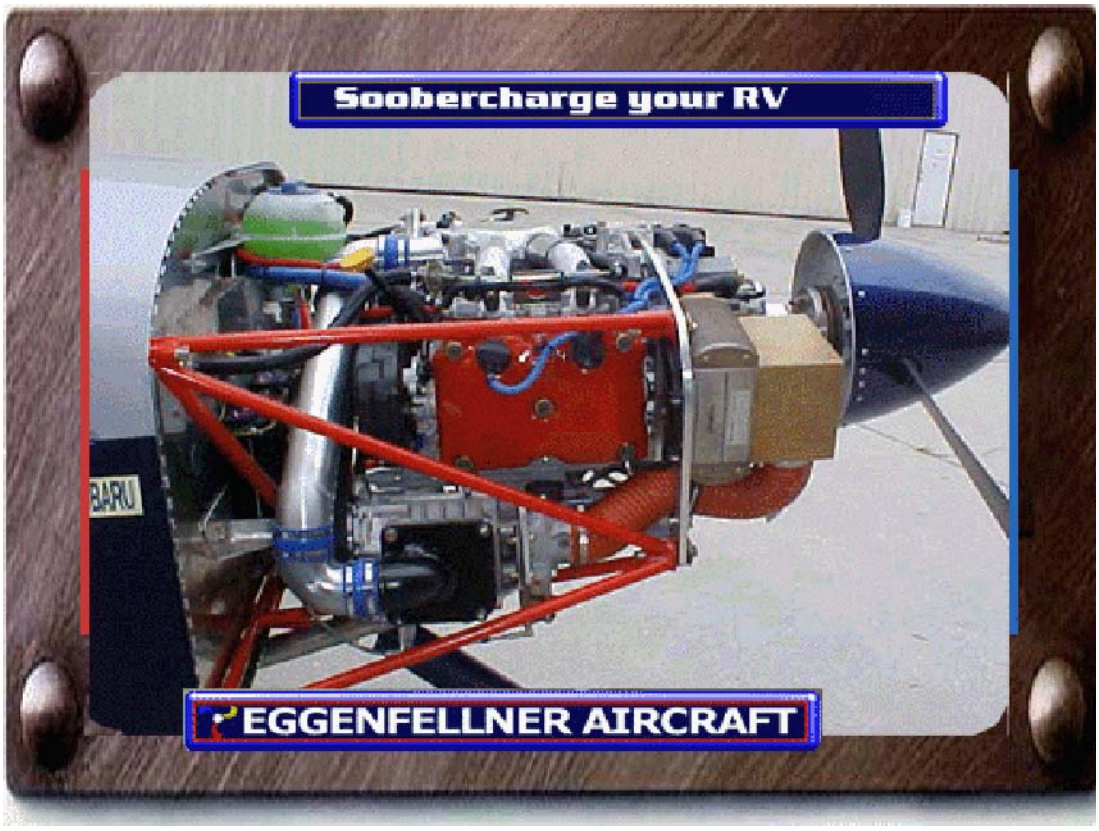
EGGENFELLNER AIRCRAFT



Eggenfellner Installation Manual

Step by step installation procedures for installing your Eggenfellner Powerplant in a Vans RV series aircraft.

Document Revision History:

- *04-Sep-2003 - Updated Chapter 6 wiring diagrams*
- *12-Jun-2003 - Added Cowl Ventilation to Chapter 7*
- *21-Feb-2003 - Posted Chapters 7 and 8*
- *03-Nov-2002 - First posting of chapter 6*
- *05-Sept-2002 - First public posting of chapters 1-5*
- *29-Aug-2002 - DRAFT includes first feedback*

NOTICE - Your Eggenfellner firewall-forward package is an "experimental" aircraft powerplant. Installation, by an amateur or licensed airframe mechanic, must comply with all relevant legal, and customary regulations and guidelines for experimental aircraft in accordance with the governing body of the country in which the aircraft will be registered and flown. Deviation from the design, installation, or manufacturer's statement of intended use of this engine package shall be discussed with Eggenfellner Aircraft Inc. in advance of use and may result in void of warranty. Eggenfellner Aircraft is not responsible for misuse, neglect, faulty practices or materials employed by the builder, owner, or operator of an aircraft using this powerplant. Workmanship and materials employed in the installation of this powerplant must be in accordance with "best practice" for aircraft construction, materials and maintenance. Reference FAA publications AC43.13-1A and AC43.13-2A for information related to acceptable methods, techniques, and practices when working on aircraft.

Thank you for purchasing an Eggenfellner powerplant. With proper installation, care and maintenance, your powerplant should deliver many years of reliable and economical service. Refer to your Eggenfellner 2.5L Maintenance Video and web site for operational and maintenance details.

This manual provides a general guideline for achieving an airworthy installation of your engine package. Although the manual depicts an installation in a Vans RV-9A, the general information and procedures can be applied to all models of RV's, Glastars, and other airframes. Because every aircraft is unique to some extent, and builders exhibit a wide variety of skills and techniques, it is impossible to define a fully standardized engine installation. Eggenfellner Aircraft comes as close as possible to providing a consistent and trouble-free installation, but the builder must posses the knowledge and skills to assure that the powerplant is integrated with the airframe and supporting systems in an airworthy manner.

This manual will attempt to deliver the required knowledge.

The required skills include basic aircraft mechanical, electrical, plumbing, and sheet metal work.

Along with mounting the engine to the firewall, you will be installing batteries and cables, fuel lines, firewall fittings, cables, hoses, and harnesses. You will be modifying your fiberglass cowling to fit the engine oil cooling system and wiring several engine sensors. Your airframe will be modified to include a "full loop" fuel system and duplex fuel selector valve. You will need to operate a portable engine hoist, and use a portable drill and drill press. The installation will involve a moderate level of stainless steel work. When working with stainless steel, you will need sharp, high-quality drill bits, tin-snips, and files.

This manual describes a soup-to-nuts installation of the 2.5 Liter powerplant in a Vans RV-9A. Other installations are very similar. Ideally, the builder should be in the fuselage construction stage of his/her project. If you are beyond this stage or are installing the powerplant into a different model of aircraft or an existing experimental aircraft, your personal creativity will be called upon to interpret and apply the guidelines described herein.

Be sure to ask the factory when in doubt about the correct procedure for your airplane and contact a licensed aircraft mechanic, inspector, or EAA technical adviser. Don't overlook the immeasurable value of the various Internet newsgroups for ongoing and up to the minute expertise. We prefer to leverage the experience of our existing customers as a means of front-line support, and we ask that you also provide your knowledge and share your experiences. With the rapidly growing number of RV builders choosing to fly modern Eggenfellner powerplants, you'll find a thriving group of enthusiasts like yourself sharing their experiences, ideas, debate, and friendship. Finally, don't miss out on the airshow circuit. Eggenfeller is proud to display at Oshkosh, Sun-N-Fun, and many other events. Stop by, say hello!

Internet Newsgroups & Websites:

www.eggenfellneraircraft.com - Home base - Jan Eggenfellner

www.groups.yahoo.com/subaruaircraft/ - Eggenfellner Aircraft News and Support group.

www.climbandcruise.com - Quinti Propellers - Bob Warfel

www.matronics.com/rv-list/index.htm - RV Builders Newsgroups (look for other RV models too).

www.vansaircraft.com - Home base for Vans Aircraft Inc.

www.vansairforce.org/links/links.html - Vans Air Force of Western Canada

www.metronet.com/~dreeves/vaf.htm - Vans Air Force World-Wide

http://p.webring.com/hub?ring=vansaf - Vans Air Force Web-Ring

In the spotlight...

The aircraft pictured throughout this manual is a customer-owned RV-9A completed in 2003. The powerplant is an Eggenfellner 2.5L firewall-forward package delivered in June 2002. The owner and builder of the plane has customized a few things, but the installation sequence and guidelines remain common to all packages. I will indicate all references to these optional customizations. You can decide if these ideas are right for your own plane.

Please send us photos of your installations and any installation-related details you would like to share with your fellow builders. We urge you to share with the group, details of anything you have changed from the original design. It is very important that you understand that there is often a valid reason for why something on your engine was put together a particular way. If you would like to deviate or change anything, please be aware that an airplane is not always the right place to test your new idea. Airplanes are not forgiving in this respect. You can't just pull over to the side of the road if your idea proves not to work as expected. We assume that the installer is either a knowledgeable mechanic, or that the assistance of such a person is sought and secured. We require that the installer/s become familair with and apply the guidelines described in this manual.

As always, we look forward to your feedback and suggestions on how we can improve our products, documentation, or service. If you feel we have missed an important point, let us know, or better yet, send us a photo and a few related words. Obviously, this manual cannot cover every possible detail, but we can try!

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Basic Navigation

The first chapter of this manual covers many topics of interest to installers, starting at the purchase decision. There are many things to plan and prepare for prior to your engine's arrival. We recommend you read through this material and become familiar with the installation sequence and tasks. Once you are ready to begin the installation, the remaining chapters are oriented along a sequence of photographs and checklists, with only as much narrative as required to get the point across.

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MISCELANEOUS STUFF

Chapter 1 - Pre-Installation Notes

How Long?

Starting from the shipping crate, plan on 2 to 4 hours to physically mount the engine to your airframe with the help of one assistant. You will need several additional solo work sessions to complete the systems integration. Time to completion varies widely based upon your selection of engine instrumentation. The Grand Rapids Engine Information System (EIS) has been enhanced specifically for Eggenfellner powerplants and provides excellent value for your dollar. It is a complete system offering which is very easy to install. If you order this option with your motor, the engine sensors will be factory installed and wired. The remaining installation of the EIS is covered in it's own manual from Grand Rapids. The EIS system now offers fuel quantity senders and display if you would like to get even more value from your system.

Ordering your Powerplant and Options

You may choose to purchase options and accessories at the time of order or as needed. Major options should be discussed at the point of initial purchase so we can provide the most complete package possible. These include items such as the "Soobercharger" and Engine Information System (EIS). Minor items can be purchased as needed. These include maintenance tools, such as clamp kits and OBD-II scanner.

Ordering the RV Finishing Kit

When ordering your Finishing Kit from Vans, be sure to specify that you will be using an Eggenfellner Firewall-Forward Package. Vans should be familiar with the special requirements of this package. The following is a summary of these requirements.

Kit Requirements from Vans:

1. You will need the RV-7/A IO-360 cowling. This cowling does not have a carb air scoop. Yes the 7 & 7A cowls fit the 9 & 9A as well as the 6 & 6A. If you are building an RV-8 or 8A, use the IO-360 RV8 cowling.
2. You will need the nose gear leg and all related hardware. The gear leg will be un-drilled.
3. **If you are building a tricycle gear model**, you DO NOT NEED the Lycoming engine mount. Vans will credit you a few hundred dollars.
4. **If you are building a tail-dragger model**, you NEED the Lycoming DYNAFOCAL engine mount so it can be modified by our factory for your motor.

Things to think about before your powerplant arrives.

Rollover image to peek Inside the Crate. Be sure to request a lift-gate truck.

- **A place to store the motor?**

  When the big truck finally arrives, you'll need a flat, dry, corner of your workshop to store the powerplant while unpacking, inspecting, and installing the motor. Be sure to request a lift-truck and hand cart for delivery unless you have a large fork-lift available. The motor in its wooden crate weighs around 400 pounds. The crate is 4' x 4' x 4'.

If you are not going to install the motor for more than 90 days, you should consider leaving it wrapped in a protective layer of plastic. Long-term storage requirements should be discussed with the factory. The normal procedure is to tilt the engine upright on the shipping skid (as it would normally be oriented), then add oil and follow operating procedures to start and run the engine for a few minutes once every month.

All motors are run at the factory before shipping to a customer. The initial oil has been drained from the crankcase for shipping. Coolant and PSRU lubricant may remain in the motor during shipping but should be checked before operation. A small amount of motor oil may leak from the exhaust pipe (if installed) when you first tip the motor off the shipping palette. This is normal and will quickly burn off when the motor is run. Expect a brief moment of smoke when you start the motor for the first time. Wipe away any obvious spillage. Refer to the section on fluids for more information.

- **A hoist and sling?**

A hoist and sling are required to lift the motor. Do not attempt to install the motor using several buddies instead of a hoist. The hoist is far more patient and less error prone. Most rental businesses will rent an automotive engine host for about $20/day. You will need it for one day (half a day if you've done this before). A sling can be made from a set of four strong, thickly strapped, ratcheting tiedown straps at least one-inch wide. The sling is required to physically attach the motor to the hoist. Slings are preferred over chains because they are less likely to scratch or damage the motor.

You should orient the sling directly over the intake manifold, but do not attach to it! Attach straps running from the hoist hook to each of the four corners of the engine mount and also around the prop shaft bearing hub (never put a sling around the prop shaft itself as this can damage the seal). Adjust the straps with the ratchets so that the motor can be picked up and remain level. The sling running under the prop bearing hub will be useful to make the motor mount parallel with the firewall. Don't forget you can move the aircraft's empennage up and down too in order to get the engine mount to mate with the firewall.

TIP: If the exhaust pipe was installed when you received your motor, remove it first while the engine is still in the crate and you will avoid damaging it. The metal exhaust gaskets can be reused if they are not crushed or damaged. Replacements can be found at your local Subaru dealer. **Ask for gaskets for a 2002 Subaru WRX Turbo car**.

- **Room to Move?**

Your fuselage is about to become four feet longer and the empennage is going to sit very tall. You will need to position your airframe so that you can approach the fuselage with your hoist. The photo above shows that it is possible to install the motor in a typical garage, in this case, by hoisting from the side.. It is always easiest to hang a motor if the firewall is oriented 90-degrees relative to the floor. For most airframes, particularly taildraggers, this can be done by raising the tail of the fuselage as needed to square-up the firewall. Be sure to pad the tail however you choose to support it. I have found that suspending the tail section using two screw eye bolts into the ceiling and a long ratcheting tiedown strap slung under the mid-tailcone bulkhead (F-707) works well. This method allows some free swinging movement of the fuselage on its wheels, which can help with alignment and lessen any damage that might be incurred during installation.

The RV-9A and RV-7A aircraft use nose or main wheel legs which are integral fixtures of the motor mount. Until your motor is bolted securely to the firewall, the fuselage tail must be adequately supported. Keep in mind that as the weight of the motor is transferred to the airframe, the airframe will sit much lower on its legs than it does right now. Don't do anything that would result in a dent to the bottom side of the fuselage or top of your rudder.

- **Assistance?**

  Two are company, three's a crowd. Hanging a motor can easily turn into a cause for Barbeque. Be forewarned of the shop lore that says increasing the number of humans, lowers the efficiency of anything involving a process. Having a second person with a good sense of what needs to be done is ideal. If they have prior experience with hanging motors, that's even better. Be sure to familiarize your assistant with the layout of the shop in case they have to fetch that special bent screwdriver thingy, or call 911, or operate the jaws-of-life to get you out!

- **Safety!**

  You should have an ample supply of this on hand. Be sure that your hoist and sling are up to the job, that you have plenty of room on a solid, level floor, and when working with fuel and wires, have good ventilation, and a fire extinguisher standing by. Avoid letting any part of your body be underneath a suspended motor or airframe. Always consider what would happen if the motor shifted or fell. Be safe!

- **Batteries?**

  If you haven't done so already, now is the time to acquire batteries. We use motorcycle size batteries. Several types are suitable, but the factory prefers the **Hawker Industries, "Odyssey PC625"** type of dry-cell batteries (Reference URL: www.Batteries4Everything.com or www.odysseydirect.com). Prices vary quite a bit for these batteries, so shop around. $60 to $90 dollars is the going price per battery.

  Whichever type of batteries you prefer, make sure they have suitable bolt-type connector studs. During cable installation, only tighten the nuts gently, using lock washers and flat washers, to avoid damaging the battery terminals. Avoid spillable batteries or ones with special venting requirements. The actual location and mounting of the batteries will be determined once the motor has been positioned on the firewall. If you intend to use your AUX battery to boost-start the engine, or you intend to parallel them for any reason, then the two batteries should be a matched pair to prevent overloading.

Eggenfellner Aircraft offers a prefabricated aluminum dual battery tray if you are interested in mounting your Odyssey batteries in the center of the firewall on the engine side. For other configuration, you will have to construct your own battery box or boxes.

- **Plumbing & Primary Wiring**?

  There's a good amount of drilling, plumbing, and wiring that needs to occur after the motor is hung. In many cases, it is easiest to access this wiring without the motor present. For this reason, you can either dry-fit the motor to the firewall for measurement, then removing it for drilling, or with some care, you can drill while the motor is hung. See how you feel about this once the motor is in place. If you have the tools to work in close quarters, it may not be necessary to remove the motor again. Many of the holes can be measured and drilled before hanging the motor the first time.

  Your powerplant requires twelve feet of #6 AWG primary power cable, ten feet of #8AWG cable, and proper terminal ends and boots. These are not part of the kit supplied by Vans. You may wish to order them early. Obtain a crimping tool of sufficient capacity to handle the cable sizes. Optionally, you may order ten feet of fireshield, fire-resistant hose covering to protect your fuel lines. The lines are size 5. If you have to slip the firesleeve over existing fittings, you can use a size 6 firesleeve as would normally be used on 3/8" lines. If you do choose to add firesleeve you will need our Oetiker Clamp Kit to remove and reinstall the hoses.

  The redundant electrical system recommended by the factory includes several high-quality aviation switches, a pressure switch, and a relay. These parts must also be special ordered. Now would be a good time to review the related electrical diagrams and parts lists, and order these parts. Some of these switches are very specialized devices, so discuss any alternatives with the factory before deviating from the recommended parts list.

- **Fuel System Preparation?**

  Your powerplant requires a continuous fuel supply loop.

  Fuel is drawn from the fuel tanks, through a six-port fuel selector valve, through an optional forward fuel-flow sensor, through an optional primer pump (interesting to aerobatic low wingers only), through a gascolator, to a pair of redundant EFI (Electronic Fuel Injection) pumps, through a high-pressure filter, to the fuel injector rails. Excess fuel pressure not consumed by the injector nozzles, is returned through a fuel-pressure regulator, through an optional reverse fuel-flow sensor, back through the six-port valve, and back to the fuel tank from which it was drawn. This fuel loop is required to maintain proper fuel temperature at the injector rails and to flush away any vapor bubbles that might form in the system. Discuss any deviation from this design with the factory.

  The optional forward and reverse fuel-flow sensors are designed to give corrected calculation of the fuel actually consumed by the powerplant. This is an optional item of the Engine Information System (EIS). A large volume of fuel is continuously circulated through the fuel system loop (approx. 35 gph), so only by subtracting the return volume from the supply volume, can you derive an accurate measurement of actual fuel consumption. The *Grand Rapids EIS* and *Blue Mountain Avionics EFIS/One* systems both support the subtraction of two sensor inputs as employed here. *Matronics* also sells a module which will perform this function if you prefer a hardware solution or wish to use other fuel flow instruments.

The standard RV kit does not provide the return fuel line as required by your powerplant. You must add this third line to each tank as described in the diagrams. The *Andair* six-port valve is required to coordinate the selection of fuel supply and return. This valve can be ordered through Eggenfellner Aircraft Inc. or from other suppliers. Fuel flow sensors must be provided by the builder if not included with their EIS option order. The FloScan 201 or 231 series are OK, but avoid the '415' series due to their limited flow rate.

Now would be a good time to review the related fuel system diagrams and parts lists, and to order the parts.

- **Cabin Heater Preparation?**

Your powerplant provides for a safe and efficient hot-water cabin heater if desired. If you intend to install the optional heater, contact the factory and request an early shipment so you can install the system in your fuselage while you still have easy access. You'll be installing the heater blower/motor, control valve, vents, hoses, fittings, cable, switches and wiring. All of this can be done prior to powerplant installation, and is best done before riveting the top deck skin on. Aside from some tips on basic hose routing and connections and photos of previous installations, the installation of the cabin heating system is an exercise left to the individual builder.

- **Firewall Preparation?**

Before starting the installation, you need to review all systems that would be hard to access once the motor is hung. This may involve installation of some or all of your instruments, rudder controls, brake system, fuel system, cabin heater and fresh air ductwork, etc. You may choose to hang the motor to mark firewall fitting and component locations, then remove the motor to actually drill and cut the various pass-throughs required for cables, wires, tubes, etc. Optionally, you may measure and drill for the various fixtures upfront before hanging the motor. If you are sticking with the advice of this installation guide, this is the preferred method.

The RV kit from Vans includes a firewall with a recessed, rectangular, stainless steel box, originally intended to provide better oil filter access when using a Lycoming motor. Since this is not needed for your motor, some builders have chosen to cover the firewall opening with a flat stainless steel plate. Do not use aluminum here! However, I have found it useful to install the box as called for in the plans. This provides a nice location for mounting components and routing cables. It also saves you the trouble of making a stainless cover plate. If you do choose to install a flat plate, Vans sells a stainless-steel plate for this purpose which would save you a lot of trouble fabricating your own.

This would be a good time to think about how you intend to run wires and tubes through the firewall. Wires are typically bundled and run through a nylon bulkhead fitting. All tubing is to be routed through the firewall using AN bulkhead fittings. Do not simply drill holes and run the tubes through grommets. Over time, a grommet will wear through and cause chaffing of fuel and coolant lines. Do not cut corners in any system that carries critical fluids!

If you are using the factory heater system, the heater should be installed such that the heater core tubes protrude into the engine compartment through the stainless steel firewall. This way the hoses are only in the engine compartment. If you install another type of heater, it is preferred that any hoses which run through the firewall use AN bulkhead fittings instead of rubber grommets.

If you intend to use our factory dual battery tray option, you should obtain this early before cutting holes in your firewall for things like heater hoses. The factory battery tray mounts in the center of the firewall, so plan ahead to avoid conflict with your heater hose and cable openings.

The throttle cable will require a swivel-eye type bulkhead fitting such as Aircraft Spruce's p/n SE961-188B (0.188" diam).

Now would be a good time to check all of the corners of the firewall to be sure they are fully sealed to prevent fumes from entering the cockpit. Use a good fire-resistant sealer and metal tape where applicable. 3M makes a good product called "Fire Barrier Caulk" (3M p/n CP-25). It is available from most contractor and industrial suppliers. It dries flexible just like silicone, with a slightly rough texture and expands as it is heated.

Finally, you might consider spending a few moments with some good metal polish while you still can.

Chapter 2 - Tank & Cabin Fuel System Installation

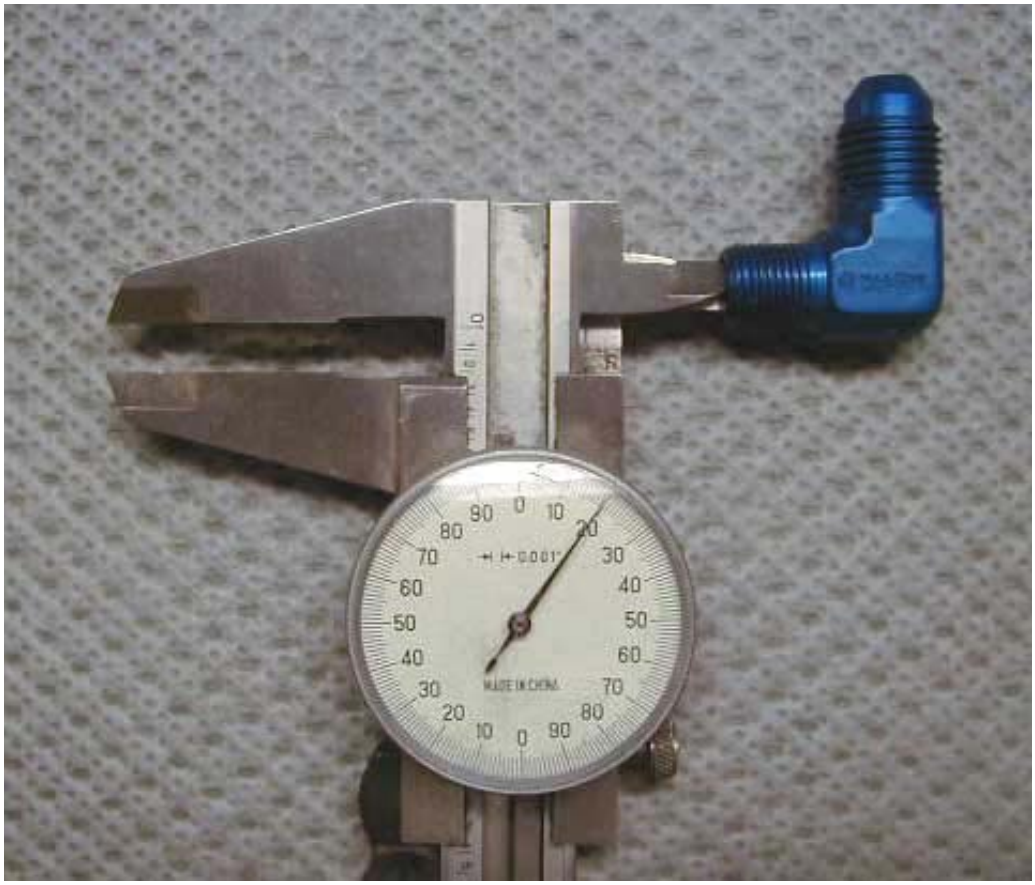
The tasks outlined in this section can be accomplished prior to the arrival of your motor. The airframe must be outfitted with an additional fuel line for returning unused fuel to the tanks. Thus, each tank will have a supply, return, and vent line. An Andair six-port "duplex" selector valve is required. This valve is available from Eggenfellner Aircraft. The duplex valve assures that fuel is always supplied and returned to the selected tank. The Andair valve can be fitted into the existing valve location. The fuel lines must be bent in fairly tight radius to mate with the valve. The AN fittings must be threaded into the valve ports prior to installing the valve ports to the valve body with the supplied screws. Orient the fittings to allow the lines to mate with the fittings. Use an appropriate ***paste type thread sealant*** such as "Tightseal" available from Aircraft Spruce on NPT pipe thread fittings (use nothing under flared fittings or nuts). Avoid using Teflon thread tape. More than one accident (none involving our engine) has been related to small pieces of thread tape plugging up fuel systems. Flared fittings install dry with no sealant. Despite the instructions that come with your *Andair* valve, we suggest that you use blue LocTite thread locker rather than "spiking" the screws. This allows you to remove the fittings if you ever need to rework a line.

Supply Line: 3/8" tubing supplied with your kit.

Vent Line: 1/4" tubing supplied with your kit.

Return Line: 5/16" tubing you must purchase (12' - Aircraft Spruce p/n 03-39400)

NOTE: 5/16" tubing and AN #5 fittings are uncommon sizes in aircraft, but they are available from Wicks, Aircraft Spruce or other quality parts supplier. URL Reference: www.wicksaircraft.com or www.aircraftspruce.com. This size tubing is very common in automotive installations. Some builders have chosen to use 3/8" return lines with AN #6 fittings. This is acceptable, although routing and bending these larger tubes is more difficult. Note also that Eggenfellner Aircraft only stocks these valves with the 5/16" fittings. Beware of using common brass fittings. Brass fittings and cheap AN style fittings have a variety of internal diameters. Brass elbows in particular are notorious for being restrictive. Ideally, your fittings should be 0.19" or greater inside diameter as shown below (0.22"). It is acceptable to drill out fittings if you use care and common sense. It is even better to use the right fittings to begin with! Aircraft Spruce sells 3003-0 "Versatube". This is coiled aluminum tubing that is much easier to install than the 5052-0 rigid tubing, particularly if you need to make tight bends.



Refer to the parts list page and drawings for a full list of required fittings and lines.

1. [ ] Note the starting time.

2. [ ] Install the 5/16" in-tank return line and fittings. An AN832-5D bulkhead fitting is used to connect the in-tank line to the tank end cover. Optionally, you may locate this fitting on the tank rib near the vent line fitting if desired. Be certain to avoid interference with fuel quantity senders and verify that the fitting will have room to mate to its counterpart on the side of the fuselage. Be aware of the location of the landing gear web and other fuselage fixtures before choosing your location. The specified location in the tank end lid is known to have ample clearance. On our factory RV-6A we were able to place the return fitting at the lower aft corner of the tank with a straight tube out into the second tank bay.

The in-tank segment of line is intended to return the fuel to a point just beyond the second rib of the tank. If you are using Vans capacitive fuel quantity senders, be sure to avoid contacting the capacitive plates with the return line. With float-type senders, bend the tube as needed to avoid interference with the float mechanism.

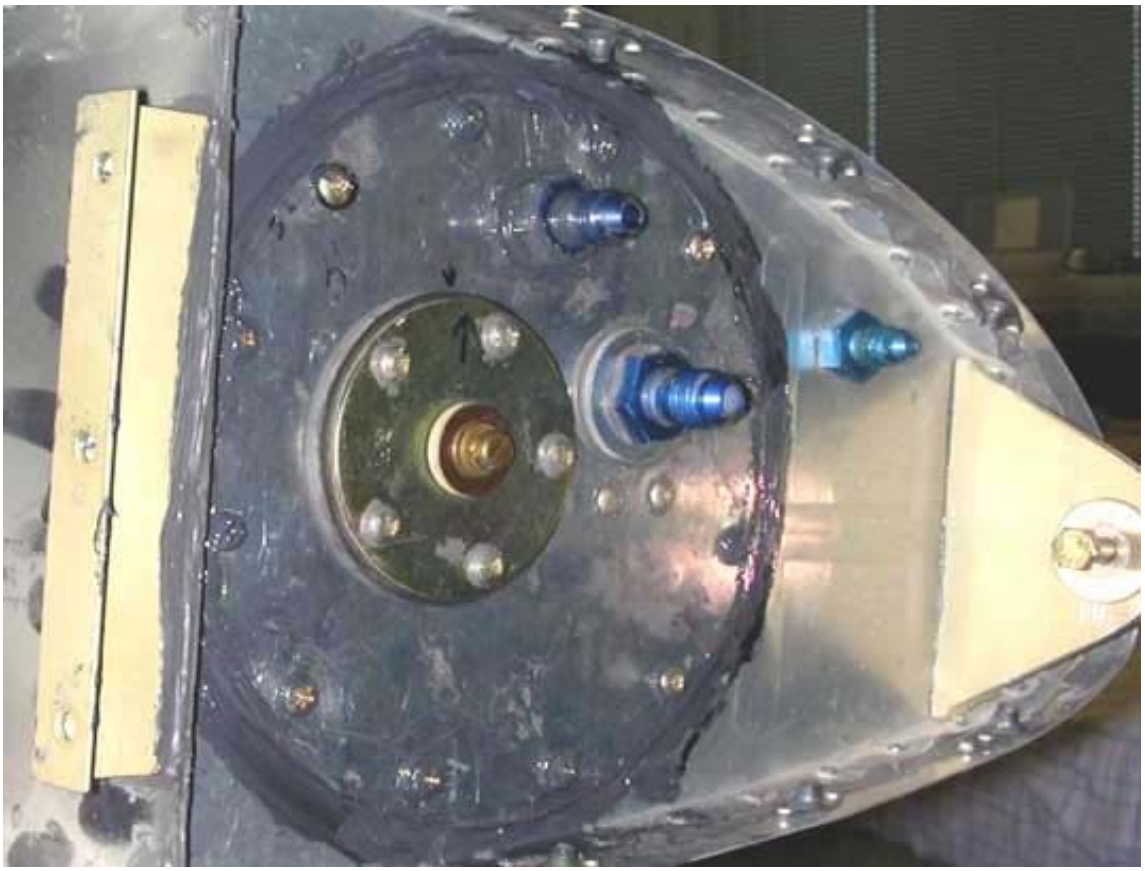
Fuel should be returned to a low point near the rear wall of the tank beyond the second tank rib. This assures that the warm fuel returning to the tanks will have a chance to mix with the cold fuel and disperse any bubbles. Keeping the return line below the level of the fuel in the tank will also help to prevent foaming.

By orienting the return tube near the rear wall of the tank, the tube will be unable to rotate and become loose. A small amount of ProSeal around the fitting nut will help to prevent tube rotation inside the tank. A snap bushing, drilled for 5/16" tubing, can be used in the second bay rib to prevent tube vibration. If you are using the capacitive fuel quantity senders you should never have a need to open the tank end plate again, so you might consider a dab of ProSeal rather than snap-bushings to prevent vibration. The same applies if you position the return fitting on the tank rib itself rather than the tank end plate.

Diagram of EFI Fuel Return System - Tank Fitting and Tube (492KB PDF File)

Photo of Tank Fitting and Tube with Float-Type senders.

3. [ ] Seal the tank cover plates with ProSeal and new cork gaskets. Van's catalog lists them if you need a new set. Note that many builders have reported leaks in their cork gaskets over the years. A general trend is to omit the gaskets entirely, in favor of straight ProSeal. This decision is yours to make.



4. [ ] Install the Andair (p/n FS-20-20-D2) six-port duplex fuel selector valve. Note that the three snap bushings are used for, top to bottom, the supply lines, return lines and brake lines. The tight radius bend at the valve can be made with a conventional hand tubing bender. A "Rigid Model 456" bender ($20 from Home Depot) was used for this installation.

To make the tight bends, thread the fuel lines in from the side of the fuselage toward the valve so that the tubing passes the valve by about 12". Next, insert the fitting nut and sleeve and make the end flare using a RoloFlare or similar **37-degree** flaring tool. (BEWARE THAT MANY AUTOMOTIVE AND PLUMBING FLARING TOOLS ARE 45-DEGREE FLARES!). Once the flare is done, insert the tube into the bender as close to the end fitting as possible and make the bend in a single smooth motion. Don't hesitate to scrap a bend if it contains dents or other defects. Tubing is cheap. Just pull some more length through and try again until you get good bends. When all the lines are properly bent and tightened, you should be able to wiggle the valve body slightly to verify that no undue stresses exist in the line installation. It is important that the lines are not under mechanical stress, otherwise cracks and leaks can develop over time.

Be sure to clean each line with a blast of air to remove any metal filings. DO NOT BLOW AIR THROUGH THE FLOW SENSORS, PUMPS, OR VALVE!

Diagram of EFI Fuel System Components and Plumbing (718KB PDF File)

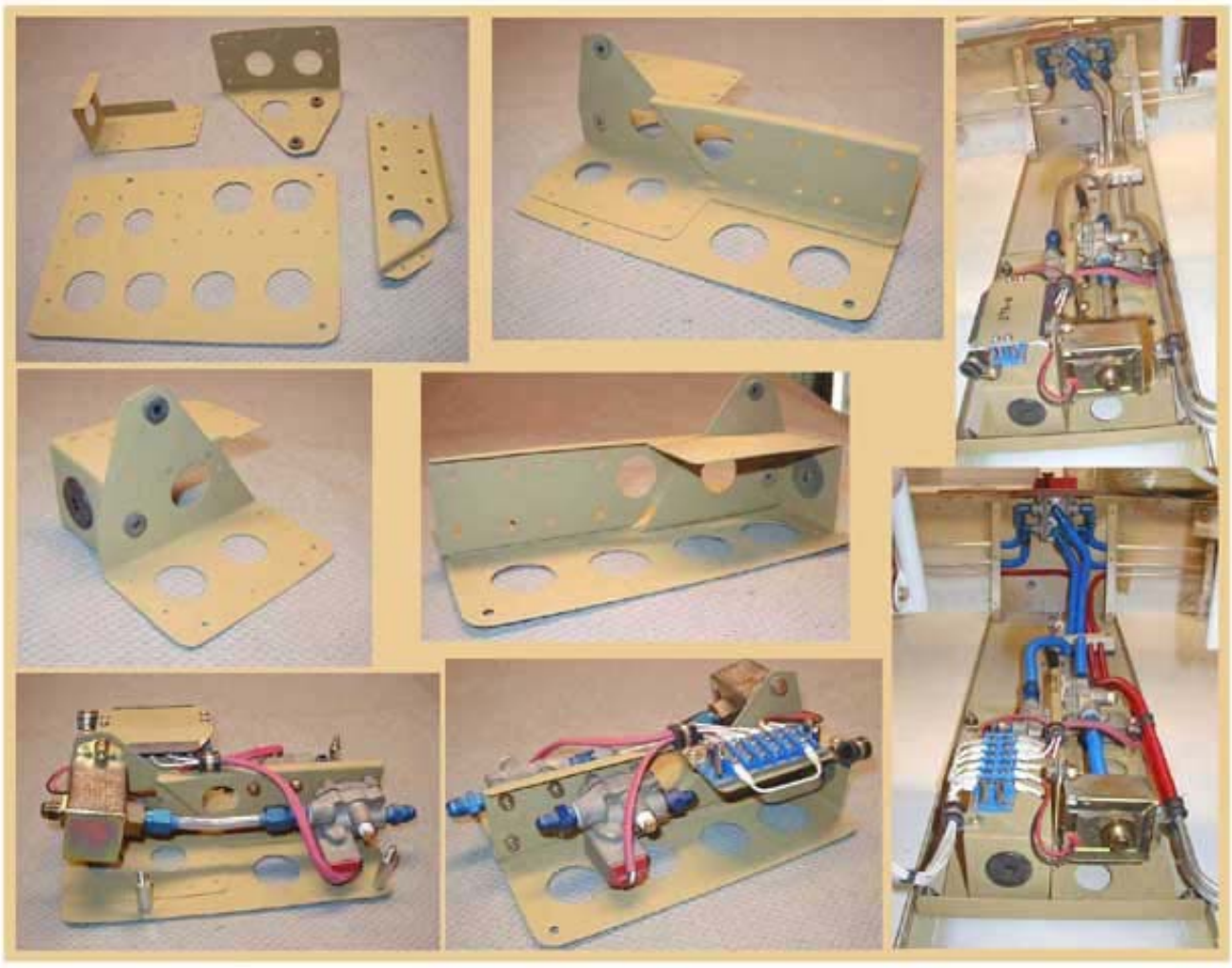
5. [ ] If you are using the optional flow sensors, you should install them inside the center cabin floor panel. Flow sensors are sensitive devices that are prone to erroneous indications if they are subject to extreme vibration, temperature, or turbulent fuel flow. Ideally, they should be mounted in a level section of straight tubing, away from heat and vibration sources. Unfortunately, Vans center console panel is only an inch tall, so if you choose to mount the large type FloScan sensors under the center panel, you will need to add aluminum strips along the sides to raise the panel. Optionally, you can fabricate your own custom center console out of aluminum or fiberglass. This is a good place for builders to express their own creativity. If you order the small type flow sensors from Grand Rapids (as used with the EIS), these will fit under the factory center cabin floor panel without modification.

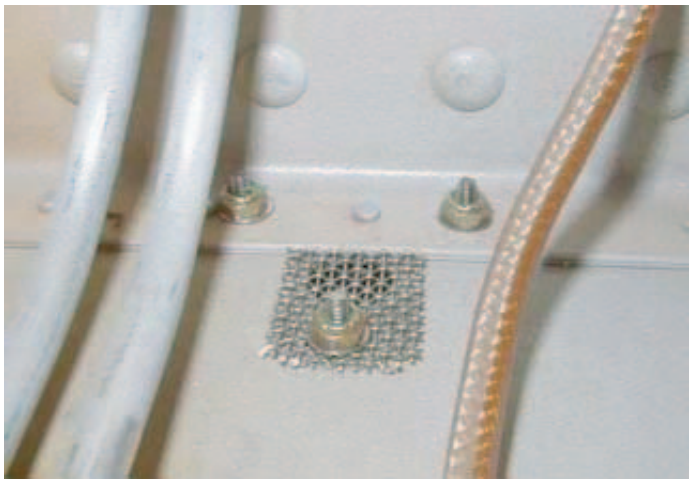
Install the supply and return lines between the optional flow sensors and selector valve. Pay attention to the orientation and direction of flow for the flow sensors. The arrow on the supply side tube will point toward the motor, whereas the arrow on the return side will point toward the selector valve. Flow sensors also have a correct "UP" side. Retain the paper calibration cards that come with your flow sensors. If you are using any sort of programmable indicators, you may need these numbers for calibration.

FloScan flow sensors come in two sizes. The larger type (p/n 264PB-15) uses 1/4" NPT fittings. The 3/8" supply line uses AN816-6D nipples which are available with 1/4" NPT thread. For the return line which uses AN816-5D fittings, you will need to install reducer bushings to adapt to your line fittings. Note that MRP and Earls Performance Parts make an AN#5 to 1/4 NPT adapter fitting if you would like to avoid using separate reducer bushings. If you are using the EIS engine monitoring system, it will come with the smaller type of flow sensors which also use 1/4" NPT fittings.

Customization

The photo below shows one example of a cabin fuel system which places both supply and return flow sensors in the center console. This particular installation uses the optional Facett low-pressure priming pump. This pump is no longer required on new installations. A homemade bracket mounts everything on rubber cushions to reduce vibration and noise. Note that the Facett pump must be mounted on an angle with the outlet fitting higher than the inlet fitting. The finished cabin plumbing is protected with PVC wrapping and a custom fiberglass console and access lid (not shown). It is not necessary to do it this same way. Note in the photo that this builder has added a small screen-covered drain hole and air vent towards the rear of the console to allow fuel to drain away if a leak should ever occur.





6. [ ] Install the supply line between the optional forward flow sensor and optional primer pump or gascolator. Testing has shown that the high-pressure EFI fuel pumps that come with your engine are capable of priming themselves under normal conditions. For this reason, the Facett low-pressure primer pump has been declared optional. If you intend to fly aerobatics where there is a high chance of un-porting a fuel tank pickup tube, you may choose to install the optional Facett primer pump, but keep in mind that it will present a slight pressure restriction during normal (Facett pump off) operation.

7. [ ] Install the supply line to the bulkhead fitting on the firewall. The exact location of the supply line firewall fitting should be determined once the motor is mounted to the firewall and you have determined the location of the batteries and fuel pumps. The diagram provides a general guideline, but it is up to the builder to make the final decision as to its location.

8. [ ] Install the return line between the optional return flow sensor and a bulkhead fitting. The diagram shows the desired location for this fitting in the upper right corner of the firewall.

9. [ ] Clamp all fuel lines as needed using Adel clamps.

10. [ ] The remaining fuel system connections on the engine side of the firewall, and all related wiring, will be described later.

11. [ ] Note the ending time.

Chapter 3 - Landing Gear & Engine Mount Preparation

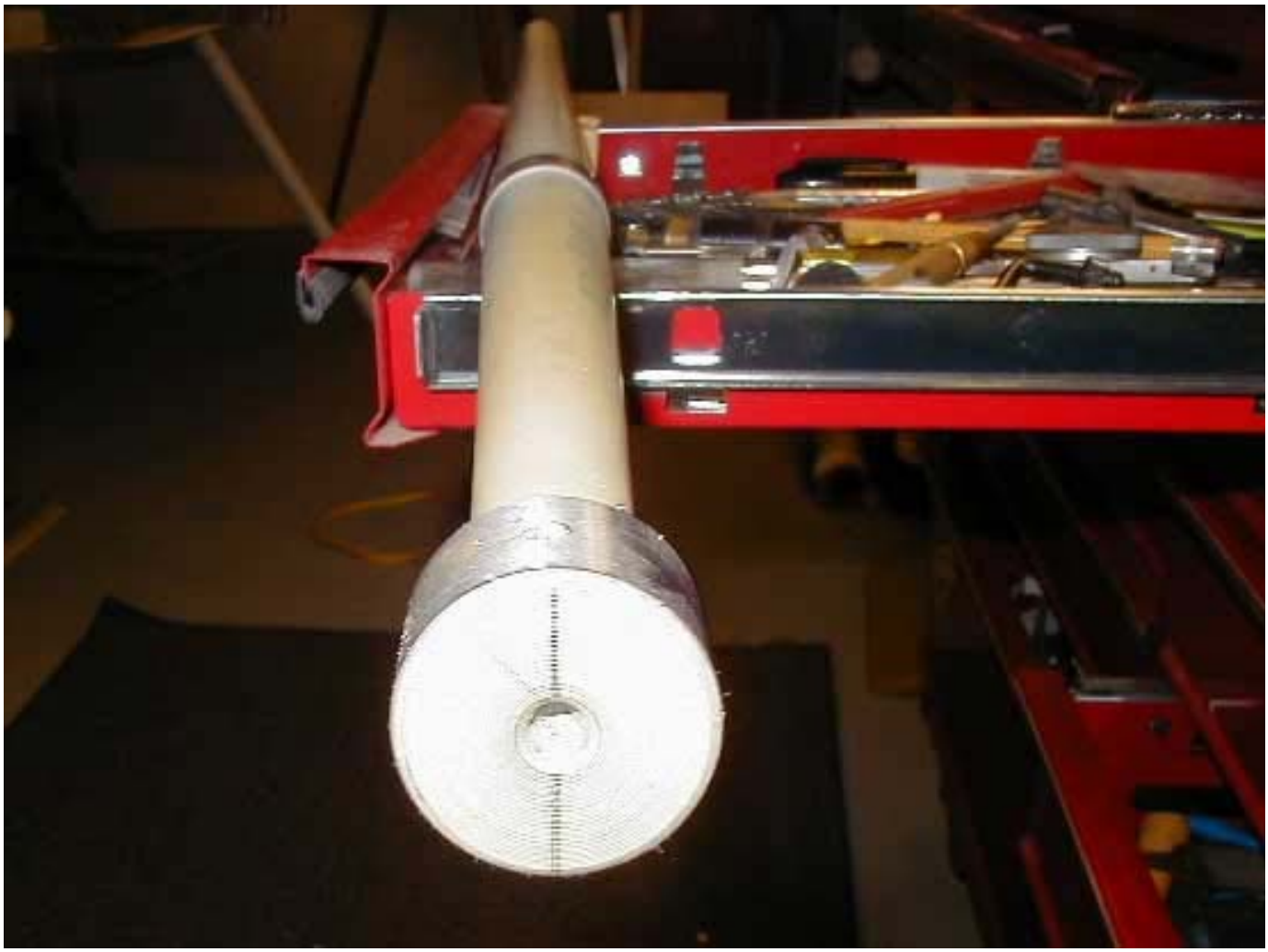
Nose Gear Leg Preparation

If you are building a taildragger, you may skip this task, or apply the guidelines to the main gear installation.

The nose gear leg will need to be drilled for the single 5/16" mounting bolt. A hole needs to be drilled through the top knob of the nose gear leg from front to rear. This hole must be a precise fit for the 5/16" bolt to avoid nose gear shimmy, so we will drill it slightly undersized and ream it to 0.310". Note that the "axle" part of the nose gear actually sits perpendicular to the floor, not parallel with it, as the main gear legs are oriented. This axle passes *vertically* through the nose gear fork. Gather the related parts and review the blueprints to become familiar with the orientation and relationship of the parts.

The nose gear leg fits into a tube in the engine mount. This tube will have a pilot hole drilled through it on one side. You can pre-drill the nose-gear leg in a drill press, then align the holes when you install the leg in the mount tube and hand-drill the final hole.

To assure that the hole is drilled straight, the leg should be marked then securely clamped in a drill press vise for drilling.



A simple means of marking the gear leg is to lay it across a wide drawer such as a toolbox cabinet drawer. The weight of the axle part of the leg will hang directly downward, swinging the leg perpendicular to the floor (or gravitational center of the earth anyway). Using a small level or plumb bob, mark a vertical centerline where the bolt will pass through the gear leg. Also mark a point to start drilling on the top face of the gear leg knob. Consult the plans for orientation.

Move the gear leg to a strong drill press vise and clamp it into position. Verify that the line remains perpendicular to the floor with a small square against the drill press base plate. Secure the gear leg in the vise and the vise to the drill press base plate.

Drill a pilot hole through the gear leg using a 3/16" cobalt, carbide, or titanium drill bit. Use a slow drill speed and apply steady pressure. If the drill bit sings or you see signs of overheating, stop and apply a drop of machine oil or dip the hot drill bit in Boelube drilling paste before proceeding. When the pilot hole is done, verify that the hole is in alignment. If not, a small amount of repositioning in the vise may be possible before continuing with the next size drill. Several increments of drill sizes should be used to allow gradual correction if you have fouled up the alignment. Best to get it right the first time! The alignment is critical because a small amount of misalignment in rotation will be very noticable at the tip of the leg. Also, play in the bolt is not good, so only increase the hole size to that of the bolt. Most bolts are a few thousandths under the actual named dimension.

Make a second pass through the hole with a 19/64" drill bit and 0.310" reamer. This is the final size. Debur the hole and chamfer the edges.

Reamers can be obtained through many sources, a few are listed below:

- MSC industrial supply (incredibly fast order delivery) - www.mscdirect.com
- McMaster-Carr - p/n 8803A47 for 12 bucks US.
- DORMER catalog - .3105" (close enough) p/n 0250525

TIP: Use only new drill bits of good quality cobalt or titanium. The most common problem when drilling this hole is to continue applying pressure to a dull drill bit. This can cause the drill to chatter and "walk" slightly off center. You must use good quality bits, securely clamped in a large drill press vise. If you are not equipped to make this hole, take the gear leg and mounting bolt to a local machine shop. You want your nose gear to run straight! A machine shop can drill a very precise hole to give you a perfect push-fit for the bolt.

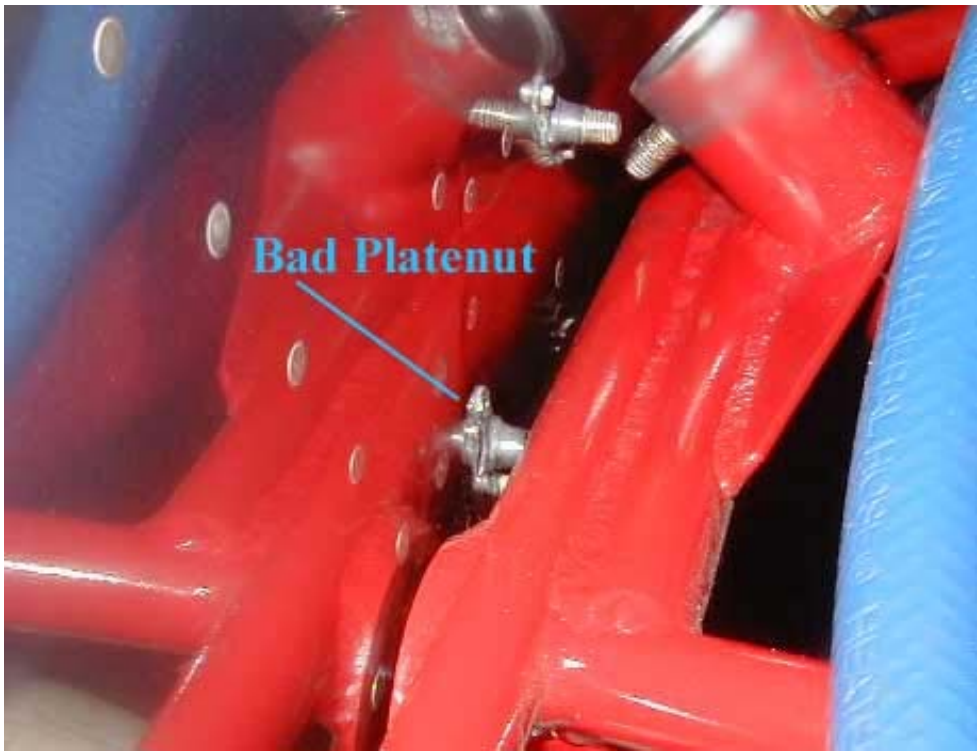
Standing on your own three feet.

The weight of the powerplant will cause the landing gear to compress. You need to prepare for this so as to avoid possibly denting the bottom fuselage skin or other parts. Your wheels should have their bearings greased and be installed before hanging the motor. You can remove them as needed later. Remove any saw horses or other objects from underneath the plane which might dent the fuselage belly. As weight is added to the nose, the tail section will tend to rise. Be certain you have enough overhead clearance to avoid damaging your airframe. If convenient, remove and store the empennage.

Assemble the nose gear leg and wheel assembly. You may choose to install the nose wheel now, before installing the gear leg, or later. If you defer wheel installation, be sure to protect the nose gear leg so the threads are not damaged.

Remove a Badly Placed Plate-Nut

If you installed the fuel pump backing plate on your firewall (specified by Vans for Lycoming motors and the Facett pump), the lower plate nut will need to be removed as it interferes with the engine mount tube. Drill out the rivets, remove the plate nut and fill the holes with dead-rivets or screws and nuts.



Inspection Checklist - I - Pre-Installation

If you are installing an optional cabin heater, now would be the time to complete the installation. It is easier to work on the heater before the engine is in the way. Return to and complete this first Checklist when you are ready to continue.

At this point you are ready to hang your motor on the firewall. Check the following details.

[ ] Have you installed your optional **Cabin Heater** main box (the valve and hoses will come later)?

[ ] Have you obtained all **tools, parts and materials** required for hanging the motor?

[ ] Do you have the correct **Engine Mount Bolts**?

[ ] Do you have a **19/64" drill and 0.310" reamer** for your **portable electric drill**?

[ ] Is the **workspace suitable** for the task?

[ ] Is an **Assistant** available and briefed?

[ ] Are the **Wheels and Tires** assembled?

[ ] **Nose gear leg**, fork, and wheel are ready to install?

[ ] **Firewall** is fully riveted and clean?

[ ] Rectangular stainless steel **firewall recess** is installed and sealed?

[ ] **Hoist and sling** are ready to go?

[ ] **Safety** measures have been considered?

[ ] Enter time and date in your Engine Logbook under "Initial Installation" including engine year, size, type, model and serial number.

Chapter 4 - Powerplant Installation

The big crate arrives!

Few things are more pleasing to the builder of a flying machine than receiving a giant wooden crate with an engine in it! If you are not yet ready to hang the motor, but just want to take a peek, open one of the side panels of the shipping crate (leaving the top panel to protect the motor).

Some general advice from the engineer...

"Somewhere in the beginning [of this guide, make] a mention of the [benefit to be found through] liberal use of blue LOCKTITE on anything installed without a locking device [this method] should be used. Also mentioning [that] the [desirable] practice of always using the specified values for torque when attaching anything to the engine aluminum casting and that less torque, together with blue LOCKTITE will make the treads last so much longer. Spark plugs should always be removed from a cold engine and new plugs with a new crush gasket and anti seize compound should be used". OK...;^)

When you are ready to attach the hoist and sling, gather at least two strong persons to uncrate the motor and tip it upright.

1. **[ ]** Remove all panels of the shipping crate. (I built my daughter a tree house with my shipping crates).
2. **[ ]** Slowly tip the engine, still bolted to the shipping palette, upright as it will go in the plane.
3. **[ ]** A small amount of oil may spill from the exhaust pipe (if installed). This is a normal side-effect of shipping the motor on end.
4. **[ ]** Position a pair of jack stands or wooden blocks under the aluminum engine mount plate so the engine rests level.
5. **[ ]** Remove the temporary screws holding the ECM (Engine Control Module) and Fuel Pumps to the shipping crate.
6. **[ ]** Coil up any excess wiring and fuel lines on top of motor. Fasten these items out of the way.
7. **[ ]** Pre-drill for the major firewall fittings. Mounting bolts, hoses, cables and conduit pass-throughs.
8. **[ ]** Polish, paint, or machine the firewall if desired.
9. **[ ]** Gather the engine mount bolts and nuts and appropriate wrenches.
10. **[ ]** Gather a spare ratcheting tiedown strap to help align the engine mount legs.
11. **[ ]** Take note of the time.

Hoisting the motor

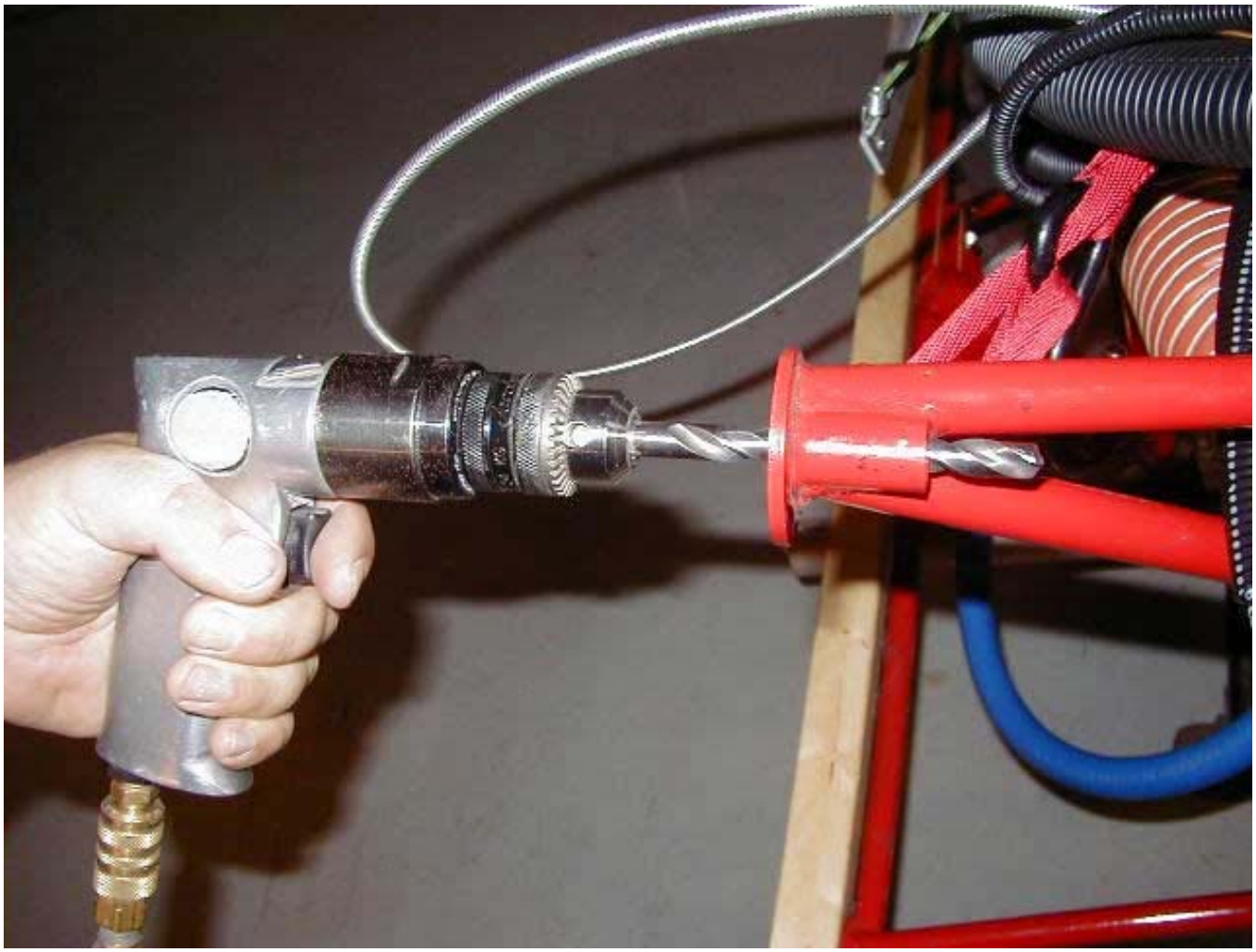
Be sure you have ample room to maneuver the engine hoist into position over the engine, all the way to the airframe. Have assistance standing by.

Do not allow the weight of the engine to rest on the engine mounting bolts until all bolts have been inserted and properly torqued.

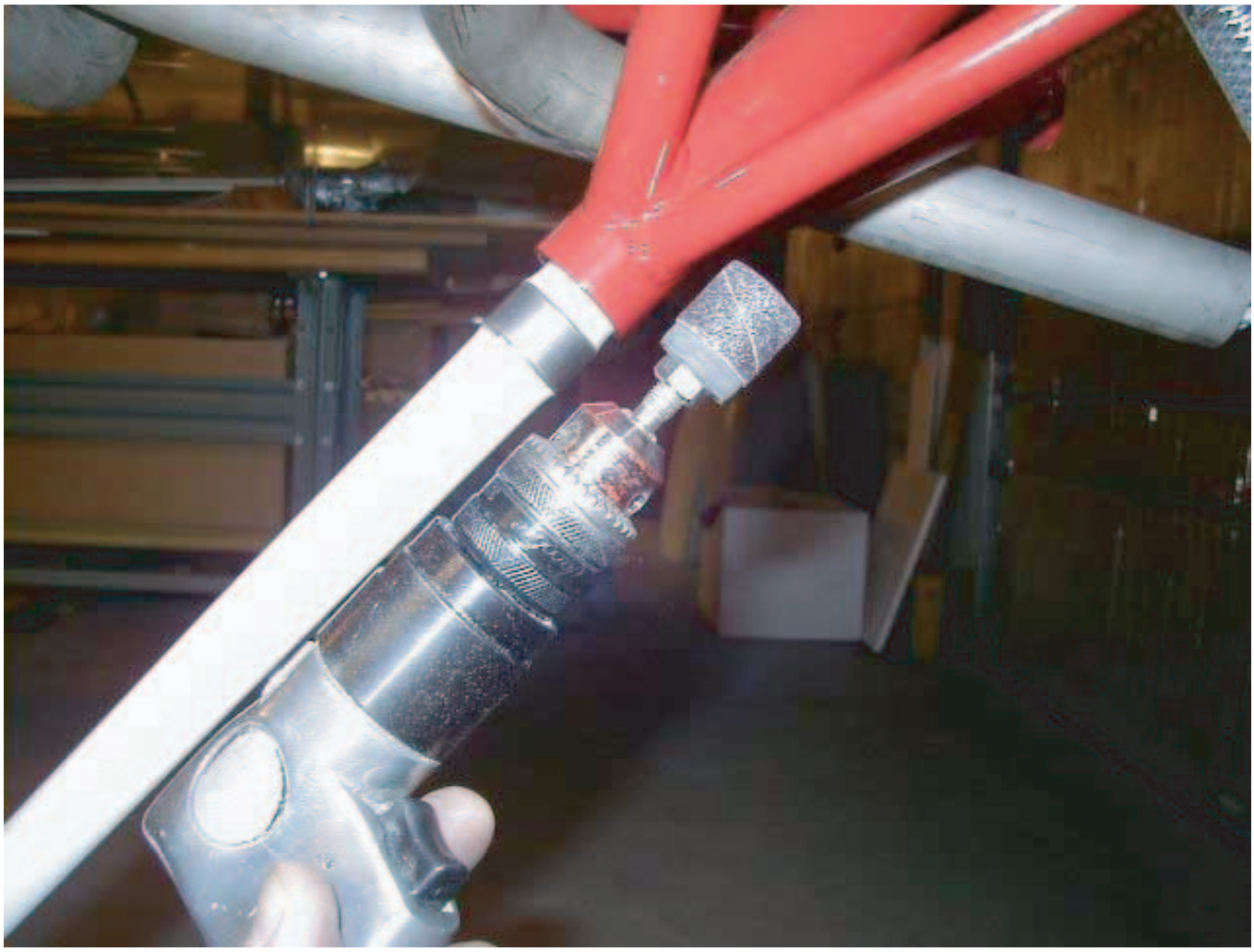
12. **[ ]** Position the hoist hook directly centered about 4" over the engine air intake manifold. Do not attach straps to the manifold itself!

13. **[ ]** Attach four strong ratcheting tiedown straps from the corners of the engine mount to the hook. Double up the straps where possible.
14. **[ ]** Attach another tiedown strap from the hook, under the PSRU bearing hub, and back to the hook. Make the ratchet handle accessible.
15. **[ ]** Slowly raise the hoist adjusting the straps as needed to balance and level the engine.
16. **[ ]** Remove the shipping palette.
17. **[ ]** Move the hoist close to the airframe but not yet into position.

Nose Gear Leg and Wheel



18. **[ ]** Clean out any scale or debris in the motor mount bolt holes using a sandpaper roll or a drill. Do not enlarge the holes!
19. **[ ]** Raise the hoist high enough to allow insertion of the nose gear leg into the receptacle.

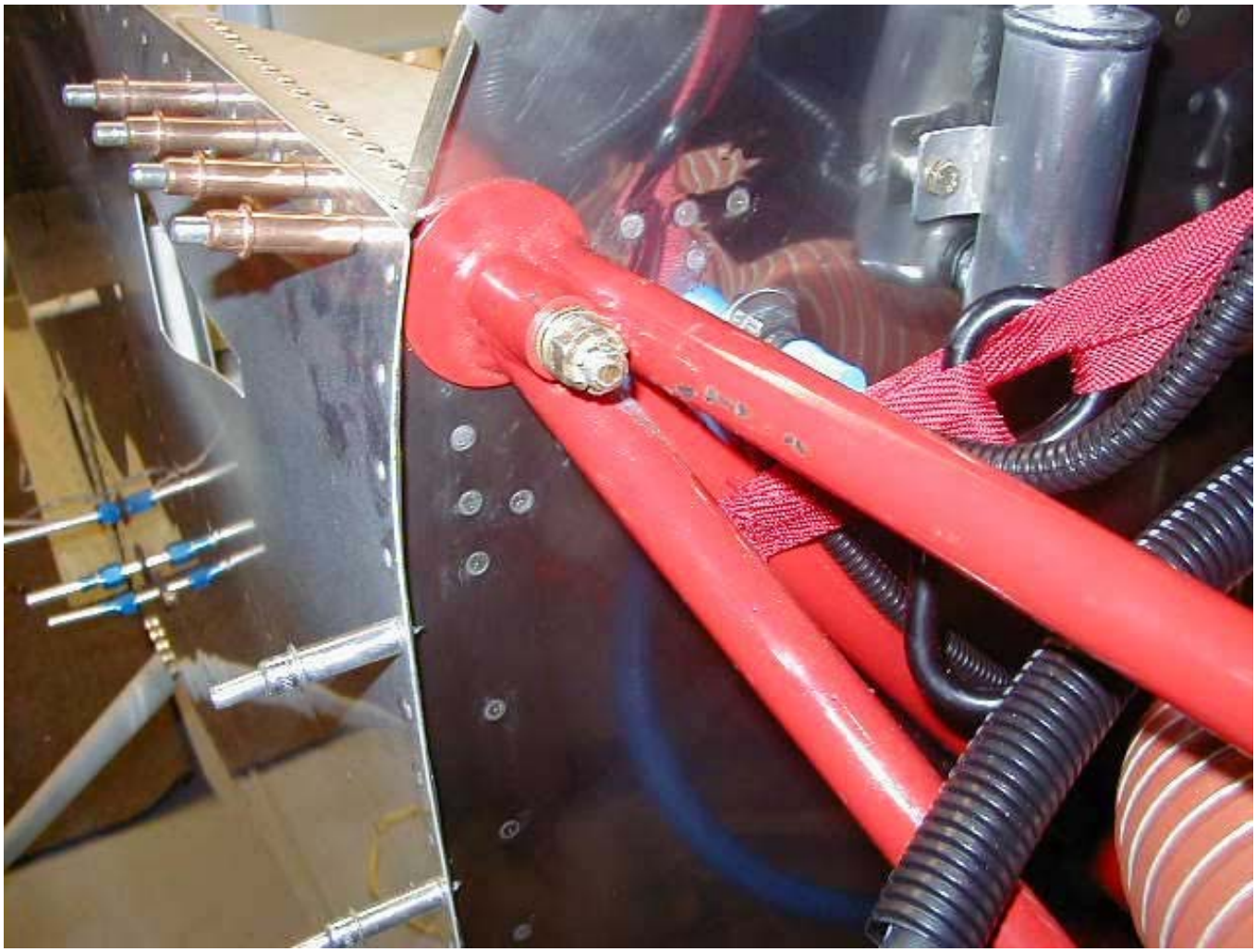


20. **[ ]** Clean out any loose scale or debris from inside the nose gear mount receptacle tube using a drum sander drill bit. If you prefer, an automotive brake cylinder hone with a splash of kerosene makes short change of this task.
21. **[ ]** Test fit the nose gear leg into the engine mount. It is likely to bind at the point where the mount tubes are welded to the gear tube.
22. **[ ]** Remove the gear leg and polish the inside of the gear tube with a drum sander drill bit or brake cylinder hone until the nose gear fits snugly into the gear tube. A tight fit is desirable, but not so tight that you must use force to insert the leg.
23. **[ ]** Swab out the inside of the gear tube with a rag on a stick.
24. **[ ]** Smear a light coating of Anti-sieze Compound onto the gear leg bearing surfaces and swab some more inside the gear tube.
25. **[ ]** Insert the nose gear leg and finish drilling and reaming the bolt hole for the 5/16" gear leg bolt. Use a 19/64" drill bit and 0.310" reamer to produce a snug bolt fit. Use a castellated lock nut to secure the bolt. Fiberlock nuts don't fare well near a hot exhaust pipe.
26. **[ ]** Raise the hoist as necessary and install the nose wheel fork components and nose wheel. Loosely fasten these for now.

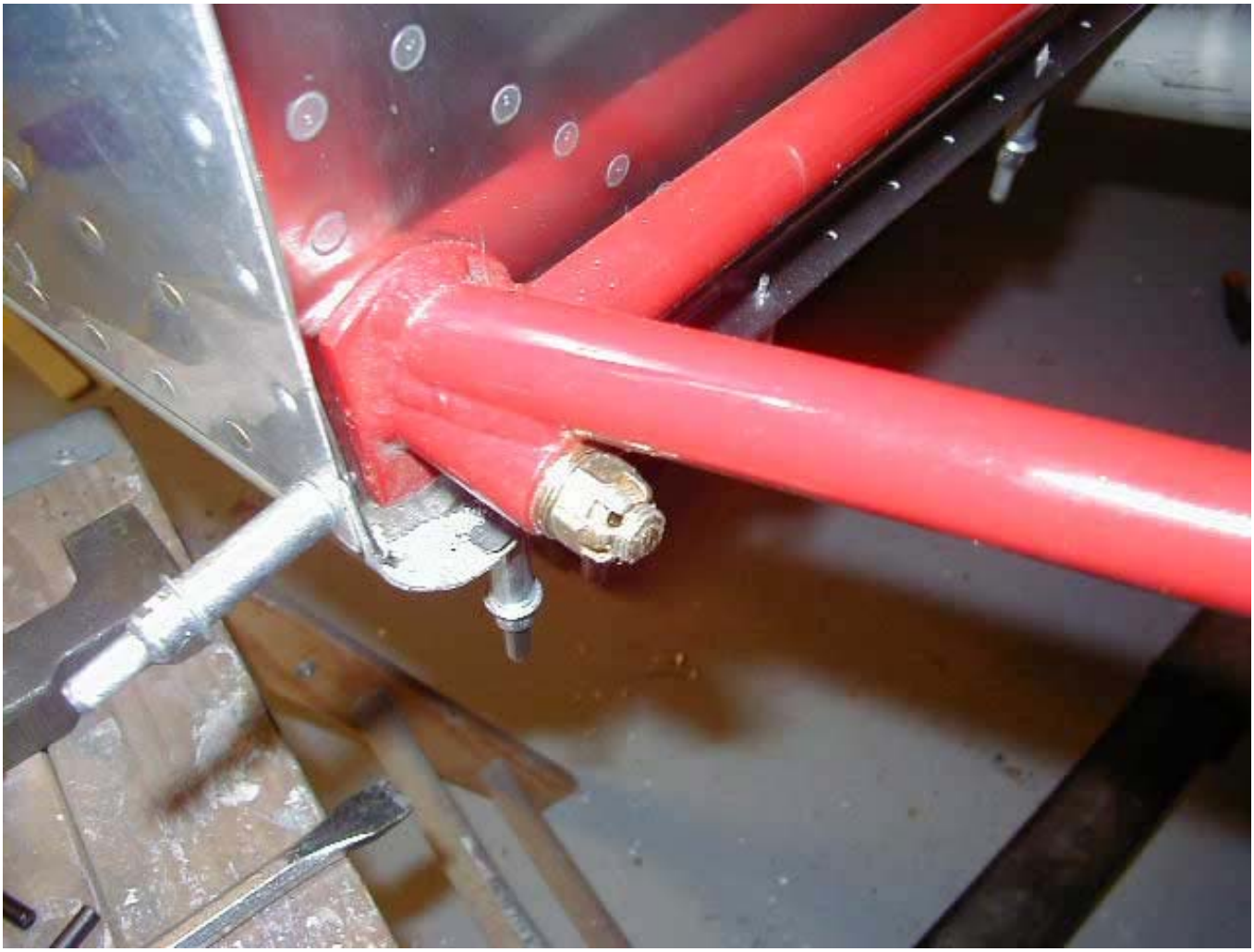
Motor Mounts

27. **[ ]** Move the hoist to position the engine against the firewall.
28. **[ ]** Shorten or lengthen the strap under the PSRU bearing hub as needed to orient the engine parallel to the firewall
29. **[ ]** Raise or lower the aircraft's empennage to help align the engine mount.

30. **[ ]** INSERT ONE OF THE UPPER BOLTS FIRST. Insert all mount bolts **from the cabin side**. Loosely install washers and nuts. Some builders have chosen to use AN6-20 (corners) AN6-22 (bottom center) bolts which are slightly shorter length than those provided by Vans. This eliminates the need for additional washers, but there's nothing wrong with using the ones Vans gives you with washers.



31. **[ ]** Note: If you need to, you can run a drill through the mount hole to ease the fit, but these bolts should be snug.
32. **[ ]** INSERT THE OTHER UPPER BOLT NEXT.
33. **[ ]** Reposition the hoist as required to bring the lower mount legs against the firewall.
34. **[ ]** INSERT THE BOTTOM OUTBOARD BOLTS NEXT.



35. **[ ]** If the mount legs appear slightly out of alignment with the firewall holes, pull the legs into place. The mount is precise, but able to flex slightly.
36. **[ ]** Snug down the four bolts we have installed thus far.
37. **[ ]** With the hoist raised just enough to hold the weight off the nose wheel, drill the center bottom pair of engine mount bolt holes through the firewall.

38. **[ ]** Clean any shavings away, and debur the holes as best you can.
39. **[ ]** INSERT THE BOTTOM INBOARD BOLTS.
40. **[ ] Torque all engine mount bolts to 200 in/lbs and install cotter pins**.
41. **[ ]** Slowly lower the hoist and observe as weight is transferred to the landing gear.

42. **[ ]** Disconnect the hoist and sling!
43. **[ ]** Reinstall the exhaust pipes. Be sure to use good metal gaskets.
44. **[ ] Torque the exhaust flange bolts to 270 in/lbs**.
45. **[ ]** A single band clamp is used in the center of the pair of pipes to prevent vibration. Another band clamp is used on the rearward pipe to secure it to the aluminum bracket hanging down from the rear of the motor. Reattach these next.
46. **[ ]** Note the time, take a well deserved break, brag to your friends about your really cool motor!

You may optionally insert a stainless steel shim stock strip around the lower nose gear tube to take up any slop between the gear leg and tube. This can be a blade removed from a feeler gauge, or just a thin strip of metal. The shim can be secured with a good glue or tape around the gear leg. This will be covered by the gear leg fairing, so don't worry too much about appearances. Understand that the nose gear leg is a giant spring. It must be able to move slightly in the tube. The purpose of the shim is just to assure there is no rattle during taxi and landing. It is wise to check this fit during every annual inspection.

Inspection Checklist II - Familiarization

The purpose of this checklist is just to gain familiarity with the engine and some of the parts involved in the next installation tasks.

- [ ] Locate and identify the spark plugs. You can identify their numbers from the numbers stamped on the ignition coil.
- [ ] Locate the **Fuel Inlet** (left side as viewed by seated pilot) and **Fuel Return** fittings (right side).
- [ ] Locate the **Coolant Temperature Probes**. The one by the starter motor is the one used by the Engine Control Module (ECM), the one in the left radiator inlet tube (if installed) will be used by your engine instrumentation.
- [ ] Locate the **Hose "Towers"**. These are the round aluminum fixtures where your radiator and heater hoses attach. There are two on top and one on the bottom. The bottom one contains your thermostat.
- [ ] Locate the **Coolant Drain Plug** on bottom of the lower hose tower.
- [ ] Locate the **PSRU Fill and Drain Plugs** (PSRU = Prop Speed Reduction Unit, a.k.a. gearbox).
- [ ] Locate the **PSRU Temperature Probe** (or plug if the probe is not yet installed).
- [ ] Locate the **PSRU Breather Tube and Filter**.
- [ ] Locate the **Crankcase Breather Tube and Filter**.
- [ ] Locate the **Oil Fill Cover Plate**. Note, it requires removal of two small bolts to add oil. The Subaru is not like other aircraft motors which need constant oil addition.
- [ ] Locate the **Oil Drain Plug**.
- [ ] Locate the **Oil Filter**.
- [ ] Locate the **Oil Temperature Probe** or plug if not installed yet.
- [ ] Locate the **Oil Pressure Sender** or plug if not installed yet.
- [ ] Locate the **Alternator Field and Output Terminals**.
- [ ] Locate the **Timing Belt Cover** and **Rubber Inspection Plug**

That should do for now. There are many more sensors on the motor, but these are factory installed and do not require our attention during installation. If you are curious, consult your Subaru repair manual for further details.

Chapter 5 - Fluid Systems Installation

This section covers the installation of your Gascolator, EFI Fuel Pumps, Fuel Return Line, Coolant Reservoir, throttle cable, and optional Heater Hoses and Heater Controls.

Fuel Pump and Gascolator Installation

A Gascolator is *required* to separate water and contaminants from the fuel supply. Both *Andair* and *Van*'s offer suitable gascolators. Be sure to get a gascolator which has O-rings and seals capable of withstanding automotive fuels. The Buna type seals are good. The *Andair* unit is a higher quality, but the *Van's* gascolator has a unique feature that also serves as the firewall bulkhead pass-through fitting. The choice is yours. Be sure to order a drain fitting too.

Your engine uses dual EFI (Electronic Fuel Injection) fuel pumps. One of these will be wired to be your MAIN pump and the other will be your AUX pump. The pump with the most direct plumbing should be designated as the MAIN pump. The pumps contain an integral check-valve so that if one pump fails, or is turned off, the other pump will not back-drive fuel through the stopped pump. This arrangement allows for simple tee fittings for both inlet and outlet plumbing. We will cover pump and fuel sensor wiring in Chapter 6.

It is never necessary to run both pumps at the same time. In fact, this consumes excess energy without providing any benefit. The pilot is provided with both manual and automatic pump control through a "Pump Select" switch. The automatic function will detect pressure loss from the MAIN pump and switch on the AUX pump before the pressure drops to a critical point. This arrangement makes it unnecessary to run both pumps simultaneously and provides the fastest possible failover switching.

The EFI pumps are not specifically rated as self-priming, but have proven to be capable of self-priming up to 24". In a high-wing aircraft, priming is a non-issue. In low-wing aircraft, the use of a (Facett) primer pump is optional. If you are building an aircraft with an overhead engine pod like many seaplanes, you will have special fuel system design issues that are not addressed in this manual. In particular, some form of vented header tank will be required. Contact the factory for further information.

The fuel that flows through the EFI pumps provides pump cooling. Our full-loop fuel system circulates enough fuel to carry away most of the heat from the pumps and injector rails; however, we recommend that you install some form of heat-shield over the pumps when they are mounted in the engine compartment. The heat-shield can be a simple aluminum or stainless-steel plate mounted between the pumps and the engine exhaust system. Active cooling air is not required, but many builders have gone the extra step to port cooling airflow over the pumps.

The fuel pumps are fastened to a pair of aluminum brackets. It is recommended that you provide some form of rubber or nylon shock-mounting to absorb vibration and reduce pump noise inside the cockpit.

You will need a set of Oetiker clamps and pliers to complete your installation. You can obtain these from the factory.

Oetiker Clamp Kit

1. [ ] Note the time

2. [ ] Position the pumps and gascolator on the lower left side of the firewall (right side if looking at the firewall from the engine side).

The pumps are to be oriented vertically and mounted as low on the firewall as practical. You will need to play with the positioning to assure that you can fit the pumps, fuel sensors, gascolator, bulkhead fitting, filter, fuel supply line, and possibly a battery in the available space. This is best accomplished by locating the pumps as far outboard as possible with the gascolator just inboard of the pumps.

When positioning the gascolator, think about where the firewall pass-through fitting will need to be. Make sure you don't inadvertently place it over the brake hose connections on the inside of the firewall. Think about the drain fitting when determining the vertical placement of the gascolator.

The *Vans* gascolator will mount on the firewall and the drain will just clear the engine mount tube. The base of this gascolator cup should be as close to the engine mount tube as possible, yet still allowing the cup to be removed for cleaning. A short brass pipe nipple will be required to extend the drain fitting so it just protrudes from under the cowling (via a hole you must drill in the cowl).

Vans Gascolator (with extended drain & built-in bulkhead fitting)

The *Andair* gascolator uses a mounting bracket and separate fuel fittings. Obtain and layout these fittings. It helps to temporarily install the fuel system pressure sender, pressure switch, and optional temperature probe before you commit to a final position. Note that this is not the only possible location for the gascolator. You may position it wherever you like, but it must be mounted low on the firewall and far away from the exhaust pipe.

Andair Gascolator (with additional fuel tube & bulkhead fitting)

3. [ ] Mark the location of the mounting holes for the gascolator and pumps.

Note: There have been a variety of types and orientations of fuel filters and plumbing on early motors. Yours may not look the same as the photos below. Nonetheless, these guidelines remain applicable to all filters and pump configurations.

4. [ ] Determine how you would like to shock-mount the pumps. Typically the use of thick nylon washers or rubber grommets will be used. Before drilling holes, verify that everything still fits with the added thickness of the shock-mounts.

5. [ ] After drilling, debur the gascolator and pump mounting holes (holes for Vans model shown).

6. [ ] Bolt the gascolator and pumps to the firewall. Use 1" diameter stainless-steel washers on the inside of the firewall to reinforce the bolts. This will help to alleviate any future stress cracks. (Vans model shown; note the wide washers).

7. [ ] Install the 3/8" gascolator fuel supply line inside the cabin using AN size 6 fittings. This will be coming from your optional primer pump, or optional flow sender, or your selector valve if you are not using either of these optional components. This should complete your in-cabin fuel system plumbing. If you are using the *Andair* gascolator, you will need to install a firewall bulkhead fitting and a short section of 3/8" line to connect the gascolator as shown below.

8. [ ] Connect the gascolator to the fuel pump inlet tee using the supplied 5/16 rubber Fuel Injection Hose.

WARNING: Fuel Injection Hose is ***NOT*** the same as regular fuel line hose. It has a far greater burst pressure rating. It must be used! Likewise, Oetiker clamps must be used on all high-pressure fuel lines. The only exception is that band-style Fuel Injection screw clamps may be used at the fuel filter for maintainability reasons.

You will need a 1/4 NPT to 5/16 barbed fitting. These are available in brass at any good hardware store. Aluminum 5/16 barbs are rare, but use one if you have it. NAPA auto parts stores have these in a "single barb" style which are more expensive but the ideal style for the application. Do not use nylon or any other plastic fittings in the fuel system. Use Oetiker clamps on all permanent connections.

9. [ ] Determine the placement of the fuel filter. The filter is to be oriented in a way which will allow air to pass through. Pay attention to how the fuel line will be routed to the motor so as to minimize bends.

WARNING: Do not use anything other than the supplied fuel filter. Automotive EFI motors with full-loop fuel systems require high-volume / high-pressure filters. The popular "cleanable" type filters do not offer the volume or pressure needed by your motor. Most are limited to around 5 gph and 15 psi. For our system, we need 40 gph and 60 psi. Stick with the filter provided by the factory.

10. [ ] Install the fuel filter using Fuel Injection Hose Clamps available at any good auto parts store. These are NOT worm-drive Breeze clamps. They are band-clamps specifically designed for fuel injection hoses. Drill a hole as needed for your filter-mounting bracket. For best serviceability, use nut-plates on the firewall. The filter will be changed during every inspection. Pay attention to the direction of flow.

Some advice from the engineer (he has a thing about clamps...)

"...Or better yet, go to your local salvage yard that handles late model cars. Bring your screw gun and remove as many of these clamps as you can from Mazda or Subaru cars. The clamps are stainless-steel rather than the plated type available at auto parts stores. Obviously, you can order them new from Subaru as well. One word of caution: 5/16 automotive fuel injection hose comes in several brands. They are not of the same outside diameter, so be sure your clamps have a good fit and that the hose is not so large as to make the screw clamp crush against itself, rather than overlap, when the screw is tightened." [Jan]

11. [ ] Measure and cut a section of Fuel Injection Hose (supplied) to run between your filter outlet and the left side fuel injector rail. Make the hose long enough to support gentle bends, but no longer than necessary.

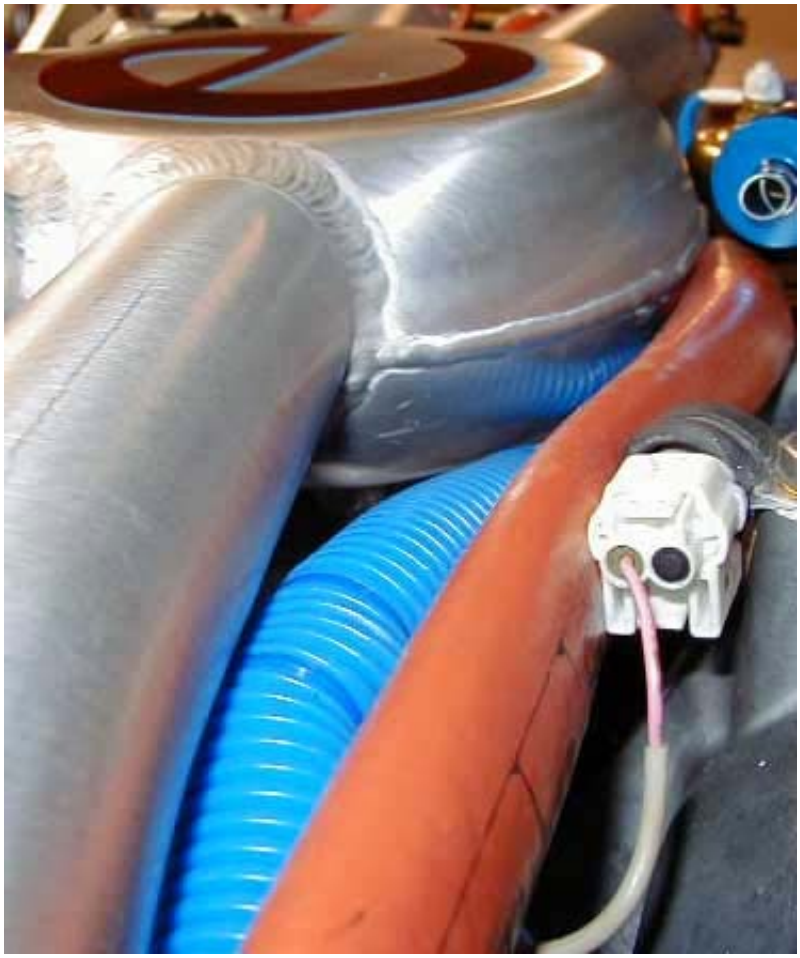
12. [ ] Optionally, cut and install a section of firesleeve material over your fuel line. The ends of the firesleeve can be clamped with firesleeve clamps, Oetiker clamps, or tie-wraps. A dab of orange high-temp RTV silicone sealer will help prevent moisture from getting inside the firesleeve matting.

13. [ ] Install the fuel line between the filter and left injector rail. Fasten the fuel line to the injector rail barb using ***TWO*** Oetiker clamps (this barb has been modified, so the extra clamp is recommended). Use a Fuel Injection Hose clamp on the filter side.

14. [ ] Support the hose as needed using Adel clamps. This installation shows a small aluminum bracket that serves to secure the fuel hose as well as the engine electrical connectors. Because this fuel hose must take up any vibration between the engine and firewall, it should be secured at each end. Do not rely on the barbs alone.

Note: The photo below shows one option for mounting the fuel filter in the supply line. This is not as desirable as fastening the filter to the firewall, but if space is limited and the two sections of hose are well clamped and supported, it works fine. Notice the firesleeve (orange), the additional Adel clamps at both ends, and the use of fuel injection band clamps at the filter to allow for easy maintenance. The small aluminum "Z" bracket clamps the forward end of the supply line as well as providing a place to secure the two engine electrical connectors.

15. [ ] If you are using the optional Firesleeve, you may remove one end of the crossover hose that runs between the injector rails and place a section of Firesleeve over it and snake it back into position. Clamp it with an Oetiker clamp.



16. [ ] Measure and cut a section of Fuel Injection Hose to run between the Fuel Regulator (right side injector rail) and the return fitting on the right side of the firewall. This is your fuel return line.

17. [ ] If you are using the optional Firesleeve, cut and install a section over this line.

18. [ ] Install the fuel return line. Use an Oetiker clamp on the fuel regulator end. The firewall end can use the supplied barb-to-AN5 fitting. The photo shows the desired position for the return line bulkhead fitting as described in earlier sections. This builder has chosen to use steel fittings at the firewall. Note the washer under the fitting nut for reinforcement. The short section of blue heater hose and large tie-wrap secure the fuel line to the engine mount. Never depend on the bulkhead fitting alone to support the fuel line.

19. [ ] Add tie-wraps or clamps to secure the hose and take up any vibration. Note the use of a large tie-wrap to secure the fuel hose to the dipstick tube and the small aluminum shield that is tie-wrapped around the fuel regulator to secure the firesleeve. The cable next to the fuel regulator is for this builder's custom heater valve. This will not exist on the stock motors.

20. [ ] Fabricate and install a heat-shield to protect your pumps from the heat of the exhaust system. This can be a simple aluminum or stainless-steel plate that is attached to your pump brackets. Make sure to mount the shield in a way that does not interfere with the wires or fuel lines. A simple shield will do the job (left), but if you really like cool fuel, you can add a full vented system such as the builder below has (right).

21. [ ] This completes the fuel system plumbing! Note the time.

Throttle Cable

The throttle cable can now be run through the firewall to the throttle body bellcrank. Some builders use a simple rubber grommet where the cable passes through the firewall. Eventually this will chaff through and create a rattle. A better solution is to use a stainless-steel "eyeball" assembly available from Aircraft Spruce for about $25. The cable should be routed through the cockpit with as few shallow bends as possible to assure smooth operation. It should penetrate the firewall next to one of the instrument panel support ribs so it has a straight shot to the throttle body bellcrank.

1. [ ] Note the time.

2. [ ] Drill a hole for the throttle cable in your firewall. If using an eyeball assembly, use the paper template that comes with the device to drill the seven holes as required. If you do not have a method of cutting this large of hole in stainless (no easy task) you will need to drill a series of small holes in a circle, punch out the center, and smooth the edges with a Dremel tool or sanding drum bit. The photo below shows two eyeballs being installed. The lower one is for a custom heater valve this particular builder is using. If you are using the factory heater option, you will not need this lower hole and eyeball.

3. [ ] Route the cable through the firewall and secure the end to the throttle cable bracket on your motor. Attach the snap-end to the throttle bellcrank and adjust the clamping position of the cable as needed.

4. [ ] The cable end that slips into the throttle bracket fork must be secured with a strong piece of safety wire or equivalent. This builder has created a clip from a section of bronze hinge pin, bent to fit the fork, then bent again once installed to secure the clip. A small piece of safety wire provides further assurance that the cable will remain secured. The blue plastic tube shown covering the cable is not required. The additional "L" bracket and second cable are for a custom heater valve, which is also not required for your stock motor.

5. [ ] Work the throttle a few times to be sure its operation is smooth and covers the full range of travel.

6. [ ] Note the time.

Swirl Pot

The cooling system uses a small spherical plastic reservoir known as the "Swirl Pot". The swirl pot is made from a type of plastic called Kynar, and is very durable if positioned and installed correctly. It is important to remove any stress on the plastic hose fittings and check the condition of the swirl pot every inspection. If any signs of stress or fatigue are apparent, replace the swirl pot.

The swirl pot mounting bracket needs to be installed on the firewall with four bolts. You might consider placing nylon washers between the bracket and firewall to prevent trapped moisture/debris and reduce the chances of corrosion. Additional nylon washers can be used behind the lower arm of the bracket as needed, in order to make it sit level on the firewall once it is filled with fluid.

1. [ ] Note the time.

2. [ ] Position the swirl pot mounting bracket so that the midpoint seam of the pot is roughly level with the center of the alternator pulley. On an RV, this equates to the point where the upper firewall is bent outward. For best strength, the bracket should be mounted to the horizontal angle that runs along the width of the firewall inside the cabin. Avoid mounting the bracket to the angled part of the firewall or to the sheet metal alone, as this will not be strong enough and would tilt the swirl pot. The swirl pot can be positioned horizontally as needed to allow clearance for the air filter box. Pay attention to where the upper coolant hose is located to avoid interference with the alternator pulley.

3. [ ] Use at least four bolts to secure the mounting bracket. Shim the bracket with nylon washers as needed to make it sit level when filled with fluid.

4. [ ] Note the time.

Heater Hose and Control Valve Installation

If you are installing the factory heater option, it will come with the necessary hoses. If you are using a different heater, you will need to obtain a section of 5/8" blue silicone heater hose from Federal Hose Inc. (URL www.federalhose.com) Federal ships hose overnight. Unfortunately, the hose is only available in 25' and 50' lengths. This is far more than required, but it is good stuff to have around. All hose connections should be made with Oetiker clamps. The factory recommends that only the Oetiker type clamps be used. There's no reason to use anything else because they are not as secure and are very bulky in comparison.

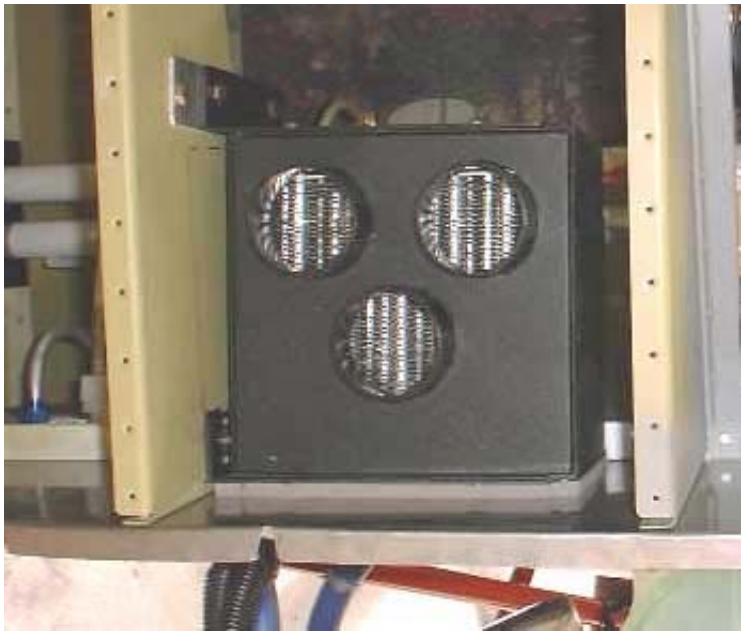
General Heater Operation: Hot coolant will emerge from the upper engine block hose-tower under the right side of the intake manifold. From there it will flow to the heater control valve. If the valve is open, the hot coolant will flow through the heater core and emerge into a tee fitting. One side of the tee will connect to the bottom of the swirl pot. The other side of the tee will return coolant to the bottom engine block hose-tower (where the thermostat and drain plug or valve are located).

1. [ ] Note the time. Start by draining the glycol coolant from your engine.

Note: The GREEN glycol coolant is only used to flush and test the system. The correct coolant to use is the ORANGE antifreeze which is designed for ALUMINUM engine blocks. Use this type when refilling your system.

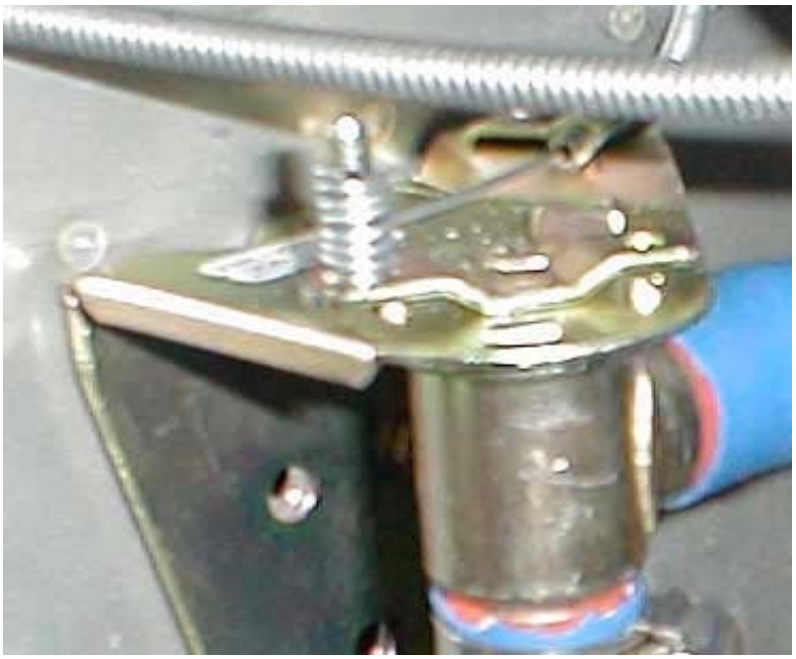
2. [ ] Determine where your heater hoses will enter the cabin. If you are using the factory heater option, the heater core barbs will protrude through the firewall into the engine compartment. If you are using another type of heater, drill the necessary holes for AN firewall bulkhead fittings (typically AN size 8) and install those fittings.

Note: The heater inlet can be either tube, it does not matter.



Customization: The author has found that the stock stainless-steel firewall recess box is a good place to locate heater hose fittings, in this case, for a custom-built heater. If you are installing the factory heater, then these fittings are not required. Notice the way the hoses are supported and secured with Adel and Oetiker clamps, and the gentle bends that provide strain relief for the swirl pot.

3. [ ] Install your heater control valve on the firewall. Locate the valve near where your heater core barbs poke through the firewall leaving enough space to allow for gentle bends in the hoses. Pay attention to where the Heater Control Cable will be routed. Note how the heater cable is formed into a loop to connect to the control valve bellcrank.



Customization: This photo shows how the author has customized a common ball-valve to thread directly into the engine block hose-tower. Note the cable-operated lever. This design allows the coolant to be turned off *at the block* in case of a heater core or hose leak. This setup is for a custom-built heater and is not necessary with the factory heater option.

4. [ ] Connect a section of heater hose between the upper engine block hose-tower and the heater control valve. Secure with Oetiker clamps.

5. [ ] Connect a short section of heater hose between the control valve and the inlet to the heater core. Secure with Oetiker clamps.

6. [ ] Connect a short section of heater hose between the outlet from the heater core to a tee fitting as shown. Secure with Oetiker clamps.

7. [ ] Connect a section of heater hose from one side of the tee fitting to the lower fitting of the swirl pot. Note that this fitting will be facing outboard. The heater hose should have a gentle 180-degree curve to meet this fitting. Secure the tee end with an Oetiker clamp and the swirl pot end with a Breeze clamp or equivalent.

8. [ ] Connect a section of heater hose from the remaining side of the tee fitting to the bottom engine block hose-tower (near the coolant drain plug / valve). Secure with Oetiker clamps.

9. [ ] Secure the hoses with Adel clamps to remove strain on all fittings, particularly the swirl pot fitting. The use of small firewall brackets may be helpful as shown in the previous photo.

10. [ ] Route your Heater Control Cable from the cockpit to the heater control valve. Fasten the push/pull housing to the valve bracket with the supplied clip and screw using some blue Locktite on the screw. Coil the end of the wire and slip it over the control arm stud (ref Step 3 photo). If needed, the stud can be drilled outboard of the coil and a small washer and cotter key can be installed to prevent the coil from disengaging the stud. Test the valve for smooth operation and adjust as needed.

11. [ ] Optionally, you may replace the coolant system drain plug with a radiator drain valve available at any auto parts store. If you use a valve, drill a small safety-wire hole in one end of the handle and secure the valve closed with safety-wire.

12. [ ] Review the entire flow path of the heater to assure it is correctly installed, hoses are free from danger, and so you understand the operation of the system.

13. [ ] You may choose to refill your cooling and heating system with ORANGE, aluminum-block antifreeze at this time, or we will get back to it before running the motor.

14. [ ] Note the time. Take a breather...

Crankcase Breather

The engine crankcase has a long breather tube attached to it to port any crankcase fumes overboard. The tube should be secured at the cowl exit facing rearward to create a slight vacuum as the plane is flying. The engine should have a small plastic breather filter element at the point where this hose meets with the crankcase. Some early motors did not have this breather filter which traps oil vapors that might otherwise form a drip over time.

1. [ ] If your motor does not have this feature, obtain one (**Purolator p/n B23165** or **FRAM p/n BA6592** approx. $4.95) from your local auto parts store and install it as described.

2. [ ] Note the time.

3. [ ] The existing short section of 5/8" tube that connects to the engine block may need to be longer. Cut a leftover section of the 5/8" silicone heater hose for this purpose. Install the breather cap with removable clamps.

4. [ ] Use a section of 1/2" silicone heater hose or equivalent high-temperature hose to replace the clear breather hose that came with your early engine.

5. [ ] A #12 Adel clamp will fasten the hose to a 8mm bolt-hole near the cylinder camshaft plug. Secure the remaining length of breather hose away from the exhaust system and again to the engine mount tubes near the cowl exit so it won't flap in the wind. Alternatively, a short section of 5/8" aluminum tube makes for a clean end. Some builders cut the end at a heavy taper and then mount it so that it is 1/16" away from the hot exhaust. Any oil will hit the exhaust and evaporate without getting on the airplane.

The photo below shows the clamp, viewed looking up from under the left radiator.

6. [ ] Note the time. You're about halfway towards throwing the starter switch and grinning from ear to ear!

Inspection Checklist - III - Fluid Systems

- [ ] The gascolator has been installed and the drain has been extended as needed?
- [ ] The gascolator uses the correct type of automotive fuel-resistant seals?
- [ ] The gascolator bowl is accessible and removable for periodic maintenance?
- [ ] The gascolator bowl has been safety-wired if/as needed?
- [ ] The fuel pumps have been mounted securely and vibration isolated?
- [ ] The fuel filter is of the right EFI type?
- [ ] The fuel filter is installed with the proper clamps and direction of flow?
- [ ] Proper hose and clamp types have been used throughout the system?
- [ ] All fuel lines are installed, routed clear of sharp objects, and tightened correctly?
- [ ] All fuel lines are secured as needed to reduce vibration?
- [ ] You have inspected the entire path of the fuel system from tanks to engine and back to the tanks and understand the logic behind it's routing and operation?
- [ ] All coolant and heater hoses are installed and clamped securely?
- [ ] All coolant hoses are routed safely away from the exhaust system and sharp objects?
- [ ] The heater core, control valve, and control cable are properly installed and functioning?
- [ ] The swirl pot is installed properly and at the right level?
- [ ] The cooling system drain fitting is installed, closed and safety-wired (if using a drain valve)?
- [ ] The crankcase breather hose is installed with the correct breather filter element?
- [ ] The crankcase breather hose is secured facing rearward and is not touching the exhaust system?
- [ ] The crankcase breather hose is secured at the point where it exits the cowl?

Congratulations! Note the time.

Chapter 6 - Electrical Systems Installation

This section covers the installation of the primary and secondary engine electrical systems. The primary systems include the batteries, grounds, and alternator wiring. The secondary systems include starter, ECM harness, fuel system, engine sensors, and switch panel.

Eggenfellner Aircraft Inc. highly recommends the use of the ControlVision EXPBUS-II electrical system. URL www.controlvision.com. This system provides most of the major switch and circuit breaker functions as well as management of the dual battery system required by your motor. This guide will describe the installation of the EXPBUS as it relates to the engine. It will not cover the additional airframe circuits supported by the EXPBUS. If builders choose not to use the EXPBUS, then it is left to the builder to determine how to adapt the details and features described in this chapter, to their own electrical system design and to take full responsibility for their actions. Some builders prefer to supply their own switches, in which case, a module-only variant of the EXPBUS is available, allowing you to use whatever switches you prefer in whatever position you chose.

READ AND UNDERSTAND - Your engine requires a constant and stable source of electricity to drive its fuel injection, fuel pumps, and the engine control computer. Unlike older engines which used carburetors, magneto ignitions and mechanical fuel pumps, the Subaru cannot tolerate a loss of electrical power. For this reason, we have designed fully redundant electrical and fuel systems with provisions for automatic fault management. It is imperative that you adhere to this design for your own safety and to assure ongoing maintainability. Eggenfellner Aircraft Inc. cannot be responsible for endorsing or supporting builders who deviate from our design, nor be responsible for any direct or indirect damages which may result from such deviations.

The quality and reliability of your aircraft is largely influenced by the materials and techniques used in its construction. This is very much the case with electrical systems. Aircraft electrical systems are subject to physical and environmental stresses that far exceed what you might find in an automobile. It is imperative that you use proper types of wire, connectors, retainers, and protective devices in your electrical system to avoid future problems. If you are unfamiliar with the techniques of aircraft wiring, I highly recommend the "The Aero Electric Connection" by Bob Nuckolls) available from www.aeroelectric.com. Although this book leans towards conventional installations, the principles and techniques apply to all aircraft electrical systems. One note regarding this book. Avoid being lured into thinking that you can create your own alternative to the EXPBUS and save time and money. Your powerplant is very sophisticated compared to a Lycoming. The EXPBUS is likewise, a very sophisticated solution for managing the requirements of your modern engine. Saving a few dollars should never be a reason for ignoring all the research, testing, and talent that has been poured into the electrical system design described in this manual.

One of the most common electrical problems is corrosion. Corrosion can creep into any electrical connection which is subject to direct environmental factors. It can also occur from contact between incompatible materials such as un-plated steel and aluminum. High-quality aircraft-grade electrical parts are not overly expensive, so please avoid the temptation to run down to the local auto parts store for your wire and connectors. Consider how many corroded trailer-hitch connectors you've had to replace over the years,

then ask yourself if you want that type of problem in your airplane? Use only aircraft-grade Teflon insulated wire and high-quality connectors.

That said, you are installing an automotive engine in your aircraft. Much of the wiring is therefore unavoidably of automotive grade. We will point out ways to route and protect your wiring harness to assure the most trouble-free operation.

Another common electrical problem is poor ground integrity. People who are unfamiliar with the electrical arts tend to think of grounds as somehow less important than "power" wires. Simply fastening ground wires to the airframe is the worst thing you can do. Although aluminum is a reasonably good conductor, the various platings, coatings, joints, and thickness' can create some real difficult problems to troubleshoot. Ground integrity problems often manifest themselves as radio noise or unexplainable circuit behaviors. Additionally, the airframe is subject to substantial electrostatic disturbance as it moves through the atmosphere. Why do you think static-wicks on your wingtips are recommended for IFR aircraft? Grounds should be treated with equal or even greater respect than "power" wires and extra care should be applied to assuring the overall integrity of the "ground system".

Think of it this way... Individual power supply wires are like brooks and streams. Power busses are like rivers. Batteries are like lakes. Grounds are like oceans. Treat each with the appropriate degree of respect and you'll do fine.

Let's get started. We will first accomplish the physical installation of your electrical system components, then move on to the wiring.

SPECIAL TOOLS YOU WILL NEED INCLUDE:

1. High-quality wire strippers (20AWG through 10AWG) AWG = Average Wire Gauge or just Gauge for short.
2. Terminal Crimping Pliers

3. A large gauge terminal crimping tool for 8AWG through 4AWG cable ends.
4. A sharp razor knife such as an Exacto knife.
5. A good soldering iron or soldering station and high-quality electrical solder.
6. A bottle of alcohol or solvent for removing soldering flux.
7. A propane torch (propane or MAPP gas). Get a self-lighting model; you'll never regret it.
8. A good assortment of shrink-tubing (various sizes and colors, including clear) and an electric heat gun to shrink it (not shown).
9. A good assortment of tie-wraps.
10. 2 or 3 rolls of high-temperature (orange-red) **silicone** tape.
11. A can of white "Liquid Electrical Tape".
12. An assortment of Teflon aviation wire and cable. Sizes are denoted as we go, or refer to the master parts list.
13. An assortment of protective rubber terminal boots (approx. 8 large ones and 12 small ones).

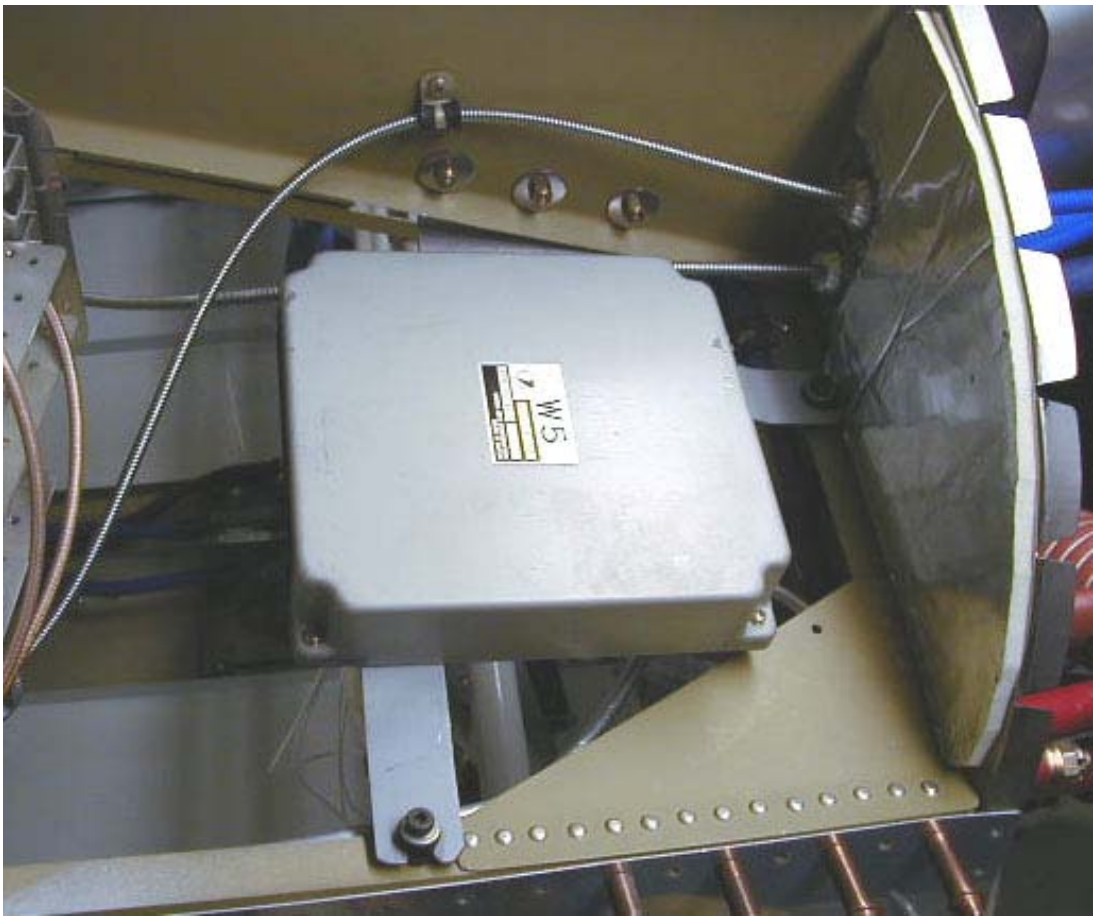
Don't forget to track your time spent in each of these steps if you care about such things.

ECM Mounting

Your engine uses a small, rugged, computer to control ignition, timing, and a wide variety of sensors. This computer is known as the Engine Control Module or ECM. It is also commonly referred to as the Engine Control Unit or ECU. We will use the correct term, ECM.

The ECM is a standard Subaru part. In a car, the ECM controls the engine as well as an array of other functions from transmission to door locks. Some modifications have been made to its wiring to eliminate unwanted circuitry and adapt it for aircraft use, but the ECM itself remains an off-the-shelf part.

The ECM has metal mounting tabs. These can be cut shorter, although we prefer that you keep the unit as-is to retain the direct-fit in the unlikely even that it should ever need to be replaced. The ECM must be mounted inside your cabin, away from sources of heat and vibration. The ECM wiring harness was adapted from its automotive counterpart and is approximately 48" long. Because of its length, we recommend that the ECM be mounted on the RIGHT side of the cabin in the forward-most bay as shown below. This allows the ECM harness to be routed across the inside of the cabin without resorting to large coils of wires. It is not strictly required that you mount the ECM as described, but we think you'll find this convenient and we have crafted the wiring harness with this location in mind. *Harness length and shape will change with different engine models.*



Close-up view of rubber shock mount on shoulder-bolt.

The ECM can be oriented horizontally as shown, or vertically. In this example, we have taken advantage of the slots cut in the stock mounting tabs to install the ECM on rubber bushings. However you choose to install the unit, try to provide a similar shock-mounting to lessen the effects of vibration. Be sure to orient the connectors in a manner that allows easy access. In this case, the connectors are facing rearward to facilitate access from under the panel.

To reduce the chances of static damage, the metal case of the ECM should be grounded to the airframe with a short ground wire or braided ground strap.

OK, you probably want to peek inside, so I'll save you the trouble... it's a very well made module.

We will return to the ECM when we are ready to install the wiring harness.

BATTERY BOX CONSTRUCTION

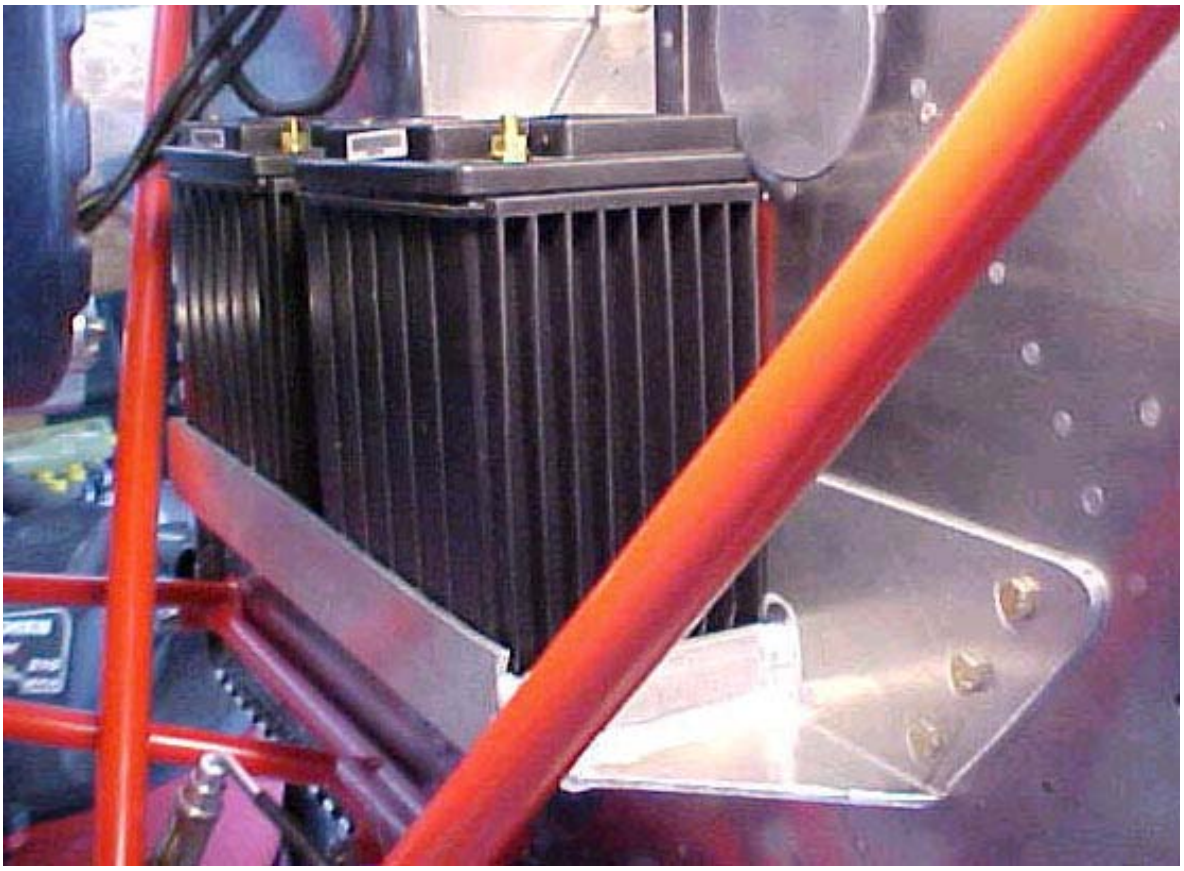
You will need to install two batteries. These should be identical types and capacities to avoid over-stressing them during charging. We highly recommend the use of Hawker Energy's Odyssey PC625 batteries. URL www.batteries4everything.com. These are high-quality dry-cell type batteries with excellent discharge capacity and outstanding lifecycle (est. 5 to 8 years). Search around for the best price. We have seen prices as low as $57 to as high as $160 for the same battery. Because they are dry-cell type batteries, they can be mounted in any position, except upside-down, and do not have special venting requirements. They handle winter operation and storage well. They can also be shipped via standard non-hazardous material methods.

Avoid the use of batteries with spillable acids or special venting requirements and be sure to get batteries that have bolt-type stud terminals rather than screw-socket types.

Your engine provides plenty of room between the back of the engine and the firewall for battery mounting. If you have special weight-and-balance concerns, you can mount the batteries inside the cabin, but we prefer to keep them in the engine compartment to simplify the wiring, keep cable lengths as short as possible, and improve crash-worthiness. A crash is bad enough without spilling battery acid all over.

Keep in mind that moving a battery position is your best option for fine tuning your weight and balance.

Eggenfellner Aircraft Inc. offers a factory solution for battery mounts. Our mounting tray positions the batteries side-by-side in the center of the firewall. The tray bolts to the stock RV firewall angles, providing a quick, strong, and simple solution.



Some builders have chosen to make their own battery mounts.

Below is an example of cabin mounted batteries.

And here is an example of individual firewall mounted batteries. This builder could not use the factory mount because he needed the center section of the firewall to route hoses for his custom heater system. More details on construction of this box can be found in the Fun Stuff section.

However you choose to mount your batteries, be sure to provide secure hold-downs (particularly if you fly upside down) and protect them from excessive heat. A simple heat-shield will do the job. Plan ahead if you intend to run a supercharger since this will occupy a good portion of the right side of the engine compartment.

AUX BOOST RELAY Mounting

Because you have redundant batteries, we felt it would be beneficial to allow the Aux Battery to assist with engine starting duties. This can be useful in cold climates, or if you've let your Main Battery run down for any reason. Obviously, you want to let both batteries reach full charge before venturing off to the big blue. This relay also serves a second purpose. If you are ever in a situation where your main power bus has failed and you are running off of your Aux Battery, activating this relay will allow you to consume whatever energy is left in your Main Battery. In a serious bind, this could extend your emergency flight time.

To provide this "AUX BOOST" feature, we use a continuous-duty "**master**" relay to parallel ("jump") the two batteries together. There are two similar types of these relays in the catalogs, one is rated for continuous-duty (aka Battery Master Relay), the other for intermittent-duty (aka Starter Relay). Aside from coil and contact ratings, they differ in the way their "coil" is activated. Our continuous-duty type requires the "coil" terminal to be grounded to activate the relay, whereas the intermittent-duty type requires 12vdc to be applied to the "coil" terminal to activate the relay. Be sure you have the **continuous-duty** (ground to activate) type. The other type will work, but you'll have to rewire the control circuit.

The correct "Master Relay" is Aircraft Spruce part number 111-226

We recommend that this relay be mounted on the firewall in a convenient location for routing the cables between both batteries. The photo below shows the relay mounted on the right side of the firewall. Don't worry about the wiring just yet aside from making sure it is within easy reach of both battery cables. The exact position of the relay will vary depending on which type of battery mount you have chosen. If you prefer, you can defer drilling the holes until you run the battery cables. Use large diameter stainless steel washers to back-up the mounting bolts on the inside of the firewall.

Ground Plate Installation

The best possible ground system is considered a "single-location-ground". That is, all ground wires should converge on a single location, not necessary (and not even desirably) a single bolt, but rather, a single "location" as near to the battery ground terminal/s as possible. By converging the grounds to a common location, you will avoid creating multiple ground paths which can lead to radio noise and all sorts of weird problems. This does NOT mean that every single ground wire in the aircraft needs to run all the way to this one point. For example, it is perfectly acceptable to create a "branched" system of grounds which collect smaller ground wires into common larger gauge ground wires which ultimately flow back to the common ground location. Often this results in a small number of distributed, and isolated, ground terminals such as one for each wing and another for the fuselage, which are then connected to the common ground point via large gauge ground wires. Keep in mind that the size of the ground wires must be sufficient to carry the combined currents of the circuits with an added margin of safety. If you don't adhere to this rule, your aircraft will be plagued with some very unusual electrical behaviors.

Because we have dual batteries, we must consider how we ground each battery. Our goal is to be redundant, so it makes sense to start with the battery cable grounds themselves. We recommend therefore that you choose a location on your firewall as the official "Ground Plate Location". This is typically in the center of the firewall where it is convenient to run wires on both sides of the firewall. Rather than to connect both battery ground cables to a single terminal bolt, we prefer to use two such bolts right next to each other. That way, if one terminal snapped off, you would still have a functional system.

Use 1/4" or 5/16" brass or bronze bolts. The photo below shows a very nice Ground Plate offered by AeroElectric Connection. The Ground Plate is mounted to the firewall inside of the cabin. The pair of brass bolts provide two ideal locations for our battery cables on the engine side of the firewall. This setup offers the option of attaching ground wires using the excess length of the bolts or the FastOn flat blade type connectors for the many smaller wires. I prefer to ground critical components like fuel pumps to the bolts using ring-type terminal lugs.

If you use the AeroElectric product, inspect the soldering and if necessary, fire up the torch to add more solder or repair any gaps.

Most A&P mechanics were trained by schools that focused on military and transport category aircraft. As such, the use of FastOn or blade type (or Molex for that matter) connectors will be foreign to them. Yet these fasteners can be found on many light aircraft and are sold by most reputable aircraft parts suppliers. We use these connectors on the EXPBUS and Ground Plate. Rather than to fuel the debate, I suggest two things. First, visit the AeroElectric website www.aeroelectric.com and read what their resident guru has to say. I agree with his analysis. Second, since the EXPBUS requires that you use blade-type connectors, try them! I believe you will find that they are more secure that you imagined. Be sure to use high quality connectors, not local auto-parts store stuff. Order them from Aircraft Spruce or AeroElectric. If you just can't shake off the military mindset, you can replace the recommended Ground Plate with a screw type model and use ring connectors.

Here's a shot of the Ground Plate from the cabin side of the firewall.

Here's a shot of the ground cables attached to the Ground Plate mounting bolts on the engine side of the firewall.

Circuit Diagrams - Sheets 1 through 7

From this point forth, refer to the main wiring diagrams, Sheets 1 through 7, for general circuit details. I strongly suggest that you print these diagrams so you have them in the shop as you install your wiring.

The following link is for a PDF format (Adobe Acrobat) document containing all seven pages. This format works best for online viewing since you can easily zoom and pan across the pages.

E-Motor Wiring Diagrams - Sheets 1 through 7 in PDF format.

The next links are individual JPG image renderings of each page. These may produce better print quality than the PDF format, but they are considerably larger and take longer to download.

Page 1 of 7 - Primary Power Distribution

Page 2 of 7 - Fuel System Wiring

Page 3 of 7 - Fuse and Breaker Wiring

Page 4 of 7 - Bus Master Switch Wiring

Page 5 of 7 - Pump Select Switch Wiring

Page 6 of 7 - Auto-Failover Relay Wiring

Page 7 of 7 - EXPBUS Wiring

Page 1of 1- Prop Controller Wiring

...go ahead and print these out, I'll wait.

Switch & Circuit Breaker Installation

Although the EXPBUS provides the majority of your secondary circuit protection, several conventional circuit breakers and fuses will be required to complete your installation. These should be Klixon, Potter & Brumfield, or equivalent button type breakers.

Additional **circuit breakers** include:

1. 60A - Main Battery to EXPBUS (May also use an ANL-Type fuse if desired)
2. 50A - Alternator to EXPBUS
3. 20A - Aux Battery to Bus Master switch
4. 10A - Starter Solenoid and Optional Cabin Heater
5. 15A - Optional Pitot Heater and/or Optional Cabin Heater

Additional **fuses** include:

1. 10A - ATO Type - Main Fuel Pump
2. 10A - ATO Type - Aux Fuel Pump
3. 5A - ATO Type - Auto-Failover circuit and additional critical equipment.
4. 3A - ATO Type - Backup Gyro (size as needed)

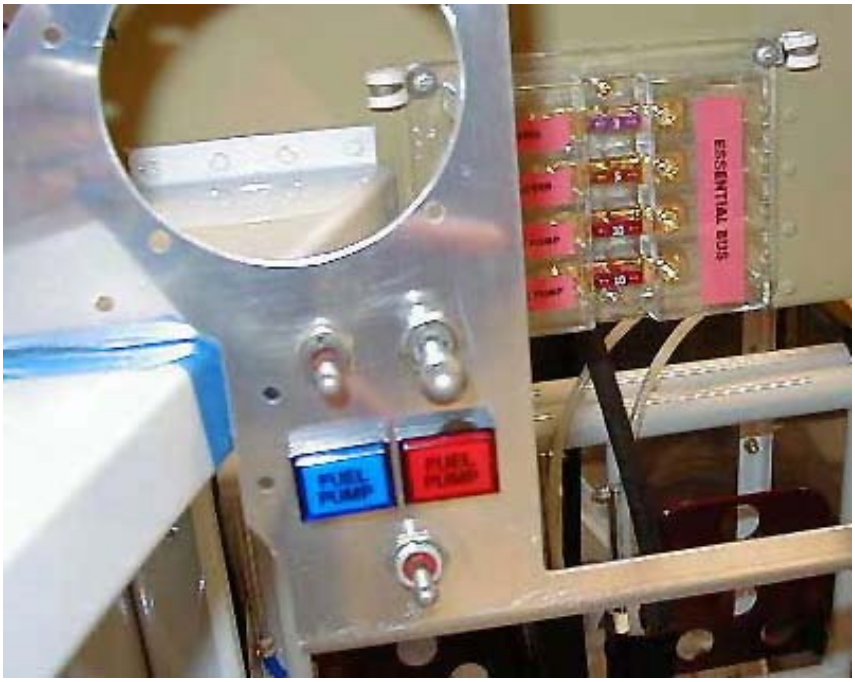
The next photo shows an ANL-Type (top) and ATC-Type (bottom) fuse next to a US Quarter. ATC "blade-type" fuses are common in modern automobiles. The ANL-Type fuse (this gold-plated one is made by "Stinger") are designed to handle high-currents. If you choose, you can use an ANL fuse instead of a circuit breaker for your Main Battery feed.

The 60A Main Battery circuit breaker is used to isolate the Main Battery in the event of a serious primary circuit short. Isolating the Main Battery could potentially offer additional emergency flight time when running off the Aux Battery by engaging the Aux Boost switch to cross-connect the two batteries. We will discuss these various operational scenarios in later sections.

Fuses 1 through 4 are ATO Type fuses. These are common automotive "blade" type fuses and can share a quad fuse block. If you really don't care for fuses you can always use resettable automotive blade type breakers in this fuse block or conventional aircraft circuit breakers. We prefer real fuses as they are more precise than breakers. Never use anything other than the specified values for these fuses. The purpose of the 10A Fuel Pump fuses is to provide a protective device which will blow *slightly before* the EXPBUS protection (11A) will trip. This allows other equipment which is using the EXPBUS circuits to continue to operate in the event of a shorted fuel pump circuit. We will discuss all of this in later sections and chapters.

The quad fuse block should be mounted near your Fuel Pump Select switch to minimize wire lengths. The photo below, shows a quad ATO type fuse block with plastic case, mounted on the bulkhead behind the instrument panel. This particular installation will have a flat-panel EFIS display in the large rectangular opening. This allows excellent access to the space behind the panel for servicing the fuses. We don't service fuses while in the air! If your installation does not offer this kind of access, you can locate the fuse panel at the side of the fuselage or any other suitable location. You can also use one of the smaller fuse blocks available at auto-parts stores as long as it *provides four individual circuits, not the type with a common power bus*.

On the panel, you see the Fuel Pump Select switch (bottom), blue Aux Pump lamp and red Low Pressure lamp (they are not yet correctly labeled in this photo). Just above the lamps are the Start (right) and Aux Boost (left) switches. I placed the Aux Boost switch next to the Start switch so I could operate both with a single finger. Both switches are momentary type. The Honeywell Start switch I used has a "detent" ON position requiring you to pull out on the switch to select the START position. Macho stuff... The orange ring around the toggle levers is a hermetic seal to prevent dust and moisture contamination.



The exact location of these breakers and fuses is up to the builder and can vary depending on what equipment you choose to install on your instrument panel and in your cabin. Many conventional aircraft place their circuit breakers on the instrument panel itself. There is much debate over whether this is worth the lost panel space, particularly on an already crowded instrument panel. Human nature says that a pilot will always attempt to reset a blown circuit breaker in flight. This can be very destructive to the equipment being protected and can even lead to electrical fires. It is always better to land the plane and investigate the cause of the tripped breaker rather than risking a potentially lethal cockpit fire.

Placing the breakers in a location which is easily accessible makes good sense, but not necessarily on the panel itself. In my own RV, I have chosen to install the breakers on the solid bulkhead behind the instrument panel. Placing them along the bottom edge allows me to easily reach them with one hand to check their status. You could also fabricate a bracket to orient them

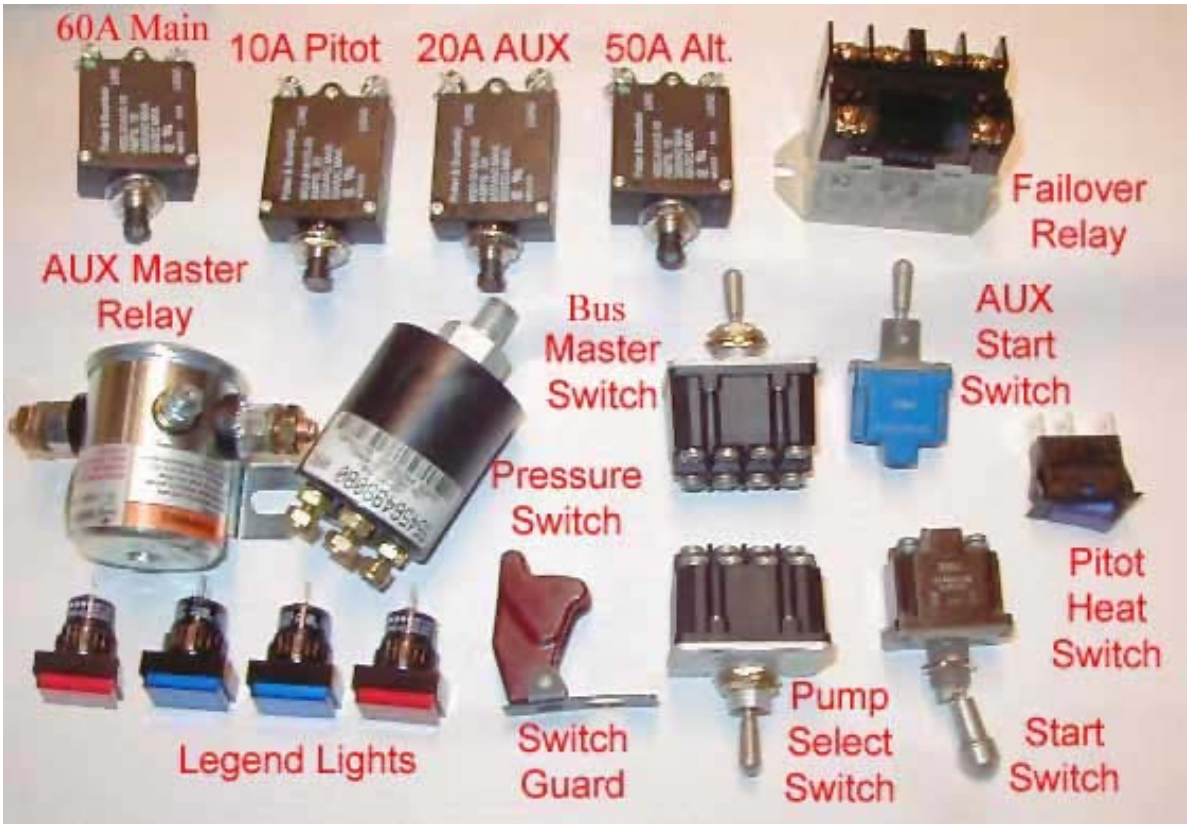
vertically so the breaker knobs will protrude downward when popped, thus becoming visible. Different builders have different ideas about their breaker positions. The decision is yours, but be sure to label thier location well for pilots.

Placement of the fuses is another matter. The whole reason for using fuses instead of resettable breakers is that if these circuits blow, you *never* want to reset them in flight. For example, if you blow a fuel pump fuse, *never* attempt to replace it in flight. You will be running on your Aux pump and landing should be your primary concern. Fuel pumps don't blow fuses unless they are seriously shorted out and you don't want to risk an in-flight fire.

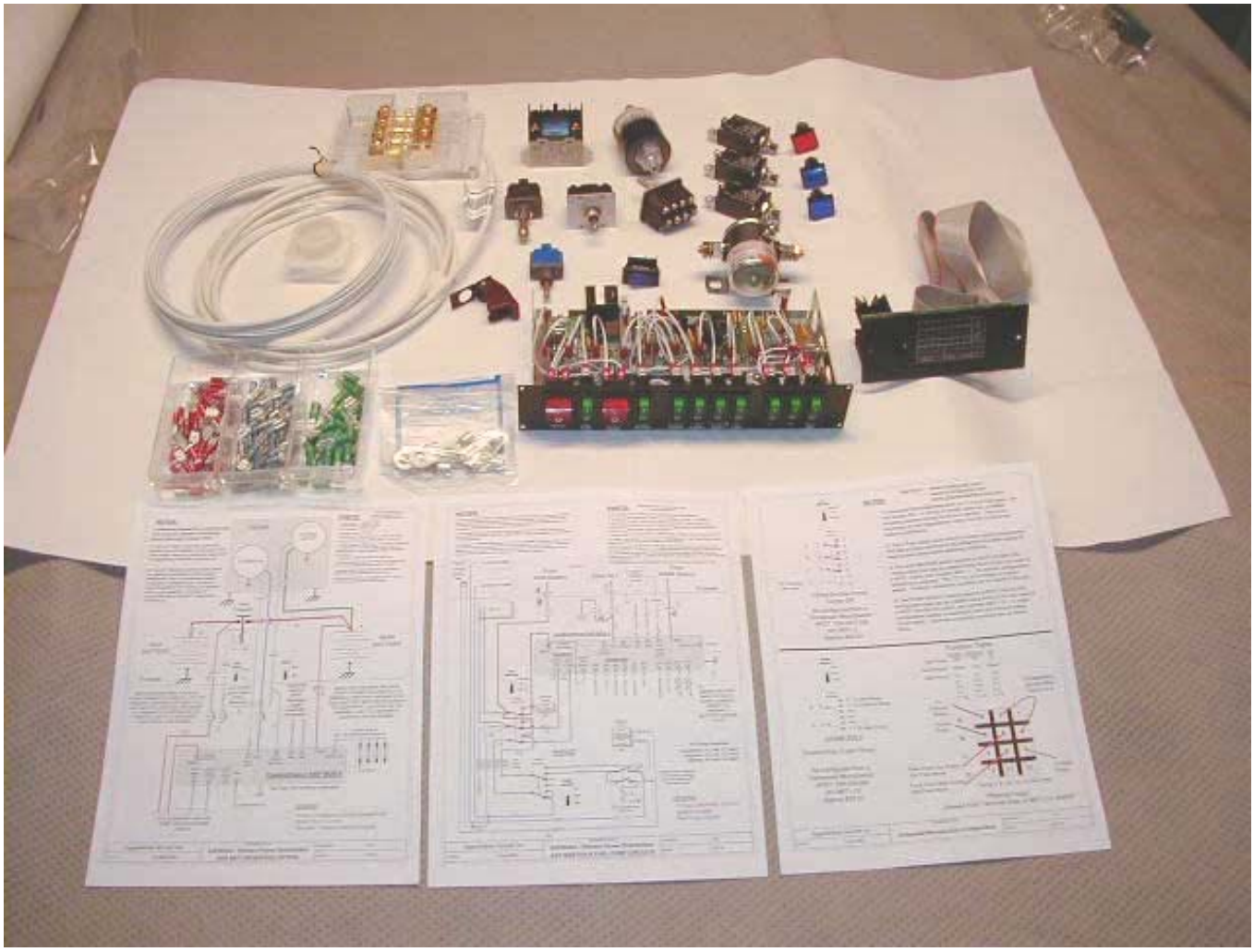
The EXPBUS provides most of the secondary circuit switches required by a typical installation, however, yours is not a typical installation. A few additional switches are required to support the redundant system design. Do not cut corners on switches. A pretty switch is not necessarily a good switch. The switches we specify are high-quality Honeywell aviation switches found on everything from 747's to Space Shuttles. These are very specialized switches, so don't try to replace them with off-the-shelf lookalikes. Stick to the part numbers we provide.

All Honeywell/Microswitch products can be obtained from www.onlinecomponents.com or through the vendor search feature of www.honeywell.com

Here's a photo which identifies the major switch components

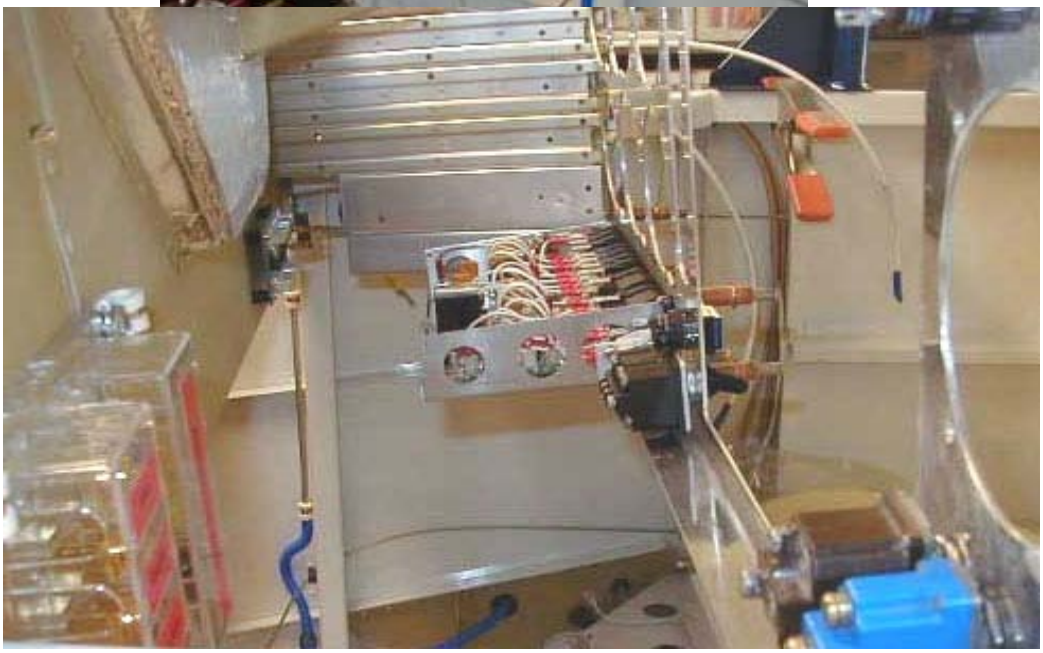


When you're ready to start, you should have a pile-o-parts like this, plus much more wire.



The EXPBUS unfortunately, comes with silk-screened labels for all of the switches. These are not appropriate for our installation, so you will need to consider making new labels for them, or as shown in the photo below, mount the EXPBUS behind the instrument panel with the banks of switches protruding through rectangular openings. This actually looks very good if you bevel the edges of the openings. If you look carefully, you will see ControlVision's optional diode module mounted on the bulkhead behind the panel. This option provides a few extra power taps and helps to protect avionics equipment from voltage spikes (although most modern equipment has internal spike protection already). The second photo below shows one last view from behind the panel before we start wiring.

Refer to diagram sheet 7 for typical EXPBUS switch assignments and labeling.



Creating Good Cable Connections

All battery cables should be constructed from 6AWG Teflon coated cable. Most other high-current cables will be constructed from 8AWG cable. Good cable terminal ends can be constructed by crimping, then soldering and cleaning the terminal lugs, then covering them with shrink tubing and finally silicone rubber boots at the battery ends. The large-size crimping tool shown below was purchased at a local hardware store for about $15. Unfortunately, it has no vendor markings or part number, but you can get these at most good hardware or electric supply stores. One good whack with a hammer makes an excellent crimp! Many electrical stores will also rent large-size crimping tools. If you've got your ducks lined up, you can crimp all of the connections in under an hour.

High-Temp Silicone Rubber Tape and Silicone Rubber Cable Boots

Cable Lugs, Step by Step

OK Clark Cable, let's give it a try!

1. Use sharp cable-cutters to cut the cables to length. Leave a little extra length to ease maintenance and prevent tugging on the battery terminals.
2. Carefully cut away a short section of the insulation from your cable end. Remove only as much as needed for the lug you are using.
3. Slip one or two pieces of shrink-tubing about 2" long over your cable. Slide them far enough down the cable so the heat of soldering will not cause them to shrink. I like to color-code my cables, red for positive, black for negative, and white for all others. You can also use a piece of clear shrink tubing over printed labels to make professional looking labeled wiring.
4. Place a lug over the bare wire and position the assembly in your cable end crimping tool with the lug seam facing up
5. Strike the crimping tool with a hammer hard enough to form a secure crimp.
6. Clamp the cable in a vise about six inches away from the terminal lug with the lug angled slightly upward.

7. Fire up your propane torch and apply just enough heat to the loop-end of the lug to melt solder. Self-igniting trigger-type torches are well worth their extra price.
8. Apply enough solder to flow into the lug and make a good airtight connection. Some prefer to touch solder to the cuff-side of the lug, but this is not necessary if you have the right amount of heat.
9. Let the assembly cool.
10. Clean off any excess solder flux with alcohol or equivalent flux cleaner.
11. Slide the first section of heat-shrink tubing up-to-but-not-over the cuff of the lug and shrink it with an electric heat-gun..
12. Slide the second section of heat-shrink tubing over the first section and over the cuff of the lug. Shrink it.
13. Where attaching to a battery, insert a silicone rubber boot. It is not strictly necessary to install boots on grounds, but it makes for a nicer appearance and helps to protect the connection from the elements.

All your cables should be secured with Adel clamps and/or tie-wraps to relieve any strain from the terminal bolts or screws. This is particularly important where the cables are attached to circuit breakers since these use only a small screw for attaching the terminal lugs. When properly clamped, with all strain relieved, a terminal lug should remain in it's right location even when you remove the screw or bolt that secures it. This little detail will go a long way towards improving the reliability of your electrical system.

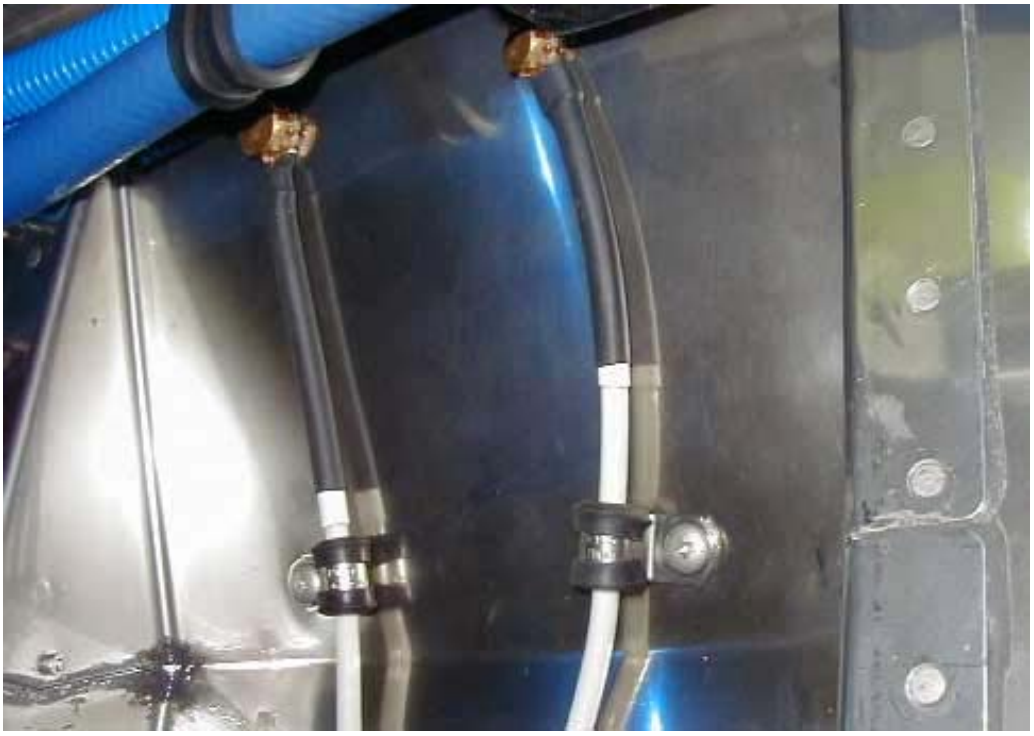
Tie-wraps are great for holding bundles of wires together, but avoid using them to attach wires to metal components that might cause abrasion against the wires. Also beware of using them in high-temperature locations. Use padded Adel clamps for these cases. Waxed lacing string is also commonly used for bundling wires, but for obvious reasons, avoid using this method in high-temperature locations.

Primary System Wiring (Step by Step)

Now that we've got the big pieces bolted together and you've had a little "ground" schooling, let's get on with the wiring. I will no longer coach you as to how to solder, crimp, label, or protect the ends of your wires. *Use the force Luke!*

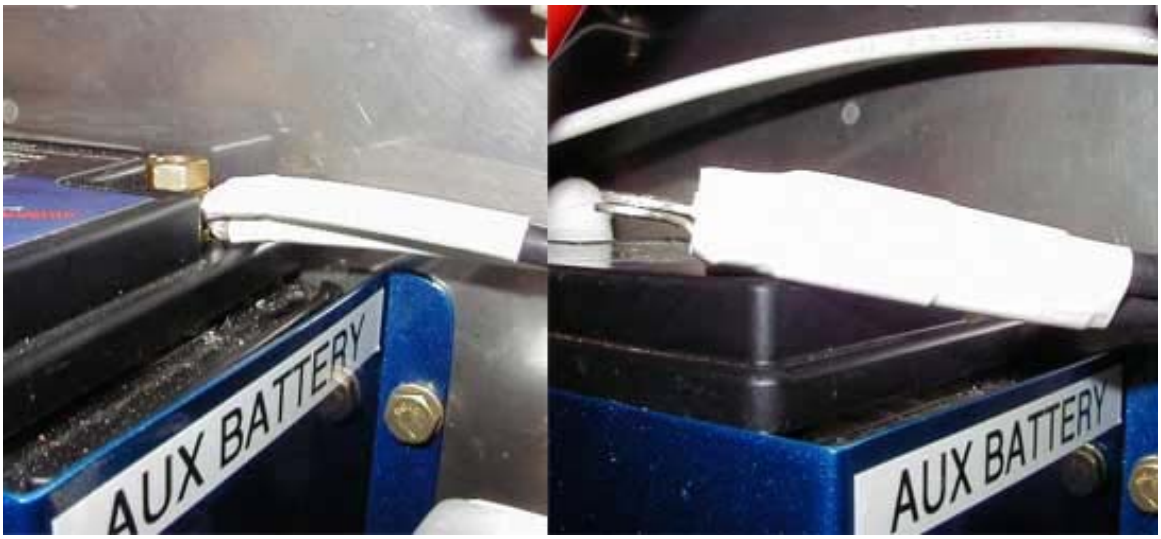
1. Note the time.
2. **FIREWALL PASS-THROUGH: Aircraft Spruce p/n NMCS45A-13 - Nylon Bulkhead Seal 3/4"**

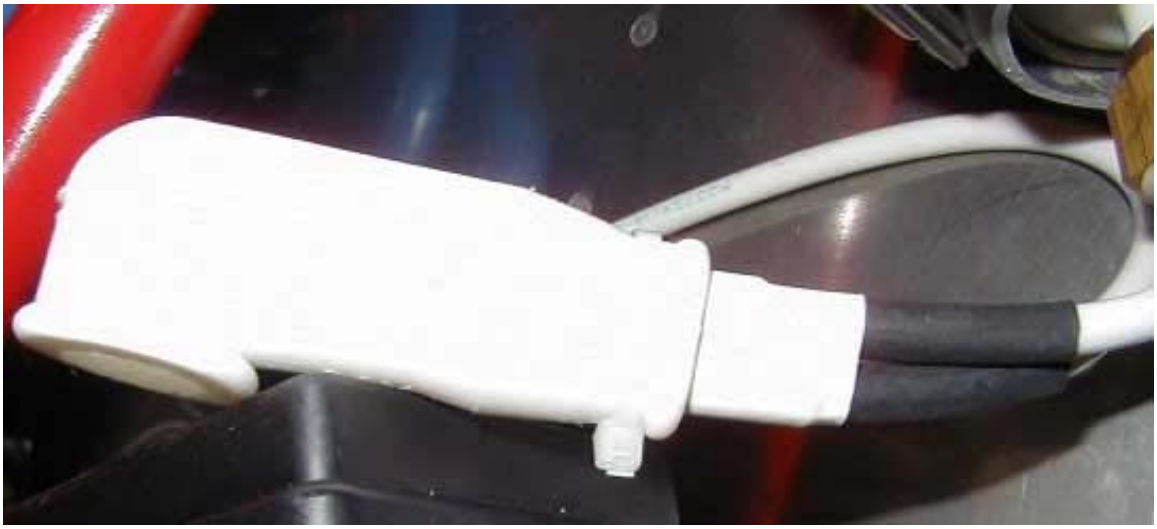
3. Drill holes as needed in the firewall to install a 0.75" nylon firewall pass-through fitting as shown below. The exact location may vary depending on where you choose to install your batteries and Aux Boost Relay. The photo below shows this fitting 3.5" below the upper right engine mount bolt and 2" in from the right fuselage skin.
4. Loosely fasten the firewall fitting with two stainless steel screws for now. We will apply some sealant and tighten it down when all the wires have been run. It is helpful to place washers under each nylon "wing" of the fitting to prevent crushing it when you tighten the screws down.
5. **BATTERIES:**
6. Install both batteries in their mounts.
7. **FIREWALL GROUND CABLES:**



8. Construct a pair of 8AWG ground cables, one from each battery ground post to the firewall Ground Plate bolts.
9. Secure the ground cables as needed with Adel clamps to prevent chaffing and loosening of the brass ground bolts. This particular installation places the cables inside the firewall recess box. You can position your Ground Plate wherever it is convenient to access from inside the cabin.
10. **LEFT-AUX ENGINE BLOCK GROUND CABLE:**

11. Construct an 8AWG ground cable from the leftmost (Aux) battery's ground post to the lower-left side of the engine block as shown.
12. Sandwich the battery end of this ground cable with the one going to the firewall as shown below, using a section of shrink-tubing and a silicone rubber boot. Notice how one terminal lug is upside down to allow the loops to lay flat against each other. This technique is useful throughout your electrical system installation. As an alternative to this method, you could insert and solder both cable ends into a single larger gauge terminal lug.





13. Install the paired cables on the Aux Battery ground post and secure with a flat washer, lock washer and nut. Some like to use a drop of blue LocTite, but I feel this interferes with good electrical connection. Do not over-torque the brass battery studs! If the cables are properly secured and strain-relieved with clamps, the bolt should not come loose.
14. Pull the boot over the connection.
15. Route the engine ground cable along the engine mount and gracefully curve it to meet the chosen ground bolt location. Secure with Adel clamps along the engine mount tube.
16. Secure the ground cable to the engine block with an appropriate METRIC bolt, flat washer, and lock washer.
17. **RIGHT-MAIN ENGINE BLOCK GROUND CABLE:**

18. Construct a 6AWG ground cable from the Main Battery's ground post to the upper-right side of the engine block as shown.
19. Sandwich the Main Battery end of this ground cable with the Main Battery Firewall Ground cable (the one going to the firewall) in the same manner as you did with the Aux Battery, using a section of shrink-tubing and a silicone rubber boot.
20. Install the paired cables on the Main Battery ground post and secure with a flat washer, lock washer and nut.
21. Pull the boot over the connection.
22. Route the engine ground cable along the engine mount and gracefully curve it to meet the chosen ground bolt location. Secure with Adel clamps along the engine mount tube.
23. Secure the ground cable to the engine block with an appropriate METRIC bolt, flat washer, and lock washer. Note in the photo how the Main Battery ground cable is routed alongside of the Starter cable and Alternator cable as they leave the engine and pass over to the engine mount tube. A single grouping of cables is better than having each cable take its own path. Note also in the photos how tie-wraps and silicone tape have been used to help secure and protect the Cam-Angle sensor and Fuel Injector connectors.

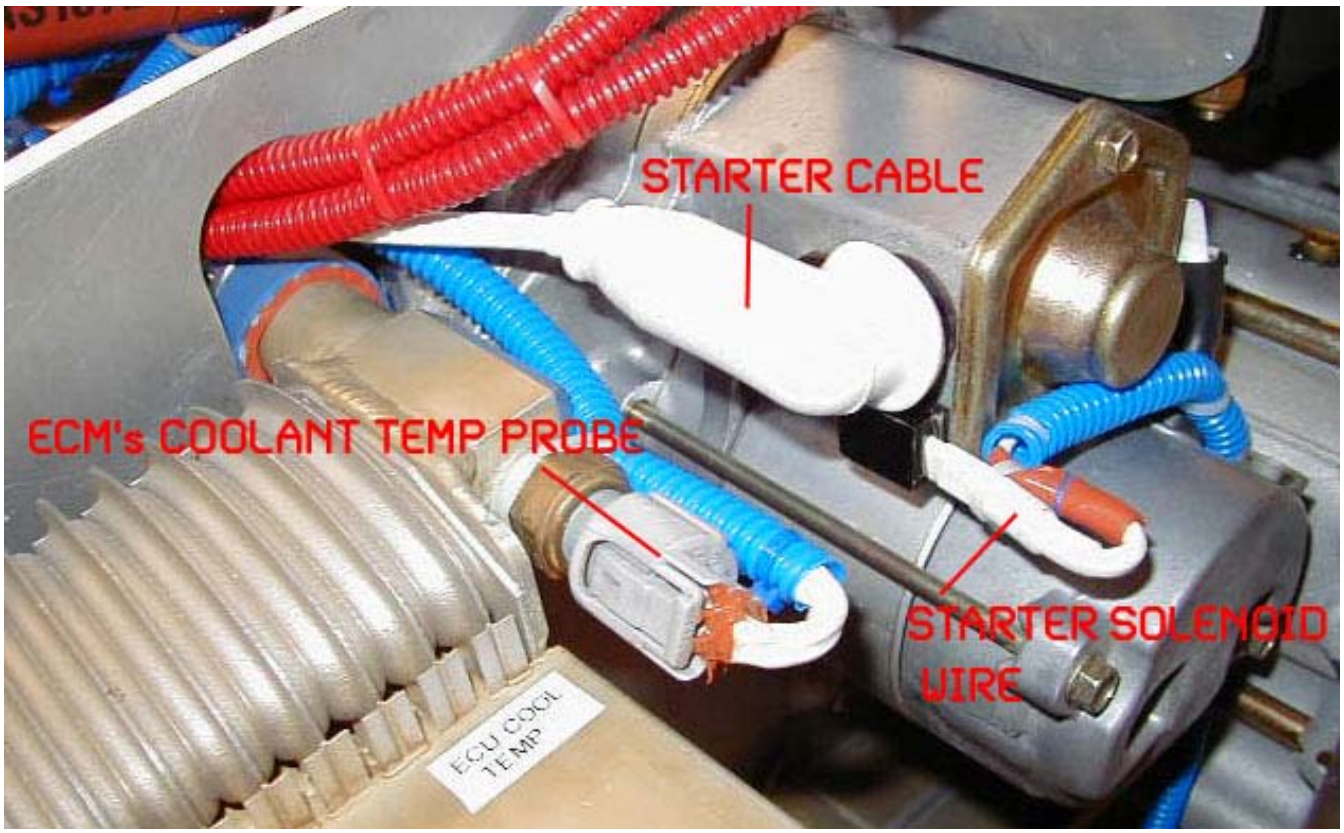
24. **LEFT-AUX POSITIVE CABLE:**

25. If you have not yet installed your AUX BOOST RELAY on the firewall, do so now.
26. Construct a 6AWG cable to run between the Aux Battery positive terminal and the left side terminal of the AUX BOOST RELAY. This is the large relay terminal NOT labeled "BAT". The length and path of this cable will vary depending on what type of battery tray/s you are using. The above photo shows two separate battery trays, thus the cable must run across the firewall to the relay. If you use the factory battery tray, this cable will be much shorter. Note also in the above photo, the firewall ground cables and the aluminum heater hose support brackets. We'll talk about these later.
27. Loosely attach one lug to the relay terminal. Finger-tight will do for now.
28. Insert a silicone rubber boot over the battery end of this cable and wrap the battery end lug with electrical tape to prevent it from shorting to the battery post for now. Place the lug next to the Aux Battery positive post but **DO NOT CONNECT IT YET**. We don't like sparks!
29. Route the cable across the firewall and secure as needed with Adel clamps.

30. **RIGHT-MAIN POSITIVE CABLE:**

31. Construct a 6AWG cable to run between the Main Battery positive terminal and the right side of terminal of the AUX BOOST RELAY. This is the large relay terminal labeled "BAT". In the above photo, the Main Battery positive cable is the short cable with the red shrink-tube label. The slight dip is provided for strain-relief and maintainability. Notice how sections of blue silicone tube and white boots are being used to protect the relay terminals. If you look closely, you'll see the Aux Battery positive cable running along the firewall to the other side of the relay, and the Main Battery ground and Oxygen Sensor (braided shield) cables running diagonally along the engine mount tube. The green bracket on the firewall is a battery hold-down.
32. Loosely attach one lug to the relay terminal. Finger-tight will do for now.
33. Insert a silicone rubber boot over the battery end of this cable and wrap the battery end lug with electrical tape to prevent it from shorting to the battery post for now. Place the lug next to the Main Battery positive post but DO NOT CONNECT IT YET.

34. **STARTER CABLE:**



35. Construct a 6AWG cable to run between the BAT side of the AUX BOOST RELAY and the Starter Motor Terminal Post.
36. This cable should run along the right engine mount tube like the ground cable does, but continue under the intake manifold, through the opening in the engine mount plate next to the radiator hose, and to the starter motor. Use care in routing the cable to avoid chaffing against any sharp edges. The photo above also shows the Starter Solenoid wire which we will install shortly.
37. Slip a silicone rubber boot over the starter end of this cable and secure the lug to the starter motor. If you prefer, apply some "liquid electrical tape" to this connection to help resist water penetration.
38. Pull the boot over the connection and tie-wrap the cable as needed.
39. Loosely attach the relay end of this cable to the relay terminal marked "BAT". It shares this terminal with the Main Battery positive cable.
40. **EXPBUS MAIN BATTERY CABLE TO MAIN BREAKER PANEL:**

41. The above photo shows one method of mounting the supplementary circuit breakers and auto-failover relay. The builder used a short section of aluminum angle to fabricate a bracket along the bottom of the bulkhead behind the instrument panel. This positions the breaker knobs downward where they can be quickly checked without consuming valuable panel space. Construct an 8AWG cable to run from the relay terminal marked "BAT" to the Main Battery Circuit Breaker. This cable shares the relay post with the Main Battery positive cable and the Starter Motor cable. Leave this cable about 12" longer than you think is necessary inside the cabin to facilitate routing and installation of the circuit breaker. Don't bother installing a terminal end for the breaker just yet.
42. Sandwich the relay lug with the starter motor cable using a section of shrink-tubing.
43. Install and tighten down the relay terminal nut using a flat washer and lock washer. There should now be three cables on this terminal post.
44. Protect the terminal post with a short section of silicone rubber hose split along one side and secured with tie-wraps as shown in the reference photo from step 30 above. Optionally, you can apply liquid electrical tape to further prevent moisture penetration.
45. Route the other end of this cable through the nylon firewall fitting. Continue routing and securing the cable as needed to mate with the 60A Main Battery circuit breaker. We will be installing another section of 8AWG cable between the circuit breaker and the EXPBUS "BAT" terminal later. The circuit breaker can be located anywhere it is convenient inside the cabin. We will cover this in more detail a little later.
46. **ALTERNATOR CABLE:**
47. Construct an 8AWG cable to run from the Alternator Terminal Post to the 50A Alternator circuit breaker inside the cabin. Put a lug on both ends of this cable. Alternators are notorious sources of radio noise. If you prefer, you can use shielded cable, or cover the alternator cable with braided copper shield, grounded at one end, to help reduce electrical noise.
48. Install a silicone rubber boot over the Alternator end of this cable and attach the cable to the Alternator terminal post with a flat washer, lock washer and nut.
49. Route the cable towards the firewall and across the rear of the motor to meet up with the right side ground cable and starter cable. The three of these cables can be tie-wrapped together and should follow a graceful curve out to the engine mount tubes where Adel clamps will secure them. These cables must have a small amount of slack at this point since the engine is rubber mounted and will vibrate a little (*very* little, it is a Subaru afterall!).

50. Continue routing the Alternator cable through the nylon bulkhead fitting and to the 50A circuit breaker location.
51. Install an appropriate sized lug on the end of the Alternator cable and secure it to one side of the 50A breaker with the supplied screw and lock washer.
52. **AUX POWER CABLE:**
53. Construct a 10AWG cable to run from the left AUX BOOST RELAY terminal post (the post NOT labeled "BAT") to the 20A Aux Battery circuit breaker inside the cabin.
54. Install the relay side lug to the relay and secure with a flat washer, lock washer and nut. This cable shares the relay post with the Aux Battery positive cable.
55. Protect the terminal post with a short section of silicone rubber hose split along one side and secured with tie-wraps as shown in the reference photo from step 30 above. Optionally, you can apply liquid electrical tape to further prevent moisture penetration.
56. Route the other end of the cable through the nylon bulkhead fitting and over to your 20A Aux Battery circuit breaker location.
57. Install an appropriate sized lug on the end of the Aux Power cable and secure it to one side of the 20A breaker with the supplied screw.
58. **EXPBUS MAIN GROUND:**
59. Construct a 14AWG wire to serve as the main ground for the EXPBUS. This wire should run from the EXPBUS "Ground" terminal to your Ground Plate. A flat blade type connector is used on the EXPBUS module end. You can use another blade-type connector on the Ground Plate end or use a ring-type connector here if you prefer. This ground is for the EXPBUS internal circuitry only, and does not carry a lot of current. Short sections of shrink tubing over the exposed end of the blade connector can help prevent a short.
60. Note the time.

Congratulations! You have just completed the wiring of your primary power distribution circuits. At this point, your major cables are finished but your positive battery posts should still be disconnected for safety. We will create a few more short cable sections to connect the circuit breakers and fuses to the EXPBUS and tie up the loose ends during the installation of your secondary power distribution circuits in a moment. Take a break!

Secondary System Wiring (Step by Step)

In this section we will install the main ECM wiring harness, wire up the Fuel Pumps, Pump Selector switch, Auto-Failover circuit and indicators, Bus Master switch, Aux Boost switch, Starter switch, and complete the EXPBUS wiring as related to engine operation.

Let's start with a brief discussion about the engine wiring harness itself. If you ordered the Grand Rapids EIS option with your powerplant, the factory has already installed and wired up the various engine sensors. If you did not order this option, you will need to obtain and install these sensors yourself, and add the additional wiring to support them. We will briefly cover the individual sensors in this section for those needing to install their own, and to become familiar with their location and function. The propeller hub wiring has not been provided by the factory, so you will need to add a few wires for the prop servo. We will cover this in a later section.

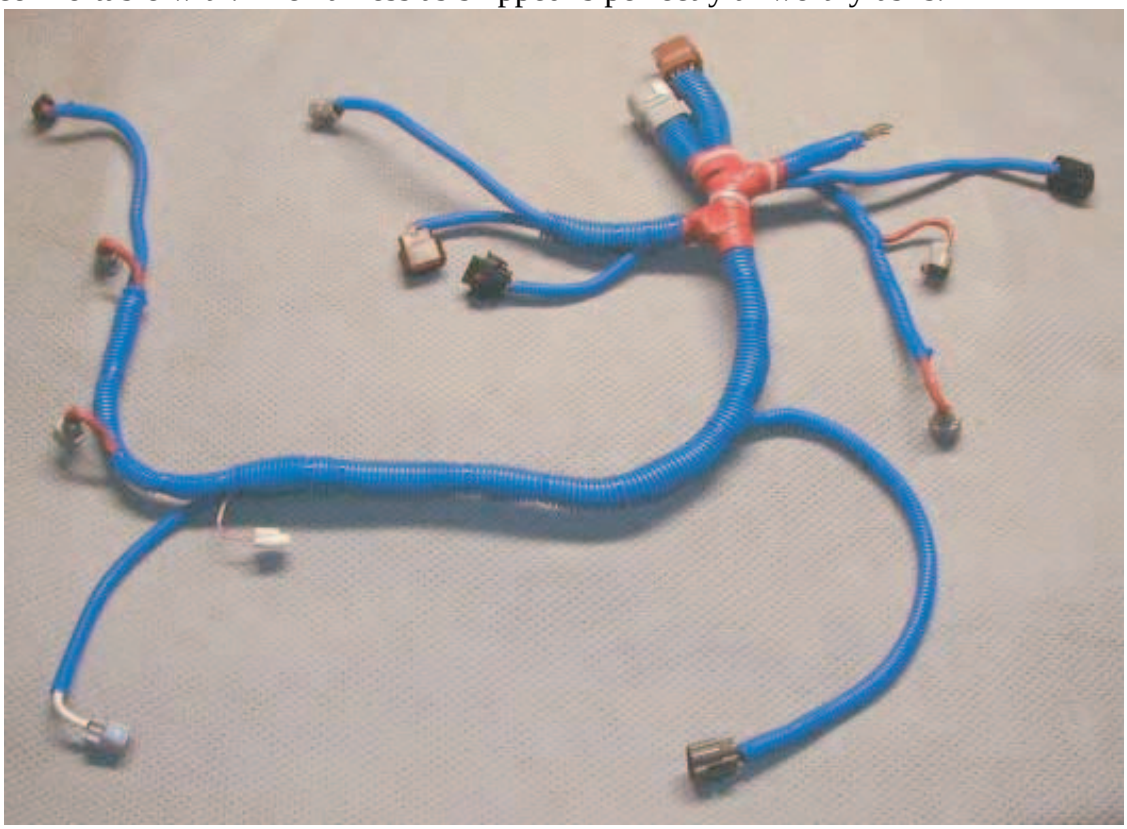
The majority of the engine wiring harness has been adapted from its automotive counterpart. The factory has taken extra care to protect the harness using corrugated, heat-resistant, tubing. The connectors themselves are of sufficient quality and do not need further attention. If you are a perfectionist, you may choose to provide some further protection for the harness.

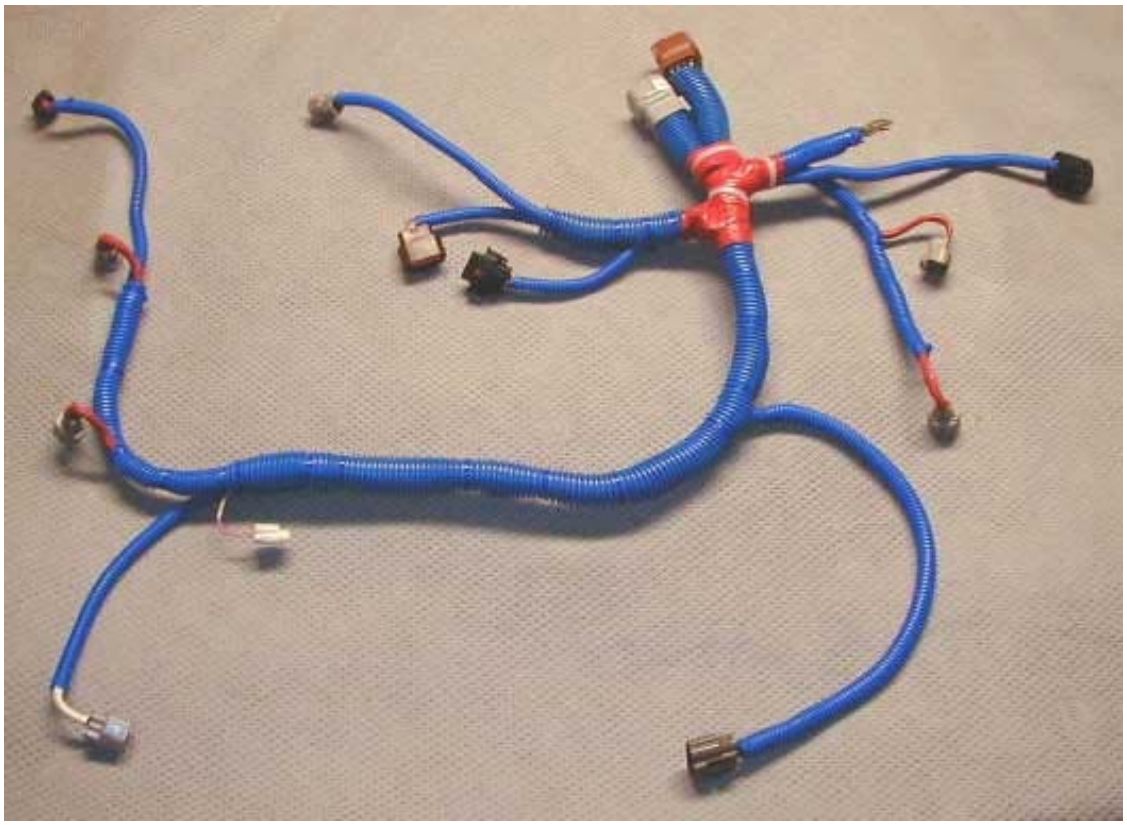
A few examples of things builders have done to improve on the factory harness include:

1. Adding a dab of high-temp RTV silicone sealer to the back side of connectors
2. Tie-wrapping connectors to prevent their accidental removal
3. Use of orange/red silicone tape to protect any exposed wire bundles
4. Further use of tie-wraps to secure the harness and relieve strain
5. Custom brackets for the main harness connectors.

None of these items are required, but builders are a fussy lot... We want you to be happy with your installation. If you choose to add or replace any of the corrugated tubing, be sure to use the high-temperature type. Often this will have a gray strip along one side of it. Secure your harness well since it will be exposed to a lot more wind than it would in a car, unless you drive awfully fast.

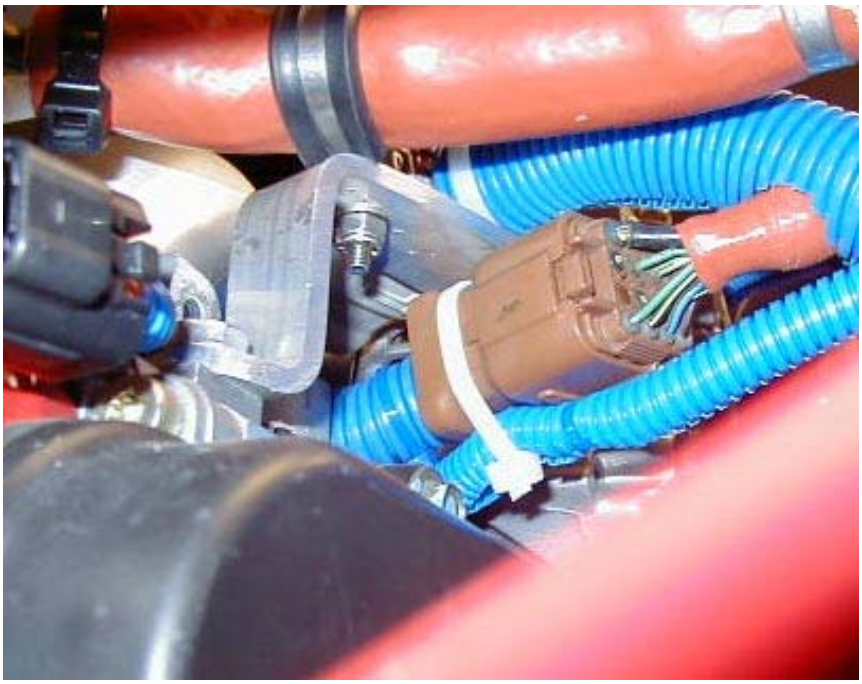
Being a wire-nut, here's what I did with my engine harness. Do as much or as little as you feel comfortable with. The harness as shipped is perfectly airworthy as is.





Fasten your seatbelt, you are cleared to wire!

1. Note the time.
2. **ENGINE HARNESS CONNECTORS:**



3. The two large connectors that mate your engine harness to the main ECM harness should be secured to a bracket using large tie-wraps or other clamping mechanism. You may want to fabricate a small aluminum bracket, like the one shown above, to hold these connectors. Because of the number of wires involved, and the fact that this harness spans the gap between the motor and firewall, you want to have these connections protected against vibration as much as possible. The connectors should be oriented such that they are facing the firewall. It is obviously easier to do this if you first disconnect these connectors. NEVER PULL ON THE WIRES THEMSELVES!!!

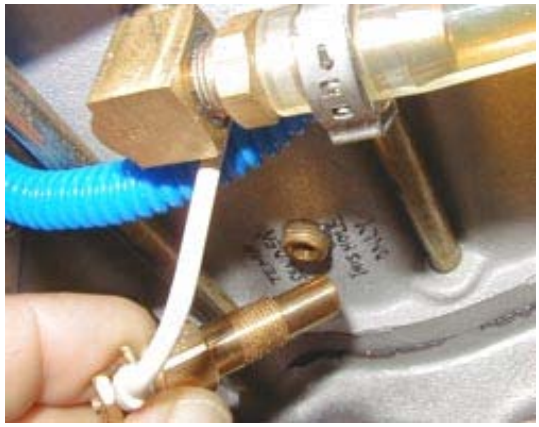
4. Give the engine harness a good inspection to make sure all engine connectors and wire bundles are secure and not chaffing against anything sharp. Add tie-wraps or clamps as needed.
5. If your engine sensors are already installed and wired by the factory, jump to the step titled "ECM Harness" now. Otherwise, continue with the next step below.
6. **ENGINE SENSOR INSTALLATION:**
7. If you have not yet obtained your engine sensors, do so now. Which sensors you chose are up to you, but consider the following list. **NOTE:** On newer motors, the location of the Oil Temperature and Oil Pressure senders will be swapped.

Oil Pressure  Install on top-front as marked. (See note above).

Oil Temperature  Install in top-rear by alternator. (See note above).

Coolant Temperature 

Install in left radiator.

PSRU Temperature  Install in PSRU as marked (avoid gear contact!).

Fuel Pressure (Active type shown)  Install in pump outlet plumbing.

Fuel Temperature (optional)  Install in pump outlet plumbing.

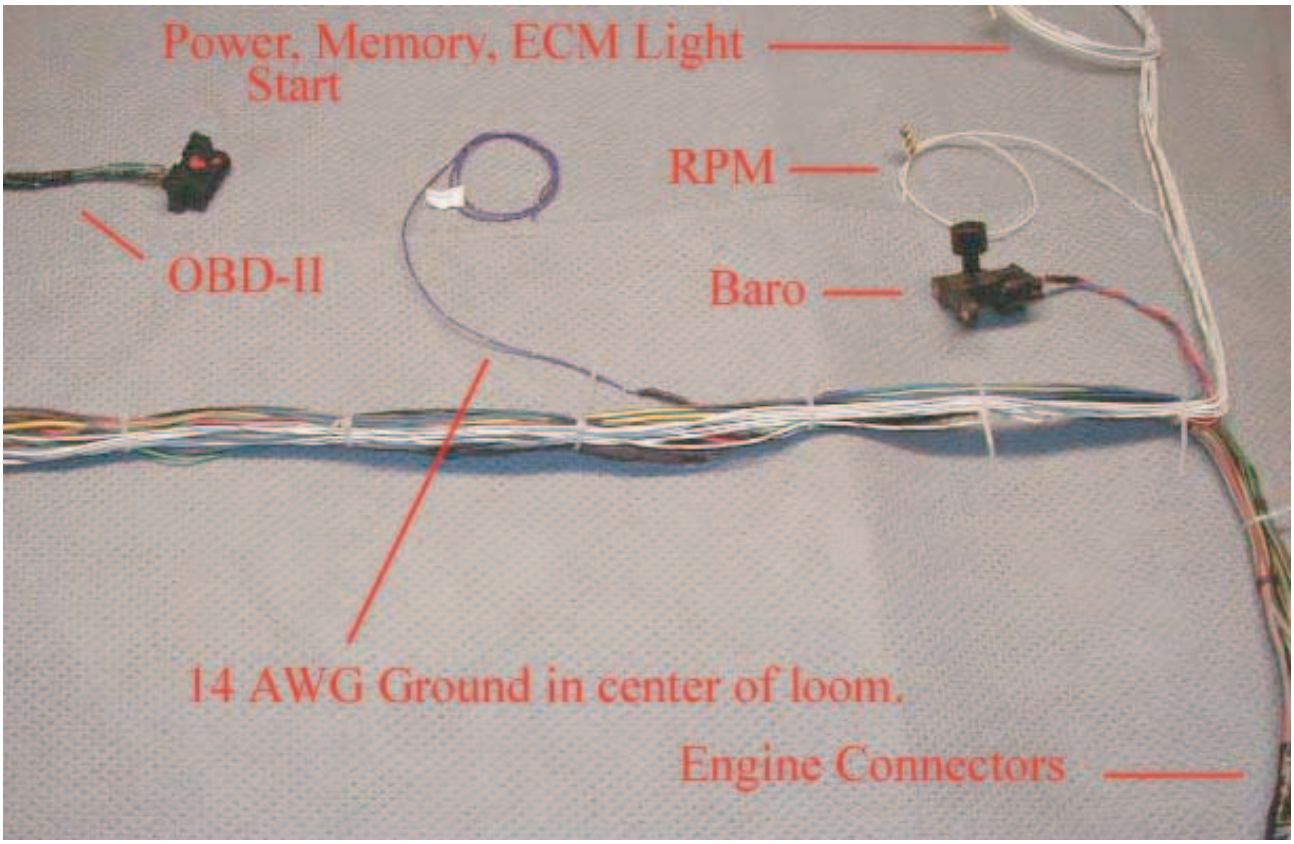
Coolant Loss (we will discuss this one separately)

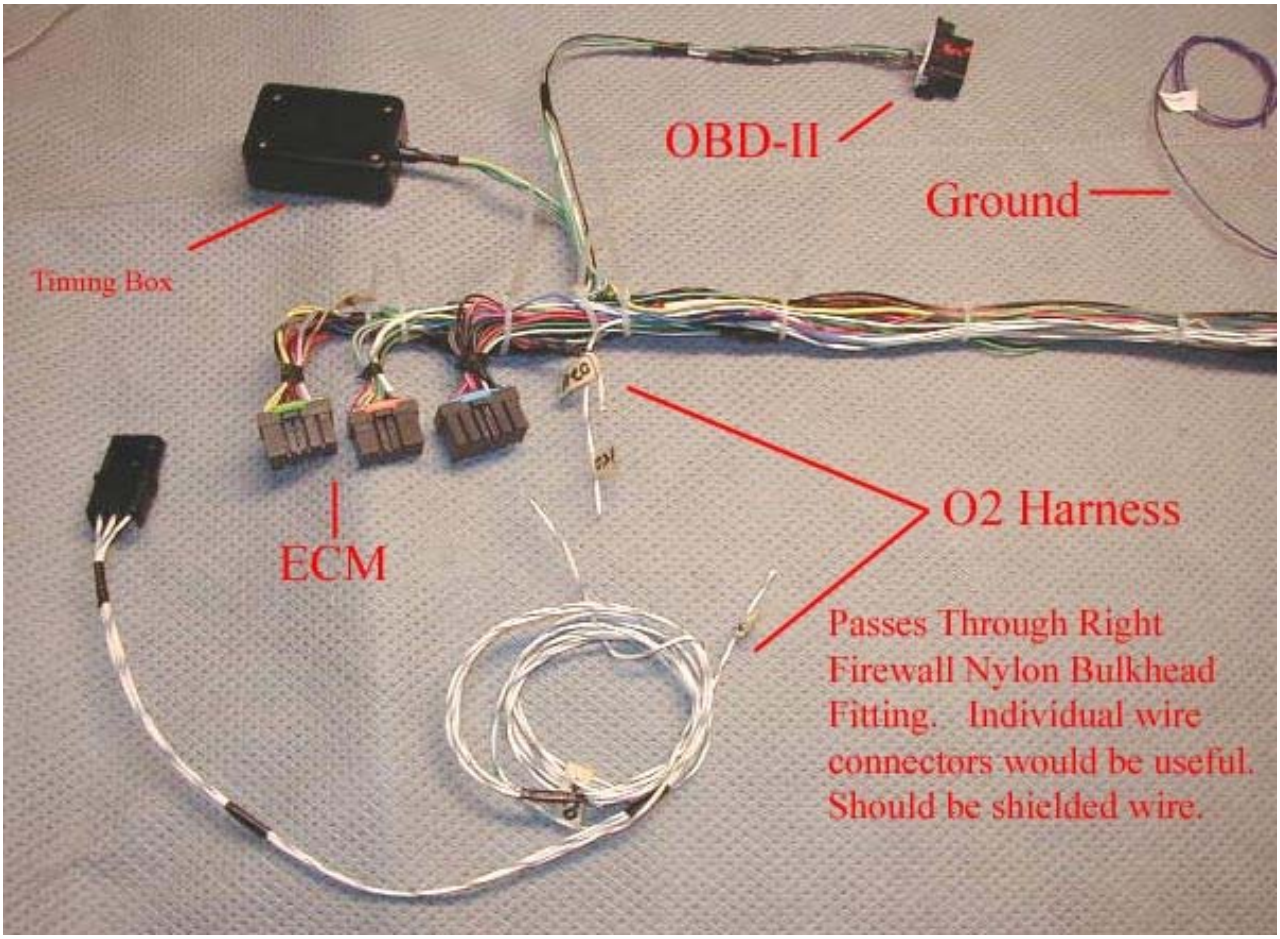
These sensors are readily available from any good parts supplier. Most use a 1/8" NPT thread side, although some may have a 1/4" NPT thread which must be adapted using a reducer fitting. Your engine will have labels indicating where these sensors go. The exact location of these sensors is subject to change with engine models and years. The important thing is to get to know where they are on your engine.

8. Install all of your sensors now. Be sure your PSRU sensor does not interfere with the gears. Use a small sensor and if needed, use a fitting to extend it out from the case to prevent contact with the gears.
9. All sensor wiring should be 20AWG Teflon insulated wire. Obtain a good length of this wire since it will be used for most of your radio installation too. It's cheap.
10. You may choose to cut some of the tie-wraps securing the existing engine harness and snake the sensor wiring through the existing tubing, or you may create a separate harness specifically for the sensors, it is up to you. Whichever way you go, be sure to use the high-temp tubing and ample tie-wraps to secure the harness when done.

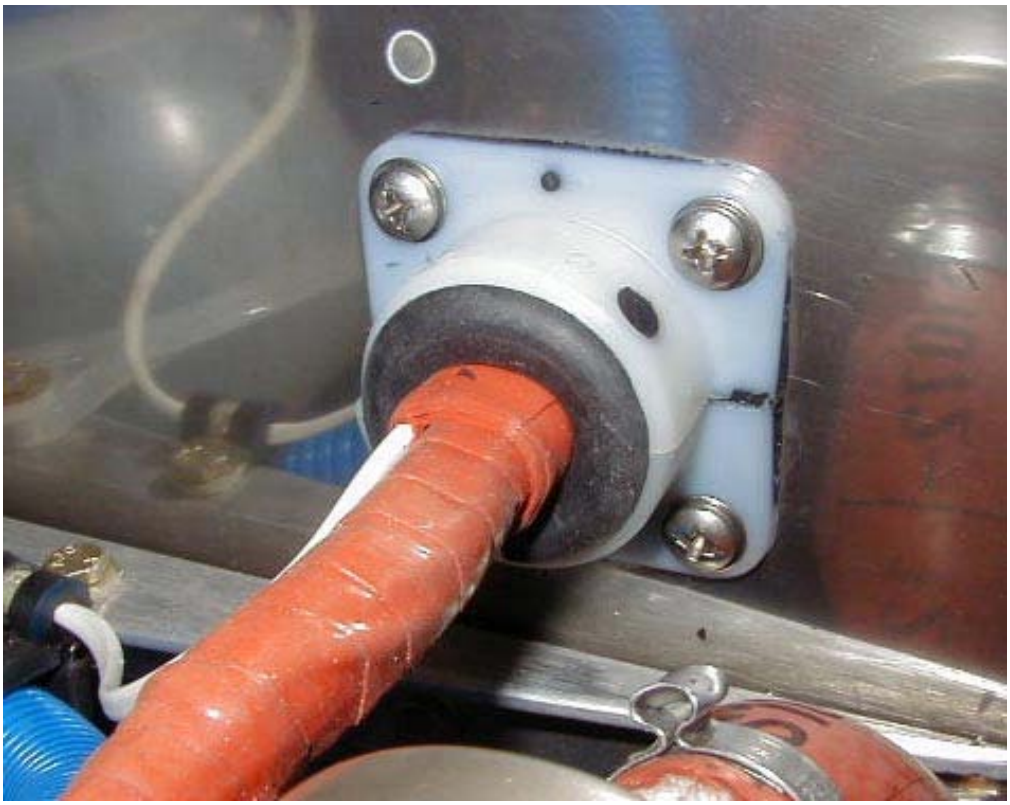
11. Some builders will prefer to use a Cannon-plug, or other pin connector at the firewall for these additional wires. We advise against this practice however, because it creates additional connections and impedance which can interfere with the sensitive sensor circuits. Instead, our preferred method is to install another nylon bulkhead fitting and run the sensor wires nonstop from the sensors into the cabin. For now, you can just leave ample length of wires and trim them to fit as we move into the cabin part of the job. For now, we are only concerned with finishing the engine side of the installation.
12. Most sensors will have a single "signal" wire and use the engine block as their ground. Some will have both a "signal" wire and a "ground" wire, in which case, you will need to run two wires and attach the ground to your Ground Plate inside the cabin or a ground stud on the engine block. Some sensors, such as fuel pressure, are available in an "active" design. This type of sensor will have three wires, "signal", "power", and "ground". About the only difference, aside from improved accuracy, is that these active sensors require power, in which case, you will run three wires to them.
13. Install 20AWG wires for each of your sensors now.
14. Route the wires carefully across the engine to avoid chaffing and contact with hot objects. Bring the wires together near the large engine connectors and leave plenty of length for continuing their journey into the cabin.
15. Secure the wires with tie-wraps, Adel clamps, or tuck them inside the corrugated tubing as needed.
16. Use silicone rubber boots (typically the small size boots about 1" long) or apply liquid electrical tape to protect the connections from moisture.
17. If you are planning on using a propeller with electric hub, you may want to run two additional 14AWG wires out to the PSRU. Leave about a foot of extra wire at the PSRU end for attaching these to the servo brushes later.
18. Label all of your wires at the firewall end for easy identification as we proceed. Simple masking tape tags will do the job.
19. **COOLANT LOSS SENSOR: - Link to a Word document showing how to build a coolant loss detector circuit.**

20. If you like, you can hook up a Coolant Loss sensor to the Swirl Pot. You will notice there are two flat blade type pins in the connector fitting on the Swirl Pot. You can attach a pair of 20AWG wires to these pins with small flat blade type connectors. The sensor probes which are built into the Swirl Pot are for a capacitance type circuit. In order to use this sensor, you will need to construct or purchase a small circuit board to drive the sensor. We can send you the plans for making this circuit board if you like. Optionally, you can simply run the wires now and worry about the circuit board at a later date. A coolant loss sensor is a nice thing to have on a liquid cooled powerplant as this would give you the earliest possible indication of a leak. *Newer engines no longer use the plastic pot shown above. Unfortunately, it will be up to you to fabricate a pair of parallel wire probes in tanks that don't provide them.*
21. **ECM HARNESS:**





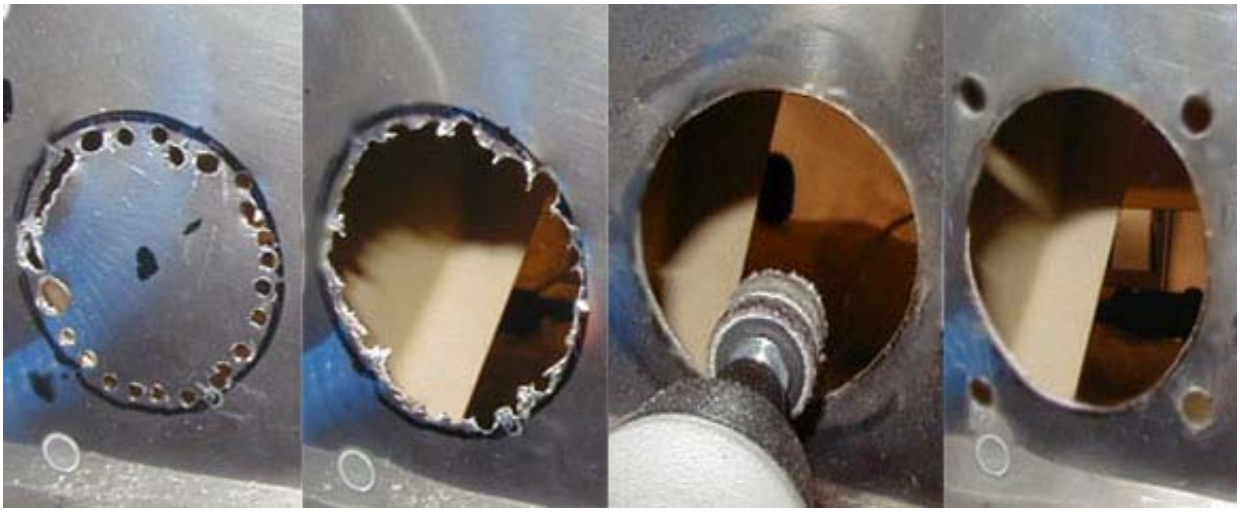
22. The ECM Harness will connect the engine harness with the ECM. Most of the length of this harness will be inside the cabin, but about a foot of it will extend from the firewall to the engine harness connectors. Note that the above photo shows the harness without any protective covering. In your installation there will be corrugated tubing and silicone tape to protect the wiring. If you add wires, you will need to reapply the protection.
23. The first step for this harness will be to determine where it will enter the firewall and construct a suitable nylon bulkhead fitting.
24. For my own RV installation, I have located the fitting approx. 8.25" to the right of the upper left engine mount bolt (right and left as viewed by a seated pilot of course, NOT as facing the firewall) and 5" down from the top of the firewall. A 1.125" (inside diameter) nylon bulkhead fitting will be used. Four stainless steel screws will attach the fitting to the firewall. Adjust the location as needed to avoid falling on top of existing rivets or other components. The general idea is to locate the fitting such that the wire bundle will run nearly straight to the firewall from the engine. It's not that critical.
25. You will find that the 1.125" ID nylon fitting is just the right size for the large corrugated tubing, but a better seal can be had by removing the corrugated tubing from the section of the harness between the nylon fitting and the engine connectors. Wrap the harness with high-temp silicone tape and use a pair of rubber grommets to adapt the nylon fitting to the harness. You will need to make a slice in the grommets to install them around the wire bundle. The grommets will fit into the grooves of the nylon fitting. Once the nylon fitting is secured, the grommets will grip the wires tightly and form a good weather resistant seal.

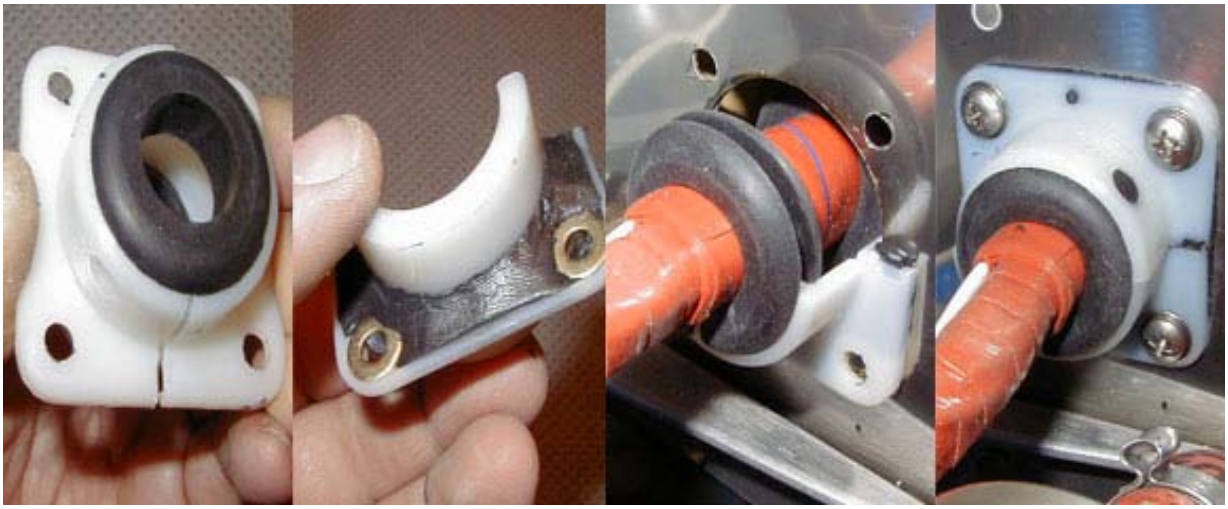


Aircraft Spruce p/n NMCS45A-11, Grommet p/n AN931-11-16 (you need 2 grommets)

26. Before installing the harness through this fitting, decide whether you are going to run any additional wires through this fitting or a separate fitting. On my own installation, I chose to create three separate harnesses. The ECM harness, an engine sensor harness (I wired my own sensors), and a fuel pump and fuel-related sensor harness. In my installation, I cut three holes in the firewall for these harnesses and use Cannon plug shells to protect the smaller harnesses as shown below (fly-market items). Note in this photo I used a stainless hose-clamp around the large nylon fitting (can't hurt...).

27. The ECM harness engine connectors will just fit through the fitting hole before the halves of the fitting are installed. Insert these connectors through the firewall and forward to their mates on the engine. Go ahead and connect the engine connectors.
28. Now assemble the nylon fitting/s. Stainless steel screws are recommended on all firewall fittings. Stainless steel is very difficult to work with. It quickly dulls your tools and slices your fingers. A fairly quick and bloodless way of cutting large holes is to drill a chain of small holes, punch out the center (twisting segments with needle-nose pliers works good), and smooth the final hole with a drum sander. The following photos show the full sequence of building the large bulkhead fitting.

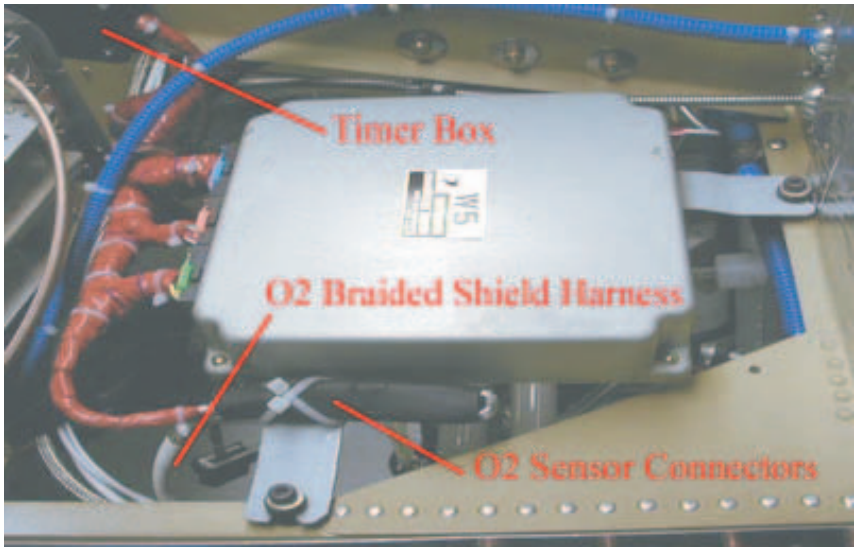




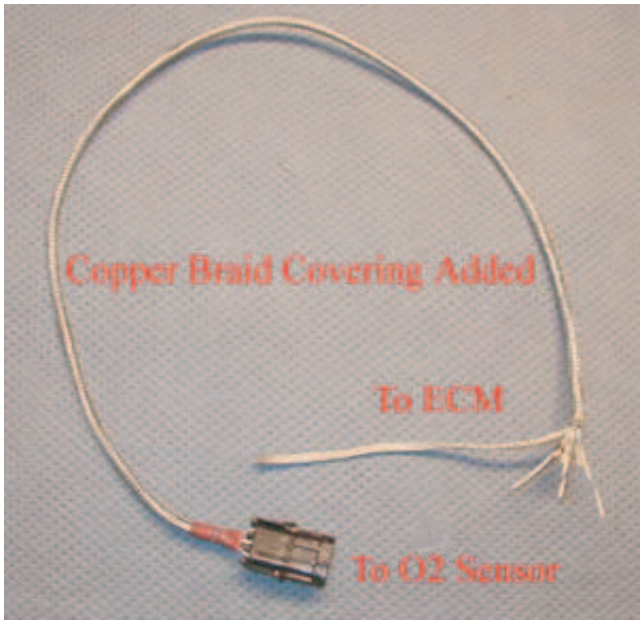
29. Inside the cabin, thread the ECM harness across the forward fuselage and under the panel support ribs (F-7107/7108 on an RV9A).
30. Suspend the harness under each panel support rib with Adel clamps. Note that I have chosen to wrap the entire length of the ECM harness in high-temp orange silicone tape. The photo below shows the harness as it enters the cabin and threads across to the ECM. The white wires are the engine sensor wiring, fuel pump wiring, and misc ECM wiring heading to the switches on the instrument panel. These wires will run along the pilots side (left) of the fuselage, to your control switches. You can drill a hole for a snap bushing in the bulkheads as needed, or suspend these wires with Adel clamps. The wires should be long enough to reach the instrument panel in the vicinity of the Start, Bus Master, and Aux Boost switches.

31. In the center of the ECM harness (in the vicinity of your Ground Plate) you will find the main ground wire for the ECM. Attach this ground wire to your firewall Ground Plate. The critical nature of this ground suggests that you use a ring type wire connector and place it on one of the ground bolts rather than using a flat blade type connector. The photo below shows how the ECM harness (in orange) takes a sharp turn towards the instrument panel, then again towards the ECM (shown in the next photo). In the vicinity of the Ground Plate, you can see a white wire attached to the ground bolt. This is the main ECM ground. The other white wire grounds the metal shell of the ECM itself.

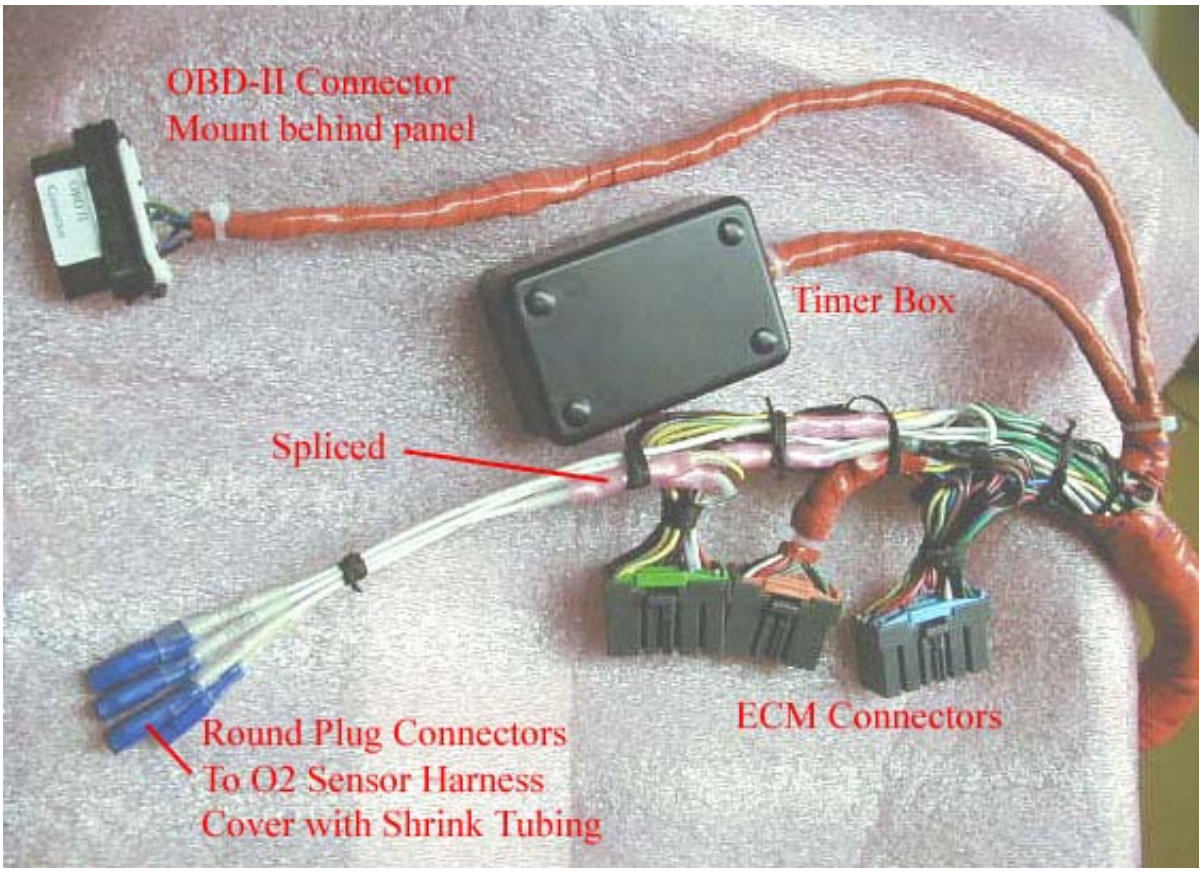
32. The wires which exit the ECM harness on the passenger side (right), will connect to your Oxygen Sensor or Starter Solenoid. Just tuck these out of the way for now.
33. Fasten the three ECM connectors to the ECM.



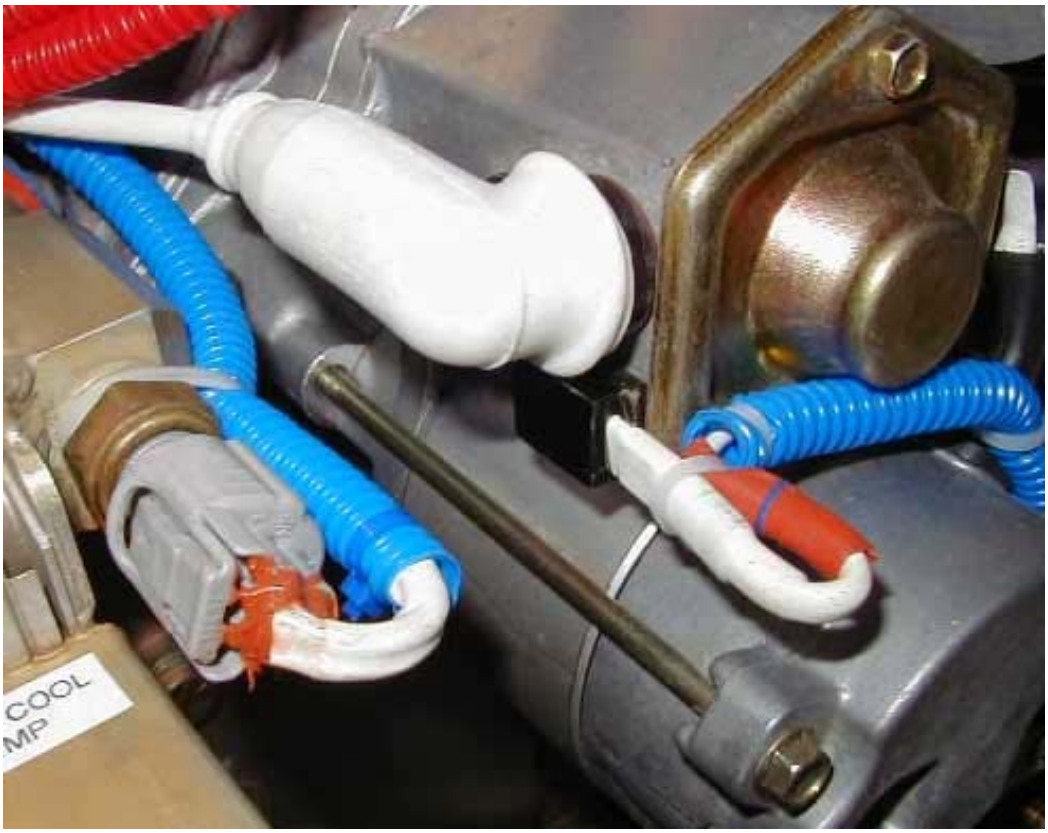
34. **OXYGEN SENSOR:**
35. The O2 Sensor is located in your exhaust pipe. If your pipe is not installed, do so now. If you have a need to remove it again for cowling work, etc. simply install the nuts finger-tight for now.
36. The O2 Sensor wiring harness consists of three or four wires depending on the model being used. Ideally, these wires should be covered with a section of braided copper shield to prevent spurious signals in this very low-voltage circuit.



37. The O2 Sensor harness can be routed through the right side nylon bulkhead fitting shared by your large cables.
38. Using crimped splice (aka butt) connectors, connect the O2 Sensor wires to their counterparts as labeled on the ECM harness. Use sections of shrink-tubing over the splices to keep out moisture.
39. Note: Early motors may not have run the O2 sensor wiring as shown and described above. Early wiring harnesses had the O2 sensor entering on the left side of the firewall. If you would like to reposition the wires and add connectors, you will need to open up the harness and splice in connectors as shown in the next two photos. This change will already have been made on later wiring harnesses. Refer to the earlier photo that shows the finished harness connected to the ECM.

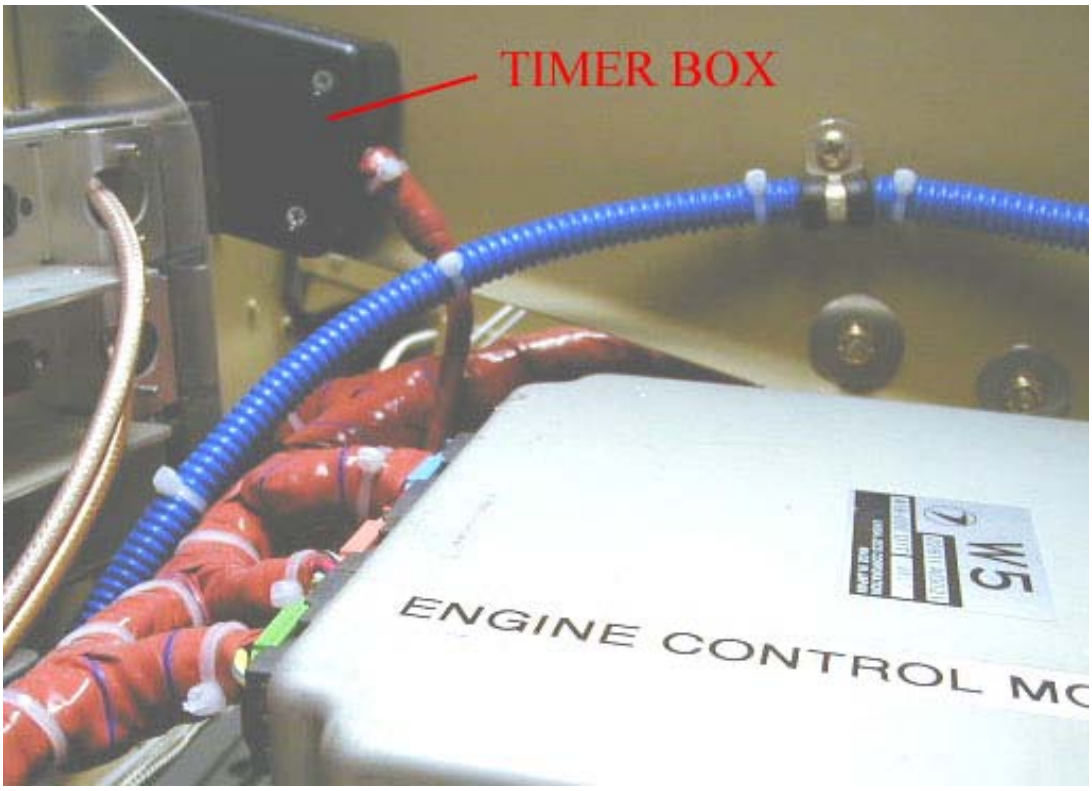


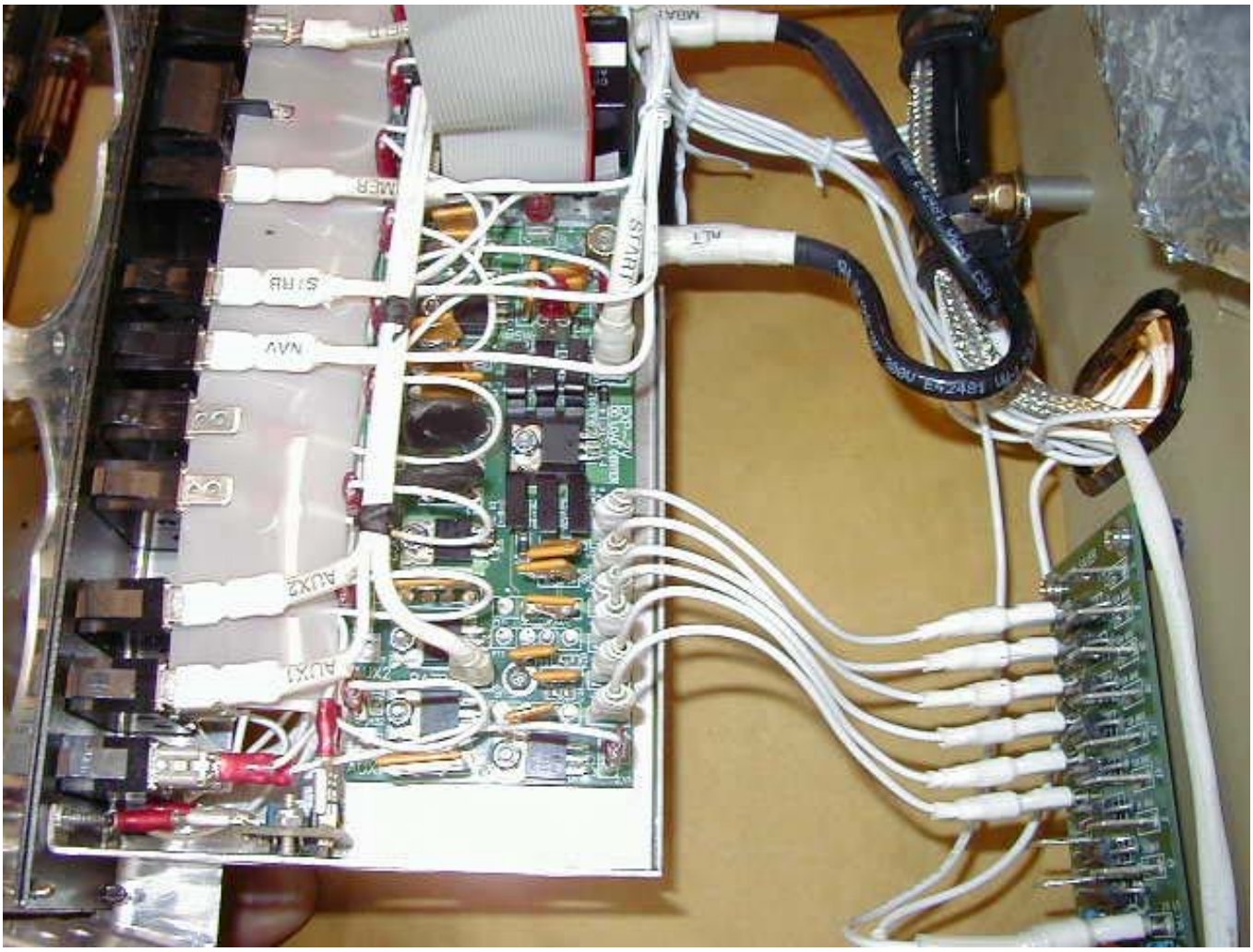
40. **STARTER SOLENOID:**

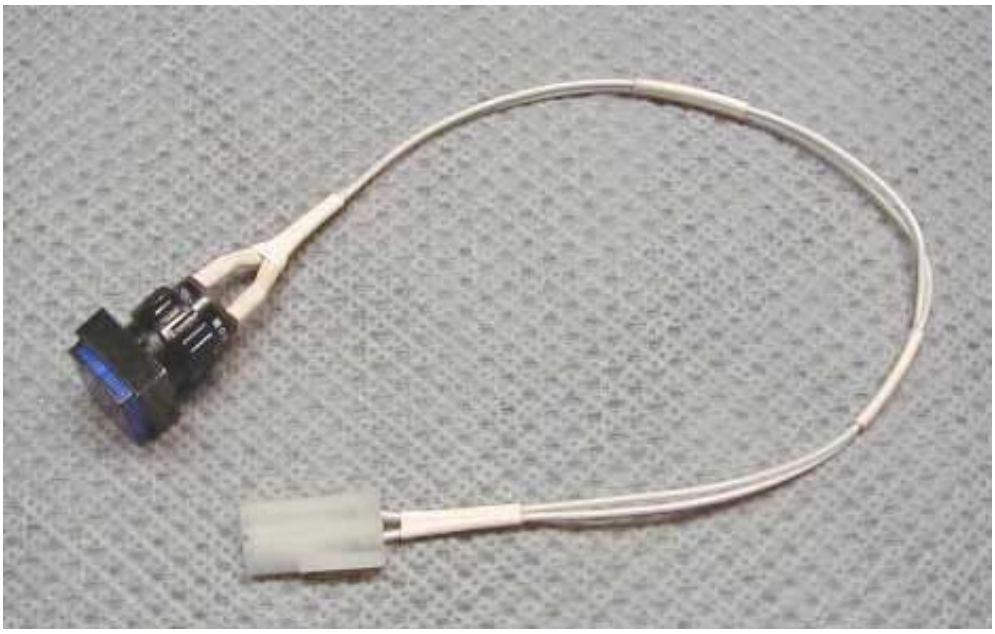


41. One of the larger, long, wires near the ECM will be labeled for the Starter. This wire is to be run through the right nylon bulkhead fitting and should follow the path of the Starter Cable to the Starter Motor.
42. Fasten the wire to the flat blade connector of the Starter Motor Solenoid using a flat blade connector and a section of shrink-tubing.
43. Fold this wire over (do not bend the connector itself) and tie-wrap it to the Starter to prevent it from vibrating loose.

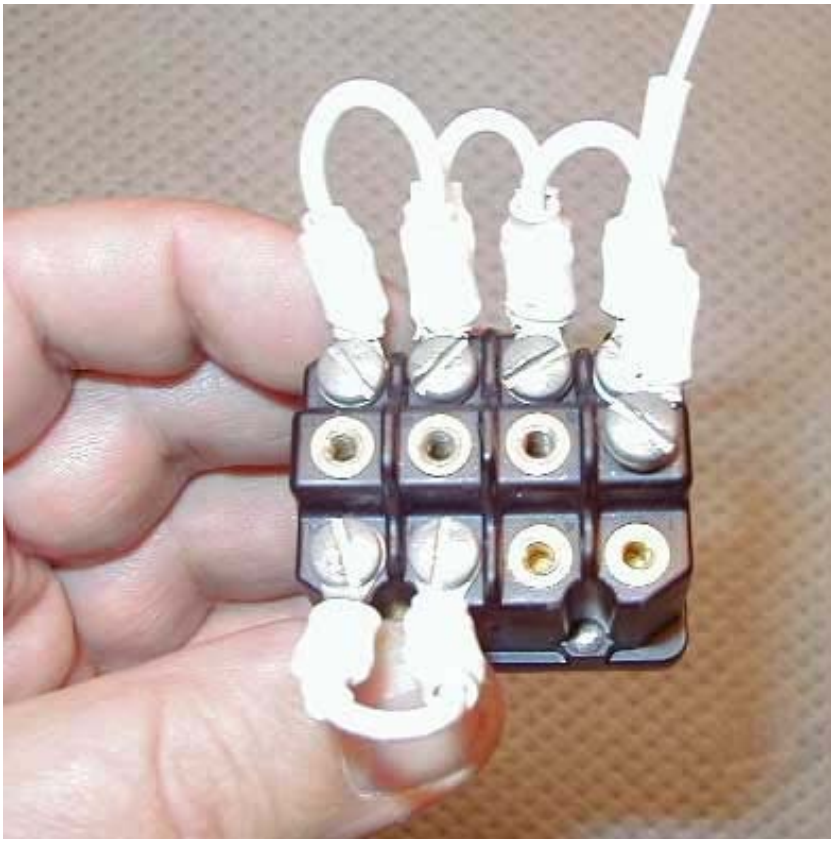
44. **TIMING PARAMETER BOX:**

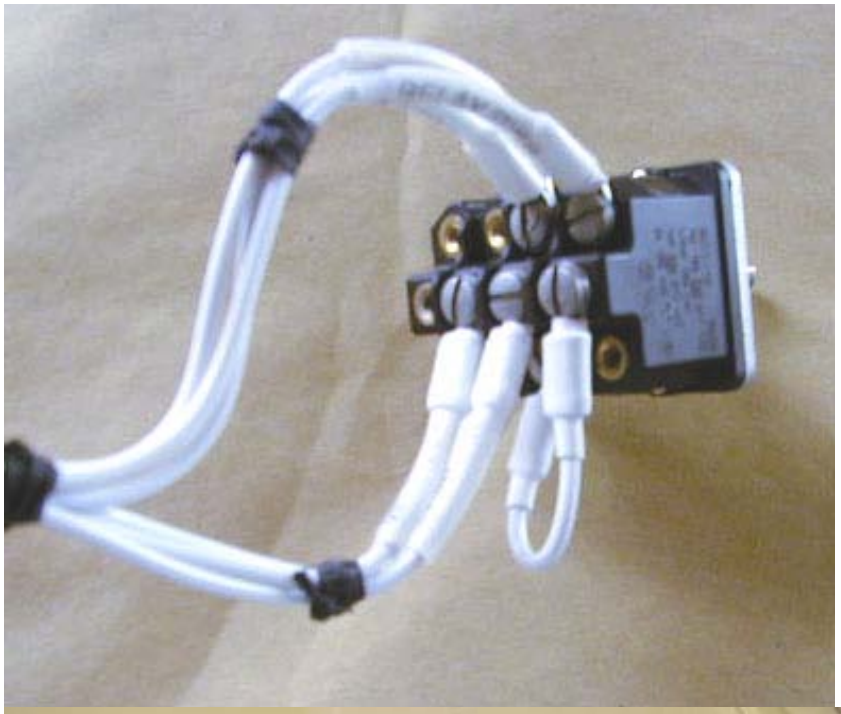


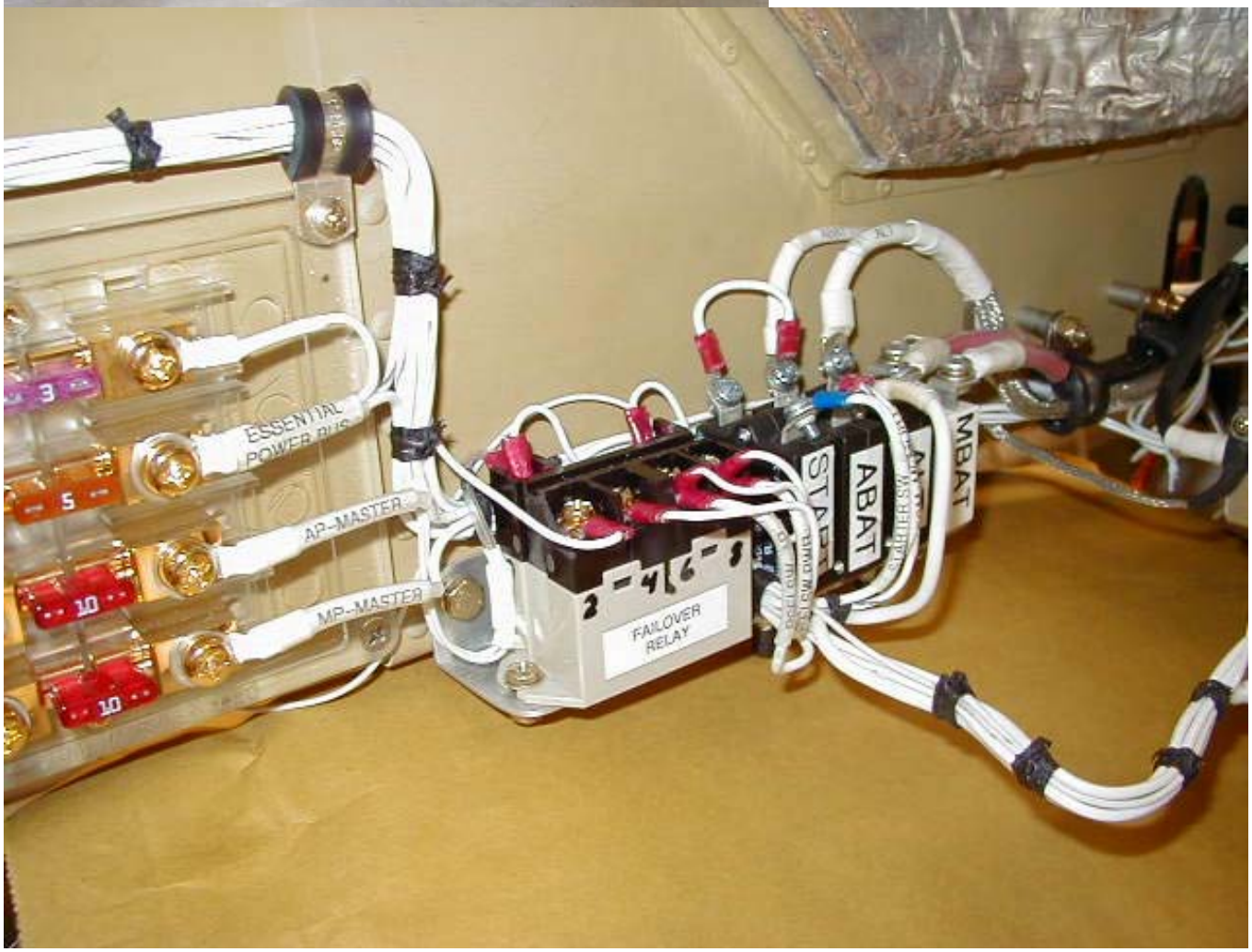

STRB
NAV
AUX2
AUX1
START

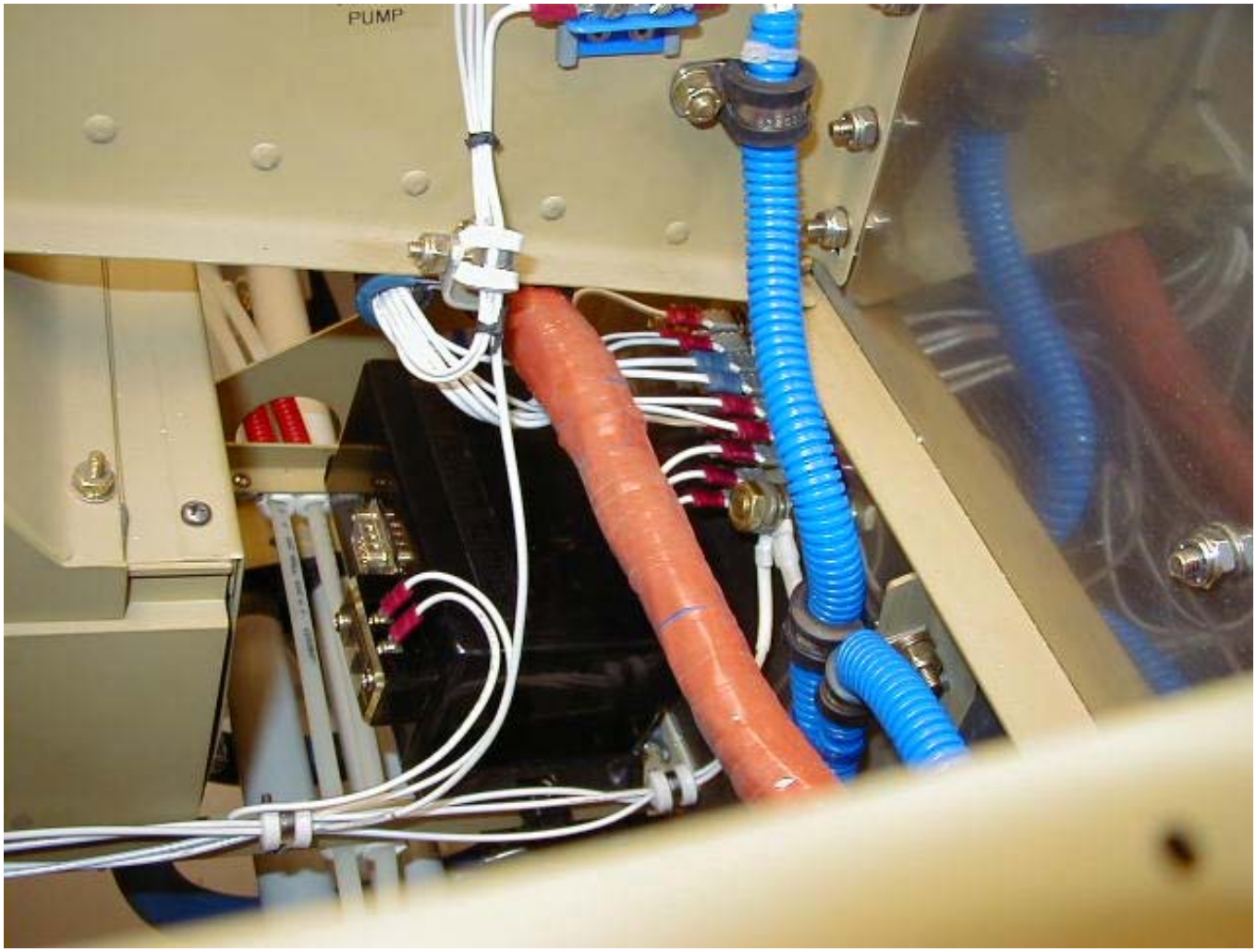


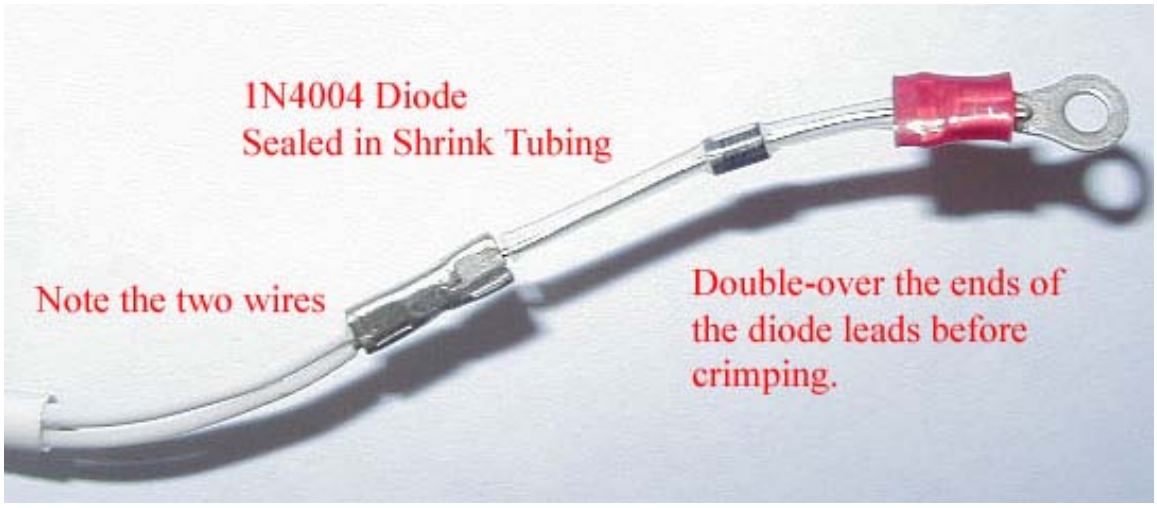

GYRO

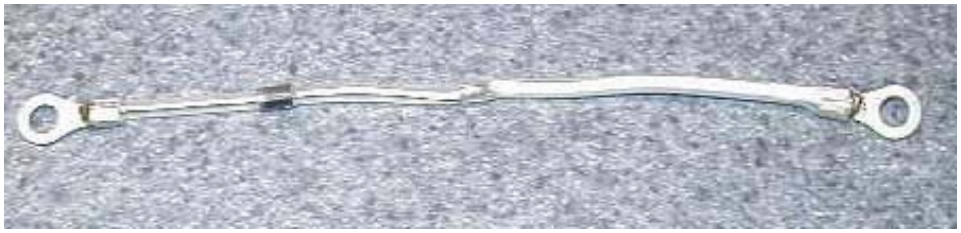





ESSENTIAL
POWER BUS
AP-MASTER
MP-MASTER
FAILOVER
RELAY
ABAT
MBAT


PUMP


1N4004 Diode
Sealed in Shrink Tubing
Note the two wires
Double-over the ends of the diode leads before crimping.




DIODE

Chapter 7- Engine Cowling Installation

This chapter will cover the modifications required to mate your stock Vans RV7-IO cowling to the e-motor. There are a variety of creative ways builders have come up with for actually fastening the cowl to the airframe. Vans prefers to use long piano hinges which make for a very clean, tight-fitting cowling installation. Others have made good use of Camloc style fasteners such as the kits offered by Skybolt Aeromotive Corporation, or even a combination of the two methods. If you think you'll be opening up your cowling often to admire and show off your e-motor, then you might consider using the piano hinges for the lower cowling and Camlocs for the upper cowling. Either method works fine and I am not going to spend any more time advising you on either technique, it's your plane!

The stock oil access door will suffice for your engine. The oil dipstick is positioned just slightly forward of the oil door cutout, but you can still get at it to check your oil level. If you are performing routine maintenance, you will probably be removing the cowling anyway, so filling the crankcase is best done with the cowling removed. If your motor just needs a small drink, you can still access the filler port using a funnel with a short piece of hose on the end. Bear in mind that your e-motor is not an oil-thirsty motor like those air-cooled ancestors. Your motor will seldom need a drink of synthetic oil, MOBIL-1 5W30

Being an old street-rodder myself, I have built motors without any oil filler cap at all, since they are notorious for leaking and getting your beautiful motor dirty. I fill these motors through the dipstick tube using a small hand-pump orchard sprayer with a nozzle made from a short piece of brake line tubing. With a hand vacuum pump attached to the sprayer tank you can extract the oil the same way. Works like a charm!

You'll be putting your fiberglass talents to work in this chapter, so stock up on the basic supplies:

1. Dust masks
2. Latex gloves
3. **EPOXY RESIN** (just a small amount, but you'll need this for your windshield and canopy too). **DO NOT USE POLYESTER RESIN** like commonly used in the automotive world. It is incompatible with your materials. West Systems 105/205 Resin/Hardener is perfect. Don't forget to buy their plastic pump kit.
4. Micro-balloons such as West Systems 410, or fiberglass flox (powdery or itchy stuff you add to the resin to form a paste)
5. As a cleaner and simpler alternative to items 3 and 4 above, you can use a good two-part aviation filler such as "Super PolyFill".
6. A couple of Bungee-cords
7. Some duct tape (similar to what was recommended for Homeland Security :^)
8. Sandpaper of a few various grits ranging from 60 to 400.
9. Some 80 or 100 grit sandpaper strips for linear body sanders, aka "board sanders", available at your auto body supply store, or you can cut open a sanding belt.
10. A Dremel or similar grinding tool
11. A Dremel Carbide Cutting & Shaping bit number 542 (works great on cowling and canopy)
12. A Dremel sanding drum bit and sandpaper sleeves
13. Some popsicle sticks, masking tape, brown paper, etc.

14. 1", 1.5" and 2.25" hole-saw drill bits (wood cutting types work fine, small teeth are best).
15. Some scrap particle board and 1/2" plywood about 24" square each to make a prop backing plate jig.
16. Misc drills, jig-saw, and common hand tools.

The tasks at hand include:

1. Making a prop disk jig
2. Fitting the lower and upper cowling
3. Fitting the cowling to the radiator shrouds
4. Fitting the oil cooler shroud
5. Making a cutout for the oil cooler inlet
6. Making a pair of cowl vents to release heat when parked.

Sounds simple! Let's do it.

Making a Prop Disk Jig

Before you begin fitting the cowling, make a wooden prop disk to help you with cowling alignment.

Start by tracing two 13.5" circles on a piece of 1/2" particle board or 1/2" plywood. Cut them out with a jig-saw or band-saw. Don't bother smoothing the edges just yet. You need two of these disks, one MUST be made from 1/2" material, the other can be thicker if you like. I used 3/4" particle board for the forward one, and 1/2" plywood for the rearward one.

In the center of the thicker forward disk (if you made one thicker), use a 2.25" hole-saw to drill a hole for the prop flange boss. Slip the disk onto your prop flange to make sure it fits and adjust as necessary. In the other disk, trace and cut out a 6.25" circle. This disk

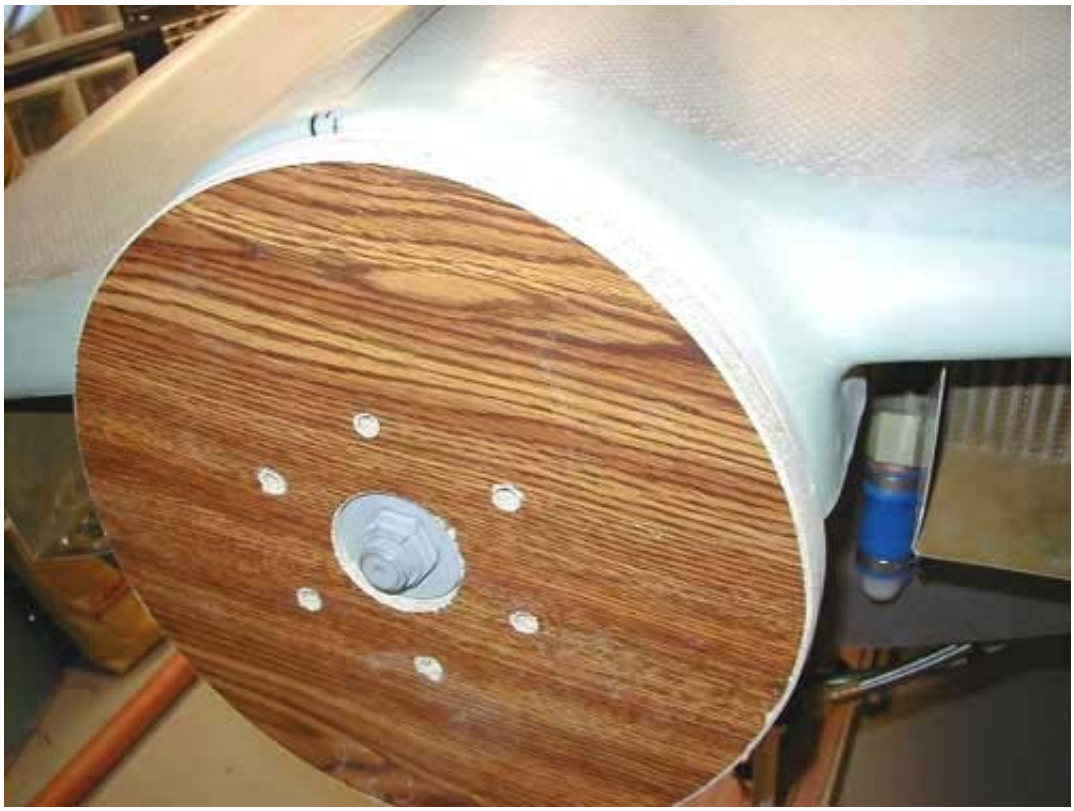
must fit loosely over the entire prop flange.

While holding the disk with the smaller center hole in place, mark the location of at least two bolt holes from the back of the prop flange. Drill these holes to size and locate some bolts and nuts to secure the disk to the flange (but don't bolt it together just yet).

Now fasten the two disks together with some glue or a few screws.

Sand the edges of the disks smooth and round on your belt sander. No need to get carried away here...

Now bolt the disk onto your prop flange with the large center hole covering the prop flange. The back side of the disk should now be flush with the back side of the flange.



Fitting the Lower Cowling

Read the entire chapter on this subject from Vans installation manual at least a few times, then set it aside.

Assuming your motor is fully and properly installed (Forgot to do that? Do so now and return here when ready).

Assuming your propeller is NOT installed (if it is, remove it and return here when ready).

You will find that the length of your mounted engine is such that only a tiny amount of cowl trimming will be required to mate with the firewall. Keep this in mind throughout the installation because while you can always remove more material, it is very hard to put it back if you sand or saw too much away. This is a slow, trial-and-error process which requires patience and perseverance. Some additional trimming will be required around the radiator shrouds before you can fully seat the cowling against the firewall. The oil cooler cutout comes later.

Some builders prefer to fit the upper cowling first, then the lower cowling. I personally

chose the opposite approach, but it will work either way. In my opinion, the lower cowling has the most material to spare and also requires the most cuts, so it seems reasonable to start there.

If you are building a tricycle gear RV, you will need to make provisions for the nose gear leg to protrude through the lower cowling. Vans suggests cutting a long slot in the lower cowling. If you are careful, you can save the piece you remove and fashion a means of screwing it back into place to cover the rear portion of the slot after installing the cowling. If you are using a three-blade prop, this slot will need to be longer since the lower cowling must drop lower to clear the three-blade prop. All of this is described and shown on Vans plans. I suggest starting with a measurement or two using a long straightedge on the belly to determine where to drill that first hole through the cowling. Use a 1.5" hole saw to make the forward-most cut, then mark the parallel lines and saw out the slot using your Dremel cutting wheel or a hacksaw blade (the cutting wheel works best and you may as well get used to it now).

As an alternative, some builders, myself included, have chosen to create a much larger cutout in the lower cowling and fashion a cowl flap mechanism. While not strictly necessary, the ability to open a larger exit area can help with ground cooling on hot days. You're deep in mod-country if you choose to go this route. I will include some photos of my cowl flap mod at the end of this chapter if you are interested in attempting something like this, but it is a lot more work and is not required.

Keep in mind that the slot must clear the nosegear leg fairing too, so you should temporarily install the gear leg fairing when making the slot. Of course, even the nose leg fairing requires some cutting and shaping to fit, so you may as well do that now. Vans suggests that you make a fiberglass fairing around the seam between the nose leg fairing and the lower cowling. You can do this later if you choose. As always, there are many ways to do this.

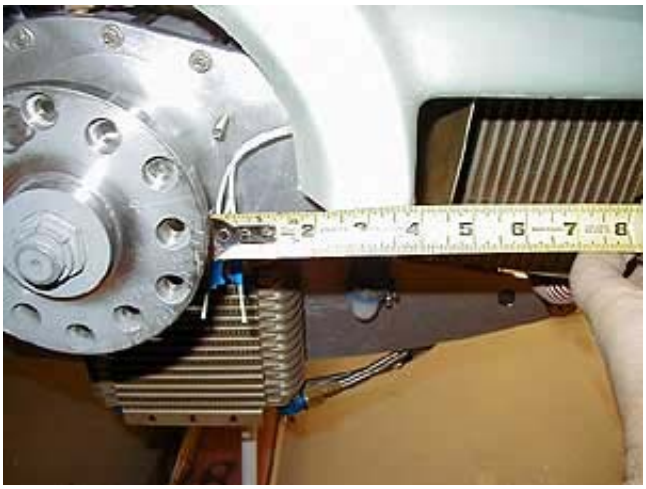
As you test-fit your lower cowling, simply let the firewall end of the cowl overhang the airframe skin for now. Do not attempt to trim it just yet. What you want at this point, is just to get the clearance of the nose gear assembly correct. The forward cowl ring should fit up against the wooden prop disk. You can prop up the rear edge of the cowl with jack-stands, boxes, paint-cans, etc. and insert a few scraps of cardboard between the front edge and wooden disk as you work to help hold the cowl in position. Keep in mind that the wooden disk represents the rear edge of the spinner, so a thickness or two of cardboard is a reasonable gap to have. Vans recommends no more than 0.25" gap, but you can do better. Just don't make the gap too little.

I had not yet installed my piano hinge material to the firewall, so I found it handy to cleco a few scraps of aluminum to the hinge rivet line to help support the cowling as shown below.

A Bungee cord hooked between the nosegear slot and somewhere on top of the motor helps to hold things up in front.

You have undoubtedly noticed by now that the front of the lower cowling does not clear the radiator shrouds. The trick here is to raise the lower cowling until it contacts the shrouds and mark where the cowling needs to be cut away to clear the metal shrouds. You have two choices here, you can cut the metal shrouds, or cut the cowling. I suggest that you cut the cowling. It is easier to work with and looks better in the end. Only cut the metal shrouds as a last resort, but you should not have to do this. Be patient and remove only as much material as you need to provide about 1/8" clearance from all radiator material. When you have a good fit, you can go back and smooth out the curves to a pleasing shape. The cuts are best made with the Dremel cutting wheel and the corners with the Dremel sanding drum. It's a dusty, itchy, messy process, so wear protective masks and gloves and try to do your cutting and sanding in a remote corner of the shop, or even outdoors. I like to have my shop-Vac running with the hose right next to my tools as I work with fiberglass so the dust is sucked up before it can spread around and make life miserable (and believe me, it CAN make life miserable).

As you get closer to a good fit, use the wooden disk to make sure you have the cowling reasonably well centered. The following photos show that the inner fiberglass ring is 2.25" from the prop flange. Make sure you maintain this centered dimension, particularly as you start to trim the cowl to firewall seam.



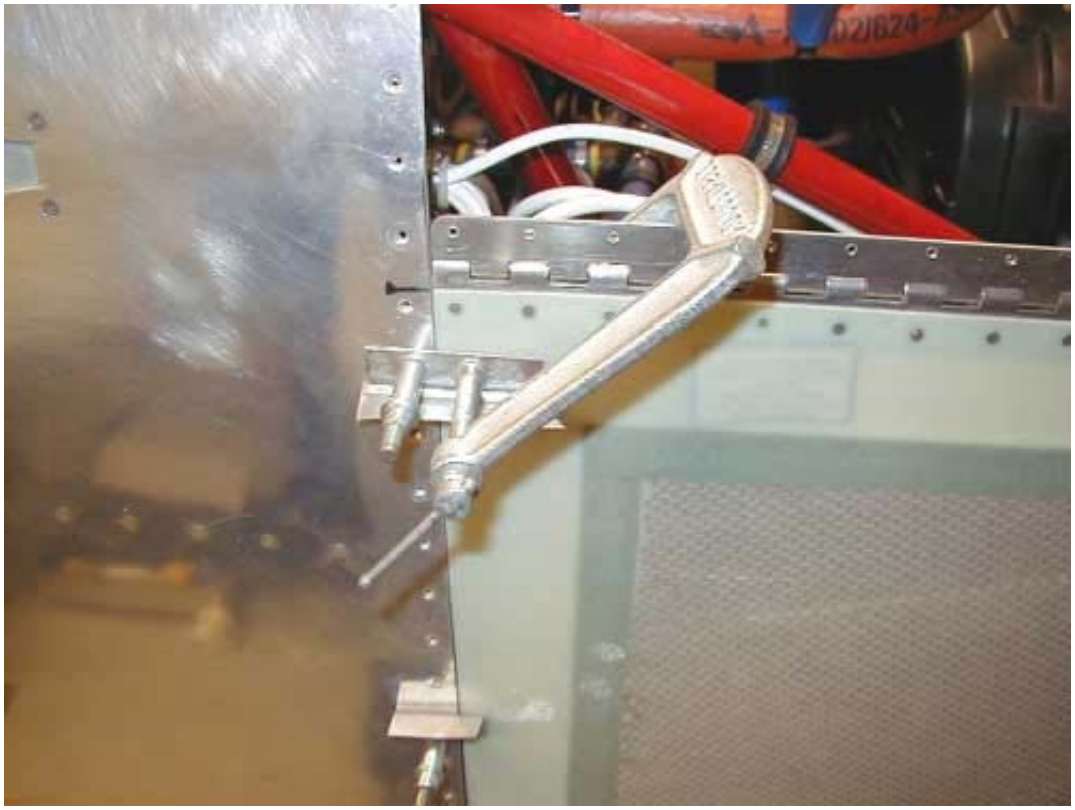
When you've got it just about perfect, you will notice that one or both of the oil cooler hose fittings may contact the bottom of the cowl. Ideally, they should just clear the cowl by about 1/16". You can locally remove ("core") a section of the honeycomb if needed to clear these fittings. I found that this was not required on my own installation. If you do core the honeycomb, lay a single layer of fiberglass mat over the cored area to reinforce it.

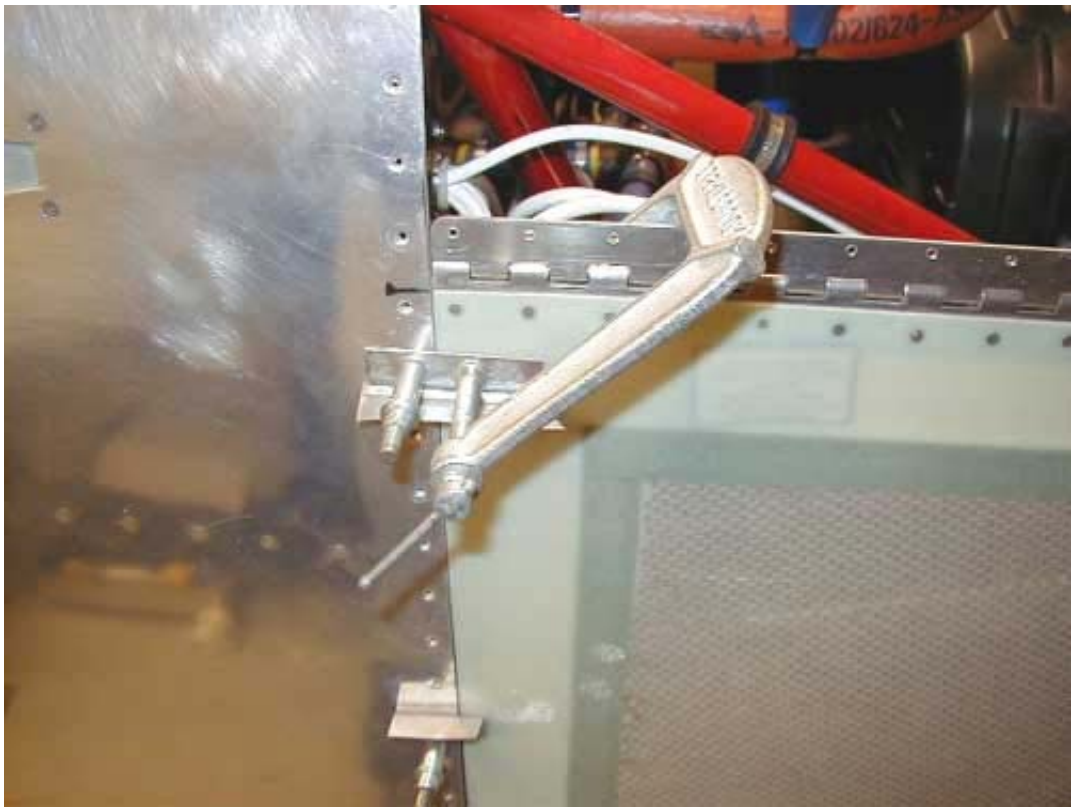
When you've got the fit as good as it's going to get, it is time to trim the firewall seam. Prop the lower cowl in position with the wooden disk installed and secure the cowling in place with Bungee cords and wedges of cardboard between the disk and cowl ring. Raise the rear edge tight against the lower skin. Place a bright shop light inside the cowling so that you can clearly see the edge of the firewall and trace where the cut needs to be with a sharp pencil. An alternative way to do this is to mark a line around the fuselage skin exactly 1" back from the firewall edge, then measure exactly 1" forward and mark the cowling. Whichever way works best for you is fine.

If you have trouble drawing a straight line, nothing beats a strip of tape. You can't tell in this photo, but there is a bright light shining through the cowling to help locate the cut line.

Once the marks have been made, remove the cowling and make your cuts with the Dremel cutting wheel. It is always best to cut just short of the mark and sand to the final fit. When sanding, use long strips of coarse sandpaper fastened to a long block of wood. It takes practice to make nice straight sanding strokes and establish a clean, straight edge. Have patience... Sand to the lines with plenty of test-fits as you go.

It is useful to clamp the seams against the firewall as you continue to fine-tune the fit.





When you're finally satisfied, clamp it into position and mark the locations of your piano hinges or fasteners. You can install all of the lower cowling fasteners now if you choose. Consult the plans or vendor documentation for these procedures.

Fitting the Upper Cowling

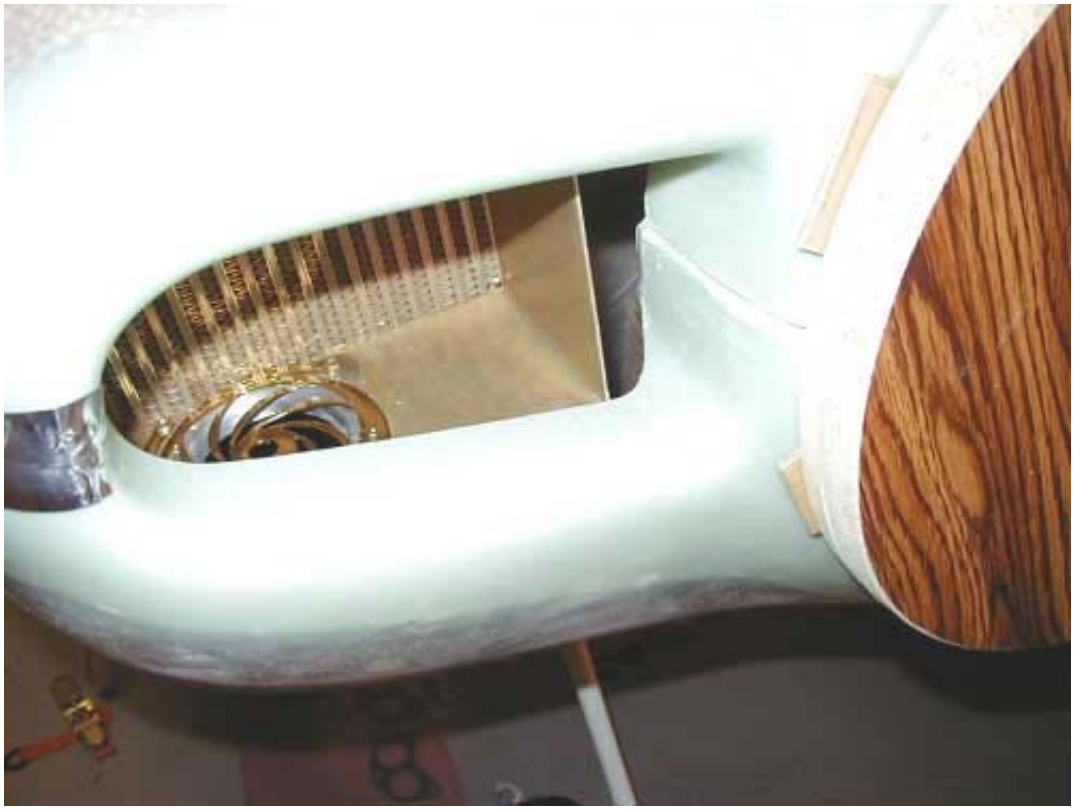
The upper cowling follows a similar process as the lower cowling, except you'll probably find it is easier to do now that you've gained experience and every stitch of clothing you own is already itchy. As before, let the rear edge of the cowling overlap the upper firewall skin while you concentrate on making the front seams fit correctly and make the cutouts around the radiator shrouds.

Here's what the rough upper cut looks like.

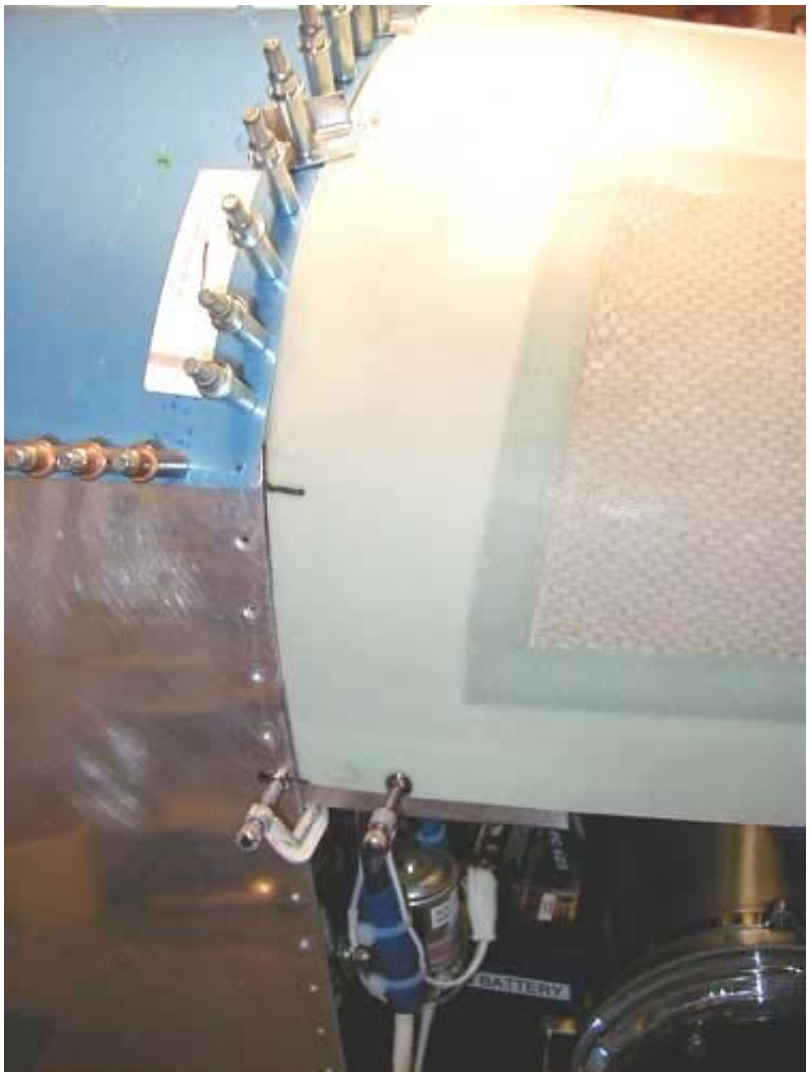
When it fits well, then go back and smooth out any curves to make it pretty. In the photo below, I continued to smooth out the upper right corner because I didn't like the look of it in this photo.

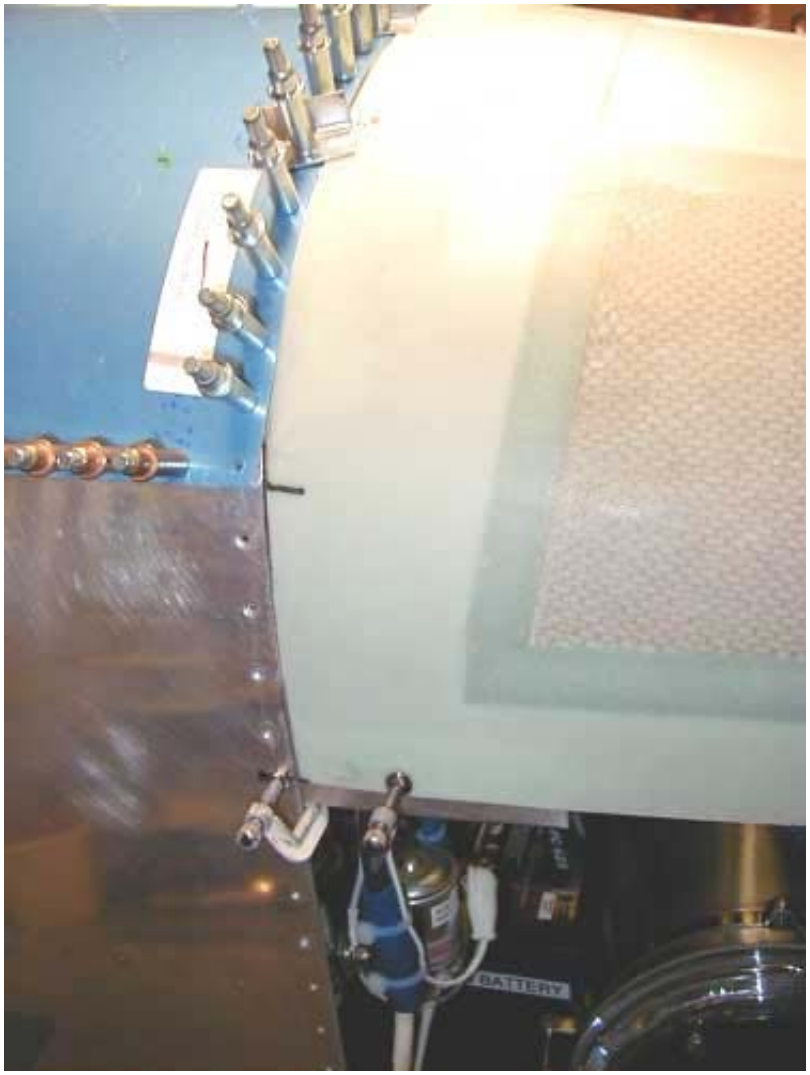
A bit-o-duct-tape works well to hold the seams together. It's a pain to peel off though.

And the final fit! Note the cardboard wedges between the prop disk and cowl ring.



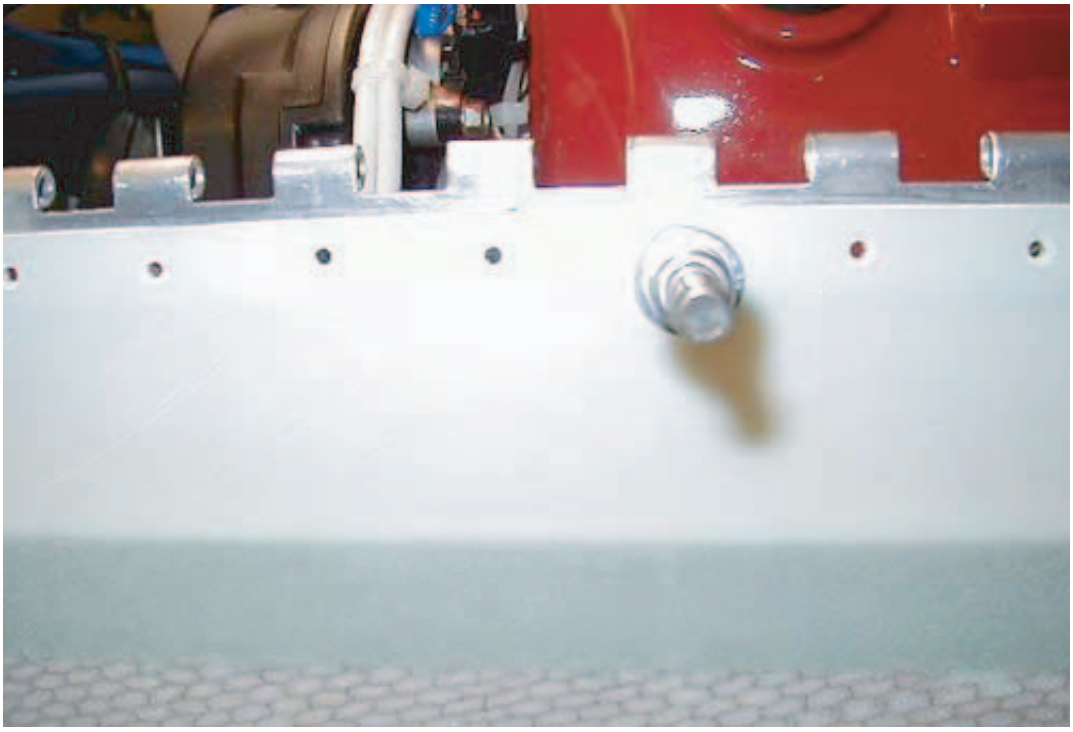
Fitting the rear seam works pretty much as it did for the lower cowling. Notice the black mark to help align it with the fuselage skin seam and the various clamps used to pull it tight. Take your time on this seam and get a good fit.



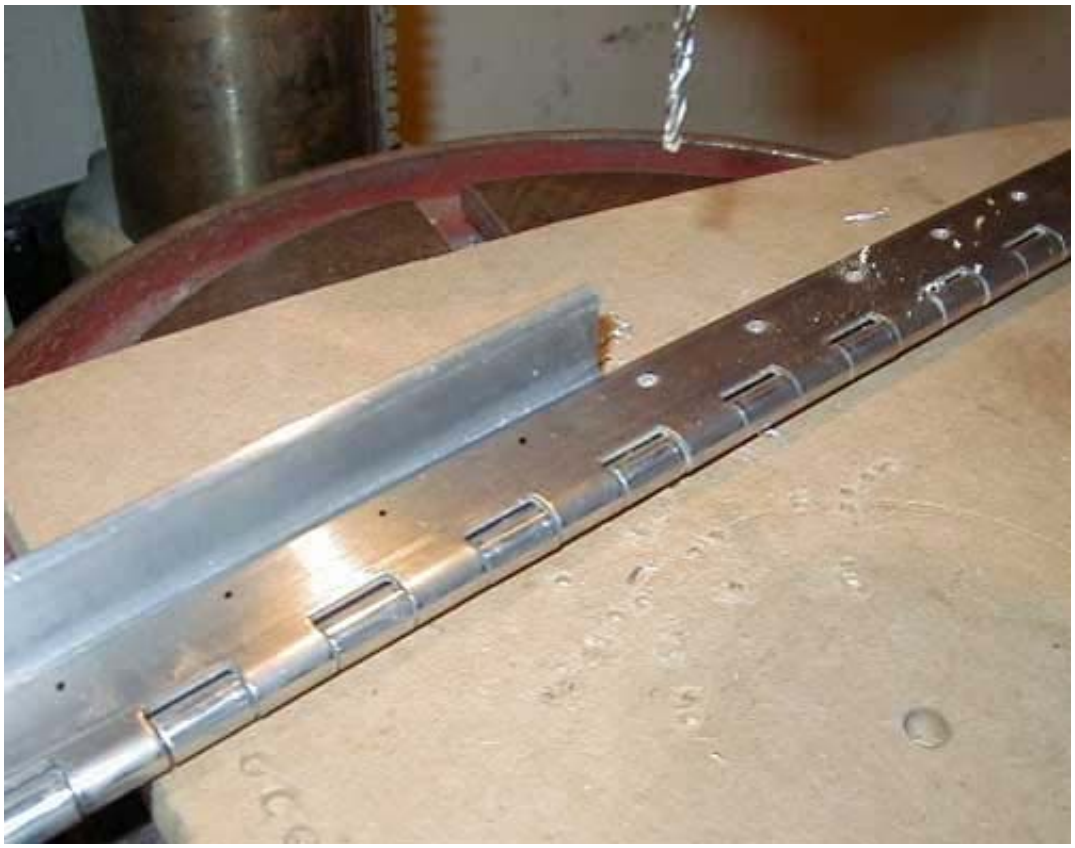


The final, and most critical cut is along the side seams. Here the top cowling is tucked inside the lower cowling and a sharp pencil is used to make the sanding line. Lots of block sanding will yield a perfect seam. Yes it can be done!

Here's a handy trick to make it look even better. Raise your hinge line just a little so that no light shows through the seam. It doesn't take much and this will help you to fit the upper cowling in place too.



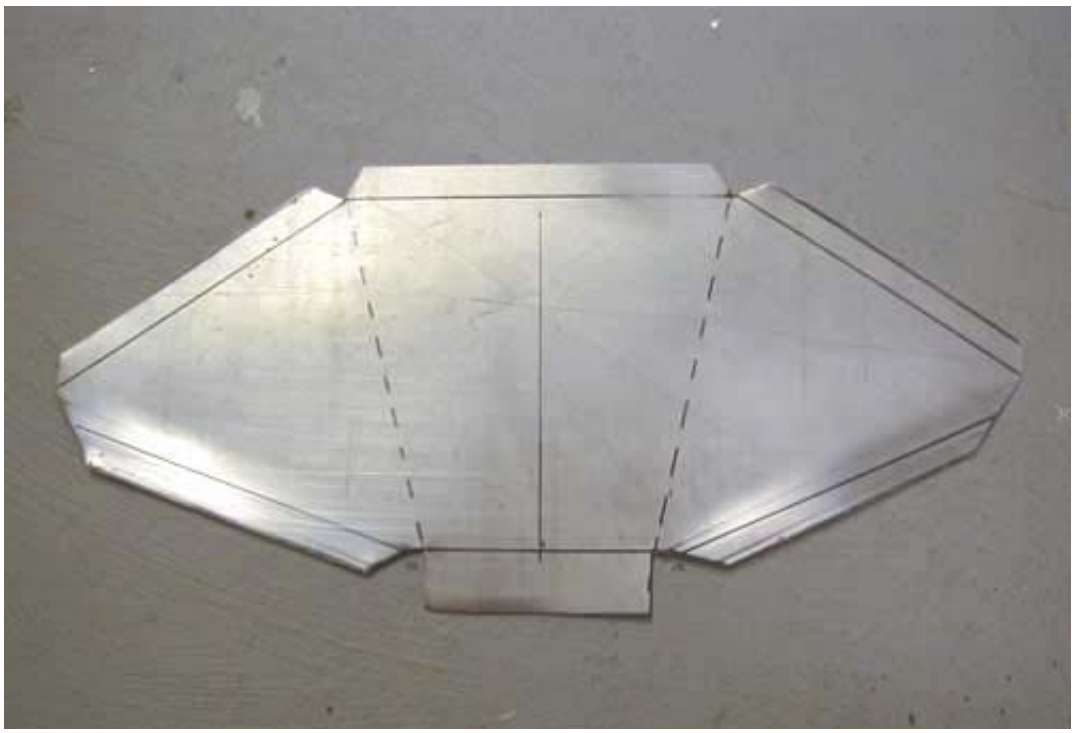
When drilling piano hinge, it is helpful to drill through both sides at the same time so the holes come out perfectly aligned. Note the piece of angle used to help hold the hinge plates parallel during drilling.



Back on the cowling, clamp the hinge plates to the outside of the cowling, using it as a drill guide, then remove it, countersink the fiberglass, and rivet it to the inside. Install the other half of the hinge using the full sized pin material, and drill a couple alignment rivet holes using the shop light behind trick to locate the holes. Drill and rivet the rest of them and your final seam should be tight and straight. We'll leave it to your own creativity to determine how to best terminate the hinge pins. Vans has a couple good suggestions, but builders have come up with plenty of alternatives.

Oil Cooler Scoop

Some of the earlier motors came with a small fiberglass oil cooler shroud with the idea of fiberglassing it into the lower cowling. Personally, I don't want to do any more fiberglass work than necessary, so I chose to fabricate a metal oil cooler shroud out of 0.025" aluminum. Rumor has it that the newer motors come with a metal shroud *strikingly similar* to this one. Anyway, the message here is that your motor may differ from what is shown here, but you will get the general idea. Here is how I fabricated my own metal shroud.



After cutting, bending, smoothing, and drilling, I made a lower attach bracket out of a piece of 0.5" angle and riveted it to the sides of the shroud. This gives me six points of attachment as well as forming a nice beveled intake.

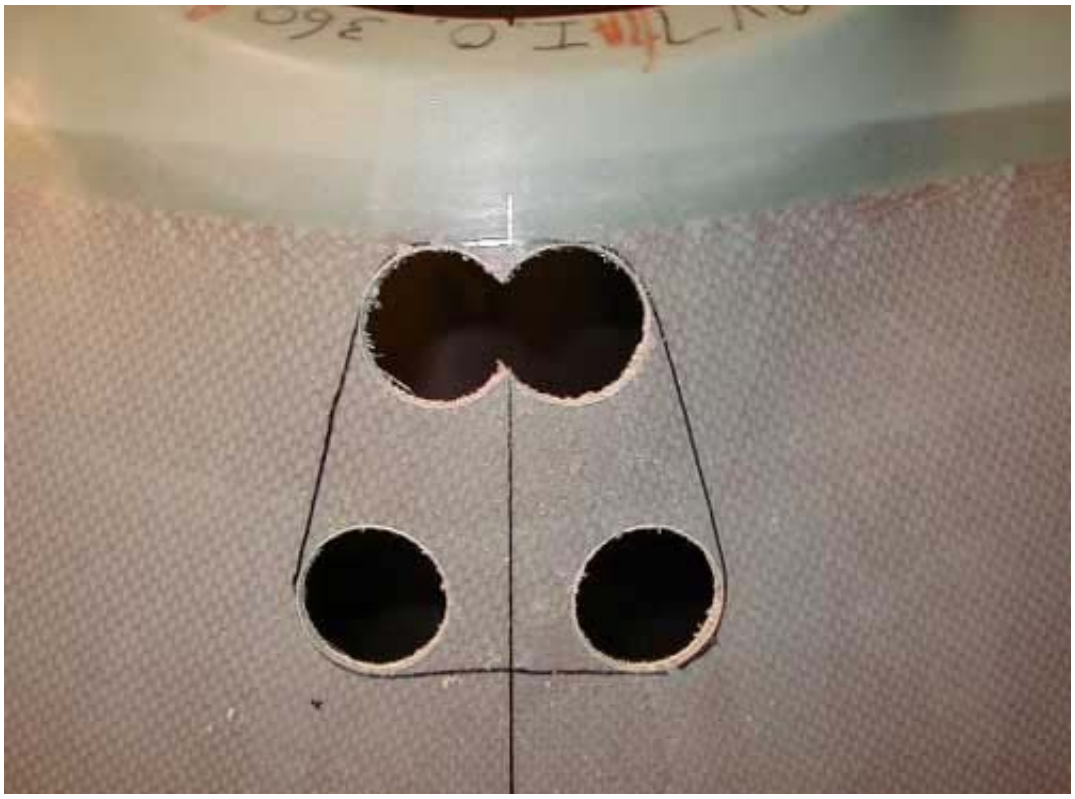
If you look closely at the photo below, you will see how I bent the lower attach angle downward so that it forms a better scoop lip and also hides the attach bolts. You'll see this again in later photos.

Oil Cooler Cutout

...and you thought you were done with fiberglass work! Not so fast Superman, we've still got to cut a hole for the oil cooler inlet.

First, install the lower cowling without installing the upper cowling or wooden prop disk jig. Peek inside and see how the cowling mates with the oil cooler scoop. Draw lines inside the cowling to mark where the cutout needs to be. You have some room for creativity here, just be sure not to make the hole bigger than the scoop! Some folks like triangles, I chose to do a semi-rounded trapezoidal thing.

Transfer your markings to the exterior if you like. In order to achieve nice round corners, I started the cut with a 1" hole saw. You are sawing through two paper-thin layers of fiberglass with a cardboard-like honeycomb interior core. Go easy!



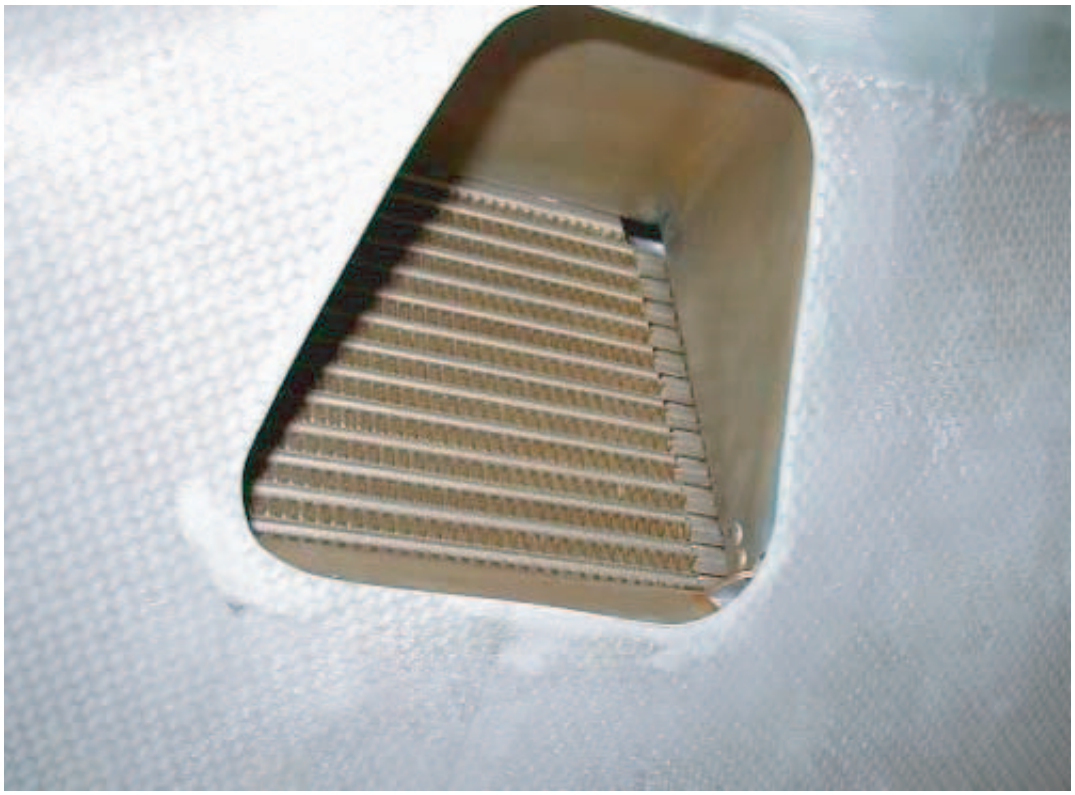
Once you've got the corners done, rough out the opening with a hacksaw blade or jig saw. It is nice to cut this opening on an angle that will follow the angle of airflow.

Now sand the edges smooth with your Dremel and a sanding drum bit. Notice how I am angling the bottom edge for a more pleasing appearance. Sand it, then sand some more.

Obviously we need to do something about the honeycomb material and the now ragged edge. The best way to deal with this is to undercut the honeycomb layer with your Dremel and a cutting wheel. Be very careful not to cut into the thin fiberglass layers. The goal here is to slice away the honeycomb only so that you can pack the edges with filler.

I apologize for not getting photos of the filling process, but the general idea is to mix up a small batch of Super PolyFill or a combination of Epoxy Resin and Flox or Micro-Balloons and pack it into the edges with a popsicle stick. Pack it in there good and smooth off the edges. Once it sets up, do some finish sanding with various grits of paper until you end up with a clean edge.

Below is a shot of my final inlet cutout and oil cooler shroud. Not seen in this photo (by design) is a piece of 1/4" foam used to seal and cushion the scoop-to-cowling seam. The seal is glued to the cowling with Automotive Goop (good gooey stuff). To finish off the inside of the cowling, I chose to spray VHT 1500-degree paint.



Cowl Ventilation

OK, so you're feeling pretty good about your fiberglass skills now, right? Well here's another chance to show off your creativity. The upper cowling will need to have some form of ventilation to let engine heat escape when the aircraft is parked. Liquid cooled motors will tend to get slightly hotter immediately after shutdown because of the loss of coolant flow. Adding upper cowl ventilation will help to preserve the fiberglass and lower the risk of engine overheating. Every automobile has these. So must your airplane.

You come to a fork in the road Grasshopper...

If you take the expeditious path, you will create ten holes along the upper rear cowling where it is a single fiberglass piece, using a 0.75" UniBit drill. (Just below the red line in the photo). The UniBit cuts a nice clean hole which doesn't look too bad and let's the heat straight out. If you like, you can add a drip rail inside the engine compartment to channel rain water to the sides. Investment $0, Time 10 minutes.

If the artist in you is lured down the creative path, the goal is simple. Cut holes. Let heat out. Make it pretty. I particularly like the side louvers on the BMW Z3. You could fabricate a set of these in fiberglass or sheet metal. On my own bird, I used a series of Marine stainless steel deck pass-through fittings bonded into the honeycomb with

SuperFill and fiberglass tape. It struck me after shooting a coat of gray primer/surfacer how shark-like this mod looks. My wife has commented about how fish-like the plane looked even before this. I like it, but it consumed several days of work, versus ten minutes if you go the easy path. Note that these vents are high on the sides of the cowl. Rain is unlikely to be a problem here and they are close enough to the top to let heat out, and even pick up a crosswind. If you overheated or sprung a cooling leak, you would see the steam escaping but it wouldn't cloud the windshield. That's my hypothesis anyway. Investment $25, Time 3 days.

Cowl Flap Mod (optional)

Finally, as promised, here are a couple of photos of my cowl flap mod. This is NOT required. I chose to do this for no particular reason. I can tell you it was a lot of work for questionable return. Instead of cutting the usual nosegear slot in the lower cowling, I removed a large portion of the cowling, using the piece I removed as the cowl flap scoop.

To this piece, I riveted a couple short hinge sections along the front edge. Note how my nose leg fairing cutout now starts at the front of the cowl flap instead of coming in from the rear of the cowling. To fit the leg fairing well, it had to taper to a point in the rear. On the inside I have riveted a small reinforcement plate around the slot. To remove the lower cowling, I pull the short hinge pin and drop the cowl flap away first. Then the main cowling drops down with no clearance problems.

Along the sides, I have roll-formed and riveted 0.015 stainless steel plates. These follow the curvature of the cowl flap and have 90-degree tabs at the top to limit the travel of the cowl flap. When in position, these plates ride firmly against the inside of the lower cowling cutout. When closed you don't see them at all. I am using a short cable to operate the flap. In the closed position, the stainless sides come very close to the exhaust pipe (which is why I made them stainless). I will leave these side plates unpainted.

Whether or not this is a useful mod is open for debate. It looks cool, but adds weight, complexity, and a lot of time to the process. It is likely to have some positive effect on ground cooling, and who knows, it may even have some speed-brake effect if I deploy it in flight!

By the way, rinsing your skin with ice-cold water without soap or scrubbing action will help to dislodge fiberglass dust. The cold water closes your pores. Follow this with a normal soapy washing. Remove and wash the bottoms of your shoes before entering the house. Also, be kind to your pets and don't let them walk around on floors covered with fiberglass dust. Most importantly, be sure to do your laundry in a separate load with a second rinse cycle to be certain the dust is gone before your wife washes her pajamas in the next load. Trust me....

A final touch is the addition of a push-pull cable and bellcrank mechanism to raise and lower the cowl flap. The 1" short connector link between the bellcrank and cowl flap is an over-center mechanism. When you fully open the cowl flap, this short link goes over-center and locks the flap in the down position. The bellcrank axle is attached to the engine mount with a pair of Adel clamps. Functionally solid, but able to absorb vibration too.

Chapter 8 - Engine Startup Procedures

Lighting the Fuse!

One of the great milestones in the process of building an airplane is firing up the motor for the first time. Unless you suffered from kid-in-a-candy-shop syndrome and started your motor while still on the shipping crate, this will be the first time you've heard your e-motor sing. Even if you did have a sneak preview, it is still rewarding to see the motor run in it's proper environment. Here we go!

Prop Prep

It is NOT necessary, or desirable, to have your prop installed during the first run. Having the prop installed just creates further safety hazards and a lot of noise and wind that you don't need right now. It does no harm to run the motor with only the PSRU (gearbox) load as long as your keep the RPM within a reasonable limit.

Cowling Prep

It is NOT necessary, or desirable, to have your cowling installed during the first run. You want to be able to look over the motor as it is running to identify any leaks, rattles, sources of smoke, etc.

Fuel Supply

It is NOT necessary to have your wings installed yet. You can simply choose one side of the aircraft and slip short sections of 3/8 and 5/16 fuel line over the supply and return stub lines respectively, and insert them both into a portable gas can.

- Run 87 octane automotive fuel if normally aspirated.
- Run 93 octane automotive fuel if supercharged.
- Use TCP additive if running 100LL avgas.

Set the can on a short stool or step ladder to minimize the height which the fuel pumps must draw fuel from.

If you do have the wings installed, add enough fuel to each tank to allow you to fully test the fuel selection functions. Even if you use the gas can method, it is good to switch sides at some point in order to verify proper operation and flush out any debris which may have accumulated in the lines and valves.

A shocking number of homebuilts suffer from early motor stoppage due to debris in the fuel lines and other needless errors which could easily be avoided through proper testing. Don't let this happen to you! Make sure you have fully tested and flushed out all fuel supply components.

Fuel Pump Auto-Failover Function

For the first test run, we are not concerned with validating the Auto-Failover function of the fuel system. Therefore, it is NOT necessary to have adjusted your MANDATORY failover pressure switch. We will return to this before our second test run.

First Test Run Duration & Location

Your first test run should be limited to no more than one minute. Without the big fan up front, there will not be enough cooling airflow for the motor, so you do not want to cause an overtemp condition. After the first test run, we will take steps to allow the motor to run for longer periods, but not now.

Except for the grin and adrenaline rush, your first test run should be no more eventful than starting a car. Still, it is a good idea to make your initial run outdoors rather than inside a garage or hangar, just in case Murphy chooses to participate. It is always a good idea to have a fire extinguisher on hand. Also, the motor can be expected to produce some smoke as a small amount of oil may be present in the exhaust ports from shipping.

Don't rush the experience. Take your time and make sure all of your systems are fully installed and properly tested. The following checklist should help you determine when the time is right for lighting the fuse.

Pre Test 1 Checklist - Final Exam!

[ ] Completed fuel system installation per Chapter 5.
[ ] Completed electrical system installation per Chapter 6
[ ] Installed both batteries, making sure they have a good charge and all cables are tight.
[ ] Completed the checklist at the end of Chapter 6, corrected any defects and re-checked as needed.
[ ] Checked all fuel line fittings (supply, return, and vent).
[ ] Checked all coolant hose clamps.
[ ] Checked for smooth operation of fuel selector valve.
[ ] Checked the gascolator drain valve. Is it installed? Tight? Does it work?
[ ] Checked for smooth operation of throttle and throttle cable. If it's dangling, secure it. Pull out for start and idle.
[ ] Checked exhaust header and optional muffler for proper installation and clearance.
[ ] Checked the O2 sensor harness to be sure it has been connected at the header pipe.
[ ] Checked crankcase breather vent tube to be sure it is not rubbing against the hot header pipes.
[ ] Added and verified proper amount of Mobil-1 synthetic 5w/50w oil.
[ ] Added and verified 20 oz. of Mobil-1 synthetic gear oil in PSRU.
[ ] Added and verified proper amount of ORANGE, Long Life anti-freeze mixed 50/50 with distilled water.
[ ] Visually checked all engine wiring and sensors to be sure everything is installed and hooked up.
[ ] Can't think of any other reason why I should not fire this baby up!

Coolant Check

Your coolant level will naturally drop after the motor is run for a few seconds, and more later on as the motor is run up to full temperature. This is an expected side-effect of purging air from the various cooling and heater passages. Just keep an eye on it so the level remains at or slightly above the center line of the swirl pot. Make sure the cap it tight. If you installed the optional coolant loss sensor circuit, it would be good to test it before adding coolant. The indicator/s should be on when the swirl pot is empty, and should go off shortly after you start adding coolant. If you've included an audible warning mechanism and "silence" switch, make sure they work as expected.

Lubrication Check

Your oil level may drop slightly after the motor is run for a few seconds. The motors were all run at the factory, but some oil may have drained from passages and the filter during shipping. As these passages fill up again, you may need to top off the oil level.

Engine Monitoring

During the first test run, we will not be running long enough for the motor to fully warm up. Monitoring temperatures and pressures is always useful, but not strictly required for the initial short duration run. Thus, if your EFIS or EIS is not fully calibrated yet or you are not familiar with them, don't get hung up on playing with them. It is better to pay attention to the motor itself during the first test run. Look and listen for unusual noises, leaks, or sources of smoke. You don't need electronics to tell you when something is seriously wrong. The goal of the first test run is to detect seriously wrong things.

Priming the Pumps

The very first time you add fuel to your system, it is quite possible that your fuel pumps will not prime without some help. This is because the impeller vanes inside the pumps are completely dry and there is likely to be a whole lot of trapped air pressure in the system.

To get the juices flowing, do the following steps as needed.

1) Get the fuel lines ready to go. If using a gas can, insert both the supply and return lines into the gas can and raise the can to approx where the wing tanks would be. If using the wing tanks, make sure you've got enough fuel in each tank to cover the pick-up tubes. Drain any water that may be in the wing tank sumps.

2) Select the correct tank source with your Fuel Select Valve.

3) We need to get fuel into the low-pressure side of the fuel system. This may happen on its own when the pumps are run, or your may need to give things a little boost. A simple way to do this is to remove and fill the gascolator cup with a small amount of fuel. Alterntaively, you can open the gascolator drain valve and squirt some fuel into the lines until it flows from the drain. One way to do this is to raise the gas can and start a siphon flowing with a squeeze bulb or apply a VERY SLIGHT (i.e. one quick puff) amount of positive pressure to the can with an air hose. Be safe please!

4) Once you have fuel in the primary lines, briefly turn on your Main Fuel Pump. If it still does not prime, as should be obvious by the sound of the

pump, lack of fuel returning from the return line to the gas can, or how about that big red LOW FUEL PRESSURE warning lamp staring at you, then you probably have a large amount of air pressure in the fuel rails preventing the prime. To resolve this, simply remove a hose from the fuel filter or fuel rail supply line (not the return side) and let the pressure out. You can stick the hose into a bottle and run the pump for a moment to see that fuel is emerging. Be careful whenever opening an EFI fuel line, there is a lot of retained pressure. Protect your eyes and just tap the switch briefly. Reconnect and tighten the lines.

5) If you still have no fuel pressure, double-check the polarity of your fuel pump wiring, and contact us for assistance. Obviously, if you don't even hear the pumps running, check your fuses and breakers.

Critical Switch Functions & Sequences

Familiarize yourself with the location and operation of the critical switches. These include the EXP Master, Bus Master, Pump Select, Start, IGN, and Fuel Pump switches. You might be surprised at how many people, myself included, are so startled by the first run that they momentarily forget how to shut the darn thing down! Below is a quick refresher.

STARTUP SWITCH SEQUENCE

1) Pull throttle OUT to IDLE
2) All breakers IN
3) BUS MASTER to NORMAL (up) (Use a switch-guard or pull-out detent on this switch)
4) PUMP SELECT to MAIN (up)
5) EXP MASTER to ON (up)
6) EXP FUEL PUMP to ON (up) - Pump/s should be running
7) EXP IGN to ON (up) - ECM Caution Light should be lit
8) START (up then release) - ECM Caution Light should go out when motor starts
9) EXP ALT to ON (up) - Get those batteries charging!

SHUTDOWN SWITCH SEQUENCE

1) Pull throttle OUT to IDLE
2) EXP IGN to OFF (down) - Motor stops
3) EXP FUEL PUMP to OFF (down) - Pumps Stop
4) EXP ALT to OFF (down)
5) EXP MASTER to OFF (down)
6) BUS MASTER to OFF (center)

EMERGENCY SHUTDOWN SWITCH SEQUENCE

1) BUS MASTER to OFF (center) - Everything stops right now!

The BUS MASTER switch will stop the motor immediately. Throwing the EXP MASTER switch or the EXP IGN or EXP FUEL PUMP switches will not always stop the motor because, depending on your BUS MASTER and PUMP SELECT switch positions, this may be seen as an EXP failure and your smart electrical system may fall back on one of its redundant modes. Thus, try to commit to memory that you want to STOP ALL ELECTRICITY to stop the motor. The BUS MASTER switch will always accomplish this in a single throw.

First Test Run

Two sets of eyes are better than one. Have somebody watching up front while you work the controls. Let them man the fire extinguisher so they feel important. Make sure you clear the area around the exhaust from anything that would blow around. Expect a few moments of pretty sky-blue smoke as the oils burn off the exhaust ports (this is another good reason for doing your initial run outdoors).

Did you forget anything? Witness? Camera? Champagne? etc... Let's rock!

1) All breakers in.

2) Throttle pulled OUT to IDLE.

3) BUS MASTER to NORMAL (up)

4) PUMP SELECT to MAIN (up)

5) EXP MASTER to ON (up) - Low Fuel Pressure light is ON

6) EXP FUEL PUMP to ON (up) - Main Pump should be running, Low Fuel Pressure light is OFF

7) EXP IGN to ON (up) - ECM Caution/Fault/Check-Engine Light should be ON

8) Open the throttle slightly. You may need to open it a little more during cranking, but get ready to close it when the motors starts. You may be startled by the sound.

9) Yell "CLEAR PROP" or perhaps,,, "CLEAR PSRU"

10) START (up then release) - ECM Caution Light should go OFF when motor starts

11) EXP ALT to ON (up) - Get those batteries charging!

12) Work the throttle slightly until the motor runs smoothly and is able to maintain a nice idle. Do not over-rev the motor! It will rev up very fast without the prop installed and you can easily red line it. Avoid this.

13) Observe and listen for abnormal sights or sounds.

14) Record any indicated values for engine pressures, temperatures, and fuel flow.

15) Run the motor for no more than one minute.

16) SHUTDOWN. Turn the BUS MASTER OFF, or follow the SHUTDOWN CHECKLIST. Don't be so wrapped up in grinning that you forget to turn things off (like I did).

17) Mark the time and date in your engine logbook.

Congratulations!

Post Test Run 1 Checks

[ ] Check all fuel fittings and lines for signs of leaks, remedy any problems.
[ ] Check around the header pipes for any signs of heat damage, remedy any problems.
[ ] Check all coolant lines for signs of leaks, remedy any problems.
[ ] Top off the coolant level if necessary.
[ ] Check and top off the oil level if necessary.

Calibrating the Auto-Failover Pressure Switch

The auto-failover pressure switch is no longer user-settable and does not need to be calibrated. It is factory preset to engage the AUX PUMP whenever fuel pressure drops below 28psi. If your engine has a user-adjustible switch, contact the factory for a replacement.

Second Test Run

For your second run, we want to run the motor a little bit longer. We are confident now that there are no serious problems to resolve, so we can turn more attention to testing other fuel and ignition system functions. Because we are going to run longer, we need to have monitoring capability for the coolant temperature. Familiarlize yourself with whatever monitoring system you are using. It normally takes the motor about five minutes to reach full operating temperature. If you would like to run longer than this, you will need to install some sort of supplementary cooling fans in front of each radiator. This is how we test our motors at the factory. As an alternative, you can now install your cowling and prop.

For this next run, we want to test the ignition modes and fuel pump modes. This includes the following:

1) Ability to run in OVERRIDE mode, bypassing the EXP.
2) Ability to run from the AUX Fuel Pump.
3) Ability to auto-failover between MAIN and AUX Fuel Pumps
4) Verify alternator output
5) Since we are running longer, we want to monitor coolant temperature and optionally test the heater.

Prep the motor for your next run as before.

WATCH THE DURATION. The motor will reach full operating temperature in about five minutes, so keep the run shorter than this, or use supplementary cooling fans (or the prop and cowling) to keep things cool.

We will need to disable the Main Fuel Pump at one point in the following test, so make sure you have access to the Main Fuel Pump Fuse before starting.

1) Start the motor using your, now memorized, startup procedures.
2) Turn ON your heater control valve, but leave the blower fan OFF for now.

3) Turn on the EXP ALT switch and verify that the batteries are charging. This can be verified using the optional enumciator panel from ControlVision if installed, or by monitoring the bus voltage and looking for an increase to 13.8 volts or better when the alternator is ON.
4) With the motor idling, lower the BUS MASTER switch to the OVERRIDE position and verify that the motor continues to run. Note: Move the switch quickly so you don't linger in the center OFF position.
5) Raise the BUS MASTER switch quickly to the NORMAL position and verify that it continues to run.
6) Lower the PUMP SELECT switch to the AUX Pump position and verify that it continues to run.
7) Center the PUMP SELECT switch to the AUTO position and verify that it continues to run.
8) Quickly pull the Main Fuel Pump fuse and verify that the AUX PUMP and indicator lamp come on and the motor continues to run. DO NOT REPLACE THE FUSE UNTIL THE SYSTEM HAS BEEN SHUT DOWN.
9) Continue to run the motor while monitoring the steady rise in coolant temperature. At approx 190 degrees, the thermostat will open and the temperature will drop a few degrees before starting to rise again.
10) Turn on the heater fan briefly to verify that good heat is being produced.
11) Record any indicated pressures, temperatures, and flow rates.
12) Shutdown the engine and systems before reaching a high temperature (195 degrees max for this run). If you are running with the prop installed or supplementary cooling fans, you should be able to continue the run as long as you like, just keep an eye on the coolant temp.

Post Second Test Run Checks

[ ] Check coolant level and top off as needed.
[ ] Remedy any other problems observed during the run.
[ ] Make engine logbook entry.

Third and Subsequent Test Runs

Further testing should be done with the prop and cowling installed. It is OK to perform other short duration test runs as above, but the next goal will be to verify proper operation under loads and higher RPMs. This is best done on a suitable airport ramp in a plane that is ready to fly.

The goals of the next tests should include:

1) Full static run-up
2) Prop pitch variations during run-up
4) Smoothness during throttle increases and decreases
5) Idle settings
6) Operation for greater than five minutes at full takeoff power.
7) OPTIONAL - Operation at takeoff attitude.

Test goals number 6 and 7 deserve a little more discussion.

"Operation for greater than five minutes at full takeoff power"

This test will verify that the ECM is performing correctly at higher RPM's than typically used in an automobile installation. The factory ECM employs some programming that is capable of automatic power reduction in the event of a stuck throttle or rollover condition. This capability has been disabled in your powerplant, but this test will validate this point. It will also help to shake out any fuel flow issues or loose parts.

"Operation at takeoff attitude"

This OPTIONAL test involves running the motor with a pilot onboard, the main wheels chocked, brakes fully applied, and the nose of the plane tilted at an angle which simulates takeoff attitude. This can be done by minimizing prop pitch (or better yet, without a prop installed) and either lowering the tail to the ground (a couple of heavy volunteers will do the job) or placing a stand under the nose wheel. Because of the precarious nature of this test, we consider it to be an optional test performed at the builders discretion. The idea is to identify any fuel delivery problems that may arrise at high angles of flight (i.e. during your first takeoff). This test has been recommended by prior builders as a wayt to identify problems with fuel tanks, pickup tubes, trapped air pockets, etc. which would otherwise not be reproducible until actual first flight. Although it seems like an extreme test, finding this type of problem on the ground is far better than during takeoff and these things do indeed occur with some frequency (albiet small) among homebuilt aircraft. A reasonable alternative would be to limit your climb angle during your first flight until you have sufficient altitude and good position for a safe landing, then performing some steep climbs and turns. Discuss this with your EAA Flight Advisor.

Before First Flight

During your first flight, you should not have to worry about your engine; you've got other things on your mind. If you have done a good job with your installation and testing, you will be free to focus on flight characteristics. Before your first flight, we ask that you do the following:

1) Drain and replace your engine oil and oil filter.
2) Remove and clean any screens in your gascolator and fuel system components, flushing the tanks is good too.
3) Replace your fuel filter (be careful, the fuel line retains pressure, open and bleed off the pressure slowly, protect your eyes).

These three steps will assure that no debris has entered your fuel and oil systems which might ruin your day. The cost of oil and filters is trivial and worth the investment.

If at any point during your installation, test process, or subsequent use, you have problems or questions which we could help with, please feel free to check in with our factory and newsgroup.

Thanks again for purchasing an Eggenfellner Powerplant and congratulations on your successful installation and test!

Happy flying!