EXPERIENCE WITH DEBOTTLENECKING OF GAS DEHYDRATION PLANTS

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ABSTRACT

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.

In most modern gas plants the contactor is a packed bed filled with conventional structured packing. 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. Several case studies will be presented showing how the capacity of such plants could be restored by upgrading of the inlet scrubber. Vane packs which are less suitable for the operating conditions of a gas plant were replaced by Shell SMS swirltube separators. The efficiency of swirltube separators was eventually further improved by the application of high performance coalescing mistmats.

In cases where the contactor itself is the limiting factor, the throughput can be increased by 20-30% by retrofitting high capacity structured packing. Conventional structured packing has a high de-entrainment capacity of itself and it is usually operated at gas loads where the outlet scubber can be a simple wire mesh demister. High capacity packing, is operated at a higher gas load and is more prone to glycol carry over. In that case the outlet scrubber becomes critical. Good results were obtained in the field with an SM swirltube demister.

Even further debottlenecking, up to 60-70% above the capacity of conventional packing, can be obtained by retrofitting the contactor with contacting swirltubes. Here the contacting is performed by dispersing glycol in the inlet of gas liquid cyclones. To achieve the very high glycol recovery rate required, a high performance outlet scrubber is essential. Applications so far, amongst others in the Gulf of Mexico, showed excellent gas drying performance. The glycol carryover was a factor 2-3 higher than anticipated which could be traced again to inadequate inlet separation: condensate slip through the contactor reduced the efficiency of the swirltube demister at the outlet.

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Introduction

Gas dehydration plants consist in essence of an inlet scrubber, a contactor and an outlet scrubber. Advanced separation and contacting swirltube technology provides all that is necessary to maximize the gas handling capacity of each of these process steps.

The first chapter of this paper discusses the upgrading of inlet scrubbers. The second chapter deals with the debottlenecking of the contactor itself and inherently the outlet demister.

1. Upgrading Of Inlet Scrubbers

In most modern gas plants the contactor is a packed bed filled with conventional structured packing. 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.

In this section it will be shown how the capacity of such plants could be restored by upgrading of the inlet separator. We will first explore the specifics of the various different demisters used in this service.

1.1. Characteristics of the Most Common Scrubber Alternatives.

The gas/liquid separators commonly used as inlet scrubbers are wire mesh demisters, vane packs and cyclone separators. The operating window of these devices for typical gas plant conditions is compared in Fig. 1.1, which shows the variation of the achievable efficiency as a function of the gas load. Filter coalescers form a separate category. This will be dealt with at the end of this section.

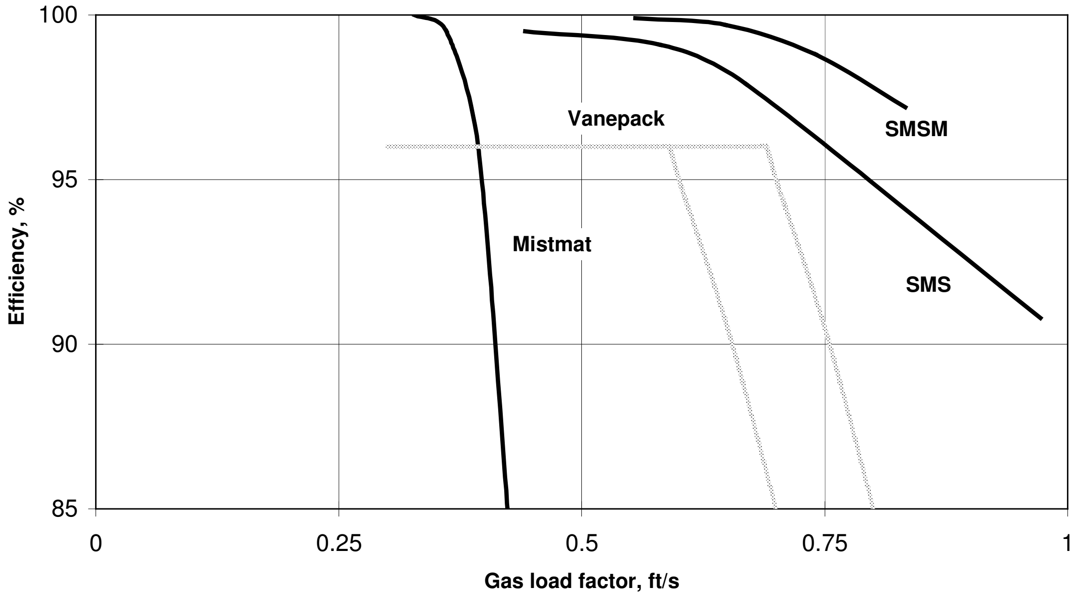

Figure 1.1. Operating window of various demisting devices.

The gas load is expressed in terms of the gas load factor λ, 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 demister, ρ_G is the gas density and ρ_L the liquid density. The factor under the square root accounts for the effect of pressure. Actually λ 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 separators.

The shape of the curves in Fig. 1.1 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 demister is restricted because in gas plants there is little room to compromise efficiency.

As can be seen from Fig. 1.1 wire mesh demisters give an almost complete liquid removal up to a gas load factor of 0.35 ft/s (0.105 m/s). With cyclonic separators such as SMS and SMSM swirltube separators the gas handling capacity can be more than doubled.

The capability of vanepack demisters lies in between, 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 Shell operating companies is that they are less efficient than wire mesh demisters and cyclone demisters, the typical efficiency is assumed to be ≤ 96%. Furthermore it has been observed that the efficiency starts to drop significantly at pressures above 900-1000 psi (65 bar), independent of the gas load. This is demonstrated in Fig. 1.2 which shows performance data of a number of Shell operated vane pack separators.

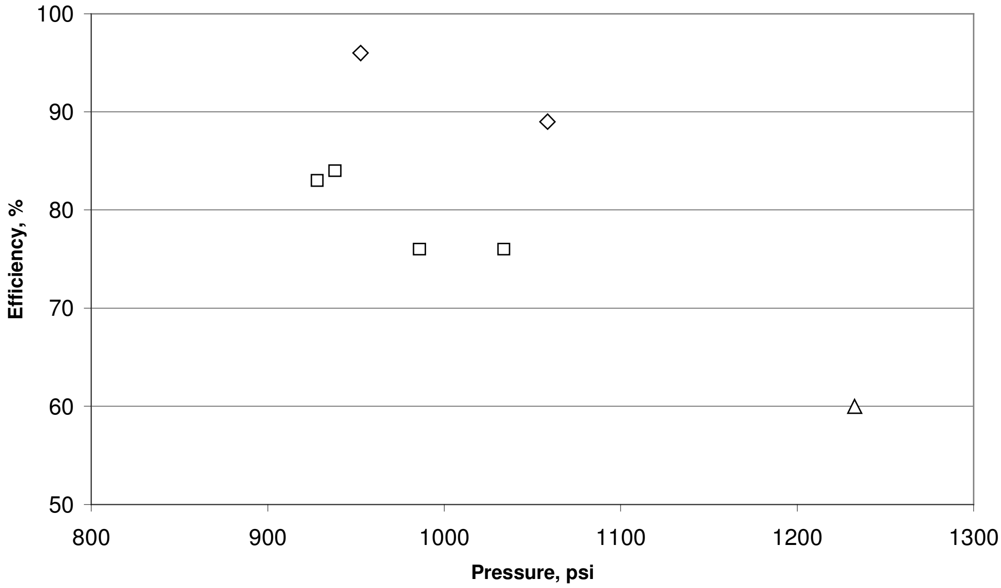

Figure 1.2. Performance data of several vanepack demisters operating at design gas loads.

In Fig. 1.1 Shell's SMS and SMSM swirltube separators have been taken as model for the capabilities of axial cyclone separators. The names are acronyms of the composing elements, i.e. a Schoepentoeter†, a vane-type inlet device, Mistmats and a Swirldeck. See Fig. 1.3. 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 or meshpad has a dual function. At higher gas loads it acts as a coalescer, it agglomerates the liquid droplets coming from below and facilitates their removal in the downstream swirltubes. This combination of a coalescing mistmat and cyclones is a proprietary feature [1]. At low gas loads the mistmat functions as a demister, thus providing a large turndown.

The swirldeck is an arrangement of swirltubes, axial flow cyclones which are illustrated in more detail in Fig. 1.3. The gas coming from below is forced into rotation by the swirler in the bottom of the tube. The demisted gas leaves the swirltubes via primary outlets at the top. The liquid accumulates on the tube wall and leaves with part of the 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. It turned out that a large proportion of the liquid carry-over, i.e. the part of the liquid that was not removed, was liquid entrained with the secondary gas. Therefore the efficiency could be improved substantially by adding a second mistmat to demist the secondary gas separately. This results in the 'SMSM' configuration. The overall separation efficiency of this combination of internals is 98-99% up to a vessel gas load factor of 0.70 ft/s (0.21 m/s).

The efficiency of comparable multicyclone separators operating without coalescing mistmat and without secondary demisting will be less than 95% at the same operating conditions.

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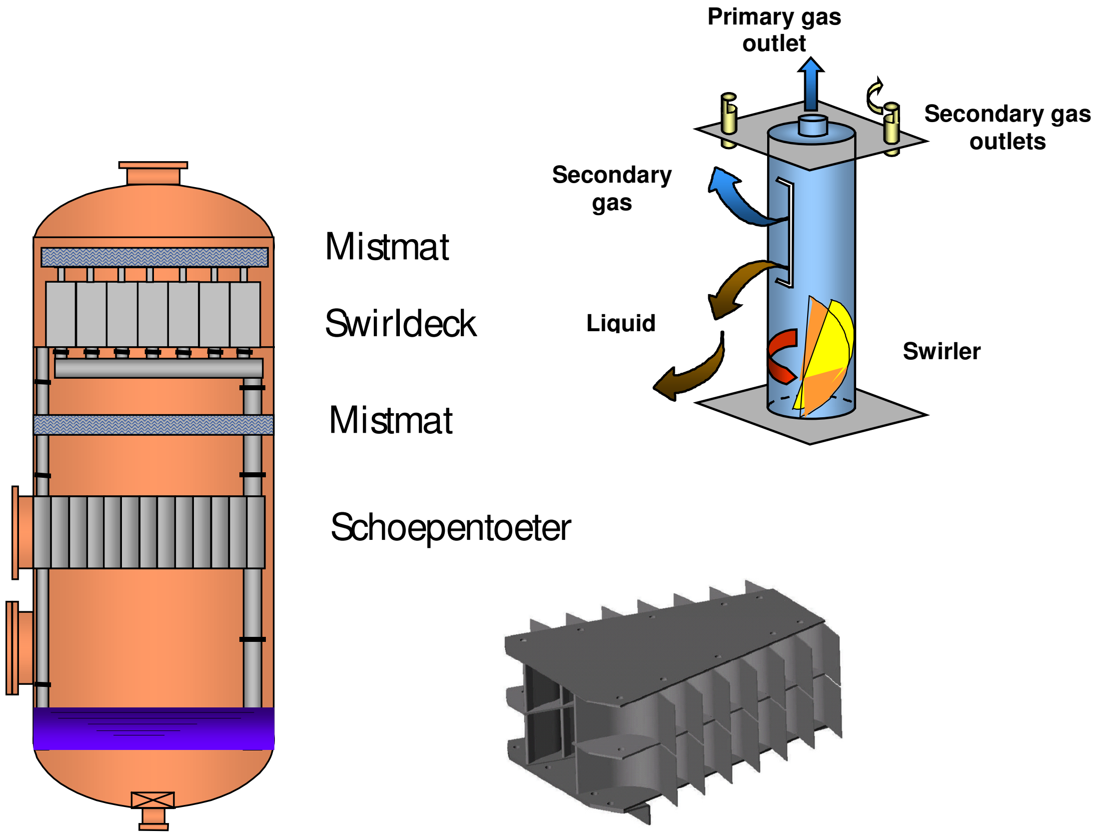

Figure 1.3. Diagram of an SMSM scrubber with details of a schoepentoeter inlet device and a separation swirltube.

Coalescing filter separators, also known as filter coalescers, form a separate category. They are used in many gas plants as second stage separator downstream of another scrubber. Their operating window is comparable to that of wiremesh demisters, cf. Fig. 1.1, with the difference that they can remove droplets which are an order of magnitude smaller. Unfortunately these separators are often undersized, in many cases they are not more than a wider section of the piping, to the extent that hardly any liquid is removed.

1.2 Inlet Scrubber Debottlenecking

Two case studies will be discussed showing how the capacity of gas plants could be increased by upgrading of the inlet scrubber. At Shearwater a vane pack demister was modified into an SMS swirltube separator. A second case study at the L9 platform shows how the efficiency of an SMS separator was further improved by the application of high performance coalescing mistmats.

Shearwater Experience: from 310 to 410 MMscfd with Proper Inlet Separation

Shearwater is a gas production platform located in the North Sea, 150 miles east of Aberdeen. It 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 $MMsm^3/d$), but the capacity appeared to be limited to about 75% of 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 extra vapour 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 vanepack demister, see Fig. 1.4. The separation efficiency of the vanepack appeared to be insufficient to protect the glycol regeneration system. 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 vanepack is minimal, which means that the gas is not adequately distributed across the cross section of the vessel. This reduces the separation efficiency even further.

The solution envisaged was to convert the inlet scrubber into an SMS separator by retrofitting a primary mistmat and a swirldeck, however the space cleared by the vane pack was insufficient. In the limited shutdown time available it was also not possible to relocate the chimney tray and the packed bed. Therefore it was decided to accelerate the release of the more compact High Performance Swirltubes which were in the final stage of development at that point in time. In this way the bottleneck was successfully removed and the design capacity achieved - even without secondary demisting. The modified inlet scrubber is also shown in Fig. 1.4.

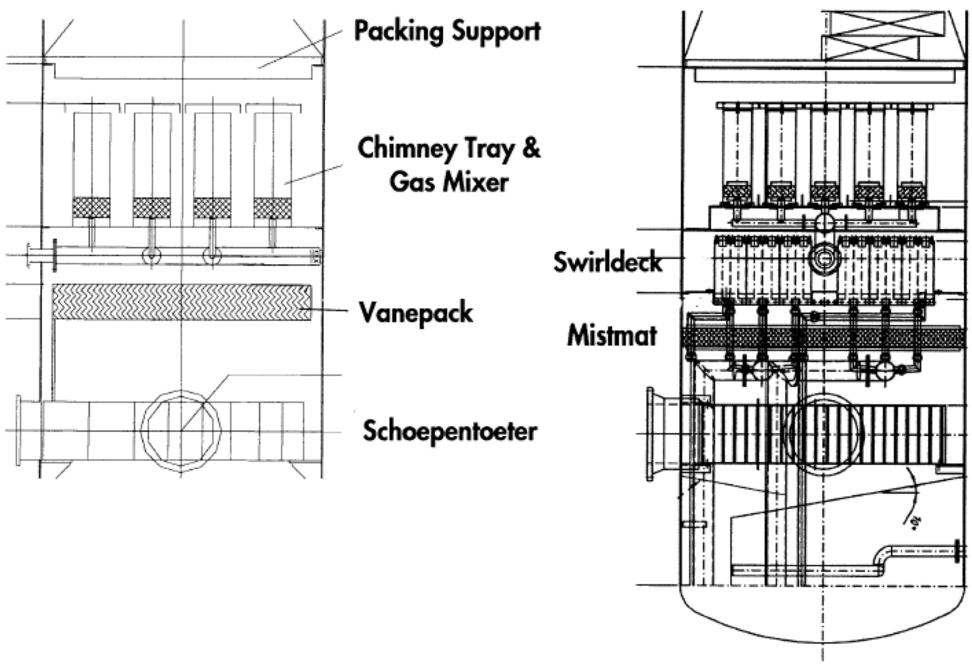

Figure 1.4. Shearwater inlet scrubber before (left) and after revamp (right).

L9 Experience: Improved Separation of Difficult Fluid Mixtures

L9 is a Shell operated platform in the Dutch sector of the North Sea. The gas dehydration plant of this platform was originally designed for 565 MMscfd (16 $MMsm^3/d$) at an operating pressure of 1160 psi (80 bar). There appeared to be scope for increasing the production to 635 MMscfd (18.0 $MMsm^3/d$), however, above 595 MMscfd (16.8 $MMsm^3/d$) the plant was bottlenecked by excessive foaming in the glycol flash drum and condensate/glycol separation problems in the slops system.

The inlet scrubber in this installation was a separate, external SMS separator upstream of the contactor. Although this was still operating in its design window its efficiency was established to be 93-96% rather than the expected 98%. Two things were unusual around this separator. In the first place the liquid entering the vessel consisted of about equal quantities of water and hydrocarbon condensate, and it was suspected that the relatively high proportion of water compromised the agglomeration efficiency of the primary mistmat. Furthermore the drain pipes returning liquid accumulating on the support plate of the swirldeck and the drain pipes from the swirldeck itself appeared to be connected to the same header. Because these drains operate at different pressure levels this can very well lead to gas bypassing and liquid reentrainment.

To improve the efficiency of this scrubber the functionality of the primary mistmat was split up over two different mats with a different structure and composition: the lower one was optimised for the separation and draining of water, the upper one for the coalescence of hydrocarbons. Furthermore a secondary mistmat was added and the drain header was modified to separate the two drain systems. With this SMMSM configuration L9 could be successfully ramped up to 630 MMscfd, the maximum gas production of the reservoir.

A similar upgrade has recently been carried out at the Sean platform in the UK sector.

2. CONTACTOR DEBOTTLENECKING

In cases where the contactor itself is the limiting factor, the throughput can be increased by 20-30% by retrofitting high capacity structured packing. If there is scope for even further debottlenecking installation of Swirltube Trays can be considered. The operating window of the various contactor options is compared in the Souders diagram of Fig. 2.1. The flow parameter is a measure for the liquid to gas ratio and is defined as

$$\varphi = \frac{M_L}{M_G}\sqrt{\frac{\rho_G}{\rho_L}}$$

with M_L and M_G the liquid and gas mass flow rates. Glycol contactors will typically operate at the low flow parameter side of the diagram.

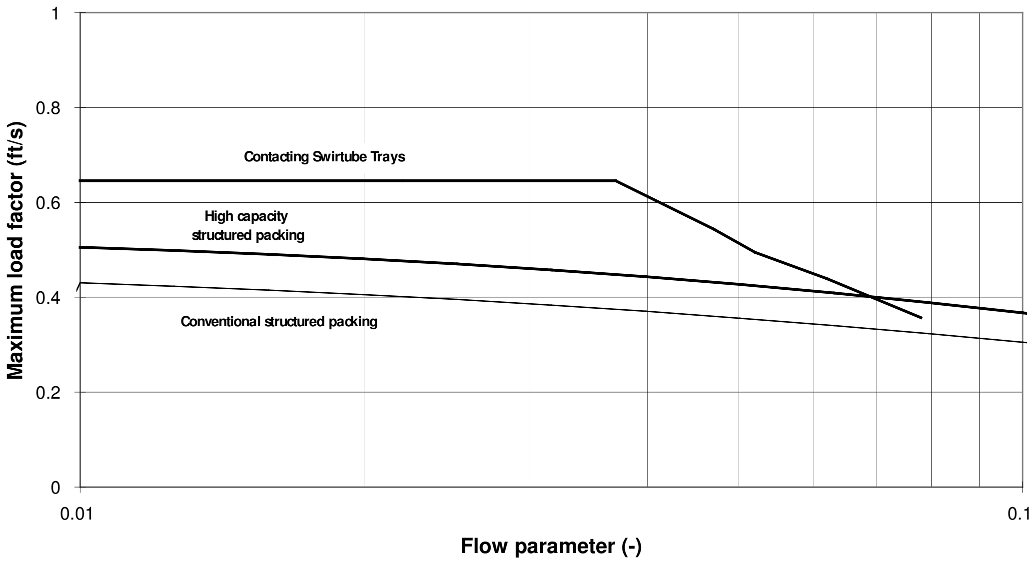

Figure 2.1. Comparison of the operating window of glycol contactors

Conventional structured packing has a high de-entrainment capacity of itself. Therefore the outlet scubber is usually a wire mesh demister. However, comparing the maximum load of a wire mesh and that of conventional structured packing it can be seen that the wire mesh is actually constraining the gas handling capacity of the contactor, cf. Figures 1.1 and 2.1. This means that there is a niche for a demisting device which has a higher capacity than a wiremesh, which is more suitable for high operating pressures than a vanepack, but without the complexity of a full flash swirltube demister. For such applications Shell Global Solutions is developing the Swirltube Light, a simpler cyclonic demisting device, this will be discussed further in section 2.1.

High capacity structured packing is operated at higher gas loads and is more prone to glycol carry over, and therefore the outlet scrubber becomes more critical. Good results were obtained in the field with an SM swirltube demister, as will be dealt with in section 2.2.

In swirltube contactors glycol is dispersed in the inlet of gas liquid cyclones. The separation efficiency of these Contacting Swirltubes had to be compromised due to their dual functionality. Therefore, to achieve the extremely high glycol recovery rate required, a high performance outlet scrubber is essential. The experience from the first applications in the field will be shared in section 2.3.

2.1. Swirltube Light

In TEG Contactors with standard structured packing often wire mesh demisters are used as top demister. However, because the hydraulic capacity of wire mesh is less than that of structured packing the demister becomes limiting for the throughput of the contactor. For these applications the 'Swirltube Light' is being developed, a new separator concept, derived from the much simpler and cheaper ConSep† swirltubes. The latter form a key element in Shell's high capacity tray technology. ConSep

(Contacting/Separation) Trays achieve high vapour handling capacities by the application of dedicated gas/liquid cyclones to separate and return entrained liquid [2]. As can be seen from Fig.2.2. it is a simple device without the extensive box construction of separation swirltubes.

The first series of tests using the latest ConSep design with and without an upstream mistmat were not successful. Efficiency and turndown were insufficient and the flow through the mistmat suffered from instabilities. Numerous attempts to remedy this by modifying the dimensions and the configuration of the swirltube failed. The final breakthrough was achieved by making a provision for intermediate draining of the liquid. In this way a stable film could be maintained. Fig. 2.3 shows the results of atmospheric tests with air/water, which demonstrate that a sufficiently efficient separation can be obtained over the operating range similar to that of a vanepack. (The optimum range can be adapted by varying the number of swirltubes.) Follow-up tests with hydrocarbons at elevated pressure are currently in progress.

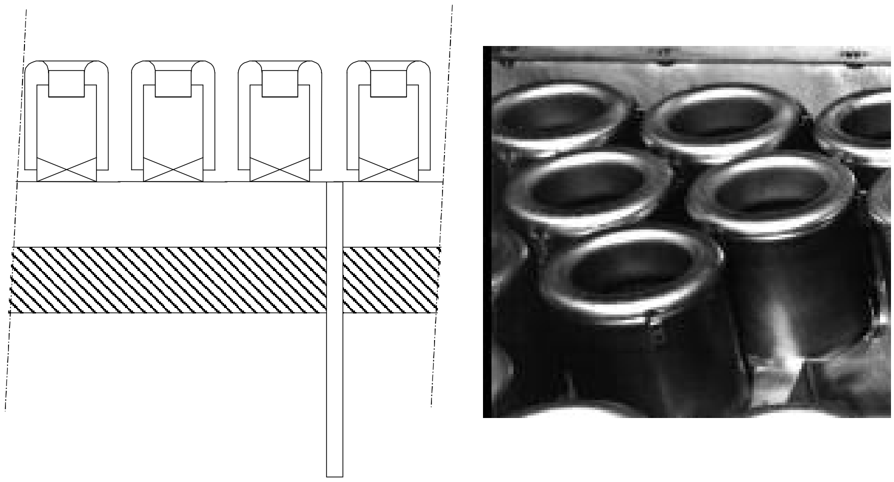

Figure 2.2. Swirltube Light separator concept

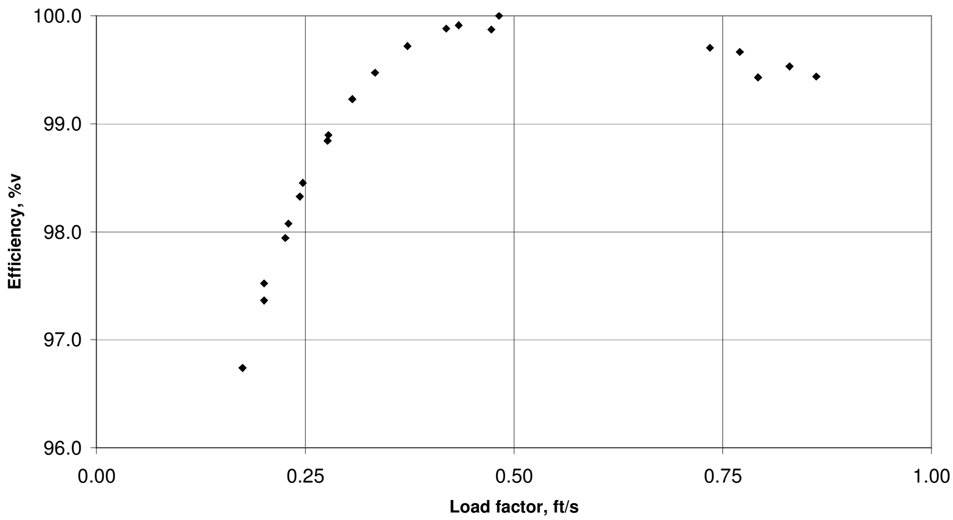

Figure 2.3. Swirltube Light atmospheric tests: variation of efficiency with gas load.

2.2. High Capacity Structured Packing

During installation in a contactor the subsequent layers of packing are usually rotated 90 degrees relative to the previous layer. With conventional structured packing this results in a change of direction of the corrugations at the transition from one layer to another, which leads to accumulation of liquid at the interface and extra hydraulic resistance. Sulzer has developed MellapakPlus‡, a new type of structured packing in which the corrugations have an S-shaped profile ending perpendicular to the top and bottom surface. This prevents liquid maldistribution, reduces the pressure drop and increases the packing capacity by 20-30% [2].

One of the first implementations of high capacity structured packing in Shell operated companies was in two parallel glycol contactors at the M1 platform offshore Serawak. The original capacity of this installation was 2x360 MMscfd. In 2002 this was extended to (nominally) 2x500 MMscfd (14.2 $MMsm^3/d$).

The contactors are 6' 9" (2.06 m) diameter vessels with an internal SMS inlet scrubber, a contacting section consisting of 13 ft (3.9 m) Sulzer Mellapak‡ 250Y structured packing and a wire mesh outlet demister. To accommodate the increased gas flow: (1) the number of swirltubes in the inlet scrubber was increased from 68 to 88, (2) the packing was replaced by MellapakPlus 252Y packing, and (3) a new outlet scrubber was installed consisting of a swirldeck with 68 swirltubes and a Knitmesh 9797 mistmat (optimised for glycol dehydration service) as secondary demister. This upgrade was successfully commissioned in 2003.

In the meantime an additional 240 MMscfd (6.8 $MMsm^3/d$) contingency capacity had become required, and in October 2003 performance tests were conducted to establish whether the M1 gas dehydration and glycol regeneration system would be able to handle this. The flow rate per vessel was ramped up in steps of 30-35 MMscfd to 600-620 MMscfd (17.6 $MMsm^3/d$). The two trains were tested separately and it was observed that the results were very similar for both..

A first problem encountered was that at flow rates of more than 500 MMscfd the *bottom inlet scrubbers* stopped functioning. All condensate was entrained and left the contactor with the spent glycol, with the usual problems of overloading the glycol regenerator system and increased glycol losses. This could be attributed to the limited height of the drain pipes which have to provide the hydraulic head to drain the separated glycol against the pressure drop across the scrubber internals. This problem could be resolved by modifying the level control system which allowed operation with a liquid level at the very minimum around the bottom tangent line of the vessel. This prevented backflow of condensate up to flow rates of as high as 620 MMscfd.

The *contacting section* could handle the extra flow without any problem. Fig. 2.4 shows the variation of the water dewpoint with gas flowrate for one of the trains. It can be seen that the water content increases slightly with flowrate but remains well below the specified maximum of 80 ppmv. Similarly the pressure gradient remained well below the maximum 1.2 inch H_2O/ft (10 mbar/m). At the maximum rates the gas load factor amounts to 0.52 ft/s (0.156 m/s).

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‡ Sulzer Chemtech Trademark

The best criterion for the performance of the *outlet scrubber* is the glycol loss. This was established from the level variation of the glycol surge drum to be about 0.2 gallon per Million scf (25 l/ $MMsm^3$/d), which can be characterised as modest. The glycol loss was independent of the gas flow rate.

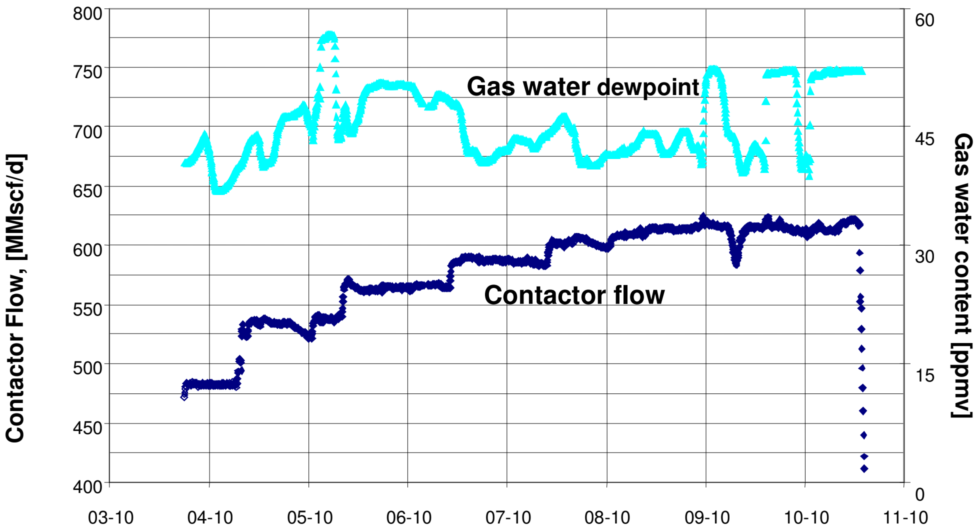

Figure 2.4. Glycol contactor with high capacity structured packing: variation of dew point with gas flow rate.

2.3. Swirltube Contactors

An even further debottlenecking, up to 60-70% above the capacity of conventional packing, can be obtained by retrofitting the contactor with Swirltube Trays. Here the contacting is performed by dispersing glycol in the inlet of gas liquid cyclones.

The operation of swirltube trays is illustrated in Fig. 2.5. The swirltubes are mounted on a double tray floor. The space inside the tray floor is used to feed glycol from the inlets towards an atomiser, placed in the inlet of the tubes. The glycol is dispersed in the gas which flows upwards through the tubes, and is immediately separated again in the centrifugal field created by the downstream swirler. The treated gas leaves at the top, the glycol flows back to the tray via the wall of the tube and a catcher cap. The tray floor is not perforated, it just creates holdup volume for the glycol. From there the glycol is partly recirculated to the inlet via recirculation ports and the rest flows down to the next tray via a number of downcomers.

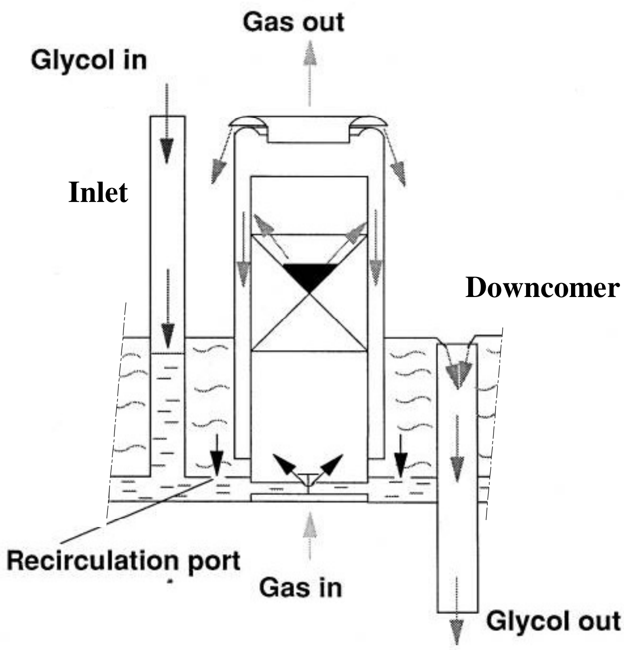

Figure 2.5. Contacting Swirltubes

The overall mass transfer capacity per tray is > 0.5 NTU. This means that, with a tray spacing of 20 inch (500 mm), the overall mass transfer capability of a swirltube contactor is equal to that of a packed bed contactor with the same height.

The separation efficiency of the contacting swirltube is limited, and to be able to achieve the very high glycol recovery rate required a high performance outlet scrubber is essential. Until now a swirldeck with a secondary demister has been applied. In future applications it will be attempted to install a primary mistmat as well.

Table 2.1. Swirltube contactors in glycol dehydration service

	GOM 1	Netherlands	Norway	GOM 2
Vessel ID	5’	9’	4’ 4”	5’ 5”
Pressure, psia	1470	960	435	1870
Capacity, MMscfd	175	247	106	280
Number of swirltubes/tray	26	48	21	36
Number of trays	7	5	7	8

Over the past ten years four contactors have been retrofitted with contacting swirltubes. An overview is given in Table 2.1. All these applications showed excellent gas drying performance, however with exception of the contactor in the Netherlands the glycol carryover was a factor 2-3 higher than anticipated. This could be traced again to inadequate inlet separation: condensate slip through the contactor reduced the efficiency of the swirltube demister at the outlet. In all these cases the debottlenecking of the inlet scrubbers was not in the scope of Shell Global Solutions.

The performance of one of the gas plants in the Gulf of Mexico (GOM 2 in the table) was exemplary. The capacity of the relevant contactor was increased from 215 MMscfd to 280 MMscfd (6.1 to 7.9 MMsm^3/d) by replacing the structured packing by swirl tube trays; a separation swirl tube deck with secondary mistmat was installed as outlet scrubber. During the same shutdown, the upstream inlet scrubber was retrofitted with third party internals to accommodate the higher gas throughput.

The contactor showed an excellent drying performance since start up with reported dew points of 1-2 lb/MMscf versus 5 lb/MMscf (80 mg/Sm^3) as per design. However, on the basis of the glycol depletion rates it could already be established that the glycol losses, though varying strongly from day to day, were much higher than designed for.

In a dedicated test campaign the carry-over of liquid with the export gas was established by isokinetic sampling. The glycol concentration appeared to be about 1 gallon/MMscf. However, the condensate concentration was more than 6 gallon/MMscf, i.e. a multiple of the glycol concentration. This is the main reason for the high glycol losses: the quantity of condensate passing through the outlet scrubber is a multiple of the quantity of glycol, whereas the swirldeck was designed for glycol separation, which requires less swirltubes.

The inlet scrubber was rather small, however, it would have been possible to achieve a better performance with a Shell proprietary separation swirldeck with secondary demisting. This has a higher liquid handling capacity and a higher separation efficiency at high liquid loads than the third-party cyclone deck actually installed.

In future prospects application of Swirltube Trays will only be considered downstream of properly designed SMSM separators.

References

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

Note

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