Build Your Skills: Metal Part 1

RV builder Dan Checkoway begins our journey through the gritty details of working with metal.

BY DAN CHECKOWAY

There is no sensation in flying that can compare to how it feels when you take to the air in an airplane you built with your own hands. Your persistence, your open mind and a vast community of people who have gone boldly before you—these things enabled you to learn as you proceeded, pick up the required skills on the fly, and solve the various problems thrown your way. Building a plane is something anybody can do, but you come out on the other end of the process a changed person with an indescribable sense of pride and accomplishment.

I built a Van's RV-7. I am not a certified metal expert—that much I'll admit—but I have been through the process from start to finish and have learned more than I ever believed was possible. Moreover, I've built an airplane that is safe, airworthy and constructed to what I think are the current high standards of the art. I did not intend to win awards; I simply wanted to please my own sense of *done right*. This is the approach, I think, that most modern builders will want to follow.

Where We're Going

In this series, I hope to pass along the education I received at the blunt end of a rivet gun and, equally important, from my friends and colleagues who have built metal airplanes as well. (Never underestimate the value of help from friends and those who have gone before.)

While I have helped lots of people on airplane projects, I myself have only

Meet Dan Checkoway, successful RV-7 builder with a no-nonsense but practical approach to building. He's confident enough in his work to leave his RV unpainted—so far.

...and now meet the enemy. Bags of rivets. (We're kidding here.) In fact, this RV training kit, in which you have the chance to produce an aileron-like assembly, comes with a modest amount of hardware. The whole airplane uses multiple grocery bags full of rivets.

built one plane. And it wasn't even a scratch-built or plansbuilt plane—I built it from a highly evolved kit. I say "evolved" because the guesswork has largely been eliminated from the process. Essential parts are, for the most part, pre-cut, pre-formed, and in many cases match-drilled. It's amazing how easy building a metal plane from a kit has become!

What exactly comes in the kit? It varies from manufacturer to manufacturer, but what you can expect to find in the big boxes will be a multitude of aluminum pieces, which by themselves don't look like much—sheets, lengths of angle, various pre-formed spars, ribs, bulkheads, and of course lots and lots of rivets! Get to know these pieces. They will be your constant companions.

Rivets In Detail

Rivets, rivets and more rivets. Your kit will most likely come with a bunch of bags full of rivets of different styles and sizes. If you've ever looked closely at a metal airplane you've no doubt seen rivets. The basic concept behind the rivet is that it's a small, lightweight way to fasten one thing to another. You know those yellow envelopes with those split metal things you use to keep the envelope flap shut? That metal thing is essentially a rivet—it pokes through a hole and then gets bent to hold the flap closed.

I suppose a rivet is also largely analogous to a staple holding sheets of paper together. You've got a piece of metal that pokes through a hole in the paper and then gets bent on the back side to prevent it from coming back out, and to bind the sheets of paper together. When you get right down to it, a rivet is a lot like a staple in principle. It doesn't really get "bent" the same way, but the concept is basically the same.

Let's stick with the staple analogy for a second. Here's an experiment you can try while sitting at your desk pretending to do work. Take a couple of sheets of paper and staple them together using a single staple. It doesn't take much force to tear the sheets apart. Now try this: Staple the paper together with 15 or 20 staples evenly spaced all along the edge. It takes much more force to pull those sheets of paper apart, doesn't it?

This is almost exactly the concept that you'll use when building a metal airplane. No single fastener can do the entire job alone, but lots of tiny fasteners act in unison to produce a strong bond. Rivets are generally tiny, but when you use thousands of them, you can achieve significant measurable strength.

We'll explore rivets and the process of riveting in painful detail in a future segment. If it's any consolation in the meantime, know this: Until I started building my plane I had never even seen a so-called solid rivet outside of the finished product. (I owned a Mooney; don't hold it against me.)

Aluminum Demystified

As you probably know, metal kit aircraft comprise aluminum predominantly. In contrast to other common metals such as steel, aluminum is very lightweight—and, somewhat more importantly, it has high strength for its weight. Technically, we don't use pure aluminum, which would be too soft for use in aircraft structure. Instead we use aluminum *alloys*, which combine one or more additional materials with pure aluminum to add strength and rigidity without adding considerable weight.

Almost all of the components that you'll find in metal airframe kits will be one of two common aluminum alloys—2024 or 6061. The skins, ribs, bulkheads and stringers will likely be made of 2024-T3. Extruded pieces such as longerons and various other angles (stiffeners and the like) will be made of 6061-T6. Gibberish to you? It was to me, too, when I started. It's actually pretty straightforward, and in reality you don't need to go out of your way to memorize the numbering system. But while we're on the topic, I'll explain what the numbers mean.

One among, oh...14,000 or so. This is a plain rivet with a countersunk head, meant to lie flat to one of the surfaces it will secure. You'll grow accustomed to its face.

Here's a look ahead to some finished work: one row of rivets along the wing. The goal is to get the rivets in securely and consistently.

As you will learn, building a metal airplane is a long series of putting something together and then taking it apart again to complete an intermediate step. This is the famed Cleco shown in its accompanying tool. These pins fit through holes drilled in the metal to hold sheets together.

Photos: Marc Cook

Aluminum alloy numbers like 2024 and 6061 are really three numeric designators. The first digit designates the alloy group by the main alloying element:

1XXX Pure Aluminum
2XXX Copper
3XXX Manganese
4XXX Silicon
5XXX Magnesium
6XXX Magnesium & Silicon
7XXX Zinc
8XXX Other Elements

The second digit designates an alloy modification. Zero means no modification, and 1 through 9 signify manufacturer-defined modifications. The last two digits designate the particular alloy within the group.

Clecos come in a wide variety of shapes and sizes, and include special C-shaped versions to hold sheets of metal by the edges.

Keep Your Temper

Alloy numbers may also include a temper designation, such as the T3 in 2024-T3, or T6 in 6061-T6. The temper refers to a process of thermal treatment, hardening, softening or any type of process that influences the character of the material significantly. I won't go into full detail on temper designations, but I will explain those two most common ones. T3 means the material was solution heat-treated, cold worked and naturally aged. T6 means the material was solution heat-treated and artificially aged.

Is it critical to know the exact science behind all of this? Not really. If you want to get into the nitty gritty of it, you might want to pick up a copy of a book by Nick Bonacci called "Aircraft Sheet Metal," which goes into much more detail. At least now you know that the 2024-T3 skins you get in your kit are made of aluminum alloyed with copper, treated in some fashion to achieve stiffness and strength. You can usually identify 2024-T3 by its shiny, almost mirror-like finish.

Most of the 2024-T3 components you'll be working with also have a coating on the surface called Alclad. This is a thin layer of pure aluminum, which is highly resistant to corrosion due to the oxides that form on it. I hesitate to mention corrosion just yet, because corrosion protection is, in and of itself, a topic that deserves more attention than we can give it here. But we'll cover that in a later installment.

6061-T6, which you now know is an aluminum alloy with magnesium and silicon, typically has a dull finish—most often used on extruded parts like angles, bars and tubing. Incidentally, most of the rivets you will be working with begin life as 2117-T4, and after you're done riveting they end up being 2117-T3. We'll cover exactly why that is in more detail in future installments.

We're getting a bit ahead of ourselves here, but you might as well know the riveting gun by sight. You'll use it a lot.

There will be cutting and there will be filing...and days when you do both. Invest now in good snips—for straight cuts and curved—and sharp, flat files.

You might think that the new pre-punched kits—sometimes called "matched-hole" designs—would cut down on the drilling, but that's not quite true. Those holes aren't punched to final size, so a good pneumatic drill, a selection of bits (always to be kept sharp) and a depth stop (the spring apparatus) are essential.

Look, You Get To Buy Tools

Let's shift gears and talk a bit about tools. Assuming you've never worked with aircraft sheet metal tools before, there's a fair amount to learn. Most of the tools you'll need are not the run-of-the-mill stuff you might have around for home improvement or tinkering with your car. But never fear—there's a multitude of tool vendors out there that have made life incredibly easy for first-timers. Most of these vendors sell tool kit packages that include just about everything you will need to build your airframe, plus or minus a few doodads.

These tool packages go a long way to help launch you right into your project without having to waste much time piecing together your tool collection. Especially if you don't have much perspective on aircraft tools, buying one of these tool kits up front can save you a ton of time. Also keep in mind the price of shipping—if you try to save money buying your tools piece by piece, you might end up spending more in the long run. There is a significant measure of convenience and savings built into the pre-packaged tool kits.

I bought my initial tool kit from Avery Tools (www.averytools.com). The company sells kits specifically catered to different aircraft models, such as the RV series, Sonex, GlaStar and Mustang II. Among the other vendors that sell packaged tool kits are Aircraft Tool Supply (www.ats.com), Cleaveland Aircraft Tool (www.cleavelandtool.com), Brown Aviation Tool Supply (www.browntool.com) and Aircraft Spruce (www.aircraftspruce.com).

Most builders, myself included, end up having more than a little "sticker shock" when they discover just how much it costs to purchase tools for their project. A quality aircraft tool kit that includes everything you'll need to get started can cost upwards of $2000. To the uninitiated, it might seem bizarre that you're spending more money on tools than you'll spend on your empennage kit! Three hundred bucks just for a drill? *You can't be serious!*

But tools are a lifetime investment and it's not an area where you want to skimp. In most cases, you do get what you pay for and sacrificing quality when it comes to buying tools may translate into trouble during construction. Better tools really do make your life easier, and you can always sell tools once the plane is flying—assuming you can bring yourself to part with them. (I know I can't!) Who knows...

maybe the first plane you build won't be your last.

As you'll quickly discover, some of the most common tools you will use when building a metal plane will be "Clecos" and a pair of Cleco pliers. Clecos are temporary clamps used to hold pieces together for assembly while drilling and again while riveting. Unlike other types of clamps, which hold things together along edges, Clecos are instead inserted through holes. You will end up using hundreds of Clecos simultaneously on some of the larger structures.

This is not a set of conjoined feeler gauges. A rivet spacer like this will help you distribute a line of rivets evenly—and, most importantly, help your work look nice.

You'll need a drill, preferably a pneumatic drill capable of turning at high speeds. And if you think you're going to use your household drill bits on your plane, forget it. When it comes to drilling on aircraft, this is one area where precision is critical. There are very specific sizes of drill bits you'll need to use for different sizes and types of fasteners.

What else? You'll need tools for deburring, dimpling and countersinking the multitude of holes you'll be drilling. You'll be using squeezers with different yokes and dimple dies and rivet sets. You'll want a rivet gun with various sets, and you'll end up using several different bucking bars. Again, pre-packaged aircraft tool kits typically include most if not all of the stuff mentioned above, as well as lots of other specialty tools.

Ready to Build

Let's wrap this up for now, before we charge ahead and start squashing rivets. In the segments to come we'll cover all of the basics of building your metal kit airplane. If you have any qualms now about being able to build your own plane, we'll fix that in no time.

Next time, we'll start with edge prep, flanging and fluting. That should get you ready to prepare ribs and skins for initial assembly and drilling. Later, we'll cover hole layout, drilling techniques, deburring, dimpling/countersinking techniques, corrosion protection, rivets, and—of course—lots of riveting techniques. *You can do this!* ✢

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Build Your Skills Metal Part 2

By carefully using a 3M Cut & Polish wheel on your bench grinder, you can make quick work of deburring edges. Notice Dan's prudent use of safety glasses.

Welcome back to our monthly series on learning to meld with metal and bash rivets without blood or tears.

BY DAN CHECKOWAY

Throughout the splendid and useful process of becoming (and, for that matter, just being) an aircraft builder, there are certain sounds to which your ears will become keenly tuned. No, not the barking of Lycomings as they tauntingly taxi by on their way out to enjoy what you're diligently working toward—that goes without saying. But there are other more subtle sounds, which ordinarily wouldn't get the attention of the layman that now command your attention. For example, there's no mistaking the clatter of that brown truck's neglected suspension as it rounds the bend and squeals to a halt just outside your door. That's right, I'm talking about the UPS guy—your new best friend as he brings cardboard-clad treasure to your doorstep.

He could be bringing new tools or the next installment of your airplane, but either way it's a good day. As we discussed last month, building an airplane—of any material, not just metal—requires practice, patience and persistence. Last month, I tried to get you started by looking at some of the tools and procedures you'll be working with for the duration of your project—and, in fact, beyond, as you'll be responsible for your fine airplane's upkeep as well.

So there you are, unfurling the long inventory list and trying to make heads or tails of all these unidentifiable pieces of metal that will someday stabilize you as you hurtle through the air at blinding speeds. What you are experiencing is the desire to rush ahead, Cleco the pieces together and start making airplane sounds. You can if you want, but such fantasy making is going to cost you time and deflect you from the real mission: to finish your gorgeous airplane.

Let's Get Started

Before we get into exciting stuff like drilling and riveting, we have to cover some of the more mundane, sometimes monotonous aspects of aircraft construction. But don't worry, your hands will still get dirty.

Take a look at those skins and ribs that came with your kit. They are likely to be CNC-cut and match-drilled—in truth, beautiful works of art. Take a closer, more objective look. Check out the edges. Even though you probably wouldn't cut yourself if you were to drag your finger across, the surfaces are not perfectly smooth. Aluminum

Here you can clearly see the difference between a rough edge as it came from the factory (bottom flange) and a deburred edge (top flange). It's worth the effort.

Photos: Marc Cook

kit components usually come from the factory with relatively "rough" edges. It's a byproduct of the way these pieces are cut (or stamped) from raw stock, and it's a good idea to finish the job the factory started.

Why bother? Because every one of those little tiny ridges is a crack waiting to happen. You may have heard the term "stress riser" before. Here's one way to illustrate the concept quite clearly. Take a roll of clear packing tape, and peel a few inches away. Try to tear the tape by hand. Good luck! That stuff doesn't tear easily. Now take scissors or a razor blade and make a tiny nick in the edge—as small as you can make it. Try to tear it now. The tape tears across with ease and little force, right?

The manufacturing process leaves rough edges on most parts, such as the one shown here. It's best to deburr all edges.

Relieve the Stress

Consider a sheet of aluminum or the edge of a rib flange. The same principle applies. Any roughness in a surface may be enough to permit the material to begin cracking from fatigue. If you give the material a good excuse to fail, you're asking for it. Even on the edges? Yes. Granted, most aircraft designs will generally not impose significant stresses along the edges of parts, but why give the material any opportunity to fail more easily if you can help it? As I mentioned, a little extra effort up front can make a big difference in the long run.

Those imperfections in the edge are sometimes called "burrs," so the process of smoothing them out is called "deburring." You may have heard and associated that term with smoothing out holes that have been drilled, but the term also applies to edges.

It's hard to beat the good old manual method—a Vixen file quickly smooths out those rough edges.

Learning Deburring

There are lots of techniques, and I'm guessing you will most likely try several of them. You can use a flat file. You can use emery cloth. You can take the part to a deburring wheel on your bench grinder or you can use a unitized wheel on your die grinder. There are deburring attachments for rotary tools. They even make about a dozen varieties of special hand tools for deburring edges. Over time you'll eventually settle into a method that works best for you.

After filing the edge, a quick pass using emery cloth and then a Scotch Brite pad will finish off those edges quite nicely.

If you decide to use a rotary tool of some sort, such as a Dremel or die grinder, be sure to stabilize the work. Preferably, clamp it to your bench to free up both hands to control the tool. If you use a deburring wheel on your bench grinder, use caution in how you feed the part into the wheel. It's easy for the part to jam up and bend, possibly taking your fingers with it. And, of course, always wear proper eye protection whenever you're working with tools that spin!

An alternative to the manual method is to use a 3M Roloc pad on a die grinder. Typically you will use a fine grade.

I actually prefer the "old fashioned" manual method. I generally start with a Vixen file, which is a great tool for removing material quickly and leaving a relatively smooth edge. After using the file to "level" the edge and radius the corners slightly, I switch to emery cloth, or aluminum oxide sandpaper (typically 80 or 100 grit). Then I finish with a Scotch Brite hand pad (#7447). I find that on long, straight edges, this process is most effective in keeping the edge nice and straight, while producing a very smooth finish. Using any

There are several different types and grades of sanding and surface conditioning pads that come in handy for smoothing out all that rough stuff.

sort of "power tool" such as a unitized wheel on a die grinder on a long edge will take less time and effort, but invariably it will introduce a slight waviness into the edge. It's hard to beat the consistency of a file for those straight edges. If you do use a rotary tool, apply even pressure using long, consistent strokes. Take your time.

Commonly referred to as the "Scotch Brite wheel," the 3M Cut & Polish wheel can be mounted on a bench grinder or a drill press.

Lightening In the Hangar

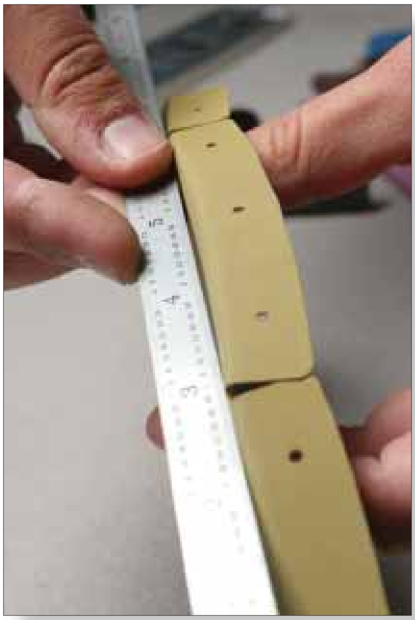
Don't forget to deburr all edges, not just the outer edges of skins and stuff. I'm talking in particular about lightening holes and inspection holes. Any spot where you might have to reach your hand or arm through later, deburring those edges also serves the purpose of saving skin. When it comes time to buck rivets through those lightening holes or every time you're reaching into that inspection panel to lubricate a rod end bearing, you'll thank yourself for taking the time now; unless, of course, you *like* bleeding. Since you can't just run a Vixen file along those curved edges, what's the best way to get it done? Again, every builder will probably prefer a different method—I like using a unitized wheel on a die grinder for these curved edges.

How smooth is smooth enough? Just get it as smooth as you can within reason. If you can't see any notches or ridges, and if you can run your fingertip or fingernail along the edge without feeling any imperfections, it's done. Different people have different standards in this area, and you need to come up with your own. I tend to lean toward the conservative side here, and I figure even if I have to spend umpteen more hours deburring over the entire course of the project, I'll sleep better at night knowing I did my best. There's no good reason to take shortcuts on something this simple. Yes, it can be monotonous, but what is worse—the monotony of deburring or the prospect of finding cracks in your airframe? Enough said.

Manage the Flange

So your edges are gorgeous, and you're probably itching to Cleco it together and start drilling. *Not so fast!* There's one more step you need to take before

Another variant used for deburring lightening holes is the "flapper" wheel. Grooves wear into it, which actually help provide stability as you work with it.



Flanges often need a fair amount of straightening. Use a straightedge to gauge how much curvature needs to be taken out by the fluting process. Go slow, it's an iterative process that requires finesse.

Fluting pliers clamp down on the flange and form little notches to straighten the part. Make sure you've got the tool oriented correctly—the notches should be formed away from the adjacent part.

You can slide a square all along the flange to determine if it is perpendicular to the web of the rib or bulkhead. Be aware that some ribs may require something other than a 90° angle.

you start assembling things. Despite these beautiful kit components having been fabricated with the help of a computer, they're not always perfect out of the box. And much like the rough edges, there's another area where the production process leaves some work for the builder to do: the flanges.

The flanges are the bent edges on spars, ribs and bulkheads. Most of the time, the flanges should be bent perpendicular to the web. Occasionally, such as on bulkhead flanges on a tapered fuselage, you'll see that the flanges should be bent at an angle that accommodates the taper. There are two common problems with flanges as they come off the press. The first arises whenever the flange is curved, such as on airfoil ribs. Ever try to fold a curve into a piece of paper? It's almost impossible. With aluminum, it takes a machine to press or stamp the rib into submission, and even then it doesn't always come out perfectly. Invariably, the web of the rib or bulkhead will be warped slightly whenever a contoured flange is formed.

What has happened is that as the flange was pressed into form, the aluminum was stretched a bit. The result is that the edge of the flange actually ends up being longer than the bend line itself. This forces the part to bow along that bend line. This is undesirable, because your rib or bulkhead flange isn't perfectly straight. Who wants to see a rivet line that curves? Not only is it unappealing aesthetically, it's also structurally undesirable. We want nice, straight rivet lines.

So how do you take the "arch" out of these parts? All you have to do is remedy the length mismatch, shortening the edge of the flange so that it has the same length as the bend line. *Shorten aluminum?* How do you do that?

You could use a metal shrinking tool, but most of us don't have access to one. The alternative is quite simple, really. What we'll do is reduce the "effective length" of the flange edge without having to remove any material. That's a fancy way of saying we'll introduce a series of curves into the flange edge. As you know, the shortest distance between two points is a straight line, so if we add some curve to the path, it's going to "absorb" some length. The tool: fluting pliers. With these, you squeeze little semi-circular notches into the edge of the flange in between rivet locations, and magically that part straightens right out.

Start out by placing the part on a flat surface or put a straightedge up against it. This will help you gauge just how much bow needs to be taken out. Sometimes you might luck out, and the part will be pretty straight from the factory. But more often than not—on a wingrib, for example—you'll have as much as one-quarter to one-half inch of bow at the center, which you'll obviously need to correct.

Before you start fluting, you need to identify the rivet hole locations so you don't accidentally flute the flange right where a rivet needs to go. If your flange already has pilot holes drilled, then the guesswork has been taken out of the equation—simply flute between the existing holes. But if your flange has not been drilled, then you will need to do some planning by determining where rivets will go. Often you can hold the piece up to the skin, assuming the skin has already been drilled, which will let you "trace" hole marks onto the rib flange. Otherwise you might have to break out the ruler or tape and measure and mark the hole pattern yourself. Sometimes kit manufacturers provide "fluting diagrams," which are printed templates that indicate where fluting is acceptable.

Once you know where to flute, the process is pretty straightforward: Just squeeze some notches in the flange. That said, it takes more of an artistic touch rather than brute force. Go slowly and gently. The last thing you want is to "overshoot" and to cause the piece to bow in the opposite direction. Start out with intentionally gentle squeezes, making notches just barely visible. Check the web against a straightedge again to see how much difference it made. Repeat iteratively until the part is straight. You may need to flute deeper in certain spots to compensate for inconsistencies in how much the flange was stretched. Just do whatever it takes, and get it as close to perfectly straight as possible. The straighter your rib and bulkhead flanges are, the easier it will be later to drill your rivet holes dead on the center line. If you accidentally go too far and introduce bow in the opposite direction, you can simply take your hand seamer, and very gently squeeze the flutes out.

A hand seamer has more uses than simply bending metal. It can also be used to change the angle of flanges, or to squeeze out flutes if you overdo it when fluting.

Don't forget, you've got two flanges that can work with or against each other. Don't try to take all of the bow out with just one flange. Wing leading edge or fuel tank ribs tend to be the most challenging, since they usually have dramatically different contour on the top and bottom flanges. It takes a bit of practice to learn how to fix a badly bowed rib. Take your time, and try not to "chase your tail" in this process. Getting slightly off track can turn that rib into a twisted mess. Go slowly, and only try to correct it a little bit at a time until the rib lays nice and flat.

Once you've got your part fluted, double check the angle of the flange again to make sure you didn't introduce any unintentional bend in either direction. You can use a square for this, assuming the flange is supposed to be perpendicular to the web. Sometimes, you'll flute your flanges, get them squared up, and then you find the part has twist again. It's definitely an iterative process, where you may have to go back and forth between fluting and flanging until everything is perfect.

Preparing the parts is definitely not the most rewarding aspect of building your plane. You might spend hours deburring edges and fluting and flanging, with basically nothing to show for it. Your family and friends may comment, "What were you doing out there in the garage for all those hours? It looks the same as it did three days ago." Just remember, as monotonous as this process can be, it is definitely time well spent. And, trust me on this, it will eventually end.

I'm personally glad we got the prep work out of the way, because next time we get to start drilling holes! In the next installment, we'll talk about assembling components, techniques for drilling all of those thousands of holes, and tips on deburring 'em. See you next month! ✢

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Build Your Skills

Metal Part 3

Dan has clamped some match-drilled pieces together with Clecos. He is carefully drilling the holes out to full size, make sure the drill is held square to the work. No oblong holes here.

Holes, bits, clamps and chucks. You know the drill.

BY DAN CHECKOWAY

Last month we discussed the subjective monotony of initial parts prep, such as smoothing out edges and fluting. Now that your flanges are squared away (sorry, couldn't resist the pun), it's time to start thinking about littering your shop floor with thousands of little curly shards of aluminum. Yep, in this installment, we're—finally—going to commit drill to metal.

Before we start, let's take a look at some of the tools used for drilling aircraft sheet metal. At the heart of it is the drill motor itself, which is simply the spinning mechanism. We typically use pneumatic (air) drills. Sure, you can use your electric drill, but there are a couple of disadvantages to doing so. Because we're dealing with conductive metal, often having to drill in confined areas rife with sharp edges, it's conceivable that you could drag the power cord across an edge and cause a short. Even rechargeable cordless drills aren't ideal. There may be occasions when you need to drill in areas with combustible fumes (i.e. fuel tanks), and the last thing you want is that electric motor igniting vapors and causing an explosion. These are the primary reasons why pneumatic drills are preferred in aircraft construction. Air drills also tend to be lighter, more durable and are capable of spinning faster, which is desirable when working with aluminum—but we'll get into the details of that technique in a bit.

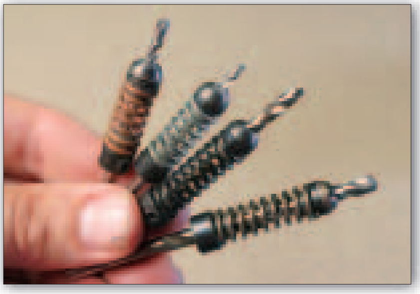
Bit Players

The drill bit itself is just a hardened metal shank with a cutting tip and spiral "flutes." The flutes are designed to serve several purposes—carry chips and shavings away from the work while allowing lubricants, if used, to flow to the work. They also add surface area and help keep the bit cool. You'll find that tool vendors sell bits made of various materials, such as cobalt or hardened steel.

For drilling aluminum, cobalt or high-speed steel seem to be the most common choices. You will end up paying more for bits with more hardness, but they will stay sharp longer and are capable of drilling tougher metals. You may notice that vendors sell bits in various lengths as well, such as short "jobber-length," 6-inch and 12-inch. You'll probably use jobber-length bits most of the time, with longer bits coming in handy occasionally when a long reach is required, such as when you're drilling into a confined area.

Lightweight, palm-sized air drills are commonly used in aircraft kit construction. They tend to be safer and more capable than electrically powered drills.

Photos: Marc Cook



Drill stops are color coded so you can easily identify their size. The spring provides a tiny bit of cushion, acting like a shock absorber as the drill stop hits the material you're drilling.

Step drills, also called by their brand name Unibit, come in different size ranges. They make quick, clean work of enlarging holes. Once you have drilled the pilot hole, a step drill can be used to enlarge the hole incrementally to the desired size.

Cleco clamps are used to hold the skin to structure while drilling and riveting. In flat areas, you can usually get by with one Cleco in every third or fourth hole. Along curves, you may opt to use a Cleco in every hole or every other hole.

Drill stops are also extremely useful accessories to have. These are adjustable spring mechanisms which fasten to the drill bit and limit how deep the drill bit will penetrate the material. A set screw allows you to adjust how far up or down the shank of the bit the drill stop is positioned. This is helpful in case you were to go jamming through once the bit penetrated the initial layer, because the bit might cut into underlying structure or a critical component (i.e. hoses, tubing, electrical wiring) behind what you're drilling. A diligent driller can avoid inadvertent damage with good technique, but the drill stop is cheap insurance and lets you work a little bit faster with less risk. Another nice feature of drill stops is that they are usually color coded according to the diameter of the drill bit. This helps you identify your drill bits quickly, assuming you leave the drill stops on the bits. The four most common drill stop colors are shown in the table below.

A New Angle

Another tool that will come in handy when drilling is an angle drill. There are several varieties, including dedicated drill motors with 45° or 90° drives, and also adapters which attach to your existing standard drill motor and provide a 90° drive. These angle drills typically use "threaded" drill bits, which instead of getting secured via a "chuck" screw directly into the drill head. So you'll most likely end up having a collection of threaded drill bits as well as standard plain-shank bits. Angle drill motors are pretty expensive, so most kit builders get by with an angle adapter. As is the case with most tools, it just depends on your budget. You get what you pay for in terms of function and form.

Rivet Diameter (inch)	Drill Number	Cleco & Drill Stop Color	Minimum Edge Distance (inch)	Minimum Rivet Pitch (inch)
3/32	40	Silver	3/16	9/32
1/8	30	Copper	1/4	3/8
5/32	21	Black	5/16	15/32
3/16	11	Gold	3/8	9/16

Lube 'er Up

Something else to consider that is not a tool per se, but belongs among your arsenal of drilling accessories, is lubricant. Drill bits do lose their sharpness with use, and a dull drill bit does very little for you, other than just heating up the work. It's important always to use sharp drill bits to form crisp, clean holes. Lubricants such as Boelube (carried by most aircraft tool vendors) help keep your drill bits cool as they are used, which ends up preserving the sharpness and prolonging the life

Lubrication helps to keep your bits sharp. With the solid form of Boelube, you can simply spin the drill bit right into the "stick" to apply lubrication.

you'll get out of them. Boelube, for example, comes in liquid, paste or solid form. Liquid can be sprayed or poured, paste can be spread, and with the solid you can just spin your bit right into it. They all work essentially the same—just pick a method of application and go with it.

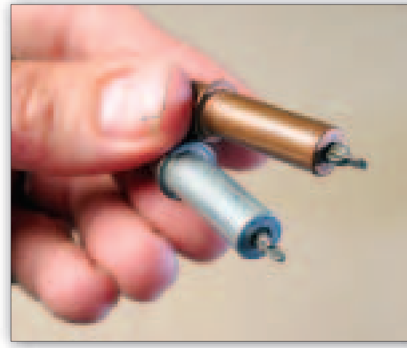
It is extremely important that you use some form of lubrication when drilling hard metals such as steel. Aluminum is soft and tends not to dull drilling and cutting tools as quickly, but it always pays to lubricate your drill bits regardless of the material you're working with.

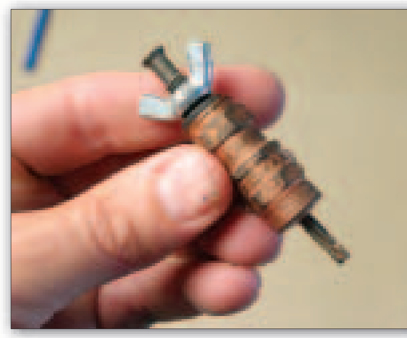
Clamps For Everything

There's one last set of tools to discuss—Cleco clamps and pliers. Cleco clamps are ingenious little devices that allow you to bind layers of materials together temporarily by clamping through holes. Clecos have a spring-loaded split shaft that inserts into a hole when compressed and, when released, the halves of the shaft are forced apart as they pull toward the body. This simulates the tension of a rivet, or any other type of hole-based fastener. As you drill holes in your components, you insert Clecos to hold everything together. Clecos are also used when riveting in order to hold the structure together until the rivets are set in place. Just like drill stops, Clecos are color coded (see Table 1). You'll end up needing hundreds of silver and copper Clecos at various stages of airframe construction.

Special pliers are used to compress and release Cleco clamps. You'll even see pneumatic Cleco tools out there, which seems like a frivolous luxury to me—but to some builders it's essential. Take my word for it—the deeper you get into aircraft building, the more strength you'll have in your hands from exercising the Cleco pliers literally thousands of times. It's good to have at least two sets of Cleco pliers, because your partner can grab the second pair and help you insert or remove those hundreds of Clecos more quickly than doing them all yourself.

There are several variations on the theme when it comes to Clecos. Other than the common pin-type Cleco, there are Cleco side clamps, and even a wing-nut-style pin clamp, which instead of being spring loaded allows you to crank down with a wing nut to achieve higher (or lower) clamping force.





Note the different styles of Cleco clamps. At the top are pin-style Clecos, where the split shaft pulls the material together through a hole. In the center is a side clamp, and you can see how the Cleco pliers actuate the clamp. At the bottom is a wing-nut-style Cleco. It's like the pin style, only adjustable—as you tighten the nut, the shaft pulls up against the material.

Matters of Size

Let's talk about hole size for a minute. Without getting into too much detail about rivets (yet), I can tell you that the vast majority of rivets you'll be using on your airframe will be one of two diameters. Most of the time they're either going to be 3/32 or 1/8 inch. Believe it or not, there aren't many exceptions. The length of the rivet will vary quite a bit based on the thickness of the layers you're riveting together, but the diameter doesn't vary much. Virtually all of the rivets holding structures together internally (ribs to spars, for example) are going to be 1/8 inch in diameter. Likewise, nearly every rivet fastening a skin to an underlying structure will be 3/32 inch in diameter. There are only two other diameters of rivets that you're likely to encounter, and they would be 5/32 and 3/16 inch. Those larger rivets may be used on wingspar doublers and that sort of beefy structure.

When Is an Eighth Not an Eighth?

When it comes to drilling holes for these rivets—or for any fastener for that matter—it's not quite as simple as just drilling a hole the same size as the rivet. You might think you'd drill a 1/8- inch hole for a 1/8 -inch-diameter rivet. Not so, because every fastener needs to have a small amount of clearance for it to fit and function properly. Over the years, metal aircraft construction techniques have evolved, and precise specifications have been developed and refined by experts. There are cut-and-dried specs on the exact clearance required for each fastener size. Generally speaking, for the sizes of rivets used in small aircraft, you'll end up drilling an oversize hole that is approximately 3 to 4 thousandths of an inch larger than the fastener itself. This allows the rivet to slide into the hole easily and also allows the rivet shank to expand slightly as it gets set.

Related to drilling is the idea of edge distance, which is the distance measured from the center of a hole to the edge(s) of the skin, flange, etc. The rule dictates that edge distance must be at least 2D, or twice the diameter of the rivet.

Let's take that 1/8-inch rivet, for example, whose diameter in decimal form is 0.1250. When drilling a hole for that rivet, you'll actually drill a hole that is 0.1285 inch in diameter. And for the 3/32-inch rivet (0.0938 inch), you'll drill a 0.0980-inch hole. Do you need to memorize those diameters? Thankfully not.

There are different systems and scales of drill sizes which make life easy. You're undoubtedly familiar with the run of the mill set of *fractional inch* drill bits—this is the stuff you probably have in your home tool chest. You know...1/16, 3/32, 1/8, 5/32, and 3/16 inch. The system you'll want to get familiar with is actually much easier to deal with than that. You'll end up using mostly numbered drill bits. The numbering system goes from #80 at the smallest to #1 at the largest. There's also a lettered drill bit system, from A to Z, which picks up where the numbers leave off at the large end of the scale.

All you have to remember is that you use a #40 drill bit for a 3/32-inch rivet and a #30 bit for a 1/8-inch rivet. OK, so it's a little confusing at first. But take my word for it, you're just going to be using #40 and #30 most of the time. You'll get used to it. See the table on page 50 for a reference of the most common rivet and drill sizes. (For a complete scale and reference on drill bit sizes, check out www.rvproject.com/drillsize.)

Other than your standard sheet metal drill bits, there are also special drilling tools called step drills, also known by the trade name Unibit. These drill bits literally have several sizes in one, with steps between them, which allow you to enlarge a hole from one size to a larger size in graduated increments. There are variations of step drills which have different ranges of the smallest and largest size. Most of them have at least eight or ten increments. What varies is the increment itself, such as 1/64 inch, 1/32 inch or 1/16 inch. One type might have a range between 1/8 inch and 1/2 inch, and another variety might range from 3/16 inch to 3/4 inch. Step drills, while we don't use them for drilling rivet holes, are an alternative to other types of larger hole cutting tools. They're typically good for anything up to about 1 inch in diameter. You'll find toward the end of your project, when you are routing wires and tubing and stuff, that Unibits come in very handy.

Ready To Drill Yet?

You're probably ready to start poking holes in metal, so let's get down to it. For the moment let's assume you need to drill holes from scratch—even though the likelihood is that with a modern airplane kit, many of the holes will have been located and pilot-drilled for you. Regardless of whether your airframe kit's skins are drilled or not, at some point in your project you will undoubtedly have to drill some holes from scratch. Here are some tips on how to lay out and drill those holes easily and effectively.

The first consideration is the location of the holes. There are a few basic rules and conventions to which you should adhere in order to produce and preserve structural integrity. One of the most important ones has to do with edge distance, which is the distance measured from the center of a hole to the edge(s) of the skin, flange, etc. The rule dictates that edge distance must be at least 2D, or twice the diameter of the rivet (D refers to the rivet diameter), and should generally not exceed 4D, or four times the diameter. Too little edge distance, and there may not be enough material to prevent shearing. On the other hand, if you have too much edge distance, the material might be prone to "peeling back." It's better to err on the side of caution and use more edge distance—just make sure you've got 2D or better. In the case of 3/32-inch rivets, you would need at least 3/16 inch from the center of the hole to the edge. With 1/8-inch rivets you would need 1/4-inch edge distance.

Another important rule to live by pertains to the spacing of rivets, which is called "pitch." The rule states that you want to have a minimum of 3D (three times the rivet diameter) between rivets, with a maximum of 12D. In the table on page 50, you can see examples of minimum edge distance and minimum rivet pitch for the most common rivet sizes.

Pattern Behavior

With these rules in mind, laying out a hole pattern is typically a simple manual affair. Let's say you need to mark out a row of a dozen or so holes. Using a felt-tip pen, such as a Sharpie, you can get out your ruler and mark the hole locations. But sometimes this is a tedious process. There are some areas where the plans may call out a number of rivets and a suggested pitch (spacing), but it may not end up being a nice even dimension. For example, let's say you have 17 rivets which span 15 inches. What's the rivet pitch? 16 even gaps...so divide 17 by 16? Um, I don't think so. Don't bother getting out your calculator. There's a much easier way to deal with this conundrum—it's a tool designed specifically for solving this type of problem. The rivet fan, which was given its name because of

You can use a ruler and marker to lay out your own hole patterns, writing directly onto the plastic coating or the bare aluminum. When laying out hole patterns, take care to provide sufficient edge distance.

the way it fans out, provides a quick and painless way to achieve perfectly even spacing without having to do any math. All you have to do is mark the end holes, or even just one hole and a center line, and the rivet fan does the rest. Just straighten it out, or compress it, until you have the spacing you desire, and then mark your hole locations through the little holes in the fingers. It makes for perfect rivet lines every time. Rivet fans are not expensive, and well worth the money.

So you've got all of the holes marked on the aluminum, and it's time to drill. If you've ever done any drilling with sheet metal, then you probably already know how difficult it can be to keep the drill centered on the mark as you start the hole. Often, you put the drill on the mark, pull the trigger, and the drill goes spinning and skipping right off the mark. Ugh... Now, of all times, it's important to hit the mark exactly.

Line Up, You Guys

Not only do we often have relatively close tolerance on edge distance, but you want your rivet lines to look nice and straight. Nobody wants to sight along a line of rivets and see zigs and zags—however slight. An out of place rivet will stand out like a sore thumb. So what's the trick for keeping the drill bit centered on the mark as you start the hole?

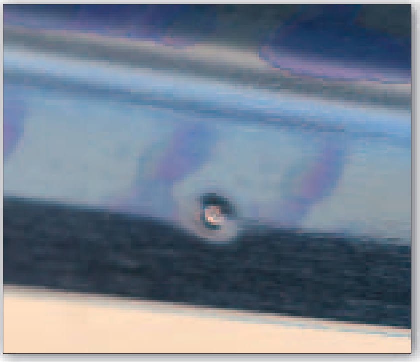
There are a couple of methods that work well. One is to use a center punch, which forms a tiny dimple in the material serving to keep the tip of the drill bit centered until it cuts in and is stabilized by the hole itself. If you use a punch, be careful not to deform the material by striking it too hard. You can use an "automatic" center punch, which is spring loaded and should apply just enough impact to make a mark, or you can use a standard punch with a hammer. Go easy: A light tap is all that's usually required with aluminum.

The rivet spacing fan is an ingenious yet simple tool that allows you to mark evenly spaced locations across arbitrary distances—without having to do any mental math!

I use a center punch when drilling steel, but on aluminum I typically don't bother. If you have a sharp drill bit, there's a simpler method. Take your drill and position the bit so it's exactly centered on the mark. Then, use just your fingers to turn the drill at the chuck while applying pressure to the work. Aluminum is soft, and a sharp bit will start cutting, forming a small pit in the metal. After a few turns by hand, the pit will be deep enough that it will keep the drill centered and stable as you pull the trigger.

Speaking of spinning the drill, most pneumatic drills are variable speed. You can pull the trigger gently to achieve a slow turning speed, or you can pull it all the way in for maximum rpm. Most air drills are capable of turning somewhere between 2000 and 4000 rpm. If you raise the air pressure to the drill, it will turn faster at the top end. Don't overboost it, however—always adhere to the drill manufacturer's recommendations. There is usually enough

CNC production is responsible for components like this, where flanges come notched and bent, and holes are already precisely pilot-drilled. You merely drill these holes to full size after Clecoing the parts together. What could be easier?



Don't overdo it when using a center punch. Aluminum is soft and will deform if you hit the punch too hard. Here is an example of that mistake. All you need is a small mark to keep the drill bit centered as it starts spinning.

sensitivity built into the trigger, assuming your drill is in good working order, to provide you with plenty of speed control, without having to mess with air pressure.

Special Steel

When it comes to drilling steel, it should be done at very low speeds. Drilling steel generates considerable heat, and lubricant is absolutely essential. If you go too fast, it will just harden the material and ruin your drill bit. When drilling aluminum, however, high speed is better. Once you're stabilized, spin that puppy right up. Aluminum is soft and cuts quickly without generating as much heat. Aluminum also conducts heat more readily than steel, so it has a sort of built-in cooling effect. Your drill bits will last much longer drilling aluminum than they do on steel. Even so, a little lubricant still works wonders with aluminum and will keep your bits sharper longer.

As far as drilling technique goes, it's straightforward. There's pretty much only one cardinal rule—keep the drill square to the work. If you drill at an angle, the hole ends up elongating instead of forming a perfect circle, which introduces undesirable slop into the fastener fit. As you start out and are getting used to it, you might want to move your head and get different perspectives on the drill to ensure you've got it squared up. Sometimes when drilling on curved surfaces, such as leading edges of wings or the curve along a fuselage bulkhead, there's no definitive reference for what is level—or perpendicular to the surface. You need to try to visualize an imaginary radial coming directly out of the surface at the point where you're drilling, and keep the drill aligned on that axis. It's a matter of practice making perfect. Then again, there's a tool for every purpose—they actually sell special drill bushings that help ensure you've got the drill perpendicular to the surface.

We talked about drilling holes from scratch, so now we can dive into the easier stuff. These days, airplane kit manufacturers often use CNC to produce aluminum kit components. CNC stands for computer numerical control, which is a process where a computer controls machinery that precisely cuts, shears, punches and bends the aluminum, forming ribs, spars, bulkheads and skins. If you're lucky enough to have a CNC-made kit, the likelihood is that your skins come from the factory "match drilled" to the ribs and bulkheads. In general, holes line right up and you can just Cleco everything together right out of the box.

Even so, the holes aren't quite ready for rivets. The factory deliberately punches all of those holes undersized, which provides a bit of tolerance for slop when the builder assembles things. When I say slop, I'm talking about a few thousandths of an inch. Generally everything lines up, but on occasion you need to use that built-in tolerance. In any case, you always want to drill all of the holes to full size. For example, the holes that the factory punched for 3/32-inch rivets might be #42, and you absolutely need to drill them out to #40 to provide the proper clearance fit, and to ensure all of the holes on overlapping structures are perfectly concentric.

Instead of using a center punch, you can start a hole by spinning the drill by hand. This works well and alleviates the need to use a hammer and punch.

Match Game

Basically, you Cleco everything together, placing a Cleco in every third or fourth hole, and drill the holes between Clecos to full size. Then you move the Clecos down a hole and drill those holes out. It goes very quickly, since all you have to do is run the drill through each hole. You don't have to worry about laying out the hole pattern, marking it, center punching or hand-spinning the drill to start the hole. Zip in, zip out, it's done. CNC has truly made aircraft construction a snap for us kit builders!

Something I need to mention is safety. You may have heard stories about builders drilling into fingers or thumbs. It does happen. As obvious as this may sound, you need to keep in mind that the drill bit is going to come out the back of the work, and it's a sharp cutting instrument that is spinning at 3000 RPM. If your finger is there, the drill bit will find it! Always be conscious of where that drill is going to pop out on the back side of your work. Use clamps instead of fingers whenever possible—they do a better job anyway. And always wear eye protection when drilling. Drilling aluminum throws little hot bits of metal every which way, and somehow those little shards know exactly where your eyes are. If you've ever had a tiny hot fleck of aluminum in your eye then you know how painful it is.

In the upcoming installment we'll cover the next steps after you're done drilling, such as deburring and dimpling. Until then, be careful and enjoy poking holes in your airframe. ✈

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Build Your Skills

Metal Part 4

Deburring and dimpling...time consuming, repetitive, you bet. But absolutely essential!

BY DAN CHECKOWAY

You spent an inordinate amount of time carefully jigging that chunk of airframe structure, plumb lines dangling from the corners, laser levels beaming every which way across your shop like a scene from Mission Impossible. You squared it all up perfectly, clamped everything in place—and eventually you had the nerve to drill some holes. After all was said and done, every hole in the semblance of a wing or tail or fuselage had been drilled out to final size. Now it sits there like a metal porcupine, adorned by silver Clecos radiating out in all directions. What's next? Well, you're about to discover an aspect of metal aircraft construction that might seem a bit counterproductive to the uninitiated.

Photos: Marc Cook

Take It All Apart

Yep, all of it, down to the last little piece. This is the process with which you should become familiar. Assemble it, then take it apart, then assemble it again. Sometimes you might repeat this cycle as often as three or four times. Unfortunately, you can't just fill all those freshly drilled holes with rivets and call it done.

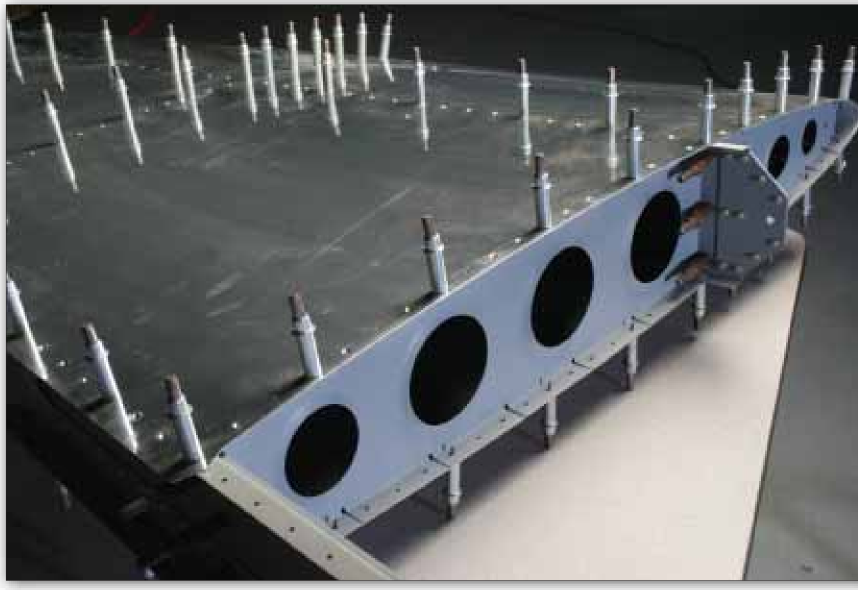
Why not? Several reasons, actually. You probably still have the plastic coating on some or all of your parts, and that obviously needs to be removed. There are also most likely little chips of aluminum sandwiched between parts—an inevitable byproduct of drilling. Those must be cleaned out, otherwise they would introduce undesirable gaps into places where parts should contact each other. Any air gap is a potential place for moisture to collect and for corrosion to form. And, of course, you will need to deburr—and most likely dimple—every last hole you just drilled. So grab your Cleco pliers—it's time for some disassembly.

Plastic Be Gone

Once you've got everything separated again, go ahead and remove the plastic coating from ribs, bulkheads, stiffeners, etc. The plastic should peel right off. If it's stubborn, you can use a heat gun or a hair dryer to help coax it off more easily. On the skins, you can actually leave most of the plastic on until after you're done riveting, but for now you do need to expose the holes for deburring and dimpling.

There's some controversy about this—whether or not you can effectively deburr and dimple skins with the plastic left on. My opinion is that the plastic hinders the deburring process (we'll get into that in a minute), because you can't really tell if the hole is smooth or not if it's covered with plastic. It also adds a thickness layer that might prevent a crisp dimple from being formed (we'll also cover that in a bit). In any case, I believe it's best to remove the plastic around holes before deburring and dimpling them.

Here's a common trick that allows you to remove the plastic from lines of holes but lets you leave the bulk of the skin protected. The idea is that you can strategically remove about one inch of plastic—only along the rivet lines. This leaves enough room for deburring and dimpling, and will leave enough area exposed for the rib or bulkhead flange to mate up without the plastic getting in the way. The plastic you leave on between rivet lines keeps the rest of the skin protected during the reassembly and riveting process. By using a hot soldering iron and a straightedge, you can easily perforate (by melting) the plastic. Grind or file the soldering tip smooth and round so it won't scratch the aluminum. Heat up the soldering iron, and carefully drag the tip along the straightedge about half an inch away from the holes. It doesn't take any force—just drag it gently and let the heat do the work. Once you're done, you can peel the strips of plastic away, exposing just the lines of holes.



There you are, feeling like a hero because you've drilled each hole to perfection. You're on a roll. You're almost done! OK, now take it all apart. Really.

OK, Let's Deburr

Once you've got the plastic off, it's time to deburr all of the holes. Any time you drill, the process leaves the edge of the hole relatively rough. The sharpness of the bit doesn't matter. The hole will always have imperfections along the edge, and each of those scraggly burrs is a stress riser just waiting to do nasty things. We discussed stress risers in a previous installment, but the idea is that anything but a smooth edge is a burgeoning excuse for a crack to form.

Take a close look at the back side of a freshly drilled hole. You might be surprised by what you see. Even if you don't see large, obvious scruff, you can run your finger over the hole and feel what I'm talking about. If your finger catches on the edge of the hole at all, it needs to be deburred.

The idea behind deburring holes is that you just want to remove those imperfections, smoothing out the edge of the hole. You don't necessarily want to countersink the hole in this step (we'll cover countersinking in a bit), you just want to "break" the sharp edge. This is a fine line, but you'll quickly get a feel for the amount of deburring as you go along.

There are several tools and methods that can be used for deburring holes. The old-school method is simply to take a drill bit (one that is at about two times larger than the hole in question) between your fingers, and rotate the tip of the bit on the hole. This cuts away just enough material to smooth out the edge of the hole. Everybody has drill bits around, so this is a good "cheapskate" method. But you can expect to get blisters on your fingertips after doing hundreds or thousands of holes this way!

Your Excuse To Buy More Tools

If you're like me and don't mind spending a few bucks to save skin—or if you ordered one of the common tool kits—you probably have some sort of "speed deburr tool" on hand. This is basically just an offset shaft with a freely rotating handle and a non-piloted countersink cutter (the deburring bit) at the tip. All it takes is a turn or two with this tool and the hole is nicely deburred.

Another variation that some tool vendors sell is a hex shaft adapter that can be used with a cordless screwdriver. Just install the deburring bit in the adapter, mount it in your cordless driver, and go to town. This is one way to make quick work of deburring lots of holes.

And if you don't mind spending a little more, they even make special deburring drill bits. These are bits that you can

The process of removing the protective plastic sheeting is easy with the right tools. Draw a hot soldering iron along your straightedge—let the heat do the work. Peel and you're done.

chuck up in your drill, and they have spring loaded cutters that take the edge off the hole as you insert it into the hole and then pull it back out. This variation deburrs both sides of the hole in one fell swoop. Nothing like a timesaver.

The burr. No matter how sharp your drill bits, the act of drilling will leave chips and flakes behind. Deburring takes this junk off. Simple as that.

Easy Does It

When deburring holes, just be careful not to overdo it. There's a fine line between adequately deburring a hole and countersinking it. You're not trying to form a bevel—you simply need to remove any sharp edges. If you can run your fingertip over the holes without feeling like it "catches," then you've done the job effectively.

Sometimes, the way flanges are bent or the way a part is formed, you won't have direct access to the back side of the hole with a conventional deburring tool. In cases like this, you can usually use a Scotch-Brite abrasive pad—like sandpaper—to smooth out the holes. If you do this, you will most likely disturb the Alclad coating on the aluminum and you might want to consider corrosion protection if you haven't already. (We'll get into this controversial topic, whether to use an anti-corrosion treatment or not, in a future installment.)

The drill-bit method is definitely old school and for certain the cheapest way to deburr a hole. But you'll wear yourself out!

Keep in mind that you need to deburr both sides of every hole. For every hole you drilled, there are technically at least four holes that need to be deburred. That is, there are at least two mating pieces that share the hole, and each piece obviously has two sides. So if you just drilled 500 holes in your wing, you now have at least 2000 holes to deburr! It's not the most exciting work, but consider it a rite of passage! Crank up the tunes and get to it...

Countersink Or Not?

Once you've finished deburring all of the holes, you're ready to move on to the next step. Depending on the particular kit you're building, the rivets in exterior surfaces may be protruding or flush. Protruding rivets have a round or domed head that sits above the surface of the skin. This is pretty much the easiest type of fastener to deal with, because once the hole is deburred it's basically ready for the rivet. The down side is that the head sticks up into the slipstream and causes a tiny amount of drag. Multiply that tiny amount by thousands of exterior rivets, and you actually have considerable room for drag reduction. Especially on faster planes, it becomes essential to streamline—which is why flush rivets are employed on those designs.

Flush (countersunk) rivets get embedded into the skin, leaving a smooth, undisturbed finish. Of course this benefit comes at a slight cost as far as your time and effort are concerned. If you're dealing with flush rivets, then you have to prepare the skins and under-structure accordingly—you need to make room for the rivets to settle into the skin. The act of forming the little "troughs" in which the fasteners sit is called countersinking.

Technically, there are two flavors of countersinking with which you'll become intimately familiar. There's "dimple countersinking," which is the act of pressing or stamping a well into a relatively thin sheet of metal; and then there's "machine countersinking," which is a process in which you actually cut material away from around

A "speed deburr" tool uses a simple fluted bit on an offset handle. One turn and you're done.

the hole to form the bevel. In the end, both methods serve the same purpose and form countersinks of identical dimensionS—but they are not necessarily interchangeable.

When you start carving away metal for rivets to be able to sit flush with the skin, you need to make sure you leave enough material for the rivet head to serve its purpose. If the material is relatively thin, once you form the countersink the rivet head might not have enough "bearing strength,"

The deburring cutters come in a variety of sizes and countersink angles.

because there's less material to "grip." To avoid this situation, there's a basic rule of thumb saying that you can machine countersink material that is .040-inch thick or thicker. Any thinner than that, and you need to dimple countersink. The premise is that when you machine countersink, you don't want the countersink to "bottom out," or go all the way through the material. On skins that are thinner than .040 you are likely to do so.

Conversely, if you try to dimple countersink material that is thicker than .040, you most likely won't be able to form a proper dimple. On thicker stock, you need to machine countersink.

On most kit airplanes, the thickest skins are .040, while most skins are anywhere from .016 to .032 inches in thickness. The point is that 99% of the time you will end up dimple countersinking your skins. On stuff like spar flanges, longerons, and anything else that's relatively thick, you will probably end up machine countersinking. There's no rule that says you can't mix and match techniques, either—and by that I mean you might have a thin skin riveting to a thick piece of angle, such as a longeron. You would dimple the skin and machine countersink the angle.

To Die For

First let's talk about dimpling, since it's the easier and more straightforward method of the two. The tools you will use to form dimples are called "dimple dies." They come as matched sets with a male and female die. Typically composed of hardened steel, dimple dies have a shaft that inserts into whatever dimpling tool you're using. On the dimpling face, there is a "pilot" on the male die, which fits into a hole in the female die. The size of the pilot and bevel determine what size the dimple dies are. For example, most builders will want to have in their tool arsenal a set of 3/32- and 1/8-inch dimple dies for typical rivet holes, as well as #6, #8, #10, etc. sizes for respectively sized screw holes (we'll cover screw sizes in a future installment). If you'll be building your own fuel tanks, then you might consider using a special set of 3/32-inch "fuel tank dimple dies," which actually form a slightly deeper dimple to accommodate a bit of tank sealant getting in there under and around the rivet head.

The deburring sets come in a variety of configurations. You've got your extension handle (left), drill chuck version (center) and basic speed handle (right).

For deburring large pieces, use this hook-shaped tool. As with all deburring, a little bit will do the job. Don't take a lot of material off.

So you've got these dimple dies—what do you do with them? There are lots of methods of dimpling, and likewise there are several tools that get the job done. As I mentioned, dimple dies have a shaft—and it is deliberately the same diameter as rivet squeezer set shafts. This means you can stick your dimple dies right into your rivet squeezer and use it to compress the dies together in each hole. This works when you're dimpling along the edges of skins, flanges on ribs and bulkheads, etc.

You can use a hand squeezer, or if you have a pneumatic squeezer you can save yourself a fair amount of effort. Regardless of the squeezer style, you need to adjust the set (either by using the threaded adjustable style, or by using shims/

washers) so that when the squeezer is fully actuated, the dimple dies contact each other. When I use an adjustable set in a pneumatic squeezer, for example, I set it up so that the dimple dies just contact, and then I tighten (expand the adjuster) an additional half turn.

Dimple dies come in various flavors, and you'll need one pair of each in the common sizes.

Nice Dimples

To form the dimple, insert the male pilot end into the hole, and then actuate the squeezer until it bottoms out. If it's a hand squeezer (and not pneumatic), give it a good, hard squeeze. You can feel it bottom out once the dimple is formed. Take care that you've got the dimple dies oriented correctly—that is, you want the dimple going toward the inside of the structure, not poking out!

The hole on the left has been deburred too aggressively. Just knock the edges off the hole; don't go so far that it starts to look countersunk.

Using your hand or pneumatic rivet squeezer for dimpling works great along the edges of things, but the holes you can reach are limited by the depth of the yoke. If you've got a huge wing skin that needs dimpling, the hand squeezer obviously isn't gonna cut it. The most common tool used for dimpling skins is the C frame. This tool is just a large C-shaped steel frame with a fixed base where you install one die and a sliding shaft above it with a female end where you insert the other die. Often the shaft is spring loaded to automatically pull up and away from the work. The idea behind the C frame is that you can slide the skin deep into it, and it has the ability to reach holes that are in the middle of the skin.

Used in a pneumatic squeezer, the dimpling die makes quick work of thin material. Just be careful of where you put the tool, and know before you pull the trigger which side you're supposed to be dimpling!

Typically you place the male die in the base, and the female die in the shaft. This way, you just position the skin until a hole pops down onto the male die's pilot. Then you lower the shaft with the female die right onto the pilot, and give the shaft a good whack or two with a dead blow hammer. Slide the skin over to the next hole, whack, repeat. You can do this solo, but it goes much more quickly with two people. One person positions the skin, and the other holds the hammer and the shaft. Especially with larger skins it's nice to have a helper.

Some builders design a recess into their workbench where the C frame sits even with the bench top. Alternatively, some people use chunks of foam, or carpet-covered wood shims to raise the material up flush with the base of the C frame.

A friend of mine, who has built several planes, came up with a brilliant modification to the C frame to make life easier. He utilized a pneumatic piston with an electric foot-switch controller to actuate the shaft. This takes the hammer out of the equation and frees up both of your hands. All you have to do is position the skin, then step on the foot switch to actuate the dimpler. It may be loud, but it sure gets the job done quickly!

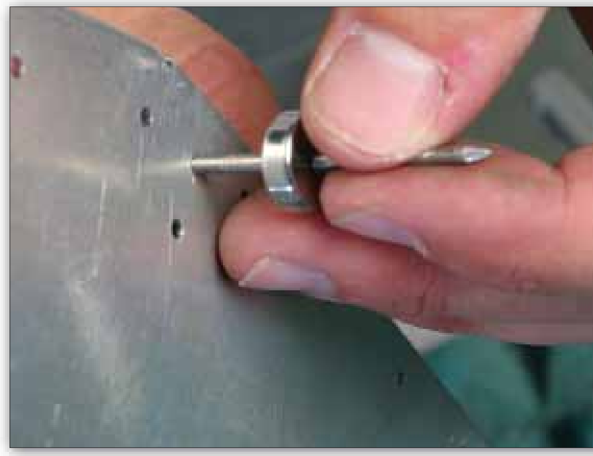
Another friend and airplane builder came up with a variation on the C frame that uses leverage instead of impact to form the dimple. All you do is pull down on a lever to actuate the plunger. It's smooth, quiet, and it forms a perfect dimple every time. That tool is called the DRDT (deep reach dimpling tool), and it's available from Experimental Aero at www.experimentalaero.com.

If you notice circular marks around each hole, don't fret. Those are normal. Most first-time builders worry when they see them, thinking they've made a mistake. Nope, the circle is just a mark that the dimple dies leave on the skin, and it means you did it right.

Alternate Techniques

Occasionally there will be times when you can't use a conventional method for dimpling a hole. A specific example would be the flanges on tapered control-surface ribs. Where the flanges come together at the end of the rib, there's just not enough room to get the squeezer's yoke in there, and you can't use the C frame or a variant of it. Never fear—there's a tool for every need. In this case, you can use the Vise-Grip dimpler, which is a modified pair of Vise-Grip pliers with


Hand squeezers can do more than just squeeze rivets. They're great at dimpling holes in flanges.


Used in tight spaces, the pop rivet dimple dies consist of a pair of dies and a common nail. You can use a common rivet puller to compress the dies together. It's slow going, but works well where you can't swing a normal tool.


It's the big whoops: You've pulled the trigger and the male die slipped out of the hole. You were either slightly off (top left) or way off (right). Believe it or not, there's a way to fix this. (See text.)

The C frame dimpler/riveter makes relatively quick work of the process. To use, carefully position the work over the dies (not shown here) and smack the head of the tool with a hammer.

dimple dies welded right onto the jaws. This tool is capable of getting into some pretty tight areas. You might have to bend the flange back slightly to gain access to the back side, and that's OK. Just bend it back when you're done. We're not talking about 90° of bend—just enough so that you can get the dimpler on there.

There's another situation in which you won't be able to use conventional dimpling methods. You might have to form a dimple in a portion of a skin that curves aggressively, and you might not be able to do this on the C frame. Or, let's say you have to form a dimple in a skin that is already installed on the airframe. You obviously can't use the C frame or a squeezer there either. Again, a specialty tool comes to the rescue. You can buy "pop rivet dimple dies" for this purpose. Such a simple, elegant concept, pop rivet dimple dies slide over a nail, and then you can use a rivet puller to compress the dies together, forming the dimple in whatever is sandwiched between them. Pop rivet dimple dies are incredibly handy to have around for these somewhat rare occasions.

Common Dimpling Mistakes

There are a couple of common mistakes people make when dimpling. Let's say you go to dimple a skin, but you didn't pay enough attention to the way you had it oriented. It was too late before you realized that you formed the dimple inside out. If you happen to accidentally form an "outie" like this, don't worry. I'm pretty sure it happens to everybody at least once. The fix is to take a pair of flush rivet sets in your squeezer and flatten out the dimple, and then you can dimple it again in the correct orientation. Keep in mind, though, that by doing so you weaken the aluminum at the dimple. Fixing one in a hundred like this is usually not a big deal—but if you messed up all of 'em, it may be wiser to replace the part. The point is, think twice before you squeeze that first dimple, and make sure you've got it oriented correctly.

There's another mistake that seems to happen to even the most experienced builders. You got ahead of yourself and you accidentally pulled the trigger on your pneumatic squeezer, or you hit the shaft on the C frame—but you did it before you had the skin lined up. The hole wasn't positioned over the male dimple die. Or maybe the skin shifted off the male die as you dimpled it. Regardless, now you've got a fresh hole staring you in the face.

The male dimple die isn't all that sharp, but it can easily poke a hole in thin aluminum. Most first-time builders freak out when they make this mistake. While you might think the world is coming to an end, it's really not that bad. You have at least two options to repair it. The easiest solution is—deburr the hole and put a rivet in it, and nobody will ever be the wiser! If the hole coincides with some understructure, then the best thing to do is to flatten the dimple out (using the method described above), deburr the hole, and leave it alone! Yes, leave it alone. If you're concerned about it cosmetically, then all you have to do is dab some filler in there when the time comes. With a little filler and paint, you will literally never know this little mishap ever occurred.

These mistakes do happen, even on award winners. There are always ways to fix them. Don't sweat it!

Ground Rules On Dimpling

Before we move on, I want to cover a couple of ground rules regarding dimpling. First of all, it is not acceptable to dimple a hole until it has been drilled to full size. As tempting as it may be, with all of these components having been match-drilled with pilot holes from the factory, you absolutely must drill all of your holes to final size before dimpling. Even though you might think you'll save a bunch of time by not drilling, not having to deburr, etc., dimpling the undersized pilot holes is a recipe for trouble.

When you form a dimple, the material around the hole is stretched very slightly as it gets reshaped. If you do this starting out with a smaller hole, the material needs to stretch even more—and the material is stressed. There's a very good chance you will

Metal Part 4 continued

introduce stress cracks, which may start out microscopic, but over time will radiate out from the hole and plague your airframe with failure points. So just don't do it—always drill holes to full size before dimpling!

And while we're on the topic of stress cracks, this is a reminder that you absolutely do need to deburr both sides of every hole before dimpling. If you dimple a hole that has not been deburred, the chances of cracks forming and radiating out are definitely increased. So deburr your holes before dimpling—you want this airframe to stand the test of time, right?

Another tight-space tactic is to use Vise-Grip dimplers, which will allow you to dimple thin materials in even the tightest confines. As with the other processes, this tool is slower than a pneumatic dimpler or a C frame, but an essential part of your tool (and skill) set.

I think we've just about worn out our welcome here with dimpling, so we'll wrap up for now. In next month's installment we'll get into the finer points of machine countersinking—the same idea as dimpling but with thicker material and a new set of tools. We're also going to dive into rivet identification in detail. ✈

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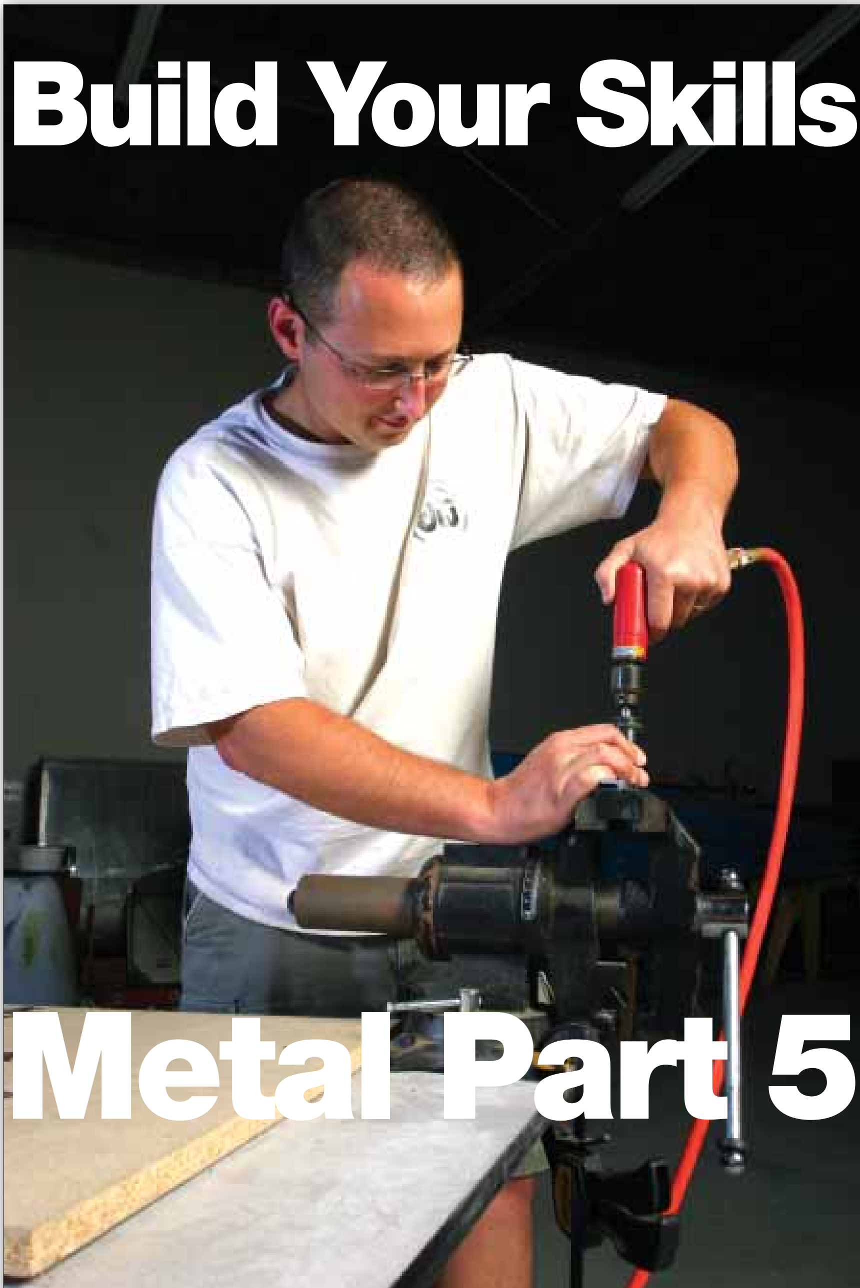
Build Your Skills



Metal Part 5

When is a dimple not a dimple? When it's a countersink. *Dig in to find out more.*

BY DAN CHECKOWAY

We left off last month on the topic of countersinking holes for flush fasteners. In the November issue, we covered dimple countersinking, and this month we'll dive right back in and talk about machine countersinking. (For those of you just joining the series, dimpling is used to create a bevel in thin material whose purpose is to accommodate flush rivets or countersunk-head screws, while what is most often called machine countersinking is reserved for thicker materials.)

We'll be using an entirely new set of tools for this—and this time we'll be making a mess. Some hardened airplane builders would argue that you're not a true builder until you've tracked aluminum shavings through every room of your house—as well as the carpet in your car or truck. Let's make a true builder out of you...

The Longeron Example

Let's look at a specific example of countersinking a thicker material—say we're talking about the longerons on your fuselage, which are usually $1/8$-inch thick or so. You've got a skin that's .025-inch thick that will be riveted to the longeron, and you've drilled all of the holes. As you know from last month's Build Your Skills, that skin can be dimpled. The longerons, however, which are thicker than the .040-inch dimpling threshold, can't be. They must be machine countersunk.

In this process, you're actually going to cut away material, forming a crisp, clean bevel around each hole. The bevel needs to be the same size as the dimple in the skin, so that each countersink forms a perfect home for the respective dimple.

At the core of the countersinking task is the cutter. A countersink cutter is like a drill bit in that it threads into a shaft that gets spun by a drill, and it cuts through metal. But that's where the similarities end. First of all, the cutter has an integral "pilot," which is just a smooth shaft with a rounded tip that sticks out the front. The pilot doesn't do any cutting. It will be the same size (or a few thousandths of an inch smaller) than the hole you're countersinking.

The purpose of the pilot is to keep the cutter centered as it does its job. Past the pilot is where the cutting portion of the tool begins. The cutter tapers out to a larger diameter, with the taper being 100° from one side to the other. This coincides with the 100° angle of aircraft rivets, screws and other types of fasteners. 100° is the industry standard...we'll get into that in more detail in a bit. The flutes are just portions of the cutter that have been cut away, leaving a sharpened edge that essentially "shaves" the material as the cutter is pushed into it (remember I mentioned aluminum shavings?). The deeper you push the cutter into the

The five stages of countersinking, from left to right: Too deep with the pilot going off center and causing chatter; still too deep but at least it's smooth; just right; too shallow; and way, way too shallow. Trial and error, together with careful setting of your microstop bit, will help.

material, the more it cuts away, and the larger the countersink will be. The goal is to form a countersink that is just large enough, no bigger and no smaller, than the fastener (or dimpled skin) that will sit in it.

Understanding the Sizes

Countersink cutters are sized in two ways—by the diameter of the pilot, and by the diameter of the cutting body. For your #40 holes, you'll use a 3/32-inch pilot cutter. For #30 holes, you'll use a cutter with an 1/8-inch pilot. And of course you want to make sure the diameter of the cutter will be sufficient for the depth of the countersinks you're making. Deeper countersinks require a cutter with a larger body diameter.

(To complicate something that's really very simple—and probably in an effort to sell more tools—manufacturers will throw variations of countersink cutters at you. You'll encounter cutters with different numbers of flutes. The three-flute version is most common, but you'll see vendors selling "chatter-less" single-flute and even zero-flute designs. Want to spend another couple of bucks? Hey, knock yourself out. Let me know if you can tell the difference. I'm not saying there isn't value in these improved designs, but I think for most of the small, simple stuff we're doing on these projects, perhaps it's overkill.)

Countersink cutters usually have a male 1/4-28 threaded end, which is the same size as threaded drill bits and various other drilling/cutting attachments. In theory, you could just thread a cutter right onto the end of the shaft that you've got chucked in your drill, and you could start countersinking right away. Just insert the pilot into the hole you're about to countersink, spin the drill up, and push the cutter toward the hole. Done deal, you've got a countersink.

Actually...Don't!

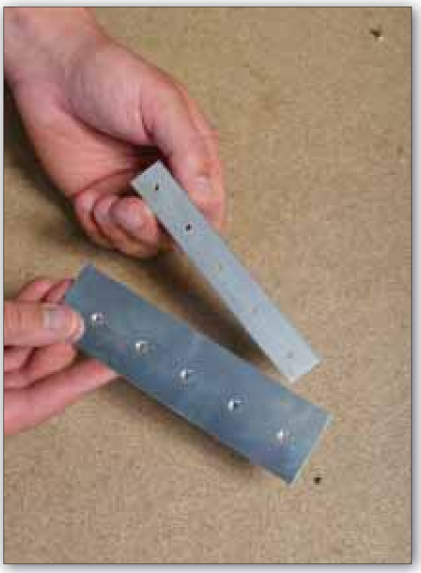
Whoa there, big feller. While that method surely works to form countersinks, think of the hundreds (or thousands?) of holes you have to countersink. How can you ensure that each one is just perfect, just deep enough for the rivet that sits in it? If you're cutting by hand,

The problem when the countersink is too shallow (as shown by the right most rivet at left) is that the head isn't fully contacting the material and, therefore, the joint will not be full strength. Above: You can feel when the rivet "stands proud" of the material.

Photos: Marc Cook

estimating by feel or by eye, you're gonna mess up a lot of holes. As I mentioned, you want to form countersinks of a precise size. Assuming we're talking about rivets sitting in these countersinks, if your countersink is too shallow, the rivet will sit above or "proud" of the surface. That's not only aesthetically unsightly, but it's structurally undesirable—part of the rivet isn't even touching the material and as a result the rivet isn't able to do its job fully. Mess up in the other direction—

More tools of the trade: Countersinking bits come in various flavors. The number of flutes isn't really critical. The nub at the end is the pilot, which is fractionally—but just fractionally—smaller than the hole you'll be countersinking.



This is a typical example of melding dimpling and countersinking. The thin materal (below) needs to "nest" with countersinking on the thicker material (above).

cutting a countersink too deep—and the rivet will literally be loose in the hole, which is another structurally undesirable effect.

So what's the secret to forming absolutely perfect, identically uniform countersinks over and over again? It's no secret, and as you may have guessed, it comes down to having yet another tool. Tired of expanding your tool arsenal yet? Heh... didn't think so!

The Mighty Microstop

The "microstop" cage is the tool for this job. If I had to come up with an analogy for this one, it would probably be like turning the business end of your drill into a drill press with an adjustable depth stop. Sort of.

The microstop is difficult to describe in writing, but if you had one in hand you could fully understand it within about 10 seconds of playing with it. I'll give it a shot, though. The microstop has a shaft that you chuck in your drill. The shaft goes through the body and has a 1/4-28 female threaded end, into which you screw the countersink cutter. The body, or the "cage" rather, is free to rotate around

The heavy-duty microstop is in the drill; the standard version below. Buy the best.

the shaft. It's actually the cage that stays stationary while the shaft rotates inside of it. The cage rests on the work, and you just press the drill and thus the cutter into the work. The cage and shaft have limited motion relative to each other, and the range of motion is adjustable—usually in increments of about one thousandth of an inch. The idea is that as you push the cutter into the work, no matter how hard you press, that cutter is going to stop when it hits the adjusted limit. It won't cut any deeper than that.

Basically what you do when getting started with a countersinking task is initially set up the depth stop by eye—to a depth that is perhaps close to the final desired depth, but definitely erring on the shallow side. From there you give it a try on the hole. Drop the rivet in to see how it sits in the countersink. It should not fit perfectly—yet. In small, conservative increments, you want to increase the depth adjustment and re-test it. If you happen to overshoot a little, don't sweat it—just back the adjustment off a little and try it on the next hole. It's an iterative process, but once you're satisfied and you've got the depth you want, that's all there is to it. From there on, just leave that adjustment alone, and you should be able to form an infinite number of identical countersinks.

Something to consider is that not all microstop cages are created

These serrations on the barrel of the microstop set the depth of the cut to a very fine degree. Once set, the tool holds its calibration well, allowing repetitive countersinking with great accuracy.

equal. The less expensive variety uses bushings, and it tends to heat up quickly with use. A more expensive variation on the theme uses ball bearings or needle bearings instead of bushings, and you'll see this type advertised as "heavy duty." There is truth in that marketing. The tool kit I purchased initially came with a bushing-style microstop. It didn't take long for me to learn the difference (What's that smell? Oh yeah, those are my fingers burning...), and I upgraded to a heavy-duty model. It's well worth the additional expense, and you might consider substituting a bushing model up front for one with bearings if you have that option when you purchase your tools.

This is the proper technique: Material secured, surface free of junk, microstop face flush with the work, and a steady hand.

Checking Your Work

I mentioned dropping a rivet (we're talking about a flush rivet here) into the hole to determine how deep the countersink needs to be. If the rivet head will end up in the countersink, then that certainly applies. But if it's dimpled skin that will rest in the countersinks, then it's a different story. Dimples are roughly the same size as the rivet that occupies them, but they're not exactly the same. In fact, it depends largely on the thickness of the skin. So how do you determine the proper countersink depth for dimples in different skin thicknesses?

Easy, actually. What you'll want to do is take a small strip, about 1-inch by 2-inch or so, of each common thickness of sheet aluminum that you're likely to encounter—.016-, .020-, .025-, .032- and .040-inch. After you cut each strip out, mark its thickness right on the strip with a marker. Drill, deburr and dimple a #40 hole in one end of each strip. Then drill, deburr, and dimple a #30 hole in the other end of each strip, and make sure the dimple is oriented opposite to the #40 dimple. These are your "test strips." Keep 'em in your tool chest. You now have a quick way of determining appropriate countersink depth for each sheet thickness, for both of the common hole sizes. Need to form a countersink for a #30 dimpled hole in .032 skin? Grab the appropriate test strip, and see if it fits in your countersink.

What's a good fit? There are two criteria. First of all, you want the dimple to fit entirely into the countersink. Push the test strip's dimple into the countersink—you shouldn't be able to see any light between the test strip and the countersunk piece. Now push the test strip around with your finger. Can it move relative to the countersunk piece? You don't want to have any slop in there, otherwise the countersink is too deep. It takes just a bit of practice and experimentation (use scrap!) to figure out just where that sweet spot is.

Some builders purchase several microstop cages and cutters up front, and they adjust and mark each one for a very specific setup—which they never change. If money is no object, this is certainly one way to save time. But microstops aren't cheap, especially the good ones, and there are literally dozens of configurations that need to be accounted for. So unless you're made of money, get used to adjusting your microstop for one task, and then readjusting it for another.

There are a few common problems associated with countersinking. We mentioned that the cutter has a pilot, the little shaft sticking out. The idea is that the pilot keeps the cutter centered in the hole, but it also serves to stabilize everything. If it weren't for the pilot, the cutter would be free to wander off, and then you've

To have an easy way to check your countersinking, make up simple test strips from the skin material you'll be using, and mark them carefully so you don't get confused.

Take extra care to keep shavings out from under the microstop face.

got an oblong countersink.

Likewise, if the pilot “runs out of” material, there is no longer anything stabilizing or centering the cutter. What happens is that the cutter will start to chatter, and the countersink formed will be nothing short of ugly. If the countersink is rough, has ridges, or is anything but smooth and shiny, it’s probably a result of the pilot running out of material—or not having deep enough material to begin with. When you’re countersinking relatively thin material, it’s key that you plan and watch for this condition. The best remedy is to have more material behind the work, into which the pilot can continue to insert and do its job. You can use wood, aluminum, plastic, or whatever you’ve got lying around. Any time you’re countersinking thin stuff, keep this in mind.

Deep Thoughts

The other problem is where you’re seeing inconsistent countersink depths, despite having adjusted the microstop and not having touched the adjustment. This one can be baffling, but it’s really quite simple. If you allow even the smallest shaving to get between the cage and the work, it elevates the cage. No matter how slightly it gets

The "suicide" mode for countersinking in tight confines has the bit placed on an extension and then into your drill. Be careful!

Check your work with your test strips. The back side of the dimple should fit against the countersink with very little free play, and the back edge of the strip should sit flush with the work.

lifted, you will notice it in the depth of the countersink. Even one or two thousandths can make a big difference. It's important to make sure the face of the cage and the work itself is clean before you seat the microstop and start cutting. Literally every hole you countersink is going to throw shavings around, so you should wipe or blow the shavings out of the way after every hole.

Something else to consider is that if you're countersinking against a flat surface, there should be no need to readjust the microstop as you go. But if the surface you're countersinking curves, or if you go from a flat area to a curved area, you can expect to have to readjust the microstop as the contour changes. This is because of the way the cage sits on the surface—it will either bias the work closer to the cutter (convex curve) or further away from the cutter (concave curve). The larger the cage diameter, the more pronounced this effect will be. The adjustment required on a changing curve might be very small, but you want to test the depth after every hole or two to make sure you're not over- or under-countersinking.

A countersink too far: If you run the cutter too deep, it will cut through far enough to enlarge the center hole. Stop, go back and do it again.

Emergency Procedures

You may occasionally get into a situation where there's not enough room for the microstop cage to fit—i.e. a hole that's very close to a protruding flange or some other nearby structure. It's unusual, but this scenario does come up from time to time in ever project.

Another situation is where the hole is adjacent to a joggle, in which case the microstop doesn't have enough surface to rest on to keep it stable. Tool vendors sell microstop cages of smaller diameters, which sometimes helps solve the problem. By using a really narrow microstop, sometimes there's enough adjacent surface area where the cage can rest.

But sometimes even the narrowest cage won't fit, in which case you've got at least a couple of options. Some people actually cut away a chunk of the cage face so it can be used closer to edges and joggles. That might work. If not, or if you don't want to mutilate your fine tool, you'll need to form the countersink in "suicide" mode. That entails putting the countersink cutter on the end of a threaded drill extension, and you'll have no means of stopping the depth of the cut automatically. This can translate into trouble if you overdo it—so be very careful to go slowly and gently. It's best to attack this countersink iteratively and creep up on it.

That's the deal on machine countersinking. It helps to practice on scrap but, once you've done the process a few times, it will seem easy. Next month, we'll actually start riveting. ✈

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Build Your Skills

Metal Part 6

Getting to know your rivets.

BY DAN CHECKOWAY

This month there's good news: You won't have to write any checks. There's no expensive whiz-bang tool that you have to run out and buy. And, for the most part, the rest of your tools can stay in the chest. We won't be making a mess of the shop, although I can't make any promises about your mind. We're going to get deep into the details of identifying rivets and their callouts, and how to pick the right rivet for the job. (Does this count as actual riveting, as promised at the end of the last installment? It does if you want to do the job right.)

Are you good with languages? It might help if you are. When you start building your first plane, you'll need to learn a new language. As you peruse the plans or inventory the numerous little bags of hardware, you're going to discover that rivets and bolts and nuts and washers and screws all have somewhat cryptic identification. (If you've been involved in the maintenance of a production airplane, it'll all be a bit more familiar.)

For most, it probably won't make any sense at first, but you might start seeing a pattern in the abbreviations—this "dash 7" (we'll just describe it as "-7" from here on) thing looks longer than the -5 over there. That makes sense. As soon as you think you have a handle on it, you find some other -4 thingie that's longer than the -7. Huh? And why isn't a 470-*something* bigger than a 426-*something?* Have no fear. Before too long, you'll be comfortable conversing with all the hangar rats in the language of "AN."

More Rivet Basics, You'll Need 'Em

As we talked about in the first installment, rivets insert into a hole and then get deformed (intentionally, controllably) to grip layers of material together. Rivets always start out with a *manufactured head*—the integral head that is pre-made by the rivet manufacturer—and a shank or shaft.

The rivets that you're likely to encounter in your metal airplane kit fall into two overarching categories: solid rivets and blind rivets. Solid rivets are composed of a single, solid piece of metal, whereas blind rivets (also referred to as *pop rivets*) actually have two components—the rivet shell and a pulling stem. We call them blind rivets because they are designed to be used where you don't have access to the back side of the rivet.

Head Cases

Regardless of whether a rivet is of the solid or blind variety, the manufactured head style falls into two general categories: universal head and countersunk. As we've covered in previous installments, countersunk, or flush rivets are generally used on exterior skins to reduce drag and improve the appearance. Universal head, or protruding rivets are used on interior structure, or in cases where drag or appearance is not a consideration.

Let's stick with solid rivets for the moment. Believe it or not, there are only two styles of solid rivets that you're likely to use on your metal kit. They are the

The AN470 round-head rivet (left) and AN426 countersunk rivet are staples—pardon the pun—of modern metal aircraft.

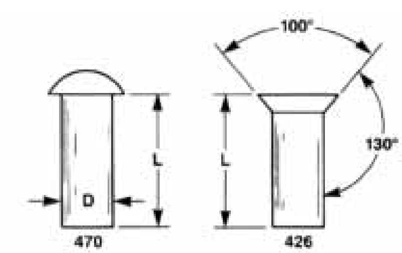
Alloy Code	Rivet Alloy	Marking on Manufactured Head	Major Alloying Ingredient	Alloy After Driving
A	1100	plain	none	1100
B	5056H32	raised cross	magnesium	5056H32
AD	2117T4	dimple	copper	2117T3
D	2017T4	raised dot	copper	2017T3
DD	2024T4	two raised shoulders	copper	2024T31
E	7050T73	raised circle	zinc	750T73

Table 1.

470 and the 426. Those numbers refer to the head style. The 470 has a universal head and the 426 has a flush/countersunk head. That's all there is to it! Well, sort of. Now that you've been introduced to the head style numbering system, let's take look at the full system in detail.

The callout system for solid-shank rivets is broken down into the following: Catalog (AN for Army/Navy or MS for Military Standard); head style (470 or 426, as two examples); alloy code (AD, see Table 1); diameter (in 1/32 inches); and length (in 1/16 inches).

For example, the AN470AD4-7 rivet has a universal head (round, protruding), is composed of 2117T4 alloy, has a diameter of 4/32 or 1/8 inch and is 7/16 inch long.



In schematic view, it's clear how the specified length of the protruding-head rivet (left) concerns only the shank, while the length of the countersunk rivet (right) includes the head. All AN426 rivets have a a 100° head.

Another example would be the AN426AD3-4, which has a flush head, has that same 2117T4 alloy, has a diameter of 3/32 inch and is 1/4 inch long.

As far as the catalog is concerned (AN or MS), there is no practical difference between AN470 and MS20470; likewise with AN426 and MS20426. Those are just two ways of cataloging the same part. The AN system, which stands for Army/Navy (or Air Force/Navy), is a bit dated, but is still widely used. The MS system, which stands for Military Standard specification, is intended (I believe) to supersede the AN system. As you'll discover in the process of building your plane, there are some parts that are referred to only by MS codes, some referred to only by AN codes and some that have both designations. To make matters worse, there's actually a NAS numbering system as well, which stands for National Aerospace Standard. While we obviously need numbering systems, we have the government to thank for the confusion. Anyway, for the point of our discussion this month, I'll stick with the AN system, since that's what you're likely to encounter in your plans.

Have a look at Table 1. It highlights the distinctions of the rivets' physical traits by their alloy codes. Fortunately, if you happened to spill a few containers of mixed rivets on your shop floor, you'd be able to identify each one. I'm not saying that would be a fun afternoon...but at least it's possible to sort it all out. The marking (such as a dimple or raised cross), or lack thereof, on the manufactured head allows you to know the rivet's composition right away.

ADs Are Common As Nails

Believe it or not, as far as solid rivets are concerned, I've never used anything but the AD type. Granted, I don't work on the Boeing assembly line, but my perspective having built a kit airplane and having been around them for a while has only exposed me to AD rivets. In all likelihood, your experience will be similar.

So the key is making sure you see that little dimple in the center of your rivet heads. I'm not suggesting that you'll need to check each rivet, but if you happen to order a batch of rivets, it's good practice to take a peek at one before you shove hundreds or thousands of them into your plane's structure. The alloys are not necessarily interchangeable; the engineers have chosen the rivet material for use in our planes for specific reasons.

A wonderful but coincidental side effect of that little AD-identifying dimple in the rivet head is that it makes drilling out rivets considerably easier! Drilling out rivets? Yeah, it's a certainty that all builders face eventually. We will definitely cover drilling out rivets in a later installment, and I'll show you what that's all about, with the little identifying dimple and all.

Rivet Shank Diameter	Minimum Driven Head Diameter	Minimum Driven Head Thickness	Maximum Driven Head Thickness
3/32	0.122	0.038	0.050
1/8	0.163	0.050	0.070
5/32	0.203	0.062	0.092
3/16	0.244	0.075	0.105

Table 2.

So there you have it. Pretty much all you need to know solid rivet-wise is that you'll be using the AN470AD and AN426AD rivets extensively in your project.

The Long and Short of It

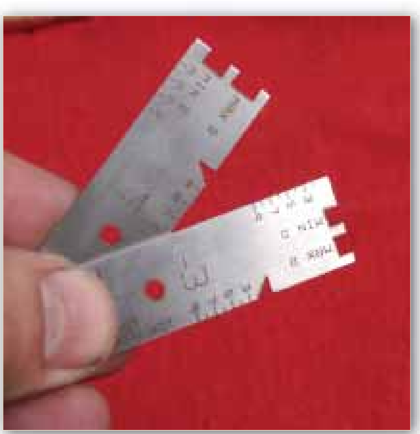
I'd like to note that the way the rivet length is measured is slightly different for the 426 and 470 styles. In general, the length callout for a rivet designates how much length is available both to grip the material and to form the bucktail. In the case of the 426 (flush) rivet, the manufactured head is part of the grip length, so the length denotes the overall length from the top of the head to

Absent special tools, you can always measure thea remaining "tail" of the rivet before setting. The dimensional rule of thumb is 1.5 times the diameter.

the end of the shank. On the 470 (universal head) rivet, the manufactured head is not included in the length, which is measured from the bottom of the head to the end of the shank.

While we're on the topic of the 426 flush rivet, it's worth noting that the countersink head angle is 100°. You'll notice that your dimple dies, countersink cutters, etc., will all have that inherent 100° angle.

OK, so let's say you have a series of 1/8-inch (#30, actually) dimpled holes in two sheets of .032-inch aluminum that need to be riveted together. Which rivet should you use? Well, since the hole is dimpled you know it's going to be a 426-style head, and based on the hole diameter you know you'll need a 1/8-inch-diameter rivet shank—so that narrows it down to AN426AD4 "dash something." All that's left to determine is the length of the rivet. In order to figure that out, we need to talk a bit about the process of squashing rivets.



Special tools, like this set of Rivet Readers, will allow you to quickly determine if the rivet is the correct length for the job, and if you have set it correctly.

When setting our rivets, three key physical changes occur regardless of the riveting method employed. First of all, a shop head is formed. The shop head, also known as a *bucktail*, is the mashed end of the rivet that you form in the shop. As the free end of the rivet gets compressed, the diameter of the shop head increases, and subsequently the length of the rivet is squashed. The second key change is that the shank of the rivet swells up as the rivet gets compressed, expanding to fill the hole. This eliminates the clearance that the rivet had—remember that we drilled a hole slightly larger than the rivet diameter. The third change is that the rivet gets cold worked in this process, and the material hardens—the temper of the rivet actually changes as a result of this.

This Rivet Reader says the unset tail is close to, but just slightly short of, the right size.

What we're left with is a fastener that now completely fills the hole, now has two bearing heads that clench the material from both sides, and the thing has hardened to provide even more strength. This is so cool! I don't know who invented the solid rivet, but if he were alive today I'd want to take this genius to lunch.

Let's get back to figuring out how long the rivet needs to be for our example. It actually involves a bit of reverse engineering. As we already discussed, the rivet length decreases as the bucktail is formed, so we need to start out with a rivet that's intentionally a little too long. How long is too long? Fortunately there's an easy rule of thumb that we can use when picking rivets. The rule is that for a rivet shank diameter "D", you want to start out with 1.5D protruding from the material.

Mental Math

In order to determine the proper length of rivet to use, all you have to do is add the grip length (the thickness of material that is being clenched) to 1.5 times the diameter of the rivet. In the example I gave above, the grip length is two sheets of .032. Adding 1.5 times .125 inch to .064 yields .2515 inch, which is roughly 1/4 inch or four 1/16ths. Thus the rivet you would use is the AN426AD4-4.

Is all of this mental math required when building your kit? Fortunately, the answer is a whopping no! Most of the time, your kit manufacturer is going to call out specific rivets on the plans for literally every hole. And if not, there's a convenient little rivet length gauge that you can use to quickly determine the appropriate length rivet to use in scenarios where you're unsure. But at least now you know the math behind this. So next time you're at your buddy's hangar and he doesn't know which rivet to use, you can smugly spout out, "Dude, just add 1.5D to the grip length." I can't promise a positive reaction...

As I mentioned, the 1.5D thing is a rule of thumb, rather than a rule. In fact, it's part of a bigger set of guidelines that suggest just how big a shop head needs to be. Without getting into detail about riveting techniques (at least not yet), I'd like to talk about proper shop heads.

We actually have a tried and true Military Specification to fall back on for this, and it's the good old MIL-R-47196A (view it on the web at http://rvproject.com/milspec). In fact, do yourself a favor and read through this document. It has several tables full of useful data. In particular, there is a table which provides precise guidance on the desired size of a driven rivet's shop head. In Table 2, we've reproduced a snippet of the table for your reference.

As you can see, the specification provides a fair amount of leeway with respect to the size of the shop head. The range in shop head height is pretty liberal—and when it comes to diameter, there's only a minimum diameter specified.

Rules of Thumb

When you get right down to it, there's a very simple rule of thumb to follow. When creating a shop head, it should be at least 1.5D in diameter and approximately .5D in height, where D is the rivet shank diameter. For a 1/8-inch shank rivet, a proper shop head will be about 3/16 inch in diameter and about 1/16 inch tall.

Don't bother breaking out the calipers...it's much easier than that. There are convenient go/no-go gauges for measuring shop heads. One end measures the height, and the other measures the diameter. There's no need for math or even quantified measurement. It's a simple matter of swiping the gauge over the shop head.

The Rivet Reader will give you a quick check of the proper set tail dimension. It should fit between the MIN and MAX lines.

The key to remember when selecting a rivet is that if it's too short, there may not be enough excess material to form a shop head of the proper dimensions. If the rivet is too long to begin with, then it presents a whole slew of other problems. We'll open up that can of worms in a future installment!

I think our discussion on rivet identification has pushed the limit of what we can talk about without getting into the actual process of riveting. After all, these shop heads have to get formed somehow, right? Let's save that for next month, when we'll (finally) start covering techniques such as back riveting, shooting and bucking, and maybe even a bit of squeezing. ✢

Build Your Skills

Metal Part 7

Let's begin a riveting performance.

BY DAN CHECKOWAY

I don't want to start on a down note, but here's the truth: You're not going to learn everything about riveting from an article in this or any other magazine. Certain skills can be picked up by reading about techniques and seeing a few photos, but shooting and bucking rivets is not really one of them. Riveting is something unlike anything I had done before, with new physical sensations that took practice to perfect. I mean, learning to *hear* when a rivet is properly set isn't something I can describe in words. Hands-on experience is required to bridge the knowledge gap. That doesn't mean turn the page and walk away. Follow along and I think you'll be better prepared for that first encounter with the rivet gun.

Back to the Basics, One More Time

The basic premise is that aluminum rivets are fairly soft to begin with, and we deliberately squash one end, compressing and flattening it, fastening stuff together and causing the rivet to harden in the process. (We've discussed this before, but it's worth repeating.)

I suppose you could take a hammer and smack the heck out of a rivet to set it—assuming you had something to back it and didn't mind the mess you'd make. But we have a much more elegant method of providing compression, and it involves some simple but very cool tools—the rivet gun and the bucking bar. The rivet "gun" should probably be called an "impact generator," because that's really what it does—it produces a series of rapid impacts. On the other side of the rivet, the bucking bar translates the mostly elastic collision into compression against the rivet shank. The two work hand-in-glove to set rivets.

Remember that the rivet is made of relatively soft aluminum (at least it starts out that way), while the bucking bar, rivet gun and set are made from cold, hard steel. The rigid impact that the rivet experiences from both ends causes compression, and the softness of the aluminum allows it to give a little and transform its shape. With every hit, the rivet shank flattens and expands slightly, and after several of these impacts the "bucktail" is formed.

Tool Talk

Let's return to the topic of tools for a minute. When it comes to shooting and bucking rivets, all you need are the rivet gun, rivet set and a bucking bar. Rivet guns are essentially just air-driven hammers. They have a deep cylindrical opening at the business end, into which you can insert a variety of rivet sets. The rivet set has a shaft that inserts into the gun, and the other end has a specific size and form designed to translate the impact to the manufactured head of a particular type of rivet. Generally you use a *cupped set* for round head rivets, or you use a *flush set* for countersunk/flush rivets. Each of these set types is available in different sizes to accommodate various rivets.

Most rivet guns allow you to *tease* the trigger to vary the speed and intensity of the impacts. The full-trigger intensity is determined by how much air pressure is being fed to the gun, and it also depends on the gun's rating. Rivet guns are commonly available in 2X, 3X and

Photos: Marc Cook

4X ratings for use on light aircraft. A bigger number before the X just means the rivet gun is capable of hitting harder and setting larger rivets. The 3X is a good all-around rivet gun, capable of striking gently enough at lower air pressures for use on thinner skins, and also able to strike harder at higher air pressures to set fatter rivets.

By the time you're done building your airplane, you will most likely own a handful of rivet sets. There's almost no doubt that you will need a straight 1/8-inch cupped set. The 1/8-inch dimension refers to the rivet shank diameter, not the size of the head. You will probably end up needing at least one variation of an *offset* set, which is used when you don't have a straight-on shot at the rivet. In this case, you can use a *single offset* set, which has one angle bent into it so you hold the gun at an angle relative to the rivet. More common—and easier to use in my opinion—is a *double offset* set, which has two bends in it to form an S shape—the rivet gun can be pointed in the same direction as the rivet, but the joggle allows the set to clear flanges and other obstacles.

If you're building a plane with flush rivets on the exterior, you will need some sort of flush rivet set, often called a *mushroom set*. A flush set has a broad, flat face that rests against the skin and rivet head. Some flush sets have an integral swivel, which will keep the face flat on the work even if the gun angle changes slightly. Other flush sets have a rubber guard ring, which protects the skin around the rivet from being damaged. Some flush sets integrate both the swivel and the rubber guard—this is the type that I personally prefer to use since it provides the maximum protection from damage due to "shooter error."

Something to keep in mind is that the rivet set doesn't "engage" with the gun or lock into place. It just slips into the hole in the end of the gun. To keep it from falling out, and to provide a modicum of safety in case you accidentally nudge the trigger while the gun isn't held up against the work, you use what's called a "beehive" spring. This is

A flush rivet set uses a flat-faced shoe in the rivet gun to apply impacts to the manufactured head of flush rivets. The rubber surround helps prevent marring the surface.

Rivet sets for driving protruding-head rivets have a specially designed recess intended to press evenly on the manufactured head.

Rivet guns are, when it comes down to it, just sophisticated air hammers, delivering a series of impacts that can be carefully controlled by the user.

coiled such that it has an opening just large enough for the rivet set on one end, and the other end threads onto the nose of the rivet gun, keeping the set in place but allowing it to actuate.

You will find a need for several rivet sets, including straight sets, angled sets and offset versions with a built-in S curve.

Buddy, Can You Spare a Buck?

You've got a gun and some rivet sets, so now you need a few bucking bars. A bucking bar is merely a block of steel that has a particular shape to it and at least one smooth surface that contacts the rivet shank and forms the shop head. Tool vendors sell a variety of bucking bar shapes, sizes and weights. Each one is specialized for access from a particular angle, possibly getting around flanges and other obstacles, and reaching into confined spaces. Bucking bars generally come in weights between one and three pounds—the heavier the bucking bar the better, but often you need to use a smaller and thus lighter bucking bar to reach into tight spaces. It helps to have several different types of bucking bars, as you'll soon see.

Bucking bars, you'll have 'em by the dozen. Differing shapes and sizes will help you buck rivets in even the most cramped quarters.

Pointers on Technique

Alright, let's quit all this yapping about physics and tools and get right down to technique. The act of shooting and bucking rivets is simple in principle. Don your ear protection (riveting is loud!). Stick a rivet in the hole. Hold the gun firmly up against the manufactured head of the rivet. Position the bucking bar squarely against the rivet shank, apply light pressure, and just hold it steady. Pull the trigger on the gun, hold it for a second or two, and release. Check the shop head dimensions to see if it's within spec. Believe it or not, despite this being an over-simplification of the process, that's pretty much all there is to it.

Let's cover some of the finer points in more detail. First of all, it's essential that you hold the gun square to the work. If the gun is tipped, you run the risk of creating "smiles" or "smileys," crescent shaped dents in the rivet or material surrounding it. If you're shooting a round-head rivet, the smile often appears across the manufactured head, or worse, it will dig into the surrounding material. If you're shooting flush rivets, the flush set has a much larger diameter, so a smile would show up as a large ring-shaped dent in the skin around the rivet. Smiles are not necessarily structurally unacceptable, but they are unsightly even in the best of cases. Just keep the gun aligned with the rivet and you won't have this problem. Use of the swivel flush set almost completely precludes the possibility of introducing smiles.

Oh my, this is ugly. The upper rivet has been worked over by a monkey, it seems. The rivet set has clearly slipped off the head and damaged the surrounding material. The middle rivet got it a bit better, but still has "smiles."

Under Pressure

Builders argue about trigger technique, and it depends on the air pressure you're feeding the gun. The higher the air pressure, the harder the rivet gun will strike the work when the trigger is fully actuated. While you might want to use up to 90 psi when shooting fatter rivets (i.e. 1/8-inch and thicker), trying to shoot rivets in the delicate, thin skins using 90 psi is likely to result in a battered finish. You must reduce the strength of the impact so it doesn't dent the skin and structure, and this is where the debate lies.

Some builders, myself included, will adjust the air pressure so that you can simply pull the trigger all the way in. For example, I use 35-40 psi when shooting 3/32-inch rivets in skins, and I use 60-90 psi when shooting 1/8-inch rivets in structure. Other builders advocate leaving the pressure set at a constant 90 psi all the time, and training your trigger finger so that you only partially actuate it when you're shooting more delicate stuff. Obviously you will settle into a technique that works for your level of coordination, but I personally want the simplest means of attaining consistency.

On the back side of the rivet, the bucktail is what the stem becomes after you've driven it. Soon, you'll have enough experience to tell by sight that the upper rivet is not driven far enough, while the bottom rivet is way, way over driven.

How do you select the right air pressure for the job? Experiment with scrap or a practice kit to get a sense of what you consider acceptable. There will be a range of air pressures for any given riveting scenario. When you get right down to it, to squash the rivet it's going to require some total amount of impact—that is, either very few very intense strikes or several lighter strikes. At higher air pressures, it will take fewer strikes—less time—to set the rivet. Maybe at 30 psi you will need to shoot for 2 seconds, while at 40 psi you'll only need to shoot for 1 second. Play with the air pressure and the shooting duration, and you'll figure it out pretty quickly. It helps to make notes early on, but you'll get the hang of it soon.

Matters of Force

Speaking of pressure, how much force should you exert on the rivet when holding the gun? The only real requirement is that the gun needs to be pushing against the rivet harder than the bucking bar—otherwise you run the risk of the rivet being pushed up out of the hole as it is set. This aspect of technique really has more to do with whoever

It's the same situation for countersunk rivets: The left rivet is driven too far—mushroomed out, they say—while the middle rivet is under-driven.

Solo riveting means holding the gun carefully in one hand and managing the bucking bar in the other. It's harder than it looks but gets easier with practice.

is holding the bucking bar, but the person holding the gun needs to apply *some* pressure against the work. Some say that you only need to apply light pressure. I tend to lean the other way. As long as the work is held firmly in a jig or fixture—at least clamped to the bench somehow—I prefer to put a fair amount of pressure into the work with the gun. It's not going to hurt anything, and it helps prevent the rivet set from walking, meaning it shifts sideways away from the rivet.

It's also important that the shooter try to hold the set in place on the work if he or she has a free hand. Obviously leaning into it a bit will help, and with round-head rivets the cupped set tends to stay in place by virtue of the rivet nesting inside the set. But it's still possible for the set to walk if the shooter lets up even slightly or applies any lateral force. If I'm shooting rivets with a bucking partner, I have one hand on the gun, and I always use my free hand to brace the set. With flush riveting I personally think this is even more essential, since you don't have anything preventing the smooth, flat set from walking to one side. I always use two fingers to hold the set in place. Don't worry, it won't bite!

Buck Up, Pardner

One way to look at bucking rivets is that somebody is holding a chunk of steel in place. How difficult could that be? Sure, it sounds easy, but there's a little more to it than most people think. When flush riveting, I much prefer to be the one bucking rather than shooting, since I think it takes more skill and finesse to create perfect, level bucktails. When using a swivel flush set with a rubber guard, the shooting end is pretty much idiot-proof. Other than controlling the shooting duration, you don't need much skill to be a reliable flush rivet shooter.

In essence all you have to do when bucking rivets is hold the smooth face of the bucking bar up against the shank of the rivet. Hold it perfectly square to the rivet, and just apply light pressure. The pressure your hand exerts is not actually doing the work—rather it's the reflected impact from the gun that does the work of squashing the rivet. Don't tire yourself out by pushing really hard—especially as doing so increases the chance of the rivet lifting out of the hole as it gets set.

Depending on the type of structure you're riveting, you may not be able to see the bucking bar in position on the rivet. This is often the case when you're closing up wingskins, reaching inside a horizontal stabilizer, or contorting yourself to

It won't be smiles all around when you see this on your airplane. Here, the riveter has failed to keep the flush set square to the surface. Bad boy!

get your arm through a lightening hole. Much of the time you're working blind. The person doing the bucking needs to have a good sense of feel, spatial relationships and visualization.

Belly Up to the Bar

The key is in how you hold the bucking bar. Ideally, you will have a thumb and one fingertip on the sides of the bar, which will feel for the Cleco and rivet in the adjacent holes. Your fingertips also keep the corners of the bucking bar from gouging into the work surrounding the rivet. Often the surface will have been primed prior to riveting; avoid allowing the bucking bar to scrape the primer off.

So you've got two *feeler* fingers on the ends, and the other seven fingers on your hand (at least sometimes it feels like you need that many fingers) stabilize the bucking bar as it receives the jolts from the rivet gun. Doing this blind definitely takes practice. You can tell the experienced riveters from the newbies based on how quickly they can get the bucking bar in position and ready for the shot.

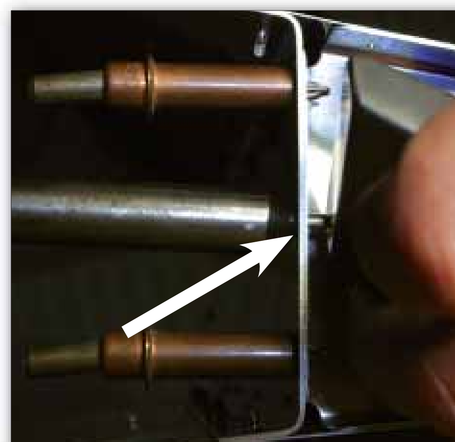
Prepare for contortions: Solo riveting seems like it requires three hands and 8-foot-long arms. Take your time and be sure the bucking bar is flat and level to the bucktail before you pull the trigger.

When riveting with a partner, use your now-free hand to stabilize the rivet set. This keeps you from making mistakes and creating smiles.

In an ideal world, the bucking bar will be held so its face is centered on the rivet. This gives the bucking bar the most room to jitter around without falling off the rivet. I mentioned that your feeler fingers will sense the Clecos or rivets on either side of the hole being riveted. This is key to maintaining the centered position.

Here's why: If the bucking bar falls off the edge of the rivet, the rivet gets mashed in a tipped, half-set mess as the edge of the bucking bar moves across the shop head. And then the really bad stuff happens, because the bucking bar will bounce against whatever structure surrounds the rivet. At that point, you're bucking the structure, not the rivet.

When riveting with a partner, you need to come up with some sort of call and response system of communication. Generally the sequence goes something like this...the shooter removes a Cleco and puts a rivet in the hole. The shooter places the gun up against the work and calls out, "Ready?" The bucker positions the bucking bar, and when ready for the shot calls out, "Hit it!" The shooter pulls the trigger. After the gun is quiet, the bucker checks the shop head, either visually, by feel, or with a shop head gauge, and calls out, "Good!" or "Needs a quick burst," or slaps the shooter in the back of the head because he shot it way too long and flattened the rivet like a pancake. Some builders prefer not to use vocal communication, but rather use the tools instead. Everything is basically the same, except the bucker can see or feel when the rivet is in place and can tell when the shooter is leaning on it. The bucker positions the bucking bar, and when ready he simply gives two firm taps on the rivet. The shooter can definitely feel this through the gun, distinguishing the taps from the normal feel and sound of the bucker rustling around back there.



Occasionally, the backside of the rivet emerges into tight spaces. Here you will need a narrow bucking bar and the sixth sense to work without seeing the bucktail.

Going Solo

Solo riveting comes with its own set of challenges. As I mentioned, I prefer to have two hands on the gun—one hand stabilizing the set. If I have to use that hand to hold the bucking bar, then there's more chance that the gun will walk and create smiles. And often times, it's hard enough to contort your arm and wrist to get the bucking bar in place without having to worry about the gun, let alone having to reach around some large structure and keep the gun stable at the same time. If you're gifted in the contortion and coordination departments, then you may find solo riveting preferable.

We still have a quite a bit to cover with respect to riveting. Next month we'll wrap up this diatribe on shooting and bucking, covering some of the key "gotchas" and a few tips for success. Eventually we'll get into the topics of back riveting and squeezing, how to measure shop heads properly, how to determine when a rivet needs to be drilled out, and even how to drill out rivets perfectly every time. If you've never done any of this riveting stuff, stay tuned—I think you'll find the next few installments enlightening! +

Build Your Skills Metal Part 8

Let's move forward in our riveting education by getting back—back riveting, that is.

BY DAN CHECKOWAY

We left off last month after introducing the not-so-simple act of shooting and bucking rivets. Hopefully you have a decent handle on the basics, or at least enough of a comfort level to get you started with a scrap project. That installment dealt primarily with topside riveting—that is, inserting the rivet from the top of the work and applying the rivet gun to that face, using a bucking bar on the shop head. That's a great technique that you'll be able to use on much of your airplane, but not all of it.

Get Back

You may have heard the term *back riveting* before, or perhaps you've seen that phrase used with certain tools in one of the many tool catalogs that litter your bathroom...er, library floor. (My wife came home one day with no fewer than three magazine racks

The back riveting plate is simply a smooth, heavy slab of steel that will be your stationary bucking bar.

for my extensive aviation library!) No, back riveting doesn't necessarily involve lying on your back—although it might. It refers to what is essentially a reversal of the tools. Instead of the gun shooting the manufactured head of the rivet, you'll shoot the shop head. The rivet doesn't really care what's striking the shank to form the bucktail, as long as it's smooth and flat.

When do you choose to back rivet, as opposed to using some other method of riveting? Back riveting comes into play predominantly when flush riveting

Practice is everything. That test kit you bought from Van's is a great teaching aid, but any bit of scrap aluminum will work. Try your hand, make mistakes and do what you can to get good before you work on real airplane parts.

Photos: Marc Cook

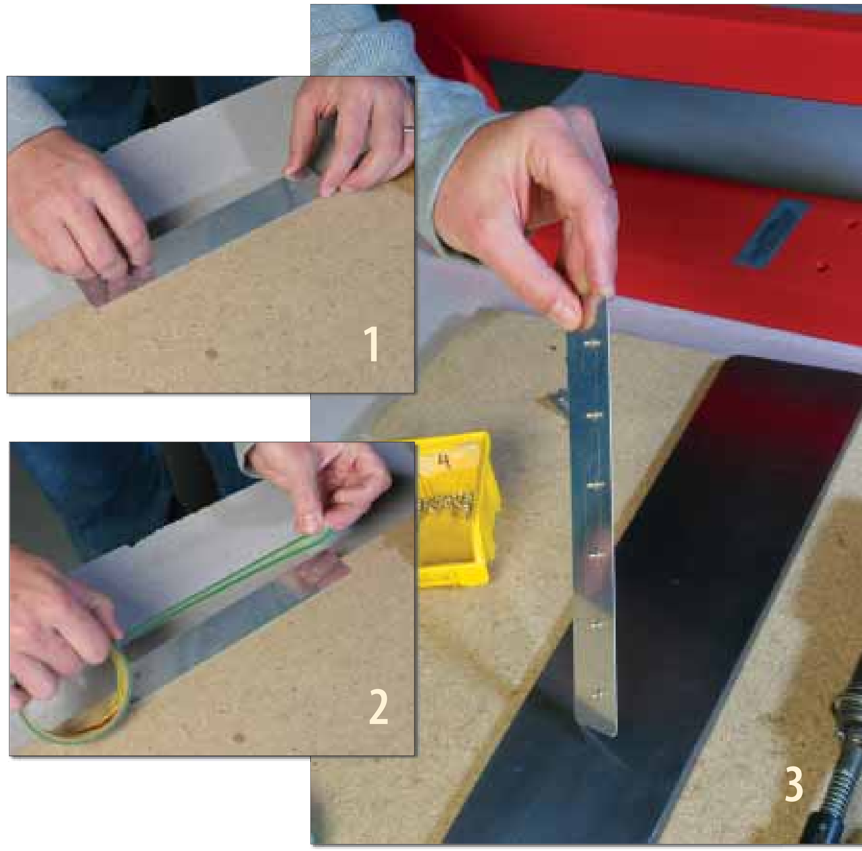
structure to exterior skins from the inside out. An example of this would be riveting stiffener angles to skins, such as on rudder or elevator skins. While you certainly could shoot and buck from the front or top side, the difficulty comes in supporting the work as you rivet, and the process is likely to produce a few dings because the material is generally pretty light. Back riveting provides stability while you work, and it produces a perfectly smooth finish every time.

What's On Your Plate?

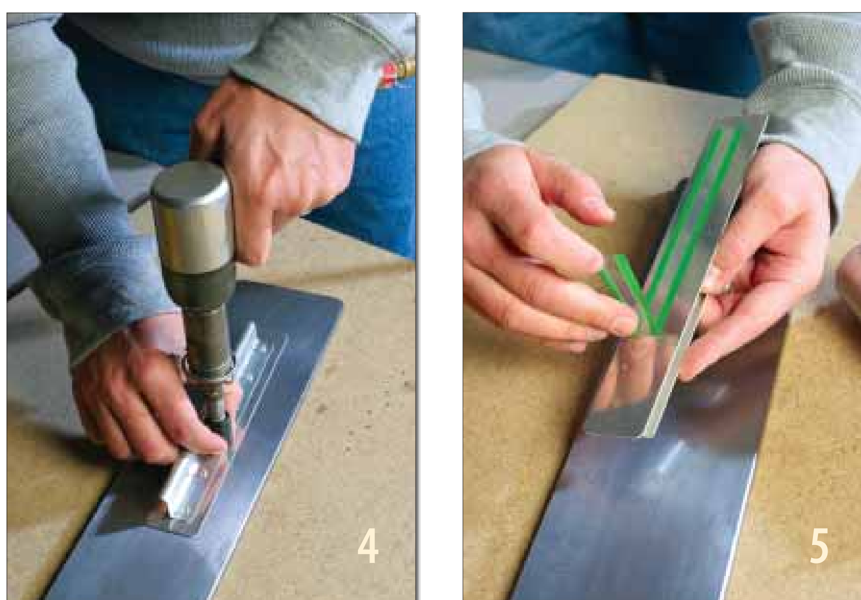
Most of the time, you'll use what's called a back riveting plate. This is just a smooth, flat plate of steel, typically $3/8$-inch thick or thicker, that you lay on your bench. Pop some rivets in the holes of the skin, lay the skin down on the plate so the flush manufactured heads are on the plate, hold the stiffener angle in place and just shoot the rivet shanks. Sound simple enough?

Let's look at this process in more detail. (While you're thinking about it, might as well begin that reflexive reach for the wallet, as you're going to want some new tools.) First of all, you might be thinking—what holds the rivets in place as I tip the skin over onto the plate? *Tape!* As you put the rivets in place in the skin, you apply strips of tape to the skin, holding the rivets in the holes so they don't fall out as you flip the work over. There's actually a specific type of tape for this, called, er, rivet tape. This tape has three strips—a center strip with no adhesive on it, which is intended to go over the rivets, and two adhesive strips on the edges.

So you've got rivets in the holes, rivet tape and all, and you place the work flush side down onto the back riveting plate. You place the stiffener angle down onto the work, rivet shanks sticking up through the holes. Now all you need is a set in your rivet gun that has a flush face, but is narrow enough so that you can get it close to the flange of the stiffener. And wouldn't it be nice if the set had a built-in spring-loaded "collar" to prevent the set from drifting off the rivet as you shot it? Today is your lucky day, because such a thing exists. It's called a back rivet set (I know, this is serious rocket science).



The first steps in back riveting components are to place the rivets through the work (1) and secure them with special rivet tape (2). With the rivet tape in place, the rivets will miraculously stay in place so you can manipulate the pieces as necessary (3).



Work carefully while back riveting, as you do with other processes, and be sure that you steady the rivet gun with your free hand (4). When you're finished, simply peel the rivet tape from the part (5) and enjoy having that rare thing: a perfect part.

A special back riveting set keeps the gun centered on the bucktails and helps you create perfectly set rivets.

Working Solo

Back riveting is usually done solo. In fact, I'm racking my brain trying to think of a case where you'd even want help when back riveting. Nevertheless, you're going to put all of your fingers to work. It's really important that you hold the stiffener (or whatever you're riveting) tightly against the skin. And, just like we talked about last month, you really need to use your spare fingers to brace the rivet set to keep it from walking. Even though the plastic collar provides a modicum of safety, there's no reason to push your luck. So you've got two fingers on the set collar, and the other three fingers are pressing on the work to hold it in place. Hold the gun square to the work, pull the trigger, count to about two and release.

After you've done a whole row of rivets, check out the exterior side. Peel that tape off (save and reuse it if you're frugal like me) to reveal an absolutely perfect line of rivets. Nice and flush, with no dings or dents—pretty much guaranteed. When back riveting against the plate, the worst thing you can do is hold the gun crooked or shoot the rivet too long. It's pretty easy to do perfect work. Not only that, but the process goes incredibly quickly. Because you don't have any Clecos to deal with, and the rivets are all just sitting there ready to be shot, you can cruise up the line of rivets and make really good time. Back riveting rules!

PRACTICE MAKES PERFECT

Working with scrap aluminum is one of the best ways to develop an intimate feel for your tools and the essential techniques. (Working on actual airplane parts runs the risk of having to order a replacement if it doesn't go quite right.) In fact, there may be some value in deliberately trying to make mistakes on practice pieces. Knowing how mistakes are made, you are more likely to be able to avoid them while working on the real deal. So your homework assignment for the weekend is to take a few pieces of scrap aluminum, drill a bunch of holes—some dimpled and some not—and practice making mistakes. This ought to be fun and quite educational! —*D.C.*

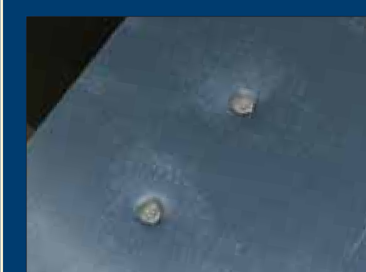
Gotcha #1: Push too hard with the bucking bar. I mentioned this briefly last month. Try screwing this up by pushing harder with the bucking bar than you do with the gun. Notice how the rivet pushes up and out of the hole as it gets set.

Gotcha #2: Pull the gun away before it's done shooting. This is particularly important when using a cupped set. If you let up pressure on the gun before it's done, you're likely to create smiles across the rivet head or around the rivet. Ugly! Always keep pressure on the gun until you're done shooting.

Gotcha #3: Pull the bucking bar away before the gun is done shooting. You may get away with this one on occasion, particularly with flush rivets, but often what will happen is you'll make a big dent around the rivet. Without any mass backing up the impacts from the rivet gun, the rivet set is allowed to do nasty things to the work. This is particularly important when using a cupped set or flush riveting thin skins or convex areas. Always keep the bucking bar in position until the shooting is done.

Gotcha #4: Hold the bucking bar at an angle to the rivet head. If the bucking bar face isn't square to the rivet, the rivet will either tip over or form a lopsided shop head. Always keep the bucking bar square to the rivet. (And, yes, the rivet is too long for the job—that's for illustration purposes.)

Gotcha #5: Allow the edges of the bucking bar to gouge the surrounding flange or material. This is an insidious little mistake—because at face value it just looks like the primer may have been scuffed a little. But what's really happening, at least in the worst cases, is that you have created deep scratches or gouges. Those are stress risers, and you never know what havoc that might wreak long term. Always be aware of where the edges of your bucking bar are, and use strips of duct tape on the corners for protection.



Gotcha #6: Shoot a flush rivet in a hole that was only partially dimpled. This one has less to do with riveting technique, but it manifests itself when flush riveting. If the hole is not fully dimpled, the rivet will sit proud of the surface. When you go to shoot it, it tends to force the rivet down, caving the skin in slightly, since the flush set seeks a uniformly flush surface. The result is that you will see a waviness in the reflection around each rivet.

Other Variations

Unfortunately, not everything can be back riveted, though there is a variation of back riveting that some builders use even when the work can't be placed flush side down on the bench. The premise is that you still want to shoot the rivets from the back side in order to get that perfectly smooth exterior without even slight dents or any waviness. For this purpose, they make a special back riveting bucking bar. It's considerably heavier than your average bucking bar. The person bucking will simply lean into the work with this heavy bucking bar, and the shooter just shoots the rivet shank to form the bucktail. Unlike conventional shooting and bucking, in this case it's critical that the bucker pushes harder than the shooter—which keeps the rivet nested firmly in place in the dimple while being shot.

This technique is most often used when riveting wing skins to ribs or fuselage skins to bulkheads. There's a catch, though. Ribs and bulkheads often have two flanges (the top and bottom of wing ribs, for example), and those flanges prevent the rivet gun from having straight-on access to the rivet shank. Surely you don't hold the rivet gun at an angle, lest your shop heads will end up tipped or crooked—not acceptable. Much like the double offset rivet set we talked about previously, there is a similar variation of the back rivet set that has a joggle built into it. It lets you work around rib and bulkhead flanges so you can keep the shooting axis aligned with the rivet.

Back Riveting For All?

Why don't all builders always back rivet their wing and fuselage skins? Good question. Some people have good luck with the technique, and others do not. I personally prefer conventional shooting and bucking. My feeling is that as long as you have a properly formed dimple, and as long as the person bucking is doing a decent job, regular old shooting is going to produce the same results as back riveting. Your mileage definitely may vary.

Speaking of variation, there's another unique way to use a rivet gun to back rivet that I'd like to discuss before we leap forward into the topic of squeezing rivets. Believe it or not, that big steel C-frame you used to dimple your skins can be employed for much more than just dimpling. Normally you would insert a dimple die into the receptacle, but nothing says you can't put a cupped set in there instead. Some (if not all) C-frames come with two accessories that help with riveting—an extension for the bottom receptacle and a rivet set shaft with a tapered end for a rivet gun. The extension is just a short shaft with both male and female ends; the rivet set shaft usually has a flush face on one end, and it accommodates a rivet gun on the other end.

You can use your C-frame to rivet as well as dimple. Remove the dimple dies (top) and install the appropriate cupped or flush set (above). Aren't tools great?

Place the extension in the base of the C-frame, then insert a cupped set into the extension. Put a rivet in the given hole, place the work manufactured head side down onto the cupped set, and lower the rivet set shaft down onto the rivet shank. As you stabilize and level the work with one hand, place the rivet gun onto the end of the shaft, and pull the trigger. As long as you hold the work level and stable, you'll get perfectly level shop heads every time.

Using the C-frame with the standard rivet gun is noisy, sure, but the frame makes one-handed operation of even fairly large pieces simple. All you gotta do is hold the work level.

Using the C-frame in this fashion is a great way to make progress when you need to work solo and aren't comfortable shooting and bucking by yourself. It's also helpful when working with lighter weight structures that may be tough to secure while riveting. Instead of securing the work, you essentially just secure the rivet—by virtue of it resting in the cupped set and the work being held stable while the shank gets back riveted.

Big Pieces Mean More People

Sometimes it's best to have a helper around when riveting with the C-frame. This comes into play if you're working with larger structures that are difficult to hold perfectly level with just one hand. An example that comes to mind would be when you're riveting doublers to a wing spar. You're always going to have at least one hand on the rivet gun. If you're solo but need some help, don't hesitate to use whatever you have laying around. Often what I do is pile up 2x4s or whatever chunks of stuff happen to add up to the right height. A little resourcefulness goes a long way.

So there you have it. Now you know some of the most common gotchas when shooting and bucking. We've shown you ways to back rivet flush rivets, and now you've been introduced to a way to back rivet universal head rivets—and it's another way that expensive C-frame can earn its keep around your shop to boot. We're making good progress, but there are still plenty of variations on riveting that we need to cover. We've been making a lot of noise with the rivet gun, but next month we'll shift gears and talk about some of the quieter riveting techniques you can use deep into the wee hours of the night without your neighbors even knowing you're out there in the garage. ✈

Build Your Skills

Metal Part 9

You say pound, I say squeeze—let's explore the other side of setting rivets.

BY DAN CHECKOWAY

Keep poundin' those rivets! You may have seen this tag line slapped on the end of motivational e-mail messages on various online builder forums. The idea behind this saying is to convey that there really is a light at the end of the tunnel—that there will come a time when you have no more rivets left to set (ah, pound), and you'll be flying the plane you built with your own two hands. I love the notion, but I actually prefer a variation on the theme: Keep squeezin' those rivets! From my perspective, I would much rather squeeze rivets than shoot and buck them.

Less expensive squeezers (top) can be more painful to use. See how stretched out your hands may need to be? It's difficult and tiring to produce much force like this. Better designed hand squeezers (above) require less hand stretching and enable you to produce more force comfortably.

In a way, we started you out with the more difficult techniques. This is most definitely subjective, and I'm positive that quite a few builders disagree with me on this, but I personally find squeezing to be the easiest and most straightforward method of squashing rivets. The advantages? First and foremost, you can achieve 100% perfect uniformity of shop heads. When shooting rivets—using the rivet gun, as we've been discussing—it's not necessarily difficult to achieve this uniformity, but it takes much more finesse and practice.

Without getting into too much detail on the tools or techniques just yet, suffice it to say that when squeezing, it's possible to adjust your tools in a "set-it-and-forget-it" mode, and they'll literally form perfect, identical shop heads right on down the line. The other advantage of squeezing is that it's *quiet!*

Can You Squeeze Them All?

If it's so quiet and easy, then why don't we squeeze every rivet on the plane? Recall our discussion on back riveting—it's a technique generally preferred over bucking rivets because it's so easy, relatively speaking. But just like there were limitations with back riveting, it's the same deal when it comes to squeezing rivets.

Photos: Marc Cook

It's not a matter of access, but rather limitations that the tools impose.

Tools, Again!

And on that note, it's time to start yapping about tools again. Because you've probably already done some dimpling, you may already have been exposed to the same tools we'll be using to squeeze rivets. Despite the variety of designs, they serve the same purpose. The anatomy of a squeezer is basically a yoke, a plunger, and some mechanism to actuate the plunger. The yoke is a rigid piece of steel, usually shaped like a C. The yoke attaches to the body of the squeezer with bolts or pins, and the plunger pushes up into the jaws of the yoke through a hole in one side. The plunger is usually adjustable by virtue of being able to screw in or out. This allows you to fine-tune the resulting gap

Here's a longeron yoke with a cupped set on one side, and a flush set on the other. You can swap the sets around if that works better with the orientation of the rivet.

between the plunger and the top of the yoke when the squeezer is fully actuated.

The plunger has a receptacle into which you can put a rivet set (or dimple die). On the opposite side of the yoke there is usually another hole (it depends on the style of yoke), in which you can place another rivet set (or complementary dimple die). If you're squeezing a universal-head rivet, you'll put a cupped set on one side and a flush set on the other. If you're squeezing a flush rivet, you'll put flush rivet sets on both sides.

Your Main Squeeze

Squeezers break down into two major categories, the first of which is hand squeezers, operated manually by hand. They all work in the same fashion, which is by using some sort of cam system or some other means of stepping up force to apply a significant amount of compression when the plunger is forced up against the opposite side of the yoke.

Despite those little rivets being made of a relatively soft aluminum alloy, it still

Here are two flush sets in a C yoke. Sets come in different thicknesses, which can be used to provide the yoke clearance over nutplates, other rivets, etc.

The adjustable set simply threads in and out of the squeezer. This lets you fine-tune the gap between sets, and it affects the dimensions of your shop heads.

takes hundreds or even thousands of pounds of compression to squash them. It's not like a pair of pliers, where there's a linear ratio between the force applied at the handle and at the jaws. Even if you eat your spinach, you're still going to need some help in the way of developing a mechanical advantage, and that's where

The yoke: It attaches to the squeezer body with two bolts or pins, has a hole in the bottom for the plunger, and typically has a hole in the top for a set or dimple die.

There's no end to the variety of shapes and sizes of yokes. Here are two C yokes and a "thin-nose no-hole yoke" (upper right).

the size of your wallet—more so than the size of your forearms—comes into play.

Don't Be Cheap

The cheap hand squeezers are just that—cheap. They are awkward for one, because of the wide angle to which the handles open. Take your hand and curl your fingers and thumb in, and slowly make a fist. Where does your hand develop the most force? I don't know about yours, but mine starts kicking in when my thumb and fingers are around 3 inches apart, and the force I'm able to generate increases the tighter it gets. So if you're trying to use a hand squeezer that starts to develop its force when the handles are 6 inches or more apart, what good is that? You really get what you pay for here.

What makes more expensive hand squeezers worth the extra bucks? For one, they have been designed with these human factors in mind, and the geometry is much more advantageous for the average clenching fist. The basic premise is that the squeezer develops the most force when the levers are within grip range of normal hands. A little engineering goes a long way, and these wrist-friendly tools do cost more. But like anything else in the tool industry, it comes down to how much you're willing to pay to avoid pain. If I'm going to have to squeeze thousands of rivets, I want the experience to be a pleasant one. Seriously, you're spending tens of thousands of dollars building your show-winning airplane—what's another 50 bucks? Keep in mind that aircraft tools are "liquid," in that you can always sell them to another builder when you're done using them.

Pneumatic squeezers, from left to right: single piston, tandem piston and alligator squeezer. The tandem is capable of squeezing much larger rivets, but is often overkill.

Hold On, You're Not Done Buying Tools

OK, so I've got you all lubed up, your checkbook is handy, and you've bought into the mindset of saving pain by spending money on nicer tools. Good deal. Let's drop a few more C-notes! The other category of squeezer is the pneumatic squeezer, which is operated by air pressure. (I'm getting goosebumps as I write this...oops, I drooled a little.) Talk about being lazy while accomplishing a tremendous amount of work. When using a pneumatic squeezer, the only thing that might get sore is your poor little thumb, because it's going to have to pull that trigger over and over again. I joke, but using the pneumatic squeezer is an absolute pleasure. You literally just pull the trigger and the thing develops thousands of pounds of force with essentially zero effort on your part.

Pneumatic squeezers are expensive. They cost on the order of $400 and up. Sometimes you can find a good deal on a used one, but be careful—you may end up spending just as much having the tool rebuilt as you would just buying a brand new one. Many builders consider the pneumatic squeezer an unnecessary luxury, and they're certainly entitled to that opinion. I suggest you find another builder who has one of these pneumatic puppies and give it a try.

If you do spring for a pneumatic, make sure it's of the variety that takes the same style yoke as whatever hand squeezer you have. Some hand squeezers such as the Tatco brand, while very nice tools, use yokes with a proprietary attachment style that is not interchangeable with any other brand of squeezer. Most other varieties of hand squeezers and pneumatic squeezers accommodate the same style yoke. Keep this in mind when shopping for tools.

Some pneumatic squeezers come with a non-adjustable set. With this configuration, the way you adjust the gap is by using shims or washers between the set and the plunger. Some people swear by this method. Using a combination of AN960-10 ($^{1}/_{16}$-inch thick) and AN960-10L ($^{1}/_{32}$-inch thick) washers, you can tweak the gap until it's close. An alternative to doing this is to purchase an adjust-

Using a pneumatic squeezer only takes one hand, which frees up the other hand to stabilize the work. All you have to do is push the trigger with your thumb.

If you don't have an adjustable set, you can use washers to adjust the gap. The author used washers for about 10 minutes, then sprung for the adjustable set!

able set, which allows you to thread it in and out and have infinite control over the gap. In my opinion, this is easier, faster and more accurate than using shims.

To make matters more confusing, pneumatic squeezers aren't all created alike. You'll find single-piston, tandem-piston and alligator varieties. The tandem is capable of generating significantly more compression force, but costs more and is larger and heavier. The tandem squeezer is pretty much overkill for the needs that arise when building most kit aircraft. It's unlikely that you'll need to squeeze any rivets larger than 1/8-inch (diameter), which are easily squashed using single-piston designs. The alligator squeezer has its advantages due to the geometry of the jaws, which can sometimes reach around larger flanges more easily than can yoke-style squeezers. Even so, I still consider the alligator squeezer less versatile than standard squeezers and yokes.

Speaking of yokes, there are all sorts of shapes and sizes available. Probably the most common and versatile would be the 3-inch C yoke. It can be used for dimpling and squeezing rivets along flanges and edges. You'll find C yokes in several sizes ranging from about 1-inch depth all the way up to 6 inches and maybe deeper. The limiting factor of yoke depths is stiffness—ideally the yoke must not flex when under stress.

A nice addition to any arsenal of yokes is the so-called longeron yoke. It gets its name due to the fact that it can reach around wide flanges, such as those of a longeron. This yoke is usually not as deep as most C yokes, but you can use it in some more challenging spots.

A third variety is a modified C yoke that doesn't take a set or die on the top. It tapers down very thin in order to reach inside tight spaces such as trailing edges of control surface ribs. It is called the "thin-nose no-hole" yoke. Because it doesn't have a hole in the top and doesn't accommodate a rivet set, the inside top surface is flat. This is a pretty useful puppy to have when riveting elevators and ailerons and that sort of thing. It's by no means a necessity, but it may make the difference between having to use a pop rivet and a solid rivet in some cases.

This is a close-up of the "thin-nose no-hole" yoke. You can see there's no hole at the top for a set. The top surface itself is flat and acts as the flush rivet set.

How many yokes does the average builder need? Technically the answer is probably zero, because these squeezers are in essence a luxury. Yokes typically cost between $100 and $150 each! But again it comes down to how much money you are willing to spend in order to avoid pain, and how smooth you want the finished product to come out. I personally recommend having each of the three yokes mentioned above.

Generally, yokes are interchangeable from squeezer to squeezer—and that applies to hand and pneumatic squeezers alike. Just pull the pins (or bolts) and swap yokes.

Using a hand squeezer is satisfying work, but it's tiring at best. If you're on a tight budget, get used to this pain. Otherwise, the pneumatic squeezer is worth its weight in gold.

Put Those Tools To Use

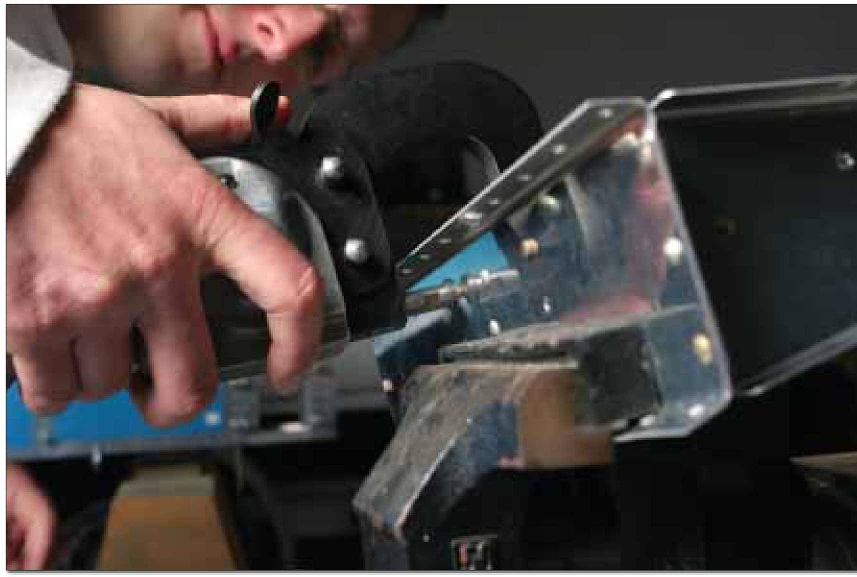
Enough babble about the tools. Let's talk about how to use them effectively. When using a squeezer on rivets, there are really only two cardinal rules. (1) Always pull/push against the manufactured head to keep the rivet firmly seated in place while you squeeze it. (2) Always keep the squeezer aligned with the rivet. If you follow those rules, you are pretty much guaranteed success.

As we discussed with respect to shooting and bucking rivets, it's important that the shooter apply more pressure on the rivet than the bucker. The same applies when squeezing, and it means you need to hold the squeezer in such a way that the manufactured head is pressed up against the work. If you get sloppy, it's really easy to mess up the rivet and allow a gap under the manufactured head. This is no good—the rivet will need to be drilled out. Always apply a good amount of force against the rivet as you squeeze it. Whether that means pulling or pushing depends on the orientation of the squeezer and the sets (cupped or flush), but the rule applies regardless. Usually it's easiest if the work itself is held in a vise or clamped to a bench or something, so you can use both hands on

Depending on how the flange is oriented, sometimes you can use a C yoke in these cases (top). It depends on whether or not you have space for the squeezer on the flange side. Here's the opposite orientation (above). You can see the standard C yoke doesn't fit the bill. The flange interferes with the yoke, preventing the set from contacting the rivet.

the squeezer to keep it stable and apply force in the right direction as you actuate it.

The alignment thing often plagues new builders. It's easy to misjudge the angle at which you're holding the squeezer, and the result of misalignment will almost always be a tipped rivet, or at best a shop head that is cocked to one side. If your shop heads aren't ending up



Keep the squeezer aligned with the rivet and square to the work. This ensures that the shop head won't tip, and that you won't have any gap under the manufactured head.

Thus the longeron yoke, which can reach around flanges like this without any interference. A combination of a C yoke and longeron yoke will pretty much serve most purposes.

parallel to the work, then you are most likely introducing some misalignment when holding the squeezer.

Rules For Pneumatic Squeezers

When using a pneumatic squeezer, things get quite a bit easier. You can almost always hold the squeezer with just one hand, freeing up the other hand to stabilize the work. And since all you have to do is move your thumb to pull the trigger, it's much easier to keep the tool stable and aligned. That's not to say that the pneumatic squeezer doesn't have its share of pitfalls.

First of all, you need to be aware of the safety risks inherent in using a pneumatic squeezer. This sucker produces thousands of pounds of compression with little provocation, which can absolutely obliterate your fingers or anything that may get caught between the jaws. You must be extremely careful when pulling that trigger. Don't rush, and don't get careless!

It's easy to over-squeeze a rivet if you don't have the set adjusted properly. I often get asked by new builders how to initially set up the adjustment when squeezing a rivet. The best answer I can give you is that you should be conservative on that first adjustment—it's always best to under squeeze the rivet and then have to tighten up the adjustment bit by bit to creep up on the proper setting. Remember from our earlier discussions that the finished length of a rivet is the grip length plus half the diameter. If you know the thickness of the layers you're riveting, you should be able to come up with an approximate measurement to shoot for between the rivet sets. Once you set it where you want it, it shouldn't require any readjustment. Cruise right on down the line of rivets, and they should all come out the same.

Sideways Is Not the Right Way

Another gotcha when using the pneumatic squeezer actually applies to the hand squeezer as well, and it comes into play when squeezing flush rivets. Those flush sets are pretty smooth and can slide around on the work a bit as you're positioning the squeezer. It's all too easy to let the flush set slip sideways a little before squeezing the rivet. If you're using a relatively narrow flush set, it might miss the rivet entirely. Worse, it might only partially cover the shank, in which case the shop head is going to be a mess. It takes some diligence, particularly with the pneumatic squeezer, to keep the flush set in place centered over the rivet as you start to squeeze it. With universal head rivets, this isn't as much of a problem, but you still could inadvertently position the cupped set off center a bit—which can result in a smile on the manufactured head, and probably a tipped shop head.

I have been around several builders who don't seem to grasp the concept of properly adjusting squeezers to achieve uniformity. They apparently don't realize that it's easiest to adjust the set for full actuation. In other words, they have the squeezer adjusted too tight, requiring them to stop before it is fully actuated—otherwise the rivet would be over-squeezed. I watch these guys do it this way, and they always have to guess when the rivet has been set properly. This makes no sense to me. I recommend adjusting the squeezer so that the rivet is perfectly set when the squeezer reaches the end of its range of travel. This applies to the hand squeezer as well as the pneumatic. That way, there is zero guesswork. Every rivet will come out the same as the last one. This may sound obvious but believe me, I've seen lots of people who don't seem to understand this simple concept! Always use the tools to your advantage.

Here's where that "thin-nose no-hole" yoke comes in handy. Any other yoke style wouldn't fit in between those flanges at the trailing edge. The thin nose *just* fits.

With a combination of yokes—and typically having the option of coming at the work from two possible orientations—you can usually come up with a way to use a squeezer when riveting structures (i.e. ribs to spars) and on most edge locations on the exterior surfaces. Nevertheless, there will be scenarios when you just can't figure out a way to finagle a squeezer in there. No sweat...you can always fall back on shooting and bucking. Maybe you'll end up preferring the shooting/bucking method over squeezing anyway. Regardless, at this point, I think we've given you a pretty solid foundation for the different types of riveting you're likely to do on your project. You'll get lots of practice using all of these methods, and you'll undoubtedly develop preferences for the techniques you like best.

Ouch! The set must have slid off the rivet head on the other side, because the set on this side only hit part of the rivet. Pretty ugly, and this needs to be drilled out for sure!

With so many different tools and methods at your disposal, you're bound to make a mistake or two as you learn. Next month we'll focus on how to fix those mistakes—in particular, the inevitable act of drilling out badly set rivets. Until then, keep squeezin' those rivets! ✈

Next Month

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PRODUCT REVIEW:
HOMEBUILT HELP DVD SERIES
Zenith CH 701 builder Jon Croke of Homebuilt Help has produced a number of instructional DVDs designed to aid novice builders in the aircraft construction process. We watched the first five productions and have some insight, if you're considering one.

PRO-BUILT PANELS:
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Build Your Skills

Metal Part 10

Humans make mistakes, even humans building airplanes. *Here's how to fix them!*

BY DAN CHECKOWAY

I can't believe I just did that." If you haven't said those very words to yourself, perhaps accompanied by a mouthful of sailor-worthy expletives, you aren't an airplane builder yet. Even the builders who win awards at Oshkosh make their fair share of mistakes. It happens, and—trust me—*it will happen to you*. Consider it a rite of passage. Which is more satisfying—knowing how to do something right, or knowing how to fix the things you do wrong? I would actually argue that the latter is more valuable knowledge in an airplane building shop.

When I was starting out, this metal-work stuff seemed pretty straightforward, and I could tell when I made a mistake. What made it tough was that I was altogether unsure when a mistake was ugly enough to warrant a remedy. How bad is bad enough that it needs fixing, rather than just leaving it alone?

Learning to Judge Mistakes

We as new builders just don't know where to draw that line at first, and I think most of us tend to be overly conservative in this area. This is a good thing in general, but over time most of us end up learning the hard way that sometimes when you try to fix something, it's easy to make it worse. I'm not suggesting that you should tolerate a high degree of imperfection, but there are often times when small boo-boos have no impact structurally, and they are best left alone—lest you cascade into a series of worsening problems as a result of your attempt to make it better.

I can't teach you where to draw the line, which is highly subjective anyway. The best advice I could give you is to join EAA and take advantage of its Technical Counselor program. Tech counselors are there to help in numerous ways—one of which is helping builders relax a bit dur-

Can you tell which of these rivets is an "oops rivet"? (Answer: It's the second flush rivet from the left. Were you right?)

Photos: Marc Cook

ing that early phase, in which every tiny mistake equates to a show stopper. You will eventually learn where you personally draw the line. It's not a lowering of standards per se, but we do relax to some extent as we learn more. First and foremost, build it to be safe, and obviously don't leave an imperfection alone if you have any doubts about it.

So on that note, I'd like to take you on a tour of some of the most common mistakes builders make—and how to fix them without making things worse.

Out With the Old...

In previous installments we pretty well covered a slew of gotchas that pop up as a result of poor riveting technique. I won't waste any more words on that stuff. Let's just assume for the sake of argument you've done some less-than-perfect riveting, and your tech counselor confirmed that indeed those rivets need to be drilled out and replaced. No sweat, but before you plunge your drill into the head of that first bum rivet, let's take the time to study the field-proven science of drilling out rivets.

First of all, what is the goal? Ideally, you want to be able to remove the bogus rivet from the part without altering, in any way, the hole itself or the material around it. If you were to take your drill and just go for it, I think you'd have a slim chance of accomplishing the goal.

Both universal-head and countersunk rivets give you an excellent starting point for drilling out: that dimple right in the middle of the head. Aren't they thoughtful?

Once you've drilled through the head to the shank, but not through the skin material itself, you can use a punch to remove the head and press the bucktail back through the work.

Start drilling the head of the rivet by hand, taking your time and watching for the tiny slivers of aluminum to come up from the head.

More likely is that you will enlarge or elongate the hole in the process. Consider this... if you use your #30 drill bit to drill a rivet out of a #30 hole, are you talented enough to get that drill bit perfectly centered and not so much as scrape the sides of the hole? I seriously doubt it—and I'm not knocking your fine skills.

So what's the secret to extracting those rivets while leaving the holes unscathed? As you may have predicted, one way to do it is to buy a special tool for the job. Various aircraft tool vendors sell rivet removal tools, which are essentially just specialized jigs that make it easy to center the drill over the rivet and thus the hole. To be honest, I've never even used one! I assume they work as advertised, but in my opinion you can save your money for other toys. Obviously there's no such thing as having too many tools, but the old school approach to extracting rivets works just fine.

As you may recall, when we discussed rivet identification we noted that the AD rivets we commonly use will always have a little dimple mark in the head—indicating that the rivet's major alloy is copper. This physical trait is a gift from the rivet alloy gods, because it's as if somebody took a center punch to the rivet with CNC accuracy. What better way to center a drill on a rivet than a pre-made center mark?

Hey, That Sounds Easy!

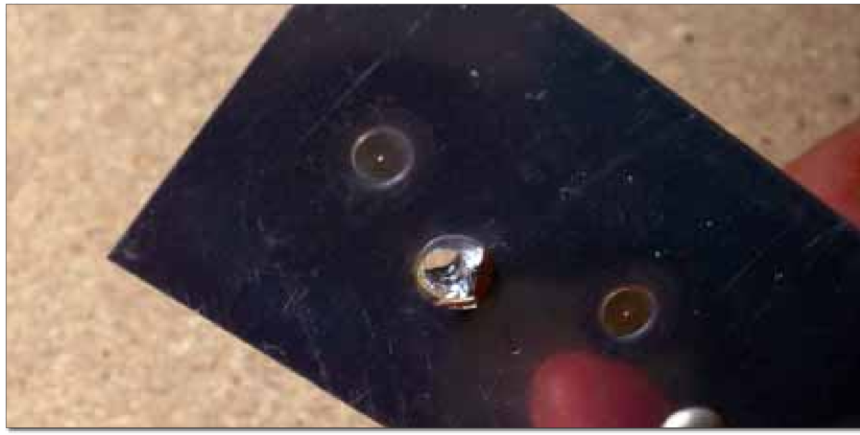
Despite this aid, we're not quite there yet. It's not as trivial as just drilling right through the center of the rivet. You might luck out if you do that, but unless you nail it exactly square to the work, there's going to be some slight enlargement or elongation of the hole. It can be avoided with a little diligence.

Here is what the rivet hole should look like if you've done the extraction well. It will be the same shape and size as before the rivet was ever driven.

First of all, I highly recommend using an undersized drill bit. If you used a #40 to drill the hole, use a 3/32-inch bit when drilling out the rivet. If you used a #30 on the hole, go with an 1/8-inch for the rivet. By going smaller, you buy yourself a few valuable thousandths of an inch to help ensure that the hole won't be altered if you accidentally drill in too far.

Using a sharp bit, center the drill in that little dimple in the rivet head, and spin the drill using only your fingers. If you apply firm pressure with the drill against the rivet and use a sharp bit, you won't even need to spin the motor up to speed. Just keep the drill square, and drill into the rivet head—but go only as deep as the rivet head. You'll see two little "spirals" of aluminum feeding out of the bit as it cuts into the rivet.

Once you've drilled to a depth about the height of the rivet head, take a pin punch and pry the rivet head right off. Use a 3/32-inch pin punch for a 3/32-inch rivet, or a 1/8-inch pin punch for 1/8-inch rivets. Seems pretty straightforward, huh? If you can't get enough leverage with the punch, drill in a bit further, but only deep enough to get that leverage. The rivet head should break off pretty easily if you get the depth right. This technique of prying the rivet head off with a punch applies to both flush and universal head rivets. The concept is exactly the same either way.



And here's what happens when you don't drill deep enough into the rivet head before trying to pry it off. Ugly, isn't it?

The process is the same for universal-head rivets, but you get a lot more meat to play with.

The Shank, My Friend

What you'll be staring at once the head is gone is the rivet shank in the hole, nicely exposed. Now you're left with a choice. The easiest next step is to take the pin punch and just hammer the rivet shank right out of the hole. It will fall out the back, shank, bucktail and all. I say you have a choice, because if you're dealing with thin material, particularly a thin flange on the back side, pounding on the shank could easily bend the flange away inadvertently—and it may be impossible to bend it all the way back into place. So either back the flange up (i.e. with a wood block) as you punch the rivet out, or go with Plan B—which is to continue drilling the rivet out with that undersized (3/32-inch or 1/8-inch) drill bit. Do your absolute best to keep the bit centered and square.

Bad, good, bad: If you continue to drill through the material to remove the rivet, you will almost certainly enlarge or elongate the hole. Your best choice now is to drive an oops rivet.

Once the rivet is out of the hole, check the condition of the hole. If you did it right, it should look exactly like it did in the first place, before the rivet went in. This is what we're trying to achieve.

Sometimes, however, it doesn't go as planned. Maybe you got a little sloppy when you drilled into the rivet head, you used a dull bit that wandered a little, you drilled at an angle and went too deep—perhaps all the way through. What you'll see is that the hole now looks elongated—like an oval rather than a circle. Or maybe it's still circular, but when you put the new rivet in, the rivet kind of swims in the hole. If you try to set the same size rivet in an elongated hole, the rivet will probably tip over. Or if the hole is badly enlarged, more of the rivet will be consumed as the rivet swells to fill the hole, leaving a shop head that will probably be too short. Use a longer rivet, and it's probably going to tip over. If you go with the same size rivet in a botched hole, you'll most likely be faced with having to drill it out again! Who's to say you won't make the same mistake the second time you drill it out, making the condition of that poor hole even worse?

At this point we're treading in territory I mentioned earlier—often the best course of action is no action at all. Popular aircraft kit manufacturers generally build huge margins for error into their designs. One single rivet whose shop head doesn't quite conform to the Mil-Spec is most likely not going to down the plane. I'm typically a proponent of leaving a bad rivet alone, especially if it's just one in several hundred.

No Rivet Left Behind

But let's proceed with this hypothetical situation of bad-gone-worse, because many new builders are pretty stubborn

Premade oops rivets have the standard head size but a larger shank—the rivet facing down is one of this clan.

about not just letting a single bad rivet go untouched. They'll learn eventually. For now, let's talk about how to dig yourself out of the proverbial hole.

So you're staring at this ugly hole, enlarged and elongated, and you know you can't just pop the same rivet in there and be done with it. What to do? The most logical solution is to step it up one size. If the hole was #40 for a 3/32-inch rivet, drill it out to #30 for an 1/8-inch rivet. If it was #30, drill it out to #21 for a 5/32-inch rivet. And so on…though in all likelihood you'll be dealing with a #40 or #30 hole to begin with. Don't forget to deburr the hole after you drill it out.

If it's a universal-head rivet you're dealing with, the prognosis is pretty straightforward. Pop the next larger diameter rivet in there, squeeze it or shoot/buck it, or whatever method presents minimal challenge. If it's a flush-head rivet you just drilled out, however, you have a dimple or countersink to contend with. Incrementing the rivet size means you would also need to form a deeper dimple or countersink. After all, the head of an AN426AD4-x won't fit in the dimple for an AN426AD3-x. But before you break out the 1/8-inch pop rivet dimple dies or the microstop countersink, there's a wonderful alternative that you should be aware of.

At this point it's time to punctuate your mistake by uttering a word that every builder eventually adds to his or her vocabulary: OOPS! Believe it or not, it's a technical term in this case. I'm referring to "oops rivets," which is shop lingo for NAS1097 rivets. The reason they were given that name is because they do so well at hiding mistakes. The beauty of the NAS1097 flush-head rivet is that it has a reduced-size head. For example, an NAS1097AD4-4 rivet has an 1/8-inch shank but its head is the same size as a regular 3/32-inch AN426 rivet. 1/8-inch shank with a head like a 3/32-inch rivet…perfect! What this means is that once you've drilled your #40 hole out to #30, you can slap an NAS1097AD4-4 rivet in that hole without needing to make the dimple any deeper. These oops rivets are truly the saving grace for common mistakes, because they are all but impossible to detect cosmetically. The smaller head blends right in with all of the other rivets.

And the after effects: The rivet on the right has been carefully squeezed, like a tiny marshmallow man. Use care and discard any homemade oops rivets that are wavy or tipped.

(I'd like to stray from the topic for just a moment to highlight another fantastic application for the NAS1097 rivet. Let's say you need to install nutplates in thin material, say .025-inch thick or so. Most nutplates are not dimpled, so you're generally faced with having to countersink the material for the rivets that hold the nutplate in place. In order to countersink the material deep enough for an AN426AD3-3.5 rivet, the countersink would bottom out, reducing the material that the rivet can grip. Instead, you can use NAS1097AD3-3.5 rivets, which still has a 3/32-inch shank but can use a considerably shallower countersink—because it has a reduced-size head. So you get to use the non-countersunk nutplate but the head of the rivet will remain fully flush, important if it is, say, around the cowling flange, where flushness is a must. In any case, the oops rivet has much more utility than just resolving oops scenarios.)

You can make your own oops rivets by partly squeezing a rivet that's ostensibly too long for the material it has to grip, with the intention of expanding the shank to the size that will fill the new hole. Easy does it, though.

Back to fixing mistakes... If you accidentally enlarge a hole but don't happen to have any oops rivets handy, and for whatever reason you can't step up to the next larger diameter rivet, it's possible to make your own oops rivets.

Take a rivet with the same size shank as the original rivet, but one size longer. Place it in your hand squeezer and just barely give it a squeeze—just enough to cause it to swell a bit. It's difficult to do without tipping the shank, but if you're careful you can indeed make your own swollen rivets that will fit in an enlarged hole.

Don't Worry, They'll Make More

If these repair methods fail for some reason, or if you find yourself making a bad thing worse, there is a surefire solution—buy a new part! Most kit manufacturers sell individual kit components and they are probably cheaper than you might think. For example, the rib from an RV-7 horizontal stabilizer only costs about nine bucks. Is it worthwhile hacking an already beaten-up part when the alternative costs so little? Sometimes, a few bucks and needing to wait for new parts to arrive is the price of a lesson learned. Most simple mistakes can be remedied, but occasionally the best solution is to start over. Know when to say when. I'm obligated to reiterate: build it safe!

At this point we can pretty much wrap up with our discussion of sheetmetal techniques. Edge prep, fluting, flanging, layout, drilling, deburring, dimpling, riveting, fixing—we've covered it all and then some. If you've been following this series from the beginning, hopefully you now have a fairly extensive foundation on which to build your own skills and knowledge. You will undoubtedly hit speed bumps from time to time, but now you have some clues as to how to recover and move forward. That said, we're not quite done with this series. In case you haven't noticed, I haven't mentioned a single word about the often taboo topic of corrosion protection. Dare I even say the "P" word? Next month, like it or not, we're going to attack this final topic in earnest!

Next Month

KITPLANES
THE INDEPENDENT VOICE FOR HOMEBUILT AVIATION

BIPLANE BOOT CAMP

For homebuilders, the piloting gold standard may very well be mastering a Pitts. An Arizona instructor runs a unique program that he says can turn any tailwheel pilot into a Pitts pilot in just 8-10 hours. Our man Wischmeyer gave it a try.

HEADSET BUYER'S GUIDE: ECONOMY MODELS

Over the next few months, we'll wring out a bunch of the common headsets on the market to help you decide which one's right for you. In Part 1, we'll take a look at economy headsets—those you can grab for $200 or less.

DO YOU NEED A TSO?

For builders and pilots of homebuilt aircraft, the question of whether you need a TSO for particular equipment often leads to a confusing answer. We'll give you the straight stuff.

BUILD YOUR SKILLS METAL, PART 11

We've covered everything from basic riveting techniques to fixing common mistakes, and you should be just about ready to start tackling your metal project. Tune in for the series finale, where author Dan Checkoway considers methods of corrosion protection for metal parts.

PLUS...
ENGINE BEAT
WIND TUNNEL
AERO 'LECTRICS

AVAILABLE MAY 9

Build Your Skills

Metal Part 11

In our final installment, a close look at the *sticky (but necessary) issue* of corrosion proofing.

BY DAN CHECKOWAY

Anodes and cathodes. Oxidation and reduction. Ionic exchange. Believe it or not, this stuff right out of your high school chemistry class has quite a bit to do with airplanes—but it's not a pretty sight when these concepts come into play. It's the dreaded C word—and I don't mean "cash" or "credit"—the cancer of your airplane's skin and bones, the carnivorous plague that no airplane owner wants to confront…corrosion!

Without getting too deep into the science behind it, corrosion is an electrochemical reaction that causes deterioration of metal when it reacts with the environment. In the context of airplanes, this is never a good thing. At a minimum, corrosion creates stress concentrations and weakens the structure; in extreme cases the material is literally consumed, leaving nothing but flakes and dust. To make matters worse, many of our airframes are built predominantly from aluminum, which happens to be one of the most reactive metals as far as corrosion is concerned. Yikes!

No, Really…Metal's OK!

Relax. Before you do something rash and put your kit up for sale on eBay and—heaven forbid—switch to an airplane kit that more closely resembles a surfboard (sorry, composite guys!), let's take a closer look at what causes corrosion and methods we can employ to ensure it won't happen to us.

There are positively and negatively charged areas on a given piece of metal. If you introduce an "electrolyte" such as water (worse, salt water) to the surface, those charged areas start exchanging electrons and react with the electrolyte. The metal combines with oxygen atoms from the electrolyte to form an oxide—it oxidizes. The longer you allow that electrically conductive moisture to be in contact with the metal, the more corrosion will occur.

If you introduce dissimilar metals into this equation, such as aluminum and steel, the problem becomes even worse. "Galvanic" corrosion occurs when two metals that have different electrical potential contact one another in the presence of an electrolyte. All those steel bolts that attach various bits of aluminum to each other…those are potential

Untreated steel will rust just waiting for you to build the airplane, just as aluminum will corrode. Your goal is to keep rust and corrosion at bay, particularly in areas of the airframe where you can't see or easily treat this metallic cancer.

Photos: Marc Cook

spots for galvanic corrosion if and when they get wet.

Obviously the solution is just to prevent an electrolyte from coming into contact with the metal in the first place and to isolate dissimilar metals from each other. Yes, *it's that simple!*

Maybe Not So Simple...

So don't leave your plane underwater, right? Yeah, but even if it's only once in a blue moon, surely every once in a while you'll fly through a little rain or leave your plane outside in not-so-fair weather. Or maybe you're based at an airport near the coast, where the air is full of salt-laden moisture. It's difficult, if not impossible, to completely avoid exposure to moisture in some form. Fortunately there are numerous treatments that can be applied to the metal parts in your airplane to prevent corrosion.

In a previous installment we talked about how most of the kit components that are 2024-T3 have a mirror-like finish—a result of the Alclad coating. This is one of the simplest forms of an anti-corrosion treatment. While 2024 aluminum is alloyed with copper, the Alclad coating is a thin layer of pure aluminum. Believe it or not, that shiny, pure, perfect-looking coating is already oxidized when you receive it. That's not to say it's corroded per se, but the pure aluminum does react with oxygen to form an oxide film that bonds strongly to the surface. This is a good thing! Aluminum's high reactance is a great attribute in this regard, because if the film is disturbed, it immediately reforms in most environments. It is this layer of oxidized pure aluminum that actually protects the underlying alloyed aluminum from corrosion. Alclad is typically about 5% of the total thickness on each side of the skin. That is, on a skin that is .040-inch thick, there would be a .002-inch thick layer of Alclad on each side.

Before we start, think about safety. And, for that matter, think about your body throughout the process. Wear gloves, skin protection and, when using anything that might kick off airborne toxins, protect your lungs.

Easy Off

While those scant thousandths of an inch do a great job inhibiting corrosion, it's altogether too easy to remove the coating if you're not careful. Let's say you accidentally dragged the tip of your drill across the skin—it's conceivable that you might have scratched right through the coating to the alloy beneath it. Sometimes just assembling parts for drilling or riveting can create unintentional scratches in the surface. Remember we mentioned that many of your kit components will come with a plastic coating? One of the biggest reasons to leave that plastic on, at least until you're done drilling and disassembling, is to protect that vital layer of Alclad.

Peligro! One of the more popular (and effective) means of cleaning metal prior to application of anticorrision treatment is MEK—methyl ethyl ketone. It's nasty stuff, so be careful. Acetone works nearly as well and isn't quite as harmful.

What should you do if you scratch or scuff a part? For that matter, does Alclad even stand alone as a reliable corrosion inhibitor? What happens if coastal rainwater collects inside a wing and stagnates there for some period of time? Is Alclad really going to do the job?

Salt spray tests have shown that an Alclad surface alone is not very corrosion resistant. Granted, we're not building submarines here...and if you look inside 50-year-old airplanes you're likely to see healthy bare Alclad aluminum. In most cases these planes have stood the test of time, but there are certainly exceptions. Still, prudence dictates that we look closely at options for extra corrosion protection.

Welcome to the Taboo Room

At this point in the discussion, I'm tempted to demand that you toss your magazine into the fire and run for the hills, because we're about to delve into extremely subjective territory. What we're about to talk about has become nothing short of taboo in builder circles. At a minimum, I'm going to don my flameproof Nomex suit at this point, because we are about to enter... *the primer zone*. Before we go head-on into complete madness about primer, let's first look at a couple of other options for anticorrosion treatment of our beloved aluminum components.

Self-etching primers—often found in the self-contained rattle can—don't need a lot of surface preparation but don't form a fully sealed surface, either.

Assuming for the moment that Alclad is all we need (just humor me for a minute), there will be other parts that come with your kit that don't have the Alclad coating. Often they are composed of 6061-T6, examples being extruded pieces like longerons or spar doublers. Is there any other recourse for protecting these parts against corrosion without mentioning that "P" word? Yep, there sure is.

Have you ever noticed the blue fittings on the ends of aircraft or high performance auto hoses? That blue coloration is not paint, and despite the fittings being

Inevitably, you'll want to mark disassembled parts prior to priming—regardless of the method you choose. Two of the most popular are scribing with an electric engraver and using a Sharpie.

aluminum, they aren't going to corrode under normal circumstances. They have been "anodized," which is an electrochemical conversion process.

Anodizing involves positively charging the aluminum with a DC voltage source and immersing it into an acid bath, with a negatively charged object present in the bath—often the tank itself. Soft oxides form on the surface of the part, which is then dipped in a bath of colored dye mixed with water. The oxides absorb the dye and then harden, forming a protective layer that is highly resistant to corrosion—and also cosmetically appealing.

Anodizing isn't exactly something you can do in your garage, because it involves using hazardous chemicals—though if you search on the Internet there are several sites that describe homebrew methods for anodizing aluminum. I'm not suggesting you go this route. In fact, some mission critical parts in your kit may already be anodized from the factory. For example, Van's ships pre-assembled wing spars that have been gold anodized for corrosion resistance. Most builders opt for other methods of corrosion protection for the parts that don't come anodized, but if you do decide you want something anodized, you can probably find a facility nearby that will do it for you. Be prepared to dish out some dough.

Anodizing Alternatives

What if you'd like to protect some aluminum part from corrosion but you don't want to deal with anodizing? There's another option that sounds remarkably similar... Alodining (not to be confused with anodizing) is a chemical chromate conversion of the aluminum surface. The part is bathed in Alodine, which is a liquid that you can buy from various sources including Aircraft Spruce (some builders use Iridite powder to make their own). Alodine 1201 has an integral gold dye that shows up when the conversion process is complete. Again, this can be confused with gold anodizing but involves a completely different process.

First you would clean the part off with MEK or acetone to remove any ink, adhesive, etc. Generally you would follow this up by scrubbing the part clean using a maroon Scotch Brite pad and a cleaning/etching solution such as Alumiprep 33. Rinse the part off with water until the water sheets off the part. Any oil or residue will show up as spots, streaks, or areas where the film of water is interrupted. If you see evidence of this, more cleaning is required. After the part is completely clean and rinsed, it is then bathed in Alodine. Some people build "troughs," while others apply it with a foam brush. After a few minutes of exposure, the surface should appear gold in color. Rinse the part thoroughly with water and let it dry. That's it. Salt spray tests have shown that aluminum treated with Alodine can withstand the abuse considerably longer than untreated aluminum before showing any signs of corrosion.

Alodined parts not only resist corrosion, but the surface helps electrical conductivity between airframe components, the process adds virtually no weight or thickness, and it even helps paint or primer "grip" better (in case you're using primer).

After a light coat of rattle-can primer, the engraved markings are hard to see but the Sharpie shines right through. Keep that in mind when you mark so that your inscriptions don't show on the exterior.

Sounds great, so what's the downside? Several, actually. First of all, Alodine is very toxic stuff. I'm not a biochemist, but even I can tell you that coming in contact with a carcinogen like a chromic solution is...uh...bad. And assuming you manage to protect yourself and your pets from it, how are you going to get rid of the stuff when you're done with it? Proper disposal, including dealing with the runoff from rinsing, is a real problem!

So we're left with this—Alclad is wonderful but not bulletproof. Anodizing is expensive and means you need to send your parts out. Alodine requires great care in the application and cleanup.

The first stages of Alodining aluminum includes scrubbing with a maroon Scotch Brite pad and then treating with Alumiprep, which removes oil and dirt. Rinse with water until it sheets off.

What About Paint?

For the sake of argument, let's assume you're planning to finish your airplane with paint (as opposed to leaving the surface as polished aluminum). That coat of paint, if applied properly, is one of the absolute best forms of corrosion protection. A good paint job will actually seal the exterior of your airplane from moisture. Since it's so effective, why not paint the inside as well? Paint is heavy and expensive, for one. But we can actually accomplish the same goal without having to use paint, but rather just using primer. The concept is that by spraying just the primer onto the internal aluminum structures, you can buy yourself extra corrosion protection compared to bare aluminum.

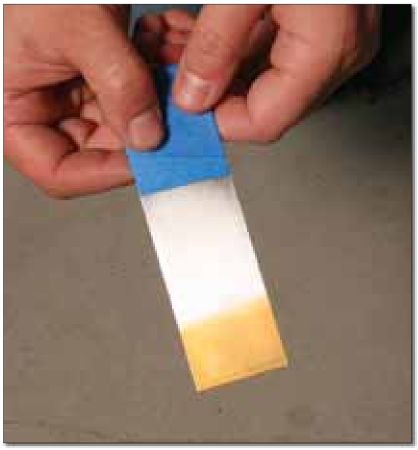
Immerse the aluminum in the Alodine for a few minutes. It will coat the metal and leave a light golden tint. Dispose of used Alodine as you would any hazmat.

Before we go any further, I need to mention that selecting a primer can be a dizzying experience, particularly if you rely on other builders' opinions. I'm not about to stick my neck out and actually recommend something specific. All primers are by far not created equal. That's not to say one is better than the other; it's just that there are major differences in terms of how they are applied and how effective they are.

How do we define effective? On one hand, if the airframe isn't affected in any major way by corrosion after 10 to 20 years of average exposure to the elements, that's considered a success. On the other hand, why not protect the airframe so it will outlive you and the next five owners? This is extremely subjective territory. What is good enough and what is operation overkill? Unfortunately, answering that question is not as cut and dried as a topic like drilling or riveting. I will at least list a few of the popular options for primer, and you can do your own research and make up your own mind.

It's What You Zinc

Zinc chromate has historically been the primer of choice until somewhat recently. If you look inside an old warbird at the museum, you'll see pieces coated in that unmistakable military-looking green shade. That's probably zinc chromate. While it has served the fleet well in general, there are more modern options that are chromate-free, and thus less carcinogenic. No primer is going to be good for you, but we can at least take strides in that direction when the opportunity is available, and when the goal isn't compromised. If it's zinc chromate you wish to use, it's still readily available—often



When the Alodine conversion process is complete, you'll see an uninterrupted layer of gold tint. If there are breaks or splotches, you probably didn't clean the part carefully enough.

in rattle-can form, which makes application simple.

If you go to your local autobody paint supply store, you can probably find some sort of self-etching primer in a rattle can. Self-etching just means you don't need to prep the surface with an acid etch (such as Alumiprep 33) in order to roughen the surface so that the primer can adhere properly. A self-etching primer has its own built-in chemical mechanism of bonding with the aluminum—which means all you have to do is clean the surface and spray the primer right on. Cleaning usually involves wiping the part down with MEK or lacquer thinner or any solution that will remove inks, oils and residues, but will evaporate quickly without leaving its own film or residue. Using a self-etching primer, particularly in a rattle can, is by far one of the simplest approaches to adding corrosion protection. Examples of rattle-can self-etching primers are Mar-Hyde, Sherwin Williams GBP-988, NAPA 7220 or SEM. They are all very similar.

There is a downside to using spray-can primers—they're not designed to stand alone. That is, they're intended for use with a top coat of paint. They provide a half decent moisture barrier, at least compared to bare aluminum, but they simply do not seal completely without paint applied over them. Maybe you're asking yourself, so why bother? I guess it comes down to the fact that something is better than nothing, and rattle-can primers are incredibly easy to apply. You won't waste a lot of precious building time on an onerous etch/alodine/mix/spray process, but taking such a shortcut comes at a slight cost—the primer is not a true sealer.

If you want the best corrosion protection your money and time can buy—without resorting to paint, I think most people will agree that using a good two-part epoxy primer is the way to go. You won't find a high quality epoxy primer in a rattle can. In fact, the best stuff isn't even self-etching. Applying a two-part epoxy primer can involve a fair amount of work—going through the motions of the clean/etch/rinse/alodine/rinse process, followed by mixing primer with catalyst, and then applying the mix to your components with a pneumatic spray gun. Don't forget to clean the gun when you're done.

Using a spray gun—particularly for two-part epoxy primers—suggests prudence toward your health. Here, the author wears a Hobbyair forced-air respirator. Smart man!

Examples of two-part epoxy primers are AKZO (available from Aircraft Spruce) or Variprime (available from a DuPont automotive finish distributor). Expect to pay more than $100 per gallon for this stuff, not to mention the cost of the etching and alodining supplies. A good epoxy primer, when applied correctly, will produce what essentially amounts to a bulletproof finish. It's not a cosmetic finish, but the underlying aluminum is completely sealed from the elements. If it's good enough for Boeing, it's probably good enough for us!

What does a company like Van's use for primer on interior components in their quickbuild kits? If you've ever seen one of these kits, you might not even realize it has been primed at all, because the primer they use is a "wash primer" with no visible pigment. It's a product from Sherwin Williams called P60G2. Van's even admits that this primer is designed to take a top coat of paint for optimum corrosion protection, but they feel it's "not necessary for the way in which most owners maintain their RVs."

So What Are the Best Options?

Confused yet? I think most new builders would probably ask the question, if you're going to bother with any primer at all, why not go with the best option available? Sure, but what is best to one builder is not necessarily the best option for another. You need to do the research and consider the environment in which you're likely to base and operate your airplane. Keeping it outside on the ramp in a coastal environment? Maybe you want to lean toward the conservative and use a two-part epoxy primer on the entire interior. Keeping it in a hangar in the desert? Maybe you'll opt for no primer at all—and you'll just keep a close eye on your airframe. If it exhibits any signs of corrosion down the line, you could always resort to using something like ACF-50 or CorrosionX to treat and protect it at that point. Or maybe you'd rather be just a bit more proactive and opt for minimal use of a rattle-can primer, sprayed only on rivet lines and where components overlap. There's definitely a balance to be struck somewhere in there that serves your mission profile. Adding corrosion protection to your airframe may increase its long-term value, if only in perception. It may give you peace of mind. But it does come at a cost—not only financially, but it adds weight, it will consume precious build time, and it will expose you and the environment to harmful elements.

Builder, Save Thyself

On that note, I can't stress enough how important it is to protect your body from potentially harmful effects of the chemicals involved in the corrosion protection process. When spraying primer, always wear gloves to protect your skin—powder-free latex should do the trick. If you're not going to wear coveralls, at least wear long sleeves and pants. Protect your eyes with painter's goggles. It would also be beneficial to wear ear plugs—nothing to do with noise, but rather minimizing exposure to toxins.

Of tantamount importance is protecting your lungs—and I'm not talking about wearing one of those cheesy dust masks. (They're fine for particulates large enough to have a part number, but nothing like good enough for the airborne toxins released by painting and priming.)

At a minimum, wear a respirator with fresh twin cartridge filters that protect from organic vapors. These supplies are readily available (and fairly inexpensive) from stores like Home Depot or Lowes. Don't skimp.

The best option when priming or painting is to use a full facemask style forced air supply system such as those made by Hobbyair. No, it's not cheap, but it's worth the expense. There is nothing good for you about these chemicals we're working with. It would be a shame to finish your airplane only to be grounded by a major nervous system disorder as a result of exposure to these toxins.

Hardware-store respirators are fine when working with solid particulates from comparatively benign sources, but they're not quite enough when there are carcinogenic toxins floating around the hangar.

Beyond Aluminum

Up until now we've been caught up discussing aluminum in particular. While it is predominantly the material you will be dealing with, there will be a number of steel components on your airframe—from tailwheel spring to engine mount. Whether the point is isolating the steel from aluminum, or just keeping the steel from rusting, it needs to be protected. A two-part epoxy primer will do a fine job at this, but with steel there is yet another option that is often more appealing. Steel parts may be powder coated, which forms a coating that is highly durable and often considered superior to paint. Powder coating involves spraying electrostatically charged, dry paint powder onto the steel part, which is oppositely charged. The powder clings to the steel, which is then baked at about 400°. The powder melts and flows smoothly and uniformly on the surface of the part. Once cooled, the coating solidifies and becomes extremely durable.

You have many choices in applying two-part primers. Inexpensive "touch up" guns (bottom) are just fine; you're not looking for a show-winning finish inside the wings, right? Check discount tool suppliers such as Harbor Freight for the best deals.

The best way to clean steel prior to priming or powder coating is by bead blasting or sand blasting. If you have parts that need to be powder coated, you can probably find a local facility that will do the bead blasting as well as powder coating.

Why not powder coat aluminum components? There are two key reasons. First of all, powder coating adds a fair amount of thickness to the surface, which would not work well in cases where parts are intended to mate under close tolerances. Also, the high temperature baking process could alter the temper of the aluminum, which could have detrimental effects on its strength (yikes!).

What about all of those steel bolts holding various aluminum parts together? Should you worry about dissimilar metal issues there? Luckily (well, deliberately), aircraft grade AN bolts, nuts, washers and cotter pins all come with a cadmium plating (gold in color) that serves to isolate the steel from the surrounding aluminum. Even so, it's not a bad idea to dab some primer inside a hole (some builders use a Q-tip to do this) before that bolt goes in, assuming you're not priming the entire part already.

The Hobbyair "compressor" should be placed outside the hangar or workshop so that it receives fresh air. No, it's not a cheap system, but lung-replacement surgery isn't a day at the beach, either.

We have just barely scratched the surface (pun intended) with respect to corrosion protection. Unlike the previous installments in this series, this particular topic is certainly the most ambiguous. Hopefully this article is food for thought and not just downright confusing. Unfortunately there's no right answer to most of the questions that come up about primer and other treatments. Ask around, and you might be surprised at how much inconsistency there is on this topic among builders. Regardless of what process you decide to use, be sure to do it safely!

It has been nearly a year since we started this series. To those readers who are contemplating building an airplane, I hope the topics we've covered have shed some light on the process involved in building a metal airframe. And to those of you who have already begun the journey, hopefully you learned a few tricks or techniques from these articles along the way. At this point I'm turning you loose, so to speak. Do the best job you can, don't hesitate to ask for help when you need it, and I look forward to seeing you and your finished airplane at a fly-in someday! ✈