GE Oil & Gas
Drilling & Production

Sondex* Wireline

Resistance Array Tool

12-Sensor Springbow, $1^{11}/_{16}$", Ultrawire™

Operation & Maintenance Manual

CE

Tool Code: RAT001
Document: MN-RAT001
Revision: G
Date: 4 September 2012

GE imagination at work

* Denotes a trademark of the General Electric Company

Contents

0 ABOUT THIS MANUAL

0.1 Manual History

Date	Issue	Description	Auth	Chk	App
27/03/08	A	Initial Release.	FV/RS	PS	PS
08/04/08	B	See ECR5449 (WD-85798 from Iss PT3 to PT4)	RS	PS	PS
15/05/09	C	Section 4.1.3 (4) correction of tool current. Also see ECRs 4814, 5370, 5390, 5415, 5429, 5437, 5525, 5570, 5661, 5706, 5735, 5771, 5835 & 5981.	RS	PS	PS
16/10/09	D	"carry tube" removed from section 2.2. Section 4.2.4 added. Also see ECR 58465 & addition of Appendix C.	RS	RW	TG
25/03/10	E	Section 1 second para second line "sensor senses" changed to "sensor detects". Recommendations added & "heavy warning" deleted to/in Section 2. Section 3 - Description now TBA. New Calibration para 4.2, 4.2.1 & Section 6.2.3 new text & 6.2.4 removed. KitU-Maps added. Amended issue for CD-85988 in appendix B.	RS	PR	PR
20/09/10	F	Section 0.2 removed, Figure 4.1 amended. Section 7: 7.1.3(1) para. changed & new figures. KitB, KitO & KitR up-issued. Appendix B: AD-85798 & CD-82333 up-issued. Appendix C: headers & footers corrected.	RS	RW	RW/PR
02/07/12	G	Manual updated to the latest template standard. This includes both procedural steps and the associated drawings. ECRs incorporated: 5-75831 and 5-72901. Drawings updated: AD-11517, AD-41113, AD-13273 and WD-85798. Company address updated. All cross-references and hyperlinks either added where missing or updated. Component names corrected to match names on drawings. Appendix A updated.	BES	RW	PR

0.2 References

Below are the manuals/links required for use in conjunction with this manual:

- Refer to: ***http://www.weeerohsinfo.com/***.
- Refer to the ***MN-MAPview*** manual.
- Refer to the ***MN-WARRIOR*** manual.
- Refer to the ***MN-PIH*** manual.

0.3 Technical Help

For further technical help, contact GE Oil & Gas Technical Services as follows:

Address: GE Oil & Gas
Building X107
Range Road
Cody Technology Park
Farnborough
Hampshire
GU14 0FG
United Kingdom

Telephone: +44 (0)1252 862200
Fax +44 (0)1252 862349
Web: www.geoilandgas.com/downholetechnology

0.4 Feedback

Please help us improve future issues of this manual by adding your comments or corrections to www.geoildandgas.com/downholetechnology 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 (For example: 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 Wireline Ltd.

1 OVERVIEW

The Resistance Array Tool (RAT001) is designed to solve the problem of accurate fluid-phase identification in either horizontal or highly deviated wells. It is run centralised within the wellbore, ideally combined with an Inclinometer tool to aid interpretation.

The tool has an array of twelve specially developed miniature Sensors that are mounted on the inside of a set of Springbows. Each Sensor detects the apparent resistance of the fluid at a specific point across the area of the pipe so the time variation of the characteristics can be monitored.

The monitored resistances (as they vary with position and time) can be interpreted to improve the understanding of what is flowing through the pipe. This insight can then aid decisions about maintenance or further development of the well or the pipeline.

An accurate cross-sectional plot can be generated because the measurements are taken in a single plane across the diameter of the wellbore (rather than spaced along it). Optional MAPview (***MN-MAPview***) 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 either in or out of the well and minimises power requirements, particularly when deployed using memory recording.

Figure 1.1 RAT001

1.1 Operating Principle

Water and hydrocarbons (oil or gas) often do not form a solution. Instead, the smaller constituent appears as 'bubbles' within the majority fluid. The 'bubbles' may be very small (as in an emulsion) and become very large that will result in a total separation into layers.

To optimise the operation of a well, it is useful to understand the relative proportions of water and hydrocarbons in a pipeline. Generally, water contains sufficient salt to make it significantly low in resistivity (high conductivity) than hydrocarbons that are high in resistivity (very low conductivity). By measuring the resistance at different points across the pipe, a clearer view of the proportion of water/hydrocarbons and the presence of 'bubbles' can be gained.

1.2 Applications

These are some of the applications for the RAT001:

- Phase identification in horizontal and highly deviated wells.
- Calculation of the percentage of each phase present.
- Plotting of phase composition along the wellbore.
- Identification of water entry areas.
- Changes of wellbore fluids with either time or different production rates.

1.3 Interfacing & Tool Combinations

These are some of the interface and tool combinations possible for the RAT001:

- Simultaneous operation with other Sondex Ultrawire™ tools.
- Memory or Surface Readout Operation (SRO) operations.
- Combines with a Production Inclinometer Accelerometer (PIA) to give well inclination.
- Standard $1^{3}/_{16}$″ UN 12 UN Sondex or GO end connectors.

1.4 Specification

Table 1-1 Specifications for RAT001

Parameter	Specification	Remarks
Temperature Range:		
Max. Temperature	177°C (350°F)	---
Normal Operation	150°C (302°F)	---
Max. Pressure	15,000psi (103MPa)	---
Tool Dimensions:		
Nominal Diameter	$1^{11}/_{16}$″ (43mm)	Springbow fully closed.
Make-up Length	51.4″ (1,305mm)	---
Overall Length	55.3″ (1,405mm)	Including thread protectors.
Depth Offset	15.4″ (391mm)	From bottom of tool. Fully open.
Tool Weight	16.2lbs (7.35kg)	---
Operating Voltage:		
Nominal	+18VDC	---
Range	+13VDC tot +23VDC	---
Maximum	+24VDC	---
Current Consumption at +18VDC:		
In Logging Mode	<100mA	---
Number of Sensors	12	One Sensor per Springbow
Width of Springbow	0.25″ (6.35mm)	---
Recommended Casing Sizes	3.5″ to 7″ (89mm to 178mm)	---
Tool Characteristics:		
Telemetry	Ultrawire™	---
Tool Address	31	---
Max. Frame Rate	6Hz	Maximum polling rate for new data. Faster polling will result in some 'Not Ready' responses.
Scan time per Sensor	4.8ms	Time interval between measurements at each Sensor.

Table 1-1 Specifications for RAT001 *(Continued)*

Parameter	Specification	Remarks
Orientation - rotation	±4.5°	5° from vertical to 100°
Orientation - deviation	±2.5°	Full range (0° to 100°)
End Connections:		
Top	$1\frac{3}{16}$" 12 UN 2A	---
Bottom	$1\frac{3}{16}$" 12 UN 2B	---
End connectors:		
Top	4mm single conductor (male pin)	---
Bottom	4mm single conductor (female socket)	---

2 SAFETY

In normal use, there are a few specific safety instructions for the safe handling of the RAT001. The information that follows is a guideline only and should be followed in addition to any specific Company and Local Rules & Regulations (Directives).

This equipment should be operated or serviced **ONLY** by qualified personnel. When the equipment is not installed, commissioned and used in accordance with the specifications of GE Oil & Gas, any protection that may have been provided may be impaired.

2.1 Hazardous Areas and 'Hot Work'

WARNING!

HAZARDOUS AREAS AND 'HOT WORK'!

This equipment may, under certain circumstances or failure modes, become a potential source of ignition.

It may be used only in Safe Areas and may not be used in classified Hazardous Areas ('Zoned' areas) unless a suitable system of work is in place (For example: Hot Work Permit) and appropriate precautionary measures have been followed (For example: monitoring for gas leaks, site inspection, fire fighting equipment, work procedures).

This must be done in accordance with local and national legislation with regard to the use of electrical equipment in potentially explosive atmospheres.

2.2 Electrical Hazard

WARNING!

ELECTRICAL HAZARD

Do not touch the chassis or the housing when powered. It might be at a hazardous potential in case of the loss of a return circuit. Check the housing is grounded properly BEFORE powering up.

Make sure the Earthing Kit (*P/N: 42703*) is attached correctly to the RAT001.

Extra care must be taken when handling the RAT001 when either the tool is wet or there are wet conditions in the area of the RAT001. **ALWAYS** power down the RAT001 before you dismantle it.

2.3 Stored Energy

WARNING!

STORED ENERGY!

The RAT001 has components that may store energy. This energy can be released at any time without warning.

Within the RAT001 there are areas that may store energy. It is possible for this stored energy to be released at any time and without warning. Refer to ***Section 4.5, Post Logging Disassembly*** and ***Section 7.1, Preventative Maintenance*** for information of how this stored energy can be released safely.

2.3.1 TRAPPED PRESSURE SAFETY PRECAUTIONS

WARNING!

TRAPPED PRESSURE!

The RAT001 has spaces within it that after a down hole leakage could retain trapped pressure. As this pressure can be released at any time without warning:

- **Contact *GE Oil & Gas Technical Services* IMMEDIATELY for advice before ANY maintenance is attempted.**
- **Make sure all trapped pressure has been removed from the RAT001 before it is transported anywhere.**

Wear an approved protective faceshield when you handle a tool that may contain trapped pressure.

Wear an approved protective apron when you handle a tool that may contain trapped pressure.

2.3.2 MANAGEMENT OF TRAPPED PRESSURE

Logging tools are subjected to harsh conditions downhole. High hydrostatic-pressure, high-temperature, shock, vibration and contact with corrosive substances can all contribute to causing possible leaks into sealed housings. Leak paths include but are not limited to:

- Permeation through the seals.
- Seal failures.
- Hairline cracks in welds.

Should such a leak occur downhole, then as the tool is removed from the well and the external hydrostatic-pressure reduces the liquid/gas that has leaked into the tool is expected to leak out again through the path by which it entered. However, some of the liquid/gas may be retained and, occasionally, the leak path may either partially or completely re-seal. This will trap the liquid/gas inside the tool. In this case, when the tool returns to the surface, it can potentially have a significant volume of liquid/gas stored inside with a significant amount of potential energy!

The trapped and pressurised fluid/gas could pose a safety hazard during handling, transportation or storage as well as when the tool is dismantled for maintenance.

When the RAT001 displays any of these characteristics it should be considered as potentially containing trapped and pressurised fluid/gas:

- Telemetry failures downhole.
- Signs of mechanical damage.
- Unusual seepage of fluid out of the tool or bubbling/hissing noises.
- Tools that have been fished.
- Tools that have been downhole for extended periods.
- Hard to undo housings or housing split nuts.

When there are signs of trapped pressure, refer to ***Section 4.5.1, Relief of Trapped Pressure at the Tool Joints*** **AND** to ***Section 5.1, Relief of Trapped Pressure - Tool Disassembly***.

Note: The above two sections of the manual **MUST** be read in the order shown to avoid unwanted injuries!

2.3.2.1 REMEMBER

1 **DO NOT** point parts of the tool (that may become projectiles) at either yourself or others.

2 **DO NOT** try to release the pressure by removing filler plugs or other small plug items, unless the instruction manual indicates specifically (***Section 4.5.1, Relief of Trapped Pressure at the Tool Joints***) that this is the correct method to release the trapped pressure.

3 **DO NOT** ignore the risk of trapped pressure and return the tool to its transportation packaging. The tool may explode at any time due to sudden mechanical shock or changes in atmospheric pressure. This could be dangerous dependant on the method of transport of the tool. For example, when the tool is being transported within an aircraft.

4 **DO NOT** open the tool either in a confined space or inside a building as there could be a risk of releasing toxic chemicals.

5 **DO NOT** install the Thread Protectors to the ends of the tool.

2.3.2.2 Recommended Precautions to Follow

1 **Always** wear Personal Protective Equipment (PPE) - hard toe boots, safety glasses and fluid resistant gloves are a minimum.

2 **Always** leave the tool to stand in a cordoned-off safe area (preferably outside) marked with hazard signs, for as long as possible (not less than 24hrs). Pressure may leak out slowly and (with sufficient time) the pressure will reduce to a less dangerous and more manageable level.

3 **Always** put (in a prominent position) a noticeable warning indicator on the tool (marker pen, sticky label, etc.) to tell others that it is suspected the tool contains trapped pressure. It is advisable also to display (at a safe distance from the tool) large signs that can be read clearly and convey the same warning.

4 **Always** make all colleagues and other operators in the area aware that the tool may contain trapped pressure.

5 **Always** allow time for the tool to cool down to the ambient (room) temperature. Fluids (especially gases) have more stored potential energy at a high temperature than at the ambient (room) temperature. When the tool is allowed to cool down, it will reduce this potential energy.

6 **Always** be aware that the well fluid inside the tool may be hazardous or toxic. For example, it may contain Hydrogen Sulphide (H_2S). Take the appropriate precautions to prevent harm to operators, such as attempting to open the tool outside and the use of toxic-chemical monitoring equipment.

7 **Always** be aware that the well fluid inside the tool may be a flammable gas or mist. Open the tool away from sources of ignition or sparking.

8 **Always** make sure the suspect tool is disassembled until all volumes inside have been found to be safe and free of pressure.

9 Refer to ***Section 4.5, Post Logging Disassembly*** **AND** to ***Section 5.1, Relief of Trapped Pressure - Tool Disassembly***.

2.3.3 COMPRESSED SPRINGS

WARNING!

COMPRESSED SPRINGS!

The RAT001 contains compressed springs.

Wear a protective faceshield when working on the tool.

There are no springs inside the tool that 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.

2.4 Danger From Machinery

2.4.1 WEIGHT

WARNING!

HEAVY ITEMS!

The RAT001 is heavy. Care MUST be taken when lifting, moving or working on the tool.

GE Oil & Gas recommends the use of correct lifting equipment.

Make sure all heavy items are supported correctly at all times.

2.5 Irritants

Take these precautions when handling, storing or disposing of an irritant:

- Refer **ALWAYS** to the applicable Material Safety Data Sheet (MSDS) for the irritant.
- Do **NOT** touch either your skin or your eyes whilst protective gloves are worn.
- Do **NOT** allow the irritant to either contact the mouth or to be ingested.

Should it be necessary to dispose of an irritant, the disposal **MUST** be in accordance with all Local Rules & Regulations (Directives) that are in force in the country where the disposal is to take place. Should there not be any, then International Rules & Regulations (Directives) **MUST** be obtained and followed.

2.5.1 LIQUID-O-RING®, TYPE 101 LUBRICANT

IRRITANT!

LIQUID-O-RING®, TYPE 101 LUBRICANT

Contact with the skin or the eyes can cause irritation.

Wear approved protective gloves.

Wear approved protective goggles/glasses.

Wash hands after use.

For more details, refer to the Material Safety Data Sheet (MSDS) for Liquid-O-Ring® type 101.

2.5.2 ISOPROPYL ALCOHOL (IPA)

IRRITANT!

ISOPROPYL ALCOHOL (IPA)

Wear approved protective gloves.

Wear approved protective goggles/glasses.

Wash hands after use.

For more details, refer to the Material Safety Data Sheet (MSDS) for Isopropyl Alcohol (IPA).

WARNING!

FLAMMABLE!

DO NOT smoke in the area where IPA is used!

DO NOT use IPA near open flames, sparks or high-heat sources.

2.5.3 *ROCOL® SAPPHIRE ENDURE GREASE*

IRRITANT!

ROCOL® SAPPHIRE ENDURE GREASE

Wear approved protective gloves.

Wear approved protective goggles/glasses.

Wash hands after use.

For more details, refer to the Material Safety Data Sheet (MSDS) for Rocol® Sapphire Endure Grease.

2.5.4 *CASTROL SPHEEROL L-EP2 GREASE*

IRRITANT!

CASTROL SPHEEROL L-EP2 GREASE

Wear approved protective gloves.

Wash hands after use.

For more details, refer to the Material Safety Data Sheet (MSDS) for Castrol Spheerol L-EP2 Grease.

2.5.5 *CASTROL HIGH TEMPERATURE GREASE*

IRRITANT!

CASTROL HIGH Temperature GREASE

Wear approved protective gloves.

Wash hands after use.

For more details, refer to the Material Safety Data Sheet (MSDS) for Castrol High Temperature Grease.

2.6 Tool Integrity

2.6.1 Greases and Sealants

CAUTION!

GREASES AND SEALANTS!

Electrical failure can occur when some greases and sealants are used. Those that contain a volatile content can produce gasses in the tool when heated.

GE Oil & Gas recommend to use **ONLY** the greases and sealants specified for the Tool.

GE Oil & Gas recommends (unless indicated specifically otherwise) the use of Liquid-O-Ring®, type 101 (*LOR101*) to grease lightly:

- The pressure seals.
- All threads for the tool joints and the pressure housings.
- All seals.

The use of the correct greases and lubricants is essential to the maintenance of all GE Oil & Gas downhole equipment. Because some threads are internal, they will not stop grease entering the tool. Do **NOT** use excessive quantities of any grease. **DO NOT** use copper loaded greases unless specified.

2.6.2 Seal Maintenance

CAUTION!

SEAL INTEGRITY!

Tool function depends upon seal integrity. Replace worn seals.

ALWAYS check **ALL** seals for damage. Remove, discard and replace when damaged.

2.7 Fluid/Gas Ingress

CAUTION!

PRESSURE WASHING

DO NOT pressure wash the Sensors, as this may result in serious damage.

CAUTION!

FLUID/GAS INGRESS!

The Split Nuts/Tool Joints **MUST** be tightened correctly and fully to prevent fluid ingress.

2.8 Electrostatic Discharge (ESD)

CAUTION!

ELECTROSTATIC DISCHARGE!

The RAT001 contains electronic circuits and devices that can suffer permanent damage when subjected to an electrostatic discharge.

When servicing the tool, take appropriate precautions to avoid electrostatic discharge damage.

The tool should be handled with care. Whenever the tool is serviced, observe these precautions:

- All work on the electronics within this tool should be carried out at a safe anti-static workstation.
- Wear an ESD wrist strap that is connected to an approved ESD point.
- Where applicable, wear approved electrostatic conducting footwear.
- Avoid touching the tool electronics, unless stated otherwise in this manual.

2.9 Hot Surfaces

WARNING!

HOT SURFACES!

The RAT001 may, under certain circumstances or failure modes, become hot.

Wear suitable protective gloves when the tool is handled.

2.10 WEEE Disposal Information

CAUTION!

ELECTRICAL EQUIPMENT DISPOSAL!

Electrical equipment must be disposed of in accordance with any Local/ International Rules and Regulations for the collection framework available to customers for the return, recycling and treatment of electrical wire and components.

For more information see: ***http://www.weeerohsinfo.com/***.

2.11 Transportation and Storage

Where the equipment is supplied in a carry tube and/or flight case, GE Oil & Gas recommend that the equipment is stored and transported in that carry tube and/or flight case for protection.

The tool should be stored and transported with the threads and O-Rings lightly greased with Liquid-O-Ring (***LOR101***) and thread protectors fitted.

3 THEORY OF OPERATION

3.1 Block Diagram

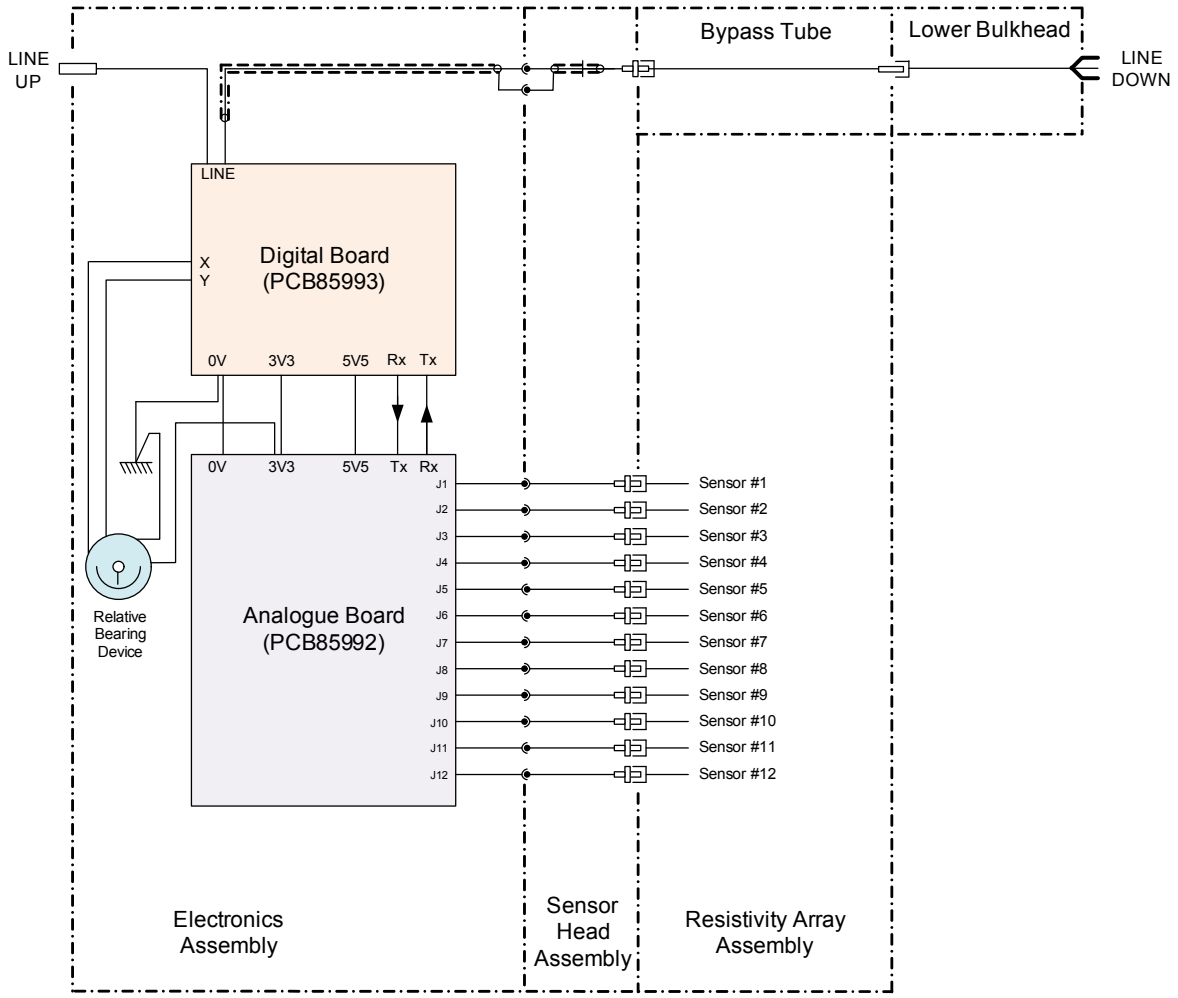


Figure 3.1 Block diagram of the RAT001

3.2 Description

3.2.1 TOOL DESIGN PRINCIPLE

Water and hydrocarbons (oil or gas) often do not form a solution. Instead the smaller constituent appears as 'bubbles' within the majority fluid. The 'bubbles' may be very small (as in an emulsion) or become very large, resulting in total separation into layers.

Typically (when drilling for and ultimately extracting) oil and gas, water enters also the pipeline. In a pipeline that is non-vertical, the lighter fluids tend to be more concentrated along the upper side of the pipe. Lighter fluids will tend also to flow faster in an upward direction than the heavier ones, even to the extent that particular fluids can end up going in the opposite direction to the general flow. This is illustrated in ***Figure 3.2***.

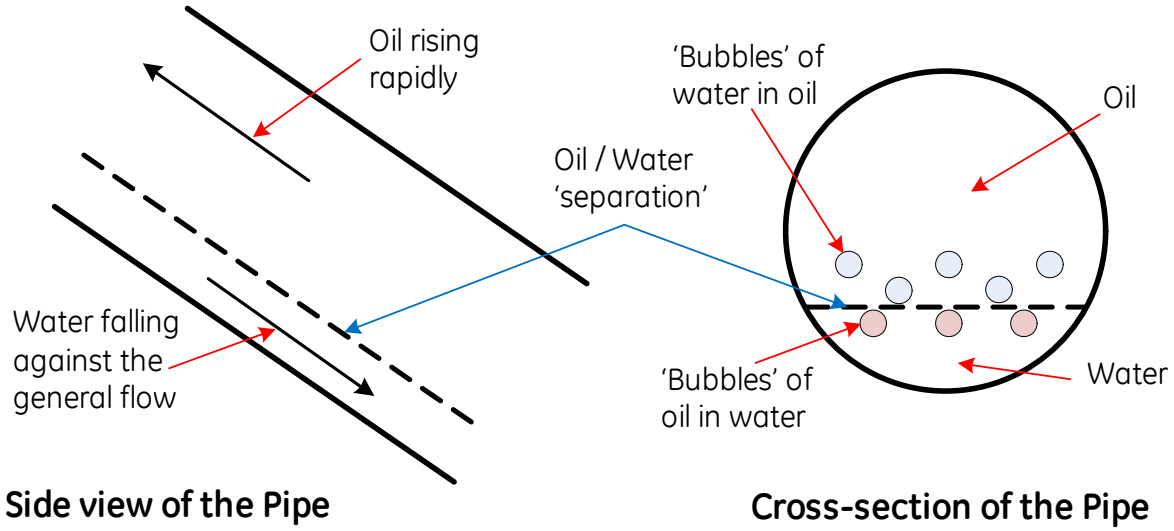


Figure 3.2 Water/Oil mix in an elevated pipe

To optimise the operation of a well, it is useful to understand the relative proportions of water and hydrocarbons in a pipeline. Generally, water contains sufficient salt to make it significantly low in resistivity (high conductivity) than hydrocarbons that are high in resistivity (very low conductivity). By measuring the resistance at different points across the pipe, a clearer view of the proportion of water/ hydrocarbons and the presence of 'bubbles' can be gained.

3.2.2 MECHANICS

The Resistance Array Tool incorporates twelve Sensors arranged around the periphery of the tool, which are deployed toward the inner surface of the pipe via Springbows. By placing Sensors in different parts of the pipe's cross section, the variation in fluid content can be monitored. The tool is closed while running in hole and opens automatically when it leaves the tubing and enters the larger diameter of the casing. When the tool passes any restriction, either up or down, the bow springs will collapse to prevent damage to the Sensors.

The Sensor bodies are clipped onto the bow spring.

The key Sensor mechanics comprise:

- A probe tip that ultimately connects to the Sensor electronics input.
- A reference contact, typically at earth potential.

The electrodes in the Sensor are positioned within a protective shroud.

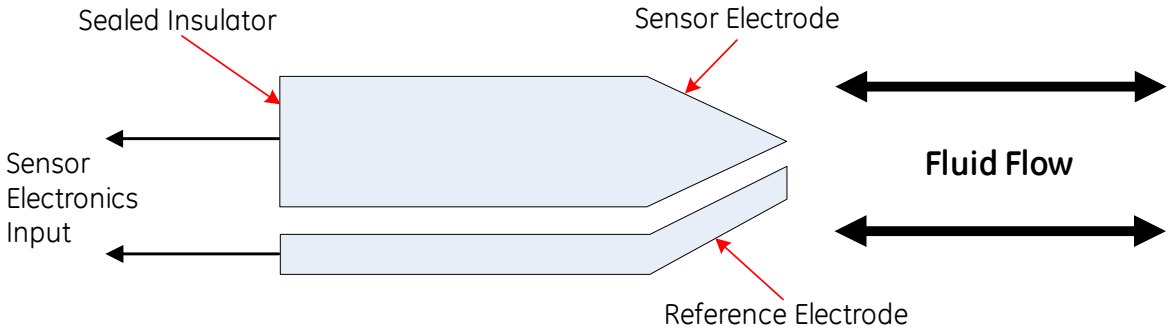


Figure 3.3 Sensor overview

A further Sensor provides information about the orientation of the tool and therefore the array.

3.2.3 ELECTRONICS

The tool operates on Ultrawire™ telemetry and accumulates data for delivery at up to six times per second. the tool may be polled in excess of 100 frames-per-second, but this results in '**Not Ready**', messages. However, other parts of the system (For example: wireline telemetry speed) will usually limit the maximum frame rate significantly. For example, the default configuration of the Warrior logging software is set at 6 samples/second.

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 that is used to measure tool rotation. It is not intended to be a survey instrument, but merely to indicate which Sensor is uppermost.

3.3 Measurement Overview

3.3.1 SIGNAL PROCESSING

Resistance measurements can be made between either the probe tips or the electrodes, at a rate of up to 10,000 samples-per-second. Each measurement results in a number that is proportional to the logarithm of the resistance detected between the Sensor electrodes and (therefore) the fluid resistivity, with a range of five decades of resistance.

Each Sensor is sampled twice every 4.8mS. The resulting information is presented through the Ultrawire™ telemetry in two ways:

- The first way is to provide a mean and a standard deviation. This pair of numbers is provided for each of the Sensors typically six times per second, dependant on the configuration of the logging software. At 30 feet-per-minute, this provides a measurement resolution of '**1 inch**'.
- The second way is to provide histograms of measurements for each of the Sensors. Data for these is collected over periods twelve times as long as for the mean and the standard deviation and this provides a more detailed view of the distribution of measurements that are made. Each histogram is divided into sixteen bins of values.

The distribution of values is illustrated in ***Figure 3.4***.

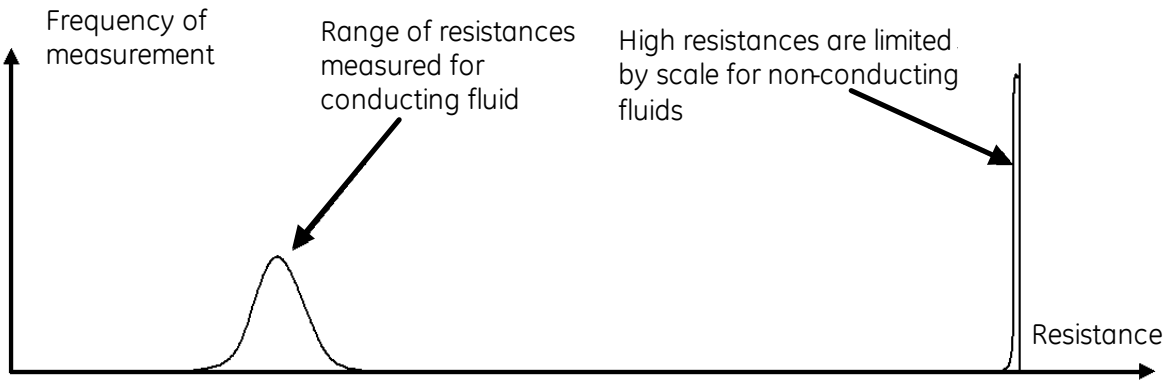


Figure 3.4 Distribution of measured values

3.3.2 MEAN & STANDARD DEVIATION

3.3.2.1 Generation of the Values

For each of the Sensors, resistance values are measured many times over the period being summarised.

The mean value can be calculated as follows:

$$m = \frac{\Sigma^{(R)}}{n}$$ **Equation 3.1**

Where:

- m = Mean value.
- R = Measured values.
- n = Number of samples taken.

To calculated the standard deviation, this function can be used:

$$S = \sqrt{\frac{\Sigma^{(R-m)^2}}{n}}$$ **Equation 3.2**

Or this function can be used:

$$S = \sqrt{\frac{\Sigma^{(R^2)}}{n} - m^2}$$ **Equation 3.3**

Where:

- S = Standard deviation.
- m = Mean value.
- R = Measured values.
- n = Number of samples taken.

3.3.2.2 Mix of Fluid Types

The conducting fluids (water) will have an apparent resistance as measured with the Sensor probe of '**Rc**'. This value may be determined by a variety of means. This includes making measurements in zones of the well that contains water, by taking a sample and dipping the probe into it. Alternatively, it could be by assuming the lowest value (as measured by the probe over the complete well) is water.

Similarly, the insulating fluids (hydrocarbons) have an apparent resistance as measured by the Sensor probe of '**Ri**'. Because the resistivity of a typical hydrocarbon is practically infinite, it should be noted that for practical purposes the circuit will either:

- Reach the end of its scale range. In which case the mean will be fixed at the limit and the standard deviation will be zero.
- Report a slightly lower value that reflects the presence of contaminants on the probe tip. Provided these contaminants are still have a very high resistance compared to the water in the well, then the accuracy of the method will not be jeopardised.

3.3.2.3 Calculation of Hold-up

The proportion of water in the fluid mix (in the well) is known commonly as '**Hold-up**'. To determine the Hold-up, the calculation that follows should be made:

$$h = \frac{A_w}{A_t}$$ **Equation 3.4**

Where:

- h = Hold-up.
- A_w = Cross sectional area of the well that is occupied by water (at any one position along the axis of the well).
- A_t = Cross sectional area of the well that is available to flowing fluids (typically pipe internal diameter).

Where the readings are polarised between either a resistance '**Ri**' for the insulating fluid or '**Rc**' for the conducting part, the mean reading will be:

$$m = (h \times Rc) + (1 - h) \times Ri$$ **Equation 3.5**

Where:

- m = Mean value.
- h = Hold-up.
- Rc = Conducting fluid resistance.
- Ri = Insulating fluid resistance.

Similarly the standard deviation will be:

$$S = \sqrt{(h \times Sc^2) + ((1 - h) \times Si^2) + h \times (1 - h) \times (Ri - Rc)^2}$$ **Equation 3.6**

Where:

- S = Standard deviation.
- h = Hold-up.
- Sc = Standard Deviation of conducting fluid resistance.
- Si = Standard Deviation of insulating fluid resistance.
- Rc = Conducting fluid resistance.
- Ri = Insulating fluid resistance.

The sampling period over which the mean average is taken must be long when compared to the natural variations in the fluid-flow regime and any prior sampling electronics. Typically one second would be sufficient.

Manipulation of the above equations leads to a formula for Hold-up that is based on the measured mean, standard deviation and the resistance '**Ri**':

$$h = \frac{x}{x + S^2}$$ **Equation 3.7**

Where:

$$x = (Ri - m)^2$$ **Equation 3.8**

Where:

- h = Hold-up.
- S = Standard deviation.
- Ri = Insulating fluid resistance.
- m = Mean value.

This only holds for the distribution being polarised between two tight distributions for water and hydrocarbon.

3.3.3 HISTOGRAMS

A more detailed view of the Sensor data can be conveyed by an histogram. A quantity of either value ranges or bins are defined and the counts accumulated for these when a sample has a value within their range. The situation shown in ***Figure 3.4*** might result in a set of histogram bins as in ***Figure 3.5***.

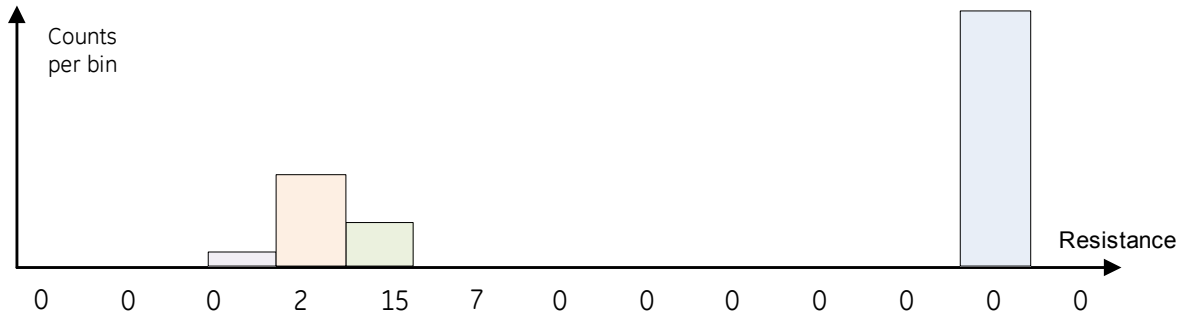


Figure 3.5 Histogram representation of measured data

The histogram data can be used to either generate the mark-space information (with the threshold set retrospectively) or produce the overall Mean and Standard Deviation (with an accuracy limitation through the pre-rounding of values). However, the view of hold-up in the proximity of a given Sensor is obtained more easily from the histogram itself, as is the distribution of the conductive part of the fluid.

The transfer of histogram information requires more data to be passed than either of the two other approaches considered above.

3.3.4 DATA COMBINATION

Within a limited bandwidth, the 'Binary States' and the 'Mean and Standard Deviation' methods allow more frequent reports to be made on the fluid status than can be done with histogram bins. The approach actually adopted for the RAT001 is to use a combination of Histograms and 'Mean and Standard Deviation' methods.

Each report consists of a 'Mean and Standard Deviation' method for each of its twelve Sensors and the histogram data for one of the Sensors. A sequence of twelve reports results in a full set of histograms for the Sensors, covering the whole period and the twelve snapshots within that period show the variation for each individual Sensor.

3.3.5 SALINITY INDICATION

The RAT001 is a tool for determining the mix of water and hydrocarbons. It is **not** intended to provide a definitive indication of the resistivity of the water and thereby its salinity. As the Sensors are susceptible to changes in sensitivity through build up of deposits on the electrodes, component wear and replacement or maintenance, they are not calibrated for direct reading of fluid conductivity. However, it is recognised that users may wish to gain some insight into the salinity of the water being encountered.

The values at the lower end of the range being returned (associated with a low standard deviation or showing at the lower end of the histogram) relate to the water content. The lower these values, the lower the resistance in the water portion.

The resistance of saline is affected by both the salinity and its temperature. Lower values will be caused either by an increase in the concentration or temperature, or a combination of both. A change in temperature from 30ºC to 120ºC (86°F to 248°F) will have a similar effect on the measured resistance as an increase in salinity concentration by a factor of '**3.2**'.

4 OPERATING PROCEDURE

4.1 Pre-Logging Checks

IRRITANT! **LIQUID-O-RING®, TYPE 101 LUBRICANT**
Refer to *Section 2.5.1, Liquid-O-Ring®, type 101 Lubricant*.

4.1.1 MECHANICAL

Complete these Mechanical Pre-Logging Checks:

1 Check all O-Rings and sealing surfaces are undamaged, clean and greased.

2 Remove and retain the Closing Ring.

3 Check all Springbows are in good condition and all Sensors are located securely within the associated Springbow.

4 Check the Locking Ring is hand tight, so the Sensors are held in the sensor head.

5 Check the Locking Ring is locked down to the central shaft.

To do this, make sure the appropriate Grub Screws are tight.

6 Check the Bow Clamp Locking-Rings are tight.

7 Check the inner Split-Ring on the Sensor Head is tight and the Grub Screws are tightened to prevent it from unscrewing.

4.1.2 ELECTRICAL

Complete these Electrical Pre-Logging Checks:

1 Make sure upper and lower electrical connectors are clean, dry and undamaged.

2 Use a Multimeter to check the through-resistance between the top and the bottom LINE connections.

The reading should be less than 0.5Ω.

3 Use a Multimeter to check the resistance between the LINE connections and the chassis (effectively the DC resistance of the internal electronics).

The reading should be greater than 100kΩ.

4.1.3 Operational

Complete these Operational Pre-Logging Checks:

1 Connect the RAT001 to a suitable telemetry controller (UMT008 or XTU009) and to a logging system via either a wireline cable or suitable Dummy Logging Cable (DLC007).

2 Attach a Bullnose Ultrawire™ Terminator (BUL006) to the bottom of the toolstring.

Although the tool may appear to work without the Bullnose Ultrawire™ Terminator, it will be more susceptible to telemetry errors when the Bullnose Ultrawire™ Terminator is not used.

3 Switch on the logging system.

4 Check the tool current is 80mA (approx.).

5 Slide the Closing-Ring off the tool, so the Springbows open.

6 Check all Springbows are opened correctly and the Sensors are held correctly within them.

4.2 Calibration

Refer to the Warrior Software Manual ***MN-WARRIOR*** for a calibration procedure.

4.2.1 Master Calibration

Calibrate the inclinometer every three months (minimum) or after eight jobs. It is a relatively short process and may be performed prior to every job. Keep records of these calibrations to monitor any drift in the tool.

4.3 Connecting to Toolstring

4.3.1 General

In terms of measurement, the position of the RAT001 within the toolstring is not critical. However, other tools can affect where the RAT001 can be placed. This is mainly where other Production Logging tools and any XSH and/or a tractor are used. The main criteria is to make sure the RAT001 is centralised.

4.3.2 Centralisation

Centralisation is very important and becomes a critical issue in horizontal wells. When the RAT001 is below centre, all the Sensors will be out of their desired positions, resulting in an overestimate of the water fraction. When the tool is very significantly decentralised, the uppermost sensor may not reach the casing (particularly in a 7″ casing). In such cases, any oil that flows along the top side of the well may go undetected.

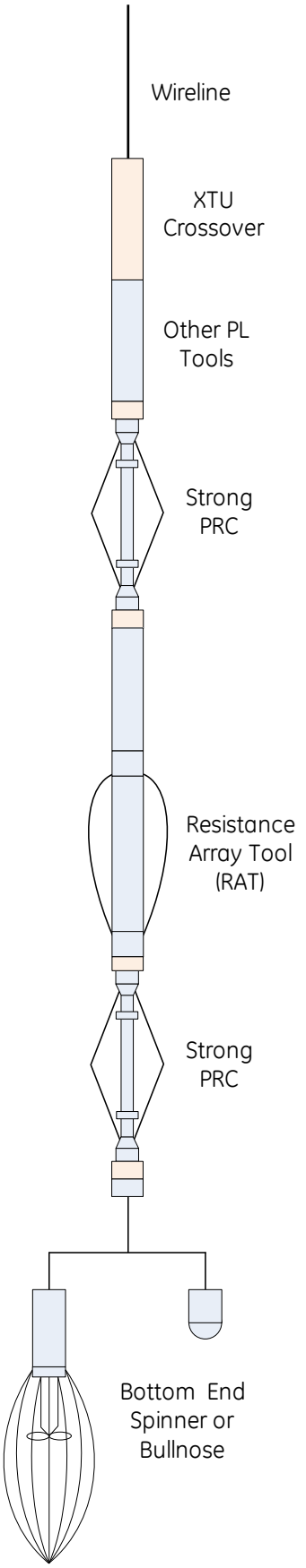


Figure 4.1 Recommended toolstring configuration

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

1 Firstly, the supporting force from the centralisers will decrease as they close more. Therefore, centralisation becomes more difficult as the casing diameter decreases. However, even in a 7″ casing, de-centralisation can still be very significant when care is not taken.

2 Secondly, toolstrings flex as they are made longer. This can cause significant decentralisation of the RAT001 when there are too many tools between the RAT001 and the centralisers.

3 Thirdly, when self-supported on the ground, there will be two arms of a centraliser to support the tool. In a horizontal well, the centraliser may be oriented such that only one arm supports the tool.

4 Finally, the support force of Centralisers decreases when moving. This is due to the frictional component between the casing and the centraliser roller being less when moving than when stationary (That is, the static friction is greater than the dynamic friction).

Therefore, as a minimum recommendation:

- There should be no tools between the RAT001 and its nearest centraliser.
- Consider the use of strong centralisers (For example: 70lbs to 100lbs rated) at each end of the RAT001. The 40lb centralisers may not be sufficient in a small (3″ diameter) casing.

Great care must be taken when other tools are added to the toolstring. Where possible, assemble the toolstring in sections, based on the diameter of the casing found in the well that is to be logged. Where this cannot be done, use more centralisers than thought to be necessary.

Knuckle joints may be used also as appropriate, particularly when 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 RAT001 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

Figure 4.2 RAS001

When more than one flow imaging tool (For example: a SAT and/or a RAT) 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) (see *Figure 4.2*) can be used to make sure all the sensors on the array tools are aligned with each other.

4.3.4 Use of Restrictor Rings with MAP Tools

The RAT001 tool will open to a nominal 7" diameter in its standard form. When logging is required where the tool is not required to open to its maximum diameter, a restrictor ring can be installed at the lower ends of the Springbow to open the Tension Spring. Three sizes of Restrictor Rings are available that give nominal maximum opening sizes of:

- 6 inches.
- 5 inches.
- 4 inches.

Installation instructions for the Restrictor Rings are given in *Appendix C, Fitment of the Restrictor Rings*.

4.4 Logging

The information that follows is a guideline 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 the tool is in deviated wells. The use of a Head Tension Unit (HTU) is highly recommended.

Note: Do not exceed the calculated safe working load of your selected weak point. When in doubt, use a Head Tension Unit (HTU), especially in deviated wells where the 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, logging down can sometimes produce superior data to logging up. This is because the relative fluid velocity is greater when running into hole. In addition, due to the design of the tool, it is recommended that stationary logs are taken at zones of particular interest.

4.5 Post Logging Disassembly

WARNING! **TRAPPED PRESSURE!**

Refer to *Section 2.3.1, Trapped Pressure Safety Precautions***.**

When any of the circumstances that follow are encountered or it is suspected that the tools may have leaked, then you must proceed as if the tools contain trapped, pressurised fluid/gas until otherwise determined. The characteristics of trapped pressure are:

- Telemetry failures downhole.
- Signs of mechanical damage.
- Unusual seepage of fluid out of the tool or bubbling/hissing noises.
- Tools that have been fished.
- Tools that have been downhole for extended periods.
- Hard to undo housings or housing split-nuts.

4.5.1 *Relief of Trapped Pressure at the Tool Joints*

When the RAT001 displays any of these characteristics it should be considered as potentially containing trapped and pressurised fluid/gas:

- Telemetry failures downhole.
- Signs of mechanical damage.
- Unusual seepage of fluid out of the tool or bubbling/hissing noises.
- Tools that have been fished.
- Tools that have been downhole for extended periods.
- Hard to undo housings or housing split-nuts.

When there are signs of trapped pressure, refer to ***Section 2.3.1, Trapped Pressure Safety Precautions*** **AND** to ***Section 5.1, Relief of Trapped Pressure - Tool Disassembly***.

Note: The above two sections of the manual **MUST** be read in the order shown to avoid unwanted injuries!

4.5.2 *Tool Preparation for Transport*

Before the RAT001 is transported, complete these actions:

1 Clean the tool, paying particular attention to the Sensors.

Use a damp cloth to clean the Sensors initially and wipe them carefully and dry thoroughly with paper tissue or a dry cloth. **DO NOT** use any abrasive material and **DO NOT** pressure wash the Sensors.

2 Keep the electrical connectors clean and dry.

3 Install the Transportation Closing Ring Assembly (***P/N: 17028***).

4 Refit the two Thread Protectors (***item 6, 09751*** and ***item 9, 09751***).

4.6 *Transport, Handling & Storage*

WARNING! **Low Temperatures & Fragile Components!**

Refer to *Section 2.11, Transportation and Storage*.

Store with end-threads greased lightly with Liquid-O-Ring®, type 101 (***LOR101***) and with the water-tight Thread Protectors (***item 6 & item 7***) fitted. Make sure the Transportation Closing Ring Assembly (***P/N: 17028***) is installed.

Do not subject the tool to extreme shock, such as dropping or hitting with a hard object. The Sensors are made of ceramic and may be cracked when the tool is dropped.

5 MECHANICAL DESCRIPTION

The RAT001 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 twelve Sensor Assemblies. Each Sensor Assembly plugs into the Sensor Head and has an O-Ring Seal to allow for easy replacement. The single wire of the Sensor Assembly (plus the chassis ground) provides connectivity with the main tool electronics. The chassis ground is made through the use of a Canted Coil Spring on the Sensor Tube. Make sure the Canted Coil Spring is in good condition.

The twelve flexible tubes of the Sensor Assembly (that flex with the Springbow) are guided (by its corresponding Springbow) by metallic clips and each Springbow carries a single wire from the Springbow-mounted resistivity-assemblies to the Sensors. The clips guide the Sensor Assembly tubes to allow the Sensors to be kept a set distance from the Springbow and therefore lessen any shielding effect on the flow by the Springbows.

The Springbows are anchored at the Sensor Head end and are actuated by an Expansion Spring at the other end. The Springbows are fixed to the tool by a Clamping Ring at each end. The Clamping Ring can be moved to allow replacement of either all Springbows or an individual Springbow.

5.1 Relief of Trapped Pressure - Tool Disassembly

WARNING! **TRAPPED PRESSURE!**

Refer to *Section 2.3.1, Trapped Pressure Safety Precautions*.

5.1.1 PRESSURE RELIEF THROUGH HOUSING SEALS

Ref.: RAT001 General Assembly ***AD-09751***

Note: Where tools are fitted either above or below the Tool Code, refer to ***Section 4.5.1, Relief of Trapped Pressure at the Tool Joints*** for instructions on how to remove safely these tools before you proceed.

To relieve the trapped pressure, complete these actions:

1 Place a rag over the end of Upper Electronics Pressure Housing (***item 8***) and the joint between the Upper Electronics Pressure Housing and the Sensor Head Assembly (***item 1***). This will diffuse any jet of gas or fluid/gas that may emerge from around the joint.

2 Disconnect **SLOWLY** the Upper Electronics Pressure Housing from the Sensor Head Assembly. Should there be trapped pressure inside the Upper Electronics Pressure Housing, the joint may well be tighter than usual and require more torque than normal to undo.

3 At some point, well before the threads of the joint have become disengaged, fluid or gas release will occur. As soon as any hissing or fluid appearance happens, the disconnection process should cease **IMMEDIATELY** and the pressure inside the Upper Electronics Pressure Housing should be allowed to escape before the joint is unscrewed further. This way, the pressure load on the tool joint can be retained safely by the threads that remain engaged.

4 Once the operator is satisfied that no more fluid or gas is escaping, resume to unscrew **SLOWLY** the joint. When further hissing or signs of fluid escape are evident, cease **IMMEDIATELY** the unscrewing and allow the pressure to dissipate.

5 Repeat these steps until all trapped pressure is released and there is no pressure loading on the tool joint.

5.2 Disassembly

5.2.1 Electronics Section Removal & Access

5.2.1.1 Electronics Section Removal

Ref.: RAT001 General Assembly *AD-09751*
Electronics Assembly *AD-85798*

Note: Item numbers refer to the General Assembly (AD-09751), unless stated otherwise.

1 Unscrew the Upper Electronics Pressure Housing (***item 8***) from the Sensor Head Assembly (***item 1***).

2 Screw **clockwise** the three Skt Hd Grub Screws (***item 21, 85798***) into the Electronics Assembly (***item 2***) until flush.

Note: Do **not** apply excessive torque, as this will hamper the removal and possibly damage the LEMO connector (***item 9, 85798***) in the Electronics Assembly.

3 The Electronics Assembly can now be unplugged from the Sensor Head Assembly (***item 1***) by simply pulling apart the two components.

See ***Figure 5.1***.

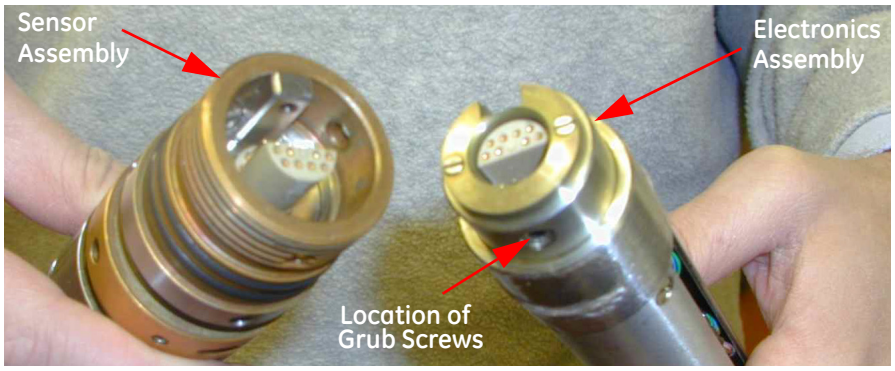


Figure 5.1 Separation of the Electronics Assembly from the Sensor Head Assembly

5.2.1.2 Electronics Access

Ref.: RAT001 General Assembly *AD-09751*
Electronics Assembly *AD-85798*

Note: Item numbers refer to the Electronics Assembly (AD-85798), unless stated otherwise.

1 Make sure the Upper Electronics Pressure Housing (***item 8, 09751***) has been removed from the Sensor Head Assembly (***item 1, 09751***).

2 To access the Programmed Analogue Board (***item 2***) and the Programmed PCB Assembly (***item 3***), remove the 'upper' half of the Electronics Chassis Assembly (***item 4***).

Note: The 'upper' half of the Electronics Chassis Assembly is fitted with seven screws (***item 12***). The 'lower' half of the Electronics Chassis Assembly has nine screws (***item 12***) as the additional two screws are used to hold the Relative Bearing Assembly (***item 1***) in place. The 'lower' half of the Electronics Chassis Assembly should **not** be removed unless access is required to the wiring of the Relative Bearing Assembly.

Note: To service the Pressure Isolation Head (***item 5***), refer to ***MN-PIH***.

5.2.2 SPRINGBOW REMOVAL

Ref.: RAT001 General Assembly ***AD-09751***
Sensor Head Assembly ***AD-41113***

5.2.2.1 Removing the Springbows

Item numbers refer to the General Assembly (AD-09751), unless stated otherwise.

To remove the Springbows, complete these steps:

1 Use two C-spanners (C-wrenches) to loosen the Bow Clamp Locking Rings (***item 15***).

See ***Figure 5.2***.

Figure 5.2 Loosen the Bow Clamp Locking Rings

2 Slide the Lower Bow Clamp Ring (***item 16***) away from the Springbows (***item 3***).

See ***Figure 5.3***.

It is possible now to disengage the Springbow from its location holes in the Lower End Termination Body (***item 14***).

Figure 5.3 Sliding away the Lower Bow Clamp Ring

Note: When only a small number of Springbows are to be removed, the Lower Bow Clamp Ring (***item 16***) can be used to lock the remaining Springbows onto the Lower End Termination Body (***item 14***) by re-tightening the two Bow Clamp Locking Rings (***item 15***). When this is done, make sure the pegs of each Springbow are aligned correctly.

3 At the other end of the Springbow, screw in the Bow Clamp Inner Split Ring Assembly (***item 7, 41113***) and then slide away from the Springbows the Bow Clamp Outer Split Ring Assembly (***item 8, 41113***) **and** the Bow Clamp Outer Ring Bursting Disc (***item 9, 41113***) in a manner similar to ***Step 2***.

See ***Figure 5.4***.

Figure 5.4 Loosening the Bow Clamp Split Rings

4 Disengage the Springbow (***item 3***) from its location holes.

See ***Figure 5.5***.

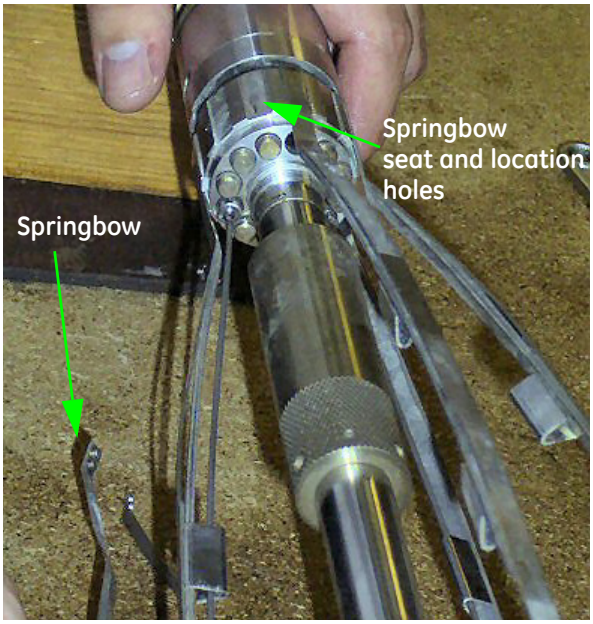


Figure 5.5 Disengage the Springbow

Note: When only a small number of Springbows are to be removed, the Bow Clamp Outer Ring (***item 8, 41113***) and Bow Clamp Outer Ring Bursting Disc (***item 9, 41113***) can be used to lock the remaining Springbows onto the Sensor Head Assembly. This is achieved by unscrewing the Bow Clamp Inner Split Ring Assembly (***item 7, 41113***). Make sure the pegs of each Springbow are aligned correctly and that the Bow Clamp Outer Ring (***item 8, 41113***) is aligned with the keyway in the Sensor Head Assembly.

5.2.2.2 Springbow Removal from Sensor Assembly

Note: Item numbers refer to the General Assembly (AD-09751), unless stated otherwise.

To remove the Springbow from the Sensor Assembly, complete these steps:

1 Push carefully the Springbow Assembly (***item 3***) toward the Lower End Termination Body (***item 14***) until the Single Pin Sensor Assembly (***item 7***) is free from the Springbow Assembly.

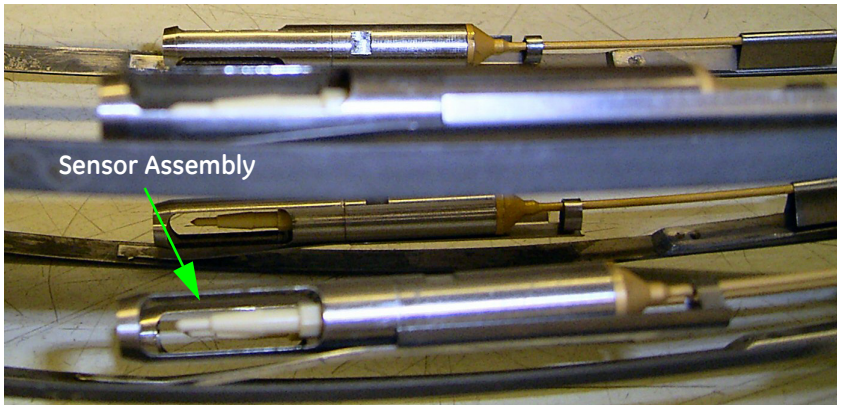


Figure 5.6 Removal of the Sensor Assembly

2 Unclip the Single Pin Sensor Assembly from the clips on the Springbow Assembly.

See ***Figure 5.6***.

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. First, the Sensor Assembly should be released from the clip closest to the Sensor.

3 Pull carefully the Single Pin Sensor Assembly toward the Sensor Head Assembly (***item 1***) and out of the Springbow Assembly.

4 Repeat ***Step 1*** through ***Step 3*** for each Springbow to be replaced.

5.2.3 REPLACING THE SENSORS

Ref.: Sensor Head Assembly ***AD-41113***
Single Pin Sensor Assembly ***AD-40330***

Note: Item numbers refer to the Sensor Head Assembly (AD-41113), unless stated otherwise.

To replace the Sensors, complete these steps:

1 Remove the Springbows as described in ***Section 5.2.2***.

When only a small number of Sensors are to be removed, it is not necessary to remove every Springbow.

2 Slacken the three Skt Hd Grub Screws (***item 18***) in the Locking Ring (***item 4***).

Do **not** try to unscrew the Locking Ring.

3 Before the Locking Ring is unscrewed, rotate the RAT001 radially so the marker that indicates the first Sensor faces down.

Note: Failure to do so might cause the Ball Bearing (located under the Locking Ring) to fall out of the assembly.

Figure 5.7 Slackening the Grub Screws

4 Unscrew the Locking Ring from the Sensor Head Assembly (***item 1***).

5 Use a small screwdriver to lever out carefully the Sensor from the socket in the Sensor Head Assembly.

There is a recess in each Sensor for this purpose.

6 Clean out the corresponding sockets in the Sensor Head Assembly to make sure there are no traces of well fluid.

Isopropanol Alcohol (***IPA***) or a similar solvent can be used. Dry out the socket with soft tissue-paper or similar.

7 Where a Sensor has leaked, it will be necessary to service the Sensor Head Assembly.

Refer to ***Section 5.2.5***.

8 Replace the Sensors.

Note: When the Sensors are replaced, check the connector and the corresponding socket in the Sensor Head Assembly are clean and thoroughly dry.

9 As a Sensor is installed back into the Sensor Head Assembly, take care to reduce the risk of damage to the O-Ring (***item 9, 40330***) and the Canted Coil Spring (***item 7, 40330***).

10 Tighten the three Skt Hd Grub Screws (***item 18***) in the Locking Ring (***item 4***).

11 Refit the Springbows (see ***Section 5.3.3***) and clip the Sensors back into the Springbows.

5.2.4 *Replace the O-Ring for the Single Pin Sensor Assembly*

IRRITANT! **Liquid-O-Ring®, type 101 LUBRICANT**
Refer to *Section 2.5.1, Liquid-O-Ring®, type 101 Lubricant*.

Ref.:	Single Pin Sensor Assembly	*AD-40330*
	Hand Tool Kit for all $1\ ^{11}/_{16}$″ tools	*40886*

Note: Item numbers refer to the Single Pin Sensor Assembly (AD-40330), unless stated otherwise.

To replace the O-Ring for the Single Pin Sensor Assembly, complete these steps:

1 Remove the Sensor Assembly from the Springbow Assembly.

Refer to ***Section 5.2.2.2, Springbow Removal from Sensor Assembly***.

2 Remove the O-Ring (***item 9***) from the Single Pin Sensor Assembly.

3 Fit the Sensor Assembly O-Ring Tool (***P/N: 15272***) over the connector end of the Sensor Assembly.

4 Use a small amount of Liquid-O-Ring®, type 101 (***LOR101***) to lubricate the seating and the replacement O-Ring (***item 9***).

5 Move carefully the O-Ring along the taper of the Sensor Assembly O-Ring Tool and into its seating.

6 Unscrew the Sensor Shield (***item 2***) and remove.

7 Use the Box Spanner (***item 8, 40886***) to unscrew the Single Pin Feedthrough Connector (***item 6***) until the thread disengages from the Sensor Tube Assembly (***item 1***).

Un-necessary rotation may damage the wiring within the Sensor Tube Assembly.

8 Withdraw gently the Single Pin Feedthrough Connector with the wire attached.

9 Remove the O-Ring from the Single Pin Feedthrough Connector.

10 Apply a thin film of Liquid-O-Ring®, type 101 to the new O-Ring and install it.

11 With some initial anti-rotation in the wire, insert the excess wire into the Sensor Tube Assembly.

12 Use the Box Spanner (***item 8, 40886***) to install the Single Pin Feedthrough Connector into the body.

DO NOT over-tighten when the Single Pin Feedthrough Connector is screwed into the Sensor Tube Assembly.

13 Replace the Sensor Shield.

5.2.5 SENSOR HEAD DISASSEMBLY

Ref.:	RAT001 General Assembly	***AD-09751***
	Sensor Head Assembly	***AD-41113***
	Wiring Diagram	***WD-41113***
	Hand Tool Kit for all 1 $^{11}/_{16}$″ tools	***40886***

Note: Item numbers refer to the General Assembly (AD-09751), unless stated otherwise.

Caution!

SENSOR DAMAGE!

The Sensor Head should **NOT** be removed, unless a leak has occurred in a high-pressure/high-temperature well.

Servicing the Sensor Head Assembly involves rewiring the Sensor Head and is not recommended, except in extreme circumstances.

Note: The O-Rings (***item 24***) can be replaced without disassembling the Sensor Head.

To disassemble the Sensor Head, complete these steps:

1 Remove the Electronics Assembly (see ***Section 5.2.1***), the Springbows (see ***Section 5.2.2***) and the Sensors (see ***Section 5.2.3***).

2 Remove the Bow Clamp Locking Ring (***item 15***) from the Sensor Head Assembly (***item 1***).

See ***Figure 5.6***).

Note: Take care not to lose the Ball Bearing (***item 26***) that is located under Bow Clamp Locking Ring (***item 15***) that locks the Main Shaft (***item 10***) to the Sensor Head Assembly (***item 1***).

3 Release but do not remove the three Skt Hd Grub Screws (***item 18, 41113***) that secure the Sensor Head Assembly to the Main Shaft.

The Skt Hd Grub Screws **MUST** be released before an attempt is made to unscrew the Main Shaft.

4 Unscrew the Main Shaft from the Sensor Head Assembly.

Note: There is a flat spanner surface on the Main Shaft for this purpose. The Sensor Head Assembly is now isolated.

5 Use the Parallel Pin Punch (***item 7, 40886***) to remove the Spirol Pin (***item 15, 41113***) from the LEMO Housing (***item 5, 41113***).

6 Pull gently the LEMO Connector Assembly (***items 2, 5 & 6, 41113***) out of Sensor Head Assembly (***item 1, 41113***).

7 Use the 4BA Hex Nut Socket (***item 15, 40886***) to unscrew the Kemlon Feedthrough Connector (***item 12, 41113***).

8 Use a suitable solder iron to unsolder the appropriate wire(s) from the 16-way LEMO (***item 6, 41113***).

Refer to the Wiring Diagram (***WD-41113***).

9 Use the Feedthrough Retaining Nut Tool Assembly (***item 22, 40886***) to unscrew the Feedthrough Retaining Nut (***item 3, 41113***).

Note: When the Feedthrough Retaining Nut is replaced, do not tighten excessively. It should only be lightly hand-tight.

10 Insert the Connector Extraction Tool (***item 21, 40886***) into the Sensor Head Assembly (from the LEMO Connector side).

11 Use a hammer on the Connector Extraction Tool to punch out carefully the desired Kemlon Feedthrough Connector (***item 12, 41113***).

Take care not to damage the wiring.

5.2.6 DISASSEMBLY OF CENTRAL SHAFT ASSEMBLY

Ref.: RAT001 General Assembly ***AD-09751***

The Central Shaft Assembly consists of these main items:

- Spring End Stock - ***item 12.***
- Spring Retaining Ring (qty. 2)- ***item 13.***
- Lower End Termination Body - ***item 14.***
- Bow Clamp Locking Ring (qty. 2) - ***item 15.***
- Lower Bow Clamp Ring - ***item 16.***
- Motor Sub Key - ***item 17.***
- Extension Spring - ***item 18.***
- Csk Hd Slotted Screw - ***item 20.***
- Spirol Pin (qty. 4)- ***item 21.***

To disassemble the Central Shaft Assembly, complete these steps:

1 Remove the Springbows (see ***Section 5.2.2***) and unscrew the central shaft assembly from the Sensor Head (see up to ***Step 4*** of ***Section 5.2.5***).

2 Unscrew the Skt Hd Grub Screw (***item 27***) from the Lower End Seal Sub (***item 11***).

3 Tap gently with a soft-faced hammer the Lower End Seal Sub to release and at least loosen the Ball Bearing (***item 26***).

4 Unscrew the Lower End Seal Sub (***item 11***) from the Main Shaft (***item 10***).

This will release any of the Ball Bearings (***item 26***) that did not fall out when the Lower End Seal Sub was tapped with the hammer.

5 Should it be necessary, the Bypass Cable Feedthrough Assembly (***item 5***) can now be pulled out of the Main Shaft (***item 10***).

6 When necessary, the Lower Connector Assembly (***item 4***) can be removed from the Lower End Seal Sub (***item 11***) by the removal of the Internal Circlip (***item 23***).

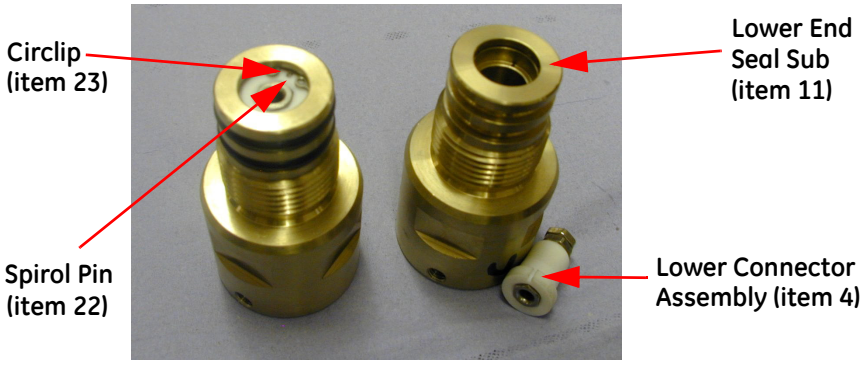


Figure 5.8 Removing the Lower Connector Assembly

7 Use the Parallel Pin Punch (***item 7, 40886***) to remove the two Spirol Pins (***item 21***) that secure the Spring Retaining Ring (***item 13***) to the Lower End Termination Body (***item 14***).

8 Slide back the Spring Retaining Ring (***item 13***) from the Lower End Termination Body (***item 14***).

9 Unscrew **clockwise** the Extension Spring (***item 18***) off the Lower End Termination Body.

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

10 The Lower End Termination Body and the Spring End Stock (***item 12***) can now be removed from the Main Shaft (***item 10***).

5.3 Reassembly

5.3.1 Reassembly of Central Shaft Assembly

IRRITANT! **Liquid-O-Ring®, type 101 LUBRICANT**

Refer to *Section 2.5.1, Liquid-O-Ring®, type 101 Lubricant*.

Ref.: RAT001 General Assembly *AD-09751*

The Central Shaft Assembly consists of these main items:

- Spring End Stock - ***item 12***
- Spring Retaining Ring (qty 2)- ***item 13***
- Lower End Termination Body - ***item 14***
- Bow Clamp Locking Ring (qty 2) - ***item 15***
- Lower Bow Clamp Ring - ***item 16***
- Motor Sub Key - ***item 17***
- Extension Spring - ***item 18***
- Csk Hd Slotted Screw - ***item 20***
- Spirol Pin (qty 4)- ***item 21***

To reassemble the Central Shaft Assembly, complete these steps:

1 Slide a Spring Retaining Ring (***item 13***) over the Extension Spring (***item 18***).

2 Screw **anti-clockwise** the Extension Spring onto the Lower End Termination Body (***item 14***).

A small amount of grease may aid with this assembly.

3 Use the two Spirol Pins (***item 21***) to secure the Spring Retaining Ring to the Lower End Termination Body.

4 Slide the second Spring Retaining Ring over the Extension Spring.

5 From the other end slide the Central shaft Assembly onto the Main Shaft (***item 10***) along with the Spring End Stock (***item 12***).

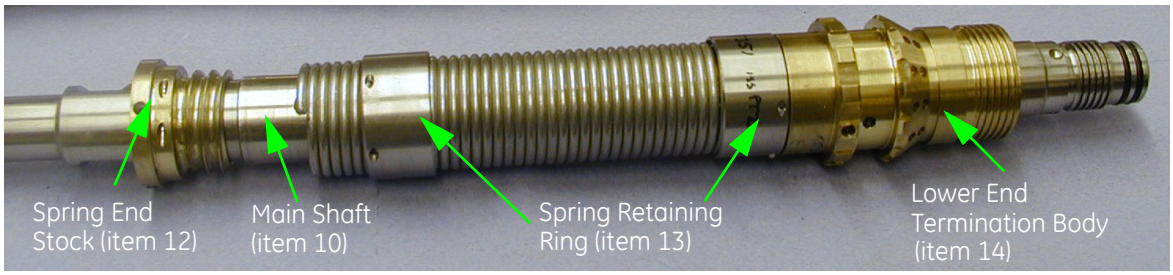


Figure 5.9 Central Shaft Assembly

6 Screw **anti-clockwise** the Extension Spring (***item 18***) onto the Spring End Stock (***item 12***).

A small amount of grease applied to the Spring End Stock will aid with this assembly.

7 Fit one of the Spring Retaining Rings (***item 13***) over the Extension Spring (***item 18***) and then secure it to the Spring End Stock (***item 12***) with the two Spirol Pins (***item 21***).

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

8 Fit the Lower Bow Clamp Ring (***item 16***) and the two Bow Clamp Locking Rings (***item 15***) to the Lower End Termination Body (***item 14***).

9 Insert the Bypass Cable Feedthrough Assembly (***item 5***) into the Main Shaft (***item 10***).

10 Apply a small amount of Liquid-O-Ring®, type 101 (***LOR101***) to the two O-Rings (***item 29***) and to the grooves on the Main Shaft.

11 Install the two O-Rings to the lower end of the Main Shaft.

12 Apply a thin film of Liquid-O-Ring®, type 101 to the O-Ring (***item 30***) and then install the O-Ring on the Lower End Seal Sub (***item 11***).

13 Where removed during disassembly, fit a Spirol Pin (***item 22***) to Lower End Seal Sub and insert the Lower Connector Assembly (***item 4***).

14 Use the Internal Circlip (***item 23***) to secure the Lower Connector Assembly to the Lower End Seal Sub (***item 11***).

15 Screw the Lower End Seal Sub onto the end of the Main Shaft.

Make sure the Lower End Seal Sub is tightened fully onto the central shaft.

16 Use the three Ball Bearings (***item 26***) and the three Skt Hd Grub Screws (***item 27***) to lock the Lower End Seal Sub in position.

17 Apply a thin film of Liquid-O-Ring®, type 101 to the O-Rings (***item 24***) and then install the O-Rings on the Lower End Seal Sub (***item 11***).

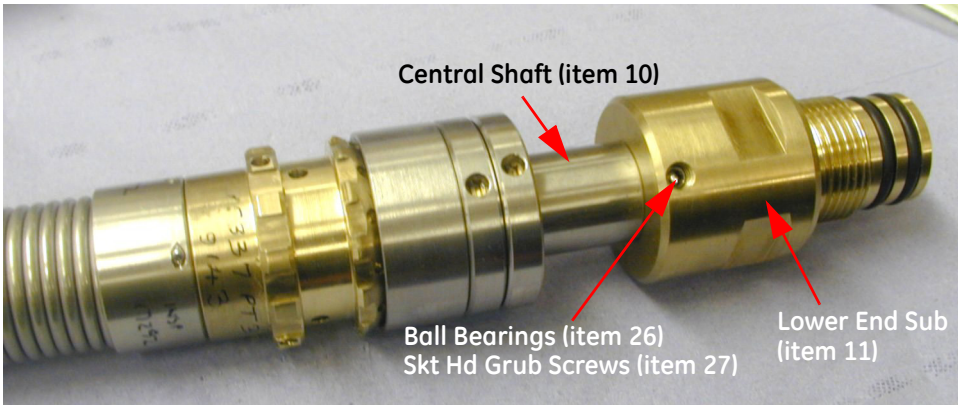


Figure 5.10 Lower End Sub screwed onto the Central Shaft

18 Lubricate the grooves on the Main Shaft and the O-Rings (***item 29***) with Liquid-O-Ring®, type 101 and install them on the end of the Main Shaft (***item 10***) that screws into the Sensor Head Assembly (***item 1***).

5.3.2 Sensor Head Assembly Reassembly

IRRITANT! **Liquid-O-Ring®, type 101 LUBRICANT**
Refer to *Section 2.5.1, Liquid-O-Ring®, type 101 Lubricant*.

Ref.:		
	RAT001 General Assembly	***AD-09751***
	Sensor Head Assembly	***AD-41113***
	Electronics Assembly	***AD-85798***
	Wiring Diagram	***WD-41113***

Item numbers refer to the Sensor Head Assembly (AD-41113), unless stated otherwise.

Note: The O-Ring (***item 10***) is replaced easier when the springbows are refitted, see ***Section 5.3.3***.

To reassemble the Sensor Head Assembly, complete these steps:

1 Apply a thin film of Liquid-O-Ring®, type 101 to the O-Rings on the Kemlon Feedthrough Connectors (***item 12***).

2 Locate carefully the Connector Extraction Tool (***item 21, 40886***) on to the Kemlon Feedthrough Connector and then gently (but firmly) punch it home fully.

3 Use the Kemlon Feedthrough Fastening Tool (***item 23, 40886***) to install a Feedthrough Retaining Nut (***item 3***) to lock in position the Kemlon Feedthrough Connector.

This should be hand tightened only.

4 Repeat ***Step 1*** through ***Step 3*** for any other Kemlon Feedthrough Connector that has to be reinserted into the Sensor Head Assembly (***item 1***).

5 Use the Kemlon Tool (***item 15, 40886***) to insert the Mono Pin Pressure Isolation Connector (***item 13***) into the Sensor Head Assembly (***item 1***).

Caution!

Damage to the Programmed Analogue Board!

When the line wire is connected inadvertently to a Sensor, the Programmed Analogue Board (***item 2, 85798***) will become damaged irreparably and will require replacement.

6 Use a suitable solder iron and SN100C solder to connect all the wires from the Kemlon Feedthrough Connectors (***item 12***) and the Mono Pin Pressure Isolation Connector (***item 13***) to the 16-Way LEMO (***item 6***) as indicated on the wiring diagram.

Refer to ***WD-41113***.

Note: Make sure the line wire connections (from each Mono Pin Pressure Isolation Connector) is shielded thoroughly. Check thoroughly all the connections are correct.

7 Carefully feed the wire loom back into the Sensor Head Assembly (***item 1***).

8 Insert the LEMO Connector Assembly (***items 5, 6 & 2***) back into the Sensor Head Assembly (***item 1***) and lock in place with the Spirol Pin (***item 15***).

9 Fit and screw the Main Shaft (***item 10, 09751***) back onto the Sensor Head Assembly (***item 1***).

There is a flat spanner surface on the central shaft for this purpose.

10 Refit the Locking Ring (***item 4***) onto the Sensor Head Assembly (***item 1***).

11 Insert the three Skt Hd Grub Screws (***item 18***) into each of the three holes in the Sensor Head Assembly.

These lock the Main Shaft to the Sensor Head.

12 Refit the Electronics Assembly (see ***Section 5.3.4***), the Springbows (see ***Section 5.3.3***) and the Sensors (see ***Section 5.2.3***).

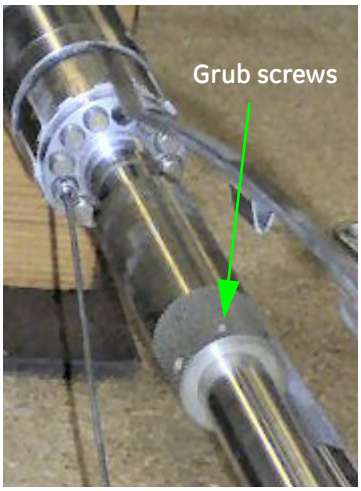


Figure 5.1 Tightening Grub Screws

5.3.3 SPRINGBOW REASSEMBLY

Ref.:	RAT001 General Assembly	***AD-09751***
	Sensor Head Assembly	***AD-41113***

Note: Item numbers refer to the General Assembly (AD-09751), unless stated otherwise.

5.3.3.1 Refitting the Single Pin Sensor Assembly

To refit the Single Pin Sensor Assembly (*item 7*), push carefully the Single Pin Sensor Assembly into the Sensor Head Assembly (*item 1*). The Sensor Tube should first be fitted into the clip nearest to the Sensor Head, then into the clip nearest to the Sensor. Take care the sharp edges on the Sensor Head do not damage the Sensors on the Sensor Assemblies.

5.3.3.2 Refitting the Springbows

To refit the Springbows, complete these steps:

1 Carefully push the Springbow Assembly (*item 3*) over the nose of the Sensor section until the nose of the Sensor section is engaged in the Springbow Assembly.

2 Clip the Single Pin Sensor Assembly (*item 7*) into the clips on the Springbow Assembly.

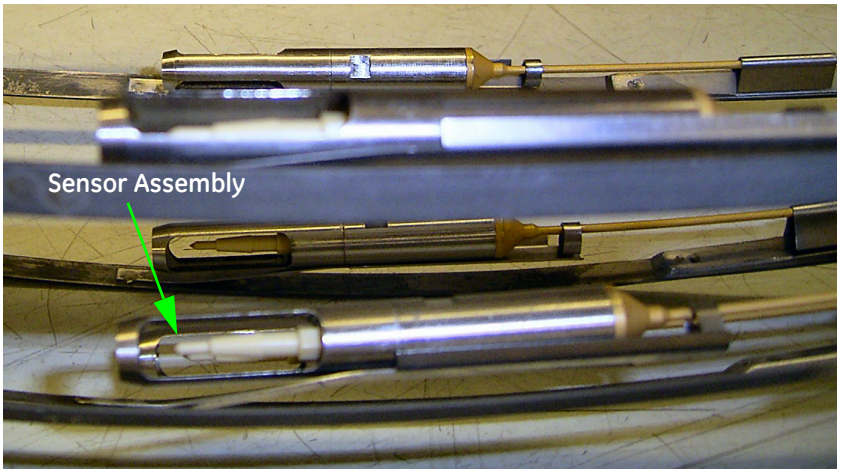


Figure 5.11 Installation of the Sensor Assembly

3 Fit a Springbow Assembly on the Sensor Head Assembly (*item 1*), orientated so the Sensor Tube clips are at the Sensor Head Assembly end.

There is a keyway at the Sensor Head end, so care should be taken to make sure this is aligned correctly.

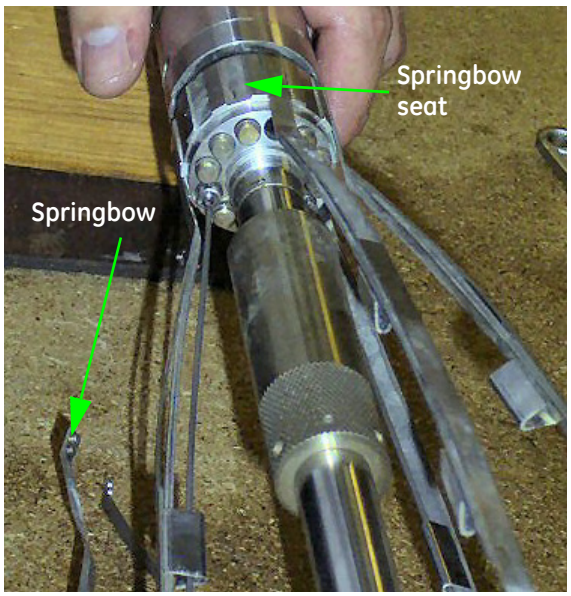


Figure 5.12 Location of the Springbow seat

4 Slide the Bow Clamp Outer Split Ring Assembly (***item 8, 41113***) and Bow Clamping Outer Ring Bursting Disc (***item 9, 41113***) in place and tighten the Bow Clamp Inner Split Ring (***item 7, 41113***).

See ***Figure 5.13***.

Figure 5.13 Installation of the Bow Clamp Outer ring and the Bursting Disc

Note: When 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 Split Rings (Inner and Outer) are tightened. Usually, this is not necessary once they have been tightened into place for some time. Repeat this procedure for each of the remaining Springbow Assemblies.

5 Use two C-spanners (C-wrenches) to loosen the Bow Clamp Locking Rings (***item 15***) on the lower end of the tool.

6 Slide the Lower Bow Clamp Ring (***item 16***) away from the Springbows.

7 Fit a Springbow Assembly (***item 3***) and secure the Springbows by re-tightening the Bow Clamp Locking Rings with C-spanners (C-wrenches).

See ***Figure 5.14***.

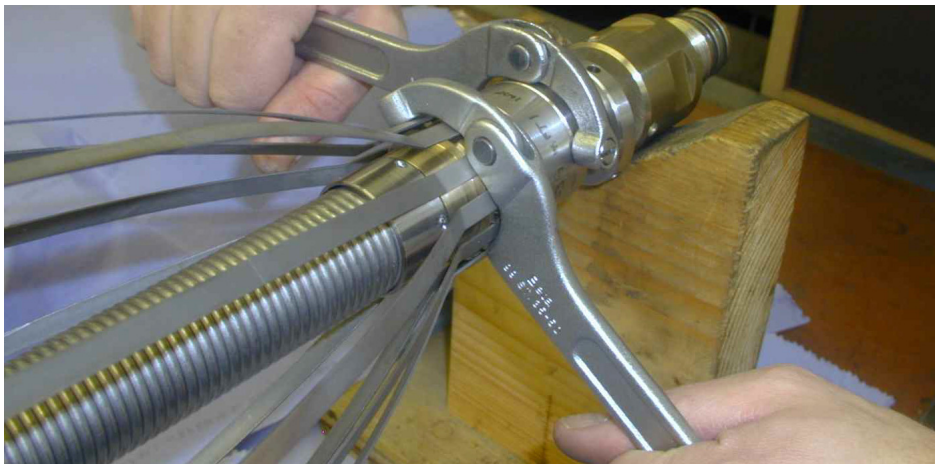


Figure 5.14 Tightening of the Bow Clamp Locking Rings

8 Tighten the two Skt Hd Grub Screws (***item 17, 41113***) in the Bow Clamp Inner Split Ring Assembly (***item 7, 41113***) to lock it onto the Sensor Head Assembly (***item 1, 41113***).

5.3.4 ELECTRONICS SECTION REASSEMBLY

IRRITANT! **LIQUID-O-RING®, TYPE 101 LUBRICANT**

Refer to *Section 2.5.1, Liquid-O-Ring®, type 101 Lubricant*.

Ref.: RAT001 General Assembly ***AD-09751***
Electronics Assembly ***AD-85798***

Note: Item numbers refer to the General Assembly (AD-09751), unless stated otherwise.

To reassemble the Electronics Section, complete these steps:

1 Plug the Electronics Assembly (***item 2***) into the Sensor Head Assembly (***item 1***).

Note the orientation of the LEMO Connectors. See ***Figure 5.15***.

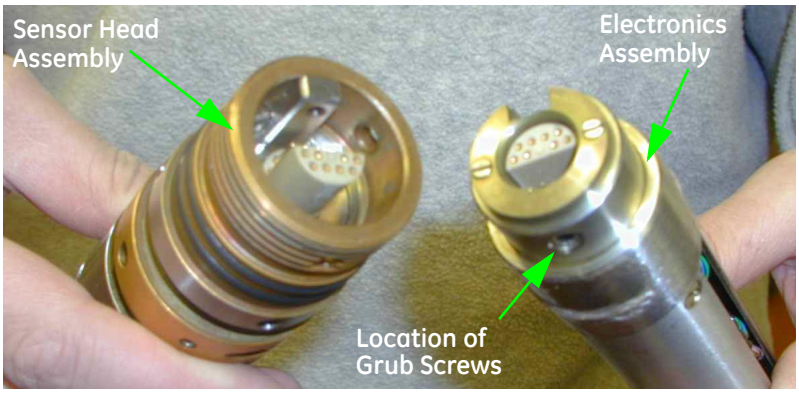


Figure 5.15 Connecting the Electronics Assembly to the Sensor Head Assembly

2 Lightly screw the three Skt Hd Grub Screws (***item 21, 85798***) **anti-clockwise** to secure the Electronics Assembly (***item 2***) to the Sensor Head Assembly (***item 1***).

3 Apply a thin film of Liquid-O-Ring®, type 101 (***LOR101***) to the O-Ring (***item 18, 85798***).

4 Install the O-Ring on the Electronics Bulkhead Isolation Assembly (***item 5, 85798***).

5 Use a 38mm Spanner (wrench) and a C-spanner (C-wrench) to install the Upper Electronics Pressure Housing (***item 8***).

6 ELECTRICAL DESCRIPTION

Ref.: Block Diagram *Figure 3.1*

6.1 Overview

The RAT001 electronics consists of two PCBs, the Programmed Analogue Board (*PCB 85992* - *CD-85988*) and the Programmed PCB Assembly (*PCB: 85993* - *CD-82333*).

6.2 Analogue Board

Ref.: Programmed Analogue Board (PCB 85992) *CD-85988*

The Programmed Analogue Board can be divided into these Sections:

- Power Supply Unit (PSU).
- Processor.
- RAT sensor driver.

6.2.1 Power Supply

The Switch Mode Power Supply (SMPS) is a AC isolated from the Ultrawire™ toolbus by an active choke. It consists of Q17 and associated circuitry. The filter, formed by this active choke together with the capacitor (C1), prevents the switching currents generated by the SMPS from appearing on the Ultrawire™ bus, where they would cause data corruption and makes sure the tool takes a steady DC current. The tool is protected against over voltage and reverse connection by the fuse (F1) and the Zener diode (D1).

The SMPS is controlled by the SMPS controller IC26. The MOSFET (TR1) and the multi-winding inductor (L1) form the core of the power supply. IC25 provides a 2.048V reference for the supply and the inductor (L2) and the capacitor (C6) form an output filter on the 4.2V output.

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 any output rail and makes it extremely robust.

L1 is tapped to provide semi-regulated outputs of +15V and -12V. The two semi-regulated outputs are linearly post-regulated to provide the various voltages required by the analogue electronics.

The 4.2V supply is switched up to 5V when the board is put into program mode.

6.2.2 Processor

The processor that controls the PCB is a PIC16F874 clocked at 12MHz. The Processor uses its internal SPI interface together with IC3 to interface with the Ultrawire™ PCB. All the strobes required for the RAT001 driver electronics are generated by the processor. The processor also drives the 'Alcopot' to measure the orientation of the tool.

IC23 is used as a serial combination lock to ensure that the processor is not reprogrammed accidentally.

6.2.3 RAT Sensor Driver

This circuit selects each probe in turn.

6.3 Digital Board

Ref.: Digital Board (PCB 85993) ***CD-82333***

The Digital Board contains three main functional blocks. These are the Switched Mode Power Supplies (SMPS), the Ultrawire™ bus interface and the system control electronics. The SMPS takes DC power from the Ultrawire™ tool bus and generates 3.3V rail that powers all the analogue and digital circuitry on the Ultrawire™ PCB. A nominally, unfiltered, 1.6V rail is also generated, for use in some tools (refer to wiring diagram). 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 over voltage and reverse connection by the fuse (F1) and the Zener diode (D1).

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

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.

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.

Control lines D3, D4, TX, RX and CLK communicate with the Analogue Board, using SPI protocol.

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 is 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. Op-amp U6 and the associated components condition the signal from the temperature probe, but this is currently unused. The output of this op-amp is connected to the microprocessor (U7) where it is converted into a digital quantity by the processor's internal analogue to digital converter.

7 EXTENDED CHECKS

7.1 Preventative Maintenance

IRRITANT!

LIQUID-O-RING®, TYPE 101 LUBRICANT

Refer to *Section 2.5.1, Liquid-O-Ring®, type 101 Lubricant*.

IRRITANT!

CASTROL SPHEEROL L-EP2 GREASE

Refer to *Section 2.5.4, Castrol Spheerol L-EP2 Grease*.

IRRITANT!

CASTROL HIGH TEMPERATURE GREASE

Refer to *Section 2.5.5, Castrol High Temperature Grease*.

Caution!

SEAL INTEGRITY!

Refer to ***Section 2.6, Tool Integrity***.

7.1.1 MECHANICAL

Refer to ***Section 5, Mechanical Description*** as required for disassembly/reassembly instructions.

Complete these checks for the Mechanical Preventative Maintenance:

1 Remove all dirt and old grease from the threads and the seals on the Upper Electronics Pressure Housing and apply new grease.

2 Inspect the seals for damage or ageing/hardening and replace where required. Apply fresh grease to the threads and seals as required.

3 Check for:

- Damaged wires.
- Wires that are loose and likely to be crushed on reassembly.
- Damaged components.
- Electrical components shorting to chassis.
- Heat or chemical damage (discoloured components).
- Incorrect thread grease or excessive quantity.
- Loose screws/nuts/components/connectors.

Note: When RTV or a similar compound is used to secure loose components, it must be fully cured before the Upper Electronics Pressure Housing is replaced.

4 Check all fixings for tightness.

7.1.2 ELECTRICAL

Ref.: Electronics Assembly *AD-85798*

Complete these checks for the Electrical Preventative Maintenance:

1 With the electronics cartridge removed, use a multimeter to check the electrical resistance at the LEMO connector at the bottom of the Electronics Assembly (*item 2* and *Figure 7.2*).

Refer to *Table 7.1:* for the values.

Use a standard multimeter and **not** a high voltage insulation tester for these tests. See *Figure 7.1* below for the pin/socket position. Pin 7 and Pin 8 are connected to 0V.

Table 7.1: LEMO connector resistance check

Connection	Component Checked	Value
Socket 13 to chassis	Sensor #1	>1MΩ
Socket 14 to chassis	Sensor #2	>1MΩ
Socket 15 to chassis	Sensor #3	>1MΩ
Socket 16 to chassis	Sensor #4	>1MΩ
Socket 9 to chassis	Sensor #5	>1MΩ
Socket 10 to chassis	Sensor #6	>1MΩ
Socket 11 to chassis	Sensor #7	>1MΩ
Socket 12 to chassis	Sensor #8	>1MΩ
Pin 5 to chassis	Sensor #9	>1MΩ
Pin 6 to chassis	Sensor #10	>1MΩ
Pin 1 to chassis	Sensor #11	>1MΩ
Pin 2 to chassis	Sensor #12	>1MΩ
Pin 3 to chassis	GND	<0.2Ω
Pin 4 to the upper banana pin	Through Line	<0.2Ω
Pin 4 to chassis	Through Line	>1MΩ

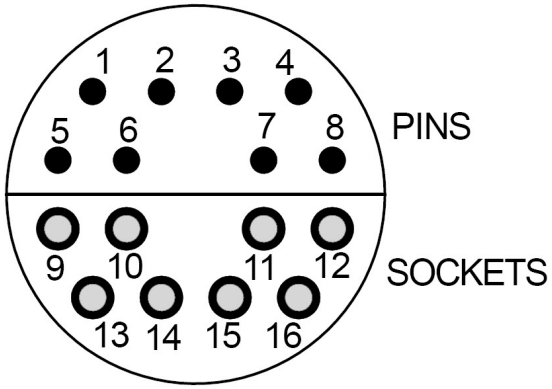


Figure 7.1 LEMO pin/socket positions (front view)

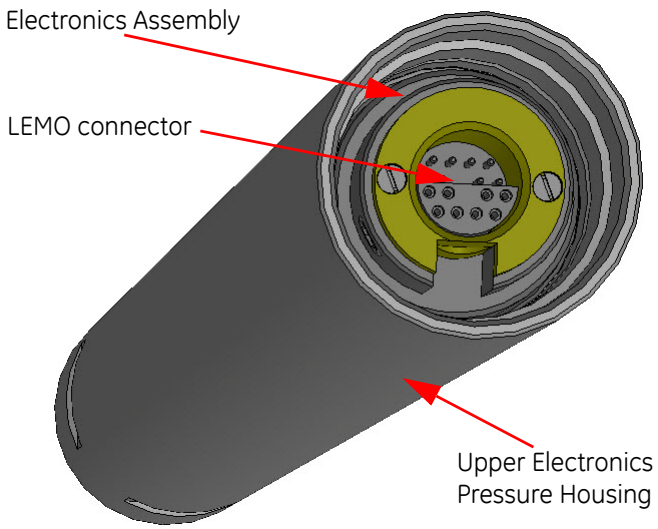


Figure 7.2 LEMO connector location

2 Replace the Electronics Assembly.

3 Check the through-line resistance and the tool current. Refer to ***Section 4.1.2, Electrical***.

4 Connect to the logging system and check for correct data.

Apply some gentle vibration and rotation to expose a potential failure.

5 Take readings of the velocity and the direction.

7.1.3 Seal Replacement Recommendations

Ref.:	RAT001 General Assembly	***AD-09751***
	Electronics Assembly	***AD-85798***
	Sensor head Assembly	***AD-41113***
	Single Pin Sensor Assembly	***AD-40330***

Refer also: ***Section 4.5 Post Logging Disassembly***.

GE Oil & Gas recommend that all the primary seals are replaced after every run or six months when the tool is not in use.

Secondary seals should be replaced under these situations:

- 25 runs or sooner when damaged.
- One year when not in use.
- When the tool is run in a well with temperatures >150°C (302°F).
- When exposed to H_2S or CO^2.

Primary Seals:

- Two O-Rings (***item 24, 09751***).
- One O-Rings (***item 18, 85798***).
- Two O-Rings (***item 11, 41113***).
- Twelve O-Rings (***item 9, 40330*** - part of ***KITO-RAT001***)

Secondary Seals:

- One O-Ring (***item 30, 09751***).
- Two O-Rings (***item 28, 09751***).
- Two O-Rings (***item 29, 09751***).
- Twelve O-Rings (part of ***item 12, 41113*** - part of ***KITO-RAT001***)
- One O-Ring (***P/N: 99008*** - part of ***item 13, 41113***)

7.1.4 Ageing of Electronics

At 150°C (302°F), significant electronic ageing failures are expected after 4000hrs typical use, hence PCB replacement should be considered at this point. Every additional 10°C (18°F) halves the time. Ageing 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 (248°F), 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.

While the tool is heated, it is recommended that the Sensors should be removed and immersed in oil.

7.1.5 Heat Testing Above 150°C (302°F)

Generally, this is not recommended since it shortens tool life expectancy. Heat testing may be required for contractual reasons, because the tool has been out of use for a long period or there is a job with an unusually high well temperature. The test should be carried out slightly above the expected well temperature only and the tool should not be kept at this temperature for more than 1-hour. Do not exceed the maximum rated temperature for the tool.

7.2 Extraordinary Maintenance

Ref.:	RAT001 General Assembly	***AD-09751***
	Sensor Head Assembly	***AD-41113***
	Single Pin Sensor Assembly	***AD-40330***

Note: All item numbers refer to the General Assembly (AD-09751), unless stated otherwise.

The guidelines that follow are appropriate for normal operating conditions. When the tool experiences harsher conditions (For example: High pressure, high temperature, H_2S, etc.), then a more thorough servicing is recommended.

To determine whether the tool has come into contact with H_2S, check for discolouration of the Lower End Seal Sub (***item 11***). This part is made of Al/Bronze and will turn black after it has been in contact with H_2S. Local well-site knowledge will contribute also to determine the possibility of H_2S exposure.

7.2.0.1 Every Run

The minimum recommendation is to replace the O-Rings at the bottom of the tool (***item 24***) every time the tool joint is broken, when the tool has been under pressure. It is recommended also that the O-rings on the Sensor Head (***item 1, 09751***) under the Upper Electronics Pressure Housing (***item 11***) are replaced prior to every job.

7.2.0.2 Every 5 Runs

In addition to the O-Rings that should be changed prior to every job, it is recommended also that all 'wet' O-Rings (For example: O-Rings that experience well pressure) should be changed every five jobs. These are:

- One O-Ring (***item 30***).
- Two O-Rings (***item 29***).
- Two O-Rings (***item 28***).
- One O-Ring (***item 18, 85798***).
- Two O-Rings (***item 11, 41113***).
- Twelve O-Rings (***item 9, 40330*** - part of ***KITO-RAT001***).

When replacing the O-Rings on the Sensor, make sure Liquid-O-Ring®, type 101 is applied to the O-Ring groove and the O-Ring before the new O-Ring is slid on. A small amount of Liquid-O-Ring®, type 101 should be applied also to the outer side of the O-Ring once it has been installed. Immersion of the O-Rings in hot water will soften them and aid their installation.

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

7.2.1 Servicing the Sensor Head

This should rarely be necessary, unless there has been a leak in a high-pressure/high-temperature well. When this has happened, the Kemlon connectors inside the Sensor Head can be cleaned and the O-Rings on them changed. Ordinarily, none of the Kemlon connectors are exposed to well fluid or well pressure. Servicing the Sensor Head Assembly involves rewiring the Sensor Head and is not recommended, except in extreme circumstances.

7.2.2 Use of the Pressure Test Blank Assembly

Pressure Test Blank Assemblies (***P/N: 15286***) can be inserted into the Sensor Head in place of a Sensor. They are primarily used for in-house testing purposes. However, they can be used also in the field and there are two main reasons for this:

- When 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 not less than six 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*** and to ***Section Appendix B, Drawings & Parts Lists***.

7.3.1 Electrical

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

Table 7.1: Fault finding symptoms and actions

Symptom	Action
Initial Inspection	Check for: • Damaged wires. • Damaged components. • Electrical components shorting to chassis. • Heat or chemical damage (discoloured components). • Incorrect thread grease or excessive quantity. Also check all fixings are tight.
Excessive Current	Remove the Electronics Assembly (***item 2, 09751***) and the Sensor Arrays from the Sensor Head to isolate fault to electronics or Sensor Head/Shaft Assembly or the Sensor Array. Disconnect wires to isolate fault to: • Interface board (PCB 85993 (***CD-82333***)). • Digital board (PCB 85988 (***CD-85988***)). • Upper head connector. • LEMO connector on electronics. • Sensor head assembly. • Shaft assembly (including the bypass tube). Fault find or replace the PCB when necessary. With the Electronic Assembly removed, the line connection at the bottom of the tool may be tested to 250V relative to chassis to check for any electrical leak. Resistance should exceed 100MΩ. Disassemble to locate the fault.
Single faulty Sensor	Swap sensors to determine whether the Sensor is faulty. Replace when necessary. When the fault is not with the sensor, check the wiring from the PCB, through the LEMO connectors, to the Kemlons on the sensor head. When a Sensor has leaked, it should be replaced.
Rotation faults	With the tool horizontal, check the Pendulum (***item 1, 11517***) (part of the Relative Bearing Device Assembly) rotates freely. The voltages on ROTx and ROTy should increase as the tool rotates clockwise (looking down the tool). Check they are offset by approximately 180°. This can be checked only roughly. However, when ROTx is at 5V, ROTy should be approximately 2.5V.

APPENDIX A EQUIPMENT & SPARES

A.1 Main Equipment

Part No	Description	Qty	Remarks
RAT001	Resistance Array Tool, $1^{11}/_{16}$″, Ultrawire™	1	---

A.2 Ancillary Equipment

Part No	Description	Qty	Remarks
15265	Flight Case, $1^{11}/_{16}$″	1	---
RAS001	Rotational Alignment Sub	A/R	This tool is not supplied with the RAT001. Order from GE Oil & Gas.
15267	Calibration Tube Assembly	1	This tool is not supplied with the RAT001. Order from GE Oil & Gas.
15272	Sensor Assembly O-Ring Tool	1	This tool is not supplied with the RAT001. Order from GE Oil & Gas.
17028	Transportation Closing Ring Assembly	1	This tool is not supplied with the RAT001. Order from GE Oil & Gas.

A.3 Maintenance Equipment

A.3.1 CONSUMABLES

Part No	Description	Qty	Remarks
LOR101	Liquid-O-Ring® type 101 Lubricant	1	5oz pot
LOR101L	Liquid-O-Ring® type 101 Lubricant	1	16oz pot
IPA01LS	Isopropyl Alcohol	1	1 litre bottle. **NOT** supplied by GE Oil & Gas.
91182	Castrol High Temperature Grease	1	---
15286	Pressure Test Blank Assemblies	A/R	Order from GE Oil & Gas.

A.3.2 SERVICE TOOLS

Part No	Description	Qty	Remarks
40886	Hand Tool Kit for all $1^{11}/_{16}$″ MAPS Tools	1	---
KITB-RAT001	Basic Spares Kit	1	To support one run in hole
KITO-RAT001	O-Rings Spares Kit	1	Includes a Canted Coil Spring
KITR-RAT001	Recommended Spares Kit	1	To support 25 runs in hole

Part No	Description	Qty	Remarks
KITU-MAPS	Upgrade Kit, restricted opening	1	Contains the three Spacer Rings. Refer to ***Appendix Appendix C, Fitment of the Restrictor Rings*** for fitting
99008	O-Ring	1	Replacement O-Ring for the Pressure Isolation Mono Connector (***item 13, 41113***).
42703	Tool Safety Clamp (Earthing kit)	1	Refer to the Tool Safety Clamp manual (***P/N: MN-TSC001***)

A.1 Kit Details

PARTS LISTING	
Part 40886	*Issue* 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	
0001	91022	Spanner Box 3/8x5/16	1	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	
0001	91086	Driver Nut 4BA	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	
0001	20318	Assy Tool - Retain Plug MTT001 'O' Rings	1	EA	
0002	20316	Assy Tool-Tapered Mandrel Sensor O Rings	1	EA	
0003	20317	Assy Sleeve MTT001 Sensor 'O' Rings	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	
0010	93999	Nut Runner M4	1	EA	
0024	16210	Tool Axle Nut Screwdriver MDT	1	EA	
0001	91455	Screwdriver Large 12mm blade 250mm shaft	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

Part	*Issue*
KITB-RAT001	A

Description

Kit, Spares, Basic, RAT001

PARTS LIST

Item	*Part No*	*Description*	*Qty*	*Units*	*Remarks*
0001	KITO-RAT001	Kit, Spares, O-Rings, RAT001	1	EA	
0004	91611	Bearing Ball 2mm Chrome Steel	3	EA	
0005	93043	Scr Grb Skt Hd M3x04mm LG 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	

PARTS LISTING

Part	*Issue*
KITO-RAT001	C

Description

Kit, Spares, O-Rings, RAT001

PARTS LIST

Item	*Part No*	*Description*	*Qty*	*Units*	*Remarks*
0001	95008	O-ring 008 Viton 75	1	EA	
0002	95009	O-ring 009 Viton 75	1	EA	
0003	95011	O-ring 011 Viton 75	1	EA	
0004	95111	O-ring 111 Viton 75	1	EA	
0005	95112	O-ring 112 Viton 75	1	EA	
0006	95211	O-ring 211 Viton 75	1	EA	
0007	99007	O-ring 007 Viton 90	12	EA	
0008	99012	O-ring 012 Viton 90	2	EA	
0009	99016	O-ring 016 Viton 90	2	EA	
0010	99026	O-ring 026 Viton 90	1	EA	
0011	99125	O-ring 125 Viton 90	2	EA	
0012	99211	O-ring 211 Viton 90	10	EA	
0013	99913	O-ring Special Mini Kemlon ref 602322	12	EA	
0014	95114	O-ring 114 Viton 75	2	EA	
0016	99903	O-ring 211 Nitrile 70	1	EA	
0017	92128	Spg Coil Canted 7mm Bore, 4.6mm ID BeCu	4	EA	

PARTS LISTING

Part	*Issue*
KITR-RAT001	B

Description

KIT SPARES RECOMMENDED (25 RUN) RAT001

PARTS LIST

Item	*Part No*	*Description*	*Qty*	*Units*	*Remarks*
0001	KITB-RAT001	Kit, Spares, Basic, RAT001	2	EA	
0004	91611	Bearing Ball 2mm Chrome Steel	3	EA	
0005	93043	Scr Grb Skt Hd M3x04mm LG 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	
0002	KITO-RAT001	Kit, Spares, O-Rings, RAT001	5	EA	
0003	40330	ASSY SINGLE PIN SENSOR RAT001	12	EA	
0001	410234	Assy Sensor Tube RAT001	1	EA	
0002	40539	SHIELD SENSOR RAT001	1	EA	
0003	15298	PIN SPACER	1	EA	
0004	15429	COLLAR RETAINING	1	EA	
0005	15430	SOCKET RETAINER	1	EA	
0006	92147	Conn FEEDTHROUGH SINGLE PIN Press ISO	1	EA	
0007	92128	Spg Coil Canted 7mm Bore, 4.6mm ID BeCu	1	EA	
0008	94234	Connector Hypertac (0100932-22-G0)	1	EA	
0009	99007	O-ring 007 Viton 90	1	EA	
0010	LOR101	Film Form Lube 5oz Pot Liq O Ring typ101	1	ML	
0020	A006-0099C	sol'r Wire Alloy Sn99.3/Cu0.7, High Acty	1	M	
0021	W004-00109	Wire, PTFE Type A, 1/0.25, White	1	CM	
0022	A011-003M2	h'srnk Slv'g, Polyvinylidene Flu, +175C	0.04	M	
0004	40540	SPRINGBOW ASSEMBLY 7" RAT	12	EA	
0001	41885	ASSEMBLY 7" SPRINGBOW	1	EA	
0002	15275	STRENGTHENER SPRINGBOW	2	EA	
0003	15251	CLIP TUBE UPPER SENSOR	2	EA	
0004	40472	spring Sensor	1	EA	
0005	40539	SHIELD SENSOR RAT001	12	EA	
0006	92147	Conn FEEDTHROUGH SINGLE PIN Press ISO	12	EA	
0007	41063	PLUG BLANK SENSOR	6	EA	
0008	20322	Assembly Tool - Sensor O'ring MTT	1	EA	
0001	20318	Assy Tool - Retain Plug MTT001 'O' Rings	1	EA	
0002	20316	Assy Tool-Tapered Mandrel Sensor O Rings	1	EA	
0003	20317	Assy Sleeve MTT001 Sensor 'O' Rings	1	EA	

PARTS LISTING

Part	*Issue*
KITU-MAPS	P1

Description

Kit upgrade MAPS restricted opening kit

PARTS LIST

Item	*Part No*	*Description*	*Qty*	*Units*	*Remarks*
0001	41171	KIT-SPACER RINGS	1	EA	
0001	41142-1	SPACER RING 6"	1	EA	
0002	41142-2	SPACER RING 5"	1	EA	
0003	41142-3	SPACER RING 4"	1	EA	
0004	93111	Pin Coiled 2.5mm x 20mm LG - SPIROL MCK	12	EA	

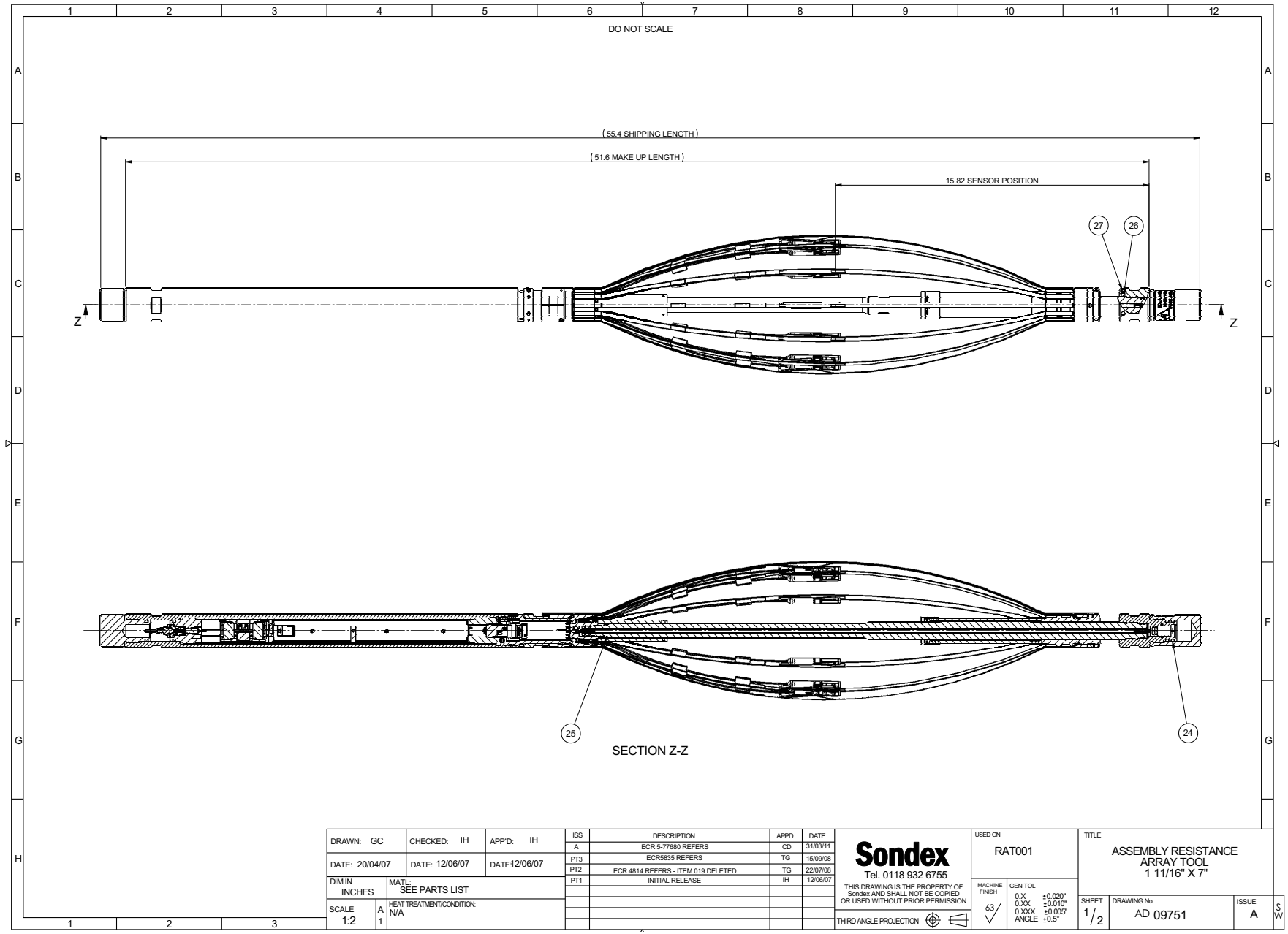
APPENDIX B DRAWINGS & PARTS LISTS

B.1 Mechanical Drawings

Description	Drawing	Parts List
RAT001 General Assembly (2-sheets) consists of:	*AD-09751-A*	See Drawing
Electronics Assembly consists of:	*AD-85798-B*	See Drawing
Electronics Bulkhead Assembly	*AD-10537-J*	See Drawing
Relative Bearing Device Assembly	*AD-11517-G*	See Drawing
Sensor Head Assembly	*AD-41113-A*	See Drawing
Single Pin Sensor Assembly	*AD-40330-B*	See Drawing
Lower Connector Assembly	*AD-13273-C*	See Drawing

B.2 Electrical Drawings

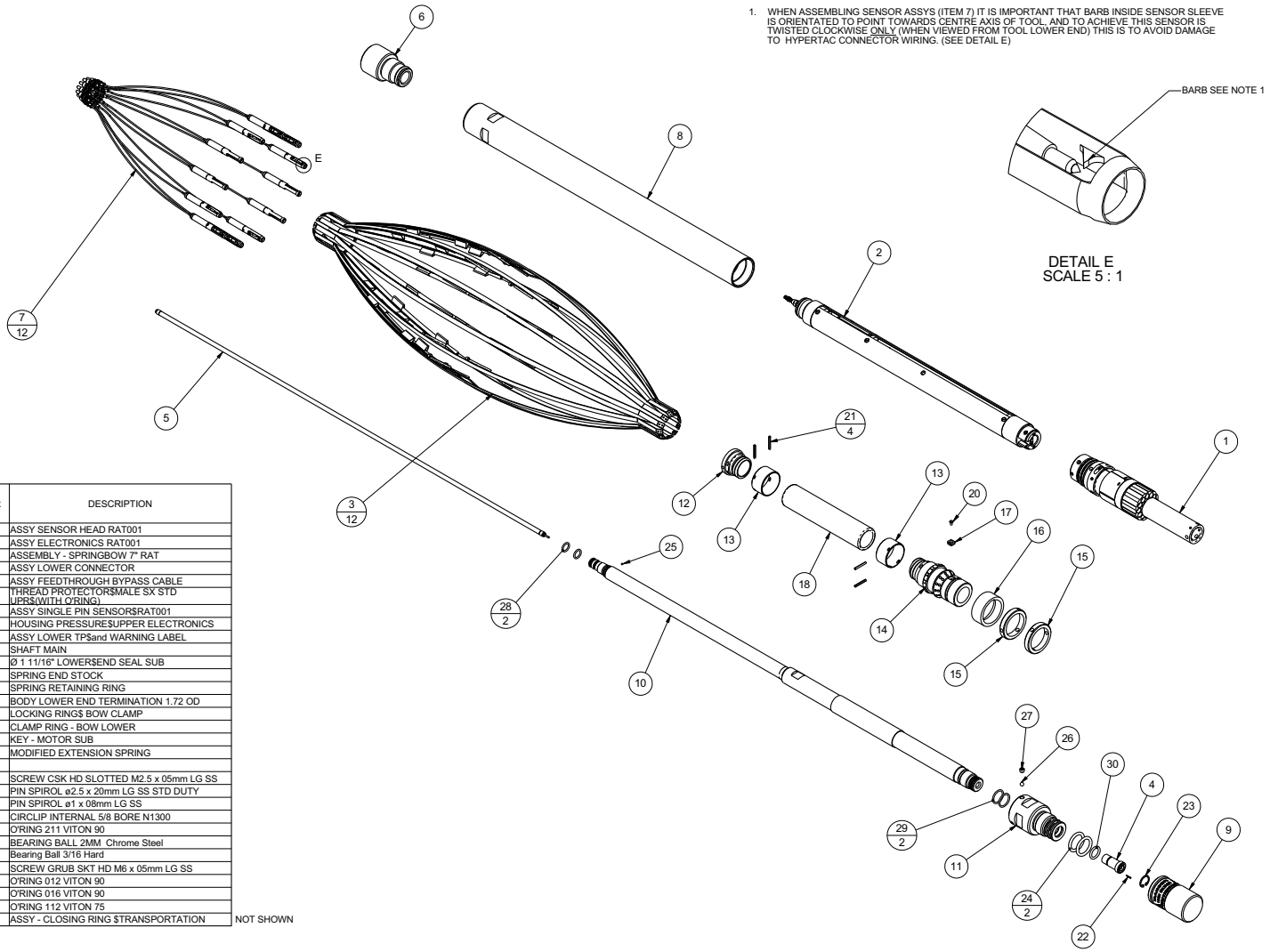
Description	Type	Drawing
Sensor Head Housing	Wiring Diagram	*WD-41113-A*
Electronics Assembly	Wiring Diagram	*WD-85798-C*
PCB Processor Assembly - Programmed (PCB 85992) (5-sheets)	Circuit Diagram	*CD-85988-Ax*
PSU/Telemetry Assembly - Programmed (PCB 85993) (2-sheets)	Circuit Diagram	*CD-82333-Kx*



DO NOT SCALE

NOTES

1. WHEN ASSEMBLING SENSOR ASSYS (ITEM 7) IT IS IMPORTANT THAT BARB INSIDE SENSOR SLEEVE IS ORIENTATED TO POINT TOWARDS CENTRE AXIS OF TOOL, AND TO ACHIEVE THIS SENSOR IS TWISTED CLOCKWISE ONLY (WHEN VIEWED FROM TOOL LOWER END) THIS IS TO AVOID DAMAGE TO HYPERTAC CONNECTOR WIRING. (SEE DETAIL E)



ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
1	1	41113	ASSY SENSOR HEAD RAT001
2	1	85798	ASSY ELECTRONICS RAT001
3	12	40540	ASSEMBLY - SPRINGBOW 7" RAT
4	1	13273	ASSY LOWER CONNECTOR
5	1	15244	ASSY FEEDTHROUGH BYPASS CABLE
6	1	10148	THREAD PROTECTOR$MALE SX STD UPR$(WITH O'RING)
7	12	40330	ASSY SINGLE PIN SENSOR$RAT001
8	1	15210	HOUSING PRESSURE$UPPER ELECTRONICS
9	1	01019	ASSY LOWER TP$and WARNING LABEL
10	1	40271	SHAFT MAIN
11	1	15242	Ø 1 11/16" LOWER$END SEAL SUB
12	1	15336	SPRING END STOCK
13	2	15351	SPRING RETAINING RING
14	1	410254	BODY LOWER END TERMINATION 1.72 OD
15	2	15340	LOCKING RING$ BOW CLAMP
16	1	15339	CLAMP RING - BOW LOWER
17	1	05846	KEY - MOTOR SUB
18	1	15354	MODIFIED EXTENSION SPRING
19			
20	1	93400	SCREW CSK HD SLOTTED M2.5 x 05mm LG SS
21	4	93111	PIN SPIROL ø2.5 x 20mm LG SS STD DUTY
22	1	93019	PIN SPIROL ø1 x 08mm LG SS
23	1	01047	CIRCLIP INTERNAL 5/8 BORE N1300
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 05mm LG SS
28	2	99012	O'RING 012 VITON 90
29	2	99016	O'RING 016 VITON 90
30	1	95112	O'RING 112 VITON 75
35	1	17028	ASSY - CLOSING RING $TRANSPORTATION

NOT SHOWN

DRAWN: GC	CHECKED: IH	APP'D: IH	
DATE: 20/04/07	DATE: 12/06/07	DATE:12/06/07	
DIM IN INCHES	MATL: SEE PARTS LIST		
SCALE 1:2.5	A1	HEAT TREATMENT/CONDITION: N/A	

ISS	DESCRIPTION	APPD	DATE
A	ECR 5-77680 REFERS	CD	31/03/11
PT3	ECR5835 REFERS	TG	15/09/08
PT2	ECR 4814 REFERS - ITEM 019 DELETED	TG	22/07/08
PT1	INITIAL RELEASE	IH	12/06/07

Sondex
Tel. 0118 932 6755

THIRD ANGLE PROJECTION

USED ON: RAT001

MACHINE FINISH: 63

GEN TOL: 0.X ±0.020" 0.XX ±0.010" 0.XXX ±0.005" ANGLE ±0.5°

TITLE: ASSEMBLY RESISTANCE ARRAY TOOL 1 11/16" X 7"

SHEET 2/2 | DRAWING No. AD 09751 | ISSUE A | S W

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
1	1	11517	Assy Relative$Bearing Device
2	1	85992	BOARD ANALOGUE PROGRAMMED RAR
3	1	85993	ASSY PCB PROGRAMMED
4	1	41111	CHASSIS ASSY ELECTRONICS$RAT001
5	1	10537	ASSY ELECTRONICS BULKHEAD SX(ISOLATION) MEM
6	1	20730	BULKHEAD ELECTRONICS$INTERMEDIATE (HALF)$TAPPED
7	1	15240	BULKHEAD LEMO CONNECTOR
8	1	01002	Bulkhead, Intermeadiate
9	1	14021	INSERT 16 WAY LEMO 4$MODIFIED
10	1	40565	TUBE LEMO RETAINER
11	1	93252	PIN SPIROL ø3 x 08mm LG SS
12	16	01029	SCREW CSK HD SLOTTED M3 X 06mm LG SS
13	3	93261	SPACER - M3 THRU$4.75mm OD x 12.7mm LG
14	6	93148	SCREW PAN HD POZI M3 x 06mm LG SS
15	1	40329	BLANK PCB$SLOT FILLER
16	2	93086	SOLDER TAG M4
17	1	93029	WASHER LOCK SERRATED EXTERNAL M4 SS (DIN6798A)
18	1	95211	O'RING 211 VITON 75
19	1	93173	SCREW PAN HD SLOTTED M4 x 08mm LG SS
20	2	93352	SCREW CSK HD SLOTTED M2 x 06mm LG SS
21	3	01082	SCREW GRUB SKT HD M6 x 05mm LG SS
55	70cm	T004-008AP	TAPE TYGAFLOR 208AP/03T 80mm X 30M

DO NOT SCALE

FIT TAPE TO INSIDE OF BOTH CHASSIS HALF SHELLS TRIM AROUND ITEMS 1, 5, 6, 7 & 8.

DETAIL A
SCALE 2 : 1

SECTION Z-Z

DRAWN: GC	CHECKED: GJD	APP'D: DJ	ISS	DESCRIPTION	APPD	DATE	
DATE: 10/05/06	DATE: 10/05/06	DATE: 11/05/06	B	REF ECR5-71390	NPB	06/07/10	
DIM IN INCHES	MATL: SEE PARTS LIST		A	ECR 5437 REFERS	IH	26/11/08	
SCALE 1:1	A 1	HEAT TREATMENT/CONDITION: N/A	PT5	ECR 5415 REFERS - ITEM 5 P/N WAS41110	NPB	03/10/08	
			PT4	ECR 4762 REFERS	NPB	04/09/07	
			PT3	AMENDMENTS ON RELEASE	NPB	22/06/07	
			PT2	ECR 4161 REFERS	NPB	16/04/07	

Sondex
Tel. 0118 932 6755

THIRD ANGLE PROJECTION

USED ON: RAT001

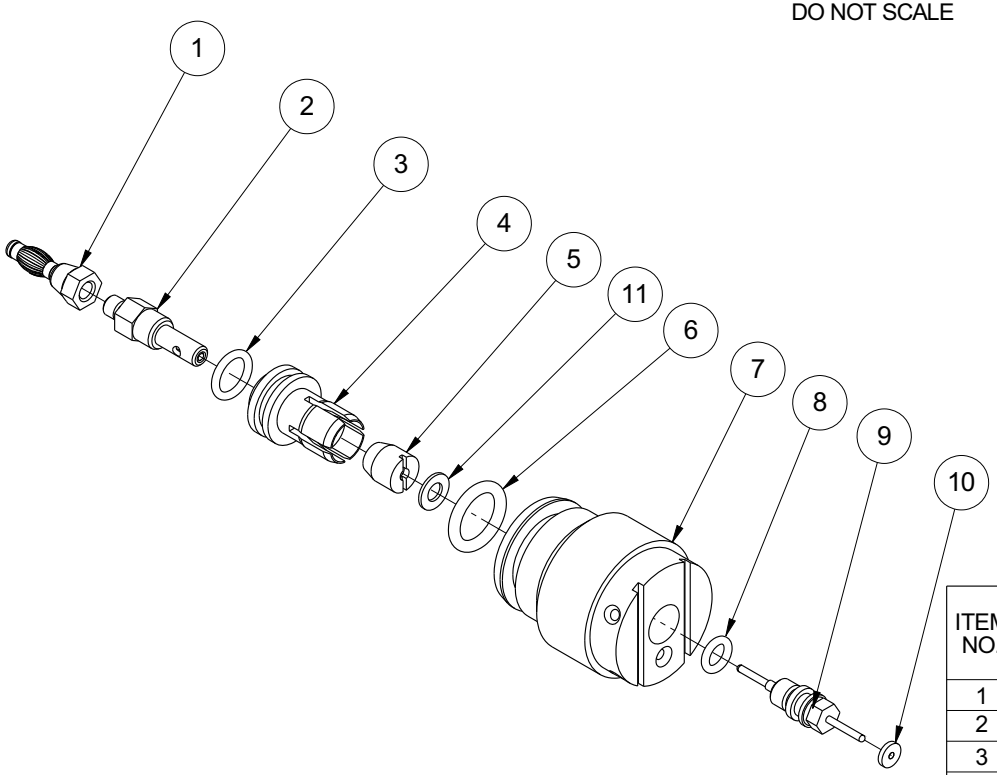
MACHINE FINISH: 63

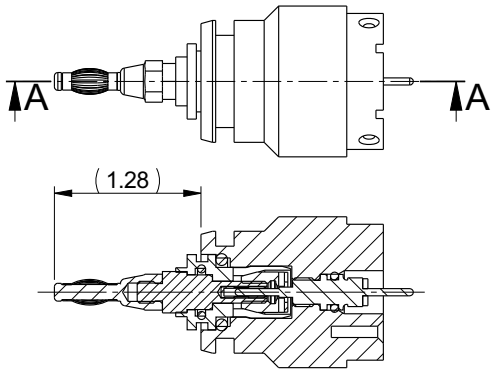
GEN TOL: 0.X ±0.020" 0.XX ±0.010" 0.XXX ±0.005" ANGLE ±0.5°

TITLE: ASSY ELECTRONICS RAT001

SHEET 1/1 | DRAWING No. AD 85798 | ISSUE B | S/W

DO NOT SCALE





SECTION A-A

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
1	1	01028	ASSY BANANA PIN (4mm)
2	1	10035	Assy, Connector, Upper, SX (Isolation Heads)
3	1	95011	O'RING 011 VITON 75
4	1	10032	INSULATOR CLAMP
5	1	10031	NUT LOCKING
6	1	95111	O'RING 111 VITON 75
7	1	01099	Bulkhead, Upper, Mem
8	1	95008	O'RING 008 VITON 75
9	1	92030	Connector Mono Pressure Isolation Pin 0 062 OD x 1 55 SHORT
10	1	10079	Disk, Insulator, Kemlon
11	1	93968	WASHER FIBRE M4

DRAWN: NGH	CHECKED: GC	APP'D:
DATE: 25/11/03	DATE: 01/11/05	DATE: 01/11/05
DIM IN: INCHES	MATL: SEE DETAIL DRAWINGS	
SCALE: 1:1	A3	HEAT TREATMENT/CONDITION: NOT APPLICABLE

ISS	DESCRIPTION	APPD	DATE
J	REF. ECR 5-74879	NPB	17/09/10
H	REF. ECR6031	NPB	07/05/10
G	UN-RESOLVED PART RE-LINKED		17/09/08
F	INITIAL RELEASE		01/10/03

Sondex
Tel. 0118 932 6755

THIRD ANGLE PROJECTION

USED ON: COM

MACHINE FINISH: 63

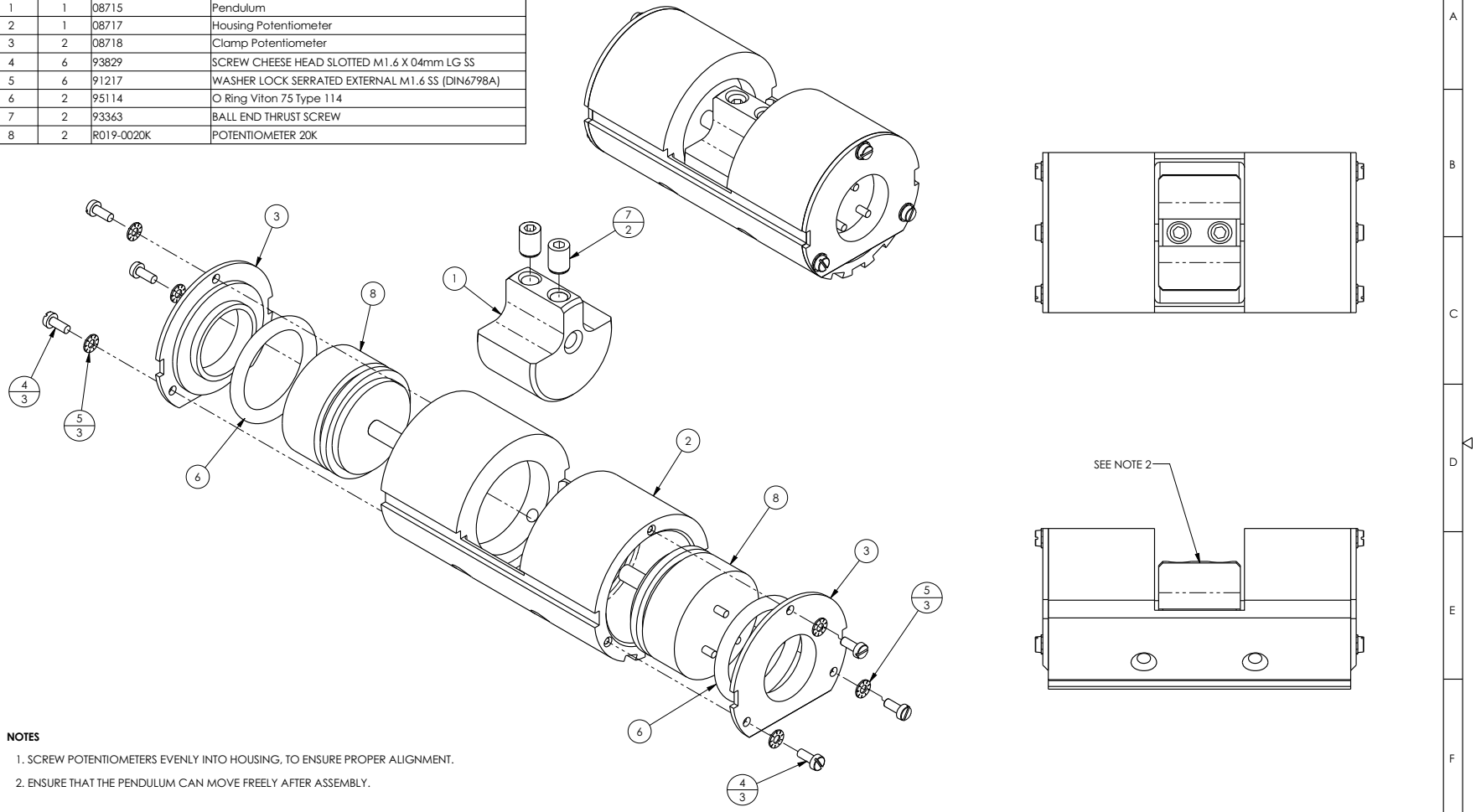
GEN TOL: 0.X 0.020" 0.XX 0.010" 0.XXX 0.005" ANGLE ±0.5°

TITLE: ASSY ELECTRONICS BULKHEAD SX(ISOLATION) MEM

SHEET 1/1 | DRAWING No. AD 10537 | ISSUE J | S W

DO NOT SCALE

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
1	1	08715	Pendulum
2	1	08717	Housing Potentiometer
3	2	08718	Clamp Potentiometer
4	6	93829	SCREW CHEESE HEAD SLOTTED M1.6 X 04mm LG SS
5	6	91217	WASHER LOCK SERRATED EXTERNAL M1.6 SS (DIN6798A)
6	2	95114	O Ring Viton 75 Type 114
7	2	93363	BALL END THRUST SCREW
8	2	R019-0020K	POTENTIOMETER 20K



NOTES

1. SCREW POTENTIOMETERS EVENLY INTO HOUSING, TO ENSURE PROPER ALIGNMENT.
2. ENSURE THAT THE PENDULUM CAN MOVE FREELY AFTER ASSEMBLY.

DRAWN: JC	CHECKED: NGH	APP'D: NGH	
DATE: 07/10/05	DATE: 29/10/04	DATE: 29/10/04	
DIM IN: INCHES	MATL: SEE DETAIL DRAWINGS		
SCALE: 2:1 A2	HEAT TREATMENT/CONDITION: N/A		

ISS	DESCRIPTION	APPD	DATE
H	ECR 5-87278 REFERS	NPB	18/06/12
G	ECR 4593 REFERS-ITEM 9 ADDED	TG	02/05/12
F	ECR 5106 APPLIED	NPB	01/07/08
E	REF ECR 3963	NPB	01/07/08
D	REF ECR 3048	NPB	07/10/05
C	BRING INTO LINE WITH EFACS	PML	29/10/04

Sondex
Tel. 0118 932 6755

THIRD ANGLE PROJECTION

MACHINE FINISH 64 | USED ON COM

GEN TOL
0.X 0.020"
0.XX 0.010"
0.XXX 0.005"
ANGLE ±0.5°

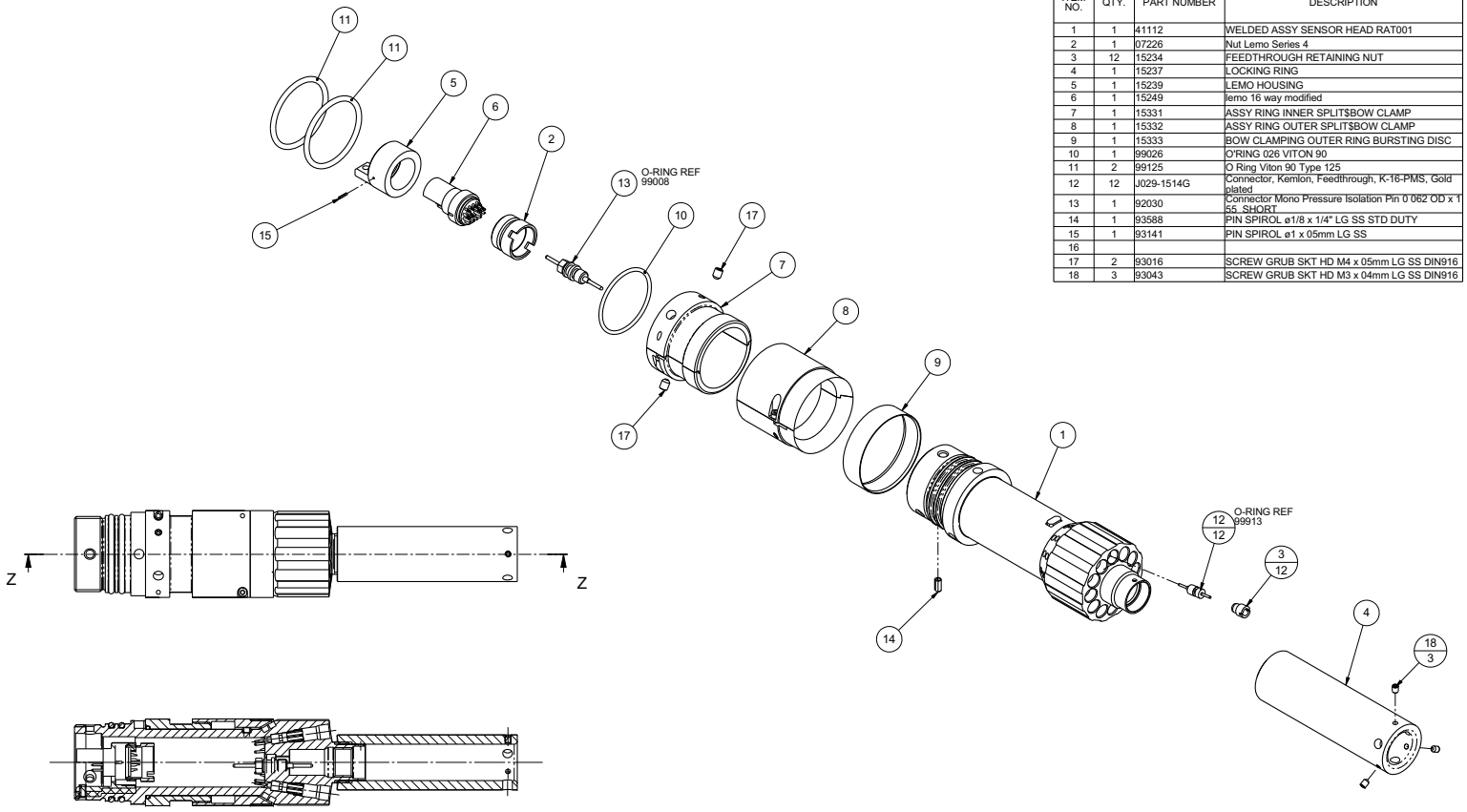
TITLE: ASSY RELATIVE BEARING DEVICE

SHEET 1/1 | DRAWING No. AD 11517 | ISSUE H | S W

SONDEX FM No: F0022

DO NOT SCALE

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
1	1	41112	WELDED ASSY SENSOR HEAD RAT001
2	1	07226	Nut Lemo Series 4
3	12	15234	FEEDTHROUGH RETAINING NUT
4	1	15237	LOCKING RING
5	1	15239	LEMO HOUSING
6	1	15249	lemo 16 way modified
7	1	15331	ASSY RING INNER SPLIT$BOW CLAMP
8	1	15332	ASSY RING OUTER SPLIT$BOW CLAMP
9	1	15333	BOW CLAMPING OUTER RING BURSTING DISC
10	1	99026	O'RING 026 VITON 90
11	2	99125	O Ring Viton 90 Type 125
12	12	J029-1514G	Connector, Kemlon, Feedthrough, K-16-PMS, Gold plated
13	1	92030	Connector Mono Pressure Isolation Pin 0 062 OD x 1 55 SHORT
14	1	93588	PIN SPIROL ø1/8 x 1/4" LG SS STD DUTY
15	1	93141	PIN SPIROL ø1 x 05mm LG SS
16			
17	2	93016	SCREW GRUB SKT HD M4 x 05mm LG SS DIN916
18	3	93043	SCREW GRUB SKT HD M3 x 04mm LG SS DIN916



SECTION Z-Z

NOTE: ASSEMBLY WIRING AND TESTING TO BE CARRIED OUT IN ACCORDANCE WITH SONDEX ASSEMBLY INSTRUCTION AI-41113

DRAWN: GC	CHECKED: IH	APP'D: IH	
DATE: 20/04/07	DATE: 12/06/07	DATE: 12/06/07	
DIM IN INCHES	MATL: SEE PARTS LIST		
SCALE 1:1	A1	HEAT TREATMENT/CONDITION: N/A	

ISS	DESCRIPTION	APPD	DATE
B	ECR 5-90584 REFERS	NPB	05/03/12
A	ECR 5771 REFERS	IH	15/12/08
PT1	INITIAL RELEASE	IH	12/06/07

Sondex
Tel. 0118 932 6755

THIRD ANGLE PROJECTION

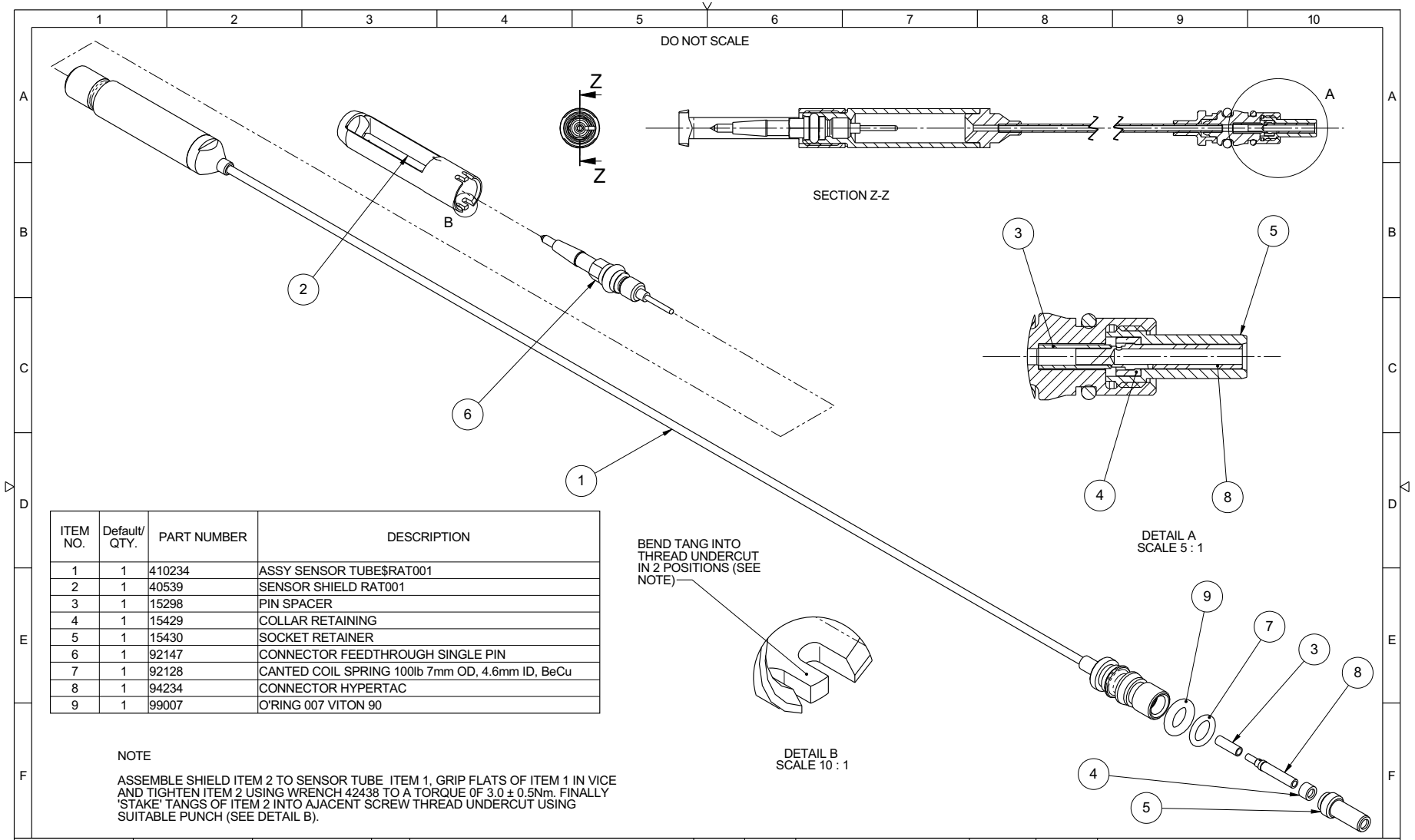
USED ON: RAT

MACHINE FINISH: 63

GEN TOL: 0.X ±0.020" 0.XX ±0.010" 0.XXX ±0.005" ANGLE ±0.5°

TITLE: ASSY SENSOR HEAD RAT001

SHEET	DRAWING No.	ISSUE	
1/1	AD 41113	B	S/W



ITEM NO.	Default/ QTY.	PART NUMBER	DESCRIPTION
1	1	410234	ASSY SENSOR TUBE$RAT001
2	1	40539	SENSOR SHIELD RAT001
3	1	15298	PIN SPACER
4	1	15429	COLLAR RETAINING
5	1	15430	SOCKET RETAINER
6	1	92147	CONNECTOR FEEDTHROUGH SINGLE PIN
7	1	92128	CANTED COIL SPRING 100lb 7mm OD, 4.6mm ID, BeCu
8	1	94234	CONNECTOR HYPERTAC
9	1	99007	O'RING 007 VITON 90

NOTE

ASSEMBLE SHIELD ITEM 2 TO SENSOR TUBE ITEM 1, GRIP FLATS OF ITEM 1 IN VICE AND TIGHTEN ITEM 2 USING WRENCH 42438 TO A TORQUE 0F 3.0 ± 0.5Nm. FINALLY 'STAKE' TANGS OF ITEM 2 INTO AJACENT SCREW THREAD UNDERCUT USING SUITABLE PUNCH (SEE DETAIL B).

DRAWN: GC	CHECKED: GJD	APP'D: DJ
DATE: 10/05/06	DATE: 17/05/06	DATE: 17/05/06
DIM IN: INCHES	MATL: SEE PARTS LIST	
SCALE: 2:1	A2	HEAT TREATMENT/CONDITION: N/A

ISS	DESCRIPTION	APPD	DATE
B	ECR 63376 REFERS	CD	02/02/10
A	ECRS 5429 & 5835 REFER	NPB	15/09/08
PT2	ASSY REDESIGNED	IH	12/06/07
PT1	INITIAL RELEASE	DJ	17/05/06

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Tel. 0118 932 6755

THIRD ANGLE PROJECTION

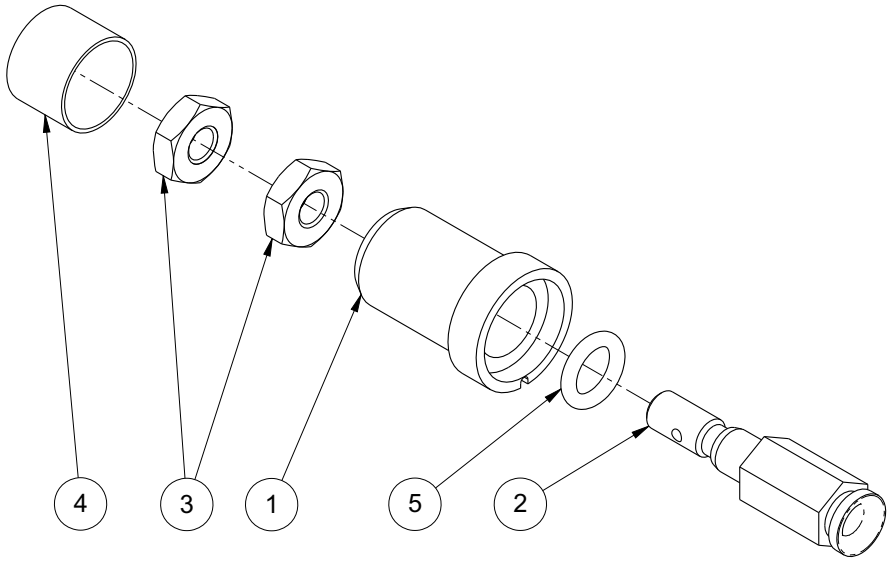
MACHINE FINISH: 64
USED ON: RAT
GEN TOL: 0.X 0.020" 0.XX 0.010" 0.XXX 0.005" ANGLE ±0.5°

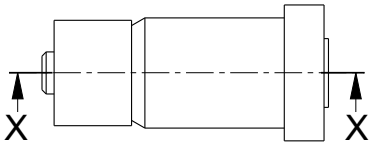
TITLE: ASSY SINGLE PIN SENSOR RAT001

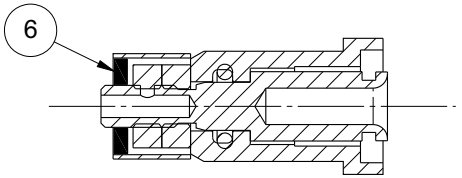
SHEET 1/1 | DRAWING No. AD 40330 | ISSUE B | S W

SONDEX FM No: F0022

DO NOT SCALE







SECTION X-X

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION
1	1	00690	INSULATOR SEALING LOWER$HEAD (STANDARD)
2	1	13278	connector
3	2	93133	NUT HEX 10-32 BNP
4	1	A065-012M7	Heatshrink Sleeving +250C 3.2 to 1 ratio (Raychen - RS)
5	1	95009	O'RING 009 VITON 75
6	A/R	T006-03140	RTV 3140

UNLESS OTHERWISE STATED:
DRAWN TO BS 8888
GENERAL TOLERANCES IN ACCORDANCE WITH ISO 2768-mK
METRIC THREADS TO BE COARSE SERIES H6/g6 FIT
UNDERCUTS TO BS1936
SURFACE TEXTURE TO BE 1.6 µm MAXIMUM INTERNAL RADII 0.5

MARK THE COMPONENT WITH ITS PART No & ISSUE IN / ON THE AREA IDENTIFIED THUS: IF NO SYMBOL IS SHOWN THE COMPONENT DOES NOT REQUIRE MARKING AND SHOULD BE IDENTIFIED BY BAGGING & LABELLING. ALL TO PROCESS SPEC: PS-075
REMOVE ALL BURRS & SHARP EDGES.

THIRD ANGLE PROJECTION
ALL DIMENSIONS IN MM.

USED ON

MASS: Kg

	MODELLED	DRAWN	CHECKED	APPR'D
	GC	GC	GHT	JDR
	31/01/06	31/01/06	04/02/11	16/02/11

MATERIAL

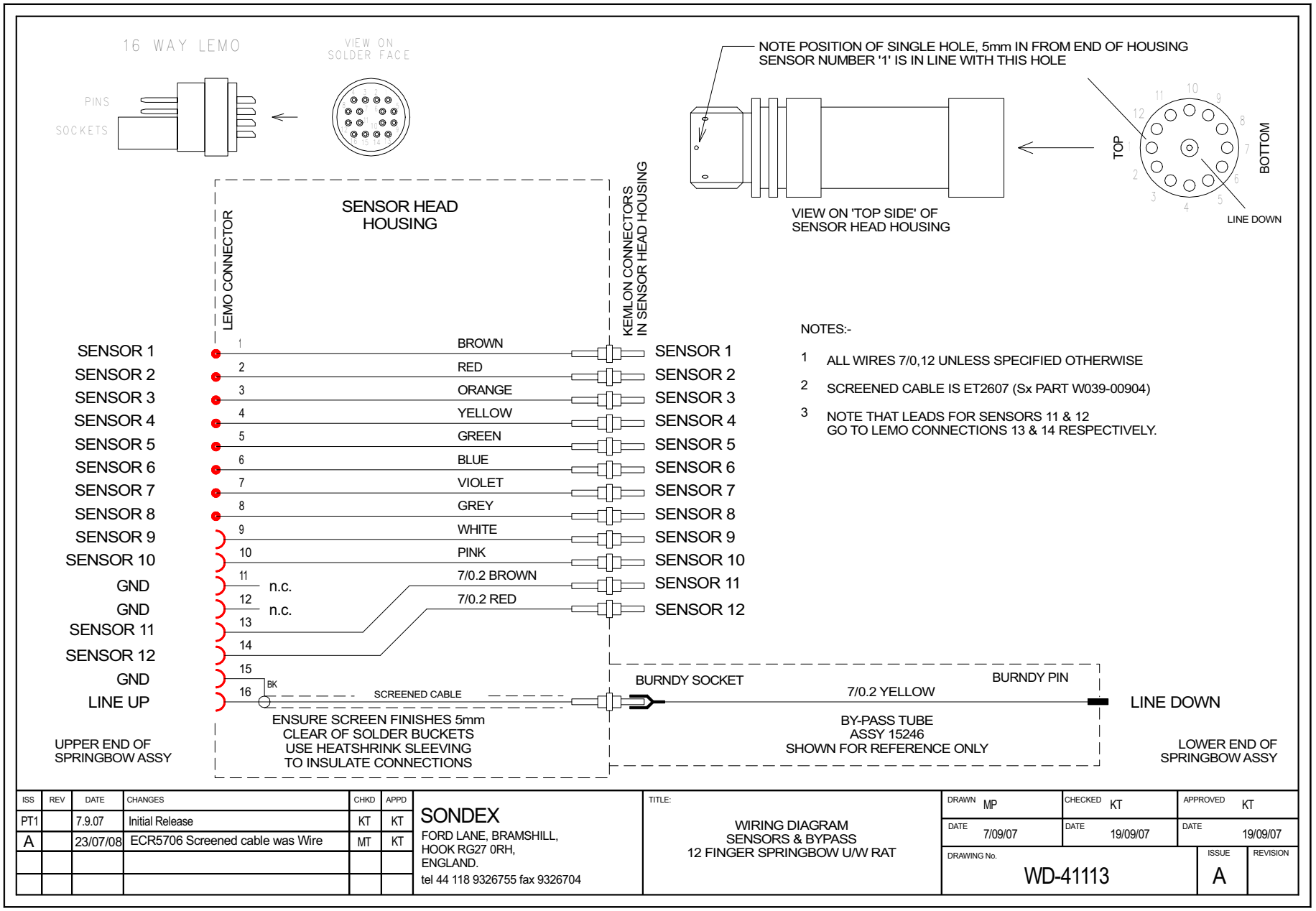
HEAT TREATMENT

ISS	DESCRIPTION	APPR'D	DATE
C			16/02/2011

Sondex

TITLE: ASSY LOWER CONNECTOR

SCALE: 2:1 | DRAWING No.: AD-13273 | ISSUE: C | SHEET: 1 OF 1 | A3



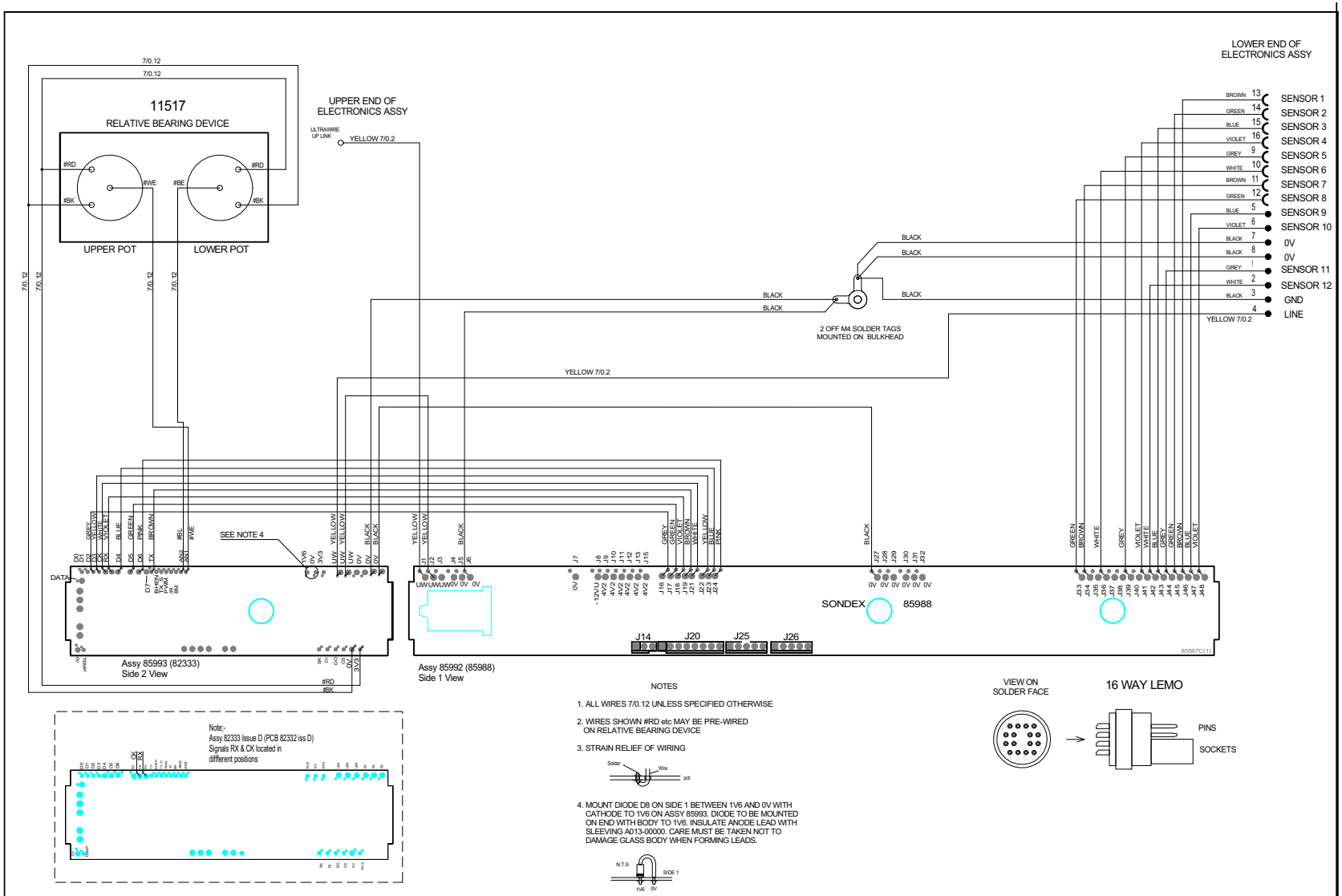
ISS	REV	DATE	CHANGES	CHKD	APPD
PT1		7.9.07	Initial Release	KT	KT
A		23/07/08	ECR5706 Screened cable was Wire	MT	KT

SONDEX
FORD LANE, BRAMSHILL, HOOK RG27 0RH, ENGLAND.
tel 44 118 9326755 fax 9326704

TITLE:
WIRING DIAGRAM
SENSORS & BYPASS
12 FINGER SPRINGBOW U/W RAT

DRAWN	CHECKED	APPROVED
MP	KT	KT
DATE 7/09/07	DATE 19/09/07	DATE 19/09/07

DRAWING No. WD-41113 | ISSUE A | REVISION



ISS	REV	DATE	CHANGES	CHKD	APPD
PT4		27/03/08	ECR5449 11517 wiring correction	MP	KT
A		30/09/08	ECR5415 BZY93C24R diode removed	MT	KT
B		30/09/08	ECR5437 Earth tags x 2 were M3 x 3	MT	MT
C		11/10/10	ECR75831 BZX79C3V9 diode added	MT	MT

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BLACKBUSHE BUSINESS PARK,
YATELY, HANTS. GU46 6AB
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FAX: +44 (0) 1252 862 349

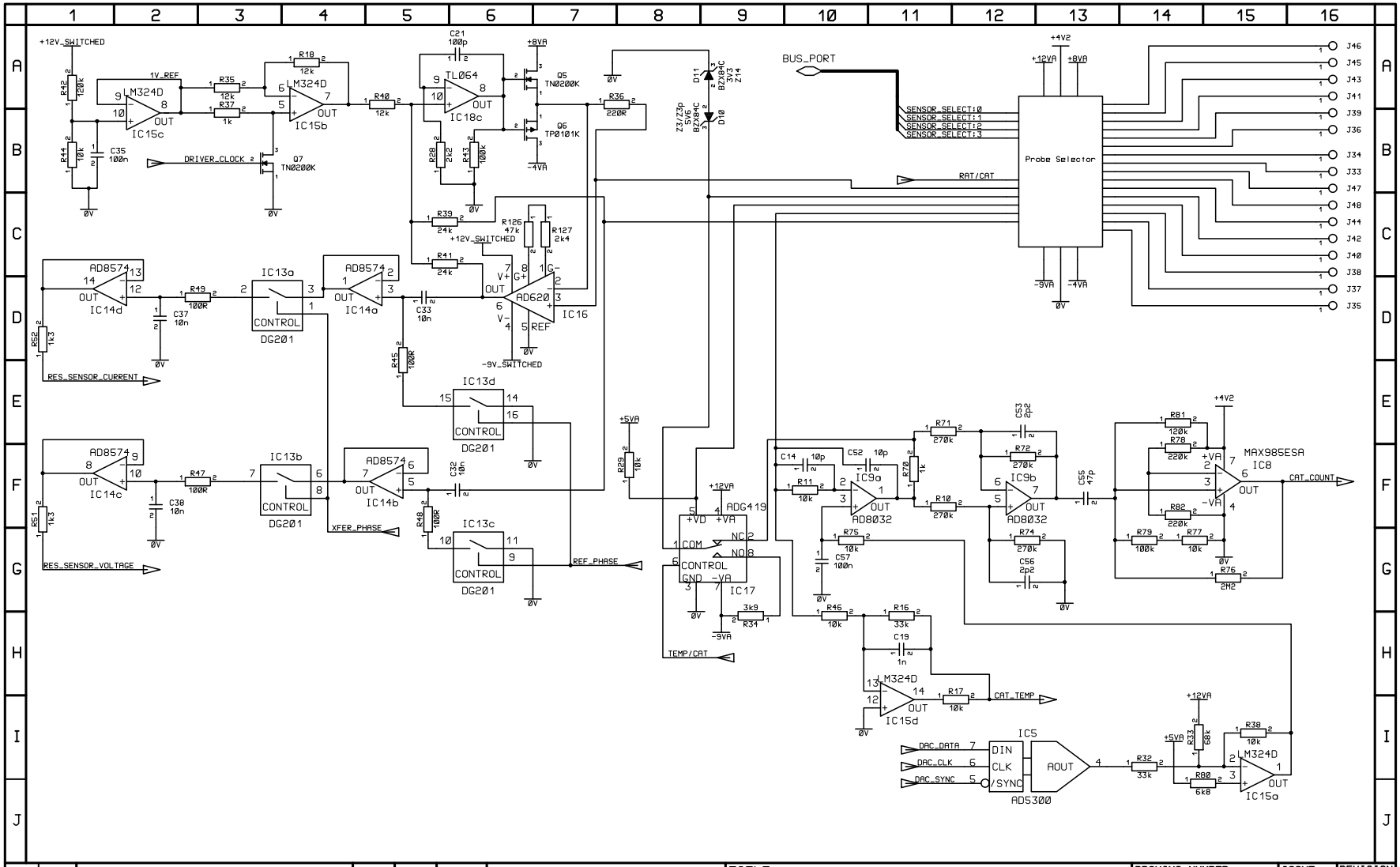
TITLE:
ELECTRONICS
RAT001
WIRING DIAGRAM

DRAWN	CHECKED	APPROVED
MP	KT	KT
DATE 6/9/07	DATE 19/02/08	DATE 19/02/08

DRAWING No. WD-85798

ISSUE C

REVISION



ISS.	REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE
PT2		Changes after Prototype Tests		KT	16/08/06
PT3		After Field Test of Prototype		KT	31/05/07
PT4		ECR5374,5420.5442,5447	KT	KT	28/04/08
PT5		ECR5390 & 5570 New issue D artwork	KT	KT	08/05/08
PT6		ECR5661 Add Q18 & 19, R118 was 330k	KT	KT	06/08/08
A		ECR5735 New Artwork iss E	KT	KT	08/08/08

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RG27 0RH, ENGLAND
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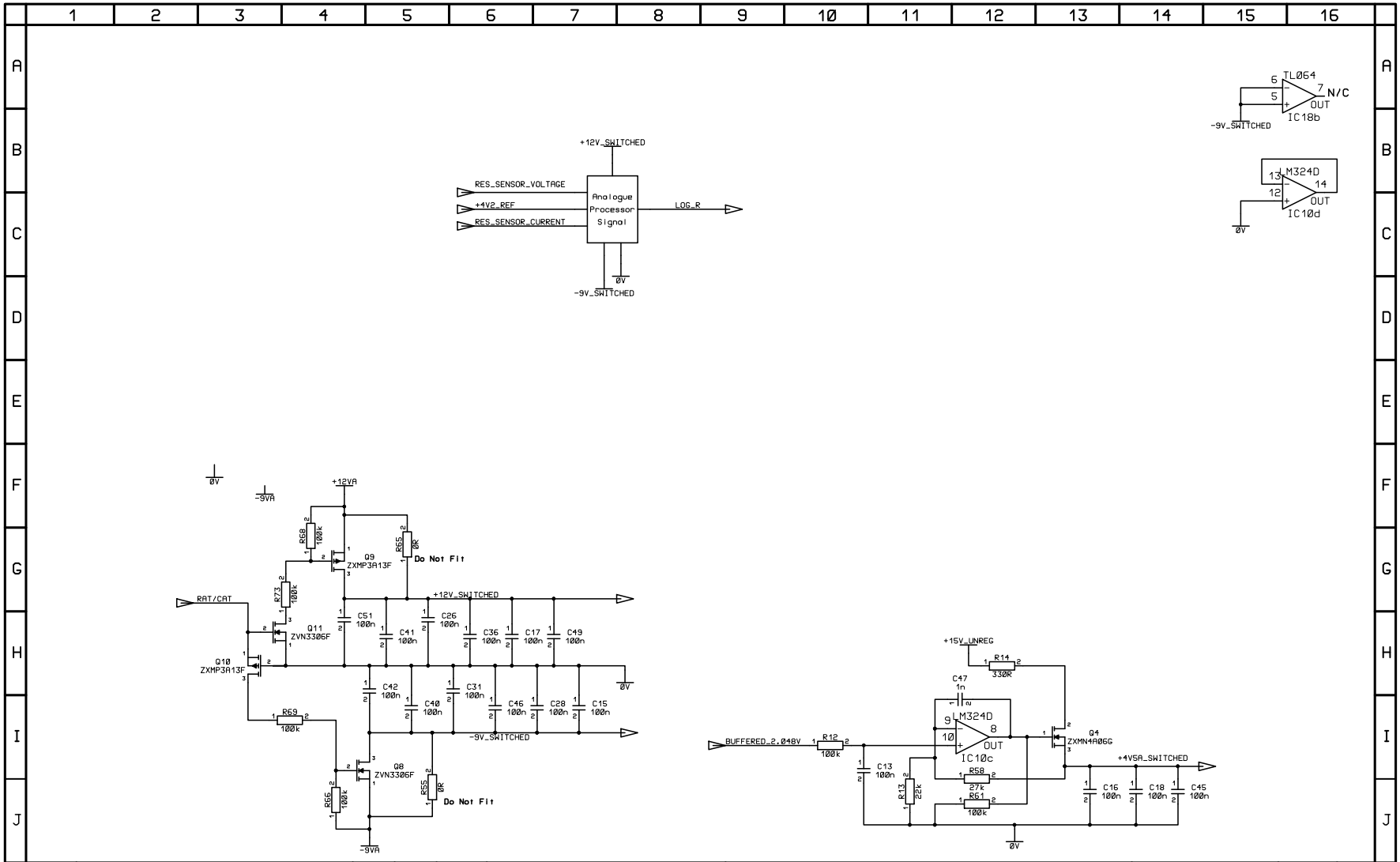
TITLE
Resistance Array Tool
Sensor Analogue
Circuit Diagram

DRAWING NUMBER	ISSUE	REVISION
CD-85988	Ax	

DRAWN	CHECKED	APPROVED
KT	JG	KT
DATE 28/06/06	DATE 28/06/06	DATE 28/06/06

SHEET 1 OF 5



ISS.	REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE
PT2		Changes after Prototype Tests		KT	16/08/06
PT3		After Field Test of Prototype		KT	31/05/07
PT4		ECR5374,5420.5442,5447	KT	KT	28/04/08
PT5		ECR5390 & 5570 New issue D artwork	KT	KT	08/05/08
PT6		ECR5661 Add Q18 & 19, R118 was 330k	KT	KT	06/08/08
A		ECR5735 New Artwork iss E	KT	KT	08/08/08

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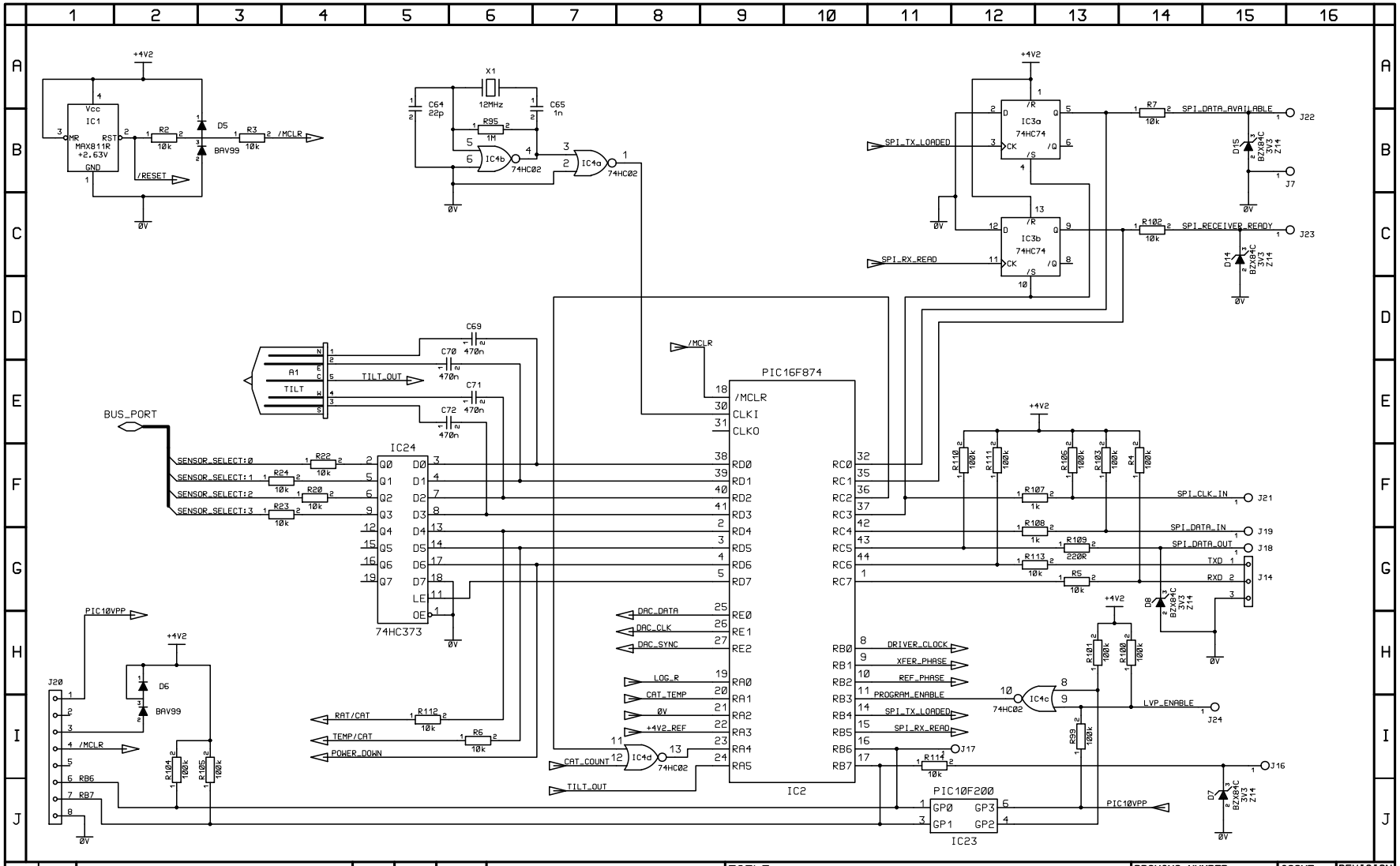
TITLE
Resistance Array Tool
Sensor Analogue
Circuit Diagram

DRAWING NUMBER	ISSUE	REVISION
CD-85988	Ax	

DRAWN	CHECKED	APPROVED
KT	JG	KT
DATE 28/06/06	DATE 28/06/06	DATE 28/06/06

SHEET 2 OF 5



ISS.	REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE
PT2		Changes after Prototype Tests		KT	16/08/06
PT3		After Field Test of Prototype		KT	31/05/07
PT4		ECR5374,5420.5442,5447	KT	KT	28/04/08
PT5		ECR5390 & 5570 New issue D artwork	KT	KT	08/05/08
PT6		ECR5661 Add Q18 & 19, R118 was 330k	KT	KT	06/08/08
A		ECR5735 New Artwork iss E	KT	KT	08/08/08

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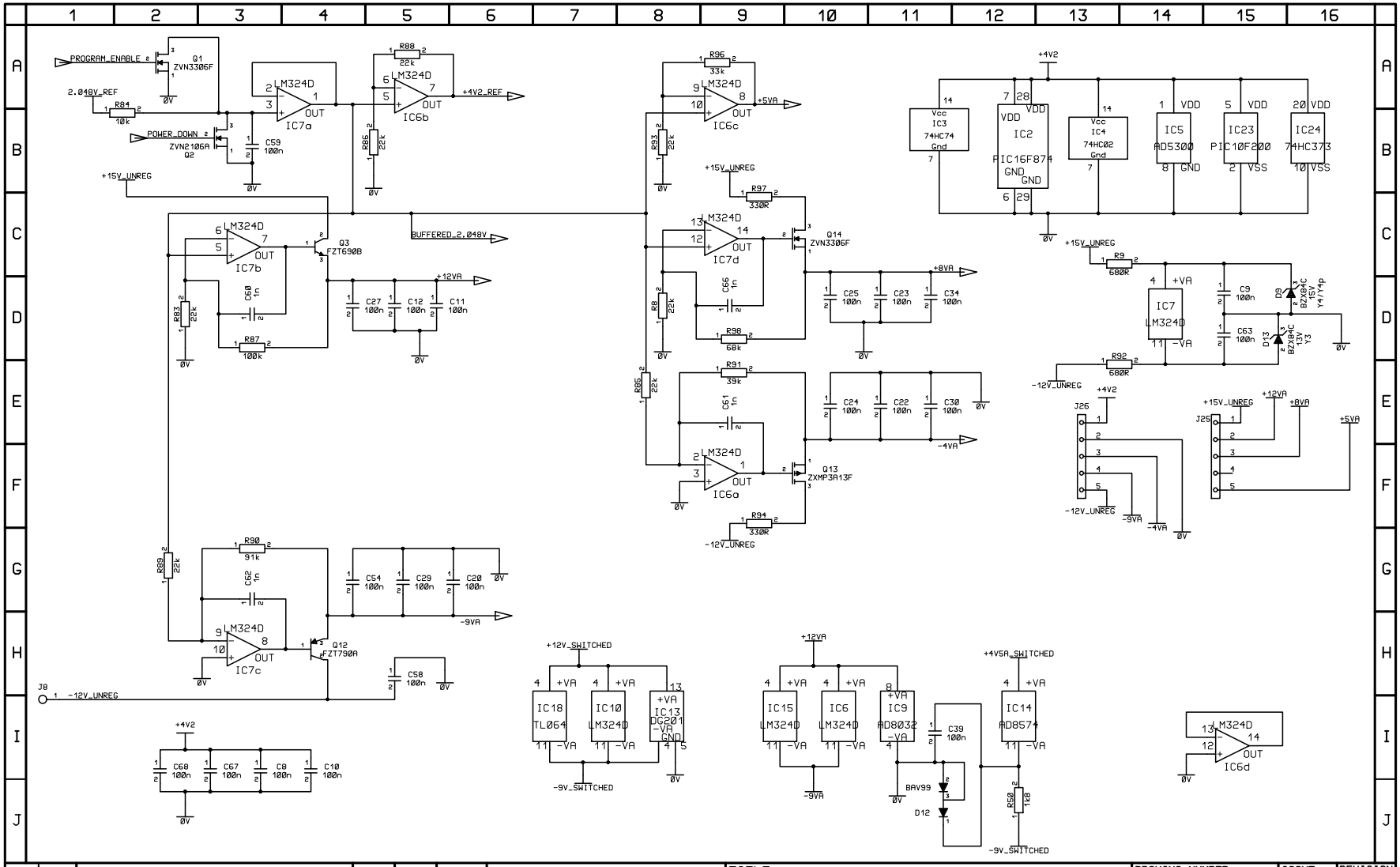
TITLE: Resistance Array Tool Sensor Analogue Circuit Diagram

DRAWING NUMBER	ISSUE	REVISION
CD-85988	Ax	

DRAWN	CHECKED	APPROVED
KT	JG	KT
DATE 28/06/06	DATE 28/06/06	DATE 28/06/06

SHEET 3 OF 5



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PT2		Changes after Prototype Tests		KT	16/08/06
PT3		After Field Test of Prototype		KT	31/05/07
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PT5		ECR5390 & 5570 New issue D artwork	KT	KT	08/05/08
PT6		ECR5661 Add Q18 & 19, R118 was 330k	KT	KT	06/08/08
A		ECR5735 New Artwork iss E	KT	KT	08/08/08

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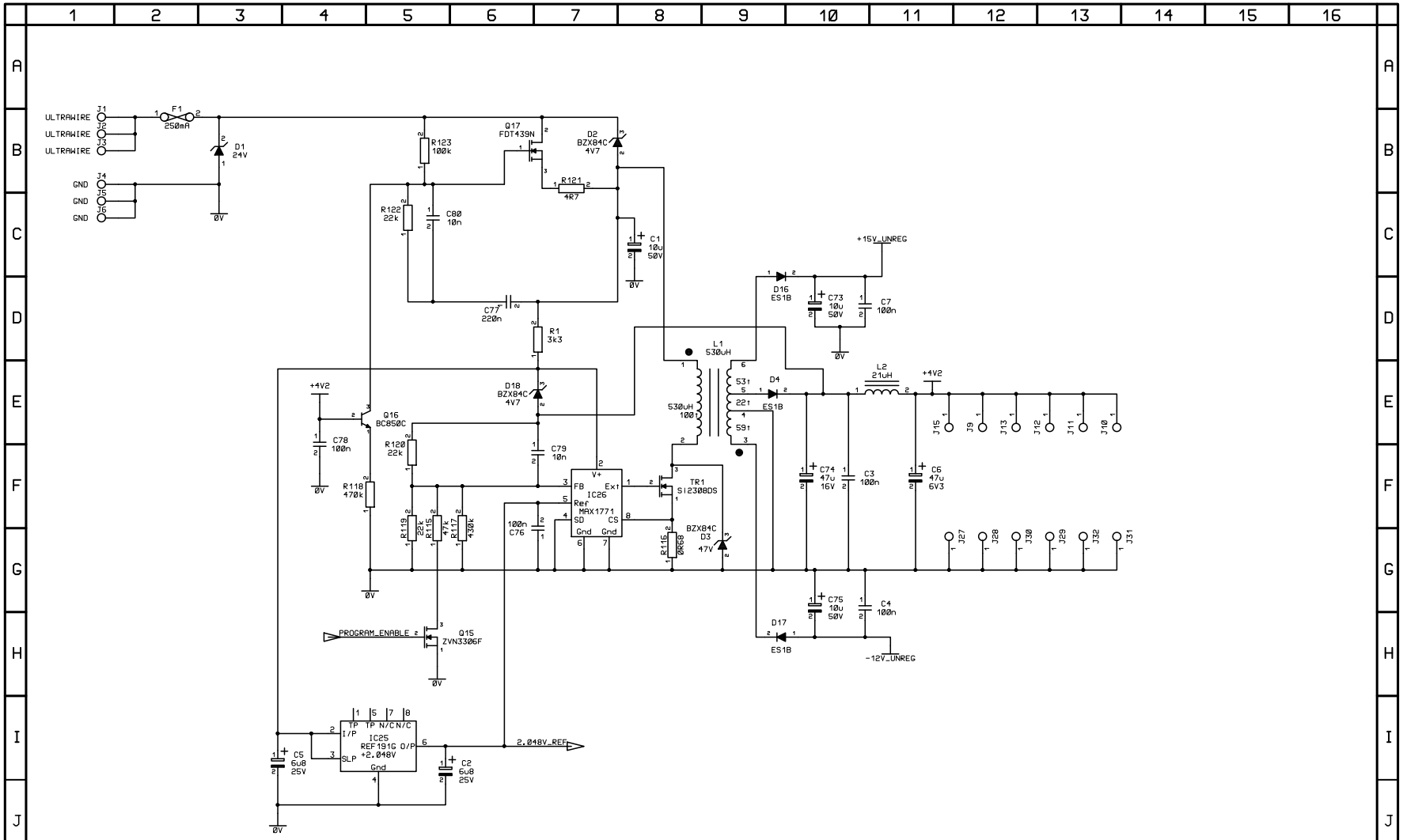
TITLE
Resistance Array Tool
Sensor Analogue
Circuit Diagram

DRAWING NUMBER	ISSUE	REVISION
CD-85988	Ax	

DRAWN	CHECKED	APPROVED
KT	JG	KT
DATE 28/06/06	DATE 28/06/06	DATE 28/06/06

SHEET 4 OF 5



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PT2		Changes after Prototype Tests		KT	16/08/06
PT3		After Field Test of Prototype		KT	31/05/07
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PT5		ECR5390 & 5570 New issue D artwork	KT	KT	08/05/08
PT6		ECR5661 Add Q18 & 19, R118 was 330k	KT	KT	06/08/08
A		ECR5735 New Artwork iss E	KT	KT	08/08/08

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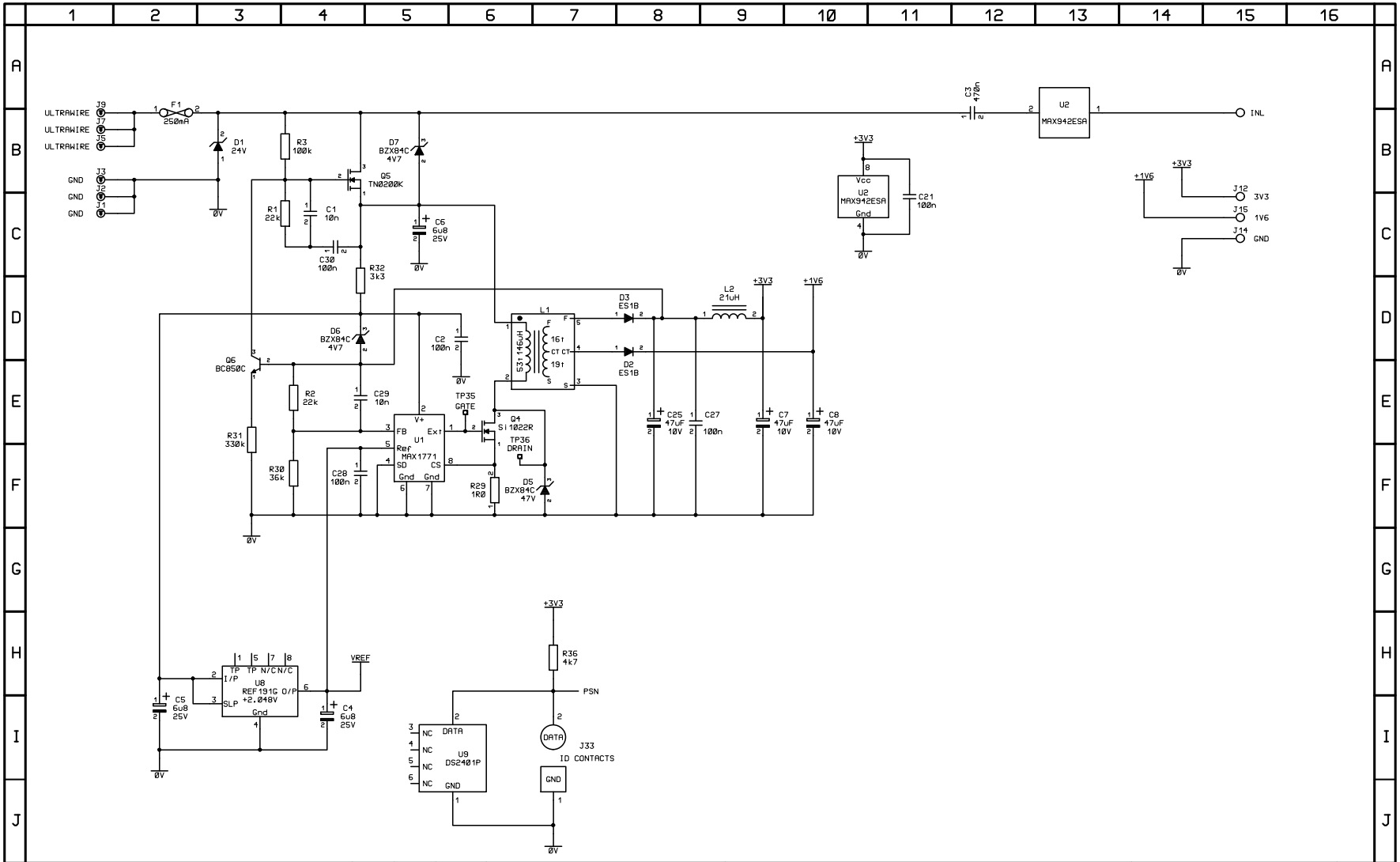
DRAWING NUMBER	ISSUE	REVISION
CD-85988	Ax	

DRAWN	CHECKED	APPROVED
KT	JG	KT
DATE 28/06/06	DATE 28/06/06	DATE 28/06/06

SHEET 5 OF 5



REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE
G	ECR5525 C7,C8,C25 was 47U 6v3	PEJR	PEJR	22/04/08
H	ECR59595 R26 & Q3 was Fitted	PEJR	PEJR	13/05/09
J	ECR60008 Add Mods into Design	PEJR	PEJR	06/08/09
K	ECR73218 D4 change value	PEJR	PEJR	18/8/10
.	.	.	.	.
.	.	.		.

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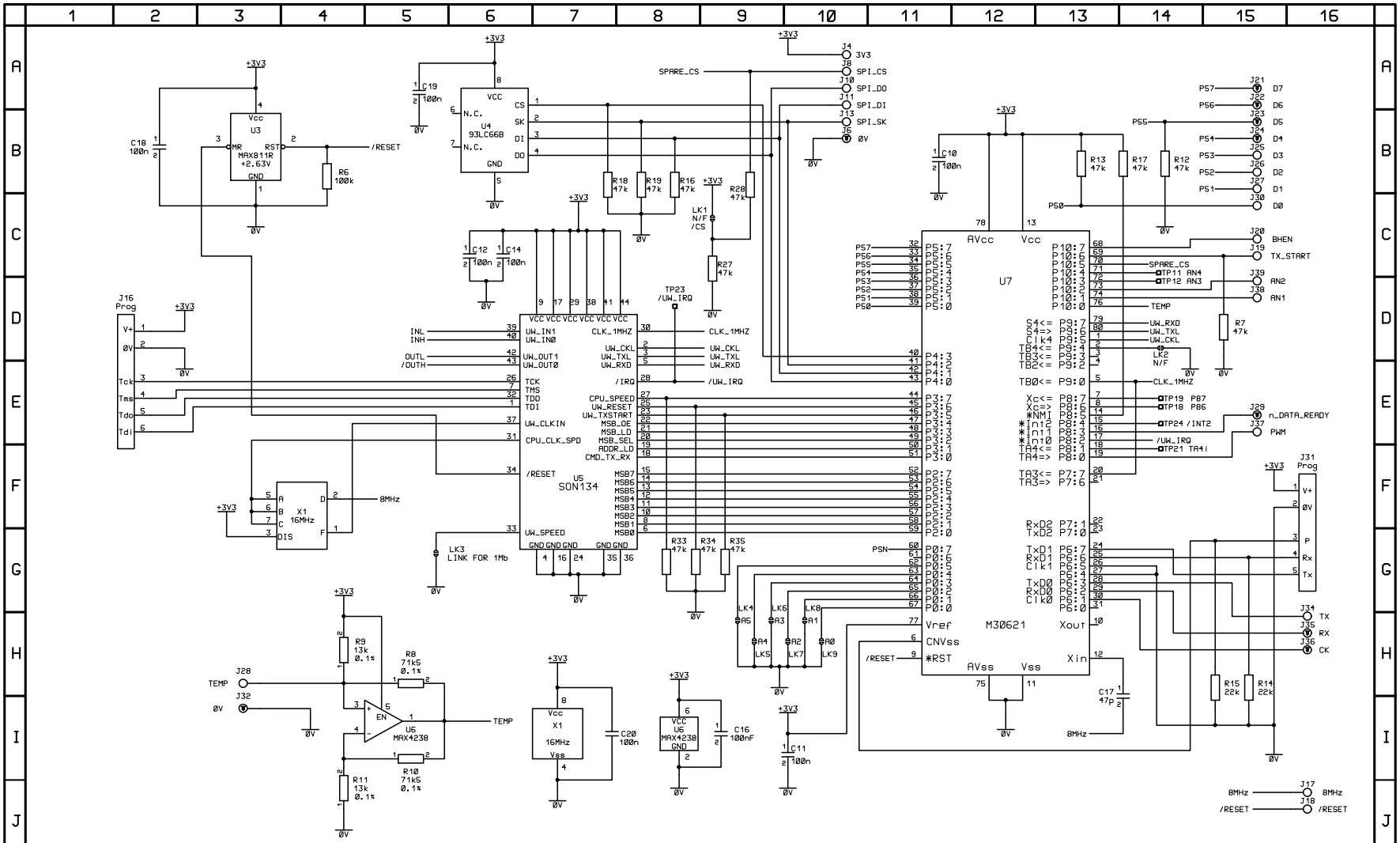
TITLE: Digital Board Circuit Diagram

DRAWING NUMBER: CD-82333
REVISION: Kx

DRAWN	CHECKED	APPROVED
APB	DJ	APB
DATE 10/12/03	DATE 10/03/04	DATE 12/03/04

SHEET 1 OF 2



REV.	ECR NUMBER, REMARKS	CHKD	APPR	DATE
G	ECR5525 C7,C8,C25 was 47U 6v3	PEJR	PEJR	22/04/08
H	ECR59595 R26 & Q3 was Fitted	PEJR	PEJR	13/05/09
J	ECR60008 Add Mods into Design	PEJR	PEJR	06/08/09
K	ECR73218 D4 change value	PEJR	PEJR	18/8/10
.	.	.	.	.
.	.	.	.	.

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TITLE: Digital Board Circuit Diagram

DRAWING NUMBER	REVISION
CD-82333	Kx

DRAWN	CHECKED	APPROVED
APB	DJ	APB
DATE 10/12/03	DATE 10/03/04	DATE 12/03/04

SHEET 2 OF 2

APPENDIX C FITMENT OF THE RESTRICTOR RINGS

Ref.: General Assembly AD-09751
Restricted Opening Kit KITU-MAPS

The Spacer Rings Kit (***KITU-MAPS***) is a set of three restrictor rings to limit the opening of the Springbows on the tool (see ***Figure C.1***):

- The shortest ring (***item 1, KITU-MAPS***) allows the Springbows to open to a 6-inch diameter.
- The medium ring (***item 2, KITU-MAPS***) allows the Springbows to open to a 5-inch diameter.
- The longest ring (***item 3, KITU-MAPS***) allows the Springbows to open to a 4-inch diameter.

Figure C.1 The three sizes of Restrictor Ring

To install one of the three Restrictor Rings beneath the long tension spring at the lower end of the tool, complete these steps:

1 To remove the Lower End Seal Sub (***item 11***) unscrew the three Skt Hd Grub Screws (***item 27***) and release the three Balls Bearings (***item 26***).

See ***Figure C.2***.

2 Unscrew the Lower End Seal Sub from the Main Shaft (***item 10***).

See ***Figure C.2***.

Figure C.2 Lower End Seal Sub removed from the Main Shaft

3 To release the Springbow Assemblies (***item 3***) from the Lower End Termination Body (***item 14***), release the two Bow Clamp Locking Rings (***item 15***) and slide back the Lower Bow Clamp Ring (***item 16***).

See ***Figure C.3***.

Figure C.3 Locking Rings, Clamp Ring and Springbows removed from the Lower End Termination Body

4 Use the Parallel Pin Punch (***item 7, 40886***) to drive out the two Spirol Pins (***item 21***) from the Spring Retaining Ring (***item 13***).

See ***Figure C.4***.

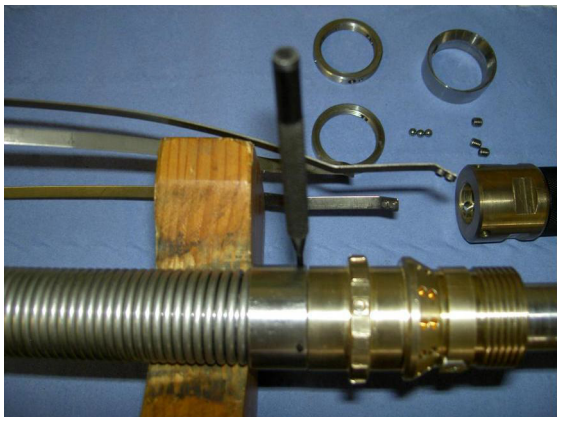

Figure C.4 Removal of the Spirol Pins from the Spring Retaining Ring

5 Unscrew the Lower End Termination Body (***item 14***) from the Extension Spring (***item 18***) (left-hand thread) and remove.

Figure C.5 Lower End Termination Body removed

Figure C.6 The three sizes of Restrictor Rings

6 Slide the required size of Restrictor Ring onto the Main Shaft up to the first shoulder.

The ring will restrict the travel of the Lower End Termination Body and the maximum travel of the Springbow.

See ***Figure C.7***.

Figure C.7 Restrictor Ring installed

7 Replace the Lower End Termination Body and then slide the Extension Spring and the Restrictor Ring over the Main Shaft and screw onto the Lower End Termination Body.

See ***Figure C.8***.

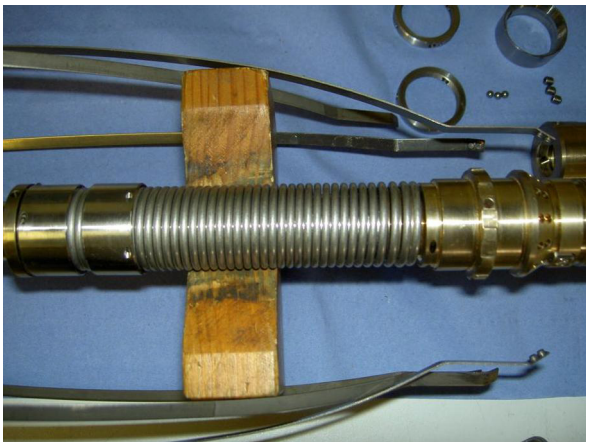

Figure C.8 Extension Spring and the Restrictor Ring installed over the Main Shaft

8 Use two new Spirol Pins (***item 21***) to retain the Spring Retaining Ring (***item 13***)

9 Refit the Springbows onto the Lower End Termination Body and hold in place with the Lower Body Clamp Ring (***item 16***).

10 Hold the Lower End Clamp Ring in position with one of the Bow Clamp Locking Rings (***item 15***) with the additional M3 tapped holes. Then screw on the second Bow Clamp Locking Ring.

See ***Figure C.9***.

Figure C.9 Lower End Clamp Ring held in position by the two Bow Clamp Locking Rings

11 The M3 tapped holes are used as a calibration aid for the rotation Sensors.

Align one of the M3 holes with the axis of Spinner '**No. 1**' before locking the Bow Clamp Locking Rings in their final position. This will allow rotation calibration points to be taken at 90° intervals.

12 Screw the Lower End Seal Sub (***item 11***) onto the end of the Main Shaft (***item 10***).

Make sure the Lower End Seal Sub is tightened fully onto the Main Shaft. Lock in position using three Ball Bearings (***item 26***) and the three Skt Hd Grub Screws (***item 27***).

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Drilling & Production

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http://www.geoilandgas.com/downholetechnology

Customer support: +44 (0)1252 862200

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