | **Elastic Allowable Stress, $\sigma_{el}$** (ksi) | **Rupture Allowable Stress, $\sigma_r$** | | | | **Rupture Exponent, *n*** |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 800 | 16.5 | | | | | |
| 820 | 16.4 | | | | | |
| 840 | 16.4 | | | | | |
| 860 | 16.3 | | | | | |
| 880 | 16.3 | | | | | |
| 900 | 16.3 | | | | | |
| 920 | 16.2 | | | | | |
| 940 | 16.2 | | | | | |
| 960 | 16.2 | | | | | |
| 980 | 16.1 | | | | | |
| 1000 | 16.1 | | | | | 6.5 |
| 1020 | 16.0 | | | | | 6.4 |
| 1040 | 16.0 | | | | | 6.3 |
| 1060 | 15.9 | | | | | 6.2 |
| 1080 | 15.9 | 16.3 | 17.7 | 18.9 | 21.2 | 6.1 |
| 1100 | 15.8 | 14.6 | 15.9 | 17.0 | 19.1 | 6.1 |
| 1120 | 15.7 | 13.2 | 14.3 | 15.3 | 17.2 | 6.0 |
| 1140 | 15.7 | 11.8 | 12.9 | 13.8 | 15.6 | 5.9 |
| 1160 | 15.5 | 10.6 | 11.6 | 12.5 | 14.0 | 5.8 |
| 1180 | 15.4 | 9.6 | 10.5 | 11.2 | 12.7 | 5.8 |
| 1200 | 15.3 | 8.6 | 9.4 | 10.1 | 11.4 | 5.7 |
| 1220 | 15.2 | 7.7 | 8.5 | 9.1 | 10.3 | 5.6 |
| 1240 | 15.0 | 7.0 | 7.6 | 8.2 | 9.3 | 5.5 |
| 1260 | 14.8 | 6.3 | 6.9 | 7.4 | 8.4 | 5.5 |
| 1280 | 14.6 | 5.6 | 6.2 | 6.7 | 7.6 | 5.4 |
| 1300 | 14.4 | 5.1 | 5.6 | 6.0 | 6.8 | 5.4 |
| 1320 | 14.2 | 4.5 | 5.0 | 5.4 | 6.2 | 5.3 |
| 1340 | 14.0 | 4.1 | 4.5 | 4.9 | 5.6 | 5.2 |
| 1360 | 13.7 | 3.7 | 4.1 | 4.4 | 5.0 | 5.2 |
| 1380 | 13.4 | 3.3 | 3.7 | 4.0 | 4.5 | 5.1 |
| 1400 | 13.1 | 3.0 | 3.3 | 3.6 | 4.1 | 5.1 |
| 1420 | 12.8 | 2.7 | 3.0 | 3.2 | 3.7 | 5.0 |
| 1440 | 12.5 | 2.4 | 2.7 | 2.9 | 3.3 | 5.0 |
| 1460 | 12.2 | 2.2 | 2.4 | 2.6 | 3.0 | 4.9 |
| 1480 | 11.8 | 1.9 | 2.2 | 2.3 | 2.7 | 4.8 |
| 1500 | 11.4 | 1.7 | 1.9 | 2.1 | 2.4 | 4.8 |

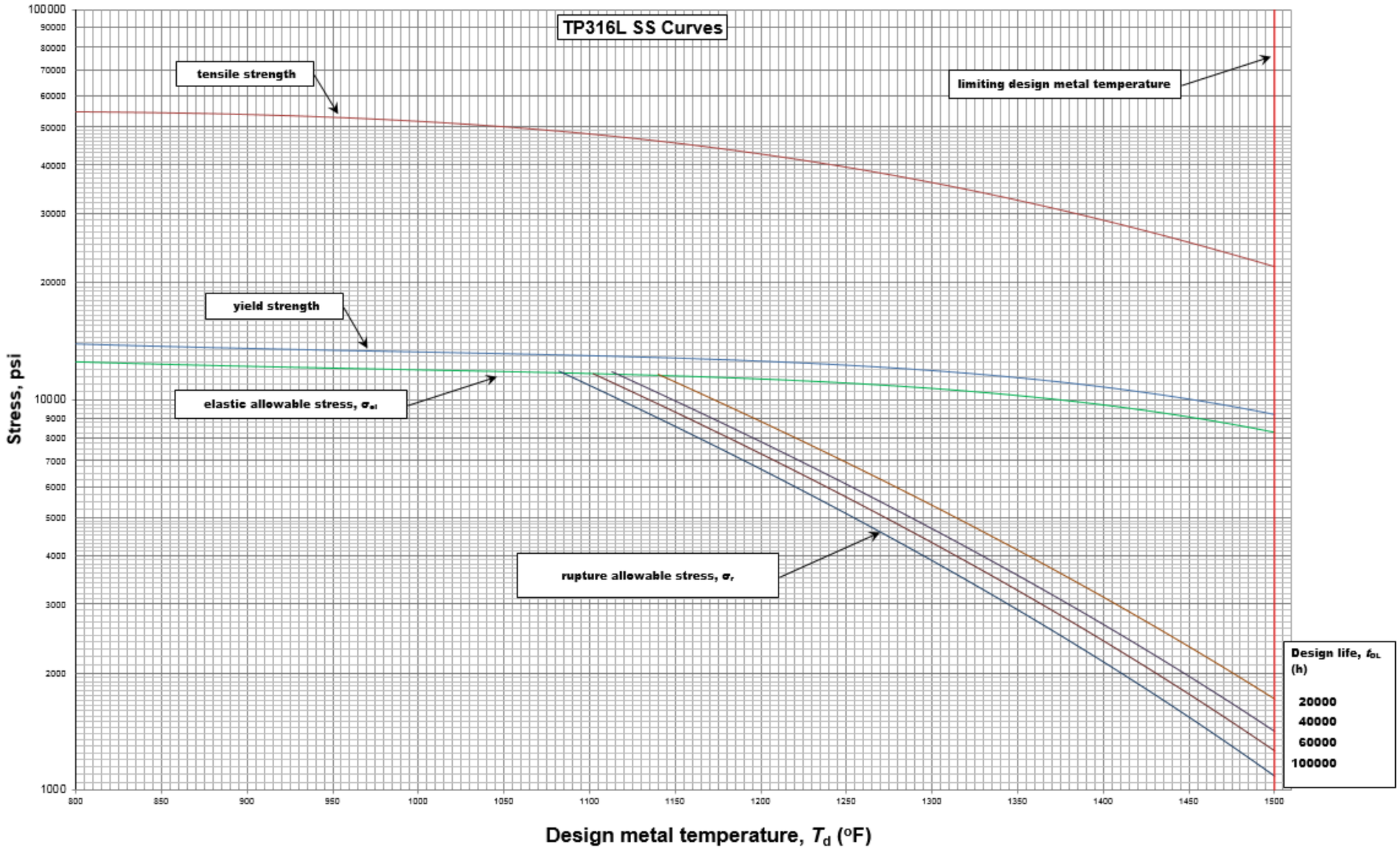



**Figure F.46—Stress Curves (USC Units) for ASTM A213, ASTM A312, and ASMT A379 TP316L (18Cr-8Ni-2Mo) Stainless Steels**

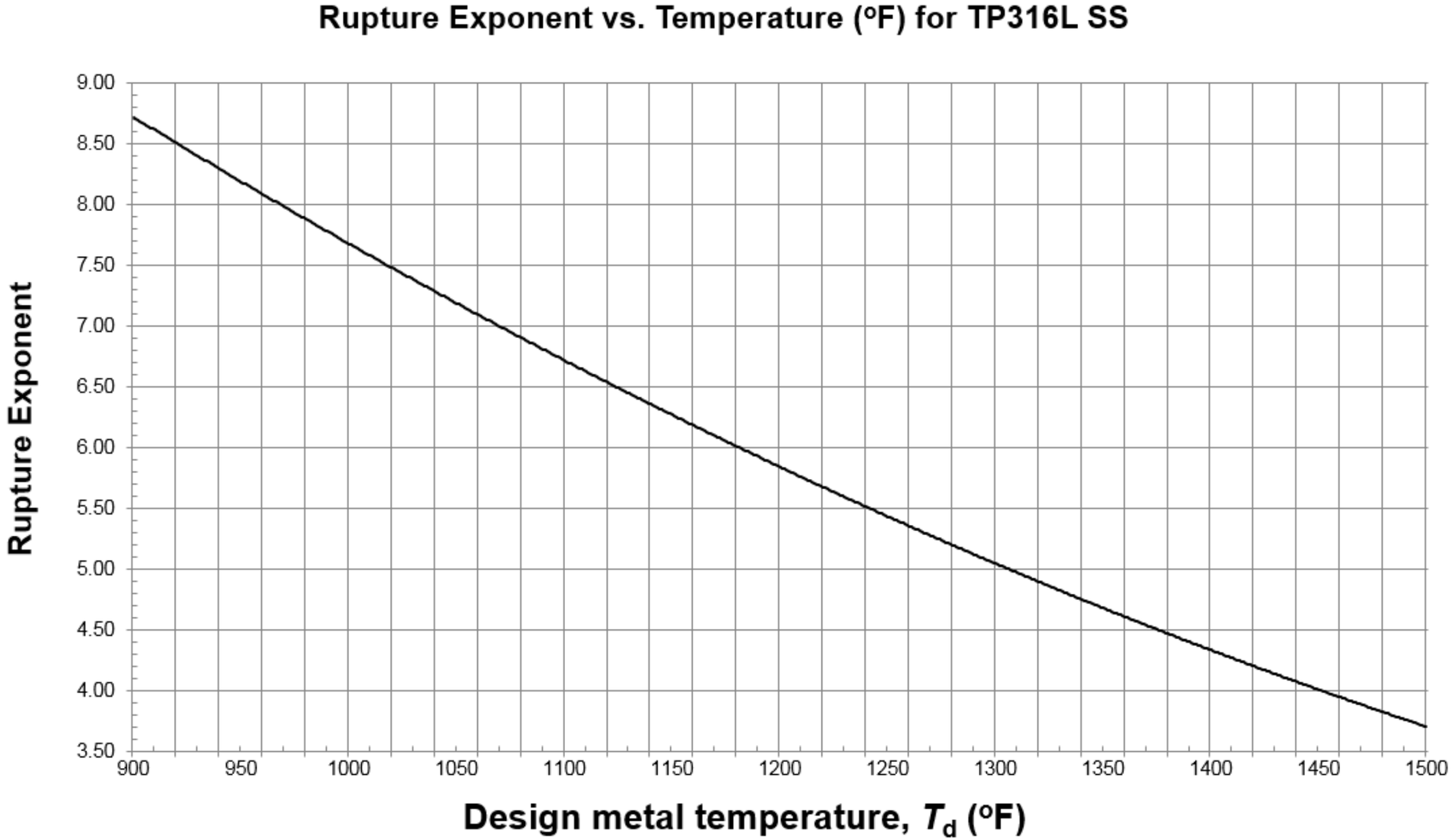



**Figure F.47—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L Stainless Steels**

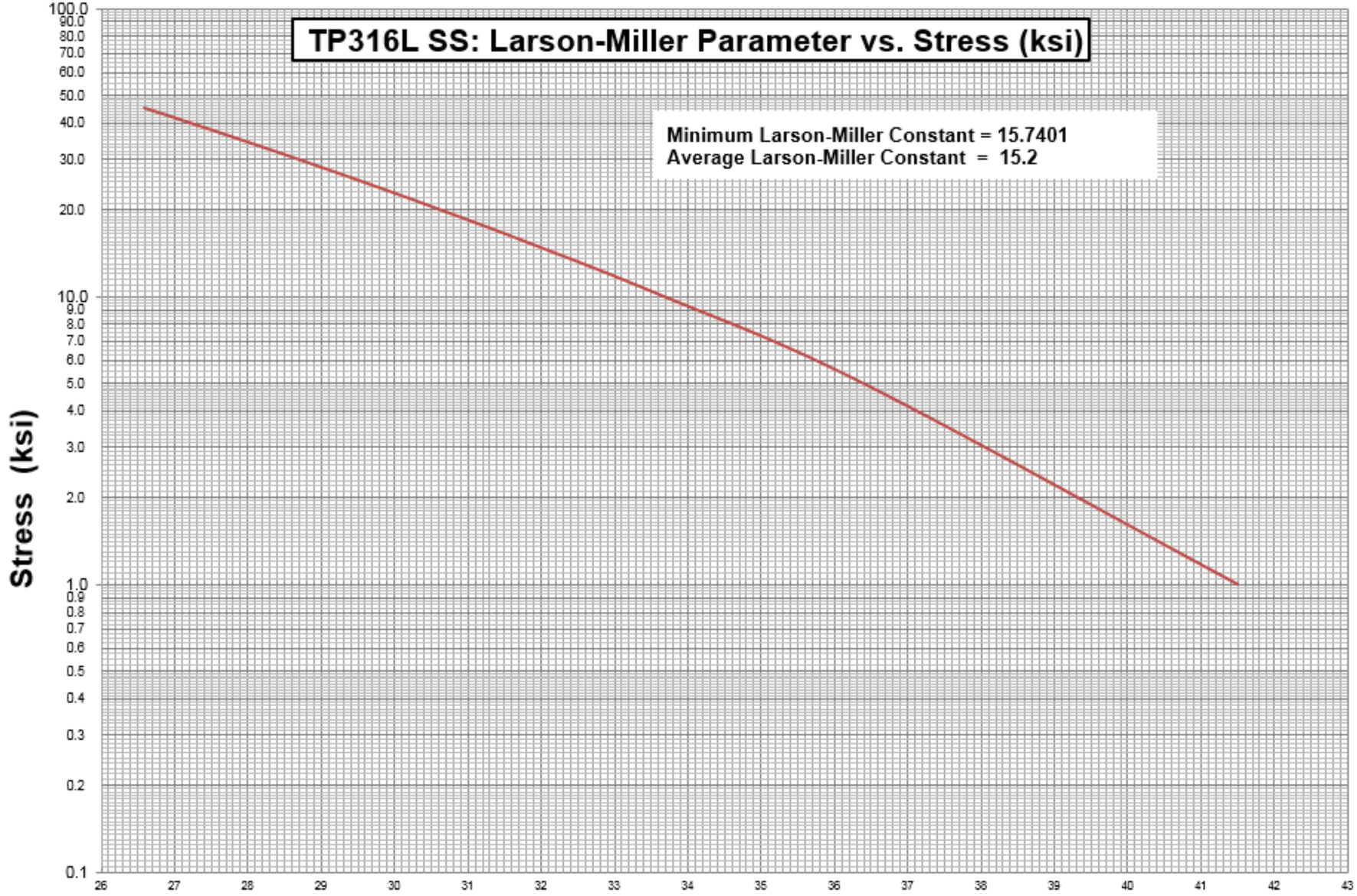



**Figure F.48—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L Stainless Steels**

**Table F.16—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L Stainless Steels**

| TP316L SS | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 800 | 12.5 | | | | | |
| 820 | 12.5 | | | | | |
| 840 | 12.4 | | | | | |
| 860 | 12.3 | | | | | |
| 880 | 12.3 | | | | | |
| 900 | 12.2 | | | | | 8.7 |
| 920 | 12.2 | | | | | 8.5 |
| 940 | 12.1 | | | | | 8.3 |
| 960 | 12.0 | | | | | 8.1 |
| 980 | 12.0 | | | | | 7.9 |
| 1000 | 12.0 | | | | | 7.7 |
| 1020 | 11.9 | | | | | 7.5 |
| 1040 | 11.9 | 14.4 | 15.5 | 16.4 | 18.0 | 7.3 |
| 1060 | 11.8 | 13.1 | 14.2 | 15.0 | 16.6 | 7.1 |
| 1080 | 11.7 | 12.0 | 12.9 | 13.7 | 15.2 | 6.9 |
| 1100 | 11.7 | 10.9 | 11.8 | 12.5 | 13.9 | 6.7 |
| 1120 | 11.6 | 9.9 | 10.7 | 11.4 | 12.7 | 6.5 |
| 1140 | 11.6 | 9.0 | 9.8 | 10.4 | 11.6 | 6.4 |
| 1160 | 11.5 | 8.1 | 8.9 | 9.5 | 10.6 | 6.2 |
| 1180 | 11.4 | 7.4 | 8.0 | 8.6 | 9.7 | 6.0 |
| 1200 | 11.3 | 6.7 | 7.3 | 7.8 | 8.8 | 5.8 |
| 1220 | 11.2 | 6.0 | 6.6 | 7.1 | 8.0 | 5.7 |
| 1240 | 11.1 | 5.4 | 5.9 | 6.4 | 7.3 | 5.5 |
| 1260 | 11.0 | 4.8 | 5.3 | 5.8 | 6.6 | 5.4 |
| 1280 | 10.9 | 4.3 | 4.8 | 5.2 | 6.0 | 5.2 |
| 1300 | 10.7 | 3.9 | 4.3 | 4.7 | 5.4 | 5.0 |
| 1320 | 10.5 | 3.5 | 3.9 | 4.2 | 4.8 | 4.9 |
| 1340 | 10.4 | 3.1 | 3.4 | 3.8 | 4.4 | 4.7 |
| 1360 | 10.2 | 2.7 | 3.1 | 3.4 | 3.9 | 4.6 |
| 1380 | 10.0 | 2.4 | 2.7 | 3.0 | 3.5 | 4.5 |
| 1400 | 9.7 | 2.1 | 2.4 | 2.7 | 3.1 | 4.3 |
| 1420 | 9.5 | 1.9 | 2.1 | 2.4 | 2.8 | 4.2 |
| 1440 | 9.2 | 1.6 | 1.9 | 2.1 | 2.5 | 4.1 |
| 1460 | 8.9 | 1.4 | 1.7 | 1.8 | 2.2 | 3.9 |
| 1480 | 8.6 | 1.3 | 1.4 | 1.6 | 1.9 | 3.8 |
| 1500 | 8.3 | 1.1 | 1.3 | 1.4 | 1.7 | 3.7 |

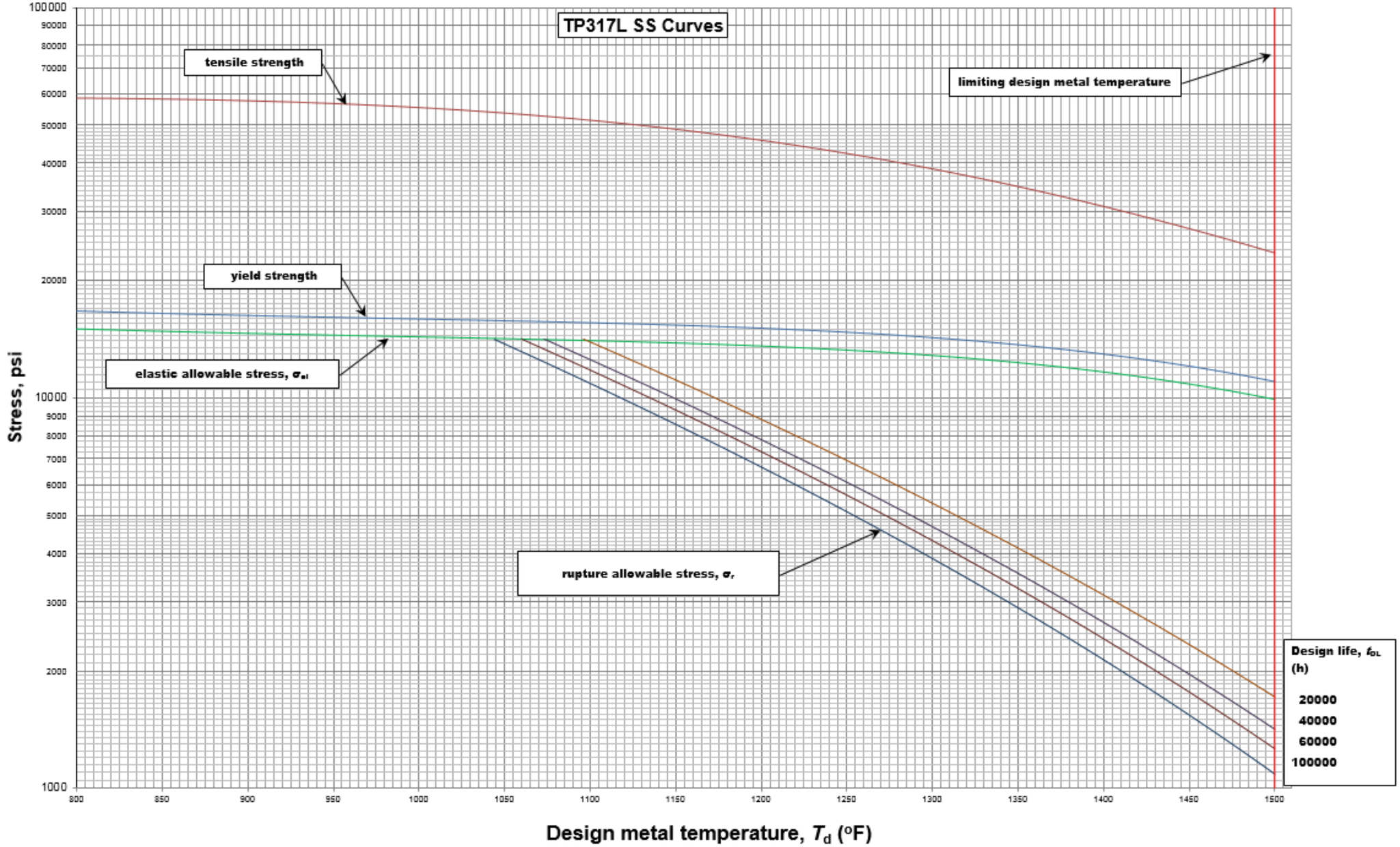



**Figure F.49—Stress Curves (USC Units) for ASTM A213, ASTM A312, and ASMT A379 TP317L (18Cr-8Ni-3Mo) Stainless Steels**

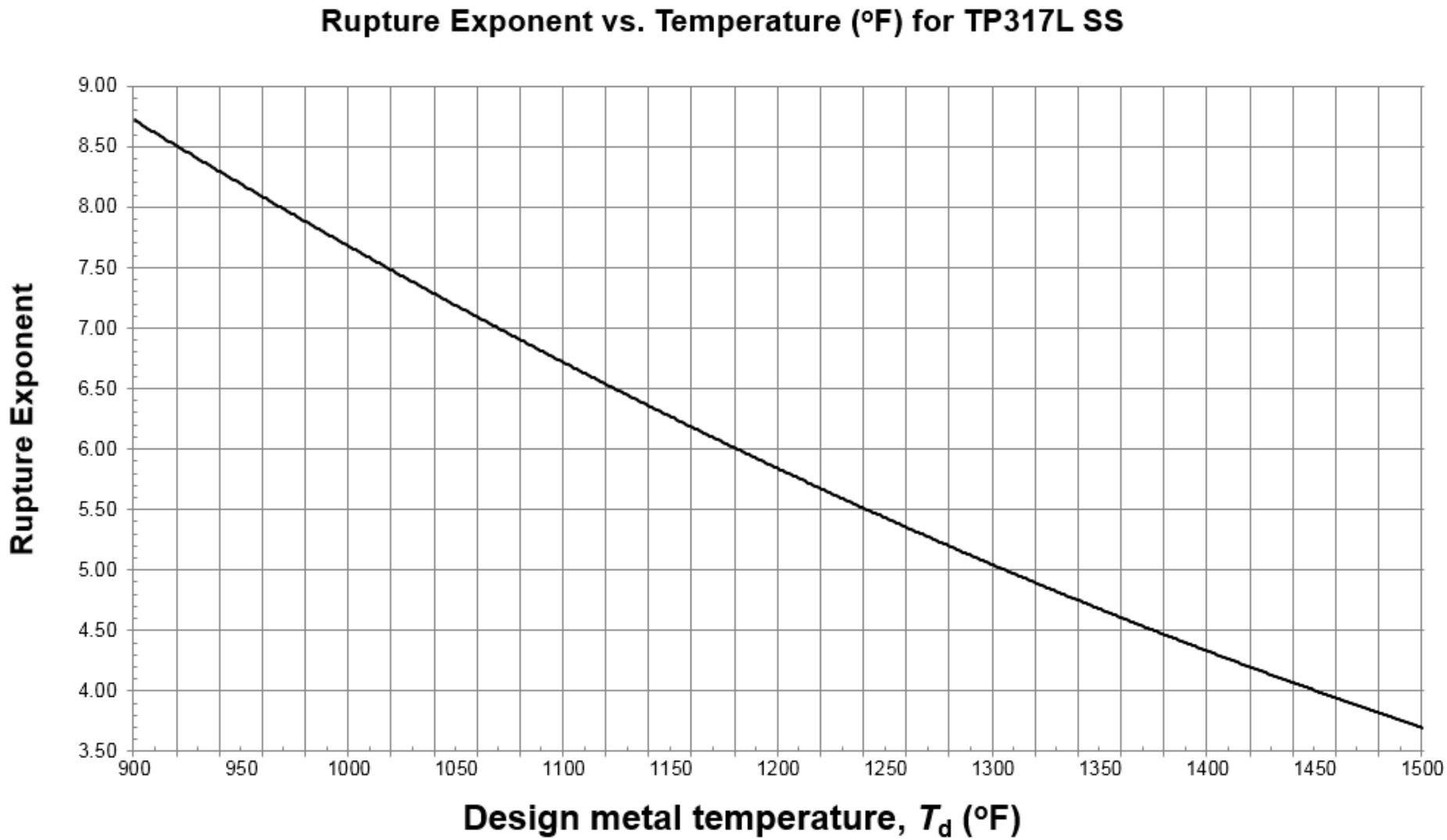



**Figure F.50—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP317L Stainless Steels**

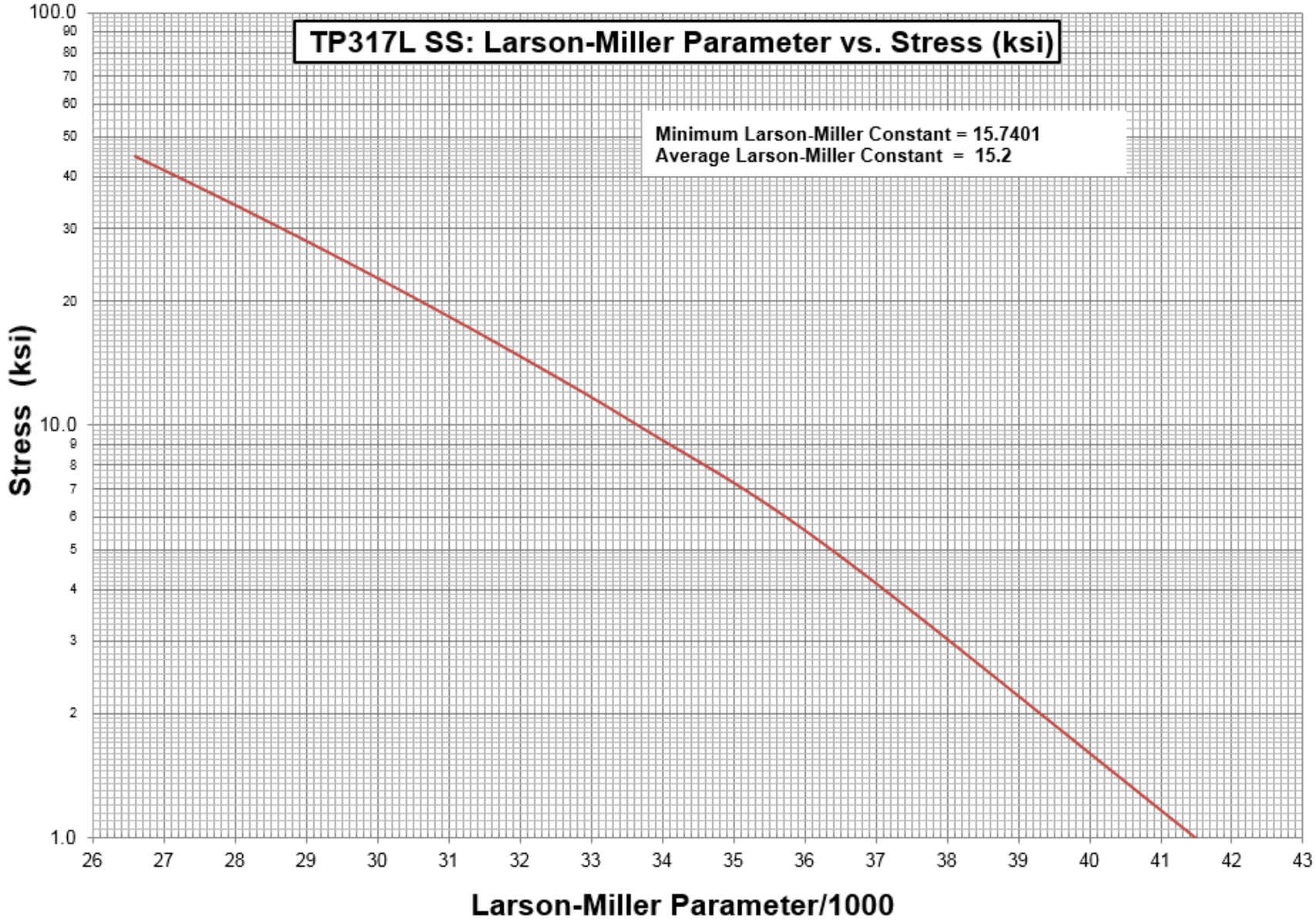



**Figure F.51—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP317L Stainless Steels**

**Table F.17—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP317L Stainless Steels**

| TP317L SS | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 800 | 15.0 | | | | | |
| 820 | 14.9 | | | | | |
| 840 | 14.9 | | | | | |
| 860 | 14.8 | | | | | |
| 880 | 14.7 | | | | | |
| 900 | 14.6 | | | | | 8.7 |
| 920 | 14.6 | | | | | 8.5 |
| 940 | 14.5 | | | | | 8.3 |
| 960 | 14.5 | | | | | 8.1 |
| 980 | 14.4 | | | | | 7.9 |
| 1000 | 14.3 | | | | | 7.7 |
| 1020 | 14.3 | | | | | 7.5 |
| 1040 | 14.2 | 14.4 | 15.5 | 16.4 | 18.0 | 7.3 |
| 1060 | 14.2 | 13.1 | 14.2 | 15.0 | 16.6 | 7.1 |
| 1080 | 14.1 | 12.0 | 12.9 | 13.7 | 15.2 | 6.9 |
| 1100 | 14.0 | 10.9 | 11.8 | 12.5 | 13.9 | 6.7 |
| 1120 | 14.0 | 9.9 | 10.7 | 11.4 | 12.7 | 6.5 |
| 1140 | 13.9 | 9.0 | 9.8 | 10.4 | 11.6 | 6.4 |
| 1160 | 13.8 | 8.1 | 8.9 | 9.5 | 10.6 | 6.2 |
| 1180 | 13.7 | 7.4 | 8.0 | 8.6 | 9.7 | 6.0 |
| 1200 | 13.6 | 6.7 | 7.3 | 7.8 | 8.8 | 5.8 |
| 1220 | 13.5 | 6.0 | 6.6 | 7.1 | 8.0 | 5.7 |
| 1240 | 13.3 | 5.4 | 5.9 | 6.4 | 7.3 | 5.5 |
| 1260 | 13.2 | 4.8 | 5.4 | 5.8 | 6.6 | 5.4 |
| 1280 | 13.0 | 4.3 | 4.8 | 5.2 | 6.0 | 5.2 |
| 1300 | 12.9 | 3.9 | 4.3 | 4.7 | 5.4 | 5.0 |
| 1320 | 12.7 | 3.5 | 3.9 | 4.2 | 4.8 | 4.9 |
| 1340 | 12.4 | 3.1 | 3.4 | 3.8 | 4.4 | 4.7 |
| 1360 | 12.2 | 2.7 | 3.1 | 3.4 | 3.9 | 4.6 |
| 1380 | 11.9 | 2.4 | 2.7 | 3.0 | 3.5 | 4.5 |
| 1400 | 11.7 | 2.1 | 2.4 | 2.7 | 3.1 | 4.3 |
| 1420 | 11.4 | 1.9 | 2.1 | 2.4 | 2.8 | 4.2 |
| 1440 | 11.0 | 1.6 | 1.9 | 2.1 | 2.5 | 4.1 |
| 1460 | 10.7 | 1.4 | 1.7 | 1.8 | 2.2 | 3.9 |
| 1480 | 10.3 | 1.3 | 1.4 | 1.6 | 1.9 | 3.8 |
| 1500 | 9.9 | 1.1 | 1.3 | 1.4 | 1.7 | 3.7 |

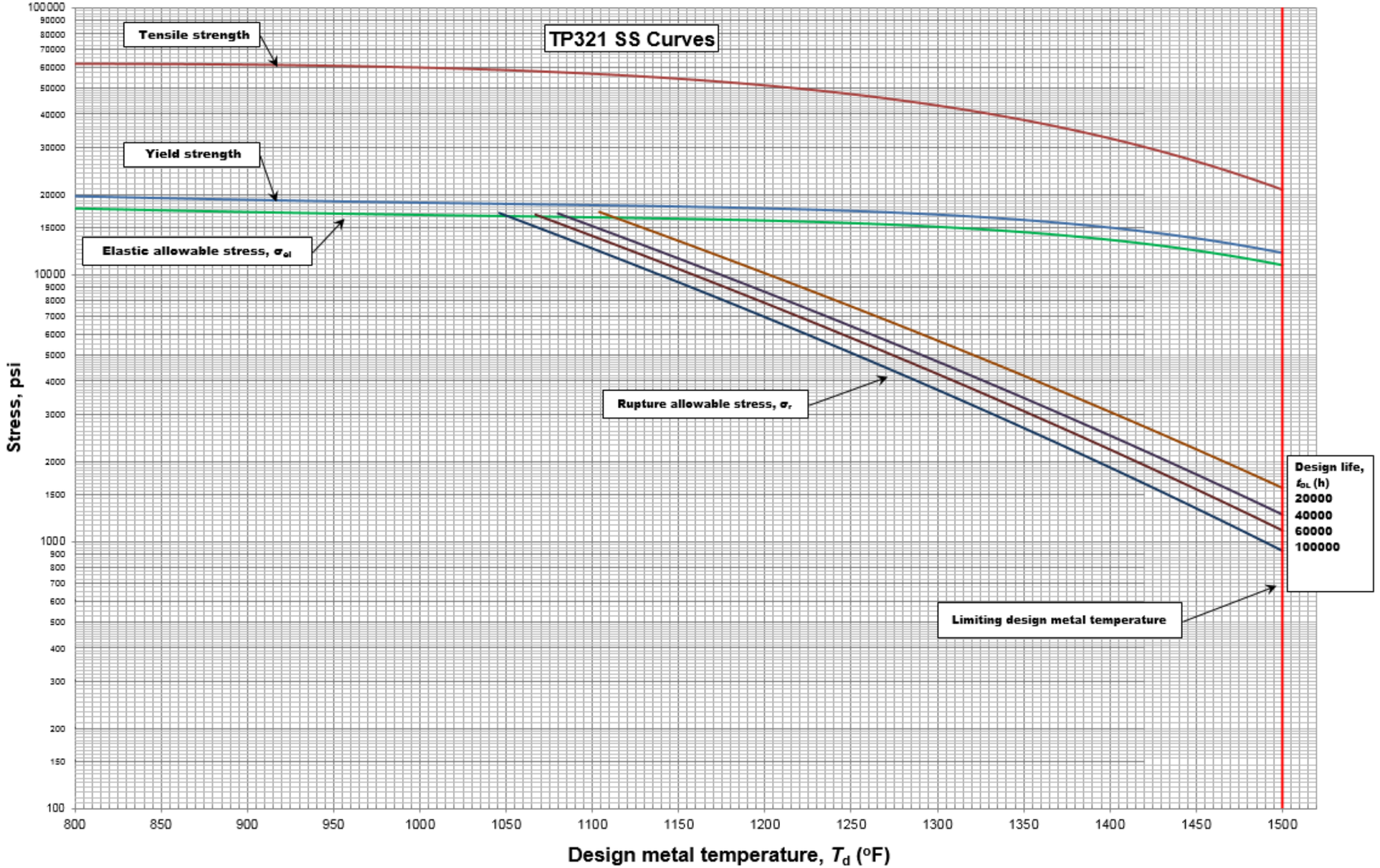



**Figure F.52—Stress Curves (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP321 (18Cr-10Ni-Ti) Stainless Steels**

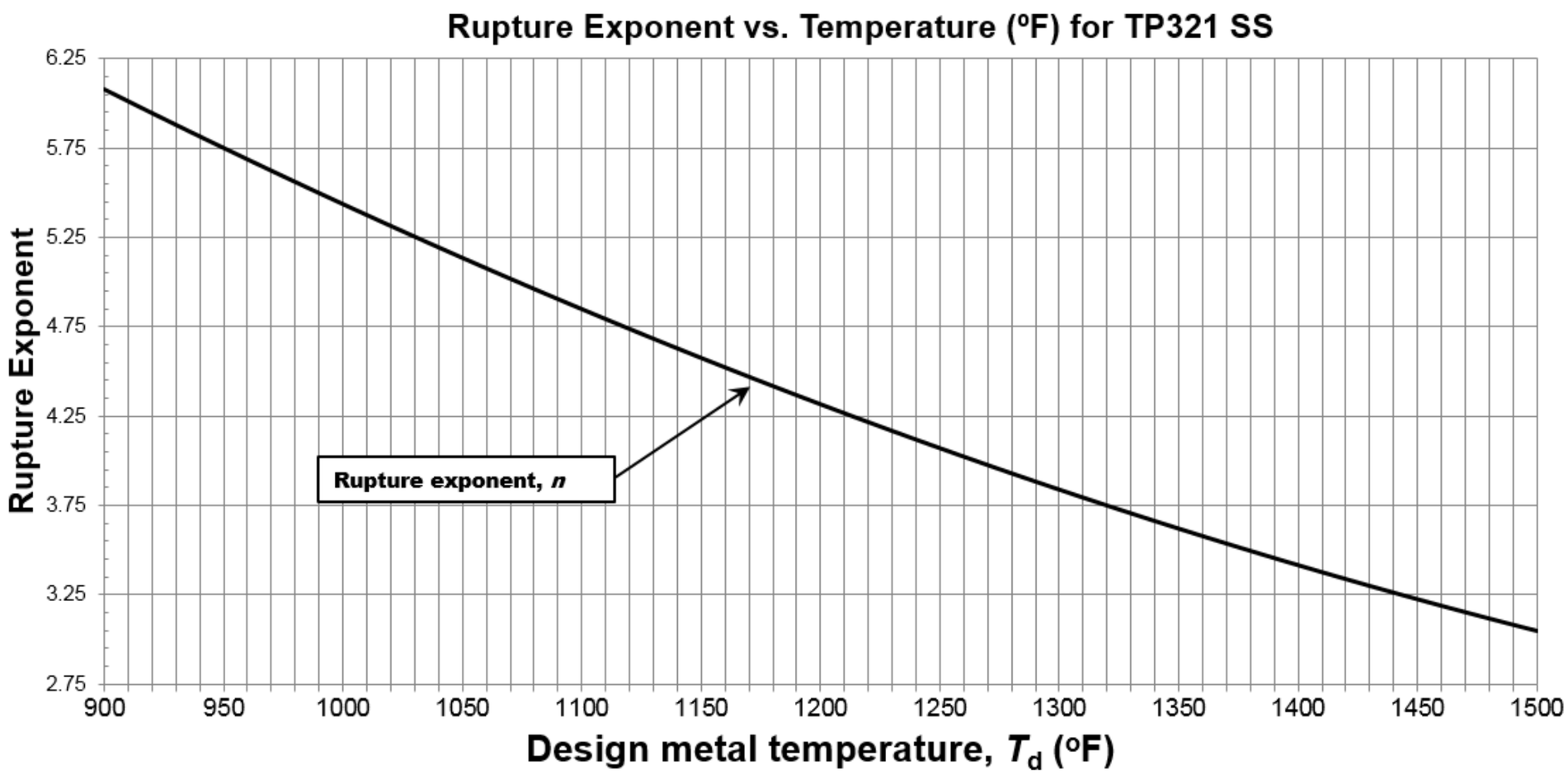



**Figure F.53—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP321 (18Cr-10Ni-Ti) Stainless Steels**

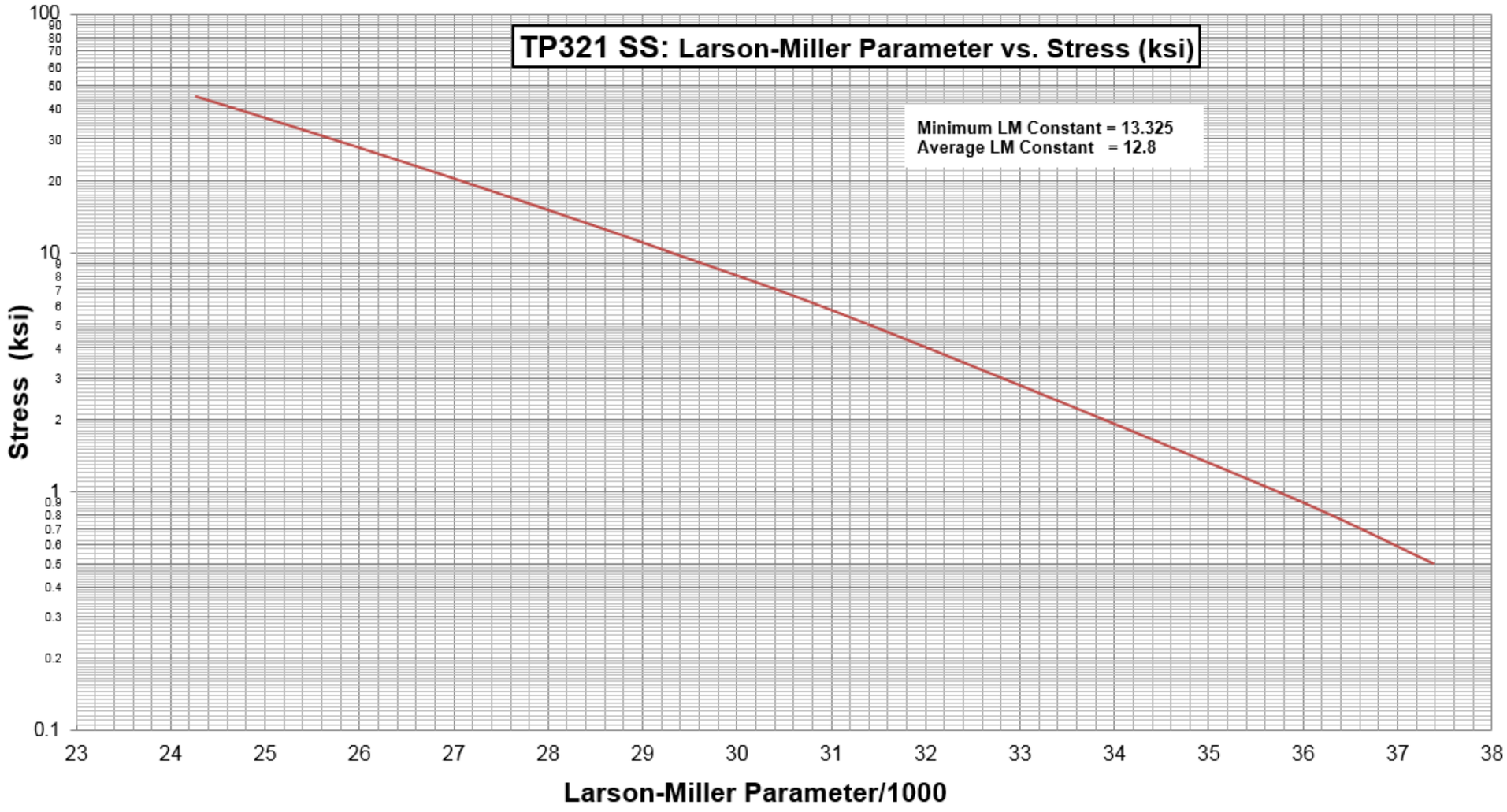



**Figure F.54—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP321 (18Cr-10Ni-Ti) Stainless Steels**

**Table F.18—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP321 (18Cr-10Ni-Ti) Stainless Steels**

| TP321 SS | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 800 | 17.7 | | | | | |
| 820 | 17.6 | | | | | |
| 840 | 17.5 | | | | | |
| 860 | 17.4 | | | | | |
| 880 | 17.3 | | | | | |
| 900 | 17.2 | | | | | 6.1 |
| 920 | 17.1 | | | | | 5.9 |
| 940 | 17.0 | | | | | 5.8 |
| 960 | 16.9 | | | | | 5.7 |
| 980 | 16.8 | | | | | 5.6 |
| 1000 | 16.8 | | | | | 5.4 |
| 1020 | 16.7 | 19.7 | 21.7 | 23.5 | 26.8 | 5.3 |
| 1040 | 16.6 | 17.6 | 19.5 | 21.1 | 24.1 | 5.2 |
| 1060 | 16.6 | 15.8 | 17.5 | 18.9 | 21.7 | 5.1 |
| 1080 | 16.5 | 14.1 | 15.6 | 17.0 | 19.6 | 5.0 |
| 1100 | 16.4 | 12.5 | 14.0 | 15.2 | 17.6 | 4.8 |
| 1120 | 16.3 | 11.2 | 12.5 | 13.6 | 15.8 | 4.7 |
| 1140 | 16.3 | 9.9 | 11.1 | 12.2 | 14.2 | 4.6 |
| 1160 | 16.2 | 8.8 | 9.9 | 10.9 | 12.7 | 4.5 |
| 1180 | 16.1 | 7.8 | 8.8 | 9.7 | 11.3 | 4.4 |
| 1200 | 16.4 | 6.9 | 7.8 | 8.6 | 10.1 | 4.3 |
| 1220 | 15.8 | 6.1 | 7.0 | 7.7 | 9.1 | 4.2 |
| 1240 | 15.7 | 5.4 | 6.2 | 6.8 | 8.1 | 4.1 |
| 1260 | 15.5 | 4.8 | 5.5 | 6.0 | 7.2 | 4.0 |
| 1280 | 15.3 | 4.2 | 4.8 | 5.4 | 6.4 | 3.9 |
| 1300 | 15.1 | 3.7 | 4.3 | 4.7 | 5.7 | 3.8 |
| 1320 | 14.9 | 3.3 | 3.7 | 4.2 | 5.0 | 3.7 |
| 1340 | 14.6 | 2.9 | 3.3 | 3.7 | 4.5 | 3.7 |
| 1360 | 14.3 | 2.5 | 2.9 | 3.2 | 3.9 | 3.6 |
| 1380 | 13.9 | 2.2 | 2.5 | 2.9 | 3.5 | 3.5 |
| 1400 | 13.5 | 1.9 | 2.2 | 2.5 | 3.1 | 3.4 |
| 1420 | 13.1 | 1.7 | 1.9 | 2.2 | 2.7 | 3.3 |
| 1440 | 12.6 | 1.4 | 1.7 | 1.9 | 2.4 | 3.3 |
| 1460 | 12.1 | 1.2 | 1.5 | 1.7 | 2.1 | 3.2 |
| 1480 | 11.5 | 1.1 | 1.3 | 1.5 | 1.8 | 3.1 |
| 1500 | 10.9 | 0.9 | 1.1 | 1.3 | 1.6 | 3.0 |

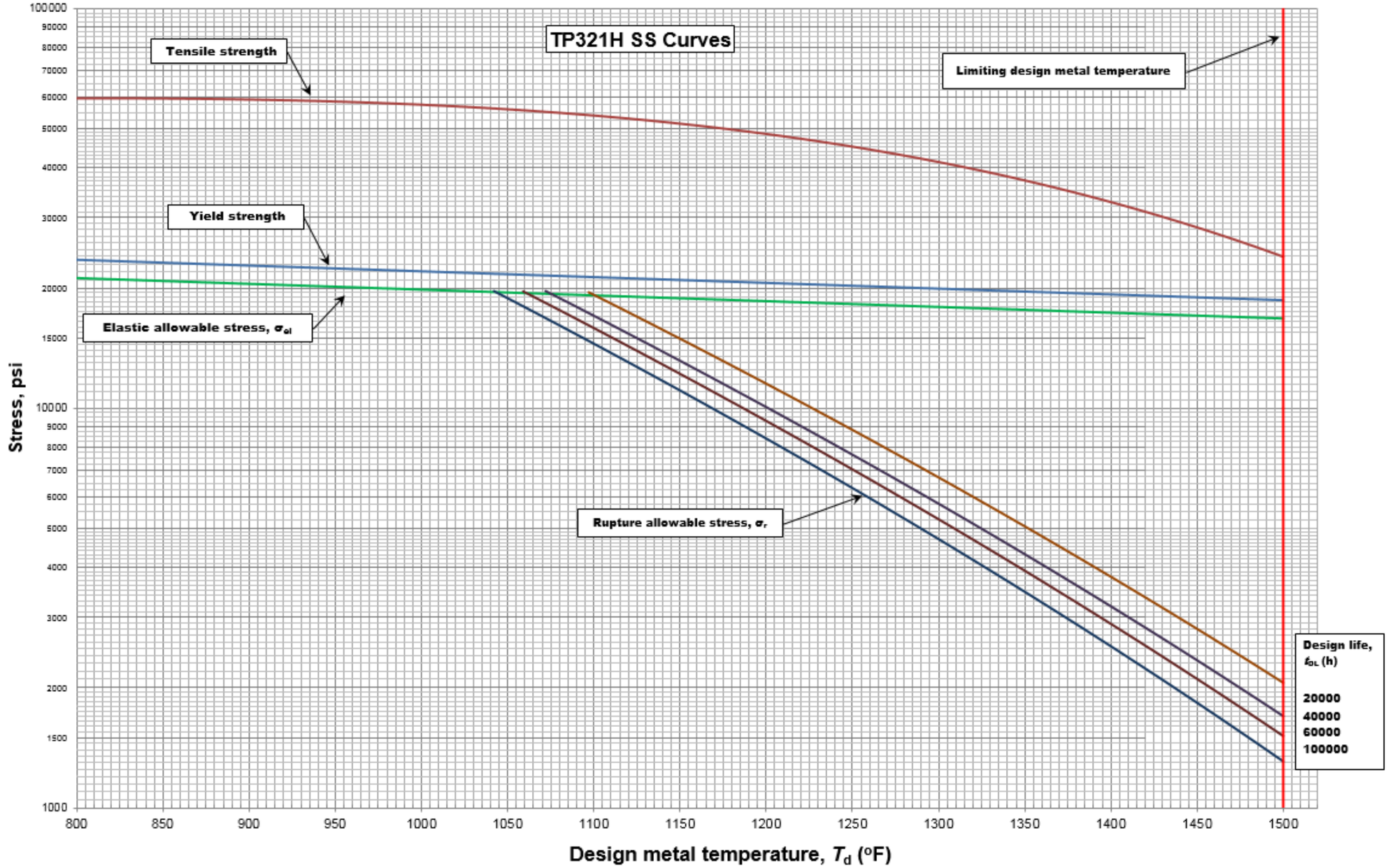



**Figure F.55—Stress Curves (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP 321H (18Cr-10Ni-Ti) Stainless Steels**

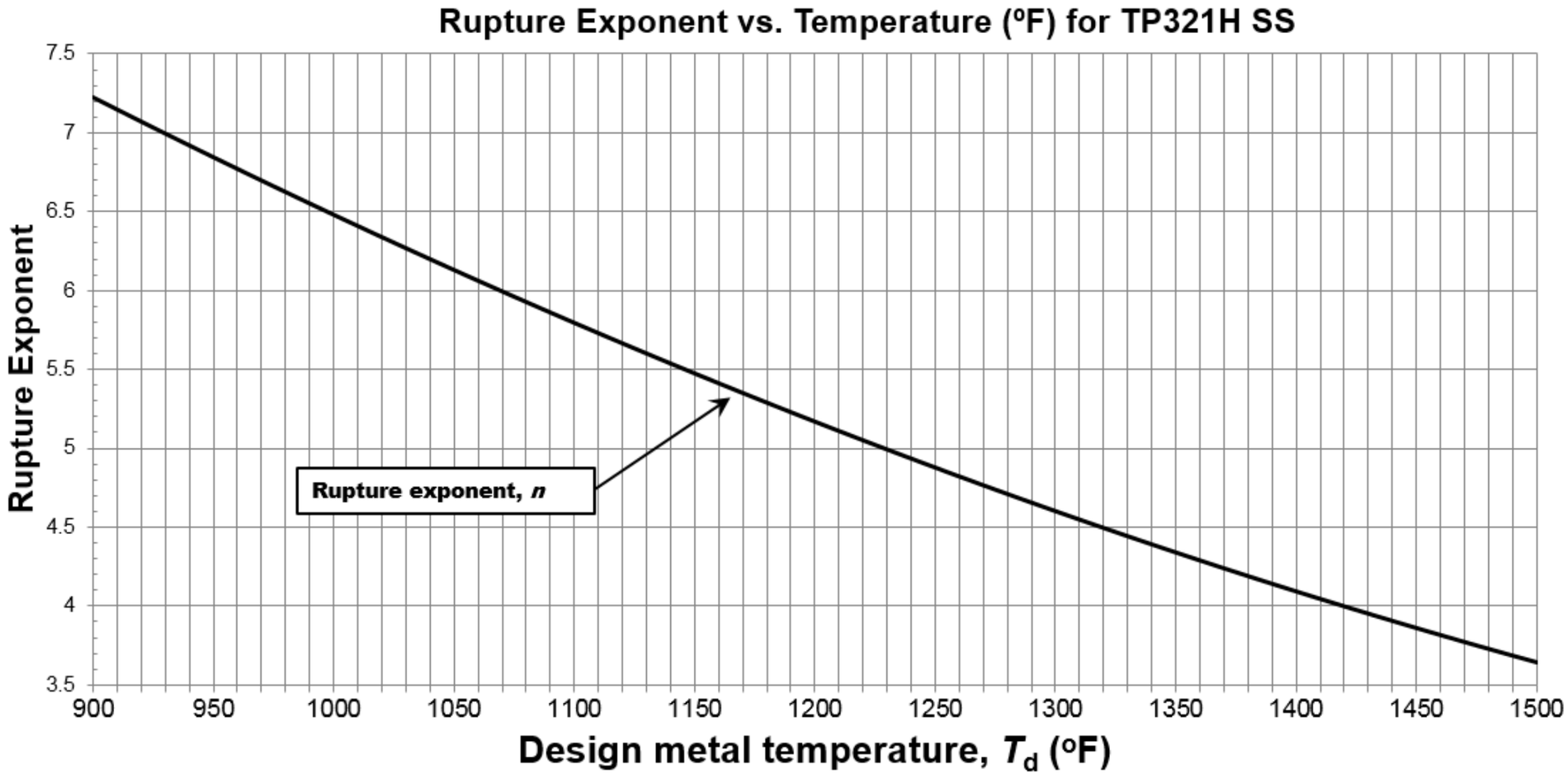



**Figure F.56—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP321H (18Cr-10Ni-Ti) Stainless Steels**

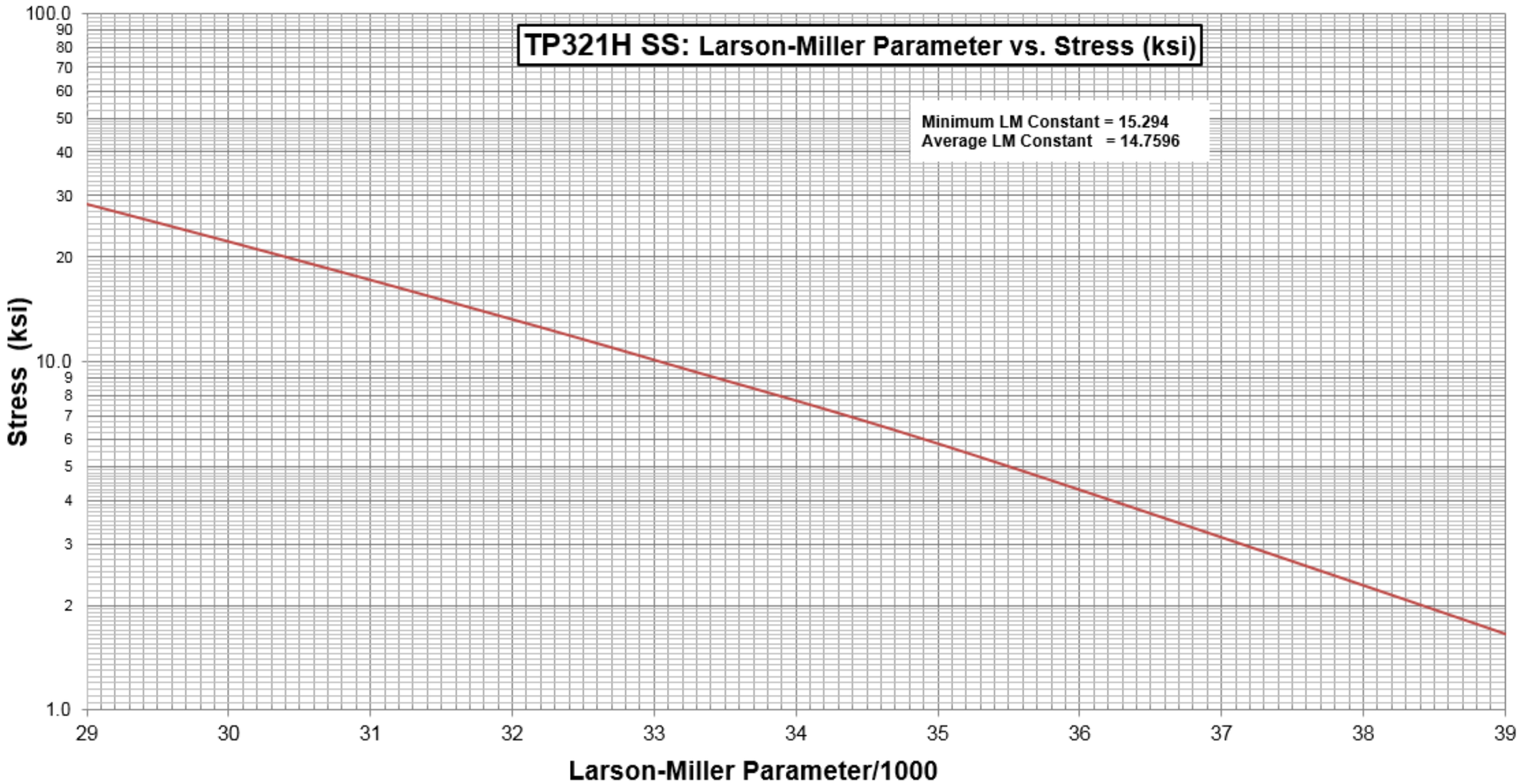



**Figure F.57—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP321H (18Cr-10Ni-Ti) Stainless Steels**

**Table F.19—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A312, and ASTM 376 TP321H (18Cr-10Ni-Ti) Stainless Steels**

| TP321H SS | | | | | | |
|---|---|---|---|---|---|---|
| **Temperature** (Fahrenheit) | **Elastic Allowable Stress, $\sigma_{el}$** (ksi) | **Rupture Allowable Stress, $\sigma_r$** | | | | **Rupture Exponent, *n*** |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 800 | 21.2 | | | | | |
| 820 | 21.0 | | | | | |
| 840 | 20.9 | | | | | |
| 860 | 20.8 | | | | | |
| 880 | 20.6 | | | | | |
| 900 | 20.5 | | | | | 7.2 |
| 920 | 20.4 | | | | | 7.1 |
| 940 | 20.2 | | | | | 6.9 |
| 960 | 20.1 | | | | | 6.8 |
| 980 | 19.9 | | | | | 6.6 |
| 1000 | 19.8 | | | | | 6.5 |
| 1020 | 19.7 | 22.0 | 23.9 | 25.5 | 28.4 | 6.3 |
| 1040 | 19.6 | 19.9 | 21.6 | 23.1 | 25.8 | 6.2 |
| 1060 | 19.4 | 17.9 | 19.5 | 20.9 | 23.4 | 6.1 |
| 1080 | 19.3 | 16.1 | 17.6 | 18.9 | 21.2 | 5.9 |
| 1100 | 19.2 | 14.5 | 15.9 | 17.0 | 19.2 | 5.8 |
| 1120 | 19.0 | 13.0 | 14.3 | 15.4 | 17.4 | 5.7 |
| 1140 | 18.9 | 11.7 | 12.9 | 13.9 | 15.7 | 5.5 |
| 1160 | 18.8 | 10.5 | 11.6 | 12.5 | 14.2 | 5.4 |
| 1180 | 18.7 | 9.4 | 10.4 | 11.2 | 12.8 | 5.3 |
| 1200 | 19.2 | 8.4 | 9.3 | 10.1 | 11.5 | 5.2 |
| 1220 | 18.4 | 7.5 | 8.3 | 9.0 | 10.4 | 5.0 |
| 1240 | 18.3 | 6.7 | 7.4 | 8.1 | 9.3 | 4.9 |
| 1260 | 18.2 | 6.0 | 6.6 | 7.2 | 8.4 | 4.8 |
| 1280 | 18.1 | 5.3 | 5.9 | 6.5 | 7.5 | 4.7 |
| 1300 | 17.9 | 4.7 | 5.3 | 5.8 | 6.7 | 4.6 |
| 1320 | 17.8 | 4.2 | 4.7 | 5.1 | 6.0 | 4.5 |
| 1340 | 17.7 | 3.7 | 4.2 | 4.6 | 5.4 | 4.4 |
| 1360 | 17.6 | 3.3 | 3.7 | 4.1 | 4.8 | 4.3 |
| 1380 | 17.5 | 2.9 | 3.3 | 3.6 | 4.3 | 4.2 |
| 1400 | 17.3 | 2.5 | 2.9 | 3.2 | 3.8 | 4.1 |
| 1420 | 17.2 | 2.2 | 2.5 | 2.8 | 3.4 | 4.0 |
| 1440 | 17.1 | 2.0 | 2.2 | 2.5 | 3.0 | 3.9 |
| 1460 | 17.0 | 1.7 | 2.0 | 2.2 | 2.6 | 3.8 |
| 1480 | 16.9 | 1.5 | 1.7 | 1.9 | 2.3 | 3.7 |
| 1500 | 16.8 | 1.3 | 1.5 | 1.7 | 2.1 | 3.6 |

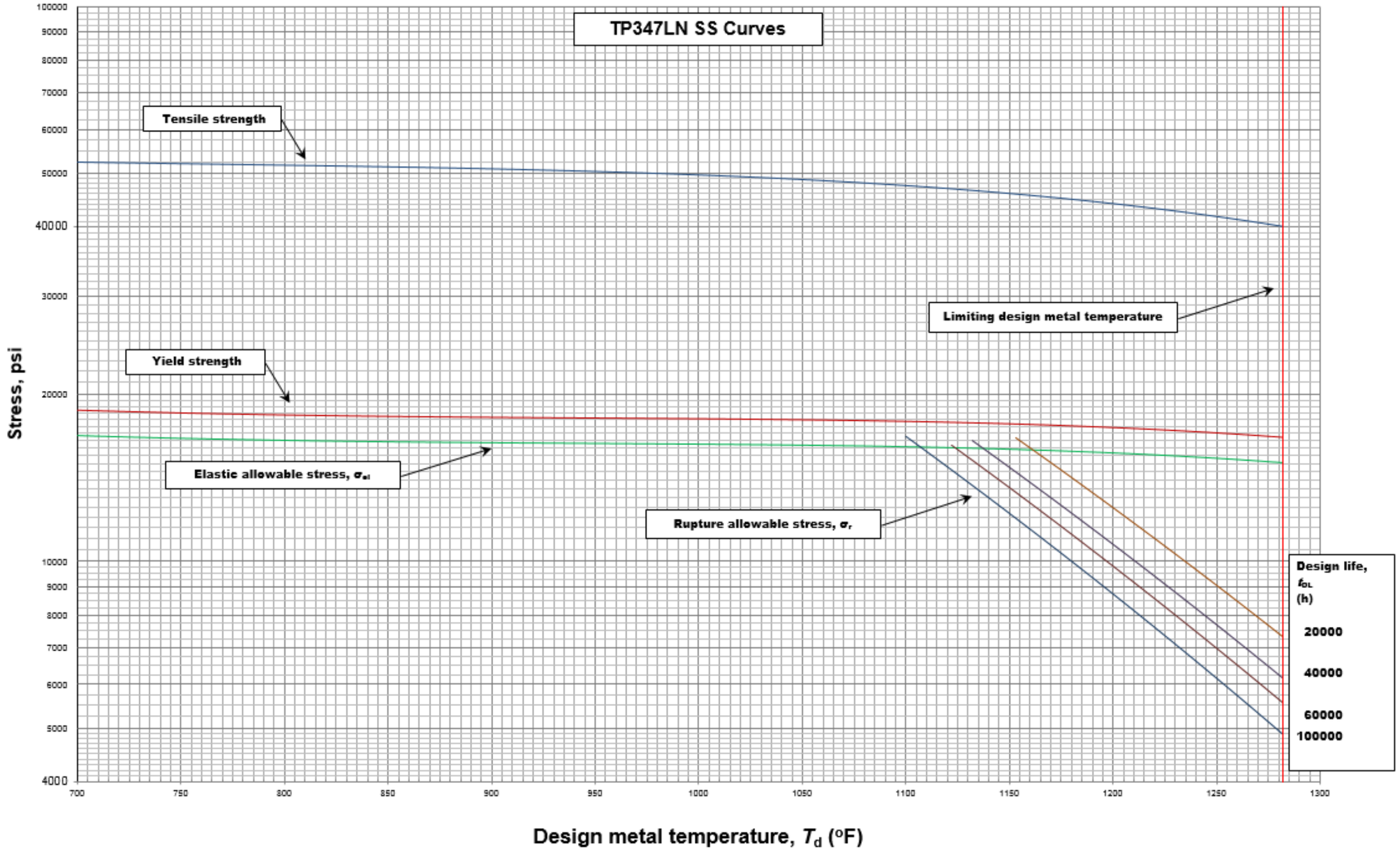



**Figure F.64—Stress Curves (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP347LN (18Cr-10Ni-Nb) Stainless Steels**

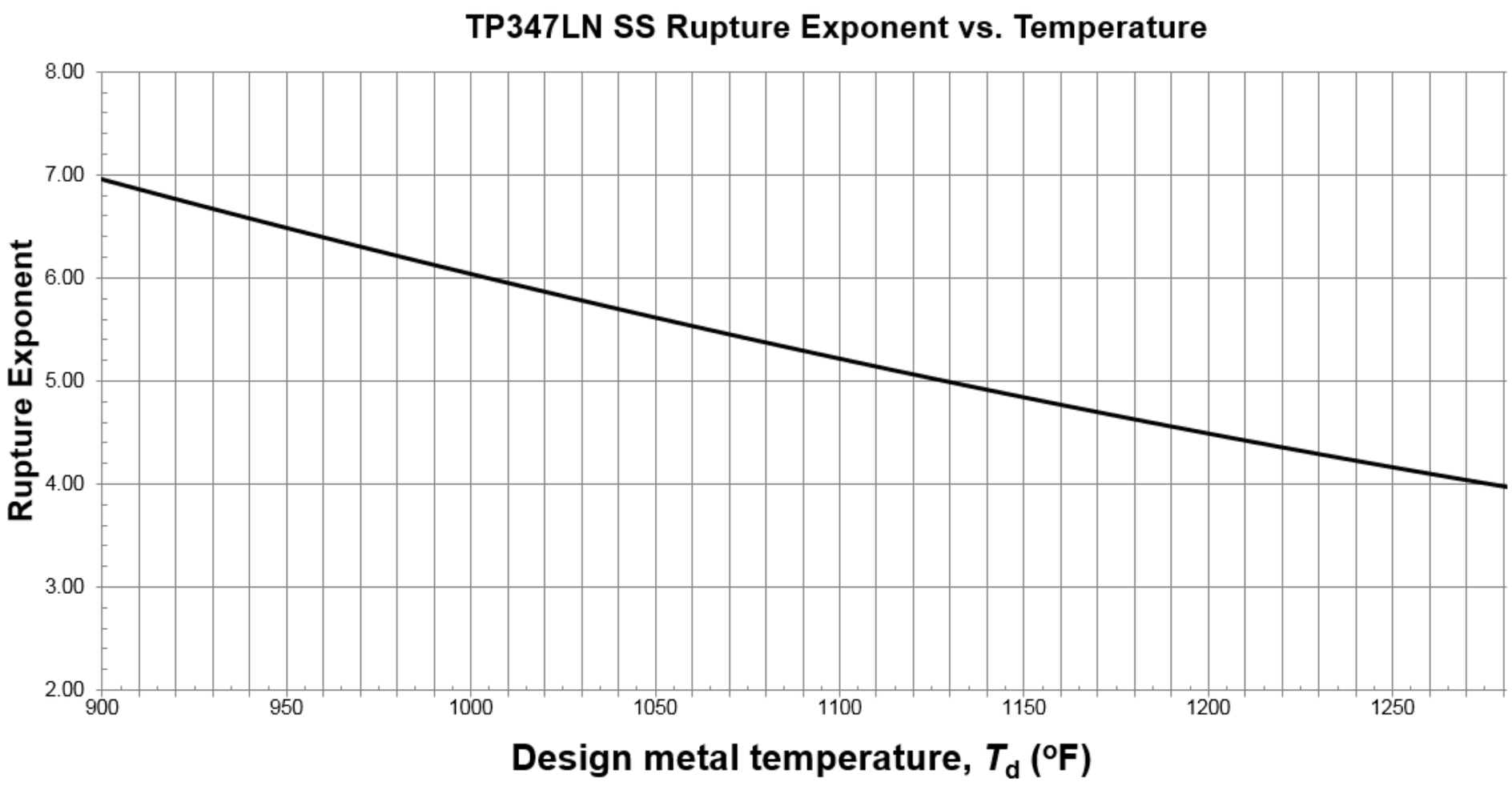



**Figure F.65—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP347LN (18Cr-10Ni-Nb) Stainless Steels**

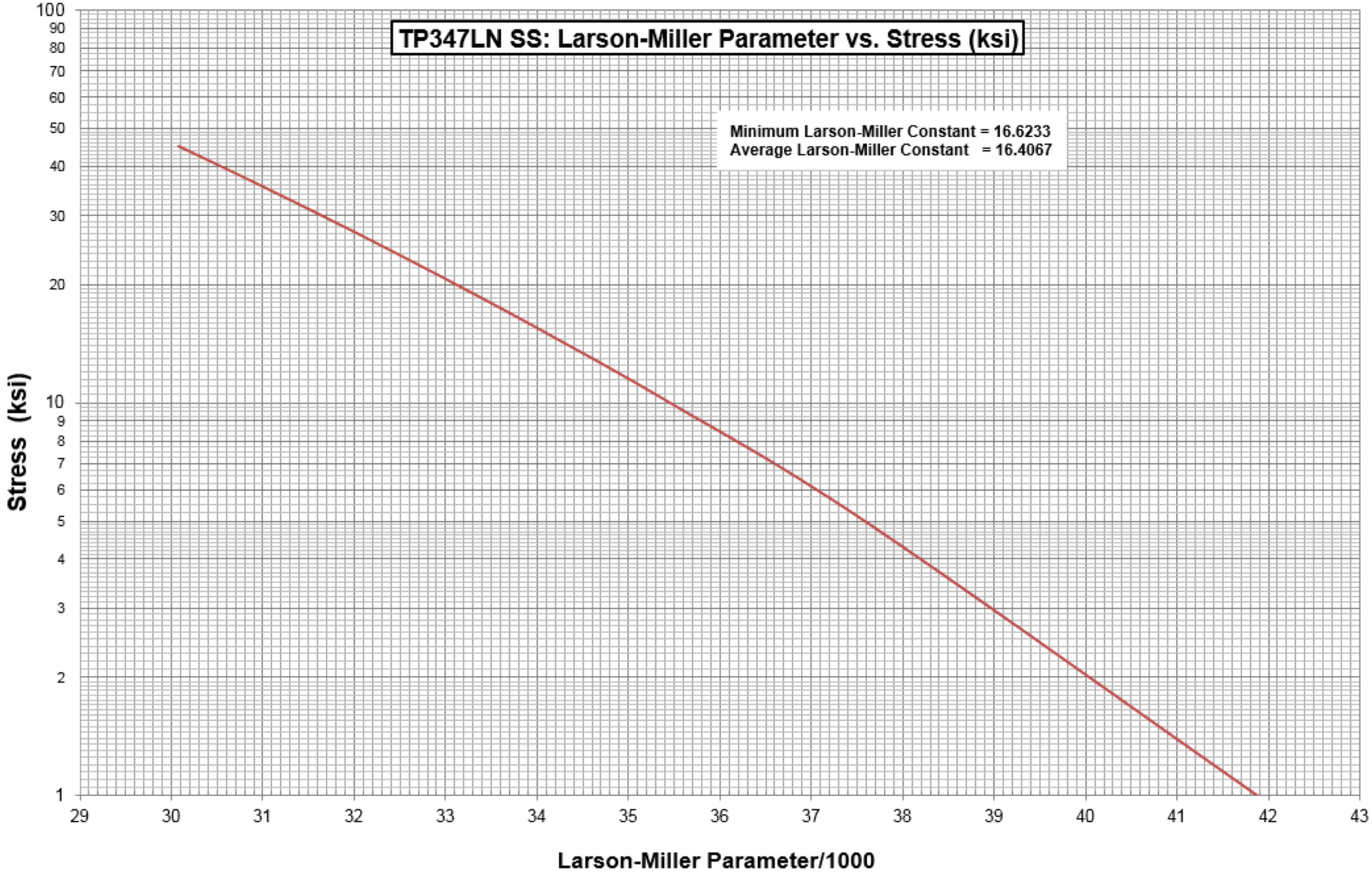



**Figure F.66—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP347LN (18Cr-10Ni-Nb) Stainless Steels**

**Table F.22—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A213, ASTM A312, and ASTM A376 TP347LN (18Cr-10Ni-Nb) Stainless Steels**

| TP347 LN SS | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, *n* |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 700 | 16.9 | | | | | |
| 720 | 16.8 | | | | | |
| 740 | 16.7 | | | | | |
| 760 | 16.6 | | | | | |
| 780 | 16.6 | | | | | |
| 800 | 16.5 | | | | | |
| 820 | 16.5 | | | | | |
| 840 | 16.4 | | | | | |
| 860 | 16.4 | | | | | |
| 880 | 16.4 | | | | | |
| 900 | 16.4 | | | | | 7.0 |
| 920 | 16.3 | | | | | 6.8 |
| 940 | 16.3 | | | | | 6.6 |
| 960 | 16.3 | | | | | 6.4 |
| 980 | 16.3 | | | | | 6.2 |
| 1000 | 16.3 | | | | | 6.0 |
| 1020 | 16.2 | | | | | 5.9 |
| 1040 | 16.2 | | | | | 5.7 |
| 1060 | 16.2 | | | | | 5.5 |
| 1080 | 16.1 | | | | | 5.4 |
| 1100 | 16.1 | 16.8 | 18.5 | 20.0 | 22.9 | 5.2 |
| 1120 | 16.0 | 14.8 | 16.4 | 17.8 | 20.3 | 5.1 |
| 1140 | 16.0 | 13.0 | 14.5 | 15.7 | 18.1 | 4.9 |
| 1160 | 15.9 | 11.4 | 12.7 | 13.9 | 16.0 | 4.8 |
| 1180 | 15.8 | 10.0 | 11.2 | 12.2 | 14.2 | 4.6 |
| 1200 | 15.7 | 8.7 | 9.8 | 10.7 | 12.5 | 4.5 |
| 1220 | 15.6 | 7.6 | 8.6 | 9.4 | 11.0 | 4.4 |
| 1240 | 15.4 | 6.6 | 7.5 | 8.2 | 9.7 | 4.2 |
| 1260 | 15.3 | 5.7 | 6.5 | 7.2 | 8.5 | 4.1 |
| 1280 | 15.1 | 4.9 | 5.6 | 6.2 | 7.4 | 4.0 |
| 1282 | 15.1 | 4.9 | 5.6 | 6.2 | 7.3 | 4.0 |

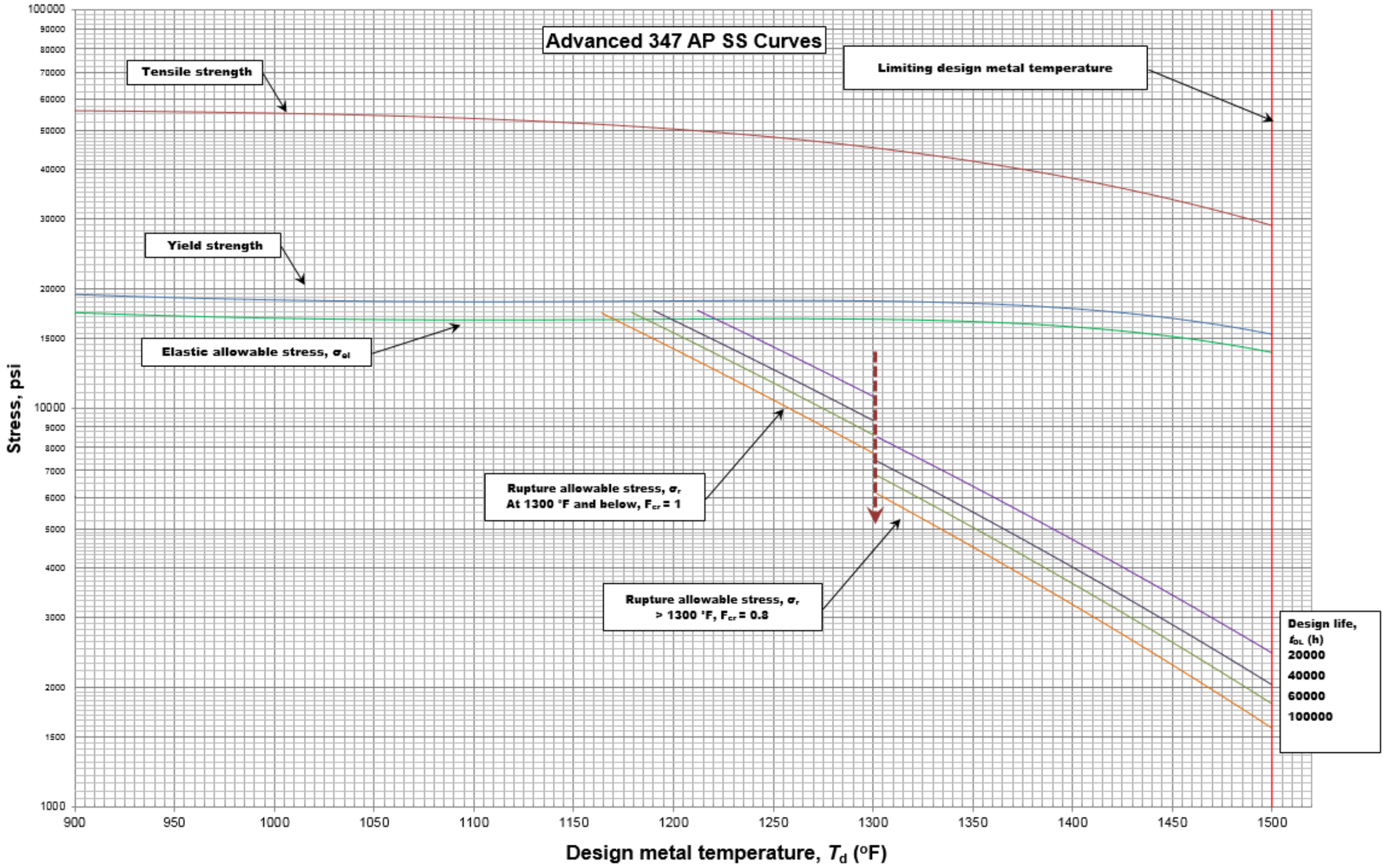



**Figure F.67—Stress Curves (USC Units) for ASTM A213 and ASTM A312 Advanced 347AP Stainless Steels**

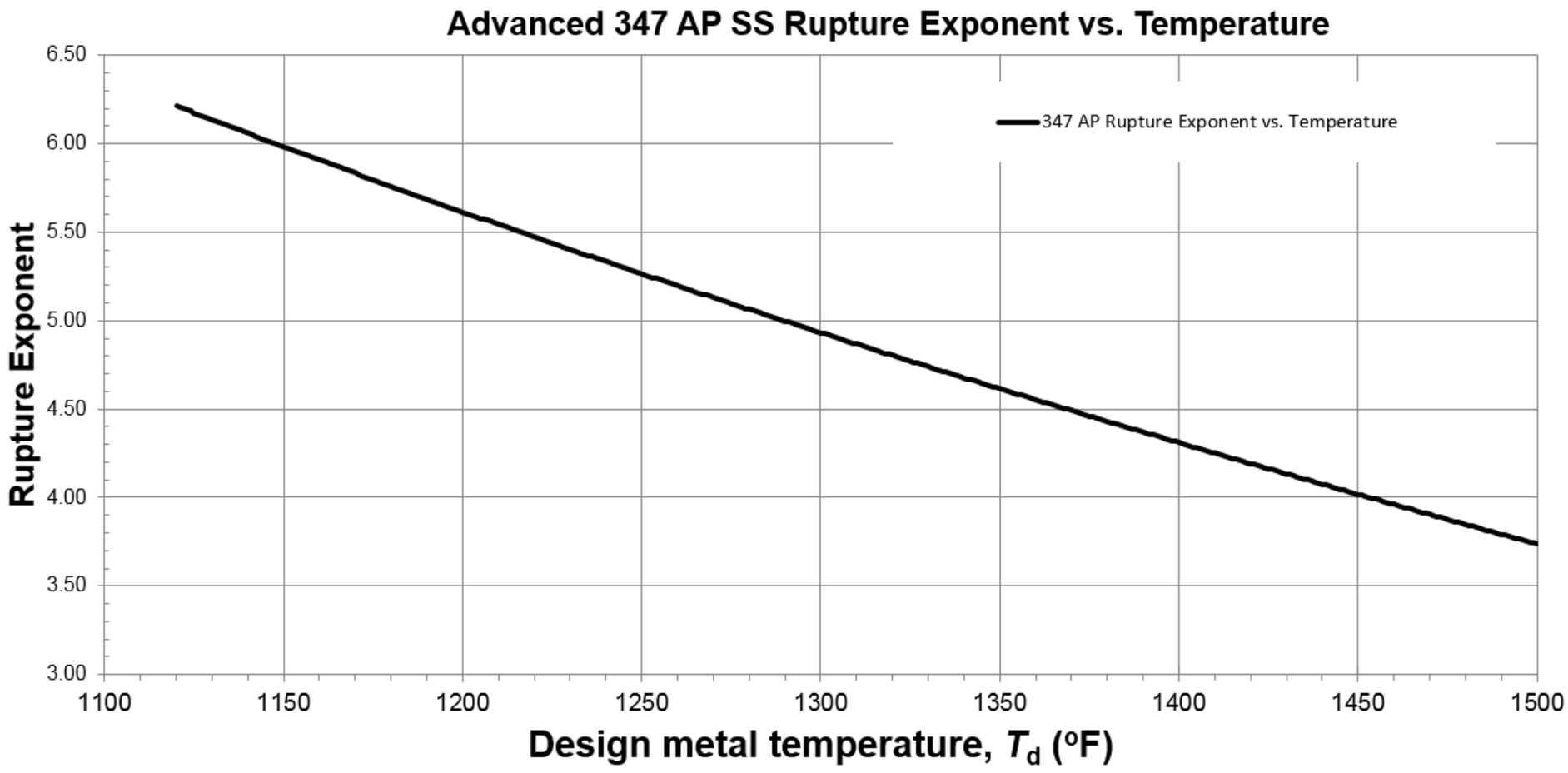



**Figure F.68—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A213 and ASTM A312 Advanced 347APStainless Steels**

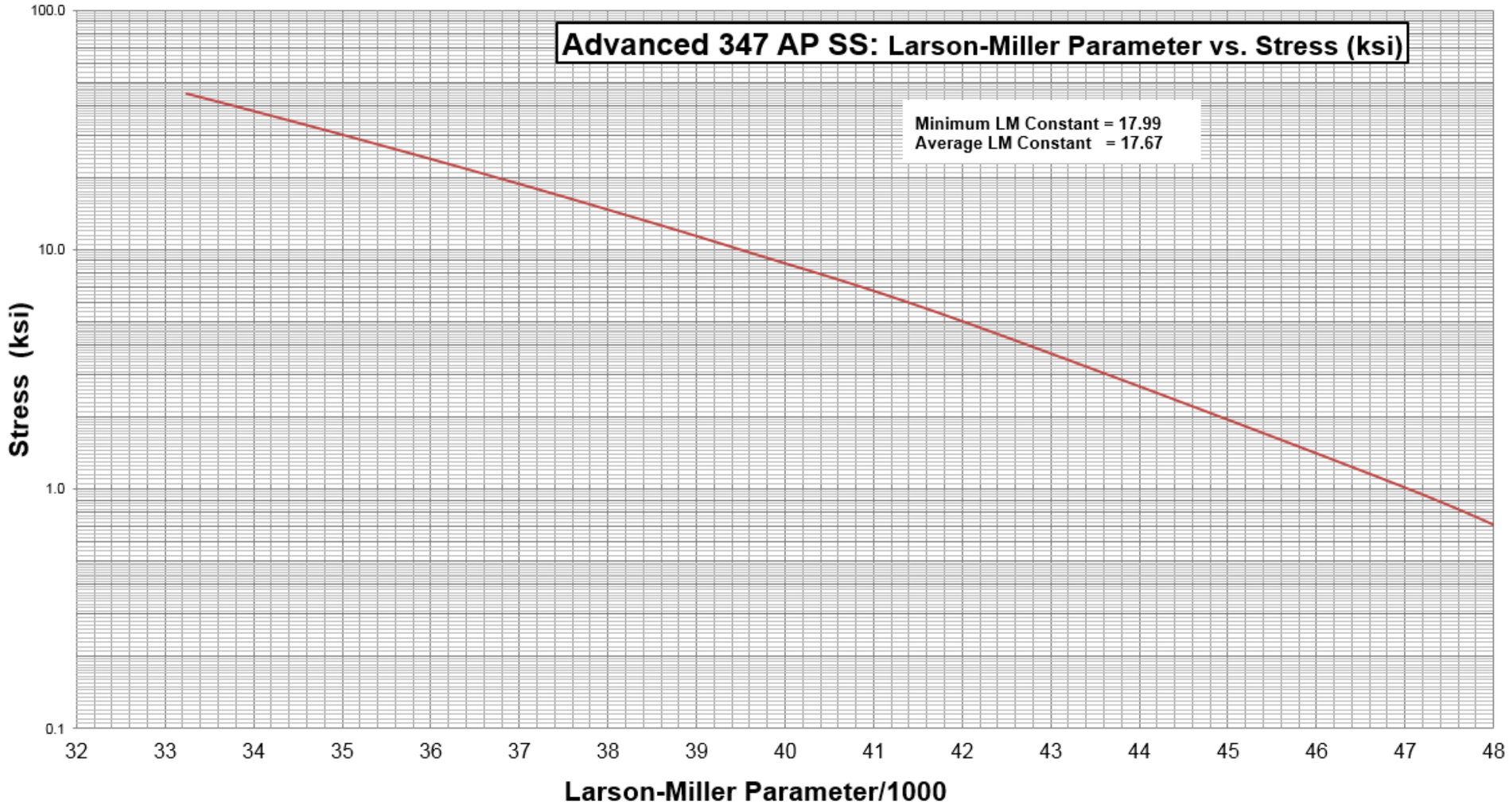



**Figure F.69—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A213 and ASTM A31 Advanced 347AP Stainless Steels**

**Table F.23—Elastic, Rupture and Allowable Stresses (USC Units) for ASTM A213 and ASTM A312 Advanced 347AP Stainless Steels)**

| Advanced 347 AP SS Steel | | | | | | |
|---|---|---|---|---|---|---|
| **Temperature** (Fahrenheit) | **Elastic Allowable Stress, $\sigma_{el}$** (ksi) | **Rupture Allowable Stress, $\sigma_r$** | | | | **Rupture Exponent, *n*** |
| | | **$t_{DL}$ = 100,000 h** (ksi) | **$t_{DL}$ = 60,000 h** (ksi) | **$t_{DL}$ = 40,000 h** (ksi) | **$t_{DL}$ = 20,000 h** (ksi) | |
| 900 | 17.4 | | | | | |
| 920 | 17.3 | | | | | |
| 940 | 17.2 | | | | | |
| 960 | 17.1 | | | | | |
| 980 | 17.0 | | | | | |
| 1000 | 16.9 | | | | | |
| 1020 | 16.8 | | | | | |
| 1040 | 16.8 | | | | | |
| 1060 | 16.7 | | | | | |
| 1080 | 16.7 | | | | | |
| 1100 | 16.7 | | | | | |
| 1120 | 16.7 | 22.2 | 24.2 | 25.8 | 28.8 | 6.2 |
| 1140 | 16.7 | 19.9 | 21.7 | 23.2 | 26.0 | 6.1 |
| 1160 | 16.7 | 17.8 | 19.4 | 20.8 | 23.4 | 5.9 |
| 1180 | 16.8 | 15.9 | 17.4 | 18.6 | 21.0 | 5.8 |
| 1200 | 16.8 | 14.1 | 15.5 | 16.7 | 18.9 | 5.6 |
| 1220 | 16.8 | 12.6 | 13.8 | 14.9 | 16.9 | 5.5 |
| 1240 | 16.8 | 11.2 | 12.3 | 13.3 | 15.1 | 5.3 |
| 1260 | 16.8 | 9.9 | 11.0 | 11.8 | 13.5 | 5.2 |
| 1280 | 16.8 | 8.8 | 9.7 | 10.5 | 12.1 | 5.1 |
| 1300 | 16.8 | 7.7 | 8.6 | 9.3 | 10.8 | 4.9 |
| 1320 | 16.7 | 5.5 | 6.1 | 6.6 | 7.6 | 4.8 |
| 1340 | 16.6 | 4.8 | 5.4 | 5.9 | 6.8 | 4.7 |
| 1360 | 16.5 | 4.2 | 4.7 | 5.2 | 6.0 | 4.6 |
| 1380 | 16.3 | 3.7 | 4.2 | 4.6 | 5.3 | 4.4 |
| 1400 | 16.1 | 3.2 | 3.6 | 4.0 | 4.7 | 4.3 |
| 1420 | 15.8 | 2.8 | 3.2 | 3.5 | 4.1 | 4.2 |
| 1440 | 15.4 | 2.4 | 2.8 | 3.1 | 3.6 | 4.1 |
| 1460 | 15.0 | 2.1 | 2.4 | 2.7 | 3.2 | 4.0 |
| 1480 | 14.4 | 1.8 | 2.1 | 2.3 | 2.8 | 3.8 |
| 1500 | 13.8 | 1.6 | 1.8 | 2.0 | 2.4 | 3.7 |

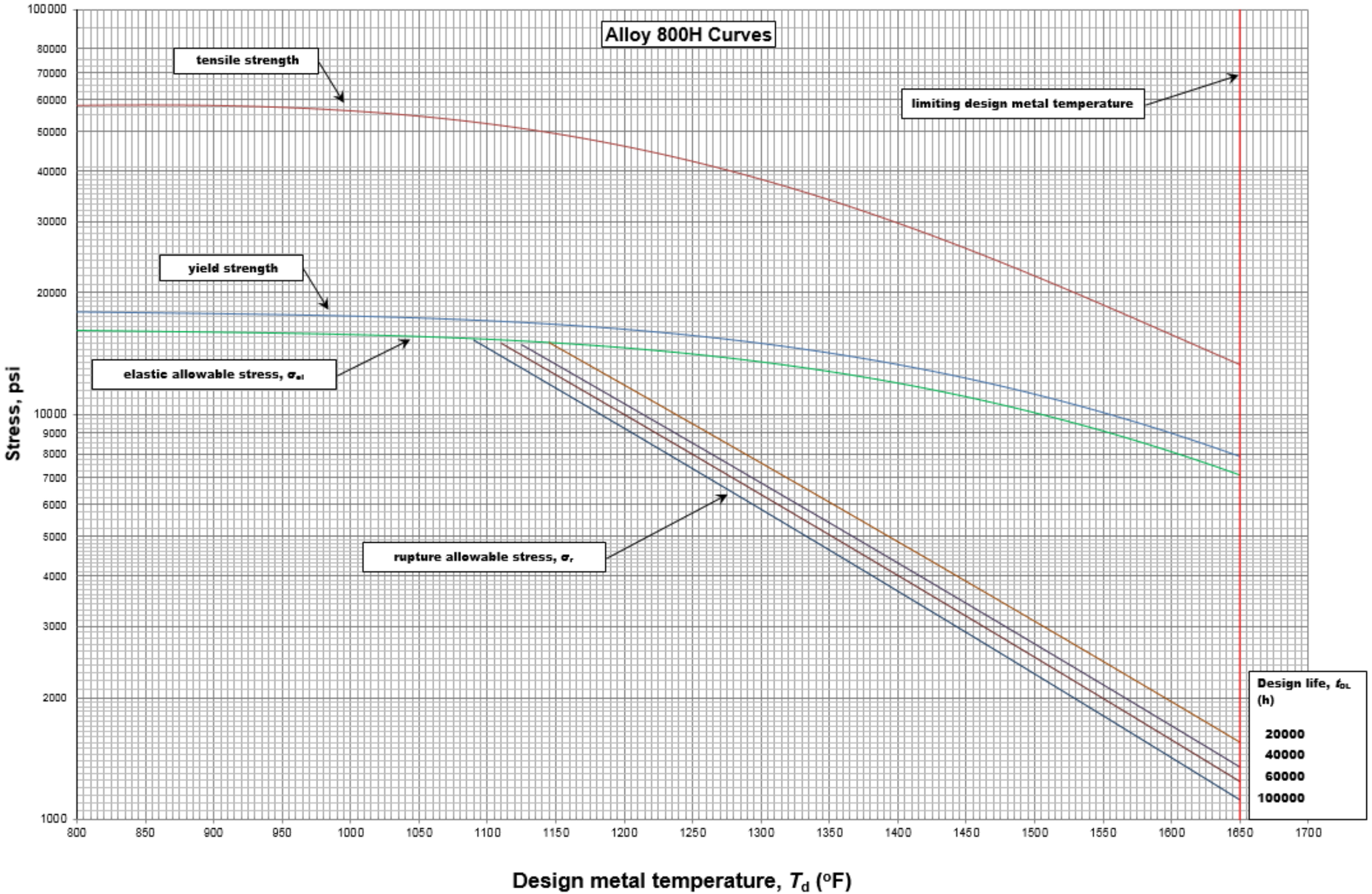



**Figure F.73—Stress Curves (USC Units) for ASTM B407 UNS N08810 Alloy 800H Steels**

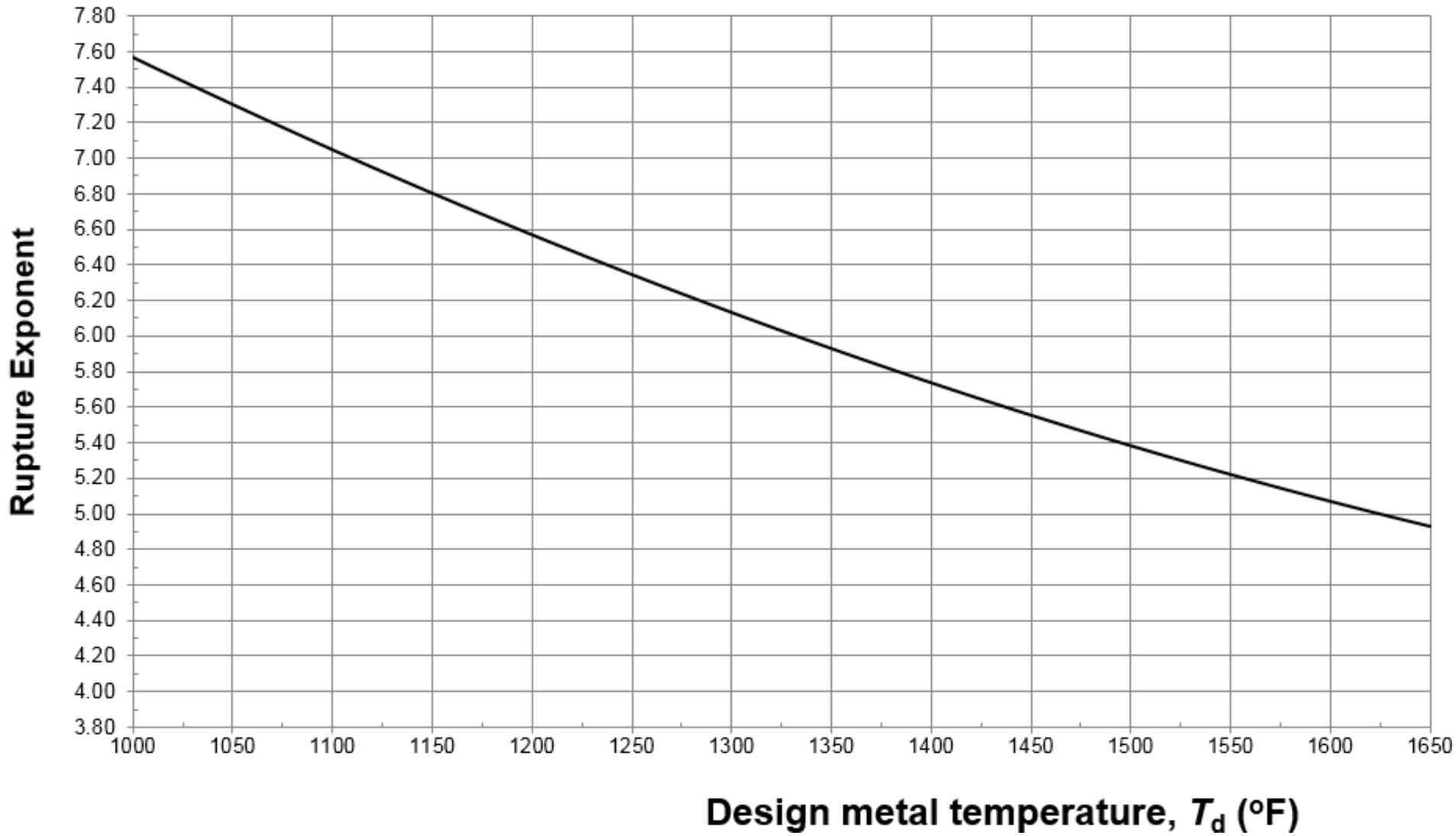



**Figure F.74—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM B407 Alloy 800H Steels**

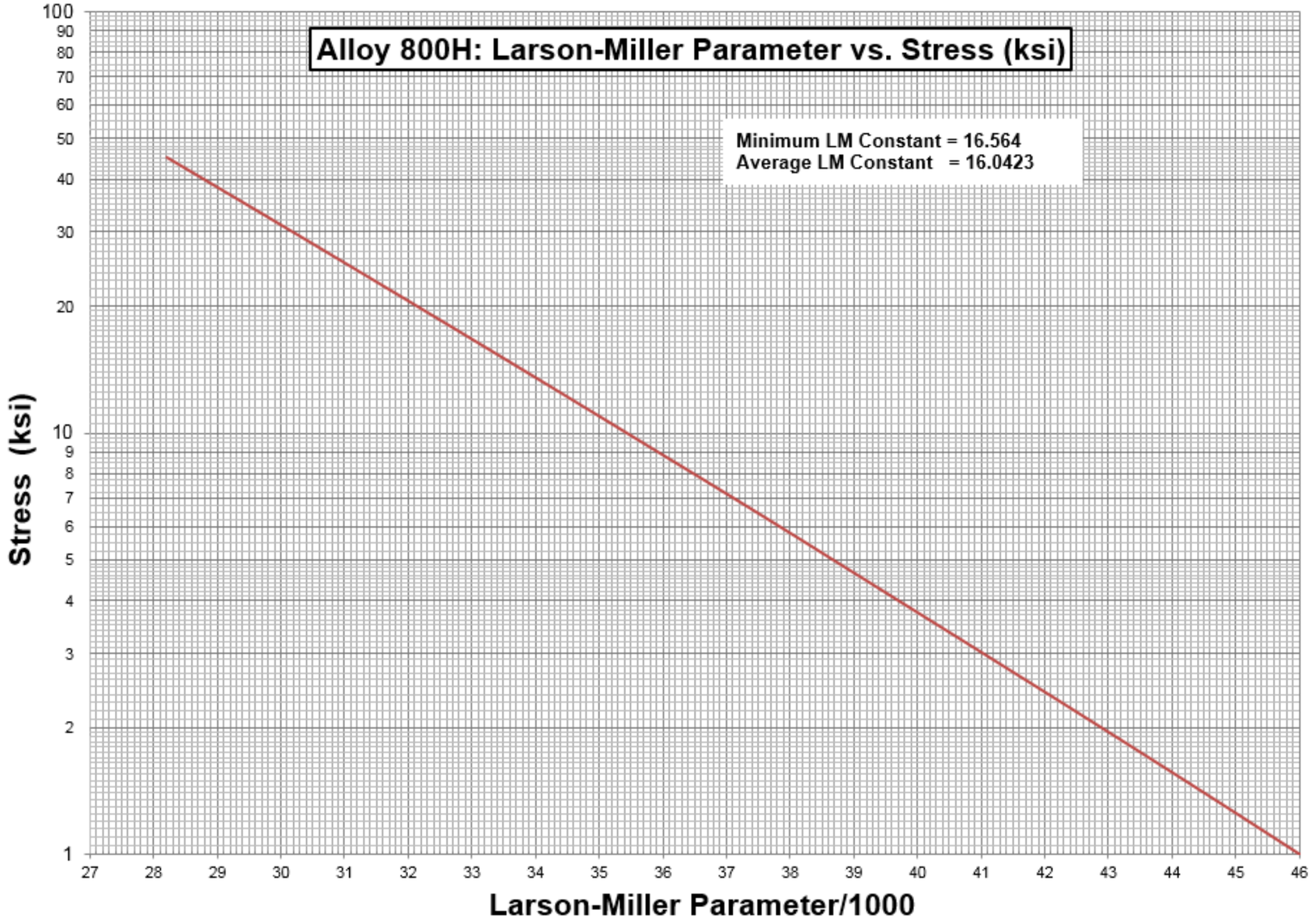



**Figure F.75—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM B407 Alloy 800H Steels**

**Table F.25—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM B407 Alloy 800H Steels**

| Alloy 800H | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 800 | 16.1 | | | | | |
| 820 | 16.1 | | | | | |
| 840 | 16.1 | | | | | |
| 860 | 16.0 | | | | | |
| 880 | 16.0 | | | | | |
| 900 | 16.0 | | | | | |
| 920 | 15.9 | | | | | |
| 940 | 15.9 | | | | | |
| 960 | 15.9 | | | | | |
| 980 | 15.8 | | | | | |
| 1000 | 15.8 | | | | | 7.6 |
| 1020 | 15.7 | | | | | 7.5 |
| 1040 | 15.6 | | | | | 7.4 |
| 1060 | 15.5 | | | | | 7.2 |
| 1080 | 15.5 | 16.0 | 17.2 | 18.2 | 20.0 | 7.1 |
| 1100 | 15.3 | 14.6 | 15.7 | 16.6 | 18.3 | 7.0 |
| 1120 | 15.2 | 13.3 | 14.3 | 15.2 | 16.8 | 6.9 |
| 1140 | 15.1 | 12.2 | 13.1 | 13.9 | 15.4 | 6.8 |
| 1160 | 15.0 | 11.1 | 12.0 | 12.7 | 14.1 | 6.8 |
| 1180 | 14.8 | 10.1 | 11.0 | 11.6 | 12.9 | 6.7 |
| 1200 | 14.6 | 9.3 | 10.0 | 10.6 | 11.8 | 6.6 |
| 1220 | 14.4 | 8.4 | 9.1 | 9.7 | 10.8 | 6.5 |
| 1240 | 14.2 | 7.7 | 8.3 | 8.9 | 9.9 | 6.4 |
| 1260 | 14.0 | 7.0 | 7.6 | 8.1 | 9.1 | 6.3 |
| 1280 | 13.8 | 6.4 | 7.0 | 7.4 | 8.3 | 6.2 |
| 1300 | 13.5 | 5.8 | 6.3 | 6.8 | 7.6 | 6.1 |
| 1320 | 13.2 | 5.3 | 5.8 | 6.2 | 6.9 | 6.0 |
| 1340 | 12.9 | 4.8 | 5.3 | 5.7 | 6.4 | 6.0 |
| 1360 | 12.6 | 4.4 | 4.8 | 5.2 | 5.8 | 5.9 |
| 1380 | 12.3 | 4.0 | 4.4 | 4.7 | 5.3 | 5.8 |
| 1400 | 12.0 | 3.7 | 4.0 | 4.3 | 4.9 | 5.7 |
| 1420 | 11.6 | 3.3 | 3.7 | 3.9 | 4.4 | 5.7 |
| 1440 | 11.3 | 3.0 | 3.3 | 3.6 | 4.1 | 5.6 |
| 1460 | 10.9 | 2.8 | 3.0 | 3.3 | 3.7 | 5.5 |
| 1480 | 10.5 | 2.5 | 2.8 | 3.0 | 3.4 | 5.4 |
| 1500 | 10.1 | 2.3 | 2.5 | 2.7 | 3.1 | 5.4 |
| 1520 | 9.7 | 2.1 | 2.3 | 2.5 | 2.8 | 5.3 |
| 1540 | 9.3 | 1.9 | 2.1 | 2.3 | 2.6 | 5.3 |
| 1560 | 8.9 | 1.7 | 1.9 | 2.1 | 2.3 | 5.2 |
| 1580 | 8.5 | 1.6 | 1.7 | 1.9 | 2.1 | 5.1 |
| 1600 | 8.1 | 1.4 | 1.6 | 1.7 | 2.0 | 5.1 |
| 1620 | 7.7 | 1.3 | 1.4 | 1.6 | 1.8 | 5.0 |
| 1640 | 7.3 | 1.2 | 1.3 | 1.4 | 1.6 | 5.0 |
| 1650 | 7.1 | 1.1 | 1.2 | 1.3 | 1.6 | 4.9 |

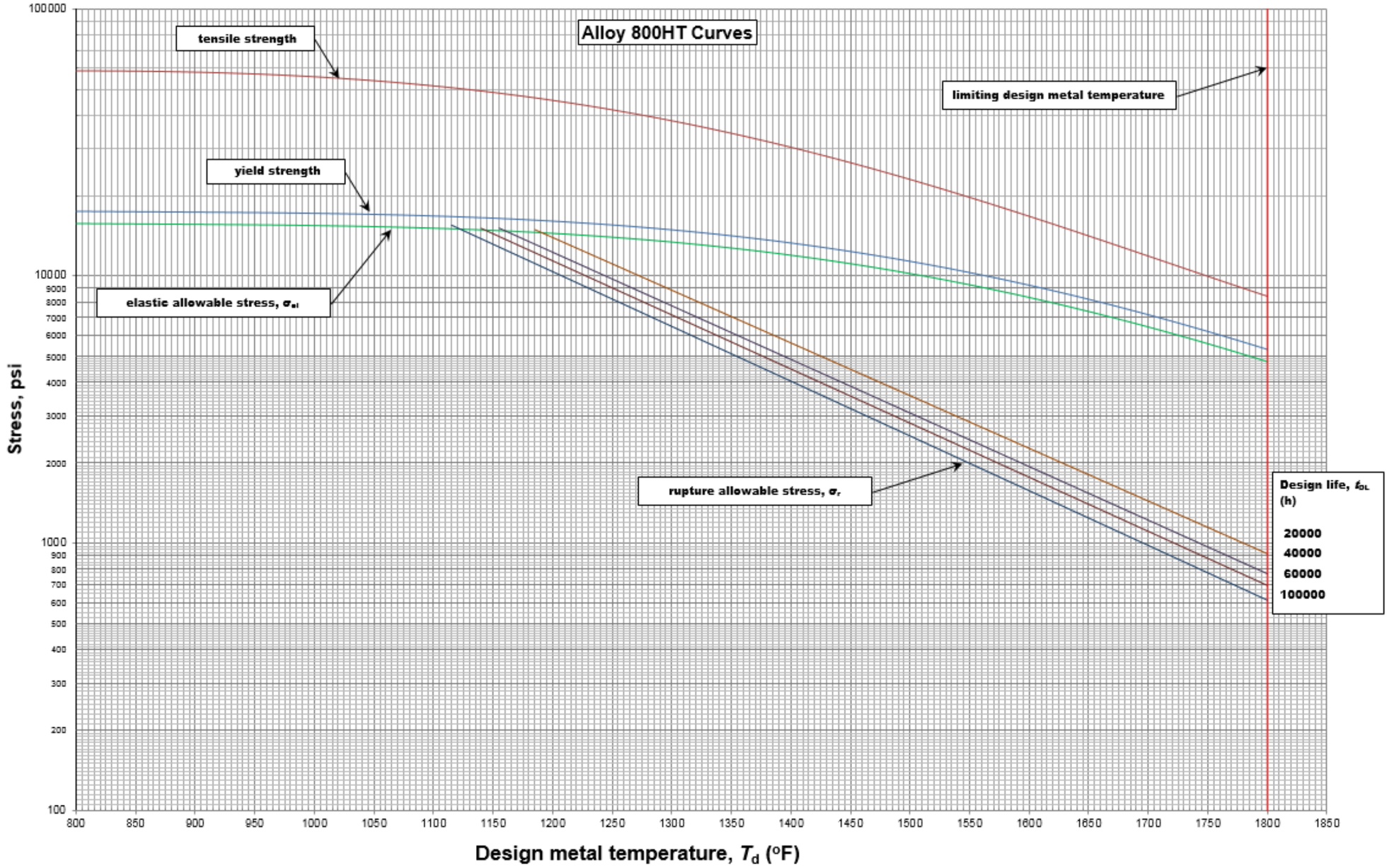



**Figure F.76—Stress Curves (USC Units) for ASTM B407 Alloy 800HT Steels**

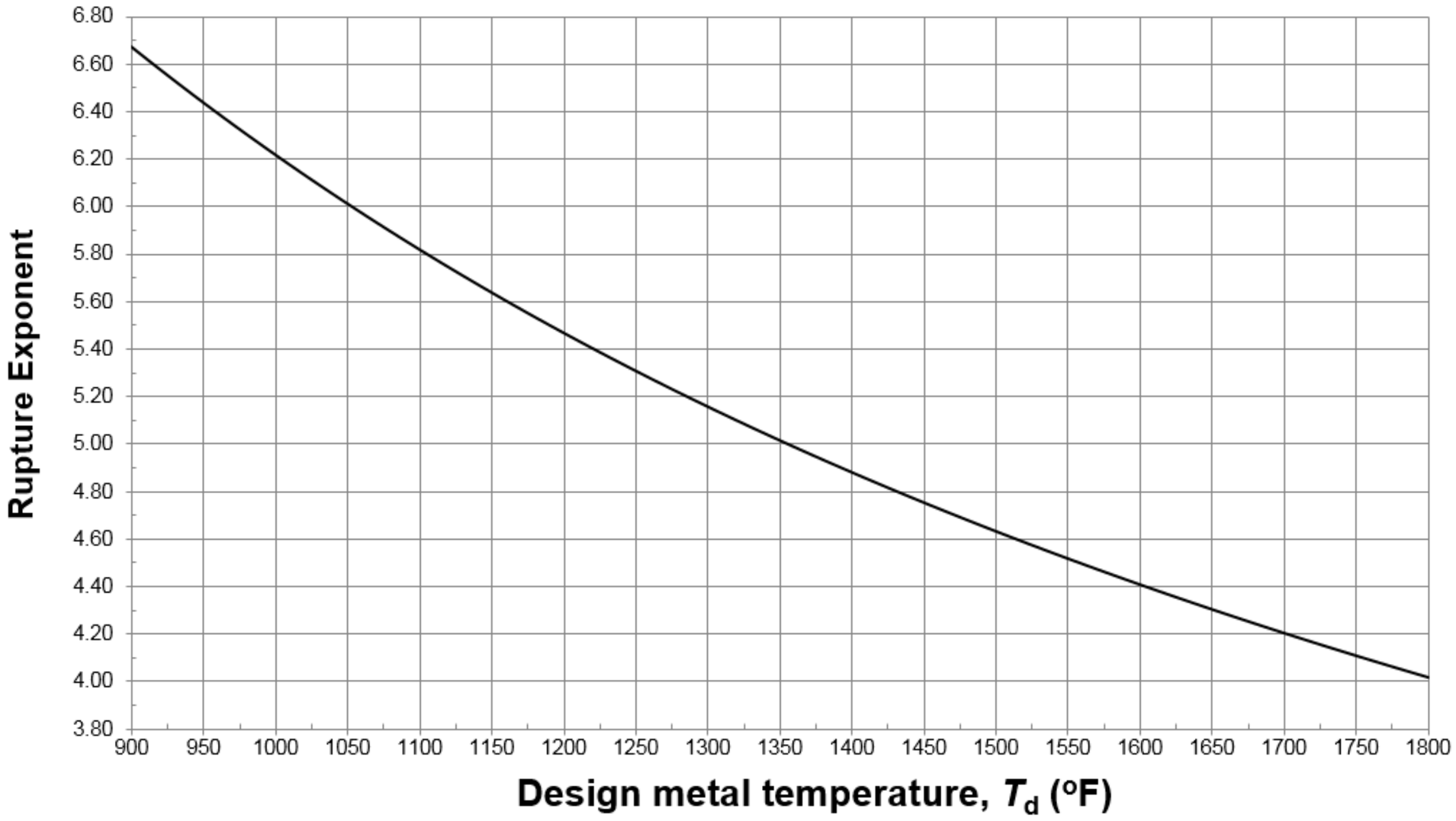



**Figure F.77—Rupture Exponent vs. Temperature Curve (USC Units) for ASTM B407 Alloy 800HT Steels**

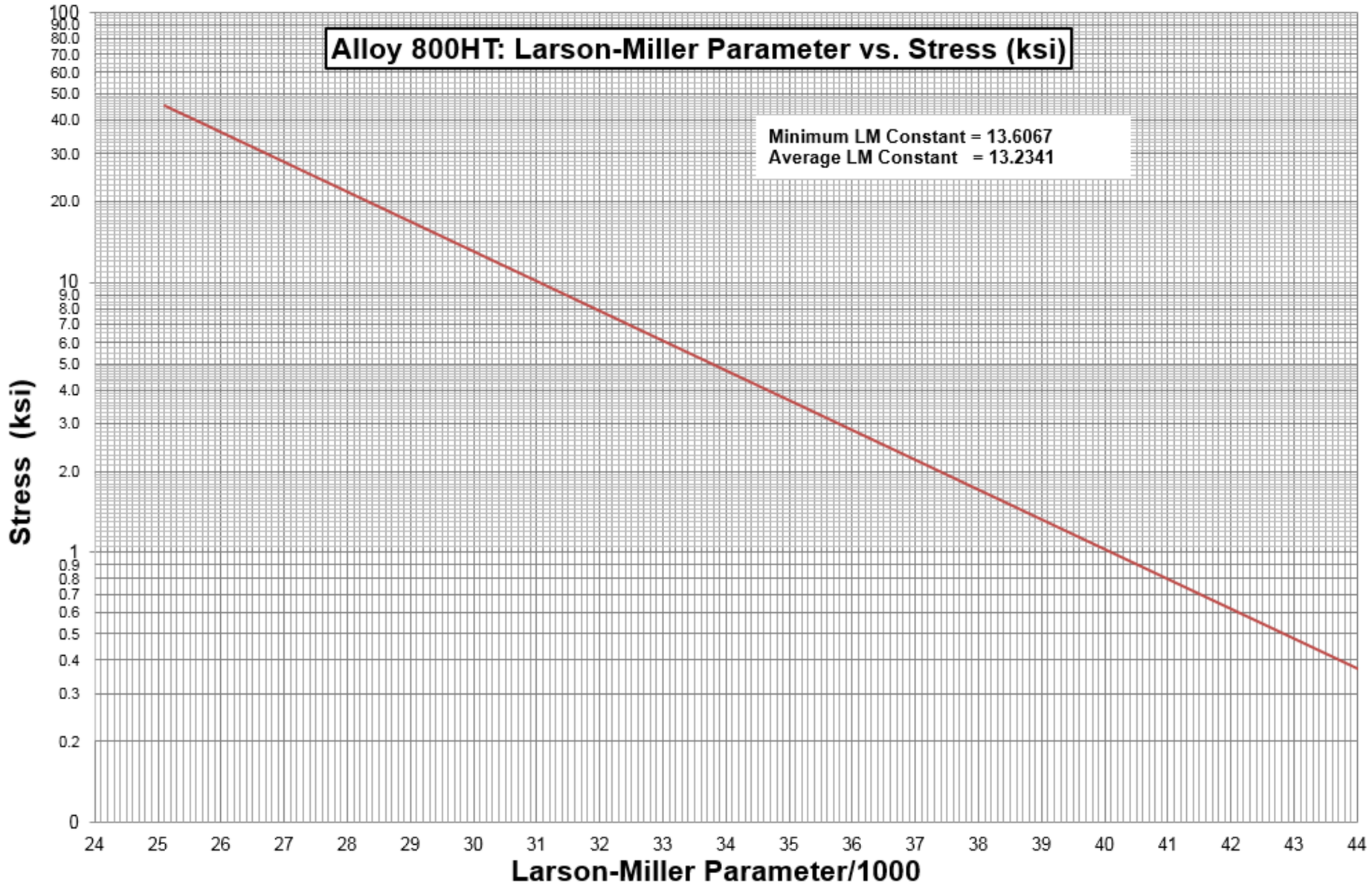



**Figure F.78—Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM B407 Alloy 800HT Steels**

**Table F.26—Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM B407 Alloy 800HT Steels**

| Alloy 800HT | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{RL}$ = 100,000 h (ksi) | $t_{RL}$ = 60,000 h (ksi) | $t_{RL}$ = 40,000 h (ksi) | $t_{RL}$ = 20,000 h (ksi) | |
| 800 | 15.7 | | | | | |
| 820 | 15.7 | | | | | |
| 840 | 15.7 | | | | | |
| 860 | 15.7 | | | | | |
| 880 | 15.6 | | | | | |
| 900 | 15.6 | | | | | 6.7 |
| 920 | 15.6 | | | | | 6.6 |
| 940 | 15.6 | | | | | 6.5 |
| 960 | 15.5 | | | | | 6.4 |
| 980 | 15.5 | | | | | 6.3 |
| 1000 | 15.4 | | | | | 6.2 |
| 1020 | 15.4 | | | | | 6.1 |
| 1040 | 15.3 | | | | | 6.1 |
| 1060 | 15.3 | | | | | 6.0 |
| 1080 | 15.2 | | | | | 5.9 |
| 1100 | 15.1 | | | | | 5.8 |
| 1120 | 15.0 | 15.2 | 16.6 | 17.8 | 20.0 | 5.7 |
| 1140 | 14.9 | 13.8 | 15.1 | 16.2 | 18.3 | 5.7 |
| 1160 | 14.8 | 12.5 | 13.7 | 14.8 | 16.7 | 5.6 |
| 1180 | 14.6 | 11.4 | 12.5 | 13.5 | 15.3 | 5.5 |
| 1200 | 14.4 | 10.4 | 11.4 | 12.3 | 13.9 | 5.5 |
| 1220 | 14.3 | 9.5 | 10.4 | 11.2 | 12.7 | 5.4 |
| 1240 | 14.1 | 8.6 | 9.5 | 10.2 | 11.6 | 5.3 |
| 1260 | 13.9 | 7.8 | 8.6 | 9.3 | 10.6 | 5.3 |
| 1280 | 13.6 | 7.1 | 7.9 | 8.5 | 9.7 | 5.2 |
| 1300 | 13.4 | 6.5 | 7.2 | 7.7 | 8.9 | 5.2 |
| 1320 | 13.1 | 5.9 | 6.5 | 7.1 | 8.1 | 5.1 |
| 1340 | 12.9 | 5.4 | 5.9 | 6.4 | 7.4 | 5.0 |
| 1360 | 12.6 | 4.9 | 5.4 | 5.9 | 6.7 | 5.0 |
| 1380 | 12.3 | 4.4 | 4.9 | 5.3 | 6.2 | 4.9 |
| 1400 | 12.0 | 4.0 | 4.5 | 4.9 | 5.6 | 4.9 |
| 1420 | 11.6 | 3.7 | 4.1 | 4.4 | 5.1 | 4.8 |
| 1440 | 11.3 | 3.3 | 3.7 | 4.1 | 4.7 | 4.8 |
| 1460 | 10.9 | 3.0 | 3.4 | 3.7 | 4.3 | 4.7 |
| 1480 | 10.6 | 2.8 | 3.1 | 3.4 | 3.9 | 4.7 |
| 1500 | 10.2 | 2.5 | 2.8 | 3.1 | 3.6 | 4.6 |
| 1520 | 9.8 | 2.3 | 2.6 | 2.8 | 3.3 | 4.6 |
| 1540 | 9.5 | 2.1 | 2.3 | 2.6 | 3.0 | 4.5 |
| 1560 | 9.1 | 1.9 | 2.1 | 2.3 | 2.7 | 4.5 |
| 1580 | 8.7 | 1.7 | 1.9 | 2.1 | 2.5 | 4.5 |
| 1600 | 8.3 | 1.6 | 1.8 | 1.9 | 2.3 | 4.4 |
| 1620 | 7.9 | 1.4 | 1.6 | 1.8 | 2.1 | 4.4 |
| 1640 | 7.6 | 1.3 | 1.5 | 1.6 | 1.9 | 4.3 |
| 1660 | 7.2 | 1.2 | 1.3 | 1.5 | 1.7 | 4.3 |
| 1680 | 6.8 | 1.1 | 1.2 | 1.3 | 1.6 | 4.2 |
| 1700 | 6.5 | 1.0 | 1.1 | 1.2 | 1.4 | 4.2 |
| 1720 | 6.1 | 0.9 | 1.0 | 1.1 | 1.3 | 4.2 |
| 1740 | 5.8 | 0.8 | 0.9 | 1.0 | 1.2 | 4.1 |
| 1760 | 5.4 | 0.7 | 0.8 | 0.9 | 1.1 | 4.1 |
| 1780 | 5.1 | 0.7 | 0.8 | 0.8 | 1.0 | 4.1 |
| 1800 | 4.8 | 0.6 | 0.7 | 0.8 | 0.9 | 4.0 |

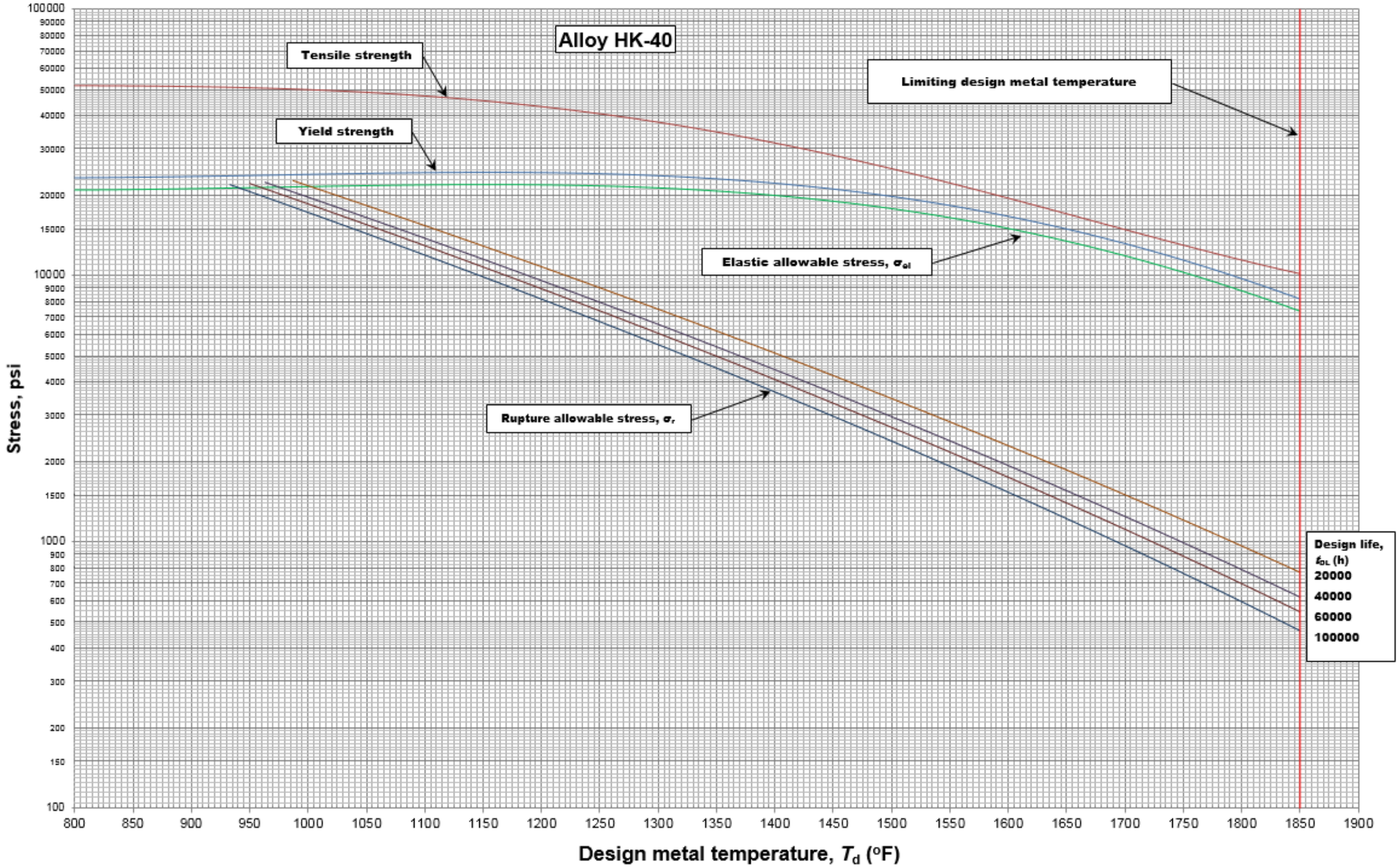



**Figure F.79 – Stress Curves (USC Units) for ASTM A608 Grade HK-40 Steels**

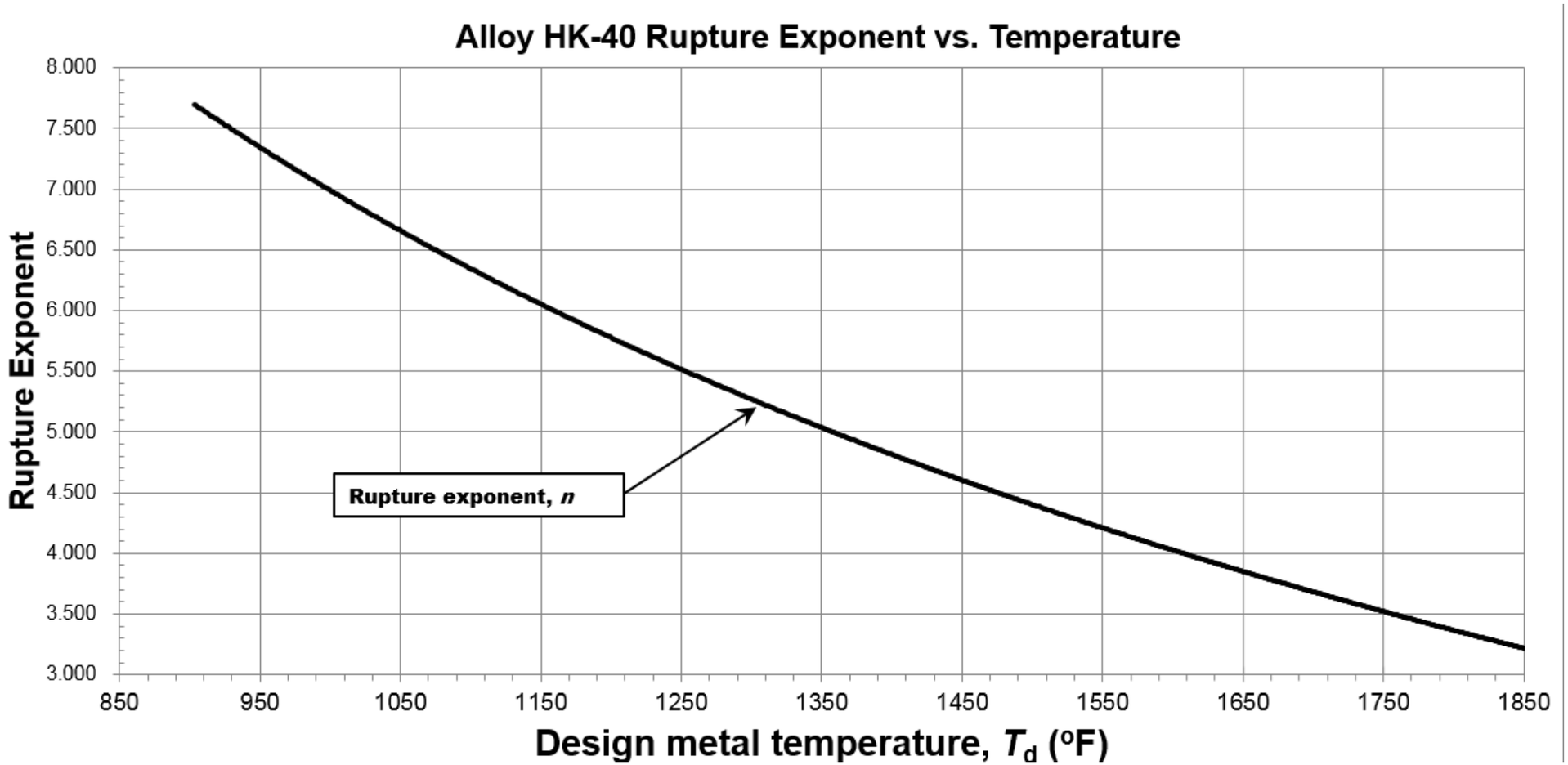



**Figure F.80 – Rupture Exponent vs. Temperature Curve (USC Units) for ASTM A608 Grade HK-40 Steels**

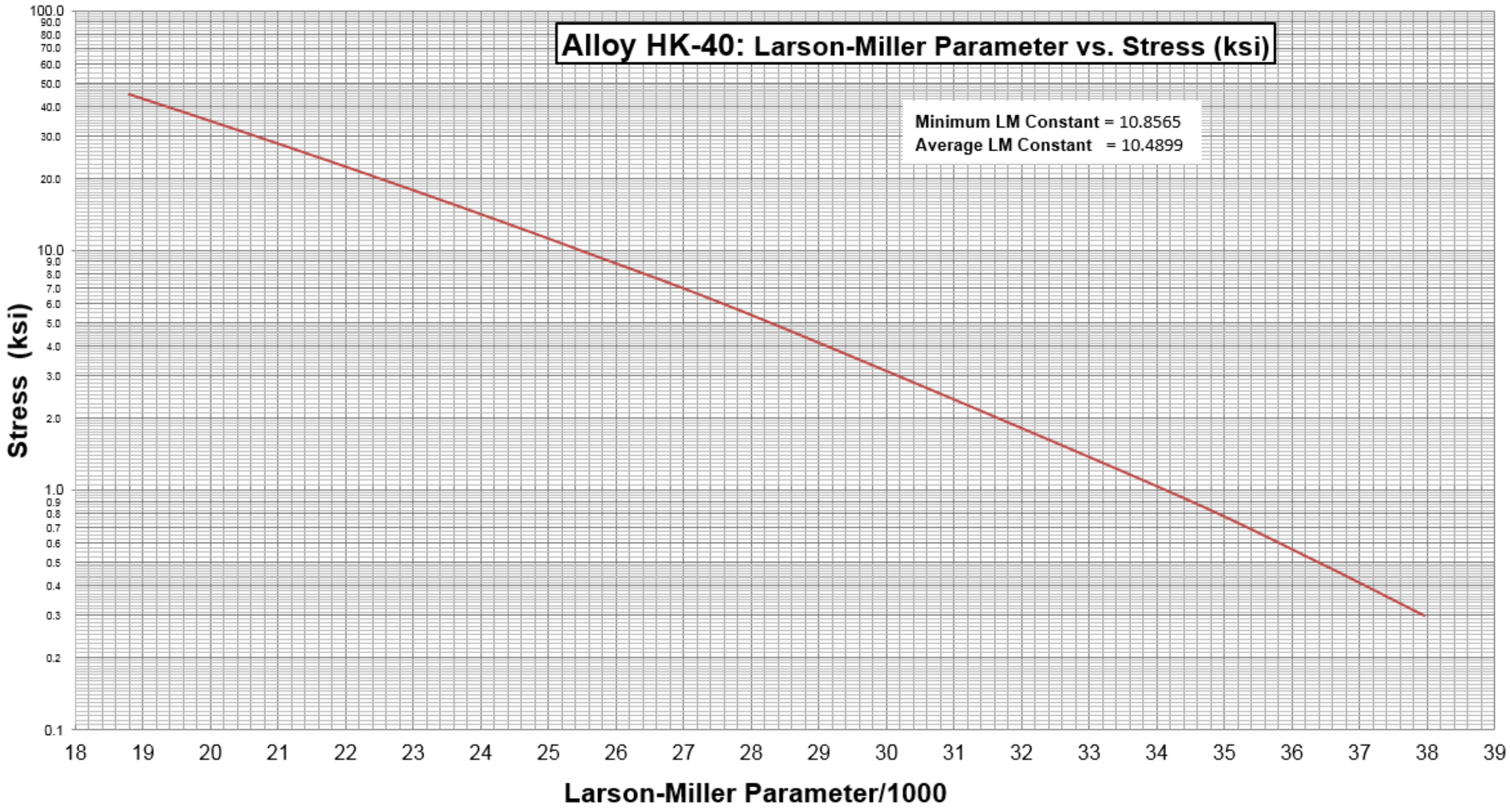



**Figure F.81 – Larson-Miller Parameter vs. Stress Curve (USC Units) for ASTM A608 Grade HK-40 Steels**

**Table F.27 – Elastic, Rupture and Allowable Stresses and Rupture Exponent (USC Units) for ASTM A608 Grade HK-40 Steels**

| Alloy HK-40 | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (Fahrenheit) | Elastic Allowable Stress, $\sigma_{el}$ (ksi) | Rupture Allowable Stress, $\sigma_r$ | | | | Rupture Exponent, $n$ |
| | | $t_{DL}$ = 100,000 h (ksi) | $t_{DL}$ = 60,000 h (ksi) | $t_{DL}$ = 40,000 h (ksi) | $t_{DL}$ = 20,000 h (ksi) | |
| 920 | 21.29 | 23.02 | | | | |
| 940 | 21.36 | 21.44 | 22.98 | | | 7.1 |
| 960 | 21.44 | 19.96 | 21.43 | 22.66 | | 7.0 |
| 980 | 21.52 | 18.58 | 19.97 | 21.15 | | 6.9 |
| 1000 | 21.61 | 17.28 | 18.61 | 19.72 | 21.77 | 6.7 |
| 1020 | 21.68 | 16.07 | 17.33 | 18.39 | 20.34 | 6.6 |
| 1040 | 21.76 | 14.93 | 16.13 | 17.13 | 18.99 | 6.5 |
| 1060 | 21.82 | 13.87 | 15.00 | 15.96 | 17.72 | 6.4 |
| 1080 | 21.88 | 12.88 | 13.95 | 14.86 | 16.54 | 6.3 |
| 1100 | 21.93 | 11.95 | 12.97 | 13.83 | 15.42 | 6.2 |
| 1120 | 21.97 | 11.09 | 12.05 | 12.86 | 14.37 | 6.1 |
| 1140 | 21.99 | 10.28 | 11.19 | 11.96 | 13.39 | 6.0 |
| 1160 | 21.99 | 9.53 | 10.39 | 11.12 | 12.47 | 5.9 |
| 1180 | 21.98 | 8.82 | 9.63 | 10.33 | 11.61 | 5.8 |
| 1200 | 21.94 | 8.17 | 8.93 | 9.59 | 10.81 | 5.6 |
| 1220 | 21.88 | 7.56 | 8.28 | 8.90 | 10.05 | 5.6 |
| 1240 | 21.79 | 6.99 | 7.67 | 8.25 | 9.34 | 5.5 |
| 1260 | 21.68 | 6.46 | 7.10 | 7.65 | 8.68 | 5.4 |
| 1280 | 21.54 | 5.97 | 6.57 | 7.09 | 8.06 | 5.3 |
| 1300 | 21.37 | 5.51 | 6.08 | 6.57 | 7.49 | 5.2 |
| 1320 | 21.16 | 5.08 | 5.62 | 6.08 | 6.95 | 5.2 |
| 1340 | 20.93 | 4.69 | 5.19 | 5.62 | 6.44 | 5.1 |
| 1360 | 20.66 | 4.32 | 4.79 | 5.20 | 5.97 | 5.0 |
| 1380 | 20.36 | 3.98 | 4.42 | 4.80 | 5.53 | 4.9 |
| 1400 | 20.02 | 3.66 | 4.08 | 4.44 | 5.12 | 4.8 |
| 1420 | 19.66 | 3.37 | 3.76 | 4.10 | 4.74 | 4.7 |
| 1440 | 19.25 | 3.09 | 3.46 | 3.78 | 4.38 | 4.6 |
| 1460 | 18.82 | 2.84 | 3.18 | 3.48 | 4.05 | 4.6 |
| 1480 | 18.36 | 2.61 | 2.93 | 3.21 | 3.74 | 4.5 |
| 1500 | 17.87 | 2.39 | 2.69 | 2.95 | 3.46 | 4.4 |
| 1520 | 17.35 | 2.19 | 2.47 | 2.72 | 3.19 | 4.3 |
| 1540 | 16.80 | 2.01 | 2.27 | 2.50 | 2.94 | 4.2 |
| 1560 | 16.23 | 1.84 | 2.08 | 2.30 | 2.71 | 4.2 |
| 1580 | 15.65 | 1.68 | 1.91 | 2.11 | 2.50 | 4.1 |
| 1600 | 15.04 | 1.54 | 1.75 | 1.94 | 2.30 | 4.0 |
| 1620 | 14.43 | 1.40 | 1.60 | 1.78 | 2.11 | 4.0 |
| 1640 | 13.80 | 1.28 | 1.46 | 1.63 | 1.94 | 3.9 |
| 1660 | 13.16 | 1.17 | 1.34 | 1.49 | 1.79 | 3.8 |
| 1680 | 12.52 | 1.06 | 1.22 | 1.36 | 1.64 | 3.7 |
| 1700 | 11.88 | 0.97 | 1.12 | 1.25 | 1.50 | 3.7 |
| 1720 | 11.24 | 0.88 | 1.02 | 1.14 | 1.38 | 3.6 |
| 1740 | 10.61 | 0.80 | 5.62 | 1.04 | 1.26 | 3.5 |
| 1760 | 9.99 | 0.73 | 0.84 | 0.95 | 5.55 | 3.5 |
| 1780 | 9.38 | 0.66 | 0.77 | 0.86 | 1.06 | 3.4 |
| 1800 | 8.78 | 0.60 | 0.70 | 0.79 | 0.97 | 3.4 |
| 1820 | 8.20 | 0.54 | 0.63 | 0.72 | 0.88 | 3.3 |
| 1840 | 7.63 | 0.49 | 0.57 | 0.65 | 0.81 | 3.2 |
| 1850 | 7.36 | 0.46 | 0.55 | 0.62 | 0.77 | 3.2 |

*Annex H.6: This section shall be replaced with the following:*

## H.6 Rupture Allowable Stress

The rupture allowable stress, $\sigma_r$ (time-dependent stress) and rupture strength for all materials listed in Table 4 may be determined from the Larson-Miller parameter calculated from Equation (H.4). The solution is given by the following equation:

$$\sigma_r = F_{cr} \times \sigma_{r*} = F_{cr} \times 10^X$$

where

$\sigma_r$ is rupture allowable stress (time-dependent);

$\sigma_{r*}$ is rupture strength at temperature, based on minimum Larson-Miller parameters;

$F_{cr}$ is the creep-rupture design factor;

$X$ is exponent computed based on the values of the coefficients in Equation (H.4). A thorough explanation of the calculation for $X$ is detailed in Section 6 of WRC Bulletin 541.

Figures E.1 to E.79 and Figures F.1 to F.79 graphically depict the materials' rupture allowable stresses for a range of temperatures in both SI and USC units, respectively, for 20,000-hour, 40,000-hour, 60,000-hour, and 100,000-hour design lives. Additionally, Tables E.1 to E.27 and Tables F.1 to F.27 list the material rupture allowable stress for a range of temperatures in both SI and USC units for each of the design life values listed above in tabular form.

The use of Figures E.1 to E.79 and Figures F.1 to F.79 or Tables E.1 to E.27 and Tables F.1 to F.27 is equally acceptable. When using the tables, semi-log interpolation can be used to determine rupture allowable stresses at intermediate temperatures.

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*Annex H.7: This section shall be replaced with the following:*

## H.7 Rupture Exponent

The rupture exponent can be obtained from the first derivative of log time with respect to stress at any temperature. The rupture exponents used in this document were determined between 60,000 hours and 100,000 hours for the minimum rupture strengths determined from the Larson-Miller parameter curves.

$$n = \text{abs}\frac{\log_{10}\left[100{,}000\right] - \log_{10}\left[60{,}000\right]}{\log_{10}\left[S_{100{,}000}\right] - \log_{10}\left[S_{60{,}000}\right]} \tag{H.5}$$

where

$n$ is the rupture exponent, at the desired temperature;

$S_{100,000}$ is the average rupture allowable stress at 100,000 hours at the desired temperature;

$S_{60,000}$ is the average rupture allowable stress at 60,000 hours at the desired temperature.

The values of the rupture exponents obtained were fitted with up to a fifth order polynomial as shown in Equation (H.6). The resulting coefficients are presented in Table 4 of WRC Bulletin 541.

$$n = C_0 + C_1T + C_2T^2 + C_3T^3 + C_4T^4 + C_5T^5 \tag{H.6}$$

Figures E.2 to E.80 and Figures F.2 to F.80 graphically depict the materials' rupture exponents for a range of temperatures in both SI and USC units, respectively. Additionally, Tables E.1 to E.27 and Tables F.1 to F.27 list the materials' rupture exponents for a range of temperatures, in both SI and USC units.

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*Annex H.8: This section shall be replaced with the following:*

## H.8 Modification of, and Additions to, Published Data

The data and equations used to generate the curves exhibited in Annex E and Annex F were obtained from WRC Bulletin 541. The tables listing all the coefficients used to calculate the Annex E and F curves are provided in Section 14 of WRC Bulletin 541; additionally, notes addressing the data group studied for each material are explained in Section 15 of WRC Bulletin 541. A summary of several material notes pertinent to Addendum 2 of the API Standard 530, 7th Edition are provided in H.9.

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*Annex H.9: This section shall be replaced with the following:*

## H.9 Updated Property Data for Tube Materials

As part of the development of the 7th Edition of API Standard 530, Section H.9 was written to detail specific updated material data for relevant alloys. For the current addendum, these details have been revised and additional commentary has been provided for newly recognized materials.

### H.9.1 9Cr-2Si-1Cu Steel (Grade 921)

A new variant of conventional 9Cr-1Mo alloy steel has been introduced. In addition to alloying additions of nominally 9 wt% chromium and 1 wt% molybdenum, this alloy also contains nominal additions of 2 wt% silicon and 1 wt% copper. The resulting material, known as Grade 921 (UNS K91201), claims enhanced resistance to coke formation and growth, as well as superior elevated temperature tensile strength properties to conventional 9Cr-1Mo, and comparable creep strength to conventional 9Cr-1Mo. WRC's analysis for 9Cr-2Si-1Cu steel is documented in WRC Bulletin 589. The available data for this material as of the publication of Addendum 2 to the 7th Edition of this standard is limited to the supplier-provided dataset for code approval, which does not satisfy all the guidelines of WRC Bulletin 546. Therefore, conservative limits are placed on both elastic and rupture allowable design stresses.

### H.9.2 9Cr-1Mo-V Steel

During the development of WRC Bulletin 541 (1st Edition), prior to the 7th Edition of this standard, new data was obtained primarily from Japan. More recently, the authors of WRC Bulletin 541 have compiled data from various European, Japanese, and U.S. sources and compared this expanded dataset to the rupture allowable stresses and Larson-Miller properties in API Standard 530, as well as those in other international codes and standards. This effort has confirmed that the properties used for Addendum 2 to the 7th Edition of this standard, and the resulting allowable stresses obtained, are appropriate.

### H.9.3 Alloy 115 (10.5Cr-V) Steel

Alloy 115 is a creep-strength enhanced ferritic (CSEF) steel similar to Grade 91 (9Cr-1Mo-V), developed to provide enhanced oxidation, sulfidation, and $H_2$ / $H_2S$ corrosion resistance to Grade 91. WRC's analysis for Alloy 115 (UNS K91060) is documented in WRC Bulletin 576. The available data for this material as of the publication of Addendum 2 to the 7th Edition of this standard are limited to the supplier-provided dataset. It

is anticipated that with API Standard 530 recognition of this material, interest and deployment will expand and additional data and operational experience will follow.

### H.9.4 Type 304L Stainless Steel

Very little rupture testing of Type 304L materials is intentionally conducted; therefore, the performance of this alloy was historically estimated from data for Type 304 stainless steel with a carbon content in the range of 0.04 %. WRC, in providing properties for Type 304L stainless steel, cautioned against relying on 100 % of the creep rupture properties for determination of allowable stresses. Reflecting this caution, the 7th Edition of this standard established the limiting design metal temperature for this low-carbon stainless alloy at 677 °C (1250 °F). In Addendum 1 to the 7th Edition of this standard, this limiting design metal temperature was lowered to 593 °C (1100 °F); up to this temperature, the rupture allowable stress was set to 100 % of the minimum stress for rupture. In Addendum 2 to the 7th Edition of this standard, designs up to 815 °C (1500 °F) are allowed; however, the rupture allowable is set to 80 % of the minimum stress for rupture ($F_{cr}$ = 0.8). API is considering a research effort to collect and compile additional published creep and rupture data on Type 304L stainless steel.

### H.9.5 Type 304/304H Stainless Steel

Only data from tube materials from overseas sources was utilized in this study; more than 450 heats were included in the final database. The high carbon grade and the normal grade materials were grouped together. The minimum was about the same, but the resulting scatter band was less than the current curves.

### H.9.6 Type 316L/317L Stainless Steel

Prior to the 7th Edition of this standard, Type 316L was the only L-grade 300-series stainless steel included in API Standard 530. The 7th Edition also recognized Type 317L (with identical creep properties to Type 316L), in addition to Type 304L. The data analysis indicates that the differences in the yield and ultimate tensile strength trend curves (i.e., strength ratio vs. temperature) for Type 316L and Type 317L materials are indistinguishable; therefore, the material parameters for these two alloys are identical. Note that the limiting design metal temperature for these low-carbon stainless alloys was originally established at 704 °C (1300 °F) in the 7th Edition of this standard. Reflecting cautionary notes from WRC Bulletin 541, 2nd Edition, in Addendum 1 to the 7th Edition of this standard, the limiting design metal temperature was lowered to 593 °C (1100 °F). Up to this temperature, the rupture allowable stress was set to 100 % of the minimum stress for rupture. In Addendum 2 to the 7th Edition of this standard, designs up to 815 °C (1500 °F) are allowed; however, the rupture allowable is set to 80 % of the minimum stress for rupture ($F_{cr}$ = 0.8). API is considering a research effort to collect and compile additional published creep and rupture data on Type 316L and Type 317L stainless steels.

### H.9.7 Type 347 Stainless Steel

For the 7th Edition of this standard, new data analyzed for this material was obtained primarily from Japan. Microstructural changes at higher temperatures associated with carbide precipitation or dissolution/formation of sigma phase cause the rupture exponent plot to increase slightly with increasing temperatures (see curve deflection in Figures E.59 and F.59). Thus, for this alloy, the minimum value is noted on the rupture exponent curves.

The owner/user should specify whether the Type 347 stainless steel heater tubes should be optimized for corrosion resistance (fine grained practice) or for creep resistance (coarse grained practice).

### H.9.8 Type 347H Stainless Steel

For the 7th Edition of this standard, new data analyzed for this material was obtained primarily from Japan. Microstructural changes at higher temperatures associated with carbide precipitation or dissolution/formation of sigma phase cause the rupture exponent plot to increase slightly with increasing temperatures (see curve deflection in Figures E.62 and F.62). Thus, for this alloy, the minimum value is noted on the rupture exponent curves.

## H.9.9 Type 347LN Stainless Steel

Prior to the 7th Edition of this standard, WRC released Bulletin 558, which documented available data and provided material properties for Type 347LN (UNS S34751) stainless steel. This alloy, which replaces a portion of the carbon content in traditional Type 347 stainless steel with nitrogen, was developed to provide resistance to sensitization and polythionic (intergranular) stress corrosion cracking (without stabilization), while maintaining creep strength similar to that of Type 347. The original limited dataset contained in WRC Bulletin 558 (1st edition, 2015) resulted in a limiting design metal temperature of 593 °C (1100°F). Since the release of the 7th Edition of this standard, new data has become available from the material supplier, nearly doubling the original dataset. A revised, 2nd edition of Bulletin 558 was released by WRC. As a result of this additional and positive operational experience, the limiting design metal temperature has been raised to 694 °C (1282 °F).

## H.9.10 Advanced 347AP Stainless Steel

As noted in H.9.9, the 347LN grade of stainless steel was originally developed to provide sensitization and SCC resistance with comparable creep strength to Type 347. The original developer of 347LN has subsequently developed a variation with alloying additions of copper and boron to provide the same sensitization and SCC resistance (again, without stabilization treatment), but with comparable or superior creep strength to that of Type 347H stainless steel. WRC's analysis for Advanced 347AP (UNS S34752) is documented in WRC Bulletin 582.

## H.9.11 Alloy 800

Material results from heats that do not take advantage of the heat treating and compositional controls imposed to obtain the Alloy 800H and Alloy 800HT grades were excluded from the analysis. Thus, this unrestricted material is not usually used for creep service and the database is relatively small.

## H.9.12 Alloy 800H

Tubular product data for yield and ultimate tensile strength was obtained for this alloy. A broad international material database is represented in the stress rupture data shown, and is generally in conformance with prior estimates. Some test results lasted in excess of 100,000 hours.

## H.9.13 Alloy 800HT

More recent material data from tubular products from overseas sources was combined with the original database for the 7th Edition of this standard. Due to the strengthening nickel-aluminum-titanium compounds and redissolving of carbides, the improvement of Alloy 800HT over Alloy 800H is not expected to be very large at intermediate temperatures, and it disappears at very high temperatures

## H.9.14 Alloy HK-40

Material properties (elevated temperature yield and ultimate tensile strength) from high carbon content Alloy HK-40 castings were evaluated for the 7th Edition of this standard. The analysis showed an increase

in yield strength in the 649 °C to 704 °C (1200 °F to 1300 °F) range due to precipitation. Lower minimums are shown, as compared to the existing API Standard 530 curves, from this large database collected.

## H.9.15 Remaining Materials

For remaining materials not listed individually above (carbon and C-0.5Mo steels, Cr-Mo alloy steels from 1.25Cr through conventional 9Cr-1Mo, 316/316H, 321, and 321H), no concerted efforts were made for the 7th Edition of this standard, or Addendum 2 to the 7th Edition, to expand the dataset significantly. Material properties for some of these alloys were updated to correct previous errors or to alter the material model for the Larson-Miller parameter regression.

*Bibliography: The following reference shall be added:*

[23] Osage, D.A., Panzarella, C.H., Sutton, N. G., O'Brien, I., Bladesberger, L.A., *Evaluation of Material Strength Data for Use in API Std 530*, WRC Bulletin 541, 3rd edition, August 2020