

SCREW THREADS

Presented By:

Glastonbury Southern Gage

Authorized Distributor
Willrich Precision
Ph 866-945-5742
email: sales@willrich.com
www.willrich.com

**An Intermediate Level Technical Seminar
Covering:**

**DESIGN, NOMENCLATURE,
ACCEPTABILITY, & GAGING**

Written By:

David T. Harris
ASQ – CMI, CQT, CQE, CQA
ISO Certified Lead Auditor

Corporate Quality Director
GlastonburySouthern Gage / Alpha Q, Inc.
TheQualityDir@cs.com

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INTRODUCTION

"One of the most common quality problems with threaded products is a lack of knowledge of 'screw threads.' This seminar is designed to give a basic understanding of 'screw threads' and ways to inspect them."

About the Presenters:

David T. Harris

Dave has been with GSG for over 25 years, serving in various capacities including Gage Design, Sales, Engineering, Manufacturing Manager of Cylindrical and Indicating Gages, Software Design, MIS Manager, and presently serving as the Corporate Quality Director.

As an active ASME member, Dave is Chairman of the ANSI committee B89.1.6 Measurement of Internal Diameters, as well as

being a member and/or an active participant in several other committees.

Dave is a Certified ISO Lead Auditor, and through ASQ is a:

(CMI) Certified Mechanical Inspector
(CQT) Certified Quality Technician
(CQE) Certified Quality Engineer
(CQA) Certified Quality Auditor

Michael W. Rose

Mike has been with GSG for over 30 years as an Engineer of Screw Thread Design and Manufacturing of gages and products.

As an active ASME member, Mike is Chairman of the ANSI committees B1.2 "Gages and Gaging For Unified Inch Screw Threads", and B1.16M "Gages And Gaging For Metric M Screw Threads", and an active member of

the following committees: B1 main committee for Screw Threads, B1.5 "Acme Screw Threads", B1.8 "Stub Acme Screw Threads", and gaging sub-committee member of the American Petroleum Institute.

Through ASQ, Mike is a
(CMI) Certified Mechanical Inspector

Note: All opinions and interpretations of the ANSI standards are the presenter's own as an employee of Glastonbury Southern Gage and not as an ANSI member. The interpretation of the standards is the responsibility of the individual user.

Good communications between the user and vendor for a mutual understanding of needs, services, and interpretations of the standards will enhance product quality



BASIC THREAD FORM TERMS

The following basic terms are necessary to understand threads of any form. The sketch illustrates each term. A listing of more thread terms is included in a glossary at the end.

CREST: The top of the thread form. The major diameter of an external thread, or the minor diameter of an internal thread.

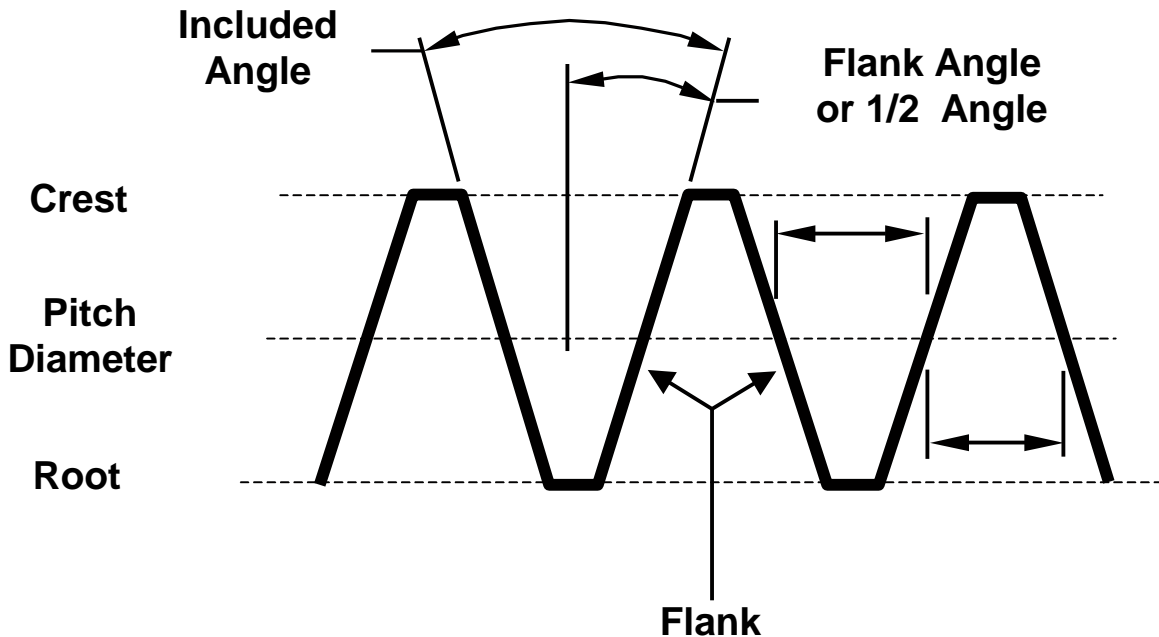
ROOT: The bottom of the thread form. The major diameter of an internal thread and the minor diameter of an external thread.

PITCH DIAMETER: The theoretical diametrical plane, which passes through a thread at the point where the width of the thread tooth and groove are equal.

FLANKS: The sides of the thread form or groove, connecting the crest and the root.

FLANK ANGLE: The angle between the flank and a line perpendicular to the axis of the thread. Also referred to as half angle or lead angle. Some exceptions to this definition will be encountered, such as tapered thread flank angles measured perpendicular to the taper, and should be noted.

INCLUDED ANGLE: Total of the two flank angles of a thread form.



Glastonbury Southern Gage
PO Box 509
Erin, TN 37061
Phone 800-251-4243, Fax 800-242-7142
www.gsgage.com

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INTERNAL THREAD BASICS

Figure #1 Internal Thread Basics

MAJOR DIAMETER - ROOT:

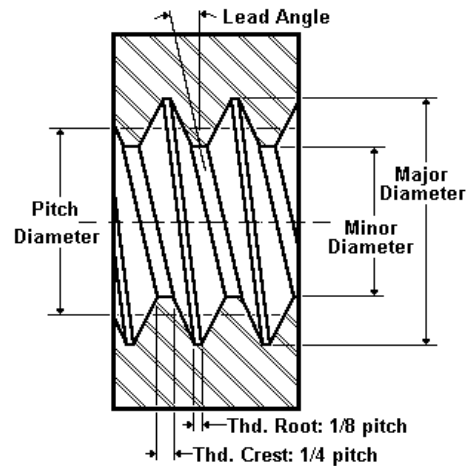
Must clear the major diameter of the mating external thread part.

MINOR DIAMETER - CREST:

Controls the strength or shear of the thread.

PITCH DIAMETER:

Controls the fit of the mating parts, looseness & tightness.



GO THREAD PLUG GAGES

Plus tolerance on OD (Outer or Major Diameter), & PD (Pitch Diameter)

Functional check; checks minimum pitch diameter, minimum major diameter, flank angles, and lead.

Engages for full length of thread free and easy

NOGO, NOTGO, HI THREAD PLUG GAGES

Minus tolerance on OD (Major Diameter), & PD (Pitch Diameter)

Checks one feature only: maximum functional pitch diameter

Engagement

Inch: Acceptable when gage does not enter product more than three complete turns. Thin or soft material, or small number of threads may require altering three-turn limit. Per ANSI B1.2-1983, page 13, par. 4.2.1

Metric: Acceptable when a definite drag from contact with the product material results on or before the second turn of entry. Per ANSI B1.16M-1984, page 15, par. 4.2.1



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EXTERNAL THREAD BASICS

MAJOR DIAMETER - BASIC:

All thread dimensions, internal & external are based on this dimension.

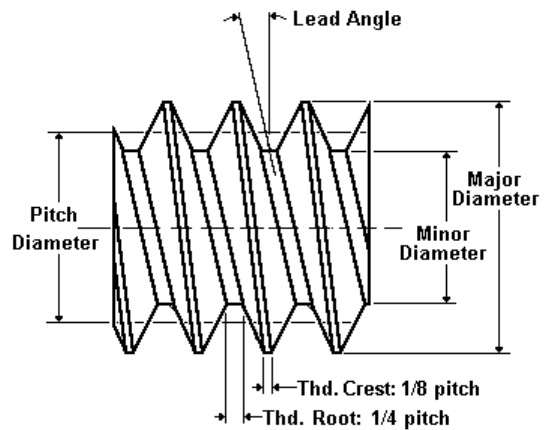
MINOR DIAMETER - ROOT:

Must clear the mating product's minor diameter.

PITCH DIAMETER:

Controls the fit of the mating parts, looseness & tightness.

Figure #2 External Thread Basics



GO THREAD RING GAGES

Minus tolerance on ID (Inner or Minor Diameter) and PD (Pitch Diameter)

Functional check; checks maximum pitch diameter, maximum minor diameter, flank angles, and lead.

Engages for full length of thread free and easy

NOGO, NOTGO, LO THREAD RING GAGES

Plus tolerance on ID (Inner or Minor Diameter) and PD (Pitch Diameter)

Checks one feature only: minimum functional pitch diameter

Engagement

Inch: Acceptable when gage does not enter product more than three complete turns. Thin or soft material, or small number of threads may require altering three-turn limit. Per ANSI B1.2-1983, page 128, par. 5.2.1

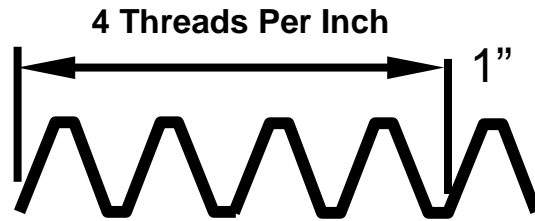
Metric: Acceptable when a definite drag from contact with the product material results on or before the second turn of entry. Per ANSI B1.16M-1984, page 75, par. 5.2.1



TPI / PITCH / LEAD

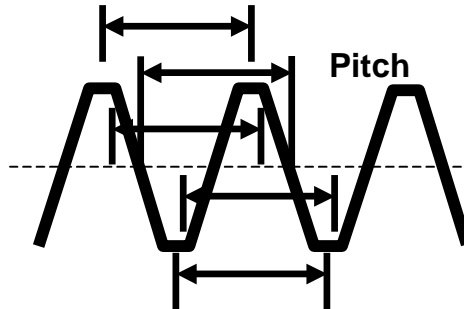
THREADS PER INCH:

The number of threads within one inch, measured along the axis of the thread.



PITCH:

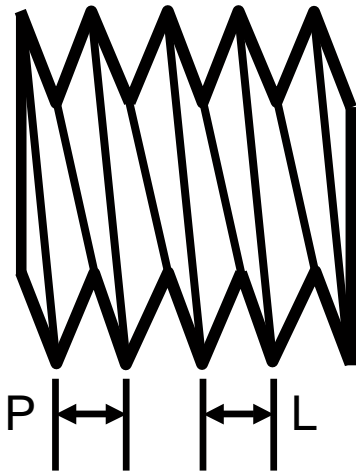
The distance between corresponding points on adjacent threads.



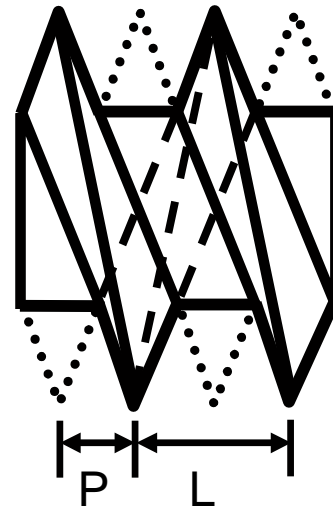
LEAD:

The distance advanced by a thread when rotated 360 degrees on its mating thread.

One Start or Single Lead Thread



Two Start or Double Lead Thread



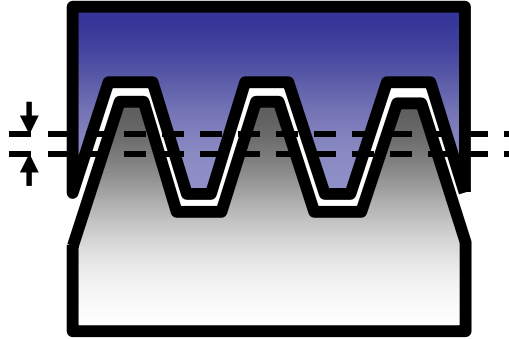
$$\text{Pitch} \times (\# \text{ of Starts}) = \text{Lead}$$



ALLOWANCE / CLEARANCE

ALLOWANCE:

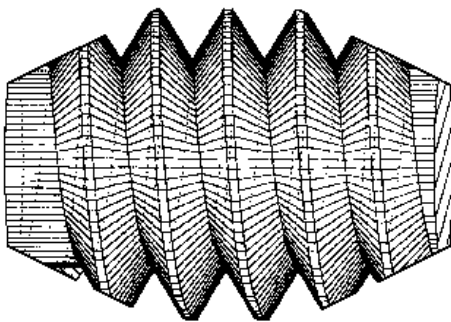
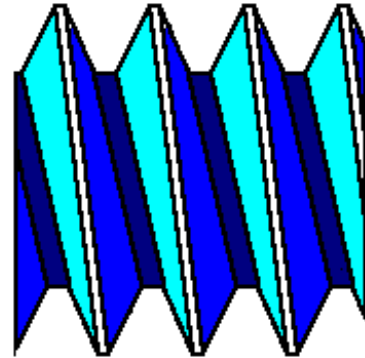
The minimum clearance between two mating parts. The variations from the basic size which are prescribed to permit the desired amount of play in a metal-to-metal fit. For threads, the difference in pitch diameters.



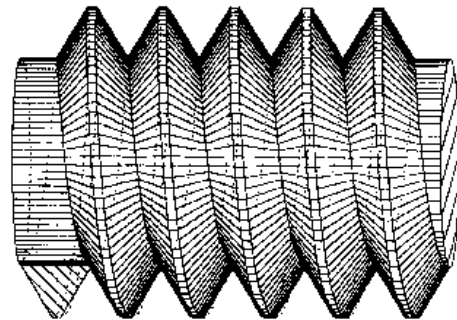
FEATHER EDGE REMOVAL

When a part is threaded, whether internally or externally, the beginning and/or ending of the thread is a partial or feather thread. The partial thread must be removed for two reasons.

- 1) Safety. The feather edge will cut like a razor on metal parts.
- 2) Function. The feather edge will roll over blocking the thread vee and not allowing the threads to assemble.



Removal by Chamfer



Removal by Convolute



THREAD FORMING

There are three common methods of creating threads.

Tap / Die

After the part is formed close to the finished diameter, major diameter for external parts and minor diameter for internal parts, the threads are cut into the part using an instrument that has the thread form on it. Slots or flutes are cut along the axis of the tap or die to create cutting surfaces. The tap or die is screwed into or onto the part, forming the thread.

Roll

Like the tap / die method, the part is formed close to the finished diameter, but with the diameters controlled for the rolling process. Thread rolls are applied to the parts with intense pressure causing the material to be displaced by the roll's thread form and extruded into the valley between the roll's threads,

forming the thread on the part.

Single-point

This method is used in most lathe thread forming processes. A single cutter with the form of the thread is forced against the part, removing material in a spiral path created by the axial movement of the cutter in combination with the axial turning of the part forming the vee of the thread. Several passes of the cutter may be required to achieve the desired vee depth to form the thread.

Plastic and soft material parts are sometimes created by a form or mold. The thread formed or molded is an inverse duplication of the mold thread. The mold thread will usually be created by one of the methods mentioned above.

**All threads, regardless of method, must conform to the same criteria.
The same gage will check threads made from any method.**

HISTORY

Prior to 1957 the only US Govt. published and recognized product and gage thread dimensions and tolerances, was the American National Series (also known as the National Series). Because of problems and a desire in the manufacturing sector for a better series of standardized threads, the Unified National Series was created and published. The 1957 publication of the government screw thread standard H-28

included this new series of threads (Unified National) along with the National Series. Manufacturers had the option of using either, but were advised to use and/or change over to the new series. This continued with each publication until 1969 when the National Series was dropped from the standard and only the Unified Series was recognized and recommended.



PRODUCT DIMENSIONS

All product dimensions are computed from a base of the basic pitch diameter. The Pitch Diameter of a thread is a theoretic diametric plane where the width of the tooth and the width of the groove are equal. The basic pitch diameter can be found by starting with the nominal size (using our example it would be 1/2 or .5000), and subtracting $.64952p$ (p = pitch, pitch is the same as the lead for a single start thread). Using the example, the pitch would be .076923 or 1/13 (a good calculator will do this for you using the 1/x key).

Using the basic pitch diameter the product limits for the internal and external thread can be computed. The basic pitch diameter becomes the minimum size for the internal thread and the maximum size for the external thread. This becomes the manufacturing window for the product. The gages are made to the extreme limits of the product tolerance or window, with the tolerance of the gages configured to

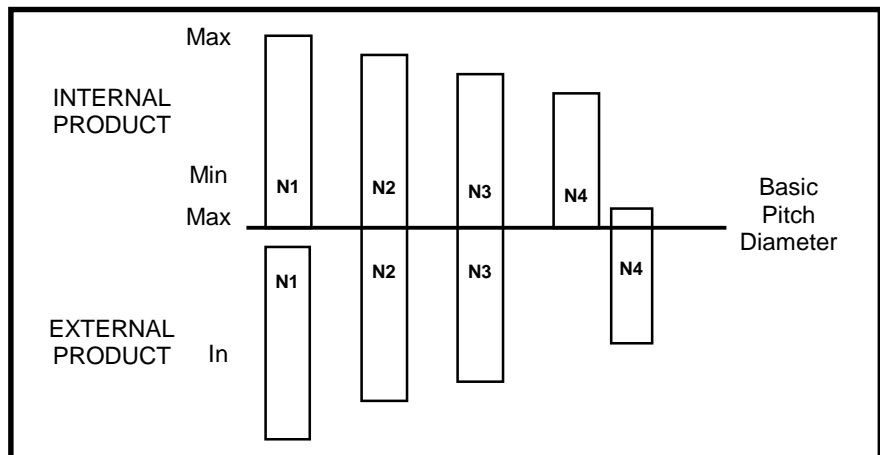
guarantee the gages are inside of the product tolerance zone (maximum being minus, and minimum being plus).

Another feature, which must be considered, is the allowance. This computed amount is subtracted from the basic pitch diameter to attain an adjusted maximum size for the external product. The purpose of this is to guarantee ease of assembling the internal and external products. For National class 1 and Unified classes 1A and 2A, the allowance is included. For National classes 2 and 3, and Unified class 3A have an allowance of zero. National classes 4 & 5 are a special case designed to create an interference fit having the allowance added to the maximum instead of subtracted.

The number designation in National and Unified Series determines the size of the product tolerance or window. The larger the number, the smaller the manufacturing window for the product.

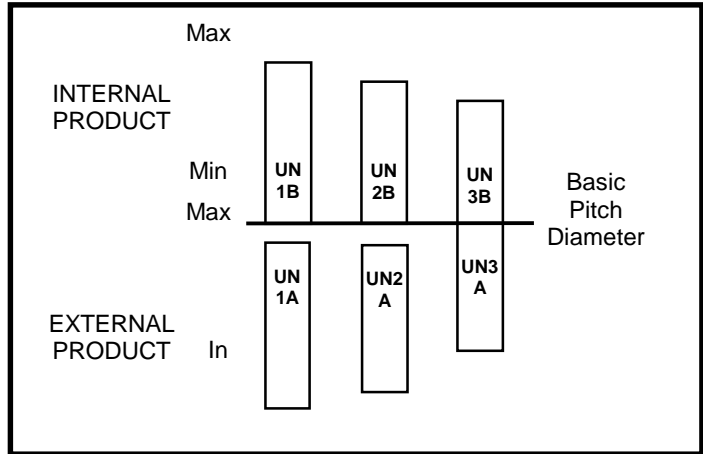
NATIONAL SERIES

In the National Series screw thread the class 2 was designed as the 'Nuts & Bolts' fit. The class 1 is also a 'Nuts & Bolts' fit but with an allowance factor between the products creating a guaranteed assembly scenario. Class 3 is the 'Machine' fit. Classes 4 & 5 are 'Interference' fit.



UNIFIED SERIES

In the Unified National Series the internal product minimum size, which is also the size of the Go plug gage, is always the basic pitch diameter. The internal product maximum size, which is also the size of the Notgo gage, varies with the class. The external product maximum size, which is also the size of the Go ring gage, is basic pitch diameter or basic pitch diameter minus the allowance. The external product minimum size, which is also the size of the Notgo ring gage, varies with the class.



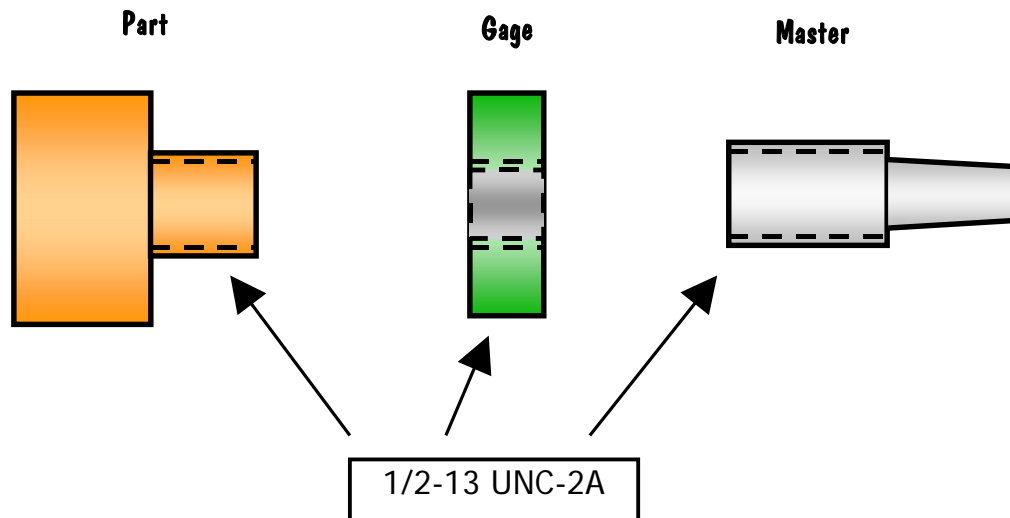
The 2A / 2B fit is generally referred to as the 'nuts and bolts fit' because of the guaranteed gap between the mating parts, where tightness is accomplished by contact against a face. The class 1A / 1B is also a 'Nuts & Bolts' fit will a larger manufacturing window and coined as 'Quick Assembly.'

The 3A / 3B fit is generally referred to as the 'machine fit' because it usually gives a tighter fit of the threads of the mating parts.

There is no class 4. Class 5 was retained but moved to a difference standard more commensurate to its application.

THREAD NOMENCLATURE PHILOSOPHY

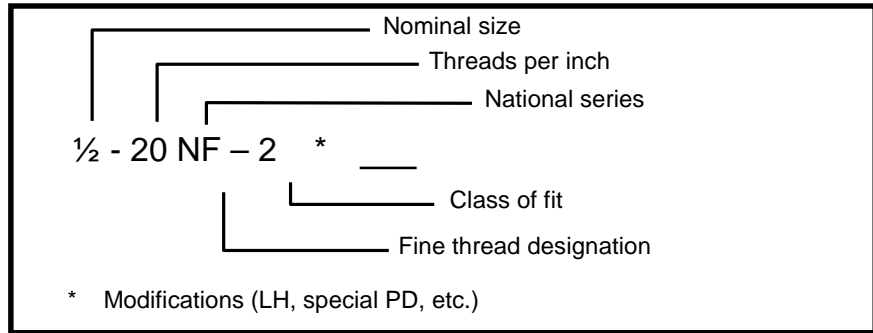
An unchanging identification flows from the product to the gage and on to the master.



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DESIGNATION

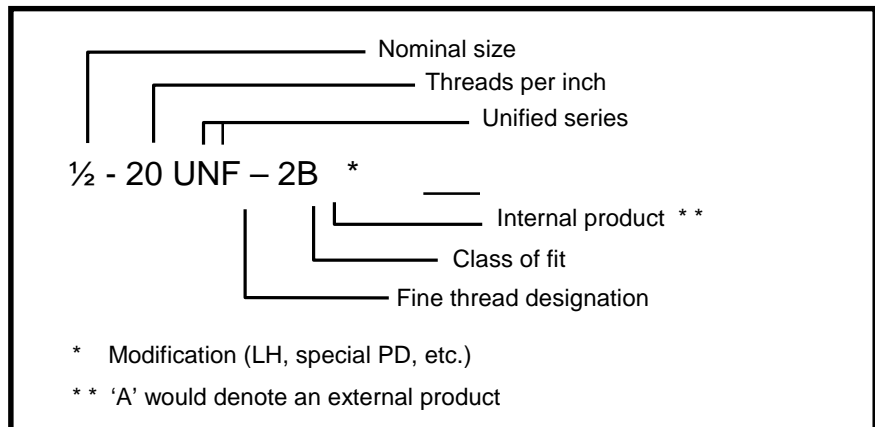
**Screw Thread
Designation
NATIONAL
SYSTEM**



With the creation of the Unified Series, the letter designation was added to distinguish between the internal & external threaded products. The letter 'A' denotes external and the letter 'B' denotes internal. This

letter follows the class of fit in the nomenclature. With the National Series, there was no way to differentiate between internal & external.

**Screw Thread
Designation
UNIFIED
SYSTEM**



MISMATCHING SERIES

**National
1/4-20 NC-2**

**Unified
1/4-20 UNC-2B**

X 1/4-20 NC-2B

X 1/4-20 UNC-2

It should be noted that it is incorrect to mix the designations of the National and Unified Series threads. For instance, it is incorrect to specify a thread as N-2A, N-3B, UN-2, or UN-3. To make this simple, just

remember: If there is a 'U' (for unified) there must also be an A or B (internal or external). If there is not a 'U' (therefore National) there cannot be an A or B.



If you have a thread designation with mismatched information, it is time to go back to the customer or engineer for clarification.

In the nomenclature, other letters are used to further clarify the type of thread. This is true for National and Unified Series threads. For instance; F-fine, C-coarse, EF-extra fine, S-standard or special. The additional letter or letters always follow the 'N'. For example: 1/2-20 UNF-2A, 1/2-13 UNC-2B, 5/8-11 NC-2.

Thread gages are always identified with the exact nomenclature of the thread they are used to inspect.

Thread plug gage nomenclatures are the same as internal threaded products, thread ring gages are the same as external threaded products, and masters are the same as the working gage they inspect. This is why a truncated set plug has a nomenclature of an external threaded product; it checks the thread ring, which checks the external threaded product.

INCH NOMENCLATURE EXAMPLES

(Size) - (TPI) (Type) - (class) (Modifiers)

✓ .250-28 UNF-3A LH

✓ 1/4-28 NF-2

✓ 1.00-.050P-.100L UN-2A

X 1/2-13 GH5

MULTIPLE LEAD THREADS NOMENCLATURE

With multiple lead, or multiple start threads all the nomenclature information is the same except for the designation for the threads per inch, as it is necessary to specify the distance between the individual threads as well as the individual leads or starts. This is accomplished by designating the pitch and lead in decimal form, rounded to 4 decimal places.

For example: A thread with a nominal size of 1/2 inch, and 20 threads per inch, with 2

starts, unified series, class 2 internal, would be given the nomenclature;

1/2 - .0500P-.1000L UNF-2B

The inverse of 20 (or 1 divided by 20) equals .0500 which is the pitch, the distance from one thread to the next thread. The lead is found by multiplying the pitch by the number of starts or leads.



TAPS VS GAGES

A gage size is based on the product tolerance dimensions known, or computable from the standards, based on the nomenclature.

A tap size is computed from the basic pitch diameter, adding .0005 times the tap size.

Using the product or gage size, the best tap size **can** be calculated. Using the tap size, the product or gage size **cannot** be calculated.

A product size (nomenclature) specifies a range of dimensions, whereas a tap size only specifies a particular dimension that will fall somewhere within the product range of dimensions.

For instance, using the 1/2-13 example;

A tap GH5 would be made to a pitch diameter of .4525 with a tolerance of minus .0005: [.4500 being the basic pitch diameter, and adding .0005 times 5 or .0025].
$$\{.4500 + (.0005 \times 5)\} = .4525$$

A product of UN-2B would be made to a pitch diameter between .4500 & .4565.

The gages would be made to the tolerance limits of the products, therefore the Go gage would be made to .4500 with a plus tolerance, and the NoGo gage would be made to .4565 with a minus tolerance.

JEWELER SIZES

.060 +/- .013 per increment

#000 = .034

#00 = .047

#0 = .060

#1 = .073

#2 = .086

#3 = .099

#4 = .112

#5 = .125

#6 = .138

#7 = .151

#8 = .164

#9 = .177

#10 = .190

#11 = .203

#12 = .216

#13 = .229

#14 = .242

Jeweler sizes were originally created for the jewelry industry as a method for designating small sizes. Several commonly used small thread sizes use this method of specifying the nominal size of the product

thread. Jeweler sizes are by theory indefinite, but seldom will a jeweler size be used beyond the 1/4 or .250 inch diameter size.



METRIC THREADS

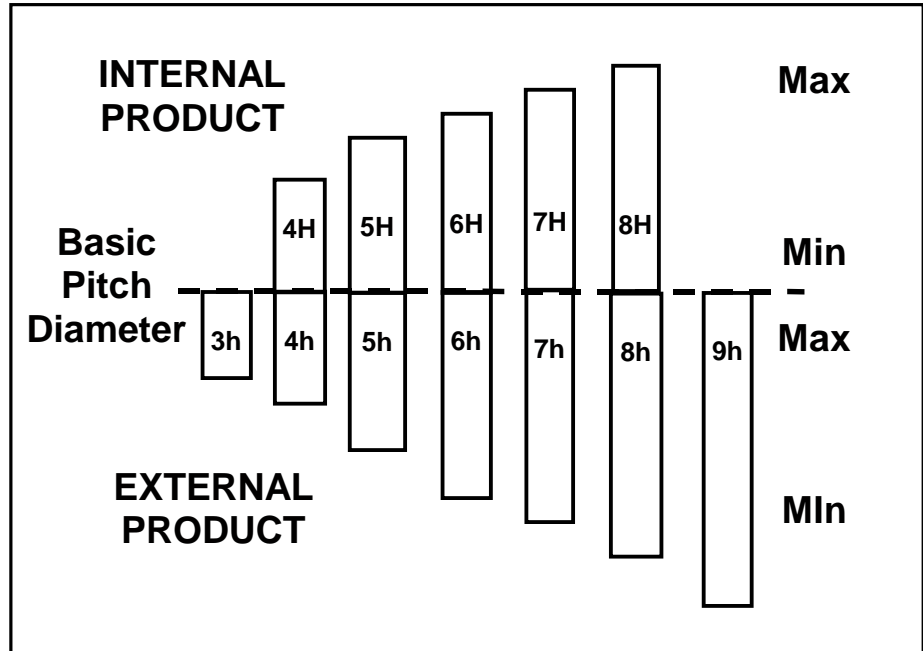
The best way to explain and understand metric threads is by comparison to inch threads. **The first and one of the most important things to remember about metric threads, is that, like inch threads, knowing the tap size is not enough information to manufacture a gage.** A proper and complete nomenclature for the gage or the product is necessary.

Metric threads have been engineered to allow for much variation while still being able to be considered a standardized product. The metric screw thread has five standard internal product classes and seven standard external product classes. The product tolerance or manufacturing window for metric screw threads is the opposite of the inch design. With

metric screw threads the larger the number designation for the class, the larger the product tolerance.

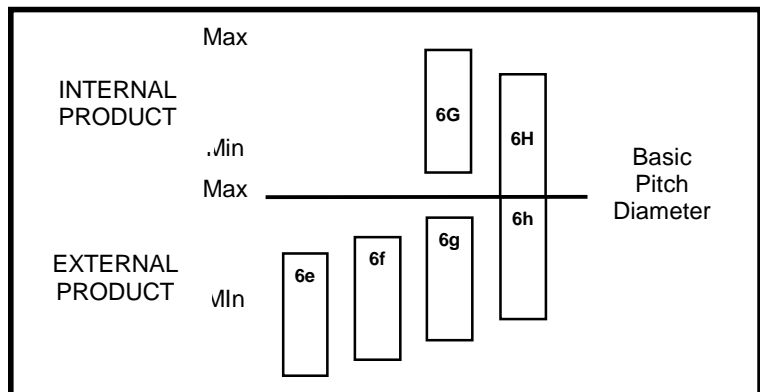
The most common metric product screw thread is the class 6g external product, and the class 6H internal product, which creates

a very similar assembly scenario to the inch 2A / 2B 'Nuts and Bolts' fit. Companies that stock metric gages, usually stock class '6H' plug gages for internal threads and '6g' ring and set plug gages for external threads, because this comprises 80%+ of the metric thread gage market.



METRIC ALLOWANCES

The 'g' & 'H' are commonly confused with the unified method of denoting internal and external of 'A' & 'B'. Here the metric uses a method that is not present in the inch series. **The internal and external threads in metrics are denoted by the case of the letter used**, lower case for external, and upper case for internal.



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The letter used denotes the amount of allowance adjustment applied to the basic size. For external threads, allowances available are 'e, f, g, & h'. For internal threads, allowances available are 'G & H'.

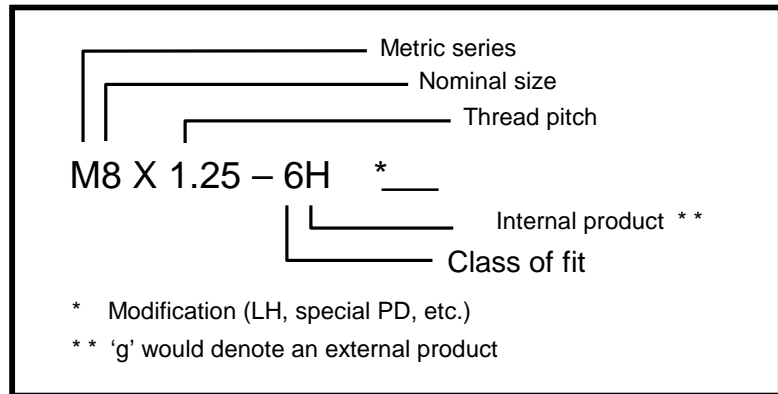
Here again we see a difference in the inch and metric systems. In the Unified, there is only one allowance available and it is only

applied to the external thread. For metric, you can apply allowances to the internal also. In both the internal and external the 'h or H' signifies an allowance factor of zero. The 'G' is the only allowance for internal threads and the 'g' is the smallest allowance available for external, the 'f' being more, and the 'e' being the greatest allowance.

METRIC DESIGNATION

The nomenclature of metric threads begins with the letter M. This is the designation showing the metric series. Other letters may be added after the M showing modifications to the standard metric series. This can be compared to the UN for Unified National, or N for National in the English thread nomenclature. Notice that in metrics, the series designation precedes the nominal size and pitch, unlike in the inch series, which follows the nominal size and pitch.

The nominal size is the first number that follows the metric series designation, followed by the pitch. The nominal size and pitch are separated by the letter 'X', which is pronounced as 'by'. In the inch series the nominal size is followed by the threads per inch, whereas in metric the inverse of the threads per inch, the pitch, the actual



distance from one thread to the next, follows the nominal size.

Following the pitch is the class of fit. The designation that denotes internal or external also signifies allowance. When the class of fit is specified with two different classes, such as 4g6g, the first one, 4g, is the tolerance applied to the product pitch diameters, and the second one, 6g, is the tolerance applied to the product major and minor diameters.

METRIC NOMENCLATURE EXAMPLES

(Type)(Size) x (Pitch) - (Class)(Allow.) (Mod.)

- ✓ M10x1.25-6H
- ✓ M8x.75-4g6g
- ✓ MJ12x1.75-6G LH
- x M6 D5



INTERNAL / EXTERNAL DESIGNATION

Inch	'A' - External 'B' - Internal	Metric	'e,f,g,h' - External 'G,H' - Internal
------	----------------------------------	--------	--

The nomenclature designation in the unified inch series is denoted by the 'A' representing the external product, and the 'B' representing the internal product. Metric series uses the case of the letter to designate the difference between internal and external products. The lower case is

for external products and the upper case is for internal products. It is important to note that blueprints, specifications and purchase orders should always show the nomenclature properly, especially the letter case.

PRODUCT ACCEPTABILITY

The acceptability of a product is established by the level of quality required by the user or design. Currently, many manufacturers are using 3 levels of acceptability as given in the ANSI standard B1.3M.

Level 21; Lowest level of acceptability

Functional limit inspection. Functional limit gages are used to inspect the threads. Used in applications where functionality is the major consideration and failure is unlikely to be fatal.

Level 22; Middle level of acceptability

A maximum material limit functional go gage may be used with an actual pitch diameter measurement made at the minimum material limit. This and all levels may be modified to include a special feature. Ex: ½-13 UNC-2A (22)(R) The (R) requires that the root radius be inspected for conformance. Used in all military applications, and in applications where failure would probably result in fatality.

Level 23; Highest level of acceptability

All elements be inspected. The functional pitch diameter and actual pitch diameter must also be compared. The difference between the two cannot be greater than ½ the part pitch diameter tolerance (40% for "J" thread). Used in many nuclear applications. Used in applications where failure would result in catastrophic fatalities. Also used in research and development applications.

Note: Variable gaging may be used for levels 22 and 23. Both Functional segments and single element (best wire, cone & vee) segments or rolls are required. In addition, optical comparators may be needed.



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ACCUMULATIVE ERROR OF THREADS

When inspecting threads, especially product threads, you must take into account the accumulative error that develops because of the geometric intricacy of threads. This accumulative error is the deviation of functional size from measured size. Each geometric element of the thread; lead, pitch, flank angle, helical path, & pitch diameter, is manufactured within a specified tolerance. The variation for each element will vary, some being positive, some negative, some bilateral, from the exact specification. The deviation from the exact specification will affect the functional size of the thread. Depending on the geometric element, the ratio of affect on the functional size will vary.

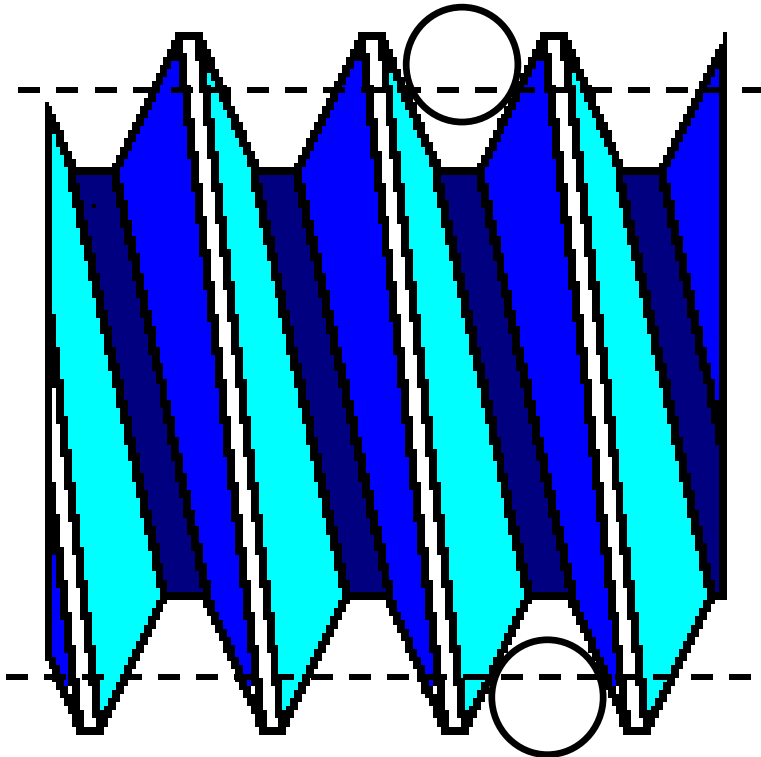
Accumulative error will always affect an external thread, whether a product or a

gage, by making the functional size larger than the measured size, and will always affect an internal thread, whether a product or a gage, by making the functional size smaller than the measured size.

Functional size is the real world reaction experienced when internal and external threads are assembled together. Fixed limit gages, which is an attribute gaging system, will measure the functional limits of the product. Pitch mics, wire methods, and single rib roll indicating instruments, cannot truly measure functional size. Three roll indicating instruments, with full profile functional rolls having multiple ribs, either straight or with a developing helical path, can be used to measure functional size, but is not as accurate as fixed limit gages.

A pitch diameter is measured by placing wires or balls into the vee of the thread at a point that is tangent or contacts at the theoretical diametrical plane of the pitch diameter. This creates a geometric configuration making it possible to formulate the measuring the pitch diameter by measuring over the wires or balls.

This type measurement does not take into consideration the errors of the flanks or helical path and therefore do not give a functional size.

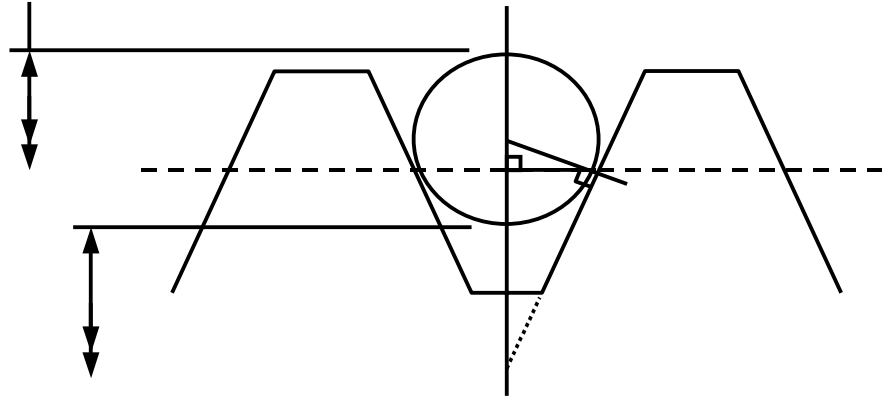


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THREAD MEASUREMENT FORMULAE

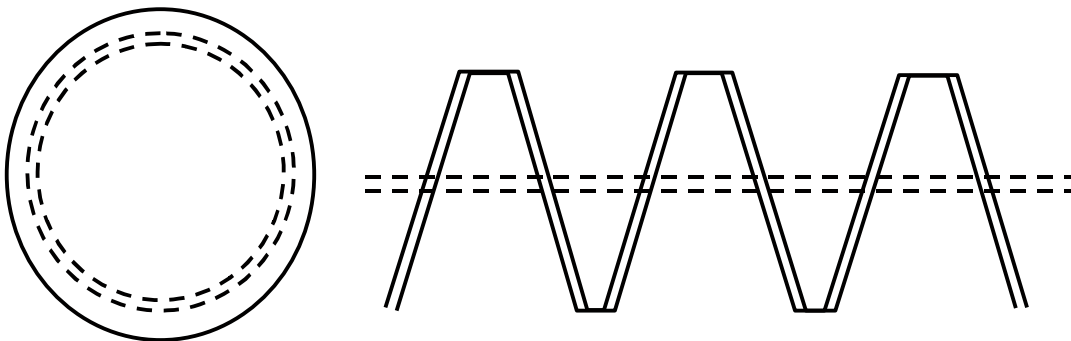
$$E - \frac{\cot \alpha}{2n} + w \left[1 + \frac{\cos ec^2 \alpha + \cot^2 \alpha \tan^2 \lambda'}{2} \right]$$



$$E - \frac{\cot \alpha}{2n} - 2w + w \left[1 + \frac{\cos ec^2 \alpha + \cot^2 \alpha \tan^2 \lambda'}{2} \right]$$

The upper formula is used when measuring an external thread over wires. The lower formula is used when measuring internal diameters over balls.

ERROR OF PITCH DIAMETER SIZE



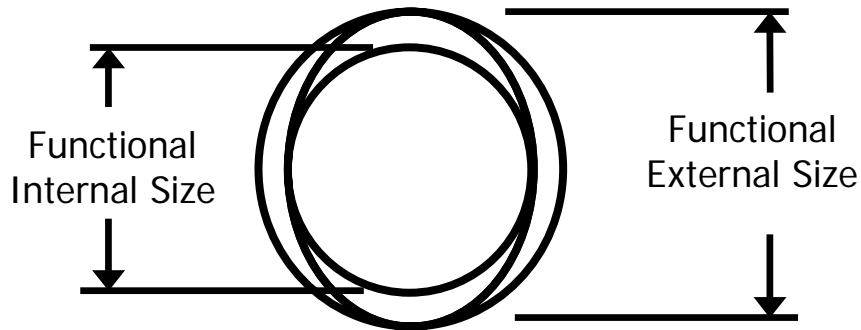
The pitch diameter of any thread is designed with a tolerance, whether a product or a gage. The variation in the pitch diameter from the specified size is error that will affect the functional assemble-ability of the thread.



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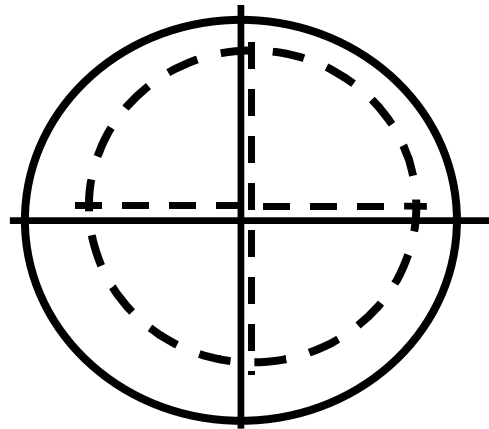
ERROR OF ROUNDNESS



There is not such thing as a perfectly round product or gage or thread. The error of the roundness in the example is called ovality because it is two point out of round. This is not always the case as roundness error can take geometric forms of many points or even erratic forms. A two point measurement is capable of revealing even lobing errors, and a three point measurement is capable of revealing odd lobing errors.

ERROR OF ECCENTRICITY

The pitch diameter of the thread of a product may not always be concentric to the crest of the thread. The crest of the thread for an external product would be the outer diameter, and for an internal product would be the inter diameter. Because many threads are formed in a manner that does not affect the major or minor, the eccentricity can functionally affect the thread size.

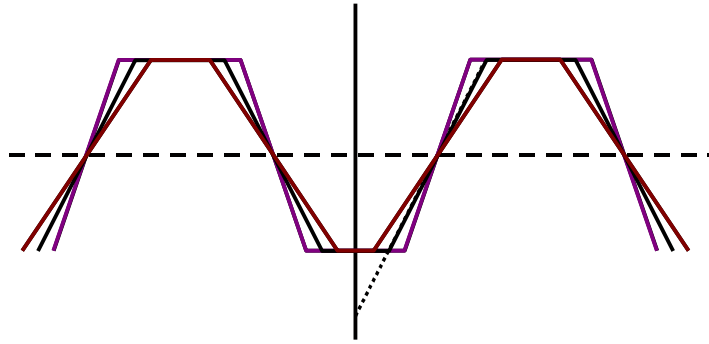


One of the areas this is most noticed is with thread ring gages that are reset during calibration. Thread rings must always be inspected for this error when calibrated.

When a thread ring is reset, the minor of the ring can become eccentric to the point of being out of its tolerance, and potentially creating a gage that will interfere at the minor diameter of the product, creating the likelihood of rejecting good product.

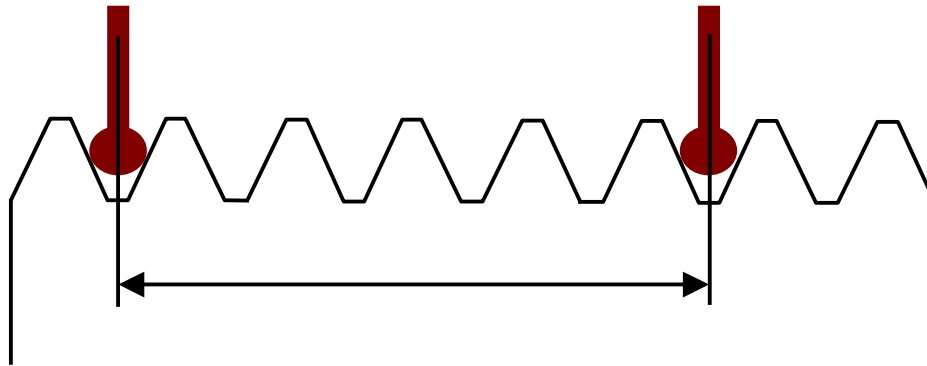


ANGLE ERROR



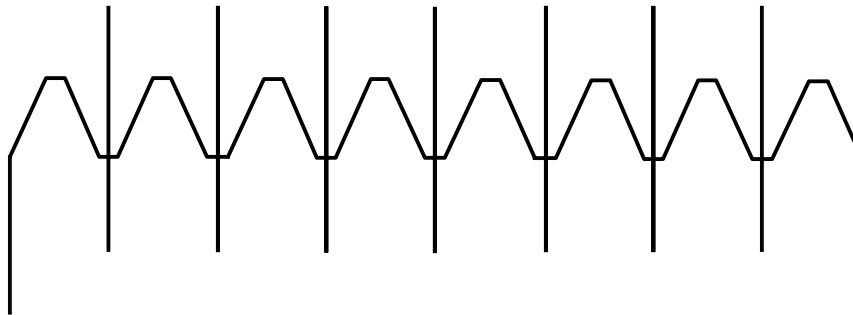
Threads do not have perfect angles, and whether open or closed the angle changes the functional size of the thread.

LEAD ERROR



Lead error is specified as the amount of lead variation that can occur over a given length or number of pitches of a thread.

PITCH ERROR



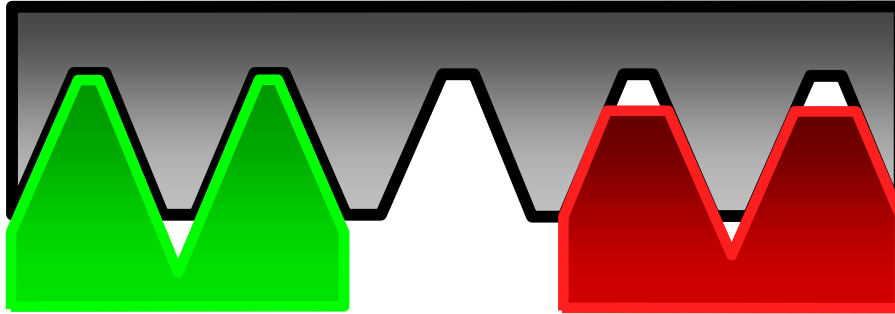
Pitch error is the error that is the difference between the maximum and minimum pitches of a thread.



ACTUAL SIZE VS FUNCTIONAL SIZE

The difference between the measured size and the functional size is the result of the accumulation of the errors of all the thread attributes. Some of the errors will add to the difference in the actual or measured size and the functional size and some will subtract from it.

PLUG GAGE CONTACT TO PART



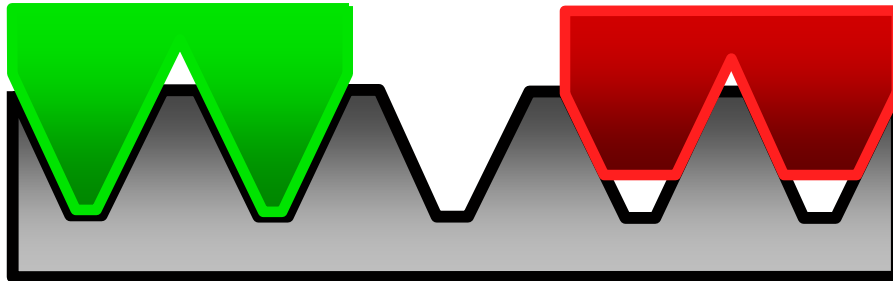
Go Gage

NoGo Gage

Minimum Major
Minimum PD
Flanks and Angles

Maximum PD

RING GAGE CONTACT TO PART



Go Gage

NoGo Gage

Maximum Minor
Maximum PD
Flanks and Angles

Minimum PD

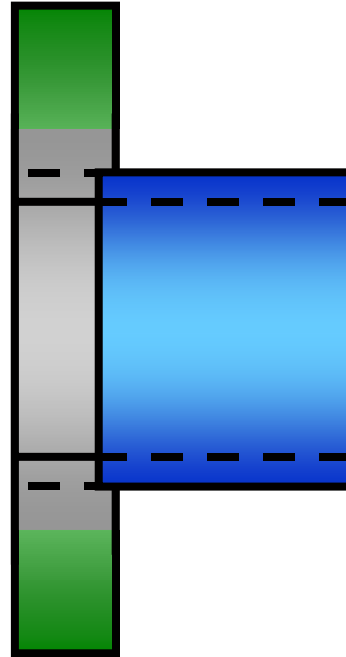


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RING GAGE APPLICATION TO PART

Go Gage Full Length Free & Easy

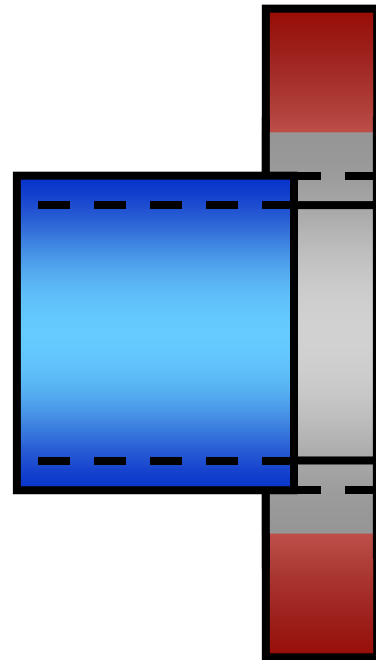
The Go gage should pass completely across or onto the product threads. Application of force to engage the Go gage member with the product indicates the product is larger than the maximum allowable size. Forcing the Go gage to engage with the product will decrease the size of the product making it acceptable but wear the gage unnecessarily resulting in a sharp decrease in the life of the Go gage.



NoGo Gage Inch: Not more than three complete turns Metric: Definite drag before the second turn

Modification of the above requirements may be necessary when the product is thin having few complete threads or when the product is of a material that may stretch or give.

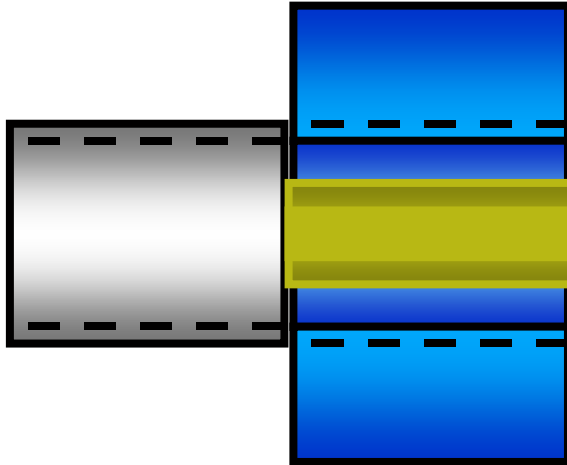
For inch threads, the NoGo should never go beyond the third thread or less if modified. For metric threads the NoGo could theoretically go the full length but should not be continued once the definite drag is felt. If the NoGo engages with the product more than the specified requirements the product is smaller than the minimum acceptable size.



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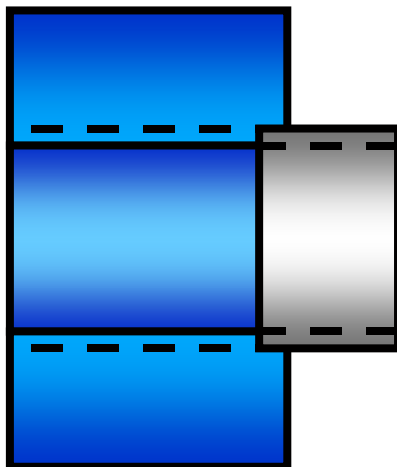
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PLUG GAGE APPLICATION TO PART



Go Gage
Full Length
Free & Easy

The Go gage should pass completely across or into the product threads. Application of force to engage the Go gage member with the product indicates the product is smaller than the minimum allowable size. Forcing the Go gage to engage with the product will increase the size of the product making it acceptable but wear the gage unnecessarily resulting in a sharp decrease in the life of the Go gage.



NoGo Gage

Inch:

Not more than three complete turns

Metric:

Definite drag before the second turn

Modification of the above requirements may be necessary when the product is thin having few complete threads or when the product is of a material that may stretch or give.

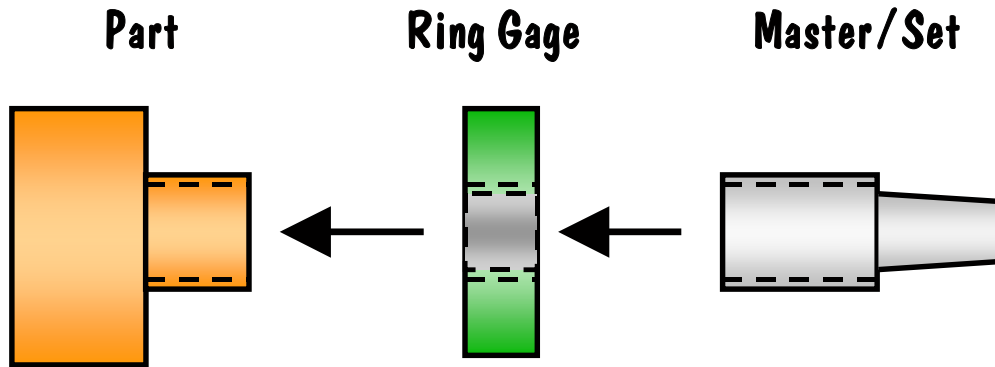
For inch threads, the NoGo should never go beyond the third thread or less if modified. For metric threads the NoGo could theoretically go the full length but should not be continued once the definite drag is felt. If the NoGo engages with the product more than the specified requirements the product is smaller than the minimum acceptable size.



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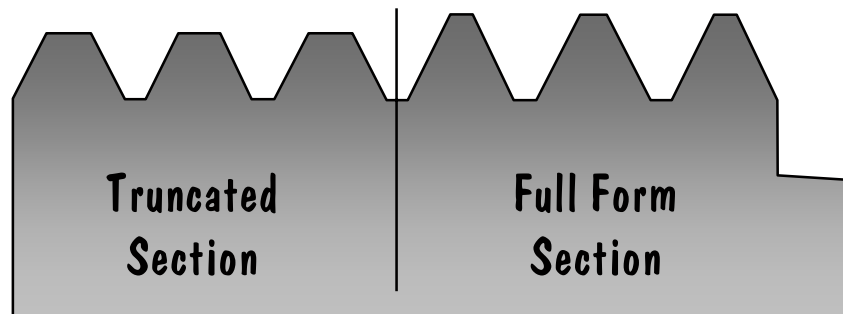
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THREAD SET PLUG GAGES



The ring gage inspects the product, and the set plug / master plug / truncated plug inspects the ring gage. Maybe because it is commonly known as the 'set plug', many lab technicians think the set plug is only for the purpose of setting the ring to the proper size. It also has the function of inspecting the ring gage for wear.

TRUNCATED SET PLUG GAGES



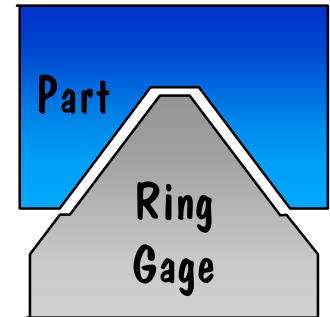
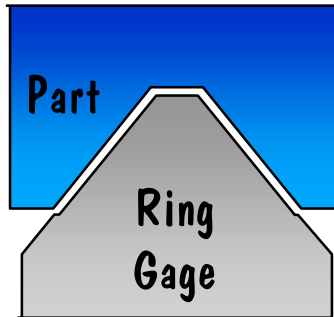
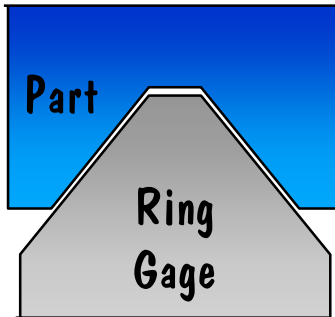
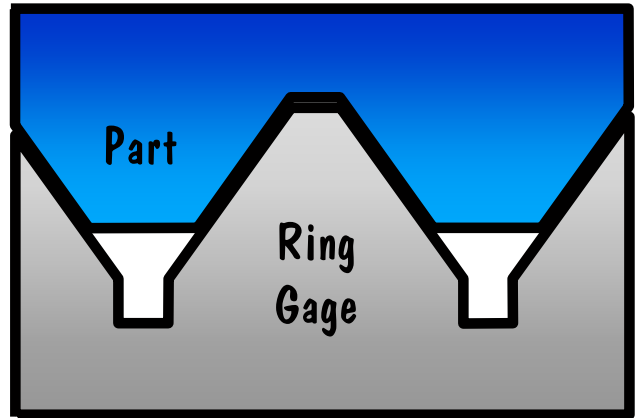
The above picture is a cut-away view of the thread form of the truncated set plug. The thread pitch diameter is the same on both sections and requiring back taper. Back taper is when the measured size of the pitch diameter is less on the back, close to the shank, than on the front. The allowable taper is half of the tolerance of the pitch diameter. Set plugs with front taper should be replaced.

When using a set plug gage to check the ring, the ring should always be engaged across the full length of the plug to create consistent wear and retain the back taper condition. Set plugs become out-of-tolerance with a front taper condition because of the ring being engaged on the front portion only, many more times than on the back portion. So, contrary to normal logic, the set plug is actually given more life by more use.



RING GAGE WEAR PLANE

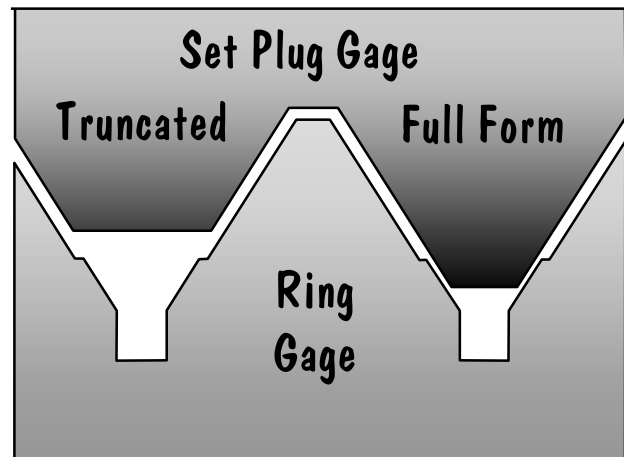
Product is produced in a manner that is designed to make the product as consistent as possible. This creates a scenario where the thread flank of the gages are contacted in the same general area consistently every time a part is inspected. This area we call the **wear plane**. As a gage is used it wears. Plug gages wear and are replaced when they wear outside of the tolerance limit. Ring gages are adjustable, and therefore present a problem we don't experience with plugs.



As a ring gage is used it wears, but it can be readjusted to be brought back into size. This means that the wear can continue until the flank is no longer a straight line. This is commonly referred to as the flank having a step wore in it.

The truncated set plug gage is designed to allow the truncated (front) section to contact the ring gage within the wear plane, While the full form (back) section is designed to contact beyond the wear plane.

When the flanks of a ring gage have a step wore in them the ring will feel much looser on the truncated section than on the full form section. This indicates the ring should be repaired or replaced.



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MASTER SETTING PLUG DESIGN

For Thread Ring Diagnostics & Setting

The Truncated Master Setting Plug Gage is designed for two functions; to set the adjustable thread ring gage, and to inspect the ring gage for wear. Two methods of using the setting plug are suggested to optimize the life of the setting plug. Pitch diameter taper on the setting plug is specified to always be in the minus direction, i.e. the PD on the front of the plug should always be larger than the PD on the back of the plug.

The first method addressed is used to inspect new ring gages, assuming your gages are not previously set by the manufacturer to your master plug. The ring should be set to the front or truncated portion, then continue onto the full form portion to inspect for root clearance, and consistent feel. The setting plug should be inserted a maximum of two threads into each end of ring for shake, inspecting for taper.

The second method addressed is used to re-inspect rings for wear after use on the

product. The ring should be set to the full form portion, then backed off to the truncated portion for feel. The setting plug should be inserted a maximum of two threads into each end of ring for shake, inspecting for taper.

The front or truncated portion of the setting plug is designed to contact the flanks of the ring in the wear plane, similar to a product. The full form portion is designed to contact the flanks of the ring beyond the wear plane. When a ring is run across the plug there will be a slight difference in the feel or tightness because there is more contact with the flanks on the full form portion of the setting plug, thus more resistance and a tighter feel.

If a significant difference in feel is noted, the ring has wear on the flank and should be repaired or replaced. Setting a ring with wear in the flanks will cause possible interference with the product major and does not properly inspect the product threads.

Tightness of Fit

There are no established torque values for degree of drag. Some judgment and common sense must be used. The resistance or drag for a small size gage should be less than for a larger size gage. A spin fit is obviously much too loose, and too tight a fit could damage or cause excessive wear on the ring or the setting plug. In-between is a fairly smooth drag. This tells you that the size of the ring is essentially the same as the setting plug.

On properly set gages with accurate lapped threads, a very little change to size

(adjustment of the ring gage) will effect a noticeable difference in drag. Two different setting plugs both within class W tolerance may feel entirely different in the same ring gage. One could be too tight and the other too loose. It must be realized that a ring gage set on one setting plug does not necessarily mean it will fit another setting plug. This is due to the allowable tolerance of the set plug.

In addition to pitch diameter variations, there may be a slight difference in the flank angle or lead of the ring versus the



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setting plug. This can also cause a small increase in the degree of drag a full engagement versus partial engagements. One should not expect absolute perfection. These differences are not serious within reason as both the ring and setting plug may be well within their respective tolerances. A ring may feel noticeably different on the set plug when engaged with the marking facing the set plug or facing away from the set plug. This is usually the result of flank angle error in the

ring and the set plug. In one direction the errors interfere while in the other direction they do not. When this happens the ring should be positioned where the flanks do not interfere (the looser fitting) and set for the proper feel. When this is done the set plug will probably not go in the ring if the ring is turned around, but this gives the closest pitch diameter size for the ring gage and is most likely to pass good product and fail bad product.

INSPECTION / SETTING PROCEDURE

AGD THREAD RING

1. CLEAN

Thoroughly clean the threads with a bristle brush and solvent, wipe clean with isopropyl alcohol and clean with kim wipe. Visually inspect the thread ring for nicks, dings or foreign material buildup.

2. INSPECT ID

Using a calibrated tapered pin, set of parallels, bore gage or other accurate method inspect the ID (minor diameter) of ring gage and record the size.

3. INSPECT PD

a. Lubricate the setting master plug with a thin film of light viscosity oil before inserting into the ring gage.

b. Turn the ring onto the setting plug 1 1/2 to 2 threads at the front. If ring will not go onto setting plug go to operation 4. There should be some resistance or drag even at this short engagement. To test for taper or bellmouth, place the ring on its face on a workbench and test for shake or looseness with the setting plug, being very careful not to damage the end threads.

c. Turn ring further onto the truncated section, remembering the feel at the 1 1/2 to 2 thread engagement. The drag should remain approximately the same although it may be slightly greater at full engagement due to more flank contact.

d. Remove the ring from the setting plug and repeat operations 3b & 3c on the opposite



side of the thread ring gage.

- e. The fit should be approximately the same on both sides of the ring to insure proper straightness. Remember if a setting plug is manufactured or worn smaller at the front, it will falsely indicate taper or bellmouth in the ring gage. Setting plugs must be reasonably straight.
- f. Turn the ring gage from the truncated section onto the full form section at the back. The drag should be approximately the same on both sections which insures good flank angle contact.
- g. If at this point nothing is found which indicates a problem skip to operation 7.

4. SET RING

NOTE: If ring will go onto setting plug skip to operation 4c.

- a. Turn the locking screw counter-clockwise until it is loosened.
- b. Turn the adjusting screw clockwise, this will open the ring to a larger pitch diameter than the setting plug.
- c. Turn the ring gage onto the setting plug truncated section so that approximately one thread of setting plug extends beyond the ring. (This will promote uniform wear over the entire thread length of the setting plug.)
- d. If it has not already been done, turn the locking screw counter-clockwise until it is loosened. Turn the adjusting screw counter-clockwise to tighten or clockwise to loosen until there is a slight drag between the ring and the setting plug.
- e. Turn the locking screw clockwise until tight. This locks the adjusting screw so that the size of the ring gage remains fixed. There should be noticeable drag between the ring and setting plug.

NOTE: Operations 5c – 5e may need to be repeated more than once to obtain the proper drag or feel.

- f. Turn the ring gage from the truncated section onto the full form section at the back. The drag should be approximately the same on both sections which insures good flank angle contact.

5. INSPECT PD

Repeat section 3a – 3f. If at this point nothing is found which indicates a problem continue to operation 6.



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6. INSPECT ID

Using a calibrated tapered pin, set of parallels, or bore gage inspect the ID (minor diameter) of ring gage.

NOTE: If an adjustment was necessary to establish the proper feel on the setting plug use the following formula to obtain the as found pitch diameter. (Setting plug pitch diameter) plus (ID size before adjustment)minus (ID size after adjustment.)

7. SEAL

Cover the adjusting and locking screws with sealing wax to prevent unauthorized tampering with the setting of the ring gage.

SOUTHERN STYLE THREAD RING

1. CLEAN

Thoroughly clean the threads with a bristle brush and solvent, wipe clean with isopropyl alcohol and clean with kim wipe. Visually inspect the thread ring for nicks, dings or foreign material buildup.

2. INSPECT ID

Using a calibrated tapered pin, set of parallels, or bore gage inspect the ID (minor diameter) of ring gage and record the size.

3. INSPECT PD

a. Lubricate the setting master plug with a thin film of light viscosity oil before inserting into the ring gage.

b. Turn the ring onto the setting plug 1 1/2 to 2 threads at the front. If ring will go onto the setting plug go to operation 4. There should be some resistance or drag even at this short engagement. To test for taper or bellmouth, place the ring on its face on a workbench and test for shake or looseness with the setting plug, being very careful not to damage the end threads.

c. Turn ring further onto the truncated section, remembering the feel at the 1 1/2 to 2 thread engagement. The drag should remain approximately the same although it may be slightly greater at full engagement due to more flank contact.

d. Remove the ring from the setting plug and repeat operations 5b & 5c on the opposite side of the thread ring gage.



e. The fit should be approximately the same on both sides of the ring to insure proper straightness. Remember if a setting plug is manufactured or worn smaller at the front, it will falsely indicate taper or bellmouth in the ring gage. Setting plugs must be reasonably straight.

f. Turn the ring gage from the truncated section onto the full form section at the back. The drag should be approximately the same on both sections which insures good flank angle contact.

g. If at this point nothing is found which indicates a problem skip to operation 5.7.

4. SET RING

NOTE: If ring will go onto setting plug skip to operation 4c.

a. Turn the locking screw counter-clockwise 1/4 turn.

b. Turn the adjusting screw clockwise 1/8 turn maximum to enlarge ring PD. Repeat, if necessary, until ring will go onto setting plug.

c. Turn the ring gage onto the setting plug truncated section so that approximately one thread of setting plug extends beyond the ring. (This will promote uniform wear over the entire thread length of the setting plug.)

d. Turn the adjusting screw counter-clockwise to loosen or clockwise to tighten.

e. Turn the locking screw clockwise until tight. This locks the adjusting screw so that the size of the ring gage remains fixed. There should be noticeable drag between the ring and setting plug.

NOTE: Operations 4c – 4e may need to be repeated more than once to obtain the proper drag or feel.

f. Turn the ring gage from the truncated section onto the full form section at the back. The drag should be approximately the same on both sections which insures good flank angle contact.

5. INSPECT PD

Repeat section 3a – 3f. If at this point nothing is found which indicates a problem continue to operation 6.

6. INSPECT ID

Using a calibrated tapered pin, set of parallels, or bore gage inspect the ID (minor diameter) of ring gage.



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NOTE: If an adjustment was necessary to establish the proper feel on the setting plug use the following formula to obtain the as found pitch diameter. (Setting plug pitch diameter) plus (ID size before adjustment) minus (ID size after adjustment.)

7. SEAL

Cover the adjusting and locking screws with sealing wax to prevent unauthorized tampering with the setting of the ring gage.

COMPUTING GAGE DIMENSIONS

Dimensions for gages can be found in the ANSI B1.2 standard. Charts for standard sizes of threads will give pitch diameters, major diameters, and minor diameters. If the size of thread is not listed in the B1.2 then the next procedure is to look in the ANSI B1.1 and compute the pitch diameter limits for the product thread. The formulae required are not included because the charts in the standards should be consulted before computing the pitch diameter limits. Once the pitch diameters are known, the following formulae may be used to compute the other gages dimensions.

$$h = 0.64952p \quad H = 0.8660254p$$

THREAD WORK PLUGS

$$\text{Go Major} = \text{Go PD} + h$$

$$\text{NoGo Major} = \text{NoGo PD} + H/2$$

SETTING/MASTER PLUGS

$$\text{Go Full Form Major} = \text{Go PD} + h$$

$$\text{Go Truncated Major} = \text{Go FF Maj.} - .060 \sqrt[3]{p^2} + .017$$

$$\text{NoGo Full For Major} = \text{Go FF Maj. or}$$

$$\text{Go FF Maj.} + .216506p - (\text{Go PD} - \text{NoGo PD} + .0017") \text{ whichever is smaller}$$

$$\text{NoGo Truncated Major} = \text{NoGo PD} + H/2$$

THREAD RINGS

$$\text{Go Minor} = \text{Go Pd} - H/2$$

$$\text{NoGo Minor} = \text{NoGo PD} - .25H$$



INTERNAL PRODUCT THREAD DEPTH

The depth of internal product threads can be measured quickly and easily with very little extra time by put depth notches or steps on the Go thread plug gage member. If the criteria for the product specifies minimum depth only, one step is all that is needed. If the criteria for the product specifies a minimum and a maximum, then two steps are needed.

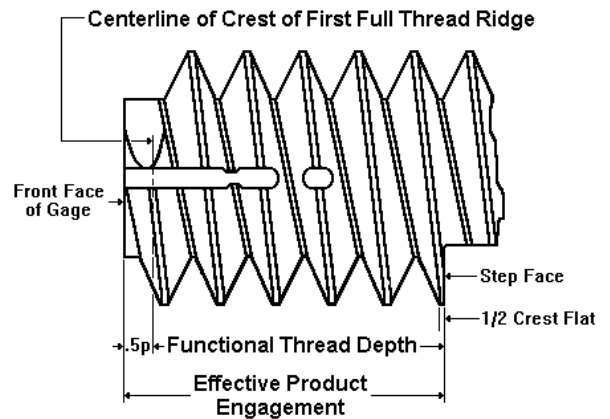
The Go member is inserted into the product until fully engaged without the application of significant force, which could tend to deform the product material. The position of the steps in relation to the face of the product is noted to determine conformance. A minimum step should be below the face, a maximum step should be above the face.

When specifying the length of the step or steps we must take into account what we want to measure, whether full functional thread depth or effective external product engagement.

When measuring the full functional thread depth, the step is measured from the centerline of the crest on the first full thread ridge of the Go plug gage to the step face. When measuring the effective external product engagement, the step is measured from the front face of the Go plug gage to the step face, and the distance from the front face to the centerline of the crest on the first full thread ridge should be held to .5p maximum.

The length of the thread depth step is marked on the Go plug gage and on the handle. Both methods are acceptable

practice, however, for consistency each company should establish which method is to be used. It is possible a company would need to use both methods, which would necessitate additional marking or notes to identify which method is used on each individual gage as well as on the blueprints for the products and the gages.



Thread Depth Figure

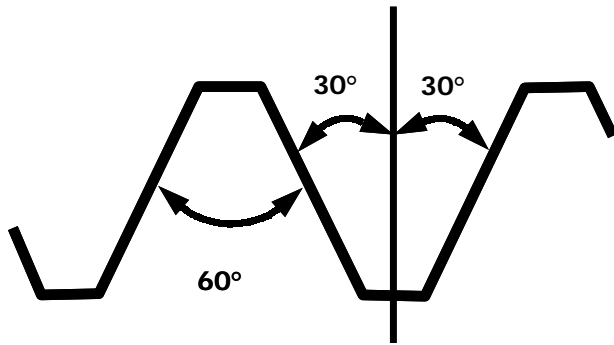
Design of the product is controlled by the application. The application is the controlling factor for which method should be utilized. If product engagement controls the design criteria then we should measure from the face of the gage to the step. If product thread depth controls the design, we should measure from the centerline of the first full thread to the step. Designs using product thread depth may be necessary because the bolt length or engagement length of the mating product could vary, as in situations where replacement parts are made by different manufacturers.



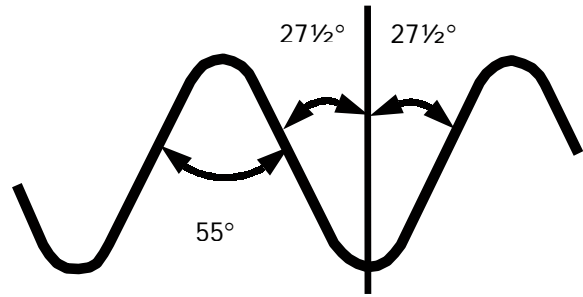
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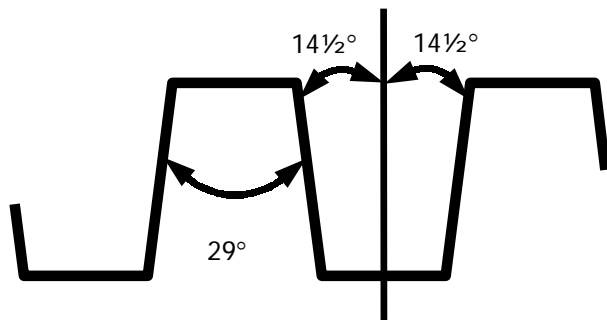
COMMON THREAD FORMS



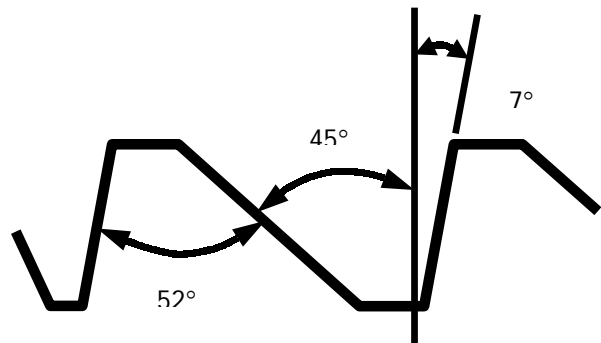
American Inch & Metric



British / Whitworth



Acme / Stub Acme



Buttress

PIPE THREADS

Pipe threads are threads that seal. Pipe threads seal by various methods, but the ones we are going to concern ourselves with here are those that are designed to seal at the threads. For threads to seal there are two ways to accomplish a seal, assemble two tapered threads or assemble a straight thread with a tapered thread.

Tapered threads use a completely different

system to determine size than the Go / NoGo system used in straight threads, (the standard inch and metric series are straight threads). There are many different types and styles of pipe threads, far too numerous to try to address here individually. The most common is the NPT, which is used in many various applications and which is the basis of which many of the other styles are modifications.



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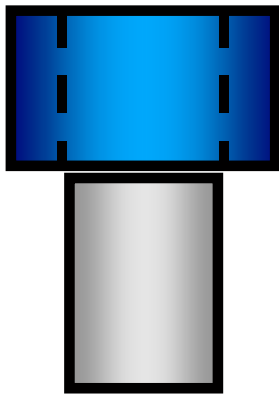
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With straight threads, the Go and NoGo gages tell you that your part is within the acceptable limitations of size. With a tapered thread, this system does not work as a gage inserted into a hole or engaged with an external thread will at some point lock together with the part. The method used is an indirect measurement where you measure the distance from a datum point on the part to a datum point on the gage and adjust for the ratio of taper to know the part size. This is not as complicated as it sounds.

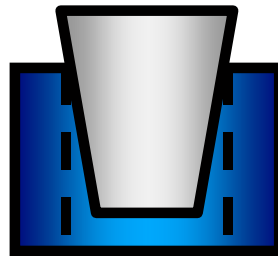
The NPT and most of the other pipe threads are made on a taper of .750" per foot, or .0625" per inch. This is an even ratio of 16:1. In other words, when you travel along the axis of the thread .016 you will experience a diametrical change of .001.

Knowing this ratio it is easy to measure the diametrical size when compared to a gage of known size.

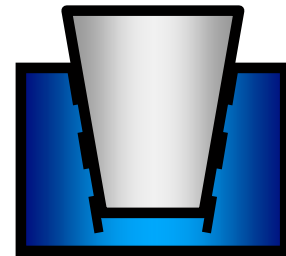
SEALING THEORY



**Straight to Straight
No Seal**



**Taper to Straight
Seals**



**Taper to Taper
- Seals**

When a straight external thread is assembled with a straight internal thread if it assembles then it will continue through the thread without sealing. When a tapered external thread is assembled with a straight internal thread it will at some point lock together and seal. When a tapered external thread is assembled with a tapered internal thread it will lock together and seal. That is

the theory that is used when the seal has to be accomplished at the threads. A seal would also be accomplished using a straight external thread and a tapered internal thread, but this configuration is not used because there would be too much shake making for an unstable connection that would not remain sealed.



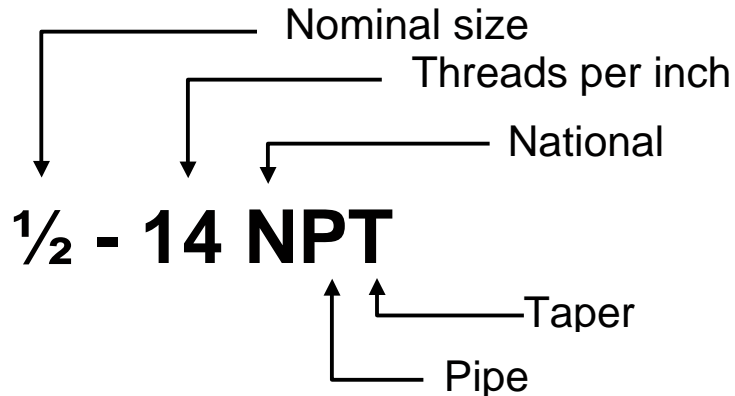
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PIPE NOMENCLATURE

The letters following the nominal size and pitch indicate the pipe thread application. The following letters are used:

A - Aeronautical
C - Coupling
F - Dryseal (Fuel)
G - Gas
H - Hose
I - Intermediate
L - Loose
M - Mechanical
N - National
P - Pipe
R - Railing
S - Straight
T - Tapered



Straight Pipe Threads Nomenclature

With straight pipe threads (the internal thread is straight, and assembled with a tapered external thread) there should always be four letters to designate the application. Without the fourth letter the application is not known and therefore the parts or gages may be incorrect causing failure of the seal.

You may encounter situations where a straight pipe thread is indicated as NPS without the fourth letter. An inquiry may result in the response, "Just give me the standard one." This response is unacceptable as there is no such thing as a standard one. The application must be known and will be indicated by the fourth letter.

COMMON PIPES

NPT - National Pipe Taper

Gages required L1 Ring Gage
 L1 Plug Gage

NPTF - National Pipe Tapered Dryseal

Gages required L1 Ring, L2 Ring, 6 Step Ring Gages
 L1 Plug, L3 Plug, 6 Step Plug Gages

ANPT - Aeronautical National Pipe Taper

Gages required L1 Ring, L2 Ring, 6 Step Ring Gages
 L1 Plug, L2 Plug, 6 Step Plug Gages



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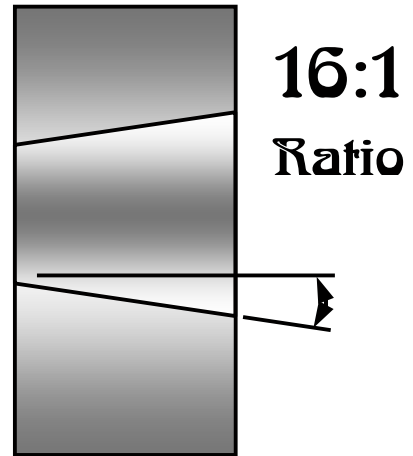
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INDIRECT MEASUREMENT

Tapered pipe fittings (nipples - external thread, coupling - internal thread) and the tapered gages used for them are all measured by a method called indirect measurement. This means simply that one feature or dimension is measured by measuring some other feature instead.

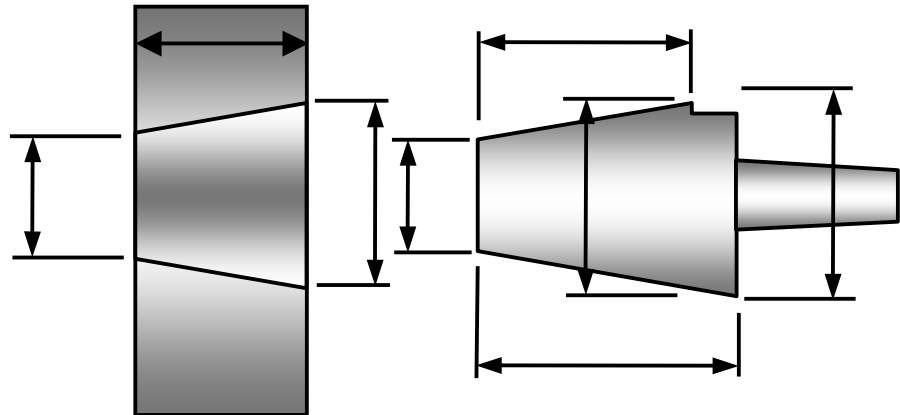
The pitch diameter of the thread cannot be easily measured directly because it is a spiral taper. A means is needed to measure product that is simple, conclusive and accurate. Indirect measurement satisfies these requirements.

The gages have been designed for quick visual use by an operator with little instruction. Understanding the method and how it works is somewhat complicated, but the using the gages to measure product is not complicated.



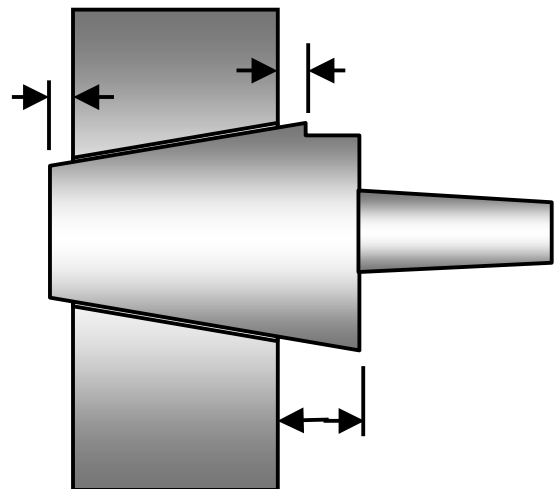
Angle that creates a known Length to Diameter ratio

A ring gage with known (calibrated) dimensions can be used to measure an external part or gage. A plug gage with known (calibrated) dimensions can be used to measure an internal part or gage.



The gage and product or master and gage are assembled and the axial distance is measured. The measured distance can then be multiplied by the ratio (16 in the case of a standard taper) and added to or subtracted from the known dimension to find the dimension of the part or gage being measured.

This basic theory is used to measure the size of product pitch diameters with the L1 plug and ring gages, and is pre-calculated to make the use of these gages visually simple.



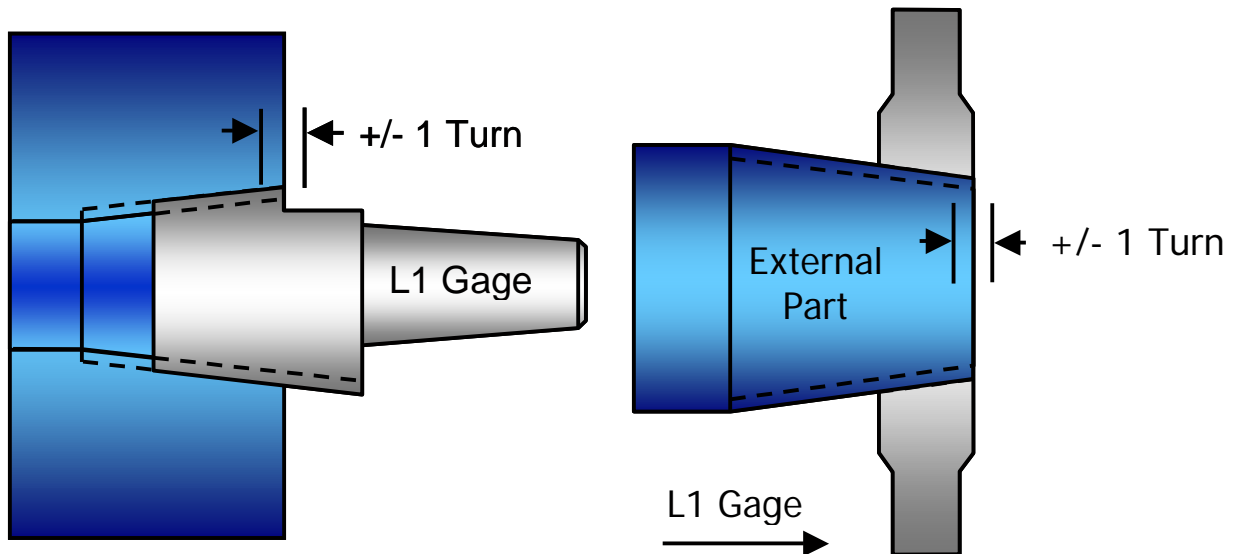
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L-1 PLUG AND RING GAGE

The purpose of the L1 gage is to measure the size of the product. To translate this measurement method into a usable form, the NPT gage designated as the L-1 is built with the thread having a .750" taper per foot, and a notch or step cut into the thread showing the plane perpendicular to the axis where the diameter of the part is to be measured. This L-1 gage is screwed into the part (internal) or onto the part (external)

using hand tight engagement. If the taper of the product is correct, the gage will seat firmly, but if the taper is beyond the allowable tolerance in either direction there will be noticeable shake in the gage. The distance is measured between the step and the scratch of the first thread (most technicians measure from the face) of the part, and if the step is anywhere within 1 turn then you have a good part.



If any element of the threaded part is incorrect the gage will not seat properly or stop in the measurement zone. This may sound like too broad a statement, but the NPT thread is designed on the premise that the mating parts will be sealed with an agent that will compensate for minor irregularities in the mating threads.

Many companies find it necessary to measure NPT threads more thoroughly than the standard requires to fully satisfy their customers. In those cases, the NPTF system is used, but not the NPTF gages.

If more precise measurement is needed than the L-1 alone gives, then the ANPT L-2, L-3, and 6-step gages are used with the NPT L-1. These ANPT gages will have the 'A' removed from the identification to eliminate confusion on the part of the user. This is the standard practice in the gage industry. If the gages are not properly marked to check NPT threads, they may not be used as they could be modified or altered. Another reason the marking must be correct is to please the quality auditors. They would disapprove use of a gage with a thread designation different from that which the specification for a part indicates is proper.



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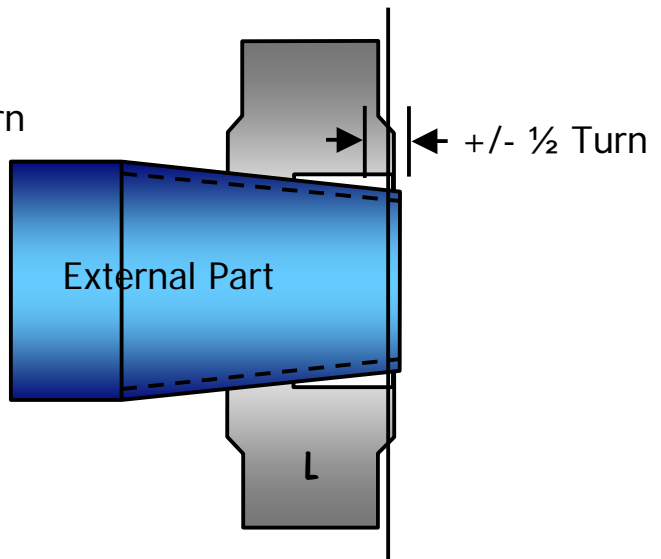
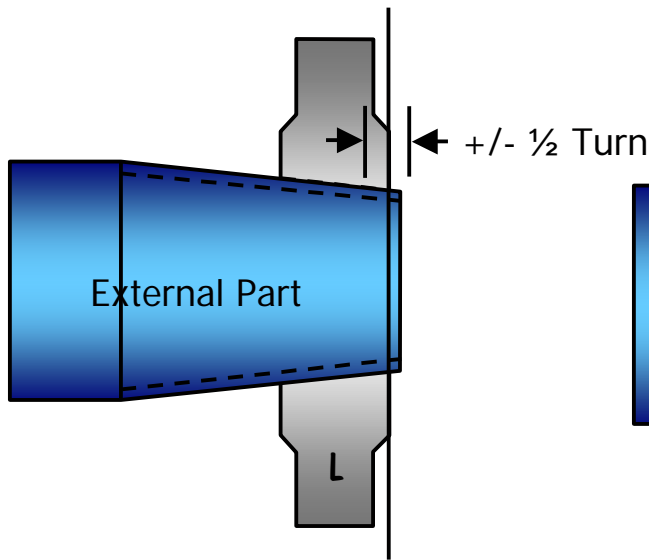
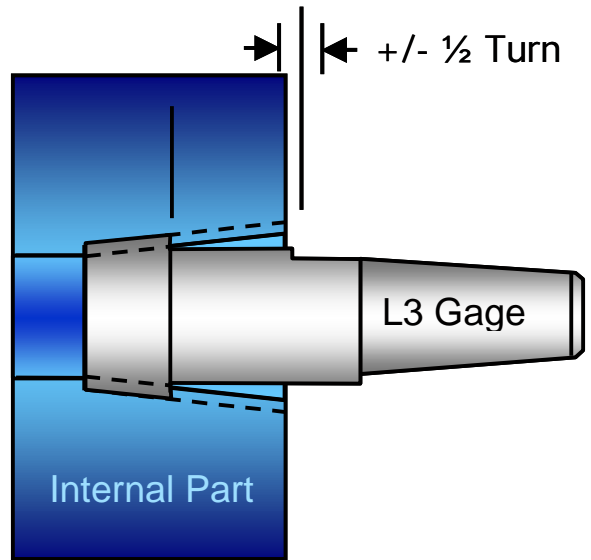
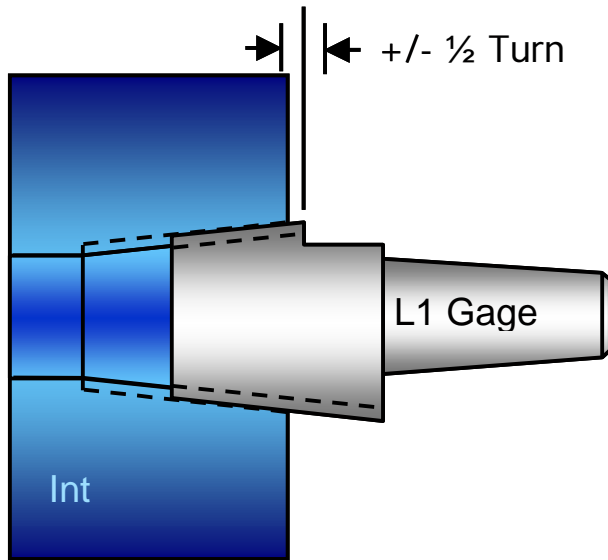
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L-2 RING / L-3 PLUG

The purpose of the L2 Ring and the L3 plug is to measure the taper of the part. This gage does not check size, it checks taper only. The L2 ring and L3 plug are used as a comparative measurement to the L1 ring or plug.

After using the L-1 gage the L2 ring or L3 plug is assembled with the part and must stop within 1/2 turn plus or minus of where

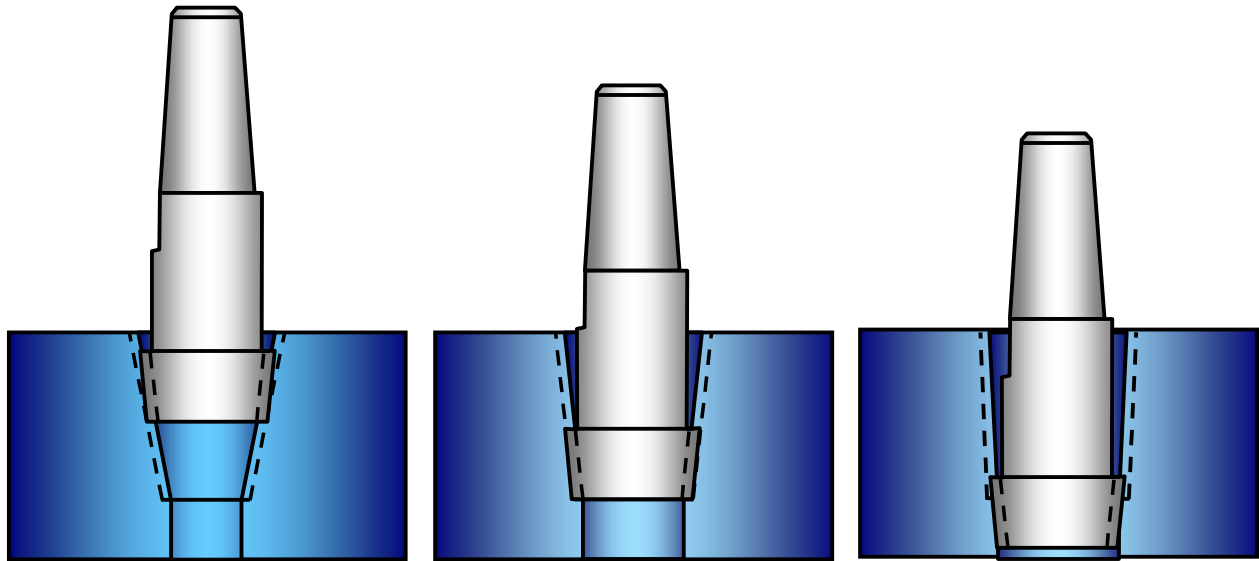
the L1 stopped. The L-2 ring and L-3 plug are designed to clear the threads of the part that the L-1 assembled with and assemble with the threads further on or in the part. This measures the taper of the thread of the part by comparing the front threads and the back threads of the part. If the taper is too severe or too straight, the L-2 ring or L-3 plug will not stop within 1/2 turn from the point where the L-1 stopped.



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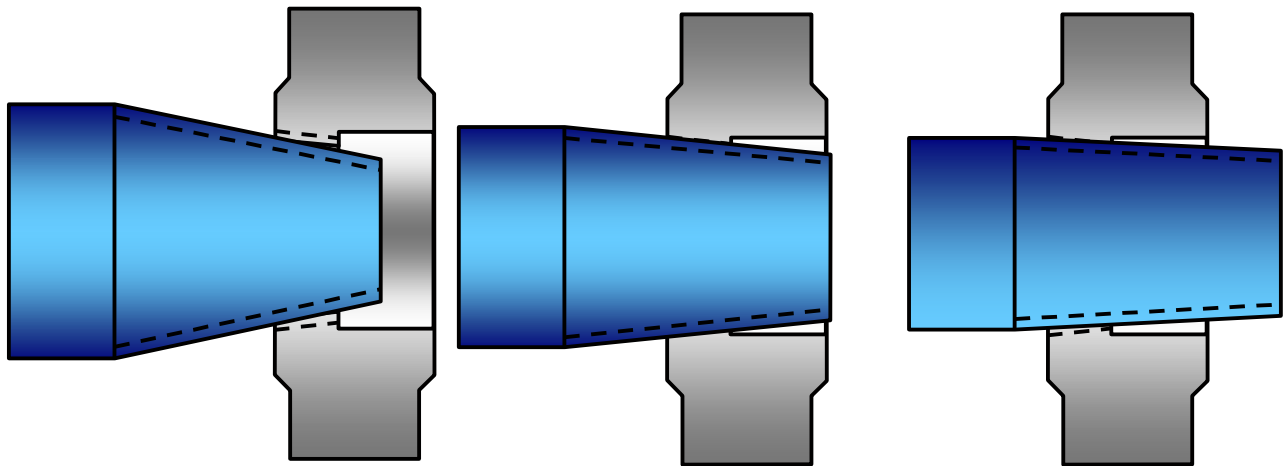
The following illustrates the three possible outcomes when using the L2 and L3 gage.



**Taper
Too Severe**

**Taper
In Tolerance**

**Taper
Too Straight**



When the taper of the product is too severe the L2 or L3 gage will lock up before reaching the point of the 1/2 turn limit.

When the taper of the product is correct the L2 or L3 gage will lock up within the 1/2 turn limit zone.

If the taper of the product is too straight, not severe enough, the L2 or L3 gage will

engage farther into or onto the product and beyond the 1/2 turn limit.

Remember, this gage has one purpose, to check the taper. It cannot be used to check the size of the product and can only be used after the L1 has been used to know where the 1/2 turn limit is for the product being inspected.



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DRYSEAL

The NPTF design is different from the NPT in that it is designed to create a seal without the use of any type of sealants, i.e. Dryseal. The standard for NPTF threads (ANSI B1.20.3) allows Class 1 and Class 2 applications.

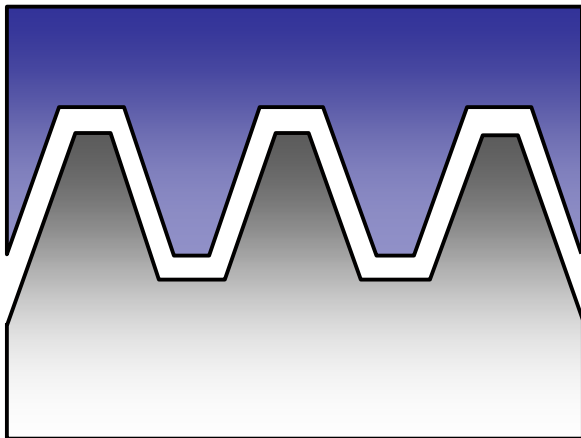
The Class 1 applications do not require inspection of the crest and root diameters. Consequently, Class 1 threads are intended for applications where close control of tooling is required for conformance of truncation or where sealing is allowed to be accomplished by means of a sealant applied to the threads. Class 2 applications require the inspection of the crest and root truncation, to create more assurance of a pressure-tight seal where sealants are not used.

The ANPT design is not a dryseal design, but because of the use of these threads in aeronautical applications, which is safety critical, the NPTF inspection method is

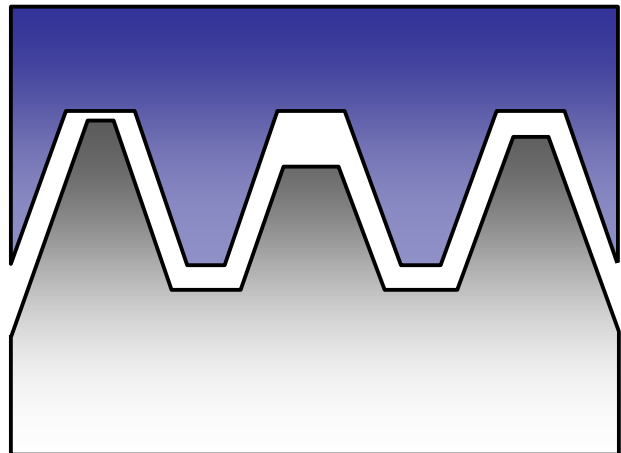
employed to assure complete inspection to guarantee maximum product application qualities.

For the dryseal application to be accomplished the threads of the internal product and the external product have to contact at very near the same time. After the two products have been assembled hand tight, the system calls for two or three more turns of engagement. This causes the threads to tear into each other, or as we say 'displace material.' For the dryseal to occur a full thread form material displacement must occur. Without this full thread form displacement the product would not seal and a leak would result.

A leak in a dryseal application could be catastrophic as dryseal applications are used in situations where high pressure could eject any sealant or in applications where corrosive agents are used and the corrosive agent could dissolve the sealant.



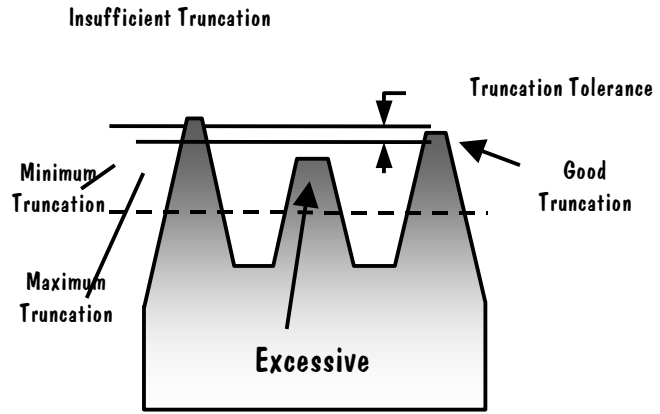
In this illustration a dryseal could be achieved because the threads would contact at near the same time along the full thread form.



In this illustration a dryseal could not be achieved because the threads would not contact at near the same time along the full thread form.



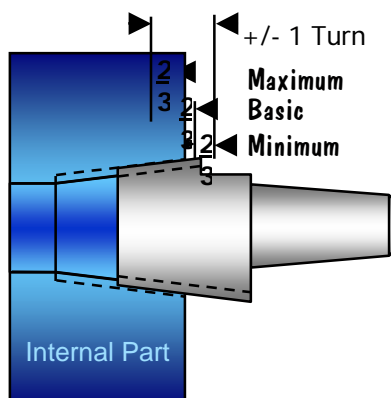
The thread form is measured by measuring the amount of thread removed from a theoretical sharp thread. Removing part of the thread height is referred to as truncating the thread. The amount of truncation is measured as a relationship to the pitch diameter. This allows us to compare the crest of the thread to the pitch diameter of the thread. In other words, we can use a gage as a comparison to the L1 gage.



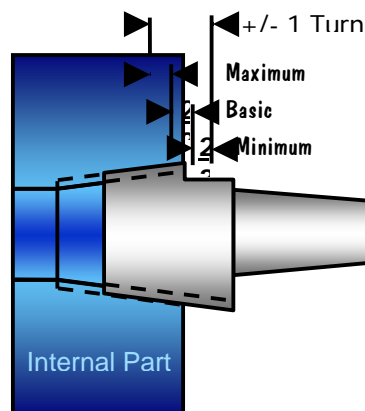
6 STEP PLUG AND RING

The NPTF system begins with the use of the L-1 gage having a 1 turn in or out limit (2 turns total) the same as the NPT system. The purpose of this gage is to measure the pitch diameter size of the part. It is necessary to refine the standoff (distance from the step to the part) to a more accurate measurement because the 2-turn total tolerance limit must be divided into 3 equal zones. These three zones are known as the minimum, basic, and maximum zones, and the part is referred to as a minimum part, basic part, or maximum part.

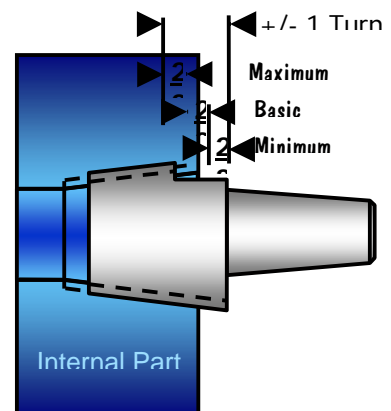
The basic zone is the linear area within 1/3 turn from the face of the part, in or out. If the plug gage is standing out from the face (or datum point) of the internal part more than 1/3 of a turn you have a minimum part because the step on the gage stops within the minimum zone. Likewise, if the plug stands in more than 1/3 of a turn you have a maximum part. The larger the hole is, the deeper the plug will enter into it. A smaller hole, but within tolerance, is a minimum part. A larger hole, but within tolerance, is a maximum part. A hole close to the target size (within 1/3 turn) is a basic part.



Minimum Part



Basic Part

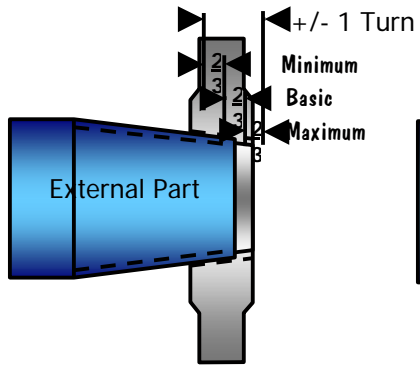


Maximum Part

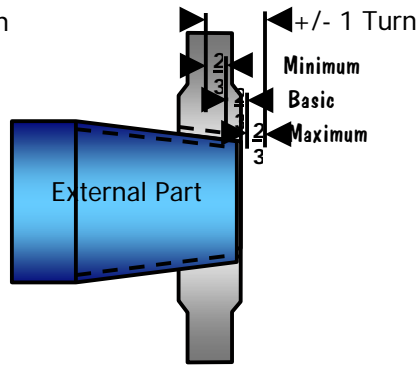


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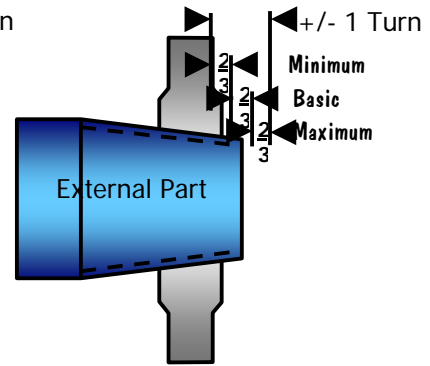
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Maximum Part



Basic Part



Minimum Part

The same ideology is true for the external product but reversed. Again, It is necessary to refine the standoff (distance from the step to the part) to a more accurate measurement because the 2-turn total tolerance limit must be divided into 3 equal zones. These three zones are known as the minimum, basic, and maximum zones, and the part is referred to as a minimum part, basic part, or maximum part.

The basic zone is the linear area within 1/3 turn from the face of the part, in or out. If

the ring gage is standing out from the face (or datum point) of the external part more than 1/3 of a turn you have a maximum part because the face on the gage stops within the maximum zone. Likewise, if the ring stands in more than 1/3 of a turn you have a minimum part. The smaller the part is, the farther the ring will engage onto it. A larger part, but within tolerance, is a maximum part. A smaller part, but within tolerance, is a minimum part. A part close to the target size (within 1/3 turn) is a basic part.

ZONES AND TRUNCATION LIMITS

Zones	Truncation Limits	6 Steps
Minimum	Minimum	Mn
	Maximum	Mnt
Basic	Minimum	B
	Maximum	Bt
Maximum	Minimum	Mx
	Maximum	Mxt

The three zones represent different pitch diameter size limits. There is a minimum and maximum limit for the proper amount of truncation that would create full thread form displacement. With three size zones and two limits each there are six possible

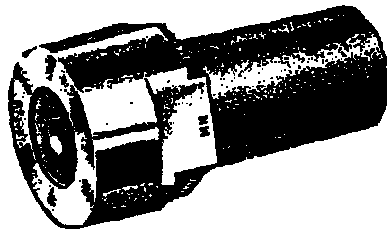
scenarios represented by the six steps on the 6 step ring and 6 step plug.

This may all sound a bit complicated, but the actual use is very simple. Only two of the six steps are used. The L1 gage identifies the part as being a minimum, maximum, or basic part. The two appropriate steps are chosen Mn and Mnt for minimum parts, B and Bt for basic parts, or Mx and Mxt for maximum parts. The 6 step gage is push into or onto the part and if the face comes to rest between the two appropriate steps, the part is acceptable.



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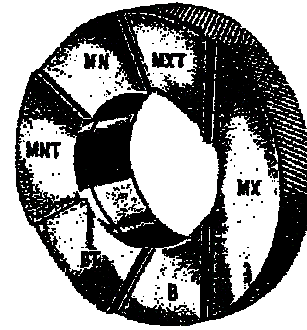
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6-STEP PLUG

It is not easy to measure by eye where these zones begin and end. Gages can be made with three steps or four steps that simplifies this for the user. The other option is to measure the distance with an instrument. 1 turn of a thread can be easily computed with the formula (1 divided by the threads per inch). This gives you the pitch. Divide the pitch by 3 and you can measure the standoff to find the type of part you have. You must know the type of part (min., basic, or max.) to use the 6-step gage.

Inspection with the non-threaded 6-step gage shown here will inspect the thread



6-STEP RING

crest truncation. The root truncation should also be inspected. This can be accomplished by means of a threaded 6-step gage using the same principles of application as the non-threaded 6-step gage.

Parts that conform to product specifications, whether minimum, basic or maximum parts, may be assembled and will achieve a dry seal. It is not necessary to mate parts together that are both basic, or both maximum, or both minimum, so there is no need to categorize the parts.

INTERCHANGEABILITY

The first consideration in gaging pipe threads is the type of gages used. Gages are specifically designed per the appropriate standard for each type of pipe thread. It is not proper to interchange or substitute gage type and pipe thread type when the correct gage is not available. For example; using NPTF gages on NPT parts.

The manufacturing tolerances for gages vary with type and this causes the gages to vary as to size, giving different inspection results.

The formula for computing the major diameters of pipe plugs gages, and minor diameters of pipe ring gages differ with each type of pipe, because of the difference in the formulas used to compute the major and minor diameters of the various types of pipe threads. This causes the thread form of the gages to mate with the thread form of the product differently when comparing different gages (of various pipe types) to the same product thread.



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PO Box 509
Erin, TN 37061
800-251-4243, Fax 800-242-7142
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Using gages **not** designed for the product being gaged can result in contact at the major or minor diameter instead of the flanks and cause incorrect inspection results.

It is possible to inspect one type of pipe with another type of gage and get a reading that says the product is good, but you do not have any assurance your results are correct. It is much more likely that you will not get a correct measurement.

NPT & ANPT threads are designed to mate and be sealed with some type of sealant. NPTF threads are designed to mate and seal without using any type of sealant (this

is the reason they are called Dryseal threads). The design of NPTF dryseal threads is not just a tightening of the standard pipes (NPT), but rather a modification. It is an incorrect assumption that you can make a better NPT product thread by using dryseal gaging. What you usually get is an incorrectly manufactured NPT product thread.

The conclusion; use the gage that is specifically designed for that particular product thread. If different pipe gages give different results, the gage designed for the product thread type has the final say, assuming of course, that the gages being used are good gages.

STRAIGHT PIPE THREADS

There are several pipe threads where the internal and external threads are both straight. In these cases the products threads are inspected using Go/NoGo type gages. These threads will always have to have a sealant applied to assure sealing.

In the cases of pipe threads where the

internal product is straight, and the external product is tapered, the product must be inspected with tapered gages to measure functional fit. When the tapered plug gage is applied to a straight internal thread, the gaging notch should be flush with the product face (or datum point) within plus or minus one and one-half turns.

CYLINDRICAL GAGE TOLERANCE

The tolerance of the gage is based on the tolerance of the part it is to inspect. The rule of thumb is to use a maximum of 10% of the part tolerance for the gages. This allows the part manufacturer to use 90% of the tolerance for their manufacturing window, as the gages are made within the part tolerance to assure quality. The 10% is split between the Go and NoGo gages.

For example: If the product has a range of .499 - .500 diameter, 10% would be .0001, which split becomes .00005 (50 millionths). Looking at the tolerance chart you would use class X gages, or better.

The tolerances given in this chart are to be applied to the diameter of the gage. Go cylindrical plugs, and NoGo cylindrical rings



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are held plus; NoGo cylindrical plugs, and Go cylindrical rings are held minus.

Straightness, taper, and out-of-roundness must be held within 1/2 of the diameter tolerance. Tolerances for Cylindrical Plug

Gages used to check the minor diameter of internal threads, and Cylindrical Ring Gages used to check the major diameter of external threads, are specified in the thread standard as Class Z.

GAGE TOLERANCE FOR PLAIN CYLINDRICAL GAGES

SIZE RANGE		TOLERANCE IN INCHES					
Above	To	XXX	XX	X	Y	Z	ZZ
0.020	0.825	.000010	.000020	.000040	.000070	.00010	.000200
0.825	1.510	.000015	.000030	.000060	.000090	.000120	.000240
1.510	2.510	.000020	.000040	.000080	.000120	.000160	.000320
2.510	4.510	.000025	.000050	.000100	.000150	.000200	.000400
4.510	6.510	.000032	.000065	.000130	.000190	.000250	.000500
6.510	9.510	.000040	.000080	.000160	.000240	.000320	.000640
9.510	12.010	.000050	.000100	.000200	.000300	.000400	.000800

GLOSSARY

ALLOWANCE: The minimum clearance between two mating parts. The variations from the basic size which are prescribed to permit the desired amount of play in a metal-to-metal fit.

BASIC SIZE: The theoretical size (usually the same as the nominal size), from which the design size limits are derived by the application of tolerances and allowances.

CLEARANCE: The radial distance between an external diameter and an internal diameter.

CONVOLUTE: Removal of the incomplete threads at the end faces of a threaded part.

CREST: The top of the thread form. The major diameter of an external thread, or the minor diameter of an internal thread.

FIT: The term used to designate the tightness or looseness of two mating parts, resulting from a combination of tolerances and allowances applied to the basic size of the parts.

FLANKS: The sides of the thread form or groove, connecting the crest and the root.



FLANK ANGLE: The angle between the flank and a line perpendicular to the axis of the thread. Also referred to as half angle or lead angle. Some exceptions to this definition will be encountered, such as tapered thread flank angles measured perpendicular to the taper, and should be noted.

FUNCTIONAL DIAMETER: The actual (measured) pitch diameter of a thread adjusted by the cumulative effects of lead error and angle error, which is always added to external threads and subtracted from internal threads.

INCLUDED ANGLE: Total of the two flank angles of a thread form.

LEAD: The distance advanced by a thread when rotated 360 degrees on its mating thread.

LIMITS: The largest and smallest extremes in the size of a dimension.

MAJOR DIAMETER: The largest diameter of a thread form. The root diameter of an internal thread and the crest diameter of an external thread.

MINOR DIAMETER: The smallest diameter of a thread form. The bore or crest diameter of an internal thread and the root diameter of an external thread.

NOMENCLATURE: In relation to a thread, the complete identification, including the nominal size, threads per inch or pitch, thread series, class of fit, and possibly a designation for internal or external.

NOMINAL SIZE: The size used for purposes of identification. Usually the same as the basic size.

PITCH: The distance between corresponding points on adjacent threads. The inverse of the threads per inch.

PITCH DIAMETER: The theoretical diametrical plane, which passes through a thread at the point where the width of the thread tooth and groove are equal.

RELIEF: Removal of material from portions of a surface or diameter to avoid contact with the mating part when it is engaged.

REFERENCE GAGE: A master gage generally held to close tolerance limits which is preserved for periodic comparison with working gages. A truncated setting plug is a reference gage that is used to inspect as well as set adjustable thread ring gages.

ROOT: The bottom of the thread form. The major diameter of an internal thread and the minor diameter of an external thread.

THREAD ANGLE: The included angle of the thread form, which has the two thread flanks as sides.

TOLERANCE: The amount of variation permitted from the designated dimension, or the difference between the minimum and maximum dimensions.

TRUNCATE: To remove the crest of a thread, thus reducing its height, usually done to guarantee non-interference.



COMMON THREAD TYPES

ACME	29 Degree included angle
ACME-C	Centralizing, eliminates radial displacement
ACME-G	General purpose
AMO	American standard microscope objective
ANPT	Aeronautical National Pipe Taper
BUTT	Buttress – Unequal flank angles Pull type – pressure away from mating parts
PUSH BUTT	Buttress with pressure toward mating parts
DIN	Deutschland (Germany) Industrial National
F-PTF	Dryseal fine taper series
Helicalcoil	Oversize internal thread for thread inserts
JIS	Japanese Industrial Standard
M	Metric Screw Threads, Standard profile 60 degrees
MJ	Metric series with rounded root & crest for strength, eliminates stress or break points
MJS	Metric J series for internal thread Class 5 interference fit
N	American national series
NC	N Coarse pitch series
NF	N Fine pitch series
NEF	N Extra Fine pitch series
NS5	National series special internal thread interference fit
NS5 IF	NS5 form for entire ferrous material range
NS5 INF	NS5 form for entire nonferrous material range
NGO	National Gas Outlet
NGS	National Gas Straight
NGT	National Gas Taper
NH	National Hose coupling full form thread
NPSC	National Pipe Straight Coupling
NPSF	National Pipe Straight Fuel, Dryseal internal thread
NPSH	National Pipe Straight Hose, coupling threads for joining to standard taper pipe threads
NPSI	National Pipe Straight Intermediate, Dryseal internal thread
NPSL	National Pipe Straight Loose, for loose fitting mechanical joints with locknuts
NPSM	National Pipe Straight Mechanical, for free fitting mechanical joints for fixtures
NPT	National Pipe Taper, for general use
NPTF	National Pipe Taper Dryseal, used in high pressure applications where sealant may not be acceptable
NPTR	National Pipe Taper Railing joints
PTF-SAE Short	NPTF modified short threads for thin wall tubing
PTF-SPL Short	PTF-SAE Short modified for thinner wall tubing
PTF-SPL Extra Short	PTF-SAE Short modified for extremely thin wall tubing
SGT	Special Gas Taper
SPL-PTF	Special NPTF



STI	Screw Thread Insert, same as Helicalcoil
STUB ACME	Shallow thread ACME form
STUB ACME M1	STUB ACME Modified Form 1
STUB ACME M2	STUB ACME Modified Form 2
UN	Unified Screw Thread series
UNC	UN Coarse pitch series
UNF	UN Fine pitch series
UNEF	UN Extra Fine pitch series
UNJ	UN modified radius root & crest for strength, eliminates stress or break points
UNJC	UNJ Coarse pitch series
UNJF	UNJ Fine pitch series
UNJEF	UNJ Extra Fine pitch series
UNR	UN modified external thread with Rounded root radius
UNRC	UNR Coarse pitch series
UNRF	UNR Fine pitch series
UNREF	UNR Extra Fine pitch series
UNM	UN Miniature series
UNS	UN Special diameter, pitch, length of engagement, pitch diameter, etc. Qualifying information must follow nomenclature if any other than diameter.

COMMON BRITISH THREADS

BSC	British Cycle
BSF	British Standard Fine
BSW	British Standard Coarse
BSPP	British Standard Pipe Parallel (straight mechanical joints)
BSPT	British Standard Pipe Taper (pressure tight joints)
WHIT	British Whitworth Special
G	BSPP (internal)
GxA	BSPP (external, class A)
GxB	BSPP (external, class B)
R	BSPT (external)
Rc	BSPT (internal, tapered)
Rp	BSPT (internal, straight)



Glastonbury Southern Gage Products & Capabilities

Services

- Calibration and Certification of fixed limit gages
- Premium / Redline Service – Expedited Delivery
- Technical assistance
 - Thread characteristics
 - Reference standards - personnel on ANSI committees
 - Custom gages
 - Special designed gages
- Gage Calibration Seminars at Erin, TN
- Seminars at customer's facilities
 - Fixed limit gage calibration
 - Thread gages & gaging
 - Comparator gages & gaging

Gage Stock

THREAD WORK PLUG GAGES

Taperlock, Trilock, & Reversible

THREAD SET PLUG GAGES

Truncated & Full Form

THREAD RING GAGES

AGD & Southern Style

PIPE RING & PLUG GAGES

NPT, NPTF, & ANPT

FLEX PLUGS

SNAP GAGES

Model C, MC, & A

VARIABLE THREAD GAGES

Tri-Rolls, ITC's & STC's

DIAMET / DIALECTRON SYSTEMS

ZERO SPINDLE FIXTURES & COMPONENTS

Gage / Product Manufacturing Capabilities

Threads

Plugs Diameters: Min. #00 (.047", 1.2MM) Max. 14 3/4", 375.0MM

Threads Per Inch: To 120 TPI

Rings Diameters: Min. #0 (.060"), 1.52MM Max. 14 1/2", 368MM

Length: Max.: 6 1/2"

Threads Per Inch: 1/2 TO 105 TPI

Cylindricals

Internal Diameters: .040" – 22.5"

External Diameters: .010" – 22.0"

Lengths: .010" – 36.0"

External Tapered Diameters: .010" – 12.0"

Internal Tapered Diameters: .160" – 12.0"

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C icrometer Masters

D aliper Masters

G epth Micrometer Masters

C eometric Chek

Z MM Masters - QuikChek

C Axis Chek

S am, Crankshaft, Brake Masters

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Copies of this material may be obtained from GSG
Ask for Thread Seminar Book # SG100