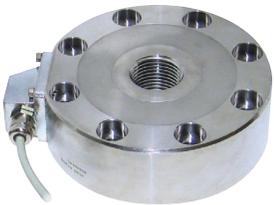


# ARMCO® 17-4 PH® STAINLESS STEEL

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 AK Steel's 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.



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# ARMCO® 17-4 PH® STAINLESS STEELS

## Product Description

AK Steel's 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 – 624 °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. AK Steel makes no intentional Ta addition.*

### AVAILABLE FORMS

AK Steel's 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 electroslag 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 H 1150, H 1150-D or H 1150-M is to be used instead of Condition A.
- 2) Precipitation hardened conditions:
  - a. Condition H 1075. Machines as well as Condition A.
  - b. Condition H 1150. 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 H 1150-D (also referred to as H 1150+1150) double precipitation hardened
  - b. Condition H 1150-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 H 900, H 925, H 1025, H 1100: Inquire for availability.



# ARMCO® 17-4 PH® STAINLESS STEELS

## 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 H 1100 and H 1150.

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
H 900	482 °C (900 °F)	1	Air
H 925	496 °C (925 °F)	4	Air
H 1025	552 °C (1025 °F)	4	Air
H 1075	579 °C (1075 °F)	4	Air
H 1100	593 °C (1100 °F)	4	Air
H 1150	621 °C (1150 °F)	4	Air
H 1150-D	621 °C (1150 °F) 621 °C (1150 °F)	4 Followed by 4	Air Air
H 1150-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

AK Steel's 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 H 1150-D and H 1150-M condition can be ordered in compliance with NACE MR0175 / ISO 15156 and NACE MR0103.

# ARMCO® 17-4 PH® STAINLESS STEELS

## Mechanical Properties

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

Property	Condition							
	H 900**	H 925	H 1025	H 1075	H 1100	H 1150	H 1150-D	H 1150M
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 <sub>0</sub>	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									
	H 900		H 925		H 1025	H 1075	H 1100	H 1150	H 1150-D	H 1150M
	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.)					
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 <sub>0</sub>	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.



# ARMCO® 17-4 PH® STAINLESS STEELS

## 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	BHN 363 max.

### SHEAR STRENGTH

TABLE 5 – SHEAR STRENGTH IN TORSION

Property	Condition			
	H 900	H 1025	H 1075	H 1150
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
H 900	1417 (205.6)	843 (122.4)	879 (127.4)	59.5	61.9
H 925	1304 (189.1)	789 (114.5)	821 (119.1)	60.6	63.0
H 1025	1136 (164.7)	716 (103.8)	721 (104.6)	63.0	63.5
H 1100	1084 (157.4)	676 (98.0)	690 (100.2)	62.3	63.6
H 1150-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.

# ARMCO® 17-4 PH® STAINLESS STEELS

## 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)
H 900	200 (29)	77 (11)
H 1025	201 (29)	76 (11)
H 1075	–	69 (10)
H 1150	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

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

FIGURE 1 – TYPICAL CONSTANT-LIFE FATIGUE DIAGRAM\*  
CONDITION H 900

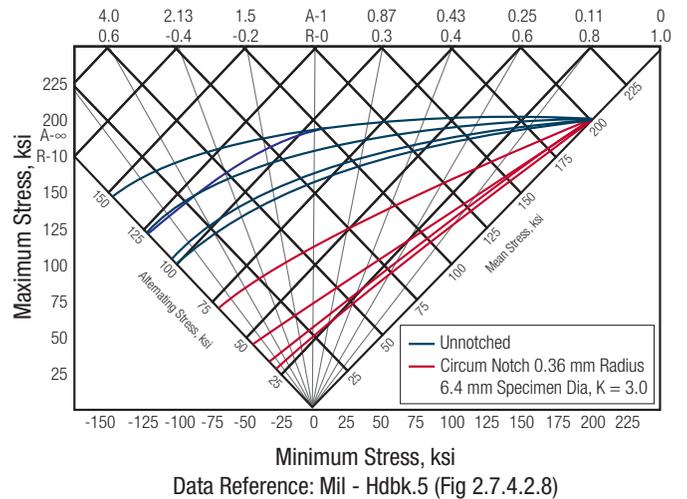


TABLE 9 – FATIGUE STRENGTH\*

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.



# ARMCO® 17-4 PH® STAINLESS STEELS

## 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 H 900	1400 (203)	1193 (173)	1165 (169)	1117 (162)	1027 (149)	820 (119)
Condition H 925	1317 (191)	1138 (165)	1110 (161)	1069 (155)	1000 (145)	800 (116)
Condition H 1025	1200 (174)	1007 (146)	979 (142)	945 (137)	869 (126)	731 (106)
Condition H 1075	1131 (164)	951 (138)	924 (134)	883 (128)	786 (114)	683 (99)
Condition H 1150	965 (140)	855 (124)	827 (120)	800 (116)	752 (109)	662 (96)
0.2% YS, MPa (ksi)						
Condition H 900	1282 (186)	1034 (150)	1007 (146)	972 (141)	910 (132)	731 (106)
Condition H 925	1255 (182)	1000 (145)	979 (142)	958 (139)	883 (128)	710 (103)
Condition H 1025	1158 (168)	931 (135)	903 (131)	883 (128)	814 (118)	696 (101)
Condition H 1075	1096 (159)	910 (132)	876 (127)	834 (121)	758 (110)	648 (94)
Condition H 1150	889 (129)	827 (120)	786 (114)	772 (112)	717 (104)	641 (93)
Elongation % in 4D <sub>0</sub>						
Condition H 900	11.0	10.0	8.0	10.0	10.0	15.0
Condition H 925	14.0	12.0	12.0	10.0	10.0	16.0
Condition H 1025	15.0	12.0	10.0	11.0	12.0	15.0
Condition H 1075	16.0	9.0	9.0	10.0	11.0	16.0
Condition H 1150	17.0	12.0	12.0	13.0	13.0	15.0
Reduction of Area, %						
Condition H 900	50.0	31.0	25.0	21.0	30.0	46.0
Condition H 925	54.0	32.0	33.0	34.0	35.0	45.0
Condition H 1025	55.0	42.0	38.0	39.0	39.0	43.0
Condition H 1075	54.0	38.0	33.0	30.0	38.0	55.0
Condition H 1150	61.0	54.0	52.0	43.0	51.0	55.0

# ARMCO® 17-4 PH® STAINLESS STEELS

## 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 H 900, H 1000 and H 1100 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
H 900	18.8 (14)	9.4 (7)	5.4 (4)	2.7 (2)	2.7 (2)	4.0 (3)	8.1 (6)
H 1000	61.1 (45)	9.4 (7)	4.0 (3)	2.7 (2)	2.7 (2)	5.4 (4)	10.8 (8)
H 1100	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)	–



# ARMCO® 17-4 PH® STAINLESS STEELS

## Mechanical Properties

TABLE 13 – STRESS-RUPTURE STRENGTH

Temperature, °C (°F)	Time to Rupture Hours	Condition	Property		
			Strength, MPa (ksi)	Elongation % in 4D <sub>0</sub>	Reduction of Area %
329 (625)	100	H 900	–	–	–
		H 925	1124 (163)	3.0	13.0
		H 1075	945 (137)	3.5	14.5
		H 1150	848 (123)	5.5	17.5
	1000	H 900	–	–	–
		H 925	1103 (160)	2.5	12.0
		H 1075	924 (134)	3.0	14.0
		H 1150	841 (122)	4.5	16.5
371 (700)	100	H 900	1076 (156)	3.0	7.0
		H 925	1062 (154)	3.0	13.5
		H 1075	869 (126)	4.0	15.5
		H 1150	786 (114)	6.5	19.0
	1000	H 900	1034 (150)	2.0	6.0
		H 925	1041 (151)	2.5	12.5
		H 1075	848 (123)	3.5	15.0
		H 1150	765 (111)	5.5	18.0
427 (800)	100	H 900	965 (140)	4.0	8.0
		H 925	883 (128)	3.5	13.5
		H 1075	745 (108)	6.0	16.0
		H 1150	689 (100)	6.5	25.0
	1000	H 900	883 (128)	4.0	6.0
		H 925	834 (121)	3.0	13.0
		H 1075	710 (103)	5.5	15.0
		H 1150	648 (94)	6.0	20.0
482 (900)	100	H 900	655 (95)	5.0	9.0
		H 925	–	–	–
		H 1075	–	–	–
		H 1150	552 (80)	9.0	40.0
	1000	H 900	414 (60)	12.0	25.0
		H 925	–	–	–
		H 1075	–	–	–
		H 1150	490 (71)	9.0	36.0

# ARMCO® 17-4 PH® STAINLESS STEELS

## 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:

- H 900 If toughness is a design criteria, this heat treatment should be used with caution, regardless of temperature.
- H 925 Down to -18 °C (0 °F) for general use. For non-impact applications, useful at temperatures as low as -196 °C (-320 °F).
- H 1150 Down to -79 °C (-110 °F). Design with caution when bar diameters exceed 25 mm (1 in.) round.
- H 1150-M Down to -196 °C (-320 °F).

**TABLE 14 – TYPICAL MECHANICAL PROPERTIES CONDITION H 900**

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 <sub>0</sub>	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 V-Notch Charpy Impact, J (ft•lbs)

Condition	Temperature °C (°F)			
	-12 (+ 10)	-40 (-40)	-79 (-110)	-196 (-320)
H 925*	22 (16)	12 (9)	7.4 (5.5)	4.7 (3.5)
H 1025*	78 (58)	54 (40)	20 (15.0)	6.1 (4.5)
H 1150*	126 (93)	102 (76)	54 (48.0)	8.8 (6.5)
H 1150-M*	–	–	–	38 (28.0)
H 1150-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.



# ARMCO® 17-4 PH® STAINLESS STEELS

## Mechanical Properties

TABLE 16 – COMPARISON OF LONGITUDINAL AND TRANSVERSE MECHANICAL PROPERTIES OF 17-4 PH CONDITION H 900

Size of Stock, Diameter	Direction of Test	Heat Treatment	UTS, MPa (ksi)	0.2% YS, MPa (ksi)	Elongation % in 4D <sub>0</sub>	Reduction of Area %
140 mm (5.5 in.)	L	1038 °C (1900 °F) H 900	1400 (203)	1248 (181)	11.5	44.5
	T	1038 °C (1900 °F) H 900	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. H 900 or H 925) 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 H 900. If hardened to more ductile conditions (Condition H 1025, H 1075, or H 1150), transverse ductility will approach longitudinal ductility and will be adequate for most applications.

# ARMCO® 17-4 PH® STAINLESS STEELS

## Physical Properties

TABLE 17 – PHYSICAL PROPERTIES

	Condition			
	A (Magnetic)	H 900 (Magnetic)	H 1075 (Magnetic)	H 1150 (Magnetic)
Density				
g/cm <sup>3</sup>	7.78	7.80	7.81	7.82
lbs/in. <sup>3</sup>	0.280	0.282	0.283	0.284
Electrical Resistivity μΩ•cm	100	80	80	–
Mean Coefficient of Thermal Expansion x 10 <sup>-6</sup> 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 <sup>2</sup> /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)	–	–



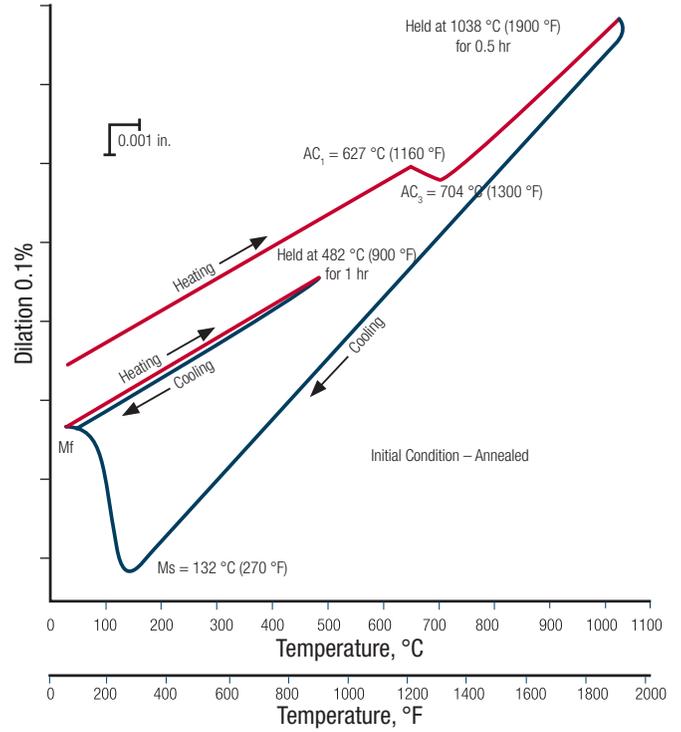
# ARMCO® 17-4 PH® STAINLESS STEELS

## Physical Properties

TABLE 18 – DIMENSIONAL CHANGE

Condition	Contraction coming from Condition A mm/mm (= in./in.)
H 900	0.00045
H 925	0.00051
H 1025	0.00053
H 1100	0.0009
H 1150	0.0022
H 1150-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



## Magnetic Properties

### MAGNETIC PROPERTIES

Normal induction and hysteresis curves are shown. There is little difference in the magnetic properties of material in Conditions H 900 through H 1075. However, Condition H 1150 produces significant change.

FIGURE 3 – NORMAL INDUCTION OF ARMCO 17-4 PH

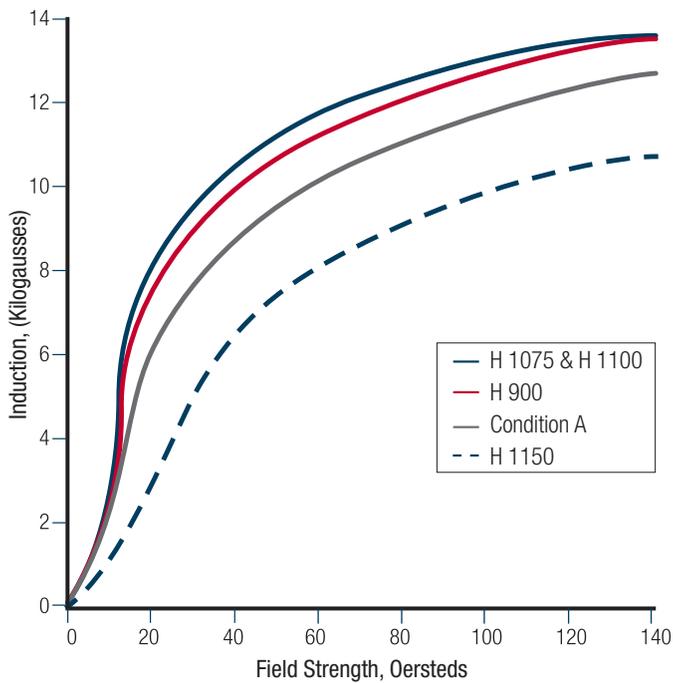
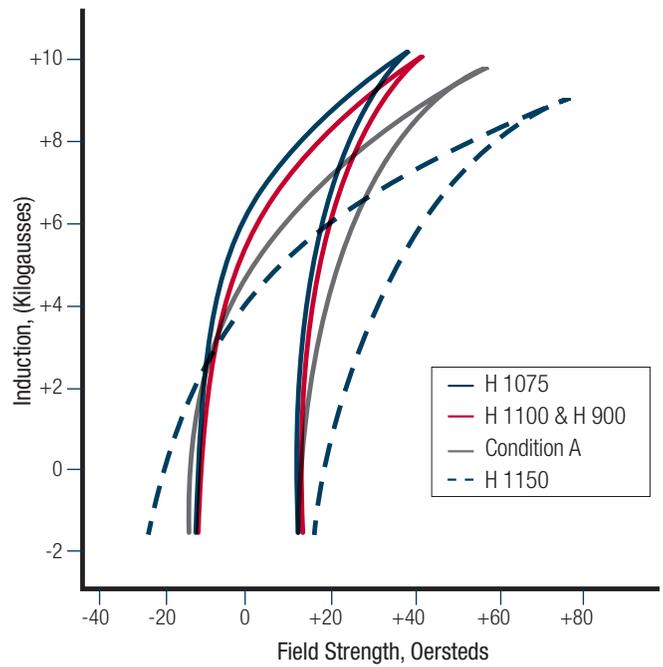


FIGURE 4 – HYSTERESIS CURVE OF ARMCO 17-4 PH



## ARMCO® 17-4 PH® STAINLESS STEELS

### Corrosion Resistance

AK Steel's 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)				
			H 925	H 1025	H 1075	H 1150	
H <sub>2</sub> SO <sub>4</sub>	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)
HNO <sub>3</sub>	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))
Acetic Acid	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 <sub>3</sub> PO <sub>4</sub>	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 <sub>3</sub> - 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 <sub>3</sub> - 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	Conc %	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 foregoing 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).



# ARMCO® 17-4 PH® STAINLESS STEELS

## 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 H 900, H 1025, H 1075, and H 1150 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 H 1025, H 1075, H 1150 + Welded.
- 2) Welded + Solution Annealed + Aged to Conditions H 1025, H 1075, H 1150.
- 3) Solution Annealed + Welded + Aged to Conditions H 1025, H 1075, H 1100.

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
H 900 (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
H 925 (Heat 2)	1193 (173) – 100% YS	1 – 61 months, 1 – 139 months, 1NF
	896 (130) – 75% YS	1 – 53 months, 1 – 52 months, 1NF
H 975 (Heat 2)	1158 (168) – 100% YS	3NF
	869 (126) – 75% YS	1 – 78 months, 2NF
H 1025 (Heat 1)	965 (140) – 90% YS	5NF
	800 (116) – 75% YS	5NF
H 1075 (Heat 1)	931 (135) – 90%YS	5NF
	779 (113) – 75% YS	5NF
H 1150 (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.

# ARMCO® 17-4 PH® STAINLESS STEELS

## Corrosion Resistance

### CORROSION FATIGUE

The corrosion fatigue strength of ARMCO 17-4 PH bar in Conditions H 925 and H 1150 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 <sup>7</sup> Cycles MPa (ksi)
17-4 PH	Solution Annealed + Condition H 925	1379 (200)	1155 (182)	207 – 276 (30 – 40)
	Solution Annealed + Condition H 1150	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 H 1150-D or H 1150-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 MRO175/ISO 15156 and NACE MRO103.



## Fabrication

### HEAT TREATMENT

For maximum hardness and strength, material from the solution-annealed condition is heated for one hour at  $482 \pm 9 \text{ }^\circ\text{C}$  ( $900 \pm 15 \text{ }^\circ\text{F}$ ) and air cooled to room temperature. Material conforming to AMS 5643 has to be heat treated with tighter restrictions:  $482 \pm 6 \text{ }^\circ\text{C}$  ( $900 \pm 10 \text{ }^\circ\text{F}$ ) and 1 hour  $\pm$  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  $482 - 621 \text{ }^\circ\text{C}$  ( $900 - 1150 \text{ }^\circ\text{F}$ ) 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  $1024 - 1052 \text{ }^\circ\text{C}$  ( $1875 - 1925 \text{ }^\circ\text{F}$ ) followed by cooling to at least  $32 \text{ }^\circ\text{C}$  ( $90 \text{ }^\circ\text{F}$ ). 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  $150 \text{ }^\circ\text{C}$  ( $300 \text{ }^\circ\text{F}$ ) 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 H 1100, H 1150 or H 1150-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  $1177 - 1204 \text{ }^\circ\text{C}$  ( $2150 - 2200 \text{ }^\circ\text{F}$ ) 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  $1177 - 1204 \text{ }^\circ\text{C}$  ( $2150 - 2200 \text{ }^\circ\text{F}$ ) and held for one hour at temperature prior to forging. On reheating, it should be soaked thoroughly. After forging, sections should be cooled to  $32 \text{ }^\circ\text{C}$  ( $90 \text{ }^\circ\text{F}$ ) to assure grain refinement. Then, to assure the best condition for the hardening operation, the parts must be reheated to  $1024 - 1052 \text{ }^\circ\text{C}$  ( $1875 - 1925 \text{ }^\circ\text{F}$ ) and air cooled (or oil quenched or water+polymer quenched in small simple parts).

Small forgings may be air cooled. Complex shapes and large forgings should be equalized at about  $1038 - 1149 \text{ }^\circ\text{C}$  ( $1900 - 2100 \text{ }^\circ\text{F}$ ) before cooling, cooled in air until black, and then slowly cooled to  $32 \text{ }^\circ\text{C}$  ( $90 \text{ }^\circ\text{F}$ ) 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's 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. AK Steel 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 $32 \text{ }^\circ\text{C}$ ( $90 \text{ }^\circ\text{F}$ ) 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  $132 \text{ }^\circ\text{C}$  ( $270 \text{ }^\circ\text{F}$ ) and  $32 \text{ }^\circ\text{C}$  ( $90 \text{ }^\circ\text{F}$ ) respectively. Because of this characteristic, it is necessary to cool parts in process at least to  $32 \text{ }^\circ\text{C}$  ( $90 \text{ }^\circ\text{F}$ ) 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  $32 \text{ }^\circ\text{C}$  ( $90 \text{ }^\circ\text{F}$ )\* is an important step to follow:

- (a) Cool to  $32 \text{ }^\circ\text{C}$  ( $90 \text{ }^\circ\text{F}$ ) after solution annealing prior to applying any of the precipitation-hardening treatments.
- (b) Cool a forged part to  $32 \text{ }^\circ\text{C}$  ( $90 \text{ }^\circ\text{F}$ ) after final forging before solution annealing.

*\*Cool any type of casting to  $21 \text{ }^\circ\text{C}$  ( $70 \text{ }^\circ\text{F}$ ) 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 H 900, 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.

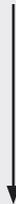
Where heat buildup from torch cutting causes high stresses in moderate to heavy sections, it is generally best to place the material in Condition H 1150 prior to cutting.



# ARMCO® 17-4 PH® STAINLESS STEELS

## 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 	H 1150 M	Best cutting rate. Surface not as good as other heat-treated condition. Not best for drilling or boring.	27	100 – 130
		H 1150	Machinability improves as hardening temperature increases. Higher cutting rates obtained with some sacrifice in surface finish.	33	80 – 100
		H 1100		34	75 – 95
		H 1075		36	70 – 90
		A (solution annealed)	Machinability cutting rate and surface finish comparable to Type 302 and 304.	34	60 – 80
		H 1025	Machinability improves as hardening temperature increases.	38	50 – 70
		H 925		42	30 – 50
H 900	High hardness and strength limit machinability especially in mailing and forming. Use carbides for maximum production.	44	20 – 30		

### DESCALING

The hardening treatments for 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 pickling 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

# ARMCO® 17-4 PH® STAINLESS STEELS

## 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.

AK Steel 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 <sub>0</sub>	Reduction of Area	Rockwell Hardness, C
1310 (190)	1103 (160)	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. AK Steel suggests that castings should never be put in service in Condition A.



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AK Steel is a leading producer of flat-rolled carbon, stainless and electrical steel products, primarily for the automotive, infrastructure and manufacturing, including electrical power, and distributors and converters markets. Through its subsidiaries, the company also provides customer solutions with carbon and stainless steel tubing products, die design and tooling, and hot- and cold-stamped components. Headquartered in West Chester, Ohio (Greater Cincinnati), the company has approximately 9,200 employees at manufacturing operations in the United States, Canada and Mexico, and facilities in Western Europe. Additional information about AK Steel is available at [www.aksteel.com](http://www.aksteel.com).

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Data referring to material properties are the result of tests performed on specimens obtained from specific locations of the products in accordance with prescribed sampling procedures; any warranty thereof is limited to the values obtained at such locations and by such procedures. There is no warranty with respect to values of the materials at other locations.

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