SWD Plant Design & Performance,

...Then and Now

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

Most SWD Plants built prior to 2008 sacrificed water quality to conserve CAPEX. The results were poor water quality, incredibly low oil capture rates, and rapidly plugging disposal wells. Today's SWD Plants are designed to capture and sell all separable oil and to remove settleable/filterable suspended solids to protect the injectivity of the disposal/injection well. The results are a significant increase in oil sales, increased ROI, and a dramatic reduction in disposal well plugging and associated OPEX.

EARLIER SWDS - FROM 1859 THROUGH 2005

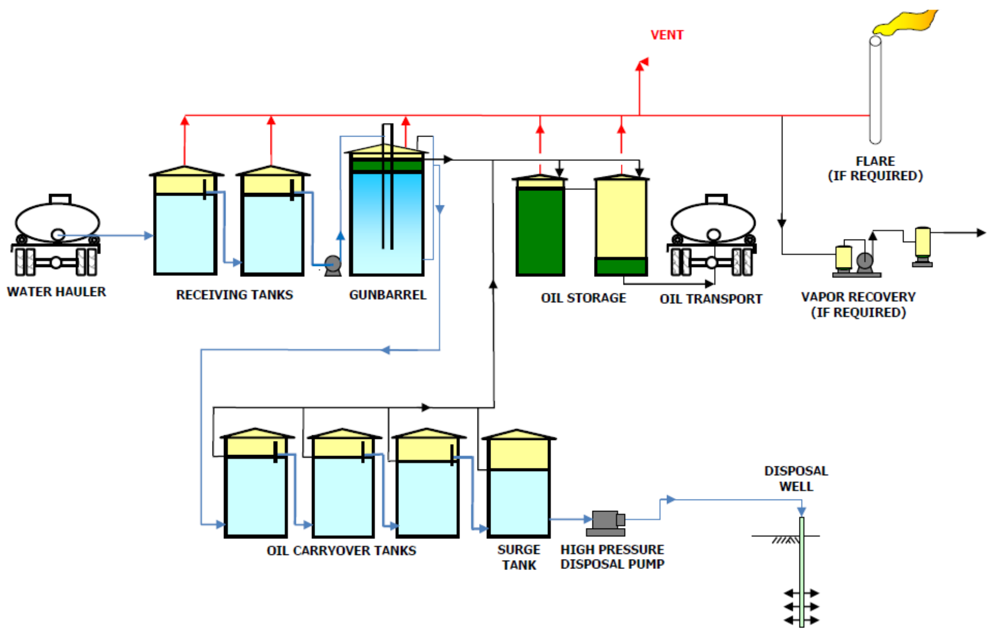
From the day Drake drilled the first 69' deep oil well in 1859, produced water has been an issue. In those earliest days, the quantity of produced water was small and of little concern.

Then the oil booms of Spindletop, Glen Pool, and many others propelled the oil industry into the 20th century where it produced millions of barrels of oil and tens of thousands of barrels of wastewater. In places like Goose Creek (now Baytown, Texas), manmade lakes contained the oil and water until the water could be pumped or drained into the ocean. Oily wastewater ran freely in those days, into rivers and basins and into nearby seas, but the results did not go unnoticed. By the 1930s water injection into shallow wells was becoming popular, and by 1950 deep well wastewater disposal had become a widespread practice. Then, in 1970 the Clean Water Act became law and the Environmental Protection Agency (EPA) was formed to enforce it. As pollution awareness grew, virtually all oil field wastewater

was routed to dedicated Salt Water Disposal (SWD) plants where rudimentary separation was commonplace and where the water was injected into very deep-water injection or disposal wells.

As time passed a basic SWD plant concept emerged and a common design emerged. That basic design used existing tank and basin designs and water handling methods to prepare it for disposal. Almost all water was trucked in those days. At the SWD, water settled in basins or tanks and was pumped into water disposal wells. That basic design looked like this:

Typical Salt Water Disposal Plant
Circa 1992



The separation of water borne contaminants was often so inefficient in the design depicted above that oily solids migrated through the entire plant, filling the tanks, and finally plugging the disposal wells. The profits from these plants began to diminish as more and more money was spent to keep disposal wells cleaned out. The cost of reworking, remediating, acidizing, or redrilling disposal wells is so onerous some SWD plants closed. Little money was available to spend on improving these water disposal plants. Most looked like the pictures on the next page.







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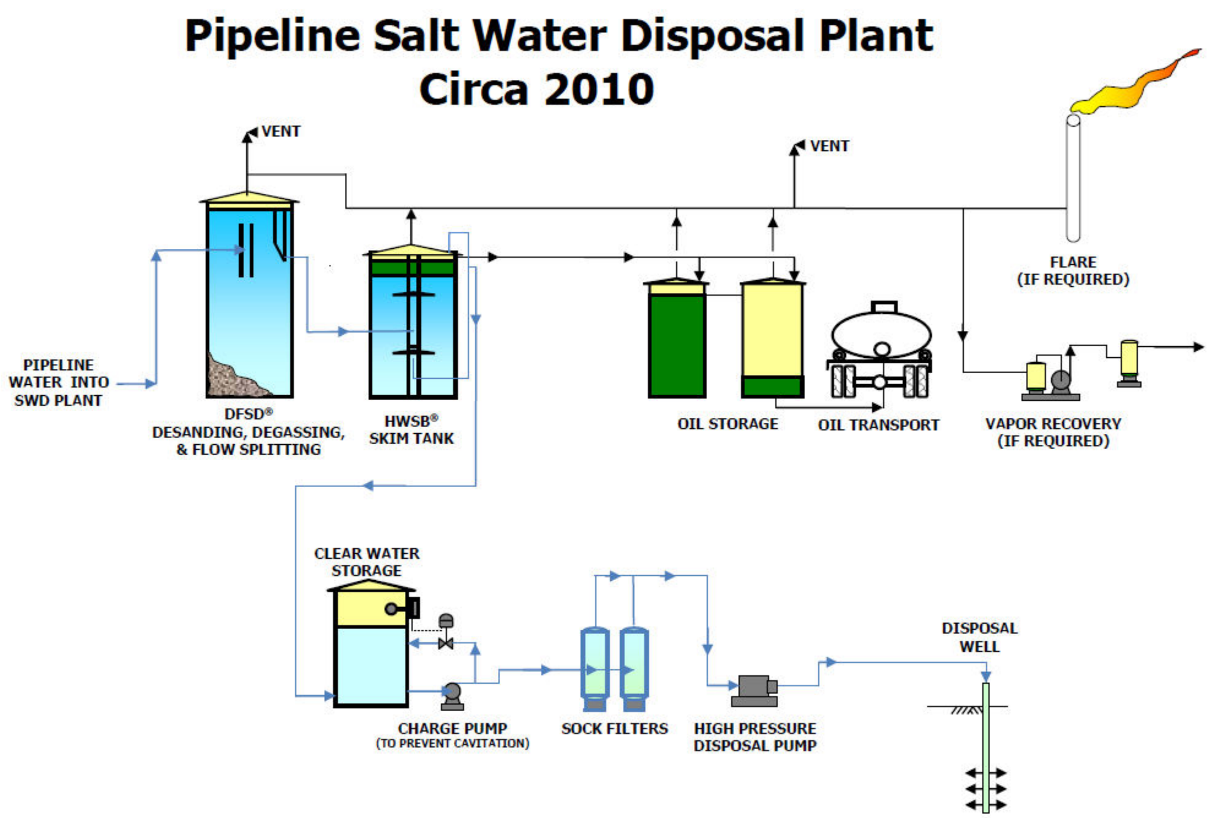
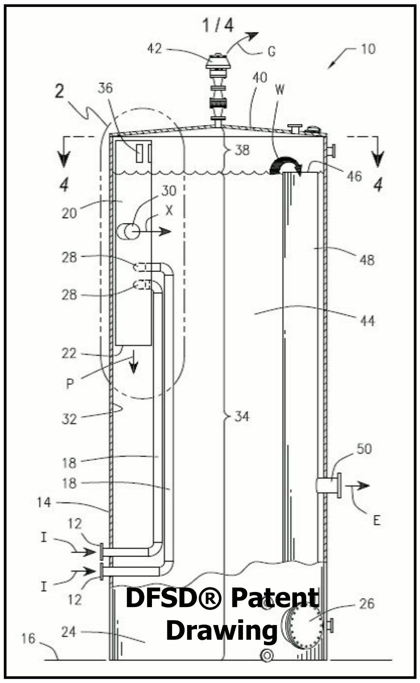
These early SWD plants were built using traditional gunbarrel tanks and rows of water storage tanks. Gunbarrel tanks were developed in the late 1800s to separate small quantities of the water produced with oil from oil wells, when water volumes were very small. As the industry matured and wells produced more and more water, gunbarrel separation began to falter. After all, these tanks were designed to clarify oil, not water! Eventually producers recognized that gunbarrel tanks struggled to clarify water sufficiently to prevent plugging in water disposal wells.

Finally, a new tank design was developed for the sole purpose of clarifying oilfield produced water. That tank is KBK's HWSB® skim tank.

STANDARD SWD PLANT DESIGNS AFTER 1992

In 1992 a new SWD tank design emerged. That tank is KBK's patented HWSB® oil skim tank. Soon thereafter KBK's DFSD® tank was introduced to eliminate solids. Gradually trucked water was pipelined to many SWDs.





DFSD® Patent Drawing

As more water was pipelined into SWD plants, and plant designs were simplified. Excess tankage was eliminated. The introduction of the patented DFSD® and HWSB® technologies allowed SWD designers to simplify their SWD layouts, cutting costs, and improving performance. These changes cut costs and maximized owner cash flow.

The timing was perfect! Just as these changes were proven effective, EOG introduced the industry to the era of long lateral horizontal and well completions using massive frac jobs. Oil and water volumes doubled and redoubled. Huge produced water volumes created the demand for more efficient SWD plants. The DFSD® and HWSB® became key components in most new plants and replaced outdated components in old ones. These more efficient designs simplified plants making them easier to construct and improved the oil recovery in each one.

The DFSD® preconditioned the water entering the HWSB® so solids were collected before the water made it to the HWSB.

The internals in the HWSB® are uniquely efficient. These internals represent a totally innovative design that maximizes retention time and vastly improves all separation. The old gunbarrel system often carried over 95+% of the oil in water. Its short internal water flow path and minimized retention time were the causes. The HWSB® captures nearly 99.99+% of all oil with nearly perfect retention


KBK HWSB® SKIM TANK

times, often reducing the remnant oil to less than 30 ppm.

These improvements in separation efficiency have created an economic benefit to all SWD Plant owners. Each HWSB® captures 99.9% of all oil; oil that creates a new revenue stream for its owner. The capture rate adds hundreds of thousands of dollars-worth of oil-related cash flow to each SWD facility fitted with KBK's HWSB®. It also reduces owners' OPEX and well workover frequencies by at least 90%.

In a typical 15,000 BWPD SWD facilities fitted with a single HWSB® the recovery rate for oil is at least 100 BOPD, worth $2,463,750 dollars each and every year at an oil price of $67.50/barrel oil price, entirely paying the cost of the HWSB® in less than one month!

FEWER IS BETTER

Once KBK's DFSD® and HWSB® are incorporated into SWD plant designs, the need for additional water storage is minimized, lowering the overall plant CAPEX.

The 4-8 tank cluster of 500-1,000-barrel tanks previously used downstream of gunbarrel tanks are now unnecessary and can be deleted. Single, or sometimes a pair of smaller 400 barrel "surge" tanks take their place. These smaller, less costly tanks provide the net positive suction head (pressure), or NPSH, to prevent cavitation in downstream pumps feeding filters and high-pressure disposal pumps.

Retention time is necessary to achieve thorough separation, but too much of it after the water is clarified can allow unwanted elements like oxygen and bacteria to contaminate the water stream. Deleting the larger and now unnecessary tanks not only reduces initial SWD Plant CAPEX by at least $145,000, it also helps to improve water quality.

Decades of experience have proven that the longer water is stored the more susceptible it is to becoming a breeding ground for fast growing micro-organisms. Micro-organisms like desulfovibrio desulfuricans (iron bacteria) reproduce and die in short gestation cycles, generating copious quantities of suspended solids in the form of dead bacteria bodies. A few colonies of these micro-organisms can generate pounds of well plugging solids in a single day. In oily produced water these microscopic organisms also adsorb oil, forming an organic sludge that is neither acid soluble nor easy to separate. When this sludge is allowed to remain in water entering disposal wells it accumulates in the pore spaces of the formation, eventually restricting or eliminating all water injectivity.

Additionally, these sulfur producing micro-organisms produce dangerous hydrogen sulfide (H_2S). H_2S is an acid gas which is lethal to humans even in small concentrations (500+ ppm).

Minimizing water storage limits the time bacteria has gestate. This helps minimize the need for frequent, and costly, injection/disposal well workovers. These well workovers can cost between $150,000 and $1 million. Avoiding well plugging and injectivity issues always reduces the OPEX of a SWD Plant.

PLANT EVALUATIONS

KBK has been involved in SWD plants for decades. Often asked to evaluate SWD plant performance, KBK has used that experience to evaluate many gunbarrels and skim tanks. During these evaluations, the influent and effluent of each gunbarrel tank is always analyzed for oil and solids concentrations. On average each gunbarrel removed less than 2% of the influent oil while each HWSB® removed over 99.9%.

In addition, the inlet and outlet of each plant is sampled and analyzed for total oil and other suspended solids to compare separation efficiency. The results show that the amounts of oil received in each plant vary considerably but are often significant, while the inlet concentration of suspended solids is normally quite low. Inlet oil, as a percentage of total

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inlet fluids, varies from 0.42% in plants farther from new well drilling activities, to over 3.31% in plants where the drilling activity is high.

Most remote plants often receive fewer than 1,500 BWPD on average, while plants near or in areas of high drilling activity receive between 10,000 BWPD and 100,000 BWPD or more. As such, the recoverable oil volume in the more remote plants is only about 6.3 barrels per day, while the recoverable oil in larger plants ranges from 100 BOPD to 350 BOPD or more.

When the plants KBK studied SWD plants using gunbarrel tanks for water-oil separation the capture rate of oil was quite low. Plants remote from new well drilling typically recover roughly 75 barrels per month or about 40% of the available oil. On the other hand, plants in areas of high oil well drilling activity capture 2,250 barrels per month, or only about 22% of the oil they received. The uncaptured oil in both cases was injected into the associated water disposal wells. In fact, uncaptured oil in these older plant designs migrates through the gunbarrel and is only partially separated in downstream water tanks. The downstream tanks are typically plumbed in series so the flow rate through each tank is the same. The flow path in each tank is straight-through, following the path of least resistance from the inlet on one side to the outlet on the other. Plant designers fitted some tanks with inlet risers and outlet downcomers, but little retention time improvement was measured as the path of least resistance remained short, limiting the overall separation efficiency. Oil carryover was commonplace.

Even worse, operators rarely have time to skim oil off of any tank, so water surge tanks often filled with oil which was pumped into disposal wells.

Most older SWD plants have little or no automation. The automation that exists is old, rudimentary, and prone to failure. Tank levels are rarely monitored electronically. Where levels are monitored the instruments used are often simple pressure transmitters, some mounted near the bottom of each tank. As the suspended solids accumulates on the tank bottoms, these transmitters either become plugged, or added the weight of the solids skews the pressure transmitter output producing false readings. The results are predictable; many tanks overflow and oil is spilled oil onto the ground.

From all of this it is easy to see why the traditional oil capture rate of many SWD plants is so poor. This also helps explain why injection/disposal well pressures increased surprisingly fast, and why disposal and injection wells plugged prematurely.

SOLUTIONS – LOW HANGING FRUIT

It is obvious that the larger the SWD plant is the better the opportunity to increase its cash flow. Plant design is critical. The water receiving tanks used in older designs should be replaced with KBK's DFSD®. This special tank first removes all 120-micron solids from the inlet stream, then degasses the water, and finally, evenly divides the inlet stream into equal effluent streams to assure efficient downstream separation.

Tank roof mounted ultrasonic or guided wave radar level transmitters should be added to all tanks to provide accurate, local, and remote (SCADA) tank level indications.

Next, gunbarrels tanks should be replaced with HWSB® skim tanks; one for every 15,000 BWPD. Each will capture over 99.99% of all inlet oil.

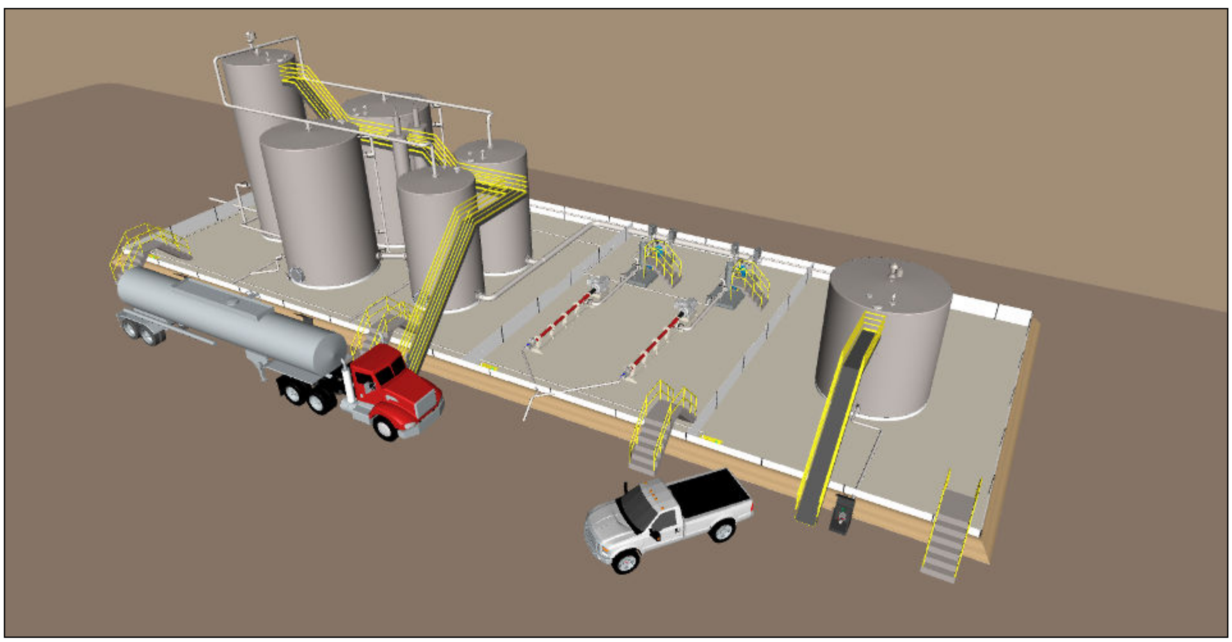
Centrifugal transfer pumps need to be changed out in favor of low shear screw pumps (see Vaughn's Triton pump) to minimize pump-related mixing and to eliminate oil droplet shearing.

And finally, all but two of the downstream (now classified as surge) tanks need to be removed, reducing the clean water storage (and potential recontamination) time. Downstream of the surge tanks, charge pumps and filters should be added to move clean water under pressure into the suction of the high-pressure injection pumps.

Pressurizing the suction of the high-pressure injection pumps. Pressurizing the inlet of any pump prevents cavitation and dramatically extends pump life. In each case the desired results are to 1) capture 99.99% of all incoming oil, increasing cash flow from the sale of capturable oil, and 2) to clarify the water for reuse or reinjection. This is the low hanging fruit. The added cash flow from oil sales is a bonus and rapidly pays for the cost of these upgrades.

Disposal/injection wells benefit too with less than 10 ppm oil remaining. Disposal wells no longer needed to be reworked near as often, if at all.

The simplified and highly efficient SWD plant of today resembles the 3D model below.



CONCLUSIONS

Old style SWD plants are obsolete and should be upgraded with 21st century technologies like KBK's DFSD® and HWSB®, IoT, and AI. KBK's DFSD® and HWSB® are the cornerstones of these plants. Professionally designed SWD Plants have an attractive return on investment. This is one more example of how doing it right pays off.

ABOUT THE AUTHORS

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