

## SECTION 6. USE OF WASHERS

### 6.1. Snug-Tightened Joints

Washers are not required in snug-tightened joints, except as required in Sections 6.1.1 and 6.1.2.

- 6.1.1. Sloping Surfaces: When the outer face of the *joint* has a slope that is greater than 1:20 with respect to a plane that is normal to the bolt axis, an ASTM F436 beveled washer shall be used to compensate for the lack of parallelism.
- 6.1.2. Slotted Hole: When a slotted hole occurs in an outer ply, an ASTM F436 washer or  $\frac{5}{16}$  in. thick common plate washer shall be used as required to completely cover the hole.

### 6.2. Pretensioned Joints and Slip-Critical Joints

Washers are not required in *pretensioned joints* and *slip-critical joints*, except as required in Sections 6.1.1, 6.1.2, 6.2.1, 6.2.2, 6.2.3, 6.2.4 and 6.2.5.

- 6.2.1. Specified Minimum Yield Strength of Connected Material Less Than 40 ksi: When ASTM A490 or F2280 bolts are pretensioned in connected material of specified minimum yield strength less than 40 ksi, ASTM F436 washers shall be used under both the bolt head and nut, except that a washer is not needed under the head of an ASTM F2280 round head twist-off bolt.
- 6.2.2. Calibrated Wrench Pretensioning: When the calibrated wrench pretensioning method is used, an ASTM F436 washer shall be used under the turned element.
- 6.2.3. Twist-Off-Type Tension-Control Bolt Pretensioning: When the twist-off-type tension-control bolt pretensioning method is used, an ASTM F436 washer shall be used under the nut as part of the *fastener assembly*.
- 6.2.4. Direct-Tension-Indicator Pretensioning: When the direct-tension-indicator pretensioning method is used, an ASTM F436 washer shall be used as follows:
  - (1) When the nut is turned and the direct tension indicator is located under the bolt head, an ASTM F436 washer shall be used under the nut;
  - (2) When the nut is turned and the direct tension indicator is located under the nut, an ASTM F436 washer shall be used between the nut and the direct tension indicator;
  - (3) When the bolt head is turned and the direct tension indicator is located under the nut, an ASTM F436 washer shall be used under the bolt head; and,

**Table 6.1. Washer Requirements for Pretensioned and Slip-Critical Bolted Joints with Oversized and Slotted Holes in the Outer Ply**

ASTM Designation	Nominal Bolt Diameter, $d_b$ , in.	Hole Type in Outer Ply		
		Oversized	Short-Slotted	Long-Slotted
A325 or F1852	$\frac{1}{2}$ - $1\frac{1}{2}$	ASTM F436 <sup>a</sup>		$\frac{5}{16}$ in. thick plate washer or continuous bar <sup>b,c</sup>
	$\leq 1$			
A490 or F2280	$> 1$	ASTM F436 with $\frac{5}{16}$ in. thickness <sup>a,b,d</sup>	ASTM F436 washer with either a $\frac{3}{8}$ in. thick plate washer or continuous bar <sup>b,c</sup>	

<sup>a</sup> This requirement shall not apply to heads of round head tension-control bolt assemblies that meet the requirements in Section 2.7 and provide a bearing circle diameter that meets the requirements of ASTM F1852 or F2280.

<sup>b</sup> Multiple washers with a combined thickness of  $\frac{5}{16}$  in. or larger do not satisfy this requirement.

<sup>c</sup> The plate washer or bar shall be of structural-grade steel material, but need not be hardened.

<sup>d</sup> Alternatively, a  $\frac{3}{8}$  in. thick plate washer and an ordinary thickness F436 washer may be used. The plate washer need not be hardened.

- (4) When the bolt head is turned and the direct tension indicator is located under the bolt head, an ASTM F436 washer shall be used between the bolt head and the direct tension indicator.

6.2.5. Oversized or Slotted Hole: When an oversized or slotted hole occurs in an outer ply, the washer requirements shall be as given in Table 6.1. The washer used shall be of sufficient size to completely cover the hole.

**Commentary:**

It is important that shop drawings and *connection* details clearly reflect the number and disposition of washers when they are required, especially the thick hardened washers or plate washers that are required for some slotted hole applications. The total thickness of washers in the *grip* affects the length of bolt that must be supplied and used.

The primary function of washers is to provide a hardened non-galling surface under the turned element, particularly for torque-based pretensioning methods such as the calibrated wrench pretensioning method and twist-off-type tension-control bolt pretensioning method. Circular flat washers that meet the requirements of ASTM F436 provide both a hardened non-galling surface and an increase in bearing area that is approximately 50 percent larger than that provided by a heavy-hex bolt head or nut.

However, tests have shown that washers of the standard  $\frac{5}{32}$  in. thickness have a minor influence on the pressure distribution of the induced bolt pretension. Furthermore, they showed that a larger thickness is required when ASTM A490 bolts are used with material that has a minimum specified yield strength that is less than 40 ksi. This is necessary to mitigate the effects of local yielding of the material in the vicinity of the contact area of the head and nut. The requirement for standard thickness hardened washers, when such washers are specified, is waived for alternative design fasteners that incorporate a bearing surface under the head of the same diameter as the hardened washer.

Heat-treated washers not less than  $\frac{5}{16}$  in. thick are required to cover oversized and short-slotted holes in external plies, when ASTM A490 or F2280 bolts of diameter larger than 1 in. are used, except per Table 6.1 footnote d. This was found necessary to distribute the high clamping pressure so as to prevent collapse of the hole perimeter and enable the development of the desired clamping force. Preliminary investigation has shown that a similar but less severe deformation occurs when oversized or slotted holes are in the interior plies. The reduction in clamping force may be offset by “keying,” which tends to increase the resistance to slip. These effects are accentuated in *joints* of thin plies. When long-slotted holes occur in an outer ply,  $\frac{3}{8}$  in. thick plate washers or continuous bars and one ASTM F436 washer are required in Table 6.1. This requirement can be satisfied with material of any structural grade. Alternatively, either of the following options can be used:

- (1) The use of material with  $F_y$  greater than 40 ksi will eliminate the need to also provide ASTM F436 washers in accordance with the requirements in Section 6.2.1 for ASTM A490 or F2280 bolts of any diameter; or,
- (2) Material with  $F_y$  equal to or less than 40 ksi can be used with ASTM F436 washers in accordance with the requirements in Section 6.2.1.

This specification previously required a washer under bolt heads with a bearing area smaller than that provided by an ASTM F436 washer. Tests indicate that the pretension achieved with a bolt having the minimum ASTM F1852 or F2280 bearing circle diameter is the same as that of a bolt with the larger bearing circle diameter equal to the size of an ASTM F436 washer, provided that the hole size meets the RCSC Specification limitations (Schnupp, 2003).