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## 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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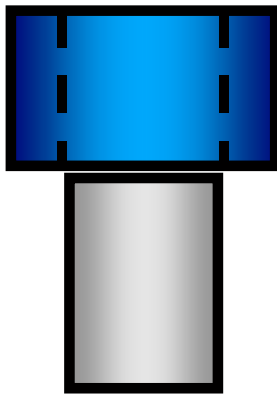
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With straight threads, the Go and NoGo gages tell you that your part is within the acceptable limitations of size. With a tapered thread, this system does not work as a gage inserted into a hole or engaged with an external thread will at some point 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.

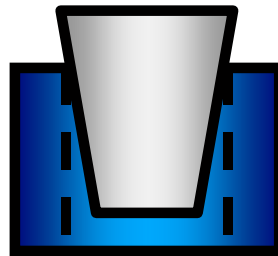
The NPT and most of the other pipe threads are made on a taper of .750" per foot, or .0625" per inch. This is an even ratio of 16:1. In other words, when you travel along the axis of the thread .016 you will experience a diametrical change of .001.

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

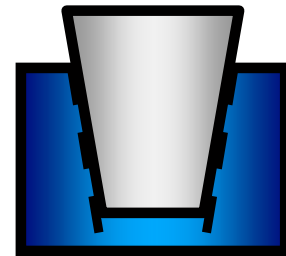
## SEALING THEORY



**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.



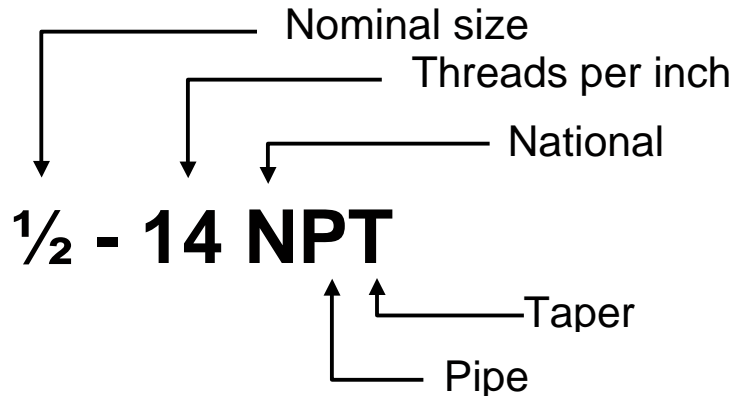
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# PIPE NOMENCLATURE

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.

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## 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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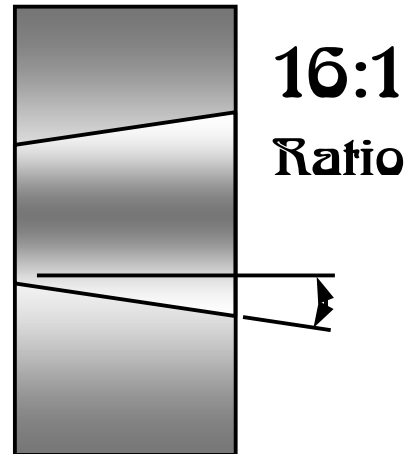
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# INDIRECT MEASUREMENT

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.

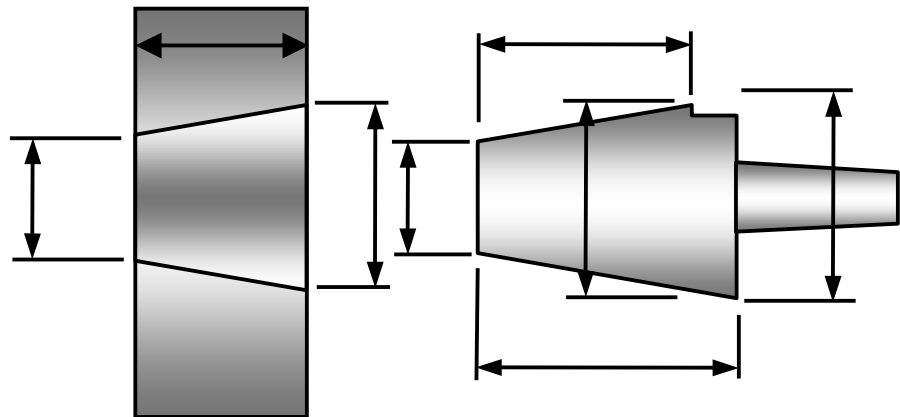
The pitch diameter of the thread cannot be easily measured directly because it is a spiral taper. A means is needed to measure product that is simple, conclusive and accurate. Indirect measurement satisfies these requirements.

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.



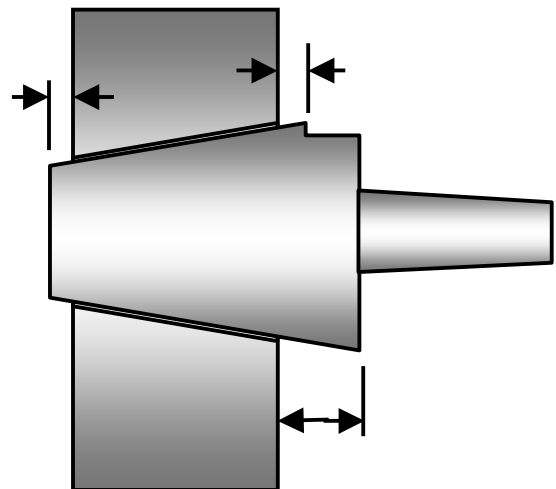
**Angle that creates a known  
Length to Diameter ratio**

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.



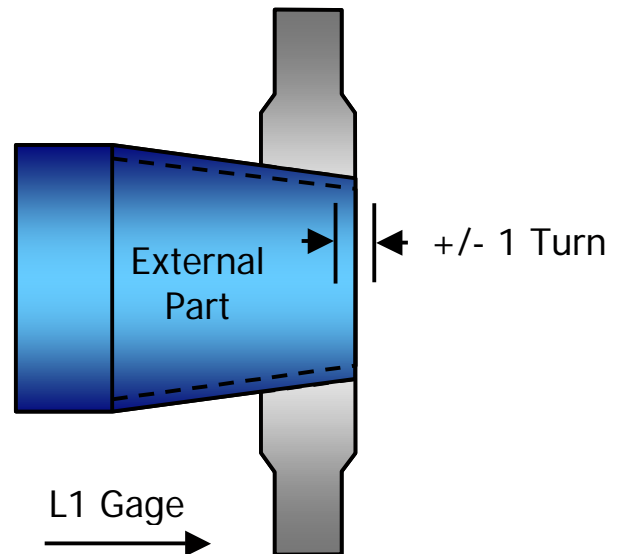
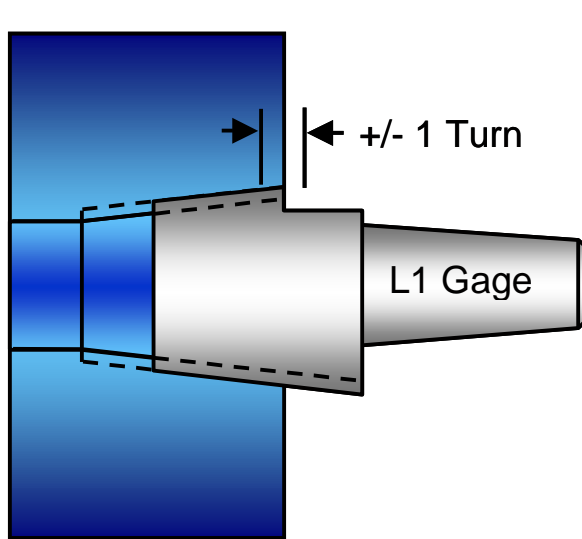
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# L-1 PLUG AND RING GAGE

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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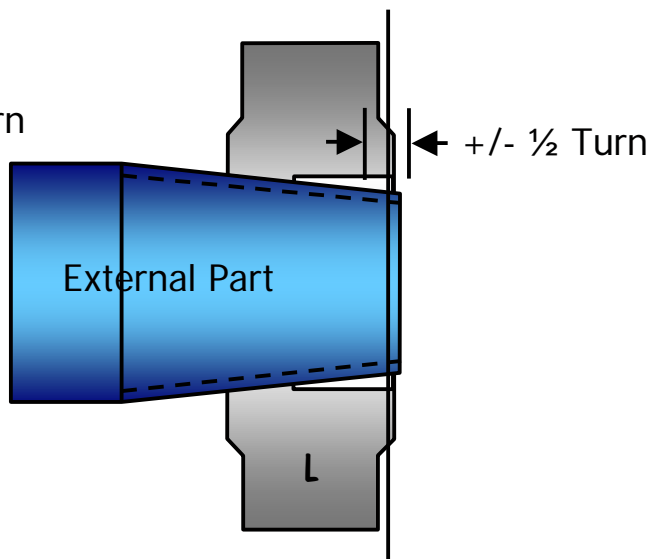
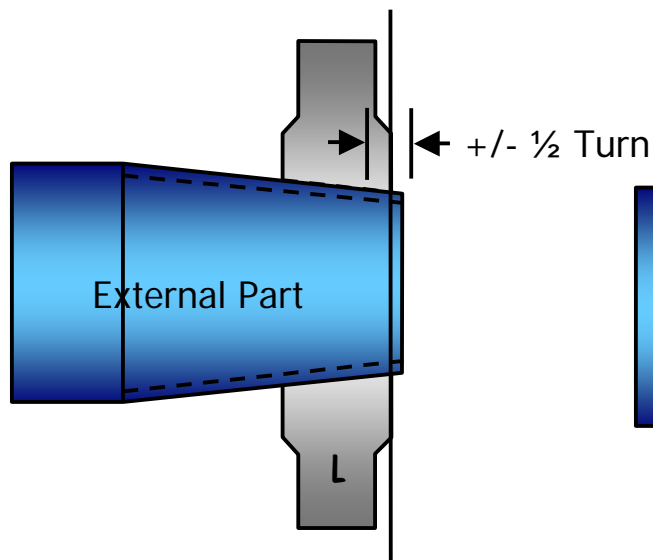
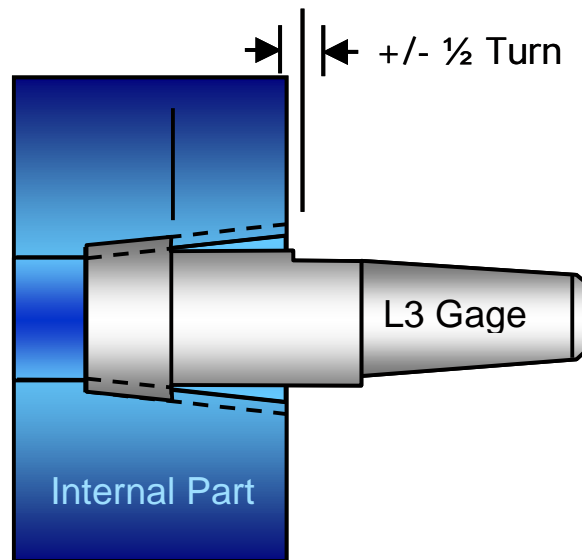
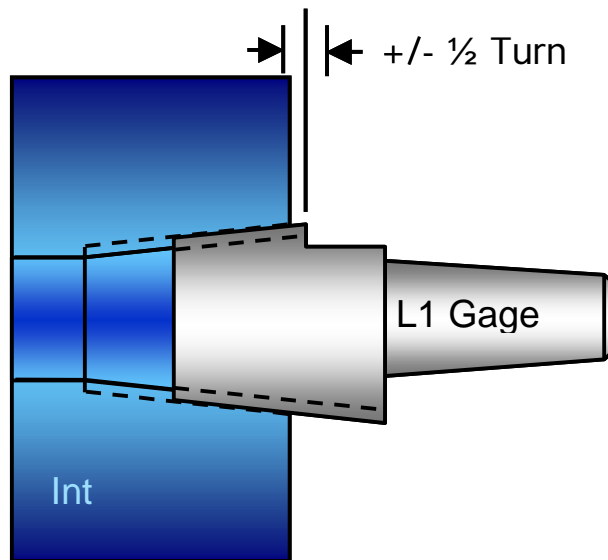
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## L-2 RING / L-3 PLUG

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

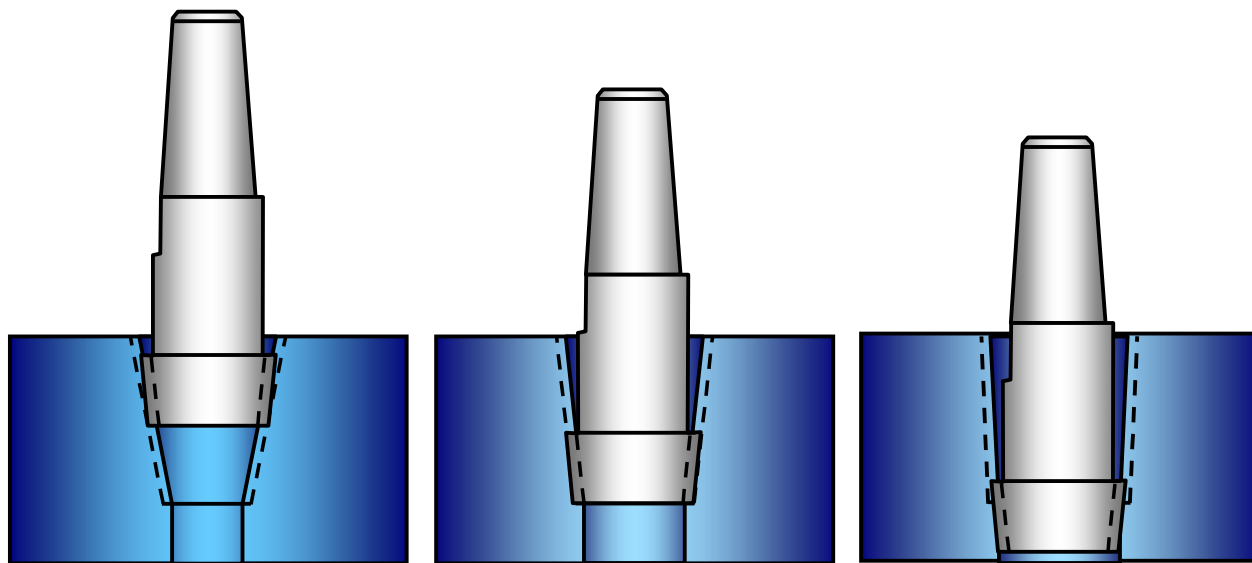
the L1 stopped. The L-2 ring and L-3 plug are designed to clear the threads of the part that the L-1 assembled with and assemble with the threads further on or in the part. This measures the taper of the thread of the part by comparing the front threads and the back threads of the part. If the taper 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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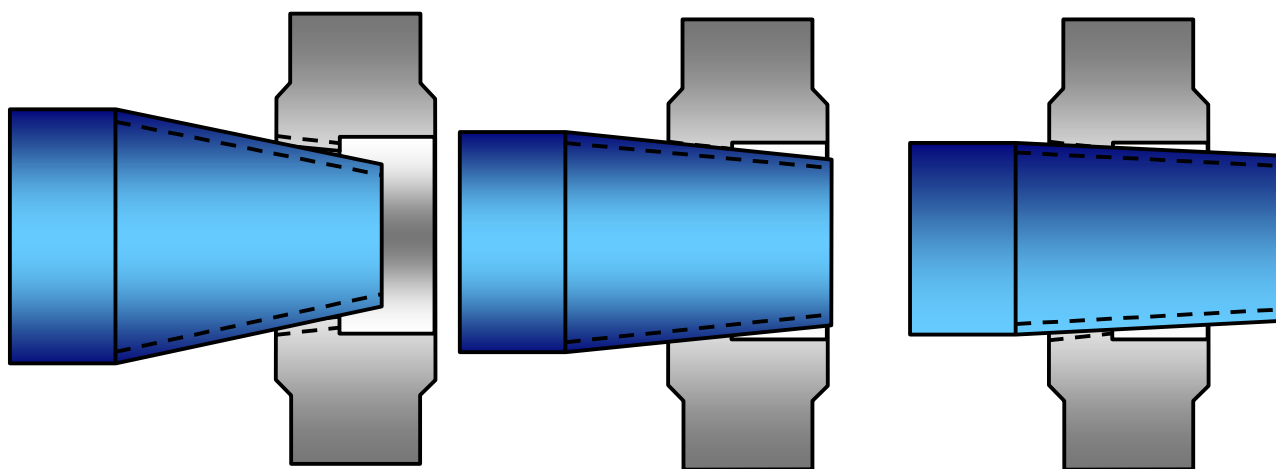
The following illustrates the three possible outcomes when using the L2 and L3 gage.



**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.

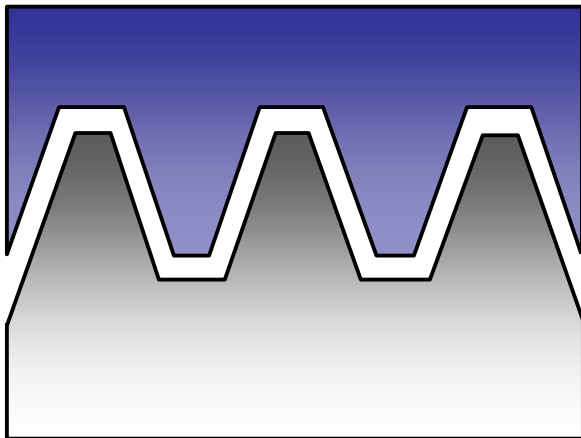
The Class 1 applications do not require inspection of the crest and root diameters. Consequently, Class 1 threads are intended for applications where close control of tooling is required for conformance of truncation or where sealing is allowed to be accomplished by means of a sealant applied to the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

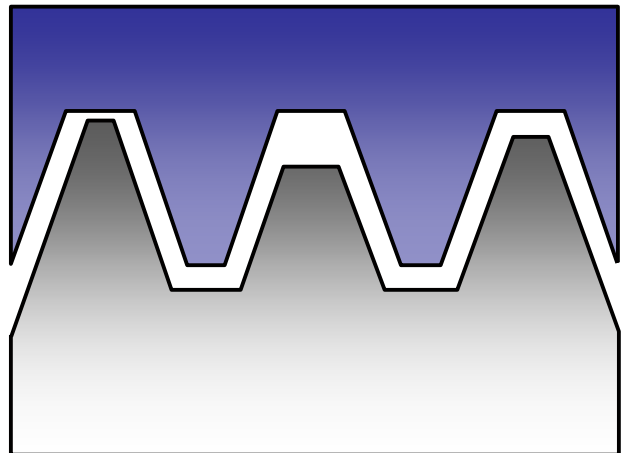
employed to assure complete inspection to guarantee maximum product application qualities.

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.

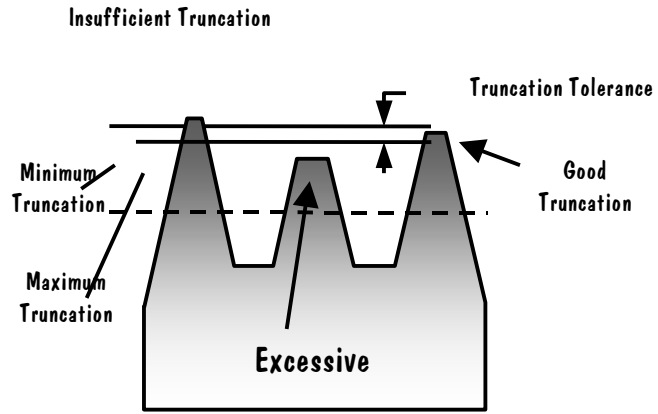


In this illustration a dryseal could not be achieved because the threads would not contact at near the same time along the full thread form.





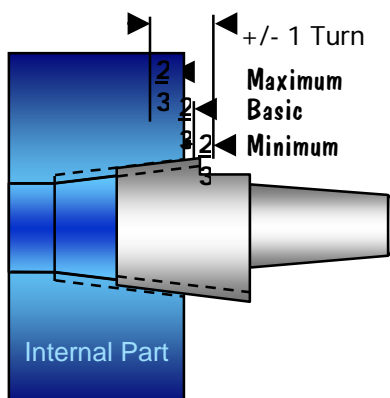
The thread form is measured by measuring the amount of thread removed from a theoretical sharp thread. Removing part of the thread height is referred to as truncating the thread. The amount of truncation is measured as a relationship to the pitch diameter. This allows us to compare the crest of the thread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



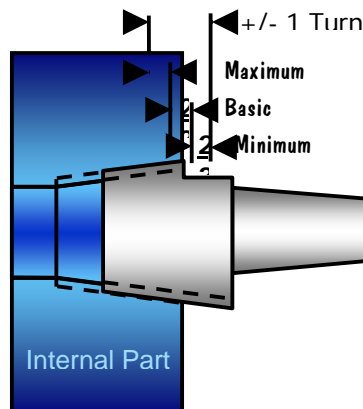
## 6 STEP PLUG AND RING

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.

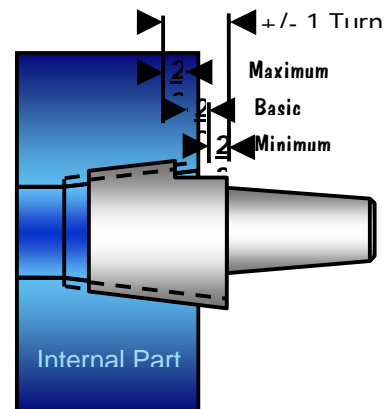
The basic zone is the linear area within 1/3 turn from the face of the part, in or out. If the plug gage is standing out from the face (or datum point) of the internal part more than 1/3 of a turn you have a minimum part because the step on the gage stops within the minimum zone. Likewise, if the plug 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**

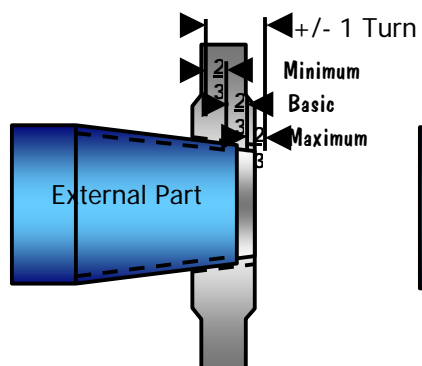


**Maximum Part**

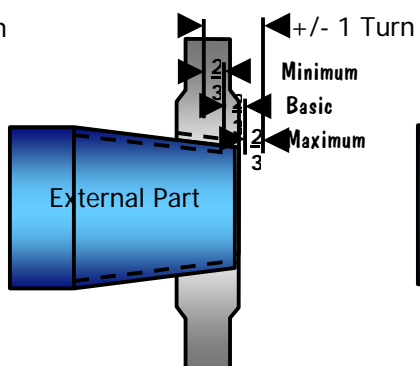


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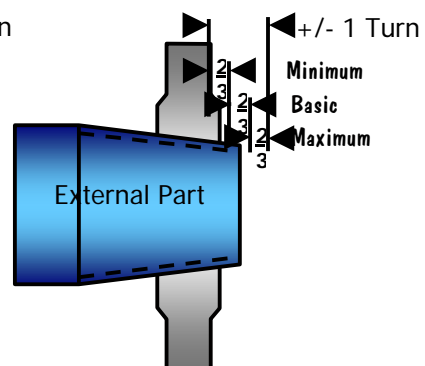
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**Maximum Part**



**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

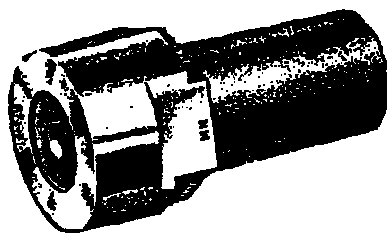
scenarios represented by the six steps on the 6 step ring and 6 step plug.

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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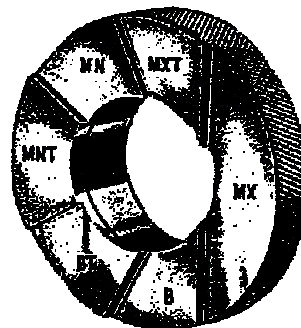
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**6-STEP PLUG**

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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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.

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## 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.

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## 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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