PRODUCED WATER TREATMENT SYSTEM
Willard Unit, Wasson San Andres Field
Yoakum County, Texas

Mark F. Sheehan
ARCO Oil and Gas Company

ABSTRACT

One major problem frequently encountered in waterflood projects is the poor quality of produced water used for reinjection. One of the main factors usually cited for poor water quality is a high solids content. Another common problem with produced water is excessive carryover from the treating facilities, which can result in a significant loss of revenue.

The produced water treatment system used at the Willard Unit near Denver City, Texas, has been successful in obtaining a good quality injection water. This paper discusses the Willard Unit treatment system and in particular emphasizes the design and operation of the dissolved gas flotation cell presently in use for oil skimming and solids removal.

INTRODUCTION

An excessive amount of undissolved and oil coated solids in injection water can lead to several problems in a waterflood system. The most serious problem is plugging of the perforated interval in an injection well. This plugging decreases flood efficiency which, in turn, decreases oil production. Therefore, it is imperative that most or all of the solids be removed from produced water before reinjection.

One of the critical factors in designing a skimming system is the amount of oil and solids that can be economically removed from the produced water. A mechanical skimming system, needing no induced additives such as chemicals, is an ideal economic method, as there are few operating costs encountered.

The dissolved gas flotation cell presently in use at ARCO Oil and Gas Company's Willard Unit is a self-contained skimming system. The solution gas remaining in the produced water after passing through the free water knockouts is flashed at the entry to the flotation cell. The gas bubbles attach to oil droplets and undissolved solids in the produced water, and float them to the surface where they are removed through a skimming line. This process yields a relatively clean water for injection.

PRODUCTION TREATMENT SYSTEM

A general description of the production system used at the Willard Unit should be helpful in understanding the produced water treating operations.

Produced fluid from the wells first goes to one of fourteen satellite test stations. At these test stations the fluid goes through a low pressure two-phase separator, where the free gas is removed and sold. The produced water and oil-water emulsion is then pumped to the Central Battery (see Figure 1).

At the Central Battery, the emulsion enters one of two 12' x 50' heated free water knockouts (FWKO). The free water knockouts operate at about 82°F and 25 PSIG. From the free water knockouts the oil goes through the chemelectrics and then to the stock tanks. The water is sent to the 2000 bbl flotation cell. After the skimming process, the clean water equalizes over to the 2000 bbl surge tank, where transfer pumps return the water to the injection system.

Approximately 5500 BO and 52,000 BW presently pass through the treating system every day. The flotation cell skims about 1650 BFPD, of which about 30 bbl is oil. The rest is a high solids content water, which is pumped to a disposal well.

FLOTATION CELL DESIGN

The original flotation cell design used at the Willard Unit consisted of a 2000 bbl tank with one external flume. The flowline pressure drop from the free water knockouts released the solution gas in the water, creating the flotation process.

The fluid entered the flotation cell at a point parallel with the level in the tank. The oil and high solids content water were skimmed through a weir parallel with and opposite from the point of fluid entry. The clean water U-tubed through a 10" equalizer to the surge tank.

Research has shown that the gas bubble-particle attachment in a flotation system is delicate, and the shear forces constantly applied during flow can cause detachment. Therefore, the farther away from the flotation cell that the flashing occurs, the more likely it is that the attachment efficiency will decrease. In the original system, most of the solution gas would flash before ever reaching the flume.

Another problem with the original system was that the maximum capacity was about 25,000 BWPD. Water production at the Willard Unit had increased to over 50,000 BWPD. This high throughput significantly affected the flotation cell's efficiency. Therefore, it was decided in 1982 to increase the capacity of the flotation cell to 100,000 BWPD.

Several modifications were required to obtain the desired increase in capacity and also improve the flotation cell's efficiency:

1. Decrease the flowline pressure drop from the FWKO's to the flotation cell to a minimum, thereby allowing a large pressure drop at the flotation cell while maintaining the FWKO's at low operating pressures and below the 50 PSI working pressure.

2. Obtain a 15-20 PSI pressure drop at the entrance to the flotation cell to increase bubble-particle attachment efficiency.

3. Obtain a low fluid velocity through the flotation system to maintain a quiescent surface for skimming.

Decreasing Flowline Pressure Drop

To decrease the pressure drop encountered from the FWKO's to the flotation cell, the flowline sizes were increased and the effective size of the FWKO discharge nozzle was increased.

Since the FWKO's operate in parallel, the discharge flowline pressure drop from each FWKO to the point where the flowlines meet must be equal to ensure even distribution of produced fluid to both vessels. A 12" fiberglass line from the west FWKO and a 10" fiberglass line from the east FWKO were installed to solve the difference in pressure drops (see Figure 1). The 10" and 12" lines were then merged into a common 14" line to the flotation cell. At the flotation cell, three 10" lines (see Figure 2) are used to distribute fluid to the three control valves. The maximum calculated pressure drop with this flowline system is about 8-10 PSI at 100,000 BWPD.

Pressure Drop at Flotation Cell

The most efficient flotation is obtained by an instantaneous pressure reduction on the saturated fluid as near as possible to the skimming process. This instantaneous pressure drop creates sufficient turbulence to disperse the gas bubbles through the liquid phase. The turbulence greatly increases the attachment efficiency of gas bubbles to undissolved solids and immiscible liquids within the influent stream.

Back-pressure valves installed at the fluid entry to the flotation cell create the pressure drop required for the flotation process. Three 8" Fisher 125 PSI W.P. control valves with Fisher 657 diaphragm actuators were installed on the flotation cell. They were placed symmetrically 120^{o} apart (see Figure 2), flanged through a swage to 10" nozzles on the tank.

One Fisher 4162 controller, mounted on the 10" riser to the south control valve, controls all three actuators. The controller is set to a 15 PSI differential, responding to the pressure upstream of the control valve. At present, the upstream pressure is about 20 PSIG, leaving just enough downstream pressure to overcome static head pressure in the tank. This helps provide a smooth skimming surface.

Maintaining a Quiescent Skimming Surface

A quiescent surface in the flotation cell is essential to attain maximum skimming efficiency. To keep the surface smooth, fluid velocities in the flumes and the equalizing line must be kept to a minimum.

A very low fluid velocity, 1 ft/sec or less, is desired in the flumes to avoid turbulence, which could decrease bubble-particle attachment efficiency. An internal 36" fiberglass flume was installed in line with each control valve. The maximum velocity in the flumes is about 0.3 ft/sec at 100,000 BWPD.

Another advantage of using internal flumes is that the fluid outlet is now perpendicular to the skimming surface, as opposed to the original system where the flume outlet was parallel to the surface. With the skimmer inlet moved to the center of the cell, the symmetry of the process is also improved.

The clean water in the flotation cell flows to the west 2000 bbl surge tank through a 24" fiberglass equalizing line. The equalizing line is connected to an internal 24" stand pipe at the surge tank. Maximum fluid velocity through the 24" line is about 2 ft/sec at 100,000 BWPD. The water level in the flotation cell is controlled by an adjustable weir on the stand pipe in the surge tank. This is very useful for increasing or decreasing the amount of fluid being skimmed.

RESULTS

Table I gives a breakdown of the results from water quality surveys performed at the Willard Unit. Although these numbers are obtained from random samples, they give a fairly close estimate of the efficiency of the skimming system.

The revisions to the flotation cell were completed late in 1982. The work on the FWKO's was completed early in 1983. Therefore, the figures for August, 1983, and June, 1984 reflect the improvements in water quality obtained due to the modifications made to the system.

REFERENCES

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Table 1
Results of Water Quality Surveys

	July, 1979	June, 1980	Oct., 1981	Sept., 1982	Aug., 1983	June, 1984
Average BOPD	13189	11069	9039	8516	6837	5891
Average BWPD	51454	50522	53460	58068	53722	51162
(1) TILS	10.8	2.00	2.70	1.31	8.05	5.35
(2) TILS	5.8	2.11	2.00	2.72	1.70	1.10

(1) Average of East and West Free Water Knockouts
(2) Transfer Pump Discharge (Downstream of Surge Tank)

TILS - Total In-Line Solids (Undissolved), MG/L

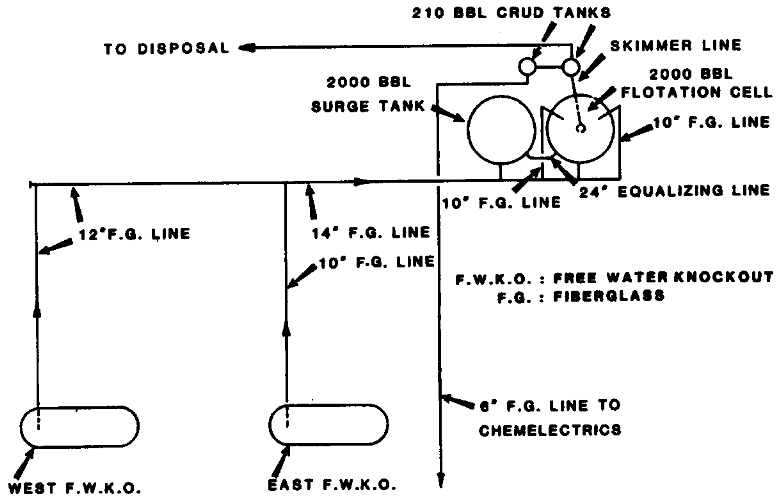

Figure 1 - General layout of central battery water treatment facilities — Willard Unit, Wasson San Andres Field, Yoakum County, Texas

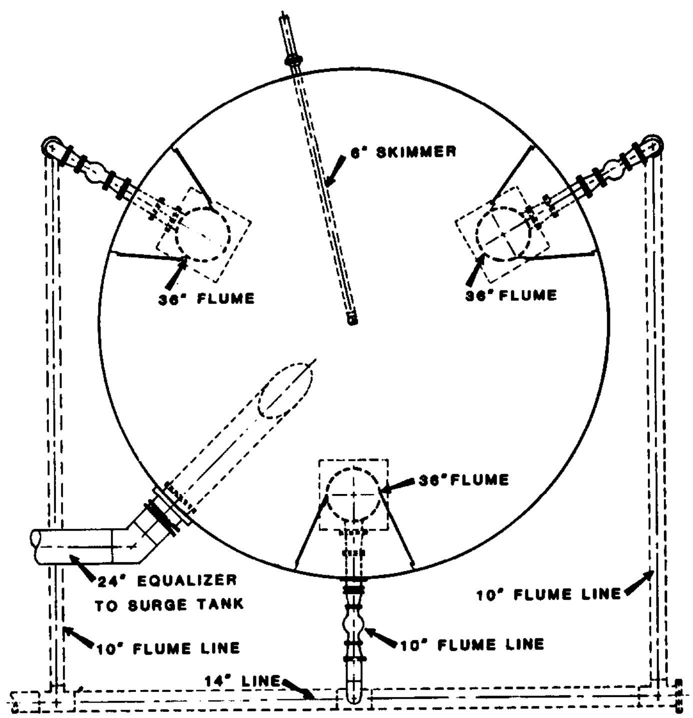

Figure 2 - 2000 bbl tank flotation cell