AK Steel International

ARMCO® 17-7 PH®

STAINLESS STEEL BAR, ROD AND WIRE

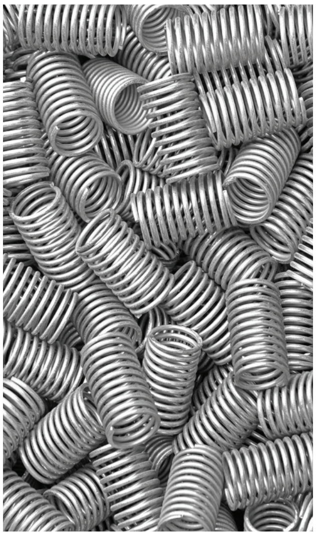
Product Data Bulletin

Aircraft Controls and Instruments

Appliance Springs

Automotive Components

Processing Equipment



ARMCO® 17-7 PH® STAINLESS STEEL is widely used for applications requiring good corrosion resistance combined with high strength. Bars, rods and forgings are used primarily in aircraft structural parts. With excellent spring properties at temperatures up to 316 °C (600 °F) and good corrosion resistance, 17-7 PH wire is used for a wide variety of springs. These include springs made of flat and round wire for appliances, aircraft controls and instruments, automotive components and processing equipment.

ARMCO

Representing ARMCO® products since 1924

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ARMCO® 17-7 PH® STAINLESS STEEL BAR, ROD AND WIRE

Product Description

ARMCO 17-7 PH Stainless Steel is a precipitation hardening stainless steel that provides excellent fatigue properties, good corrosion resistance and minimum distortion on heat treatment. Hard-drawn 17-7 PH wire is an excellent spring material. When heat treated at 482 °C (900 °F), it exhibits elastic properties like those of the best music wire and alloy spring steels. Solution heat treated (annealed) 17-7 PH wire can be readily cold formed before heat treating to high tensile strengths and high hardness. At service temperatures up to about 316 °C (600 °F), ARMCO 17-7 PH Stainless Steel has higher strength than nickel-chromium, nickel-copper, nickel-aluminum and copper-beryllium alloys.

ARMCO 17-7 PH Stainless Steel bar, rod, wire and forgings are used primarily in components also utilizing ARMCO 17-7 PH Stainless Steel sheets and plate. When these components are subjected to transverse stresses ARMCO PH 13-8 Mo should be used. For most machined or forged parts not used in conjunction with 17-7 PH sheet or plate, a different precipitation-hardening stainless steel, ARMCO 17-4 PH®, ARMCO 15-5 PH® VAC CE, or ARMCO PH 13-8 Mo is generally specified. Similar mechanical properties, higher impact strength, and comparable corrosion resistance can be obtained with ARMCO 17-4 PH or 15-5 PH VAC CE stainless steels. Higher tensile strength, higher impact strength and better corrosion resistance are obtained with ARMCO PH 13-8 Mo stainless steel.

Composition		(wt %)
Carbon	(C)	0.09 max.
Manganese	(Mn)	1.00 max.
Phosphorus	(P)	0.04 max.
Sulfur	(S)	0.04 max.
Silicon	(Si)	1.00 max.
Chromium	(Cr)	16.00 – 18.00
Nickel	(Ni)	6.50 – 7.75
Aluminum	(Al)	0.75 – 1.50

Specifications

SPECIFICATIONS

The following specifications cover ARMCO 17-7 PH Stainless Steel. The grade is listed as Type 631, grade 631 or as UNS S17700.

ASTM A564 Grade 631 Bars and Shapes
ASTM A313 Grade 631 Spring Wire
ASTM A705 Grade 631 Forgings
AMS 5644 Bars and Forgings
AMS 5678 Wire Spring Tempe
AMS 5528 Sheet, Strip and Plate
AMS 5529 Sheet and Strip-Cold Rolled
AMS A693 Plate, Sheet and Strip

Contact your AK Steel International sales representative for additional information.

METRIC PRACTICE

The values shown in this bulletin were established in U.S. customary units. The metric equivalents of U.S. customary units shown may be approximate.

Standard Heat Treatments

STANDARD HEAT TREATMENTS

The highest mechanical properties obtainable from ARMCO 17-7 PH Stainless Steel are found in wire treated to Condition CH 900. To obtain these properties, Condition A material is transformed to martensite at the mill by cold reduction. This is designated as Condition C. Hardening to Condition CH 900 is accomplished with a single low-temperature heat treatment.

Cold Drawn at Mill
RESULT: **Condition C**

Fabricate

Heat to 482 ± 6 °C
(900 ± 10 °F)
Hold 1 hr Air Cool
RESULT: **Condition CH 900**

For the heat treatment of ARMCO 17-7 PH Condition A products, the following three essential steps are required to develop the high strengths of Conditions TH 1050 and RH 950:

1. Austenite conditioning
2. Cooling to effect transformation of austenite to martensite
3. Precipitation hardening

Material purchased in Condition A can be heat treated to develop these high strengths by one of the following procedures:

Solution Heat Treated
Annealed 1038 ± 14 °C
(1900 ± 25 °F)
Hold 30 minutes min.
RESULT: **Condition A**

Fabricate

Heat 760 ± 14 °C (1400 ± 25 °F) Hold 90 minutes	Austenite Conditioning	Heat 954 ± 9 °C (1750 ± 15 °F) Hold 10 min. Air Cool to Room Temperature RESULT: **Condition A 1750**
Air Cool within 1 hr to 16 $^{+0}_{-6}$ °C (60$^{+0}_{-10}$ °F) Hold 30 minutes min. RESULT: **Condition T**	Transformation	Cool within 1 hr to -73 ± 6 °C (-100 ± 10 °F) Hold 8 hrs RESULT: **Condition R 100**
Heat to 566 ± 6 °C (1050 ± 10 °F) Hold 90 min., Air Cool RESULT: **Condition TH 1050**	Precipitation Hardening	Heat to 510 ± 6 °C (950 ± 10 °F) Hold 1 hr Air Cool RESULT: **Condition RH 950**

Mechanical Properties

Tables 1 and 2 list properties acceptable for material specifications.

TABLE 1 – PROPERTIES ACCEPTABLE FOR MATERIAL SPECIFICATION BAR, ROD AND WIRE

Condition	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Red. of Area %	Hardness	
					HB	Rockwell
Condition A*	1034 (150 max.)	–	–	–	229 max.	B98 max.
Condition** TH 1050 up to 76.2 mm (3 in.) incl.	1172 (170 min.)	965 (140 min.)	6 min.	25 min.	363 min.	C38 min.
Condition** RH 950 up to 76.2 mm (3 in.) incl.	1276 (185 min.)	1034 (150 min.)	6 min.	10 min.	387 min.	C41 min.

**Condition of material was as received from the mill.*
***Condition of material was with final heat treatment conditions.*

TABLE 2 – PROPERTIES ACCEPTABLE FOR MATERIAL SPECIFICATION COLD DRAWN WIRE

	UTS, MPa (ksi)	
Wire Diameter, mm (in.)	Condition C* range	Condition CH 900** range
0.406 – 0.508 incl. (0.016 – 0.020)	1710 – 2102 (248 – 305)	3309 – 2516 (335 – 365)
Over 0.508 – 0.635 incl. (0.020 – 0.025)	1675 – 2068 (243 – 300)	2275 – 2482 (330 – 360)
Over 0.635 – 0.737 incl. (0.025 – 0.029)	1648 – 2034 (239 – 295)	2240 – 2447 (325 – 355)
Over 0.737 – 1.04 incl. (0.029 – 0.041)	1613 – 1999 (234 – 290)	2206 – 2413 (320 – 350)
Over 1.04 – 1.29 incl. (0.041 – 0.051)	1586 – 1965 (230 – 285)	2137 – 2344 (310 – 340)
Over 1.29 – 1.55 incl. (0.051 – 0.061)	1551 – 1931 (225 – 280)	2102 – 2309 (305 – 335)
Over 1.55 – 1.80 incl. (0.061 – 0.071)	1503 – 1875 (218 – 272)	2048 – 2254 (297 – 327)
Over 1.80 – 2.18 incl. (0.071 – 0.086)	1489 – 1862 (216 – 270)	2013 – 2220 (292 – 322)
Over 2.18 – 2.29 incl. (0.086 – 0.090)	1427 – 1793 (207 – 260)	1944 – 2151 (282 – 312)
Over 2.29 – 2.54 incl. (0.090 – 0.100)	1407 – 1772 (204 – 257)	1924 – 2130 (279 – 309)
Over 2.54 – 2.69 incl. (0.100 – 0.106)	1386 – 1744 (201 – 253)	1889 – 2096 (274 – 304)
Over 2.69 – 3.30 incl. (0.106 – 0.130)	1372 – 1731 (199 – 251)	1875 – 2082 (272 – 302)
Over 3.30 – 3.50 incl. (0.130 – 0.138)	1338 – 1689 (194 – 245)	1793 – 1999 (260 – 290)
Over 3.50 – 3.71 incl. (0.138 – 0.146)	1324 – 1675 (192 – 243)	1779 – 1986 (258 – 288)
Over 3.71 – 4.11 incl. (0.146 – 0.162)	1310 – 1662 (190 – 241)	1765 – 1972 (256 – 286)
Over 4.11 – 4.57 incl. (0.162 – 0.180)	1296 – 1648 (188 – 239)	1751 – 1958 (254 – 284)
Over 4.57 – 5.26 incl. (0.180 – 0.207)	1282 – 1634 (186 – 237)	1737 – 1944 (252 – 282)
Over 5.26 – 5.72 incl. (0.207 – 0.225)	1262 – 1606 (183 – 233)	1710 – 1917 (248 – 278)
Over 5.72 – 7.77 incl. (0.225 – 0.306)	1227 – 1572 (178 – 228)	1669 – 1875 (242 – 272)
Over 7.77 – 11.18 incl. (0.306 – 0.440)	1193 – 1531 (173 – 222)	1620 – 1827 (235 – 265)
Over 11.18 – 15.88 incl. (0.440 – 0.625)	1165 – 1503 (169 – 218)	1586 – 1793 (230 – 260)

Note: Tensile strength of Condition C wire in straight lengths may be slightly less than minimum value shown. However, tensile strengths after aging will be within the range shown for Condition CH 900. Hardness of Condition C material will be Rockwell C44 min., while Condition CH 900 material will have a minimum hardness of Rockwell C48.

**Condition of material was as received from the mill.*
***Condition of material was with final heat treatment conditions.*

Typical Mechanical Properties

TABLE 3 – ROOM TEMPERATURE PROPERTIES

Property	Condition				
	A*	T	R 100	TH 1050**	RH 950**
UTS, MPa (ksi) – Tension	–	–	–	1207 (175)	1379 (200)
0.2% Yield Strength, MPa (ksi) – Tension	–	–	–	1069 (155)	1207 (175)
Elongation % in $4D_0$	–	–	–	12	10
Reduction of Area, %	–	–	–	34	30
Hardness					
Brinell	187	311	321	402	430
Rockwell	B90	C32	C34	C42	C44
Fatigue Strength (% of tensile strength)					
10 million cycles	–	–	–	44	–
100 million cycles	–	–	–	41	–

Elastic Limit: Tension – Approximately 75% UTS (Condition CH 900)
Torsion – Approximately 55% UTS (Condition TH 1050 AND RH 950)
Approximately 45% UTS (Condition CH 900)

Condition of material was as received from the mill.

***Condition of material was with final heat treatment conditions.*

TABLE 4 – FATIGUE STRENGTH BY ROTATING WIRE ARC FATIGUE TEST CONDITION CH 900

	Endurance Limit, MPa (ksi) 10^8 cycles
Commercial Surface (Cold Drawn)	448 (65)
Machined and Polished	552 (80)
Electropolished	689 (100)
Centerless Ground	862 (125)
Centerless Ground and Electropolished	689 (100)

Spring Properties

TABLE 5 – FATIGUE PROPERTIES OF HELICAL COMPRESSION SPRINGS CONDITION CH 900

Wire Size, mm (in.)	Surface Condition	Endurance Limit 10 000 000 cycles – 69 MPa (10 ksi) min. Stress Fatigue Strength, MPa (ksi)
1.70 (0.067)	Cold Drawn	586 (85)
1.70 (0.067)	Electropolish	724 (105)
2.16 (0.085)	Cold Drawn	586 (85)
2.67 (0.105)	Cold Drawn	586 (85)
2.67 (0.105)	Shot Peened	827 (120)
2.67 (0.105)	Electropolished + Shot Peened	896 (130)
3.18 (0.125)	Cold Drawn	503 (73)
3.18 (0.125)	Electropolished	586 (85)

ARMCO 17-7 PH Stainless Steel hard drawn wire has elastic properties comparable to those of the best music wire and alloy spring steels. It provides a unique combination of ultra high strength and good corrosion resistance that makes it ideal for a wider variety of spring applications. For service at elevated temperatures, up to 316 °C (600 °F), ARMCO 17-7 PH Stainless Steel in Condition CH 900 is the most economical spring material available.

ARMCO 17-7 PH Stainless Steel has good dimensional stability when formed into springs. The dimensions of ARMCO 17-7 PH Stainless Steel springs are unaffected by the hardening treatment, and the ends and hooks on helical springs do not change position.

Springs made of ARMCO 17-7 PH Stainless Steel can be treated at 538 – 566 °C (1000 – 1050 °F) to eliminate initial tension and still maintain good spring properties for room temperature applications. This treatment results in a constant spring rate.

ARMCO 17-7 PH Stainless Steel springs show considerably lower loss of load at elevated temperatures than music wire springs. The results of relaxation tests conducted at various temperatures and stress levels on helical compression springs are shown in Table 6. Tables 7 and 8 show mechanical property data and dimensions of the various springs tested.

ARMCO 17-7 PH Stainless Steel Condition C wire is supplied with a lubricating coating suitable for automatic spring coiling in sizes 2.38 – 8.40 mm (0.0937 – 0.331 in.) diameter with any of the following: Apex, Couperdine, lime, oxalate or copper: also, molydisulphide or lime and Apex drawn with any of these coatings. Oxalate, lime and Apex can pick up moisture and therefore should be stored in a dry room, preferably with constant temperature. All the subject coatings can be removed before or after heat treatments with a 10% nitric acid solution at 43 – 60 °C (110 – 140 °F). If difficulty is encountered, a 10% nitric acid-2% hydrofluoric acid solution at the same temperature can be used.

Spring Properties

TABLE 6 – RELAXATION PROPERTIES

Type	Size, mm (in.)	% Loss in Load					
		177°C (350 °F)	232 °C (450 °F)	288 °C (550 °F)	343 °C (650 °F)	399 °C (750 °F)	454 °C (850 °F)
Initial (RT) Stress 276 MPa (40 ksi). Time 96 Hours							
17-7 PH(1)	1.02 (0.040) Rd.	0.0	1.1	1.8	6.1	15.6	–
17-7 PH(1)	2.03 (0.080) Rd.	–	–	2.0	3.9	10.7	–
18 Cr-8 Ni(2)	1.02 (0.040) Rd.	0.0	1.6	5.6	11.4	–	–
*Inconel "X"(3)	2.16 (0.085) Rd.	–	–	–	0.96	4.91	15.8
Music Wire(4)	1.02 (0.040) Rd.	3.3	9.1	–	–	–	–
Initial (RT) Stress 552 MPa (80 ksi). Time 96 Hours							
17-7 PH(1)	1.02 (0.040) Rd.	0.0	0.9	1.26	5.55	20.9	–
17-7 PH(2)	2.03 (0.080) Rd.	–	–	3.7	4.0	13.2	–
18 Cr-8 Ni(2)	1.02 (0.040) Rd.	1.5	2.1	6.9	16.5	–	–
*Inconel "X"(3)	2.16 (0.085) Rd.	–	–	–	2.16	7.6	22.9
Music Wire(4)	1.02 (0.040) Rd.	5.07	13.7	–	–	–	–

(1) Aged 482 °C (900 °F) – 1 hour, air cool
(2) Stress relieved 454 °C (850 °F) – 0.50 hour, air cool
(3) Aged 732 °C (1350 °F) – 16 hours, air cool
(4) Stress relieved 399 °C (750 °F) – 0.50 hour, air cool
Relaxation tests were conducted on "spring temper" wire aged at 732 °C (1350 °F) for 16 hours.

Mechanical Properties

TABLE 7 – MECHANICAL PROPERTIES

Grade	Size, mm (in.)	Hardness	Modulus in Torsion, GPa (Mpsi)		Max. Stress MPa (ksi[2])
			Calculated	Published[1]	
17-7 PH	1.02 (0.040) Rd.	–	70.1 (10.16)	75.8 (11.00)	650 (94.4)
17-7 PH	2.03 (0.080) Rd.	RC54	73.9 (10.72)	75.8 (11.00)	687 (99.8)
18 Cr-8 Ni	1.02 (0.040) Rd.	RC47	71.4 (10.35)	68.9 (10.00)	576 (82.6)
Inconel "X"[3]	2.16 (0.085) Rd.	RC47	71.0 (10.30)	75.8 (11.00)	670 (97.2)
Music Wire	1.02 (0.040) Rd.	–	83.2 (12.06)	79.3 (11.50) 82.7 (12.00)	697 (101.25)

(1) Mechanical Springs – Their Engineering and Design, Wallace Barnes Company. Division of Associated Spring Corporation
(2) Governed by design of spring
(3) Springs supplied in spring temper condition

TABLE 8 – SPRING DIMENSIONS

Type	d	OD	D	H	N	K	Type of Ends
17-7 PH	1.02 mm (0.040 in.)	9.14 mm (0.360 in.)	8.13 mm (0.320 in.)	17.14 mm (0.675 in.)	6	1.175	Squared & Ground
17-7 PH	2.03 mm (0.080 in.)	18.26 mm (0.719 in.)	16.20 mm (0.638 in.)	33.66 mm (1.325 in.)	6	1.180	Squared & Ground
18 Cr-8 Ni	1.02 mm (0.040 in.)	9.32 mm (0.367 in.)	8.30 mm (0.327 in.)	16.69 mm (0.657 in.)	6	1.175	Squared & Ground
Inconel "X"[3]	2.16 mm (0.085 in.)	19.61 mm (0.772 in.)	17.45 mm (0.687 in.)	36.83 mm (1.450 in.)	6	1.175	Squared & Ground
Music Wire	1.02 mm (0.040 in.)	9.14 mm (0.360 in.)	8.13 mm (0.320 in.)	16.76 mm (0.660 in.)	6	1.775	Squared & Ground

d = Wire Diameter
OD = Spring Diameter
D = Mean Diameter of Coil
H = Free Length
N = Number of Active Coils
K = Curvature Correction Factor

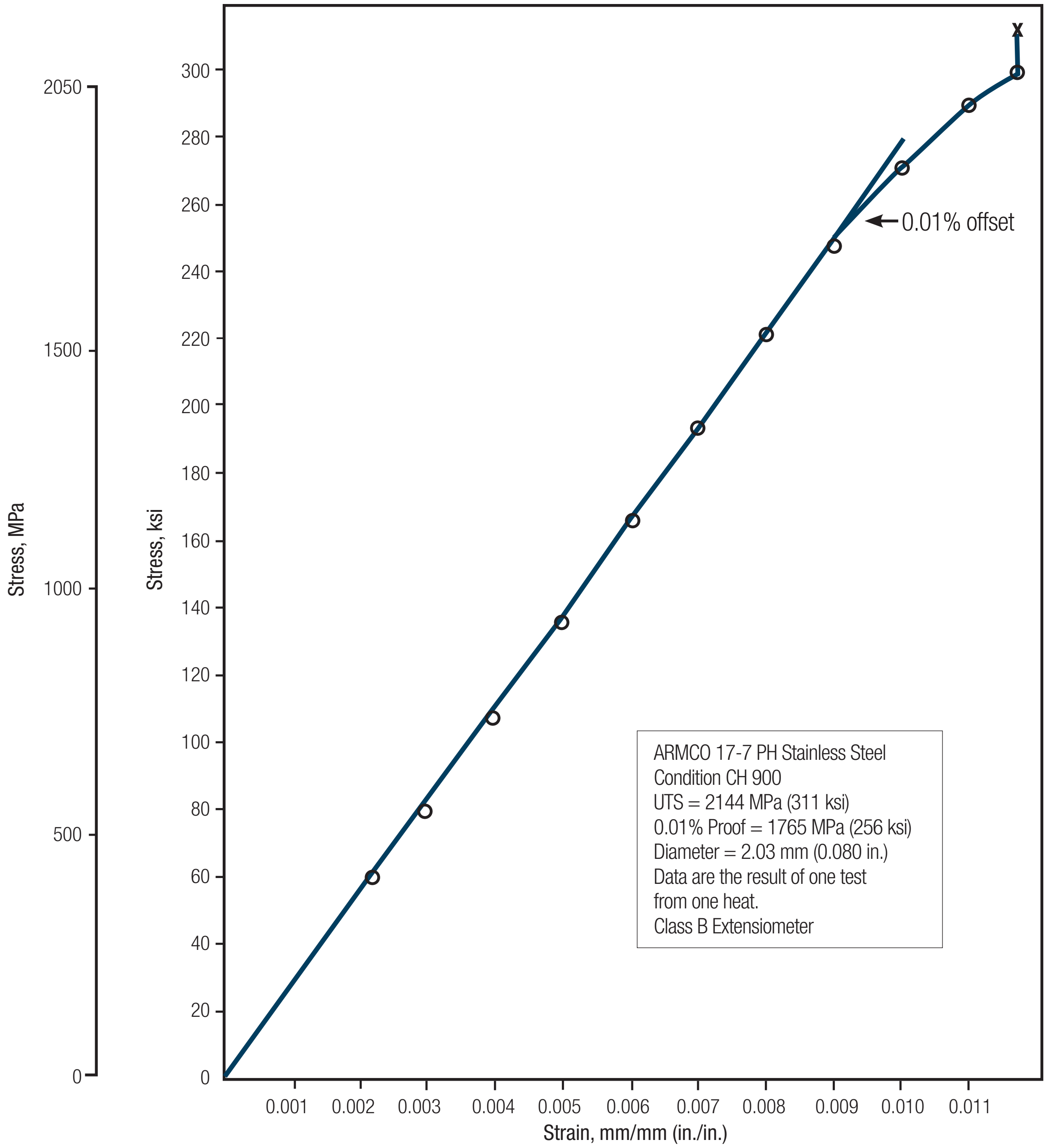
Table 9 shows the effect of temperature on the torsional modulus of spring materials. The change in modulus was determined on compression springs in a temperature range of -76 – 399 °C (-105 – 750 °F). In calculating the torsional modulus at various temperatures, the room temperature 27 °C (80 °F) modulus of the compression springs was considered as 100%.

TABLE 9 – EFFECT OF TEMPERATURE ON TORSIONAL MODULUS

Material	% Change of Torsional Modulus									
	-76 °C (-105 °F)	-54 °C (-65 °F)	-18 °C (0 °F)	27 °C (80 °F)	121 °C (150 °F)	177 °C (350 °F)	232 °C (450 °F)	288 °C (550 °F)	343 °C (650 °F)	399 °C (750 °F)
17-7 PH	2.4	1.8	1.5	0	-2.4	-4.8	-6.9	-9.2	-11.4	-15.4
Type 302	2.9	2.7	1.6	0	-3.8	-6.8	-8.7	-11.6	-14.5	–
Music Wire	–	–	–	0	-3.2	-5.5	-7.5	-12.9	–	–

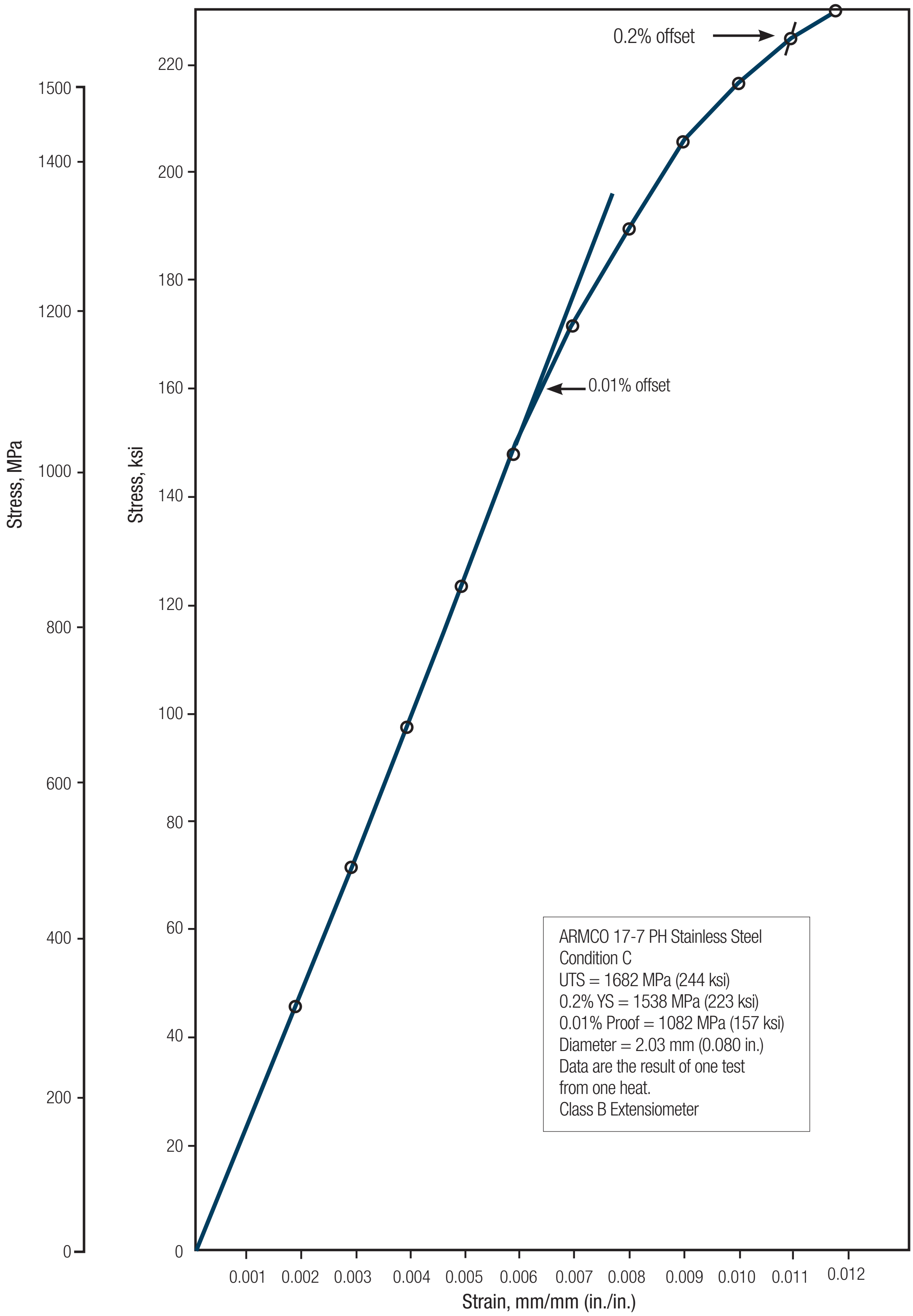
Mechanical Properties

FIGURE 1 – STRESS VS. STRAIN – CONDITION CH 900



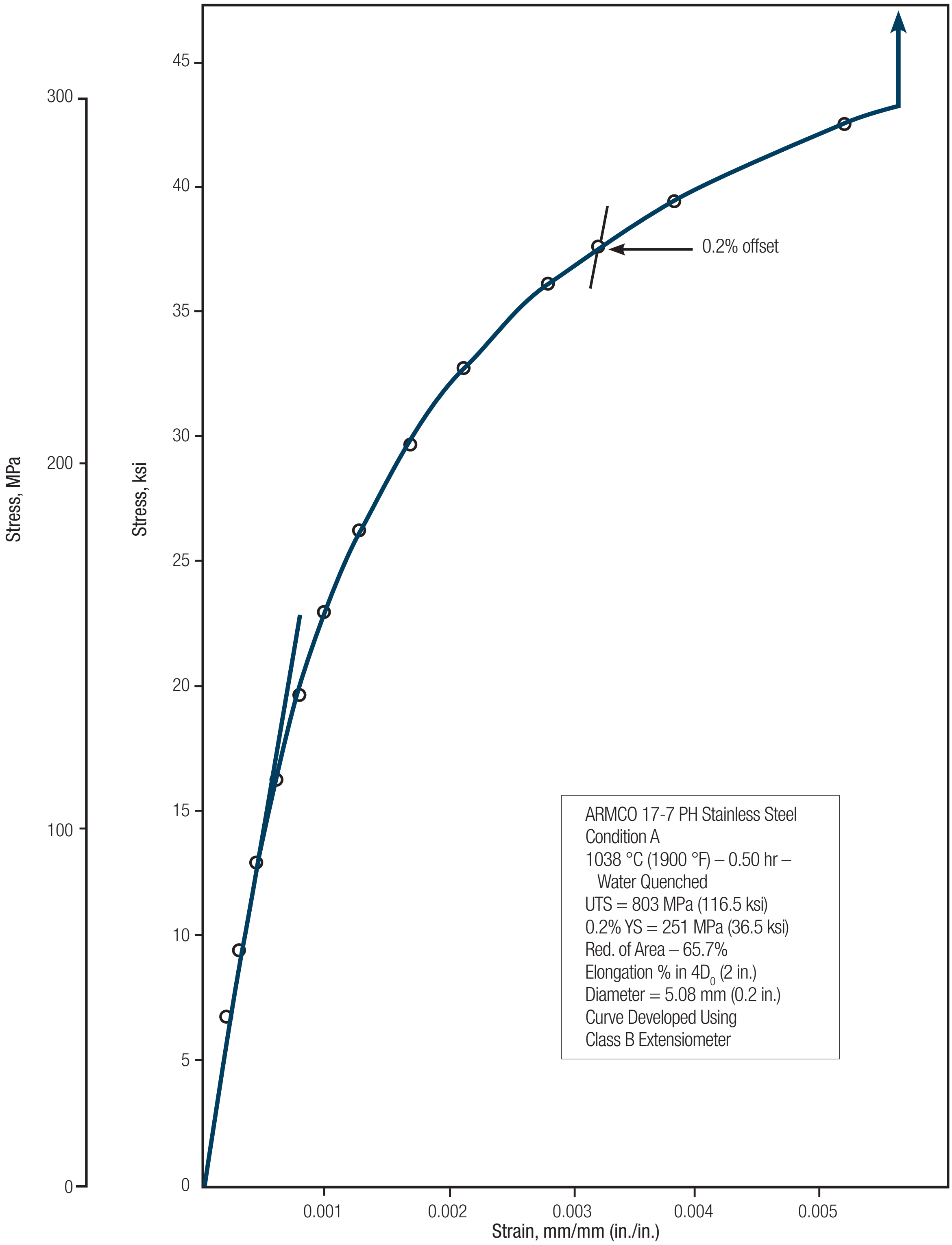
Mechanical Properties

FIGURE 2 – STRESS VS. STRAIN – CONDITION C



Mechanical Properties

FIGURE 3 – STRESS VS. STRAIN – CONDITION A



Mechanical Properties

EFFECT OF HEAT LOADING ON RELAXATION PROPERTIES

Heat loading is known to improve the resistance to relaxation. Heat loading is accomplished by preloading the springs to a stress 10% above the predetermined test stress and holding for one hour at a temperature 100 °F above the test temperature. Test results for ARMCO 17-7 PH and Type 302 stainless steel compression springs are shown in Table 10.

As indicated by the test data, heat loading effectively increased the resistance to relaxation in both 17-7 PH and Type 302 compression springs.

TABLE 10 – EFFECT OF HEAT LOADING ON RELAXATION PROPERTIES

Test	Type	Size	% Loss in Load	
			343 °C (650 °F)	399 °C (750 °F)
Initial RT Stress 276 MPa (40 ksi) Time 96 Hours	17-7 PH(1) Type 302(2)	1.02 mm (0.040 in.) Rd. 1.02 mm (0.040 in.) Rd.	1.0 3.4	2.4 –
Initial RT Stress 517 MPa (75 ksi) Time 96 Hours	17-7 PH	1.02 mm (0.040 in.) Rd.	–	7.64
Initial RT Stress 552 MPa (80 ksi) Time 96 Hours	17-7 PH(1)	1.02 mm (0.040 in.) Rd.	2.44	–

(1) Aged 482 °C (900 °F), 1 hour, air cool.
(2) Stress relieved, 454 °C (850 °F), 1 hour, air cool.

Physical Properties

TABLE 11 – PHYSICAL PROPERTIES

Property	Condition			
	A	TH 1050	RH 950	CH 900
Density: g/cm^3 (lbs/in^3)	7.81 (0.282)	7.65 (0.276)	7.65 (0.276)	7.67 (0.277)
Electrical Resistivity: µΩ•cm	80	82	83	83.8
Magnetic Permeability				
25 oersteds (199 A/m)	1.4 – 3.4	132 – 194	82 – 88	–
50 oersteds (398 A/m)	1.4 – 3.6	120 – 167	113 – 130	–
100 oersteds (796 A/m)	1.4 – 3.5	80 – 99	75 – 87	70
200 oersteds (1592 A/m)	1.4 – 3.2	46 – 55	44 – 52	43.5
maximum	1.4 – 3.6	134 – 208	119 – 135	125
Mean Coefficient of Thermal Expansion µm/m/K (10^{-6} in./in./°F)				
21 – 93 °C (70 – 200 °F)	15.3 (8.5)	10.0 (5.6)	10.3 (5.7)	11.0 (6.1)
21 – 204 °C (70 – 400 °F)	16.2 (9.0)	11.0 (6.1)	11.9 (6.6)	11.2 (6.2)
21 – 316 °C (70 – 600 °F)	17.1 (9.5)	11.3 (6.3)	12.2 (6.8)	11.5 (6.4)
21 – 427 °C (70 – 800 °F)	17.3 (9.6)	11.9 (6.6)	12.4 (6.9)	11.9 (6.6)
Thermal Conductivity: W/m•K (BTU/hr/ft^2/in./°F)				
149 °C (300 °F)	–	16.9 (117)	16.9 (117) (est.)	16.4 (114)
260 °C (500 °F)	–	18.4 (128)	18.4 (128) (est.)	18.3 (127)
448 °C (840 °F)	–	21.1 (146)	21.1 (146) (est.)	21.6 (150)
482 °C (900 °F)	–	21.1 (146)	21.1 (146) (est.)	21.8 (151)

Variations in heat treating temperature have negligible effect on electrical resistivity. Annealing, transforming and hardening treatment variations of ±56 °C (100 °F) will not cause the resistivity to vary more than ±3%, from the listed value. The electrical resistivity value for Condition T is 107 µΩ•cm.

MODULUS OF ELASTICITY

The static modulus of elasticity of ARMCO 17-7 PH Stainless Steel (Condition CH 900) is:

Tension – 200 GPa (29.5 Mpsi)

Torsion – 72 GPa (10.5 Mpsi)

The dynamic modulus of elasticity of 17-7 PH (Condition H 1050) is 200 GPa (29.5 Mpsi).

DIMENSIONAL CHANGES

When ARMCO 17-7 PH in Condition A is heat treated to Conditions T or R (after austenite conditioning and transforming), a predictable expansion of 0.0045 mm/mm (in./in.) will occur. Upon precipitation hardening to develop Condition TH 1050 or RH 950, there is a contraction of about 0.0005 mm/mm (in./in.). The combined net effect is an expansion of about 0.004 mm/mm (in./in.).

Fabrication

HEAT TREATING AND ANNEALING

When solution heat treating (annealing) hot worked or forged material, the metal should be heated to 1038 ± 6 °C (1900 ± 10 °F), held for a minimum of 30 minutes at this temperature, and water quenched.

Condition C material is heat treated to high strength levels by a 482 °C (900 °F) heat treatment for 1 hour followed by air cooling. The heat treatment may be done either in a reducing atmosphere or in air. If an open furnace is used, the material will develop a light heat tint that is easily removed.

EQUIPMENT AND ATMOSPHERE

Thorough cleaning of parts and assemblies prior to heat treatment facilitates scale removal. The removal of oils and lubricants with solvents also assures that the steel will not be carburized from this source. Carburized 17-7 PH parts do not develop the minimum mechanical properties shown.

Selection of heat treating equipment depends to some extent upon the nature of the particular parts to be treated. However, heat source, atmosphere and control of temperature are primary considerations.

Furnaces fired with oil or natural gas are difficult to use in the heat treatment of stainless steels, particularly if combustion control is uncertain and if flame impingement on the parts is possible. Electric furnaces or gas and oil fired radiant tube furnaces generally are used for heat treating ARMCO 17-7 PH Stainless Steel.

Air has proved to be the most satisfactory furnace atmosphere for heat treating operations. Controlled reducing atmospheres such as bright annealing gas and dissociated ammonia introduce the hazard of carburizing and nitriding. Scale-free heat treatment in dry hydrogen atmosphere is difficult to achieve because of the extremely low dew point required at the heat treating temperatures of 760 °C (1400 °F) and lower. If complete freedom from scale or heat discoloration is necessary, a vacuum furnace is required. Dry hydrogen may be used for the 954 °C (1750 °F) heat treatment outlined for Condition RH 950 and will provide a scale-free surface.

When heat treating to the RH condition, it is necessary to cool ARMCO 17-7 PH Stainless Steel to a temperature of -73 °C (-100 °F) for a period of 8 hours. Commercial equipment is available for refrigeration at this temperature, but a saturated bath of dry ice in alcohol or acetone maintains a temperature of -73 to -78 °C (-100 to -109 °F) without control equipment.

FORGING

Forging practices for ARMCO 17-7 PH Stainless Steel are similar to those used with Type 302 stainless steel. Forging temperature should not exceed 1232 °C (2250 °F), but the material may be worked at lower temperatures of 1177 °C (2150 °F) or less, depending on size and shape. Scale loss will be lessened when lower forging temperatures are used. There is no critical temperature range in which the material may not be worked.

Charging practice is not critical and ARMCO 17-7 PH Stainless Steel may be charged in either a hot or cold furnace. Air cooling, oil or water quenching may be employed.

SCALE REMOVAL

Scale develops during most heat treating operations. The amount and nature of the scale formation varies with the cleanliness of the parts, the furnace atmosphere and the temperature and time of heat treatment. A variety of descaling methods may be employed, and the method chosen often depends upon the facilities available. A tabulation of the recommended methods of scale removal after various heat treatments is shown in the following table.

Fabrication

TABLE 12 – SCALE REMOVAL METHODS

Heat Treated to Condition	Preferred Methods After Heat Treatment	Secondary Methods
A	Wet Grit Blast[1] or Pickle[2]	Scale Condition and Pickle[3]
CH 900	Wet Grit Blast[1] or Pickle[2]	–
A 1750	Wet Grit Blast[1]	Pickle[2] or Scale Condition and Pickle[4]
T and R 100	Wet Grit Blast[1]	Pickle[2] or Scale Condition and Pickle[5]
TH 1050 and RH 950	Wet Grit Blast[1]	Pickle[2] or Scale Condition and Pickle[3]

[1] Wet grit blasting processes are widely used and have been found to be highly satisfactory. These methods eliminate the hazard of intergranular attack from acid pickling. There also are advantages in better fatigue strength and corrosion resistance.

[2] 10% HNO_3, + 2% HF at 43 – 60 °C (110 – 140 °F) for three minutes maximum. This pickling time limit is necessary to keep intergranular attack by the acid to a minimum. Removal of loosened scale may be facilitated by the use of high pressure water or steam spray. A scale conditioning treatment is not necessary for parts that have been thoroughly cleaned. Uniform pickling of the entire surface is evidence of a well cleaned part. A spotty scale and nonuniform removal is evidence of a poorly cleaned part, and a scale conditioning process is a necessity prior to pickling.

[3] Scale conditioners:
a) Hooker Electrochemical – Virgo Salts
b) Kolene Process
c) DuPont Hydride Process
d) Caustic permanganate (boiling aqueous solution 10% NaOH + 3% $KMnO_4$ for one hour)

[4] Use caustic permanganate scale conditioning followed by HNO_3 – HF pickle only. Do not use fused salts. The use of fused salts as scale conditioners on ARMCO 17-7 PH Stainless Steel in Condition A 1750 will prevent the steel from developing maximum transformation upon subsequent refrigeration.

[5] Scale condition and pickle as in footnote 3. The Virgo and Kolene fused salt baths may be operated at temperatures up to 593 °C (1100 °F) so that the hardening and scale conditioning treatment may be combined if desired. However, the operation of a salt bath at such temperatures should be checked with the manufacturer before proceeding.

Some degree of intergranular penetration occurs during any pickling operation. However, in Condition CH 900, the penetration resulting from the short-time pickling is generally slight. Other conditions of heat treatment are more susceptible to intergranular penetration during pickling, and pickling methods should be avoided or carefully controlled if they must be used for such removal.

For removal of light discoloration or heat tint produced by final hardening treatment at 482 – 649 °C (900 – 1200 °F), the standard 10% HNO_3 + 2% HF acid bath may be used.

MACHINING

Machining characteristics of ARMCO 17-7 PH Stainless Steel are similar to those of Type 302 stainless steel. Transformed and heat-treated ARMCO 17-7 PH Stainless Steel machines like other materials of equal hardness. Normal practice for machining materials in the hardness range of 275 – 400 BHN should be followed.

WELDING

ARMCO 17-7 PH Stainless Steel is readily welded by methods normally used for stainless steels. One of the most desirable welding characteristics is the elimination of preheating and post-annealing practices necessary for standard hardenable stainless steels.

Corrosion Resistance

In general, the corrosion resistance of ARMCO 17-7 PH Stainless Steel in Conditions TH 1050 and RH 950 is superior to that of the standard hardenable chromium types of stainless steels such as Types 410, 420, and 431, but not quite as good as the chromium-nickel Type 304. The corrosion resistance of ARMCO 17-7 PH Stainless Steel in Condition CH 900 approaches that of Type 304 in most environments.

ATMOSPHERIC EXPOSURE

Samples exposed to a marine atmosphere show considerably better corrosion resistance than hardened chromium stainless steels such as Type 410 Although there is little difference between any successive two ratings in the following table, samples indicate the following order of corrosion resistance based on general appearance:

1) Type 301 stainless steel
2) ARMCO 17-7 PH Stainless Steel, Condition CH 900
3) ARMCO 17-7 PH Stainless Steel, Condition TH 1050
4) ARMCO 17-7 PH Stainless Steel, Condition RH 950

In all heat-treated conditions, ARMCO 17-7 PH Stainless Steel, like other types of stainless steels, will develop superficial rust in some environments. For example, in a marine atmosphere, stainless steels show evidence of rusting after relatively short periods of exposure. However, after exposure of one or two years, the amount of rust present is little more than that which was present at six months.

CORROSION RESISTANCE AND COMPATIBILITY IN ROCKET FUELS

Oxygen – While oxygen is highly reactive chemically, liquid oxygen is noncorrosive to most metals. The precipitation hardening stainless steels have no problem in this media.

Ammonia – ARMCO 17-7 PH Stainless Steel is satisfactory for handling ammonia.

Hydrogen – Liquid hydrogen and gaseous hydrogen at low temperatures are noncorrosive.

HYDROGEN SULFIDE ENVIRONMENTS

Like all martensitic stainless steels, ARMCO 17-7 PH Stainless Steel may be subject to cracking when exposed under stress in environments containing hydrogen sulfide.

Springs made from ARMCO 17-7 PH Stainless Steel in Condition CH 900 have cracked readily in laboratory testing in synthetic sour well solution (5% NaCl + 0.5% acetic acid, saturated with H_2S). In this type of environment, the use of a cold-drawn austenitic stainless steel such as Type 304 or NITRONIC® 50, or A-286 (an age-hardenable alloy), is suggested.

CHEMICAL MEDIA

Hundreds of accelerated laboratory corrosion tests have been conducted on the precipitation hardening stainless steels since their development. Table 13 shows typical corrosion rates for ARMCO 17-7 PH and Type 304 stainless steels in seven common reagents. Sheet coupons and chemically pure laboratory reagents were used. Consequently, the data can be used only as a guide to comparative performance.

Corrosion Properties

TABLE 13 – CORROSION RATES* MILS PER YEAR**

Media	17-7 PH Condition TH 1050	17-7 PH Condition RH 950	Type 304 Annealed
H_2SO_4, 35 °C			
1%	0.013 (0.5)	0.005 (0.2)	0.010 (0.4)
2%	0.023 (0.9)	0.018 (0.7)	0.033 (1.3)
5%	3.150 (124)	3.353 (132)	0.196 (7.7)
H_2SO_4, 80 °C			
1%	1.270 (50)	7.544 (297)	0.564 (22.2)
2%	9.500 (374)	22.45 (884) [2]	1.651 (65)
HCl, 35 °C			
0.5%	1.651 (65)	0.102 (4)	0.180 (7.1)
1%	17.65 (695) [2]	11.35 (447) [3]	0.439 (17.3)
HNO_3, Boiling			
25%	0.483 (19)	0.518 (20.4)	0.030 (1.2)
50%	1.778 (70)	2.057 (81)	0.076 (3)
65%	3.251 (128)	3.454 (136)	1.829 (72)
Formic Acid, 80 °C			
5%	0.069 (2.7)	0.109 (4.3)	0.104 (4.1)
10%	0.140 (5.5)	0.145 (5.7)	0.457 (18)
Acetic Acid, Boiling			
33%	0.079 (3.1)	0.142 (5.6)	0.066 (2.6)
60%	0.312 (12.3)	0.076 (3)	0.277 (10.9)
H_3PO_4, Boiling			
20%	0.178 (7)	0.457 (18)	0.041 (1.6)
50%	0.610 (24)	1.168 (46)	0.216 (8.5)
70%	2.642 (104)	8.001 (315)	0.991 (39)
NaOH, 80 °C			
30%	0.333(13.1)	0.094 (3.7)	0.023 (0.9)
NaOH, Boiling			
30%	1.702 (67)	1.473 (58)	0.445 (17.5)

**Rates were determined by total immersion for five 48-hour periods. Specimens were activated last three test periods except in the 65% nitric acid. Rate is average of number of periods indicated in parenthesis.*
***1 mil = 0.0254 mm*

STRESS CORROSION CRACKING IN MARINE ENVIRONMENT

The hardenable chromium stainless steels are known to be subject to spontaneous fracture when stressed and exposed to some corrosive environments. Likewise, the precipitation hardening stainless steels may, under some conditions, also fail by stress cracking. The tendency appears to be associated with the type of stainless steel, its hardness, the level of applied tension stress, and the environment.

ARMCO has conducted stress-cracking tests on the precipitation hardening alloys in a marine environment, using two-point loaded bent-beam specimens.

Data reported here are the results of multiple specimens exposed at stress levels of 50 and 75% of the actual yield strength of the materials tested. Test specimens were 1.27 mm (0.050 in.) thick sheet coupons, heat treated to Conditions TH 1050 and RH 950. Specimens in Condition CH 900 were 1.04 mm (0.041 in.) thick. The long dimension of all specimens was cut transverse to the rolling direction.

When comparing the various heat-treated conditions, data show that ARMCO 17-7 PH Stainless Steel has the greatest resistance to stress cracking in Condition CH 900. Condition TH 1050, although somewhat less resistant than Condition CH 900, appears to be more resistant to stress cracking than Condition RH 950.

Corrosion Properties

The following table summarizes the test data. In addition, in the mild industrial atmosphere specimens stressed at 90% of their yield strength had not broken after 730 days of exposure.

TABLE 14 – SUMMARY OF STRESS CRACKING FAILURES IN MARINE ATMOSPHERE – 244 m (800 ft)

Material and Heat Treatment	Stressed at 50% of the 0.2% YS			Stressed at 75% of the 0.2% YS		
	Stress, MPa (ksi)	Days to Failure	Range Days	Stress, MPa (ksi)	Days to Failure	Range Days
17-7 PH						–
TH 1050	694 (100.8)	No Failures in 746 days	–	1043 (151.3)	100 [2]*	82 – 118**
TH 1050	614 (89.0)	No Failures in 746 days	–	921 (133.6)	No Failures in 746 days	–
RH 950	769 (111.6)	30.2	16 – 49	1154 (167.5)	7.4	6 – 10
RH 950	759 (110.2)	116 [1]*	–	1141 (165.4)	51.6	26 – 71
CH 900	986 (142.8)	No Failures in 746 days	–	1476 (214.2)	No Failures in 746 days	–

**Number in brackets indicates number of failed specimens. Remainder of 5 specimens unbroken after 746 days.*
***Range of unbroken specimens only. Remainder of 5 specimens unbroken after 746 days.*

Note: All tests made in transverse direction. Tests discontinued after 746 days exposure.

MAKING INNOVATION HAPPEN

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