AM13 AND AM15 ENGINE INSTALLATION MANUAL

This engine installation manual covers the AM13u (upright) AM15u (upright) AM13h (low profile) and AM15h (low profile). Please make sure to follow the relevant parts for your version.

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ABOUT

The AM family of engines are based on the well proven Suzuki G series automotive, light truck, marine and outboard base engines. These engines are aluminum block and head with single overhead cam and 16 valves. Fuel and ignition are controlled by an open source port fuel injection system.

YOUR INSTALLATION

The AM engines are some of the simplest engines to install and maintain but you still need to do this correctly or you will have problems and possible engine failure. This is YOUR installation and both the life of the engine and your life depend on it. Not all required information needed for a safe and successful installation can be or is included in this manual. You need skills and knowledge to install this or any other engine. What works best for one engine may not be best or even workable for another.

There are many resources available to help including but not limited to the EAA, the FAA, APs, IAs, books, ACs etc. As a general guide you should study AC 90-89B (https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_90-89B.pdf).

Each airframe is different and can have additional requirements. In general, the information presented here is the minimum for a successful installation for normal use and in average climates.

In addition to the items discussed in this document, there are many opportunities to compromise the safety and reliability of your EAB aircraft, either through poor practice or bad choice of materials or components. I've given a few examples from my own experience in this document. Given the one-off nature of this project, and essentially every homebuilt airplane project, the procedures I implemented and the materials and components I recommend may not be correct for your airplane.

Specific information for installation in the RV-12 is available on our website. This is also a great reference for all builders and should be considered mandatory reading.

WARNING LABELS

The following warning labels come attached to the engine and must be observed:

The Maximum Permitted Propeller Flange Moment of Inertia is 6000 kgcm2 (2050 lb.in2). Use of propellers and other prop flange mounted accessories over this limit can result in total engine and/or gearbox failure and voids the warrantee.

ADD OIL to engine and gearbox before starting engine. Failure to do so will result in total engine and/or gearbox failure.

Only Use "Metric" BSP Fittings! The use of NPT fittings will cause a sliver if metal to be pushed into the oil galley causing catastrophic engine failure.

GENERAL

While a liquid-cooled engine runs a lot cooler than an air-cooled engine the exhaust is still just as hot. All of the nyloc nuts we use on the engine are in areas that they are not subjected to temperatures over their ratings. In mounting and also in general in the engine compartment you can also use nyloc nuts if your DAR finds it acceptable and it is not near (within 3 inches the exhaust system. Metal to metal lock nuts are also acceptable. Any nuts or bolts exposed to twisting need to have positive locking (safety wire, cotter pin or similar) and this is also acceptable for all others.

Depending on the airflow in your specific installation you may need to add heat shielding and ventilation for heat sensitive components. For example, you may need to add a heat shield to protect the rubber engine mounts, oil filter, oil senders, etc. from the exhaust. You may need to add a cooling blast tube to the alternator, fuel rail, coil packs, etc. Heat shielding requirements vary greatly from one installation to another but you can rarely have too much in any installation. In general, open installations need very little if any and tightly cowled engines need more.

We highly recommend adding some heat shield and sound insulation to the firewall. It is also a good idea to coat the inside of the cowling and engine side of the firewall with intumescent paint.

MOUNTING

The engine mount must be a sufficient strength. For Part-23 aircraft the FAA requires the mount is sufficient for 9G loading in all directions and we use this loading when we design our mounts. On the upright version we use a propitiatory bed mount but use Lycoming style rubber dampers. On the low-profile versions, we use the same spacing and locations of the mounting ears relative to the prop center line as Lycoming straight mount. The rubber dampers in all cases are the same as used by a Lycoming O-320 straight (conical) mount. Our part number for these is EM1-004. The Lycoming part number is 71032. Please refer to Lycoming installation instructions for these rubber bushings. The torque of the engine mount bolt using these rubber bushings is 40 in-lbs or alternately you can use a squish distance of 1.84". Make sure the rubber bushings are properly seated. A large area thick washer must be used against the rubber bushing under the end of the bolt. When we supply this washer, it is aluminum. A washer is not needed against the engine mount itself but can be used to shim the engine to the correct location and angle. The threads of the bolt cannot be against the rubber bushings or the bushings will experience rapid wear. Since our engines are lighter than the Lycomings that use this mount you can use 3/8" bolts and an aluminum sleeve (bushing) with 3/8" ID and ½" OD. We offer the required rubber bushings, aluminum bushings, bolts, washers and other parts. Washers can be used to adjust the engine alinement. The length of the mounting bolts required for you installation can/will be different.

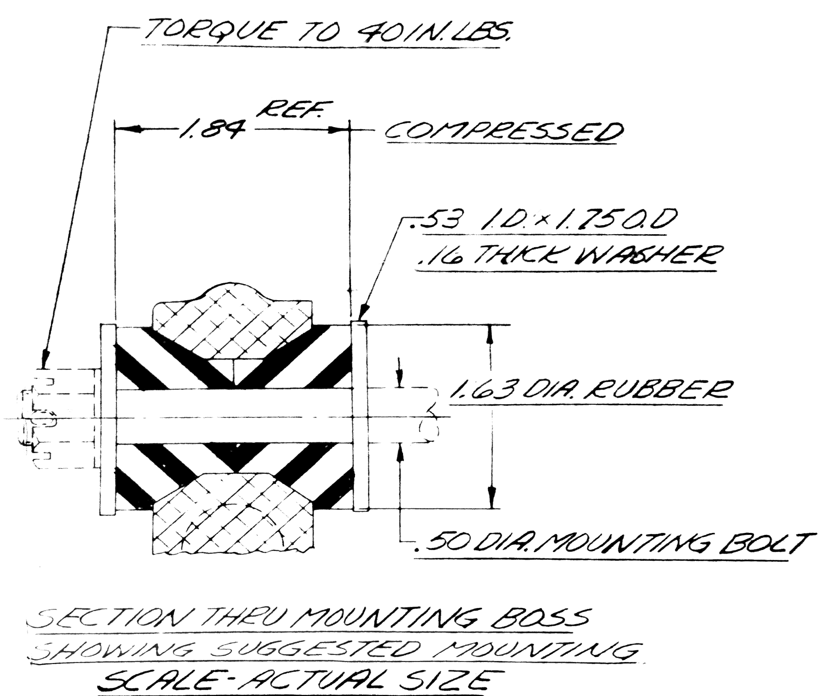

Figure 1 Vibration Isolator Installation

Figure 2 Rubber Bushings and Hardware

Different aircraft require different mounts. We produce mounts for some aircraft but for others you will need to build your own or use existing mounts. Our low-profile engines not only use the Lycoming rubber bushings but also use the Lycoming straight mount pattern so will bolt to a Lycoming mount.

Some of the mounts we produce are welded stainless steel and others are CNCed aluminum. We do not predrill the holes where they attach to the airframe due to large variations in even pre punched airframes. To install, first make sure all airframe mounting holes line up before you drill the holes where they attach to the airframe.

HANGING THE ENGINE

Buy or borrow a good engine hoist on casters. Harbor freight has them for under $200. (Item# 61858. $175. Cheap).

Remove the engine from the wooden crate. If you already did this, you know it takes two big guys or creative use of the engine hoist. It also takes an engine stand to bolt it to, because there's no flat bottom surface that would allow you to put it on the floor without damaging something! (Harbor Freight again: Item# 61238. $50 Cheap.)

Lift the engine with your engine hoist, using ratcheting tie-down straps (Harbor Freight $10), and roll it over to the aircraft and align it with the motor mount plate so that insertion of the hardware through the mounts is smooth and easy.

After struggling with the 'smooth and easy' part, you'll pretty quickly wish you had an engine leveler (yep...Harbor Freight: item# 67441. $29.00 Cheap) but you can use the ratcheting feature of the tie-down straps to help.

If your feathers are ruffled by all these cost 'surprises', remember two things:

$100.00 is a mere 1/10 of an $Aircraft Unit. Think in $AU's – not Dollars!

These are not just tools, they're Man-Toys!

….and suck it up!

Finally! Assemble the engine mount rubber isolators to the engine mounting ears. You might want to lubricate them with a thin wipe of synthetic grease, so they'll compress and expand nicely when you torque them up later. Insert the metal "bushings", which will help hold them in place. These can be AL or steel – the proper length is 1.84 inches. Make sure they're all equal length. See pic:

Insert the AN-6 bolts thru the top mounts from the rear. Use AN970 or AM thick aluminum washers as shown. Additional washers may be used to fine-tune engine alignment and the bolt/thread length when torqued.

Because of the left-rotation of the propeller, we require some degree of left rudder trim in level flight. This is opposite from most aircraft engines, because they rotate their prop backwards, requiring right rudder trim. In either case a common practice is to use a rudder trim tab to accomplish this.

Trim tabs are ugly. So...to reduce the size and/or deflection of our trim tabs, we'll shim the engine just a little to the left. For the AM13, one AN970-6 behind each engine isolator on the passenger side (one top, one bottom) will do the job nicely. You'll still need a trim tab, but not as ugly.

For the AM15, especially the AM15-HP, you'll probably need two.

Snug everything up all around, then begin torqueing progressively as per normal practice. Use standard torque tables as a guide.

PS: as you can see above, don't even think about trying this with the exhaust installed ;)

Figure 3 Low Profile Mounting

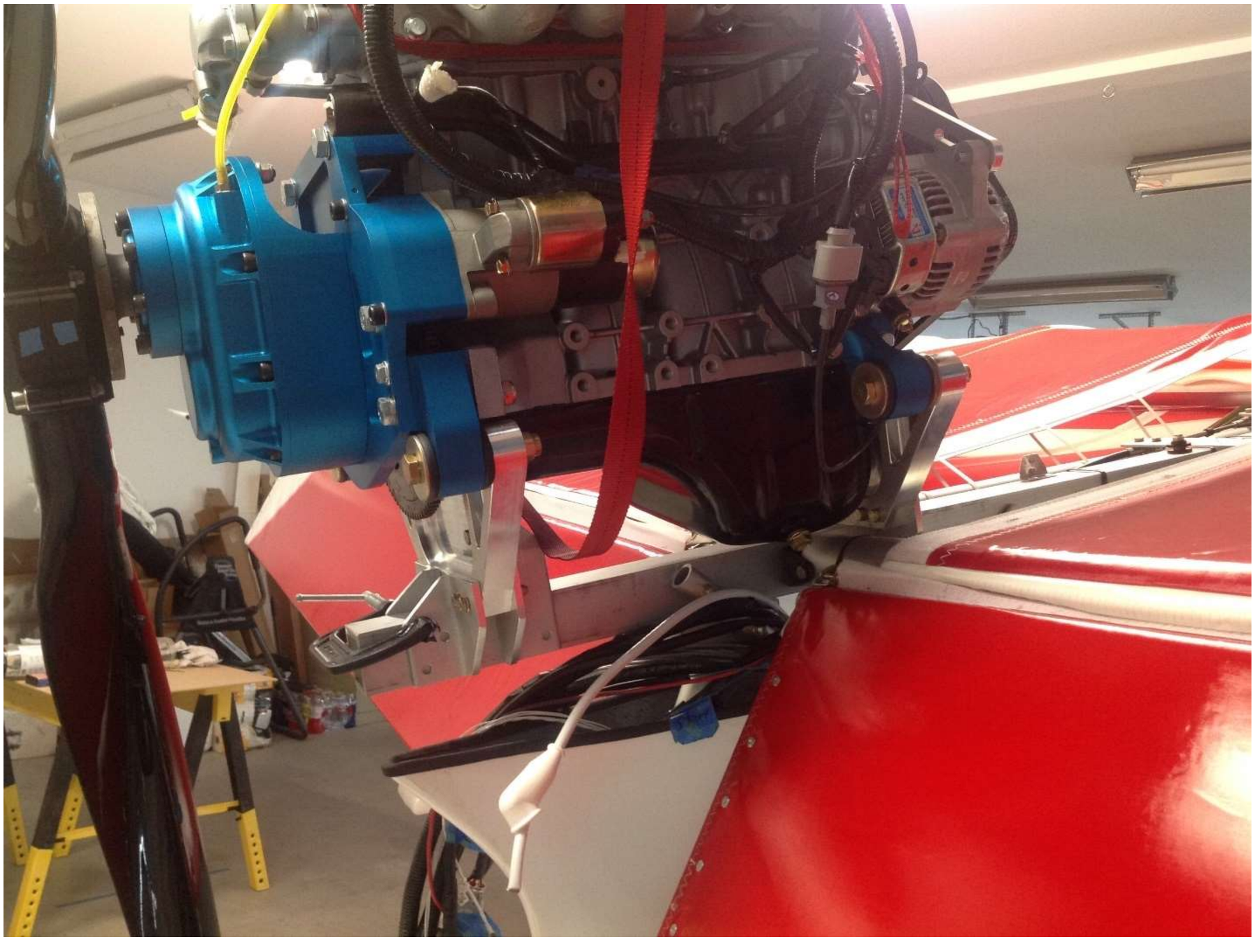

Figure 4 Upright Mounting

COOLING SYSTEM

In any engine cooling is critical and the AM family is no exception. Cooling is via liquid and a radiator. If the radiator is mounted below the engine there is also an expansion tank. The radiator (expansion tank) cap must be at the highest point in the system. **It is absolutely critical that all air is removed from the cooling system for the engine to cool properly. If you do not remove all the air from the system the engine will overheat and could seize. Do not use straight rubber hose longer than 6" since they are prone to collapsing/kinking and blocking flow. Use preformed aluminum tubes and short rubber couplers and elbows where required.** The warrantee is void if the engine overheats.

The cooling system MUST have one low point and one high point and all hoses must be routed monotonically. No ups and downs to trap air bubbles. You must remove all air from the system. One method is to fill the system and mark the level in the overflow tank. Then run the engine up to temperature but do not let it overheat. When hot, the level should be higher in the overflow tank. Then let the engine cool to ambient. The system will suck the coolant from the overflow tank back into the engine. Do this until both the hot and cold levels stabilize with no change from cycle to cycle. This method is described below.

Another method is via vacuum filling. If using this method follow the instructions that come with the vacuum filling equipment. When removing the radiator cap the system must be full to the bottom of the cap hot or cold.

The radiator must be mounted so that there is a minimum of 3 inches of H2O differential air pressure between the front and back. If you do not have this differential air pressure there will not be adequate airflow for cooling. You can use a water manometer to verify this required pressure and airflow. In general, the inlet should have ram air and the outlet should be in a low-pressure area. The inlet area must be no less than 40% the area of the radiator (more for slower aircraft) and the outlet should be about twice the total inlet area. Keep in mind aerodynamics and how they affect the airflow both in and out of the cowling. Sharp corners at the lower edge of the firewall can have a profoundly reduce the exit airflow. High pressure at the bottom of the aircraft especially during climb can reduce the exit airflow. Obstructions like the tailpipe can reduce the exit area and airflow.

Figure 5 Cooling Inlet

If there are auxiliary air inlets care must be taken so that they do not pressurize the cowling reducing airflow through the radiator. For example, in the RV-12 cowling that is part of our FWF package there are two additional inlets. Duct and seal these so that one goes to the induction and the other to the optional oil cooler or is used for cooling blast tubes.

The outlet from the thermostat cover connects to the inlet of the radiator. The outlet of the radiator goes to the water pump inlet. All of these connections must be monotonic and are 1" diameter.

The expansion tank is plumbed into the small line on the water neck and the small line into the water pump. The line from the water neck goes into the upper inlet on the expansion tank. If you are installing a heater core it is place in this line. The line from the lowest (outlet) on the expansion tank goes to the inlet on top of the water pump inlet tube. You must also install an overflow tank that connects to the top connection of the expansion tank.

Figure 6 Radiator Mounting

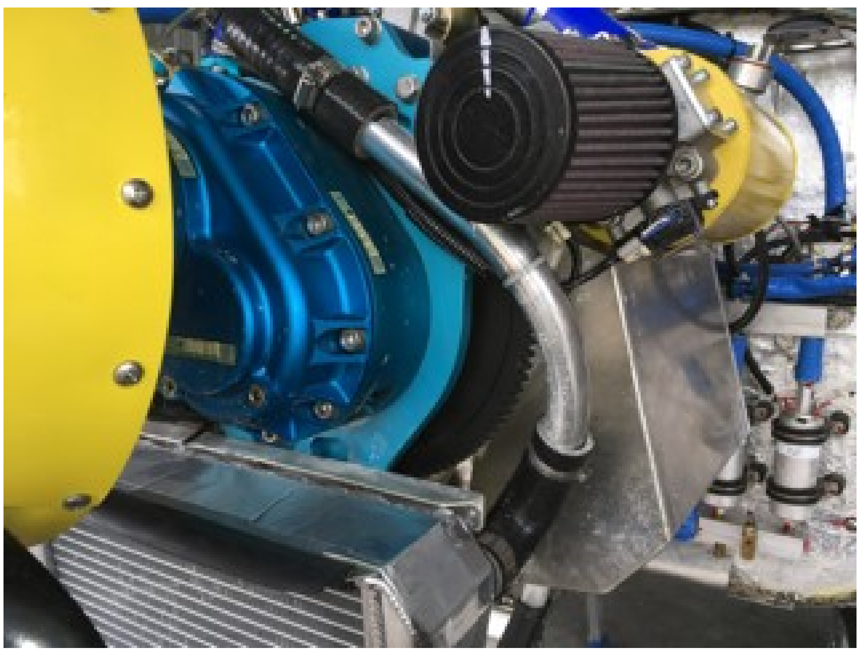

Figure 7 Radiator Connections Left Side

Figure 8 Radiator Connections Left Upper

The radiator must be mounted so that the air pressure cannot force it back and allow it to hit and rub on anything especially the plate mounting bolts. Use rubber (not shown) to isolate the radiator from vibration or it will fail over time.

The best coolant mix is dependent on your ambient temperature. Water has a higher heat capacity than antifreeze so provides better cooling. In warm areas use 30% ethylene glycol antifreeze and 70% distilled/deionized water and Water Wetter or equivalent. Do not use propylene glycol. Do not mix coolant types. Some coolant types are not compatible and can clog or coat your system causing overheating. In cooler areas use 50/50 and Water Wetter or equivalent.

All hoses, tube, pipes and the radiator need to be well secured using standard aircraft practice or vibration will lead to failure.

Figure 9 Heater Hose

The radiator must be mounted so that the ram air cannot push it back.

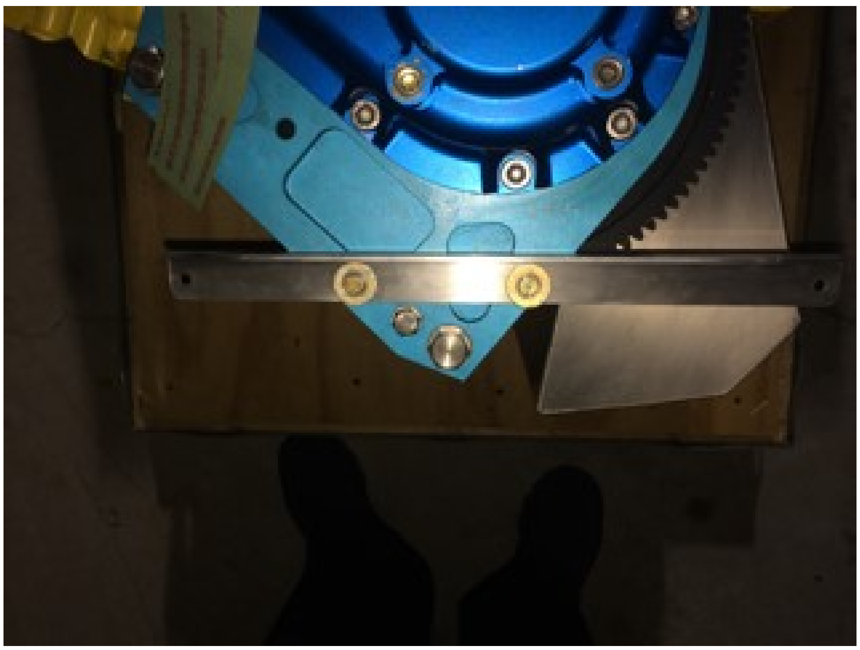

Figure 10 Radiator Upper Mount

Figure 11 Radiator Lower Mount

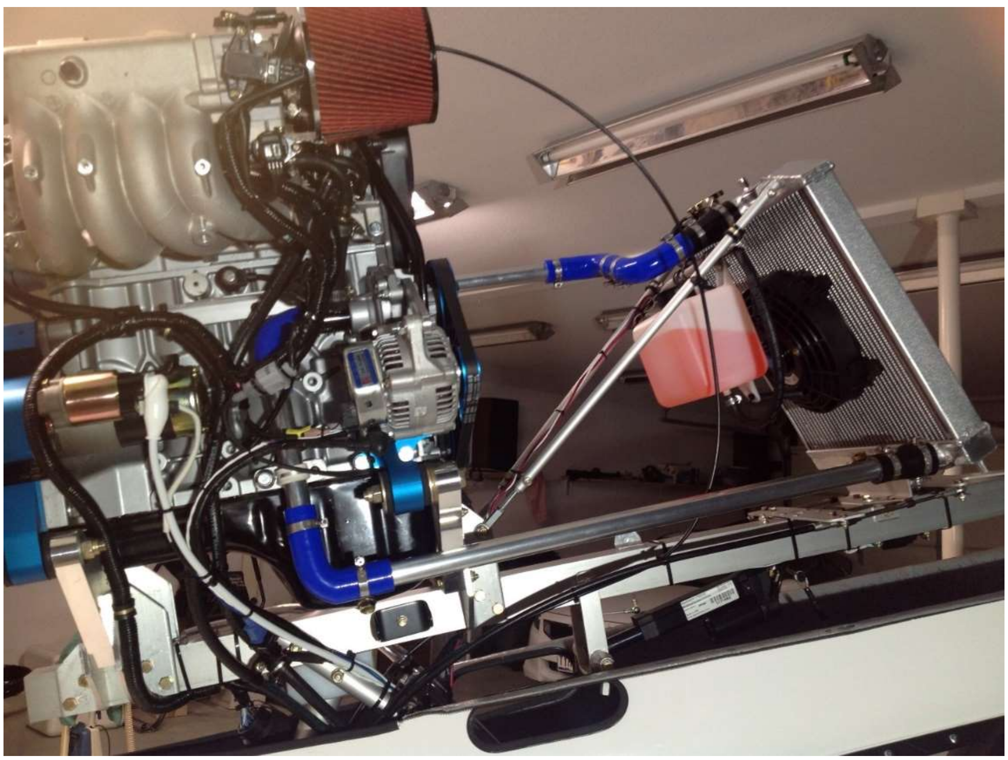

Figure 12 Large Area Radiator Mount Right

Figure 13 Large Area Radiator Mounting Left

The system must be burped to remove all air.

As a guideline, the AM15 (slant version) will require approximately a gallon of coolant mix – more or less, depending on radiator size, hose lengths, and whether you use a heater core.

Add the coolant mix into the expansion tank (radiator cap). Pour as much as can fit, or until the engine won't accept any more – but this does not mean the engine is actually full; there will be quite a bit of air trapped in the radiator, the heater core, and the engine head itself – up to a quart of air.

Obviously, you don't want to overheat things in this condition, but repeated short runs will purge the air eventually.

Purging the air

We recommend the first runs be done without the propeller installed. Easier and safer, too. You'll be pleased to see how smoothly the engine runs....and again, make sure you've got oil in the engine and gearbox!

Fill the overflow bottle to 50 percent and use a piece of tape as a marker at that level.

For the first run, start the engine at idle and let it run at about 1700 RPM for 30 seconds or so, then vary the RPM between 2000 and 3500 over about a minute. Watch the coolant temp gauge closely, and don't let it get over 150 deg F on this first run. Now shut it down and visually check everything over.

After a few minutes rest run it again, varying the RPM from 2000 to 3500 by aggressively blipping the throttle, but this time keep going until the thermostat opens. This will occur around 175 deg F. You might see a momentary fluctuation in coolant temp as the cold air/coolant from the radiator begins to flow. Shut it down when you've reached 185 deg F.

Now install the propeller and prepare for more extensive and higher temp runs. The prop provides cooling air to the radiator, which will be necessary as we progress here.

For the next several runs, we will take the engine up to higher temperatures, but nowhere near redline. Caution is needed here, because much of the air is still trapped in the engine and local hot spots can occur in the cooling jacket – especially in the head. Don't exceed 210 deg F.

With the engine fully cooled off (to ambient temperature) refill the overflow bottle to the marked level.

With each successive heat cycle, the engine will purge air from the system, then it will suck in coolant from the overflow bottle during cool-down. Refill to the marker after each cool-down.

Eventually, you'll see the overflow level rise when the engine is hot, then drop back down to the marker when the engine cools. When this pattern is repeatable, and no more fluid is needed at ambient temperature, the air has been purged and you're good to go. This may require four to five run sessions.

High engine temperatures can also cause preignition, detonation and knocking that will reduce power and can cause catastrophic engine failure.

If there is air in the cooling system it will at some time end up at the thermostat or water pump or aerate the coolant. In all cases this will cause overheating.

EXHAUST SYSTEM

The tune or our engines assumes the use of our header and muffler. You will not getter better power without our muffler. On the outlet of the header you must have a slip and/or ball joint to isolate the header and exhaust system from each other. The muffler and tailpipe must be fully supported and not by the header or there will be cracking issues. It is preferred to rigidly support this from the engine as is standard aircraft practice. The O2 sensor is best placed in the bung at the collector.

Figure 14 Exhaust System

The use of a muffler or tail pipe support to the airframe is not recommended but has been done successfully. We recommend a rigid support directly to the engine as is standard aircraft practice. In any case the muffler and tailpipe need to be supported or the header will crack.

Figure 15 Exhaust Support

FUEL SYSTEM

The AM family use a return fuel system with dual electric fuel pumps. The general system is from the tank(s) to a fuel valve to a prefilter to the two pumps in parallel to a 5 micron filter to a fuel pressure "T" to the fuel rail. Then from the fuel pressure regulator back to the tank(s). While a header tank can be used, we do not recommend header tanks due to the statistically high rate of off airport landings caused by header tank issues.

The pumps we provide are positive displacement and do not require the use of a check valve. Since they are positive displacement, they also act like an electric fuel valve. If the pump is off the fuel is off.

The fuel line from the tank(s) up to the inlets of the dual pumps is 3/8". From the pump outlets to the engine is 5/16". From the engine returning to the tank(s) is ¼". Flexible fuel lines can be used and they are required for the connections to the engine. We recommend metallic fuel lines in the cockpit. All nonmetallic fuel lines in the cowling must be covered with fire sleeve and even metallic fuel lines are best covered with heat shielding.

The fuel pumps should be mounted as low as possible to help prevent vaporization at the inlets due to suction. They must be protected from heat. Do not mount them near or above the exhaust. Our preferred location is behind the baggage area. If you mount them to the engine side of the firewall some airflow around them is required even though the one that is running is cooled by the fuel it is pumping.

The fuel feed from the tanks must be at the lowest point on the fuel tank. The return can be anywhere on the fuel tank but is best near the bottom of the tank and 3 inches or more away from the fuel feed port.

Note the gascolator is not used. It is not effective (as a gascolator) because of the high 40GPH fuel flow – any water will just be flushed through it and eaten by the engine or recirculated. Worse, it's designed for pressure, not suction, so it can fail as an air leak, at which time your pump(s) will cavitate and you will soon thereafter land.

Instead, install a lockable drain fitting under the fuel feed port on the fuel tank sump. This will be the lowest point in the system and can be used to sump for water or as a handy way to drain the entire system, if necessary.

Fuel filtering is critical (!): Assuming you bolt the engine on correctly and put the wing spar pins in before flight, this is the most critical part of the whole aircraft.

Inside each injector nozzle, there are four extremely small, laser-drilled nozzle holes. These give the benefit of a highly aspirated (and targeted) fuel spray pattern for each intake stroke of each cylinder. Great for smooth running and fuel economy.

However, if any of these (16) tiny orifices become blocked, that cylinder will run lean. At takeoff power, detonation could occur, so absolutely clean fuel is essential.

There are two keys to this:

Filtration. The pump must be pre-filter (normally 50-100 microns) to protect the pumps, but a post-pump "final filter" is required to protect the injectors. Use the filter provided for this by Aeromomentum. It is around 5 microns. and does a great job filtering out the tiniest particles. However, being extremely fine, it is subject to possible blockage. Therefore, sumping your fuel regularly is a good idea. Filtering it with one of those funnel/filter gizmos is good too. Make sure to follow the required flow direction indicated on the filters via an arrow or lettering.

Figure 16 Fuel Filter Inlet

There are two common ways to screw this pooch. Allowing auto gas to sit in your fuel lines for long periods. As you might remember, mogas with ethanol entrains moisture and is also an oxidant and, over time produces Olephins – something like fuel-proof wax. If you let that occur, your injectors will suffer. Further, it's possible that the 5-micron final filter will become partly clogged, which is not good either. While this does also happen with Avgas and ethanol free gas it happens much slower.

Do not use "EZ-Turn". EZ-Turn is a "fuel-resistant" lubricant widely used among homebuilders. It's really pasty – kind of like "water-proof grease" used in plumbing. You can't get it off your fingers without acetone or MEK. Works nicely to prevent galling on aluminum fittings, etc.

Some people use it on O-rings – like the ones in cleanable, re-useable filter assemblies. Don't do it! Exposed to the warm temps near the engine, especially with mogas, this "fuel-resistant" lube gradually melts and flows! The tiniest amount turns to a thick, sticky, varnish that absolutely and positively will coat and block your final filter or the injectors themselves.

If you have a tube of this stuff, don't let it anywhere near your fuel system. I threw mine away...in somebody else's trash can two hangars down.

If you want to lube O-rings before assembly (of anything) use a synthetic grease.

Don't use EZ-Turn on NPT fittings either. Do you commonly see red/wet stains or dripping on NPT fittings at brake assemblies? That's because hydraulic fluid eats EZ-Turn. And I just told you what happens if you use it in the fuel system!

Throw it away and go buy a tube of Loctite 567. It's a true sealing lubricant. It contains TEFLON. Most importantly - like all Loctite products you're used to, it is ANEROBIC. This means it remains thick and pasty until it is deprived of air – like in the threads of an NPT fitting - at which time it cures and expands. Nothing eats it and it'll never leak.

Worm-clamps can be reliable but do require the correct torqueing. Over or under torqueing will cause problems. They can be secure enough, but they tend to promote leaks. This is due to the not-a-perfect-circle shape created by the worm mechanism itself. A better solution is to use OETIKER clamps but they do require a special tool to install. Get the one with front and side jaws. These are high quality, German stainless steel "ear clamps". They are single-use, and are removed by prying up a small tab to release the clamp. They have a near perfect-circle, inter-lapping construction that forms a perfect, step-less circular clamping action. They're inexpensive, and bulletproof....and they don't leak.

Figure 17 Oetiker tool

They are available in 30 different mm sizes from Oetiker directly.

https://www.oetiker.com/en/Products/Clamps-and-rings/Ear-Clamps

Or from their US distributor, TJ Longda Tools. Search on Amazon for Oetiker Clamps, and find TJ Longda's ads. You want the single ear step-less clamps by Oetiker. Cheap.

If you're making up your own hoses, as I did, take a look at Phenix push-lock fittings from Aircraft Spruce: They are the PHENIX line of connectors and hose-end fittings Just search Spruce for Phenix fittings and they'll come up. They are made for high grade EFI hose like the GATES Barrier Hose I mentioned above, but the best choice is the exact hose recommended by Phenix. Secure with Oetiker clamps and you're good to go.

BTW, measure hose length twice and cut once – cause when you push one of these babies into your hose-end, it isn't coming' off.

Hoses: It's important to remember that this is a pressurized fuel delivery system and that it will likely be exposed to a variety of fuels during its life. This governs the choice of fuel hose. Use only highest quality hose, fittings and clamps. One of these is GATES "BARRIER" hose. For example, Gates 27340, which happens to be 5/16 ID EFI hose. It conforms to SAE J30R14-T2, which is a high temp, 250 psi specification. It's expensive.

(Note that SAE J30R14-T1 is carburetor hose, only 50 psi and should not be used. It's expensive too.)

We supply Helix racing fuel hose or SAE J30R9 hose with of FWF assist kits, which is more commonly available and equally acceptable. Both were designed to handle our temperatures and pressures, and both tolerate ethanol/mogas without swelling or leakage.

A better (but heavier, and even more expensive) option would be aircraft-grade Teflon hoses. A good choice for these is TS Flightline Aircraft Hoses. Tom Swearengen is well known in the VANS community, and will crank out custom hoses/fittings of any imaginable size, configuration, or material virtually overnight. It's expensive.

Fire sleeve: All fuel hoses must be fire sleeved in the engine cowling. A good selection is available from Aircraft Spruce. https://www.aircraftspruce.com/catalog/appages/fyrejacket58.php

Fuel Pressure is one of the required gauges for your airplane. For this installation, this needs to be measured after the final filter.

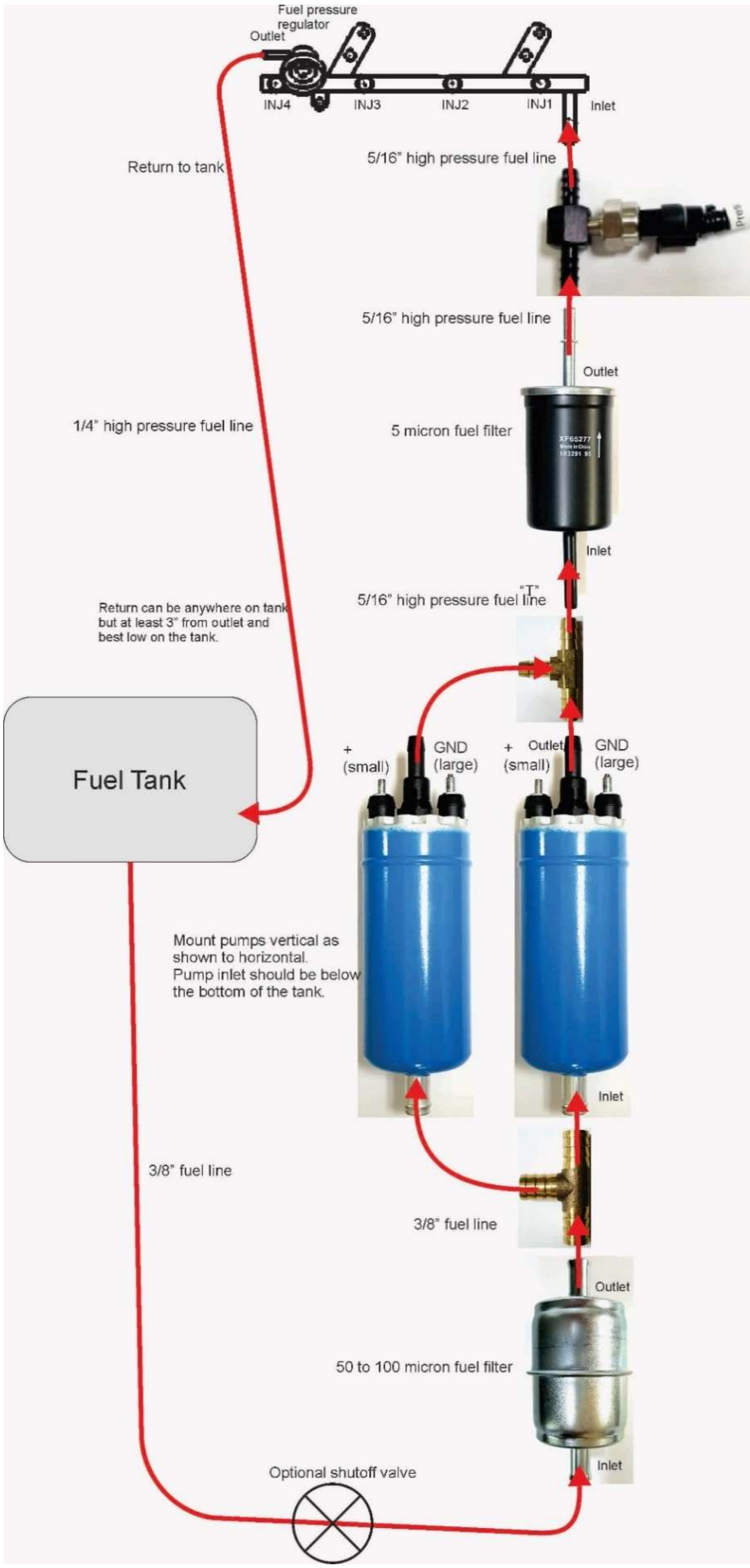

Figure 18 Single Tank Fuel System

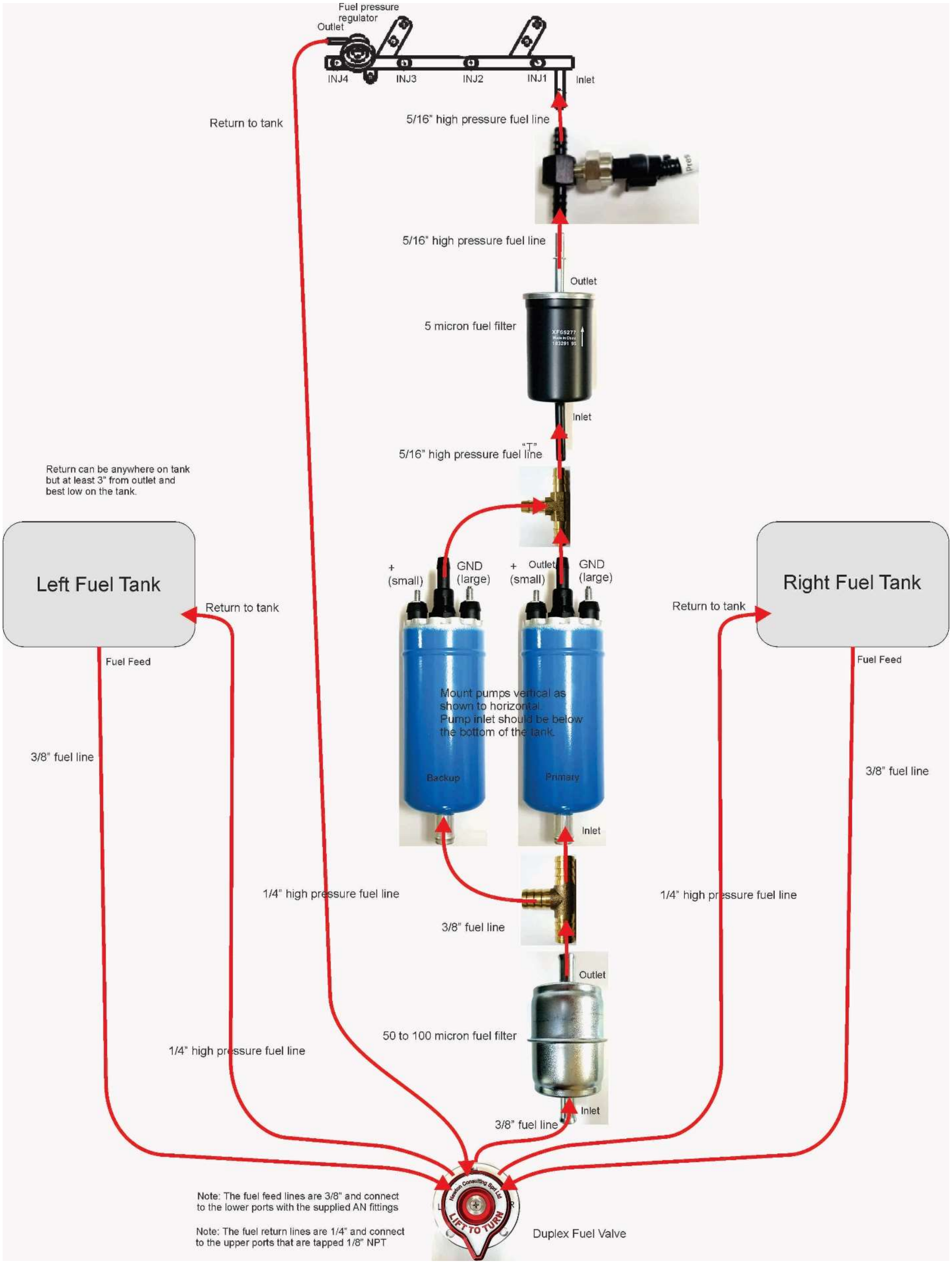

Figure 19 Dual Tank Fuel System

All hoses and tubes need to be well secured or vibration will lead to failure. This is especially true with connections to the fuel rail. If you connect heavy hoses to the fuel rail without proper support you will risk cracking the fuel rail and spraying your hot engine with fuel.

FIREWALL PENETRATIONS

There are a few main firewall penetrations to be located and created: the ECU harness, the fuel lines and the battery cable. Depending on your choice of avionics, especially EMS (Engine Management), you'll need pass-through's for antennas, sensors, etc. as well, but you can bundle these to minimize the number of openings.

Locating these penetrations will depend on what's occupying space behind your panel.

For example, where you locate the battery, whether in the engine compartment or behind the firewall on the instrument shelf, will determine where some holes can or can't be located. Any appliance or fuse block, etc. you mount directly to the firewall will do the same. So, step one is to plan out, and maybe install your entire panel and most of the wiring, etc. that takes up space on or near the firewall.

Having done that, create a hole for the ECU harness. There are many ways to do this. Rather than risking damage to one of the many harness legs and their connectors, you may want to cut a rounded rectangular hole large enough to push the ECU main connector from the engine side through the hole sideways, and then eventually seal it up with stainless steel plates and Hi-Temp Silicone Hookempucky. Search for Momentive RTV 103, Black.

Aircraft Spruce has cover plates for this type of installation or you can make your own. There was an article in Kitplanes on how to do this.

Figure 20 Firewall Penetration

Figure 21 Firewall Penetration Parts

If your battery is behind your firewall you will need to pass this through the firewall. If not, you will still need to pass power to the aircraft bus. I highly recommend not having any connections between the battery and the starter motor. This cable should run directly. If it passes through the firewall make sure it is well protected from chafing, etc. Also the cable from the battery to the key switch and from the key switch to the starter solenoid should be direct with no connections.

Fuel lines can use bulkhead connectors or pass though holes with protection from chafing, etc.

ELECTRICAL/ECU

The AM family of engines use the MicroSquirt ECU. The complete engine wiring harness is provided and is plug and play. This harness is complete to and including the ignition switch and engine circuit breakers. You do need to wire power, ground, alternator and any engine instruments that we do not provide as an option.

Do not modify or extend the wires provided.

Never forget this is an all-electric controlled engine! Next to fuel issues, this one can be pretty lethal as well. While it's true we have some redundancy, in that the engine will continue to run on either the battery or the alternator alone, that is an over-simplification. A poorly thought out or poorly wired electrical system will cause you to land eventually – maybe right away and un-ceremoniously.

A whole book could be written on this... but Bob Nuckolls already has:

"The Aeroelectric Connection" - available from Spruce – part# 10-03877.

In my experience, builders generally get the need for solid, robust POWER connections, but sometimes get a little sloppy when it comes to GROUND. This can occur in any electrical system in the airplane, manifesting itself as headset noise, alternator whine, intermittent radios, etc. etc. But let's focus on the engine.

The block and anything bolted onto it needs to be heavily grounded. This is because all currents are routed back to the battery through that one connection. "Battery lug" connectors must be properly swaged on each end. Connected one end to the starter mount bolt, and the other to a robust stud on the metal airframe or better directly back to the battery negative terminal.

If you don't do this well, the first thing you'll notice is the starter won't turn over like it should on a cold day. If you didn't clean and corrosion-proof the connection points (dielectric grease works for this), they will degrade over time and this will get worse.

A more subtle effect of poor grounding is faulty or erratic EMS data. Temps will be off, maybe by a lot. Those same temps will shift when you turn the alternator on or off.

It is for this reason, by the way, that companies like Garmin recommend only “2 or 3 -wire” temp and pressure senders. These senders have their own ground wire that goes back to the aircraft ground, not the engine block.

Proper grounding and power connections are absolutely critical. If you do not get these correct from the start you will have problems later. For example, if the starter is not correctly grounded the starter or the solenoid will soon fail.

Starter Wiring:

Poor wiring to the starter is the main cause of starter issues and can even cause the alternator diodes and regulator to fail. Suzuki (and some others) starters are very dependent on the correct wiring. The main wire from the battery to the starter must be the correct gauge and this is dependent on the round-trip distance of the wiring from the battery to the starter. The battery should be mounted as near to the engine as possible. You must calculate the required wire gauge based on 100-amp starter current with under 2% total voltage drop. Keep in mind that the battery voltage will also drop due to internal resistance and each connection can have some drop.

Below is a wire size table.

Wire Size	Maximum round trip length
6 AWG	4.4 ft
4 AWG	6.3 ft
2 AWG	9.9 ft
1 AWG	12.6 ft
1/0 AWG	15.9 ft
2/0 AWG	20 ft
3/0 AWG	25.2 ft
4/0 AWG	31.7 ft

There must also be a fuse or circuit breaker. The preferred size is 150 amps. Minimum size is 125 amps for a circuit breaker. Again, closer to the battery is better.

We do not recommend any added connections, relays, contactors, etc. in the connection between the battery and the starter. Each of these can cause additional voltage drop and reduce the reliability and life of your starter and/or alternator.

Connect the battery cable directly to the starter mounted solenoid. Connect the ground directly to the starter mounting bolt. There must also be a ground strap from the starter mounting bolt to the engine block (provided). Not following these requirements will cause your starter and/or alternator to fail.

Batteries:

The type and size of the battery and distance from the engine to the battery are important. The connections to the battery are also important and must be like in the wiring diagram provided. As above, use breakers or fuses on or very near the battery.

There are 3 main types of batteries currently in common use for EAB aircraft. Lead acid with liquid acid, Absorbed Glass Mat (AGM) and Lithium. They each have their advantages and disadvantages and all three types can be used successfully. Traditional lead acid batteries do not need any additional precautions. AGM and especially Lithium batteries tend to have very low internal impedance to a point. While this is great for providing cranking amps they can produce higher inrush current when the starter is released. These high currents can be hard on the alternator. They also do not damp the voltage spikes as well and this can also be hard on the alternator and starter solenoid. You may want to consider additional alternator protection. Damage to the alternator due to the use of an AGM or Lithium battery is not covered by the warrantee.

Some more information about Lithium battery caused alternator issues can be found here:

https://www.victronenergy.com/blog/2019/10/07/careful-alternator-charging-lithium/

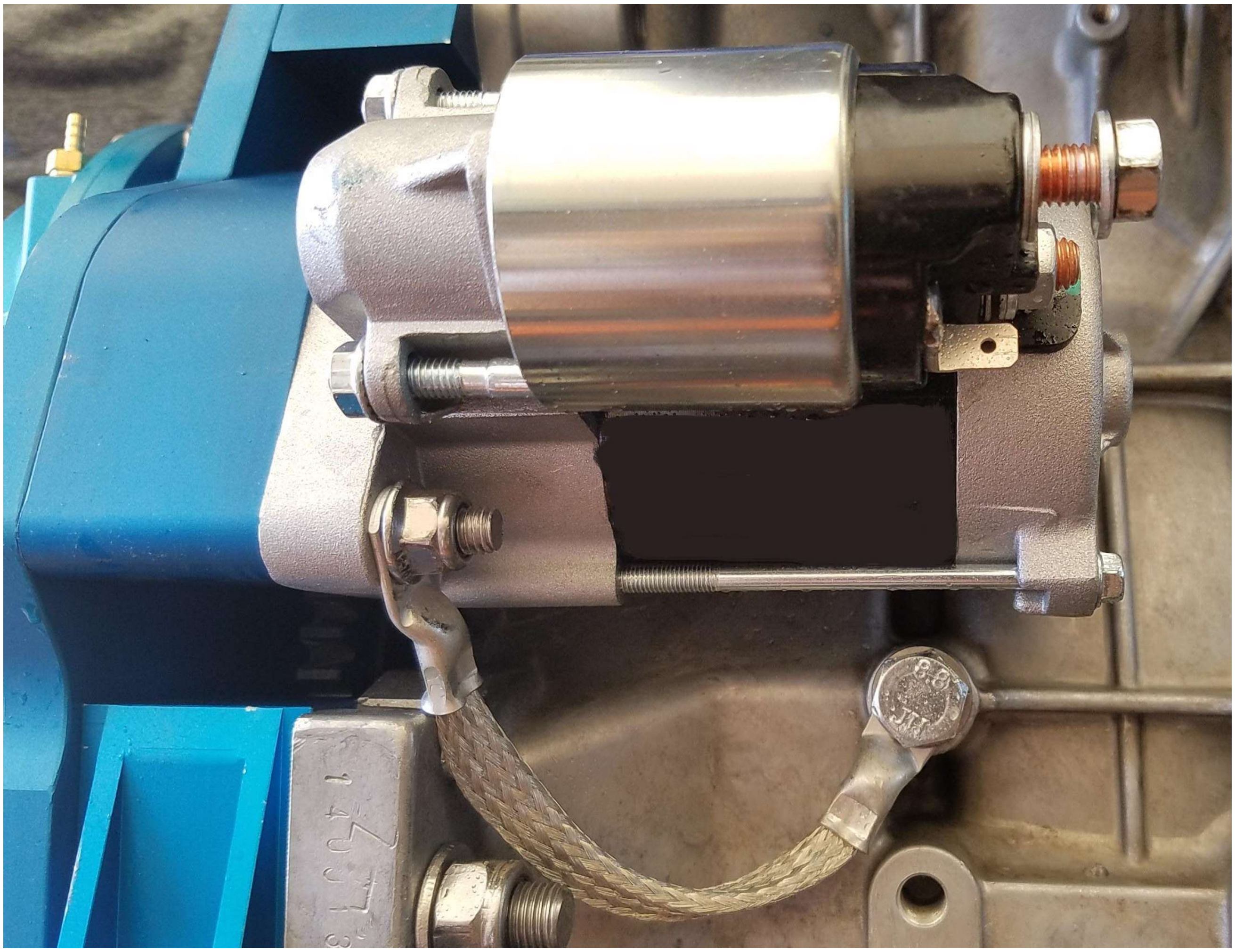

Figure 22 Starter Grounding

Alternator:

The wire from the output binding post on the alternator to the battery must be 12 AWG for any run under 5 feet and 10 AWG for runs over 5 feet. You must firmly secure this wire within 4" of the binding post. Failure to follow wire size and binding can cause the binding post to fatigue and fracture. Do not use thicker wire since this can put too much strain on the alternator terminal and does not provide the needed impedance to protect the alternator from spikes. If the binding post breaks, the wire can short to ground and cause a complete electrical system failure leading to the engine stopping. Do not make this connection via the starter solenoid. Connect directly to the battery.

Like all wiring, there needs to be a fuse or circuit breaker for protection and the alternator output is no exception. This circuit is critical since it is a large wire and shorting to ground will stop the engine. Current standard automotive practice is to use a fuse right at the terminal of the battery. The location is up to the builder but closer to the battery is preferred. This fuse should be 70 amps. If you use a circuit breaker it can be from 60 to 70 amps.

Since the alternator uses an external sense wire the alternator will compensate for the voltage drop on the alternator wire. We use as small of a wire as possible not just to save weight and cost but to add a little impedance. This impedance helps protect the alternator diodes and voltage regulator from spikes caused by the starter and other sources.

Ignition/Starter Switch:

The wire size going from the key switch to the starter mounted solenoid is 12 AWG and can not be extended without increasing the size of the wire for the whole length. Again, there cannot be any added connections, etc. The wire from the battery to the ignition switch must also be sized so that voltage drop is minimal. Below is the battery to ignition switch "B" terminal wire size table.

Wire Size	Maximum length
12 AWG	4 ft
10 AWG	10 ft
8 AWG	19 ft
6 AWG	30 ft

The ECU wiring harness is included and should not be modified. Connect as in the wiring diagram. In general, there is just a power connection to the "B" terminal of the ignition switch and the grounds provided at the engine. All of the power wires in our harness are protected by the provided circuit breakers. We do not recommend any changes. If you use a different switch to replace the key switch it must be rated 20 amps continuous and 40 amps intermittent.

Figure 23 Key Switch

All of the wires are to the color code in the diagram and have a label printed on the wire about every 4 inches. The wiring harness provides some additional optional connections including CAN bus, Tach drive, coolant temperature, RS232 (USB with adapter) data and more. None of these connections are required for you engine to run. They may be useful for connecting to instruments or in the future. The wires not used can be cut short and the ends must be protected from shorting to other wires or the airframe.

The following wires are generally used to connect to engine instruments and EIS systems:

Tach

Coolant

ALED

The following wires are generally used to connect to the AeroGraph or other compatible CAN bus systems:

CAN H

CAN L

Power

Ground

These come prewired to a 4 pin

The following wires are used to connect to Android, Windows or some iDevices:

RX

TX

GND

These come wired to a female 1/8" 3 conductor phone socket. A cable to connect to a RS232 DB9 connector is provided.

The following wires are not used:

Boot
VR2+
ADC2
WLED
FID
FP
VR2-
ADC1

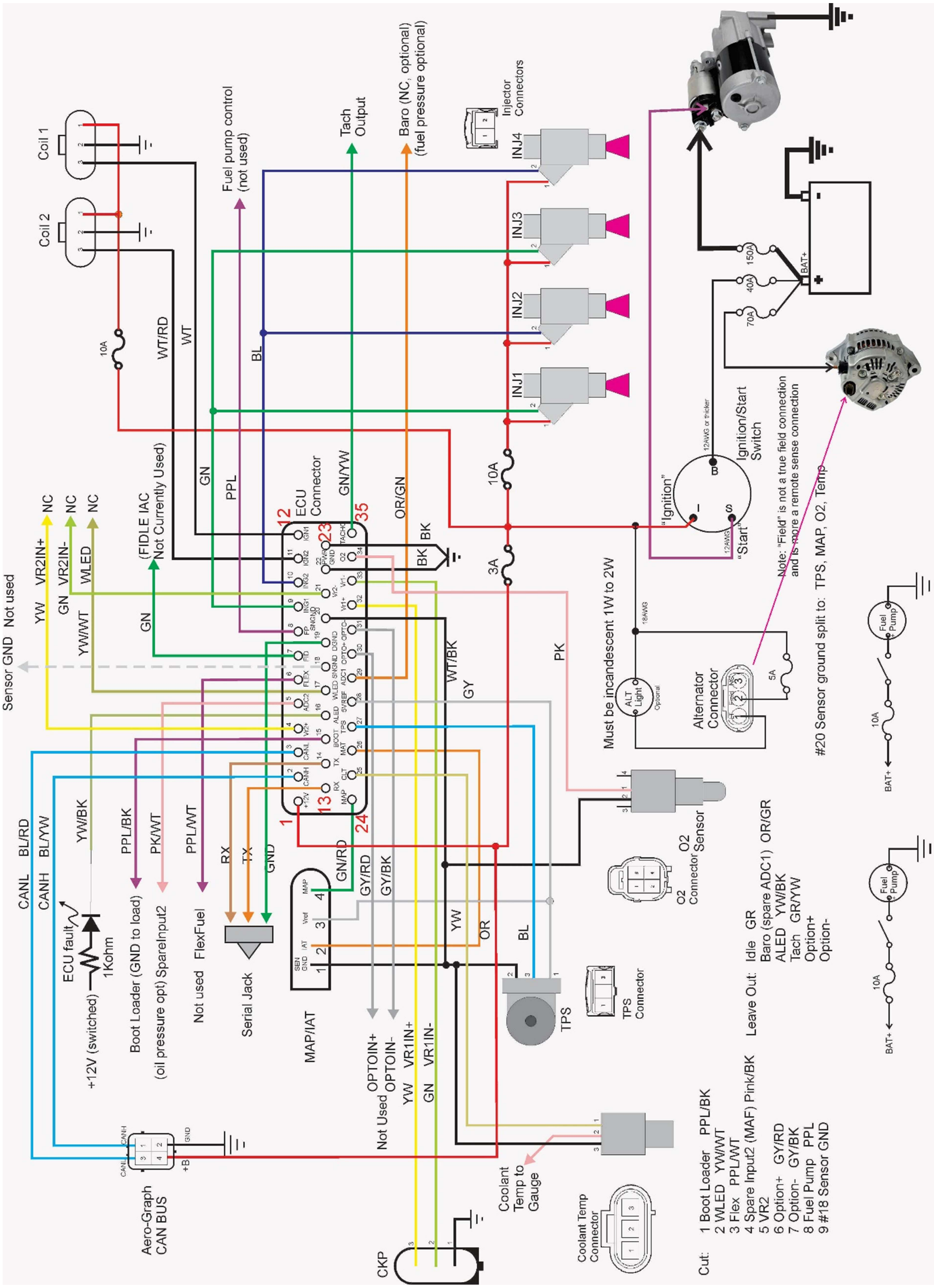

Figure 24 Wiring Diagram

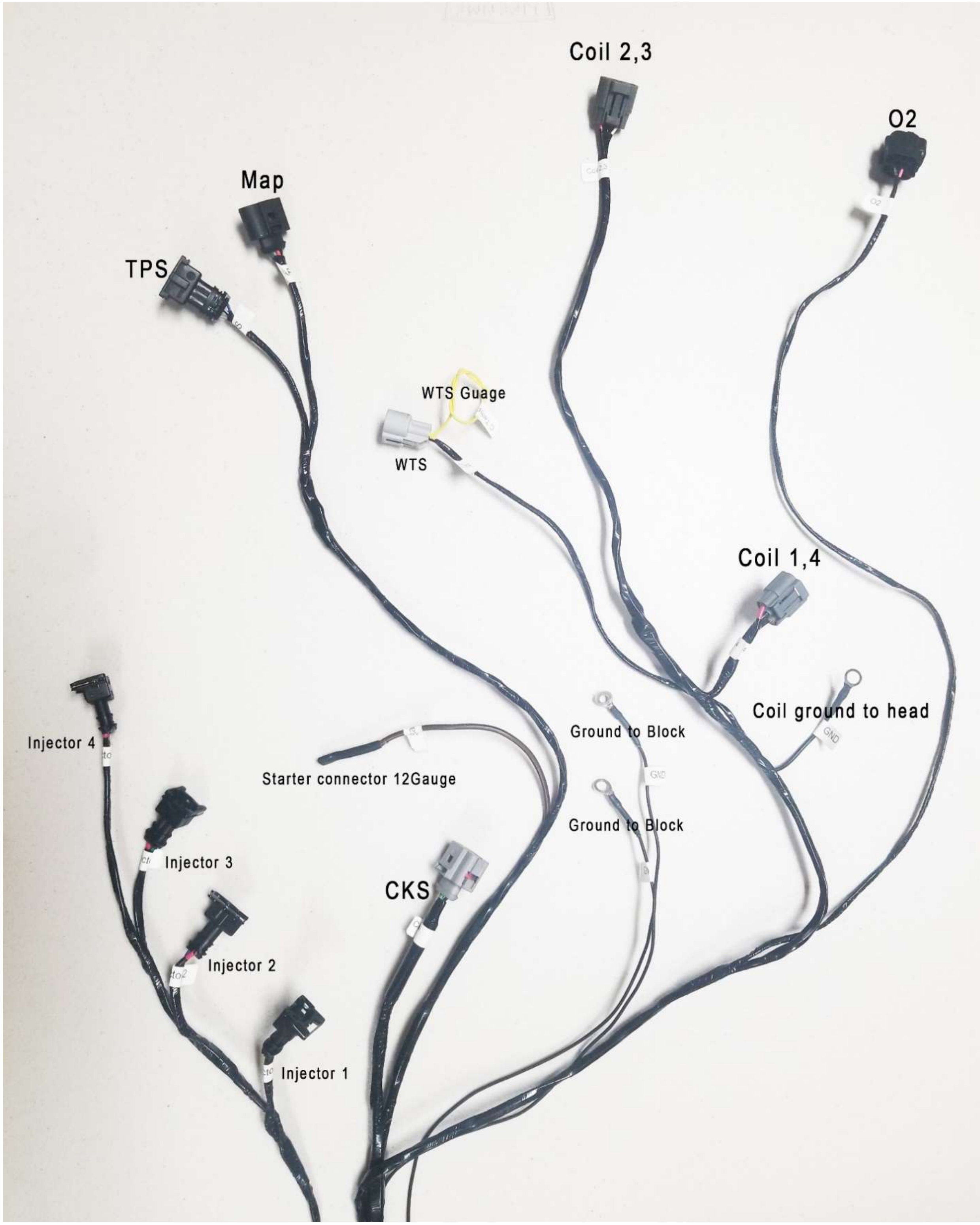

Figure 25 Wiring Harness

All wires need to be well secured or vibration will lead to failure. Securing: Be careful to isolate/support the harness so that it doesn't flop around in flight and, more importantly, wires are not allowed to rub on anything! Don't forget that bit about this being an all-electric airplane engine!

There are two easy ways to do this:

1. Use “split loom” or “slit corrugated sheathing” to encase wires and wire bundles. Some of that is used in the harness already. I used it almost everywhere. BTW, Harbor Freight will not do here. Their split loom stock is cheap plastic. It will soften/deform when in contact with a hot engine. What you want is NYLON split loom, available from McMaster Carr in various sizes. Item# 2569K93, for example. Cheap.

BTW, you can spot good, nylon split loom by the thin gray stripe running lengthwise. (This is a voluntary standard adopted by industry)

2. Stand wires and looms off from everything with ty-wraps, standoffs, or ADEL clamps

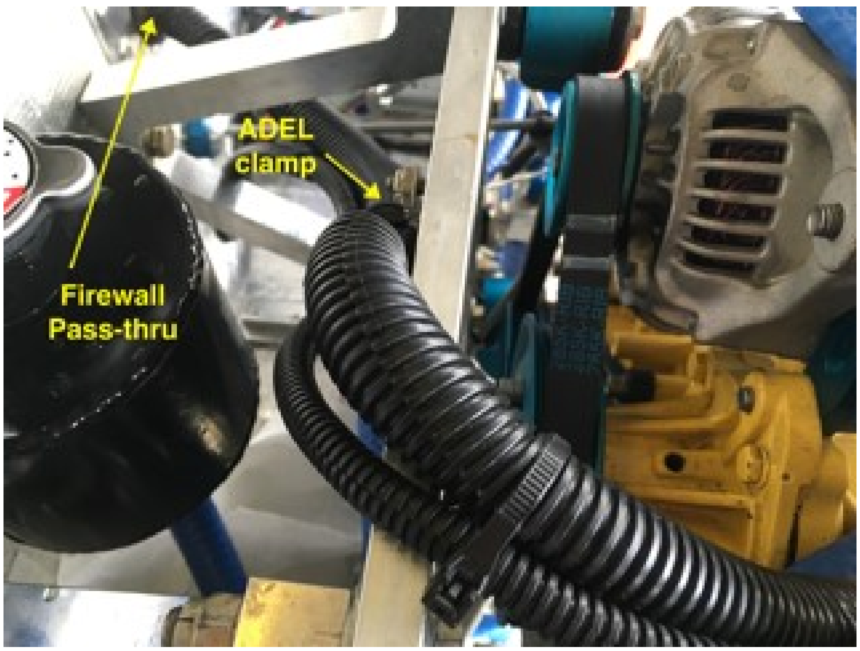

Figure 26 Securing Wiring

BATTERY

Ok, you just blew your alternator. No worries – the engine will continue to purr along on the battery alone. The size (and condition) of your battery will determine how far you can go to get it on the ground – and you should get it down at the nearest and first opportunity. I know you want to get it home where your tools are, but don't push it! Replacing the alternator, even with borrowed tools, is quick and easy.

To extend your options somewhat, choose a high quality, large capacity battery. No cheap alternative here. Personally, I'd recommend at least the Odyssey PC680 or PC625. Or better yet the largest EarthX battery you can fit.

Here's the way to think about this. If your airplane is equipped as is fairly common, the fuel pump (~5 amps), ignition (~1.7 amps), injection (~0.3 amps), ECU (~0.2 amps) and a single screen Garmin (or Dynon) will draw about 11 amps in flight. The PC680 capacity is about 16 amp-hours – meaning it can (ideally) supply 16 amps for about an hour. That would mean you have more than an hour to live after the ALT goes Tango Uniform. The fact is, due to age or mistreatment (hi-temps) it's often less than that sometimes quite a bit less than that.

So: Remember Dirty Harry! ("feel lucky, punk?")

Note: Recently I learned that Earth-X has actually TSO'd the battery I bought. Apparently, certification testing convinced the FAA that the battery chemistry, together with the Battery Management System (proprietary to Earth-X) produced a stable, well managed storage system deemed acceptable for aircraft use.

The difference is the TSO'd version has a dual-shell, double-vented case with a vent hose routed overboard. It fits in the same space as mine (and the PC680) within a few millimeters. Very, Very expensive.

ENGINE MONITORING

The minimum engine monitoring consists of tachometer, coolant temperature, oil pressure and fuel pressure. We also recommend oil temperature, manifold pressure and inlet air temperature. Gearbox oil temperature tends to be very cool and stable but monitoring this helps to provide warning if there is low or no oil.

The oil pressure, oil temperature and other ports, threaded holes and bolts are BSP and metric. Do not attempt to use NPT sensors or fittings directly into the engine. Doing so will most likely produce a small metal shaving pushed into the oil galley after the oil filter. This will cause catastrophic engine failure. Adapters from BSP to NPT are available from AMI. The oil pressure BSP to NPT adapter is provided with the engine.

The ECU measures RPM, coolant temperature, manifold pressure and inlet air temperature. There is also a narrow band O2 sensor. Optionally an Android or iDevice can be used to monitor engine parameters read by the ECU. To do this you need an adapter from RS232 to USB. We have these available on our web site. Most of the lower cost ones available from other sources do not work with our ECU. You will also need an adapter to the style of connector on your Android device. A free app is available on the Google play store. iDevices require other adapters and apps.

Figure 27 Android Based EMS

In addition to the digital ECU data, it is required that there is an oil pressure gauge and fuel pressure gauge. Oil pressure should be 50 to 63 psi @ 4000 rpm or higher. The internal oil pressure relief valve is at about 57 psi. Fuel pressure should be 43 psi higher than the manifold pressure. At full throttle you should see near 43 psi. At closed throttle (idle) you should see about 30 psi.

Optionally we offer and recommend the truly plug and play AeroGraph Engine Information System (EIS) that connects to the engine ECU via CAN bus and it comes with additional sensors for oil pressure, fuel pressure and oil temperature. The AeroGraph offers a complete EIS in a very small and low-cost package. You can chain 2 or more AeroGraph instruments together for additional display area. We highly recommend the AeroGraph for accuracy, warnings, light weight and simplicity of installation and it is available on our web site.

Figure 28 AeroGraph EMS

Figure 29 Oil Pressure and Temperature Senders

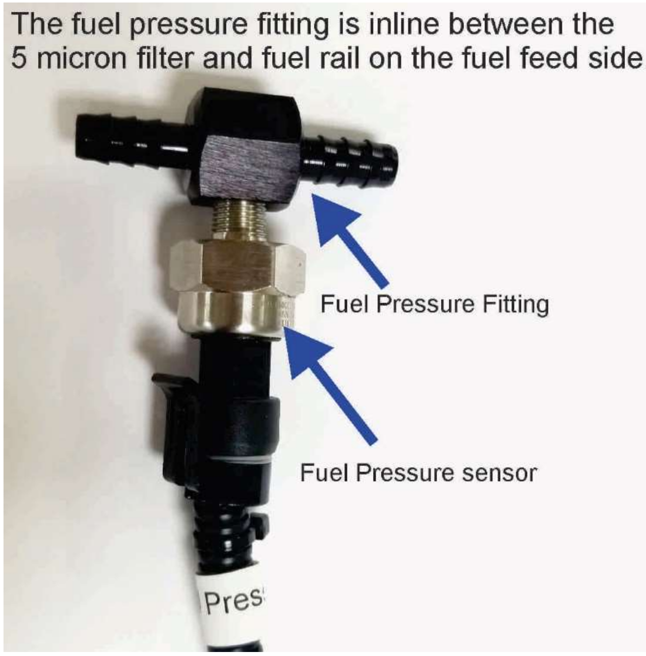

Figure 30 Fuel Pressure Sender

It is also possible to use analog instruments and any of the glass panel displays. Contact them for their specific installation information. There are signals available for tach and coolant temperature. The tach signal is 2 pulses per revolution as is standard for a 4-cylinder engine. This will connect directly to most standard automotive or marine tachometers that have a setting for 4 cylinders. It will also work with most universal electronic aircraft tach's that read to 6000 rpm or higher. It will not work with Rotax only style tach's. The coolant sensor is of the thermistor type and decreases with higher temperature. This connects to many electric temperature gauges that use a low resistance sender. The VDO 310-039 (Aircraft Spruce Part# 10-01647) works well but reads a little high. This can be calibrated by adding a small resistor in series. Calibrate the gauge to your instrument by placing the tip of the sender in boiling water and adjusting the resistor until the gauge reads correctly. Normally the resistor is about 2 to 4 ohms. This method can also be used to calibrate the temperature to glass panel systems that do not allow software calibration.

Again all wires need to be well secured or vibration will lead to failure.

ENGINE PARAMETERS:

RPM: 1800 to 5800 rpm normal operating with 6500 rpm redline

Coolant Temperature: 160 to 210 F normal operating range with 225 F maximum

Manifold pressure: 2 to 15 psi (4 inhg to 30 inhg)

Fuel Flow: 0.5 to 11.5 gph, 65% cruise should be about 4.2 gph for the AM13 and 5.2 gph for the AM15

% Power: 0 to 100%, for longer engine life and better economy cruise power should be 65% or less.

Timing advance: -5 to+36 degrees, normally with good fuel you should have 34 to 36 degrees at cruise.

Note: Timing advance of less than 33 degree will reduce the available power

If at any time the engine is operated outside of the allowable parameters expect power loss, land as soon as possible and fully inspect the engine before further flight.

If the ECU avoids operating closed loop the O2 sensor may need replacing.

OIL COOLER (optional)

Depending on your installation, application and version, you may need an oil cooler and one is recommended for most installations. We offer an optional oil cooler kit.

CABIN HEATER (optional)

Liquid cooling allows for safer cabin heart is via the engine coolant. No dangerous exhaust heat exchangers are required. The heater is plumbed

Fluids

Engine oil is a good quality 20W50 GF-5 automotive oil. Synthetic is highly recommended for use with unleaded fuels. The gearbox oil must be good quality GL-5 80W90, 75W90 or 75W110 conventional or synthetic gear oil. Synthetic is very highly recommended. Avoid high viscosity range oils like 75W140 GL-5 since they tend to spit out the vent tube. We recommend Amsoil SEVERE GEAR® 80W-90.

Coolant must be aluminum compatible ethylene glycol automotive antifreeze mixed as above with deionized or distilled water. Add only the same type as was used to fill the system. The addition of Red Line water wetter is recommended. As an alternative Evans or Dex-cool can be used following their applicable instructions but keep in mind that they have less heat capacity so are NOT recommended. Never mix types of antifreeze since some are not compatible and can cause gelling. Even a small amount of incompatible coolant can cause the inside of the engine and radiator to become coated greatly reducing the cooling efficiency. If this happens your engine may overheat.

Shock cooling

Shock cooling is not possible due to thermostatically controlled liquid cooling. Rapid and large throttle movements are allowed and not an issue for the engine but should be avoided for potential airframe and propeller interactions.

OIL CHANGE

The oil drain plug has a magnet. Inspect the magnet for metal particles. When reinstalling the oil drain plug tighten to 6 ft-lbs. Do not over tighten the oil drain plug or it will break.

FUEL

Standard power versions of the AM13 and AM15 require 90 octane (AKI) or better gasoline. High power versions require 93 octane (AKI). Keep in mind that in your country the method of rating octane may be different. For example, 100LL is 99.5 MON minimum or about 95 AKI. While the engine items we provide are compatible with up to 10% ethanol there may be incompatibility with your fuel tanks. Gasoline with ethanol also has a short life and other issues. Old or oxidized gasoline may also have reduced octane rating and can cause catastrophic damage. If using 100LL we recommend the use of ALCOR BY TEMPEST TCP FUEL TREATMENT.

INDUCTION AIR

The induction air must be clean and cool for proper running and engine life. Hot induction air can cause detonation, loss of power and possible engine failure.

PROPELLERS

The Maximum Permitted Propeller Flange Moment of Inertia is 6000 kgcm2 (2050 lb.in2). Use of propellers and other prop flange mounted accessories over this limit can result in total engine and/or gearbox failure and voids the warrantee.

Our propeller hub is drilled and tapped (M8) for Rotax 75mm pattern and drilled for Rotax 4” and SAE-1. For use with Rotax 4” and SAE-1 drive lugs are required. We offer threaded drive lugs on our parts page.

With the tested Luga props there are no RPM restrictions within the above specified normal operating range. With other propellers do not operate where there is a torsional resonance or failure will result.

Information on the Luga propellers can be found on our web site. Luga prop installation instructions come with the propellers.

BREAK-IN

Before delivery we run each engine for a minimum of 3 heat cycles and 2 hours but this is far from broken-in. The total break-in period is 20 additional hours. While we allow and encourage you to run the engine first without a prop so that the engine can safely inspected when running this should be kept to a minimum (5 minutes) since the engine needs some load to help seat the rings. Do not allow the engine to sit and idle. Constantly and aggressively blip the throttle but still keep the RPM under 3500. As soon as you can safely install the propeller pitched for flight to provide some load to the engine. Even with the propeller do not let the engine sit and idle. Run between 2000 and 4500 RPM.

Your AM13 / AM15 engine is at its core, a highly developed automotive engine. As such, you would not expect much caution during break-in. However, the automotive application assumes relatively low power duty cycle, but this application is more demanding. Your first takeoff will require full power in relatively low airspeed / low cooling conditions (climb-out). Care must be taken to limit the extremes of this on your first flights.

Your first few takeoffs should be restricted to a shallower climb and higher airspeed profile than you might use later. Pushing over to level flight and reducing power to a cruise setting (say, 20 - 22 inches MAP) will see the coolant and oil temps come down in the first few flights.

The first 5 hours are most critical. During break-in use conventional (non synthetic) break in oils. Break in oils are high in zinc. We recommend Lucas Oil High Zinc Break In Oil 20W-50. Run the engine with some load (propeller) but at low power (under 45%) and low RPM (under 4500 preferably) as can be done safely. At the end of 5 hours change and inspect the engine oil, filter and gearbox oil. For the next 5 hours run the engine with some load (propeller) but at low to medium power (under 65%) and low RPM (under 5200) as can be done safely. For the next 10 hours run the engine with some loaded but keep the power under 75% and RPM under 5500 as can be done safely. Again, change and inspect the oils and filter. After these 20 hours the engine is considered broken-in and you can change to synthetic oils as above.

Initial break-in will occur over about 5 hours in cruise. An interesting indication of this will be the engine breather output. If you route the breather line into a catch-bottle (instead of overboard), you will collect about an ounce of oil in the first couple hours. As break-in progresses, this will subside. After the first five or so hours, it will virtually stop, indicating a successful break-in is under way – though not yet complete. Typically, we like to see about 20 hours before declaring victory. At that point, we recommend changing the oil to synthetic or synthetic blend.

OPERATION

On your preflight you should make a general inspection of the engine

Do not turn off the fuel pump to turn off the engine. Just turn it off with the key. When the key is turned off the injectors stop squirting fuel instantly so there is no raw fuel injected into the engine at shutdown. Turning off the fuel pump will cause the engine to lean out and stumble causing damaging rough running at shutdown.

Please refer to the “AM13 and AM15 Engine Operating Manual” for more information.

TROUBLE SHOOTING

Your AM engine should provide you with many years of trouble-free service. By far the largest issues we have seen are due to poor wiring and modification. Most wiring issues are poor grounds, poor power connections, too many connections, too much added complexity and the use of undersized wire. Always check your grounding an power first and this must be done under load.

Like any gasoline engine the AM engines need compression, fuel and spark to run. Please refer to the "AM13 and AM15 Engine Manual" for checking and specifications for these items.

The fuel and spark are provided by the ECU. All parameters that the ECU measures can be viewed with a connection to the CAN bus or the serial port. To connect to these please refer to earlier in this manual. Once connected you can read all the sensor data and monitor the ECU via your preferred device.

Fuel pressure must checked and correct.

Figure 31 Have A Safe Flight