17-4PH - Precipitation Hardening Stainless Steel

(UNS S17400)

INTRODUCTION

17-4 precipitation hardening stainless steel (S17400), Type 630, is a chromium-nickel-copper precipitation hardening stainless steel used for applications requiring high strength and a moderate level of corrosion resistance. High strength is maintained to approximately 600°F (316°C). This alloy is designated Grade or Type 630 in several specifications.

The S17400 alloy is martensitic in structure in the annealed condition and is further strengthened by a low temperature treatment which precipitates a copper containing phase in the alloy. In comparison to many alloys in the precipitation hardening family, the S17400 alloy requires a simple heat treatment; a one step process conducted at a temperature in the range 900°F (482°C) to 1150°F (621°C) depending on the combination of strength and toughness desired. A wide range of properties can be produced by this one step heat treatment. Heat treatment in the 900°F (482°C) range produces highest strength, although slightly less than that of alloys like S17700 or S15700. The latter precipitation hardening stainless steels generally require more steps to complete heat treatment.

SPECIFICATIONS & CERTIFICATES

The 17-4 precipitation hardening stainless steel (S17400) is covered by the following wrought product specifications.

Specification	Product Form
AMS 5604	Sheet, Strip and Plate
AMS 5643	Bars, Forgings, Tubing and Rings
AMS 5825	Welding Wire
AMS 5827	Welding Electrodes
AMS 7474	Bolts
ASTM A564 **ASTM SA 564**	Bars, Wire and Shapes
ASTM A693 **ASME SA-693**	Sheet, Plate and Strip
ASTM A705 **ASME SA-705**	Forgings

17-4 PH (630)

PRODUCT FORMS

17-4 precipitation hardening stainless steel is furnished as plate, sheet, strip and long products. In all forms, the material is furnished in the annealed condition.

Element	Typical Composition (Weight Percent)
Carbon	0.04
Manganese	0.40
Phosphorus	0.020
Sulfur	0.005
Silicon	0.50
Chromium	15.5
Nickel	4.5
Columbium + Tanlalum	0.30
Copper	3.50
Iron	Balance

CORROSION RESISTANCE

Tests have shown that the corrosion resistance of 17-4 precipitation hardening stainless steel is comparable to that of Type 304 stainless steel in most media. In general, the corrosion resistance of 17-4 alloy is superior to that of the hardenable 400 series stainless steels. As with other precipitation hardening stainless steels, 17-4 precipitation hardening stainless steel is more susceptible to stress corrosion cracking at peak strength. Consequently, in applications where chloride stress corrosion cracking is a possibility, the material should be precipitation hardened to produce the lowest hardness compatible with the intended end use. This is done by heat treating at the highest temperature which will produce suitable minimum properties.

Material in the annealed condition should not generally be put into service. In this condition, the material has an untempered martensite structure and is less ductile than aged material. The untempered martensite may be subject to unpredictable brittle fractures. In corrosive environments, the untempered martensite is more sensitive to embrittling phenomena such as hydrogen embrittlement than material that has had one of the precipitation hardening heat treatments. Similarly, untempered martensite is more sensitive to chloride stress corrosion cracking than material in which the martensite has been tempered.

OXIDATION RESISTANCE

The oxidation resistance of the 17-4 alloy is superior to that of 12 percent chromium alloys like Type 410, but slightly inferior to that of Type 430. Precipitation hardening will produce surface oxidation.

PHYSICAL PROPERTIES

	Condition A	Condition H 900	Condition H 1075	Condition H 1150
Density lb / in^3	0.280	0.282	0.283	0.284
g / cm^3	7.75	7.81	7.83	7.86
Linear Coefficient of Thermal Expansion Units of 10^{-6} / °F (10^{-6} / °C)				
Temperature Range				
-100 °F to +70 °F (-73 °C to +21 °C)		5.8 (10.4)	6.0 (10.8)	6.1 (11.0)
+70 °F to 800 °F (+21 °C to +427 °C)	6.3 (11.3)	6.5 (11.7)	6.8 (12.2)	7.2 (13.0)
Magnetic Permeability	**Strongly Ferromagnetic in all Conditions**			
Thermal Conductivity Btu - ft / hr -ft^2 °F (W / m - K)				
70 - 212 °F (21 - 100 °C)	10.6 (18.3)	10.3 (17.8)		
70 - 932 °F (21 - 500 °C)	13.1 (22.7)	13.1 (22.7)		
Electrical Resistivity microhm-cm	98	77	80	86

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17-4 PH (630)

MECHANICAL PROPERTIES

	Condition A	Condition H 900	Condition H 1075	Condition H 1150
Modulus of Elasticity 10^6 psi (GPa)	28.5 (196)	28.5 (196)	28.5 (196)	28.5 (196)
Modulus of Rigidity 10^6 psi (GPa)	11.2 (77.2)	11.2 (77.2)	11.2 (77.2)	11.2 (77.2)

Room temperature tensile properties can vary substantially with heat treatment in the 900°F (482°C) to 1150°F (621°C) range. Values shown below are typical room temperature properties that may be expected for various precipitation hardening heat treatments as well as for the 1950°F (1066°C) solution heat treatment.

	Condition A	Condition H 900	Condition H 1075	Condition H 1150
0.2% Offset Yield Strength **psi** **(MPa)**	110,000 760	180,000 1,240	135,000 930	125,000 860
Ultimate Tensile Strength **psi** **(MPa)**	150,000 1,030	195,000 1,340	155,000 1,070	145,000 1,000
Elongation (percentage in 2")	8	10	10	10
Hardness Rockwell C scale	33	43	36	31

HEAT TREATMENT

SUMMARY OF HEAT TREATING 17-4 ALLOY				
Minimum Properties Specified in Aerospace Material Specification (AMS) 5604				
Heat Treat to Produce Martensitic Structure	**Precipitation Heat Treatment to Produce Desired Strength**			
	Precipitation Hardening Heat Treatment	**Yield Strength psi (MPa)**	**Tensile Strength psi (MPa)**	**Hardness Rc**
Solution Heat Treatment at 1950 °F (1066 °C) **Condition A**	900 °F (482 °C) 60 minutes Condition H 900	170,000 (1170)	190,000 (1310)	40 to 47
	925 °F (496 °C) 4 Hours Condition H 925	155,000 (1070)	170,000 (1170)	38 to 45
	1025 °F (552 °C) 4 Hours Condition H 1025	145,000 (1000)	155,000 (1070)	35 to 42
	1075 °F (579 °C) 4 Hours Condition H 1075	125,000 (860)	145,000 (1000)	33 to 39
	1100 °F (593 °C) 4 Hours Condition H 1100	115,000 (790)	140,000 (965)	32 to 38
	1150 °F (621 °C) 4 Hours Condition H 1150	105,000 (725)	135,000 (930)	28 to 37
	1400 °F (760 °C) 2 Hours + 1150 °F 4 Hours Condition H 1150-M from SA 693	75,000 (515)	115,000 (790)	26 to 36

The 17-4 precipitation hardening stainless steel is furnished in the annealed condition. This is also called the solution heat treated condition, or Condition A. Annealing is conducted by heat treating at approximately 1900°F (1040°C) to 1950°F (1065°C) and cooling to room temperature. In this condition, the material possesses a martensitic structure. As a martensitic structure, the 17-4 alloy possesses a relatively high strength and hardness in the annealed condition. The strength and hardness of the material is generally somewhat lower in the H 1150 overaged condition.

To develop further increase in strength, the annealed material is precipitation hardened by heat treatments at 900°F (482°C). These precipitation hardening heat treatments increase ductility and toughness while they harden the material. Heat treatments above 1075°F (579°C) generally result in material softer than material in the annealed condition. The heat treatments are usually specified as shown in the preceding table.

The precipitation hardening reaction can be driven past peak strength by heat treating at an excessively high temperature or by excessive time at the precipitation hardening temperature. The table on page 3 shows the effect of higher temperature heat treatment. A less dramatic downward shift in strength results from excessively long precipitation hardening times.

MECHANICAL PROPERTIES

The heat treatments used for the 17-4 precipitation hardening stainless steel are summarized below.

Condition	Temperature	Time
H 900	900 °F ± 10 (482 °C ± 5)	60 min. ± 5 min.
H 925	925 °F ± 10 (496 °C ± 5)	4 hrs. ± 0.25 hr.
H 1025	1025 °F ± 10 (552 °C ± 5)	4 hrs. ± 0.25 hr.
H 1075	1075 °F ± 10 (579 °C ± 5)	4 hrs. ± 0.25 hr.
H 1100	1100 °F ± 10 (593 °C ± 5)	4 hrs. ± 0.25 hr.
H 1150	1150 °F ± 10 (621 °C ± 5)	4 hrs. ± 0.25 hr.

WELDABILITY

The 17-4 precipitation hardening stainless steel is readily welded using conventional inert gas methods used for stainless grades. Preheating is not usually required. Postweld heat treating is needed to produce the various precipitation hardened heat treatment properties.

If matching filler material is used, properties comparable to those of the parent metal can be produced in the weld by postweld precipitation hardening heat treatment.

When a number of welding passes are made, a substantial thermal cycling has been conducted on the material. More uniform mechanical properties can be obtained by solution annealing the material before conducting precipitation hardening heat treatments. The solution anneal has the effect of minimizing the effects of the thermal cycling.

In the case of welding with non-matching filler, an austenitic stainless steel such as Type 308L or other ductile austenitic should be used. This filler will not produce the precipitation hardening response, however.

FORMABILITY

The tensile data for the 17-4 precipitation hardening stainless steel indicate that the alloy does not possess the high tensile elongation characteristic of the austenitic stainless steels. The material is capable of being mildly formed but is not capable of being severely formed. Forming is more easily accomplished in the overaged (such as H 1150-M from SA 693) condition than in the annealed condition.

CUTTING

Water jet or saw cutting are the safest methods for cutting. Wet abrasive cutting is typically acceptable, but may produce small cracks due to local overheating. Plasma torch cutting may create cracking in the as-annealed condition, especially if the material is greater than approximately 1 inch (25.4 mm) thick. These cracks may propagate far into the base material. This cracking associated with torch cutting is more likely if bending or machining is performed in the as-annealed condition. As noted elsewhere, in the as-annealed condition only mild forming is reasonably safe.

Aging the material at 1150°F (621°C) or higher (as described previously under "Formability") before torch cutting can minimize the cracking risk, depending on the particular torch practice. Re-solution annealing and final heat treatment are then needed after the cutting and machining of aged material.

The torch cut edge should be cleaned by grinding or milling, and the pattern should include an appropriate clean-up allowance. (See ASTM A480.)