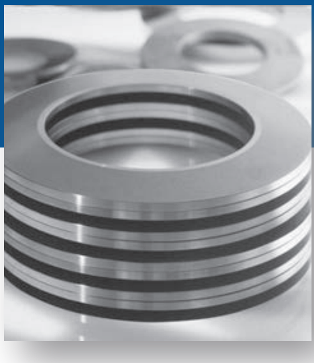
17-7 PH®
STAINLESS STEEL



- **Aerospace**
- **Belleville Washers**
- **Eyelets**
- **Flat Springs**
- **Strain Gauges**

Cleveland-Cliffs **17-7 PH® STAINLESS STEEL** provides valuable property combinations particularly well suited for aerospace applications. This special alloy also provides benefits for other applications requiring formability, high strength and good corrosion resistance, as well as excellent properties for flat springs, belleville (conical spring) washers, eyelets and strain gauges at temperatures up to 600 °F (316 °C).

Product Description

Cleveland-Cliffs 17-7 PH Stainless Steel is a semi-austenitic precipitation-hardening stainless steel that provides high strength and hardness, excellent fatigue properties, good corrosion resistance and minimum distortion upon heat treatment. It is easily formed in the annealed condition, then hardened to high strength levels by simple heat treatments to Conditions RH 950 and TH 1050. The exceptionally high strength of Condition CH 900 offers many advantages where limited ductility and workability are permissable.

In its heat-treated condition, this alloy provides exceptional mechanical properties at temperatures up to 900 °F (482 °C). Its corrosion resistance in both Conditions TH 1050 and RH 950 is superior to that of the hardenable chromium types. In some environments, corrosion resistance approximates that of the austenitic chromium nickel stainless steels. In Condition CH 900, its general corrosion resistance is comparable to that of Type 304. Fabricating practices recommended for other chromium-nickel stainless steels can be used for this material.

Composition		(wt %)
Carbon	(C)	0.09 max.
Manganese	(Mn)	1.00 max.
Phosphorus	(P)	0.040 max.
Sulfur	(S)	0.030 max.
Silicon	(Si)	1.00 max.
Chromium	(Cr)	16.00 – 18.00
Nickel	(Ni)	6.50 – 7.75
Aluminum	(Al)	0.75 – 1.50

AVAILABLE FORMS

Cleveland-Cliffs 17-7 PH Stainless Steel is produced in sheet and strip in thicknesses from 0.015 – 0.19 in. (0.38 – 4.66 mm). Material is supplied in Condition A, ready for fabrication by the user. Sheet and strip material of 0.040 in. (1.02 mm) and thinner is also produced in the hard-rolled Condition C for applications requiring maximum strength.

SPECIFICATIONS

The following specifications are listed without revision indications. Contact ASTM Headquarters, AMS Division of SAE or Department of Defense Index for latest revisions.

- **AMS 5528** Sheet, Strip and Plate
- **AMS 5529** Sheet and Strip – Cold Rolled
- **ASTM A 693** Plate, Sheet and Strip
  (Listed as Grade 631- UNS S17700)

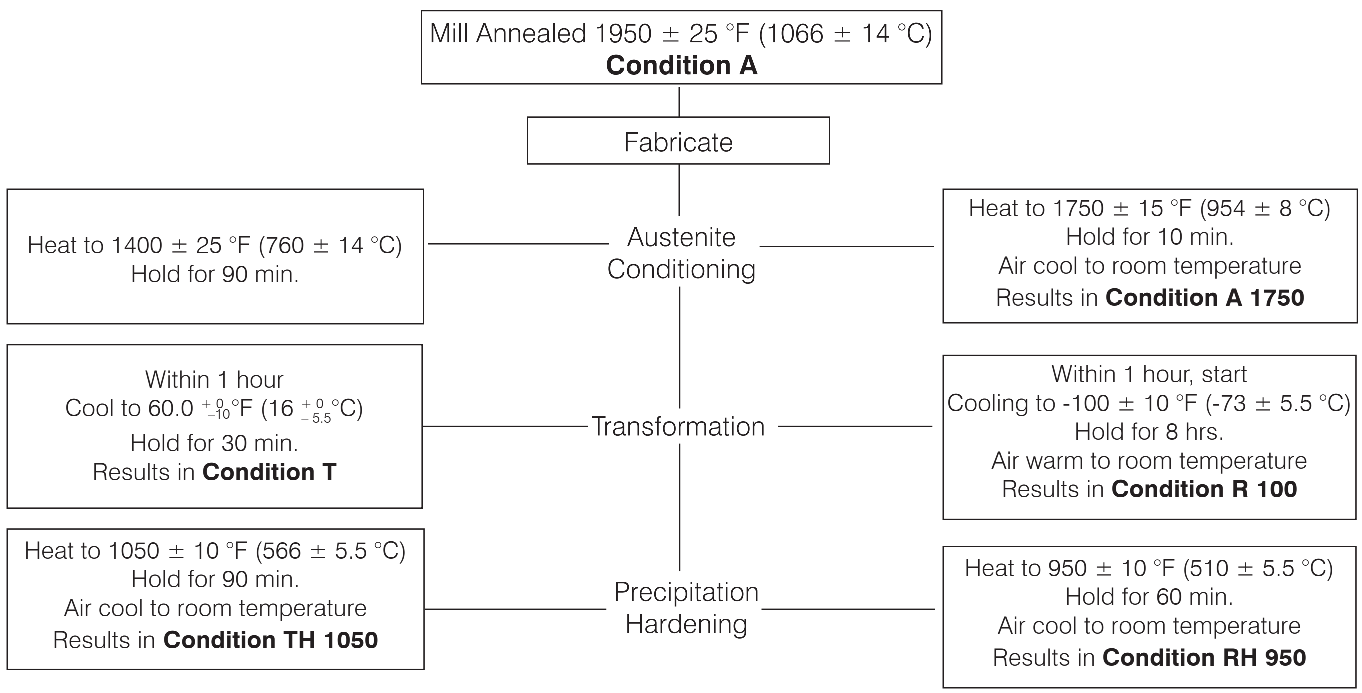
The values shown in this bulletin were established in U.S. customary units. The metric equivalents may be approximate.

Standard Heat Treatments

Cleveland-Cliffs 17-7 PH Stainless Steel requires three essential steps in heat treating:
1) Austenite conditioning
2) Cooling to transform the austenite to martensite
3) Precipitation hardening

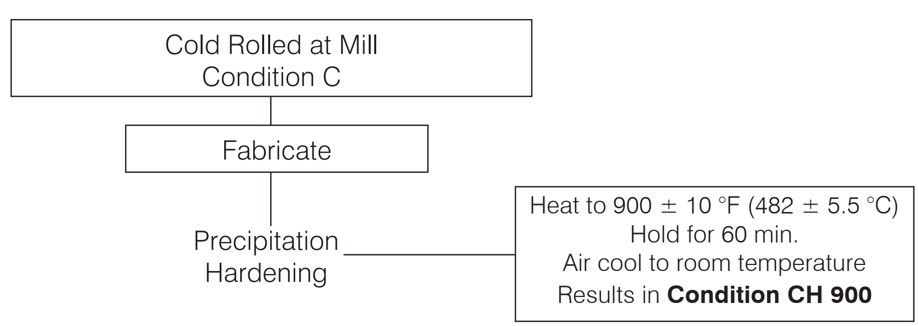
FIgure 1 presents the procedures for heat treating material in Condition A to Conditions TH 1050 and RH 950.

FIGURE 1 – STANDARD HEAT TREATMENTS



Note: Full TH 1050 properties may not be developed when PH 15-7 Mo® Stainless Steel (cold worked) is heat treated to Condition TH 1050. However, full properties will be developed by using one of the following methods:
1) Re-anneal the fabricated part to Condition A and heat treat to Condition TH 1050.
2) Heat treat fabricated part to an RH 1050 Condition.
3) Use a modified TH 1050 heat treatment. For further information on this heat treatment, contact Cleveland-Cliffs or your distributor.
No variation in properties is encountered when heat treating fabricated parts to Condition RH 950.

The highest strength levels obtainable from Cleveland-Cliffs 17-7 PH Stainless Steel are produced by Condition CH 900. To obtain these properties, Condition A material is transformed to martensite at the mill by cold reduction to Condition C. Hardening to Condition CH 900 is accomplished with a single, low-temperature heat treatment.



Mechanical Properties

TABLE 1 – TYPICAL MECHANICAL PROPERTIES

Property	Condition							
	A	T	TH 1050	A 1750	R 100	RH 950	C	CH 900
UTS, ksi. (MPa)	120 (827)	145 (1000)	200 (1379)	133 (917)	175 (1207)	230 (1586)	230 (1586)	295 (2034)
0.2% YS, ksi. (MPa)	45 (310)	100 (690)	185 (1276)	42 (290)	115 (793)	210 (1448)	190 (1310)	275 (1896)
Elongation % in 2 in. (50.8 mm)	35	9	8	19	9	7	5	2
Rockwell Hardness	B85	C31	C43	B95	C37	C48	C44	C52

TABLE 2 – PROPERTIES ACCEPTABLE FOR MATERIAL SPECIFICATION*

Property	Condition				
	A	TH 1050	RH 950	C	CH 900
UTS, ksi. (MPa)	150 max. (1034)	180 min. (1241)	210 min. (1448)	200 min. (1379)	240 min. (1655)
0.2% YS, ksi. (MPa)	55 max. (379)	150 min. (1034)	190 min. (1310)	175 min. (1207)	230 min. (1586)
Elongation % in 2 in. (50.8 mm)	20 min.	—	—	1 min.	1 min.
0.036 – 0.1874 in. (0.91 – 4.7 mm)	—	6 min.	5 min.	—	—
0.20 – 0.0359 in. (0.50 – 0.89 mm)	—	6 min,	4 min.	—	—
0.10 – 0.0199 in. (0.25 – 0.49 mm)	—	5 min.	3 min,	—	—
Rockwell Hardness**	B92 max.	C38 min.	C44 min.	C41 min.	C46 min.

**Material 0.010 in. (2.54 mm) and thinner will have a maximum yield strength of 65 ksi. (448 MPa).*
***Applies to material 0.010 in. (0.25 mm) and thicker. Selection of hardness scale is determined by material condition and thickness. Where necessary, superficial hardness readings are converted to Rockwell B or C.*

TABLE 3 – FATIGUE STRENGTH AND ENDURANCE LIMIT

	Condition				
	Property	TH 1050	C	CH 900	RH 950
Endurance Limit (15 x 10^6 cycles), ksi. (MPa)					
Heat-treated Surface	63.5 (438)	—	—	77.5 (534)	—
Pickled Surface	62.5 (431)	—	—	—	—
Vapor Blasted Surface	82.1 (566)	—	—	100.0 (690)	—
Polished Surface (120 grit)	88.3 (609)	—	—	—	—
Fatigue Strength (10^7 cycles), ksi. (MPa) Heat-treated, Pickled or Polished Surface	—	—	82.3 (567)	—	—
0.2% Compressive Yield Strength, ksi. (MPa) Transverse Direction	203 (1400)	218 (1503)	300 (2068)	240 (1655)	—

Mechanical Properties

TABLE 4 – TYPICAL ELEVATED TEMPERATURE SHORT-TIME TENSILE PROPERTIES

Property	Temperature °F (°C)						
	75 (24)	300 (149)	500 (260)	600 (316)	700 (371)	800 (427)	900 (482)
UTS, ksi. (MPa)							
Condition TH 1050	193 (1331)	179 (1234)	167 (1151)	162 (1117)	156 (1076)	143 (986)	124 (855)
Condition RH 950	230 (1586)	208 (1434)	195 (1345)	189 (1303)	181 (1248)	160 (1103)	133 (917)
Condition CH 900	261 (1805)	248 (1710)	228 (1572)	222 (1531)	—	207 (1427)	182 (1258)
0.2% US, ksi. (MPa)							
Condition TH 1050	182 (1255)	170 (1172)	160 (1103)	155 (1069)	146 (1007)	130 (896)	100 (690)
Condition RH 950	217 (1496)	192 (1324)	176 (1213)	169 (1165)	162 (1117)	137 (945)	114 (786)
Condition CH 900	245 (1695)	233 (1610)	214 (1476)	203 (1403)	—	176 (1115)	143 (989)
Elongation % in 2 in. (50.8 mm)							
Condition TH 1050	10.0	8.0	4.5	4.0	4.5	6.2	10.0
Condition RH 950	6.0	4.5	4.5	5.0	7.0	12.0	15.0
Condition CH 900	5.0	4.0	3.0	3.0	—	5.0	6.0

TABLE 5 – STRESS TO RUPTURE

Property	Temperature °F (°C)			
	600 (316)	700 (371)	800 (427)	900 (482)
In 100 hrs., Stress, ksi. (MPa)				
Condition TH 1050	170 (1172)	130 (896)	110 (758)	78 (538)
Condition RH 950	188 (1296)	160 (1165)	113 (779)	61 (421)
Condition CH 900	220 (1517)	194 (1338)	135 (931)	53 (3651)
In 1000 hrs., Stress, ksi. (MPa)				
Condition TH 1050	158 (1089)	122 (841)	90 (620)	52 (358)
Condition RH 950	180 (1241)	146 (1007)	92 (634)	44 (303)
Condition CH 900	216 (1489)	180 (1241)	73 (503)	36 (248)
In 100 hrs., Elongation at rupture, % in 2 in. (50.8 mm)				
Condition TH 1050	19.0	21.0	21.0	30.0
Condition RH 950	13.0	21.0	15.0	33.0
Condition CH 900	10.0	11.0	20.0	14.0
In 1000 hrs., Elongation at rupture, % in 2 in. (50.8 mm)				
Condition TH 1050	17.0	24.0	23.0	40.0
Condition RH 950	11.5	17.0	26.0	26.0
Condition CH 900	8.0	9.0	9.0	12.0

Mechanical Properties

TABLE 6 – CREEP STRENGTH

Stress in ksi. (MPa) to produce	Temperature °F (°C)			
	600 (316)	700 (371)	800 (427)	900 (482)
0.1% permanent deformation in 1000 hours Condition TH 1050	87.0 (600)	57.0 (393)	40.0 (276)	15.0 (103)
Condition RH 950	105.0 (724)	60.0 (414)	31.0 (214)	12.5 (86)
0.2% permanent deformation in 1000 hours Condition TH 1050	105.0 (724)	70.0 (483)	45.0 (310)	18.0 (124)
Condition RH 950	126. 0 (869)	87.0 (600)	36.0 (248)	14.0 (96)

TABLE 7 – PHYSICAL PROPERTIES

	Condition			
	A	TH 1050	RH 950	CH 900
Density, lbs./in³ (g/cm³)	0.282 (7.81)	0.276 (7.65)	0.276 (7.65)	0.277 (267)
Modulus of Elasticity, ksi. (GPa)	–	29.0×10^3 (200)	29.0×10^3 (200)	–
Electrical Resistivity, µΩ•cm	80	82	83	83
Magnetic Permeability, H/m				
@ 25 oersteds	1.4 – 3.4	132 – 194	82 – 88	–
@ 50 oersteds	1.4 – 3.6	120 – 167	113 – 130	–
@ 100 oersteds	1.4 – 3.5	80 – 99	75 – 87	70
@ 200 oersteds	1.4 – 3.2	46 – 55	44 – 52	43.5
Maximum	1.4 – 3.6	134 – 208	119 – 135	125
Thermal Conductivity, BTU/hr./ft²/°F (W/m/K)				
300 °F (149 °C)	–	117 (16.9)	117 (est) (16.9)	114 (16.4)
500 °F (260 °C)	–	128 (18.5)	128 (est) (18.5)	127 (18.3)
840 °F (449 °C)	–	146 (21.1)	146 (est) (21.1)	150 (21.6)
900 °F (482 °C)	–	146 (21.1)	146 (est) (21.1)	151 (21.8)
Mean Coefficient of Thermal Expansion in./in./°F (µm/m/K)				
70 – 200 °F (21 – 93 °C)	8.5×10^{-6} (15.3)	5.6×10^{-6} (10.1)	5.7×10^{-6} (10.3)	6.1×10^{-6} (11.0)
70 – 400 °F (21 – 204 °C)	9.0×10^{-6} (16.2)	6.1×10^{-6} (11.0)	6.6×10^{-6} (11.9)	6.2×10^{-6} (11.2)
70 – 600 °F (21 – 316 °C)	9.5×10^{-6} (17.1)	6.3×10^{-6} (11.3)	6.8×10^{-6} (12.2)	6.4×10^{-6} (11.5)
70 – 800 °F (21 – 427 °C)	9.6×10^{-6} (16.0)	6.6×10^{-6} (11.9)	6.9×10^{-6} (12.4)	6.6×10^{-6} (11.9)

Variations in heat-treating temperatures have negligible effect on electrical resistivity. Annealing, transforming and hardening treatment variations of ± 100 °F (56 °C) will not cause the resistivity to vary outside ± 3% from the listed value. Electrical resistivity value for Condition T is 107 µΩ•cm.

No appreciable change in effective magnetic permeability exists in either Condition A or Condition TH 1050 between room temperature and 500 °F (260 °C).

DIMENSIONAL CHANGES

When Cleveland-Cliffs 17-7 PH Stainless Steel is heat treated from Condition A to either Condition RH 950 or TH 1050, a net dimensional expansion of approximately 0.004 in./in. occurs. This dimensional change is the result of an expansion of about 0.0045 in./in. resulting from the transformation treatment and a contraction of about 0.0005 in./in. resulting from the precipitation-hardening treatment.

Heat treating Condition C to Condition CH 900 results in a contraction of about 0.0005 in./in.

Corrosion Resistance

Corrosion resistance of Cleveland-Cliffs 17-7 PH Stainless Steel in Conditions TH 1050 and RH 950 is generally superior to that of the standard hardenable chromium types of stainless steels, such as Types 410, 420 and 431, but is not quite as good as chromium-nickel Type 304. Corrosion resistance in Condition CH 900 approaches that of Type 304 stainless steel in most environments.

ATMOSPHERIC EXPOSURE

In coastal exposure, samples show considerably better corrosion resistance than hardened chromium stainless steels, such as Type 410. Although there is little difference between any successive two ratings shown in Table 8, samples indicated the following order of corrosion resistance based on general appearance:

1. Type 301
2. 17-7 PH Stainless Steel in Condition CH 900
3. 17-7 PH Stainless Steel in Condition TH 1050
4. PH Stainless Steel in Condition RH 950

In all heat-treated conditions, the alloy, like other types of stainless steel, will develop superficial rust in some environments. For example, in a marine atmosphere, stainless steels show evidence of rusting after relatively short exposure periods. However, after exposure for one or two years, the amount of rust present is little more than that which was present at six months.

CHEMICAL MEDIA

Hundreds of accelerated laboratory corrosion tests have been conducted on the precipitation-hardening stainless steels since their development. Table 8 shows typical corrosion rates for Cleveland-Cliffs 17-7 PH Stainless Steel and Type 304 in seven common reagents. Sheet coupons and chemically pure laboratory reagents were used. Consequently, the data can be used only as a guide to comparative performance.

TABLE 8 – CORROSION RATES IN VARIOUS MEDIA, MILLS PER YEAR*

Corrosive Medium	Cleveland-Cliffs 17-7 PH SS		Type 304
	TH 1050	RH 950	Annealed
H_2SO_4 – 95 °F (35 °C)			
1%	0.5	0.2	0.4
2%	0.9	0.7	1.3
5%	124	132	7.7
H_2SO_4 – 176 °F (80 °C)			
1%	50	297	22.2
2%	374	884(2)	65
HCl – 95 °F (35 °C)			
0.5%	65	4	7.1
1%	695(2)	447(3)	17.3
HNO_3 – Boiling			
25%	19	20.4	1.2
50%	70	81	3.0
65%	128	136	7.2
Formic Acid – 176 °F (80 °C)			
5%	2.7	4.3	4.1
10%	5.5	5.7	18.0
Acetic Acid – Boiling			
33%	3.1	5.6	2.6
60%	12.3	3.0	10.9
H_3PO_4 – Boiling			
20%	7.0	18	1.6
50%	24	46	8.5
70%	104	315	39
NaOH – 176 °F (80 °C)			
30%	13.1	3.7	0.9
NaOH – Boiling			
30%	67	58	17.5

**Rates were determined by total immersion for five 48-hour periods. Specimens were activated during last three test periods in the 65% nitric acid. Rate is average of number of periods indicated in parentheses, if fewer than five periods were run.*

Corrosion Resistance

CORROSION RESISTANCE AND COMPATABILITY IN ROCKET FUELS

Oxygen – While oxygen is highly reactive chemically, liquid oxygen is noncorrosive to most metals. The precipitation hardening stainless steels experience no problem in this medium.

Ammonia – Cleveland-Cliffs 17-7 PH Stainless Steel is satisfactory for handling ammonia.

Hydrogen – Liquid hydrogen and gaseous hydrogen at low temperatures are noncorrosive.

STRESS CRACKING IN MARINE ENVIRONMENTS

The precipitation-hardening stainless steels, like the hardenable chromium stainless steels, may be subject to stress corrosion cracking when stressed and exposed to some corrosive environments. The tendency is related to the type of stainless steel, its hardness, the level of tensile stress and the environment.

Cleveland-Cliffs has conducted stress cracking tests on the precipitation-hardening alloys in a marine atmosphere 82 ft. (25 m) from the waterline using two-point loaded bent-beam specimens.

Data reported here are the results of multiple specimens exposed at stress levels of 50% and 75% of the actual yield strength of the materials tested. Test specimens of 0.050 in. (0.127 mm) thick were heat treated to Conditions TH 1050 and RH 950. Specimens in Condition CH 900 were 0.041 in. (1.04 mm) thick. The long dimension of all specimens was cut transverse to the rolling direction.

When comparing the various heat-treated conditions, the data show that Cleveland-Cliffs 17-7 PH Stainless Steel has the greatest resistance to stress cracking in Condition CH 900. Likewise, Condition TH 1050, although somewhat less resistant than Condition CH 900, appears to be more resistant to stress cracking than Condition RH 950.

Table 9 summarizes the test data. In addition, in the mild industrial atmosphere in midwest United States, specimens stressed at 90% of their yield strength had not broken after 730 days of exposure.

TABLE 9 – SUMMARY OF STRESS-CRACKING TESTS IN COASTAL EXPOSURE

Heat Treatment	Stressed at 50% of the 0.2% Yield Strength			Stressed at 50% of the 0.2% Yield Strength		
	Stress, ksi. (MPa)	Days to Failure	Range Days	Stress, ksi. (MPa)	Days to Failure	Range Days
TH 1050	100.8 (694)	No failures in 746 days	–	151.3 (1043)	100 (2)**	82 – 118***
TH 1050	89.0 (614)	No failures in 746 days	–	133.6 (921)	No failure in 746 days	–
RH 950	111.6 (769)	30.2	16 – 49	167.5 (1154)	7.4	6 – 10
RH 950	110.2 (759)	116(1)**	–	165.4 (1141)	51.6	26 – 71
CH 900	142.8 (986)	No failures in 746 days	–	214.2 (1476)	No failures in 746 days	–

Exposed Marine Atmosphere
*** Number in brackets indicates number of failed specimens unbroken after 746 days.*
****Range of broken specimens only. Remainder of 5 specimens unbroken after 746 days.*
NOTE: All tests made in transverse direction. Tests discontinued after 746 days of exposure.

FORMABILITY

Cleveland-Cliffs 17-7 PH Stainless Steel in Condition A can be formed comparably to Type 301. It work hardens rapidly and may require intermediate annealing in deep drawing or in forming intricate parts. Springback is similar to that of Type 301.

This alloy is extremely hard and strong in Condition C. Therefore, fabrication techniques for such materials must be used.

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 poorer weldability compared to the most common alloy of this stainless class, Cleveland-Cliffs 17-4 PH® Stainless Steel. A major difference is the high Al content of this alloy, which degrades penetration and enhances weld slag formation during arc welding. Also, the austenite conditioning and precipitation hardening heat treatments are both required after welding to achieve high strength levels. When a matching weld filler is needed, AMS 5824/UNS S17780 is most often specified.

COATINGS

Protective coatings offer little advantage in reducing oxidation of the metal surface during heat treatments if the parts are thoroughly cleaned. However, when thorough cleaning is impractical, coatings may be beneficial. If such coatings are used, extreme caution must be exercised to provide free air circulation around the coated parts, or carburization may result.

SCALE REMOVER

Scale develops during most heat-treating operations. The amount and nature of the scale formation varies with the cleanliness of the parts, the furnace atmosphere and the temperature and time of heat treatment. A variety of descaling methods may be employed, and the method chosen often depends upon the facilities available. A tabulation of the recommended scale removal methods after various heat treatments is shown in Table 10.

Properties

HEAT TREATMENT

Heat Treating and Annealing

For in-process annealing, the alloy should be heated to 1950 ± 25 °F (1066 ± 14° C) for three minutes for each 0.1 in. (2.5 mm) of thickness, and air cooled. This treatment may be required to restore the ductility of cold-worked material so that it can take additional drawing or forming. Although most formed or drawn parts do not require re-annealing prior to hardening, annealing is required on severely formed or drawn parts to be heat treated to Condition TH 1050 if full response to heat treatment is required. Annealing is unnecessary in the case of the RH 950 heat treatment.

Equipment and Atmosphere

Selection of heat-treating equipment depends to some extent on the nature of the particular parts to be treated. However, heat source, atmosphere and control of temperatures are the primary considerations.

Furnaces fired with oil or natural gas are difficult to use in the heat treatment of stainless steels, particularly if combustion control is uncertain and if flame impingement on the parts is possible. Electric furnaces, gas-and oil-fired radiant tube furnaces or vacuum furnaces generally are used for heat treating this material.

Air provides a satisfactory furnace atmosphere for heat treating and annealing operations. Controlled reducing atmospheres such as dissociated ammonia or bright annealing gas introduce the hazard of nitriding and/or carburizing or decarburizing and should not be used.

Bright annealing may be accomplished in a dry hydrogen, argon, or helium atmosphere (dew point approximately -65 °F (-54 °C); if a cooling rate, approximately that obtained in an air cool can be used. Dry hydrogen, argon or helium (dew point approximately -75 °F (-59 °C) may be used for the 1750 °F (954 °C) heat treatment outlined for Condition RH 950, and will provide an essentially scale-free surface. At heat-treating temperatures of 1400 °F (760 °C) and lower, scale-free heat treatment in a dry hydrogen, argon or helium atmosphere is difficult to achieve. A vacuum furnace is required for complete freedom from scale or heat discoloration.

Multiple exposures to a nitrogen atmosphere during annealing or quenching from vacuum may result in a surface layer of uniformly distributed small nitrides. These inclusions tend to decrease fabricability in subsequent cold-forming operations. Furnace loads should be such that cooling to 1000 °F (538 °C) may be effected within eight minutes to achieve best results.

It is necessary to cool this material to a temperature of -100 °F (-73 °C) for a period of eight hours when heat treating to the RH condition. While commercial equipment is available for refrigeration at this temperature, a saturated bath of dry ice in alcohol or acetone maintains a temperature of -100 to -109 °F (-73 to -78 °C) without control equipment.

Annealing at 1950 °F (1066 °C) or austenite conditioning at 1750 or 1400 °F (954 or 760 °C) in molten salts is not recommended because of the danger of carburization and/or intergranular penetration. However, hardening at 900 – 1200 °F (482 – 649 °C) has been done successfully with a few salts of the hydride or nitrate types.

Cleaning Prior To Annealing or Heat Treating

Thorough cleaning of parts and assemblies prior to heat treatment greatly facilitates scale removal and is necessary for the development of uniform properties. Removal of oils and lubricants with solvents also assures that the steel will not be carburized from this source. Carburized Cleveland-Cliffs 17-7 PH Stainless Steel will not respond properly to heat treatment.

Cleaning may be accomplished by the following two step procedure:

1. Vapor degrease or solvent clean. This step removes oil, grease and drawing lubricants.
2. Mechanical scrubbing with mild abrasive cleaners, Oakite 33 or similar proprietary cleaners to remove dirt or other insoluble materials. All traces of cleaners should be removed by rinsing thoroughly with warm water.

A light, tightly-adherent, uniform-appearing oxide after heat treatment is evidence of proper cleaning.

TABLE 10 – SCALE REMOVER METHODS

Heat Treated to Condition	Preferred Methods After Heat Treatment	Secondary Methods
A	Wet Grit Blast(1) or Pickle(2)	Scale Condition and Pickle(3)
CH 900	Wet Grit Blast(1) or Pickle(2)	–
A 1750	Wet Grit Blast(1)	Pickle(2) or Scale Condition and Pickle(4)
T and R 100	Wet Grit Blast(1)	Pickle(2) or Scale Condition and Pickle(5)
TH 1050 and RH 950	Wet Grit Blast (1)	Pickle(2) or Scale Condition and Pickle(3)

(1) Wet Grit Blasting processes are widely used and are highly satisfactory. These methods eliminate the hazard of intergranular attack from acid pickling. Added advantages are better fatigue strength and corrosion resistance.

(2) 10% $HN0_3$ + 2% HF at 110 – 140 °F (49 – 60 °C) for three minutes maximum. Removal of loosened scale may be facilitated by the use of high-pressure water or steam spray. Scale-conditioning treatment is unnecessary for parts that have been thoroughly cleaned. Uniform pickling of the entire surface is evidence of a well-cleaned part. A spotty scale and non-uniform removal is evidence of a poorly cleaned part, and a scale conditioning process is necessary prior to pickling.

(3) Scale conditioners:
(a) Kolene Process
(b) DuPont Hydride Process
(c) Caustic permanganate (boiling 10% NaOH + 3% $KMn0_4$ for one hour)

(4) Use caustic permanganate scale conditioning followed by $HN0_3$ – HF pickle only. Do not use fused salts. The use of fused salts on Cleveland-Cliffs 17-7 PH Stainless Steel in Condition A 1750 will prevent the steel from developing maximum transformation upon subsequent refrigeration.

(5) Scale condition and pickle as in method 3. The Virgo and Kolene salt baths may be operated at temperatures up to 1100 °F (593 °C) so that the hardening and scale conditioning treatment may be combined if desired. However, the operation of a salt bath at such temperatures should be checked with the manufacturer before proceeding.

Some degree of intergranular penetration occurs during any pickling operation. However, the penetration from the short-time pickling of this material in Condition CH 900 is generally slight. Other conditions are more susceptible to intergranular penetration during pickling. Consequently, pickling should be avoided or carefully controlled if it must be used for such removal.

The standard 10% HN0 + 2% HF acid bath may be used for removal of light discoloration or heat tint produced by the final hardening treatment at 900 – 1200 °F (482 – 649 °C), providing immersion times are kept short (in the order of one minute or less).

About Cleveland-Cliffs Inc.

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.

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