P R O D U C T D A T A B U L L E T I N

15-5 PH STAINLESS STEEL

UNS S15500

AK Steel

- High Strength
- Good Toughness
- Good Corrosion Resistance
- Ferrite Free

Applications Potential

AK Steel 15-5 PH® is the ferrite-free version of AK Steel 17-4 PH® Stainless Steel. To improve transverse mechanical properties, both alloys are widely used in the aerospace, chemical, petrochemical, food processing, paper and general metalworking industries.

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PRODUCT DESCRIPTION

AK Steel 15-5 PH is a martensitic precipitation-hardening stainless steel that provides an outstanding combination of high strength, good corrosion resistance, good mechanical properties at temperatures up to 600°F (316°C) and good toughness in both the longitudinal and transverse directions in both base metal and welds. Short-time, low-temperature heat treatments minimize distortion and scaling.

This alloy is air melted and AOD refined. For data not available on this alloy, use AK Steel 17-4 PH Stainless Steel sheet data as a guideline when available.

Composition

	%
Carbon	0.07 max.
Manganese	1.00 max.
Phosphorus	0.040 max.
Sulfur	0.030 max.
Silicon	1.00 max.
Chromium	14.00 - 15.50
Nickel	3.50 - 5.50
Copper	2.50 - 4.50
Columbium plus Tantalum	0.15 - 0.45

Available Forms

AK Steel produces 15-5 PH Stainless Steel sheet and strip in thicknesses from 0.015" to 0.125" (0.38 to 3.18 mm). Material is supplied in Condition A, ready for fabrication and subsequent hardening by the user. Since the material transforms to martensite on cooling to room temperature, flatness requirements should be considered and discussed as part of the order.

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. Conversion to the metric system, known as the International System of Units (SI) has been accomplished in accordance with ASTM E380.

The newton (N) has been adopted by the SI as the metric standard unit of force. The term for force per unit of area (stress) is the newton per square meter (N/m^2). Since this can be a large number, the prefix mega is used to indicate 1,000,000 units and the term meganewton per square meter (MN/m^2) is used. The unit (N/m^2) has been designated a pascal (Pa). The relationship between the U.S. and the SI units for stress is: 1000 pounds/in^2 = 1 kip/in^2 (ksi) = 6.8948 meganewtons/m^2 (MN/m^2) = 6.8948 megapascals (MPa).

Standard Heat Treatments

As supplied from the Mill in Condition A, AK Steel 15-5 PH Stainless Steel can be heat treated at a variety of temperatures to develop a wide range of properties. Eight standard heat treatments have been developed. The following chart outlines the times and temperatures required.

This alloy exhibits useful mechanical properties in Condition A. Tests at Kure Beach, NC, show excellent stress corrosion resistance for close to 20 years. 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
Standard Heat Treatments

	Condition	Heat To ± 15°F (8.4°C)	Time at Temperature, hours	Type of Cooling
Condition A Solution Treated 1900°F ± 25°F (1038°C ± 14°F) Air cool below 90°F (32°C)	H 900	900°F (482°C)	1	Air
	H 925	925°F (496°C)	4	Air
	H 1025	1025°F (551°C)	4	Air
	H 1075	1075°F (580°C)	4	Air
	H 1100	1100°F (593°C)	4	Air
	H 1150	1150°F (621°C)	4	Air
	H 1150 + 1150	1150°F (621°C)	4	Air
			followed by	
		1150°F (621°C)	4	Air
	H 1150-M	1400°F (760°C)	2	Air
			followed by	
		1150°F (621°C)	4	Air

Mechanical Properties

AK Steel 15-5 PH Stainless Steel provides excellent mechanical properties. For applications requiring high strength and hardness plus corrosion resistance, this alloy is an outstanding choice. In addition, it is more cost effective than many high-nickel, non-ferrous alloys.

Table 2

Typical Mechanical Properties*

				Condition			
Property	A	H 900	H 925	H 1025	H 1075	H 1150	H 1150-M
UTS, ksi (MPa)							
Longitudinal	161 (1110)	209 (1438)	181 (1249)	174 (1200)	162 (1114)	150 (1035)	136 (938)
Transverse	162 (1116)	213 (1466)	184 (1272)	175 (1204)	162 (1114)	152 (1050)	137 (944)
0.2% YS, ksi (MPa)							
Longitudinal	140 (963)	201 (1385)	175 (1208)	171 (1176)	160 (1102)	140 (967)	111 (765)
Transverse	143 (988)	202 (1393)	177 (1222)	171 (1176)	161 (1112)	146 (1009)	111 (765)
Elongation, % in 2" (50.8 mm)							
Longitudinal	8.4	10.1	12.2	12.2	12.8	14.6	18.8
Transverse	7.6	9.4	9.8	9.3	11.4	13.1	17.8
Hardness, Rockwell C							
Longitudinal	35	46	41	40	38	36	31
Transverse	35	46	42	39	38	36	31

*Average of two heats, 0.090" (2.3 mm) gage.

Table 3

Properties Acceptable for Material Specification*

				Condition			
Property	A	H 900	H 925	H 1025	H 1075	H 1100	H 1150
UTS, ksi (MPa)	185 max. (1276)	190 min. (1310)	170 min. (1172)	155 min. (1069)	145 min. (1000)	140 min. (965)	135 min. (931)
0.2% YS, ksi (MPa)	160 max. (1103)	170 min. (1172)	155 min. (1069)	145 min. (1000)	125 min. (862)	115 min. (790)	105 min. (724)
Elongation, % in 2" (50.8 mm)	3 min.	5 min.	5 min.	5 min.	5 min.	5 min.	8 min.
Hardness, Rockwell C	38 max.	40-48	38-46	35-43	31-40	31-40	28-38

*Sheets and strip.

Table 4

Sheet Charpy Impact Resistance*

Condition	Impact Energy, in-lb/in^2 (J)** Room Temperature	-65°F (-54°C)
A	3265 (10.8)	2669 (8.8)
H 900	2857 (9.4)	2361 (7.8)
H 1025	3974 (13.2)	3378 (11.2)
H 1150	4626 (15.3)	4248 (14.0)
H 1150-M	5616 (18.6)	5049 (16.7)
	Pressed Notch Tests	
H 900	2184 (7.3)	1360 (4.5)
H 1150	3406 (11.2)	2557 (8.4)

* Average of triplicate tests for two heats.
** Samples were 0.093" (2.36 mm) thick with a depth beneath the notch of 0.314" (7.98 mm).

Table 5

Modulus of Elasticity*

	Condition H 900	H 1025	H 1075	H 1150
Modulus in Tension, psi (MPa)	28.5×10^6 (196×10^3)	–	–	–
Modulus in Torsion, psi (MPa)	11.2×10^6 (77×10^3)	11.0×10^6 (76×10^3)	10.0×10^6 (69×10^3)	10.0×10^6 (69×10^3)

*Data represent average of two tests from one heat.

The modulus of elasticity of AK Steel 15-5 PH Stainless Steel at elevated temperatures can be expressed conveniently as % of room temperature modulus. At temperatures ranging from room to 600°F (315°C), this material showed the following:

Temperature °F (°C)	Modulus of Elasticity* (% of Room Temperature Modulus)
72 (22)	100.0
100 (38)	99.6
200 (93)	97.8
300 (149)	96.3
400 (204)	94.7
500 (260)	93.0
600 (315)	91.4

Poisson's Ratio in all hardened conditions is 0.272.
*Data represent average of two tests from one heat.

Table 6

	Condition A	Condition H 900	Condition H 1075	Condition H 1150
Density, lbs/in^3 (g/cm^3)	0.28 (7.78)	0.282 (7.80)	0.283 (7.81)	0.284 (7.82)
Electrical Resistivity, microhm-cm	98	77	–	–
Specific Heat Btu/lb/°F (32 - 212°F) kJ/kg•K (0 - 100°C)	0.11 (0.46)	0.10 (0.42)		
Thermal Conductivity BTU/hr/ft^2/in/°F (W/m•K)				
300°F (149°C)		124 (17.9)		
500°F (260°C)		135 (19.5)		
860°F (460°C)		156 (22.5)		
900°F (482°C)		157 (22.6)		
Mean Coefficient of Thermal Expansion in/in/°F (µm/m•K)				
–100 - 70°F (–73 - 21°C)	–	5.8 x 10^{-6} (10.4)	–	6.1 x 10^{-6} (11.0)
70 - 200°F (21 - 93°C)	6.0 x 10^{-6} (10.8)	6.0 x 10^{-6} (10.8)	6.3 x 10^{-6} (11.3)	6.6 x 10^{-6} (11.9)
70 - 400°F (21 - 204°C)	6.0 x 10^{-6} (10.8)	6.0 x 10^{-6} (10.8)	6.5 x 10^{-6} (11.7)	6.9 x 10^{-6} (12.4)
70 - 600°F (21 - 316°C)	6.2 x 10^{-6} (11.2)	6.3 x 10^{-6} (11.3)	6.6 x 10^{-6} (11.9)	7.1 x 10^{-6} (12.8)
70 - 800°F (21 - 427°C)	6.3 x 10^{-6} (11.3)	6.5 x 10^{-6} (11.7)	6.8 x 10^{-6} (12.2)	7.2 x 10^{-6} (13.0)
70 - 900°F (21 - 482°C)	–	–	–	7.3 x 10^{-6} (13.1)

Dimensional Change in Hardening

On hardening AK Steel 15-5 PH Stainless Steel, a dimensional change will take place. Typical dimensional changes are shown in Table 7. They can vary from heat to heat.

Table 7

Contraction from Heat Treatment

H 900		0.00045 in/in (mm/mm)
H 925		0.00051 in/in (mm/mm)
H 1025		0.00053 in/in (mm/mm)
H 1100		0.0009 in/in (mm/mm)
H 1150		0.0022 in/in (mm/mm)
H 1150-M	1400 ——>	0.00037 in/in (mm/mm)
	1150 ——>	0.00206 in/in (mm/mm)
	∴1400 + 1150 —>	0.00243 in/in (mm/mm)

* Data represent single tests from one heat.

Corrosion Resistance

The general level of corrosion resistance of AK Steel 15-5 PH Stainless Steel exceeds that of Types 410 and 431, and is approximately equal to that of AK Steel 17-4 PH Stainless Steel. This is indicated by laboratory tests in both strongly oxidizing and reducing media, as well as by atmospheric exposures. In all heat-treated conditions, this alloy exhibits very little rusting after 500 hours' exposure to 5% salt fog at 95°F (35°C). When exposed to seacoast atmospheres for long periods of time, the material gradually develops a superficial layer of rust like other precipitation-hardening stainless steels. The general level of corrosion resistance is best in the fully hardened condition, and decreases slightly as the aging temperature is increased.

Table 8

Corrosion Rates in Various Media

Corrosive Media	Time	Condition	Corrosion Rate
65% HNO_3	Average 5 - 48 hour periods	H 900	0.0083 IPM*
		H 1025	0.0106 IPM
		H 1150	0.0083 IPM
1% HCl, 95°F (35°C)	Average 5 - 48 hour periods	H 900	0.025 IPY**
		H 1025	0.085 IPY
		H 1150	0.730 IPY
Commercial bleach 95°F (35°C)	7 days	H 900	0.0016 IPY
		H 1025	0.013 IPY
		H 1150	0.0083 IPY

* Inches per month
** Inches per year

Table 9

SSC Test Results of AK Steel 15-5 PH*

Heat	Heat Treatment	0.2% YS, ksi (MPa)	Time to failure, days under stress of 100% YS	75% YS
F	Condition A	133 (917)	NF, NF, NF	NF, NF, NF
E	H 900	180 (1241)	22, 22, 22	22, 22, 22
F		173 (1193)	21, 21, 21	21, 21, 28
E	H 925	172 (1186)	22(1), 22(1), 266(1)	22(1), 22(1), 109(1)
F		166 (1145)	23(1), 23(1), 23(1),	23(1), 23(1), 23(1)
E	H 975	163 (1124)	NF, NF, NF	NF, NF, NF
F		159 (1096)	NF, NF, NF	NF, NF, NF
E	H 1025	159 (1096)	NF, NF, NF	NF, NF, NF

* NF indicates no failure. Tests in triplicate were begun on June 3, 1971 for Heat E and June 5, 1973 for Heat F and discontinued circa 1990.
(1) Cracked at code numbers that were stamped near ends of specimens. Materials Performance, Vol. 26, No. 2 (1987).

Table 10

5% Salt Fog Exposure for 10 Days

Condition	Rating
H 900	A+ (0% rust and stain covered)
H 1025	A (0-5% rust and stain covered)
H 1150	A (0-5% rust and stain covered)

Fabrication

Because AK Steel 15-5 PH Stainless Steel in Condition A is strong, forming normally should be limited to mild operations. However, fabrication can be improved greatly by heat treating before cold working. Table 11 indicates minimum bend radii for forming this material.

Table 11

Minimum Bend Radii*
(180° Bend)

Condition	Direction	Minimum Bend Radii
A	Longitudinal	2T
	Transverse	4T
H 900	Longitudinal	3T
	Transverse	5T
H 925	Longitudinal	3T
	Transverse	–
H 1025	Longitudinal	3T
	Transverse	3T
H 1150	Longitudinal	2T
	Transverse	2T
H 1150-M	Longitudinal	2T
	Transverse	2T

*0.090" (2.3 mm). Average of two heats.

Weldability

The precipitation hardening class of stainless steels is generally considered to be weldable by the common fusion and resistance techniques. Special consideration is required to achieve optimum mechanical properties by considering the best heat-treated conditions in which to weld and which heat treatments should follow welding. This particular alloy is generally considered to have equivalent weldability to the most common alloy of this stainless class, 17-4 PH Stainless Steel. When a weld filler is needed, AWS E/ER 630 is most often specified. AK Steel 15-5 PH Stainless Steel is well known in reference literature and more information can be obtained in the following ways:

1. ANSI/AWS A 5.9, A 5.22, and A 5.4 (filler metals, minimum UTS and elongation).
2. "Welding of Stainless Steels and Other Joining Methods," SSINA, (800-982-0355).
3. "Welding Armco Stainless Steels," FDB #SF-1.

Heat Treatment

For maximum hardness and strength, material in the solution-treated condition is heated for one hour at 900°F ± 15°F (482°C ± 8.4°C) and air cooled to room temperature. If the material is purchased in the solution-treated condition (Condition A) and not subsequently hot worked, the hardening treatment can be performed without solution treating before hardening.

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

If the alloy is not sufficiently ductile in any given hardened condition, it can be reheated at a higher hardening temperature to increase impact strength and elongation. This can be accomplished without a solution treatment prior to final heat treatment. However, strength will be reduced.

For hot-worked or overaged material, a solution treatment at 1875 - 1925°F (1024 - 1052°C) for three minutes for each 0.1" (2.5 mm) of thickness, followed by cooling to at least 90°F (32°C) must be done prior to hardening. The solution treatment refines the grain size and makes hardened material more uniform.

When fabricating AK Steel 15-5 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 completion of the martensite transformation (M_f) occur. These temperatures are approximately 270°F (132°C) and 90°F (32°C) respectively.

Because of this characteristic, it is necessary to cool parts in process at least to 90°F (32°C) prior to applying subsequent heat treatments if normal final properties are to be obtained. This practice is essential to assure grain refinement and to assure good ductility.

Descaling

Hardening treatments produce only a light heat tint on surfaces. This tint can be removed easily by mechanical means such as wet grit blasting or with a short pickle in 10% nitric - 2% hydrofluoric acid (by volume) at 110 - 140°F (43 - 60 °C). Where pickling is undesirable, heat tint may be removed by a light electropolishing operation. The latter two treatments also clean and passivate the surfaces for maximum corrosion resistance.

Where solution treating is performed, the following pickling method satisfactorily removes surface scale. The use of molten salts such as sodium hydride or Kolene processes to descale is limited since these methods partially harden solution-treated material.

In pickling operations, time and temperature should be controlled closely to obtain uniform scale removal without over etching. Scale softening methods may be used on material that has been solution treated (not pickled) and precipitation hardened.

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

Specifications

The following specifications are listed without revision indications. Contact ASTM Headquarters for latest ASTM revision. For AMS revision, contact AMS Division of SAE.

AMS 5862
ASTM A 693 Plate, Sheet and Strip
(Listed as Grade XM-12 - UNS S15500)