KBK's MARVELOUS HWSB ® TECHNOLOGY

The Best 21st Century Crude Oil-Water Separation Tank

Innovation has been slow in the oil and gas industry. A key reason is the paradigm "Because we've always done it that way." Together, we can change that!

A Technical Paper

Prepared for

Facility Engineers and Designers

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EXECUTIVE SUMMARY

A new separation tank was conceived in the late 1980s. It was modeled in and evaluated in an R&D lab and found to be amazingly efficient. The initial patent was followed by several upgrade patents during subsequent years as user feedback was used to improve the design. The design grew in popularity, and today over 5,000 are in service worldwide.

The first application was in Alberta, Canada. It was a retrofit project. The internals were fabricated in a fiberglass shop in the USA, shipped to the job site, erected inside the tank, and started up. The results were startling. It far outperformed the clients' expectations. As a second retrofit was ordered, the client wanted to know what to call it. A discussion of its amazing performance ensued, and it was agreed that it needed a special name. The consensus was that it should be called a "hydrodynamic water separation breakthrough," or simply HWSB®.

In 1989 representative of ExxonMobil met with the inventor to discuss using HWSB®s in a sour gas field in Talco, Texas. Uncertain of the validity of the design, he returned to Houston, built, and tested a HWSB® scale model. He was amazed that its retention time was nearly perfect, reflective of pure piston displacement. Ten HWSB®s were installed in Talco tank batteries, and then ten more.

Word spread rapidly, as is often the case in the upstream oil industry. The numbers of installed HWSB®s grew, slowly at first, and then exponentially as SWD plants found that replacing gunbarrel tanks with HWSB®s dramatically increased their revenue stream due to increases oil captured by their HWSB®s. Many SWD plants reported increased revenue of over $1,000,000 in just the first year thanks to their new HWSB®s!

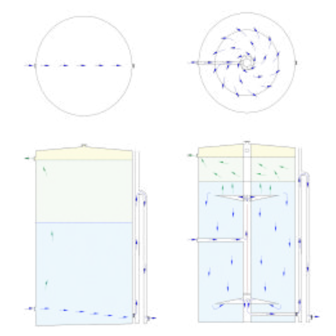
RETENTION TIME AND THE HWSB®

In the 1960s, as produced water volumes began to increase, operators observed significant amounts of oil carryover. In those years it had been assumed that if the volume of fluid flowing through a tank in one day equaled the total fluid volume it would hold, the tank had one full 24-hour day of fluid retention time. In other words, 750 barrels per day the fluid flowing through a 750-barrel tank had one day of retention time … or so it was thought.

In the 1970s, as the nation focused on producing more oil to offset the effects of the Arab Oil Embargo, retention time studies were conducted help understand why so much more oil was leaving tank separators with effluent water. Colored dyes were used as tracers. These dyes were either oil soluble for oil retention time studies, or water soluble for water retention time studies. One or the other was injected into the inlet fluid stream, and the time was noted. Outlet fluids were then sampled until the water changed to the color of the dye, and the time was recorded again. The difference was the actual retention time.

These studies showed that actual retention times were actually far shorter than had been assumed. In many cases the real retention times were so short that the tests were almost unbelievable, so the tests were repeated. When test after test produced the same results, the conclusion was validated. Tanks that were thought to have many hours of retention time rarely had more than a few minutes; some only had seconds!

The lesson learned was that when the velocity of a predominant fluid (water in this case) flowing from A to B is greater than the separation rate of an immiscible fluid in it (oil in this case), the immiscible fluid will not separate, but instead will be carried out of the tank with the predominant fluid. This is illustrated in the tank on the left side of this graphic.



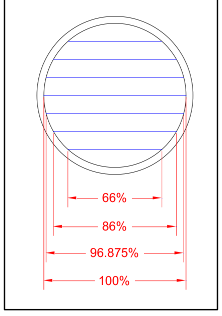
TYPICAL SKIM TANK HWSB® SKIM TANK

It became quite clear that the fluids flowing into a tank did not distribute throughout the tank before leaving it. Instead, fluids took the path of least resistance, which was always directly from the inlet to the outlet. In contrast, the flow through the HWSB® is distributed uniformly throughout the entire tank from top to bottom so fluids stay in the tank much longer. The added time allows the two fluids (oil and water) to completely separate. Oil leaves the HWSB® ready to be sold. Water leaves the HWSB® free of 99.9% of all oil.

Additionally, oil-water interfaces were observed to rise and fall with changes in flow rates, re-entraining water in oil and oil in water. Studies showed that the cause was undersized water legs. Water legs are designed to establish a pre-determined oil-water interface level, but when the flow through them is too great the interconnecting piping between the two vertical legs floods, and they cease to maintain a constant oil-water interface. The solution was to redesign the water leg.

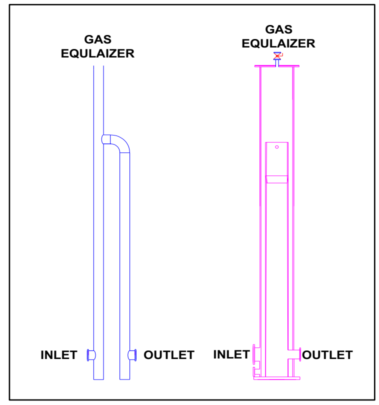
WATER LEG REDESIGN

As water leg designs were studied it became clear that the cross-over pipe between the two legs of the original water leg was the flaw. It acts like a dam, but since it is round, the effective length of this dam increases as the flow increases until the level inside reaches its center line. Then, as flow increases even more, the length of the dam decreases, forcing the crest height over the dam to rise until the dam floods. Once the cross-over pipe is flooded (full), the water leg loses control of the oil-water interface inside the tank. The oil-water interface inside the tank reacts to these changes, rising and falling with changes in flow. Once it floods, the



interface rises and falls indiscriminately, forcing oil and water to remix, defeating most separation.

The solution was to rethink the water leg design. The most obvious solution was to increase the diameter of the spillover pipe. Larger diameter pipe has a larger diameter cress section, so this was considered. However, the spillover length of a vertical pipe is its circumference, and its circumference is must longer than its diameter. For instance, an 8" pipe has an 8" cross section, but its circumference is 8" x 3.1416 or 25.13"! With this in mind the water leg was redesigned using two sections of pipe, one inside the other. The water would flow up the annulus between the two sections and overflow its much longer circumference down into that center pipe.

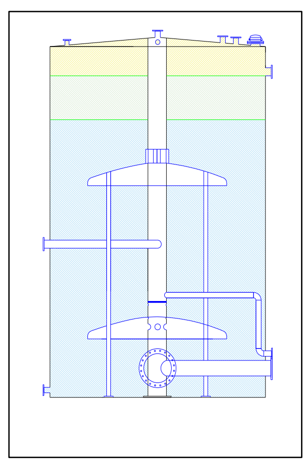


HWSB® IMPROVEMENTS

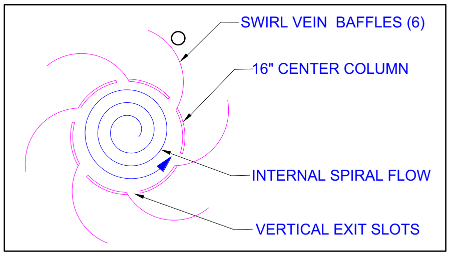
As more HWSB®s were installed, user feedback prompted improvements. The first was the inversion of the upper spreader baffle because one end user reported that the center column in their HWSB® had filled with sand and silt. These solids we produced with oil and water. The solids had separated in the center column, filling it, and then built up filling the inverted portion of the upper funnel-shaped spreader. The weight of these solids overwhelmed the structure, and the upper spreader collapsed, falling into the bottom of the tank.

This prompted the first of several design improvements:

- The entire upper spreader was turned 180° so solids could fall off, preventing any build solids up on the upper surface of the spreader.
- The upper and lower fluid spreader baffles were changed from the API sloped roof pattern to curved fiberglass tank heads for added strength.
- Support legs were added.
    - These were fixed to the bottom of the tank and extended upward through and fixed to the lower spreader and to the underside of the upper spreader.
- The inlet to the center column was adjusted to attach on tangent rather than straight-on.
    - This was done to enhance the centrifugal separation of solids from water so solids would accumulate down inside the center column rather than rising to deposit on the upper spreader and eventually on the bottom of the tank.

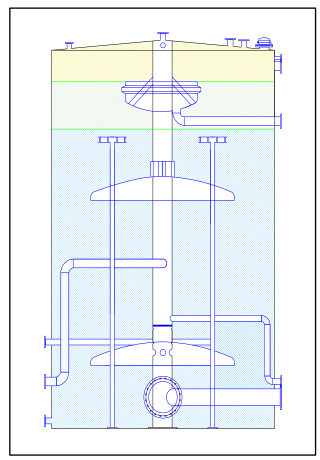


- Taking advantage of the centrifugal flow in the center column, the exit slots in the center column were modified to promote the spiral flow of fluids exiting the center column.



  - This way, the farther the inlet flow was from the center column, the larger its radius and the slower its velocity, forming a unique helical flow path.
  - A center column solids draw-off connection was added so operators could drain off solids collecting above the blanking plate in the center column. Frequent draining prevents solids from building up and eventually overflowing the center column, depositing onto the spreaders and the tank bottom. Frequent draining minimizes downtime and tank cleaning.

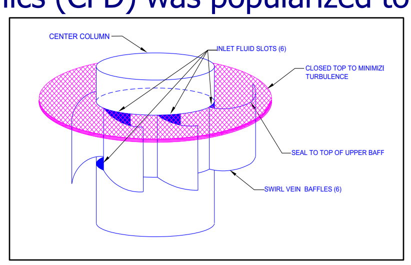
These improvements are described and protected in current and active patents.



As produced water volumes increased, so did oil volumes and thick emulsion layers. User feedback prompted the next design improvements to the HWSB®:

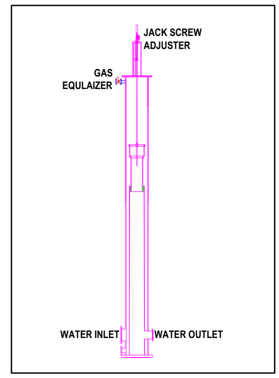
- The inlet nozzle was relocated to nearer grade elevation to make piping connections easier and quicker for installation crews.
- Three of the six baffle six support legs were extended through the upper spreader to just below the normal oil-water interface, where the emulsion layer would naturally form.
- The top of the leg extensions was capped with horizontal baffles so emulsion draw-off would be horizontal, avoid all possible vortex flow during draw-off.
- The three draw-off legs were piped into a common single emulsion drain.
- A large round oil spillover trough was installed to increase the length of the spillover from that of a sidewall connection, thus minimizing the crest height of any/all large oil inflows and eliminating tank overflow events.

As computer modelling advanced, computerized fluid dynamics (CFD) was popularized to predict the flow of fluids. A CFD model of the HWSB® was generated. It proved the unusually high hydraulic efficiency of the HWSB® design and suggested one key improvement: the addition of a horizontal baffle immediately above the inlet slots of the center column to minimize the mixing energies of inlet turbulence. The CFD



study showed an improvement in oil capture rate and an improvement in effluent oil quality could be achieved with this simple modification. All HWSB®s manufactured since have had this feature.

Increased produced water flows and the effects of frac cocktails on oil and water quality heightened user interest in the possibility of adjusting the oil water interface in old and new HWSB®s. This challenge resulted in the development of a water leg that could be adjusted on-line, without the need for a shutdown, or a crane, or a crew to rebuild the inside spillover pipe.

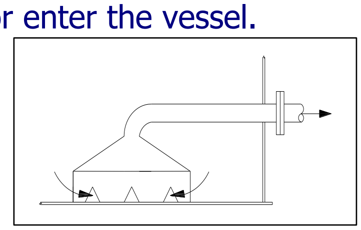


The new water leg uses an O-ring sealed sliding upper spillover pipe section. The upper spillover pipe is attached to a connection rod. A connecting rod is attached to a hand turned, gear reduced, jack screw mounted on top of the upper blind flange of the water leg. The lease operator can adjust the jack screw to raise or lower the spillover pipe inside the water leg without having to disassemble the water leg or interrupt flow. The adjustment spans 24", sufficient to accommodate oil and water of all densities, and changes the overall oil-water interface inside the HWSB® from 2'-5' depending on fluid densities.

As with all previous improvements, these improvements are also patent protected.

As more and more HWSB®s were placed in service, some end users had requests for special options. These included:

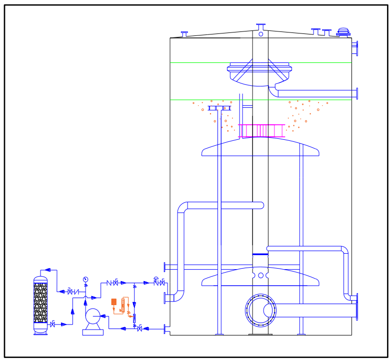
- Tank bottom solids removal systems are designed to remove most accumulating debris without having to shut down operations, empty or enter the vessel.
  - Sand pan systems like the one shown here had been proven in other applications in previous decades, so this technology was not new to the oil industry; just new to application in the HWSB®.



- Electronic level indicators for either the oil-water interface, the oil-emulsion interface, or the emulsion-water interface, or all three. While several controls companies offer a variety of these controls, the most popular was the guided wave radar system since it is not affected by fluid densities or a buildup of foreign matter.

The latest advancement is the addition of a dissolved gas flotation system.

- This system pulls gas from the gas layer above the oil in a HWSB®, disperses it in water, and then dissolves it into the water through a packed column. Once dissolved under pressure, the pressure is dropped and the mix is injected into the inlet HWSB® feed stream. As the gas comes out of solution it forms bubbles. The bubbles grow in size as their pressure equilibrates with the pressure of the inlet fluid. As the bubble grow their surface tension builds, attracting all non-aqueous substances like oil and suspended solids to their surfaces. The aggregate density of the mix of gas and adsorbed oil and solids is much less than either water or oil as the gas bubbles act like balloons, floating rapidly upward to the oil-gas interface. Virtually all oil and suspended solids are captured in this unique and patented KBK process.



CONCLUSION

Today's HWSB® is an ultra-efficient oil-water separation system. The basic design has been improved and re-patented time and again using feedback from many end users. Its 5,000+ installations capture well over 1,000,000 barrels of crude oil annually, creating a significant revenue stream for all users. It is truly a marvelous system, one KBK Industries is proud to provide.

ABOUT THE AUTHORS

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CONTACT

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