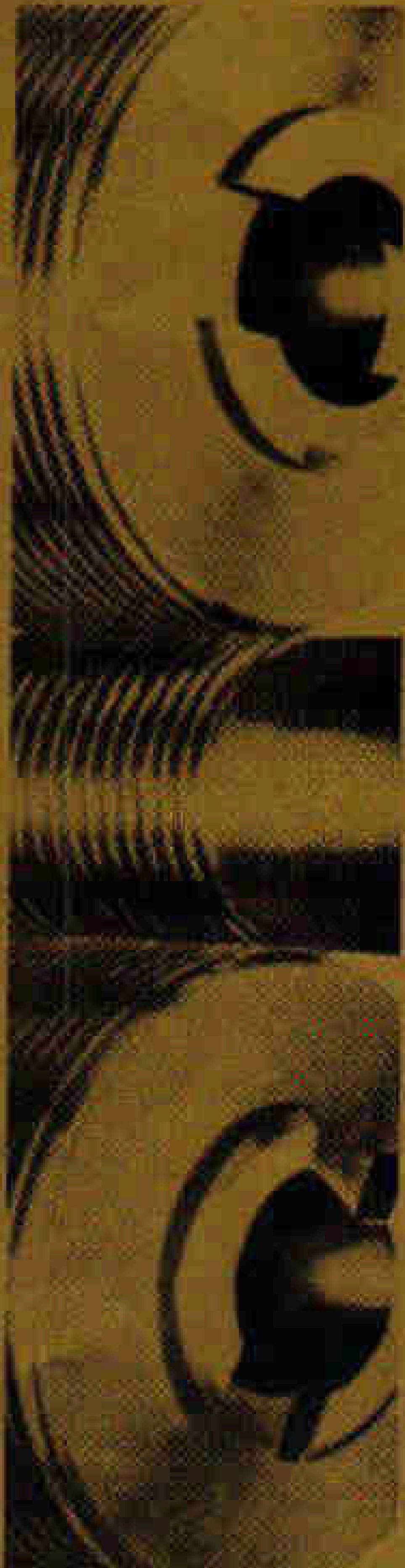

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TR/USA INC.

TR-2000

THREAD ROLLS AND THREAD ROLLING ON AUTOMATICS

PRODUCTS MANUAL & OPERATOR'S REFERENCE GUIDE

CONTENTS

THREAD ROLLS AND THREAD ROLLING
THE ART, THE SKILLS, THE EXPERIENCE

Thread rolls are precision tools designed and made to roll a specific thread size.

There is a definite relationship between the roll and the part for a corresponding thread size. The roll diameter is derived from somewhat modified multiples of thread size. These multiples are called starts. We can change the roll diameter by increasing or decreasing the number of starts, but the relationship between the roll start and the thread size always remain constant. This relationship is very important, otherwise, the synchronization, or timing, between the multiple start roll and a single lead part, or any lead part for that matter, during the rolling process would be impossible.

Experimenting with thread rolling goes back some 150 years. In 1851, in the midst of the Industrial Revolution, a rather primitive thread rolling machine using flat dies was introduced for the first time in England. Although the machine itself never achieved any appreciable measure of success, the idea of the thread rolling process, however, was sound, and apparently quite well understood.

Thread and form rolling became an impressive and diversified field only in the last 50 years. First it was adapted to the then existing equipment, and soon thereafter, special equipment was developed - powerful thread rolling machines, capable of rolling far beyond what had been possible on turning equipment, and later on screw machines.

Basically, we now have three types of thread rolling machines: *cylindrical die machines,* using two or three cylindrical dies, *planetary die machines*, using a combination of a rotary die and stationary segments, and *reciprocating thread rolling machines*, using movable and stationary flat dies. Special dies for these machines are capable of performing various rolling operations other than threading - from knurling, oil grooving, and burnishing, to rolling involute splines, gears, and even balls for bearings.

Only cylindrical type machines are capable of producing both in-feed and thru-feed rolling. Several different designs of dies are being used for thru-feeding, depending on the capability of the machine. They can be of a skewed axis design, parallel axis design, or annular groove design. Most of these dies will roll only an opposite hand thread, although, in some specific cases, same hand thread can be rolled on the piece part as it is on the rolls. With annular groove dies, however, rolling both right and left hand threads is possible.

On automatic screw machines, thread rolling is being accomplished by two different methods. One involves the use of end-rolling heads mounted in a turret. These heads, depending on the size, employ two, three, or more annular groove rolls and are capable of thru-feed rolling to desired thread length, limited only by the head capacity.

The other method, strictly an in-feed operation, involves the use of thread rolling attachments or holders, mounted on the machine's cross-slide. This is the most widely used method in the thread rolling industry, as over 100 models of various holders and attachments will attest to that. There are two distinct types of attachments: *radial (scissor)* type and *tangential (straddle)* type.

Even though most of them are at least similar in design, still there is a wide range of differences between many of them, both in design as well as in method of operation. For this reason, a setup procedure for any given attachment should be done in accordance with the operating manuals provided by the manufacturers. Their recommendations should also be followed throughout the entire operating procedure. Our efforts, in trying to provide additional help, will be focused on thread rolls only.

To this end, we have prepared this handy reference material dealing with the rolls and their part in the thread rolling process, the roll life and how to maximize it. Through helpful hints, tips, and suggestions, as well as good sound practice, we will explore the ways and means to prevent, or at least minimize some of the most frequent causes of premature roll failure, and through that prevention, help the operator to achieve top roll performance and better roll life.

We hope you will find this material both informative and useful.

ROLL LIFE EXPECTANCY

What kind of production can the user expect from a set of rolls? Fair enough question and surely deserves just as fair an answer.

It is not uncommon for a set of rolls to produce over a million parts, but, by the same token, another set made and purchased at the same time will fail after producing only a few hundred, a few thousand, or for that matter only a few parts. What went wrong?

In an attempt to provide an answer to this question, a multitude of contributing factors and conditions, having a direct bearing on the roll life must be considered. These factors and conditions can be divided into two groups: **inherent** and **operator reliant**.

INHERENT GROUP

The inherent group includes factors and conditions which are entirely, or at least to a certain extent, beyond the operator's control, such as the severity of emerging factors accompanying the thread rolling process itself, the nature of the work material, and the thread size itself.

In order to fully understand and appreciate roll life requires some basic understanding of the thread rolling process.

From the very first contact with the blank, a thread roll is being subjected to a series of rather negative and yet inherent obstacles, which it must overcome in order to make the process a success.

First, it must overcome the **obstacle of resistance** of the rolled material, called yield point.

It must overcome a **second** obstacle, call it an **obstacle of conflict**, created by the incompatibility between the roll and the blank diameter.

A **third** force, called **axial force**, stemming from lack of positive drive of the rolls by the blank.

And finally, a **fourth** factor - **thread size.**

OBSTACLE OF RESISTANCE

The rolls are capable of overcoming the resistance quite well. They were designed to do that, but as for how long depends largely on the nature of the material being rolled.

It is the resistance of materials, along with other metallurgical properties, that cause either normal or accelerated wear on the rolls.

Softer materials pose only a mild resistance and cause normal wear, and as the resistance of the material increases due to their initial hardness or other properties, such as abrasiveness, work-hardening, etc., so does the wear on the rolls.

OBSTACLE OF CONFLICT (INCOMPATIBILITY)

In the process of thread rolling, left hand rolls produce right hand threads and vice-versa. Running in opposite directions with the same rate of surface speed, and being in firm contact under constant cross-slide pressure, theoretically, no axial movement should result.

As the rolls penetrate the blank, the relationship between the roll diameter and the blank diameter, in reality, the root diameter of the blank, constantly changes. The blank root diameter becomes gradually smaller, until a full amount of penetration has been reached.

This constant change in the blank diameter causes a considerable breakdown in the all important relationship between the rolls and the blank.

To minimize this condition, since the full remedy would be impossible, the roll diameter was established to be in perfect synchronization with the blank at about the half-way point of full penetration.

And so, it could be said that except for a brief moment, the entire amount of penetration is being accomplished with the mismatched diameters, and what makes it possible to accomplish, is constant corrective adjustments by the rolls.

Due to these corrective adjustments, mainly through the slippage, a complete synchronization between the rolls and the blank is being achieved throughout the entire thread roll advance distance.

AXIAL FORCES

It must be remembered that the contact between the rolls and the blank is only firm, not positive, since it is, after all, only a friction drive and, therefore, not always a sufficient amount of slippage occurs. This lack of sufficient slippage can and does lead to an axial movement of the rolls, sometimes quite violent, both toward and away from the collet.

The amount of this movement can consume the entire allowance for such a movement provided in the attachment through the roll clearance and the gear train.

At that point, the rolls will be forced to correct themselves again through the slippage. In some extreme cases, however, the excessive side pressure can restrict the slippage of the rolls to the point where they would just cease on the piece part, and could only be separated by force.

Needless to say that such conditions must be eliminated, or at least minimized as soon as they are noticed, otherwise, it can lead to serious consequences, such as damage to the rolls, the attachment, and even the machine tool.

Several things having a direct bearing on excessive side pressure should be reviewed: feed, speed, material being rolled, sufficient lubrication of the rolls and attachment, improper matching, and the roll diameter. As in eliminating any other problem, the cause must be eliminated.

THREAD SIZE

Thread size also has a direct bearing on roll life expectancy. Coarse pitch rolls must work harder than fine pitch rolls, as more material must be displaced. Larger thread sizes usually dictate the use of fewer start rolls, and one or two start rolls have to work harder than multi-start rolls, as the total amount of work load is evenly divided into each start.

The ratio of rotation between the part and the roll is 1 : 1/number of starts. For example, when using a five start roll, the piece part will make 5 complete revolutions to each one revolution of the rolls. Whereas, a one start roll will make as many revolutions as the part, causing an accelerated wear on the rolls' outer diameters and bores.

In the preceding illustrations of inherent factors and conditions in thread rolling, the different origins of slippage, the side pressures, more corrective slippage of the rolls, the nature of material being rolled, the thread size itself - all play a substantial part in determining roll life.

Although some of them may have a potential of being detrimental to the roll life, they all are a part of the process, regardless of whether they occur out of necessity or some other influences and reasons. They are simultaneously the cause and the cure, interacting with each other in response to the common need.

And although the entire process may seem at times a total calamity, something that should have never gotten off the ground in the first place, in reality, proves to be the very best method of mass producing threaded parts yet in comparison to any other threading method. From the standpoint of quality, uniformity, accuracy, superior finish and strength, to economy, versatility, and speed.

OPERATOR RELIANT GROUP

The second group of factors and conditions that have a direct bearing on the roll life is an operator reliant group.

We will try to focus on some of them grouped in the following five points. They are not listed in any particular order of importance. We think they are all important enough to have a potential bearing on roll life. They are:

1) care and proper use of the rolls
2) care and proper blank preparation
3) feeds, speeds, and cam design
4) coolants used
5) equipment condition.

Now let us take a somewhat closer look at the above points and briefly discuss them one by one.

1) CARE AND PROPER USE OF THE ROLLS

The roll's threaded sections are a very delicate area, readily susceptible to nicks and chipping and, therefore, should be handled with extra care. Areas where rolls are handled extensively, should be somehow protected with suitable floor covering to prevent damage to the rolls if accidentally dropped.

Always look for free roll action in the attachment when installing or exchanging the rolls. Any interference with that free action may lead to a problem ahead.

Check the gear train for lubrication, residue buildup, damaged gears. Check the roll arbors for possible burrs and lubrication. Check the roll bores for possible galling. Check the thrust bushings or bearings for excessive wear, chip build up or scoring.

Should arbors be replaced, make sure the new arbors have a lapped finish. A lesser finish, even a fine ground finish, will usually generate more heat due to friction, and may cause galling of the bores under heavy loads.

When using two or more sets of rolls on the same job, always check, and if necessary, readjust the gap setting to compensate for possible variations in roll diameters, not only due to manufacturer's tolerance, but also due to different methods of determining the roll diameters by various manufacturers. This is especially true in the case of rolls for Davenport style attachments and similar rolls for other attachments.

In straddle rolling, the cross-slide of the machine moves the rolls tangentially into the workpiece until the centerline of the rolls reaches the centerline of the workpiece. This is a very critical point! Any amount of overtravel beyond this point can result in damage to the rolls.

Various aids, called *center finder gages*, have been devised by the attachment manufacturers to eliminate this problem. Other methods for finding the centerline have also been used for years and are described under **PROBLEMS AND SOLUTIONS** (see page 13).

When working without center finder gages, it is far better and cannot be overemphasized to have the rolls retracted a few thousandths short of reaching the centerline than to take a chance of going beyond it (see **FIG. 1**).

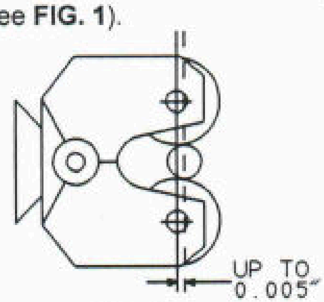


FIG. 1

MATCHING (SYNCHRONIZING)

Rolls for two roll attachments are provided in sets and should be used that way. Each set is prematched with timing lines (see **FIG. 2**). On reversible rolls, timing lines are provided on both sides of the rolls and care must be taken to align corresponding sides and lines.

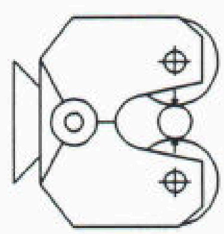


FIG. 2

Essentially, the timing lines are only a reference point and, generally, some deviation may be necessary, as various elements such as hardness of rolled material, length of thread, and rate of penetration - all have considerable bearing on proper matching. Accurate timing is perhaps the most important single factor in terms of roll life expectancy, and no extra time or effort should be spared to assure optimum timing. Poorly matched rolls will create an excessive axial movement of the rolls, leading to damaging side pressure and shorter roll life.

Inadequate matching may not always manifest itself in all its' usual telltale signs such as poor thread forms, slivery threads, or unbalanced crest formation, but always, without exception, will shorten the roll life.

For that reason, instead of depending on naked eyesight alone, some sort of optical aid may be perfectly in order.

Matching, being a part of the setup procedure, should be done in accordance with operating manuals provided by attachment manufacturers, since the procedure itself will vary from one manufacturer to another.

The object in proper matching is to have both rolls following the same path around the blank (see **FIG. 3**).

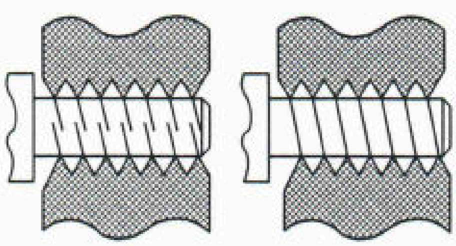


FIG. 3

In most cases, a symmetrical formation of the crest on the threaded part, a nice clean root, and sliver free flanks will indicate a desirable match.

SETTING THE ROLL GAP

The term *roll gap*, as being referred to here, is the distance between the two rolls assembled in the attachment. This spacing approximates the root diameter of the thread being rolled, and could be calculated by subtracting one thread depth from the blank diameter.

Various aids can be used to accomplish the gap setting task: an adjustable parallel, a round pin gage of the right size, a straight block ground to the right size, a thread gage, a piece part of the right size, or even an old gage block setup (see **FIG. 4**).

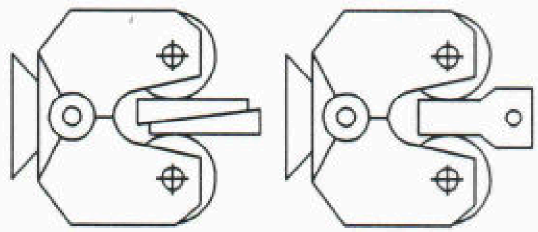


FIG. 4

An additional adjustment in the gap can be expected before satisfactory thread size is finally obtained, due mainly to two reasons: unpredictable flow of material, and the other is the spreading or stretching of the attachment assembly under load.

SELECTION OF THREAD ROLLS

The best guide in selecting the most suitable roll style is the piece part configuration (refer to pages 15-17 for thread roll styles).

Determining the cutoff end of work will place the threaded section either at the cutoff end (next to the collet) or at the outboard end.

Just about any style of rolls with standard working face could be used when rolling on the outboard end, providing that the working face is at least two thread pitches longer than the piece part thread length, and the position of the attachment is not restricted.

For this application, reversible rolls are particularly suitable, whenever the piece part thread length permits, taking advantage of their two setting capabilities, without repositioning the attachment or any other tooling, and without readjustment of the roll gap.

Rolling at the cutoff end, or often called rolling behind the shoulder, almost always requires a specific working face on the rolls.

When selecting the rolls and the attachment for a job, a stock diameter clearance must also be considered. Most attachment manufacturers list shoulder or largest stock diameter clearances in their manuals right next to the thread sizes of rolls for any particular attachment.

Style TQ-2 rolls are being used when rolling taper pipe threads on the outboard end (see **FIG. 5**).

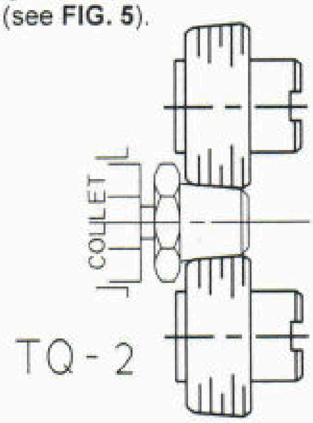


FIG. 5

Style TK-2 rolls are being used when rolling taper pipe threads at the cutoff end (see **FIG. 6**).

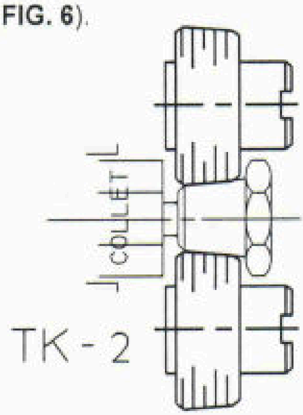


FIG. 6

DETERMINING ROLL WORKING FACE

When rolling behind the shoulder, as mentioned before, some calculations are required to determine the working face on the rolls. The easiest method of doing this calculation is to take the actual thread length of work and add 2 1/2 thread pitches.

EXAMPLE:
thread size = 5/16-18
pitch = 1/tpi = 1/18 = 0.056"
actual thread length of work = 0.500"
thread roll working face =
0.500+(2.5 x 0.056) = 0.640"

The above method should be used whenever possible. However, when room does not permit for the above calculation, take the actual thread length of work and add 1.8 multiplied by the thread pitch to obtain the thread roll working face.

EXAMPLE:
thread size = 5/16-18
pitch = 1/tpi = 1/18 = 0.056"
actual thread length of work = 0.500"
thread roll working face =
0.500+(1.8 x 0.056) = 0.601"

There are other methods for determining thread roll working face, but they require some tedious calculations. The above examples provide quick and easy calculations and prove to be just as effective as the more complicated methods (see **FIG. 7**).

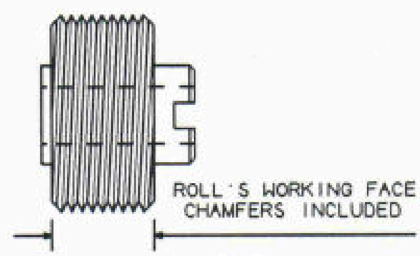


FIG. 7

Note: All thread rolls provided by TR/USA have a 45 degree chamfer. Rolling very close to the shoulder, or using a very narrow cutoff blade may require a 60 degree chamfer on the rolls. This, however, should be avoided whenever possible, as it may shorten the roll life by premature chipping of weakened end threads.

If it should become necessary to utilize a 60 degree chamfer on the rolls, then the following method of calculation should be used to determine the thread roll working face. Take the actual thread length of work and add 1.25 multiplied by the thread pitch as shown in the following example.

EXAMPLE:
thread size = 5/16-18
pitch = 1/tpi = 1/18 = 0.056"
actual thread length of work = 0.500"
thread roll working face =
0.500+(1.25 x .056) = 0.570"

THREAD LENGTH LIMITS

In a brief discussion on setting the roll gap, we mentioned that one of the reasons for readjusting the gap setting is the stretching or spreading of the attachment under heavy load. Longer threads, along with other factors, may contribute to a load greater than the attachment can safely tolerate, resulting in serious damage to the attachment, the rolls, and even the machine tool.

Most attachment manufacturers provide charts, or at least some general guidelines on maximum thread lengths for various conditions, and should be referred to whenever in doubt. A word of caution - not all attachments are created equally. Some can tolerate greater loads than others, and for that reason, recommendations for a specific attachment by its' manufacturer should only be used as a guideline.

2) CARE IN PROPER BLANK PREPARATION

When preparing the blanks, it is very important to remember that the thread rolling process does not remove any metal, nor does it compress any. It simply *displaces* the material radially and axially. Therefore, the blank must contain just the right amount of material. Too little material will not fill up the threads and too much will overload the rolls.

Since the threads, such as American National, Unified, and Isometric, are nearly symmetrical, whose addendum and dedendum are equal or nearly equal, we can say that the blank diameter should be about the same as the pitch diameter (specified or calculated) of the thread size being rolled. For safety reasons, we recommend the blank diameter to be 0.0010" to 0.0015" below the maximum pitch diameter of the thread. The closer the tolerance of the blank, the more uniform thread outside diameter (OD) will result.

We recommend the use of a shaving tool in blank sizing, wherever possible, and to hold the blank tolerance to within 0.001", which will produce the part outer diameter within 0.003" (3 to 1 ratio). Having said that, from a practical standpoint, the range of the blank diameter should be such as to allow both the smallest and the largest blank to produce an acceptable threaded part.

There are some specific problems in thread rolling that may require some deviation from recommended blank diameters. Coarse pitches on threads of around 0.250" in length is one of them, especially when rolling soft material (see **PROBLEMS AND SOLUTIONS** pgs. 11-14).

During thread rolling, as mentioned before, material is being displaced radially (upwards) and axially (endwise).On short threads, coarse pitches, and soft materials, this endwise flow is much more pronounced, requiring an increase of the blank diameter. Material hardness and even surface finish on the blank may also require some minor blank deviations.

To prevent chipping of the rolls, the blanks must be chamfered. A 30 degree chamfer to the axis of the blank is recommended. Other chamfers should be avoided as they may be harmful to the rolls. The small end diameter of the chamfer should be about 0.005" below the root diameter of the thread, and on taper pipe blanks - about 0.010" (see **FIG. 8**).

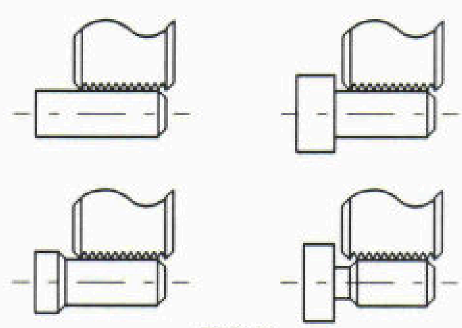
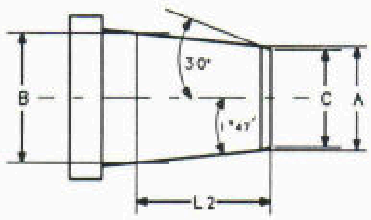


FIG. 8

Thread rolling will not correct any imperfections present in the blank. If there is a taper in the blank, then there will be a taper on the finished part. If the blank is out of round so will be the part. Rough finish on the blank will manifest itself as a rough finish on the thread outer diameter. *Only quality blanks will produce quality threads and will greatly improve roll life* (see **FIG. 9** for suggested dimensions of standard taper pipe blanks).



PIPE SIZE	BLANK DIMENSIONS FOR SET-UP			
	A	B	C	L2
1/16-27	0.271	0.288	0.233	0.261
1/8-27	0.364	0.380	0.322	0.264
1/4-18	0.477	0.503	0.424	0.402
3/8-18	0.612	0.638	0.560	0.408
1/2-14	0.758	0.792	0.692	0.534
3/4-14	0.968	1.002	0.902	0.546
1-11 1/2	1.214	1.256	1.136	0.683
1 1/4-11 1/2	1.557	1.601	1.480	0.707
1 1/2-11 1/2	1.796	1.841	1.718	0.724

FIG. 9

3) FEEDS, SPEEDS, AND CAM DESIGN

FEEDS AND SPEEDS

As a general rule, the cross-slide feed should be as heavy as the limit of part configuration will allow. It is a known fact that the roll life and the quality of thread are at their best when the thread is formed in the fewest possible revolutions of work.

This is especially important when rolling high strength materials, such as stress-proof and stainless steels (particularly the 300-series) with a high rate of work hardening properties. Working with these materials will result in considerably shorter roll life and, of course, each additional and yet unnecessary work revolution will only pave the way to even shorter roll life. Feeds of 0.012" to 0.014" per work revolution would be considered quite normal when working with stainless and stress-proof materials.

Before feed per revolution of the cross-slide can be determined, a number of work revolutions to complete the part must first be determined. Various tables with suggested work revolutions for any particular thread have been made available by the attachment manufacturers, or a simple calculation can provide the answer. Practical work revolutions to produce a thread are based on a radial roll penetration rate of 0.0015" per work revolution. Since the roll penetrates the blank by only half of the thread depth, the number of work revolutions can be obtained by dividing half the thread depth by 0.0015".

EXAMPLE:

thread size = 5/16-18
h = thread depth = 0.036"
h/2 = half the thread depth = 0.018"
0.018"/0.0015" = 12 work revolutions.

We now have established that it would take 12 work revolutions to complete a 5/16-18 thread. It must be remembered that the above suggested penetration rate of 0.0015" pertains only to rolling with radial approach holders, such as bump rolling and rolling with scissor-type attachments (see **FIG. 10**).

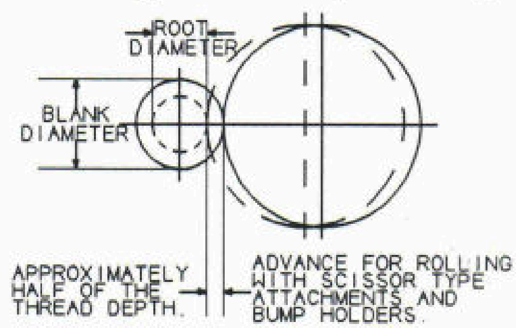
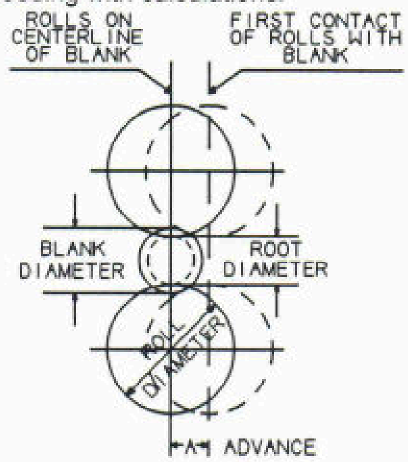


FIG. 10

Although, using this penetration rate determines the number of work revolutions to complete the thread using scissor-type holders, it may not be used as actual penetration rate when using tangential approach attachments (straddle-type holders).

With straddle-type rolling, the rate of penetration, or the feed per revolution, is based on *thread roll advance* (see **FIG. 11** on following page). This is the distance between an initial contact of the rolls with the blank, to the centerline of the blank. There, it gets a little more complicated. Tables of trigonometric functions must be available and the roll diameter must be known before proceeding with calculations.



THREAD ROLL ADVANCE FOR STRADDLE TYPE ROLLING

FIG. 11

A = thread roll advance
B = (roll diameter + part root diameter)/2
C = (roll diameter +part blank diameter)/2
cosine(Z) = B/C
A = C x sine(Z)

EXAMPLE:
thread size = 5/16-18
roll diameter = 1.557"
B = (1.557 + 0.240)/2 = 0.899"
C = (1.557 + 0.275)/2 = 0.916"
cosine(Z) = (.899/.916) = 0.98144
$Z = 11^{\circ}\ 11'$
$A = 0.916 \times \text{sine}(11^{\circ}\ 11') = 0.178"$
or
0.180" when rounded to nearest zero

After making this calculation, a cross-slide feed can now be determined by dividing thread roll advance by the number of work revolutions established earlier.

EXAMPLE:
A = 5/16-18 thread roll advance = 0.180"
B = work revolutions = 12
cross slide feed/revolution = A/B = 0.015"

The above calculations and suggestions are based on rolling thread lengths equal to twice the diameter being rolled or shorter, and rolling close to the collet in soft materials. Harder materials above Rockwell"C" 15, longer threads, or rolling away from the collet may require smaller feeds and more work revolutions.

As for the machine spindle speeds, thread rolling is almost never a limiting factor. It can be successfully accomplished at any speed suitable for other tooling in a cycle.

Whenever roll revolutions begin to exceed 700 rpm, it may become necessary to use bronze bushed rolls, or at least bronze roll arbors on relatively shorter runs. This occurs most often when using single start rolls, where spindle revolutions equal roll revolutions.

Whenever bronze bushed rolls are used, always replace carbide arbors with high speed steel (HSS) arbors.

To determine roll revolutions, divide the spindle speed by the number of starts in the roll being used.

CAM DESIGN

A suitable cam for thread rolling must be capable of advancing the cross-slide at a specific rate of feed per work revolution and must never have any amount of dwell at the high point, thereby, allowing the slide to withdraw instantly. Any amount of dwell at the full penetration of the rolls, which is the cam's high point, will cause the rolls to move sideways on the part, and this most certainly will have a detrimental effect on roll life.

There is a concern among some thread roll people that from an eye appeal standpoint, the thread should be rounded out at the end of the rolling cycle to enhance the thread appearance. Actually, threads are being rounded out, unintentionally as it may be, by an "effective dwell", equivalent from 2 to 3 work revolutions. This "effective dwell" is being provided by clearance and wind-up of the cam follower and running fit allowance of the lever pins, which provides sufficient thread round out, and we absolutely oppose any notion for even a minimal amount of dwell at the high point of the cam.

4) COOLANTS

Considerable amount of pressure required in the thread rolling process will, by its' very nature, generate some heat. In in-feed rolling, where the rolls stay in contact with the blank typically for only under a second, heat is almost never a serious factor, and for this application we recommend a good grade of cutting oil to be used as a coolant. It dissipates heat quite well, but more importantly, unlike other coolants, provides excellent lubrication to the attachment, and thereby, reduces friction between the rolls and the roll arbors as well as friction between the rolls and the part.

There will be times where various considerations will dictate the use of coolants other than oil. It must be remembered that such coolants may not provide sufficient lubrication and, therefore, consideration should be given to the use of bronze bushed rolls to minimize friction. Remember to use high speed steel roll arbors with bronze bushed rolls.

5) EQUIPMENT CONDITION

Although condition of the attachment and the rolls are of our primary concern, condition of the machine tool itself, however, should not be taken for granted. The most obvious thing common to all attachments is the gear train. Check and, if necessary, replace worn out or damaged gears and make sure they are generously lubricated. Make sure that all adjusting screws adjust and locking screws lock properly. Check roll clearances for side play as recommended by the attachment manufacturer and replace, if necessary, any thrust devices as recommended. Carefully check roll arbors for wear and smoothness. When using any attachment where the thread roll head and the adapter are coupled with pins, check the entire coupling assembly for proper tipping and fit.

Check the cross-slide springs, check the gibs, make sure they are in good working order. Remember any delays, hesitations, or jerks of the slide may delay the all important quick separation of rolls from the workpiece and inevitably shorten roll life and reduce thread quality. And, of course, inspect the cam before installation, and on longer runs, check the cam periodically for wear at the high point, as roll life depends on cam condition.

SUMMARY

All of the above reviewed materials, in time, will become routine, almost second nature, to the conscientious and experienced operator, and may serve only, from time to time, as a memory refresher on a particular setup facet. For less experienced operators, hopefully it will serve as a guide and a tool to make their job rather easier.

And now, after getting somewhat more familiar with the odyssey of an average thread roll, what kind of production can the user expect from a set of rolls? The best guess would be somewhere between 1 and 1,000,000 parts. The rolls have the potential for maximum production, but it all comes down to the attention paid to the details and dedication to the job. And with credentials such as these, the rolls will give you very generous production every time.

PROBLEMS AND SOLUTIONS

SIZING THE THREAD

PITCH DIAMETER TOO LARGE OR TOO SMALL.

Readjust thread roll gap (ratio 1:1) until PD gages properly.

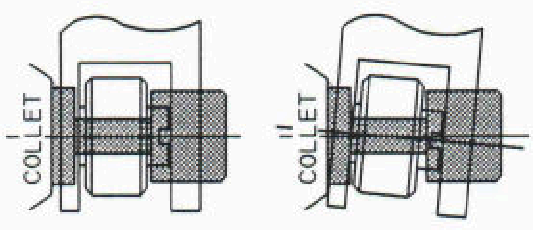
OD TOO LARGE OR TOO SMALL.

Increase or decrease the blank diameter gradually, until proper OD is obtained. Remember the 3:1 ratio in this case, meaning for each one unit of blank increase or decrease, the OD will increase or decrease by approximately three units.

IMPORTANCE OF PARALLELISM

In thread rolling it is very important that the centerline of rolls and the centerline of work are as parallel to each other as possible. Lack of this parallelism will inevitably result in producing any one of the following conditions: *out-of-round threads, drunken threads, slivers and flakes, and poor thread appearance in general.*

And the longer the thread, the more aggravated these conditions will become (see **FIG. 12**).



CORRECT INCORRECT

CENTERLINE OF WORK AND ROLLS MUST BE PARALLEL AS SHOWN IN THIS TOP VIEW OF THE ATTACHMENT. SHADED AREA REPRESENTS WORK BLANK.

FIG. 12

CAUSES OF POOR THREAD AND THREAD FORM

Poorly matched rolls.

Work deflection - rolling away from the collet on smaller diameters, or feed rate too high.

Material build-up in root of rolls.

Going beyond center of work.

Lack of parallelism between centerlines of rolls and work.

Binding in the gear train of the attachment.

Retraction of the attachment too slow (lazy cross slide).

Rough finish on the blanks.

Feed rate too low (i.e. too many work revolutions).

Overfilling the thread.

Poor ductility of the work material.

Specific roll not contacting the work first.

Some attachments without compensators require a specific roll to contact the work blank first, to assure that the tension in the gear train is relieved before the second roll contacts the blank. Refer to operating manuals of the particular attachments to determine which roll should contact the blank first. Other attachments with built-in compensators allow either roll to contact the the blank first.

ROLLING ON THIN WALLS

A number of problems can be encountered when rolling hollow work. The best solution would be, of course, to machine the holes after rolling, whenever possible. Otherwise, the use of supporting plugs must be implemented.

The degree of success in using such devices lies largely in proper sizing of these plugs. If they are too large, the part ID will grow after rolling and so will the threads' OD. If too small, the ID will shrink along with the threads' OD. Even if successful rolling is achieved, some stretching of the part length can be expected.

The following equation may be used to quickly determine the minimum wall thickness:

A = part ID
B = thread root diameter
= PD minus one thread depth
A/B = 0.7 maximum.

If the result obtained from the above division is 0.7 or less, the wall thickness of the part is most likely heavy enough to be thread rolled. We are saying most likely because thread length and the part material have a direct bearing on a safe wall thickness. The result of 0.7 in the above formula is based on thread length equal to one thread diameter and rolling carbon or alloy steel up to Rockwell "C" 15. Longer threads and/or harder materials, including stainless, may require some moderation to the above ratio of 0.7, probably to 0.65 or even less (see **FIG. 13**).

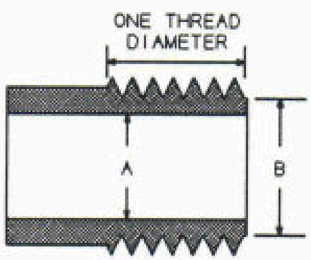


FIG. 13

MATERIALS FOR THREAD ROLLING

Several studies have shown that any material, ferrous as well as non-ferrous, with an elongation factor of 12% or higher should be considered ductile enough for practical cold forming. And while this is generally accepted as a practical measure of ductility of material, other inherent properties of that material, such as yield strength, initial hardness, degree of work hardening, presence of additives, such as lead or sulfur must also be evaluated to determine the material's true rollability. Some materials including stainless steels, Inconel, Monel, titanium alloys, and others, while soft with low yield and high elongation percentage, due to their high degree of work hardening may raise the yield during thread rolling, and thereby drastically reduce roll life.

Other materials with such additives as lead and sulfur, as well as those containing tellerium or sellenium, may cause intolerable flaking and exceedingly poor surface finish on thread flanks.

Half hard brass and some grades of aluminum, due to their low ductility, will tend to crumble at the crest, resulting in poor thread form and appearance.

The purpose for the above brief discussion on material evaluation is to point out the pitfalls that some materials can present with the informed opinion as to what can be expected under given circumstances.

It should be noted also that the above suggested conditions, primarily as to elongation and yield strength, are given here with most economical and most practical results in mind. Otherwise, threads can be rolled under much harsher conditions. Materials with only 5% of elongation and tensile strength of some 250,000 PSI can be thread rolled if the drastic sacrifice of roll life can be justified.

Another phenomenon that the operator should be aware of is expansion or contraction of the threads' lead on some materials after rolling.

Some grades of stainless steel, for instance, have a tendency to stretch axially after rolling, resulting in longer lead.

On the other hand, some high strength steels with high initial hardness (usually over Rockwell "C" 42), and even some grades of aluminum alloys, tend to shrink axially after rolling, causing a shorter lead.

For the most part, this lead variation will be too small to have any significant bearing on pitch diameter of the part. However, in the case of more severe deviations, special lead thread rolls would be required to correct these conditions.

CENTERLINE OF ROLLS AND WORK

To bring the centerline of rolls on the centerline of work is very important when using two roll attachments in order to achieve a fully formed thread.

For this purpose, special devices are available from all attachment manufacturers to accurately accomplish this task.

However, in the absence of such devices, other methods that proved to be successful over the years can be used to accomplish the same, and some of them are as follows.

1) With rolls assembled in the attachment, set the proper roll gap (this is important, otherwise, positioning will not be accurate). Remove the rolls from the attachment but leave the roll pins in place. Insert a spare roll pin or any other pin of the same diameter in the machine spindle with the help of a collet or a drill chuck. With the cross-slide on a high point of the thread rolling cam, slide the attachment to approximate center of work where both roll pins and an insert in the spindle are in line, using a straight edge for checking and moving the attachment in or out when necessary until perfect alignment is achieved. Clamp down the attachment.

2) Again, set the roll gap and then remove the roll that will contact the blank first. With only one roll in place, slide the attachment to the approximate center of the blank in the spindle. Make sure the slide is on the high point of the cam. Clamp an indicator on any suitable surface, with the needle resting on the attachment. Move the attachment in and out, causing the thread roll to roll over the blank. The high point of the indicator needle will be the centerline. Clamp down the attachment.

3) A variety of reasonably functional, "home-made" devices are also being used to find the centerline, as well as sole dependence on eyesight alignment, which unfortunately is still quite frequent. We strongly discourage these practices, for they are dangerously unreliable. For those, however, who are not quite convinced, a word of caution - it is by far better to stay back a few thousandths prior to reaching centerline, than to go beyond it (see **FIG. 14**).

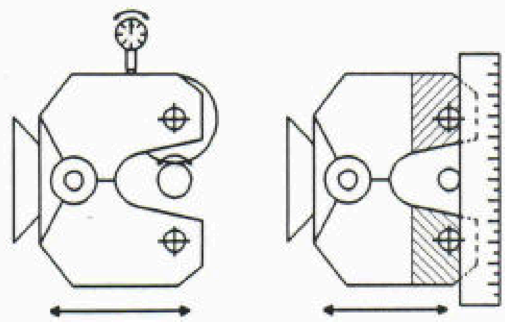


FIG. 14

ROLLING SHORT THREADS

We have previously mentioned that rolling coarse pitch threads on short thread lengths in soft materials may require an increase of the blank diameter to compensate for end wise material flow. While on the subject, a couple of other things come to mind that may present yet another challenge when rolling under the same conditions.

Increased blank diameter will eventually roll up to the proper thread OD, but most likely only in the middle of the thread and gradually tapering toward the ends. This may occur only in extremely ductile materials with more than 20% elongation factor. One solution could be to roll a longer thread and the tapered thread can then be cut off in the cut-off operation. Another remedy would be to form a slightly concave blank which will permit to raise more metal at the ends of the blank and thereby eliminating taper (see **FIG. 15**). However, if none of these solutions can be implemented for various reasons, a change to a lesser ductile material must then be considered.

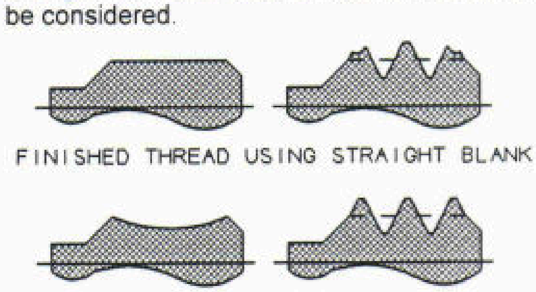


FIG. 15

ROLLING OVER CROSS-HOLES

Drilled cross-holes in the blank will cause fluctuation of the rolling pressure every time the rolls pass over the cross-hole.

Two negative results can be expected under this condition: out-of-round (oval-shaped) threaded parts and premature breakage of the segments of roll threads that pass over the cross-hole.

Countersinking the holes will decrease the chipping of the rolls, but will increase the out-of-roundness of the threaded parts, especially on the smaller thread diameters.

Drilling and chamfering the cross-holes should only be done after thread rolling.

THREAD ROLL O.D. VARIATION

Sooner or later, you will notice the slight difference in the roll diameters between two or more identical sets of rolls. This, of course, is due to manufacturing tolerance, especially when rolls were purchased at different times from the same manufacturer.

On the other hand, if identical thread rolls were purchased from two different manufacturers, the roll diameters may vary substantially because of a different method of determining the roll diameters by various manufacturers.

Basically, manufacturers follow one of two formulas for this calculation: the so called basic (universal) formula and the other which is somewhat more involved, and considers more thread elements.

The general consensus seems to be that there are no significant differences in the rolls' performance, regardless which formula is being used to determine the roll diameter.

We, at Thread Rolls U.S.A., adhere to the latter, more involved formula. We believe that even though no significant differences are clearly evident from one set to another, a quite substantial difference in terms of roll life can be realized in the long run with many sets, over many years.

EXTENDING THE WORKING FACE OF ROLLS

If the working face on the rolls is not quite wide enough for the job that was due "yesterday", and there is no time to order a new set of rolls, there is a rather quick fix way to use the rolls on hand with some modification which can be accomplished in your own tool room.

1) Determine how much wider the working face on the rolls should be, say 0.050".
2) Take one roll (either one) and grind off 0.050" from the drive side.
3) Regrind drive slot by 0.050" deeper.
4) Grind a 0.050" thick spacer, whose O.D. approximates the hub diameter of the rolls, and I.D. to fit the roll arbor. This spacer should be hardened.
5) Rematch the rolls in the following manner. Place both rolls on surface plate with drive slots facing up and spacer under the shorter roll. Slide the rolls together and rotate them until the threads are interlocked (see **FIG. 16**).

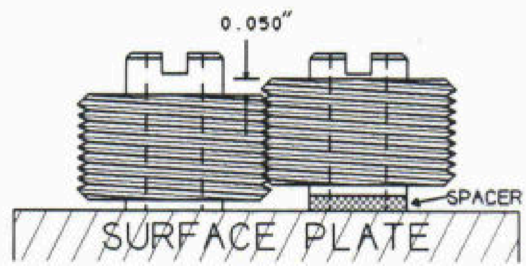


FIG. 16

Scribe new matching lines at the tangent point of both rolls in their interlocked position (see **FIG. 17**).

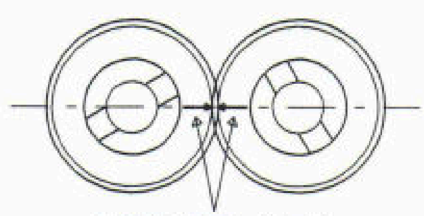
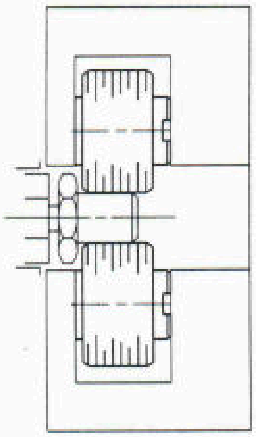


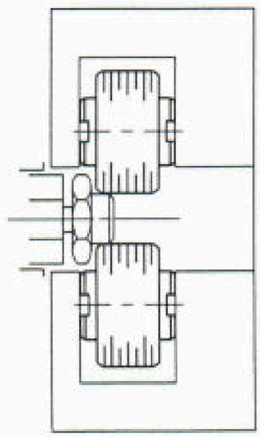
FIG. 17

You now have a set of rolls that will thread 0.050" longer than their working face.

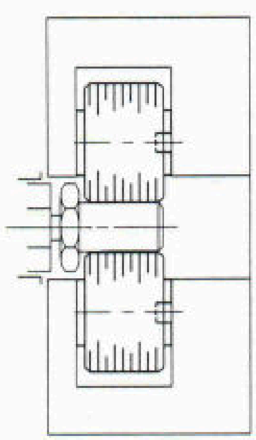
THREAD ROLL STYLES



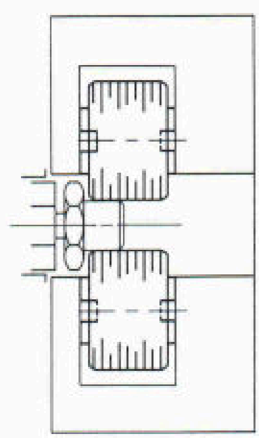
TC - 1



TCR - 1



TD - 1



TDR - 1

STANDARD WORKING FACES for THREAD ROLL *STYLE TYPES 1*

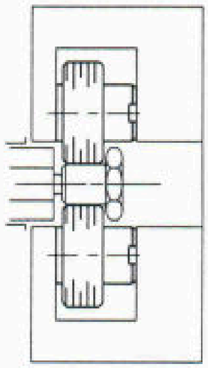
THREAD ROLL STYLE

	TC-1	TCR-1	TD-1	TDR-1
DAVENPORT				
1421SA	0.625	0.500	0.750	0.750
1431SA	0.625	0.500	0.750	0.750
1448SA	0.625	0.500	0.750	0.750
DETROIT				
76000 (0-375)	0.468	0.344	0.593	0.593
76100 (6-625)	0.625	0.500	0.750	0.750
76200 (10-750)	0.812	0.688	0.938	0.938
76300 (30-1000)	0.812	0.688	0.938	0.938
76400 (25-1125)	1.062	0.938	1.188	1.188
LANDIS				
14GA	0.625	0.500	-	-
18GA	0.844	0.750	-	-
20GA	1.000	0.813	-	-
22GA	1.375	1.000	-	-
24GA	1.500	1.250	-	-
REED				
B-5	0.500	-	-	-
B-8	0.500	0.437	0.560	0.560
B-10 (500-G2A)	0.625	0.500	0.750	0.750
B-13 (750-G2A)	0.875	0.750	1.000	1.000
B-18 (1000-G2A)	1.125	1.000	1.250	1.250
B-36	1.125	1.000	1.250	1.250
SALVO				
CBL	0.812	0.750	0.937	0.937
BBL	1.062	0.937	1.187	1.187
DBL	1.312	1.187	1.437	1.437
SOB	1.062	0.937	1.187	1.187
WINTER				
125-SA	0.550	0.487	0.636	0.636
134-SA	0.625	0.500	0.750	0.750
141-SA	0.875	0.750	1.000	1.000
151-SA	0.875	0.750	1.000	1.000
160-SA	1.530	1.417	1.656	1.656
162-SA/163-SA	1.265	1.135	1.390	1.390
170-SA	1.530	1.417	1.656	1.656
172-SA/173-SA	1.265	1.135	1.390	1.390

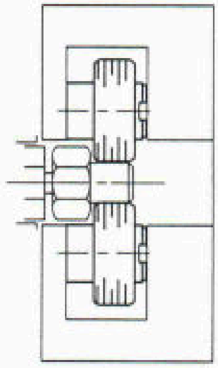
THREAD ROLL STYLES (cont'd)

*** WORKING FACE MUST BE SPECIFIED** for ***STYLE TYPES 2, 3, and 4***

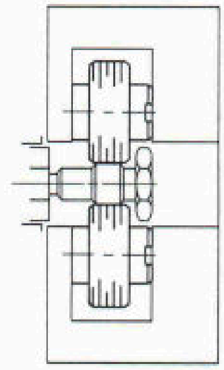
**** WOKING FACES & SHOULDER (OR GROOVE) DIAMETER MUST BE SPECIFIED** for ***STYLE TYPES 5***



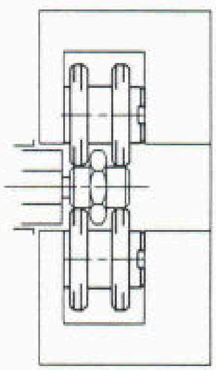
TC - 2*



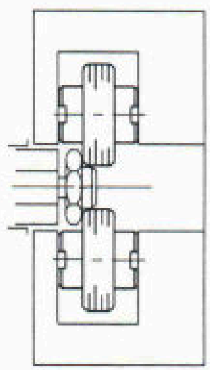
TC - 3*



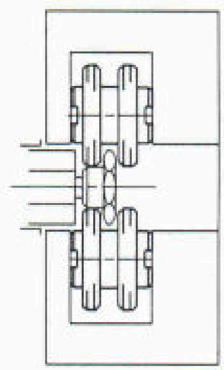
TC - 4*



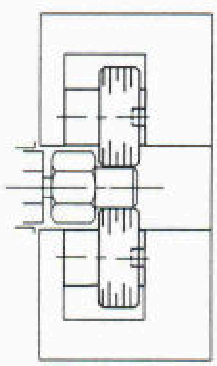
TC - 5**



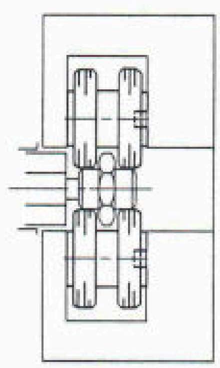
TCR - 4*



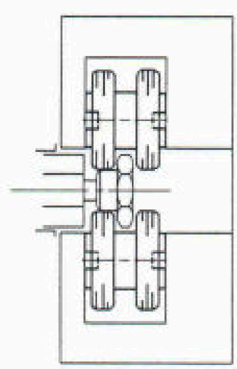
TCR - 5**



TD - 3*

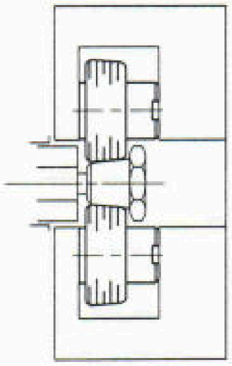


TD - 5**

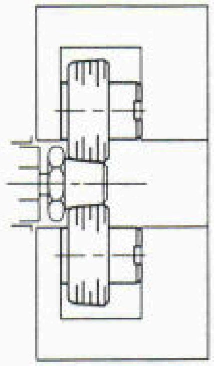


TDR - 5**

THREAD ROLL STYLES (cont'd)



TK - 2

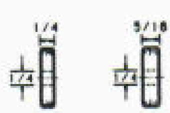
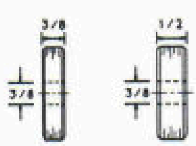
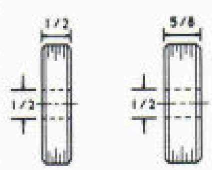
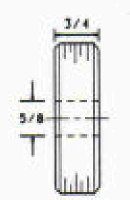
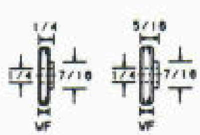
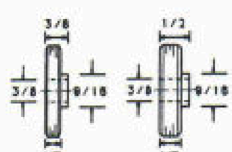
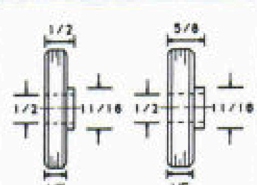
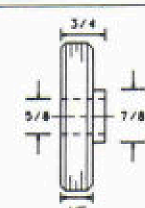
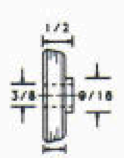
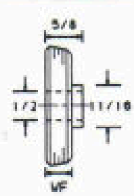
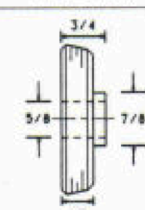


TQ - 2

STANDARD WORKING FACES for TAPERED PIPE THREAD ROLL *STYLES TK-2 & TQ-2*

THREAD SIZE	STANDARD WORKING FACE
1/16-27	0.375
1/8-27	0.375
1/4-18	0.562
3/8-18	0.562
1/2-14	0.712
3/4-14	0.724
1"-11 1/2	0.900
1 1/4-11 1/2	0.924
1 1/2-11 1/2	0.941

BUMP TYPE THREAD ROLLS

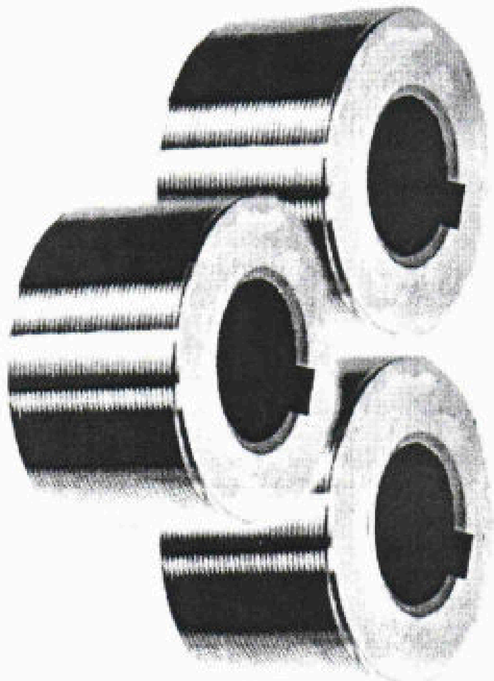
B & S: 83-200 **DETROIT:** 309-5 **REED:** A00-54 **SALVO:** SA-00	**B & S:** 83-120/84-100 **DETROIT:** 309-4 **REED:** A00-86/A0-86 **SALVO:** SA-0/SB-00	**B & S:** 83-122/84-120 **DETROIT:** 309-6 **REED:** A0-108/A2-108 **SALVO:** SA-2/SB-0	**B & S:** 84-122 **REED:** A2-1210 **SALVO:** SB-2
 TF-1-44 TF-1-54	 TF-1-66 TF-1-86	 TF-1-88 TF-1-108	 TF-1-1210
 TF-2-44 TF-2-54	 TF-2-66 TF-2-86	 TF-2-88 TF-2-108	 TF-2-1210
STANDARD WORKING FACES FOR TAPERED PIPE BUMP ROLLS ARE THE SAME AS THOSE LISTED ABOVE FOR STYLES TK-2 & TQ-2	 TY-2-86	 TY-2-108	 TY-2-1210

TR/USA ORDERING INFORMATION FOR THREAD ROLLS

1) Thread size.
2) Right or left hand thread on piece part.
3) Pitch diameter being rolled.
4) Holder (attachment) used.
5) Style of thread rolls (refer to pages 15-17).
6) Working face, if not standard.
7) Stock/shoulder diameter.
8) Chamfer (30°, 45°, 60°, other).
9) If ordering bump rolls, specify hole diameter and overall width.
10) If ordering pipe rolls, specify NPT, NPTF, PTF, NPSM, etc.
11) Material being rolled.
12) Special markings, if applicable.
13) Quantity.

WARNING - PERISHABLE FORMING TOOLS CAN SHATTER - USE SAFEGUARDS!

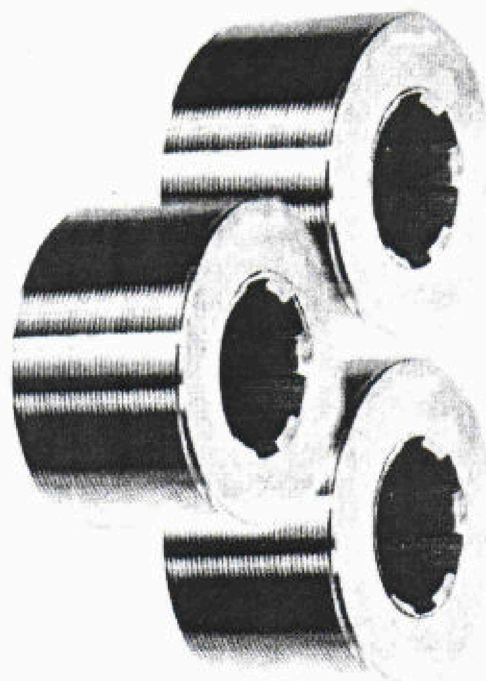
TR/USA THREAD ROLLS FOR 3-DIE MACHINES



OVERHUNG DIE HOLDERS
TYPE C ROLLS

DIE HOLDERS	STD. ROLL FACE
10C	3/4"
20C	1"
30C	1 1/4"
40C	1 1/4"
50C	1"
60C	1 1/4"
90C	1 1/4"
220HD	1 5/8"

SPECIAL DIE FACES AVAILABLE IN 1/8" INCREMENTS



DOUBLE SUPPORT DIE HOLDERS
TYPE B ROLLS (ALSO A)

DIE HOLDERS	STD. ROLL FACE
1B	1 5/8"
2B	1 5/8"
3B	1 5/8"
4B	1 5/8"
5B	1 5/8"
6B	1 5/8"
9B	1 5/8"

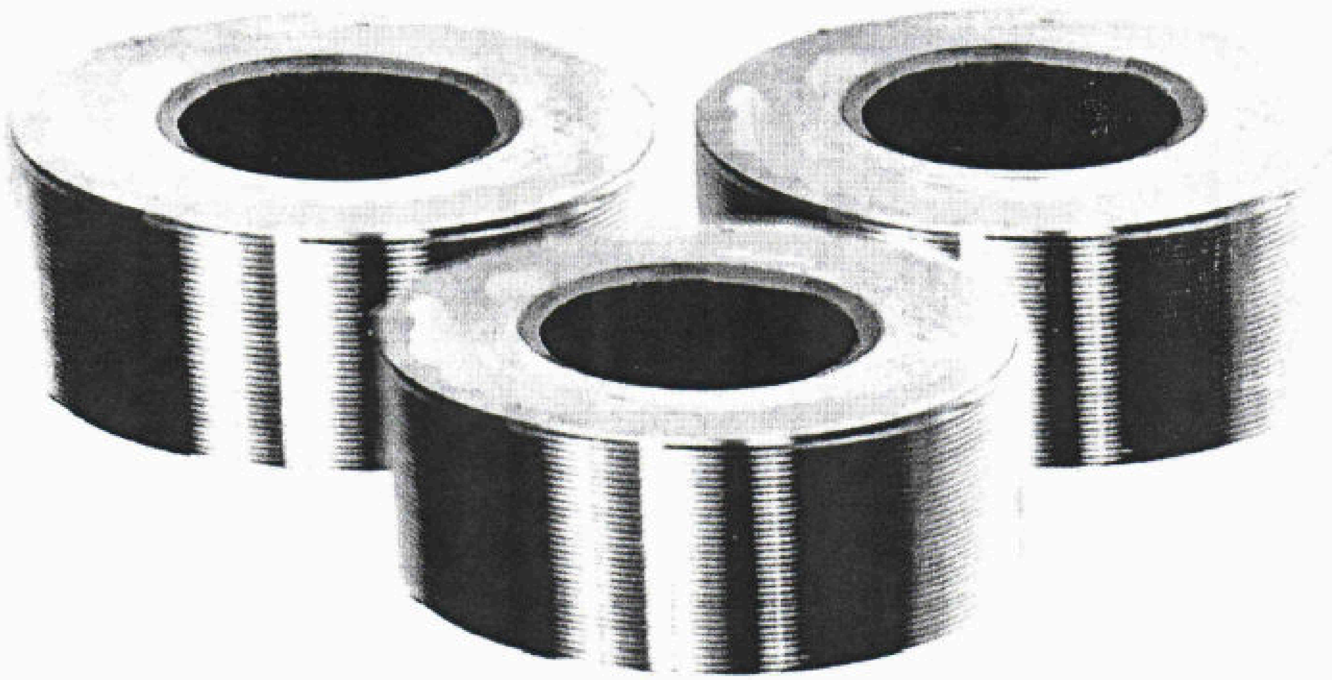
SPECIAL DIE FACES AVAILABLE IN INCREMENTS OF 1/8" UP TO MAX. OF 2 3/8" WIDE

ORDERING INFORMATION

1) Thread size.
2) Right or left hand thread on piece part.
3) Holder used.
4) Roll face if not standard.
5) Material being rolled.
6) In-feed or through-feed.
7) Special markings, if applicable.
8) Quantity.

WARNING - PERISHABLE FORMING TOOLS CAN SHATTER - USE SAFEGUARDS!

THREAD ROLLS FOR END ROLLING HEADS



END ROLLING THREAD ROLLS AVAILABLE

- for all FETTE type heads
- for all ACME-FETTE type heads
- for all NAMCO type heads
- for all ALCO type heads
- for 7/16, 5/8, and 7/8 GEOMETRIC type heads

ORDERING INFORMATION

1) Thread size.
2) Thread rolling head used.
3) Throat chamfer preferred (short 1-1 1/2 threads; long 2-2 1/2 threads, other).
4) Material being rolled.
5) Special markings, if applicable.
6) Quantity.

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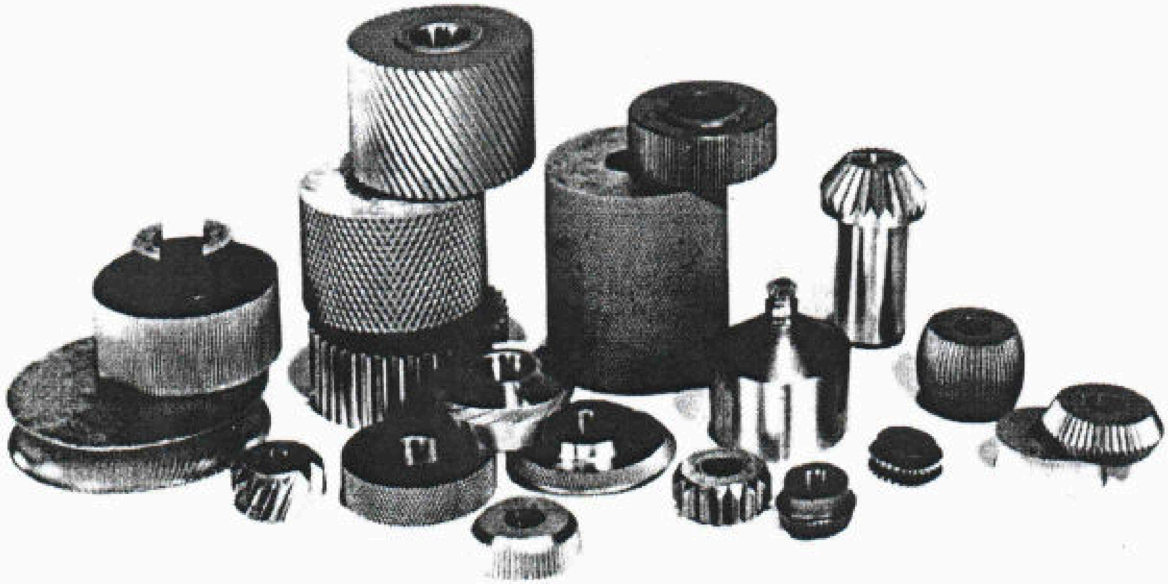
KNURLS



QUALITY KNURLS - to fit any knurl or thread rolling holders and attachments. Furnished with lapped tooth finish, to impart smoother, cleaner tooth surfaces on parts and also to prolong tool life.

LIST OF STANDARD & SPECIAL SIZES AVAILABLE

- circular and diametral pitches for straight knurls
- circular and diametral pitches for diagonal, normal or transverse, 30^{o} or 45^{o} helix angles
- diamond knurls, male or female
- metric pitches, straight and diagonal
- convex, concave, or conical type knurls
- special tooth form knurls
- standard, HSS, or high cobalt material
- shank type knurls for face knurling

ORDERING INFORMATION

Standard knurls are stocked for standard knurl holders only, and can be ordered by the manufacturers' code numbers stamped or etched on existing knurls. All other knurls are considered special and require the following information to provide a correct knurling tool for your particular application.

1) Attachment or holder to be used (cross-slide or turret mounted).
2) TPI or diametral pitch of knurl on piece part.
3) Knurl pattern on piece part (straight, diagonal, male or female diamond).
4) Working face required on piece part.
5) Blank diameter, shoulder or stock diameter, and finished part diameter.
6) Material to be knurled.
7) Specify if exact number of teeth are required on piece part.
8) Special markings, if applicable.
9) Quantity.

WARNING - PERISHABLE FORMING TOOLS CAN SHATTER - USE SAFEGUARDS!

GAGES

PRECISION GAGES - made to the highest degree of accuracy from the finest materials available.

LIST OF GAGES AVAILABLE

- standard and special thread rings
- standard and special thread plugs, taperlock, tri-lock, and reversible
- standard and special setting plugs
- standard and special metric rings and plugs
- pipe thread gages, plugs, and rings

ORDERING INFORMATION

Certification of gages furnished upon request in either short or long forms. Short forms certify compliance to class and are of no charge. Long forms certify compliance to actual size and require a nominal charge.

1) Types of gages: thread plugs, thread rings, set plugs, plain plugs, plain rings.
2) Nominal thread size, thread series, class of fit, and right or left hand piece part. If plain gage, then specify go and no-go diameters and class XX, X, Y, or Z.
3) Go and no-go pitch diameters of special thread gages - plugs or rings.
4) Special markings, if applicable.
5) Quantity.

TAPS

STANDARD & SPECIAL TAPS - ENGLISH & METRIC

Precision ground from the finest grade of HSS for trouble free performance and longer wear.
~ hand taps ~ extension taps ~ nut taps ~ spiral flute taps (slow & hy-spiral) ~ pipe taps ~ Acme taps ~ combination drill & tap taps ~ cold forming or thread rolling taps ~ solid carbide taps ~ carbide brazed taps ~ coolant feeding taps ~ spiral point taps ~ special design taps

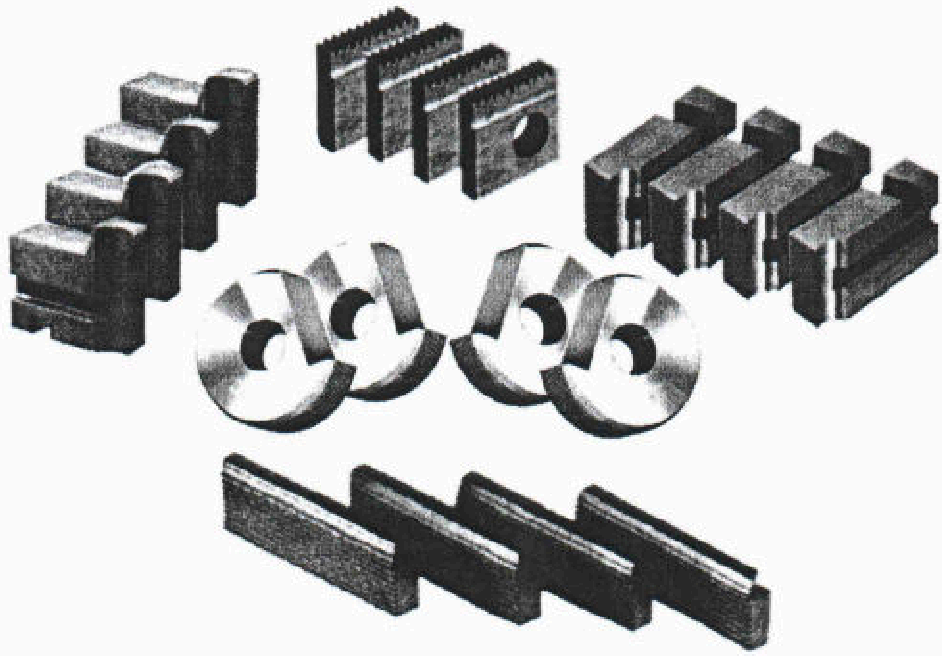
ORDERING INFORMATION

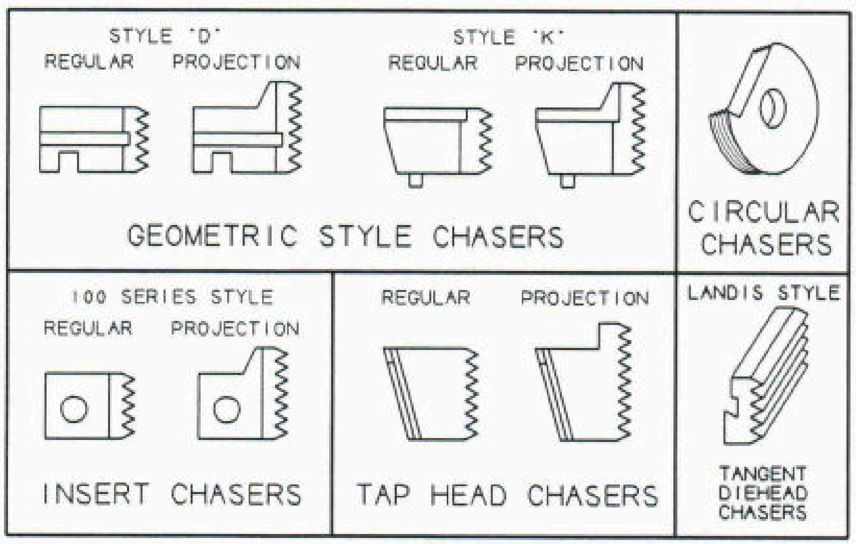
1) Thread size and right or left hand thread on piece part.
2) Class of fit, P.D. limits or H limit.
3) Chamfer required (plug, bottoming, taper, other).
4) Number of flutes.
5) Material to be tapped.
6) Any special features and/or dimensions (tang drive, pilot, special shank diameter, coolant passage, spiral point, spiral flutes, etc.). For Acme taps, specify tapping depths, hole diameter before tapping.
7) Quantity.

Numerous surface treatments are available, depending on the material being tapped, to further extend the life of the tap: nitride, titanium nitride, titanium carbo-nitride, black oxide, chrome, steam oxide, and others.

WARNING - PERISHABLE CUTTING AND FORMING TOOLS CAN SHATTER - USE SAFEGUARDS!

CHASERS





ORDERING INFORMATION

GEOMETRIC STYLE CHASERS

1) Size & style of die head.
2) Thread size.
3) Right or left hand thread.
4) Regular or projection type.
5) Chamfer angle.
6) Material threaded.
7) Quantity.

LANDIS STYLE CHASERS

1) Chaser size (width & length).
2) TPI.
3) Throat angle.
4) Throat length (short or long).
5) Materal threaded.
6) Quantity.

TAP CHASERS

1) Size & style of tap.
2) Thread size.
3) Right or left hand thread.
4) Chamfer angle.
5) Material threaded.
6) Regular or overhang style.
7) Quantity.

CIRCULAR CHASERS

1) Size & style of die head.
2) Thread size.
3) Chamfer angle.
4) Material threaded.
5) Quantity.

WARNING - PERISHABLE CUTTING TOOLS CAN SHATTER - USE SAFEGUARDS!

THREAD LIMITS OF SIZE - UN, UNC, UNF, UNEF

THREAD SIZE	SERIES	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
0-80	UNF	2A	0.0496"	0.0514"	0.0563"	0.0595"	0.0442"
		3A	0.0506	0.0519	0.0568	0.0600	0.0447
1-64	**UNC**	**2A**	**0.0603**	**0.0623**	**0.0686**	**0.0724**	**0.0532**
		3A	**0.0614**	**0.0629**	**0.0692**	**0.0730**	**0.0538**
1-72	UNF	2A	0.0615	0.0634	0.0689	0.0724	0.0554
		3A	0.0626	0.0640	0.0695	0.0730	0.0560
2-56	**UNC**	**2A**	**0.0717**	**0.0738**	**0.0813**	**0.0854**	**0.0635**
		3A	**0.0728**	**0.0744**	**0.0819**	**0.0860**	**0.0641**
2-64	UNF	2A	0.0733	0.0753	0.0816	0.0854	0.0662
		3A	0.0744	0.0759	0.0822	0.0860	0.0668
3-48	**UNC**	**2A**	**0.0825**	**0.0848**	**0.0938**	**0.0983**	**0.0727**
		3A	**0.0838**	**0.0855**	**0.0945**	**0.0990**	**0.0734**
3-56	UNF	2A	0.0845	0.0867	0.0942	0.0983	0.0764
		3A	0.0858	0.0874	0.0949	0.0990	0.0771
4-40	**UNC**	**2A**	**0.0925**	**0.0950**	**0.1061**	**0.1112**	**0.0805**
		3A	**0.0939**	**0.0958**	**0.1069**	**0.1120**	**0.0813**
4-48	UNF	2A	0.0954	0.0978	0.1068	0.1113	0.0857
		3A	0.0967	0.0985	0.1075	0.1120	0.0864
5-40	**UNC**	**2A**	**0.1054**	**0.1080**	**0.1191**	**0.1242**	**0.0935**
		3A	**0.1069**	**0.1088**	**0.1199**	**0.1250**	**0.0943**
5-44	UNF	2A	0.1070	0.1095	0.1195	0.1243	0.0964
		3A	0.1083	0.1102	0.1202	0.1250	0.0971
6-32	**UNC**	**2A**	**0.1141**	**0.1169**	**0.1312**	**0.1372**	**0.0989**
		3A	**0.1156**	**0.1177**	**0.1320**	**0.1380**	**0.0997**
6-40	UNF	2A	0.1184	0.1210	0.1321	0.1372	0.1065
		3A	0.1198	0.1218	0.1329	0.1380	0.1073
8-32	**UNC**	**2A**	**0.1399**	**0.1428**	**0.1571**	**0.1631**	**0.1248**
		3A	**0.1415**	**0.1437**	**0.1580**	**0.1640**	**0.1257**
8-36	UNF	2A	0.1424	0.1452	0.1577	0.1632	0.1291
		3A	0.1439	0.1460	0.1585	0.1640	0.1299
10-24	**UNC**	**2A**	**0.1586**	**0.1619**	**0.1818**	**0.1890**	**0.1379**
		3A	**0.1604**	**0.1629**	**0.1828**	**0.1900**	**0.1389**
10-32	UNF	2A	0.1658	0.1688	0.1831	0.1891	0.1508
		3A	0.1674	0.1697	0.1840	0.1900	0.1517
12-24	**UNC**	**2A**	**0.1845**	**0.1879**	**0.2078**	**0.2150**	**0.1639**
		3A	**0.1864**	**0.1889**	**0.2088**	**0.2160**	**0.1649**
12-28	UNF	2A	0.1886	0.1918	0.2085	0.2150	0.1712
		3A	0.1904	0.1928	0.2095	0.2160	0.1722
12-32	**UNEF**	**2A**	**0.1915**	**0.1947**	**0.2090**	**0.2150**	**0.1767**
		3A	**0.1933**	**0.1957**	**0.2100**	**0.2160**	**0.1777**
1/4-20	UNC	1A	0.2108	0.2164	0.2367	0.2489	0.1876
		2A	0.2127	0.2164	0.2408	0.2489	0.1876
		3A	0.2147	0.2175	0.2419	0.2500	0.1887
1/4-28	UNEF	1A	0.2208"	0.2258"	0.2392"	0.2490"	0.2052"
		2A	0.2225	0.2258	0.2425	0.2490	0.2052
		3A	0.2243	0.2268	0.2435	0.2500	0.2062
1/4-32	**UNEF**	**2A**	**0.2255**	**0.2287**	**0.2430**	**0.2490**	**0.2107**
		3A	**0.2273**	**0.2297**	**0.2440**	**0.2500**	**0.2117**
5/16-18	UNC	1A	0.2691	0.2752	0.2982	0.3113	0.2431
		2A	0.2712	0.2752	0.3026	0.3113	0.2431
		3A	0.2734	0.2764	0.3038	0.3125	0.2443
5/16-20	**UN**	**2A**	**0.2747**	**0.2788**	**0.3032**	**0.3113**	**0.2500**
		3A	**0.2770**	**0.2800**	**0.3044**	**0.3125**	**0.2512**
5/16-24	UNF	1A	0.2788	0.2843	0.3006	0.3114	0.2603
		2A	0.2806	0.2843	0.3042	0.3114	0.2603
		3A	0.2827	0.2854	0.3053	0.3125	0.2614
5/16-28	**UN**	**2A**	**0.2848**	**0.2883**	**0.3050**	**0.3115**	**0.2677**
		3A	**0.2867**	**0.2893**	**0.3060**	**0.3125**	**0.2687**
5/16-32	UNEF	2A	0.2879	0.2912	0.3055	0.3115	0.2732
		3A	0.2897	0.2922	0.3065	0.3125	0.2742
3/8-16	**UNC**	**1A**	**0.3266**	**0.3331**	**0.3595**	**0.3737**	**0.2970**
		2A	**0.3287**	**0.3331**	**0.3643**	**0.3737**	**0.2970**
		3A	**0.3311**	**0.3344**	**0.3656**	**0.3750**	**0.2983**
3/8-20	UN	2A	0.3372	0.3413	0.3657	0.3738	0.3125
		3A	0.3394	0.3425	0.3669	0.3750	0.3137
3/8-24	**UNF**	**1A**	**0.3411**	**0.3468**	**0.3631**	**0.3739**	**0.3228**
		2A	**0.3430**	**0.3468**	**0.3667**	**0.3739**	**0.3228**
		3A	**0.3450**	**0.3479**	**0.3678**	**0.3750**	**0.3239**
3/8-28	UN	2A	0.3471	0.3507	0.3674	0.3739	0.3301
		3A	0.3491	0.3518	0.3685	0.3750	0.3312
3/8-32	**UNEF**	**2A**	**0.3503**	**0.3537**	**0.3680**	**0.3740**	**0.3357**
		3A	**0.3522**	**0.3547**	**0.3690**	**0.3750**	**0.3367**
7/16-14	UNC	1A	0.3826	0.3897	0.4206	0.4361	0.3485
		2A	0.3850	0.3897	0.4258	0.4361	0.3485
		3A	0.3876	0.3911	0.4272	0.4375	0.3499
7/16-16	**UN**	**2A**	**0.3909**	**0.3955**	**0.4267**	**0.4361**	**0.3594**
		3A	**0.3934**	**0.3969**	**0.4281**	**0.4375**	**0.3608**
7/16-20	UNF	1A	0.3974	0.4037	0.4240	0.4362	0.3749
		2A	0.3995	0.4037	0.4281	0.4362	0.3749
		3A	0.4019	0.4050	0.4294	0.4375	0.3762
7/16-28	**UNEF**	**2A**	**0.4096**	**0.4132**	**0.4299**	**0.4364**	**0.3926**
		3A	**0.4116**	**0.4143**	**0.4310**	**0.4375**	**0.3937**
7/16-32	UN	2A	0.4128	0.4162	0.4305	0.4365	0.3982
		3A	0.4146	0.4172	0.4315	0.4375	0.3992
1/2-13	**UNC**	**1A**	**0.4411**	**0.4485**	**0.4822**	**0.4985**	**0.4041**
		2A	**0.4435**	**0.4485**	**0.4876**	**0.4985**	**0.4041**
		3A	**0.4463**	**0.4500**	**0.4891**	**0.5000**	**0.4056**
1/2-16	UN	2A	0.4533	0.4580	0.4892	0.4986	0.4219
		3A	0.4559	0.4594	0.4906	0.5000	0.4233
1/2-20	**UNF**	**1A**	**0.4598**	**0.4662**	**0.4865**	**0.4987**	**0.4374**
		2A	**0.4619**	**0.4662**	**0.4906**	**0.4987**	**0.4374**
		3A	**0.4643**	**0.4675**	**0.4919**	**0.5000**	**0.4387**

THREAD LIMITS OF SIZE - UN, UNC, UNF, UNEF

THREAD SIZE	SERIES	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
1/2-28	UNEF	2A	0.4720"	0.4757"	0.4924"	0.4989"	0.4551"
		3A	0.4740	0.4768	0.4935	0.5000	0.4562
1/2-32	**UN**	**2A**	**0.4752**	**0.4787**	**0.4930**	**.04990**	**0.4607**
		3A	**0.4771**	**0.4797**	**0.4940**	**0.5000**	**0.4617**
9/16-12	UNC	1A	0.4990	.05068	0.5437	0.5609	0.4587
		2A	0.5016	0.5068	0.5495	0.5609	0.4587
		3A	0.5045	0.5084	0.5511	0.5625	0.4603
9/16-16	**UN**	**2A**	**0.5158**	**0.5205**	**0.5517**	**0.5611**	**0.4844**
		3A	**0.5184**	**0.5219**	**0.5531**	**0.5625**	**0.4858**
9/16-18	UNF	1A	0.5182	0.5250	0.5480	0.5611	0.4929
		2A	0.5205	0.5250	0.5524	0.5611	0.4929
		3A	0.5230	0.5264	0.5538	0.5625	0.4943
9/16-20	**UN**	**2A**	**0.5244**	**0.5287**	**0.5531**	**0.5612**	**0.4999**
		3A	**0.5268**	**0.5300**	**0.5544**	**0.5625**	**0.5012**
9/16-24	UNEF	2A	0.5302	0.5342	0.5541	0.5613	0.5102
		3A	0.5324	0.5354	0.5553	0.5625	0.5114
9/16-28	**UN**	**2A**	**0.5345**	**0.5382**	**0.5549**	**0.5614**	**0.5176**
		3A	**0.5365**	**0.5393**	**0.5560**	**0.5625**	**0.5187**
9/16-32	UN	2A	0.5376	0.5411	0.5554	0.5614	0.5231
		3A	0.5396	0.5422	0.5565	0.5625	0.5242
5/8-11	**UNC**	**1A**	**0.5560**	**0.5643**	**0.6051**	**0.6233**	**0.5118**
		2A	**0.5588**	**0.5643**	**0.6112**	**0.6233**	**0.5118**
		3A	**0.5619**	**0.5660**	**0.6129**	**0.6250**	**0.5135**
5/8-12	UN	2A	0.5639	0.5693	0.6120	0.6234	0.5212
		3A	0.5668	0.5709	0.6136	0.6250	0.5228
5/8-16	**UN**	**2A**	**0.5782**	**0.5830**	**0.6142**	**0.6236**	**0.5469**
		3A	**0.5808**	**0.5844**	**0.6156**	**0.6250**	**0.5483**
5/8-18	UNF	1A	0.5805	0.5875	0.6105	0.6236	0.5554
		2A	0.5828	0.5875	0.6149	0.6236	0.5554
		3A	0.5854	0.5889	0.6163	0.6250	0.5568
5/8-20	**UN**	**2A**	**0.5869**	**0.5912**	**0.6156**	**0.6237**	**0.5624**
		3A	**0.5893**	**0.5925**	**0.6169**	**0.6250**	**0.5637**
5/8-24	UNEF	2A	0.5927	0.5967	0.6166	0.6238	0.5727
		3A	0.5949	0.5979	0.6178	0.6250	0.5739
5/8-28	**UN**	**2A**	**0.5969**	**0.6007**	**0.6174**	**0.6239**	**0.5801**
		3A	**0.5990**	**0.6018**	**0.6185**	**0.6250**	**0.5812**
5/8-32	UN	2A	0.6000	0.6036	0.6179	0.6239	0.5856
		3A	0.6020	0.6047	0.6190	0.6250	0.5867
11/16-12	**UN**	**2A**	**0.6263**	**0.6318**	**0.6745**	**0.6859**	**0.5837**
		3A	**0.6293**	**0.6334**	**0.6761**	**0.6875**	**0.5853**
11/16-16	UN	2A	0.6407	0.6455	0.6767	0.6861	0.6094
		3A	0.6433	0.6469	0.6781	0.6875	0.6108
11/16-20	**UN**	**2A**	**0.6493**	**0.6537**	**0.6781**	**0.6862**	**0.6249**
		3A	**0.6517**	**0.6550**	**0.6794**	**0.6875**	**0.6262**
11/16-24	UNEF	2A	0.6552	0.6592	0.6791	0.6863	0.6352
		3A	0.6574	0.6604	0.6803	0.6875	0.6364
11/16-28	UN	2A	0.6594"	0.6632"	0.6799"	0.6864"	0.6426"
		3A	0.6614	0.6643	0.6810	0.6875	0.6437
11/16-32	**UN**	**2A**	**0.6625**	**0.6661**	**0.6804**	**0.6864**	**0.6481**
		3A	**0.6645**	**0.6672**	**0.6815**	**0.6875**	**0.6492**
3/4-10	UNC	1A	0.6744	0.6832	0.7288	0.7482	0.6255
		2A	0.6773	0.6832	0.7353	0.7482	0.6255
		3A	0.6806	0.6850	0.7371	0.7500	0.6273
3/4-12	**UN**	**2A**	**0.6887**	**0.6942**	**0.7369**	**0.7483**	**0.6461**
		3A	**0.6918**	**0.6959**	**0.7386**	**0.7500**	**0.6478**
3/4-16	UNF	1A	0.7004	0.7079	0.7343	0.7485	0.6718
		2A	0.7029	0.7079	0.7391	0.7485	0.6718
		3A	0.7056	0.7094	0.7406	0.7500	0.6733
3/4-20	**UNEF**	**2A**	**0.7118**	**0.7162**	**0.7406**	**0.7487**	**0.6874**
		3A	**0.7142**	**0.7175**	**0.7419**	**0.7500**	**0.6887**
3/4-28	UN	2A	0.7218	0.7256	0.7423	0.7488	0.7050
		3A	0.7239	0.7268	0.7435	0.7500	0.7062
3/4-32	**UN**	**2A**	**0.7250**	**0.7286**	**0.7429**	**0.7489**	**0.7106**
		3A	**0.7270**	**0.7297**	**0.7440**	**0.7500**	**0.7117**
13/16-12	UN	2A	0.7511	0.7567	0.7994	0.8108	0.7086
		3A	0.7542	0.7584	0.8011	0.8125	0.7103
13/16-16	**UN**	**2A**	**0.7655**	**0.7704**	**0.8016**	**0.8110**	**0.7343**
		3A	**0.7682**	**0.7719**	**0.8031**	**0.8125**	**0.7358**
13/16-20	UNEF	2A	0.7743	0.7787	0.8031	0.8112	0.7499
		3A	0.7767	0.7800	0.8044	0.8125	0.7512
13/16-28	**UN**	**2A**	**0.7842**	**0.7881**	**0.8048**	**0.8113**	**0.7675**
		3A	**0.7864**	**0.7893**	**0.8060**	**0.8125**	**0.7687**
13/16-32	UN	2A	0.7874	0.7911	0.8054	0.8114	0.7731
		3A	0.7894	0.7922	0.8065	0.8125	0.7742
7/8-9	**UNC**	**1A**	**0.7914**	**0.8009**	**0.8523**	**0.8731**	**0.7368**
		2A	**0.7946**	**0.8009**	**0.8592**	**0.8731**	**0.7368**
		3A	**0.7981**	**0.8028**	**0.8611**	**0.8750**	**0.7387**
7/8-12	UN	2A	0.8136	0.8192	0.8619	0.8733	0.7711
		3A	0.8167	0.8209	0.8636	0.8750	0.7728
7/8-14	**UNF**	**1A**	**0.8189**	**0.8270**	**0.8579**	**0.8734**	**0.7858**
		2A	**0.8216**	**0.8270**	**0.8631**	**0.8734**	**0.7858**
		3A	**0.8245**	**0.8286**	**0.8647**	**0.8750**	**0.7874**
7/8-16	UN	2A	0.8280	0.8329	0.8641	0.8735	0.7968
		3A	0.8307	0.8344	0.8656	0.8750	0.7983
7/8-20	**UNEF**	**2A**	**0.8367**	**0.8412**	**0.8656**	**0.8737**	**0.8124**
		3A	**0.8391**	**0.8425**	**0.8669**	**0.8750**	**0.8137**
7/8-28	UN	2A	0.8467	0.8506	0.8673	0.8738	0.8300
		3A	0.8489	0.8518	0.8685	0.8750	0.8312
7/8-32	**UN**	**2A**	**0.8499**	**0.8536**	**0.8679**	**0.8739**	**0.8356**
		3A	**0.8519**	**0.8547**	**0.8690**	**0.8750**	**0.8367**
15/16-12	UN	2A	0.8761	0.8817	0.9244	0.9358	0.8336
		3A	0.8792	0.8834	0.9261	0.9375	0.8353

THREAD LIMITS OF SIZE - UN, UNC, UNF, UNEF

THREAD SIZE	SERIES	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
15/16-16	UN	2A	0.8904"	0.8954"	0.9266"	0.9360"	0.8593"
		3A	0.8932	0.8969	0.9281	0.9375	0.8608
15/16-20	**UNEF**	**2A**	**0.8991**	**0.9036**	**0.9280**	**0.9361**	**0.8748**
		3A	**0.9016**	**0.9050**	**0.9294**	**0.9375**	**0.8762**
15/16-28	UN	2A	0.9092	0.9131	0.9298	0.9363	0.8925
		3A	0.9113	0.9143	0.9310	0.9375	0.8937
15/16-32	**UN**	**2A**	**0.9123**	**0.9161**	**0.9304**	**0.9364**	**0.8981**
		3A	**0.9144**	**0.9172**	**0.9315**	**0.9375**	**0.8992**
1"-8	UNC	1A	0.9067	0.9168	0.9755	0.9980	0.8446
		2A	0.9100	0.9168	0.9830	0.9980	0.8446
		3A	0.9137	0.9188	0.9850	1.0000	0.8466
1"-12	**UNF**	**1A**	**0.9353**	**0.9441**	**0.9810**	**0.9982**	**0.8960**
		2A	**0.9382**	**0.9441**	**0.9868**	**0.9982**	**0.8960**
		3A	**0.9415**	**0.9459**	**0.9886**	**1.0000**	**0.8978**
1"-16	UN	2A	0.9529	0.9579	0.9891	0.9985	0.9218
		3A	0.9557	0.9594	0.9906	1.0000	0.9233
1"-20	**UNEF**	**2A**	**0.9616**	**0.9661**	**0.9905**	**0.9986**	**0.9373**
		3A	**0.9641**	**0.9675**	**0.9919**	**1.0000**	**0.9387**
1"-28	UN	2A	0.9716	0.9756	0.9923	0.9988	0.9550
		3A	0.9738	0.9768	0.9935	1.0000	0.9562
1"-32	**UN**	**2A**	**0.9748**	**0.9786**	**0.9929**	**0.9989**	**0.9606**
		3A	**0.9769**	**0.9797**	**0.9940**	**1.0000**	**0.9617**
1 1/16-8	UN	2A	0.9725	0.9793	1.0455	1.0605	0.9071
		3A	0.9762	0.9813	1.0475	1.0625	0.9091
1 1/16-12	**UN**	**2A**	**1.0010**	**1.0067**	**1.0494**	**1.0608**	**0.9586**
		3A	**1.0041**	**1.0084**	**1.0511**	**1.0625**	**0.9603**
1 1/16-16	UN	2A	1.0154	1.0204	1.0516	1.0610	0.9843
		3A	1.0181	1.0219	1.0531	1.0625	0.9858
1 1/16-18	**UNEF**	**2A**	**1.0202**	**1.0250**	**1.0524**	**1.0611**	**0.9929**
		3A	**1.0228**	**1.0264**	**1.0538**	**1.0625**	**0.9943**
1 1/16-20	UN	2A	1.0240	1.0286	1.0530	1.0611	0.9998
		3A	1.0266	1.0300	1.0544	1.0625	1.0012
1 1/16-28	**UN**	**2A**	**1.0341**	**1.0381**	**1.0548**	**1.0613**	**1.0175**
		3A	**1.0363**	**1.0393**	**1.0560**	**1.0625**	**1.0187**
1 1/8-7	UNC	1A	1.0191	1.0300	1.0982	1.1228	0.9475
		2A	1.0227	1.0300	1.1064	1.1228	0.9475
		3A	1.0268	1.0322	1.1086	1.1250	0.9497
1 1/8-8	**UN**	**2A**	**1.0348**	**1.0417**	**1.1079**	**1.1229**	**0.9695**
		3A	**1.0386**	**1.0438**	**1.1100**	**1.1250**	**0.9716**
1 1/8-12	UNF	1A	1.0601	1.0691	1.1060	1.1232	1.0210
		2A	1.0631	1.0691	1.1118	1.1232	1.0210
		3A	1.0664	1.0709	1.1136	1.1250	1.0228
1 1/8-16	**UN**	**2A**	**1.0779**	**1.0829**	**1.1141**	**1.1235**	**1.0468**
		3A	**1.0806**	**1.0844**	**1.1156**	**1.1250**	**1.0483**
1 1/8-18	UNEF	2A	1.0827	1.0875	1.1149	4.1236	1.0554
		3A	1.0853	1.0889	1.1163	1.1250	1.0568
1 1/8-20	UN	2A	1.0865"	1.0911"	1.1155"	1.1236"	1.0623"
		3A	1.0890	1.0925	1.1169	1.1250	1.0637
1 1/18-28	**UN**	**2A**	**1.0966**	**1.1006**	**1.1173**	**1.1238**	**1.0800**
		3A	**1.0988**	**1.1018**	**1.1185**	**1.1250**	**1.0812**
1 3/16-8	UN	2A	1.0972	1.1042	1.1704	1.1854	1.0320
		3A	1.1011	1.1063	1.1725	1.1875	1.0341
1 3/16-12	**UN**	**2A**	**1.1260**	**1.1317**	**1.1744**	**1.1858**	**1.0836**
		3A	**1.1291**	**1.1334**	**1.1761**	**1.1875**	**1.0853**
1 3/16-16	UN	2A	1.1403	1.1454	1.1766	1.1860	1.1093
		3A	1.1431	1.1469	1.1781	1.1875	1.1108
1 3/16-18	**UNEF**	**2A**	**1.1452**	**1.1500**	**1.1774**	**1.1861**	**1.1179**
		3A	**1.1478**	**1.1514**	**1.1788**	**1.1875**	**1.1193**
1 3/16-20	UN	2A	1.1490	1.1536	1.1780	1.1861	1.1248
		3A	1.1515	1.1550	1.1794	1.1875	1.1262
1 3/16-28	**UN**	**2A**	**1.1590**	**1.1631**	**1.1798**	**1.1863**	**1.1425**
		3A	**1.1613**	**1.1643**	**1.1810**	**1.1875**	**1.1437**
1 1/4-7	UNC	1A	1.1439	1.1550	1.2232	1.2478	1.0725
		2A	1.1476	1.1550	1.2314	1.2478	1.0725
		3A	1.1517	1.1572	1.2336	1.2500	1.0747
1 1/4-8	**UN**	**2A**	**1.1597**	**1.1667**	**1.2329**	**1.2479**	**1.0945**
		3A	**1.1635**	**1.1688**	**1.2350**	**1.2500**	**1.0966**
1 1/4-12	UNF	1A	1.1849	1.1941	1.2310	1.2482	1.1460
		2A	1.1879	1.1941	1.2368	1.2482	1.1460
		3A	1.1913	1.1959	1.2386	1.2500	1.1478
1 1/4-16	**UN**	**2A**	**1.2028**	**1.2079**	**1.2391**	**1.2485**	**1.1718**
		3A	**1.2056**	**1.2094**	**1.2406**	**1.2500**	**1.1733**
1 1/4-18	UNEF	2A	1.2075	1.2124	1.2398	1.2485	1.1803
		3A	1.2103	1.2139	1.2413	1.2500	1.1818
1 1/4-20	**UN**	**2A**	**1.2114**	**1.2161**	**1.2405**	**1.2486**	**1.1873**
		3A	**1.2140**	**1.2175**	**1.2419**	**1.2500**	**1.1887**
1 1/4-28	UN	2A	1.2215	1.2256	1.2423	1.2488	1.2050
		3A	1.2237	1.2268	1.2435	1.2500	1.2062
1 5/16-8	**UN**	**2A**	**1.2221**	**1.2292**	**1.2954**	**1.3104**	**1.1570**
		3A	**1.2260**	**1.2313**	**1.2975**	**1.3125**	**1.1591**
1 5/16-12	UN	2A	1.2509	1.2567	1.2994	1.3108	1.2086
		3A	1.2540	1.2584	1.3011	1.3125	1.2103
1 5/16-16	**UN**	**2A**	**1.2653**	**1.2704**	**1.3016**	**1.3110**	**1.2343**
		3A	**1.2681**	**1.2719**	**1.3031**	**1.3125**	**1.2358**
1 5/16-18	UNEF	2A	1.2700	1.2749	1.3023	1.3110	1.2428
		3A	1.2727	1.2764	1.3038	1.3125	1.2443
1 5/16-20	**UN**	**2A**	**1.2739**	**1.2786**	**1.3030**	**1.3111**	**1.2498**
		3A	**1.2765**	**1.2800**	**1.3044**	**1.3125**	**1.2512**
1 5/16-28	UN	2A	1.2840	1.2881	1.3048	1.3113	1.2675
		3A	1.2862	1.2893	1.3060	1.3125	1.2687

THREAD LIMITS OF SIZE - UN, UNC, UNF, UNEF

THREAD SIZE	SERIES	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
1 3/8-6	UNC	1A	1.2523"	1.2643"	1.3453"	1.3726"	1.1681"
		2A	1.2563	1.2643	1.3544	1.3726	1.1681
		3A	1.2607	1.2667	1.3568	1.3750	1.1705
1 3/8-8	**UN**	**2A**	**1.2844**	**1.2916**	**1.3578**	**1.3728**	**1.2194**
		3A	**1.2884**	**1.2938**	**1.3600**	**1.3750**	**1.2216**
1 3/8-12	UNF	1A	1.3096	1.3190	1.3559	1.3731	1.2709
		2A	1.3127	1.3190	1.3617	1.3731	1.2709
		3A	1.3162	1.3209	1.3636	1.3750	1.2728
1 3/8-16	**UN**	**2A**	**1.3277**	**1.3329**	**1.3641**	**1.3735**	**1.2968**
		3A	**1.3305**	**1.3344**	**1.3656**	**1.3750**	**1.2983**
1 3/8-18	UNEF	2A	1.3325	1.3374	1.3648	1.3735	1.3053
		3A	1.3352	1.3389	1.3663	1.3750	1.3068
1 3/8-20	**UN**	**2A**	**1.3364**	**1.3411**	**1.3655**	**1.3736**	**1.3123**
		3A	**1.3390**	**1.3425**	**1.3669**	**1.3750**	**1.3137**
1 3/8-28	UN	2A	1.3465	1.3506	1.3673	1.3738	1.3300
		3A	1.3487	1.3518	1.3685	1.3750	1.3312
1 7/16-6	**UN**	**2A**	**1.3188**	**1.3268**	**1.4169**	**1.4351**	**1.2306**
		3A	**1.3232**	**1.3292**	**1.4193**	**1.4375**	**1.2330**
1 7/16-8	UN	2A	1.3469	1.3541	1.4203	1.4353	1.2819
		3A	1.3509	1.3563	1.4225	1.4375	1.2841
1 7/16-12	**UN**	**2A**	**1.3757**	**1.3816**	**1.4243**	**1.4357**	**1.3335**
		3A	**1.3790**	**1.3834**	**1.4261**	**1.4375**	**1.3353**
1 7/16-16	UN	2A	1.3901	1.3953	1.4265	1.4359	1.3592
		3A	1.3930	1.3969	1.4281	1.4375	1.3608
1 7/16-18	**UNEF**	**2A**	**1.3950**	**1.3999**	**1.4273**	**1.4360**	**1.3678**
		3A	**1.3977**	**1.4014**	**1.4288**	**1.4375**	**1.3693**
1 7/16-20	UN	2A	1.3989	1.4036	1.4280	1.4361	1.3748
		3A	1.4014	1.4050	1.4294	1.4375	1.3762
1 7/16-28	**UN**	**2A**	**1.4088**	**1.4130**	**1.4297**	**1.4362**	**1.3924**
		3A	**1.4112**	**1.4143**	**1.4310**	**1.4375**	**1.3937**
1 1/2-6	UNC	1A	1.3772	1.3893	1.4703	1.4976	1.2931
		2A	1.3812	1.3893	1.4794	1.4976	1.2931
		3A	1.3856	1.3917	1.4818	1.5000	1.2955
1 1/2-8	**UN**	**2A**	**1.4093**	**1.4166**	**1.4828**	**1.4978**	**1.3444**
		3A	**1.4133**	**1.4188**	**1.4850**	**1.5000**	**1.3466**
1 1/2-12	UNF	1A	1.4344	1.4440	1.4809	1.4981	1.3959
		2A	1.4376	1.4440	1.4867	1.4981	1.3959
		3A	1.4411	1.4459	1.4886	1.5000	1.3978
1 1/2-16	**UN**	**2A**	**1.4526**	**1.4578**	**1.4890**	**1.4984**	**1.4217**
		3A	**1.4555**	**1.4594**	**1.4906**	**1.5000**	**1.4233**
1 1/2-18	UNEF	2A	1.4574	1.4624	1.4898	1.4985	1.4303
		3A	1.4602	1.4639	1.4913	1.5000	1.4318
1 1/2-20	**UN**	**2A**	**1.4613**	**1.4661**	**1.4905**	**1.4986**	**1.4373**
		3A	**1.4639**	**1.4675**	**1.4919**	**1.5000**	**1.4387**
1 1/2-28	UN	2A	1.4713	1.4755	1.4922	1.4987	1.4549
		3A	1.4737	1.4768	1.4935	1.5000	1.4562
1 9/16-6	UN	2A	1.4436"	1.4518"	1.5419"	1.5601"	1.3556"
		3A	1.4481	1.4542	1.5443	1.5625	1.3580
1 9/16-8	**UN**	**2A**	**1.4717**	**1.4791**	**1.5453**	**1.5603**	**1.4069**
		3A	**1.4758**	**1.4813**	**1.5475**	**1.5625**	**1.4091**
1 9/16-12	UN	2A	1.5007	1.5066	1.5493	1.5607	1.4585
		3A	1.5040	1.5084	1.5511	1.5625	1.4603
1 9/16-16	**UN**	**2A**	**1.5151**	**1.5203**	**1.5515**	**1.5609**	**1.4842**
		3A	**1.5180**	**1.5219**	**1.5531**	**1.5625**	**1.4858**
1 9/16-18	UNEF	2A	1.5199	1.5249	1.5523	1.5610	1.4928
		3A	1.5227	1.5264	1.5538	1.5625	1.4943
1 9/16-20	**UN**	**2A**	**1.5238**	**1.5286**	**1.5530**	**1.5611**	**1.4998**
		3A	**1.5264**	**1.5300**	**1.5544**	**1.5625**	**1.5012**
1 5/8-6	UN	2A	1.5060	1.5142	1.6043	1.6225	1.4180
		3A	1.5105	1.5167	1.6068	1.6250	1.4205
1 5/8-8	**UN**	**2A**	**1.5342**	**1.5416**	**1.6078**	**1.6228**	**1.4694**
		3A	**1.5382**	**1.5438**	**1.6100**	**1.6250**	**1.4716**
1 5/8-12	UN	2A	1.5632	1.5691	1.6118	1.6232	1.5210
		3A	1.5665	1.5709	1.6136	1.6250	1.5228
1 5/8-16	**UN**	**2A**	**1.5775**	**1.5828**	**1.6140**	**1.6234**	**1.5467**
		3A	**1.5805**	**1.5844**	**1.6156**	**1.6250**	**1.5483**
1 5/8-18	UNEF	2A	1.5824	1.5874	1.6148	1.6235	1.5553
		3A	1.5851	1.5889	1.6163	1.6250	1.5568
1 5/8-20	**UN**	**2A**	**1.5863**	**1.5911**	**1.6155**	**1.6236**	**1.5623**
		3A	**1.5889**	**1.5925**	**1.6169**	**1.6250**	**1.5637**
1 11/16-6	UN	2A	1.5684	1.5767	1.6668	1.6850	1.4805
		3A	1.5730	1.5792	1.6693	1.6875	1.4830
1 11/16-8	**UN**	**2A**	**1.5966**	**1.6041**	**1.6703**	**1.6853**	**1.5319**
		3A	**1.6007**	**1.6063**	**1.6725**	**1.6875**	**1.5341**
1 11/16-12	UN	2A	1.6257	1.6316	1.6743	1.6857	1.5835
		3A	1.6289	1.6334	1.6761	1.6875	1.5853
1 11/16-16	**UN**	**2A**	**1.6400**	**1.6453**	**1.6765**	**1.6859**	**1.6092**
		3A	**1.6429**	**1.6469**	**1.6781**	**1.6875**	**1.6108**
1 11/16-18	UNEF	2A	1.6449	1.6499	1.6773	1.6860	1.6178
		3A	1.6476	1.6514	1.6788	1.6875	1.6193
1 11/16-20	**UN**	**2A**	**1.6488**	**1.6536**	**1.6780**	**1.6861**	**1.6248**
		3A	**1.6514**	**1.6550**	**1.6794**	**1.6875**	**1.6262**
1 3/4-5	UNC	1A	1.6040	1.6174	1.7165	1.7473	1.5019
		2A	1.6085	1.6174	1.7268	1.7473	1.5019
		3A	1.6134	1.6201	1.7295	1.7500	1.5046
1 3/4-6	**UN**	**2A**	**1.6309**	**1.6392**	**1.7293**	**1.7475**	**1.5430**
		3A	**1.6354**	**1.6417**	**1.7318**	**1.7500**	**1.5455**
1 3/4-8	UN	2A	1.6590	1.6665	1.7327	1.7477	1.5943
		3A	1.6631	1.6688	1.7350	1.7500	1.5966
1 3/4-12	**UN**	**2A**	**1.6881**	**1.6941**	**1.7368**	**1.7482**	**1.6460**
		3A	**1.6914**	**1.6959**	**1.7386**	**1.7500**	**1.6478**

THREAD LIMITS OF SIZE - UN, UNC, UNF, UNEF

THREAD SIZE	SERIES	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
1 3/4-16	UN	2A	1.7025"	1.7078"	1.7390"	1.7484"	1.6717"
		3A	1.7054	1.7094	1.7406	1.7500	1.6733
1 3/4-20	**UN**	**2A**	**1.7112**	**1.7160**	**1.7404**	**1.7485**	**1.6872**
		3A	**1.7139**	**1.7175**	**1.7419**	**1.7500**	**1.6887**
1 13/16-6	UN	2A	1.6933	1.7017	1.7918	1.8100	1.6055
		3A	1.6979	1.7042	1.7943	1.8125	1.6080
1 13/16-8	**UN**	**2A**	**1.7214**	**1.7290**	**1.7952**	**1.8102**	**1.6568**
		3A	**1.7256**	**1.7313**	**1.7975**	**1.8125**	**1.6591**
1 13/16-12	UN	2A	1.7506	1.7566	1.7993	1.8107	1.7085
		3A	1.7539	1.7584	1.8011	1.8125	1.7103
1 13/16-16	**UN**	**2A**	**1.7650**	**1.7703**	**1.8015**	**1.8109**	**1.7342**
		3A	**1.7679**	**1.7719**	**1.8031**	**1.8125**	**1.7358**
1 13/16-20	UN	2A	1.7736	1.7785	1.8029	1.8110	1.7497
		3A	1.7763	1.7800	1.8044	1.8125	1.7512
1 7/8-6	**UN**	**2A**	**1.7558**	**1.7642**	**1.8543**	**1.8725**	**1.6680**
		3A	**1.7604**	**1.7667**	**1.8568**	**1.8750**	**1.6705**
1 7/8-8	UN	2A	1.7838	1.7915	1.8577	1.8727	1.7193
		3A	1.7881	1.7938	1.8600	1.8750	1.7216
1 7/8-12	**UN**	**2A**	**1.8131**	**1.8191**	**1.8618**	**1.8732**	**1.7710**
		3A	**1.8164**	**1.8209**	**1.8636**	**1.8750**	**1.7728**
1 7/8-16	UN	2A	1.8275	1.8328	1.8640	1.8734	1.7967
		3A	1.8304	1.8344	1.8656	1.8750	1.7983
1 7/8-20	**UN**	**2A**	**1.8361**	**1.8410**	**1.8654**	**1.8735**	**1.8122**
		3A	**1.8388**	**1.8425**	**1.8669**	**1.8750**	**1.8137**
1 15/16-6	UN	2A	1.8181	1.8266	1.9167	1.9349	1.7304
		3A	1.8228	1.8292	1.9193	1.9375	1.7330
1 15/16-8	**UN**	**2A**	**1.8463**	**1.8540**	**1.9202**	**1.9352**	**1.7818**
		3A	**1.8505**	**1.8563**	**1.9225**	**1.9375**	**1.7841**
1 15/16-12	UN	2A	1.8756	1.8816	1.9243	1.9357	1.8335
		3A	1.8789	1.8834	1.9261	1.9375	1.8353
1 15/16-16	**UN**	**2A**	**1.8899**	**1.8953**	**1.9265**	**1.9359**	**1.8592**
		3A	**1.8929**	**1.8969**	**1.9281**	**1.9375**	**1.8608**
1 15/16-20	UN	2A	1.8986	1.9035	1.9279	1.9360	1.8747
		3A	1.9013	1.9050	1.9294	1.9375	1.8762
2"-4 1/2	**UNC**	**1A**	**1.8385**	**1.8528**	**1.9641**	**1.9971**	**1.7245**
		2A	**1.8433**	**1.8528**	**1.9751**	**1.9971**	**1.7245**
		3A	**1.8486**	**1.8557**	**1.9780**	**2.0000**	**1.7274**
2"-6	UN	2A	1.8805	1.8891	1.9792	1.9974	1.7929
		3A	1.8853	1.8917	1.9818	2.0000	1.7955
2"-8	**UN**	**2A**	**1.9087**	**1.9165**	**1.9827**	**1.9977**	**1.8443**
		3A	**1.9130**	**1.9188**	**1.9850**	**2.0000**	**1.8466**
2"-12	UN	2A	1.9380	1.9441	1.9868	1.9982	1.8960
		3A	1.9414	1.9459	1.9886	2.0000	1.8978
2"-16	**UN**	**2A**	**1.9524**	**1.9578**	**1.9890**	**1.9984**	**1.9217**
		3A	**1.9554**	**1.9594**	**1.9906**	**2.0000**	**1.9233**
2"-20	UN	2A	1.9611"	1.9660"	1.9904"	1.9985"	1.9372"
		3A	1.9638	1.9675	1.9919	2.0000	1.9387
2 1/8-6	**UN**	**2A**	**2.0054**	**2.0141**	**2.1042**	**2.1224**	**1.9179**
		3A	**2.0102**	**2.0167**	**2.1068**	**2.1250**	**1.9205**
2 1/8-8	UN	2A	2.0335	2.0414	2.1076	2.1126	1.9692
		3A	2.0379	2.0438	2.1100	2.1250	1.9716
2 1/8-12	**UN**	**2A**	**2.0630**	**2.0691**	**2.1118**	**2.1232**	**2.0210**
		3A	**2.0663**	**2.0709**	**2.1136**	**2.1250**	**2.0228**
2 1/8-16	UN	2A	2.0774	2.0828	2.1140	2.1234	2.0467
		3A	2.0803	2.0844	2.1156	2.1250	2.0483
2 1/8-20	**UN**	**2A**	**2.0860**	**2.0910**	**2.1154**	**2.1235**	**2.0622**
		3A	**2.0888**	**2.0925**	**2.1169**	**2.1250**	**2.0637**
2 1/4-4 1/2	UNC	1A	2.0882	2.1028	2.2141	2.2471	1.9745
		2A	2.0931	2.1028	2.2251	2.2471	1.9745
		3A	2.0984	2.1057	2.2280	2.2500	1.9774
2 1/4-6	**UN**	**2A**	**2.1303**	**2.1391**	**2.2292**	**2.2474**	**2.0429**
		3A	**2.1351**	**2.1417**	**2.2318**	**2.2500**	**2.0455**
2 1/4-8	UN	2A	2.1584	2.1664	2.2326	2.2476	2.0942
		3A	2.1628	2.1688	2.2350	2.2500	2.0966
2 1/4-12	**UN**	**2A**	**2.1880**	**2.1941**	**2.2368**	**2.2482**	**2.1460**
		3A	**2.1913**	**2.1959**	**2.2386**	**2.2500**	**2.1478**
2 1/4-16	UN	2A	2.2023	2.2078	2.2390	2.2484	2.1717
		3A	2.2053	2.2094	2.2406	2.2500	2.1733
2 1/4-20	**UN**	**2A**	**2.2110**	**2.2160**	**2.2404**	**2.2485**	**2.1872**
		3A	**2.2137**	**2.2175**	**2.2419**	**2.2500**	**2.1887**
2 3/8-6	UN	2A	2.2551	2.2640	2.3541	2.3723	2.1678
		3A	2.2601	2.2667	2.3568	2.3750	2.1705
2 3/8-8	**UN**	**2A**	**2.2833**	**2.2914**	**2.3576**	**2.3726**	**2.2192**
		3A	**2.2878**	**2.2938**	**2.3600**	**2.3750**	**2.2216**
2 3/8-12	UN	2A	2.3129	2.3191	2.3618	2.3732	2.2710
		3A	2.3163	2.3209	2.3636	2.3750	2.2728
2 3/8-16	**UN**	**2A**	**2.3273**	**2.3328**	**2.3640**	**2.3734**	**2.2967**
		3A	**2.3303**	**2.3344**	**2.3656**	**2.3750**	**2.2983**
2 3/8-20	UN	2A	2.3360	2.3410	2.3654	2.3735	2.3122
		3A	2.3387	2.3425	2.3669	2.3750	2.3137
2 1/2-4	**UNC**	**1A**	**2.3190**	**2.3345**	**2.4612**	**2.4969**	**2.1902**
		2A	**2.3241**	**2.3345**	**2.4731**	**2.4969**	**2.1902**
		3A	**2.3298**	**2.3376**	**2.4762**	**2.5000**	**2.1933**
2 1/2-6	UN	2A	2.3800	2.3890	2.4791	2.4973	2.2928
		3A	2.3850	2.3917	2.4818	2.5000	2.2955
2 1/2-8	**UN**	**2A**	**2.4082**	**2.4164**	**2.4826**	**2.4976**	**2.3442**
		3A	**2.4127**	**2.4188**	**2.4850**	**2.5000**	**2.3466**
2 1/2-12	UN	2A	2.4378	2.4440	2.4867	2.4981	2.3959
		3A	2.4413	2.4459	2.4886	2.5000	2.3978
2 1/2-16	**UN**	**2A**	**2.4522**	**2.4577**	**2.4889**	**2.4983**	**2.4216**
		3A	**2.4553**	**2.4594**	**2.4906**	**2.5000**	**2.4233**
2 1/2-20	UN	2A	2.4609	2.4660	2.4904	2.4985	2.4372
		3A	2.4637	2.4675	2.4919	2.5000	2.4387

THREAD LIMITS OF SIZE - SELECTED UNS

THREAD			PITCH DIA.		MAJOR DIA.		MINOR
SIZE	SERIES	CLASS	min.	max.	min.	max.	DIA.
10-28	UNS	2A	0.1625"	0.1658"	0.1825"	0.1890"	0.1452"
10-36	UNS	2A	0.1681	0.1711	0.1836	0.1891	0.1550
10-40	UNS	2A	0.1700	0.1729	0.1840	0.1891	0.1584
10-48	UNS	2A	0.1731	0.1757	0.1847	0.1892	0.1636
10-56	UNS	2A	0.1752	0.1777	0.1852	0.1893	0.1674
12-36	UNS	2A	0.1941	0.1971	0.2096	0.2151	0.1810
12-40	UNS	2A	0.1960	0.1989	0.2100	0.2151	0.1844
12-48	UNS	2A	0.1990	0.2017	0.2107	0.2152	0.1896
12-56	UNS	2A	0.2011	0.2036	0.2111	0.2152	0.1933
1/4-24	UNS	2A	0.2181	0.2218	0.2417	0.2489	0.1978
1/4-27	UNS	2A	0.2214	0.2249	0.2423	0.2490	0.2036
1/4-36	UNS	2A	0.2280	0.2311	0.2436	0.2491	0.2150
1/4-40	UNS	2A	0.2300	0.2329	0.2440	0.2491	0.2184
1/4-48	UNS	2A	0.2330	0.2357	0.2447	0.2492	0.2236
1/4-56	UNS	2A	0.2350	0.2376	0.2451	0.2492	0.2273
5/16-27	UNS	2A	0.2837	0.2873	0.3047	0.3114	0.2660
5/16-36	UNS	2A	0.2905	0.2936	0.3061	0.3116	0.2775
5/16-40	UNS	2A	0.2924	0.2954	0.3065	0.3116	0.2809
5/16-48	UNS	2A	0.2954	0.2982	0.3072	0.3117	0.2861
3/8-18	UNS	2A	0.3333	0.3376	0.3650	0.3737	0.3055
3/8-27	UNS	2A	0.3462	0.3498	0.3672	0.3739	0.3285
3/8-36	UNS	2A	0.3528	0.3560	0.3685	0.3740	0.3399
3/8-40	UNS	2A	0.3548	0.3579	0.3690	0.3741	0.3434
25/64-27	UNS	2A	0.3612	0.3648	0.3822	0.3889	0.3435
7/16-18	UNS	2A	0.3957	0.4001	0.4275	0.4362	0.3680
7/16-24	UNS	2A	0.4053	0.4092	0.4291	0.4363	0.3852
7/16-27	UNS	2A	0.4086	0.4123	0.4297	0.4364	0.3910
7/16-36	UNS	2A	0.4152	0.4185	0.4310	0.4365	0.4024
7/16-40	UNS	2A	0.4173	0.4204	0.4315	0.4366	0.4059
1/2-12	UNS	2A	0.4389	0.4443	0.4870	0.4984	0.3962
		3A	0.4419	0.4459	0.4886	0.5000	0.3978
1/2-14	UNS	2A	0.4471	0.4521	0.4882	0.4985	0.4109
1/2-18	UNS	2A	0.4582	0.4626	0.4900	0.4987	0.4305
1/2-24	UNS	2A	0.4678	0.4717	0.4916	0.4988	0.4477

THREAD			PITCH DIA.		MAJOR DIA.		MINOR
SIZE	SERIES	CLASS	min.	max.	min.	max.	DIA.
1/2-27	UNS	2A	0.4711"	0.4748"	0.4922"	0.4989"	0.4535"
1/2-36	UNS	2A	0.4777	0.4810	0.4935	0.4990	0.4649
1/2-40	UNS	2A	0.4796	0.4828	0.4939	0.4990	0.4683
9/16-14	UNS	2A	0.5096	0.5146	0.5507	0.5610	0.4734
9/16-27	UNS	2A	0.5335	0.5373	0.5547	0.5614	0.5160
9/16-36	UNS	2A	0.5401	0.5435	0.5560	0.5615	0.5274
9/16-40	UNS	2A	0.5421	0.5453	0.5564	0.5615	0.5308
5/8-14	UNS	2A	0.5720	0.5771	0.6132	0.6235	0.5359
5/8-27	UNS	2A	0.5960	0.5998	0.6172	0.6239	0.5785
5/8-36	UNS	2A	0.6026	0.6060	0.6185	0.6240	0.5899
5/8-40	UNS	2A	0.6045	0.6078	0.6189	0.6240	0.5933
3/4-14	UNS	2A	0.6970	0.7021	0.7382	0.7485	0.6609
3/4-18	UNS	2A	0.7079	0.7125	0.7399	0.7486	0.6804
3/4-24	UNS	2A	0.7176	0.7217	0.7416	0.7488	0.6977
3/4-27	UNS	2A	0.7208	0.7247	0.7421	0.7488	0.7034
3/4-36	UNS	2A	0.7275	0.7310	0.7435	0.7490	0.7149
3/4-40	UNS	2A	0.7294	0.7328	0.7439	0.7490	0.7183
7/8-10	UNS	2A	0.8021	0.8082	0.8603	0.8732	0.7505
7/8-18	UNS	2A	0.8328	0.8375	0.8649	0.8736	0.8054
7/8-24	UNS	2A	0.8425	0.8467	0.8666	0.8738	0.8227
7/8-27	UNS	2A	0.8457	0.8497	0.8671	0.8738	0.8284
7/8-36	UNS	2A	0.8523	0.8559	0.8684	0.8739	0.8398
7/8-40	UNS	2A	0.8544	0.8578	0.8689	0.8740	0.8433
1"-10	UNS	2A	0.9270	0.9332	0.9853	0.9982	0.8755
1"-14	UNS	1A	0.9441	0.9520	0.9829	0.9984	0.9108
		2A	0.9467	0.9520	0.9881	0.9984	0.9108
		3A	0.9496	0.9536	0.9897	1.0000	0.9124
1"-18	UNS	2A	0.9578	0.9625	0.9899	0.9986	0.9304
1"-24	UNS	2A	0.9674	0.9716	0.9915	0.9987	0.9476
1"-27	UNS	2A	0.9707	0.9747	0.9921	0.9988	0.9534
1"-36	UNS	2A	0.9773	0.9809	0.9934	0.9989	0.9648
1"-40	UNS	2A	0.9793	0.9828	0.9939	0.9990	0.9683
1 1/8-10	UNS	2A	1.0519	1.0581	1.1102	1.1231	1.0004
1 1/8-14	UNS	2A	1.0717	1.0770	1.1131	1.1234	1.0358

THREAD LIMITS OF SIZE - SELECTED UNS

THREAD SIZE	SERIES	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
1 1/8-24	UNS	2A	1.0923"	1.0966"	1.1165"	1.1237"	1.0726"
1 1/4-10	UNS	2A	1.1768	1.1831	1.2352	1.2481	1.1254
1 1/4-14	UNS	2A	1.1966	1.2020	1.2381	1.2484	1.1608
1 1/4-24	UNS	2A	1.2173	1.2216	1.2415	1.2487	1.1976
1 3/8-10	UNS	2A	1.3018	1.3081	1.3602	1.3731	1.2504
1 3/8-14	UNS	2A	1.3215	1.3270	1.3631	1.3734	1.2858
1 3/8-24	UNS	2A	1.3422	1.3466	1.3665	1.3737	1.3226
1 1/2-10	UNS	2A	1.4267	1.4331	1.4852	1.4981	1.3754
1 1/2-14	UNS	2A	1.4464	1.4519	1.4880	1.4983	1.4107
1 1/2-24	UNS	2A	1.4672	1.4716	1.4915	1.4987	1.4476
1 5/8-10	UNS	2A	1.5517	1.5581	1.6102	1.6231	1.5004
1 5/8-14	UNS	2A	1.5714	1.5769	1.6130	1.6233	1.5357
1 5/8-24	UNS	2A	1.5921	1.5966	1.6165	1.6237	1.5726
1 3/4-10	UNS	2A	1.6766	1.6831	1.7352	1.7481	1.6254
1 3/4-14	UNS	2A	1.6963	1.7019	1.7380	1.7483	1.6607
1 3/4-18	UNS	2A	1.7073	1.7124	1.7398	1.7485	1.6803
1 7/8-10	UNS	2A	1.8015	1.8080	1.8601	1.8730	1.7503

THREAD SIZE	SERIES	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
1 7/8-14	UNS	2A	1.8213"	1.8269"	1.8630"	1.8733"	1.7857"
1 7/8-18	UNS	2A	1.8323	1.8374	1.8648	1.8735	1.8053
2"-10	UNS	2A	1.9265	1.9330	1.9851	1.9980	1.8753
2"-14	UNS	2A	1.9462	1.9519	1.9880	1.9983	1.9107
2"-18	UNS	2A	1.9573	1.9624	1.9898	1.9985	1.9303
2 1/16-16	UNS	2A	2.0149	2.0203	2.0515	2.0609	1.9842
		3A	2.0179	2.0219	2.0531	2.0625	1.9858
2 3/16-16	UNS	2A	2.1399	2.1453	2.1765	2.1859	2.1092
		3A	2.1428	2.1469	2.1781	2.1875	2.1108
2 1/4-10	UNS	2A	2.1764	2.1830	2.2351	2.2480	2.1253
2 1/4-14	UNS	2A	2.1961	2.2019	2.2380	2.2483	2.1607
2 1/4-18	UNS	2A	2.2071	2.2123	2.2397	2.2484	2.1802
2 5/16-16	UNS	2A	2.2648	2.2703	2.3015	2.3109	2.2342
		3A	2.2678	2.2719	2.3031	2.3125	2.2358
2 7/16-16	UNS	2A	2.3897	2.3952	2.4264	2.4358	2.3591
		3A	2.3928	2.3969	2.4281	2.4375	2.3608
2 1/2-10	UNS	2A	2.4263	2.4330	2.4851	2.4980	2.3753
2 1/2-14	UNS	2A	2.4461	2.4519	2.4880	2.4983	2.4107
2 1/2-18	UNS	2A	2.4570	2.4623	2.4897	2.4984	2.4302

THREAD LIMITS OF SIZE - ISOMETRIC

THREAD SIZE	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
M1.6 x 0.35	6g	0.0509"	0.0533"	0.0589"	0.0622"	0.0419"
M1.8 x 0.35	6g	0.0588	0.0611	0.0668	0.0701	0.0498
M2 x 0.4	6g	0.0652	0.0677	0.0743	0.0779	0.0549
M2.2 x 0.45	6g	0.0716	0.0743	0.0819	0.0858	0.0601
M2.5 x 0.45	6g	0.0834	0.0861	0.0938	0.0976	0.0719
M3 x 0.5	6g	0.1016	0.1045	0.1132	0.1173	0.0889
M3.5 x 0.6	6g	0.1183	0.1216	0.1321	0.1369	0.1030
M4 x 0.7	6g	0.1352	0.1387	0.1512	0.1566	0.1173
M4.5 x 0.75	6g	0.1536	0.1571	0.1708	0.1762	0.1345
M5 x 0.8	6g	0.1717	0.1754	0.1900	0.1959	0.1513
M6 x 1.0	6g	0.2052	0.2096	0.2282	0.2351	0.1797
M7 x 1.0	6g	0.2446	0.2489	0.2675	0.2745	0.2191
M8 x 1.25	6g	0.2773	0.2818	0.3056	0.3138	0.2454
M8 x 1.0	6g	0.2840	0.2883	0.3069	0.3139	0.2584
M10 x 1.5	6g	0.3489	0.3540	0.3832	0.3924	0.3102
M10 x 1.25	6g	0.3560	0.3606	0.3843	0.3925	0.3241
M12 x 1.75	6g	0.4205	0.4263	0.4607	0.4711	0.3758
M12 x 1.25	6g	0.4342	0.4393	0.4630	0.4713	0.4023
M14 x 2.0	6g	0.4923	0.4985	0.5387	0.5496	0.4412
M14 x 1.5	6g	0.5061	0.5115	0.5407	0.5499	0.4677
M16 x 2.0	6g	0.5710	0.5772	0.6175	0.6284	0.5199
M16 x 1.5	6g	0.5849	0.5903	0.6194	0.6286	0.5465
M18 x 2.5	6g	0.6364	0.6430	0.6939	0.7070	0.5725
M18 x 1.5	6g	0.6636	0.6690	0.6982	0.7074	0.6252
M20 x 2.5	6g	0.7152	0.7218	0.7726	0.7857	0.6513
M20 x 1.5	6g	0.7423	0.7477	0.7769	0.7861	0.7039
M22 x 2.5	6g	0.7939	0.8005	0.8513	0.8644	0.7300
M22 x 1.5	6g	0.8211	0.8265	0.8556	0.8648	0.7827
M24 x 3.0	6g	0.8584	0.8662	0.9283	0.9429	0.7817
M24 x 2.0	6g	0.8856	0.8922	0.9324	0.9433	0.8345
M27 x 3.0	6g	0.9765	0.9843	1.0464	1.0611	0.8999
M27 x 2.0	6g	1.0037	1.0103	1.0505	1.0614	0.9526
M30 x 3.5	6g	1.0812	1.0895	1.1623	1.1790	0.9917
M30 x 2.0	6g	1.1218	1.1284	1.1686	1.1796	1.0707
M33 x 3.5	6g	1.1993	1.2076	1.2804	1.2971	1.1099
M33 x 2.0	6g	1.2399	1.2465	1.2867	1.2977	1.1888
M36 x 4.0	6g	1.3039	1.3126	1.3963	1.4149	1.2017
M36 x 3.0	6g	1.3309	1.3386	1.4007	1.4154	1.2542
M39 x 4.0	6g	1.4220	1.4307	1.5144	1.5330	1.3198
M39 x 3.0	6g	1.4490	1.4568	1.5188	1.5335	1.3723

THREAD SIZE	CLASS	PITCH DIA. min.	PITCH DIA. max.	MAJOR DIA. min.	MAJOR DIA. max.	MINOR DIA.
M1.6 x 0.35	6g	1.291mm	1.354mm	1.496mm	1.581mm	1.063mm
M1.8 x 0.35	6g	1.491	1.554	1.696	1.781	1.263
M2 x 0.4	6g	1.654	1.721	1.886	1.981	1.394
M2.2 x 0.45	6g	1.817	1.888	2.080	2.180	1.525
M2.5 x 0.45	6g	2.117	2.188	2.380	2.480	1.825
M3 x 0.5	6g	2.580	2.655	2.874	2.980	2.256
M3.5 x 0.6	6g	3.004	3.089	3.354	3.479	2.614
M4 x 0.7	6g	3.433	3.523	3.838	3.978	2.979
M4.5 x 0.75	6g	3.901	3.991	4.338	4.478	3.414
M5 x 0.8	6g	4.361	4.456	4.826	4.976	3.841
M6 x 1.0	6g	5.212	5.324	5.794	5.974	4.563
M7 x 1.0	6g	6.212	6.324	6.794	6.974	5.563
M8 x 1.25	6g	7.042	7.160	7.760	7.972	6.231
M8 x 1.0	6g	7.212	7.324	7.794	7.974	6.563
M10 x 1.5	6g	8.862	8.994	9.732	9.968	7.879
M10 x 1.25	6g	9.042	9.160	9.760	9.972	8.231
M12 x 1.75	6g	10.679	10.829	11.701	11.966	9.543
M12 x 1.25	6g	11.028	11.160	11.760	11.972	10.217
M14 x 2.0	6g	12.503	12.663	13.682	13.962	11.204
M14 x 1.5	6g	12.854	12.994	13.732	13.968	11.879
M16 x 2.0	6g	14.503	14.663	15.682	15.962	13.204
M16 x 1.5	6g	14.854	14.994	15.732	15.968	13.879
M18 x 2.5	6g	16.164	16.334	17.623	17.958	14.541
M18 x 1.5	6g	16.854	16.994	17.732	17.968	15.879
M20 x 2.5	6g	18.164	18.334	19.623	19.958	16.541
M20 x 1.5	6g	18.854	18.994	19.732	19.968	17.879
M22 x 2.5	6g	20.164	20.334	21.623	21.958	18.541
M22 x 1.5	6g	20.854	20.994	21.732	21.968	19.879
M24 x 3.0	6g	21.803	22.003	23.577	23.952	19.855
M24 x 2.0	6g	22.493	22.663	23.682	23.962	21.194
M27 x 3.0	6g	24.803	25.003	26.577	26.952	22.855
M27 x 2.0	6g	25.493	25.663	26.682	26.962	24.194
M30 x 3.5	6g	27.462	27.674	29.522	29.947	25.189
M30 x 2.0	6g	28.493	28.663	29.682	29.962	27.194
M33 x 3.5	6g	30.462	30.674	32.522	32.947	28.189
M33 x 2.0	6g	31.493	31.663	32.682	32.962	30.194
M36 x 4.0	6g	33.118	33.342	35.465	35.940	30.521
M36 x 3.0	6g	33.803	34.003	35.577	35.952	31.855
M39 x 4.0	6g	36.118	36.342	38.465	38.940	33.521
M39 x 3.0	6g	36.803	37.003	38.577	38.952	34.855

NOTES

TERMS AND CONDITIONS

Thread Rolls U.S.A. Inc. warrants to the original equipment manufacturers, distributors, and industrial users of it's products that each new product manufactured or supplied by Thread Rolls U.S.A. Inc. shall be free from defects in material and workmanship. Thread Rolls U.S.A. Inc.'s sole obligation under this warranty is limited to furnishing without additional charge a replacement for, at it's option, repairing or issuing credit for any product which shall, within one year from the date of sale by Thread Rolls U.S.A. Inc., be returned freight prepaid, and upon inspection is determined by Thread Rolls U.S.A. Inc. to be defective in materials or workmanship. Complete information as to the operating conditions, machine setup, and application of coolant or cutting fluid should accompany any product returned for inspection. The provisions of this warranty shall not apply to any Thread Rolls U.S.A. Inc. product which has been subjected to misuse, improper operating conditions, machine setup, or application of coolant or cutting fluid, or which has been repaired or altered if such repair or alteration in the judgment of Thread Rolls U.S.A. Inc. would adversely affect performance of the product. This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular purpose. Thread Rolls U.S.A. Inc.'s sole liability on any claim of any kind, whether in contract, tort, or otherwise, for any loss or damage arising out of, connected with, or resulting from the manufacture, sale, delivery, or use of the products sold hereunder shall in no case exceed the cost of replacement or repair as provided herein. In no event shall Thread Rolls U.S.A. Inc. tools be liable for any special, incidental, or consequential damages. There are no other warranties, expressed or implied, made by Thread Rolls U.S.A. Inc. except the warranty against defects in material and workmanship set forth above and Thread Rolls U.S.A. Inc. neither assumes nor authorizes any other person or firm to assume for it any other obligations or liability in connection with it's products.

CONVERSION CHARTS

FRACTION	inch	mm
1/64	.015625	0.397
1/32	.03125	0.794
3/64	.046875	1.191
1/16	.0625	1.588
5/64	.078125	1.984
3/32	.09375	2.381
7/64	.109375	2.778
1/8	.1250	3.175
9/64	.140625	3.572
5/32	.15625	3.969
11/64	.171875	4.366
3/16	.1875	4.763
13/64	.203125	5.159
7/32	.21875	5.556
15/64	.234375	5.953
1/4	.2500	6.350
17/64	.265625	6.747
9/32	.28125	7.144
19/64	.296875	7.541
5/16	.3125	7.938
21/64	.328125	8.334
11/32	.34375	8.731
23/64	.359375	9.128
3/8	.3750	9.525
25/64	.390625	9.922
13/32	.40625	10.319
27/64	.421875	10.716
7/16	.4375	11.113
29/64	.453125	11.509
15/32	.46875	11.906
31/64	.484375	12.303
1/2	.5000	12.700
33/64	.515625	13.097
17/32	.53125	13.494
35/64	.546875	13.891
9/16	.5625	14.288
37/64	.578125	14.684
19/32	.59375	15.081
39/64	.609375	15.478
5/8	.6250	15.875
41/64	.640625	16.272
21/32	.65625	16.669
43/64	.671875	17.066
11/16	.6875	17.463
45/64	.703125	17.859
23/32	.71875	18.256
47/64	.734375	18.653
3/4	.7500	19.050
49/64	.765625	19.447
25/32	.78125	19.844
51/64	.796875	20.241
13/16	.8125	20.638
53/64	.828125	21.034
27/32	.84375	21.431
55/64	.859375	21.828
7/8	.8750	22.225
57/64	.890625	22.622
29/32	.90625	23.019
59/64	.921875	23.416
15/16	.9375	23.813
61/64	.953125	24.209
31/32	.96875	24.606
63/64	.984375	25.003
1"	1.000	25.400

mm	inch	mm	inch
.1	.00394	48	1.88976
.2	.00787	49	1.92913
.3	.01181	50	1.96850
.4	.01575	50.8	2.000"
.5	.01969	51	2.00787
.6	.02362	52	2.04724
.7	.02756	53	2.08661
.8	.03150	54	2.12598
.9	.03543	55	2.16535
1	.03937	56	2.20472
2	.07874	57	2.24409
3	.11811	58	2.28346
4	.15748	59	2.32283
5	.19685	60	2.36220
6	.23622	61	2.40157
7	.27559	62	2.44094
8	.31496	63	2.48031
9	.35433	63.5	2.500"
10	.39370	64	2.51969
11	.43307	65	2.55906
12	.47244	66	2.59843
12.7	.500"	67	2.63780
13	.51181	68	2.67717
14	.55118	69	2.71654
15	.59055	70	2.75591
16	.62992	71	2.79528
17	.66929	72	2.83465
18	.70866	73	2.87402
19	.74803	74	2.91339
20	.78740	75	2.95276
21	.82677	76	2.99213
22	.86614	76.2	3.000"
23	.90551	77	3.03150
24	.94488	78	3.07087
25	.98425	79	3.11024
25.4	1.000"	80	3.14961
26	1.02362	81	3.18898
27	1.06299	82	3.22835
28	1.10236	83	3.26772
29	1.14173	84	3.30709
30	1.18110	85	3.34646
31	1.22047	86	3.38583
32	1.25984	87	3.42520
33	1.29921	88	3.46457
34	1.33858	88.9	3.500"
35	1.37795	89	3.50394
36	1.41732	90	3.54331
37	1.45669	91	3.58268
38	1.49606	92	3.62205
38.1	1.500"	93	3.66142
39	1.53543	94	3.70079
40	1.57480	95	3.74016
41	1.61417	96	3.77953
42	1.65354	97	3.81890
43	1.69291	98	3.85827
44	1.73228	99	3.89764
45	1.77165	100	3.93701
46	1.81102	101.6	4.000"
47	1.85039	127	5.000"

DISTANCES ACROSS

FLATS	CORNERS HEX	CORNERS SQUARE
1/4	.289	.354
5/16	.361	.442
3/8	.433	.530
7/16	.505	.619
1/2	.577	.707
9/16	.650	.795
5/8	.722	.884
11/16	.794	.972
3/4	.866	1.061
13/16	.938	1.149
7/8	1.010	1.237
15/16	1.083	1.326
1	1.155	1.414
1 1/16	1.227	1.503
1 1/8	1.299	1.591
1 3/16	1.371	1.679
1 1/4	1.443	1.768
1 5/16	1.516	1.856
1 3/8	1.588	1.945
1 7/16	1.660	2.033
1 1/2	1.732	2.121
1 9/16	1.804	2.210
1 5/8	1.876	2.298
1 11/16	1.949	2.386
1 3/4	2.021	2.475
1 13/16	2.093	2.563
1 7/8	2.165	2.652
1 15/16	2.237	2.740
2	2.309	2.828
2 1/32	2.345	2.873
2 1/16	2.382	2.917
2 3/32	2.418	2.961
2 1/8	2.454	3.005
2 5/32	2.490	3.049
2 3/16	2.526	3.094
2 1/4	2.598	3.182
2 5/16	2.670	3.270
2 3/8	2.742	3.359
2 7/16	2.815	3.447
2 1/2	2.887	3.536
2 9/16	2.959	3.624
2 5/8	3.031	3.712
2 11/16	3.103	3.801
2 3/4	3.175	3.889
2 13/16	3.248	3.977
2 7/8	3.320	4.066
2 15/16	3.392	4.154
3	3.464	4.243
3 1/16	3.536	4.331
3 1/8	3.608	4.419
3 3/16	3.681	4.508
3 1/4	3.753	4.596
3 5/16	3.825	4.685
3 3/8	3.897	4.773
3 7/16	3.969	4.861
3 1/2	4.041	4.950
3 9/16	4.114	5.038
3 5/8	4.186	5.127
3 11/16	4.258	5.215
3 3/4	4.330	5.303
3 13/16	4.402	5.392
3 7/8	4.474	5.480
3 15/16	4.547	5.568
4	4.619	5.657