PRODUCED WATER CHARACTERISATION AND CHEMICAL TRIALS USING VISUAL PROCESS ANALYSING TECHNOLOGY

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ABSTRACT

The optimisation of an oil/water production system can maximise oil recovery whilst minimising losses, expenditure and environmental impact, but typically to achieve any level of optimisation requires time and dedicated experienced manpower. In a system where there maybe the potential to optimise the process there is often reluctance by the company or operators due to the lack of time and resources. In some locations namely remote or unmanned installations the logistics almost prohibit changes unless the process is failing. This paper presents actual field data from an operator who wanted to identify if rapid optimisation could be achieved with minimal manpower and using existing visual process analysis technology. The ultimate goal was to prove that a system could be introduced to enable the optimisation of remote or unmanned platforms.

INTRODUCTION

The purpose of this trial was to evaluate the potential for the Jorin ViPA (Visual Process Analysing Technology) to provide real-time rapid information for remote chemical optimisation and produced water characterisation on an offshore installation. This document summarises the key findings from the trial conducted on the installation and demonstrates that the technology could be used for both produced water characterisation and chemical optimisation. The client also considered that this technology should possibly be included as part of their produced water separation system for their future fields to enable remote chemical and plant optimisation in addition to its use as their produced water re-injection quality monitor.

BRIEF INTRODUCTION TO VISUAL PARTICLE ANALYSING TECHNOLOGY

The Jorin ViPA, Visual Process Analyser, provides information on oil drop size, oil concentration, solids size distribution and solids concentration which is a critical set of data for understanding and controlling produced water separation systems. ViPA analysers have been operating successfully in diverse applications around the world for almost 10 years. The Jorin ViPA, is an on-line instrument that can be used for monitoring the physical characteristics of multiple classes of dispersed objects within a given process stream or re-circulating lab sample. In complex multi-phase systems these dispersed ‘objects’ may include any mixture of solid (particles), liquid (droplets), gas (bubbles) or macromolecular (e.g. high molecular weight polymers, micelle agglomerates etc.) species. The ViPA system uses image analysis techniques and sets of user-defined descriptive parameters (such as shape factor and optical density) to differentiate between the various species of objects present within a sample and then outputs the physical information on each of these independently. Field experience with the ViPA system has been successful; and there are many case studies demonstrating the value of the data produced in the context of the processes studied.

SCOPE OF WORK

- Establish if the ViPA analyser can identify if the process system has any valves or other equipment operating in a sub optimal manner
- Establish if the ViPA analyser can be used for on-line demulsifier and/or water clarifier optimisation
- Establish if asset's wells produce any sand or fines which have gone undetected by other measurement methods
- Establish if the production team can perform accelerated chemical optimisation or plant produced water system optimisation in days rather than weeks which could help free up or optimise offshore bed space

CASE STUDY

Figure 1 shows the process flow diagram for the offshore installation. There were various sample points utilised throughout this investigation and this is denoted by the ViPA monitoring point symbol. The chemical injection points used are also showed in the diagram.

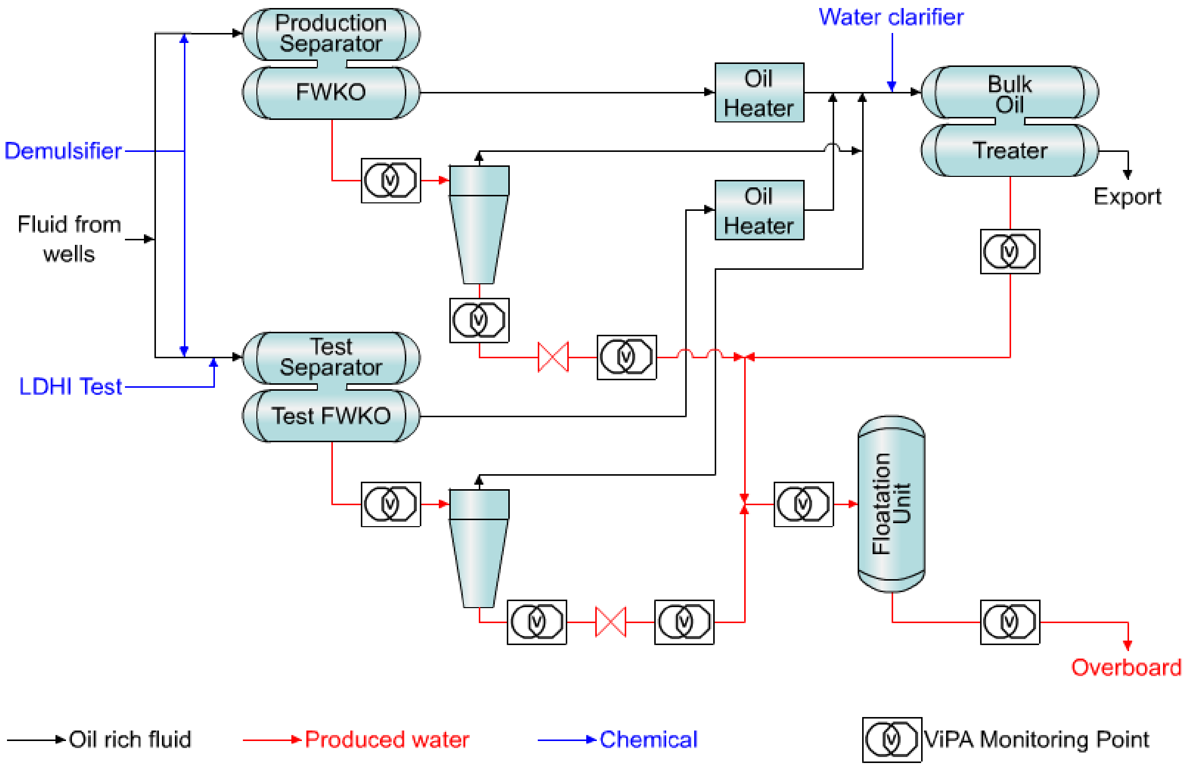

Fig 1: Process Flow Diagram

TEST HYDROCYCLONE PERFORMANCE

Two different wells were routed to assess the performance on the test hydrocyclone. Well A was in test until a little after 15:00 and Well B for the rest of the trial period. When Well A was in test, the average droplet size for the hydrocyclone inlet was calculated to be 18 microns.

When Well B was routed through the test separator, there was a 28% decrease in mean oil droplet size and a 22% increase in water flow rate from Well A at 3916 bwpd to Well B at

4802 bwpd. This resulted in poorer hydrocyclone performance, a reduction from 36% to 30% efficiency. Figure 2 shows images taken from the ViPA flow cell window, upstream and downstream of the test hydrocyclone.

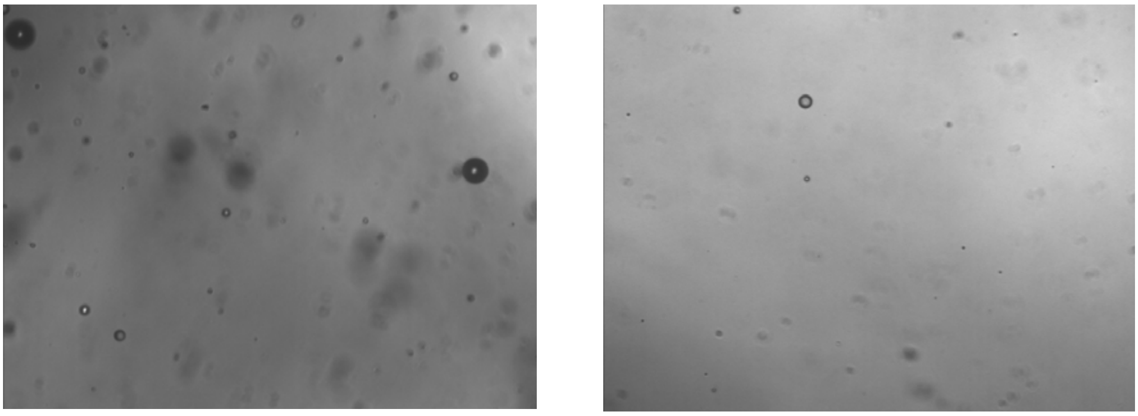

Fig 2: Images taken from the Jorin ViPA flow cell window. Image on the left is of the test hydrocyclone inlet and image on the right is the test hydrocyclone outlet

It should be noted that this performance is significantly lower than that expected from this type of device. However, the measured flowrate through the vessel is less than a third of its design capacity and consequentially there is a significant reduction in separation efficiency and a likelihood of deposition of material and coalescence. These issues will be causative to the low and negative efficiencies seen in Figure 3.

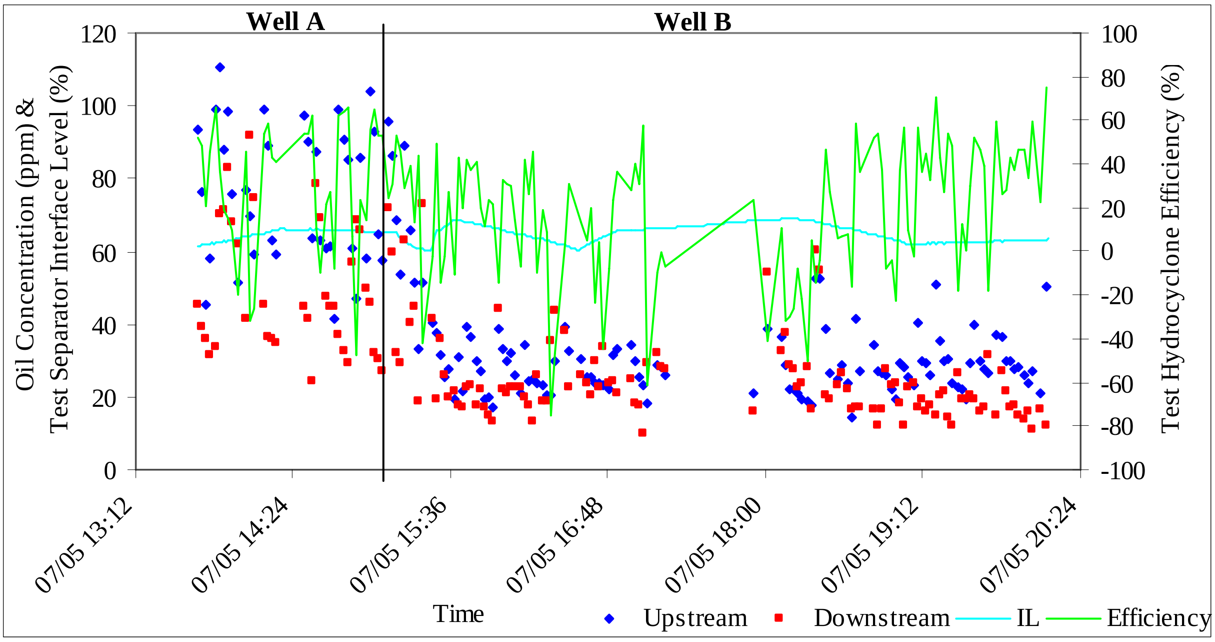

Fig 3: Test Hydrocyclone Efficiency Graph

TEST DEMULSIFIER OPTIMISATION

Figure 4 shows the reported oil concentrations for the Test Hydrocyclone Inlet throughout the demulsifier optimisation steps when Well C was in test. Jorin believe that the high degree of initial scatter in the data is due to a combination of effects, namely a new well being routed into the test separator, causing control difficulties of the interface level, coupled with the demulsifier being overdosed, at 19 ppm. It can be clearly seen that there is a positive effect on the oil in water concentration when the demulsifier dose rate was reduced.

The measured flowrate through the vessel is less than a third of its design capacity and there is a high likelihood of coalescence of oil droplets occurring. It appears that at lower chemical dose rates the predominant effect is coalescence and this overwhelms the apparent benefit, as seen on the vessel inlet, of a reduced chemical dose rate.

The negative efficiencies reported by the ViPA are supported by the lab samples taken. Initially these negative efficiencies were thought to be a function of the hydrocyclone not being backflushed regularly. A backflush was performed at 14:00 which caused the inlet and outlet concentration to be approximately equal but within 15 minutes of the backflush, the outlet concentration was once again higher than the inlet.

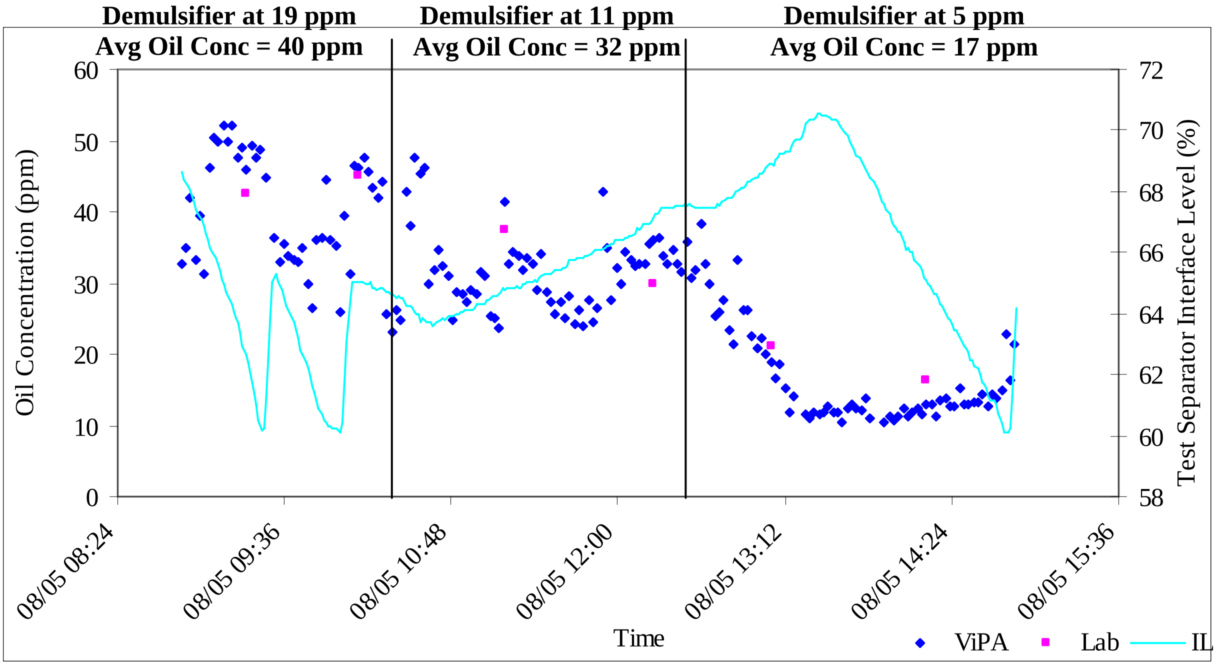

Fig 4: Oil concentrations for the Test Hydrocyclone Inlet

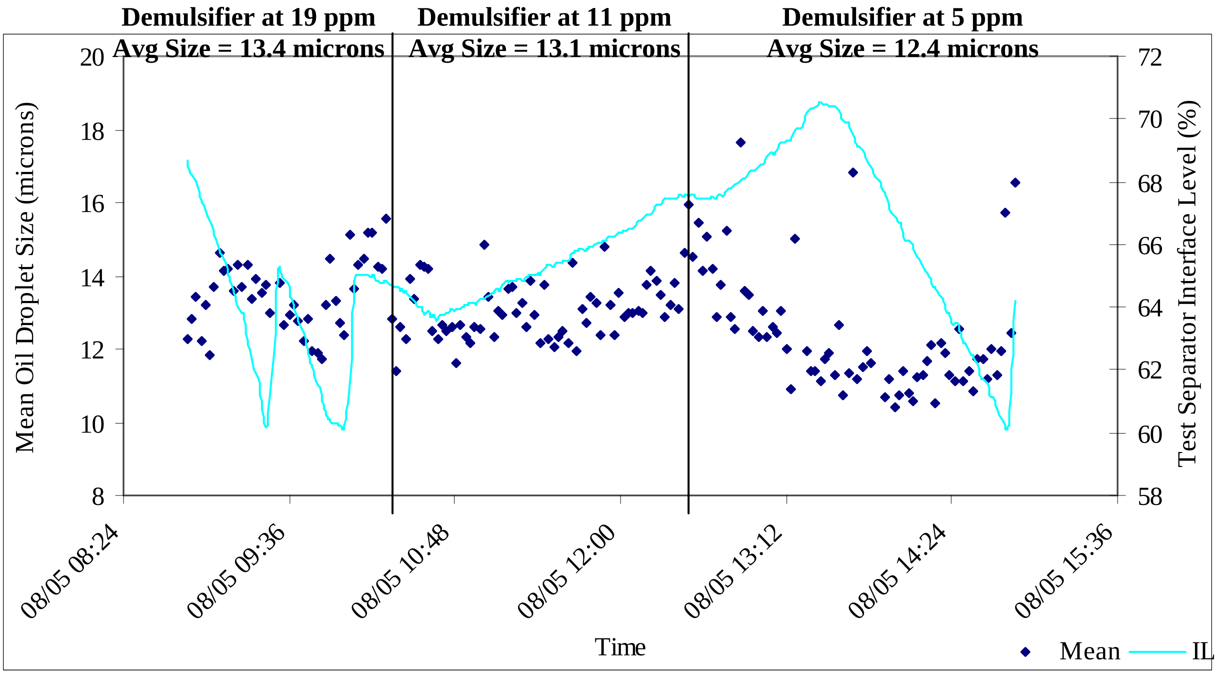

Fig 5: Mean oil droplet size for the Test Hydrocyclone Inlet

Figure 5 shows the effect of the demulsifier concentration on the interface level and the mean oil droplet size. Soon after the first reduction in demulsifier from 19 ppm to 11 ppm there was an increase in the interface level, which provided an increase in residence time in addition to an increase in the mean oil droplet size.

When the demulsifier dose rate was further reduced to 5 ppm, an immediate decrease in mean oil droplet size was observed: however, the interface level was seen to continue to rise which resulted in a reduction in oil concentration leaving the separator. The relationship between the interface level and the demulsifier dose rate is not fully understood and therefore the extent of the reduction of the mean oil droplet size and concentration cannot be clearly attributed to one or the other.

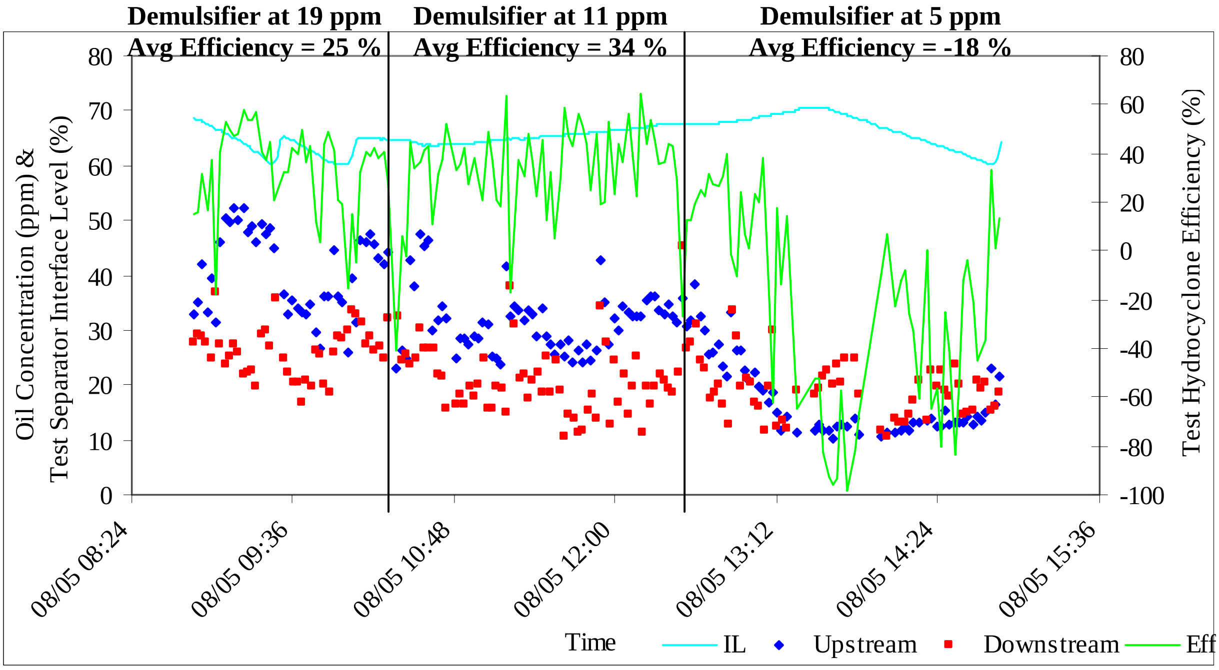

Fig 6: Test Hydrocyclone efficiency graph for the demulsifier optimisation

EFFECT OF TEST SEPARATOR CONTROL VALVE

The control valve on the test train was analysed to determine its effect on the mean oil droplet size. The analysis started with Well B routed to the test separator, and then at 07:14 Well C was routed to the test separator.

It would appear that when the fluids produced from Well B were being analysed the oil droplets were coalescing downstream of the control valve. However, as soon as Well C was routed to the test separator a noticeable change occurred in terms of the water flow rates and the % open of the control valve, as can be seen in Figure 7.

When this change occurred the control valve sheared the oil droplets by an average of 3.2 microns. This could be due to either the change in process fluids from different wells with a different stability of emulsions or the % open of the control valve. The reduction in mean drop sizes from 14 to 9 microns will have a significant effect on downstream separation efficiencies and could potentially require an increase usage of clarifier to achieve discharge specifications.

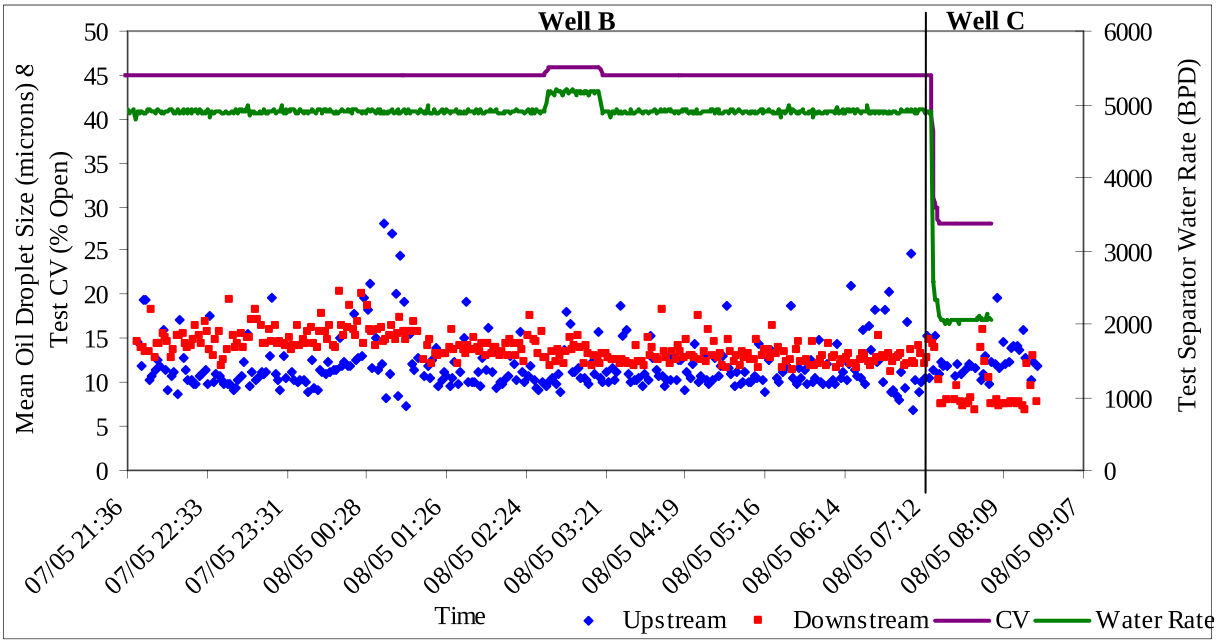

Fig 7: Effect of Test Separator Control Valve

PRODUCTION HYDROCYCLONE PERFORMANCE

Figure 8 shows the oil concentration of the production hydrocyclone inlet; along with the production separator interface level. It can be seen that when the interface level increases, the oil concentration decreases and vice versa; however Figure 10 shows the production hydrocyclone inlet and outlet oil concentrations along with the calculated efficiencies, this graph shows no direct correlation with the change in interface level to the efficiency of the hydrocyclone. With the average oil drop size of about 20 microns, as shown in Figure 9, the current hydrocyclone liners were observed to be performing in line with expectations.

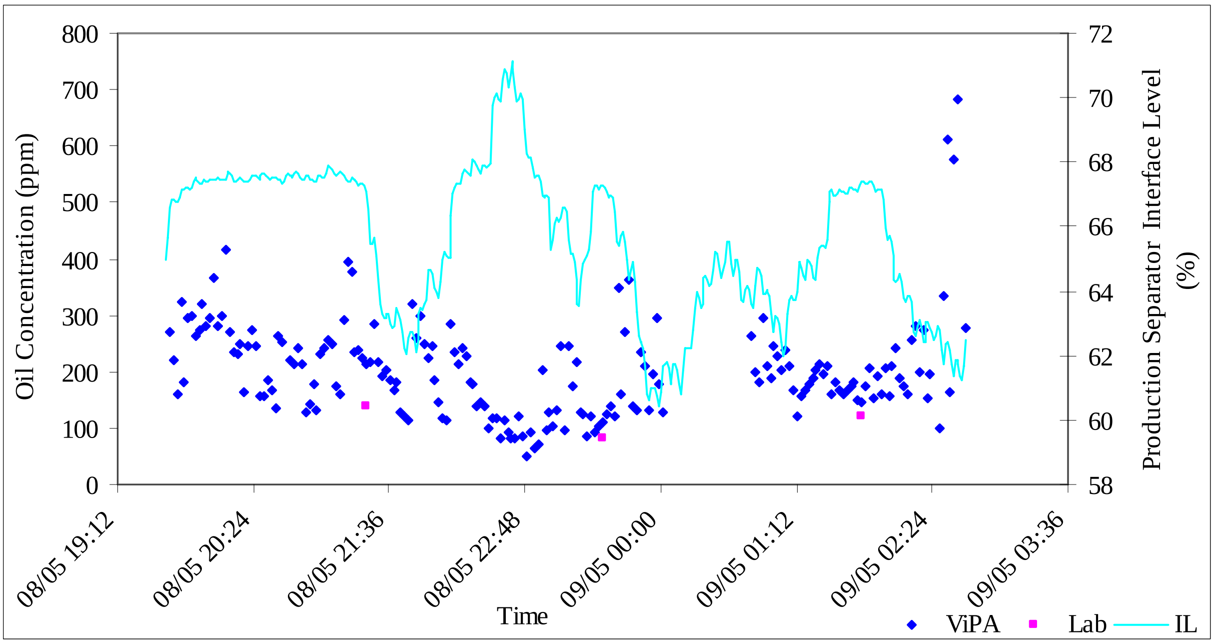

Fig 8: Oil concentration for the Production Hydrocyclone Inlet and Production Separator Interface Level

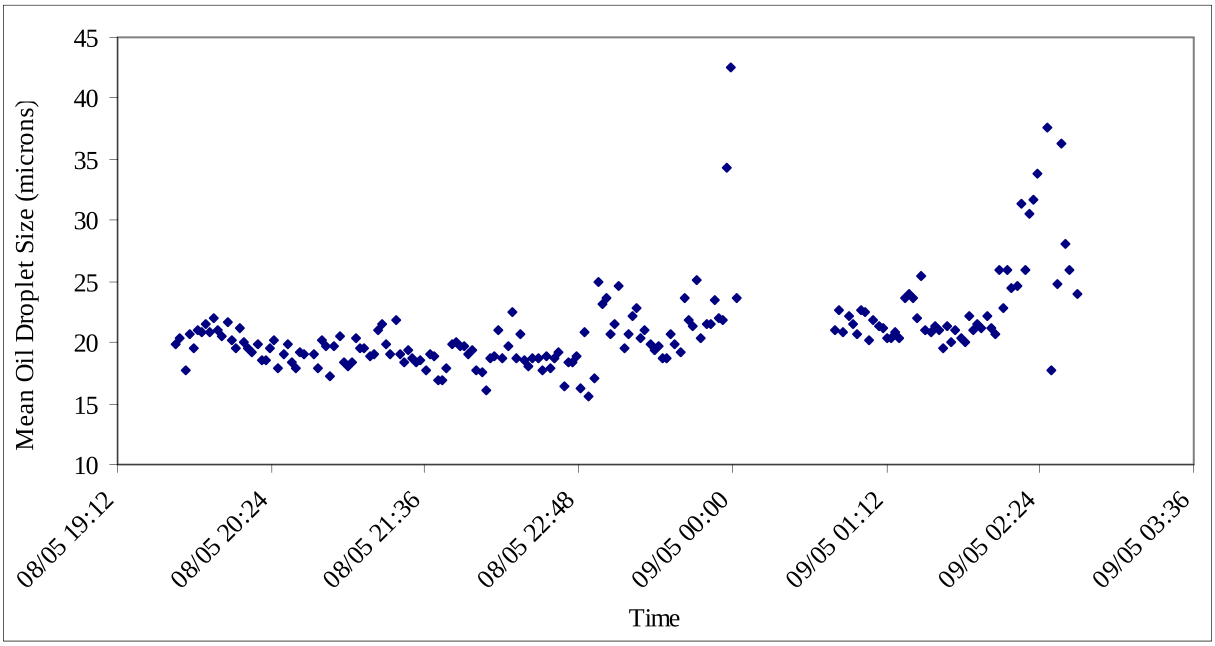

Fig 9: Mean oil drople size for the Production Hydrocyclone Inlet

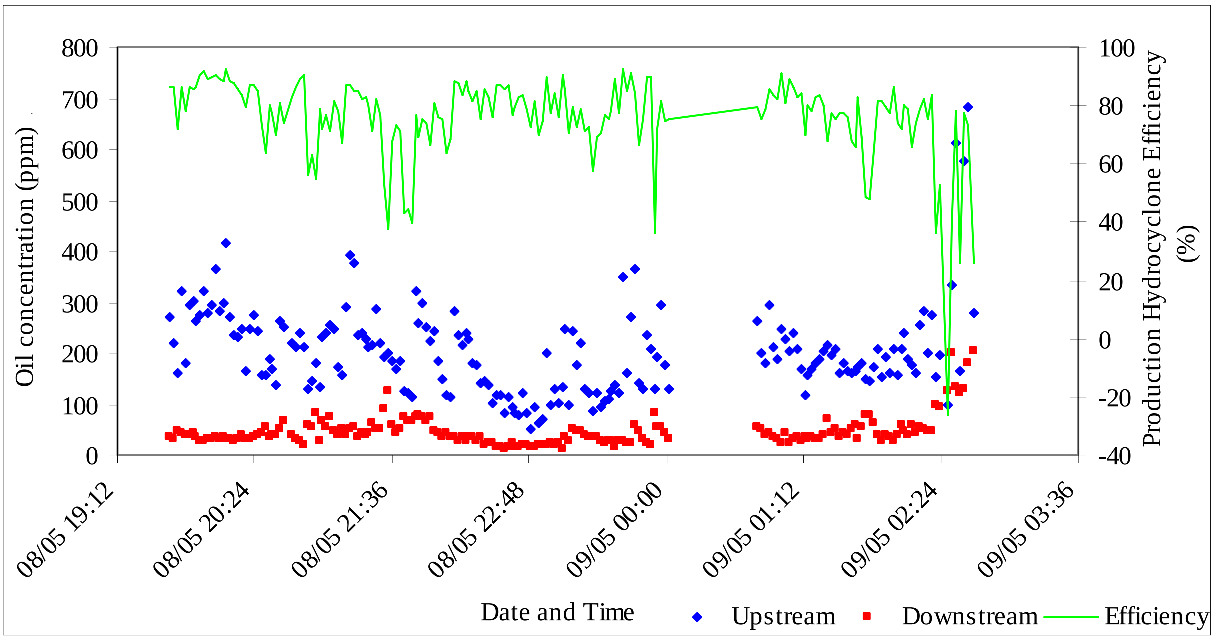

Fig 10: Production Hydrocyclone Efficiency Graph

EFFECT OF PRODUCTION SEPARATOR CONTROL VALVE

Figure 12 shows the effect of the Production separator control valve. At about 03:55, the demulsifier had stopped pumping as it had run dry but it was started again at 04:10. This caused an upset in the system as shown by the variation in the interface level and % open of the control valve. The fluctuations lasted approximately 2 hours and resulted in a high degree of variation in downstream oil concentration. However, after 06:00 process conditions began to stabilise and the production separator control valve was not recorded to shear the oil droplets. Figure 11 shows images taken from the ViPA flow cell window, upstream and downstream production separator control valve.

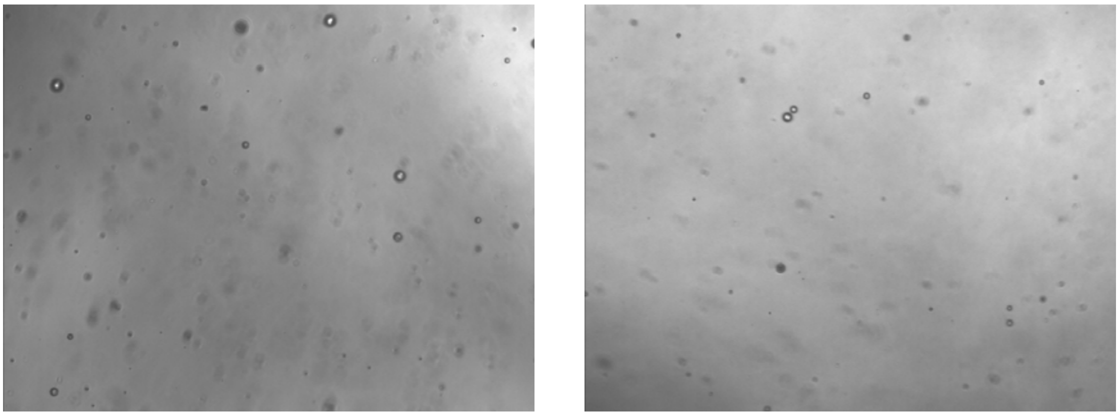

Fig 11: Images taken fron the Jorin ViPA flow cell window. Image on the left is upstream the control valve and the image on the right is downstream the valve

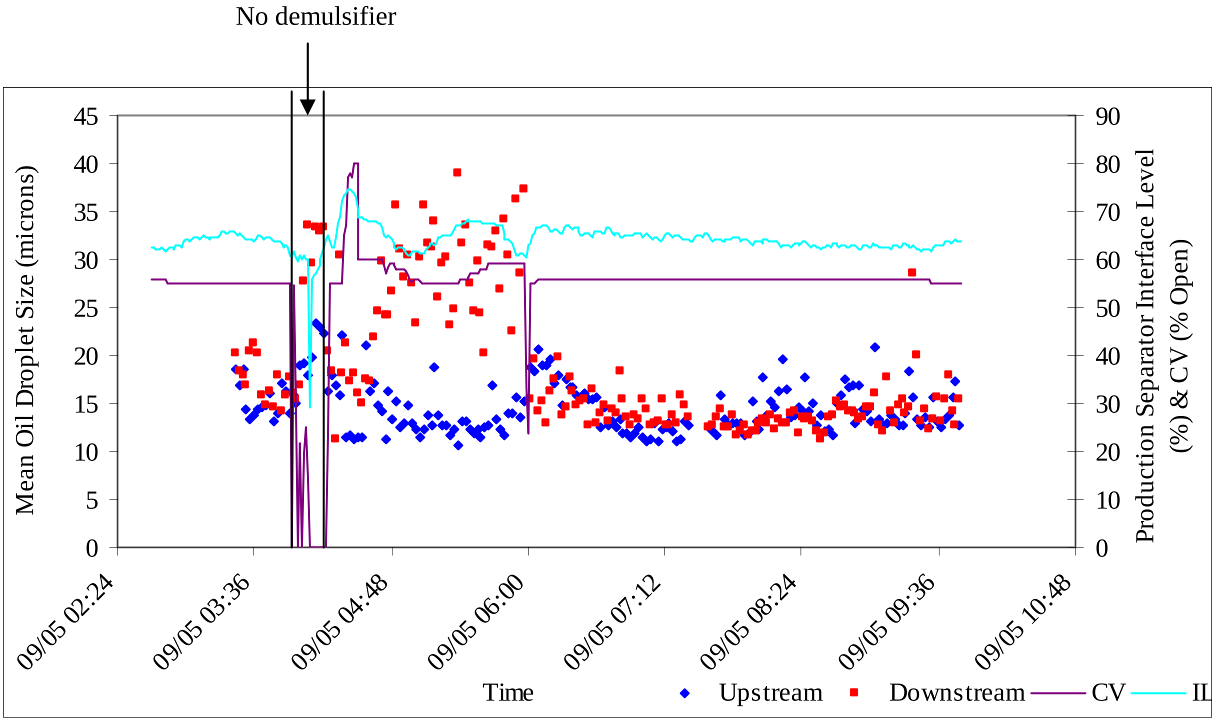

Fig 12: Effect of Production Separator Control Valve

PRODUCTION DEMULSIFIER OPTIMISATION

For the demulsifier optimisation step, the two ViPA units were positioned on the production hydrocyclone outlet and downstream of the bulk oil treater. Figure 13 shows the oil concentrations for the outlet of the production hydrocyclone throughout the demulsifier optimisation step. The process, in terms of the interface level, was more unstable at demulsifier concentrations of 20 ppm and 5 ppm. This evidence suggests that either 10 ppm or 7.5 ppm would be the more optimum demulsifier concentration but more investigation is needed to determine the precise dose rate.

A further demulsifier optimisation step was completed where a dose rate of 8 ppm was trialled. Figure 14 shows the correlation between the oil concentration and the interface level for the production hydrocyclone outlet. It can be clearly seen that at 8 ppm there was poor control of the process.

Figure 15 shows the oil concentration downstream of the bulk oil treater and the correlation to the export BS&W, which supports 10 ppm as the best trialled demulsifier concentration, as the BS&W improved when the demulsifier was changed to 10 ppm.

Key:

A → Demulsifier at 10 ppm (average oil concentration = 64 ppm)
B → Demulsifier at 20 ppm (average oil concentration = 126 ppm)
C → Demulsifier at 7.5 ppm (average oil concentration = 81 ppm)
D → Demulsifier at 5 ppm (average oil concentration = 85 ppm)
E → Demulsifier at 10 ppm (average oil concentration = 45 ppm)

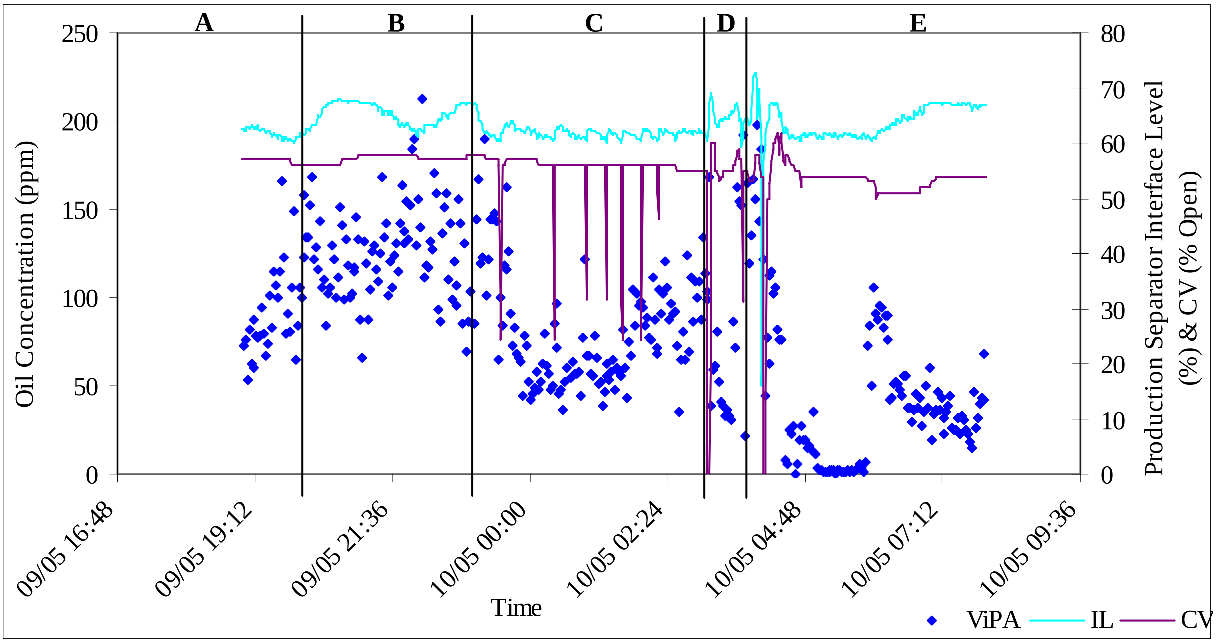

Fig 13: Oil concentrations for the Production Hydrocyclone Outlet on Day 1

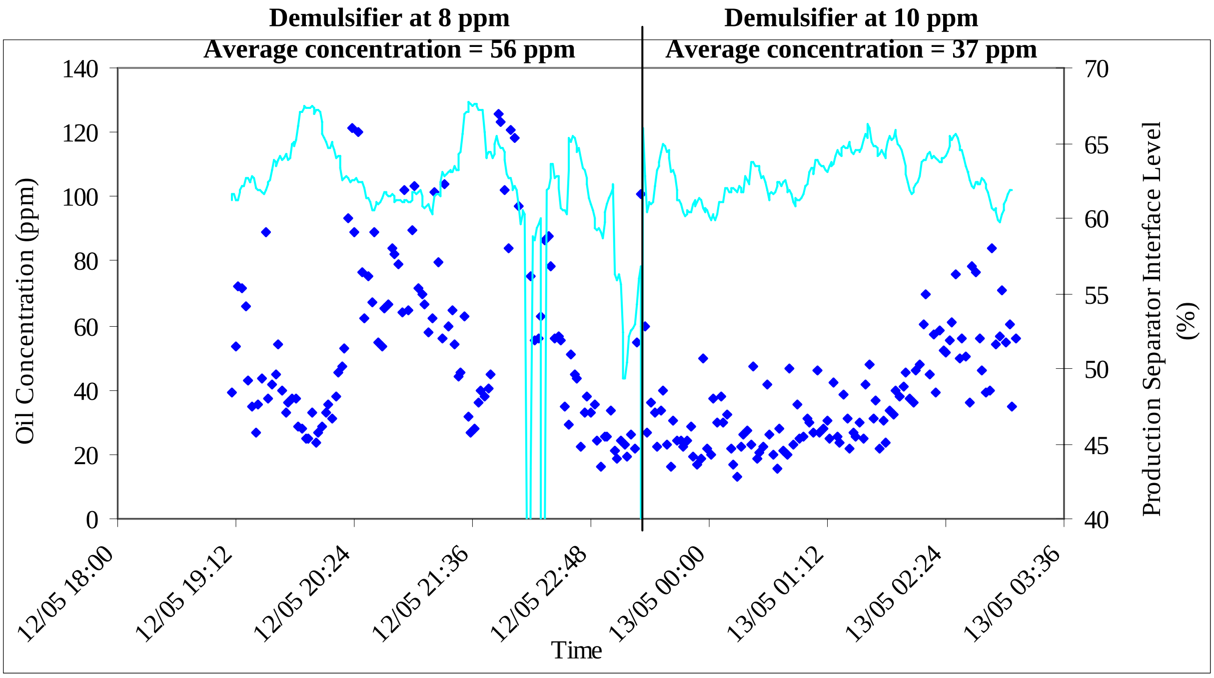

Fig 14: Oil concentrations for the Production Hydrocyclone Outlet on Day 2

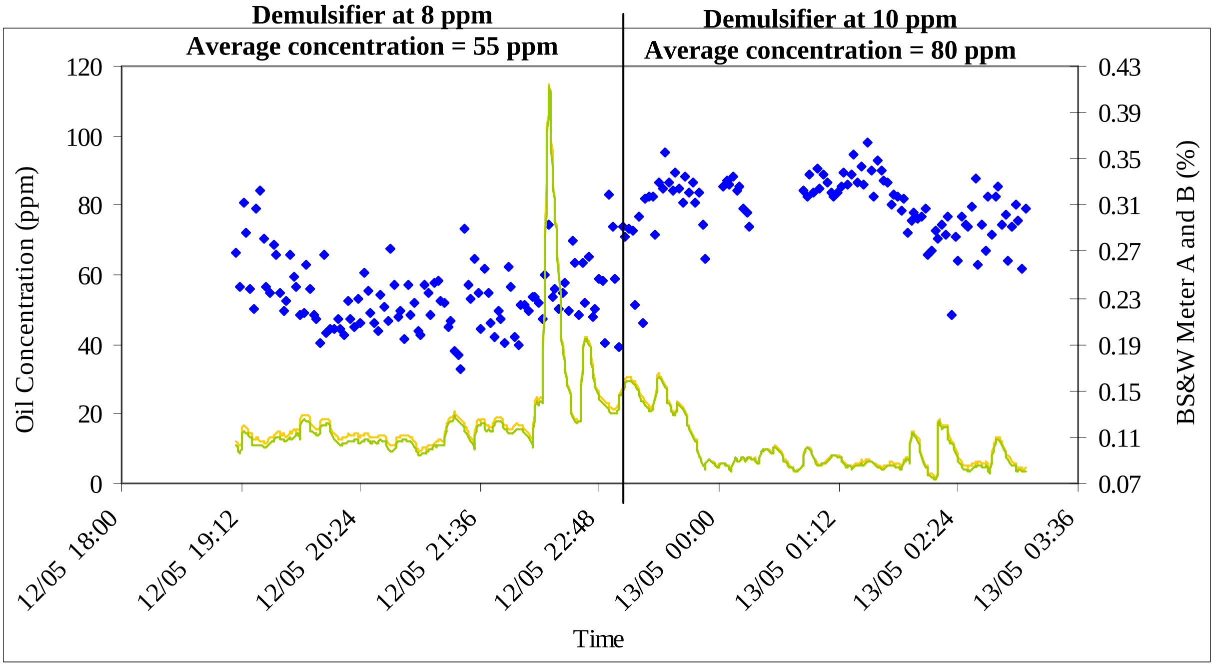

Fig 15: Oil concentrations downstream the Bulk Oil Treater

LDHI OPTIMISATION

The operator wanted to assess 2 different LDHI (Low Dose Hydrate Inhibitor) chemicals for use prior to cold start-ups. For the majority of the LDHI optimisation step, the process fluids were outside the operating range of the ViPA preventing the system from generating any useful data, as the fluid with the dosed LDHI absorbed too great a proportion of the light energy to allow transmission microscopy. Figure 16 shows images taken from the ViPA flow cell window, before and after the LDHI was injected.

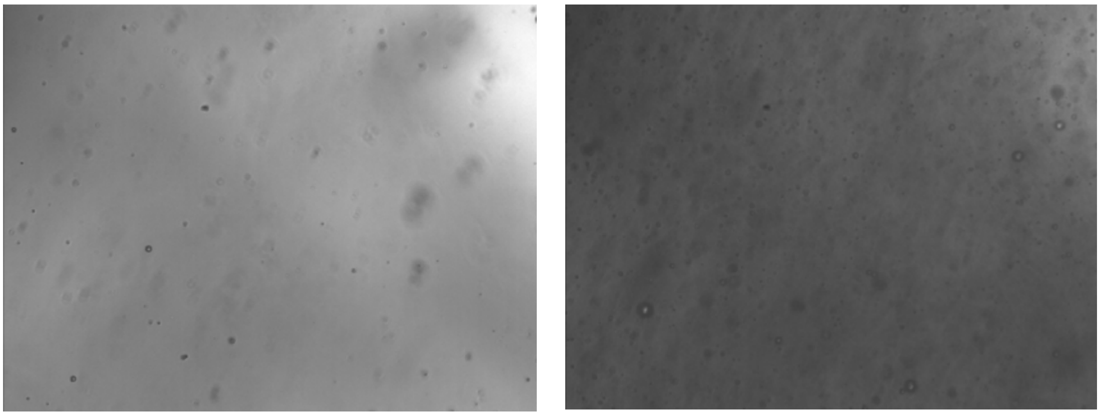

Fig 16: Images taken from the Jorin ViPA flow cell window. Image on the left is downstream of the test hydrocyclone prior the LDHI and the image on the right is after the LDHI

WATER CLARIFIER OPTIMISATION

The water clarifier optimisation was conducted with the ViPA units located on the inlet and outlet of the floatation unit both of which are downstream of the chemical injection points. Three different chemicals were tested, Chemical I, Chemical II and Chemical III. Figure 18 shows the solids concentrations for the inlet and outlet throughout the water clarifier optimisation steps. The purpose of the clarifier is to promote the coalescence of oil into flocculated oily agglomerates, these would be identified as solids by the ViPA and therefore the solids data has been used to assess their performance.

Figure 17 shows images taken from the ViPA flow cell window, upstream and downstream of the floatation unit.

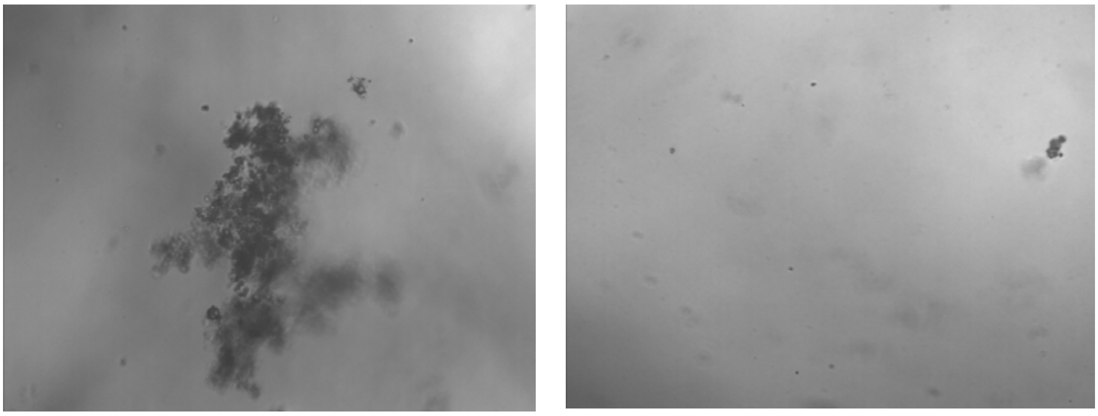

Fig 17: Images taken from the Jorin ViPA flow cell window. Image on the left is upstream of the floatation unit and the image on the right is downstream of the floatation unit

It can be seen that when Chemical II was dosed at 12.8 ppm the floatation unit had the highest solids removal efficiency of 74%. Chemical III did not perform well in terms of creating any solids flocs, as reported by the ViPA in Figure 18. The mechanical operating regime of the floatation unit was maintained throughout the chemical trials and to obtain maximum performance should be optimised for the chemical and dose rate in use.

Key for Figure 18
A → Chemical I at 16 ppm
(Average inlet and outlet solids concentration = 119 & 44 ppm)
B → Chemical II at 12.8 ppm
(Average inlet and outlet solids concentration = 133 & 34 ppm)
C → Chemical II at 9.6 ppm
(Average inlet and outlet solids concentration = 67 & 34 ppm)
D → Chemical II at 8 ppm
(Average inlet and outlet solids concentration = 60 & 35 ppm)
E → Chemical I at 16 ppm
(Average inlet and outlet solids concentration = 124 & 60 ppm)
F → Chemical III at 6.5 ppm
(Average inlet and outlet solids concentration = 9 & 11 ppm)
G → Chemical III at 9.6 ppm
(Average inlet and outlet solids concentration = 8 & 9 ppm)
H → Chemical I at 16 ppm
(Average inlet and outlet solids concentration = 123 & 39 ppm)

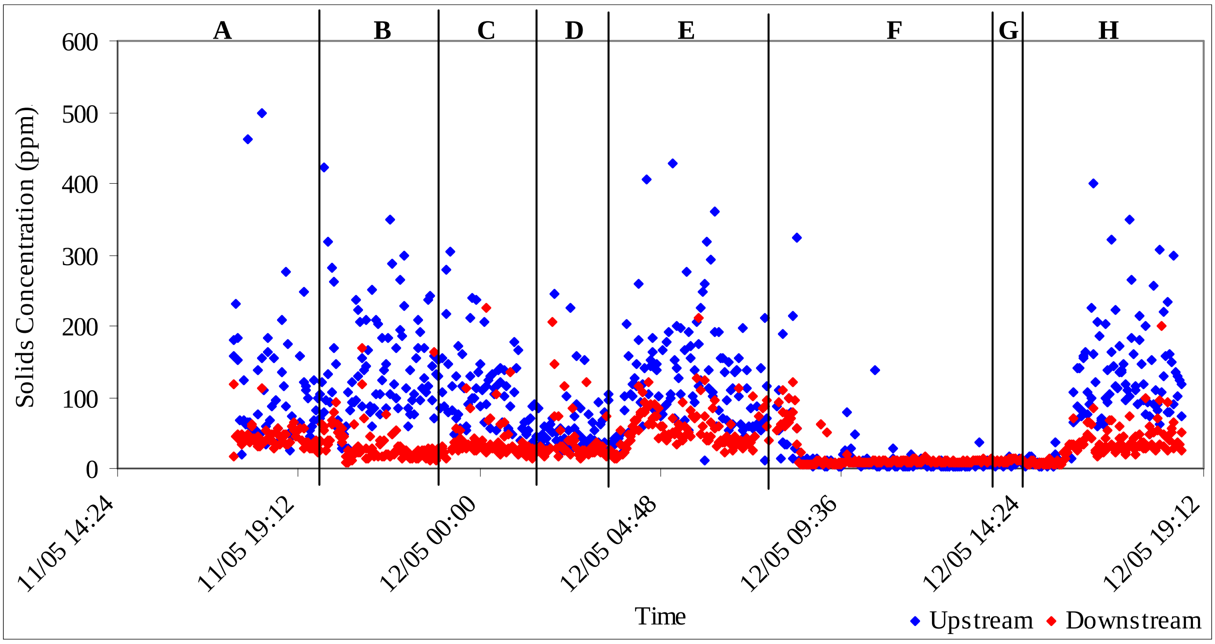

Fig 18: Solids concentrations for the Floatation unit Inlet and Outlet

LAB AND VIPA DATA CORRELATION

Figure 19 shows the correlation between the oil and water concentrations as analysed by the offshore laboratory and the corresponding ViPA data points. It should be noted that the timing of the two corresponding samples were as near to simultaneous as possible; and the sample points were located in the same area of the process but were not common.

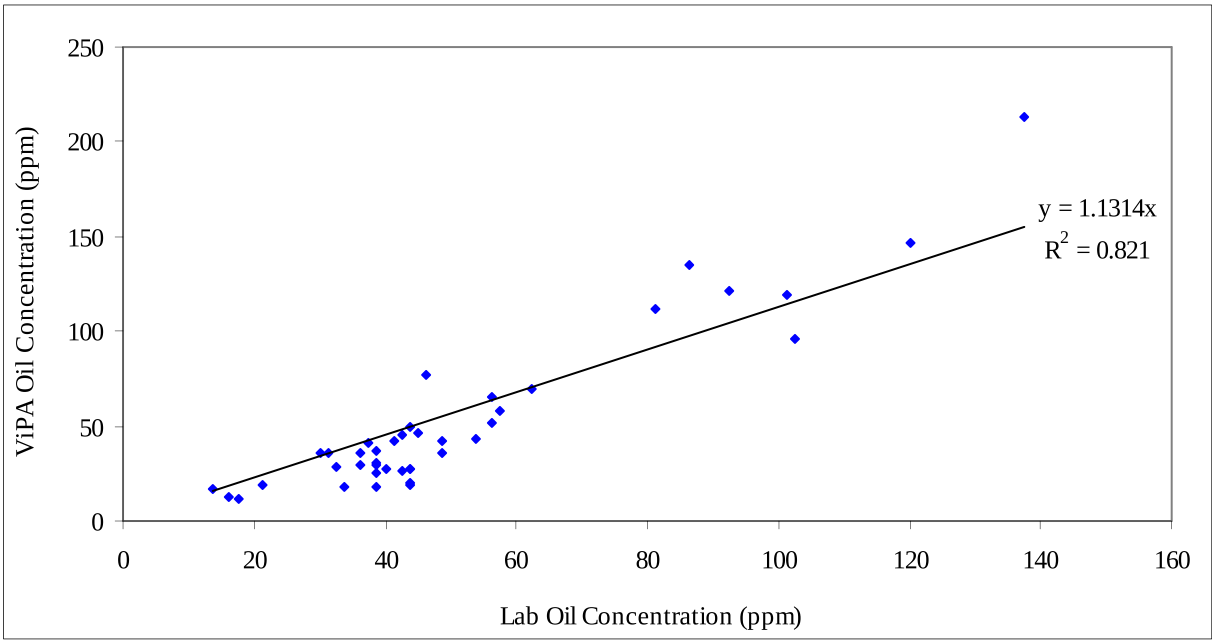

Fig 19: Lab and ViPA correlation

CONCLUSIONS

The ViPA proved it could identify the operating efficiencies of the separation equipment in use on the asset. The Test hydrocyclones are performing sub-optimally and the number of liners in use requires optimising in accordance with their manufacturer's recommendation for flow rate range. Sections of the pod should be closed to match the installed liners to the flowrate of the water cut of the wells being routed to the test separator. The test level control valve is shearing oil droplets under certain flow regimes that will lead to difficulty in downstream separation. The ViPA clearly shows that the oil concentration in the outlet of the production separator is sensitive to interface level. Efforts should be made to minimise the variability of the interface level, additional monitoring may be required to achieve this.The Production hydrocyclones performed with an average efficiency of 76%. The mean oil droplet size feeding the hydrocyclones was in excess of 21 microns, reference should be made to the manufacturer's specification and an assessment made regarding the expectations for performance. The production separator control valve was not found to have a significant effect on oil drop size.

The ViPA proved that it could quickly establish the effects of variation of type and dose rate of demulsifiers and clarifiers. The Operations team should adjust the demulsifier injected to the test separator in accordance with produced fluids of the well under test. The optimum demulsifier dose trialled in production was 10 ppm but there is evidence to suggest further testing may produce a further reduction in required dosing. Demulsifier dose rate of 10 ppm enhanced process separability and improved BS&W. The optimum water clarifier chemical and dose that was trialled was Chemical II at 12.8 ppm. The efficiency of the floatation unit would be further enhanced by optimising its operating parameters. The team was able to test and evaluate 20 chemical dosing regimes in 8 days of active testing using ViPA technology. Correlation with lab data was shown to be good with an R^2 value in excess of 0.8.

Jorin have demonstrated the advantages of using ViPA technology for process and chemical optimisation studies. ViPA has provided data that could be used in the context of process control and the further availability of this data should be assessed commercially. An automated Jorin ViPA at the process system outlet prior to discharge could be used as an early warning for plant upsets affecting overboard water quality.