Installation, operation and maintenance manual

for

Roxar subsea Pig detector Roxar subsea Sand monitor







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1. PURPOSE

This document provides instructions to ensure that the Roxar subsea Sand monitor or the Roxar subsea Pig detector is properly installed, configured and put into service in accordance with the Roxar guidelines. Installation and functional verification are described step by step. This document also includes check sheets to be filled in and signed by those responsible for the commissioning.

2. ABBREVIATIONS / DEFINITIONS

2.1 Abbreviations

Roxar SSAM	Roxar subsea Sand monitor	Roxar SPDS	Roxar subsea Pig detector
CAN	Controller area network	ANL	Average noise level
ESS	Environmental stress screening	CP	Cathodic protection
FAT	Factory acceptance test	IDS	Instrumental data sheet
PC	Personal computer	ROV	Remotely operated vehicle
SEM	Subsea electronics module	SIIS	Subsea Instrumentation Interface
			Standardisation

2.2 Definitions

Retrievable detector unit Complete detector unit with ROV handle and spring loaded locking mechanism. (The detector can be installed and retrieved by ROV) Non-retrievable detector unit Complete detector with handle and spring loaded locking mechanism. (detector to be installed onshore/topside) Funnel Complete funnel assembly with U-bolts and nuts used together with Retrievable detector unit (Funnel to be installed onshore/topside) Tube fixture Complete tube fixture assembly with U-bolts and nuts. Used together with Non-retrievable detector unit. (Fixture to be installed onshore/topside). Common description for both Funnel and Tube fixture assembly Clamp assembly MKII fitting adapter Adapter interfacing a standard Omnitech MKII hose fitting to the detector unit canister top. Harness assembly consisting of connecting cables in an oil filled hose Jumper that is terminated to an MKII fitting adapter at one end (connected to the detector) and a subsea instrumentation connector at the other end (connected to the SEM). (If the detector is equipped with a bulkhead connector instead a harness assembly, the jumper could be a separate subsea cable with mate-able connectors.)





3. REVISION HISTORY

Revision	Issued	Reason for issue	Author	Checker	Checker	Releaser
С	13.03.2007	Update bolt lubrication.	Rune Torma	Gunnar Wedvich		Gunnar Wedvich
D	14.05.2008	Update insulation description ++.	Gunnar Wedvich	Morten I. Andersen		Bengt Eliassen
E	30.09.2009	General update, included CAN bus, included preservation and storage recommendations.	Hugo Barateiro	Morten I. Andersen		Bengt Eliassen
F	16.11.2009	Update section 3.	Hugo Barateiro	Morten I. Andersen		Gunnar Wedvich
G	20.08.2012	Updated into new template. Restructuring document. Adding installation check sheet. Improving installation description. Removed pres. and storage section	Rune Torma	Gunnar Wedvich	Stein Ove Rinde	Rune Torma

4. DOCUMENTATION4.1 Standard documentation and records

	Document name	Туре	Doc. Reference
[1]	Instrument data sheet		Project specific
[2]	General arrangement (GA) drawing – Retrievable detector unit	Drawing	Project specific
[3]	General arrangement (GA) drawing – Non – retrievable detector unit	Drawing	Project specific
[4]	General arrangement (GA) drawing – Funnel assembly	Drawing	Project specific
[5]	General arrangement (GA) drawing – Tube fixture assembly	Drawing	Project specific
[6]	Data exchange document for Modbus	Instruction	ROX00003262
[7]	Data exchange document for CANbus Roxar subsea Sand monitor	Instruction	ROX000092526
[8]	Data exchange document for CANbus Roxar subsea Pig detector	Instruction	ROX000092527

4.2 Location and precautions

Doc. level: 4.

Document Classification: Open.

All records from this process shall be stored in the document system under relevant folder.

4.3 Storage time

The records shall be stored during the products life time or as specified in the clients' contract, a minimum of 20 years is required.

Note: If the client requires notification before records are discarded, this must be stated on the record itself.





5. INTRODUCTION

5.1 Description on Roxar subsea Sand monitor

The Roxar SSAM system is an acoustic detector that measures sand production in oil, gas or multiphase pipeline flows. It is installed onto the outside of subsea production pipework in a fixed funnel or tube fixture. The detector provides real-time quantitative monitoring of sand in production flow, thus helping the operator to optimise production while limiting erosion of valves, inline process equipment and flow lines. A sketch of the detector and mounting fixture is shown in Figure 1.



Figure 1 – Sketch of a Roxar SSAM installed in a funnel



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5.2 Description of Roxar subsea Pig detector

The Roxar SPDS is a non-intrusive instrument that provides transport systems personnel with accurate real-time detection of passing pigs in oil, gas and multiphase pipeline systems. The detector is spring loaded on to the outside of the pipe.



Figure 2 – Sketch of a Roxar SPDS installed in a funnel

The Roxar SPDS is based on the detection and interpretation of ultrasonic noise generated by pigs scraping along the inside pipe wall while passing the detector. The Roxar SPDS is truly passive, with no moving parts or active emission sources. No modifications to the piping or pig are necessary.

The Roxar SPDS is capable to detect all types of pigs, such as cleaning or sealing.





5.3 Design specifications

5.3.1 Mechanical

5.3.1.1 Detector body

- Material: UNS S31803 (duplex) and A4-80 bolts
- Coating: Xylan 1070
- Retrievable dimensions: OD=128 mm, H= 505 mm (approximately, see [2])
- Non-retrievable dimension: OD=128 mm H= 416 mm (approximately, see [3])
- Depth: 3000 m
- Pipe temperature range: -40°C to +225°C

The detector canister has two primary metal seals, one for the detector front end and one for a glass sealed electrical penetrator closing the rear end of the detector. Each metal seal have supplementary O-rings with support rings for seal back-up. Once the canister body is sealed, it is Helium leakage tested and filled with dry Nitrogen, through the canister test port, before the port is sealed off by means of a steel ball seated by a piston screw with double O-rings.

The detector body is designed to be compact, to eliminate the need for welding and to be directional sensitive to acoustical noise.

Centralizing polymer wedges between the detector and the clamp assembly improve the acoustic isolation between the two parts, shown in Figure 3. The separation prevents alien acoustic noise picked up by the clamp assembly from entering the detector.



Figure 3 – Detector with polymer wedges

5.3.1.2 Clamp assembly

The Roxar SSAM / SPDS are available with two different mounting arrangements. The equipment can be delivered as an ROV retrievable version or a fixed (permanent) installed version. The mode of operation and placement is identical for the two.

Both the funnel and tube fixture installation are permanent and must be completed entirely topside before template deployment.



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Funnel

- Material: UNS S31603 and A4-80
- Dimensions: OD=378mm, H= 402 mm, (approximately, see [4])
- Depth: 3000 m
- Pipe temperature range: -40°C to +225°C

The funnel assembly is installed to the pipe with U-bolts. The funnel is equipped with J-slots for slide in and lock installation of the spring loaded detector by means of a ROV.

The funnel assembly can be separated in two major parts, the funnel and the base plate, where the base plate is the physical adaptation to the pipe. These two parts are joined together without welding, to prevent weld seam corrosion and to reduce costs. The funnel is attached to the base plate with 10 x A4-80 bolts.

Tube fixture

- Material: UNS S31603 and A4-80
- Dimensions: OD=168.3 mm, H= 411 mm, (approximately, see [5])
- Depth: 3000 m
- Pipe temperature range: -40°C to +225°C

The tube fixture is designed for permanent detector installation. The detector is mounted rigidly with two locking screws, positioning the detector with correct spring force against the pipe.

The tube fixture is designed to save space and utilize the same base plate as the funnel. It is made from the same material and uses the same bolts (A4-80) to connect the tube to the base plate.

5.3.2 Electrical

5.3.2.1 Operational features

Note: Features depending on detector model and configuration

- All signal processing /sand calculations executed in the detector, only processed data needs to be sent to the surface
- Two way communication
- Redundant signal processing units
- Can download new software configuration and calibration
- Modbus RTU / RS485 communication line or CANopen SIIS Level 2 communication
- Low bandwidth for data transfer up to SEM (i.e. no large amounts of data transfer required)
- Flexible constant or variable polling intervals allowed
- No software or "black-box" required on surface data straight into SEM or equivalent
- Functional error checking



5.3.2.2 Power interface

24 VDC nominal
± 6 VDC
Current limit: 340 mA/ 8.2 W at internal short circuit
400 mV pk-pk
(240 kHz switching frequency)
Modbus version: <2.16 W continuous
Canbus version: < 4 W continuous
KOSPROT version <1.5 W continuous
Modbus version: 4x nominal, <1 sec
Canbus version: 2x nominal, <1 sec
KOSPROT version: 4x nominal, <1 sec
> 1GΩ

*Check IDS [1] for confirmation. Power consumption can vary depending on redundancy settings.

5.3.2.3 Signal interfaces

Modbus RTU / RS485

• RS485 transceiver ground referenced to DC power source return

Galvanic isolation is NOT normally maintained between the Modbus slave sensor electronics and the field bus.

• Modbus communications protocol implemented

The bus will be run at 9600 or 19200 bits per second. Both bit rates shall be fully supported by the sensors electrical and software interface.

The processing unit represents two Modbus slaves in one unit and the two slaves communicate with an external Modbus master on one common RS485 serial port. This provides full redundancy. Each slave is given its own name and unique slave ID. Hence, each unit can be addressed with either of the two IDs. Up to 16 detector units may share the same RS485 communication line. The 32 Modbus slaves represented by these detectors must all have different names and slave IDs. For configuration and set-up of the detector, a service computer running a Modbus master program will be sufficient.



EMERSON. Process Management

Canbus – CANopen

CANopen higher level protocol on CAN physical layer. CAN bus SIIS Level 2 Available baud rates 50kBit/s (default) and 125kBits/s selectable via LSS. CAN applicable standards:

ISO11898-3 Road vehicles – Controller area network (CAN) – Part 3: Low-speed, fault-tolerant medium dependent interface

According to CIA DS 301 CANopen application layer and communication profile According to CIA DS 305 Layer settings services and protocol (LSS) According to CIA DS 443 SIIS Level 2 device profile

KOSPROT / RS485

- RS485 transceiver ground reference to DC Power Source return
- Galvanic isolation is NOT normally maintained between the sensor electronics and the SCM
- Communication baudrate is 1200 bits per second.
- Single electronics unit
- One way communication
- Sensor identification and raw data output only
- Fixed output update frequency (1/sec)





6. INSTALLATION INSTRUCTIONS

6.1 Detector location

6.1.1 Roxar subsea Sand monitor mounting location

The clamp assembly shall be attached to the pipe prior to installation of the subsea template. The location of the clamp shall be close to and downstream of a 90° bend. The installation shall be positioned such that the detector tip makes contact with the pipe surface just outside of the sand particles impact area at the inside of the pipe wall. This is usually on the larger radius, on the outside of the bend.

In order to achieve the best sensitivity, the detector must be located as close as possible, maximum 750 mm, to a 90° bend as shown in Figure 4.

Installation of the detector should be avoided close to the choke valve, as this valve sometimes produces unwanted noise that may disturb the detector and cause false sand alarms.

Figure 5 and Figure 6 show the Roxar SSAM retrievable version but the same principle applies to the non-retrievable version.



Figure 4 – Installation just downstream of a 90° bend



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The Roxar SSAM can be installed and operated in several orientations in order to achieve the best sensitivity. Figure 5 below shows both acceptable positions which meet the installation requirements described above, and also some challenging potential positions which may be acceptable depending on the well flow conditions. Numbers indicate the preferential placement, 1 being the most preferred. All positions might not be suitable depending flow conditions. Each position is described on the following page to give a better understanding on how the sand monitor position can be optimized to give the best results, and what challenges are related to the different pipe geometries. Priority is based on pipe geometry and instrument rotation on the pipe.



Figure 5 – Orientation positions for a Roxar SSAM



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Position 1 is after vertical downwards flow, on the outside of a 90deg bend. Installation after a vertical segment with downwards flow is preferred, as gravity will help accelerate particles, improving impact energy. Installation might not be practical for retrieval purposes. Position 1 is suitable for wells with all flow conditions.

Position 2 is after horizontal flow, on the outside of a 90deg bend. A long straight pipe section prior to the bend is optimal, as the sand particles will not be exposed to turbulent flow, and will have a concentrated impact in the bend. Position 2 is suitable for wells with all flow conditions.

Position 3 is after horizontal flow, on the outside of a 90deg bend. This position meets all installation requirements and is suitable for wells with all flow conditions

Position 4 is after vertical upwards flow, on the outside of a 90deg bend. Due to the vertical upwards flow prior to the installation area, velocity of the sand particles will be reduced. Position does meet the installation requirements and is suitable for wells with all flow conditions

Position 5 is after horizontal flow, rotated 90deg to the plane of the bend. The detector contact area is rotated from where sand is expected to impact the pipe. This will lead to reduction in functionally in terms of particle detection limit, minimum sand rate and minimum velocity requirement. Position is suitable for medium-high velocity wells, preferably gas flow.

Position 6 is after horizontal flow, rotated 90deg to the plane of the bend. See position 5. Position is suitable for medium-high velocity wells, preferably gas flow.

Position 7 is installed after vertical downwards flow on the inside of a 90deg bend. The detector contact area is on the opposite side to where the sand is expected to impact. See position 5. The pipe geometry in this section increases the probability that sand sediments in the pipe for with low flow velocities. This could potentially reduce the acoustic energy generated by the particles. Position is suitable for medium-high velocity wells, preferably gas flow.

Position 8 is after vertical upwards flow, on the inside of a 90deg bend. See position 5. The venturi in the multiphase flow meter increases the flow velocity, thus theoretically increases the acoustic energy generated by the particles. Position is suitable for high velocity wells, preferably gas flow.

Note: If the position is close to a choke valve, this can in some degree can generate noise within the frequency area of the detector and cause disturbance.

Roxar would like to be involved in the design phase as early as possible give our recommendation on the sand detector position. Roxar's metering advisors will be able to evaluate flow conditions, identifying pipe geometry or other instrumentation that can affect the performance of the instrument in early phase. 3D models in step format can be provided to ensure that there are no physical conflicts in the installation area.





6.1.2 Roxar subsea Pig detector mounting location

The Roxar SPDS can be installed at any suitable location along the pipe.

However, installation should be avoided close to valve actuators, pumps, or other noise sources that may degrade signal-to-noise ratio and potentially produce invalid pig signals.



Figure 6 – Roxar subsea Pig detector installation

6.2 Installation

6.2.1 Preparation

Note! Before starting to install the pipe brackets on the pipe, always ensure that the funnel or tube fixture's footprint on the pipe is free from any insulation, concrete, neoprene, obstacles such as cables or plastic straps. Anything wedged between the detector front and pipe will interfere with proper function.

6.2.1.1 Documentation

Document the installation by taking pictures of the instrument installation area. I.e. pictures showing the clamp assembly installation point showing the surrounding infrastructure. (Pipe geometry, nearby instruments etc.) Also ROV video / pictures from the installation verifying successful locking and pipe contact.



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6.2.1.2 List of special tools / consumables

- Loctite 243
- Torque wrench for M12 nuts

6.2.2 Installation clamp assembly

The funnel is to be installed in accordance with the project specific general arrangement drawing [4]. The tube fixture is to be installed in accordance with [5].

Place the clamp assembly at the pre-described position on the pipe (without detector units installed). The U-bolts may have to be adjusted a bit to fit the pipe. Apply Loctite 243 to the threads of the U-bolts and hand-tighten the nuts. The U-bolt has to exceed the locking nut 20-40 mm. A torque of 43 Nm is to be applied to each nut. The nuts shall be tightened up in a cross pattern manner with a stepwise increase of applied torque.

Note: To increase the sensitivity and performance of the instrument, one can reduce or completely remove the pipe coating in the contact area between detector and pipe (80mm²).



Figure 7 – Retrievable unit in funnel



Figure 8 – Non-retrievable unit in tube fixture







6.2.3 Verification of installation

A topside test installation of the detector should be carried out to ensure that the clamp assembly is properly positioned and mounted. For the retrievable unit, check and verify also the ROV access space, and the force needed to install and retract the detector in the funnel.

Make sure that no CP wires or other material is located near the contact point between the detector and pipe.

6.2.4 Detector mating – Retrievable version

As standard, the detector is equipped with an ROV handle suitable for most standard ROV tools.



Figure 9 – Detector unit - Retrievable version

- Before installing the retrievable detector unit into the funnel, verify that the funnel is free of any fish nets, plastic straps or cables that can interfere with mating and contact area of the detector unit.
- Jet the contact area between the pipe and detector to ensure there are no debris compromising the pipe contact.
- Grab the detector by the ROV handle.
- See Figure 10 colour drawing for key marking. Position the detector above the funnel and rotate the detector handle to approximate alignment with a straight line between the black markings on the funnel top ring.
- Set the ROV grabber in a free position.
- Insert the detector into the funnel in a straight movement. Push the detector inwards using a force of maximum 500 N and let the detector rotate in a clockwise manner into the slot until the markings on the funnel top ring are in line with the ROV handle.
- Verify that the pin for the locking mechanism is in the correct place at the J-slot as shown in Figure 11.
- Verify that the canister front end have physical contact with the pipe
- If applicable, lift the electrical connector from its parking position and connect it to the connector on the detector. Ensure correct position, check [2], [3]







Info: A ROV mating video is available upon request.

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Figure 10 – Funnel with position markings

Figure 11 – Detector in locked position

6.2.5 Detector mating - Non-retrievable version



Figure 12 – Detector unit non-retrievable version

- The mating of the detector unit to the tube fixture is performed topside/onshore.
- Insert the detector in a straight movement. Align the tube fixture handle with the grooves in the tube fixture. Make sure to align the detector in the tube fixture in a way that makes the jumper termination accessible.
- Apply Loctite 243 on the threads of the two DIN912 M8x20 (A4-80) bolts, and install in the tube fixture handle. Torque: max 22 Nm.
- Apply Loctite 243 on the threads of the two DIN912 M10x16 (A4-80) locking bolts, and install on the sides of the tube fixture. Torque: max 33 Nm



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6.2.6 Detector retrieval

Retrievable unit

- Grab the detector by the ROV handle. The ROV grabber must be set in a free position.
- Push the detector downwards using a force of max 500 N. Let the detector rotate in a counterclockwise manner out of the slot. Retract the detector straight out of the funnel in a controlled manner; aim to avoid abrupt and nonlinear movements.

Non-retrievable unit

N/A

6.3 Cathodic protection

The CP surface area exposed to seawater (not including pipe brackets, U-bolts and connector) is:

- Retrievable version 975000 mm2
- Non-retrievable version 844400 mm2

See GA drawing for details.

Note that Roxar does not supply anodes.

6.3.1 Detector unit

The canister is manufactured of Xylan coated duplex steel (UNS S31803), and shall be connected to CP system. This is either accomplished through the connector interface connection or via continuity with clamp assembly which is connected to the installation's CP system.

6.3.2 Clamp assembly

The clamp assembly is manufactured of Xylan coated stainless steel (UNS S31603), and shall be connected to CP system

The clamp assembly are equipped with an M8 threaded hole for electrical termination to the template CP system. The threaded hole is located at a corner on the fixture's base plate (see Figure 13).

Recommended bolt: DIN 912, M8x16, A4-80 (Not supplied by Roxar)





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Figure 13 – Base plate CP termination point

6.4 Installation of clamp assembly on insulated pipe

If the clamp assembly is to be enclosed by insulation materials, make sure that no insulation material blocks the detector contact with the pipe or obstructs free motion of the detector inside the fixture.

Insulation of pipe and clamp assembly must not prevent contact between the detector front and the pipe surface. The locking mechanism may come as close as 4 mm from the pipe surface when the spring is compressed during installation of the detector. A pipe contact area of about 40 mm in diameter should be left free of insulation material. It is recommended that no insulation material touches the detector.



Figure 14 – Insulation between the pipe and the Roxar SSAM / Roxar SPDS

Thermal insulation:

Maximum recommended insulation height above the funnel base plate is 150 mm.

Maximum recommended insulation height above the tube fixture base plate is 94 mm.

Note! Roxar can provide clamp assemblies designed for improved thermal insulation. Please contact Roxar for further information.

Figure 15 shows recommended insulation height for tube fixture (left) and funnel (right). In this case the detector unit is installed after insulation and is necessary to assure free access to the bolt holes or to the J-slot.



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Figure 15 - Insulated tube fixture (left); Insulated funnel (right)

7. OPERATION INSTRUCTIONS

7.1 Topside function testing

Topside function testing of a fixture-mounted detector should ideally be carried out prior to insulation of the pipe and funnel structure.

Hook-up

• Connect the detector in accordance with the pin assignment specified in the instrument data sheet, see [1]. For direct addressing of the registers, see [6],[7],[8], depending on type of detector and model)

Measure and record reference level

- Observe the 'Raw Data' reading displayed in the main window.
- Measure and record the 'Raw Data' base level (in units of [100 nV]) while avoiding acoustic stimulation of the detector. (Avoid mechanical contact with vibrating structures while performing the test).
- Verify that the 'Raw Data' base level is within a range of 1400 [100 nV] to 2000 [100 nV].

Perform function test, record result

- With fixture-mounted detector on pipe: induce acoustic noise in the pipe by rubbing an abrasive pad at a position close to the detector point of contact. (Evidently needs to be done prior to insulation of the pipe and funnel structure). With free detector: induce acoustic noise by rubbing vigorously with dry palm of hand on the detector tip at the front.
- While rubbing to induce acoustic noise, verify a marked increase in 'Raw Data' reading. (Note: dependent on client set-up specifications the output update rate may be as low as 10 seconds. Rub for >10 sec).



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7.2 Subsea function testing

Hook-up

• Power up the unit after connecting the detector jumper hose to the SEM. (Check instrument data sheet, see [1], for details on pin configuration). For direct addressing of the registers, please refer to Data exchange document [6],[7],[8], depending on type of detector and model)

Perform function test(s), record result

- Observe 'Raw Data' values through the SEM. The raw data readings should fall within a range of 1400 [100 nV] to 2e6 [100 nV].
- Verify that there is signal variation within the normal range. (Caused either by flow noise in the subsea piping, or by the pick-up of ROV noise).
- If feasible, induce extra noise by scraping one of the ROV manipulator arms along the pipe, close to the detector clamp. This should give a marked signal response. (With spring-loaded mounting, a good acoustic coupling should indicate successful locking in the clamp receptacle).

7.3 Operation principle and calibration of the Roxar subsea Sand monitor

The operating principle of the Roxar SSAM is based on passive acoustic detection of ultrasonic noise created by sand particles in the process flow. The detector, located downstream of a bend, uses the signals generated when sand particles hit the pipe wall to detect and quantify sand production.

Broadband sand-induced noise will always be superimposed on broadband fluid flow noise and detector self-noise with frequency content in the same range. Passive acoustic sand detection is therefore by nature a relative measurement, where the level of 'background noise' needs to be discriminated and compensated for.

The level of background noise is an increasing function of flow velocity, and is further influenced by flow parameters such as gas-oil-ratio, water cut, temperature, pressure, etc, as well as piping and mounting. For the system to function as intended one is therefore fully dependent on a background noise 'calibration' on site, for each individual detector.





7.3.1 Background noise compensation

Background noise calibration is concerned with finding the 'no sand' reference level of measured noise as a function of fluid flow velocity. In practice it involves the observation of background noise level over a set of discrete flow velocities¹, spanning a representative range, and establishment of a 'best fit' curve (a third order polynomial) to the data. Noise exceeding this 'Background Noise Curve' at any given velocity is interpreted as being induced by sand.

The background noise curve is expressed as:

$$G(v) = A \cdot v^3 + B \cdot v^2 + C \cdot v + D$$

Where: G(v) represents the expected background noise level at the current mixed flow velocity, v, and A through D are polynomial coefficients from the curve fitting.

7.3.2 Sand calibration

The background noise curve defines a 'no sand' reference level as a function of flow rate, and all noise exceeding the reference is interpreted as being 'sand noise'. Sand calibration is to relate the level of sand noise to the actual sand production rate by establishing a corresponding velocity dependent 'Sand Noise Curve'. The curve should represent the expected sand noise level for a reference rate of 1 gram sand per second, assuming a linear relationship between sand rate and noise level². As for background noise the sand noise curve is represented by a third order polynomial:

$$F(v)\Big|_{1g/s} = E \cdot v^3 + F \cdot v^2 + G \cdot v + H_{(2)}$$

The polynomial coefficients *E* through *H* are established by calibration, when possible, or by default. In practice the relationship is normally defined by tuning in a default curve, incorporating input such as sand model calculations, sand trap measurements, or other verification where available.

Note that sand calibration is not required for systems used for sand indication only.

7.3.2.1 Sand model calculations

This method of calibration uses a combination of data from laboratory experience and reference data from other wells in the same or other fields with similar production parameters. Together with site-specific parameters, such data is used to model well conditions and to determine sand calibration coefficients. This method is used when no field reference data is available for the particular well. This will be the case if there is no present production of sand, or if production or test schedules do not permit performing other calibration procedures. If the well starts producing sand at some future point in time, the accuracy of the quantitative measurement can be verified and improved by re-calibrating the system using sand trap measurements or other reference data.

² This is a fair assumption for most applications, although not strictly correct. For subsea wells it will not be a dominating factor in measurement uncertainty.





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¹ In this context flow velocity refers to a 'mixed' velocity found as the sum of fluid volume flow at actual process conditions divided by the cross sectional area of the pipe: Velocity = (Qw + Qo + Qg) / Area [m/s]

7.3.2.2 Sand traps

Sand collected in sand traps can be measured and related to the accumulated sand production recorded by the Roxar SSAM over the same period of time. The reference data is used to tune in the sand calibration coefficients of Equation 2. The measured quantity collected in a trap is however likely to represent only a small proportion of the total sand production during the collection period, and must be scaled accordingly. The method is suitable for sand-producing wells.

7.3.2.3 Production samples and sand filters

As for sand traps, sand found in production samples or filters may be measured to provide reference values for tuning of the Roxar SSAM sand calibration.

7.3.3 Sand rate calculation

Sand rate is found as:

Sand rate =
$$\frac{N - G(v)}{F(v)|_{1g/s}}$$
 [g/s] (3)

N = measured noise level (Raw Data) [100 nV]

V = mixed flow velocity [m/s]

G(v) = expected background noise at mixed flow velocity [100 nV]

 $F(v)|_{1g/s}$ = expected sand noise for 1 g/s sand rate at present velocity [100 nV]

See also equation (1) and (2)

The polynomial coefficients of G(v) and F(v) would normally be found using Service Software and downloaded to detector memory as configuration parameters for the sand calculation algorithm. However, for detector interface options where only raw data is communicated topside, the sand rate algorithm will need to be implemented in the client system.

7.3.4 Detector sensitivity

Sensitivity to particle impact is dominated by two factors:

- Fluid velocity
- Particle mass

As a guide, detection may become uncertain at fluid velocities below 1 m/s and particle diameters below 50 μ m. At very large sand rates the particles may tend to form an acoustic barrier on the pipe wall, limiting the range of maximum detectable sand mass flow. The graph below shows the nominal minimum and maximum sand production rates that can be accurately measured.





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Figure 16 - Sand rate detection limits as a function of mixed flow velocity



Figure 17 – Sand rate detection threshold in gas flow



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7.4 Operating principle and configuration of the Roxar subsea Pig detector

7.4.1 Basic detection principle

When the Roxar SPDS is powered, it will automatically start calculating the current ANL (Average noise level) as the noise floor reference. When a pig is approaching the detector, the noise generated by the pig rises above the ANL. When the noise level exceeds the Li = ANL + Approach Threshold, the processing unit generates a 'Pig Approach' signal. The noise level drops again, after the pig has passed the detector. When the noise level drops below Lo = ANL + Passed Threshold, the processing unit generates a 'Pig Passed' signal. The Approach Threshold and Passed Threshold can be set to suit the typical noise level for any type of pig. An example of a pig noise-level during a passage is shown in Figure 18.



Figure 18 – An example of a Pig passage noise signal

7.4.2 Sensitivity

Pigs generate sufficient noise to allow detection at velocities of approximate 0.05 metre/sec. and upwards. Noise within the ultrasonic frequency band of the sensor will be largely dominated by that induced by passing pigs, and contributions from other external sources are negligible. This minimises the risk for spurious and false readings.

7.4.3 Configuration and set-up

Setting threshold levels

The thresholds Li and Lo are set to suitable levels based on a recorded noise peak signal for the actual pig type. The procedure is simply to record a raw signal while a pig is passing, analyse the amplitude of the peak signal, and type in appropriate numbers for Li and Lo.

Once the pig detector is started up, an average noise level (ANL) will be established automatically, Figure 18. The averaging period and update rate of the ANL is defined by the setting of 'Average Noise



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Level [ANL] Interval'.

Pig approaching is triggered if:Detector signal -Li > 0Pig passed is triggered if:Pig approaching flag is set and Detector signal -Lo < 0

Setting of maximum and minimum approach time

Certain timing criteria need to be fulfilled for a signal to be recognised and accepted as a Pig signal. This is to avoid triggering on 'false' pig signals induced by events that are either 'too short' or 'too long' (e.g. short spikes from mechanical impacts on the pipe, or a sustained increase in background noise caused e.g. by changes in flow parameters or other instrumentation).

- The setting of 'Minimum approach time' is to prevent the system from triggering on short noise peaks.
- The setting of 'Maximum approach time' is to prevent the system from triggering on long lasting changes in the noise level.

If an increase in the noise level is long lasting(> Max. Approach Time) then a new ANL will be calculated and the system will automatically check if the change in noise level was due to a pig passed or not. (If the peak signal amplitude > Li + new ANL level, a 'Pig Passed' signal will be generated.)

Debris indicator

The Roxar SPDS is equipped with a debris indicator.

When a pig has passed, the Debris indicator indicates the amount of debris that has been carries along with the pig. The Debris indicator number is proportional to the integral of the signal above the ANL noise line between 'Pig approach' and 'Pig passed' registrations. The Debris indicator is dimensionless, and can be used for comparison of repeated pig runs. The Debris indication number is placed in a register that can be read by the SEM system

8. MAINTENANCE INSTRUCTIONS

The Roxar SSAM / Roxar SPDS are designed for a maintenance free service after it is properly installed in a subsea environment. Unless the detector connector or jumper cable is damaged by other operational activities in the vicinity of the detector, no need for maintenance is expected subsea.

8.1 Detector retrieval

If the detector is retrieved and brought to the surface for any reasons, the detector and harness should immediately be rinsed with fresh water to prevent fouling and oxidation/ corrosion.

8.2 Re-installation

Before the detector is re-installed in its funnel structure, the funnel and pipe surface should be cleaned by water jetting or by an appropriate cleaning tool prepared for the funnel. Ask Roxar for advice.



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APPENDIX 1 – CHECK SHEET

Date:	Customer representative:	
Roxar SN:	Roxar representative:	
Customer:	Project:	

Installation steps		Verified
6.1 Detector	Roxar have verified that the proposed detector location is acceptable	
location	Verify that the position is in accordance to the requirement in GA drawing [3],[4] including the requirements defined in this procedure	
	Verify that there is room to retrieve and install the detector by hand or with ROV	
6.2.2 Installation clamp assembly	Ensure that there are no cables or plastic straps where the clamp assembly is installed	
	Apply Loctite 243 on the U-bolts	
	Apply a torque of 43 Nm to each not in a cross pattern manner	
	Record distance from the detector to bend (Sand only)mm	
	Record location and distance to choke valve:m Upstream or downstream:	
	Verify that the clamp assembly is free from anything that can interfere with mating the detector, or debris that can compromise the acoustic contact between pipe and detector	
6.2.4 Detector mating –	If subsea installation, jet the clamp assembly, with special attention to the pipe contact area	
Retrievable version	Insert the detector with maximum force of 500 N	
	Verify that the pin for locking mechanism is correctly installed in J-slot	
	Verify that the ROV handle is in-line with the black markings on the funnel top ring	
	Verify that there is physical contact between the detector front-end and pipe	
	Install electrical connector interface	
6.2.5 Detector	Verify that the clamp assembly is free from anything that can interfere with mating the detector, or can compromise the contact between pipe and detector	
mating – Non-	Install the bolt (total 4 off) on handle and locking mechanism	
retrievable version	Verify that there is physical contact between the detector front-end and pipe	
	Install electrical connector interface	
6.3 Cathodic	Install CP strap between CP system and instrument	
protection	Verify continuity between template CP system and instrument	
	Connect instrument in accordance to IDS [1]	
7.1 Topside function testing	Record raw data reading base level:	
_	Record raw data reading when inducing noise:	
7.2 Subsea function	Record raw data reading base level:	
testing	Record raw data reading when inducing noise:	





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Installation steps		Verified
7.3 Operation	Background noise compensation completed within normal operation range	
principle and calibration of the Roxar subsea Sand monitor	Adjusting sand calibration curves	
7.4 Operating	Setting of threshold levels	
principle and	Setting of maximum and minimum approach time	
Roxar subsea Pig detector	Ensure that 'Enable Pig detection' is activated.	

Comments:

Please return a signed copy of the form to Roxar DCC [dcc.svg@emerson.com] and to Roxar Global Service Centre [gsc@roxar.com] for integration to project documentation.



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