JULY 2019

TECH SHEET

PEM® REF/ AXIAL THREAD CLEARANCE

SUBJECT: METHOD FOR PROVIDING ADEQUATE AXIAL THREAD CLEARANCE

In our long history of working with customers in the application of our self-clinching nuts, PennEngineering has seen numerous instances of thread interference preventing proper clamp load when the mating screw is tightened. If the total joint thickness is not sufficiently larger than the sum of the unthreaded length of the screw and the clinch nut shank length, then there may be interference between the incomplete run-out thread under the screw head and the thread in the shank of the clinch nut. The torsional strength of this interference may exceed the specified tightening torque and stop the tightening process prematurely. When this happens little or no preload is developed in the joint and the joint likely will not perform as intended. Although this type of problem is most common with thin panels and flat head screws installed flush, it is good practice to always verify there is adequate thread clearance using the methodology in this Techsheet.

As with any design verification, tolerances must be considered and worst case dimensions must be assumed. Considering first the simpler case of a non-countersunk screw head as shown in **Figure 1**, worst case dimensions are as follows:

- Panel 1 (panel the fastener is clinched into) thickness at minimum
- Panel 2 (attached panel or panels) thickness at minimum
- Clinch nut shank length at catalog maximum
- Mating screw unthreaded length at maximum

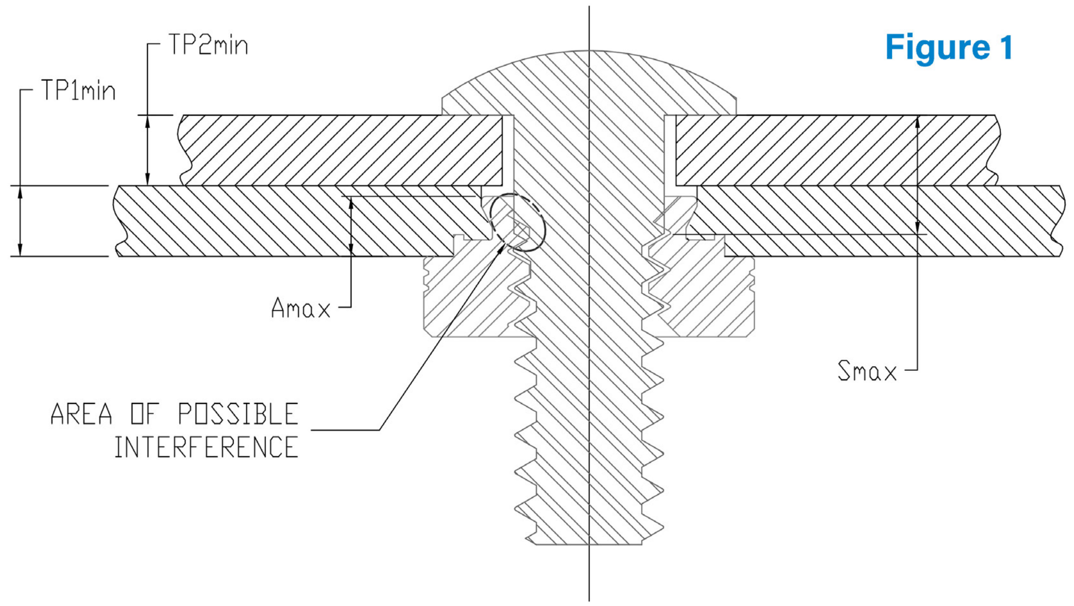

Figure 1

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For adequate tightening allowance, we recommend a thread clearance of one quarter thread pitch. Values of one-quarter pitch are given in **Table I** (on page 4) for common sizes of self-clinching nuts offered by PennEngineering. Thread clearance can be expressed by the following equation.

Equation [1]

$TC = TP1MIN + TP2_{MIN} - A_{MAX} - S_{MAX}$

Where: TC is the thread clearance

$TP1_{MIN}$ is the minimum thickness of the panel the nut is installed into

$TP2_{MIN}$ is the minimum thickness of the attached panel(s)

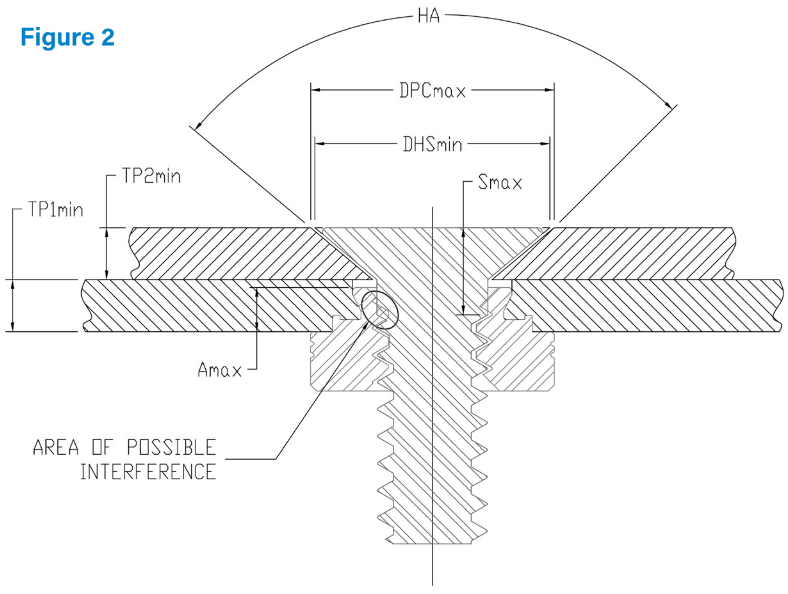
A_{MAX} is the maximum length of the clinch nut shank from the catalog bulletin

S_{MAX} is the maximum unthreaded length under the screw head from the screw supplier

Considering next the case of a countersunk screw as shown in **Figure 2**, three additional dimensions need to be considered:

- Nominal screw head included angle (typically either 82° or 100° for unified and 90° for metric)
- Minimum screw head diameter to sharp theoretical corners
- Maximum countersink diameter in panel 2

Figure 2



It is assumed that the countersink angle in the panel matches the screw head angle. Angle tolerances are not included in this analysis, but may be if known. It is also important to note that the equation below uses the screw head diameter to sharp theoretical corners. **Appendix A** shows how to calculate the minimum diameter to sharp theoretical corners from the information given in manufacturer's publications for 82° socket screw products and in industry standards for other flat head screws. Also note that the maximum unthreaded length is from the top surface of the screw head.

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Appendix B shows how to calculate the maximum unthreaded length from the information given in manufacturer's publications for 82° socket screw products and in industry standards for other flat head screws. Similar logic should be applied to other countersunk head screws.

Equation [2]

$TC = TP1_{MIN} + TP2_{MIN} - A_{MAX} - S_{MAX} - \{[(DPC_{MAX}-DHS_{MIN})/2]/\tan(HA/2)\}$

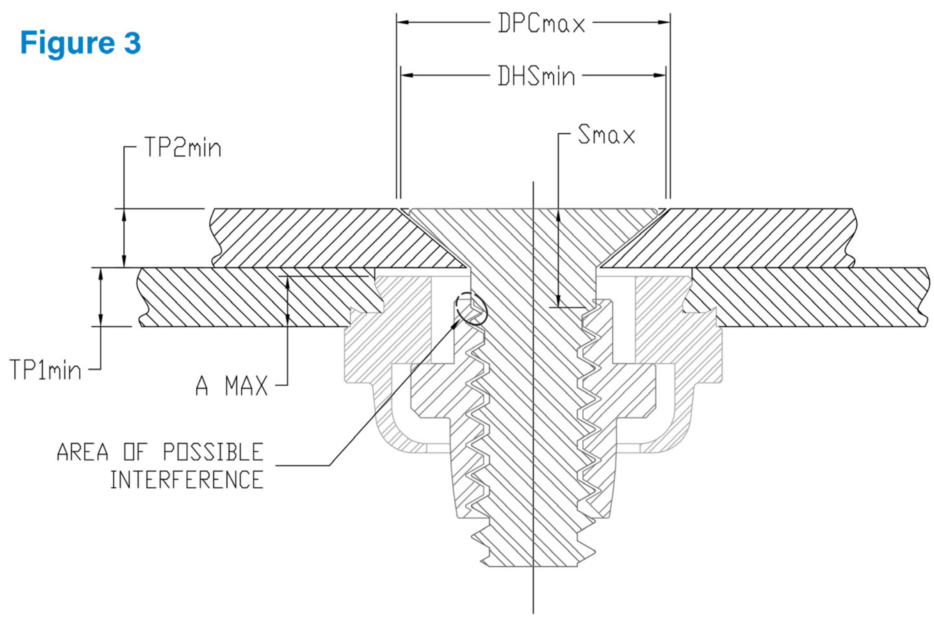
Where: TC is the thread clearance

- $TP1_{MIN}$ is the minimum thickness of the panel the nut is installed into
- $TP2_{MIN}$ is the minimum thickness of the attached panel(s)
- A_{MAX} is the maximum length of the clinch nut shank from the catalog bulletin
- S_{MAX}X is the maximum unthreaded length under the screw head from the screw supplier
- DPC_{MAX} is the maximum diameter of the panel countersink
- DHS_{MIN} is the minimum head diameter to sharp theoretical corners
- HA is the nominal included angle of the screw head and panel countersink

To verify any given design, calculate the thread clearance, TC using either **Equation 1** or **Equation 2** as applicable and compare it to the one quarter pitch value in **Table I** (on page 4). Unified thread sizes should use inch dimensions and metric thread sizes should use millimeter dimensions. If the thread clearance is greater than or equal to one quarter pitch, there should be no issues with thread interference preventing clamp load when the mating screw is tightened. If it is less than one quarter pitch, there could be an issue and the dimensions and tolerance should be revised to yield a thread clearance of one quarter pitch or greater.

Note that in some cases **Equation 1** and **Equation 2** may evaluate to a negative number. This means that there will actually be thread interference before the screw head contacts panel 2 when all dimensions are at the worst case as described above. AS, AC, A4, LAS, LAC, and LA4 self-clinching floating fasteners are a special case regarding the catalog AMAX dimension. If a -2 assembly is used, the -1 AMAX should be used because both assemblies use the same threaded insert and therefore the -1 AMAX is also applicable to -2 shank length assemblies. A cross section of a joint using a floating fastener assembly and a flat head screw is shown in **Figure 3**.

Figure 3



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The methodology above is conservative in that it does not consider the countersink in the shank end of the self-clinching nut. If you are having difficulty achieving adequate thread clearance, contact Techsupport@pemnet.com for details on the countersink of a given part number. It may also be necessary to contact them for situations not addressed in this general publication.

Table 1

Minimum Axial Thread Clearance for Selected Thread Sizes

Unified Thread Sizes				Metric Thread Sizes		
Common Designation	Alternate Designation	Min Axial Thread Clearance, inch	Two Pitches, inch (see Appendix B)	Designation	Min Axial Thread Clearance, mm	Two Pitches, mm (see Appendix B)
# 0 - 80	.060 - 80	0.003	0.025	M1 x 0.25 (or S1)	0.06	0.50
# 1 - 64	.073 - 64	0.004	0.031	M1.2 x 0.25 (or S1.2)	0.06	0.50
# 1 - 72	.073 - 72	0.003	0.028	M1.4 x 0.3 (or S1.4)	0.08	0.60
# 2 - 56	.086 - 56	0.004	0.036	M1.6 x 0.35	0.09	0.70
# 2 - 64	.086 - 64	0.004	0.031	M2 x 0.4	0.10	0.80
# 3 - 48	.099 - 48	0.005	0.042	M2.5 x 0.45	0.11	0.90
# 3 - 56	.099 - 56	0.004	0.036	M3 x 0.5	0.13	1.00
# 4 - 40	.112 - 40	0.006	0.050	M3.5 x 0.6	0.15	1.20
# 4 - 48	.112 - 48	0.005	0.042	M4 x 0.7	0.18	1.40
# 5 - 40	.125 - 40	0.006	0.050	M5 x 0.8	0.20	1.60
# 5 - 44	.125 - 44	0.006	0.045	M6 x 1	0.25	2.00
# 6 - 32	.138 - 32	0.008	0.063	M8 x 1.25	0.31	2.50
# 6 - 40	.138 - 40	0.006	0.050	M8 x 1	0.25	2.00
# 8 - 32	.164 - 32	0.008	0.063	M10 x 1.5	0.38	3.00
# 8 - 36	.164 - 36	0.007	0.056	M10 x 1.25	0.31	2.50
# 10 - 24	.190 - 24	0.010	0.083	M10 x 1	0.25	2.00
# 10 - 32	.190 - 32	0.008	0.063	M12 x 1.75	0.44	3.50
# 12 - 24	.216 - 24	0.010	0.083	M14 x 2	0.50	4.00
# 12 - 28	.216 - 28	0.009	0.071	M16 x 2	0.50	4.00
1/4 - 20	.2500 - 20	0.013	0.100			
1/4 - 28	.2500 - 28	0.009	0.071			
5/16 - 18	.3125 - 18	0.014	0.111			
5/16 - 24	.3125 - 24	0.010	0.083			
3/8 - 16	.3750 - 16	0.016	0.125			
3/8 - 24	.3750 - 24	0.010	0.083			
7/16 -14	.4375 - 14	0.018	0.143			
7/16 - 20	.4375 - 20	0.013	0.100			
1/2 - 13	.5000 - 13	0.019	0.154			
1/2 - 20	.5000 - 20	0.013	0.100			
5/8 -11	.6250 -11	0.023	0.182			
5/8 - 18	.6250 - 18	0.014	0.111			
3/4 - 10	.7500 - 10	0.025	0.200			
3/4 - 16	.7500 - 16	0.016	0.125			

Note: Minimum axial thread clearance is equal to 0.25 x P (pitch) or one quarter pitch in all cases

Appendix A

Calculating Minimum Screw Head Diameter to Sharp Theoretical Corners

For the methodology used in this Techsheet calculating the minimum head diameter to sharp theoretical corners is required. This can be done by using three pieces of information which are typically given in the standards for flat head screws. These three pieces of information are:

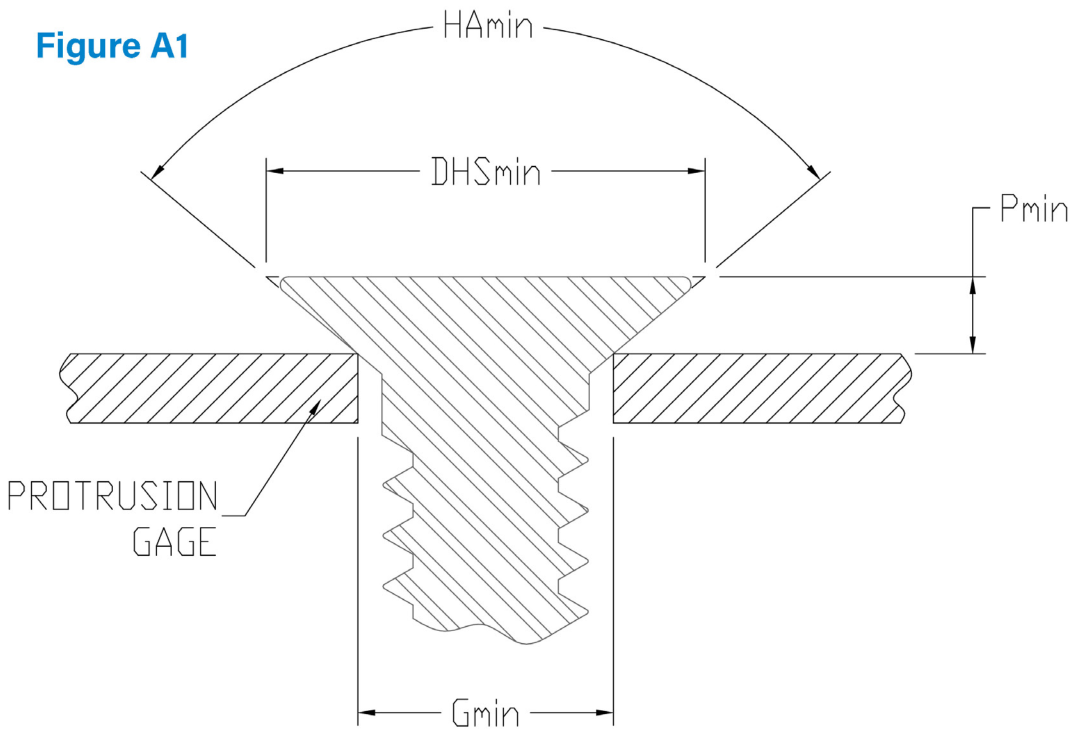
1. The minimum diameter of the protrusion gage. This diameter is typically denoted “G” for Gage diameter and may have a .001” tolerance or be given as a nominal value only. If tolerance is given use the minimum value, otherwise use the nominal value given.
2. The minimum protrusion value which is the minimum the head must protrude above the surface of the gage. This value is always given as a range, so always use the minimum. It may be denoted as “P” for protrusion or by “F” in some standards.
3. The minimum included angle of the screw head. This is usually 80° for 82° screw heads, 90° for 90° screw heads, and 99° for 100° screw heads.

Examples of standards containing the above information include:

- ASME B18.6.3 for unified flat head machine screws
- ISO 7221 for metric flat head machine screws
- ASME B18.3 for unified flat head socket screws
- ISO 10642 for metric flat head socket screws

From these three values, the minimum head diameter to sharp theoretical corners can be calculated using the equation below. The geometry is shown in **Figure A1**.

Figure A1



Equation [A1]

$DHS_{MIN} = G_{MIN} + 2 \times [P_{MIN} \times \tan(HA_{MIN}/2)]$

Where: DHS_{MIN} is the minimum head diameter to sharp theoretical corners G_{MIN} is the diameter of the protrusion gage per item 1 above P_{MIN} is the minimum protrusion for the subject screw per item 2 above HA_{MIN} is the minimum included angle of the screw per item 3 above

Note: Although some metric standards use a penetration gage with a tapered hole instead of a straight sided hole used for unified sizes, the logic above will work as long as the protrusion value used is at or above (as screws are oriented in **Figures 1, 2 and 3**) the gage diameter used. This may require reducing the gage diameter by twice (for 90° screws) the protrusion tolerance and using this new gage diameter and zero protrusion in **Equation [A1]**.

Appendix B

Determining Maximum Unthreaded Screw Length

For the methodology used in this Techsheet it is necessary to determine the maximum unthreaded length of the subject screw. The preferred method is to have the screw supplier provide the information. For many types of screws this is not a published dimension, the screw supplier will need to be contacted. Customers should ask for the maximum unthreaded length measured from the top of the head surface for flat head screws and from the underside of the head for all other head types.

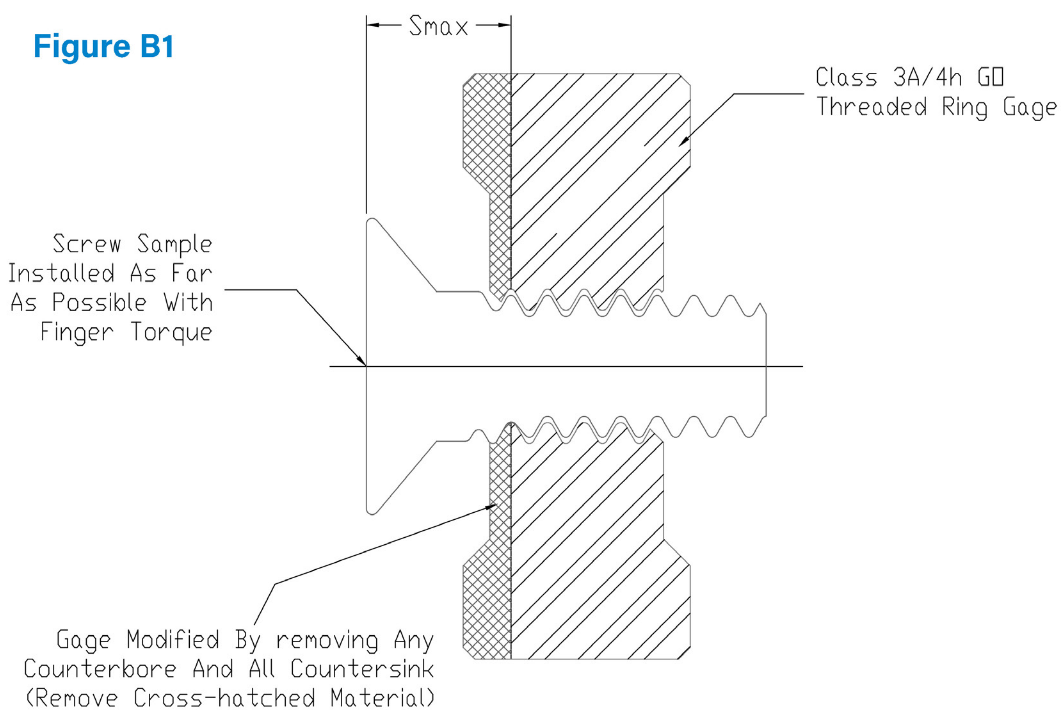
Another method is to get the information from the applicable standard. In some standards, this length is defined rather straightforwardly as the symbol L_{GB} Max (representing length of grip for bolt), but that is applicable only to longer screw lengths which are not fully threaded. These longer screw lengths would typically not be used in joints for which adequate axial thread clearance is an issue. For shorter screw lengths, the max unthreaded screw length is not defined as straightforwardly. Some flat head screw standards specify a max unthreaded length as two thread pitches plus the head height. The problem is that for this purpose the head height of flat head screws is to be the distance from the top of the head to the intersection of the under-head angle and the nominal major diameter. When the standard uses this definition of maximum unthreaded length, a very close approximation will result from using the reference head height from the applicable standard or screw suppliers catalog information and adding 2 thread pitches. Values of two thread pitches are included in **Table I** (on page 4) for convenience. Do not use this method unless you have information verifying that the specification is two pitches plus the head height for flat head screws and two pitches from under the head for other head types.

A third method can be used when the applicable standard is unknown or unavailable, but physical samples of the screws are available. This method involves measuring the unthreaded length on 10 samples and then doing some statistical analysis to account for variation within the lot and then making a broad assumption to account for lot to lot variation. Actual unthreaded screw length can be measured using one of the following two methods.

Modified Go Threaded Ring Gage Method – This method requires a Go threaded ring gage with tolerance class 3A for unified and 4h (or any other class ending in h) for metric. Class 2A or 6g Go ring gages can also be used, but may be conservative resulting in slightly longer unthreaded length values. The ring gage must be modified to have the counterbore removed and all of the thread countersink removed. These modifications can both be accomplished by removing the correct amount of metal from one face of the gage. This is typically accomplished by surface grinding. This setup is shown in **Figure B1**. The modified gage is used as follows:

1. Insert the screw into the gage from the modified side as far as it goes with light finger torque
2. Measure the unthreaded length directly
    a. For non-flat head screw measure from the gage face to the underside of the screw head using inside calibers or optical comparator
    b. For flat head screws measure from the gage face to the top of the screw head using a depth micrometer or optical comparator.

Figure B1



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Optical Comparator Method – An optical comparator with a minimum of 20 X magnification should be used. See **Figure B2** for definition of terms used below. Proceed as follows for each sample:

1. Measure the actual minor diameter and divide by 2 to get half the actual minor
2. Look up or calculate (Nominal Major – 1.08253 x Pitch) the basic minor and divide by 2 to get half the basic minor
3. Add half the actual minor and half the basic minor together
4. Rotate the part as needed so that the distance from the actual minor to the increasing (from thread run-out) minor on the opposite side is equal to the value found in step 3
5. Measure the unthreaded length as the distance from the top of the screw head (or underside of the head as applicable based on head type) to the intersection of the increasing minor found in step 4 and the thread flank farthest from the screw head.

After the unthreaded length on 10 samples has been measured in one of the above ways, calculate the mean and sample standard deviation of the 10 values. Add three standard deviations to the mean. This value represents the highest expected value in that lot. Next multiple by 1.2 for worst case assumptions that 1) the tested lot had the lowest unthreaded length of all lots and 2) that lot to lot variation is ±10%.

Figure B2