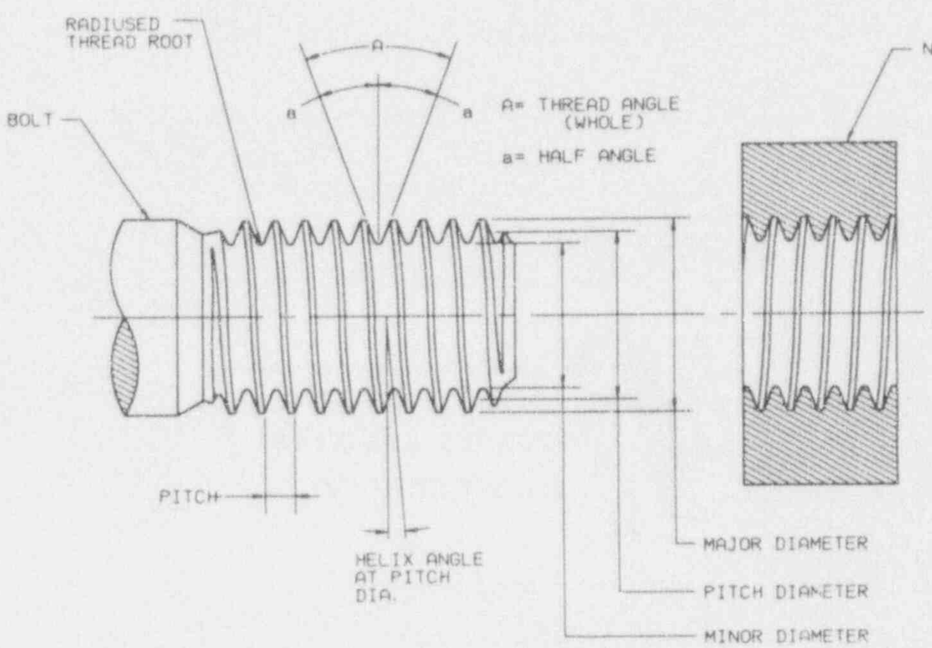
RECOMMENDATIONS FOR FASTENER THREAD ACCEPTABILITY



- Threads must FIT and FUNCTION to be acceptable.
- Thread Acceptability System 21 (Method A) is most practical for all threads, except for Class 3A external threads where System 22 (Method B) is recommended.
- Thread acceptability System 23 (Method C) should not be used as a routine inspection of threaded fasteners. These requirements should be limited to research and analysis as recommended in FED-STD-H28/20A.
- When higher quality confidence levels are required, sampling plans should be adjusted or statistical process control should be required instead of adding thread characteristic measurements.
- Fastener buyers should not modify existing procurement specifications to improve quality when supplier non compliance has been the real issue.

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I. FOREWORD

The INDUSTRIAL FASTENERS INSTITUTE is an association of the leading North American manufacturers of bolts, nuts, screws, rivets, and all types of special formed parts. IFI member companies combine their technical knowledge to advance the technology and application engineering of fasteners and formed parts through planned programs of research and education.

In 1985, suppliers of raw material, primary/secondary machinery, quality assurance/inspection controls and engineering services commonly used in fastener manufacturing joined the Institute as Associate Members to ensure and enrich the technical capabilities of the North American fastener industry.

The Institute and its member companies work closely with leading national and international technical organizations in developing standards and technical practices.

Users of fasteners and formed parts in all industries benefit from the continual advances made by IFI member and its associate member companies in the design, manufacture, and application of fasteners and formed parts. Thus, users are assured of sound engineering and reliability for completed assemblies at the lowest possible cost.

II. THE SITUATION IN BRIEF

At this time, industry and several governmental agencies have expressed growing concern over the quality of all assembly components, including fasteners. Some have taken steps to create more stringent requirements in terms of what to inspect, how to inspect, and how many to inspect in an attempt to ensure themselves that components they receive will FIT and FUNCTION reliably in their intended applications.

To assist industry and government meet the objective of obtaining fasteners of reliable, consistent quality, this document has been prepared.

Its purpose:

1. To define a "good quality" fastener.
2. To review current thread acceptability and gaging specifications.
3. To review fixed limit vs. indicating thread gaging.
4. To present IFI's recommendations for practical fastener inspection, gaging practices and techniques to ensure the supply of reliable, consistent quality fasteners to industry and government agencies.

III. DEFINITION OF THE TERM FASTENER

IFI defines the term "fastener" as a mechanical device for holding two or more bodies in definite position with respect to each other. A high percentage of fasteners have threads as part of their design, but unthreaded items such as rivets, clevis pins, machine pins, etc. are considered fasteners as well.

Conversely, it should be understood that not all component parts which have threads as part of their design are considered fasteners. IFI restricts its interest to components specifically meeting the above stated definition of a fastener. Threaded shafts, fuel line coupling threads, sealing tube threads, pipe threads, etc. are not considered fasteners by industry definition.

IV. GOOD QUALITY FASTENER DEFINED

A good quality fastener is one which conforms to its specification(s) and is suitable for its intended application in terms of both FIT and FUNCTION. FIT is determined by dimensional inspections; FUNCTION is determined by physical and chemical tests.

This is felt to be a simple, yet comprehensive definition which should be used in guiding fastener manufacturers, distributors and fastener users in establishing inspection and testing requirements. It has been noted that a frequent reaction to a fastener problem is to add more measurements and tests. Closer scrutiny, however, usually proves that the previous tests were in fact adequate, but not performed properly. There is no evidence of a deficient specification problem; instead, there is simply a compliance problem.

IFI is in favor of the practice of ANSI, ASME and ASTM in which the validity of each test requirement included within every standard is periodically confirmed or dropped from the applicable specification.

Determination of fastener thread quality does not have to be complicated. One must simply seek the answers to these questions:

A. Do the dimensional inspections required ensure that mating parts will consistently FIT? FIT as it is being used here means that an external thread that gages properly will be assembleable with a female thread which also gages properly and vice versa.

B. Do the tests required ensure that the fastener will consistently FUNCTION as required by the design? FUNCTION as it is used here means that the fastener will perform the physical task it is designed to do in tension, shear, etc.

C. Have all redundant or irrelevant measurements or tests which do not ensure consistent FIT or FUNCTION been eliminated from the specification?

If the answer to all three of these questions is "yes," then the fastener specification is effective. If, on the other hand, the specification is deficient in one or more areas, the specification should be modified until all answers are "yes." Only practical, logical and technically sound specifications provide users the opportunity to employ the widest range of capable suppliers at the lowest practical cost.

V. CURRENT THREAD ACCEPTABILITY AND GAGING SPECIFICATIONS

Below is a list of the most widely referenced specifications related to threads and their gaging:

ANSI/ASME B1.2-1983, Gages and Gaging for Unified Inch Screw Threads

ANSI/ASME B1.3M-1986, Screw Thread Gaging Systems for Dimensional Acceptability — Inch and Metric Screw Threads (UN, UNR, UNJ, M and MJ)

Mil-S-7742B Amendment 1 15 March, 1973, Screw Threads, Standard, Optimum Selected Series: General Specification for

Mil-S-8879A Amendment 1 15 March, 1973, Screw Threads, Controlled Radius Root With Increased Minor Diameter, General Specification for

Mil-S-007742C (USAF) 29 July, 1988, Screw Threads, Standard, Optimum Selected Series: General Specification for

Mil-S-008879B (USAF) 29 July, 1988, Screw Threads, Controlled Radius Root With Increased Minor Diameter, General Specification For

FED-STD-H28/20A 21 September, 1987, Inspection Methods for Acceptability of UN, UNR, UNJ, M and MJ Screw Threads

These specifications identify a variety of thread characteristics and group their requirements for measuring such characteristics into either "Systems" or "Methods." Groupings vary in the number of characteristics to be measured. The more critical the application of the fastener being evaluated, the more characteristics will require measurement. These groupings are designated as Systems 21, 22 and 23 in ANSI/ASME B1.3M-1988, with 23 the most stringent, having the most required measurements and 21 the least stringent, having the fewest.

In Mil-S-7742B and Mil-S-8879A, such groupings are referred to as Methods A, B, and C. These correspond very closely with Systems 21, 22 and 23, respectively. The U.S. Air Force specifications Mil-S-007742C (USAF) and Mil-S-008879B (USAF) which are draft proposals at this time (Jan. 1990) use the terms "Other Thread" and "Safety Critical Thread." These specifications are similar to, but more stringent and demanding than Methods B and C, respectively. The Air Force does not have an equivalent to Method A.

Tables 1 and 2 on page 10 of this document compare the requirements of these specifications for both external and internal threads. Thread characteristics are listed as follows.

A. Maximum Material or Functional GO
B. Minimum Material Pitch Diameter or Single Element Pitch Diameter
C. Major Diameter
D. Minor Diameter
E. Root Radius Profile
F. Pitch Diameter Taper
G. Circularity or Roundness
H. Flank Angle
I. Lead
J. Runout or Eccentricity
K. Surface Roughness or Surface Texture

Specification ANSI/ASME B1.2-1983 clearly illustrates the design parameters and types of fixed limit and indicating gages suitable for properly measuring thread characteristics designated in the systems and methods listed above. For reference, refer to illustrations on pages 11 thru 15.

As part of the overall review of fastener thread quality, these thread acceptability specifications were put to the three-part test outlined in Part IV (page 3). All of the systems provide for fastener FIT. ANSI/ASME B1.3M-1986, System 21 (Method A) provides for fit with functional maximum material limit control. Additional thread dimensional controls specified in the other systems (and methods) will now be discussed as to their ability to improve thread quality regarding FIT or FUNCTION.

The Class 3A thread specifications do have specific dimensional limits on minimum material condition and amount of pitch (lead) error which can be tolerated. These dimensional requirements dictate that in addition to functional pitch diameter, the size of the single element pitch diameter and its relationship to functional size needs control.

The initial definition of a good quality fastener states in part that it must FIT and it must FUNCTION. The content of these specifications has only to do with FIT. Fasteners manufactured to performance specifications are subject to physical requirements to determine FUNCTION.

Such required mechanical performance tests must be conducted and the fasteners must meet all requirements. It is obvious that an "unhardened" SAE Grade 8 bolt may conform dimensionally, making its FIT good, but it will be totally unsuitable to FUNCTION.

Tests such as tensile, proof, hardness, fatigue, impact, ductility, torsional, shear, stress rupture, etc. are the criteria for determination of a fastener's functional acceptability.

Research conducted as far back as 1943 by Earle Buckingham, Ph.D. at M.I.T., and later computer studies and research done by Alexander Blake of Lawrence Livermore National Laboratory in California show that only a few thread characteristics have any significant effect on performance. These characteristics are:

1. Depth of thread engagement, which is a function of the major diameter on external threads and the minor diameter on nuts, to prevent stripping.

2. Root radius on external threads.

3. The amount of lead variation.

Both Buckingham and Blake conclude that functional performance of fastener threads of the same material, hardness, root radius and major diameter is unaffected by differences in pitch diameter.

Extensive tests were conducted in which the only variable was the class of thread fit. Bolts of Classes 1A, 2A, and 3A, having different pitch diameters, showed no significant difference in tensile strength.

Both researchers noted that thread lead has an effect on tensile and fatigue strengths. Positive lead on external threads, threads being further apart than nominal as opposed to closer together, led to lower failure values. However, Blake states in his book, "What Every Engineer Should Know About Threaded Fasteners, Materials and Designs," (1986), "computer analyses have shown that lead deviations within the limits accepted by standard attribute gages (GO and NOT GO thread ring gages and GO and NOT GO thread plug gages) have a negligible effect on the strength of threads."

The following thread characteristics are, therefore, the only ones significant in measuring to determine FIT. Requirements for these characteristics, if met, do provide a minimal prediction of FUNCTION, which, as stated before, must be verified by testing.

EXTERNAL THREAD	INTERNAL THREAD
Major Diameter	Functional Pitch Diameter
Functional Pitch Diameter	Minor Diameter
Minimum Pitch Diameter (Class 3A)	
Minimum Root Radius (UNJ only)	
Minor Diameter (UNJ only)	

This position seems to be in agreement with the Federal Government's Fed-Std-H28/20A (21 September 1987) which states the following:

"5.1.3 System 21

5.1.3.1 System 21 provides for interchangeable assembly with functional size control at the maximum limits within the length of standard gaging elements; and also control of characteristics identified as NOT-GO functional diameters or as HI (Internal) and LO (External) functional diameters. These functional gages provide some control at the minimum material limit when there is little variation in thread form characteristics such as lead, flank angle, taper and roundness.

5.1.3.2 System 21 is suggested for use under any one (or more) of the following conditions:

a. Where product threads do not need specific mechanical strength properties, or where mechanical strength requirements are not specified for the product threads by either material strength and dimensional limits or by testing strength of the threads.

b. The threaded product has all the mechanical properties specified; mechanical property testing of the threads is required; and the testing requires that screw threads be subject to shear and beam loading by matching threads (i.e., full size tensile testing of externally threaded product threads and full size proof-load testing of nuts). If the threads have a locking element incorporated, locking torque values and tests must be specified and run on matching thread inspected by either System 22 or System 23.

c. For standard, off-the-shelf, general application fasteners when considered acceptable.

d. Internal thread is less than 0.190 inch (5mm) nominal size."

Section 5.1.3.2 (b) is interpreted to mean that System 21 (Method A) is acceptable in all cases where the fastener is subjected to and passes all applicable mechanical (function) tests.

If one carefully reviews ANSI/ASME B1.3M-1986, Tables 3 and 4, it will be noted that all systems indicate acceptable "attributes/fixed limit control gages" and "variables/indicating control gages." As stated elsewhere in this document, IFI suggests the use of System 22 for all Class 3A (external) products and System 21 for all other products. Even though IFI feels both "fixed limit" and "indicating control" gages are acceptable, it is felt that "indicating control" gages are preferred for production use when implementing statistical process control (SPC).

The measuring with indicating gages and charting of major diameter and functional pitch diameter on external threads and minor diameter and functional pitch diameter on internal threads regardless of class of fit is the most practical and effective approach to minimizing significant thread variation in production.

Use of System 22 (Method B) for external threads utilizes the minimum material limit and the restrictions that the simple pitch diameter control places on lead (pitch) instead of the many functional tests needed to evaluate the effects of this characteristic. This system is applicable to Class 3A external threads. The additional requirements in System 23 (Method C) are either redundant or irrelevant in assuring FIT over what is proven by System 21 (Method A) or System 22 (Method B). There are no known data to indicate that the FUNCTION of the fastener is in any way enhanced by the additional dimensional evaluations of System 23 (Method C).

IFI agrees with Fed-Std-H28/20A Section 5.1.5.2, which states that System 23 is applicable:

a. When thread element control is required to determine the extent of deviation in any of the elements of the thread; normally special applications.

b. For threaded product used in research investigations and testing to determine the effect that a specific thread element variation has on the attributes of the threaded product or the attributes of the threaded product's application.

c. The conducting of investigation and testing in analysis of thread failures.

System 23 may also be applicable for critical assembly components, particularly in sizes over 1½ inches, which are threaded, such as shafts, couplings, tubes, etc. IFI takes no position on these types of parts since they are not "fasteners" by industry definition.

IFI recommends that System 23 (Method C) not be used for the inspection of production fasteners. There is no known technical data to prove that the inspection of additional thread characteristics beyond those specified in Systems 21 and 22 (Methods A & B) improves the assurance of thread quality or fastener performance.

If users want to increase their confidence level in very critical parts, IFI recommends this be dealt with by increasing sampling plan requirements to statistically reduce the possibility of accepting non conforming parts instead of increasing the numbers of different thread characteristics to be measured. To do both would create a physical and economical situation which, for the reasons stated herein, would not improve FIT or FUNCTION of the parts.

Measuring the characteristics recommended in System 21 (Method A) for screws, bolts and nuts (except those having Class 3A threads) and System 22 (Method B) for bolts and screws with Class 3A threads would provide essentially the same level of confidence as the eleven measurements presently required in System 23 (Method C) and USAF "Safety Critical" classification.

Below are the characteristics listed in various current specifications that are better suited to research applications and that do not significantly add confidence in the inspection of production fasteners.

a. *Minimum material pitch diameter (single element pitch diameter)*
This characteristic does not define FIT. If a thread passes "functional GO limit" or "functional pitch diameter size" it is assured of fitting and being assembleable. "Single element pitch diameter" is therefore a redundant fit measurement. This measurement, however, is beneficial on roll threaded external threads at machine set up to indicate die match and alignment. It is felt that if single element pitch diameter and functional diameter are within 40% of the pitch diameter tolerance, die life will be optimized. After machine set-up, the functional diameter actually determines thread quality adequately. Its measurement in conjunction with "functional GO," however, can indicate that thread angle and lead errors are within limits which helps to ensure that tensile and fatigue requirements are met. This measurement is not felt to be a beneficial indicator on any internal threads.

The basic problem with single element pitch diameter measurement of internal threads has to do with the calibration of master rings. As of December 28, 1988, the Defense Industrial Supply Center (DISC) acknowledged that the ANSI B1.2 committee has no standard procedure for calibration of Class "W" master setting thread rings for pitch diameter. Calibration currently must be done with a matching externally threaded setting plug.

When mated with the master ring, it only proves that the ring's functional pitch diameter is correct. At this time there is no assurance that any internal "single element pitch diameter" gage is providing dependable and accurate measurements.

It should also be noted that many internally threaded fasteners intended for use in critical applications have some type of deflected thread design or other means of creating a prevailing torque effect. The final product is literally impossible to measure for either "functional GO" or "single element pitch diameter."

IFI is not aware of any research which proves that measurement of "single element pitch diameter" of internal threads provides any beneficial information about FIT or FUNCTION beyond that provided by the measurement of "functional pitch diameter." "Single element pitch diameter" measurement is therefore redundant and inconclusive regarding nut quality.

NOTE: If "single element pitch diameter" measurement is required, its non conformance alone should not be grounds for rejection if "functional GO" requirements are met. Such parts should be tested mechanically and the product considered acceptable if passed by those tests. The precedent for this type of approach has been in existence for many years in terms of hardness vs. tensile strength. ASTM F606 and many government procurement documents, such as Mil-B-87114A and AMS6487E, state that if hardness is below specification, but the product meets its tensile requirement, the product is to be judged acceptable. Hardness, like single element pitch diameter, is at best merely a rough indicator of performance. True fastener functional suitability is determined by tensile and other widely accepted mechanical tests.

Some major fastener users such as Ford Motor Company and the US military services also require that single element pitch diameter must be measured on all Class 2, as well as Class 3, products. Users always have the right to require any inspections they feel have value for them. The IFI simply knows of no independent research which warrants making this measurement a recommendation for classes of products other than Class 3A.

b. *Flank angle and lead variation*
"Functional GO/NO GO" gaging and "functional GO" size measuring indicate that thread flank angles and thread lead are within limits of thread fit. A reduced thread profile caused by angle or lead errors will be detected in tensile or proof testing if it is too severe. When both "functional GO" and "single element" pitch diameter measurements are within limits of size, as is recommended for Class 3A external threads, the accuracy of angle and lead size are indicated.

Excessive flank angle and/or lead variations can adversely affect performance in terms of tensile strength, fatigue strength or prevailing torque. Excessive lead variation can also cause assembly problems in longer than normal lengths of engagement.

c. *Thread eccentricity (runout) and circularity (roundness)*
These considerations may be significant on larger diameter threaded components and their measurement should be used in those instances. On volume roll threaded fasteners (screws, bolts and studs) between #0 and 1½ inch nominal diameter, the possibility of problems in these characteristics is unlikely due to the nature of manufacturing processes involved. The System 23 "Circularity" requirement dictates that pitch diameter must be measured at both 120 and 180 degrees on both internal and external threads. This is impossible to comply with on internal threads under 1.500 inches diameter because no gages for measuring internal threads at 120 degrees exist at this time.

d. *External thread minor diameter*
Only the minor diameter of UNJ external threads should be measured. ANSI B1.1-1982 specifically states that the minor diameter of UN and UNR threads is a reference dimension only and is not to be measured as an individual thread element.

e. *Nut major diameter*
This thread element should not be individually measured because ANSI B1.1-1982 states that only a ***minimum*** major diameter is specified to ensure the ability to assemble. This dimension is inspected with either the fixed limit "GO" threaded plug gage or with the indicating gage "GO" functional measuring fingers. This is a part of the functional measurement. A deficient internal major diameter will result in a failure of the "GO" functional inspection.

f. *Root radius profile*
Currently, the measurement of root radius is only required on UNJ external threads. Measurement of minor diameter is also required. Because of the manufacturing methods employed, if the minor diameter is within limits, the root radius must also be within practical limits. Since root radius can only be measured on an optical comparator, it is the most time-consuming measurement required. Also, measurements obtained using an optical comparator are much less repeatable and more subjective than those obtained by use of mechanical measuring devices. If the parts measure within limits on functional minimum pitch diameter, major diameter and minor diameter, the exact root radius of a rolled thread is not significant in predicting function as long as the minimum root radius is met.

Only ***minimum*** root radius measurement should be required on external UNJ rolled threads. Measuring the minor diameter within limits assures fit and helps predict tensile strength. If this is within acceptable limits, maximum root radius is insignificant and should not be a required measurement. As long as the minimum root radius is maintained, it is a helpful predictor of fatigue strength. This characteristic should never be required for 100% inspection in lieu of a sampling plan because as tooling wears, root radius tends to become larger instead of smaller. When it becomes so large it affects fit, the minor diameter (which is much easier to measure) becomes oversized. From a functional standpoint, the larger the radius, the better the fatigue strength. Thus, measurement of maximum root radius is unnecessary.

g. *Surface finish (surface texture)*
There is no known equipment available to make an empirical measurement on surface finish of thread flanks except on very large external threads. Characteristics which cannot be measured should not be a part of any specification.

VI. FIXED LIMIT VS. INDICATING THREAD GAGING

Both the older, more familiar, GO/NO GO fixed limit thread gages and the newer, indicating thread gages can ensure users of quality fasteners if properly calibrated and utilized.

Fixed limit gages are less expensive to purchase initially and in some ways it is easier to train inspectors in their use. They are, however, more likely to lose their calibration due to wear and plating buildup and are generally slower to use than indicating gages. Fixed limit thread gages are not applicable if statistical process control is to be used.

Indicating thread gages, in particular those with electronic indicators, add new and valuable capabilities to thread measuring.

a. Indicating thread gages are calibrated with master setting rings or plugs at appropriate intervals to ensure accuracy. Fixed limit gages are recertified periodically. That frequency must be carefully established and maintained to ensure that no parts are inspected with an "out of tolerance" gage. Depending on the threads being inspected, fixed limit gages may wear or load up with plating relatively quickly. Calibration schedule must be sensitive to these possibilities.

b. Several types of indicating thread gages are faster to use than the corresponding fixed limit gages. On a fixed limit gage, one must thread a product completely into or onto the GO gage, remove it and try it on the "NO GO" gage. To use most types of indicating gages, the gaging elements are simply opened and the product placed between them. The parts should be rotated ¼ to ½ turn. The gaging elements embrace the part and indicate measured size. As sample sizes are increased, this factor becomes more important in terms of inspection efficiency.

c. Electronic indicating thread gaging can input measurements into data collection systems and/or printers to record results. This speeds the inspection process and eliminates hand recording errors.

d. Indicating thread gages are used when implementing statistical process control because the manufacturer must collect and analyze measurements. This is becoming increasingly important as major fastener purchasers make the use of SPC an integral part of their contract requirements. This emphasis stresses non-conformance avoidance instead of non-conformance detection.

e. Electronic indicating thread gages can be directly connected to SPC data collectors to facilitate SPC implementation in the threading operation.

VII. IFI RECOMMENDATIONS FOR FASTENER THREAD INSPECTION

a. To determine true fastener thread quality, parts must be MEASURED for FIT and TESTED for FUNCTION.

b. All fastener thread measurement and test requirements should be technically scrutinized to ensure that each one is valid in determining conformance and that redundant requirements have not been specified.

c. The most practical thread measuring systems currently in existence which should be used are ANSI/ASME B1.3M-1986 System 21 (Method A) for all internal and external threads, except Class 3A external threads, where System 22 (Method B) is applicable. This position is interpreted to be in basic agreement with FED-STD-H28/20A.

d. The requirements of System 23 (Method C) should not be used for routine fastener thread inspection. These requirements should be limited to research and analysis in accordance with the position of FED-STD-H28/20A.

e. Fastener threads for extremely critical applications should be scrutinized more carefully by increasing the applicable sample size or statistical process control should be required instead of increasing the number of characteristic measurements.

f. Indicating thread gages are essential in the implementation of statistical process control in the threading operation.

Members of IFI represent a major body of fastener technology knowledge, expertise and talent. This entity is dedicated to meeting industry and government needs in terms of a supply of consistent, reliable fasteners which meet practical, valid requirements for both FIT and FUNCTION. This IFI publication is presented as a guide and recommendation for specification revisions to eliminate redundant and inconclusive gaging requirements. Practical, non-redundant fastener thread requirements will provide users in industrial, aerospace and government with the broadest supply base at the most reasonable cost, and the greatest degree of confidence that fasteners will FIT.

Table 1 — EXTERNAL THREAD MEASURING REQUIREMENTS

Thread Characteristics	Industrial			Military						USAF			
	ANSI B1.3M-1986			MIL-S-7742B			MIL-S-8879A			MIL-S-007742C		MIL-S-008879B	
	21	22	23	A	B	C	A	B	C	OT[1]	SC[1]	OT[1]	SC[1]
"GO" functional diameter	X	X	X	X	X	X	X	X	X	X	X	X	X
Pitch diameter size		X	X		X	X		X	X	X	X	X	X
Major diameter size	X	X	X		X	X		X	X	X	X	X	X
Minor diameter size		X[3]	X					X	X			X	X
Root radius (UNJ only)		X[3]	X					X	X			X	X
Flank angle			X			X[2]			X[2]		X		X
Lead (including helix variations)			X			X[2]			X[2]		X		X
Circularity			X			X			X		X		X
Taper			X			X			X		X		X
Runout			X			X			X		X		X
Surface roughness (when applicable)			X			X			X		X		X

NOTE: [1] "OT" is "Other Thread" and "SC" is "Safety Critical"

[2] These must be measured only if "GO" functional and pitch diameter size vary by more than 40% of the pitch diameter tolerance

[3] Applicable to UNJ threads only

Table 2 — INTERNAL THREAD MEASURING REQUIREMENTS

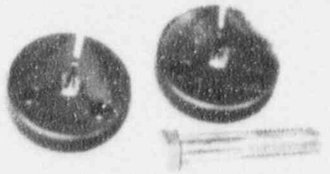
Thread Characteristics	Industrial			Military						USAF			
	ANSI B1.3M-1986			MIL-S-7742B			MIL-S-8879A			MIL-S-007742C		MIL-S-008879B	
	21	22	23	A	B	C	A	B	C	OT[1]	SC[1]	OT[1]	SC[1]
"GO" functional diameter	X	X	X	X	X	X	X	X	X	X	X	X	X
Pitch diameter size		X[3]	X[3]		X[3]	X[3]		X[3]	X[3]	X[3]	X[3]	X[3]	X[3]
Major diameter size						X			X				
Minor diameter size	X	X	X		X	X		X	X	X	X	X	X
Flank angle			X			X[2]			X[2]		X		X
Lead (including helix variations)			X			X[2]			X[2]		X		X
Circularity			X			X			X		X		X
Taper			X			X			X		X		X
Runout			X			X			X		X		X
Surface roughness (when applicable)			X			X			X		X		X

NOTE. [1] "OT" is "Other Thread" and "SC" is "Safety Critical"

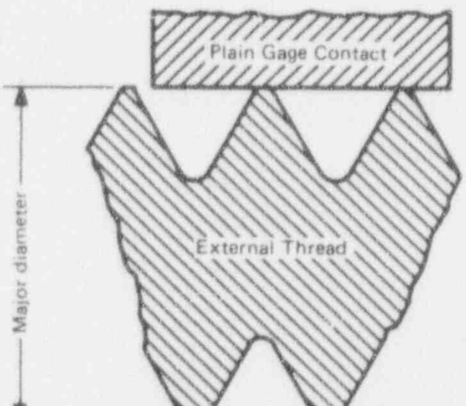
[2] These must be measured only if "GO" functional and pitch diameter size vary by more than 40% of the pitch diameter tolerance

[3] Not a required measurement for threads under .190 inches basic size

ANSI/ASME B1.3M - 1986 SYSTEM 21
GAGING CONFIGURATIONS FOR EXTERNAL THREADS
FROM ANSI/ASME B1.2 - 1983



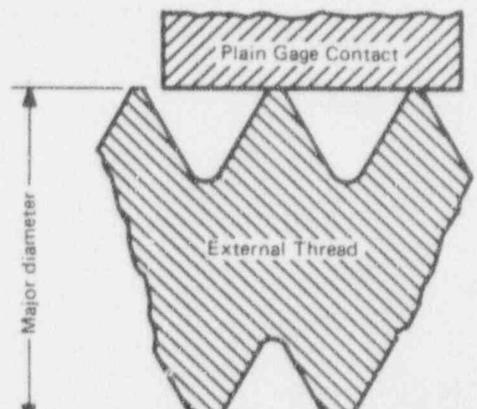
FIXED LIMIT GAGING



PLAIN DIAMETER GAGE — MAX.-MIN. MAJOR DIAMETER LIMIT

Gages 3.1(a), 3.1(b), 3.2, 3.4

INDICATING GAGING

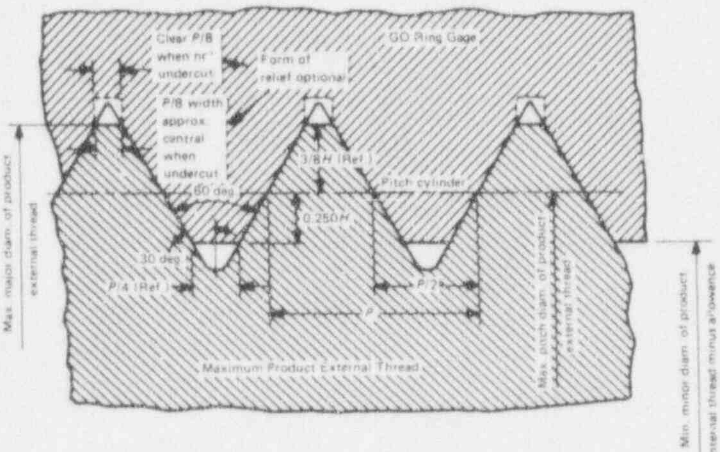


INDICATING PLAIN DIAMETER GAGE — MAX.-MIN. MAJOR DIAMETER LIMIT AND SIZE

Gages 5.1, 14

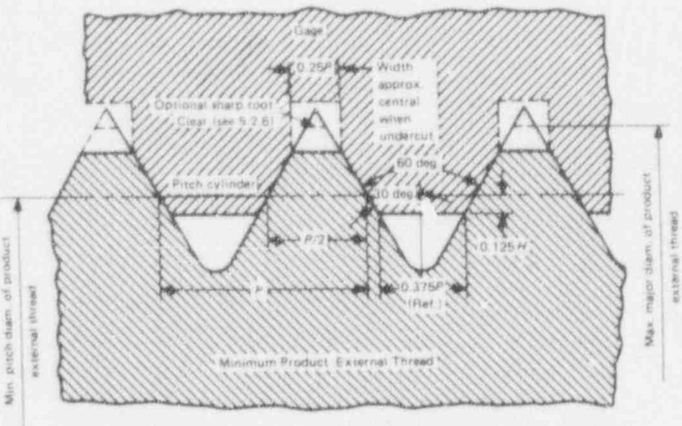
ANSI/ASME B1.3M - 1986 SYSTEM 21
GAGING CONFIGURATIONS FOR EXTERNAL THREADS FROM ANSI/ASME B1.2 - 1983 (Continued)

FIXED LIMIT GAGING



MAXIMUM-MATERIAL GO FUNCTIONAL LIMIT

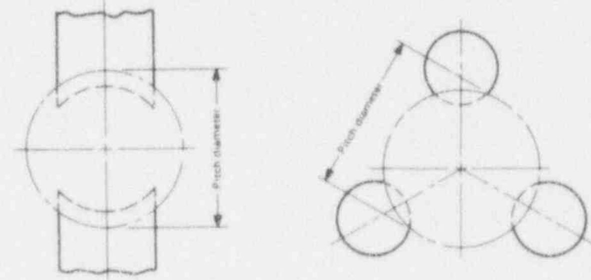
Gages 1.1, 2.1, 2.3

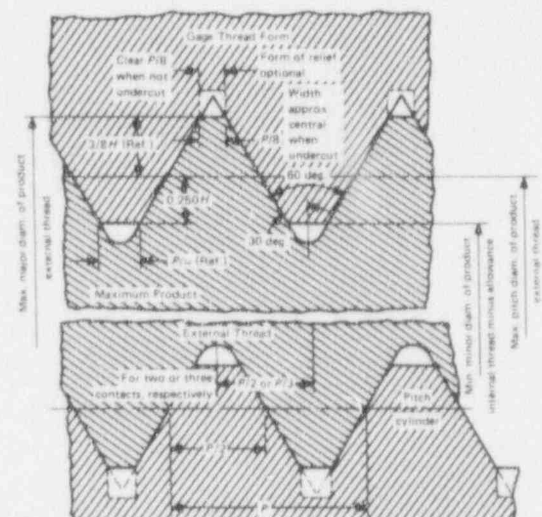


NOT GO (LO) FUNCTIONAL DIAMETER LIMIT

Gages 1.2, 2.2, 2.4

INDICATING GAGING





INDICATING THREAD GAGES — MAXIMUM-MATERIAL GO FUNCTIONAL DIAMETER LIMIT AND SIZE

Gages 4.1, 4.3

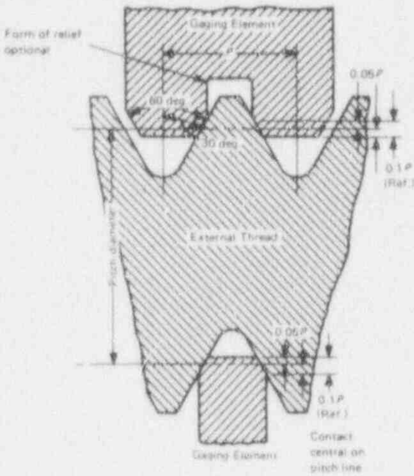
SYSTEM 22 (Recommended for Class 3A only)
GAGING CONFIGURATIONS FOR EXTERNAL THREADS FROM ANSI/ASME B1.2 - 1983

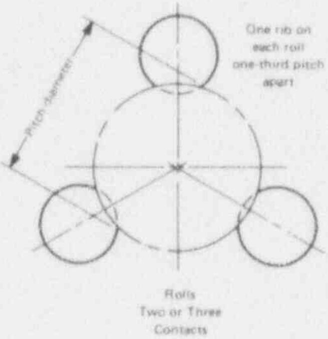
MAJOR DIAMETER — SAME AS SYSTEM 21
FUNCTIONAL PITCH DIAMETER — SAME AS SYSTEM 21

ROOT RADIUS

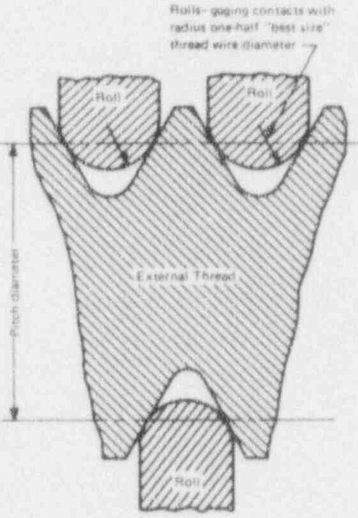
This characteristic is to be measured on an optical comparator or profile tracer gages 9, 10.

SINGLE ELEMENT PITCH DIAMETER





OR optional design



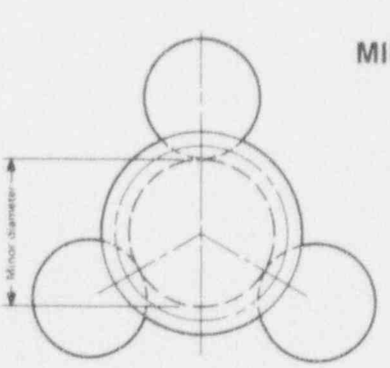
INDICATING THREAD GAGES — MINIMUM-MATERIAL PITCH DIAMETER LIMIT AND SIZE — CONE AND VEE

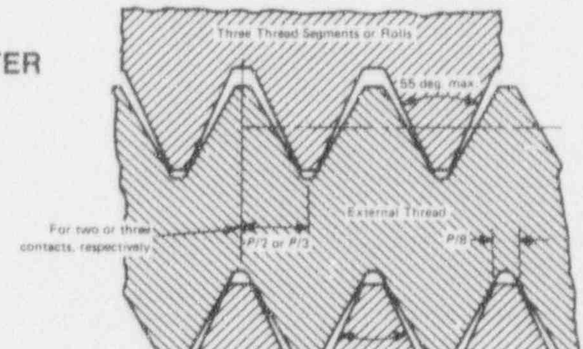
Gages 2.5 (fixed limit)
4.5, 7 (indicating)

INDICATING THREAD GAGES — MINIMUM-MATERIAL THREAD GROOVE DIAMETER LIMIT AND SIZE

Gages 2.6 (fixed limit)
4.6, 8 (indicating)

MINOR DIAMETER



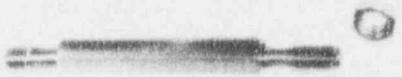


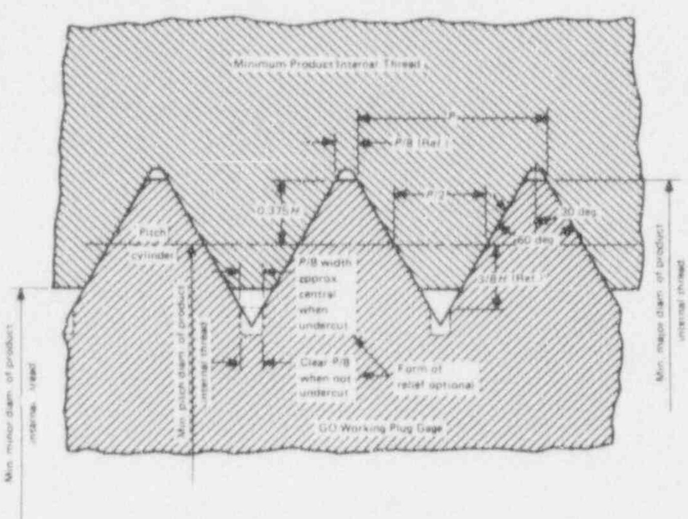
INDICATING DIAMETER GAGES — MAX.-MIN. MINOR DIAMETER LIMIT AND SIZE

Gages 3.3, 3.5 (fixed limit)
5.2, 9 (indicating)

ANSI/ASME B1.3M - 1986 SYSTEM 21
GAGING CONFIGURATIONS FOR INTERNAL THREADS
FROM ANSI/ASME B1.2 - 1983

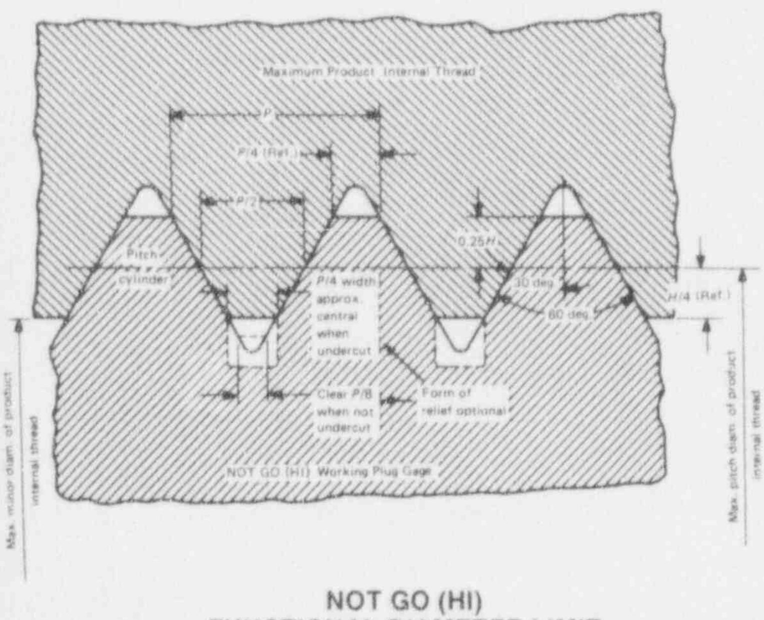
FIXED LIMIT GAGING





MAXIMUM-MATERIAL GO FUNCTIONAL LIMIT

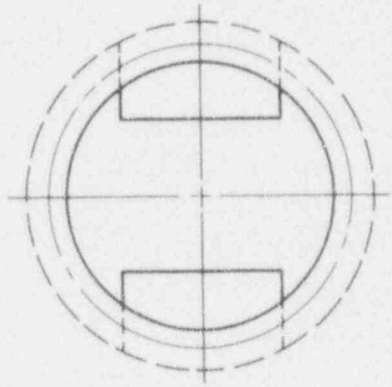
Gages 1.1, 1.3, 2.1, 2.3

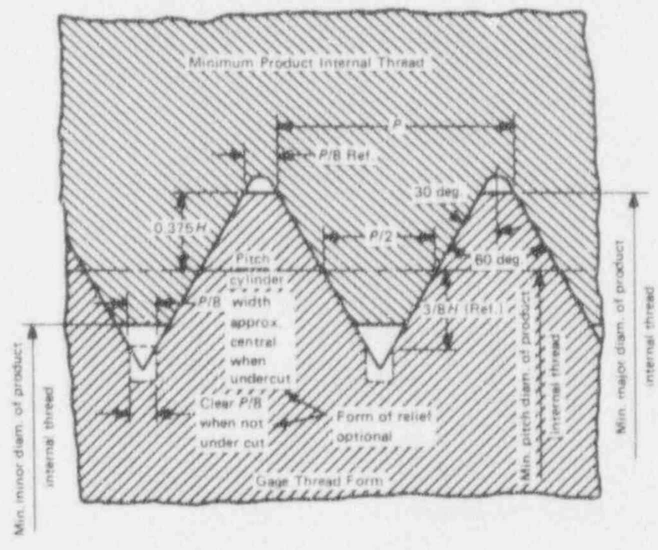


NOT GO (HI)
FUNCTIONAL DIAMETER LIMIT

Gages 1.2, 2.2, 2.4

INDICATING GAGING



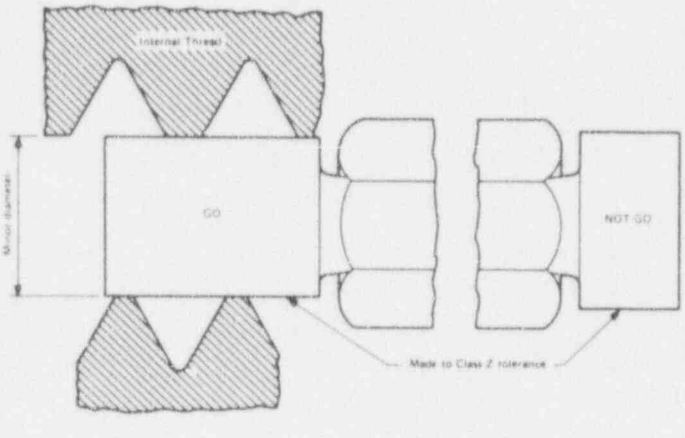


INDICATING THREAD GAGES —
MAXIMUM-MATERIAL GO FUNCTIONAL
DIAMETER LIMIT AND SIZE

Gages 4.1, 4.3

ANSI/ASME B1.3M - 1986 SYSTEM 21
GAGING CONFIGURATIONS FOR INTERNAL THREADS FROM ANSI/ASME B1.2 - 1983 (Continued)

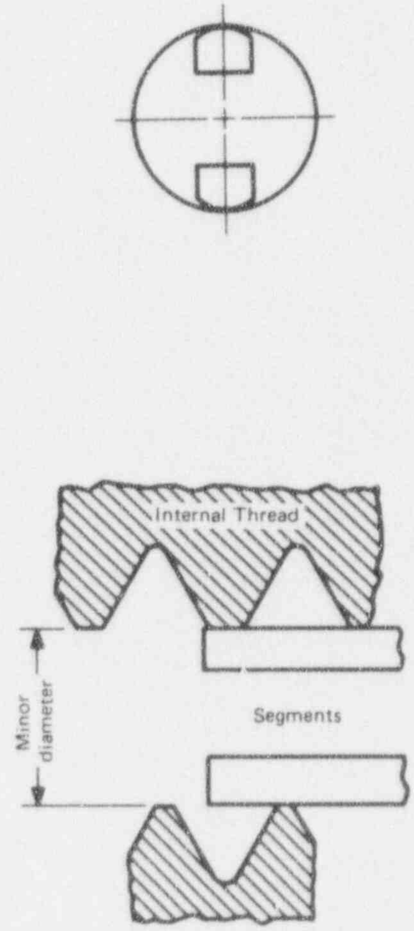
FIXED LIMIT GAGING



MINOR DIAMETER LIMIT — CYLINDRICAL PLUG GAGES

Gages 1.3, 3.1(a)
3.1(b), 3.3, 3.5

INDICATING GAGING



INDICATING PLAIN DIAMETER GAGES — MAX.-MIN. MINOR DIAMETER LIMIT AND SIZE

Gage 5.2

- NOTES -

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