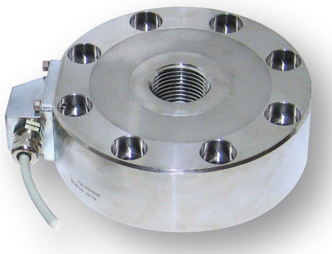
ARMCO® 17-4 PH®

STAINLESS STEEL
PRODUCT DATA BULLETIN

- **Balls for Valves**
- **Bushings and Trim**
- **Load Cells**
- **Pump Shafts**
- **Valve Stems**



The unique high strength/high hardness/excellent corrosion resistance/easy heat treatment combination makes **ARMCO® 17-4 PH® STAINLESS STEEL** the "workhorse" of the precipitation hardening stainless steels. It's widely used in the aerospace, chemical, petrochemical, food processing, paper and general metalworking industries. Applications include pump shafts, valve stems, balls, gates, bushings and trim: mixing screws, fasteners, couplings, rocket hold-downs, wear rings, rollers, hydraulic actuators, load cells and screws.

CLIFFS
AK STEEL INTERNATIONAL

ARMCO® 17-4 PH® STAINLESS STEEL

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ARMCO® 17-4 PH® STAINLESS STEEL

Product Description

ARMCO® 17-4 PH® is a martensitic precipitation hardening stainless steel that is widely accepted in a broad range of industries. A very useful combination of high strength and hardness, excellent corrosion resistance, and easy heat treatment makes this an important alloy to designers and engineers. Fabrication of ARMCO 17-4 PH Stainless Steel follows many practices established for the regular grades of stainless steels. The material provides excellent welding characteristics, can be forged or cast, and machines well. The normal hardening treatments require only 482 – 62.1 °C (900 – 1150 °F) and employ air cooling, thereby virtually eliminating scaling and distortion. Additional features include high resistance to crack propagation, good transverse properties, and proven resistance to stress corrosion cracking in marine environments. Because of the simplicity of fabrication, even low-alloy carbon steels can often be replaced economically with ARMCO 17-4 PH Stainless Steel.

Composition		(wt %)
Carbon	(C)	0.07 max.
Manganese	(Mn)	1.00 max.
Phosphorus	(P)	0.04 max.
Sulfur	(S)	0.03 max.
Silicon	(Si)	1.00 max.
Chromium	(Cr)	15.00 – 17.50
Nickel	(Ni)	3.00 – 5.00
Copper	(Cu)	3.00 – 5.00
Niobium plus Tantalum	(Nb)	0.15 – 0.45

**ASTM A693 requirements call for Niobium plus Tantalum = 0.15 – 0.45. Cleveland-Cliffs AK Steel International makes no intentional Ta addition.*

AVAILABLE FORMS

ARMCO 17-4 PH Stainless Steel is supplied as forging billets, plate, sheet strip, rod, bar, and wire. As shipped from the mill, it is usually in the solution annealed condition (Condition A), ready for fabrication and subsequent hardening by the user. However, it is also supplied hardened or in overaged conditions for cold heading or forging if desired and specified by the customer. Although ARMCO 17-4 PH Stainless Steel is generally air melted, consumable electrode electro-slag remelting (ESR) and consumable electrode vacuum arc remelting (VAC CE) are available as optional refinements. The VAC CE process in particular lowers gas content, reduces and disperses inclusions, and minimizes alloy segregation during solidification. This results in improved mechanical properties and cleanliness. (When superior transverse mechanical properties are important, ARMCO 15-5 PH VAC CE Stainless Steel should be considered). Air-melted ARMCO 17-4 PH Stainless Steel will meet the magnetic Particle Inspection requirements of Aerospace Materials Specification AMS 2303. Consumable electrode vacuum arc remelted ARMCO 17-4 PH VAC CE meets the magnetic Particle Inspection requirements of Aerospace Materials Specification AMS 2300.

CONDITIONS AVAILABLE FROM THE MILL

1) Condition A (Solution Annealed, also referred to as solution heat treated or solution treated) Material for fabrication and precipitation heat treatment by the user. If severe cold forming is required Condition H1150, H1150-D or H1150-M is to be used instead of Condition A.
2) Precipitation hardened conditions:
   a. Condition H1075. Machines as well as Condition A.
   b. Condition H1150. More readily fabricated than Condition A. No further heat treatment necessary where no severe cold working is involved.
3) NACE MR0175/ISO 15156 and NACE MR0103 sour service compliant conditions:
   a. Condition H1150-D (also referred to as H1150+1150) double precipitation hardened
   b. Condition H1150-M double precipitation hardened with softened martensite matrix to provide the best cutting rate and the highest impact strength achievable.
4) Overaged Conditions:
   a. Overaged for Forging, allowing cold sawing of large sections without cracking
   b. Overaged, Copper Coated and Cold Drawn for Cold Heading. Maximum softness for cold heading. Materials in this condition will not respond to aging treatments without first solution treating.
5) Other Conditions such as H900, H925, H1025, H1100: Inquire for availability.

Specifications

STANDARD HEAT TREATMENTS

In the solution annealed condition, Condition A, ARMCO® 17-4 PH® Stainless Steel can be heat treated at different temperatures to develop a wide range of properties. Eight standard heat treatments have been developed. Table 1 outlines the times and temperatures required.

ARMCO 17-4 PH Stainless Steel exhibits useful mechanical properties in Condition A, and tests show excellent stress corrosion resistance. Condition A material has been used successfully in numerous applications. The hardness and tensile properties fall within the range of those for Conditions H1100 and H1150.

However, in critical applications, the alloy is used in the precipitation-hardened condition rather than Condition A. Heat treating to the hardened condition, especially at the higher end of the temperature range, stress relieves the structure and may provide more reliable resistance to stress corrosion cracking than in Condition A.

TABLE 1 – HEAT TREATMENTS FOR 17-4 PH

Condition A Solution Treated at 1038 ± 14 °C (1900 ± 25 °F)
0.5 hr Oil, Water+Polymer or Air Cool to below 32 °C (90 °F)

Condition	Hardening Temp, ± 9 °C (± 15 °F)	Hardening Time (hours)	Type of Cooling
H900	482 °C (900 °F)	1	Air
H925	496 °C (925 °F)	4	Air
H1025	552 °C (1025 °F)	4	Air
H1075	579 °C (1075 °F)	4	Air
H1100	593 °C (1100 °F)	4	Air
H1150	621 °C (1150 °F)	4	Air
H1150-D	621 °C (1150 °F) 621 °C (1150 °F)	4 Followed by 4	Air Air
H1150-M	760 °C (1400 °F) 621 °C (1150 °F)	2 Followed by 4	Air Air

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.

SPECIFICATIONS

ARMCO 17-4 PH Stainless Steel in bar, wire, forgings, and forging stock is covered by one of the following Government or Society specifications, listed as 17-4 PH, Grade/type 630, UNS S17400, X5CrNiCuNb16-4, X5CrNiCuNb17-4-4, 1.4542 and/or 1.4548:

AMS 5622 – Bar, wire, billets, ESR/VAC CE
AMS 5643 – Bar, wire, billets
AMS 5825 – Welding wire
AMS 5827 – Welding electrodes
AWS A5.4 – Classification E630, Covered welding electrodes
AWS A5.9 – Classification ER630, bar and welding rods
AMSQQS763 – Class 324, bars and wire
MIL-DTL-24527C – Stainless forging stock
ASTM A564 – Type 630, Standard Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes
ASTM A705 – Grade 630, Standard Specification for Age-Hardening Stainless Steel Forgings

The grade can also be ordered conform the following standards and/or specifications:

ASTM F899 – Standard Specification for Wrought Stainless Steels for Surgical Instruments

NF S94-090 – Medico-surgical Equipment – Materials For Ancillary Positioning Instruments For Bone Surgery – Martensitic, Precipitation Hardening, Austenitic And Austeno-ferritic Stainless Steels

EN 10088-3 – Stainless steels – Part 3: Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes

ARMCO 17-4 PH Stainless Steel in H1150-D and H1150-M condition can be ordered in compliance with NACE MR0175 / ISO 15156 and NACE MR0103.

Mechanical Properties

TABLE 2 – TYPICAL MECHANICAL PROPERTIES (LONGITUDINAL DIRECTION) – BAR

Property	Condition							
	H900**	H925	H1025	H1075	H1100	H1150	H1150-D	H1150M
UTS, MPa (ksi)	1379 (200)	1310 (190)	1172 (170)	1138 (165)	1034 (150)	1000 (145)	965 (140)	862 (125)
0.2% YS, MPa (ksi)	1276 (185)*	1207 (175)	1138 (165)	1034 (150)	931 (135)	862 (125)	758 (110)	586 (85)
Elongation % in $4D_0$	14.0	14.0	15.0	16.0	17.0	19.0	20	22.0
Reduction of Area %	50.0	54.0	56.0	58.0	58.0	60.0	60.0	68.0
Brinell Hardness	420	409	352	341	332	311	302	277
Rockwell Hardness	C44	C42	C38	C36	C35	C33	C31	C27
Impact, Charpy *V-Notch, J (ft•lbs)	20 (15)	34 (25)	47 (35)	54 (40)	61 (45)	68 (50)	108 (80)	135 (100)

**0.2% Compressive YS – 1227 MPa (178 ksi)*
***In applications requiring greater impact toughness, aging for four hours will develop typical properties: UTS – 1351 MPa (196 ksi). 0.2% YS – 1248 MPa (181 ksi). Elong in 50 mm (2") – 14%. Reduction of Area – 52%. Rockwell Hardness C43. Impact Charpy – 27 J (20 ft•lbs)*

PROPERTIES ACCEPTABLE FOR MATERIAL SPECIFICATIONS

TABLE 3 – MINIMUM PROPERTIES FOR STANDARD CONDITIONS* – BAR

Property	Condition									
	H900		H925		H1025	H1075	H1100	H1150	H1150-D	H1150M
	Up to 75 mm (3 in.) Incl	Over 75 mm (3 in.) to 200 mm (8 in.)	Up to 75 mm (3 in.) Incl	Over 75 mm (3 in.) to 200 mm (8 in.)	Up to 200 mm (8 in.)	Up to 200 mm (8 in.)	Up to 200 mm (8 in.)	Up to 200 mm (8 in.)	Up to 200 mm (8 in.)	Up to 200 mm (8 in.)
UTS, MPa (ksi)	1310 (190)	1310 (190)	1170 (170)	1170 (170)	1070 (155)	1000 (145)	965 (140)	930 (135)	860 (125)	795 (115)
0.2% YS, MPa (ksi)	1170 (170)	1170 (170)	1070 (155)	1070 (155)	1000 (145)	860 (125)	795 (115)	725 (105)	725 (105)	520 (75)
Elongation % in $4D_0$	10.0	10.0	10.0	10.0	12.0	13.0	14.0	16.0	16.0	18.0
Reduction of Area %	40	35	44	38	45	45	45	50	50	55
Brinell Hardness	388	388	375	375	331	311	302	277	255	255
Rockwell Hardness	C40	C40	C38	C38	C35	C32	C31	C28	C24	C24
Impact, Charpy *V-Notch, J (ft•lbs)	**	**	7 (5)	7 (5)	20 (15)	27 (20)	34 (25)	41 (30)	41 (30)	75 (55)

**These values are based on samples taken from mid-radius (1.5 in cross section and over).*
***Minimum impact properties cannot be accepted in this condition.*

Mechanical Properties

TABLE 4 – MAXIMUM HARDNESS OR TENSILE STRENGTH IN CONDITION A

Round, Hexagons and Squares				Flats	
t ≤ 3 mm (0.125 in.)	3 < t ≤ 12 mm (0.5 in.)	12 < t ≤ 75 mm (3 in.)	> 75 mm (3 in.)	t ≤ 75 mm (3 in.)	t > 75 mm (3 in.)
1207 MPa (175 ksi) max.	RC 38 max.	BHN 363 max.	BHN 363 max.	BHN 363 max.	BHN 363 max.

SHEAR STRENGTH

TABLE 5 – SHEAR STRENGTH IN TORSION

Property	Condition			
	H900	H1025	H1075	H1150
Unit Shear Strength, MPa (ksi) at Elastic Limit-Torsion	676 (98.0)	566 (86.2)	466 (67.5)	294 (42.5)
Ultimate Shear Strength, MPa in Torsion (ksi)	1179 (171.0)	972 (141.0)	931 (135.0)	855 (124.0)

TABLE 6 – SHEAR STRENGTH IN DOUBLE SHEAR

Condition*	UTS, MPa (ksi)	Double Shear MPa (ksi)		Shear/Tensile Ratio %	
		NAS-498 (a)	Boeing (b)	NAS-498	Boeing
H900	1417 (205.6)	843 (122.4)	879 (127.4)	59.5	61.9
H925	1304 (189.1)	789 (114.5)	821 (119.1)	60.6	63.0
H1025	1136 (164.7)	716 (103.8)	721 (104.6)	63.0	63.5
H1100	1084 (157.4)	676 (98.0)	690 (100.2)	62.3	63.6
H1150-M	930 (134.9)	610 (88.5)	622 (90.1)	65.6	66.8
Condition A	1159 (168.1)	680 (98.7)	692 (100.5)	58.7	59.8

(a) National Aircraft Standard No. 498 – Specification for Bolts in Shear
(b) Boeing Aircraft Co. D2 – 2860. Procedures for Mechanical Testing of Aircraft Structural Fasteners. Section 4. Pages A13 – A18; Figures 13 – 15. Pages AD114 – AD116
**Test specimens came from a single heat considered typical. Duplicate tests were made for each condition.*

Shear strength in Double Shear of ARMCO 17-4 PH is approximately 68% of the ultimate tensile strength. Shear tests, conducted in accordance with the national Aircraft Standard No. 498, shown in Table 6 average values.

Mechanical Properties

MODULUS OF ELASTICITY

The modulus of elasticity of ARMCO® 17-4 PH® Stainless Steel at elevated temperature can be conveniently expressed as a % of room temperature modulus as shown in Table 8.

TABLE 7 – MODULUS OF ELASTICITY

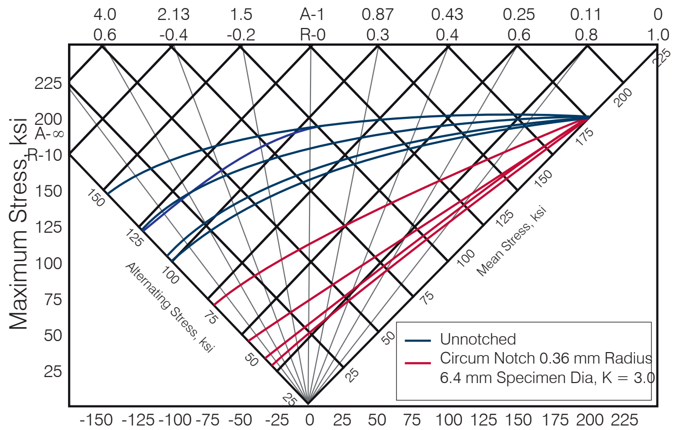
Condition	Tension, Gpa (Mpsi)	Torsion, Gpa (Mpsi)
H900	200 (29)	77 (11)
H1025	201 (29)	76 (11)
H1075	–	69 (10)
H1150	201 (29)	69 (10)

TABLE 8 – EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY

Poisson's Ratio 0.291
(All Hardened Conditions)

Temperature, °C (°F)	% of Room Temperature Modulus
22 (72)	100.0
38 (100)	99.6
93 (200)	97.8
149 (300)	96.3
204 (400)	94.7
260 (500)	93.0
316 (600)	91.4

FIGURE 1 – TYPICAL CONSTANT-LIFE FATIGUE DIAGRAM* CONDITION H900



Minimum Stress, ksi
Data Reference: Mil - Hdbk.5 (Fig 2.7.4.2.8)

17-4 PH (H 900) Bar
25.4 and 38 mm diameter
UTS = 201.5 ksi
TYS = 194.5 ksi
Axial Load
1800 cpm
Room Temperature
Longitudinal
Polished

TABLE 9 – FATIGUE STRENGTH*

Property	Room Temperature				316 °C (600 °F)	
	H 900	H 925	H 1025	H 1150	H 900	H 1025
Fatigue Strength, MPa (ksi)						
10 million cycles	621 (90)	607 (88)	572 (83)	621 (90)	531 (77)	517 (75)
100 million cycles	503 (73)	510 (74)	538 (78)	621 (90)	427 (62)	448 (65)

**R. R. Moore Rotating Beam Fatigue using samples prepared from 18 – 25 mm (0.75 – 1 in.) diameter bar.*

Mechanical Properties

ELEVATED TEMPERATURE PROPERTIES

TABLE 10 – SHORT-TIME TENSILE PROPERTIES

Property and Condition	Temperature °C (°F)					
	24 (75)	316 (600)	371 (700)	427 (800)	482 (900)	538 (1000)
UTS, MPa (ksi)						
Condition H900	1400 (203)	1193 (173)	1165 (169)	1117 (162)	1027 (149)	820 (119)
Condition H925	1317 (191)	1138 (165)	1110 (161)	1069 (155)	1000 (145)	800 (116)
Condition H1025	1200 (174)	1007 (146)	979 (142)	945 (137)	869 (126)	731 (106)
Condition H1075	1131 (164)	951 (138)	924 (134)	883 (128)	786 (114)	683 (99)
Condition H1150	965 (140)	855 (124)	827 (120)	800 (116)	752 (109)	662 (96)
0.2% YS, MPa (ksi)						
Condition H900	1282 (186)	1034 (150)	1007 (146)	972 (141)	910 (132)	731 (106)
Condition H925	1255 (182)	1000 (145)	979 (142)	958 (139)	883 (128)	710 (103)
Condition H1025	1158 (168)	931 (135)	903 (131)	883 (128)	814 (118)	696 (101)
Condition H1075	1096 (159)	910 (132)	876 (127)	834 (121)	758 (110)	648 (94)
Condition H1150	889 (129)	827 (120)	786 (114)	772 (112)	717 (104)	641 (93)
Elongation % in $4D_0$						
Condition H900	11.0	10.0	8.0	10.0	10.0	15.0
Condition H925	14.0	12.0	12.0	10.0	10.0	16.0
Condition H1025	15.0	12.0	10.0	11.0	12.0	15.0
Condition H1075	16.0	9.0	9.0	10.0	11.0	16.0
Condition H1150	17.0	12.0	12.0	13.0	13.0	15.0
Reduction of Area, %						
Condition H900	50.0	31.0	25.0	21.0	30.0	46.0
Condition H925	54.0	32.0	33.0	34.0	35.0	45.0
Condition H1025	55.0	42.0	38.0	39.0	39.0	43.0
Condition H1075	54.0	38.0	33.0	30.0	38.0	55.0
Condition H1150	61.0	54.0	52.0	43.0	51.0	55.0

Mechanical Properties

EFFECT OF TEMPERATURE ON IMPACT TOUGHNESS

In all heat-treated conditions, long-time exposure at temperatures of 371 – 482 °C (700 – 900 °F) causes a sharp decrease in room temperature impact strength. Izod impact values were determined on specimens heat treated to Conditions H900, H1000 and H1100 and exposed for 1000 and 2000-hour intervals at 371, 427 and 482 °C (700, 800 and 900 °F).The results are shown in Table 11.

TABLE 11 – IZOD IMPACT VALUES, J (ft·lbs)

Condition	Room Temperature Aged	371 °C (700 °F)		427 °C (800 °F)		482 °C (900 °F)	
	No Exposure	1000 hrs	2000 hrs	1000 hrs	2000 hrs	1000 hrs	2000 hrs
H900	18.8 (14)	9.4 (7)	5.4 (4)	2.7 (2)	2.7 (2)	4.0 (3)	8.1 (6)
H1000	61.1 (45)	9.4 (7)	4.0 (3)	2.7 (2)	2.7 (2)	5.4 (4)	10.8 (8)
H1100	75.2 (56)	9.4 (7)	5.4 (4)	4.0 (3)	2.7 (2)	8.1 (6)	14.8 (11)

TABLE 12 – CREEP STRENGTH CONDITION H 900

Property and Creep Rate	Temperature °C (°F)			
	316 (600)	371 (700)	427 (800)	482 (900)
Creep Strength MPa (ksi)				
0.1% in 1000 hrs	931 (135)	724 (105)	414 (60)	159 (23)
0.01% in 1000 hrs	862 (125)	689 (100)	310 (45)	–

Mechanical Properties

TABLE 13 – STRESS-RUPTURE STRENGTH

Temperature, °C (°F)	Time to Rupture Hours	Condition	Property		
			Strength, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area %
329 (625)	100	H900	–	–	–
		H925	1124 (163)	3.0	13.0
		H1075	945 (137)	3.5	14.5
		H1150	848 (123)	5.5	17.5
	1000	H900	–	–	–
		H925	1103 (160)	2.5	12.0
		H1075	924 (134)	3.0	14.0
		H1150	841 (122)	4.5	16.5
371 (700)	100	H900	1076 (156)	3.0	7.0
		H925	1062 (154)	3.0	13.5
		H1075	869 (126)	4.0	15.5
		H1150	786 (114)	6.5	19.0
	1000	H900	1034 (150)	2.0	6.0
		H925	1041 (151)	2.5	12.5
		H1075	848 (123)	3.5	15.0
		H1150	765 (111)	5.5	18.0
427 (800)	100	H900	965 (140)	4.0	8.0
		H925	883 (128)	3.5	13.5
		H1075	745 (108)	6.0	16.0
		H1150	689 (100)	6.5	25.0
	1000	H900	883 (128)	4.0	6.0
		H925	834 (121)	3.0	13.0
		H1075	710 (103)	5.5	15.0
		H1150	648 (94)	6.0	20.0
482 (900)	100	H900	655 (95)	5.0	9.0
		H925	–	–	–
		H1075	–	–	–
		H1150	552 (80)	9.0	40.0
	1000	H900	414 (60)	12.0	25.0
		H925	–	–	–
		H1075	–	–	–
		H1150	490 (71)	9.0	36.0

Mechanical Properties

SUB-ZERO MECHANICAL PROPERTIES

ARMCO® 17-4 PH® Stainless Steel maintains good ductility at sub-zero temperatures, making it particularly valuable for such applications as valves, pumps and aircraft parts. No general statement can be made regarding preferred heat treatments for sub-zero applications because much depends upon design requirements.

However, many engineers have approved ARMCO 17-4 PH Stainless Steel to the following low-temperature limits:

H900	If toughness is a design criteria, this heat treatment should be used with caution, regardless of temperature.
H925	Down to -18 °C (0 °F) for general use. For non-impact applications, useful at temperatures as low as -196 °C (-320 °F).
H1150	Down to -79 °C (-110 °F). Design with caution when bar diameters exceed 25 mm (1 in.) round.
H1150-M	Down to -196 °C (-320 °F).

TABLE 14 – TYPICAL MECHANICAL PROPERTIES CONDITION H900

Property	Temperature °C (°F)				
	24 (75)	0 (32)	-40 (-40)	-62 (-80)	-196 (-320)
UTS, MPa (ksi)	1365 (198)	1400 (203)	1441 (209)	1503 (218)	1813 (263)
0.2% YS, MPa (ksi)	1220 (177)	1241 (180	1282 (186)	1338 (194)	1675 (243)
Elongation % in $4D_0$	10	16	17	17	7
Reduction of Area %	52	53	53	52	10
Charpy V-notch, J (ft•lbs)	26 (19)	24 – 27 (18 – 20)	9 – 12 (7 – 9)	11 (8)	4 – 6 (3 – 4.5)

TABLE 15 – TYPICAL IMPACT STRENGTH
Below Room Temperature Charpy V-notch Impact, J (ft·lbs)

Condition	Temperature °C (°F)			
	-12 (+ 10)	-40 (-40)	-79 (-110)	-196 (-320)
H925*	22 (16)	12 (9)	7.4 (5.5)	4.7 (3.5)
H1025*	78 (58)	54 (40)	20 (15.0)	6.1 (4.5)
H1150*	126 (93)	102 (76)	54 (48.0)	8.8 (6.5)
H1150-M*	–	–	–	38 (28.0)
H1150-M**	115 (85)	101 (75)	88 (65)	6.8 (5)

**Test samples from 25 mm (1 in.) Round Bar – Longitudinal Direction.*
***Test samples from 100 mm (4 in.) Round Bar – Longitudinal Direction.*

Mechanical Properties

TABLE 16 – COMPARISON OF LONGITUDINAL AND TRANSVERSE MECHANICAL PROPERTIES OF 17-4 PH CONDITION H900

Size of Stock, Diameter	Direction of Test	Heat Treatment	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in $4D_0$	Reduction of Area %
140 mm (5.5 in.)	L	1038 °C (1900 °F) H900	1400 (203)	1248 (181)	11.5	44.5
	T	1038 °C (1900 °F) H900	1386 (201)	1241 (180)	5.0	17.0

TRANSVERSE PROPERTIES

In common with other high-strength steels, the ductility of fully hardened ARMCO® 17-4 PH® Stainless Steel (i.e. H900 or H925) may be appreciably lower in the transverse direction as compared to the ductility in the longitudinal direction, parallel to the grain flow. When parts are highly stressed in the transverse direction, consideration should be given to using ARMCO®15-5 PH® VAC CE Stainless Steel or ARMCO® PH 13-8 Mo® Stainless Steel. Table 16 compares longitudinal and transverse properties of an ARMCO 17-4 PH Stainless Steel bar in Condition H900. If hardened to more ductile conditions (Condition H1025, H1075, or H1150), transverse ductility will approach longitudinal ductility and will be adequate for most applications.

Physical Properties

TABLE 17 – PHYSICAL PROPERTIES

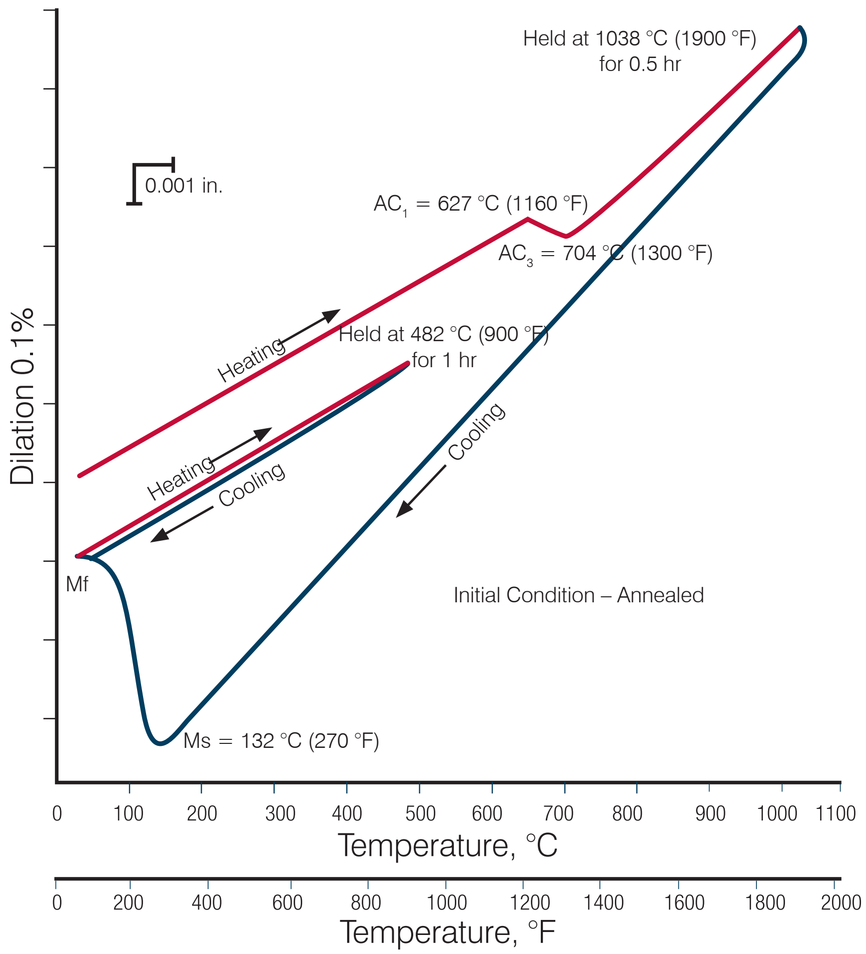
	Condition			
	A (Magnetic)	H900 (Magnetic)	H1075 (Magnetic)	H1150 (Magnetic)
Density				
g/cm^3	7.78	7.80	7.81	7.82
lbs/in^3	0.280	0.282	0.283	0.284
Electrical Resistivity µΩ•cm	100	80	80	–
Mean Coefficient of Thermal Expansion x 10^{-6} mm/mm/°C (in./in./°F)				
-73 – 21 °C (-100 – 70 °F)	–	10.4 (5.8)	–	11.0 (6.1)
21 – 93 °C (70 – 200 °F)	10.8 (6.0)	10.8 (6.0)	11.3 (6.3)	11.9 (6.6)
21 – 204 °C (70 – 400 °F)	10.8 (6.0)	10.8 (6.0)	11.7 (6.5)	12.4 (6.9)
21 – 316 °C (70 – 600 °F)	11.2 (6.2)	11.3 (6.3)	11.9 (6.6)	12.8 (7.1)
21 – 427 °C (70 – 800 °F)	11.3 (6.3)	11.7 (6.5)	12.2 (6.8)	12.9 (7.2)
21 – 482 °C (70 – 900 °F)	–	–	–	13.1 (7.3)
Thermal Conductivity W/m/K (BTU/hr/ft^2/in./°F)				
149 °C (300 °F)	–	17.9 (124)	–	–
260 °C (500 °F)	–	19.5 (135)	–	–
460 °C (860 °F)	–	22.5 (156)	–	–
482 °C (900 °F)	–	22.6 (157)	–	–
Specific Heat J/kg/K (BTU/lb/°F)				
0/100 °C (32/212 °F)	460 (0.11)	460 (0.11)	–	–

Physical Properties

TABLE 18 – DIMENSIONAL CHANGE

Condition	Contraction coming from Condition A mm/mm (= in./in.)
H900	0.00045
H925	0.00051
H1025	0.00053
H1100	0.0009
H1150	0.0022
H1150-M	To 760°C (1400°F) 0.00037 To 621°C (1150°F) 0.00206 Full precipitation heat treatment: 0.00243

FIGURE 2 – DILATOMETER CURVE OF ARMCO® 17-4 PH® STAINLESS STEEL



ARMCO® 17-4 PH® STAINLESS STEEL

Magnetic Properties

MAGNETIC PROPERTIES

Normal induction and hysteresis curves are shown. There is little difference in the magnetic properties of material in Conditions H900 through H1075. However, Condition H1150 produces significant change.

FIGURE 3 – NORMAL INDUCTION OF ARMCO® 17-4 PH®

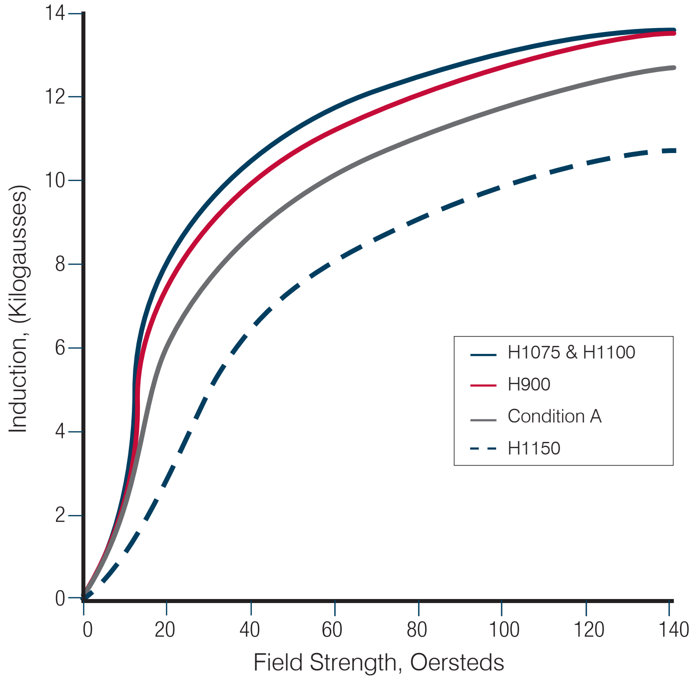
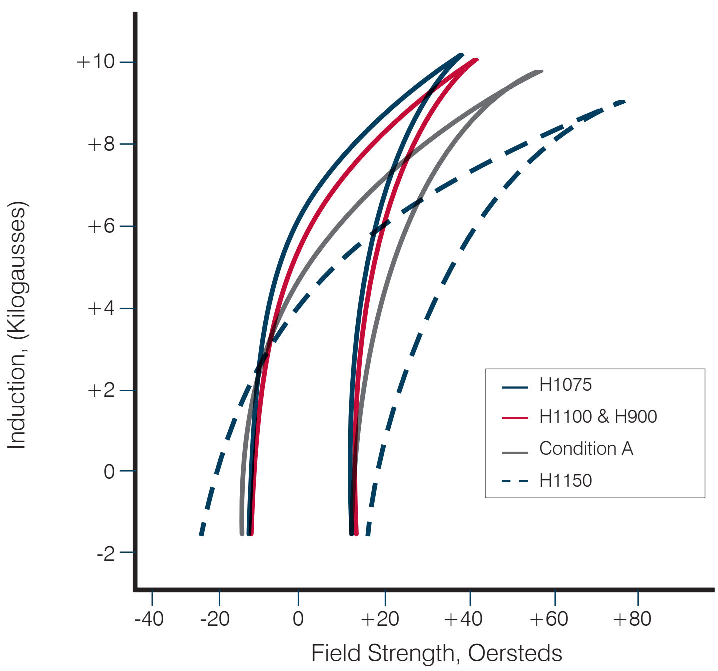


FIGURE 4 – HYSTERESIS CURVE OF ARMCO® 17-4 PH®



Corrosion Resistance

ARMCO® 17-4 PH® Stainless Steel has excellent corrosion resistance. It withstands corrosive attack better than any of the standard hardenable stainless steels and is comparable to Type 304 in most media.

This has been confirmed by actual service in a wide variety of corrosive conditions in the petrochemical, petroleum, paper, dairy and food processing industries and in applications such as boat shafting. Additional proof of its durability is the replacement of chromium-nickel stainless steels and high-alloy non-ferrous metal by ARMCO 17-4 PH Stainless Steel for a broad range of parts requiring excellent resistance to corrosion.

LABORATORY TEST

Hundreds of laboratory corrosion tests have been conducted on ARMCO 17-4 PH Stainless Steel to provide data for comparison with other stainless steels. As chemically pure reagents were used, the data are useful as a guide to the comparative ranking of ARMCO 17-4 PH with the other materials, but are not a measure of their performance under actual operating conditions. Typical corrosion rates for ARMCO 17-4 Ph Stainless Steel in a variety of media are listed in the following table along comparable data for Type 304.

In general, the corrosion resistance of ARMCO 17-4 PH Stainless Steel is similar to Type 304 in the media tested, depending on heat treated conditions. For specific applications, see the details of Table 19 or conduct pilot corrosive tests.

Corrosion Resistance

TABLE 19 – CORROSION RATES OF 17-4 PH® BAR IN VARIOUS CHEMICAL MEDIA

Chemical Medium	Conc. %	Temp. °C	Corrosion Rate, mm/Y (in./Y) (a)				Type 304 (b) Annealed
			17-4 PH (b)				
			H925	H1025	H1075	H1150	
H_2SO_4	1	35	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)	0.71 (0.028)
	2	–	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)	1.45 (0.057)
	5	–	0.10 (0.004)	0.18 (0.007)	0.28 (0.011)	0.23 (0.009)	6.10 (0.24)
	1	80	0.03 (0.001)	0.03 (0.001)	0.03 (0.001)	0.03 (0.001)	6.10 (0.35)
	2	–	0.20 (0.008)	0.23 (0.009)	0.33 (0.013)	0.43 (0.017)	12.19 (0.48)
	98	35	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)	–
	98	80	0.13 (0.005)	0.13 (0.005)	0.18 (0.007)	0.15 (0.006)	–
HCL	0.5	35	0.05 (0.002)	0.05 (0.002)	0.08 (0.003)	0.41 (0.016)	0.84 (0.033)
	1	–	0.81 (0.035)	4.42 (0.174)	13.16 (0.518)	16.51 (0.65)	6.10 (0.24)
$HN0_3$	25	Boil	0.36 (0.014)	0.15 (0.006)	0.18 (0.007)	0.20 (0.008)	0.05 (0.002)
	50	–	1.78 (0.07)	0.89 (0.035)	1.19 (0.047)	0.79 (0.031)	0.10 (0.004)
	65	–	3.18 (0.125)	2.16 (0.085)	2.72 (0.107)	2.01 (0.079)	0.25 (0.01)
Formic Acid	5	80	0.08 (0.003)	0.03 (0.001)	0.03 (0.001)	0.05 (0.002)	2.06 (0.081)
	10	–	0.05 (0.002)	0.08 (0.003)	0.08 (0.003)	0.13 (0.005)	2.54 (c) (0.1 (c))
	33	Boil	0.15 (0.006)	0.15 (0.006)	0.10 (0.004)	0.10 (0.004)	7.62 (0.3)
	60	–	0.05 (0.002)	0.05 (0.002)	0.05 (0.002)	0.05 (0.002)	6.35 (0.25)
H_3PO_4	2.5	Boil	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)
	20	–	0.03 (0.001)	0.03 (0.001)	0.03 (0.001)	0.05 (0.002)	0.05 (0.002)
	50	–	0.10 (0.004)	0.10 (0.004)	0.08 (0.003)	0.13 (0.005)	0.1778 (c) (0.007 (c))
	70	–	2.18 (0.086)	1.45 (0.057)	1.52 (0.06)	3.02 (0.119)	0.81 (0.032)
NaOH	30	80	0.13 (0.005)	0.13 (0.005)	0.18 (0.007)	0.20 (0.008)	Nil (Nil)
	50	–	0.08 (0.003)	0.08 (0.003)	0.10 (0.004)	0.13 (0.005)	0.03 (0.001)
	30	Boil	0.20 (0.008)	0.18 (0.007)	0.28 (0.011)	0.28 (0.011)	1.73 (0.068)
	50	–	12.19 (0.48)	11.43 (0.45)	14.22 (0.56)	14.22 (0.56)	2.03 (0.08)
Ammonium Hydroxide	10	Boil	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)
10% HNO_3 - 1% HF	–	35	38.10 (1.5)	38.10 (1.5)	38.10 (1.5)	38.10 (1.5)	9.65 (0.38)
10% HNO_3 - 3% HF	–	–	109.22 (4.3)	109.22 (4.3)	109.22 (4.3)	109.22 (4.3)	21.34 (0.84)
Cola-Soft Drink Syrup	Pure %	35	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)
Salt-Sugar-Vinegar	–	Boil	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)	Nil (Nil)

(a) Rates were determined by total immersion of 16 mm (0.625 in.) diameter x 16 mm (0.625 in.) long cylindrical test specimens for five 48-hour periods. Specimens were electrolytically activated for the last three periods except for the boiling 65 percent nitric acid test and also for Type 304 bar in boiling sodium hydroxide. For Type 304 bar, passive periods were not averaged. In most cases, where rates of replicates varied, the highest is given. Other exceptions to all of forging are marked.

(b) Numbers in parentheses indicate the number of periods in testing. Nil-indicates rates of less than 1 mil/year.

(c) Rates increase from period to period. Rate is average of 5 periods.

Data Reference: J. J. Halbig & O.B. Ellis, "Observations on Corrosion Resistance of High Strength Stainless Steels for Aircraft", Corrosion. Vol. 14, pp. 389t-395t (1958).

Corrosion Resistance

ATMOSPHERIC EXPOSURE

In rural and mild industrial atmospheres, ARMCO® 17-4 PH® Stainless Steel has excellent resistance to general corrosion in all heat-treated conditions. It is equivalent to Type 304 stainless steel in these environments. ARMCO 17-4 PH Stainless Steel exposed to seacoast atmosphere will gradually develop overall light rusting and pitting in all heat-treated conditions. It is almost equal to Type 304 and much better than the standard hardenable stainless steels in this environment.

SEAWATER EXPOSURE

The combination of high mechanical strength and good corrosion resistance makes ARMCO 17-4 PH Stainless Steel well suited for many marine applications such as valve parts and pump and propeller shafting. However, in common with other stainless steels, ARMCO 17-4 PH is subject to crevice attack if exposed to stagnant seawater/for any length of time. If equipment exposed to seawater is not operated continuously, cathodic protection is highly desirable to prevent such attack.

STRESS CORROSION CRACKING

Stress corrosion cracking, although occurring infrequently, can be a source of failure in stainless steels. It usually takes place in highly stressed parts that are exposed under conditions that permit local concentration of chlorides.

Tests using smooth bent beam specimens stressed up to the 0.2% yield strength of the material and exposed to marine environments on a 24.4 m (80 ft) lot, 25 m (82 ft) from the waterline, show that ARMCO 17-4 PH Stainless Steel is quite susceptible to stress corrosion cracking when in Condition H 900. When hardened at temperatures of 552 °C (1025 °F) and higher, the alloy is highly resistant to stress corrosion cracking. In addition, many years of service experience in marine atmospheres and in high-purity water at high temperatures demonstrate the resistance of ARMCO 17-4 PH Stainless Steel to this type of failure.

For maximum resistance to chloride stress corrosion cracking, ARMCO 17-4 PH Stainless Steel should be hardened at the highest aging temperature that will yield required properties, but not less than 552 °C (1025 °F).

Another set of smooth bent beam specimens involving welded ARMCO 17-4 PH in Conditions H900, H1025, H1075, and H1150 were stressed at 90% of the 0.2% yield strength of the material and exposed to marine environments on a 24.4 m (80 ft) lot, 25 m (82 ft) from the waterline. The samples were divided into three groups:

1) Not welded (Solution Annealed + Aged)
2) Solution Annealed + Welded + Aged
3) Welded + Solution Annealed + Aged

All specimens in Condition H 900 failed in 68 days or less, regardless of whether welded or not. None of the other specimens failed after more than 25 years in test.

In addition, welded specimens were made by fusing 50.8 mm (2 in.) diameter circular weld beads onto one face of 6.35 mm (0.25 in.) thick ARMCO 17-4 PH plate. After welding and final heat treatment, the surfaces were ground to a smooth finish. The internal stresses caused by welding are very high and can equal or exceed the yield strength of the material. These specimens were exposed to quiet seawater. The welding and heat treating conditions were as follows:

1) Solution Annealed + Aged to Conditions H1025, H1075, H1150 + Welded.
2) Welded + Solution Annealed + Aged to Conditions H1025, H1075, H1150.
3) Solution Annealed + Welded + Aged to Conditions H1025, H1075, H1100.

Careful examination showed there was no evidence of stress corrosion cracking in any of the test specimens after one year in test.

TABLE 20 – STRESS CORROSION CRACKING*

Condition	Applies Stress, MPa (ksi)	Time to Failure**
A (Heat 2)	855 (124) – 100%YS	3NF
	641 (93) – 75% YS	3NF
H900 (Heat 2)	1289 (187) – 100% YS	2 – 21 days, 1 – 37 days
	965 (140) – 75% YS	1 – 21 days, 1 – 28 days, 1 – 35 days
H925 (Heat 2)	1193 (173) – 100% YS	1 – 61 months, 1 – 139 months, 1NF
	896 (130) – 75% YS	1 – 53 months, 1 – 52 months, 1NF
H975 (Heat 2)	1158 (168) – 100% YS	3NF
	869 (126) – 75% YS	1 – 78 months, 2NF
H1025 (Heat 1)	965 (140) – 90% YS	5NF
	800 (116) – 75% YS	5NF
H1075 (Heat 1)	931 (135) – 90%YS	5NF
	779 (113) – 75% YS	5NF
H1150 (Heat 1)	703 (102) – 90% YS	5NF
	586 (85) – 75% YS	5NF

**Smooth bent beam strip specimens were exposed on a 24.4 m (80 ft) lot, 25 m (82 ft) from the waterline. Five replicates of 2.3 mm (0.090 in.) thick strip from Heat 1 were exposed. Samples of 1.6 mm (0.062 in.) thick strip from Heat 2 were exposed in triplicate in each heat-treated condition.*

***NF indicates No Failure in 15 years of testing.*

Corrosion Resistance

CORROSION FATIGUE

The corrosion fatigue strength of ARMCO® 17-4 PH® bar in Conditions H925 and H1150 has been determined in flowing seawater using cantilever beam specimens rotating at 1450 rpm. Data obtained are shown in Table 19, along with comparable test results obtained from similar tests on Cu-Ni alloy K-500.

TABLE 21 – CORROSION FATIGUE

Alloy	Condition	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Corrosion Fatigue Limit at 5 x 10^7 Cycles MPa (ksi)
17-4 PH	Solution Annealed + Condition H925	1379 (200)	1155 (182)	207 – 276 (30 – 40)
	Solution Annealed + Condition H1150	1089 (158)	1034 (150)	207 – 276 (30 – 40)
K-500	Solution Annealed + Aged	1055 (153)	738 (107)	172 – 207 (25 – 30)
	Hot Rolled + Aged	1172 (170)	862 (125)	172 – 207 (25 – 30)
	Cold Drawn + Aged	1213 (176)	1007 (146)	172 – 207 (25 – 30)

SULFIDE STRESS CRACKING

Laboratory tests run in synthetic sour well solution (5% sodium chloride + 0.5 % acetic acid saturated with hydrogen sulfide), following NACE test method TM-01-77, show that ARMCO 17-4 PH Stainless Steel should be aged to Conditions H1150-D or H1150-M for best resistance to stress cracking in this highly aggressive environment. In either of these heat-treated conditions, 17-4 PH Stainless is considered by NACE as acceptable for use in sour (sulfide) service and is included in NACE MR0175/ISO 15156 and NACE MR0103.

Fabrication

HEAT TREATMENT

For maximum hardness and strength, material from the solution-annealed condition is heated for one hour at 482 ± 9 °C (900 ± 15 °F) and air cooled to room temperature. Material conforming to AMS 5643 has to be heat treated with tighter restrictions: 482 ± 6 °C (900 ± 10 °F) and 1 hour ± 5 minutes.

Where ductility in the hardened condition is of importance, better toughness can be obtained by raising the hardening temperature. Unlike regular hardenable materials that require hardening plus tempering or stress relieving treatment, ARMCO® 17-4 PH® Stainless Steel can be hardened to the final desired properties in a single operation. By varying the heat treating temperature between 482 – 621 °C (900 – 1150 °F) for one to four hours, a wide range of properties can be attained. (See Table 1).

Material that is in the as-hot worked, as-forged, or as-cast condition must be solution annealed prior to hardening. This solution heat treatment will refine the grain structure and make the hardened material more uniform. Solution heat treating is done at 1024 – 1052 °C (1875 – 1925 °F) followed by cooling to at least 32 °C (90 °F). The time has to be long enough to allow the core of the material to be at temperature for at least 30 minutes. Oil or water+polymer quenching, rather than air cooling, may be used on small, simple sections. Uniform cooling, especially below about 150 °C (300 °F) is important to keep residual thermal stresses to a minimum. The solution annealed condition, Condition A, can also be referred to as solution heat treated condition or solution treated condition.

COLD FORMING

Limited cold bending can be performed on ARMCO 17-4 PH Stainless Steel in Condition A. For more severe cold working, the material may be heat treated to Conditions H1100, H1150 or H1150-M. This will help prevent possible cracking. Stress corrosion resistance is improved by re-aging at the precipitation-hardening temperature after cold working.

FORGING

Forging is an excellent forming method for intricate shapes of ARMCO 17-4 PH Stainless Steel. Small forging blanks should be heated uniformly to 1177 – 1204 °C (2150 – 2200 °F) and held at temperature at least 15 minutes before forging. On sections over 19 mm (0.75 in.) diameter or thickness, the material should be heated for one-half hour per inch of thickness at 1177 – 1204 °C (2150 – 2200 °F) and held for one hour at temperature prior to forging. On reheating, it should be soaked thoroughly. After forging, sections should be cooled to 32 °C (90 °F) to assure grain refinement. Then, to assure the best condition for the hardening operation, the parts must be reheated to 1024 – 1052 °C (1875 – 1925 °F) and air cooled (or oil quenched or water+polymer quenched in case of simple parts).

Small forgings may be air cooled. Complex shapes and large forgings should be equalized at about 1038 – 1149 °C (1900 – 2100 °F) before cooling, cooled in air until black, and then slowly cooled to 32 °C (90 °F) under cover of light-gauge nongalvanized sheet or a thin insulating blanket.

SURFACE CONTAMINATION

During heating for forging and solution treating, protective atmospheres containing carbon or nitrogen should be avoided because either element can be absorbed into the steel surface. Upon cooling, this absorption will result in the formation of a soft austenitic skin which is incapable of age hardening.

Carbonaceous residues present on the surface before heating can similarly contaminate the steel surface. Also, nitrogen atmospheres can be absorbed into the steel surface during aging. This may cause nitriding, resulting in lower corrosion resistance. Cleveland-Cliffs AK Steel International suggests using argon or helium in place of nitrogen as protective atmospheres or for back filling when vacuum heat treating is used.

IMPORTANCE OF COOLING TO 32 °C (90 °F) IN FABRICATION AND HEAT TREATING ARMCO 17-4 PH STAINLESS STEEL

When fabricating ARMCO 17-4 PH Stainless Steel, it is important to keep in mind the low temperatures at which the start of transformation to martensite (M_s) and the finish of the martensite transformation (M_F) occur. These temperatures are approximately 132 °C (270 °F) and 32 °C (90 °F) respectively. Because of this characteristic, it is necessary to cool parts in process at least to 32 °C (90 °F) prior to applying subsequent heat treatments if normal final properties are to be obtained. This practice is essential to assure grain refinement and good ductility. Examples of situations where cooling to 32 °C (90 °F)* is an important step to follow:

(a) Cool to 32 °C (90 °F) after solution annealing prior to applying any of the precipitation-hardening treatments.

(b) Cool a forged part to 32 °C (90 °F) after final forging before solution annealing.

**Cool any type of casting to 21 °C (70 °F) prior to solution annealing*

Fabrication

WELDING

ARMCO® 17-4 PH® Stainless Steel provides excellent weldability under production welding conditions. It's used in a wide variety of welded assemblies. Welded sections of ARMCO 17-4 PH Stainless Steel range from thin sections or minute machined fittings to heavy members prepared from blooms, bars or forgings. Successful applications for welded ARMCO 17-4 PH Stainless Steel include hose mandrels, aircraft landing hooks, shaft and gear assemblies, poppet valve beads, small bellows and diaphragm assemblies.

Sound joints can easily be produced in ARMCO 17-4 PH Stainless Steel through proper welding practice and properties comparable to those of the parent metal can be achieved in the weld by post weld heat treatments. Any of the arc and resistance welding process used on the regular grades of stainless steel are applicable to ARMCO 17-4 PH Stainless Steel. The most outstanding attribute of this steel is its ability to withstand welding operations without requiring preheating in sections up to 100 mm (4 in.).

Favorable chemical composition accounts for the good performance of ARMCO 17-4 PH Stainless Steel in welding. Copper in the alloy is present in a form that does not affect welding behavior. The small amount of niobium that is present plays no significant part in welding. The low carbon content is an important feature for it restricts the hardness of rapidly cooled material and minimizes the chance of cracking in the weld metal and the heat-affected zone of the base metal. The low hardness eliminates the need for preheating in most applications. While ARMCO 17-4 PH Stainless Steel shows low susceptibility to spontaneous underbead cracking from weld hardening, it does not possess the high ductility and toughness of austenitic chromium-nickel steels and, therefore, should not be subjected to unnecessary notch effects which might initiate cracking. Weldment design should be given the attention that ordinarily would be required for any high-strength alloy steel to avoid the concentration of residual welding stress or reaction stress at square corners, unfused notches, and sharp threads. Consideration should also be given to the condition of the base metal prior to welding.

MACHINING

ARMCO 17-4 PH Stainless Steel can be machined in both solution-annealed and precipitation-hardened conditions. One of the cost-saving advantages of the alloy is it can be machined to final dimensions in Condition A without allowance for scaling or distortion because the final hardening temperatures are low. However, on large sections, allowance must be made for the predictable contraction on hardening discussed on page 12.

Machining rates for ARMCO 17-4 PH Stainless Steel in Condition A do not differ materially from those of Type 302. In the hardened Condition H900, this material should be machined at 60% of the rate used for Condition A. Surface finishes in either condition are excellent.

CUTTING

In general, cutting procedures commonly used for standard chromium nickel stainless steel also apply to ARMCO 17-4 PH Stainless Steel.

Cold Sawing is recommended for cutting bars and forging billets. Hot cutting or abrasive wheel cutting with a large volume of coolant has been used successfully. However, it should be noted that abrasive wheel cutting can cause small surface cracks on the cut face.

Torch cutting of ARMCO 17-4 PH Stainless Steel requires a process suited for cutting stainless steel, such as powder cutting, oxy-arc, or arc-air methods. Since the heat-affected zones of ARMCO 17-4 PH Stainless Steel are not significantly hardened or embrittled by the localized heat of welding or torch cutting, this alloy offers good possibilities for oxygen or air-torch cutting. Many ARMCO 17-4 PH Stainless Steel bars in thicknesses up to 25 mm (1 in.) have been torch cut by Airco's flux-injection process with excellent results. Cutting tests were carried out on sections of round bars as large as 225 mm (9 in.) in diameter with the iron powder cutting method without encountering difficulty.

Where heat buildup from torch cutting causes high stresses in moderate to heavy sections, it is generally best to place the material in Condition H1150 prior to cutting.

Fabrication

TABLE 22 – RELATIVE MACHINABILITY OF 17-4 PH IN VARIOUS CONDITIONS

Machinability	Surface Finish	Condition	Comments	Rockwell Hardness, C	Cutting Rate SF/M (Automatic)
Improving Machinability ↑	Improved Surface Finish ↓	H1150 M	Best cutting rate. Surface not as good as other heat-treated condition. Not best for drilling or boring.	27	100 – 130
		H1150	Machinability improves as hardening temperature increases. Higher cutting rates obtained with some sacrifice in surface finish.	33	80 – 100
		H1100		34	75 – 95
		H1075		36	70 – 90
		A (solution annealed)	Machinability cutting rate and surface finish comparable to Type 302 and 304.	34	60 – 80
		H1025	Machinability improves as hardening temperature increases.	38	50 – 70
		H925		42	30 – 50
		H900	High hardness and strength limit machinability especially in mailing and forming. Use carbides for maximum production.	44	20 – 30

DESCALING

The hardening treatments for ARMCO® 17-4 PH® Stainless Steel produce only a light heat tint on the surfaces. The presence of this oxide film will, in certain applications, degrade the corrosion resistance of the alloy. Heat tint can be removed easily, either by mechanical means such as wet grit blasting, or by light pickling for several minutes in 10% nitric- 2% hydrofluoric acid (by volume) solution at 43 – 60 °C (110 – 140 °F). Where pickling is undesirable, the heat tint may be removed by light electropolishing. The latter two treatments also passivate or clean the surfaces for maximum corrosion resistance. The most satisfactory method of removing scale resulting from solution treatment or from forging is grit blasting. The scale softening and picking method given in Table 23 also is satisfactory. Use of the sodium hydride, Virgo or Kolene process is limited, since these methods harden solution-annealed material.

In pickling operations, close control of time and temperature is necessary to obtain uniform scale removal without over-etching.

TABLE 23 – DESCALING

Procedure	Acid Bath	Temperature, °C (°F)	Time, Minutes	Rinse
Step 1	Caustic Permanganate	71 – 82 (160 – 180)	60	Water
Step 2	10 % Nitric Acid + 2% Hydrofluoric Acid	43 – 60 (110 – 140)	2 – 3	Hot water, high pressure or brush scrub

Fabrication

NITRIDING

While nitriding decreases the corrosion resistance of any stainless steel, it is done when increased resistance to galling and wear is required. Nitriding has been used successfully to increase the case hardness of ARMCO® 17-4 PH® Stainless Steel for parts such as jet engine fuel pump shafts. The advantage in using ARMCO 17-4 PH Stainless Steel, rather than an 18-8 or chromium stainless steel, lies in its extremely strong, tough core. Using the gas-phase method, case hardnesses of approximately Rockwell Hardness C67 have been obtained to a depth of 0.100 – 0.150 mm (0.004 – 0.006 in.). This method of nitriding utilizes a temperature of about 538 °C (1000 °F) and results in a strong core with good toughness.

CASTINGS

Castings of ARMCO 17-4 PH Stainless Steel can be produced in many intricate shapes. They may vary in size from parts only a few ounces in weight with 3 mm (0.125 in.) minimum section to large castings with thicknesses as great as 150 mm (10 in.). Centrifugal castings also have been produced.

Cleveland-Cliffs does not make castings, but does produce ARMCO 17-4 PH Stainless Steel remelting stock for those wishing to buy such material.

Castings should be solution annealed at 1038 ± 14 °C (1900 ± 25 °F) and cooled in air or oil (for small sizes) to 21 °C (70 °F). After solution heat treating, the material should be hardened by aging. Material hardened at 496 °C (925 °F) for 90 minutes will attain the following typical (not minimum) properties.

TABLE 24 – TYPICAL MECHANICAL PROPERTIES OF CAST ARMCO 17-4 PH STAINLESS STEEL

UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation in $4D_0$	Reduction of Area	Rockwell Hardness, C
1310 (190)	1103 (160i)	8%	18%	39

Castings aged at temperatures higher than 496 °C (925 °F) will show improved ductility and impact strength with a subsequent reduction in tensile strength and hardness. Cleveland-Cliffs suggests that castings should never be put in service in Condition A.

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Cleveland-Cliffs is the largest flat-rolled steel producer in North America. Founded in 1847 as a mine operator, Cliffs also is the largest manufacturer of iron ore pellets in North America. The Company is vertically integrated from mined raw materials, direct reduced iron, and ferrous scrap to primary steelmaking and downstream finishing, stamping, tooling, and tubing. The Company serves a diverse range of markets due to its comprehensive offering of flat-rolled steel products and is the largest supplier of steel to the automotive industry in North America. The Company is headquartered in Cleveland, Ohio with mining, steel and downstream manufacturing operations located across the United States and in Canada. For more information, visit www.clevelandcliffs.com.

AK Steel International markets specialized steel products such as ARMCO® Pure Iron, stainless steel, metal products and composite auxiliary materials for the aerospace, automotive and industrial sectors. For more information, visit www.aksteel.eu.

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