

## About the Author, Ron Alexander

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Ron has been flying since the age of 16; he flew for the Air Force for five years (including one year in Vietnam) and started flying for Delta Airlines in 1969, where he now pilots the Boeing 767. He currently owns a J-3 Cub, C-3B Stearman, and a Beech 18. Ron started restoring antique airplanes in the early 1970's and could not find parts so he founded the Alexander Aeroplane Company which he operated for 17 years. He sold the company to Aircraft Spruce and Specialty in 1995 so that he could focus his efforts on providing education within the sport aviation industry.

Ron is currently president of Alexander SportAir Workshops, a series of "hands-on" workshops on building airplanes is presented throughout the country for education. For a schedule of locations and dates of upcoming workshops and information (prices, curriculum, etc.), call 800-967-5746 or visit their web site at [www.sportair.com](http://www.sportair.com)

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## **AIRCRAFT HARDWARE** *What You Need To Know*

*By Ron Alexander*

The quality of our workmanship in building an airplane is very important. We all take the needed time and spend the necessary money to ensure we have a high quality airplane. We want it to not only look attractive, but also to be safe. But what about the materials that hold the airplane together the aircraft hardware? Do we try to cut expenses by using questionable bolts or used nuts? Is it really necessary to spend money on high quality aircraft hardware? **Absolutely!** The hardware used to assemble your airplane should be nothing but the best. Why take the time to build a perfect wing only to attach it to the fuselage with used hardware. It makes no sense. To quote *the Airframe and Powerplant Mechanics General Handbook* . . . "The importance of aircraft hardware is often overlooked because of its small size; however, the safe and efficient operation of any aircraft is greatly dependent upon the correct selection and use of aircraft hardware." Very well stated. The same book also

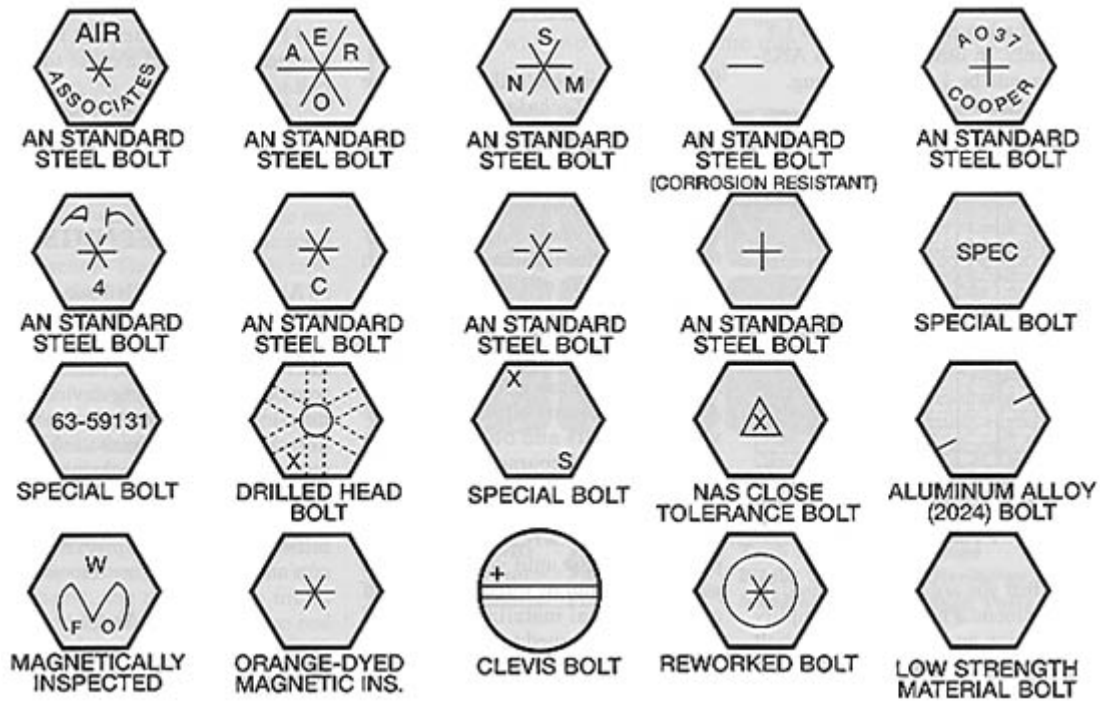
provides us with a very good definition of aircraft hardware. "Aircraft hardware is the term used to describe the various types of fasteners and miscellaneous small items used in the manufacture and repair of aircraft."

The subject of aircraft hardware can certainly be confusing. Thousands upon thousands of small items are used on a typical airplane. What does the custom aircraft builder really need to know about hardware? Where do you find the information? What reference is really the end authority on proper installation? What do all of those AN numbers mean and do I have to know them? What types of hardware should I really learn more about in order to build my own airplane?

These questions will be answered in this series of articles on aircraft hardware. I hope to eliminate some confusion over what type of hardware to use and how to properly install it. To begin our discussion, it is absolutely imperative that you use nothing but aircraft grade hardware. Commercial grade hardware found in hardware or automotive stores is legal to use on an experimental airplane **but should not be considered for even a moment**. Why? Let's look at bolts as an example. Common steel bolts purchased from a hardware store are made of low carbon steel that has a low tensile strength usually in the neighborhood of 50,000 to 60,000 psi. They also bend easily and have little corrosion protection. In contrast, aircraft bolts are made from corrosion resistant steel and are heat treated to a strength in excess of 125,000 psi. The same comparison applies to most hardware items. So, **use only aircraft quality hardware** on your airplane. Save the other hardware for your tractor.

If aircraft hardware is special, then there must be a standard against which it should be measured and manufactured. That standard was actually developed prior to World War 11, but became more definitive during that war. Each branch of the military originally had its own standard for hardware. As time went on these standards were consolidated and thus the term AN which means Air Force-Navy (some prefer the older term Army-Navy). Later the standards were termed MS which means Military Standard and NAS which means National Aerospace Standards. Thus, the common terms AN, MS and NAS. Together they present a universally accepted method of identification and standards for aircraft hardware. All fasteners are identified with a specification number and a series of letters and dashes identifying their size, type of material, etc. This system presents a relatively simple method of identifying and cataloging the thousands and thousands of pieces of hardware. Several pieces of hardware will have both an AN number and an MS number that are used interchangeably to identify the exact same piece. A cross reference exists that compares these two numbers. So in the end, you are able to read your plans or

assembly manual and identify, by number and letter, each piece of hardware on your airplane. You can then obtain that piece and properly install it in the right place. Imagine trying to do that without a system of numbers. The specifications for each piece of hardware also define the strength, tolerance, dimensions, and finish that is applied. If you would like further information on this numbering system, you can contact the National Standards Association in Washington, DC.



**FIGURE 1**

Out of all the thousands of hardware pieces manufactured, which ones are important to the custom aircraft builder? The following types and categories of hardware will be discussed:

- Bolts
- Nuts
- Washers
- Screws
- Cotter pins and safety wire
- Rivets
- Turnlock fasteners
- Miscellaneous items such as O-rings, crush washers, etc.
- Control cable hardware
- Fluid lines and fittings

- Electrical wiring and connectors

Where do you find information concerning aircraft hardware? Your aircraft plans or assembly manual should provide you with a general overview of hardware used on your project. Use the hardware the aircraft designer or kit manufacturer recommends. Do not substitute with your own ideas. This can be dangerous. The manufacturer has tested the design and its safety is dependent upon the proper pieces of hardware. FAA Advisory Circular 43-13-IA is an excellent reference source. *The Airframe Mechanics General Handbook* also has a very good section on the selection and use of hardware. These two books are considered the primary authority on the proper use of hardware. In addition, I would recommend two other small reference books: the *Standard Aircraft Handbook* and the *Aviation Mechanic Handbook*. Both of these provide a good reference source. The Aircraft Spruce & Specialty catalog also contains good reference material on hardware. If you have any doubts about the quality of the aircraft hardware you are purchasing, request a copy of the manufacturer's specifications. These specifications along with a specific manufacturer's lot number should be available.

## **BOLTS**

Bolts are used in aircraft construction in areas where high strength is needed. Where this strength is not necessary screws are substituted. Aircraft quality bolts are made from alloy steel, stainless or corrosion resistant steel, aluminum alloys and titanium. Within our industry the first two are the most common. Aircraft bolts will always have a marking on their head. If you see no markings at all on the head of a bolt, do not use it. It is probably a commercial grade bolt. The markings on bolts vary according to the manufacturer. You should see an "X" or an asterisk along with a name, etc. If you purchase a corrosion resistant (stainless steel) bolt, the head of that bolt should have one raised dash. An aluminum bolt will have two raised dashes on its head. Aluminum bolts have limited use. They should not be used in tension applications or where they will be continuously removed for maintenance or inspection. A chart of typical bolt heads is presented in Figure 1. NAS bolts have a higher tensile strength (usually about 160,000 psi) and can be identified by a cupped out head. Close tolerance bolts are machined more accurately than general purpose bolts and they are used in applications requiring a very tight fit. Close tolerance bolts can be either AN or NAS and typically have a head marking consisting of a raised or recessed triangle.

The standard bolts used in aircraft construction are AN3 through AN20. Each bolt typically has a hexagon shaped head and a shank that fits into the hole. The

*shank* is threaded on the end and the unthreaded portion of the bolt is termed the *grip*. The diameter of a bolt is the width of the grip. The shank of a bolt will be either drilled to accept a cotter pin or undrilled. Another option is to purchase a bolt that has the head drilled for the purpose of accepting safety wire. Clevis bolts are manufactured with a slotted head and are used for control cable applications. The size, material, etc. of a bolt is identified by an AN number. A breakdown of a typical bolt AN number follows:

### **AN4-8A**

- AN means the bolt is manufactured according to Air Force-Navy specs.
- 4 identifies the diameter of the bolt shank in 1/16" increments
- 8 identifies the length of the shank in 1/8" increments
- A means the shank of the bolt is undrilled (no letter here means a drilled shank)

So, this particular bolt is a 1/4 inch diameter AN bolt that is 1/2 inch long measured from just under the head to the tip of the shank. The bolt also has an undrilled shank which means it cannot accept a cotter pin. Also, bolt length may vary by +1/32" to -1/64". If the letter "C" follows the AN designation (ANC) that identifies a stainless steel bolt. The letter "H" after AN (ANH) identifies a drilled head bolt.

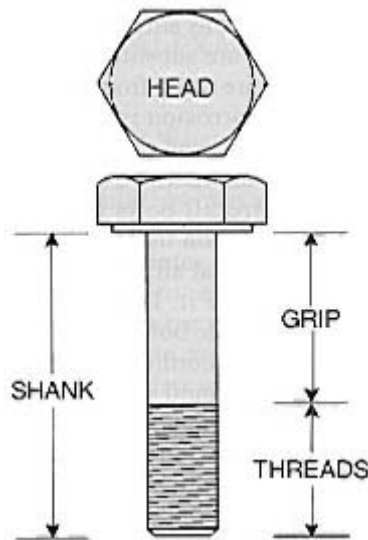
### **[FIGURE 2: AN Aircraft Bolt Dimensions](#)**

In constructing your airplane, you will not encounter many bolts larger than an AN8 (1/2 inch diameter). To add a bit more confusion, if the dash number defining the length of the bolt has two digits, the first digit is the length in whole inches and the second number the length in additional 1/8" increments. In other words, an AN514 bolt would be 1- 1/2 inches long.

Now that you are totally confused let me recommend a hand tool to simplify bolt selection and sizing. An AN bolt gauge is available that will assist you in identifying a bolt (click on the above link to Figure 2).

If you need to determine the proper size of a bolt, the length must be sufficient to ensure no more than one thread will be inside the bolt hole. This is the *grip length* of the bolt and it is measured from the underneath portion of the head to the beginning of the threads (see Figure 3 below). The grip length should be equal to the material thickness that is being held by the bolt or slightly longer. A washer may be used if the bolt is slightly longer. A piece of welding rod or safety wire can be used to measure the length of the hole. In his book titled

*Sportplane Construction Techniques*, Tony Bingelis shows a simple tool that can be made for this purpose.



**FIGURE 3**

It is important that you do not "over tighten" or "under tighten" a bolt or the nut attached to a bolt. Under torque or under tightening results in excessive wear of the hardware as well as the parts being held. Over tightening may cause too much stress on the bolt or nut. The best way to avoid this is to use a torque wrench. AC43-13 presents a table of torque values for nuts and bolts. It shows fine thread and coarse thread series with a minimum and maximum torque limit in inch pounds. I recommend using a torque wrench whenever possible, at least until you get an idea as to the amount of force required. Of course, critical installations should definitely be torqued to proper values. A torque wrench is not that expensive and will be a worthwhile investment for a custom builder.

### ***Basics of Bolt Installation***

Certain accepted practices prevail concerning the installation of hardware. A few of these regarding bolt installation follow:

1. In determining proper bolt length - no more than one thread should be hidden inside the bolt hole.
2. Whenever possible, bolts should be installed pointing aft and to the center of an airplane.
3. Use a torque wrench whenever possible and determine torque values based on the size of bolt.
4. Be sure bolt and nut threads are clean and dry.
5. Use smooth, even pulls when tightening.

6. Tighten the nut first - whenever possible.
7. A typical installation includes a bolt, one washer and a nut.
8. If the bolt is too long, a maximum of three washers may be used.
9. If more than three threads are protruding from the nut, the bolt may be too long and could be bottoming out on the shank.
10. Use undrilled bolts with fiber lock nuts. If you use a drilled bolt and fiber nut combination, be sure no burrs exist on the drilled hole that will cut the fiber.
11. If the bolt does not fit snugly consider the use of a close tolerance bolt.
12. Don't make a practice of cutting off a bolt that is too long to fit a hole. That can often weaken the bolt and allow corrosion in the area that is cut.

## **AIRCRAFT NUTS**

Aircraft nuts usually have no identification on them but they are made from the same material as bolts. Due to the vibration of aircraft, nuts must have some form of a locking device to keep them in place. The most common ways of locking are cotter pins used in castle nuts, fiber inserts, lockwashers, and safety wire. The aircraft nuts you will most likely encounter are castle nuts, self-locking nuts, and plain nuts. Wing nuts and anchor nuts are also used.

### ***Castle Nuts***

AN310 and AN320 castle nuts are the most commonly used (see Figure 4). Castle nuts are fabricated from steel and are cadmium plated. Corrosion resistant castle nuts are also manufactured (AN310C and AC320C - remember, when you encounter a "C" it will designate stainless). Castle nuts are used with drilled shank bolts, clevis bolts and eye bolts. The slots in the nut accommodate a cotter pin for safetying purposes. The thinner AN320 castellated shear nut has half the tensile strength of the AN310 and is used with clevis bolts which are subject to shear stress only. The dash number following the AN310 or AN320 indicates the size bolt that the nut fits. In other words, an AN310-4 would fit a 1/4 inch bolt.



**FIGURE 4**

### ***Self-Locking Nuts***

Self-locking nuts, as the name implies, do not need a locking device. The most common method of locking is derived from a fiber insert. This insert has a smaller diameter than the nut itself so that when a bolt enters the nut it taps into the fiber insert producing a locking action. This fiber insert is temperature limited to 250-deg. F. The designation of these nuts is AN365 and AN364. This brings us to an example of a cross-reference MS number. An AN365 is also termed MS20365 with the AN364 being MS20364. Both of these nuts are available in stainless. The AN364 is a shear nut not to be used in tension.

An all metal locking nut is used forward of the firewall and in other high temperature areas. In place of a fiber insert, the threads of a metal locking nut narrow slightly at one end to provide more friction. An AN363 is an example of this type of nut. It is capable of withstanding temperatures to 550-deg. F.

The dash number following self-locking nut defines the thread size. Self-locking nuts are very popular and easy to use. They should be used on undrilled bolts. They may be used on drilled bolts if you check the hole for burrs that would damage the fiber. One disadvantage, self-locking nuts should not be used on a bolt that is connecting a moving part. An example might be a clevis bolt used in a control cable application.

### ***Plain Aircraft Nuts***

Plain nuts require a locking device such as a check nut or lockwasher. They are not widely used in most aircraft. AN315 is the designation used for a plain hex nut. These nuts are also manufactured with a right hand thread and a left hand thread. The check nut used to hold a plain nut in place is an AN316. If a lockwasher is used a plain washer must be under the lockwasher to prevent damage to the surface.

## ***Other Aircraft Nuts***

There are a number of other aircraft nuts available. Wing nuts (AN350) are commonly used on battery connections or hose clamps where proper tightness can be obtained by hand. Anchor nuts are widely used in areas where it is difficult to access a nut. Tinnerman nuts, instrument mounting nuts, pal nuts, cap nuts, etc. are all examples of other types that are used.

## ***Basics of Aircraft Nut Installation***

1. When using a castle nut, the cotter pin hole may not line up with the slots on the nut. The *Mechanics General Handbook* states "except in cases of highly stressed engine parts, the nut may be over tightened to permit lining up the next slot with the cotter pin hole." Common sense should prevail. Do not over tighten to an extreme, instead, remove the nut and use a different washer and then try to line the holes again.
2. A fiber nut may be reused if you are unable to tighten by hand.
3. At least one thread should be projecting past the fiber on a fiber nut installation.
4. No self-locking nuts on moving part installations.
5. Do not use AN364 or AN365 fiber nuts in areas of high temperature - above 250' F.
6. Shear nuts are to be used only in shear loads (not tension).
7. Plain nuts require a locking device such as a lockwasher or a check nut.
8. When using a lockwasher, place a plain washer between the surface of the airplane part and the lockwasher.
9. Shear nuts and standard nuts have different torque values.
10. Use wing nuts only where hand tightness is adequate.

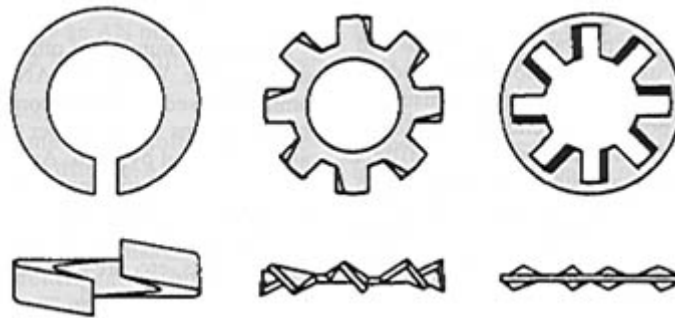
## **WASHERS**

Finally, a hardware item that is simple. You are likely to encounter only a couple of different types of washers AN960 and AN970. The main purposes of a washer in aircraft installation are to provide a shim when needed, act as a smooth load bearing surface, and to adjust the position of castle nuts in relation to the drilled hole in a bolt. Also, remember that plain washers are used under a lockwasher to prevent damage to a surface.

AN960 washers are the most common. They are manufactured in a regular thickness and a thinner thickness (one half the thickness of regular). The dash number following the AN960 indicates the size bolt for which they are used. The system is different from others we have encountered. As an example, an

AN960-616 is used with a 3/8" bolt. Yet another numbering system. If you see "L" after the dash number, that means it is a thin or "light" washer. An AN960C would be - yes, a stainless washer. I can tell you are getting more familiar with the system so I will throw another wrench into the equation - an AN970 washer has a totally different dash number system. I am not even going to tell you what it is. I will tell you that an AN970 is a larger area flat washer used mainly for wood applications. The wider surface area protects the wood.

There are other types of washers. I mentioned lockwashers that are made several different ways. They are often split ring, they are sometimes internal tooth and even external tooth (see Figure 5). You will also find nylon washers and finishing washers that usually have a countersunk head. So, as you can see, washers are not quite as confusing as other hardware even though we can make it difficult if we wish.



**FIGURE 5**

## **COTTER PINS AND SAFETY WIRE**

The cotter pins mostly used on custom aircraft are AN380 and AN381. Cadmium plated cotter pins are AN380 and stainless are AN381. Cotter pins are used for safetying bolts, screws, nuts and other pins. You will normally use them with castle nuts. The MS number you may see is MS24665. The dash numbers indicate diameter and length of the pin. As an example, AN380-2-2 would be a cadmium plated pin 1/16" in diameter and 1/2" long. All supply companies will have charts showing the various sizes versus the reference number.

Safety wire is also widely used. The most used sizes in diameter are .020, .032 and .041 or small variations thereof. The material is usually stainless steel or brass. The easiest method of installation is acquired by using safety wire pliers (see Figure 6). The pliers are used to twist the wire. The wire is installed so that if the nut or bolt begins to loosen it will increase the tension on the wire. Be sure you do not overtwist the wire - doing so will weaken the safety wire.

Leave about 36 twists and then cut off the excess wire and bend its end so you do not snag it with your hand at a later time.



**FIGURE 6**

I want to emphasize the major point of this article. **USE ONLY AIRCRAFT QUALITY HARDWARE.**

Do not assume the engineer role by using hardware types or sizes that are contrary to your plans or assembly manual. In future articles I will discuss the other hardware items including control cable installation, screws, rivets, turnlock fasteners, etc.