AN ECONOMIC MODIFICATION TO AN OIL/WATER SEPARATING TANK WHICH IMPROVES FLUID RETENTION TIME

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ABSTRACT

This paper shows how an existing water holding tank designed to separate oil and water is economically modified to increase fluid retention time. A case history from a waterflood in Andrews County, Texas where this design is used is discussed. The results of this study show increased retention time reduced oil carryover and suspended solids in the injection water.

INTRODUCTION

Efficient separation of entrained oil and suspended solids from water used for subsurface injection in a waterflood is economically beneficial to an operator. Removal of these substances from the water improves the reservoir sweep efficiency of the flood to recover oil. Costly injection well workovers due to the perforations plugging are minimized. And, the entrained oil is recoverable instead of injected into the formation.

Oil and suspended solids are separated gravitationally from produced water in large holding tanks in a Central Tank Battery. Separation efficiency is dependent on the quiescence period the fluid has in the vessel. Separation is often inefficient because the Battery was designed to handle less fluid than is now processed, and fluid flow characteristics are not considered when the tanks are built.

Separation efficiency is improved by adding more holding tanks to the system or installing new larger vessels to replace the undersized tanks. This increases retention time. Chemicals are used to decrease the time to naturally separate the oil and solids from the water. These are costly solutions.

Another solution is to modify the existing vessels. The purpose of this paper is to show how existing holding tanks are modified to increase the quiescence period the fluid has in the vessel by considering fluid flow characteristics. This is accomplished without adding internals to the tank, and is achieved with minimal capital costs.

DISCUSSION

An existing tank is modified as shown in Figure I. The inlet water is piped to the top of the vessel. It is sprayed by a perforated pipe, shown in Figure II, parabolicly to the fluid level in the tank. This level is held constant by a waterleg at the outlet. An oil blanket is maintained at the fluid surface which collects the solids and oil in the incoming water. The oil layer becomes thicker as oil is separated from the water. A skim line is attached to periodically remove and recover the excess oil.

Retention time is increased by designing the perforated pipe inlet to spray the water over the entire fluid surface of the tank. The water contacts the fluid surface as small droplets. These droplets have less momentum individually than the collective inlet stream. The only force drawing the water to the outlet is gravity. There isn't any turbulence in the tank to agitate the liquids.

The fluid flow characteristics are mathmatically modeled to show this. Fluid motion in a vessel is described by the stream function, Ψ, and the fluid potential function, Φ. The intersection of these functions are the streamlines of motion.

The stream function is the path a packet of fluid has through a continuous fluid medium. In a water tank it is developed as follows. The position of the fluid is related to its velocity by:

1) $d\vec{s} = vdt$ where: s = position
v = velocity
t = time

This is related to cartesian coordinates in three dimensions by:

$$dx = udt$$
$$dy = vdt$$
$$dz = wdt$$

At any instant in time, i.e., the lim $t \to o$

2) $$\frac{dx}{u(x,y,z,t_0)} = \frac{dy}{v(x,y,z,t_0)} = \frac{dz}{w(x,y,z,t_0)}$$

In this problem the xy plane is the only solution of interest since the x and z planes are the same by symmetry.

$$\frac{dx}{u} = \frac{dy}{v}$$

The velocity, u, in the x direction is influenced by two forces. The shear force of the fluid medium and the draw to the outlet deviates the fluid path from being vertical. The draw force is much greater than the shear force since the droplets do not have much initial momentum.

The draw force acts on the velocity, u, to give

3) $\frac{du}{dx} = \frac{k}{x^2}$ or $u = \frac{-k}{x} + x_0$

The velocity, v, in the y direction is influenced by gravity, the draw to the outlet, and the shear force. The shear force is small compared to the others. The change in velocity, v, is

4) $\frac{dv}{dy} = \frac{k}{y^2} + 2g$ or $v = \frac{-k}{y} + 2\ gy + y_0$

The fluid continuity equation states:

5) $\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y} = 0$

This means an exact differential, Ψ, can be defined as

$$d\Psi = udv - vdx$$

and $d\Psi = \frac{\partial \Psi}{\partial x} dx + \frac{\partial \Psi}{\partial y} dy = udy - vdx$

by inspection $u = \frac{\partial \Psi}{\partial y}$; $v = -\frac{\partial \Psi}{\partial x}$

The stream function Ψ is solved by separating the exact differential and solving it by parts. The solution is not differentiable otherwise. An assumption that the draw in the x direction is the same as the draw in the y direction is made. Therefore,

$$d\Psi = udy - vdx$$

$$d\Psi = (-\frac{k}{x} + x_0)dy - (-\frac{k}{y} + 2gy + y_0)dx$$

Since the draw force is the same dy = dx or

$$d\Psi = (-k + x_0)dx - [(-k + y_0)dy + 2gydy]$$

$$\Psi_{xy} = (-k\ln x + \frac{x_0^2}{2}) + (k\ln y + \frac{y_0^2}{2}) + 2gy^2$$

or

$$\Psi_{xy} = k(\ln y - \ln x + \frac{x_0^2}{2} + \frac{y_0^2}{2}) + gy^2$$

The coordinates are chosen so x_0 and $y_0 = 0$, and g is negative

$$\Psi_{xy} = k\ (\ln y - \ln x) + gy^2$$

The solution is plotted to generate the streamlines. Ψ_{xy} is set to any constant, i.e., [0, 1, 2, 3, ..., n][3]

The streamline solution is the set of (x,y) satisfying this equation. This is shown in Figure III.

A radioactive tracer test was done on a tank designed with two different inlet configurations. The spray nozzle design was compared against a side inlet design chosen to swirl the water in the tank. The results are shown in Figure IV. The spray nozzle design had five times the retention time as the swirl effect design. Furthermore, there wasn't any channeling in the spray design. This is shown by the sharp peak observed at the peak retention time. The swirl effect design has a rough jagged peak originating at almost time equals zero. This indicates channeling. Both curves are predicted by using the mathmatical model.

Oil carryover and suspended solids results are shown in Table I comparing water quality from the two designs. Water quality is much improved in the discharge of the spray nozzle tank.

Implementing this design has minimal capital costs. The only materials needed are additional pipe and a spray nozzle.

There are 26 water tanks in West Texas with this design. The first was built three years ago. All have operated virtually maintenance free since installation.

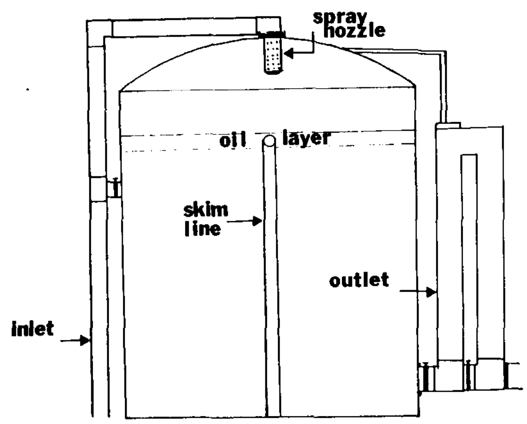

Figure I - Water tank configuration

Table I
Water Quality Comparison

Diffuser Cone

Oil Carryover In	Oil Carryover Out	Suspended Solids In	Suspended Solids Out
94	45	57	38
117	114	63	41
187	115	71	44
74	39	59	27
60	33	43	24
118	52	86	52
120	58	79	37
118	52	76	40

Spray Nozzle

Oil Carryover In	Oil Carryover Out	Suspended Solids In	Suspended Solids Out
94	7	57	10
117	10	63	12
187	16	71	18
74	5	59	8
60	3	43	8
118	10	86	12
120	14	79	16
118	7	76	11

Results are in mg/l

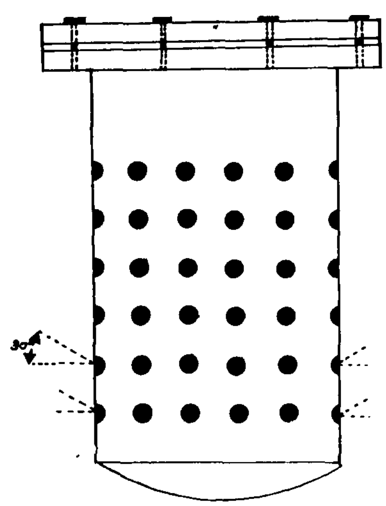

Figure II - Nozzle configuration

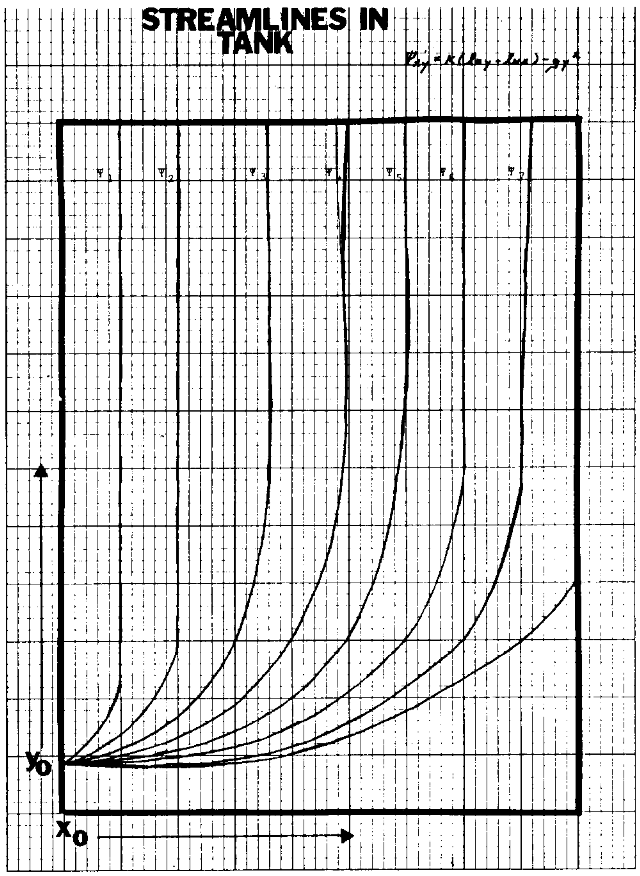

Figure III

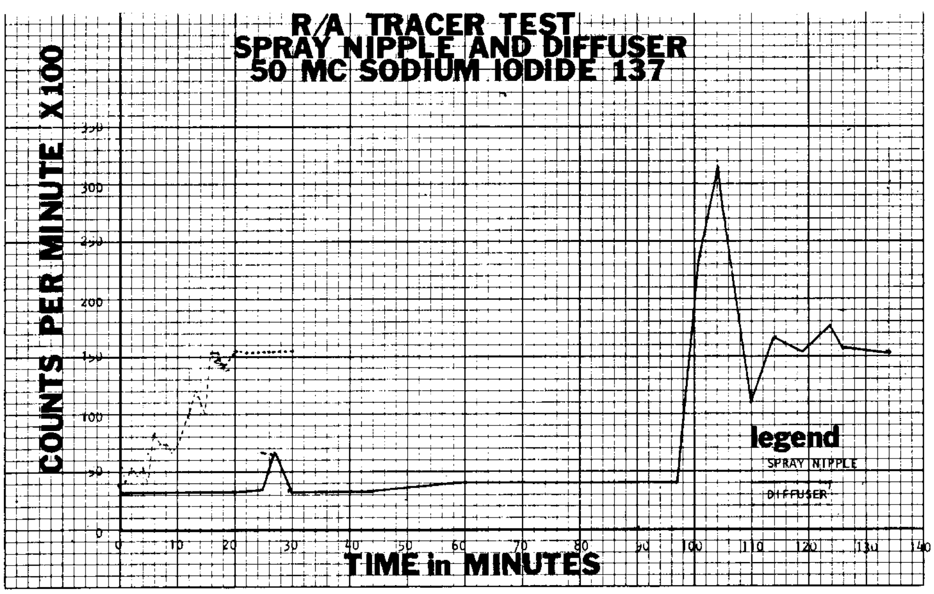

Figure IV