Update on the Development of Subsea Produced Water Sensors for Seabed Discharge Applications

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OUTLINE

- ❑ Acknowledgements
- ❑ Background
- ❑ Overview of RPSEA 12121-6301-03 Project
- ❑ Technology Status
- ❑ Subsea Produced Water Sensor Requirements
- ❑ Upcoming Workshop on Technology Gap Analysis
- ❑ Concluding Conclusions

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- NETL
- RPSEA
- Working Project Group Members
  - Anadarko
  - BG
  - ExxonMobil
  - Fluor
  - OneSubsea
  - Petrobras
  - Total
- Attendees to the Workshop on Subsea Produced Water Sensor Requirements
- Other contributors to the project

PRODUCED WATER HANDLING

- Over 80% of Produced Liquids Is Water
- Offshore Most of the PW Is Discharged
  - Discharge quality regulations
  - Regulatory compliance measurements
- Water Handling Key to Some Major Upcoming US GoM Developments
  - EOR with water flooding
  - Subsea treatment and disposal is becoming an important and even sometimes enabling development option

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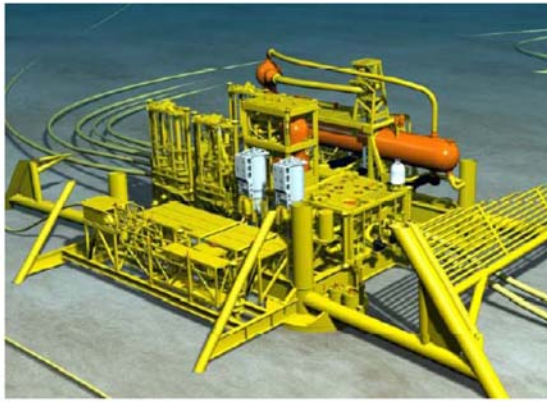
SUBSEA PRODUCED WATER DISPOSAL

- **Subsea PW Separation & Re-Injection**
  - Statoil Tordis (2007)
  - Petrobras Marlim (2011)
- **Subsea PWRI Sensors**
  - Recent/Ongoing JIPs
- **Subsea PW Discharge**
  - RPSEA 10301 Study on Subsea Discharge (2010)
    - Survey of Regulations
    - Technology Gap Analysis
    - Roadmap
  - RPSEA 12121-6301-03 (Current Project)
    - Sensor requirements
    - Sensor gap analysis
    - Sensor bench-scale testing



Source: FMC

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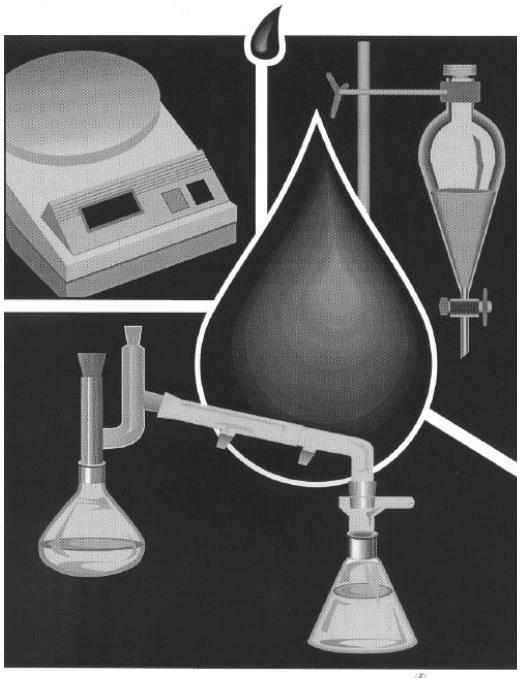
US REGULATIONS ON PWD

- Oil and grease: 29 mg/L max monthly average, 42 mg/L daily max
  - By EPA 1664A, a gravimetric method
- Toxicity: Mysid shrimp and Inland Silverside minnow chronic static renewal 7-day larval survival and growth test
  - Annually for discharge rate below 4600 bbls/day
  - Quarterly for higher discharge rates
- No free oil can be discharged (no sheen)
- No sand discharge



NO SPECIFIC REGULATIONS ON SUBSEA DISCHARGE

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CURRENT PRACTICES (SURFACE)

- **Compliance Monitoring**
  - **Take a sample (location / time may be pre determined)**
  - **Pre-treat the sample**
  - **Analyze the sample using either an approved reference method or a method that would produce equivalent results**
    - **US regulations requires EPA 1664 testing. Alternative methods are not accepted**
  - **Record and report**
- **Points to Note**
  - **OIW is method dependent**
  - **To date, no online continuous monitoring has been approved for regulatory compliance monitoring**

CURRENT PRACTICES (SUBSEA)

- No subsea sensor available
- Current practice
  - ROV / sampling / surface analysis
- Problems
  - Time consuming and costly
  - Huge time lag
  - Not-continuous
  - Not suitable for process operations

R&D TOWARD SUBSEA

- **Statoil & Petrobras**
  - Aim: to develop and qualify a subsea oil-in-water monitor in 2015/2016
  - Pressure range: 20-100 barg; OIW: 10-3000 ppm
- **ExxonMobil**
- **FMC Technologies, Aker Solutions**
- **Sensor Vendors: J M Canty, Advanced Sensors, Jorin, Mirmorax**
- **NEL Joint Industry Projects**
  - 2009-2010 – Develop Operating Envelope(s) and Test Protocol for Subsea Water Quality Measurement Devices
  - 2011-2013 – Independent Evaluation of the Technology of Subsea Water Quality Measurement Devices
  - 2014-2016 – Development of Subsea Water Quality Measurement Technology Up to TRL 5
- **The Current Project**

POTENTIAL TECHNOLOGIES FOR SUBSEA

- **Well Established Technologies**
  - **LIF**
  - **Microscopy Based Image Analysis**
  - **Ultrasonic Acoustic**
  - **Light Scattering**
- **New and Emerging Technologies**
  - **Confocal Laser Fluorescence Microscopy (CLFM)**
  - **Combination of LIF with Microscopy**

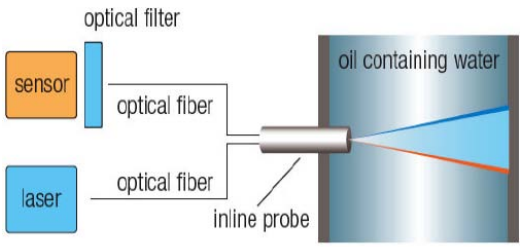
POTENTIAL TECHNOLOGIES FOR SUBSEA

MICROSCOPY	LIGHT SCATTERING	FLUORESCENCE	ULTRASONIC
Jorin	Rivertrace Engineering	Turner Designs (UV)	Mirmorax
Canty	Deckma	Sigrist (UV)	Kimman Process Solutions
Fluid Imaging	Hach	Arjay Engineering (UV)	
Advanced Sensors		Advanced Sensors (Laser)	
Clearview Subsea (CLFM)		Pro Analysis (Laser)	

ESTABLISHED TECHNOLOGIES

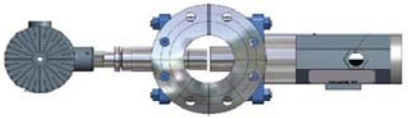
Laser Induced Fluorescence

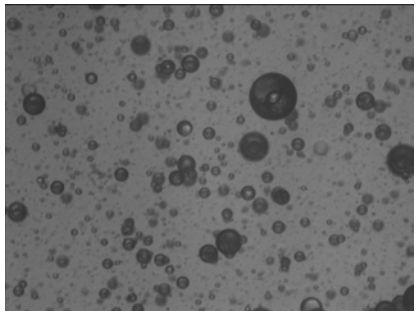
Figure Source: ProAnalysis



Microscopy

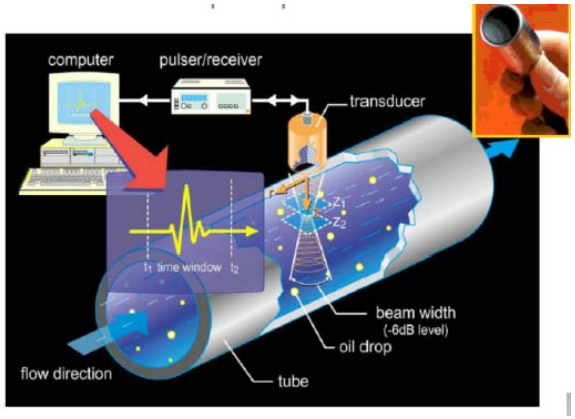
Figure Source: J M Canty





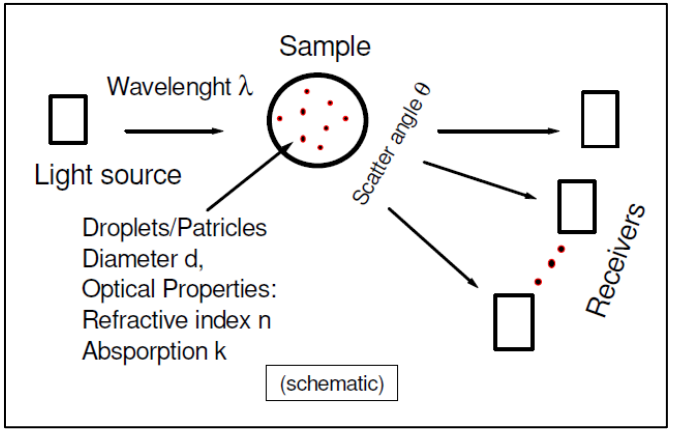
Ultrasonic

Figure Source: Roxar / Mimorax



Light Scattering

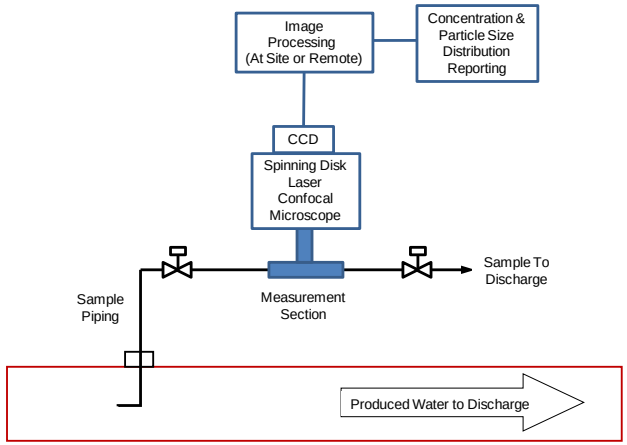
Figure Source: Deckma

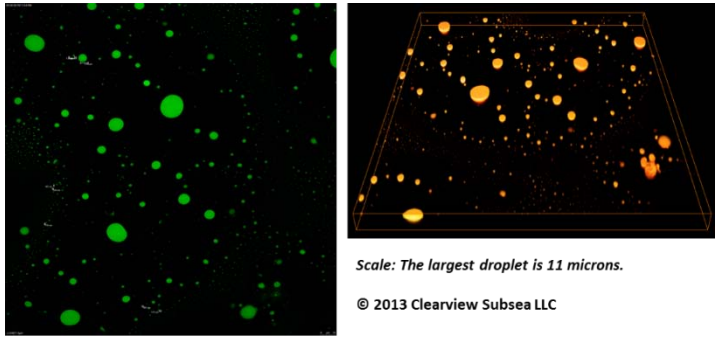


NEW & EMERGING TECHNOLOGIES

CLFM
(Confocal Laser Fluorescence Microscopy)

Figure Source: Clearview Subsea





Scale: The largest droplet is 11 microns.

Combined LIF and Microscopy

Figure Source: Advanced Sensors

OVERVIEW OF PROJECT

- **Project: RPSEA 12121-6301-03, *Subsea Produced Water Development***
- **Project Goal**
  - **Progress Subsea Sensors to TRL 3-4**
  - **Focus on PWD Sensor**
    - **Developing technology toward enabling measurement of PW quality for regulatory compliance reporting**
- **Project Schedule: September 2014 to September 2016**

PROJECT SCOPE

- **Phase 1 (9 Months)**
  - **Develop Subsea Produced Water Sensor Requirements by Collecting Industry and Regulatory Input**
  - **Analyze the Technology Gaps in the Current Sensors**
  - **Proof of Concept on Confocal Laser Fluorescence Microscopy (CLFM)**
    - **New technology**
  - **Select up to 3 Sensors for Further Development in Phase 2**
    - **2 sensors from well established technologies**
    - **CLFM will be tested if concept is proven in phase 1**
- **Phase 2 (15 Months)**
  - **Design and Construct Prototypes**
  - **Bench-Scale Testing of the Prototypes**

SUBSEA PW SENSOR REQUIREMENTS

- **Industry Workshop Held on December 16, 2014**
  - **Collect industry input**
  - **Attended by representatives from operators, subsea system suppliers, engineering companies and consultants, standard organizations**
- **Preliminary Requirements Developed from Workshop Discussions**
  - **To be presented in the next several slides**
  - **PRELIMINARY – for information sharing only**
  - **Input from seminar audience is welcome**
- **Planning to Review with Regulatory Agency (BSEE) to Seek Input**

PRELIMINARY SENSOR REQUIREMENTS

Preliminary

- Based on Input from Workshop
- For NPDES Permit Compliance
  - Sensors will only measure oil and grease amount
  - Toxicity tests will be by sampling (annually or quarterly)
  - Must correlate with EPA 1664 Measurements
    - Approval by BSEE will be required
    - Accuracy of 10% as Compared with EPA 1664 was considered a reasonable level. EPA 1664 Method precision is 8.7% - 11%.
    - Once correlation is proven, the sensor readings can be considered as the actual oil and grease amount for compliance reporting
    - Periodical validation/verification of the correlation needed. Method to be determined. One potential method: Sampling loop tapping for checking/verifying sample
  - Potential Impact of Variation of EPA 1664 Measurement – TBD

PRELIMINARY SENSOR REQUIREMENTS (2)

Preliminary

- Based on Input from Workshop
- For NPDES Permit Compliance
  - Sheen: Not Measured
    - No Sheening due to discharge at seabed
  - Water Soluble Organics: Not Directly Measured. The oil and grease contribution would be accounted for by the correlation with EPA 1664 measurements
    - Most WSOs are fatty acids
  - Sand and Solids: Direct Measurement Is Optional
    - No specific requirements on measuring sand and solids content
    - Oil on sand and solids will be accounted for by the oil and grease amount reading

PRELIMINARY SENSOR REQUIREMENTS (3)

Preliminary

- **For Ensuring Quality of PW Discharge**
  - **Alarming for flow diversion/process shutdown**
    - **Frequency of reporting measurements for this purpose: hourly or faster – Preventing excessive false alarms**
    - **Operators will have different procedures they follow so the measurement devices need to be able to comply**
  - **Redundancy is important**
    - **May likely need multiple sensors – Voting and redundancy. Sensors may be different technologies**
    - **May combine inline and online technologies**
  - **Detecting Upsets: Continuous Measurements**
    - **Spikes of oil and grease concentration may be caused by problems in separation or PW treatment system**
  - **If there is emergency or error, system should be fully shutdown until an ROV can take a sample to re-allow the discharge**
- **Sensor Requirements for Subsea Process Monitoring**
  - **Not Developed – the objective was to develop sensor requirements for checking PW discharge quality**

PRELIMINARY SENSOR REQUIREMENTS (4)

Preliminary

Parameter	Value
Oil Concentration	0 – 100 mg/L
Solid Concentration	0 – 100 mg/L
Accuracy	10% (Difference with EPA 1664 Measurements)
Water Depth	Up to 10,000 ft
Seawater Temperature	33 F (28 F as next step)
Design Temperature	33 – 300 F (350 F as next step)
Operating/Service Temperature	38 – 150 F (also refer to EPA/company limits)
Design Pressure	10,000 psig (15,000 psig as next step) *Maximum SITHP
Operating/Service Pressure	0 – 5000 psig
Flow Velocity	Up to 15 ft/s desired (Each sensor manufacturer to determine the specific limit)
Oil Density	11 – 35 API

PRELIMINARY SENSOR REQUIREMENTS (5)

Preliminary

Parameter	Value
Produced Water Salinity	0 – 250,000 ppm
Chemicals in Produced Water	Typical deepwater chemicals and concentrations. Completion fluids including ZnBr.
Entrained Gas	TBD
Response Time	Hourly or faster
Design Service Life	20 years
Mean Time Between Failure	5 years minimum
Maintenance by ROV	Max quarterly or annually (as toxicity test schedule)
Maintenance by Retrieval	Max once every 5 years
Shock	Per ISO 13628-6: Q1 (5 g) or Q2 (10 g) as applicable
Vibration	Per ISO 13628-6

UPCOMING WORKSHOP

- For Collecting Industry Input on the Methodologies for Technology Gap Analysis and Technology Ranking
- February 23, 2015 in Houston
- Agenda
  - Scene setting
  - Subsea PW discharge sensors - technical requirements
  - Subsea PW discharge sensors - technology gaps seen by the end users and vendors
  - Technology selection for inclusion in the gap analysis
  - Gap analysis methodology
  - Methodology in ranking the different technologies
  - How to close technology gaps

PARTICIPATING IN THE WORKSHOP

- **Workshop Open to**
  - **All those who are interested in subsea separation and PW handling (in particular subsea discharging)**
  - **All who can contribute to the various discussions planned for the Workshop**
- **Anticipated to Have 40 – 50 Attendees**
- **Contact the Organizers if Interested in Participating**
  - **Including if interested in making a technology presentation**
    - **For vendors whose technologies are potentially applicable for subsea**
  - **Contact either**
    - **Stewart Baskin: sbaskin@clearviewsubsea.com**
    - **Ming Yang: myang@tuvnel.com**

CONCLUSIONS

- Preliminary requirements for subsea produced water sensors for discharge quality have been developed. Additional input is welcome.
- Planning to seek the input of regulators on the requirements. A final Subsea PW Sensor Requirement document will be developed with the input.
- A number of established and new/emerging technologies have the potential to be used on subsea PW discharge.
- Upcoming work will assess the technology gaps. The technologies will be ranked.
- Several technologies with the best potential will be prototyped and tested in Phase 2 of the current project.

Thank You!

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