Final Technical Report- "A low cost oil water separator for stripper well applications"

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Final Report

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Abstract
Low cost oil-water-gas gravity type separators located in well, inside the production tubing, and used in conjunction with low volume submersible pumps were tested over the last nine months in four separate experiments in the field. The purpose of the tests was to show the usefulness of low cost separators in oil and gas wells, and to identify any problems that would limit their use in the field. The gravity separator technology tested was previously patented by Pumping Solutions Incorporated, and before this project, had not been field tested.

Four tests were performed, three at the RMOTC test facility in Teapot dome Wyoming and one at the Sanchez #1 well in the San Juan Basin in New Mexico. The separator as tested was low cost, and performed well in the field, except for a tendency to paraffin clog under some conditions. 99.7% oil-water separation was consistently achieved over a 6 month period with almost no operator intervention. As a bonus test, a gas well separator was designed and tested to demonstrate the use of the same concept to retrieve waste gas, contained in the pumped fluid, that is normally vented to atmosphere.

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Introduction
Over the past nine months, Pumping Solutions Incorporated, has been performing tests on a novel, low cost gravity separator that is used in conjunction with submersible pumps. These separators have the potential to replace more expensive, less environmentally friendly, surface separators commonly used today. The patented gravity separator technology uses the volume inside the production tubing as the separator volume, and is most useful at lower flow rates (less then 100 BPD) commonly found in stripper wells. Two types of separators were tested, oil-water and gas-water.

Executive Summary
Three low cost oil-water separators have been deployed to test wells at RMOTC, and a gas-water separator has been deployed in the San Juan Basin in a shale gas well. The oil-water separators were installed into Shannon formation wells with an average production of 20 BWPD and 3 BOPD. The average pump set depth was 800 feet. All wells were produced with submersible diaphragm pumps. The separators were installed into the standard 2 inch 8 round tubing from the surface after the submersible pump was installed. The total cost of the each separator was less than $50, not including the pump, cable, and standard tubing.

The first separator installed used 1 _ " PVC pipe as the separator "cup". Although the separator worked as designed, the separator "cup" was too large of a diameter, and eventually choked the flow and caused a downhole pump overload after about 1 week of operation.

The second separator installed was installed into the same well with a new pump. It had an improved separator "cup" which performed much better. The separation efficiency was measured by RMOTC to be 99.7%, which is better than standard surface gravity separators that had been used in that installation. The separator and pump ran continuously for 6 months, at which time, colder weather cause a paraffin clog near the surface that caused the pump to overload.

The third separator was installed on October 19th, 2002 in a nearby well of the same type. The separator performed the same as the previous installation for 2 months until extremely cold temperatures cause the surface tubing to freeze, causing the downhole pump to fail.

The fourth test was conducted in the San Juan basin, on a shale gas well. In wells of this type, most of the gas is produced in the annulus between the tubing and the casing, but a small amount of gas is produced up the tubing. This gas is normally vented to atmosphere when the pumped fluid is deposited into the water tank. A separator installed at the top of the tubing was able to separate the gas produced in the pumped fluid from the water, and was returned to the pipeline, thus creating more gas production and less greenhouse causing methane in the atmosphere.

The gravity separator as tested did perform well in a limited number of wells. Several problems were uncovered that will need to be addressed in future design iterations, but in general the separator performed better than expected, and PSI, under its own funding, will continue to test and deploy separators and will eventually offer these separators for sale with submersible pumps.

Experimental

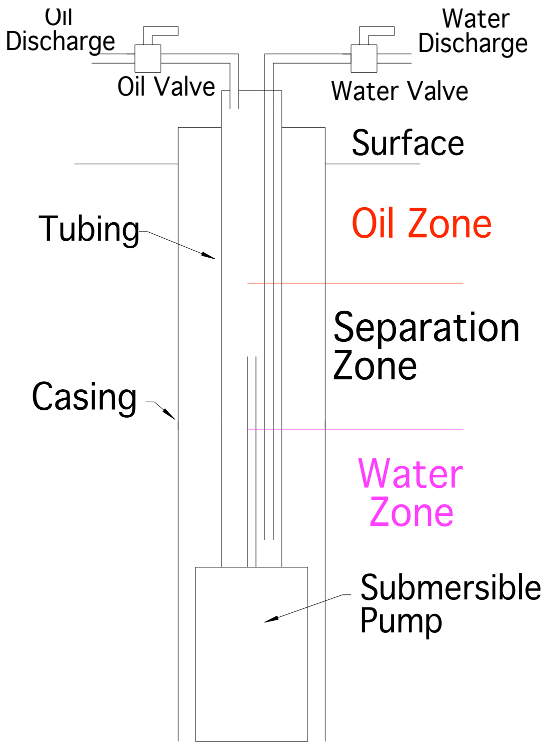
Four tests were performed during this Project. The first was installed on June 15 on a RMOTC Shannon well, which is producing stripper oil from the Shannon formation at about 1000' depth. The submersible pump was installed normally on 2" 8 round tubing by RMOTC personnel. The pump was started and run without a separator for a few hours. PSI personnel installed the PSI separator from the surface without a workover rig with the assistance of a RMOTC engineer. Once installed, the pump was turned on and the valves on the surface were adjusted to balance the flow of oil and water from the separator.

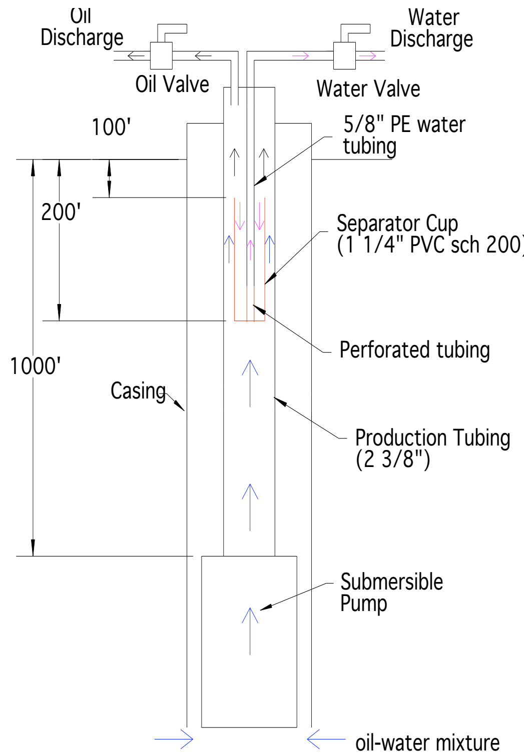
It was noticed that the exact adjustment of the valves is relatively sensitive, but once the proper flow rates are established, the flow of oil and water remains constant and completely separated. After the PSI personnel left to return to Albuquerque, the pumper continued to make minor adjustments to balance the flow. After about a week the pump failed, and was pulled and shipped to Albuquerque.

The pump was examined, and determined to have failed due to overload. Post test evaluation of the test hardware determined that the clearance between the separator "cup" and the wall of the 2 inch 8 round was too small, and an accumulation of sand had choked of the flow, and resulted in a buildup of excessive pressure, leading to pump failure.

A new pump was installed into the same well on Jun 21. The same day, the improved test separator was installed. The new design worked much better, and was less sensitive to small changes to the relative flow rate of the control valves. After a few days, a sample of the post separation fluids was tested by RMOTC and determined to consist of 99.7% oil, 0.3% water. The produced water had a "trace" of oil. The separator ran without incident for over 6 months, and after a few days of initial adjustment, has not required any additional adjustment to maintain relative flows. In mid December 2002, record cold temperatures were recorded in Wyoming. This froze over 45 wellheads in the area including the wellhead where this test was conducted. The freezing choked off flow, resulting in pump overload and failure, ending this particular test.

The third test unit was installed on October 19, 2002, into a Shannon well in the teapot dome field in Wyoming. It was essentially the twin of the unit installed in June and produced the same flow and separator characteristics, establishing the repeatability of the method. This unit ran approximately 2 months and was removed from service after an electrical failure of the submersible pump.





Test Hardware concept **Actual Test Hardware**

For all three wells described above, the tubing and casing was standard 4.5" casing, and 2 inch 8 round tubing that extended 1000' from the surface to the bottom of the well. It was installed in a conventional manner with the power cable banded to the outside. Once the pump was installed and operating, the separator was installed from the surface.

For units two and three, the separator was 100' long, consisting of a separator cup that was three sections of 20' 1 _" pvc schedule 200 pipe, joined by friction couplers. At the bottom end of the cup, the end was closed with a standard PVC cap. The cap was attached to an adaptor that connected the cap to the inner tube. The inner tube was attached to the cap through a 6 inch long, _"d pipe that had a number of holes drilled through it to allow the water to flow from the separator cup to the inner tube.

The pipe was attached to schedule 200, _" rigid pvc pipe, in 20' screw together sections. This extended from the pipe and the cap at the bottom of the separator cup to the surface. At the surface, the pvc pipe was connected to a bull plug that allowed flow through the wellhead through the bull plug.

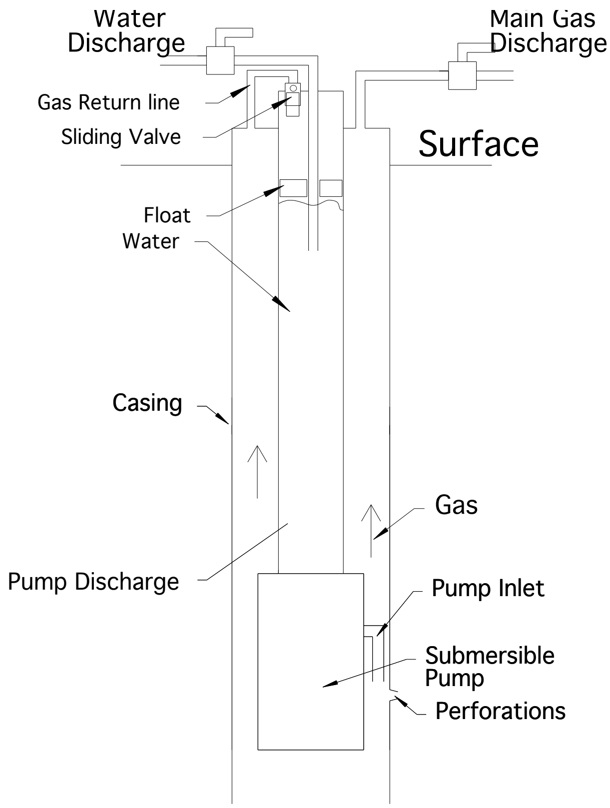
This inner pipe was connected to the water discharge control valve, which was a _" ball valve at the surface. The standard discharge control valve and discharge tubing at the surface, previously used to remove fluid from the top of the tubing string, was used to regulate the flow of oil at the surface

Separator ready for install

Post installation Wellhead

For the gas well unit number 4, the setup was much simpler, with a _" schedule 40 PVC water pickup tube extending inside the tubing from a fitting in a bull plug on the wellhead to inside of the tubing down 40 feet. At the surface, a "burp" valve was installed, where a floating ball would open or close a sliding type valve at the surface. When the ball was in the upper position, indicating little or no gas in the tubing, the sliding valve is closed, preventing the flow of gas from the tubing to the annulus. When the floating ball moved away from the sliding valve, the sliding valve would open, allowing gas to flow from the tubing to the annulus. The float was shaped like a "donut" allowing the water discharge tube to flow through the center.

The fourth test was conducted in the San Juan basin Sanchez well number two, installed on February 26, 2003, on a shale gas well. The well was 1900 feet deep and the pump was set below the perforations at 1800 feet. Unfortunately, this pump did not continue to run after the first day due to electrical problems. During the short time it did run, we were able to install the valves and float, but could not verify proper operation over a long time period. During the short time it did run, the separator seemed to be working, although some fluid leakage occurred around the gas purge valve. This problem will be corrected by adding o-rings, and after the completion of this project, this separator will be further tested with industry funding.



Gas Well Downhole
Separator

Results and Discussion

The gravity separator as tested did perform well in a limited number of wells and conditions. It appears that for situations of medium gravity oil, low flow rates, no emulsification, and limited paraffin formation, this low cost method will work very effectively. The major results of the testing were:

- For the types of oil and flow rates tested, 99.7% separation efficiencies were achieved
- A 200' long separator is all that is needed at apx 30 BFPD in 2 inch ID tubing
- Manual control valves work well, no need for automatic controls
- The separator can run long times with little attention if operated steady state
- Paraffin clogs can cause the separator to fail or require maintenance.
- Standard hardware costing less than $50 will create an effective gravity separator
- In well gravity separators can enable other techniques such as downhole water disposal and "tankless" direct injection into disposal wells

For the gas separator tested, the major results were:

- In well gas separators are practical, and although limited testing was conducted, such separators can be implemented with minimum hardware

- In well gas separators can reduce the amount of greenhouse causing gasses emitted from normally operating gas wells by recycling gas to the pipeline from the pumped fluid
- Only 20 feet of tubing is needed to create an effective separation zone
- A float operated valve works well, although more testing is needed

The test program performed is a good start to prove the concept is feasible, which was the goal of the project. Many more follow on tests are needed to show the extent to which the technique is useful. For the very limited conditions tested, the technique worked surprisingly well. Of interest is the single gas well separator tested, which allows an operator to produce a small quantity of gas from the pumped fluid, but more importantly, allows the operator to reduce methane emissions with little or no expense.

The operators used during this test program were lukewarm to the idea of using this type of separator, because it requires the use of a submersible pump and until the reliability and availability of low volume submersible pumps improves, it will be difficult to get operators to take the next step and install separators. PSI, under it's own funding, will continue to test and deploy this type of separator on a limited basis in conjunction with submersible pump testing. On the positive side, the technology will reduce costs, improve operations, and reduce pollution as advertised. The limited testing conducted shows the feasibility of the techniques, and the project has received notice of claims allowed for a US patent on the base separator technology (the patent was filed before this project started).

Follow on work that is suggested as a result of this field testing is:

- higher flow rates, and different types of oils and gasses.
- Direct reinjection of produced water into the same wellbore
- Tankless operations where the downhole pump pushes the separated water into a separate injection well under pressure
- In well oil storage for ultra low cost wells
- Use of larger liners with internally installed pumps

This work was sponsored by the Stripper Well Consortia, and that group has provided tremendous support for the development of low cost oil and gas well pumps and related techniques such as this project. The ultimate availability of low cost equipment such as described here can be attributed in large part to the efforts of the SWC.

Conclusion

When this project was proposed less than 1 year ago, the goal was to design, build, and test an entirely new type of downhole separator that would be a cost and performance breakthrough, reducing the cost of these operations an order of magnitude. The project has accomplished exactly what was proposed in about nine months. Although the magnitude of the project was relatively small, the design and field testing provided the proof required to perfect the design and make this a commercial product, able to reduce costs to producers. The task ahead is to make this now proven and tested technology commercial by refining the design, and completing the development and test of the low volume submersible pumps required to make it work.

Several surprising results were achieved. First, the proposers were not at all sure that the separator would work without complex (and expensive) controls. It turns out the system is very robust, and will work over a relatively wide range of manual valve positions. We are still investigating the physical basis of this welcome result. We believe that the differential density of oil vs water can explain this at least partially. The other pleasant surprise was the relatively short separator needed to achieve good separator efficiencies. We were expecting to need longer dwell times to achieve high efficiencies, but this was not the case.   We may experience more difficulty trying to separate oils with different properties, but this will be part of later work. The third surprising result was the relative ease of integrating a gas separator into a gas production environment to recycle gas from the produced water to the annulus. This relatively painless technique does not really produce all that much more gas, but does eliminate some environmental and safety concerns using a relatively simple, cheap and reliable piece of equipment.

The goal of the next phase is to further demonstrate this technology and make it standard practice in the industry. The “big project” is to introduce low volume submersible pumps as a standard, but the availability of the technologies and techniques will make that easier, and will eventually make oil and gas operations lower cost and more environmentally acceptable.