Inline Oil in Water Particle Analysis and Concentration Monitoring for Process Control and Optimization in Produced Water Plants

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1 INTRODUCTION

It is becoming increasingly important to monitor the concentration of oil in water throughout produced water plants. The increased concentration of water in oil fields is a critical area to optimize since the cost of produced is significant factor in profitability. It is equally important to monitor the particle size distribution, and concentration, of all the component particles within the produced water. In addition to oil, this may include gas, sand and other solids or foreign mater. Analysis of oil in water concentration throughout the plant is becoming more and more important, not only from an environmental point of view, but also from a process optimization viewpoint.

In the PW plant, separation is generally achieved by either mechanical equipment (cyclones, centrifuges etc.) or chemical additions (emulsion breakers). The system is complicated by the fact that input conditions to the Produced water plant vary as time progresses and any of the components can change in concentration and particle distribution. As we say there is no on spec waste stream.

Mechanical separators are designed & operated around a range of particle sizes, which determine the performance and efficiency of the equipment. Accurate particle analysis at both the input and discharge would enable separators to operate at their maximum potential. This would allow for greater control over the equipment operation, give the user a more in depth insight into how their equipment is performing, and therefore allow them to optimize the set up and running conditions.

Chemical addition is an effective form of oil and water separation. However, the relationship between amount of additive and separation performance is non-linear. In addition some of the curves for chemical addition are inverting. This means that for beyond this optimum amount, the separation performance does not increase in fact it is likely to decrease, and only increases the overall cost to the user. Also, this optimum amount can vary greatly from one produced water plant to another, or even from different parts of the process within the same plant. The availability of accurate particle analysis and concentration would enable the user to optimize separation, and prevent any over usage of chemical addition which will minimize cost and reduce environmental impact.

Knowing the particle size distribution and concentration of the component particles within the produced water in real time would give greatest process control, and therefore allow for process optimization within the produced water plant.

It is time to make use of all the advantages of the current technology and get the proper inputs in order to optimize the process. He every Produced Water conference there is always the comment brought up by the equipment suppliers, chemical suppliers and end user that if we knew what the conditions where as they occur we would handle things differently.

Now it is time to get the proper sensing throughout the process of the key parameters ….particle size and concentration of oil and sand. Trying to determine what is going on in the process by measuring the PPM level at discharge is like trying to count 6 lanes of traffic by standing in the middle of the highway. You know it is either crowded or empty but you don't have a real idea of what has happen to the traffic before it reached you. Proper monitoring throughout the process can now be done at pressure, at temperature and in real time. In addition the reliability of non-imaging system is always a major problem due to their sensitivity to chemical additions, sample line not being representative and fowling of optics, components feed lines. The use of these systems has always been problematic and limited. The idea of increasing their use has always been resisted. With the track record of online dynamic imaging being used in the chemical pharmaceutical, mining, polymer industries all in online applications we see this industry as bring able to take advantages of the same reliability and increased data analysis.

1.1 Reliability

System reliability is a key factor to expanding the use of particle analysis in produced water. This has been achieved through the following 3 factors.

1) Use of Fusion of Glass to Metal (Fuseview). This bonds the glass and metal together to avoid crevices that cause build up and fowling
2) High Intensity, Fiber Optic cold light which allows the process to be viewed at high speed. Keeping the process flowing prevents build up and fowling. In addition the cold light won't cause the product to "Bake On" the glass.
3) Optional Spray rings haven't been needed in Produced water application in concentrations all the way up to full Crude Oil. Spray rings designs are used in level and foam applications where the process cameras aren't in the center of the stream where you have high velocity.
4) Advanced imaging software that detects any stopping of the process flow and eliminates "stuck particle"from the data until they are cleaned off when the process stream is flowing.
5) Use of large diameter process piping 1 inch through full process pipe diameters avoid the build up due to small sample lines with low flow rates which natural plug and misrepresent the process conditions.

1.2 Explosion proof, Weather proof and portable

In order to truly effective explosion proof equipment must be used in produced water so that the monitoring of particle since and concentration can be accomplished directly in the process avoiding sampling and purging of the systems. Explosion proof imaging systems have been well established and are both FM (class 1 div 1 groups b,c and D) and Atex approved (eexdIIc t6) for all areas of the production platform.

2 DYNAMIC IMAGING OF LIQUID AND SOLID PARTICLES

Vision based technology is now at the forefront of process instrumentation across a large variety of industries and is well suited to use in produced water plants. JM Canty's vision based technique combines the latest CCD Ethernet camera technology, Canty's trademark fused glass and lighting technology, and Cantyvision Client software to provide real time measurement of oil in water

2.1 Technology Developments of Vision Based OIW Monitors

The simplest form of oil in water measurement available using vision based technology is using turbidity measurements. Using a non-microscopic camera, the system measures the amount the amount of light entering the CCD camera chip, from a light source on the opposite side of the produced water flow stream. The amount of light can be calibrated to represent a real world NTU value

Figure 1 illustrates turbidity readings taken from an installed offshore vision based turbidity unit. Simultaneous to the readings taken by the vision system, the facility also takes samples from the line and measures mg/l of OIW in a lab environment. Process upsets such as that recorded on 17th September shadowed the data recorded for the same period in the facilities laboratory.

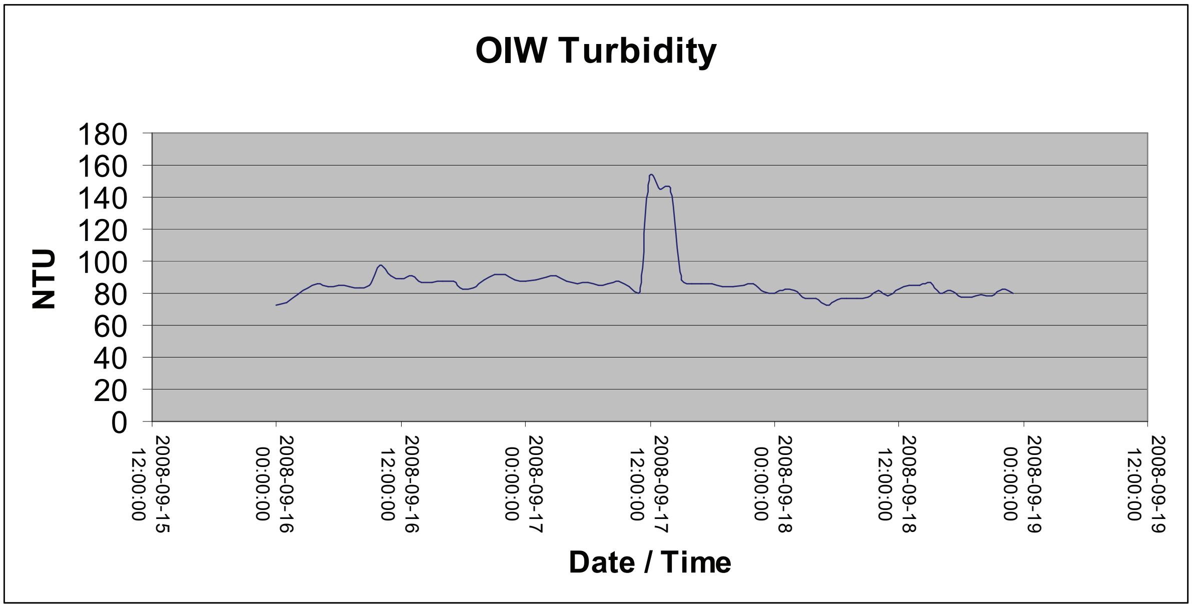


Figure 1 - OIW Turbidity Data

Vision based technology has moved on from this more simple form of measurement and has been greatly developed to give significantly more data up to a point where it can now give simultaneous PPM values for oil, gas and solids within a produced water stream, as well as sizing the individual particles. This development in vision based technology provides the operator with a mass of information giving an opportunity for increased process control and optimization

2.2 Dynamic Imaging Systems Design

Figure 2 - Microflow, Inflow and Particle Probe

Particle analysis of the components of produced water (oil, gas, sand, other foreign matter) needs to be measured at varied locations within produced water plants so it is important that the technology can be adapted to suit different conditions and applications. The technology used in JM Canty's system has been designed to fit into 3 different types of imaging units.

The Microflow, Inflow, and Particle Probe all combine the same technology which has been adapted to suit a variety of possible installation locations and applications. The Microflow has been designed as a laboratory unit, or a portable imaging system. The Inflow is used for inline applications. The Particle Probe is used on vessels or larger pipelines where the design becomes more economical, than using the Inflow. Each of the three designs work on the same principle, and combine the same Ethernet camera technology, with high intensity lighting, and very importantly, fused glass technology.

2.3 Dynamic Imaging Systems Functionality

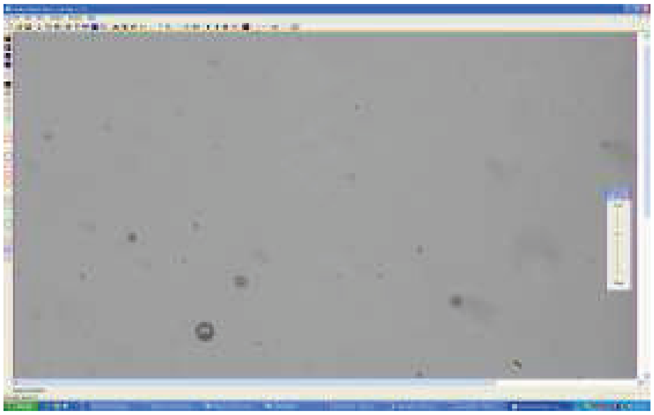
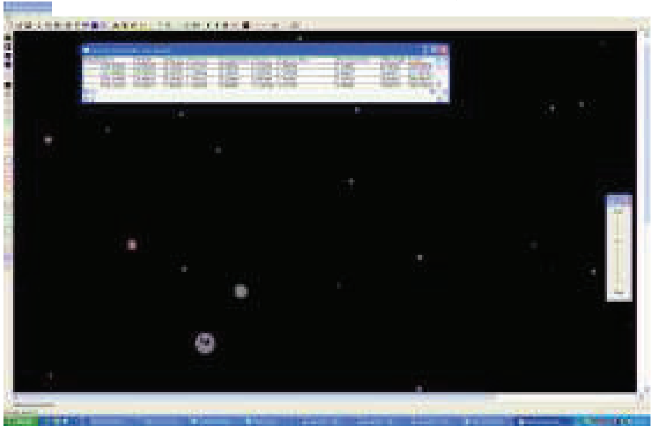


Figure 3 – Raw Image & Analysed Image



Dynamic imaging based systems developed by JM Canty work on the principle of presenting the produced water to a gigabit Ethernet camera. This is achieved by flowing the produced water through a backlit measurement zone in front of the camera which is looking through a fused glass lens to see the particles.

Images are captured, and each individual particle within the image is digitally mapped and analyzed using Cantyvision Client software (Figure 3). Each particle is characterized under a number of different parameters including major axis, minor axis, circularity, aspect ratio etc., as well as giving particle count and concentration outputs. The systems can be used to measure particles as small as 1 micron.

Particle filters within the software allow the separate yet simultaneous measurement of oil, gas and solid particles allowing for greater process control. Visual verification means that there will not being any doubts as to a measurement in a vision based system.

2.4 System Setup & Calibration

2.4.1 Particle Size Calibration

Figure 4 - Size Calibration Reticule

The system is visually calibrated and programmed to correlate each pixel in the camera array into a real world measurement value to create a pixel scale factor. A known size reference or a simple reticule will be correlated with the cameras pixel array providing an accurate scale for particle size analysis.

2.4.2 Particle Concentration Calibration (Theoretical)

The percent oil in water can be calculated using the formula below:

% Oil in Water = (Volume of oil in water / Volume of water) x 100

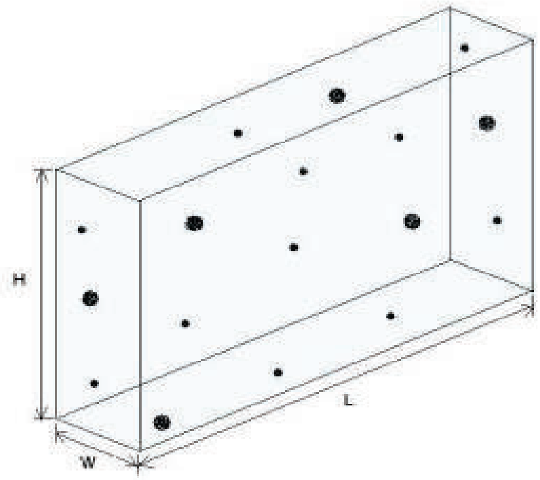


Figure 5 – Concentration Calibration Theory

We can calculate the volume of the oil droplets using the formula:

$4 / 3*\pi*r3$

Therefore we can calculate the concentration using the formula;

$$\text{Percent Oil in water} = \frac{\Sigma\ (\text{volume of oil particles})}{((\ W * L * H\ )* \text{number of images})} *100\%$$

where

N = Number of oil particles
Oil volume = Σ volume of oil particles

Volume of water = W * L * H

2.4.3 System Setup & Calibration (Actual)

A controlled sample of known concentration is run through the imaging unit. This sample is scanned and analyzed by the particle sizing software, which outputs a total area percent value. This relationship between this value and the sample PPM concentration is then inputted to the calibration field within the software.

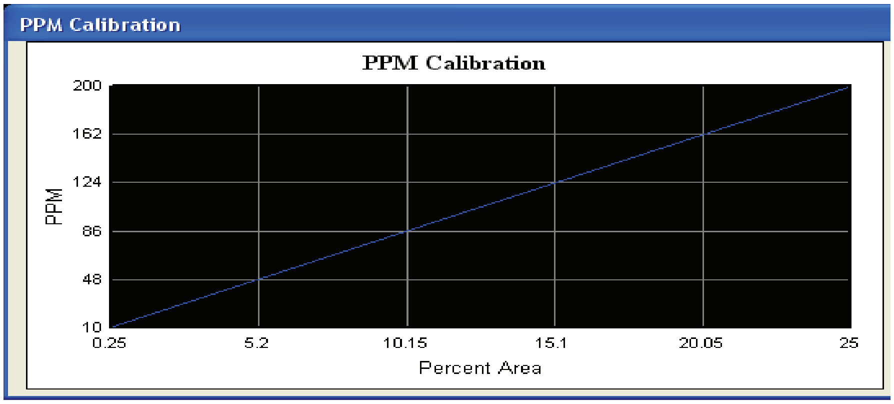
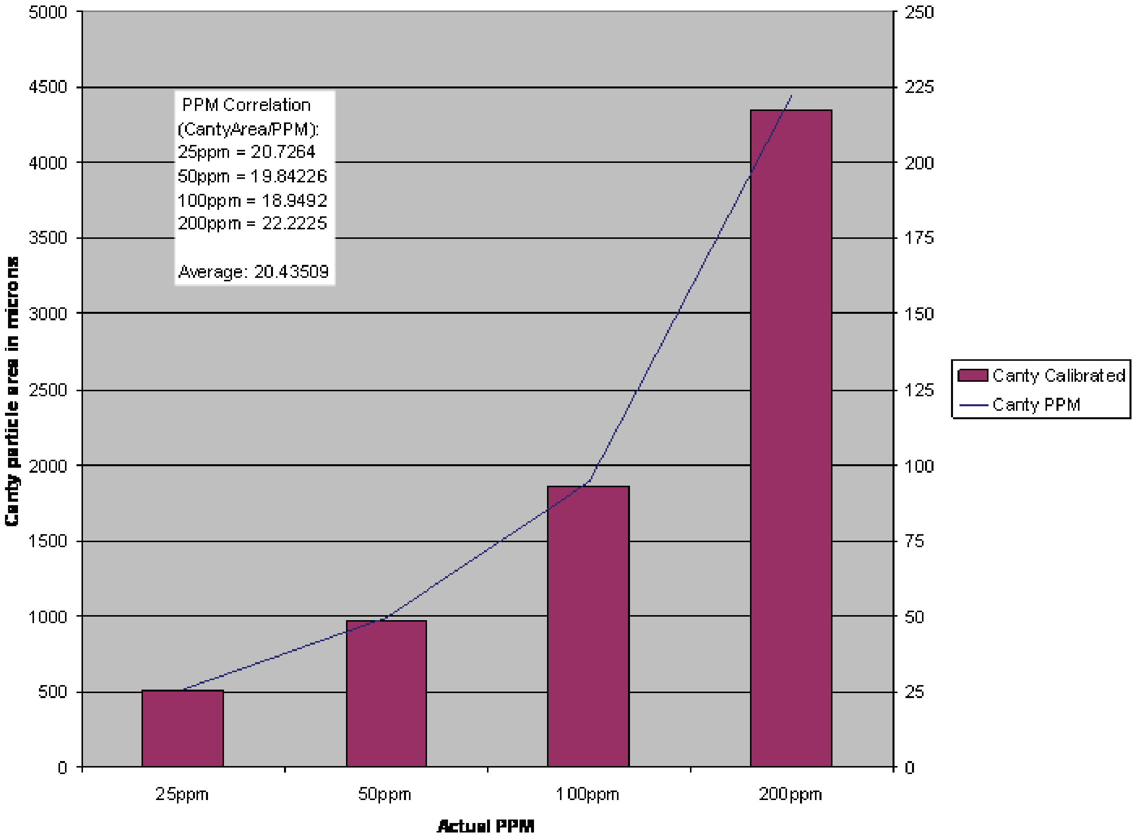


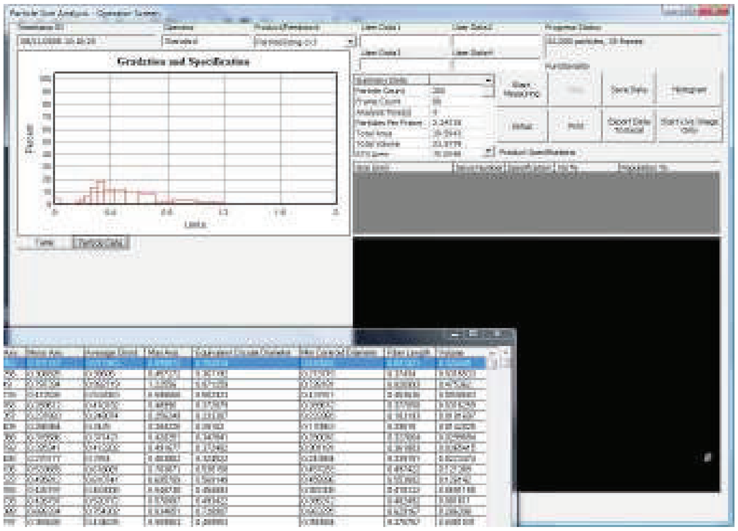
Figure 6 - CantyVision Calibration Screen


PPM Correlation (CantyArea/PPM):
25ppm = 20.7264
50ppm = 19.84226
100ppm = 18.9492
200ppm = 22.2225

Average: 20.43509

Figure 7 - Particle Area / PPM Correlation

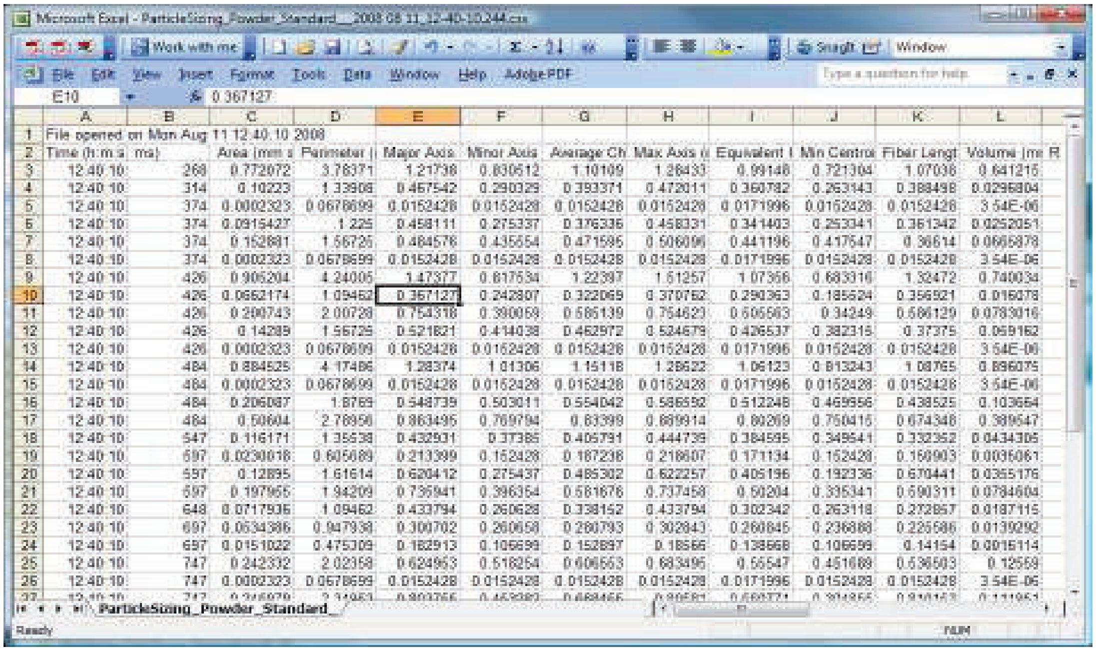
2.5 System Data Analysis and Outputs



Cantyvision Client software analyses in real time and outputs measured data into an MS Excel database, and onto an operator screen, which puts the information and configuration in an easy to read format for ease of operator control. This provides real time data updates so reactions can be quickly made and process control parameters adjusted as necessary.

Figure 8 - CantyVision Operator Screen

The outputted data is configurable specific to a particular application so depending on how the process is to be controlled; the relevant data can be outputted and used as a basis for control and optimization. The particle size distribution can be set based on a number of parameter (major axis, minor axis, area, perimeter etc.). Measurement outputs are provided via OPC or 4-20mA direct to the DCS allowing for greatest process control within the produced water plant.



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1	File opened on Mon Aug 11 12:40:10 2008												
2	Time (h:m:s ms)		Area (mm s	Perimeter (	Major Axis	Minor Axis	Average Ch	Max Axis (	Equivalent I	Min Centroi	Fiber Lengt	Volume (m	R
3	12:40:10	268	0.772072	3.78371	1.21738	0.830512	1.10109	1.28433	0.99148	0.721304	1.07036	0.641215	
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7	12:40:10	374	0.152881	1.56725	0.484578	0.435554	0.471595	0.506096	0.441196	0.417547	0.38614	0.0665878	
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9	12:40:10	426	0.905204	4.24005	1.47377	0.817534	1.22397	1.51257	1.07356	0.683316	1.32472	0.740034	
10	12:40:10	426	0.0662174	1.09462	0.367127	0.242807	0.322069	0.370762	0.290363	0.185524	0.356921	0.016078	
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12	12:40:10	426	0.14289	1.56725	0.521821	0.414038	0.462972	0.524679	0.426537	0.382315	0.37375	0.059162	
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18	12:40:10	547	0.116171	1.35538	0.432931	0.37385	0.405791	0.444739	0.384595	0.349541	0.332352	0.0434306	
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26	12:40:10	747	0.0002323	0.0678699	0.0152428	0.0152428	0.0152428	0.0152428	0.0171996	0.0152428	0.0152428	3.54E-06	

2.6 System Advantages

- Lighting
  Vision based systems require highly developed lighting technology to be most effective for process optimization. The Microflow, Inflow and Particle Probe all use a high intensity halogen light source with IR energy removed to prevent heating of the viewing surface which reduces the likelihood of product adhering to the glass. With high velocity produced water lines, the shutter speed of the camera in the vision based system will need to be increased so consistent lighting conditions are necessary. The high intensity light source used is a non-strobe source and so can cope with high shutter speeds required to capture usable images within a high velocity fluid stream without any synchronising issues between light and camera.

- Fused Glass
  The vision based system's ideal operating position is in the centre of the produced water pipeline. At this point the fluid is moving at its greatest speed with minimum drag effect from the pipe walls. The fused glass technology eliminates any pockets or recesses where product can adhere to and start to build up causing plugging issues (Figure 10). A hermetic seal exists between the glass and metal making it a one piece construction, and so makes obsolete the use of gaskets or o-rings. This fused glass together with the fact that the flow velocity of produced water is greatest in the centre of the pipeline essentially make the vision based system a self cleaning unit. Fused glass technology allows the systems to be installed at pressures up to 400 BAR.

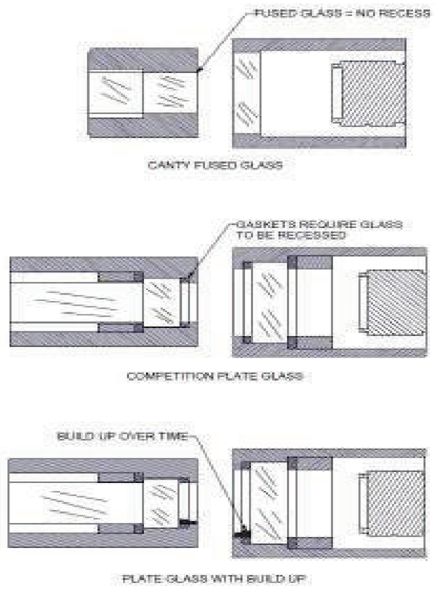

Figure 10 - Fused Glass Technology

- Environmental Ratings (No Purge)
  NEMA 4 / IP66
  FM Explosion Proof Class I, Div. 1 Groups B, C & D
  Class II, Div. 1 Groups E, F & G
  ATEX Flame Proof Eex d IIC T6

- Inline Unit
  For greatest process control and optimization, the ideal installation is inline as it gives the most accurate representation of what is happening in the system, as well as allowing for speedier analysis without a time lag between process readings and current process conditions.

3 CONCLUSIONS & OBSERVATIONS

Process control and optimization within produced water plants today is critical from both an environmental and process performance viewpoint. The technology currently available within imaging systems is at the forefront of process instrumentation as a whole. This technology has been proven to be applicable for particle analysis of produced water and so should be utilised to the fullest within produced water plants. Dynamic imaging based systems can provide operators with a view and understanding of what is happing within the separation process which no other instrumentation can compete with. It is only through greater process understanding that we can hope for greater process control.