Case History:

Application of Best Available Technology to Upgrade the Produced Water Treatment System and Continuously Monitor Oil & Grease (O&G) Content to Operate within Environmental Discharge Limits

Enviro-Cell™

Advanced Sensors

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1. INTRODUCTION

A Major Oil Company has been interested in implementing an Advanced Warning System (leading indicators) to manage the potential problems associated with National Pollutant Discharge Elimination System (NPDES). Recently the platform recorded an NPDES discharge exceeding the required discharge limits set by Bureau of Ocean Energy Management, Regulation and Enforcement (BOEM) (formerly MMS). This exceedance was due in part to equipment failure combined with human error resulting in non-compliance. Other problems were cited but not considered main causes such as the efficiency and effective operation of the existing Skimmer and Flotation Cell. Because of events like this the Major Oil Company has chosen to be proactive holding firm to their Tenants of Operation. Their proactive approach on this project includes two main items of focus:

1. To anticipate events through advanced technology thus preventing the ultimate event of hydrocarbon discharge into the Gulf of Mexico.
2. Upgrade and or Replace existing Produced Water Treatment equipment to meet the Best Available Technology (BAT) requirements including surge protection, upset management and minimal equipment downtime.

The Major Oil Company and Enviro-Tech System's combined efforts on this project are discussed in detail in the following pages of this technical presentation highlighting their efforts in improving operation through advanced technology.

2. ORIGINAL PROCESS

The existing process for handling the produced water phase included a fired vessel (Heater Treater) to treat the incoming oil and water for maximum treatability of the water phase. The water phase exits the Heater Treater with a high concentration of hydrocarbon in the water. This portion of the water phase enters the Horizontal Skimmer at approximately <500 PPM with an exit effluent of < 200 PPM before entering the Petrolite Flotation Cell which acts as a water polisher removing remaining hydrocarbon down to a tolerable rate of < 29 PPM. The events which lead up to the non-compliance are as follows:

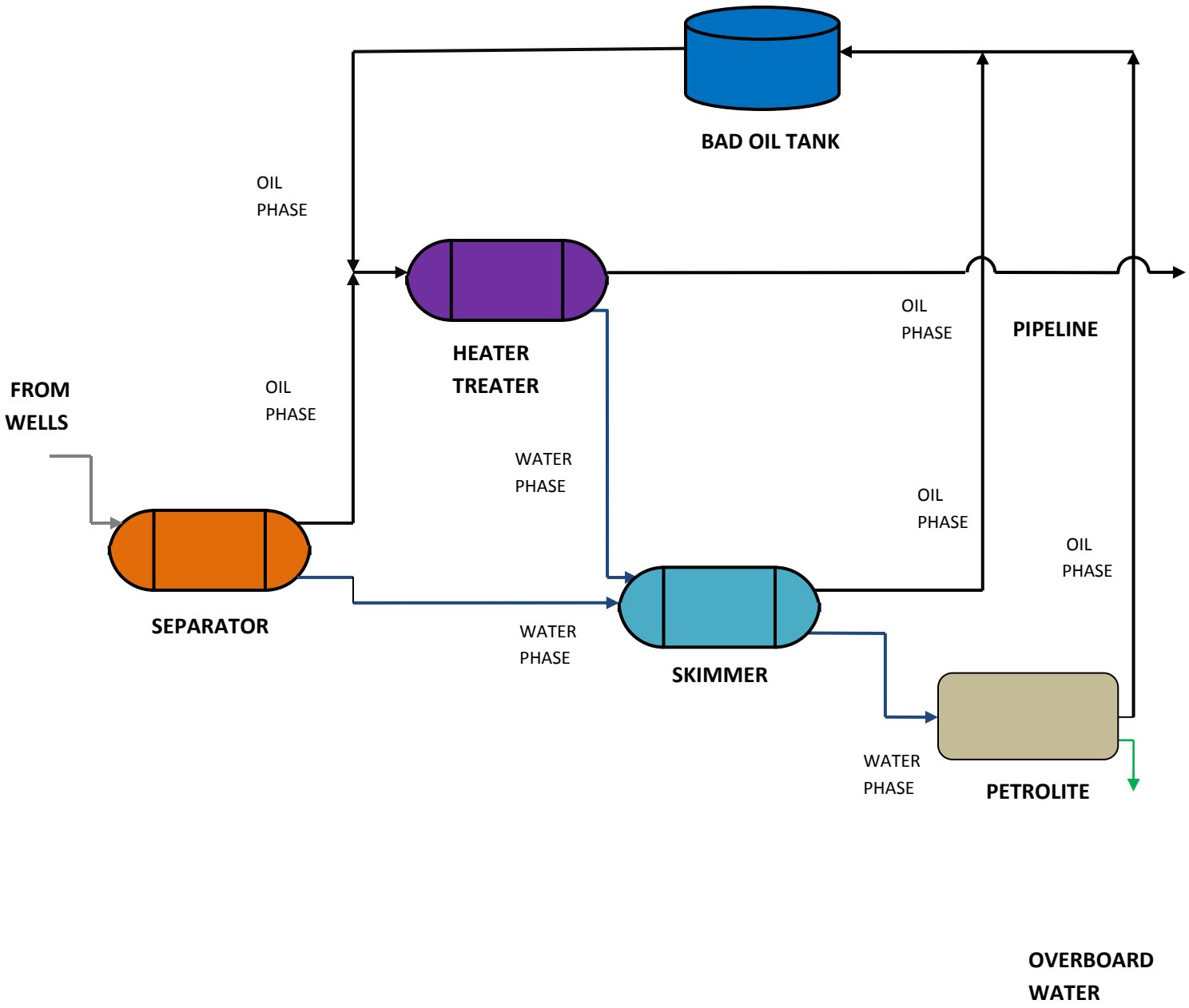
2.1 Description of the Existing System

1. Heater Treater discharge control valve opens and closes on demand from a proportional level controller mounted on the vessel. The internal level of the Heater Treater is controlled by a snap acting controller which holds the level relatively constant until there is demand to remove the liquid level for further treatment. The control valve opens periodically to allow treated water to leave the Heater Treater and enter the Skimmer for further treatment.
2. The Skimmer is sized to provide approximately 10-15 minutes of retention time thus allowing for ample separation to occur to the incoming produced water so that the final treatment is substantial enough to meet the discharge requirement.
3. The final stage of treatment is the Induced Gas Flotation Cell which is designed to provide approximately 5 minutes of retention time which is sufficient time for a final polishing step before the water is discharged overboard.

2.2 Sequence of Events Leading to Non-Compliance

1. It is understood that the control valve on the Heater Treater stuck in the open position (normally closed valve) thus allowing for the contents of the Heater Treater to be dumped continuously to the Skimmer.
2. The Skimmer sized with 10-15 minutes retention time was unable to handle the high influx of oil with effectiveness thus began to dump pure hydrocarbon to the Induced Gas Flotation Cell.
3. The Petrolite Flotation cell having 90% removal efficiency saw an increase in hydrocarbon well beyond its normal capability resulting in non-compliance.

2.3 Process Flow Diagram of the Existing System



3. DEFINING THE SOLUTION

The existing process for handling the produced water phase was properly sized and functioning properly for the existing process. There were three (3) issues determined that needed further evaluation:

1. **Future prevention and anticipation of the unforeseen event**. The ultimate event of hydrocarbon discharge can be foreseen and prevented using continuous Oil-in-Water (OIW) monitoring that would be a reliable and accurate source of Oil and Grease (O&G) content. The continuous online monitoring will give operators 24 hr surveillance thus indicating any potential or apparent problems or pending upsets in all equipment that is part of the water phase. Traditional grab samples are time consuming. Visual inspection is typically after the fact and not always clear and apparent.
2. **Routine and regular maintenance to the existing equipment**. The Petrolite unit at the platform is a mechanical induced gas flotation cell and hence requiring considerable maintenance. This unit has experienced a periodic maintenance plan over the last 3-4 years. The efficiency of the Petrolite unit can be compromised during maintenance when maintenance of the agitators is required. Taking one out of service for any length of time may mean reduced efficiency. Since the induced gas flotation cell is a critical part of the produced water treatment system it is critical to keep it in service at full capacity unless a redundant system is in place.
3. **Review of Best Available Technology** should be considered especially when deciding to replace existing equipment.

The Major Oil Company is in search of alternatives to upgrade the produced water treatment system and continuously monitor the O&G content. This has been a concern of the company for a long time and extensive research has been done on their part to find a methodology to prevent human error through technology.

3.1 The Solution:

1. **Replace existing equipment which is outdated and in need of extensive repair and maintenance**
2. **Monitor the operation of the Full Water Treatment system along with individual monitoring of each component to pinpoint trouble spots.**

3.1.1 Replace aging equipment

First step was to find an improved method of handling produced water adding features that would assist in this prevention of the unforeseen discharge. The Enviro-Cell was found to have inherent features that would benefit that cause and not compromise the overboard water quality.

3.1.2 Features and Benefits of the Enviro-Cell. Why chosen?

1. Cylindrical design providing better structural integrity and less opportunity for corrosion and collection of solids that cause that corrosion.
2. Increased Inlet surge capacity allowing for inlet flow surge up to 20% without a decline in efficiency.
3. Full 5 minute retention time with consideration to the recirculation rate being included in the retention time.
4. Improved efficiency without the probability of downtime from mechanical agitation.
5. Improved recirculation system reducing the recycle rate and increasing the discharge pressure therefore increasing the gasification of each cell providing more bubble per cross sectional area of each cell.
6. Low maintenance due to less moving parts.

Figure 1 below shows the cut away of the Enviro-Cell unit to illustrate the above mentioned features.

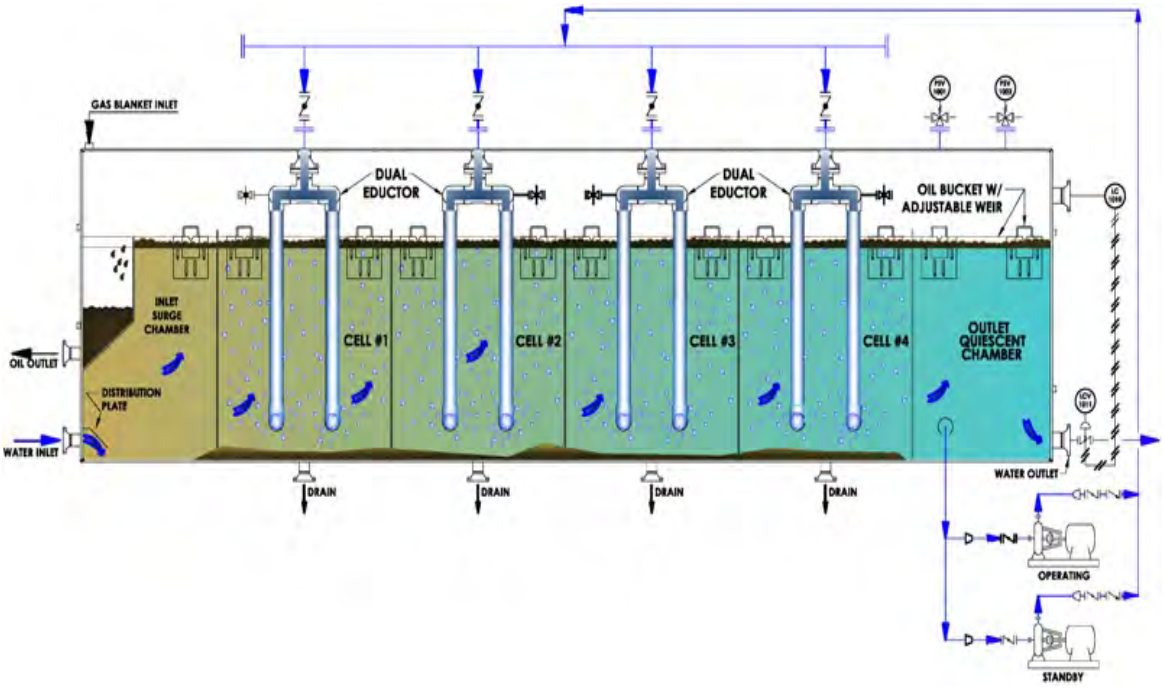


Figure 1: Cut Away of the Enviro-Cell unit to illustrate the operational features and benefits the float cell.

Figure 2 below shows the unit installed on the platform.

Figure 2: Enviro-Cell unit installed on the platform.

Figure 3 below shows the performance of Enviro-Cell unit installed at the platform from 10/15/2010 to 10/16/2010. From the chart it can be observed that the effluent readings from the Enviro-Cell were in the range of 8-18 PPM.

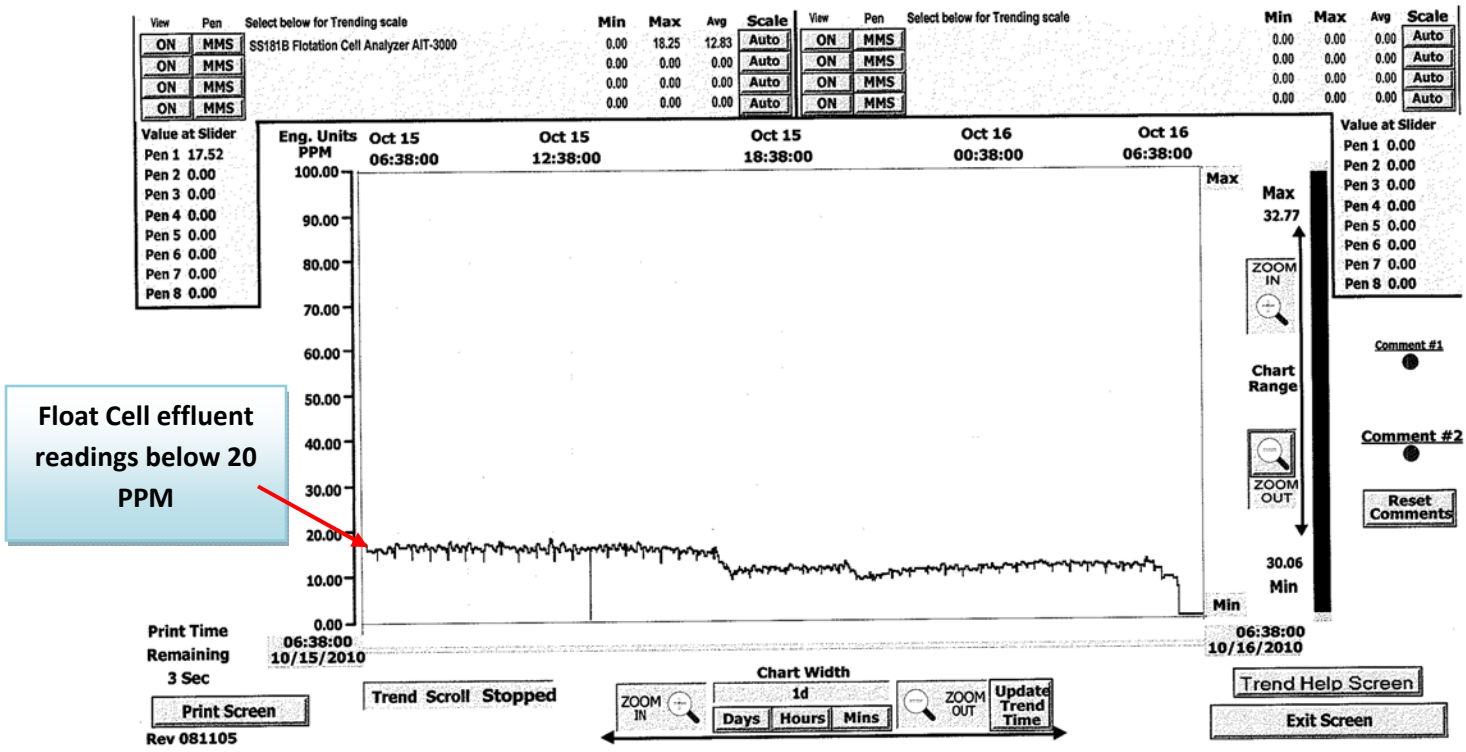


Figure 3: Performance of Enviro-Cell unit installed on the platform.

3.2 The Solution: Monitor Full Water Treatment System using Advanced Technology for Continuous Online PPM Monitoring

3.2.1 Overview

In an attempt to prevent NPDES overboard water violations the company researched various available technologies that would alarm platform operators of upsets and give personnel the opportunity to locate and repair/ adjust system prior to discharge into the GOM.

A variety of analytical methods have been developed to monitor the O&G or TPH in produced water. The common methods currently utilized for monitoring hydrocarbons in water include gravimetric, ultraviolet-visible (UV-vis), infrared (IR), Turbidity meters and fluorescence (FS) spectrometry. There are many challenges associated with these devices which affect their

accuracy and reliability. They are as follows:

1. **Optics Fouling:** Caused by oil build up, scaling and precipitates.
2. **Oil Droplet Size Variation:** Process variation, sample flow, location, sample tap point, sample collection Method
3. **Chemical Additive Interference:** Process chemicals are hydrocarbon derived and often cause interference with fluorescence analyzers.
4. **Operating Range:** Varying compositions and conditions.
5. **Accessibility:** Constant Mobilization to the field for Calibration and cleaning by Technicians is undesired

In the search for continuous oil-in-water (OIW) monitor that could overcome the above mentioned challenges the decision to purchase and install the **Advanced Sensor monitor** was made. The study was designed to determine if new generations of OIW monitors could improve operations through alarms and trend analyses.

3.2.2 Measurement Technique

The measurement technique incorporated in the Advanced Sensor's monitors is laser induced fluorescence. The transducer sensor head is a patented, combined Optical and Ultrasonic component. Water passes through a measurement chamber (300mL), within the chamber there is a small sapphire window used for measurement and a larger sapphire window for viewing the inside of the chamber. The laser passes through a smaller sapphire window to excite the water sample, the fluorescent properties are captured via Optical fiber light guides and taken to:

• An optical filter and photo multiplier tube (PMT), the optical filter selected depends on the wavelength properties in the water.

• And an optical UV spectrometer (for the EX1000)

Figure 4 below shows the equipment layout of the Advanced Sensors self-cleaning, continuous, online OIW monitor.

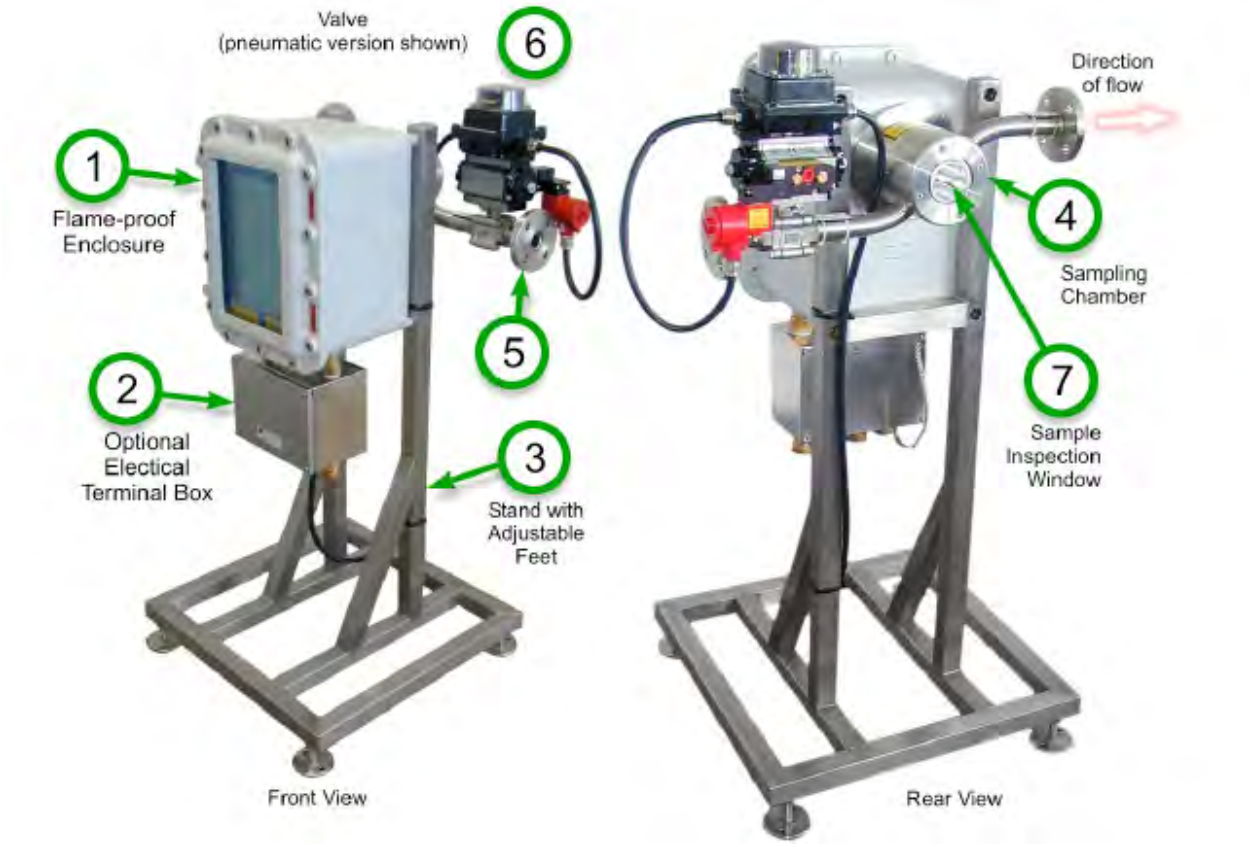


Figure 4: Equipment layout of the Advanced Sensors OIW Monitor.

Figure 5 below shows the sampling chamber of Advanced Sensor's OIW monitor.

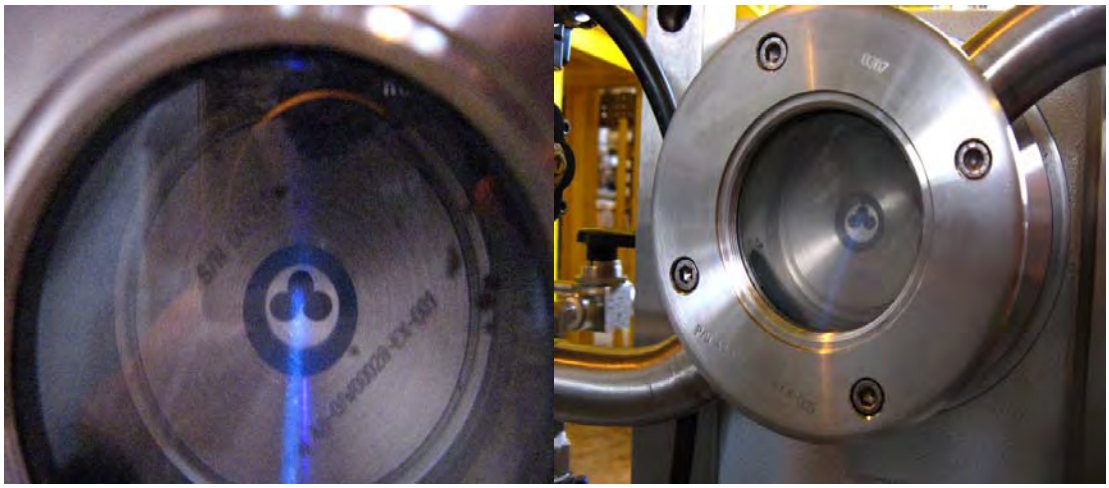


Figure 5: Sampling Chamber of Advanced Sensors OIW Monitor.

Figure 6 below shows a simplified schematic of Advanced Sensors OIW monitor.

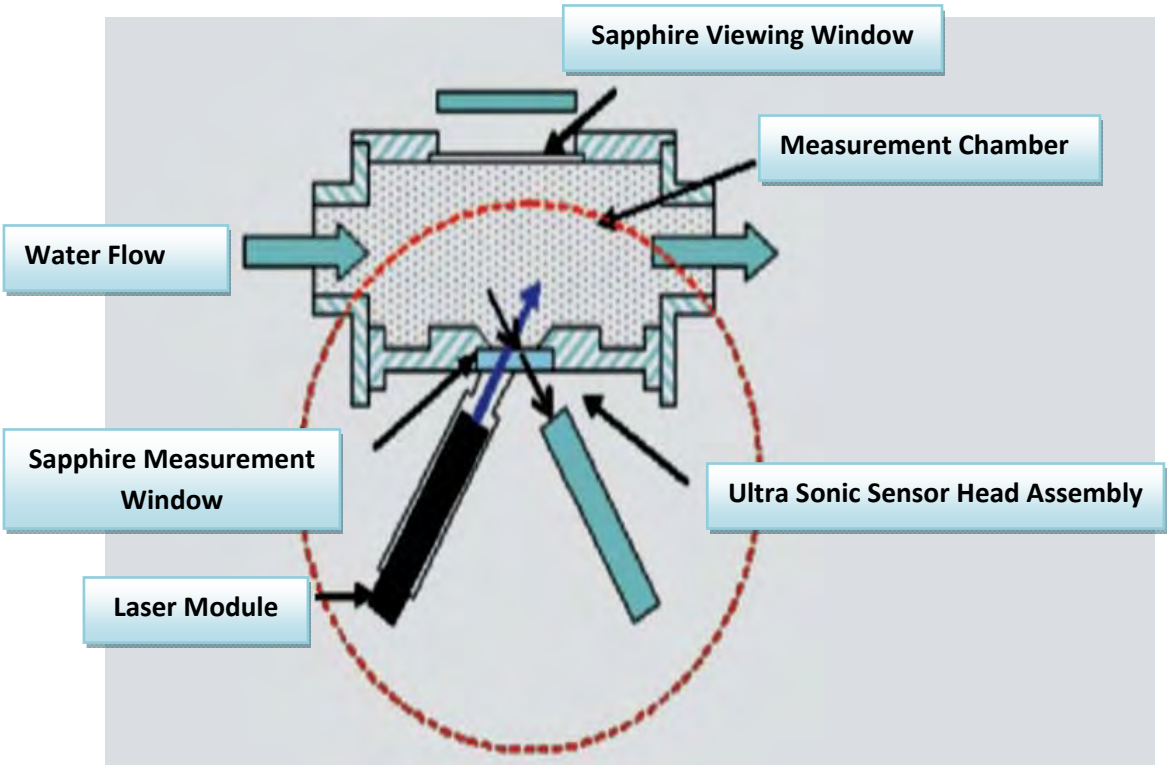


Figure 6: Simplified Schematic of Advanced Sensors OIW Monitor.

3.2.3 Installation

The Hydrocarbon discharge incident urged the need for continuous online monitoring and hence two (2) Advanced Sensor's unit were installed at the platform. The platform's produced water process train is as follows: Separators--Skimmer--Flotation Cell--Overboard. One (1) unit was installed to monitor the inlet and outlet O&G concentrations for the Skimmer and the other unit was installed to monitor the effluent O&G concentration for Enviro-Cell Flotation unit.

Table 3 below shows the initial results tested against the lab at the platform for the overboard water from the Enviro-Cell. It can be observed that the PPM readings from IR device closely match the PPM readings from Advanced Sensor's unit.

Sample	Location	Advanced Sensor Reading (PPM)	Platform IR Device (PPM)
1	Overboard from Enviro-Cell	6.2	5.7
2	Overboard from Enviro-Cell	6.2	5.9
3	Overboard from Enviro-Cell	6.4	6.3
4	Overboard from Enviro-Cell	6.1	6
5	Overboard from Enviro-Cell	5.9	6
6	Overboard from Enviro-Cell	6.2	5.9
7	*Overboard from Enviro-Cell *By Platform Personnel	12	14

Table 3: Initial results tested against the lab at the platform for overboard water from Enviro-Cell.

Table 4 below shows the initial results tested against the lab at the platform for the Skimmer outlet. It can be observed that the PPM readings from IR device closely match the PPM readings from Advanced Sensor's unit.

Sample	Location	Advanced Sensor Reading (PPM)	Platform IR Device (PPM)
1	Skimmer Outlet	172.5	187.5
2	Skimmer Outlet	195.5	201.7
3	Skimmer Outlet	191.0	196.4
4	Skimmer Outlet	176.0	185.4
5	Skimmer Outlet	189.8	198.7

Table 4: Initial results tested against the lab at the platform for overboard water from Skimmer outlet.

* Skimmer Inlet Oil Concentration too high to verify against the field instrument, however there was a considerable difference between the inlet and outlet which tracked the monitor's graphs.

Figure 7 and 8 below show the O&G PPM readings at the Skimmer Inlet.

Figure 7: O&G Concentration of 449 PPM at the Skimmer Inlet.

Figure 8: O&G Concentration of 384 PPM at the Skimmer Inlet.

Figure 9 below shows the chart for the PPM readings at the Skimmer Inlet.

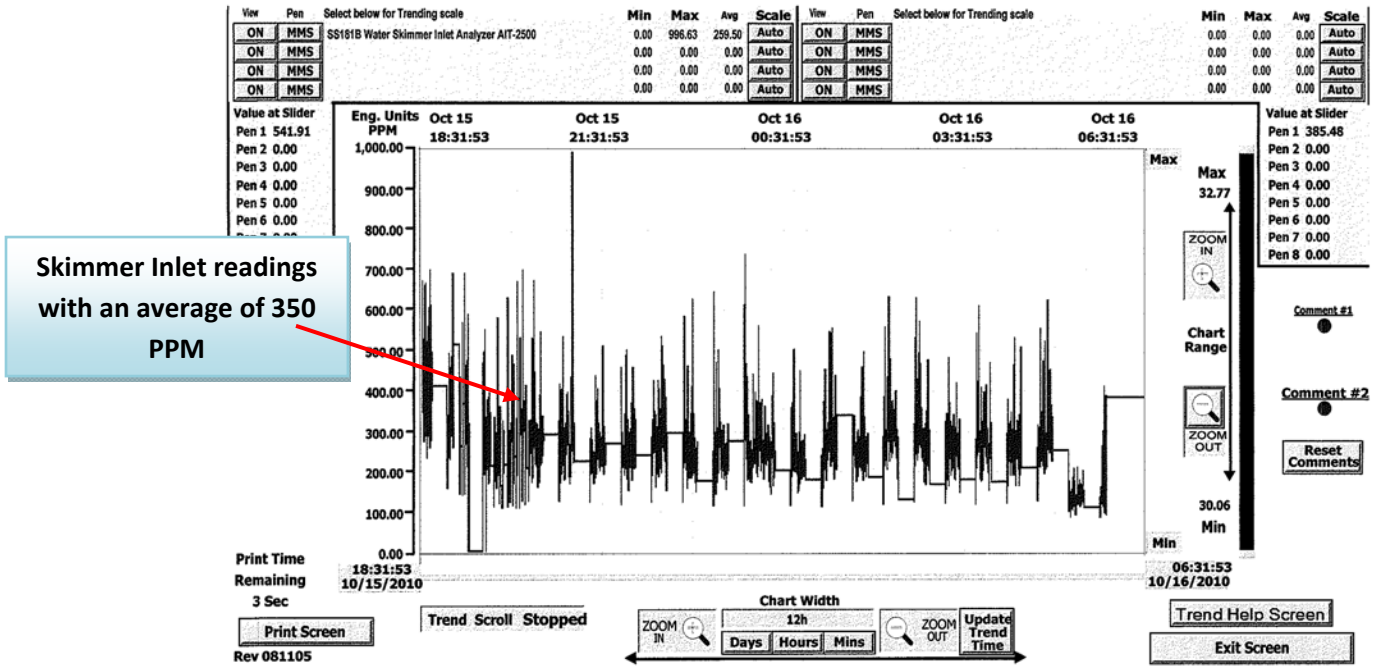


Figure 9: O&G Concentration chart recorded by the Skimmer Inlet Analyzer AIT-2500.

Figure 10 below shows the upset experienced by the Skimmer Inlet on October 13, 2010.

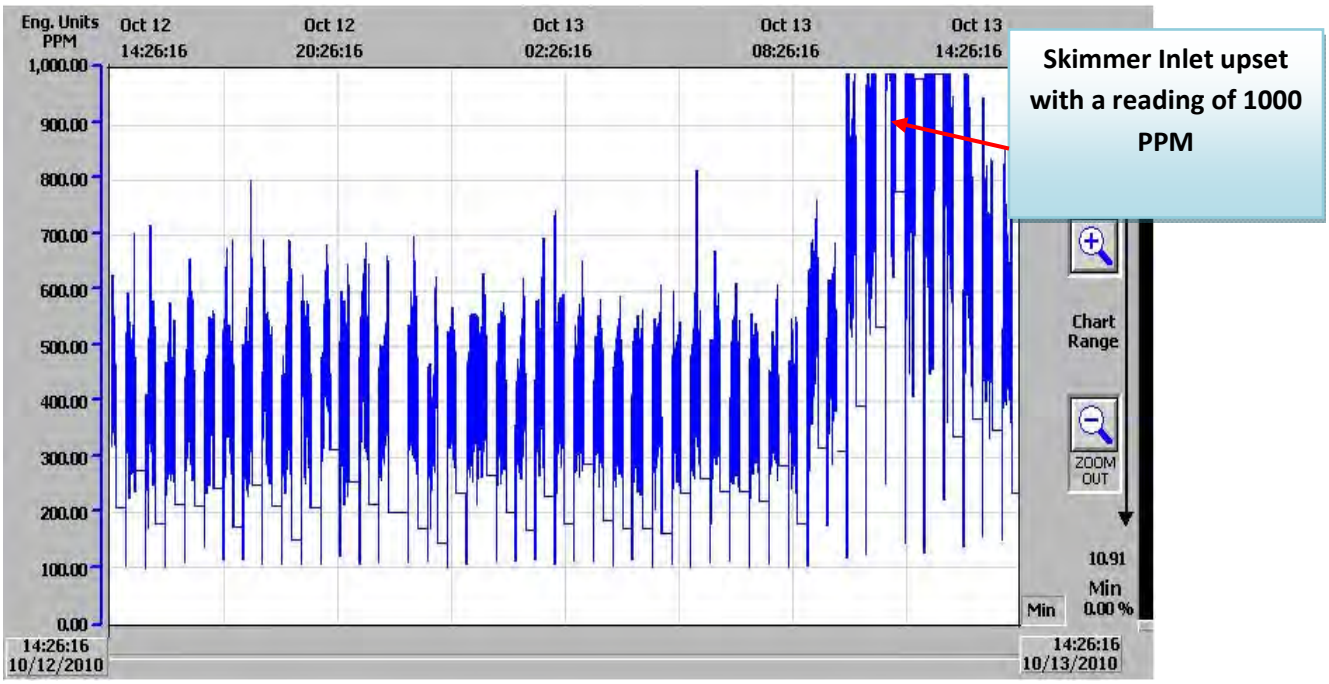


Figure 10: Upset experienced by the Skimmer Inlet on October 13, 2010.

Figure 11 and 12 below show the O&G PPM readings at the Skimmer Outlet.

Figure 11: O&G Concentration of 159 PPM at the Skimmer Outlet.

Figure 12: O&G Concentration of 177 PPM at the Skimmer Outlet.

Figure 13 below shows the chart for the PPM readings at the Skimmer outlet.

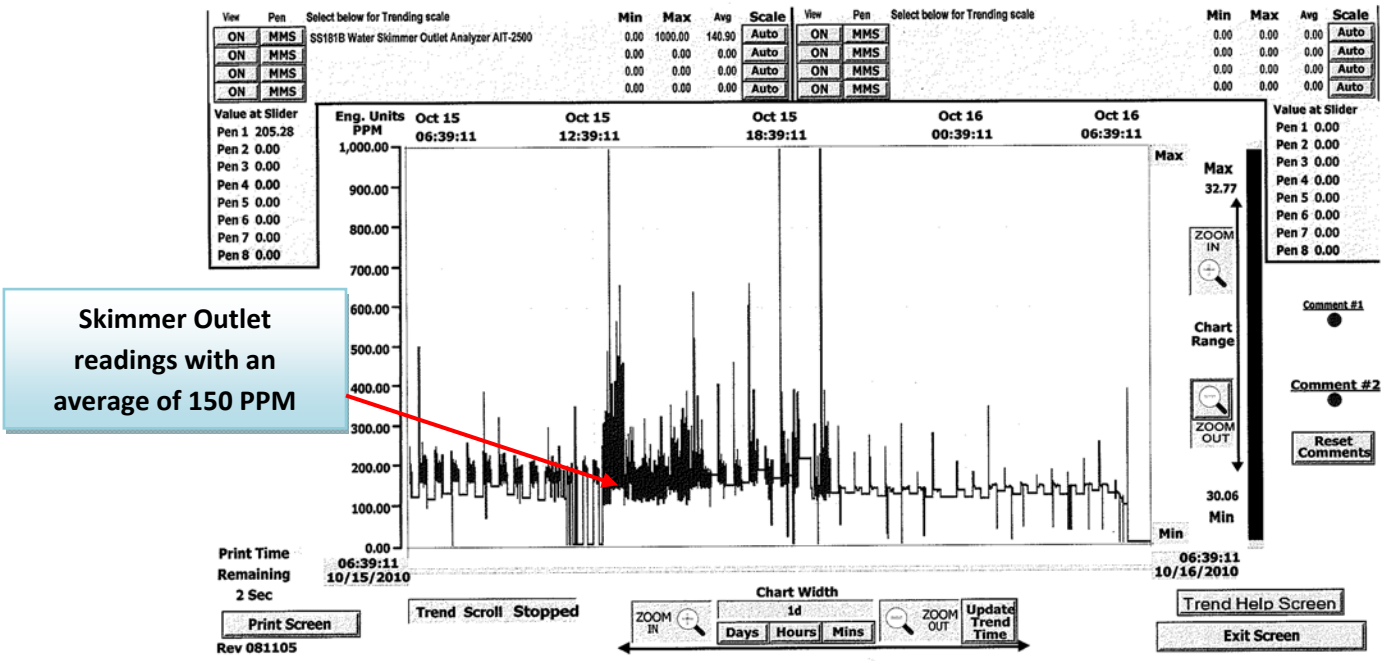


Figure 13: O&G Concentration chart recorded by the Skimmer Outlet Analyzer AIT-2500.

Figure 14 below shows the upset experienced by the Skimmer Outlet on October 13, 2010.

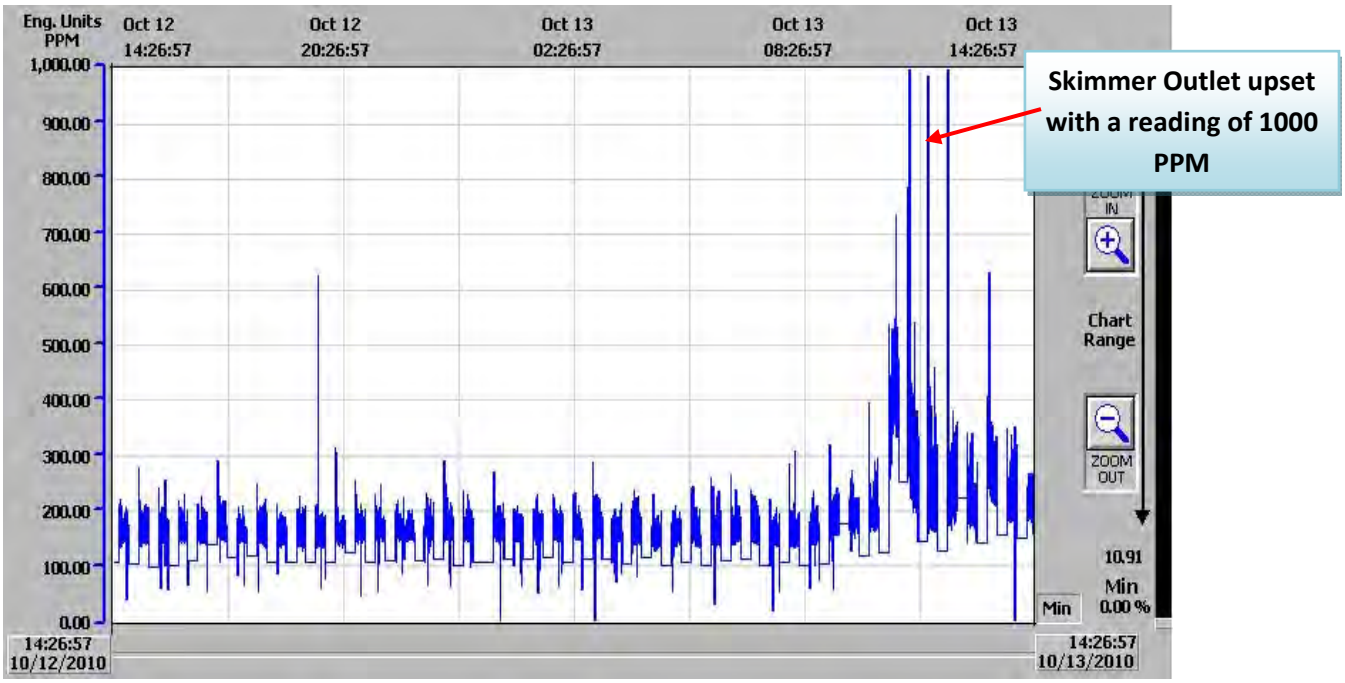


Figure 14: Upset experienced by the Skimmer Outlet on October 13, 2010.

Figure 15 and 16 below shows the O&G PPM readings at the Enviro-Cell Outlet.

Figure 15: O&G Concentration of 11 PPM at the Enviro-Cell Outlet.

Figure 16: O&G Concentration of 14.8 PPM at the Enviro-Cell Outlet.

Figure 17 below shows the chart for the PPM readings at the Enviro-Cell outlet.

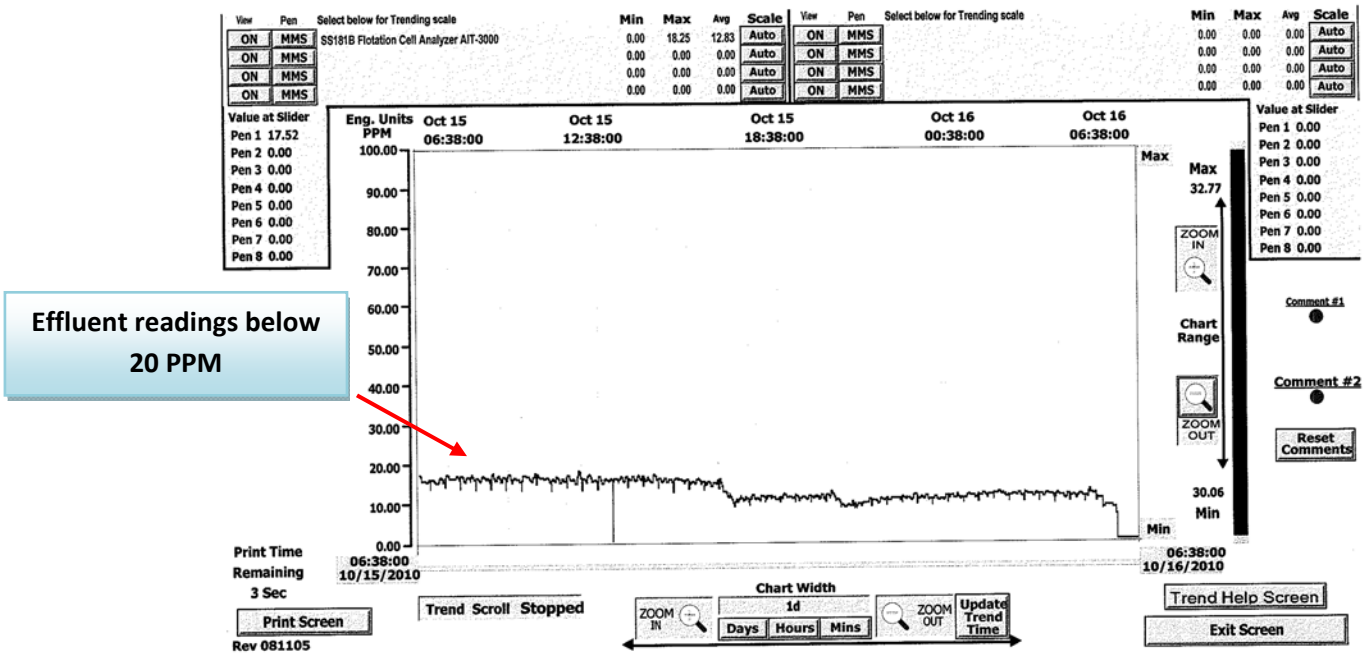


Figure 17: O&G Concentration chart recorded by the Enviro-Cell Outlet Analyzer AIT-3000.

Figure 18 below shows the upset experienced by the Float Cell on October 13, 2010.

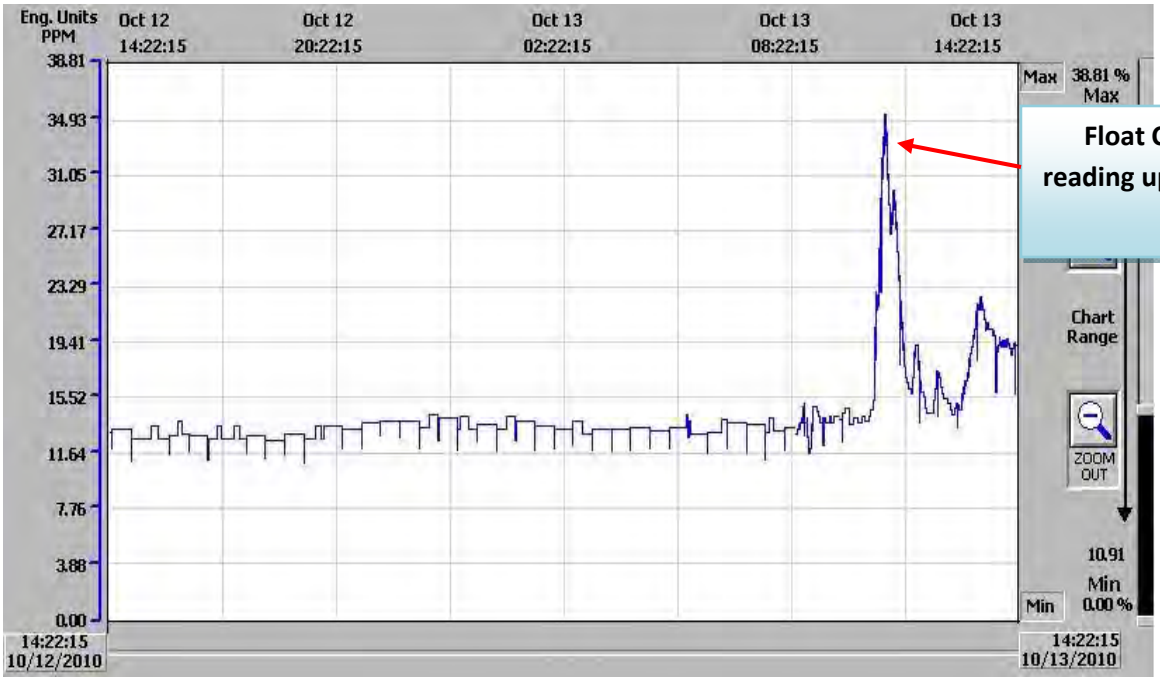
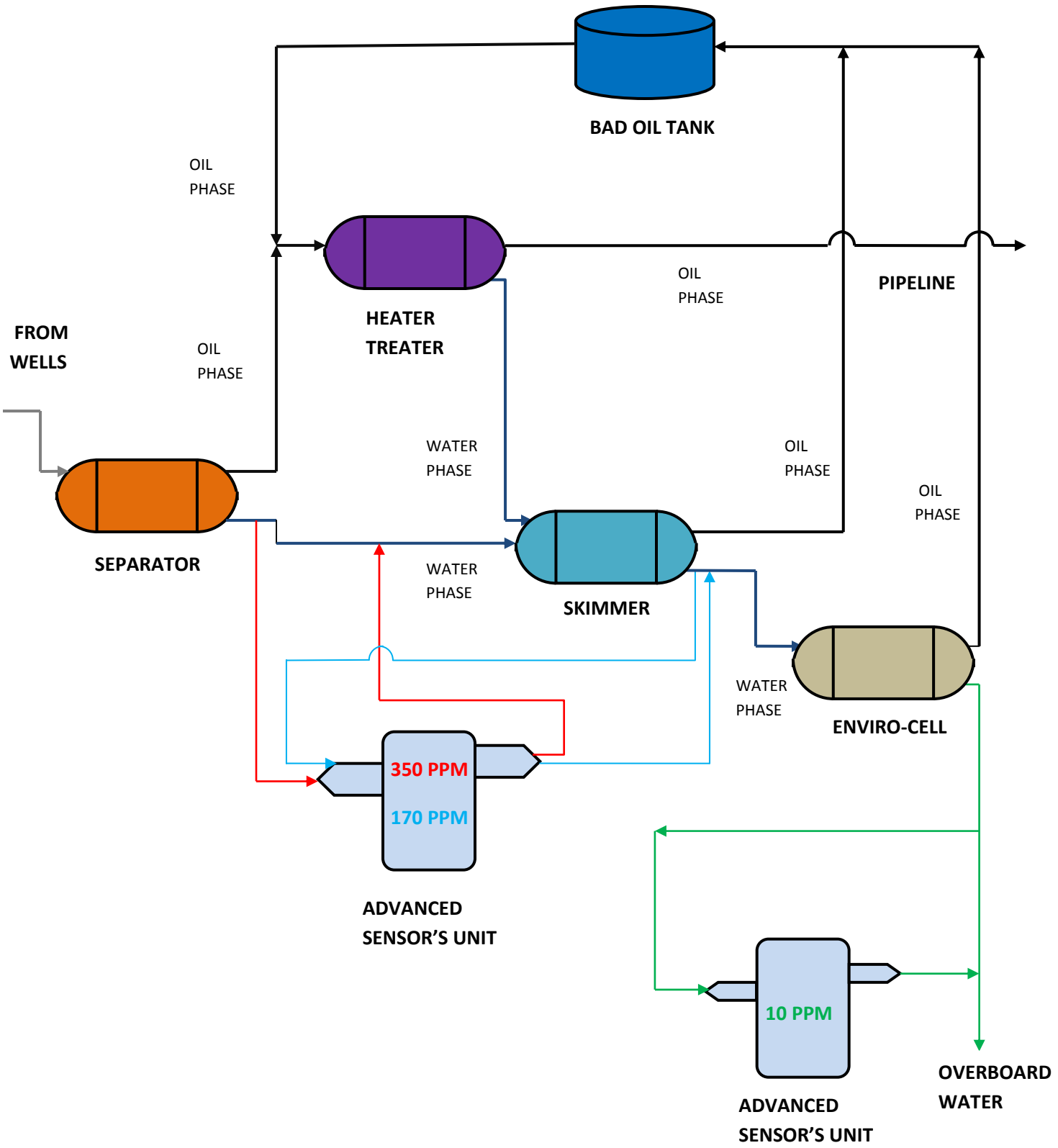


Figure 18: Upset experienced by the Float Cell on October 13, 2010.

3.3 Process Flow Diagram after Modifications



4. POTENTIAL ADVANTAGES OF ADVANCED SENSOR

1. The Advanced Sensors OIW monitor reduces daily lab technician time and solvent use/exposure.
2. Platform can use the analysis from Advanced Sensors OIW monitor for reporting.
3. Real-time production analysis & improved process control.
4. Process optimization for achieving higher oil production without increased oil discharges.
5. Potential for analysis of production chemicals concentrations.
6. Remote connectivity, monitor setting changes can be done from Engineers desk, thus eliminating field visits.
7. Unmanned platform surveillance
8. Highest accuracy and reliability in the industry

5. CONCLUSIONS

1. The Advanced Sensors unit installed on the platform helps the operators to continuously monitor the O&G or TPH concentration in the discharged produced water and provides real-time environmental analysis ensuring that the Major Oil Company is operating within their “Tenets of Operation”.
2. The Advanced Sensors OIW monitors provide an immediate alarm to control rooms when there is an upset in water treatment system. Because the units are monitoring three points in the system, Platform operators are able to locate the root cause of the upset and can fix issue without platform shut in and prevent oil to sea discharge.
3. The Advanced Sensors OIW monitor is self-cleaning and is maintenance free. Since installation the monitor has not been cleaned or re-calibrated.
4. The Enviro-Cell is far exceeding the NPDES discharge requirements of 29 PPM.
5. The Enviro-Cell is a hydraulic induced gas flotation cell and has no moving parts internal to the vessel.
6. The Enviro-Cell is a low maintenance flotation unit matching and exceeding water quality provided by previous mechanical Induced Gas Flotation Cell units which are high maintenance devices.
7. Based on the observations, operation ease and maintenance issues, it can be concluded that the Enviro-Cell is the next generation, low maintenance viable machine for produced water treatment.
8. The combination of the Enviro-Cell and the online monitoring system using Advanced Sensors unit is the best available technology.