Turbine Dynamics

Down Hole Power and EM Telemetry

"Performance beyond Expectation"

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100 Watt Turbine Alternator Manual.

Contents.

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1.0) Introduction

This document describes the tools and methods required to assemble and disassemble the Turbine Dynamics 100 Watt closed loop mud alternator for cleaning and general inspection prior to a down hole run. The body of the turbine is 55mm OD (2-1/6”) by 1250mm (49.2”) long and designed to nominally produce 33V and 3A at full load, making it nominally compatible with existing battery stack voltages. Although the turbine electronics are fully potted for shock and vibration resistance, end user can programme the regulated voltage to suit their application after manufacture or in the field by changing one or no more than two surface mount resistors. The turbine is delivered with a customer specific impeller and two centralisers to suit the customer’s collar ID. The minimum centraliser OD Turbine dynamics recommend is 2-13/16” to suit a standard 4-3/4” OD drill collar. Larger drill collars can be accommodated simply by fitting correspondingly larger impellers and centralisers to suit the increased ID of the drill collar. No other changes to the tool are required because unlike any other turbine currently available, this turbine is self regulating and automatically compensates for changing down hole flow conditions. A detailed analysis of the turbines’ performance against flow rate is outside the scope of this document, but is available from our web site together with its oil field specification and other supporting documents. Under certain circumstances a flow sleeve can be added between the centralisers to increase stiffness, but we recommend this option is discussed with Turbine Dynamics Ltd before it is implemented.

2.0) The Turbine

Fig 1 illustrates the turbine in two possible states of assembly. The top image shows the turbine without a flow sleeve and illustrates the main sections under discussion. The bottom image shows the turbine fitted with an optional 2-13/16” flow sleeve which surrounds the rotor and impeller. Top and bottom pressure cases are not shown for clarity and the brass transit nut shown in Fig 1 is used to keep the lower centraliser and if fitted, the flow sleeve in place during transportation. Flow is from bottom left to top right.

Fig 1: Closed Loop Turbine with and without the 2-13/16” flow sleeve.

Fig 2 is a schematic representation of the turbine.

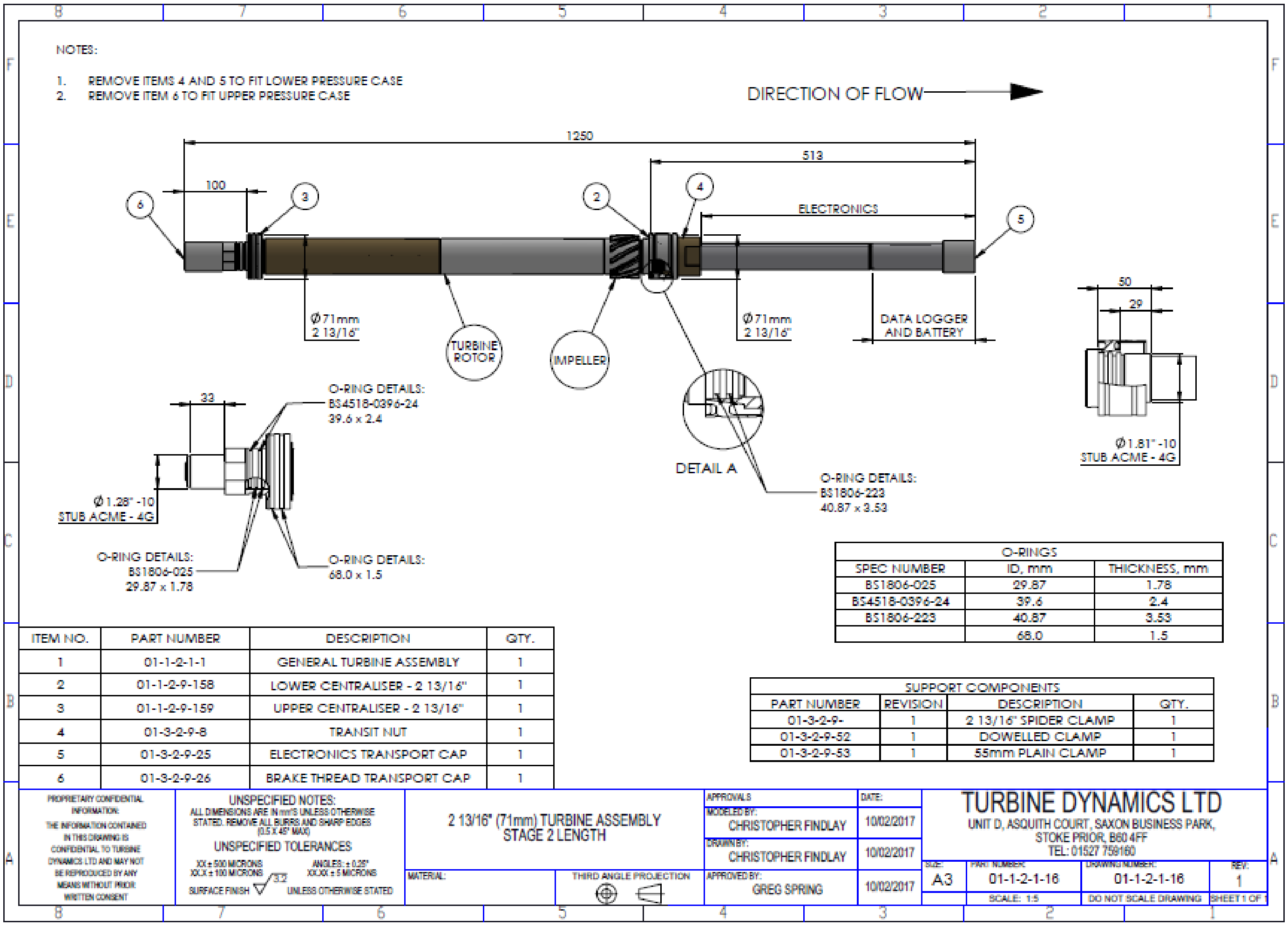

Fig 2: 2-13/16” Closed Loop Turbine Schematic.

3.0) Assembly & Disassembly Tools

There are four special tools needed to assemble and disassemble the turbine and these are shipped with each turbine to ensure it can be routinely maintained and serviced any where in the World. These are illustrated as follows:

1) Fig 3: 55mm Pressure Case Clamp.
2) Fig 4: 55mm Turbine Clamp.
3) Fig 5: 70mm Spider Clamp.
4) Fig 6: 35mm Rotor Alignment Tool.

In addition, a 52mm open spanner is required to remove the transit nut, a 41mm open spanner is required for the upper centraliser lock nut and a 17mm spanner is required for the three clamping tools. A soft faced mallet is also useful for removing the upper and lower centralisers as will be discussed later. These tools are not supplied with the turbine.

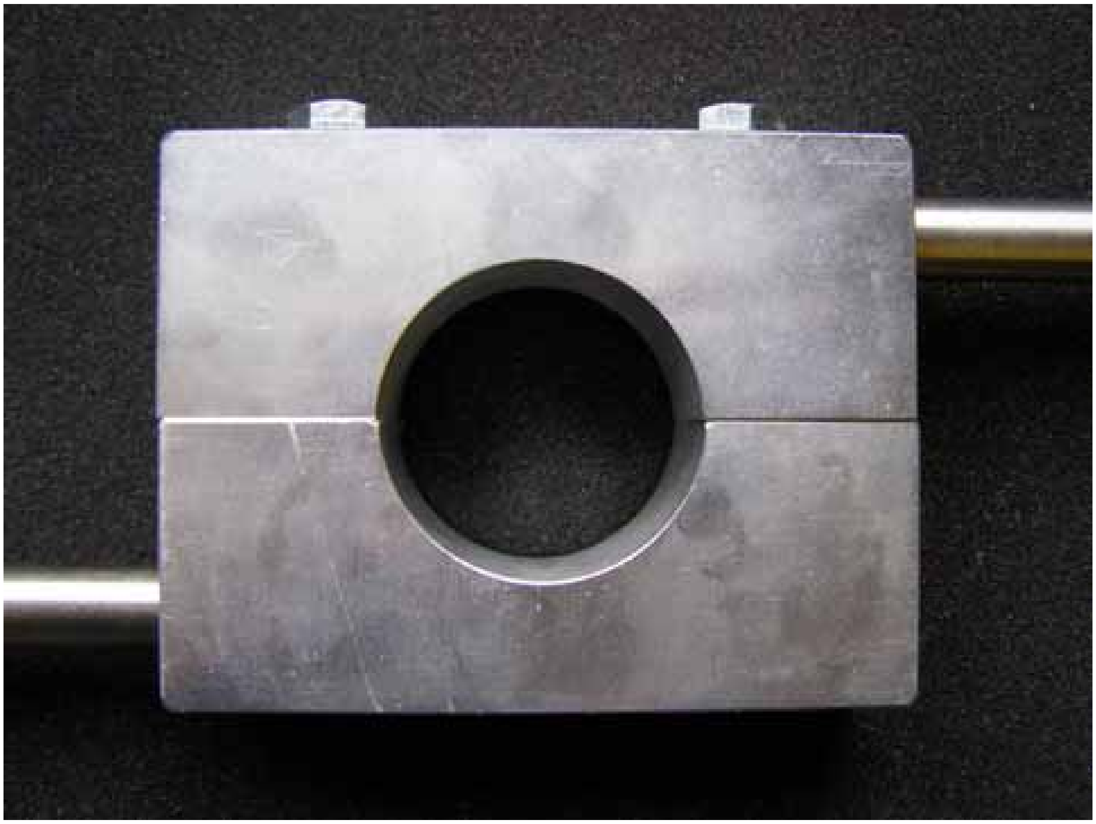

Fig 3: 55mm Pressure Case Clamp.

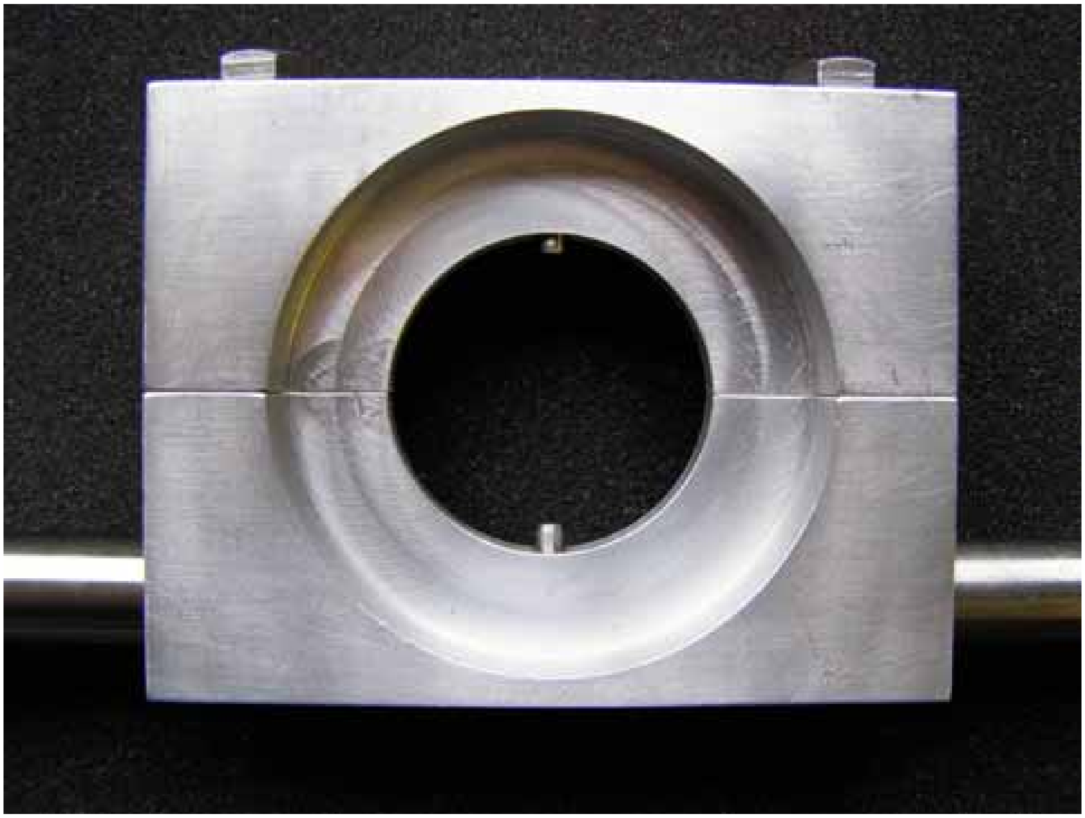

Fig 4: 55mm Turbine Clamp.

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Fig 5: 70mm Spider Clamp.

Fig 6: 35mm Rotor Alignment Tool.

4.0) Electrical Tools

The turbine is fitted with two 19 way Lemo sockets wired end to end to allow the turbine to fit seamlessly within existing drill string instrumentation. Wiring diagram 011143 copied to Fig 9 documents the function of each pin and how they relate to the turbine's electronic regulator. To facilitate accurate and reliable wiring to third party equipment, each turbine is shipped with two Lemo test plugs shown in Fig 7 and wiring diagram 011144 copied to Fig 8 documents the pin to pcb wiring of this component.

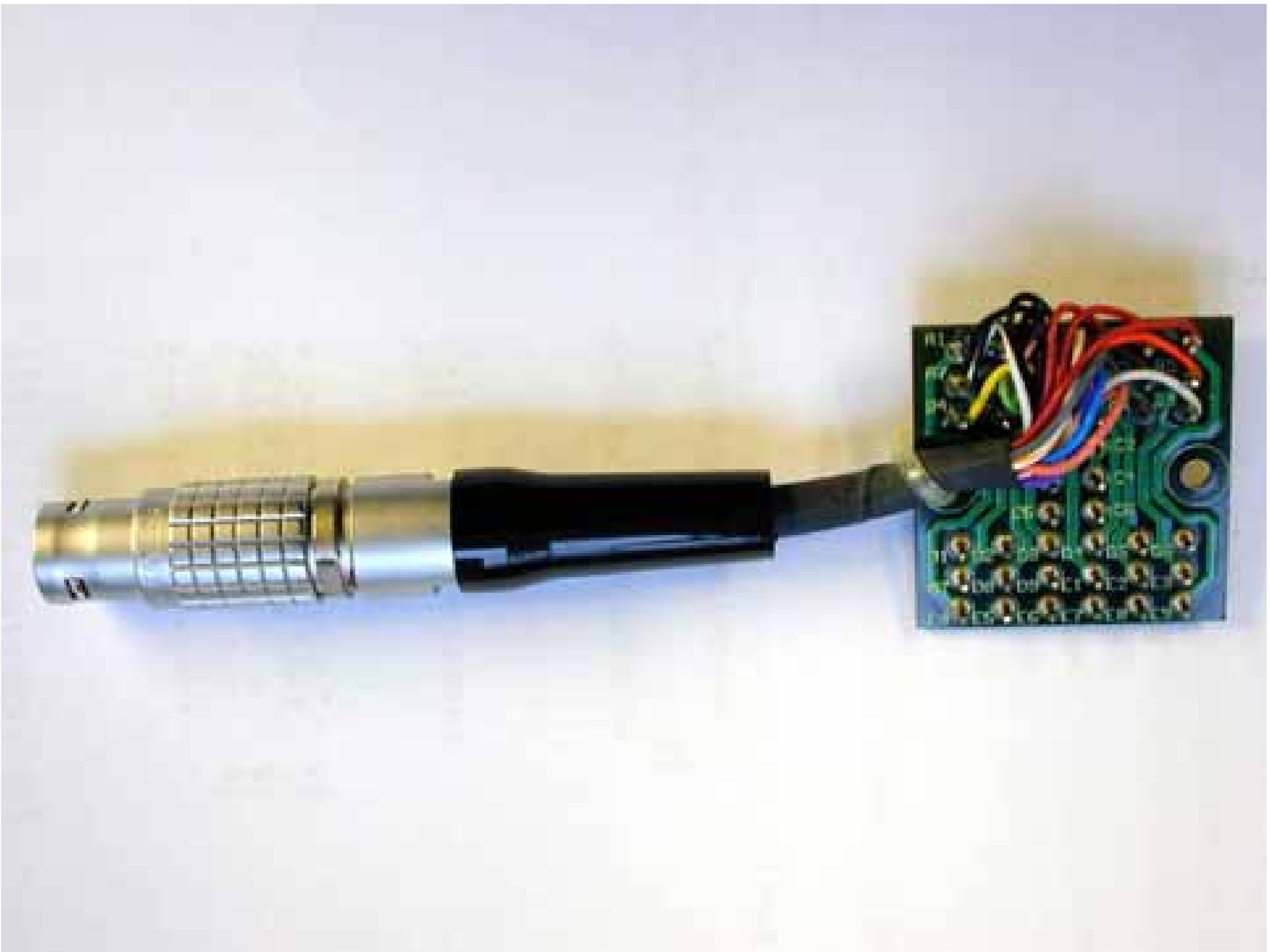

Fig 7: 19 Way Lemo Test Plug.

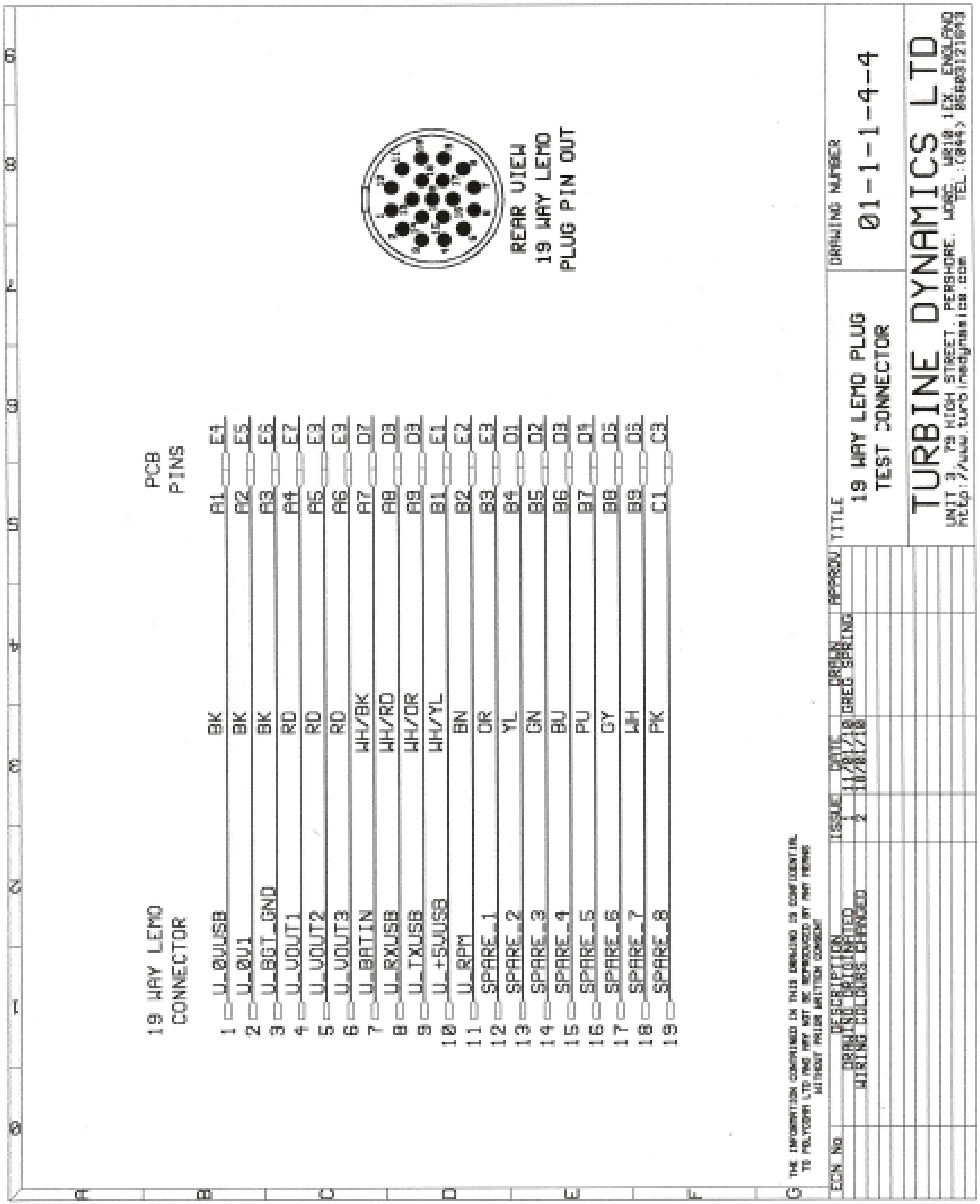

Fig 8: 19 Way Lemo Test Connector Wiring Diagram 011144.sch

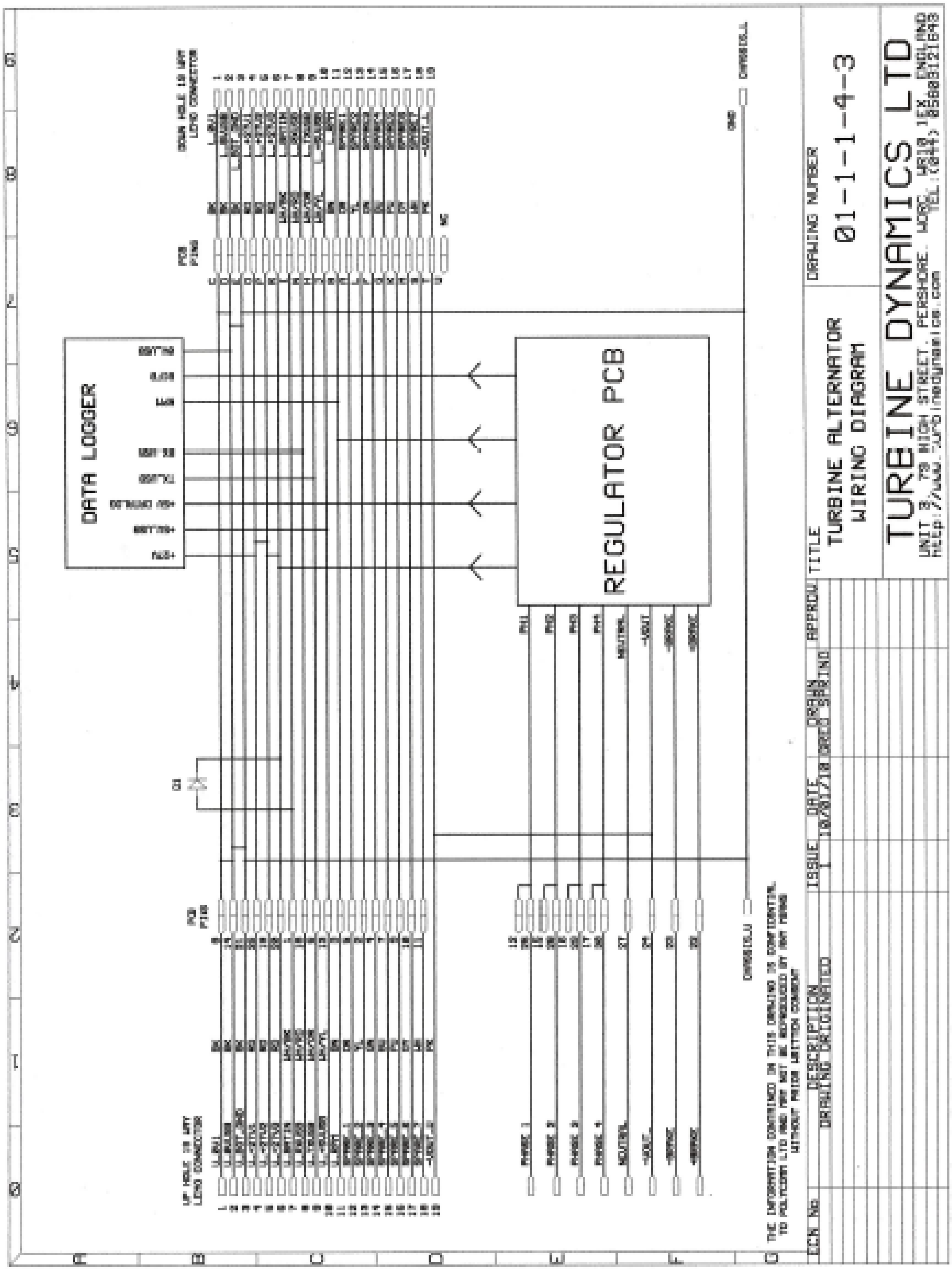

Fig 9: Turbine Alternator Wiring Diagram 011143.sch

5.0) Disassembly

Most Engineers will want to immediately take the turbine apart to inspect the various components and understand how the tool fits together. To facilitate this interest, the following illustrations detail how to safely disassemble and reassemble the turbine for down hole service. With a 2-13/16" flow sleeve fitted as shown in Fig 10, it is essential that the upper centraliser and flow sleeve are removed before any attempt is made to remove the transit nut and lower centraliser. Fig 10 illustrates the top of the turbine delivered straight from the transit case with the upper protective cap removed to show the upper Lemo connector, lock nut, upper centraliser, pressure case 'O' rings and the 2-13/16" flow sleeve, shown here by way of example.

Fig 10: Top Turbine detail showing Lemo cap, lock nut, upper centraliser and flow sleeve.

5.1) Removing the Upper Centraliser and Flow Sleeve.

To begin disassembly, slide the 70mm clamp over the upper centraliser and tighten the M10 clamp bolts. Take the 41mm open spanner and release the tension in the lock nut shown in Fig 11.

Fig 11: Removing the turbine lock nut with a 41mm spanner and the 70mm clamp.

Remove the lock nut by hand and take a soft faced mallet to gently tap the 70mm clamp to ease the upper centraliser away from the flow sleeve and to release it from the upper spindle ’O’ rings located underneath the centraliser. Note that once the upper centraliser is moved about 3mm away from its locked position, the flow sleeve will suddenly drop. It is recommended that there should be some support under the flow sleeve ready to catch its fall.

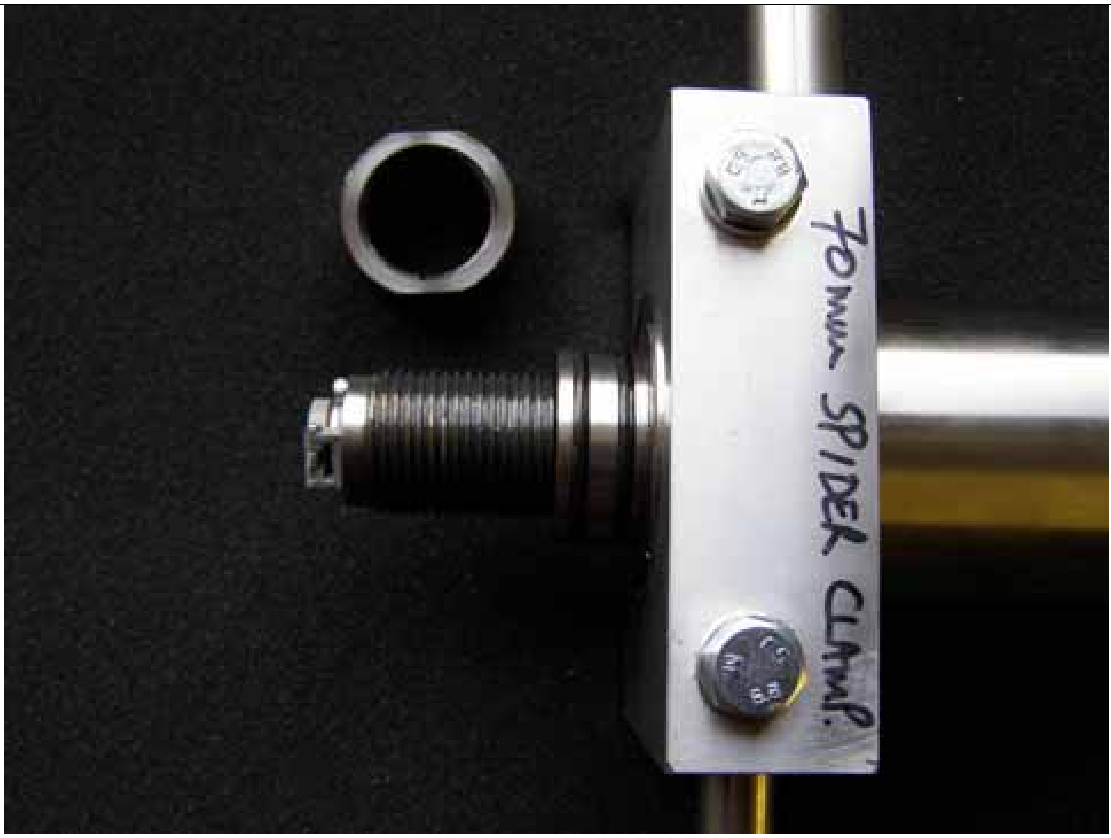

Fig 12: Turbine lock nut removed.

Fig 13: Upper Centraliser separated from the Flow Sleeve.

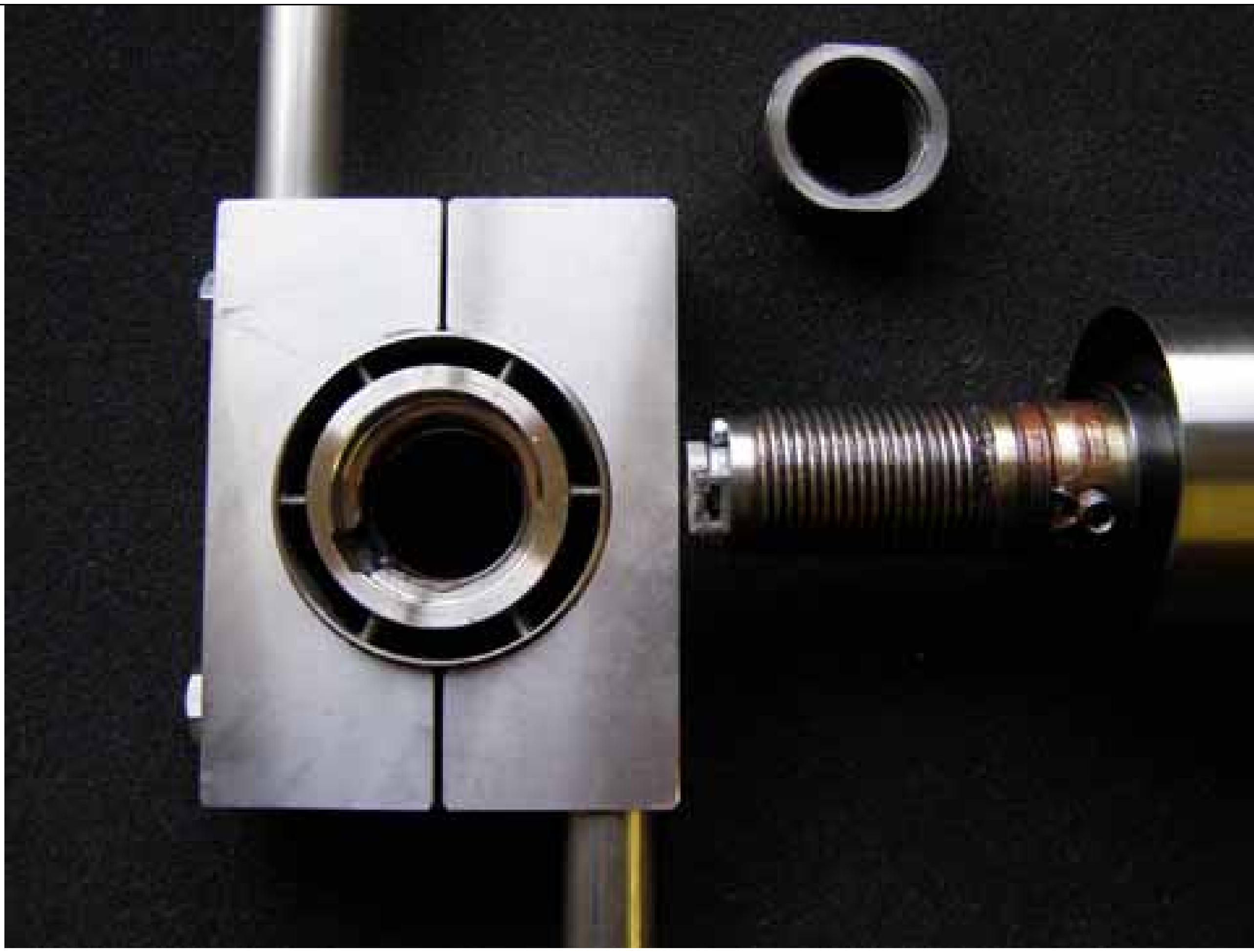

Fig 14: Upper centraliser removed from the turbine stator spindle.

At this point it’s easier to remove the flow sleeve with the turbine vertical. This method of disassembly avoids scrapping the flow sleeve along the impeller blades, is easier to implement and kinder to the turbine components. However, remember to ensure the lower protective cap is in place to protect the bottom Lemo connector from damage.

5.2) Removing the Transit Nut and Lower Centraliser.

Fig 15 shows the position of the transit nut in relation to the impeller and lower centraliser.

Fig 15: Location of the brass Transit Nut relative to the Impeller and Lower Centraliser.

Return the turbine to the work bench and rest it on one vee block and half of the 55mm turbine clamp as shown in Fig 16, taking care to ensure the clamp pin engages with the holes drilled in the turbine stator flange. Position the mating half of the 55mm turbine clamp in the opposite drilled hole and clamp both halves together with the two M10 bolts as shown in Fig 17.

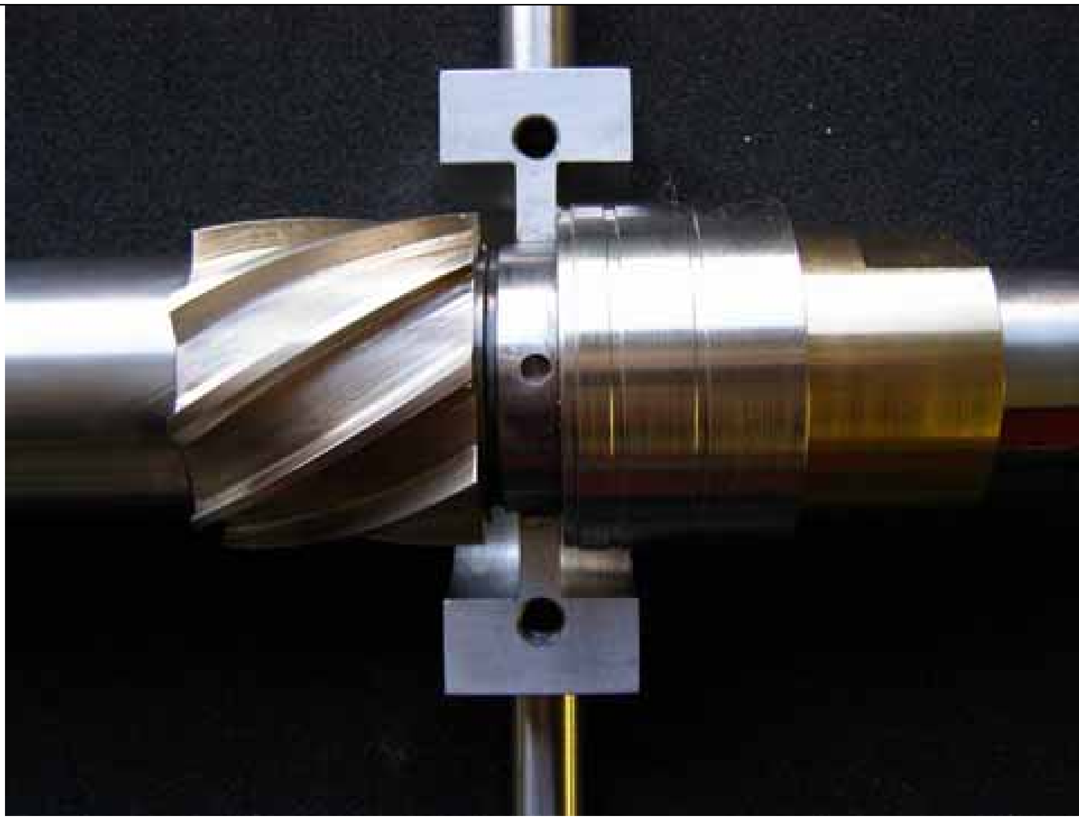

Fig 16: Position of the 55mm clamp under the turbine to remove the transit nut.

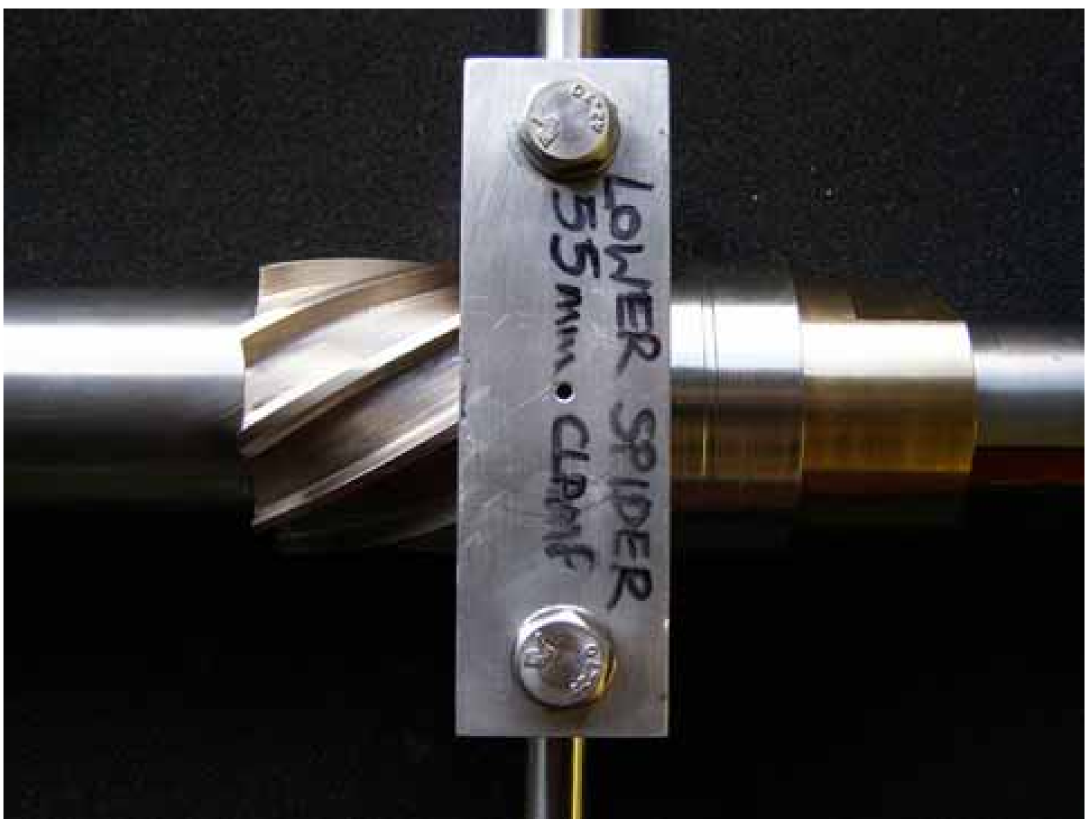

Fig 17: Turbine locked ready to remove the transit nut.

Take a 52mm open spanner and unscrew the transit nut by one half to one full turn, then stop. Due to the 7º taper in the lower centraliser profile, it can get stuck to the transit nut making the pair difficult to remove. At this point, gently tapping the lower spider off the transit nut with a soft faced mallet will make it easier to unscrew the transit nut and remove the lower centraliser as shown in Fig 18.

Fig 18: Transit Nut and Lower Centraliser Unscrewed from the Turbine .

5.3) Removing the Upper Stator Bearing.

Return the turbine to the Vee blocks and remove the M10 centraliser anti rotation grub screw and the M5 upper stator bearing anti rotation grub screw as shown in Figs 19 & 20.

Fig 19: Upper Stator Bearing Detail.

Fig 20: M5 & M10 Anti Rotation Centraliser and Bearing Grub Screws Removed.

Gently remove the upper stator bearing by hand (Figs 21 & 22) and place this and the grub screws in a safe, clean place as shown in Fig 23.

Fig 21: Removing the Upper Stator Bearing.

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Fig 22: Upper Stator Bearing Free.

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Fig 23: Upper Stator Bearing Removed.

5.4) ROTOR REMOVAL WARNING

With the removal of the upper stator bearing, the rotor may be removed by sliding it off the stator. However, extreme care must now be exercised to avoid any accident to personnel or damage to the turbine. The rotor weighs approximately 6Kg (~13lbs) and every care should be taken to ensure it does not fall off the stator onto a technician's foot or hard surface. One or more bones in a technician's foot could easily be broken by a falling rotor or the rotor itself could suffer permanent damage to the upper rotor bearing and housing were it allowed to fall onto a hard surface.

When removing the rotor, the technician will experience resistance due to the strong permanent rotor magnets reacting with the stator. The rotor must be eased off the stator with no unnecessary or excessive use of force which might cause loss of handling to the rotor and/or stator assembly. Once removed, both rotor and stator may be set aside for inspection and cleaning. Due to the length of the turbine, it has been necessary to show the following images of the alternator and brake assemblies separately to fit them on to one page. See Figs 24 & 25.

Fig 24: Alternator Rotor & Stator Assembly shown side by side.

Fig 25: Brake Rotor & Stator Assembly shown side by side.

5.5) The Rotor.

The rotor consists of two halves. The magnet section housed in stainless steel and the brake section housed in aluminium bronze. Providing the rotor bearings are in good condition, maintenance is limited to cleaning foreign body material from the stator exterior and the rotor interior. This material can be best removed using solvents or a power jet wash. The brake section needs the flutes cleaned of drilling mud and the magnet section needs any parasitic ferrous particles removed to leave the interior walls clean and debris free. The two rotor sections screw together and are locked with a torque of 150Nm (~110ftlbs). They should not be separated unless there is failure or damage to either half of the rotor.

5.6) Removing the Impeller.

With the rotor separated from the stator, the impeller may be removed for inspection, repair or replacement. The important detail to remember is that the impeller screws onto the rotor with a left hand thread. This design detail ensures that the impeller always tries to tighten itself against the rotor in service and can therefore never accidentally unscrew itself in a down hole environment.

Fig 26: Impeller removed from the Rotor.

5.6.2) Impeller Inspection and Cleaning.

The impeller is the major consumable item of the turbine as it spends all its active life in the full flow of the drilling mud. Blade wear and erosion is therefore a major consideration and the impeller should be inspected for size and erosion after each run. The impeller thrust bearing is of secondary concern because it is made from a much harder material than the impeller and will probably service several impellers before it finally wears out and needs replacing. The impeller thrust bearing is an interference fit and may be removed and fitted into a new impeller with a press tool. If this is performed by the customer, very special care must be taken to ensure the bearing and impeller mating surfaces are clean and free from debris prior to fitting. Any subsequent misalignment of the impeller thrust bearing will cause drag between the rotor and the stator bearings which will compromise low flow performance and sensitivity. The upper rotor bearing is also pressed in and requires a special tool, (not supplied) to remove and replace it. For the same reason, this bearing is also expected to last much longer than the stator bearings and will seldom need to be replaced.

Fig 27: Close up of the impeller thrust bearing.

5.7) Removing the Stator Thrust Bearing.

For practical reasons the stator bearings are the sacrificial pair of the four bearings that allow the rotor to spin around the stator. The stator bearings are each retained in service with a single M5 grub screw which is easily removed to allow each bearing to be pulled off the stator for inspection and/or replacement. Fig 28 illustrates the stator and rotor thrust bearings working as a pair and Fig 29 provides an image of the exposed stator thrust bearing prior to removal.

Fig 28: Close up of the rotor and stator thrust bearing pair.

Fig 29: Close up of the stator thrust bearing.

Fig 29 illustrates the M5 grub screw used to retain the stator thrust bearing in service and removal of this grub screw allows the stator thrust bearing to be pulled from the stator for inspection, cleaning or replacement. The process of removal is identical to the process used to remove the upper stator bearing shown between Figs 19 to 23.

5.7.1) Stator Inspection and Cleaning.

The turbine stator is a fully potted and welded assembly and is not a field serviceable item. Inspection and cleaning is therefore limited to ensuring the skin of the stator is in good condition and shows no signs of distress, erosion or pressure damage. Any sign of failure or potential failure in the stator skin should be treated very seriously and the tool removed from service. Failure to observe this advice could result in a breach of the turbine stator under pressure, causing drilling mud to seep into the tool compromising itself and possibly any third party equipment. Turbines deemed unsuitable for drilling service should be returned to Turbine Dynamics Ltd for analysis and when necessary, repair.

5.8) Removing the Upper and Lower Pressure Cases.

5.8.1) Removing the Upper Pressure Case.

Note: This section does not apply to a new turbine which is delivered without pressure cases.

Before describing the removal of the upper and lower pressure cases, it is very important to note that the upper pressure case is ALWAYS removed before the lower pressure case when a flow sleeve is fitted. There are two reasons for this:

1) The clamping point for the lower pressure case is obscured by the flow sleeve, so no attempt can or should be made to remove the lower pressure case when the flow sleeve is fitted.
2) Attempts to remove the upper pressure case by clamping over the full length of the turbine may impart excessive torque through the stator assembly which could induce turbine stator failure by fracturing a welded joint, or in an extreme case, may even cause the stator to sheer.

Fig 30 illustrates the turbine fitted with an upper pressure case and flow sleeve.

Fig 30: Pressure Case fitted to the top of the Turbine.

The upper pressure case is removed with the 55mm pressure case clamp and the 70mm upper spider clamp as shown in Fig 31.

Fig 31: Correct use of the 55mm and 70mm Clamps for removing the upper pressure case.

Once the upper pressure case has been removed, return to section 5.0), Figs 11 to 14 to complete the disassembly of the turbine.

5.8.2) Removing the Lower Pressure Case.

The turbine design includes a special detail to the lower pressure case and lower centraliser which demands some explanation. This detail is a 7º taper cut into the lower pressure case and lower centraliser which was required to provide adequate flow annulus and minimise flow erosion through the lower centraliser. The 7º taper is also used to locate the lower centraliser against the turbine body and is locked in place when the lower pressure case is torqued in position. When removing the lower pressure case, the procedure is to rotate the lower pressure case between one half to one full turn and gently tap the lower centraliser off the lower pressure case to relieve compression in the 7º taper. This technique allows the lower pressure case to be removed much more easily compared to leaving the lower centraliser attached.

With the rotor and impeller exposed as shown in Fig 32, place one half of the 55mm lower turbine clamp under the turbine between the impeller and the lower centraliser. Rotate the turbine with the lower pressure case until the holes drilled in the turbine flange engage with the clamp pin. Attached the other half of the 55mm lower turbine clamp ensuring it also locates with its matching hole. Clamp in place with the two M10 bolts as illustrated by Fig 33.

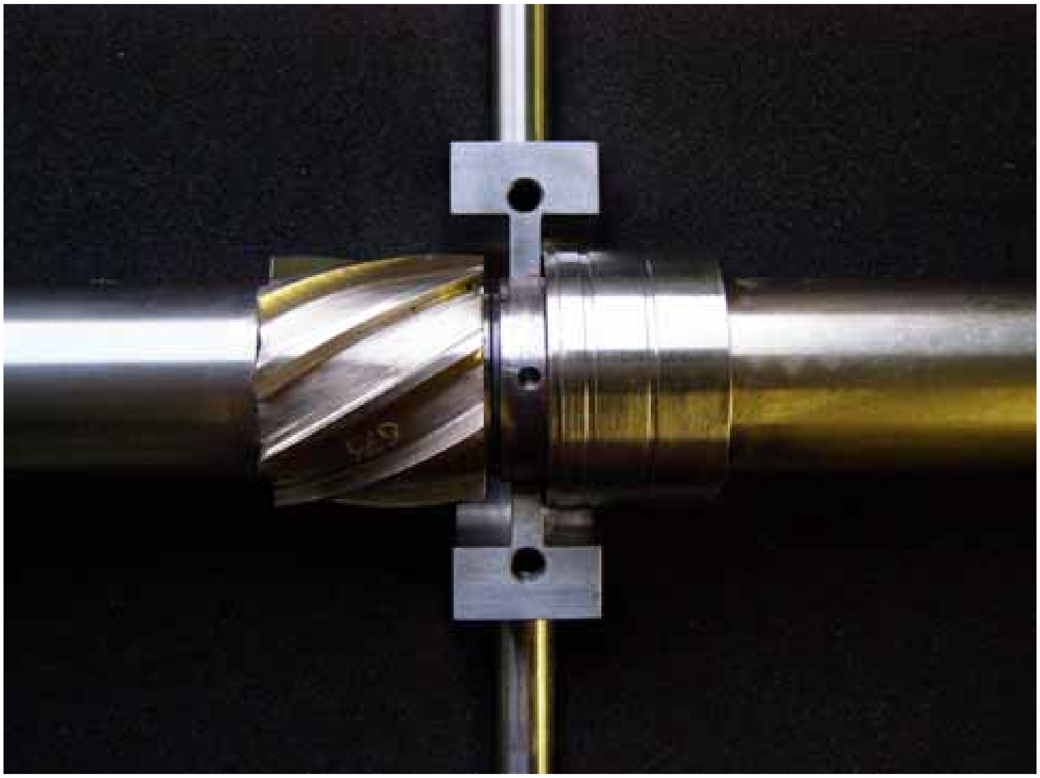

Fig 32: Initial alignment and lock achieved with the 55mm Turbine Clamp.

Fig 33: 55mm Turbine Clamp prepared to remove the Lower Pressure Case.

Attach the 55mm pressure case clamp as shown in Fig 34.

Fig 34: 55mm Turbine and Pressure Case Clamps in place.

Rotate the 55mm lower pressure case clamp one half to one full turn and remove the clamp to gently tap off the lower centraliser with a soft faced mallet as shown in Fig 35.

Fig 35: Soft faced mallet to release the lower centraliser from the 7º lower pressure case taper.

Fig 36: Separated turbine, lower centraliser and lower pressure case.

The lower pressure case may be much more easily unscrewed from the turbine body once the lower centraliser has been tapped off its taper. At this stage of disassembly, these components can be removed for cleaning, inspection or replacement.

6.0) The Electronic Regulator.

The turbine's electronic regulator is a fully potted assembly and is not a field serviceable component. It is shown in Fig 37 for reference only.

Fig 37: Potted Electronic Regulator.

7.0) Assembly.

Turbine assembly is identical to disassembly with the exception of an addition stage to prepare the stator with the rotor alignment tool, illustrated in Fig 6. The process of sliding the rotor over the stator is improved by placing the rotor alignment tool over the end of the stator as shown in Figs 38 and Fig 39. This tool also protects the Lemo connector from potential damage and foreign body contamination when sliding the rotor over the stator and is an essential addition to the turbine tool kit. Despite its apparent simplicity, the rotor alignment tool is a precision extrusion and every care should be taken it to ensure it remains a serviceable item by protecting it from damaged or distortion at all times.

Fig 38: Rotor Alignment Tool prior to fitting.

Fig 39: Rotor Alignment Tool Fitted.

It will be noted that the rotor alignment tool also protects the 'O' rings from the rotor and butts against the spider hard shoulder for reference. In this position the rotor may be carefully slid over the rotor alignment tool and stator until it engages with the stator thrust bearing shown in Figs 15, 16, 28 & 32.

7.1) ROTOR ASSEMBLY WARNING

At this stage of the manual it is important to repeat the safety warning of section 5.1

When handling the stator, rotor and rotor alignment tool to restore the rotor to the stator, extreme care must now be exercised to avoid any accident or damage to the turbine or personnel handling the assembly process. Even without pressure cases, the combined weight of the turbine is about 14Kg, (~31lbs) with the rotor weighing about 6Kg (~13lbs). Every care should be taken to ensure none of the components fall to the ground or on to the feet of any personnel. These are heavy components which could easily break one or more foot or toe bones or may themselves be damaged if allowed to fall on to a hard surface.

When restoring the rotor to the stator, the technician will experience the strong magnetic attraction between the rotor magnets and the stator shaft. The rotor must be eased on to the stator with no unnecessary or excessive use of force which might cause loss of handling. This is especially important when the rotor approaches the stator thrust bearings. The impeller and stator thrust bearings are made from hard and hence, brittle materials and every care should be taken to ensure these components are brought together slowly to avoid either being chipped or cracked by the use of excessive force.

Rotor to stator assembly is a delicate operation which may be assisted by holding the turbine in a vertical position and using gravity to help guide the rotor over the stator until it settles against the stator thrust bearing. Once in position, the turbine can be returned to the horizontal position in vee blocks to have the upper stator bearing, flow sleeve and upper centraliser assembled.

7.2) Final Assembly with a flow sleeve.

With the rotor safely positioned over the stator, restore the upper stator bearing and the M5 & M10 anti rotation grub screws as shown in Figs 19 to 23. Restore the lower centraliser and lower pressure case to the turbine using the tools and methods described section 6.2, Figs 32 to 36. When fitting the flow sleeve, it is very convenient to hold the turbine in a vertical position whilst sliding the flow sleeve over the rotor and impeller. This method also minimises contact between the flow sleeve and the impeller saving the flow sleeve's inner surface from unnecessary damage during assembly. Presenting the upper centraliser for assembly is another delicate operation and demands a separate explanation of the process.

7.3) Fitting the Upper Centraliser.

Extra special care is required to assemble the upper centraliser to the turbine to avoid damage to the flow sleeve or the anti rotation grub screws. Before it can find its proper location on the turbine stator, the upper centraliser must compress two ‘O’ rings and fit within the flow sleeve before the lock nut can be tightened to secure it in place. The assembly process begins by manually presenting the upper centraliser to the stator, taking care to align the slot in the upper centraliser with the M10 anti rotation grub screw. Manually present the lock nut until it comes to rest against the upper centraliser. At this position, the upper centraliser is pressed against the first stator ’O’ ring which will offer resistance to the upper centraliser. Take the upper centraliser in one hand and rotate from side to side to assess the engagement between the upper centraliser slot with the M10 grub screw. Centre the upper centraliser and begin tightening the lock nut with the 41mm spanner. Initial resistance to motion will be quite high as the lock nut forces the first stator ‘O’ ring into compression, but will suddenly drop when in compression to the extent that the lock nut may be tightened by hand until the second stator ‘O’ ring is met. Check again, the centre position of the upper centraliser about the M10 grub screw by rocking it from side to side before finding centre again. Use the 41mm spanner to compress the second ‘O’ ring and stop. At this stage of the assembly, lock the upper centraliser in the 70mm clamp taking care to position the clamp so that the flow sleeve mating edge remains visible. Use the 41mm spanner to continue moving the upper centraliser closer to the flow sleeve and with the other hand, lift and position the flow sleeve to accept the upper spider. It is essential to ensure the upper centraliser engages properly with the flow sleeve and does not foul the flow sleeve’s leading edges. Inadvertent compression of the centraliser against a badly fitted flow sleeve will damage the flow sleeve’s leading edge and may prevent further assembly. Figs 40 & 41 illustrate the fitting detail of the flow sleeve between upper and lower centralisers.

When the upper centraliser is fully engaged with the flow sleeve, tighten the locknut to 100Nm (74ftlbs) torque. Turbine assembly is complete and it may progress to being fitted within the customer’s drill string instrumentation.

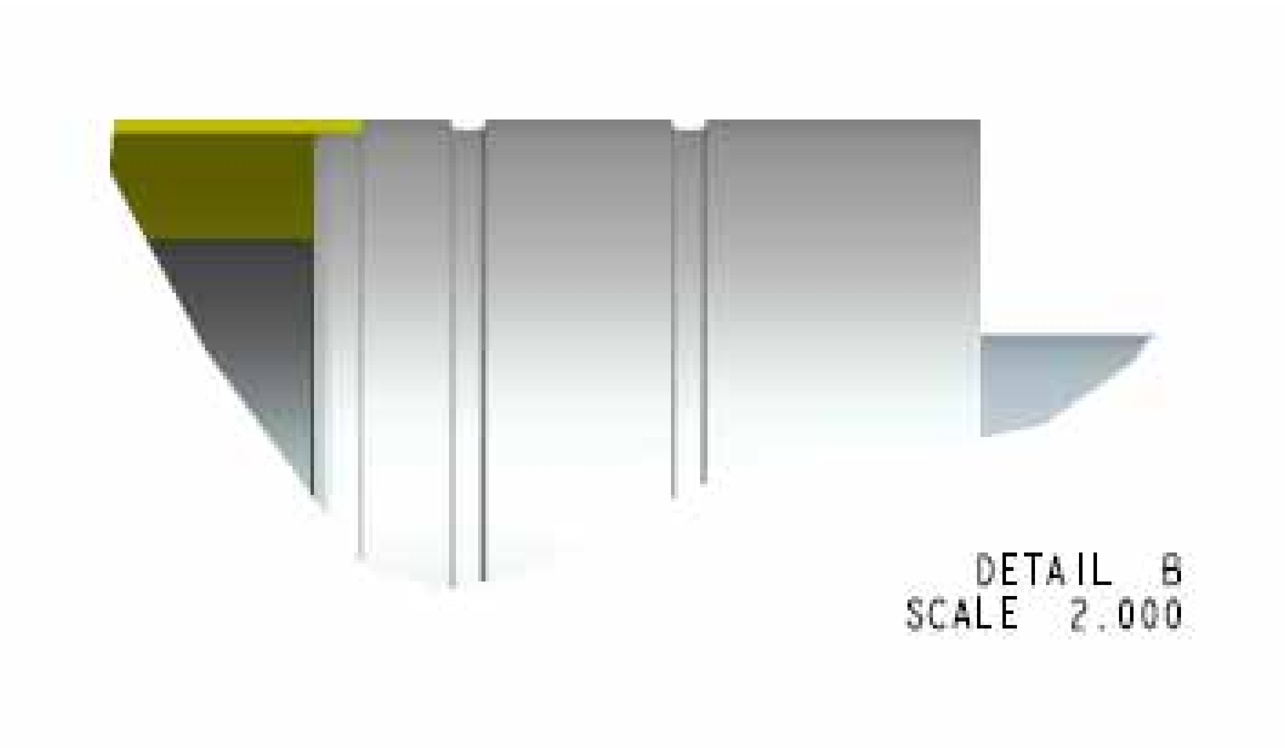

Fig 40: Lower centraliser engagement with a flow sleeve.

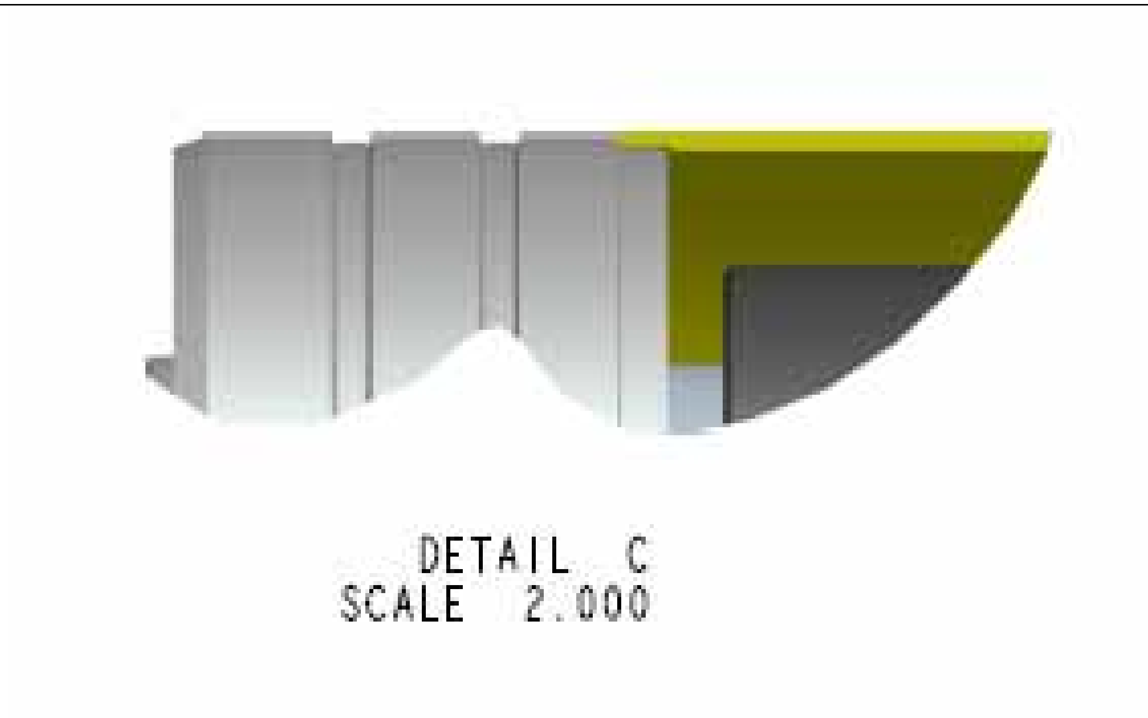

Fig 41: Upper centraliser engagement with a flow sleeve.

7.4) Final Assembly without the flow sleeve.

Final assembly without the flow sleeve simplifies the final assembly, but removes some stiffness to the turbine which may be considered undesirable for some down hole applications. The decision to run with or without the flow sleeve is outside the scope of this manual and must be made in consideration of the field demands at the time of build. Final assembly of the turbine without the flow sleeve is identical to assembly with the flow sleeve except it is recommended that a 70mm impeller is used for a 2-13/16" flow environment to maintain turbine performance, efficiency and sensitivity. Replacing the 67mm5 impeller with a 70mm impeller requires the turbine be disassembled to section 5.5, Fig 26. Customers who choose to employ the turbine without the flow sleeve should also consider measures in the collar to protect it from flow erosion about the impeller.

8.0) 'O' Rings.

There are four places to fit 'O' rings in the turbine and these places are identified with their 'O' rings with the help of the following diagrams.

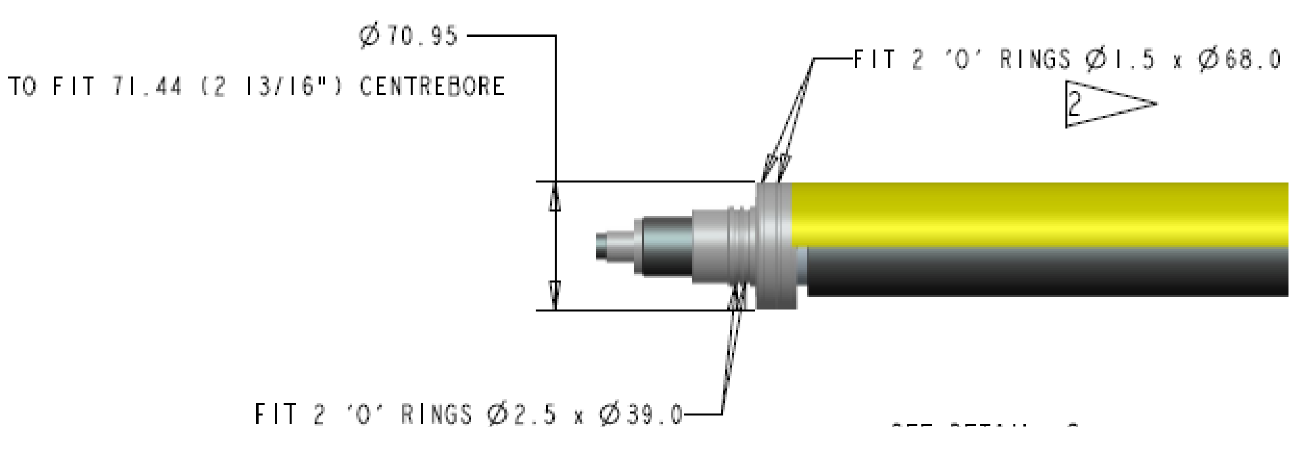

Fig 42: Upper centraliser 'O' ring detail.

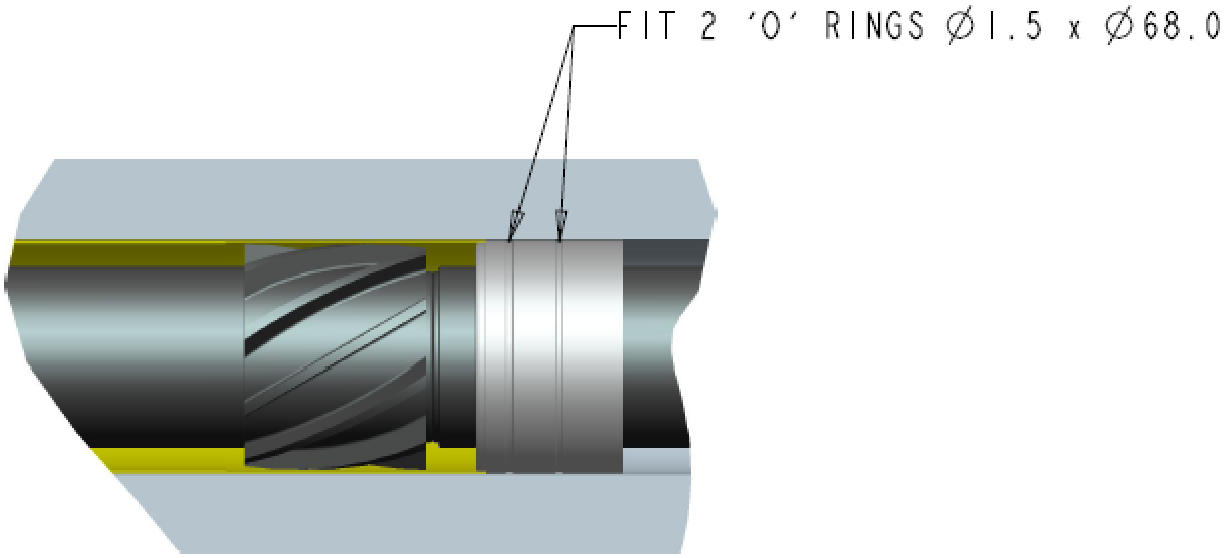

Fig 43: Lower centraliser 'O' ring mounting detail.

The upper and lower centralisers provide shallow 68 x 1.5mm 'O' ring grooves to afford the turbine some degree of vibration isolation when mounted within a 475 drill collar. Eriks part number is 68x1.5FPM75 or alternatively 68x1.5FPM90 for the slightly harder and higher temperature version.

The upper centraliser to upper pressure case 'O' rings shown in Fig 42 are 39x2.5FPM75 or 39x2.5FPM90. Eriks part numbers used for reference.

Fig 44: Upper stator spindle 'O' ring detail.

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The upper stator spindle ‘O’ rings are Eriks BS025FPM75 or BS025FPM90, 29.87 x 1.78mm located in the two grooves shown. The lower stator spindle to pressure case ‘O’ rings are Eriks BS031FPM75 or BS031FPM90 44.17 x 1.78mm located in the two grooves shown in Fig 45.

Fig 45: Lower stator spindle ‘O’ ring detail.

9.0) End of Manual.