# Roundabouts

## A field guide to aircraft washers

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Behind every well-built airplane is an owner who understands the nuts and bolts of aircraft construction. Make that the nuts, bolts, and *washers* of aircraft construction.

Despite their backup-singer status in the composition of solid joints, washers play an important role in making sure what's bolted together stays together. If washers are improperly used, or not used at all, structural attachment points can wear excessively or prematurely fail—potentially at an inconvenient time for both you and your passengers. As a result—or a precaution—it's important to use the right washer for each job.

A typical installation includes one bolt, one nut, and one washer.

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The washer goes under the part that will be torqued, generally the nut. Most washers are cadmium-plated steel, although other materials are available, including stainless steel (for high-corrosive environments and denoted with a "C" after the size code), brass (nonconductive), and aluminum alloy (for aluminum bolts and nuts, or for fabric stitching on tube-and-rag airplanes). Nylon flat washers are also used for such applications as installing instruments.

First, an obligatory note on AN hardware. While aircraft parts and hardware store specials may look the same, they're not. AN hardware is hardened to withstand more than twice the pressure before breaking as run-of-the-mill bolts and nuts.

Face it, holding a deck onto the side of a house isn't the engineering challenge that holding the wings onto an airplane can be. Besides, even Friday-night dirt-track car-racing guys use AN hardware because they've figured out it's stronger.

As we were saying, there are three general types of washers you'll encounter in the assembly of your airplane: flat ones, locking ones, and special-purpose ones. Each is designed for a specific use, and by understanding what each does and how, you'll be able to make sense of little things that came in little plastic baggies with your kit.

## Flat Washers

AN960 flat washers and AN970 large-area washers provide a smooth bearing surface under hex nuts for tight structural connections. They prevent bolt heads from pulling through or otherwise damaging the parts you're connecting, they increase the tightness of a fastener and distribute the force of the bolt, and they can prevent friction or leaking.

When instructions or catalogs describe flat washers, they use its AN960 designation, plus a dash, and another series of numbers. That's the size code of the washer. For example, the AN960-10 fits a size 10 bolt or screw, and AN960-916 fits 9/16-inch hardware. If there's an L after the number, it's a "light" washer. Lights are half the thickness of normal-weight washers, or 0.032-inch thick for a size AN960-10L and larger, and 0.016-inch thick for washers size AN960-8L and smaller.

AN970 washers are sized a little differently. If you need to know specific inside or outside dimensions, check with your parts supplier or the *Standard Aviation Maintenance Handbook* for exact measurements. These large-area washers are placed under the head of the bolt and under the nut in wooden or composite assemblies to prevent the

base material from being crushed or cracked.

AN960 flat washers can also act as a spacer to adjust the height of a castellated nut to permit locking of the cotter pin, as a base for lock washers to prevent damage to the surface material, and as a shim under a bolt-nut assembly.

To determine if you need a spacer washer, look at the end of the bolt that's protruding from the bolt hole in the parts you're connecting. The grip portion of the bolt—the smooth section of the shank that doesn't have threads—is the part that's designed to carry the shear loads, and the shank has to be long enough that no more than one thread is still in the bolt hole.

If it doesn't pass the test, use a longer bolt—they come in 1/8-inch increments—and use washers to shim the length. Likewise, if your nut bottoms out on the last thread of the bolt before it tightens the joint up, add a washer or two to make the joint "thicker" so you can torque down on the nut. A maximum of three washers can be used as spacers.

## Lock Washers

There are two general categories of lock washers: split locks (or helical locks) and shakeproof lock washers.

AN935 split lock washers, also known by their military spec number MS35338, look like flat washers that have been cut with a set of snips. The ends are off-set, creating a strong spring force that pushes against the nut or bolt and the work piece to keep the nut from wiggling loose, and the upward and downward projections on the split allow the washer to grasp adjoining materials.

They're usually installed under the nut, and they're measured just like flat washers. The FAA recommends against using steel lock washers against an aluminum alloy nut or aluminum fitting because of unlike-metals corrosion problems.

AN936 shakeproof lock washers have sharp teeth that give special holding power by digging into the surfaces pressed against them. There are two main styles—internal teeth (the "A" style) and external teeth (the "B" style). The former looks like an angry donut, while the latter looks like a child's doodle of the sun.

Shakeproof lock washers are described with the AN936 designation, plus a dash, plus the letter A or B for the type, plus the code for the washer size. For example, AN936-A916 denotes a 9/16-inch internal-tooth washer. An A-type shakeproof lock washer is also known as MS35333, while the B-type goes by MS35335.

Shakeproof washers are designed with tabs deflected up and down and at an angle to provide a spring action. The tabs have a hardened cutting edge that retains the fastener under normal conditions. They withstand higher heat than other methods of safetying and are designed to be used in high-vibration situations.

As joints shake, the flexed teeth absorb vibration, making the grip tighter, and the twisted teeth compress as torque is applied to the bolt. The teeth, which want to return to their fully twisted position, push out on the bolt and nut with a strong spring action to maintain tension. Plus, the teeth bite into the work nut head and the flat washer to provide continuous resistance to the rotation in the direction of removal.

Mechanics recommend the internal style for applications where the finished appearance is a factor, or where there's a risk of snagging or scratching, because the washers are completely hidden under the bolt

or nut. External varieties are the preferred choice for most applications because they offer the greater area of contact between the nut and the work piece.

A word of caution: Shakeproof lock washer teeth can be crushed under normal torquing pressures, which makes the locking function ineffective, and the spring tabs of the washer bend and can lose their locking capability after their first use. Consequently, shakeproof lock washers, and all other safetying devices, should only be used once and discarded after.

As handy as they are, there are places where lock washers of either kind shouldn't be used, even once. These include any attachment where failure of the joint would cause a danger to passengers or the aircraft, where it would open the airframe to the airstream, where the washer itself is in the airstream or otherwise exposed to the elements, where it is subject to frequent removal, or where the washer doesn't have a flat washer underneath so that it can damage the underlying material. Best leave these applications to various types of locking nuts, castellated nuts, or other fasteners.

## Special Purpose Washers

You'll see a couple of other washer types in aircraft construction. Shaped a little like a sombrero, the tinnerman washer allows you to countersink screws for a low-profile appearance while still distributing the force of the joint around a wider ring of fragile material, such as window acrylic or composite wheelpants halves. They're used with 100-degree flat-head screws such as MS24693 and MS24694.

AN975 taper pin washers are installed with AN386 threaded taper pins, and safetied with shear nuts or self-locking nuts. They're used in joints that carry shear loads and where the absence of play is essential. They look like thick flat washers with a little ledge rabbeted out of the hole.

Finishing washers are useful when you're installing interior fabric materials to the airframe. They act—and look—like a grommet to fit a screw through and come in counter-sunk and flush-type styles. You might also see some counter-sunk lock washers or ball socket (AN950) and seat washers (AN955), which are used in special applications where the bolt is installed at an angle to the surface or when perfect alignment with the surface is required. These washers are used together as a pair, with the seat washer riding inside the ball socket.

Something as small and as simple as a washer can play an important role in the safety of your aircraft. By understanding what is what, and who is who, you can be sure your installations are solid and secure. And that's a construction technique you can get into.