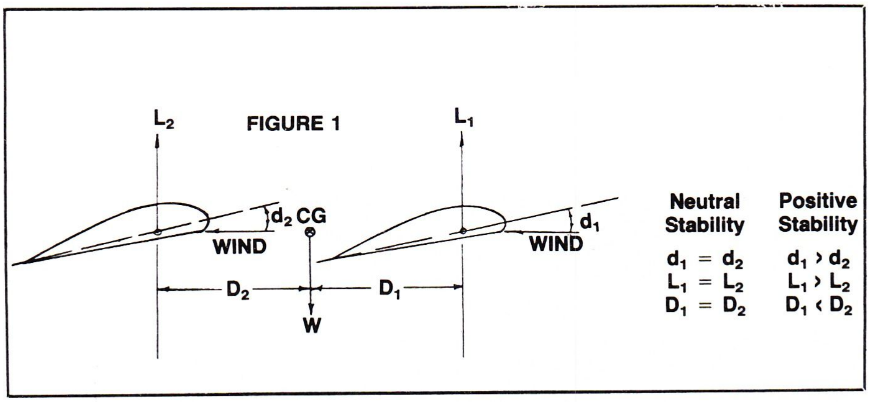
stability



equal amount on both wings, the percentage increase of the angle-of-attack on the rear wing is greater, and the pitching moment about the center of gravity changes to produce a net driving moment that will reduce the angle-of-attack. For instance, the angle-of-attack increases 100 percent on the rear wing and only 50 percent on the front wing. This will cause more lift on the rear wing causing the aircraft to pitch-down. Likewise downward changes in angle-of-attack bring about similar results in the opposite direction.

If the pitch angle is reduced one degree, the new angle on the tail is zero and only one degree on the front wing. This results in a 100 percent change on the tail and only 50 percent change on the front wing, which causes the airplane to pitch upward. The arrangement is therefore stable. This principle is used in all present day airplanes, although the rear wing is usually made substantially smaller than the front wing with the center of gravity very near the center of pressure of the front wing. Longitudinal stability thus seems to depend upon the horizontal location of the center of gravity.

Calculations of the neutral point is not a simple matter. The displacement of the stick-fixed neutral point from the center of pressure of the combined wing and fuselage is a function of many variables. These are:

1. The ratio of the tail area to wing area.
2. The ratio of the tail lift coefficient to the wing lift coefficient.
3. The ratio of tail length (CG to tail center of pressure) to wing chord.
4. Tail efficiency, which accounts for dynamic pressure losses due to the tail being immersed in the wing wake, and
5. The downwash on the tail which is effected by wing aspect ratio and tail position.

ACROBATIC LIMITS

The aft limit has an added restriction if the airplane is used for acrobatic flight. The most aft limit for acrobatics is determined by the spin-recovery characteristics of a particular design. When the CG is too far aft, the airplane can get into a flat spin whereby the control surfaces are ineffective. This is a very dangerous condition and usually results in loss of the aircraft. It is not absolutely necessary to run spin tests on your homebuilts, but it is preferable to do so. Spin tests should be performed cautiously with each successive spin held for a quarter turn longer. Any change in control forces during the spin should be noted. The approach of a flat spin is marked by a loss or reversal of control forces.

FORWARD LIMIT

Entirely different factors limit the most forward CG location and the most aft location.

As the CG is moved forward, the stability of the airplane increases but it takes increasingly larger control movements and forces to maneuver and to change the trim position of the control surface. The forward CG limit is therefore determined by control considerations rather than stability considerations. The two most important limitations on the most forward CG locations are:

1. The maximum gradient of stick force per "G", and
2. The amount of elevator required to land.

All methods for predicting hinge moments of the elevators are subject to rather large errors and are quite unreliable. Fortunately, the elevator required for landing is generally a more severe limitation for conventional aircraft with horizontal tail aft of the wing. Equations are given in Perkins and Hague which permit calculation of the forward CG location with the stick force gradient limitation. The process is complicated by the need for aerodynamic coefficients and downwash angles for a specific design. These data can be obtained from wind tunnel data or from the educated guesses of an experienced designer.

The amount of elevator required to land is that required to trim the aircraft while it is developing maximum lift in ground effect. This elevator deflec-

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aircraft hardware

Since aircraft hardware is manufactured and inspected in accordance with rigid specifications, only genuine aircraft hardware may be used in the construction of this aircraft. Although the hardware used in the Acro Sport is specified on the plans, the builder should be generally familiar with all types and their applications.

BOLTS

Aircraft bolts are either general purpose AN (Army-Navy) bolts, or NAS (National Aircraft Standard) internal wrenching or close-tolerance bolts.

AN type bolts may be made of cadmium-plated alloy steel, corrosion resistant steel, or aluminum alloy. AN bolts are identified by the coded markings on the bolt-heads. These markings generally denote the bolt manufacturer, the material of which the bolt is made and whether the bolt is a standard AN type or a special purpose bolt. AN standard steel bolts are marked with either a raised dash or asterisk, corrosion resistant steel is indicated by a single raised dash, and AN aluminum alloy bolts are marked with two raised dashes. The strength and dimensions of AN bolts are specified by Army/Navy Aeronautical Standards.

Special purpose bolts include high-strength, low-strength and close-tolerance types. Such bolts are usually inspected by magnetic, fluorescent, or equivalent inspection methods. Typical markings include "SPEC" (usually highly heat treated), the manufacturer's part number stamped on the head, or plain heads (low strength). Close-tolerance NAS bolts are marked with either a raised or recessed triangle. The material markings for NAS bolts are the same as for AN bolts, except that they may be either raised or recessed. Bolts inspected magnetically or by fluorescent means are identified by means of colored lacquer or a distinctive type head marking.

Hex-head aircraft bolts are the all-purpose structural bolts used for general applications involving tension or shear loads. The basic specifications for aircraft bolts are AN 3 through AN 20. AN 3 bolts are 3/16 inch in diameter, AN 4 bolts are 1/4 inch in diameter, AN 5 bolts are 5/16 inch in diameter, etc. The first number indicates the diameter of the bolt in sixteenths of an inch. The dash number which follows indicates the length of the bolt. The lengths of AN bolts increase by 1/8 inch increments. An AN 3-4 bolt is 1/2 inch long, an AN 3-5 bolt is 5/8 inch long, etc. A 1 inch long bolt is designated as AN 3-10. An AN 3-11 bolt is 1 1/8 inches long, an AN 3-12 bolt is 1 1/4 inches long, and so on up to 2 inches, which is designated as AN 3-20. The next longest is AN 3-21, etc.

Close tolerance bolts are used in applications where the bolted joint is subjected to severe load reversals and vibrations. They are designed by AN-173 through AN-186 (Hex-head) and NAS-80 through NAS-86 (100° countersunk).

NAS internal wrenching bolts are designated under the numbers NAS 144 through NAS 158 and NAS 495. These are extra-strength bolts for use in applications where high tension and shear loads are developed. An internal wrenching bolt of more recent design and even greater strength than the NAS bolt is the MS 20004 through MS 20024. The MS (Military Standard) — series bolt is of very high strength and requires special washers and nuts for proper installation.

Clevis bolts are designated AN 21 through AN 36. These bolts are made from cadmium plated alloy steel. Clevis bolts are generally used for applications where shear is the principal stress.

The AN-73 drilled head bolt is similar to the standard hex-head bolt, but has a deeper head which is drilled to receive wire for safetying. The AN-3 and AN-73 series of bolts are interchangeable for all practical purposes from the standpoint of tension and shear strengths.

In general, the length of the grip (threaded portion) of a bolt should equal the thickness of the material through which it passes. However, a bolt with a slightly greater grip length may be used provided washers are placed under the nut or bolt head.

Many boltholes, particularly those in primary fittings, have close tolerances. Generally, it is permissable to use the first lettered drill size larger than the normal bolt diameter, except where the AN hexagon bolts are used in light-drive fit (reamed) applications and where NAS close-tolerance bolts or AN clevis bolts are used. Bolt holes are to be normal to the surface involved to provide full bearing surface for the bolthead and nut, and not be oversized or elongated.

The importance of the correct application of torque when tightening nuts and bolts cannot be overemphasized. Undertorque can result in unnecessary wear of nuts and bolts as well as the parts they are holding together. When insufficient pressures are applied, uneven loads will be transmitted throughout the assembly which may result in excessive wear or premature failure due to fatigue. Overtorque can be equally damaging because of bolt or nut failure from overstressing the threaded areas.

SCREWS

In general, screws have lower material strength and a looser thread fit than bolts. Screw heads are formed to engage a screwdriver, and the shank is threaded along its entire length without a clearly defined grip. Screws are usually made of carbon steel rather than the alloy steel used for AN bolts. Certain high-strength screws require the use of alloy steel. However, several types of structural screws are available that differ from standard structural bolts only in the type of head.

The material is equivalent and a definite grip is provided. The AN-525 washerhead screws, the AN-509 100° countersunk structural screws and the NAS-204 through NAS-235 are such parts. The material markings are the same as those used on standard AN bolts.

Structural screws are designated NAS-204 through NAS-235 and AN-509 through AN-525. This type of screw, when made of alloy steel such as SAE 4130 and heat treated from 125,000 psi may be used for structural assembly in shear applications similar to structural bolts.

The AN-504 and AN-506 self-tapping screws are used for attaching minor removeable parts such as nameplates. AN-530 and AN-531 self-tapping screws are used in blind applications for the temporary attachment of sheet metal for riveting and the permanent assembly of non-structural items. The AN-535 is a plain head self-tapping screw used in the attachments of nameplates or in sealing drainholes in the corrosion proofing of the tubular structures, and is not intended to be removed after installation. Self-tapping screws must never be used to replace standard screws, nuts, bolts, or rivets in the structure.

Plain and threaded taper pins, AN-385 and AN-386, are used in joints which carry shear loads and where the absence of play is essential. The flathead pin, or clevis pin, (MS-20392), is used in conjunction with tie rod terminals and in secondary controls which are not subject to continuous operation.

NUTS

Self locking nuts are used to provide tight connections which will not shake loose under severe vibration. There are two types currently in use, the all-metal type and the fiber or nylon lock type. Self locking nuts may not be used at points which subject either the nut or bolt to rotation. They may be used with antifriction bearings and control pulleys provided the inner race of the bearing is clamped to the supporting structure by the nut and bolt. Nuts must be attached to the structure in a positive manner to eliminate rotation or misalignment when tightening the bolts or screws.

All-metal locknuts either have threads in the locking insert that are out of phase with the load — carrying section, or a saw cut insert with a pinched-in thread. The locking action of the all-metal nut depends upon the resiliency of the metal when the locking section and load-carrying section are engaged by screw threads.

Fiber or nylon locknuts are made with an unthreaded fiber locking insert held securely in place. The insert has a smaller diameter than the nut, and when a bolt or screw enters it taps into the insert, producing a locking action. After the nut has been tightened, bolts and screws with rounded or chamfered ends should extend at least the full round or chamfer through the nut. Flat end bolts and screws should extend at least 1/32 inch through the nut. Locknuts may not be re-used if they can be run up finger tight. Bolts 5/16 inch diameter and over with cotter pin holes may be used with self-locking nuts but only if free from burrs around the holes. Bolts with damaged threads and rough ends are not acceptable. Self-locking nut bases are made in a variety of forms for riveting and welding to aircraft structures or parts.

The aircraft castle nut (AN-310) is used with drilled shank AN hex-head bolts, clevis bolts, drilled head bolts or studs. It is designed to accommodate a cotter pin or lockwire as a means for safetying.

The plain nut (AN-315 and AN-335) has limited use on aircraft and requires an auxiliary locking device such as a checknut or lockwasher.

Light hex nuts (AN-340 and AN-345) are used in miscellaneous applications and must be locked by an auxiliary device.

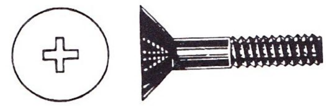
The checknut (AN-316) is used as a locking device for plain nuts, screws, threaded rod ends, and other devices.

The castellated shear nut (AN-320) is designed for use with clevis bolts and threaded taper pins which are normally subjected to shearing stresses only.

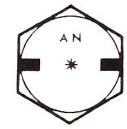
Wing nuts (AN-350) are intended for use on hose clamps, battery connections, etc. where the desired tightness is ordinarily obtained by the use of the fingers or hand tools.

Sheet spring nuts are used with standard and sheet metal self-tapping screws in non-structural applications. They may be used to support hose clamps, conduit clamps, electrical equipment, access doors, and the like.

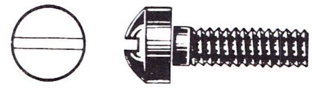
Two types of internal or external wrenching nuts are available. Both are of the self-locking type, are heat treated, and are capable of carrying the high-strength bolt-tension load.



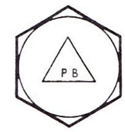
Structural screw.



24ST aluminum alloy bolt.

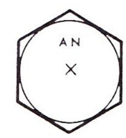


Fillister head screw.

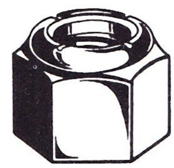


NAS phosphor-bronze bolt.

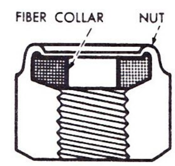
Self tapping screw.



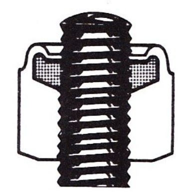
AN steel bolt.



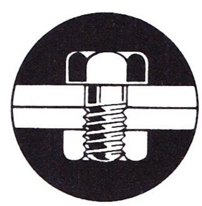
Elastic stop nut.



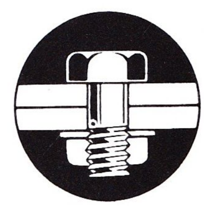
Fiber collar is not tapped.



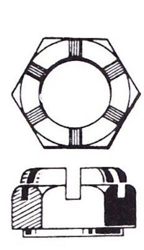
Bolt taps fiber collar as it passes through it.



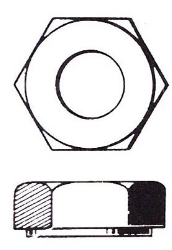
Bolt and grip length too short.



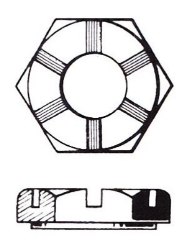
Bolt grip length correct.



Castle nut.



Plain nut.



AN castellated shear nut.

WASHERS

There are three types of washers used in aircraft structure. They are plain washers, lockwashers, and special washers.

Plain washers for use under hex nuts and for spacing are covered by AN specifications 960 and 970. Washers provide a smooth bearing surface, act as a shim and adjust holes in bolts. Plain washers are used under lockwashers to prevent damage to surfaces. The AN 960 flat washer is a general-purpose washer and is used for all normal installations requiring washers. Standard washers with an inside diameter for Nos. 2 through 8 screws are made .032 inches thick, sizes 10 through 5/8 inch are made .063 inches thick, and sizes for a 3/4 inch bolt are larger and are made .090 inches thick. AN 960 washers are also made in a light (thin) series.

The AN-970 washer has a large outside diameter and is designed for use with wood or other soft materials.

Lock washers are used to prevent the turning of nuts and may be used for limited applications in aircraft. They are designated AN-935 and AN-936 and are used with machine screws or bolts whenever the self-locking or castellated type of nut is not applicable. They should not be used as fastenings to primary or secondary structures or where they are subject to frequent removal.

Special washers are necessary for particular applications where plain flat washers will not suffice. Ball-seat and socket washers, AN-950 and AN-955, are used in special applications where the bolt is installed at an angle to the surface or where perfect alignment with the surface is required at all times. These washers are used together to provide the required angle between the surface and the nut.

Special washers for use with NAS internal wrenching bolts are the NAS-143 and the MS-20002 washers. The type C washer is countersunk to seat the bolt-head shank radius, and a plain type washer is used under the nut.

COTTER PINS

There are two types of cotter pins. These are AN-380 and AN-381. The AN-380 is a cadmium plated, low-carbon steel cotter pin used for safetying nuts, bolts, screws, and other pins and in various other applications where safetying is necessary. The AN-381 cotter pin is made for corrosion resistant, nonmagnetic steel and is used in safetying applications where these features are desired.

Standard aircraft rivets are designated by AN numbers as follows:

AN-420 90° countersunk head
AN-425 78° countersunk head
AN-426 100° countersunk head
AN-430 Roundhead rivet
AN-435 Roundhead rivet
AN-441 Flathead rivet
AN-442 Flathead rivet
AN-455 Brazier-head rivet
AN-456 Modified brazier head
AN-470 Universal-head rivet

Rivet sizes and materials are indicated by the numbers and letters following the basic AN number. For example, AN-470-AD-3-4 indicates a universal head rivet made of 2117 aluminum alloy (AD), 3/32 inches in diameter and 4/16 inches in length. The first dash number designates the diameter in thirty-seconds of an inch, and the second dash number indicates the length of the rivet in sixteenths of an inch. The letters indicate the type of materials from which the rivet is made. A, B, D, AD, and DD indicate different types of aluminum alloys, C indicates copper, F indicates stainless steel, and M indicates monel metal. The materials are also indicated by markings on the heads of the rivets.

TURNBUCKLES

Turnbuckles are commonly used for adjusting the tension of control cables. A standard turnbuckle consists of a barrel and two steel ends, one with a right-hand thread and the other with a left-hand thread. When the barrel is rotated the ends move together or apart.

Turnbuckles are supplied with several different types of ends. Some of these are the cable eye, the fork, the pin eye, and the swage fitting. The barrel of the turnbuckle is made of brass and is grooved around one end to indicate the left-hand thread.

When a turnbuckle is tightened, not more than three threads may show outside the barrel at each end. The turnbuckle must also be properly satetied.

Turnbuckle parts are designated by AN numbers as follows:

AN-155 Standard barrel
AN-161 Fork
AN-170 Cable eye
AN-165 Pin eye
AN-669 Swaging terminal

CABLE FITTINGS

Cable fittings are needed to connect a cable to control arms, other fittings, turnbuckles, etc. When it is necessary to attach a cable to a turnbuckle or other device and swageable fittings are not available, the AN 100 cable thimble is used. A method for splicing the cable around a thimble or bushing is the Nicopress swaged-sleeve method. The Nicopress sleeve is made of copper and is swaged (pressed) on the cable by means of a special tool.

Getting Ready to Build

by Antoni (Tony) Bingelis

THAT PLEASURABLE ANTICIPATION of trying to decide which airplane to build is over. Now you know. You have decided.

"Yes, sir! That's the one! That's what I want to build! I've just got to have it!"'

Off goes the money for the plans, and again suspenseful expectation. The seemingly endless wait for the plans to arrive begins. So now you wait, right? Nope!

The plans might take two to four weeks in arriving, and there's no need to waste building time by waiting passively. Why not start on your project now . . . immediately?

Would you believe it if I told you that the actual construction time expended on an aircraft is probably only 50% of the time devoted to the total building process? All the rest is getting ready to do something and cleaning up after you do it.

As a builder you could at least get a head start and build up some good momentum before your plans even reach you. Here's how.

Call It Attitude Adjustment

You should, immediately, begin to psyche yourself up for the long term building of an airplane. I call this phase "attitude adjustment"'. Things will be different around the house. Not only you but the rest of the family must be aware of this. That new thing out in the garage workshop) will become part of your lifestyle . . . part of the family, you might say.

The only way to get an airplane built is to devote the total hours necessary to accomplish that feat. It will take from 1000 to 4000 hours to do it . . . depending on the design and the method of construction. It cannot be built in 50 hours or even 150 hours of intensive work. Realizing this, you won't be expecting the impossible. At one hour per day it could take you between 2½ years to 8 years . . . if you don't skip any work days.

Here is a fuselage assembly taking place in a one car garage shop. On completion components such as wings are often suspended from overhead rafters.

I'm sure the obvious thought has crossed your mind that the calendar span for constructing an airplane would be reduced if you could only work on it every day. This is true but it is virtually impossible to do. Nevertheless, with a little luck you might be able to come close to that goal.

Anyone who has a traveling job may have to resign himself to sporadic building sessions. One consolation, some traveling jobs, and shift jobs, do often permit free time in large increments, and longer building sessions at any given time would be possible. These larger building sessions would be more effective than being able to work only 30 minutes at a time. A 2-4 hour work session is most effective for me but I find that any time devoted to the project can be productive.

A lot of time is often lost in getting ready to get ready. So determine beforehand what you intend to do during that work session. You do not have to meet any deadline for the airplane's completion and you can work as few or as many hours per day as you like, when you like. You simply must realize that some complicated designs will require up to 4,000 hours of involvement and labor. A most satisfying labor, I might add. Realize this and accept it before you begin and you will feel a lot better with yourself and acquire a greater confidence in your ability to see the project through to completion.

. . . And About Your Family

Now is the time for you to be on your best behavior around the house and family. Catch up with all the little chores you have been putting off. This will enhance your image with your mate. However, remember one good turn deserves another in return, so don't get too carried away. You cannot stockpile good will! You have to dribble it out in bits and pieces on a continuing basis. Haven't you heard the saying . . . "but what have you done for me lately?"'

I try to set aside a regular work period with the understanding that I won't be harassed either knowingly or unknowingly by phone calls and spur-of-the-minute "gotta do"' interruptions.

In return, I remind myself that I must not slight the family no matter how feverishly involved I become with the airplane's construction. I find that good will and progress on my airplane go hand in hand when I devote at least one day each week to family activities. It doesn't have to be a whole day or any specific day, but you really should allow yourself a change in pace once a week and what better way than sharing it with someone else?

Where Are You Going To Build It?

Where are you going to build this magnificent machine? At home in the garage? In somebody else's garage? A nice room workshop? A carport? Attic? Living room? Outside in the open? All of these places have been the locale for somebody's project. You really can build an airplane almost anywhere if you are adequately motivated. (A cliche . . . "where there's a will there's a way".) Of course, a nice roomy workshop will always be the best place but each of us must make do with what we have.

You'll need to get busy right now to make room for your workshop. Some airplanes can be built in a surprisingly small work area. Some cannot. Airplanes featuring a single-piece cantilever wing, for example, will require a work area large enough to accommodate the entire wing. Other designs can be built easily enough in a single-car garage or even out on the porch. Perhaps the design you selected was influenced by the space you will be able to provide for the project.

Now that your interests have a new inspired direction (you are going to build an airplane, right?), you won't be using or needing all that stuff cluttering up your intended work area (garage, etc.). Things like baby buggies, strollers, two or three non-working lawn mowers, and bicycles (also non-working), etc. Call Good Will to come and pick them up or move them out or give the spouse a treat and have a nice garage sale to clear the area for the garage's new mission . . . a homebuilder's workshop. If you are too attached to get rid of all that memorabilia, at least move the treasures out (for safe keeping). A garden storage shed is a good solution. It can, in effect, double the effective work area you will have for building your project. Most of those storage buildings look pretty nice and, strategically located, would enhance the appearance of the backyard . . . besides, wherever you locate it, the grass won't have to be mowed . . . another fringe benefit. If, after looking around, you see that you still have too much cluttering up the workshop area, why not loan all that stuff out to your friends . . . that should solve things nicely for a few years.

How About Making A Workbench?

A solid workbench is essential for any project. Its construction should be undertaken immediately. Some projects require a very long work table while others do not need much more than a bench made from a single 4' x 8' sheet of masonite board or plywood. A space-effective bench, if you don't already have one, may be made of a single sheet of ¾' plywood ripped to a 24'" width. It will make into a 16' long bench. If even a longer length work surface is needed for a cantilever spar, for example, short extensions may be added to it.

You may already have an idea as to your work table requirements from other builders, or from your own research. Don't overlook the fact that beneath any bench is a good place to store long material and odds-and-ends accumulated during the building of the airplane, so do add a couple of long racks or shelves for this purpose.

Who Else Is Building One

Scan through the past issues of *SPORT AVIATION* to see who else might be building or has built the airplane you have selected. Establish contact with these builders. Some will prove to be more helpful than others but you never know where the mother lode of information lies. Incidentally, if you do write and expect a reply it is only fair that you enclose a self-addressed stamped envelope . . . otherwise why should anyone respond to your initial query at his own expense?

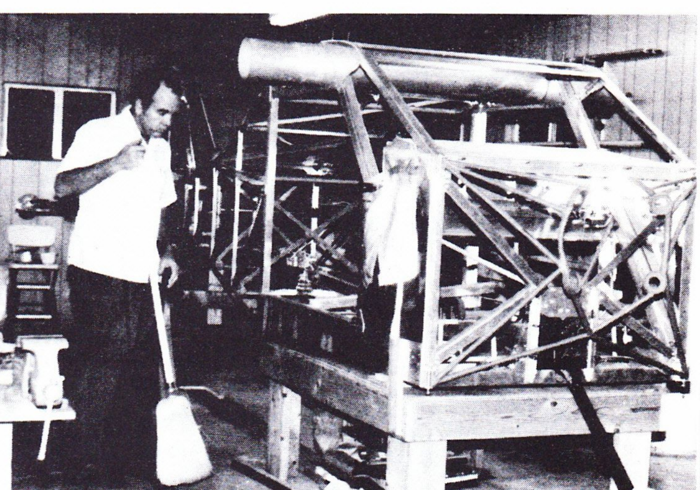
What About the Materials You Will Need?

You will need a lot of materials to build an airplane. Where will you get them? Now is the time to line up potential supply sources. Try to find out who locally has any material left over from his project. On the other hand, projects are being abandoned almost daily. An abandoned project can provide you with a source of material at an attractive price. No need to order materials and suffer the long wait when it might be possible to acquire at least enough aluminum, 4130 sheet, tubing or wood, or whatever, to get started immediately on your own project.

An advantage of building an aircraft design enjoying current popularity or, for that matter, a well known and long established design, is the ready availability of kits, parts and components made especially for the builders of such aircraft. Conversely, a new or unproven design is often difficult to build because you may have to fabricate all of your own parts including the cowling and windshield or canopy. So, while you are waiting for your plans, do spend some time looking through the latest *SPORT AVIATION* magazine advertisements. Select those sources which may be selling the materials and parts you will need. Send for their catalogs. Most material and kit sources now charge for catalogs although the price is often refunded with the first order.

If you are fortunate enough to be near a local EAA Chapter or other independent builders, seize the opportunity of talking with as many of them as you can. Ask them about their material sources and the reliability of the suppliers they have dealt with. Unfortunately, you may learn that a few suppliers do not have a reliable record of performance with builders. Remember, an advertisement in a magazine is no testimonial to the supplier's capability for performing. Some sources are shoestring operations and the supplier may in fact be operating as a sort of middleman. That is, his is a part-time business and he really has little or no stock on hand. When he receives an order, he, in turn, orders the material from his supplier. This explains why some builders anxiously wait and wait and wait for their order. Anyway, if you can, check out your supply sources before you send off your hard-earned money.

Something else may cause needless delay. Not only are there unreliable suppliers, there are unreliable builders. I don't think many EAA members are and the EAA has a fine reputation, but since the supplier has undoubtedly been stuck with worthless checks, more than once, you may find that he will not ship your order until your personal check clears his bank. This can



Clean up time should be a regular chore.

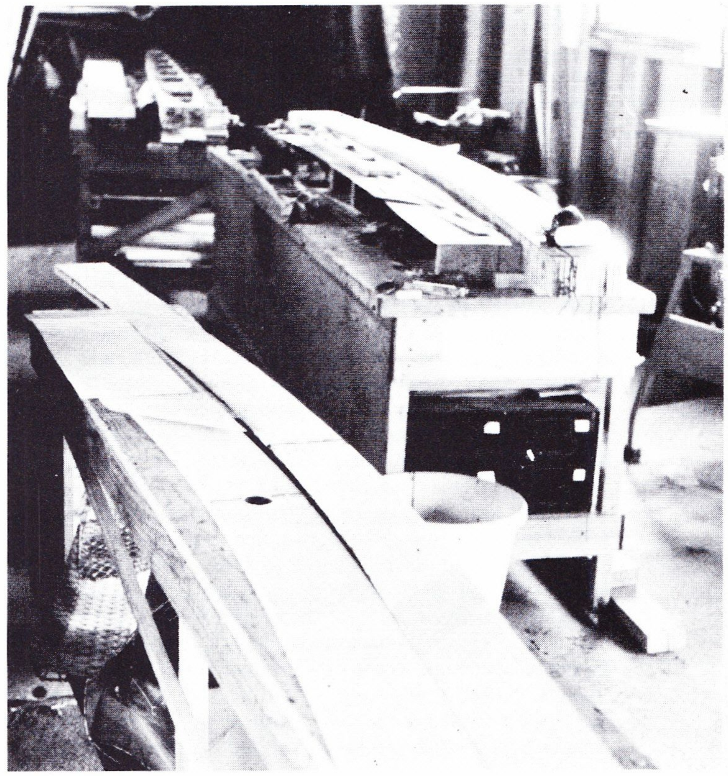
mean an additional 10 day, or more, delay. To eliminate the delay, I suggest you use money orders or cashiers checks, at least until you're established with the supplier. Don't worry about the exact amount. It is better to err on the excess of funds side, as most suppliers are very good about returning any excess. Once you have established yourself with a supplier you will receive all sorts of cooperation from him.

So much for suppliers. There is another good material supply source, particularly if you live near an EAA Chapter or are a member of it. At your first opportunity, announce your decision to build and that you would be interested in purchasing any excess materials and parts from local builders before sending in your order. It is surprising how much material the average builder will have left over . . . and usually the price is right because the material was purchased in the good old days (a few months ago or last year) when things were less expensive. All these things will help take your mind off the long wait for the plans and contribute to the speeding up of your project. Actually, your project begins the day you send off for the plans.

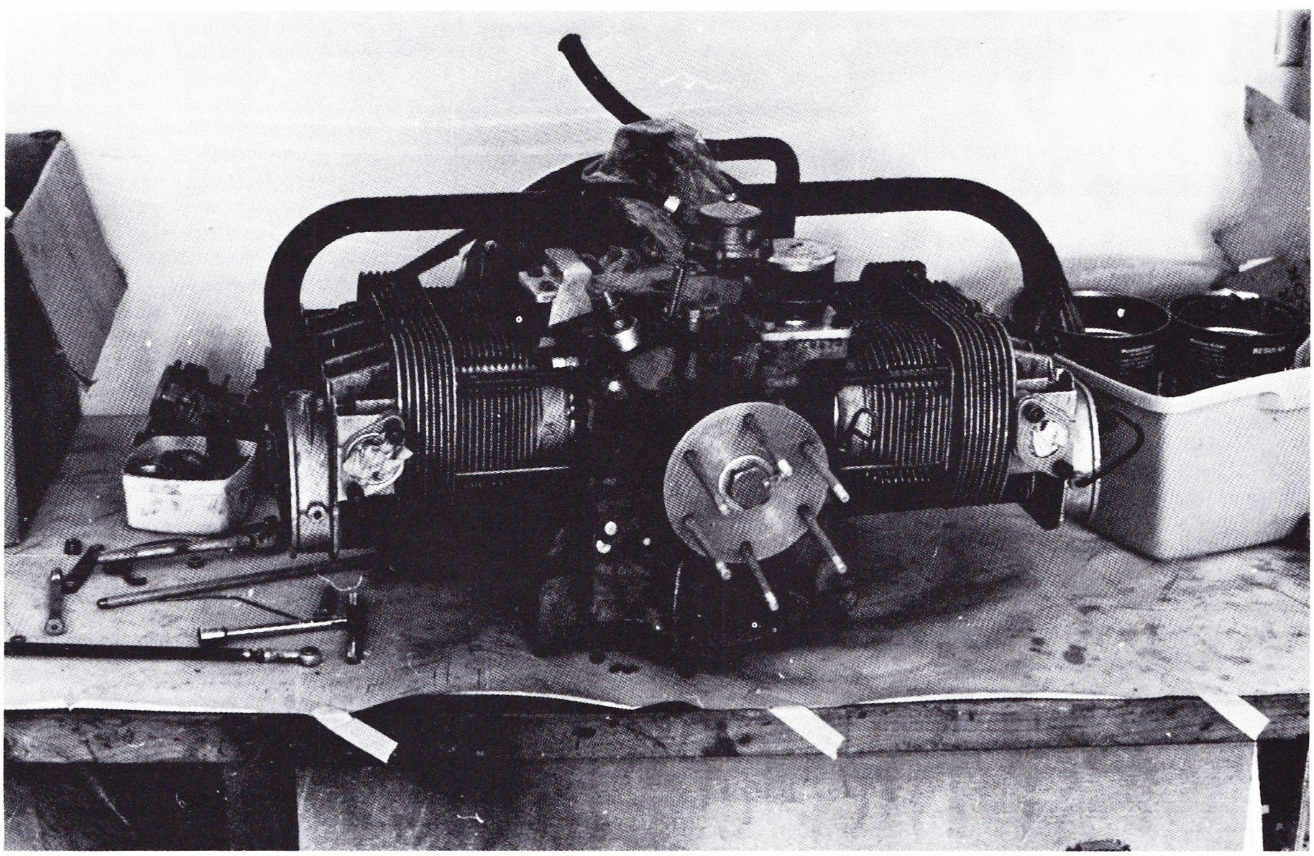
How About Tools And Equipment

Now is a good time to inventory your tools to see what you have and might need.

Nobody ever really has all the tools and equipment he needs but this is not a serious situation. You can build an airplane with but a few primitive hand tools if you are determined enough although your task will be difficult and time consuming. Some types of construction require more tools/machinery than others although, surprisingly enough, most types of construction utilize



Two of the benches are extensions to the main bench in the center. Such an arrangement would be useful in making a one-piece cantilever wing spar. Two or three benches are very handy if you can spare the space.



You could overhaul an engine while you're waiting. Actually it is a good time to do it before you get too deeply into the project.

many of the same sort of tools. An electric hand drill, for instance, is quite essential. Of course, if you have a drill press and variable speed band saw, you are ready to cope with any kind of construction.

Cutting tools should be sharpened and saw blades replaced if they cannot be sharpened.

A bench saw is very useful for wood projects and you can save considerable money by milling your own stock. A disc sander with carborundum self-adhesive sandpaper is a great tool and a great time saver for working any kind of material (aluminum wood/steel/ fiberglass, etc.).

Let's admit it. It **is** better to have all the tools and equipment you will need and have them in your own workshop. But what if you don't? What alternatives do you have when your time of need comes around?

1. You can rent it from a rent-all store.
2. You can contract to have a specific job done (machine work-welding, etc.).
3. You can buy the part ready made and you won't need the tool.
4. A friend may have the tool you need and maybe you can borrow it or arrange to use it at his place.

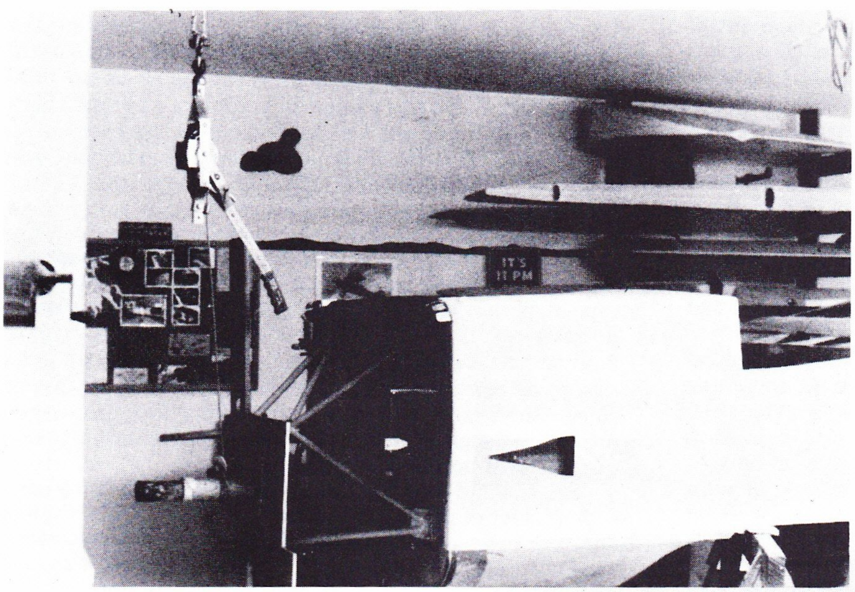
The Etiquette of Borrowing Or Using (A Sermon)

Shakespeare said it . . . "neither a lender nor a borrower be, for loan oft loses both itself and friend" . . . but since ol' Shakespeare said "oft" and not "always" — we homebuilders have a loophole.

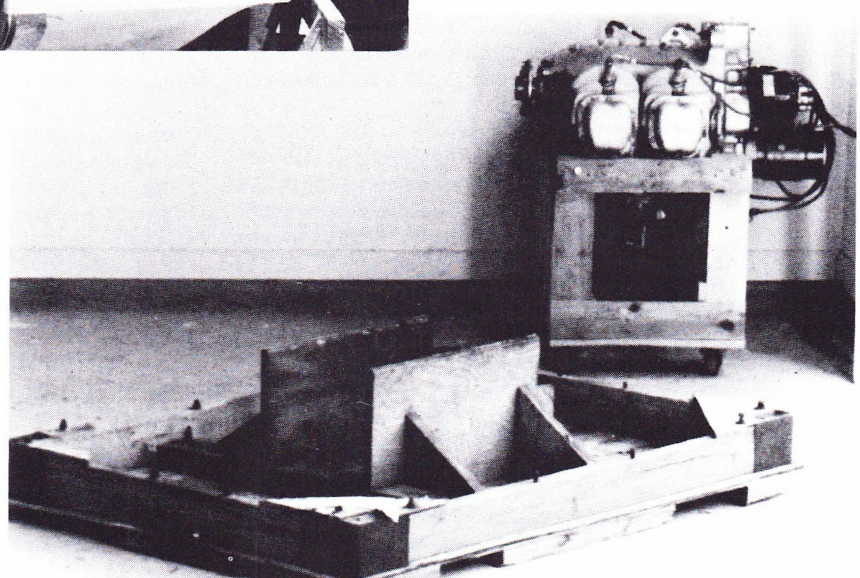
As a borrower, the main thing to remember is that you must be willing to use equipment belonging to somebody else at their convenience and under their conditions. It is an imposition to ask in the first place. Some people don't mind. Others do mind but would rather drop dead than tell you so. Still others are really delighted to be able to help. Regardless of the degree of enthusiasm accorded your request, certain behavior on your part would be prudent and most welcome.

In essence, that's it. Now, I'll probably be accused of singling out some local builders by bringing up "borrowing, the use of etiquette" but that is not so. This is essentially what I hear from a number of other gents who are fortunate enough to have well equipped shops. Most really don't mind but it is a two way street.

Sorry, folks. Gotta go now. UPS just delivered my plans and I won't have time to say anymore on the subject 'cause I'm ready . . . already!



Why not rig an engine hoist and build some racks for control surfaces while you're waiting for your plans to arrive?



You already have an engine? Wouldn't it be better to remove it from that big heavy shipping crate and make a mobile stand before you start building? Space is hard to come by, you know.

Build it Light

By M. B. "Molt" Taylor (EAA 14794)

OUR MANY YEARS of work in the development of light aircraft have brought us in contact with a great number of individual projects for the construction of many different designs. Many of these have been prototypes of designs which had not been constructed before. Others have been copies of well known configurations that have been built by a great number of other individual builders. There is ONE problem that every one of these projects seems to have in common and that is the problem of weight control. This is probably the biggest single problem that the average "homebuilder" of lightplanes will encounter. Yet, despite the fact that he is warned against it, given all kinds of advice against it, and told how to avoid it, almost invariably, unless he is an experienced builder (and even they have the same trouble, including the writer), the end result comes out either heavier than it should or heavier than was expected. It is a natural human tendency to "add a bit here, and add a bit here — for grandma". While it isn't apparent that the use of a few more nails, or the addition of another pass with the spray gun is going to make any different, it is just this sort of thing that ends up making your "dream machine" not perform as well as it could or should, or results in your total dissatisfaction with the whole project once you get it finished and flying.

It is apparently impossible to convey to the average homebuilder the importance of weight control. He invariably will want to make changes or additions to things despite the fact that he hasn't the slightest good reason for wanting to make them different. However, homebuilding, being what it is, is really supposed to be an expression of the individual builder and one of the reasons people build their own airplanes is to try out some of their own ideas. If they are building a design that was originally built by someone else, they should remember that they are "second-guessing" the original builder. Further, they should remember that the original builder probably found out that he himself had overbuilt. If he had underbuilt he quite obviously would have discovered it quickly (when the wings fell off). If he was marginal on anything, it would have obviously shown up if the design was well tested, and if a few other copies of the design had been built any shortcomings of the structure would, in all probability, have been discovered. Accordingly, if the design is one that has seen a few other examples constructed to the basic plans it is a **sure** bet that the structure is going to be quite adequate. Thus, the new builder has absolutely no excuse for **over**building. Adding anything to the structure should be considered overbuilding.

The "homebuilder" should study the plans of any design he contemplates building and try to determine what portion of the **structure** of the aircraft is **basic.** Most designs embody some portion of their structure which really carries the bulk of the loads imposed by flying and landing. The rest of the aircraft usually merely comprises shape and form. When a person does consider making changes to any established design, he should obviously confine himself to making changes **only** to the shape and form of the aircraft unless he is a competent structural engineer or has access to the assistance and service of a **capable** advisor who can advise him as to whether his new idea is going to alter the basic structure. And, if so, whether the new idea is structurally adequate. "Gut-feeling" engineering, or "seat-of-the-pants" modifications of basic structure can end up in disaster for anyone who tries it. Some designers are considerate enough of their builders to include a listing of the basic loads to which their particular design has been constructed. If this information is available to the "modifier", he at least has a "fighting chance" of making modifications to the structure with some assurance that he might not break his neck. If the original designer is experienced at all, he no doubt has already built quite a safety factor into the structure. Or, he has personally already statically tested the **basic** structure to the loads that can be expected in normal flying. The FAA has established certain **minimum** criteria for the design of commercially built light aircraft and these are well spelled out in the Federal Air Regulations Part 23. This information is available from the Government Printing Office at modest cost. The experienced and capable designer will have at least not only engineered his design to these minimum requirements, but probably has also checked his own engineering by performing some basic static testing of his prototype structure to assure himself that he hasn't dropped a decimal point, or "slipped his slip-stick" in his original engineering calculations or estimates. If he hasn't, his design deficiencies would probably have caught up with him if the design has been around very long since there are many people who do check these things in the process of their own building projects.

So, the builder who must rely on building to some existing set of plans has every reasonable assurance that there is little reason for him to beef-up the **basic** structure of most existing designs. What this means is that he still has lots of "leeway" to try most of his own personal design ideas and still not compromise the structural integrity of the design if he doesn't modify things in the **basic** structure. This leaves the door open for him to make changes in the shape of cowlings, canopies, wing tips, etc., etc. and to add all of the little "goodies", instruments, avionics, and creature comforts that his heart desires. The only real danger in this lies in the fact that too few "modifiers" have any idea of what they are going to end up with when it comes to the final empty weight of the "dream machine". It is here that they get into trouble.

Homebuilding is supposed to be for "educational purposes". However, it is a disappointing end to your "education" when you suddenly discover that you have come out with your "dream-machine" weighing a couple of hundred pounds more empty than it should and it flies like a lead brick. While you can expect to learn something from building a homebuilt whether it comes out heavy or not, it is a heck of a lot more fun to end up with both the educaton and a good flying example of any design. There is nothing that spoils the flight capabilities of any airplane any more than being either too heavy or underpowered. While overweight conditions can often be corrected by adding more power (what commercial manufacturer hasn't gone that route?), the homebuilder is usually faced with financial restraints on buying that new, more powerful engine and has to content himself with the results of his own folly.

It is difficult to put your finger on any one single thing that can cause a project to end up overweight. However, it is a whole bunch of "little things". These by themselves do not seem to be of any consequence. Like the "one more pass with the spray gun" — they just don't seem to be important. However, too many coats of dope have spoiled the flight capabilities of many homebuilts as well as rebuilt commercial lightplanes. While things like poor fitting doors and canopies, or the lack of fairing can also spoil flight performance, weight and power and their relationship to performance are far more important than better streamlining or a gleaming surface finish. The weight added by filing and smoothing a dimpled rivet can easily destroy the performance of an aircraft far more than any benefit in performance that might be gained by the filling and smoothing if there is much weight added and great care is not used in the process. Accordingly, it is essential that the homebuilder must be continually aware of the little things that add weight here and there an ounce at a time. One thing that seems to get a lot of homebuilders into the overweight problem is their poor selection of purchased parts. Too often they are guided by cost and availability. It may take a few more days or cost a dollar more to find a light weight switch or push-pull cable, but if you can possibly find one that is lighter, then DO IT. Use of some old surplus World War II junk push-pull cable (instead of a new modern unit that you could have bought at your local marine supply house for maybe even less money) and ending up with a pound or two more weight in your homebuilt airplane is one sort of "foolishness" that can make your whole project end up unsatisfactory. The same thing goes for instruments. There are lots of low cost commercial instruments that are available for boats and sports cars that are just as good as the old surplus stuff (particularly engine instruments). And they are a heck of a lot lighter. Wiring is a good example of overweight installations. Lots of homebuilt projects are full of wiring that is far heavier than need be. Check with easily available manuals and don't run wire around your plane that is any heavier than is needed for the load it is going to carry. Just because some friend has a roll of wire that he will give you is no reason to use it if it isn't exactly what you need. Any way you cut it, your homebuilt lightplane is going to end up costing you a lot of money, and trying to save a couple of dollars here and there through the use of cheap materials that are not the very lightest things you can find is very poor economy.

It is amazing how light things like canopies and windshields can be built and still be completely adequate for your homebuilt project. This is particularly true if your plane is not going to be flying over 150 mph (in a dive). Plastic windshields do not need to be made of 3/16 or 1/4 inch thick material when 1/8 or 1/16 material will be completely adequate. Take a look at a J-3 Cub or an old Taylorcraft and see how light they built things. Remember, these early two place lightplanes would weigh around 600 pounds empty and you could dive them up to 140 mph and they still wouldn't come apart — with two heavy people in them. Of course, the seats were nothing more than a canvas sling with a pad and not some overupholstered fiber-glass bucket seat designed for a sports car. Such light aircraft seldom had anything in them made out of steel tube with over a 0.035 wall, and lots of parts were made from 0.028 wall tube. The aluminum leading edges were made of 0.012, and they were covered with the lightest grade fabric available. Everything possible to save weight was done in order to get the best possible performance from the low power installed in such designs.

When making your own modifications to some design the builder should concentrate on seeing how light he can make the installations. It is amazing how stiff even a piece of paper can be made with a few light balsa wood strips glued on the back of it. By the same token a very thin sheet of metal can be stiffened with a light stringer riveted on the back of it, or a piece of fiber-glass sheet stiffened with a foam stringer covered with a strip of glass tape. A good example to consider in this regard is the structural strength and stiffness of a conventional aluminum beer can. Try crushing one by standing it on end and then putting your whole weight on it. Or consider a steel beer can and then look at the gauge of the metal that is used in its construction. These same principles can be used in designing many modifications to the shape and form of most lightplanes.

Engine installations are one place where many homebuilders get carried away with adding unnecessary weight. They seem to feel that the engine is going to be pulling on the airplane with hundreds of pounds of force. In general the thrust load of a 120 hp engine will not exceed 500 pounds. A **single** 3/16 bolt will take more than that in single shear (in fact almost twice as much). Engine mounts must carry the load of the engine weight, but that, too, isn't measured in tons. A VW engine at 150 pounds can only develop acceleration loads of 9 times its weight even in an acrobatic design, and that single 3/16 bolt in double shear will more than carry that loading. So, using four 1/4 or 3/8 bolts for engine attachments (for a VW engine) just do nothing but add weight. Heavy steel firewalls are another place where many designs go overboards. The FAA only requires that a firewall be 0.015 thick if it is made of steel whether the airplane is a single place homebuilt or a twin engine transport. Engine accessories are a good place to look when it comes to weight savings. Many of the older engines are equipped with rather heavy generators. These can be easily replaced with modern lightweight alternators. Not only are alternators lighter weight but they are much more suitable to aircraft operations than the old generators. Of course, if you really do not expect to be doing a lot of instrument and night flying with your homebuilt, then the thing to do is consider the performance improvement you can get by leaving the entire electric system out of the airplane. Batteries are, of course, extremely heavy. However, we have seen examples of homebuilding where the builder has used a fairly lightweight battery and then ended up having to put lead ballast in the airplane to get the CG in the proper location. The battery should be one of the last things you put in the machine if you are making modifications that might alter the CG location. Then, you can put the battery in a location where it will help balance the plane as required. Copper battery cable is very heavy and if the battery is some distance from the engine, it is going to add weight; on the other hand you will find that conventional aluminum house wiring cable can be easily obtained that will carry just as much current and will only weight about 1/3 as much.

One thing the potential homebuilder can do to improve his chances of building a good example of any design is to study the detail of every homebuilt lightplane he can get a look at. He should examine every part with the thought in mind, "How could this have been built lighter?" Lightness need not mean flimsiness. Remember that beer can. Since there is nothing that will make an airplane fly better than to make things light and since flying is the whole reason for the airplane, then lightness should be the guiding thought. There is no need to make a bridge light since it is supposed to carry weight. If anything, an airplane should compromise to the benefit of lightness in every detail. Remember, almost anyone can build an airplane if they don't have to consider weight. However, it is also an assured fact that if they do, it won't fly very well.

We would be remiss to our Coot builders if we didn't mention that "lightness" is probably even more important in an amphibian or flying boat design example. This is due to the fact that designers of such aircraft must obviously consider the displacement of the hull or floats since this determines how far down into the water the aircraft will sink when it is loaded. If the displacement is not adequate for the loaded weight of the machine, then it will end up sinking so deeply in the water that it will form a bow wave over which it cannot climb and get 'on the step' so that it can accelerate to take-off speed. This inability to 'get on the step' is complicated by the fact that engines equipped with fixed pitch propellers must be moving ahead at considerable velocity in order to let the engine turn-up and develop rated power. So, if the hull cannot be brought up on the step to let it accelerate, the engine cannot develop rated power. Without the power it can't get on the step. Land planes can easily roll ahead on limited power and accelerate enough to let the engine develop enough power to take-off. For this reason amphibians and water borne aircraft are extremely critical in regard to being overweight.

So, BUILD IT LIGHT — particularly if you want it to have good performance and especially if it is a design that is going to be operating off the water or at high altitude fields on a hot day.

Working With 4130 Tubing

By Bob Stewart (EAA 318)

PIPE HOLDER

1) To solve the problem of holding pipe for cutting, etc., I built a set of ½" soft wood inserts to fit a 6" woodworking vise bought for $8.95. One face of this wood was grooved out at a 45 degree saw cut angle on a radial saw set to a depth of about ¼". Two passes on the saw are necessary to produce each groove. As can be seen in Fig. 1, one horizontal, two vertical and two 45 degree angle grooves are cut into the face of one block. These grooves could be cut by hand using a medium coarse file if a power saw is not available. This rig holds pipe securely in any position with little tension on the vise and absolutely no danger of crushing the tube. The wooden blocks are held to the face of the vise by screws through the holes provided when the vise was manufactured. Mount vise on your work table to save steps. This vise works well with all normal and irregular shapes of wood, metal, fittings, etc. and can be utilized for any purpose after the plane is complete.

TUBING GRINDER

2) A used washing machine motor at $6.00, a stub mandrel at $1.29 and a $4.00 6" grinding wheel (medium coarse) was all it took to make a perfect grinder. I mounted this, plus a switch box, switch and steel cover plate at 98c on a piece of scrap ¾" plywood. The plywood is then clamped or bolted to the work table preferably behind the tubing vise. This little gem will save many hours of hand filing on a fuselage.

WORK TABLE

3) When building your work table for the fuselage, make it about 2 feet longer than is required. This will allow space to mount the grinder, vise and an assortment of necessary tools. Construct table top so that it has an overhang of 1" to 2". This is used to C-clamp grinder, vise, etc. around perimeter of table.

CENTERLINES MADE EASY

4) Obtain a fat bodied red or black marker containing permanent ink with a fine nylon point for marking centerlines on tubes. This works a lot better than the silver drafting pencil in common use. The silver pencil is still valuable for fine measurements such as marking location of rosette weld drill holes, etc.

5) Attach a scrap piece of lumber to the side of your work table or bench. I used a piece of ¾" plywood 2" wide and about 3' long. This was nailed in place ⅜" below the top surface as shown in Fig. 3 to handle tube sizes from ½" to 1¼". This is used to mark the centerline on tubes by placing the tube on this ledge and holding against the table as in the side view Fig. 4. Run the ink marker back and forth on the tube at the point where the tube touches the top of the table. Two or three strokes puts on a highly visable permanent centerline.

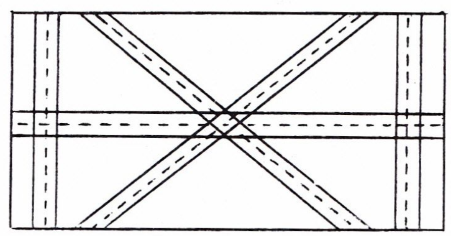


Fig. 1

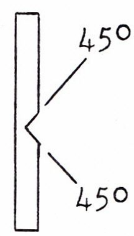


Fig. 2

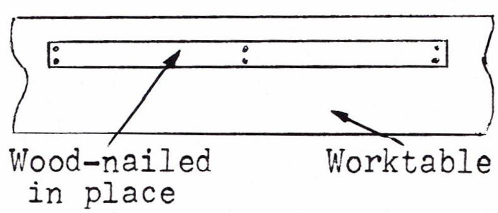


Fig. 3

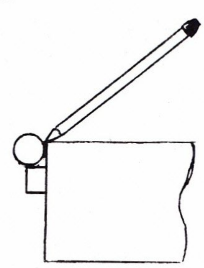


Fig. 4

Electrical Systems/Part 1

by Antoni (Tony Bingelis

WHAT IMAGE IS conjured in your mind when someone tells you that he has a full electric system in his airplane? Have you ever seen a half-full electric system? What of the builder who says he has a complete electrical system in his bird. Pray tell, how does an incomplete one work? This is silly, I know but it does offer an excuse to point out that electrical systems can vary greatly in complexity from the bare minimum to those chock full of all sorts of lights, buzzers, switches and dials.

What do you want in your electric system? A good basic system will provide you with an electric start capability, power for a variety of lights and for a radio. Such an installation can be deluxed by the addition of all sorts of other functions depending upon the complexity of the airplane.

Homebuilder's aircraft plans rarely include a master wiring diagram or a wire table and equipment list. Most builders therefore, although familiar with basic electricity and common circuits, naturally feel a bit unsure about undertaking an aircraft wiring job on their own. Let's dispell this uncertainty.

The circuitry of most electrical systems is similar . . . only the details vary from aircraft to aircraft. Because of this uniformity, it is practical to present a basic electrical system which should be adequate for most aircraft. A discussion of the installation and functions of each of its components follows:

THE BATTERY

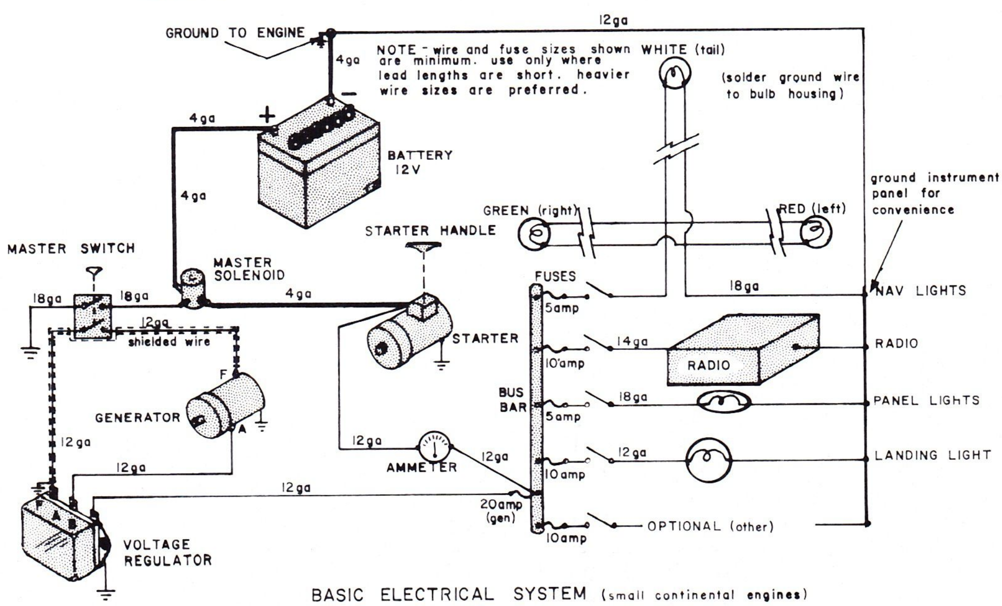
Note that the battery is the basic power source for the electrical system. Although an engine driven generator (or alternator) provides all electrical power (other than ignition) during flight in addition to maintaining a battery charge, do not lose sight of the fact that the battery supplies power for initial starting and serves as an ever ready auxiliary source of power in the event the generator fails.

Your battery should be located as near as possible to that heavy current user . . . the starter. Working counter to that requirement, however, is the need to protect the battery against high temperatures when it is installed in the engine compartment. Battery separators deteriorate when subjected to temperatures much over 110° F.

A considerable amount of information about the battery and its functions may be found in the October and November 1975 issues of *SPORT AVIATION*.

With a new or untried voltage regulator installation, it is quite possible for the battery to suffer from excessive overcharging in flight. If this should happen, a dangerously explosive condition may develop. Therefore, always install a vent tube from the battery box vent opening to a point of negative pressure outside the aircraft. Don't underestimate the importance of this provision. Incidentally, a battery installed in a light aircraft without a generator (VW installations, for ex-

FIGURE 1



BASIC ELECTRICAL SYSTEM (small continental engines)

TWO WIRE SYSTEM FOR WOOD AIRCRAFT

ample) does not require a venting and drainage system because no gassing will occur.

Make your two battery cables of different lengths to help prevent an inadvertent reversal of the connections at the battery terminals. Always attach the negative terminal last and remove it first as a guard against objects dropping across the terminals (mostly screw drivers and pliers).

And a final note, remember that poor accessibility of the battery leads to infrequent servicing and inspection.

MASTER SWITCH

A master switch is used to control the operation of the battery and generator system. Actually, its function is to disconnect the battery from all electrical equipment.

As you know, the engine will continue to function regardless of whether the master switch is ON or OFF.

The master switch controls two circuits so it must be a double pole, single throw (dpst) switch. It can be a toggle, rocker or push-pull type of switch. The rocker type scores high in popularity today.

A look at the schematic illustration (Figure 1) shows that one-half of the master switch completes the battery-to-starter circuit through a battery solenoid. The other half of the master switch completes the circuit between the F (field) terminal of the generator and the F terminal of the voltage regulator. Fear not, both the connector terminal on the generator and the one on the voltage regulator are marked or embossed with the letter F for identification. In reality then, when the master switch is turned on, you activate the aircraft's power system (battery and generator).

SOLENOIDS, CONTACTORS, RELAY SWITCHES

Cessna calls them contactors (battery contactor and starter contactor). Others call them solenoids (battery solenoids and starter solenoids) while others refer to them as relays (battery relay and starter relay). While there are technical differences, they may all be talking about the same gadgets.

Relays and solenoids (or contactors) are electromagnetic switches which can be remotely operated from the cockpit to activate heavy current circuits such as the one from the battery to the starter.

These units should be located directly between the power source and the unit to be controlled in order to keep the cables carrying the heavy current as short as possible.

Since relays, solenoids, or contactors require only a small wire and a like amount of current to activate, they eliminate the need for running the heavy battery to starter cable all the way to the cockpit master switch. This saves weight and removes a potential fire risk which would be created if a long heavy power cable had to be connected to the cockpit's master switch.

These electromagnetic switches must be selected for the function to be performed. Some are designed for continuous operation, others are not. The starter relay (or starter solenoid) is made for intermittent operation and would overheat if used continuously. The battery solenoid (or battery relay switch) on the other hand, can be operated continuously because its coil has a high resistance which keeps it from overheating.

To keep cables short, the battery contactor (battery relay or battery solenoid also referred to as the master solenoid) is usually bolted directly to the battery case or on the firewall nearby. Adjacent to one larger terminal of the battery contactor will be the word "BAT" stamped into its case. This terminal should be connected to the cable from the battery's positive post. The other contactor terminal must be connected to the cable running to the starter. The third, and smaller terminal, is for the master switch wire.

If the engine is a small Continental with a manual pull-to-start switch, no starter solenoid is necessary. As the starter is engaged manually, the electric circuit is activated simultaneously. FIGURE 1.

With a key-start switch or a push-button-start operation, you will also have to obtain and install a starter solenoid. It can be wired into the system as shown in Figure 2.

GENERATORS AND VOLTAGE REGULATORS

Energy for the in-flight operation of the electrically operated equipment in the aircraft depends on the electrical output supplied by the generator. Adding the generator to the electrical system is a simple matter. Its case automatically provides the ground for the unit on installation to the engine. All that remains for you to do is to connect the voltage regulator to the generator using the two terminals provided on the generator. One terminal is marked with an embossed letter "A" and the other a letter "F". The A connector is to the armature and the F connector is to the generator's field. The voltage regulator, likewise, has terminals identified as "A" and "F". A third is marked "B".

The typical voltage regulator consists of three electrical units mounted on a common base and enclosed in a single case. This explains the three terminals. One of the elements is the reverse current (generator cut out) cut out. It opens and closes the circuit magnetically between the battery and generator when the engine starts or stops preventing a wasteful discharge of the battery through the generator. Another unit is the current regulator. Its function is to prevent the generator from exceeding its maximum rated output. The third is the voltage regulator portion which protects the circuit from high voltage and prevents battery overcharging by tapering off the generator output as the battery nears its fully charged condition.

Connecting the voltage regulator to the generator is also simply a matter of matching the cables from the terminals on the generator to the like connectors on the voltage regulator. The A terminals are cable connected directly to each other. The cable connecting the F terminals of the voltage regulator and the generator runs through the master switch.

The B voltage regulator's terminal connects a cable, through a fuse or circuit breaker (to protect the generator), to the bus bar providing a power source for all electrical equipment. This is graphically depicted in the schematic drawing (Figure 1).

Select your voltage regulator to match the output characteristics of the generator used. Automotive regulators, if used, will probably require adjustment in most instances. Since the initial voltage regulator adjustments are often made with the engine running on the ground, a degree of bodily risk is involved. This is particularly true if the voltage regulator's access is difficult. So, be careful!

Because the voltage regulator is normally attached to the firewall, it would be wise to install nutplates behind the firewall for its attachment before doing something silly like installing the gas tank first and eliminating easy access to the nuts.

In general, the voltage regulator should be as close to the main bus as practicable to provide uniform voltage for all loading conditions and to keep the heavier cable lengths as short as possible. Incidentally, if not otherwise grounded, the voltage regulator base must be grounded to the engine.

Some antique and classic aircraft rebuilders might be faced with the prospect of utilizing a wind-driven generator. Failure of the propeller of a wind-driven generator has been known to cause serious structural damage. The prop disc, when extended, should not intersect cockpit locations in the aircraft, unless protection is afforded.

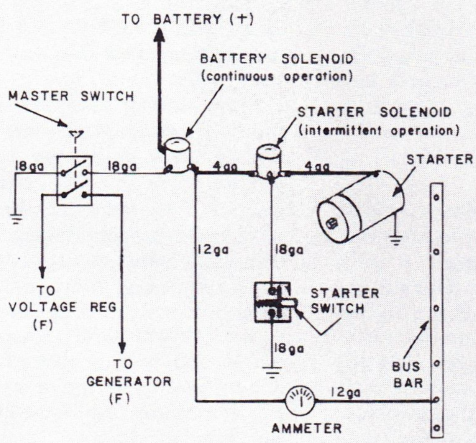
A protective barrier of .032' aluminum or a piece of ¼" plywood can be assumed to furnish adequate protection.

AMMETER

An ammeter is a valuable instrument for an electrical system as it indicates the amount of current flowing to or from the battery. A low battery, with the engine operating at cruise speed will cause the ammeter to show full generator/alternator output when all electrical equipment is off. When the battery is fully charged and cruise rpm is maintained and all electrical equipment off, the ammeter should show a minimum charging rate.

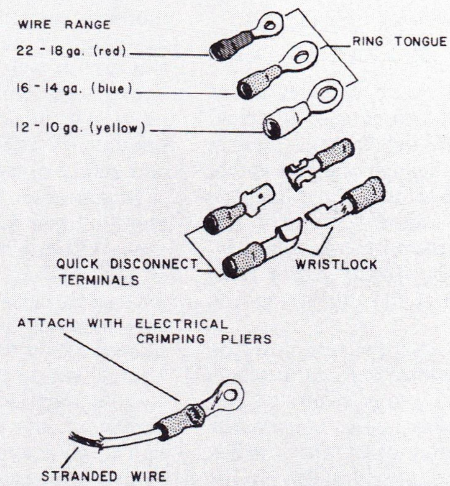
Normally, a generator starts charging at 1000 to 1200 rpm. Alternators, however, produce charging current at much lower rpms. Note that the ammeter is hooked up between the power cable to the starter and the bus bar. (Figure 1)

Next month we will discuss wiring considerations, the bus bar, fuse and circuit breakers and other electrical circuits.



STARTER SWITCH
POWER DISTRIBUTION DIAGRAM

FIGURE 2.



SOLDERLESS INSULATED TERMINALS

FIGURE 3.

Good Torquing Practice

By Tony Bingelis

The old adage, "As tight as you can get it plus one turn" won't do the job any more. Of course, it never did, but in looking over some accident reports, one wonders if that isn't the method some mechanics use to torque fasteners. In other cases, however, the indications are that no torque method was used at all. Fasteners were left loose or not even connected.

A review of maintenance-caused accidents indicates that at least some were caused by under-or over-torquing of fasteners including "B" nuts on fuel, oil, hydraulic and air conditioning lines. Just about every fastener on an airplane has been at one time either over-or under-torqued.

However, it seems that in most cases where a group of nuts are massed together, they do receive proper torque attention. It seems that far more emphasis is being placed on torquing these than is being placed on torquing "B" nuts and other miscellaneous type fasteners. This may be because of the emphasis placed during maintenance training on the necessity for torquing groups of nuts. It may be, too, that some individuals have a tendency to be lax about getting a torque wrench for just one fastener.

NOTE: If you don't have a torque wrench . . borrow one. Always refer to the manufacturers data for proper torque values. This is especially true in all engine build-up work.

Don't wait until you strip a stud or a spark plug plumb out of an aluminum crankcase before you catch on. Putting on just a teensy-bit more torque than the manufacturer specifies is a mark of poor craftsmanship.

Electrical Systems/Part 2

by Antoni (Tony) Bingelis

THE BUS BAR

It is impractical to connect all of the wires from each of the electrical units directly to the battery. Therefore, the power to operate the radio, navigation lights and other electrical equipment is obtained from a central pickup point called the bus bar. The bus bar receives its power from the battery when the master switch is turned on.

Inasmuch as the bus bar must be an excellent electrical conductor, it is made of a piece of heavy copper wire or preferably, a ⅛" copper bar about ⅜" wide and about 5 to 6 inches long to accommodate all of the circuit protectors you require.

Normally, one terminal of each circuit protector (fuse or circuit breaker) is attached to the bus bar to simplify wiring. If you choose to install fuses, attach them by soldering one terminal of each fuse directly to the copper bus bar. Circuit breakers, on the other hand, are normally attached to the bus bar using small machine screws and nuts.

Once the circuit protectors are secured to the bus bar, their opposite terminals can then be individually connected to the different switches and to the electrical units to be operated.

CIRCUIT BREAKERS VS FUSES

Circuit breakers or fuses are installed to protect individual circuits from electrical overloads . . . whatever their cause.

You will probably find fuses to be lighter in weight and somewhat more economical to buy than circuit breakers. However, in service they could be a bit inconvenient as they have to be replaced when blown, whereas, circuit breakers can often be safely reset after they pop.

Technically, fuses and circuit breakers are not intended to protect the equipment. They are installed to protect the cables and not the units activated. In other words, when a cable is matched with the recommended capacity circuit breaker or fuse, that protective device will open the circuit before the cable gets hot enough to start smoking. The fuse capacity of any cable, logically enough, is the maximum circuit it can safely carry.

In general, all essential circuits should have separate protective devices. Otherwise, for example, a fault in the landing light circuit could result in the loss of the position lights if a common protective device were shared. This does not mean though, that a single protective device cannot be used for all of the position lights . . . nor does it mean that you can't use a single circuit breaker to protect a couple of unrelated circuits of lesser importance.

Locate your circuit breakers or fuses where they can be serviced in flight. Label, or otherwise identify the function (and rating, if not already embossed) of each protective device adjacent to its mounted location.

Provide a place to stow spare fuses for easy replacement in flight. At least 1 spare fuse or 50% of the number installed should be provided for each fuse rating.

WIRING CONSIDERATIONS

The only special tool required for wiring your aircraft is a pair of electrical crimping pliers for securing terminals to the cables. You will also need an assortment of insulated terminals to fit the cable sizes selected and a few short machine screws with nuts, for making connections to switches, circuit breakers and/or fuses. (The proper aircraft term for wire is cable, but . . .)

Stranded electric cable (not the solid single core wire) is used in aircraft because it better resists breaking under the abuses of installation and prolonged in-flight vibration.

By all means, use standard aircraft cable as it ordinarily is more abrasion resistant than automotive wire and it will not support combustion or emit toxic fumes. Before considering the use of non-aircraft cable, put a match to it to see how it reacts to open flame. Take a good sniff of the fumes, too.

If no wiring diagram and equipment list came with your plans, you should draw your own detailed layout for even after your aircraft has been wired, such a schematic will always be useful. Retain it with the aircraft records for future reference. It is surprising how quickly the details of installation are forgotten.

You might find it expedient to adapt one of the electrical systems shown in this series of articles. Simply eliminate any equipment circuit not needed. Figure 1 illustrates a typical alternator system. Although it may appear complex when viewed in its entirety, tracing each circuit, cable by cable, will reduce the jumble to simple operational segments.

Mentally relate to your aircraft the location for each of the items of equipment to be installed. This process should provide you with a rough estimate of the amount and type of cable that will be needed.

Some electrical units, the generator, starter, and navigation lights, for example, have fixed locations and cannot be relocated. Nevertheless, exercise restraint and give plenty of thought to the routing of all cables because in most complex aircraft, it is ever so easy to assemble a wiring maze rivaling, in appearance, a bombed-out spaghetti factory.

The cable gages noted in the schematic electrical systems illustrated last month and this month are suggested only as a general use compromise. Some builders may want to substitute other sizes for those shown . . . not for technical reasons but because they happen to have something else. There is really no problem with substitution if a larger cable is to be used. None, that is, except for extra weight. The use of smaller gages than those shown, however, should be approached cautiously. Remember, that the cable gage selected must be capable of carrying the current required of it without getting so hot (even during sultry summer days) that it starts to smoke.

Cable determination is based on the current consumption of each particular unit, taking into consideration the voltage drop over the length of the cable required. After a calculation of the maximum voltage drop, at rated equipment current, the smallest cable size to meet that requirement is selected. However, once in a while, although a cable size may be adequate as far as the heating effect is concerned, a larger cable must be used because the voltage drop becomes excessive due to its length. Long battery cables are a problem in this regard and the longer they are, the heavier they must be. For motors, and for other rotating equipment applications, the cable size is selected on the basis of the equipment's normal operating current, rather than on the starting load. Ordinarily, a starting load is imposed for a short time only and will not raise the cable temperature significantly.

WHY SHIELDED WIRES?

It is necessary to use shielded cable for some portions of the electrical system to keep the cable from emitting radio frequency noise. As I understand it, the cable's metallic shielding causes the high frequency voltage or interference to be induced in the shield mesh of the wire rather than in other nearby units. For example, we all know that two types of ignition harness (and spark plugs) are in use . . . shielded for use with radios, and unshielded where no radios are installed. Many builders, however, may be unaware that it is as important to use shielded cable for similar reasons, for the generator/alternator circuits. See Figure 1. Also, not commonly known is the need for grounding at least one end of the cable's shielding. A short portion of the shielding mesh can be unraveled (use a needle or ice pick for this purpose) and a terminal crimped on (or soldered) to provide an attachment point to a nearby ground connection. See Figure 2. Shielded wire is easily recognized by the metal mesh encompassing the insulation. However, frequently the shield will have a fabric cover over it making it difficult to identify as a shielded wire until the cut end of the cable is examined.

ELECTRICAL BONDING AND GROUND RETURNS

Bonding is the process of connecting the various nonconnected metal parts of the aircraft to form a continuous, low resistance, electrical ground path.

The bonding strips used in aircraft are made of a tinned-copper braid containing 120 strands of No. 36 tinned-copper wire. A larger braid capable of carrying 40 amperes is required for bonding the engine mount. Two separate bonding straps are recommended for this purpose.

The bonding jumpers and strips can be used as a convenient grounding source in wood aircraft. An electrical unit's ground wire is simply connected to the bonding strap wherever the need arises. Otherwise, a separate ground cable must be strung along with the power cable to complete each electrical circuit. This is one complication common to wood aircraft since there is no natural common ground as in a metal aircraft.

Not having a common ground is a bit of a handicap for the wood aircraft builder because equipment such as navigation and landing lights does not have a negative terminal connector built-in. As a result, the builder has to solder the ground wire to the unit's case or housing.

The claim is frequently made that electrical bonding is important in minimizing the danger of lightening discharges (what are you doing out there, man?) and in preventing the build-up of static charges between parts of the aircraft. And, that this in turn, eliminates a potential fire hazard.

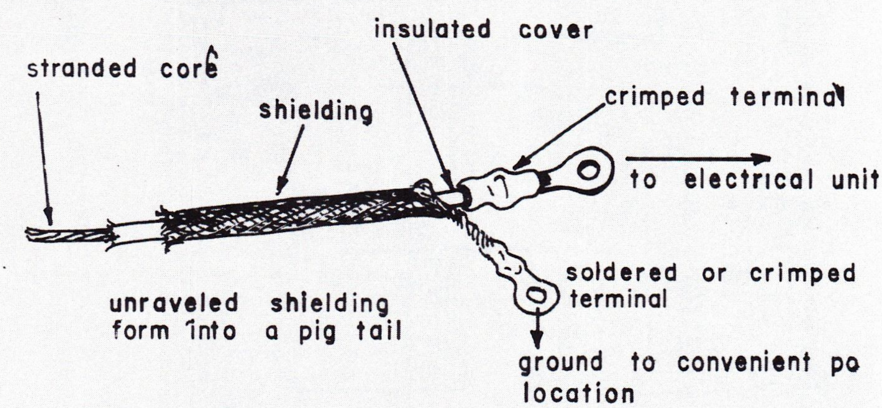
Bonding also allows the structure to serve as a counterpoise ground for the radio circuit and reduces radio interference from electrical disturbances . . . especially important in wood and composite structures.

All-wood and composite aircraft require a convenient ground connection in the cabin area. The instrument panel, if made of aluminum, can serve in this capacity. An effective and handy ground terminal may be made as follows. Drill a 3/16" hole in the instrument panel in some inconspicious area for the installation of an AN 3 bolt about one inch long. Cut extra threads on the bolt and secure it to the panel with a self-locking nut. The extra threaded portion of the bolt protruding behind the panel serves as a convenient attachment point for ground wires terminating in the cockpit area.

Be sure to obtain a good electrical connection to bare metal. It might be worthwhile to install two such ground connectors . . . one on each side of the panel.

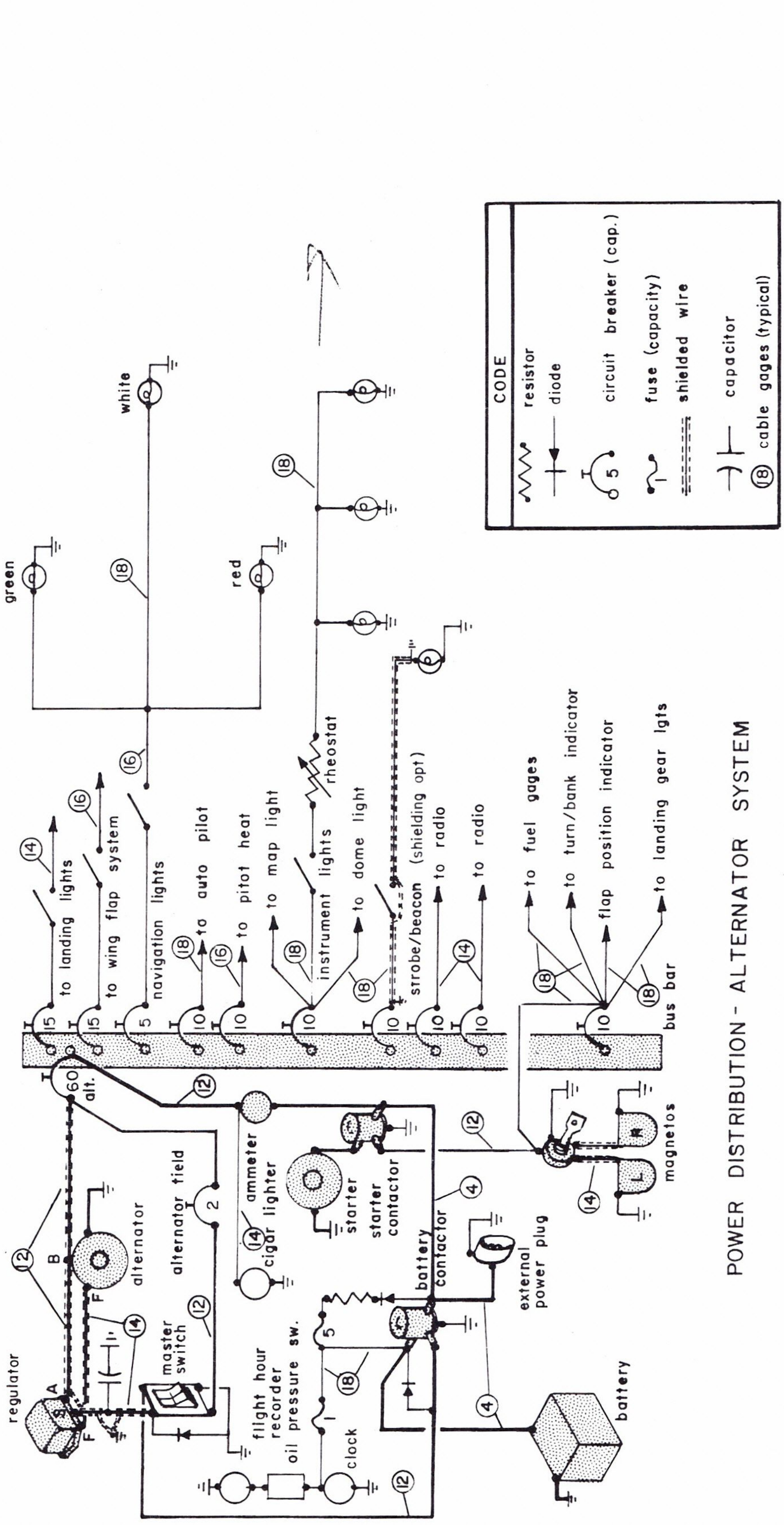
SOME MISCELLANEOUS NOTES

Although we are occasionally confronted with a dead battery, small sportplane engines are so easy to hand start that I see little merit in providing for an external power re-



ANATOMY OF A SHIELDED CABLE

FIGURE 2.



POWER DISTRIBUTION - ALTERNATOR SYSTEM

FIGURE 1.

ceptacle . . . just so much more weight going along for a free ride. In view of the past severe winter, however, some of our ice country homebuilders-fliers may disagree. If much cold weather flying is done, of course, an external power source could be used to save wear and tear of the battery.

Identify and label each wire at both ends of the circuit using indelible ink and a small tab made of adhesive tape. Even a tab of masking tape is better than nothing. This is particularly advisable for wood aircraft which, of necessity, utilize a two wire system.

When an electric clock is installed, it should be wired so that it will continue to run after all the power has been shut off. You can accomplish this by running the plug cable from the clock to the battery side of the master solenoid. Include a one or two amp fuse in the circuit.

You will find that most electrical systems include a radio interference capacitor at the alternator. Note also which of the wires are shielded.

In some installations, a silicon diode is used to protect the transisterized radio equipment. When used, the cathode or plus terminal of the diode connects to the battery terminal side of the battery connector. The anode or the negative terminal of the diode connects to the same contactor terminal as the master switch wire. This places the diode directly across the contactor solenoid so that, as one radio whiz phrases it, "inductive spikes originating in the coil are clipped when the master switch is opened".

People sometimes do forget to turn off the master switch after a flight. When this happens, the next time they arrive at the hangar, they find the battery dead. So, the inspiration might come to combine the ignition switch with the master switch function in a single control. Not a good idea because a fault in one system could affect the other.

My own experience leads me to believe that the electrical system can be one of the most trouble free installations in the homebuilt. Install the proper sized wiring, adequately support it to keep the cables from chaffing, make good connections, and you will be rewarded with a reliable system subject only to the frailities of the store-bought motors and like equipment.

Making Fittings/Part 1

by Antoni (Tony) Bingelis

FITTINGS, ALTHOUGH UNDESIRABLE from a design-structural point of view, are, none the less, essential because to build a one-piece airplane would impose horrendous construction conditions on any builder (or manufacturer).

Fittings are undesirable because they add weight, because they add to the cost of construction, because they add to the time taken to build, and because they add to the complexity of the structure. Additionally, they are difficult to analyze accurately and pose installation and alignment problems which would not exist if the structure were in one piece.

Don't let these introductory remarks dupe you into assuming that fittings are unimportant. They are important, indeed! Poorly made fittings can result in lost wings in flight, the engine falling out, the gear busting off and other even more serious consequences. So, make your own fittings with care.

Some Things Aren't Obvious

Using the proper material for making the fittings is very important. You should abide by the designer's plans call-out. This means the correct steel alloy or aluminum alloy should be used, and in the thickness designated. Sometimes a fitting could be made of a lighter gage and still have the strength necessary for its assigned function. However, there is another consideration . . . that of rigidity. Substituting a lighter gage metal may result in a fitting that lacks the rigidity it needs for a particular function and location. This increased flexibility could contribute to an early failure of the part or, in some locations, result in jammed controls.

You are on safe ground, usually, if your substitution is to a heavier gage (when you have no practical alternative), but then, you will suffer the consequences of added weight. The substitution urge, if encouraged, soon develops into a mental attitude hard to break.

Grain Orientation In Metal

The direction of metal grain is a matter of importance when laying out any part that must be bent. That is, the bend should always be made across the grain or as close to that orientation as practical. If the fitting is to be a flat one (with no bends), the direction of the grain in the part is of no concern and may be ignored. See Figure 1.

About Fittings In General

Some plans provide full size layouts (flat patterns) for all fittings but many plans show only the more important fittings. A few plans show none at all in detail.

A first-time builder will naturally try to do the best he can when drawing his own full-size flat patterns.

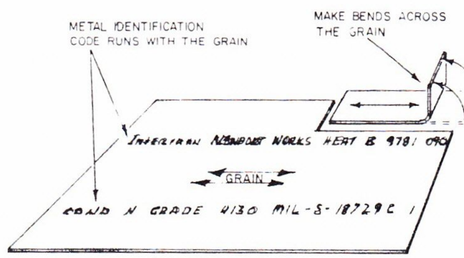


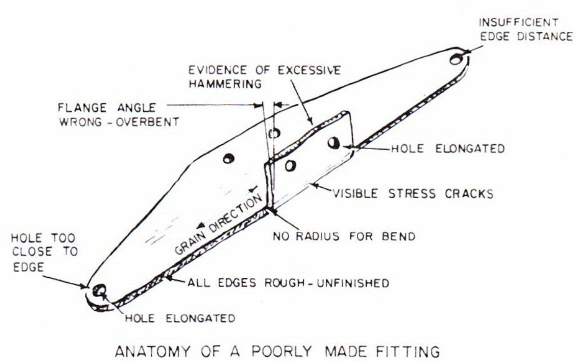
FIGURE 1.
METAL GRAIN ORIENTATION

However, not knowing the intricacies of metal working, things like bend allowance, setback, bend radius and sight line mean nothing to him, and the builder simply doesn't consider any of that at all. As a result, the scenario that often takes place is as follows.

The builder draws his layout using the overall dimensions shown on the plans. Then, he cuts out and traces this pattern onto the metal. Next, he drills the correct size bolt holes . . . most likely without first punch-marking their locations. After that, he saws the fitting out with a hack saw following the outline as closely as possible. And finally, he clamps the part in a vise, and after many less than gentle whacks of the hammer, he has his first bent-up fitting . . . but what kind of a part does he really have? Maybe he has a fitting something like the one illustrated in Figure 2. A fitting that doesn't fit, or worse, one that is unsafe to use.

An informed builder knows that he must not make sharp corner bends in metal, and that, instead, the part should have a generous radius for the bend in order to avoid creating abnormal stresses and a crack potential along the bend line.

A builder not as informed will probably attempt to make a bend using a vise as his bending block. The vise



ANATOMY OF A POORLY MADE FITTING

FIGURE 2.

jaw has a rather sharp edge and it will cut into the bend and cause the fitting to crack or (if he's lucky) break. Mr. Builder now has two pieces where he only needed one. But, even if the part doesn't break, it is almost certain to show visible evidence of damage in the form of an imbossed crease on the inside of the bend and stress marks on the outside of the bend. That kind of a fitting would be unfit for use in any aircraft! It should be discarded.

But what of the rest of us builders who know about the need for a minimum radius in bends. Wouldn't our fittings be O.K.? Maybe, maybe not. There are other factors. If we do not first smooth the edges of metal parts to remove all saw marks and imperfections before bending them, we too might find cracks in the edges. Additionally, if we had in our eagerness already drilled the bolt holes to the correct size before bending the fittings, we may also find that they are no longer dimensionally accurate, that on installation they do not match an opposite mating fitting. If the part happens to be a control hinge fitting, we may learn that its hinge axis is now slightly higher than required, or that each hinge is a bit different from the other. Yes, a lot of us still have difficulty in making multiple fittings to exact dimensions due to that invisible culprit known as Ben D'Allowance.

Coping With Bend Allowance

If it were possible to make a sharp 90 degree — some call it a square — bend in metal like you can in a sheet of paper, the dimension for each leg of the part would be the same after bending as it was before the bend was made. However, if an identical piece were to be bent around a radius, the material would, in effect, take a "short cut" to its destination and not as much material will have been used in making the bend. This being the case, the end result will be a part that is slightly taller and longer. See Figure 3. Obviously, bend allowance is a factor to be compensated for when laying out a flat pattern for any metal fitting which must be bent.

One way to nullify the bend allowance problem is to ignore it. Ignore it, that is, provided you are willing to do a little extra work in preference to working with traditional metal-working formulas. For my part, I don't mess with the calculation of bend allowances in simple fittings. If the designer was kind enough to provide a full size layout for the part with the bend allowance already provided for . . . fine. Otherwise I use the screw driver and hammer technique (picturesque patter). It is so much simpler to cut a fitting to its given dimensions, ignoring bend allowance as a factor. The bend is made first, and then the standing end and base ends are remeasured to see how much has to be trimmed off. I never drill any holes until after the bends are made. There you have it . . . a fitting with the correct height and base dimensions. Not a very professional way to make fittings, but they will be accurate . . . consistently more accurate than many you'd make using the metal working formulas involving bend allowance charts, setback tables and that sort of thing.

How Do You Cut Small Pieces Out Of A Big Sheet?

Before you can even make your first fitting, you have to cut a small piece out of a big sheet of steel or aluminum. This chore alone can become an overwhelming problem for some builders. Here are a number of ways to do this. One or two of them could work satisfactorily for you under certain conditions.

Method One . . . The Hack Saw

Sure, a hack saw will work in a corner of a large metal sheet provided the part you intend to cut out is no more than 3 inches wide. That is about as deep as the hack saw can reach. Sometimes by rotating the blade in its frame 90 degrees a much longer cut is possible.

Of course, you could increase the depth of cut for a hack saw by removing the blade, wrapping it with a rag, and sawing away in that primitive hand-held style . . . but is it ever tiring!

Method Two . . . The Sabre Saw

A sabre saw! Why not use your sabre saw! Wouldn't it be easier than using that hand-held hack saw blade? Couldn't you take a fine tooth (24 to 32 teeth per inch) blade intended for metal cutting and slip it in the sabre saw and be ready to go? Or maybe you could even make your own metal cutting sabre saw blade from a hack saw blade by breaking off a 3½ inch length and grinding it to fit the sabre saw socket. That would work too, wouldn't it?

Sure, but that would be good enough only for cutting aluminum and not for cutting steel. Most sabre saws do not have a slow enough speed for cutting steel, and even a high quality hack saw blade will not last long if you try cutting 4130 steel with a sabre saw having only that one speed . . . too fast!

If your sabre saw is not a variable speed unit, you had better find an alternative way to cut 4130.

CAUTION: Always clamp your work securely and do not overlook the fact that the sabre saw cuts on the up-stroke. Don't take a chance with eye injury . . . wear safety glasses.

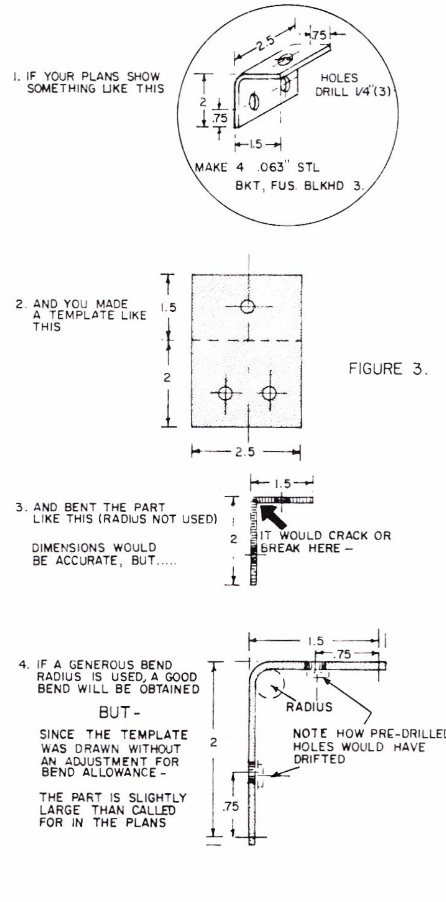


FIGURE 3.