Austenitic Stainless Steels

Introduction

The austenitic stainless steels may be divided into three groups: (a) the normal unstabilized compositions, such as types 201, 202, 205, 301, 302, 303, 304, 304N, 305, 308, 309, 310, 316, 316N, 329, 330, and 384 (of these, 201, 202, 304N, and 316N are high-nitrogen grades); (b) the stabilized compositions, principally types 321, 347, and 348; and (c) the extra-low-carbon grades, such as types 304L, 316L, and 317L.

Recommended Heat Treating Practice

The steels listed in the table on this page cannot be hardened except by cold working. Only three types of heat treatments are applicable: (a) full annealing, (b) stress relieving, and (c) nitriding.

Regardless of the treatment used, loading austenitic stainless parts into the furnace requires special consideration because of their high thermal expansion, approximately 50% greater than for carbon or alloy steels. Therefore, spacing between the parts must be adequate to allow for this expansion. Stacking, when necessary, should be employed judiciously to avoid deformation of the parts at elevated temperature.

Annealing the Unstabilized Grades. Steels of the 200 series, members of the 300 series from 301 through 317, and types 329, 330, and 384 are all unstabilized. These steels are annealed to ensure maximum corrosion resistance and to restore maximum softness and ductility, which result from cold working. During annealing, carbides, which markedly decrease resistance to intergranular corrosion, are dissolved. Annealing temperatures, which vary somewhat with the composition of the steel, are given in the adjoining table.

Because carbide precipitation can occur at temperatures between 425 and 900 °C (795 and 1650 °F), annealing temperature should be safely above this limit. Moreover, because all carbides should be in solution before cooling begins and because the chromium carbide dissolves slowly, the highest practical temperature consistent with limited grain growth is selected. This temperature is in the vicinity of 1095 °C (2005 °F).

Cooling from the annealing temperature must be rapid, no more than approximately 3 min in cooling from 870 to 425 °C (1600 to 795 °F), but it must also be consistent with limitations of distortion. Whenever considerations of distortion permit, water quenching is used, thus ensuring that dissolved carbides remain in solution. Because they precipitate carbides more rapidly, types 309 and 310 invariably require water quenching. Where practical considerations of distortion rule out such a rapid cooling rate, cooling in an air blast is often used. With some thin-section parts, even this intermediate rate of cooling produces excessive distortion, and parts must be cooled in still air. If cooling in still air does not provide a rate sufficient to prevent carbide precipitation, maximum corrosion resistance will not be obtained. A solution to this problem is the use of a stabilized grade.

Annealing the Stabilized Grades. Types 321, 347, and 348 contain controlled amounts of titanium or columbium plus tantalum, which render the steel nearly immune to intergranular precipitation of chromium carbide and its adverse effects on corrosion resistance. Nevertheless, these alloys may require annealing to relieve stresses, increase softness and ductility, or provide additional stabilization.

To obtain maximum softness and ductility, the stabilized grades are annealed at the temperatures shown in the Table below. Unlike the unstabilized grades, these steels do not usually require water quenching or other acceleration of cooling from the annealing temperature to prevent subsequent intergranular corrosion. Air cooling is generally adequate. However, sections thicker than approximately 6.4 mm (0.25 in.) should be quenched in oil or water.

Full Annealing Temperatures for Austenitic Stainless Steels

Type		Annealing temperature	
AISI	UNS	°F	°C
201	S20100	1850-2050	1010-1120
202	S20200	1850-2050	1010-1120
205	S20500	1950	1065
301	S30100	1850-2050	1010-1120
302	S30200	1850-2050	1010-1120
302B	S30215	1850-2050	1010-1120
303	S30300	1850-2050	1010-1120
303Se	S30323	1850-2050	1010-1120
304	S30400	1850-2050	1010-1120
304L	S30403	1850-2050	1010-1120
...	S30430	1850-2050	1010-1120
304N	S30451	1850-2050	1010-1120
305	S30500	1850-2050	1010-1120
308	S30800	1850-2050	1010-1120
309	S30900	1900-2050	1040-1120
309S	S30908	1900-2050	1040-1120
310	S31000	1900-2100	1040-1150
310S	S31008	1900-2100	1040-1150
314	S31400	2100	1150
316	S31600	1850-2050	1010-1120
316L	S31603	1850-2050	1010-1120
316F	S31620	2000	1095
316N	S31651	1850-2050	1010-1120
317	S31700	1850-2050	1010-1120
317L	S31703	1900-2000	1040-1095
321	S32100	1750-2050	955-1120
329	S32900	1750-1800	955-980
330	N08330	1950-2150	1065-1175
347	S34700	1850-2050	1010-1120
348	S34800	1850-2050	1010-1120
384	S38400	1900-2100	1040-1150

When maximum corrosion resistance of type 321 is required, using a corrective heat stabilizing treatment may be necessary. This treatment consists of holding at 845 to 900 °C (1555 to 1650 °F) for up to 5 h, depending on section thickness. Such a treatment may be applied before or during the course of fabrication. If needed, this treatment may be followed by a short stress relieving treatment at 705 °C (1300 °F) without danger of carbide precipitation. This treatment is seldom, if ever, used for grades 347 and 348.

Annealing the Extra-Low-Carbon Grades. Types 304L (extra low carbon), 316L, and 317L are intermediate in precipitation of chromium carbides to the stabilized and unstabilized grades. Carbon content (0.03 maximum) is low enough to reduce precipitation of intergranular carbides to a safe level. Thus, these steels can be held in the sensitizing range of 425 to 815 °C (795 to 1500 °F) for periods up to 2 h and cooled slowly through this range, without danger of susceptibility to intergranular corrosion in natural atmospheric environments. This characteristic is of particular value in welding, flame cutting, and other hot working operations. These grades do not require the quenching treatment that unstabilized grades require to retain carbon in solid solution. Nevertheless, the low-carbon alloys are not satisfactory for long service in the sensitizing temperature range, because they are not completely immune to the formation of carbides deleterious to corrosion resistance.

Stress Relieving the Austenitic Grades. Quenching from the annealing temperature range within the usual period of 3 min is a drastic thermal treatment. This treatment may generate new stresses, particularly if the overall cooling is not uniform or if the fabricated article is not of symmetrical contour. Excessive warpage (thermal distortion) may be encountered. Cooling rates should be as uniform as possible, regardless of whether the fabricated article is fast cooled in air, by water sprays, or by complete immersion.

Stress relieving of the quench-annealed parts may be accomplished by heating them within the temperature range of 230 to 400 °C (445 to 750 °F) for relatively long periods of time, often several hours. This treatment will not impair corrosion resistance or mechanical properties. It can be applied to any of the austenitic grades, although it is most often used for the unstabilized grades because they are more often subjected to drastic quenching, as described above.

Nitriding the Austenitic Grades. Austenitic stainless steels can be nitrided by the gas process, wherein the ammonia is dissociated in a separate cracking unit prior to its entry into the workpiece zone.

Only the stabilized or extra-low-carbon grades are recommended for nitriding, for the obvious reason that the nitriding temperature of approximately 540 °C (1000 °F) is in the sensitizing range.

Further, the nitrided case that can be achieved on the austenitic grades is very thin, seldom more than 0.125 mm (0.005 in.). Therefore, no finishing operations can be permitted or the case will be removed. In addition, nitriding seriously impairs resistance to corrosion in most media. Thus, nitriding of austenitic stainless steels is done only for highly specialized applications; for example, where the material must be nonmagnetic and still have an abrasion-resisting surface.

Forging the Austenitic Grades. These steels are more difficult to forge than are carbon or alloy steels, because austenitic stainless steels have high hot strength. However, because they do not undergo a phase change, most of them can be forged over a reasonably broad temperature range above 925 °C (1695 °F). Exceptions to the above are types 309, 310, and 314, which should not be forged at temperatures much above 1095 °C (2005 °F) because they are susceptible to formation of delta ferrite, which impairs forgeability.

In forging of the austenitic grades, the finishing temperatures are more important. Preferably, finishing temperature should not drop below 925 °C (1695 °F) and never below 870 °C (1600 °F).

All but the stabilized grades 321, 347, and 348 and those bearing the suffix letter L (extra low carbon) should be cooled, liquid quenched if necessary, from approximately 870 °C (1600 °F) to a black heat in no more than 3 min. Cooling rates for the stabilized and the extra-low-carbon grades are less critical. In addition, the more highly alloyed grades 309, 310, and 314 are limited in finishing temperature, because at lower temperatures they are susceptible to both hot tearing and formation of sigma phase.

201

Chemical Composition. **AISI/UNS (S20100):** 0.15 C max, 5.50 to 7.5 Mn, 0.060 P max, 0.030 S max, 1.00 Si max, 3.50 to 5.50 Ni, 16.00 to 18.00 Cr, 0.25 N max

Similar Steels (U.S. and/or Foreign). ASME SA412; ASTM A412, A429, A666; FED QQ-S-766; SAE J405 (30201)

Characteristics. An austenitic grade using a combination of manganese and nickel. Used primarily in corrosive environments or where bright metal appearance is required. Hardenable by cold work only. Heat treatment limited to: annealing to restore maximum corrosion resistance, softness, and ductility after cold working; stress relieving when required for stresses that occur from drastic quench from annealing temperature; and, on rare occasion, nitriding to impart thin, wear-resistant surface

Forging. Start forging at 1150 to 1230 °C (2100 to 2245 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners

should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding is adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

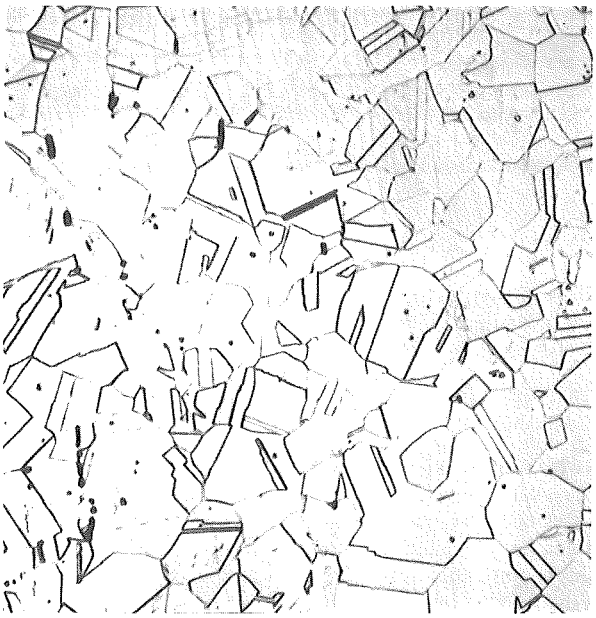
- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

201: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

201: Microstructure. HNO_3-acetic-HCl-glycerol, 250X. Strip, annealed at 1065°C (1950 °F) for 5 min. Cooled rapidly to room temperature. Equiaxed austenite grains and annealing twins



202

Chemical Composition. AISI/UNS (S20200): 0.15 C, 0.06 P, 0.030 S, 1.00 Si, 4.0 to 6.0 Ni, 17.00 to 19.00 Cr, 7.50 to 10.00 Mo, 0.25 N

Similar Steels (U.S. and/or Foreign). ASTM A314, A412, A429, A4763, A666; FED QQ-S-763, QQ-S-766 STD-66; SAE J405 (30202)

Characteristics. A basic, highly available austenitic grade. Similar to type 302, except some nickel replaced by manganese. Used primarily in corrosive environments or where bright metal appearance is required. Hardenable by cold work only. Heat treating limited to: annealing to restore maximum corrosion resistance, softness, and ductility after cold working; stress relieving when required for stresses that occur from drastic quench from annealing temperature; and, on rare occasions, nitriding to impart thin, wear-resistant surface

Forging. Start forging at 1150 to 1230 °C (2100 to 2245 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to

remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F), 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

202: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

205

Chemical Composition. **AISI:** Nominal. 0.12 to 0.25 C max, 14.00 to 15.50 Mn, 0.060 P max, 0.030 S max, 1.00 Si max, 1.00 to 1.75 Ni, 16.50 to 18.00 Cr, 0.32 to 0.40 N. **AISI/UNS (S20500):** 0.12 to 0.25 C, 14.0 to 15.5 Mn, 0.06 P, 0.03 S, 1.00 Si, 1.0 to 1.75 Ni, 0.32 to 0.40 N

Characteristics. Lower rate of work hardening and less change of magnetic permeability than type 202 when cold worked. Used for spinning and special drawing operations

Forging. Start forging at 1230 °C (2245 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1065 °C (1950 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing condi-

tions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F)

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding is adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

301

Chemical Composition. **AISI/UNS (S30100):** 0.15 C, 2.00 Mn max, 0.045 P, 0.030 S, 1.00 Si max, 6.0 to 8.0 Ni, 16.00 to 18.00 Cr

Similar Steels (U.S. and/or Foreign). AMS 5517, 5518, 5519; ASTM A167, A177, A554, A666; FED QQ-S-766; MIL SPEC MIL-S-5059; SAE J405 (30301); (Ger.) DIN 1.4310; (Fr.) AFNOR Z 12 CN 17.08; (Ital.) UNI X 12 CrNi 17 07; (Jap.) JIS SUS 301

Characteristics. Used under mild by corrosive conditions, this steel is capable of high tensile strength and ductility with moderate or severe cold working. Nonmagnetic when annealed. Magnetic when cold worked

Forging. Start forging at 1150 to 1260 °C (2100 to 2300 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). For maximum ductility and softness, use minimum annealing temperature of 1040 °C (1905 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the

oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

301: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

302

Chemical Composition. AISI/UNS (S30200): 0.15 C, 2.00 Mn, 0.045 P, 0.030 S, 1.00 Si, 8.00 to 10.00 Ni, 17.00 to 19.00 Cr

Similar Steels (U.S. and/or Foreign). AMS 5515, 5516, 5636, 5637, 5688; ASME SA240, SA479; ASTM A176, A240, A313, A314, A368, A473, A478, A479, A492, A493, A511, A554, A666; FED QQ-S-763, QQ-S-766, QQ-W-423; MIL SPEC MIL-S-862; SAE J230, J405 (30302)

Characteristics. Can be cold worked to high tensile strengths, but with slightly lower ductility than type 301. Nonmagnetic when annealed. Slightly magnetic when cold worked

Forging. Start forging at 1150 to 1260 °C (2100 to 2300 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of −62 to −74 °C (−80 to −100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than −54 °C (−65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.25 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen

atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F), 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle, from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

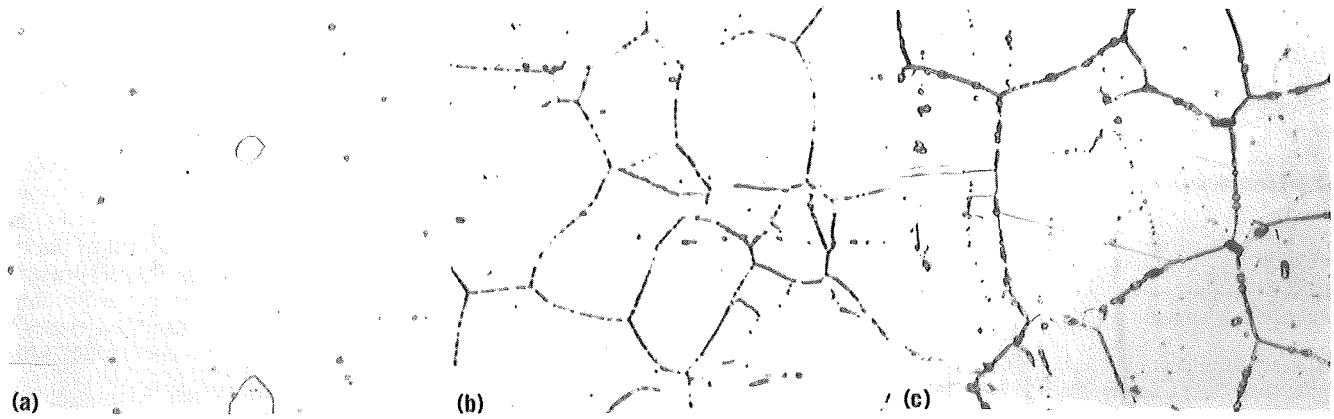
- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

302: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

302: Microstructures . (a) Electrolytic: 10% sodium cyanide, 500×. Strip, 1.56 mm (0.062 in.) thick. Annealed at 1065 °C (1950 °F). Cooled rapidly to room temperature. Ferrite pools (globules) in austenite matrix. (b) Electrolytic: 10% sodium cyanide, 500×. Containing 0.15 carbon. Sensitized 1 h at 650 °C (1200 °F). Etched 5 min. Almost continuous network of carbide at austenite grain boundaries. (c) Electrolytic: 10% chromic acid, 500×. Same as (b), except etch was in 10% chromic acid for ½ min. Grain-boundary carbide network, twinning, and evidence of carbon diffusion within austenite grains



302B

Chemical Composition. AISI/UNS (S30215): 0.15 C, 2.00 Mn, 0.045 P, 0.03 S, 2.0 to 3.0 Si, 8.0 to 10.0 Ni, 17.00 to 19.00 Cr

Similar Steels (U.S. and/or Foreign). ASTM A167, A276, A314, A473, A580; SAE J405 (30302 B)

Characteristics. Resistance to scaling at elevated temperatures superior to type 302 because of added silicon. Nonmagnetic when annealed. Slightly magnetic when cold worked

Forging. Start forging at 1120 to 1230 °C (2050 to 2245 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). For maximum ductility and softness, use a minimum annealing temperature of 1040 °C (1905 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

302B: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

303

Chemical Composition. **AISI/UNS (S30300):** 0.15 C, 2.00 Mn, 0.200 P, 0.150 S min, 1.00 Si, 8.00 to 10.00 Ni, 17.00 to 19.00 Cr, 0.60 Mo (optional)

Similar Steels (U.S. and/or Foreign). AMS 5640 (1); ASME SA194, SA320; ASTM A194, A314, A320, A473, A581, A582; MIL SPEC MIL-S-862; SAE J405 (30303); (Ger.) DIN 1.4305; (Fr.) AFNOR Z 10 CNF 18.09; (Ital.) UNI X 10 CrNiS 18 09; (Jap.) JIS SUS 303; (Swed.) SS_{14} 2346; (U.K.) B.S. 303 S 21

Characteristics. The addition of sulfur aids machinability. Used to minimize seizing or galling. Must be annealed after welding. Suitable for use in automatic screw machines. Less resistant to corrosion than other 300 steels. Shows good resistance to oxidation up to 925 °C (1695 °F)

Forging. Start forging at 1150 to 1290 °C (2100 to 2355 °F). Finish forging at 925 to 955 °C (1695 to 1750 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

303: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

303Se

Chemical Composition. **AISI/UNS (S30323):** 0.15 C, 2.00 Mn, 0.200 P, 0.060 S min, 1.00 Si, 8.0 to 10.0 Ni, 17.0 to 19.0 Cr, 0.15 Se

Similar Steels (U.S. and/or Foreign). AMS 5640 (Type 2), 5641, 5738; ASME SA194, SA320; ASTM A194, A314, A320, A473, A581, A582; MIL SPEC MIL-S-862; SAE J405 (30303 Se)

Characteristics. Selenium addition promotes machinability. Used to minimize seizing or galling. Must be annealed after welding. Suitable for use in automatic screw machines. Less resistant to corrosion than other 300 steels. Shows good resistance to oxidation up to 925 °C (1695 °F)

Forging. Start forging at 1150 to 1290 °C (2100 to 2355 °F). Finish forging at 925 to 955 °C (1695 to 1750 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides

can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

303Se: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

304

Chemical Composition. **AISI/UNS (S30400):** 0.08 C, 2.00 Mn, 0.045 P, 0.030 S, 1.00 Si, 8.0 to 10.5 Ni, 18.0 to 20.0 Cr

Similar Steels (U.S. and/or Foreign). AMS 5501, 5513, 5560, 5565, 5566, 5567, 5639, 5697; ASME SA182, SA194 (8), SA213, SA240, SA249, SA312, SA320 (B8), SA358, SA376, SA403, SA409, SA430, SA479, SA688; ASTM A167, A182, A193, A194, A213, A240, A249, A269, A270, A271, A276, A312, A313, A314, A320, A368, A376, A409, A430, A473, A478, A479, A492, A493, A511, A554, A580, A632, A651, A666, A688; FED QQ-W-423, Q763, QQ-S-766, STD-66; MIL SPEC MIL-F-20138, MIL-S-862, MIL-S-5059, MIL-S-23195, MIL-S-23196, MIL-T-6845, MIL-T-8504, MIL-T-8506; SAE J405 (30304); (Ger.) DIN 1.4301; (Fr.) AFNOR Z 6 CN 18.09; (Ital.) UNI X 5 CrNi 18 10; (Jap.) JIS SUS 304; (Swed.) SS_{14} 2332; (U.K.) B.S. 304 S 15, 302 S 17, 304 S 16, 304 S 18, 304 S 25, 304 S 40, En. 58 E

Characteristics. Corrosion resistance higher than type 302. Nonmagnetic when annealed. Slightly magnetic when cold worked. Less susceptible to precipitation of carbides during welding

Forging. Start forging at 1150 to 1260 °C (2100 to 2300 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). For maximum ductility and softness, use a minimum annealing temperature of 1040 °C (1905 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will

seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

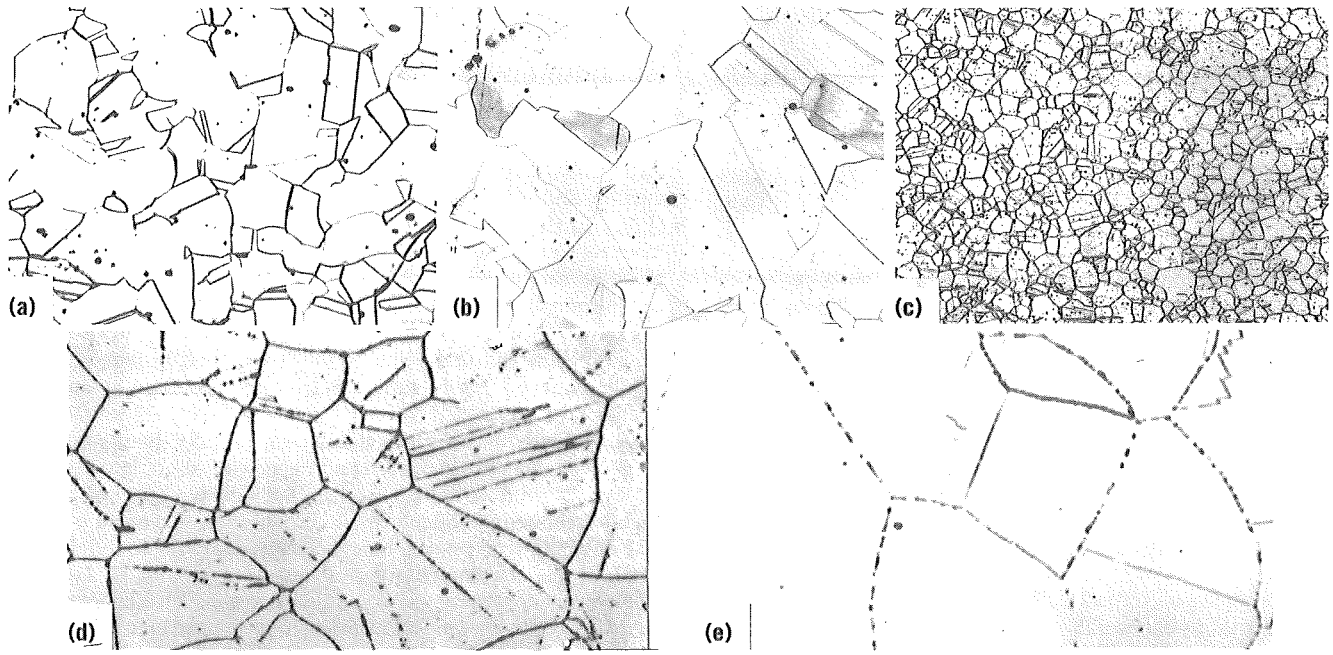
In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

304: Microstructures. (a) HNO_3-acetic-HCl-glycerol, 250×. Strip. Annealed 5 min at 1065 °C (1950 °F). Cooled in air. Equiaxed austenite grains and annealing twins. (b) Electrolytic: 10% oxalic acid, 100×. Forging. Annealed at 1065 °C (1950 °F), 1 h. Quenched in water. Irregular austenite grains. Etch pits at dispersed carbide particles. (c) Electrolytic: HNO_3-acetic, then 10% oxalic acid, 100×. Strip. Annealed 2 min at 1065 °C (1950 °F). Air cooled. Equiaxed austenite grains (ASTM No. 8), annealing twins, small stringer inclusions. (d) Electrolytic: 10% oxalic acid, 500×. Strip. Annealed at 1040 °C (1905 °F). Sensitized by reheating at 650 °C (1200 °F), 1 h. Carbide precipitation at grain boundaries and at twin boundaries. (e) Boiling Murakami's reagent, 500×. Plate with 0.062 carbon content. Annealed for carbide agglomeration by being held at 1065 °C (1950 °F), 1 h. Sensitized by cooling to 800 °C (1475 °F) and held at temperature, 100 h. Water quenched. Precipitation of chromium carbide at austenite grain boundaries



LIVE GRAPH
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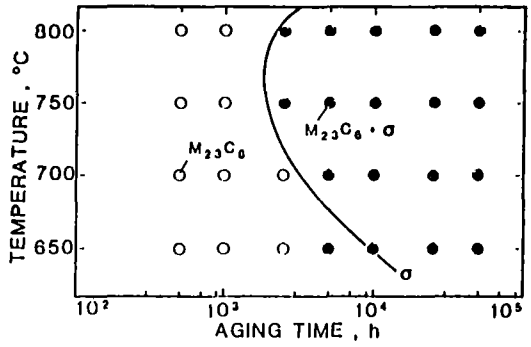
304: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

304: Precipitation Diagram. Composition: 0.05 C, 1.73 Mn, 0.60 Si, 0.028 P, 0.012 S, 9.0 Ni, 18.7 Cr, 0.026 N. Solution treated at 1050 °C (1920 °F) for 30 min, water quenched, aged at 600 to 800 °C (1110 to 1470 °F) for up to 50,000 h



304H

Chemical Composition. AISI/UNS (S30409): 0.04 to 0.10 C, 2.00 Mn, 0.045 P, 0.03 S, 1.00 Si, 8.0 to 10.5 Ni, 18.0 to 20.0 Cr

Recommended Heat Treating Practice

Annealing. In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

304H: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

304L

Chemical Composition. AISI/UNS (S30403): 0.03 C, 2.00 Mn, 0.045 P, 0.030 S, 1.00 Si, 8.0 to 12.0 Ni, 18.0 to 20.0 Cr

Similar Steels (U.S. and/or Foreign). AMS 5511, 5647; ASME SA182, SA213, SA240, SA249, SA312, SA403, SA479, SA688; ASTM A167, A182, A213, A240, A249, A276, A312, A314, A403, A473, A478, A479, A511, A554, A580, A632, A688; FED QQ-S-763, QQ-S-766; MIL SPEC MIL-S-862, MIL-S-23195, MIL-S-23196; SAE J405 (30304 L); (Ger.) DIN 1.4306; (Ital.) UNI X 2 CrNi 18 11, X 3 CrNi 18 11, X 2 CrNi 18 11 KG, X 2 CrNi 18 11 KW; (Jap.) JIS SUS 304 L, SCS 19; (Swed.) SS_{14} 2352; (U.K.) B.S. 304 S 12, 304 S 14, 304 S 22, S 536

Characteristics. Extra low-carbon version of type 304 for restriction of carbide precipitation during welding. Ranks between stabilized and unstabilized grades, because of tendency to precipitate chromium carbides. Used extensively for welding applications, particularly on parts which cannot be subsequently annealed. Parts are limited to service up to 425 °C (795 °F). Hardenable by cold work only. Heat treating limited to: annealing to restore maximum corrosion resistance, softness, and ductility after cold

working; stress relieving when required for stresses occurring from water quench, when this rapid quench is necessary; and on rare occasion, nitriding to impart thin, wear-resistant surface

Forging. Start forging at 1150 to 1260 °C (2100 to 2300 °F). Do not forge after forging stock drops below 925 °C (1695 °F)

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). For maximum ductility, use a minimum annealing temperature of 1040 °C (1905 °F). Parts can be air cooled from annealing temperature. Water quenching not necessary. At 815 to 425 °C (1500 to 795 °F), slow cooling can occur for up to 2 h without subsequent danger of susceptibility to intergranular corrosion in natural atmospheric environments. However, for some applications in the chemical industry, intergranular corrosion would result from this treatment.

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Recommended Processing Sequence

- Cold work
- Anneal and cool
- Stress relieve (optional)
- Depassivate (if nitriding)
- Nitride (if required)

304L: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

S30430

Chemical Composition. **AISI/UNS (S30430):** 0.8 C max, 2.00 Mn max, 0.045 P max, 0.030 S max, 1.00 Si max, 8.00 to 10.00 Ni, 17.00 to 19.00 Cr, 3.04 to 4.0 Cu

Similar Steels (U.S. and/or Foreign). ASTM A493 (XM-7)

Characteristics. Lower work hardening rate than type 305. Used for severe cold heading applications

Forging. Start forging at 1150 to 1260 °C (2100 to 2300 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). For maximum ductility and softness, use a minimum annealing temperature of 1040 °C (1905 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to

several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

S30430: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

304LN

Chemical Composition. AISI/UNS (S30453): 0.03 C, 2.00 Mn, 0.045 P, 0.03 S, 1.00 Si, 8.0 to 12.0 Ni, 18.0 to 20.0 Cr, 0.10 to 0.16 N

Recommended Heat Treating Practice

Annealing. In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

304LN: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

304N

Chemical Composition. AISI/UNS (S30451): 0.08 C max, 2.00 Mn max, 0.045 P max, 0.030 S max, 1.00 Si max, 8.00 to 10.50 Ni, 18.00 to 20.00 Cr, 0.10 to 0.16 N

Similar Steels (U.S. and/or Foreign). ASME SA182, SA213, SA240, SA249, SA312, SA358, SA376, SA430, SA479; ASTM A182, A213, A240, A249, A312, A358, A376, A403, A430, A479

Characteristics. Contains added nitrogen to increase strength with minimum effect on ductility and corrosion resistance. Type 304N is nonmagnetic when annealed. More resistant to increased magnetic permeability on cold working than type 304

Forging. Start forging at 1150 to 1260 °C (2100 to 2300 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). For maximum ductility and softness, use minimum annealing temperature of 1040 °C (1905 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided case. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

- Cold work
- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
- Nitride (if required)

304N: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
	Atmosphere furnace min	Salt bath min
up to 2.50 (0.100)	20	17
over 2.50 to 6.25 (0.100 to 0.250)	25	18
over 6.25 to 12.50 (0.259 to 0.500)	45	35
over 12.50 to 25.00 (0.500 to 1.00)	60	40
over 25.00 to 37.50 (1.00 to 1.50)	75	45
over 37.50 to 50.00 (1.50 to 2.00)	90	50
over 50.00 to 62.50 (2.00 to 2.50)	105	55
over 62.50 to 75.00 (2.50 to 3.00)	120	60
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4

305

Chemical Composition. AISI/UNS (S30500): 0.12 C max, 2.00 Mn max, 0.045 P max, 0.030 S max, 1.00 Si max, 10.50 to 13.00 Ni, 17.00 to 19.00 Cr

Similar Steels (U.S. and/or Foreign). AMS 5514, 5685, 5686; ASME SA193, SA194, SA240; ASTM A167, A240, A249, A276, A313, A314, A368, A473, A478, A493, A511, A554, A580; FED QQ-S-763, QQ-W-423; SAE J405 (30305); (Ger.) DIN 1.4303; (Ital.) UNI X 8 CrNi 19 10; (Jap.) JIS SUS 305, SUS J1

Characteristics. This austenitic chromium-nickel steel has lower rate of work hardening than types 302 and 304. Less change of magnetic permeability. Used for spinning, special drawing, and cold heading applications

Forging. Start forging at 1150 to 1260 °C (2100 to 2300 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

Recommended Heat Treating Practice

Normalizing. Do not normalize

Annealing. Anneal at 1010 to 1120 °C (1850 to 2050 °F). For maximum ductility and softness, use a minimum annealing temperature of 1040 °C (1905 °F). To guard against distortion of thin, delicate parts, leave ample room for expansion between parts. Stainless grades expand about twice as much as carbon and low-alloy steels. Allow enough time for through heating after thermocouple has reached temperature. Stainless grades have approximately half the thermal conductivity of carbon and low-alloy steels. Choice of atmosphere depends on finish desired and whether surface stock will be removed. For bright annealing, use vacuum or an atmosphere of hydrogen or dissociated ammonia at dew point of –62 to –74 °C (–80 to –100 °F). Parts must be thoroughly clean and dry. Inert gases argon and helium (although expensive) and nitrogen, with dew points of less than –54 °C (–65 °F), can be used. They lack the reducing effect of hydrogen, so slight discoloration in the form of chrome oxide can result. Salt, exothermic, or endothermic atmospheres are satisfactory for nonbright annealing. Salt is difficult to remove, and rinse quenching at 595 °C (1105 °F) is not recommended, because interrupted quench at elevated temperature cannot be tolerated. Exothermic and endothermic atmospheres must be carefully controlled at equivalent carbon potential to avoid carburization, which will seriously lower corrosion resistance. Same problem with atmosphere annealing. If oxidizing conditions are present, scale will form. Difficult to remove in subsequent descaling operations.

Cool rapidly from annealing temperature; no more than 3 min to black color. Section size determines quenching medium: water for heavy sections, air blast for intermediate sizes, and still air for thin sections. Carbides can precipitate at grain boundaries when parts are cooled too slowly between 425 to 900 °C (795 to 1650 °F).

In aerospace practice, parts are annealed at a set temperature of 1065 °C (1950 °F) and quenched in water with one exception: parts under 2.5 mm (0.10 in.) thick may be air cooled or polymer quenched to minimize distortion. See table for soaking times. Note: approval of the cognizant engineering organization is required for annealing material in a strain-hardened condition, such as ¼ hard; for stress relieving; or for dimensional stabilization. Heat treating or slow cooling unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L

Stress Relieving. Parts can be relieved after quenching to achieve dimensional stability, by heating to 230 to 400 °C (445 to 750 °F) for up to several hours, depending on section size and without change in metallographic structure.

In aerospace practice, parts are stress relieved at 900 °C (1650 °F), and quenched in water. As an alternative, parts may be stress relieved at annealing temperatures. Sections under 2.5 mm (0.10 in.) thick may be air cooled to minimize distortion. Parts fabricated from steel in the strain-hardened condition, such as ½ hard, shall not be stress relieved without permission of the cognizant engineering authority. When stress relieving after welding, hold for 30 min minimum at the stress relieving temperature. Heat treating or slow cooling of unstabilized grades between 470 to 815 °C (875 to 1500 °F) is prohibited, except for 304L and 316L. See table for soaking times

Nitriding. Not recommended. Case seriously impairs corrosion resistance in most media. Case seldom more than 0.127 mm (0.005 in.) deep. Only used in specialized applications where material must be nonmagnetic and have wear-resistant surface. If nitrided, parts must be in annealed condition to prevent flaking or blistering of nitrided ease. All sharp corners should be replaced with radii of not less than 1.59 mm (0.06 in.). Film of primarily chromium oxide, that protects stainless alloys from oxidation and corrosion, must be removed prior to nitriding. Accomplished by wet blasting, pickling, chemical reduction in reducing atmosphere, submersion in molten salt, or by one of several proprietary processes. If doubt exists that complete and uniform depassivation has occurred, further reduction of the oxide may be accomplished in furnace by means of reducing hydrogen atmosphere or suitable proprietary agent. After depassivation, avoid contamination of surface by finger or hand marking. Single-stage nitriding adequate at 525 to 550 °C (975 to 1020 °F) for 20 to 48 h (depending on case depth required). Dissociation rates for single-stage cycle are from 20 to 35%. Hardness is as high as 1000 to 1350 HK on surface. 48-h cycle produces case extending to 0.127 mm (0.005 in.) with approximately 800 to 1000 HK. Case will rapidly drop to 200 HK core hardness, at approximately 0.165 mm (0.0065 in.)

Recommended Processing Sequence

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- Anneal and quench
- Remove surface contamination (if required)
- Stress relieve
- Depassivate (if nitriding)
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305: Soaking Times (Aerospace Practice)

Diameter or thickness(a) of maximum section mm (in.) inclusive	Minimum soaking time	
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over 50.00 to 62.50 (2.00 to 2.50)	105	55
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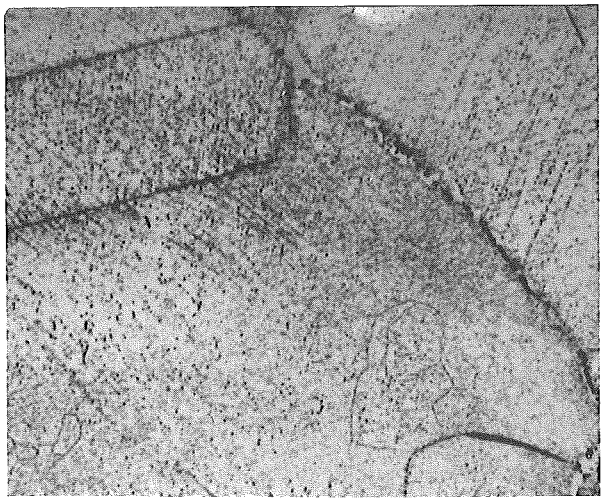
over 75.00 (3.00)	(b)	(c)

(a) Thickness is minimum dimension of heaviest section of part or nested load of parts. (b) 2.25 h plus 15 min for every 12.5 mm (0.5 in.) or increment of 12.5 mm (0.5 in.) over 75 mm (3 in.). (c) 1 h, 5 min plus 5 min for every 12.5 mm (0.5 in.) or increment of 12.5 (0.5 in.) over 75 mm (3 in.). Source: AMS 2759/4



305: Microstructure. Electrolytic: 50% phosphoric acid, 1000×. Creep-rupture specimen. Annealed at 1120 °C (2050 °F), ½ h. Tested at 650 °C (1200 °F), 371 h. Carbon migration and precipitation of chromium carbide ($Cr_{23}C_6$) at austenite grain boundaries.

308

Chemical Composition. **AISI/UNS (S30800):** 0.08 C, 2.00 Mn, 0.045 P, 0.030 S, 1.00 Si, 10.0 to 12.0 Ni, 19.00 to 21.00 Cr

Similar Steels (U.S. and/or Foreign). ASTM A167, A276, A314, A473, A580; SAE J405 (30308); (Ger.) DIN 1.4303; (Ital.) UNI X 8 CrNi 19 10; (Jap.) JIS SUS 305, SUS 305 J 1

Characteristics. Corrosion and heat resistance superior to type 304. Used for welding wire. Nonmagnetic when annealed. Slightly magnetic when cold worked

Forging. Start forging at 1150 to 1260 °C (2100 to 2300 °F). Do not forge after forging stock drops below 925 °C (1695 °F). Cool to black color in less than 3 min, using liquid quench if necessary

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