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Addendum 1

Introduction

This addendum contains updated elastic and rupture stress data for materials based on WRC 541, 2nd Edition. Updated data is provided in SI and USC units for 9Cr-1Mo, TP304L, TP316L, TP317L, Alloy 800HT, and HK-40. New data is provided in SI and USC units for TP 347LN on the following pages. Paragraph 6.7 and 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. This addendum also incorporates corrections to errors found after the 7th Edition of API Standard 530 was published.

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, Washington, DC 20001, standards@api.org.

This addendum to API 530, 7th Edition, contains the following changes:

— Updated rupture stress data for 9Cr-1Mo material: The rupture allowable stresses the addendum have been lowered to match the values given by the constants in WRC 541, 2nd Edition.

— The limiting design metal temperature for TP304L, TP316L, and TP317L have been decreased to 593 °C/1100 °F to match WRC 541 maximum temperatures for designs governed by creep properties. The allowable stress curves for TP304L, TP316L, and TP317L have been extended to 816 °C/1500 °F to match WRC 541 data for short-term exposure.

— The limiting design metal temperatures for 800HT and HK40 have been increased to 1010 °C/1850 °F to match WRC 541. The allowable stress curves also extend to this value.

— New material 347LN has been added based on data from WRC 541.

Section 6.7: The section shall be replaced by the following.

6.7 Limiting Design Metal Temperature

The limiting design metal temperature for each heater-tube alloy is given in Table 5. The limiting design metal temperature is the upper limit of the reliability of the rupture strength data, and the stress rupture curves are intended for use where the design stress is greater than 6.9 MPa (1 ksi). Higher temperatures, i.e. up to 28 °C (50 °F) below the lower critical temperature, are permitted for short-term operating conditions, such as those that exist during steam-air decoking or regeneration (approximately 25 hours or less). Operation at higher temperatures can result in changes in the alloy's microstructure. Lower critical temperatures for ferritic steels are shown in Table 5. Austenitic steels do not have lower critical temperatures. Other considerations can require lower long-term operating temperature limits, such as oxidation, graphitization, carburization, and hydrogen attack. These factors shall be considered when furnace tubes are designed.

Table 4: The table shall be replaced with the following:

Table 4—Larson-Miller Constants

Material	**Type or Grade**	**Larson-Miller Constants** C_{LM}	
		minimum properties	average properties
Low-carbon steel	—	18.15	17.70
Medium-carbon steel	B	15.6	15.15
C-½Mo steel	T1 or P1	19.007756	18.72537
1-¼Cr-½Mo steel	T11 or P11	22.05480	21.55
2-¼Cr-1Mo steel	T22 or P22	19.565607	18.9181
3Cr-1Mo steel	T21 or P21	15.785226	15.38106
5Cr-½Mo steel	T5 or P5	16.025829	15.58928
5Cr-½Mo-Si steel	T5b or P5b	16.025829	15.58928
9Cr-1Mo steel	T9 or P9	20.946	20.5
9Cr-1Mo V steel	T91 or P91	30.886006	30.36423
18Cr-8Ni steel	304 or 304H	16.145903	15.52195
18Cr-8Ni steel	304L	18.287902	17.55
16Cr-12Ni-2Mo steel	316 or 316H	16.764145	16.30987
16Cr-12Ni-2Mo steel	316L	15.740107	15.2
16Cr-12Ni-3Mo steel	317L	15.740107	15.2
18Cr-10Ni-Ti steel	321	13.325	12.8
18Cr-10Ni-Ti steel	321H	15.293986	14.75958
18Cr-10Ni-Nb[a] steel	347	14.889042	14.25
18Cr-10Ni-Nb[a] steel	347H	14.17	13.65
18Cr-10Ni-Nb[a] steel	347LN	16.6233	16.4067
Ni-Fe-Cr	Alloy 800	17.005384	16.50878
Ni-Fe-Cr	Alloy 800H	16.564046	16.04227
Ni-Fe-Cr	Alloy 800HT	13.606722	13.2341
25Cr-20Ni	HK-40	10.856489	10.4899

[a] Formerly called columbium, Cb.

Table 5: The table shall be replaced with the following:

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

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	(1 30)
2¼Cr-1Mo steel	T22 or P22	650	(1 200)	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)
18Cr-8Ni steel	304 or 304H	815	(1500) [2]	—	—
18Cr-8Ni steel	304L	593 [1]	(1100) [1]	—	—
16Cr-12Ni-2Mo steel	316 or 316H	815	(1500) [2]	—	—
16Cr-12Ni-2Mo steel	316L	593 [1]	(1100) [1]	—	—
18Cr-12Ni-3Mo steel	317L	593 [1]	(1100) [1]	—	—
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	593	(1100)	—	—
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)	—	—

NOTE 1 The maximum temperature should be limited to 593 °C (1100 °F) for designs governed by creep properties.

NOTE 2 The maximum temperature should be limited to 593 °C (1100 °F) when carbon content is less than 0.04 on heat analysis.

Table 6: The table shall be replaced with the following:

Table 6—Index to Allowable Stress Curves

Steel Type	Figure Number	Alloy
Ferritic	E.1 (F.1)	Low-carbon steel (A 192)
	E.4 (F.4)	Medium-carbon steel (A 106B, A 210A1)
	E.7 (F.7)	C-½ Mo Steel
	E.10 (F.10)	1¼ Cr-½ Mo Steel
	E.13 (F.13)	2¼ Cr-1 Mo Steel
	E.16 (F.16)	3Cr-1 Mo Steel
	E.19 (F.19)	5Cr-½ Mo Steel
	E.22 (F.22)	5Cr-½ Mo-Si Steel
	E.25 (F.25)	9Cr-1Mo Steel
	E.28 (F.28)	9Cr-1Mo-V Steel
Austenitic	E.31 (F.31)	18Cr-8Ni (304 and 304H) Stainless Steel
	E.34 (F.34)	18Cr-8Ni (304L) Stainless Steel
	E.37 (F.37)	16Cr-12Ni-2Mo (316 and 316H) Stainless Steel
	E.40 (F.40)	16Cr-12Ni-2Mo (316L) Stainless Steel
	E.40 (F.40)	16Cr-12Ni-3Mo (317L) Stainless Steel
	E.43 (F.43)	18Cr-10Ni-Ti (321) Stainless Steel
	E.46 (F.46)	18Cr-10Ni-Ti (321H) Stainless Steel
	E.49 (F.49)	18Cr-10Ni-Nb (347) Stainless Steel
	E.52 (F.52)	18Cr-10Ni-Nb (347H) Stainless Steel
	E.65 (F.65)	18Cr-10Ni-Nb (347LN) Stainless Steel
	E.55 (F.55)	Ni-Fe-Cr (Alloy 800)
	E.58 (F.58)	Ni-Fe-Cr (Alloy 800H)
	E.61 (F.61)	Ni-Fe-Cr (Alloy 800HT)
	E.64 (F.64)	25Cr-20Ni (HK-40)

Section 7.4: The entire section shall be replaced with the following:

7.4 Rupture Design with Linearly Changing Temperature

Suppose the tube described in 7.3 operates in a service for which the estimated tube metal temperature varies from 635 °C (1175 °F) at the start of run to 690 °C (1275 °F) at the end of run. Assume that the run lasts a year, during which the thickness changes by about 0.33 mm (0.013 in.).

Assume that the initial minimum thickness is 8.0 mm (0.315 in.); therefore, using Equation (1), the initial stress is as follows:

In SI units:

$$\sigma_o = \frac{p}{2}\left(\frac{D_o}{\delta} - 1\right)$$

$$\sigma_o = \frac{5.8}{2}\left(\frac{168.3}{8.0} - 1\right) = 58.1 \text{ MPa}$$

In USC units:

$$\sigma_o = \frac{840}{2}\left(\frac{6.625}{0.315} - 1\right) = 8413 \text{ psi}$$

At the start-of-run temperature, $n_0 = 4.96$. From Table 3, A is 3.74×10^5 MPa (5.43×10^7 psi). The parameters for the temperature fraction are, therefore, as follows:

In SI units:

$$V = n_o \left(\frac{\Delta T^*}{T^*_{sor}}\right) \ln\left(\frac{A}{\sigma_o}\right)$$

$$N = n_o \left(\frac{\Delta\delta}{\delta_o}\right)$$

$$V = 4.96\left(\frac{55}{908}\right) \ln\left(\frac{3.74\times10^5}{58.1}\right) = 2.64$$

$$N = 4.96\left(\frac{0.33}{8.0}\right) = 0.2$$

In USC units:

$$V = 4.96\left(\frac{100}{1635}\right) \ln\left(\frac{5.43\times10^7}{8413}\right) = 2.64$$

$$N = 4.96\left(\frac{0.013}{0.315}\right) = 0.2$$

From Figure 2, f_T = 0.62, and the equivalent temperature is calculated using Equation (6) as follows:

In SI units:

$$T_{eq} = 635 + (0.62 \times 55) = 669\ °C$$

In USC units:

$$T_{eq} = 1175 + (0.62 \times 100) = 1237\ °F$$

A temperature allowance of 15 °C (25 °F) is added to yield a design temperature of 684 °C (1262 °F), which is rounded up to 685 °C (1265 °F). Using this temperature to carry out the design procedure illustrated in 7.3 yields the following:

In SI units:

$$\delta_\sigma = 16.0\ \text{mm}$$

$$\delta_{min} = 16.0 + (0.54 \times 3.2)$$

$$\delta_{min} = 17.7\ \text{mm}$$

In USC units:

$$\delta_\sigma = 0.622\ \text{in.}$$

$$\delta_{min} = 0.622 + (0.54 \times 0.125)$$

$$\delta_{min} = 0.690\ \text{in.}$$

This thickness is different from the 8.0 mm (0.315 in.) thickness that was initially assumed. Using this thickness, the initial stress is calculated as follows:

In SI units:

$$\sigma_o = \frac{5.8}{2}\left(\frac{168.3}{17.7} - 1\right) = 24.7\ \text{MPa}$$

In USC units:

$$\sigma_o = \frac{840}{2}\left(\frac{6.625}{0.690} - 1\right) = 3613\ \text{psi}$$

With this stress, the temperature-fraction parameters V and N become the following:

In SI units:

$$V = 4.96\left(\frac{55}{908}\right)\ln\left(\frac{3.74\times10^{5}}{24.7}\right) = 2.89$$

$$N = 4.96\left(\frac{0.33}{17.7}\right) = 0.09$$

In USC units:

$$V = 4.96\left(\frac{100}{1635}\right)\ln\left(\frac{5.43\times10^{7}}{3613}\right) = 2.92$$

$$N = 4.96\left(\frac{0.013}{0.690}\right) = 0.09$$

Using these values in Figure 2, f_T = 0.62, the value that was determined in the first calculation. Since the temperature fraction did not change, further iteration is not necessary. This design calculation is summarized in the calculation sheet in Figure 6.

CALCULATION SHEET SI units (USC units)					
Heater	______	Plant	______	Refinery	______
Coil		Material	Type 347	ASTM Spec.	A 213/A 213M

Calculation of minimum thickness	**Elastic design**	**Rupture design**
Outside diameter, mm (in.)	$D_o =$	$D_o =$ 168.3 (6.625)
Design pressure, gauge, MPa (psi)	$p_{el} =$	$p_r =$ 5.8 (840)
Maximum or equivalent metal temperature, °C (°F)	$T_{eq} =$	$T_{eq} =$ 669 (1237)
Temperature allowance, °C (°F)	$T_A =$	$T_A =$ 15 (25)
Design metal temperature, °C (°F)	$T_d =$	$T_d =$ 685 (1265)
Design life, h	—	$t_{DL} =$ 100,000
Allowable stress at T_d, Figure E17.1 (Figures F17.1) MPa (psi)	$\sigma_{el} =$	$\sigma_r =$ 27.7 (4050)
Stress thickness, Equation (2) or (4), mm (in.)	$\delta_\sigma =$	$\delta_\sigma =$ 16.0 (0.622)
Corrosion allowance, mm (in.)	$\delta_{CA} =$	$\delta_{CA} =$ 3.2 (0.125)
Corrosion fraction, Figure 1, $n = 4.5$; $B = 0.322$	—	$f_{corr} =$ 0.54
Minimum thickness, Equation (3) or (5), mm (in.)	$\delta_{min} =$	$\delta_{min} =$ 17.7 (0.690)

Calculation of equivalent tube metal temperature		
Duration of operating period, years	$t_{op} =$	1.0
Metal temperature, start of run, °C (°F)	$T_{sor} =$	635 (1175)
Metal temperature, end of run, °C (°F)	$T_{eor} =$	690 (1275)
Temperature change during operating period, K (°R)	$\Delta T^* =$	55 (100)
Metal absolute temperature, start of run, K (°R)	$T^*_{sor} =$	908 (1635)
Thickness change during operating period, mm (in.)	$\Delta\delta =$	0.33 (0.013)
Assumed initial thickness, mm (in.)	$\delta_0 =$	8.00 (0.315)
Corresponding initial stress, Equation (1), MPa (psi)	$\sigma_0 =$	58.1 (8,413)
Material constant, Table 3, MPa (psi)	$A =$	3.74×10^5 (5.43×10^7)
Rupture exponent at T_{sor}, Figures E.1 to E.19 (Figures F.1 to F.19)	$n_0 =$	4.96
Temperature fraction, Figure 2, $V = 2.64$; $N = 0.2$	$f_T =$	0.62
Equivalent metal temperature, Equation (6), °C (°F)	$T_{eq} =$	669 (1237)

Figure 1—Sample Calculation for Rupture Design (Changing Temperature)

Figure B.1: The key shall be changed as indicated in the red box:

Key

1 Curve 1 for a double row against a wall, triangular spacing

2 Curve 2 for a double row with equal radiation from both sides and two diameters between rows, triangular spacing

3 Curve 3 for a single row against a wall

4 Curve 4 for a single row with equal radiation from both sides

Annex E, List of Figures and Tables (SI Units): The titles of the indicated tables shall be changed to the following:

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

Table E.12—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for A213, ASTM A312, and ASTM 376 TP 304L (18Cr-8Ni) Stainless Steels

Figure E.40—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASMT A379 TP316L (18Cr-8Ni) Stainless Steels

Figure E.41—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L-317L Stainless Steels

Figure E.42—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L-317L Stainless Steels

Table E.14—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP316L-317L Stainless Steels

Table E.21—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM B407 UNS N08811 Alloy 800HT Steels

Table E.22—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A608 Grade HK-40 Steels

Annex E, List of Figures and Tables (SI Units): The following titles shall be added to the list:

TP 347LN Stainless Steels

Figure E.67—Stress Curves (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels

Figure E.68—Rupture Exponent vs. Temperature Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels

Figure E.69—Larson-Miller Parameter vs. Stress Curve (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels

Table E.23—Elastic, Rupture and Allowable Stresses and Rupture Exponent (SI Units) for ASTM A213, ASTM A312, and ASTM A376 TP 347LN (18Cr-10Ni-Nb) Stainless Steels