

COLD FORMING STAINLESS STEEL BAR AND WIRE

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Design Versatility of Stainless Steels

Probably the most significant characteristic of stainless steels, from the design viewpoint, is versatility. This unique family of corrosion-resistant metals has few limitations to restrict the free flow of fresh ideas from design drawing boards. For example, consider the following:

Stainless steels resist rusting and corrosive attack in a broad range of environments, from benign rural atmospheres to harshly aggressive, hot acid solutions. The selection of the right stainless steel type for a specific end-use requirement can be made from a wide variety of standard AISI grades or from numerous proprietary alloys.

Stainless steels are versatile in terms of mechanical properties, with some grades, for example, having yield strengths exceeding 250,000 psi (1724 MPa). This versatility is enhanced by the fact that strength and hardness values can be altered either by heat treatment or by cold working, depending upon the stainless steel type involved.

Versatility in appearance is an important quality of stainless steels. In lustrous elegance, stainless flatware and tableware grace fashionable dining tables; shining sculptures are bright focal points at museums, office building courtyards, and neighbourhood shopping malls; and architectural components, in a variety of surface finishes, add lasting beauty and character to many a structure.

On the other hand, stainless steels are used throughout industry for other applications in which function rather than appearance is of primary concern such as coal-handling conveyors, steam generators in nuclear power plants, pipe, pumps and valves in petroleum refining and for pressure vessels in chemical processing.

The product forms in which stainless steels are available provide designers with a multiplicity of sizes and shapes from which to choose. These include sheet, strip, plate, bar, wire, rod, tubing, pipe, and extrusions or other special shapes.

Versatility is also reflected in the fabricability of stainless steels, which is the ability to be made into finished products by any of the manufacturing techniques in common use.

Cold forming is one method used in the manufacture of stainless steel products, which is performed without the necessity of heating the work piece beyond the recrystallization temperature. Cold forming embraces several metalworking techniques, including brake forming or roll forming of sheet and strip, and heading, extrusion, or thread rolling of bar and wire. This publication deals with the last three methods, with emphasis on cold heading.



Cold Forming – The Processes

If cold forming of products from bar and wire is justified on the basis of volume, size, and material, the cold forming processes offer substantial advantages over methods such as hot forging or machining. The advantages can be expressed in terms of

Materials Savings—Cold forming minimizes waste. Cold heading, for example, which is one method for cold forming wire, can keep waste to less than 10-20%, whereas a similar machined part might result in scrap losses of up to 65%.

Increased Production Rates—Parts cold formed by heading can be produced at rates about 10 times faster than machining. Modern cold heading machines, for instance, turn out 35,000 or more pieces per hour, depending on part complexity.



Hospital equipment—Type 430

Enhanced Material Properties—Cold forming improves the strength and other mechanical properties of the stainless steels, especially the chromium-nickel 300 Series stainless steels. From the design standpoint, this means that the designer can create a smaller, lighter weight part without sacrificing strength, or he can utilize the advantages of a stronger component elsewhere in his product design.

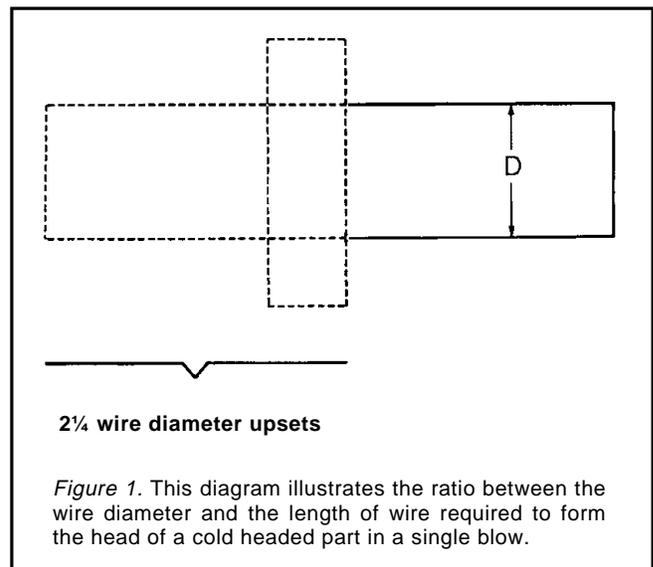
Good Surface Finishes—Cold forming offers good surface finishes and dimensional accuracies. Parts can be complete and in many instances ready to use as they come from the cold forming equipment.

Favourable Economics—When volume justifies its use, cold forming provides an economical edge over other methods. This edge is further enhanced when the design uses the inherent characteristics of stainless steels—corrosion resistance, strength, durability, attractiveness, low maintenance, etc.—to the fullest extent.

Cold Heading

One of the more important cold forming techniques is cold heading.

Basically, it is the reshaping of unheated metal by striking blows on a length of wire inserted in a die. The force of the blow (or blows, as the case may be) creates enough pressure to cause the metal to flow outward unrestricted into a die cavity. The head, or *upset* portion of the part, generally is larger in diameter than the original blank, and the length has been decreased. Generally speaking, normal cold heading permits upsets of about $2\frac{1}{4}$ times the diameter of the wire in a single blow, as diagrammed in Figure 1. Improved techniques and minor tooling changes can increase this ratio to a limited extent, as shown in Figures 2 and 3.



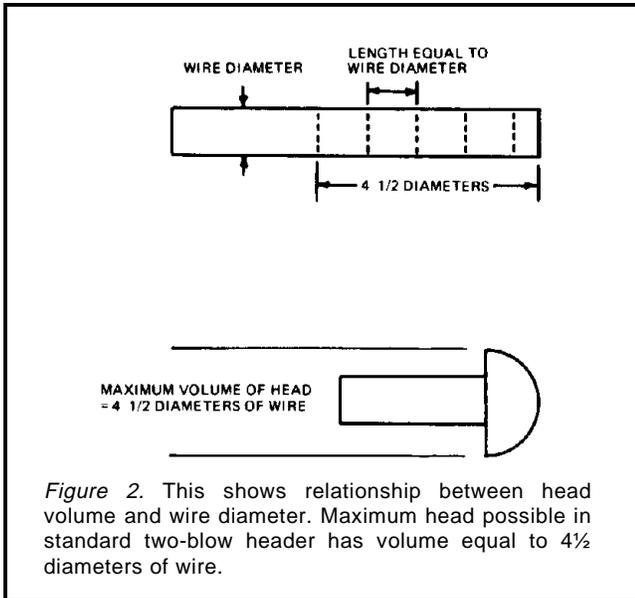


Figure 2. This shows relationship between head volume and wire diameter. Maximum head possible in standard two-blow header has volume equal to 4½ diameters of wire.

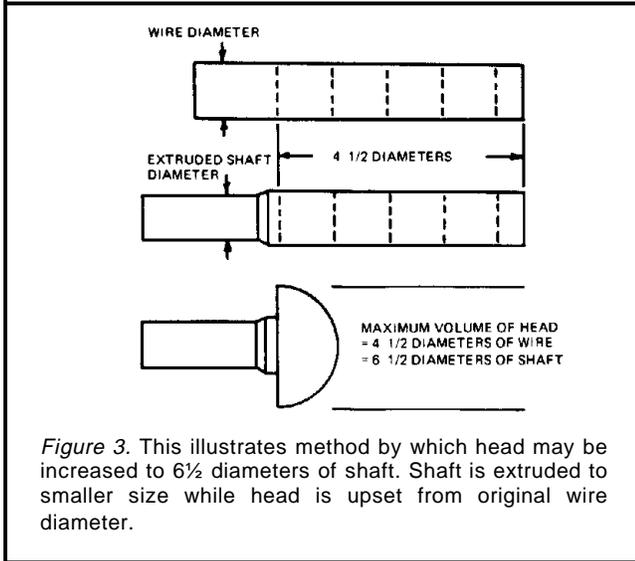


Figure 3. This illustrates method by which head may be increased to 6½ diameters of shaft. Shaft is extruded to smaller size while head is upset from original wire diameter.

For more complex shapes, multiple blows may be struck, with the blank moving through a sequence of dies. The high production rates and “no chips” concept of cold heading led to its becoming the principal process for producing nuts, bolts, screws, rivets, and other fasteners, a position cold heading has enjoyed for about 100 years.

More complex shapes also can be made, including some that are not in the fastener or shaft categories, such as spark plug shells. Additional operations enhance cold heading versatility: trimming, piercing, extrusion, and warm heading.

Trimming

For parts having other than round heads, an additional heading operation called trimming (Figure 4) is performed. A typical application is cold forming hex-head cap screws, such as the one shown in Figure 5.

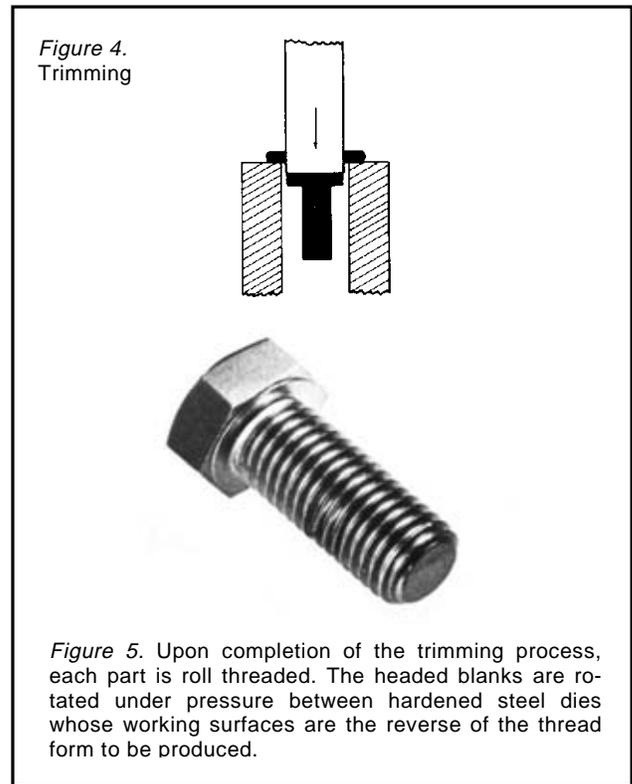


Figure 4. Trimming

Figure 5. Upon completion of the trimming process, each part is roll threaded. The headed blanks are rotated under pressure between hardened steel dies whose working surfaces are the reverse of the thread form to be produced.

Piercing

A final operation in the heading sequence for making nuts is piercing (Figure 6) in which the hole is punched out as a step prior to threading.

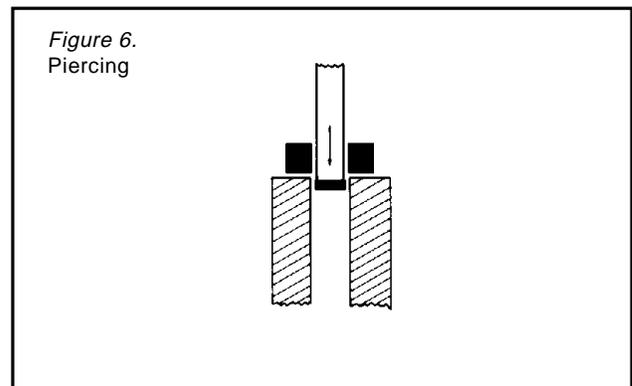
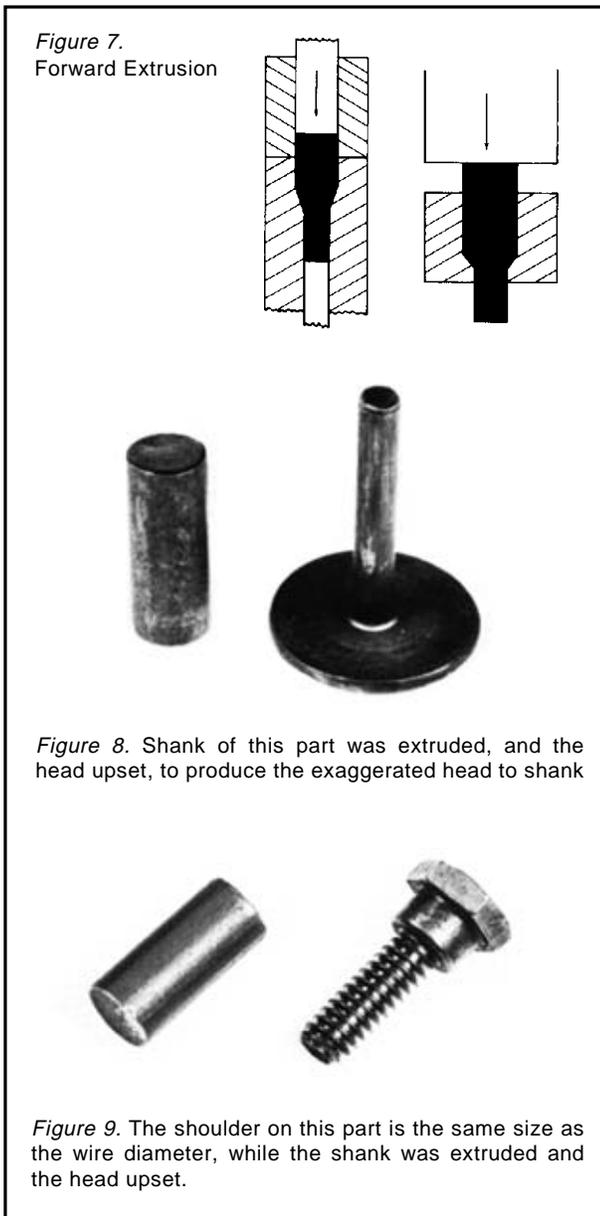


Figure 6. Piercing

Extrusion

Extrusion, as it applies to cold heading, is the forcing of the metal into a die smaller in diameter than that of the original wire stock, which increases its length, as illustrated in Figure 7. This is an efficient and highly economical method for creating two or more diameters in the part being formed. Also, increasing the ratio of head-to-shank size beyond the normal cold heading capability is possible, as shown in the examples in Figures 8 and 9.



Warm Heading

Exceptionally good results are obtained when heading stainless steels that are first heated to a temperature between 200 and 750°F (93 and 399°C). Warming decreases the work hardening character of the metal, particularly the austenitic 300 Series stainless steels, thus improving headability.



The result is that less pressure is required to fill the die cavity, sharper corners and shoulders are achieved, and the possibility of cracking is minimized. The accompanying illustrations in Figures 10 and 11 show examples of the improved forming made possible by warm heading techniques.

Qualifications for Cold Heading

There are several basic conditions that justify cold heading:

Volume—In general, cold heading jobs run in excess of 5,000 pieces, most often over 25,000 pieces for economical production. The actual quantities are predicated in part by the relative complexities of header dies and the type material being formed.

Sizes—The largest size stainless steel slug that can be cold formed on standard one- or two-blow headers is about 1 inch (25.4 mm) in diameter, with a $\frac{3}{4}$ inch (19.05 mm) shank diameter.

Material—Various AISI stainless steel types especially suited to cold heading operations are available, such as AISI Types UNS-S30430*, 305, and 384, which are discussed in greater detail beginning on page 14. Other stainless steels are also available as cold heading wire, among them including Types 303, 410, 430, 440C, UNS-S17400, and a number of proprietary stainless steels.

*Type UNS-S30430 is a copper-bearing stainless steel often referred to as Alloy 302 HQ, which is a proprietary trade name. Type UNS-S30430 is described on page 17.



Disc spindle for water meter (formerly screw machined)—
Type S30430



Type AB self-tapping screw—
Type 410



Dishwasher pump blade screw—
Type 430



Cold heading Design Considerations

Before discussing the specifics of designing a product to be cold headed, a brief review of cold heading equipment is appropriate.

Single-Blow Headers—Although seldom used now, single-blow headers are the simplest and fastest. They can produce hundreds of pieces per minute but are limited to minor shank extrusion and simple head shapes. In single-stroke machines, wire is sheared to length, transferred to a die, struck one blow, and ejected. Single-blow headers are adequate when head diameters or volume is relatively small, and the material lends itself easily to upsetting. The straight-chromium stainless steels, such as Types 410 and 430 are quite often processed on such machines. (Figure 12).

Double-Blow Headers—The most commonly used cold heading machine for the chromium-nickel stainless steels such as Types UNS-S30430, 304, 384, and 305 is the double-stroke header.

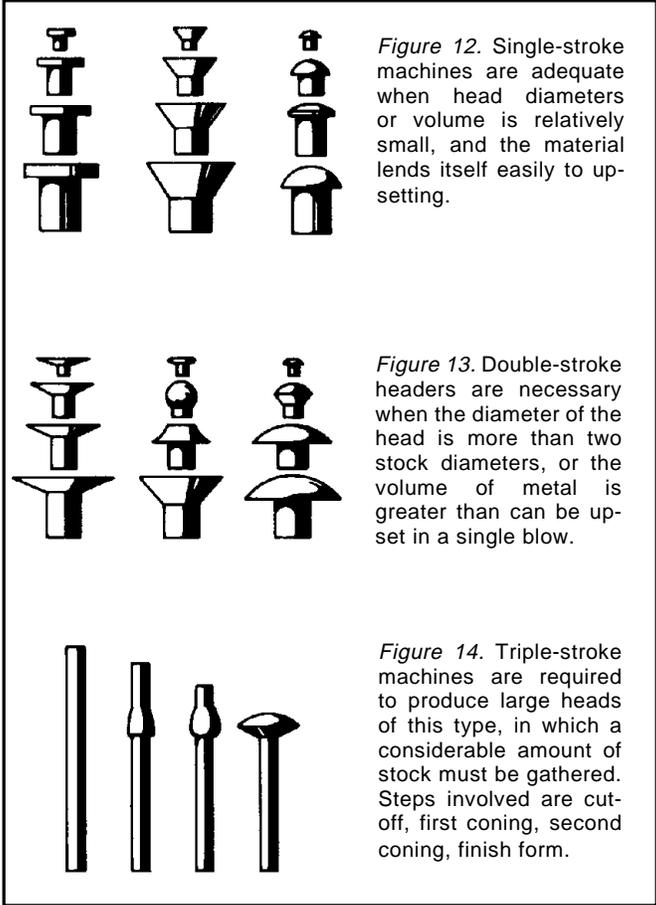


Figure 12. Single-stroke machines are adequate when head diameters or volume is relatively small, and the material lends itself easily to upsetting.

Figure 13. Double-stroke headers are necessary when the diameter of the head is more than two stock diameters, or the volume of metal is greater than can be upset in a single blow.

Figure 14. Triple-stroke machines are required to produce large heads of this type, in which a considerable amount of stock must be gathered. Steps involved are cut-off, first coning, second coning, finish form.



When two blows are used to form the shape, the first punch starts the metal flow in a given direction so the desired shape can be completed with the second blow, as shown in Figure 13. The punches oscillate between blows to one die so that a finished part is produced with every other stroke.

Multiple-Die Machines—Where additional strokes are required for more intricate contours, multi-station or progressive headers are used. On such machines, parts are mechanically transferred from one die to the next, and all stations work simultaneously so that a part is finished and ejected at each stroke. These machines may have as many as six stations or dies. (Figure 14).

Obviously, the best results in cold heading are obtained when the tooling engineer and product designer work together. However, the designer can approach the subject with greater authority if he is aware of cold heading design criteria.

For instance, the maximum length of unsupported cold heading quality stainless steel wire that can be successfully upset in one blow to form a good concentric head is from 2 to 2½ times the original wire diameter. If additional blows are used, this length can be doubled. Figure 15 illustrates the problem of trying to head a wire of unsupported length exceeding that which has been recommended.

The maximum diameter that can be formed in this same wire in one blow is about 2¼ times the original wire diameter. Additional blows can upset the chromium-nickel types to maximum diameters ranging from 3 to 3.5 times that of the stock diameter, while the straight-chromium grades can be worked to the same extent as mild steel.

The overall part length that can be produced by cold heading is a function of many things: the equipment being used, the type of dies used, coatings, and whether or not the part is to be extruded or pointed.

Other design considerations concern corner or fillet radii, number of parts to be produced, die wear, tolerances, etc. Typical tolerances that can be expected of cold heading are shown in Table 1. (See Figure 16.)

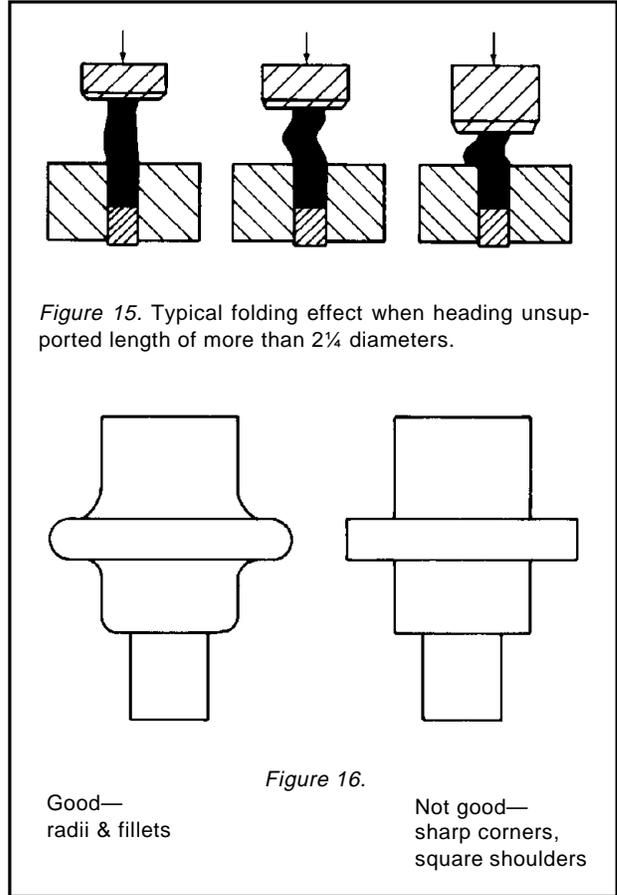


Figure 15. Typical folding effect when heading unsupported length of more than 2¼ diameters.

Figure 16.

Good—
radii & fillets

Not good—
sharp corners,
square shoulders

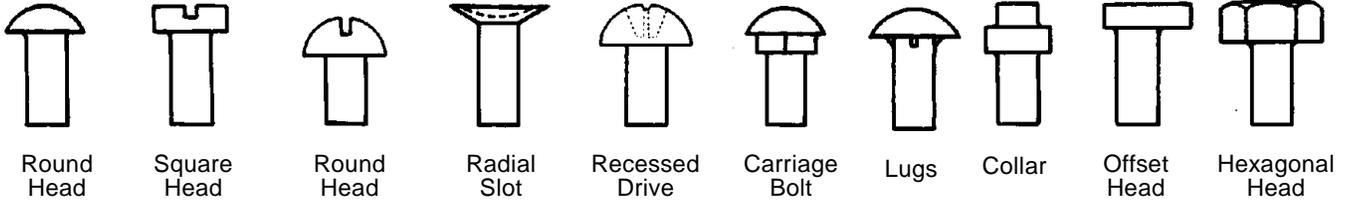
TABLE 1

**TYPICAL TOLERANCES FOR
COLD HEADED PARTS**

Dimension in. (mm)	Tolerance in. (mm)
Diameter:	
Up to 3/16 incl. (4.76)	±0.001 (0.0254)
Over 3/16 to 3/8 incl. (4.76—9.53)	±0.0015 (0.0381)
Over 3/8 to 9/16 incl. (9.53—14.29)	±0.002 (0.0508)
Length:	
Up to 1 (25.4)	±0.005 (0.127)
1 to 3 (25.4—76.2)	±0.030 (0.762)
3 to 6 (76.2—152.4)	±0.040 (1.016)

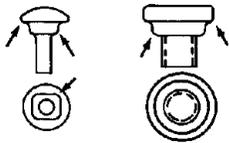
Source: ASM Engineering Bookshelf, "Forming of Stainless Steels."

Examples of Cold Heading Design



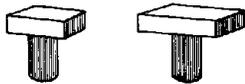
Avoiding Design Pitfalls

Corners are critical. It is difficult to force or flow metal into sharp corners of the die so generous fillets and 1/32 in. minimum corner radii represent best cold heading conditions for most low-carbon and alloy steels. Nickel alloys are likely to gall, and both nickel and stainless steel parts



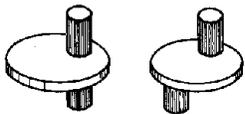
develop high pressures during forming so parts made from these metals should be designed with even larger radii, fillets, and clearances than those recommended for low-carbon steel.

Square or rectangular heads require subsequent trimming (while oval or round shapes do not) because the



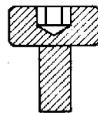
displaced metal usually assumes a cylindrical shape when it is formed in the header.

Eccentric or off-centre formations are harder to produce than concentric shapes. However, certain parts with



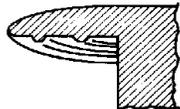
eccentric cams, serrations, or sections can be cold headed successfully.

Hollow upsets require more die maintenance, and cracks may form



around the edges of the recess.

Concentric ridges added to the underside surface of large, flat sec-



tions make a part easier to eject from the die.

Long sections of cold headed parts are more likely to distort during



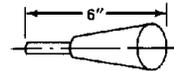
subsequent heat treatment operations.

Extensions such as lugs, fins, and wings can be included in the head design, but the diameter of the blank



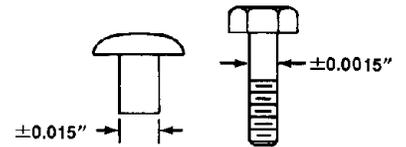
and configuration of the head determine the size and quantity of such features.

Maximum length of a cold headed part that can be produced in most machines is usually about six inches.



Designs that represent exceptions to this rule may require special machinery.

Cold heading tolerances generally are closer than hot heading tolerances. Parts made on single-stroke cold headers have wider tolerances than parts made from two or more strokes. For example, rivets (which



are often formed in single-stroke machines) have tolerances of ± 0.015 in. except when specified otherwise. On the other hand, shanks for rolled threads (which are formed in several strokes) may have only ± 0.0015 in. tolerance. Generally, small parts can have closer tolerances than large parts.



A



B



C



D

Example A

The use of a “heading quality” Type UNS-S30430 stainless steel wire for the production of recessed and slotted head machine screws enabled a Connecticut manufacturer to reduce raw material costs, increase tool life, and minimize rejects. This special analysis stainless steel exhibits resistance to corrosion comparable with Type 304, and it offers basic production advantages comparable with Type 384.

Example B

A Michigan manufacturer has perfected a proprietary technique to cold head 6½” to 24” (165.1 to 609.6 mm) long hex head bolts from Type 305 stainless steel on a production basis. Until now, long-shank stainless steel fasteners have only been available from screw machine sources. The long-shank Type 305 cold headed bolts have strength levels in excess of 90,000 psi (621 MPa) which is superior to strengths achieved in machined fasteners of similar design.

Example C

A Michigan spring company fabricates eye-bolt shafts from Type 302 stainless steel. These specials are used to actuate the locking device in electric automotive door locks.

The heading-quality alloy is supplied 0.1875” (4.7625 mm) in diameter, annealed and cold drawn. The company forms 3,000 bolts per hour, followed by threading at 1,000 per hour.

Example D

A California manufacturer makes marine eye terminals for standard rigging on sail boats and yachts in a complex fabrication sequence using Type 303 Se stainless steel. The blanks are formed from 3/16” to ½” (4.76 to 12.7 mm) round, annealed, cold drawn wire and from ½” to 1-1/16” (12.7 to 26.99 mm) round, centreless ground stock. Blanks are formed on Acme Grindley and Conamatic screw machines, after which parts are made through grinding, drilling, coining, and countersinking operation. Final assembly, after cleaning, includes insertion of the wire rope and swaging of the end section.

The manufacturer credits the success of the fabrication sequence to Type 303 Se stainless, which can be both machined and cold formed with minimal trouble.

Cold Extrusion

Cold extrusion technology permits the forming of a part to the desired size and shape by moving the metal — at room temperature—into a die. Sufficient force is required to exceed the yield strength of the stainless steel. Plastic deformation results, which enables the metal to fill out the die cavities to extremely close tolerances.

Although there are many different cold extrusion operations, all are variations of one or more of the following:

Forward Extrusion forces the metal to flow in the same direction as the descending punch and through a hole in the die to form the required shape and dimensions, as shown in Figure 17. Forward extrusion is especially useful in the production of bolts and screws, stepped shafts, and cylinders.

Backward Extrusion forces the metal to flow upward around the descending punch, as illustrated in Figure 18. Extrusion pressures are generally higher and slug preparation is more critical.

Upsetting is the gathering of metal in certain sections along the length of a bar, rod or wire as shown in Figure 19. The metal is forced to flow at right angles to the motion of the tooling. Upsetting is often performed in conjunction with backward or forward extrusions.

Production runs as small as 500 pieces are practical, depending on part size and the type stainless steel used. The 400 Series stainless steels, for instance, are as readily extrudable as carbon steel, whereas the austenitic 300 Series grades—which work harden—require more force. Because of the higher pressures required for the 300 Series types, die wear will be higher.

About 100 pounds is the maximum weight of a stainless steel part that can be cold extruded.

Six inches is about the maximum diameter of a part that can be cold extruded in stainless steel and lengths of up to 80 inches are possible.

Warm extrusion, i.e., heating the slug slightly prior to extruding, can enhance the above-mentioned capabilities somewhat.

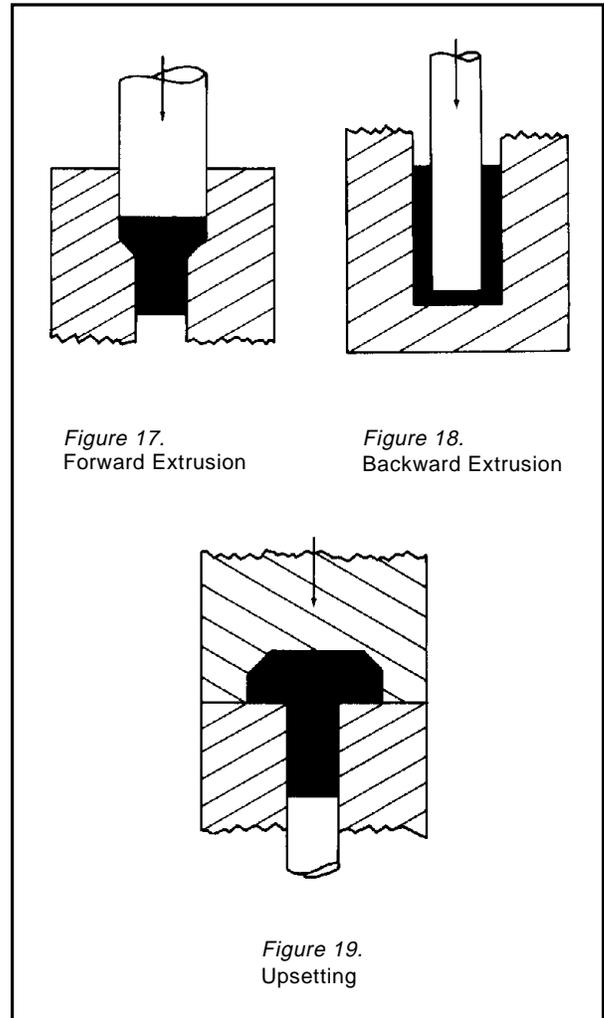


Figure 17.
Forward Extrusion

Figure 18.
Backward Extrusion

Figure 19.
Upsetting

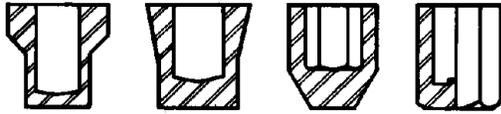


Coin return knob—Type 430

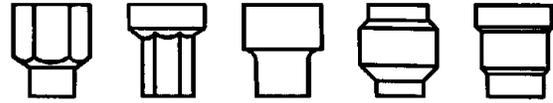


Hex-head machine screw with special Sems washer for tamper-proof cable TV adaptors — Type S30430

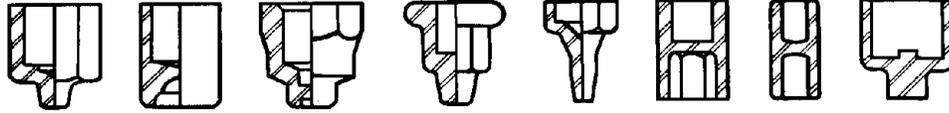
Examples of Cold Extrusion Design



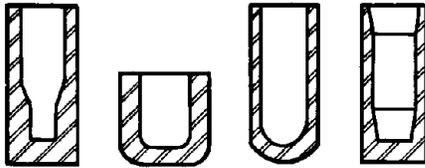
One-Hit Backward Extrusions



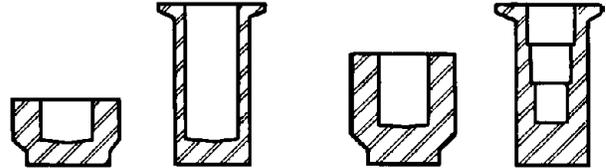
One-Hit Forward Extrusions



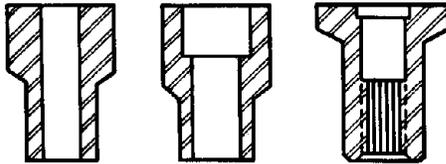
One-Hit Backward, Forward Combination



Backward Extrude and Iron



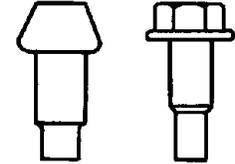
Backward and Forward Extrusions



Backward Extrude, Pierce, Forward Extrude



Two-Hit Forward Extrusion



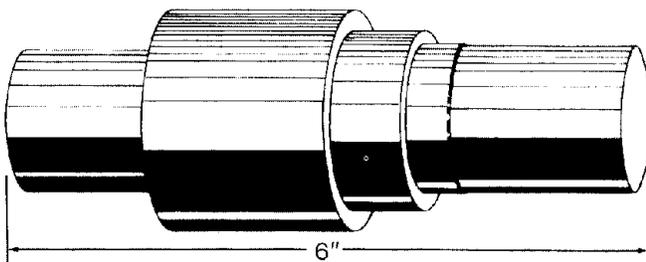
Forward Extrude and Upset

Although most configurations are symmetrical, the number of asymmetric parts being cold extruded is increasing. Refinements also permit the making of intricate parts, such as gears, that require little finishing subsequent to extrusion.

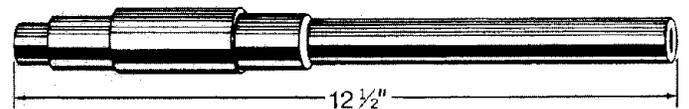
As for design details, sharp corners should be avoided (particularly in bores) because they act to concentrate stresses and can cause dies to fracture under

the extreme pressures. Furthermore, coatings and lubricant films are apt to separate at sharp edges as the extrusion progresses.

Most stainless steels can be cold extruded although it is well to keep in mind that, as with cold heading, some types are better suited to cold forming than others. The principal cold forming stainless steels are Types UNS-S30430, 305, and 384. The stainless steels are discussed in greater detail beginning on page 13.



Inboard/Outboard Motor Tilt Shaft 410 Stainless Steel 3 lbs. This part was originally machined from bar stock, with a material loss of 1.7 lbs. per part. As a cold extrusion, only 0.03" (0.762 mm) is left for cleanup. The part is supplied in the blank form shown; final finishing is done by the customer.



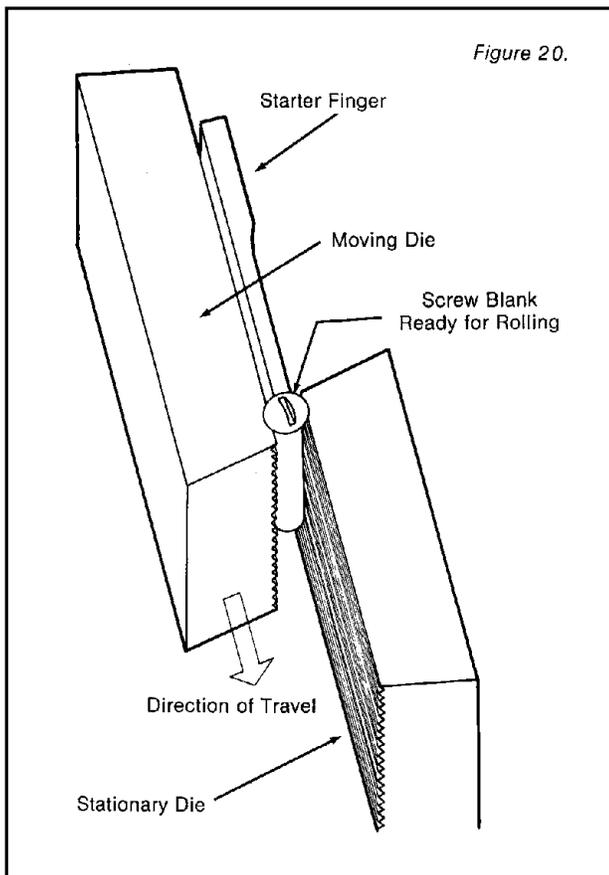
Outboard Motor Prop Shaft 410 Stainless Steel 3 lbs. After extrusion, this part is milled, heat treated, and finished by grinding.

In comparison to bar stock, there is a 60% saving in material. All tracer lathe operations are eliminated, and concentricity of the cold extrusion is held to 0.010" (0.254 mm) maximum T.I.R.

Other Cold Forming Methods

Thread Rolling

Thread rolling consists of nothing more than passing a round section of cold finished stainless steel between two special roll-threading dies, which are mounted in a machine in such a way as to make the material move in a through-feed manner (Figure 20). The surface material is stressed beyond its yield strength, causing it to flow plastically out of place to form the root grooves and crests. Roll-threaded parts have better strength properties and better wear resistance than similar parts that have been machined.



Several grades of stainless steels are being roll-threaded, with Types UNS-S30430, 304, 305, 410, and 430 being the most common.

Swaging

For many parts made of stainless steels, swaging is used as a finishing operation. In swaging, a ring of hammers is rotated around the workpiece at high speed, with some machines delivering up to 1000 strokes per minute to the part in reducing its diameter. The outer surface of a swaged part is always round.

Probably the largest single stainless steel usage for swaging is in the production of cable fittings from Types 303 Se or 305. Items such as ball ends, terminals, turn-buckles, clevises, and eye ends are fabricated using stainless steel bar stock ranging from 1/2 to 3 1/2 inches (12.7 to 88.9 mm) in diameter. Type 303 Se is preferred because of its superior machinability on automatic screw machines, which drill the holes that will accommodate 1/16 to 1-inch (1.59 to 25.4 mm) diameter wire rope, plus its ability to then withstand the cold swaging operation without splitting when the cable is secured.

Simple Bending

Round stainless steel bars up to 2 inches (50.8 mm) in diameter are being cold formed into coil springs by winding on mandrels.

Stainless steel chain is being produced from 1/2 - to 1-inch (12.7 to 25.4 mm) diameter bar and rod. Large tonnages of Types 304 and 309S are made into kiln chain, as one example.

Sections other than round bars are also being cold formed. Some examples are: hot rolled, annealed and pickled Types 304 and 316 angles are being cold formed into rings and pipe flanges. Types 430 and 304 half-rounds are being cold formed into conveyor railing for canning and bottling machines. Flat bars of Type 304 stainless steel are being cold formed into push bars for doors and other structural uses.

Stainless Steels

Identification

Stainless steel is not just one material but a family of many different but related corrosion-resistant alloys containing from about 10.5% chromium on up. The American Iron and Steel Institute (AISI) designates 57 stainless steels as standard compositions, all of which are described in the AISI publication, "Steel Products Manual—Stainless and Heat-Resisting Steels—December 1974." Also available are numerous special analysis and proprietary stainless steels. Table 2 on page 20 is a Trade Name Directory of cold heading stainless steels.

Stainless steels are commonly identified by a system of 200, 300, or 400 Series numbers. The 200 Series stainless steels contain chromium, nickel, and manganese; the 300 Series contain chromium and nickel while the 400 Series are straight-chromium stainless steels.

A new Unified Numbering System (UNS) which applies to all commercial metals and alloys is also used. UNS is a five-digit number. In the case of stainless steels the number is preceded by the letter S, such as UNS-S30400 (Type 304), S31600 (Type 316), or S30430.



Also used are the terms austenitic, martensitic, ferritic, and precipitation hardening, which identify categories of stainless steels on the basis of their metallurgical structure. Stainless steels grouped within these cate-

gories tend to have similar characteristics with respect to corrosion resistance, hardenability, and fabricability.

Austenitic stainless steels are the 200 Series (chromium-nickel-manganese) and 300 Series (chromium-nickel) types. They are generally nonmagnetic in the annealed condition and are hardened only by cold working.

Ferritic stainless steels are the 400 Series straight-chromium alloys. They are magnetic, and they cannot be hardened significantly by heat treatment and only slightly by cold working.

Martensitic stainless steels are also straight-chromium, 400 Series stainless steels, but which are hardenable by heat treatment. They are also magnetic.

Precipitation hardening stainless steels are chromium-nickel steels that are hardenable by solution heat treating and aging.



Meat slicer assembly screw—Type 430

Selection

Selection of the proper grade of stainless steel from the many types available requires an evaluation based upon four important criteria. Listed in order of descending importance, they are:

Corrosion or Heat Resistance—the primary reason for specifying stainless steel. The specifier needs to know the nature of the environment and the degree of corrosion or heat resistance required.

Mechanical Properties—with particular emphasis on strength. The combination of corrosion resistance and strength is the principal basis for selection.

Fabrication Operations—such as cold heading. This is a third-level consideration.

Total Cost—To put everything into proper perspective, a total value analysis should consider not only material and production costs, but the long-term benefits of low maintenance and protracted service life.

Selection procedures are covered thoroughly in technical publications and product literature available from the companies represented on the Committee of Stainless Steel Producers.

Design engineers and specifiers often have to find a compromise from among the four above-mentioned factors to obtain optimum benefits. With regard to cold forming, however, there is little need to compromise, because most stainless steels can be cold formed. However, some types are better suited to cold forming, such as heading, and these will be discussed.

Cold Heading Stainless Steels

Type 304 serves as a general purpose stainless steel for a broad range of applications from cookware to chemical plant equipment. It contains about 18% chromium and 8% nickel (commonly referred to as 18-8 stainless) and it is the most widely used stainless steel. Type 304 has good cold forming qualities and is often used for cold headed and extruded parts.

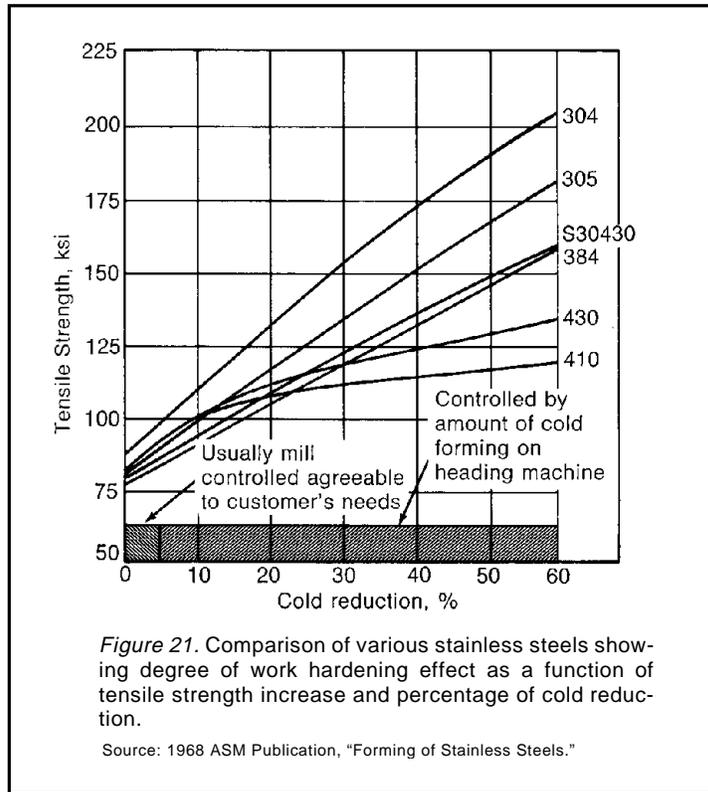
However, Type 304 is an austenitic stainless steel and it work hardens as it is cold worked. The resulting increase in strength and hardness, but decrease in ductility, reduces its capacity for further cold working, unless an interim annealing step is employed. Consequently, it is sometimes preferable to use an alternate to Type 304, such as Types UNS-S30430, 305, or 384, which have lower work-hardening characteristics.

Thread-cutting screw—
Type 410



Lens screw with shoulder—
Type 410





Work-hardening characteristics of various stainless steels are compared in Figure 21. Among the types shown, Type 304 has the greatest strength increase as a result of cold work. Types UNS-S30430, 305, and 384 are less affected by cold work, and the straight-chromium Types 430 and 410 are affected least of all.

Type UNS-S30430

One of the most widely used cold heading stainless steels is Type UNS-S30430, which is identified by most cold heading engineers as 302 HQ. The 302 HQ identification, however, is a trade name; the AISI designation is Type UNS-S30430. It is similar in composition to Type 304 (UNS-S30400) except that it contains 3-4% copper, which results in a significant reduction in its cold work characteristics.

Some parts that are cold formed also involve machining, in which case a free-machining stainless steel can be specified, such as Types 303 and 303 Se. The free-machining improvements in these two types result from increased sulfur and selenium levels, respectively, which can lower their corrosion-resistant properties, especially in parts that will be in contact with water.

In any situation in which corrosion is a critical factor,

it is always good practice to consult a corrosion engineer or metallurgist experienced in stainless steel.

The straight-chromium, 400 Series stainless steels, such as Types 410 and 430, are so little affected by cold working that their cold forming characteristics are similar to those of carbon steel.

Type 410 is used when, after forming, a heat treatment is desired to obtain high strengths, such as for self-tapping sheet metal screws.

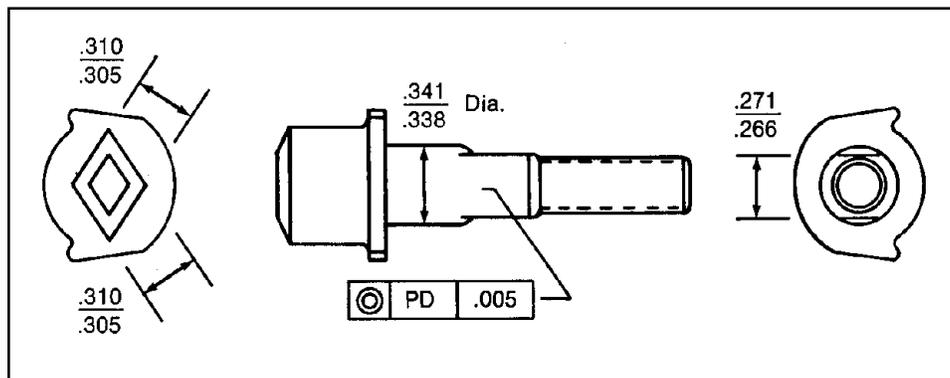


Typical stainless steel part produced by combining extrusion and upsetting on a multiple die forming machine. Extrusion reduces the diameter of the initial stock while increasing its length, and upsetting increases diameter and decreases length.



Impact Extrusion
+ Cold Heading
= 80% Material Savings

By switching from screw machining to cold heading, a reduction of 17¢ in raw material costs was achieved in the manufacture of this valve assembly part. In addition, the cold forming of the chromium-nickel stainless steel significantly increases its tensile and yield strengths, which are vital factors in part reliability.



Type 430 is the most widely used and most readily formed straight-chromium ferritic stainless steel. It has good corrosion resistance and can be upset as much as 3½ to 1, and recessed heads can be readily formed.

Table 3 lists the standard stainless steels that are most frequently cold headed or extruded, and it shows their chemical compositions. Because an alloy is not listed does not suggest that it is not used. For example, Type 316 is used when parts must withstand the severe corrosion encountered in chemical plants and petroleum refineries. Type 321 is occasionally used for elevated temperature applications.

Following is a detailed description of three standard AISI stainless steels that were developed specifically for cold forming operations.



Terminal Stud Originally produced by machining, this electrical terminal stud is now cold headed of Type 430 stainless steel at 1/3 the cost. The wafer-thin collar is upset with two flats that prevent its turning in an insulator. The top half of the shank is extruded, also with two flats, and the threaded end is extruded. Secondary operations include roll-threading and drilling of the top shank where a Nichrome wire is resistance welded.

The finished stud is 1.88" (47.6 mm) long with a body diameter of 0.190" (4.8 mm). Diameter of the collar is 0.312" (7.9 mm).

Type UNS-S30430 (302 HQ) Stainless Steel

Chemical Composition

Carbon.....	0.08	Max.
Manganese.....	2.00	Max.
Phosphorus.....	0.045	Max.
Sulfur.....	0.030	Max.
Silicon.....	1.00	Max.
Chromium.....	17.00/19.00	
Nickel.....	8.00/10.00	
Copper.....	3.00/4.00	

Description

Type UNS-S30430 is an austenitic (300 Series) stainless steel exhibiting a lower work hardening rate than Type 305 and is used for severe cold heading applications. The composition, which includes 3.00-4.00% copper, eliminates cracking and results in improved tool performance. It is being used successfully for cold headed nuts and all standard head configurations of recessed head fasteners. It becomes mildly magnetic after severe cold working.

Corrosion Resistance

Type UNS-S30430 exhibits corrosion resistant properties comparable to Types 304 and 305. When heated above 1000°F (540°C), it becomes subject to carbide precipitation, which can lead to intergranular corrosion in aggressive environments, and, therefore, is not usually recommended for most applications involving welding.

Scaling Resistance

Type UNS-S30430 has a safe scaling temperature in continuous service of 1600°F (870°C).

Physical Properties

Density—lb/in ³ (Kg/m ³).....	0.289 (8060)
Mean coefficient of thermal expansion	
in/in/F x 10 ⁻⁶ (32-1200°F).....	10.4
cm/cm/C x 10 ⁻⁶ (0-649°C).....	18.7
Electric resistivity	
ohm—cir mil ft.....	435
Microhm—cm.....	72

Mechanical Properties (Wire)

	Annealed	Soft Temper
Yield strength (0.2% offset)		
ksi.....	31	55
MPa.....	214	379
Tensile strength		
ksi.....	73	81
MPa.....	503	558
Elongation in 2" (50.8 mm) %.....	70	
Reduction in area %.....	80	
Hardness, Rockwell.....	B70	

Thermal Treatment

Annealing temperature
1850-2050°F (1008-1120°C)
Followed by rapid cooling

Hardening

Hardenable by cold work only

Type 384 (UNS-S38400) Stainless Steel

Chemical Composition %

Carbon.....	0.08 Max.
Manganese	2.00 Max.
Phosphorus.....	0.045 Max.
Sulfur.....	0.030 Max.
Silicon	1.00 Max.
Chromium	15.00/17.00
Nickel	17.00/19.00

Description

Type 384 is an austenitic, chromium-nickel stainless steel that is particularly useful for cold headed and upset parts because it work hardens the least of the conventional 18-8 types. It remains nonmagnetic during cold working.

It is used for fasteners, cold heading bolts, screws, upset nuts and instrument parts, as well as for jobs involving severe coining, extrusion and swaging. The most important use, however, is for cold headed screws and bolts and for upset and punched nuts. Type 384 is ideally suited for thread rolling.

Corrosion Resistance

Type 384 resists a wide variety of organic and inorganic chemicals and foodstuffs. It resists nitric acid well and sulfuric acid moderately, but not hydrochloric and other halogen acids. It is subject to carbide precipitation if heated or cooled slowly in the range of 800/1650°F (427/899°C), in which case it should have a corrective anneal by water quenching from at least 1900°F (1038°C).

Scaling Resistance

Type 384 has a safe scaling temperature in continuous service of 1600°F (871°C).

Physical Properties

Density—lb/in ³ (Kg/m ³)	0.29 (8060)
Mean coefficient of thermal expansion	
in/in/F x 10 ⁻⁶ (32-1200°F)	10.4
cm/cm/C x 10 ⁻⁶ (0-649°C)	18.7
Electrical resistivity	
ohm—cir mil/ft	476
Microhm—cm	79
Specific heat	
Btu/lb/F (32-212°F)	0.12
J/kg•K (0-100°C)	502

Mechanical Properties (Wire)

	Annealed	Lightly Drafted
Yield strength (0.2 offset)		
ksi	35	45
Mpa	241	310
Tensile strength		
ksi	75	78
Mpa	517	538
Elongation in 2" (50.8 mm) % ...	55	
Reduction in area %	72	
Hardness, Rockwell	B70	

Thermal Treatment

Annealing temperature
1900-2100°F (1036-1149°C)
Followed by rapid cooling

Hardening

Hardenable by cold work only

Type 305 (UNS-30500) Stainless Steel

Chemical Composition %

Carbon	0.12	Max.
Manganese.....	2.00	Max.
Phosphorus	0.045	Max.
Sulfur	0.030	Max.
Silicon	1.00	Max.
Chromium	17.00/19.00	
Nickel.....	10.50/13.00	

Description

Type 305 is available in bar and wire form for cold heading and extrusion processes. It is used also where the finished part must remain nonmagnetic after severe cold work.

The chromium/nickel ratio is such that it has less tendency than Type 304 to work harden during cold work, so that a greater amount of deformation is possible before process annealing is necessary.

Corrosion Resistance

Type 305 resists nitric acid well and sulfuric acid solution only moderately, but does not resist the halogen acids, such as hydrochloric. It is entirely satisfactory in a wide range of organic or inorganic chemicals, food-stuffs, and sterilizing solutions. It is subject to carbide precipitation when heated or cooled slowly through the range of 800/1650°F (427/899°C); so a corrective anneal by water quenching from 1900°F (1038°C) should be used.

Scaling Resistance

Type 305 can be used safely in continuous service at 1600°F (871°C).

Physical Properties

Density—lb/in ³ (Kg/m ³)	0.29 (8060)
Mean coefficient of thermal expansion	
in/in/F x 10 ⁻⁶ (32-1200°F)	10.4
cm/cm/C x 10 ⁻⁶ (0-649°C)	18.7
Electrical resistivity	
ohm—cir mil/ft	455
Microhm—cm	75.6
Specific heat	
Btu/lb/F (32-212°F)	0.12
J/kg•K (0-100°C).....	502

Mechanical Properties (Wire)

	Annealed	Soft Temper
Yield strength (0.2% offset)		
ksi	47	54
Mpa	324	372
Tensile strength		
ksi	85	100
Mpa	586	689
Elongation in 2" (50.8 mm) % ...	60	58
Reduction in area %	77	74
Hardness, Rockwell	B78	B82

Thermal Treatment

Annealing temperature
1850-2050°F (1008-1120°C)
Followed by rapid cooling

Hardening

Hardenable by cold work only

TABLE 2

COLD HEADING STAINLESS STEELS TRADE NAME DIRECTORY

AISI TYPES	(UNS)	AIRCO	ALLEGHENY LUDLUM	ARMCO	ATLAS STEELS	CARPENTER TECHNOLOGY	REPUBLIC	US STEEL	UNIVERSAL CYCLOPS
410	(S41000)		Type 410	Type 410	Type 410	Carpenter 410	Endure 410	Type 410	Uniloy 410
430	(S43000)		Type 430	Type 430	Type 430	Carpenter 430	Enduro 430	Type 430	Uniloy 430
440C	(S44004)				Type 440C	Carpenter 440C			Uniloy 440C
303	(S30300)			RP 303	Type 303	Carpenter 303	Enduro 303		Uniloy 303 Uniloy 303 MA*
304	(S30400)		Type 304	Type 304	Type 304	Carpenter 304	Enduro 304	Type 304	Uniloy 304
	(S30430)		Type 302 Cu	18-9 LW		Custom Flo 302 HO		Type S30430	Uniloy 302 HO
305	(S30500)		Type 305	Type 305	Type 305	Carpenter 305	Enduro 305	Type 305	Uniloy 305
384	(S38400)		AL 10			Carpenter #10		Type 384	Uniloy 16-18
	(S17400)			Armco 17-H PH		Custom 630			
	(S44625)								*E-Brite 26-1*

*Special Analysis Stainless Steel

TABLE 3

STANDARD STAINLESS STEELS MOST COMMONLY USED FOR COLD HEADING

Type	(UNS)	C Max	Mn Max	P Max	S Max	Si Max	Cr	Ni	Other
410	(S41000)	0.15	1.00	0.040	0.030	1.00	11.50-13.50	—	
430	(S43000)	0.12	1.00	0.040	0.030	1.00	16.00-18.00	—	
440C	(S44004)	0.95-1.20	1.00	0.040	0.030	1.00	16.00-18.00	—	0.75 Mo Max
304	(S30400)	0.08	2.00	0.045	0.030	1.00	18.00-20.00	8.00-10.50	
	(S30430)	0.08	2.00	0.045	0.030	1.00	17.00-19.00	8.00-10.00	3.00-4.00 Cu
305	(S30500)	0.12	2.00	0.045	0.030	1.00	17.00-19.00	10.50-13.00	
384	(S38400)	0.08	2.00	0.045	0.030	1.00	15.00-17.00	17.00-19.00	
	(S17400)	0.09	1.00	0.040	0.040	0.040	16.00-18.00	6.50- 7.75	0.75-1.50 Al

Source: Steel Products Manual Stainless and Heat-Resisting Steels, December, 1974

SPECIAL ANALYSIS

303 MA	0.15	2.00	0.04	0.11-0.16	1.00	17.00-19.00	8.00-10.00	0.60-1.10 Al
E-Brite 26-1	0.01	0.04	0.020	0.020	0.40	25.00-27.50	0.50 Max	0.75-1.50 Mo 0.015 N Max Ni+Cu 0.50 Max