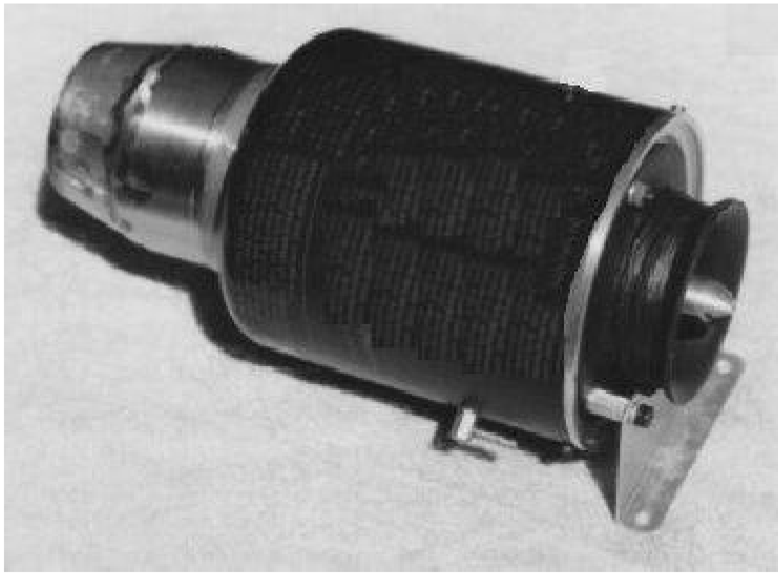
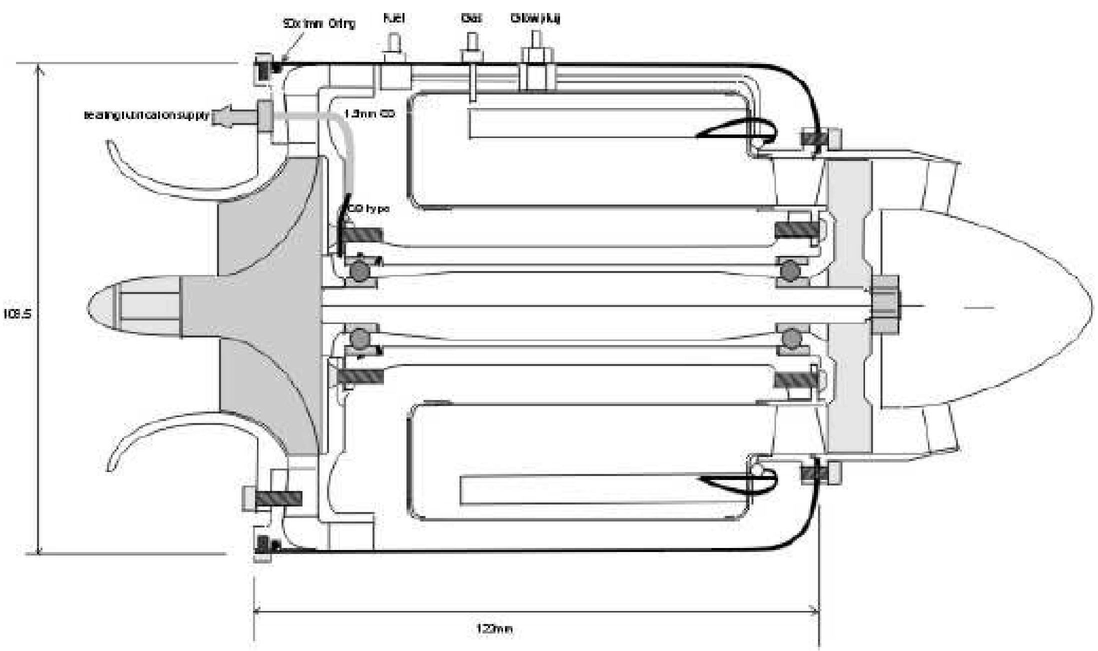
BUILD YOUR OWN RC TURBINE ENGINE

By Bob Englar



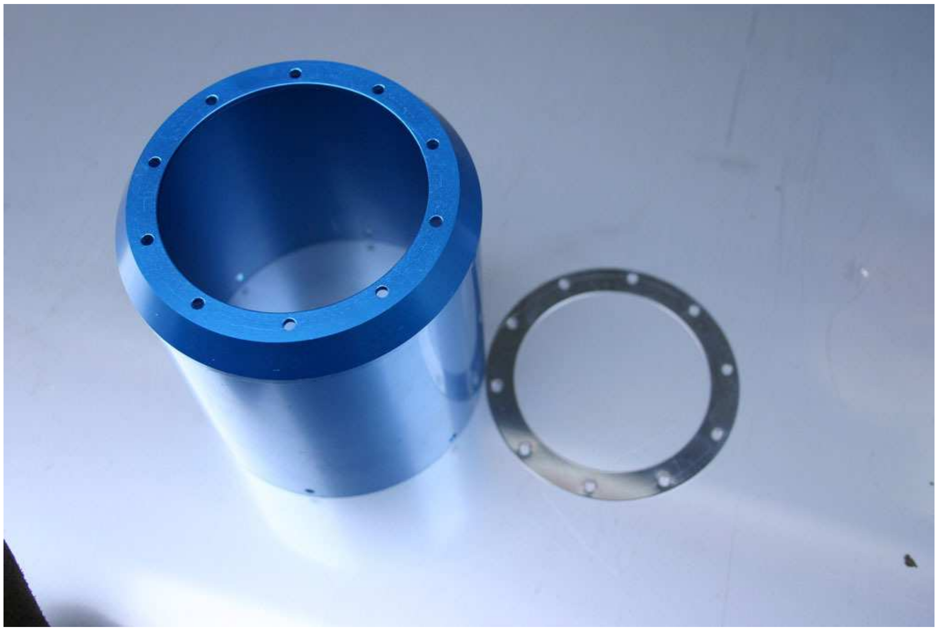


This Turbine engine is “state of the art” as it currently applies and is designed to deliver high power with reliability. While using the same compressor and turbine wheels as in the KJ66 design, it is simpler to make and cheaper to maintain in the longer term. The KJ66 provided a quantum leap in the design of miniature gas turbines and we should all be grateful to the design team for placing it in the public domain. Starting at the front of the Engine, the compressor wheel shroud is machined aluminum. The diffuser requires a simple turning and milling operation as the 6 deg slope is on the front of the wedges with a mating slope on the diffuser cover. Therefore the diffuser can be milled while held flat on the table. Also the front bearing can be replaced by simply removing the compressor shroud and shaft. The diffuser cover is slotted for an “O” ring to provide a case seal and the assembly is held in place in the case by a ring of 12 machine screws. The front end is extremely rugged and should survive even the most severe crash. The shaft is made from 4140 (60 ton, 90 ton after heat treatment) steel and runs in ceramic ball races with front preload provided by a wave washer bearing on the front ball race outer ring. The bearings also ride in ‘O’ rings. This keeps them centralized when the shaft tunnel expands with temperature and also results in quieter running. Lubrication is provided by mixing 5% Jet oil with the kerosene and a “Tee” in the external fuel line delivers this to the front bearing. Air under case pressure is fed to the front bearing via slots in the rear of the diffuser and this carries the lubrication down the shaft tunnel through the rear bearing to provide it’s lubrication, then to atmosphere via the turbine exhaust. This system has several advantages: As soon as the engine gets fuel, it gets lubrication. The kero/oil mix with air provides good cooling as well as lubrication for bearings. A separate oil tank is not required so its one less thing to have to worry about. The downside is a slight increase in fuel consumption. The combustion chamber incorporates radial air jets at the front and these can be easily adjusted to optimize the combustion burn pattern. The rear lip of the chamber slots into the inside of the NGV outer ring and this provides an extremely smooth transition for the high velocity gas. The rear of the inner sleeve slides over a matching rebate on the inner NGV ring and this also provides a step free gas path. The glow plug and starter gas inlet are positioned over a vaporizer tube and this provides instant ignition of the gas with the engine turning over. The nozzle guide vanes are brazed to the inner ring while the outer ends ride freely in slots in the outer ring. This allows temperature expansion of the blades to occur without stressing the assembly and maintains an accurate turbine wheel tip clearance. Nozzle guide vane blades can be individually replaced as required and this saves the expense of a complete replacement. The traditional outer case for owner built engine has been the CV470 gas canister. This can is lightweight as it is just 0.3mm (0.012") thick, however I have had cracks develop in the case in the NGV area. When you consider that at 1.2BAR case pressure, the load on the rear face is nearly 70kg, its amazing that the CV470 does so well when subjected to the continuous pressure cycles of a running engine. Also there are two sizes of CV470 cans about, one is some 3mm longer and there is a small difference in inside diameters. An alternative is a Z161X oil filter case of which there a several brands. The RYCO one is the same ID as the CV470 canister while others can be a fraction larger in diameter, 108 instead of 107.4mm. The compressor wheel is the same as the 2019 wheel used in the JT67, the manufacturers have just changed the part number. The turbine wheel is to KJ66 design as cast in 713 Inconel and is available from several sources including the GTBA. The prototypes have all used the Artes KJ66 wheel and they have proved to be ultra reliable even when dreadfully abused by subjecting them to over speeding and over temperature during development. The prototypes have delivered 6KG of thrust at 0.9 bar with an EGT of around 500deg C. The engine weighs 1.2KG.

Assembly

The parts must be accurately made, for example the shaft size tolerances are specified at five thousands of a millimeter maximum. To make the Turbine Engine you will need access to; a lathe, milling machine, drill press, spot welder and silver soldering and brazing equipment, plus assorted hand tools. You can also take the AutoCAD drawings to a machine shop and they can convert the drawing to CAM which is the program for the CNC machine. The shaft is made from 4140 steel to 0.5mm oversize, except the threads which are cut first, is hardened and ground to finished size.

The outer case



The Z161X oil filter case fits a (Toyota Land Cruiser).
To prepare the filter can, simply cut off the heavy end with a Dremel cutoff wheel, scribe a circle of 68mm diameter centered on the other end and cut this out. Measure the inside diameter of the can and note this. The OD of the diffuser and diffuser cover are sized to fit the case due to possible slight variations in case size between filter manufacturers.

Diffuser

The diffuser supplied from the parts list is completely machined and only requires minor finishing, while the drawing shows the outer vanes as separate and glued into slots cut in the diffuser body. Use a high temperature epoxy such as LC3600. After gluing and curing the blades, machine them to fit the case. Then profile the leading edges of both supplied and assembled diffusers as detailed.

Compressor cover

Made from Aluminum, the cover expands at engine operating temperature to fit tightly into the diffuser cover and provide an airtight seal. I ground up a form tool from an old file to shape the radiuses on the prototypes and it worked well. After machining it you can make it pretty by dyeing it using RIT cloth dye. Just follow the instructions on the packet. The prototypes are colored red. You may have to re-machine the mating flange if the cover expands when dyed.

Nozzle guide vanes

The drawings provide templates for marking out the slots in both inner and outer rings and for the blades. Glue the templates to the rings using a glue stick, then cut out the slots to the outline on the templates. I first drill a 1mm hole at the end of each slot, then with a cut down DuBro or Dremel heavy cut off disc in the Dremel carefully cut the slot until it reaches the drilled holes. Then clean up the ends with a cut down hacksaw blade. Cut out the blades, bend them to the radius, profile them and place them in the inner slots. Use a hose clamp to keep them aligned in place while brazing the inner ends. After brazing the blades opposite the clamp screw, rotate the clamp 180 deg and then braze the remainder. The brazing only serves to hold them in place while machining the outer diameters. I have had blades crack at the base after several hours running when they where TIG welded but have had no problems with simple brazing. To machine the outer sizes, mount the NGV on the shaft tunnel, chuck the front, put a 608 bearing in the rear end so that it can engage the tail post dead center. With access to a tool post grinder the blades can be carefully ground to diameter. Otherwise fill between the blades with polyester filler to support them and CAREFULLY TAKING SMALL CUTS, turn the outer dimensions to size. The finished diameter is 0.1mm less than the ID of the turbine shroud while the locating tongues are sized just less then the OD of the NGV outer. Finally, tap the twelve holes in the NGV outer ring 3mm.

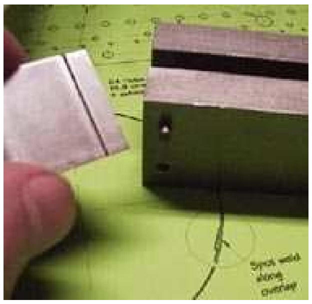
Combustion chamber

I may be wrong, but a lot of machinists are intimidated by any sheet metal work. I'd rather machine a tray from solid than try to bend one up from sheet metal. But there was no way around the fact that the gas turbine would take a bit of work with stainless steel sheet. Fortunately, with the purchase of the combustion chamber *pack of parts,* most of the hard work is already done. All that remains is rolling, extruding the air holes, and assembling the chamber.

The Combustion Chamber Assembly

This is the heart of the engine and needs to made accurately.

	There are three stainless cylinders which must be formed or rolled into tubes... the combustion chamber (cc) inner, cc outer, and



the outer case. Each of these requires an overlap seam be formed in the end of the sheet. Note the green plan print which shows the overlap. This can be done with a lot of beating with a hammer, or it can be done neatly and elegantly with a die.

I constructed a die from the crs rectangles shown. This is a simple mill-drill job, with the step being milled on both sides of the die, so the steel is shaped into somewhat of a "z" shape when pressed. A scrap with a successful seam is show.

When you make your die, make it long enough to do all three parts. If you size it for just the combustion chamber, it will be too short for the case outer wrap!

With the seam in place, the trusty (but crusty) grizzly roll came into play. This was a lot easier than I thought it would be. Rather than roll it in one pass, I slowly crept up to the correct diameter through several passes. I was afraid that the roll would press out the seam, but it doesn't hurt the seam too badly.

Here, the cc inner is being rolled to the rather tight diameter required.

Ahh, thank goodness for cable ties! I was having a devil of a time wrapping up (and holding) the tube to the correct diameter for spot welding of the seam. The idea was to hold the tube stationary and at the correct diameter, and then deliver a couple of preliminary welds. A pair of cable ties did the job perfectly. I was even able to cinch the cable tie down rather tightly around the flange spun into the cc front, shown to the left as the disk at the bottom.

The first spot weld of the seam. Note that I am delivering a single spot as close to the cc front as I

could get. Next, the cc inner was tested for size with the nozzle guide vanes, a portion of which grips this from the outer diameter of the tube.

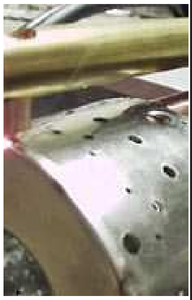
After the second spot, the cc inner seam was welded along through its length.

The two larger sets of holes in the cc inner must be swaged out to a larger diameter. The main purpose of the swaging is to create a "crater" in the steel which will inject the air deep into the combustion chamber. Note that this is the cc inner, which surrounds the shaft tunnel, and is open through its middle to pressurized air from the compressor output; hence, the holes must be swaged as shown so as to inject the air into the combustion chamber.

I turned a 1/4" square of CRS into the required male 60 degree cone, and clamped it into a big boring bar, which I then held in a bench vise. The cc inner hole is positioned over the punch, and a female die is used to swage the hole. Note the shape of the resulting swage. Two rows of holes are completed in this fashion in the cc inner tube.

Now, we can proceed with welding the cc inner to the cc front. I had to modify my spot welder a bit to get into the tight confines of this joint. A couple of welds start the process, and then, when alignment is verified, the entire seam is welded tight. It is important to minimize air leaks in the chamber seams, especially at the front.

The cc outer is produced in much the same way as the cc inner, including a set of swaged holes. Once it was sized and seamed, it too is welded to the cc front. Still required on the cc outer are the



swirl jets, and the two plug bosses. I plan on using a 1/4 x 32 spark plug for ignition rather than a glo-plug.

Here is a cool shot of the actual weld taking place. Each spot weld takes exactly one second.

Overall, the chamber is proceeding nicely, and is actually a lot easier than I thought it would be.

Fuel injection sticks and combustion chamber rear

At the rear of the combustion chamber, held by a diameter of the NGV, are a set of 12 curved SS sticks which receive the fuel from the fuel pump via a set of hypodermic needles. The sticks, as well as the combustion chamber (cc) rear, come as part of the cc pack of parts, available from Wren and J.D. Enterprises. These would be difficult to make, and the pack of parts is highly recommended.

The plans call for the sticks to be secured to the cc rear via spot welding, and the front of the sticks form a 54 mm circle towards the front of the chamber.

The sticks as supplied from Wren are close but not exactly to print. Some of the sticks have more acute bends than others, which makes even positioning of the tips on the 54 mm circle difficult. I tried to bend them a bit more evenly, but once they are in this cut state, they are almost impossible to bend.

Trimming to length is easy, though... I applied a bit of blue, layed them over the plans, and marked them with a scribe. A fine-toothed hack saw, followed up with a bit of sanding, took care of them.

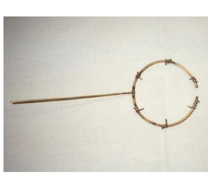
It is desireable to have as even a distribution of fuel at the front of the cc as possible. Rather than guessing, I created a thin aluminum jig, with 12 holes drilled on the desired 54 mm circle. A bit of reaming and fidgeting allowed me to assemble the sticks into the correct formation on the cc rear.

Wren suggests using four spots per stick flange to secure the sticks into position. I was not able to get more than one per stick, and even then I blew 2 very small holes in the thin sheet steel. I elected then to seal and secure the flanges to the cc rear with silver braze. I selected Harris 45 Safety-Silver as the alloy of choice, as it fillets nicely and flows sluggishly at 1370 degrees

	f. This will provide a more secure joint than a thinner, more fluid braze.
	The joints are cleaned and wire brushed with a stainless brush, soap, and water. I used Harris flux for the brazing, and applied this material liberally... a piece the size of a lima bean smeared around each joint. Apply the flux to all 12 joints, and do the brazing in one sitting. The wire diameter I used was 1/32", and this worked perfectly. A *very* small propane torch is all that is necessary, as stainless steel does not conduct heat well and the local area heats quickly. *Don't* use oxy-acetylene, you would surely melt the steel, and it is simply not necessary.
	The silver braze flowed beautifully around the sticks, and produced a perfect fillet on the underside of the joint. With the jig removed, the sticks maintain their perfect and even spacing. On to the swirl jets!

The ends are spun over forms although dies could be made to press them out. Save yourself a lot of work and order them from the parts list. Templates are provided for the hole layout on outer and inner sleeves, just glue them in place with a glue stick, center punch the holes and drill them. I use ordinary twist drills and have never had any problems. Then swage the holes as per the drawings. Wrap the outer around the two ends, hold in place with hose clamps and mark the join line. I cut it slightly oversize and chamfer the ends at 45deg so that spot welding the join works. A butt joint can be TIG welded. Wrap the inner around a mandrel and join as per the outer. The rear end is squared up and spot welded to the outer sleeve, then the vaporizer tubes are brazed in place. They must be straight, and finish at the same distance from the outer sleeve. Silver solder the air jet tubes in place in the front end, they must be aligned as per the drawing. Spot weld the three SS strips on the rear that locate the fuel manifold. Assemble the shaft tunnel and NGV. The inner sleeve, front face and outer assembly are trial fitted to this assembly, it must be concentric with the shaft tunnel, and then the front end and inner sleeve silver soldered in place. Also silver solder the three locating struts on the outer front and braze the glow plug fitting in place.

Fuel manifold



This must be made and kept perfectly clean internally as the hole sizes are very small and can be easily blocked. Anneal a length of K&S 1/8” brass pipe by heating it to red and plunging it into water. Bend the tube around a mandrel to achieve the diameter then cut to length leaving a joining gap of 6-8mm. Hold the circle of tube in place on the rear end of the combustion chamber (the join lies between the holes) and mark it opposite the center of each vaporizer tube for the six needle positions. With the ring on a flat surface punch holes in the rear side of the tube using a darning needle and a light hammer. Drill the 5/32” joiner to take the 3/32” feed tube and silver solder the straight 3/32” tube to both the joiner tube and fuel fitting. Then silver solder the joiner in place on the ring. Grind the end of the hypo needles as shown in the drawings and insert each one in the tube with the angled face facing the direction of fuel flow. That’s three one way and three the other. Screw a Festo fitting (PN 12255) into the fuel feed fitting and attach a length of fuel tube to it. Stick the other end in your mouth and blow gently while silver soldering the needles in place. This pressure will prevent the silver solder and flux getting into and blocking the needle and or tube. When completed place the manifold in water and blow and ensure all needles are clear. Next is to hook the fuel manifold up to the LPG start gas bottle and just slightly, very slightly crack the valve open. Light each needle and ensure that the flames from each are of equal length. Any needles showing a low flame should be removed and checked. Pressurize the fuel manifold with lung pressure while heating the needle joint to remove it. Check the angle on the end of a new needle and solder it in place, then repeat the testing procedure. THIS MUST BE DONE PROPERLY. Finally lay a 5mm drill shank against each needle and bend each in turn around it so that they point forward into the vaporizer tubes where the needle ends must touch the inner face.

Balancing

For high performance running it is essential that the rotor (shaft, bearings, spacers and wheels) are balanced. Hand balancing is just not good enough. A turbo charger repair center should be able to balance your rotor, suggest that they use the T6 settings and get better a than 50 milligrams/cm result (20mg/inch). Once your rotor is balanced, mark each part with an indent so that it is always assembled the same as it was balanced. Note than any radial clearance between the wheels and shaft may result in the balance changing when the rotor is re-assembled. To prevent this happening balance the rotor with the rear bearing installed and do not disassemble the turbine end before fitting to the engine. For the compressor, a slight interference fit that requires heating the wheel to install it will minimize any unbalance. Here is a link to build a balancer. If You want to balance it your self and are going to make several engines you might want to follow this link and build your own balancer.
http://www.technologie-entwicklung.de/Gasturbinen/Wuchtmaschine/wuchtmaschine.html

Assembly

Place the diffuser on the shaft tunnel and mark and drill the 2.5mm holes in the shaft tunnel, then tap them 3mm. Drill the six 2.5mm and two 2mm diameter holes through the diffuser wedges, hold the diffuser cover in place on the diffuser, it must be concentric so use a hose clamp around the outside or machine and use a centering mandrel. Drill the eight holes back through the diffuser into and through the cover. Tap the 2.5mm holes in the diffuser 3mm and open out the 2.5mm holes in the cover to 3.1mm. Drill out the 2mm holes in the cover to 4.2mm and tap them 5mm. Screw the two Festo fitting into the cover and grind away the excess so they are flush with the rear face of the cover. Remove the two fittings and assemble them with the 1.5mm tubing as detailed in the drawings making sure they are not blocked. Assemble the compressor and diffuser cover and check that there is no lip at the rear face where they meet. Machine the compressor cover to remove any lip. Also file the cover away to provide clearance for the lubrication and case pressure fittings. Position the NGV inner on the shaft tunnel and mark, drill and tap the six holes in the tunnel. Place the turbine shroud in the cutout on the back of the case and using it as a template drill the case holes to 3mm. Remove the shroud and open up the case holes to 3.2mm. CLEAN ALL SWARF FROM ALL PARTS. Assemble the diffuser to the shaft tunnel. Lightly oil the bearings, then place the rear bearing (the one with no cage) with the thicker inner ring to the rear on the shaft, then the spacer and turbine wheel and tighten the nut. Put the wave washer into the front of the shaft tunnel, then the "O" ring, push the bearing in place and push the shaft into place from the rear. Place the compressor spacer and compressor and tighten the compressor nut. Do not over tighten the nuts. The shaft should spin without binding and should rotate for about four seconds with a spin of the compressor nut with your fingers. Any less than this and the preload is too high. Check that the outer front edge of the compressor wheel lines up with the face of the diffuser. Behind is a NO slightly in front is OK, but flush is best. The preload and compressor wheel alignment are adjusted by means of 8mm x 12.5mm shims behind or in front of the front bearing for preload adjustment and if the compressor wheel is behind the diffuser. If the wheel is forward of the diffuser the compressor spacer thickness needs to be reduced. If the spacer thickness is reduced the faces must be finished ABSOLUTELY PARALLEL otherwise you will do very expensive bearings in. Install the compressor wheel cover and again check that the shaft spins freely and there is not excessive clearance (greater than 0.2mm) between the wheel and cover. See the how to fix it panel if there is. Once the alignment and preload is OK remove the shaft and front bearing. Attach the NGV inner to the shaft tunnel, slide the NGV outer ring in place and slide the lot into the case. Put the front bearing in place and slide the shaft into place then assemble the turbine shroud to the case and NGV outer ring with the twelve 6mm long cap head screws. Using a pair of tin snips cut the front of the case off so it finishes flush with the compressor cover. Mark out equally around the case forward of the "O" ring slot and drill the twelve 1.6mm holes then tap them 2mm and install the cap head screws. Check that the shaft spins freely and with pretty equal clearance between the turbine wheel and turbine shroud. If there is unequal clearance and all the parts have been accurately made then place the assembly face down on a block of wood with the shaft extending through a drilled hole so that it takes no load. Using a soft drift, copper or aluminum and a hammer, strike the turbine shroud flange on the smaller clearance side to slightly bend the case rear face to align it. Undo the case screws and then remove the shaft and assembly from the case. Make indent marks on the Tunnel, NGV inner and outer, turbine shroud, case and diffuser cover so that they can always be reassembled in the same alignment. Remove the diffuser from the shaft tunnel and then assemble the fuel manifold to the combustion chamber. Make a slight "S" bend in the straight fuel line ensuring that it does not cover any air holes in the outer sleeve. Assemble the chamber to the NGV and slide the lot back into the case and install the turbine shroud. Measure the position of the glow plug and fuel fittings, remove the assembly and drill the case at the measured positions. Measure forward from the glow plug hole for the gas fitting and silver solder a 5mm nut in position, then drill 4mm through the nut and tap 5mm through the case. Cut the threads from a DuBro pressure fitting and silver solder it in the center at the bottom of the case. Drill through the fitting and through the case. Disassemble and remove all burrs and swarf from the case both inside and out and the sharp front edge that was cut with the tin snips. For a pretty engine get the case chrome plated.

Final assembly.

Assemble the diffuser and it's cover. Screw the lubrication assembly into place and bend the tube so that the needle lies in a slot in the diffuser rear face. Bend the needle so that it lies freely in the slot and is not loaded when the tunnel is assembled. Cut a small strip of aluminum, place it over the tube and drill and tap it 2mm so that it clamps the line in place. Install the screws and grind off any excess that protrudes through the front face of the diffuser. Screw the case pressure fitting in place, it should extend just past the diffuser rear face. Blow through both fittings to ensure they are not blocked. REMOVE ANY SWARF. Install the "O" ring, wave washer and the oiled front bearing as well as any shims needed in the shaft tunnel. Assemble the turbine end of the shaft and use some anti seize compound on the thread before tightening the nut. Assemble the tunnel and NGV, oil the rear bearing and install the shaft. Smear a light and even film of exhaust seal compound on the rear face of the NGV outer flange. Insert the assembly into the case and install the turbine shroud using shims placed between the turbine wheel outer and shroud to keep it all centered and evenly tighten the twelve did indent mark it right, because 6mm long cap head screws. Slide the combustion chamber into place in the case, ensuring that it engages with the NGV and install and tighten the glow plug. Check that the chamber is centered within the case, you can bend and adjust the three struts to center it. This is very important. Install the gas fitting. Use an annealed copper washer on the fuel fitting and a small amount of plumbers thread sealing tape on the thread then install the fitting. Hold the brass fitting inside the case with a spanner and securely tighten the fuel fitting. IT IS VITALLY IMPORTANT THAT THERE ARE NO LEAKS IN THIS ASSEMBLY. Install the case sealing “O” ring, then screw the diffuser with compressor cover to the tunnel, you remember the twelve tapped holes around the outside. Do they line up? Assemble the compressor spacer, shims if required and compressor wheel, use some anti seize on the thread and lightly tighten the compressor nut. Remove the screws used to hold the diffuser and cover together, install the compressor cover and install and tighten the 12mm long cap heads that hold the lot together. Finally install the twelve 2 x 6mm long screws in the front end of the case. Remove the glow plug and using a pin pull carefully out the element so that it extends past the end of the plug. Then reinstall the glow plug, check that the shaft spins freely and it’s run time. Note that the tailbone has not been installed as yet, we leave this until after the initial running as without it the EGT is a bit lower.

How to fix things

Turbine wheel rubs. There are two reasons why the turbine is not concentric within the shroud. The rear end of the engine must be made accurately, to size, concentric and with no loose fits. The clearance between the NGV blades and outer should be no more than 0.05mm, that’s 0.1mm in diameter. The 68mm diameter hole in the end of the case must be in the center. Also the case is slightly domed and this is flattened out when the twelve NGV assembly screws are tightened. Therefore the screws must be tightened evenly and also ensure there is no swarf from the hole drilling left inside the case.
Compressor wheel clearance. For maximum efficiency the wheel to cover clearance should not exceed 0.1mm. While the engine will run at greater clearances, this will be at the expense of a higher EGT and increased fuel consumption. To improve a loose fit, make up a thick paste of high temperature epoxy and micro balloons. Coat the inside of the cover with this paste and allow it to cure. Assemble the shaft tunnel and diffuser, fit standard 608 bearings and install the shaft. (Don’t use your expensive ceramic bearings for this operation). Push the compressor cover into place and then turn the shaft from the turbine end using the turbine wheel as a handle. The compressor wheel will leave a mark on high spots on the inside of the cover. Sand them away and keep repeating the process until a good fit is obtained. Then bolt the cover in place and spin the shaft from the rear using a model engine starter to exert forward pressure on it. Ensure the compressor wheel does not rub. When happy with the fit, disassemble the engine and blow out any dust, then reassemble as per the instructions.

Modifications from early drawings

Vaporizer tube length increased to 64mm Air jets at front are not flared and point between center and outer edge of vaporizer tube but still in plane and moved rearwards to locate in outer wrapper just behind front end flange. NGV is held to shaft tunnel with six screws. Shaft tunnel rear flange to attach NGV is moved back by 2mm. Glow plug and gas fitting now located above a vaporizer tube.

Running the Engine

Assembling the engine was described so now we will turn our attention to the exciting bit, starting it. To run the engine you need, a test stand, fuel/oil, an electric fuel pump and means of controlling it, an LPG source, I use a small camping gas bottle, a hot glow plug source, the plug must glow orange, and a means of spinning the engine over, fan, electric motor or high pressure air. The LPG is used simply to preheat the vaporizer system so that the kero will initially burn. Think of it like a pilot light. The connections to the engine are made as shown in the diagram.
The fuel is kerosene with 5% turbine mixed with it. Heating kero is fine, but as I have to go to the airport to get the oil I use Jet A1 kero. I tip an US quart tin of oil into a 20 liter drum, then have it filled up with Jet A1. They tend to look at you in a strange way when you do this but after a few visits they get the picture. Before running your engine, don’t invite all and sundry to watch, just two or three are needed and if possible one of these with previous turbine experience. And have a fire extinguisher on hand!

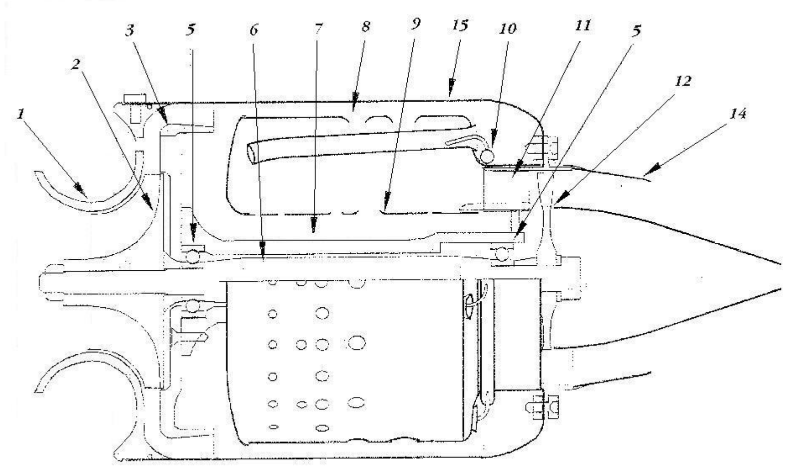
With the TX or pump controller set to idle, about 1.15 milliseconds pulse width, so to the start:

1 Spin the engine over for several seconds and make sure it rotates freely. This also helps to blow out any residue fuel.
2 Prime the fuel pump
3 Close the shutoff valve
4 Connect glow plug power.
5 Switch on ECU
6 Just crack open the LPG valve and a POP should come from the engine as the gas ignites.
7 Start the engine spinning and then open the gas valve a little more.
8 Keep opening the gas valve and let the engine stabilize on gas.
9 When the EGT reaches 150C open the shut-off valve. The ECU will start the fuel pump
10 As the fuel reaches the engine it should accelerate away.
11 Adjust the fuel pump control to stabilize the RPM and then turn off the gas and glow plug.
Sounds simple enough so what can go wrong?
1 Gas will not ignite.
Too much gas initially.
Too high an engine RPM so that the flame blows out.
Not a hot enough glow plug, it must be at least orange.
2 Engine will not accelerate on kero with flames coming out the back.
Too high a fuel flow caused by either or a combination of;
Too high a fuel pump setting.
Not enough starting RPM.
Mechanical bind in the engine;
Check the compressor and or turbine clearance as it can change as the engine gets hot.

The engine is now running so its on with the hearing and eye protection. Advance the pump control and check for vibration by gently touching the engine case, at the front with your finger, at the rear with a small screwdriver. If the rotor has been properly balanced, then any vibration present is caused by a compressor (at the front) or turbine (at the rear) rub. Dismantle the engine and increase the clearance where the rub occurs. You can paint the inside of the compressor cover with flat paint and any rub will then show up. A shiny spot in the turbine housing indicates a turbine rub. Restart and recheck and fix until there is absolutely no vibration present. With the engine running at idle and with safety glasses on, stand some five meters behind the engine and look inside. You could also use a mirror. At idle you should see a ring of yellow/blue flame inside, the more blue the better. Advance the fuel pump control and check again and the flame ring should now be only blue. If yellow flame or red hot spots are present make a note of their location and stop the engine. Dismantle the engine and check the following: Check the compressor and or turbine housing for rubs. The combustion chamber is centered in the case. The inside of each vaporizer and air jet tube is not restricted and they are in alignment as per the drawing. Pressurize the fuel manifold with water using the fuel pump and check for leaks and equal fuel flow from all needles. Assemble the fuel manifold only to the case and connect the LPG to the fuel nipple. Just crack the gas valve and light the gas inside the case. Check for any leak (the leaking gas will burn) at the through case connection. Apart from gross inaccuracies in machining, the above are the only reasons for the engine not performing. One machining or assembly error that will cause one segment of the engine to run hotter is if the there is unequal clearances between the compressor wheel and cover. This causes a reduction of airflow on the excess clearance side and a subsequent hot spot in the combustion. Once all is well, power can be increased and the EGT checked. Engines constructed so far, show an EGT of around 540-620C at idle dropping to below 500C with power. A high EGT is caused by, mechanical friction in the rotor for example; compressor or turbine rubs, too much preload, misaligned bearings or inaccurate machining. Another cause is low efficiency in the compressor or turbine caused by too much clearance. Once the engine is performing within these specs, you can fit the tailbone and try full power. The turbine should deliver 6KG of thrust at between 0.9 and 0.95 bar depending on the ambient conditions and with good reliability. How much more is possible? I have had

8KG but my test stand is really not good enough to handle this power level. The next step is to fit a restrictor to the lubrication line. I use a 5mm long piece of 23G hypo needle silver soldered inside brass tubing and simply inserted into the line between the "T" and the engine lubrication connection. This will make a dramatic improvement in the fuel consumption as the 21G needle fitted to the end of the lubrication tube does deliver excess lubrication to the bearings, thus keeping them very cool during the initial setup stage.

TURBINE PARTS AND MATERIAL



Cross-section of the Micro-Turbine.

NO	DESCRIPTION	QTY	MATERIAL	NOTES
1	Compressor Cover	1	Aluminum	Turned
2	Compressor Wheel	1	Al-Si Alloy	KKK\5326 123 2037
3	Compressor Diffuser	1	Aluminum	Compound Component
3.1	Guide Vane	18	Aluminum	1 mm thick sheet
4	Spacer Disk	1	Steel	Precision Turned
5	Ball bearing	2	ISO 608	
6	Engine Shaft	1	Screw Steel12,9	Turned from machine screw
7	Shaft Tunnel	1	Aluminum	Turned
8	Combustion Chamber Jacket	1	Stainless Steel	Spot-welded
8.1	Combustion Chamber Sleeve	1	Stainless Steel	Sheet 0.3-0.5 mm thick
8.2	Rear section	1	Stainless Steel	Sheet 0.5 mm thick
8.3	End piece	1	Stainless Steel	Sheet 0.5 mm thick
8.4	Stick	6	Inconel 601	¼ tube alternatively 6 mm
9	Combustion Chamber inner section	1	Stainless Steel	Welded
9.1	Inner tube	1	Stainless Steel	Sheet 0.5 mm thick
9.2	Front Section	1	Stainless Steel	Sheet 0.5 mm thick pressed
10	Injector ring	1	Brass	Soldered
10.1	Injector ring	1	Brass	0.5 mm
10.2	Injector needle	6	Syringe needle	Size 2, 0.8 X 40 mm
10.3	Guide	1	M4 socket head screw	Drilled out
11	Nozzle guide vane	1	Inconel 601	Compound Component
11.1	Inner Ring	1	Stainless Steel	Turned

11.2	Tunnel guide	11	Stainless Steel	Turned
11.3	Blade	11	Inconel 601	Sheet 0.7-1 mm
11.4	Turbine jacket	1	Stainless Steel	Sheet 1.5 mm
11.5	Flange	1	Stainless Steel	Sheet 1.5 mm
12	Turbine wheel	1	Inconel 601	Ready made
13	Spacer dick	1	Stainless Steel	Precision Turned
14	Thrust nozzle	1	Stainless Steel	Spot welded
14.1	Outer cone	1	Stainless Steel	Sheet 0.3-0.5 mm thick
14.2	Inner cone	1	Stainless Steel	Sheet 0.3-0.5 mm thick
14.3	Lug	3	Stainless Steel	Sheet 0.5 mm
14.4	Spacer	1	Stainless Steel	Sheet 0.3 mm
14.5	Mounting ring	2	Stainless Steel	Sheet 0.5 mm
15	Case	1	Stainless Steel	Spot welded
15.1	Housing jacket	1	Stainless Steel	Sheet 0.3 mm
15.2	Rear section	1	Stainless Steel	Sheet 0.5 mm thick pressed
15.3	Hole reinforcement	3	Stainless Steel	Sheet 0.5 mm
15.4	Guide	1	Steel	Tube 50 X 12 mm
16	Lubrication tube	1	Brass	30 X 0.3 mm
17	Per-load spring	1	Steel	Thrust pressure 15 N
18	Pressure takeoff nipple	2	Brass	From 6 mm rod
19	T-piece	1	Brass	Injector needle soldered in
20	Aux gas injector	1	Brass	Injector needle soldered in

You can purchase the most difficult parts such as the turbine and compressor, diffuser, and the NGV.

STARTER MOTOR

This is a link that will tell you how to build a starter motor for your Turbine.
http://www.technologie-entwicklung.de/Gasturbines/KJ_Starter/kj_starter.html

ECU

The ECU or Electronic Control Unit can be built from plans from the following link.

http://www.5bears.com/ecu.htm

WIRELESS INTERFACE

A wireless interface for the ECU

http://www.5bears.com/wireless.htm

If you have any questions please contact me at benglar@comcast.net

The Following parts are available from Jetjoe and they are the PP-1800 Engine
http://www.jetjoe.com/main.php

Part No	Part Name	US$
8001	Front spacer	$5.00
8003	Diffuser cover and air intake	$70.00
8004	Shaft spacer	$10.00
8005	Diffuser	$110.00
8007	Tunnel Assembly	$40.00
8009	Rear spacer	$5.00
8012	Combustion chamber, completed including Gas manifold & fuel injector	$120.00
8013	Lubrication line. Pre-formed with built-in restrictor	$15.00
8014	Glow plug	$8.00
8015	Aluminum front cover.	$36.00
8016	Exhaust cone	$35.00
8017	Steel outer Case	$40.00
8018	Ceramic ball race #D608 (8 x 22 x 7 mm) Qty 2	$120.00
8020	Oring set	$8.00
8021	Screw set	$8.00
8022	fittings x 3 (4mm)	$10.00

Total $643.00

These parts can be purchased from Changzhou E&E Turbo-Power Co., Ltd. They will let you

Do a one time purchase for each part. Then it's in lots of 10.
http://turbo.fuzing.com/
Contact Yunbing Tang <turbotyb@gmail.com>

66mm Compressor
$15.00

66mm Turbine
$85.00

NGV
$115.00

Shaft
$30.00

Turbine Nut
$2.50

Compressor Nut
$2.50

Total 1 $643.00