INSTALLATION MANUAL
FOR 4th GENERATION
JABIRU 2200 and 3300 AIRCRAFT ENGINES

DOCUMENT No. JEM0008-3

This Manual is a guide to correctly install the Jabiru 2200 engine into an airframe.

If you have any questions or doubts about the contents, please contact Jabiru Aircraft P/L.

Applicable to Jabiru Generation 4 2200 from S/No. 22A3936 and 3300 engines from S/No. 33A2974

1.1 Table of Figures

1.2 List of Effective Pages

- This manual is revised as a complete document. All pages must display the same revision number. See the table below for the revision history

Table 1 - Manual revision history

Issue	List of Changes	Issued By	Date
1	Initial Issue	DM	10/8/21
2	Section 2.1 Choke cable dimension updated	DM	21/4/22
3	Section 2.1 Added to choke cable instructions Section 4.8.2 Oil temperature sender info. Section 8 Propeller & Spinner – non Jabiru spinner reference Section 10. Never reuse a contaminated oil cooler info Section 4.8.1 delete inductive pickup use	DM DM DM SW SW	29/4/22

1 Engine Information

All specification data relevant to the Gen 4 2200 and 3300 engine is found in the following manuals:

- JEM0005: Maintenance Manual – contains the following
  - General Specifications
  - Fuel and Oil specifications
  - Detailed list of all operating limitations (temperatures, pressures, RPM etc)
  - General dimensions
  - Maintenance procedures

- JEM0004: Engine Overhaul – contains the following.
  - Fastener torque settings
  - Build tolerances and clearances
  - Engine disassembly
  - Engine assembly
  - Build logs

- JEM0007: Production and Parts Book – contains the following
  - Illustrated parts lists
  - Production assembly procedures
  - Run in guidelines.

These manuals can be found at https://jabiru.net.au/service/manuals/

Engine Mount

The design of the engine mount must balance many requirements:

- The mount must be strong enough to carry the loads applied by the weight and power of the engine.
- The mount must be stiff enough that the engine does not sag or move too much when power is applied.
- The mount must position the engine at the correct height and angle so that the engine's thrust line suits the aircraft. In most installations, Jabiru Engines need to have their thrust axis offset to the right (tractor installations) by between 1° and 3° (depending on the model)
- The mount must position the engine at the right place. The weight of the engine is a very significant part of the overall aircraft weight, and the position must be accounted to place the centre of gravity of the aircraft (CG) in the correct location.
- The mount must be designed to allow enough room for the air intake to the Carburettor as well as accessories like vacuum pumps. Access for maintenance must also be considered.
- All Jabiru aircraft models have specially designed engine mounts available. Firewall forward kits have also been developed for a number of other light sport aircraft. Contact Jabiru aircraft or an authorised dealer for more information
- The engine has four engine mounting points located at the rear of the engine. JEM0005 provided detailed diagrams and dimensions for these mounting points). An optional bed mount may be fitted, which adds 2 additional mount points at the front of the engine.

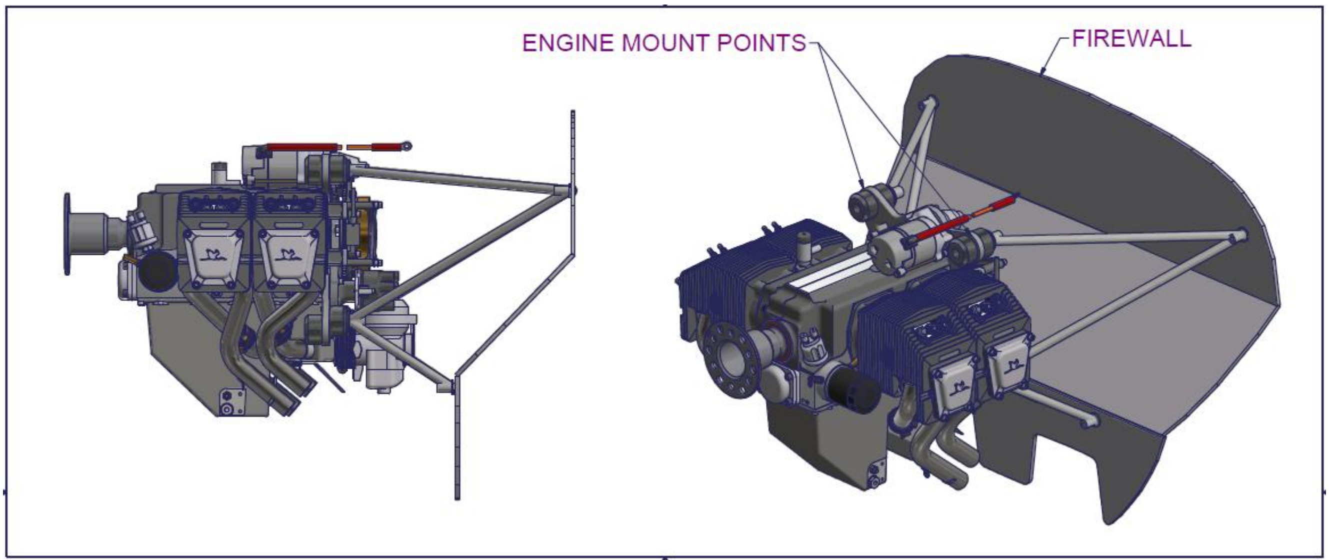

Figure 1. Engine Mount Point Locations

- Each engine mounting point is rubber mounted to dampen the engine vibrations. The correct installation of these rubbers is shown later in Figure 36.
- If required, corrections of the engine angle or propeller position can be made by fitting spacers under the rubber cushions. The maximum spacer thickness on any one mount is 3mm.

2 Controls

This section comprises of the mechanical controls and electrical switches.

2.1 Throttle and Choke

- The throttle cable attaches to the cable mount arm fitted to the carburettor.

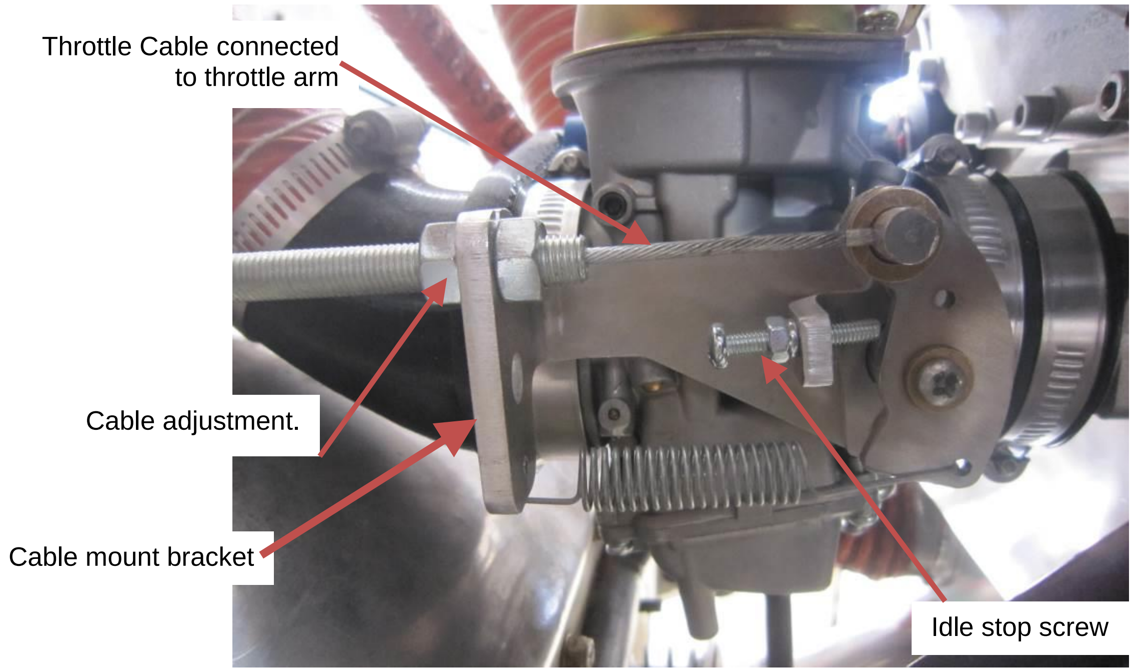

Figure 2: Throttle cable connections.

- Note: Since a pressure compensating carburettor is used there is no mixture control.
- The idle stop for the throttle can be adjusted using the adjuster screws and nuts shown in Figure 2. A 7mm spanner and a Phillips screwdriver/ another 7mm spanner is required.
- The cable should be adjusted so that just before the throttle hits the full throttle stop, the carburettor throttle lever hits the stop.
- The cables used must have an adequate radius wherever they turn a corner. Bending the cables too sharply will increase the cable friction, making it difficult to use the control accurately. This is a particular problem for the throttle cable as it will make setting the idle accurately, very difficult.
- The Idle Stop Screw (shown in Figure 2) must be adjusted as a part of the engine installation process to correctly set idle RPM.

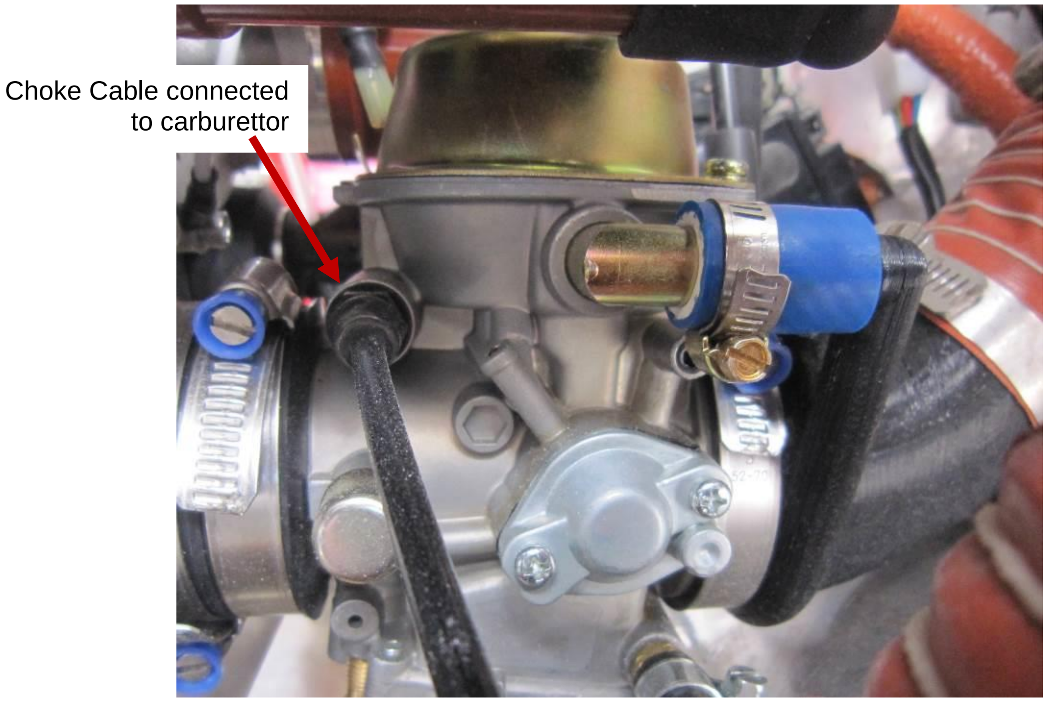

Figure 3: Choke cable fitted

- Choke cable doesn't have any adjustment.
- Install choke cable in the aircraft and trim the overall length to reach the carburettor without tight curves, before fitting end ferrule to choke cable. The inner cable needs to be at least 35mm longer than the outer sheath.
- With the choke knob pushed fully in, the small cylinder-shaped ferrule is soldered on to the inner cable in the location shown below. The inner cable is then trimmed off flush with the base of the ferrule.

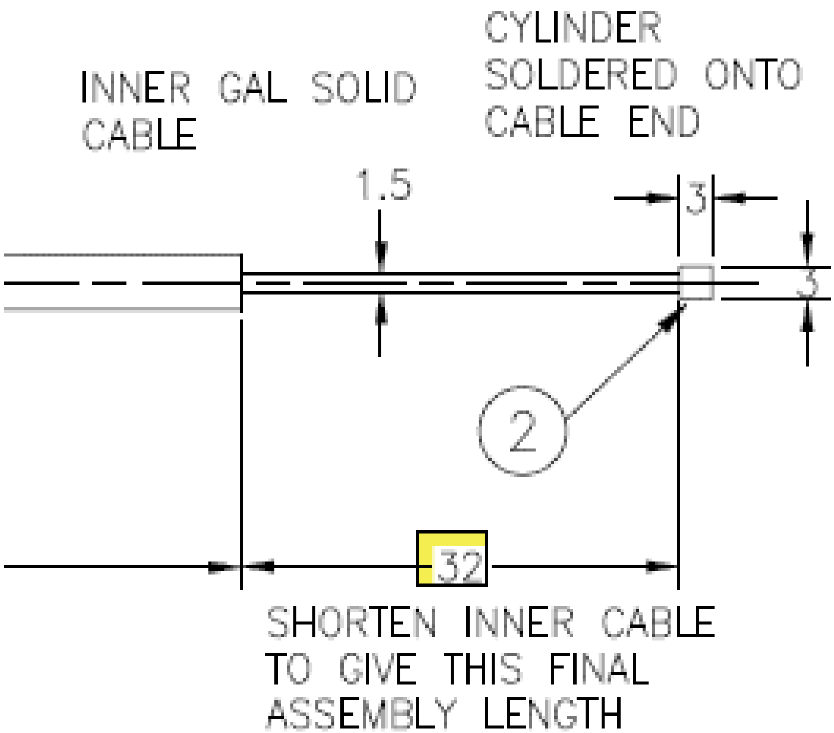

Figure 4: Choke cable end drawing

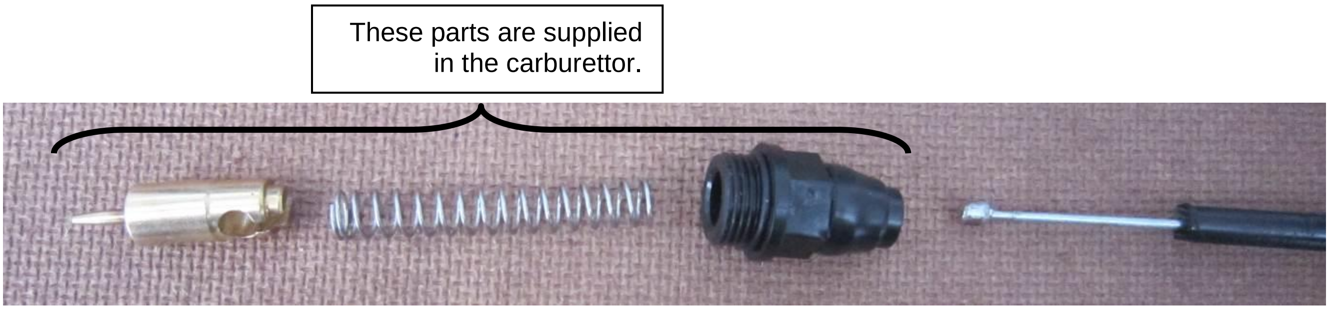

Figure 5: Choke cable end parts in order of assembly.

Figure 6: Choke cable end assembled.

Once the choke parts are assembled onto the end of the cable, slide into the carburettor and screw in the retaining nut. Finger tight plus 1/8 of a turn is all the tightening that is required.

2.2 Ignition and Starter Systems

- The only electrical controls for the Jabiru Engine are the ignition switching and the start button or starter key.
- The ignition switches earth the corresponding coil to ground, to turn the coil off.
- The starter button provides 12V to the starter solenoid, when pressed, for engine starting.
- Section 4 gives details of the electrical systems for the engine.

3 Engine Crankcase Breather, Catch Bottle and Dipstick

- The Jabiru 2200 and 3300 Gen4 engines have a crankcase breather connection built into the dipstick housing. This is to be connected as shown in Figure 7 below.
- The catch bottle is designed to catch most oil vapour from the crankcase breather air. It must be monitored in service and periodically emptied of waste oil.
- Figure 54 shows more clearly the outlet from the catch bottle – the catch bottle outlet is secured in the cowl outlet. The position of this outlet and the catch bottle itself must be assessed and oriented so that the crankcase of the engine is exposed to pressure close to ambient. If the breather is open to a high or low pressure (partial vacuum) area the pressure inside the crankcases will also change, with unpredictable effects on engine oil consumption, and oil flow within the engine. This is because several areas of the engine are lubricated via low pressure or spray oil feeds and drained by gravity – pressure differences cause airflow changes, and modified airflow can significantly affect the oil feeds in these areas.
- When installed in a tail-dragger aircraft, re-calibration of the dipstick will be required by the owner so that it can be read accurately with the aircraft sitting on its wheels.

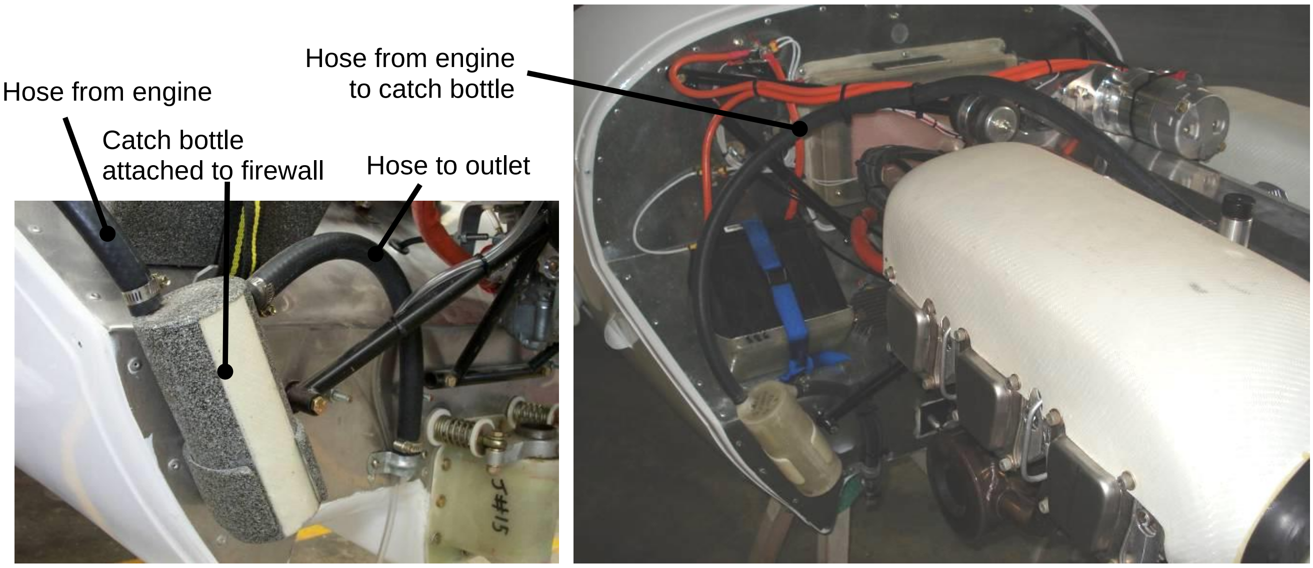

Figure 7. Crankcase Breather Installation

4 Electrical Equipment

4.1 Alternator

- The alternator fitted to the Jabiru 2200 engine is a single phase, permanently excited with a regulator.
- The rotor is mounted on the flywheel and the stator is mounted on the alternator mount plate at the back of the engine. The alternator mount plate is also the mount for the ignition coils and the vacuum pump.
- Note: The electrical system is Negative Earth

Specifications

Power (Max): 200W Continuous (approx. 18 Amps)

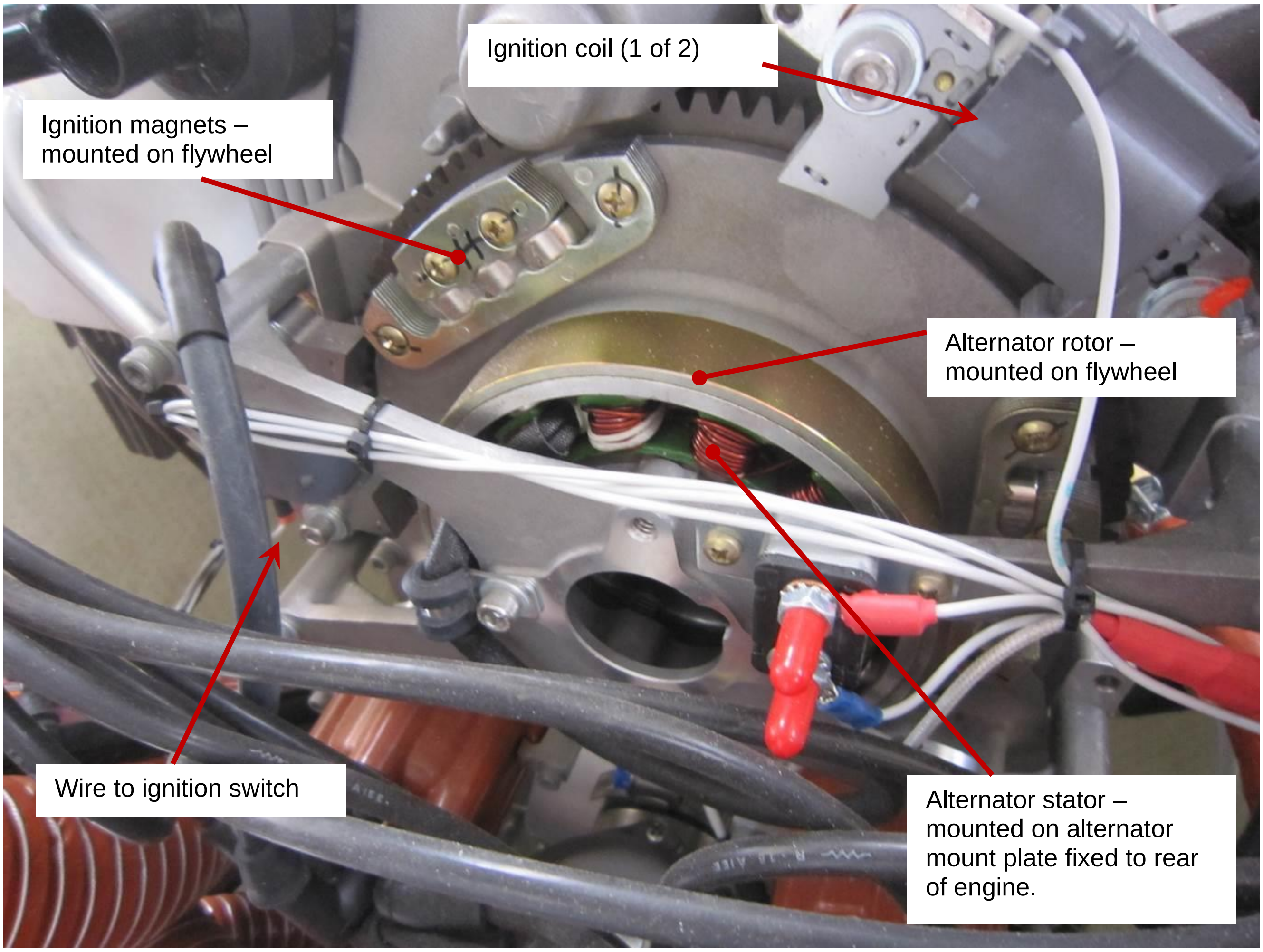

Figure 8. Ignition and Alternator Detail

4.2 Regulator

- The regulator has been selected to match the voltage and current of the integral alternator. Only Jabiru supplied regulators should be used. (The regulator charge voltage is 14.5 volts + 0.1 volt.).
- Recommended wiring of regulator is positive and negative of the regulator directly to the battery. A 30A fuse or circuit breaker may be used between the regulator and battery
- The voltage sense wire should be connected directly to the battery via a separate wire. Note: The JA11E regulator has a small current draw when off. If the aircraft is to be stored for a more than a month disconnect the battery.

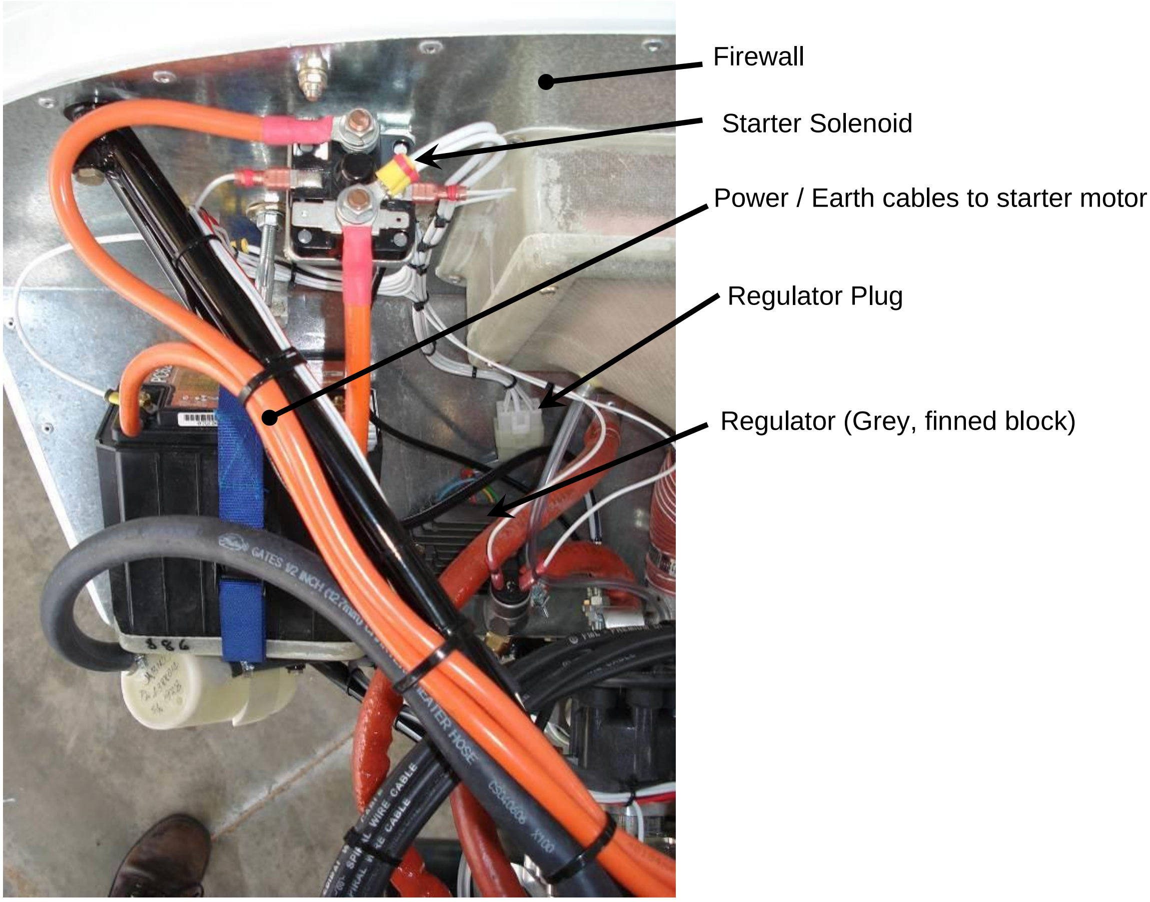

Figure 9. Electrics Installation to Firewall

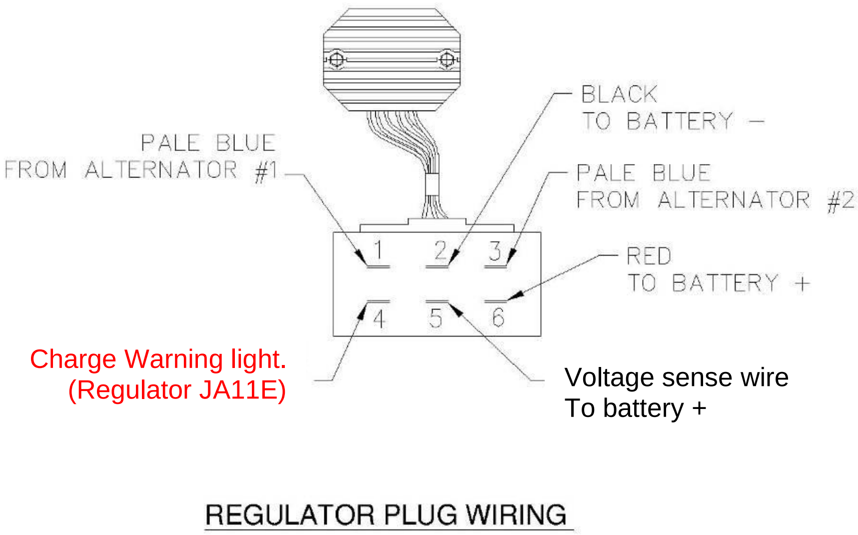

Figure 10. Regulator Plug Wiring Details

4.3 Ignition

- The ignition unit has dual breakerless transistorised ignition with the magnets mounted on the flywheel and the coils mounted on the alternator mount plate. Figure 8 shows the coils of a Jabiru 6-cylinder engine. For the 2200 engine the system is the same, however the position of the coils and the magnets on the flywheel are slightly different.
- The current from the coils flows to the distributor from where it is distributed to the spark plugs.

- The ignition is turned OFF by grounding the coils via the ignition switches. This is the reverse of most electrical systems: when the ignition switch is in the open (not connected) position the coil is LIVE and will fire. Wiring details are shown in Figure 13
- The ignition is timed to 25° BTDC. Ignition timing is fixed – it is set by the position of the flywheel magnets relative to the crankshaft.
- The temperature limit for the ignition coils is approximately 70°C. This should be checked by the installer. It is recommended that pipes of 12mm dia be fitted to the top rear of each air duct directing air onto the coils for cooling purposes.
- Coil gaps are set at 0.25mm to 0.30mm (0.010" to 0.012").
- When installing new ignition coils the output leads go in the direction of prop rotation. RHS coil output lead is up LHS coil output lead goes down – See Figure 8.

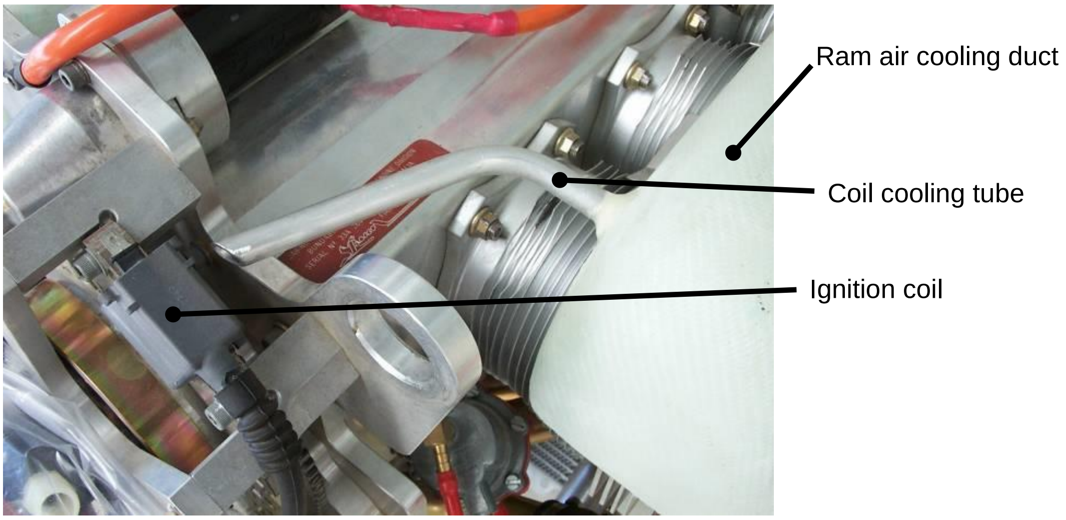

Figure 11. Ignition Coil Cooling Tube

4.4 Starter Motor

- The starter is mounted on the top of the engine and drives the ring gear on the flywheel.
- The motor is activated by engaging the starter button (the master switch has to be ON) which trips the solenoid, hence current flows from the battery to the motor.
- The cable from Battery to starter should be minimum 16mm^2 copper.
- Wiring details are shown in Figure 13.

4.5 Starter Solenoid

- The starter Solenoid is mounted on the firewall as shown in Figure 9.
- The Solenoid body forms a part of the electrical circuit and MUST be earthed to function correctly.

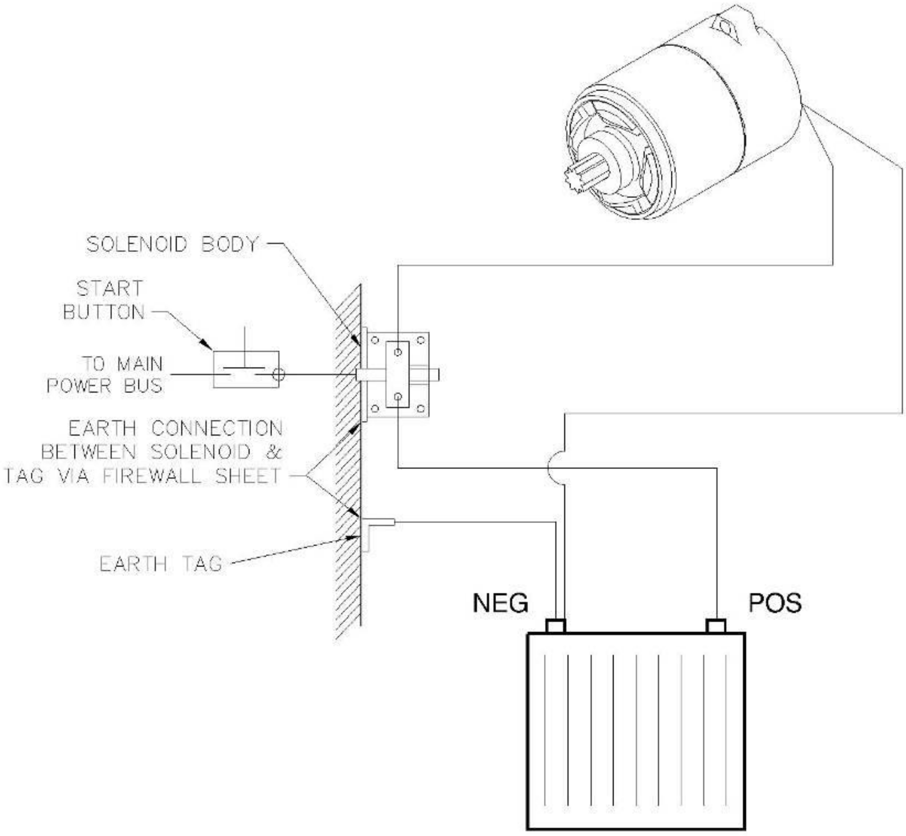

Figure 12. Starter Wiring Details

4.6 Battery

- The battery should be of a light weight, 12V, 20 Ah type able to accept a charging voltage up to 14 V (+ 0.8V) and a 30 AMP Input.
- For optimum starting the battery used must have a high Cranking Amp Capacity (also known as Pulse Amp Capacity). The standard battery used by Jabiru Aircraft has a Pulse Amp rating of 625 Amps. Batteries with higher Pulse Amp ratings may be used and will improve engine starting in colder climates.
- Only use lead acid batteries as this is what the alternator regulator is designed to use. **Do not** use other battery chemistries (e.g. Lithium). Possible consequences include a battery fire.

4.7 Wiring Practices

- Using aircraft grade wiring is strongly recommended. Compared to other grades of wire aircraft grade can carry higher currents for the same physical size and weight. The insulation used on aircraft grade wire is also frame resistant and is designed for better resistance to damage caused by chaffing or rubbing.
- Care should be taken to identify each wire via labels or similar. This makes troubleshooting electrical issues much easier.
- Wherever possible wires should be identified as carrying “Power” or “Earth”. This can be done by using different colour connectors or applying rings of coloured heat-shrink during assembly. Again, this step simplifies troubleshooting or later modification.
- Wires should be laid out in bundles and supported along their length to prevent failures due to fatigue.

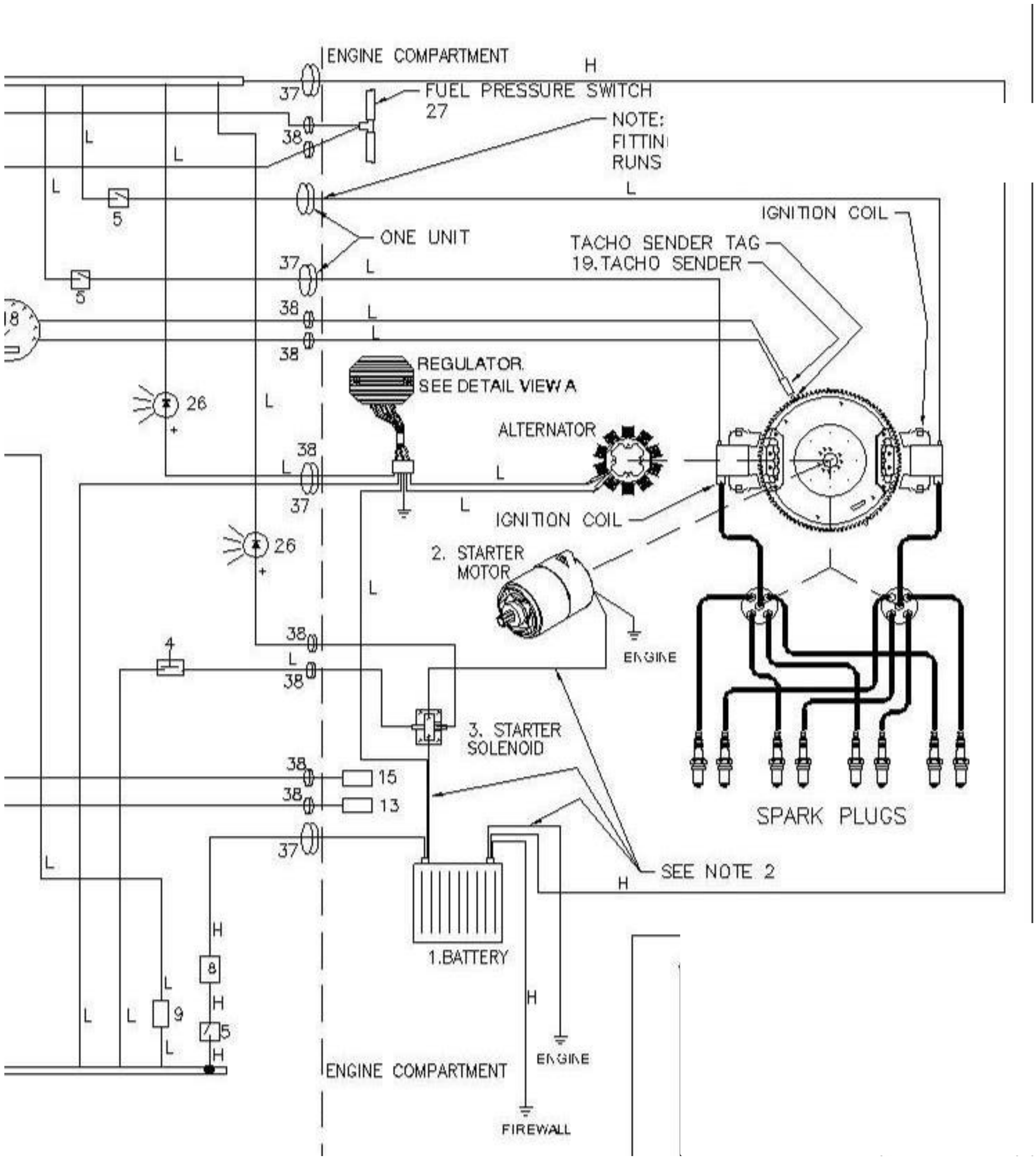

Figure 13: Example of engine wiring connections.

4.8 Instrumentation

4.8.1 RPM

- The engine can be fitted with a Hall Effect Sender as Gen 4 engines are not fitted with a mount for an inductive pickup.

Hall Effect Sender Installation

- The inductive pickup works with the VDO tachometer as stocked by Jabiru and also with some electronic engine monitors.
- The Sender senses the magnetic fields of the ignition magnets as they pass.
- Mounts to the unused coil mount location on a Gen 4 engine.
- The output signal from the sender is a 0 – 12V square wave with a rising edge each time the magnet passes.
- This sender requires 12V power.
- Set tachometer or EMS to 2 pulses for 2200 and 3 pulses for 3300.
- Check the tacho reading at cruise rpm. On a VDO tachometer the pulses can be adjusted by increments of 0.01 to correct any error.

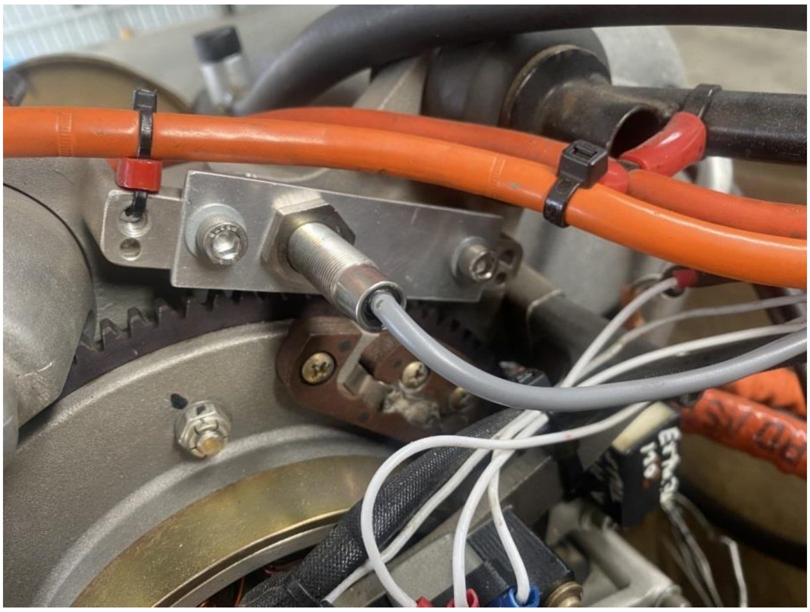

Figure 14: Hall effect sender location on 2200 engine.

Figure 15: Hall effect sender mounting location on 3300 engine.

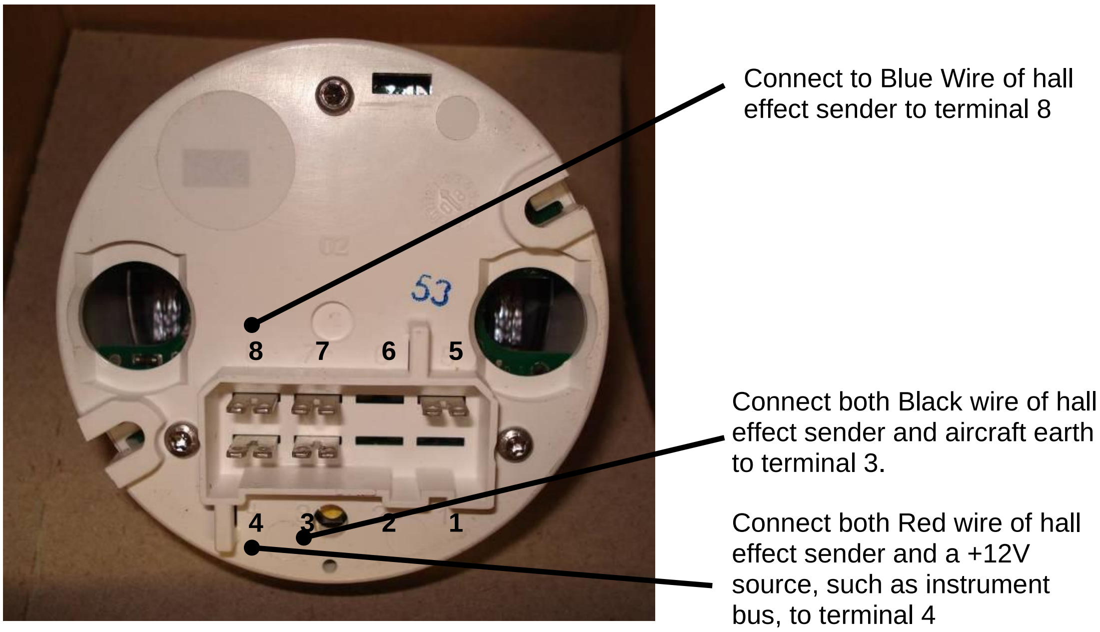

Figure 16: Hall effect sender connections.

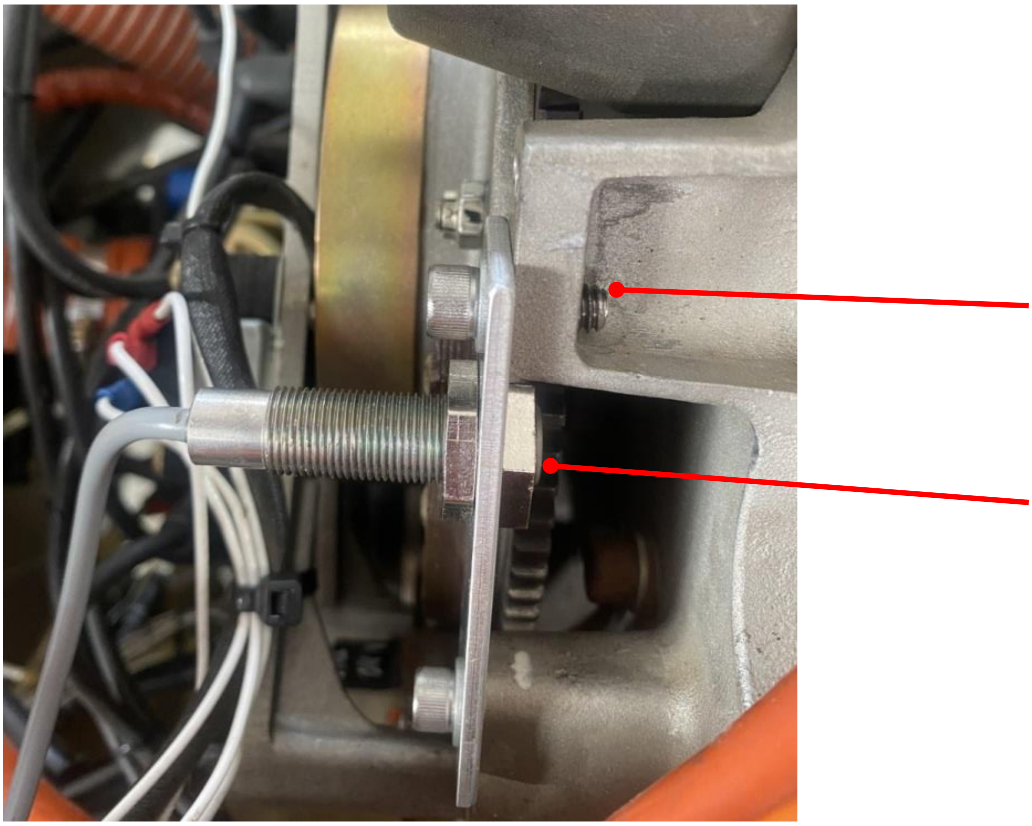

Figure 17: Sender position.

Alternator pulses

- Many Electronic Engine monitoring systems (EMS) can read the pulses from the ac voltage generated by the alternator to measure engine rpm.
- Read EMS instructions carefully as some require resistors or fuses in this sense wire to protect the instrument.
- If your installation uses the JA11E regulator the sense wire needs to have a capacitor of approximately 47uF install in line. This is in addition to the resistor that some EMS's require.

4.8.2 Oil Temperature Sender

- The Oil Temperature Gauge uses an electric probe mounted in the base of the sump. Jabiru supplied oil temperature senders are recommended which will work with the Jabiru supplied analogue oil temperature gauges and many EMS systems. Jabiru also supply Dynon oil pressure senders for Dynon EMS.
- The temperature sender is a brass fitting installed in the engine sump beside the drain plug.
- A female spade connector is used to connect to the tip of the sender (if insulated the insulation will need to be cut away.).
- This temperature sender is an NTC thermistor.
- The sender operates from 50 -150 °C in the resistance range 323 to 18Ω. (This isn't a linear response)
- The oil temperature relies on a good earth connection between the sensor, the engine and the airframe earth terminal. If there is excess resistance at any of these points gauge reading errors will occur.

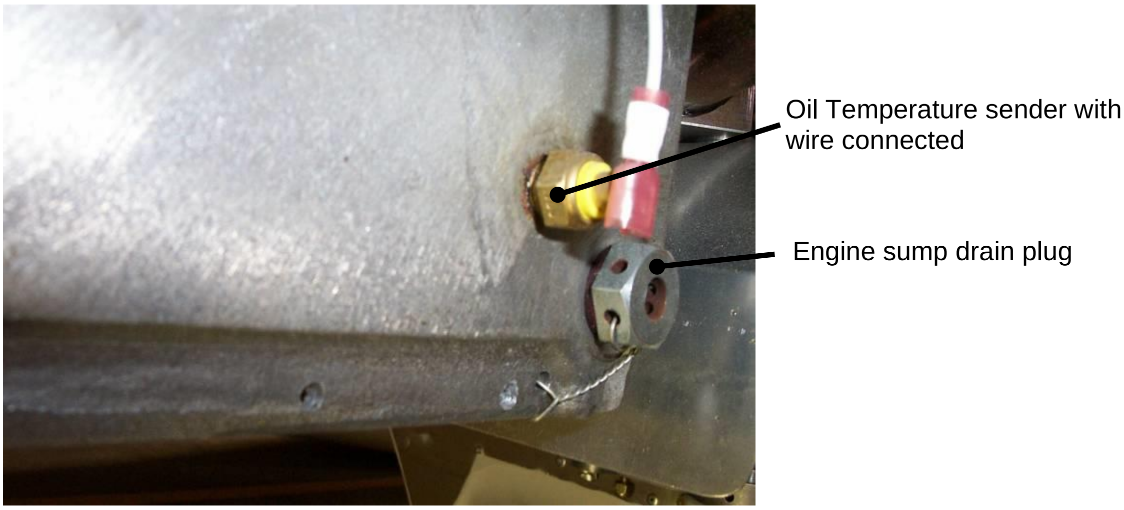

Figure 18. Oil Temperature Sender

4.8.3 Oil Pressure Gauge

- An electric oil pressure sender is fitted to the engine for an Oil Pressure Gauge.
- On the oil pressure sender the terminal labelled G is for oil pressure. If sender has a WK terminal, this is for an oil pressure warning light.
- The standard Jabiru sender is 0 – 5 bar and 10 – 180 ohms. (This is linear).
- The gauge has 3 pins, one marked "+" – which is connected to power, one "S" – which is connected to the sensor and one un-marked – which is connected to earth.

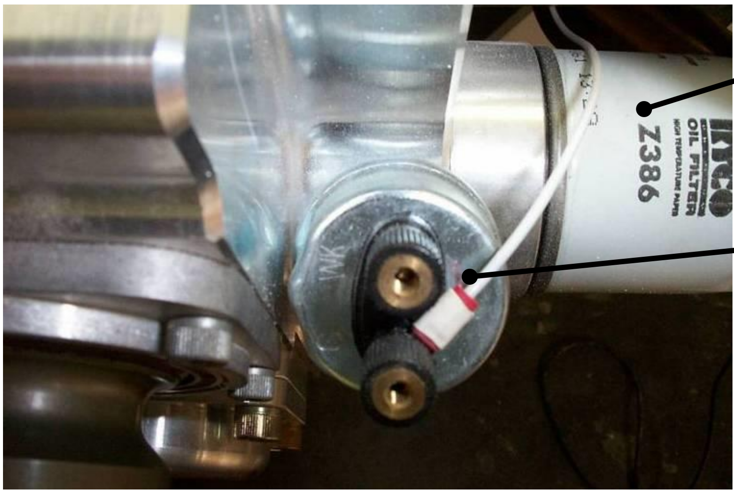

Figure 19. Oil Pressure Sender

Figure 20. Oil Pressure Connections

4.8.4 Cylinder Head Temperatures

- The cylinder head temperature (CHT) is measured using a thermocouple which is installed on a screw on between the spark plugs. (Figure 23)
- The head temperatures of air-cooled engines are typically quite variable – differences of 50°C (90°F) between the hottest and coolest head are not uncommon. Refer to Section 12 for additional information on cooling.
- It is recommended that all cylinder head temperatures are monitored. If only one CHT will be used an audit must be done to establish which is the hottest cylinder. The CHT thermocouple is then fitted to that cylinder. Cylinder number 4 often runs hottest in normal tractor installations, however for new installations this MUST be checked and confirmed. The parts supplied by Jabiru are recommended.
- If a single CHT gauge, Loom and Thermocouple sensor are purchased from Jabiru, these must be installed as per the instrument manufacturer's directions. If the cable is too long it must be looped as many times as necessary and strapped behind the instrument panel. **Do not cut to length**. No power connection is required – the instrument reads directly off the voltage created by the thermocouple wire.
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  The Thermocouple sensor works by reading small voltages generated by the sensor wires, and cutting the wire upsets the instrument's calibration.

- If a system that monitors all CHTs is used, it is recommended that the thermocouple is extended using thermocouple extension wire.
- Ensure that wire is not chaffing on the fibreglass air duct or cooing fins.

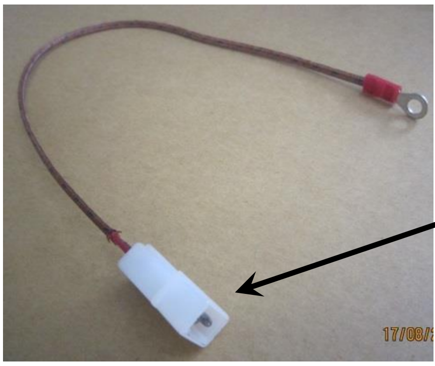


Figure 21: VDO CHT sender.

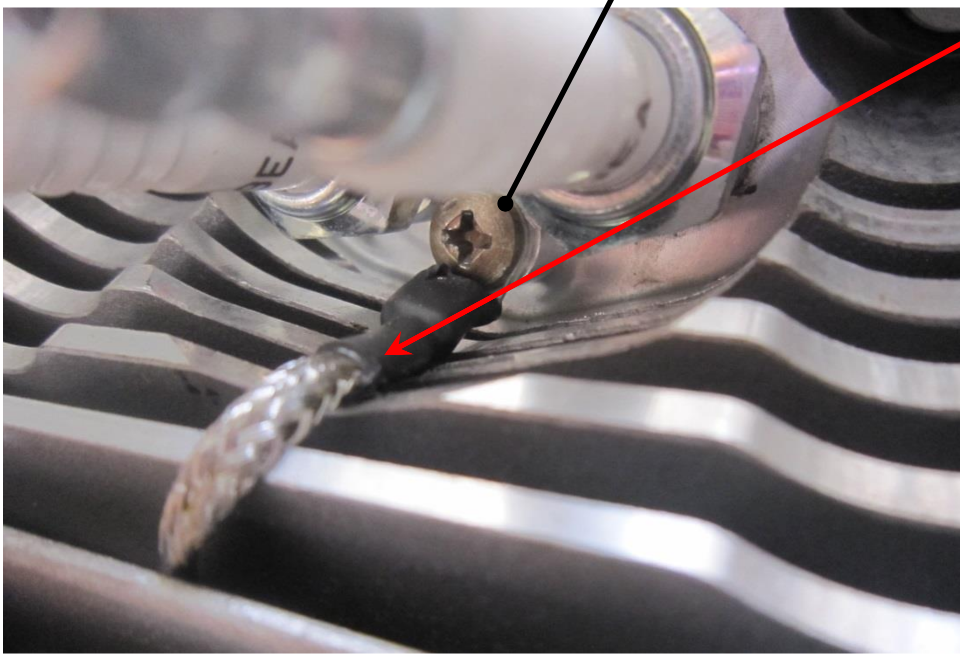


Figure 22: CHT Sender (Thermocouple) Installation

4.8.5 Exhaust Gas Temperatures

- Exhaust Gas Temperature Sensors can be fitted. It is recommended to monitor all the egt on all cylinders. This will enable help with checking engine tuning intitially, and monitoring for changes throughout the life of the engine.
- The probe should be positioned 120mm from the port flange on the exhaust pipe.
- EGT sensors use thermocouples. For accurate measurements thermocouples should be extended with thermocouple extension wire rather than copper wire.

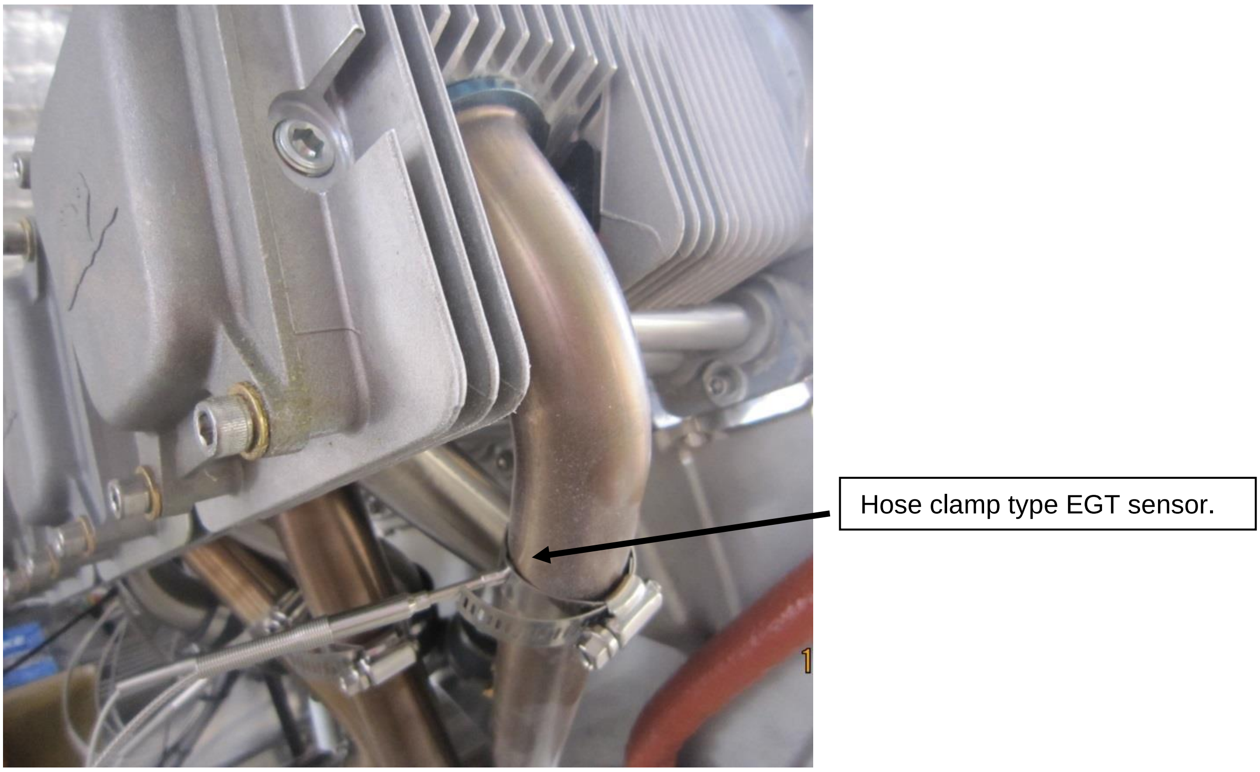


Figure 23: EGT sensor installation example.

4.9 Radio Frequency (RF) Noise Reduction

- RF noise is a common problem with aircraft. Symptoms include:
  - i. Radio squelch setting needs to be high
  - ii. Excess noise in the background during transmissions
  - iii. Squeals or other feedback noises heard during transmission
  - iv. Intermittent static or noise breaking through the squelch.
- RF noise is a complex problem and is influenced by many different factors. The following points do not contain everything there is to know about RF noise, but they are given as recommendations of general good practice to minimise its effect.
- Ensure all connections, particularly engine earths, are clean and un-corroded.
- If the aircraft has a metallic firewall it can be used as a shield to block the majority of RF noise. To be most effective any wire that passes through the firewall should be fitted with a Ferrite Bead (also known as a Suppressor or RF Suppressor). Bundles of wires can have a single large Suppressor fitted rather than a Suppressor for each wire. The wiring diagram in Figure 13 shows suppressors in schematic form. These suppressors are readily available at local electronics stores.
- A Noise Filter can be fitted to the radio's power supply. Again, these filters are readily available from local electronics stores. The manufacturer's instructions must be followed for installation.
- Cables passing through the firewall (such as throttle cables, choke, carburettor heat and cabin heat cables) can transmit RF noise back into the cabin. This can be minimised by earthing the cables at ONE end. On the Jabiru Engine an earth wire is provided connecting the carburettor to the rest of the engine, so the throttle and choke cables are connected to earth through this wire.
- It is normal and unavoidable that the engine's ignition system produces some RF noise. This can be minimised by:
  - i. Ensuring all spark plug gaps are set properly.
  - ii. Ensure ignition coil gaps are set properly
  - iii. Ensure all high-tension leads (Spark plug leads) are firmly fitted at both ends – to the spark plug and to the distributor. In addition, the lead from each ignition coil to the distributor must be firmly fitted to the distributor.
  - iv. Ensure Distributor caps and rotors are in good condition.

- To counteract RF noise, Jabiru Aircraft run shielded wiring on all radio and intercom wiring. In our experience, the “Earth Return” method of shielding (where the shield for the wire is also used to form the earth connection) does not work as well as the “Faraday Cage” (where the shield is a shield only – it is not a part of the circuit) method of shielding
- “Earth Loops” – where a wire is connected to earth at both ends – can introduce RF noise into the system. All shields should be connected to the aircraft’s earth system at one end only.
- The cable used for the Antenna should be high quality, such as RG400 (Shown in Figure 24). This cable has a double layer of shielding and better RF insulation than other cable types. Note that the coaxial cable included in most antenna kits tends to have a single layer of insulation. BNC connectors are recommended for most applications, and wherever possible crimped connectors which require a special crimper to assemble should be used. Crimped connectors are much less prone to RF leakage or assembly issues than other types (such as screw-together BNC connectors).
- Wires and antenna cables must be routed carefully. Bending or coiling Co-axial cable (such as is used for antennas) sharply will significantly degrade the cable’s RF shielding and must be avoided wherever possible. Coiling antenna cables or any wire carrying current (sensor wires carry very low current so are generally exempt from this requirement) into loops can induce RF noise in other systems. GPS antennas in particular are powered – both the antenna and any excess antenna cable must be positioned carefully, as far away from the radios, antennas and intercom as possible.
- While not a part of the engine installation, strobes can produce significant RF noise. Most brands of strobes require that the box containing the strobe head unit electronics is earthed, and this is essential to minimise noise. The cables used for the strobe lights themselves must be shielded and the shield must be earthed properly, at ONE end only. The Box containing the strobe electronics can also be installed on the engine side of the firewall to further reduce RF noise. The strobe unit’s manufacturer normally provides good instructions for minimising their effect on radio noises.

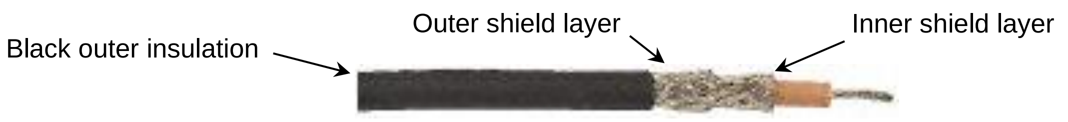


Figure 24. RG400 Co-Axial Antenna Cable

5 Fuel Supply System

5.1 Fuel Tank

- The fuel tank must be fitted with an outlet strainer of between 8 and 16 mesh per inch, with a minimum total mesh area of 5 cm^2.
- Ensure the fuel tank is properly vented.

5.2 Fuel Filtration

- A Fuel filter capable of preventing the passage of particles larger than 0.1mm (100um) must be installed between the fuel tank outlet and the fuel pump.
- The filter must be present in the system for the fuel flow test. The size of the filter should give consideration to allow adequate flow with a used filter.
- A Ryco Z15 disposable paper element automotive filter has been used successfully. Note that this filter, or any other filter with a plastic body must not be used on the engine side of the firewall – regulations and common sense both require that all fittings in the fuel system on the engine side of the firewall must be fire resistant.

5.3 Mechanical Fuel Pump

- The mechanical fuel pump is mounted on the engine crankcase and is camshaft driven. It is designed to supply fuel at the pressure described in the following paragraph.
- Many airworthiness categories require that a backup fuel pump be fitted in case the primary pump fails. Jabiru Aircraft recommend fitting an electrical boost pump. If fitted, this pump must also fulfil the fuel input criteria for the carburettor, given below.
- Some airworthiness categories also require an additional drip tray be fitted to the fuel pump. This optional tray is shown in Figure 25.

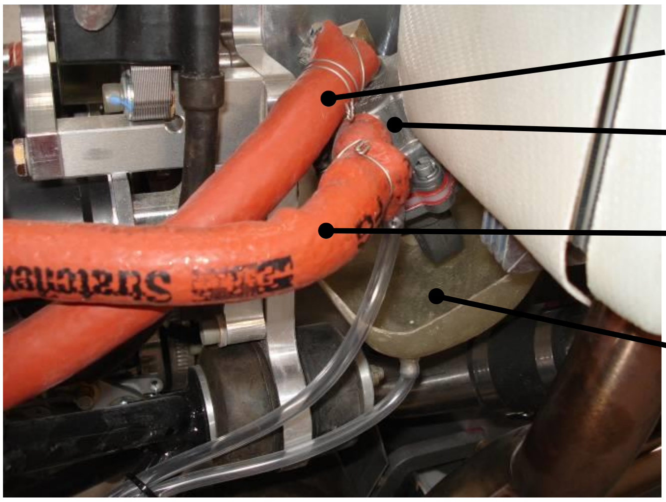


Figure 25. Mechanical Fuel Pump

5.4 Fuel Flow Meters

- Where a Fuel Flow Meter is to be installed to the aircraft, Jabiru Aircraft recommend that the flow transducer is not installed on the engine side of the firewall. Most transducers are made of either plastic or light aluminium and are not fire resistant. Regulations and common sense both require that every part of the fuel system on the engine side of the firewall must be fire resistant. If a fuel flow meter must be installed on the engine side of the firewall it could be inside a metal enclosure or wrapped in fire-sleeve.

5.5 Carburettor

- A constant depression carburettor designated PD42J is used. This carburettor has a minimum delivery pressure of 13.7 kPa (2 Psi) and a maximum pressure of 34.5 kPa (5 psi). WARNING

When using auto fuels, the fuel delivery system must be designed to prevent fuel vaporization.

To check pressure, insert a 'T' piece between the mechanical pump and carburettor. Test boost pump with engine off, then mechanical fuel pump with engine on, then combine with electrical boost pump as well, before first flight.

- A method for performing a fuel flow test is available from Jabiru if required. In brief, the fuel line is disconnected from the carburettor, fuel is pumped into a calibrated container and the rate at which the fuel is pumped (or drained, for gravity-fed systems without a pump) is calculated.
- Most regulations require that the fuel system (including pumps) supplying the engine be capable of delivering 1.25 to 1.5 times the maximum flow rate required for the engine. See engine specifications in Maintenance Manual JEM0005. The electric boost pump used on Jabiru Aircraft generally manages a flow rate of approximately 60 litres per hour.
- The PD42J carburettor has a vent port for the diaphragm that moves the slide. This needs to be connected to the induction system. Both 2200 & 3300 engines must use an induction adapter (cobra head) supplied by Jabiru.
- If a non-standard cobra head is required, contact Jabiru.
- EGTs should be checked for correct mixtures.
- 

Figure 26: 3300 cobra head. (other bends are available)

- A drip deflector to deflect overflowing fuel from the exhaust system is supplied as standard equipment on the engine.
- Because idle adjustments cannot accurately be made on the dynamometer (the testing equipment for every engine run before dispatch), some adjustment of the 7mm idle set screw may be required. A hot idle of around 900RPM (2200) or 800RPM (3300) is desirable.
- An earth strap from carby to crankcase fitted to eliminate possible radio interference.

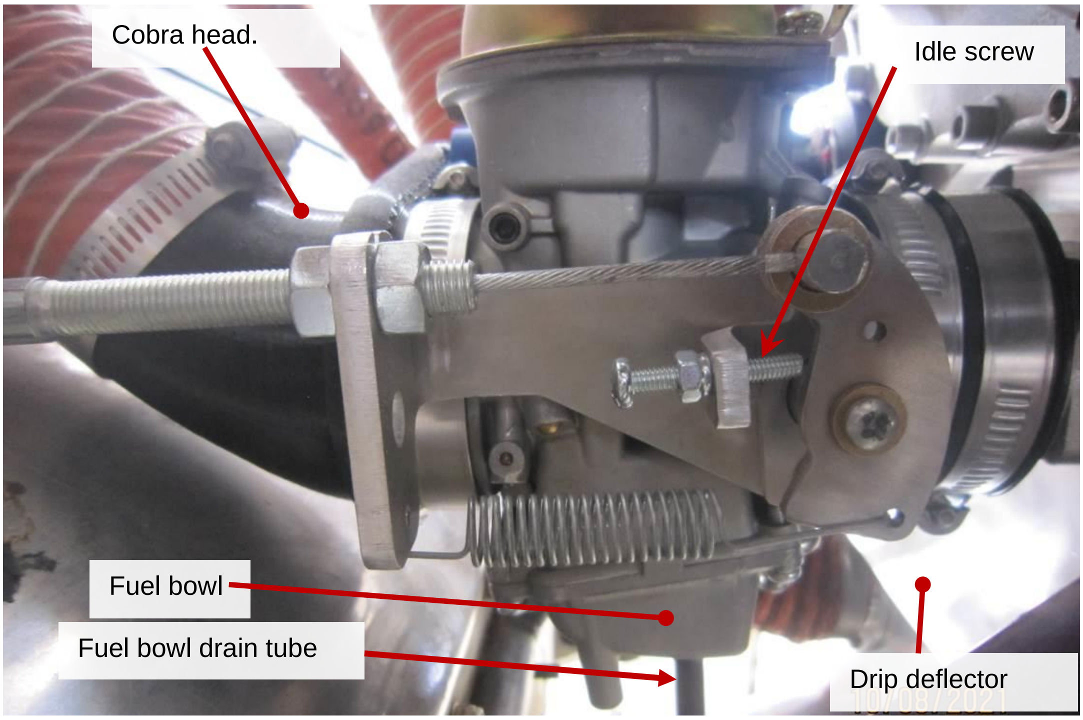
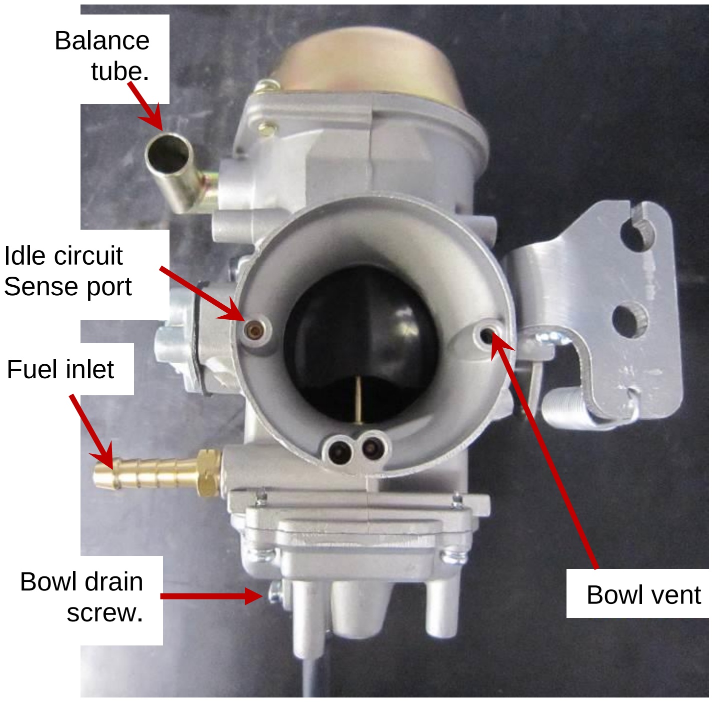


Figure 27. Carburettor Installation



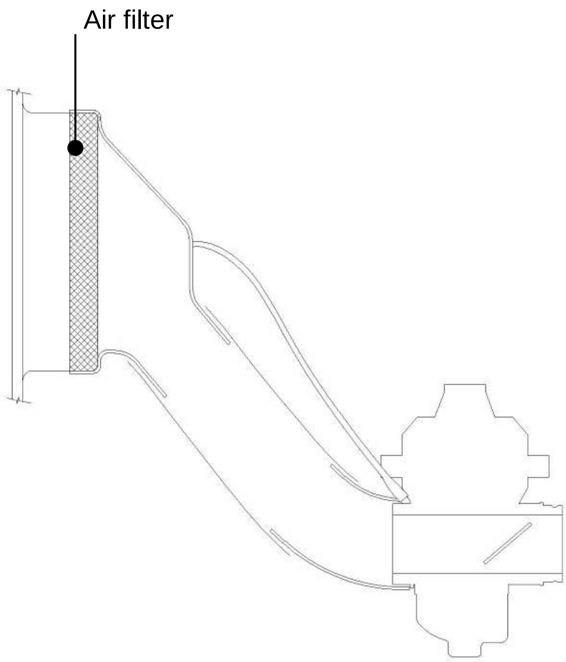


Figure 28. Carburettor Intake and Airbox Detail

5.5.1 Carburettor Operation

- The PD42J carburettor uses bowl float level and two main air circuits – the idle and the needle/main – to control the mixture. Both circuits use jets to meter the rate at which fuel is allowed to flow. The jets are small brass parts with precisely controlled openings (both the size of the opening and the shape surrounding the opening affect fuel flow rate) which can be changed to adjust engine mixture.

- The main and idle jets have simple fixed apertures, while the effective size of the needle jet aperture varies, depending on the diameter of the needle. Figure 29 below shows three different throttle settings in the needle jet and the corresponding difference in aperture. On the left is a low power setting, where the needle jet is nearly completely blocked by the needle. The middle throttle setting corresponds approximately to a high cruise power setting. The gap between the needle and the sides of the jet is much larger. The final setting corresponds approximately to wide open throttle. The needle jet is now effectively not there, and the amount of fuel flowing is controlled by the main jet (located upstream of the needle jet in this circuit).
- The shape of the taper of the needle controls the mixture at a given throttle setting. The needle used in Jabiru engines has been optimized for use with a propeller, which puts a very non-linear load on the engine; to double the RPM of a propeller a lot more than double the power has to be applied.
- To achieve a good mixture with the type of load applied by a propeller, the Jabiru needle uses two-stage taper and a straight tip. The more gradual taper at the upper end of the needle gives a leaner mixture in low-power cruise settings and at lower RPM where the propeller is using relatively little power. The sharper taper at the lower end ramps up rapidly to a much richer mixture at higher power settings. The straight tip of the needle is used when the throttle is wide open and the engine's mixture is being controlled by the main jet. This rich mixture at full power protects the engine from detonation.
- The transition from lean, cruise mixtures to richer full-power mixture will occur at around 2800 – 3000 rpm on 4 and 6 cylinder engines, when fitted with an appropriate propeller. For most efficient operation, the transition must be above cruise rpm. The transition can clearly be seen by changes in the EGT.

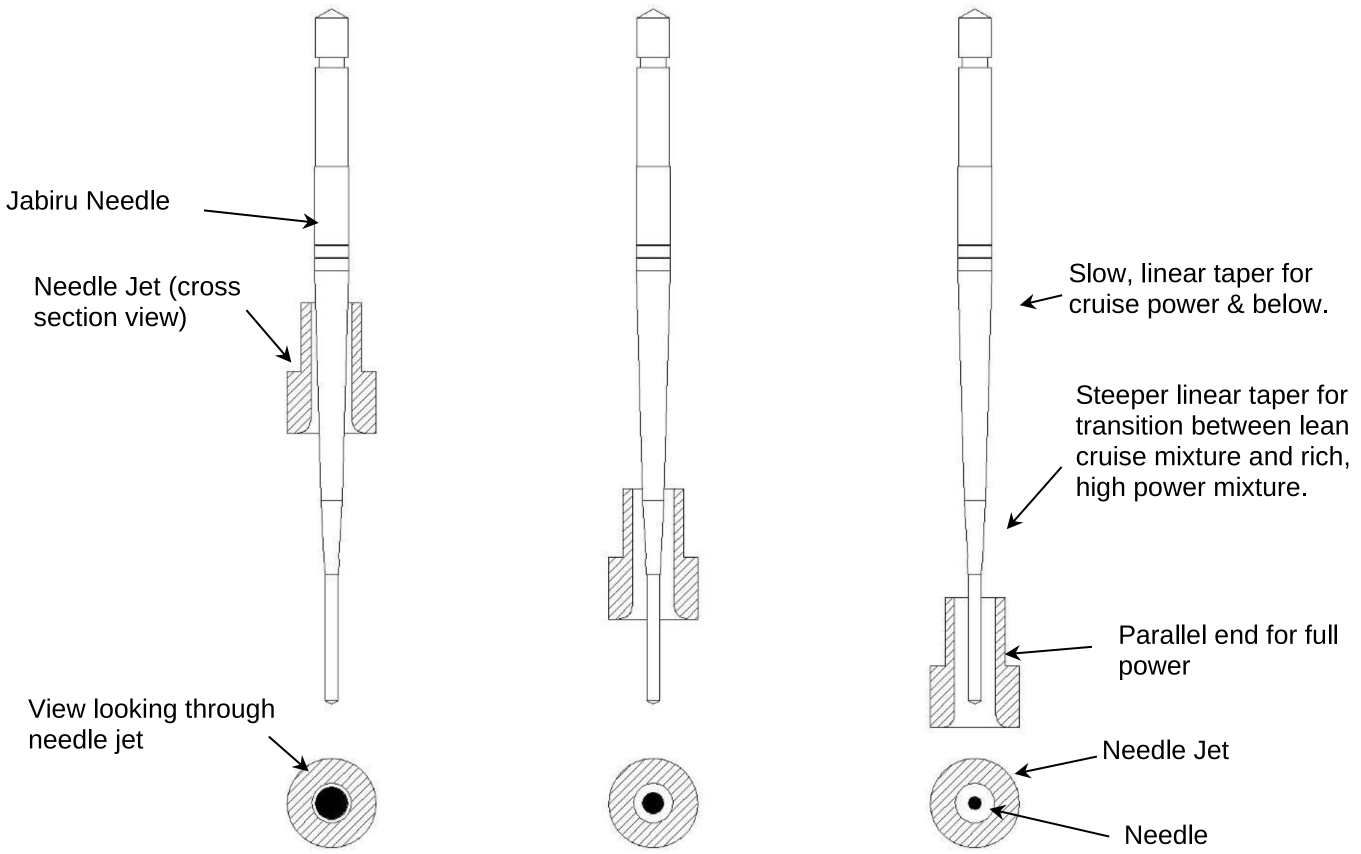


Figure 29. Needle Jet (Jabiru Needle)

- Because of the way the carburettor uses the sense ports and balance tube to regulate the mixture, it is sensitive to the way the intake air moves, and to the conditions of the intake system.
- Section 6 below contains information on setting up the induction system.

5.5.2 Carburettor Tuning

- The mixture supplied to the engine by the carburettor is affected by a large number of variables, including:
  i. Ambient temperature
  ii. Propeller size (coarse or fine) and loading

iii. Whether the engine is cowled or open (by affecting the temperature of the induction pipes and carburettor)

iv. The airframe type

v. The intake system

- Because of these factors, we recommend that whenever a new engine installation is being developed that the engine be fitted with EGT probes and the tuning checked.
- Jabiru Aircraft or our local representative can provide assistance during this phase.

5.6 Fuel Lines

- Fuel lines are nominally 6mm bore.
- All hoses forward of the firewall require fire resistant sheathing (visible as an orange covering on the fuel lines in Figure 25 above). Note that wherever possible the sheathing should be extended past the hose clamp. The ends of the sheath must be held in place using safety wire to prevent the sheathing moving and exposing the fuel line.
- Fuel lines between moving sections such as between engine and firewall should be flexible. SAE standard automotive rubber hoses are adequate, provided they are protected with fire resistance sheathing.
- In many countries (including Australia) standard airworthiness requirements state that all flexible hoses must be changed every two years, though if there are visible signs of degradation (such as cracking or hardening) the hose should be changed immediately.

6 Air Intake System

6.1 Intake Air Heating

- The Jabiru engines can experience carburettor icing in some conditions. Jabiru Aircraft strongly recommend that a system for heating engine intake air be included in the induction system design.

6.2 Intake Hose and Air Filter Box

- Jabiru Aircraft recommend that engine intake air be drawn from outside the cowl wherever possible.
- Due to the way the carburettor works (as described above) it is sensitive to the air flowing into it. Turbulence, swirl and sharp edges all affect the mixture metering system of the carburettor.
- The hose type recommended for induction systems is SCAT aircraft type.

WARNING

SKEET type, which has an inner liner must NOT be used. Over time the inner lining can detach and collapse, blocking the hose. SKEET hose should be used for positive pressure applications only.

- Tight corners in the hose (as shown in Figure 30) can introduce both swirl and turbulence to the air flowing into the carburettor.
- Use the supplied cobra head and connect the scat hose to that, from the airbox.
- Sharp corners inside the air filter box cause turbulence and a pressure drop. The pressure drop means that the carburettor balance tube pressure reading is inaccurate, while the turbulence affects the readings at the carburettor sense ports. Both items can cause power loss and rough running – particularly at high power settings.
- The intake hose should align as closely as possible with the carburettor body – having the intake duct come at the carburettor from one side encourages swirl and can give uneven mixture.

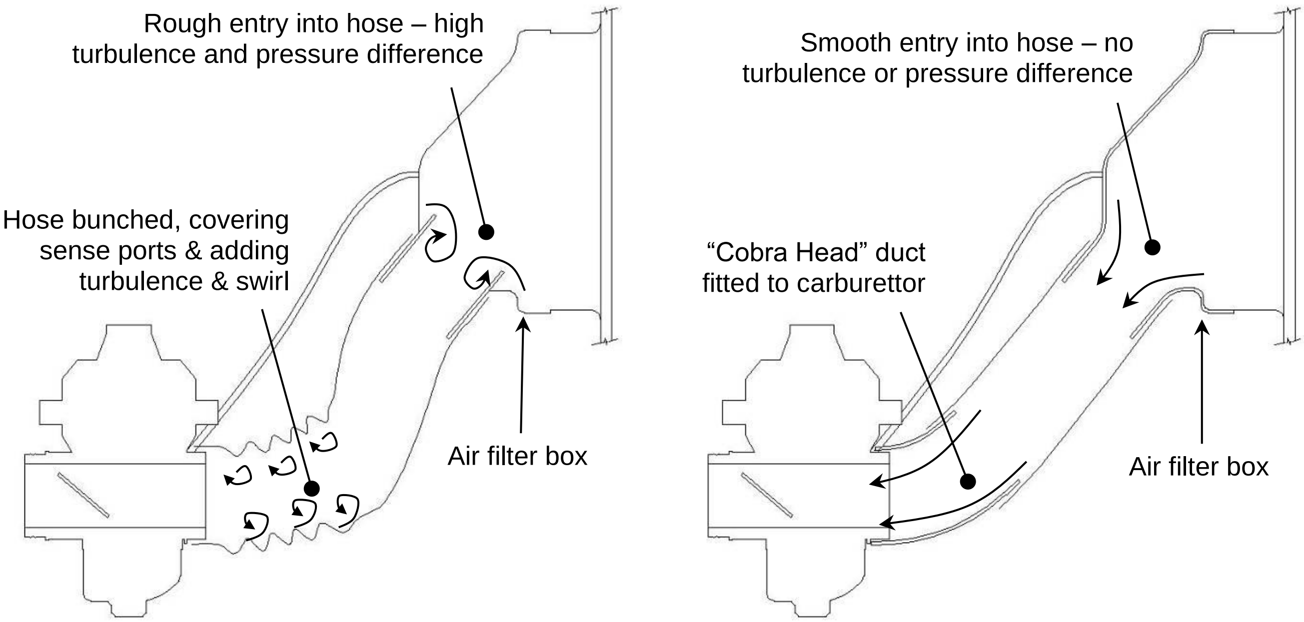


Figure 30. Air Intake Connections

Figure 31. Air Filter Box Plumbing – Incorrect

Correct plumbing – sharp lips & abrupt corners rounded & smoothed off.

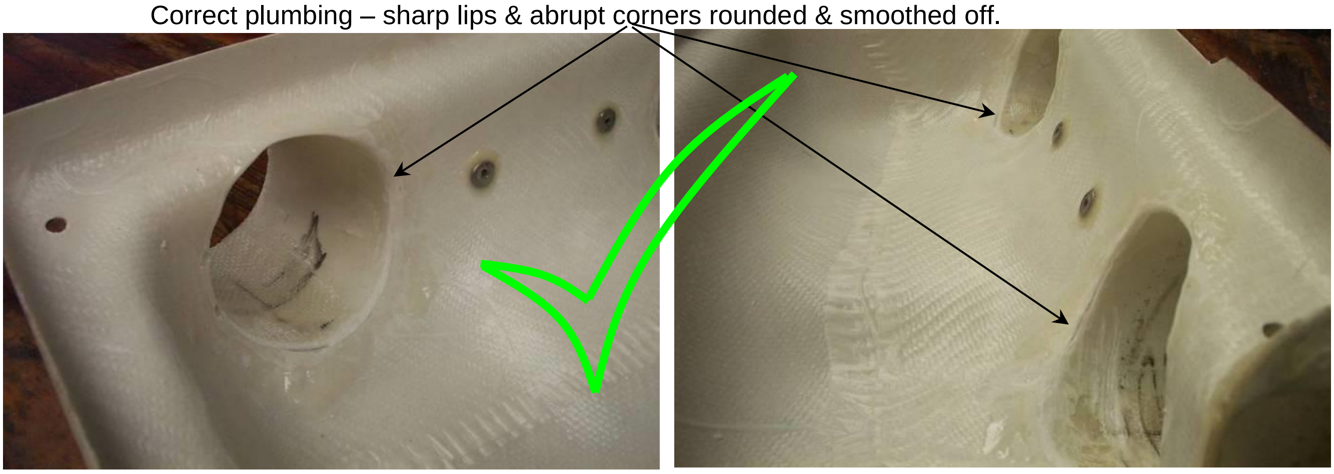
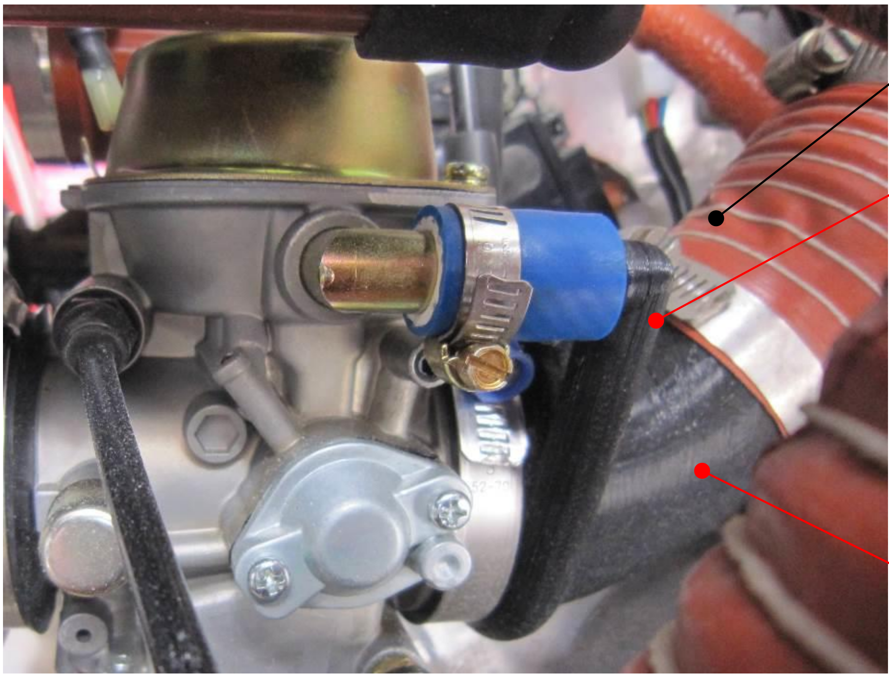


Figure 32. Air Filter Box Plumbing – Correct



Gradual bends only in SCAT hose

Balance tube port integrated in Cobra head helps with mixture stability.

Induction duct "Cobra Head" removes a sharp corner in SCAT tube and prevents bunched SCAT hose.

Figure 33. Typical "Cobra Head" Installation on a Jabiru Aircraft

6.3 Air Filter

- The induction system must not cause positive RAM induction pressure as this will have an unpredictable affect the fuel/air mixture supplied to the engine.
- The filter must be capable of supplying 250 kg/hr (550 pph) of air
- The filter may have to be changed at regular intervals if the engine is to be used in a dusty environment.
- Air flow should be as direct as possible, no tight bends and air taken from outside the cowl. The air filter supplied by Jabiru is recommended.

6.4 Ram Air Bleed

- The hot air mixer box / filter boxes manufactured by Jabiru Aircraft have a Ram Air Bleed flap incorporated.
- This flap prevents excess ram air pressure in the induction system.
- If the engine ever backfires, the flap also acts as a relief valve to let the excess pressure escape without damaging the induction system.

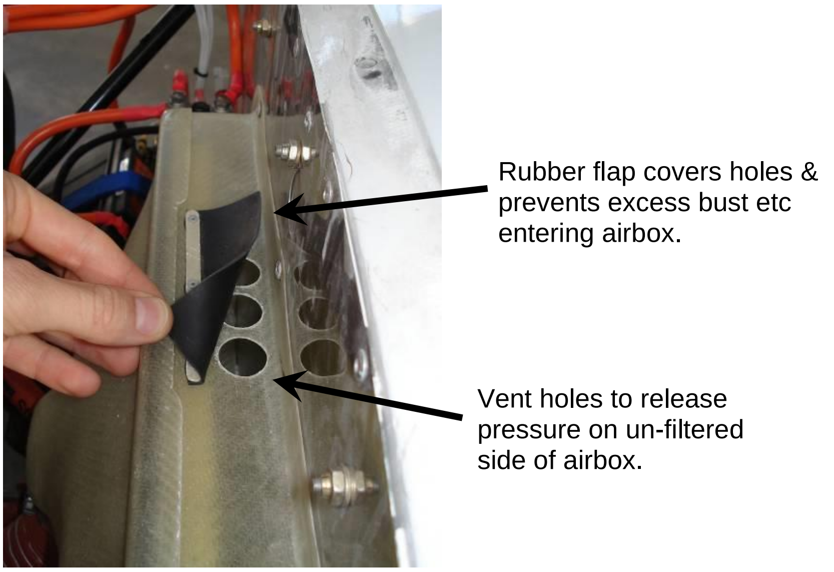


Figure 34. Ram Air Bleed

7 Exhaust System

- An exhaust system is provided with the engine. Both Pusher and Tractor systems are available.
- Muffler Volume – Capacity 3 litres
- Back pressure at Takeoff Performance – Max 0.2 bar (2.9 psi). Readings taken 70mm from muffler flange connections. Only complete mufflers supplied with Jabiru Aircraft are welded – all others require tail pipes to be TIG welded to the muffler body. NOTE: Drilled ends of pipes go inside muffler cavity. The tail pipes go completely through the muffler body and are welded on both top and bottom.
- When fitting the muffler one or more of the exhaust pipes can be loosened at the connection to the cylinder head to allow easy fit of the muffler. They then must be tightened.
- Exhaust Gas Temperature (EGT) limits are given in JEM0005

8 Propeller and Spinner

When choosing a propeller for your Jabiru engine installation, a Jabiru approved propeller is recommended. Propellers that aren't approved have additional maintenance requirements. Many propeller brands and models **are not approved by Jabiru Aircraft**. In certain categories operators, may choose to use these propellers; **however they do so at their own risk**. For information on which propellers are approved, please contact Jabiru P/L or our local representative. (See maintenance manual JEM0005).

Installation and maintenance instructions for Jabiru propellers can be found in manuals JPM0001 and JPM3L01.

If choosing a propeller other than those sold by Jabiru:

- The hub of the propeller must be drilled with holes to match the flange.
- Fixed pitch wooden propellers are preferred. To safely use a propeller made of metal or composite a crankshaft vibration resonance survey has to be conducted to ensure that there are no damaging vibrations. Note that this refers to each new propeller design using composite or metal blades – once tested and approved by jabiru the propellers do not need to be tested for each individual installation.
- Wooden propellers require periodic inspections to maintain proper attachment bolt tension – Typically every 50 or 100 hours, depending on the propeller manufacturer's recommendations.
- Belleville washers are used to allow for expansion and contraction of Jabiru wooden propellers.
- The propeller must be carefully selected to match the airframe and the engine: Propellers up to 1727mm (68") in diameter and between 762mm (30") and 1219mm (48") in pitch[1] may be used. The propeller flange is drilled with two sets of holes which can be used for propeller mounting. 6 holes at both 101.6mm (4") PCD and 111.12mm (4 3/8") PCD (total of 12 holes).
- The Jabiru Engine does not have a hydraulic pressure supply or a governor mounting pad required for a hydraulic constant speed or variable propeller.
- Propellers with excess pitch can cause high temperatures and engine damage. Nominally, all propellers must be able to obtain 2800rpm static and 3150rpm to 3300rpm wide open throttle straight and level. However, in some particularly low-drag airframes it may be necessary to use a propeller which does not achieve 2800 static rpm. In these cases propellers should be chosen based on their RPM at wide open throttle (straight and level flight).
- Do not cruise or climb in the range 2100rpm – 2400rpm.
- The design of Non Jabiru spinners may affect the inspection intervals of the Jabiru composite propeller. See the propeller installation manual.

Engine Variant	**Minimum Recommended Propeller Inertia (non-approved propeller installations)**	**Maximum Recommended Propeller Inertia (non-approved propeller installations)**
2200	0.1 kg.m2	0.25 kg.m^2
3300	0.1 kg.m2	0.30 kg.m^2

- Applications outside this range should be referred to Jabiru.

WARNING

THE ENGINE MUST NEVER BE RUN WITHOUT THE PROPELLER. DAMAGE WILL OCCUR IN THIS STATE.

[1] Pitch measurements are taken from the angle of the rear face of the prop blade. Other propeller manufacturers may specify pitch measured from the blade mean chord line or other reference. Make sure you are comparing equivalent pitch units when specifying a propeller.

9 Engine Installation Procedure

- Attach male engine mount rubbers to all engine mount pins on the engine mount. Place an AN4-31A bolt through each mount. Note that an engine mount spacer washer is fitted between the male rubber and the lower engine mount pins (Refer to Figure 37 below).
- With the tail of the aircraft supported and the wheels chocked, lift the engine onto the engine mount.
- Insert the upper engine mount rubbers into the engine backing plate first by tilting the front of the engine up. Once both upper rubbers are through the engine backing plate, fit the female rubber, engine mount spacer washer, engine mount washer, ¼" washer and Heat Proof nut.
- To place the nuts on the mount bolts the rubbers must be compressed. Do this by using a deep reach socket inside the engine mount pins and clamping the rubber mount assembly using a G-clamp with the swivel taken off the ball. See Figure 36. Start nuts on both upper mount bolts.
- Once bolts of the upper rubbers are started, continue lowering the front of the engine and align the lower engine mount pins with the engine backing plate.
- Use the weight of the engine to compress the lower rubbers and fit the nuts to the bolts.
- The lower engine mount rubbers are assembled in the same way, except the male engine mount rubber is fitted to the engine mount pins first. Refer to Figure 37 below.
- Tighten nuts until firm. (Engine mount washer will touch the engine mount pin as the rubbers compress)
- Connect the fuel line to fuel pump (Refer to Figure 36). Ensure the fireproof sleeve is in place.
- Ensure the fuel line from the fuel pump to the carburettor is connected and protected by fireproof sleeve.
- Ensure that the fuel overflow line is in place, and secured to vent overboard. This is the small, clear hose shown leading from the fuel pump in Figure 36.
- Fit the oil over flow bottle to the firewall by drilling and Riveting oil bottle holder in place using 73AS 6-6 rivets. Refer to Figure 7.
- Connect the oil breather line from the engine breather.
- Ensure that the oil overflow line is in place and vents overboard.
- Fit Scat hoses from cowl air intake to Air Box cold air inlet, from hot air muff to Air box hot air inlet on the hot and from the Air box to carburettor – shown in Figure 39.
- Fit throttle cable to carburettor. Note that Jabiru Aircraft kits come with a throttle cable cut to length and with the correct end fitting attached. Engines used in firewall-forward kits will be supplied with a length of throttle cable with no end – the builder must cut the cable to length and fit the carburettor end fitting. 5/16" washers are used on the cable end fitting (one washer either side of cable end fitting) to align cable. Use R-clip to assemble.
- Fit choke cable to carburettor. The choke is shown in Section 2.1
- Fit cylinder head temperature (CHT) sensors.
- The Oil Temperature Sensor is located in the bottom of the sump as shown in Figure 18.
- The oil pressure sensor is located at the base of the oil filter and this can be seen in Figure 19.
- Fit Exhaust Gas Temperature (EGT) sensors.
- Connect tachometer sensing.

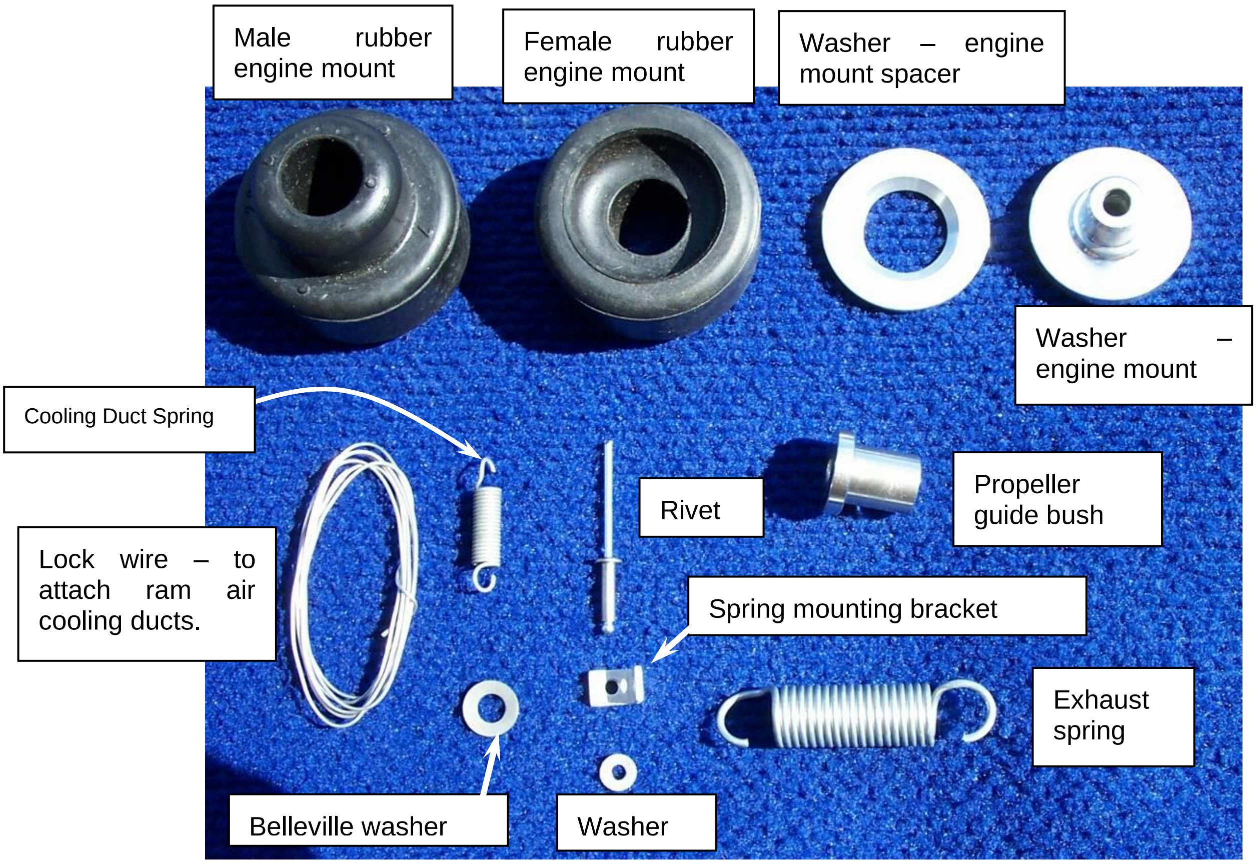


Figure 35. Engine Accessory Pack Contents

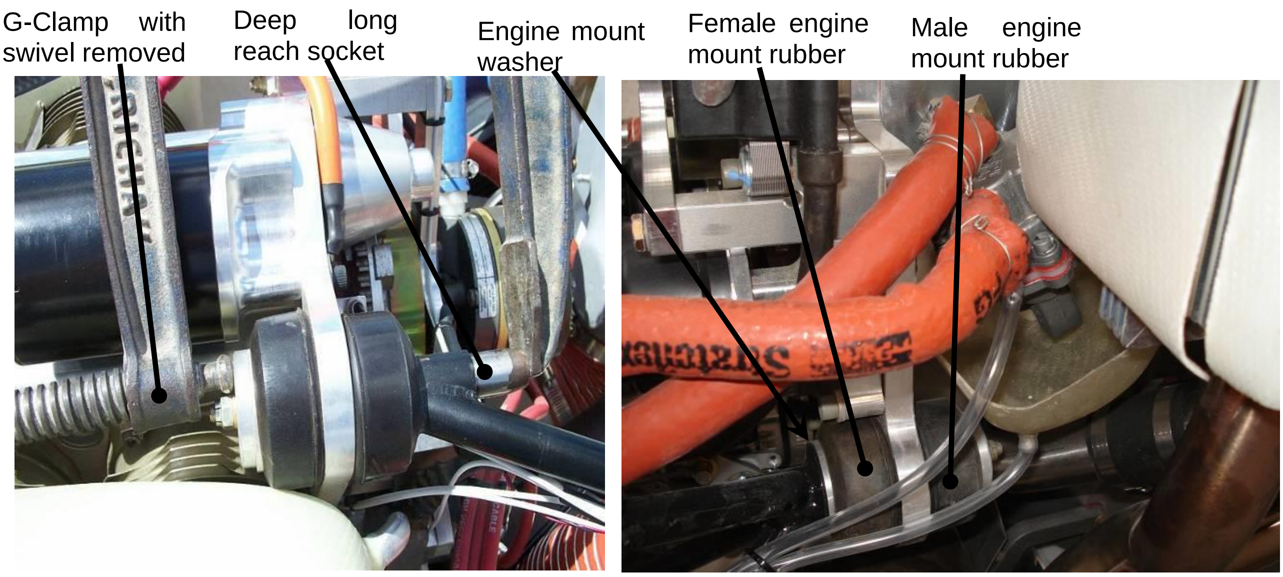


Figure 36 Upper and Lower Engine Mount Detail

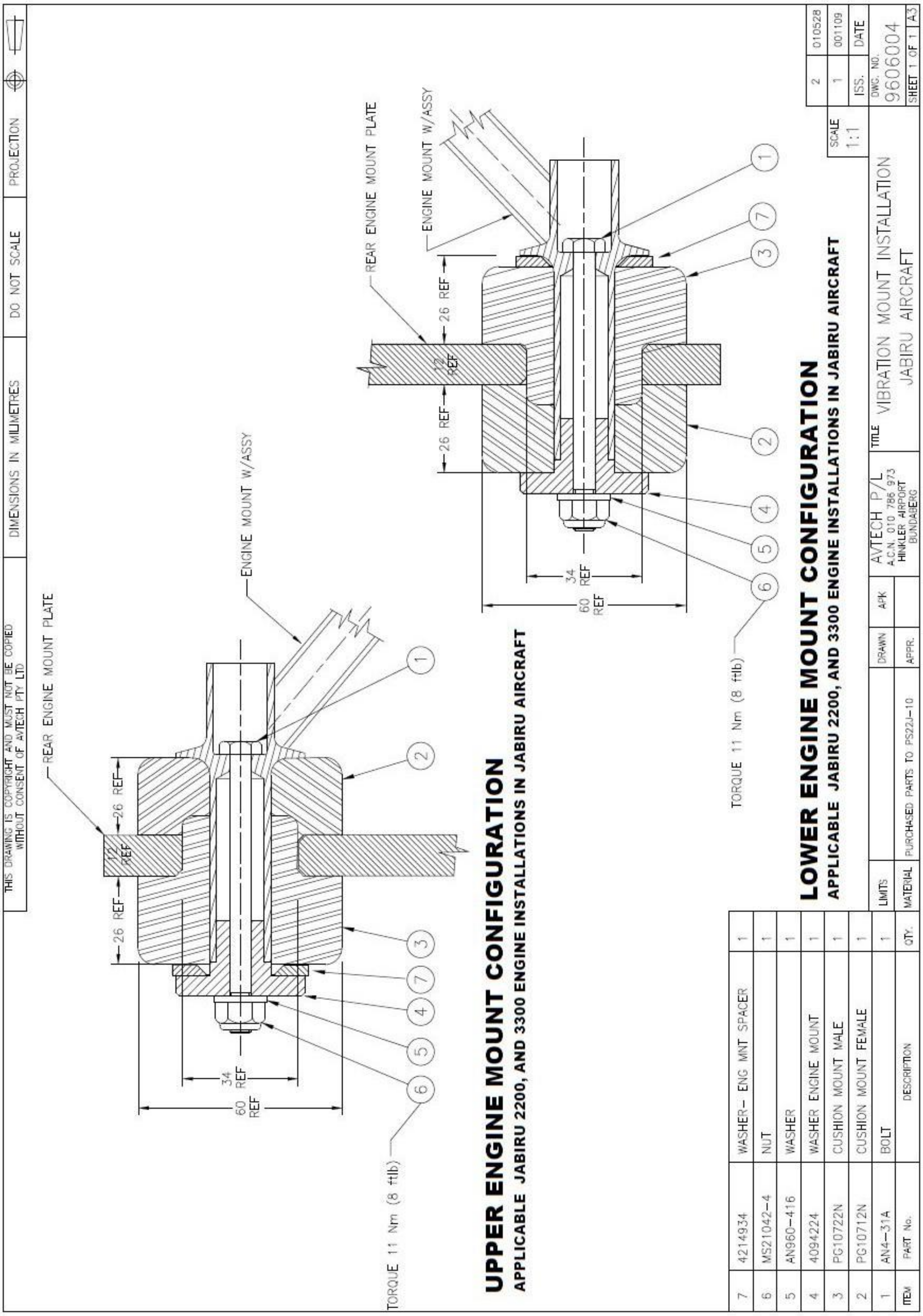


Figure 37. Engine Mount Detail

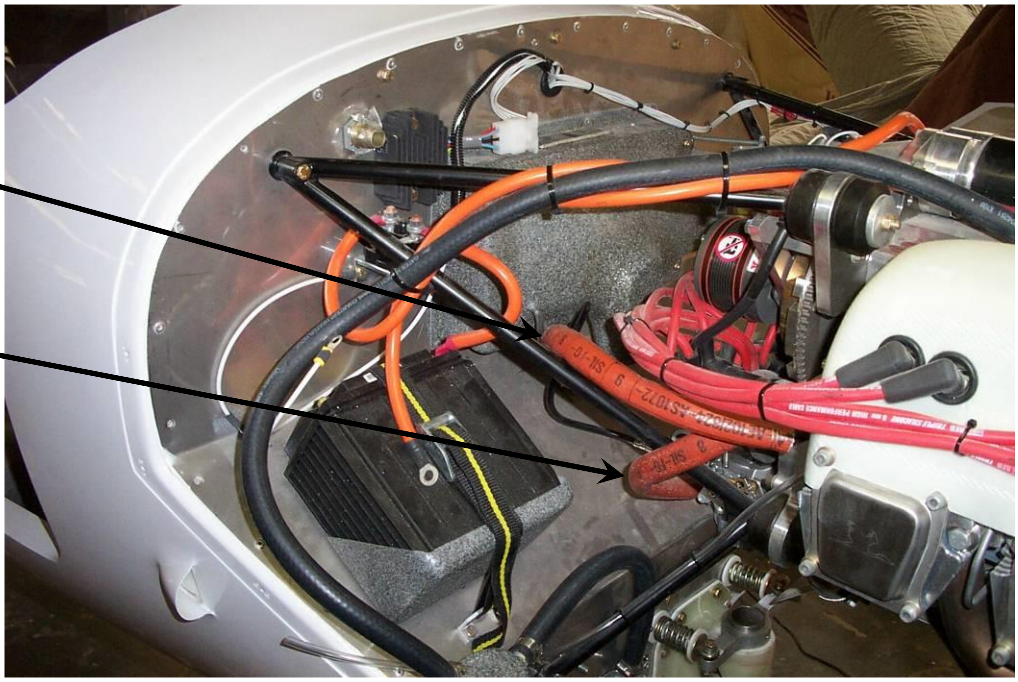


Figure 38. Fuel Connections General

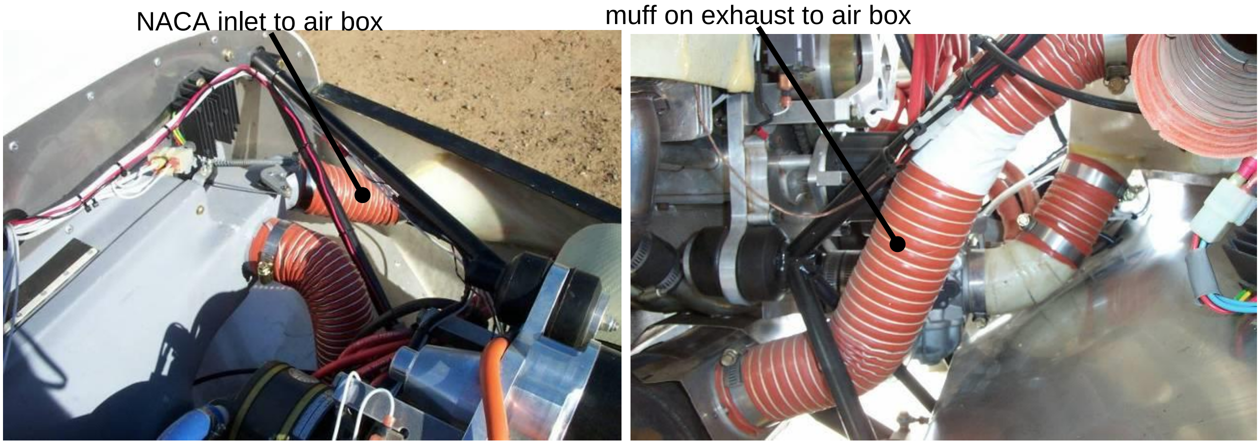


Figure 39. SCAT Hose Detail

10 Before First Start

- Expel inhibiting oil from cylinders and pressure up (wind engine on starter until the oil pressure gauge shows a reading) before first start.
- Ensure correct run-in type oil is used for the first 25 – 30 hours to ensure proper ring bedding-in.
- Once past the initial 25-30 hours, ensure the oil used meets the specifications given above.
- Oil coolers are mandatory unless operating in very cold ambient temperatures. Refer to Oil Cooling section above for allowable oil operating temperature ranges. NEVER REUSE AN OIL COOLER THAT HAS BEEN CONTAMINATED WITH METAL. FLUSHING WILL NOT REMOVE THE METAL COMPLETELY.
- Do not overfill the engine – this may result in high oil temperatures.
- Check for contact of engine, cooler or ducts on cowl. Any contact will cause excessive vibration and if the oil cooler is rubbing it will eventually fail and leak.

11 Auxiliary Units

11.1 Vacuum Pump Drive Pad

- The engine has a vacuum pump drive pad at the rear of the engine. This can be used to drive auxiliary devices such as a vacuum pump or secondary alternator. The drive pad is dry and the drive is directly off the crankshaft.
- The pad and spline are SAE Standard.
- The vacuum pump drive spline is an optional extra not included with the standard engine – it must be ordered separately.

12 Cooling Systems

12.1 General Principles

- An ideal cooling system:
  - i. Controls engine temperatures through speeds ranging from taxiing on the ground through to V_{NE}.
  - ii. Controls the engine temperatures through a wide range of angles of attack.
  - iii. Is simple to build, install and maintain
  - iv. Produces minimum drag
  - v. Requires no pilot attention
  - vi. Is not affected by rain, dirt or insects sticking to it.
  - vii. And weighs next to nothing
- For the sake of the following discussion, a “gap” is considered an opening roughly large enough to slide two fingers into – around 13mm by 32mm (0.5” by 1 ¼ “).
- The total area of the air intakes (combined cylinder head and oil cooling openings) should generally be no more than one third the total area of the cowl outlet (the outlet area must be a minimum of about 3 times as large as the total area of the inlets). This assumes that the outlet area is oriented effectively (see Figure 54).
- Each cowl cylinder head Inlet of a Jabiru Aircraft has an area of approximately 10,500mm^2 (16.25 in^2). Oil cooler inlets have an area of approximately 12,500mm^2 (19.4 in^2). This gives a required total outlet area of approximately 100,500mm^2 (155 in^2). These sizes are based on a Jabiru Aircraft. Inlet and outlet sizes required will vary depending on the aircraft’s speed, drag and the positions of the inlets and outlets – the areas given should be used as a guide and starting point only.
- A generalised picture of the airflow and air temperature is shown in Figure 40.
- Most of the time, air leaking through gaps instead of flowing through cylinder head fins, oil cooler or similar is waste air – it does not transfer heat and does not cool the engine. Sometimes air leaking through controlled gaps – such as the holes in the front of the ram air ducts or the gaps between cylinders – can have beneficial effects. However, it is recommended that gaps around the engine and oil cooler be closed as a starting point.
- The propeller and rush of air from the aircraft’s speed make it easier to get air into the cowl than to get it out.
- Too much air flowing through the oil cooler can restrict airflow through the cylinder heads, and vice versa.
- The pressure difference between the low-pressure outlet area of the cowls and the high-pressure inlet area controls the amount of air flowing through the engine. The pressure differential testing described in Section 12.5 gives target pressures.
- During developmental work it is strongly recommended that each cylinder head has its own temperature sensor. Modifications to cowls etc can have unpredictable effects and normally a change will affect each cylinder head differently – i.e. head #4 may cool down while head #3 heats up.
- Testing of an installation in a Jabiru Aircraft showed that the heat radiating from the engine exhaust system normally has a minimal effect. Wrapping the exhaust in insulation etc does not produce a measurable temperature reduction during taxi or in the air.

WARNING

The limits in the Specification Sheet, contained in Appendix B, must be strictly adhered to. Warranty will not be paid on engine damage attributed to overheating of cylinders or oil.

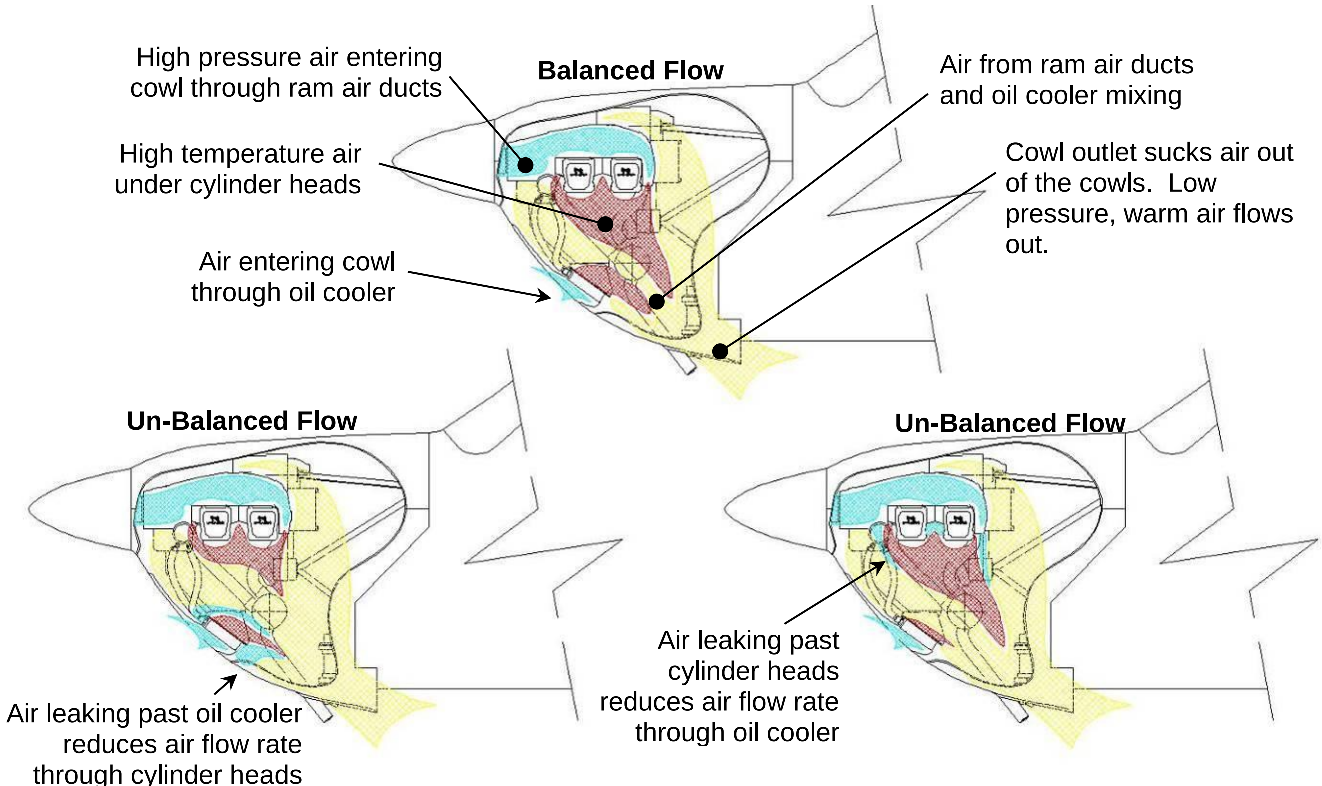


Figure 40. Cowl Airflow (Best Viewed in Colour)

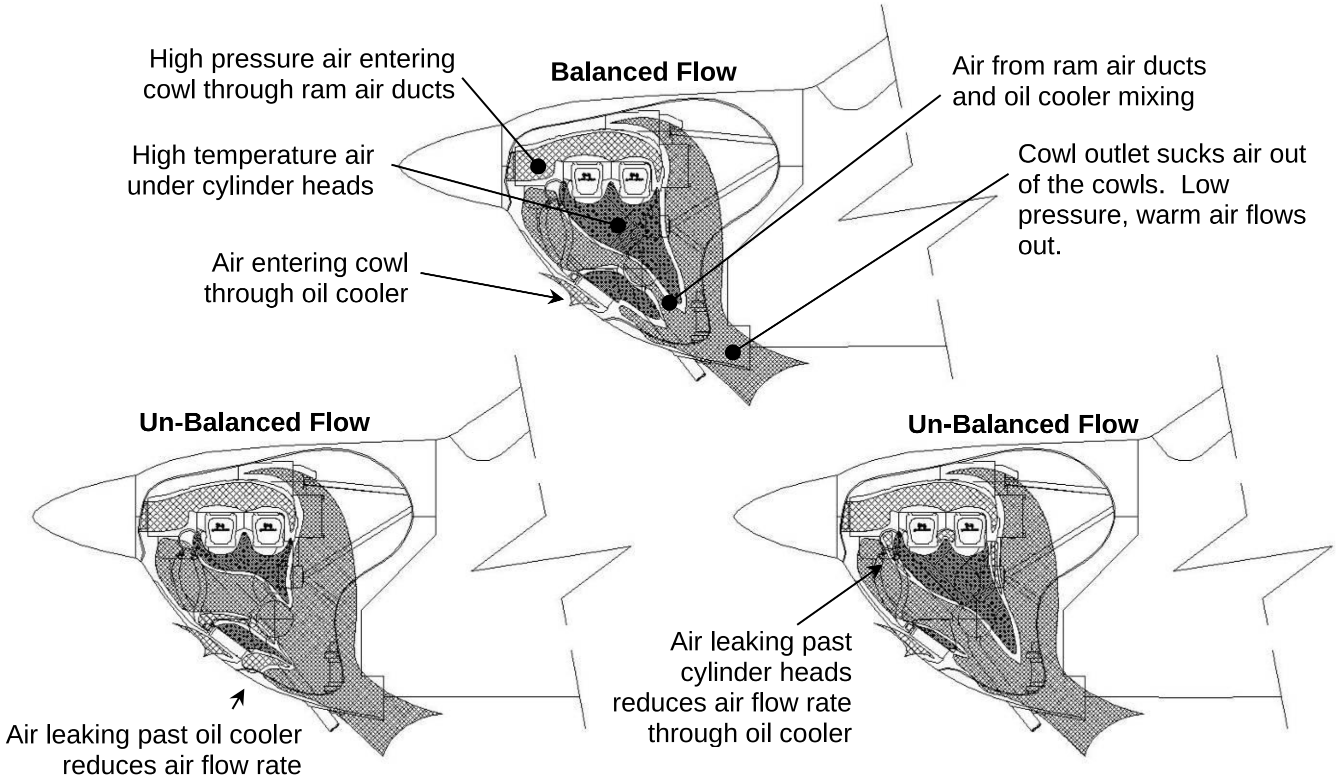
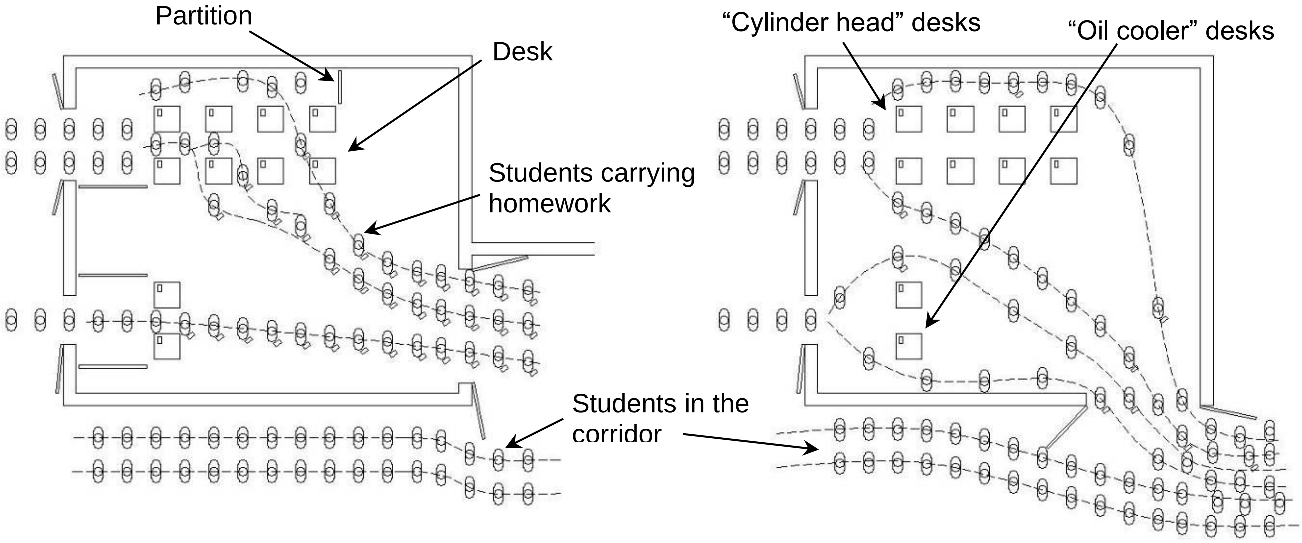


Figure 41. Cowl Airflow (Black and White Version)

12.2 Flow Visualisation

- In designing the cooling system the designer must have a basic understanding of how air flows and behaves inside the cowl. The pictures below are intended to explain it in simple terms.
- Figure 42 shows two schoolrooms, drawn as if seen from above. Each room represents an engine and oil cooler inside a cowling.
  - i. There are two doors in the inlet side of the room and one on the outlet side.
  - ii. Several desks are placed in the room, representing the engine cylinders and the oil cooler.
  - iii. Students walk through from left to right, representing the air flow through the cowls.
  - iv. On each desk is a pile of homework papers, representing heat generated by the engine.
- Air always takes the path of least resistance. It tries to escape quickly to the playground without taking the homework.
- The desks and doorways form restrictions. If the desks are too close, not enough students can pass through. If the desks are too far apart some students will not pick up their homework. If the inlet doorways are too large then there will be a traffic jam trying to get out of the outlet door.
- Gaps can leave room for students to pass without picking up homework.
- Given a group of desks as shown, students can follow many paths through them – from front to rear, from top to bottom or any combination.
- Slowing down the students as they pass through the desks means they will pick up their homework, but if they are slowed down anywhere else it only reduces the amount of students that can get through the room.
- If the exit becomes jammed with people, installing bigger inlet doors will not increase the number of students passing through the room. Exits should be as clear and free of obstructions as possible to let people out.
- Students will often have a preferred desk to take their homework from, meaning that some cylinder heads will have more heat removed than others – temperatures will wary between different heads.



- Partitions are used to force the students to walk through the desks.
- Each student picks up the homework.
- Outlet door is 90° to the flow of students in the corridor; there is no restriction & jostling at the exit

- No partitions are used, so students walk around the desks instead of through them.
- Most students don't come close enough to a desk to pick up the homework
- Outlet door is parallel to the flow of students in the corridor, causing restriction & jostling at the exit

Figure 42. Flow Visualisation

12.3 Air Inlet and Ram Air Ducts

- The engine should be installed using RAM AIR ducts provided with the engine. The ducts themselves must be assembled as detailed in Section 12.3.1.
- Ramair ducts must be secured to the engine using two rocker cover screws and a spring tag at the front of the engine to prevent them being blow off the engine in flight.
- For best cooling on the ground, during climb and low speed flight the propeller used must have significant pitch and blade area on the section immediately in front of the air inlets. At low speeds the airflow does not have much energy, and the acceleration and pressure provided by the propeller greatly assists in getting air into the ram air ducts.
- Each duct must have a 25mm hole at the inside top front to bleed air over the crankcase.
- The pressure differential between the inside the cooling ducts and the cowl outlet should not be lower than 60mm (2.4") water gauge at when the aircraft's speed is 1.3 times the stall speed (1.3 x V_S).
- The cooling ducts provided are a starting point in establishing effective engine cooling. Any given individual installation may require modification to baffles inlet size or even the cowl outlet to achieve good cooling in all flight conditions on all cylinder heads.
- Tubes of approximately 12mm diameter are required to provide cooling air to the ignition coils -Figure 47.
- For an air cooled engine it is entirely normal for there to be differences in the temperature of each cylinder head. Often the head which is hottest in the climb will not be the hottest during cruise and descent. This is only a problem if the hotter heads exceed the engine's set limits.
- Check for contact of engine, cooler or ducts on cowl. Any contact will cause excessive vibration and if the oil cooler is rubbing it will eventually fail and leak.

12.3.1 Ram Air Duct Assembly and Installation – Standard Jabiru airframe tractor installation

- Remove the top two rocker cover capscrew from all cylinder heads. Place each ram-air duct on the engine.
    - Push the ducts forward on the engine until there is a gap approximately 8-10mm between the rear cylinder barrel and the edge of the duct.
    - Standard tractor ducts are placed with the duct side wall sitting between the second and third fins from the base of the cylinder barrel.
    - Other ducts vary and may be have the side wall placed one or two fins further out. Check where the outside wall lies. It should sit flush (or close to flush) again the rocker cover face.

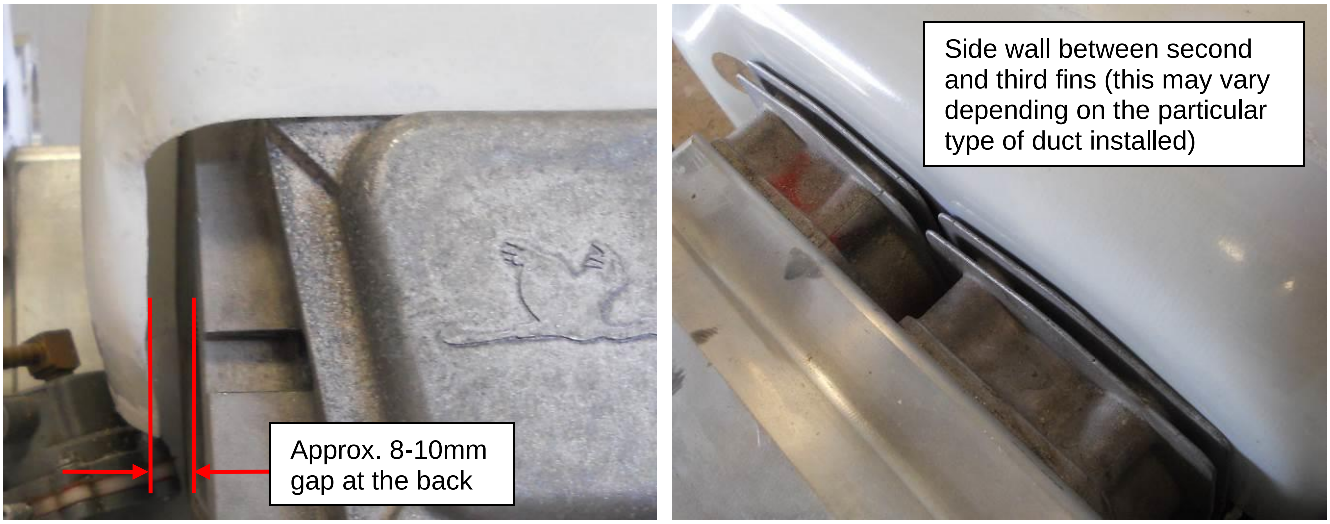


Figure 43 - Position ram-air duct on engine

- With the ram-air duct in place mark the position of all rocker cover capscrew hole (four marks for a 2200, 6 marks for a 3300)
    - Remove the duct so as to avoid damage to the engine when drilling and sanding.
    - Drill the two outside holes to 1/4inch (it doesn't matter if the holes have to be elongated slightly to get them to align with the engine).

- For the other holes, sand a circular relief in the duct using round tube wrapped in coarse emery cloth or garnet paper. The reliefs should be 12-14mm typically)

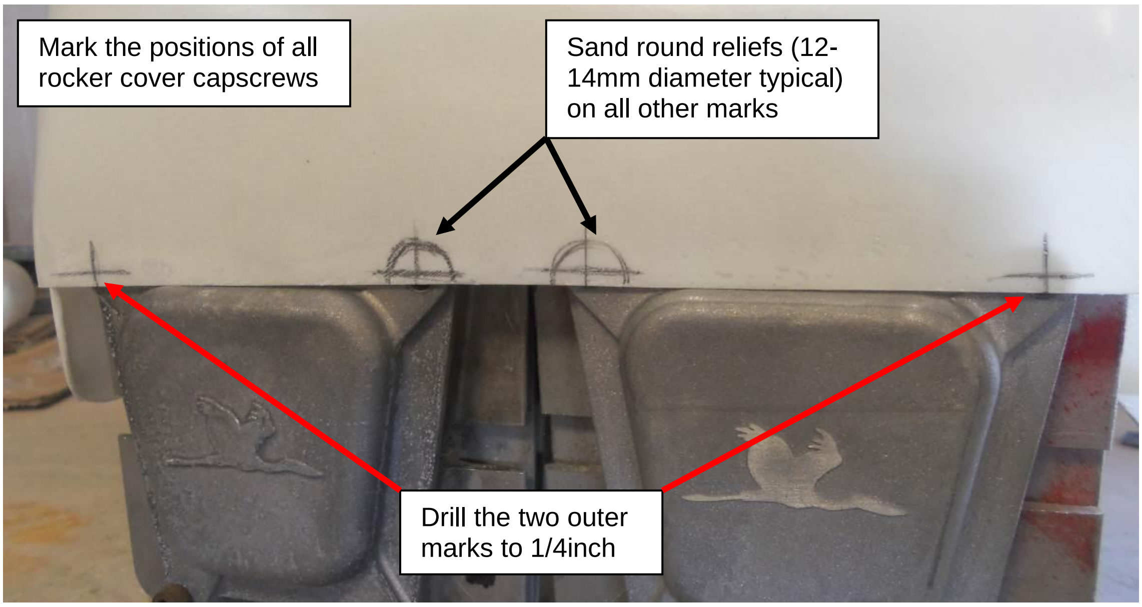


Figure 44 - Mark, Drill and sand holes and reliefs

- Place the ducts back on the engine with the previously drilled 1/4inch holes aligned with the rocker cover holes.
  - Place stainless steel tags over the holes and install a capscrew to retain the tag over the previously drilled 1/4inch holes.
  - With the tag pointed upwards mark and drill through the two smaller holes in the stainless steel tag with a 1/8inch drill.
  - Remove the duct from the engine. Permanently fix the tags in place using 1/8inch rivets. Install rivets from the outside and use a steel backing washer on the inside.
  - The duct should now be installed with capscrews to hold it in the correct position for all other fitting operations.

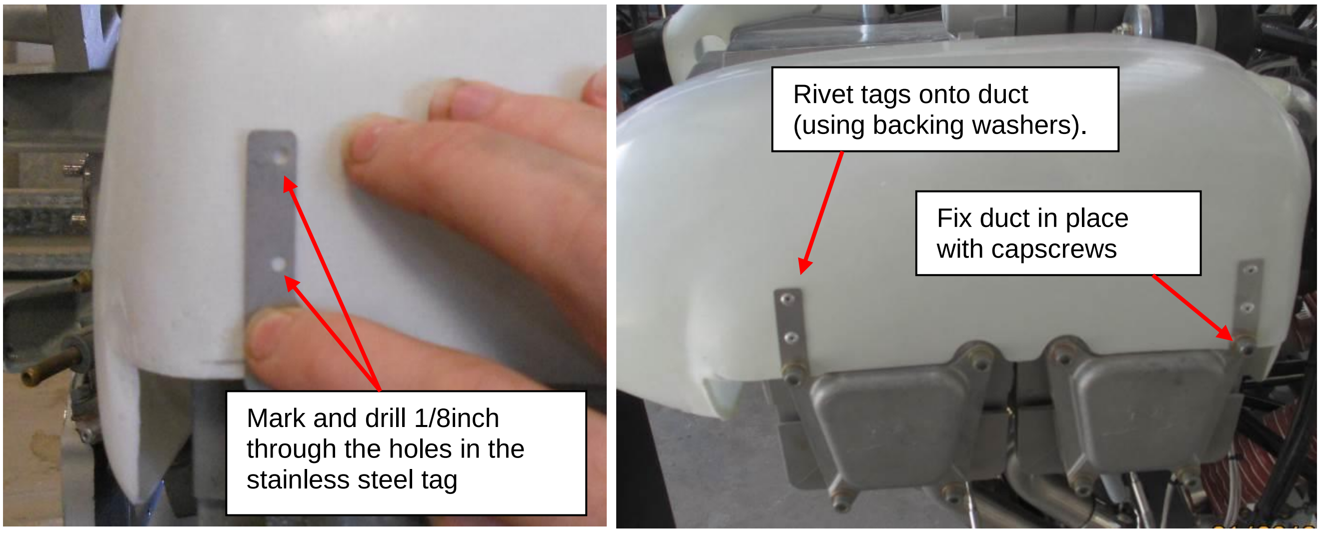


Figure 45 - Fitting stainless steel tags

- Install the small tension spring on the tag at the front of the engine.
  - Pull the spring up to the duct and mark the position where the duct is closest to install corresponding tag.
  - Drill through the marked position (1/8inch) and install the small angled tag with a 1/8inch rivet from the outside with a steel washer backing on the inside.

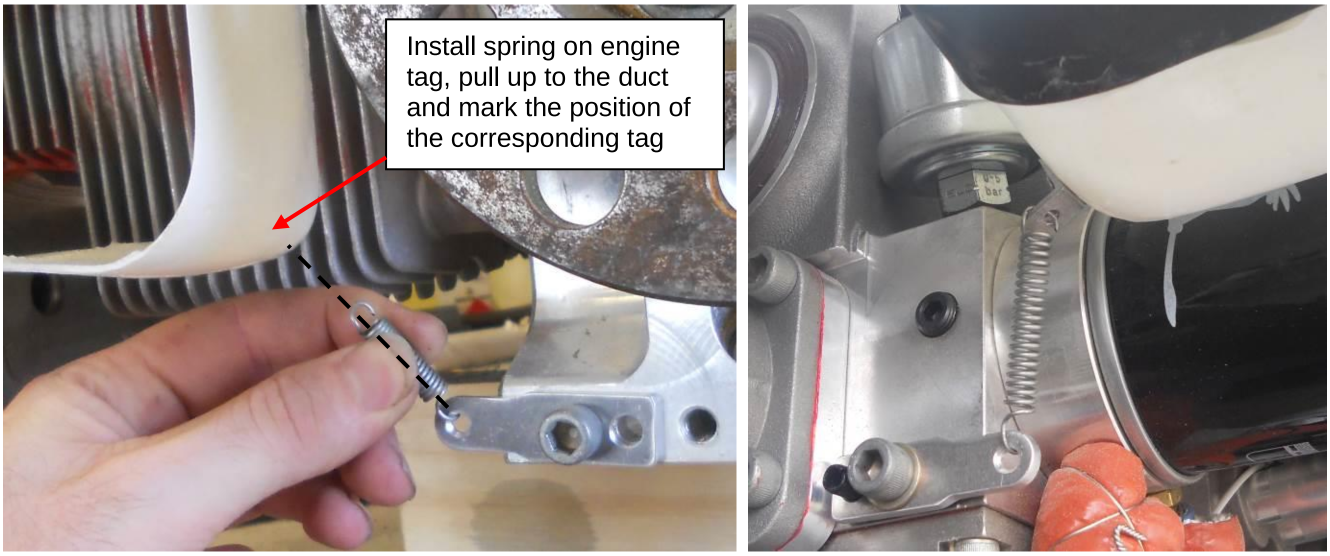


Figure 46 - Front tag installation

- Place bent aluminium tube on ducts to determine the position for these tube to direct air onto each ignition coil (the left duct does the left coil and right does right).
  - Mark the position of the holes, drill out holes to size sufficient to accommodate tubes (it is best if the ducts are removed from the engine for drilling).
  - Reinstall ducts on engine and install cooling tubes to point at the coils. Bond the tubes in place with 5 minute epoxy (the bonding surface of the tube should first be roughened with a coarse sanding disk to aid bond adhesion.

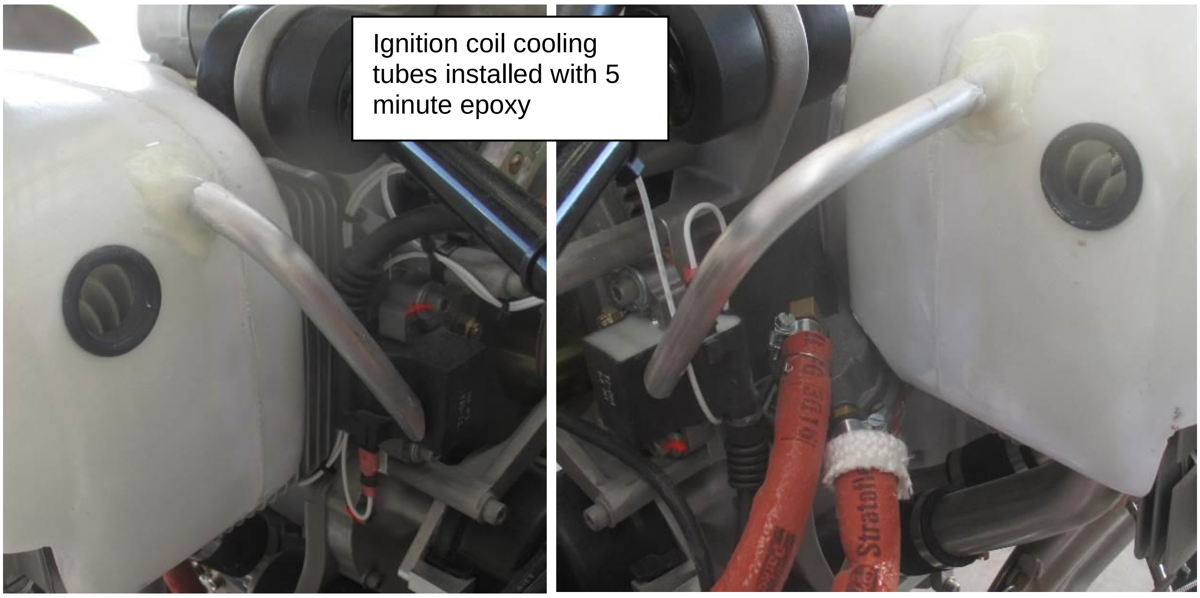


Figure 47: Ignition coil cooling tubes

- With the ducts installed on the engine the front air dams are sized, trimmed and bonded into the ram-air cooling ducts.
    - Place each dam in the front of the ducts so the upper lip is in contact with the cylinder and the bottom of the dam in contact with a duct itself
    - Mark the outline of the duct to trim away, then using sharp snips, trim the excess material away, refit and check, retiming or sanding as necessary.
    - Mix some 5 minute epoxy with flock, position the dam in the duct and apply a bead of epoxy around the join line.
    - When fitting the left side duct (on a tractor installation) note the cut-out needed to clear the oil filter and trim the dam accordingly.

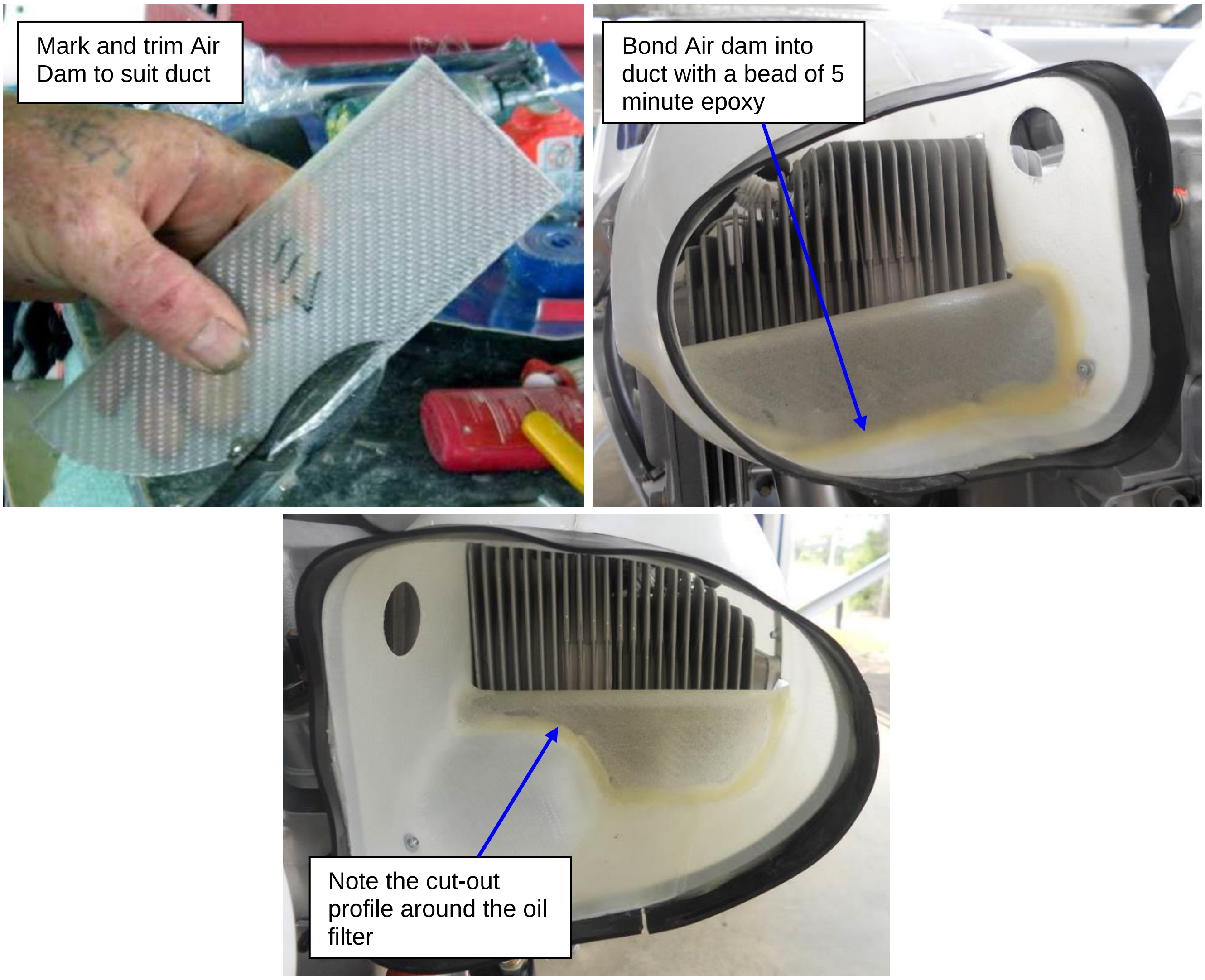


Figure 48. Air Dam Installation

- Finally bond the black insertion rubber strip around the perimeter of the ram-air duct inlet
    - The rubber strip should protrude 10-15mm past the edge of the duct

- Use 5-minute epoxy and flock to bond the rubber to the duct
- Before bonding the contact area of the rubber strip must be roughened with a coarse sanding wheel to aid bond adhesion.
- The split in the rubber strip should be placed at the bottom of the duct.

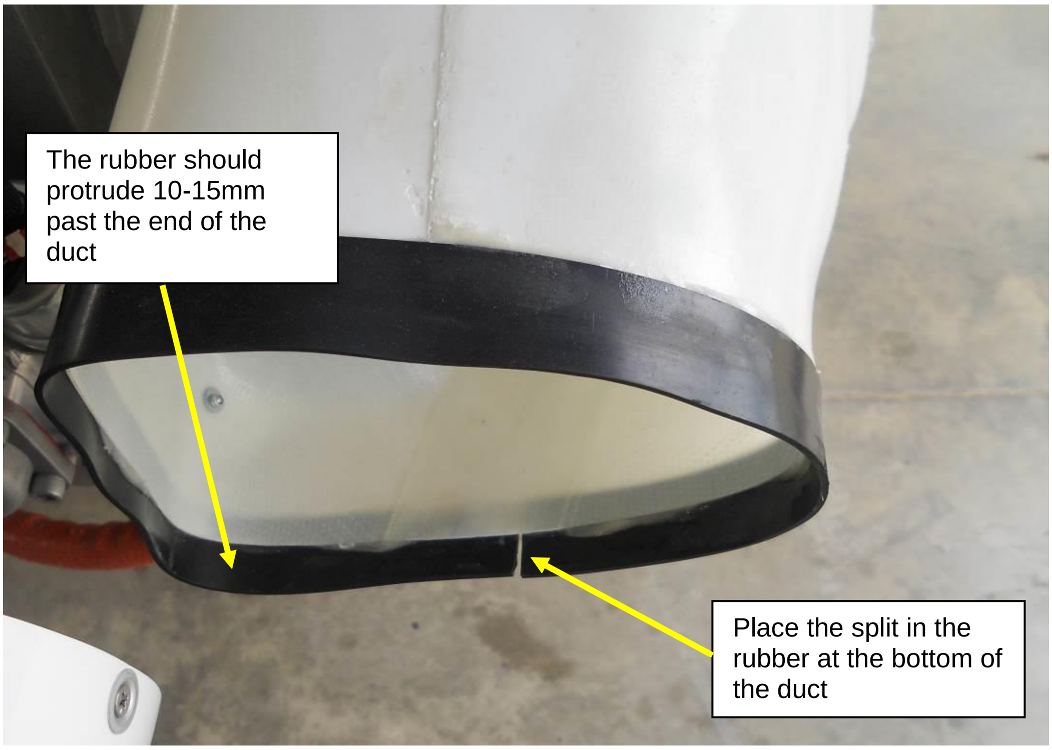


Figure 49 - Attach insertion rubber strip

12.4 Oil Cooling

- The dipstick cap must be screwed fully in before removal for reading oil level.
- An oil cooler adapter is supplied with the engine and fits under the oil filter. The cooler can be plumbed either way to the adaptor – flow direction is not important. Oil coolers are available from Jabiru Aircraft.
- Unless consistently operating in low temperatures, oil coolers are mandatory. Note: if you fly in cold weather and don't have an oil cooler you can't fly if it warms up. You can always block the oil air off in cold conditions.
- In continuous operation oil temperatures between 80°C and 90°C (176°F – 194°F) are desirable. 70°C (158°F) is the minimum allowable temperature for continuous running and 100°C (212°F) is the maximum allowable temperature for continuous running.
- Over filling with oil is not desirable. It can cause elevated temperatures and excessive oil use and loss.
- Hoses should be nominally 10mm (3/8") bore.
- Hoses must be changed every 2 years or if visible degradation (cracking, hardening) is visible at inspection.
- A pressure drop of at least 60mm (2.4") water pressure between the air flowing into the cooler and the air flowing out of the cowls should provide sufficient oil cooling if using a standard Jabiru oil cooler.
- Section 12.1 noted that air leaking through gaps in the cooling system ducts is generally waste air, not contributing to cooling – though it noted that there were exceptions to this rule. Oil cooling is the feature of engine installations that is most often improved by "leaks" like this. A controlled amount of free air blowing over the sump, crankcase and underside of the engine can significantly improve oil temperatures (Figure 50 shows a duct of this type fitted to a Jabiru 6-cylinder engine). However, for this to work the cowl installation must be able to cope with the extra volume of air flowing into the cowl space – the outlet area or outlet lip size may need to be increased to suck out the extra volume.
- Figure 51 shows an oil cooler installation of a Jabiru 2200. Note Detail C in the lower corner of the drawing, which shows the cooler being fitted using rubber mounts. This is very important as it insulates the cooler from engine vibrations – coolers installed with a soft mount, Figure 50, are much less likely to fail in service.

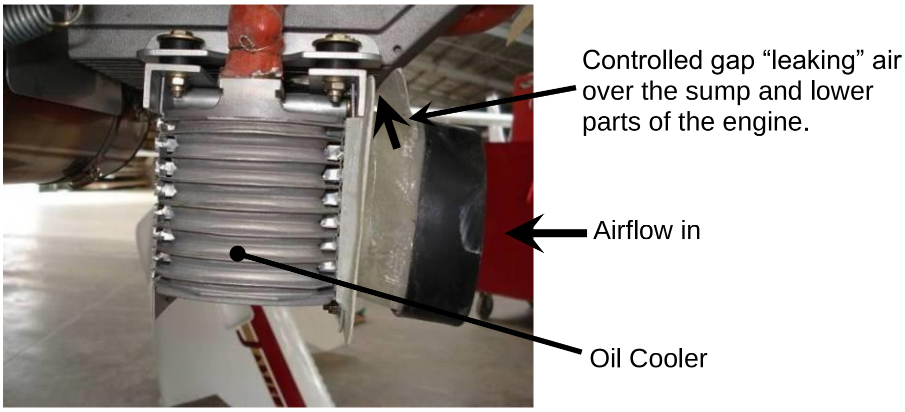


Figure 50. Oil Cooler Duct Design

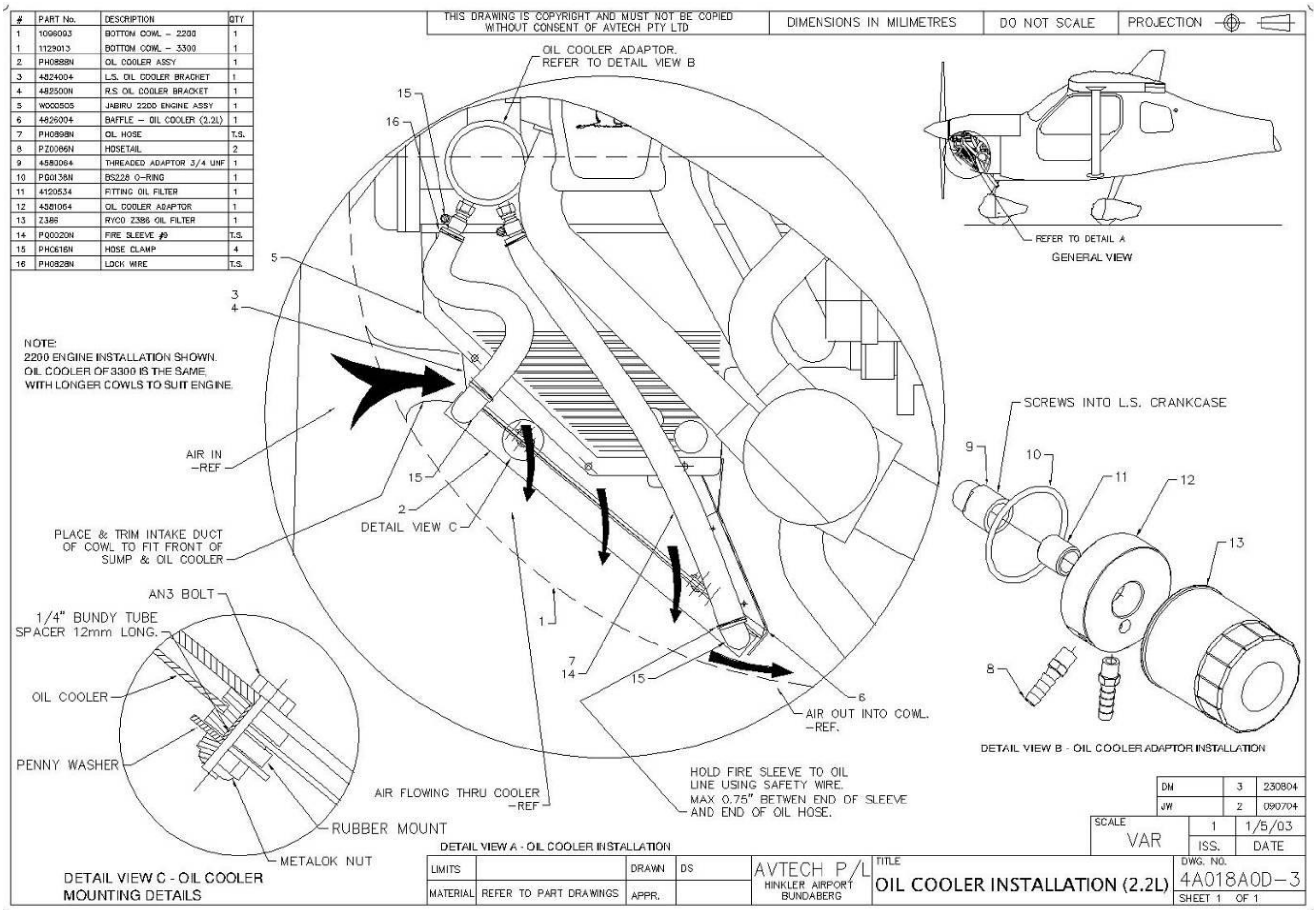


Figure 51. Oil Cooler Installation

12.5 Air Outlet

- As the sections above describe, getting air out of the cowling is often the factor limiting how much air can be pushed through the engine and how well it is cooled.
- The shape of the outlet of the cowls controls how effectively air is sucked out of the cowling and is arguably the single most important aspect of cowling design.
- As noted above, as a rule of thumb the cowl outlet area should be at least 3 times the combined area of all the cowl inlets.
- Figure 52 shows a small lip added to the rear of the cowls of a Jabiru Aircraft. This lip gives a large improvement to pressure differentials and engine cooling.
- Figure 53 shows an aircraft at varied angles of attack to the surrounding air. The cowl inlets and outlets must both be designed to work effectively at all angles which the aircraft will normally experience.

- Figure 54 shows two different cowl outlets – one is basically an opening in the flat bottom of the cowl, while for the other the opening is oriented at 90° to the airflow direction. Vertical orientations (Deep Outlet) give better pressure differentials and are less affected by aircraft angle of attack than horizontal (Long Outlet).
- Figure 54 also shows the lower firewall section of a Jabiru Aircraft. The lower part of the fuselage has two large ramps moulded in which increase the depth and area of the cowl outlet (and also provides mounting points for the rudder pedals). This type of feature is not mandatory for good engine cooling but it does help. An alternative is to make the bottom corner of the firewall as smooth and rounded as possible to help airflow and minimise the outlet restriction.
- Some aircraft types have a flange running around the firewall. Particularly on metal types, this flange is a useful way of mounting the cowls. However, if the flange runs across the edge of the firewall where the cowl outlet is located then it causes a significant flow restriction. Figure 55 shows a drawing of the lower section of a firewall with a flange of this type. Wherever possible flanges across the cowl outlet should be avoided. Alternatively a fairing can be built inside the cowl to smooth airflow over the lip and reduce flow restriction.

Figure 52: Lip to aid cooling as installed on a Jabiru.

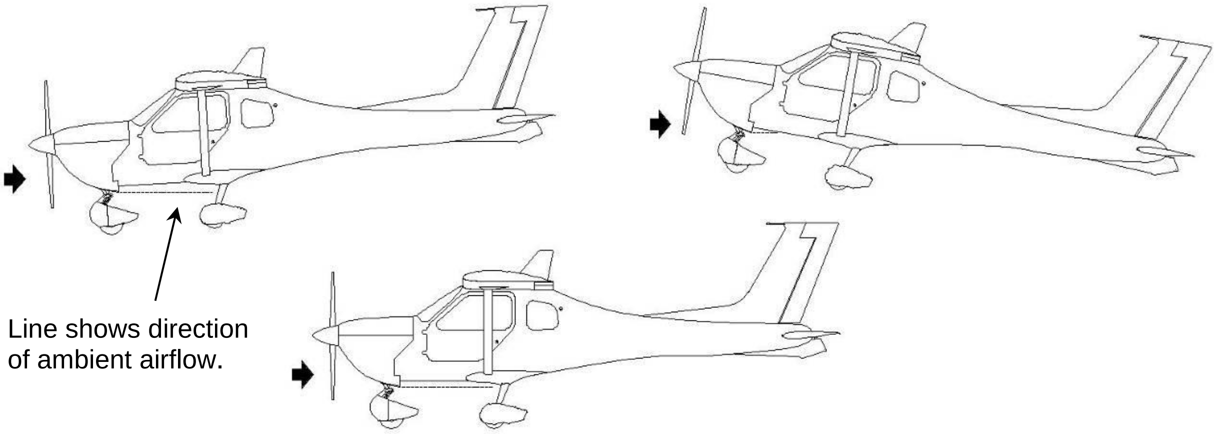


Figure 53. Effect of Angle of Attack on Cowl Outlets

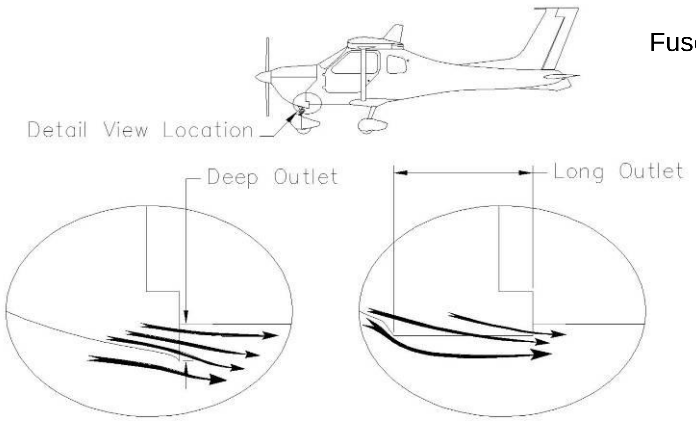


Figure 54. Cowl Outlet Geometry

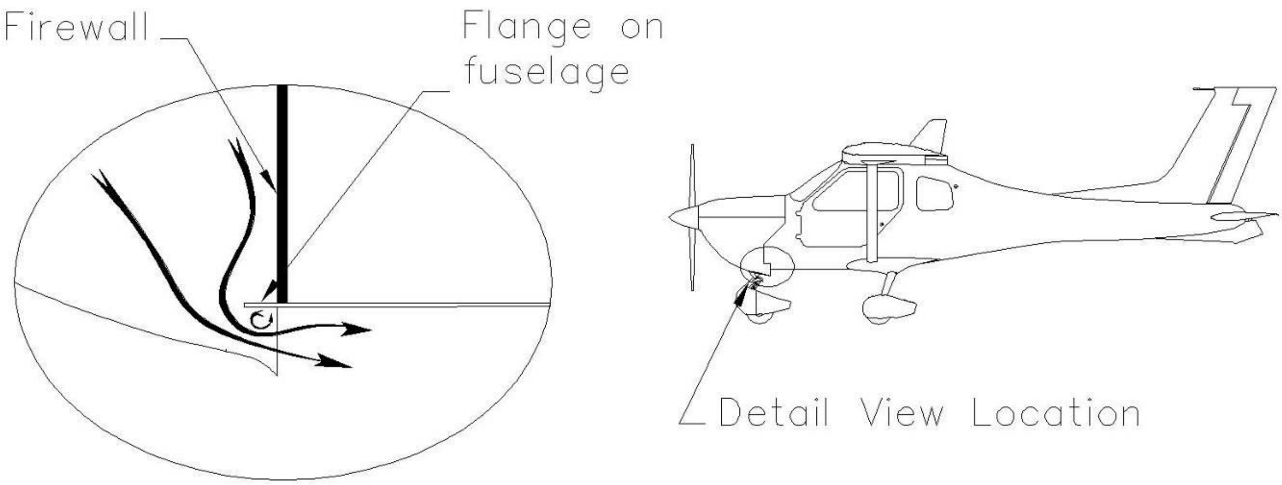


Figure 55. Outlet Restriction Caused By Flange On Lower Firewall

Cooling System Testing and Evaluation

- For new installations (new designs rather than new aircraft of a known type) the pressure drop across both Ram air ducts must be checked.
- The following is a guide to evaluating an engine installation to see if it meets minimum cooling requirements.
- The easiest way to measure the air pressure drop across the engine and oil cooler is using a U tube manometer using water. It is basically a piece of clear tube bent into a "U" and half filled with water (if the water is hard to see add a bit of food colouring).
- For ram-air duct pressure, connect one side of U to a static port inside the ram air duct and the other to a static probe inside the cowl near the outlet. For the pressure drop across the oil cooler, plumb a static probe against the front of the cooler and a static probe inside the cowl near the outlet. The further the probe is in front of the cooler the less the static pressure that will be measured, so place the probe no more than 5mm in front of the cooler and parallel to it.
- Using multiple U-tubes several measurements can be taken in one flight.
- Details of a typical static probe are shown in Figure 56.
- Note that probes must be fitted in the same place each time to ensure you get consistent measurements.

Some hints.

- Usually, the most critical situation for cooling is climb however this is not always true, so check all situations.
- The change in air temperature is approximately the same as the change in engine temp. For example, if you did all your testing in 15°C and you want to flying in up to 35°C weather, in 35°C all your engine temps will be approximately 20°C higher. Check you have sufficient margin for all conditions you plan to fly in.
- If the engine gets too hot during testing don't push it. Something needs to be changed.
- For low speed cooling a lip on the front edge cowl outlet can add up to 20mm of pressure drop at 65kts (a lip 25mm deep at 60° to the airflow – shown in Figure 52).

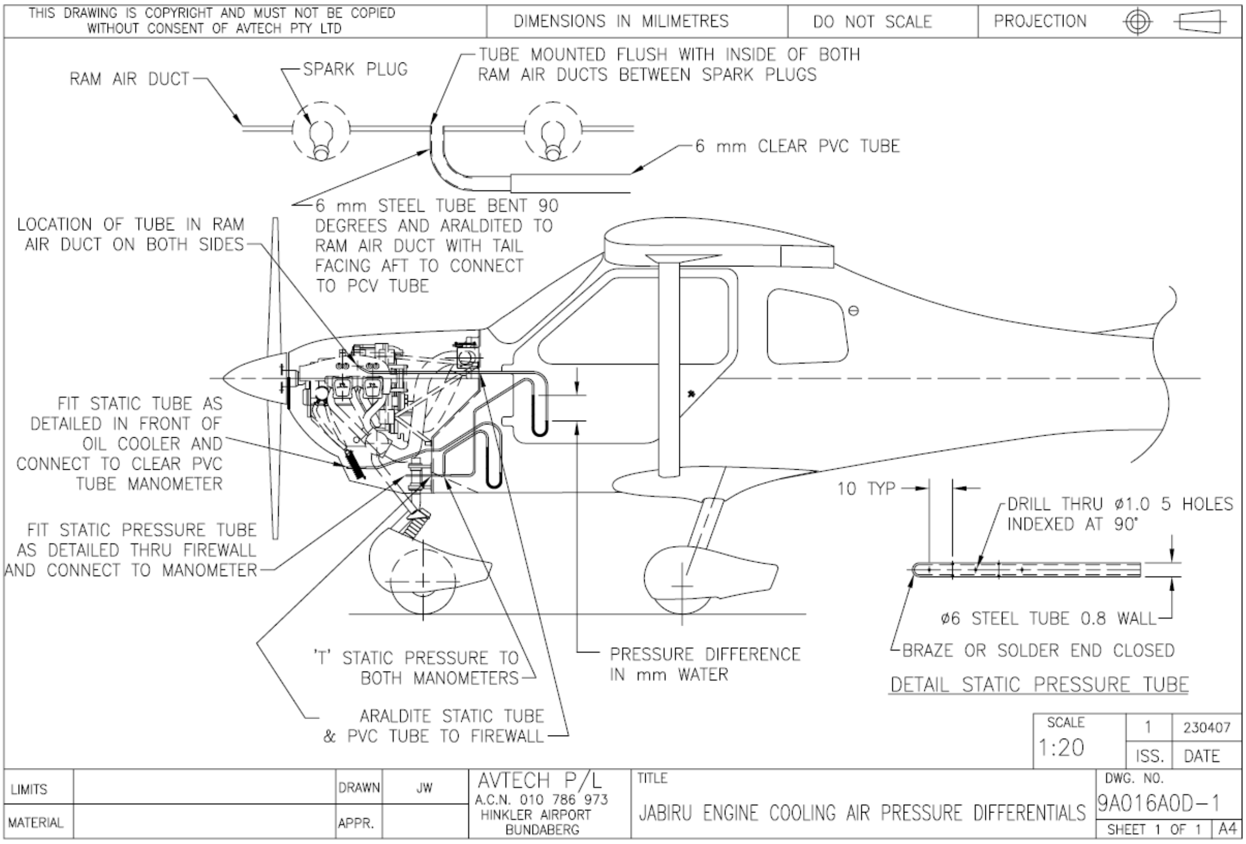


Figure 56: Cooling pressure measurement.

Figure 57: Ram Air duct pressure tapping.

12.6 Pusher Installations

- For pusher installations the details given above hold, though some changes are necessary for the different configuration.
- Versions of Jabiru ram air ducts are available for high speed and low speed pusher installations.
- The propeller can be used to suck air out of the cowls, using the following as a guide:
  - i. Wherever possible the cowl outlets should be vertical openings with lips that come close to the propeller – as close a possible without the blades hitting the cowls.
  - ii. The propeller blade must have significant pitch and chord in the section which passes over the outlets.
  - iii. The cowl openings should each be reasonably small. As each blade passes the opening it will create a suction in the cowl behind it, but if the cowl opening is large this effect will be dissipated. Alternatively, larger openings can be divided up by fitting louvers or vanes.
- Augmentor type exhausts (Figure 58) can also be used to suck air out of the cowlings.
- In pusher installations the inlets into the cowl are harder to get right than in a tractor installation. Intake ducts should be as straight as possible with no sharp corners or other restrictions to the flow.
- The position of the cowl air inlets is critical – inlets on the upper surface of the aircraft are generally in low pressure zones while those on the underside are normally in high pressure zones. Depending where the inlet is located, the area ratio between inlet and outlets may need to be modified.

12.7 Amphibian or Seaplane Installations

- Water taxiing requires relatively highpower settings for long periods and this is often the most critical condition for cooling systems in these aircraft.
- Increased duct size (scooping more air through the engine) may be necessary.
- For amphibian or seaplane aircraft using a pusher engine installation the methods outlined above can use the propeller to suck air out of the cowls, but ultimately the effect is limited and can conflict with cooling requirements in other modes of flight. For these installations some form of active venting for the cowls – such as flaps, fans or an augmentor-type exhaust system (See Figure 58) may be required.

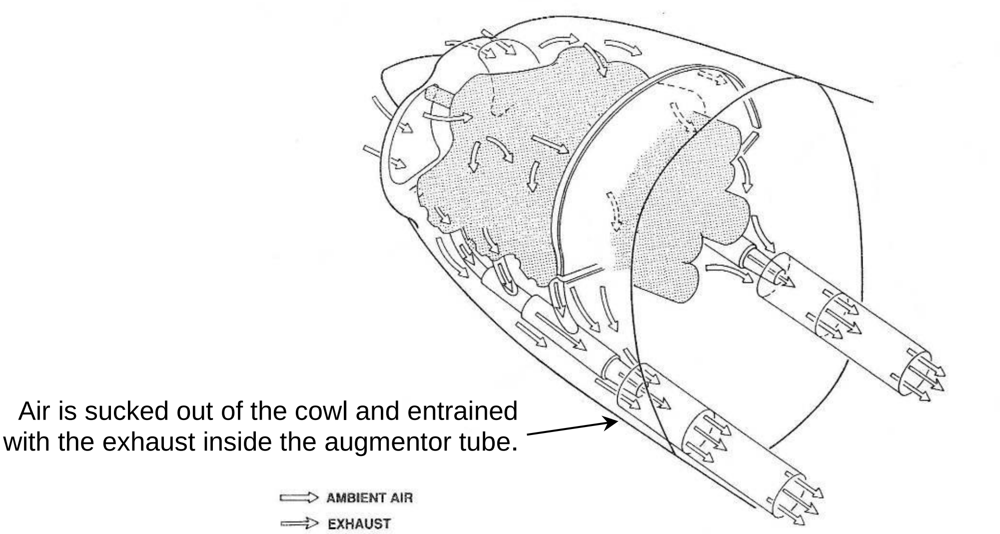


Figure 58. Augmentor Exhaust System

12.8 Slow Speed Installations

- Installations where the cruise speed is below around 70 – 80 knots are considered slow speed installations.
- Jabiru ram air ducts are available for slow speed installations. These are larger than the ducts used for faster aircraft.
- Increased duct size (scooping more air through the engine) may be necessary for slow speed installations.
- Increased outlet size and more aggressive outlet lips may be required.
- In some of these installations where the airframe has a lot of drag it is preferable to do away with cowls altogether and run an open installation. Aircraft such as the Thruster (Vision), Drifter, X-Air and some RANS models are examples of this. In these cases large ram air ducts are used, and the rest of the engine is exposed to the propeller wash for cooling.

13 Appendix B – Jabiru Aircraft Installation

- The following information describes the installation and performance of a typical Jabiru airframe installation.
- The information given can be used to estimate the performance of different designs, though obviously there will be differences depending on how similar the aircraft is to the Jabiru described below.
- Poor installations will result in poor performance, so installations must be designed referencing the information given in the main body of this manual.

13.1 Known Airframe / Engine Details

- Jabiru SP (2 Seater)
- Propeller 60” x 42” (1525mm x 1067mm) <u>or</u>
- 60” x 44” (1525mm x 1118mm)

13.2 Normal Operation Data

- The following are typical values for the engine in a typical Jabiru airframe installation:

Idle Hot: 2200 .... 900 - 950 RPM
3300…………………………………………….800 - 850 RPM
Take Off Power:... 2850 - 3000 RPM
Full Power Straight and level:................................. 3150 - 3250 RPM
Cruise At 75% Power:... 2800 - 2850 RPM
Oil Temperature Cruise: .... 80˚C (175 °F)
Oil Temperature Climb:... 95°C (203˚F)
Cruise CHT: .... 121°C (250°F)
Climb CHT: .... 150°C (350°F)

14 Engine Installation Checklist

ENGINE MOUNT

- ☐ Positions engine for correct aircraft CG
- ☐ Positions engine for correct thrust line
- ☐ Sufficient strength
- ☐ Sufficient stiffness
- ☐ Provides access for maintenance
- ☐ Provides clearance – the engine and mount are not rubbing on other parts of the aircraft.

ENGINE CONTROLS

- ☐ Control cables bend radii sufficient
- ☐ Control cables not rubbing on other parts.
- ☐ Control cables set up to work in the correct direction

ELECTRICAL SYSTEMS

- ☐ Correct sized circuit breakers used
- ☐ Connections for power and earth correct size
- ☐ Correct type of sender units used for instruments (i.e. resistive or voltage type).
- ☐ Sender units used chosen to suit typical parameter ranges of a Jabiru Engine
- ☐ Aircraft grade wiring used.
- ☐ CHT/s correctly fitted.
- ☐ EGT probe/s located correctly.
- ☐ Starter solenoid earthed
- ☐ Regulator earthed
- ☐ Battery mounted close to the engine
- ☐ Anti RF noise measures taken

FUEL SUPPLY SYSTEM

- ☐ Electric backup pump installed
- ☐ Electric pump supply pressure within limits
- ☐ Fuel line bend radii sufficient
- ☐ All fittings forward of firewall fireproof
- ☐ System designed to prevent vapour-lock

AIR INDUCTION SYSTEM

- ☐ “Cobra Head” fitted
- ☐ Duct to carburettor as direct as possible
- ☐ No sharp edges or sharp corners in system
- ☐ Carburettor heat system working correctly
- ☐ Backfire flap fitted to air box
- ☐ Drain holes drilled in air box
- ☐ Carburettor sense pipe connected correctly
- ☐ EGT’s evaluated

EXHAUST SYSTEM

- ☐ Sufficient clearance – no rubbing on aircraft.
- ☐ Heat muffs for carb and cabin heat included.
- ☐ Outlet positioned correctly
- ☐ Noise levels satisfactory

COOLING

- ☐ Cowl inlet / outlet ratio correct
- ☐ Cowl inlets located and shaped correctly
- ☐ Cowl outlets located and shaped correctly
- ☐ Cowl inlets “sealed”
- ☐ Crankcase and coil cooling correct
- ☐ Pressure differentials correct
- ☐ Engine temperatures correct