REVIEW OF OIL/WATER SEPARATION EQUIPMENT USED IN OIL PRODUCING OPERATIONS

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Introduction

Gunbarrel tanks, which are also known as wash tanks, are one of the primary pieces of equipment used to separate oil and water, in oil producing operations. To improve the hydraulics and residence time of fluid in gunbarrel tanks, they are usually outfitted with some type of internal fluid flow control system. There are numerous designs of internal fluid flow control systems. These designs include spreader pipes, spreader tables, inverted troughs, baffles, etc. An uncommonly used design, is the installation of parallel vertical baffles to achieve a serpentine shaped path of fluid flow within the tank. The serpentine style internals are simple, and are one of the more foolproof systems being used to reduce the possibility of fluids channeling or short circuiting through a gunbarrel tank separator.

This paper presents: a brief discussion of the purposes of oil/water separation in oil producing operations; the factors that affect the oil/water separation process; a basic review of mechanical separator equipment used for primary and secondary oil/water separation; a review of gunbarrel tank internal designs, and the benefits and/or drawbacks of these designs; and a review of the flow performance tests on different gunbarrel tank designs.

Purposes Of Oil/Water Separation

The primary reasons for oil/water separation in oil producing operations are: to make the oil salable, and to remove the residual oil from the water before either disposing of it in a disposal well, or using it in an EOR project. Many times the separation required for these two purposes must be done in two steps. The first, or primary oil/water separation process, usually makes the oil salable(i.e. BS&W less than some value, such as 1% or 2%). Sometimes the residual oil level left in the water requires that a secondary oil/water separation process to be performed.

The secondary oil/water separation is usually performed for economic reasons. If the residual oil in the water is great enough, it can be worthwhile to remove the oil for its value. There are situations where removal of residual oil from water is not economic for the value of the oil, but is economic to prevent damage to either equipment handling the water for an EOR project, or to the reservoir formation. EOR projects include waterflood and steamflood projects. In a steamflood project, residual oil in water can cause scale buildup in heating equipment. Scale buildup results in increased cost for maintenance and repair of the equipment. Residual oil in water can also cause plugging of the formation in water disposal wells and waterflood injection wells. Cleanup or repair of these wells, results in additional well operating cost.

Factors Affecting Oil/Water Separation

There are several factors that affect the separation process of oil and water. The factors that contribute significantly to the separation process include: time; oil and water gravities; the oil particle size; direction of bulk flow of the fluid; the distance oil particles must float to get out of the water phase; and temperature gradients of fluids within the separator.

Time - Time is required for oil and water to physically separate. In any oil/water separation process, the key to success is having adequate time to allow the oil and water to separate. The time that oil and water have to reside in a separator, is known as retention time. The more efficient the hydraulics of a separator are, the greater the available retention time is for the separator. The hydraulic efficiency of separators can vary greatly. When designing or selecting oil/water separation equipment, it is desirable to optimize the hydraulic efficiency to obtain the best retention time.

Fluid Gravities - The greater the difference is in oil and water gravities, the greater the gravitational force is to assist in the separation of the two fluids. This greater gravitational force results in the oil floating to the surface at a faster speed. This is why there is the tendency for the lighter gravity oils to separate from water easier and quicker than heavier gravity oils.

The gravity of a fluid can be altered by the addition or removal of heat. Heater treaters are sometimes used to assist in the oil/water separation process. By heating the production stream, the gravity of the oil is decreased at a greater rate than the gravity of the water. This results in greater gravity differential between the two fluids, and increases the gravitational forces for separation.

Oil Particle Size - The size of oil particles in the water phase affects the separation process. As the oil particle diameter gets smaller, their upward floating velocity decreases. This results in an increase in time for the completion of the separation process. Stoke's Law can be used to determine the terminal velocity of oil particles moving up through the water phase. The variables used to determine this velocity with Stoke's Law are the gravities of the two fluids, the diameter of the oil particle size, and the viscosity of the water. As a guideline, if the diameters of lighter gravity oil particles are less than 50 microns(0.002 in.), separation will be slow. The velocity for a 50 micron diameter oil particle would range around one(1) inch per minute.

There are a couple of things that can be done in operations to control the size of oil particles. Shearing the fluid stream with equipment that violently mixes the fluid, such as centrifugal pumps, will break the oil particles into smaller sizes. This shearing action should be kept to a minimum, to reduce this negative effect on the oil particles. Oil particle size can also be increased with the use of treating chemicals. These chemicals cause oil particles to attract to each other and join together. As they join together, they become larger oil particles. Chemical coagulants, or reverse emulsion breakers, are used to do this.

Bulk Flow Direction - The direction of bulk flow for fluids, is the general direction that the bulk of the fluid is flowing. In the separators reviewed below, the direction of bulk flow is either vertical or horizontal. Vertical bulk flow can be detrimental to the separation process in some cases. If the velocity at which fluids are separating is slow, downward vertical bulk flow can have a negative effect on the time required for separation. If the bulk flow is horizontal, the velocity at which the fluids are separating is essentially not effected. In most gunbarrel tank separators the direction of bulk flow is vertical. In the serpentine gunbarrel tank separator and the horizontal free water knockout, the direction of bulk flow is horizontal.

Distance to Surface - The distance that oil particles must float up to get out of the water phase of a separator, can affect the separation process. If the oil particle sizes are small, their upward velocity will be slower. If there is a combination of small oil particles and a large distance to the water surface, additional time will be required to complete the separation process.

Temperature Gradients - Temperature gradients within the fluids of a gunbarrel tank or free water knockout separator, can also affect the internal flow paths of the fluids within the separator. Differing fluid temperatures within a separator can cause less restrictive flow paths for the fluid to take, and this can result in channeling or short circuiting of fluids. These temperature gradients can also change over time. There is no easy way to determine the internal temperature gradients, and the effects they would have on the internal fluid flow.

Primary Oil/Water Separation Equipment

The purpose of primary oil/water separation in oil producing operations, is to make the oil salable. The complete removal of oil from the produced water is not always the main concern at this point in the production treating process. The primary types of separation equipment used for this purpose are gunbarrel tank separators and free water knockouts.

Gunbarrel Tanks - Gunbarrel tank separators are probably the most widely used oil/water separator, for primary oil-water separation. These tanks are essentially atmospheric tanks, but are usually maintained at a slight positive pressure(2 to 4 ounces). They are usually connected to a tank vapor system and/or a vapor recovery unit. These separators are usually equipped with a gas boot and flume to remove residual gas in the production stream, before it enters the tank. This is done to keep the gas from entering the tank with the fluid stream, and disrupting the separation process when it bubbles to the fluid surface. Gunbarrel tanks are very simple separators and there are little or no moving parts or pieces required for their operation. Gunbarrel tanks operate at a constant fluid level and with a constant oil pad thickness. This is achieved by skimming the oil off of the top of the tank through a skim line, and allowing the water to exit the tank through a waterleg.

In most installations, gunbarrel tanks are outfitted with some type of internal fluid control system to improve the hydraulics of the tank. These fluid control systems are installed to reduce channeling of fluid through the tank, thus improving the retention time of the fluid in the tank. The commonly used fluid control systems include single spreader tables, double spreader tables, and spreader pipe systems. A less commonly used fluid control system, is serpentine baffles. The serpentine fluid control system utilizes parallel vertical baffles to route fluids along a serpentine path through the tank. This design has not been widely used or known about in the Permian Basin, but there are several of these systems in service in the Basin. The serpentine style gunbarrel tank has been in use as early as the late 1950's. A more detailed description of these gunbarrel tank fluid control systems is given below.

Free Water Knockouts - The free water knockout is the other separator that is widely used for primary oil/water separation. Knockouts are sometimes used in conjunction with a gunbarrel tank separator for oil treatment. When used with a gunbarrel tank, they are placed in the fluid stream ahead of the tank. The oil stream from the knockout is then directed to the gunbarrel tank.

Free water knockouts were initially built to remove free water from the production stream, before heating the production stream to complete the oil/water separation process. By diverting the free water from the production stream, the heat requirement necessary for treating the production was reduced. Free water knockouts are built in both horizontal and vertical styles. Currently the horizontal style is the most commonly used style for primary oil/water separation.

A generic schematic of a horizontal free water knockout is shown in Figure 1. Free water knockouts operate at a relatively constant fluid level, and a constant oil pad thickness. Produced fluids enter at one end of the separator vessel, and the oil and water separate as they move through the vessel. The oil usually exits the vessel through a downcomer pipe installed through the top of the vessel. The water exits the vessel through a dump valve located on or near the bottom of the vessel. In some applications, knockouts also remove gas from the production stream.

Free water knockout separators are not as simple to operate as gunbarrel tank separators. There are a number of moving parts and equipment that are required for the knockout to function. These parts and equipment can include a, safety relief valve, gas make-up valve, backpressure relief valve, float, and water dump valve. All of this equipment requires periodic maintenance, repair, and adjustments for the knockout to function properly.

Free water knockouts are pressure vessels, and must be classified as ASME Code vessels if operated at or above 15 psig. Because most free water knockouts must be classified as code vessels, they require additional operating maintenance, inspection, and record keeping, to be in compliance with applicable rules and regulations. The safety equipment required on code vessels must also be inspected and tested routinely.

The overall capital cost of free water knockout separators is greater than gunbarrel tank separators, when looking at it from a fluid residence time standpoint. Looking at it from this standpoint, the investment cost of free water knockout equipment is 1.5 to 2.5 times greater than the cost of gunbarrel tank equipment. The knockout equipment also has continuing operating and maintenance costs that gunbarrel tank equipment does not have.

Secondary Oil/Water Separation Equipment
Common types of equipment used for secondary oil/water separation are: skim tanks; gas floatation cells; and filters. Sometimes this equipment is used in conjunction with each other, depending on the amount of oil removal that is required.

<u>Skim Tanks</u> - A skim tank is essentially the same as a gunbarrel tank separator. Skim tanks are also outfitted with the same types of internal fluid control systems that are used in gunbarrel tanks. In most cases, skim tanks are not equipped with a gas boot and flume. Gas boots are not necessary at this point in the process because most all of the gas has already escaped from the fluid stream. Skim tanks work very well in capturing and separating large slugs of oil, that can carryover from primary separation equipment during an upset condition.

<u>Gas Flotation Cells</u> - Gas floatation cells are another type of equipment used for secondary oil/water separation. This equipment can be very effective in removing residual oil from water. The residual oil can be reduced to as low as 1 ppm or less, depending on the oil content of the incoming water. Floatation cell equipment is widely used in the heavy oil fields of California, but is not commonly used in the Permian Basin.

There are two basic designs of floatation cells that have been used. These are the sequential floatation cell, and the pressured floatation cell. The sequential floatation cell is the more commonly used design. A schematic of this design is shown in see Figure 2. Fluid enters the unit at one end, and then passes through four floatation cells. Gas or air is continually introduced into each of the four cells by rotor vortexes, or eductor nozzles. The gas or air bubbles up through the fluid and to the surface. As these small bubbles move up through the fluid in each cell, oil particles attach to them and are carried to the surface. At the surface the oil particles attach to each other and are skimmed off. The cleaned fluid exits at the far end of the unit after traveling through each of the four sequential cells.

The pressured floatation cell design, utilizes a round tank(such as a 500 bbl tank) for the cell. Inside the tank there is an internal circumferential baffle. Fluid enters the cell through the annular space between the tank shell and the circumferential baffle. Prior to the fluid entering the cell, pressured gas or air is introduced into the fluid stream. When the fluid enters the tank, the gas or air bubbles to the surface. As with the sequential cell design, oil particles attach to the bubbles, are carried to the surface, attach to each other, and are skimmed off.

Most floatation cells are basically atmospheric containers, and are sometimes operated with a gas blanket. These cells operate consistently if the incoming fluid stream does not have large swings in residual oil content. Floatation cells do not handle large slugs of oil coming in with the fluid stream very well. Therefore, they have quite a problem handling an oil carry over from primary separation equipment during an upset condition.

Filters - Filters are also used for secondary oil/water separation. They can also be used as a polisher(tertiary separation), following other secondary oil/water separation equipment. There are various types of filters that have been used. The types of filters that have been used for this purpose include: cartridge, bag, sand media bed, crushed walnut and/or pecan shell media bed, and DE(diatomaceous earth) filters.

A disadvantage with most filters, is that there is a waste product that must be handled, and disposed of. This waste product is primarily oil saturated filters, or filter media. These waste products would include filter cartridges and bags, and DE media. When using these type filters, the oil removed from the fluid stream is usually not recovered.

The sand media bed and nut shell media bed filters normally don't generate a waste product that must be disposed of. The oil removed by these filters is usually recovered during a filter media backwash process, and the filter media is then reused.

Some advancements have been made with the nut shell media bed filters. The efficiency of the oil removal process from these filters has been improved. Oil removal efficiency has improved because the shell media is water wet and there is less tendency for oil to bond to the media. Also, during the backwash process to remove the oil, the media bed is fluidized and agitated.

In general, the use of filters to remove oil from water does not work real well. Most filters are primarily designed to remove solids from fluids. Many of the filters will collect oil up to some saturation point, and then they will start to pass oil. At that point they are essentially filtering the oil. For this reason, filters cannot handle large slugs of oil that could come from primary separation equipment during an upset condition.

Installation of secondary or tertiary oil/water separation equipment can be expensive, and sometimes be of limited success. Before designing, sizing, and selecting this type equipment, it is recommended that accurate fluid property data be collected and analyzed. If possible on-site pilot testing of the type of equipment planned for use, is also recommended.

Gunbarrel Tank Designs
Many gunbarrel tank separators in use today have very inefficient hydraulics, and do not take advantage of their available volume, to optimize retention time. Many gunbarrel tanks use as little a 5% of their theoretical residence time. The reasons for this inefficient operation is primarily due to poor designs of flow control systems, or no internal flow control system. However, many of these tanks are performing the oil/water separation expected of them. This

satisfactory performance is probably due to the tank being oversized, or by the use of additional chemical treatment to accelerate the separation process.

No Control System - Some gunbarrel tanks have been installed without any internal fluid control system. Figure 3 is a schematic drawing of a gunbarrel tank without any internal fluid control system. With this design, there is a good chance that incoming fluids will channel across to the water outlet of the tank. When doing this, there is very little retention time of the fluid to allow the smaller oil particles to escape this fluid channel before the fluid exits the tank. This is a very inefficient separator, and it is not recommended that a gunbarrel tank be installed in this manner.

Single Spreader - The single spreader table design is probably the most widely used fluid control system in a gunbarrel tank separator. This design incorporates a round spreader table, as shown in Figure 4. The points at which produced fluids enter the tank, and the water exits the tank, affect the hydraulic efficiency, and fluid retention time for the tank. The placement of these inlet and outlet points, as shown in Figure 4, usually results in the best hydraulic efficiency. Produced fluids enter the tank, at the tank center and above the spreader table. The water exits the tank at a point below the spreader table, and at the center of the tank. The inlet fluid distributor nozzle has the incoming produced fluids entering the tank in a horizontal radial pattern. The water exits the tank through an outlet collector which tends to pull water to the center of the tank in a radial pattern. These radial flow patterns created by the distributor nozzle and outlet collector, also improve the hydraulic efficiency and help reduce the channeling tendencies. The spreader table also acts as a baffle to create a longer flow path between the inlet and water outlet points.

Many single spreader table gunbarrel tanks have been built, such that the fluid entering the tank, enters at a point below the center of the spreader table. The water outlet through the side of the tank is normally located radially outward from this inlet point, and at a lower elevation. This is a poor design, and lends greatly toward channeling fluid to the water outlet of the tank. The distance from the fluid inlet to the water outlet is very short when compared to this distance for the design shown in Figure 4. In fact, this design can be less efficient than a gunbarrel tank without any internals, if the produced fluid inlet is on the opposite side of the tank from the water outlet.

Double Spreader - Another gunbarrel tank separator design used, is a double spreader table system. This system was designed by Conoco, and reported in an SPE paper titled "Design of a High-Rate, High-Volume Oil/Water Separator"[2]. See Figure 5 for a typical layout of a double spreader table system. This design incorporates two round spreader tables. In this design, produced fluids enter the tank at the tank center and below the upper spreader table. The water exits the tank at a point below the lower spreader table, and at the center of the tank. The fluid inlet distributor and outlet water collector are the same at those described above for the single spreader table.

The fluid inlet distributors and the outlet water collectors are usually designed or sized for specific throughputs. Most of the time the gunbarrel tank separator will not be operating at these throughputs, so the tank is not operating at its optimum point. Because of this, fluids in the tank may preferentially flow to one side of the tank, which results in reduced retention time. This would also apply to the single spreader table system. For detailed design calculations of the double spreaders and inlet and outlet nozzles, refer to the paper mentioned above.

Pipe Spreaders - The use of pipe spreaders is another system of distributing incoming produced fluids in a gunbarrel tank separator. Once the fluid has entered the tank by this system, there is usually no other control of the fluid flow path. There have been a number of pipe spreader designs used in gunbarrel tanks. Most all of them strive to introduce the incoming fluid over a large horizontal area, in the bottom space of the tank. The spreader pipes are designed with some type of slot or hole arrangement, to allow even distribution of fluid entry into the tank. The pipes for these spreaders can be configured in various ways. Typical configurations are a circumferential style, a center manifold with lateral legs, and H and T configurations.

Pipe spreader systems in gunbarrel tanks have very inefficient hydraulics. This is caused by the water outlet being in relatively close proximity to, and near the same elevation as the fluid entering the tank. This often results in extreme short circuiting of the water. The spreader pipe system is also limited in achieving even distribution of flow through the many slots, or holes, in the spreader pipes. Fluids exiting the spreader may preferentially exit through a very few number of the slots or holes. The distributor pipes can also become plugged with trash and sediments from the incoming fluids, because the velocities within these pipes may not be great enough to carry the trash out of the pipes. As trash and sediments build up inside spreader pipes, the desired fluid distribution is effected.

Serpentine Baffles - A less commonly used design of gunbarrel tank separator, is the gunbarrel with a serpentine style interior fluid control system. The serpentine style gunbarrel gets its name from the path that fluids must take to pass through the tank. This style of gunbarrel tank separator is simple and provides one of the longer paths that fluids must flow before they can exit the tank.

A serpentine flow path is created by the installation of parallel vertical baffles inside the tank. These baffles extend from the bottom of the tank, to above the fluid level, near the top of the tank. The number of baffles that can be practically installed inside of a tank, depends on the diameter of the tank. A typical layout of these baffles is shown in Figure 6. The oil and water enter the tank at the beginning of the serpentine path, moves through the maze of baffles in a horizontal bulk flow direction, and exits at the end of the serpentine path. All fluids must follow the serpentine path before they can exit the tank. There is physically no way the fluids can shortcut the serpentine path. While the fluid is moving through the maze, separation of the oil and water takes place.

Incoming fluids enter the tank through an inlet distributor nozzle at an elevation midway up the tank. Water exits the tank through a water collector nozzle at an elevation approximately midway up in the water phase of the tank. See Figure 7 for a cutaway side view of a typical serpentine gunbarrel. There can be various designs for both the distributor and collector nozzles. These nozzles usually direct or receive the fluid in a horizontal direction.

There are some advantages that the serpentine system has over other fluid control systems used in gunbarrel tanks. These include ease of cleaning, ease of installation, and ease of coating for corrosion protection. The serpentine system is easier to clean because all of the sediments end up on the bottom of the tank, and not on the tops of spreader tables and spreader piping. Removal the sediments from these tanks is also easier because the bottom area of the tank is not cluttered with other piping. Installation of a vertical baffle system with inlet and outlet nozzles is simpler because supporting structures do not have to be built such as those required with spreader tables and piping. Support for spreader tables may also have to be designed to support sediment loading. The inlet and outlet piping for these other systems is also more complicated. Most gunbarrel tank separators put into service, require an internal protective coating for corrosion protection. Overall the internal baffles are easier to coat than spreader tables and their supporting structure. The internal coating of inlet and outlet piping is also much less involved for the serpentine system.

Flow Characteristics

The flow characteristics of fluids through gunbarrel type oil/water separators vary significantly. In this report a simplistic look is being taken to determine flow channeling or short circuiting characteristics of these separators. To look at the channeling characteristics, the mean theoretical retention time has been compared to the breakthrough time of a tracer material injected into the incoming fluid stream. The simplistic calculation for mean theoretical retention time, is to divide the total volume available in the separator for fluid retention by the fluid throughput rate. The breakthrough time for the tracer is obtained from testing the concentration of the tracer material exiting the separator. The breakthrough time is the time between tracer injection into the separator, and the time when the tracer reaches a peak concentration at the outlet of the separator. Peak concentrations are obtained from residence time distribution curves. These curves are made up from the tracer concentration test data.

Some designs of gunbarrel tanks perform very poorly, and their range of performance can be very surprising. The following summarizes test results of several different gunbarrel tanks, which demonstrate how poorly gunbarrel tanks can perform. Test results for two styles of floatation cells are also summarized. These test results have also been tabulated in Table 1.

2,000 bbl Wash Tank w/Spreader - This 2,000 bbl wash tank was used to treat separated produced water. It contained a spreader and other internal baffling. The mean theoretical retention time for the water in this tank was 455 minutes. From the residence time distribution curve, breakthrough of the tracer material occurred in 18 minutes. This is approximate 4% of mean residence time.[1]

The spreader and baffle design are not known. It is clear that fluid was channeling through the tank. The water outlet point from the tank may have been in close proximity to the inlet point, or the spreader and baffling were not properly design to prevent channeling from the inlet to the outlet.

15,000 bbl Wash Tank w/Pipe Spreader - This 15,000 bbl wash was used for primary separation of heavy oil(12° API) and produced water. The incoming oil/water stream was distributed through a circular pipe spreader system, located near the bottom of the tank. The mean theoretical residence time for oil was 45 hours, and it was 26 hours for the water. From the residence time distribution curves, breakthrough time for the oil was approximately 8 minutes, and it was 2 minutes for the water. Oil breakthrough time was approximately 0.7% of the mean oil residence time, and water breakthrough time was approximately 0.3% of mean water residence time.[1]

These breakthrough times represent extreme short circuiting of both oil and water. However, the tank was performing adequate oil/water separation. For this tank to perform adequately, the oil and water was probably separating before entering the tank. This tank was primarily functioning as a storage tank.[1] The water outlet point from the tank was probably in very close proximity to some point on the pipe spreader where most of the incoming fluids were exiting the spreader.

1,000 bbl Skim Tank w/Double Spreader - This 1,000 bbl skim tank was used as a water-polishing device following primary oil/water separation. Free water knockouts were performing the primary oil/water separation. This skim tank contained a double spreader table system, designed by Conoco, as described above. From information and data reported in Conoco's SPE paper titled "Design of a High-Rate, High-Volume Oil/Water Separator", initial breakthrough of the test tracer occurred in 19 minutes.[2] Without knowing further specifics about this tank, it was determined that breakthrough occurred at approximately 33% of the mean water residence time.

The breakthrough time test results for this design, indicate that this design is much more efficient than many of the other gunbarrel or wash tank designs.

1,500 bbl Skim Tank w/Serpentine Baffles - This 1,500 bbl skim tank is a Texaco tank being used as a secondary oil/water separator, following primary oil/water separation by a gunbarrel tank separator. This skim tank contains parallel vertical baffles as described above for a serpentine style gunbarrel tank. The mean theoretical retention time for the water in this tank was 325 minutes. From the residence time distribution curve, breakthrough of the tracer material occurred in 90 minutes. This is approximately 28% of the mean residence time.

The breakthrough time test results for this design, indicate that this design is also much more efficient than many of the other gunbarrel or wash tank designs. Initial testing of this style gunbarrel tank indicate that it is comparable with the double spreader gunbarrel tank design.

Conclusions

Several of the gunbarrel tank separator designs are very ineffective in their ability to prevent short circuiting or channeling fluids through the separator. Residence time testing of these separators have verified this. The more effective gunbarrel tank designs are the double spreader table design and the serpentine design.

The serpentine style gunbarrel tank is probably the most simple and foolproof design to prevent short circuiting of fluids. It accomplishes this by providing a long route that fluid must pass before it can exit a separator. By having this long route, the residence time of fluid in the separator is improved, and this results in better separation.

When installing secondary oil/water separators in critical applications, or applications where there is a small economic benefit, accurate design, sizing, and selection of the separator equipment is important. To achieve this, accurate fluid property data should be collected and analyzed. In some cases, on-site pilot testing of equipment should also be performed.

References

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2. Stires, John: "Design of a High-Rate, High-Volume Oil/Water Separator" paper(SPE 8307) first presented at the 1979 SPE Annual Technical Conference and Exhibition held in Las Vegas, NV. (Sept. 1979).

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Table 1
Retention Time Summary for Various Oil/Water Separators

Oil/Water Separator Description	Max.Theoretical Retention Time(minutes)	Break-Through Time as a % of Max. Theoretical Retention Time
2,000 bbl Wash Tank w/Spreader	445	4%
15,000 bbl Gunbarrel Tank w/Pipe Spreader	2700(oil) 1560(water)	0.7%(oil) 0.3%(water)
1,000 bbl Gunbarrel Tank w/Double Spreader	58(approx.)	33%
1,500 bbl Skin Tank w/Vertical Baffles	325	28%

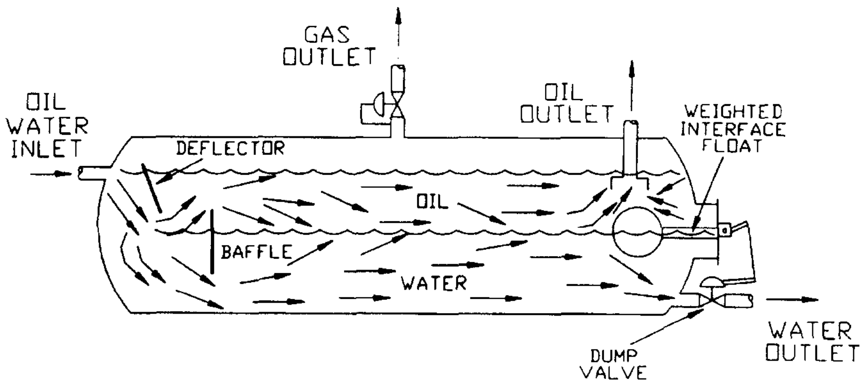

Figure 1 - Typical Free Water Knockout - Side View

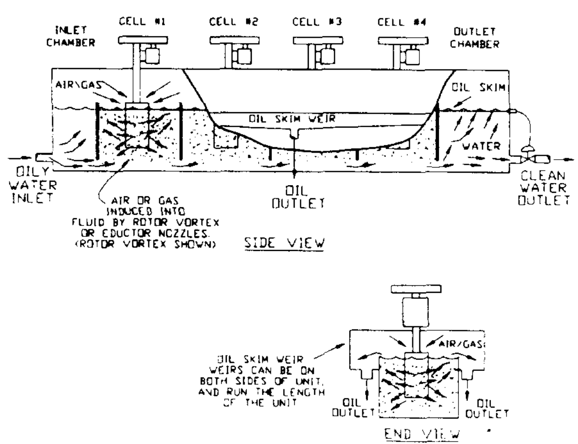

Figure 2 - Sequential Gas Flotation Cell-Side View

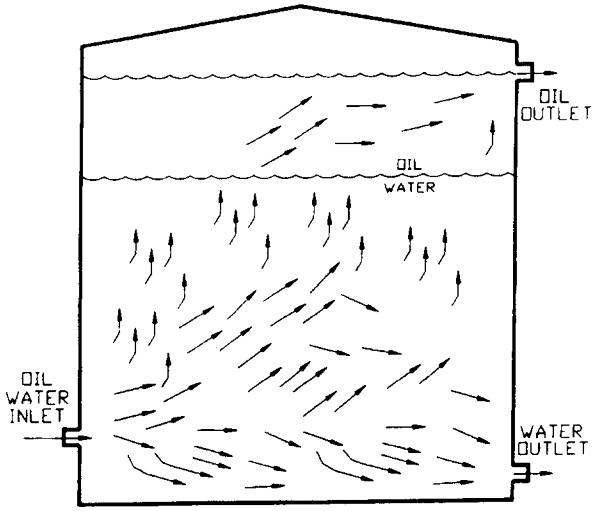

Figure 3 - Typical Gunbarrel with no Internals

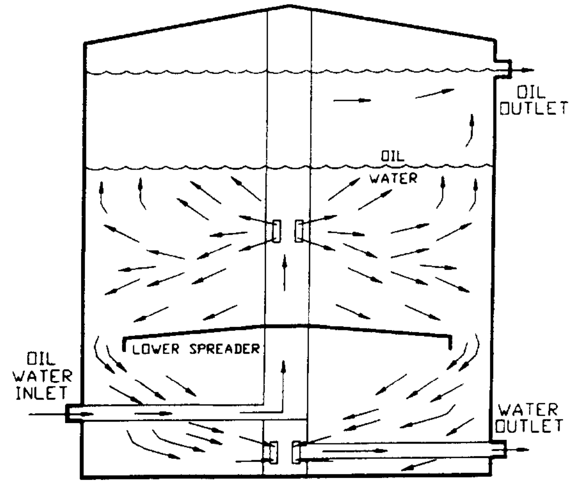

Figure 4 - Typical Single Spreader Design Gunbarrel Tank

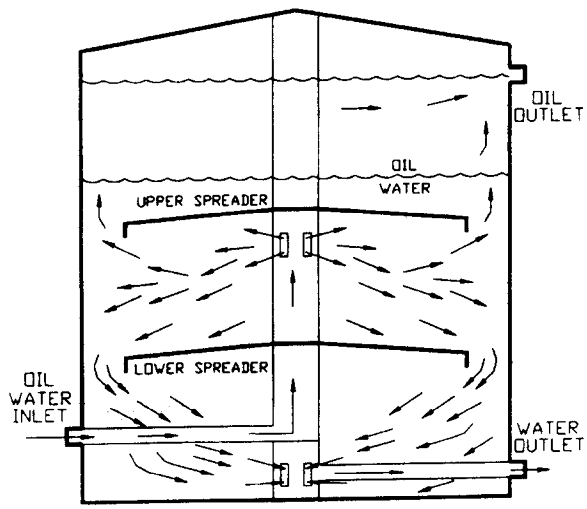

Figure 5 - Typical Double Spreader Design Gunbarrel Tank

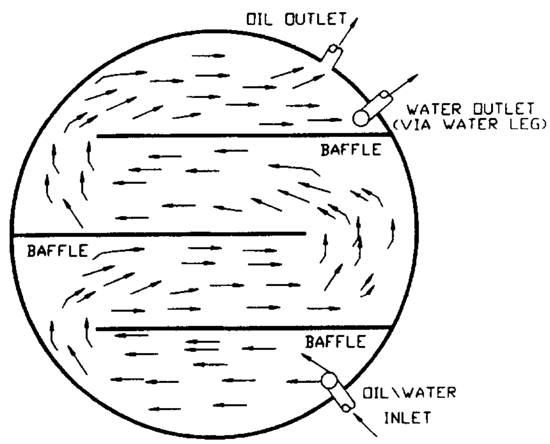

Figure 6 - Typical Serpentine Style Gunbarrel Tank - Plan View

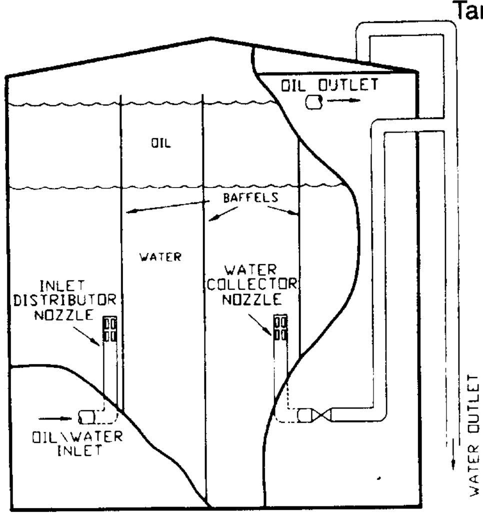

Figure 7 - Serpentine Style Gunbarrel Tank - Side View