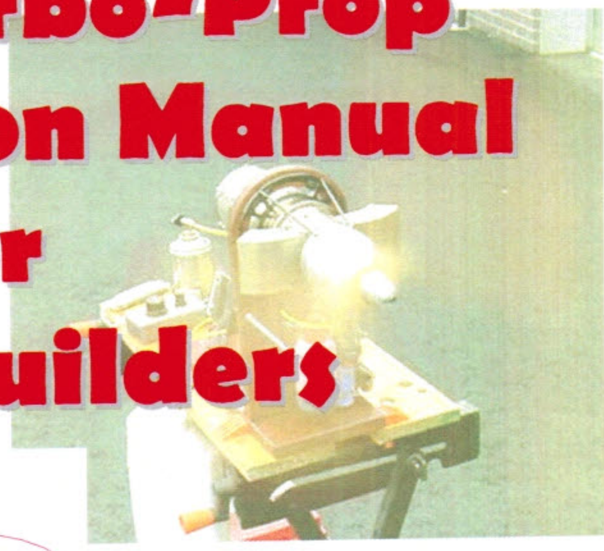
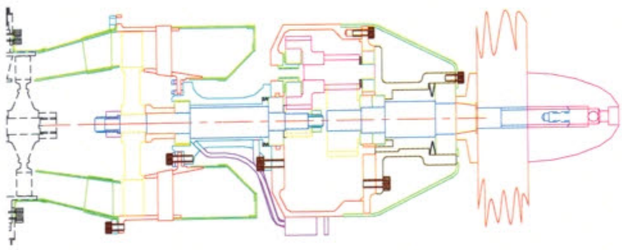
NEW

WREN

Turbines Ltd.

MW54 Turbo-Prop Construction Manual For Homebuilders





Construction and Operation Manual

By Mike Murphy, 3/2002

The Wren Turbines MW54 Turbo-Prop Manual

About this book.

The purpose of this manual is to provide sufficient detail for experienced homebuilders of small gas turbines to construct and operate a small turbo-shaft power unit based on our successful MW54 gas turbine. The unit described is not an engine itself but an add-on to the Wren Turbines MW54 engine. The text assumes the builder already has a working MW54 gas turbine, preferably a gas generator version.

It is not the intention of this manual to describe the workings of a small gas turbine as this has already been well documented in publications such as Kurt Schreckling's book "Gas Turbines for Model Aircraft" and Thomas Kamps's book "Model Jet Engines". Both publications are by Traplet Publications and are readily available at the time of print. Readers looking for the theory behind turbine operation will find all the detail they need there.

This manual and it's accompanying plan set provides details for making a real working turbo-prop and is in response to the many requests I have had to provide such detail, ever since the first public display of the prototype at the Isle of Man Manx Fly-In at the end of July, 2000.

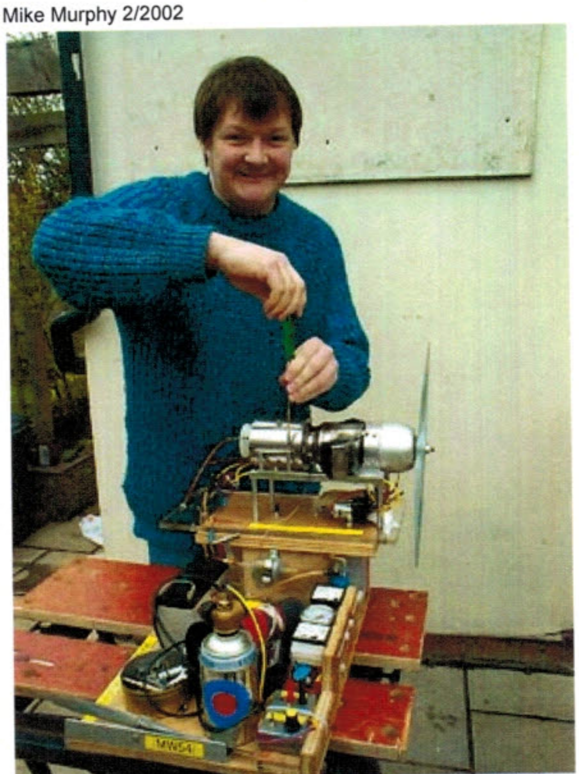
The power plant was installed into a 2.4m span Pilatus "Turbo-Porter" which has flown many times since and proved the ruggedness and reliability, and above all, the total practicality of such an unusual power plant.

This manual brings the technology firmly into the hands of the home builder and to aid the builder, Wren Turbines have prepared a series of special packs of basic materials, pre-machined castings, gear sets, bearing packs, laser cut exhaust parts, and a widening range of accessories. We have concentrated on making a functional and practical power unit for use in model aircraft and certain concessions have been made with the design to simplify construction and make the unit more accessible to a wider modelling audience. The design makes use of several complex castings for the hot section around the power turbine – eliminating at a stroke a large amount of highly specialised fabrication and allowing the emphasis on the more easily constructed gearbox assembly.

The exhaust system is shown as a spot-welded assembly and a set of laser cut components are available to make this. We are working towards having this component made up as a series of stainless pressings to enhance operational effectiveness and aesthetic appeal. We hope to be able to offer different forms of exhaust system to suit different installations. The design is refined to the extent that it works well - it is the intention of Wren Turbines that we will eventually produce more ready made components and ultimately a screw-together kit, mirroring the work just completed with our Mk2 MW54 kit engine.

For now then, we will confine ourselves to making a practical, affordable, and useable power unit that will be the envy of all at the flying field. Whether you yearn for a single engine "Tucano" or "Pilatus", a "Beech" twin or your dreams are more for the mighty 4-engine C130 Hercules, this book is especially for you and I hope you find it as useful and fulfilling as I have found it writing and preparing it for you.

Mike Murphy 2/2002



The author, with the prototype MW54 Turbo-Prop on it's test stand, April 2000.

Thanks.

Finally I need to thank my colleagues at Wren Turbines Ltd. Terry Lee, who worked long and hard in converting my basic CAD into something you could actually use to make something with. Roger Parish who is the demon toolmaker responsible for all the cast components particularly the interstage NGV and spider components and including all the turbine wheels that made the MW54 the engine we have today and which forms the basis of this project.

Finally to Sara Parish, who ensured the phone and e-mail were not neglected whilst I prepared this book for you.

Mike Murphy 3/2002

Turbo-shaft concept

The idea of using a jet engine to provide shaft power to a propeller, is not new. In 1944, Sir Frank Whittle and his company, Power Jets Ltd, had completed an example and were about to start test running when it was decided in government circles that such a power plant had no potential application, and was therefore a waste of public money (Power Jets Ltd had by this time been nationalised). So, as with many other pioneering works of genius at the time, the unit was consigned to the scrapheap due to lack of political insight.

Rolls Royce developments.
The idea however did not die and Rolls Royce, who were producing gas turbines to Power Jet's design, started experimenting using a "Derwent II" engine, with an extended shaft to a simple gearbox. This was called the Trent (RB.50). A five-bladed propeller was attached and tests in March 1945 proved the viability of the system. The unit was fitted to an early Gloster Meteor and flight tested successfully in Sept 1945.

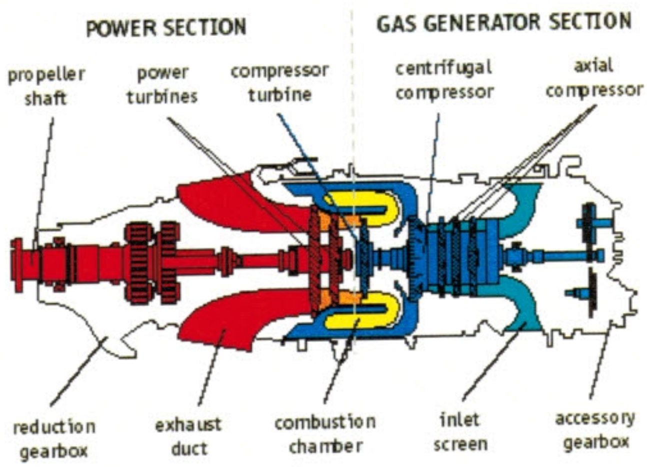
Rolls Royce "Dart"
This work laid the groundwork in April 1945 for the very successful Rolls Royce Dart turbo-prop (or RB.53 as it was initially known). This took the Derwent II principle several stages further by adding additional compressor and power turbine stages and a separate drive from the power turbine to the gearbox.

The Dart originally started out with the aim of 1000shp and went on to provide over 2970shp and has become one of the success stories of the 20th Century with over 120 million flying hours being accumulated by 1990 with over 7,000 engines. The engine is still flying with over 200 airlines around the world and Rolls Royce intend maintaining it's support for the engine until well after 2005, by which time it will have been around for over 60 years.

The Dart principle is not easily adopted for use in miniature gas turbines as it relies on power taken direct from the engine shaft. The engine shaft runs at 13,000 rpm loaded, whilst our engines run at 120-160,000 rpm and produce little or no additional power on the shaft that can be harnessed, even if such a high-speed gearbox could be constructed. For inspiration for a practical power take-off we need to look to another successful turbo-prop design, that of the compact Pratt and Whitney PT6.

Pratt and Whitney PT6 and variants.
The PT6 is a lightweight turboprop engine, which provides a power range from 580 to 920 shaft horsepower (ESHP). It is the most popular gas turbine engine in its class and since production started in 1964, more than 60 versions of the PT6 engine have been certified.

For our purposes the layout is most favourable as it is a split-shaft engine with two turbines, the first powering the compressor and the second geared to the propeller. Dividing the engine into two parts - gas generator and power section enables us to consider other ways of achieving the same aim in miniature form.



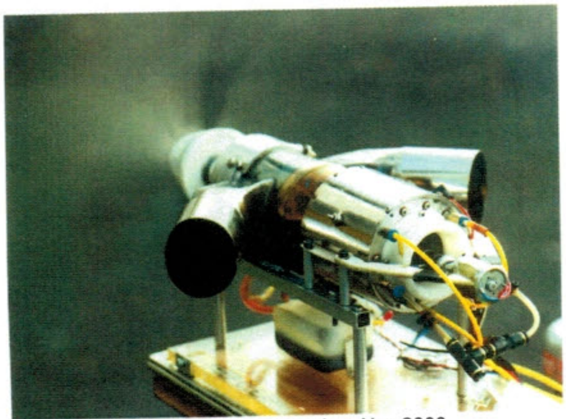
The two sections of the Pratt & Whitney PT6a (by kind permission from P&W Canada).

Gas generator
The gas generator is really another name for a gas turbine that has been optimised for cooler running and high pressure and does not have the propelling nozzle fitted. For our purposes we can therefore substitute - a gas turbine that has been modified to reduce it's exhaust temperature and enhance case pressure. The power section is really an add-on to the engine, therefore we can do just. By making the power section a bolt-on accessory the engine can be fully tested independently, and maintenance on either section can occur without disturbing the other. An advantage for the modeller is that the engine may be made up first and used in it's thrust form as a normal jet, the power section being added later to convert to turbo-prop.

Although there is no full-size precedent for this bolt-on approach, Sir Frank Whittle did propose what he called a "thrust augmentor" during the war years, which was an additional power turbine with an extra row of blades arranged around the outside which acted as a powered fan - this is known nowadays as a bypass turbo-fan. It was however unusual, in that most modern bypass fans are front mounted, alleviating the particular problems of lengthy blades in the hot exhaust area.

In the spirit of support for his efforts that prevailed at the time, Sir Frank did not receive any backing for the unit and it was quietly shelved. Nowadays such an arrangement is receiving new attention and a new generation of transport plans will have what is called a "prop-fan". This is like an un-ducted fan, with too many blades to be called a propeller and not ducted so it would not fit the description for turbo-fan. The promise is exceptional fuel economy for very long haul. Sir Frank would have been tickled to see how his idea is now taking off after 60 years.

"Haven't you got it the wrong way round"?



1st prototype Mw54 turbo-prop running, Nov 2000.

Many people who see the power unit comment that it is "back-to-front" and "surely the inlet should be at the front end"? However, having the hot exhaust system closest to the front ensures it is kept well away from other parts of the aircraft and more importantly, is closest to the cooling airflow from the propeller.

It has been found that inlet air for the engine should be as cool as possible and an ideal arrangement would have a separate air-scoop or entry for intake air which is not derived from contact with the exhaust. Air passing over the exhaust cools it initially but makes the engine run hotter which makes the exhaust hotter etc, etc.

Losses not having intake to the front.

Having the intake at the rear is not noticed by the engine, as having it facing forward would provide no useful benefit in normal flight, the forward speed and propeller thrust being very low in relation to the intake airflow speed.

Matching the power turbine speed to the gas generator

In a lengthy series of experiments, the importance of providing smooth gas-flow from the gas generator and optimum guide vane sizes and angles is heavily underlined, and departures from this will make the engine run excessively hot or may fail to run at all.

This may be through;

1) A poorly matched power turbine
2) A poorly matched secondary ngv shape and angle
3) Excessive loading on the power turbine or:
4) Poor choice of gear ratio to propeller load
5) Poorly shaped power stage gas path.
6) Insufficient exhaust area
7) Oversize gas generator compressor
8) Attempting too high a throughput through gas generator turbine.

As it can be seen there are a great many variables to consider, simply adding an extra turbine and gearbox to an existing gas turbine is likely to lead to disappointment.

We have prepared the "hot section" components as a pair of ready-machined castings and a matching power turbine, for you to use as the basis of your shaft power unit with the MW54 fitted gas generator turbine wheel. The gear ratio chosen for the gearbox is set at a medium torque, medium speed range to enable prop sizes up to 21x10 (530x250) 2-blade, 18x10 3-blade or 16x12 (405x300) 4-blade to be driven successfully up to around 9,000rpm static.

Please note that prop rpm will increase up to 20% in the air and users should take care to ensure the power turbine rpm is kept well within its safe operating ceiling of 65,000rpm, which corresponds to a prop rpm of 11,600rpm. Loading the prop-shaft to keep static rpm below 9,500rpm at max power with the gear ratio shown, should ensure a satisfactory safety margin. Larger props or those with greater pitch can also be used, subject to normal engine running temperature not being exceeded – this being the guide to loading.

Very Important

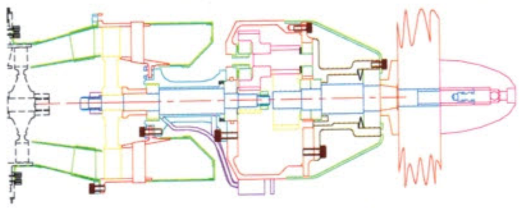
It is most important you do not attempt to run the power section without a suitable load fitted. Even running to just idle speed on the engine can cause the power turbine to overspeed if run off-load. This will cause blade rubbing initially and can result in blade and turbine shroud damage.

If you wish to check the free running of the power turbine without a prop or load fitted then use your on-board starter or starter wand to spin the engine cold, or connect a vacuum cleaner set to "blow".

"Pilatus PC7" – an ideal modelling subject for your newly completed turbo-prop – who will be the first?!

General arrangement and component description

Arrangement.
The arrangement of the gearbox is straight-forward and based on normal engineering principles together with some additional features which have arisen out of our development work with small gas turbines.



Gas is supplied via the gas generator engine at around 450'C and fed via a set of guide vanes, we call these "interstage nozzle guide vanes", which deflect the gas to an angle to impinge on the power turbine blades and thence generating torque in the high speed shaft.

The interstage NGV angle is a compromise between generating maximum torque, and coolest running for the gas generator. The gas passages are larger than would be normal to allow for a broader operating range with a wider loading tolerance.

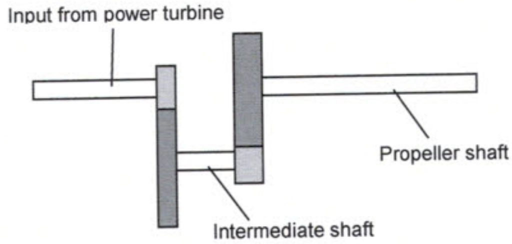
After passing through the power turbine the gas is collected in the exhaust plenum and is released out through two side mounted exhausts. The exhausts are angled rearwards to mix with the propeller wash, ensuring rapid cooling of the gas to about 90'C, at 200mm from the exit point.

A set of vanes are mounted immediately after the power turbine which support the high speed shaft tunnel and keep the power turbine centered in the turbine housing – we call this the "spider".

Gear-train.
Torque is transferred to the power turbine shaft at up to 65,000rpm. At the other end of the shaft is the high-speed drive pinion, the whole shaft being supported on two ball races. The pinion is of helical pattern, and this pattern is repeated throughout the gearbox for quietness and power handling. The high-speed pinion is of 13teeth and drives a larger gear of 32 teeth on the intermediate shaft, giving a first stage reduction of 2.46:1.

The intermediate shaft, which is supported on a pair of ball-races, drives a smaller pinion of 11teeth on the same shaft. This smaller pinion then drives a larger gear of 25teeth on the propeller shaft giving a second stage reduction of 2.272:1. The two-stage reduction gives an overall ratio of 5.6:1 and this can be altered to suit the rpm and load required by simply selecting alternative gear-sets. For smooth running all bearings are preloaded using special pre-load springs.

The propeller shaft is supported by three substantial ball-races, two to retain the side thrust from the gears and the larger front bearing to absorb the forward thrust. The propeller is driven via a prop driver plate mounted on a taper on the shaft, which affords some protection to the gears and gearbox, in the event of a prop strike on the ground. There is no positive key system to ensure some slippage can occur in overload situations.



Diagrammatic arrangement of gears in gearbox

Lubrication system.
Lubrication of the gears is via external electrically driven pump, powered by a single cell supply and switched via a pressure switch from the engine. This ensures a regular supply at a useful pressure and flow rate. Oil is fed via two injectors to precisely the point on the gear-sets where it is required. It then drains down and out via a drain point back to the remotely mounted tank and recycled. It is therefore a dry sump system and oil level and oil quality is easy to check and confirm. The rapid movement of the gears ensures that plenty of oil is flung into the gearbox bearings and keeps these well lubricated and cool.

Power turbine lubrication.
The power turbine bearing is a special case as this is in a most hostile environment and needs special care if it is to survive this punishing regime and still give useful service life. The bearing is of cageless ceramic construction and is fed with a fuel/oil mix direct from the main fuel supply via a metering system. A supply of compressed air is used for cooling and forcing the lubricant through the bearing.

The importance of a proper cool-down regime after running the engine, is clear. Auto-starting ECU's with this function built-in are very useful here.

Further heat insulation is provided by mounting the bearing in a *tolerance ring*. These are stainless steel pressings primarily designed to grip bearings in aluminium housings, eliminating the need for precision machining. They are used here to help limit the heat transfer from the housing to the bearing, and to hold the bearing firm as the housing expands when it warms up.

Power turbine bearing pre-load.
As the ceramic bearing is of a thrust pattern it needs a pre-load arrangement and this is provided by a pair of purpose made pre-load springs, against the larger bearing at the gearbox end of the shaft. The bearing is a sliding fit into it's housing which has an O-ring fitted in a groove, to provide a compliant seating and prevent rotation of the outer race.

Exhaust
The exhaust assembly is made up of stainless steel sheet, with a number of formed parts spot-welded together. Although Inconel or similar heat resistant alloy can be used it is extremely expensive and hard to work and the extreme temperature and hot corrosion resistant properties are not useful to us. The moderate temperatures we are working with make stainless a good choice. Patterns will be needed for some of these and these are described in the plans for each part. A set of laser-cut stainless parts are available from Wren Turbines, eliminating the tedious marking up and cutting out.

The emphasis for this section has been on functionality and make-ability, and the shapes subject to certain compromise in order to keep the project practical. The exhaust assembly slips over the power turbine shroud and is held in alignment by means of a pair of screws inserted into the spider casting.

The exhaust outlet pipes are shaped such as to provide a continually expanding gas path, a pre-requisite as the gasses are losing their momentum as they pass through the passages and out to atmosphere. The sharp turn at the front is particularly important, in that plenty of space is provided for the gasses to turn the 130' to exit. The angle allows the remaining energy to push the gas clear of the fuselage and thus minimise heat problems. A nice rounded shape would have been preferable for the twin exhaust outlets but this would have greatly increased the complexity and number of parts for this assembly and it was decided a compromise was needed.

Ready-made exhaust system.
We are exploring sources for a pre-made exhaust assembly, which will address some of the aesthetic issues above. Details will be published as these parts come on stream

Gearbox.
This assembly is made up as four aluminium sections screwed together at the front and back. The shape is such as to provide a large area for heat conduction and a stiff structure to withstand all likely thrust loadings and a good degree of crash resistance in the event of an "unfortunate arrival". The assembly is based on concentric disks and all parts are referenced from the prop-shaft backwards, ie "front" means prop end!

The main body of the gearbox carries the connections for the various services – oil, fuel/oil, air and oil-drain.

Power turbine shaft.
The shaft tunnel towards the rear carries the power turbine shaft and Spider assembly, which provides the means for centring the exhaust assembly.

Front cover.
The front-cover which forms the front end of the gearbox, carries the front intermediate shaft bearing and the rear prop-shaft bearing as well as providing the main mounting point for the prop driver shaft tunnel.

Prop Driver
This assembly is at the front of the power unit and carries the prop-shaft and it's bearings. It is screwed to the gearbox front cover, and also retains the gearbox cowling, which is secured by screws fitted behind the prop driver.

Construction
The MW54 turbo-prop is a complex machine and requires a good standard of engineering skill if it is to work successfully. All builders are asked to seek guidance if there are elements that you are unsure of your ability to complete safely. At all times, remember this is not a toy and must be treated with respect. It is a machine powered by heat, which is liberated in vast quantities inside the engine and only safely harnessed if correct procedures are adopted.

A great many experiments have been carried out to ensure the design should work well from the outset, and readers are asked not to attempt to re-design it along the way or substitute alternative materials. It may not be easy or obvious to appreciate the effects such changes may have. The author or Wren Turbines Ltd cannot accept responsible for circumstances arising from changes outside the boundaries of the design.

We will go through the construction of each piece in order and discuss the developments and design of each element as the need arises. I will try to describe any special equipment I have made to enable parts to be constructed along the way. Much of this equipment has been used many times before and since this project was undertaken, therefore I do not apologise for requiring it's use as I know you will find much use for it again in future projects. For many operations the phrase " a picture is worth a thousand words" could have been invented as this text would have gone on forever, but for my trusty camera. I hope you will find the pictures helpful and that they will convey my intention as I had hoped.

Equipment.
For the construction you will need; a good lathe (around 3" or 75mm centre-height minimum), vertical drilling machine, drilling spindle for the lathe, simple headstock dividing device, small bending rolls, belt or disk sander, small spot welder, drills, small metric taps and dies, accurate set of calipers, a micrometer, access to a decent height gauge, the ubiquitous "Dremel" high speed drill/grinder or equivalent, safety glasses, and of course plenty of patience and enthusiasm!

The text assumes you have all these items, or are able to borrow or access them. I have not shown a milling machine as I didn't use one for milling purposes, although its use for marking out is useful.

Often in the text I will say to turn housings parallel, to a particular depth, as so much of the turbo-prop arrangement relies on very good alignment for long life and quiet running. It is most important that if you are using your top-slide to turn to a specific depth, please ensure you have set it exactly parallel to the lathe centre-line. I know we often rely only on the graduations marked on the base of the top-slide for this but really we need something much more accurate for bearings, so please be watchful.

Other items of equipment are implicated when we get to the point where we are running the gas generator. For the purposes of this manual, we will assume you already have equipment for running your MW54 turbine (ie fuel pump, tank, ECU where applicable, etc).

Measurements.
We live in a world where measurements know no boundaries, with inches and metres vying with each other for prominence. I will however bow to the metric system as my first indication and where useful will include the imperial alternative. If I mix them then I apologise as my schooling was in imperial!

Conversions:

To convert millimetres to inches divide by 25.4.
To convert inches to millimetres multiply by 25.4.

"Yippee"!
There is always a certain amount of excitement and elation when a new project runs for the first time – particularly when it's the first MW54 turbo-prop, and for myself it was no exception!
(April 2000)

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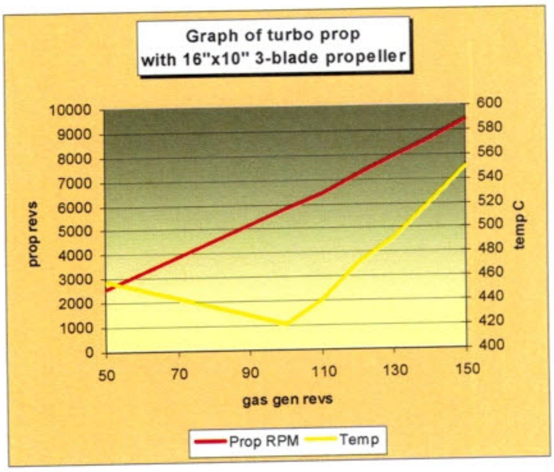
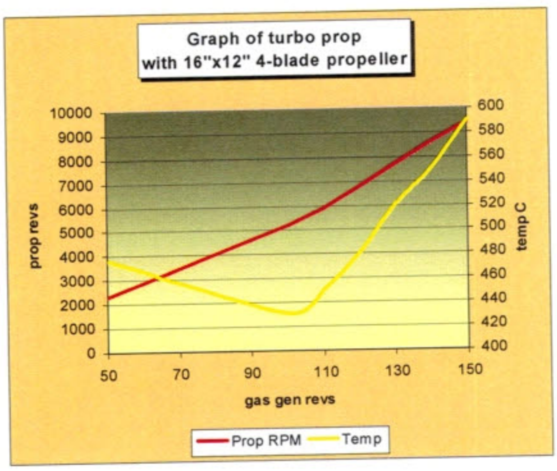
Performance figures.

The figures shown are for information only and were measured using a standard MW54 kit engine with gas generator turbine fitted. Ambient temp on test day was 10^0. Engine was controlled with a "FADEC" Full Autostart ECU. Temperature measurements were taken by the ECU thermocouple probe from inside the interstage gas passage, 25mm from the gas generator turbine. Propeller rpm was measured with MFA Digital Tacho. All props were balanced before use.



Master Airscrew, carbon filled nylon.



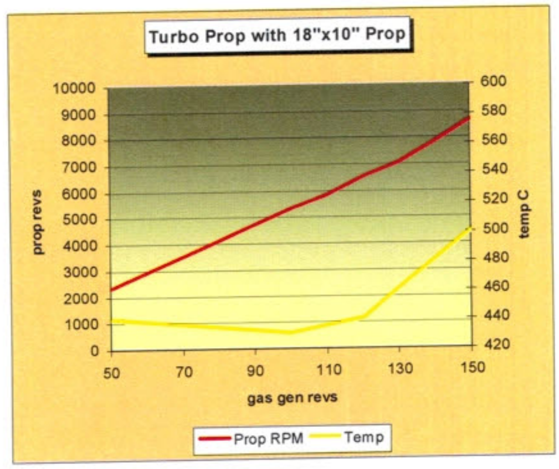
APC scimitar bladed, glass filled nylon.

Power produced guideline.

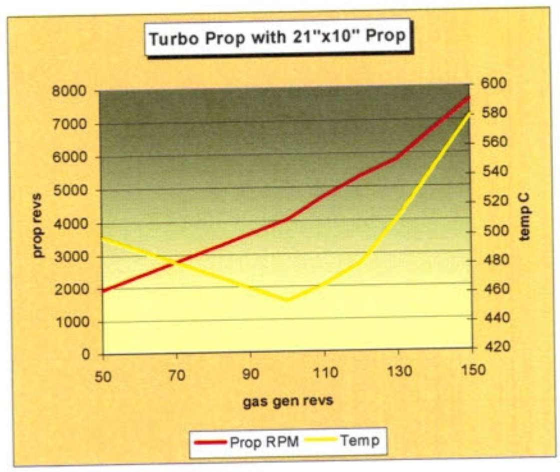
Power produced to drive the 21"x10" prop at 8,000rpm at a gas generator rpm of 155,000rpm is 7.1HP or 5.1Kw.

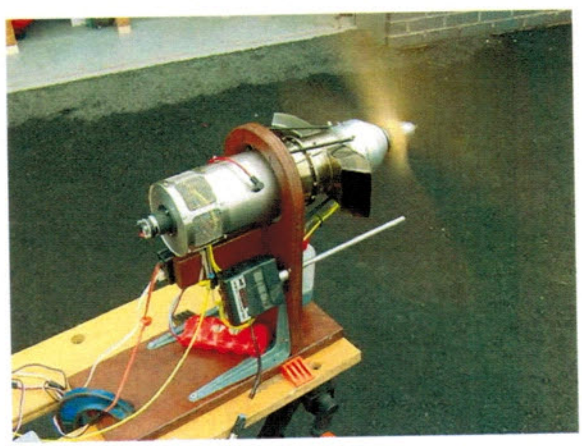
From experiments and reviewing the temperature figures, there is a top limit on power imposed due to temperature considerations. It is suggested you set this limit at 600^0C and work below this point in normal operation. You will also notice the temperature is lowest at around 100,000rpm on the engine and at idle is higher than this. With this in mind it is sensible to keep your idle running to comparatively short periods, or to raise the idle slightly to allow the engine to run cooler – raising to 60,000rpm makes a big difference.

Dynathrust carbon filled nylon.



Robbe Dynamic, wooden.





Turbo-prop idling gently with 21"x10" prop at 1700rpm.

Be aware that the thrust from almost all props used on the turbo-prop is sufficient to pull over most portable test-stands. Please ensure before you do any running that your test stand is sufficiently rigid to withstand 35 to 40Lbs of static thrust, test by attaching a spring balance through the spinner hole and pulling. It is better if your test stand is solidly anchored.

Modifying the thrust engine for turbo-shaft duty.

The MW54 Thrust Engine

The MW54 engine is arranged to provide the largest possible airflow to be converted into thrust by squeezing it through the exhaust nozzle, for driving the aircraft. It's turbine and compressor arrangement is therefore optimized so that the torque provided by the turbine wheel is used to drive the compressor with little extra remaining. The limitation to this is the maximum temperature that can be sustained by the ngv (nozzle guide vanes) and turbine stages. We have kept these to a sensible limit of around 650'C.

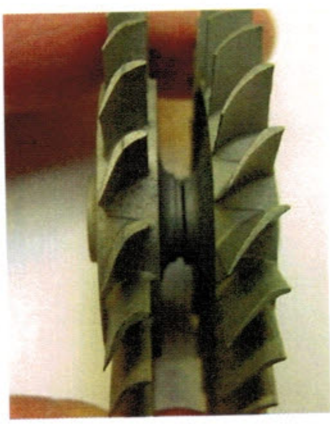
Gas generator

Successful gas generator engines provide gas at useful pressure that can be expanded to drive a second turbine stage and thus extract further power in the form of torque. The term "gas generator" is thus given to a gas turbine which has been modified to provide excess air and for our purposes, more importantly, at a temperature which is sustainable by normal materials and exhaust ducting arrangements, and where an exhaust nozzle is not fitted.

Effect of power turbine

The last point is most important as experiments have shown, that adding a succeeding power turbine stage to a gas turbine increases its exhaust temperature by around 200'C, depending on the power being extracted from the gas. Contrary to popular belief the engine does notice if there is a restriction downstream of it's turbine and it has an impact on the free flow of gas, and thus it's operating temperature. If we are to keep to our limitation of 600'C TET (turbine entry temperature) then we must ensure our gas turbine has a maximum exhaust temperature of around 400'C prior to adding the power section.

Modifying the MW54 for Gas Generator duty



To enable the MW54 to achieve this low running temperature, we need to increase the power supplied to the shaft and hence increase the drive to the compressor.

This is easily achieved by reducing the angle of the turbine blades, in particular the blade exit angles by simply swapping the thrust turbine for a gas generator turbine. The gas generator is shown above left, compared to the thrust turbine at right. The existing ngv remains unchanged.

Before making the change to your MW54, please ensure all other elements of the engine are in good order, in particular the vaporiser stick and swirl jet positions. It is strongly recommended that Inconel tube is used for vaporisers as the engine will run hotter internally and you will find some erosion of the sticks ends after only a relatively short time running with stainless.

Fitting a replacement turbine wheel is easy enough and does not require much explanation other than to stress the importance of good balancing for smooth and quiet running. Check the condition of your rear bearing before mounting the turbine wheel. If it is sloppy or gritty when spun it may need replacement.

Tip clearance.

Mount the turbine on a mandrel and running in mid back-gear, carefully skim the outside diameter to give an overall clearance of 0.3mm (0.15mm tip). This is best achieved by grinding using the "Dremel" grinder held on the cross slide and taking 0.05mm (1-2 thou) off at a time. It is not recommended that you try turning with a lathe tool as the slightest catch will snap a blade off, and you wouldn't want that! Check the balance of your rotor by following the instructions in the engine instruction manual. Wren Turbines will shortly be able to offer a full balancing service if you need this.

Auto-starting system.

If you are planning to fit an automatic starting system to your engine such as the "FADEC", "Orbit", or "GB Hobbies" versions, then please fit this to the bare engine first and get it starting and running the engine reliably before fitting the power turbine stage. Any set-up problems can cause overheating and possible damage to the turbo-prop unit so ensure the system is properly set up and tested beforehand.

The best set-up is one in which the engine is briskly run up to idle around 45,000rpm, with minimal labouring around the self sustain point (20,000rpm) which is where the engine will run hottest. Set up your ECU to aim for a peak start temp of 600-650'C. Ensure your starter components are working correctly, as you will need to use the "cool-down" function of the ECU after the run, to get the temperature of the power turbine quickly down to 100' C or less.

Manual on-board starters.

If you do not plan to fit an auto-starting ECU, but plan an aircraft installation, then please consider using an on-board starter worked from a micro-switch on a servo, at least. On landing you will still need to provide a means of cooling down after the run, and this is the simplest system and was used very effectively on the 1st MW54 turbo-prop "Pilatus Porter".

A manual system can be used for quick and simple starting using manual ECU's using external gas and glow supply. For running using a gas generator turbine a very low running temperature of around 350-450'C is correct without any cone. Limit power to about 1Bar or around 140,000rpm initially as this will greatly enhance bearing life and when you get your turbo-prop attachment on you will be amazed at the power this gives.

Construction.

Keep the relevant drawing open as you work through the construction. We have made them in two books to help you with this. We have checked the plans and instructions carefully but small errors may have crept in so use the drawing as reference.

Work carefully and safely. ***MGM 3/2002***

Wren Turbines

MW54 Turbo-Prop Construction Manual

Assembly:

Operation:

Copyright Notice

Wren Turbines Ltd, 5 Stoneham Street, Coggleshall, Colchester, Essex, C06 1TT

Wren Turbines Ltd is a company formed by Roger Parish, John Wright, Mike Murphy and Terry Lee.

The Company was formed initially to launch the MW54 gas turbine design and to manage the design and production of cast turbine wheels and ngv's for the engine. This brief has now been much widened to incorporate the production and supply of a wide range of parts and accessories for the turbine enthusiast.

The company has also designed and developed turbo-shaft applications for the MW54 engine for turbo-prop and helicopter applications. This manual is in response to requests for a formal manual for home constructors, to build their own turbo-prop based on the MW54.

Wren Turbines MW54 Turbo-Prop – Safety Notice.

This Turbo-Prop is intended for use in model applications and users should satisfy themselves of the suitability of the engine as power plant, and the provision of a safe and appropriate installation, before carrying out any engine running. Please read and digest the following for your safety:

Adopt a safe code of practice.

The MW54 turbo-prop is most definitely not a toy and must always be operated with due care both for the operator and any members of the public that may be nearby. Be especially on your guard toward the inquisitive spectator who may not realise the dangers of gas turbine operation and the potentially invisible rotating propeller.

The engine must be operated only in accordance with the Gas Turbine Builders Association code of practice and the accompanying appendix – obtainable from the GTBA web site http://www.gtba.cnuce.cnr.it. New turbine users are recommended to read the information contained therein and to familiarise themselves with turbine operation and special precautions needed.

There are some precautions that we would like to take this opportunity to highlight: -

1 NEVER stand or allow anyone else to stand close (within 30 feet or 10mtrs) in line with the propeller when the engine is running. It is always possible that the hub or blade could fail. Also, never run a damaged propeller.

2 All spectators should stand behind the engine ideally behind a barrier several metres from the engine, so they are not tempted to point at parts of the engine when it is running. The operator should also stand behind and to one side of the engine i.e. in behind and to one side of the plane of the turbine.

3 All spectators should be briefed before the run on how to behave, always have a safety person with you when engine running/flying.

4 Always have a fire extinguisher to hand when running/flying, CO_2 or BCF is ideal – dry powder, foam or water is not recommended.

5 In the UK it is suggested that you join the BMFA to take advantage of their insurance cover, even if you do not wish to fly the engine.

Above all, enjoy!

Parts and accessories for this turbo-prop are available from Wren Turbines Ltd. Please state your date of purchase to help us ensure the right part is supplied.

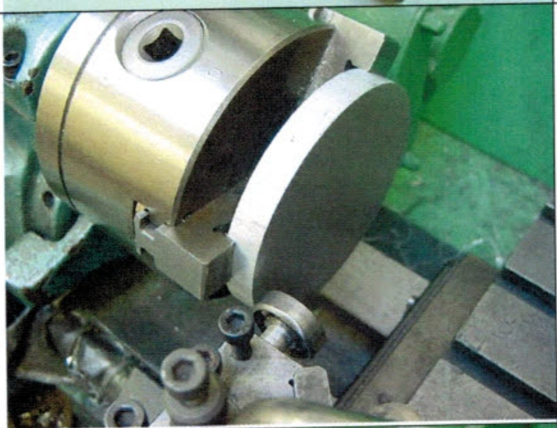
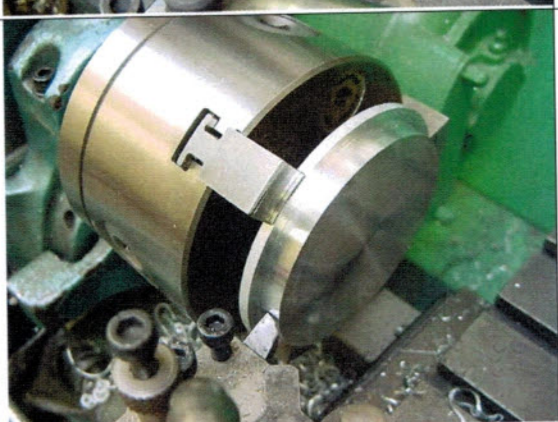
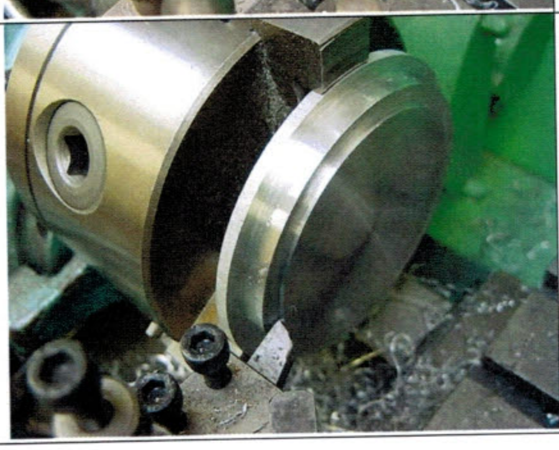
With thanks to all our past and present customers whose continued support have made this new design worthwhile.

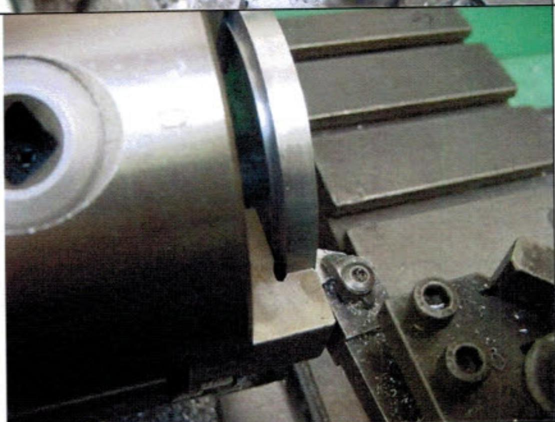
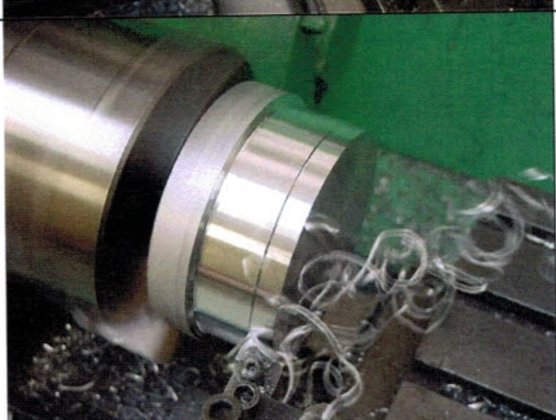
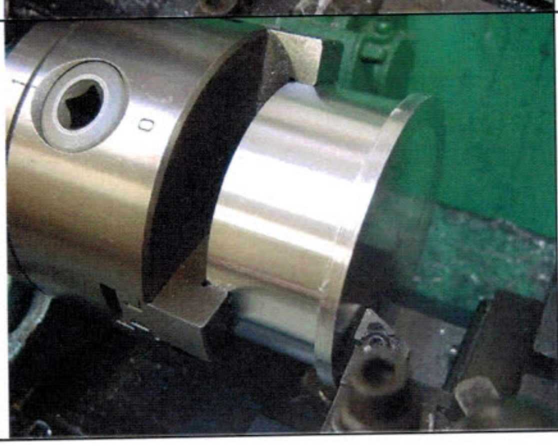
Mike Murphy,
Wren Turbines Ltd
March 2002.

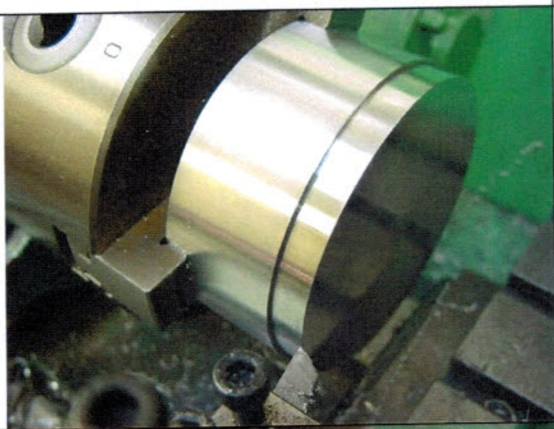
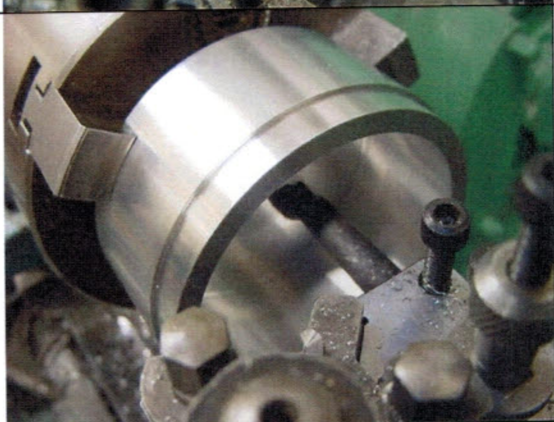
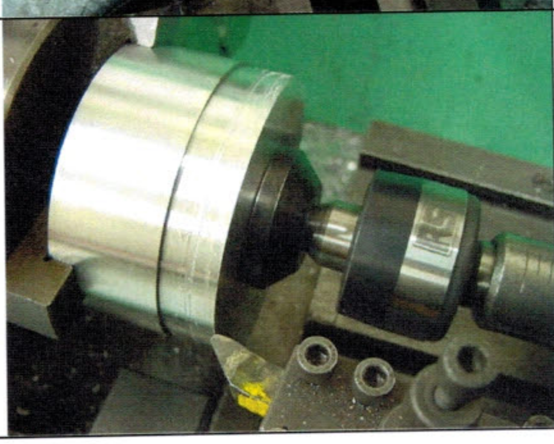
Wren Turbines welcome feedback on this or other of their products, email on info@wrenturbines.co.uk or write to:

Wren Turbines Ltd, Unit 19, Century Park Network Centre, Manvers Way, Rotherham, S63 5DE, England

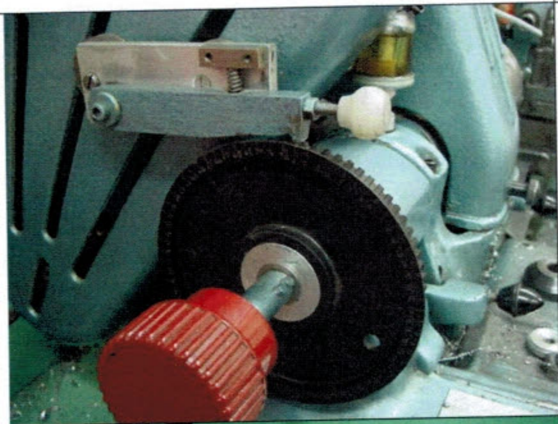
Tel +44 (0) 1709 877 439, Fax +(0) 1709 875 935

Construction starts here!	
	**Materials pack, available from Wren Turbines Ltd.** 83 dia x 40, HE30 aluminium 83 dia x 9, HE30 65 dia x 35, HE30 45 dia x 45, HE30 35 dia x 38, HE30 4dia x 500mm mild steel, x2off 35 dia x 20, mild steel 15 dia x 100 En24t high tensile steel, x3 off 20 x 20 x 13, brass 8 dia x 15, brass 8 hex x 25, brass 10 dia x 20, brass 10 hex x 8, stainless 1.6 dia x 120, brass tube 2.4 dia x 80, brass tube 3 dia x 70, brass tube
	**Gearbox Front, 157.** Set up the 83 dia x 9 blank in the outside jaws of your 3-jaw chuck – set it well forward if you can, and square up. To help when squaring thin blanks in the chuck I use a ballrace on a bar in the toolpost. Tighten gently and use the ballrace to roll it back into perfectly square and then you can tighten up firmly. Try it, it works! Once running reasonably true, face off. When turning HE30, which is a very tough alloy, you need a sharp tool and lots of rigidity. Keep a brush dipped in a pot of paraffin and apply this as required, the finish will then be ok.
	Watch for build-up of fumes after a lengthy series of cuts, keep plenty of ventilation going. Turn outside diameter to 73.5mm dia and as far back as you can get to the jaws.
	Turn the locating boss to 63.5 outside diameter and 1mm long.

Gearbox Front	
	Using your boring tool, turn out the internal diameter of the locating boss to 61.5mm and a depth of 1mm.
	Turn the front cover around in the chuck and grip gently. Face off the plate to square it up. We only need it 5mm thick (6mm including the locating boss) so face it as near to this as your chuck jaws will allow. The final finishing to length will be performed whilst mounted on the gearbox main body so as long as we are near this size, you can leave the rest for later.
	**Gearbox Case, 155.** Mount the 83 dia x 40 blank into your 3-jaw chuck and square up as before, and grip firmly. Face the end and turn the outside to 75.5mm for a length of about 30mm. This end will form the rear of the gearbox – do not turn the chamfer yet though. Use the paraffin as suggested earlier and be sure not to try to clear the swarf with your fingers as this operation will generate a great pile – it is very hard and razor sharp, use a pair of pliers instead.
	Turn around in the chuck and grip the end you have just machined, ensuring it is firmly seated against the chuck rear and as square as you can get. Turn the blank to 36mm long, finishing cleanly.

Gearbox Case	
	Turn the cowling shoulder to 73.5 diameter and 8mm long.
	Centre drill and drill out as large as you need to get your boring tool started, and to a depth of around 30mm – do not drill through the gearbox rear as yet. Using your boring tool, bore out the inside to 63.5mm (so the gearbox front cover is a snug push fit) and a depth of exactly 31mm deep.
	Machine out the internal profile – I found I needed a combination of different tools to get the rounded shapes required. To finish the recessed side wall and rear face I set over the top-slide to 63^0, and used the micrometer to check wall thickness regularly. The recessing is partly to lose some weight and also to provide room for the intermediate gear. Once the boring is completed, the front cover needs to be slotted onto the front and a few drops of cyno' glue applied to secure it in position.
	I know engineers grimace at the thought of this but I assure you it's quite practical! Cyno' does not form a permanent bond, due to the instantaneous formation of oxides on the aluminium and a couple of taps from the inside will break the bond and release the cover. Turn the cover plate to thickness of 5mm. Support the cover plate using the tailstock centre, use something to spread the pressure evenly. Using a rounded tool and with support from the tailstock, the recess in the outer edge of the cover plate can now be machined. We are now ready to drill for the cover securing screws.

Marking up for Intermediate Shaft



As we are coming up to drilling the front cover and gearbox I thought it worth looking at my arrangements for indexing and drilling in the lathe. I will assume you have something similar but a couple of snaps will help illuminate the benefits these bits of kit bestow.

My indexing device is simply a 72tooth, toothed belt pulley mounted on a shaft with an expanding centre that grips the headstock spindle at the outside end. The expanding centre is operated via a large plastic knob (from an old typewriter!) and a shaft going down the centre. The ratchet tool is spring loaded and is permanently attached to the lathe, and engages into the pulley teeth.

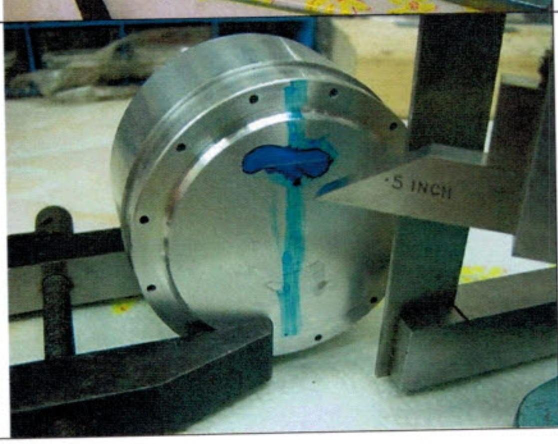
The whole system is ultra simple and alternative gears can be fitted to give different index numbers.

My drilling spindle is equally simple – a shaft fitted with a pair of ballraces and a ¼" chuck, with a toothed belt pulley for drive. The bearings are mounted in a tube welded to a piece of angle. The shaft is driven via a toothed belt from a larger pulley mounted on a cheap mains motor bought "surplus". The motor runs at 2800rpm and there is a 2:1 step up, giving a useful 5600rpm – ideal for the small drills.

The angle plate base has a bolt fixing to a length of tee-nut slotted into the cross-slide tee slots. It can thus be taken on and off with ease.

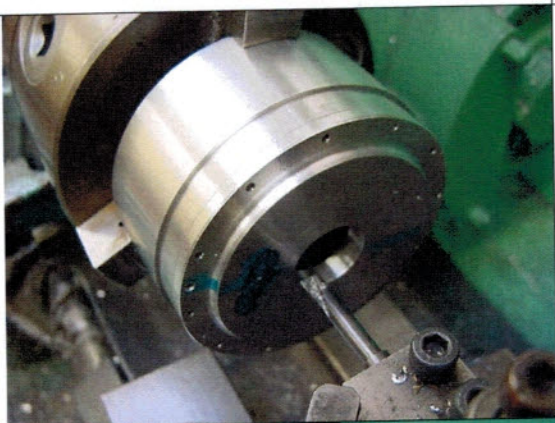
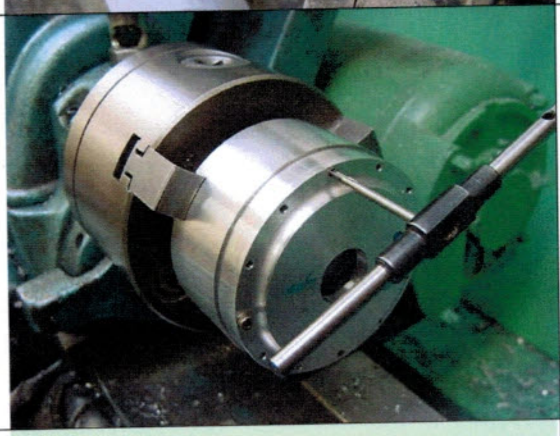
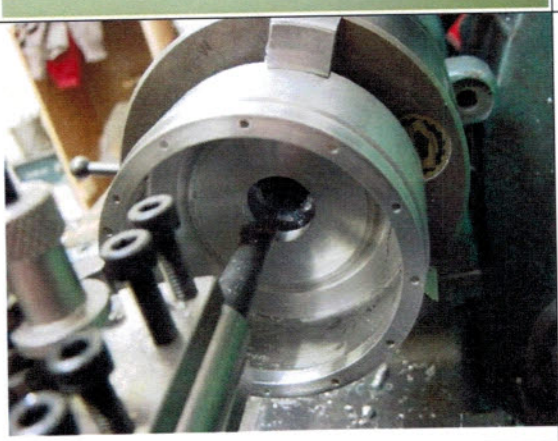
The twelve front cover screw holes are centred and drilled 2mm diameter to a total depth of 10mm. The dowel hole can also be drilled 2.4mm, in between one pair of the holes – all on 68.5mm PCD.

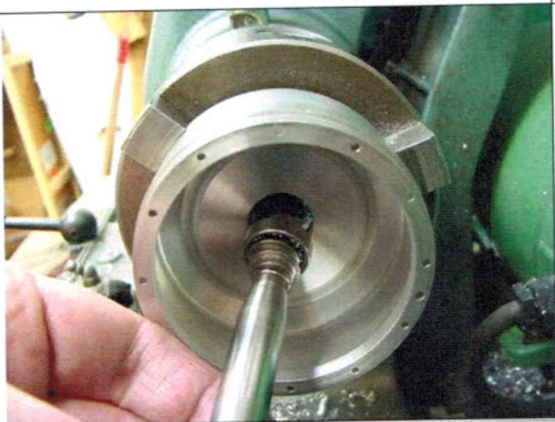
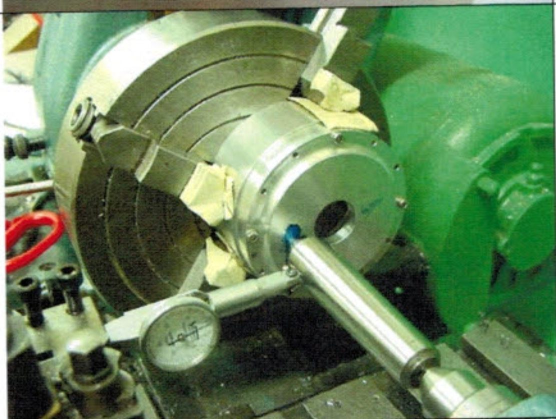
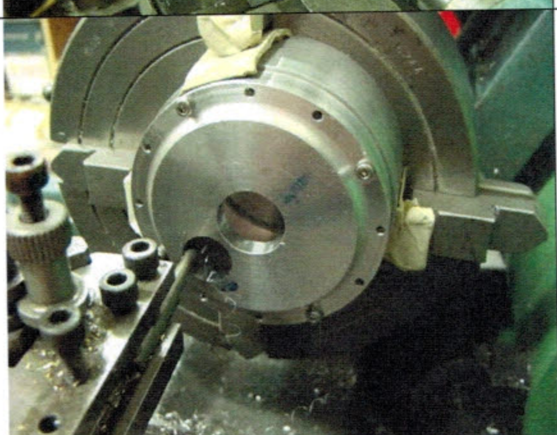
The gearbox can be de-mounted now and we need to mark out for the intermediate shaft. It is important this is achieved with accuracy as the gear centre tolerance is only -0.00 to +0.05mm at the specified centre distance of 18.90mm. I found the easiest way to achieve this was to use a height gauge. Set the gauge to exactly the gearbox height whilst being held firmly on it's edge (see left). It is easy then to dial in half the height, ie half of 73.5mm (or the exact size of your gearbox) and scribe a line across the face of the cover.



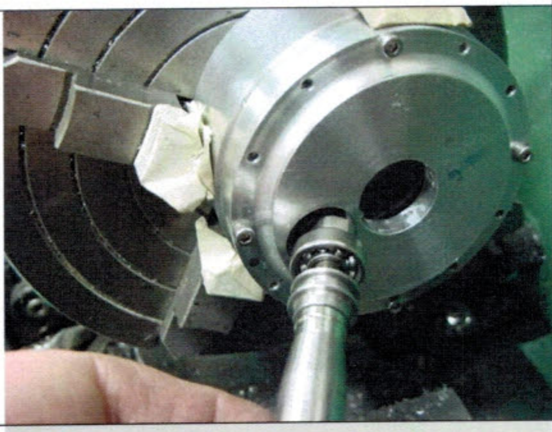
The gearbox is then rotated 90' – use an engineers square and align so the scribed line is running vertically. The height gauge can then have 18.90mm added to the previous setting, and a new line scribed to indicate the position of the intermediate shaft. Very carefully centre pop at the junction of the two scribed lines, using a freshly sharpened fine-point centre punch – use an eyeglass to help get the pop exactly on the crossed lines.

Once marked with the centre pop, use a tiny centre drill to make a clear and accurate centre.

Boring for Prop Shaft Rear	
	The gearbox assembly can be re-fitted to the chuck now and centred and bored for the rear prop-shaft bearing. Check to ensure it is running nice and true first. Use a fine boring tool for finishing the hole and aim for a close sliding fit. Use the 19mm bearing as a plug gauge to check the fit.
	The fixing screw holes are tapped M2.5 – use paraffin to lubricate, and clean the tap well after each hole to stop the threads picking up and spoiling. Heat the gearbox case with a hot air gun to soften the cyno', and pull off the front cover. We now need to bore the rear centre hole and cut the groove for the O-ring cord on which the bearing seats.
	**O-ring groove tool.** This is the ideal shape tool for the O-ring cord, width is 1.5mm and maximum depth of cut is about 2.5mm – we only need 1.5mm though. The tool is ground from an old boring tool and is kept especially for this kind of job.
	Centre drill the rear hole and drill and bore out to 19mm diameter. Be careful you don't run into the chuck jaws behind!

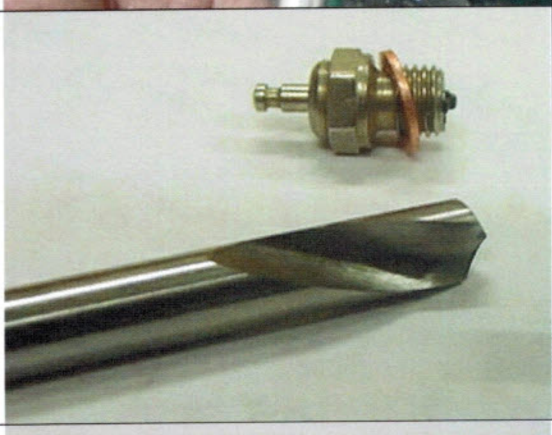
Boring for Intermediate Shaft	
	Use your ISO607 bearing-on-a-bar again as a plug gauge. Aim for a sliding fit. The side thrust from the gears should be taken on the aluminium but the O-ring cord (see next stage) should prevent the bearing outer rotating and fretting the bore.
	Using the O-ring tool, turn a recess 1.5mm deep (cord is usually 1.55mm diameter) by 1.7mm wide. The extra width allows some expansion of the cord to take up the compression caused by fitting the bearing into place. The O-ring cord should not be so tight that the bearing pre-load is unable to function. A length of 65mm should work well as a starting point – smear with silicon grease and ease into place. If the bearing is too tight, reduce the length by 1 mm and try again. If still too tight the groove will need deepening slightly. Once fitted, leave the cord in place. The front cover can now be refitted and held in place with four of the fixing screws.
	**Intermediate shaft.** You now need to set up a 4-jaw chuck to turn the intermediate shaft holes. Locate a hard (or "dead") centre into the previously centred hole indicating the intermediate shaft position. Rest the gearbox casing against the chuck and bring the tailstock with another hard centre installed, up to engage the rear of the hard centre (see left). You can now rest the stylus of a dial indicator against the hard centre and clock the point at which there is zero run-out by sliding the gearbox around the chuck face and rotating the chuck gently. Use scraps of card against the jaws and bring each one up to grip the gearbox in position.
	Keep checking the dial indicator until the gearbox is held firm and there is no detectable movement in the dial as the chuck is turned. The hole can now be drilled and bored out to size.

Boring for the Intermediate Shaft.



Use an ISO607 bearing on a bar to act as a plug gauge and take small cuts as you get near to size.

Aim for a firm sliding fit on the bearing.



Boring for the bearing support spigot, 156.

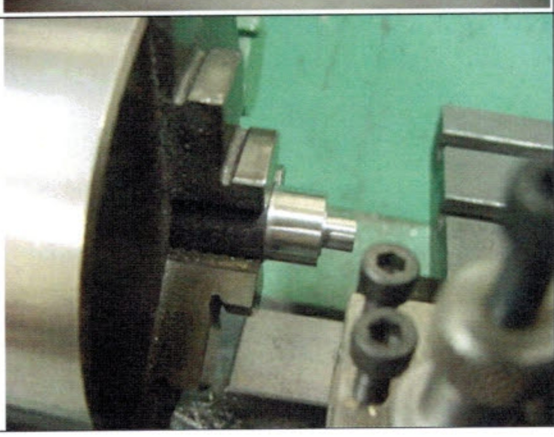
This is a tricky job as the hole is only 6mm and is located at the rear of the gearbox with little access to get a proper start. Do not try to use an ordinary drill – it will certainly wander off-centre and the gear clearance will be well out of tolerance.

One approach is to use a **spot drill** with a 120' point (see left). This has a short rigid shank and can accurately drill a centre even at some distance from the chuck where a centre drill is too short. It is not expensive and is a valuable tool for this sort of work. Use the drill to start the hole in the rear of the gearbox.

Once you have a hole, drill out to 5.9mm and finish with a 6mm reamer.

The second approach is more accurate but more expensive! Bore the hole by boring through using a miniature boring bar, like that at left. This way you are less dependant on getting the hole dead centre to start off.

Bore right to the 6mm dimension if you can measure it accurately, or stop just short and finish off with a 6mm reamer.

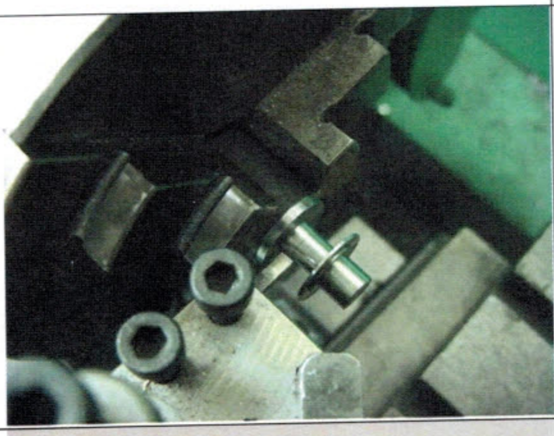


Bearing support spigot, 156.

The spigot is turned from 16mm high tensile steel En24t. Chuck with about 20mm overhang and turn the outside diameter to 15mm. Turn the bearing location to 7.05-7.1mm and then finish to a smooth sliding fit on the bearing. Use the bearing as a ring gauge to check the fit as you go. Whenever doing shafts to fit bearings you will find just polishing up normal machining marks or filing marks will remove 0.05mm.

If you have 0.1mm to come off, you will need to do a little gentle filing and then finish with oiled emery.

Bearing Support Spigot



To ensure concentricity, you need to machine the rear section of the spigot whilst the part is still in the chuck.

Use a parting tool or similar to get in, and machine the diameter to 6.05mm.

We now need to centre drill and drill through to 3.3mm for about 15mm, and tap M4.

When completed, part off to length.

Lightly hold the spigot in the chuck with the 6.05mm portion facing out and put on a small lead (slight chamfer) with a fine file, to enable it to be press-fitted into the gearbox rear without scoring the hole and jamming.

The finished part should appear like this (left).

It is intended to be a tight press-fit into the gearbox rear, as once fitted it does not need to come out again.

Offer the spigot up to the hole on the inside of the gearbox and insert an M4 countersunk screw from the back. The countersink will ensure the spigot is starts truly central and straight.

Tighten gently a couple of turns, to get the spigot started and then take out and replace the countersunk screw with the socket screw 193, using a couple of washers to prevent scoring the gearbox.

Tighten up and draw the spigot back into position until it rests flat on its rim. Confirm the spigot is fully home and remove the screw and apply locking compound to the threads, and refit the screw firmly.

Gear set.

The complete gear set is available ready to use, from Wren Turbines and consists of the following:

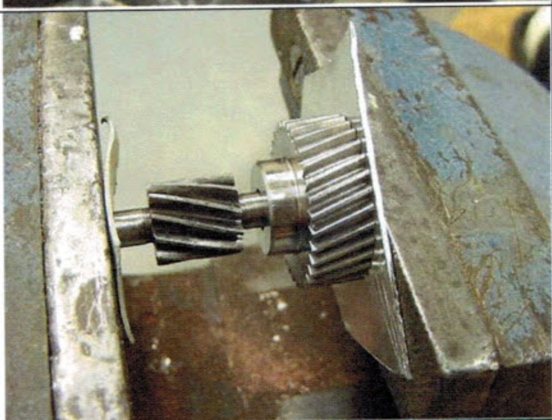
13t 0.8 Mod through hardened
32t 0.8 Mod, En24t
11t 1 Mod, through hardened
25t 1 Mod, En24t.

Assembling the intermediate shaft.

Intermediate Gears 171, 172.

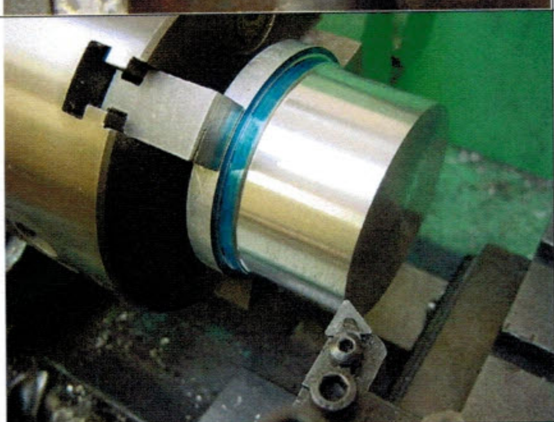
With the gear-set from Wren there is not much to do here apart from de-scaling the pinion gear – a stainless rotary wire brush works well. If your intermediate shaft comes in two pieces, they need pressing together to form a solid shaft. The fit is a tight interference fit and the two parts need accurate alignment first.

Turn a short stub 6mm diameter and about 8mm long, onto which you slide on the large gear of the pair, which should sit accurately centred. Place the pinion shaft (which is case hardened) to the hole at the outer end of the larger gear, with the centre-drilled portion facing out. Bring up your tailstock centre to accurately centre the shaft and press it home as far as you can with the tailstock handwheel.



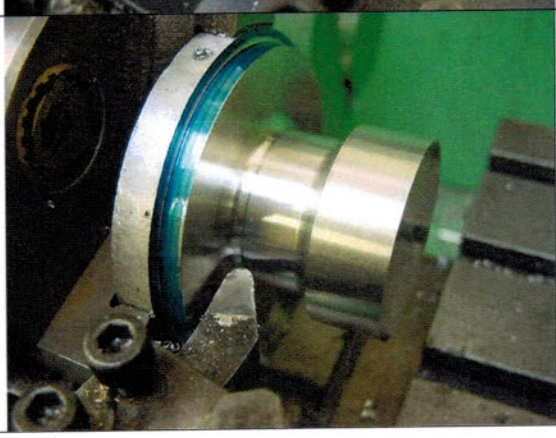
When you have got the pinion shaft well started in the larger gear, transfer the assembly to the bench vice. Use a couple of pieces of soft aluminium to protect the surfaces, and press the gear fully home being careful to ensure the gear is pressed centrally.

We had considered pinning the two together but they are so tight we decided it was highly unlikely they could ever loosen without shearing the gear faces first.

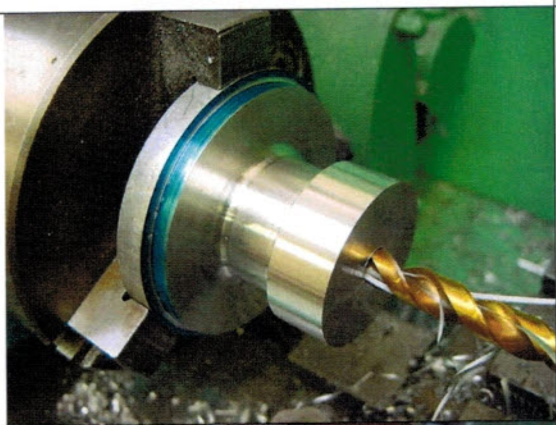
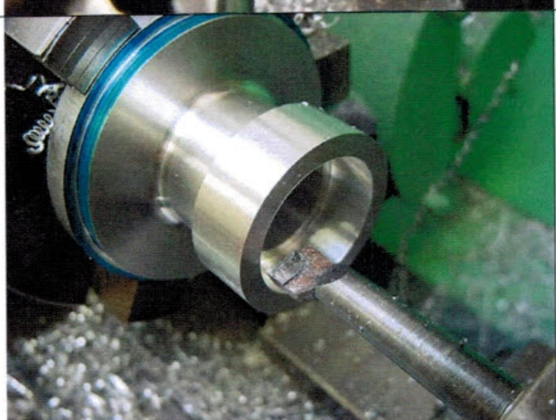
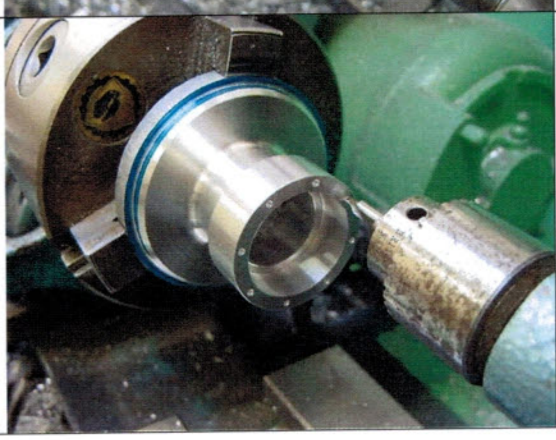


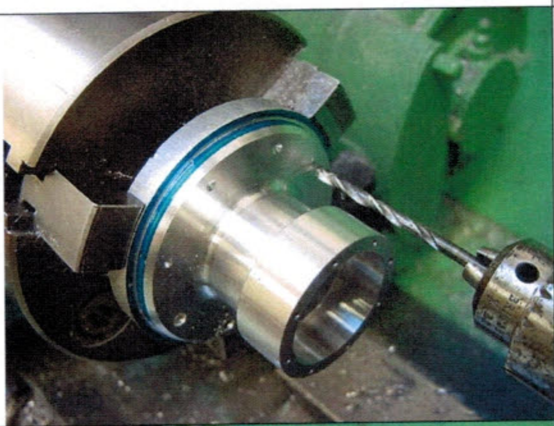
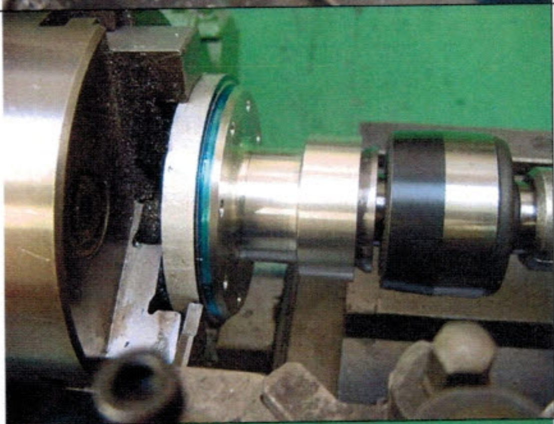
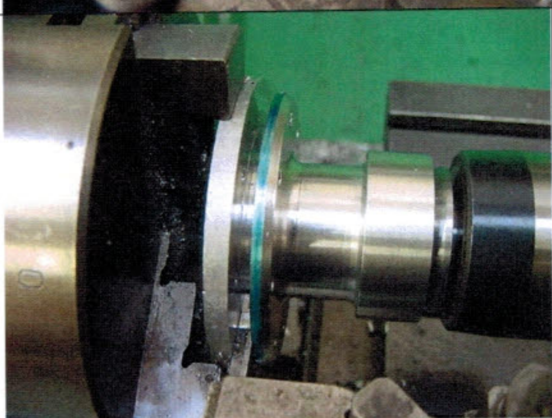
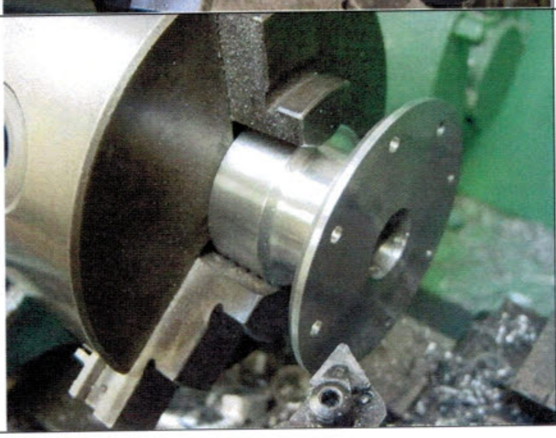
Prop-shaft housing, 158.

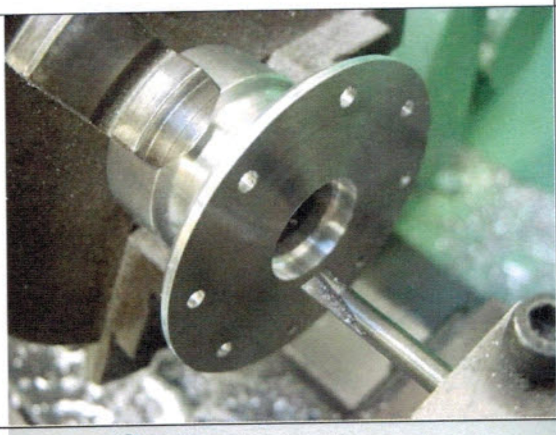
This is turned from a block of HE30 aluminium diameter 65 x 35mm long. Chuck and face off and turn the outside to 58mm diameter.



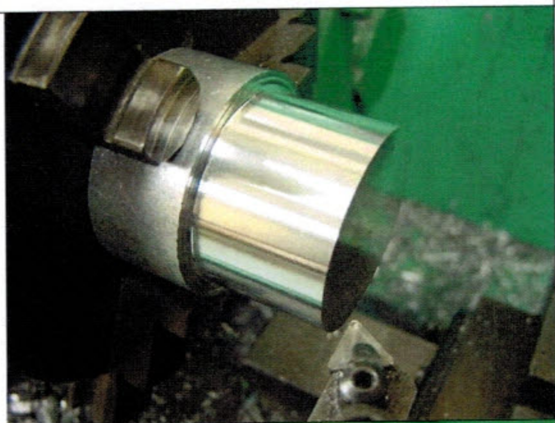
Using a round nose tool turn the profile to the drawing. Take small cuts as you get right into the corner to avoid chattering of the tool.

Propshaft Housing.	
	Centre and drill out to around 10mm diameter to start your boring tool off.
	Bore right through at 16mm diameter, and then machine the recess to a diameter of 23mm and a depth of 25mm.
	Bore the bearing seat at 28mm to be a sliding fit, and a depth of 10.5mm.
	Set up your indexing attachment to the lathe mandrel and fit your drilling spindle to the lathe saddle. The eight cowl fixing screw holes can now be centred and drilled 2mm diameter to 8mm deep, & tap M2.5 x 6mm deep.

Prop-shaft housing	
	At this point, the eight securing screw holes can also be centred and drilled 3mm diameter. Without disturbing any settings on the drilling spindle, remove the prop-shaft housing and fit the gearbox front cover to the chuck. The eight prop-shaft housing fixing holes can now be centred and drilled 2.5mm, and finally tapped M3. This ensures the holes are at the identical PCD to match the prop-shaft housing. You cannot get a drill bit into the fixing holes past the larger diameter front bearing section of the housing, and this is an easy way to ensure they match up.
	Re-fit the prop-shaft housing to the chuck, and using support from the tail-stock, set up a parting tool positioned to cut just over the required thickness. Bring the job out of the jaws slightly if required, to get in close enough and to avoid fouling the chuck jaws. For supporting these larger-than-normal hole sizes, I made an oversize 60' cone to fit onto the normal tail-stock rotating centre – very useful! If your blank is not long enough to allow for parting off, then reverse the jaws and hold the other way round in the chuck – see below.
	Using the parting tool, carefully part off the housing. Use plenty of paraffin for this job and firm but steady feed on a low speed.
	Once parted, re-chuck the housing on the bearing end, and grip lightly in the 3-jaw. Face off to length cleanly using small cuts. Check to ensure the job is running well-centred and if necessary use scraps of paper to offset to get true centre. If you cannot get the job running with the hole dead centre then substitute your 4-jaw independent chuck as we need to bore for the rear bearing.

Prop-shaft housing, boring the rear bearing, 179.	
	Once running true, bore out for the prop-shaft rear bearing. Aim for a firm or hand press fit this time, as the bearing does not require to be sliding in service, once fitted. As before, use a bearing on a stick as a bore gauge.
	The eight cowl securing screw holes can also now be tapped M2.5 x 6mm deep.
	**Propshaft housing, clearance for bearing journal.** The intermediate shaft, front bearing requires a small relief in the prop-shaft housing to ensure the centre journal of the bearing runs free. I made a firm centre-pop and used a 9mm drill bit to make a recess about 0.5mm deep – enough to clear the bearing centre. If you have a milling machine, a neater job could be made with a 10mm slot drill, 1mm depth is enough. Once the recess is completed, the bearing can be secured using "Bearing Lock" – a "Loctite" variant for securing bearings. De-grease bearing and hole, apply a few drops around the housing and slide the bearing into place ensuring none gets into the bearing. Leave to set.
	The completed prop-shaft housing loosely fitted to the gearbox front cover. One of the rear bearings can just be seen down the centre, this helps ensure the concentricity of the housing to the front cover.

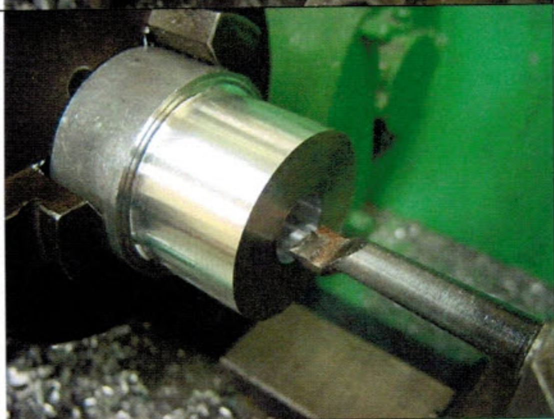
Turbine Shaft Tunnel.



Shaft Tunnel, 145.

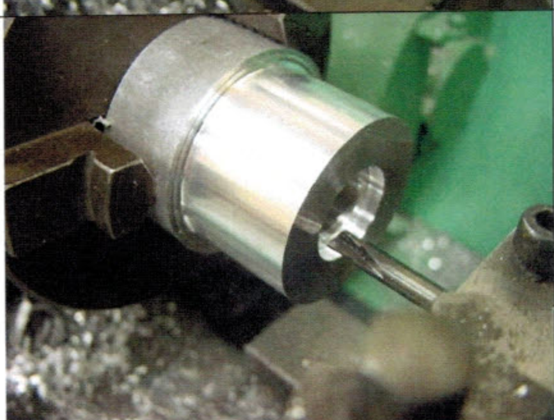
Start by chucking the 45 diameter by 45 long HE30 blank.

Face the end and turn the outside to a diameter of 38mm as far as you can.



Centre and drill right through to 13mm.

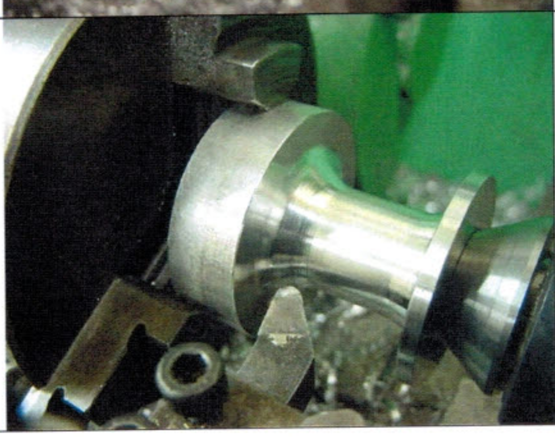
Fit a long boring bar and bore out to a clean finish and 14mm internal diameter – be careful not to run into the chuck.



Fit a small boring tool and bore out for the bearing housing, 19mm diameter and 3.35mm deep.

Bore until you get a firm sliding fit, ie without slackness but not binding on the 19mm bearing otherwise the pre-load will not work – use the bearing as a bore gauge as before.

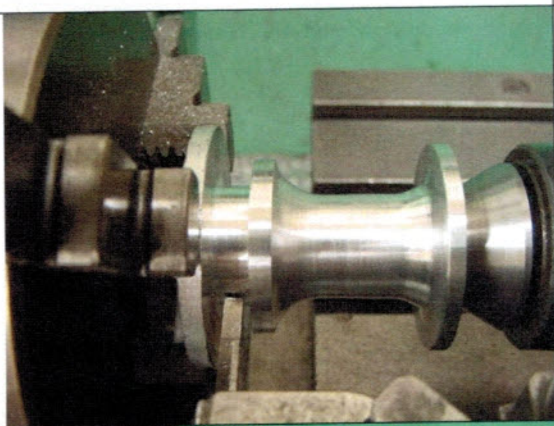
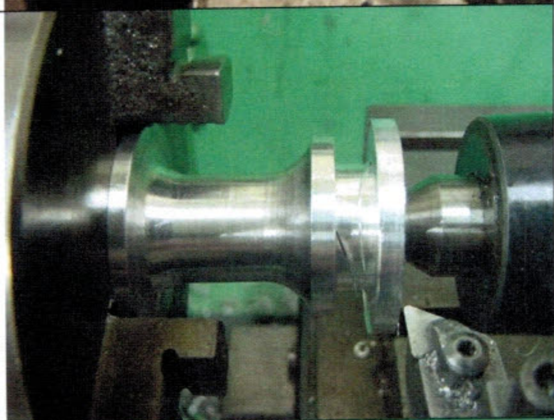
Remember this bearing has a pre-load spring to keep it under tension.



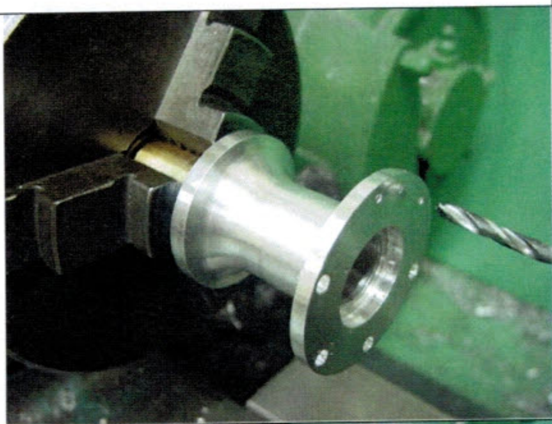
Slide the shaft tunnel out slightly and bring up your tail-stock for support.

Use a round-nose tool to turn the external profile shown.

Machine the inside face of the mounting flange leaving a gentle radius.

Shaft Tunnel, 145	
	Once the profile is completed, use a parting tool or square end tool to turn the spigot for the spider casting.
	Reverse the shaft tunnel in the chuck, holding gently. Bring up the tail-stock to accurately centre on the 14mm bore and machine off the excess material to bring the shaft tunnel end that locates in the spider down to 22mm diameter.
	Square off the mounting boss if it is not already so, and check that the overall length from the gearbox mounting face is exactly 34.5mm. Most likely it will be a little over – this can now be machined off to bring it to length.
	Using a small boring tool, and taking small cuts, carefully bore out for the rear bearing. Don't forget the size includes extra for the tolerance ring.

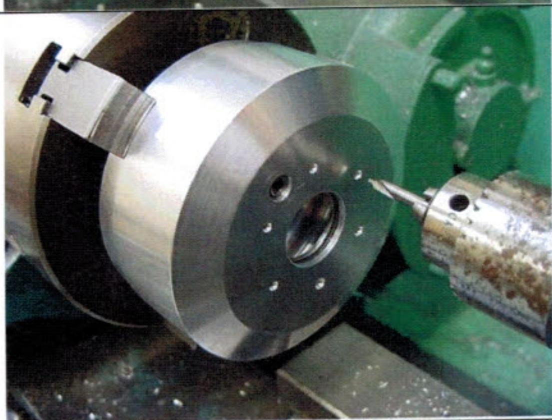
Shaft tunnel – drilling for the securing screws.



We now need to drill the shaft tunnel mounting holes. The shaft tunnel can be gripped directly in the 3-jaw but needs to be accurately centred. I had a mandrel from brass which I had used before and therefore I used this.

If you wish, you can machine up a mandrel from brass or mild steel. There should be at least about 30mm protruding from the chuck and around 14mm diameter, the shaft tunnel should be a firm push fit onto it.

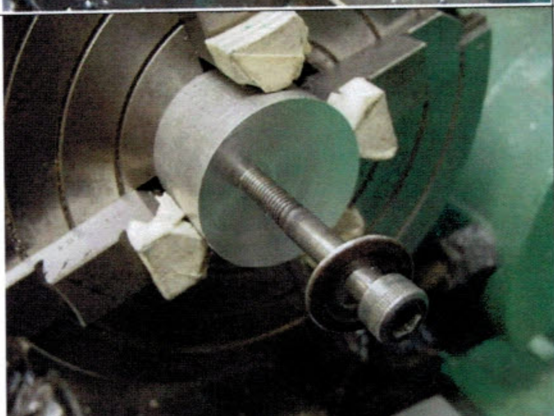
Once centred accurately, the six shaft tunnel mounting holes can be centred and drilled 3mm diameter.



To ensure the shaft tunnel fixing screws match up to the gearbox accurately, leave the drilling spindle in position and fit the gearbox to the chuck.

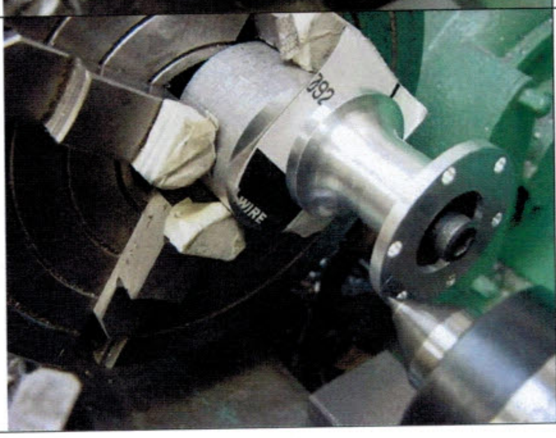
The fixing holes can now be drilled in the gearbox rear at precisely the same PCD as the shaft tunnel – ensuring the two will line up correctly.

Stagger the hole placement so they are equally spaced either side of the intermediate stub shaft securing screw.



We now need to turn our attention to the cut-out for the intermediate shaft securing screw. This can be simply filed using a round file but a better job can be made if it is turned or milled. If you have access to a milling machine, then simply secure the tunnel down with a suitable bolt and run a slot drill into the edge at the correct position.

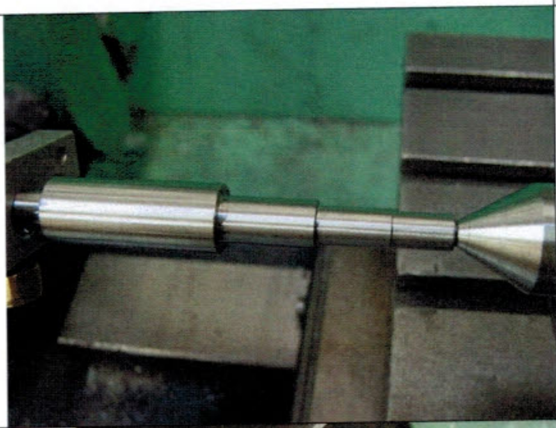
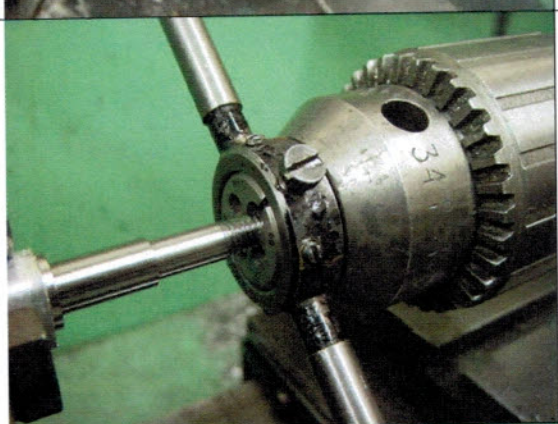
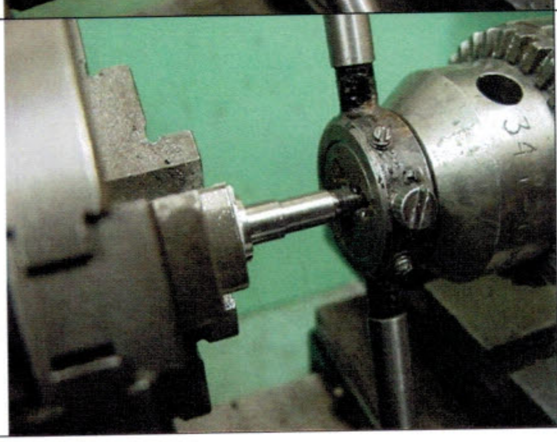
If like me you do not have a miller then make a simple off-set mandrel like this at left. It is a piece of aluminium with a 6mm tapped hole drilled well off-centre. This is mounted in the four jaw to enable it to be set off-centre to the correct amount.

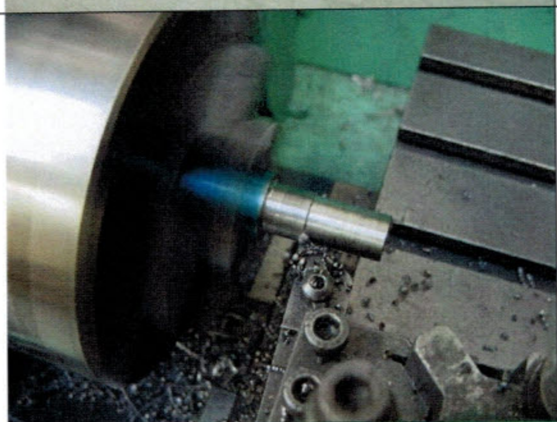
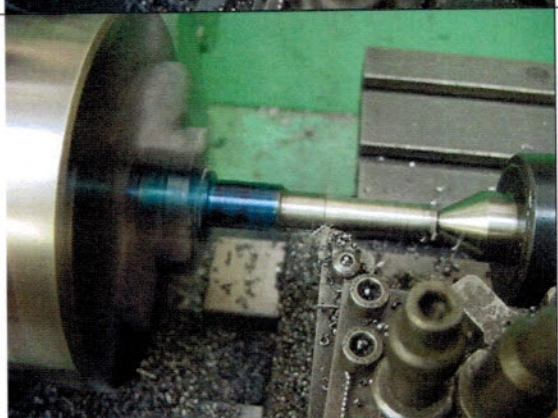


The shaft tunnel is bolted to the fixture using a piece of card as a packing piece between the tunnel and the block, which will help ensure it is not marked and stops it slipping, bearing in mind it will be an interrupted cut.

Bring up the tail-stock centre to align the pointer against the edge where the recess is required and jiggle the jaw positions until the pointer is located exactly in place.

Shaft Tunnel, Turbine Shaft 146.	
	Use a small boring tool and take small cuts until you have made a recess right through. Open out the cut-out to the desired radius (4.2mm) gently. Once done, use a de-burring tool to remove the sharp edges.
	The finished recess, nesting neatly around the screw.
	**Turbine Shaft, 146.** This shaft is made from En24t high tensile steel, and carries the power turbine at one end and the high-speed pinion at the other. It is supported between two bearings. It must be made very precisely if it is to run at high speed without run-out or vibration. Do not substitute any other material or attempt to harden this shaft. Start by chucking the material and facing and turning to length. Centre the ends and rough out the main body of the shaft to just over 12mm diameter and then each section is turned oversize by about 0.3mm.
	Once all sections are roughed out, set up between centres and drive using a lathe driving-dog. Use a narrow tool, which can get in easily and reduce each diameter in turn down to about 0.01mm oversize and the exact length required. Work the lengths from the end to the largest diameter end to next largest diameter and so on. Finally remove the last trace and polish up a little, by using a bit of fine emery paper and a little oil. Use the bearing as ring gauges to check the fits – aim for a firm sliding fit. Use a fine file to take the sharp corners of each change of diameter and put on a small lead for the bearings.

Turbine Shaft.	
	Leave the turbine journal oversize by 0.01mm or so in order that you can work the fit after you have bored the wheel. The turning is largely completed, only the threaded portions to deal with.
	I found it easiest to grip the shaft with the 3-jaw with protection from a wrap of 1mm soft aluminium sheet. Use a file to put a lead on to help the die start the thread cleanly. Use a good quality cutting compound and preferably turn the chuck by hand.
	Thread the turbine end using an M6 die and stock, with support and regular pressure from the tail-stock. You can of course, screw-cut the thread and finish with a thread chaser or die if you prefer.
	Cut the thread on the other end for the pinion retaining nut 196, this time a 5mm die and stock used.

Turbine Shaft, Propshaft, 163.	
	The shaft finished, apart from the slightly oversize turbine journal.
	**Prop-shaft, 163.** The prop-shaft carries all the torque generated from the power unit and is made from En24t steel. It needs to be tough so do not substitute anything else. Follow a similar procedure to the turbine shaft, machining from 16mm x 100 bar from the materials pack. Machine to length, face and centre ends etc.
	Use support from the tail-stock centre if required for roughing out. I find blueing the shaft with marking blue helps to make it clear which section I am working on and where I am going. I also make regular use of a saddle stop, each journal length being set by butting the lathe stop and making fine adjustments with the top-slide. This is simply a threaded rod screwed into the saddle and butting up against the gearbox side. This enables you to concentrate on getting a good finish and the right diameter without the fear of over-cutting on the lengths or hitting the chuck with the tool.
	Once roughed out and turned to close on size, finish the bearing journals with the file and emery treatment. Do not wrap emery paper around the shaft to polish – it can suddenly grab and could take your fingers with it. As you get near to size put on a small lead (chamfer) at the edge of the bearing journal to help ease the bearing on without jamming. Keep checking the fit using the bearings as ring gauges as before. Aim for firm sliding fits.

Prop-shaft.

Turn the taper for the prop driver by off-setting the top-slide to the 8^0 required. We need this angle later for boring the matching prop driver, so see if you can find a way to reset to exactly this angle when required.

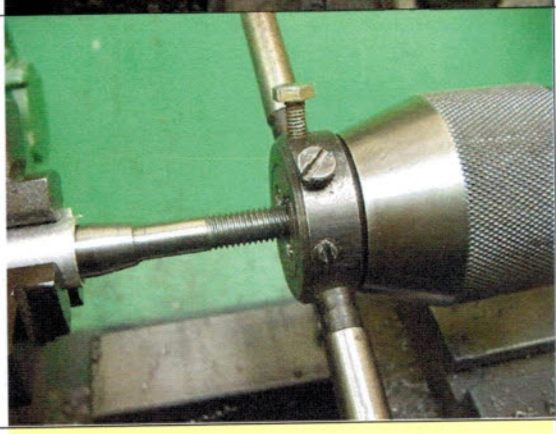
Watch to ensure you leave the correct 8mm distance between the thick section and the start of the taper.

Aim for a fine finish on the taper, but <u>do not</u> file or polish as this may round off the corners and cause easy slipping.

To cut the prop retaining thread, screw cutting can be used to start the thread off if you wish.

Otherwise set up the M8 x 1.25 die and stock as before.

Use tapping compound to help ensure clean threads.



Use a support to ensure the die-stock is held dead square to the shaft – if it runs off at an angle the shaft is scrap and after all this work it is a pain (yes, I've done it!). I use my tail-stock drill chuck with the jaws retracted to help support the die – you probably have your own system.

Finish the thread to size and check with an M8 nut to ensure the threads are clean. Drill the end of the shaft 3.3mm to a depth of 10mm and thread M4 to 8mm. This is for the spinner nut retention bolt, which is an M4 x 25mm socket screw.

The shaft is ready for securing the drive gear.

Left: the prop-shaft with bearings fitted to check fits.

Securing the drive gear, 173.

We need to secure the driving gear to the end of the propshaft, to prevent it turning in either direction, and I depart from conventional wisdom here, in that I neither use a screw-thread, splined shaft or key-way.

I considered the screw-thread but this would require a fixture for holding the gear to cut the thread and would still be able to unscrew in extreme situations. Splines and keyways are not practical to do at home, so I present my solution.

Securing the driver gear, Oil Thrower, 166.

Start by removing and cleaning the two bearings and refit them firmly into place with a drop of "Bearing Lock", a low strength locking compound.

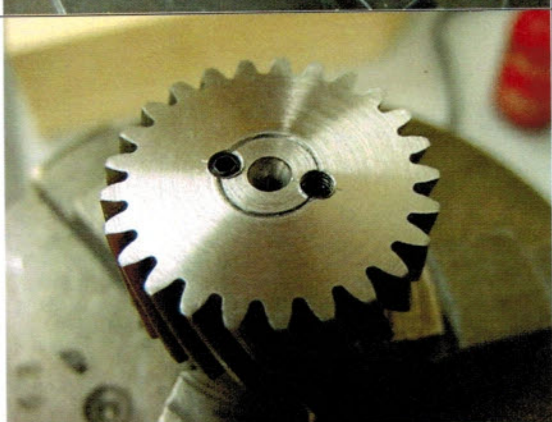
Use a high strength retainer compound on the gear seat and press the gear firmly into place being careful not to get any into the bearings. Allow time for this to go off before moving to the next stage.

Hold the prop-shaft in the 3-jaw chuck and mark a scribed line across the centre and a few millimetres beyond. A lathe tool set accurately at centre height does this easily.

Centre-punch firmly, the line at the junction of the shaft to gear.

Use a small centre drill to open the centre punch out to a proper drilled hole.

Follow this with a 2.5mm drill, and drill to a depth of 8mm.



Thread the two holes M3, to full depth.

Fit a pair of M3 x 6mm hard steel grub-screws, use a drop of screw locking compound and screw fully home (below the surface of the gear face).

This fixing has been used on both prototype turbo-props and has worked well.

Oil Thrower, 166.
This item is turned from En24t steel with a slight relief in one face. It is fitted between the small pinion gear and bearing 175. Its purpose is to prevent oil being forced through the bearing as it is squeezed along by the action of the helical gears. The relief forms a channel where oil is deflected away gently whilst still allowing a small amount on the bearing for normal lubrication.

Chuck the remainder of the bar used for 142 and 156, face off and turn to 14mm diameter. Centre and drill out to 6.5mm and bore to 7mm for a snug fit on the bearing journal. Use a round nose tool to turn the relief to a depth of 0.5mm and then part off carefully to length. Remove internal burrs carefully, and rub on emery to ensure flatness.

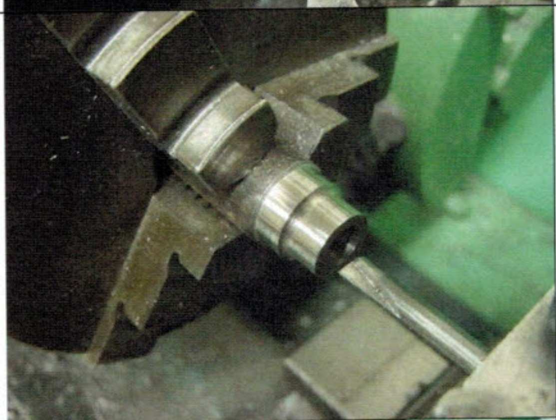
Turbine Collar, 142. Power Turbine Nut, 140.

Turbine Collar, 142.

The Collar acts as a spacer between the power turbine and the rear bearing. It is proportioned to lengthen the heat conduction path to preserve our precious bearing.

Make from same bar as part 156. Machine from 16mm diameter En24t bar and faced, centred and drilled 7.5mm. The outside is turned to shape – I used a round-nose tool to put a nice radius on and to get the diameters required.

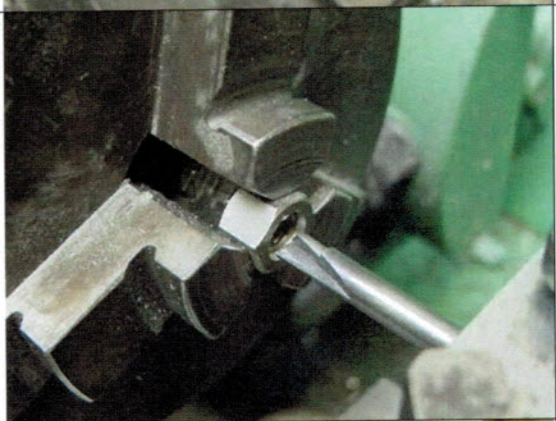
What is important is that the internal bore is a close fit and the two end faces are perfectly square.



The collar is bored using a small boring tool to a close fit on the 8mm section of the power-turbine shaft.

Note the bearing will almost certainly be less than 8mm, 7.994mm is typical so do not just put a reamer through – it will be too loose! Aim for a firm, but sliding fit.

Once done, part off to just over length. Reverse in the chuck and check it is running accurately, and face off the collar to correct length, and a neat finish. If your chuck runs out, make up a brass mandrel and press fit the collar on to turn to length.

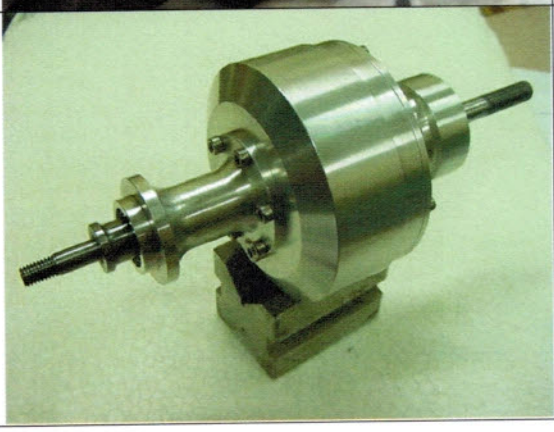


Power turbine nut, 140.

The turbine nut, is simply turned from the short length of 10mm A/F stainless hexagonal bar – don't substitute steel as this can jam on the shaft.

Face off each end and turn to 6mm long overall. Centre the end and drill through 5mm. Thread M6 x 1, right hand – hold the tap in the tailstock to ensure it is dead square.

The recess can be turned using a small boring tool to the 1.5mm deep dimension. Whilst in the lathe, the corners of the nut can lightly chamfered – be careful to keep clear of the chuck.



How does it look?

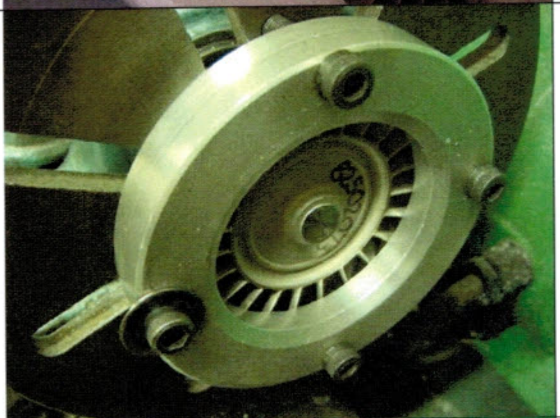
This is a good point to assemble all the components you have completed and see how your project is coming along, and check the fits of the components.

Boring the Power Turbine.

Power Turbine, 141.

This is available as a precision casting from Wren turbines. It is cast in Inconel 713c to full aerospace specification. It is nominally 72mm diameter and has 23 blades and has a balance ring cast into each face.

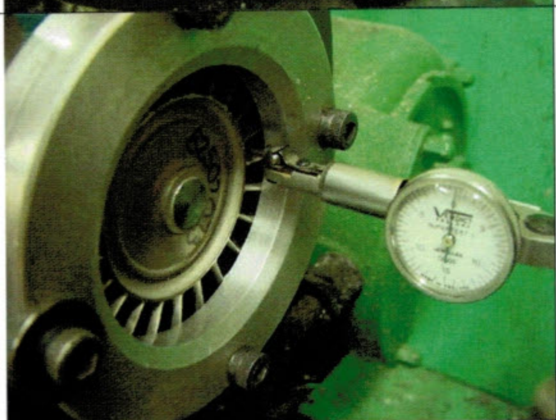
The blade profile is optimised to generate high torque on its shaft with minimal residual thrust. The blade shape is quite different from a thrust turbine and it is specially made for this duty. It is rated at 65,000rpm maximum. Each turbine has its own unique serial number and comes with a matching test certificate.



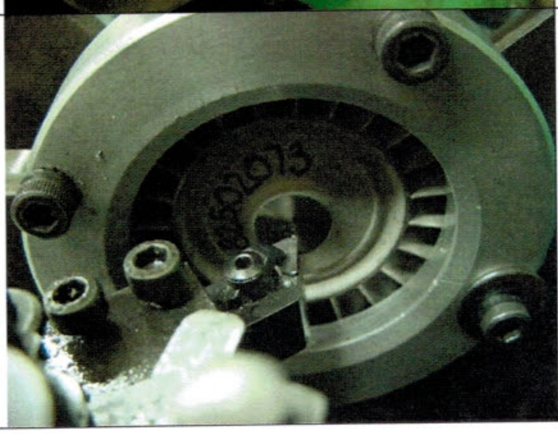
Boring the power turbine.

If you have bought your power turbine unbored, you will need to bore it and grind the outside diameter before you can mount it to your shaft and the turbine housing. You need a fixture like the one to the left. It is an aluminium block with a machined recess for the turbine to sit into. The block is secured with four M5 screws, inserted through the rear of the faceplate.

To retain the turbine, an aluminium ring with four M6 fixing bolts screwed into the faceplate, pulls it gently into the recess in the back and holding it secure on the wreath. Drilling pressure is therefore taken on the rim of the wreath and not the blades.



Use a dial gauge with a probe-type stylus to centre the turbine blade root. Note, do not try to centre on the inner rim of the blades as this can vary slightly and you will end up with an off-centre and wobbly turbine.



Once centred and secured, angle a turning tool to face off the centre boss and to leave a central depression to help start a centre drill dead in the middle.

The turbine material is Inconel 713c and you will see it is not particularly hard but is mighty tough! High speed steel will not last long here and solid carbide tools are "de-rigour".

Boring the Power Turbine.

To drill the centre hole you ideally need a short, solid carbide stub drill of around 6mm diameter. Cobalt drills will do one good hole but if they hit a hard spot they give up half way through, leaving you in a pickle!

The drill on the right is a straight 2-flute solid carbide "Roc-drill", intended for drilling HSS so is pretty good!

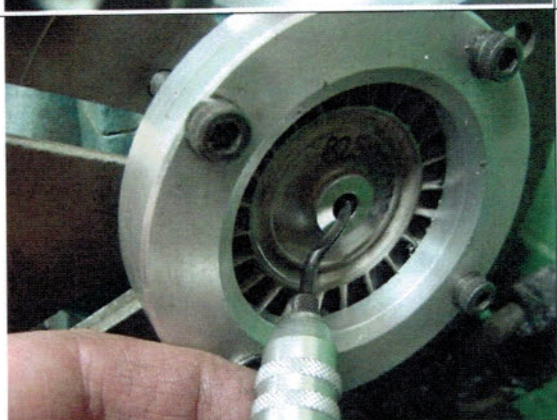
The one on the left is a 3-flute solid carbide intended for hardened steel and "exotics", so is also ideal.

Both will do the job well, but the 2-flute is about half the price – about £15 or just over 20 Dollars US. Consult a decent tool catalogue and look for drills intended for hardened steel and nickel chromium alloys.

Use a brand new centre drill to just start the hole – do not go in more than 1mm or so, as it may break off the tip in the hole.

Use very low speed (80-100rpm or so) in the lathe and get everything rigid. Line up the drill and use cutting oil and very firm pressure and try to keep going all the way through without stopping. Do not relax the feed or the cutting edges will rub and dull them. Ease slightly when you feel the point breaking through. Wear safety glasses as these drills can shatter without warning.

Once through, follow up with a small carbide boring tool and carefully bore out to 6.35mm in small steps. Leave the bore a fraction too tight for the shaft.



There will be a sharp edge to the bore, and a hand-held de-burring tool is ideal to get rid of this.

Do not use a countersink or centre drill as they both leave another burr inside the bore and prevent the shaft going in. A boring tool set at an angle works if fine cuts are taken.

Once done reverse the turbine in the fixture and face the boss on the other side, de-burr as before.

Oil the shaft with a little light oil and check the fit on the shaft. We want it to be a close sliding fit. This means going on without slackness or wobble.

To help it, make a honing tool from a wooden tapered plug with a saw-cut down the middle. Place some fine emery in the slot and wind it round the plug.