Version 1.0

Hardware Basics

1 THE NUTS AND BOLTS

Bolting two pieces together is simple. Run a bolt through matching holes, place a washer over the end, then add a nut to hold the bolt in place. Just about the same as working on the car. However, there are several rules to follow.

Probably about the biggest one is the requirement to use aircraft-grade hardware, which usually includes an "AN" (Army/Navy) designator. Over the years, the government has established a number of standards for the construction and testing of aircraft hardware. When Pete calls for the installation of an AN4-32A bolt, it means something more than a mere manufacturer's part number. The number refers to a federal standard specification, and the specifications will list the minimum and, in some cases, maximum requirements for approval. These requirements include dimensions, tolerances, strengths, and finishes. Pete would have selected these unis for a reason.

Most AN hardware is made from steel, then cadmium-plated. The cadmium gives the metal a goldish color and provides corrosion resistance. Bolts and washers are also available in aluminum. They're half as strong as the steel hardware, so do not use them unless the plans call for it.

1.1 Bolt Basics

The standard bolts used in Fly Babies are the AN3 through AN20 series. A bolt consists of two parts, the <u>head</u> and the <u>shank</u>. The head is the hexagonal portion that fits the wrench. The shank is the portion designed to slip into the hole. It's threaded at one end, with the unthreaded portion called the <u>grip</u>.

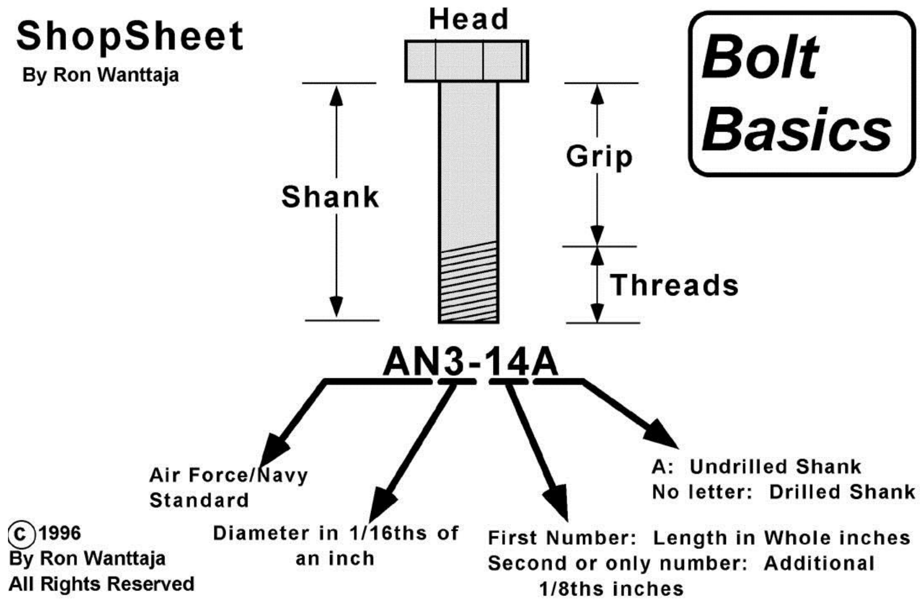
Whether a bolt is aircraft quality can often be determined by looking at the head. The usual marking is a four- or six-pointed star, possibly accompanied by a couple of letters. If the bolt has no markings on the head, it isn't an approved bolt.

A typical bolt specification is <u>AN3-14A</u>:

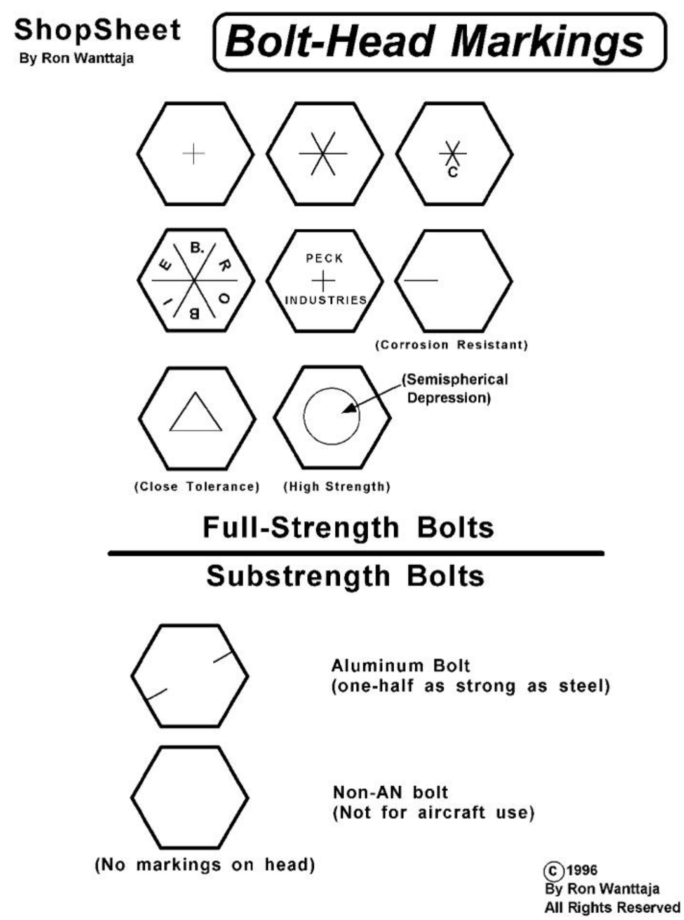
- <u>AN</u> indicates the bolt meets the AN standards.
- <u>3</u> is the diameter of the bolt, in 1/16ths of an inch.
- <u>14</u> is the approximate shank length.
- <u>A</u> indicates the thread area isn't drilled for a cotter pin.

The <u>diameter</u> is the width of the grip. There is a small amount of allowed tolerance, so don't be surprised if one bolt fits more tightly than another.

The <u>length</u> description is rather tricky. The first digit indicates the number of whole inches; the second digit is the number of 1/8 inches. So an AN3-14 bolt is about 1 and 4/8ths (1/2) inches long from the bottom of the head to the tip of the shank.



Whether the threads are drilled or not is important depending upon how the nut will be secured. The undrilled type uses self-locking nuts. Most of your installations will use self-locking nuts, so buy undrilled bolts.



<u>Castle nuts</u> require drilled bolts in order to pass the cotter pin. Although there are special jigs available to make it easier, avoid drilling the bolts yourself. Not only won't your work match the exact specifications of the standard, but the new hole won't be cadmium-plated. It's OK only for non-structural purposes.

<u>Drilled-head bolts</u> are available for special cases; for instance, if the bolt is installed into a threaded hole in a part. Safety wire is then passed through the hole to secure the bolt. Drilled-head bolts are identified by the addition of an H after the code for bolt diameter: AN3H-10A, for example. The AN76 series has a larger head with multiple holes.

1.2 Nuts

Aircraft nuts must not come off accidentally. They undergo a lot of vibration that tends to loosen plain nuts. The consequences are obvious. There are three ways to secure them: <u>lock washers</u>, <u>self-locking nuts (stop nuts)</u>, or <u>external safetying</u>.

AN-standard lock washers are rarely used. Weight is one reason--every bolt must have a lock washer in addition to the nut and a regular washer. Longer bolts are necessary, and installation is more complex.

Self-locking nuts are the most common method. The self-locking feature is implemented in one of two ways. First, the nut might incorporate an elastic fiber collar slightly smaller than the bolt. The pressure of the fiber on the threads then keeps the nut from turning. Second, the threaded portion of the nut can be manufactured with a slight distortion that adds sufficient friction to resist vibration.

The AN365 elastic stop is the most popular self-locking nut. They are cheap, less than a dime each in the 3/8" size. They can be reused as long as the fiber still holds the nut in place. If the nut can be turned by hand, junk it. The AN364 is a low-profile version, but it can only be used in shear applications. Use the AN365 unless your plans say otherwise.

Dash numbers after the main specification are used to differentiate sizes: AN365-428. The dash number indicates the thread size. The system is rather awkward to memorize, but here's a short cut: For AN4 and larger bolts, the first digit of the dash number is the same as the AN bolt diameter: AN4 takes AN365-428, AN5 takes AN365-524, AN6 takes AN365-624, and so forth. The short cut doesn't work for AN3, so you'll just have to remember that it uses an AN365-1032 nut.

Elastic stop nuts are the most popular, but they have one drawback: The fiber insert is certified to only 250^{o} F. This is adequate for most of the airframe, but they can't be used forward of the firewall. An all-metal stop nut is necessary.

The most common of these is the AN363. By using threaded metal fingers, the hole diameter narrows slightly at one end and applies enough friction to prevent self-rotation. The AN363 uses the same dash number scheme as the AN365, and is about 20 percent more expensive.

Self-locking nuts aren't the universal solution, though. If the bolt is intended to connect moving parts, the motion might overcome the nut's self-locking ability. An example would be a clevis attached to a control horn, hardly the place you'd want a nut to disappear from.

Castle nuts are designed for these applications. They look like conventional nuts with notches cut out of one side like a castle's ramparts. The notches pass a cotter pin through the hole in a drilled bolt. The AN310 castle nut is for all uses, or the low-profile AN320 for shear-only applications. Just to add to the confusion, the dash numbers of the AN310/320 series actually correspond to the AN bolt size the nut goes with: AN310-3 for AN3 bolt, AN320-6 for AN6 bolts. AN310/320 nuts cost about twice that of the equivalent AN365.

1.3 Washers

Washers have multiple functions. They act as shims, spread the compressive forces over a wider area, and protect the surface from the rotation of the nut during installation.

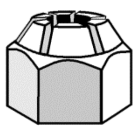
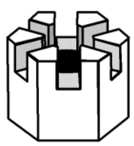
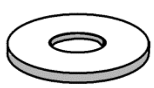
The AN960 is aviation's standard washer. It comes in <u>regular</u> and <u>thin</u> (one-half the thickness of the regular washer). The light washer is used as a shim, especially when using castle nuts. Stock up on the regular variety, and get just a few thin ones.

The dash number of the AN960 washers gives the size bolt they're designed for. And guess what? It's yet <u>another</u> system.

A typical washer spec is AN960-416. The three-digit dash number gives the diameter of the center hole in 1/16ths of an inch; in this case, 4/16ths or 1/4 inch. Light washers will have an L suffix, as in AN960-416L.

However, dash numbers of one or two digits indicate the bolt or screw size. An AN960-8 washer goes with a #8 screw, while an AN960-816 is for a 1/2-inch bolt. The right washer for AN3 bolts is the AN960-10.

As mentioned, one function of the washer is to spread the load over a wider area. When the bolt goes through a softer material like wood, you'd like to spread the load even more. Hence the AN970 flat washer, which has at least twice the diameter of equivalent-sized AN960. There is no thin model of AN970. Just to make your day, the AN970 uses a different scheme for the dash number; the dash number on the AN970 is the same as the bolt it goes with. In other words, for an AN6 bolt, you could use either an AN960-616 or an AN970-6. But don't try an AN960-6 because it's too small.

		To Fit AN3 (3/16") Bolt	To Fit AN4 (1/4") Bolt	To Fit AN6 (3/8") Bolt
Elastic Stop Nut		AN365-1032A AN364-1032A*	AN365-428A AN364-428A*	AN365-624A AN364-624A*
Metal Stop Nut		AN363-1032	AN363-428	AN363-624
Castle Nut		AN310-3 AN320-3*	AN310-4 AN320-4*	AN310-6 AN320-6*
Washer		AN960-10 AN960-10L* AN970-3**	AN960-416 AN960-416L* AN970-4**	AN960-616 AN960-616L* AN970-6**
Cotter Pin		AN380-2-2	AN380-2-2	AN380-3-3

* Thin unit... use only when called for
** Extra-wide washer

1.4 Bushings

Bolts are sometimes used as a pivot for a moving part, or to make things easier if a bolt has to be put a long way through wood. In these cases, a <u>bushing</u> is installed between the bolt and the part. Bushings are tubular pieces of moderately-hard metal with a hole drilled down the middle. They're pressed into a slightly-undersized hole in the part, and the pivot bolt runs through the hole in the bushing.

Typically, bushings are aluminum, bronze, or a grade of steel softer than the bolt. The bushing wears at a slower rate than aluminum or wood. But its tubular shape makes it easy to replace: when fit gets too sloppy, push out the old bushing and insert another.

There isn't really an AN standard for bushings--they aren't really under load. They just pass the loads to the components designed for them.

1.5 Other Common Hardware

Clevis pins are like bolts without threads, used solely in shear applications. A typical application is in cable shackles and forks. The most common ones are the AN393 (3/16 inch diameter) and the AN394 (1/4 inch diameter). A dash number divides the number of 1/32ths of an inch between the head to the cotter pin hole. In other words, an AN393-39 clevis pin in 3/16 inch in diameter and 39/32nds of an inch long; or 1 and 7/32 inches.

Clevis pins and castle nuts are locked by the AN380/MS24665 cotter pin. The diameter and length are given by a bizarre little dash-number code. One big thing to remember about cotter pins is that they cannot be reused. Don't bend them straight and reinstall them.

Anchor nuts are lock nuts that can be solidly attached to the surrounding structure by rivets or screws. With the nut fixed in place, you don't have to hold it in place with a wrench whenever the component is removed or installed. If the plans call for an anchor nut, don't use the regular variety. You'll hate yourself if the part has to be removed later.

1.6 Typical Installation

Let's assume we're bolting a piece of 1/8-inch angle to a 1-inch diameter steel tube. Let's operate on the assumption that the bolt diameter is the only thing specified. Selecting the right nut should be easy. We know the size of the bolt. If the bolt were meant to act as a pivot, we'd know to use a castle nut and cotter pin. Instead, the simpler self-locking nut will do. Because the assembly doesn't mount near the engine, the cheap elastic stop nut is acceptable. Should you use the AN364 shear-only style or the AN365 full-tension one? Without any guidance from the plans, better use the AN365.

Because neither of the items being joined are made of wood, we won't need the large diameter AN970 washer. That leaves the AN960-10 washer; for right now, let's assume we won't need the thin variety.

Which leaves the bolt. Because we're using a self-locking nut, whatever bolt we select should have the "A" (undrilled) suffix. The bolt's grip length must be approximately equal to the total thickness of the pieces being joined. Selecting the right bolt is awkward, as the AN system refers to total length, not grip length. On AN3 bolts, the threaded area is about 7/16ths of an inch long. For AN4, the threads are 15/32 inch, while AN5 and AN6 is about 1/2 inch.

The threaded area develops the bolt's full strength in tension, but is not designed for shear loading. So the threaded length of the shank should start just where the bolt emerges from the material. A little bit (at most, one full turn of threads) can still be inside. But you don't want too much coming out, either. If the bolt is too long, the nut will reach the end of the threads before it applies pressure to the work. Up to three washers can be used to compensate for overlong bolts, but a shorter bolt would be lighter.

The absolute limits to bolt length are no more than one turn of the threads should be left within the hole and no more than three washers can be used to allow the bolt to apply its proper tension.

Select the correct grip length one of two ways: intellectual or practical. By adding the thicknesses of the material together, you derive the proper grip length. Or, hold the pieces together, take a wire or piece of wood, and slide it into the hole to measure its depth. Then measure the length or compare it to several bolts until the correct one is found.

Slide the bolt into the hole. It's strongly preferred that the head faces up or forward, so if the nut comes off, gravity or the slipstream will hold the bolt in place. But if there's some reason you can't install the bolt that way, don't worry about it. If you're installing the bolt into wood, there MUST be a bushing, or you need to coat the bolt hole with varnish first, and let it dry. Otherwise, simple corrosion will lock the bolt in place and you'll have a hard time getting it out if you need to.

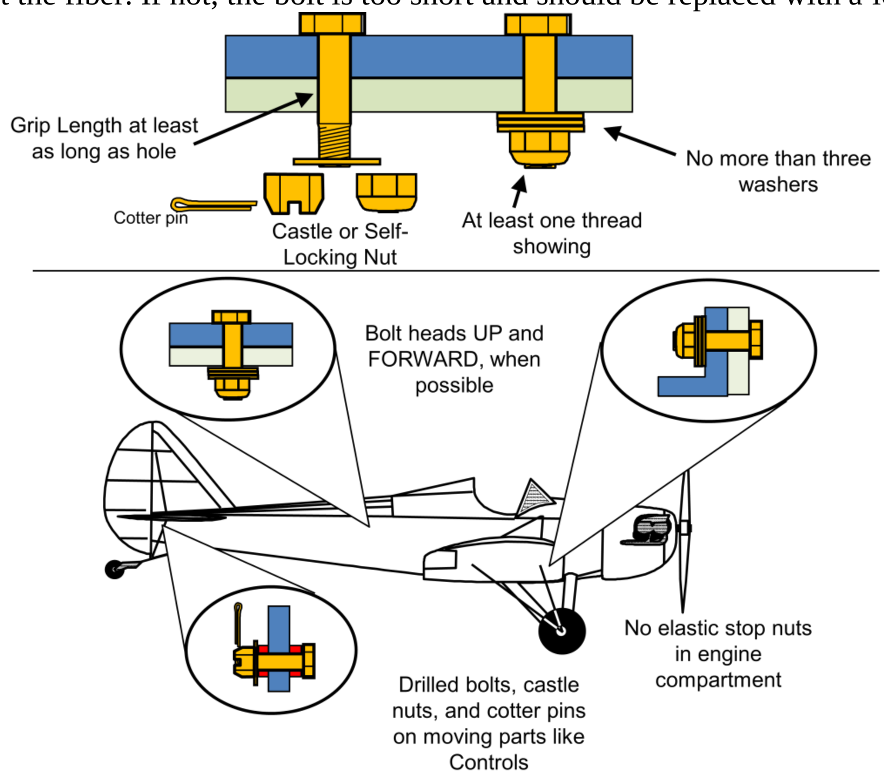
Slide the washer over the end, then start the nut by hand. The fiber locking material inside the nut should make it impossible to turn by hand after the first turn or so. If the nut can be tightened all the way by hand, throw the nut away and use another.

When the nut gets hard to turn, take a combination wrench and socket wrench (3/8 inch for AN3 bolts) and tighten it the rest of the way. You'd prefer to use the socket on the nut and the combination wrench on the head. Otherwise, the cadmium gets scraped off the bottom of the bolt head and the material below the head gets scraped. Turn the head if necessary; space constraints might dictate the situation.

Massive amounts of pressure aren't necessary. The maximum torque of the AN3 bolt is 25 inch-pounds. If you're using a ratchet wrench with a 6-inch handle, that's only <u>4 pounds</u> (4 pounds x 6 inches = 24 inch-pounds) of pressure on the end of the handle. AN4 bolts specify a maximum of 11 pounds at the end of the wrench; AN5 gets all the way to 23. Less if your wrench is longer.

Tighten them up until they're snug, and don't apply insane amounts of torque. Use a torque wrench occasionally and compare the readings with the figures given in AC 43-13.

Once the bolt is in place, look at the end of the nut. You should see at least one thread projecting past the fiber. If not, the bolt is too short and should be replaced with a longer one.



If there are more than three threads showing, the bolt might be too long. Try to rotate the bolt with the wrench without holding the other end. If it turns, the nut bottomed out before proper pressure could be applied. Remove the nut and add another washer. Re-tighten, recheck, and repeat if necessary. If the bolt still isn't tight in the hole with three washers on it, replace with a shorter bolt.

If installing a drilled bolt and using a castle nut, the nut must be in a position to allow the cotter pin to pass through the drilled hole in the bolt. The thinner washer (AN960-10L for AN3) can be used to ensure both proper torque and positioning. Bend both prongs of the cotter pin after insertion. Remember, never reuse one.

2 AIRCRAFT CABLE AND ACCESSORIES

Fly Babies are really into cable. Not only are the rudder and horizontal stabilizer moved by them, the wings themselves are braced with aircraft cable.

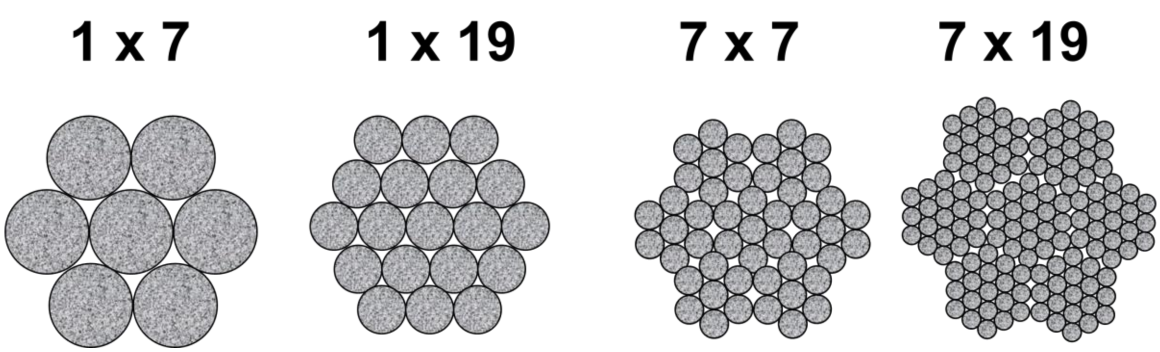
2.1 Cable Construction

The basic unit of aircraft cable is a single wire formed of galvanized (zinc-coated) steel or stainless steel. The cable could consist of this single wire; if the wire were 1/8 inch thick, it'd be as strong as 1/8-inch steel rod. And that's exactly what it would be, a solid, strong, and stiff steel rod. Unfortunately for those wanting to move control surfaces, a 1/8-inch rod won't go around a pulley. It has no flexibility. We could use a smaller-diameter wire, but we'd lose strength. But use a bundle of these tiny wires, and the resulting cable is almost as strong and far more pliant. You get both strength and flexibility.

Aircraft cable consists of a number of wires (usually seven or 19) twisted around each other to form a strand. If more flexibility is needed for a given outside diameter, smaller wires are used in multiple strands, which, in turn, are also twisted together.

Aircraft cable is specified by diameter, construction, and material. While all three factors affect the cable's strength, diameter has the greatest effect. One-sixteenth-inch cable can withstand about 500 pounds, and its strength approximately doubles for every 1/16-inch increase in diameter.

Construction affects strength to a lesser degree. A cable's construction is described by the number of strands and the number of wires per strand. Hence, 1 x 19 cable has one strand consisting of 19 wires, while 7 x 19 has seven strands, each of which has 19 wires. If both cables have the same outside diameter, the individual wires of the 1 x 19 cable are thicker, and some sizes can be 30 percent stronger than the same diameter in 7 x 19. But the thick wires reduce flexibility.



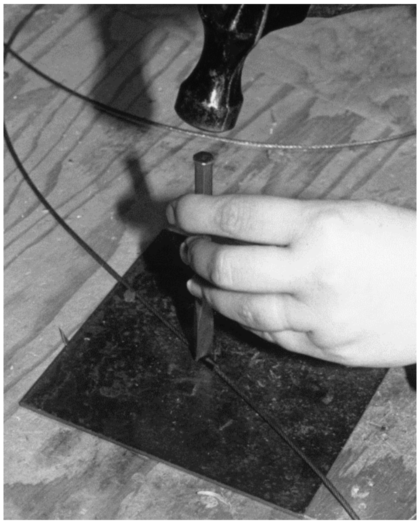
Single-strand cable is best for bracing and other applications that don't pass through fairleads or pulleys, so you’ll see 1x19 specified for Fly Baby wing bracing. The so-called flexible cables (7 x 7 or 7 x 19) are best for control systems. The 7 x 19 construction is sometimes called extra-flexible. For a given cable diameter, the wires of 7 x 19 are smaller, and hence more easily damaged. Go with 7 x 19 construction if your design uses small pulleys. Otherwise, 7 x 7 gives reasonable flexibility and wears better.

The relationship between material and strength is interesting. For single-strand cable, galvanized or stainless steel cables are equal. However, galvanized is stronger in multistrand construction.

The Fly Baby uses 1/8” cable exclusively. Here's a comparison of the wire strengths:

Diameter	Material	One Strand	Seven Strands
1/8”	Galvanized	2,100	2,000
1/8”	Stainless	2,100	1,760

2.2 Cutting Aircraft Cable



Cutting galvanized or stainless cable is easy. Don't use a cutting torch--the heat will anneal and weaken the cable. It must be cut mechanically. Cable cutters are available for $15 and up, but a $3 cold chisel and a hammer work quite well. Wrap a piece of tape around the cable. Position the cable on a hard surface. An anvil works best, or the flat top of a vise. Set the chisel on the taped cable, and rap it sharply with the hammer. This might seem crude, but tools for cutting thick steel cable work on the same principle.

2.3 Cable Terminations

Whichever type and size of cable is selected, we have to be able to attach the cable to the structure. A terminal must be added; either an appropriate fitting must be swaged directly onto the cable, or an eye must be formed to allow connection via other hardware. This termination must develop the same mechanical strength as the cable itself.

Pete Bowers used the Nicopress system, where the loop is held by a swaged copper sleeve. It's ugly, but perfectly serviceable. This has become the standard homebuilder's terminal--it's fast, easy, and costs only about 40 cents per end. It was developed by the National Telephone Supply Company.

You must use a Nicopress tool to compress the sleeves. Don't use a vise or a locking pliers. It doesn't work. One homebuilder used locking pliers on the flying wires of his Fly Baby. He died. Surely your life is worth $20.

2.4 Making a Nicopress Termination

Let's assume we're installing a cable terminal using the Nicopress system. To begin, pass a 1-inch-long piece of rubber hose over the end of the cable. Its inside diameter must be large enough to pass two cables. Automotive vacuum system hose is adequate and cheap.

Next, slide a Nicopress sleeve over the end of the cable. Make sure to use the correct sleeve; one intended for larger cable won't make good contact. Plain copper sleeves are used on galvanized cable, but zinc-plated ones must be used on stainless steel.

Bend the cable back upon itself and insert the end through the other hole in the sleeve, then through the rubber hose. If you're forming the eye inside one end of a turnbuckle, pass the cable through the turnbuckle before inserting it back into the sleeve and hose.

A loop has been formed, but it won't work on its own. Tension will flatten it out and concentrate the stress at one point, resulting in quick failure. A steel thimble placed inside the loop will equalize the forces. Like the sleeves, different sized cables take different thimbles. The exception is 3/32-inch and 1/8-inch cable, which take the same size.

Before inserting the thimble, clip off the four points at the ends with a pair of sidecutters. This gives a tighter assembly. If using a turnbuckle, the ends of the thimble might have to be spread a bit to get it over the turnbuckle's end. If an AN115 shackle is going to be used, insert it now. The shackle <u>can</u> be added once the terminal is complete, but not very easily.

Now the is ready for compression. Make sure the cable is lying flat in the thimble. Slide the rubber hose toward the loop, shoving the copper sleeve as close as possible to the thimble. Clamp the whole assembly in position using a hardware-store cable clamp around the hose. Hand-tightening the nuts on the hardware clamp is usually sufficient.

Position the Nicopress tool around the major axis of the sleeve. The intent is to squeeze down the largest dimension to make the sleeve more circular, not flatter. The standard tools have multiple grooves with a letter code to indicate cable size. The most common codes are: C (1/16"), G (3/32"), M (1/8"), and P (5/32"). You'll want 1/8" for all the Fly Baby cables.

Incidentally, the same code is used when ordering sleeves. The miniswages are easier to figure out; they're just marked with cable sizes.

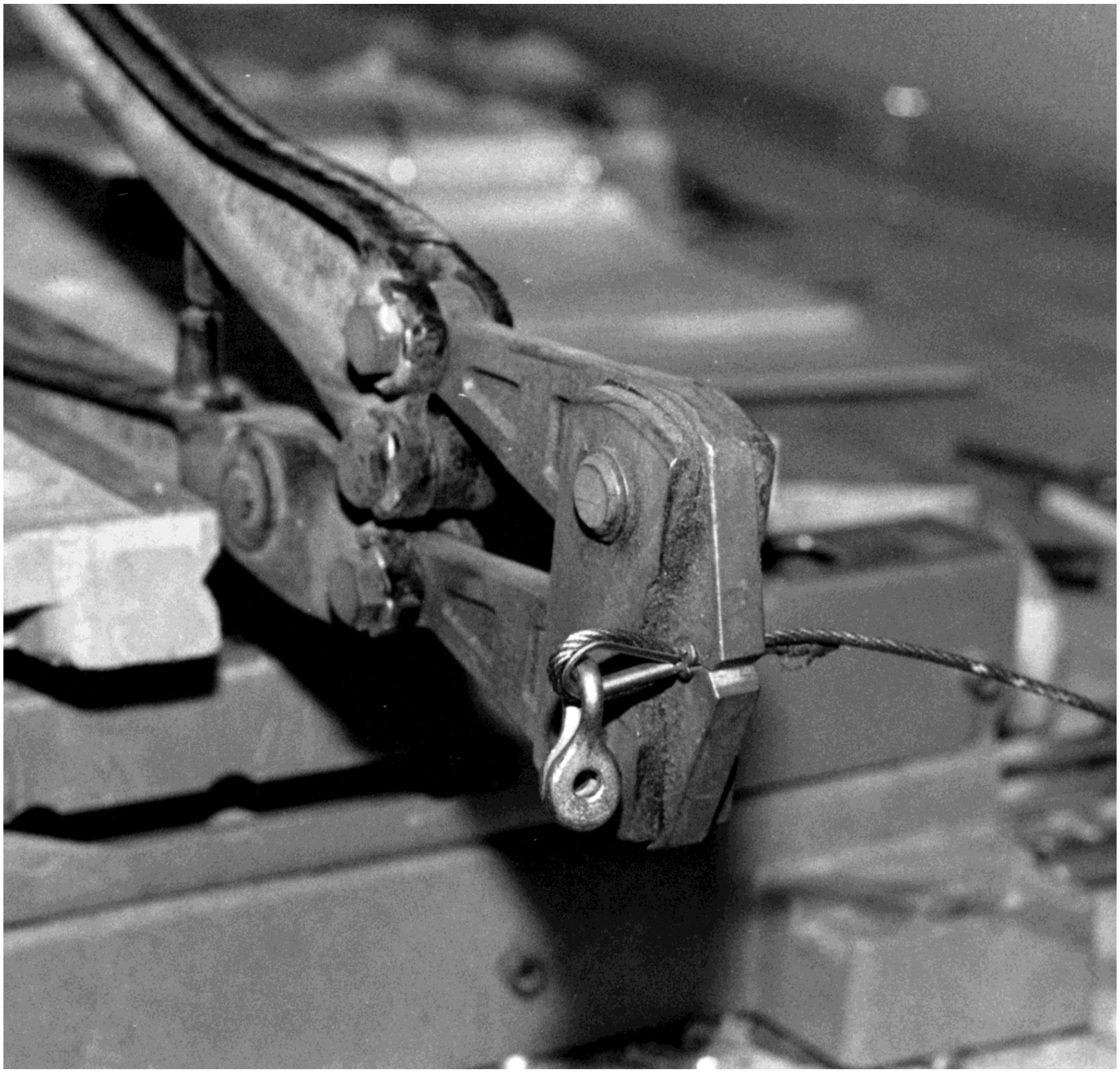
Center the tool between the sleeve ends and begin compression. Use a slow, steady motion.

When complete, release pressure. 1/8" cables need at least two more compressions. Reposition the tool to the end nearest the thimble, and repeat the process. Finally, compress the sleeve at the opposite end.

Undo the cable clamp and cut the hose free of the cable. Trim away the excess cable on the free end, leaving at least 1/8 inch sticking out of the sleeve.

To develop full strength, a 1/8 sleeve must be compressed to 0.3532" or smaller. Check the dimensions of the long axis with either a Nicopress gauge, caliper, or a micrometer.

That completes the Nicopress process. But the cable has to actually get to something and connect to it. Let's look at cable-related hardware.



2.5 Cable Shackles

In many places on a Fly Baby, the cable eye is formed directly through a hole in the structure. This is fine…except if, at some point in the future, you have to replace the cable. Then you're left with trying to cut its cable eye away without damaging the structure it's attached to.

The AN115 cable shackle fixes this problem. It passes through the eye (although far easier prior to forming the eye) and allows the cable to be attached to the structure with a bolt or clevis pin. When using a bolt, don't use a self-locking nut. Use a castle nut and cotter pin, instead.

The dash number of the cable

shackle indicates its rated strength in hundreds of pounds. An AN115-21 shackle, for instance, is rated at 2,100 pounds. This is the smallest shackle that can be used with 3/32-inch or 1/8-inch cable.

One problem with shackles is the lack of throat depth. The side of the shackle might touch the edge of a control horn before the surface reaches full throw. If this is the case, replace the shackle with two flat straps of .050-inch steel or aluminum with holes drilled in either end. Aluminum for low-load application only, please. Sandwich the horn and cable eye between the plates and bolt them through the hole and eye.

Because the horn is probably thinner than the eye, add washers on either side to keep the straps parallel. The plates shouldn't be allowed to clamp down on the thimble or cable. Use a longer-than-necessary bolt. Or slide a piece of tubing over the bolt to keep the plates apart.

Remember, when using bolts on moving structures like control horns, don't use self-locking nuts. Normal motion can loosen them. Use drilled bolts, castle nuts, and cotter pins. A clevis pin is a lighter and cheaper alternative.

2.6 Turnbuckles

Because cables apply tension, there must be a way to preload the cable to the proper amount. If the cable hangs slack, it can't do its job. The usual way is using turnbuckles.

They're not <u>entirely</u> necessary. It's possible to make the cables exactly the right size by building them in place. Run the cable between tangs, tighten it as much as possible, and then clamp in place and compress the Nicopress sleeves. The cable would probably maintain the original tension, but is it the correct amount? What happens if the structure changes slightly? What happens if it's just a teensy bit off? How will you reattach the cable if it must be removed? These are all problems a turnbuckle will solve.

A turnbuckle is a brass barrel with removable fittings screwed into either end. The ends are threaded in opposite directions; when the barrel is rotated, both fittings move inward or outward simultaneously, hence increasing or decreasing the total length of the assembly. Up to three inches of adjustability are available.

Turnbuckle specifications cover complete assemblies and individual components

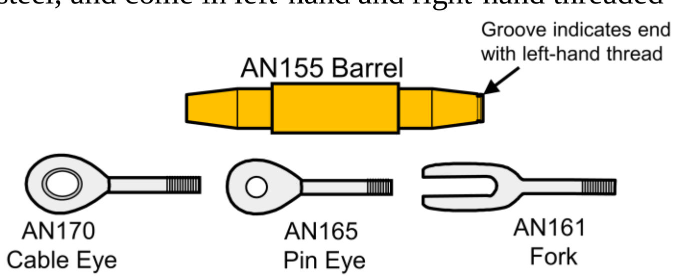
AN155 Barrel. Tube-shaped piece of brass threaded at either end. The left-hand-threaded end is indicated by a ring scored around the brass.

AN161 Fork. An end designed to be bolted or clevised directly to a tang, bellcrank, eyebolt, and the like.

AN165 Pin Eye. Designed to fit between the tines of a fork and secured with a bolt or clevis pin.

AN170 Cable Eye. Similar to the pin eye, the hole through this end unit is curved to match a cable and thimble.

The ends are steel, and come in left-hand and right-hand threaded versions.



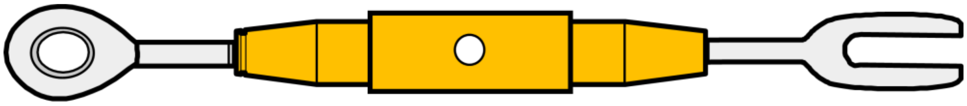
A barrel is combined with two ends to form standard assemblies:

AN130. Barrel, cable eye, and fork: this is probably the most commonly used assembly, and typically is used between the cable and a control bellcrank or tang.

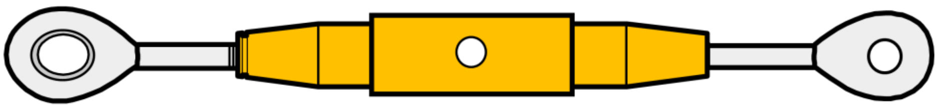
AN135. Barrel, cable eye, and pin eye: this is the most common assembly, used to attach cable to structure.

AN140. Barrel and two cable eyes.

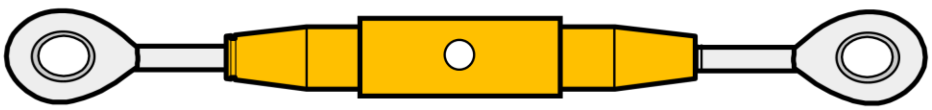
AN150. Barrel and two forks.



AN130 Assembly

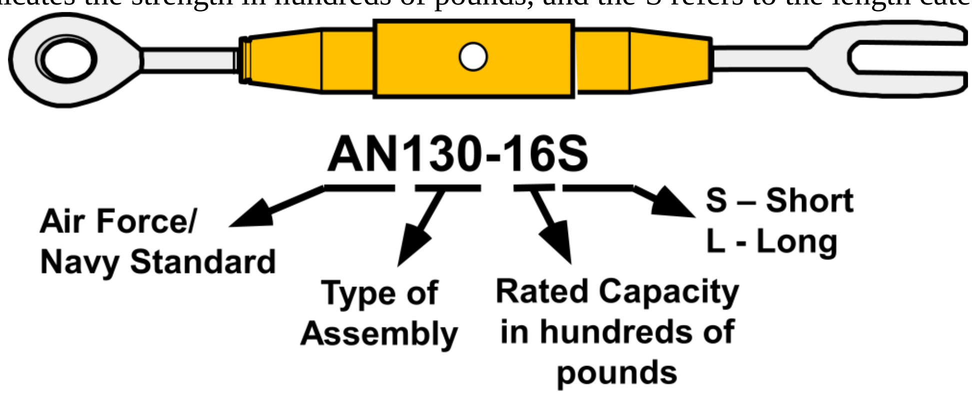


AN135 Assembly



AN140 Assembly

Additional characteristics are given by a dash number. A typical specification is AN135-16S. The 16 indicates the strength in hundreds of pounds, and the S refers to the length category.



The farther the ends are screwed into the barrel, the stronger the turnbuckle. The strength ratings require that no more than three threads are exposed at either end of the barrel. If past that point, the cable must be replaced with a longer one.

Turnbuckles come in two length categories: short and long, indicated by an S or L suffix (AN140-16L, AN135-22S). Short models are about 4 1/2 inches in length and the long ones are about 8 inches. The long version has an inch-and-a-half additional length adjustment, or take-up. For example, the AN130-16S has a take-up of 1.125 inches and the AN130-16L is 2.875 inches.

The additional take-up of the long models is a lot of adjustment. But they can save you from making a whole new cable assembly if one ever comes out slightly too short. Cut the cable away from the short turnbuckle and install a long one instead. Make sure it has the same strength rating as the short one being replaced.

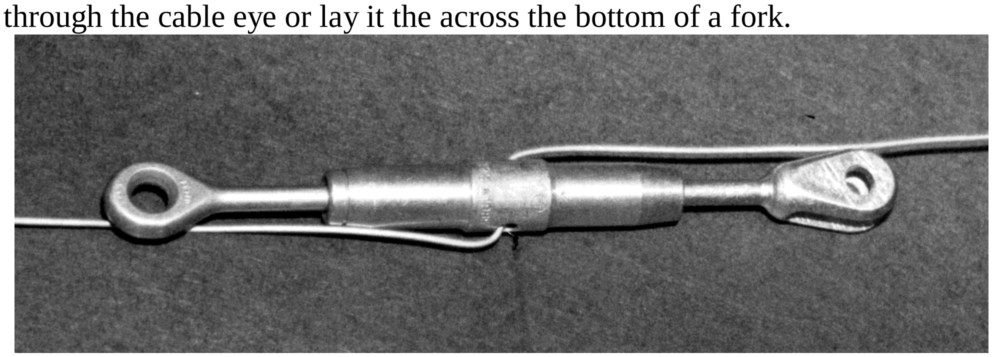
The barrel and the ends are both longer for the L models. The individual components use a similar dash number scheme to indicate strength and length. So a typical barrel might be an AN155-32S. Turnbuckle end specifications also insert an R or L before the short or long identifier to indicate whether the end is left- or right-hand threaded. Thus, an AN161-16RS turnbuckle end is a right-hand threaded short fork, good for 1,600 pounds.

Remember three main things when using turnbuckles. First, enough screw threads of the cable end must be contained within the barrel to allow the unit to meet fully rated strength. One cannot expect a single thread to withstand a 2,000-pound load. Therefore, make sure no more than three threads are exposed at either end of the barrel.

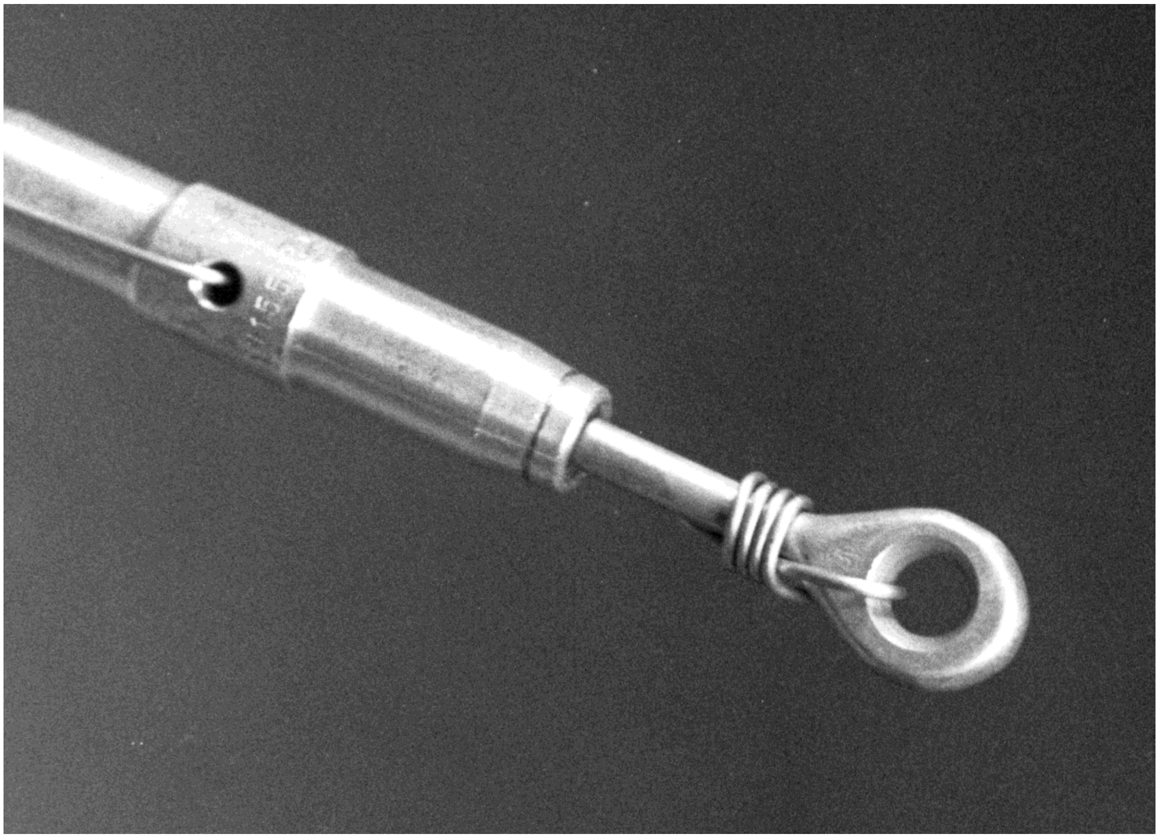
Second, do not lubricate the threads. Turnbuckle rotation is necessary for installation, not while the aircraft is in operation. Lubrication would only make it easier for the turnbuckle to rotate on its own.

On this note, the third item is prevention of inadvertent slackening. Because tension tries to force turnbuckles to loosen, they must be safety-wired to prevent rotation. The single-wrap method is fastest. Start with a new piece of safety wire about three times the length of the turnbuckle. Never reuse an old piece. It's tempting to just loosen the ends, adjust tension, and rewrap with the same wire. Don't because the changes reduce strength.

Push half the wire through the barrel's center hole. Bend each end in opposite directions, and poke through the cable eye or lay it the across the bottom of a fork.



Wrap the ends of the wire around the shanks of the turnbuckle ends at least four times and cut off the excess.



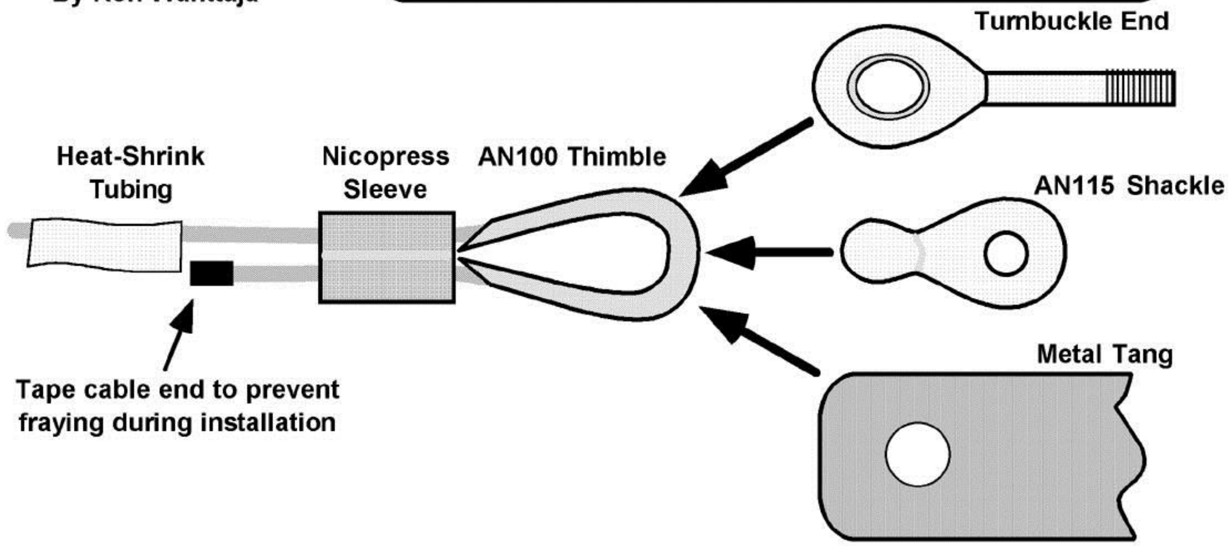
The single-wrap method can be used on turnbuckles connected to 1/8-inch or smaller cables. Brass safety wire is acceptable on 1/16-inch and 3/32-inch cables, but stainless steel is required for 1/8 inch. Whichever type is used, it must be at least 0.040 inch in diameter. Cables 5/32 inch and larger can be single-wrapped, but only with .057-inch stainless steel. This thicker wire is harder to bend.

Double-wrapping is similar, but uses two pieces of wire with the ends wrapped in opposite directions around the shanks. Don't wrap one wire directly atop another; instead, move down the shank a bit. Double-wrapping lets you use .040-inch stainless steel on cables 5/32 inch or larger.

Double-wrapping is actually the FAA's preferred method in all cases, but single-wrapping is acceptable if the above rules are followed. To avoid safety wire entirely, buy the more modern MS212XX-series turnbuckles. These use a quickly-installed safety clip, instead. But like all things fast and neat, they cost more than the ordinary item.

ShopSheet Cable Terminations

By Ron Wanttaja



Cable Dia.	Material	Strength*	Thimble	Sleeve	Shackle
1/16"	Galv.	480	AN100-3	18-1-C	AN115-8
	Stainless	480	"	28-1-C	"
3/32"	Galv.	1000	AN100-4	18-2-G	AN115-21
	Stainless	920	"	28-2-G	"
1/8"	Galv.	2000	AN100-4	18-3-M	AN115-21
	Stainless	1760	"	28-3-M	"
5/32"	Galv.	2800	AN100-5	18-4-P	AN115-32
	Stainless	2400	"	28-4-P	"

* In pounds, for 7x19 Cable (7x7 for 1/16")