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# Stainless Steel & Stainless Steel Fasteners

Chemical, Physical and Mechanical Properties

Stainless steel describes a family of steels highly resistant to tarnishing and rusting that contain at least two separate elements alloyed together. In its most basic form, chromium is added to ordinary steel in order to become corrosion resistant. The mechanical properties of stainless steel (eg strength, ductility), and how well the alloy withstands corrosion depends entirely on which elements were alloyed together and their relative proportions.

## Corrosion Resistance

The corrosion resistance of stainless steel is derived from chromium. Chromium has a strong affinity for oxygen and when added to steel in sufficient quantity (minimum 11%), it will form a microscopic film of chromium oxide on the surface of the alloy. The film is only about 0.01 microns thick but prevents further surface corrosion as well as any corrosion from spreading into the metal's internal structure. This chromium oxide film is non reactive with other materials and does not promote further oxidation of adjacent chromium. It is also bonded solidly to the surface of the alloy and in the event of surface damage (eg scratching), the newly exposed chromium will react immediately with oxygen in the air to renew the protective chromium oxide film.

Besides chromium, another important element often added to stainless steel to increase corrosion resistance is molybdenum. Molybdenum becomes far more important than chromium to further enhance corrosion resistance in stainless steel once the amount of chromium in the alloy exceeds 18%.

## Strength and workability

Nickel is added to stabilize the austenitic structure of stainless steel making the alloy more workable and improve ductility. Manganese is added to partially replace nickel in order to stabilize the austenitic structure. Similar to nickel, molybdenum improves the workability of the alloy, and also increases yield and tensile strengths in concentrations above 2%. The addition of sulfur and selenium to the austenitic grades of stainless steel improves machining of the alloy. The addition of carbon and nitrogen directly impact the strength of stainless steel. Nitrogen added to these alloys improves the mechanical properties of low carbon grades of austenitic stainless steels. Other elements like aluminum, titanium and/or columbium can be added to stainless steel to increase the mechanical properties of stainless steel. They also help to increase the strength of the alloy while retaining corrosion resistant properties.

## Grades

Many different grades of stainless steel are available. Each contains varying ratios of steel to chromium in addition to varying amounts of other elements such as nickel, molybdenum and manganese. Each specific grade of stainless steel has its own unique chemical, mechanical and physical property profile making it ideal for specific applications. To compare corrosion resistances of common stainless steel grades see table 1.

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Table 1 Corrosion Resistance Comparison Among Common Stainless Steels

| Grade | UNS No | Mild Atmospheric and fresh water | Atmospheric | | Chemical | | |
|---|---|---|---|---|---|---|---|
| | | | Industrial | Marine | Mild | Oxidizing | Reducing |
| 201 | (S20100) | x | x | x | x | x | |
| 202 | (S20200) | x | x | x | x | x | |
| 205 | (S20500) | x | x | x | x | x | |
| 301 | (S30100) | x | x | x | x | x | |
| 302 | (S30200) | x | x | x | x | x | |
| 302B | (S30215) | x | x | x | x | x | |
| 303 | (S30300) | x | x | x | | | |
| 303 Se | (S30323) | x | x | x | x | | |
| 304 | (S30400) | x | x | x | x | x | |
| 304L | (S30403) | x | x | x | x | x | |
| 304N | (S30451) | x | x | x | x | x | |
| 305 | (S30500) | x | x | x | x | x | |
| 308 | (S30800) | x | x | x | x | x | |
| 309 | (S30900) | x | x | x | x | x | |
| 309S | (S30908) | x | x | x | x | x | |
| 310 | (S31000) | x | x | x | x | x | |
| 310S | (S31008) | x | x | x | x | x | |
| 314 | (S31400) | x | x | x | x | x | |
| 316 | (S31600) | x | x | x | x | x | x |
| 316F | (S31620) | x | x | x | x | x | x |
| 316L | (S31603) | x | x | x | x | x | x |
| 316N | (S31651) | x | x | x | x | x | x |
| 317 | (S31700) | x | x | x | x | x | x |
| 317L | (S31703) | x | x | x | x | x | |
| 321 | (S32100) | x | x | x | x | x | |
| 329 | (S32900) | x | x | x | x | x | x |
| 330 | (N08330) | x | x | x | x | x | x |
| 347 | (S34700) | x | x | x | x | x | |
| 348 | (S34800) | x | x | x | x | x | |
| 384 | (S38400) | x | x | x | x | x | |
| 403 | (S40300) | x | x | | | | |
| 405 | (S40500) | x | x | | | | |
| 409 | (S40900) | x | x | | | | |
| 410 | (S41000) | x | x | | | | |
| 414 | (S41400) | x | x | | | | |

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Table 1 cont.

| Grade | UNS No | Mild Atmospheric and fresh water | Atmospheric | | Chemical | | |
|---|---|---|---|---|---|---|---|
| | | | Industrial | Marine | Mild | Oxidizing | Reducing |
| 416 | (S41600) | x | | | | | |
| 416 Se | (S41623) | x | | | | | |
| 420 | (S42000) | x | | | | | |
| 420F | (S42020) | x | | | | | |
| 422 | (S42200) | x | | | | | |
| 429 | (S42900) | x | x | x | x | | |
| 430 | (S43000) | x | x | x | x | | |
| 430F | (S43020) | x | x | x | | | |
| 430F Se | (S43023) | x | x | x | | | |
| 431 | (S43100) | x | x | x | x | | |
| 434 | (S43400) | x | x | x | x | x | |
| 436 | (S43600) | x | x | x | x | x | |
| 440A | (S44002) | x | x | | | | |
| 440B | (S44003) | x | | | | | |
| 440C | (S44004) | x | | | | | |
| 442 | (S44200) | x | x | x | x | | |
| 446 | (S44600) | x | x | x | x | x | |
| | (S13800) | x | x | x | x | | |
| | (S15500) | x | x | x | x | x | |
| | (S17400) | x | x | x | x | x | |
| | (S17700) | x | x | x | x | x | |

"X" stainless steel type displaying resistance to specific corrosive environment categories.
For use as a guideline only.

The many grades of stainless steel can be further sub-classified into one of five distinct metallurgical “families” or classifications:

1) Austenitic
2) Ferritic
3) Martensitic
4) Precipitation hardening
5) Duplex

Each familiy defines the metallurgical composition of the alloys within each classification, and in turn, reflects differences in property profiles (corrosion resistance, durability, workability) and potential uses.

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## Austenitic Grade Stainless Steels

Austenitic stainless steels are chromium-nickel-manganese or chromium-nickel containing alloys identified by the 200 and 300 series, respectively. The 300 series stainless steels are the most widely used of all stainless steels. The austenitic stainless steels, because of their high chromium and nickel content, are highly corrosion resistant, nonmagnetic, workable and are hardened by cold working. For chemical and physical properties of austenitic stainless steels see table 2.

## Basic properties

- excellent corrosion resistance
- excellent for welding
- excellent formability, fabricability and ductility
- excellent cleaning and hygiene characteristics
- good high and excellent low temperature properties
- non magnetic
- hardened by cold work only

## Straight Grades

The straight grades of austenitic stainless steel contain a maximum of .08% carbon, with no minimum carbon requirement as long as the material meets the physical requirements of the specific grade.

### "L" Grades

The "L" grades are typically used in welding for optimal corrosion resistance. The "L" after a stainless steel grade indicates low carbon (eg 304L). The carbon is kept to .03% or under to minimize carbide precipitation. Carbon in steel precipitates out when heated to temperatures between 800$^{o}$F to 1600$^{o}$F and then combines with the chromium. This interferes with chromium's ability to protect the steel and results in corrosion adjacent to the grain boundaries. By reducing the amount of carbon precipitation, corrosion is reduced.

### "H" Grades

The "H" grades contain a minimum of .04% carbon and a maximum of .10% carbon and have the letter "H" following the alloy number. The "H" grades are most typically used when the alloy is to be exposed to extreme temperatures as the higher carbon content in the alloy improves the strength of the metal under those conditions.

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Table 2

**AUSTENITIC STAINLESS STEELS**

| | Chemical Analysis % (Max. unless noted otherwise) | | | | | | | | | Nominal Mechanical Properties (Annealed Sheet unless noted otherwise) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Tensile Strength | | Yield Strength (0.2% offset) | | Elongation in 2" (50.80mm) | Hardness (Rockwell) | Product Form |
| Type | C | Mn | P | S | Si | Cr | Ni | Mo | Other | ksi | MPa | ksi | MPa | % | | |
| 201 | 0.15 | 5.50/7.50 | 0.060 | 0.030 | 1.00 | 16.00/18.00 | 3.50/5.50 | | 0.25N | 95 | 655 | 45 | 310 | 40 | B90 | |
| 202 | 0.15 | 7.50/10.00 | 0.060 | 0.030 | 1.00 | 17.00/19.00 | 4.00/6.00 | | 0.25N | 90 | 612 | 45 | 310 | 40 | B90 | |
| 205 | 0.12/0.25 | 14.00/15.50 | 0.030 | 0.030 | 0.50 | 16.50/18.00 | 1.00/1.75 | | 0.32/0.40N | 120.5 | 831 | 69 | 476 | 58 | B98 | (Plate) |
| 301 | 0.15 | 2.00 | 0.045 | 0.030 | 1.00 | 16.00/18.00 | 6.00/8.00 | | | 110 | 758 | 40 | 276 | 60 | B85 | |
| 302 | 0.15 | 2.00 | 0.045 | 0.030 | 1.00 | 17.00/19.00 | 8.00/10.00 | | | 90 | 612 | 40 | 276 | 50 | B85 | |
| 302B | 0.15 | 2.00 | 0.045 | 0.030 | 2.00/3.00 | 17.00/19.00 | 8.00/10.00 | | | 95 | 655 | 40 | 276 | 55 | B85 | |
| 303 | 0.15 | 2.00 | 0.20 | 0.15 (min) | 1.00 | 17.00/19.00 | 8.00/10.00 | 0.60* | | 90 | 621 | 35 | 241 | 50 | | (Bar) |
| 303Se | 0.15 | 2.00 | 0.20 | 0.060 | 1.00 | 17.00/19.00 | 8.00/10.00 | | 0.15Se (min) | 90 | 621 | 35 | 241 | 50 | | (Bar) |
| 304 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 18.00/20.00 | 8.00/10.50 | | | 84 | 579 | 42 | 290 | 55 | B80 | |
| 304L | 0.030 | 2.00 | 0.045 | 0.030 | 1.00 | 18.00/20.00 | 8.00/12.00 | | | 81 | 558 | 39 | 269 | 55 | B79 | |
| S30430 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 17.00/19.00 | 8.00/10.00 | | 3.00/4.00Cu | 73 | 503 | 31 | 214 | 70 | B70 | (Wire) |
| 304N | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 18.00/20.00 | 8.00/10.50 | | 0.10/0.16N | 90 | 621 | 48 | 331 | 50 | B85 | |
| 305 | 0.12 | 2.00 | 0.045 | 0.030 | 1.00 | 17.00/19.00 | 10.50/13.00 | | | 85 | 586 | 38 | 262 | 50 | B80 | |
| 308 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 19.00/21.00 | 10.00/12.00 | | | 115 | 793 | 80 | 552 | 40 | | (Wire) |
| 309 | 0.20 | 2.00 | 0.045 | 0.030 | 1.00 | 22.00/24.00 | 12.00/15.00 | | | 90 | 621 | 45 | 310 | 45 | B85 | |
| 309S | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 22.00/24.00 | 12.00/15.00 | | | 90 | 621 | 45 | 310 | 45 | B85 | |
| 310 | 0.25 | 2.00 | 0.045 | 0.030 | 1.50 | 24.00/26.00 | 19.00/22.00 | | | 95 | 655 | 45 | 310 | 45 | B85 | |
| 310S | 0.08 | 2.00 | 0.045 | 0.030 | 1.50 | 24.00/26.00 | 19.00/22.00 | | | 95 | 655 | 45 | 310 | 45 | B85 | |
| 314 | 0.25 | 2.00 | 0.045 | 0.030 | 1.50/3.00 | 23.00/26.00 | 19.00/22.00 | | | 100 | 689 | 50 | 345 | 40 | B85 | |
| 316 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 16.00/18.00 | 10.00/14.00 | 2.00/3.00 | | 84 | 579 | 42 | 290 | 50 | B79 | |
| 316F | 0.08 | 2.00 | 0.20 | 0.10min | 1.00 | 16.00/18.00 | 10.00/14.00 | 1.75/2.50 | | 85 | 586 | 38 | 262 | 60 | B85 | |
| 316L | 0.030 | 2.00 | 0.045 | 0.030 | 1.00 | 16.00/18.00 | 10.00/14.00 | 2.00/3.00 | | 81 | 558 | 42 | 290 | 50 | B79 | |
| 316N | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 16.00/18.00 | 10.00/14.00 | 2.00/3.00 | 0.10/0.16N | 90 | 621 | 48 | 331 | 48 | B85 | |
| 317 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 18.00/20.00 | 11.00/15.00 | 3.00/4.00 | | 90 | 621 | 40 | 276 | 45 | B85 | |
| 317L | 0.030 | 2.00 | 0.045 | 0.030 | 1.00 | 18.00/20.00 | 11.00/15.00 | 3.00/4.00 | | 86 | 593 | 38 | 262 | 55 | B85 | |
| 317LMN | 0.030 | 2.00 | 0.045 | 0.030 | 0.75 | 17.00/20.00 | 13.50/17.50 | 4.00/5.00 | 0.10/0.20N | 96 | 662 | 54 | 373 | 49 | B88 | |
| 321 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 17.00/19.00 | 9.00/12.00 | | 5xC Ti (min.) | 90 | 621 | 35 | 241 | 45 | B80 | |
| 330 | 0.08 | 2.00 | 0.040 | 0.030 | 0.75/1.50 | 17.00/20.00 | 34.00/37.00 | | 0.10Ta 0.20Cb | 80 | 552 | 38 | 262 | 40 | B80 | |
| 347 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 17.00/19.00 | 9.00/13.00 | | 10xC Cb (min) | 95 | 655 | 40 | 276 | 45 | B85 | |
| 348 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 17.00/19.00 | 9.00/13.00 | | Cb + Ta 10xC (min) Ta 0.10 max Co 0.20 max | 95 | 655 | 40 | 276 | 45 | B85 | |
| 384 | 0.08 | 2.00 | 0.045 | 0.030 | 1.00 | 15.00/17.00 | 17.00/19.00 | | | 75 | 517 | 35 | 241 | 55 | B70 | (Wire) |

* May be added at manufacturer's option.

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## Ferritic Grade Stainless Steels

Stainless Steels of the ferritic family, have low carbon (.08 to .20%), high chromium but no nickel, and identified by the 400 series numbers. As such they do not harden by heat treatment. They are all magnetic, resist corrosion and oxidation, and are highly resistant to stress induced cracking. They can be cold worked and softened by annealing. They are highly resistant to atmospheric oxidation and strong oxidizing solutions. As a group, they are more corrosion resistant than the martensitic grades, but inferior to the austenitic grades. They are typically used for decorative trim, sinks, and automotive applications, particularly exhaust systems. For chemical and physical properties of ferritic stainless steels see tables 3 & 4.

## Basic properties

- moderate to good corrosion resistance increasing with chromium content
- not hardened by heat treatment
- always used in the annealed condition
- magnetic
- poor welding properties
- formability not as good as austenitics

### Ferritic Stainless Steels

Table 3 Chemical Analysis % (Max. Unless otherwise noted)

| Type | Cr | Ni | C | Mn | P | S | Si | Mo | Other |
|---|---|---|---|---|---|---|---|---|---|
| 405 | 11.50/14.50 | 0.60 | 0.08 | 1.00 | 0.040 | 0.030 | 1.00 | | 0.10/0.30 Al |
| 409 | 10.50/11.75 | 0.50 | 0.08 | 1.00 | 0.045 | 0.045 | 1.00 | | 6x C/0.75 Ti |
| 429 | 14.00/16.00 | 0.75 | 0.12 | 1.00 | 0.040 | 0.030 | 1.00 | | |
| 430 | 16.00/18.00 | 0.75 | 0.12 | 1.00 | 0.040 | 0.030 | 1.00 | | |
| 430F | 16.00/18.00 | | 0.12 | 1.25 | 0.060 | 0.015 (min) | 1.00 | 0.60 | |
| 430F Se | 16.00/18.00 | | 0.12 | 1.25 | 0.060 | 0.060 | 1.00 | | 0.15 Se (min) |
| 434 | 16.00/18.00 | | 0.12 | 1.00 | 0.040 | 0.030 | 1.00 | 0.75/1.25 | |
| 436 | 16.00/18.00 | | 0.12 | 1.00 | 0.040 | 0.030 | 1.00 | 0.75/1.25 | |
| 442 | 18.00/23.00 | 0.60 | 0.20 | 1.00 | 0.040 | 0.030 | 1.00 | | |
| 446 | 23.00/27.00 | 0.75 | 0.20 | 1.50 | 0.040 | 0.030 | 1.00 | | 0.25 N |

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## Ferritic Stainless Steels

Table 4 Mechanical Properties (Annealed Sheet Unless otherwise noted)

| Type | Tensile Strength | | Yield Strength (0.2% offset) | | Elongation in 2" (50.80mm) % | Hardness (Rockwell) | Product Form |
|---|---|---|---|---|---|---|---|
| | Ksi | MPa | Ksi | MPa | | | |
| 405 | 65 | 448 | 40 | 276 | 25 | B75 | |
| 409 | 65 | 448 | 35 | 241 | 25 | B75 | |
| 429 | 70 | 483 | 40 | 276 | 30 | B80 | Plate |
| 430 | 75 | 517 | 50 | 345 | 25 | B85 | |
| 430F | 95 | 655 | 85 | 586 | 10 | B92 | |
| 430F Se | 95 | 655 | 85 | 586 | 10 | B92 | Wire |
| 434 | 77 | 531 | 53 | 365 | 23 | B83 | |
| 436 | 77 | 531 | 53 | 365 | 23 | B83 | |
| 442 | 80 | 552 | 45 | 310 | 20 | B90 | Bar |
| 446 | 80 | 552 | 50 | 345 | 20 | B83 | |

## Martensitic Grade Stainless Steels

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The martensitic grades are straight chromium steels containing no nickel. They are a group of stainless alloys that are corrosion resistant, hardened by heat treating and are magnetic. They are suited for applications that require corrosion resistance, hardness, strength, and wear resistance (resist atmospheric oxidation, mildly corrosive chemicals and wet or dry corrosion, such as in steam and gas turbine parts, bearings and cutlery). For chemical properties of martensitic stainless steels see tables 5 & 6.

## Basic properties

- moderate corrosion resistance
- hardened by heat treatment (high strength and hardness levels obtainable)
- poor welding properties
- magnetic

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## Martensitic Stainless Steels

Table 5 Chemical Analysis % (Max. Unless otherwise noted)

| Type | Cr | Ni | C | Mn | P | S | Si | Mo | Other |
|---|---|---|---|---|---|---|---|---|---|
| 403 | 11.50/13.00 | | 0.15 | 1.00 | 0.040 | 0.030 | 0.50 | | |
| 410 | 11.50/13.50 | | 0.15 | 1.00 | 0.040 | 0.030 | 1.00 | | |
| 414 | 11.50/13.50 | 1.25/2.50 | 0.15 | 1.00 | 0.040 | 0.030 | 1.00 | | |
| 416 | 12.00/14.00 | | 0.15 | 1.25 | 0.060 | 0.015 (min) | 1.00 | 0.60* | |
| 416 Se | 12.00/14.00 | | 0.15 | 1.25 | 0.060 | 0.060 | 1.00 | | 0.15 Se (min) |
| 420 | 12.00/14.00 | | 0.12 | 1.20 | 0.040 | 0.030 | 1.00 | | |
| 420 F | 12.00/14.00 | | 0.15 (min) | 1.25 | 0.060 | 0.015 (min) | 1.00 | 0.60* | |
| 422 | 11.00/13.00 | | 0.15 (min) | 1.00 | 0.025 | 0.025 | 0.75 | 0.75/1.25 | 0.15/0.30 V |
| 431 | 15.00/17.00 | 0.50/1.00 | 0.20/0.25 | 1.00 | 0.040 | 0.030 | 1.00 | | 0.75/1.25 W |
| 440 A | 16.00/18.00 | | 0.60/0.75 | 1.00 | 0.040 | 0.030 | 1.00 | 0.75 | |
| 440 B | 16.00/18.00 | | 0.75/0.95 | 1.00 | 0.040 | 0.030 | 1.00 | 0.75 | |
| 440C | 16.00/18.00 | 1.25/2.50 | 0.95/1.20 | 1.00 | 0.040 | 0.030 | 1.00 | 0.75 | |

## Martensitic Stainless Steels

Table 6 Mechanical Properties (Annealed Sheet Unless otherwise noted)

| Type | Tensile Strength | | Yield Strength (0.2% offset) | | Elongation in 2" (50.80mm) % | Hardness (Rockwell) | Product Form |
|---|---|---|---|---|---|---|---|
| | Ksi | MPa | Ksi | MPa | | | |
| 403 | 70 | 483 | 45 | 310 | 25 | B80 | |
| 410 | 70 | 483 | 45 | 310 | 25 | B80 | |
| 414 | 120 | 827 | 105 | 724 | 15 | B98 | |
| 416 | 75 | 517 | 40 | 276 | 30 | B82 | Bar |
| 416 Se | 75 | 517 | 40 | 276 | 30 | B82 | Bar |
| 420 | 95 | 655 | 50 | 345 | 25 | B92 | Bar |
| 420 F | 95 | 655 | 55 | 379 | 22 | 220 (Brinell) | Bar |
| 422 | 145 | 1000 | 125 | 862 | 18 | 320 (Brinell) | Bar |
| 431 | 80125 | 862 | 95 | 655 | 20 | C24 | Bar |
| 440 A | 105 | 724 | 60 | 414 | 20 | B95 | Bar |
| 440 B | 107 | 738 | 62 | 427 | 18 | B96 | Bar |
| 440C | 110 | 738 | 65 | 448 | 14 | B97 | Bar |

## Precipitation Hardening Stainless Steels

Precipitation Hardening stainless steels can be hardened by a combination of a low-temperature aging treatment and cold working. They are identified by UNS numbers (e.g. Type S17400), but often referred to by proprietary trade names (eg 17-4PH). Precipitation hardening stainless steels are particularly useful because uniform hardening can be obtained without a high-temperature treatment that can result in distortion and scaling. For chemical and physical properties of precipitation hardening stainless steels see tables 7 & 8.

## Basic properties

- moderate to good corrosion resistance
- very high strength
- good welding properties
- magnetic

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## Precipitation Hardening Stainless Steels

Table 7 Chemical Analysis % (Max. Unless otherwise noted)

| Type | Cr | Ni | C | Mn | P | S | Si | Mo | Other |
|---|---|---|---|---|---|---|---|---|---|
| S13800 | 12.25/13.25 | 7.50/8.50 | 0.05 | 0.10 | 0.010 | 0.008 | 0.10 | 2.00/2.50 | 0.90/1.35 Al/0.01 N |
| S15500 | 14.00/15.50 | 3.50/5.50 | 0.07 | 1.00 | 0.040 | 0.030 | 1.00 | | 2.50/4.50 Cu 0.15/0.45 Cb + Ta |
| S17400 | 15.50/17.50 | 3,005.00 | 0.07 | 1.00 | 0.040 | 0.030 | 1.00 | | 3.00/5.00 Cu 0.15/0.45 Cb + Ta |
| S17700 | 16.00/18.00 | 6.50/7.75 | 0.09 | 1.00 | 0.040 | 0.040) | 0.040 | | 0.75/1.50 Al |

## Precipitation Hardening Stainless Steels

Table 8 Mechanical Properties (Annealed Sheet Unless otherwise noted)

| Type | Tensile Strength | | Yield Strength (0.2% offset) | | Elongation in 2” (50.80mm) % | Hardness (Rockwell) |
|---|---|---|---|---|---|---|
| | Ksi | MPa | Ksi | MPa | | |
| S13800 | 160 | 1103 | 120 | 827 | 17 | C33 |
| S15500 | 160 | 1103 | 145 | 1000 | 15 | C35 |
| S17400 | 160 | 1103 | 145 | 1000 | 15 | C35 |
| S17700 | 130 | 896 | 40 | 276 | 10 | B90 |

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## Duplex Grade Stainless Steels

DUPLEX stainless steels are characterized by their 50% austenitic 50% ferritic structures, containing relatively high chromium (between 18 and 28%) and moderate amounts of nickel (between 4.5 and 8%). The nickel content is insufficient to generate a fully austenitic structure and the resulting combination of ferritic and austenitic structures is called duplex. Most duplex steels contain molybdenum in a range of 2.5 - 4% which allow these materials to offer the corrosion resistance for the austenitic grades of material while providing good design properties. For chemical and physical properties of duplex stainless steels see tables 9, 10 & 11.

## Basic properties

- high resistance to stress corrosion cracking
- increased resistance to chloride ion attack
- higher tensile and yield strength than austenitic and ferritic steels
- good welding properties and formability
- work hardened
- magnetic

**Duplex Stainless Steels**

Table 9 Chemical analysis %

| Grade | UNS No | Typical Compositions (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | Mn | Si | P | S | Cr | Mo | Ni | N | Cu |
| 2205 | S31803/S32205 | 0-0.03 | 2.00 | 1.00 | 0-0.03 | 0-0.03 | 21-23 | 2.5-3.5 | 4.5-6.5 | 0.08-0.2 | - |
| UR52N+ | S32520/S32550 | 0.03max | 1.50 | 0.80 | 0.035 | 0.035 | 34-36 | 3.0-5.0 | 5.5-8 | 0.2-0.35 | .5-3 |

**Duplex Stainless Steels**

Table 10 Mechanical Properties

| Grade | Tensile Strength (MPa) | Proof Stress 0.2% (MPa) | Elongation A5 (%) |
|---|---|---|---|
| 2205 | 620 | 450 | 25 |
| UR52N+ | 770 | 550 | 25 |

**Duplex Stainless Steels**

Table 11 Physical Properties

| Common Name | Density ($g.cm^3$) | Modulus of Elasticity (GPa) | Electrical Resistivity (Ω.m) | Thermal Conductivity (W/m.K) | Thermal Expansion (m/m.K) |
|---|---|---|---|---|---|
| 2205 | 7.805 | 200 | $0.085x10^{-6}$ | 19 at 100℃ | $13.7x10^{-6}$ to 100℃ |
| UR52N+ | 7.81 | 205 | $0.085x10^{-6}$ | 17 at 100℃ | $13.5x10^{-6}$ to 200℃ |

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## Stainless Steel Fasteners

The two primary methods for producing fasteners; machining and cold heading still apply in the fabrication of stainless steel fasteners.

**MACHINING** is common for very large diameters and for small production runs. However machining disrupts the structural integrity of the alloy particularly in the head-to-shank area causing a reduction in load-carrying capability as well as fatigue resistance.

**COLD HEADING** a common and economical method of forming wire into various types of standard and specialty bolts, screws, nails and rivets, particularly for large production runs. Cold heading also cold works the alloy resulting in significant increases in strength for the 300 Series austenitic steels.

Following heading, the blank is ready for secondary processes like threading. This is achieved typically by either cutting or rolling. The best quality highest-strength thread is achieved by thread rolling because it is considered a form of cold working and thus increases yield and tensile strength of the austenitic family of alloys.

**TENSILE STRENGTH** ultimately determines how much load the fastener can carry before failure. Yield strength is a measure of the resistance to deformation under load, both of which can be increased by either cold working or heat treating see Table 12

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Table 12

MECHANICAL PROPERTIES OF STAINLESS STEEL BOLTS, SCREWS, STUDS AND NUTS (per ASTM F593-91)

| | | BOLTS, SCREWS AND STUDS | | | | | | NUTS | |
|---|---|---|---|---|---|---|---|---|---|
| | | FULL SIZE BOLTS, SCREWS, STUDS | | MACHINED TEST SPECIMENS OF BOLTS, SCREWS, STUDS | | | | | |
| GRADE | DESCRIPTION | YIELD[2] STRENGTH min ksi | TENSILE STRENGTH min ksi | YIELD[2] STRENGTH min ksi | TENSILE STRENGTH min ksi | ELON-GATION[3] % Min | HARDNESS ROCKWELL Min | PROOF LOAD STRESS ksi | HARDNESS ROCKWELL Min |
| 303<br>304 | Austenitic<br>**Sol[n] annealed** | 30 | 75 | 30 | 75 | 20 | B75 | 75 | B75 |
| 304<br>305<br>316<br>384<br>XM7 | Austenitic<br>**Cold Worked** | 50 | 90 | 45 | 85 | 20 | B85 | 90 | B85 |
| 304<br>305<br>316 | Austenitic<br>**Strain Hardened** | -> 5/8" 100<br>5/8" -> 1" 70<br>1" -> 1-1/2" 50 | 125<br>105<br>90 | 90<br>65<br>45 | 115<br>100<br>85 | 16 | C25 | 125<br>105<br>90 | C20 |
| 410<br>416 | Martensitic<br>**Hardened and Tempered*** | 95 | 125 | 95 | 125 | 20 | C22 | 125 | C22 |
| 410<br>416 | Martensitic<br>**Hardened and Tempered**** | 135 | 180 | 135 | 180 | 12 | C36 | 180 | C36 |
| 430 | Ferritic | 40 | 70 | 40 | 70 | 20 | B75 | 70 | B75 |

* hardened and tempered at 1100°F min.
** hardened and tempered at 525°F± 50°F

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**SHEAR STRENGTH** - Shear is resistance to lateral forces perpendicular to the axis of the material. It is defined as the load required to cause rupture, divided by the cross sectional area in square inches of the part along the rupture plane. Acceptable shear stresses for stainless steel bolts are given in Table 13.

Table 13 Permitted Shear Stress of Stainless Steel Bolts

| Type | Finish | Condition & Specification | Dia (in.) | Min. Tensile Requirement | | Shear Stress (ksi) | |
|---|---|---|---|---|---|---|---|
| | | | | 0.2% Yield Strength (ksi) | Tensile Strength (ksi) | No Threads in Shear Plane | Threads in Shear Plane |
| 302<br>304<br>316 | Hot Finished | Condition A (Annealed) in ASTM A276-71 Class 1 (solution treated) in ASTM A193-71 | all | 30 | 75 | 15 | 10.5 |
| 302<br>304<br>316 | Cold Finished | Condition A (Annealed) in ASTM A276-71 | </=1/2 | 45 | 90 | 18 | 12.6 |
| 302<br>304<br>316 | Cold Finished | Condition B (cold-worked) in ASTM A276-71 Class 2 (solution treated and strain hardened) in ASTM A193-71* | </=3/4 | 100 | 125 | 25 | 17.5 |

**TORQUE –** defined as the twisting force applied to a fastener. Table 14 illustrates maximum torque acceptable for 304 and 3-16 stainless steel fasteners.

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Table 14 Maximum Torque for S/S Bolts

| BOLT SIZE | 304 | 316 |
|---|---|---|
| 2-56 | 2.5 | 2.6 |
| 2-64 | 3 | 3.2 |
| 3-48 | 3.9 | 4 |
| 3-56 | 4.4 | 4.6 |
| 4-40 | 5.2 | 5.5 |
| 4-48 | 6.6 | 6.9 |
| 5-40 | 7.7 | 8.1 |
| 5-44 | 9.4 | 9.8 |
| 6-32 | 9.6 | 10.1 |
| 6-40 | 12.1 | 12.7 |
| 8-32 | 19.8 | 20.7 |
| 8-36 | 22 | 23 |
| 10-24 | 22.8 | 23.8 |
| 10-32 | 31.7 | 33.1 |
| 1/4"-20 | 75.2 | 78.8 |
| 1/4"-28 | 94 | 99 |
| 5/16"-18 | 132 | 138 |
| 5/16"-24 | 142 | 147 |
| 3/8"-16 | 236 | 247 |
| 3/8"-24 | 259 | 271 |
| 7/16"-14 | 376 | 393 |
| 7/16"-20 | 400 | 418 |
| 1/2"-13 | 517 | 542 |
| 1/2"-20 | 541 | 565 |
| 9/16"-12 | 682 | 713 |
| 9/16"-18 | 752 | 787 |
| 5/8"-11 | 1110 | 1160 |
| 5/8"-18 | 1244 | 1301 |
| 3/4"-10 | 1530 | 1582 |
| 3/4"-16 | 1490 | 1558 |
| 7/8"-9 | 2328 | 2430 |
| 7/8"-14 | 2318 | 2420 |
| 1"-8 | 3440 | 3595 |
| 1"-14 | 3110 | 3250 |
| 1 1/8"-7 | 413 | 432 |
| 1 1/8"-12 | 390 | 408 |
| 1 1/4"-7 | 523 | 546 |
| 1 1/4"-12 | 480 | 504 |
| 1 1/2"-6 | 888 | 930 |
| 1 1/2"-12 | 703 | 732 |

Torque values upto 1" diameter are in inch pounds;
over 1" diameter in foot pounds.

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# Stainless Steel Fastener Types In Stock at Aspen Fasteners

**Materials:**

18-8, 316, 410 stainless steel

**Plating:**

stainless steel are typically available with no additional coating, but in some cases are also available with a black oxide and oil finish is available.

## Stainless Steel Bolts:

Stainless Steel Carriage Bolts

Stainless Steel Flange Bolts


Stainless Steel hanger Bolts

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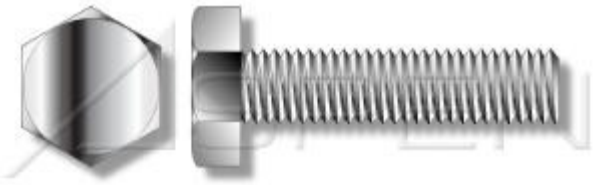
Stainless Steel hex tap Bolts



## Stainless Steel Nuts:

Stainless Steel Spring Nuts

Stainless Steel Cage Nuts

Stainless Steel hex Nuts

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## Stainless Steel lock Nuts

## Stainless Steel Nylon Insert Lock Nuts

## Stainless Steel Spring Nuts

## Stainless Steel Weld Nuts

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Stainless Steel Wing Nuts

## Stainless Steel Screws:

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Stainless Steel Hi Lo Tapping Screws

Stainless Steel lag Screws

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Stainless Steel machine Screws

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Stainless Steel Self Drilling Screws

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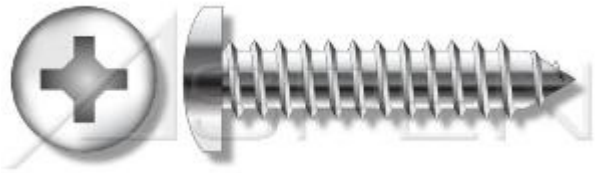
[Stainless Steel Self Tapping Screws]



[Stainless Steel Sems Screws]


[Stainless Steel Taptite Screws]


[Stainless Steel Thread Cutting Screws]

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Stainless Steel Thumb Screws

Stainless Steel U Drive Screws

Stainless Steel Wood Screws

**Stainless Steel Washers:**

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## Stainless Steel Flat Washers

## Stainless Steel lock Washers

## Stainless Steel tooth lock Washers