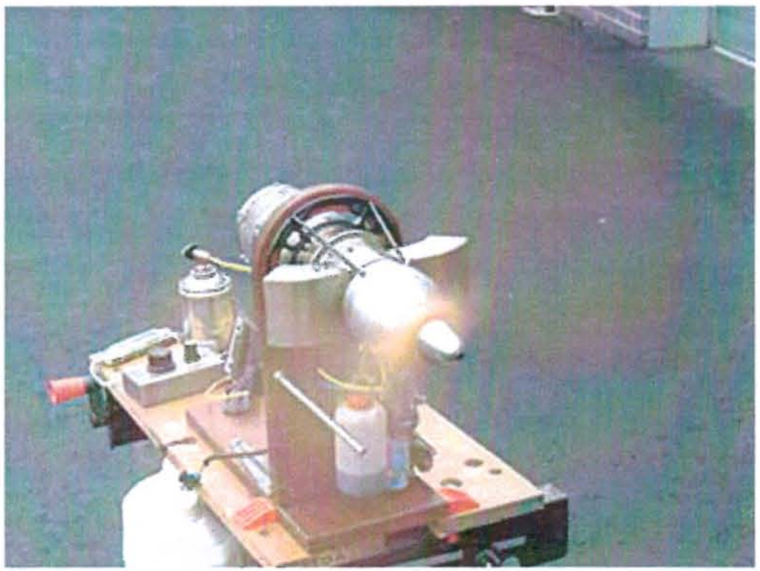
WREN

Turbines Ltd.

NEW

MW54 Turbo-Prop Drawing Set



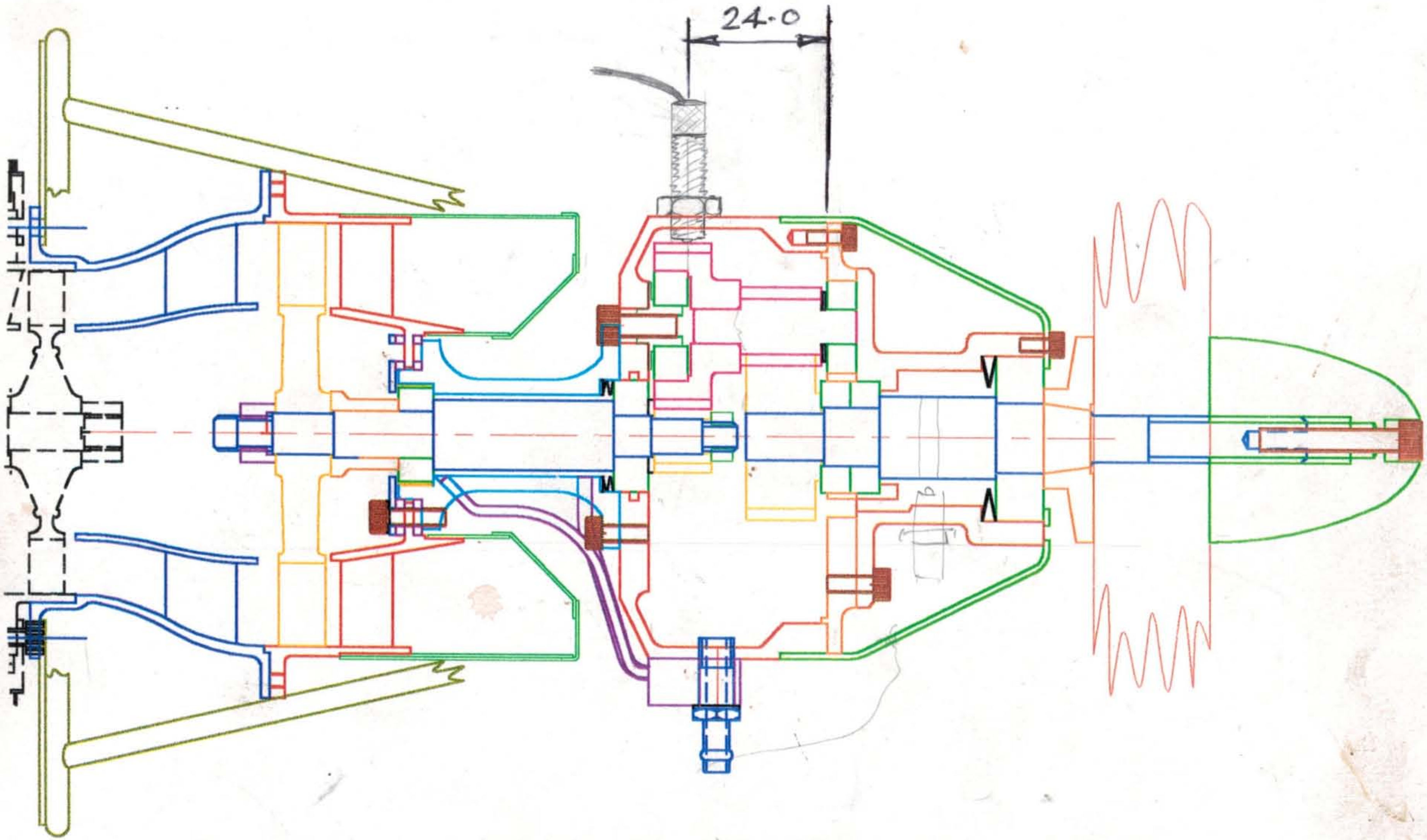
Fully Dimensioned and Detailed Plans

Item No	Description	No Off	Issue	Manufacturer	Remarks
128	Exhaust inner	1			
129	Overlap plate	1			
130	Exhaust outer	1			
131	Exhaust front	1			
132	Exhaust cone	1			
133	Exhaust stack rear	2			
134	Exhaust stack top/bottom	4			
135	Exhaust stack front	2			
136	Exhaust wadding	1			
137	Mounting lug	4			
138	Wadding retainer	1			
139	Locking wire	250 mm			
140	Turbine nut	1			
141	Power turbine	1			
142	Collar	1			
143	Clamp ring	1			
144	Gasket	2*			
145	Tunnel	1			
146	Turbine shaft	1			
147	Shaft lube sub assy	1			
148	Manifold	1			
149	Air pipe	1			
150	Lube pipe	1			
151	Oil drain fitting	1			

Issue: 1	**Item List Turbo Prop Sht.2**

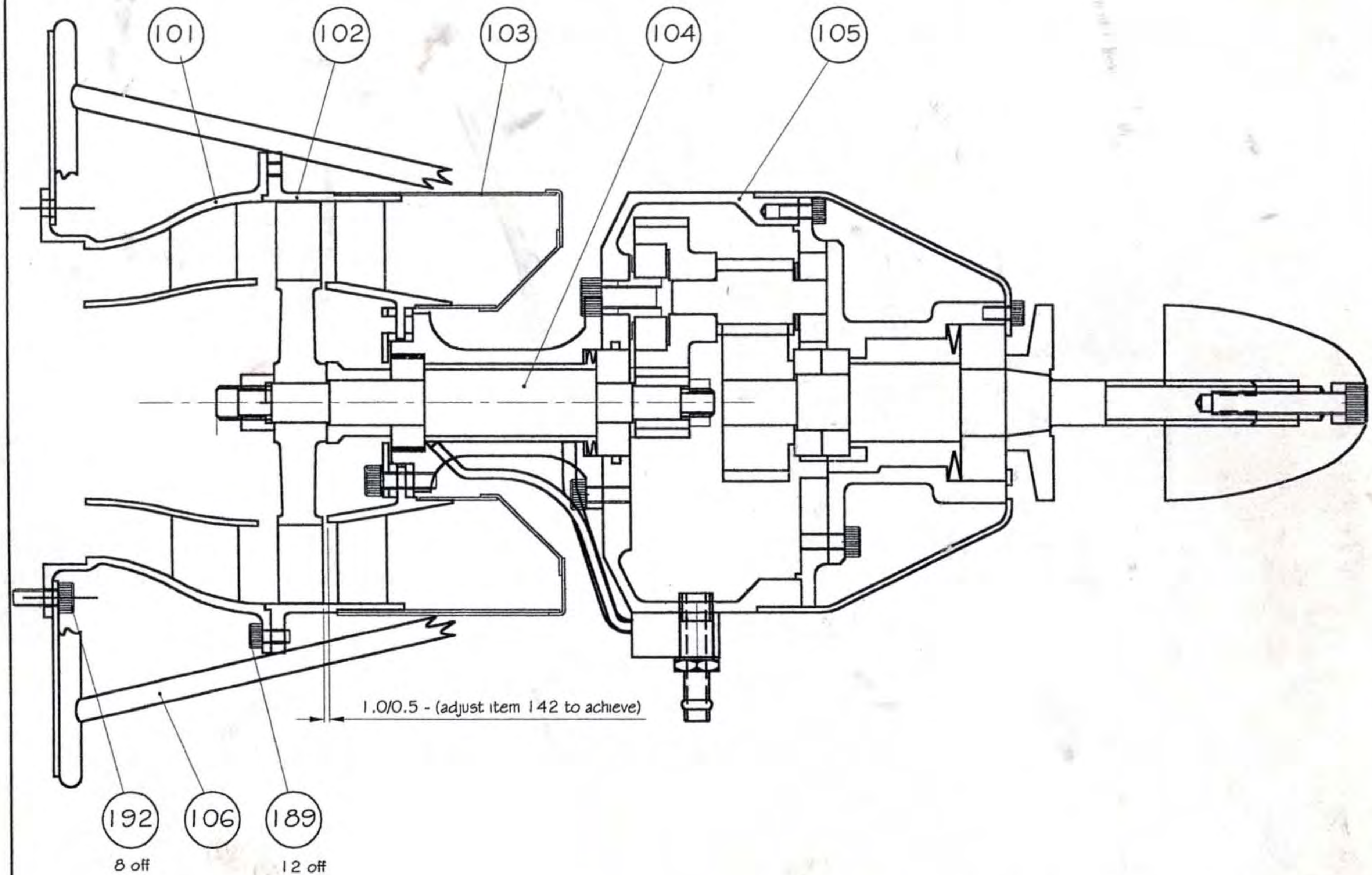
Item No	Description	No Off	Issue	Manufacturer	Remarks
155	Gear case	1			
156	Bearing support spigot	1			
157	Gearbox front	1			
158	Propshaft housing	1			
159	Cowl	1			
160	Prop driver	1			
161	Spinner nut	1			
162	Prop shaft sub assy	1			
163	Prop shaft	1			
164	Gear lube sub assy	1			
165	Bearing retainer	1			
166	Oil thrower	1			
167	Fibre washer - 6 dia.	1			
168	Locknut - M5	1			
169	Gear set	1			
170	Gear 1	1			
171	Gear 2	1			
172	Gear 3	1			
173	Gear 4	1			
174	Bearing ceramic 688	1			
175	Bearing - special	1			
176	Bearing	1			
177	Bearing	1			
178	Bearing	1			
179	Bearing	2			
180	Shim	1*			
181	Spring washer	1			
182	Tolerance ring	1			

Item No	Description	No Off	Issue	Manufacturer	Remarks
183	Wavy washer	(4)			To suit
184	'K' slotted spring	2			
185	Washer - 3 dia.	4			
186	'O' ring	1			
187	'O' ring	1			
188	Dowel pin	1			
189	Cap screw M2.5 x 5	20			
190	Cap screw M2.5 x 6	12			
191	Cap screw M3 x 10	6			
192	Cap screw M3 x 8	26			
193	Cap screw M4 x 10	1			
194	Cap screw M4 x 25	1			
195	Grub screw M3 x 6	2			
196	Nut M5 (high tensile)	1			
198	Domed nut M3	4			
199	Star washer 3 dia.	6			



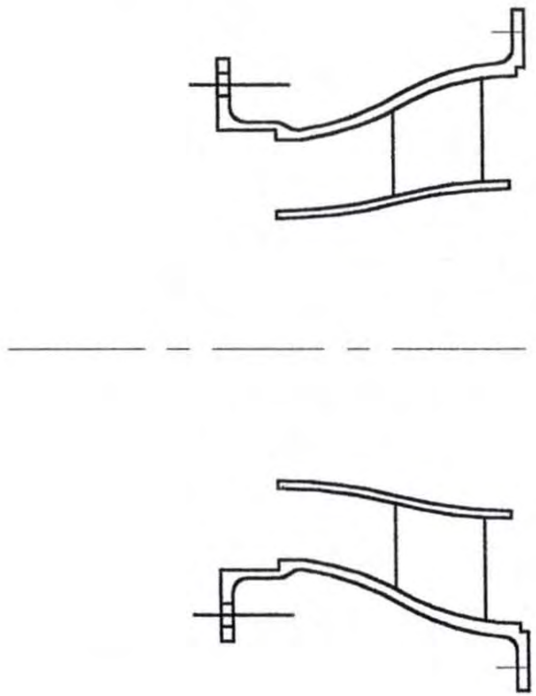
MW 54 TURBOPROP

Dimensions in Millimeters



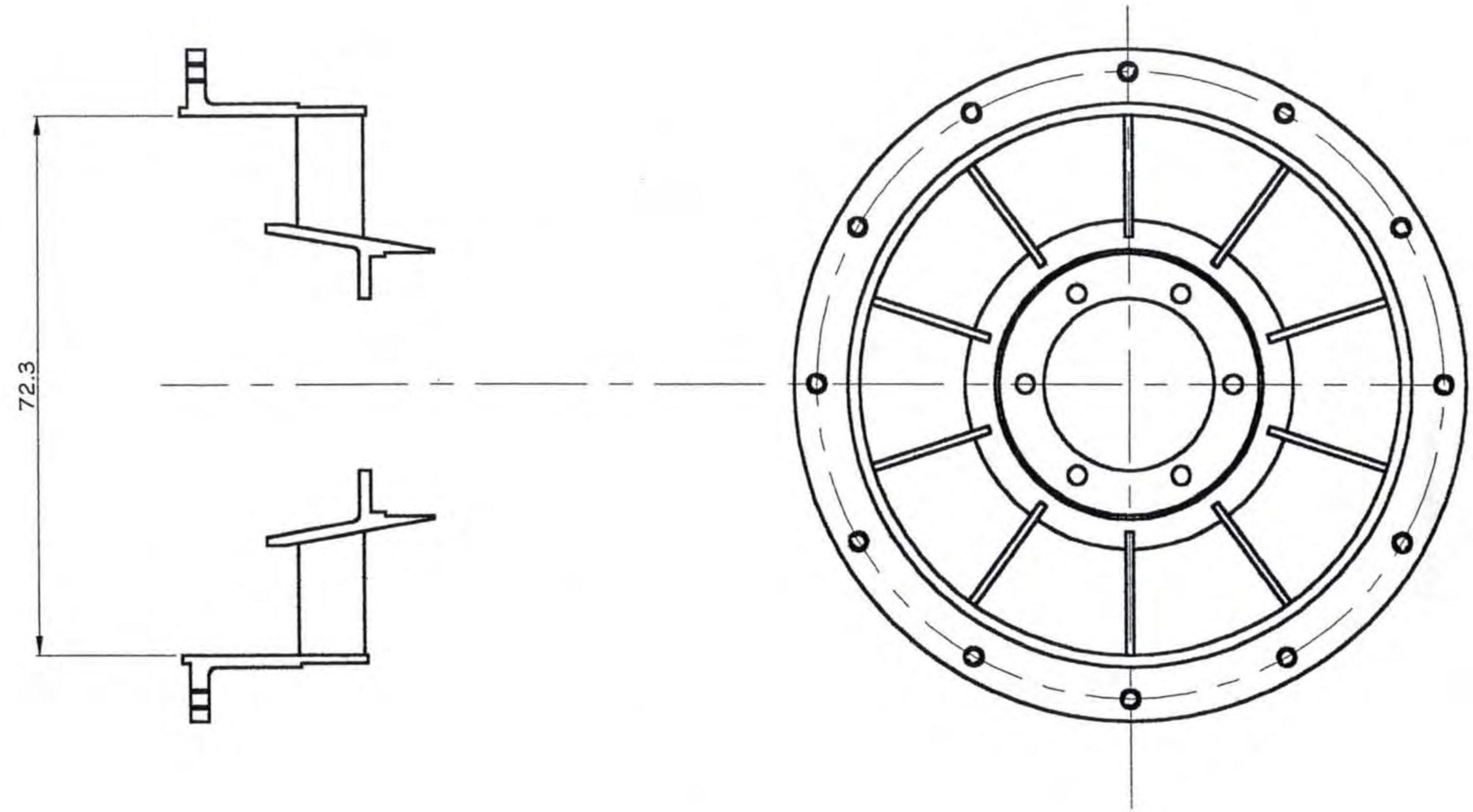
Designed by: Mike Murphy				Material: As details		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: General Arrangement	Issue: 1	Part No. 100

Dimensions in Millimeters



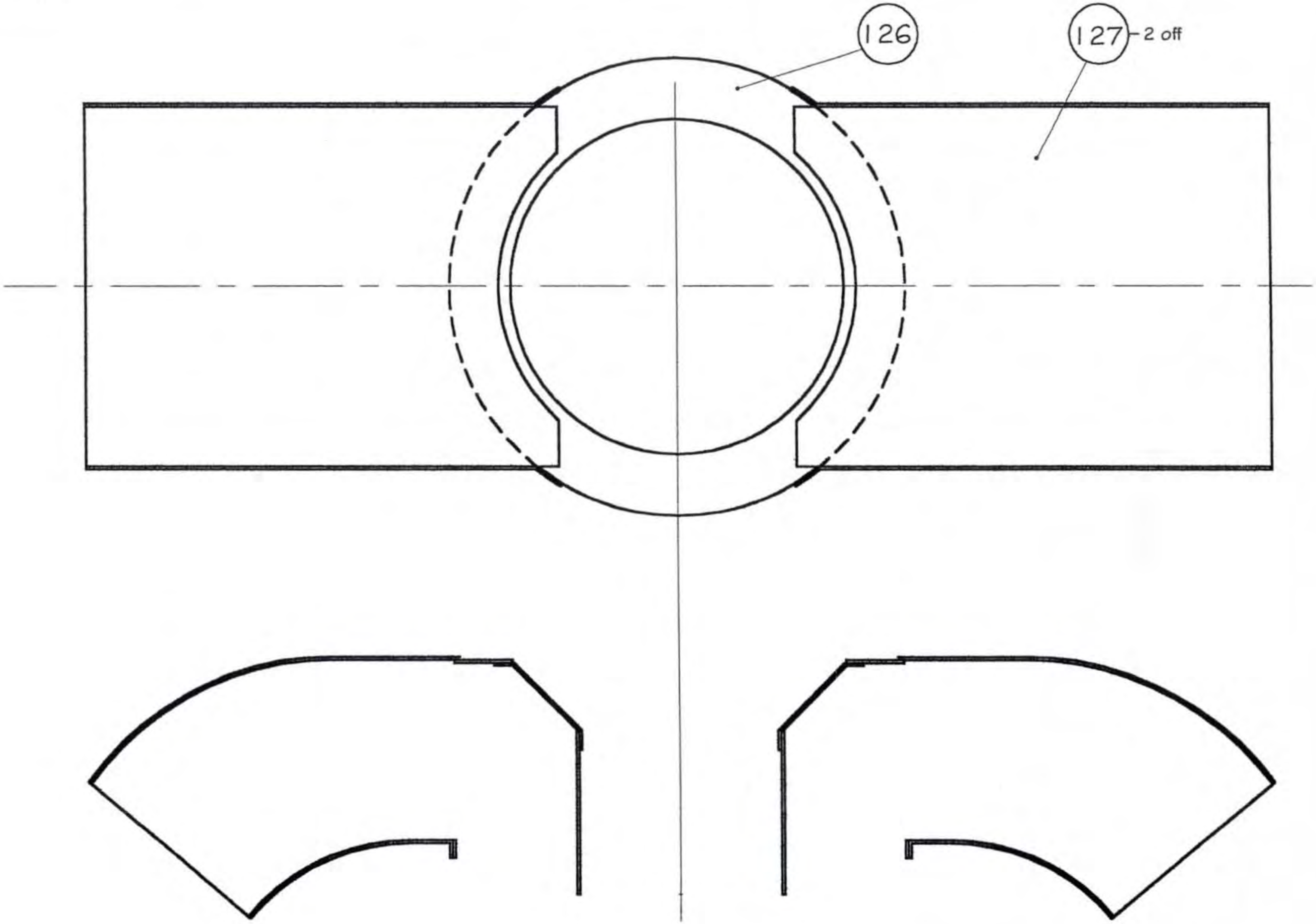
Designed by: Mike Murphy				Material: High nickel steel		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Interstage NGV (cast)	Issue: 1	Part No. 101

Dimensions in Millimeters



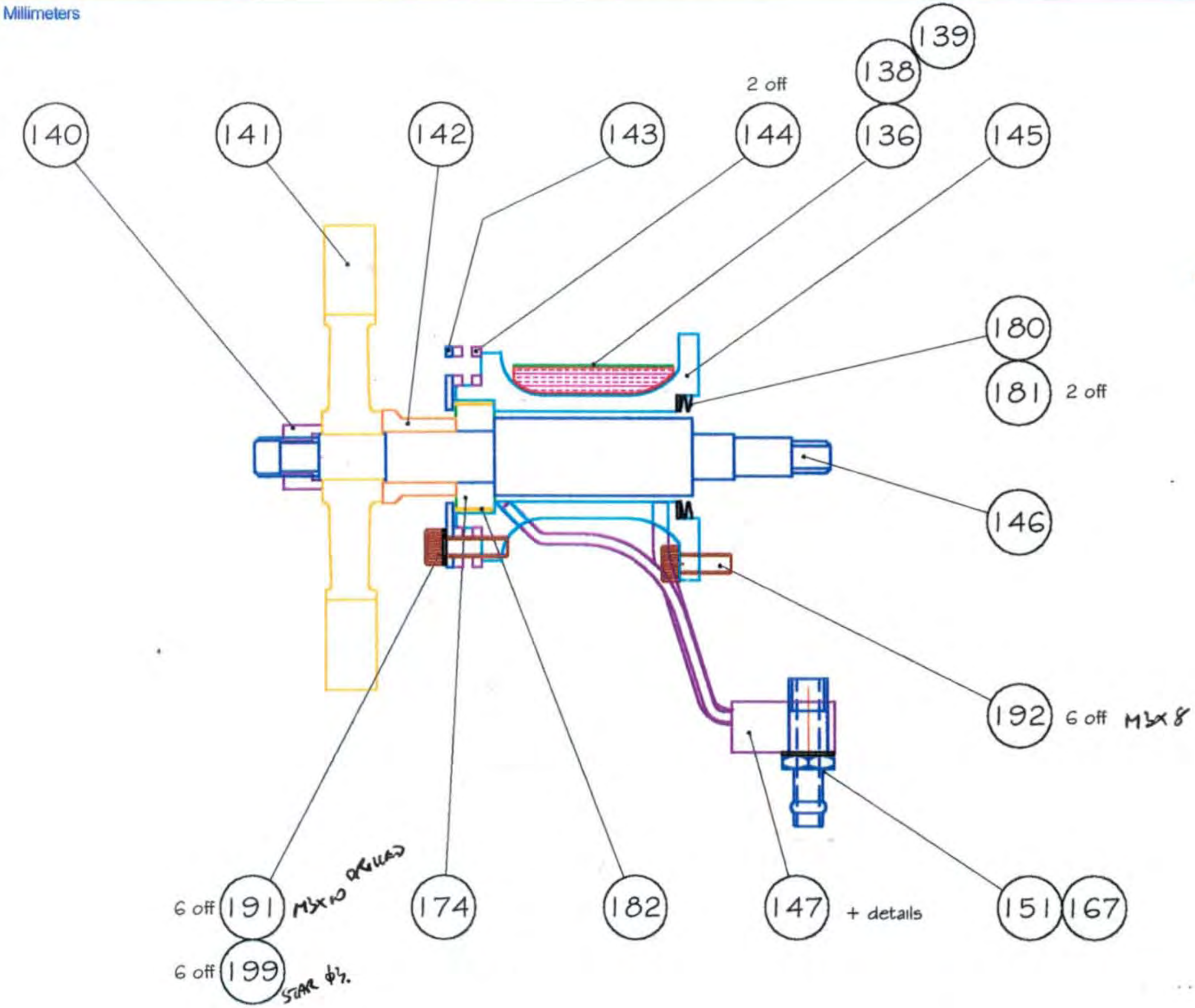
Designed by: Mike Murphy				Material: As details	
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Spider (Outline)	Issue: 1	Part No. 102

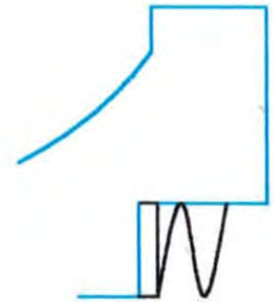
Dimensions in Millimeters



Designed by: Mike Murphy				Material: As details		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Assy	Issue: 1	Part No. 103

Dimensions in Millimeters





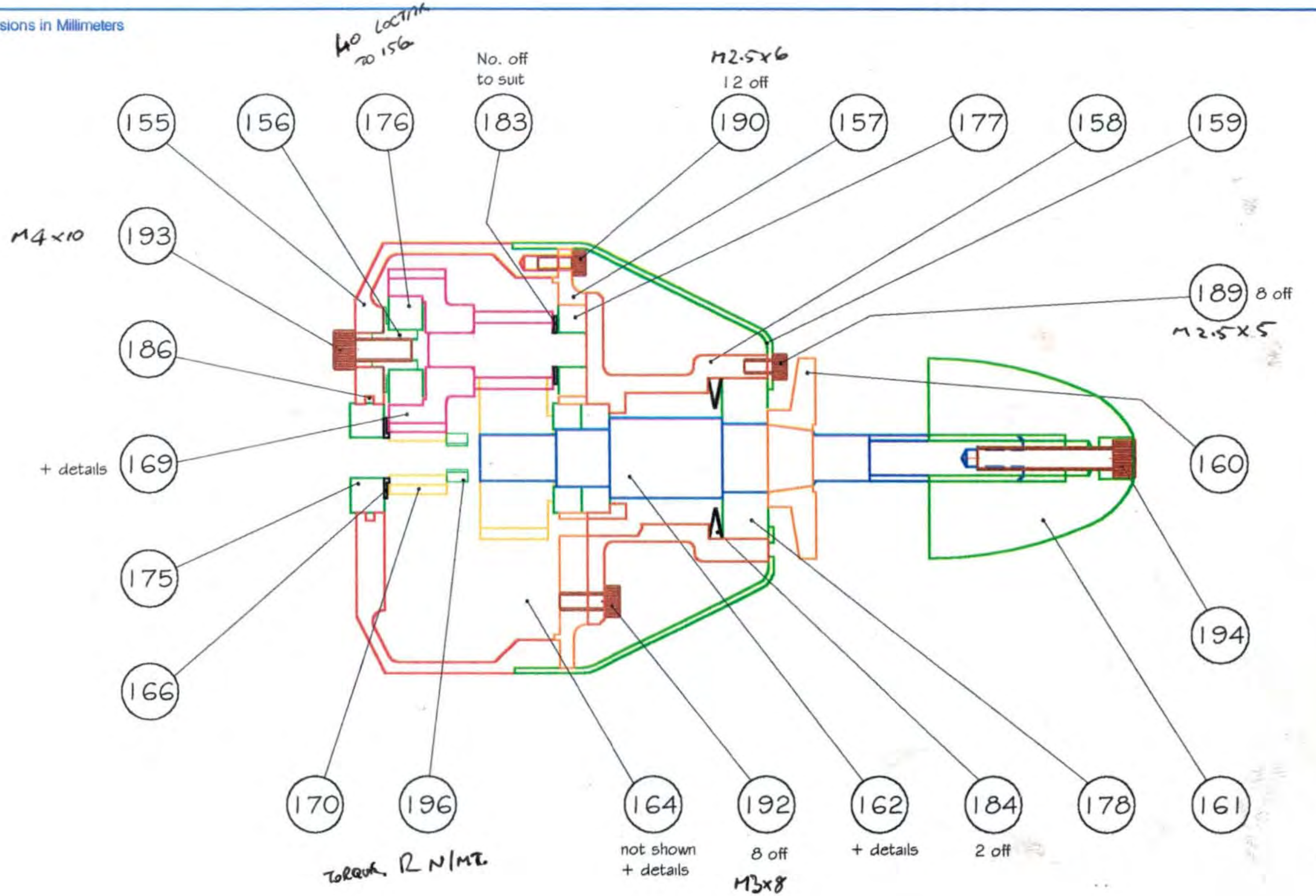
Enlarged view showing orientation of shims

Designed by: Mike Murphy				Material: As details
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Shaft sub assembly

Issue: 1

Part No. 104

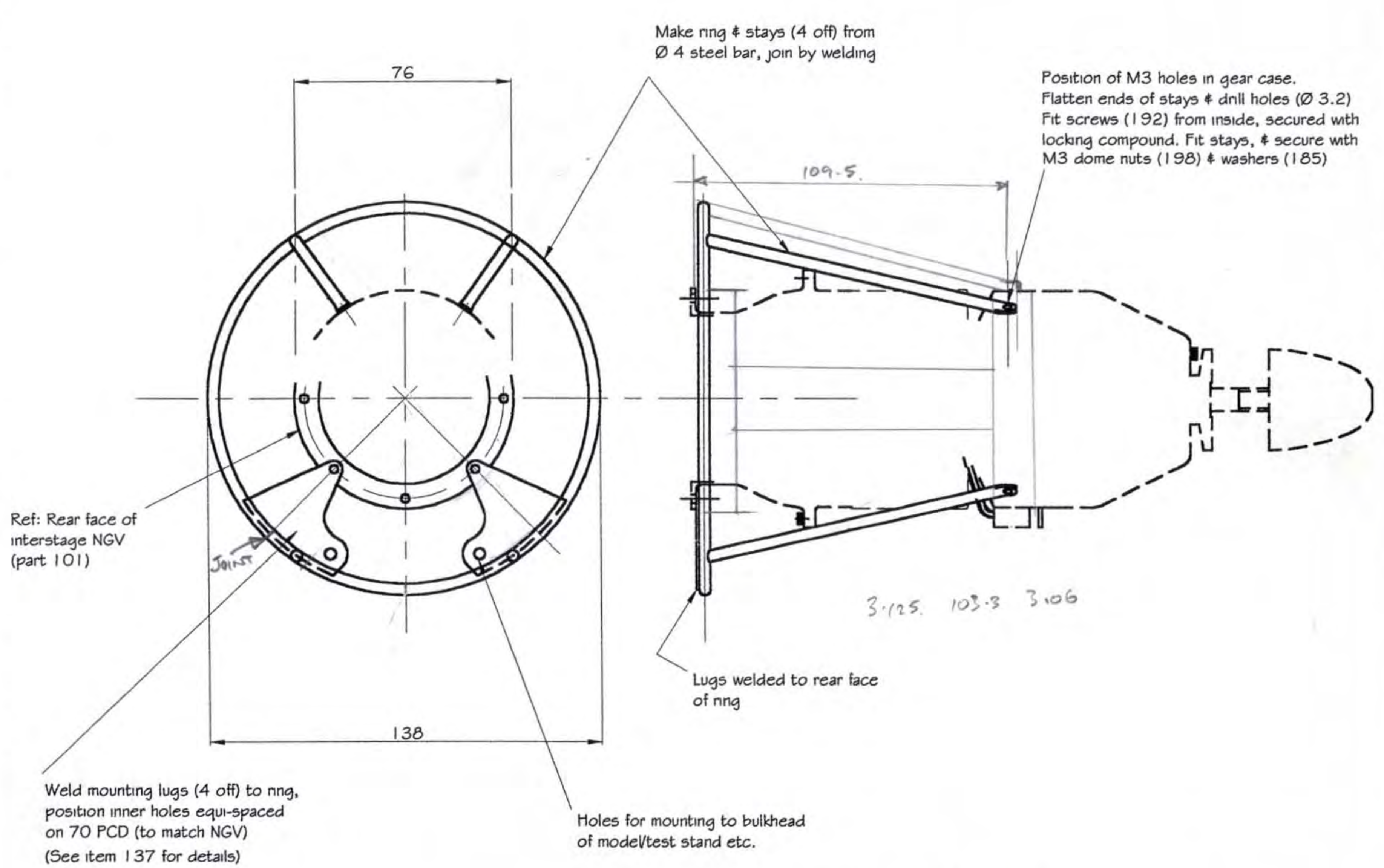
Dimensions in Millimeters



Designed by: Mike Murphy				Material: As details
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Gearbox Sub assy

Issue: 1 | Part No. 105

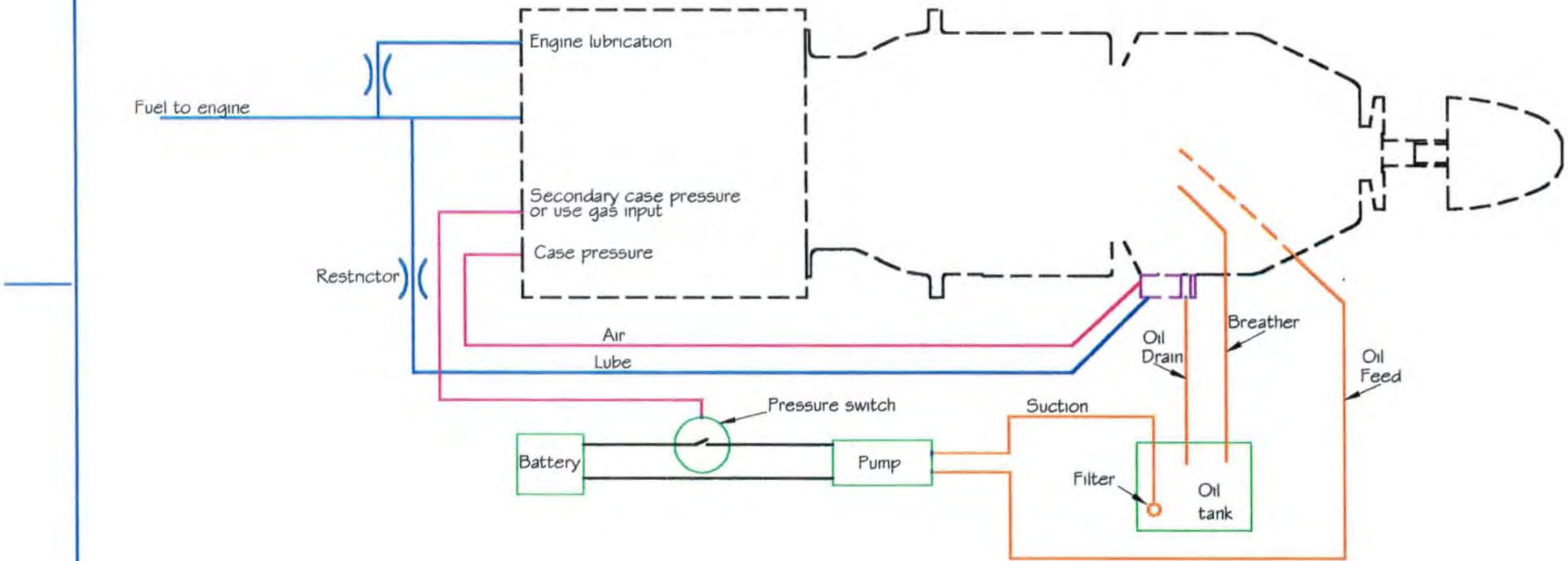
Dimensions in Millimeters



Scale: Half size

Designed by: Mike Murphy				Material: As shown		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Engine mount - radial	Issue: 1	Part No. 106

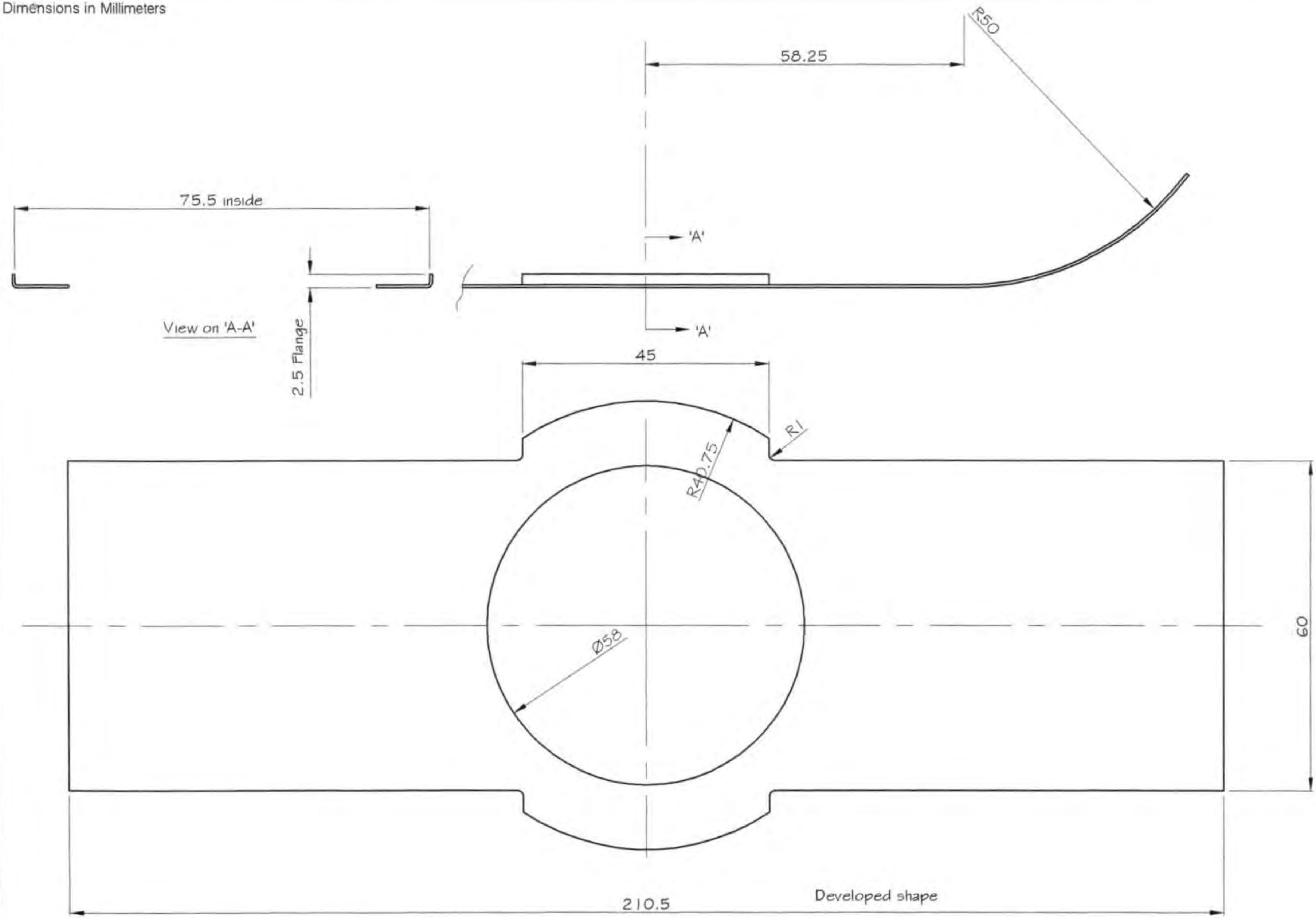
Dimensions in Millimeters



Designed by: Mike Murphy				
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	

Material:		
Title: Lubrication schematic	Issue: 1	Part No. 107

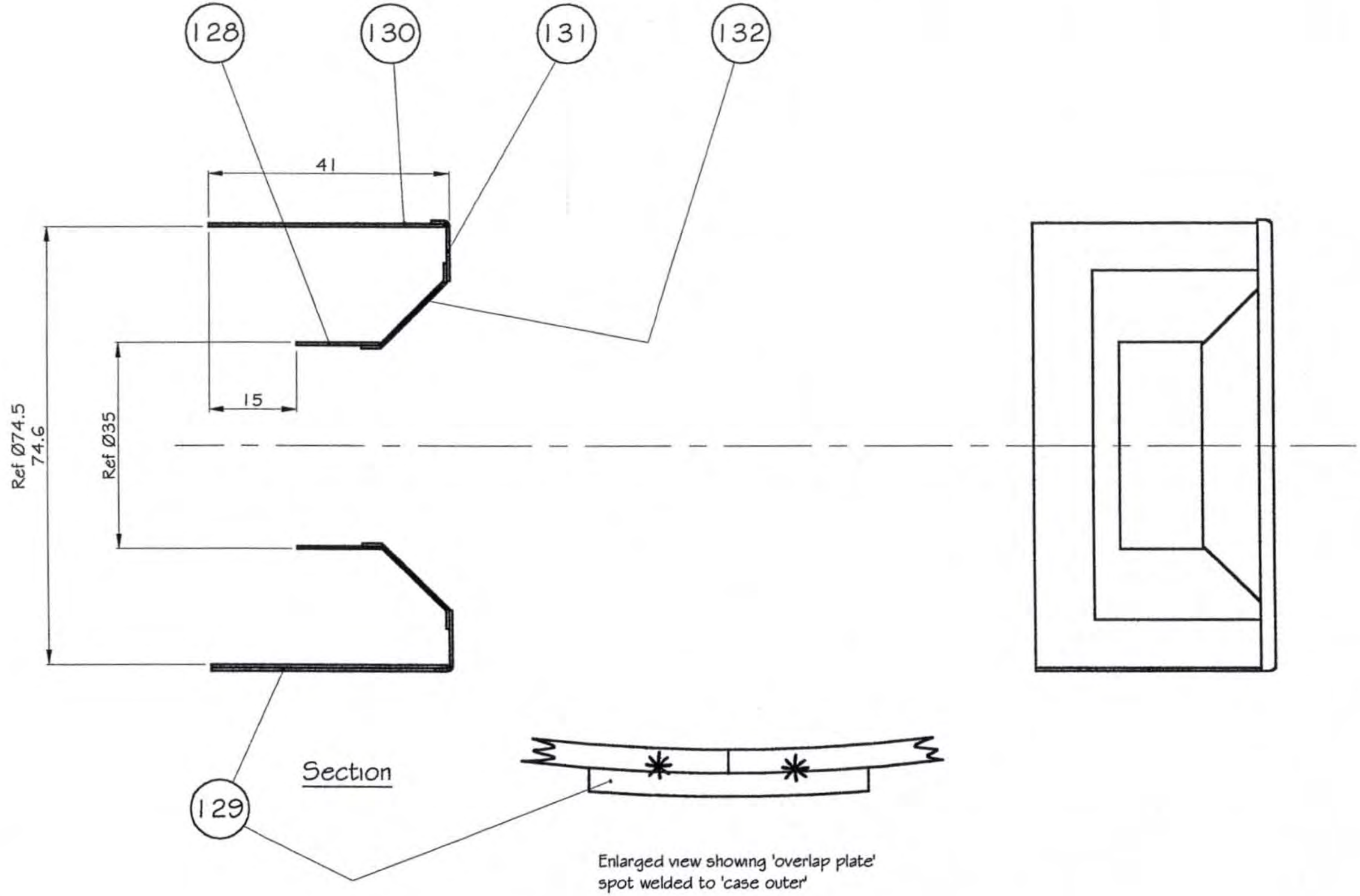
Dimensions in Millimeters



NOTE: This item replaces items 131 & 135

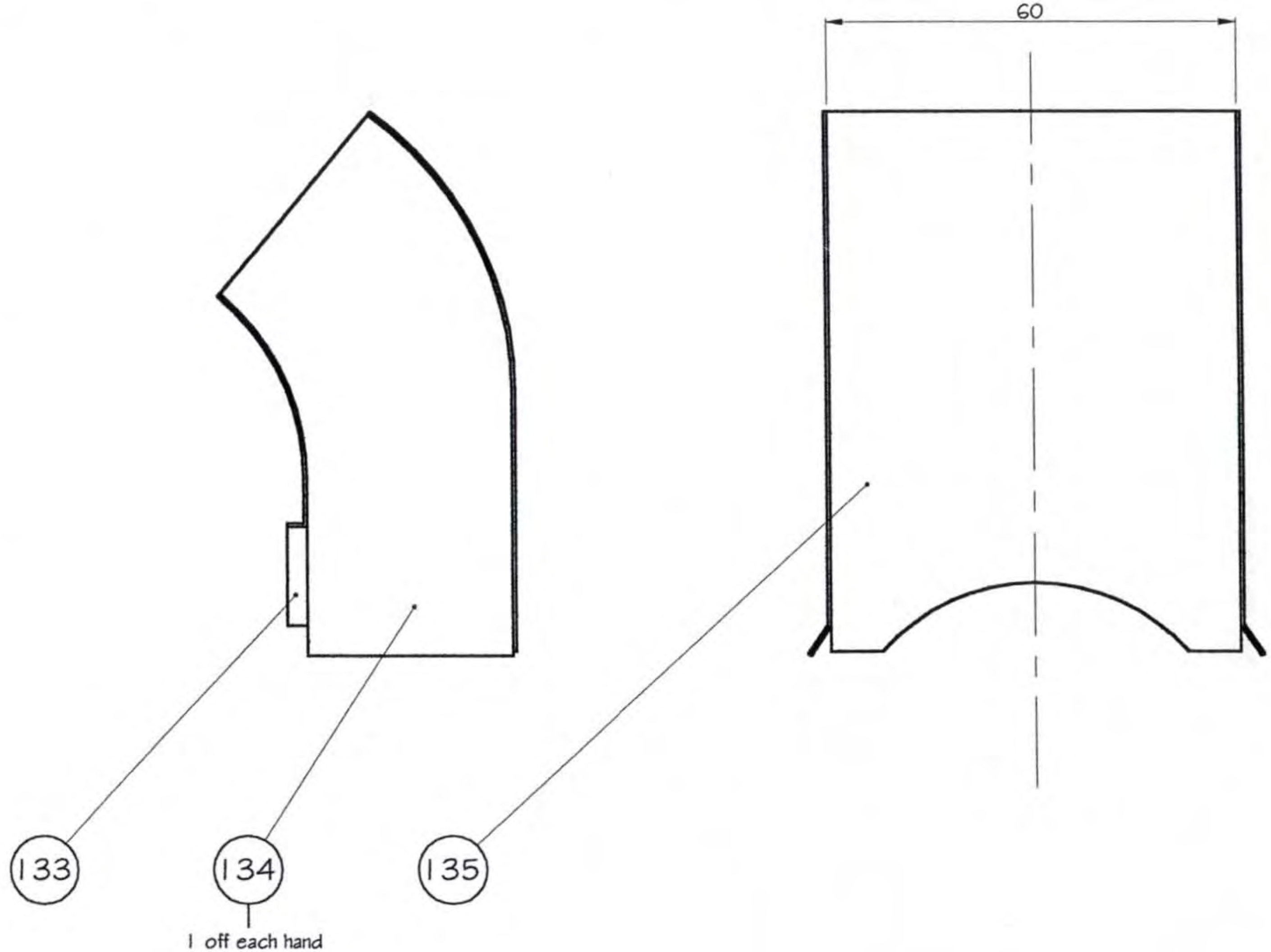
Designed by: Mike Murphy		Material: Stainless Steel Sheet - .5 thick		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	Title: Exhaust 1 piece Front	Issue: 1	Part No. 125

Dimensions in Millimeters



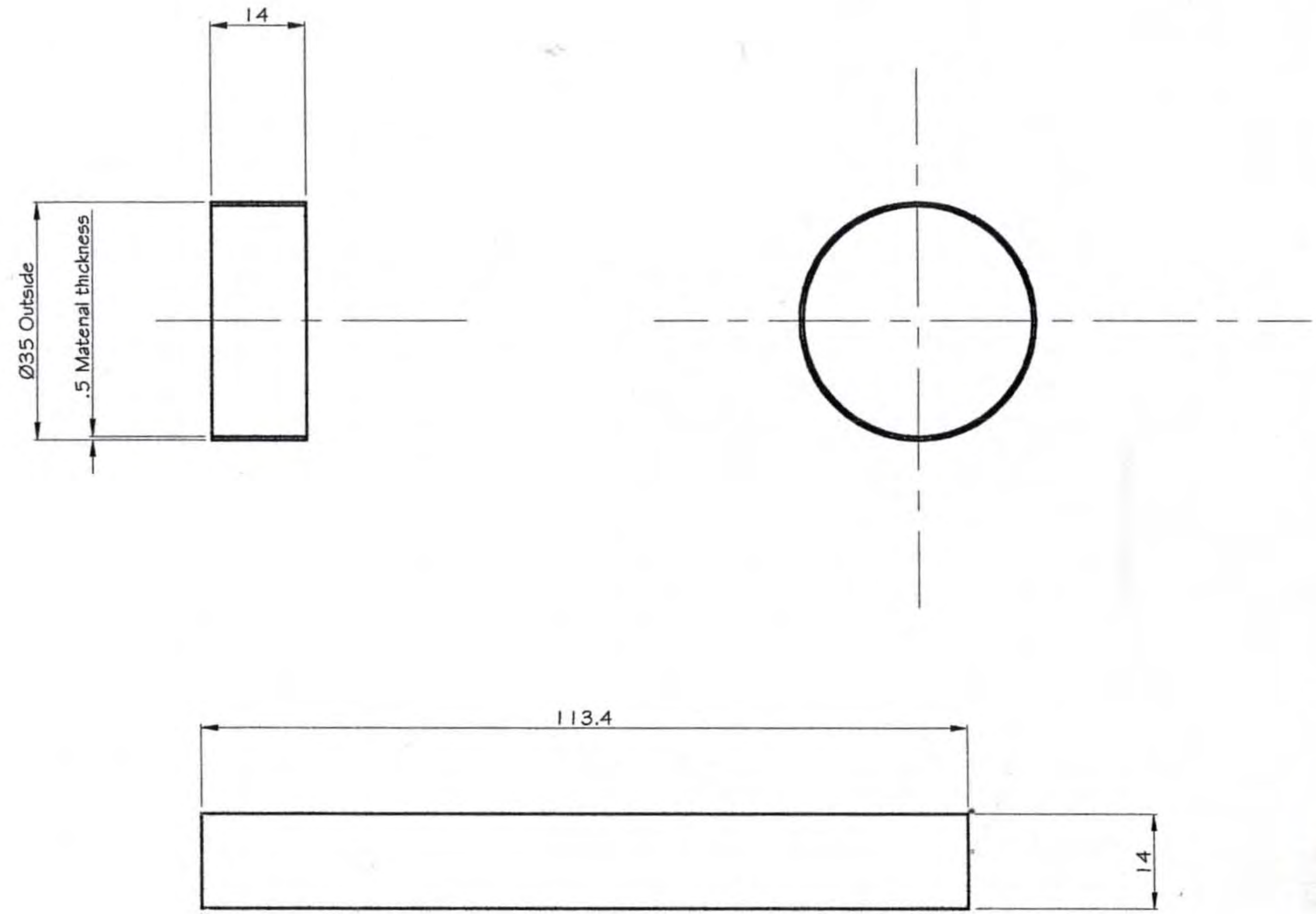
Designed by: Mike Murphy				Material: As details		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust manifold	Issue: 1	Part No. 126

Dimensions in Millimeters



Designed by: Mike Murphy				Material: As details		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Stack	Issue: 1	Part No. 127

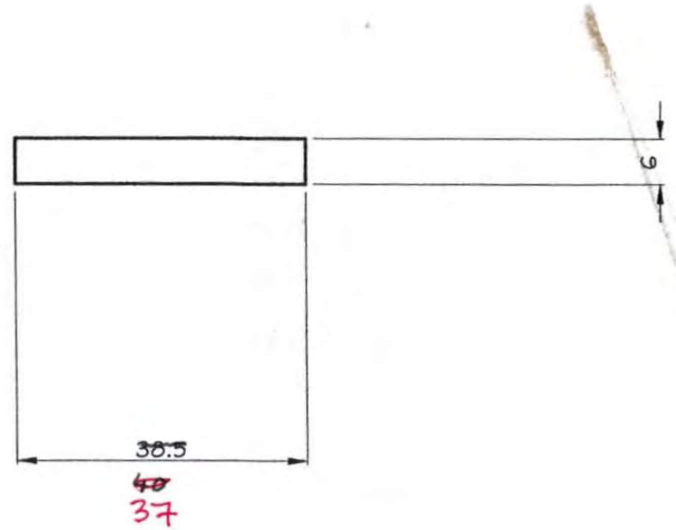
Dimensions in Millimeters



Developed shape (including 5mm overlap)

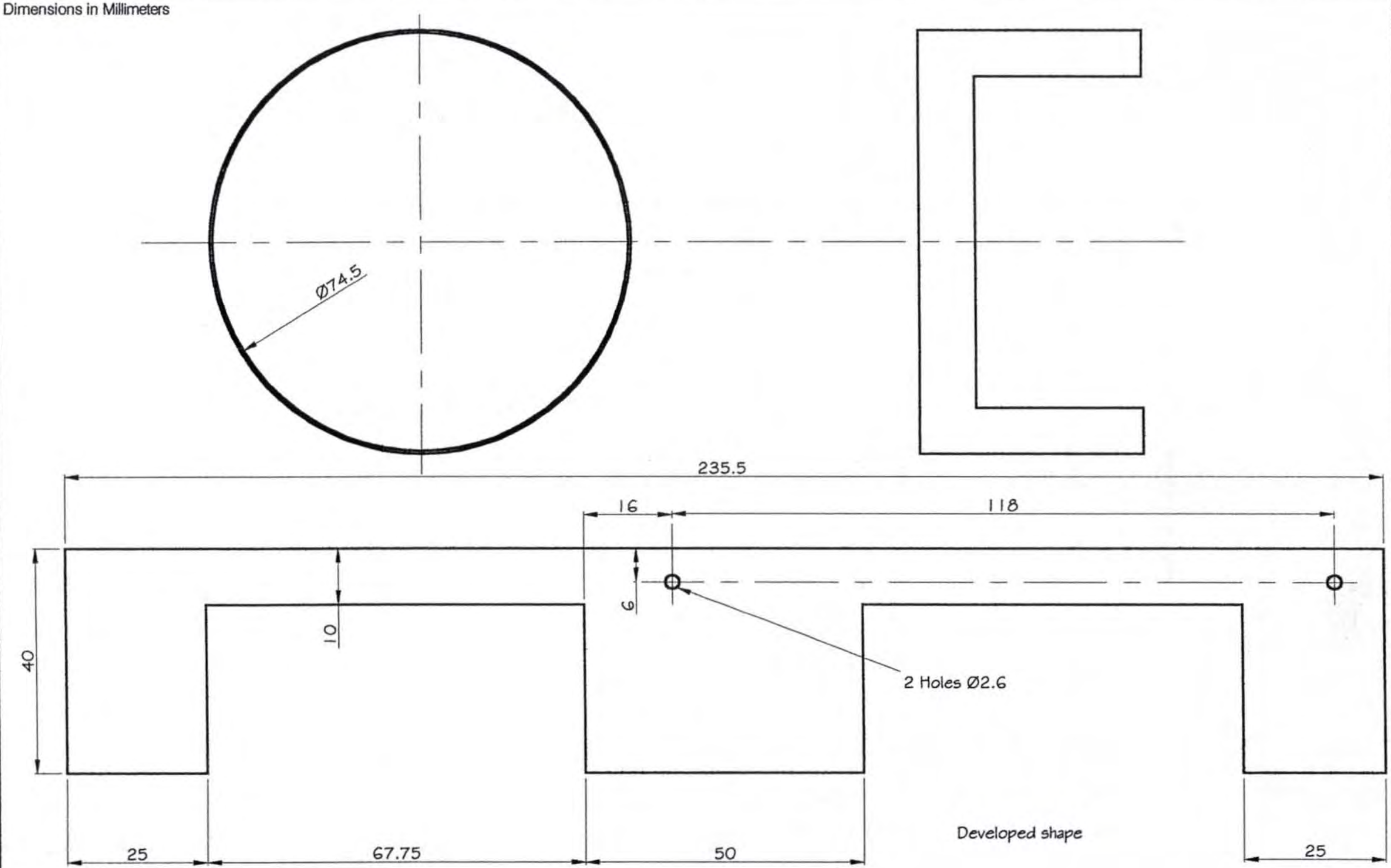
Designed by: Mike Murphy				Material: Stainless Steel Sheet		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Inner	Issue: 1	Part No. 128

Dimensions in Millimeters



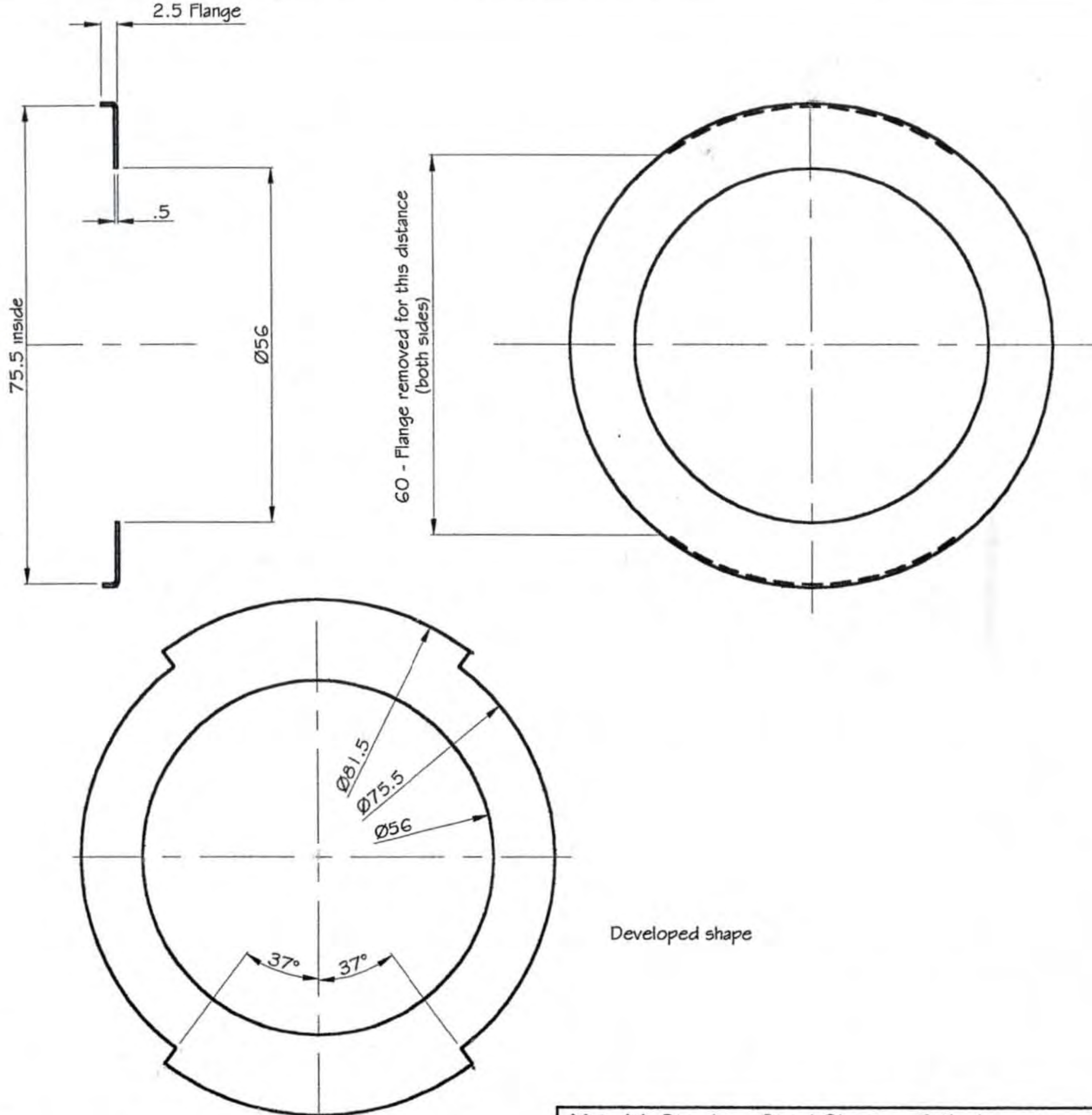
Designed by: Mike Murphy				Material: Stainless Steel Sheet (316) - .5 thick		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Overlap plate	Issue: 1	Part No. 129

Dimensions in Millimeters



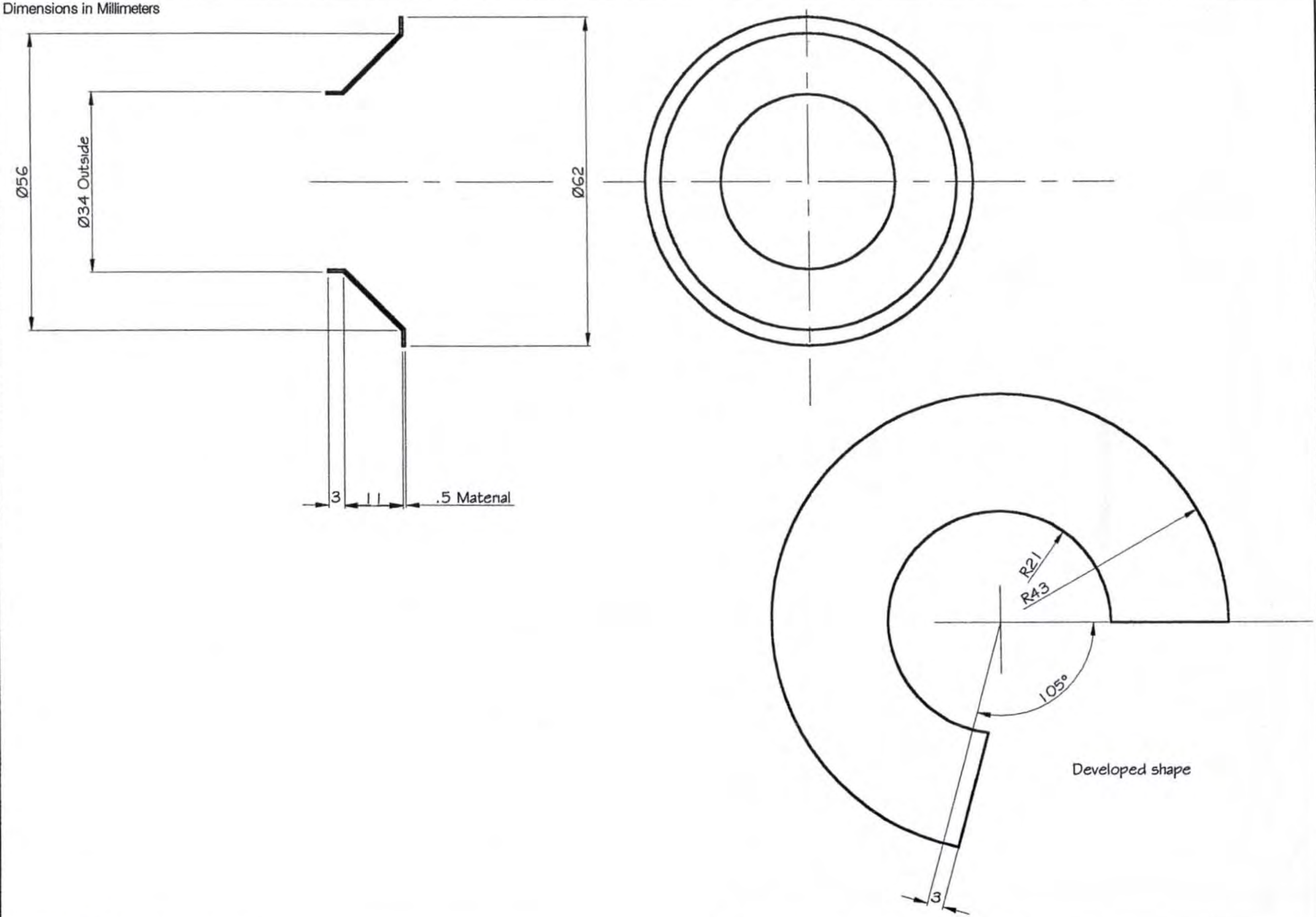
Designed by: Mike Murphy			Material: Stainless Steel Sheet (316) - .5 thick
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Outer	Issue: 1	Part No. 130

Dimensions in Millimeters



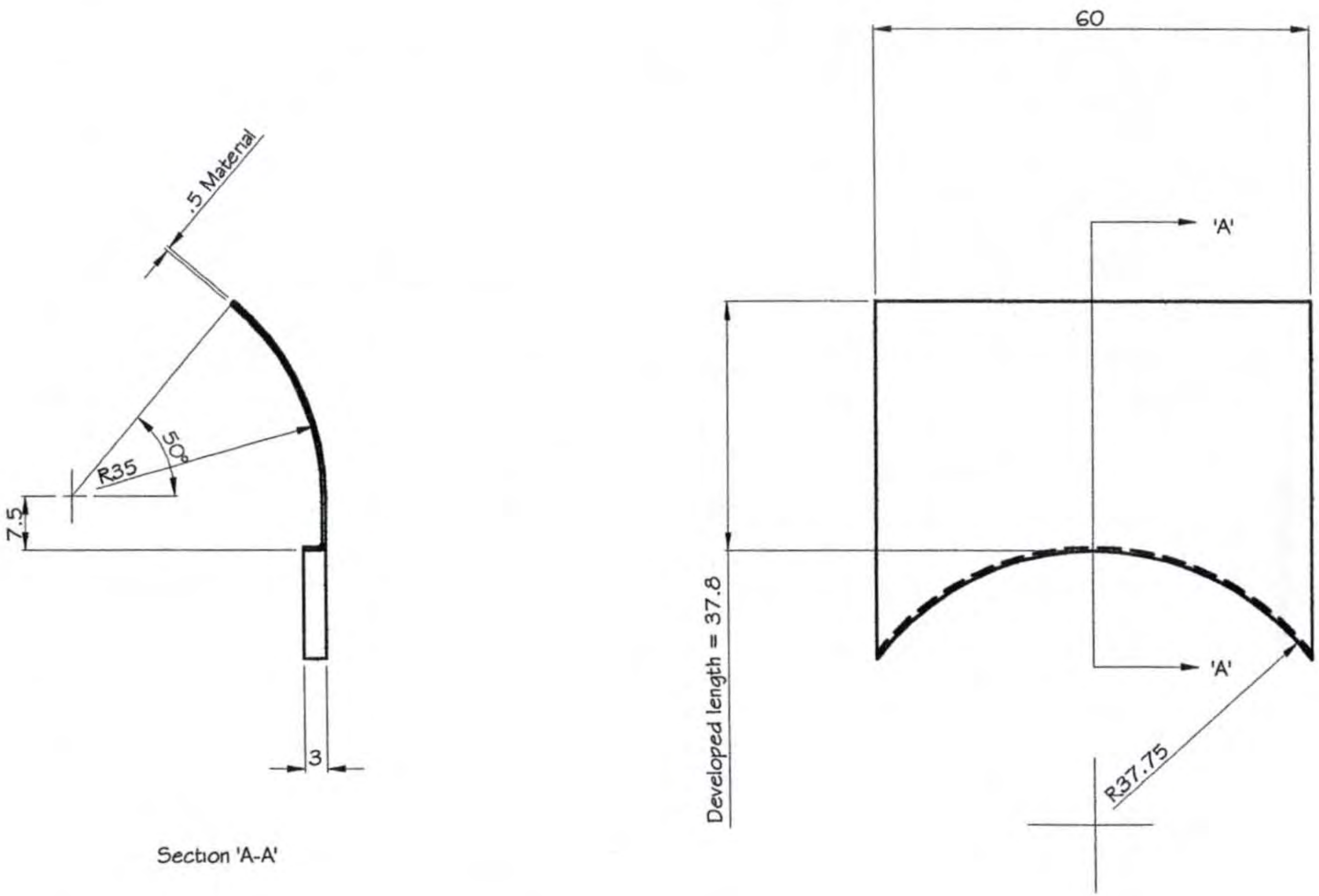
Designed by: Mike Murphy				Material: Stainless Steel Sheet - .5 thick		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Front	Issue: 1	Part No. 131

Dimensions in Millimeters



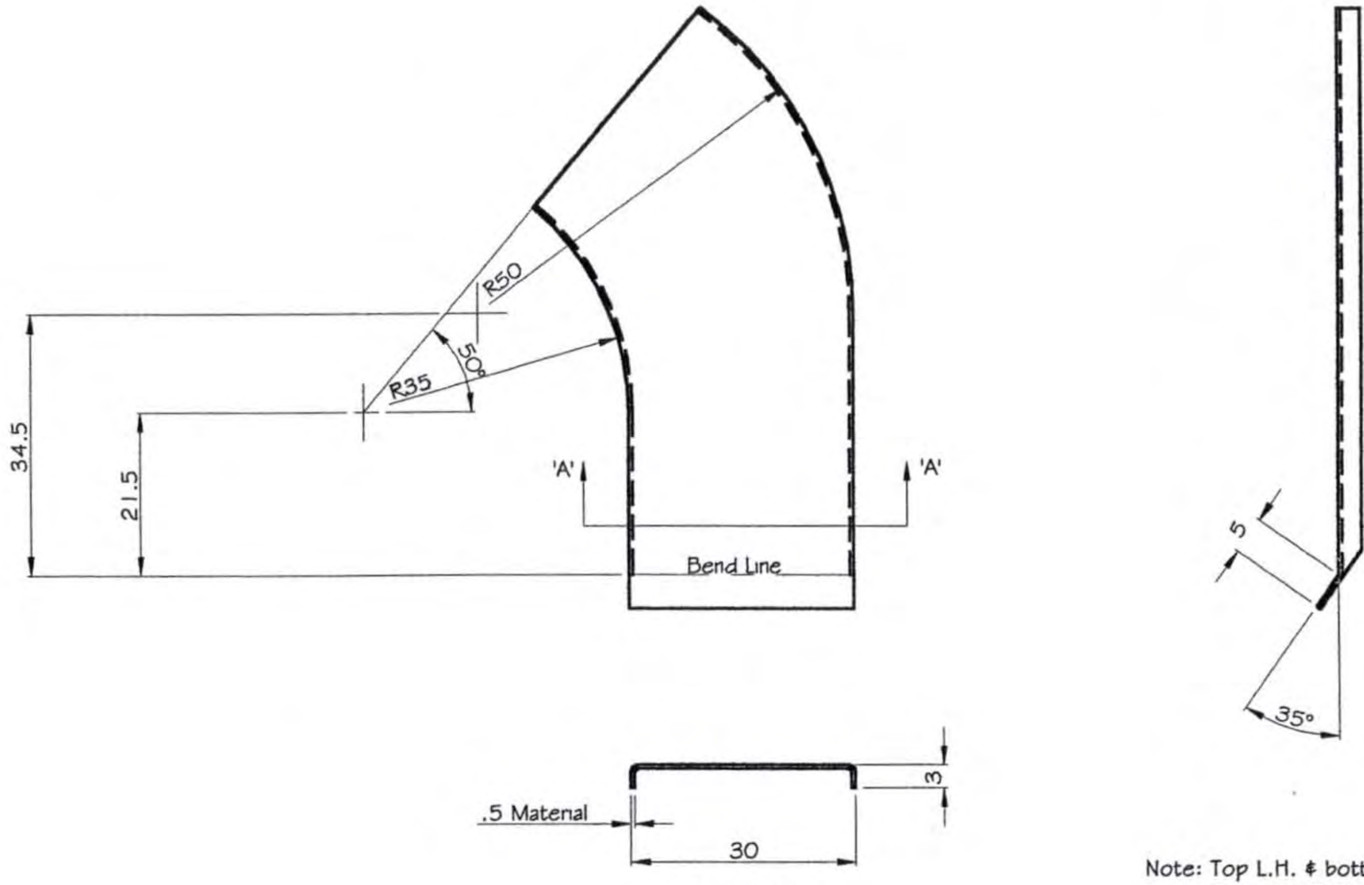
Designed by: Mike Murphy				Material: Stainless Steel Sheet		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Cone	Issue: 1	Part No. 132

Dimensions in Millimeters



Designed by: Mike Murphy				Material: Stainless Steel Sheet		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Stack Rear	Issue: 1	Part No. 133

Dimensions in Millimeters

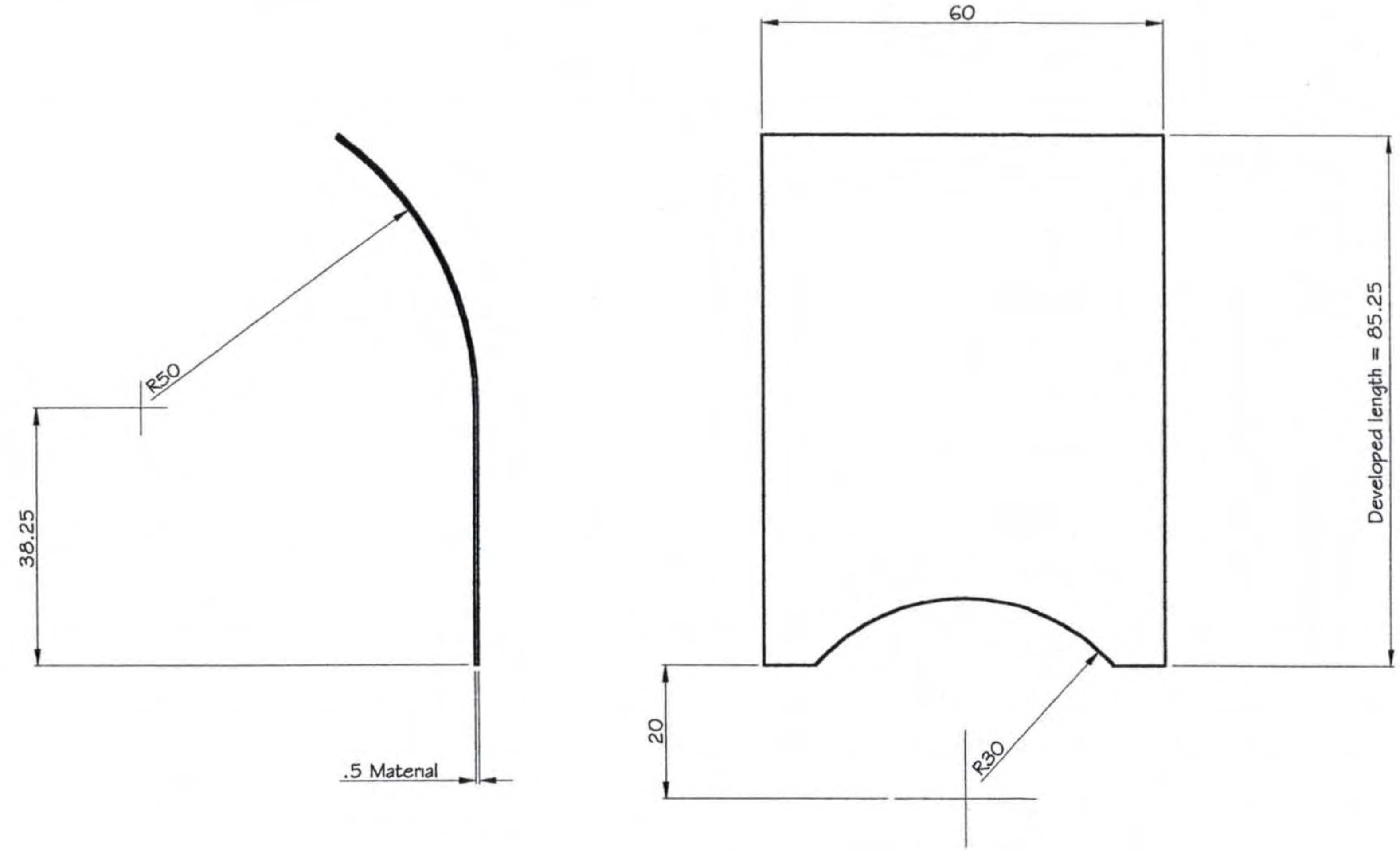


Section 'A-A'

Note: Top L.H. & bottom R.H. as drawn
Bottom L.H. & top R.H. opposite

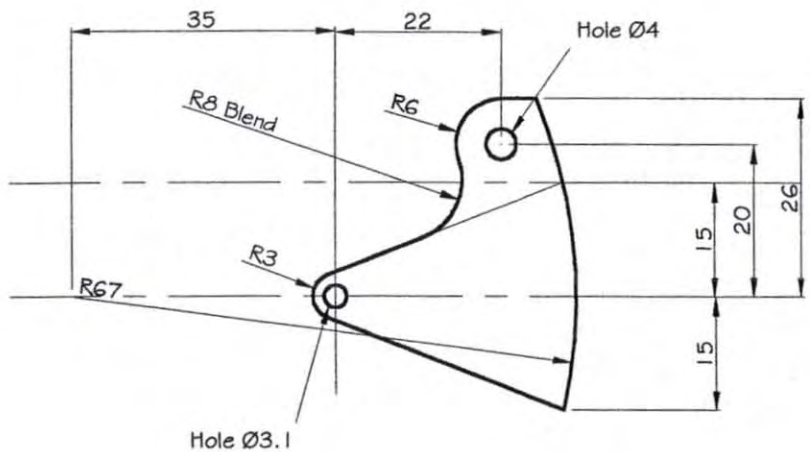
Designed by: Mike Murphy				Material: Stainless Steel Sheet		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Stack Top/bottom	Issue: 1	Part No. 134

Dimensions in Millimeters



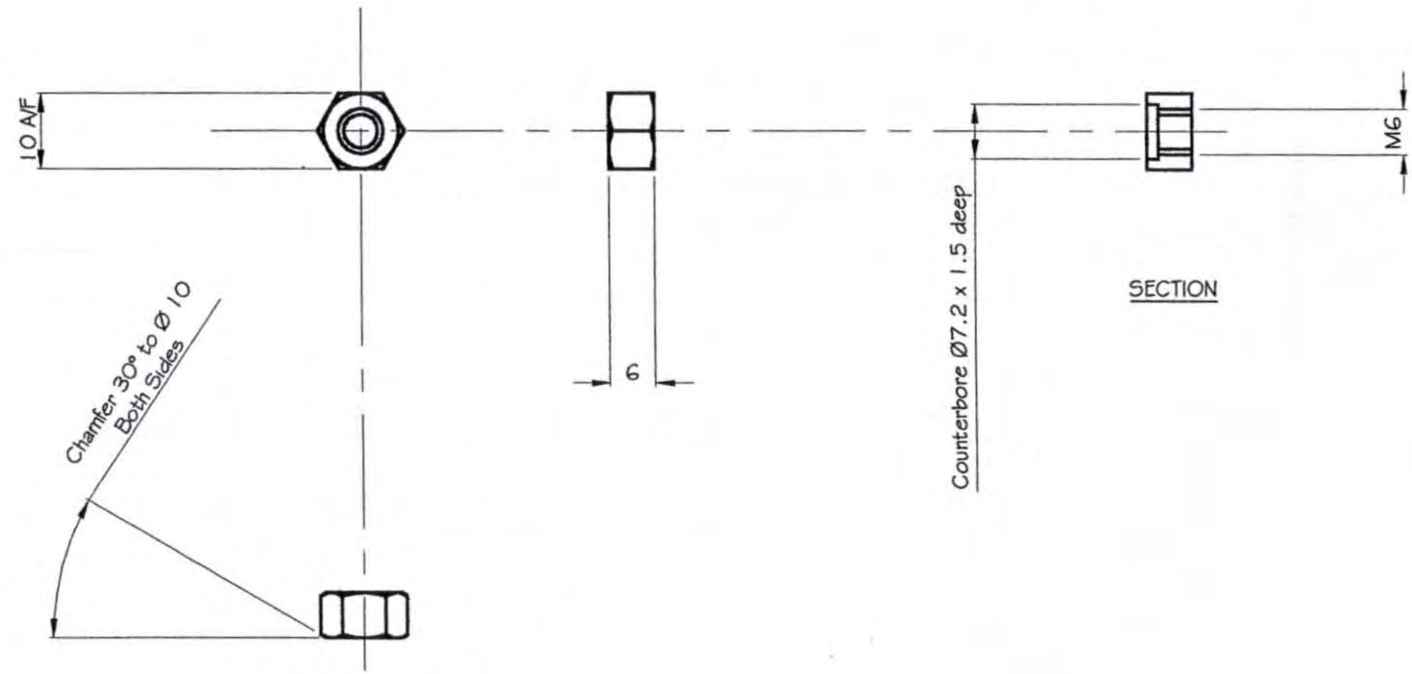
Designed by: Mike Murphy				Material: Stainless Steel Sheet		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Exhaust Stack Front	Issue: 1	Part No. 135

Dimensions in Millimeters



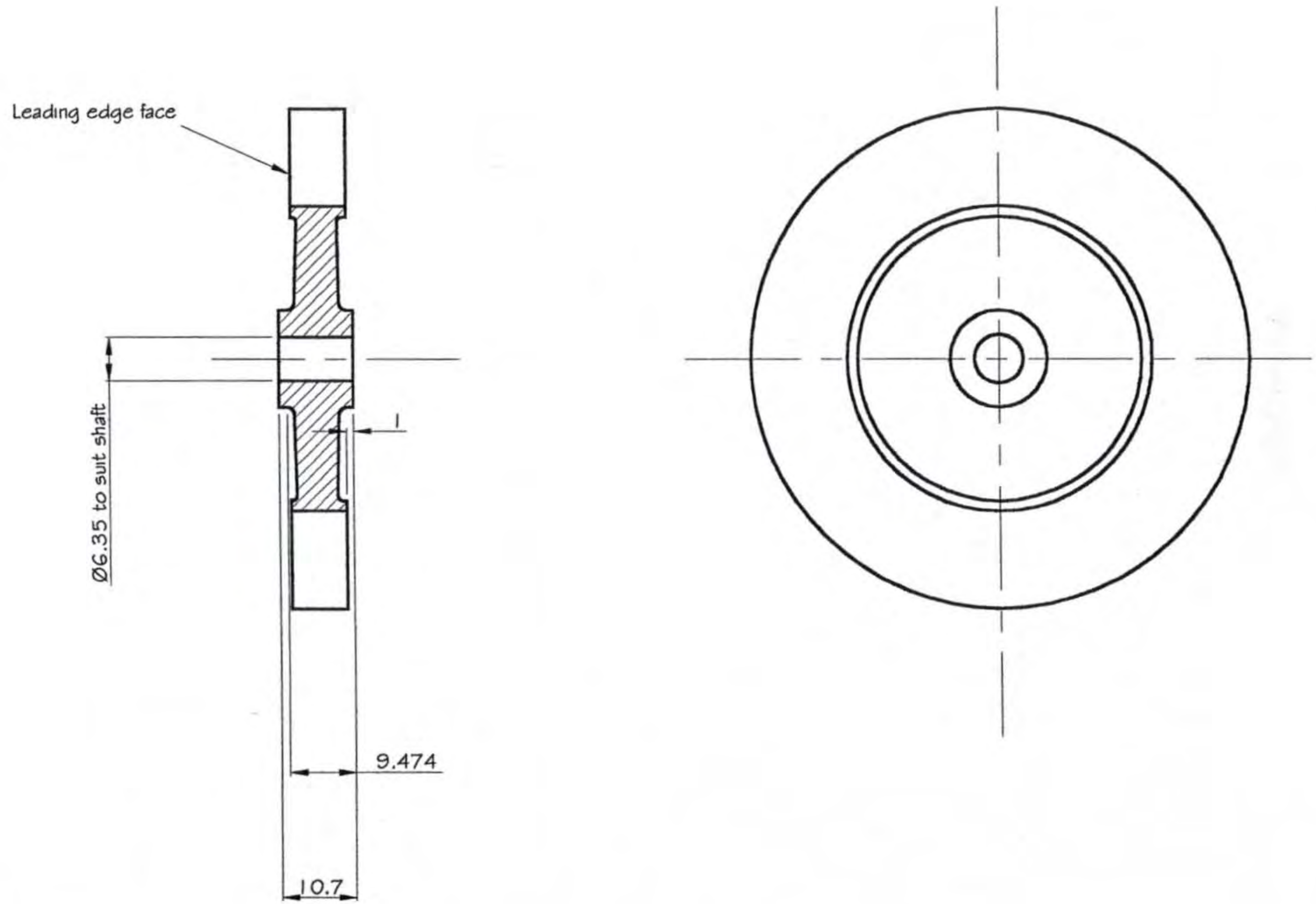
Designed by: Mike Murphy				Material: Mild steel - 1 mm thick		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Mounting lug	Issue: 1	Part No. 137

Dimensions in Millimeters



Designed by: Mike Murphy				Material: Stainless Steel		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Turbine Nut	Issue: 1	Part No. 140

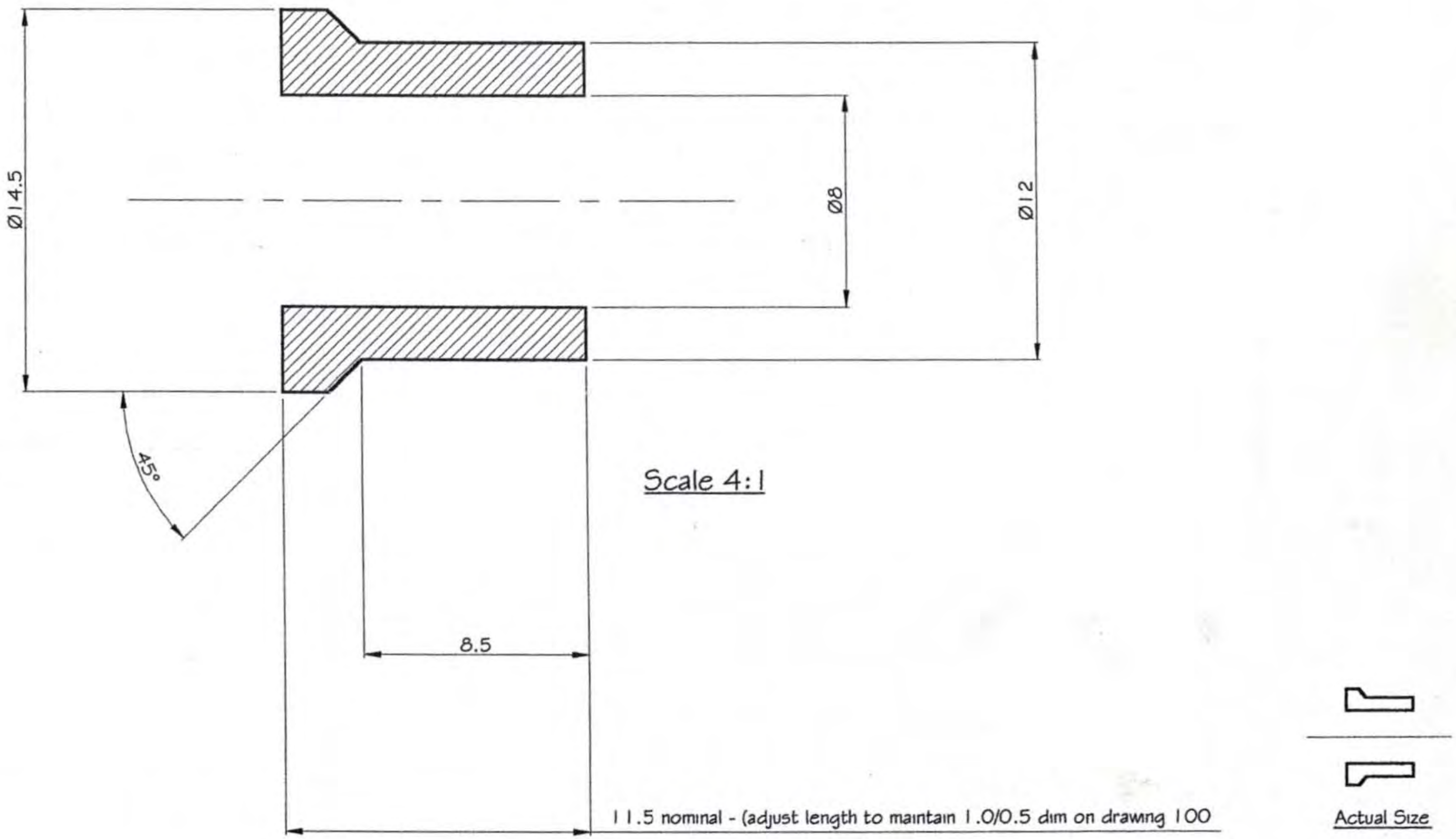
Dimensions in Millimeters



Designed by: Mike Murphy			
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop

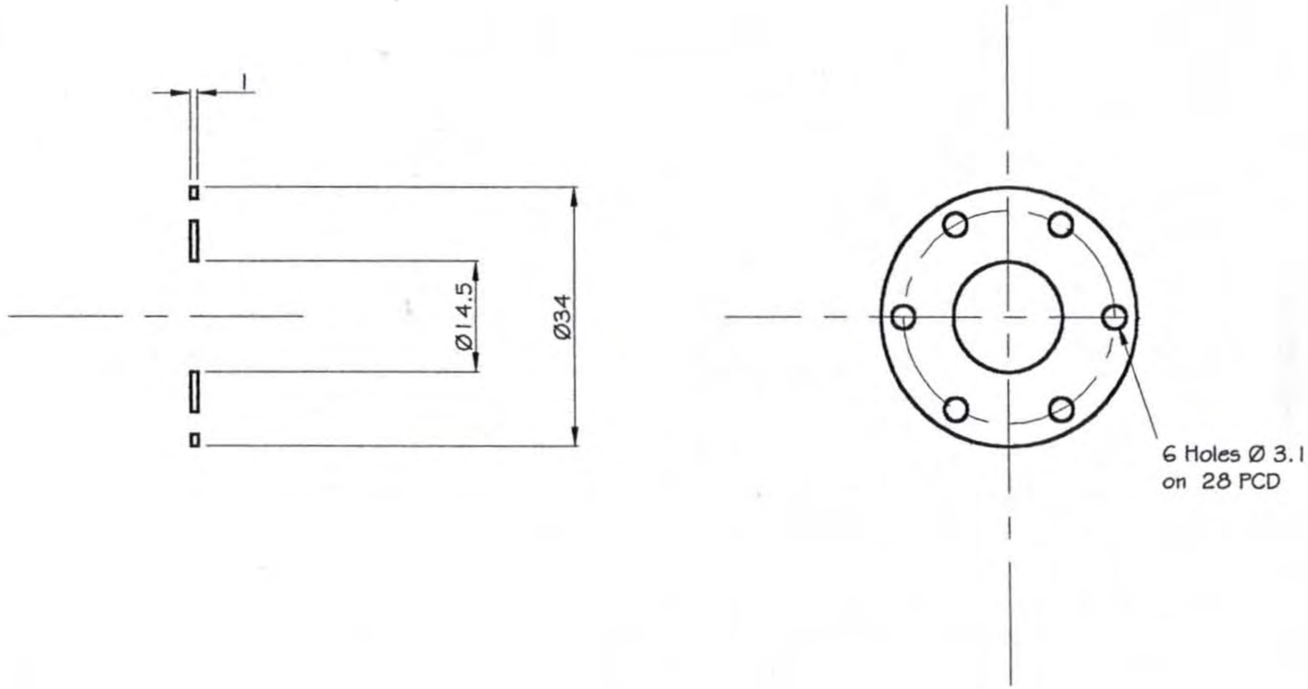
Material: Inconel		
Title: Power Turbine	Issue: 1	Part No. 141

Dimensions in Millimeters



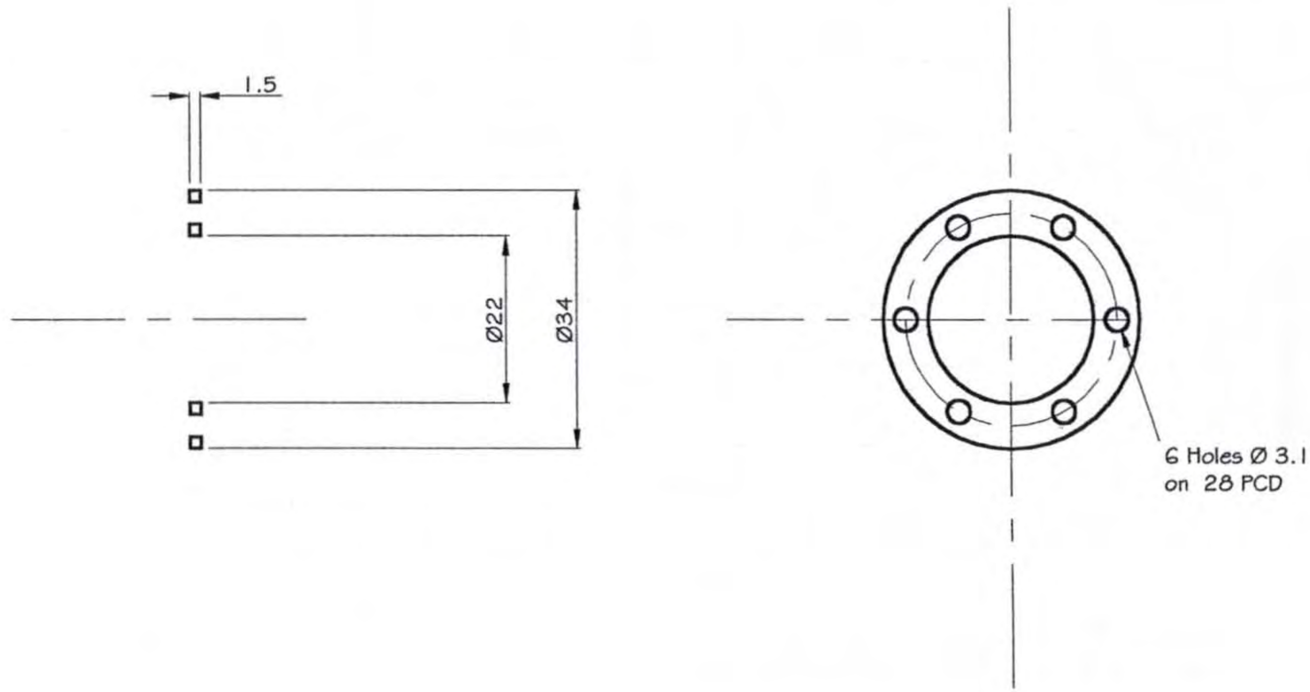
Designed by: Mike Murphy				Material: Steel - En24		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Collar	Issue: 1	Part No. 142

Dimensions in Millimeters



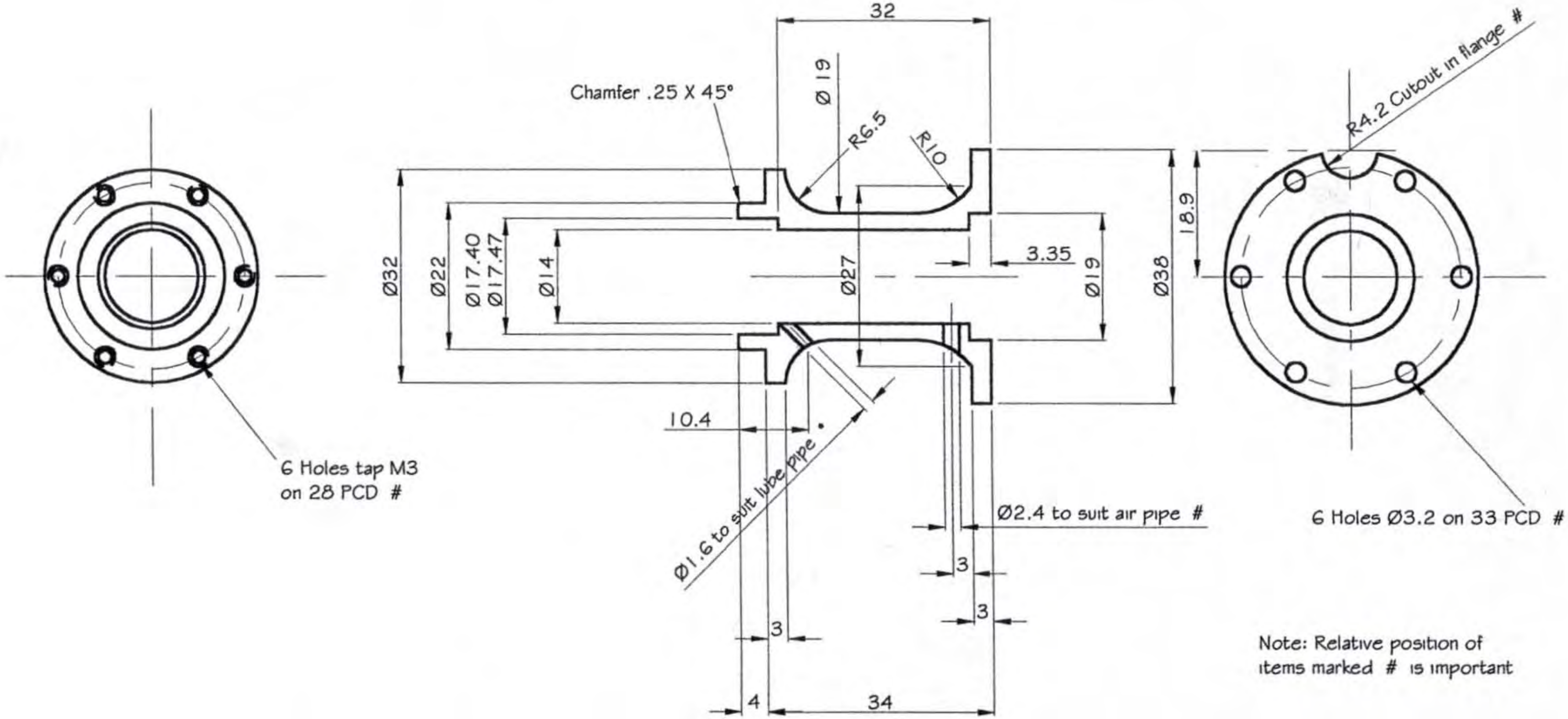
Designed by: Mike Murphy				Material: Stainless steel		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Clamp ring	Issue: 1	Part No. 143

Dimensions in Millimeters



Designed by: Mike Murphy				Material: High temperature gasket material		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Gasket	Issue: 1	Part No. 144

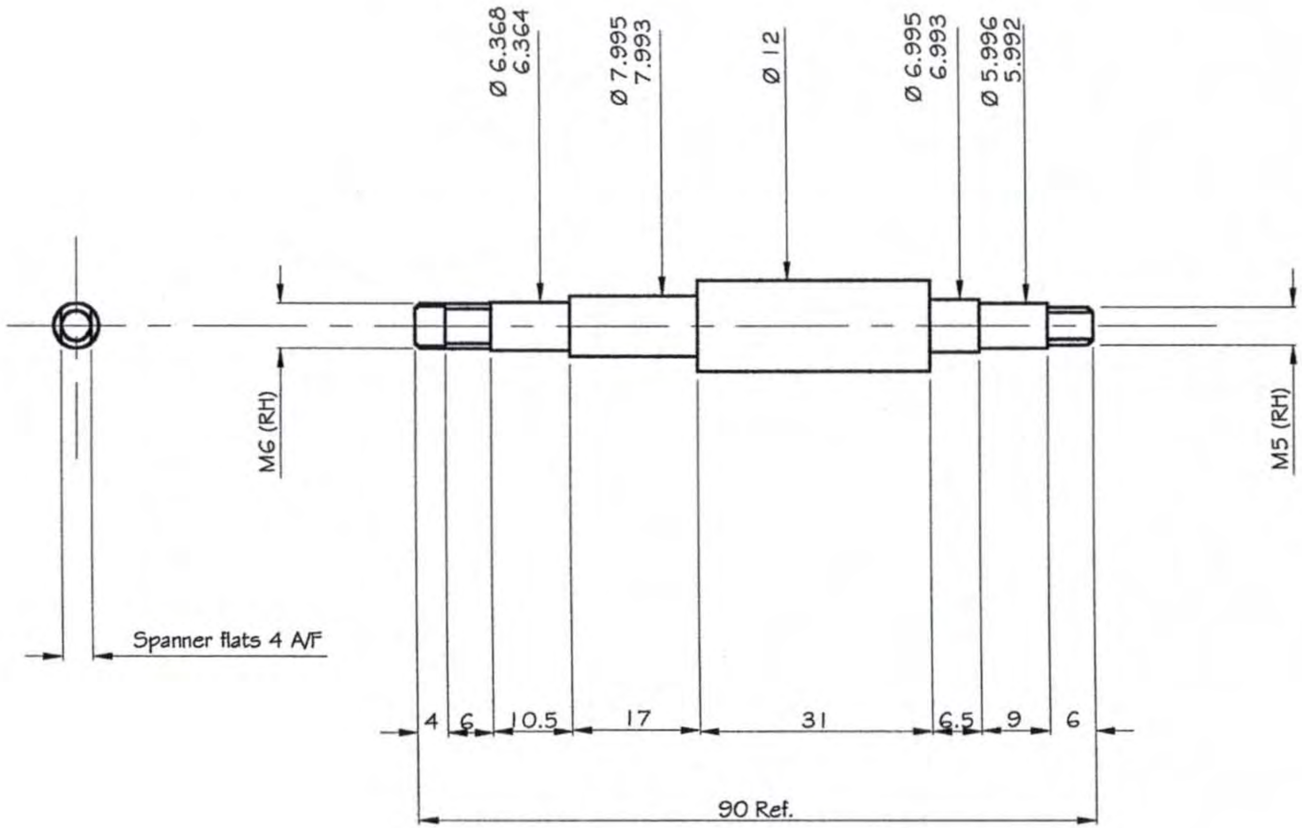
Dimensions in Millimeters



Note: Relative position of items marked # is important

Designed by: Mike Murphy				Material: Aluminium		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Shaft Tunnel	Issue: 1	Part No. 145

Dimensions in Millimeters



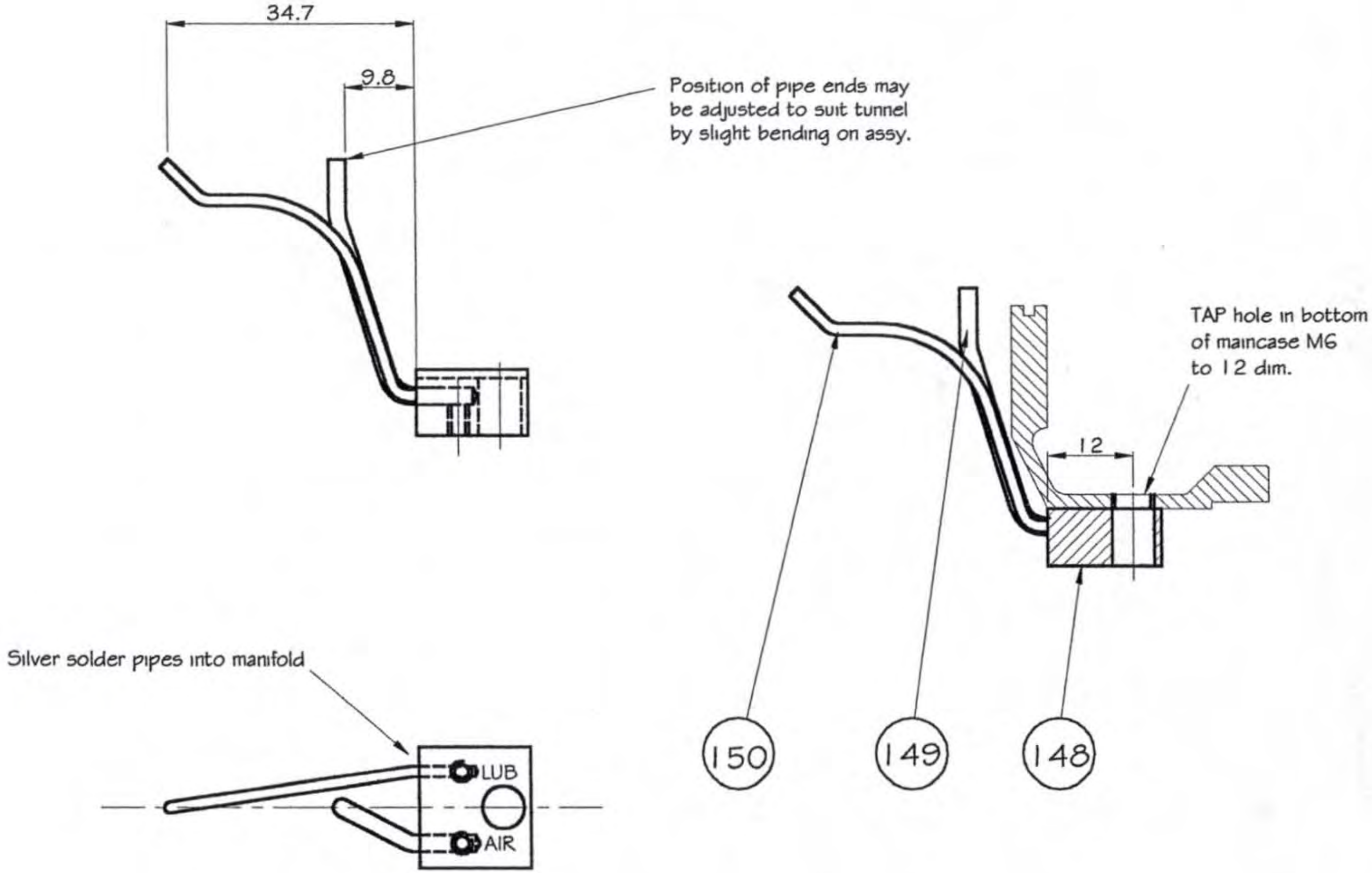
Designed by: Mike Murphy

Drawn: Terry Lee | Third Angle Projection | © WREN Turbines | MW54 - Turboprop

Material: Steel - En24

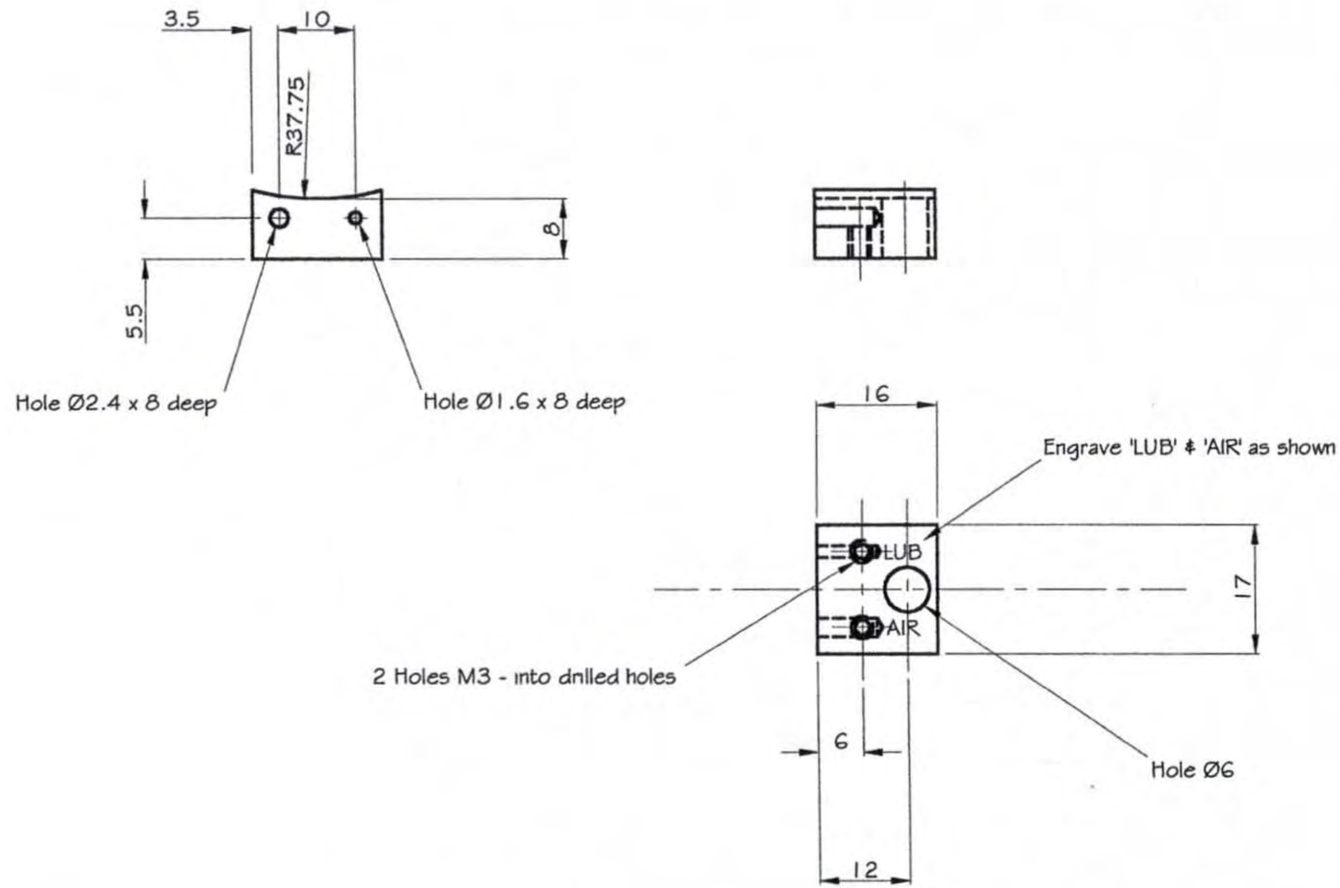
Title: Turbine shaft | Issue: 1 | Part No. 146

Dimensions in Millimeters



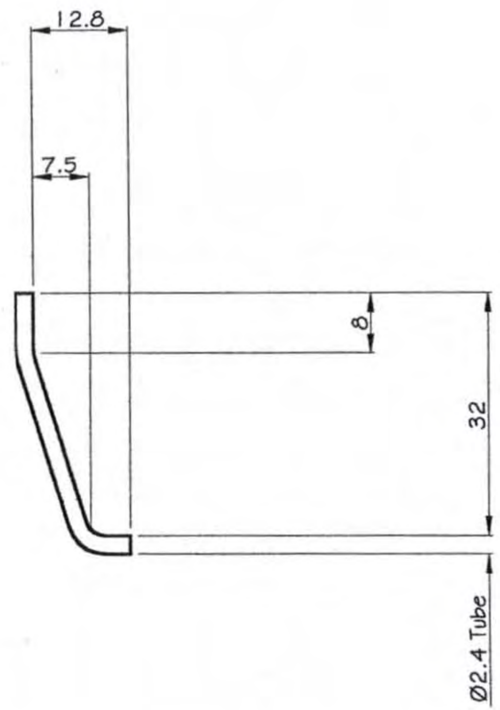
Designed by: Mike Murphy				Material: As details		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Shaft lube Sub Assy	Issue: 1	Part No. 147

Dimensions in Millimeters



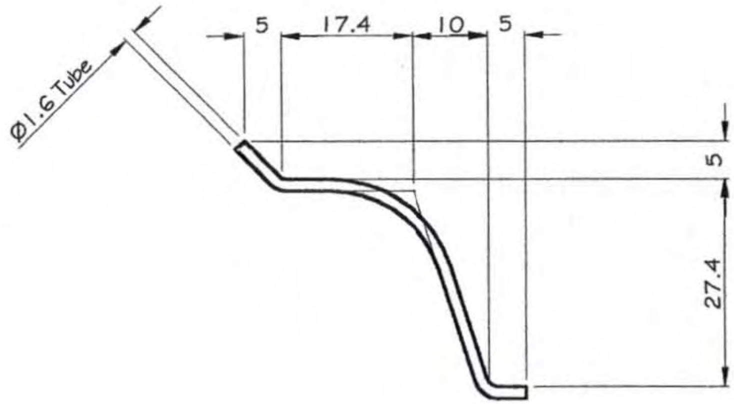
Designed by: Mike Murphy				Material: Brass		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Manifold	Issue: 1	Part No. 148

Dimensions in Millimeters



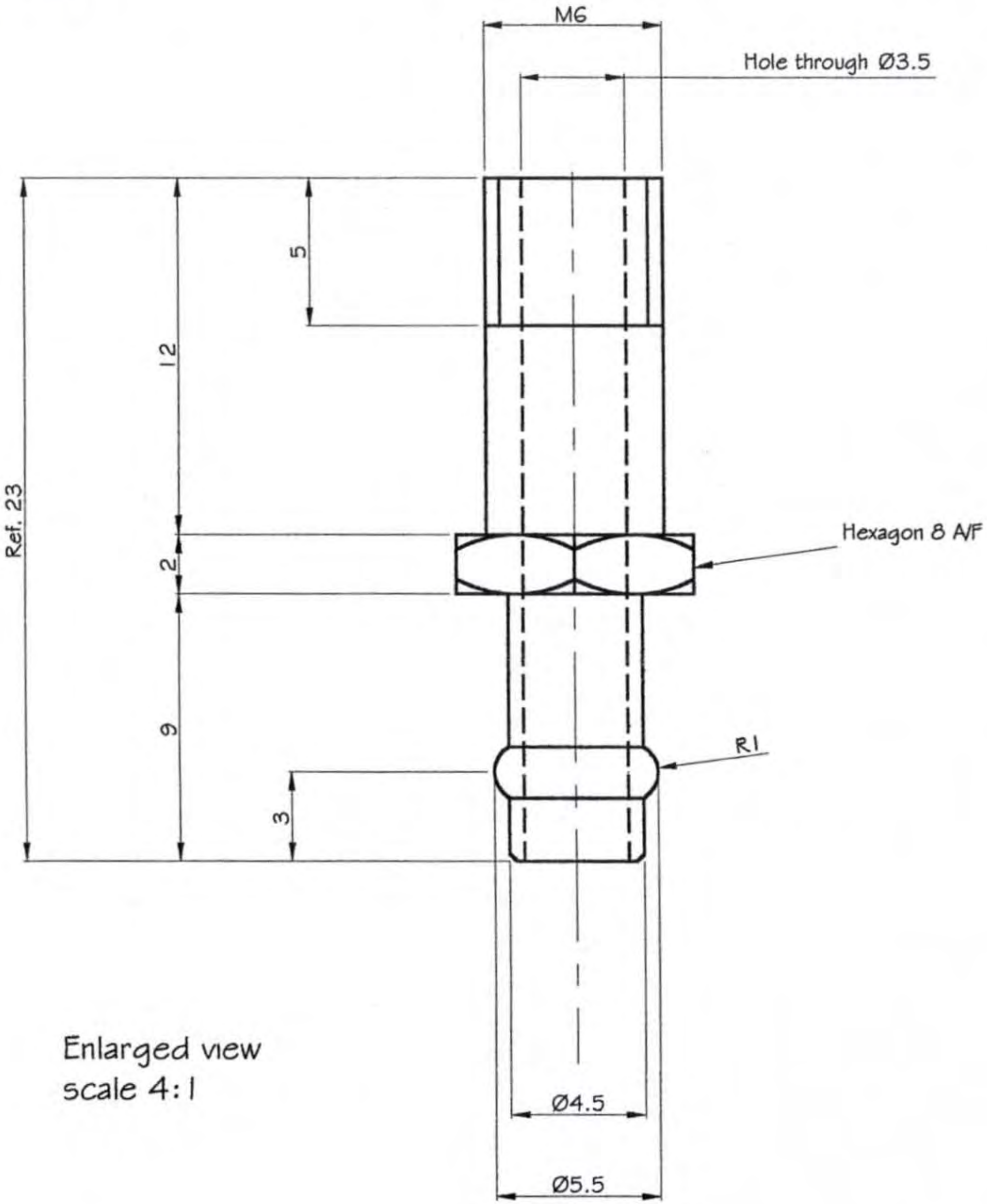
Designed by: Mike Murphy				Material: Brass tube		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Air Pipe	Issue: 1	Part No. 149

Dimensions in Millimeters

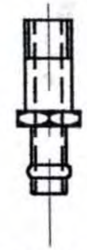


Designed by: Mike Murphy				Material: Brass tube		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Lube Pipe	Issue: 1	Part No. 150

Dimensions in Millimeters



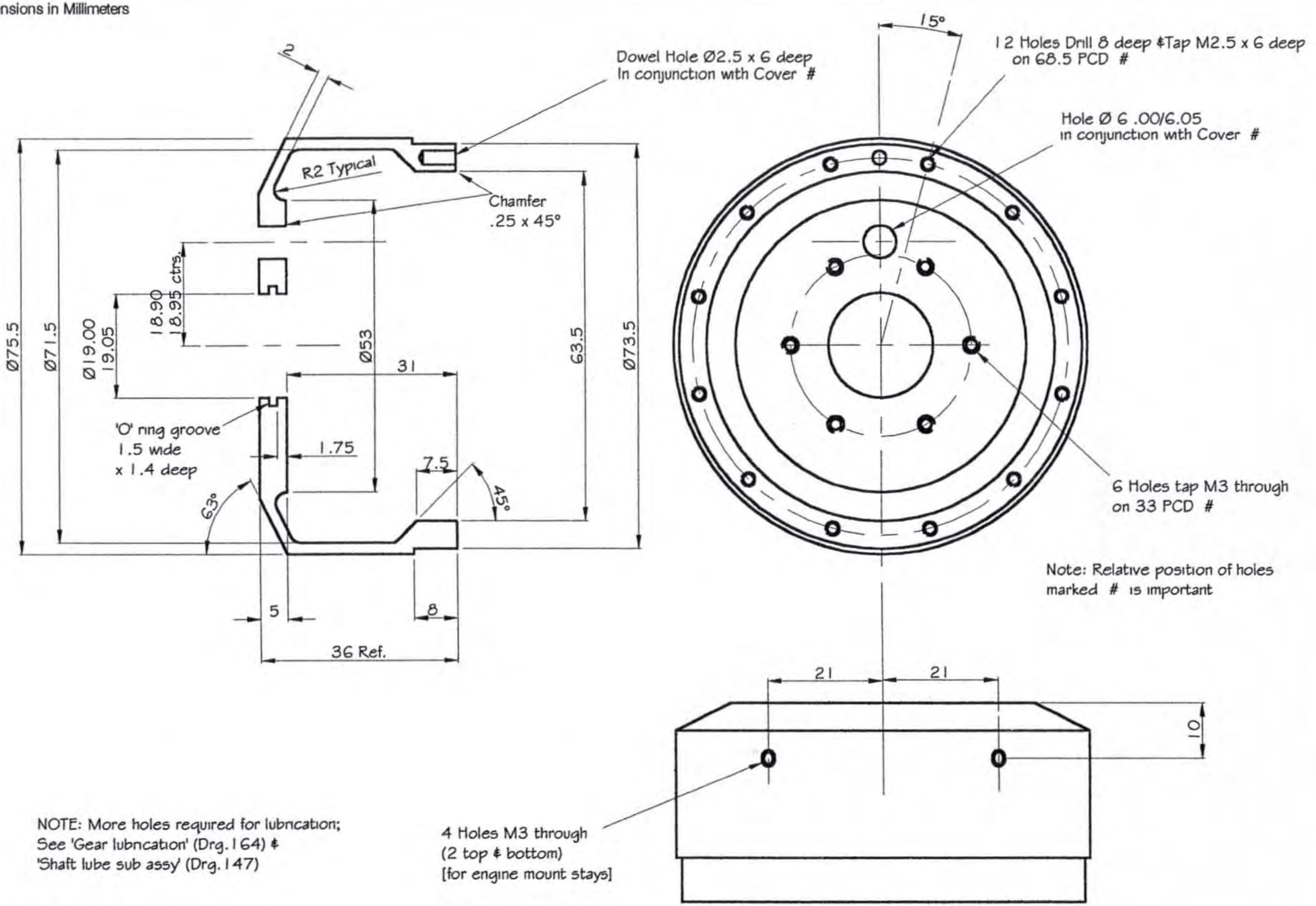
Enlarged view
scale 4:1



actual size

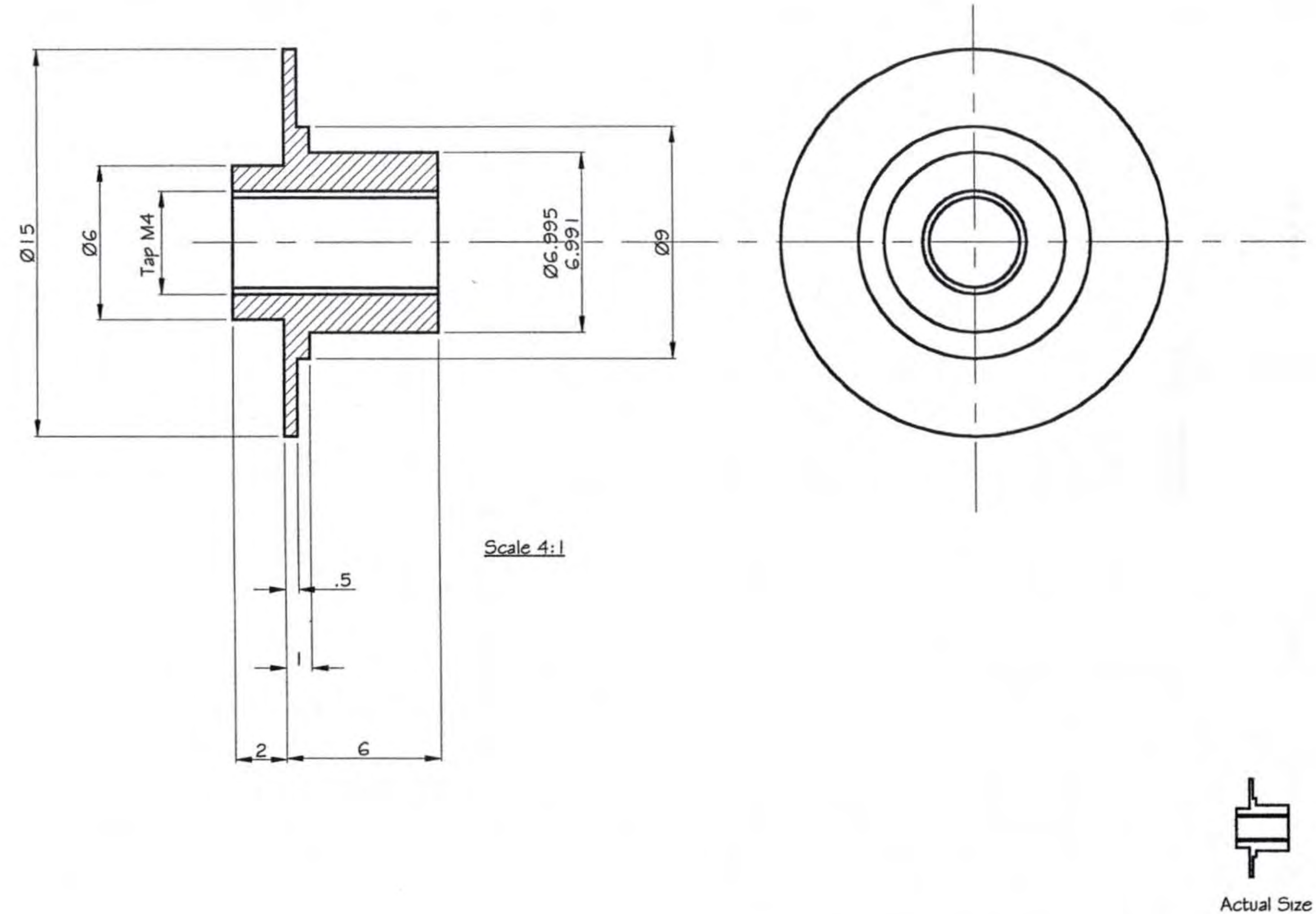
Designed by: Mike Murphy				Material: Steel		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Oil drain fitting	Issue: 1	Part No. 151

Dimensions in Millimeters



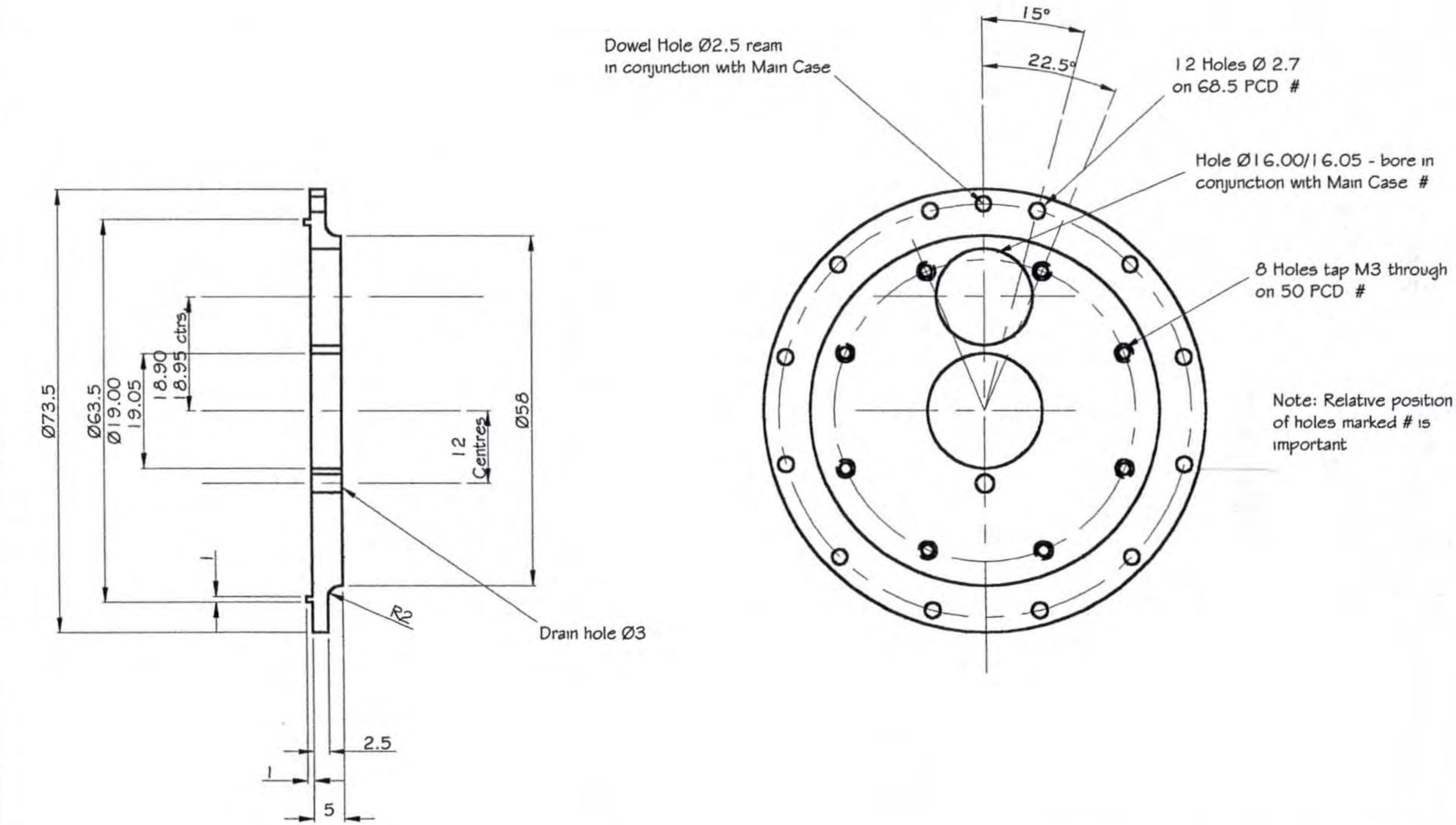
Designed by: Mike Murphy				Material: Aluminium		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Gear Case	Issue: 1	Part No. 155

Dimensions in Millimeters



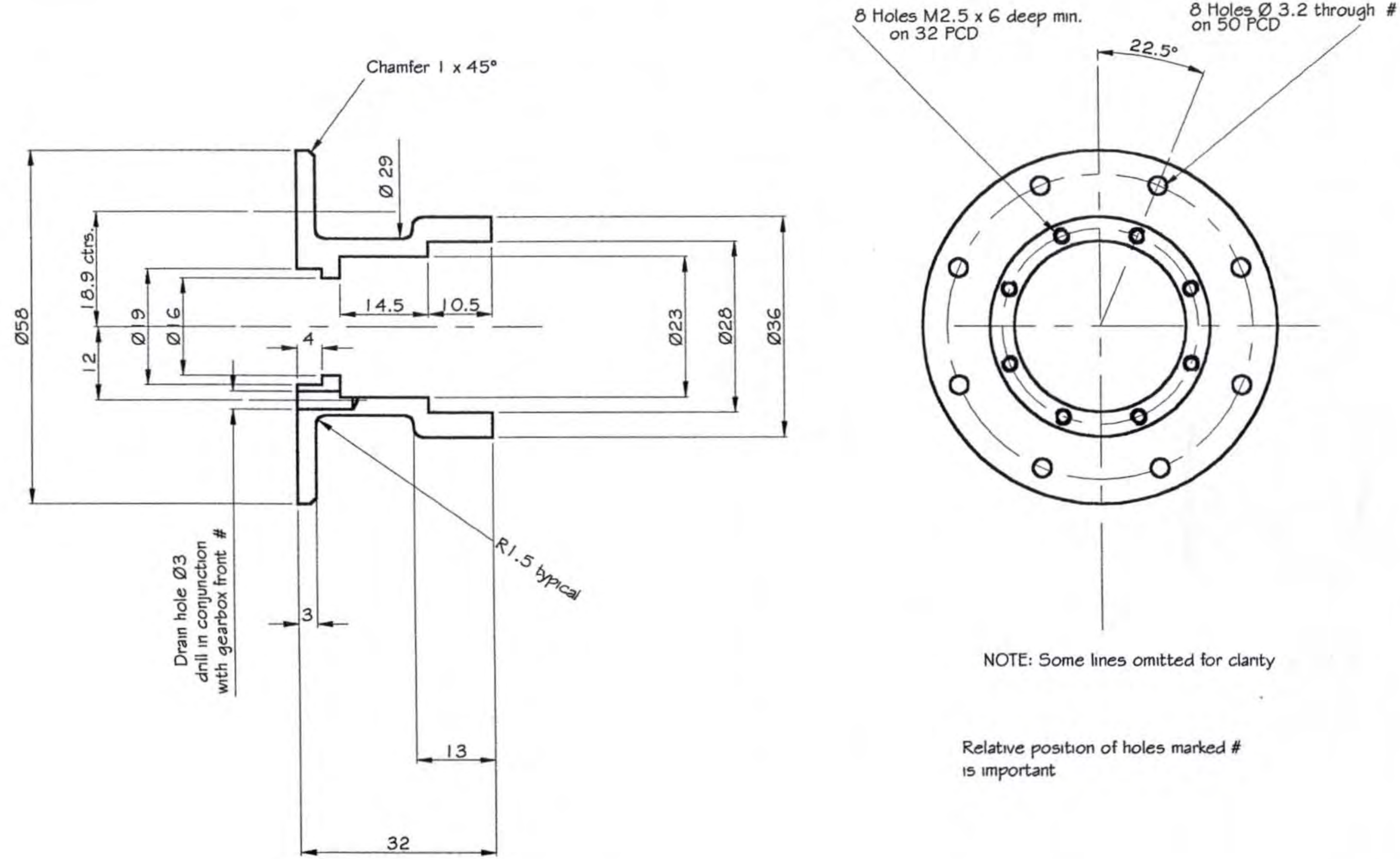
Designed by: Mike Murphy				Material: Steel - En24		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Bearing Support spigot	Issue: 1	Part No. 156

Dimensions in Millimeters



Designed by: Mike Murphy				Material: Aluminium alloy		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Gearbox front	Issue: 1	Part No. 157

Dimensions in Millimeters

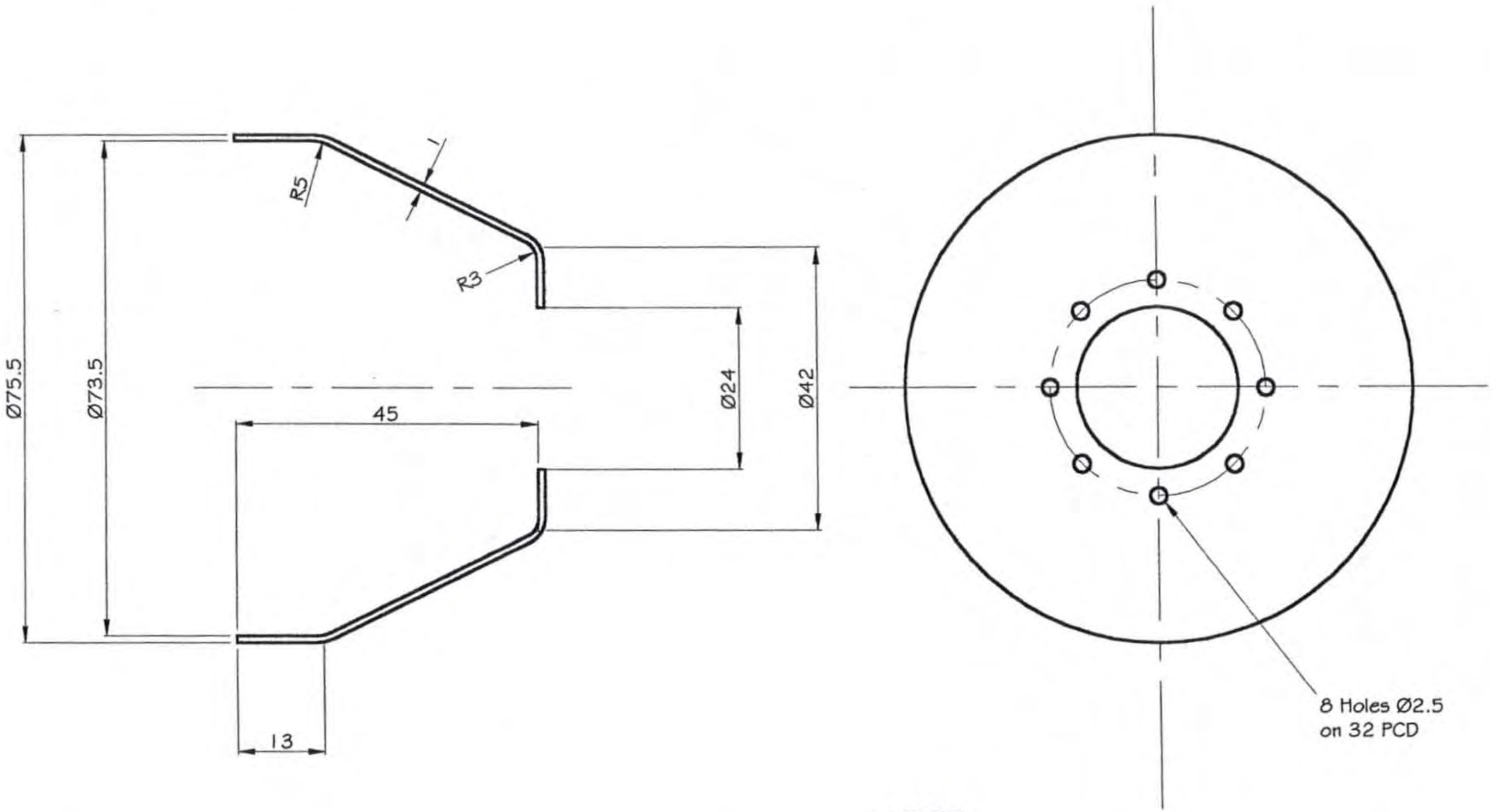


NOTE: Some lines omitted for clarity

Relative position of holes marked #
is important

Designed by: Mike Murphy				Material: Aluminium		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Prop shaft Housing	Issue: 1	Part No. 158

Dimensions in Millimeters

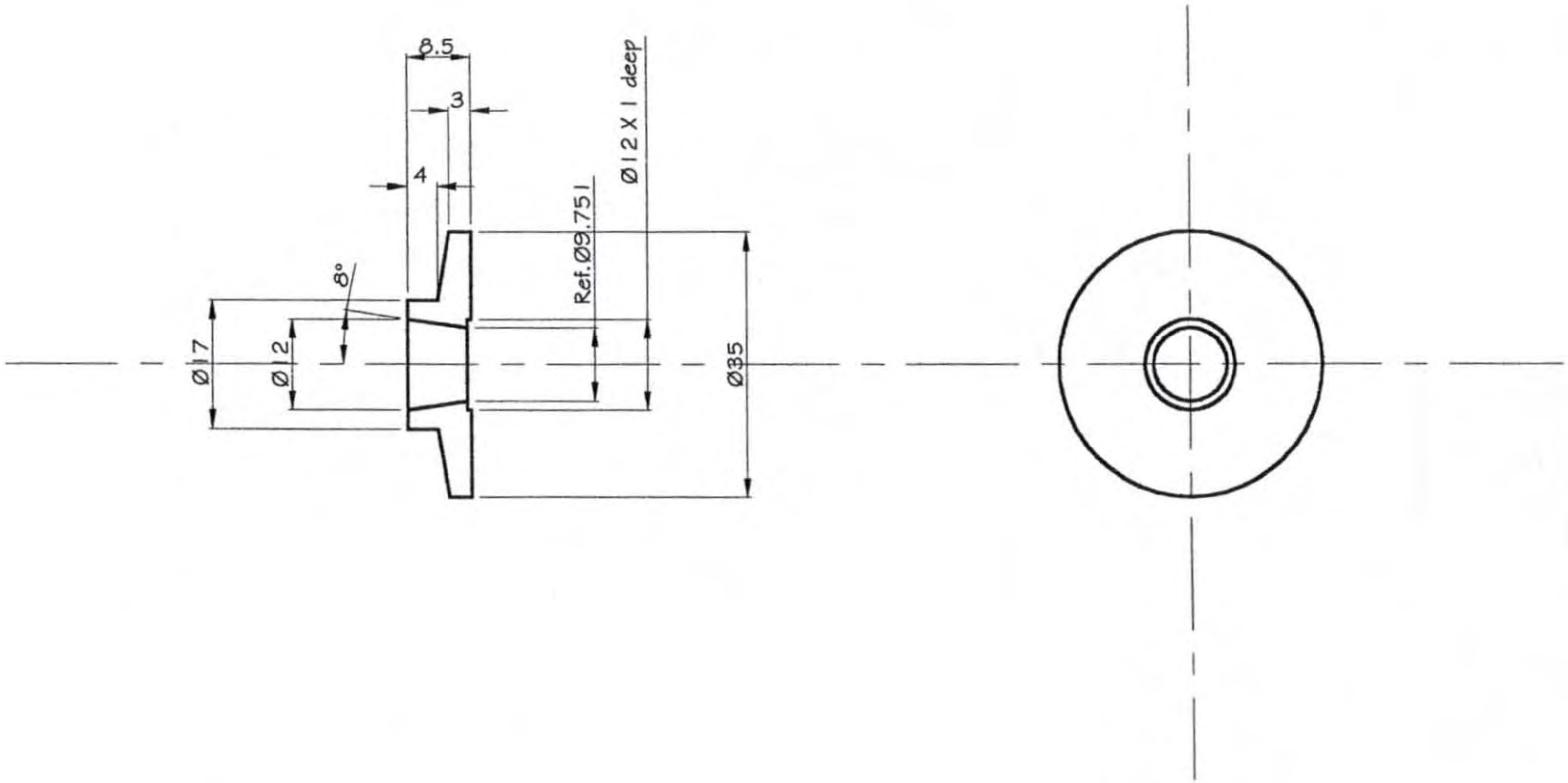


NOTE

This item is for decorative purposes only.
Method of manufacture to suit builder:
i.e spun, machined from solid etc.
Shape may be modified if required.

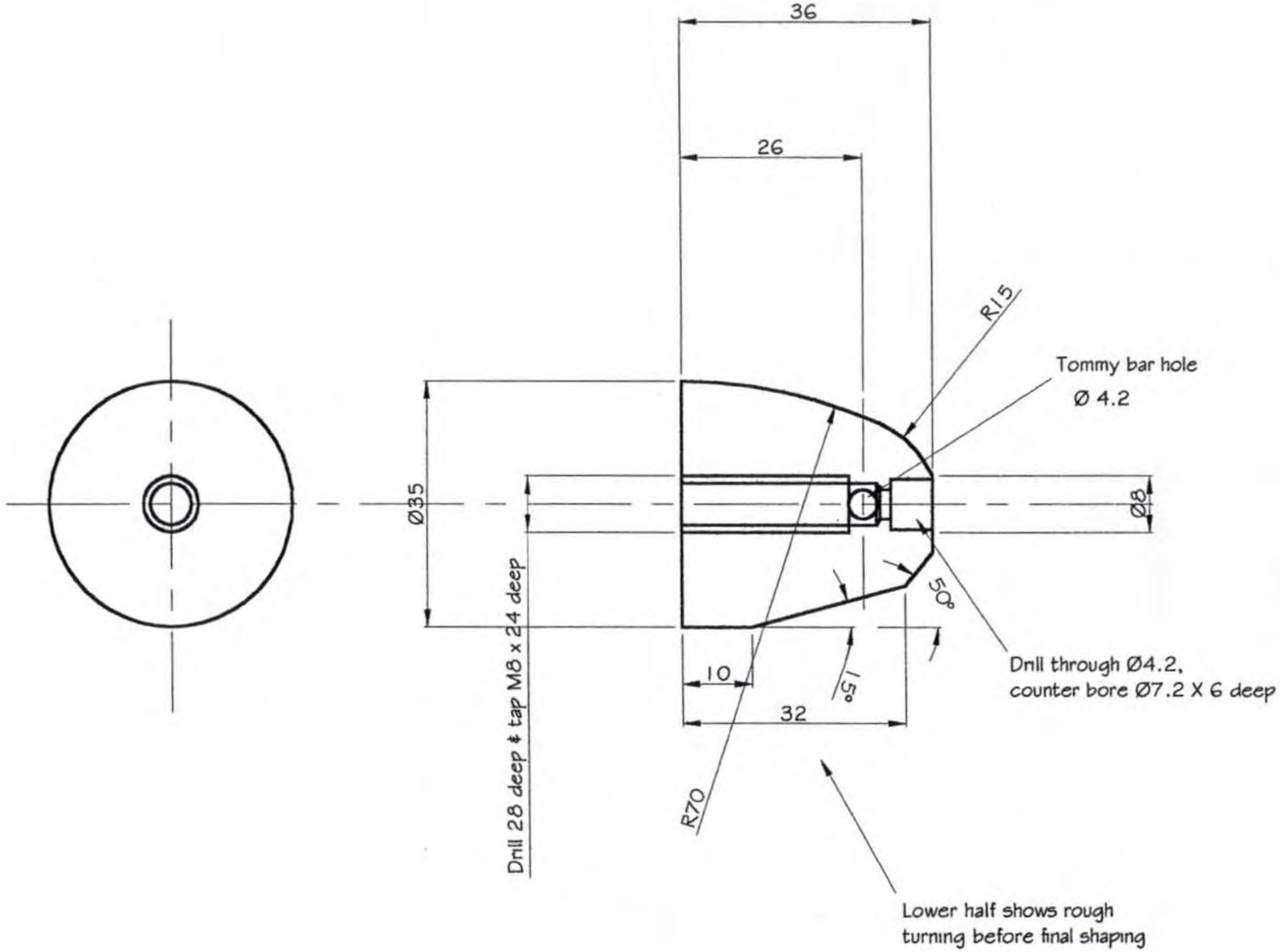
Designed by: Mike Murphy				Material: Aluminium Alloy		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Cowl	Issue: 1	Part No. 159

Dimensions in Millimeters



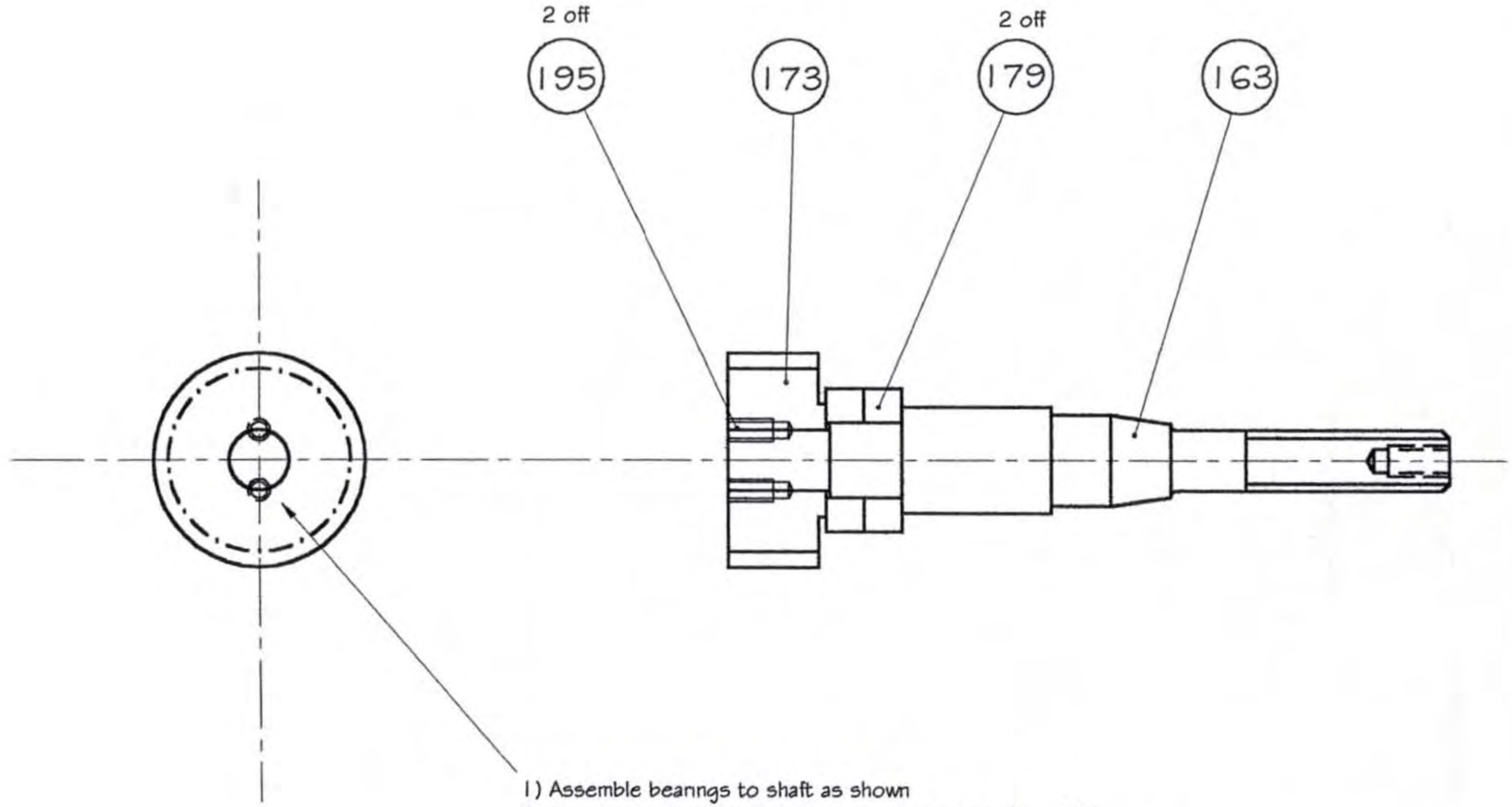
Designed by: Mike Murphy				Material: Steel		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Prop Driver	Issue: 1	Part No. 160

Dimensions in Millimeters



Designed by: Mike Murphy				Material: Aluminium alloy		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Spinner nut	Issue: 1	Part No. 161

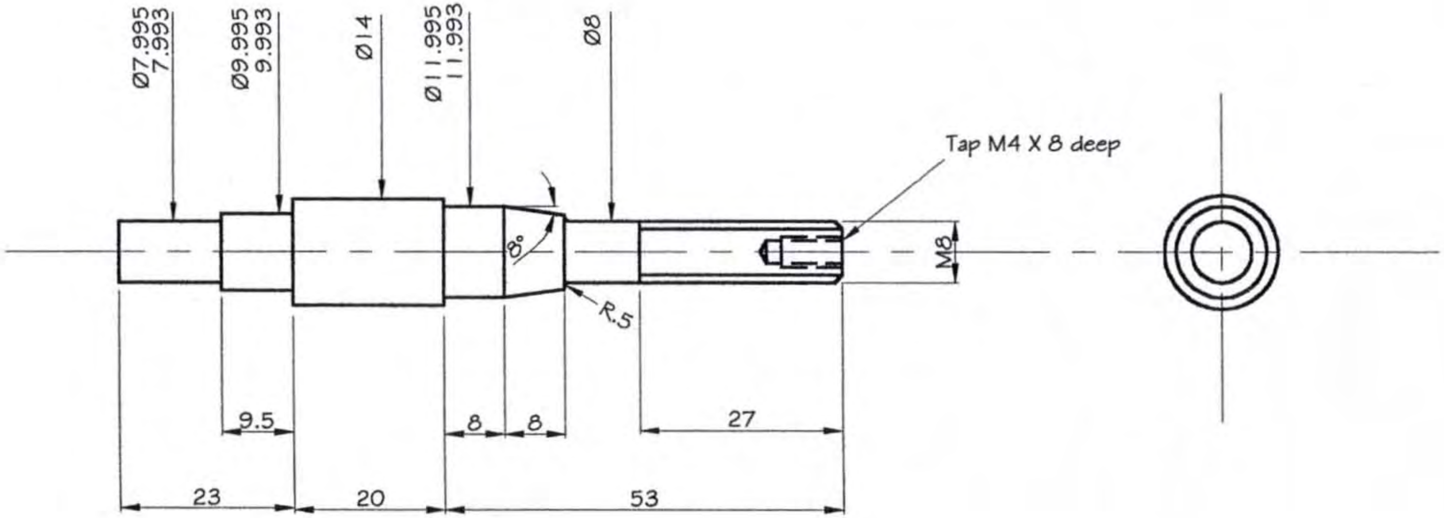
Dimensions in Millimeters



1) Assemble bearings to shaft as shown
2) Fit gear to shaft using retaining compound 'Loctite 601'
3) Drill 8 deep & tap M3 X 6 deep (on joint between shaft & gear)
4) Fit 2 grub screws M3 X 6 long until they 'bottom'

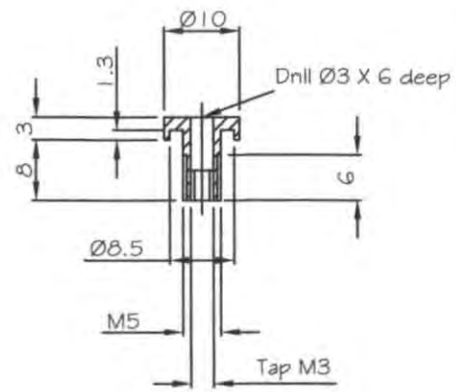
Designed by: Mike Murphy				Material: As details		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Prop shaft sub assy	Issue: 1	Part No. 162

Dimensions in Millimeters

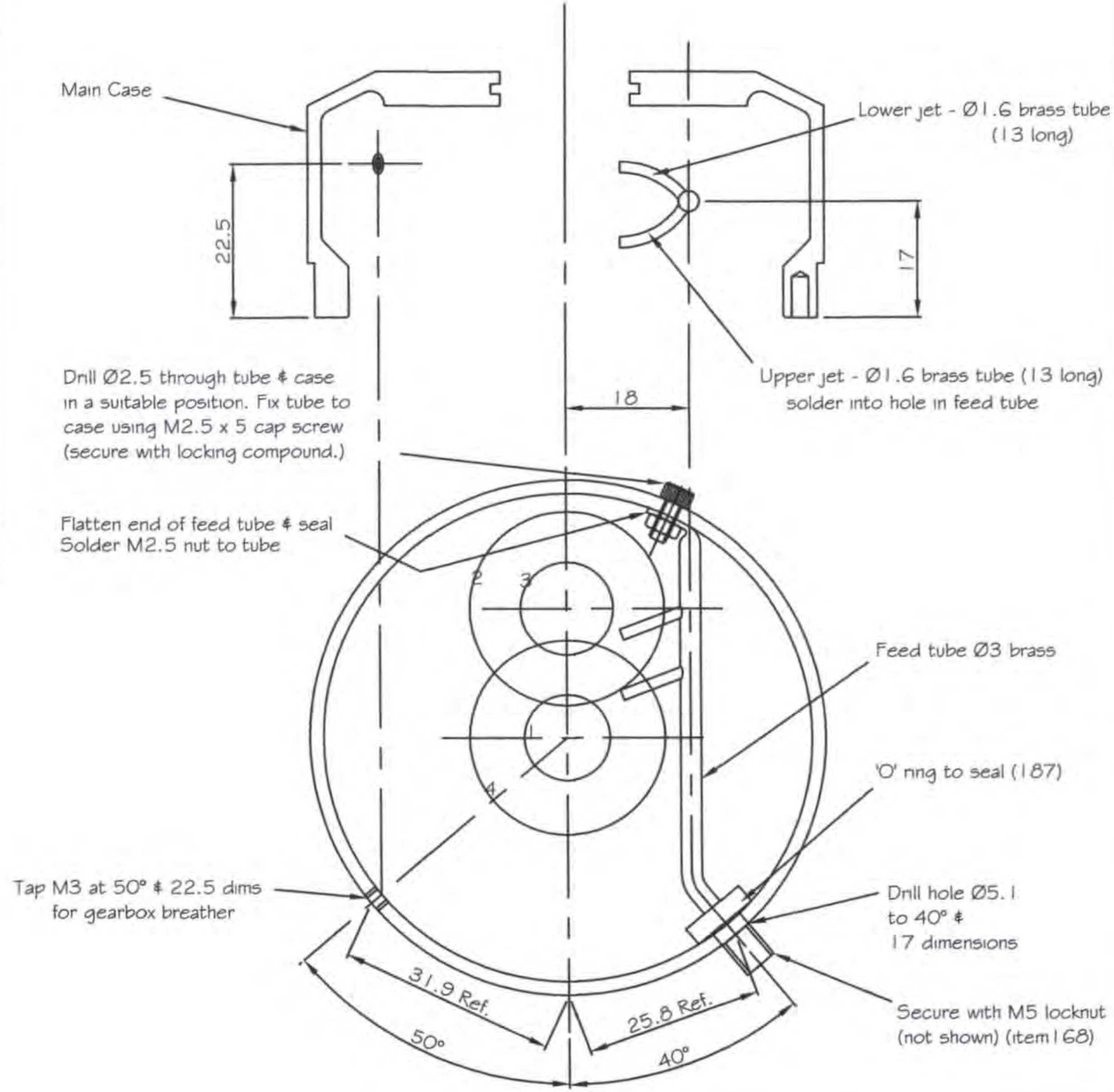


Designed by: Mike Murphy				Material: Steel - En24		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Prop Shaft	Issue: 1	Part No. 163

Dimensions in Millimeters

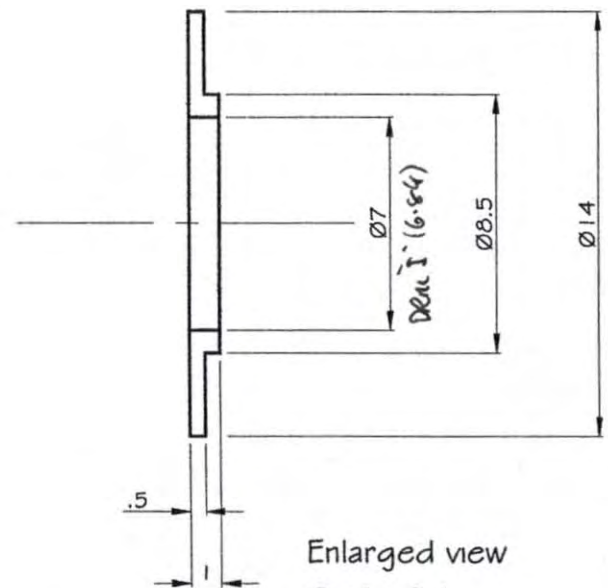


Pipe end fitting - Mtl: brass



Designed by: Mike Murphy				Material: As details		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Gear lubrication system	Issue: 1	Part No. 164

Dimensions in Millimeters



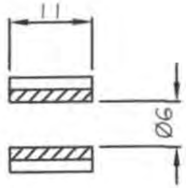
Enlarged view

Scale 4:1

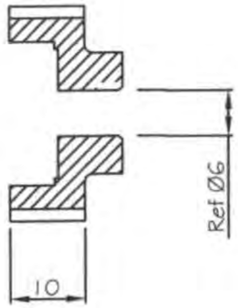
Actual Size

Designed by: Mike Murphy				Material: Steel		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Oil Thrower	Issue: 1	Part No. 166

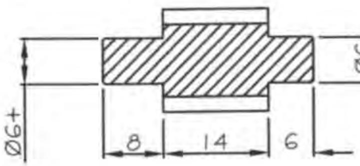
Dimensions in Millimeters



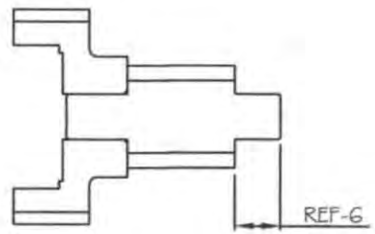
Gear 1
13 teeth
Item 170 - (Part No PHS 0.8-13 RH)



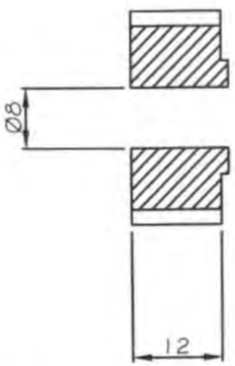
Gear 2
32 teeth
Item 171 (Make from Part No SH 0.8-32 LH)



Gear 3
11 teeth
Item 172 -(Special gear, but can be made from Part No SH 1-11 LH)



Gear 3 pressed into gear 2



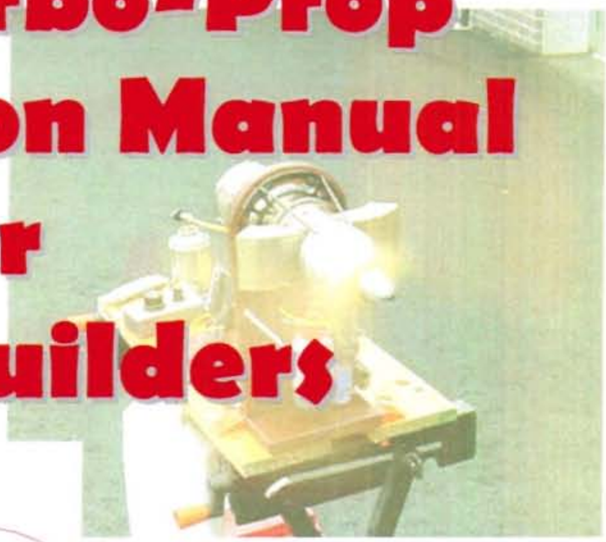
Gear 4
25 teeth
Item 173 (Part No SH 1-25 RH)

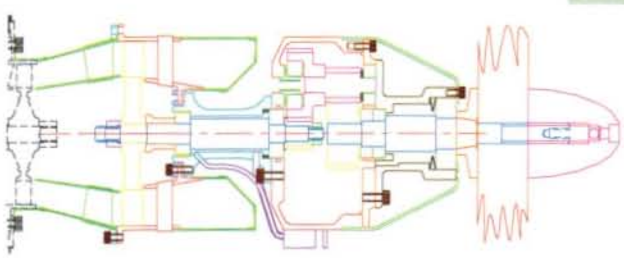
Designed by: Mike Murphy				Material: As details		
Drawn: Terry Lee	Third Angle Projection	© WREN Turbines	MW54 - Turboprop	Title: Gear set	Issue: 1	Part No. 169

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.

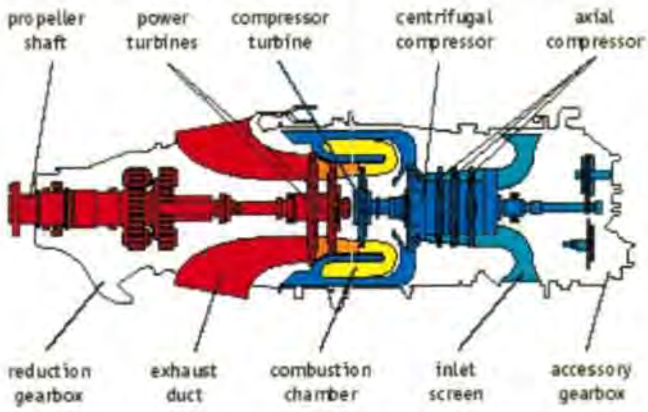
Rolls Royce "Dart"
This work laid the groundwork in April 1945 for the very successful Rolls Royce Dart turbo-prop (or RB.53 as it was initially known). This took the Derwent II principle several stages further by adding additional compressor and power turbine stages and a separate drive from the power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

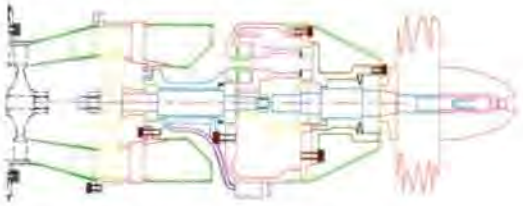
It is most important you do not attempt to run the power section without a suitable load fitted. Even running to just idle speed on the engine can cause the power turbine to overspeed if run off-load. This will cause blade rubbing initially and can result in blade and turbine shroud damage.

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.

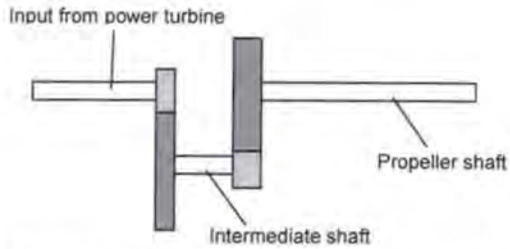
After passing through the power turbine the gas is collected in the exhaust plenum and is released out through two side mounted exhausts. The exhausts are angled rearwards to mix with the propeller wash, ensuring rapid cooling of the gas to about 90'C, at 200mm from the exit point.

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.

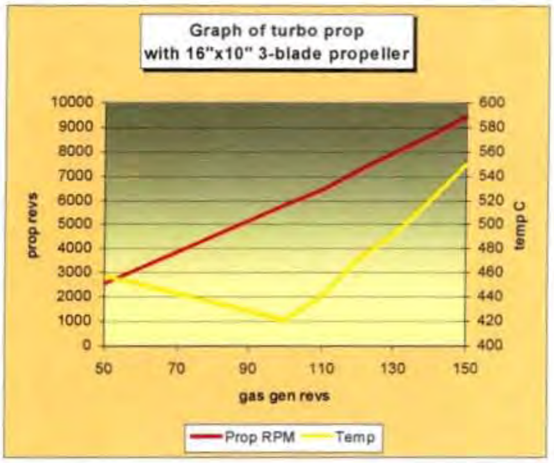
"Yippee"!
There is always a certain amount of excitement and elation when a new project runs for the first time – particularly when it's the first MW54 turbo-prop, and for myself it was no exception!
(April 2000)

Wren Turbines Ltd are at: Unit 19, Century Park Network Centre, Manvers, Rotherham, South Yorkshire, England. S63 5DE.

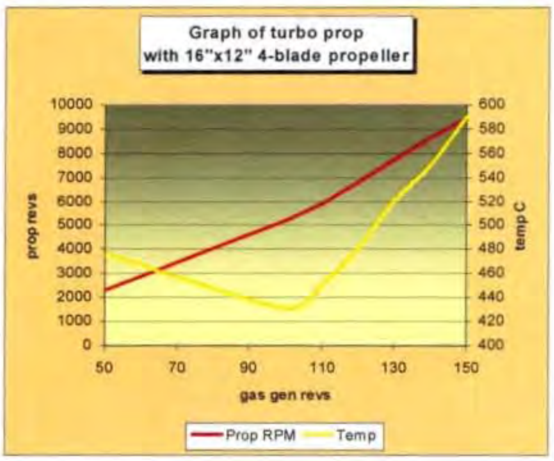
Tel. +44 (0)1709 877439. Fax. +44 (0)1709 875935
Email info@wrenturbines.co.uk

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.



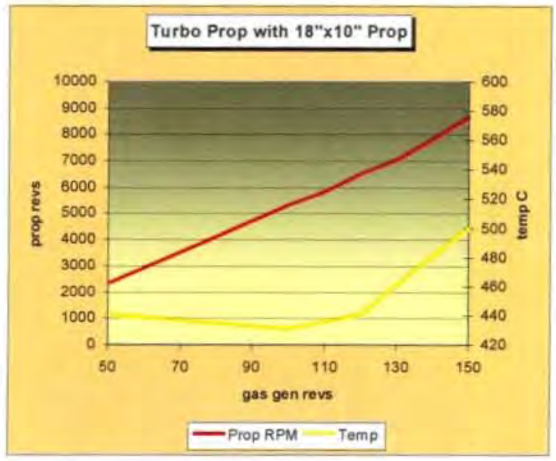
APC scimitar bladed, glass filled nylon.

Power produced guideline.

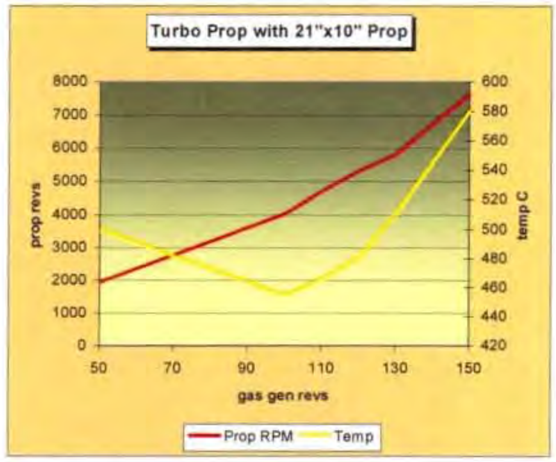
Power produced to drive the 21"x10" prop at 8,000rpm at a gas generator rpm of 155,000rpm is 7.1HP or 5.1Kw.

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, CO2 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.

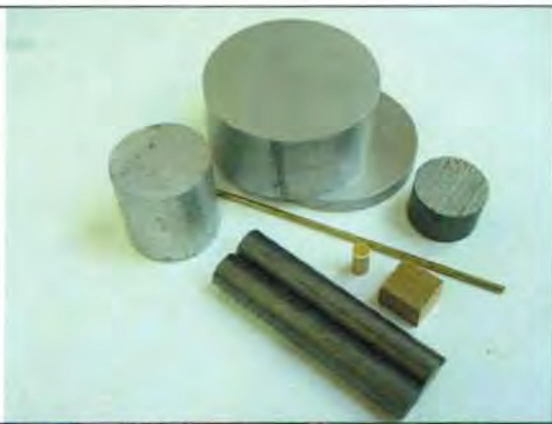
Mike Murphy,
Wren Turbines Ltd
March 2002.

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".

<table>
<tr><td>Boring the Power Turbine.</td><td></td></tr>
<tr><td></td><td>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.</td></tr>
<tr><td></td><td>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.</td></tr>
<tr><td></td><td>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.</td></tr>
<tr><td></td><td>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.</td></tr>
</table>

Fitting the Power Turbine.

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

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

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

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

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

Shaft Locking Flats.

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

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

Sizing the Power Turbine, 141.

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

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

Sizing the Power Turbine.. Lubrication System.

Power Turbine tip clearance.

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

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

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

Oil Drain Fitting, 151.

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

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

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

Turbine Bearing Lubrication System

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

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

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

Drilling the oil drain hole.

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

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

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

Drilling the shaft tunnel for oil and air pipes.

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

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

Manifold Block 148

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

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

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

Turbine Bearing Lubrication System

Mark out the various holes in the block. I used a felt marker to provide an easy to see surface for marking. Centre punch and drill holes to depths shown. A depth-stop on the drilling machine helps here. Be careful when drilling through with brass as it has a habit of snatching – use a drill vice, do not try to hold with your fingers, they will lose the argument!

When drilling for the pipes, drill slightly (0.1mm) undersize, and lightly linish (belt-sand) the pipe end to be a tight fit – this stops the silver solder wicking in.

Once the holes are drilled, tap the two M3 holes for the service fittings. Finally, remove the sharp corners with a fine file.

Air and Oil feed pipes 149 & 150.

Prepare the two feed pipes to the length shown and lightly chamfer the end to be a snug fit into the block (as above). Anneal the brass tubes to prepare for bending by heating to red hot and quenching in water. Clean up with fine emery.

Make the bends to suit the drawing – I found this easy if you turn a mandrel in brass in the lathe (see left). This is simply a couple of grooves turned to the same width as the tubes, square bottom grooves are ok. This stops the tube collapsing as you form the bend and is then quite easy to do with the fingers.

Securing the oil and air pipes to the manifold.

Attach the shaft tunnel to the gearbox with a couple of screws. Secure the manifold block to the gearbox using the oil drain fitting and then insert the oil and air pipes into the shaft tunnel and manipulate them into a comfortable position.

Carefully remove the shaft tunnel and manifold from the gearbox and attach a clamp to act as a heatsink on the air pipe. Carefully flux and silver solder the pipes into the manifold using a low temperature (605'C) silver solder such as "EasyFlo No.2" or similar. Once cool, any misalignment in the pipes can be corrected.

(N.B. note tolerance ring in position, at left)

The lube sub-assembly can now be carefully removed and cleaned up to remove flux and get a clean finish. Fine emery paper does a good job in conjunction with a rotary stainless steel wire brush inserted into your "Dremel" to get into the awkward bits.

Mark the two service ports with a fine engraving tool to show "oil" and "air".

Turbine Lubrication System.	
	The position of the oil pipe outlet can be seen at left, exiting by the bearing seat.
	**Sealing the oil and air feed pipes.** Refit the shaft tunnel to the gearbox with a couple of screws and secure the manifold to the gearbox using the oil drain fitting. Adjust the pipes to the correct alignment and seal the pipes into the shaft tunnel using thick cyno' glue. When set, apply a smear of sealing compound to cover the joints.
	**Gear Lubrication System, 164.** The "dry sump" lubrication system is the part of the system that feeds lubricating oil to the gear-train inside the gearbox. It consists of a feed-pipe assembly, mounted in the gearbox with a pair of injector pipes protruding from the side and bent to flow the oil directly into the mesh of each pair of gears. Connection to the oil pump is via 3mm quick release connector. A special fitting at the base of the feed pipe under the gearbox, contains a sealing o-ring to prevent oil leaks and to provide a firm mounting to the gearbox case.
	**Pipe end fitting.** The end fitting is the first item. This can be turned as a single item or made up in two pieces silver soldered together. I show it made in two pieces. Turn the 8mm brass rod from the materials pack, down to 6mm diameter and then turn to 5mm for 10mm long. Thread M5 to a length of 6mm. Centre and drill right through 2.5mm and tap M3 x 4mm deep.

Gear Lubrication System.

Turn the rod around and machine the other end to 4.5mm diameter up to the 6mm portion, leaving this as a flange 1mm thick. Turn to 14mm long overall. Drill the end one drill size smaller than the pipe for a distance of 6mm.

Remove from the chuck. The drilled hole is to take the brass pipe included in the materials pack. At this stage it will be too tight to go in.

Grip the brass tube gently in the chuck and with the lathe running, gently file a shallow taper sufficient to allow the pipe to go into the hole fairly tightly. This ensures when the part is silver soldered the solder does not block the pipe.

Grip the 10mm brass bar in the chuck, face and centre and drill through 4.5mm.

Use a small boring tool to bore a recess into the end 8.5mm diameter and 1.5mm deep. This is to take the O-ring and allows 0.1mm of compression to seal the ring tightly against the gearbox inner wall.

Finally, part off to a length of 3mm.

De-burr the inner and outer edges using an appropriate tool.

The two parts can now be assembled together and should look like this.

The small flange goes against the top of the O-ring "cup".

The brass tube can now be inserted firmly and the whole assembly fluxed and silver soldered together.

Use low melting point silver solder – "Easyflo No.2" or similar which melts around 605'C.

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

Lubrication System – Internal	
	Silver solder an M2.5 nut to the flattened portion of the brass pipe, and seal the flattened pipe end at the same time. Grease any screw you use to hold it into place as it will all blend into a solid lump otherwise!
	Mark off and drill the two 1.5mm holes for the brass injector pipes. Cut these from a length of 1.6mm (1/16") brass pipe. One end of the pipes should be lightly reduced by linishing or filing in the lathe until they just push fit into place in the 1.5mm hole. Silver solder into place, and then clean up the fitting with fine emery. Relocate the fitting into the gearbox as we need to mark the securing screw hole.
	Use a steel rule to point to the M2.5 soldered nut, and sight along this to highlight the location for the drilled hole for the fixing screw, for securing the flattened end of the fitting. Mark the gearbox at the point with a line or arrow (see left). Continue the line down the outside with a square. Measure 17mm from the front face of the gearbox along the line, and make a centre-punch mark. Drill through 2.5mm diameter for the fixing screw.
	Fit the intermediate gear onto its bearing and fit onto the stub-shaft. Fit the power turbine shaft with its bearing the small pinion gear and M5 nut, and locate into the gearbox rear. The exit position of the lower injector is adjusted by gently bending, until it points at the centre of the meshing gears, with about 2mm clearance. If less than this make a felt pen mark for shortening later. Hold the larger prop-driver gear into mesh on the intermediate gear and in the correct position right over the smaller pinion gear. The upper injector is then adjusted in the same way, pointing halfway along the gears and with 2mm clearance. When done remove, and trim the injectors as required.

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

Drilling the prop-shaft tunnel oil drain.

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

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

Clamp Ring, 143.

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

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

Prop Driver, 160.

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

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

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

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

Err on the generous side if unsure.

Prop Driver.

Once the taper is completed, turn the rear boss to 17mm diameter and a length of 4mm. Only do this after the taper is completed as there is plenty of material for you to keep making adjustments if required.

When the boss is complete, reverse in the chuck and grip with the smallest overhang you can on the outside.

Machine the bulk of the excess material off to get to about 9mm length, then grip on the smaller boss diameter to machine to finish length of 8.5mm.

Use a small boring tool to bore out the centre recess to 12mm diameter and 1mm deep.

Grip the outside of the Prop-driver and machine the taper in the rear. This angle and shape is not critical as it is to tidy it up and lose some weight. I machined the back taper with a parting tool, considerably extended to get the reach, and took small cuts. You can use your flair to get a shape you like, but don't make it too thin at the centre as it may not grip so well on the taper.

Finally, grip on the boss and clean the outer faces up with fine emery. Do not polish the taper or the prop face as both need a certain amount of roughness to grip. You will find the prop will self-tighten during running and this is normal.

When the prop is first tightened and the power unit is run, the prop driver will lock into place onto the shaft taper.

If you need to remove the prop-driver, gentle heating with a hot-air gun or blowtorch will expand it slightly and release it. Do not try bashing it or levering it from behind – you will almost certainly damage the bearings and the prop-shaft housing.

The front bearing will only seat fully back into place when the cowl is fitted, so do not worry if there is a slight protrusion of the front bearing before the cowl is on.

Spinner.

Spinner, 161.

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

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

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

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

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

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

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

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

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

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

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

Exhaust System.

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

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

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

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

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

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

Exhaust cone, 132.

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

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

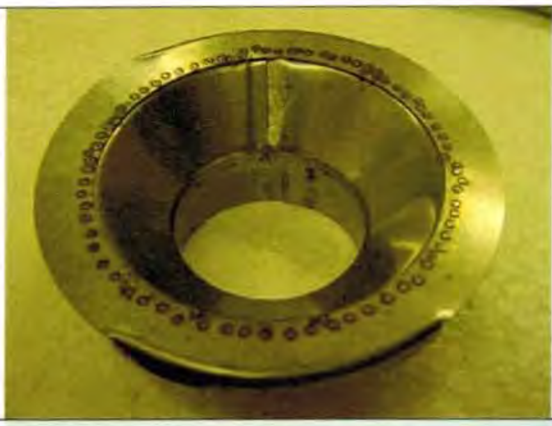
Once done, apply a weld to the other end and then weld the seam with welds about 2-3mm apart.

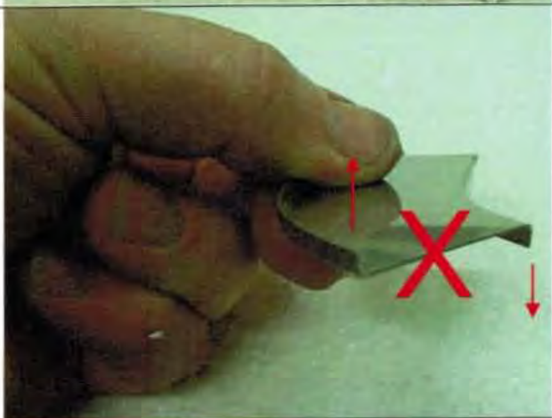
Sand/grind the seam on both sides to smooth the joint and take some of the bump out of it, as we need to spin the inner and outer flanges and a large bump here can cause trouble.

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

Exhaust Cone and Inner	
	The flange can be seen in the centre of the block from the rear. The block shown, was previously used to spin combustion chamber fronts for the prototype MW54 – hence the extra chamfer!
	**Exhaust Inner, 128.** This is simply rolled up from the strip of 0.5mm stainless laser cut set, and welded to make a tube of 34mm internal diameter, which is a tight press fit to the Exhaust Cone.
	The Exhaust Inner is aligned carefully and spot-welded into place. Make a couple of opposite tacks first, check and confirm alignment and then weld all around. Once welded, use a sanding drum and sand/grind the seams to tidy them up and enable a sliding fit into the centre section of the spider casting.
	**Exhaust Front, 131.** This part is a 0.5mm thick stainless disk with a centre hole and pair of "ears" which are folded down to provide flanges for the top and bottom sections of the exhaust to weld to. The disc is part of the laser-cut component pack and only needs a simple pair of formers to make the flange required. Cut two disks from 10mm thick birch plywood or MDF, diameter 75.5mm and with a 6mm centre hole. Finish them on the lathe if needed, to get then nicely round. Round off one edge of one of the disks very slightly, to about 0.25mm radius (just take off the sharp corner).

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

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

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

Exhaust Stack.

Exhaust Stack Front, 135.

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

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

Exhaust Stack Rear, 133.

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

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

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

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

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

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

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

Exhaust System

Exhaust Outer, 130.

This is simply rolled up and spot welded from the laser cut piece. Make the seam 3mm overlap, and do a single spot at each end of the seam and check the fit over the Interstage Spider casting – it should be a firm push-fit.

Check also the fit into the Exhaust Front – this should also be snug. If either are not quite right, break the tack and correct. When fits are good, you can weld up the seam properly.

Finally, clean up the seam with the drum sander as before.

Fit the Exhaust Front onto the Exhaust outer, aligning each component as best you can.

Apply a couple of spot tacks on each side, pressing the front firmly in position before each one. Once positioned correctly you can weld up the seam with the Exhaust Front. Tap along the seam with a small hammer to gently flatten any bumps and close up the seam.

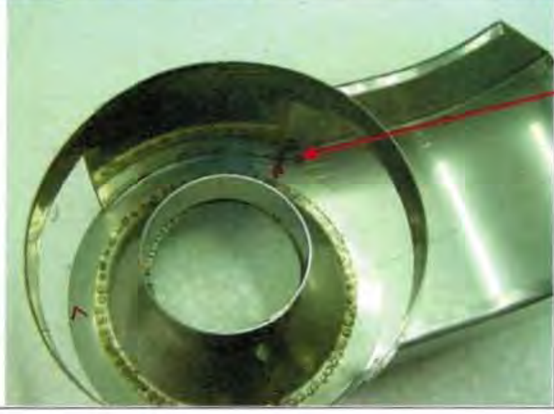
Use a drum sander in the "Dremel" to clean up and remove all weld traces.

Exhaust Stack, 127.

Each exhaust can now be built up.

Start by spot tack-welding the Exhaust Fronts onto the outer edge of the flange on the Exhaust Stack, Tops and Bottoms.

Align the tops and bottoms with the edge of the Exhaust Front.



Offer up the right-hand exhaust assembly to the Exhaust Front and Outer, and align the top right hand edge with the opening in the Exhaust Outer – see left.

This recognises that the gas flow from the power turbine still contains considerable swirl in the clockwise direction, and this tends to hug the top right and bottom left of each exhaust pipe. Providing a clearer opening for this helps to ensure more efficient excavation of gases and cooler running for the engine

Exhaust System

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

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

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

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

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

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

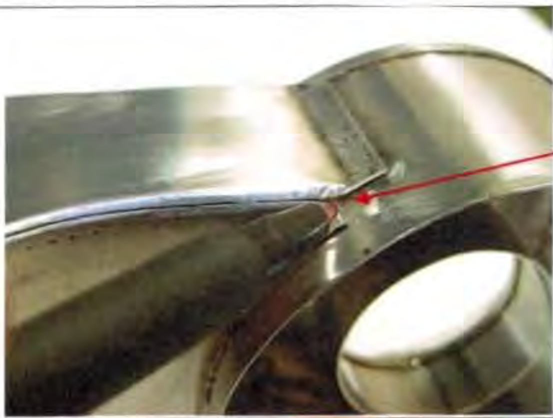
Hold a straight-edge across the front of both Exhaust Stacks to ensure they are in line with each other.

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

Exhaust Stack Rear, 133.

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

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

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

Balancing the Power Turbine

Balancing.

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

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

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

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

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

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

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

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

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

Assembly.	
	**Assembling the power unit.** It is assumed that all parts have been made and that items shown as assemblies have also been completed. These include prop shaft, intermediate shaft, intermediate shaft bearing support spigot, power turbine shaft tunnel lubrication assembly, internal lubrication assembly. Any bearings that have been used for assembly purposes need a thorough cleaning and oiling. All parts need cleaning to remove swarf or dirt. Many of the parts are thread-locked on assembly and we recommend "Loctite" products, the relevant product number will be quoted to aid selection. Others can also be used as long as they are selected with regard to duty required.
	The high-speed pinion must be securely held on the shaft as it transmits all the turbine torque. Grip the shaft in the vice after wrapping in 1mm aluminium sheet. Slide the special bearing 175, into place after lightly oiling the race, ensuring the cage faces the gear end. Degrease the shaft end and pinion hole. Slide on the oil thrower, large diameter to bearing, and apply a coating of Loctite 601 "Retainer" locking fluid. Slide pinion in place with a twisting action ensuring liquid spreads along the hole. Apply Loctite 601 to the M5 thread and screw on the nut firmly. Wipe away any surplus fluid ensuring none gets into the bearing. If you have not already done so, fit the O-ring cord 186, into place in the gearbox rear using a light smear of silicon grease.
	Slide the tolerance ring 185, into place at the turbine end of the shaft tunnel. Carefully insert the ceramic turbine bearing with the arrow pointing out. Gently press this into place by pressing against the outer race – not the centre. Insert the shim washer 180, into the front end of the shaft tunnel followed by the two wavy washers 181. Lightly coat the outside of the front bearing on the turbine shaft using a smear of silicon grease – note do not get any in the bearing raceway. Carefully insert the shaft into the shaft tunnel and check you have about 0.5mm movement until the shaft meets the shoulder of the turbine bearing inner ring. Do not force this as you may push the bearing inner out.
	Leaving the shaft in place, apply a smear of low strength liquid gasket compound, available from car accessory stores, to the front face of the shaft tunnel and the underside of the manifold 148. Wait a minute or so for the compound to thicken and ease the shaft tunnel onto the gearbox rear, using the bearing as a peg to ensure perfect centring. Fit the six securing screws 192, into place using a trace of thread locking compound ie "Loctite 241" or similar on each. Tighten evenly and firmly. Check the shaft is able to slide out of the shaft tunnel forward into the gearbox. Replace the shaft into position.

Assembly.	
	Slide the fibre washer 151, onto the oil drain adapter 167, and smear some liquid gasket compound onto the thread and screw it into the gearbox, securing the manifolds into place. Clean up any excess gasket compound squeezed out with cellulose thinners, before the compound has set.
	Insert from the inside, the four M3 x 8mm (192) screws through the tapped holes in the gearbox. Thread-lock these firmly into place. The exhaust, spider and power turbine assembly needs fitting now. It is assumed you have attached the Spider 102, to the Exhaust assembly 103. To minimize heat transfer from the exhaust to the turbine bearing, the shaft tunnel has to have an insulating blanket fitted. Wrap the shaft tunnel in a thin layer of the ceramic fibre wadding and secure with the strip of metal supplied. Wind a couple of turns of stainless locking wire around to hold the strip into place. The strip supplied may be different from shown, but will do the same job.
	Fit one of the special gaskets 144, into the inner face of the Spider casting, orientating the holes carefully, and slide the whole Spider/Exhaust assembly over the end of the shaft tunnel. Align the holes in the Spider to the shaft tunnel and confirm the correct location. The lubrication manifold 148, should sit at 90^0 to the Exhaust Stacks. Fit the second gasket onto the shaft tunnel over the Spider and again orientate the holes.
	Place the Clamp Ring 143, over the end of the shaft and orientate the holes. The six M3 x 10mm screws 191, can now be fitted complete with their locking washers 199, (note the prototype (left) shows pozi-drive screws but cap heads should be used. Apply a drop of thread locking compound on the threads before insertion, to provide a doubly secure fixing.

Assembly, Mounting System.

Fitting the turbine wheel, 141.

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

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

Mounting system, 106.

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

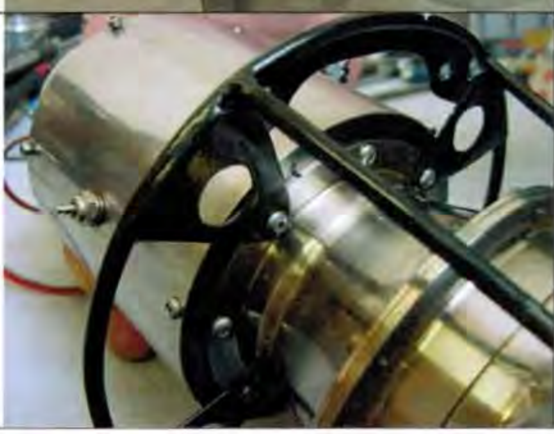
The mounting secures to the outside edge of the gearbox with four bolts, and the junction of the interstage ngv and engine, picking up on the ngv screws, lengthened for the purpose. The turbo-prop assembly can then be simply mounted to a bulkhead in the aircraft or test-stand, using four M4 bolts and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

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

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

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

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



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

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

Bulkhead Mounting, Assembly.

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

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

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

Assembly - Gearbox assembly, 105.

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

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

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

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

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

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

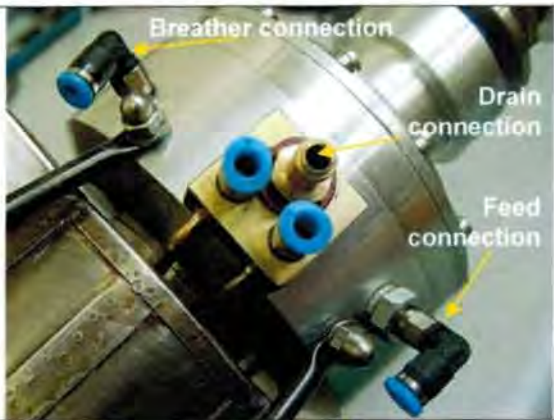
Intermediate shaft pre-load springs, 183.

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

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

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

Assembly.	
	Fit two wavy washers onto the end of the intermediate shaft and ease the front cover into place, ensuring the dowel pin aligns correctly. When there is sufficient pre-load you should find a small gap of approximately 0.5-0.8mm between the front cover and gearbox case. Use a feeler gauge to check the gap. If the gap insufficient add one washer, if too large then remove one washer. Once the gap is correct remove the cover to fit the prop-shaft sub-assembly.
	Insert the prop-shaft sub-assembly 162, into the front cover and ensure the bearings are fully seated. Fit the two spring washers 184, back to back as drawn and apply a smear of gasket compound to the front bearing 178. Slide the bearing onto the prop-shaft and into the prop-shaft housing. The rubber shield should face outwards.
	Apply a smear of gasket compound to the front of the gearbox and refit gearbox front assembly, ensuring the intermediate shaft wavy washers are in position. Secure with twelve M2.5 x 6 screws 190, using a drop of thread-lock on each and tighten evenly. Wipe off any excess compound whilst still fluid.
	Fit the cowl in place using the eight M2.5 x 5mm securing screws, 189. Use a smear of locking compound on each and tighten evenly. Note, the cowl will push the front bearing back into its working position as you tighten the screws. Picture shows earlier plain cowl with 4 screw fixing – now eight and anodised green! By now it should be possible to turn the prop-shaft and feel how the gears run. They may feel a little stiff initially but this will ease after a few minutes running. If they feel tight you will need to investigate further.

Installation - Gearbox Oil System	
	The gearbox oil system is a dry sump system – ie no oil is held in the gearbox. Oil is pumped from a separate oil tank with a small electric pump to the oil manifold and onto the gears. The gearbox has a breather which is connected to the tank, so that oil droplets are saved. A pick-up filter is fitted to the suction line to the pump at the tank end. A magnet in the bottom of the tank retains any small metal particles and sludge helping to keep the oil clean. Oil contents should be 60ml or greater. A low friction additive (10%) is mixed to the oil to enhance gear life. An air pressure switch is used to turn on the oil pump when the engine has reached about 0.05Bar (about 1psi).
	The **breather** pipe needs to finish at the top of the oil tank. The oil **drain line** must be a minimum internal diameter of 3.5mm. The **feed line** connects pump outlet to oil feed connection. The **suction line** connects the tank pickup to the oil pump, via a suitable filter fine mesh filter (not felt). The **oil pump** is a standard fuel-type pump operating on 1-cell switched with a pressure switch, or via an output from the ECU. The **oil tank** must be positioned so that the oil level in the tank is at least 25mm below the bottom of the gearbox, when installed in the model. To ensure correct operation position oil tank as close to drain connection as possible, preferably directly underneath the gearbox.
	**Lubricating and cooling the power turbine bearing.** The power turbine bearing is lubricated with fuel tapped off the engine fuel pressure line. The feed is taken from a special restrictor and enters via a **fuel connection** on the manifold block. The bearing is also cooled using a supply of cooling air taken from the engine case pressure. This air is fed to an **air connection** on the manifold block. Both these service pipes need routing past the exhaust system – be sure to protect them from possible heat damage.
	**Prop-driver, spinner and spinner retention bolt.** The prop driver 160, is locked into place when the propeller is fitted to the shaft and tightened up with the spinner nut 161, for the first time. After this the driver should remain in position. To remove, heat with a hot air gun to expand it, when it should release easily. The spinner retention bolt should be adjusted in length until it sits flush with the end of the spinner (as left), **note; it must not be fitted right into the recess.** If you plan to use a range of props with different thickness hubs, you will need to make additional retention bolts for each thickness of hub.

Installation – mounting.

Mounting options.

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

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

The first prototype turbo-prop to fly was fitted to a 2.4m span "Pilatus Turbo-Porter". This used the power unit secured to a pair of 13mm square aluminium rails, which were subsequently bolted to the airframe. All up weight was 8.2Kg (18Lbs).
The nose of the aircraft was too narrow to allow sufficient airflow to the intake of the engine and the power unit ran hot. Cutting an extra inlet with a forward facing scoop helped greatly and many successful flights were subsequently made. The ideal position for additional cooling air is right over the intake, as this allows cool air to pass directly to the engine. If taken from further forward, the exhaust system tends to pre-heat the air somewhat, raising the engine running temperature.

Our second flying plane was a 2m span "Tucano". For this we extended the exhausts slightly to clear the nose and made an extra-long prop-shaft to enable the engine to be sited further into the fuselage. Weight here was 10Kg (22lbs).
All the engine oil system, oil tank, fuel pumps etc, were mounted on the rails as earlier, but built-up as a complete sub-assembly to enable quick fitting and refitting by unscrewing just four bolts and disconnecting the fuel feed pipe (to show off mainly!). This was the first time an ECU was used to run the engine and this was also mounted on the base. To stop the engine "finding" small bits of balsa and screws etc, a metal grill was fitted to the intake and the electric starter and other services were attached to the back of this.

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

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

Setting Up for Testing.

Test stand.

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

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

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

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

Temperature sensing.

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

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

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

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

Setting Up for Testing.

Preparing for first starts.

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

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

Lubricating Oil.

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

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

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

Starting for the first time.

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

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

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

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

After Running In.

Exploring the Power Curve.

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

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

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

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

Lubrication – Service Intervals.

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

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

Servicing checks.

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

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

Servicing Checks, Cont.

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

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

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

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

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

Cool-down after running, procedure.

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

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

ECU Settings.

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

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