



Tool Code: SAT002

Document: MN-SAT002-C

Spinner Array Tool

SPINNER ARRAY TOOL

6 Sensor Springbow, 1¹¹/₁₆" , Ultrawire™

Operational & Maintenance Manual



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Created: May 13, 2009

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0 ABOUT THIS MANUAL

0.1 MANUAL HISTORY

Date	Issue	Description	Auth	Chk	App
18/12/06	A	Initial Release.	FV	TW	TW
03/12/07	B	See ECR4594	RS	RH	RH
23/10/08	C	See ECRs 4479, 4781,4814, 5055, 5276, 5370, 5380, 5395, 5525, 5530, 5552, 5673, 5706, 5729 & 5771	RS	BS	TG

0.2 UPDATES TO BE USED WITH THIS MANUAL

Consult the CD Directory for the appropriate Manual Updates to be used with this Manual.

0.3 TECHNICAL HELP

For further technical help contact Sondex as follows:

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0.4 FEEDBACK

Please help us improve future issues of this manual by adding your comments or corrections to www.ge-energy.com/oilfield, referencing the document number.

Thank you.

Photographs and sketches are for illustration purposes only. Depending on the tool model that you have, certain features or dimensions may differ from those shown.

Documents from external sources (i.e. MSDS), supplied with/referenced in this manual, are considered the latest version at time of manual issue. However, the document can be altered by the external source without prior notice to Sondex.

1 EQUIPMENT

The Spinner Array Tool (SAT) is designed to solve the problem of accurate fluid velocity identification in horizontal or highly deviated wells. It is run centralised within the wellbore.

The tool has an array of 6 specially developed miniature spinners, mounted on the inside of a set of springbows. Each spinner of the array measures the fluid velocity and direction of the surrounding fluid close to the well casing. Rotation is sensed by Hall effect detectors, which eliminate drag and optimise measurement flow rates. The normal output is 3 pulses per revolution with indication of direction.

All 6 values are simultaneously transmitted to either the surface or into a Memory section. Because the measurements are taken in a single plane across the diameter of the wellbore, rather than spaced along it, an accurate cross-sectional plot can be generated. Optional software can be used to provide a 3D image of the phases along the well.

The use of springbows allows the tool to be used when running in or out of the well and minimises power requirements, particularly when deployed using Memory recording.

1.1 OPERATING PRINCIPLE

The SAT is designed for use in horizontal and deviated wells. In such cases, there is often a separation of the oil, water and gas components, and traditional PL tools are notoriously unreliable in this situation.

The tool can identify a velocity and direction profile in these cases and thus provides previously unattainable information for PL interpretation.

In combination with other flow imaging tools, the tool can provide comprehensive volumetric flow information of water/oil/gas distribution.

1.2 APPLICATIONS

- Fluid identification in horizontal & highly deviated wells.
- Plotting of fluid velocity and direction along the wellbore.
- Changes of wellbore fluids with time or different production rates.
- Injection Flow Measurement.

1.3 INTERFACING & TOOL COMBINATIONS

- Simultaneous operation with other Sondex Ultrawire™ tools.
- Memory or SRO operations.
- Combines with PIA to give well inclination.
- Standard 1³/₁₆" UN 12tpi Sondex or GO end connectors.

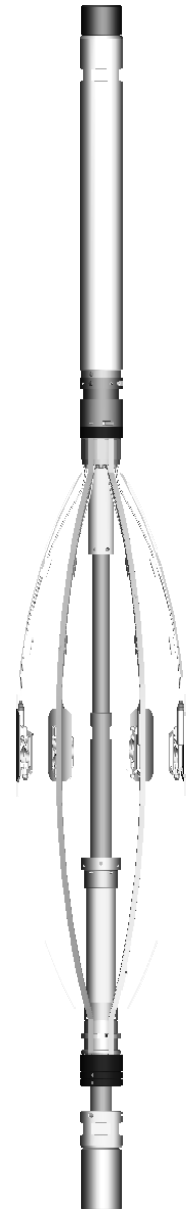


Figure 1.1 SAT

1.4 SPECIFICATION

Parameter	Specification	Remarks
Max. Pressure	15,000psi	
Max. Temperature	177°C	
Nominal Diameter	1 ¹¹ / ₁₆ " (43mm)	Springbow fully closed.
Make-up Length	45.5" (1155.7mm)	
Overall Length	49.3" (1252.2mm)	Including thread protectors.
Depth Offset	16.5" (419.1mm)	From bottom of tool to sensors.
Weight	6.5kg (14.3lbs)	
Number of spinners	6	1 sensor per springbow.
Width of springbow	0.25" (6.35mm)	
Recommended Casing sizes	3" - 7"	
Telemetry	Ultrawire™	
Tool Address	30 dec.	Set by links on telemetry board.
Operating Voltage:		
• Nominal	+18V DC	
• Range	+13V to 23V DC	
• Absolute Max	+24V DC	
Operating Current (logging mode)		
Typical:	25mA	
Max. Frame Rate	2Hz	Polling interval usually limited by bus controller/wireline telemetry speed & Warrior configuration.
Relative Bearing accuracy (Rotation)	5°	
Relative Bearing Range	>5° to <175°	From vertical.
End threads (top/bottom)	1 ³ / ₁₆ " 12 UN2A GO (female/male)	
End connectors (top/bottom)	4mm single conductor (male pin/female socket)	Sondex Ends

2 SAFETY

In normal use, there are few specific safety instructions for the safe handling of the SAT. The following are guidelines only and should be followed in addition to any specific company and regional regulations.



Warning!

HOT WORK! Sondex equipment may, under certain circumstances or failure modes, become a potential source of ignition. Using it must therefore be considered "**HOT WORK**" and appropriate precautionary procedures should be followed when testing at surface in areas where there is a risk of gas leaks or other potentially explosive atmospheres.

There are no springs inside the tool which could pose a hazard through high compression/tension. However, one spring is visible from the outside. This spring is under low compression and therefore poses very little hazard to the operator.



Caution!

The spinners may be damaged when the tool is dropped. To protect the spinners, the closing ring must be fitted around the spring bows to avoid damaging the spinners. The tool must be transported in its carry tube and/or flight case.



Liquid O-ring

LOR101 is used for lubricating the tool during maintenance. Contact with skin or eyes can be harmful. For more details, refer to the Material Safety Data Sheet for Liquid O-ring.

The tool contains very sensitive electronic circuitry. Consequently the tool should be handled with care.



Caution!

Electro Static Discharge (ESD)

All tools with electronic boards that contain solid state circuits (transistors, diodes, semiconductors) may become damaged when contacted with an electrostatic charge.

When handling tools that contain electronic parts that are ESD sensitive, the following guidelines should be followed to reduce any possible electrostatic charge build-up on the user's body and the electronic parts:

- Always make sure proper ESD precautions are taken when handling electronic parts that are ESD sensitive during maintenance.
- Avoid touching the tool electronics, unless stated otherwise in this manual.

NOTE: ESD is less likely to affect tools when the housing is fitted.

2.1 RECOMMENDATIONS



The product should be installed, adjusted and serviced by qualified electrical maintenance personnel. Improper installation or operation of the equipment may cause injury to personnel or equipment. Before beginning any installation or commissioning work ensure that electrical power is disconnected and locked out.

NOTE: Installation must meet National Wiring Regulations in accordance with IEC/UL 61010 latest revision.

WARNING 1: The outer casing of the product should be connected to a known good system ground before making any other electrical power connection. This system ground to be maintained until all electrical power connections are disconnected and locked out.

WARNING 2: Units with exposed Electrical Connectors are supplied with protective insulating end caps bearing a warning of High Voltage. These end caps should only be removed when Electrical Power is disconnected and locked out for the purposes of interconnection to other Units. Under no circumstances should equipment be operated with the Electrical Connectors exposed.

WARNING 3: Units with moving parts such as callipers can be activated immediately on application of Electrical Power. A safe area should be established around any such Units before the application of Electrical Power.

WARNING 4: Units with moving parts such as springs can retain significant Potential Energy. Great care should be exercised when removing Closing Rings or handling over tightened assemblies.

WARNING 5: Units containing seals may entrap pressure. Disassembly should only be carried out in accordance with recommended procedures ensuring the release of pressure prior to the disengagement of cap threads.

WARNING 6: If the equipment is not installed, commissioned and used in accordance with the manufacturer's specifications, protection provided may be impaired.



Standard Personal Safety Gear must be worn at all times including but not limited to: Safety glasses, gloves and steel-toed boots.

Equipment exceeding 18Kg in weight should be handled with extreme care. Heavy items should be mechanically lifted. Any installation of equipment over 10Kg to be lifted over 1 metre should be at least a two man lift. Good lifting practice should be exercised at all times including but not limited to:

- Use of correct personal safety gear.
- Lift using legs not back
- Not proceeding with a lift in the presence of any doubt of completing the lift safely
- Use of mechanical lifting aids wherever possible
- Ensuring work area is free of clutter and tripping hazards

3 THEORY OF OPERATION

3.1 BLOCK DIAGRAM

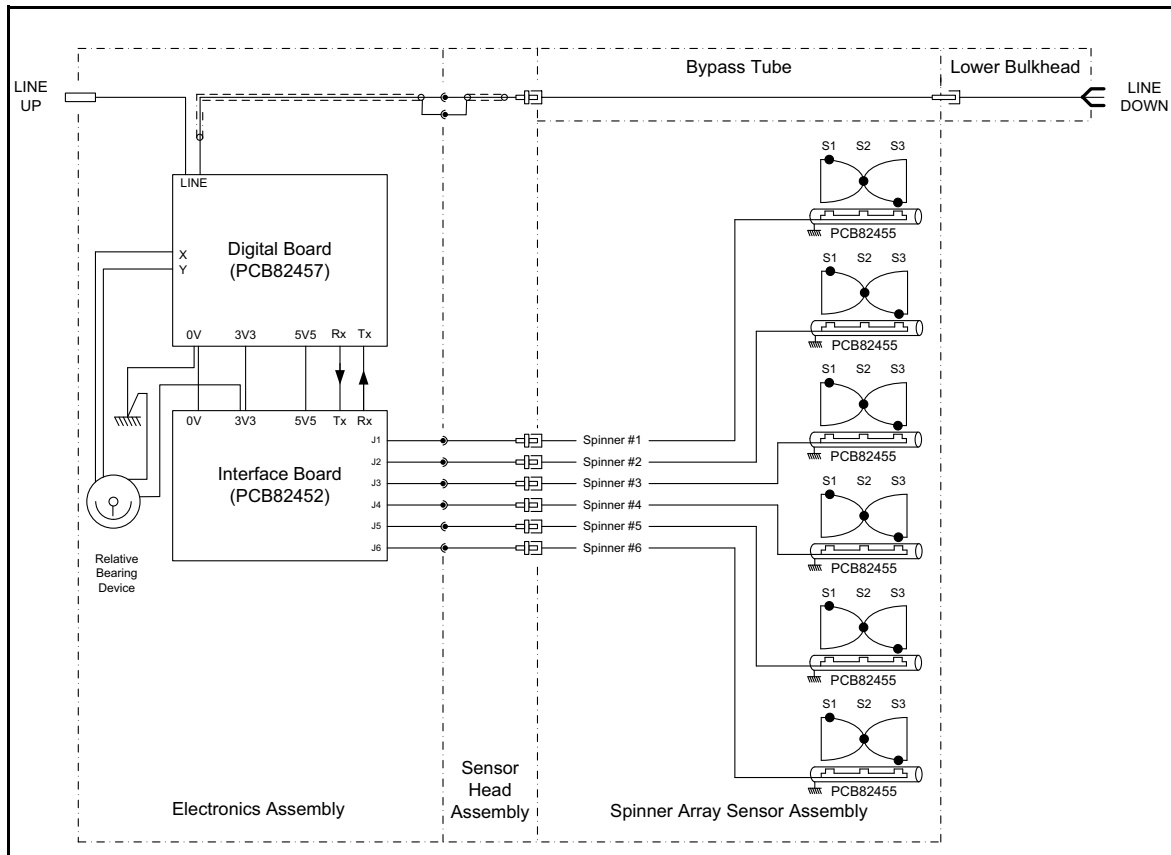


Figure 3.1 Block Diagram

3.2 DESCRIPTION

3.2.1 GENERAL

The Spinner Array Tool incorporates 6 miniature spinners, which are deployed toward to ID of the tubing via springbows. The tool is closed while running in hole and opens automatically when it leaves the tubing and enters the larger diameter of the casing. If the tool passes any restriction, either up or down, the bow springs will collapse to prevent damage to the spinners.

The spinner bodies are clipped onto the bowspring and house sensor electronics, including Hall effect sensors and a temperature sensor. The spinner is mounted between 2 jewelled bearings and houses 3 magnets, which are located along the axis of the full spinner length.

3.2.2 HALL EFFECT SENSORS

The Hall effect sensors are integrated circuits, which monitor the magnetic field of the magnets. The output of the sensors are switched to ground when the magnetic field passes a certain threshold and thus create a pulse each pass. As there are 3 magnets and Hall effect sensors, 3 pulses will be generated per revolution.

The sequence of the pulses, generated by the sensors determine the flow direction, i.e. sequence 1-2-3-1 is positive and sequence 3-2-1-3 is negative. See [Figure 3.2](#) for a graphic representation of the magnet and Hall effect sensor location.

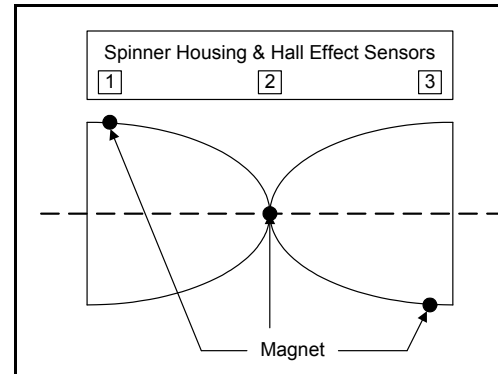


Figure 3.2 Magnets & Hall Effect Sensor Location

3.2.3 ELECTRONICS

The tool operates on Ultrawire™ telemetry and can collect data in excess of 100 frames per second. However, other parts of the system, e.g. wireline telemetry speed, will usually limit the maximum frame rate significantly. For example, the default configuration of the Warrior logging software is set at 24 samples/foot.

Further details can be found in [Section 6 Electrical Description](#).

3.2.4 RELATIVE BEARING DEVICE

The relative bearing device is a pendulum based device, which is used to measure tool rotation. It is not intended to be a survey instrument, but merely to indicate which spinner is uppermost.

Calibration: This is done once at the factory, and should not need to be repeated by the customer.

3.3 CALIBRATION THEORY

3.3.1 SPINNER ROTATION

The rotational velocity of the spinner is measured to provide the flow velocity.

The rotation frequency of a real spinner is given by Equation 3.1 below. This assumes that the friction (i.e. around the bearings) has no viscous component and that the viscous effect is to slow fluid moving along the blade face. This equation only applies to a rotating spinner; it does not apply to a stationary spinner in a very slow flow:

$$f = aV - \left(\frac{b}{\rho}\right)V - c \sqrt{\frac{V\mu}{\rho}} \tag{Equation 3.1}$$

where:

f is the frequency of rotation of the spinner cps (Hz).

V is the fluid velocity.

a is a constant depending on blade pitch.

b is a constant depending on ratio of friction to blade moment of inertia.

c is a constant depending on skin friction of fluids moving over the blade surface.

ρ is fluid density.

μ is fluid viscosity.

Neglecting friction and inertia terms:

$$f = aV \quad \text{Equation 3.2}$$

3.3.2 FLUID VELOCITY DETERMINATION

The operating procedure in the well allows the flowmeter to be calibrated by recording several passes at different logging speeds, see [Section 4.2](#) for information on tool calibration. Plots of logging speed versus tool reading enable the apparent fluid velocity (V_{app}) to be determined.

The more linear the tool response, the more accurate is the velocity determination. Non-linearity of [Figure 3.2](#), for example bearing friction and viscosity, can be accounted for in the above plots. The plots also compensate for the alteration to flow velocity due to the insertion of the toolstring. Sondex flowmeters are linear over their full operating range under normal well conditions.

3.3.3 TOTAL FLOWRATE DETERMINATION

The velocity of fluids is largest at the centre of the pipe and varies to zero at the pipe wall. Spinner flowmeters generally read a fluid velocity close to that of the centre. However, the SAT measures at the pipe wall. The true average fluid velocity (V_t) is therefore somewhat more than that indicated by the spinner flowmeter (V_{app}) and requires correction. This correction factor is a function of the spinner blade diameter with respect to the inside diameter of the pipe and the Reynolds number of the flow. Typical approximate corrections necessary to determine true average flow velocity (V_t) in turbulent flow from the velocity measured by the spinner are:

$$V_t = V_{app}^{x0.00} \quad \text{Equation 3.3}$$

Total flowrate can be directly calculated by multiplying the flowrate by the casing internal cross-sectional area (and a scaling factor). The following converts directly to barrels per day (bpd).¹

$$\text{Total Flowrate (bpd)} = 1.4 \times V_t(\text{ft/min}) \times (\text{casing I.D. (inch)})^2 \quad \text{Equation 3.4}$$

3.3.4 TYPICAL APPROXIMATE SPINNER ROTATION RATES

Note: The figures shown in the table below are to be used to derive the *approximate* spinner rotation rate for a given fluid velocity, or to derive the *approximate* fluid velocity for a given spinner response. *Accurate* fluid flowrate can only be derived by multipass calibration of the spinner in the flow downhole.

Design pitch inch/revolution	Flow loop slope rps/fpm	Nominal Slope	
		fpm/rps	rps/fpm
2	10		

1. For a more detailed discussion, see "Cased-hole Log Analysis and Reservoir Performance Monitoring", R.M. Bateman, 1984. (ISBN 90-277-1922-5).

4 OPERATING PROCEDURE

Note: Also refer to [Section 7.2 Extraordinary Maintenance](#).

4.1 PRE-LOGGING CHECKS

4.1.1 MECHANICAL

- 1 Check that O-rings and sealing surfaces are undamaged, clean and greased.
- 2 Remove the closing rings.
- 3 Check that all springbows are in good condition.
 - Check that all spinners are free to rotate and located securely within the appropriate springbow. The spinners should continue to rotate for up to 13-16 seconds when held horizontal (18-20 seconds in vertical position).
- 4 Check that the locking ring is hand tight, so that the sensors are held in the sensor head. Also check that the locking ring is locked down to the central shaft by ensuring that the appropriate grub screws are tight.
- 5 Check that the bow clamp locking rings are tight.
- 6 Check that the inner split ring on the sensor head is tight and also that the grub screws are tightened to prevent it from unscrewing.
- 7 Ensure that there is no iron scrapings on the magnets, as this will influence the tool accuracy. When iron scrapings are visible, flush the magnets with a light oil, like WD-40[®]. Ensure the magnets are not damaged, replace if necessary.
- 8 Check that there is no dirt or debris between the bearings and the shaft, which might impair the free movement of the shaft. Flush with a light oil if required.
- 9 Check that the spinners are balanced.

4.1.2 ELECTRICAL

- 1 Ensure that upper and lower electrical connectors are clean, dry and undamaged.
- 2 Using a Multimeter, check the through-resistance between the top and bottom LINE connections. It should be a short-circuit and the resistance should be $<0.5\Omega$.

Note: The resistance of the connecting leads should be taken into account when taking this measurement.

- 3 Using a Multimeter, check the resistance between the LINE connections and the chassis (effectively the D.C. resistance of the internal electronics). The resistance should exceed $100k\Omega$.

4.1.3 OPERATIONAL

- 1 Connect the SAT to a suitable telemetry controller, and to a logging system via a wireline cable or suitable dummy cable.
- 2 Attach a Bullnose Ultrawire™ Terminator (BUL006) to the bottom of the toolstring. Although the tool may appear to work without the Bullnose, it will be more susceptible to telemetry errors if the Bullnose is not used.
- 3 Switch on the logging system.
- 4 The SAT tool current should be approximately **25mA**.
- 5 Slide the closing ring off the tool, so that the springbows open.
- 6 Check that all springbows are opened correctly and that the sensors are held correctly within them.
- 7 No counts should be observed if the spinner is not rotating.
- 8 Counts should occur at the rate of 3 counts per revolution when rotating.

Check both *forward* and *reverse* direction of rotation and make sure decoding by the data acquisition system is correct.

4.2 CALIBRATION

Calibration data is not supplied with the tool as it is best performed in the well. Calibration is a standard procedure for flowmeters of this type. There is little variation between Sondex tools of the same type.

Log data must be obtained over several passes in both up and down directions at different speeds during every logging operation. More than one set of data should be collected, for example before and after a survey. This enables a cross plot of *spinner rps* against *speed* to be made at any depth. From this cross plot, the apparent flow velocity (V_{app}) can be determined (see [Section 3.3 Calibration Theory](#)).

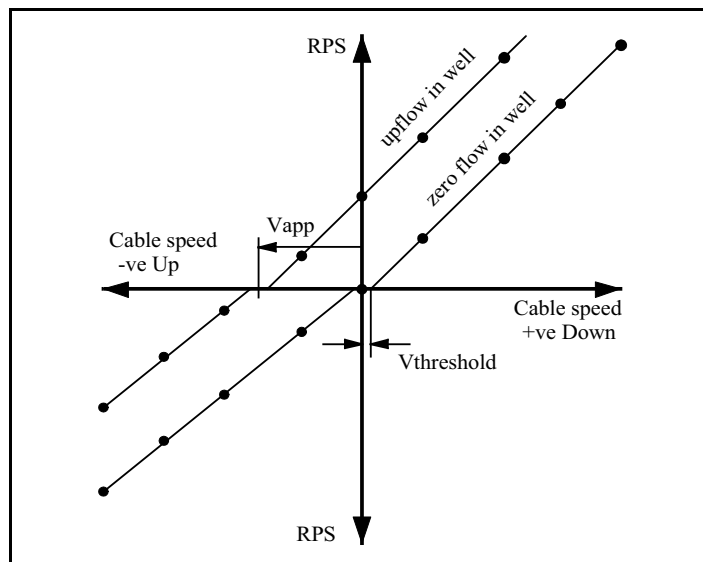


Figure 4.1 Flowmeter Fluid Velocity Response

Calibration data may be transferred to other logging runs, but this is not recommended since the response curve of [Equation 3.1](#) may have altered due to a change in fluid properties or bearing friction.

Plots must be made of tool reading against cable (tool) velocity.

Note: Sensitivity to flow in one direction or the other may be reduced by the shielding effect of the toolstring above or below the spinner.

Flow in the well shifts the zero rotation point along the cable velocity axis by the apparent average flow in the centre of the well V_{app} . Note that no calibration, other than this crossplot, is needed.

Note: In high flowrate wells it may not be possible to apply sufficient upward tool velocity to produce a zero tool reading (spinner stationary). In this case there are 2 options:

- 1 Since the tool response (*Figure 4.1*) is closely linear and any zero offset will be negligible, extend the best straight line through the plotted readings until it cuts the cable speed axis. The cable speed reading here will be V_{app} .
- 2 Refer to a calibration data set run with the well shut in. This will include readings close to zero. There may be a lower section of the same well where determination of the threshold is possible.

4.3 CONNECTING TO TOOLSTRING

4.3.1 GENERAL

In terms of measurement, the position of the SAT within the toolstring is not particularly critical. However, other tools can affect where the SAT can be placed. This is mainly where other PL tools, any XSH and/or a tractor are used. The main criteria is to ensure that the SAT is centralised.

4.3.2 CENTRALISATION

Centralisation is very important, and becomes a critical issue in horizontal wells. If the SAT is below centre, all the spinners will be below their desired positions, resulting in an overestimate of the water fraction. If the tool is very significantly de-centralised, the uppermost sensor may not reach the casing (in 7" casing); in such cases, any oil flowing along the top side of the well may go undetected.

A common mistake is to believe that just because a toolstring supports itself on the ground, it will centralise in a horizontal well. This is not necessarily the case, for the following reasons:

- 1 Firstly, the supporting force from centralisers decreases as they close further. Thus, centralisation becomes more difficult as the casing diameter decreases. However, even in 7" casing, de-centralisation can still be very significant if care is not taken.
- 2 Secondly, toolstrings flex as they become longer. This can cause significant decentralisation of the SAT if there are too many tools between the SAT and its centralisers.
- 3 Thirdly, when self-supported on the ground, there will be two arms of a centraliser supporting the tool. In a horizontal well, the centraliser may be oriented such that only one arm is supporting the tool.

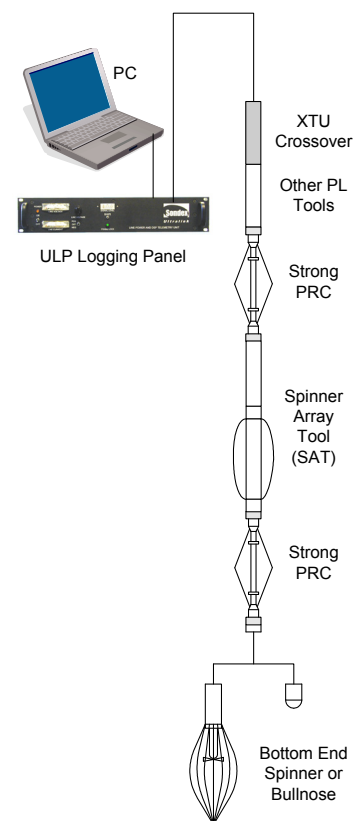


Figure 4.2 Recommended Toolstring configuration

- 4 Finally, it is believed that the supporting force of Centralisers decreases when moving. This is due to the frictional component between the casing and centraliser roller being less when moving than when stationary, i.e the static friction is greater than the dynamic friction.

As a minimum therefore:

- There should be no tools between the SAT and its nearest centraliser.
- Consider the use of strong centralisers (e.g. 70-100lbs) at each end of the SAT; 40lb centralisers may not be sufficient in small (3" diameter) casing.

Great care must be taken when other tools are added to the toolstring. If possible, assemble the string in sections, based on casing diameters found in the well to be logged. If this cannot be done, use more centralisers than thought to be absolutely necessary.

Knuckle joints may also be used as appropriate, particularly if weight bars are used.

It is a useful exercise to assemble the tool horizontally in sections of 6" casing to see the effect of adding extra tools. Even the effect of adding an extra tool between the SAT and a centraliser is usually quite significant. In 3" casing or tubing the centralisation problems are even greater.

4.3.3 ALIGNMENT OF MULTIPLE ARRAY TOOLS

When more than one flow imaging tool (i.e. CAT & SAT) are run in one string, it is advisable to keep the distance between the imaging tools to a minimum.

When multiple array tools are combined in a toolstring, a Rotational Alignment Sub (RAS001) can be used to ensure all sensors on the array tools are aligned with each other.

Refer to [A.1 Ancillary Equipment](#) for part numbers and O-ring replacement for the RAS001.

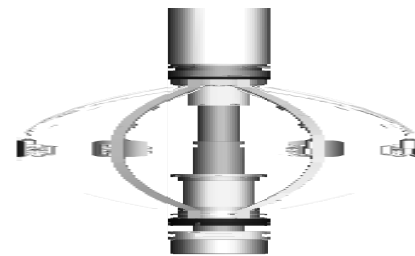


Figure 4.3 RAS

4.4 LOGGING

The following are guidelines only and must be used in conjunction with local policy and specific well site conditions both downhole and at surface. The table below is appropriate for near vertical wells and must be adjusted accordingly when in deviated wells. Use of a Head Tension Unit is highly recommended.

Note: Do not exceed the calculated safe working load of your selected weakpoint. If in doubt, use a head tension unit, especially in deviated wells where calculation from surface tension is less accurate.

Depth (ft)	Speed Pulling Out of Hole	Speed Running in Hole
In/out of catcher (pressure rig up only)	Dead slow or manual.	
30 to 150	30ft/min	
150 to 400	60ft/min	
>400 clear cased hole	Surface tension not to exceed 120% of tension when tool stationary. Speed not to exceed 150ft/min.	Surface tension should not be less than 80% of tension when tool stationary. Speed not to exceed 150ft/min.
>400 clear open hole	Surface tension not to exceed 130% of tension when tool stationary. Speed not to exceed 150ft/min.	Surface tension should not be less than 70% of tension when tool stationary. Speed not to exceed 150ft/min.
Approaching potential obstacles ^a	30ft/min	
Logging Data	Do not exceed the above speeds. Recommended speed is <30ft/min.	

a. For example: Reduced diameters, gas lift mandrels, fluid levels, valves, tubing shoes, packers, cross overs and other downhole equipment.

Logging can (and normally would) be done whilst logging both up and down. However, the down-passes can sometimes produce superior data to the up-passes. This is because the relative fluid velocity is greater when running downhole. Also, due to the unique design of the tool, it is recommended that stationary passes are taken at zones of particular interest.

4.5 POST LOGGING DISASSEMBLY

- 1 Clean the tool before disassembly, paying particular attention to the spinners.
- 2 Keep electrical connectors clean and dry.
- 3 Refit thread protectors.

4.6 TRANSPORT, HANDLING & STORAGE

Store with end threads lightly greased and with water tight thread protectors fitted.

When not in use, keep the tool inside the aluminium carry tube.

The tool should be transported to site in the transport case provided.

Do not subject the tool to extreme shock, such as dropping or hitting with a hard object.

5 MECHANICAL DESCRIPTION

5.1 OVERVIEW

The tool consists of three main sections:

- Electronics Section
- Sensor Assembly
- Central Shaft Assembly.

The electronics section plugs into the sensor head to allow for easy removal.

The sensor head acts as a hub for the 6 sensor assemblies; the sensors plug into the sensor head and have an O-ring Seal, which allow for easy replacement. The single wire of the sensor assembly (plus the chassis ground) provides power to the sensors, and in addition, the frequency signal from the sensor is sent back down this single wire to the main tool electronics. The chassis ground is ensured by utilising a canted spring on the sensor tube. Ensure this spring is in good condition.

The 6 flexible tubes of the sensor assembly, which flex with the springbow, are guided under its corresponding springbow by metallic clips and each springbow carry a single wire from the springbow-mounted spinners to the sensors. The clips guide the sensor assembly tubes to allow the sensors to keep a set distance from the springbow and therefore lessen the shielding effect on the flow from the springbows.

The springbows are anchored at the sensor head end and actuated by an expansion spring at the other end. The springbows are fixed to the tool by a clamping ring at each end, which can be backed off to allow replacement of all or individual springbows.

5.2 DISASSEMBLY

5.2.1 ELECTRONICS SECTION REMOVAL & ACCESS

5.2.1.1 Electronics Section Removal

Ref.: SAT002 General Assembly 09753
Electronics Assembly 85797

Note: Item numbers refer to the General Assembly, unless stated otherwise.

- 1 Unscrew pressure housing (item 11) from the sensor head assembly (item 1).
- 2 Lightly screw in grub screws (3x item 14, 85797) **clockwise** into the electronics assembly until flush.

Note: Do not apply excessive torque, as this will hamper removal and possibly damage the Lemo connector in the electronics assembly (item 2).

- 3 The electronics assembly (item 2) can now be unplugged from the sensor head assembly (item 1) by simply pulling them apart, see [Figure 5.1](#).



Figure 5.1 Separating Electronics from Sensor Head Assembly

5.2.1.2 Electronics Access

Ref.: SAT002 General Assembly 09753
 Electronics Assembly 85797

Note: Item numbers refer to the Electronics Assembly, unless stated otherwise.

- 1 Unscrew pressure housing (item 11, 09753) from the sensor head assembly (item 1, 09753).
- 2 The electronics boards (items 3 & 4) can be accessed by removing the upper half shell (item 7).

Note: The lower half shell should not be removed unless access to the wiring of the relative bearing assembly (item 2) is required. The upper half shell is fitted with 6 screws (item 16); the lower half shell has 10 screws (item 16) as the additional 4 screws (item 16) hold the relative bearing assembly (item 2) in place.

Note: For servicing the pressure isolation head (item 1), refer to *MN-PIH*.

5.2.2 SPRINGBOW REMOVAL

Ref.: SAT002 General Assembly 09753
 Sensor Head Assembly 40560

Note: Item numbers refer to the General Assembly, unless stated otherwise.

5.2.2.1 Removing the Springbows

- 1 Using two 'C' spanners, loosen the bow clamp locking rings (2x item 16).

Figure 5.2 Loosen Bow Clamp Locking Rings



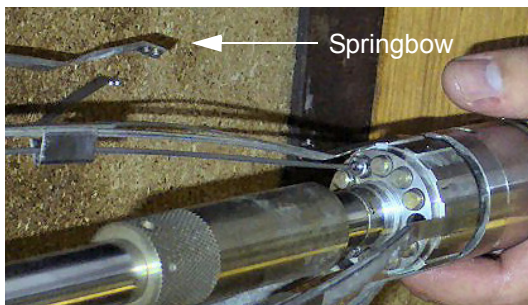
- 3 Slide the lower bow clamp ring (item 17) away from the springbows. It is now possible to disengage the Springbow (item 4) from its location holes.

Figure 5.3 Sliding lower bow clamp ring away.

Note: If only a small number of springbows are to be removed, the lower bow clamp ring (item 17) can be used to lock the remaining springbows onto the lower bow end termination body (item 15) by retightening the bow clamp locking rings (2x item 16). Ensure that the pegs of each springbow are correctly aligned.

- 4 At the other end of the springbow, screw in the bow clamp inner split ring (item 3, 40560), and slide the bow clamp outer ring (item 2, 40560) and bow clamp outer ring bursting disc (item 4, 40560) away from the springbows in a similar fashion as in operation 2.

Figure 5.4 Loosening Bow Clamp Split Rings



- 5 Disengage springbow (item 4) from its location holes.

Figure 5.5 Disengage springbow.

Note: If only a small number of springbows are to be removed, the bow clamp outer ring (item 2, 40560) and bow clamp outer ring bursting disc (item 4, 40560) can be used to lock the remaining springbows onto the sensor head assembly, by unscrewing the bow clamp inner split ring (item 3, 40560). Ensure that the pegs of each springbow are correctly aligned, and that the bow clamp outer ring (item 2, 40560) is aligned with the keyway in the sensor head assembly.

5.2.2.2 Springbow removal from SAT Sensor Assembly

- 1 Carefully push the springbow assembly (item 4) towards the lower bow end termination body (item 15) until the spinner section is free from the springbow assembly (item 4).

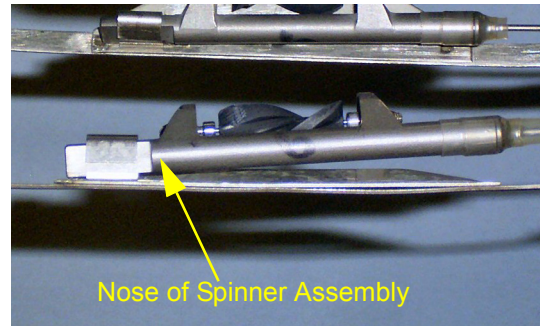


Figure 5.6 Sensor Assembly Removal

- 2 Unclip the SAT sensor assembly (item 3), fitted to the clips on the springbow assembly (item 4).
- 3 Carefully pull the SAT sensor assembly (item 3) towards the sensor head assembly (item 1) and out of the springbow assembly (item 4).
- 4 Repeat for each springbow to be replaced.

Note: This can be done by applying sufficient force behind the tube to overcome the spring force of the clip, and simultaneously levering the clip open. The SAT sensor assembly should first be released from the clip closest to the spinner.

5.2.3 REPLACING SENSORS

Ref.: Sensor Head Assembly 40560

Sensor Tube Assembly

40552

Note: Item numbers refer to the Sensor Head Assembly, unless stated otherwise.

- 1 Remove the springbows as described in [Section 5.2.2](#).

Note: If only a small number of sensors are to be removed, it is not necessary to remove every springbow.

- 2 Slacken the grub screws (3x item 17) in the locking ring (item 16).
- 3 Prior to unscrewing the locking ring, rotate the SAT radially so the marker, indicating the first sensor, is facing down.

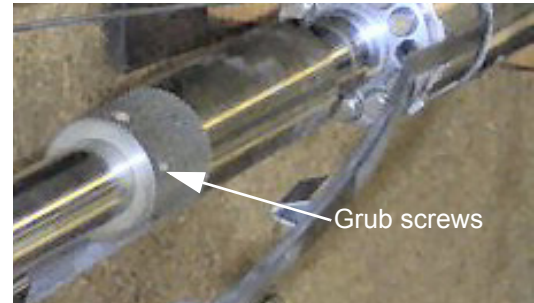


Figure 5.7 Slackening Grub Screws

Note: Failing to do so might cause the bearing ball (located under the locking ring) to fall out of the assembly.

- 4 Unscrew the locking ring (item 16) from the sensor head.
- 5 Using a small screwdriver, carefully lever out the desired sensors from the sockets in the sensor head. There is a recess in each sensor for this purpose.
- 6 Clean out the corresponding sockets in the sensor head to ensure that there are no traces of well fluid left. Isopropanol or a similar solvent can be used. Dry out the socket with soft tissue paper or similar.
- 7 If a sensor has leaked, it may be necessary to service the sensor head, see [Section 5.2.4](#).
- 8 Replace sensors.

Note: When replacing the sensors, check that the connector and corresponding socket in the sensor head are clean and thoroughly dry.

- 9 When replacing the sensors, take care when inserting them back into the sensor head. This will reduce the risk of damage to O-ring (item 9, 40552) and canted coil spring (item 3, 40552).
- 10 Retighten the grub screws (3x item 17) in the locking ring (item 16).
- 11 Refit the springbows (see [Section 5.3.3](#)) and clip the sensors back into the springbows.

5.2.4 SENSOR HEAD DISASSEMBLY

Ref.: SAT002 General Assembly
Sensor Head Assembly

09753
40560

Wiring Diagram

WD-40560

Note: Item numbers refer to the General Assembly, unless stated otherwise.

Note: O-rings (item 6, 40560) can be replaced without disassembling the sensor head.



Caution! The sensor head should not be removed, unless a leak occurred in a high pressure / temperature well. Servicing the sensor head assembly involves rewiring the sensor head and is not recommended, except in extreme circumstances.

- 1 Remove the Electronics Assembly (see [Section 5.2.1](#)), springbows (see [Section 5.2.2](#)) and sensors (see [Section 5.2.3](#)).
- 2 Remove locking ring (item 16, 40560) from Sensor Head (item 1, see [Figure 5.6](#)).

Note: Take care not to lose the ball bearing (item 26), located under locking ring (item 16, 40560), which lock the shaft (item 10) to the sensor head.

- 3 Remove 3 ball bearings from sensor head before unscrewing shaft.
- 4 Unscrew the central shaft (item 10) from the sensor head (item 1).

Note: There is a flat spanner surface on the central shaft for this purpose. The sensor head is now isolated.

- 5 Using a punch, remove spirol pin (item 18, 40560).
- 6 Gently pull Lemo connector assembly (items 14, 13 & 12, 40560) out of sensor head (item 1).
- 7 Unscrew the Kemlon Connector (item 10, 40560), using the Kemlon Tool (p/n 10051).
- 8 Desolder the appropriate wire(s) from the Lemo Connector (item 13, 40560), refer to the Wiring Diagram.
- 9 Using a Feedthrough Retaining Nut Assembly Tool (p/n 15283), unscrew the Feedthrough Retaining Nut (item 9, 40560).

Note: When replacing the Feedthrough Retaining Nut (item 9, 40560), do not tighten excessively. It should only be lightly hand-tight.

- 10 Insert the Kemlon Removal Tool (p/n 15263) into the sensor head (from the Lemo side), and using a hammer, carefully punch out the desired sensor Kemlons. Take care not to damage the wiring.

5.2.5 DISASSEMBLY OF CENTRAL SHAFT ASSEMBLY

Ref.: SAT002 General Assembly

09753

- 1 Remove the springbows (see [Section 5.2.2](#)) and unscrew central shaft assembly from the Sensor Head (see up to operation 4 of [Section 5.2.4](#)).
- 2 Unscrew grub screws (3x item 28) from the lower end sub (item 12) and tap the lower end sub (item 12) with a hammer to release, or at least loosen the ball bearings (3x item 27).
- 3 Unscrew the lower end sub (item 12) from the central shaft (item 10).

Note: This will release any of the ball bearings (item 27) that did not fall out when tapped with the hammer.

- 4 If desired, the bypass cable assembly (item 6) can now be pulled out of the central shaft (item 10).
- 5 Also if desired, the lower connector assembly (item 5) can be removed from the lower end sub (item 10) by removing the circlip (item 24) and then the spiro pin (item 23).

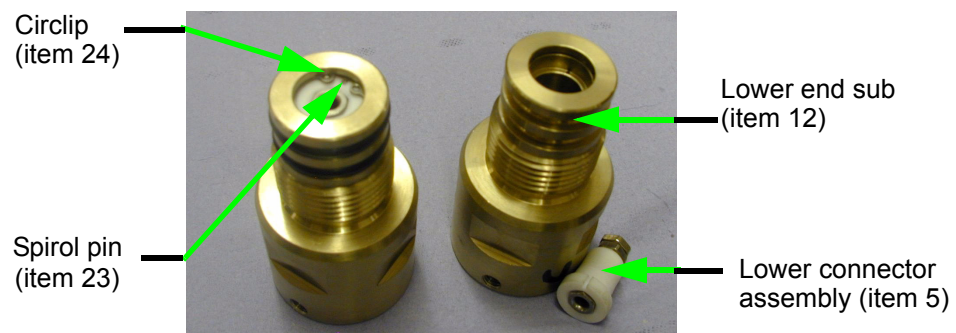


Figure 5.8 Removing Lower Connector Assembly

- 6 Using a punch, remove spiro pins (2x item 22) that secure the spring retaining ring (item 14) to the lower end bow termination body (item 15).
- 7 Slide back spring retaining ring (item 14) from the lower end bow termination body (item 15), and unscrew the spring (item 19) **clockwise** off the lower end bow termination body (item 15).

Note: A small 'C' spanner can be used to open up the spring in order to help this task.

- 8 The lower end bow termination body (item 15) and the assembled spring end stock (item 13) can now be removed from the central shaft (item 10).

5.3 REASSEMBLY

5.3.1 REASSEMBLY OF CENTRAL SHAFT ASSEMBLY

Ref.: SAT002 General Assembly 09753

- 1 Slide a spring retaining ring (item 14) over extension spring (item 19) and screw spring (item 19) **anti-clockwise** onto lower end bow termination body (item 15).

Note: A small amount of grease may aid with this assembly.

- 2 Secure the spring retaining ring (item 14) to the lower end bow termination body (item 15) with spirol pins (2x item 22).
- 3 Slide the second spring retaining ring (item 14) over the spring (item 19) and slide the assembly onto the central shaft (item 10), along with the spring end stock (item 13) from the other end.

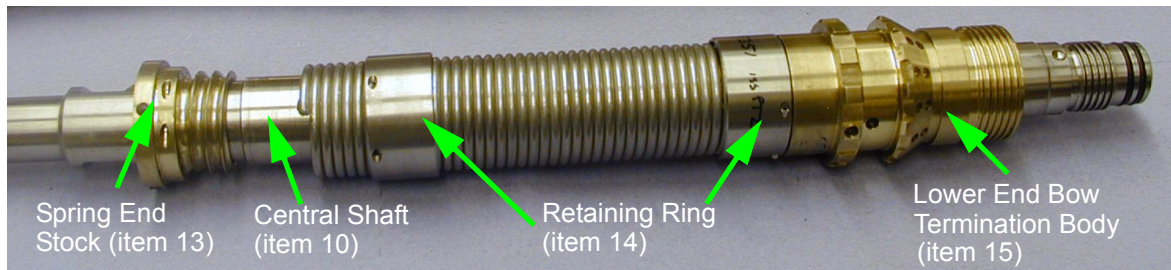


Figure 5.9 Central Shaft Assembly

- 4 Screw the extension spring (item 19) **anti-clockwise** to the spring end stock (item 13).

Note: A small amount of grease applied to the end stock will aid with this assembly.

- 5 Fit one of the retaining rings (item 14) over the spring (item 19) and secure to the spring end stock (item 13) with spirol pins (2x item 22).

Note: The assembly should now be assembled as shown in Figure 5.9.

- 6 Fit the bow clamp ring (item 17) and clamp locking rings (2x item 16) to the lower end bow termination body (item 15).
- 7 Insert the bypass cable assembly (item 6) into the central shaft (item 10).
- 8 Fit O-rings (2x item 30) to the lower end of the central shaft (item 10).

Note: Grease the grooves on the central shaft (item 10) and the O-rings with Liquid O-ring prior to fitting the O-rings.

- 9 Fit O-ring (item 31) to Lower End Sub (item 12) and apply Liquid O-ring.
- 10 If removed during disassembly, fit spirol pin (item 23) to lower end sub (item 16) and insert lower connector assembly (item 5). Secure lower connector assembly to the lower end sub (item 12) using a circlip (item 24).

- 11 Screw the lower end sub (item 12) onto the end of the central shaft (item 10). Lock in position using Bearings (3x item 27) and Grub Screws (3x item 28).

Ensure the lower end sub (item 12) is fully tightened onto the central shaft (item 10).

- 12 Fit O-rings (2x item 25) to lower end sub (item 12). Apply Liquid O-ring prior to fitting.

- 13 Fit O-rings (2x item 29) to the end of the central shaft (item 10) that screws into the sensor head assembly (item 1).

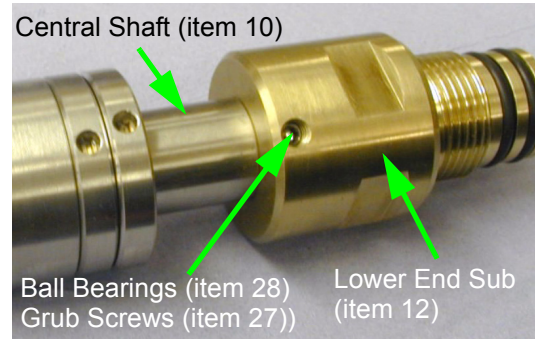


Figure 5.10 Lower End Sub screwed onto Central Shaft

Note: Lubricate the O-ring grooves on the shaft (item 10) and the O-rings with Liquid O-ring prior to fitting.

5.3.2 SENSOR HEAD REASSEMBLY

Ref.:	SAT002 General Assembly	09753
	Sensor Head Assembly	40560
	Wiring Diagram	WD-40560

Note: Item numbers refer to the Sensor Head Assembly, unless stated otherwise.

Note: O-ring (item 5) can easier be replaced when the springbows are refitted, see [Section 5.3.3](#).

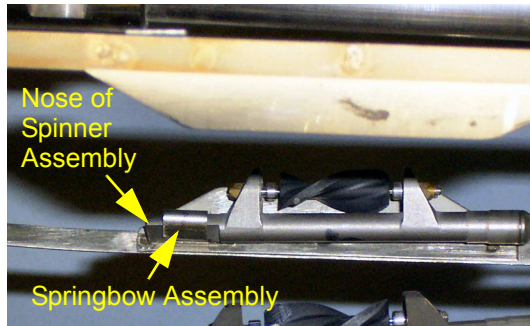
- 1 Grease O-rings on the sensor Kemlons (item 11) with a little Silicone Grease.
- 2 Insert each sensor Kemlon (item 11) into the sensor head assembly (item 1) by hand as far as possible. Then, gently but firmly, punch it fully home, using the Kemlon Removal Tool (p/n 15263).
- 3 Lock it in place with a feedthrough retaining nut (item 9) using the Feedthrough Retaining Nut Assembly Tool (p/n 15283). This should be hand tightened only.
- 4 Insert the line Kemlon (item 10) into the sensor head assembly (item 1) using the Kemlon Tool (p/n 10051).
- 5 Re-solder all wires to the Lemo connector (item 13) as indicated on the wiring diagram.

Note: Ensure that the line connection is thoroughly shielded. Thoroughly check that all connections are correct.



Caution! If the line wire is inadvertently connected to a sensor, the corresponding sensor will be destroyed.

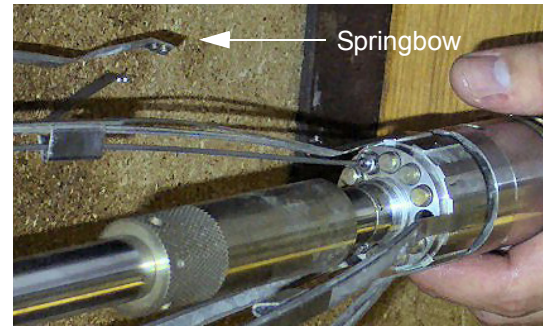
5.3.3.2 Refitting the Springbows



- 3 Fit a springbow assembly (item 4) on the sensor head assembly (item 1), orientated so the sensor tube clips are at the sensor head (item 1) end.

Note that there is a keyway at the sensor head end, so care should be taken to ensure that this is correctly aligned. (SAT001 sensor head shown. SAT002 sensor head only has 6 holes.)

- 1 Carefully push the springbow assembly (item 4) over the nose of the spinner section until the nose of the spinner section is engaged in the springbow assembly (item 4).
- 2 Clip the SAT sensor assembly (item 3) into the clips on the springbow assembly (item 4).



- 4 Slide the bow clamp outer ring (item 2, 40560) and bow clamp outer ring bursting disc (item 4, 40560) in place and tighten the bow clamp inner split ring (item 3, 40560).

Note: If the springbows are new, it may be convenient to use an elastic band at each end to hold them in place until the bow clamp rings are tightened. This is not usually necessary once they have been tightened into place for some time. Repeat this procedure for each of the remaining springbow assemblies.

- 5 Using two 'C' spanners, loosen the bow clamp locking rings (2x item 16) on the lower end of the tool.
- 6 Slide the lower bow clamp ring (item 17) away from the springbows.
- 7 Fit a springbow assembly (item 4) and secure the springbows by retightening the rings with 'C'-Spanners.



- 8 Tighten the grub screws in the bow clamp inner split ring (item 3, 40560) to lock it onto the sensor head (item 1).

5.3.4 ELECTRONICS SECTION REASSEMBLY

Ref.: SAT002 General Assembly 09753
 Electronics Assembly 85797

Note: Item numbers refer to the General Assembly, unless stated otherwise.

- 1 Plug the electronics assembly (item 2) into the sensor head assembly (item 1)

Note: Note the orientation of the Lemo Connectors.



Figure 5.12 Connecting Electronics to Sensor Head

- 2 Lightly screw grub screws (3x item 14, 85797) **anti-clockwise**, securing the electronics assembly (item 2) to the sensor head assembly (item 1).
- 3 Refit O-ring (item 11, 85797) on the pressure isolation head (item 1, 85797). Apply liquid O-ring before refitting.
- 4 Refit Pressure Housing (item 11), using a 38mm Spanner and a 'C'-Spanner.

6 ELECTRICAL DESCRIPTION

Ref.: Block Diagram
Wiring Diagram

Figure 3.1
WD-85797

6.1 SAT SPINNER ELECTRONICS

Ref.: Spinner Sensor Electronics (PCB82455)

CD-82453

The SAT incorporates six spinners or impellers each of which has a small printed circuit board containing rotation sensors, a temperature sensor and a 'one-wire' interface. The spinners are connected to an interface board in the tool body.

The rotation sensing circuit comprises three low-power Hall effect sensors, connected to a PIC microcontroller. Each Hall effect sensor is axially aligned with one of three magnets spaced along the spinner impeller such that the circumferential spacing between magnets is one third of a rotation.

The microcontroller scans these sensors at high speed and determines the direction of rotation from the order in which the sensors are operated by the magnets. A firmware counter is incremented or decremented accordingly.

The temperature sensor is a precision thermistor which is monitored by a microcontroller ADC channel.

The one-wire interface operates using coded current pulses; the microcontroller pulls 'long' and 'short' pulses of current from the supply to signal data to the SAT interface board. This pulse code transmission is initiated by the interface momentarily taking the spinner supply (the 'one-wire') to a higher voltage.

6.2 INTERFACE BOARD

Ref.: Interface Board (PCB85452)

CD-82450

The SAT interface board collects data from the six spinners and an orientation electrolevel and passes this to the Ultrawire™ interface board using a 250kBaund serial interface.

The spinners are interrogated by momentarily switching their supply voltage to 5.5V from a nominal 3.3V. This initiates the current pulse data transfer, referred to above. A PIC microcontroller, U10, in conjunction with a HC138 decoder selects which of the switches U1..U6 operates. Current pulses are detected by U7 and U9 and routed to a PIC microcontroller input. The PIC measures and decodes the pulses to extract spin count, temperature and time of last count information.

The electrolevel (often referred to as a tilt sensor or 'alcpot') is energised by the PIC in a particular sequence and various readings taken by the PIC ADC channels.

The PIC is clocked at 4MHz, which is obtained from the Ultrawire™ board 8MHz clock through the divider U11. This facilitates a 250kBaund asynchronous serial interface, which sends the data to the Ultrawire™ interface board.

6.3 DIGITAL BOARD

Ref.: Digital Board (PCB82333) *CD-82333*

The SAT Digital Board contains 3 main functional blocks. These are the switched mode power supply, the Ultrawire™ bus interface and the system control electronics.

The switched mode power supply (SMPS) takes DC power from the Ultrawire™ tool bus and generates two outputs, a 3.3V rail that powers all the analogue and digital circuitry in the sensing section and a nominally 5.5V rail, used solely on the Interface Board. The SMPS is isolated from the Ultrawire™ toolbus by an active choke consisting of Q5 and associated circuitry. The filter, formed by this active choke together with capacitor (C6), prevents switching currents, generated by the SMPS from appearing on the Ultrawire™ bus, where they would cause data corruption, and ensures that the tool takes a steady DC current. The tool is protected against overvoltage and reverse connection by fuse (F1) and zener diode (D1).

The SMPS is controlled by SMPS controller (U1), which together with MOSFET (Q4) and transformer (L1) form the core of the power supply. U8 provides a 2.048V reference for the supply, and inductor (L2) and capacitor (C7) form an output filter on the 3.3V output. The 5.5V rail is unfiltered.

The SMPS operating frequency is variable and increases with increased demand on the output rails. This design of power supply is inherently protected against a short circuit on either output rail, making it extremely robust.

The Ultrawire™ interface consists of PLD (U5) and the circuitry, contained in the lower right of sheet 1 of the SAT Digital Board circuit diagram. Capacitor (C3) couples the bi-directional telemetry signals between the Ultrawire™ bus and the bus interface.

The Ultrawire™ PLD (U5) is effectively a UART, handling communications between the system microprocessor (U7) and the Ultrawire™ bus. The various control lines between the two enable the microprocessor to receive commands and data from the bus and to transmit data on the bus.

System control is performed by the microprocessor (U7), which in addition to communicating with the Ultrawire™ bus via PLD (U5), controls the acquisition of data from the various sensors within the sensing section.

Serial lines TX and RX form a high speed (250kBaud) connection to the SAT Interface Board.

The relative bearing sensor comprises two weighted servo potentiometers in antiphase. The track ends connect to P5:2 and P5:1 which are configured as digital outputs, and the wipers connect to P10:2 and P10:1 which are configured as ADC inputs.

U3 is a voltage monitor and system reset generator that only allows the tool to operate when the 3.3V power rail is stable.

X1 is a crystal oscillator, generating the system clock for the sensing section. Under normal operation this an 8MHz clock signal, but may be switched down to 64kHz by the microprocessor (via PLD U5 CPU_CLK_SPD line) to save power while the tool is idle.

7 EXTENDED CHECKS

7.1 PREVENTATIVE MAINTENANCE

7.1.1 GREASE & LUBRICANTS

Sondex recommends the use of “Liquid O-ring type 101” (p/n LOR101) on threads and O-rings.

All O-rings and housing threads are assumed to be and must be lightly greased, unless specifically indicated otherwise.

Correct use of grease and lubricants is essential to the maintenance of all Sondex downhole equipment.

Note that some threads are internal, which can cause grease to get inside the tool. Do not use excessive quantities.

Sondex does not recommend Copper loaded greases since some types can cause electrical leaks. Some types for grease are not suitable for use on O-rings. Silicone grease may be used on O-rings, but must be kept clear of threads, especially stainless steel to stainless steel.



Caution!

The use of certain greases, which contain volatile content, (e.g. some types of Lubriplate) can cause electrical failure due to production of corrosive gasses inside the tool when burned off.

7.1.2 MECHANICAL

Refer to [Section 5 Mechanical Description](#) as required for disassembly / re-assembly instructions.

- 1 Remove dirt and old grease from pressure housing threads and O-rings and replace with fresh.
- 2 Inspect O-rings for damage or ageing/hardening and replace where required.
- 3 Check for:
 - Damaged wires.
 - Wires that are loose and likely to be crushed on re-assembly.
 - Damaged components.
 - Loose screws/nuts/components/connectors.

Note: If RTV or similar compound is used to secure loose components, it must be fully cured before housing is replaced.

- Electrical components shorting to chassis.
 - Heat or chemical damage (discoloured components).
 - Incorrect thread grease or excessive quantity, see [Section 7.1.1 Grease & Lubricants](#).
- 4 Check any connectors for cleanliness and loose / bent pins before replacing.
 - 5 Check all fixings for tightness.

7.1.3 ELECTRICAL

Ref.: SAT Electronics Wiring Diagram [WD-85797](#)

- 1 With the electronics cartridge removed, make the following meter checks at the Lemo connection at the bottom of the electronics assembly. Use a standard Multimeter and not a high voltage Megohm Meter for these tests. See [Figure 7.1](#) below for pin/socket position.

Pin 14 to chassis	Spinner #1	> 1MΩ
Pin 16 to chassis	Spinner #2	> 1MΩ
Pin 10 to chassis	Spinner #3	> 1MΩ
Pin 12 to chassis	Spinner #4	> 1MΩ
Socket 6 to chassis	Spinner #5	> 1MΩ
Socket 2 to chassis	Spinner #6	> 1MΩ
Socket 3 to chassis	GND	< 0.2Ω
Socket 4 to Upper Banana Pin	Through Line	< 0.2Ω
Socket 4 to chassis	Through Line	> 1MΩ

Pins 7 and 8 are not connected, the remainder of the pins and sockets (pins/sockets 1, 5, 9, 11, 13 and 15) are connected but not used. Testing is not necessary.

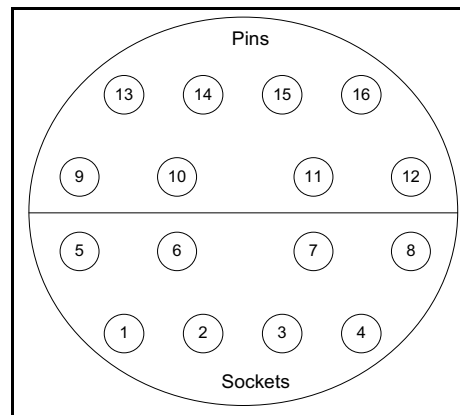


Figure 7.1 Lemo pin/socket positions (Rear View)

- 2 Replace the electronics cartridge.
- 3 Check through line resistance and tool current, see [Section 4.1.2 Electrical](#).
- 4 Connect to logging system and check for correct data. Apply some gentle vibration and rotation to expose potential failure.
- 5 Take velocity and direction readings.

7.1.4 AGEING OF ELECTRONICS

At 150°C, significant electronic ageing failures are expected after 4000hrs typical use, hence PCB replacement should be considered at this point. Every additional 10°C halves the time. Life of the electronics is also accelerated by vibration and corrosive gas inside the chassis. Visual inspection and logging previous history is recommended, but is unlikely to predict premature failure.

Tools that may be suspected of reliability problems due to age or unusual log response may be heated to 120°C, which would not normally age the electronics, and afterwards subjected to moderate vibration. A moderately hard blow from a wooden hammer is recommended.

DO NOT USE METAL HAMMERS.

Whilst heating the tool, it is recommended that the sensors should either be removed, or be immersed in oil.

7.1.5 HEAT TESTING ABOVE 150°C

This is not generally recommended since it shortens tool life expectancy.

Heat testing may be required for contractual reasons, tool out of use for a long period, or job with unusually high well temperature. The test should be carried out slightly above expected well temperature only and the tool should not be kept at temperature for more than 1 hour.

7.2 EXTRAORDINARY MAINTENANCE

7.2.1 O-RING REPLACEMENT

Ref.:	SAT002 General Assembly	09753
	Sensor Head Assembly	40560
	Single Pin Sensor Assembly	40552

Note: All item numbers refer to the General Assembly, unless stated otherwise.

The following guidelines are appropriate for normal operating conditions. If the tool experiences harsher conditions (e.g. high pressure, temperature, H₂S), then more thorough servicing is recommended.

To determine contact with H₂S, check for discoloration of the and lower sub (item 12). This parts are made of Al/Bronze and will turn black when in contact with H₂S. Local well site knowledge will also contribute to determine the possibility of H₂S exposure.

7.2.1.1 Every Run

Minimum recommendation is to replace the O-rings at the bottom of the tool (item 25) every time the tool joint is broken, when the tool has been under pressure, It is also recommended that the O-rings on the sensor head under the pressure housing (items 6, 40560) are replaced prior to every job.

7.2.1.2 Every 5 Runs

In addition to the O-rings that should be changed prior to every job, it is recommended that all "wet" O-rings (i.e. O-rings that experience well pressure) should be changed every 5 jobs. These are:

- 2x O-rings (item 29).
- 2x O-rings (item 30).
- 6x O-rings (item 9, 40552)

When replacing the sensor O-rings, **ensure that grease is applied into the O-ring groove prior to sliding on the new O-ring. A small amount of grease should also be applied to the outer side of the O-ring.** Immersing the O-rings in hot water will also soften them and aid their insertion, refer to Section 7.2.1 O-ring Replacement.

During replacement of the O-rings, the tool is stripped down to its base assemblies, allowing the tool to be cleaned and serviced thoroughly.

7.2.2 SERVICING SENSOR HEAD

This should rarely be necessary, unless there has been a leak in a high pressure / temperature well. If this has happened, the Kemlons inside the sensor head can be cleaned and the O-rings on them changed. Ordinarily, none of the Kemlons are exposed to well fluid or pressure. Servicing the sensor head assembly involves rewiring the sensor head and is not recommended, except in extreme circumstances.

7.2.3 USE OF PRESSURE TEST BLANK ASSEMBLY

Pressure Test Blank Assemblies (p/n15286) can be inserted into the Sensor Head in place of a sensor.

They are primarily used for in-house testing purposes; however they can also be used in the field and there are two main reasons for this:

- If a sensor has failed and no spares are available, one of these can be inserted into the Sensor Head. This will prevent the associated Kemlon in the Sensor Head from being contaminated with well fluid.
- In very low diameter tubing, there may be concerns over whether the tool will obstruct the flow too much, possibly causing it to be blown out of the well. In such cases, one may wish to operate the tool with fewer sensors. The Pressure Test Blank Assemblies can then be inserted into the unused positions in the Sensor Head.

7.3 TROUBLESHOOTING

Refer to [Section 5 Mechanical Description](#) for disassembly instructions and [Appendix B Drawings & Parts Lists](#) where necessary.

7.3.1 ELECTRICAL

An Oscilloscope, Multimeter and other basic test equipment will be required.

<p>Initial Inspection</p>	<p>Check for:</p> <ul style="list-style-type: none"> • Damaged wires. • Damaged components. • Electrical components shorting to chassis. • Heat or chemical damage (discoloured components). • Incorrect thread grease or excessive quantity; see Section 7.1.1 Grease & Lubricants. <p>Also check all fixings are tight.</p>
<p>Excessive Current</p>	<p>Remove the electronics assembly and spinner arrays from the sensor head to isolate fault to electronics or sensor head / shaft assembly or spinner array.</p> <p>Disconnect wires to isolate fault to:</p> <ul style="list-style-type: none"> • Interface board (PCB82452). • Digital board (PCB82457). • Upper head connector. • Lemo connector on electronics. • Sensor head assembly. • Shaft assembly (incl. bypass tube). <p>Fault find or replace PCB if necessary.</p> <p>With the electronics assembly removed, the line connection at the bottom of the tool may be tested 250V relative to chassis to check for electrical leak.</p> <p>Resistance should exceed 100MΩ. Disassemble to locate fault.</p>
<p>Little or no current</p>	<p>On PCB85754 check LINE = 18V, 12Va = 12V, 5Vs = 5V, 5Vt = 5V and 0V wire connects to chassis. Fault find or replace PCB.</p>
<p>No telemetry reply</p>	<p>On PCB85754 check LINE = 18V, 12Va = 12V, 5Vs = 5V, 5Vt = 5V and 0V wire connects to chassis. Fault find or replace PCB.</p> <p>On PCB85752 check TP6 for 4MHz clock. Replace U3 if faulty. Reduce R7 if clock < 3V amplitude.</p> <p>Check line for +1V and -1V, 1.8µs pulses from the controller and similar pulses from the tool. Logic pulses should be present on TP1 - 4.</p> <p>Fault find or replace PCB85752 or PCB85754.</p>

<p>All Sensor data reads zero</p>	<p>On PCB85765 check for:</p> <ul style="list-style-type: none"> • Pulses on Fo. • Signals on pads S1 - S12. Each should go high for 288µs • Address lines A0 - A3 are operating. <p>On PCB85752 check for:</p> <ul style="list-style-type: none"> • Pulses on Fo. • Address lines A0 - A3 and B1 are operating.
<p>Single faulty Sensor</p>	<p>Swap sensors to determine if the sensor is faulty. Replace if necessary.</p> <p>If the fault is not with the sensor, check the wiring from the PCB, through the Lemo connectors, to the Kemlons on the sensor head.</p> <p>If a sensor has leaked, it should be replaced.</p>
<p>Rotation faults</p>	<p>With the tool horizontal, check that pendulum rotates freely.</p> <p>The voltages on ROTx and ROTy should increase as the tool rotates clockwise (looking down the tool).</p> <p>Check that they are offset by approximately 180°. This can only be checked roughly, but when ROTx is at 5V, ROTy should be approximately 2.5V.</p>

7.3.2 MECHANICAL

<p>Damaged O-rings.</p>	<p>Visually inspect O-rings. Check that the O-rings are clean and greased. Replace the O-rings if the following occurs:</p> <ul style="list-style-type: none"> • Cracks or tears in the O-rings. • The O-rings will have an excessive size when taken out of the hole (due to moisture intake). • The tool experienced temperatures in excess of 150°C. • The tool experienced contact with H₂S gas.
<p>Damaged Magnets.</p>	<p>Visually inspect the magnets. Replace complete spinner assembly if:</p> <ul style="list-style-type: none"> • Data is spiked. • Irregular count rate or missed counts are noticed. • Magnets are damaged (e.g. chipped). <p>If iron scrapings are visible, they might be washed away with a light oil.</p>
<p>Spinner does not rotate smoothly or does not rotate at all. If the spinner is unbalanced</p>	<ul style="list-style-type: none"> • Ensure the bearings are clean and the bearings are not damaged. Replace if necessary. • Check that there is no dirt or debris between the bearings and the shaft, which might impair the free movement of the shaft. Flush with a light oil if required. • If the spinner doesn't appear to be balanced. Replace or Contact Sondex for alternative options. • Ensure that the pivot pin tips are not damaged. Replace if necessary.

APPENDIX A EQUIPMENT & RECOMMENDED SPARES

Item	Part No	Description	Qty	Remarks
1	SAT002	Spinner Array Tool, 1 ¹¹ / ₁₆ " ¹ , Ultrawire™	1	

A.1 ANCILLARY EQUIPMENT

Item	Part No	Description	Qty	Remarks
1	15265	Flight Case, 1 ¹¹ / ₁₆ "	1	
2	40196	Rotational Alignment Sub (RAS001). ^a	AR	Not supplied with the tool.

a. The RAS001 has 4 O-rings in total, which might need replacing. Refer to items 4 & 5 of [Appendix A.3](#). Apply Liquid O-ring to O-rings and threads before fitting.

A.2 MAINTENANCE EQUIPMENT

Item	Part No	Description	Qty	Remarks
1	40886-PT2	Hand Tool Kit for all 1 ¹¹ / ₁₆ " SAT tools	1	
2	15263	Kemlon Removal Tool	1	Included in KITR-SAT002 .
3	15283	Feedthrough Retaining Nut Assembly Tool	1	Included in KITR-SAT002 .
4	15272	O-ring Removal Tool	1	Included in KITR-SAT002 .
5	LOR101	Grease for O-rings and threads	1	5oz pot.
6	LOR101L	Grease for O-rings and threads	1	16oz pot.

A.3 RECOMMENDED SPARES

Item	Part no.	Description	Qty	Remarks
1	KITB-SAT002	Basic Spares Kit	1	To support one run in hole.
2	KITR-SAT002	Recommended Spares Kit	1	To support 25 runs in hole.
3	KITU-MAPS	Kit Upgrade	1	
4	KITREM-SAT002	Remote Spares Kit	AR	Suitable for remote logging operations

Recommended Spares for Rotational Alignment Sub (RAS001):

Item	Part no.	Description	Qty	Remarks
1	99124	Viton O-ring 90 Type 124.	2	Parts for RAS001 not included in spares kits.
2	99211	Viton O-ring 90 Type 211.	2	

All spares kits and parts, mentioned in this section, can be supplied upon request. However, Sondex recommends the purchase of these kits and parts to properly support your logging tools from job to job. Contact Sondex and quote the part number of the spares kit or part for additional information or when ordering the item.

As a guidance:

- A Basic Spares Kit mainly contains essential maintenance equipment, O-rings and parts, which are likely to need replacing on a run-by-run basis (including spare parts for the initial tool run) or parts that can be lost easily (like grub screws).
- A Recommended Spares Kit has got a multitude of the same parts as a Basic Spares Kit, supplemented by parts that might need replacement at a lower frequency (i.e.: 5 runs and/or 25 runs).

Note that the information above is a guidance only and Sondex reserves the right to change the contents of the Spares Kits as required.

PARTS LISTING	
Part	Issue
40886	P2
Description	
HAND TOOL KIT - 1 11/16 MAPS TOOLS	

PARTS LIST					
Item	Part No	Description	Qty	Units	Remarks
0001	91005	Spanner Open Ended 42mmx38mm	2	EA	
0002	91019	Spanner C 50mm 35mm	2	EA	
0003	10038	Spanner Box 3/8 x 5/16 Modified	2	EA	
0004	94262	SCREWDRIVER FLAT BLADE 2.5 x 75MM	1	EA	
0005	91409	Spanner Open-Ended 18x19mm	1	EA	
0006	91029	Key, Hex Metric (Set)	1	EA	
0007	91030	Punch Pin Parallel set	1	EA	
0008	40883	BOX SPANNER MODIFIED	1	EA	
0009	91293	Screwdriver Parallel tip (3 0 x 75)	1	EA	
0010	91105	Toolroll With SX Badge Large Black	1	EA	
0011	91104	Screwdriver Parallel tip (5 5 x 200)	1	EA	
0012	91103	Pliers Circlip 812 Chrome/Van	1	EA	
0013	91102	Pliers Mini Flat Nose 5 Inch	1	EA	
0014	10037	Bar Tommy	2	EA	
0015	10051	Kemlon tool Sondex - 4BA Hex Socket	1	EA	
0016	91280	Hammer, 4oz ball pein	1	EA	
0017	91130	Pin C Spanner 35-50mm	1	EA	
0018	91822	Medium Flat Blade Screwdriver, 5mm	1	EA	
0019	91255	T15 Torx driver, Sandvik Belzer 8915	2	EA	
0020	20322	Assembly Tool - Sensor O'ring MTT	1	EA	
0021	15263	Tool Removal Connector Kemlon	1	EA	
0022	15283	Assy Tool Feed-Through Retaining Nut	1	EA	
0023	10099	Miniature Kemlon tool Sondex - Modified	1	EA	
0024	16210	Tool Axle Nut Screwdriver MDT	1	EA	
0025	91197	Pliers Long Nose (Small)	1	EA	
0026	91229	Medium Pozi Screwdriver	1	EA	
0027	LOR101	Film Form Lube 5oz Pot Liq O Ring typ101	1	ML	

PARTS LISTING	
<i>Part</i>	<i>Issue</i>
KITB-SAT002	NC
<i>Description</i>	
Kit, Spares, Basic, SAT002	

PARTS LIST					
<i>Item</i>	<i>Part No</i>	<i>Description</i>	<i>Qty</i>	<i>Units</i>	<i>Remarks</i>
0001	KITO-SAT002	Kit, Spares, O-Rings, SAT002	1	EA	
0004	91611	Bearing Ball 2mm Chrome Steel	3	EA	
0005	93043	Scr Grb Skt Hd M3x04mmLG SS-A2 (DIN 916)	3	EA	
0006	91000	Bearing Ball 3/16 Hard	6	EA	
0007	01082	Scr Grb Skt Hd M6 x 5 LG SS FLAT POINT	3	EA	
0008	01047	CIRCLIP INTERNAL 5/8 SS N1300	2	EA	
0009	01029	Screw Csk Hd(Slotted) M3 x 06mm LG SS	10	EA	
0010	92128	Spg Coil Canted 7mm Bore,4.6mm ID BeCu	4	EA	

PARTS LISTING	
<i>Part</i>	<i>Issue</i>
KITR-SAT002	A
<i>Description</i>	
KIT SPARES RECOMMENDED (25 RUN)SAT002	

PARTS LIST					
<i>Item</i>	<i>Part No</i>	<i>Description</i>	<i>Qty</i>	<i>Units</i>	<i>Remarks</i>
0001	KITB-SAT002	Kit, Spares, Basic, SAT002	2	EA	
0002	KITO-SAT002	Kit, Spares, O-Rings, SAT002	5	EA	
0003	40554	ASSY SENSOR FLOW METER	6	EA	
0004	40046	Assy Springbow 7" SAT	6	EA	
0005	41577	ASSY SPINNER SAT	6	EA	

PARTS LISTING	
<i>Part</i>	<i>Issue</i>
KITU-MAPS	P1
<i>Description</i>	
Kit upgrade MAPS restricted opening kit	

PARTS LIST					
<i>Item</i>	<i>Part No</i>	<i>Description</i>	<i>Qty</i>	<i>Units</i>	<i>Remarks</i>
0001	41171	KIT-SPACER RINGS	1	EA	

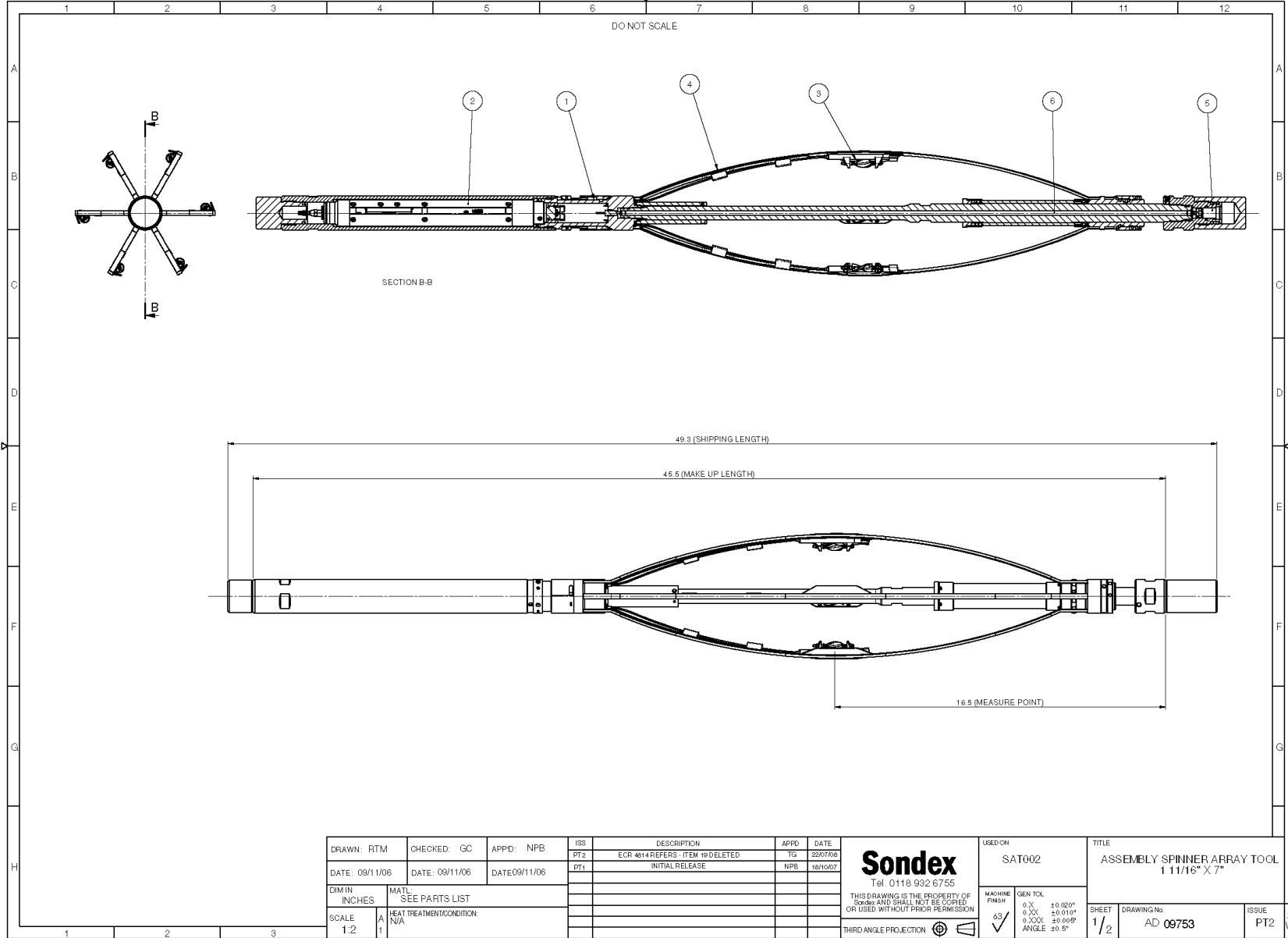
APPENDIX B DRAWINGS & PARTS LISTS
B.1 MECHANICAL DRAWINGS

Description	Drawing^a
SAT002 General Assembly - 2 sheets	09753-PT2
Electronics Assembly	85797-PT3
Sensor Isolation Sub	40560-A
Flowmeter Sensor Assembly	40554-PT2
.Single Pin Sensor Assembly	40553-PT2
--Sensor Tube Assembly	40552-PT1

a. Parts Lists shown on drawings.

B.2 ELECTRICAL DIAGRAMS

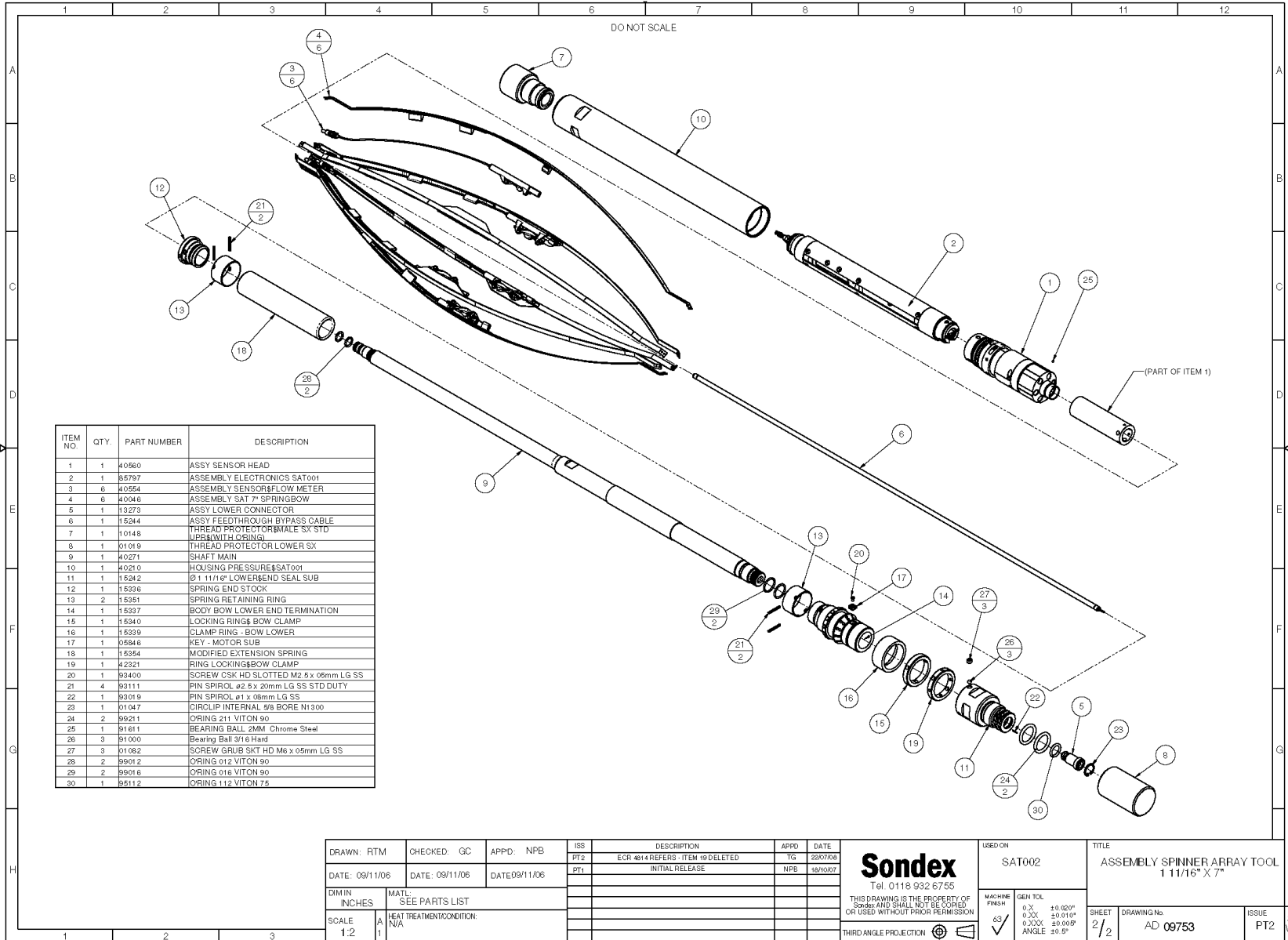
Description	Type	Drawing
Electronics Assembly	Wiring Diagram	WD-85797-E
Sensors Head	Wiring Diagram	WD-40560-A
Interface Board (PCB85452)	Circuit Diagram	CD-82450-B
Digital Board (PCB82333) - 2 sheets	Circuit Diagram	CD-82333-G00
Spinner Sensor Electronics (PCB82455)	Circuit Diagram	CD-82453-G00



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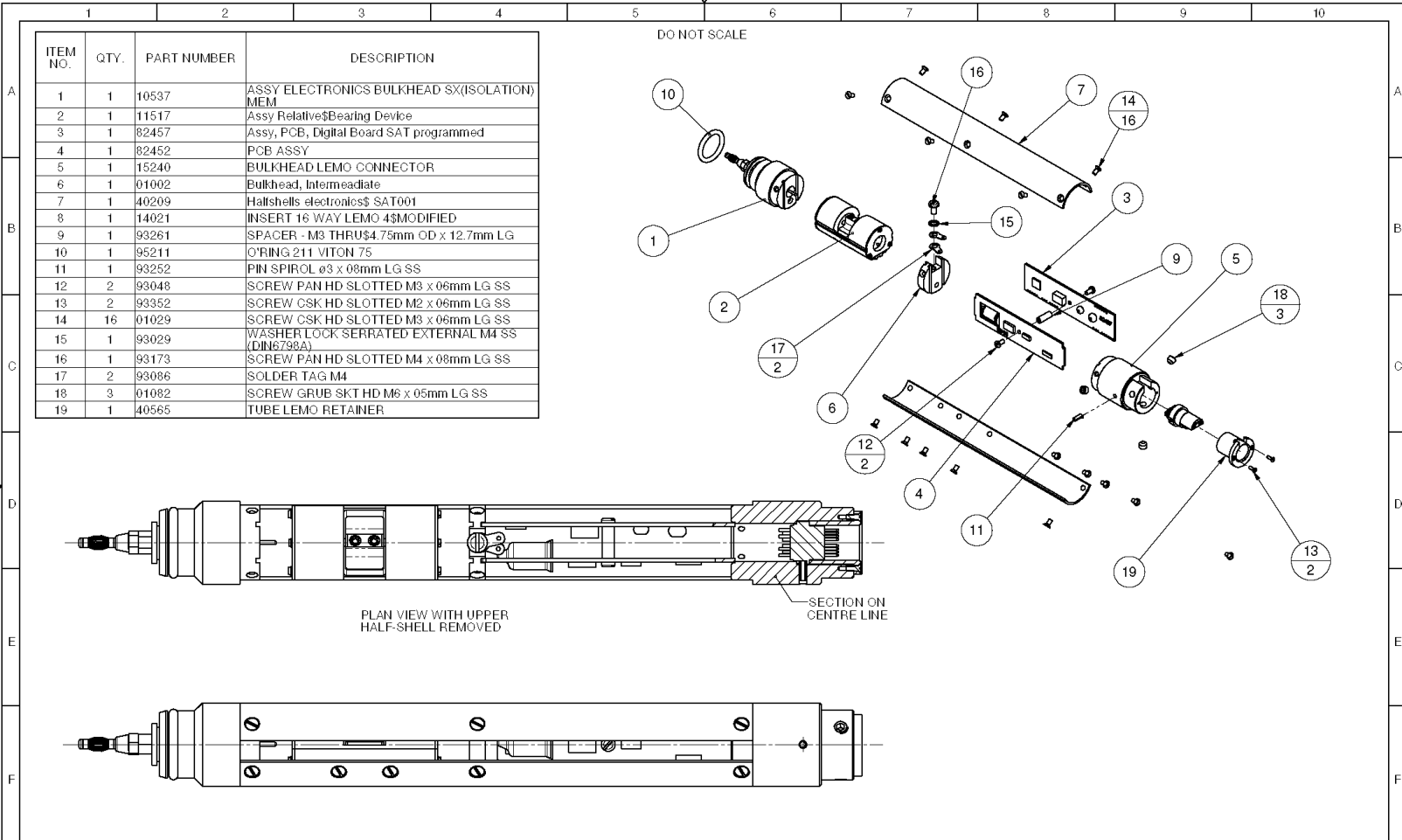
ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
1	1	40560	ASSY SENSOR HEAD
2	1	85797	ASSEMBLY ELECTRONICS SAT001
3	8	40554	ASSEMBLY SENSOR&FLOW METER
4	8	40046	ASSEMBLY SAT 7 th SPRINGBOW
5	1	13273	ASSY LOWER CONNECTOR
6	1	15244	ASSY FEEDTHROUGH BYPASS CABLE
7	1	10148	THREAD PROTECTOR<M>MALE SX STD UPR<WITH O-RING>
8	1	01019	THREAD PROTECTOR LOWER SX
9	1	40271	SHAFT MAIN
10	1	40210	HOUSING PRESSURE<SAT001
11	1	15242	Ø 1.1174" LOWER&END SEAL SUB
12	1	15396	SPRING END STOCK
13	2	15351	SPRING RETAINING RING
14	1	15337	BODY BOW LOWER END TERMINATION
15	1	15340	LOCKING RING<BOW CLAMP
16	1	15339	CLAMP RING - BOW LOWER
17	1	15348	KEY - MOTOR SUB
18	1	15354	MODIFIED EXTENSION SPRING
19	1	42321	RING LOCKING<BOW CLAMP
20	1	93400	SCREW CSK HD SLOTTED M2.5 x 0.5mm LG SS
21	4	93111	PIN SPIROL ø2.5 x 20mm LG SS STD DUTY
22	1	93019	PIN SPIROL ø1 x 0.8mm LG SS
23	1	01047	CIRCLIP INTERNAL 9/16 BORE N1900
24	2	99211	O-RING 211 VITON 90
25	1	91611	BEARING BALL 2MM Chrome Steel
26	3	91000	Bearing Ball 3/16 Hard
27	3	01082	SCREW GRUB SKT HD M6 x 0.5mm LG SS
28	2	99012	O-RING 012 VITON 90
29	2	99016	O-RING 016 VITON 90
30	1	85112	O-RING 112 VITON 75

DRAWN: RTM	CHECKED: GC	APPD: NPB	ISS: PT2	DESCRIPTION: ECR 4814 REFERS - ITEM 19 DELETED	APPD: TGT	DATE: 22/07/08	USED ON: SAT002	TITLE: ASSEMBLY SPINNER ARRAY TOOL 1 11/16" X 7"
DATE: 09/11/06	DATE: 09/11/06	DATE: 09/11/06	PT1	INITIAL RELEASE	NPB	16/03/07		
DIM INCHES	MATL: SEE PARTS LIST							
SCALE: 1:2	HEAT TREATMENT/CONDITION: N/A							
Sondex Tel 0118 932 6755 THIS DRAWING IS THE PROPERTY OF SONDEX AND SHALL NOT BE COPIED OR USED WITHOUT PRIOR PERMISSION THIRD ANGLE PROJECTION						MACHINE FINISH: 63 GEN TOL: 0.X ±0.004" / 0.XX ±0.010" / 0.XXX ±0.005" / ANGLE ±0.5°	SHEET: 2/2 DRAWING No: AD 09753 ISSUE: PT2	S W

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ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
1	1	10537	ASSY ELECTRONICS BULKHEAD SX(ISOLATION) MEM
2	1	11517	Assy Relative\$earing Device
3	1	82457	Assy, PCB, Digital Board SAT programmed
4	1	82452	PCB ASSY
5	1	15240	BULKHEAD LEMO CONNECTOR
6	1	01002	Bulkhead, Intermediate
7	1	40209	Halfshells electronics\$ SAT001
8	1	14021	INSERT 16 WAY LEMO 4\$MODIFIED
9	1	93261	SPACER - M3 THRU\$4.75mm OD x 12.7mm LG
10	1	95211	O\$RING 211 VITON 75
11	1	93252	PIN SPIROL ø3 x 08mm LG SS
12	2	93048	SCREW PAN HD SLOTTED M3 x 06mm LG SS
13	2	93352	SCREW CSK HD SLOTTED M2 x 06mm LG SS
14	16	01029	SCREW CSK HD SLOTTED M3 x 06mm LG SS
15	1	93029	WASHER LOCK SERRATED EXTERNAL M4 SS (DIN6798A)
16	1	93173	SCREW PAN HD SLOTTED M4 x 08mm LG SS
17	2	93086	SOLDER TAG M4
18	3	01082	SCREW GRUB SKT HD M6 x 05mm LG SS
19	1	40565	TUBE LEMO RETAINER

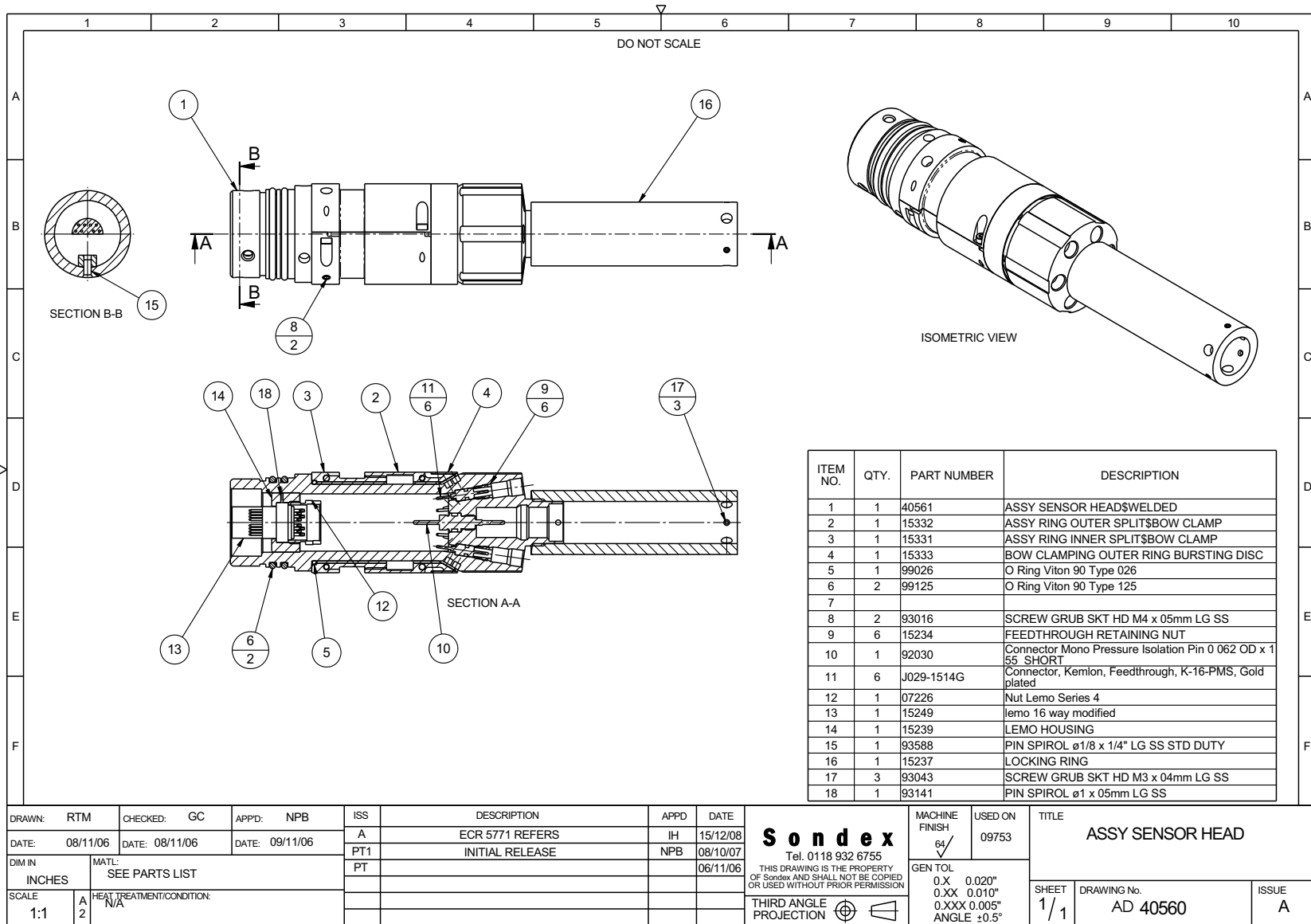
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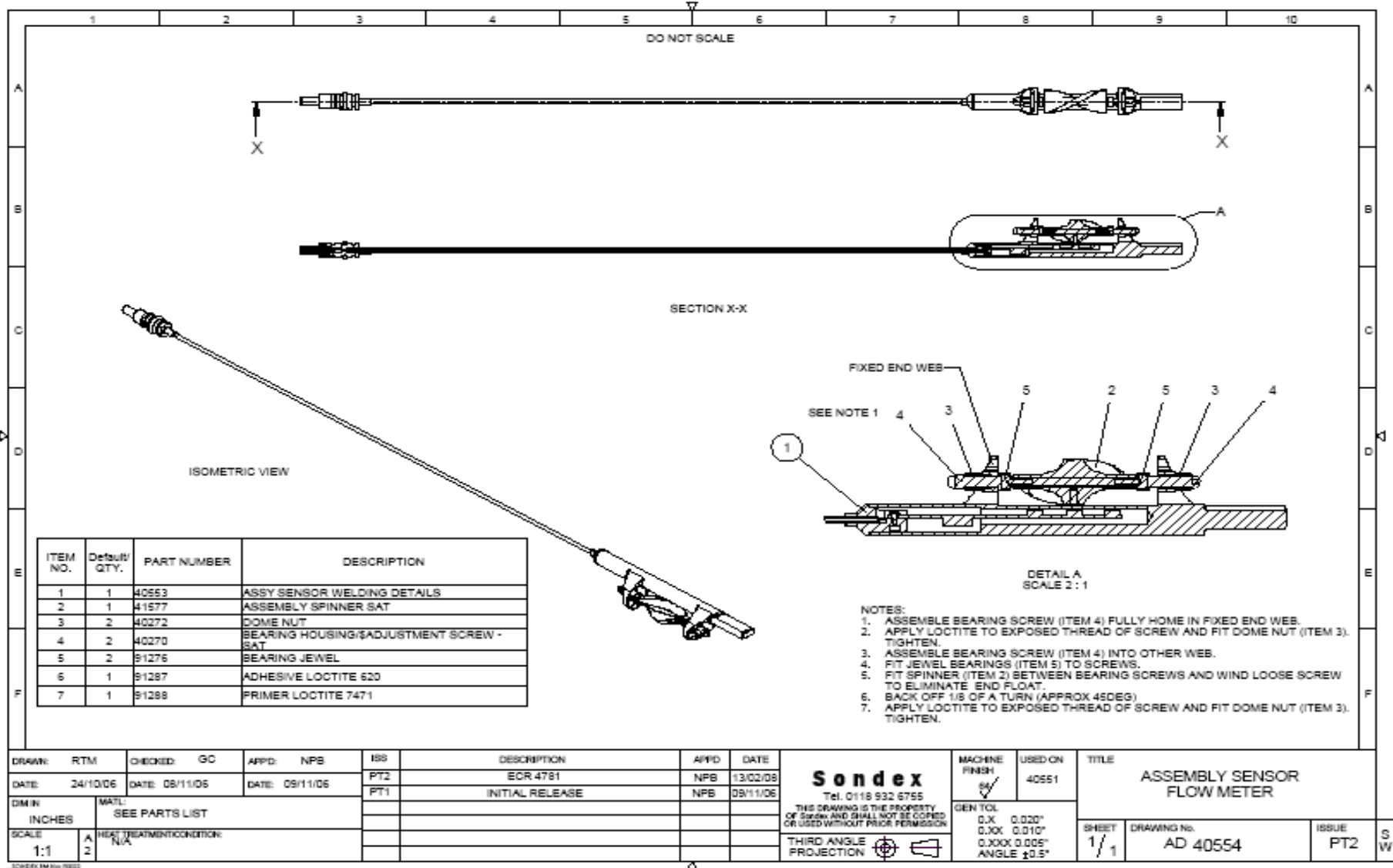
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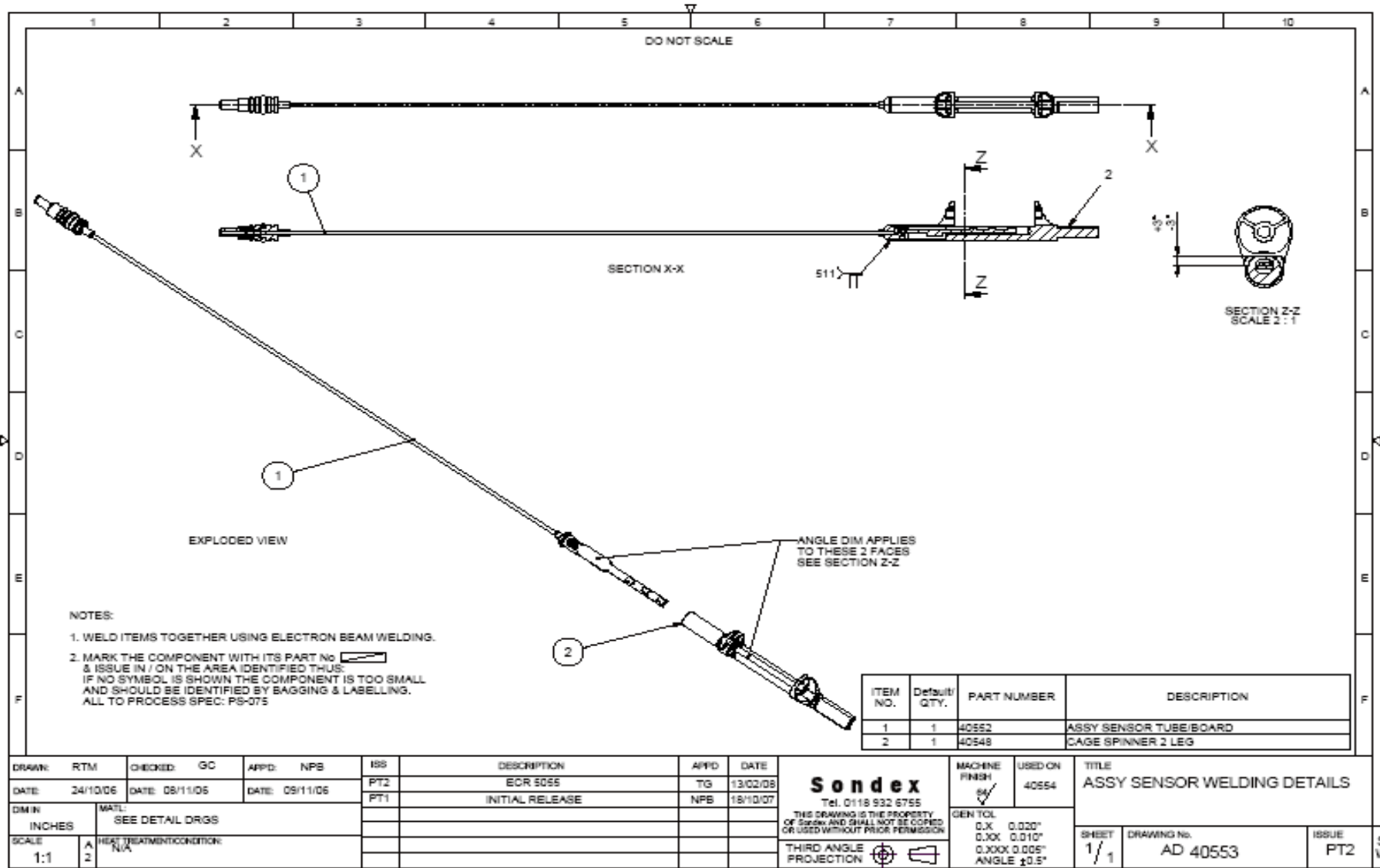


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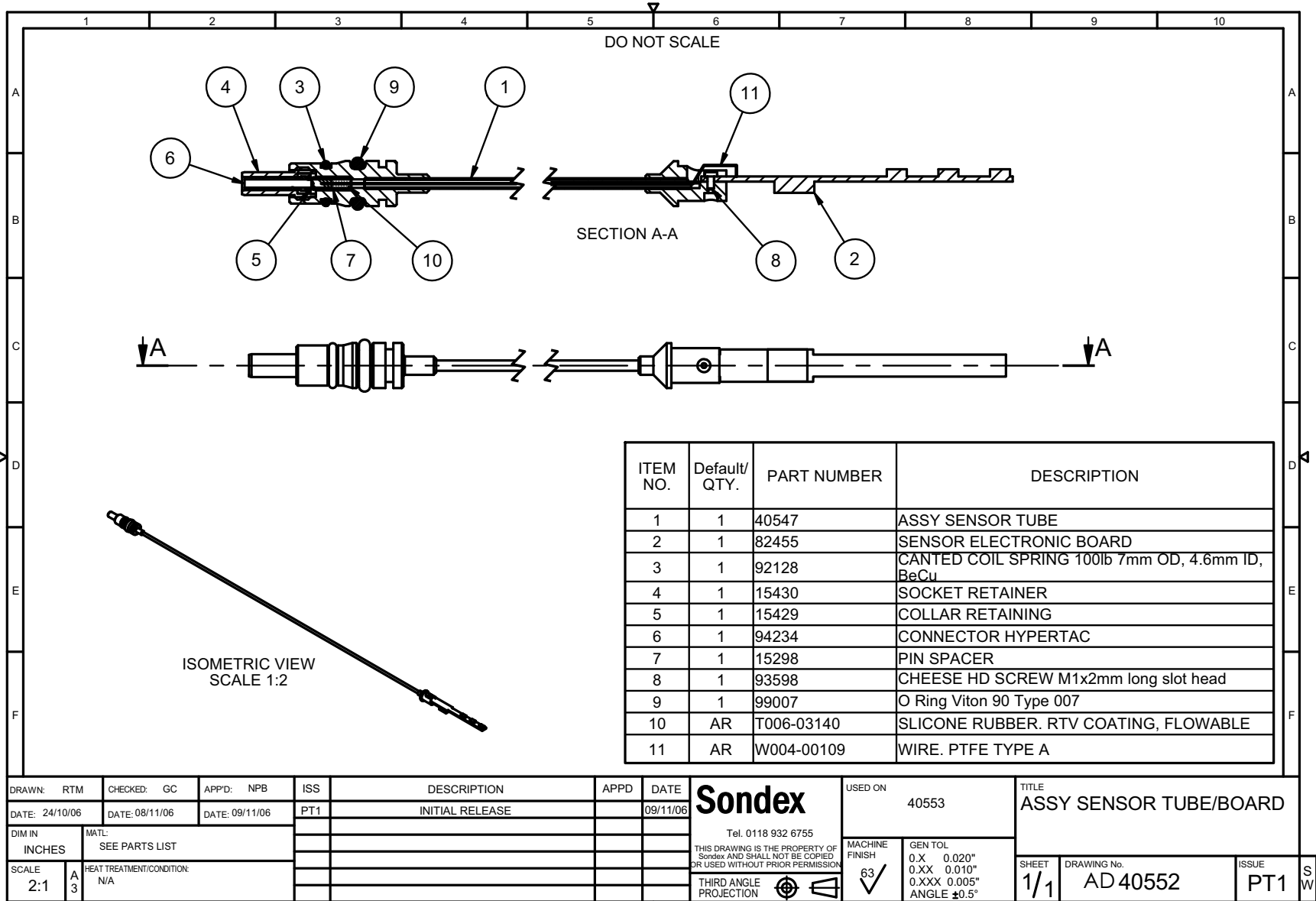
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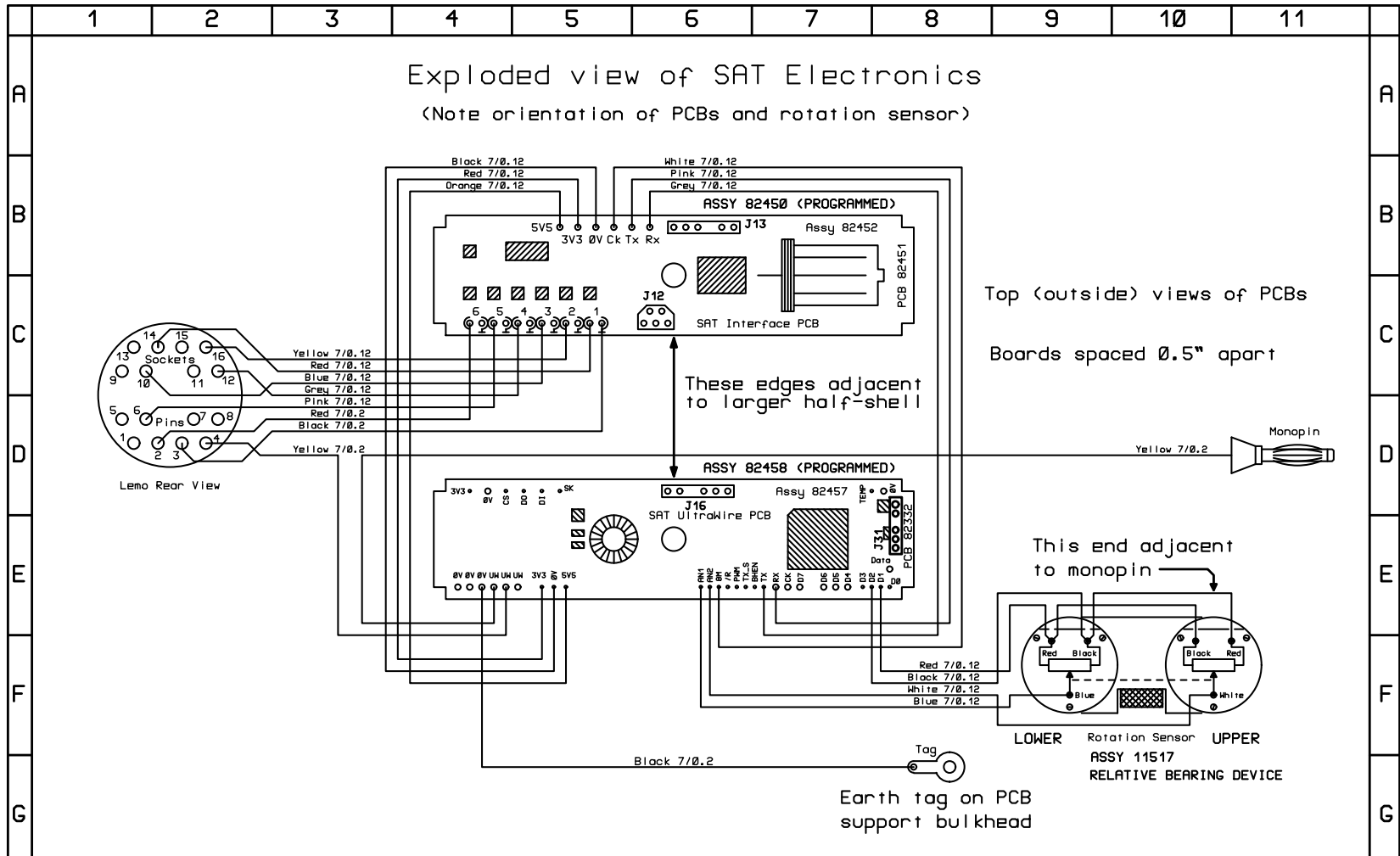
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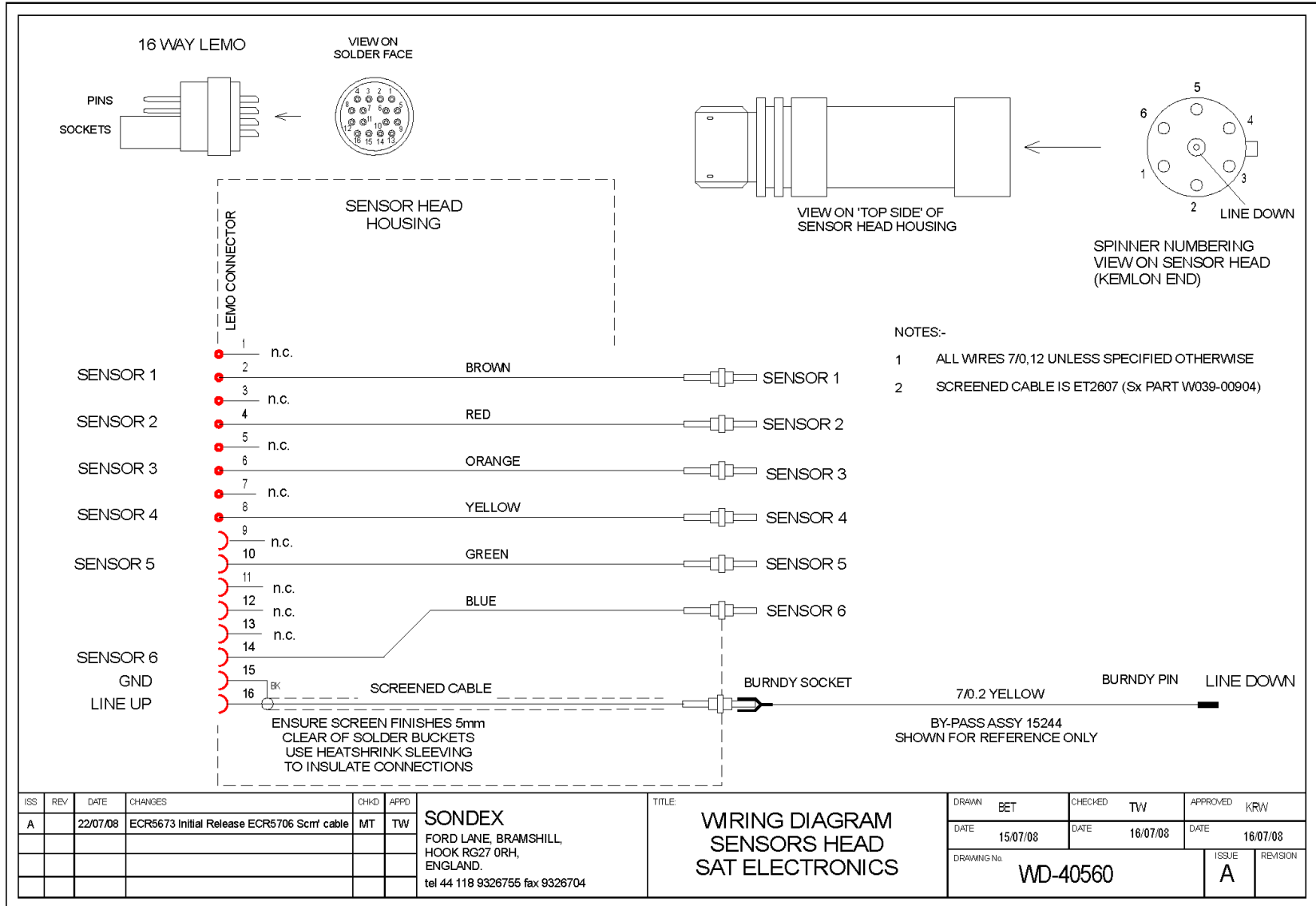


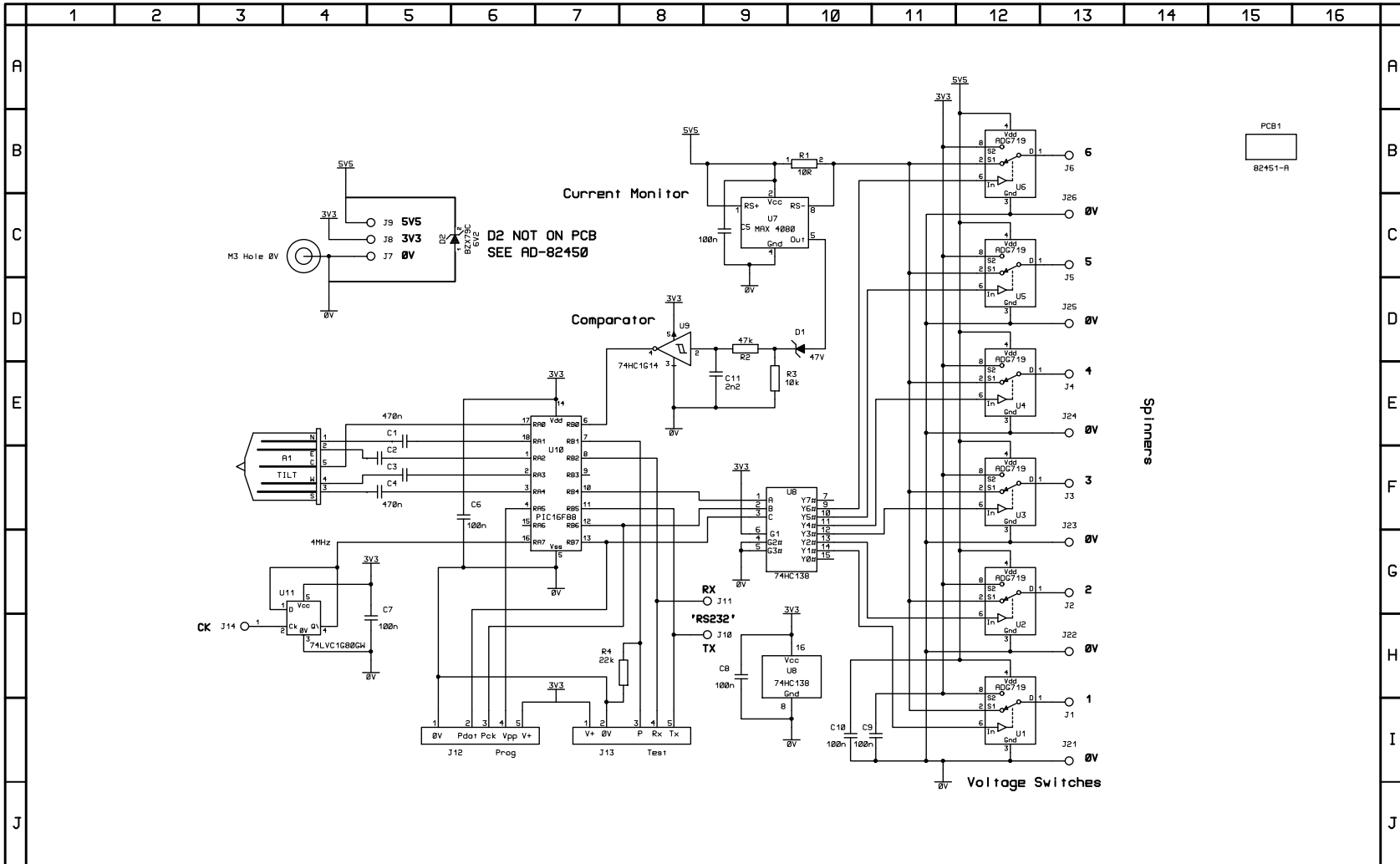
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D	ECR5530 J numbers added	KRW	KRW	21/05/08	SONDEX LTD FORD LANE, BRAMSHILL, HOOK, HAMPSHIRE, RG27 0RH, ENGLAND TEL: +44 (0) 118 932 6755 FAX: +44 (0) 118 932 6704	WD-85797	E	
E	ECR5673 Sheet 2 Renamed WD-10560	TW	KRW	02/07/08				
A	PRODUCTION RELEASE	TW	KRW	24/09/07				
B	Notes added	TW	KRW	25/10/07				
C	ECR5395	TW	KRW	29/02/08				
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						DATE 15/05/06	DATE 29/09/06	DATE 29/09/06
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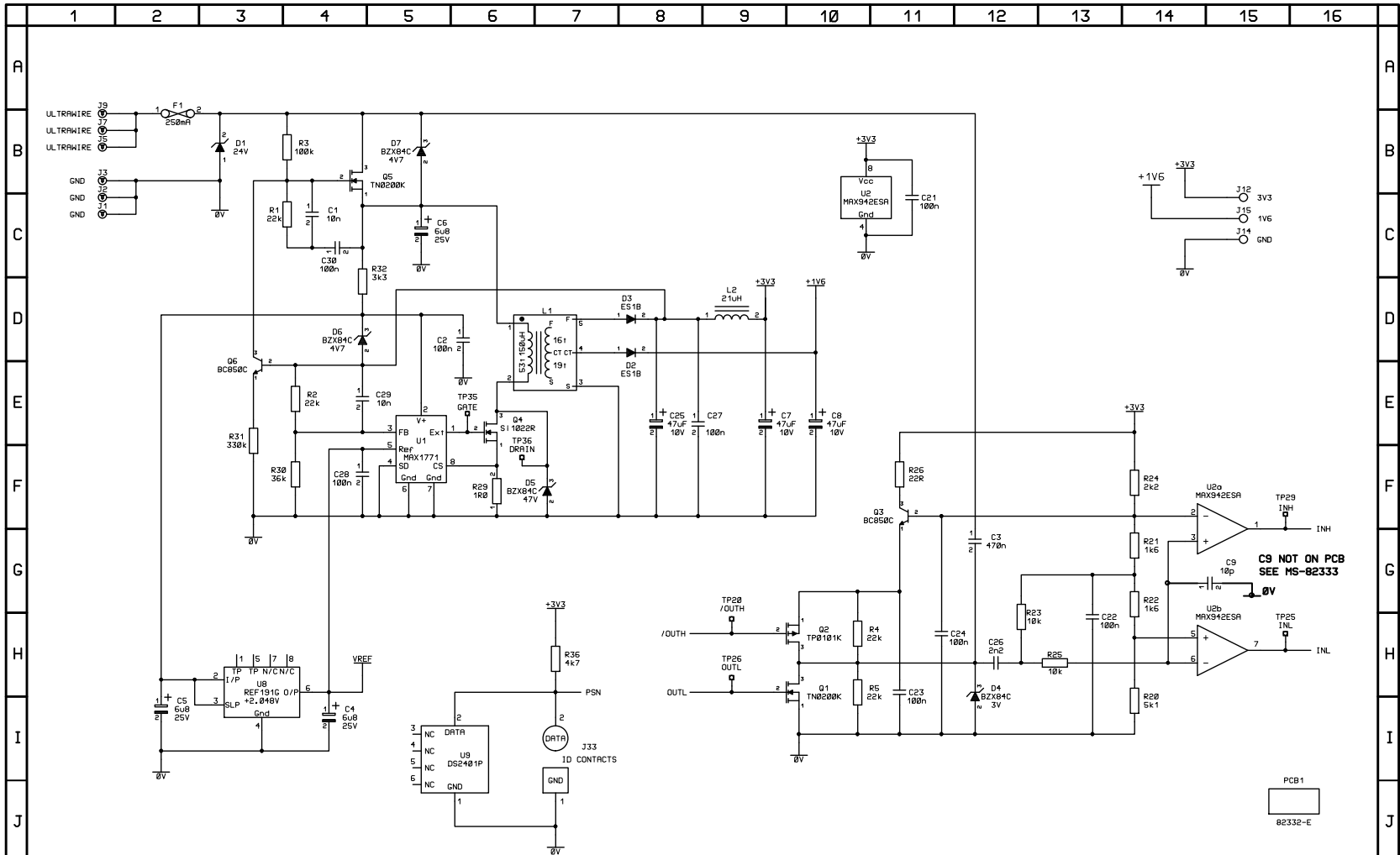
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PT1		Initial Release	KRW		15/12/04	SONDEX LTD FORD LANE, BRAMSHILL, HOOK, HAMPSHIRE, RG27 0RH, ENGLAND TEL: +44 (0) 118 932 6755 FAX: +44 (0) 118 932 6704	CD-82450	B		
A	00	ECRS061 R1 was 18R	KRW	KRW	23/10/07		Spinner Array Tool Interface Board Circuit Diagram	DRAWN KRW	CHECKED KRW	APPROVED KRW
B		ECRS552 D2 Mod added; ECR5546 Labels	KRW	KRW	16/09/08		DATE 15/12/04	DATE 23/10/07	DATE 23/10/07	
							SHEET 1 OF 1			

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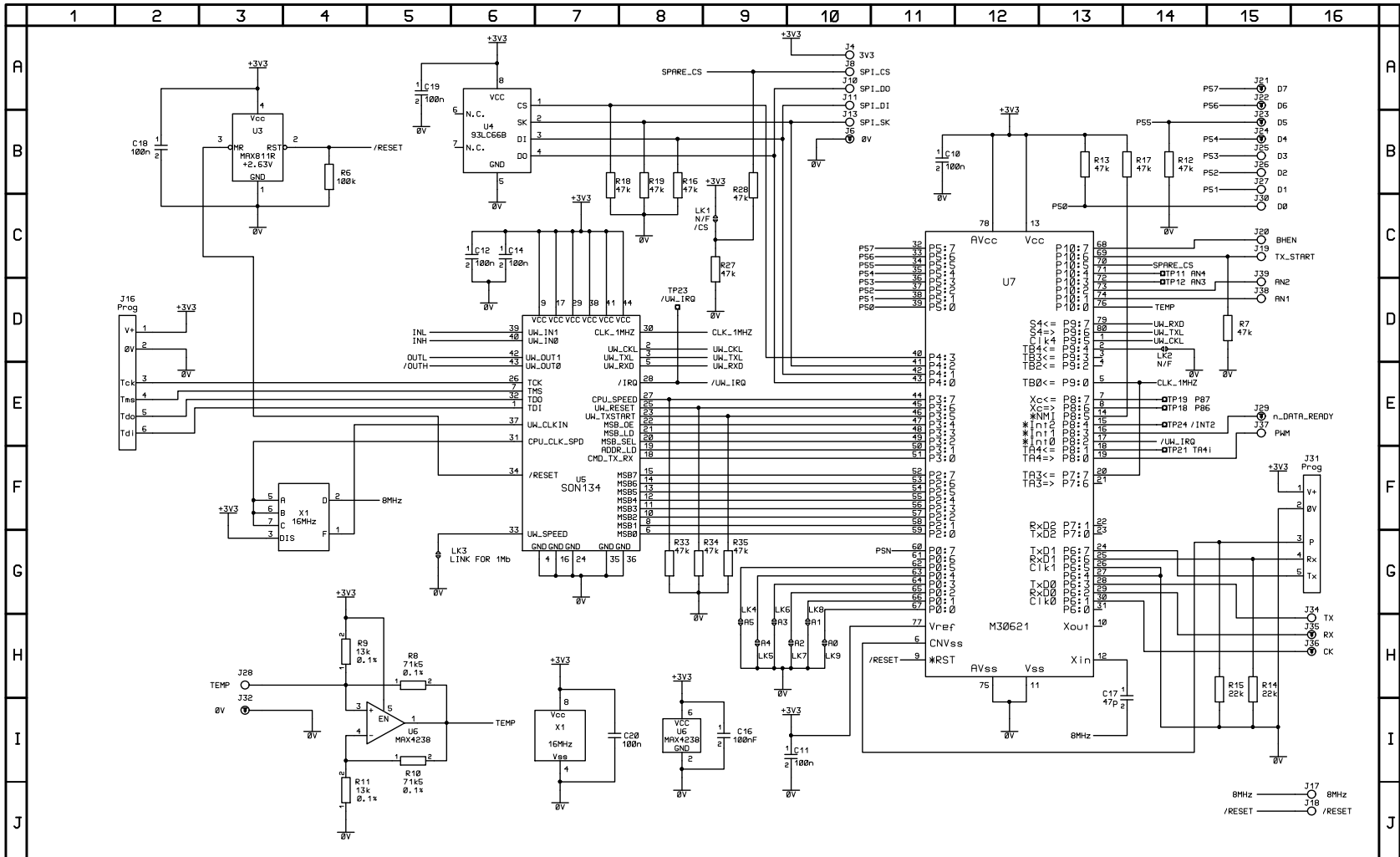
Spinner Array Tool

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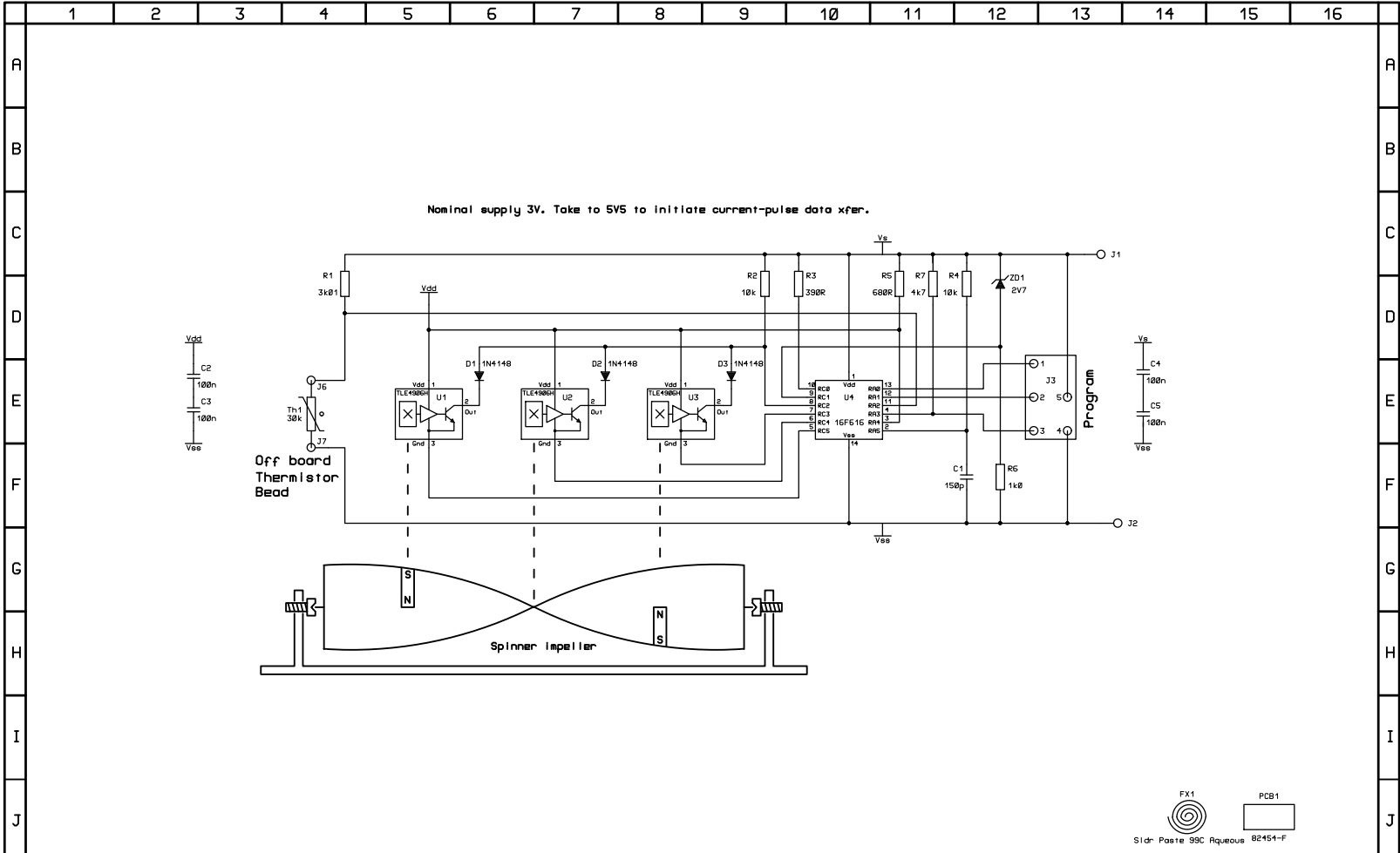
SAT002



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PT2		Circuit Updated	APB	APB	15/07/04				
C	00	Minor Update	APB	APB	23/11/04				
D	00	ECR2840 Hole size ECR2718 Ident C25	BET	PEJR	08/07/05				
E	00	ECR3011 I/O pads moved	APB	APB	05/08/05				
F	00	ECR4594 C9 Added	KT	KT	19/04/07				
This document contains proprietary information. Copyright 2004 © Sondex Ltd.						Digital Board MIT2 Circuit Diagram	DRAWN APB	CHECKED DJ	APPROVED APB
							DATE 10/12/03	DATE 10/03/04	DATE 12/03/04
							SHEET 1 OF 2		



ISS. REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE	TITLE	DRAWING NUMBER	ISSUE	REVISION	
G 00	ECR5525 C7,C8,C25 was 47U 6v3	PEJR	PEJR	22/04/08	SONDEX LTD FORD LANE, BRAMSHILL, HOOK, HAMPSHIRE, RG27 0RH, ENGLAND TEL: +44 (0) 118 932 6755 FAX: +44 (0) 118 932 6704 This document contains proprietary information. Copyright 2004 © Sondex Ltd.	CD-82333	G	00	
PT2	Circuit Updated	APB	APB	15/07/04		Digital Board MIT2 Circuit Diagram	DRAWN APB	CHECKED DJ	APPROVED APB
C 00	Minor Update	APB	APB	23/11/04		DATE 10/12/03	DATE 10/03/04	DATE 12/03/04	
D 00	ECR2840 Hole size ECR2718 Ident C25	BET	PEJR	08/07/05		SHEET 2	OF 2	2	
E 00	ECR3011 I/O pads moved	APB	APB	05/08/05					
F 00	ECR4594 C9 Added	KT	KT	19/04/07					



ISS.	REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE	DRAWING NUMBER			ISSUE	REVISION
PT2		R1,R2,R3 & R5 Value change	KRW	KRW	15/08/06	CD-82453			G	00
PT3		ECR4062 C4 was 22p, R5 was 82k	KRW	KRW	07/09/06	DRAWN	CHECKED	APPROVED		
PT4		ECR4099 Thermister added	KRW	KRW	26/09/06	KRW	KRW	KRW		
PTS		ECR4306 D1 was R7	KRW	KRW	28/11/06	DATE	DATE	DATE		
F	00	ECR4568 New Design	KRW	KRW	24/06/07	19/11/04	19/11/04	10/11/05		
G	00	ECR4810 C1,2,3,4 were 10n, U4 was 16F616	KRW	KRW	13/07/07	SHEET 1 OF 1				

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TITLE
 Array Spinner
 Sensor Electronics
 Circuit Diagram



Spinner Array Tool