Enhancements to Conventional Wastewater Treatment Equipment

by
Frank A. Richerand Sr.

ENVIRO-TECH
SYSTEMS
WASTEWATER SPECIALISTS

Presented at

OSEA 2006 Conferences
Suntec Singapore
December 5-8, 2006

17327 Norwel Drive, Covington, LA 70435
Tel: (985) 809-6480 Fax: (985) 809-6422
www.envirotechsystems.com

Abstract

As government ordinances for the treatment and disposal of wastewater become more stringent, it is important for operators to obtain a better working knowledge of available treatment methods as well as a better understanding of how to improve the performance of existing equipment. Manufacturers must strive to improve present technology while researching new methods of treatment entering the marketplace. The purpose of this paper is to inform the reader of the improvements available to conventional treatment equipment, i.e. Corrugated Plate Separators (CPI) and Induced Gas Flotation Cells, (IGF), In addition, we will focus on how these improvements can aid the operator to comply with present ordinances and take aim at the projected target of future regulations, all within reasonable budget constraints.

Introduction

The mandate from the U.S. Government for offshore disposal of produced water is 42mg/l maximum and 29-mg/l average. This mandate for produced water disposal comes to us as the Federal Register Document 40 CFR Part 435. Quoted directly from this document:

> **Under BAT and NSPS, the discharge of oil and grease in produced water will be limited to a maximum for any one day (referred to as daily maximum) of 42 mg/l and an average of daily values for 30 consecutive days (referred to as monthly average) of 29 mg/L based on improved operating performance of gas flotation technology. BCT (Best Conventional Pollutant Control Technology) for produced water is being established equal to the current BPT (Best Practicable Control Technology) limitations on oil and grease.**
>
> **Federal Register March 4 ,1993**

It suggests that the Best Available Technology (BAT) be applied for treatment and discharge applications. To currently comply with these regulations, wastewater treatment equipment must be designed to treat water effluents down to less than 29 mg/l, remove and contain solids for disposal and dispose of effluents all within a limited toxicity. Our discussion will not only enable the operator to make better choices for equipment in new applications but more importantly it will enable him to correctly respond to improving any existing equipment now in service to meet new and future regulations.

A Brief History of Conventional Wastewater Treatment Equipment

In the early 1950's, Royal Dutch Shell was working to improve treatment of the water phase of a production train. At that time, the most practical method was bulk oil skimming in a tank, with large intervals of retention time. Shell's, most significant improvement to this skimmer design was the addition of closely spaced plates (Figure-1) to improve separation. With the addition of the pack section, Shell Oil Co. was able to decrease the distance of rise required for an oil particle to travel to be removed from the flow stream, thus reducing the required retention time and space requirements for a gravity settling device.

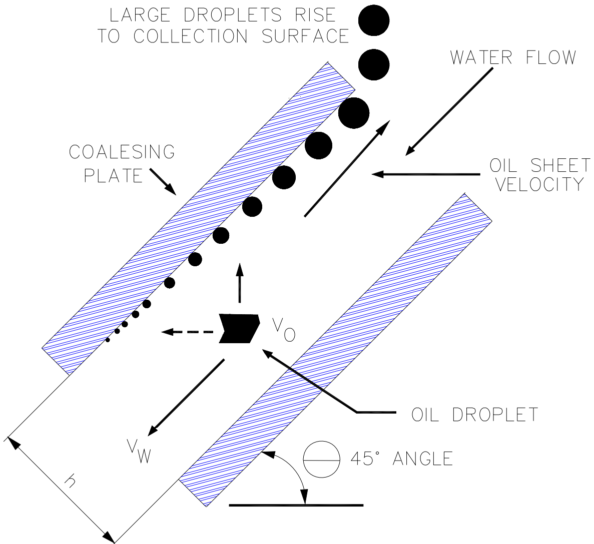


Figure-1
Closely Spaced Plates

The CPI design (Figure-2) has been employed in the oil and gas industry as well as many other industries from automotive to food processing. With discharge ordinances coming into focus in the early 1970's, operators again began to look for improvements to the performance of wastewater disposal equipment, and to add equipment down stream of the CPI. At that time, the mining industry was using a method of agitation / flotation to remove solids from the spoils of the mine. Again, Shell Oil Company. familiar with the operation. began to test this same principle in the oil field. The first Flotation Cell pilot unit was installed on a Shell platform around 1970 and the combination of the CPl and IGF proved to be the forerunner of the present day conventional water treatment system, 28 years later.

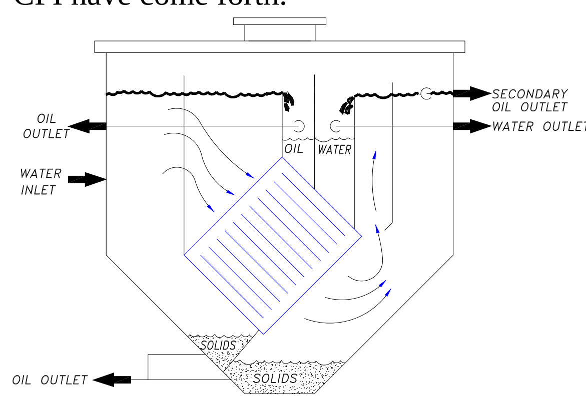
Ordinance Changes

Until the 1970's there was no real ordinance in place for disposal of wastewater in the Gulf of Mexico. At that time the USGS (now Minerals Management Services) developed a set of regulations for monitoring the disposal of wastewater into federal waters, hence the OCS orders. Since that time, there has been a steady reduction in acceptable effluent oil concentration at the point of discharge. With laws now in place, there has been a flurry of different techniques employed to improve on the basic principle of gravity separation. Unfortunately, there has been only moderate improvement to those principles within the last twenty-five (25) or so years.

Change to Meet the Challenge

Corrugated Plate Separators

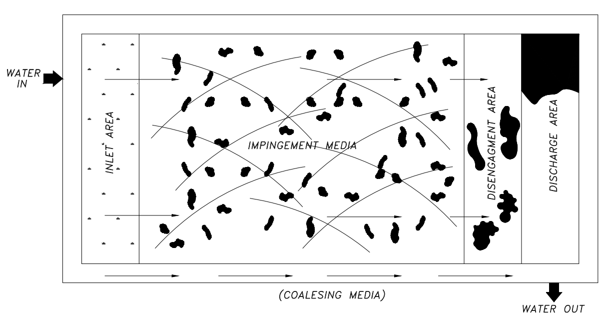
Although the actual principle of plate separation has been improved only moderately over the years. a closer look at the design and operation of this technique will give us better insight on methods to improve its operation. For years, the single most troubling problem associated with CPI's was plate pack plugging. Other significant problems have been proper sizing of the plate pack, removal of a thick floating oil layer, level control, inlet oil coalescence, easy entry into the vessel, visual contact with the CPI internals and durability of the pack during maintenance operations. From a study of these problems, the following changes to the design of the CPI have come forth.



Corrugated Plate Separator
Down Flow
Figure-2

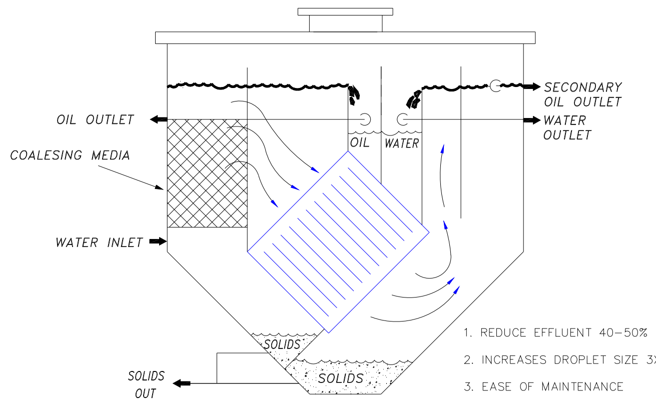
Coalescence

For coalescence to take place properly, certain conditions must be met (see Figure 3). Impingement media type and size is of prime concern for this operation. Making sure to use oleophillic material loosely packed should be our primary choice. Since the CPI is strategically located in the waste stream, it becomes a perfect place to provide coalescence of incoming oil droplets. There have been many attempts at successfully coalescing oil droplets, the most successful being the SP Pack developed by MPE creating a high velocity for impingement along with internal plates for collection and particle growth. Field testing indicates that applying the correct flow to the correct area of media being careful not to create undue pressure drop is sufficient to provide proper coalescence. In the Plate Separator, placing the coalescing material at the inlet of the vessel just above the inlet and after the initial separation of oil droplets and solids is the optimum location for coalescence (Figure-4). This placement will allow maximum particle growth, (theoretically 3 times) before entering the final stage of separation in the plate pack sections. The SP Pack can either be added internal to the CPI or external. For field modifications the external choice is the optimum.



The Coalescing Process

Figure 3



CPI with Coalescing Media

Figure 4

Plate Pack Sizing

Plate pack sizing is based on Stoke's Law. A common calculation most recognized for the sizing of the plate pack is as follows:

Standard Plate Pack

40" x 41" x 69"
¾" Plate Spacing (1/2" & 1" Optional)
45° Plate Angle (60 Optional)

Sizing Formula

Q_w = Flow Rate (BWPD).

U_w = Viscosity of the water (cp).

d_m = Diameter of the oil droplet(micron).

ΔSG = Difference in Specific Gravity.

C = Constant

Plate Packs Required

$$\text{No. PP} = \frac{C Q_w u}{\Delta SG\,(d_m)^2}$$

As important as the plate pack sizing, but generally overlooked is **Reynolds' Number,** the calculation for determining laminar flow. After carefully considering the Stoke's Law calculation to size the pack, we should then turn our attention to the Reynolds' Number calculation making sure not to exceed a 1000 Reynolds Number. Water treatment authorities have agreed that flowrates below 1000 Reynolds Number are generally in a laminar flow regime Only after comparing both the oil separation capability of the CPI (Stoke's Law) and the flow characteristics (Reynolds' Number) can we make the correct choices for the proper size of the CPI.

<u>Reynolds Number</u>

$$Re = \frac{C\,Q_w h}{HWu_W}$$

Q_w	=	Flow Rate
H	=	Plate Spacing
U_w	=	Viscosity of Water
H	=	Height of Wetted Perimeter
W	=	Width of Wetted Perimeter
C	=	Constant

Oil Removal

One of the most common problems associated with the removal of oil from the CPI is the placement of the adjustable oil spillover point in relation to the fixed weir, which maintains the water level in the vessel. Most commonly, CPIs are operated at atmospheric pressure, however there is an increasing movement within offshore operations to maintain the vessel under pressure making the transfer of liquid easier. Sizing and designing the weir is made easy by using this calculation.

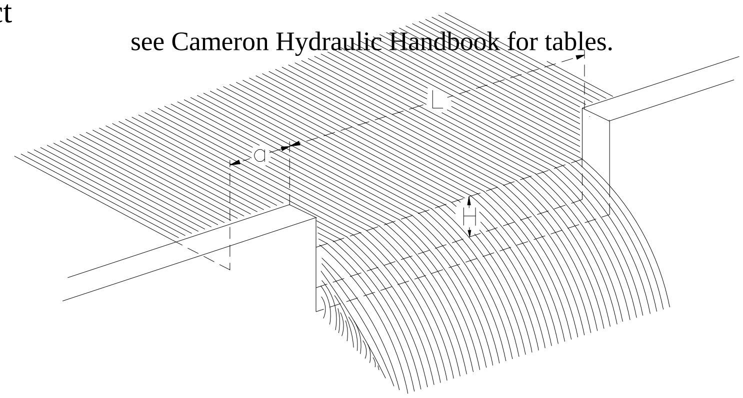
Straight Weir Calculation

$$Q = C\,(L - 0.2H)\,H$$

in which

Q	=	ft^3 of water flowing per second.
L	=	length of weir opening in feet.
H	=	head of weir in feet
a	=	should be at least 3 H
C	=	Constant

see Cameron Hydraulic Handbook for tables.



Straight Weir

Figure-5

V-Notch Weir Calculation

$$Q=(C)(4/15)(L)(H)v2gH$$

in which

Q	=	flow of water in ft^3/sec.
L	=	width of notch in feet at H distance above apex.
H	=	head of water above apex of notch in feet.
C	=	constant varying with conditions.
a	=	should not be less than ¾L.

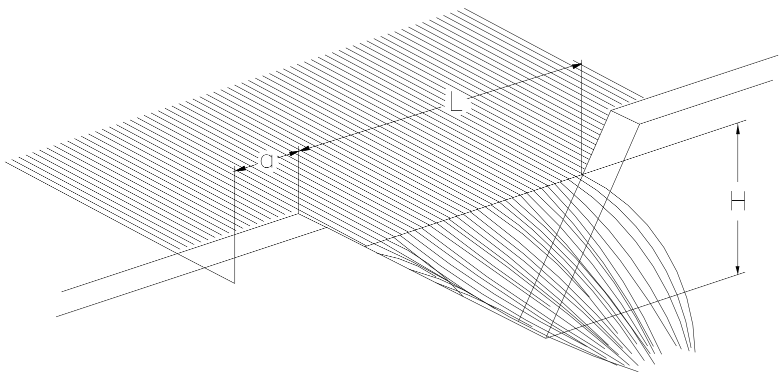
For 90° notch the formula becomes

$$Q = C\,H^{5/2}$$

For 60° notch the formula becomes

$$Q = C\,H^{52}$$

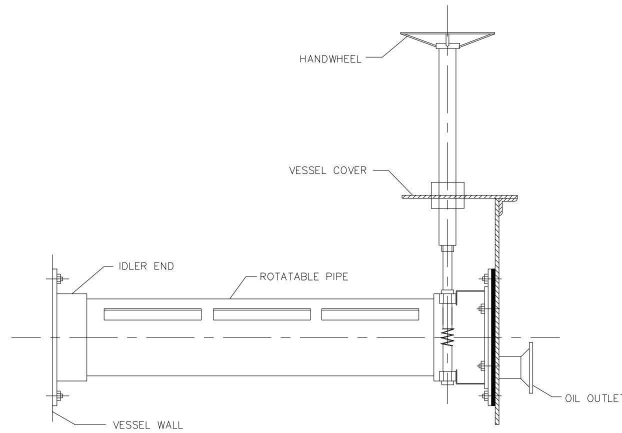
See Cameron Hydraulic Handbook for tables.



V-Notch Weir

Figure-6

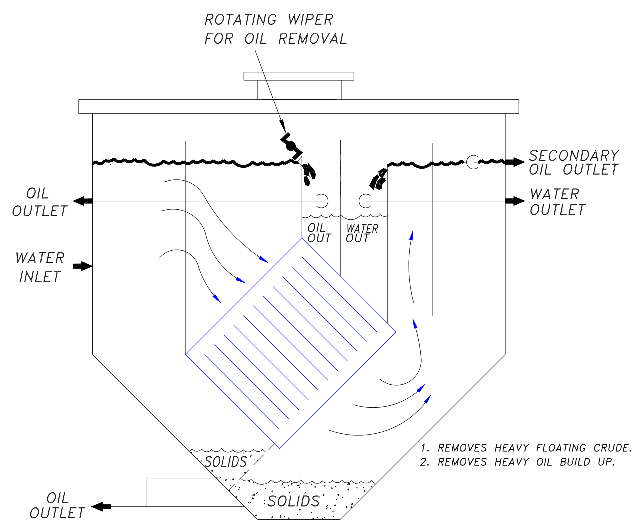
Generally straight weirs are used for the control of water spillover and v-notch weirs are used for the oil spillover. The v-notch weir concentrates the collected oil for a more pure oil spillover into the oil bucket. Adjustability becomes important where there are large flow fluctuations, surges and multiple oil and/or water density. If this is the case, a more novel approach may be recommended for removal of the oil. Consider a fully rotatable pipe skimmer. allowing external adjustment of the spillover point to match the oil pad height (Figure-7). Level adjustment can be made easily with this design, just by turning a handwheel. the spillover point can be moved quickly either up or down within 180 degrees. The pipe acts as a oil bucket for minimal oil storage.



Rotatable Pipe Skimmer

Figure-7

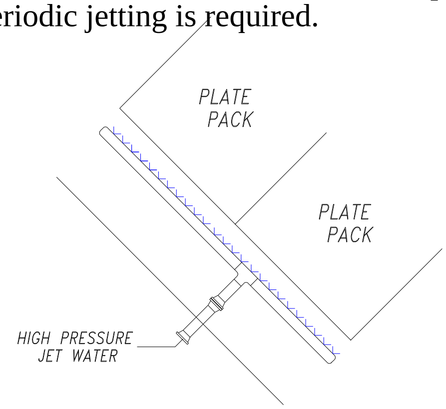
Another little used method of oil removal is a rotating wiper mounted at the oil spillover point (Figure-8). This method has been employed in applications where thick viscous crude has been separated in the CPI and it is unable to physically spill over the weir. A slowly rotating wiper blade at the spillover point will allow the collected oil to be easily removed.



CPI with Rotary Wiper Blade
Figure-8

Plate Pack Jetting

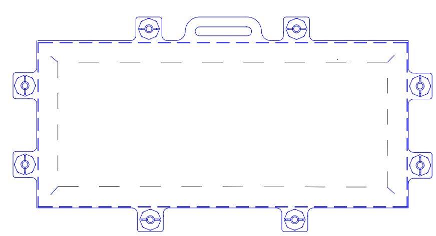
Plugging of the plate pack has been a major concern over the years. Solids concentrations can be high at this point in the wastewater stream. Preparation for the collection and handling of the solids is mandatory for proper operation. In the early years of the CPI, provisions for solids handling were not considered, and the CPI had a tendency to plug under heavy solids conditions. To prevent this from occurring, a careful look at the solids handling design is required. First, let us look at the inlet chamber of the CPI. Initially, solids entering the CPI must have a place to settle. If proper Reynolds numbers are applied to the operation of the CPI, settling of the solids will occur naturally. Having a large inlet chamber with provision to hold a specified amount of solids is mandatory. Second, a way to concentrate, jet and remove these collected solids is important. By placing a minimum of a 60° angle on the hopper section of the CPI, will allow for the free fall of oil wet solids into an area where they can be contained, slurried and removed. Therefore a jetting header in the primary solids compartment is preferred. During periods of normal operation, a jet-slurry cycle is sufficient to remove collected solids. Often times, all the solids are not collected in the primary solids chamber and can be transferred through the pack section and settle in the secondary solids section. In similar fashion, the secondary solids section should also contain jetting for removal of solids. Please note that a manway should be included for access into these areas. Due to the 45 degree angle (angle of repose of oil wet sand is around 55 degrees) the plate pack may have a tendency to collect some of the solids that pass through the system. To prevent this from becoming a problem, the pack may be placed on a 60 degree angle or jetting should be considered. (Figure 9) Plate pack jetting consists of using a jetting manifold just on the underside of the plate pack with closely spaced nozzles, jetting high pressure water or chemically treated water to the underside of the pack to dislodge any and all solids that may have adhered to the bottom of the pack. Field experience shows that solids will accumulate at the base of the pack initially and work their way upward until they close off the pack entirely. As the pack section begins to plug. there will be a noticeable rise in level on the inlet side of the pack. Periodic jetting is required.



Jetting Header
Figure -9

Oxygen Exclusion and Ease of Access

Entry into the CPI is often encumbered with bolt on manways. There is generally little access space above the pack and usually some difficulty associated with removing the pack. An important part of any CPI design is to allow for quick and easy access to certain areas, (Figure-10) the most critical areas being above and below the plate packs and the adjustable weirs. A removable top is necessary for access to clean and remove the plate pack section .



Hatch Cover Detail
Figure-10

Adjustable oil weirs must be able to be visually seen through a manway to offer a comfort factor in validating the correct weir heights for oil spillover. Access to the primary and secondary solids chambers must be available in the event of a solids overload.

Plate Pack Construction

Plate pack construction is typically fiberglass, but can be provided from a variety of materials such as PVC, polypropylene, carbon steel, galvanized steel and stainless steel (Figure-11). In the past, the packs have been constructed so that under normal conditions they would support their own weight along with a small portion of solids adhering to the pack. In situations where maintenance has been overlooked, one might find a plate pack with substantially more solids collected between the plates. To prevent the pack from complete collapse during operation or removal, it is necessary to reinforce the perimeter of the pack with structure and use stainless steel lifting eyes securely attached to the reinforced frame. Lifting along with a spreader bar for distribution of the load is mandatory. Once this is accomplished. the pack can be lifted even under partially full conditions without fear of collapse. Another important area of concern is the thickness of the outer shell of the plate pack. This area must be of sufficient thickness to give strength to the plates and also durability to the corrosive materials found in wastewater. In addition to the above reinforcement rods running the length of the pack become imperative for the lift out of the pack during the cleaning or removal process..

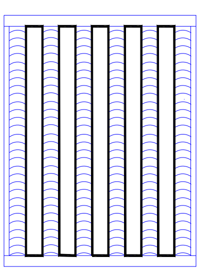
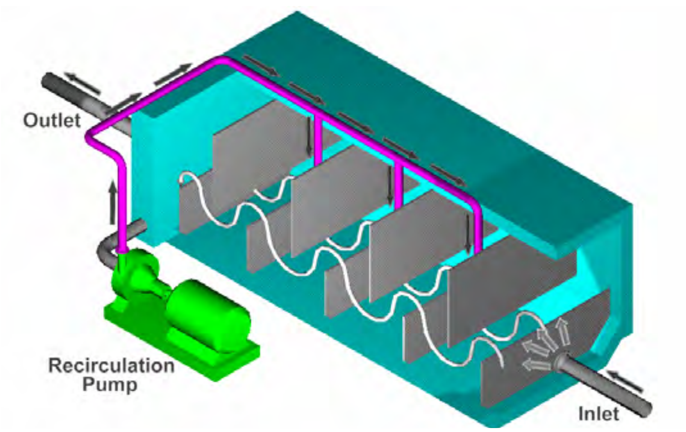
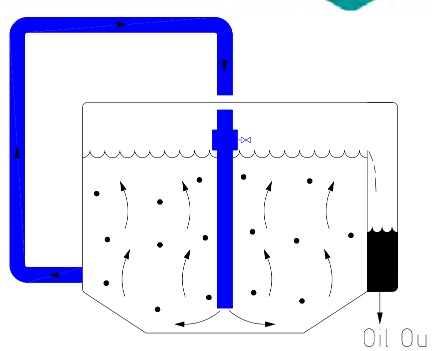


Plate Pack End View
Figure-11

Induced Gas Flotation and Sparger Flotation Cells

Flotation Cells on the other hand have gone through a metamorphosis in design (see Figure 12). The first real attempt at oil removal with a flotation device was a single cell design allowing for minimal retention time in providing the source lift to remove oil. Later designs began to incorporate multiple cells to provide more bubble contact time and retention time for separation to occur. Of these later models there are two types: mechanical and hydraulic. The mechanical design incorporates the use of agitators to create the bubbles required for separation. The hydraulic type utilizes a single pump to do the same. Both are same in principle but different in method. In either case, there are certain improvements that will benefit the operation of Flotation Cells.





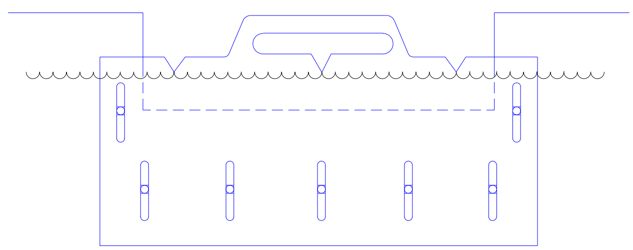
Hydraulic Flotation Cell
Figure-12

Coalescence in Flotation

Coalescence in the IGF can also be advantageous. Growing particles before separation in the IGF will increase the efficiency of each cell and therefore the overall efficiency of the IGF. Similar to that of the CPI, coalescing at the inlet of the unit is best. This allows any small particles entering the unit to grow to a more reasonable size for separation in the unit. Using the technique of coalescence between each cell can provide particle growth throughout the vessel increasing greatly the overall performance. As a final method of panicle growth, a fine mesh of polypropylene in the final cell will polish the outlet water before leaving the IGF and will coalesce the remaining fine particles in the effluent water. To minimize the possibilities of plugging the coalescing media, backwashing of the media should be considered. Because a Hydraulic Flotation Cell has recirculation pumps it is an easy task to tap into the discharge of the recirculation pump and utilize this pressure to periodically clean the coalescing media.

Rotating Wiper or Adjustable Weir

The Rotating Wiper System is the most commonly used method of oil removal in the IGF. This method employs a series of rotating wipers continuously rotating at the level of the floating oil froth. As it rotates. it wipes the floating oil and pushes it into a segregated oil chamber. Although the wiper system requires some periodic maintenance, it is the most accepted method for removing the collected oil.
The wiper assembly construction is 316 stainless steel, i.e. shaft and brackets and clips. The wiper material itself can either be metal or flexible material and if properly set will skim the oil and leave behind the water, minimizing any water carry over. In a properly operated system, one would expect about 3-5% carryover of water and oil. Often times only one wiper needs to be in service allowing the second to be a stand-by thereby reducing maintenance and water oil carryover. The most common problems associated with a Rotating Wiper System is of course the fact that they are a moving part requiring maintenance. There has been a push in the industry to eliminate as many moving parts on flotation cells as possible leading to the replacement of the rotating wiper system with an adjustable spillover weir. Each cell is equipped with an adjustable v-notch weir allowing for a 4"-6" range of adjustment in each cell. To properly skim each cell it is common for excessive amounts of oil and water to spill over the adjustable weir for collection. A good design number for this collected oil and water is about 10% of the design flow. If your system is capable of handling this excess water this method is worth while considering as it eliminates moving parts.



Adjustable Oil Weir Detail

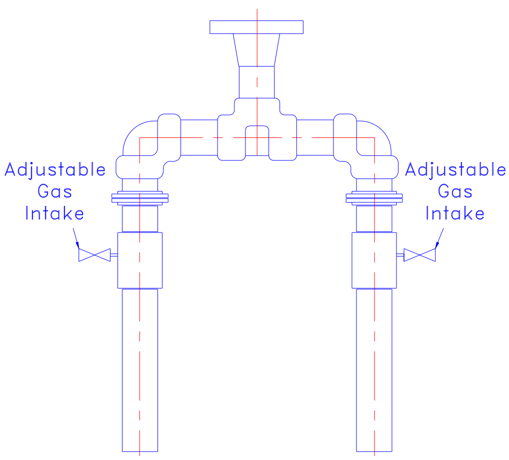
Figure-13

Forced Gas Eductors

Hydraulic Flotation Cells utilizes an eductor system to create the bubbles for separation. In the course of normal operation upsets occur in the eductor system due to paraffin buildup, scale, salt precipitants and other materials which come from the water handling process. These materials have a tendency to clog the Eductor orifice. To prevent this from occurring it is recommended to force feed gas directly to the inlet of the Eductor. This will virtually eliminate plugging and actually improve the bubble pattern allowing for better separation.

Multiple Eductors

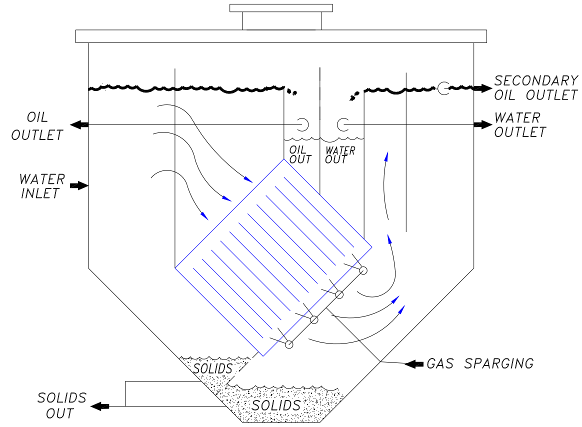
Using multiple eductors especially in the larger units becomes advantageous for improved efficiency. The addition of multiple Eductors increases the bubble quantity per cross sectional area of the cell. More bubbles mean more contact will oil particles and therefore better efficiency.



Dual Eductors
Figure-14

SPARGER CPI and FLOTATION CELL

The addition of spargers to the CPI seems to be a logical step in improving CPI performance. Correct placement of the spargers will greatly enhance CPI performance. Spargers placed under the CPI pack will provide the greatest effectiveness, adding bubbles to provide lift to any lingering small particles which may pass through the pack surface. Sparging will also enhance the cleanliness of the pack providing a gentle gas uplift dislodging solids, which might normally adhere to the pack surface.

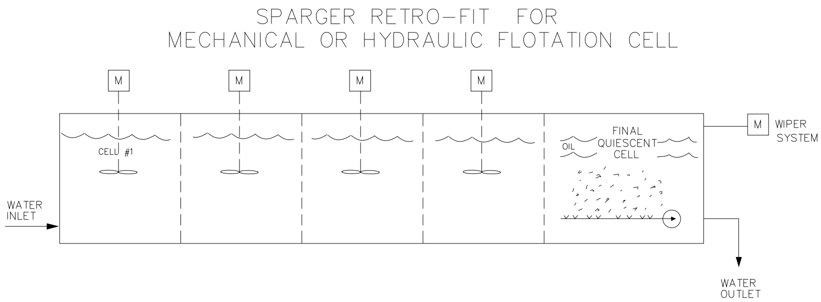


Addition of Spargers in CPI

Figure-15

The Sparger Flotation Cell is a unique method of flotation creating a similar technique as found in conventional equipment but without the need for rotating equipment i.e. pumps and motors. As long as there is a sufficient gas supply available at the location Sparger Flotation is an acceptable means of treating process water to meet the effluent ordinance. MPE of Houston has been developing this product in cooperation with Chevron the patent holder of this technique and has had a good measure of success in handling effluents down to $<$ 15 ppm. Case Histories are available from MPE to verify this process.

Oftentimes there are cases when existing flotation equipment is not achieving the desired effluent results perhaps due to either water chemistry or increased water quantity. The addition of Sparging to existing equipment helps to enhance performance. The most appropriate area to add Sparging would be in the quiesent cell, the last cell in the unit. Generally this cell is at least the same size as other cells or even larger. Proper Sparging technique requires 3-5 minutes of retention time. This final cell has only about 1-2 minutes depending on the manufacturer which is not enough for the most efficient Sparging. In our consideration of this technique our desire is only to enhance performance not to rely solely on Sparging. In effect this technique will work to provide a slight reduction of effluents.



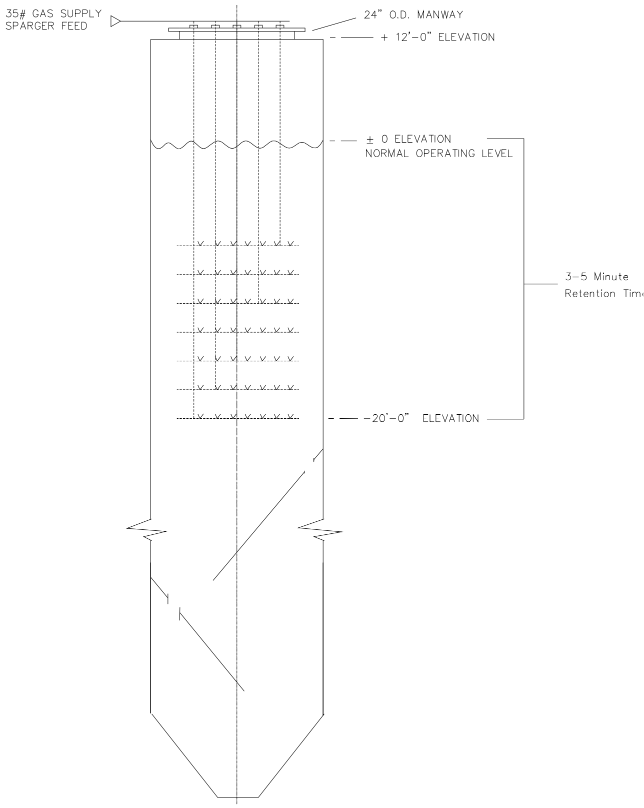
Addition of Spargers in Flotation Cells

Figure – 16

SPARGER FLOTATION CELL

An area of great interest is the combining IGF/ Sparger technology with a Sump Caisson design. thus creating the "Sparger" Flotation Pile. The basic principles are already proven, IGF's/ Spargers and the Sump Caisson have been used for nearly three decades. The premise of the design is to place a Gas Sparger or Eductor in the upper section of a caisson for maximum oil removal., following this with a typically designed Sump Caisson to provide final separation, disposal all the while minimizing internal wave motion.

The unique benefits from this design are self-explanatory. As costs continue to rise and space on decks is purchased at a premium, the Sparger Flotation Pile offers lower space requirement and lower maintenance costs.

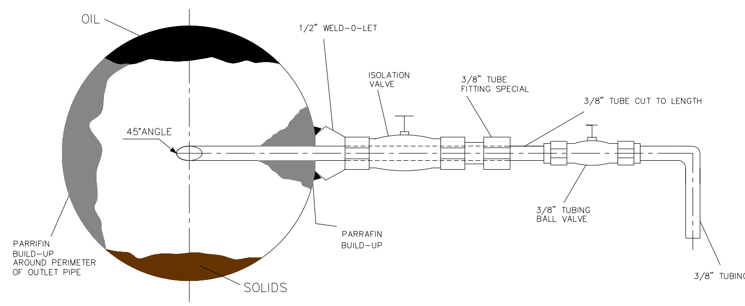


Sparger Flotation Pile
Courtesy of MPE

Figure-17

SAMPLING

One of the single most important aspects of produced water handling is proper sampling technique. Proper technique is simple but generally overlooked. Because of the nature of the process there tends to be materials found at the sample point which if passed into the sample will reduce the operators chance of meeting discharge. Simply put, this is the operators last point of defense in proper water treating. If proper care is taken in arranging the sample point and technique you will achieve your best results. The criteria for proper sampling is three fold; first locate the sample point in the center of the outlet piping to alleviate the change of contamination in the sample from paraffin and loose particulate which might be on the side wall of the pipe.; secondly use a retractable sample probe for ease of maintenance and cleaning. and finally use the proper valving to allowing for the sample point to be closed during maintenance.



Retractable Sampler
Figure-18

ETS TECHNICAL SERVICES

As stated above, environmental issues are in the forefront of today's business decisions. Wastewater treatment and disposal regulations continue to become more stringent. Therefore, the cost of disposal, fines and penalties will continue to rise. To optimize the cost / benefit of produced water treatment, operators and manufacturers must develop a comprehensive and economically feasible plan to enhance and upgrade the existing technology for wastewater treatment equipment. For this reason, ETS has developed a Technical Services group to provide the link between the operator and the supplier. Our innovative solutions (Case Histories on request) have been applied to each of the improvements listed in this discussion. Full laboratory analysis, bench testing, pilot testing and field trials are available upon request.