Collection and Treatment of Oily Wastewater:
Selection and Design of Oil/Water Separator

Prepared by:
Gregory G. Aymong
Highland Tank & Manufacturing Company, Inc.

Published on www.lorman.com - May 2020

COLLECTION AND TREATMENT OF OILY WASTEWATER

Gregory G. Aymong
Highland Tank
grega@highlandtank.com

ABSTRACT

The public's increasing interest is the conservation of the nation's water resources, which has directly affected many industries. Impacted industrial facilities are facing increasingly more stringent regulations covering the treatment and discharge of oily wastewater and now risk costly penalties resulting from public pressure for the government to control harmful oil spills and pollutant discharges.

Treatment and spill control can be accomplished in several ways; with an oil/water separator, and in some cases, with the addition of an Advanced Hydrocarbon Filtration System. The method of treatment depends on the concentration and the type of contaminants in question as well as the location of the discharge.

INTRODUCTION

The public's increasing interest is the conservation of the nation's water resources, which has directly affected many industries. Impacted industrial facilities are facing increasingly more stringent regulations covering the treatment and discharge of oily wastewater and now risk costly penalties resulting from public pressure for the government to control harmful oil spills and pollutant discharges.

SELECTION AND DESIGN OF OIL/WATER SEPARATOR

Project plans and specifications for an impacted industrial facility will require that the surface area on which oil spills may accidently occur should be fully paved, curbed, and drained so that all spills quickly flow to adequately sized drains without any back up of liquids. Drainage must be capable of removing the oil, run-off from natural precipitation, or water resulting from the intentional hose down operations used to remove the potentially dangerous film of volatile and flammable materials remaining on the surface area. Solid particles, owing to their large surface area, are capable of absorbing oils resulting in the formation of a mixed solid oil contaminant. The result is that, if not removed, the discharge will contain a high content of oil which is mixed with the solids as an oily coated solid.

The problem of oil/water separation can be divided into five elementary categories that describe the ways in which oil can exist in water:

1. Free oil: oil that rises quickly to the surface of the water when given a short retention period.
2. Oily-coated solids: oil that coats the surface of solid particles. Such solids have a very

wide range of origins, densities, and compositions.

3. Mechanical dispersions: distributions of fine oil droplets ranging in size from microns to fractions of millimeters and having stability because of electrical charges and other forces and not because of the presence of surface-active agents.
4. Chemically stabilized emulsions: distributions of oil droplets that are like the mechanical dispersions but have additional stability as a result of chemical interactions typically caused by surface active agents.
5. Dissolved oil: oil that is truly dissolved in a chemical sense plus that oil dispersed in such fine droplets (less than 0.5 microns) that removal by normal physical means (e.g., gravity separation, coalescence, filtration) is impossible.

The degree of difficulty of an oil/water separation problem is, therefore, a function of the oil particle size, distribution (distinguishing free oils from dispersions), and the presence of surface-active agents, dissolved oils, and oily-coated (or non-oily-coated solids). Most separation problems involve chemicals other than oil. This has a wide variety of effects on the treatment required.

The basic unit for recovering oil from wastewater discharge lines is the gravity differential oil/water separator, which is in general use throughout industry. Operation of the separator depends on the difference in specific gravity of the oil and water. For the sake of simplicity, let us consider those categories that respond well to gravity separation; free oil, oily-coated solids, and mechanical dispersions.

Gravity separation methods, which may include provision for extended plate surfaces, are used to move free oil to the surface of a water body for subsequent pump out or skimming. Research and experimental work conducted on gravity differential separators have led to the adoption of fundamental principles which provide a mathematical basis for determining separator designs. The formulas involved, their relationship to separator design, and their derivation are an expression of Stokes' Law for terminal velocity of spheres in a liquid medium, that is applicable to the rate of rise of oil globules in water.

Let us examine the basic theory dealing with the differential gravity separation of particles. Gravity separation permits removal of particles which exhibit densities different from their carrier fluid. Separation is accomplished by retaining the flow stream for a sufficient period of time in order to permit particles to separate out. In the most common wastewater treatment application, let's say the hosing down of an oily petroleum loading rack, we have present in the wastewater stream oil and oily sand-grit. We can assume, because of its specific gravity, that the oil particles will rise to the surface of the carrier fluid, in this case, water. The oil particles are said to possess rise rates. Conversely, the oily sand-grit particles which settle to the bottom exhibit settling rates. Both types obey Stokes Law which establishes the theoretical terminal velocities of the rising and/or settling particles. When considering a rising oil droplet, Stokes Law states:

$$Vr = \frac{g \ (\rho w - \rho o) \ D^2}{18\mu}$$

where:

Vr = rise velocity of the oil droplet in cm/sec
g = gravity constant (980 cm/sec)
μ = absolute viscosity of water in poise
ρw = specific gravity of the water in gm/cm3
ρo = specific gravity of the oil in gm/cm3
D = diameter of the oil droplet in cm

A thorough examination of Stokes Law reveals:

1. The larger the diameter of the oil particle, the faster the rate of rise and, consequently, the faster the rate of separation from the water. Figure 1.
2. The greater the specific gravity difference between the oil and water, the faster the rate of rise of the oil and, again, the faster the rate of separation from the water.
3. The less viscous the water, the faster the rate of separation between the oil and water.

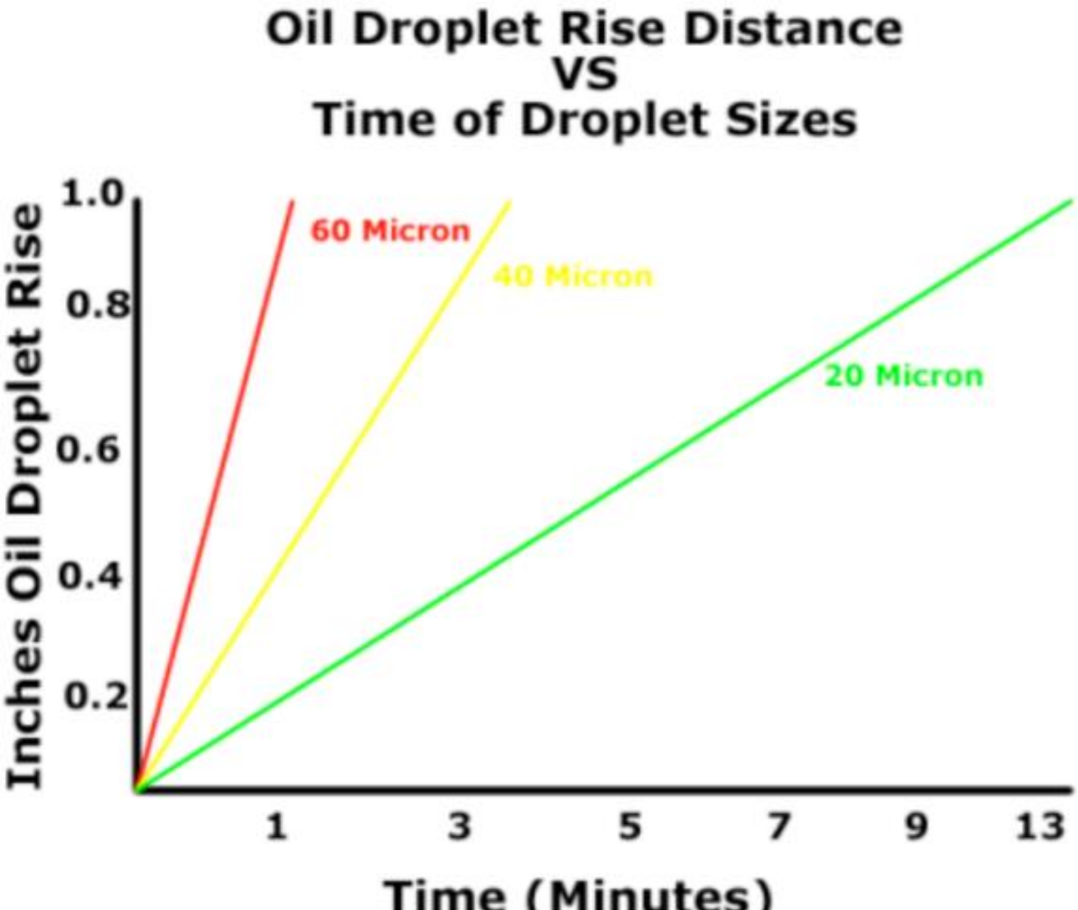
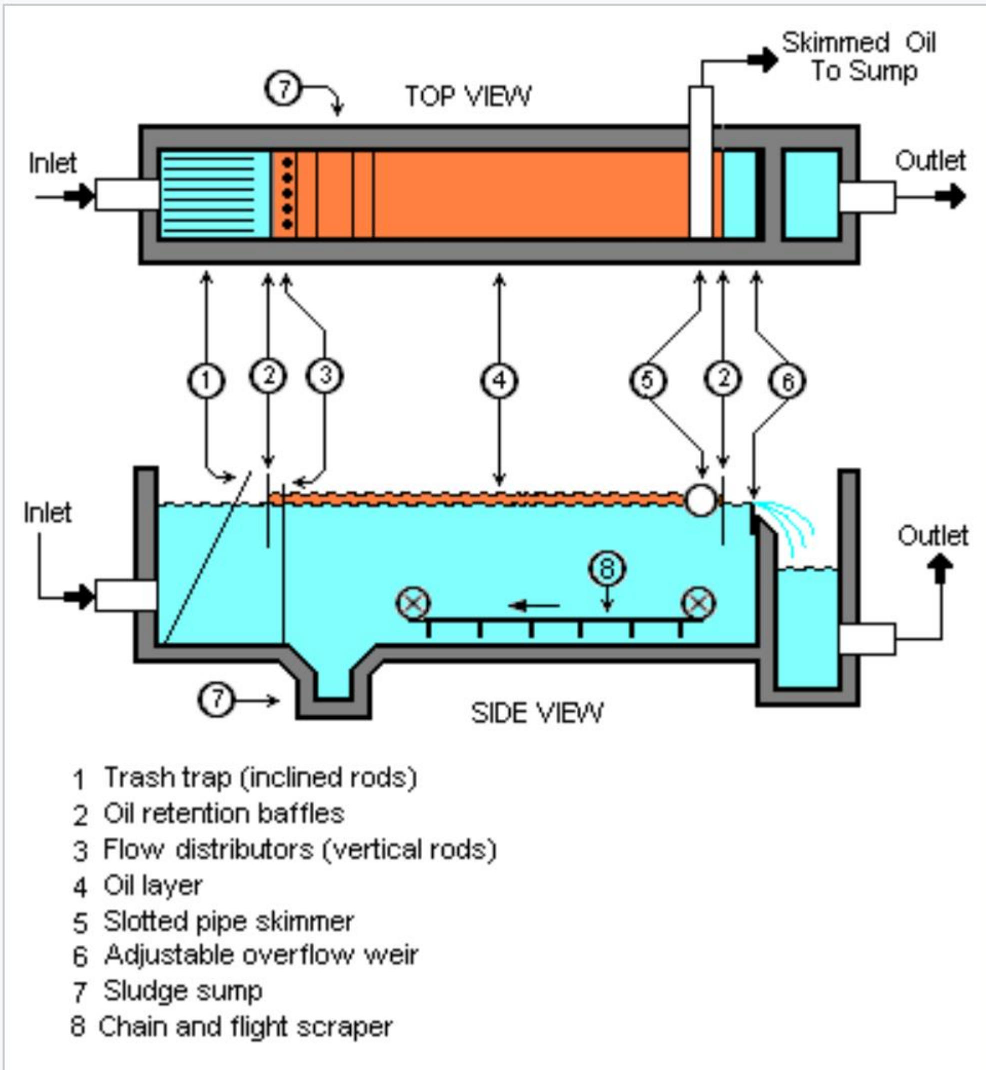


Figure 1

The resulting design is what is commonly known as an API Oil/Water Separator. Figure 2. (NOTE: API stands for American Petroleum Institute.) The conventional API Separator consists of a long, rectangular, horizontal, flow-through vessel, usually constructed of reinforced concrete or of steel. API Separators, simply stated, provide a quiescent zone in which oil droplets can rise to the surface of the vessel and be skimmed off. The design of the API Separator is based on the removal of free oil globules 150 microns in size and larger. Oil globules that are smaller in size than that or that are loaded with suspended solids may remain in the wastewater since they rise too slowly to reach the surface of the water before discharge. The overall size of the API Separator depends on the wastewater flow rate, specific gravity of the oil, and the temperature of the water. More than likely, the common API Separator will be extremely large and voluminous.

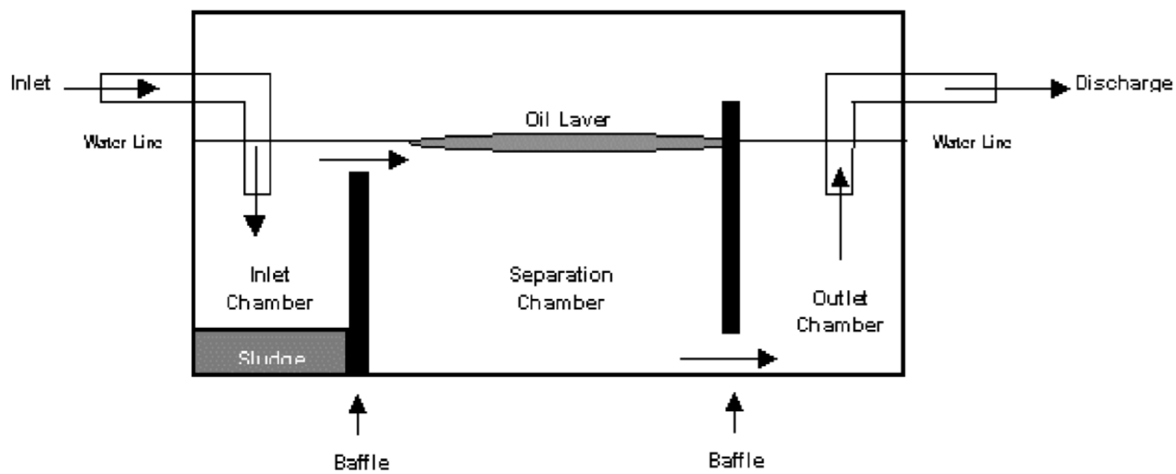
Most facilities operate under conditions that make the API Separator less than suitable. Some disadvantages are limited space, potential for freezing during the winter months, evaporation of volatile hydrocarbons (posing air pollution and fire hazards) and, most commonly, a low number of trained operating personnel available.



A typical gravimetric API separator

Figure 2

The initial attempts to alleviate some of the problems encountered with the API Separators by placing baffled tanks below ground have met with limited success. These separators are more commonly referred to as Oil Interceptors. Figure 3. These interceptors are relatively simple, requiring nothing more than an underground, horizontal, cylindrical or rectangular vessel with influent and effluent tees and divided into compartments by a series of vertical baffles. With no complex internal structure, this simple underground oil separation tank receives the wastewater flow by gravity. The flow is retained for enough time to permit the oil and water to separate because of their difference in specific gravities. Surface oils are skimmed or pumped from the interceptor to an oil slop tank or tanker and the effluent discharge is drained to other treatment points or to final discharge.



Oil Interceptor
Figure 3

Due to their limited capabilities, Oil Interceptors should be connected to a sanitary sewer with discharge requirements of $\geq$100 mg/L. With stricter effluent requirements, Oil Interceptors are impractical. They may be able to remove large droplets of oil and oily coated solids relatively easily but as droplets become smaller, the treatment methods required to remove them for compliance become more complicated.

To further improve the efficiency of the API Separator, we would have to increase the size of the separator in order to increase the distance between the inlet and the outlet to increase the retention time. As a result, we would be increasing the surface area of the API Separator. If this surface area could be subdivided and stacked in layers, this would considerably decrease the required ground area without effecting separator efficiency. This is the basic principle achieved with parallel coalescing plate oil/water separators.

The operating principle of the parallel coalescing plate oil/water separator is that the efficiency of the unit is not dependent on the retention time or the depth of the tank, but on the plate's projected surface area.

In the conventional API Separator, an oil globule must traverse the full depth of the vessel to separate out. In the parallel coalescing plate separator, the oily water flows between closely stacked, parallel corrugated plates. The oil particles rise and are stopped or blocked by the plate above. Since the oil particles build up on the underside of the plates, they coalesce as large globules of oil of a greater diameter that rapidly rise to the surface.

The plates in this type separator have a corrugated configuration and are stacked so that the corrugations are parallel to each other and are angled to the wastewater flow. The corrugations of each of the plates are shaped and positioned to provide alternating acceleration and deceleration to the fluid flow enhancing collisions between the oil particles and coalescence between them.

Thus, in the parallel coalescing plate separator, the maximum distance that an oil particle must rise for effective removal is the few inches between the plates instead of a few feet, as in the API Separator. Because of this characteristic in design, these units are about one-fifth the size of the API Separator and can achieve greater removal efficiency – down to a 60 micron diameter oil droplet. In addition, the parallel coalescing plate separators are less subject to the turbulence that can reduce conventional API Separator efficiency.

DEFINITIONS

OIL: Oil means oil of any kind or in any form, including, but not limited to: fats, oils, or greases of animal, fish, or marine mammal origin; vegetable oils, including oils from seeds, nuts, fruits, or kernels; and, other oils and greases, including petroleum, fuel oil, sludge, synthetic oils, mineral oils, oil refuse, or oil mixed with wastes other than dredged spoil. See the "List of Petroleum and Non-Petroleum Oils" on the USCG Web site at: https://homeport.uscg.mil/mycg/portal/ep/contentView.do?contentTypeId=2&channelId=30565&contend=120944&programId=117833&programPage=%2Fep%2Fprogram%2Feditorial.jsp&pageTypeId=13489&BVSessionID=@@@@1350455393.1250257064@@@@&BV_EngineID=cccdadehmkjifjkcfjgcfgfdffhdghm.0

DISSOLVED OIL: The oil fraction that forms a solution with water; or oil that is $\leq$ 0.5 microns.

EMULSIFIED OIL: Small oil droplets (in the range of 1 to 20 microns diameter) that form a stable suspension in the water as a result of the predominance of interparticle forces over buoyant forces.

FREE OIL: Oil droplets that are of sufficient size (greater than 20 microns in diameter) so that they can rise as a result of buoyant forces to form a defined oil layer on top of the water in an oil/water separator.

RISE RATE: The velocity at which oil droplets move upwards toward the surface of the oil/water separator.

OIL INTERCEPTOR: A gravity oil/water separator designed to remove free oil (150 microns or greater) and some suspended solids. Interceptors are relatively simple, requiring nothing more than an underground, horizontal, cylindrical or rectangular vessel with influent and effluent tees and divided into compartments by a series of vertical baffles.

ENHANCED OIL/WATER SEPARATOR: A gravity oil/water separator that uses more technically sophisticated methods to remove oil globules as small as 20 microns. Enhanced coalescer technology combine the features of both a flat plate coalescer and a corrugated plate coalescer into a new “self-cleaning” design that performs better than traditional plate separators. Equipped with secondary, impingement coalescers, they meet the new Underwriter’s Laboratories, Inc. UL SU2215 design, construction, and performance standards for engineered oil/water separators rated at 10-ppm oil and grease.

REFERENCES

API, *Monographs on Refinery Environmental control – Management of Water Discharges, Design and Operation of Oil-Water Separators,* Washington, DC: American Petroleum Institute.

Branion, R. “Principles for Separation of Oil Drops from Water in Gravity Type Separators.” In *Oil in Freshwater: Chemistry, Biology, Countermeasure Technology,* New York, NY; Pergamon Press.

Dull, L. Survey of Oil/Water Separating System Technologies or Methods and Their Application id Controlling Pollutants of Concern in Wastewater from Transit Buses, Seattle, WA: Metro, 1984

OSHA, *Title 29, Code of Federal Regulations (CFR) Part 1910*, Washington, DC, Occupational Safety and Health Standards.

U.S. EPA, *Title 40, Code of Federal Regulations (CFR), Part 112, National Pollutant Discharge Elimination System*, Washington, DC; United States Environmental Protection Agency.

U.S. EPA, *Title 40, Code of Federal Regulations (CFR), Part 280, Technical Standards and Requirements for Owners and Operators of underground Storage Tanks,* Washington, DC; United States Environmental Protection Agency.

U.S. EPA, *Title 40, Code of Federal Regulations (CFR), Part 112, Oil Pollution Prevention*, Washington, DC; United States Environmental Protection Agency.

UL, *Subject 2215 Outline of Investigation for Oil/Water Separators,* Northbrook, IL: Underwriters Laboratories, 2000.

ABOUT THE AUTHOR

Gregory G. Aymong is Vice President of Sales for Highland Tank, the largest producer of Storage and Wastewater Treatment Tanks and in the United States. He is also the inventor of the patented Highland Tank Oil/Water Separator and Corella® enhanced coalescer technology and has worked for Highland Tank for 34 years. His numerous equipment and process patents and designs are used extensively by petroleum, industrial, municipal, military and commercial facilities worldwide for the prevention of oil, grease, and hazardous materials spills into the environment.

Mr. Aymong has worked in the industry in the United States and overseas for 40 years and has authored numerous articles on oil/water separators and storage tanks and vessels. Gregory has lectured on "Water Storage Tanks: From Construction to Rehabilitation" for Lorman Education Services. He has spoken about storage and wastewater treatment tanks at many Petroleum Equipment Institute (PEI), National Petroleum Management Association (NPMA), National Institute for Storage Tank Management (NISTM), American Society of Plumbing Engineers (ASPE), American Society of Sanitary Engineering (ASSE), Constructions Specifications Institute (CSI), Water Environmental Association (WEA), American Society of Civil Engineers (ASCE), and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) chapter meetings in the United States and Canada.