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**Guidelines**

**for**

**U-Bolt**

**Bending**





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Guidelines for U-Bolt Design

Guidelines for U-Bolt Design



## Guidelines for U-Bolt Bending

### Introduction

The design and manufacturing of various types of U-bolts generally does not receive prolonged attention from engineers, buyers or production personnel. However, the materials and processes used to construct these items have undergone significant technological changes. The push for quality, cost-effective manufacturing, increased physical demands and the ever present sensitivity to liability issues have made threaded products a highly engineered component of critical importance in any joint.

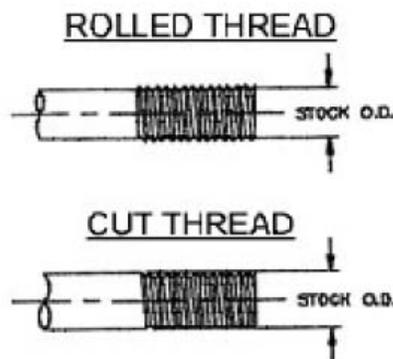
The past practice of hot forging U-bolts from cold-finished bars with cut threads has given way to less-costly high speed production of rolled threads on cold drawn wire. Modern materials and cold working often attain strength levels that previously required heat treatment, while retaining toughness and reducing cost.

In particular, rolled threads have several advantages over cut threads:

- Fine surface finish
- High rates of production with no material waste
- Strong threads with a work-hardened surface

The purpose of this guide is to provide engineers and other interested users with the informal rules of thumb that will allow U-bolt designs that can be consistently manufactured within tolerances that modern practices permit while avoiding unnecessary cost. It must be understood that these are only general guidelines and there are exceptions to every rule. Clamps Incorporated assumes no responsibility for the use of these guidelines by any party. The design, testing, construction, inspection and use of any products are the responsibility of the customer. Clamps Incorporated manufactures products to customer specifications and assumes no liability beyond that point.

### Wire Diameter for 2A Threads



Wire for cut threads is drawn at the nominal major diameter, but as the illustration shows, wire for stronger rolled threads is drawn to a smaller diameter, approximately equal to the pitch diameter of the threads. The rolled threads are squeezed by die pressure into the roots and crowns of the threads.



## Guidelines for U-Bolt Bending

The value and tolerances of blank diameters for imperial or metric rolled threads should be governed by published standards for pitch diameter 2A or 6g threads. As an example, if a 1/2-13 UNC-2A thread is desired, the standard pitch diameter ranges is 0.4435 to 0.4485 inches. The wire diameter should be less than 0.0005 of an inch.

The following are desired wire diameters for stated 2A thread sizes:

UNC-2A	
Thread Size	Wire $\phi$
1/4-20	0.2146-0.2153
5/16-18	0.2732-0.2740
3/8-16	0.3309-0.3318
7/16-14	0.3874-0.3383
1/2-13	0.4470-0.4480
9/16-12	0.5050-0.5070
5/8-11	0.5630-0.5650
3/4-10	0.6785-0.6815
7/8-9	0.7960-0.7990
1"-8	0.9120-0.9150

UNF-2A	
Thread Size	Wire $\phi$
1/4-28	0.2242-0.2248
5/16-24	0.2825-0.2832
3/8-24	0.3449-0.3457
7/16-20	0.4016-0.4024
1/2-20	0.4641-0.4649
9/16-18	0.5170-0.5190
5/8-18	0.5840-0.5860
3/4-16	0.7040-0.7070
7/8-14	0.8230-0.8260
1"-12	0.9400-0.9430

### Cold Drawing and Bolt Strength

The need to accurately size the wire for the best pitch diameter has led to the use of cold drawn material. This tight diameter control has led to other advantages, better surface conditions and higher tensile strengths due to cold working of the wire. Most used bolt material, 1018 will have greater than average strength and toughness after cold working, especially if cold-headed quality rod is used.

The advantage of lower cost is accompanied by an increased toughness and failure resistance. The hardness of a cold drawn bolt may run lower than a heat treated bolt of similar tensile strength. This advantage during manufacturing may be first seen to be detrimental during use, but there are normally additional considerations.

1. Hardness as a method of estimating tensile strength is not as reliable as a standard tensile test.
2. As the vast majority of U-bolts are subject to a tensile service load, tensile strength is the primary determining factor of grade, material and diameter selection.
3. The general hardness of a U-bolt is usually not a consideration in the service life as there is often no wear involved. The threads are much harder, due to the tremendous cold working they undergo during rolling, than the rest of the bolt. Because of the thread geometry, a hardness test is not practical in the threads themselves and a tensile test is a better indication of overall bolt strength. The additional hardness of the threads provides the necessary torque values during assembly. If higher hardness values are required, a stress relieved or heat treated bolt is necessary.

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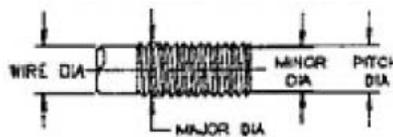
## Guidelines for U-Bolt Bending

The yield strength can be a governing factor in the design due to a fear of plastic deformation of the bolt when strength is exceeded. This causes a loss of joint preload. In this case, redesign of the material, bolt diameter, or joint should be considered in order to provide an adequate safety margin. A joint load that consumes a large percentage of the yield strength is not a safe joint. While it may not fail under static load, cyclic will cause premature failure.

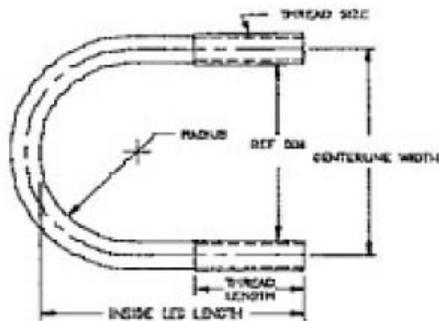
### Selection of Material

The determining factor in material selection for U-bolts is generally the load carrying capacity of the unit. The forces experienced in the joint, including normal shock and cyclic, must be evaluated to determine the capacity required. In conjunction with published inch and metric standards, a nominal diameter should be selected to provide a sufficient capacity with a safety margin. If weight is not a consideration, a large diameter may prove less expensive than heat treatment of a higher alloy.

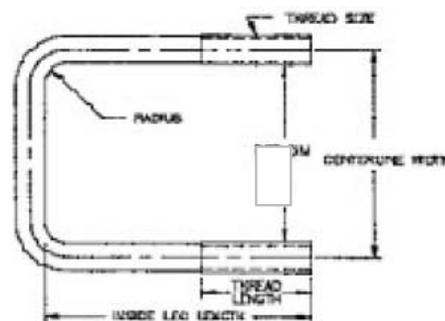
#### Rolled Thread



#### Round Bend U-Bolt



#### Square Bend U-Bolt



The torque requirements during assembly may demand a higher grade material than the load requirements. For example, a 5/8-11 bolt with a 90,000 P.S.I. tensile requirement would normally use 1038 steel. If a minimum torque requirement of 105 ft-lbs is specified an increase to 1541 steel would be required. The hardness and matching of materials of both the bolt and nut are critical. Selection of washer material also affects torque readings.

Corrosion resistance can be accomplished with a variety of coatings including zinc plating, paint and other coatings. Plated U-bolts may also be baked after zinc plating to avoid hydrogen embrittlement at the radii and thread roots, especially bolts of high tensile material. Stainless steel grades are also available for corrosion resistance or improved appearance. There are several stainless steel grades that are easily roll threaded and formed at a variety of strength levels.

Guidelines for U-Bolt Design

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## Guidelines for U-Bolt Bending

### General Definitions

U-bolts come in all sizes and shapes, with many common features. In the manufacture of millions of these items, there is a common nomenclature that appears throughout the industry for many of the dimensional characteristics. The illustrated round bend and square bend U-bolts demonstrate the dimensioning and symbology of these rolled-threaded products.

Inside Leg Length: Distance from the inside radius or flat to the end of the leg.

Thread Length: The full thread length shall be measured, parallel to the axis of the thread, from the extreme end of the bolt to the last complete (full form) thread that will accept a gauge or nut.

Reference Dimension: Perpendicular distance between major thread diameters of two legs, measured within six threads of the end of the legs.

Centerline Width: Perpendicular distance between the centerlines of the legs, measured at the end of the legs.

Radius: Inside radius of the bolt form.

Major Diameter: Maximum outside diameter of the threads.

Minor Diameter: Diameter of the threads from root to root.

### General Tolerances

The tolerances of the above dimensions vary. There are general levels of compliance that the U-bolt industry expects equipment and tooling to meet. Tighter tolerances may not be economically attainable in high volume production or may be negated by subsequent processing. Cold forming can meet a requirement of +/- .030 inches for the centerline width of a medium tensile U-bolt. Tumbling in a barrel during zinc plating may cause the legs to spring back in an unpredictable manner, resulting in rework to return the legs to specifications. Loose tolerances have no manufacturing or assembly advantage and may affect other features of the U-bolt.

Feature	Tolerance
Inside Leg Length	+/- .060
Threaded Length	+/- .060
Centerline Width	+/- .030 Min - +/- .120 Max
Reference Dimension	+/- .030 Min - +/- .120 Max
Radius	+/- .015
Pitch Diameter	Published Standards
Major Diameter	Published Standards
Wire Diameter	Within +/- .030 of Pitch Diameter
Angles	+/- 3 degrees



## Guidelines for U-Bolt Bending

Centerline tolerances are determined based on the bolt leg length. The following are recommended tolerances:

Leg Length	Tolerance
0" - 5"	+/- .030
5" - 8"	+/- .060
8" - 12"	+/- .090
Over 12"	+/- .120

U-bolts with legs lengths that exceed 20 inches should be assigned a tolerance on a part by part basis as determined by the Customer and Clamps Incorporated.

If tighter tolerances are required, Clamps should be consulted to ensure capability on the part by part basis. If the centerline width is assigned a tolerance, the reference dimension will be assigned the same tolerance.

### Chamfering

A chamfer can be rolled on the end of the thread to aid in assembly. This is normally done in a separate operation to a fine threaded bolt. Fine threaded bolts may become cross threaded when the nut is started on the threads. The chamfer allows the nut to be centered on the end of the bolt creating proper alignment between the threads of both. Chamfer adds to cost, but cost saved during assembly may justify the chamfer. Roll chamfering of U-bolts 3/8 inches and 10mm in diameter is not recommended.



An alternate to chamfering is to have the first thread rolled undersize (this is sometimes referred to as “rolled thread chamfer”) as the illustration above shows. This accomplishes the same purpose as a chamfer, and is done during the threading operation with no additional cost. It is especially useful on coarse threaded bolts. If chamfering is necessary, it is better to chamfer a U-bolt with fine threads and to roll the threads undersize on a coarse threaded U-bolt. All Clamps Incorporated roll threaded products, both fine and course threads have the first threads rolled undersize.

### Minimum Bend Radius

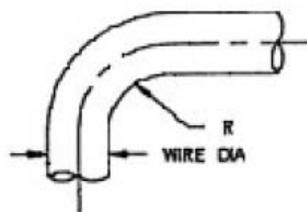
On rolled bend U-bolts, the bend radius is a function of the centerline width and has little to no affect with material integrity. On square bent or V-bolts, the radii may be a function of the mating member of the joint. On large radius (1.5 times the wire diameter), there is less deformation at the radius during the forming operation than the small radius. Deformation occurs at the radii as the material on the outside of the bend stretches further than the material at the inside of the bend. The yield point of the material is exceeded and plastic deformation in the form of diameter loss or necking can be seen. This is discussed in the next section.



## Guidelines for U-Bolt Bending

In order to minimize this deformation, the inside radius should be made as large as possible. The minimum radius should exceed  $.50 \times$  the wire diameter for low tensile materials and  $.70 \times$  the wire diameter for high tensile materials. Alloys with low toughness and elongation values should have the radius above  $.80 \times$  the wire diameter. When radii are below these minimums, large residual stresses are induced in the bends and cracks may occur during the forming process.

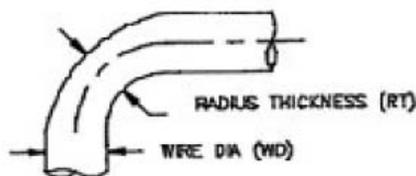
### MIN BEND RADIUS



### Necking at the Radius

In reference to the above, necking occurs when the yield point of the material is exceeded at the bend due to small radius values. Necking is a loss of cross-sectional area and proportional loss of load carrying ability of the U-bolt. The loss area and capacity of 5% is not uncommon and in cases of very tight radii in high tensile U-bolts an 8% reduction of area is possible. At this point a U-bolt designer should remember that different mill heats of the same steel chemistry will have a range of tensile and toughness properties. There is no way to predict that a U-bolt experiencing a 1% reduction of area will not see 4% on the next production run. The best way to avoid necking is designing the radius to reduce plastic deformation.

### NECKING AT RADIUS



Diameter loss at the radius is a less severe condition that is due to the outer layer of material stretching further than the inner layers. This change in wire diameter is also a function of the outside radius value and may be reduced by using a larger value for the radius. The cross section of the bend changes from circular to elliptical with the major axis of the ellipse being perpendicular to the plane of the U-bolt. The diameter loss cannot be predicted from one heat of steel to the next.

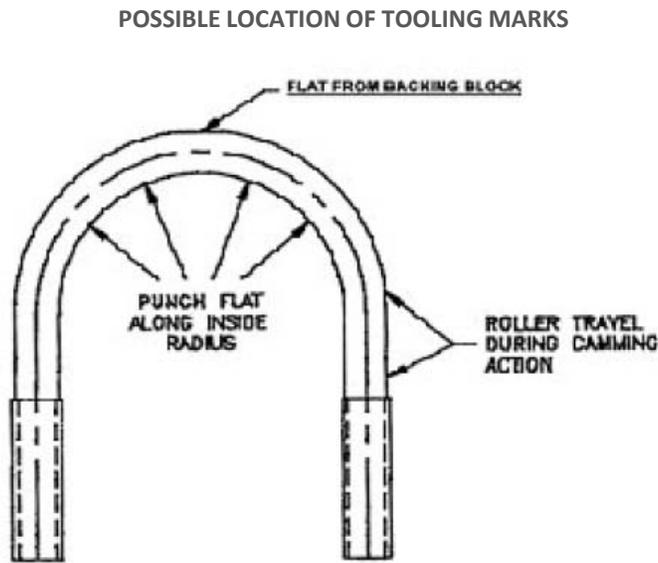
While diameter loss and necking cannot be eliminated, they can be reduced. A guideline for diameter loss is that it should either be 15% less of the wire diameter or account for when a safety margin is established for the load carrying capacity of the U-bolt. If diameter constraints are tight in the design, and the diameter loss should not exceed 15%, then a tougher more ductile material should be used.



## Guidelines for U-Bolt Bending

### Common Tool Marks

Generally, the effects of cold drawing, straightening, cutting and threading leave few to no tool marks on the surface of the U-bolt. To form the bolt into a round bend, square bend or V-bolt shape requires a forming die and considerable force. The pressure to cold form the work piece results in localized plastic deformation.



The punch imparts the shape of the radius and determines the lower limits of the centerline width. The back-up pad grips the straight bolt between itself and punch. The rollers on the outside of the leg control the exact centerline required. All of these may leave tool marks on the U-bolt, depending on the material, shape and hardness. Though some of the tooling marks can be reduced by modification of the tooling, the additional tooling cost should be considered as a function of quantity and production rate.

As the ratio of bend radius to wire diameter decreases, or as yield strength of the material decreases, the width of the tooling marks will increase. Often there is no change in cross sectional area, but a change in the shape of the cross section. Tooling marks will not be harmful unless stress concentrations are introduced by the marks or nicks that are transverse instead of parallel to the wire axis. Since the majority of U-bolts are under tensile load, a sharp transverse mark that is deeper than  $1/4$  the difference between the pitch and minor diameter reduces the load carrying capacity at that point.

Tooling that is properly maintained should not leave sharp indentations. It must be remembered that a U-bolt cannot be formed without this tooling and the resulting flats and roller marks.

Guidelines for U-Bolt Design

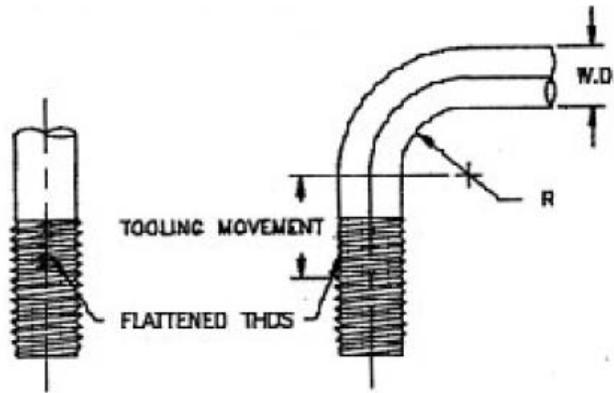
Guidelines for U-Bolt Design



## Guidelines for U-Bolt Bending

### Interference of Threads and Radius

The rollers are used to bend the legs. Without this action there would be no U-bolt. The rollers travel past the end of the outside radius up the leg. A problem arises when the threads which are rolled first, are designed to have a length that approaches the radius. As the "U" shape is made, the rollers flatten the lower threads on the outside of the leg, often rendering them unusable, as seen in the following illustration.

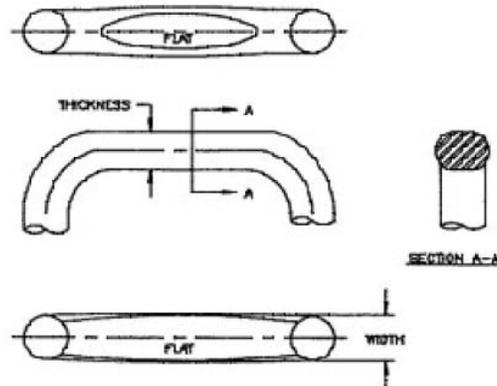


This often happens with smaller U-bolts and some damage to the threads may not be preventable. The U-bolt should be formed after the threads are rolled. The best remedy is to leave about one inch of distance between the finish of the radius and that start of the threads during the design process. The minimum safe distance would be two times the wire diameter.

### Flattened/Coined U-Bolts

The inside area of a U-bolt radius can be flattened to spread the force it applies to the mating part of the joint over a larger area. Flattening can be done on virtually any shape of U-bolt. It sometimes can be done with an increase of force or it may require special tooling to maintain the flat area. The material deforms out of the plane of the U-bolt in an amount inversely proportional to the thickness of the flat. Either the thickness or width of the flat can be specified, usually to a +/- 0.030 inch tolerance but not both dimensions. The deformation is dependent on the yield strength of the steel and is difficult to predict the exact material flow.

GENERAL APPEARANCE OF A  
FLATTENED / COINED U-BOLT



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## Guidelines for U-Bolt Bending

A flat normally has little to no effect on the cross sectional area, but does leave large residual stresses. If the flat overlaps into a tight radius, necking cannot be avoided. A reduction of area as large as 12% would be seen in this area. Reducing the width of the flat, decreasing the length of the flat, or increasing the radius would be necessary.

### Metric Threads

Metric threads are grouped into diameter pitch combinations differentiated by pitch applied to the specified diameters. The pitch for metric threads is the distance between corresponding points on adjacent teeth. In addition to a coarse and fine pitch series, a series of constant pitches is available.

Each of the two main thread elements - pitch diameter and crest diameter, there are numerous tolerance grades. The number of the tolerance grade reflects the tolerance size, for example: Grade 4 tolerances are smaller than Grade 6 tolerances; Grade 8 tolerances are larger than Grade 6 tolerances. In each case, Grade 6 tolerances should be used for medium quality length of engagement applications. The tolerances grades below Grade 6 are intended for applications involving fine quality and/or short lengths of engagement. Tolerance grade above Grade 6 are intended for coarse quality and/or long periods of engagement.

Position tolerances are also required. The positional tolerance defines the maximum material limits of the pitch and crest diameters of the external and internal threads and indicates their relationship to the basic profile.

In conformance with current coating (or plating) thickness requirements and the demand for ease of assembly, a series of tolerance positions reflecting the application of varying amounts of allowance has been established.

#### External Threads:

- Tolerance Position "e" (large allowance)
- Tolerance Position "g" (small allowances)
- Tolerance Position "h" (no allowance)

#### Internal Threads:

- Tolerance position "G" (small allowance)
- Tolerance position "H" (no allowance)

ISO metric screw threads are defined by nominal size (basic major diameter) and pitch, both expressed in millimeters. An "M" specifying the ISO metric screw thread precedes the nominal size and "X" separates the nominal pitch. Coarse thread series, the pitch is shown only when the dimension for the length of the thread is required. When specifying the length of thread, an "X" is used to separate the length of thread from the rest of the designations. External threads, the length of thread may be given as a dimension on the drawing.



## Guidelines for U-Bolt Bending

As an example, a 10 mm diameter, 1.25 pitch, fine thread series is expressed as M10 x M.12. A 10 mm diameter, 1.5 pitch, coarse thread series is expressed as M10, the pitch need not be shown unless the length of the thread is required. If the thread was 25 mm long and this information was required on the drawing, the thread callout would be M10 x 1.5 x .25.

The complete designation for ISO metric screw thread includes the tolerance class identification. A dash separates the tolerance class identification from the basic designation and includes the symbol for the pitch diameter tolerance followed immediately by the grade tolerance followed by a letter indicating the tolerance position (a capital letter for internal threads and lowercase letter for external threads). Where the pitch and crest diameter symbols are identical, the symbol is necessary only once. Figure A illustrates the labeling of metric threads

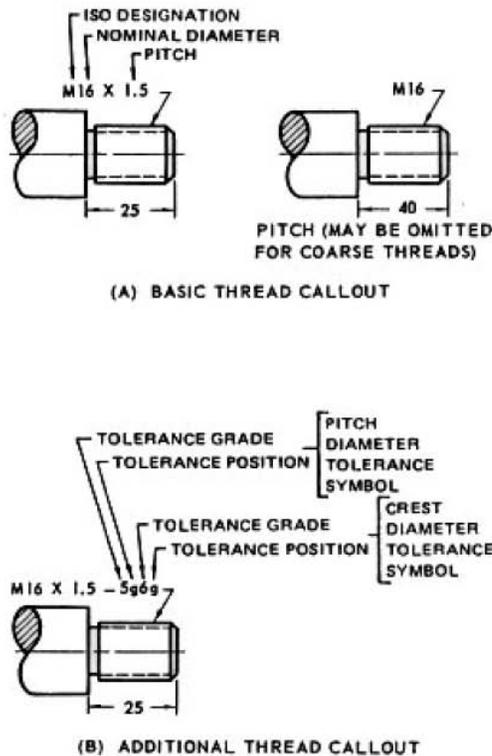


Figure A - Specifications for metric threads

INCH THREADS	METRIC THREADS
#10 (.190)	M5
1/4 (.250)	M6
3/8 (.375)	M8
1/2 (.500)	M10
5/8 (.625)	M12
3/4 (.750)	M14*
7/8 (.875)	M16
1 (1.000)	M18*
1 1/8 (1.125)	M20
1 1/4 (1.250)	M22*
1 3/8 (1.375)	M24
1 1/2 (1.500)	M27*
	M30
	M33*
	M36
	M39*

\*NONPREFERRED SIZES

Figure B - Size Comparison of Inch to Metric Threads

### Thread Standards

There are several places to search for published standards relating to bolts and threaded items. Listed below are some of the major sources with links to their website.



## Guidelines for U-Bolt Bending

### Standard Organizations

#### Screw Thread Standards -

- ANSI B1.1 - Unified Screw Threads
- ANSI B1.13M - Metric Screw Threads - M Profile
- IFI - "Fastener Standards"
- IFI - " Metric Fasteners Standards"

#### Material Standards

- ASTM Volume 15.08 - Fasteners
- ASTM A193/93M - Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service
- ASTM A307 - Carbon Steel Bolts and Studs, 60,000 P.S.I. Tensile strength.
- ASTM A325 - Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.
- SAE J429 - Mechanical and Material Requirements for Externally Threaded Fasteners.
- SAE J1199 - Mechanical and Material Requirements for Metric Externally Threaded Fasteners.

#### Plating Standards

- ASTM A153 - Specification for Zinc Coating (Hot Dipped) on Iron and Steel Hardware.
- ASTM B633 - Electrodeposited Coating of Zinc on Threaded Components.
- ASTM F871M - Electrodeposited Coating of Threaded Components (Metric).
- ASTM A165 - Specifications for Electrodeposited Coating of Cadmium on Steel.

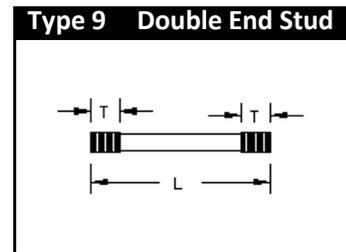
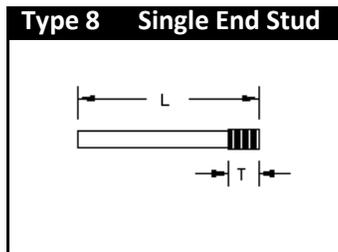
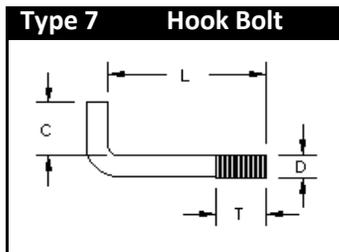
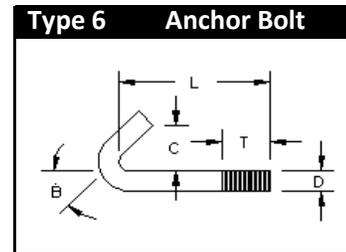
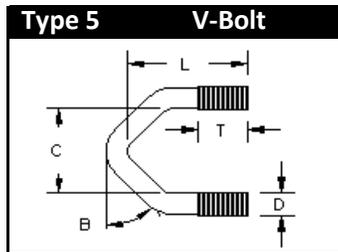
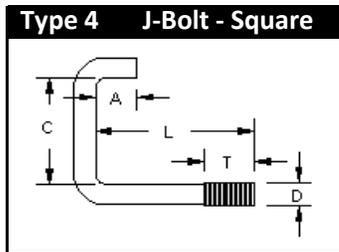
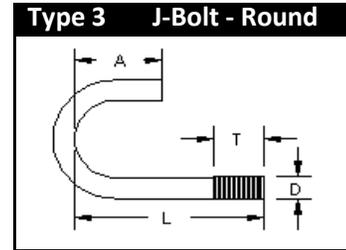
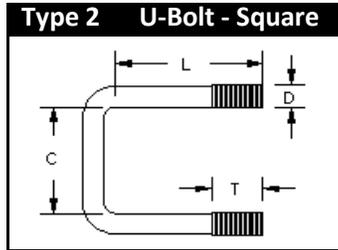
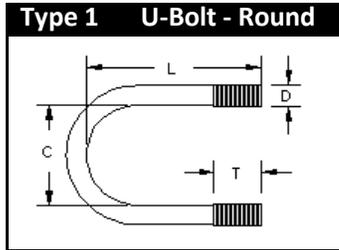
### \*Acknowledgement

Written by (1978):	Gordon Hanson
Illustrated by (1978):	Brian Jacobson
Revised and updated by (1992):	Richard Hildman
Updated and re-illustrated by (1994):	Gordon Hanson, Richard Hildman & Steve Santee

\*The above are former employees of the former Formed Steel Products. Select assets of Formed Steel Products was purchased by Clamps Incorporated in 1992.



## Custom Bent / Threaded Bolts



Guidelines for U-Bolt Design

Guidelines for U-Bolt Design

Not all dimensions are applicable to each bolt type

<b>Bolt Type:</b> _____	<b>A:</b> _____
<b>Part Number:</b> _____	<b>B:</b> _____
<b>Material:</b> _____	<b>C:</b> _____
<b>Quantity:</b> _____	<b>D:</b> _____
<b>Finish:</b> _____	<b>L:</b> _____
	<b>T:</b> _____

Dimensions

**Company Name:** \_\_\_\_\_

**City, State:** \_\_\_\_\_

**Your Name:** \_\_\_\_\_

**Ph / :** \_\_\_\_\_

**Fx / :** \_\_\_\_\_

**Em / :** \_\_\_\_\_



## Clamps Incorporated Company Profile

### Profile



Clamps Incorporated was founded in 1957 by the late Water F. Riker who designed and patented the guillotine exhaust clamp for use in the heavy duty truck and off-road equipment markets.

The success of the guillotine style clamp and Clamps Incorporated represents years of dedicated effort by employees of Clamps Incorporated and the Riker family, past and present.

### Quality Policy

Clamps Incorporated quality policy is to achieve total customer satisfaction by understanding our customer needs through continual improvement of product, services and quality management systems.

Clamps Incorporated is certified to ISO 9001:2008 standards.



### Products

#### U-Bolt Clamps



**Heavy Duty and Standard Duty Clamps:** A complete product line of heavy duty and standard / light duty round and flat u-bolt clamps with guillotine, double edge, closed and open end saddle clamps. Size range from 1.13" to 8.00" depending on style.

#### Band Clamps



**Band Clamps:** "CI" and Torca® band clamps in preformed, flat and narrow band styles. Single bolt and double bolt installation. Size range from 1.75" to 6" depending on style.

#### Custom Bent Bolts & Stampings



**Custom Bent Bolts:** Wire form bent bolts; round and square J-Bolts; L-Hooks; U-Bolts; Anchor Bolts; Single and Double End Threaded Studs.

**Custom Stampings:** Equipped with 75 to 400 ton press ratings for progressive and single die stampings for brackets and mounting rings.

### Administration

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