INNOVATIVE GAS-LIQUID SEPARATOR INCREASES GAS PRODUCTION IN THE NORTH SEA

Roy Viteri  
Sulzer Chemtech USA, Inc.  
4106 New West Drive  
Pasadena, TX 77507  
(281) 604-4119  
Roy.viteri@sulzer.com

Daniel Egger  
Sulzer Chemtech Ltd  
P.O. Box 65  
CH-8404 Winterthur, Switzerland  
+41 52 262 5008  
daniel.egger@sulzer.com

Dr. Hugo Polderman  
Shell Global Solutions International B.V.  
P.O. Box 38000  
1030 BN Amsterdam, The Netherlands  
+31 20 630 2518  
hugo.polderman@shell.com

ABSTRACT

Innovative gas/liquid separation equipment has increased the throughput to design levels at the Shearwater oil and gas production platform in the central North Sea. The platform is about 150 miles off the east coast of Britain in 300 feet deep water and is operated by Shell UK Exploration and Production and backed by Shell, ExxonMobil and BP.

Shearwater was the largest producing high-pressure, high-temperature field in the North Sea when it came on stream in September 2000. Its gas condensate reservoir has wells that are 17,000 feet deep, with pressures up to 14,500 psi and temperatures up to 380°F. The gas is dried and processed on the platform before it is sent directly into the UK network for industrial and domestic use.

Gas dehydration plants consist in essence of an inlet scrubber, a contactor and an outlet scrubber, either in separate vessels or integrated in one vessel. Prior to processing the gas through the low-temperature conditioning plant and then into the export pipeline, water vapor is removed in a TEG contactor to avoid condensation in, and corrosion of, the subsea line; however, condensate carryover from the TEG inlet separator restricted the plant capacity to about 75% of the 410 MMscfd design capacity. At the prevailing high operating pressure, the efficiency of the original vane mist eliminator, installed in the bottom of the TEG contactor, was insufficient to capture entrained liquid hydrocarbons in the gas and protect the contactor from contamination.
To remove the bottleneck, the TEG contactor’s inlet scrubber separator required an upgrade to a Shell SMS (Schoepentoeter, Mistmat, Swirltube) configuration. Shell’s standard Swirltube gas-liquid separation equipment was commercially available; however, the standard configuration was too tall for direct installation into the TEG contactor. At that point in time, Shell Global Solutions was developing a high performance separation Swirltube that had a more compact design; however, they had only been tested at atmospheric conditions using air and water.

Within a 6-month period, the new compact High-Performance Swirltube (HPST) separator was designed by Shell Global Solutions and Sulzer Chemtech. It was tested against the standard Swirltube, and the performance of the new Shell HPST equalled that of the original Swirltube. The decision was then made to install the high-efficiency Swirltube internals as per the Shell SMS design.

Since the retrofit, the Shearwater platform has been operating smoothly at its designed production levels with an excellent safety record.
Innovative Gas-Liquid Separator Increases Gas Production in the North Sea

Roy Viteri, Sulzer Chemtech USA, Inc., Pasadena, Texas
Daniel Egger, Sulzer Chemtech Ltd., Winterthur, Switzerland
Dr. Hugo Polderman, Shell Global Solutions International B.V., Amsterdam

Introduction

In most modern offshore gas plants, the contactor is a packed bed filled with conventional or high capacity structured packing [1]. Often the performance of these plants is compromised by an inadequate inlet scrubber. Condensate carried over into the contactor accumulates in the glycol regeneration system, eventually limiting the gas handling capacity of the entire installation. The Shearwater case study will be presented showing how the capacity of such a plant could be restored by upgrading of the inlet scrubber. Vane packs are often less suitable for the operating conditions of a gas plant, which was the case with the Shearwater platform. The existing vane was replaced by the Shell SMS Swirltube separator. This paper discusses the upgrading of the inlet scrubber.

1. The Shearwater Platform

The Shearwater oil and gas production platform in the central North Sea is about 150 miles off the eastern coast of Britain in 300 feet deep water and is operated by Shell UK Exploration and Production and backed by Shell, ExxonMobil and BP. It is one of the industry’s most technically challenging developments.

Shearwater was the largest producing high-pressure, high-temperature field in the North Sea when it came on line in September 2000. Its gas condensate reservoir has wells that are 17,000 feet deep, with pressures up to 14,500 psi and temperatures up to 380°F. After being separated from the condensate, the gas is processed through a glycol dehydration plant, a hydrogen sulfide removal plant and a turbo-expander driven cold plant on the platform. The gas has a hydrocarbons dewpoint, dryness and H2S level of sales-gas quality. No further processing of the gas is required. The gas processed on the Shearwater platform is sent directly into the UK network for industrial and domestic use.

A typical flow scheme for a glycol dehydration system can be seen in Fig. 1. Prior to processing the gas through the low-temperature conditioning plant and then into the export pipeline, water vapor is removed in a TEG contactor to avoid condensation in, and corrosion of, the subsea line; however, condensate carryover from the TEG inlet separator restricted the plant capacity to about 75% of the 410 MMscfd design capacity. At the prevailing high operating pressure, the efficiency of the original vane mist eliminator, installed in the bottom of the TEG contactor, was insufficient to capture the entrained liquid hydrocarbons in the gas and protect the contactor from contamination. The condensate that was carried over into the contactor was vaporized in the vent system of the glycol regenerator and restricted the capacity of the whole plant.
The capacity of the plant was restored by upgrading the TEG contactor’s inlet scrubber section. We will first explore the specifics of the various different mist elimination devices that were considered for this service and then how the decision was made to retrofit the existing equipment to incorporate the Swirltube (cyclone) separators.

![Diagram](Figure 1: Typical flow scheme of a gas dehydration system with integral scrubber section in the contactor bottom section)

2. **Comparison of Mist Elimination Devices Considered for the Shearwater Platform**

The gas/liquid separator that was originally installed in the Glycol Contactors inlet scrubber was a typical vane. It was chosen because of its simplicity. After the vane was unable to handle the design gas and its specified separation requirement, a wire mesh mist eliminator and cyclone separator were considered for the integral inlet scrubber. The operating window of these devices for typical gas plant conditions is compared in Fig. 2, which shows the variation of the achievable efficiency as a function of the gas load.

The gas load (K-value) is expressed in terms of the gas load factor $\lambda$, which is defined as:

$$\lambda = \frac{Q}{A} \sqrt{\frac{\rho_G}{\rho_L - \rho_G}}$$

where $Q$ is the volumetric gas flow, $A$ is the available cross sectional area of the mist elimination device, $\rho_G$ is the gas density and $\rho_L$ is the liquid density. The factor under the square root accounts for the effect of pressure. Actually $\lambda$ can be considered as the ratio of the drag force and gravity as experienced by the liquid droplets; therefore it is particularly suitable to describe the (re-)entrainment related processes occurring in gas-liquid separators.
The shape of the curves in Fig. 2 shows that there is a certain trade-off between efficiency and gas handling capacity; however, in practice this will mean that the capacity of a Mistmat (wire mesh mist eliminator) is restricted because in gas plants there is little room to compromise efficiency.

As can be seen in Fig. 2, wire mesh mist eliminators give an almost complete liquid removal up to a gas load factor of 0.35 ft/s (0.105 m/s); however, as this factor should be derated with increasing operating pressure due to a decrease in liquid surface tension. With cyclonic separators such as the SMS and SMSM Swirltube separators, the gas handling capacity can be more than doubled while maintaining similar separation efficiencies.

The capability of a vane mist eliminator lies somewhere between the capabilities of mesh pads and cyclones. Their capacity can be comparable to that of cyclonic separators, but their gas handling capacity depends more directly than that of the other devices on droplet stability and hence on interfacial tension. The experience in the Shearwater case, along with other Shell operating companies, is that they are less efficient than wire mesh mist eliminators and cyclone separators. The typical efficiency is assumed to be $\leq 96\%$. Furthermore, it has been observed that the efficiency starts to drop significantly at pressures above 900 psi (65 bar) independent of the gas load. This is demonstrated in Fig. 3 which shows performance data of a number of Shell operated vane separators.
In Fig. 2, Shell’s SMS and SMSM Swirltube separators have been taken as the model for the capabilities of cyclone separators. The acronyms represent the first letter of the composing elements, i.e. a Schoepentoeter\(^\dagger\) (a vane-type inlet device), Mistmat (wire mesh pad) and a Swirldeck (consisting of Swirltubes). The arrangement of a typical knockout vessel with SMSM equipment can be seen in Fig. 4.

The Schoepentoeter inlet already removes 50-70\% of the incoming liquid, depending on the gas load in the vessel, and distributes the gas over the vessel cross section. The primary Mistmat has a dual function. At higher gas loads it acts as a coalescer, agglomerating the liquid droplets coming from below in order to facilitate their removal in the downstream Swirltubes. This combination of a coalescing Mistmat and Swirltube cyclones is a proprietary feature [2]. At low gas load conditions, the Mistmat functions as a wire mesh mist eliminator, thus providing a large turndown.

The Swirldeck is an arrangement of Swirltubes or cyclones that are illustrated in more detail in Fig. 4. The gas coming from below is forced into rotation by the swirler in the bottom of the tube. The primary gas, free of the entrained liquid droplets, leaves the Swirltube via the primary outlet at the top. The liquid accumulates on the tube wall and leaves with the secondary gas via a number of longitudinal slits. The box around the Swirltube functions as a knockout vessel where the liquid drops out. From there it is removed to the sump in the bottom of the vessel via drainpipes. The secondary gas leaves the box via secondary gas outlets and is recombined with the main gas stream.

\(^\dagger\) Shell Group Trademark
3. **Shearwater Platform: from 310 to 410 MMscfd with Proper Inlet Separation**

The Shearwater platform is operated by Shell, but the original equipment design and selection was made by others. The gas from Shearwater goes straight into the UK domestic gas grid; therefore, the plant is equipped with extensive process facilities for acid gas removal and water and hydrocarbon dewpointing. The installation was designed for 410 MMscfd (11.6 MMs/m³/d), but the capacity appeared to be limited to about 75% of the design due to excessive condensate carry over into the glycol contactor and from there into the spent glycol. The venting system of the glycol regenerator could not handle the accompanying additional vapor load and bottlenecked the whole process.

The glycol contactor is equipped with an internal inlet scrubber, originally consisting of a Schoepentoeter inlet device in combination with a vane mist eliminator. The contactor also contains a chimney tray, a 22'-0” tall bed of Sulzer Mellapak\(^\text{TM}\) M250Y structured packing and channel-type liquid distributor. The separation efficiency of the vane device appeared to be insufficient to minimize the condensate carryover into the contactor. This can to a large extent be attributed to the high operating pressure of about 1200 psi (85 bar). Furthermore the pressure drop across the vane was minimal, which means that the gas did not adequately distribute across the cross section of the vessel. This was confirmed when a CFD study was performed on the original equipment design as noted in Fig. 5.

\(^{\text{TM}}\) Sulzer Chemtech Trademark
The vane originally selected for the inlet scrubber was a simple vane with overall dimensions of 4'-9" x 5'-0" x 12" high for a total cross sectional area of about 24 ft². Using the Souder-Brown equation to verify the load factor (K-value), the vane was operating at a K-value of 0.62 ft/s. This was within its acceptable operating window of 0.40 - 0.65 ft/s.

In the CFD study, the incoming feed has its highest velocity as it goes through the inlet and into the body of the Schoepentoeter; however, as the fluid exits the inlet device, the fluid velocity decreases. This is due to the Schoepentoeter’s inherent increase in flow area, which helps decrease the momentum of the feed. This allows for the removal of any bulk liquids and solids that may be present and also distributes the gas flow evenly over the vessel cross section. This even distribution maximizes gravity separation before the gas enters the downstream equipment. The Schoepentoeter also does not direct the fluids downwards directly into the liquid sump so re-entrainment of liquid is minimized.

Figure 5: CFD Study of Original Internals (including Vane Separator)
As the gas exited the Schoepentoeter, the CFD study shows that the gas velocities were low to moderate signifying an even distribution across the cross section of the vessel; however, as the gas exited the vane, there was an increase in velocity toward the outer edge of the vane and a decrease in velocity as it approached the center. The study assisted in understanding the flow characteristics through the internals. This led to the finding that the vane had minimal pressure drop across it, which did not evenly distribute the gas across the separator. This irregular distribution, along with the lowering of the liquid surface tension, helped lead to the inadequate condensate separation from the gas before it entered the TEG contactor. For further clarification, we also studied the gas flow from the chimney tray was also studied and the CFD revealed that there was even distribution of gas into the structured packing.

The proposed solution was to convert the inlet scrubber into an SMS separator by removing the vane retrofitting it with a primary Mistmat and a Swirldeck; however, the space cleared by the vane was insufficient. The distance between the top of the Schoepentoeter inlet device and the outlet of the vane was less than 40” (1 m). In the limited shutdown time available, it was also not possible to relocate the chimney tray and the bed of structured packing; therefore, it was decided to accelerate the release of the more compact High Performance Swirltubes that were in the final stage of development by Shell Global Solutions at that point in time. The new High Performance Swirltubes were 14½” tall, whereas the conventional Swirltube design was 20” tall.

This height difference between the two types of Swirltubes was all that was needed in order to allow for the installation of the primary Mistmat coalescer upstream of the Swirldeck with High Capacity Swirltubes along with the piping required to drain the Swirldeck. The primary Mistmat consists of a single density wire mesh pad (4” thick) sandwiched between top and bottom support grids (1” high each). The Swirldeck consists of boxes containing 4 to 6 High Performance Swirltubes. The original Schoepentoeter inlet device was maintained. Fig. 6 compares the original vane configuration to the current SMS design.

Figure 6: Shearwater inlet scrubber before (left) and after revamp (right)
The retrofit project began in early January of 2003. Risk evaluation of the new technology application, including testing of the new prototype High Performance Swirltube, was completed by the end of March 2003. The testing showed that the new Swirltubes equalled the performance of the conventional Swirltubes. The decision to install the new SMS separator was made the following month and the new internals (primary Mistmat, Swirdeck, piping, etc.) were manufactured by Sulzer Chemtech and installed in June 2003 during the platform’s re-scheduled shutdown period. Replacing the vane with the High Performance SMS configuration removed this bottleneck from the system and the platform’s design capacity was achieved. The inlet side of the actual Shearwater High Performance Swirrdeck can be seen in Fig. 7.

Figure 7: Shearwater’s High Performance Swirrdeck

References

1. www.sulzerchemtech.com
2. ‘Column for removing liquid from a gas’, U.S. Patent 4767424

Note

The technical information contained in this presentation is controlled for export by the US Government under EAR99. Please do not forward the contents without obtaining authorization from the author.