SECONDARY SEPARATION TECHNIQUES

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INTRODUCTION

Primary separation methods (such as free water knockouts, gun barrels and skim tanks) often leave substantial amounts of oil and solids in waterflood injection water. Removing oil and solids from produced and supply water streams by secondary separation techniques such as corrugated plate inceptors (CPI) and gas flotation units can provide four benefits:

1. Increased oil sales.
2. Improved water injectivity.
3. Improved waterflood sweep efficiency.
4. Lowered injection pump discharge pressure.

Corrugated plate interceptors (CPI) and gas flotation units historically have been limited to the offshore industry. In this work, the required design and operational data for both of these units will be presented for onshore use. In-house design and construction of these units will improve the economics of these highly efficient systems.

This short course will present the basic theory of separation; why primary separation methods may not achieve sufficient water quality for waterflood injection; the design, operation and limitations of four types of secondary separation systems; what is currently available from manufacturers; and a review of two ongoing projects.

BASIC THEORY OF SEPARATION

Historically oil and water separation equipment has been designed by combining Stokes' Law for drag coefficient and Archimedes' principles for buoyancy to determine the settling velocity of a particle in a medium as shown below:

$$V = (2gr^2)(d1-d2)/9\mu \qquad \text{Equation 1}$$

Where

V = velocity of fall (cm/sec),
g = acceleration of gravity (cm/sec^2),
r = "equivalent" radius of particle (cm),
dl = density of particle (g/cm^3),
d2 = density of medium (g/cm^3),and

μ = Viscosity of medium (dyne-sec/cm^2).

For discussion purposes, this may be reduced to the following:

$$V = \frac{C^*(\Delta SG)^*d^2}{\mu} \qquad \text{Equation 2}$$

Where

V = velocity of fall or rise
C= unit conversion factor, including the gravitation constant (1.78 x 10^{-6} for English units)
ΔSG = difference in specific gravity
d = drop diameter, microns
μ = Viscosity of major phase, cp

This simplified equation shows the three keys to gravity separation:

1. Specific Gravity. Settling velocity varies directly with the difference in specific gravity.
2. Particle Diameter. Settling velocity varies directly with the square of the particle diameter.
3. Major Phase Viscosity. Settling velocity varies inversely with the major phase viscosity.

Separation can be improved by reducing the distance an oil droplet must rise before meeting a coalescing surface, increasing the droplet size on a coalescing surface, decreasing the major phase viscosity and increasing the difference in specific gravity. An historic example of these techniques is the typical oil field heater treater. When the viscosity of the water is decreased by heating and the particle diameter is increased in the coalescence (hay) bed separation occurs.

Primary separation devices may not provide sufficient water quality for injection because primary devices are generally sized for departing oil droplets in the 100 to 500 micron range.

FOUR SECONDARY SEPARATION TECHNIQUES

Droplet size of the minor phase has a large effect on the terminal velocity, the most difficult term to measure, and is often inferred from minor phase concentration and physical conditions. Four commercially available techniques successfully accomplish these philosophies without the addition of heat, which decreases the major phase viscosity. These are the SP pack, plate coalescers, the hydroclycone and the gas flotation unit. Additional information on all these units may be obtained from the book titled "Surface Production Operations" by Ken Arnold and Maurice Stewart. This reference can be obtained from Gulf Publishing Company in Houston, Texas.

SP Packs[1]

The SP pack was developed by Paragon Engineering and is marketed by Modular Production, Houston. This device grows oil droplets by creating a special flow regime that is just turbulent enough to promote growth and not so turbulent as to create shearing of the oil droplet. This device can be placed inside or in series with gravity settling devices to increase the droplet size distribution, as shown in Figure 1. Figure 2 shows a series staged installation allowing more oil to be settled.

The Plate Coalescer[1]

Several configurations of plate coalescers have been devised and are commonly know as parallel plate interceptors (PPI), cross flow separators and corrugated plate interceptors (CPI). These units all increase oil recovery by decreasing the distance an oil droplet rises to meet a coalescing surface as shown in Figure 3.

A common form of this type of device is the corrugated plate interceptor (CPI). The enhancements made to the PPI included a decreased plan area and increased tolerance to sand. Similar to roofing material, the plates are corrugated and placed at a 45^{O} angle to allow sand to settle with the down flow of the water stream. A typical unit is show in Figure 4.

The Hydrocyclone[2]

The hydrocyclone uses centrifugal force to remove oil droplets from water. Water tangentially enters (usually at about 100 psi) the cylindrical swirl chamber creating a high-velocity vortex with a reverse-flowing central core. The water accelerates through the fine-tapered section, separating large oil droplets, while smaller droplets are removed in the tail section (Figure 6). Hydrocyclones may be installed between primary and secondary separation devices where significant pressure is available for operation, as shown in Figure 5.

The Gas Flotation Unit[1]

The gas flotation unit does not separate oil from water by gravity-settling principles in the traditional sense. These units operate by producing large quantities of very small gas bubbles, which rise to the top of the unit and are skimmed off either mechanically or by a batch-overflow process. Two types of units are available: a dissolved gas unit and a dispersed gas unit. These units normally have a constant removal efficiency of about 50% per cell, and about 90% efficiency can be achieved by using four cells.

Dissolved gas units saturate a side stream of water (20% to 50%) with natural gas (usually at 20 to 40 psi) in a contactor and then inject this gas-saturated stream into the flotation chamber. Gas then breaks out of solution in small-diameter bubbles that contact the oil and rise quickly to the top in a froth that is separated.

Two types of dispersed gas units are commercially available: mechanical-rotor type and the eductor type (Figure 6). The mechanical unit's rotor creates a vortex and a vacuum-mixing gas, creating a froth. This oily froth is directed to a skimming tray by the swirling motion where it is removed from the unit. Eductor-type units circulate about a 125% side stream of effluent water to each treating cell. Each cell includes gas venturo eduction to suck gas (less than 10 ft^3 per BBL) from the vapor space of the unit. This gas rises to the top of the unit creating an oily froth, which is skimmed from the unit. These units are normally sized for a retention time of five minutes based on normal capacity.

ONGOING PROJECTS

Burlington Resources Inc. has completed three successful projects using these techniques.

McCamey Water Flood

The original facilities installation used standard gun barrels as primary settling devices for production. However the well bore production is about 0.5% oil in water (5,000 PPM). The gun barrel was separating only about 80% of the oil, the oil was not sellable without addition treating and about 1,000 ppm oil remained in the water. This poor performance was due to several factors:

1. High gas oil ratios were entering the gun barrel causing excessive turbulence,
2. High feed rates (+15,000 BPD) to the gun barrel,
3. Cold temperatures,
4. No coalescence chambers,
5. Long distances for the oil to rise.

The solution included the installation of used and reconditioned horizontal butane storage tanks including a 3 stage coalescing section from Natco (LOUV-A-CHEK). The LOUV-A-CHEK™ was used as a coalescing media. At the design rates of 50,000 BPD the separators have a retention time of about one-hour. Post project testing has shown that water leaving the vessels have about 100 PPM oil in water and the oil have less than 0.5 percent BS&W. Total project cost was about $250,000 per vessel.

Darst Creek Water Injection System

In 1994 Meridian Oil needed to replace one 20,000 BBL gun barrel because of its poor condition. The tank was replaced with five 500 BBL fiberglass tanks with internal PVC coalescing packs to treat 120,000 BWPD and recover an additional 30 BOPD. These tanks also included an inlet distribution baffle and an outlet collection baffle. These baffles created a straight flow pattern through the coalescing pack. The PVC coalescing pack was a similar material used in the top of cooling towers to decrease water vapor loss.

Conclusion

Increased oil recovery in waterflood waters can be achieved by paying close attention to the separation design keys presented in this paper. These keys are as follows:

1. Reduce the distance an oil droplet must rise,
2. Increase the oil droplet size with steel, fiberglass or PVC plates. Remember – doubling the droplet size increases the rising velocity by a factor of 4.
3. The addition of very small gas bubbles can assist oil recovery by adhering to the droplet and increase the difference in specific gravity.

References

1. **Surface Production Operations.** Ken Arnold and Maurice Stewart. Gulf Publishing Company, Houston, LA
2. **Facilities Certification Specialist Course Notes.** Maurice Stewart. International Training & Development. New Orleans, LA.

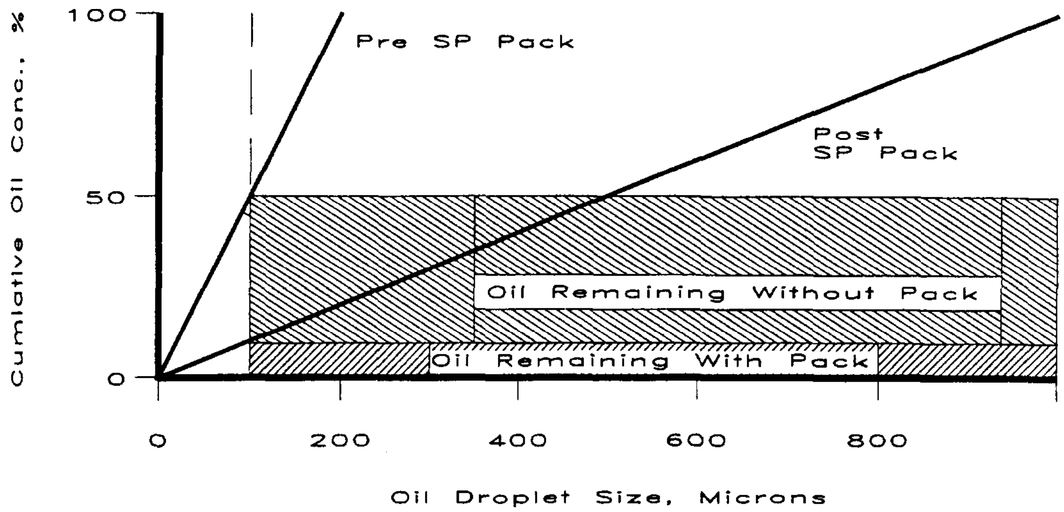


Figure 1 - The SP Pack Grows Drop Size

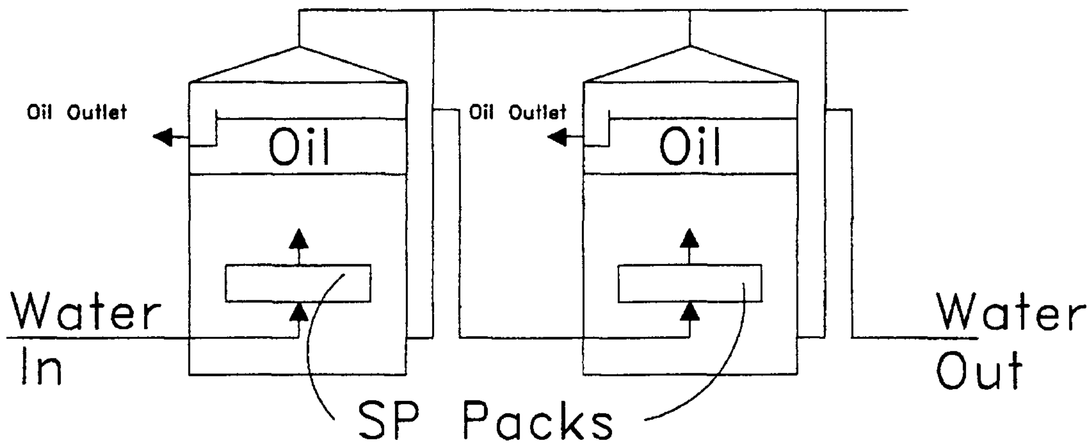


Figure 2 - SP-Packs in Series

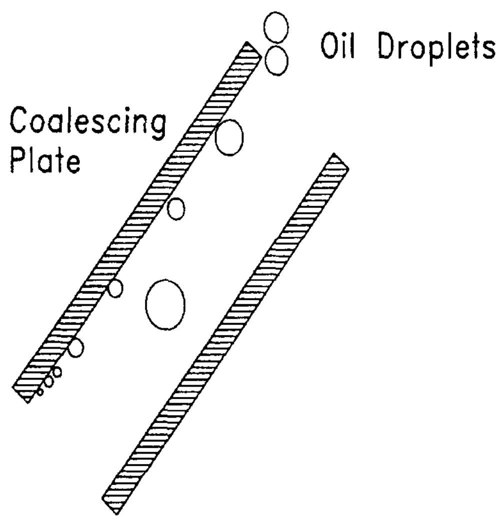


Figure 3 - Plate Coalescers

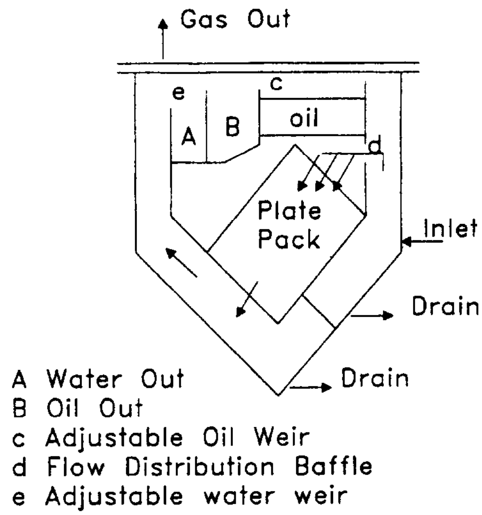
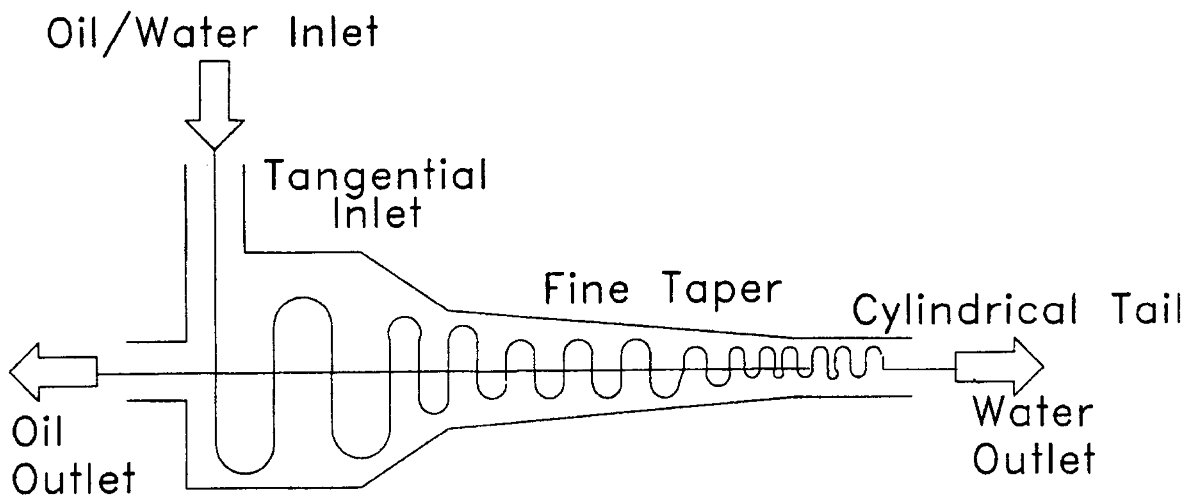


Figure 4- CPI Flow Pattern



Fgure 5 - Vortoil Hydrocyclone Separator

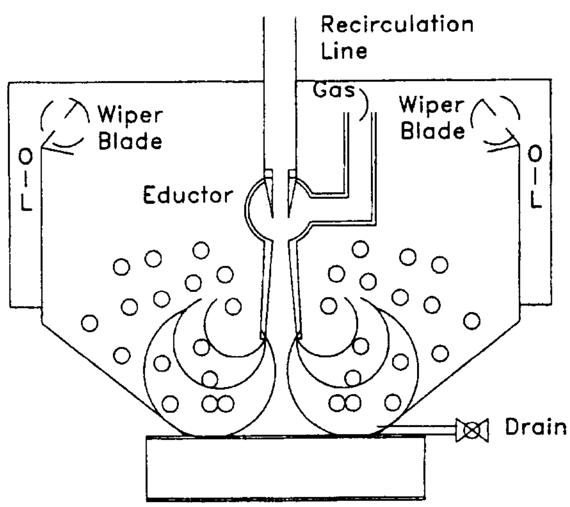


Figure 6 - Cross Section of a Hydraulic Flotation Unit