Companion Guide: "Building Fly Baby"
Article 7: Powerplant and Related Installations

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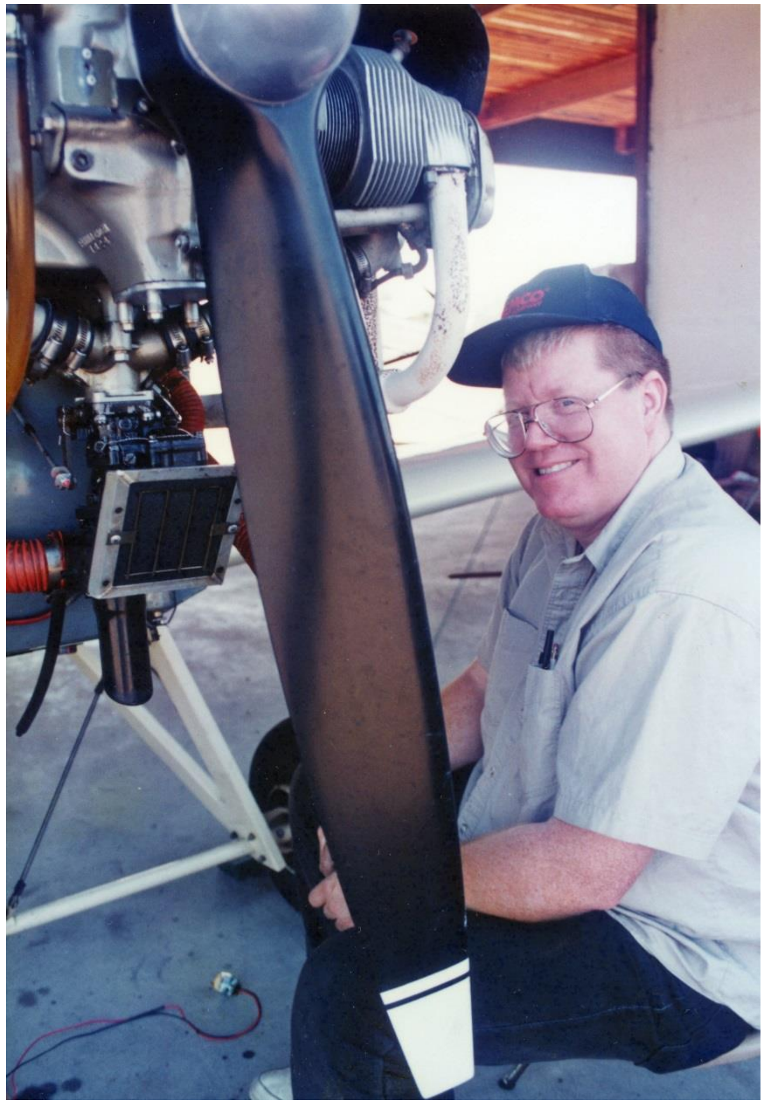
and the Fly Baby Community

This Companion Guide is written to accompany the seventh of Pete Bowers' Fly Baby construction articles in EAA SPORT AVIATION magazine. The article covered the building and installation of the tail surfaces, as well as some recommendations and details of powerplant selection and installation. However, all the tail surface documentation was addressed in the previous Guide (#6); this guide only refers to powerplant information.



You will need to download these articles from the EAA Archives. This Companion Guide merely supplies additional background information and some helpful hints on the actual construction. A full Table of Contents is included on the next page.

There are two kinds of figure references in this Companion Guide. If the reference is "Figure 1-1" (with a hyphen), it's a figure in the original EAA articles. Figures without a hyphen are contained in this document and should closely follow the text which refers to them.

For specific assistance in building the components described, see the Workmanship and Hardware articles on the PB100 Web Page.

Many thanks to Matt Wise, Jim Katz, Jim Hann, William Beauvais, Olan Hanley, Harry Fenton, Bill Hills, Drew Fidoe and the others of the Fly Baby community for providing some great pictures to illustrate the points in this Guide.

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1 OVERVIEW

Proper installation and setup of the engine and its support hardware is vital on any type of airplane, including Fly Babies.

Yet… the Sport Aviation article covering this subject is only two pages long…and half the material is about the tail section! Even in the plans themselves, the powerplant section was only nine pages, and four of those pages are full-size figures that were four-to-a-page in the article.

Now, this is a critical, key point of the construction of ANY homebuilt. Why so little detail?

Two good reasons. First, the Fly Baby was designed essentially use the entire engine package from a J-3 Cub or similar airplane. Back in 1962, scrap yards were cluttered with wrecked Cubs, Champs, Taylorcrafts, etc. They all used the basic Continental A65 engine package, with slight differences in engine mounts and hardware connections. You could buy a wrecked Cub for $400, wipe the dirt off the engine, and install it, practically intact, on your Fly Baby. No need for Pete to give you a whole lot of detail. You'd also use the Cub's wheels, brakes, tires, fuel tanks, instruments, cowling, and a whole lot of little stuff.

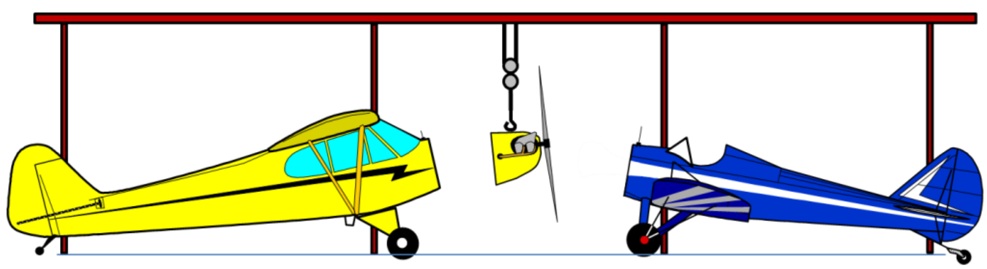

Figure 1: Cub-To-Fly-Baby Engine Transplant

Nowaways, of course, you'd have to be batshit[1] crazy to do this. Even an average-condition J-3 sells for about three times what a Fly Baby would be worth. So Fly Baby builders are left assembling their own powerplant packages.

The SECOND reason Pete didn't provide more engine detail? Because Pete wasn't an engine expert. He wrote a lot of articles, and a lot of books, but he never wrote any on the basic care and feeding of engines. He knew the small Continentals pretty well (He did earn an A&P ticket in 1943) but just didn't feel he was expert enough to give folks engine advice.

Well, guess what, folks: I ain't an engine expert, either.

This Companion Guide is going to be a bit different from the others. I'm going to try to capture a lot of advice given by Fly Baby owners, and some of the advice given by some of our engine specialists. Being an opinionated sort, I'll also give you some of my own recommendations.

<u>Keep in mind that this guide does NOT tell you how to install the engine.</u> I'm not an engine expert. What it DOES tell you is how to use existing references to guide your engine installation, and especially what features of the Fly Baby may affect the installation.

[1] This, I believe, is the first time I've ever used a bad word in any of my formal writing. It is with good cause, because, you would, indeed, have to be batshit crazy to cut up a J-3 for Fly Baby parts in this day and age.

What existing references? There are many, but there are two that you should consider bibles. They're both by Tony Bingelis: *Firewall Forward*, and *Tony Bingelis on Engines*.

Now…many of the chapters of these books started as columns in EAA Sport Aviation magazine. When possible, I have provided references to the original columns in the appropriate section. As an EAA member, you'll be able to download them for free.

The layout of this Companion Guide will reflect the different approach to the open-ended subject of engine installation. Rather than the "Safety", "Errata", and "Alternatives" sections, we'll look at engines other than the Continental first, then cover the key points of installation of Continental engines.

Why not cover installation points for the other engines, too? Well, look at Figure 2. It graphically illustrates the number of Fly Baby registrations with given engine types. Notice how many Continental engines there are…versus other types.

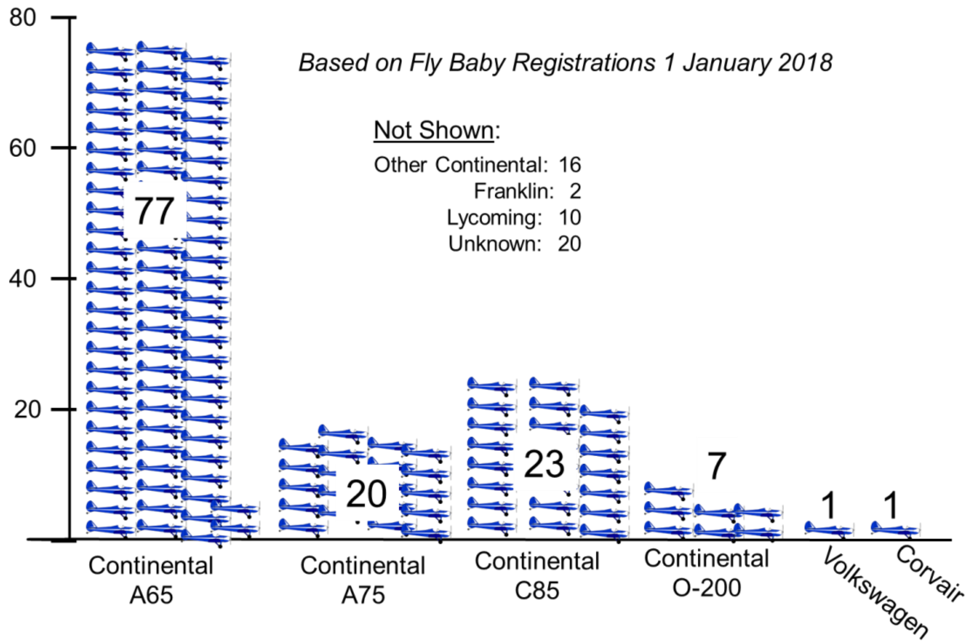

Figure 2: Installed Engines on Fly Babies

So there's quite a bit of folks with experience on Continental engines in Fly Babies, but only one or two of other types of engines. So the kind of data you'd like to have for these other engines just isn't available. I'm even less an expert on, say, Corvair engines than I am on Continentals.

1.1 Note about Illustrations

To make things clearer, I have drawn up a lot of sketches to illustrate some of the aspects of the assembly. Peripheral details on these sketches are just there to complete the drawing—they may not, exactly, match the original Pete Bowers figures. My sketches always are in color; Pete's are black and white.

Where there is a difference between my sketches and those from the Pete Bowers articles, assume the original article sketches are correct.

If two pieces in my sketches are supposed to be the same size but look different, just assume that was an error.

1.2 Workmanship

Let's review the Basic Workmanship rules for building Fly Babies. Key notes:

- Do not varnish any areas which will subsequently be glued
- Varnish any closed areas (double-plywooded forward section, etc.) before they are closed up.
- Drill holes in wood directly to size, using a brad-point drill bit
- Varnish all bolt holes
- Varnish all areas where metal parts will be in contact with the wood
- All metal components should be painted or otherwise protected.

2 ALTERNATIVE ENGINES

Sigh.

I know a lot of you are looking at this section expectedly, assuming I'll present some good news about solid, low-cost alternatives to the Continental engine.

Well, there isn't really much good news. Pete Bowers was very supportive of folks installing alternative engines, but as discussed in the last section, very few people have actually done this. I haven't heard from anybody with long-term experience in an alternative engine in a Fly Baby.

2.1 Why <u>Not</u> Try an Alternate?

It's a cherished privilege of the Experimental category to be able to use non-aircraft engines. I fully support it. The Fly Baby, being a well-proven design with benign handling qualities, makes a good test bed for new engines.

Yet I'm going to try to talk you out of it. Why?

2.1.1 Technical Issues

<u>Thrust</u>. When talking about aircraft engines, there's one factor you have to understand. *It's not just about horsepower*. It's about the amount of thrust the engine produces. And by "thrust", I mean just "pull."

No matter what's on the front of the airplane, the engine will need to produce the same thrust as an A65 or larger Continental. This boils down to the need to turn the same propeller used with the A65 at ~2200 RPM. Any deviation from this might mean the engine may not have enough power for the airplane…despite having a rating that should be adequate. Most A65 use a prop with ~71-72 inches of diameter, and 46-50 inches of pitch. If your engine can't turn a 71x48 prop at 2200 RPM or higher, it isn't going to work on a Fly Baby.

It's been an axiom for over a hundred years: Big, slow airplanes require large slow-turning propellers. The modern crop of VW-powered WWI fighters can't hold a candle to the originals, despite having engines that are the same horsepower. A big prop, turning slowly, pushes more air more efficiently than a small prop turning faster.

If your engine requires a smaller-diameter or lower-pitched propeller, it's probably not going to do very well.

A lot of alternate engines get their horsepower by turning at a higher RPM. Volkswagens on airplanes turn at ~3400 RPM, and need a little toothpick prop to turn that fast.

A Propeller Speed Reduction Unit (PSRU) is one common way to get the prop turning at the proper speed with an engine turning at a higher, horsepower-producing RPM.

Keep in mind that the PSRU is usually a belt or gear-operated device, and it changes the thrust line of the engine. The builder must make sure that the thrust line of the PSRU is the same as a Continental would be, so the engine will need to be installed lower.

<u>Fuel supply</u>. Most auto engines install the carburetor on top. Since the air flows through it downward, it's referred to as a "Downdraft carburetor."

Aircraft engines put the carburetor at the very bottom: An "updraft carburetor."

There are advantages and disadvantages with each. The downdraft carburetor atop an engine stays warm; it does not have a strong tendency to carburetor icing.

However, for simple airplanes like Fly Babies, the updraft carburetor has a distinct advantage: It doesn't require a fuel pump, because gravity does the work.

Look at the fuel tank feeding an auto engine (on the left) and a Continental in Figure 3. Since the downdraft carburetor is actually above much of the fuel tank, it means that a fuel pump is necessary. For aircraft, of course, this means TWO fuel pumps, since you'll want some redundancy.

Contrast that with the Continental engine. The updraft carburetor is all the way at the bottom, so fuel flows to it by the force of gravity alone. Gravity doesn't require electrical power, nor must a mechanical lever be pumped. Gravity is reliable; two fuel pumps are required on airplanes in case one fails. In addition, in case of flooding the carburetor or even a carburetor failure, all excess gasoline in the Continental installation flows to the ground in instead of onto potentially hot components on the top of the converted auto engine.

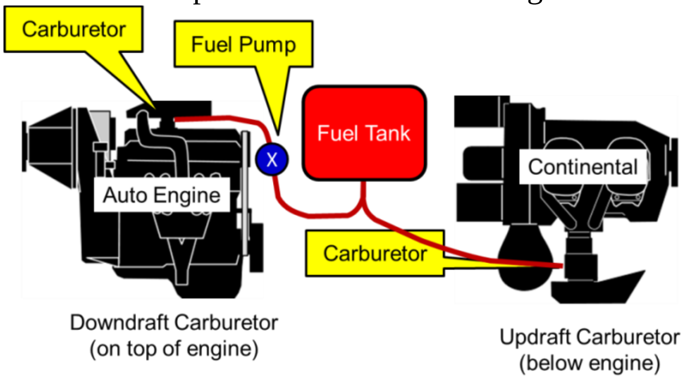

Figure 3: Downdraft vs. Updraft Carburetors

Most Volkswagen and Corvair conversions also use updraft carburetors, and thus can use gravity-feed fuel systems.

Electrical Power. Note that use of the auto engine as shown will probably require reliable electrical power to the fuel pump, for the backup pump if nothing else (perhaps a mechanical pump can be used for primary). But, in all likelihood, you'd need reliable electrical power anyway, since the auto engine will probably have electronic ignition.

The Continental spark plug can be fired by two completely independent magnetos, but the auto engine needs constant electrical power. Auto-engine conversions suffer ignition issues about four times as often as traditional aircraft engines, and much of the time, that's due to faults associated with powering the electronic ignition.

Cooling. Most auto conversions are liquid cooled, so you'd have to install a radiator, expansion tank, run hoses, run instruments to the cockpit, etc.

2.1.2 Construction Time

There are a lot of different problems that need to be solved if you use an alternative engine in your Fly Baby. How will it affect the Center of Gravity? How will you get the thrust line the same as a Continental?

There's also the cumulative effect of all the additional systems you'll need to install. See Figure 4. These are all systems that a Continental

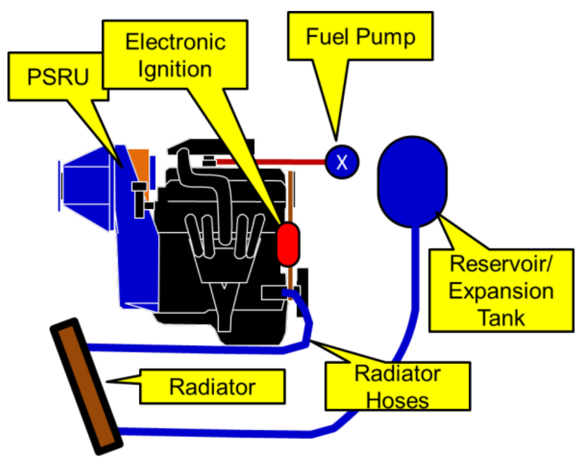

Figure 4: Auto Conversion Systems

engine *won't* require[2]. Installing them and trouble-shooting them will take some time.

When building an auto-engine conversion for a homebuilt aircraft, the usual rule-of-thumb is that building up the engine takes the same amount of time as building the airframe.

In other words, it'll double your construction time.

2.1.3 Reliability

Ah, well, there's the bugaboo.

When you look at the overall homebuilt fleet, about 19% of its accidents are triggered by failure of the propulsion system. This includes both failure of the engine itself, as well as related systems.

If you look at just the certified engines (the Continentals and Lycomings), about 14% of their accidents are triggered by propulsion system failures.

Auto-engine conversions? *Thirty seven percent*… more than twice as often!

Note that the overriding factor is NOT the engine itself. Most of the time, the problem is in the supporting systems…the PSRU, the cooling system, the fuel system, and the ignition system. If these sound familiar, take another look at Figure 4. Traditional aircraft engines don't have (most of) these systems, so they don't quit working because of them.

Figure 5 shows the results for the overall homebuilt fleet (not just Fly Babies). The plot shows how many engine failures were due to given causes. Note the contribution of ignition, drive systems, and cooling systems problems to the auto-engine conversion results. The standard engines lead in carburetor ice cases…but these are often a pilot failing to activate the heat in time.

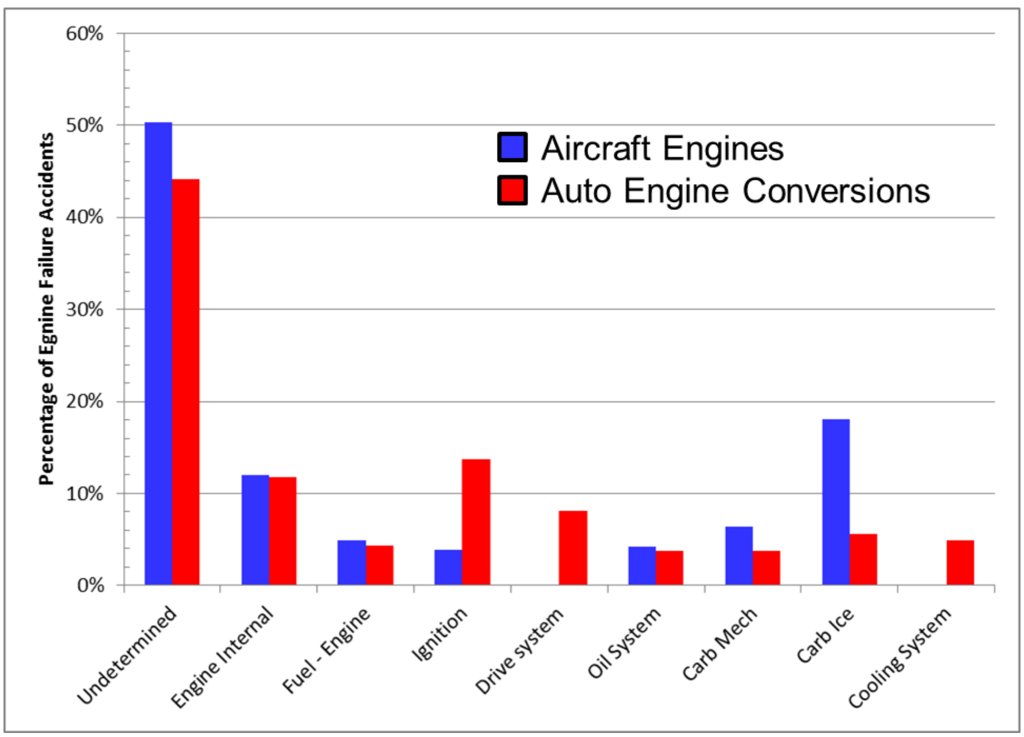

Figure 5: Cause of Engine Failures

[2] The Corvair and Volkswagen conversions are obvious exceptions.

Many people tackle these conversions to save money; they don't want an expensive aircraft engine in their homebuilt. The trouble is, unless the conversion is reliable, it's not really saving money.

> Installing an alternate engine to save money is only a valid option if the engine is *reliable*. No amount of cost savings will compensate for destruction of the aircraft after an engine failure, or the injuries or deaths that might occur.

If the engine isn't reliable, you don't want to be flying behind it.

Proponents of auto-engine conversions will insist that these conversions can be built to be just as reliable as traditional engines.

And they're absolutely correct. I've known a couple of folks that flew their auto-engined airplanes for years without issues.

But these were, essentially, engine gurus. They knew what they were doing. The safety rate of these conversions indicates that most users don't fully understand what's needed to produce a reliable aircraft power plant. And, often, it requires a monetary expenditure roughly equal to what a good used Continental would cost. There are companies that offer ready-to-bolt-on conversions. They aren't cheap.

2.2 What it All Boils Down To

As far as I'm concerned, the decision whether to use an alternate engine boils down to two factors:

If your primary interest is in the engine **itself**…if you're primarily looking forward to tackling the technical challenges of an alternate engine…go right ahead. The Fly Baby is an excellent test bed for this sort of work.

But…if you're looking at an alternate engine solely to save money, for just a fun-flying airplane…then seriously reconsider. There is nothing as cost-inefficient as an unreliable aircraft engine.

The exception to this would depend on your qualifications for working on engines. If you're what we used to call a "Hot-Rod" type; if you've been rebuilding engines for years; your chance of pulling it off increases. If nothing else, it'll give you the smarts to detect engine issues early.

Fly Baby builders have over fifty years of success using Continental engines. Alternate engine uses have been tried, but they've all faded into the past, leaving little history. If you're not already an engine expert, I'd recommend sticking with the reliable option.

2.3 Examining Engine Options

Before we move on to talking about Continentals exclusively, let's take a brief look at some of the alternatives folks tend to mention.

2.3.1 Corvair

Frankly, if you want an alternative engine, the Corvair would be your best shot. The Pietenpol community has met some success with Corvair engines…there are about 15 registered examples, plus others whose engines types are not reflected in the FAA registry. If it works on a Piet, it should work on a Fly Baby.

Yet I'm aware of only one flying example on a Fly Baby.

Unlike most auto-engine conversions, building a Corvair is very well documented. There's good documentation, and even seminars to help you build your engines. See http://www.flycorvair.com/.

Obviously, I'm not too enthusiastic about alternatives to the Continentals in Fly Babies. But the Corvair looks like the best option.

2.3.2 Volkswagen

Nope. Uhh-Uhh.

I'm aware of two attempts to use Volkswagen engines on Fly Babies. The second one used a popular belt reduction drive. Neither provided enough power.

An engine specialist I respect (the late R.S. Hoover) stated that the most sustained power a VW could generate reliably is 50 HP. Beyond that, heat would build up in the cylinder heads. Most successful aircraft with VWs are small, low-drag higher-speed planes that shove more cooling air past the engine. The Fly Baby certainly doesn't qualify.

2.3.3 Radial Engines

The Rotec R2800 Radial is a modern engine, manufactured in Australia (Figure 6). The test-bed used by the manufacturer is a two-seat Hevle Fly Baby! I've actually flown this aircraft.

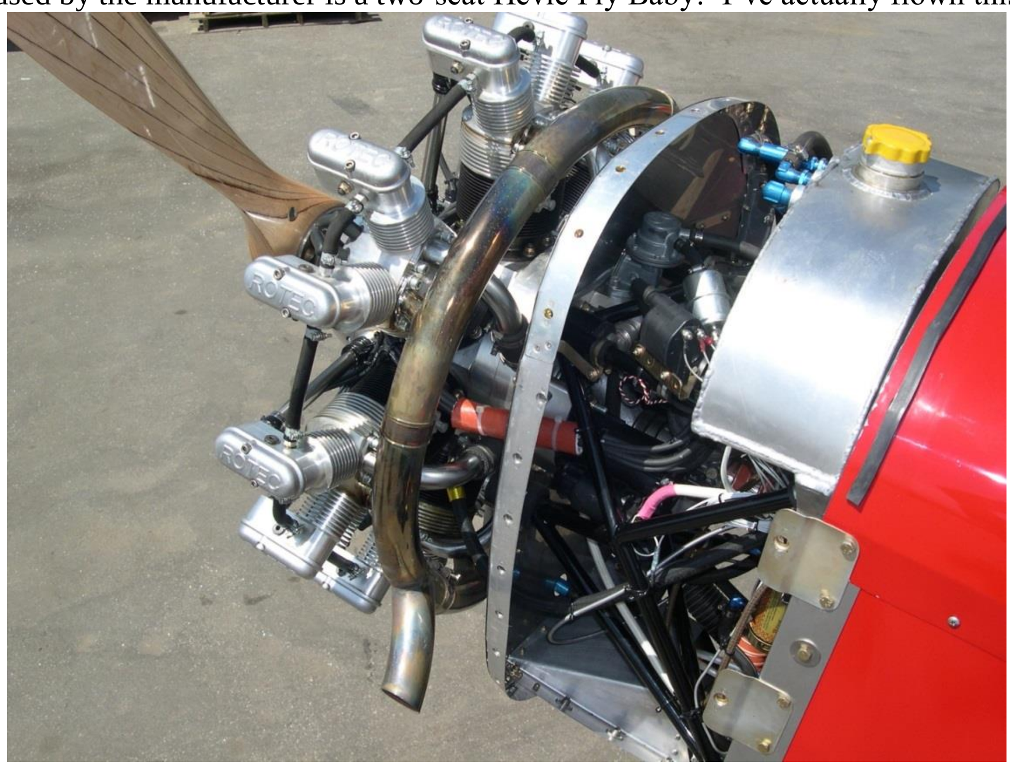

Figure 6: Rotec Radial

However, the Rotec is a bit heavier than the typical Continental, and it's also quite expensive.

Other radials have recently become available. Verner motors have lightweight units of about 80 horsepower and more. Not too many in service, yet, though.

2.3.4 LOM/Micron

The Walter Micron (Also called the LOM) is an inline engine that has been around for decades. It's made in the Czech Republic, and there's a photo making the rounds of a Fly Baby mounting that engine.

The biggest problem with a LOM is probably getting one. Importation to the US has been spotty, and even if you have one, there's the problem with finding spare parts.

Harry Fenton had a bit to say about the LOM:

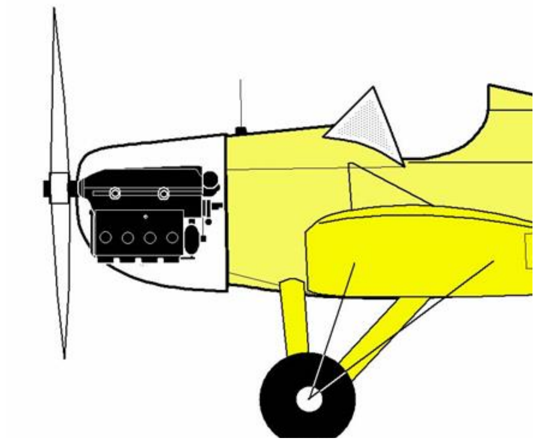

Figure 7: Walter Micron Engine

> *In general, the Walter Mikron is not a bad engine, but a bit pokey for 75 hp. It suffers the same problem as the supposed 65/75 hp Lycoming- it just doesn't have the same torque as the venerable A65.*
>
> *The engine is a jewel, though, very well built, fun to look at and sounds great. The bigger LOM engines are simply too heavy for the Fly Baby. I have a LOM M337 in hand for a 1930's racer replica that I'm building, so I've got some first hand experience. The published weight is appealing, until you consider that it is a 24 volt dry sump engine with no prop flange. If the 24 volt electrical system is retained, the battery will be significantly heavier than a 12 volt. I am converting mine to 12 volt, but it is a lot of work. The engine conversion alone has added 18 months (or more) of building to my racer project. The LOM is also a dry sump engine which requires the complexity and weight of an external oil tank, lines, cooler, etc. The CG moment of the engine is longer due to the in-line design, also, which would wreak havoc on weight and balance issues.*
>
> *In summary, the Mikron/Lom engines are not bad, but are kind of orphans in the industry, so be cautious.*

2.3.5 Rotax 912

I get accused a lot of being too much a Continental advocate. I have a confession to make: I'm jonesing for a Rotax 912.

The Rotax 912 is essentially the modern replacement for the Continental O-200 (despite the O-200 still being around!). It produces between 80 and 100 HP (depending on model), has a 5800 RPM redline but uses a geared reduction drive, and will run on both auto and aviation fuel.

It's been proven in thousands of small aircraft.

Remember when I mentioned that about 14% of Continental and Lycoming-powered aircraft accidents were due to problems with the engine? The percentage is *less* with the Rotax 912: 12%. It appears to be more reliable!

The only two drawbacks to the Rotax 912 are the price, and the fact that the engine is liquid-cooled (thus one needs to install a radiator and associated hardware).

Actually the 912 is BOTH air- and liquid-cooled; if one loses coolant, the engine will not immediately overheat and lock up.

And, cost-wise…well, enough Rotax 912s are out there that used engines are available. Most of us couldn't afford to install a new A65, either, assuming they were being produced.

2.3.6 Subaru

Conversions of various Subaru engines are often mentioned, in the Fly Baby world. Yet it hasn't happened yet.

Nearly 30 years ago, I saw a Cessna 150 taxi by with an odd-sounding engine. This was the test bed for the Stratus Subaru conversion. If it worked on a Cessna, it'd work fine in a Fly Baby.

Figure 8 shows a Subaru installed in a Murphy Rebel. This exhibits how complex such a conversion can be.

Hans Teijgeler, who owns a Fly Baby, also has a Jodel with a Subaru engine. He says, "I LOVE it, however it has easily cost me 4 times what my (very nice) Fly Baby owes me…. As long as you don't attempt a direct drive setup, but use a reduction drive instead, you'll end up with a solid O-200 replacement."

"It is NOT a straightforward thing to do though. It took me 3 attempts and a LOT of time and money to get mine (EJ-25 on Jodel) to work properly."

"On the Fly Baby, I think I'd stick to a nice Continental engine. Different kind of bird..."

Figure 8: Subaru Engine Installed on Murphy Rebel

3 CONTINENTAL ENGINE OVERVIEW

Let's take an in-depth look at the typical Continental engine. This chapter describes some of its features, and the typical accessories used.

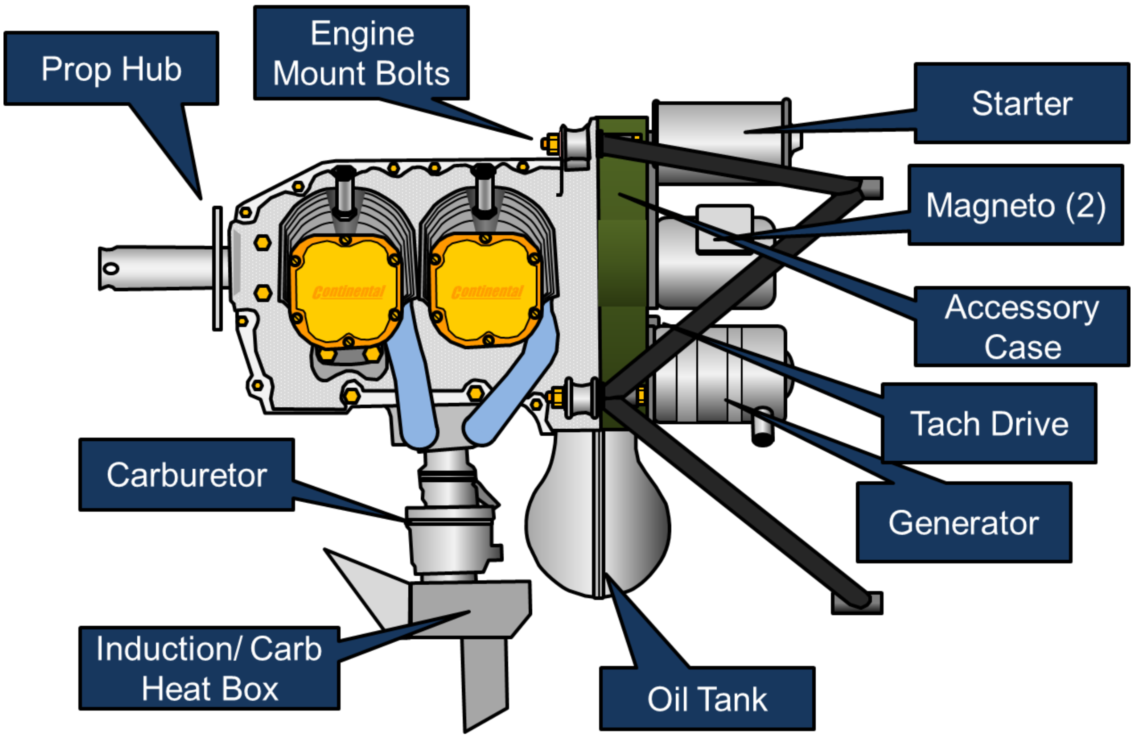

Figure 9: Continental C85 Engine (Exhaust system not shown)

3.1 Continental Models

When you look at small Continental engines, you find a lot of variation in designations…A65, A75, C75, A80, O-200, and so on. What does it all mean?

It's pretty simple, really: The number indicates the rated horsepower of the engine. Beyond that, the letters are used to group engines of the same displacement.

- "A" series engines (A65, A75, A80) all have a displacement[3] of 171 cubic inches.
- "C75" and "C85" series engines have a displacement of 188 cubic inches
- "C90" and "O-200" series engines have a displacement of 201 cubic inches

So, if a group of engines have the same displacement but different horsepower, how do they do that?

Pretty simple, again: They run the engines faster. The A65, A75, and A80 engines all have the same displacement, but the A80 gets its 15 additional HP by being rated to run at 2700 RPM, not 2300 RPM like the A65.

It's not just a case of adding throttle travel. Usually, there are some components that have to be replaced with beefier ones, and the carburetor needs changes to feed more gas to the engine.

Figure 10 shows the designation of a typical Continental engine.

[3] "Displacement" is the total swept volume of all the pistons inside the cylinders in a single movement from top dead center to bottom dead center.

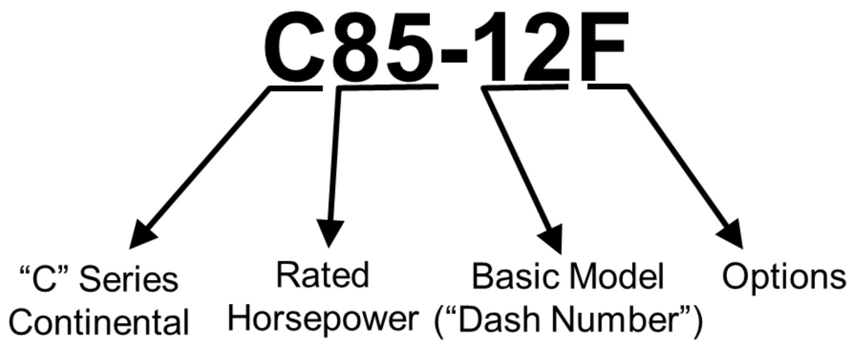

Figure 10: Typical Continental Engine Designation

The "C" indicates that this is a "C"-series Continental. There are some parts commonality with A-series engines, but generally, the "C" series is different.

"85" is the rated horsepower of the engine.

"-12" is the model number of the engine… also referred to as the "Dash number," Dash numbers are similar across the A and C series engines A -8 engine doesn't have a provision for a starter or generator, while a -12 does. A "-14" or "-15" indicates that a different type of engine mount is used.

Finally, one or more letters may be added to the end to show some specific configuration for this engine. These would include:

- "F": The crankshaft has a built-in propeller flange, vs. the tapered shaft and separate flange used by other small Continentals
- "J": The engine is set up for Continental's fuel injection system. It could be converted back to a normal carburetor, but there are a few parts that will be needed.
- "H": The engine has the provision for controlling a constant speed prop. This capability can usually be disabled (not needed for a Fly Baby, and, in fact, the installation of a constant speed prop takes it out of the Light Sport definition).
- "P": The engine is set up for a pusher application.

Not all of these designations are used in all engines. The O-200 series foregoes this convention and uses a single letter to show different configurations.

The following table decodes the designations for the small Continentals. It also shows whether the engine has a provision for a starter. The number of the Type Certificate Data Sheet (TCDS) is also shown; this is the official FAA certification of the engine.

Engine Model	Dash #	HP	@RPM	Starter	Notes
A- Series Continentals					
A65 (TCDS E-205)					
	-3	65	2300		Upward Exhaust
	-6	65	2300	Yes	Upward Exhaust
	-7	65	2300		
	-8	65	2300		
	-9	65	2300	Yes	
	-12	65	2300	Yes	

Engine Model	Dash #	HP	@RPM	Starter	Notes
	-14	65	2300		Special pistons, rocker arms and exhaust valves, seats and guides.
A75 (TCDS E-213)					
	-3	75	2600		Upward Exhaust
	-6	75	2600	Yes	Upward Exhaust
	-8	75	2600		
	-9	75	2600	Yes	
A80 (TCDS E-217)					
	-3*	80	2700		
	-6*	80	2700	Yes	
	-8	80	2700		
	-9	80	2700	Yes	
C- Series Continentals (Both TCDS E-233)					
C75					
	-8	75	2275		
	-12	75	2275	Yes	
	-15	75	2275	Yes	Lord Mounts
C85					
	-8	85	2575		
	-12	85	2575	Yes	
	-14**	85	2575	Yes	Lord Mounts
	-15**	85	2575	Yes	Lord Mounts
C90/O-200 (Both TCDS E-252)					
C90					
	-8	90	2475		
	-12	90	2475	Yes	
	-14	90	2475	Yes	
	-16	90	2475	Yes	Provision for Vacuum Pump
O-200					
	-A	100	2750	Yes	
	-B	100	2750	Yes	For Pusher prop
	-C	100	2750	Yes	Provision for constant-speed prop
	-D	100	2750	Yes	Lightweight version (for LSA market)

3.2 Which Engine?

Which Continental you use is really going to depend on the accessories you want, and your ability to find an acceptable engine.

The Fly Baby was designed to accept the A65 engine, and performs well when the plane is built reasonably light. Yet there's not a pilot alive who doesn't want more power.

My Fly Baby has a C85…and the original Fly Baby (which I flew for seven years) had the same engine, so I've never flown an A65 Fly Baby. But I know a number of folks with the A65, and they all seem pretty happy.

One of the drawbacks of the A65 is the lack of a starter. Now, I flew N500F for seven years without a starter. I enjoyed myself, and came up with good, safe ways to do the hand propping.

Back then, of course, I was in my late 30s. Since then, I've owned my own Fly Baby, with a starter, for 35 years. I'm getting old, my knees are bad, my shoulder aches, and I'm quite happy to plop down in the cockpit and hit the starter.

So I can't argue if you'd just as soon avoid the whole hand-propping thing.

If you looked at the table above, you'll see what is apparently your salvation…the A65-9, the A65-12, A75-9, A75-9, and A80-9 engines, complete with starters. Yay!

Not so fast. These engines with starters ARE very popular…but very rare, and what's out there has been hunted to extinction. They just don't come up, and when they do, the Cub guys scarf 'em up fast, regardless of the price.

There is a bit of good news, here. I looked at the FAA registration database, to determine how many aircraft are still out there with A65s, C85s, or O-200 engines:

A65: 9,934
C85: 7,130
O-200: 10,957

The O-200 is the most prevalent engine out there…and, in fact, ALL are designed to take generators and starters. There's no way to tell how many of the C85s are the -8 model (no starter) but I'm guessing many are.

This should indicate what used engines might be available. The O-200 is a good pick for a Fly Baby, but the downside is that they're used in a lot of Cessna 150s so there might be more competition for them.

In any case, it sounds like there are still a lot of engines out there. The A65 hasn't been made for 60+ years, but the part situation hasn't gotten too bad, yet. Going with a C85 or O-200 will delay those issues, too.

3.3 A Closer Look

Let's take a few minutes to examine a typical Continental engine, and to address some of the issues involved. Start by stripping away the accessories and look at the engine from the point of view of the major connections under the cowling. Figure 11 show the engine mount attached to the aircraft firewall, and the three major components coming together.

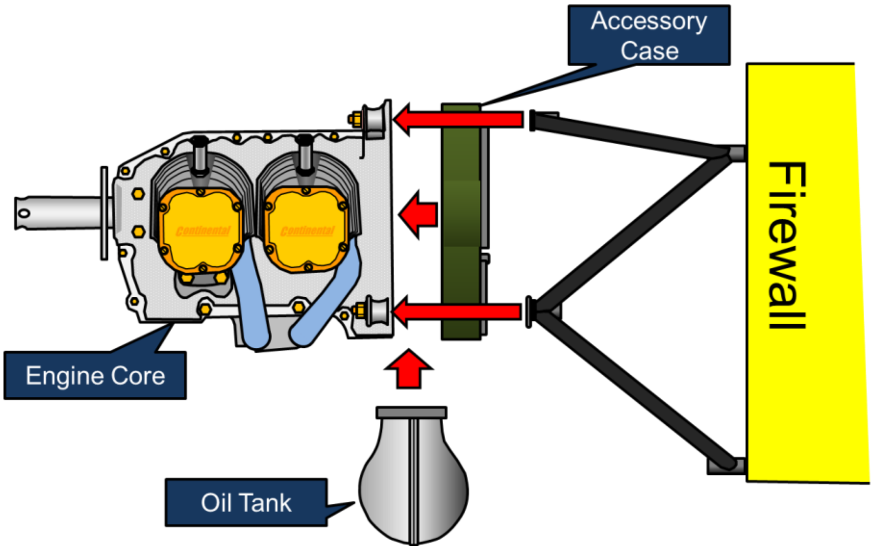

Figure 11: Engine Configuration

The main unit is the engine core. This is the engine casing, with the cylinders and the crankshaft.

The accessory case attaches to the back. The aircraft magnetos will attach to the accessory case, which includes the necessary gears to drive them. It also includes a small port for attaching the tachometer cable.

However, if you have a -12, -14, or -15 engine, the accessory case is thicker and includes more "pads" for attaching the generator and the starter. If you don't want to include a generator or starter on your engine, you can just use a small steel plate to cover the areas on the accessory case (with the same gasket there to close it off).

The big accessory case is what gives some Continentals the ability to mount a starter. Sadly, it's not just the case itself...it doesn't fit the "non-starter" engines, so you can't use it as a short cut to adding a starter.

The kidney-shaped oil tank bolts to the bottom, at the joining of the core and the accessory case.

When the engine bolts onto the airframe, the engine mount connects with mounting pads on the engine core. The accessory case bolts to the back of the case, clear of the engine mounts, as shown in Figure 12.

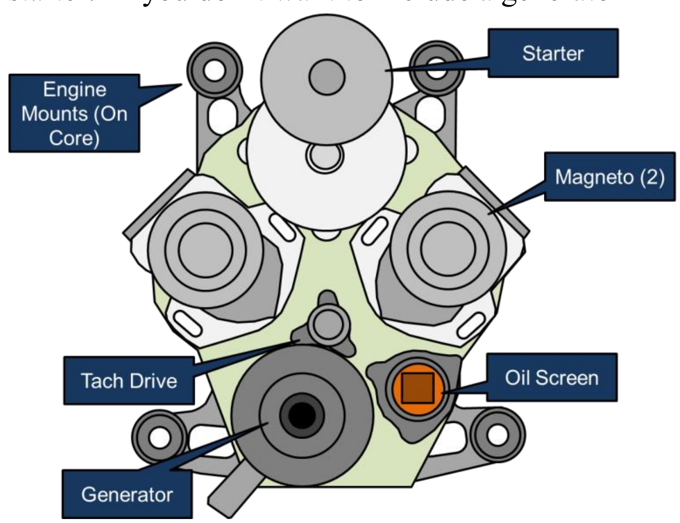

Figure 12: Rear View of Accessory Case for C85-12 Engine

The figure is representative of the accessory case on a -12 engine; it includes both the generator and the starter. The -8 accessory case will include the magnetos, tach drive, and the oil screen. The -8 case is shallower than the -12 one, and the magnetos will be almost vertical, rather than slanted outboard on either side.

3.3.1 Magnetos

Like all aircraft engines, the small Continentals mount two magnetos. These can be various models, depending on the age of your engine and whether a previous owner had replaced them. The three typical manufacturers are Eiseman, Bendix, and Slick.

Eiseman magnetos are pretty common, but they are the oldest of the bunch. They haven't been made since the '60s. A company called Fresno Air Parts (https://www.fresnoairpartsco.com/) stocks parts for them.

Bendix and Slicks are much more modern, and parts are available from a variety of sources.

Some older Continentals have Case magnetos. It's tougher to find parts for these, but the same magnetos were used in older tractors.

To make starting easier, magnetos sometimes include a feature that retards the spark (e.g., makes it happen slightly later) at low RPM. You'll want at least one magneto with this feature, especially if you're going to hand-prop.

One important thing to remember about magnetos: The "Mag Switches" turn the magneto off by shorting the P-lead to ground. Hence, when you "shut off" the engine, you're actually closing a switch, not opening it.

Each magneto will require a matching ignition harness. The standard ones are shielded to reduce radio noise, and terminate in a cigarette-shaped contact and a large nut, as shown in Figure 13.

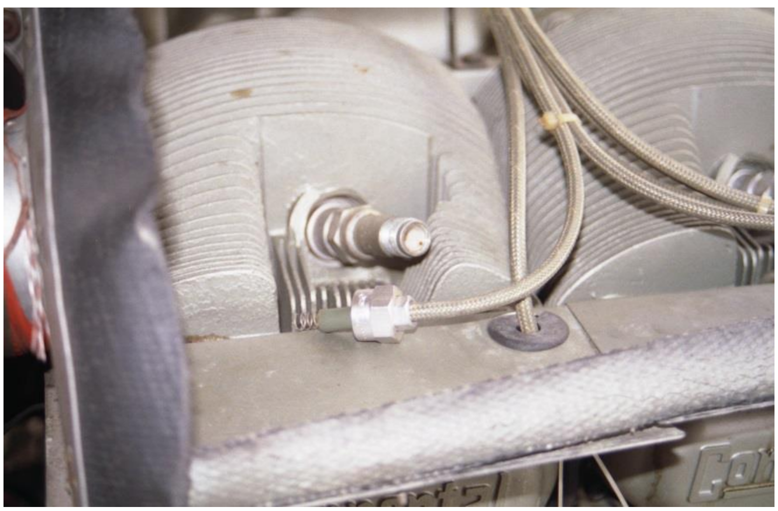

Figure 13: Shielded Plug

Non-shielded ignition harnesses terminate in an open brass clip. Figure 14 shows an example of one of these clips, although it's connected to a desiccant plug[4] instead of a spark plug. You'd like to avoid using the non-shielded systems, as they make it difficult to hear any radios you have installed.

[4] Used to purge the cylinders of moisture while the engine is in storage.

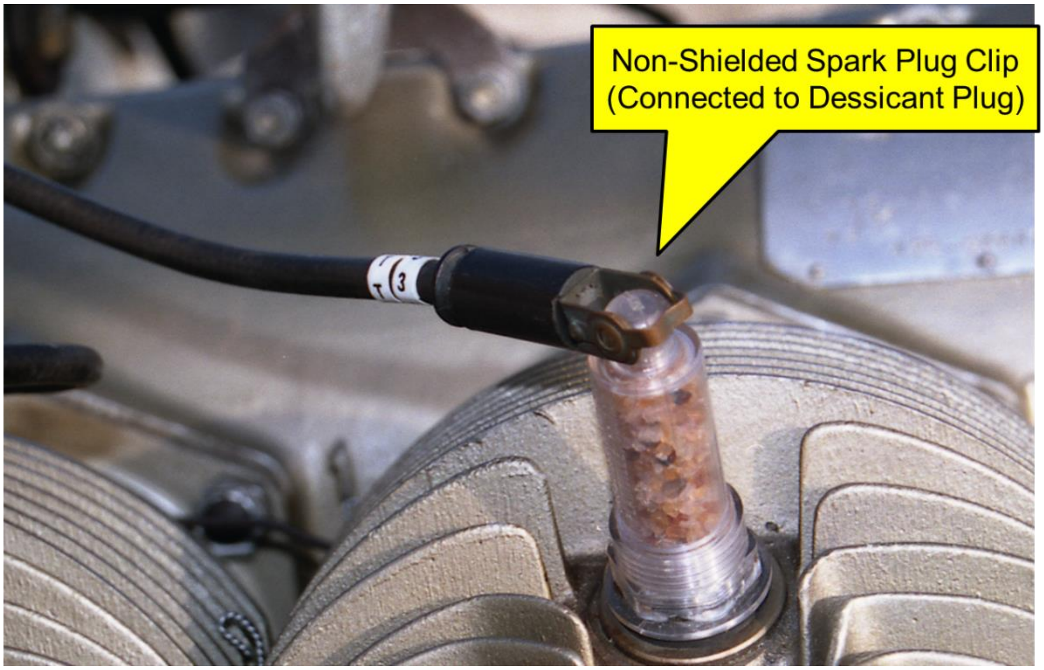

Figure 14: Non-Shielded Ignition Harness

3.3.1.1 MAGNETO ROTATION

Note that different models of Continentals require magnetos that rotate in different directions. All engines with a -8 model number (A65-8, C85-8, etc.) use clockwise rotation magnetos. All -12, -14, -16, and the O-200 use counterclockwise rotation magnetos.

Basically, if the engine is set up to run a generator and a starter, it's counterclockwise.

3.3.1.2 REFERENCES TO TONY BINGELIS ARTICLES

See Section 8:
February 1976 Page 20: "Messing Around with Magnetos"
April 1980 page 55, "Ignition Switches"

3.3.2 Starters

The -12, -14, and -15 engines, and all O-200s, are set up for a starter. There are two basic kinds on Continentals: Pull-type, and Bendix-Type.

The pinion gear on the starter must engage a large gear inside the accessory case (Figure 15). For the pull-type starter, pulling a cable shoves the pinon gear into mesh, with an electrical switch activating the starter by the time the pinon is fully engaged. This is relatively simple, but does require a long pull-cable and handle running back to the pilot position. It sometimes takes a bit of adjustment to time the motor activation vs. the amount the cable is pulled.

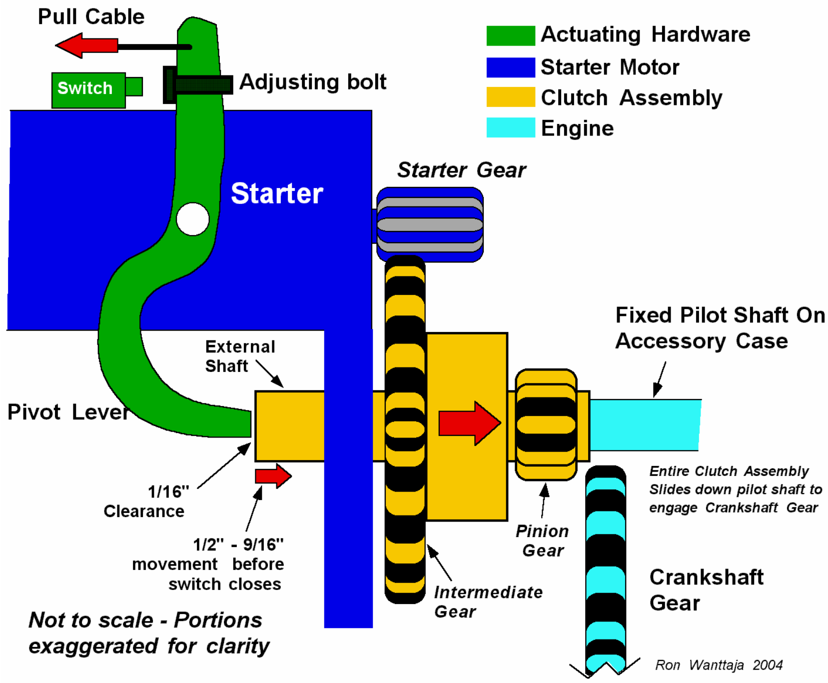

Figure 15: Pull-Type Starter

The other type of starter uses a Bendix gear. This automatically engages the pinion gear when power is applied to the starter…just like every car you've ever driven.[5]

The starters aren't interchangeable; if your engine is set up for a pull starter, you can't just install a Bendix unit on it. Even early O-200s have the pull-type starter…my 1965 Cessna 150 had one.

There are several good aftermarket starters for small Continentals, such as the Sky-Tec starter. However, be warned: They are NOT direct replacements for the pull-type starters.

Oh, sure, they'll WORK on an engine set up with a pull starter, but the engine internals need to be modified. If you look back at Figure 13, you'll see a "Fixed Pilot Shaft". This is part of the accessory case, and would need to be removed to install one of these aftermarket starters. Removed as in getting a cutting wheel and cutting it out of the inside of the accessory case.

Brrrr.

They publish a procedure for this, which includes packing the starter hole with clay to keep the metal bits from dropping down into the engine. Probably works, but makes me nervous just to think about it.

If you're overhauling the engine, it would be a good time to perform this modification. Otherwise, you'd probably want to stick with the pull-type starters.

3.3.3 Engine-Driven Generators

The -12 has a provision for a generator, usually a Delco-Remy model. There were four models available, all 12 volts, but varying in output capacity from 15 to 35 Amps. The smaller ones are adequate for just about any Fly Baby owner. They had an externally-grounded field.

The generators require a regulator. The regulators look similar to those used on older car engines, but they are different. I had a bad regulator, and went through a lot of effort to find a

[5] Well, maybe not, if you're an old guy like me. I owned an early-model Willys Jeep with a mechanical-type starter. Though it was a pedal on the floor, instead of a pull cable.

replacement. Aircraft regulators are what Delco calls a "Three Unit" type, vs. the Auto regulator which is a "Two Unit" type (Figure 16). The difference? The "Units" refer to the number of control relays inside the regulator. Both have a cut-out relay and a voltage regulator relay, but the Three Unit type adds a current regulator as well. Because the current limiter is connected to the voltage regulator by a bus bar, the terminals associated with the two relays are closer together.

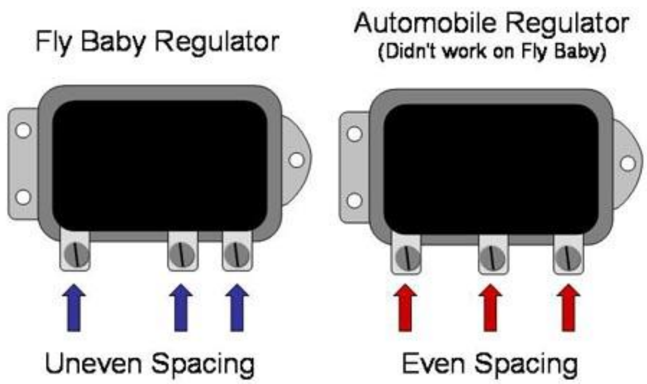

Figure 16: Electrical Regulators

The two-unit type was designed for a **three-brush** generator... the third brush design means the generator doesn't need an external device to limit the current output! So, if you need a regulator for the stock Delco generator, don't go to the car parts store to buy one. It won't work. I know.

I eventually replaced mine with a unit sold by Zeftronics. It's a solid-state unit compatible with the Delco generators. Has been working fine for several years.

There are companies that sell alternatives to the stock generators. B&C makes a nice little alternator which bolts right on the accessory case. However, you usually have to supply the drive gear from a standard alternator to B&C to fit your engine.

3.3.3.1 Leave the Generator Off?

One thing to keep in mind is the FAA's rules regarding the installation of Transponders and ADS-B units. They must be installed to fly in Class B and C airspace.

They're also required to fly within the 30-mile "Veil" around Class B airports, unless the aircraft was originally certificated without an engine-driven electrical system, or had been re-certificated with one.

I recommend you do not install a generator. Install a standard battery, and include a jack for quickly hooking up a battery charger on the ground. Without a transponder, a standard battery will provide a number of starts between chargings, and will run an aircraft comm radio without difficulty. Put a plate across the generator's mounting hole, using the same gasket.

Now… later, you can remove the plate and install a generator if you wish. But get the plane certified without the generator. It keeps your options open.

3.3.3.2 What about a Wind Generator?

The transponder and ADS-B rule are based on an engine-driven generator. What about a wind generator?

To quote Harry Fenton:

"A couple of basic problems with wind driven alternators- drag and consistent voltage output through the airframe speed range.

"Typically, the alternator is tuned for max output when in cruise. However, when the airplane is at pattern speed, the alternator has no output as it is turning too slowly.

"Drag is an issue, too. The alternator has to be a pretty good size and the prop can provide a lot of drag. I had a torpedo shaped wind driven alternator on my old Stinson 105 and it cut the airspeed by 5mph and made a pretty loud whirring noise when it ran.

"If you start searching on the internet, you will find that there have been quite a number of home brewed wind driven alternators. I figure that they are a less than complete solution because I don't see all that many installed on planes at airshows like Sun n Fun and Oshkosh. There is a certain validation of ideas via numbers.

"My solution to electrics has been a battery and a trickle charger. A motorcycle sized battery will run most electrics for a days worth of flying and then can be charged overnight via a charge. Just run a quick disconnect umbilical cord between the battery and the charger."

One owner has installed a Gennipod (Figure 17) and reports good luck with it. They're relatively cheap (~$250) though they only produce 4 amps at 75 MPH. Four amps isn't much, really…it's barely a quarter of the capacity of the smallest Delco generator used on Continentals. Be enough to run a comm radio, though if you've got a starter, it may not be sufficient if most of your flights are short.

Figure 17: Gennipod Wind Generator

3.4 Carburetor

You find two kinds of carburetors on small Continental engines: Those made by Stromberg, and those by Marvel-Schebler. The Stromberg units seem the most common. They're out of production, but parts are quite available.

Neil Wright wrote up some great material on the care and feeding of Stromberg carburetors. His information can be found at: http://www.bowersflybaby.com/tech/engines.htm#stromberg

Some of the internal parts for the Stromberg carbs have varied over the years, and Neil's write-ups take you through the thicket of information. Because of some issues with internal parts, Stromberg carburetors often leak. It's not dangerous, it doesn't affect performance, and it doesn't leak much or fast, but you'll often come back to the hangar to find a bit of staining on the floor below the carb. I refer to this as the "Stromberg drool." Mine's done it for years.

Another bit of weirdness about the Stromberg: Not all Strombergs include a mixture control, and those that do usually don't lean far enough to starve the motor and make it quit. So if you've learned to pull the mixture out to kill the engine, you're going to be waiting a long time if the plane has a Stromberg. Mine's like that; I just kill the engine with the mag switches.

Marvel-Schebler carbs are still in production (https://msacarbs.com/) and can be purchased in rebuilt condition.

3.4.1 Carburetor Heat

I like the little Continentals a lot, but there's one little fly in this particular ointment: The small Continentals have a tendency to collect carburetor icing. It's probably because the air induction system (including the carb) is so completely isolated from the warmth-producing parts of the engines. Lycomings, for instance, bolt their carbs to the oil pan and aren't as liable to carb ice.

It's not a problem, as long as the plane includes an adequate carburetor heat system. This includes a heat exchanger to warm intake air using the exhaust, and a unit that allows the pilot to feed that warmed air to the engine. This is handled by the Carburetor Heat Box attached to the bottom of the carburetor (Figure 18)

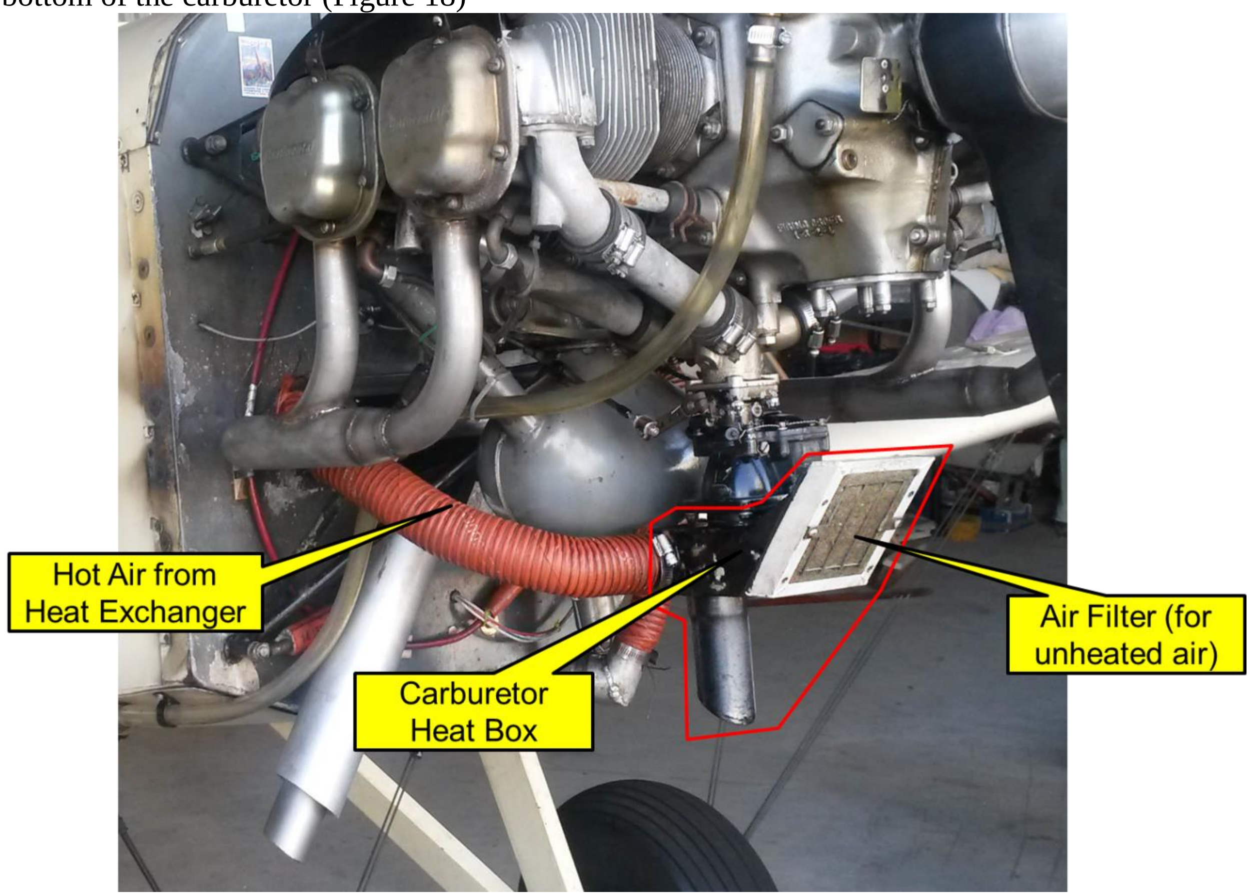

Figure 18: Carburetor Heat System

Normally, fresh air flows through the filter on the front of the box, and takes a 90-degree turn to go up the carburetor. A large "flapper" value inside the box is connected to a control in the cockpit. When the control is pulled, the flapper blocks the cold filtered air from up front, for air that has been passed through the heat exchanger. In the above photo, the heat exchanger is located on the back of the engine. Other configurations are also used (See Section 4.4)

These units are pretty standard and readily available.

Once you're flying, checking the proper operation of the carb heat system is vital for each flight.

3.5 Propellers

"What size of prop should I put on my Fly Baby?"

Seems like that should be a very simple question to answer, shouldn't it?

But it isn't. While prop manufacture, itself, is surprisingly straightforward, prop design isn't. And, by extension, finding the right prop for your Fly Baby isn't either.

3.5.1 Nomenclature

First, let's get some definitions out of the way. Props are identified by their diameter and their pitch...as in "72x48".

Diameter is easy enough...just the distance from tip to tip. The pitch is a bit more complex, but still pretty simple: It is the distance the prop would move forward in one revolution, assuming it has perfect "bite" into the air. Imagine the prop as a screw going into wood. If the screw goes 50" into the wood with one rotation, that's a 50-inch pitch. See Figure 19.

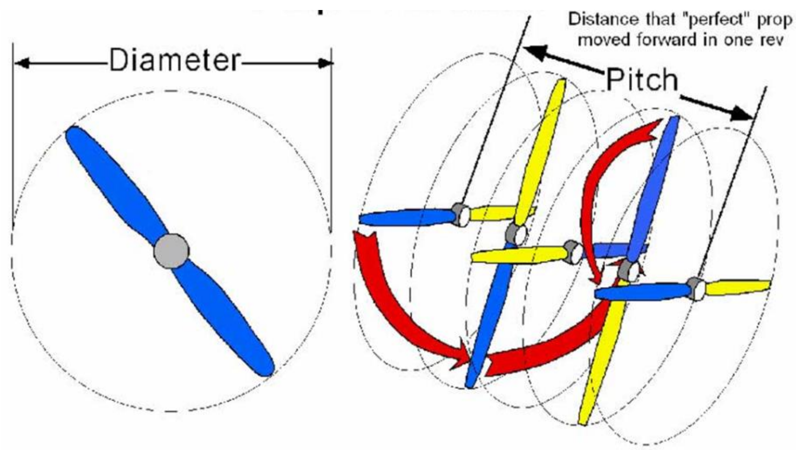

Figure 19: Prop Definitions

3.5.2 So What's the Problem?

If both have the same diameter and pitch, one propeller should be the same as another, right?

Take a look at Figure 20, illustrating three 72x48 props:

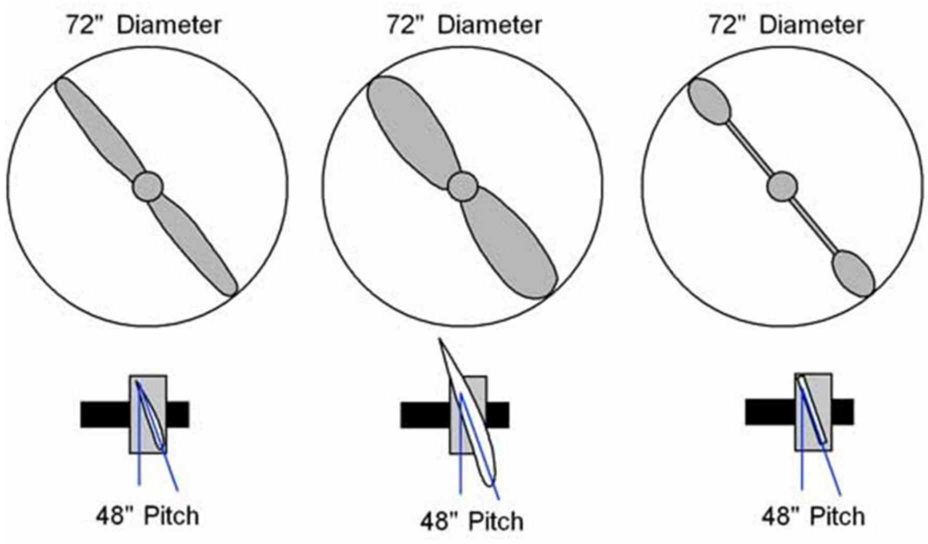

Figure 20: Prop Design Issues

All three props are the "same," from the marketing point of view. But obviously, they won't generate the same thrust!

And hence, here is where the difficulty lies: The pitch definition assumes the prop has perfect "bite" into the air, but in the real-world, these three props will actually grab the air quite differently. The middle prop will probably grab so MUCH air that the engine will lug down and won't produce maximum power. And the one on the right will probably be less effective than the typical ceiling fan. The one on the left might be OK...but a similar prop with less chord might not.

3.5.3 The Ugly Truth

The fact is, there is no propeller specification that establishes how efficient a given propeller is...that is, how well it produces engine power to thrust.

Without a specification, comparing propellers between manufacturers is meaningless. If the owner of Fly Baby N100A replaces his 70x43 prop carved by Joe Smith with a 70x43 built by Ed Jones, the chances that the airplane will perform the same are very small. Smith's may have broad blades, but Jones may have a skinnier design intended to allow the engine to turn up to full RPM.

Pete Bowers once surveyed Fly Baby owners to find out, among other things, their prop selection. You will see a surprising variation in the propeller specifications for the same engine. This indicates how the props vary between manufacturers.

Engine	Diameter	Pitch
A65	71	46
A65	71	47
A65	70	44
A65	68	50
A65	74	46
A65	72	44
A65	76	44
A65	72	42
A65	69	48

Engine	Diameter	Pitch
C75	72	44
C75	72	51
C85	71	48
C85	74	48
C85	74	51
C85	71	50
C90	72	42

3.5.4 Picking a Prop

So, how do you pick a prop? If your engine came with a propeller, you might as well consider that the starting point. An A65-powered Fly Baby should do fine with a Cub prop, or Aeronca prop.

Otherwise, selection is pretty easy. If someone else's Fly Baby is running a certified prop and your Fly Baby has the same engine, you should be able to run the same model of propeller.

Or you can order a new prop. You don't have to know what the propeller specifications should be. Instead, just tell the propmaker what you have, and want you want. "I've got a Bowers Fly Baby mounting an A65 with a tapered crankshaft, and I'd like a climb prop."

Most prop carvers have built units for Fly Babies before, so should have a good idea of the proper diameter and pitch for their particular blade shape(s). In most cases, wooden prop makers are able to do some amount of adjusting even after they deliver the prop. They'll send you the prop, and have you test fly it. If it's not letting you climb fast enough or cruise is too slow, they can then re-shape the blades accordingly.

Make sure you discuss the ability to make changes as you discuss the prop with the carver.

The Sensenich web page includes a lot of great technical information on propellers.

3.5.5 References to Tony Bingelis Articles

***See Section 8**:*

February 1973, page 35, "Propeller Sizing"
August 1986 page 28, "Propellers, Fixed Pitch"

3.6 The Starter Conundrum

So: You'd love to have a Fly Baby, but really prefer having a starter.

Back in the 80s and early '90s, I flew Pete's original Fly Baby, N500F, as part of an EAA flying club. It didn't have a starter, so I had to learn to hand-prop. I found it easy and (reasonably) safe, and flew quite happily for seven years. I was ~35 years old when I started flying this airplane.

About two years after Pete sold N500F, I bought my own Fly Baby. This airplane has a starter, and I've been flying it now for 23 years.

So I'm nearly 65 now…and after long experience with a starter-equipped Fly Baby, I wouldn't really want to go back.

So I don't blame you for NOT wanting an A65 without a starter. What can be done?

Get an A65-6,-9, or -12, which DO have starters? Great idea, but they were rare to begin with and have since been hunted to extinction.

Fly Baby engine guru Harry Fenton answers a lot of question on the Fly Baby engines page….

www.bowersflybaby.com/tech/fenton.html

… and the starter issue comes up quite often.

There ARE aftermarket starters for the A65. But it isn't easy…nor is it cheap.

I really hate to say this, but if you aren't willing to hand-prop the airplane, you'd better limit yourself to engines that include starters. Don't presume that you'd be able to add one to an A65.

If you DO decide to go with a starter-less A65, make sure you get dual instruction on hand-propping. And install a glider hook….

3.6.1 Tail Hooks for Hand-Propping

Hand-propping isn't that tough or dangerous...it's pretty easy, and you can always count on some shocked attention from people in the vicinity.

It's funny to consider, but most hand-prop accidents don't involve the person losing their footing or whatever and falling into the spinning prop (though it *is* a hazard to watch out for). Most hand-prop accidents involve the airplane getting loose and hitting something.

It's vitally important to secure the airplane when you're hand-propping. Attach tiedowns, use chocks.

However, after the engine's running, there's that awkward moment where you untie the last rope or remove the last chock, and you have to trot into the cockpit before the plane starts rolling away.

The best solution for hand-propping is a remote-release tail hook. This allows you to tie a loop in a tiedown rope, slip it into the hook, start the engine, climb into the cockpit, and release the tail hook by pulling a handle attached to a cable. These were originally made for towing gliders. Figure 21 shows an actual hook, and Figure 22 illustrates how it works.

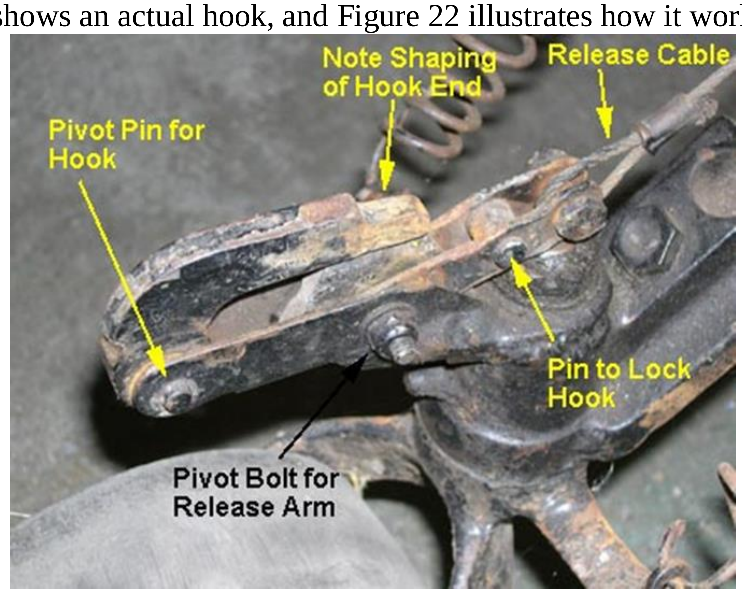

Figure 21: Glider Hook for Hand-Propping

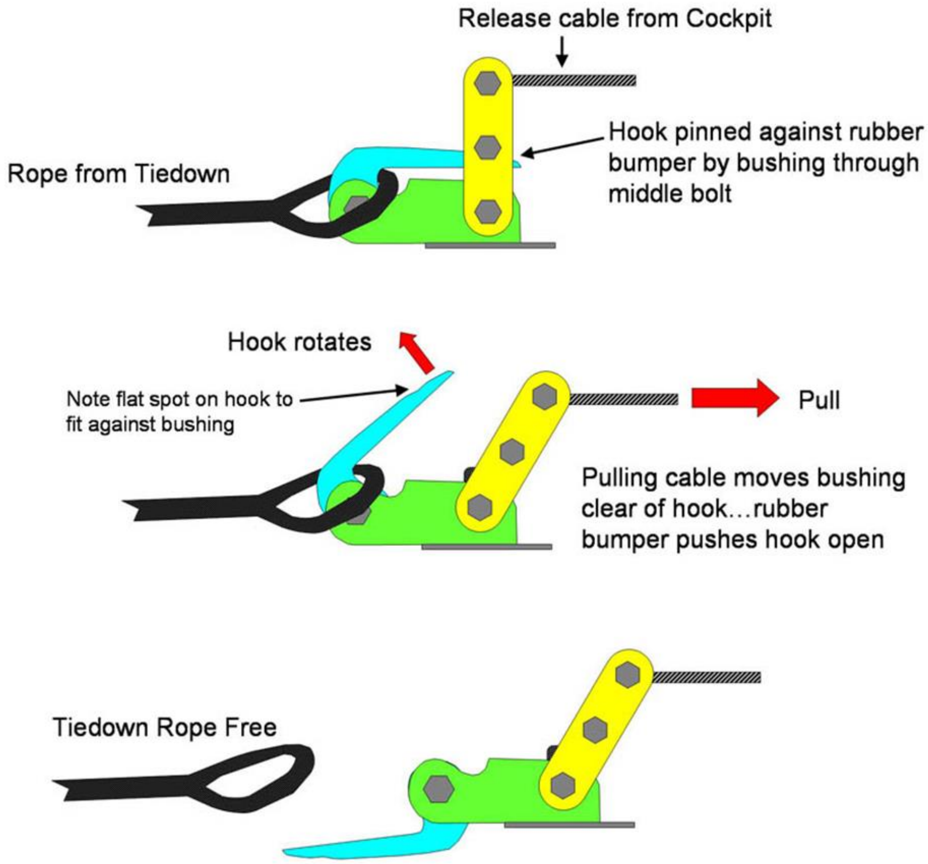

Figure 22: Tail Hook Operation

Anyway, the hook above is a commercial unit, available from places like Wag-Aero. Unfortunately, they charge about $250 for one of these. I've seen a number of Fly Babies and other homebuilts with scratch-built release hooks. They all seem to work OK. They basically have to be strong enough to withstand the thrust of the engine at full throttle (about 500 pounds or so), yet release with a fairly gentle tug on the cable.

R. S. Hoover designed the tail hook shown in Figure 23. You can find the drawings for this hook at http://www.bowersflybaby.com/tech/Tail%20Hook%20Drawings.pdf.

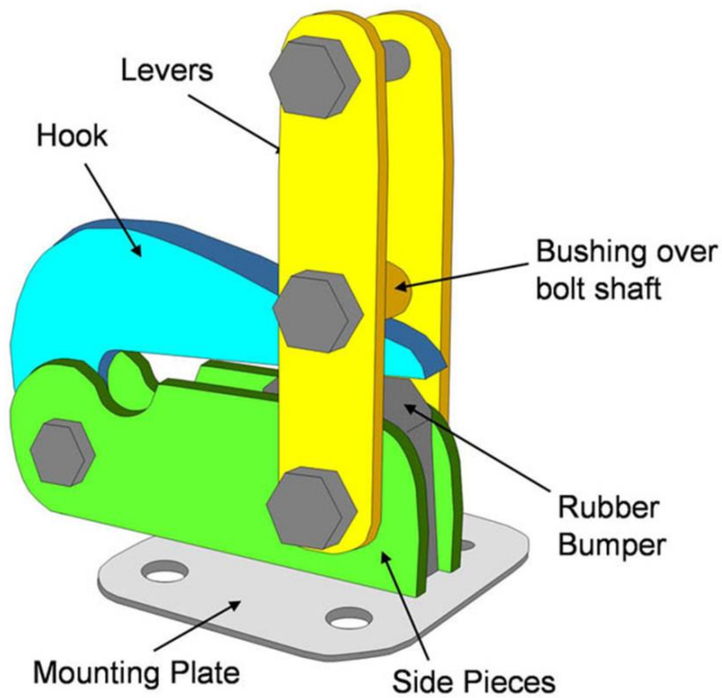

Figure 23: R.S. Hoover's Tail hook Design

4 CONTINENTAL INSTALLATION NOTES

The late Tony Bingelis built about ten homebuilt airplanes, and wrote hundreds of great articles to help folks like us be successful with their own airplanes. Some of these articles were collected in one of four books.

Mr. Bingelis used a Continental engine in at least two of his homebuilts, and many of his articles had a Continental slant. Section 0 in this Guide is a catalog of Tony Bingelis articles that Continental engine users may find useful.

This section has some of my own suggestions regarding installation of a Continental engine on a Fly Baby.

4.1 Firewall

We tend to use the term “Firewall” for just the bulkhead that separates the engine compartment from the main fuselage, but in reality, there IS supposed to be a “Fire Wall” there: Something to delay the effects of an engine fire from affecting the pilot long enough for the plane to reach the ground.

It’s something that probably will never be needed, but if it is…man, you want it. Certified aircraft are required to have a firewall that withstands a 2,000ºF flame for 15 minutes (14 CFR 23.1191). It’s a really good idea for Fly Babies, too.

In Article 7, Pete says the firewall can be formed from “0.020 inch aluminum, terneplate, or plain galvanized iron from the local tinsmith[6].”

While Pete says you can use aluminum, aluminum melts at about 1,200ºF. This wouldn’t meet the Part 23 requirement, though, of course, as a homebuilt the Fly Baby is not required to. Part 23 says the firewall should be made of the following materials:

- Stainless steel sheet, 0.015 inch thick
- Mild steel sheet (coated with aluminum or otherwise protected against corrosion) 0.018 inch thick
- Terne plate, 0.018 inch thick. (Terne plate is thin steel sheet coated with an alloy of lead and tin)
- Monel metal, 0.018 inch thick
- Steel or copper base alloy firewall fittings
- Titanium sheet, 0.016 inch thick

Stainless steel is the most common.

One of the things I might suggest is to put a layer of Fiberfrax between the firewall metal and the wood front of the airplane. Fiberfrax is a modern replacement for asbestos; it withstands temperatures of up to 2300ºF. Using it will delay the effect of any fire for a bit longer. It’s pretty cheap, about $30 for a Fly Baby firewall.

Cut the metal firewall about one inch wider than the firewall bulkhead, then slit the excess with tin snips and bend it back (Figure 24). It might be easier to pre-drill a hole where the slit is going to terminate.

[6] “Local tinsmith.” No doubt his shop is next door to the Five-and-Ten store.

Figure 24: Slitted/Bent Firewall Metal

Oh, and fair warning: Stainless steel is tough to drill and cut.

If you've modified the fuselage shape (such as adding stringers, etc. to make the fuselage more circular) the firewall has to match and overlap the new shape Figure 25. No airframe wood or fabric should be accessible from the engine side of the firewall.

Figure 25: Matching the Bulkhead Shape for the Firewall

Part 23 also requires that the openings in the firewalls of certified airplanes be sealed with close fitting, fireproof grommets, bushings, or firewall fittings. Not a legal requirement for a homebuilt, but a good idea nevertheless. Keep it in mind as you install stuff on the firewall, later.

4.1.1 References to Tony Bingelis Articles

See Section 8:
May 1989 Page 36: "Grommet Shields"
March 1990 page 29, "Stainless Steel Firewalls"

4.2 Engine Mount

Think about the Fly Baby firewall as it currently sits on your airplane. It's a 3/4" piece of plywood, glued to the ends of four 3/4" square longerons. Will that take the thrust from a rip-roaring A65 Continental?

Not hardly. It'd rip right out, bouncing down the taxiway to your dismay and the shock of the guy down the row with a Lamborghini parked by his hangar.

So this is where the angle mentioned in Article 4 comes in. This piece of angle is 1/8" thick, with each arm 1½" wide. You'll need two pieces, each 22" long. Each piece is bolted in with seven AN4 (1/4") bolts. The engine mount bolts go through the firewall and into this bit of aluminum, which solidly attaches the engine to the airframe. This is illustrated in Figure 1-16 in Article 4, and in Figure 26.

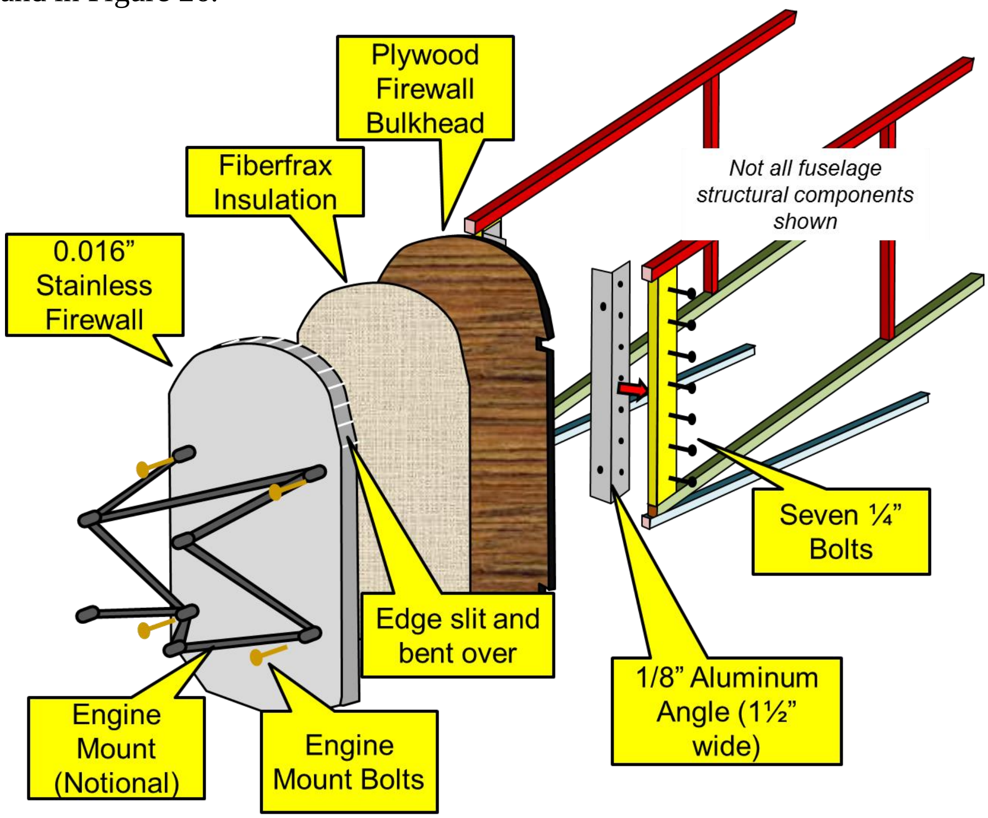

Figure 26: Firewall Assembly

As the figure shows, the bolts go through the locations on the engine mount, through the metal and plywood of the firewall, and into the 1/8” angle bolted to the fuselage uprights behind the firewall. Pete shows a notional engine mount design as Figure 5-2 in Article 7.

4.2.1 Finding an Engine Mount

You could built one (or have one built for you), but consider: As mentioned earlier, the Fly Baby was essentially designed around the J-3 Cub firewall forward. While no one is scrapping J-3s to build a Fly Baby these days, the fact is there’s a considerable amount of business in keeping the J-3s flying. A lot of companies make things like engine mounts, and the mounts will fit the Fly Baby. They cost around $700 or so, but you might well find something used at an aviation flea market or advertised online.

Whatever engine was previously bolted onto the mount doesn’t make much difference: The bolt pattern at the engine is identical on all four cylinder Continentals.

As mentioned above, -14 and -16 engines have multi-piece Lord mounts. This applies to the O-200 as well. However, the mounts are still interchangeable, but a spacer on the engine mount may be required to keep the prop flange at the same relative location.

So a wide variety of mounts from small Continental-powered light aircraft will work. The big thing when looking at these other mounts is that they have to bolt into the (approximate) centers of the two 1/8” aluminum angles that are bolted to the uprights in the fuselage behind the firewall. If the mount is from a side-by-side airplane (like a Taylorcraft or Cessna 120) it might be too wide to fit. If you find a good deal, an aircraft welder should easily be able to modify the mount to the right width.

If the mount is too narrow, they can modify it as well. However, Pete did have a quick fix for these kinds of cases. The bottom part of Figure 1-16 in the seventh article (reproduced as Figure 27 below) shows how a hardwood spacer can be inserted to narrow the spacing of the aluminum angles.

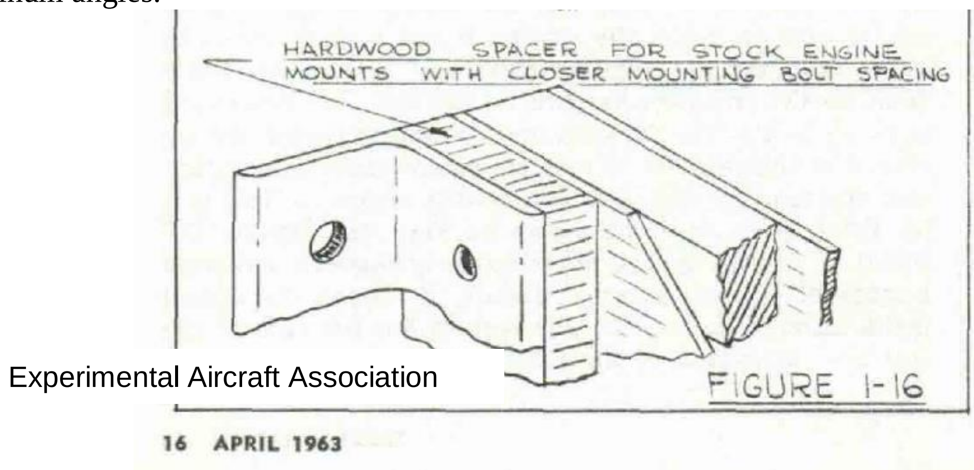

Figure 27: Adjusting Aluminum Angle to Accommodate Narrow Engine Mounts

Figure 28 shows the jig Jim Katz made for building an engine mount from scratch. The plywood panels are fixed in location with wooden spacers to hold the proper spacing and angles.

Figure 28: Jig for Welding Engine Mount

4.2.2 Accessory Clearance

OK, now: There's something you lucky stiffs with starters have to be concerned with.

The engine mounts from any small Continental engine will fit, BUT: The bigger accessory cases, and the need for having room to pull out the starter or generator, require more space between the engine and the firewall. As Figure 29 shows, you'll need at least $11^{5/8}$ inches from the engine mounting lugs to the firewall, to be able to remove and replace these components. The magneto requires only $8^{1/2}$". If modern, lightweight starters or generators are used, the clearances can be less

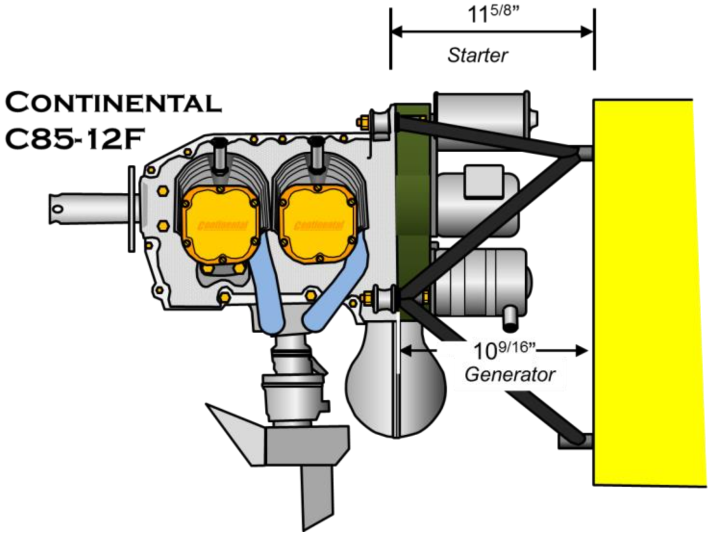

Figure 29: Clearance Required for Removal and Replacement of the Stock Starter and Generator on a Continental C85-12 engine.

Most engine mounts, even for the A65s, project the engine more forward for Center of Gravity purposes. But sometimes, there still isn't quite enough clearance behind the engine.

Figure 30 shows a very common solution: Adding a stack of washers between the engine mount and the engine case. A longer bolt needs to be used, but this trick is used on many aircraft. The picture, in fact, is of my own Fly Baby…and the same was done on Pete's original prototype when a C85 was installed.

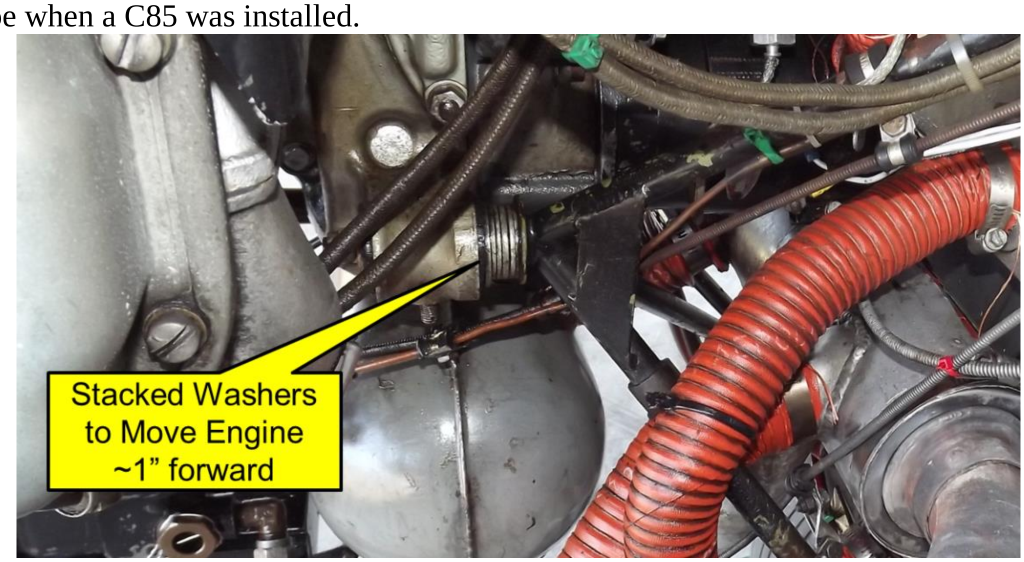

Figure 30: Stacked Washers to Give More Clearance

WARNING WARNING WARNING: Don't make your aircraft's cowling until you're convinced that there's enough room to remove accessories, and until you're happy with the engine location (CG issues, etc.). Adding/subtracting washers later, or changing the engine mount, would necessitate a whole new cowling.

Speaking of CG, while that extra inch further forward does move the CG forward (slightly), it's generally not a problem. Most planes tend to come out a bit tail heavy anyway.

4.2.3 Painting the Engine Mount

The engine mounts are typically made from 4130 steel, so they need to be painted for corrosion-proofing.

One trend has been to have the engine mount powder-coated. It applies a plastic layer of paint that is darn near permanent.

However, there is a drawback: The powder-coating is a bit flexible, and if the engine mount cracks, the crack may or may not be externally visible! Normal paints will crack with the steel. Makes the annual condition inspection a little easier.

So clean it, prime it, and paint it with ordinary enamel paint.

4.3 Cooling

Cooling the little Continentals can be simple…or a bit harder.

There are two approaches. The traditional one, with the cylinders hanging in the breeze, and the more-modern closed cowling system. Both are shown in Figure 31.

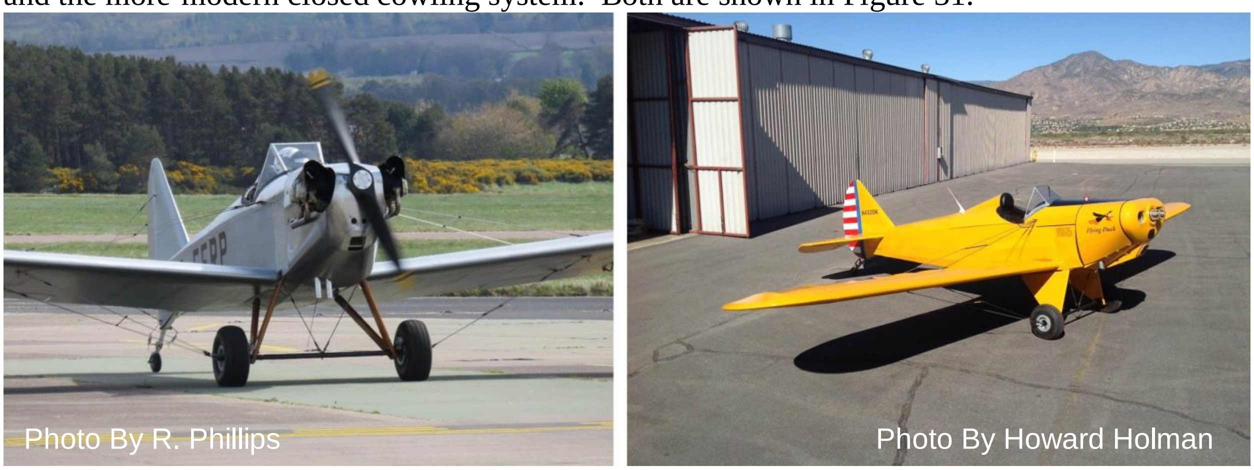

Figure 31: Traditional and Modern Engine Cooling Approaches

Both work—though the "modern" approach takes more effort—so it depends on your own personal preferences.

4.3.1 Traditional Cooling Approach

The traditional approach is that of the J-3 Cub and many of its contemporaries: Just hang the cylinders out in the breeze and let the wind cool them.

It works pretty well, and really is the least amount of work. All it takes is the addition of two aluminum or fiberglass "eyebrows" to route the cooling air past the engine.

Figure 32: Cooling "Eyebrows"

The eyebrows can be found commercially. In addition, the plans for them can be found at little cost through the Cub Club (https://cubclub.org/:

- Select "Technical information"
- Select "Blueprints"
- Open the PDF
- Search for "Eyebrow"

The cost is just $10, basically just the copying and postage.

The third option is to just build a set from scratch, using your own design. They're not complex, you can probably take some pictures of a Cub or other similar aircraft to see how they are made.

Eyebrows will be different between the A- series, C- series, and the C-90/O-200. The Cub Club drawings will be for the A65, but the drawings will give you a good leg up on working out the eyebrows for the larger engine.

There's actually supposed to be a small baffle between the cylinders, but many folks don't include it. You can see an example, and a good shot of the bracket at the cylinder bases that hold the eyebrows, at:
http://forums.matronics.com/files/img_1852_812.jpg

A lot of folks don't have them, and their absence doesn't appear to be causing any problems.

4.3.2 Modern Cooling Approach

Some folks don't like the "old fashioned" look of the cylinders hanging in the breeze. They like the smooth look of the modern "pressure" cowling (Figure 33).

Figure 33: Fly Baby with Pressure Cowling

Cosmetically, there's a lot to be said for them. Nowadays, few airplanes use anything BUT pressure cowlings.

That doesn't mean they've become simple to execute.

There's more to a cowling like this than just putting a big nose bowl at the front and wrapping aluminum around the rest. This isn't just a pair of eyebrows with a cosmetic cover. The air isn't just blowing past things randomly, it's getting put to work.

Take a look at Figure 34. The front of the cowl has the two familiar openings. These lead to the area above the engine called the "plenum". Other than the cowl opening up front, the air has only one way out of the plenum…it turns ninety degrees and is forced down through the cylinder fins (picking up heat on the way). The lower cowling has one opening, on the bottom at the back. The used air flows out here.

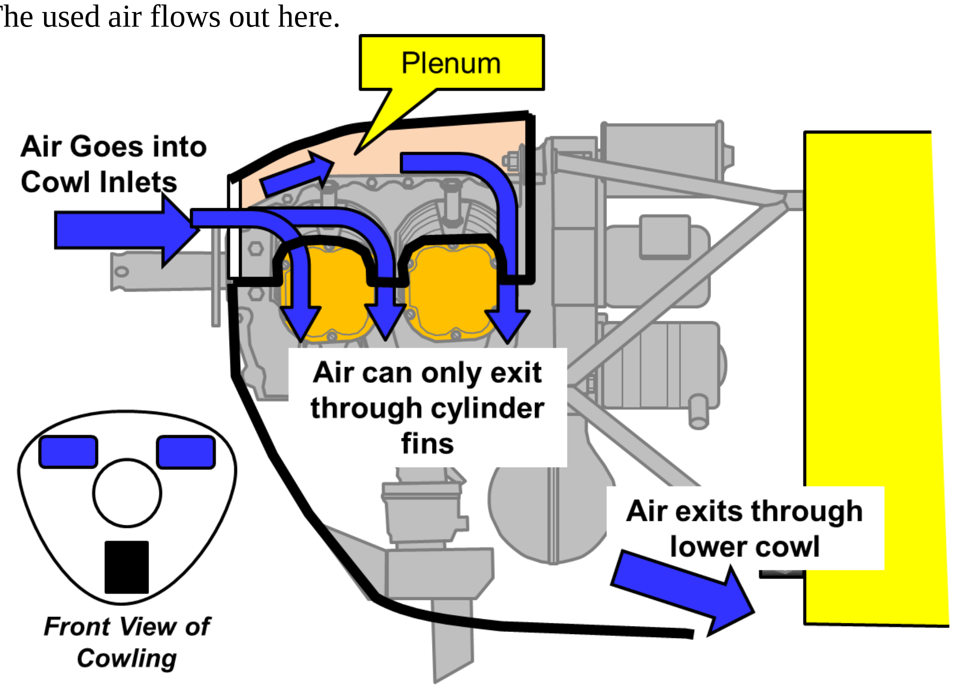

Figure 34: Pressure Cowling

The sealing of the plenum is vital to the cooling of the engine, but it complicated by the need to be able to remove the cowling for servicing the engine. As seen in Figure 35, the edges of the plenum have flexible seals installed so the area closes up when the top cowling is installed. If the seal doesn't work properly, the plenum leaks and cooling doesn't work as well.

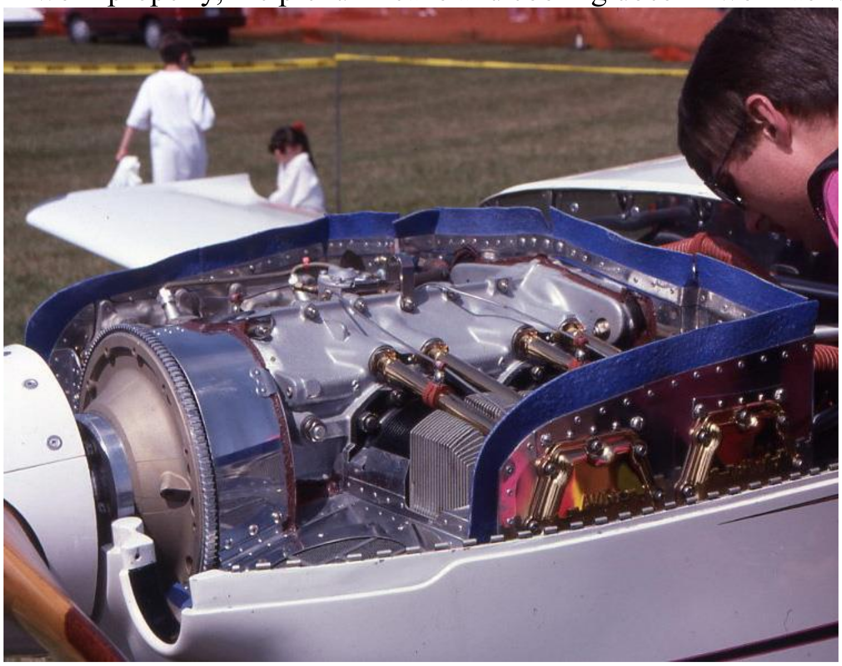

Figure 35: Typical Engine Plenum with Top Cowling Removed

Note, too, the bulkheads that have to be installed just inside the gold valve covers of the engine. The purpose of the plenum is to force air past the cooling fins on the cylinders, so the valve covers are walled off.

Now, there's nothing unusual about pressure cowlings. But they have to be done right, or the engine doesn't cool properly. Someone with a Vans RV will be working to standard templates (probably even kit parts), but if you're putting a pressure cowl on a Fly Baby, it's all up to you.

It's a lot more work than cutting out, bending, and attaching a set of eyebrows. Only go this route if you're sure the final product will be worth it.

4.3.3 References to Tony Bingelis articles

***See Section 8**:*

October 1973 Page 14: "Engine Baffles"
August 2993 page 38, "Engine Cooling"
October 1973 page 14: "Engine Baffles for C85 and O-200 Continentals"

4.4 Exhaust

Exhaust systems on Fly Babies can be just standard aviation units. There are three basic styles, as illustrated in Figure 36. The exhaust system also provides warm air for carburetor heat. Some sort of heat exchanger must be attached to warm outside air.

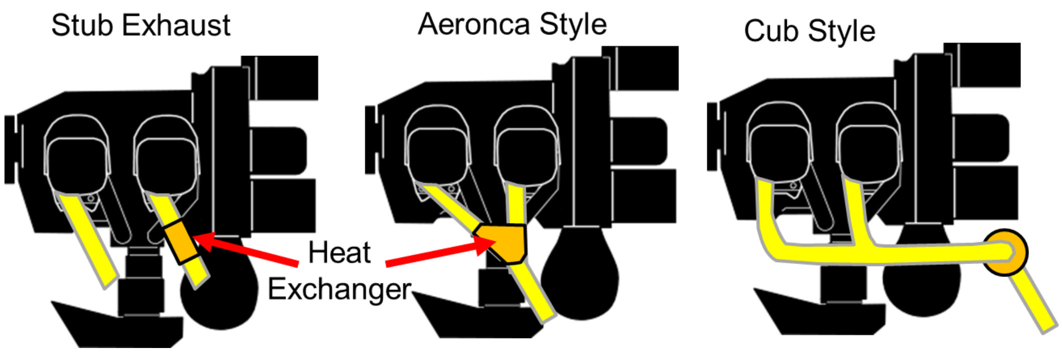

Figure 36: Exhaust System Styles

The Stub Exhaust just attaches four short steel tubes to the exhaust outlets of the four cylinders. The pipes ensure cold air doesn't hit a hot exhaust valve, and carry the corrosive exhaust gasses clear of the rest of the engine. A minimum 6" long tube is needed, and that's probably not short enough to route the gases from the engine.

Note that just one of the pipes in this example of the Stub Exhaust carries a heat exchanger to produce warm air for carburetor heat. The small size shown may not be sufficient; heat exchangers on more than one pipe will probably be necessary.

Aeroncas tend to join the two pipes together on one side. A short outlet pipe can be used (per this example) or a longer one attached to route the exhaust gasses more towards the bottom of the fuselage. The short-pipe version works for Cub-type cowlings, but if you go to a pressure cowling, you'll need to make more effort to get the hot gasses away.

Neither of these setups includes a muffler. Not much can be done for the straight pipes edition, but mufflers could be added to the ends of the "Y"-tubes on the Aeronca system. In this case, two mufflers will be necessary.

Instead, one could go with a Cub style exhaust. In this case, two double-J type tubes connect to the exhaust ports on the cylinders, and the J-tubes go into the end of a combination muffler and heat exchanger. A final exhaust pipe exits from the center of the muffler.

For what it's worth, a lot of A65-powered planes don't have mufflers.

I've got a Cub-type on my airplane, you can see it in Figure 37[7]. A stock J-3 exhaust will work for an A65-powered Fly Baby, but if you're running a larger engine you'll probably need one customized to ensure it misses the bottom of the generator.

[7] Why, yes, that IS a hole rusted through the "elbow" of the exhaust pipe. Thanks for noticing.

Figure 37: Cub-Type Exhaust System

4.4.1 Heater

Heater? In an open-cockpit plane?

Sure. The Fly Baby has a pretty snug cockpit. It's not as drafty as many open-cockpit planes, and the area around the pilot's lower torso and legs is usually pretty calm.

So a heater dumping its output into the front fuselage isn't as silly as it might sound.

My airplane has a Cub-type muffler/heat exchanger system, and it came with two heated-air outlets: One for carb heat, and the other for cabin heat. The airplane has a simple slide-valve control leading to an outlet on the pilot side of the firewall.

Does it keep me toasty in winter? No, even in the mild Seattle climate. But it does warm the front section of the fuselage enough so I don't have to wear heavy pants and boots.

Some builders add a long hose to the output of their heater and stuff it up the bottom of their flight jackets.

The heater valve installation on my airplane is shown in Figure 38.

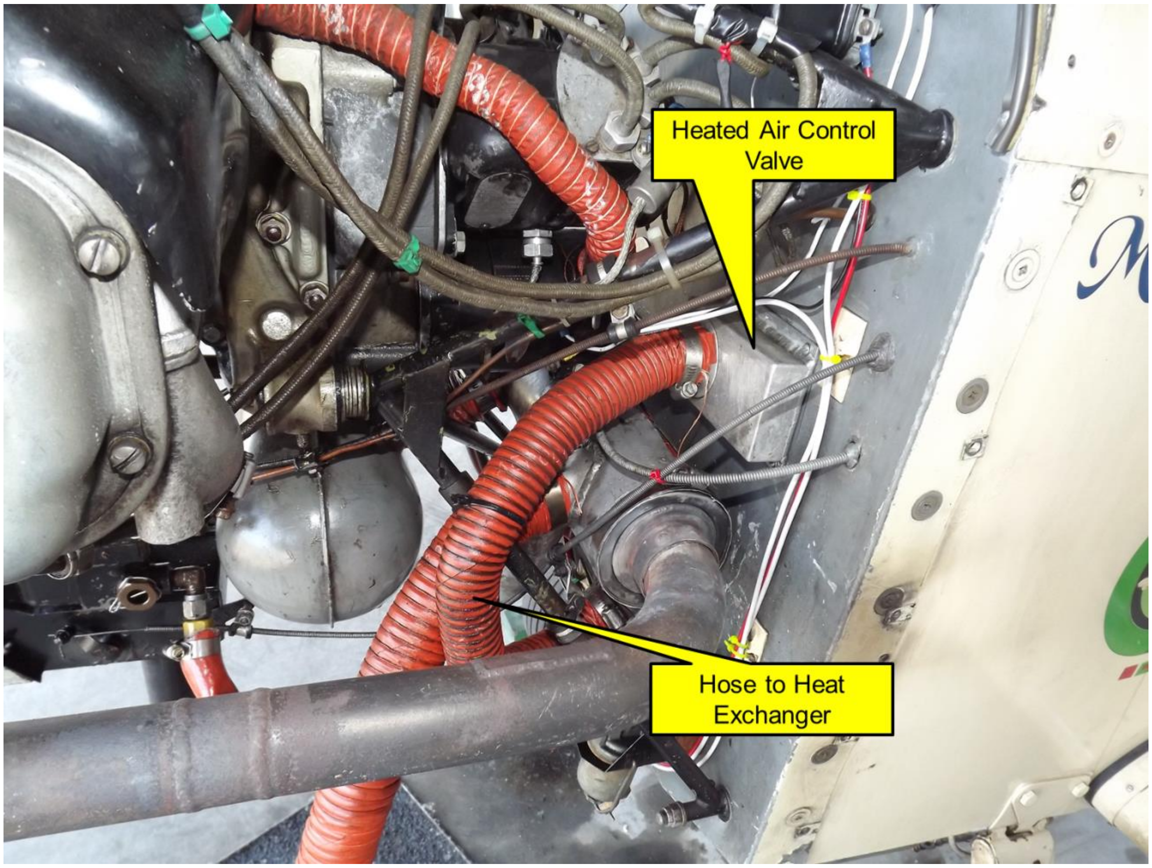

Figure 38: Heater Control

4.4.2 References to Tony Bingelis Articles

See Section 8*:*
November 1989 Page 40: "Exhaust Stack Painting"
July-October 1974, "Exhaust System Construction" parts 1-4
December 1992 page 82: "Exhaust Systems"

4.5 Cowling

Pete's plans for building the cowling are actually in Article 10 of the magazine series, in Figure 6-16. The cowling is basically a stock Cub cowling, with a Cub-type attachment system. It seems like cowling fits in better, here, so let's cover it in this Guide.

We'll be discussing on the stock Cub-type cowling here; if you're building a pressure cowl, see the Tony Bingelis references.

4.5.1 Construction

The Fly Baby cowling is pretty simple: A J-3 Cub "Nose Bowl" at the front, and two sheets of aluminum forming the top and bottom. The two halves the nose bowl are attached to the aluminum sheeting to produce an upper and lower cowling half (Figure 39).

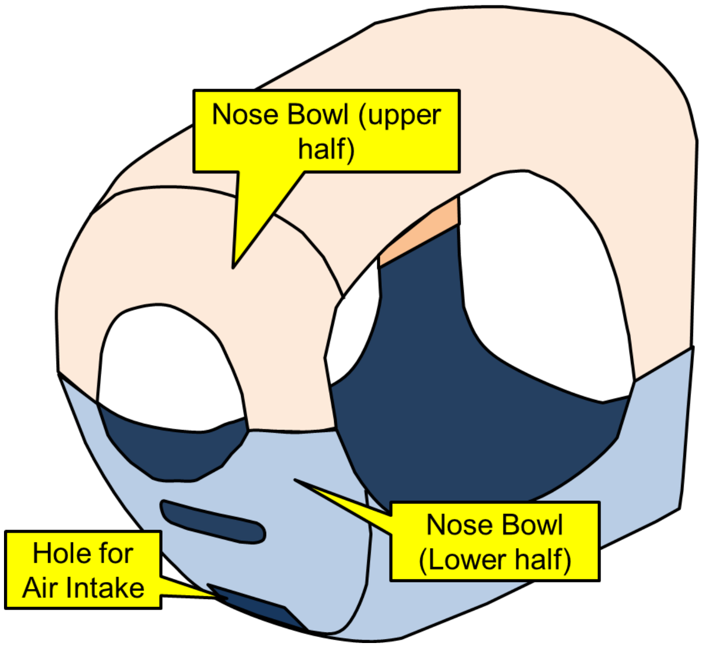

Figure 39: Sample Cowling

The nose bowl can be made from either aluminum or fiberglass. You could try to tackle making one yourself, but the commercial units would be a lot easier. Figure 40 shows the non-PMA[8] unit Wag-Aero sells for $250. They come up occasionally in the used market, too.

The nose bowl is split into an upper and lower unit. The two sides are attached to the upper and lower aluminum, typically by rivets.

Commercial companies like Wag-Aero, Aircraft Spruce and Specialty, and Univair sell full cowlings, too. However, these are generally PMA'd parts and are priced accordingly. Also, depending on your own engine installation, some of the mounting holes on the firewall end might not be right.

Figure 40: Wag-Aero J-3 Nose Bowl

In Article 10, Pete specifies 0.025" aluminum for the sheet part of the cowling. The top part of the cowling is pretty easy, since it just wraps around the curved forward turtledeck. The bottom cowl is more complex, since it meets the rectangular lower fuselage.

Obviously, you'd probably want to build a mockup first, using cardboard or similar material, to get the shape right before cutting the metal.

4.5.2 Overlap

The upper and lower cowlings do not just butt up against each other. They overlap by an inch or so. The fittings that attach the cowling to the airframe (pins, screws, etc.) should be installed through these overlap areas to hold both units. Figure 41 shows the overlap areas

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[8] "PMA" stands for "Parts Manufacturing Authority." Companies selling parts for certified airplanes must receive authority to do so from the FAA. Since the Fly Baby is not a certified airplane, a non-PMA'd part is perfectly OK.

between top and bottom. The top cowling always goes on top of the joined areas; this allows you to just remove the top cowling when working on the engine.

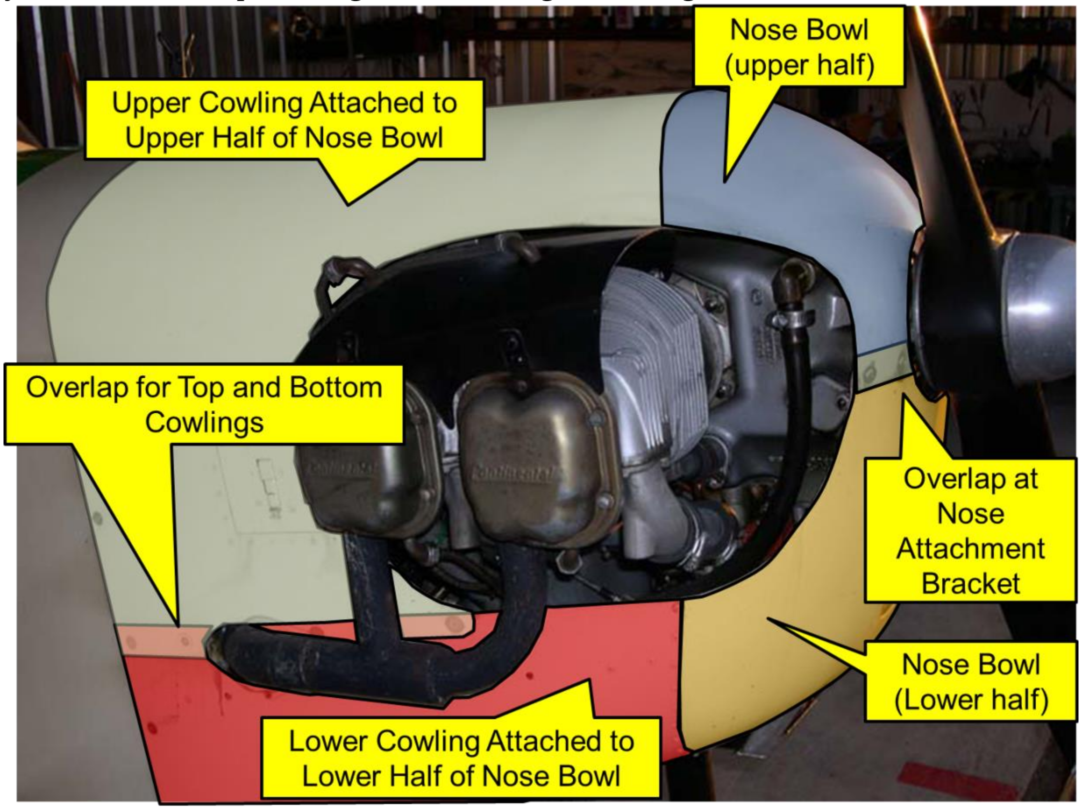

Figure 41: Overlap of Cowling Pieces

4.5.3 The Holes in the Cowling

The nose bowl will include one of the significant "holes" needed, such as a gap for the air intake (visible at the bottom of Figure 40). Depending on your particular setup, you may have to alter these holes a bit.

You might need additional holes for the exhaust, if you're using a Cub-type system. The exhaust tubing must enter the cowling to go into the muffler behind the engine. If you look at Pete's illustration 6-16, you'll see a circular hole behind the cylinder hole. This is for the exhaust pipe. Figure 42 shows the implementation on my own cowling…note the hole is kind of oval since my exhaust pipe curves in a bit. Note that the position of the exhaust pipe pretty much sets where the "split" between the upper and lower half of the cowlings goes.

Figure 42: Hole in Cowling for Exhaust Pipe

If you're using a stub or Aeronca exhaust, this additional hole won't be necessary.

The final set of holes is the big ol' ones: The ones for the cylinders.

In my opinion, there should be a good bit of room, here. The builder of my Fly Baby made the cylinder holes (Figure 42 above) a bit too tight. It looks good, but the ignition cables run a bit too close to the edge of the cowling. The section of the top cowling that curves forward under the cylinders is a bit of a pain, too. I have to carefully hook it around the cylinders whenever taking the cowling off.

To me, the right side is worse. The hole follows the cowling so closely that a separate door for accessing the oil cap is needed. How much time do you think it took to make that door? If you look at the pictures of the right side of J-3 Cubs, you'll see the cylinder opening on the right side is large enough that the oil cap can be accessed directly.

Figure 43 compares my cowling (with the oil-check door) with that of N500F, the original prototype Fly Baby. The right side opening on N500F is enlarged to the extent that the circular hole for the exhaust pipe isn't even needed. This size of hole also allows a better ability to inspect the engine during pre-flight, and even to do some minor maintenance without removing the cowling.


Figure 43: Cowling Comparison

It's up to you, of course. But I'd at least make the right-side hole big enough so you don't need a separate door for checking the oil.

4.5.4 Cowling Attachment

Figure 43 shows two different approaches for attaching cowlings. N500F uses the same method as the J-3 Cub, as described in Article 10. Two L-shaped brackets with ~1/4" pins are attached to the lower part of the firewall. The cowling portions have matching holes. A bracket is attached to the front of the engine, with two similar pins. Safety pins are slipped into cross-holes in the ends of the pins. That's a total of six pins that have to be pulled to remove the cowling.

On the right side…well, my cowling requires me to remove 15 screws and undo six dzus fasteners. It takes a bit more time, of course. Sure, it's sturdy, but the cowling on N500F has ~1500 hours on it with no problems.

Where things get a little tricky is the attachment at the front of the engine. Brackets of some sort usually attach the front of the cowling to the engine. C-series engines and the O-200 have provisions for tapped holes around the exit point for the propeller shaft. A steel bracket can be bolted here with appropriate connections.

A-series engines (normally) don't have these holes. Cubs attach a pair of triangular brackets to the through-bolts in the engine case.

These options are shown in Figure 44; a picture of the triangular brackets is inset at the lower right. This picture is of my own C85, and the bracket using the tapped holes is visible. One caution: When installing things this close to the propeller, make sure they're solidly secure! Safety wire as needed.

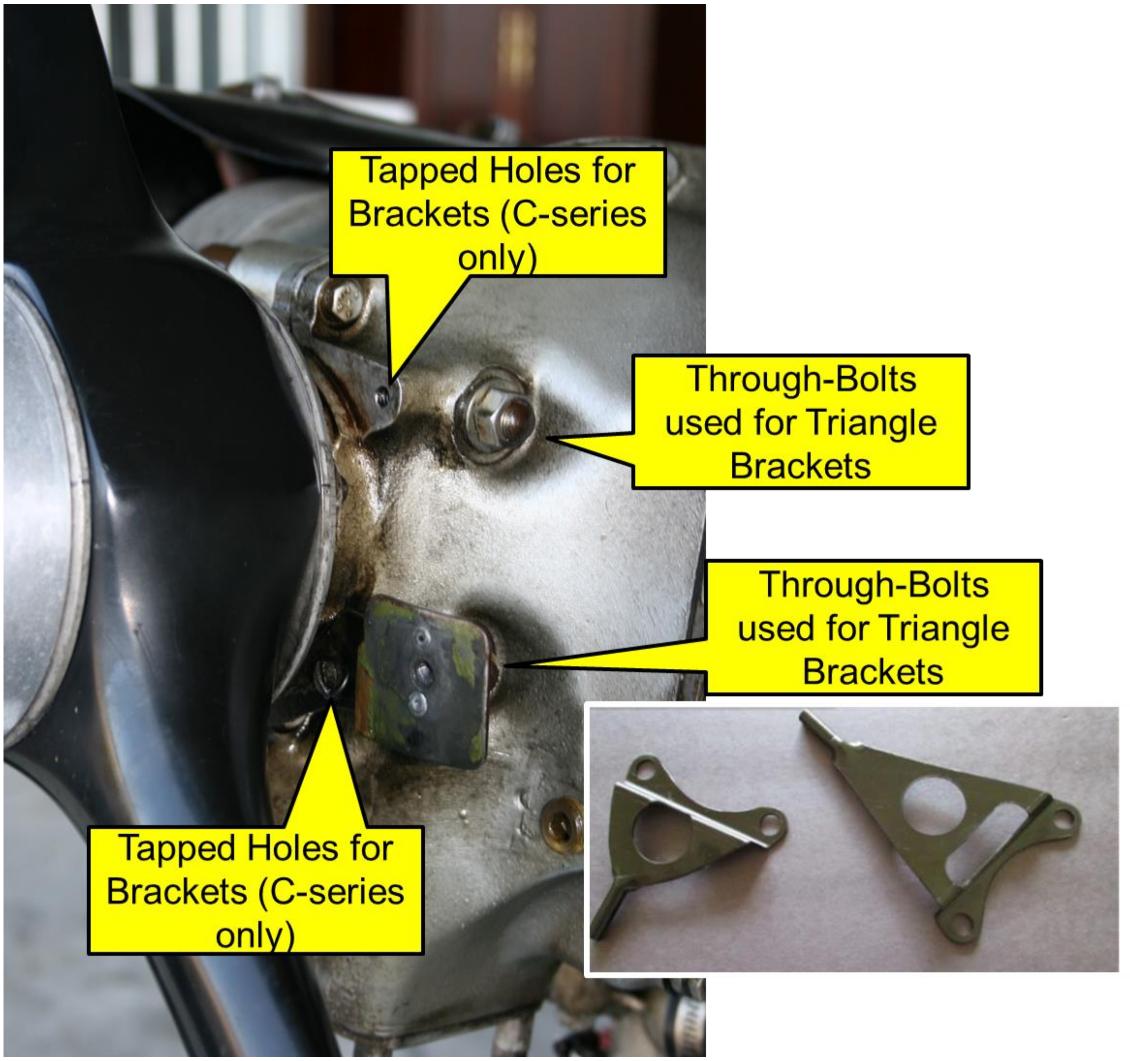

Figure 44: Cowling Front Attachment Options

The final option is to NOT include a front cowling attachment. Figure 45 shows Ross Bowden's cowling. The top and bottom cowling halves attach to each other in front, but there is no bracket holding the joined section to the engine. Instead, Ross added many attachment screws at the firewall.

Note that this is the same approach used by some production airplanes, so this isn't that unusual. It has the advantage of isolating the cowling from engine vibration. It has the drawback of having to extract ~25 screws from the cowling to remove it.

Figure 45: Cowling Without Forward Attachment

4.5.5 References to Tony Bingelis Articles

See Section 8:

February 1974 Page 51: "Cowling Installation"
May 1986 Page 23, "Cowling Installation"
October 1996, "Cowling Installation Notes"
October 1973 page 14: "Engine Baffles for C85 and O-200 Continentals"

5 FUEL TANK

In Article 7, Pete recommends a J-3 Cub fuel tank.

Certainly a good option. However, a J-3 tank is just twelve gallons capacity. It'd be nice to carry a bit more, especially as engines like the O-200 burn about 5.5 gallons per hour.

5.1 Design Considerations for Fuel Tanks

No matter what they're made out of, Fly Baby fuel tanks look pretty much like Figure 46.

The forward fuselage where the fuel tank sits has a rounded turtledeck on top, hence the tank top should be rounded as well. It doesn't have to be an exact, or even close match, but having the tank top rounded puts the filler neck closer to the outside of the fuselage. If you use a flat-top tank, you're not only giving up some capacity, you'll need a much longer filler neck. Things vibrate with the engine running, and the longer the filler neck, the more likely something will eventually crack.

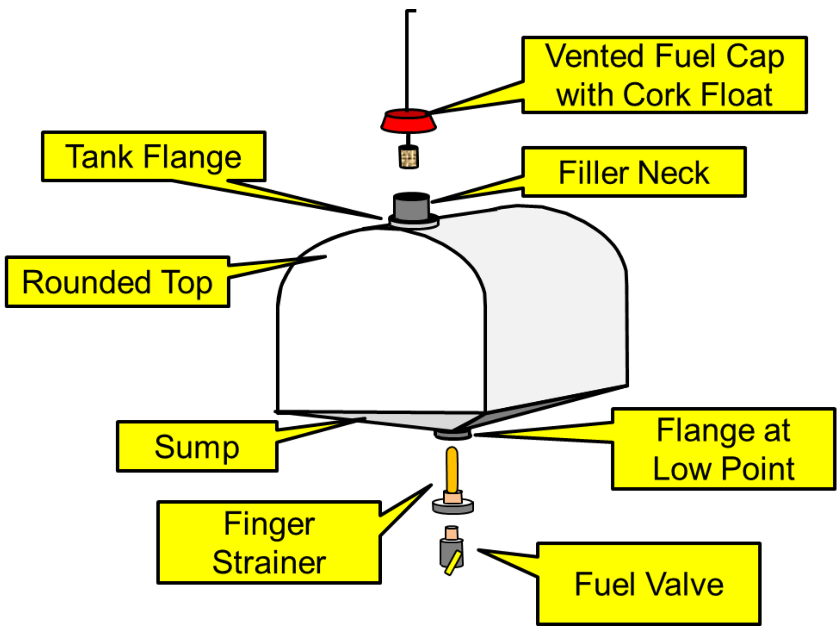

Figure 46: Typical Fly Baby Fuel Tank

The bottom of the tank MUST have a low point, the sump. *This point must be the lowest when the plane is sitting on the ground in three-point attitude*. Why? If water gets in your fuel, it collects at the lowest point of the fuel system. If the sump is the lowest point in the fuel tank, the water goes there, and eventually down to the gascolator where it can be removed. This is illustrated in Figure 47.

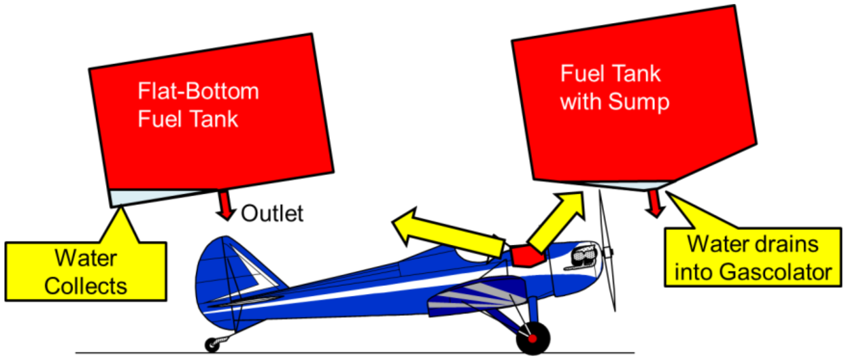

Figure 47: Fuel Tank Sump Helps Remove Water from Gas

Built-in to the sump is a metal flange with a threaded opening. A Finger Strainer is inserted here. The Finger Strainer is a mesh tube, very much like a finger. It eliminates the larger contaminates before they enter the rest of the fuel system.

Figure 48 shows the bottom of a commercial Fly Baby fuel tank. Note how the bottom tapers and has a small cylindrical sump as well. The threaded fitting for the finger strainer is clearly visible.

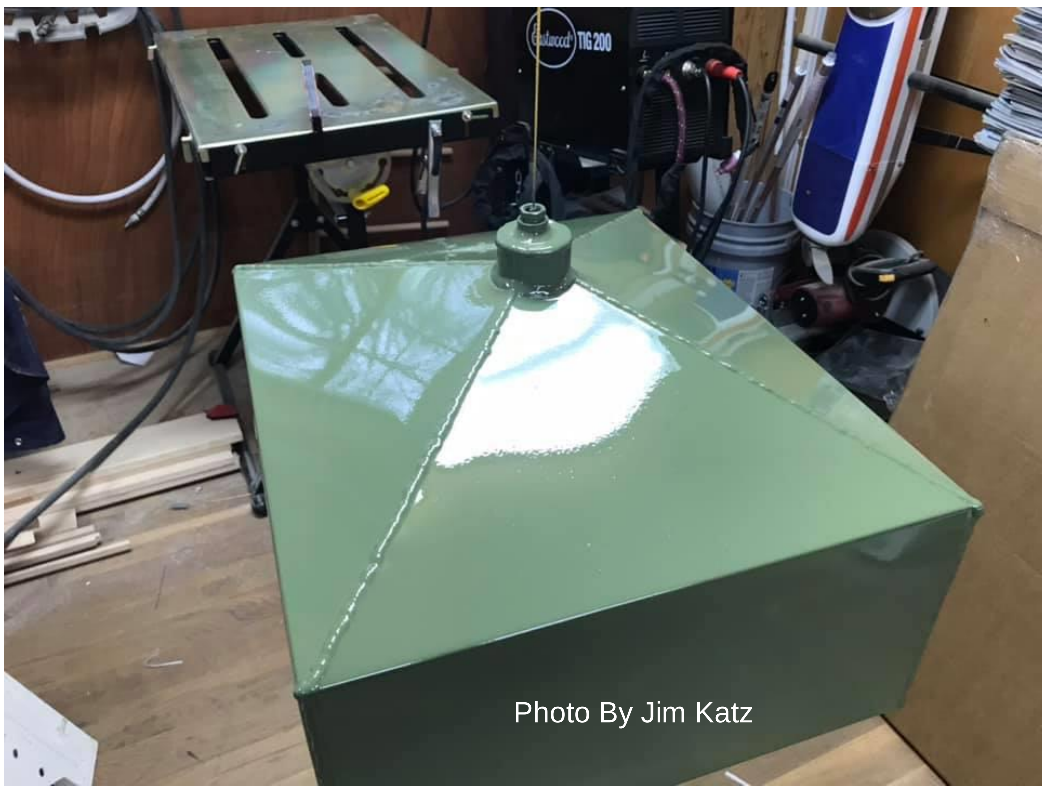

Figure 48: Bottom of Fuel Tank

The fuel valve is attached at the very bottom. A valve is necessary both during emergencies (such as an engine fire) and for routine maintenance, such as cleaning the gascolator. It may attach directly to the finger strainer, or at a lower point with a bit of tubing.

Another, larger flange is attached to the top of the tank. The fuel filler neck screws into this, topped by the fuel cap.

5.2 Fuel Gauge

Most Fly Babies (but not all) use a Cub fuel cap, which includes a wire and cork float for showing the fuel quantity (Figure 49). The metal tube that the wire slides through is large enough that it acts as a vent as well, so none needs to be added to the fuel tank. It's basically an off-the shelf item

Figure 49: Combination Fuel Cap, Vent, and Gauge

Occasionally, the cork will need to be recoated with shellac.

A few Fly Babies have used sight gauges…these are lengths of clear tubing connected to the fuel tank that allows the pilot to physically see the fuel level. Usually, in these cases, a vented fuel cap is used.

An electric gauge could be installed, but I haven't seen many in Fly Babies.

If anything but a Cub cap is used, be sure the fuel tank has enough venting. Air has to get in as the fuel gets pulled out.

5.3 Bulkhead Fitting and Gascolator

Punching a hole in the firewall for a rubber fuel hose is a bad idea…not only does it hurt the sealing of the firewall, the edge of the firewall material might eventually grind through the hose.

So a metal fuel fitting is installed on the firewall. It goes into the gascolator on the engine side. The gascolator is installed on the bottom of the firewall, at the lowest point in the fuel system even when the airplane is sitting on the ground in three-point attitude (Figure 50). Water and contaminates will collect in the bottom of the gascolator, where they can be drained off using the standard aviation "quick drain" installed in the gascolator cup.

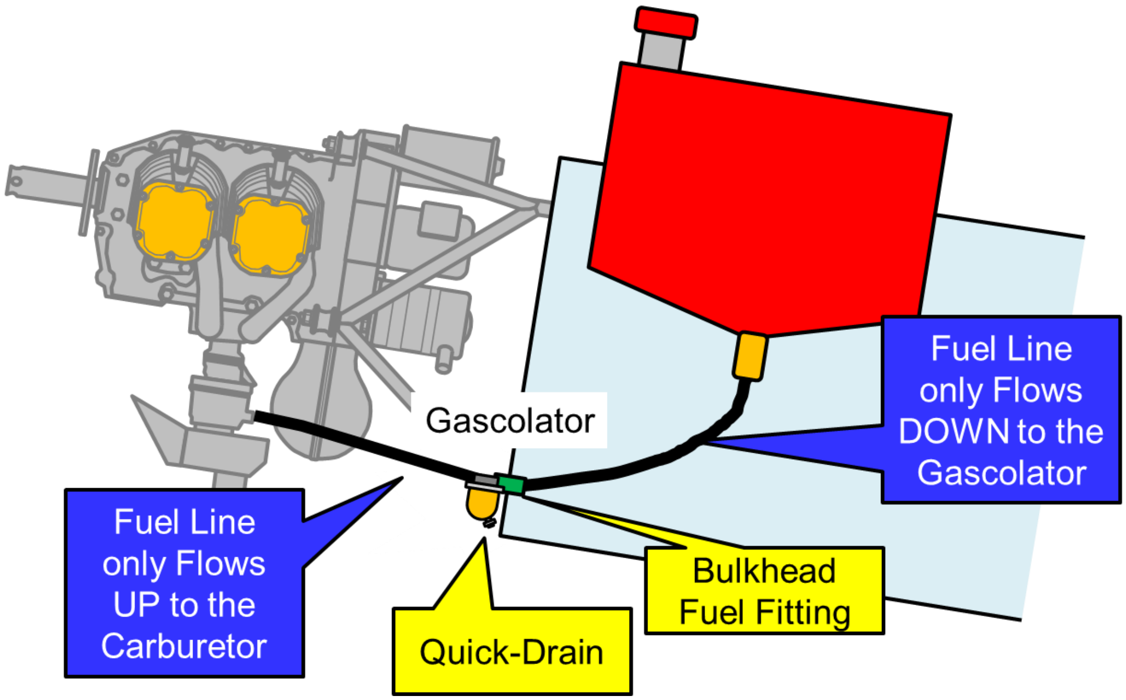

Figure 50: Gascolator Installation

Note the way the fuel lines flow… down from the fuel tank to the gascolator, and up from the gascolator to the carburetor. This means any water or other contaminates slide down the first hose into the gascolator and will collect there. Check the quick-drain before every flight, and during the Condition Inspection every year, shut off the fuel valve, and remove the gascolator cup to clean out any sediment and clean the gascolator screen.

Why is it important that the fuel line runs UP from the gascolator to the carburetor? If fuel gets too warm, it tends to convert to vapor, which collects in the high point of the fuel system. If the carburetor ISN'T the high point, the flow of gasoline may stop, a condition referred to as Vapor Lock.

While it might be tempting, don't install the gascolator so the quick-drain (or any portion) of the fuel tank is projecting below the firewall. This unfortunately means you'll have to cut a largish hole in the bottom of the cowling to get access to the quick-drain with a sample tube during preflight. This FORTUNATELY means that, if the plane crashes so hard the landing gear fails, that the gascolator WON'T be ripped off the airplane and start spilling fuel.

This last item is considered a good thing. None of us want to crash, but if it happens, we hope to minimize the threat of fire.

Finally, note the position of the fuel filler neck. It's installed on the forward end of the tank. A moments thought should show that this allows the tank to be more-completely filled….if it were at the back, the fuel would be to the bottom of the filler neck before the front of the tank filled.

5.4 Tank Sizing and Positioning

With the fuselage sitting yawning in front of you, it might seem like there's a lot of room for the fuel tank.

But note, in the illustrations above, that the fuel tank is not installed directly against the front of the fuselage. There are controls, wires, and hoses that need to come through the firewall and feed back towards the cockpit. There has to be room to pass around the fuel tank.

You'll also need room in front of the instrument panel, to fit the gauges. Plus any radios, transponders, etc. if you're installing them in the panel (Figure 51).

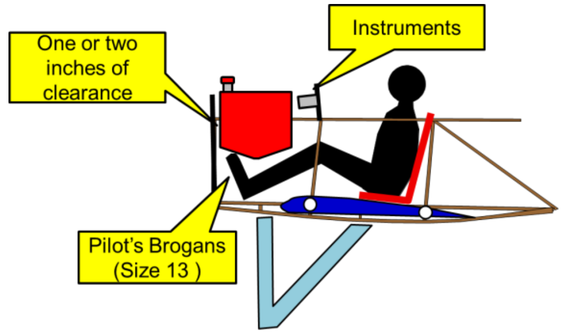

Figure 51: Fuel Tank Clearance

Figure 52 shows the installation of the fuel tank in my own Fly Baby. The top of the firewall bulkhead has the standard 3/4" reinforcement installed, and it's obvious the fuel tank is about a quarter-inch short of the plane of this arch. So there's about an inch between the back of the firewall itself and the fuel tank.

Figure 52: Fuel Tank Clearances

Figure 53 shows a measurement of the clearance between the fuel tank and the panel on my…just six inches at roughly the mid-height of the panel (since the panel slopes, there's slightly more room below, slightly less above).

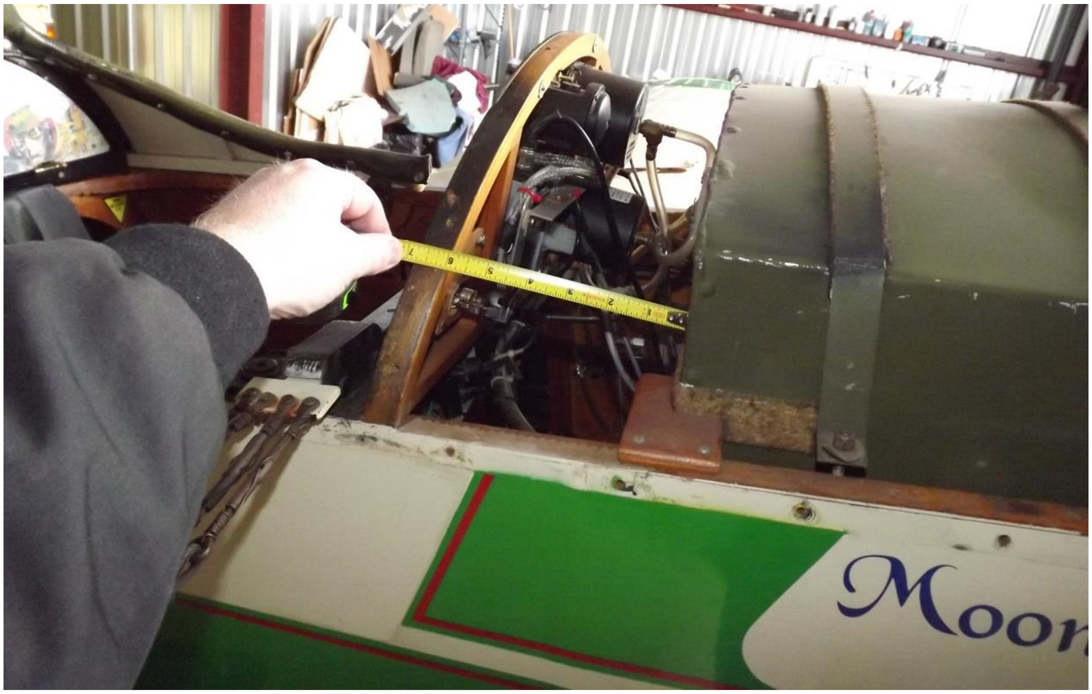

Figure 53: Fuel Tank to Instrument Panel Clearance

Most radios, <u>when the coaxial connector is attached</u>[9], require about seven inches. My Microair Transponder required additional room, so when I reworked my panel, I installed a wooden mockup ("Mapleair") to test whether there was enough room (Figure 54)

Figure 54: Wooden Mockup of Transponder for Fit Check

The final point of concern is the vertical space. Of course the tank can't exceed the shape of the forward turtledeck above it. But don't forget: Your legs and feet are going to be below it! If it's too deep, you won't be able to work the rudder pedals. One builder discovered that with the gas tank in place, his toes were actually touching it. He had to acquire another tank.

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[9] This is a very important point. Just don't work from the listed depth of the radio itself; the co-ax will require at least another inch of depth.

So, it wouldn't be a bad idea to mock up your fuel tank before actually buying one or building one. Thin plywood would work, even foam core.

5.5 Acquiring the Fuel Tank

You have two basic decisions: Buy or Build.

5.5.1 Buying a Fuel Tank

Pete specifies a J-3 fuel tank because, again, back then they were common and inexpensive. They're still made now, so it's easy to get one.

However, the Cub tank is only 12 gallons, and it's always better to carry a bit more. Many sources sell "homebuilders fuel tanks", which might be the better way to go. Aircraft Spruce and Specialty actually sells a fuel tank for Fly Babies (Figure 55). It's Part Number 05-18900, and as of this writing, sells for $516. That's about the same as the Cub tank.

Figure 55: Aircraft Spruce and Specialty Fly Baby Fuel Tank

One thing that has been mentioned occasionally is buying non-aviation fuel tanks, specifically fuel cells for auto racers. These can be attractive, with the prices not too bad, a wide variety of capacity, and provisions to reduce the potential of fuel ignition in an accident.

The drawback? They usually rectangular blocks. It's designed to sit flat in a car. This makes them more difficult to achieve a working installation in an airplane.

If you install it under the curved turtledeck it'll need a long filler tube to put the gas cap outside the airplane. This is illustrated in Figure 56. That long neck will tend to shake with engine vibration, and you could end up with cracking.

Depending on the type of fuel cell, the filler opening may be offset to one side. You then may not need as long of a neck.

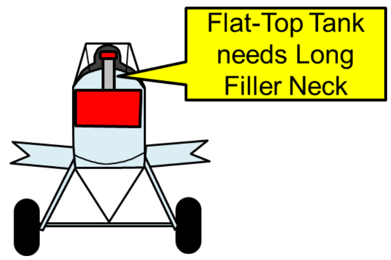

Figure 56: Long Filler-Neck Needed with Racing Fuel Cell

The other drawbacks on these tanks is the sump…if any. Some don't have one, and if it does, it may not be well suited to installing in an aircraft. Most of these fuel cells seem to have the fuel fittings sticking out horizontally off the end of the tank. If the sump is position on the low side of the airplane when it's sitting in three-point attitude on the ground…that means it's point at the pilot, not the engine (Figure 57). Rather inconvenient for running the fuel line.

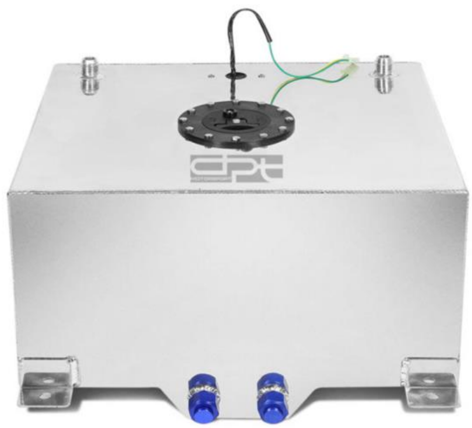

Figure 57: Automotive Fuel Cell

If it has a sump, it's likely small…cars generally don't need one. It may tend to starve the engine if the fuel is low and the airplane is in a nose-down glide (Figure 58).

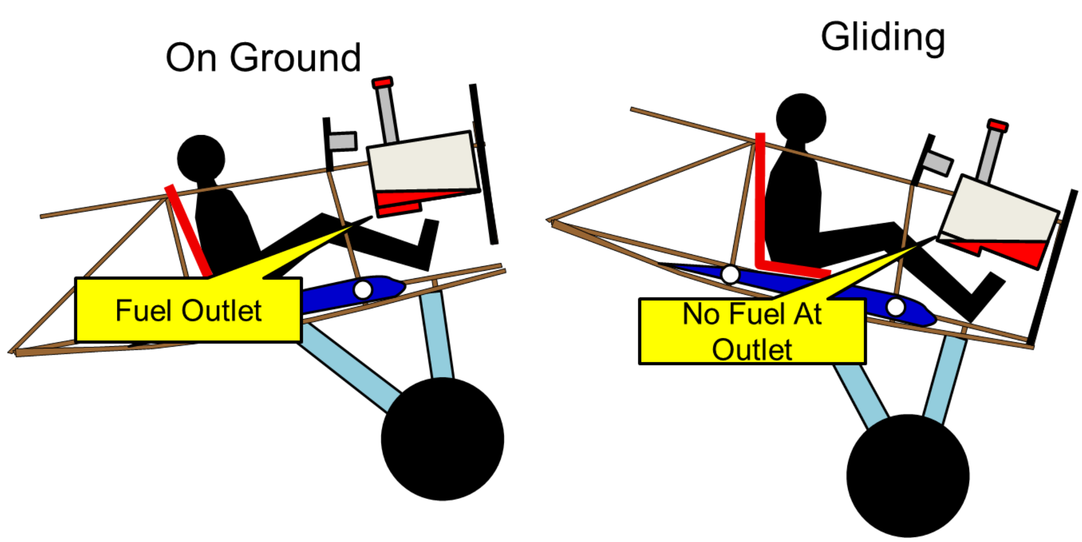

Figure 58: Fuel Starvation of Flat-Sump Engine During Glide

What it boils down to is an increase in unusable fuel. You'll have to determine the point at which the tank cannot supply fuel in any normal attitude, and set your gauge appropriately.

Now, I don't believe this problem is insurmountable. But it's something you'll have to account for, if you want to use a racing fuel cell in the airplane.

Frankly, I'd love to see it done. However, be advised: These fuel cells aren't any cheaper than standard aircraft fuel tanks.

5.5.2 Building Fuel Tanks

Fuel tanks for homebuilt aircraft can be made in a variety of ways, with a variety of materials. Builders have used aluminum (generally the softer alloys), thin steel, and fiberglass. They can be welded, riveted, or bonded. All will produce an acceptable fuel tank.

The various flanges, etc. are very available through the homebuilder supply houses such as Aircraft Spruce or Wag-Aero.

Again, build a mockup of plywood or foam core before spending the time on actual fabrication.

5.6 Installing the Fuel Tank

Pete shows some suggestions for installation in Figure 5-5 on Page 19 of Article 7. It's really going to have to depend on your actual fuel tank, though.

Remember, the mount doesn't have to just handle the weight of the tank. Or even just the weight of the tank and the fuel. You're going to have to design the mount so it withstands the fuel weight at a ~6G load…About 600 pounds. Figure 59 shows one of the mounts being installed in Jim Katz's Fly Baby. This is per Pete's diagram in Article 7.

Figure 59: Fuel Tank Supports

AND you'll need straps to hold it in position, too. Not to -6 Gs, but certainly it should hold for negative three Gs. Jim Katz used .035 4130 steel for his straps. You can see them back in Figure 55.

Finally, make sure the tank is protected against the straps. The fuel tank will always be shifting around slightly (from engine vibration if nothing else) and over time, a metal strap can cut right through an aluminum or fiberglass tank. There needs to be padding installed.

See the Tony Bingelis articles referenced below for details on the fuel lines.

5.7 Fuel Flow Test

Even if the fuel system seems properly designed and built, there is the potential for undetected restrictions in the lines. A large majority of first-flight accidents on homebuilts are due to fuel system issues, so it's best to test to ensure sufficient fuel will flow. The Fly Baby's gravity flow system is reliable, but it's best to check.

To test the fuel system, place the aircraft in an attitude roughly equivalent to flight. Just roughly speaking, it'd look to put the main wheels ~one foot higher than normal, with the tailwheel still on the ground. This is just an approximation.

Ideally, the plane won't have any fuel in it at this point. Ensure the fuel valve is off, and disconnect the fuel line at the carburetor. Hang the end of the line low, and place it in a fuel container. Open the fuel valve, and pour two gallons of gasoline into the tank.

Now, the tank is going to have an "unusable fuel" point. Watch the gas coming out, and when the flow stops, shut off the fuel valve. Measure the fuel that came out…that about subtracted from the two gallons you poured in will give you your unusable fuel measurement[10].

Pour the can with the drained fuel into another container, and prepare a fuel can with exactly one gallon of gas. Move the disconnected end of the fuel line to the same height as the carburetor (off to the side slightly), and place the end into a catch-can at that height.

Pour the single gallon of gas into the tank. Replace the cap[11]. Then open the fuel valve while starting a timer. Stop the timer when the one gallon of fuel has entered the catch-can.

The FAA standard is that the fuel system be capable of feeding fuel to the engine at 150% of the full-throttle fuel consumption rate. For the C85, the full-power fuel consumption is about 8.3 gallons/hour, while for the O-200, it's 11.3. So if one assumes a desired flow rate of 12 gallons/hour, and adds the FAA's 50% margin, it should encompass all expected engines. This means that the one gallon should make its way to the catch can within three and one-third minutes. Figure 60 illustrates the test procedure, and provides the timing for typical engines.

[10] It's entirely possible that your unusable fuel is MORE than two gallons. If nothing comes out, pour another gallon in.

[11] The cap is important, because the only vent for your tank is likely the area around the wire that has the cork on it.

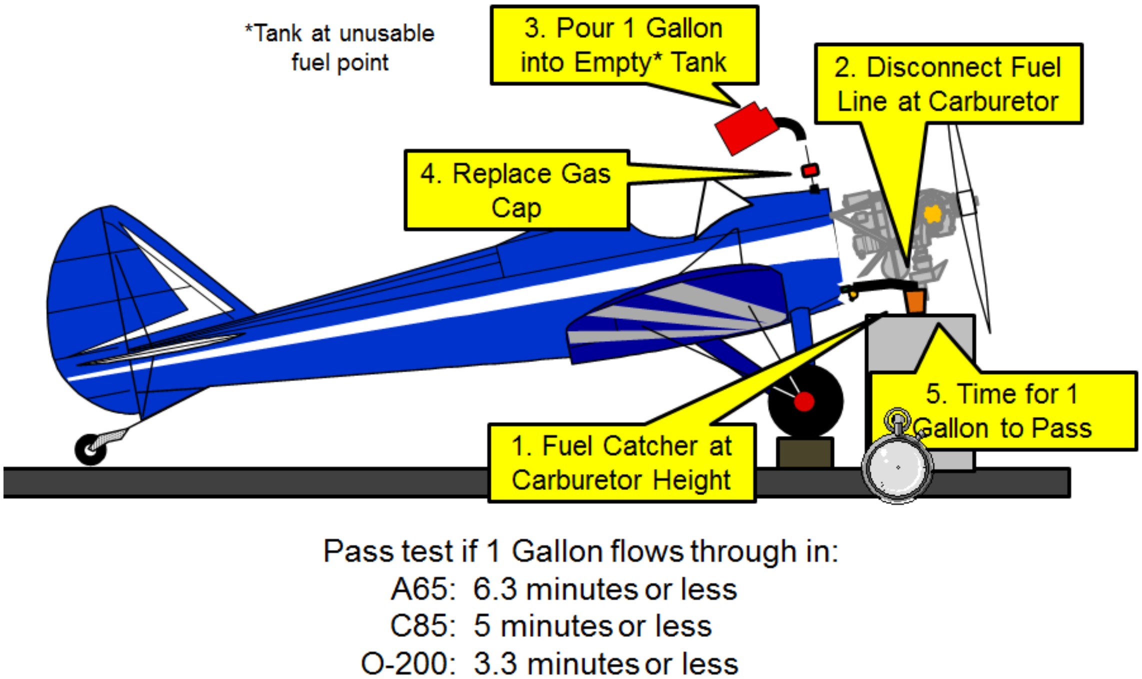

Figure 60: Fuel Flow Test

5.8 References to Tony Bingelis Articles

Tony Bingelis wrote a number of articles on fuel system design and construction. One is available at:
https://www.eaa.org/en/eaa/aircraft-building/building-your-aircraft/while-youre-building/building-articles/fuel-systems/how-about-an-aluminum-fuel-tank

He had a major series on fuel tank design and construction from August to December 1982.

He had a great article in March 1973 (Page 16), "The Gravity Flow Fuel System." This is the how-to for Fly Baby fuel systems.

Other references (See Section 8):

October 1979 Page 24: "The Fuel System Management Problem"
March 1973 Page 16: "The Gravity Flow Fuel System"
July 1982 Page 14: "Flexible Aircraft Hoses"
June 1978 Page 27: Sealing Riveted Aluminum Fuel Tanks"

6 ENGINE INSTRUMENTS AND CONTROLS

Pilots have to control the engine operation, and certain engine information has to be conveyed to the pilot to help him or her understand how things are working.

The pilot has five cockpit controls for the engine: The throttle, the carburetor heat, the mixture control, the primer, and the magneto switch.

These consist of three push-pull Bowden cable controls, a small pump, and a dual-pole electrical switch.

14CFR 91.205 tells us what engine controls the pilot must have. For Fly Baby drivers, it's a tachometer, an oil pressure gauge, and an oil temperature gauge. The tach information is (normally) brought back to the cockpit by a flexible mechanical shaft, the oil pressure gauge is a thin pipe/hose from the crankcase, and the oil temperature is an reading from a bulb immersed in the oil.

The key factor is much of this hardware is mechanical…items that can't make sharp turns, like an electrical cable can. All this stuff gets installed in the cockpit…but where?

The available locations are more limited than you might think. For the most part, you can't put the tachometer or other gauges in the middle of the panel. Figure 61 shows why: the fuel tank blocks the direct access from the instrument panel to the engine…and you can't run cables through the middle of the fuel tank

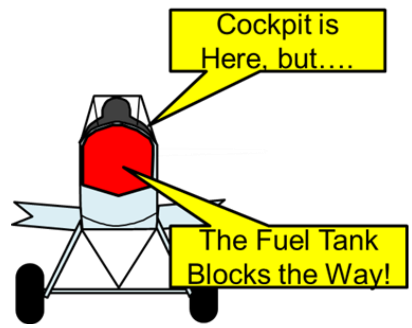

Figure 61: Blockage Courtesy of the Fuel Tank

Get it? Airplanes with fuel tanks elsewhere can install this engine controls and readouts whererever is best, but with a fuselage gas tank, all these controls…and most of the information being brought back to the pilot…are on the sides of the cockpit or sides of the panel, since the cables, etc. have to skirt the edges of the gas tank.

This is why Pete's figure 5-4 on page 19 of Article 7 shows all the engine-control and –readout stuff on the extreme left side of the cockpit: So the controls can sneak past the fuel tank.

Figure 62 illustrates this. The carburetor is where all the controls end up, and they're all be routed between the left side of the fuel tank and the left cockpit sidewall (note where they emerge from the firewall). What this means is that you may want to wait until the fuel tank is in place before routing the engine controls. Remember, too, that you might have to REMOVE some of those lines in the future…don't install them so that can't be taken out once the fuel tank is in the way. I had to replace my tachometer drive cable several years ago, and it had to snake around the fuel tank. Thankfully, it didn't have any brackets or cable ties locking it to out-of-reach areas.

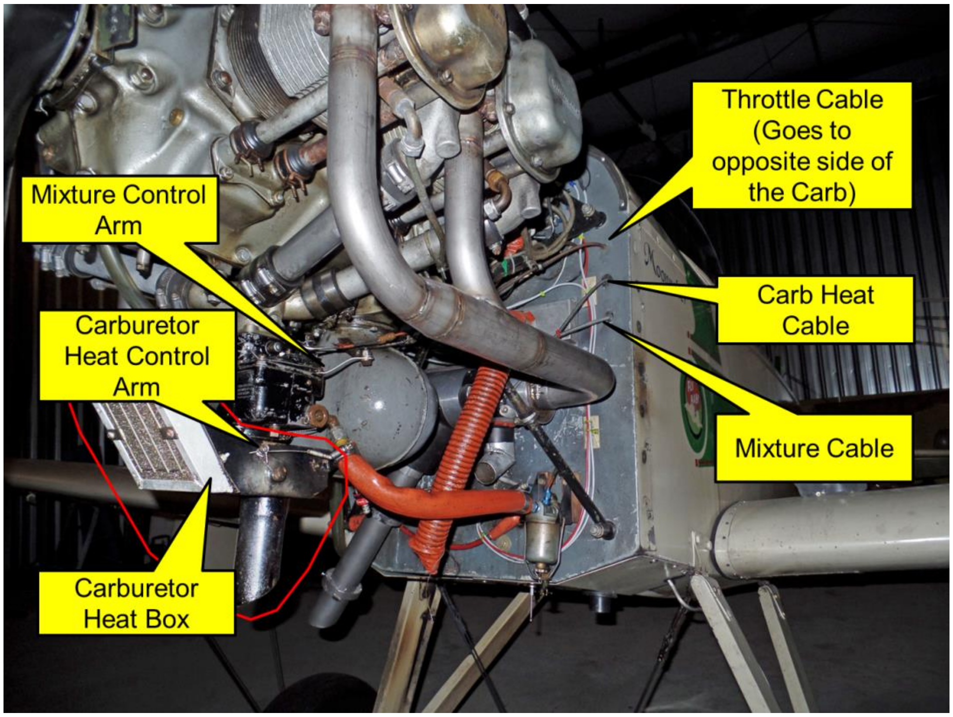

Figure 62: Engine Controls vs. Firewall Exits

6.1 Gauges

6.1.1 Tachometer

The Tach cable is going to be the sportiest installation, just because of the location of the tach output on the back of the engine. As Figure 63 shows, it's about dead-center in the back of the engine. The drive cable has to go backwards, curve around the fuel tank, and go into the panel where the tachometer is mounted.

The Continental tach cable is identical to those used in car speedometers, and if you need a custom length, you can just go the places that repair speedometers. I brought mine in, explaining as I often do, "It's for an off-road vehicle" and the technician shrugged and said, "It looks more like an airplane unit. We do those all the time."

One member of the Fly Baby community cautioned us that some brands of tachometer have accuracy problems. He recommends using a hand-held optical tachometer to check the accuracy during the annual Condition Inspection.

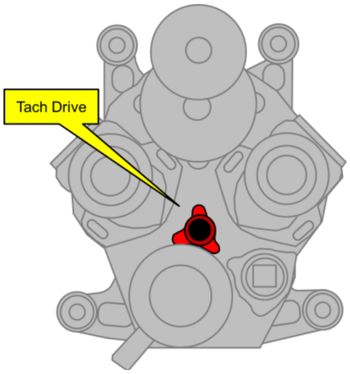

Figure 63: Tach Drive Location

6.1.1.1 TACH DRIVE DIRECTION

Now: There's a big ugly truth that you have to understand about Continental engines: The different models spin the tachometer cable in different directions. All engines with -8 model numbers have counter-clockwise tachometer drives, all with -12, -14, -16 and the O-200 use clockwise tachometers.

This may make things look a bit strange, if you've been used to modern aircraft. The A65 tachometer will actually work backwards to what you're used to… it has zero on the right, and rotates around to the left to maximum RPM (Figure 64). However, there are adaptors that will let you use a more traditional tach on an A65. "Right Angle Drives" change the tachometer cable direction tightly, for instances where there isn't much room, and they also change the rotation direction for the tach cable. So they can be used if you own a regular tach and want to use it on the A65.

Figure 64: Counter-Clockwise Tach

6.1.1.2 Hour Meter

If the tach includes an hour meter, this has to be set (by an instrument shop) to indicate the hours properly at the desired cruise RPM. This varies by engine.

Engine	Recommended Cruise RPM
A65	2150
A75	2350
A80	2450
C75	2275
C85	2400
C90	2350
O-200	2500

6.1.1.3 Electronic Tachometers

One way around the issue of feeding a long snaky mechanical tach cable is to use an electronic tachometer. These connect to either the magneto P-line or wrap a sensor wire around a spark plug lead with standard small-gauge wire. Some require electrical power, but some have their own built-in batteries so they can be used on A65-powered aircraft.

The tach drive on my C85 went bad about ten years ago, and I replaced it with a "Tiny-Tach", a self-contained unit with a built-in battery. I installed it on a piece of thin plywood that fit in the standard 3.5" instrument hole that the original tachometer used (Figure 65)[12].

Figure 65: Tiny-Tach Installation

The Tiny-Tach installs by wrapping a wire around one of the spark plug leads. Any lead will do.

The process begins by installing the gauge in the cockpit, and feeding the sense wire through the forward fuselage and into the engine compartment.

Then use an exacto knife to carefully cut the metal shielding braid away from one of the wires over a ~1" gap. Cut only the braid away…the rubber insulation on the plug wire is underneath, and try not to cut or nick it.

Then wrap the sense wire around the open section of braid. Restore the shielding effect by using self-stick copper tape around the open section. Careful, don't lay the sense wire parallel to the plug wire under the copy tape…it should come out of the copper at a 90-degree angle.

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[12] Why, yes, I did repaint the panel after taking this picture….

Figure 66 illustrates this process.

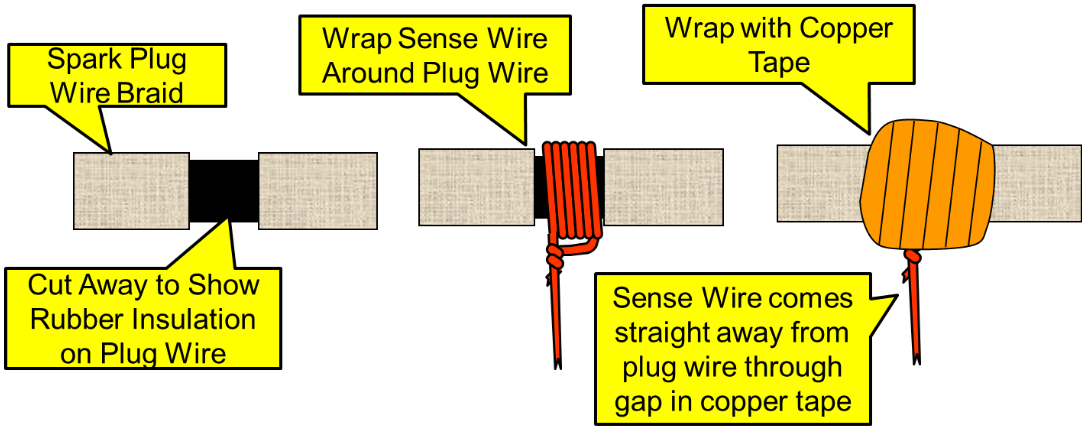

Figure 66: Connecting the Sense Wire for a Tiny-Tach

Being connected to a single spark plug wire, the Tiny Tach will not show RPM when that mag is shut down during a pre-flight runup. To me, this isn't a problem…it's easy enough to tell if the RPM is dropping too much, just compare the engine smoothness compared to the other magneto during the mag check. During the annual condition inspection, you may want to use an optical tachometer to check the actual amount of mag drop. These units are designed for Radio Control airplanes, and cost just $40 or so.

The Tiny-Tach's battery is good for five years, but is not replaceable. There are places online that give instructions on how to cut open the case and replace the battery, but the Tiny-Tachs cost only $60.

In addition, while it includes an hourmeter (which it displays when the engine is not running), once the hourmeter reaches 200 hours, it stops indicating tenths of hours (e.g., switches from reading 199.8 and 199.9 to just 200, 201, etc.). In my case, the Tiny-Tach was close enough to the 200 hour value when the battery went bad, it was a lot easier to just replace the whole unit.

6.1.2 Oil Pressure Gauge

The oil pressure gauge is a simple pressure meter. It's plumbed into the side of the engine, just forward of the oil screen.

The tubing is typical aviation medium-pressure hose with AN fittings. Typical installation puts a bulkhead fitting at the firewall, and separate hoses running to the gauge and to the engine. The hose to the engine should have a little slack in it to accommodate engine vibration.

6.1.3 Oil Temperature Gauge

The oil temperature gauge is a capillary devices, it has a sensing bulb that plugs screws into the end of the aircraft oil screen. You have to buy the complete gauge with the capillary tubing, and the tubing comes only in fixed lengths and cannot be altered. A 60" (five foot) gauge is probably sufficient, but measure. A 72" unit isn't that much more expensive.

6.2 Engine Controls

Section 6.3 includes a number of photos showing the variety of locations builders have used to install their controls. The baseline installation, as Pete shows in Page 19 of Article 7, is addressed here. Figure 67 shows a closer look.

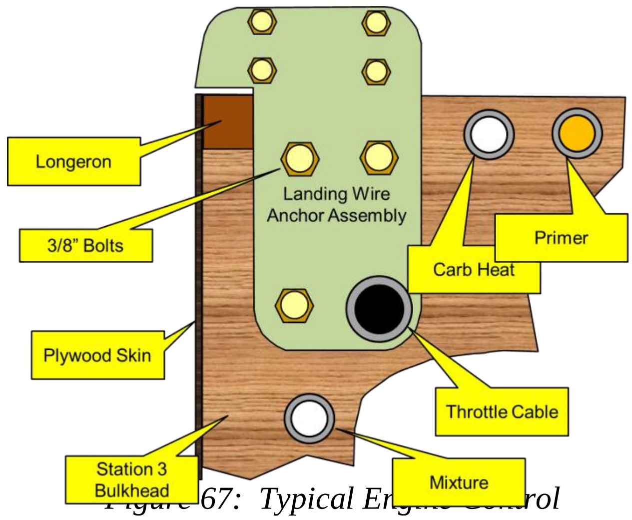

Figure 67: Typical Engine Control Mounting Locations

6.2.1 Throttle

Typical throttle is usually a push-pull device; Tony Bingelis addresses these in the April 1972 issue of Sport Aviation, page 27.

The common practice is to install the throttle through the lower right hole of the landing-wire support bracket on the Station 3 bulkhead. General consensus is that only one non-bolt device should be added to the landing-wire assembly bracket…so don't put the mixture or carb heat controls here as well.

Some builders have used-military style throttle quadrants on the cockpit sidewall. This is a "to each his own" situation; I've traditionally not had quite enough elbow room in the cockpit and would be reluctant to give up any room for a quadrant. It certainly would be a convenient place for the carb heat.

One warning from a quadrant user: Make sure it has a lock. Some of these quadrants start inching the throttle forward as the engine vibrates.

6.2.2 Carburetor Heat/Mixture Controls

Both the carburetor heat and mixture controls are simple push-pull controls. Bowers shows the carb heat next to the landing wire assembly.

He puts mixture on the vertical portion of the station 3 bulkhead. In actuality, by the time I flew it, the Mixture and Carb heat controls has swapped locations.

The lower location (labeled "Mixture" in Figure 67) actually had the carb heat. This was actually kind of an awkward location…it was in a recessed area (between the Station 3 bulkhead and a diagonal brace) and manipulating the carb heat was a bit awkward. I'd recommend the installation location as shown in Figure 67.

6.2.3 Primer

The primer system taps off the fuel line (typically at the gascolator) and connects to a small pump. The output of the pump is fed into the cylinders to aid starting.

Tony Bingelis discusses the primer in his article in the March 1973 Sport Aviation magazine, page 16: "The Gravity Flow Fuel System." This is the how-to for Fly Baby fuel systems.

The primer is located on my airplane as shown in Figure 67 above. One uses it only once per flight, so the accessibility isn't that important.

6.3 Photos of Sample Installations

The Fly Baby community came through in a big way when I asked for photos of their panels. I'm going to show them, and point out some of the features. You'll note that nearly NOBODY sets up their engine instruments and controls the way Pete says.

I'm going to point out the features of each installation, and explain where I think the advantages and disadvantages might lie. This doesn't mean what the builder did was WRONG….it's just something another builder might want to think about.

The owner of each photo will be given in the section name.

6.3.1 Ron Wanttaja

Only fair I show mine first (Figure 68). I have the throttle in the conventional location (through the landing wire anchor) and the mixture and primer along the top of the Station 3 bulkhead. On the right side landing wire anchor is the T-handle for the starter. Engine gauges are in the traditional locations.

Figure 68: Ron Wanttaja's Panel

The carb heat control is located on a wooden sub-panel glued to the front of the Station 3 bulkhead below the throttle. This is extremely convenient, but it is literally a pain in the knee. The edge of this sub-panel is right where my knee wants to rest. It's very uncomfortable to rest my knee on. I suspect the original builder was quite a bit shorter than I am and didn't encounter this issue.

The right side had a similar sub-panel, holding the heater push-pull control. I cut that out and repositioned it on the fuel tank support beam. It's out of sight, but I can easily find it by tough.

I'd love to reposition the carb heat, but I'd have to unstring the carb heat cable completely, all the way from the cockpit to the carburetor. So I'll pass on that. The edge of the sub-panel used to be pointy-er, until I took a file to it.

6.3.2 Mike Melau

Mike has both his throttle and the carb heat on a sub-panel, but it has a flat edge and probably doesn't dig into one's knees as much. Note the "backward" tachometer for the A65.

Figure 69: Mike Melau's Panel

Mike didn't group his engine gauges, but used a nice symmetrical arrangement. Notice that everything's clearly labeled, that is an FAA requirement.

6.3.3 Christopher Reynolds

Chris has his throttle in the conventional location (Figure 70), but the mixture and carb heat high above the bulkhead on the panel itself. Nothing wrong with that, if you have the panel space, and Chris does. Note the digital tachometer, and that all the engine gauges are on the right side. Again, a matter of taste.

Figure 70: Christopher Reynold's Panel

6.3.4 Kurt Gubert

You might look at Kurt Gubert's panel in Figure 71 and think, "Ron! You printed the photo the wrong way around, the throttle's on the right side!"

Well, no. Kurt has a lot of time in small side-by-side aircraft where the pilot flies with his left hand while the right hand handles the throttle. Kurt just made the plane like he was used to…nothing wrong with that, and it's one of the nice things about homebuilt aircraft.

Another thing you might notice is the lack of the landing-wire anchor fittings. Kurt built a Fly Baby biplane, which doesn't need them. Like Chris Reynolds, he's got his engine gauges on the right. Again, it's probably similar to the side-by-side airplanes he's been flying.

And isn't that a clean-looking panel? Note that Kurt has simple toggle switches instead of the more-common key-type mag switch. Most of us keep our planes in locked hangars anyway. And frankly, in this day and age, few airplane thieves want to hand-prop.

Figure 71: Kurt Gubert's Panel

6.3.5 Hans Teijgeler's Panel

Hans bought this Fly Baby in Canada a number of years ago, and imported it to his home in the Netherlands.

Here in Figure 72 you see an example of a quadrant-type throttle.

Figure 72: Hans Teijgeler's Panel

6.3.6 Jim Katz's Panel

Jim's airplane is still under construction, but you can see it's going to have a pretty panel (Figure 73). The controls and gauges are going in about the way Pete suggested.

Figure 73: Jim Katz's Panel

6.4 References to Tony Bingelis articles

This is another area where Tony Bingelis' two books, *Firewall Forward* and *Tony Bingelis on Engines* are going to be vital. *Firewall Forward* especially, as it has large chapters on controls and engine instrumentation.

References from Sport Aviation (See Section 8):

April 1972 Page 27: "Push-Pull Controls"
April 1980 Page 55: "Ignition Switches"

7 ELECTRICAL SYSTEM

Do you need an electrical system?

If you've got an A65 or a C85-8 type airplane, it seems an odd question. The engines don't have generators, so why put on an electrical system?

Nowadays, it's tough to get around without some kind of radio. Sure, the old Icom works fine on its built-in batteries, but it will run a lot longer with a battery in the airplane. Install the battery, add an external power port, and charge it when convenient.

As mentioned back in Section 3.3.3, if your Fly Baby doesn't have an engine-driven electrical system, it won't need to install either a Transponder or ADS-B Out unless you actually want to fly it into Class B or C airspace. If you don't have a generator, you don't have to have either to fly within the Mode B "Veil".

Again, it doesn't mean you can't have a battery. It doesn't even mean you can't have a starter, if you've got an engine so equipped. All you have to do is occasionally re-charge the battery from a ground source.

7.1 Electrical System Construction

Again, Tony Bingelis is going to be your reference as far as electrical systems are concerned. Here are two fundamental resources from EAA Sport Aviation:

May 1977 Page 29: "Electrical Systems Part I"

June 1977 Page 27: "Electrical Systems Part II"

And, of course, his books.

7.2 Ron's Suggestions

Here's some of my own suggestions, as far as the electrical work on your own airplane:

Use aircraft-quality wire. The insulation is much tougher, and the wire has better quality.

Use crimp-on fittings, not solder. I'm a rather dab hand at soldering, and always figured I'd use it on the airplane. The trouble is, airplanes are high-vibration devices. Solder binds the strands of the wire together, and actually makes it more vulnerable to fatigue failure. So use crimp-on fittings.

Get your crimp-on fittings from an aviation vendor. Yes, I've gone to the car store late at night when I only needed one or two. But aviation-grade units are obviously better.

Use a professional crimping tool. A professional tool is actually a ratcheting device. Once you start the crimp, it doesn't release until it has compressed the fitting all the way[13]. That give a lot more consistency to your work. The crimping tools sold by most auto stores and big-box hardware stores are junk. Get a professional model; Cleveland Aircraft tools has the WTC-380 for $40.

Physically test each crimp. That means give it a real good tug when it's done. If it comes apart, you obviously did something wrong.

For a battery, I'd suggest an Odyssey Dry Cell. They are light, can be mounted in any position, and are fairly cheap ($100). I bought mine off Amazon…free shipping. I've got the Odyssey PC680 for my C85 and it's been very good.

[13] Yes, there is a way to release it early if something's wrong, but you have to flip a lever.

7.3 Sample Schematic

Figure 74 shows how I rebuilt my own electrical system a few years back. The link takes you to an article. All of this was done in accordance to Bingelis's articles.

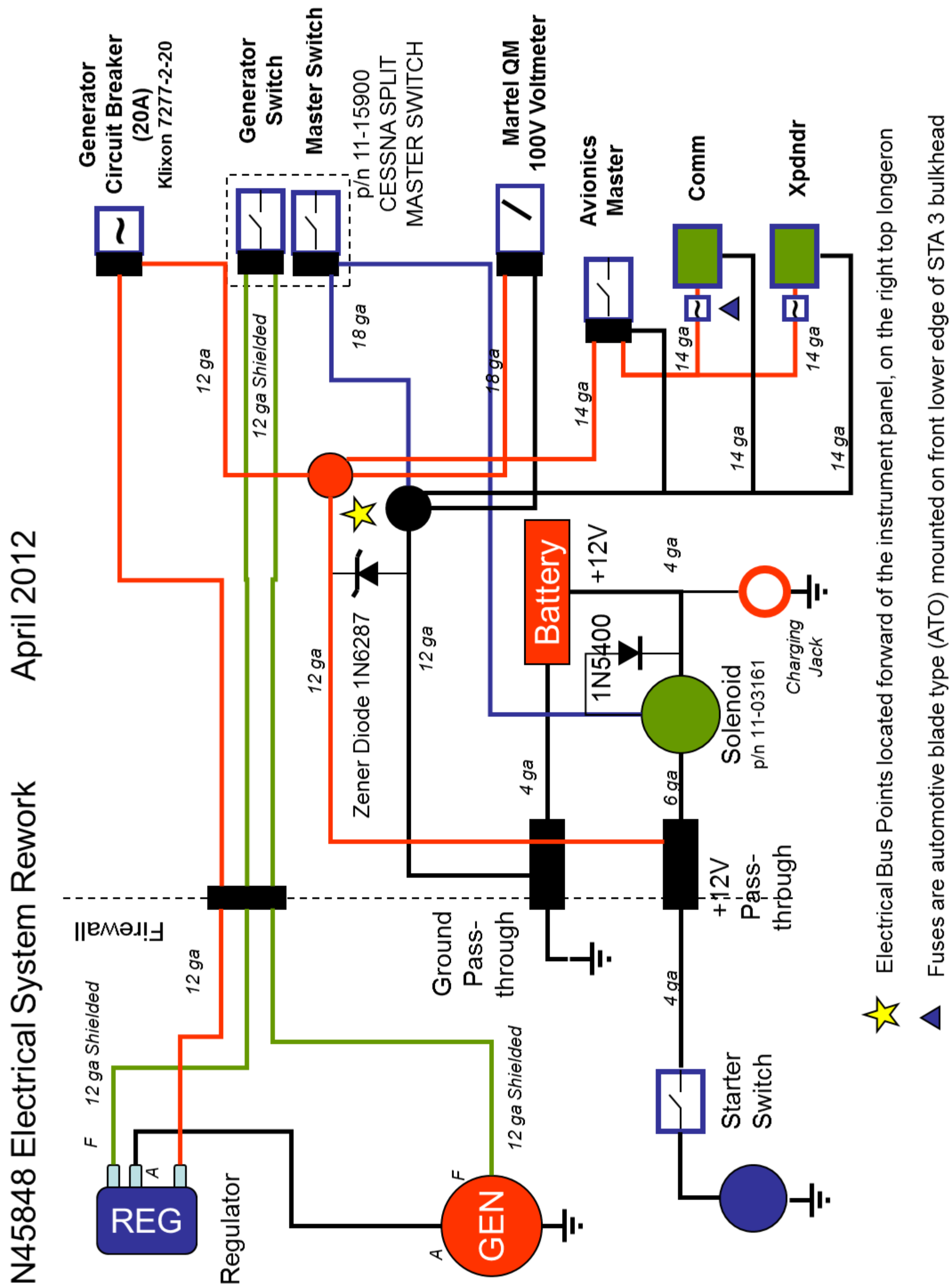

Figure 74: Sample Schematic

8 TONY BINGELIS REFERENCES

The late Tony Bingelis built about ten homebuilt airplanes, and wrote hundreds of great articles to help folks like us be successful with their own airplanes. Some of these articles were collected in one of four books.

Mr. Bingelis used a Continental engine in at least two of his homebuilts, and many of his articles had a Continental slant. You will find his two engine books:

Firewall Forward, and

Tony Bingelis on Engines

… to be of great assistance.

These books are collections of his previously-published articles in EAA Sport Aviation magazine. You can find a complete listing of Bingelis' articles here:

https://www.eaa.org/eaa/aircraft-building/building-your-aircraft/next-steps-after-your-airplane-is-built/eaa-tony-bingelis-award/learn-more-about-tony-bingelis

EAA members can download these articles for free.

https://www.eaa.org/en/eaa/news-and-publications/eaa-magazines-and-publications/eaa-sport-aviation-magazine/sport-aviation-archive

You will need to register with EAA using your EAA Number.

The following are the articles I felt were particularly applicable to Continental engine users.

April 1972 Page 27: "Push-Pull Controls."
October 1973 Page 14: "Engine Baffles for the C85 and O-200 Continentals"
March 1973 Page 16: "The Gravity Flow Fuel System"
October 1974 Page 27: "Mufflers and heat muffs"
November 1974 Page 18: "The Care and Feeding of Wood Airscrews"
July 1974 Page 31: "Planning Your Exhaust System"
August 1974 Page 50: "Exhaust System Weldments"
September 1974 Page 47: "Exhaust System Construction Practices"
February 1976 Page 20: "Messing Around with Magnetos"
April 1976 Page 33: "Cabin Cockpit Heat"
May 1977 Page 29: "Electrical Systems Part I"
June 1977 Page 27: "Electrical Systems Part II"
November 1978 Page 40: "Coping with the Uninstalled Engine in Your Shop"
April 1980 Page 55: "Ignition Switches"
July 1982 Page 14: "Flexible Aircraft Hoses"
September 1982 Page 21: "Fuel Tank Components and Accessories"
July 1984 Page 42: "Wire Installation Practices"
December 1986 Page 33: "How About an Aluminum Fuel Tank?"
June 1987 Page 27: "Sealing Riveted Aluminum Fuel Tanks"
August 1989 Page 27: "Engine Hook-Up Tips"
April 1990 Page 37: "Basic Preparations for Your Electrical System"
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