Continued Success of the Monosep Flotation Pump

Paul C. "SKIP" Broussard Jr.
Vice President of Monosep Corporation

ABSTRACT

The treatment of produced water continues to be one of the biggest world wide economic and environmental concerns. Oil and Gas Producers are looking for economic ways to treat the produced water for disposal or re-injection. The need for efficient equipment to clean the produced water has led to much research and a variety of methods have been developed to treat this water. Both onshore and offshore locations require equipment to treat produced water with flow rate capacities from 500 BPD up to 500,000 BPD. Supplying the needs for such equipment has kept companies looking for new and creative ideas. One such idea developed and patented by Monosep is a Dissolved Gas Flotation (DGF) pump. This pump creates the micro-fine bubbles needed for the flotation process. This paper will provide the background, the development and the continued success of this new flotation pump.

I. INTRODUCTION

Offshore platforms and onshore locations with space limitations require compact and efficient flotation systems to clean the produced or processed water. Oil and Gas Producers are looking for new technology to increase the efficiency and/or reduce the size of the flotation equipment. Monosep has developed and patented a new flotation system to meet these needs. This break through in technology is centered on a new type of pump that creates the micro-fine bubbles needed for the flotation process. The pump dissolves the gas into the water creating extremely small gas bubbles. The pump is called a Dissolved Gas Flotation (DGF) Pump. Monosep has installed over 50 DGF pump systems and have had excellent results. The pump is patented by a major pump manufacture. Monosep owns a patent for the process system for produced water treatment.

The following paper will present the development of this technology. First, the background and importance of the flotation process will be discussed. Second, the mechanical aspects of the pump will be explained, followed by the results of the shop testing, the field-testing and the continued success of the systems installed. This presentation will close with a brief summary and Monosep's outlook for the DGF PUMP.

II. FLOTATION PROCESS

Flotation systems are used for a variety of applications throughout the world. This process floats solids, oils and other contaminates to the surface of liquids. Once on the surface these contaminates are skimmed off and removed from the liquids. Oil and gas production facilities have used flotation systems to remove the oils and solids from their produced and processed water for many years.

The key to good flotation is both gravity and the creation of millions of very small bubbles. Based on Stokes Law, the size of the oil droplet and density of the droplet will effect the rate of rise to the surface.

The larger and lighter the droplet the faster it will rise to the surface. By attaching a small gas bubble to an oil droplet it will decrease the density of the droplet which will increase the rate at which it will rise to the surface. Therefore the smaller the gas bubbles created the smaller the oil droplet floated to the surface. Therefore the key to flotation is to create as many small bubbles as possible. How the bubbles are introduced into the water stream is also important. The bubbles need to fill up the cells entirely. The retention time of the produced water in the treatment equipment is important. The average retention time for a vertical unit is about 4 to 5 minutes and 6 or more minutes for a horizontal unit.

There are a few different types of flotation systems.

1. There is a Dissolved Air Flotation (DAF) system. In this method the air is compressed and dissolved into the water stream. These bubbles are very small and give good results, but the system requires a compressor and a saturation tank. This system is not suited for offshore platforms due to space and maintenance requirements.

2. There are Induced Gas Flotation (IGF) systems. These IGF systems can be mechanical or hydraulic.

   a) The mechanical system uses a motor and paddle assembly to basically shear the gas out of the water. As the paddle spins in the water it agaiates the cell with small bubbles. This system requires a good bit of maintenance. The motors, bearing, and paddles need to be greased and oiled.

   b) The hydraulic system uses a recirculation pump to drive an eductor, which induces fine gas bubbles into the water. Each flotation cell is filled with many micro-fine gas bubbles. The recirculation pump recycles from 25% to 125% depended on the equipment design.

3. There is a Gas Sparging system. This system uses a porous SST tube to sparge small gas bubbles into the water. The gas bubbles are very small and provide good results. The sparging tubes however are prone to plugging with scale and/or hydrocarbons.

Figure 1. Comparison of mechanical and hydraulic systems.

These methods have been in the industry for many years. Several years ago Monosep introduced a new hydraulic method for flotation without the need of eductors. The recirculation pump used in this system dissolves the gas bubbles within the pump and associated piping.

III. DGF PUMP CONCEPT

A. About the DGF Pump

The impeller in the DGF Pump is designed with dual sides. One side is designed to drive the liquid like a normal centrifugal pump and the other side is designed to draw in a vapor into the pump and mix it with the liquid. In addition to the new impeller a special seal was invented to extend the life of the pump. With these innovations the pump creates a sub-atmospheric pressure region within the pump's seal chamber. As the impeller draws in the vapor it is mixed with the liquid being pumped and compressed into micro-fine bubbles. Because of the close tolerance between the backvanes of the impeller and the backplate of the pump the vapor is sheared into fine bubbles and then they are compressed in the sub-atmospheric pressure region of the pump. These fine bubbles become dissolved into the liquid within the discharge piping of the pump. The result of this process provides similar size bubbles to Dissolved Air Flotation systems. The bubble size in this new DGF Pump is estimated to be 1 micron or less.

B. Flow and Pressure

The flow rate of the liquid in the discharge piping and the backpressure on the pump are key factors to creating the smallest bubbles possible. The way the pump is piped up to a process tank or vessel is very important. An optimum velocity of the pump piping should be 1 to 2 feet per second. Also a minimum saturation time of ten (10) seconds is needed in the discharge piping before the backpressure valve. An optimum backpressure on the pump is between 55 and 65 PSI. To calculate the discharge piping size and length the follow formula can be used.

$Q = V * A$

Q = flow rate
V = velocity of fluid media
A = area of pipe

Multiply the Velocity by 10 seconds to calculate the length of pipe needed before the backpressure valve.

Figure 2. Vessel and pump with discharge piping.

This flotation pump has been applied to the processing of produced water. The liquid driven by the pump is produced water; the vapor drawn into the pump to be dissolved into the produced water is produced gas. In the clarification of produced water the elimination of oxygen for the treatment system is essential. Therefore produced gas is used for the flotation vapor. Gas vapor has more infinity to oil and will attach to an oil droplet easier than oxygen. Most importantly oxygen will precipitate iron oxide into the produce water stream which has a tentecy to become oil wet and contaminate the discharge.

IV. SHOP AND FIELD TESTING

A. SHOP TESTING

The first time Monosep tested the DGF Pump was in an existing unit in 1997. A vertical (CYCLOSEP with a sparging system) rental unit was fitted with the new DGF Pump at the shop. The internal sparging tubes were removed and the existing external piping for the sparging system was utilized. The liquid used in the vessel was fresh water. The vapor inlet of the pump was open to the air for this test. The results were fantastic. The vessel was quickly filled with billions of micro-fine bubbles which turned the water milky white. The ½"piping for the sparging system provided the right amount of backpressure on the pump to allow the air to dissolve into the water. These great results lead Monosep to have a few more pumps built for testing.

The next test was done on a horizontal unit (VEIRSEP with an eductor system). The existing eductor piping was used and the eductors were not removed. The results were poor because the backpressure on the pump was not enough. The water traveled through the piping too fast for the air to dissolve into the water.

A small test unit was used for further testing. The unit was about 2-½ foot by 2-½ foot by 4 foot tall. This box was built on legs and had plexi glass sides so that the bubbles could be seen. The pump suction came off the bottom and the pump discharge was piped down into the water from the top.

The first test was with one ½" down comer. The results were not very good. The next test was with four ½" down comers. The end of each down comer was capped and a 1/8" hole drilled into the cap as an orifice to create the necessary backpressure on the pump. In this test the pump did not produce any bubbles because the backpressure was too great. Next the holes were drilled to ¼" and the pump worked great. The next test was with 3/8" holes and the bubbles were not as good as with the ¼" hole. Our conclusion was that four (4) ¼" orifices provided the right amount of backpressure on the pump.

Figure 3. Test system with four down comers.

Monosep next began to design a new vertical unit (SPINSEP) especially for the DGF Pump. Before the construction on the new unit began a client agreed to retrofit an existing sparging unit offshore with the DGF Pump. The installation went fine and the results where very good. The discharge water quality of the new DGF Pump was better than the previous sparging system. The client was very pleased.

Before the new vertical unit was finished another client agreed to retrofit a sparging unit on an offshore platform. Again the results were very good. So before the new test unit was finished, two DGF Pumps were in service offshore and proving to work very well. On these units, the backpressure on the pump was controlled by valves keeping the pressure around 50 psi.

The new test unit was designed with two manways on opposite sides of the vessel and plexi glass covers were made so that the bubbles could be seen and filmed. The first test was with fixed orifices ranging from ¼" to 3/8". Both internal and external orifices were used. The bubble size was not consistent so the orifices were removed and the ball valves were used to regulate the backpressure. This method gave good results. The results where taped on video camera. The piping was redesigned with globe valves to replace the ball valves for better control. Again the results were great and a tape was made to show the billions of fine bubbles.

Figure 4. Monosep SPINSEP complete with DGF pump.

Once the valves where pinched off to provide the right backpressure, clouds of micro-fine bubbles filled the vessel. The clear water became milky white. A small red sign was placed in the water about 8" from the plexi glass. Before the pump was turned on the sign was clearly visible. Within a few moments after the pump is turned on the sign becomes hard to see due to the billions of fine bubbles clouding up the water. The bubbles are so small they begin to float sideways and downwards. The bubbles became suspended in the water rising very slowly to the surface. It was noted that rust particles and oils from the steel floated to the surface because of the very fine bubbles.

B FIELD TESTING

After these great results Monosep rented this test unit to an offshore client who achieved 8 to 12 PPM discharge. This test unit was then sold to another client after another successful trial test. Over the past few years now several DGF pump systems have been built. By the beginning of 2003 Monosep has built numerous new vertical units, a few new horizontal units, and refurbished or retrofitted quite a few horizontal and vertical units. In addition we have added the DGF pump system to existing skimmer vessels by piping the discharge of the pump through the bottom drains.

The vertical units have shown good results but because DGF system can create such fine bubbles the bubbles tended to flow out with the water rather than rise to the surface. Therefore the backpressure valve was opened lowering the pressure which increased the bubbles size. The slightly larger bubble tended to rise to the surface bringing the oil droplets upward.

On some units some in-line sight glasses where installed in the discharge piping of the pump to observe the bubbles size change as the backpressure valve was regulated. It was observed that a 15 to 25 psi pump discharge pressure there where more bubbles. With a higher pressure of 35 to 45 psi there where less bubbles. However these bubbles seemed to be smaller. The higher backpressure gave smaller bubbles while the lower pressure gave slightly larger bubbles. The DGF pump is capable of actually creating a bubble size so small it's rise rate to the surface is too slow for proper oil and water separation in a unit with only 5 to 7 minutes retention time.

As with the normal eductor system the DGF horizontal units are more efficient at removing oil from the water than the vertical units. Due to the extremely small bubbles size, having an extra chamber or cell for the bubbles to rise to the surface improves the performance. We ran tests on a horizontal unit offshore. We tested the backpressure settings and number of active flotation cells. We found that the unit preformed better than expected. The bubble size in each cell can be controlled. In the first cell we created extremely small bubbles and in the next few cells created slightly larger bubbles. The flexibly to change the bubble sizes in each cell and have a combination of bubble sizes in the unit has increased the efficiency of the equipment.

As mentioned earlier Monosep has even added the DGF pump system to existing skimmers and the performance of the equipment improved.

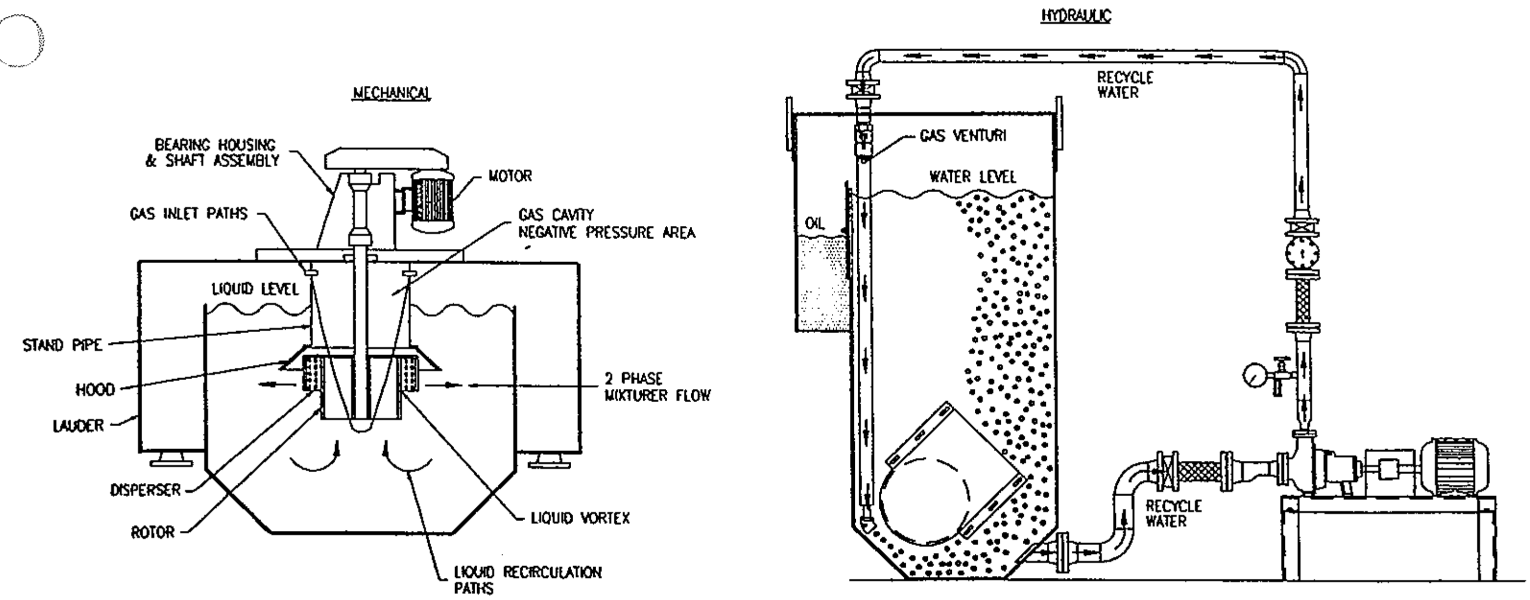
V. FUTURE TESTING

A new horizontal rental unit will be built with both the traditional eductor system and the DGF Pump system. We hope to test the unit offshore to see the difference between a proven IGF system and the new DGF Pump system. By turning a few valves the same produced water can be treated using an IGF eductor system or the DGF Pump system.

Monosep is looking to test this new technology in other oily water treatment applications. Many refineries have API pits to treat the processed water. This process water contains oil and solids. These pits are not very efficient by offshore standards. By adding the DGF Pump into the pit the flotation should greatly improve the performance of these pits. Steel mills and paper mills use flotation technology to remove oils and solids. Monosep has installed a DGF pump system to float solids from river water as a pre-treatment for refinery process water. Monosep hopes to test this new technology in these and many other applications in the next few years.

VI. SUMMARY

The future of the Dissolved Gas Flotation Pump looks very clear. With over 50 units in operation providing excellent results Monosep is moving forward by expanding the supply of this new pump to our customers. We are looking at many retrofit situations and we are looking at supplying our equipment for more than just produced water. In the past five years we have had a numerous repeat customers who have been pleased with this new technology. Due to this success of the DGF technology, Monosep has provided large capacity flotation equipment on several recently commissioned deepwater production facilities. In addition, we have commissioned two 105,000 BPD units for a major refinery client in Brazil in order to remove both collected solids and organics.



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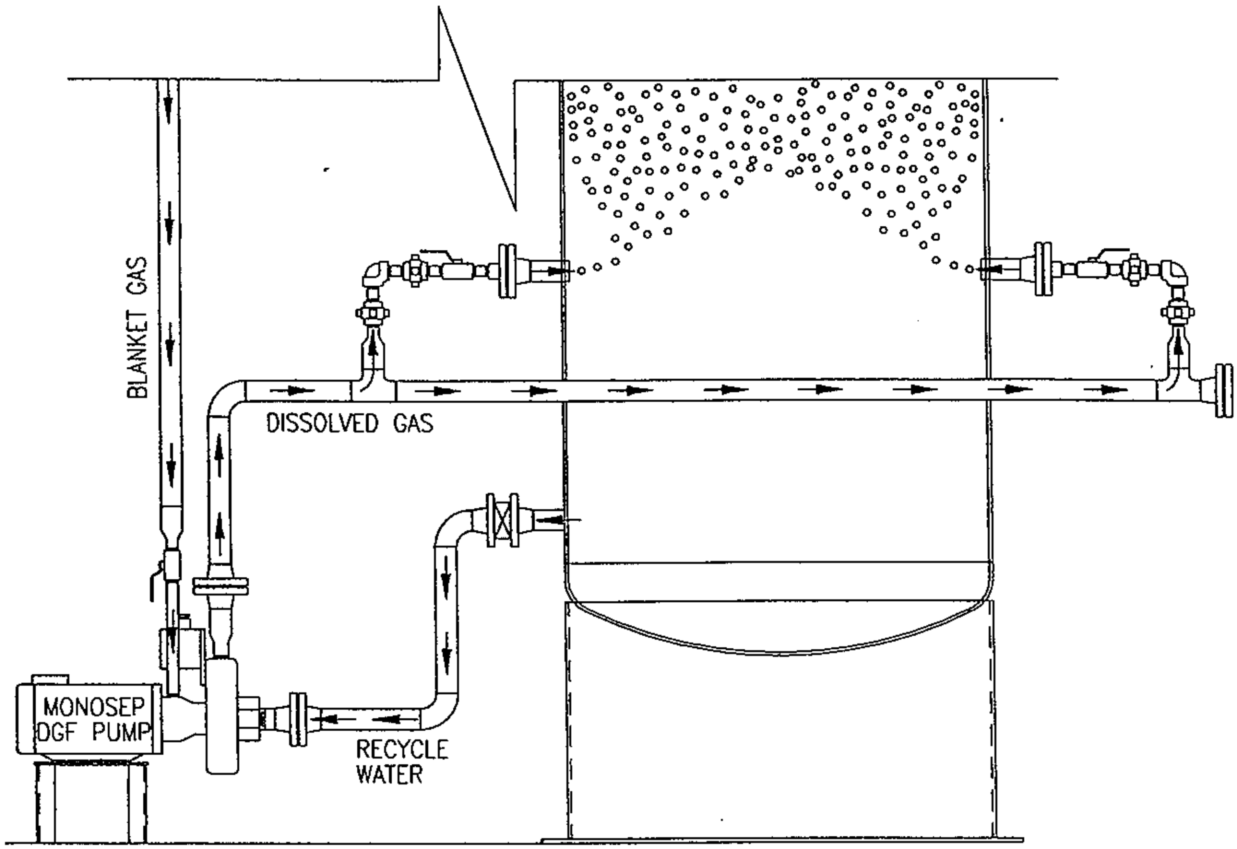

Figure 2. Vessel and pump with discharge piping.

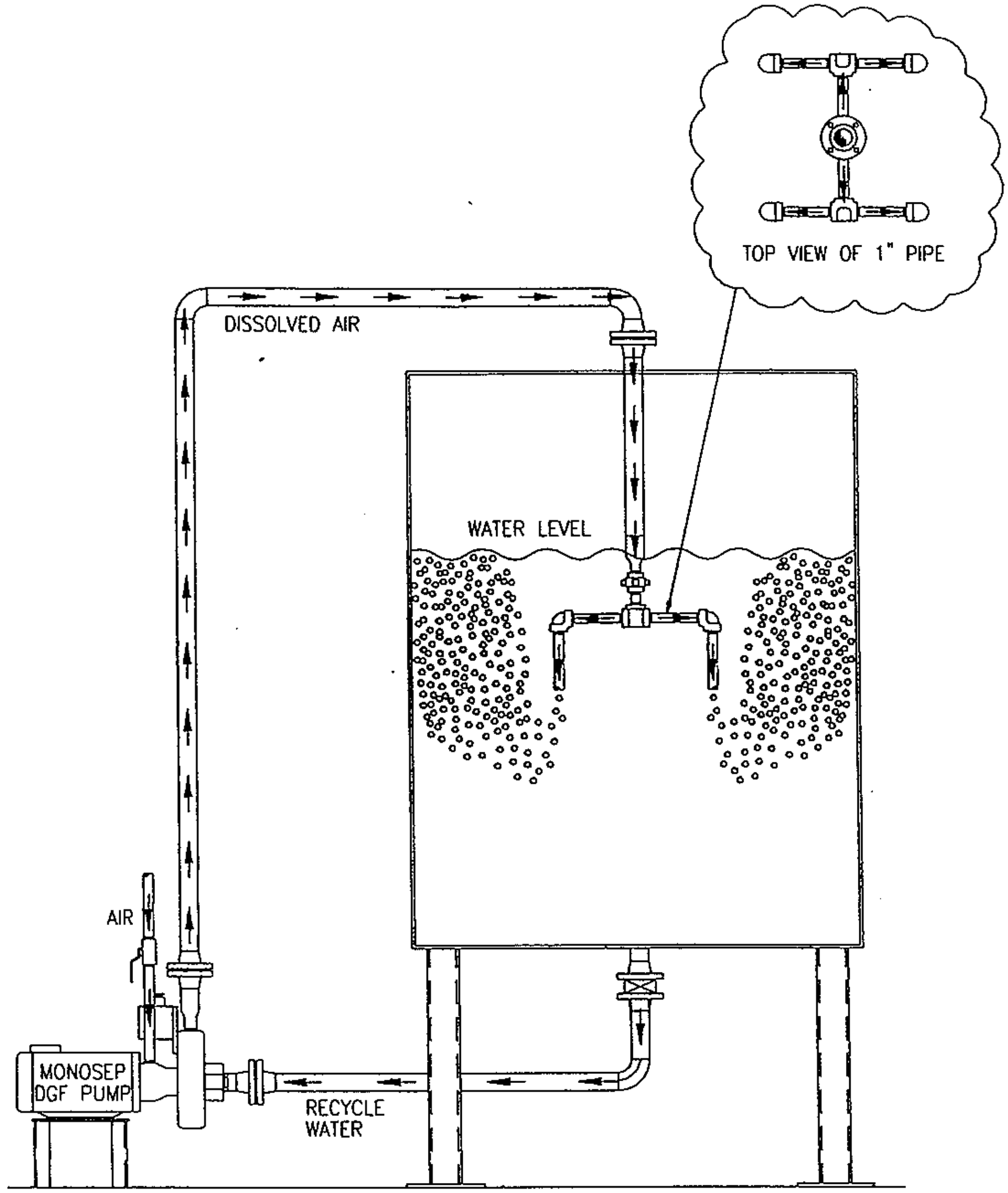

Figure 3. Test system with four down comers.

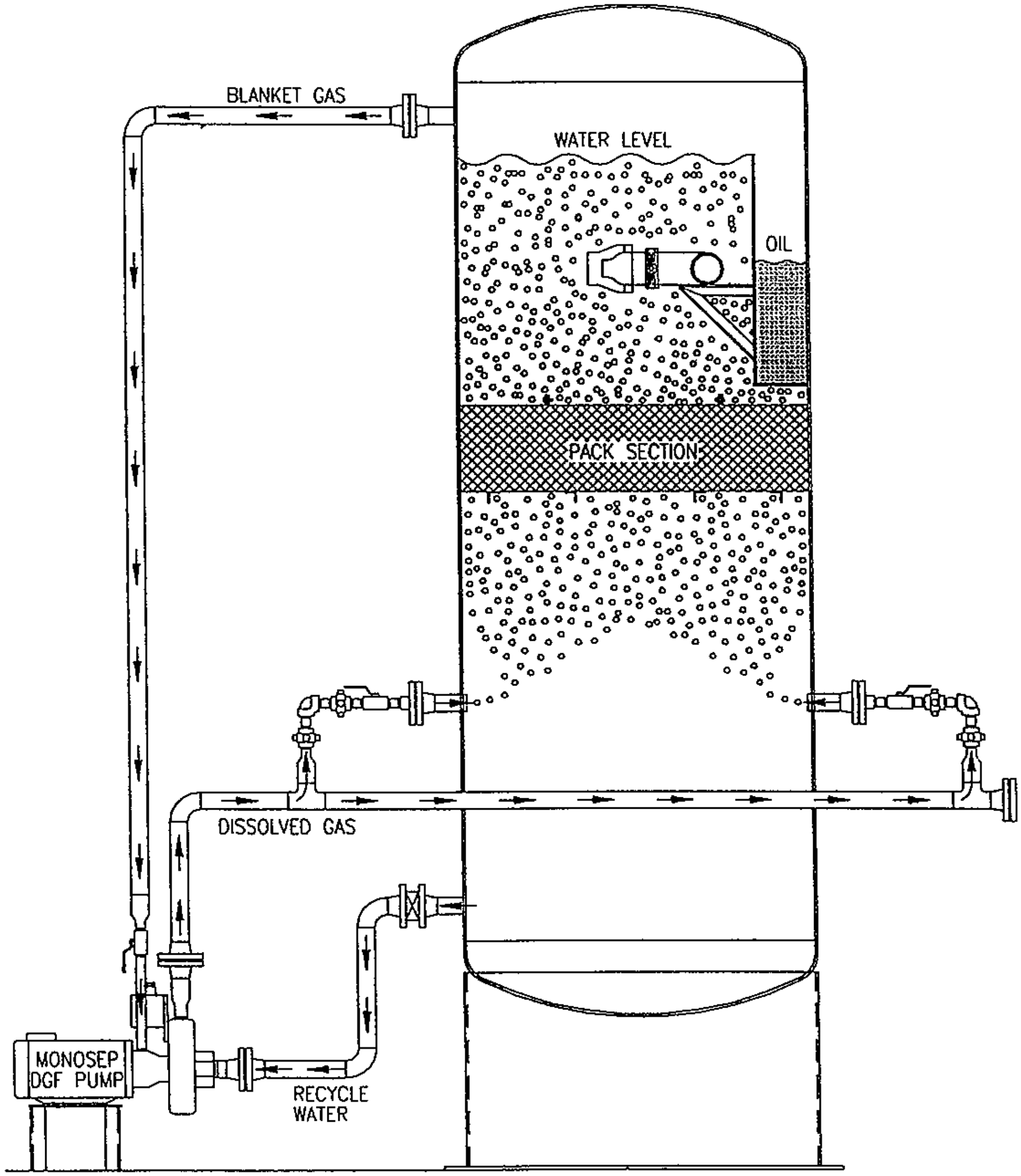

Figure 4. Monosep spinsep complete with dgf pump.