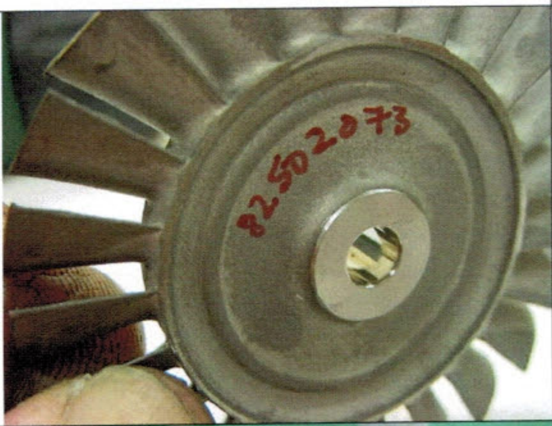
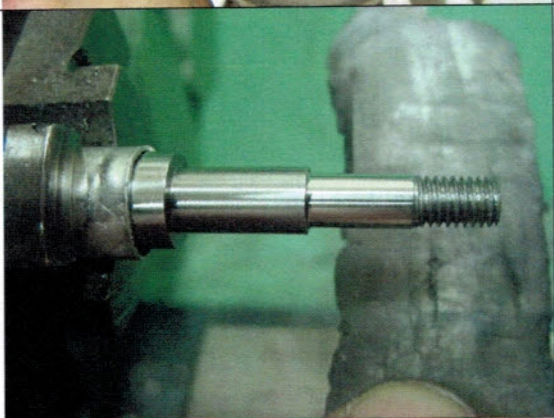
Fitting the Power Turbine.



Give the hone a little oil and fit to a cordless power drill and polish the bore slightly to ease it, by spinning the tool and moving it in and out.

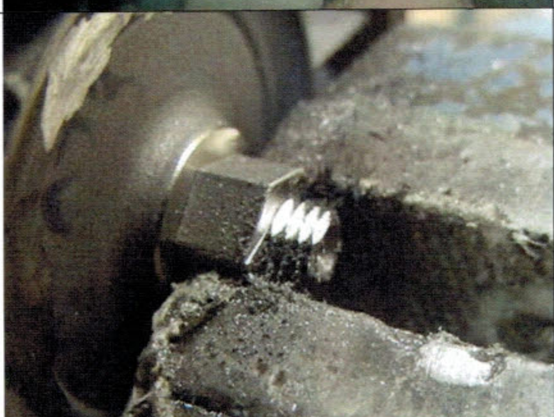
This will only remove a couple of microns but will impart a fine finish and may be all you need.



If the fit needs easing a touch more then you need to polish the shaft a little. Use the emery on the back of a fine file and keep checking as you go.

If you have to remove a lot more material, use the fine file directly and then finish with the emery/oil treatment to polish.

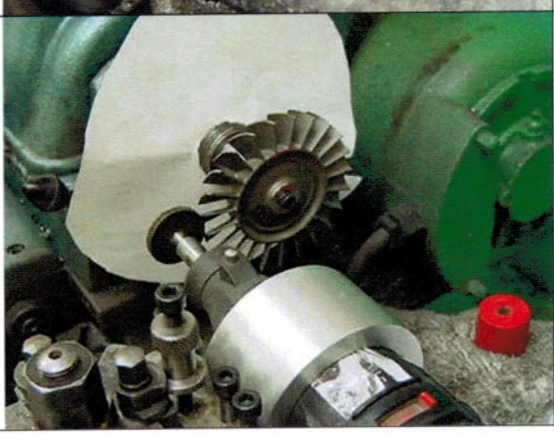
If the turbine gets jammed on it is because the shaft has "picked up". Do not try to twist it off as this will only make it worse. Tap the shaft back through with a nylon faced hammer, and then re-polish the shaft and bore before trying the fit again.



Shaft Locking Flats.

There is no access to the shaft once the turbine is in position and therefore no possibility of locking the shaft to tighten the turbine nut. To alleviate this, a pair of flats are filed onto the end of the shaft to enable a small spanner to be used for locking.

Fit the collar and turbine onto the turbine shaft and screw on the nut until it locks. Grip the nut gently in the bench vice and file the two shaft locking flats using the nut to index exactly the 180' required. File evenly until the flats are 4mm across. Keep checking with a 4mm spanner.



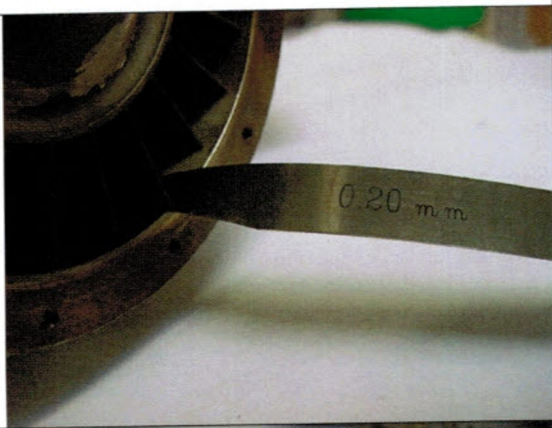
Sizing the Power Turbine, 141.

Before use, the power turbine needs reducing in diameter to the correct tip clearance for running. The blades need to be ground to size. The operation is simple and you first need a 6.35 diameter mandrel for holding the turbine in the lathe and a means of holding the "Dremel" grinder in the toolpost. Use a small grinding wheel or a stack of 3 or 4 cutting discs run fast. Run the lathe very slow – about 50rpm works best, use auto-feed for best finish.

Note - *Wear your safety glasses and a respirator.*

The picture shows the operation. Remove excess material in 0.05mm (1 thou) steps.
Protect the lathe from ingress of grinding dust.

Sizing the Power Turbine.. Lubrication System.

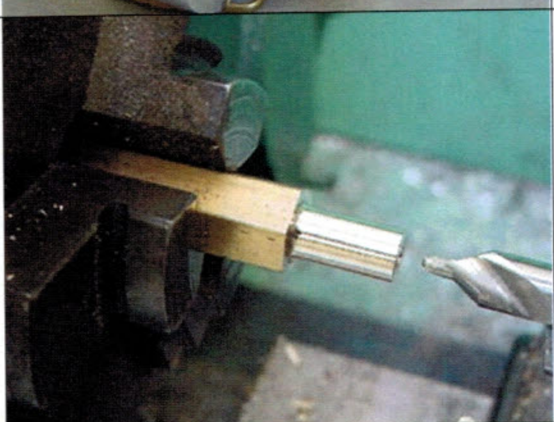


Power Turbine tip clearance.

Grind the turbine until the tip clearance reaches 0.2mm, ie 0.4mm overall across the diameter, measured by inserting the turbine into the Spider and inserting a feeler gauge. The power unit will run perfectly well with a larger clearance but the efficiency (ie shaft torque) reduces. Do not try running with a smaller clearance as the tips stretch in normal running and will catch on the spider casting, damaging them.
The clearance specified assumes the turbine is running perfectly centred and it is important to ensure this is so. Once ground to diameter, there will be a small amount of flash on the tips of the turbine blades, and this should be gently filed or linished off.

Turbine Bearing Lubrication System, 147.
The power turbine bearing runs in a hot and dry atmosphere so to have a good lifespan we need to cool and lubricate it. The system works by supplying cooling air via a pressure take-off from the gas generator case and piping this to the shaft tunnel. Lubrication is achieved using a small supply of fuel tapped from the main fuel pressure line, fed to just behind the bearing. Cooling air helps to ensure this lubrication passes through he bearing and enhances the cooling effect of the fuel. Lick your hand and blow on it to see the effect!

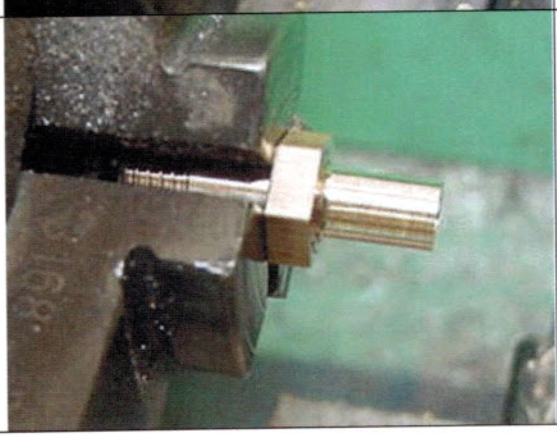
External connections to the shaft tunnel are via a manifold fitted with two pipes and secured to the gearbox base. (Gearbox at left, shown upside down)



Oil Drain Fitting, 151.

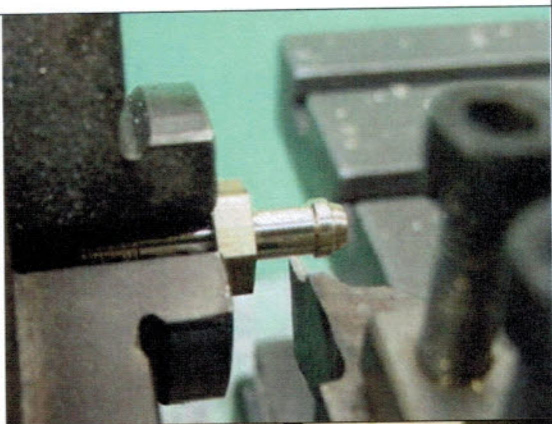
This is a brass turning located at the bottom of the gearbox and acts as an oil drain point and also secures the manifold block. It connects to the oil tank via 3.5mm internal diameter "Tygon" (paraffin proof) tubing. The large bore size is required as only gravity is used to drain the tank. If too small, the gearbox will fill up faster than the drain can empty it and oil may escape into the engine bay – potentially a fire hazard.

Start by turning the 8mm brass hex to 6mm diameter for a distance of 12mm. Thread M6 x 1 for 5mm. Centre drill and drill through 3.5mm diameter.



Reverse in the chuck and machine to length of 23mm, and turn the last 9mm to 5.5mm diameter.

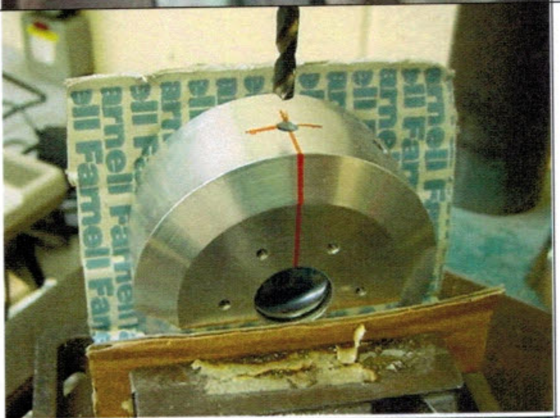
Turbine Bearing Lubrication System



Using a narrow tool, turn the barb which retains the drain pipe. File or turn the chamfer on the end to assist the pipe on when pushing into place.

The remaining section is turned down to 4.5mm diameter. The precise shape is not important but do not go thinner than 4.5mm – remember the 3.5mm inner hole. Use a small file to remove the sharp edges on the hex.

The fitting can be screwed into place by using a standard glow-plug box-type spanner, once the manifold block is completed.

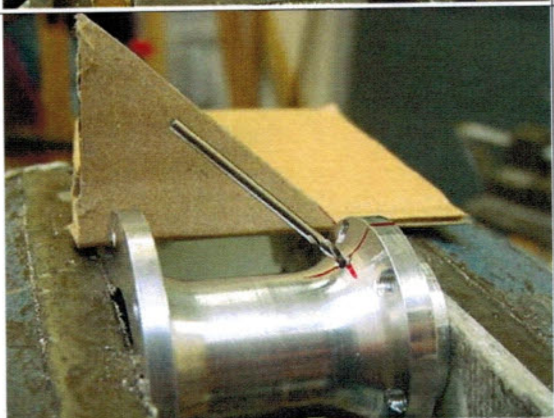


Drilling the oil drain hole.

Mark a vertical line down opposite the bearing support spigot and carry this line around to the underside of the gearbox.

Mark back 12mm from the chamfer and centre-pop. Mount the gearbox in the drill vice, protecting the faces with card, so that the line is nicely vertical (see left).

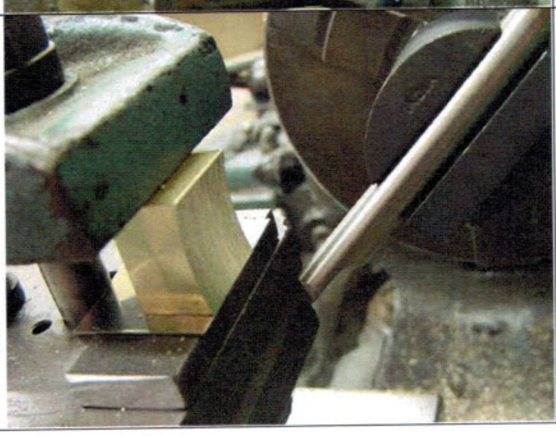
Drill through 5mm diameter, and finally tap M6 x 1mm.



Drilling the shaft tunnel for oil and air pipes.

Both pipes fit into holes drilled in the underside of the shaft tunnel, following a marked centreline. Mark off the oil pipe hole location onto the shaft tunnel by referencing back from the end a distance of 11.4mm. I used a caliper for this.

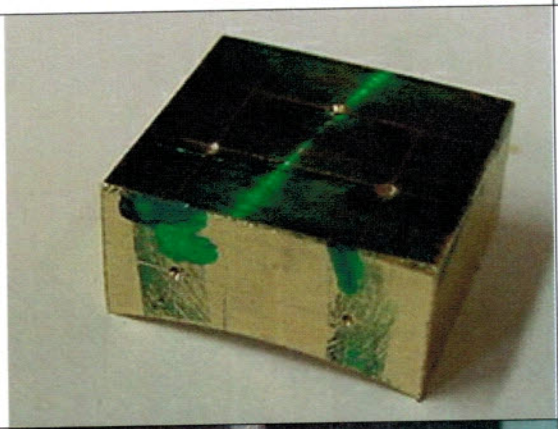
The shaft tunnel is held in the bench vice (tape jaws to prevent scoring) and the oil pipe hole is drilled 1.6mm diameter at 45'. I aligned my pistol drill by eye with the aid of a card template (see left). The aim is for the oil hole to end right behind the bearing race and this was successfully achieved using the method show. If an angled vice is available this should also work well.



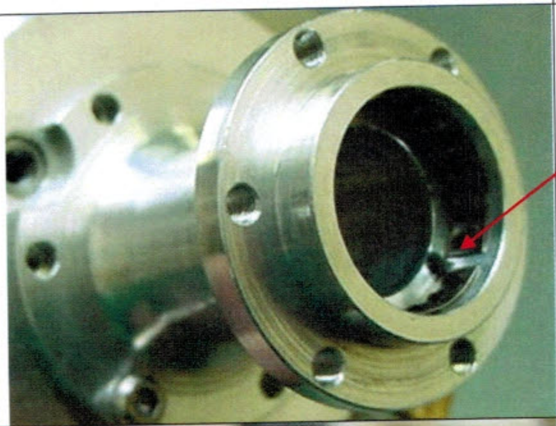
Manifold Block 148
This is machined from a block of brass, the top-side of which is concave to match the curved underside of the gearbox to which it is fixed. Start by machining the block to 16x17mm in the 4-jaw chuck.

To machine the concave, secure the block in the tool-post and set square to the chuck. Set up a fly-cutting tool set to a radius of 37.75mm. Aim to get a cut across the whole face – do not machine to thickness yet. Auto-feed will help to get a clean finish here – take many small cuts as the set-up is delicate.

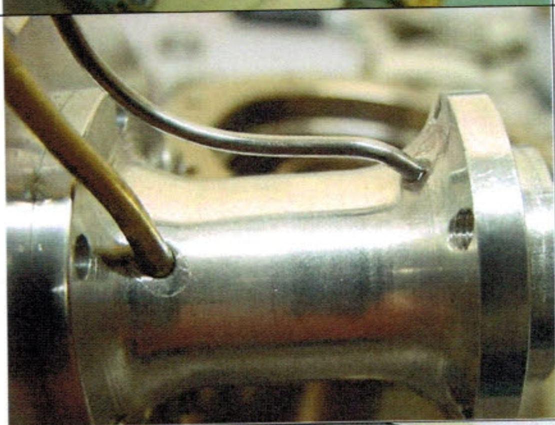
Finally, hold in the 4-jaw chuck and machine to thickness. Protect from the jaws with tape or card.

Turbine Bearing Lubrication System	
	Mark out the various holes in the block. I used a felt marker to provide an easy to see surface for marking. Centre punch and drill holes to depths shown. A depth-stop on the drilling machine helps here. Be careful when drilling through with brass as it has a habit of snatching – use a drill vice, do not try to hold with your fingers, they will lose the argument! When drilling for the pipes, drill slightly (0.1mm) undersize, and lightly linish (belt-sand) the pipe end to be a tight fit – this stops the silver solder wicking in. Once the holes are drilled, tap the two M3 holes for the service fittings. Finally, remove the sharp corners with a fine file.
	**Air and Oil feed pipes 149 & 150.** Prepare the two feed pipes to the length shown and lightly chamfer the end to be a snug fit into the block (as above). Anneal the brass tubes to prepare for bending by heating to red hot and quenching in water. Clean up with fine emery. Make the bends to suit the drawing – I found this easy if you turn a mandrel in brass in the lathe (see left). This is simply a couple of grooves turned to the same width as the tubes, square bottom grooves are ok. This stops the tube collapsing as you form the bend and is then quite easy to do with the fingers.
	**Securing the oil and air pipes to the manifold.** Attach the shaft tunnel to the gearbox with a couple of screws. Secure the manifold block to the gearbox using the oil drain fitting and then insert the oil and air pipes into the shaft tunnel and manipulate them into a comfortable position. Carefully remove the shaft tunnel and manifold from the gearbox and attach a clamp to act as a heatsink on the air pipe. Carefully flux and silver solder the pipes into the manifold using a low temperature (605'C) silver solder such as "EasyFlo No.2" or similar. Once cool, any misalignment in the pipes can be corrected. *(N.B. note tolerance ring in position, at left)*
	The lube sub-assembly can now be carefully removed and cleaned up to remove flux and get a clean finish. Fine emery paper does a good job in conjunction with a rotary stainless steel wire brush inserted into your "Dremel" to get into the awkward bits. Mark the two service ports with a fine engraving tool to show "oil" and "air".

Turbine Lubrication System.



The position of the oil pipe outlet can be seen at left, exiting by the bearing seat.



Sealing the oil and air feed pipes.

Refit the shaft tunnel to the gearbox with a couple of screws and secure the manifold to the gearbox using the oil drain fitting.

Adjust the pipes to the correct alignment and seal the pipes into the shaft tunnel using thick cyno' glue. When set, apply a smear of sealing compound to cover the joints.

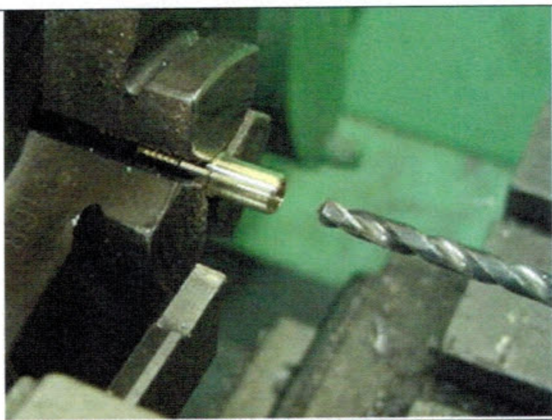
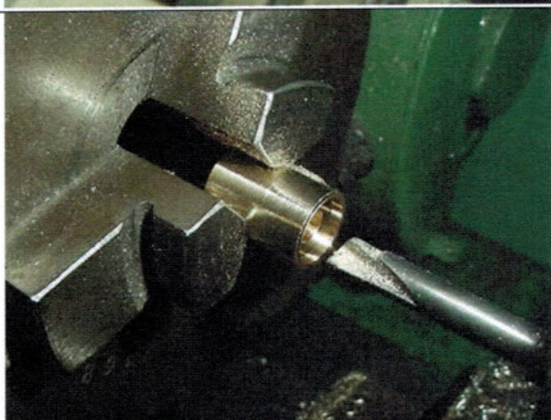
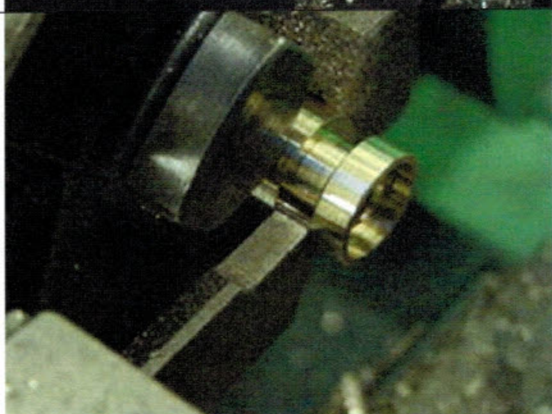
Gear Lubrication System, 164.

The "dry sump" lubrication system is the part of the system that feeds lubricating oil to the gear-train inside the gearbox. It consists of a feed-pipe assembly, mounted in the gearbox with a pair of injector pipes protruding from the side and bent to flow the oil directly into the mesh of each pair of gears. Connection to the oil pump is via 3mm quick release connector.

A special fitting at the base of the feed pipe under the gearbox, contains a sealing o-ring to prevent oil leaks and to provide a firm mounting to the gearbox case.

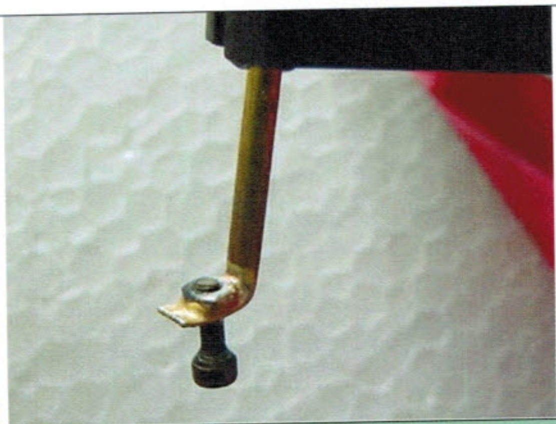
Pipe end fitting.

The end fitting is the first item. This can be turned as a single item or made up in two pieces silver soldered together. I show it made in two pieces. Turn the 8mm brass rod from the materials pack, down to 6mm diameter and then turn to 5mm for 10mm long. Thread M5 to a length of 6mm. Centre and drill right through 2.5mm and tap M3 x 4mm deep.

Gear Lubrication System.	
	Turn the rod around and machine the other end to 4.5mm diameter up to the 6mm portion, leaving this as a flange 1mm thick. Turn to 14mm long overall. Drill the end one drill size smaller than the pipe for a distance of 6mm. Remove from the chuck. The drilled hole is to take the brass pipe included in the materials pack. At this stage it will be too tight to go in. Grip the brass tube gently in the chuck and with the lathe running, gently file a shallow taper sufficient to allow the pipe to go into the hole fairly tightly. This ensures when the part is silver soldered the solder does not block the pipe.
	Grip the 10mm brass bar in the chuck, face and centre and drill through 4.5mm. Use a small boring tool to bore a recess into the end 8.5mm diameter and 1.5mm deep. This is to take the O-ring and allows 0.1mm of compression to seal the ring tightly against the gearbox inner wall.
	Finally, part off to a length of 3mm. De-burr the inner and outer edges using an appropriate tool.
	The two parts can now be assembled together and should look like this. The small flange goes against the top of the O-ring "cup". The brass tube can now be inserted firmly and the whole assembly fluxed and silver soldered together. Use low melting point silver solder – "Easyflo No.2" or similar which melts around 605'C.

Lubrication System - Internal	
	Once soldered, (quench from hot to crack off the flux) the end of the brass tube needs bending close to the fitting. This is easily accomplished by laying over a bar of about 8mm diameter and gently forming by hand. As the tube is fresh from silver soldering it will be annealed and quite soft. Be careful to make the bend an even radius, and not squash the tube.
	Marking out for the mounting hole. The hole position is easily found by viewing the gearbox face on and locating the Front Cover securing hole at the 5-o-clock position. Mark a felt pen line back from the face using a square. Mark off a point 17mm back from the face.
	At the 17mm point, mark 3.2mm to the left and at the intersection make a centre punch mark. The gearbox can now be held in the drill vice (use scraps of card to protect the faces) and set up so the mark is in the vertical position. Centre drill and drill through 5mm diameter.
	Trim the end of the brass tube to length and flatten the end by reference to the drawing. Clean up the fitting with emery paper to remove scale etc. The fitting can now be offered up into the previously drilled hole and any slight bending required to make the fitting fit well, performed.

Lubrication System – Internal



Silver solder an M2.5 nut to the flattened portion of the brass pipe, and seal the flattened pipe end at the same time.

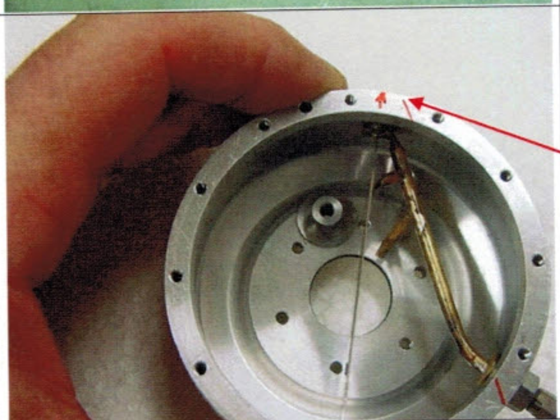
Grease any screw you use to hold it into place as it will all blend into a solid lump otherwise!

Mark off and drill the two 1.5mm holes for the brass injector pipes. Cut these from a length of 1.6mm (1/16") brass pipe.

One end of the pipes should be lightly reduced by linishing or filing in the lathe until they just push fit into place in the 1.5mm hole.

Silver solder into place, and then clean up the fitting with fine emery.

Relocate the fitting into the gearbox as we need to mark the securing screw hole.

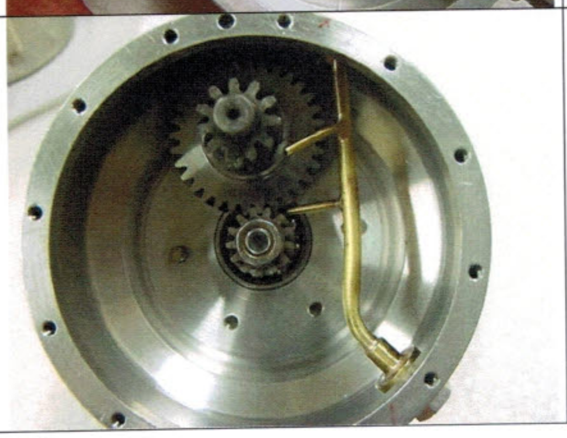


Use a steel rule to point to the M2.5 soldered nut, and sight along this to highlight the location for the drilled hole for the fixing screw, for securing the flattened end of the fitting.

Mark the gearbox at the point with a line or arrow (see left). Continue the line down the outside with a square.

Measure 17mm from the front face of the gearbox along the line, and make a centre-punch mark.

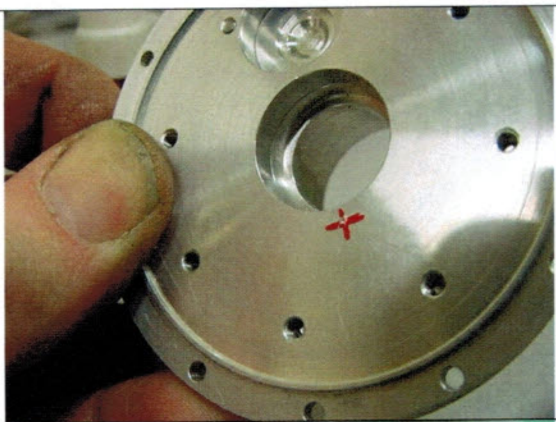
Drill through 2.5mm diameter for the fixing screw.



Fit the intermediate gear onto its bearing and fit onto the stub-shaft. Fit the power turbine shaft with its bearing the small pinion gear and M5 nut, and locate into the gearbox rear.
The exit position of the lower injector is adjusted by gently bending, until it points at the centre of the meshing gears, with about 2mm clearance. If less than this make a felt pen mark for shortening later.

Hold the larger prop-driver gear into mesh on the intermediate gear and in the correct position right over the smaller pinion gear. The upper injector is then adjusted in the same way, pointing halfway along the gears and with 2mm clearance. When done remove, and trim the injectors as required.

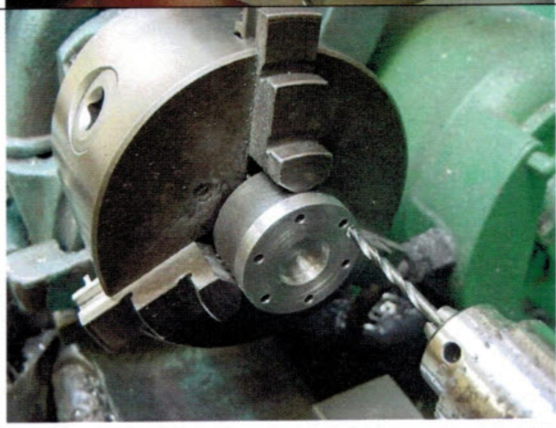
Oil Drain. Clamp Ring 143, Prop-Driver 160.



Drilling the prop-shaft tunnel oil drain.

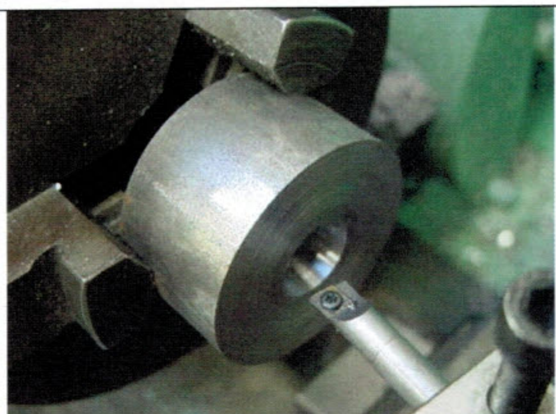
The drain hole is required as there will be a natural seepage of oil past the metal seals of the two rear prop-shaft bearings – this is normal operation. To avoid a build-up of oil behind the front prop-shaft bearing and possible leakage, there is a drilling to return the oil back to the gearbox. Attach the prop-shaft housing to the gearbox cover with a couple of screws first.

Mark the hole position by running a vertical line through the centre on the back of the gearbox cover. Using dividers, scribe a cross mark at 2.5mm below the bearing housing. Centre punch and drill 3mm to a depth of 15mm total, through both parts. Tidy the exit of the hole to remove burrs and swarf.



Clamp Ring, 143.
This part retains the spider casting onto the power turbine shaft tunnel. It is secured used six M3 screws which pass through the Clamp Ring, the two insulating gaskets and the spider. It also prevents the tolerance ring from sliding out of alignment as the power turbine shaft moves with respect to the load and helps maintain a small reservoir of lubricant for the bearing. Use mild or stainless steel – mild is included in the materials pack.

Face the 35mm steel blank. Turn the outside to clean it up – about 34mm for a length of 6mm. Bore the centre to 14.5mm and 6mm deep. Set up your drilling spindle and indexing attachment and centre and drill the six 3mm mounting holes on a pcd of 28mm. Finally, part off to 2mm thick.



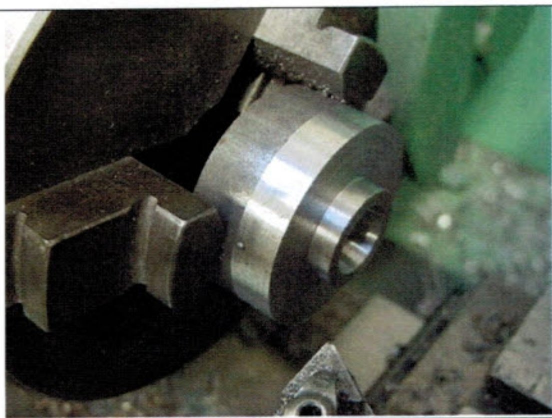
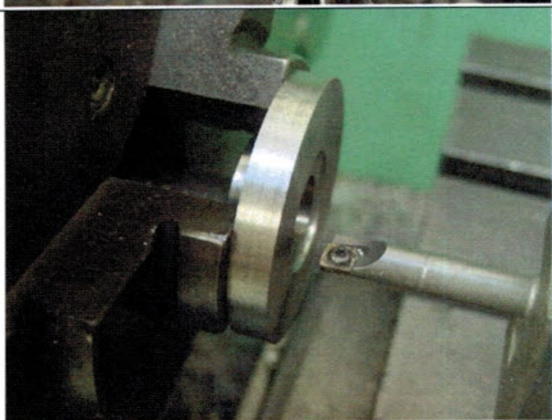
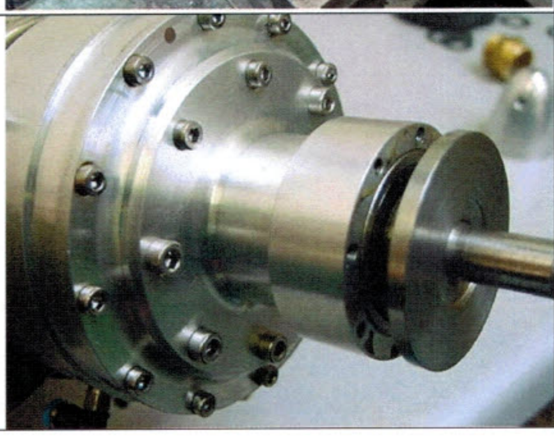
Prop Driver, 160.
The Prop Driver transmits torque from the gearbox to the propeller, via a simple taper on the Prop-shaft. This enables a certain degree of overload protection for the gears in the event of a prop-strike on landing etc. It needs to be made with a small clearance in front of the front bearing to ensure a firm seating on the taper.

Start by chucking the remainder of the 35mm steel blank in the 3-jaw and face and centre the end. Drill out to 9.5mm and then set over your top-slide to 8^0, as accurate as you can to bore the taper. Use a small boring tool and bore out the taper to just under 12mm as measured at the face end. Use the Prop-shaft as a bore gauge.

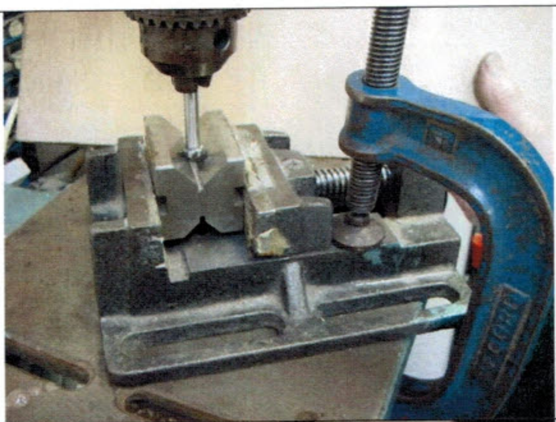
Using a feeler gauge, check the gap in front of the front bearing when the Prop-shaft is pushed fully home on the taper.

Aim for a minimum of 0.2mm (8 thou). Much more than this gives excessive end-float in the shaft, less can mean the taper is not fully home when tightened up. This can cause the prop-driver to slip under load, and possible over-speed of the turbine, which must be avoided – so check carefully.

Err on the generous side if unsure.

Prop Driver.	
	Once the taper is completed, turn the rear boss to 17mm diameter and a length of 4mm. Only do this after the taper is completed as there is plenty of material for you to keep making adjustments if required. When the boss is complete, reverse in the chuck and grip with the smallest overhang you can on the outside.
	Machine the bulk of the excess material off to get to about 9mm length, then grip on the smaller boss diameter to machine to finish length of 8.5mm. Use a small boring tool to bore out the centre recess to 12mm diameter and 1mm deep.
	Grip the outside of the Prop-driver and machine the taper in the rear. This angle and shape is not critical as it is to tidy it up and lose some weight. I machined the back taper with a parting tool, considerably extended to get the reach, and took small cuts. You can use your flair to get a shape you like, but don't make it too thin at the centre as it may not grip so well on the taper. Finally, grip on the boss and clean the outer faces up with fine emery. Do not polish the taper or the prop face as both need a certain amount of roughness to grip. You will find the prop will self-tighten during running and this is normal.
	When the prop is first tightened and the power unit is run, the prop driver will lock into place onto the shaft taper. If you need to remove the prop-driver, gentle heating with a hot-air gun or blowtorch will expand it slightly and release it. Do not try bashing it or levering it from behind – you will almost certainly damage the bearings and the prop-shaft housing. The front bearing will only seat fully back into place when the cowl is fitted, so do not worry if there is a slight protrusion of the front bearing before the cowl is on.

Spinner.



Spinner, 161.

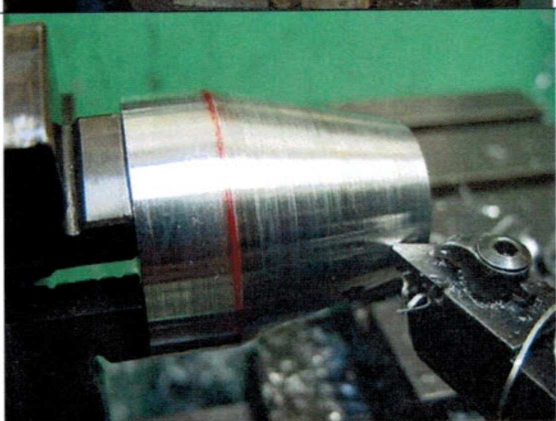
This is made from 35dia x 38mm long HE30 or good machining quality aluminium. Grip in the chuck and face the end and mark a line at 26mm from the faced end. We need to drill the cross hole whilst the blank is cylindrical so this is the next operation.

Set up a vee block in the drilling vice on your drilling machine exactly centred on the drill spindle, (I used a 90^0 countersink – see left).

Align the marked line carefully using a centre drill held in the chuck.

Spot the mark with the centre drill and then set up a 4.2mm drill and set your drill stop so it does not hit the vee-block. Use a clamp to hold the blank firmly onto the vee block and drill right through with 4.2mm drill – be careful as the drill breaks through and be careful of the drill snatching.

Transfer back to the lathe and grip with the faced end out. Centre and drill 6.8mm for a depth of 28mm (to the end of the cross hole). Tap the hole M8 x 1.25 to a depth of 24mm. Deburr the end of the thread with a suitable countersink.

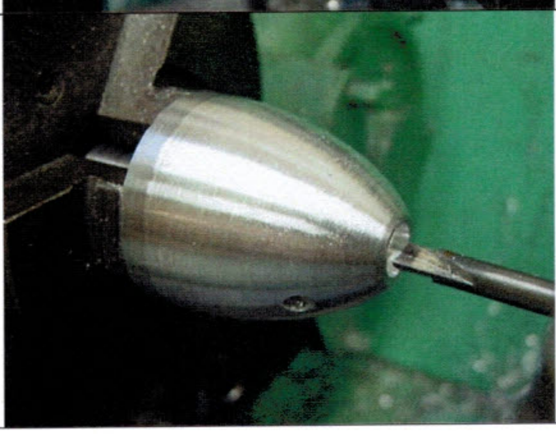


We now need to mount the spinner blank on a mandrel to machine the outside profile.

Make a steel mandrel with an M8 thread of about 20mm long protruding from the chuck. Mount the spinner blank on the mandrel and tighten, and check it runs true. Skim down to 34mm diameter and face to a length of 36mm.

Set the topslide to an angle of 15^0 and mark a line with a felt pen 10mm in from the chuck end. Machine a slope up to the mark.

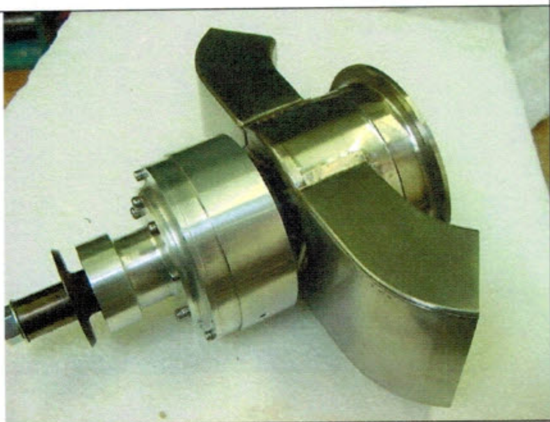
Mark a second line 32mm from the chuck and set the topslide to a new angle of 50^0.



Machine the blank at the 50^0 angle, up to the new mark. Manipulate the cross-slide and carriage handwheels to create a smooth profile with the angles forming the basis of the shape. The exact profile is not important but it will be more esthetically pleasing if the curves flow neatly. When you have machined the profile roughly to shape, use a hand file to smooth into a gentle curve.

Centre the end and drill through 4.2mm diameter for the spinner retaining bolt. Using your small boring tool open out the end to 7.5mm and a depth of 6mm. Finally, use emery and oil to smooth the exterior profile and polish up to a high sheen with metal polish if desired.

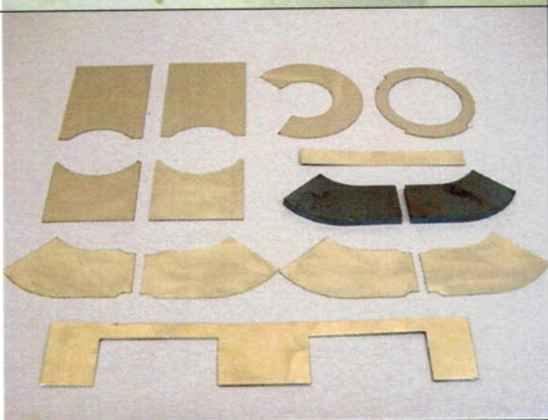
Exhaust System.



The exhaust system is a simplified version of the ideal shape, as the first criteria for a home-builders plan is that it has to be able to be made by homebuilders!

We have made use of simple parts and spot welding to construct the assembly, and only a few simple jigs are needed. The steps are presented in sequence and it is suggested home builders use this order as their starting point, to avoid distortion and poorly fitting components.

It is assumed builders have access to a spot welder suited for thin stainless steel (0.5mm).



Left shows the laser-cut stainless steel exhaust materials pack, available from Wren Turbines.

This saves a large amount of messing about with printed profiles and hand cutting with tin snips – all you need to do is roll them and weld them together!

Also included, is a pair of formers laser cut from 6mm mild steel plate for the Exhaust Stack Top and Bottom, as these really need to made of metal and are a fiddly shape to make by hand.

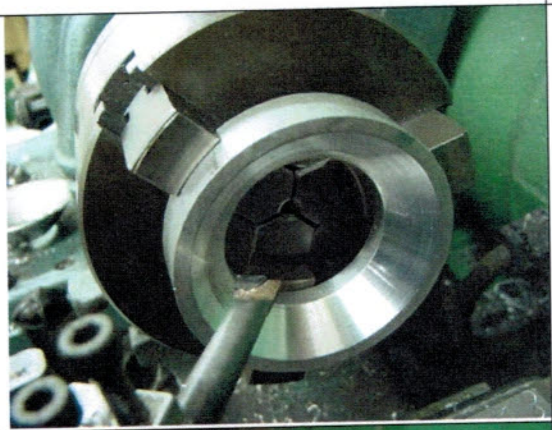
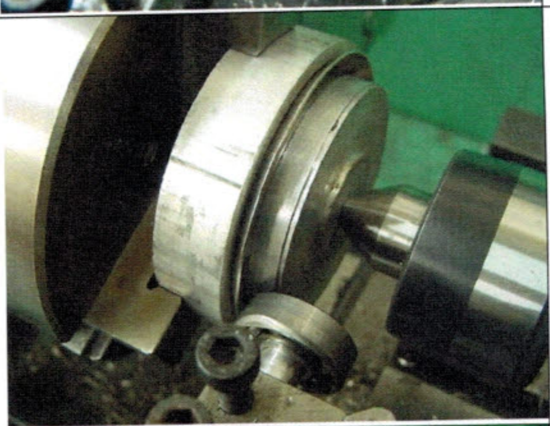
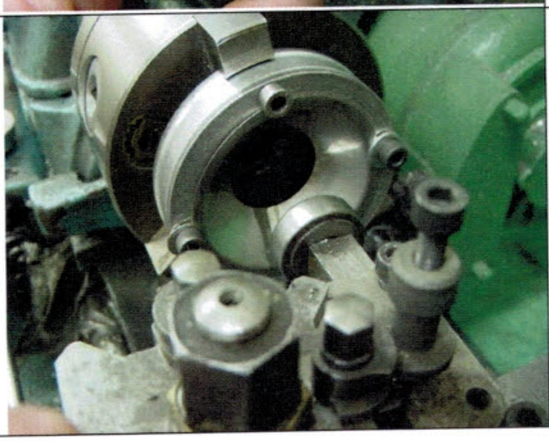
Exhaust cone, 132.

This laser cut item only requires hand forming around a metal bar to create the cone-shape. Aim for a 3mm overlap at the joint.

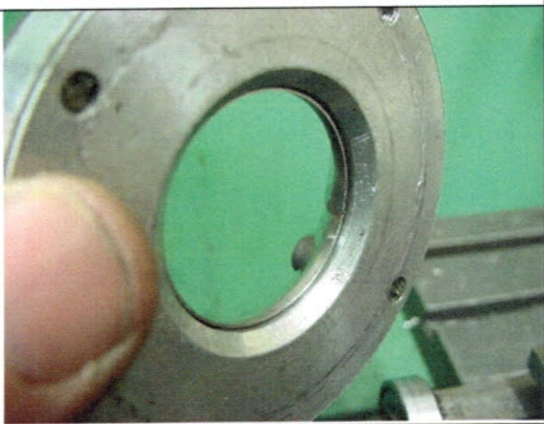
Apply a spot weld to the outer end and then manipulate the cone to its correct shape.

Once done, apply a weld to the other end and then weld the seam with welds about 2-3mm apart.

Sand/grind the seam on both sides to smooth the joint and take some of the bump out of it, as we need to spin the inner and outer flanges and a large bump here can cause trouble.

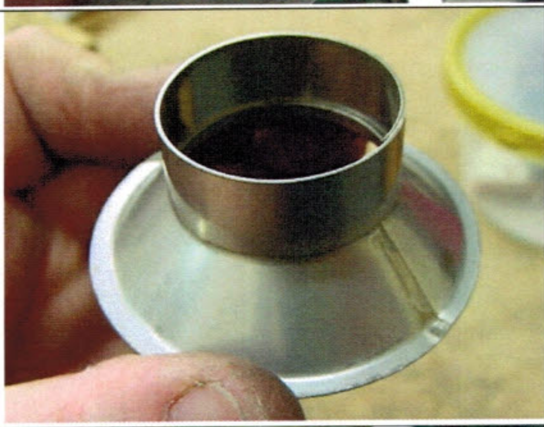
Exhaust Cone, 132	
	Machine a ring for spinning the outer flange on the exhaust cone, from a bit of scrap aluminium of diameter at least 65mm (ideally 90mm), with an inner hole of 35mm and a slope of 45', tapering out.
	Make or find a thick round washer of about 45mm diameter and 5mm thick minimum, with a centre-drilled hole. Bring up the tail-stock to hold the washer centred and hold the cone in position by trapping it under the washer and your spinning tool. Fit a ball-race (ISO608 size or similar) to a piece of bar held in your tool-holder (see left). Get the cone turning true by loosening the tail-stock and making adjustments as necessary.
	Run your lathe in mid speed (about 350rpm), and use the ballrace to press the edge of the cone flat against the spinning tool, to form a flange. Once done, the cone should look like this (see left).
	We now need to hold on to the outer diameter of the cone and spin the inner 3mm inwards to form the flange for the exhaust inner. I used an aluminium block with four threaded holes into which I fitted screws and washers to hold the flange. The block was machined with a 10mm recess of 56mm diameter and then a centre hole of 34mm internal diameter was turned. If a 90mm block is used for spinning the taper, the screws can be screwed to the same block. The cone was held in place with the four screws, and the bearing inserted into the hole in the cone. The lathe was then started and the bearing used to roll the inner cone out onto the inner diameter of the block to form the 34mm diameter flange.

Exhaust Cone and Inner



The flange can be seen in the centre of the block from the rear.

The block shown, was previously used to spin combustion chamber fronts for the prototype MW54 – hence the extra chamfer!



Exhaust Inner, 128.

This is simply rolled up from the strip of 0.5mm stainless laser cut set, and welded to make a tube of 34mm internal diameter, which is a tight press fit to the Exhaust Cone.

The Exhaust Inner is aligned carefully and spot-welded into place.

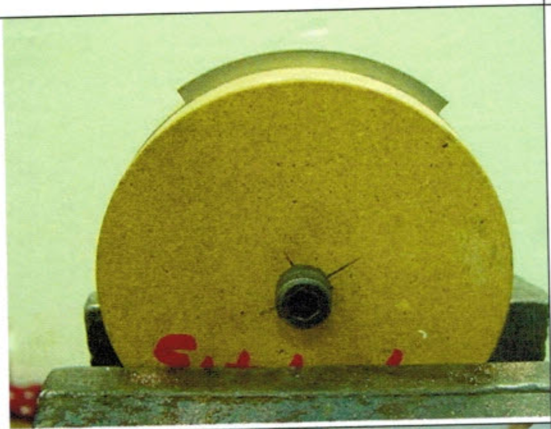
Make a couple of opposite tacks first, check and confirm alignment and then weld all around.

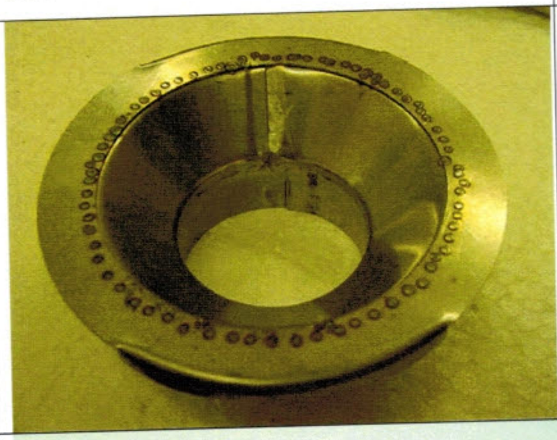
Once welded, use a sanding drum and sand/grind the seams to tidy them up and enable a sliding fit into the centre section of the spider casting.

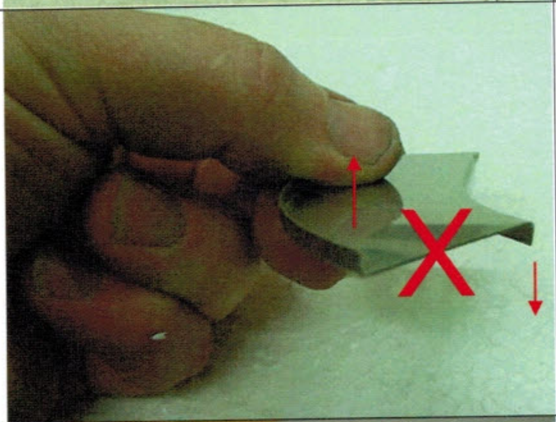
Exhaust Front, 131.

This part is a 0.5mm thick stainless disk with a centre hole and pair of "ears" which are folded down to provide flanges for the top and bottom sections of the exhaust to weld to. The disc is part of the laser-cut component pack and only needs a simple pair of formers to make the flange required.

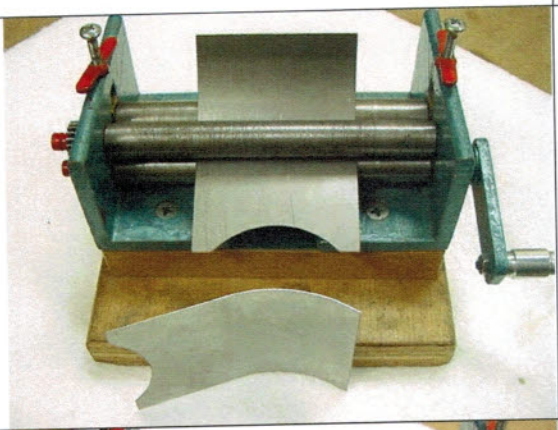
Cut two disks from 10mm thick birch plywood or MDF, diameter 75.5mm and with a 6mm centre hole. Finish them on the lathe if needed, to get then nicely round. Round off one edge of one of the disks very slightly, to about 0.25mm radius (just take off the sharp corner).

Exhaust Front	
	Place the discs together and trap the Exhaust Front between them, aligning the edges carefully. Put an M6 bolt and nut through the centre to hold them together. Place the whole assembly low in a vice and tighten firmly.
	Use a nylon hammer to form the edge over, using small taps and working back and forth along the bend line to keep it even. The ideal shape has a sharp corner so keep the radius as small as you can.
	Once one side is well formed, remove from the vice, rotate and do the same to the other side – keep them going the same way though! Once complete the formers can be removed and put to one side ready to weld onto the Exhaust Cone.
	Place the Exhaust Front over the Exhaust Cone and centre. Place a single spot weld and check alignment of the assembly. When confident everything is in place, apply a series of opposite welds to secure.

Exhaust Stack	
	Finally, weld the entire seam all round. Put to one side while we move onto the Exhaust Stack Top and Bottom.
	**Exhaust Stack assembly, 127 (2-off).** This assembly is made up of a top, bottom, front and back 0.5mm stainless sheet part. The four parts are spot-welded to form a box which acts as the exhaust gas passage. Two complete sets are required. Start with the top and bottom, which require a flange and a pair of formers are included for this. Pick out the two 6mm mild steel formers and using a file round off the sharp edges of each side and smooth out any cut marks. Using emery, polish up each face to a smooth finish with no bumps or raised scratches. Place the formers on each side of one of the exhaust parts, so that it lies flush with the broad end and centred with equal overhang from the former.
	Hold the three pieces together carefully and grip firmly in a vice. Using a nylon hammer, the protruding edge can be tapped over as before, tapping gently and evenly along the line to avoid any bulges.
	Finally, follow up with a small engineers hammer to flatten down any last small bumps. Turn the whole assembly over in the vice and do the same to the opposite edge, ensuring the former does not slip during the changeover. Be sure to make two opposite pairs – not four the same!

Exhaust Stack, Top and Bottom.	
	You should end up with two opposite pair like this.
	The official word for making a piece where one side goes up and the other down is AAAAHHHHHGGGGGG! (We carry spares if this happens to you!)
	Fit each piece in turn back between the formers and tap over the narrow end tab to about 45 degrees.
	Check to ensure the tab is straight and reasonably constant along its length.

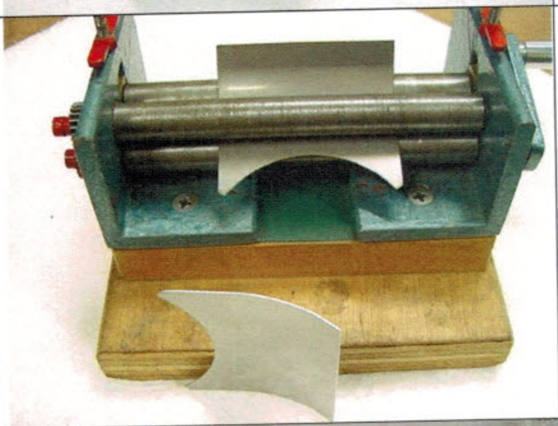
Exhaust Stack.



Exhaust Stack Front, 135.

These are two more components from the set of laser cut pieces and form the front curved wall of each exhaust pipe. The fronts are the longer of the two pairs in the parts set

Roll the outer part of each piece to roughly form to the shape required to match up with the outer curve of the Exhaust Stack Top and Bottom, made previously.



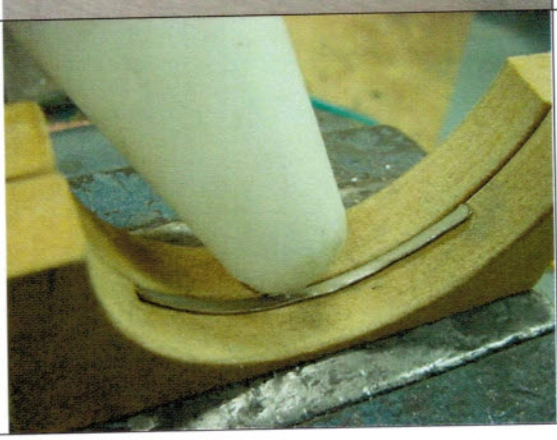
Exhaust Stack Rear, 133.

Similar to the Front, these are made from the shorter of the two pairs in the laser cut parts set.

The inner curved portion needs a flange forming to mate with the Exhaust Outer to enable it to be welded into position.

The former is made as two parts from 10mm plywood or MDF about 60mm x 50mm. A curve of 37.75mm radius is cut into one of the long sides on each piece.

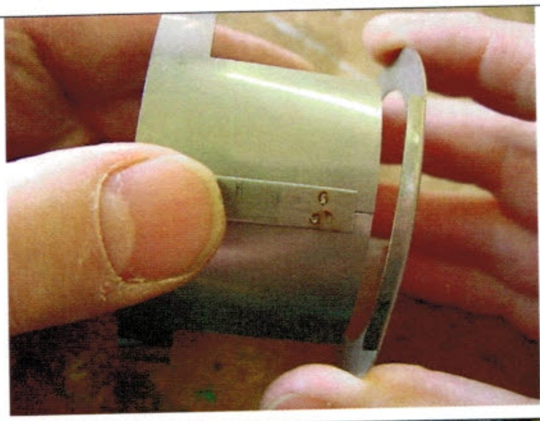
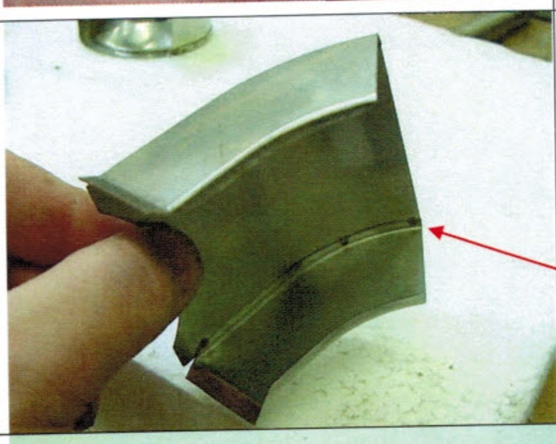
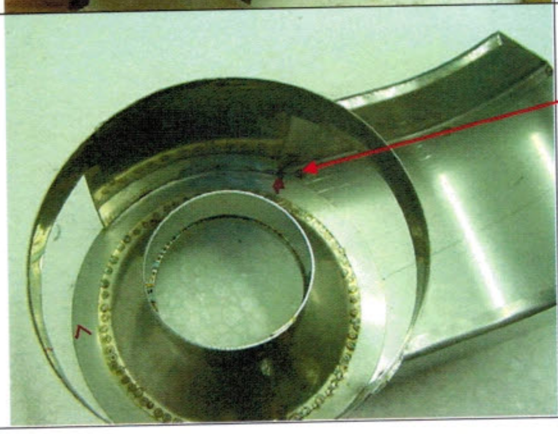
Each of the Exhaust Stack rear pieces, is clamped between the two formers with a 3mm overhang into the curved part of the former.



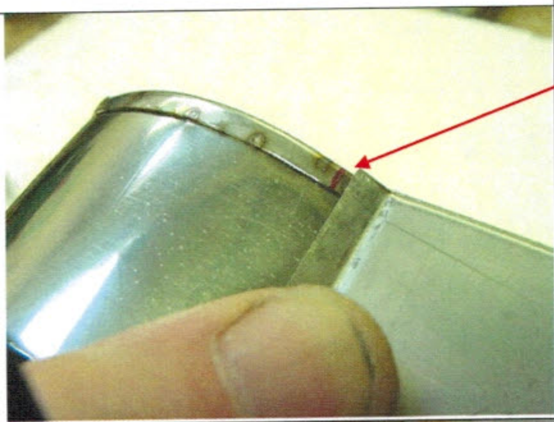
The assembly is clamped into a vice firmly and the flange formed by lightly hammered over with a nylon hammer.

As before the forming should be done evenly along the length of the curve to avoid ripples starting.

Do not finish with a metal hammer as this will crush the wood and leave dents in the flange.

Exhaust System	
	**Exhaust Outer, 130.** This is simply rolled up and spot welded from the laser cut piece. Make the seam 3mm overlap, and do a single spot at each end of the seam and check the fit over the Interstage Spider casting – it should be a firm push-fit. Check also the fit into the Exhaust Front – this should also be snug. If either are not quite right, break the tack and correct. When fits are good, you can weld up the seam properly. Finally, clean up the seam with the drum sander as before.
	Fit the Exhaust Front onto the Exhaust outer, aligning each component as best you can. Apply a couple of spot tacks on each side, pressing the front firmly in position before each one. Once positioned correctly you can weld up the seam with the Exhaust Front. Tap along the seam with a small hammer to gently flatten any bumps and close up the seam. Use a drum sander in the "Dremel" to clean up and remove all weld traces.
	**Exhaust Stack, 127.** Each exhaust can now be built up. Start by spot tack-welding the Exhaust Fronts onto the outer edge of the flange on the Exhaust Stack, Tops and Bottoms. Align the tops and bottoms with the edge of the Exhaust Front.
	Offer up the right-hand exhaust assembly to the Exhaust Front and Outer, and align the top right hand edge with the opening in the Exhaust Outer – see left. This recognises that the gas flow from the power turbine still contains considerable swirl in the clockwise direction, and this tends to hug the top right and bottom left of each exhaust pipe. Providing a clearer opening for this helps to ensure more efficient excavation of gases and cooler running for the engine

Exhaust System



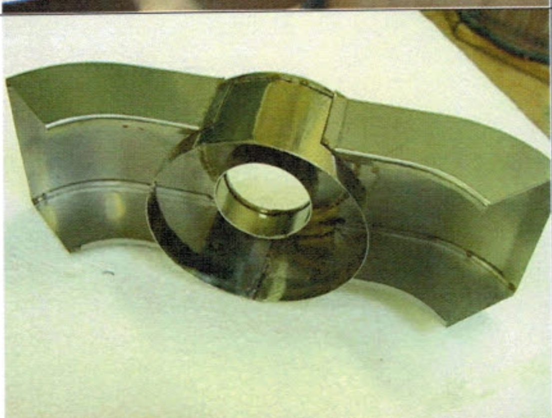
When in position, turn over and check for any overlap over the flanged portion of the Exhaust Front, grind this away if required.

Each Exhaust Stack assembly must seal against the Exhaust Outer to the best that can be achieved as any holes are difficult to close later. This is particularly important at the corners.

Once in place, apply a couple of tacks at the front end, to hold. Do not tack at the rear edge of the Exhaust-Stack yet as we need to fit the other Stack and align them both into position.

Offer up the left-hand Stack into position by aligning the bottom left edge on the inside, (ie diagonally opposite the r/h section).

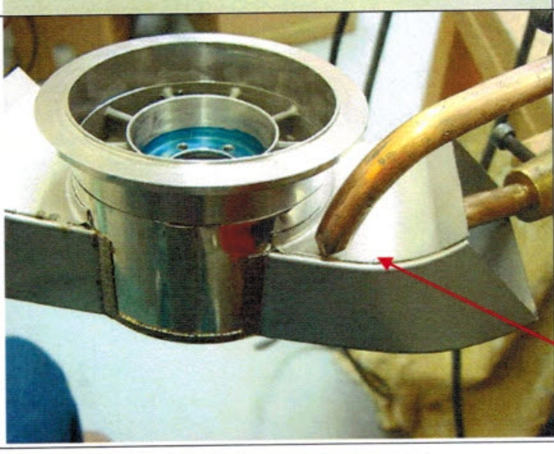
Check and grind away any overlap over the Exhaust Front as before, and tack in position at the front edge only.



Your exhaust system should now look similar to this. Fit the Spider casting into the Exhaust Outer, this will ensure it is held perfectly circular.

Hold a straight-edge across the front of both Exhaust Stacks to ensure they are in line with each other.

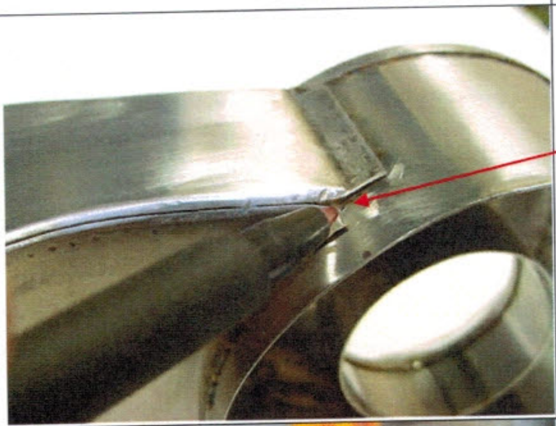
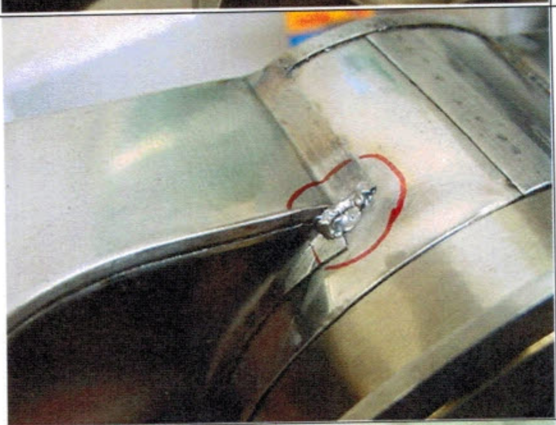
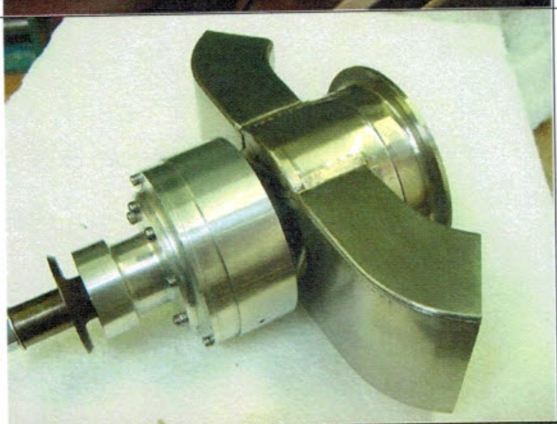
Press the rear edge of each Exhaust Stack in turn and apply a tack on the top and bottom sections to lock them in place. Access to spot weld can be achieved through the exhaust opening. Leave the Spider casting in place for this, to ensure the Exhaust Outer does not go out of shape due to the spot welding.



Exhaust Stack Rear, 133.

Each of the Exhaust Stack Rears can be offered up to the exhausts. They need to be a snug fit to the Exhaust Outer and to achieve a good seal at the corners where the parts meet. Make any small adjustments to the flange as required to get the best possible fit. When satisfied, make a couple of tacks to hold the Rears into place after pressing firmly into position.

When satisfied the Rear is properly in position, make further tacks about 15mm apart, along the exhausts. Close up or pull out the Exhaust Stack Top and Bottoms to maintain the distance apart – note the finish is neater if they are held just short of the edge.

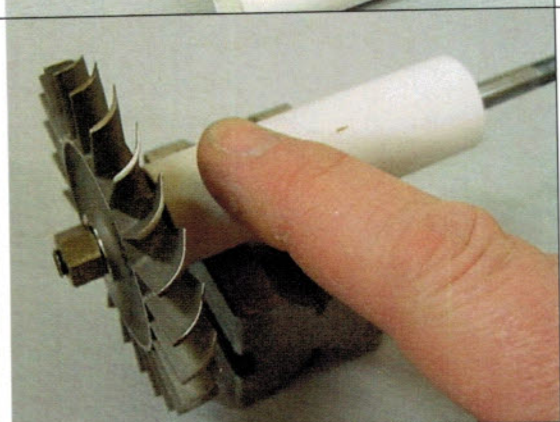
Completing the Exhaust System	
	All the seams can now be spot-welded firmly using close spaced welds to achieve reasonable gas tightness. The junction of the Exhaust Stack Rear and the Exhaust Outer is difficult to fully seal. It is suggested the help of a skilled TIG welder is enlisted to apply a small weld into these corners to seal them firmly. If you cannot get someone to do this or do not have the equipment the small hole can be sealed with car exhaust compound such as Holts "Gun Gum" or similar.
	The corner gap sealed with a small TIG weld. Check carefully to make sure there are no small pin holes anywhere as these can cause hot exhaust leaks into your engine bay, not recommended!
	Once welded up, the whole exhaust system can be cleaned up. All welded edges can be smoothed with a fine file or the sanding drum and linisher. Polish up by rubbing over with fine emery to remove the bulk of the scratch and weld marks. Offer up the spider and gearbox to the exhaust and you can see how it is all coming together. The exhaust is a complex part to make but its completion gets us over the major hurdle of the project.
	The two exhaust securing holes need drilling in the spider casting. You need to orientate the exhaust so the two exhaust stacks are at 90^0 to the drain hole in the base of the gearbox. The hole positions are marked on the plan and they should be pre-prepared for you on the laser cut Exhaust Outer, 130. The holes should be drilled 2mm diameter and are then tapped out M2.5mm. The material is very tough so you need a sharp drill, slow speed and cutting paste. The hole positions are arranged so the securing screws locate between the vanes of the spider casting.

Balancing the Power Turbine

Balancing.

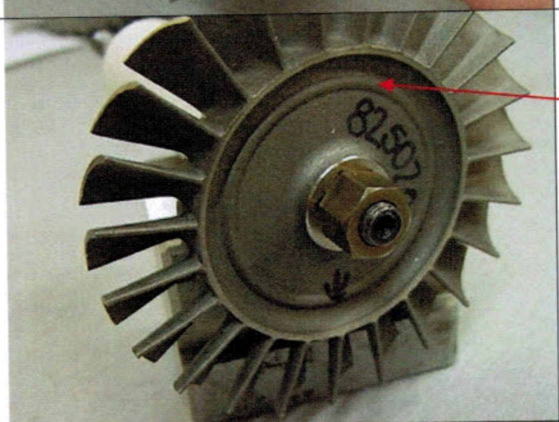
Before the power turbine can be fitted you need to balance it to below 50mg/mm imbalance. The exac\t figure is not important but you should aim for the best balance you can. This is not difficult and does not take so long to do. First you need to mount the turbine on a shaft with a nice fit and a couple of easy running bearings with a spacing of around 50-60mm. I found an old shaft from an MW54 was ideal. You may have to make something specially for the task.

The picture shows the set-up needed. In addition to the shaft you need a tube which is a loose fit on the bearings – 20mm smooth bore, cold water pipe is ideal.



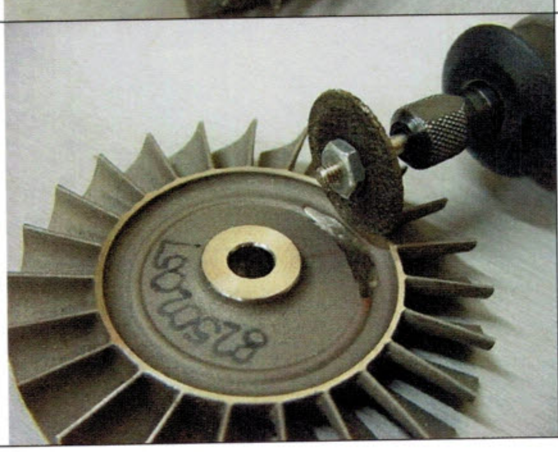
Slide the shaft assembly into the tube and rest it on a raised flat surface - a vee block or even over the edge of your table is fine. Place a finger on top of the tube and rock it back and forth. The turbine will rotate so that the heavy point is downwards.

If the bearings are not free running, soak them in paraffin for a while. If they are gritty they will need cleaning out. It is worth buying a couple of low cost 688 size bearings for the task and removing any seals to keep them really easy running. Keep them in a sealed plastic bag for the future. Balancing will not work if the bearings are too stiff.



Mark this bottom position and remove the turbine from the shaft. The imbalance must be ground from the ring cast into both faces of the turbine.

We have found you often need to grind both sides and quite a large amount as the wheel hub is quite thick and any imbalance is quite pronounced.



Use a cutting disc in the "Dremel" to perform the grinding. Don't forget to wear your goggles and try to grind away from you as the dust is harmful. If this is tricky to do, then wear a face mask.

Be very careful not to grind into the rim as this can weaken the turbine. Check the balance regularly and you will notice it takes longer to make the wheel come to rest in any one position. Keep going until the wheel stops at random points only. Take a break mid-way as coming back afresh helps keep the concentration going.

The grinding process can be a couple of hours so be patient and stick with it. The smoothness of your turbo-prop gearbox depends on the care and accuracy of this operation.

Assembly.

Assembling the power unit.

It is assumed that all parts have been made and that items shown as assemblies have also been completed. These include prop shaft, intermediate shaft, intermediate shaft bearing support spigot, power turbine shaft tunnel lubrication assembly, internal lubrication assembly.

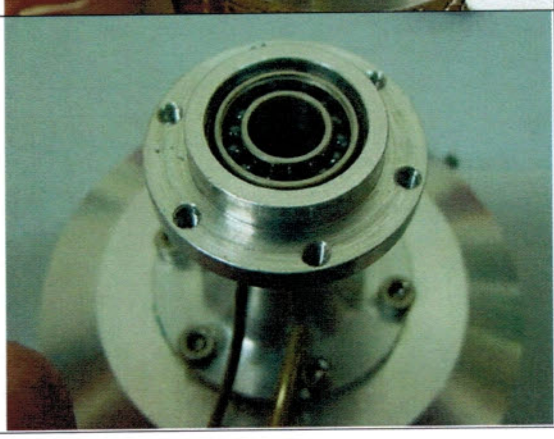
Any bearings that have been used for assembly purposes need a thorough cleaning and oiling. All parts need cleaning to remove swarf or dirt. Many of the parts are thread-locked on assembly and we recommend "Loctite" products, the relevant product number will be quoted to aid selection. Others can also be used as long as they are selected with regard to duty required.

The high-speed pinion must be securely held on the shaft as it transmits all the turbine torque. Grip the shaft in the vice after wrapping in 1mm aluminium sheet. Slide the special bearing 175, into place after lightly oiling the race, ensuring the cage faces the gear end. Degrease the shaft end and pinion hole. Slide on the oil thrower, large diameter to bearing, and apply a coating of Loctite 601 "Retainer" locking fluid. Slide pinion in place with a twisting action ensuring liquid spreads along the hole.

Apply Loctite 601 to the M5 thread and screw on the nut firmly. Wipe away any surplus fluid ensuring none gets into the bearing. If you have not already done so, fit the O-ring cord 186, into place in the gearbox rear using a light smear of silicon grease.

Slide the tolerance ring 185, into place at the turbine end of the shaft tunnel. Carefully insert the ceramic turbine bearing with the arrow pointing out. Gently press this into place by pressing against the outer race – not the centre.

Insert the shim washer 180, into the front end of the shaft tunnel followed by the two wavy washers 181.
Lightly coat the outside of the front bearing on the turbine shaft using a smear of silicon grease – note do not get any in the bearing raceway. Carefully insert the shaft into the shaft tunnel and check you have about 0.5mm movement until the shaft meets the shoulder of the turbine bearing inner ring. Do not force this as you may push the bearing inner out.



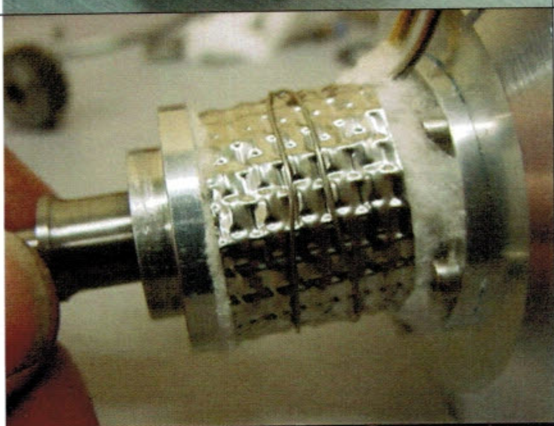
Leaving the shaft in place, apply a smear of low strength liquid gasket compound, available from car accessory stores, to the front face of the shaft tunnel and the underside of the manifold 148. Wait a minute or so for the compound to thicken and ease the shaft tunnel onto the gearbox rear, using the bearing as a peg to ensure perfect centring.

Fit the six securing screws 192, into place using a trace of thread locking compound ie "Loctite 241" or similar on each. Tighten evenly and firmly. Check the shaft is able to slide out of the shaft tunnel forward into the gearbox. Replace the shaft into position.

Assembly.

Slide the fibre washer 151, onto the oil drain adapter 167, and smear some liquid gasket compound onto the thread and screw it into the gearbox, securing the manifolds into place.

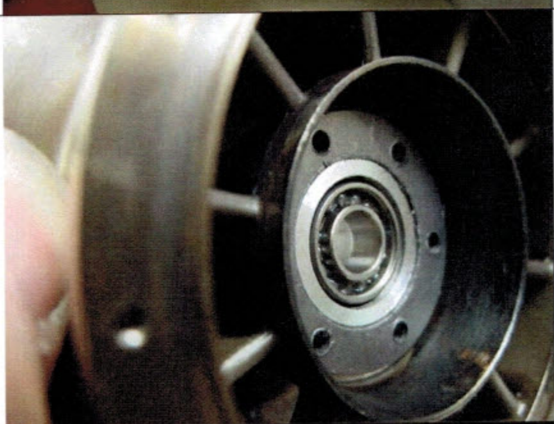
Clean up any excess gasket compound squeezed out with cellulose thinners, before the compound has set.



Insert from the inside, the four M3 x 8mm (192) screws through the tapped holes in the gearbox. Thread-lock these firmly into place.

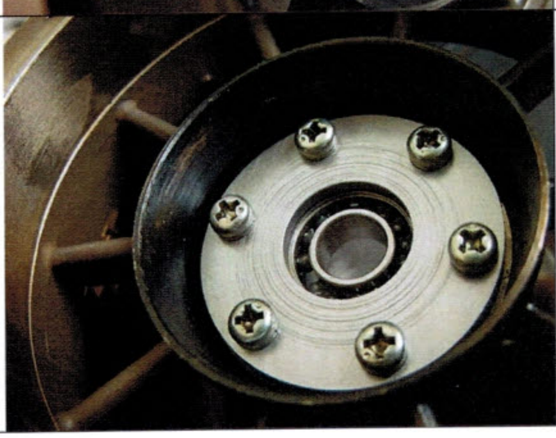
The exhaust, spider and power turbine assembly needs fitting now. It is assumed you have attached the Spider 102, to the Exhaust assembly 103. To minimize heat transfer from the exhaust to the turbine bearing, the shaft tunnel has to have an insulating blanket fitted.

Wrap the shaft tunnel in a thin layer of the ceramic fibre wadding and secure with the strip of metal supplied. Wind a couple of turns of stainless locking wire around to hold the strip into place. The strip supplied may be different from shown, but will do the same job.



Fit one of the special gaskets 144, into the inner face of the Spider casting, orientating the holes carefully, and slide the whole Spider/Exhaust assembly over the end of the shaft tunnel. Align the holes in the Spider to the shaft tunnel and confirm the correct location.

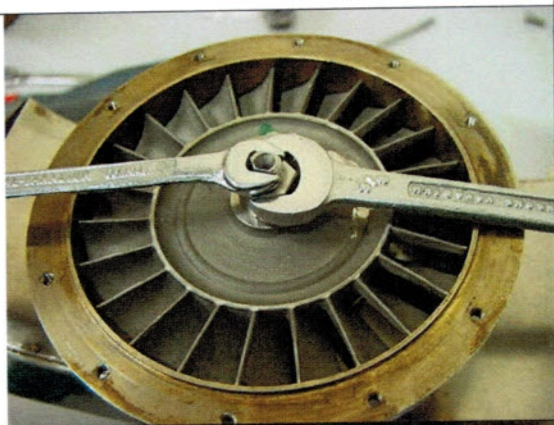
The lubrication manifold 148, should sit at 90^0 to the Exhaust Stacks. Fit the second gasket onto the shaft tunnel over the Spider and again orientate the holes.



Place the Clamp Ring 143, over the end of the shaft and orientate the holes. The six M3 x 10mm screws 191, can now be fitted complete with their locking washers 199, (note the prototype (left) shows pozi-drive screws but cap heads should be used.

Apply a drop of thread locking compound on the threads before insertion, to provide a doubly secure fixing.

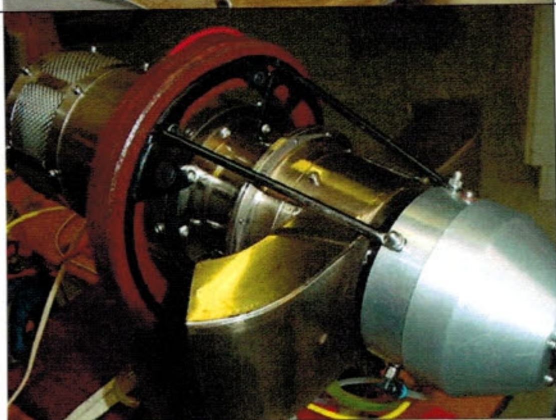
Assembly, Mounting System.



Fitting the turbine wheel, 141.

Slide the Collar 142, onto the shaft followed by the Power Turbine itself – note the orientation – leading edge faces out. You need to have already dealt with the turbine tip clearance and balancing (P.54). Fit the turbine nut 140, and tighten hand tight. It is not possible to tighten the turbine nut without access inside the gearbox, the shaft must be held using a 4mm spanner to the end of the shaft, and the nut can now be tightened firmly. Check to ensure the turbine turns freely – a slight resistance will be felt due to the pre-load.

This is a good stage to build up the mounting system if you have not already done so. This will enable you to utilise the assembly completed so far as a jig to align and orientate the mounting system parts.

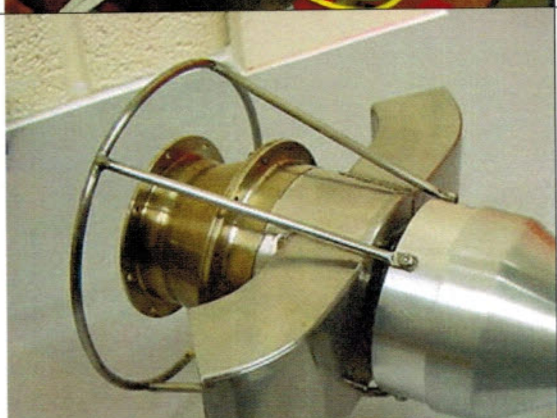


Mounting system, 106.

The turbo-prop places severe loadings due to propeller thrust, on the junction of the spider and power turbine shaft tunnel, and external restraint is required. There are many variants of possible mounting depending on application.

The mounting secures to the outside edge of the gearbox with four bolts, and the junction of the interstage ngv and engine, picking up on the ngv screws, lengthened for the purpose. The turbo-prop assembly can then be simply mounted to a bulkhead in the aircraft or test-stand, using four M4 bolts and nuts.

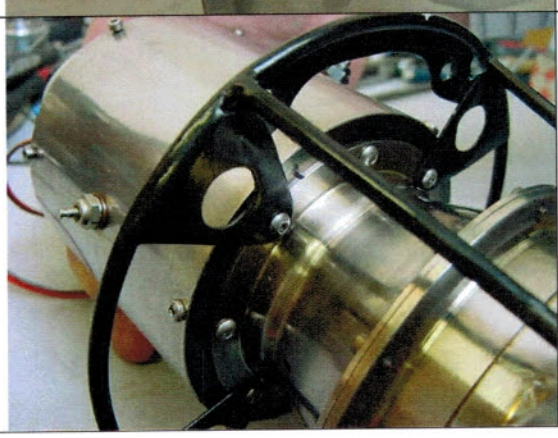
The outer ring is made from 4mm diameter mild steel, rolled into a ring and welded or brazed at the joint.



The four stays of the mounting are made from 4mm mild steel. Cut them a few mm over-size. Heat the last 15mm to bright red and hammer onto hard surface such as a vice to thin down to about 2mm.

Centre-punch and drill the 3mm mounting hole in each flattened portion. Use a file or belt sander to profile the end neatly. The stays should now be adjusted to be exactly 107mm long from the centre of the mounting hole to the end.

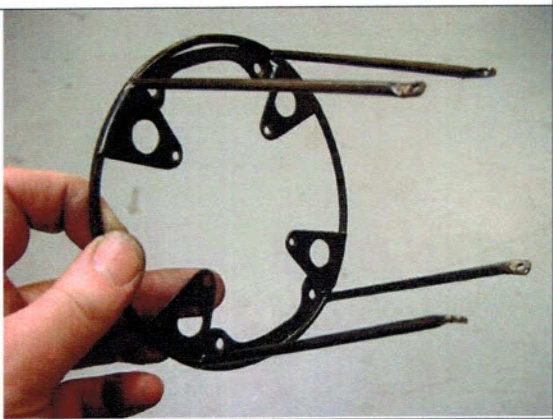
Mark off the position of the stays on the ring and tack weld them in place with a TIG welding machine and small steel welding wire – I used 0.6mm.



Have your turbo-prop assembly ready to hand, complete with interstage and gearbox held together with a few screws. Position the stays in place over the gearbox bolts and hold in place with four nuts, temporarily. Use four M3 screws and nuts and secure the four steel mounting lugs to the interstage ngv in the correct orientation - see the drawing to confirm this position. (Left shows the mounting in place, after painting). Carefully, tack-weld the mounting plates in position on the ring. When cool, ease the complete mounting off the gearbox and separate the interstage from the spider. I found I had to bend one of the lugs slightly to do this.

Once off, weld the lugs and stays securely into position.

Bulkhead Mounting, Assembly.



After welding the complete mounting can be cleaned up using files and emery to remove any unsightly lumps and blend the welds neatly. Left, shows the prototype mounting – yours will be simpler as the lugs now have the mounting holes included!

For a neat presentation and to stop rusting, apply a coat of metal primer and satin black spray paint. Enamel is no good so stick to cellulose or Finnigans "Hammerite Smooth", the latter had very good adhesion and fuel resistance.

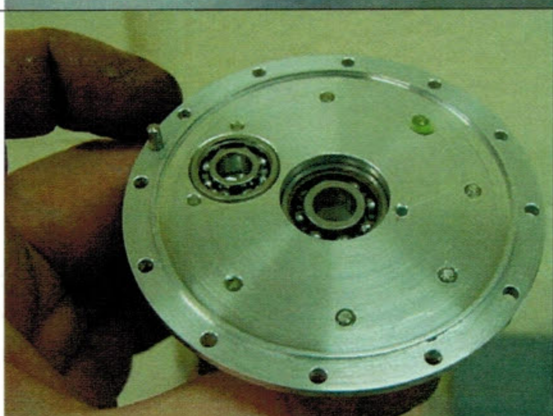
Make sure you do your spraying in plenty of fresh air and away from naked flames- see the can for the recommended precautions.

Assembly - Gearbox assembly, 105.

With the bulkhead mounting completed, we are now ready to continue building up the gearbox and prop-shaft assemblies.

Pick out the intermediate gear assembly 171/172, and degrease thoroughly. Apply a smear of "Loctite 641 Bearing Lock" (a locking fluid especially made for securing bearings) onto bearing 176, and slide the bearing gently into position in gear no.2 (171).

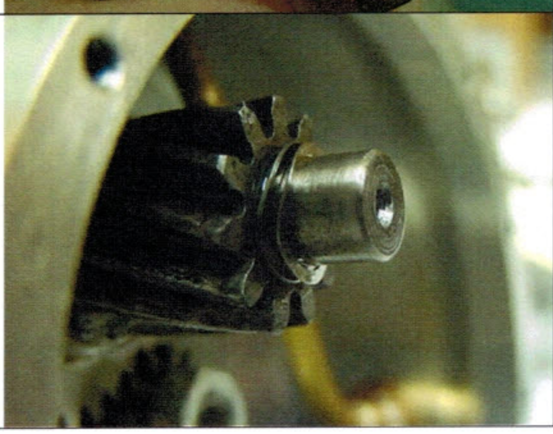
Wipe away any excess carefully, ensuring none gets into the bearing.



Apply a smear of gasket compound to the rear face of the prop-shaft housing 158, and insert a standard ISO607 bearing to the gearbox front cover to centralise it. Fit the eight M3 x 8mm securing screws 192, apply locking fluid to the threads and tighten firmly.

Apply a smear of "Bearing Lock" to the intermediate shaft front bearing 177, and slide into position in the gearbox front cover.

Give the "Bearing Lock" 30 minutes for the fluid to set, before proceeding to the next stage.



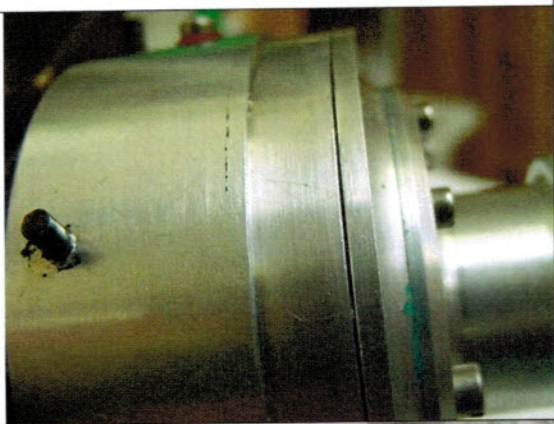
Intermediate shaft pre-load springs, 183.

The intermediate gear assembly can slipped over the bearing support spigot 156, and we need to decide how many of the small wavy washers 183, to fit to the shaft end as there is a tolerance build-up to consider and take care of.

The wavy washers ensure there is a constant axial loading on the bearings to allow them to run quietly and stop the shaft moving back and forth during acceleration and deceleration.

Give the bearings and gears a little oiling before you put the front cover into place.

Assembly.

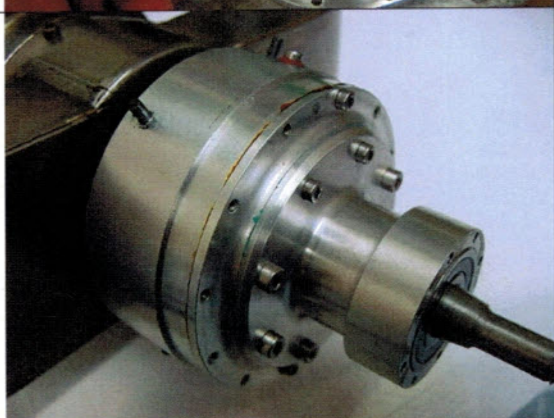


Fit two wavy washers onto the end of the intermediate shaft and ease the front cover into place, ensuring the dowel pin aligns correctly. When there is sufficient pre-load you should find a small gap of approximately 0.5-0.8mm between the front cover and gearbox case. Use a feeler gauge to check the gap.

If the gap insufficient add one washer, if too large then remove one washer. Once the gap is correct remove the cover to fit the prop-shaft sub-assembly.

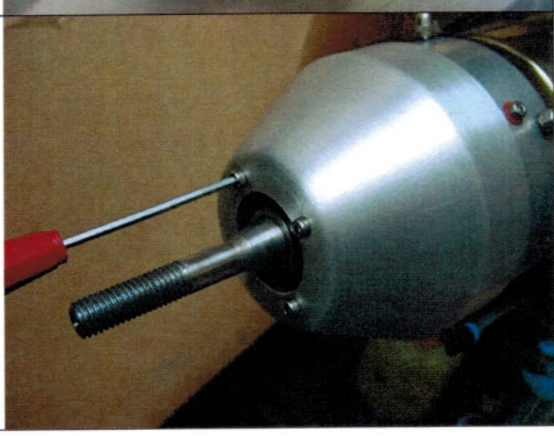
Insert the prop-shaft sub-assembly 162, into the front cover and ensure the bearings are fully seated. Fit the two spring washers 184, back to back as drawn and apply a smear of gasket compound to the front bearing 178. Slide the bearing onto the prop-shaft and into the prop-shaft housing.

The rubber shield should face outwards.



Apply a smear of gasket compound to the front of the gearbox and refit gearbox front assembly, ensuring the intermediate shaft wavy washers are in position.

Secure with twelve M2.5 x 6 screws 190, using a drop of thread-lock on each and tighten evenly. Wipe off any excess compound whilst still fluid.

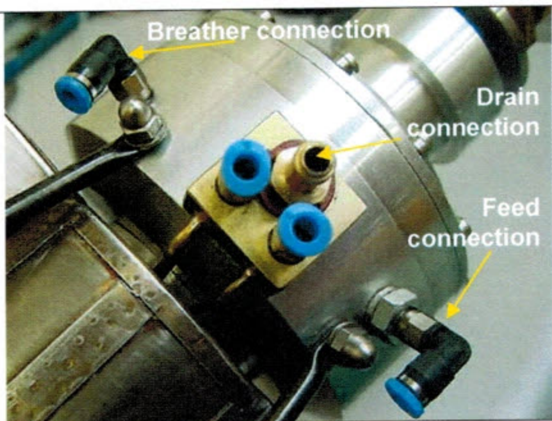


Fit the cowl in place using the eight M2.5 x 5mm securing screws, 189. Use a smear of locking compound on each and tighten evenly. Note, the cowl will push the front bearing back into its working position as you tighten the screws.

Picture shows earlier plain cowl with 4 screw fixing – now eight and anodised green!

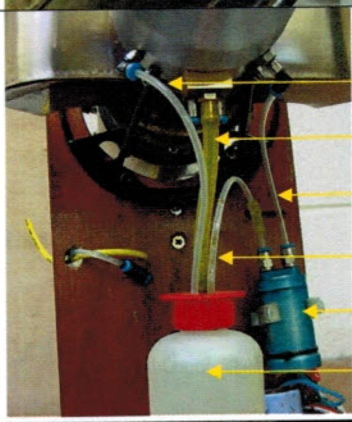
By now it should be possible to turn the prop-shaft and feel how the gears run. They may feel a little stiff initially but this will ease after a few minutes running. If they feel tight you will need to investigate further.

Installation - Gearbox Oil System



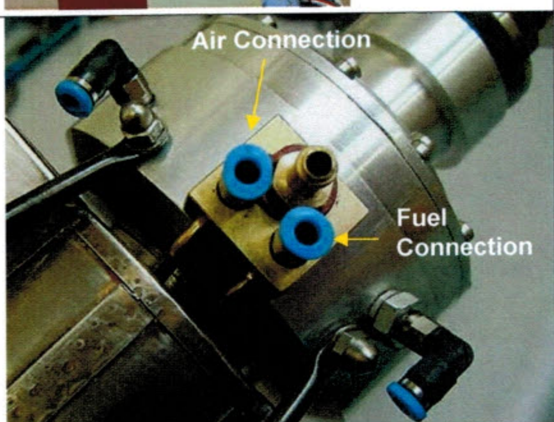
The gearbox oil system is a dry sump system – ie no oil is held in the gearbox. Oil is pumped from a separate oil tank with a small electric pump to the oil manifold and onto the gears. The gearbox has a breather which is connected to the tank, so that oil droplets are saved. A pick-up filter is fitted to the suction line to the pump at the tank end. A magnet in the bottom of the tank retains any small metal particles and sludge helping to keep the oil clean. Oil contents should be 60ml or greater. A low friction additive (10%) is mixed to the oil to enhance gear life.

An air pressure switch is used to turn on the oil pump when the engine has reached about 0.05Bar (about 1psi).



The **breather** pipe needs to finish at the top of the oil tank. The oil **drain line** must be a minimum internal diameter of 3.5mm. The **feed line** connects pump outlet to oil feed connection. The **suction line** connects the tank pickup to the oil pump, via a suitable filter fine mesh filter (not felt). The **oil pump** is a standard fuel-type pump operating on 1-cell switched with a pressure switch, or via an output from the ECU.

The **oil tank** must be positioned so that the oil level in the tank is at least 25mm below the bottom of the gearbox, when installed in the model. To ensure correct operation position oil tank as close to drain connection as possible, preferably directly underneath the gearbox.



Lubricating and cooling the power turbine bearing.

The power turbine bearing is lubricated with fuel tapped off the engine fuel pressure line. The feed is taken from a special restrictor and enters via a **fuel connection** on the manifold block.

The bearing is also cooled using a supply of cooling air taken from the engine case pressure. This air is fed to an **air connection** on the manifold block.

Both these service pipes need routing past the exhaust system – be sure to protect them from possible heat damage.

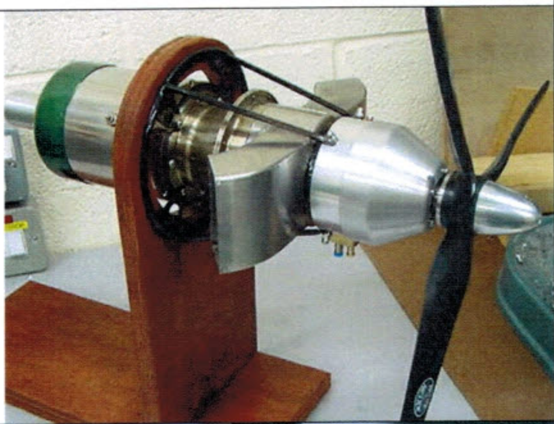
Prop-driver, spinner and spinner retention bolt.

The prop driver 160, is locked into place when the propeller is fitted to the shaft and tightened up with the spinner nut 161, for the first time. After this the driver should remain in position. To remove, heat with a hot air gun to expand it, when it should release easily.

The spinner retention bolt should be adjusted in length until it sits flush with the end of the spinner (as left), **note; it must not be fitted right into the recess.**

If you plan to use a range of props with different thickness hubs, you will need to make additional retention bolts for each thickness of hub.

Installation – mounting.



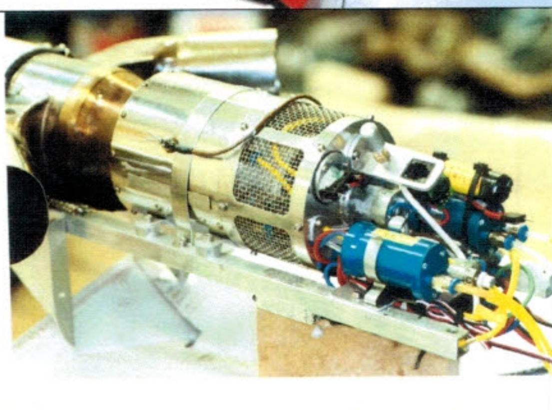
Mounting options.

The power of the complete turbo-prop power unit is considerable and you need a rigid bulkhead to bolt to absorb the thrust. Models designed for the larger two/four-cycle engines are usually intended to absorb considerable vibration and these are ideal for our purpose, though we have no vibration problems.

A clearance hole of about 100mm or more will allow the power unit to be fitted, you must ensure there is sufficient strength remaining to suit the purpose. The metal bulkhead mounting shown is rigid enough to enable securing with just the four securing bolts, providing captive nuts or similar are fitted to the rear of the bulkhead itself.

The first prototype turbo-prop to fly was fitted to a 2.4m span "Pilatus Turbo-Porter". This used the power unit secured to a pair of 13mm square aluminium rails, which were subsequently bolted to the airframe. All up weight was 8.2Kg (18Lbs).

The nose of the aircraft was too narrow to allow sufficient airflow to the intake of the engine and the power unit ran hot. Cutting an extra inlet with a forward facing scoop helped greatly and many successful flights were subsequently made. The ideal position for additional cooling air is right over the intake, as this allows cool air to pass directly to the engine. If taken from further forward, the exhaust system tends to pre-heat the air somewhat, raising the engine running temperature.



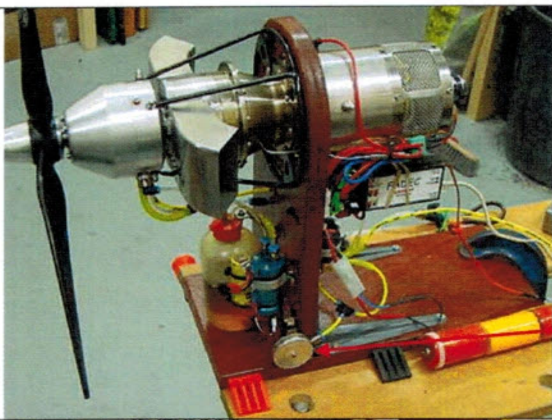
Our second flying plane was a 2m span "Tucano". For this we extended the exhausts slightly to clear the nose and made an extra-long prop-shaft to enable the engine to be sited further into the fuselage. Weight here was 10Kg (22lbs).

All the engine oil system, oil tank, fuel pumps etc, were mounted on the rails as earlier, but built-up as a complete sub-assembly to enable quick fitting and refitting by unscrewing just four bolts and disconnecting the fuel feed pipe (to show off mainly!). This was the first time an ECU was used to run the engine and this was also mounted on the base. To stop the engine "finding" small bits of balsa and screws etc, a metal grill was fitted to the intake and the electric starter and other services were attached to the back of this.

The "Tucano" (see left) was a fast flyer and showed the uncanny quietness a turbo-prop runs with. It was a strain to hear the engine at all in the air. All inlets in the fibreglass fuselage were opened up and used to get air into the engine and it was found that the engine needed to be run with the cowl on otherwise the engine ran hot. With cowl fitted, the engine pulled cool air directly and ran fine. Without the cowl it pulled air across the hot exhausts, which raised the exhaust temp considerably.

The moral for turbo-props is – keep intake air away from the exhaust sections – preferably route them completely separately and the engine will remain happy!

Setting Up for Testing.



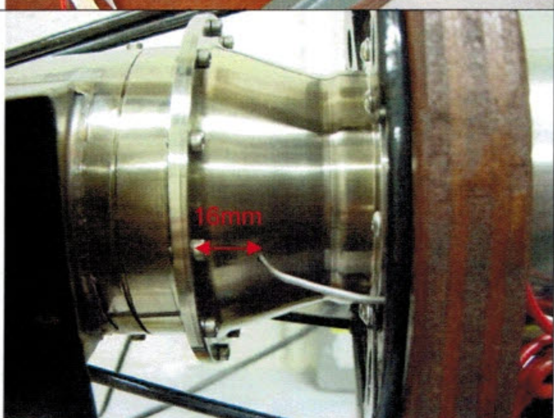
Test stand.

It is advised that you run the unit on a test-stand for the first few runs, to familiarise yourself with the handling and setting up. The simple test stand can be screwed together from a couple of pieces of 18mm plywood and a pair of strong shelf brackets for extra rigidity – see left. The base should be securely anchored to the workbench using a strong clamp. The stand allows plenty of space to add the services and spring clips allow quick and easy fixing for most of the items. The oil tank in front is positioned below the gearbox by about 60mm to allow easy observation of returning oil back to the tank and to monitor oil level. The pressure switch and single nicad cell can be seen here which operates the oil pump. It senses pressure from the gas line as the case pressure line is used for power turbine cooling.

I added a ply bracket to allow the ECU to be held in position and allow easy access for all the cables and connectors used. The fuel and oil pumps were held on spring clips. The FADEC Autostart has gas and fuel solenoids and these were also held in spring clips to keep them secure and allow easy plumbing to the engine.

The fuel tank can be a 1Ltr standard tank, secured in the space behind the bulkhead and well clear of the exhaust outlets. Alternatively, a larger tank can be attached to the side or underneath of the workbench to allow for extended running.

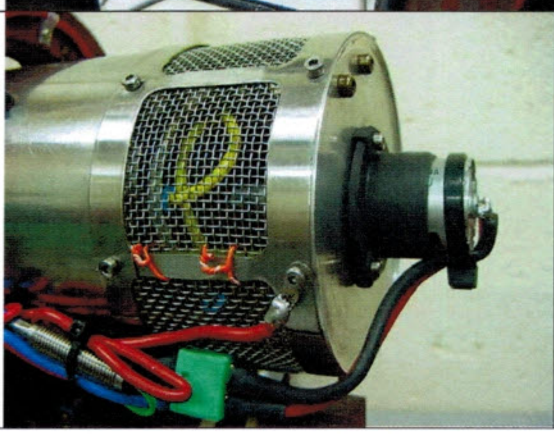
If you are using a radio link for your ECU, position the receiver and battery and secure in position.



Temperature sensing.

The ECU requires temperature feedback from a thermocouple probe for controlling start-up and max temperature protection. The probe usually has a diameter of 1.5mm. The best place to sense temperature is at the Interstage NGV, between the engine and power turbine at about 4 O'clock as viewed from the propeller end. It is here that any hot start will show first. The probe is inserted through a 1.6mm diameter hole drilled 16mm back from the bolting flange, this ensures you will miss the start of the vanes.

Insert the probe 6-7mm making the bend gentle and secure the remainder of the probe to stop it rattling and causing radio interference.

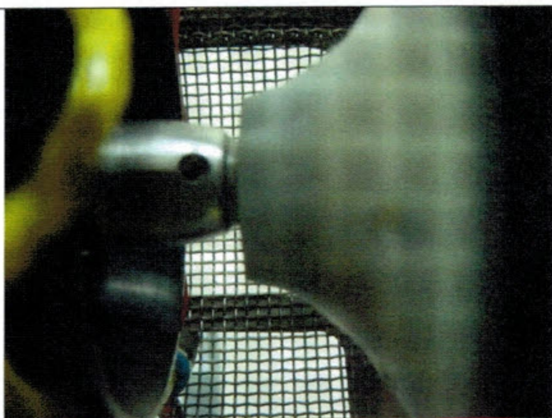


The MW54 engine has 4 service fittings, fuel, case pressure, lube and gas. We need to make use of the case pressure fitting to supply cooling air for the power turbine bearing. The fuel supply is also tee'd off before the engine and fed via an inline restrictor to the power turbine bearing (included in fittings kit). Both these services are fed via the brass manifold under the gearbox. See the diagram for this in the plan section.

I enclosed the inlet end of my engine with a grilled cover and aluminium backplate, to tidy up the front of the engine and to provide a mounting for the starter. In this case, the starter is mounted on three rubber grommets which help the clutch assembly to self-align to the engine and allows the ECU to control the start reliably.

Setting Up for Testing.

Preparing for first starts.



The grilled inlet cover works best if there is a cone shape on the inside to help guide the incoming air towards the engine intake. A secondary advantage is that it stops the starter clutch getting exposed to dust and grit and consequent danger of jamming. The dimensions are not critical but the curve would be better if it continually expands as it progressed from the centre, outwards.

The services can be fed out through a single access hole at the bottom of the inlet for neatness – fit a rubber grommet or sleeve to avoid chaffing.

Lubricating Oil.

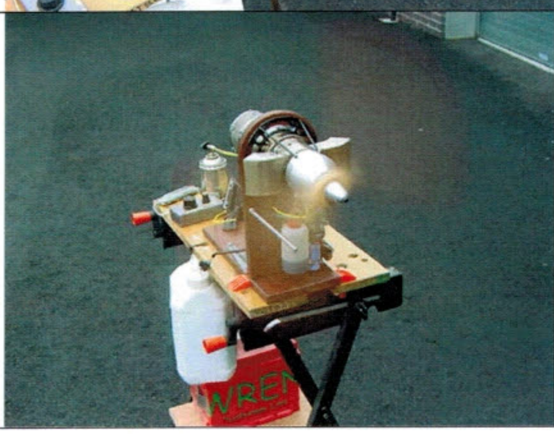
The lubricating oil for the gearbox is a mixture of standard turbine oil and a high pressure additive and the tank contents should be a minimum of 60ml. Suitable oils are "Aeroshell 500" and "Exxon 2380".

The additive is "Danco TEC2000" which is a petroleum based lube concentrate designed to reduce surface friction and contains no solid particles such a PTFE, Teflon or lead. The additive is added to a ratio of 1:10, ie 10% additive to 100% turbine oil. The additive is stocked by Wren Turbines Ltd.

As with all oils, these require care in handling and should not come into contact with exposed skin.

Starting for the first time.

Ensure your propeller is balanced and securely fitted.
The turbo-prop is a little different from a normal jet engine in that the safe place for you to stand is behind the propeller, which unfortunately also means you get covered in the engine exhaust! The angle of the exhaust pipes ensures you are not directly in-line should there be a problem but the propeller wash tends to focus the exhaust behind. If you are using an Autostart ECU you can start and run standing off to one side of the exhaust and not in line with the prop. Check the operation of the oil pump by operating the pressure switch. After a few seconds oil should begin to return back to the tank through the drain connection.



Weight the test stand to ensure it cannot pull over. Ensure you have your fire extinguisher handy for all running and all your batteries are charged (don't forget oil pump cell). Set your ECU to 100,000rpm maximum engine rpm.

Start the turbine in the normal way and allow acceleration to come up to idle. As soon as you can, raise engine rpm up to 80,000rpm or so as it runs cooler. Allow the engine to settle for a few minutes at this setting and check you have oil flow coming back to the tank. Check your temperature – 400-450°C is typical. The gears need about fifteen minutes running to bed in and the oil will go dark coloured.

After a few minutes you can run the engine up to the 100,000rpm setting and the gearbox will run smoother.

After Running In.

Exploring the Power Curve.

After the gearbox has bedded in you can explore the upper end of the power curve. Please be careful as regards securing the test stand and also your choice of propeller. Never stand in-line of the prop when the engine is running.

Remember that at a setting of 155,000rpm on the engine there is more than 7HP available at the prop-shaft and you should build up to this gently and using strong propellers. It is suggested that wooden props are used in evaluating the top performance. Most runs can be limited to about 140,000rpm at the engine and this will give more than adequate performance in an aircraft.

Fuel Consumption.
The prototype turbo-prop used 194ml/min at 155,000rpm. This would give around 6-8mins flying at moderate power levels for 1Ltr of fuel. Consumption is slightly higher than a standard engine due to extra fuel used for lubrication of the power turbine bearing.

Oil Consumption.
The oil is not consumed as such but if your oil pump is too fast it can fill the gearbox faster than it can drain and this can cause the oil to escape via the turbine shaft front bearing – you will see big smoke puffs from the exhaust in this case.

Lubrication – Service Intervals.

After you have accumulated about 1 hour of running drain the oil tank and give it a good clean internally including the pick-up filter, and change the oil. It will look very dirty by then as all the scale and running-in muck will be in suspension. Keep used oil in a marked container and take it to a waste oil compound for disposal.

After the first hour running you will need to change the oil at roughly 2-hour intervals to ensure it remains in good condition. Keeping a couple of magnets in the bottom of the tank helps to keep hold of metal particles and stop them circulating.

Servicing checks.

Before each engine run, turn the prop gently to feel for any stiffness that may have developed. Listen especially for signs of any bearing "rumbling" or stickiness that might indicate a bearing in distress. If found it must be investigated before any further running. Listen also for any sign of the power turbine catching on the shroud – a metallic scratching. This also must be resolved and you must not try to run the engine in this condition – you will only make the condition worse.

Look also for oil leaks after running. Small seepage is not a problem but any weeping joints need curing.

Servicing Checks, Cont.

Before each run, ensure the oil pump battery is charged and has enough power left for the run. Measure the current consumption and make a note of how long it will last. Check the operation of the pressure switch regularly and that it is operating the oil pump correctly. Check pump delivery by observing oil draining back to tank. Gear life will be very short if the pump battery fails in flight. A new ECU is being developed which will include the oil pump supply within the normal fuel pump battery.

Check all the pipes and services regularly, especially those which pass near the exhaust system. Check the power turbine lube' supply every tankful of fuel, to ensure it is clear.

Check regularly the security of the bulkhead securing bolts, the domed nuts holding the stays on the gearbox, and the screws holding the Interstage NGV to the engine. All must be kept firm.

Don't forget to fit the spinner retaining bolt, after changing a prop, and make a new one if the new prop thickness is different. Remember it should end flush with the end of the spinner when tight on the shaft, and not tightened onto the spinner itself – the spinner must be allowed to undo at least two turns before it reaches the head of the retaining bolt.

Never run with a damaged prop – if a blade breaks off it could wreck the engine and your model, and result in a serious injury to someone.

Cool-down after running, procedure.

After each engine run, ensure you cool the engine down to below 100°C indicated - do not simply shut off the engine and leave it. The power turbine and spider will remain at 250-300°C for half a minute or so after shutdown and this will shorten the life of the turbine bearing if cool-down is not undertaken. Auto-start ECU's can handle this procedure easily if programmed correctly. Make a record of each run and check back to see if temp's change etc, that might indicate a bearing problem.

Note; Beware the hot exhaust parts that are accessible to inquisitive fingers after shutdown – keep those fingers well away!

ECU Settings.

It is suggested that engine idle is set to 50,000rpm for the turbo-prop as this gives a cooler run and quicker pick-up than the normal 40-45,000rpm. Ramp-Up needs to be set slightly longer than normal to allow time for the power turbine to spool up. Ramp-Down will need to be considerably longer as the momentum in the power turbine and propeller needs time to dissipate. If you try to ramp down too quickly you risk flaming out the engine.

Maximum temperature needs to be monitored as in hot climates the start can exceed 700°C if performed too quickly. It is however always better to have a quick start than a laboured one where everything gets overheated.