

Flat Washer Design & Application Considerations (Inch-Size)

Introduction: Consider the lowly flat washer. It does so many good things for us that it is overlooked and trivialized in many ways. This monograph sets forth the primary mechanical tasks assigned to this piece of hardware. The focus here is on simple applications of inch-sized flat washers as there are still too many incompletely established portions of the standards for metric flat washers. Cataloging all the variations dating to the separate *national* systems would make this document too long and complex for a simple monograph.

General Application: There are four main reasons to incorporate a washer into a mechanical design: (1) to provide a surface with a consistent smoothness and coefficient of friction to aid in torquing screws or nuts to even tension; (2) to have a sacrificial surface to protect the actual part from deformation or digging due to tightening of the harder screw or nuts over softer part material; (3) to increase the area of compression in softer/weaker materials to allow for an adequate compressive force balance between the tension of the bolt and the compression of the material being clamped; or (4) to provide a galvanic layer to protect the assembly. Structural components often use a special flat washer with an elastomeric insert indicator to qualify torque. This is an application beyond the scope of this monograph.

Nomenclature & Dimensions: The most commonly available flat washer sizes are defined under the ASTM/ ASME/ANSI specification B18.22.1-1965(R2003) and are generally referred to as: SAE (ANSI Type A Narrow); USS (ANSI Type A Wide); and Fender (which is based on the ANSI Type B Wide series of washer). The Type, Width, and Size define the rest of the dimensions. Additionally, there are: National Aerospace Standard (NAS); Air Force-Navy (AN); and Military Standard (MS) washers for flight structure and military applications as well as non-standard, but commercially available washers.

ANSI Type A Narrow (SAE)				ANSI Type A Wide (USS)			
Size:	ID:	OD:	Thick:	Size:	ID:	OD:	Thick:
No 1	.078	.188	.020				
No 2	.094	.250	.020				
No 4	.125	.313	.032				
No 6	.156	.375	.049				
No 8	.188	.438	.049				
No 10	.219	.500	.049				
No 12	.250	.563	.065				
.250	.281	.625	.065	.250	.313	.734	.065
.313	.344	.688	.065	.313	.375	.875	.083
.375	.406	.813	.065	.375	.438	1.000	.083
.438	.469	.938	.065	.438	.500	1.250	.083
.500	.531	1.063	.095	.500	.563	1.375	.109
.563	.594	1.156	.095	.563	.625	1.469	.109
.625	.656	1.313	.095	.625	.688	1.750	.134
.750	.813	1.469	.134	.750	.813	2.000	.148
.875	.938	1.750	.134	.875	.938	2.250	.165
1.000	1.063	2.000	.134	1.000	1.063	2.500	.165
1.125	1.250	2.250	.134	1.125	1.250	2.750	.165
1.250	1.375	2.500	.165	1.250	1.375	3.000	.165
1.375	1.500	2.750	.165	1.375	1.500	3.250	.180
1.500	1.625	3.000	.165	1.500	1.625	3.750	.180

Table 1: ANSI B18.22.1 Type A Washer Dimensions

The table above shows standard sizes for ANSI Type A washers normally sold under the SAE and USS general classifications. The shaded areas show sizes not normally stocked and available only as special order products. They are usually available in plated carbon steel, stainless steel, and hardened and plated alloy steel. Tolerances and allowances on the basic dimensions may be found in *Machinery's Handbook* and other standard references.

ANSI Type B Narrow				ANSI Type B Regular				ANSI Type B Wide			
Size:	ID:	OD:	Thick:	Size:	ID:	OD:	Thick:	Size:	ID:	OD:	Thick:
No 0	.068	.125	.025	No 0	.068	.188	.025	No 0	.068	.250	.025
No 1	.084	.156	.025	No 1	.084	.219	.025	No 1	.084	.281	.032
No 2	.094	.188	.025	No 2	.094	.250	.032	No 2	.094	.344	.032
No 3	.109	.219	.025	No 3	.109	.312	.032	No 3	.109	.406	.040
No 4	.125	.250	.032	No 4	.125	.375	.040	No 4	.125	.438	.040
No 5	.141	.281	.032	No 5	.141	.406	.040	No 5	.141	.500	.040
No 6	.156	.312	.032	No 6	.156	.438	.040	No 6	.156	.562	.040
No 8	.188	.375	.040	No 8	.188	.500	.040	No 8	.188	.625	.063
No 10	.203	.406	.040	No 10	.203	.562	.040	No 10	.203	.734	.063
No 12	.234	.438	.040	No 12	.234	.625	.063	No 12	.234	.875	.063
.250	.281	.500	.063	.250	.281	.734	.063	.250	.281	1.000	.063
.313	.344	.625	.063	.313	.344	.875	.063	.313	.344	1.125	.063
.375	.406	.734	.063	.375	.406	1.000	.063	.375	.406	1.250	.100
.438	.469	.875	.063	.438	.469	1.125	.063	.438	.469	1.469	.100
.500	.531	1.000	.063	.500	.531	1.250	.100	.500	.531	1.750	.100
.563	.594	1.125	.063	.563	.594	1.469	.100	.563	.594	2.000	.100
.625	.656	1.250	.100	.625	.656	1.750	.100	.625	.656	2.250	.160
.750	.812	1.375	.100	.750	.812	2.000	.100	.750	.812	2.500	.160
.875	.938	1.469	.100	.875	.938	2.250	.160	.875	.938	2.750	.160
1.000	1.063	1.750	.100	1.000	1.063	2.500	.160	1.000	1.063	3.000	.160
1.125	1.188	2.000	.100	1.125	1.188	2.750	.160	1.125	1.188	3.250	.160
1.250	1.312	2.250	.160	1.250	1.312	3.000	.160	1.250	1.312	3.500	.250
1.375	1.438	2.500	.160	1.375	1.438	3.250	.160	1.375	1.438	3.750	.250
1.500	1.562	2.750	.160	1.500	1.562	3.500	.250	1.500	1.562	4.000	.250
1.625	1.750	3.000	.160	1.625	1.750	3.750	.250	1.625	1.750	4.250	.250
1.750	1.875	3.250	.160	1.750	1.875	4.000	.250	1.750	1.875	4.500	.250
1.875	2.000	3.500	.250	1.875	2.000	4.250	.250	1.875	2.000	4.750	.250
2.000	2.125	3.750	.250	2.000	2.125	4.500	.250	2.000	2.125	5.000	.250

Table 2: ANSI B18.22.1 Type B Washer Dimensions

The table above shows standard sizes for ANSI Type B washers. The Wide class is the same as the most commonly available commercial Fender washers. They are commonly available in a broad range of materials and finishes from such specialty suppliers as Boker's, Inc. (3104 Snelling Ave, Minneapolis, MN 55406, 612.729.9362, <http://www.bokers.com/>) or Fastenal (<http://www.fastenal.com/web/home.ex>) and the like to cite only two. Tolerances and allowances on the basic dimensions may be found in *Machinery's Handbook* and other standard references.

Materials & Finishes: Flat washers are commonly available in low carbon steel (typically C1020/C1015) finished with a zinc plating. Other materials and finishes are available, but must be separately specified. Stainless steel in a passivated finish is the second most common material and finish for flat washers. Check with your supplier for more details.

Installation Considerations: Flat washers are commonly punched out of sheet or strip steel and only slightly finished. Normal (No 3) edges with deformed material, but no hanging burrs are the basic die-edge supplied. The punched-edge will have a slight radius. Re-finished die-faces where the deformed material is mechanically reduced are an option if you are ordering a large enough quantity of washers or have a specific fatigue requirement to justify the processing expense. In any case, the usual practice is to place the die-face (which has what is left of the cutting burr on it) of the washer should face **away** from the fastener head when it is installed.

When a washer is used to provide a consistent torque or protection against a scratched surface, the flat washer is located beneath the element to be tightened. In the case of a screw which is retained by a threaded hole, that element is the screw head. In the case of a bolt which passes through parts to be retained by a nut, that element is the nut. A washer placed under the head of a bolt only makes sense if the purpose is to distribute the clamp-load across a broader area.

Application; Consistent Smoothness and Coefficient of Friction: ANSI Type A washers are designed for this application. Narrow (SAE) type have a tighter fit to the major diameter of the screw or bolt than Wide (USS) type. A dab of lubricant placed on the washer or nut at assembly can improve the consistency of friction even more. Addition of a low-friction plastic (polyethylene or acetal) washer serves the same purpose. The washer in this type of application would be placed under a screw's head or a nut in the case of a bolt. A washer in this application needs only to be as wide as the bearing surface of the fastener.

Application; Hardness to Reduce Surface Damage: ANSI Type A washers usually fit this need best. Hardened washers that are not part of the standard, but are generally available will fill in when standard washers will not service the need. The washer in this type of application would be placed under a screw's head or a nut in the case of a bolt. A washer in this application needs only to be as wide as the bearing surface of the fastener.

Application; Increase Area to Balance Compressive Load: When the material being held by a screw or bolt (most commonly a bolt) has a significantly lower compressive strength than the tensile strength of the screw or bolt, an ANSI Type B washer can equalize areas to balance the stress. If we consider a ½ inch bolt (with nut) passing through Douglas Fir beam which has a compressive strength of 7100 psi parallel to the grain, we can see that full yield on a Grade 2 .5000-13UNC bolt is 8800 lbs. Thus we need to have (8800 lbs/7100 psi =) 1.24 in² of washer bearing to not crush the beam. If the ID of the washer is .562 nominal inches, then we need an OD of (at least) $[(4A/\pi) + ID^2]^{1/2}$ or 1.38 inches. An ANSI Type B Regular washer has an OD of 1.250 inches and a Wide washer has an OD of 1.750 inches. An ANSI Type B Wide standard washer would be selected. In this case, such a washer would be placed under **both** the bolt head and the nut. Use of a lock-washer or other mechanical locking feature should be employed because the bolt **may not** be fully preloaded to yield and can have a tendency to loosen.

Application; Provide Galvanic Protection to the Joint: The details of this application are beyond the scope of the monograph. The basic idea is that a flat washer of appropriate material and finish may be used as either a sacrificial anode or a conduction path to a sacrificial anode by design. This is a topic for advanced materials (chemistry) science rather than an introductory mechanical text.

Other Standards and Non-Standard Flat Washers: As noted above, aerospace and military design have their own standards. The most commonly used of these are: AN960 which has been redefined under the NAS1149 specification. Many of these standards, filed under the previous military identifications may be found at <https://assist.daps.dla.mil/quicksearch/>. Additionally as noted above, Boker's, Inc. and Fastenal – and other suppliers – gladly supply information on washers that are readily available, but not covered by formal standards. Hardened and ground flat washers are a standard tooling item. They are readily available from tooling suppliers such as Carr-Lane Manufacturing (4200 Carr Lane Ct, St. Louis, MO 63319, 312.647.3200, <http://www.carrlane.com/>) and others.