Mohr Separations Research, Inc.

UPGRADING PETROLEUM TERMINAL SEPARATORS USING COALESCING PLATES

Kirby S. Mohr, P.E.
Mohr Separations Research, Inc.
1278 FM 407 Suite 109
Lewisville, TX 75077
Phone: 918-299-9290 Cell: 918-269-8710

Jairo Macias Gutierrez
Full-Filters de Colombia. LTDA
Barranquilla, Colombia

Diego Mamuscai
Mobil de Colombia S.A.
Cartagena, Colombia

A paper presented at the WEF Industrial Wastes Technical Conference in St. Louis, Missouri, 2000

ABSTRACT

In 1999, a project was instituted to replace two oil-water separators at Mobil de Colombia's terminal facilities in Cartagena, Colombia in order to bring the facility into compliance with environmental law.

The separators were concrete in-ground pits equipped with rudimentary baffles and skimmers, as well as built-in tanks for accumulation of separated oil. They processed water from equipment washing, as well as from rainwater runoff. Inlet to the separators was by gravity flow sewers.

It was suggested that it might be possible to inexpensively upgrade the performance of the existing separators using multiple angle coalescing plates instead of providing above-ground steel separators. This would also avoid the additional cost of pumps and utilities to pump the oily water into the proposed new separators.

The existing pit separators were evaluated using a proprietary computer program and it was determined that the existing pits were large enough to meet the national environmental regulations for effluent oil content if fitted with multiple angle coalescing plates.

This paper will present information on the legal requirements, a discussion of how the operating conditions were determined, the new internals designed, and a discussion of how the new internals will affect the quality of the water exiting the facility.

Keywords: Upgrading, petroleum, terminal separators, oil-water separator, multiple angle coalescing plates, Mobile de Colombia

INTRODUCTION

Oil has been refined for various uses for at least 1000 years. An Arab handbook written by Al-Razi, in approximately 865 A.D., describes distillation of “naft” (naphtha) for use in lamps, and thus, shows the beginning of oil refining (Forbes).

Kerosene distilled from coal was patented in the US in 1854 as an inexpensive alternative to whale oil (Scientific American), and it was subsequently found that it could more easily be refined from crude oil. The discoverer, Dr. Gesner of Williamsburgh, NY, planned to pass air through the kerosene and pipe the resulting mixture all over town as a “splendid illuminating gas”! It is not recorded if he carried out this plan, but it would certainly have been dangerous to do so.

The main product of early commercial-scale refineries was kerosene; both lighter and heavier fractions of the crude oil were considered waste disposal problems (Nelson).

Hydrocarbons in the environment did not present much of a problem until the advent of the automobile as a major mode of transportation because petroleum products were not in general use, except as lubricants and in oil lamps. Eventually, kerosene, lubricating oils, and gasoline from petroleum became major industrial products and subsequently began entering the environment in larger quantities.

Refinery effluent water contains various hydrocarbon components, including gasoline blending stocks, kerosene, diesel fuel and heavier liquids. Also present may be suspended mineral solids, sand, salt, organic acids and sulfur compounds. The nature of the components depends on the constituents of the inlet crude oil as well as the processing scheme of the refinery (Jorgensen). Most of these constituents would be undesirable in the effluent water, so it is necessary to treat the water to remove the contaminants.

At the Mobil de Colombia terminals in Cartagena, Colombia, two concrete pit in-ground separators were installed. These pits were designed with some baffles and provided with skimmers, but they were not provided with any coalescing plates or other internals designed to provide low effluent oil content. Both separators were small, about a meter wide and a meter deep, and both had oil holding tanks. The overall configuration was substantially different with separator #1 being much longer. The plan views of these separators, before addition of high-efficiency internals, are shown below in Figure 1 and Figure 2, respectively. Effluent from the separators flows into a stream which flows into the Bay of Cartagena.

FIGURE 1

SEPARATOR NUMBER 1

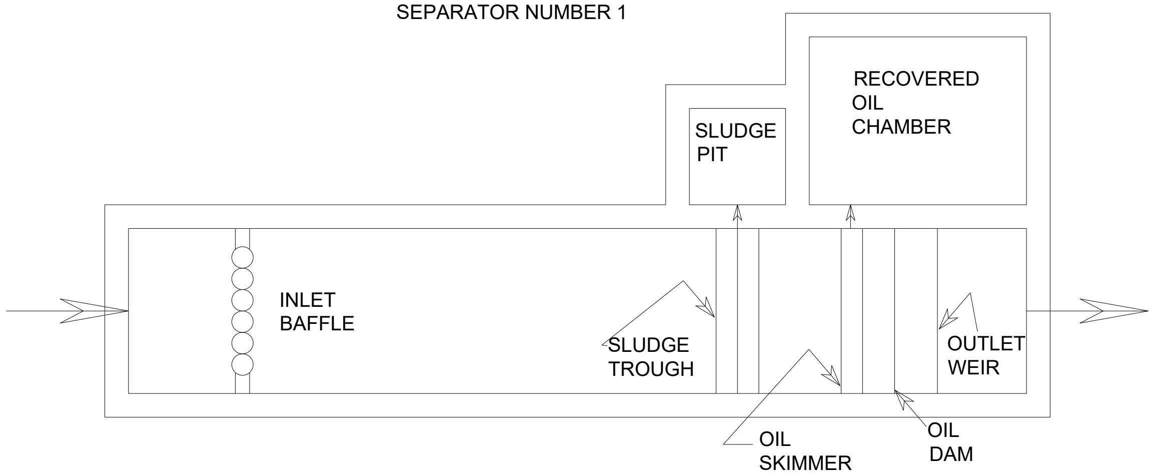
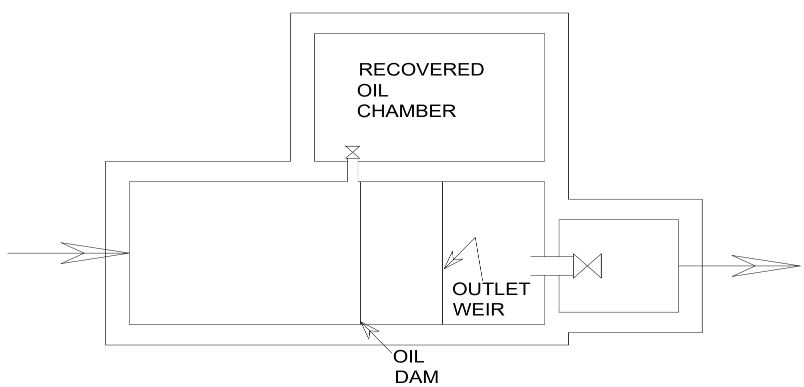


FIGURE 2

SEPARATOR NUMBER 2



LEGAL REQUIREMENTS

Colombian law requires a hydrocarbon effluent quality of 15 mg/L or less. Phenols must be less than 0.2 mg/L and BOD and TSS must be 80% removed. The law is administered by various department (state) agencies. In Cartagena, the agency responsible for enforcement is CARDIQUE. Testing is required to show proof of compliance. The facility is required to test the influent and effluent of the separators during the rainy season as well as the stream upstream and downstream of the effluent (Government of Colombia).

HYDROCARBONS IN WATER

Mobil determined that it was necessary to improve the separation of hydrocarbons from water in order to meet the legal requirements. Hydrocarbons in water can be present in a variety of forms. These are shown below, arranged in general order of difficulty of removal (Cheremisinoff):

1) Free oil - large droplets or sheets that rise freely to the surface. This oil is easily removed in simple gravity separators.

2) Mechanically dispersed oil - fine droplets ranging in size from a few microns up to a few millimeters. The oil found in droplets is usually the result of some mechanical mixing of oil and water, such as is found in pumping or in turbulent flow through a pipe. The oil droplets can be found in a "bell curve" of droplet sizes with some small, some large and a predominance of average size droplets. The average size will vary dependent on the amount of mixing that the two liquids have undergone, as well as the presence or absence of emulsion causing surfactant chemicals. These dispersions may be removed by the use of an enhanced gravity system.

3) Chemically stabilized emulsions - droplet dispersions similar to mechanically dispersed oil, but with droplets stabilized by surface-active agents (surfactants). More surfactants or more mixing will cause a smaller average droplet size. The average droplet size is important because many separation devices are designed to capture droplets by gravity or enhanced gravity separation, and if the average droplet size is smaller, the separator will have to be larger and consequently more expensive.

4) Oil adhering to solid particles. These can be removed by filtration or by enhanced gravity separation if the combined specific gravity is different from the water.

5) Dissolved oil - either truly dissolved oil or finely dispersed droplets, so small (less than 5 microns) that removal by normal physical means is impossible. Dissolved oil must be removed by biological treatment, absorbents, distillation, or other non-gravity means.

In a refinery or terminal wastewater stream, the majority of the oil will be present as either free oil or mechanical dispersions of oil. These may be treated readily by enhanced gravity systems for removal of the hydrocarbons. Most hydrocarbon removal systems depend on gravity or enhanced gravity separation, taking advantage of the buoyancy of the droplets.

The rising of hydrocarbon droplets in a separator is governed by Stokes's Law (Perry). This function, simply stated, is shown in the following equation:

$$Vp = \frac{G}{(18 x \mu)} x (d_p - d_c) x D^2$$

Where:

V_p = droplet settling velocity, cm/sec
G = gravitational constant, 980 cm/sec^2
μ = absolute viscosity of continuous fluid(water), poise
d_p = density of particle (droplet), gm/cm^3
d_c = density of continuous fluid, gm/cm^3
D = diameter of particle, cm

From the above equation, it may be seen that the important variables are the viscosity of the water, the difference in specific gravity of the water and hydrocarbons, and the hydrocarbon droplet size. After these are known, the droplet rise velocity, and therefore, the size of separator that is required, may be calculated. Stokes's Law is only valid for spherical particles or droplets and only in a laminar flow range.

MULTIPLE ANGLE DESIGN TO MEET THE CONDITIONS AND FIT IN THE EXISTING SEPARATOR PITS

Calculations were completed to determine what could be done without major revisions to the separators to ensure compliance with Colombian law. Because the influent quality is variable, conservative assumptions of 1000 mg/L and an average droplet size of 110 microns were used. The separator #1 was provided with four rows of multiple angle type coalescing plates, but separator #2 only required two rows, which was sufficient to ensure that the separator effluent would be less than the required 15 mg/L. The difference in number of rows occurred because separator #1 was not wide enough to provide space for sufficient media in only two rows. Figure 3 and Figure 4 below show separator #1 and separator #2, respectively, after the modifications.

FIGURE 3

SEPARATOR NUMBER 1
(WITH COALESCING PLATES)

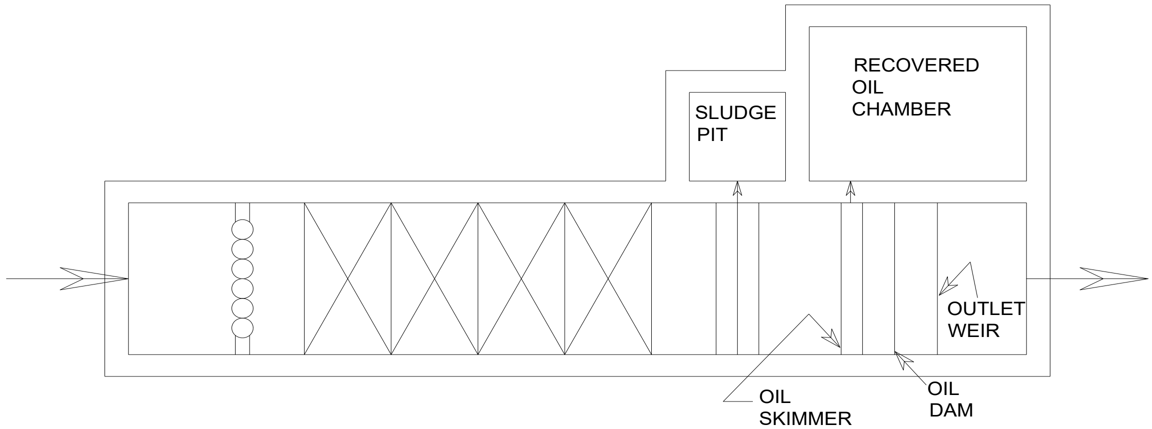
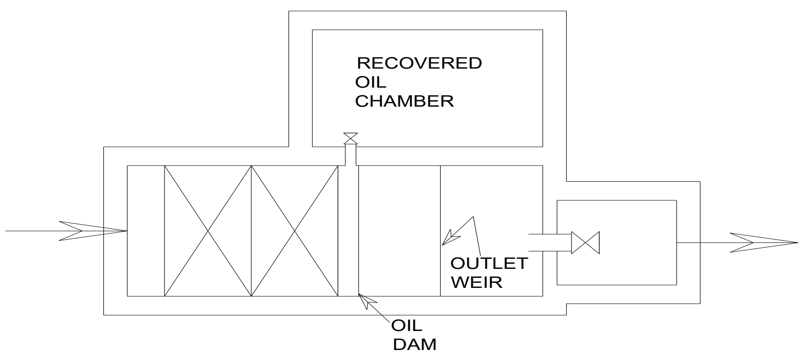


FIGURE 4

SEPARATOR NUMBER 2
(WITH COALESCING PLATES)



SUMMARY AND CONCLUSIONS

Empty pit type separators, even if equipped with oil skimmers, are not capable of removing oil from runoff streams from petroleum facilities to levels allowable under most environmental laws. This is because the oil droplets present in the water streams are smaller than design and will not be captured.

It is expected that the addition of the coalescing plates to the separators at the terminal will improve separation and ensure that the effluent hydrocarbon content will be in compliance with Colombian law, while minimizing construction and disruption of operations within the facility. Long term operations of the separators will be monitored to ensure suitable operations and legal compliance.

REFERENCES

Chereminisoff, P.E. (1993) "Oil/Water Separation", *The National Environmental Journal*, Vol. 3, No. 3, pp. #32-36.

Forbes, R. J. *Studies in Early Petroleum History;* E.J. Brill Co.: Leiden, Netherlands, 1958.

Government of Colombia "Aguas De Vertimeientos Industriales"; 1999.

Jorgensen, S. E. *Industrial Waste Water Management;* Elsevier Scientific Publishing Company: New York, NY, 1979.

Nelson, W. L. *Petroleum Refinery Engineering;* 4 ed. McGraw-Hill Book Publishing Company: New York, NY, 1969.

Perry, J. H.; Perry, R. H.; Chilton, C. H.; Kirkpatrick, S. D. *Chemical Engineers' Handbook;* 4 ed. McGraw-Hill Book Company: New York, NY, 1963.

Scientific American *Patent for Kerosene* **1854**, *9*(46).