SPE: PFC Luncheon; Subsea Produced Water Treatment Measurement Challenges

Society of Petroleum Engineers, Gulf Coast Section

By Tim Daigle, Fluor Offshore Solutions, April 17, 2012

Norris Center, Houston, Texas, USA

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Presentation Agenda

- Introduction – RPSEA Study
- Discuss and Highlight some significant advances within the Produced Water Industry and How Can they be used Subsea
- Sensing Layout
- Regulatory Requirements
- News Sensors
- Conclusion – Questions

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DW3100-01 Project Objectives

- Study for Discharge of Produced Water and/or Solids at the Seabed
- Study Regulations in the Industry with an emphasis on key Deepwater locations, i.e. GOM, North Sea, Brazil, West Africa
- Study Marine Life @ Seabed depths of 5,000 – 8,000 ft
- Study Produced Water Techniques by Performing a State of the Art Market Sweep
- Use research results to derive a new Subsea Produced Water Treatment Process
- Submit Final Report

Advance Subsea Processing Systems

- **Today the industry is developing and testing a number of new subsea processing system.**
- **Use of desanders and hydrocyclones, CFUs, Polymer based filtration systems, Adsorption, etc.**
- **Use of pipe separators like FMC's Harp used on Petrobras' Marlim**
- **Use of Subsea Slug Catchers**
- **Use of Separation Caissons like Perdido and BC-10**

- **A must for these systems is the Proper use of sensing and measurement to "see" successful process in the operation**

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Saipem Multi Pipe Separator

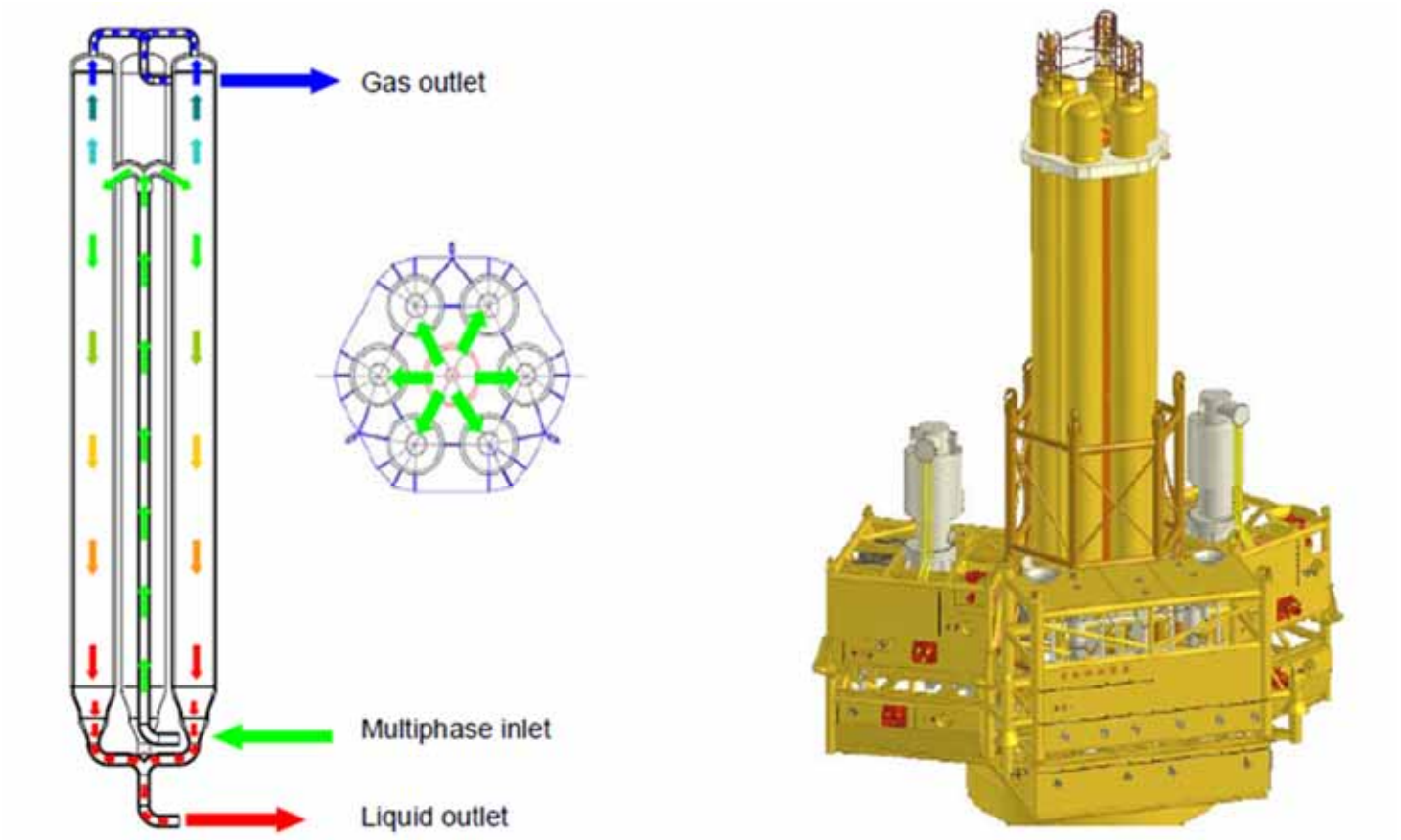

Figure 4: Multi-pipe separator principle and its associated subsea station

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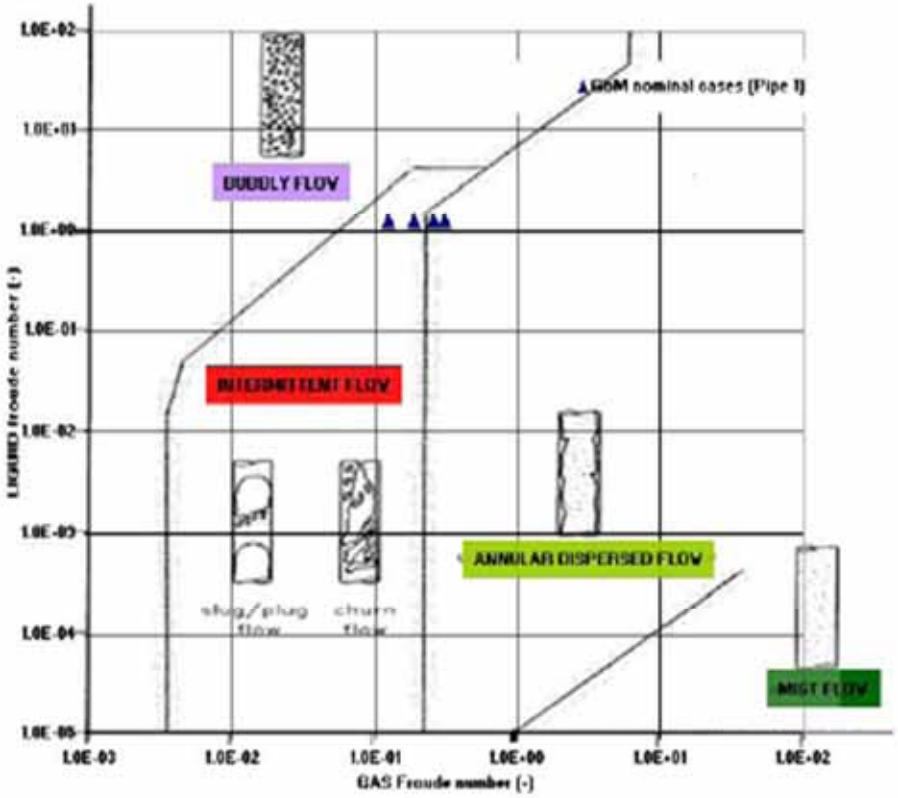
Saipem - Flow Regime Dependency helps determines Efficiency

OTC 21394



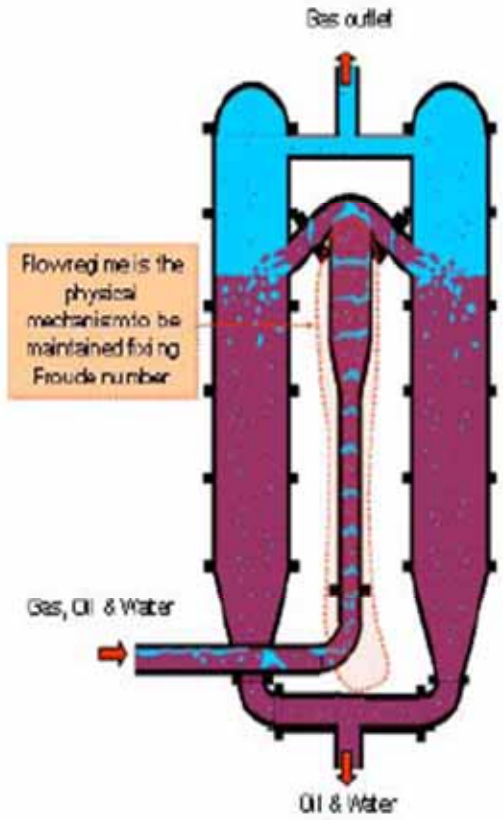


Figure 11: Two-phase flow map for vertical feed pipes (up flow)

Subsea water processing system built by FMC Technologies

Petrobras' Marlim field, offshore Brazil

JPT • AUGUST 2011

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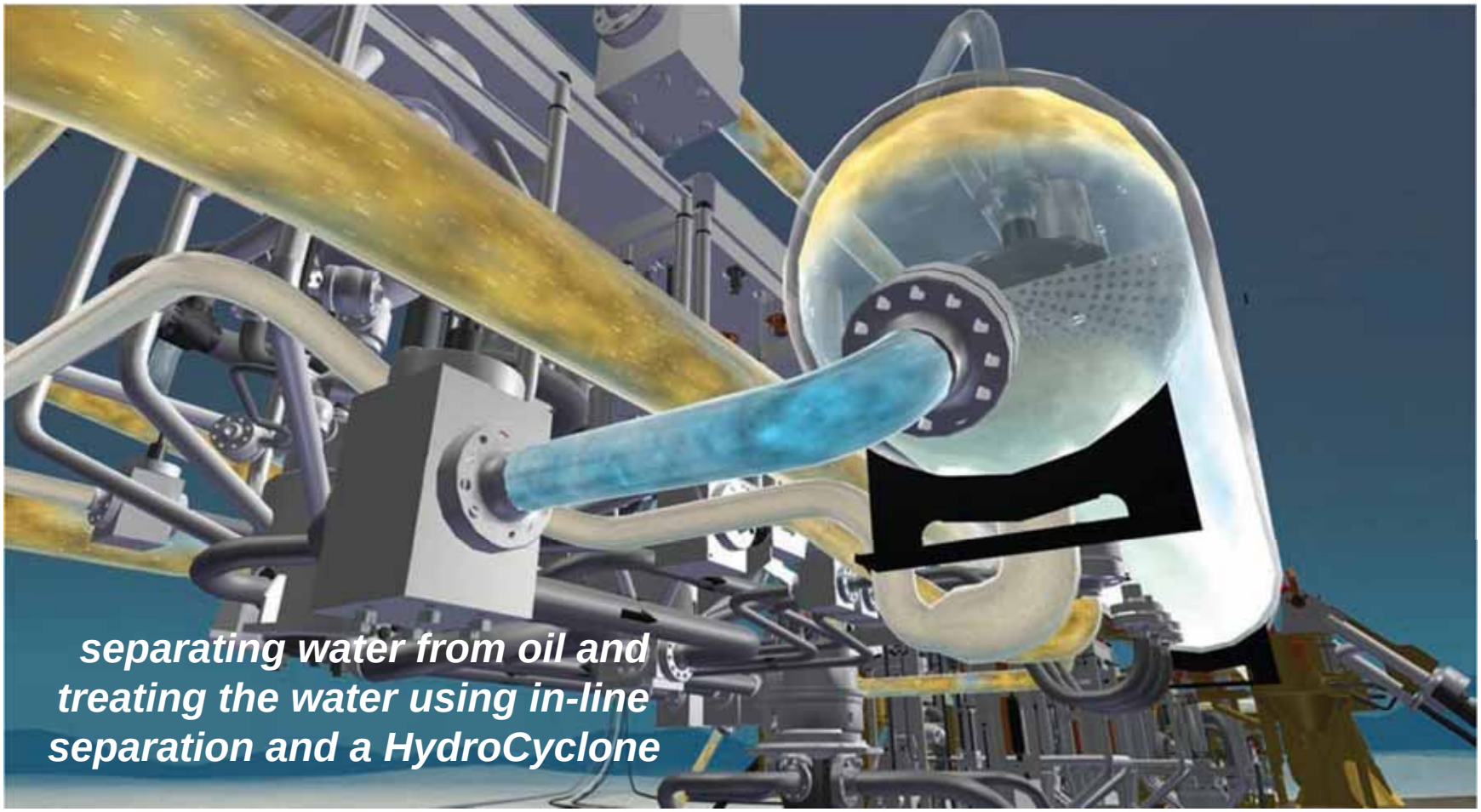
FMC Technologies water treatment unit for Petrobras' Marlim



separating water from oil and treating the water using in-line separation and a HydroCyclone

JPT • AUGUST 2011

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Pazflor Vertical Subsea Separator - 2011

- Vertical Gas-Liquid Separation
- Purpose to reduce gas volume fraction to enable multiple pump
- Vessel design including curved lower section to prevent sand accumulation
- A sand handling system w/sand flushing used back-up solution to remove sand build-up

FMC Pazflor SS Gas/Liquid Separation & Boosting, Courtesy of FMC

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Monitoring and Sensing is extremely important here!

FMC Pazflor SS Gas/Liquid Separation & Boosting, Courtesy of FMC

FMC Tordis Subsea Separation System, Courtesy of FMC

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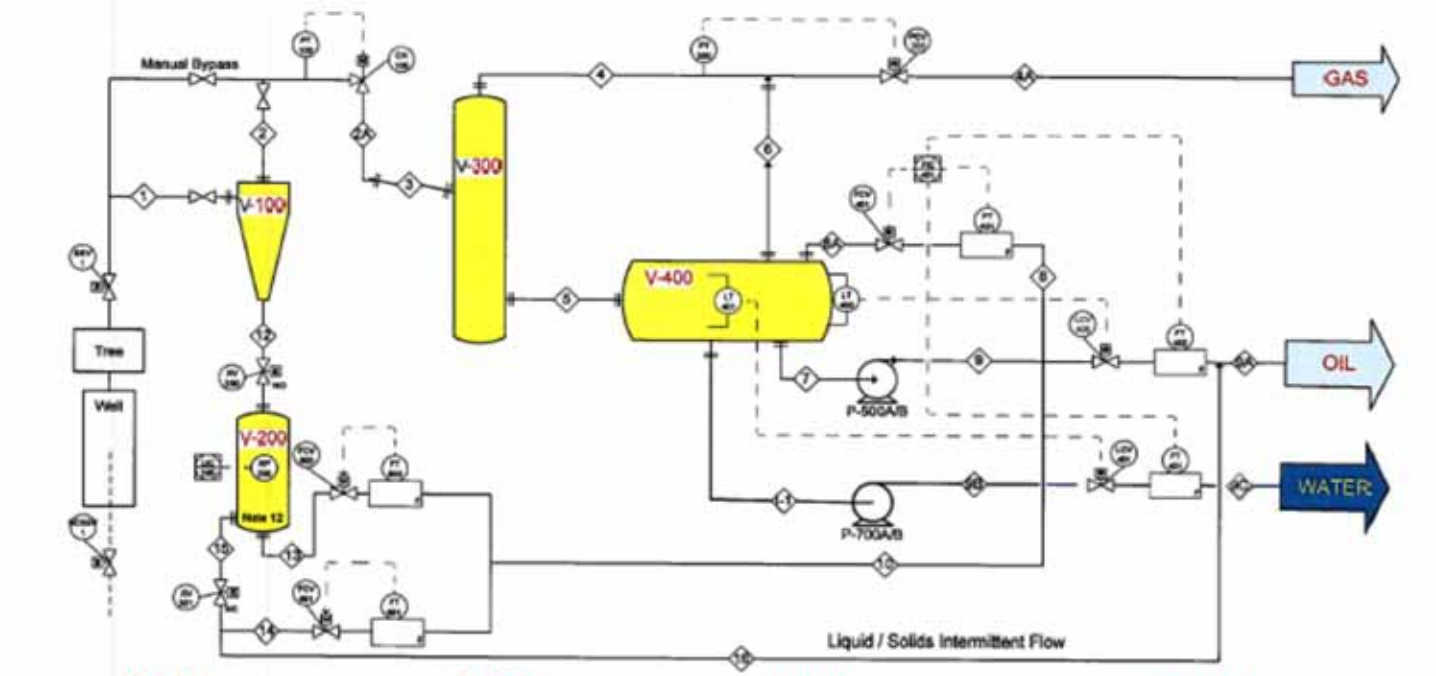
Flow Diagram with Potential Technologies

Three Phase Subsea Separation Process



V-100
Wellhead Desander
Petreco Model WHD16
16" ID x 9' – 3"

V-200
Desander Accumulator
16" ID x 3' – 0"

V-300
GLCC Compact Separator
24" ID x 13' – 0"

V-400
GLCC Accumulator
42" ID x 36' – 0"

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CAMERON

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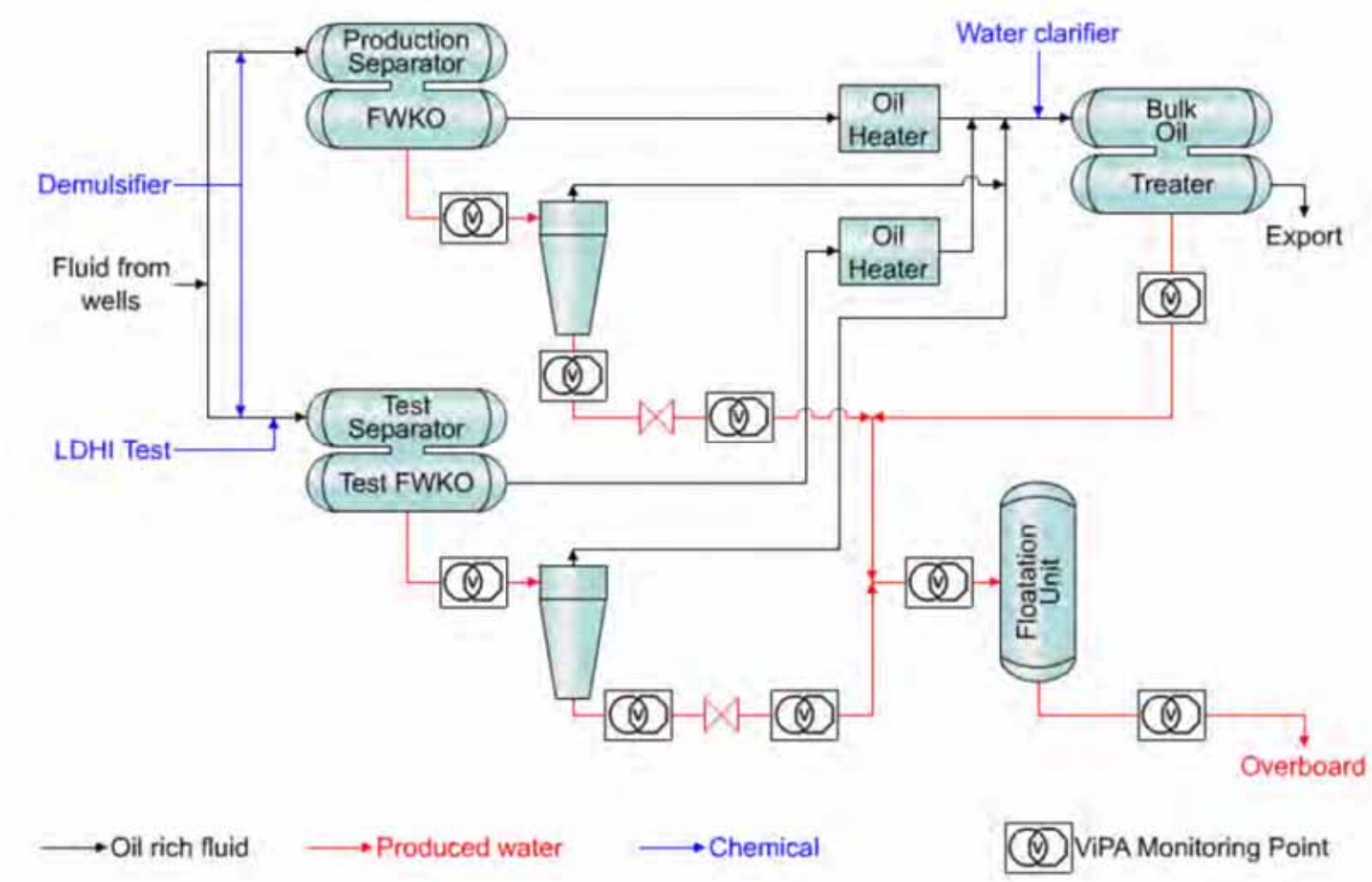
Visual Process Analyzer



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US Regulations (Gulf of Mexico)

- Philosophy of Whole Effluent Toxicity Testing
- Limits set at 29mg/L monthly average, 40 mg/L daily maximum
- Sampling Minimum Once per Month
- Toxicity Testing Quarterly (high volume) or Annually
- No free oil discharged - Visual sheen method on the surface of the receiving water. Monitoring done daily
- Observed sheens must be recorded on NPDES permit
- No discharge of sand

US Regulations (Gulf of Mexico)

- Toxicity test required, per EPA Lab Method
  - 7-day avg minimum for the test effluent to be diluted and placed in 8 different test replicas, each containing at least 5 organisms of mysid shrimp
- ½ must remain alive for the 7 day test
- A No Observable Effect Concentration (NOEC) => specified critical dilution concentration
- Dilution rates set on discharge pipe diameter and water depth from the seafloor

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Regulatory Impact on Seabed Discharge

- **No Discharge of Sand**
  - Sand must be collected for retrieval to shore, or send to platform
  - Radioactivity monitoring may be required
- **Monitoring and Reporting Challenges**
  - Oil and Grease Monitoring
  - Toxicity
- **Toxicity**
  - Dilution allowed by, adding seawater, using diffuser, or using multiple ports
  - Specific software to use if diffuser is used to increase dilution
  - Are the critical dilution tables or software applicable to deepwater seabed (potentially very little current)?
- **Visual Sheen**
  - Observation required for seabed discharge?
  - Observation method and frequency issues
  - Water sampling requirement after observing sheen may cause difficulty
- **Total dissolved solids**
  - No regulation other than through toxicity

Subsea Water Quality Monitoring

- **5 typical measurement principles to distinguish oil-in-water and perform water quality measurements.**
  - Direct weight measurement (being the preferred EPA method),
  - Colorimetric,
  - Infrared,
  - Ultra violet fluorescence
  - Particle counting
- **Use in the subsea environment is nonexistent and methods, designs and tests need to be performed to bridge the gap of subsea oil-in-water quality monitoring.**

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Direct Weight Measurement – ASTM 1664

- **Direct weight measurement (being the preferred EPA method),**
- The only test that can be done to verify that discharge in the US meets EPA oil-in-water standards.
- To be done in a laboratory if being used to meet EPA requirements
- Acidify a one liter water sample to pH 2 or less, then extract it using n-hexane. but other extractants may be specified.
- The extractant is then evaporated and the remaining residue is weighed.
- The mass of this residue is recorded in milligrams, and this gives a direct mg/L concentration.

The others typical measurements used today

- The following methods described are indirect methods of measurement, meaning that the recorded value of whatever property is being measured must be correlated to a standard in order to determine the oil-in-water concentration.

Colorimetric method - HACH

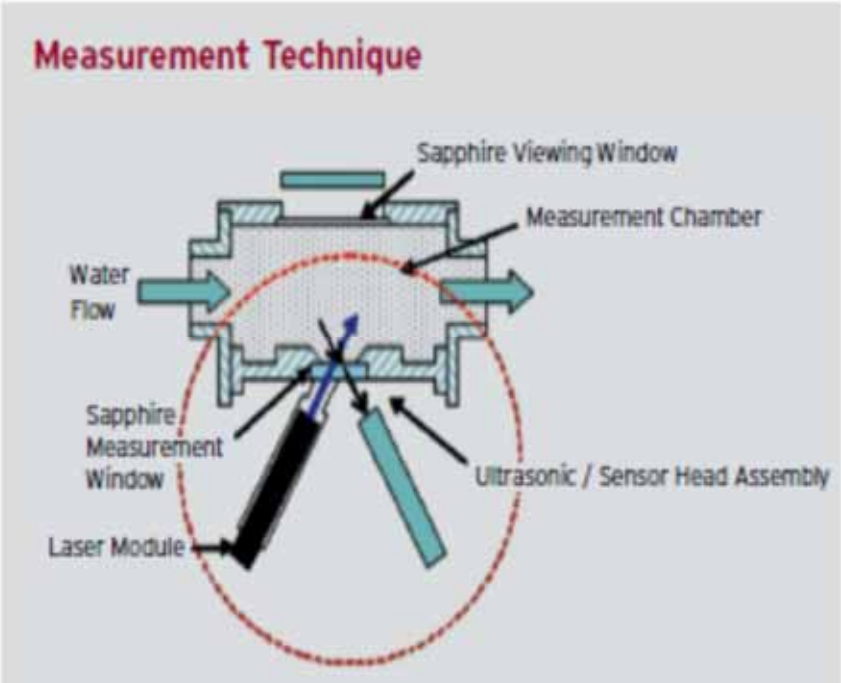
- Method oil-in-water tests measure the absorption of energy in the visible light range.
- This test only works well with dark oils.
- The measurement is then correlated to a sample with a known concentration to determine the concentration of the test water.
- One major problem associated with this method is that a calibration sample of the oil is needed, and if the sampling quality or process flow changes the hydrocarbon ratio in the sample, the analysis can have a large uncertainty and degree of error associated with the final resultant oil-in-water measurement.

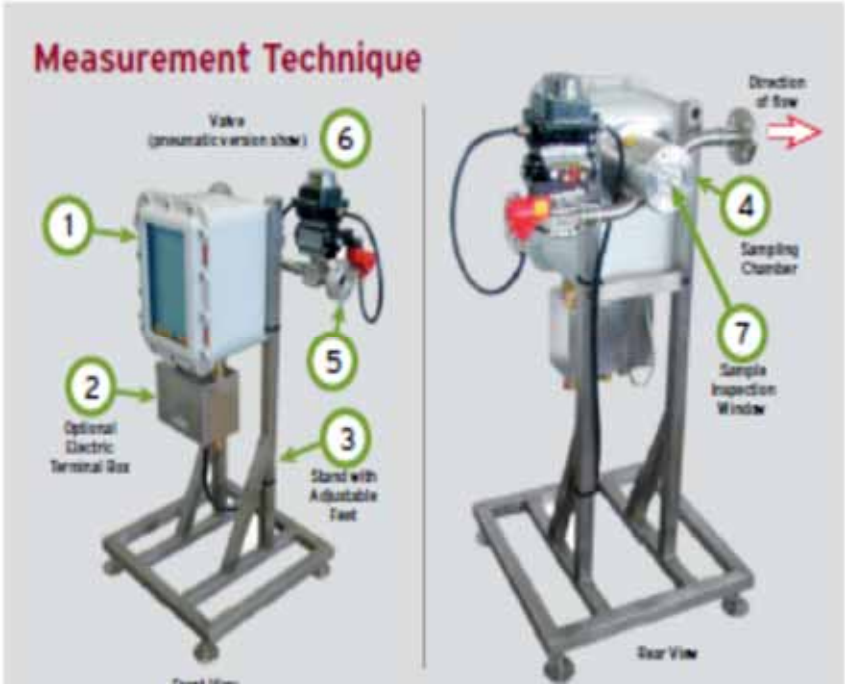
Infrared

- Infrared (IR) measurement of oil-in-water uses instruments that target carbon hydrogen (C-H) bonds.
- C-H bonds adsorb IR energy at a 3.41 micron wavelength.
- The instrument measures the absorption of IR energy and correlates that measurement to an oil concentration using a standard.
- The standard must be free of carbon and hydrogen.
- Originally, Freon was used, and today several other chemicals are used as reference.
- What is important is the procedure to create the calibration fluid in each sample.
- The process is not easy to perform and consists of inherent user errors contributing to the final result.
- Due to the challenges associated with this method, it is not commonly used today and may not be considered a preferred method for subsea discharge of produced water.

Advanced Sensor

- **Highly successful new technology, breaking trends with operators**





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Advanced Sensor

- Employed the use of an internal ultra sonic agitation technology which keeps the sensor window clean and free of build up.
- They suggest using both the UV Fluorescence technique along with the particle counting method to provide the best part per million oil-in-water readings.

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Ultra Violet Fluorescence

- Ultraviolet (UV) Fluorescence measurement methods look at the aromatic compounds in a sample and how they absorb UV radiation and fluoresce at another wavelength.
- The amount of fluoresced light is proportional to the concentration of aromatic compounds in the water. Therefore, the amount of fluorescence measured is proportional to the oil in the water sample.
- Recommend Turner Designs to learn more.

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Particle Counting

- The particle counting method can be further broken down into three techniques: measuring turbidity, Coulder counter, and visual recording of particles and their size characteristics.
- Measuring turbidity was one of the earliest particle counting methods. Dispersed particles cause water to appear cloudy due to the scattering of transmitted light. An upper turbidity limit would often be specified to limit the maximum particle size and number of particles per unit volume in water to be injected.
- HACH has a good turbidity meter.

Coulder Counter

- Uses a small circular orifice with known dimensions and an electrical current. The particles that pass through reduce the area of the current in proportion to the size of the particle.
- Method must be performed in a laboratory and has limited usefulness as an oil-in-water monitor because it does not differentiate between solid particles and oil droplets.

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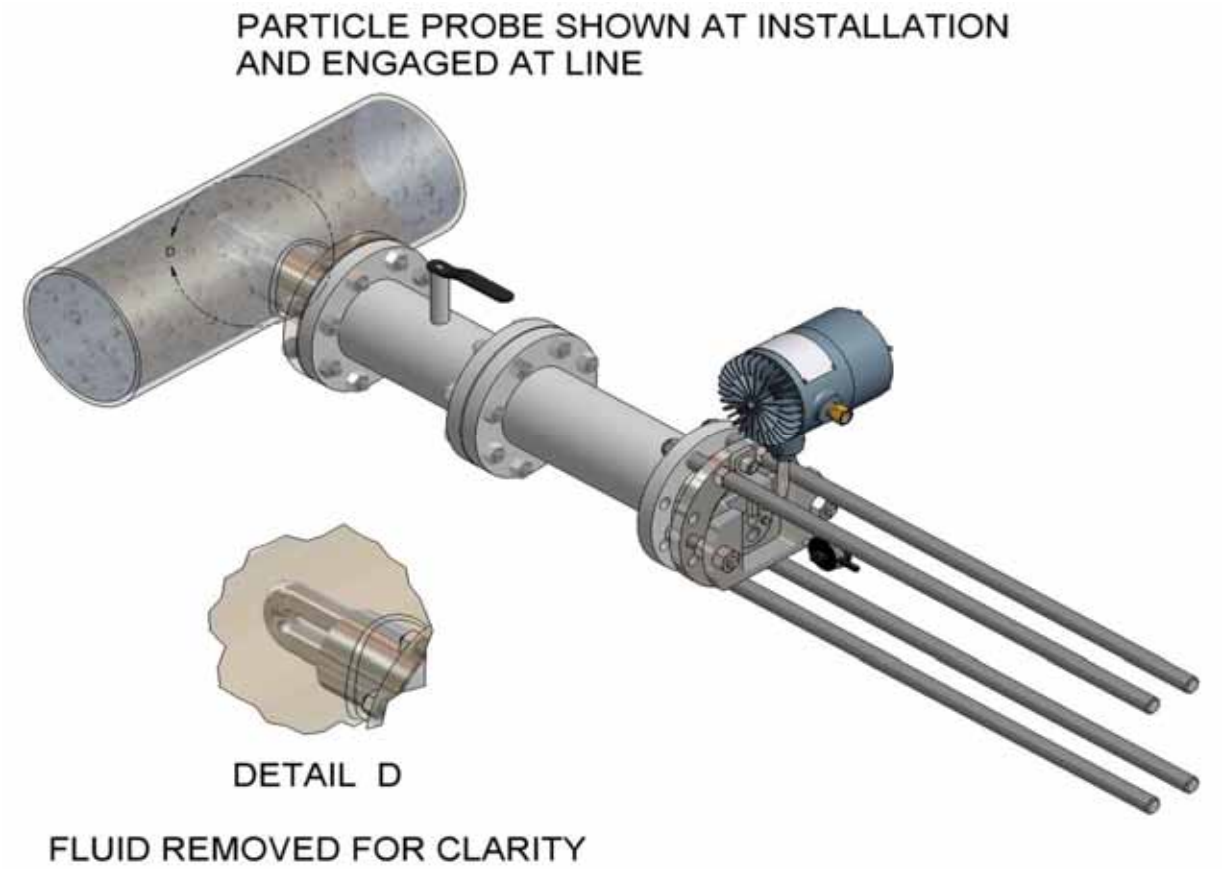
Microscopic Video Cameras

- Can be used to actually look at particles in a stream.
- Computer algorithms are used to count, size and identify those particles.
- Method can determine if a particle is a solid, oil, or gas bubble. The size and volume of all of the oil droplets seen in a volume of water can then be added together to determine the oil-in-water concentration.
- One limitation to all particle counting methods is that usually any particle below two microns cannot be seen
- Soluble oil concentrations cannot be determined using particle counting methods.

Microscopic Video Cameras - JM Canty

- Already working on a Subsea Version



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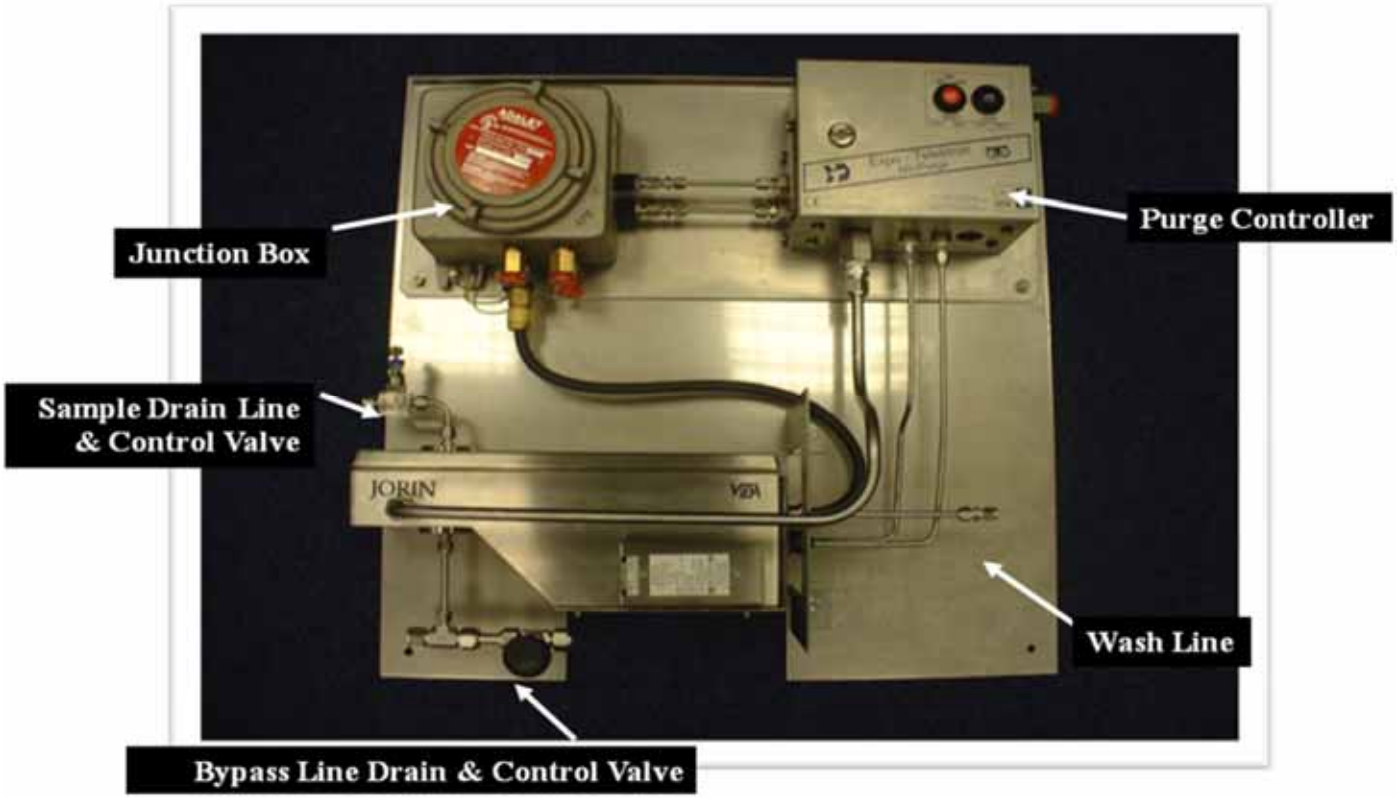
Microscopic Video Cameras - Jorin

- Visual Process Analyzer – Uses a Flow Cell streamed off the main flow line.



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New Technologies To Be Implemented

- **New methods:**
  - Inductance
  - Microwave
  - Near infrared absorption
  - Ultrasonic
  - Photometry

- **These new methods can be combined with the proven 5 typical measurement principles leading to new methods to improve the reliability of monitoring systems deployed subsea.**

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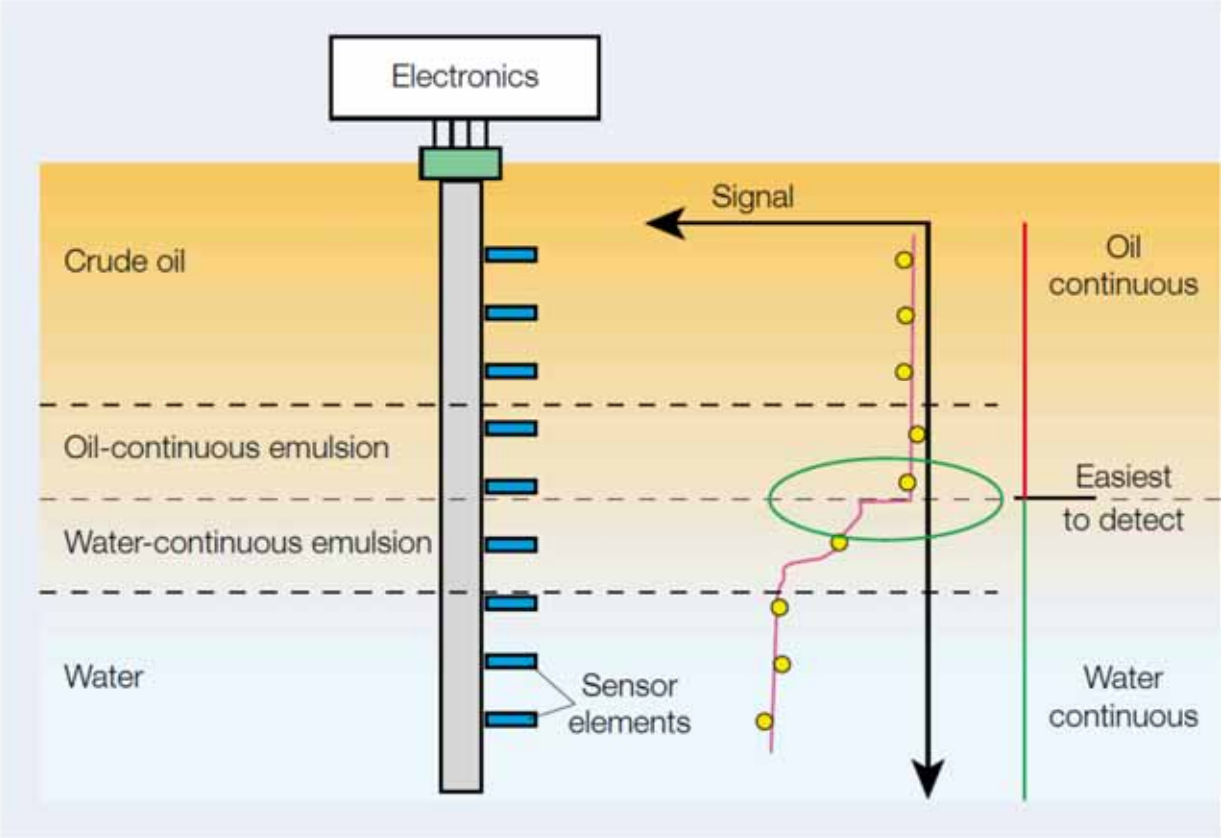
Inductance

The ILMS is made up of a vertical stack of sensor elements, each measuring the conductivity in its vicinity.



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Microwave

- Used to Measure Level and Water Cut Detection
- Do not perform to accuracy levels in ppm, but useful in level control and WC
- Refraction, scattering and absorption of the microwave, change of speed and phase of the microwaves.
- Resonators, transmission sensors, reflection and radar sensors, radiometers, holographic and tomographic sensors and special sensors.
- Measure distance, movement, the shape of an object, the particle size of a particle and most commonly the material properties of an object or medium.
- Permittivity and Permeability

Agar Meter installation

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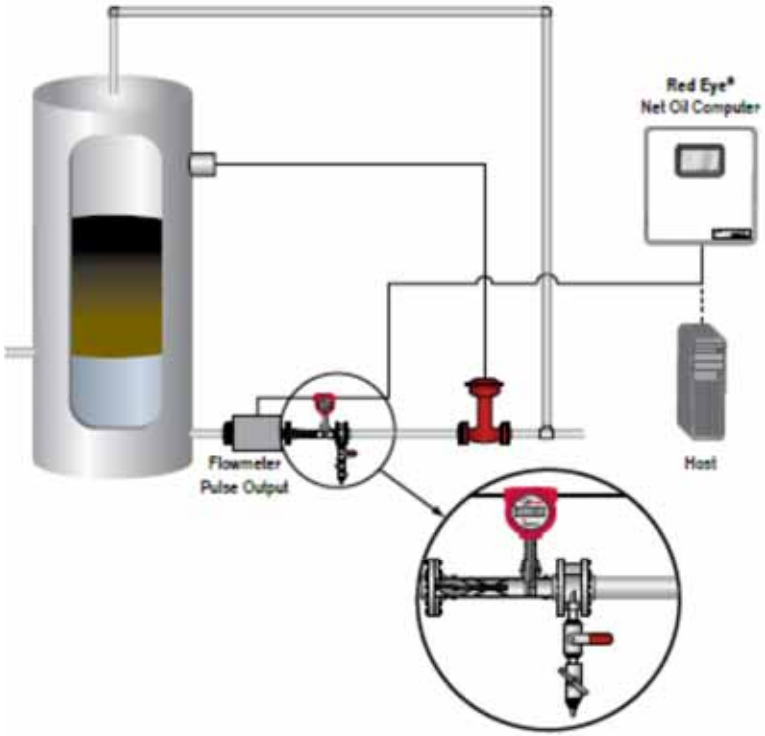
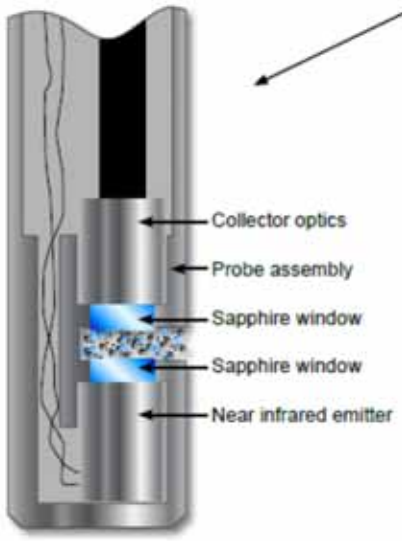
Near Infrared Adsorption





A local two-line display provides an instantaneous water-cut reading, active well number and instrument status information for user convenience.

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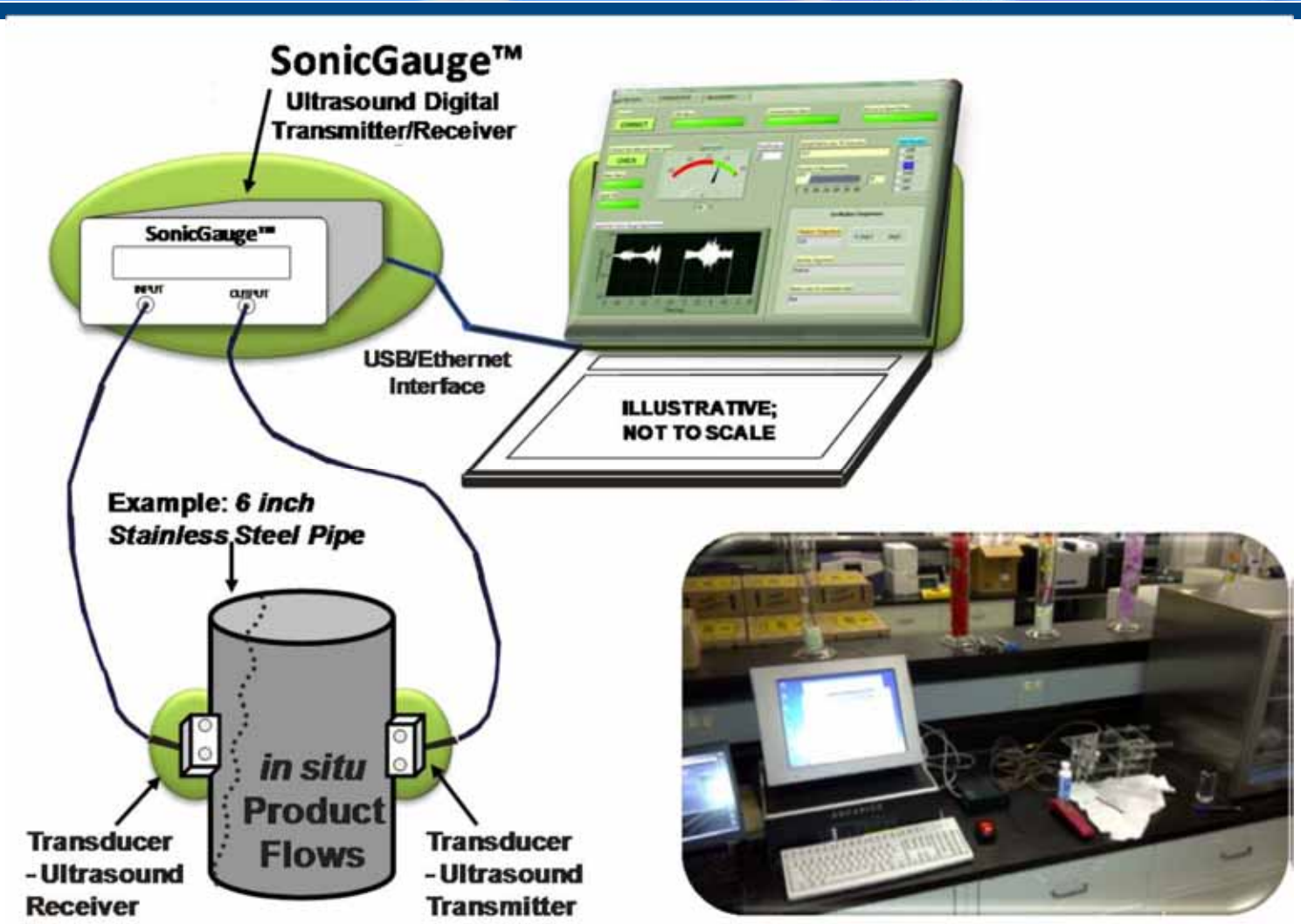
Ultrasonic



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Photometry

- Precisely focused light beam to penetrate the process medium.
- A photoelectric silicon cell measures the resulting light intensity.
- The change in light intensity caused by light absorption and/or light scattering is described by the Lambert-Beer law.
- The amount of light emerging from a sample is diminished by three physical phenomena:
- The amount of absorbing material in its path length (concentration)
- The distance the light must travel through the sample (optical path length OPL)
- The probability that the photon of that particular wavelength will be absorbed by the material (absorptivity or extinction coefficient)

Optek, model TF16

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Subsea Water Quality Montoring – Dynamic Developments

- These new methods can be combined with the proven 5 typical measurement principles leading to new methods to improve the reliability of monitoring systems deployed subsea.
- RPSEA having a forum on subsea water quality monitoring.
- Operators and Manufacturers are pushing the envelope and better utilizing these new technologies
- Eventually giving us “20/20 vision subsea”

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Conclusion

- Questions?

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