RA17-4 stainless

Introduction

RA17-4 is an age-hardening martensitic alloy combining high strength with the corrosion resistance of stainless steel. Hardening is achieved by a short-time, simple low-temperature treatment. Unlike conventional martensitic stainless steels, such as type 410, RA17-4 is quite weldable. The strength, corrosion resistance and simplified fabrication can make RA17-4 a cost-effective replacement for high strength carbon steels as well as other stainless grades.

Features

- High tensile strength and hardness to 600°F (316°C)
- Corrosion resistant
- Excellent oxidation resistance to about 1100°F (593° C)
- Fabricable
- Simple low-temperature heat treatment
- Creep-rupture strength to 900°F (482°C)

Applications

- Gate Valves
- Aircraft structures, accessories, engine parts
- Chemical processing equipment
- Food processing machinery
- Pump shafts, gears, plungers
- Valve stems, balls, bushings, seats
- Pulp & paper mill equipment
- Fasteners

Chemical Composition Range

Chromium	15.00 - 17.50
Nickel	3.00 - 5.00
Copper	3.00 - 5.00
Manganese	1.00 max
Silicon	1.00 max
Columbium + Tantalum	5XC - 0.45
Carbon	0.07 max
Phosphorus	0.040 max*
Sulfur	0.030 max*
Molybdenum	0.50 max
Iron	remainder

* 0.025 max, AMS 5622

Specifications

UNS S17400

AMS 5604	Sheet, Strip and Plate
AMS 5622	Bars, Wire, Forgings, Tubing, and Rings, Consumable Electrode Melted
AMS 5643	Bars, Wire, Forgings, Tubing and Rings
AS 7474	Bolts and Screws, Upset Headed, Heat Treated, Roll Threaded

ASTM A 564	Type 630	Bars and Shapes
A 693	Type 630	Plate, Sheet and Strip
A 705	Type 630	Forgings
ASME SA-564	Type 630	Bars and Shapes
SA-693	Type 630	Plate, Sheet and Strip
SA-705	Type 630	Forgings

UNS S17480

AMS 5825	Welding Wire
AWS A5.9 ER630	Bare Stainless Steel Welding Electrodes and Rods

UNS W37410

AMS 5827	Covered Welding Electrodes
AWS A5.4 E630	Stainless Steel Electrodes for Shielded Metal Arc Welding

The chemistry limits for RA17-4 are nearly identical to DIN 1.4548, X5CrNiCuNb17-4-4.

Physical Properties

Melting Range 2560-2625°F (1404-1440°C)

	Heat Treated Condition of Material			
	annealed	H900	H1075	H1150
Density, lb/in^3	0.280	0.282	0.283	0.284
Electrical Resistivity, ohm • circular mil/ft	590	463	--	--
Magnetic Permeability,				
at H = 100 Oersted	74	90	88	59
H = 200 Oersted	48	56	52	38
Maximum	95	135	136	71
Mean Coefficient of Thermal Expansion, inch/inch °Fx10^{-6}				
-100 to 70°F	--	5.8	--	6.1
70 to 200	6.0	6.0	6.3	6.6
70 to 400	6.0	6.1	6.5	6.9
70 to 600	6.2	6.3	6.6	7.1
70 to 800	6.3	6.5	6.8	7.2
Thermal Conductivity Btu • ft/ft^2 • hr • °F				
at 300°F	--	10.3	--	--
500	--	11.3	--	--
860	--	13.0	--	--
900	--	13.1	--	--
Specific Heat, Btu/lb°F	0.11	--	--	--
Poisson's Ratio, 70°F	--	0.272	0.272	0.272
Modulus of Elasticity, psi x 10^6				
Tension, 70°F	--	28.5	--	--
200°F	--	28.0	--	--
400°F	--	27.0	--	--
600°F	--	26.0	--	--
Torsion, 70°F	--	11.2	10.0	10.0

Mechanical Properties

MINIMUM PROPERTIES IN THE HARDENED CONDITIONS
ASTM A 693 thickness from 0.626 to 4.0"

CONDITION

Property	UTS ksi	0.2% YS ksi	Elong. % in 2" or 4XD	Red. Of Area %	Hardness Brinell	Hardness Rockwell	Impact, Charpy V-Notch ft-lbs
H 900	190	170	10	30	388/477	C 40/48	**
H 925	170	155	10	30	375/477	C 38/47	**
H 1025	155	145	12	35	321/415	C 33/42	15
H 1075	145	125	13	35	293/375	C 29/38	20
H 1100	140	115	14	35	293/375	C 29/38	20
H 1150	135	105	16	40	269/352	C 26/36	30
H 1150-M	115	75	18	45	248/321	C 24/34	55

** Minimum impact properties cannot be accepted in this condition.

Mechanical Requirements in Condition A (Solution Treated)
0.015 to 4.0" (0.38 to 102 mm)

Tensile Strength maximum ksi	Tensile Strength maximum N/mm^2	Yield Strength maximum ksi	Yield Strength maximum N/mm^2	Elongation in 2" or 50mm minimum, %	Hardness, max Rockwell	Hardness, max Brinell
185	1255	160	1105	3	C38	363

TYPICAL ELEVATED TEMPERATURE SHORT-TIME TENSILE PROPERTIES

Property and Condition	Temperature, °F °C 75 (24)	600 (316)	700 (371)	800 (427)	900 (482)	1000 (538)
UTS, ksi (N/mm^2)						
H 925	191 (1317)	165 (1138)	161 (1110)	155 (1069)	145 (1000)	116 (800)
H 1025	174 (1200)	146 (1007)	142 (979)	137 (945)	126 (869)	106 (731)
H 1150	140 (965)	124 (855)	120 (827)	116 (800)	109 (752)	96 (662)
0.2% YS, ksi (N/mm^2)						
H 925	182 (1255)	145 (1000)	142 (979)	139 (958)	128 (883)	103 (710)
H 1025	168 (1158)	135 (931)	131 (903)	128 (883)	118 (814)	101 (696)
H 1150	129 (889)	120 (827)	114 (786)	112 (772)	104 (717)	93 (641)
Elong. % in 2" (50mm)						
H 925	14	12	12	10	10	16
H 1025	15	12	10	11	12	15
H 1150	17	12	12	13	13	15
Reduction of Area, %						
H 925	54	32	33	34	35	45
H 1025	55	42	38	39	39	43
H 1150	61	54	52	43	51	55

EFFECT OF TEMPERATURE ON IMPACT TOUGHNESS

In all heat treated conditions long term exposure in the temperature range of about 700 to 900°F (371 to 482°C) can result in a sharp drop in room temperature impact strength in precipitation hardenable martensitic stainless steels.

Typical Izod Impact Values, foot-pounds (Joule)

Condition	Room	Exposure for 2000 hours at temperature indicated 700°F (371°C)	800°F (427°C)	900°F (482°C)
H 900	14 (19)	4 (5.4)	2 (2.7)	6 (8.1)
H 1000	45 (61)	3 (4)	2 (2.7)	8 (11)
H 1100	56 (76)	4 (5.4)	2 (2.7)	11 (15)

STRESS-RUPTURE STRENGTH
Typical Values

Condition	Test Temperature		Stress for Rupture in			
			100 hours		1000 hours	
	°F	°C	psi	N/mm^2	psi	N/mm^2
H 925	625	329	163,000	1124	160,000	1103
H 1150	625	329	123,000	848	122,000	841
H 925	700	371	154,000	1062	151,000	1041
H 1150	700	371	114,000	786	111,000	765
H 925	800	427	128,000	883	121,000	834
H 1150	800	427	100,000	689	94,000	648
H 1150	900	482	80,000	552	71,000	490

Heat Treatment

RA17-4 is a martensitic, precipitation-hardening stainless steel. Its hardening mechanism is different from that of standard hardenable stainless steels.

At the solution treating temperature, 1900°F (1040°C), the metal is austenitic but undergoes transformation to a low-carbon martensitic structure on cooling to room temperature. This transformation starts about 270°F (132°C) but is not complete until the temperature drops to 90°F (32°C). The precipitation-hardening compounds remain in solution as the metal is cooled. Subsequent heating to temperatures of 900 to 1150°F (480 to 620°C) for one to four hours precipitates submicroscopic particles of metallic compounds that materially increase both strength and hardness. In addition, this hardening treatment also tempers the martensitic structure, increasing ductility and toughness.

After solution annealing, the metal must be permitted to cool to room temperature in order to complete the transformation to martensite, before beginning the precipitation hardening process. Otherwise the structure may contain enough retained austenite that it will not achieve expected hardness after final heat treatment.

Solution annealing should be performed in air, argon or dry hydrogen. Cracked ammonia may contaminate RA17-4 and endothermic atmospheres will carburize and damage the metal's properties. Wash off machining oils and forming lubricants before solution annealing. Plasma cut surfaces should be ground or machined off before heat treatment to avoid possible cracking.

Heat Treatments for RA17-4 and Their Designation

Designation	Processing
Condition A*	Heated at 1900°F ± 25°F for 1/2 hour, air (Solution treated) cooled or oil quenched to below 90°F. Normally performed at mill.
H 1075, H 1150	Condition A material heated at 1075 or 1150°F ± 15°F for 4 hours and air cooled.
H 900	Condition A material heated at 900°F ± 15°F for 1 hour and air cooled. Maximum hardness but low toughness. Sensitive to stress corrosion cracking.
H 925, H 1025, H 1100	Condition A material heated at specified temperature for 4 hours and air cooled.
H 1150-M	Condition A material heated at 1400 ± 25°F for 2 hours, air cooled, then heated at 1150 ± 15°F for 4 hours and air cooled. This heat treatment used for maximum toughness, and for cryogenic applications to -320°F.

* For most applications, RA17-4 should not be used in Condition A. This is true even though the desired tensile strength may be provided by that condition. While the alloy is relatively soft in Condition A, the structure is untempered martensite that has low fracture toughness and ductility, with poor resistance to stress-corrosion cracking. Superior service performance is assured by using RA17-4 in the heat-treated condition.

Dimensional Change in Hardening - As indicated by the density values, RA17-4 undergoes a volume-contraction when it is hardened. This produces a predictable change in dimensions that must be taken into consideration if parts made of RA17-4 must be manufactured to close tolerances.

The dimensional contraction in hardening Condition A material to Cond. H 900 amounts to 0.0004-0.0006 inches per inch. Hardening to Cond. H 1150 produces a contraction of 0.0009-0.0012 inches per inch. Dimensional changes for other conditions are proportional.

Welding

RA17-4 has been welded by GTAW, GMAW, SMAW, PAW, Electron-beam (EB) and resistance welding. For GMAW a shielding gas of 75% argon and 25% helium is suggested.

Sections up to 1” thick are normally welded in the annealed (A) condition. Highly restrained joints or heavier sections are best welded in conditions H1100 or H1150. Welding of RA17-4 in conditions H900 through H1075 is not recommended.

No preheat is usually necessary for sections up to 4” thick. For restrained welds a 200-300°F (100-150°C) preheat is beneficial.

Matching composition ER630 wire or E630 covered electrodes (AMS 5803, 5825 or 5827) are normally used. Joints to carbon or low alloy steel may be made with ERNiCr-3 wire (alloy 82) or ENiCrFe-3 covered electrodes (alloy 182).

Postweld heat treatment (PWHT) is required. For single pass welds on condition A base metal, simply aging to condition H 900 through H 1150 usually suffices (H 900 condition has very low notch toughness). For multipass welds the structure should be solution annealed after welding, followed by an aging treatment 900-1150ºF.

Notches must be avoided, and partial penetration welds with their built-in notches are quite undesirable. If design considerations force the use of partial penetration welds consider making the root pass only with ERNiCr-3 (alloy 82) wire to minimize notch sensitivity.

Machining

Typical machining speeds for RA17-4, using high speed steel tools are:

Operation	Speed SFPM	Feed IPR
Turning, Single Point	80-95	0.015-0.007
Drilling 1/4” dia	50	0.004
3/4” dia	50	0.008
Reaming		
under 1/2”	60	0.003
over 1/2”	60	0.008
Die Threading		
3--7 1/2 TPI	5-12	--
8--15 TPI	8-15	--
over 16 TPI	10-20	--
Tapping	12-25	--
Milling, End and Peripheral	85	0.001-0.004
Broaching	10	chip load 0.002 IPT

When using carbide tools, surface speed feet/minute (SFPM) may be increased 2 to 3 times over high speed suggestions. Feeds can be increased 50 to 100%.

Material from the following sources was used in preparation of this document:

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Aerospace Structural Metals Handbook, 17-4, Code 1501

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