Produced Water Primary Treatment Options

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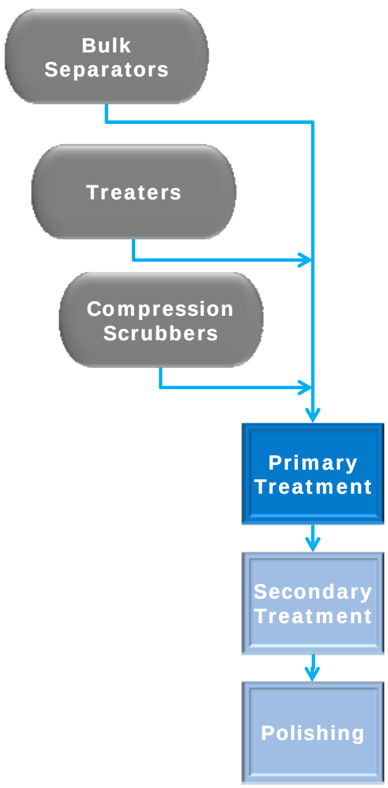

Produced water systems are typically designed in stages. These stages are primary treatment, secondary treatment, and polishing. Each stage has select equipment that specialize in the removal of oil and solids from the water.

This GATEKEEPER focuses on the primary treatment equipment options for produced water systems. The following primary deoiling treatment items are explored:

- Skimming Tanks & Vessels
- Hydrocyclones
- Voraxial® Separator

Sources of Water to Primary Treatment

Inlet water to primary treatment equipment typically contains 500 to 2,000 ppm of oil. Typical sources of water that will need to be cleansed by primary treatment include:

- Water from Bulk Separators
- Water from Treaters
- Water from Compression Scrubbers

Primary Treatment Objectives

The objective of the primary deoiling stage is to remove up to approximately 90% of the dispersed oil, typically with a skim tank or with hydrocyclones. Effluent from this stage is typically desired to be 50 to 200 ppm oil in water. The primary treatment equipment should also provide a steady flow to the downstream secondary treatment equipment.

Skimming Tanks

Skimming tanks or skimmers are gravity based separation equipment that are designed for continuous separation of oil droplets from water. Skimmers are often provided for surge protection and large slug removal.

Oil droplets rise to the surface and are skimmed off the water surface. The larger the oil droplet, the more likely it is that it will rise to the surface.

Skimmers include vertical and horizontal variations, each with their own advantages and disadvantages. While vertical skimmers are good for locations where large surges in liquid levels occur or high solids loading is expected, they are not preferred for efficient separation. In vertical skimmers, oil droplets must flow upwards against the flow of water. Horizontal skimmers are most often preferred due to their oil removal efficiency.

Hydrocyclone

Hydrocyclones use pressure to force water in a spiral path. They enhance oil removal by increasing the g-force and minimizing the distance an oil droplet has to traverse. As the oily water swirls around the cylindrical chamber, the centrifugal forces force the oil droplets to the center of the chamber, where they coalesce and form a thin core of oil that flows in the reverse direction of the water. The oil exits through a reject oil orifice. The water remains near the hydrocyclone walls and exits out through the hydrocyclone tail section.

Though it's an 'off-label' application, a hydrocyclone can also act as a coalescer. By blocking the overflow, oil is forced to exit with the water in the underflow. Oil droplets forced to the center core coalesce into larger droplets making them easier to remove in downstream equipment.

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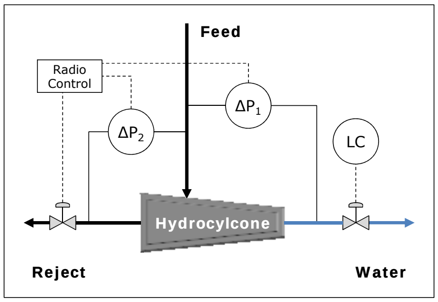

Figure 1: Hydrocyclone Level Control Valve

Pros & Cons of Voraxial® Separators

Pros:
- Does not rely on pressure drop to operate.
- Works for high or low pressure systems and varying flow rates.
- Compact and light weight and low energy usage.
- Variable speeds allow for optimization of separation.

Cons:
- One moving part, the impeller, used to drive the separations.
- Relatively new technology.

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Hydrocyclone performance is a function of the reject stream ratio (Equation 1). If the ratio is too small, too little of the oil will be contained in the reject stream and too much oil will, therefore, exit with the water stream. Though the minimum effective reject ratio may be well under 1%, it is common practice to add a significant safety margin and reject 1.5 – 2% of the inlet flow. The reject orifice size is then based on this ratio.

Equation 1:

$$\text{Reject Stream Ratio} = \frac{\text{Reject Oil Stream Flow Rate}}{\text{Feed Stream Flow Rate}}$$

The reject stream flowrate is governed by the orifice size and controlled by controlling pressure differentials as shown in Figure 1. Where the hydrocyclone is fed from a separator, the liquid level control valve should be installed downstream of the hydrocyclone (also in Figure 1). If the control valve is installed upstream of the hydrocyclone, it will shear oil droplets decreasing the effectiveness of the hydrocyclone.

Hydrocyclones are very sensitive to changes in flow rates which are common in flows from separators due to flowline slugs and/or from poorly tuned or snap-acting level controllers.

Hydrocyclones have poor turndown characteristics. Since the produced water flow rate may change dramatically over field life, some means of accommodating the low turndown must be designed into the system. An effective practice is to install two hydrocyclones, one rated for 67% of design and the other for 33%. It is also common practice to install a limited number of internals initially and increase the number as the water flow rate increases.

Hydrocyclones need a minimum pressure drop of around 100 psi to operate effectively, though this may be lower depending on the size of the hydrocyclone. Pumps may be required upstream of the hydrocyclones in order to increase the pressure drop and get effective separation; however, pumps tend to shear oil droplets. For this purpose, disc pumps or low shear, progressive cavity pumps should be used. Progressive cavity pumps are the most desirable pump, when compared to centrifugal pumps, due to their capability of pumping necessary flow rates at high pressures, around 130 psi, with little slippage and minor oil droplet shearing. Disc pumps use the principles of boundary layer and viscous drag and essentially "pull" the product through the pump instead of "pushing" the product like other pumps. This allows for laminar, pulsation-free flow.

Voraxial® Separator

Hydrocyclones require significant pressure drop to operate. Where such pressure drop is not available, a Voraxial® separator may be a suitable substitute. A Voraxial® separator uses an open impeller to create a vortex with the water and solids drawn to the outside and the oil drawn to the center, forming a core. A special manifold is used to collect the separated streams at the outlet.

Voraxial® separators come in 1", 2", 4" and 8" models ranging from flows of 100 to 100,000 BWPD. Performance similar to hydrocyclones is claimed by the manufacturer and has been achieved in limited field testing. Voraxial® separators are compact and light-weight, require no pressure drop and can be used in high and low pressure systems, making them an easy retrofit for an existing process. Voraxial® separators also have the ability to remove solids down to 50 μm from the feed stream.

Conclusion

Primary treatment is designed to treat water leaving the bulk separation equipment. Water leaving the bulk separation and entering the primary treatment may have oil concentrations between 500 to 2,000 ppm with oil droplet sizes generally less than 150 μm. The water leaving the primary treatment and feeding secondary treatment should have an oil concentration of approximately 50 to 200 ppm with oil droplet sizes around 50 μm.

Future GATEKEEPERs will explore the different equipment for secondary treatment and polishing. Coalescers associated with each stage will also be explored.