Secondary Produced Water Treatment Through Micro-Bubble Flotation, Within Float/Surge Tanks

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INTRODUCTION

Oil wells run in dynamic conditions providing variable production quantity and quality. Over time as a reservoirs lifecycle progresses the amount of water produced increases and the management and quality of this produced water becomes an increasingly important issue with respect to the viability of the well.

The management of produced water quality presents a diverse set of challenges to Oil & Gas producers, particularly for those who have tight formations and rely on water for reinjection. In these circumstance water treatment equipment must be highly efficient at oil and suspended solids removal to ensure that the water which is reinjected is of high enough cleanliness so that it does not cause or contribute to the formation becoming blocked or damaged by impurities in the water which can lead to expensive down hole treatments (workovers) and decreased revenue through lost production.

In an effort to achieve this high quality for injection water, a number of producers are employing advanced phase separation technologies at a high capital and operating costs which often do not achieve the desired result.

This paper provides a case study of how one producer addressed issues that developed at a site where over time significant water quality problems developed resulting in significant increases in operating costs. The case study profiles the use of a Micro-Bubble Flotation technology developed by GLR Solutions Ltd. For use in Floatation/Surge Tanks and documents the resulting costs savings and water quality improvements over an extended time period.

CASE BACKGROUND

An oil producer based in Alberta, Canada, owns and operates a battery for treatment of oil and water prior to the oil entering a pipeline and the water being re-injected downhole to the formation. At the time of this case study (April 2002 – October 2003) the battery was treating 2,000 – 2,500 m$^3$/day water/day. The oil produced to this battery is quite light (API 39) yet oil is passing through primary and secondary water recovery equipment causing numerous operational challenges for the operators.

The formation receiving this water is fairly tight (low hydraulic conductivity) and is sensitive to loading of oil and solids. The producer finds that if oil and suspended solids are not effectively removed prior to re-injection that the injection pressures rise and ultimately lead to expensive well workovers.
Over years as this reservoir has been produced and additional wells tied into the battery, the producer has found that water cuts have increased and quality decreased necessitating additional water treatment capacity and processes. A simplified representation of the process flow utilized at the battery is illustrated in Figure 1.

![Figure 1: Process Flow (Water Treatment)](image)

The process is designed to do primary separation of oil and water within the pressurized Free Water Knockout (FWKO). Separated water is then moved through a Skim Tank where there is approximately 5 hours of retention time allowing residual oil to float and be skimmed. Clean water from the bottom of the skim tank then passes through a filter pot (Produced Filters) containing 15 micron bag filters for further de-oiling and solids removal. Filtered water is allowed to collect in a surge tank and prior to processing by a filter pot (Commingled Filters) containing 5 micron bag filters and subsequently 5 micron cartridge filters for polishing (Polishing Filters). Water passing through the entire treatment train is then injected back to the formation.

Historical data from this treatment process presented in Figure 2, documents a steady rise in filter use and a corresponding cost increase from $0.50/ m³ water injected in 1999 to over $2.50/ m³ injected by mid 2002. The reduced water quality created a much greater load on the existing filters. In the space of one year (November 2000 - November 2001) the filter cost per cubic meter injected doubled from $1 to $2. This is a significant cost when the volume of water injected is considered. Associated with the cost of the filters is the changing of the filters. There are three sets of filters on site each requiring manual filter changes. Every filter change than has a corresponding cost for the related requisite labour. The main observation on the filters during change out was the oil fouling as oil passed through the skim tank and was caught within the bag filters. Frequent filter change outs were then required to ensure the filters maintained their capabilities.

Over time as the water quality through the filters continued to deteriorate the associated costs continued to grow and the quality of the injected water became jeopardized. The existing water treatment process of tanks, filters and chemicals proved to be inadequate as the amount of solids and oil passing through the filters continued to grow with time.
The significant increase in operating costs motivated the producer to evaluate alternative technologies to recover oil and suspended solids prior to entering the filters. In selecting an alternative technology priority was placed on a solution that would have a high oil removal efficiency at a low capital and operating cost. A secondary objective was to utilize as much of the existing infrastructure and piping arrangement on site to minimize any operational disruptions and down time.

**SOLUTION**

A number of technology and operational alternatives were evaluated to improve water treatment at a lower operating cost. After some investigation, the solution chosen was to add a Micro-Bubble Flotation (MBF) unit attached to a conventional skim/flotation tank. The MBF technology was expected to reduce Oil and Grease as well as Total Suspended Solids in produced water leaving the skim tank which would result in significantly lower concentrations of oil and solids reaching the filters.

The GLR Solutions Ltd., Micro-Bubble Flotation is a proven technology that is used to create micron sized gas bubbles in liquids for various purposes. The application of MBF in the oil patch is very similar to the application of induced gas flotation (IGF), systems also in the oil patch. The principles of this application involve tiny gas bubbles that adhere to oil droplets and solids in produced water and help float them to the surface.
A major difference between induced gas flotation and micro bubble flotation exists in the size of the gas bubbles in the liquid. MBF uses bubbles that are 5-50 microns (10 micron nominal) in diameter. These smaller bubbles, approximately one trillion per cubic foot, allow for a greater total number of bubbles and this creates a higher probability for oil droplets to contact the more buoyant gas bubbles. The smaller bubbles also provide a larger total surface area for attachment and surface tension of the bubble and oil droplet; thereby, attaching to more droplets of oil for a longer period of time as the bubbles are rising and coalescing within the water column. Another significant difference between MBF and IGF is that the MBF technology does not require new vessels or piping arrangements. Instead the MBF technology can be applied directly to the skim tank allowing flotation to be enhanced at the point that was already engineered for water deoiling and oil skimming. The MBF process as applied to a skim tank is illustrated below in Figure 3.

![Figure 3: MBF Process as Applied to a Skim Tank](image)

The MBF system chosen recycles a portion (approx. 33%) of the clean produced water stream and adds fuel gas to the liquid. Water and gas then pass through a Gas Liquid Reactor (GLR) pressure vessel where they experience shear impact and increased pressure. These conditions cause the entrained gas to be broken into micron sized bubbles as it passes through the GLR unit into the water stream. The gas-entrained water is then blended with the oily inlet stream of the skim tank (FWKO outlet). As the tiny micron sized bubbles float to the surface they attach themselves to oil droplets and carry the oil to the top. The increased buoyancy of an oil droplet attached to a gas bubble increases its rise velocity and reduces the time required for tiny droplets to leave the water. This effect allows for more oil to be skimmed in a shorter time. Figure 4 provides an example of the process flow within the MBF skid for the creation of Micro-Bubbles.
In late August of 2002 the GLR MBF system was added to the existing facility and was piped into a 2000 bbl. skim tank. This tank contained internals for dispersion of inlet water across the surface area of the tank as well as a skimmer for recovery of oil. Figure 5 outlines the process flow for water treatment inclusive of the MBF system on the skim tank.
RESULTS

The installation of the GLR MBF system had immediate results that benefited the economics and operations at this site. Figure 6 provides a graph of data compiled from November 2002, several months after continuous MBF operation. The figure compares the performance of the prior skim tank arrangement to that of the skim tank retrofitted with the GLR MBF. Results demonstrate a significant reduction in oil & grease, TSS, and Delta P across the produced water filters and most importantly a 51% reduction in the cost of injection water treatment. Given the water volumes treated at this site these figures correlate to annual savings of $1,034,775 provided this level of performance was maintained for the year. Operators at the site also note that plant upsets (high inlet oil loads &/or water volumes), no longer result in a large spike in outlet Oil & Grease concentrations leaving the Skim Tank. Previously upsets at the plant would force operators to change out all filters requiring a large investment of time and money.

November 2002 Performance Comparison

Analytical data from continuous operations was gathered intermittently over the following year to track MBF performance and economics over an extended period of time. Samples were collected at the inlet to the skim tank and again downstream of the skim tank to quantify removal efficiency with the MBF operational on the skim tank. Parameters tracked over this time period included oil & grease (Figure 7), total suspended solids (Figure 8), filter use and filter costs (Figure 9).
Oil & Grease Data

Inlet oil and grease concentrations to the skim tank were variable over the extended time period as production activities were constantly changing fluid feeds to the FWKO. Sampling of outlet water was completed during relatively normal operating periods (nonupset conditions) to ensure that conditions were fairly equivalent for comparison of data points.

Results of oil and grease testing show outlet concentrations ranging from 8-32 ppm with a mean oil removal efficiency of 93.6% over the test period. It is also notable that this removal efficiency was relatively constant over the test period even as inlet concentrations increased.

Total Suspended Solids Data

Data on total suspended solids concentrations to the skim tank was available from a larger time period, including two points prior to the MBF being operational in September 2002. Inlet TSS concentrations were fairly constant over this time period despite the constantly variable inlet fluid feeds to the FWKO. Sampling of outlet water was completed during relatively normal operating periods (non-upset conditions) to ensure that conditions were fairly equivalent for comparison of data points.
Results of TSS testing show outlet concentrations ranging from 10-12 ppm with a mean TSS removal efficiency of 52.9% over the test period, significantly higher than the 13.4% removal efficiency that was observed from the skim tank prior to the MBF installation.

**Filter History vs. Filter Cost**

![Figure 9: Long Term Filter Use and Costs](image)

Data on filter use and costs was available from January 1999 – April 2003 which provides a much larger data set to observe trends. In the period from December 2001 – August 2002 filter use averaged 15.1 produced, 10.4 commingled and 10.9 polished per month for a mean monthly cost of $2.39/m³ water injected over this period. Following the MBF installation filter use averaged 5.8 produced, 7.4 commingled and 16.7 polished per month for a mean monthly cost of $1.42/m³ water injected. This performance correlates to a 61.9% reduction in use of produced filters, 29.4% commingled and 20.3% polished filters for a mean cost reduction of 39.7%. This long term operations data can be used to estimate an annual operating cost savings of approximately $750,000 due to the MBF performance.
CONCLUSION

When searching for a perfect solution to solve the many challenges that are presented by increased water cuts during the production of oil it becomes clear that there are numerous options available to producers. In this case study we have examined some of the water management challenges that presented themselves at an oil battery in Alberta which are certainly not new or unique to the industry. What is significant and notable, but also not exclusive to this case, is the speed at which the battery was able to realize and measure financial benefits from the application of an innovative secondary produced water treatment solution to their site, the GLR Micro-Bubble Floatation system.

In one year the MBF system paid for itself 6 times over in operational savings alone. The $750,000 in annual operational savings documented by the producer themselves, in this case study, does not even take into account the reduction in man hours from the less frequent need to change out the filters or more importantly the increase in revenue realized by the site from the additional oil recovered at the skim tank.

In addition to the already discussed increased oil recovery at the skim tank which is always a benefit of the system, the MBF will reduce the use of chemicals used as flocculants, will reduce the load or in some cases may eliminate the need for filters and other downstream water treatment and polishing. The system has a moderating effect on the quality of water at the outlet of the skim tank even under upset conditions the normal spikes in outlet concentrations are diminished and therefore of less impact to operations.

The success of the MBF system comes from the advanced engineering that has gone into its design, the simplicity of its implementation and most importantly the results that are generated by the application of micron sized bubbles to the treatment of produced water in the skim tank of the battery.

The system is easily retrofitted to most battery sites with only minor interruptions to production or can be built into the design of a new facility to reduce the need for downstream filters and other tertiary water treatment systems and devices. There is also no need for maintenance of the MBF itself, the only part of the system that may require some maintenance is the centrifugal (re-circulation) pump and even that would be according to normal manufacturer’s recommendations.