Photoacoustic Oil in Water Monitor

Ongoing Development, Marinisation & Field Trials

JIP Proposal

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1 Summary

Kvaerner Oilfield Products (Kvaerner) is pleased to present this proposal for a joint industry project to complete the development of their photoacoustic oil in water monitor (OIWM) through to field trials, marinisation and full commercialisation. The technical workscope will be performed by Kvaerner together with Heriot-Watt University, while JIP administration and management services will be provided by Offshore Technology Management Ltd (OTM). Further information about the contractors is included in Appendix 1.

A reliable, small, in-line OIWM will open up new possibilities in both topsides and subsea processing and be of great benefit to the industry as a whole. This JIP offers the opportunity for operators to be fully involved in shaping the development of this unique technology, being the first to apply and also to enjoy the benefits of preferential commercial terms when the monitor is offered for sale in the market.

The total project cost is estimated to be £800K (GBP), £200K of which will be borne by Kvaerner. The target number of oil company participants is 6. The initial outlay is £42.5K per participant, with further payments dependent upon the satisfactory completion of project milestones outlined in sections 8 and 9. The payments add up to a total contribution per participant of £100K over two and a half years.

Therefore, the leverage on this important project is considerable and budgeting is made simpler by spreading payments across three financial years. In addition, the need to meet well defined milestones as the project continues will minimise risk both to the participants and Kvaerner.

2 JIP Objectives

The main objective of this JIP is to produce a fully qualified, commercial in-line photoacoustic oil in water monitor suitable for monitoring produced water re-injection quality both topsides or subsea. The monitor's suitability for the monitoring of produced water for discharge to sea will also be assessed but will be a secondary target of this JIP.

The technical objectives are as follows:

- Identify and prove a technique for preventing or correcting for fouling of the instrument window - this is seen as an essential requirement of a subsea instrument
- Fully define and test an algorithm to provide a reliable ppm oil concentration read-out
- Undertake monitored topsides field trials and implement modifications resulting from field trial feedback
- Revise and update the OIWM design basis
- Marinise the OIWM, including packaging and system interfaces
- Undertake successful qualification of the OIWM against both environment factors and measurement duty

3 Background

3.1 Technology Need

Re-injection of produced water is an environmentally sound and cost effective way of disposing of produced water and boosting hydrocarbons recovery. However, excessive oil concentration into a re-injection well can reduce the permeability of the reservoir, hinder re-injection and prevent full recovery of the hydrocarbons. There is therefore a requirement to continually monitor re-injection water quality both topsides and subsea. The usual specification for this service is 200-500ppm.

Monitoring of oil in water concentration in produced water re-injection lines has been identified as a key enabling technology for subsea processing systems. At present, the only available means of checking the quality of produced water subsea is through regular sampling - as employed on Norsk

Hydro's Troll Pilot. This is expensive and does not facilitate a quick response to decreasing water quality. An oil in water monitor could be linked into the subsea control system to provide automatic adjustment to ensure water quality remains within specification and to signal an alarm to indicate process upsets.

In addition, it is an aim of the JIP to assess the monitor's capability to provide on-line measurement of discharge water quality. The duty for this is more onerous with a requirement to measure accurately down to <20ppm. Hence, the monitor's performance in this area will not determine the direction of the JIP.

3.2 Summary of Work to Date

Back in 1997 at the beginning of the CoSWaSS (Configurable Subsea Water Separation System) phase 2 JIP, the founding group of operators identified subsea oil in water monitoring as a major technology gap. A comprehensive study was undertaken to identify the best emerging or available technologies which CoSWaSS could support. The photoacoustic monitor scored very highly, particularly when later coupled with Kvaerner's proven subsea track record and commercial strength.

CoSWaSS supported conceptual design, initial laboratory characterisation and the detailed design, build and rigorous testing of a prototype OIWM at the Environmental Resource Technology flow loop in Orkney during the early part of 2000. It is considered that in the comprehensive programme of design, build and testing of this prototype, the majority of potential design issues have been encountered and either addressed or noted for further development work. The test work justified the confidence placed in the technology by the CoSWaSS participants (Amerada Hess, BP, Chevron, ExxonMobil, Norsk Agip, Norsk Hydro, Statoil, Texaco and TotalFinaElf), see section 4.5 for details.

Since then the huge amount of data generated has been analysed and used to profile the OIWM's operating capabilities and define remaining work to be carried out. In addition, with the surplus monies at the end of phase 2, CoSWaSS has funded a small fouling study which is looking at both cleaning mechanisms and a means of adjusting for fouling through the readout algorithm. This study is currently ongoing and the results will be made available to CoSWaSS phase 2 participants.

Concurrently with the CoSWaSS supported programme, a second prototype was built and tested at Norsk Hydro's facilities in Porsgrunn and Bergen. The results from this work yielded supporting data to the conclusions from the ERT data analysis and gave confidence in the capability of the OIWM to operate successfully within a real field development incorporating subsea pumps and valving. A small amount of study work has also been undertaken with the support of Demo 2000 to look at the feasibility of the technology being deployed downhole.

Kvaerner and Heriot-Watt are continuing to undertake assessment of the OIWM outside of the JIP particularly to confirm its response to particular parameters, such as velocity and noise.

3.3 Title

Title to the technology, which is fully patented, rests with Kvaerner Oilfield Products. Much of the early development work was undertaken by Heriot-Watt University, and Kvaerner and Heriot-Watt have since worked hand in hand during all development and testing work. This relationship will continue throughout the proposed JIP.

4 Technology Description

4.1 Summary

The OIWM measures the level of hydrocarbons in water systems using a photoacoustic technique. The technique measures the acoustic response of hydrocarbons to a pulsed laser source input, the level of acoustic response being proportional to concentration of oil in water. The monitor will measure the oil content in the range 200-2000ppm. In the existing prototype unit the electronics are packaged in a rack unit and the instrument head in a flanged mounting. The head contains pressure and temperature sensors to provide on-line data which facilitates ppm algorithms. In the subsea unit the electronics will be packaged with the sensor head in a single pressure vessel.

4.2 The PA Process

A laser fires pulses of light through a sapphire window into the fluid. The optical energy is absorbed causing sudden local heating. The subsequent thermal expansion of molecular bonds in the analyte generate a pressure wave which can be detected with a sensitive acoustic transducer. A photoacoustic transducer (PZT) in the head detects the resulting acoustic response which is termed the PA response. In order to confirm that the energy delivered in the laser pulse is consistent, a beam splitter is used to reflect a small proportion of the light and a photodiode converts this to an electronic pulse, which is termed the energy detection. In real time, the PA and energy detection pulses are indistinguishable from the noise, however after averaging a series of repetitions (around 1500) a recognisable AC pulse is measured.

4.3 General System Operation

The height of the PA response peak indicates the strength of the PA response and therefore how much oil is in the water. There are other factors which affect the PA response such as pressure, temperature and salinity. Separate pressure and temperature transducers are included within the system. To obtain an estimate of the salinity, the time delay from the pulse being fired to the PA response being received is measured. The time delay allows identification of any change in the speed of sound, termed the acoustic velocity and after correction for the process temperature and pressure, estimation of brine salinity is possible. Laser diode drivers of two commercially available wavelengths (currently 905 and 1550Nm) are used sequentially, in order to provide further information on the fluid response.

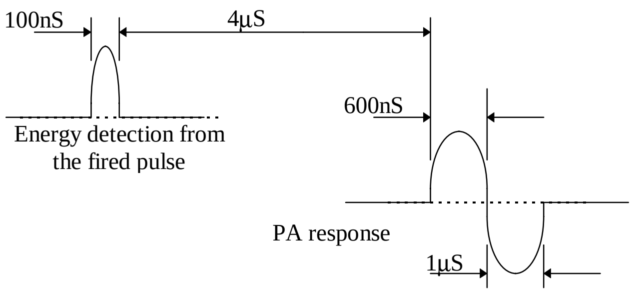


Figure 1 Energy detection and PZT Signals

4.4 The Oil in Water Monitor Prototype

Below is a block diagram of the oil in water monitor:

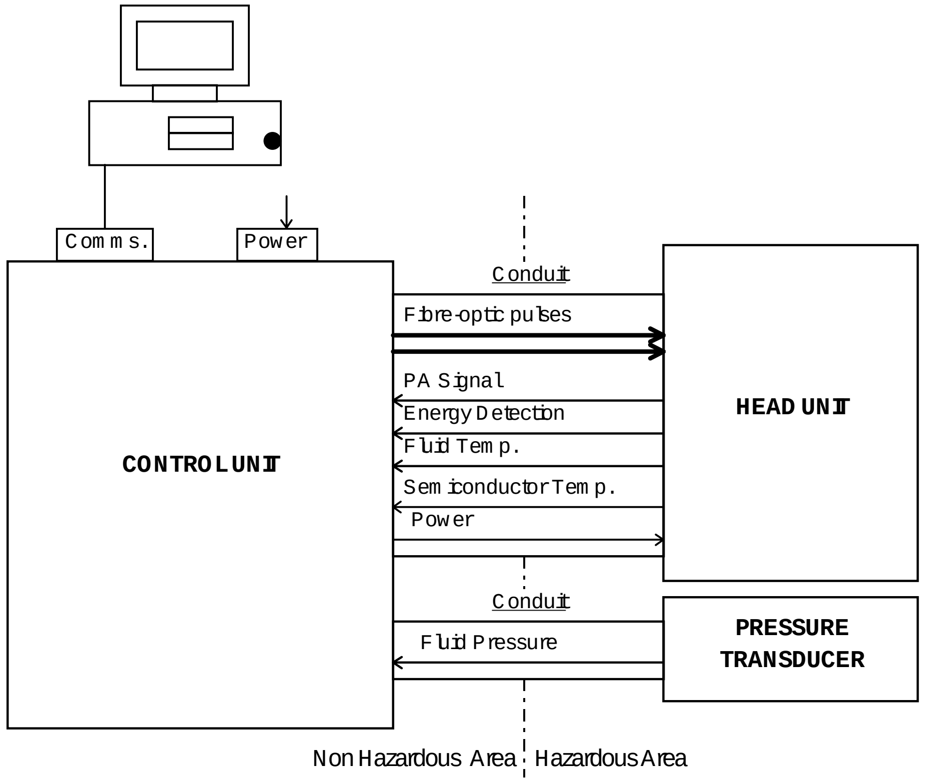


Figure 2 Oil In Water Monitor Block Diagram

The head unit contains the laser delivery optics, piezo-electric acoustic transducer (PZT), pre-amplifier and energy detection circuits and semiconductor pressure and temperature transducer in a flanged duplex mounting rated for working pressure up to 100 bar and process temperatures up to 100°C. The pre-amplifier is required to be located near to the PZT, to reduce signal attenuation and maximise signal to noise ratio. Mounting is by a 3 inch ANSI B31.3 900# flange to a weldolet or tee branch. Installation is recommended to be in a vertically upward flow stream.

Below is a detailed block diagram of the OIWM head unit.

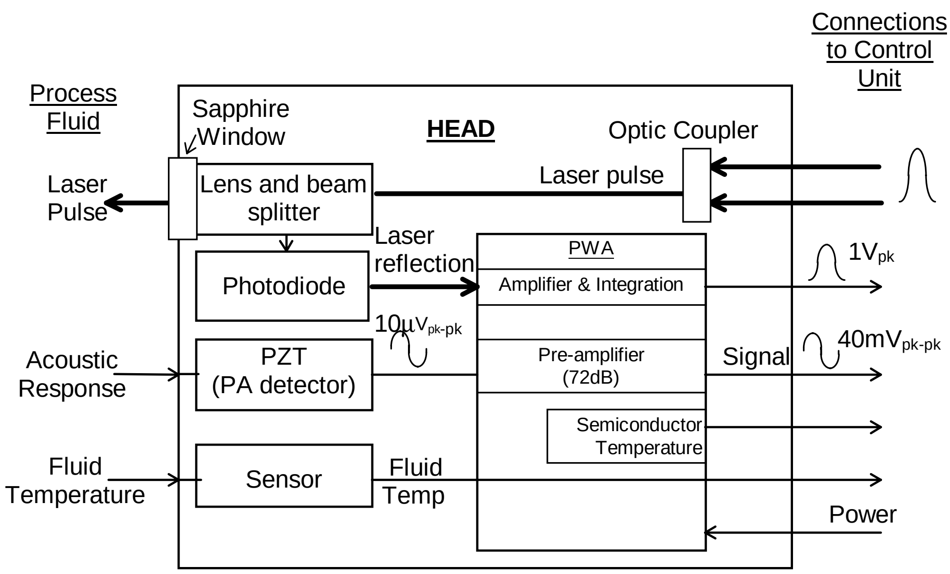


Figure 3 Head Unit Block Diagram

Two lenses focus the light just before the sapphire window into the fluid. A beam splitter between these two lenses reflects a small proportion of the light which is detected by a photodiode and used to monitor the laser diode energy output.

The head unit is linked to the control unit by fibre-optics and signal wiring. These are carried through armoured conduit. The control unit contains the data processing, power supply, communications interfaces and laser drivers for the system. The control unit determines and co-ordinates laser firing and data acquisition, performs data reduction and outputs processed data to the display unit over a serial communication link using Modbus protocol.

Below are photographs of the OIWM:

Figure 4: Photograph of OIWM assembly

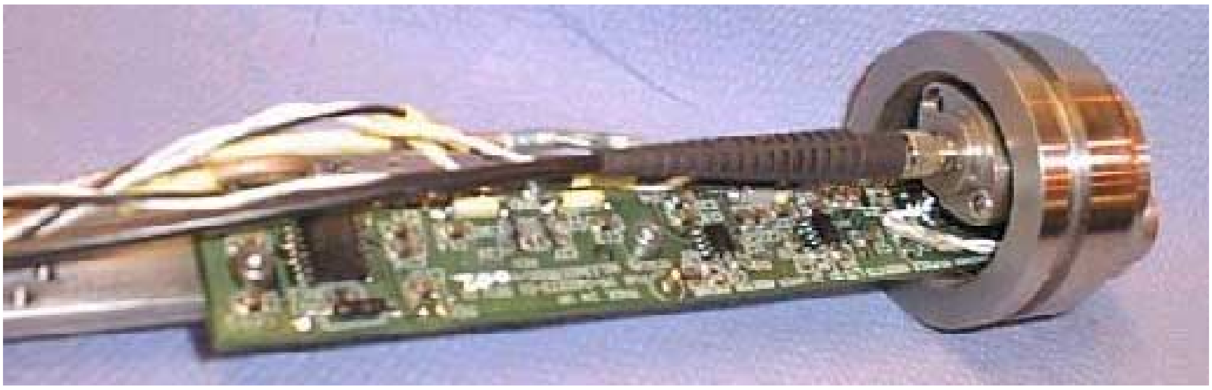


Figure 5: Photograph of sensor head electronics

4.5 ERT Test Results

The OIWM was tested against a range of parameters at ERT as shown in the following test matrix:

Oil concentration (20, 100, 500, 1000, 2000 ppm)	Pressure (5, 10, 20 bar)	Flow rate (1.5, 2.5, 4, 5m/s)
Oil type (Flotta, Foinaven)	Oil droplet size (20, 50, 100 microns)	Solids (25, 100, 300 ppm)
Temperature (15, 30, 45, 90 °C)	Chemical additions (corrosion inhibitor, demulsifier and scale inhibitor)	Fouling (effects of three months build-up studied)
Salinity (0, 33, 66, 99 g/l)	Gas content (0.05, 0.1, 0.2% gas)	Noise (gate valve noise studies)

Table 1: Test matrix used in ERT test programme

The following table provides a summary of the results from the testing:

Response to oil concentration	12 reproducibility runs were made during the test period. The PA signal increases in a linear response between 20 and 1000 ppm and this is unaffected by other process parameters (see Figure 6). The 2000 ppm response fell below the straight line and is due to agglomeration of droplets - in a field installation a shear mixer would be mounted upstream of the OIWM.
Response to temperature variations	As the process temperature increased, the PA response also increased at a given oil concentration. The curves closely matched those achieved under static conditions in the laboratory. The temperature sensor in the head will enable on-line correction of the measured PA response.
Response to salinity variation	The PA response increased with salinity for a given oil concentration. The salinity of the process water was related to the signal time delay under dynamic and static conditions - this enables accurate calibration of the OIWM to account for the effect of salinity on the ppm measurement.
Response to pressure variation	Very small increases in PA response were registered in the 5-20 bar range - initial static tests had indicated a 7% increase in response per 100 bar. The pressure sensor on the head will enable on-line correction of the PA response.
Response to fouling	Fouling was discovered to be the cause of shifting the linear response of the OIWM for an given set of conditions. The presence of fouling and its extent is revealed by a 'pre-peak' in the recorded response. This pre-peak can be used to trigger a cleaning mechanism, the implementation of which is a matter for this JIP. The fouling at ERT was largely corrosion products from the upstream pipe, rather than oil filming.
Reliability	The OIWM was in use for 7 months continuously at ERT. For 3 months the monitor was regularly removed, cleaned and replaced. No failures were recorded during the testing (beyond initial infant mortality of a hard disk).
Response to oilfield chemicals	No quantifiable response.
Response to flow rate	Apparent effects on one oil type were due to fouling. No effect was seen on OIWM performance with second oil type at up to 4m/s, although further testing is required to confirm.
Response to droplet size	No discernible effect at range tested (<100ppm). At 2000ppm, some signal attenuation was caused by agglomeration of droplets.
Response to noise	Installation noise caused by near-closed control valves can prevent correct operation of the OIWM. Normal levels of installation noise have no effect on OIWM operation (OIWM tested alongside Troll subsea pumps with no effect).
Response to solids	Some evidence of reduced response at high solids loading. Further testing and analysis required.
Response to gas	Free gas at concentrations used did not significantly affect the monitor.

Table 2: Summary of test results at ERT

In summary therefore, excellent reliability, accuracy and reproducibility was demonstrated by the monitor during 7 months of independent testing. The data acquired was used to develop a calibration algorithm for the clean head data. The calculated measurements at 1000ppm and below (see table 3) are well within +/- 10% of the averaged measurements from the measurement of samples taken at the flow loop outlet. The 2000ppm calculation was affected by the agglomeration of droplets (see table 2) attenuating the PA signal.

Set-Point	Average OIWM (PPM)	Average IR (PPM)	Error (%)
20	22	22	-0.3
100	115	110	4.4
500	471	499	-5.5
1000	1015	1000	1.4
2000	1607	2068	-22.3

Table 3: Oil concentration prediction by OIWM

5 Proposed Workscope

5.1 Technical

The effort required to achieve the JIP objectives has been grouped into tasks, these are described by section below:

5.1.1 Preparation for Field Trials

Objective: To prepare and qualify the OIWM for safe and reliable use in a field trial

Fouling

During the CoSWaSS trials a coating of corrosion products and salt deposits partially obscured the optical window and promoted oil filming. The coating caused a change in the response of the OIWM to oil concentration during the tests. Two methods of correcting for the presence of fouling were devised, one used signal analysis to correct the OIWM measurements and the other used maintenance intervention to physically clean the window area.

A short study funded by CoSWaSS is currently ongoing which is due for completion end September 2001 which will recommend one or more optimum technologies. Further investigation of the types of fouling likely to occur and methods of prevention or removal will be required to define and implement the best solution(s) for the OIWM. The investigation will identify the most prevalent types of fouling and the strategies which may be used to prevent the fouling, or to remove the fouling from the optical window. Help will be sought from participants in providing data on types and quantities of fouling/ scaling encountered in practice and in accessing existing emerging technologies. Once the most appropriate anti-fouling technology has been identified, it will be implemented in an OIWM for a field trial.

Cost: £33,450

Concentration Algorithm

During the CoSWaSS trials the influence of various parameters, such as temperature, pressure and produced water salinity on the OIWM response were characterised. Resulting from this characterisation a prototype algorithm for predicting the oil concentration in a produced water stream has been derived. The algorithm will be further refined, implemented into the OIWM software and then tested during the field trial.

Cost: £22,430

Field test site

Suitable test sites will be sought from the project sponsors from the start of the project. During this stage in the project the best match to the requirements will be identified. As part of this process the deviations between the OIWM specification and the test site's required standards will be identified, and a work package to carry out any required modifications will be specified. A draft specification for a field trial site is attached as Appendix 2.

Cost: £10,140

OIWM modifications

The specified OIWM modifications, expected to at least require qualification of the OIWM prototype for hazardous area use, will be made during this task. Other required changes, such as the addition of a modem to permit remote access, will be made simultaneously. Once the modifications and qualifications have been achieved, the OIWM will be re-built and characterised in readiness for a field trial.

Cost: £70,138

5.1.2 Field Trial 1

Objective: Determine the effectiveness of the anti-fouling technology and the suitability of the OIWM for field use

The trial will be planned for a six month duration on a topsides produced water re-injection or discharge line. Following installation and commissioning the topsides prototype OIWM will be left to be run by the site operations group, with data analysis and support provided by KOP throughout the trial. A report will detail the performance of the system during the trial and describe any improvements required prior to qualification of the final OIWM design.

Cost: £44,912 – Kvaerner costs

Cost: <£100K – Available to host site for rig modifications

5.1.3 OIWM modifications

Objective: Implement changes which are required as a result of the field trial and concurrent design work; re-build and re-characterise in readiness for a further field trial

It is anticipated that some modifications may be required to improve the OIWM performance in combating fouling and scaling, or in other functional aspects. As it is not possible to define these changes prior to the field trial, the cost of this segment of work is estimated.

Cost: £69,662

5.1.4 Subsea OIWM design

Objective: A specification for the subsea OIWM will be produced, and this will form the basis for the subsea design package.

The design of the OIWM will be largely common between topsides and subsea versions. A basis of design will be formulated for the OIWM and will cover the requirements for topsides, subsea and down-hole versions of the instrument. From this overall basis of design the subsea specification will be produced. The design work for the subsea OIWM is anticipated to fall into three main categories; system and electronics design; software design; and packaging design.

Electronics and system design

As a result of the testing carried out on the CoSWaSS OIWM, some of the current electronics may be redundant. If significant redundancy can be identified there will be benefits to reliability in simplifying the system design. In addition there may be significant benefits to be gained in re-design of some system components for the subsea OIWM to improve reliability and to reduce the size and weight of the packaging required.

Cost: £49,497

Software design

Good software design is critical to the reliability and successful operation of subsea instruments. The software will be split into modules allowing operation of the OIWM in different modes. These modes will allow zero calibration, normal operation and software download so that should software up-grades become available these can be downloaded into the in-situ instrument. The software will be ported onto the KOP standard subsea operating system and will provide an interface compatible with subsea control modules. ***Cost: £50,573***

Subsea packaging design

As part of the marinisation process the OIWM will be packaged into a suitable containment for subsea application. The containment has to fulfil key criteria as defined in the basis of design. The containment will protect the instrument from the external environment, maintain a stable internal environment and ensure that temperature fluctuations, shock and vibration do not adversely affect the integrity of the instrument. The experience which KOP has accumulated over many years of designing, building and deploying subsea electronics will be used to ensure the highest standard of design for the subsea OIWM.

The qualification procedure against which the subsea OIWM will be tested to prove its design will be defined against the basis of design. The subsea OIWM will be tested against the qualification procedure to ensure the integrity of the instrument is adequate for subsea use.

Cost: £110,341

5.1.5 Field Trial 2

Objective: Determine the effectiveness of the modifications to the OIWM following the first field trial. Feed in any design improvements required prior to finalising the design of the subsea OIWM as the trial progresses.

The trial will be similar to the first field trial, planned for a six month duration on a topsides produced water re-injection or discharge line. Following installation and commissioning the OIWM will be left to be run by the site operations group, with data analysis and support provided by KOP throughout the trial. A report will detail the performance of the system during the trial. It is proposed that the unit used will still be the topsides OIWM since subsea design and implementation will not be complete before the start of this trial - although the steering group may determine any changes as the project progresses.

Cost: £38,322

5.1.6 Qualification

Objective: Qualify the subsea OIWM for immunity to environmental factors which may adversely influence its performance and for performance in measurement of oil in water

Environmental qualification

Once equipment is deployed subsea it becomes very time-consuming and expensive to retrieve for repair or modification. Because of this the qualification of equipment is of prime importance. The subsea OIWM will be put through similar qualification tests to other KOP subsea electronics. The tests will cover operation at low and high temperature extremes, thermal cycling, storage at low and high temperature extremes, operation during various vibration modes, shock testing, pressure and hyperbaric testing. The subsea OIWM interfaces to control systems will also be verified and the OIWM will be qualified by testing against relevant EMC directives.

Cost: £67,781

Duty qualification

Following completion of the environmental qualification, the subsea OIWM will be put through a qualification process to ensure that the instrument's capability to measure oil in water concentration has not been diminished by any design changes. The qualification will characterise the OIWM responses to temperature, pressure and produced water salinity and ensure these match with previous versions of the instrument. Following completion of the characterisation the OIWM will be qualified for stability and repeatability. The final qualification test will be a flow test in oily water to define the measurement performance of the subsea OIWM.

Cost: £52,504

5.2 Project Management

The scope of work to be carried out within this activity includes the following:

- Development (in conjunction with Kvaerner and participants) of the final JIP proposal plus assistance with the definition of required tasks
- Development of the participation agreement (liasing with companies' legal departments, issuing final documents for signature, and expediting of signatures)
- Marketing of JIP
- Provision of focal point for enquiries (from participant and non-participant organisations, suppliers, potential suppliers, press, potential new participants etc)
- Maintaining project schedule and expediting own and other tasks to meet budget, deadline and quality targets
- Progress reporting
- Organisation, facilitation and documentation of meetings/ workshops (steering committee or working group meetings every 2-3 months)
- Maintenance of JIP account
- Document control, including
  - maintenance of document register
  - maintenance of participant mailing list
  - distribution of documents
- Administrative support to steering committee chairman and working groups
- Tender management (if required) including:
  - production of invitation to tenders
  - research into tender lists
  - facilitation of tender evaluation
  - liaison with tenderers before and after tender process
  - launch meetings with successful contractors
  - Contract management
- Publicity, including production and distribution of regular press releases (including research of media list), preparation of publicity material as required (eg conference presentations etc)
- Maintenance of JIP archive and audit trails (in order to answer questions on procedure, why certain decisions were made etc)
- Development and maintenance of OIWM website (probably accessed via Kvaerner's own site)
- Other administrative and ad hoc tasks (eg seeking field trial sites etc.)

Cost: £80,250

6 Deliverables

- Tried and tested anti-fouling technique, implemented on the OIWM
- Proven algorithm to provide a ppm readout from the OIWM in a range of environments
- Control system and maintenance interfaces
- Fully qualified and proven instrument for topsides deployment
- Fully marinised, qualified and proven instrument for subsea deployment
- Regular progress reports during JIP
- Final report including
    - Full background information on the OIWM
    - Detailed drawings and layout diagrams
    - OIWM specification and operating envelope
    - Conclusions and lessons learnt from the field trials
    - Deployment examples showing commercial and operational benefits
    - Required utilities and interfaces (including any implications for subsea field design)
    - Reliability analysis
    - Expected commercial costs and lead times
- Other documentary deliverables including minutes and agenda and interim reports
- OIWM website and own password to quickly access documents, view status of the JIP and transfer the technology into the wider organisation

7 Benefits of Participation

- The opportunity to facilitate the development of a unique technology with the potential to:
    - Monitor re-injection water in both topsides and subsea applications
    - Enable more confident application of subsea processing technology
    - Facilitate the choice of complete subsea developments
    - Provide the missing technology to enable the exploitation of remote reserves, satellite pools and smaller, currently uneconomic reservoirs
    - Potentially continually monitor the quality of produced water for discharge direct to the sea
- Participants will be offered monitors on beneficial commercial terms (details to be proposed during the JIP programme - eg number of monitors to which an agreed discount will apply)
- Opportunity to host a field trial with expected immediate benefits to the volunteering business unit
- Gain insight and knowledge of the OIWM, its range of duty and operational benefits
- Be first to apply novel new technology and gain competitive advantage
- Leadership within the JIP:- have the opportunity to determine the direction of the JIP, influence the OIWM final design and development; be confident that the final product truly meets your needs
- Leveraged funds:- collaboration with other operators means you can join the JIP at a greatly discounted rate, while still ensuring your full involvement and influence and a fully developed product

8 JIP Organisation

8.1 JIP Structure

A JIP will be formed with Kvaerner signing participation agreements with each of the participants. The steering committee will comprise one representative from each of the participant companies (more people from participant companies are welcome to attend meetings or be added to the JIP mailing list to aid technology transfer), plus the Kvaerner project manager. A Chairman will be elected at the first proper meeting of the JIP. OTM will be engaged as a sub-contractor to Kvaerner.

Steering committee meetings will be held regularly, usually at 4-6 month intervals. Smaller working groups may meet to discuss specific issues as required (eg a field trial host may wish to have a detailed meeting with Kvaerner). All meetings will be open to all participants. The steering committee will be responsible for providing direction to the JIP by voting on work package options or agreeing amendments to the work programme, approving any further sub-contractors and approving the release of any documentation to third parties.

8.2 Participation costs

The total project cost is £800K, of which Kvaerner will be contributing £200K, the equivalent of 2 'tickets' in the JIP. The remaining funds are sought from 6 oil company participants. A company will become a participant upon signing the participation agreement and paying the initial joining fee (see table below). Invoices for the joining fee will be raised by Kvaerner upon the signing of the agreement by both parties.

Further payments will become payable only on completion of milestones identified in section 9 below. The steering group will determine whether those milestones have been adequately met within the terms and objectives of the JIP. Should these milestones not be met, the steering group can determine whether to continue the JIP under an amended workscope or to terminate the project. If the project continues without a milestone having been met, individual participants have the right to withdraw.

Date	**Milestone identifier**	**Amount (GBP '000s)**
Following signature of agreement by both parties (or 31 January 2002)		£42.5K
31 January 2003	1	£42.5K
31 January 2004	2	£15K
Total payment		£100K

Table 3: Participation fee and milestone payments with 6 participants

Participation is open to operators and those engaged in the supply and manufacture of subsea equipment. Kvaerner has the right to approve or disapprove of any potential participant whose participation in the project might jeopardise Kvaerner's competitive position.

Participants are expected to participate properly in the JIP and to fully co-operate in helping to meet its objectives, for instance through the provision of field trial sites and data regarding fouling experience.

9 Schedule

9.1 Milestones

The table below shows the measures of success for each milestone.

Milestone 1	• Preparation of OIWM for field trial 1:
	  • Resolution of fouling issue either through means of cleaning window or correcting for fouling through algorithm
	  • Refinement of concentration algorithm to acceptable level of accuracy when compared with other analysis technologies and implementation into OIWM software
	  • Successful undertaking of modifications and characterisation necessary to prepare OIWM for specific field trial site
	• Successful field trial 1:
	  • Provision of reliable concentration data on a platform or an onshore field for up to 6 months
	• Successful start to modifications to OIWM design to be undertaken concurrently with field trial as a result of learnings from the field trial

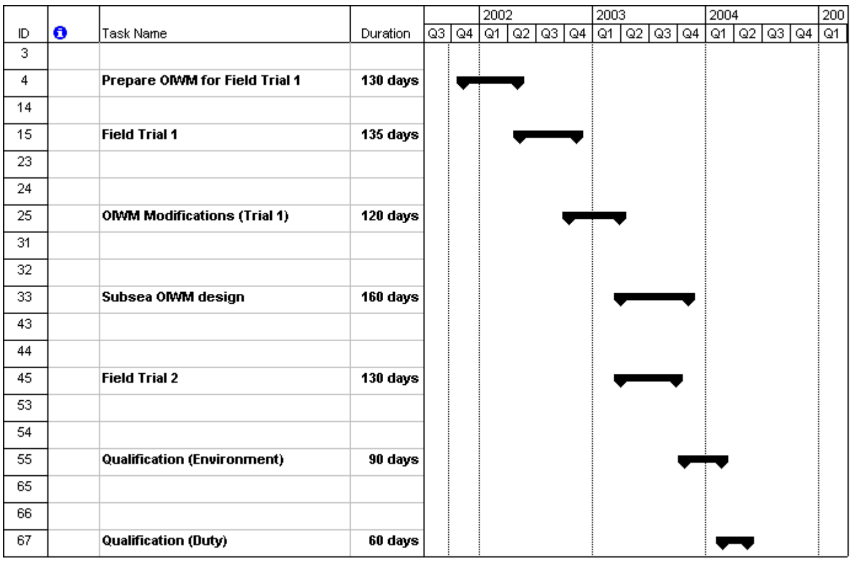
Milestone 2	• Completion of modifications to OIWM as a result of learnings from field trial 1
	• Subsea OIWM design:
	  • Production of specification
	  • Electronics and system design
	  • Software design
	  • Subsea packaging design
	• Successful field trial 2:
	  • Provision of reliable concentration data on a platform or an onshore field for up to 6 months such as to give confidence of the OIWM's suitability for commercialisation
	• Beginning of work to qualify OIWM for both environmental and duty applications

Remaining activities	• Completion of environmental qualification • Completion of duty qualification • Provision of final report

Table 4: Activities to be completed and measures of success for each payment-related milestone

9.2 Project schedule

The project is scheduled to begin in the first week of November 2001, with completion in Q2 2004.



10 Contacts

For further information or any queries relating to this proposal, please refer to:-

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Appendix 1

About the Contractors

Kvaerner Oilfield Products Ltd, Flow Measurement Group

Introduction

Kvaerner Oilfield Products (KOP) is a fully integrated company that provides a complete range of surface and subsea solutions for the oil and gas industry from conceptual and detail design, where we operate as an independent engineering consultant, through to EPCI contracting where the Group provides the engineering, management and procurement capability for projects involving product and fabrication supply from both within the Kvaerner organisation and from our partners and subcontractors.

We are committed to best value business solutions and these are delivered by:

- Minimising project cost and time drivers
- Quantifying and reducing risk
- Maximising production availability
- Due regard for safety and the environment

We also involve the utilisation of best in class products and services to satisfy the above criteria.

Kvaerner Oilfield Products is part of Kvaerner Oil and Gas (KOG), a total supplier of oil and gas installations. KOG has operations world-wide and over 11,000 employees.

Achievements

In recent years Kvaerner Oilfield Products has achieved:

- Deepwater record for subsea production control systems on the Albacora and the Mensa developments
- First subsea multiphase meter
- First truly diverless pull-in and connection system in the Norwegian sector with the TOGI project for Norsk Hydro
- First integrated steel tube umbilical
- Development of the first splitter wellhead system
- Development of an improved metal sealing side valve tree system
- First subsea use of High Integrity Pipeline Protection System (HIPPS)
- First free-flow ROV change-out of control modules and choke inserts
- Dynamic steel tube umbilicals

Business Streams

A main strength of the Group is the Kvaerner corporate commitment to subsea technology through investment in subsea product development. KOP's ability as a total system provider is backed by a wide portfolio of products which are maintained for the complete life of field. KOP's capability is available for both new and existing fields either as individual activities or complete packages. World-wide activities are supported by 5 regional centres which, in turn, are backed by 8 business streams:

- Subsea Systems
- Subsea Wellheads
- Control Systems
- Umbilicals
- Flow Measurement
- Mechanical Products
- Subsea Processing
- Surface Wellheads
- Downhole Processing

Flow Measurement

The requirement for improved reservoir management and cost effective production and processing has focused on the need to develop metering technology able to discriminate between oil, water and gas in multiphase transport and process systems.

The Kvaerner DUET Multiphase Meter can assist production in well testing to reduce testing costs and obviate the need for a test separator. KOP also provides other types of flow measuring devices, such as a water-cut meter and venturi flow meters, to enhance recovery optimise reservoir management. Flow Measurement has recently been developing and testing the Oil in Water Monitor, which is the subject of this JIP proposal.

Quality Assurance and Control Activities

Kvaerner Oilfield Products operates a Quality Management System certified to ISO 9001 by NCS. The certificate covers the Kvaerner Oilfield Products Ltd, Kvaerner Oilfield Products a.s. and Kvaerner Oilfield Products Inc: Engineering, manufacture and service of subsea and surface hydrocarbon production systems. A KOP Group Quality Manual outlining the company's commitment to quality is available upon request.

Health, Safety & Environment

KOP's Policy Statement on Health, Safety and Environment is part of the Safety Manual. The Safety Manual defines the Safety Management System which is applicable to all of KOP's operations and is not project specific. Any project specific requirement would be defined in a Project Safety Plan. Latest copies of the Safety Manual can be made available upon request.

Contacts

The Flow Measurement Group is based in Aberdeen:

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Offshore Technology Management Ltd

OTM is a small, dynamic organisation specialising in the provision of services related to technology management. These include initiation, launch and management of collaborative research programmes; market studies and market analyses; technology strategy enhancement and technology knowledge base development. The company offers a personalised service, backed by a 9 person team with complementary skills. The company's steady growth is attributable to personal recommendations from satisfied clients, and has been controlled and sustainable, focusing on core skills.

To add value to this JIP, OTM will call on the experience gained in providing a full secretariat and programme management service to a wide range of JIPs including:

- COREL (Corrosion resistant liners) phases 1-3
- CoSWaSS (configurable subsea water separation system)
- DEA (E) (Drilling Engineering Association) Technology Transfer JIP
- DISH (Deepwater Installation of Subsea Hardware)
- ICON (Intelligent Completions on the Net)
- PEA (Production Engineering Association) Technology Transfer JIP
- SLOOP (deepwater production strategies simulation tool)
- STRIDE (steel risers for deepwater environments)
- TRF (Threaded risers & flowlines)

OTM strongly believes that the JIP service offered enables clients to focus upon the all-important technical issues, and ensures that programmes remain on course in terms of meeting participants' quality, budget and timing expectations.

Oil Company Clients:

Amerada Hess	BG International	BHP
BP	Chevron	Conoco
ENI Agip	Enterprise Oil	ExxonMobil
Hibernia	INA-Naftaplin	Kerr-McGee
Lasmo	Maersk	Marathon Oil
Norsk Hydro	OMV	Phillips Petroleum
Ranger Oil	RWE-DEA	Shell
Statoil	Talisman	Texaco
TotalFinaElf	Unocal	Veba Oil & Gas

Supplier/ Contractor Clients:

2H Engineering	ABB Offshore Systems	Alstom Automation
Atofina	Baker Oil Tools	BMT Fluid Mechanics
Caltec	CAPCIS	CiDRA
Deloro Stellite	DSND	EMC
Europipe	Garrad Hassan	Glynwed Pipe Systems
Halliburton	Kongsberg Offshore	Kvaerner Oilfield Products
Marine Acoustics	McDermott	PES
Petroline	Petrology	Phoenix Petroleum Services
Polyline Technology	Roxar Production Management	Safetyliner
Schlumberger	Shell Chemicals	Subterra
The Expro Group	Weatherford	Wood Group Production Technology

Government/ Agency/ Other Clients:

DTI	Enterprise Partnership	IACMST
NERC	Robert Gordon University	Society for Underwater Technology
Southampton Oceanography Centre		

Appendix 2

OIWM Field Test: Site requirements

During the CoSWaSS programme the OIWM has been tested at ERT to determine the sensitivity of the instrument to a variety of parameters. While this test was extremely useful in defining the performance of the system in a well controlled environment, further field tests are required to demonstrate the suitability of the technology for a field environment.

The following are the prime requirements of a field test site:

- A process line which is already instrumented to a sufficient degree to allow accurate and frequent comparison between trends displayed by the OIWM and existing instrumentation.
- A sampling point close to the installed OIWM which can be used to provide samples for analysis to compare between established measurement methods, the OIWM concentration reading and direct analysis of the sample.
- The test site should be a surface installation (onshore or offshore)
- Host flow line should run full under normal conditions
- Host flow line size should be a minimum of 3-inch
- The flow velocity at the installation should be in excess of 1.5 m/s for correct operation
- Flow line pressure should be less than 100 barg and greater than atmospheric pressure
- Flow line temperature should be less than 100°C
- The OIWM should be installed as remotely as possible from any control valves

The following are further preferred requirements:

- The site requires an improvement in oily water measurement for operational reasons. This requirement will assist in obtaining ‘buy-in’ from the site and enhance the commitment and drive of the operating team to resolve any issues which may occur during the field trial.
- The oily water process stream should have concentration within the range 0 – 2000 ppm.
- More than one process stream can be switched through the OIWM to allow assessment at a number of different conditions.
- Local pressure at the OIWM installation should be as high as possible to minimise the possibility of free gas in the process stream.