Retrofitting a glycol contactor to prevent carryover

A revamp of glycol contactor column internals, following CFD studies, resolved problems with gas production caused by glycol carryover

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The gas production rate on an offshore platform was constrained due to a high level of glycol carryover from glycol contactors. The existing column internals were investigated and it was found that the area of the mesh pad in the top of the column was around half of the column area. In addition, the gas outlet location and associated piping arrangement appeared to create vapour maldistribution. A high-capacity Shell Swirltube separator and Sulzer structured packing internals were proposed in conjunction with a new gas outlet arrangement and the existing separator support system. CFD studies were carried out to evaluate the possible vapour distribution, based on which a revamp proposal was fine-tuned. New internals were manufactured and installed on site in 2012. Recently, the design was validated in high-rate trial runs, with significantly lower triethylene glycol (TEG) carryover.

All together, there are three trains on the platform. The facility dehydrates the gas and condensate separately, and then recombines the dried products before transportation via trunkline(s) to the gas plant. Subsequently, the gas plant processes these fluids to produce LNG, condensate and LPGs.

In 2006, a customer in the Asia Pacific region decided to proceed with the design of a new bridge-linked facility to its plant. The compression installed on the new plant would allow 20 000 t/d of gas throughput per train. Specification of the glycol content of the export gas plant must be less than 4 m^3/d to prevent onshore upsets.

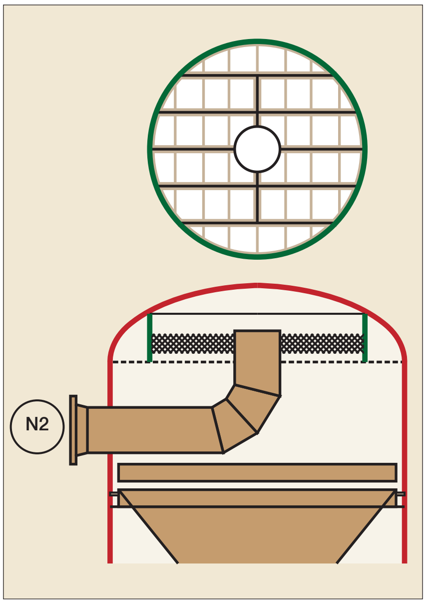


Figure 1 Sketch of the existing mesh pad and the gas outlet arrangement

During a trial in 2007, dehydration capacity as well as TEG losses were evaluated at various flow rates. The gas rate was increased to around 18 000 t/d per train, at which point it was found that the glycol losses reached the maximum limit of 4m^3/d (total of three trains). Dew points were found to increase and were worse at the higher rates. Condensate dehydration was established to be adequate. Overall, dehydration performance was found to be acceptable for the first and second trunklines, where the saturation specification had basically not been affected and remained at around 25% and 19%, respectively, which was less than the integrity limit of 75% and the operating limit of 65%. Therefore, it was concluded that the dehydration of both gas and condensate was sufficient at 18 000 t/d. This gas throughput became constrained by glycol carryover losses. It was decided by the customer to revamp the third train in early 2012 and leave the other trains to a later date. This would allow confidence and experience to be gained with minimum exposure (a single train rather than all three trains). Sulzer was selected to revamp the internals of the contactor to minimise the TEG losses at higher gas rates in the customer's complex.

In the late 1980s, to increase throughput, the original bubble cap trays in the glycol contactor were upgraded to structured packing (GEMPAK 3A, which is comparable to Sulzer Mellapak 350Y). In the column top, a mesh pad was installed to prevent glycol losses. It covered about half of the column area (see Figure 1). A lean glycol distributor was installed above the structured packing, and in the bottom there was a chimney tray to collect the rich TEG before being directed to the glycol regeneration system (see Figure 2). This was the column internal configuration to be revamped. To avoid having to stress release the column after revamp, welding to the column wall was not permitted. The existing separator support system had to be reused for the various revamp options.

Gas-liquid separator in the column's top section

The location and arrangement of the gas outlet was relatively unique, as the gas outlet nozzle is located laterally below the mesh pad. An elbow-shaped internal pipe passes

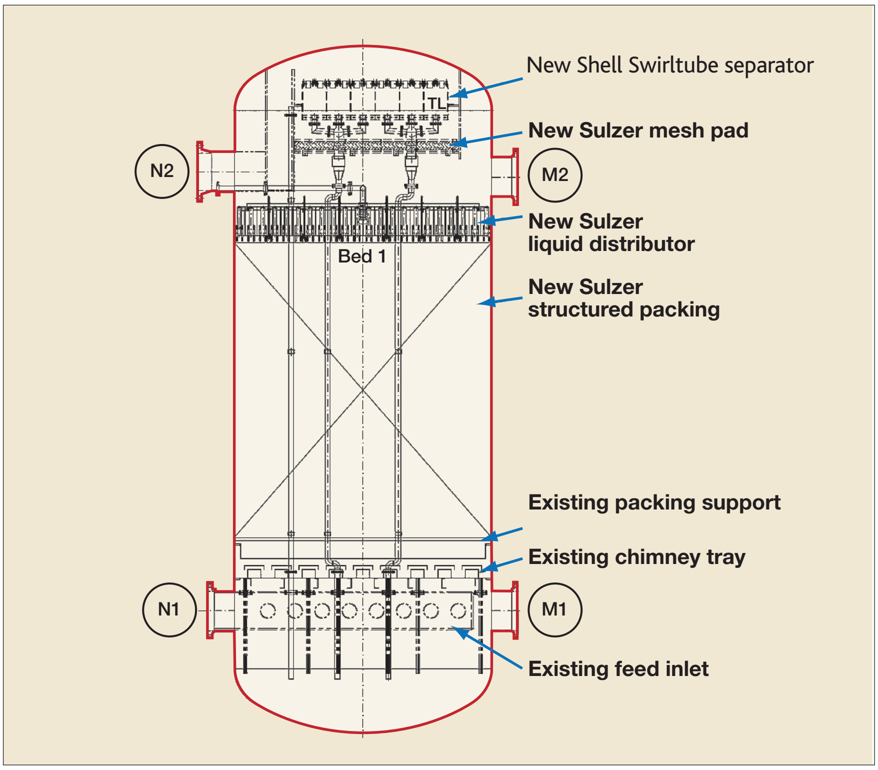


Figure 2 Proposed Sulzer KnitMesh coalescer and Shell Swirltube separator

through the centre of the mesh pad. This pad was supported by a shroud welded to the column head. Usually, the gas- loading capacity of structured packing in TEG contactors is higher than that of a wire mesh pad. Obviously, the excessive glycol entrainment observed during the trial in 2007 could immediately be attributed to the small mesh pad area, which was only half of the packing cross-sectional area. The arrangement of the existing mesh pad was perfectly symmetrical, but the space between the column head and mesh pad was very narrow, causing a poor inflow to the gas outlet piping above the mesh pad and an uneven vapour distribution through the mesh pad. This maldistribution also contributed to the observed excessive entrainment of TEG.

Any revamp proposal was limited by two key factors:

- The gas outlet could not be relocated
- Hot work to the column wall was prohibited.

Therefore, the existing shroud had to be reused, and it was necessary to install high-capacity demisting equipment to compensate for the limited area available for a separator.

There are several types of gas-liquid separators on the market, and they can usually be classified into three categories: mesh pad, vane pack and axial cyclone types. The selection of different types depends on required capacity, pressure drop and efficiency (indicated by cut-off size). Table 1 shows a simple summary of the selection criteria. It has to be noted that values in the table are indicative only. They are subject to individual separator products and operation systems.

With increasing operating pressures, vane packs, even if they are equipped with a coalescer in the front, suffer higher efficiency loss than axial cyclones. The operating pressure of this TEG contactor is 108 bar. Axial cyclones are the best option for having up to three times higher capacity than mesh pads per unit area. They can compensate for the limitation caused by the smaller area available for separation. A Shell Swirltube separator was used in the investigation of various options.

Direct welding to the column wall was forbidden, so it was proposed that the existing shroud be extended downwards by welding additional parts onto it. To

Performance of various types of gas-liquid separators

	Mesh pad	Vane pack	Centrifugal device
Capacity (per unit area)	1	1-3	3
Pressure drop	Base	Low	High
Cut-off size (glycol)	Down to 3-5 µm	Down to 20-30 µm	Down to 10 µm
Operating pressure limit	-	Up to 50 bar in particular if hydrocarbon liquids are present	-

Table 1

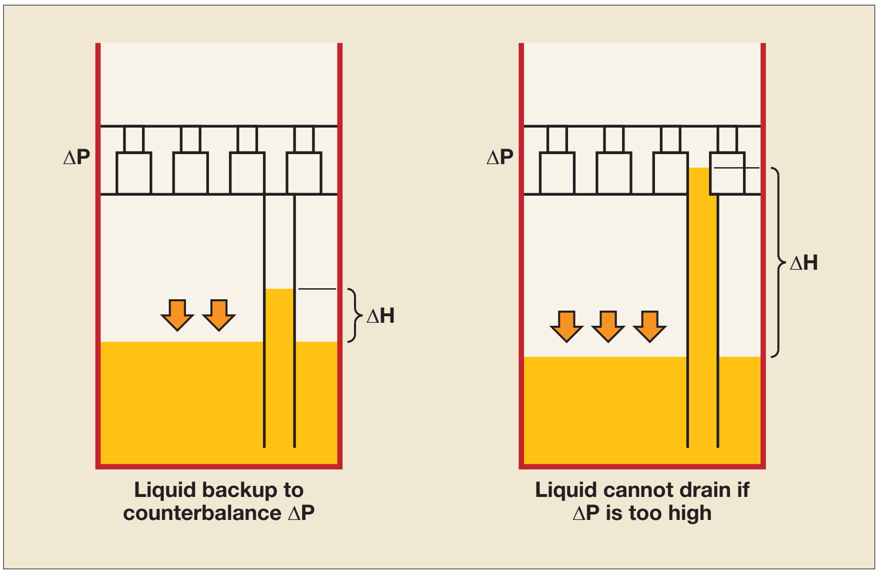


Figure 3 Principle of liquid backup in a drain pipe

maximise the number of Swirltubes and to take into account the dimensions of the standardised cyclone modules, the outlet piping had to be shifted from the centre to the side of the shroud. Internal piping for the dry gas outlet nozzle needed to be cut and welded onto the extended shroud. A schematic of the proposed new arrangement is shown in Figure 2. This arrangement posed some uncertainty with regard to vapour distribution across the new Swirltube deck due to sudden changes in the vapour flow direction of 90 degrees after passing through the Swirltube separator and the asymmetry of the new arrangement in general. The typical pressure drop of a Swirltube separator is much higher than for a mesh pad (30 mbar versus 0.5 bar). This helps to improve vapour distribution but, because the concern for maldistribution could not be eliminated, CFD studies were conducted to understand and quantify the risk.

There is another aspect to consider in the design of the axial cyclones. The liquid drops separated by the Swirltubes are collected in liquid collection chambers, from where the liquid is drawn off through a pipe system. The downpipe is subject to liquid backup caused by the pressure drop through the Swirltube deck. If the drainpipe's vertical height is not sufficient to accommodate the liquid backup, the liquid may flow back onto the deck and cause failure of the separator.

The customer's previous experience showed that there was significant condensate carryover from the upstream production separator to the glycol contactor. It was therefore expected that condensate could be entrained together with TEG into the packing section and further upwards to the demisting device itself. Due to the huge difference in density between TEG and condensate, and the limited height between the separator and TEG distributor, the downpipes for the separator should extend to the rich glycol sump to cope with the condensate backup. Equation 1 describes how the liquid

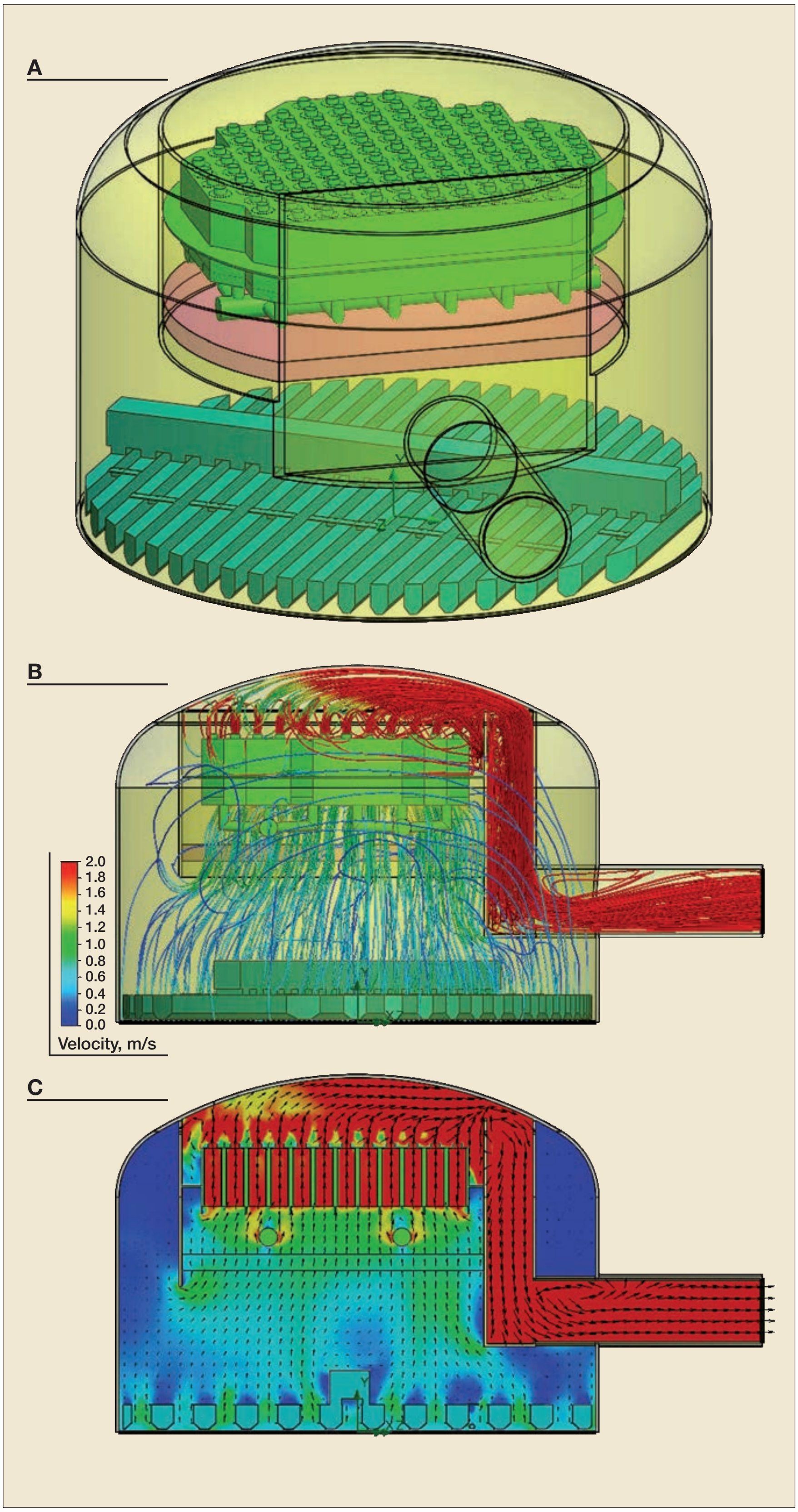
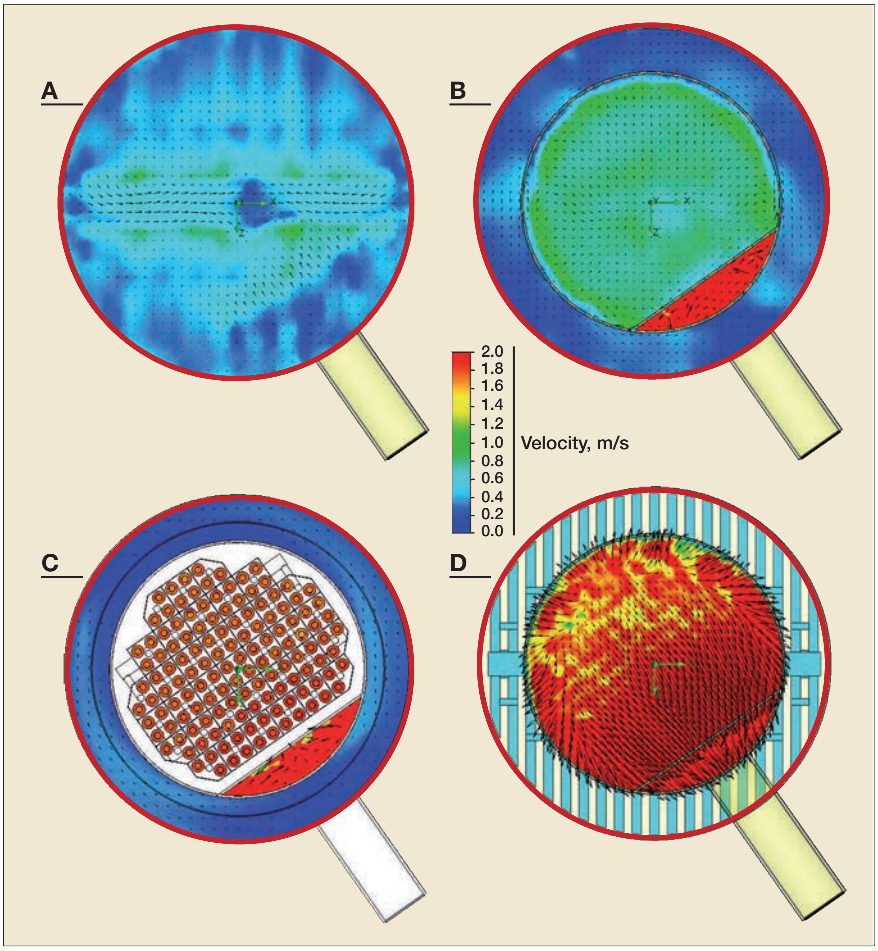


Figure 4a CFD model configuration showing the high-capacity separator (green), the mistmat (pink), the liquid distributor (cyan) and the gas exit nozzle (side draw) arrangement

Figure 4b CFD vapour flow trajectories represented by the velocity magnitude, where blue represents the low velocity and red represents the velocity peak of the scale

Figure 4c CFD vapour flow vector plot represented by the velocity magnitude, where blue represents the low velocity and red represents the velocity peak of the scale



Figures 5a-d CFD vapour flow velocity vector plots: a) above the liquid distributor; b) below the mistmat; c) across the high-capacity separator ;and d) at the downcomer entry after the separator

backup is calculated, where H is the backup height of fluid in the drainpipe, ρ is the density of the fluid, and g is the gravitational acceleration constant. Figure 3 demonstrates the principles of this consideration:

$$H_{fluid} = \frac{\Delta P}{\rho_{fluid} \times g} \qquad (1)$$

A typical arrangement of the Swirltube separator consists of a Sulzer KnitMesh mistmat placed in front of and at the back of the Swirltube deck. They both serve different purposes. The one below the deck is the coalescer mistmat and serves to coalesce the small droplets coming from below. To help collection and drainage of the collected droplets by the swirltubes, some purge gas guides the liquids into the liquid collection chambers. A small amount of liquid droplets might be carried with this purge gas. The secondary KnitMesh mistmat above the deck serves to catch these droplets. Unfortunately, the available space above the separator would not be sufficient to fit a secondary KnitMesh for the glycol contactors, as this involves extending the primary gas outlet, and the resultant space between the outlet and the vessel head would become too small. The final proposal consisted of a coalescer mistmat plus a deck. It is worth noting that the overall glycol entrainment could be decreased further if using a secondary KnitMesh in this case.

A new distributor was proposed to eliminate a concern of entrainment caused by the distributor itself. The revamp also included the installation of a better support grid suitable for the expected higher loads.

CFD verifications

CFD tools can provide more detailed insights using the actual tower configuration and process loading conditions.[1] The cramped top conditions of the TEG contactor and asymmetric configuration of the proposed arrangement caused concerns over possible maldistribution of the vapour and uneven loading of the individual swirltubes of the deck. CFD studies were carried out for four operating load cases. These cases represented minimum and maximum loadings corresponding to pre- and post-revamping conditions to verify the risk by looking into the velocity profiles across internals and column cross-section at various elevations of the tower.

The CFD model configuration is illustrated in Figure 4a. The vapour flow through the column is simulated numerically using a general-purpose commercial fluid dynamics code.

To model the turbulence behaviour of the flow, the standard k-ε model is used. The pressure drop over the mistmat is described by means of the resistance law:

$$\Delta p = k\, H\, \rho\, v^2/2, \qquad (2)$$

Where k is dependent on the operating condition and the type of mistmat.

Porous media has replaced the mesh pad in the CFD model configuration. The liquid distributor and high-capacity separator are modelled as accurately as possible to represent the actual pressure drop through these devices. Separator drain downpipes and the liquid distributor feed pipe are not included in this study, as they are not needed to simulate the vapour flow inside the vessel. The projected horizontal cross-sectional area perpendicular to the vapour flow direction of the liquid distributor feed pipe (T-shaped pipe) and separator downpipes with respect to the column cross-sectional area is less than 2%.

CFD analysis results of the load case corresponding to 20 000 t/d are used to validate the models against the available plant test data for this load case. Figures 4b and 4c demonstrate the CFD vapour flow trajectories and vector plots represented by velocity magnitude, where blue represents the low velocity and red represents the velocity peak of the scale. It can be clearly observed from the vector plot that there are small eddies, turbulent flows, observed in the exit nozzle duct and the top of the downcomer due to the sudden change in the vapour flow direction by 90 degrees and the cramped top conditions. They do not have a serious impact on the separation efficiency of the column, as they are not propagated towards the high-capacity separator. The vapour distribution across the tower cross section at various elevations has also been investigated.

Figures 5a-d show the CFD vapour flow velocity vector plots above the liquid distributor, below the mistmat, across the high-capacity separator and at the downcomer entry after the separator. As vapour distribution across the high-capacity separator has a more significant impact on the gas-liquid separation efficiency of the tower, statistical analysis was used to determine the vapour distribution quality. This quality is calculated by comparing the vertical velocity values at points on a regular grid cut plane across the high-capacity separator.

Figure 6 shows the CFD vapour flow vertical velocity plot across the high-capacity separator used for analysis.

Based on this investigation, the following conclusions may be drawn on the model configuration:

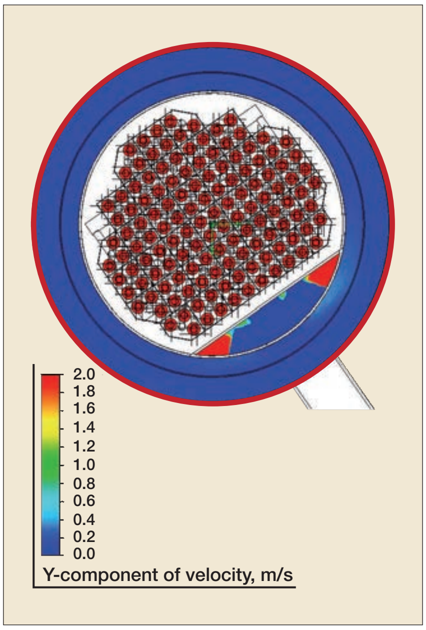


Figure 6 CFD vapour flow vertical velocity plot across the high-capacity separator

- Pressure drop values across the mistmat and the high-capacity separator are within the design specification
- The cramped top conditions of the TEG contactor do not detrimentally affect high-capacity separator performance
- The vapour vertical velocity variation across the high-capacity separator was found to be very low. Based on Sulzer's experience with comparable high-capacity separators, the measured values show a very good vapour distribution quality. Due to the even vapour distribution across the device, the required liquid separation can be achieved.

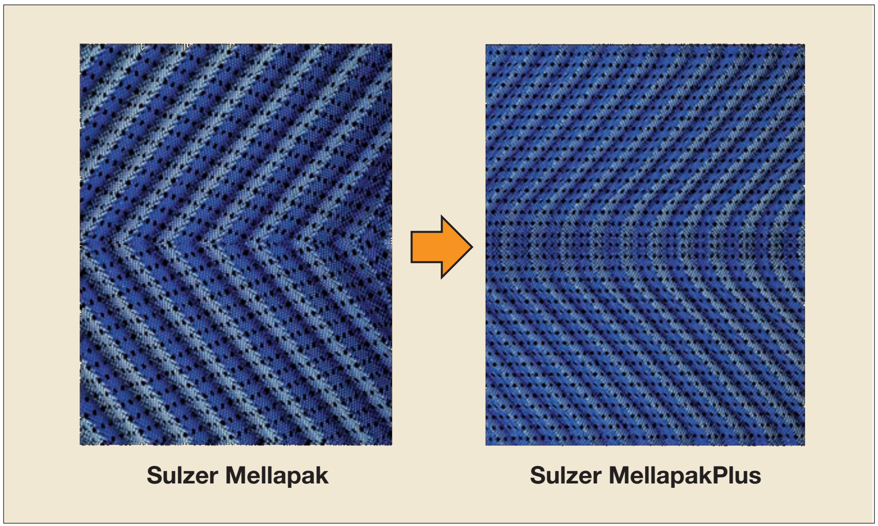


Figure 7 Progressive change of the corrugation angle at the both ends of the element

Change of packing

The capacity possible through a contactor is determined by the maximum gas load factor. If this gas load factor is exceeded, significant entrainment will occur before the column becomes inoperable. Sulzer MellapakPlus 452Y was chosen as a replacement for the existing packing. This packing allowed a much higher capacity than the originally installed packing, up to a throughput of 25 000 t/d. The higher capacity of this packing is attributed to the use of smooth bends within the packing rather than 90-degree directional changes at the packing layer interface (see Figure 7). By avoiding directional changes of 90 degrees by vapour, the liquid hold-up and subsequent vapour pressure drop over the packing are reduced, thereby allowing higher vapour throughput for the same pressure drop. This effectively increases the maximum gas rate. By replacing the packing and operating well within its maximum capacity limit, the liquid entrained to the top of the column should be minimised, reducing the liquid load on the Shell Swirltube separator. The combination of the new packing and Swirltubes was seen as essential to minimise glycol losses.

Since the packing bed height was constrained by the existing column dimensions, checks were performed to confirm that the packing height would be sufficient for the given dehydration duty. These checks confirmed that the packing height required was just within the height available. Further improvements in dehydration performance are possible by focusing on the regeneration system, primarily TEG purity and, to a lesser extent, circulation rate. This is not the subject of this article. It may be noted that the dehydration performance of Sulzer MellapakPlus 452Y packing is intrinsically better than the one of the existing Gempak 3A for the same TEG purity and vapour load.

Bottom arrangement

At the bottom section, there is an inlet sparger, immediately above which a chimney tray is installed.

There is no possibility of revamping the bottom arrangement due to narrow space and the hot work required. Evaluation of these internals was necessary, as they could be the bottleneck at an increased feed rate of 20 000 t/d.

The general description of this type of chimney tray or vapour distributor can be found in the literature.[2] However, it is rarely seen in industry nowadays due to the high pressure drop caused.

The chimney tray collects rich TEG and then discharges it to the vessel sump via downpipes (see Figure 2). Vapour released from the gas inlet sparger rises up to the packing bed, around 500 mm above the inlet, via risers that are small in diameter and low in height. The chimney tray basically serves as a vapour distributor. The total open area of the risers is very low, only 8% of the column area.

The momentum calculated for the gas inlet nozzle is 21 600 $Pa^{0.5}$ at 20 000 t/d, which is very high. The back pressure of the inlet could be higher than the pressure drop in the entire packed section, and the suction effect immediately above the inlet could lead to severe non-uniform pressure and velocity profiles, and eventually reverse the flow in the packing beds.[3] The chimney tray can bring in additional pressure drop to the bottom section of the vessel, smooth the pressure profile inside the column, and hence eliminate problems linked to the high inlet momentum.

It was found that if all rich TEG drains down via downpipes, assuming a 4.6 l/s rich glycol lean TEG flow rate, the liquid velocity is about 0.18 m/s. For a normal chordal downcomer of a tray, the downcomer area should not have a liquid velocity higher than 0.13 m/s, based on vapour and liquid physical properties in a TEG contactor, to avoid downcomer flooding. In our case, this maximum velocity must be derated, as degassing in the tiny downpipes becomes much more difficult.[4] It is worth noting that the above guideline is applicable to a normal tray, where liquid is aerated by rising vapour. On the other hand, for a normal chimney with partial draw-off, the downcomer can be sized with a velocity larger than 0.5 m/s. Whether the existing downpipes have the capacity to handle rich TEG depends on the severity of aeration. The liquid height built up on this chimney is estimated at 15 mm, lower than the 70 mm riser height, which means no interaction between rising vapour and descending liquid is expected on this tray. The liquid-handling capacity of the downpipes should be sufficient.

Results of trial runs

The maximum gas throughput achieved was 20 500 t/d through the modified glycol contactor (T300). The key observations from the test run were:

- Glycol carryover with Train 3 was acceptable, approximately 0.4 m^3/day on average, which is well below the 1.3 m^3/day per train limit
- Gas dewpoint was -2.6°C, limited by TEG regeneration capacity, not linked to the packing
- Overall trunkline saturation, gas and condensate, was at 28%, well below the integrity limit of 75% and the operating limit of 65%.

The maximum gas throughput achieved was 20 500 t/d through the modified glycol contactor

This was achieved with the following key glycol regeneration system parameters:

- Lean glycol purity = 99% w/w
- Lean glycol circulation rate = 4.4 l/s
- Glycol reboiler bottom temperature = 190°C.

In addition, the success of the test runs proves that the chimney tray and liquid-handling capacity of the downpipes are sufficient, which provides a good reference for industry.

Conclusions

A TEG contactor's capacity was constrained by a conventional mesh pad in the top of the column. A high-capacity Swirltube separator was designed to adapt to the existing supporting system rather than risk welding to the vessel wall. In addition, the packing was replaced with Sulzer MellapakPlus M452Y and a new lean glycol distributor was installed. A subsequent test run demonstrated that these internal modifications allowed an increase in gas throughput from 18 000 t/d to greater than 20 000 t/d, while reducing TEG carryover from 1.3 m^3/day to around 0.4 m^3/day. An increase (worsening) in gas dewpoint was observed due to not-yet-optimised TEG regeneration, but the overall performance of the unit remained within trunkline saturation limits.

GEMPAK is a registered trademark of Koch-Glitsch.
Swirltube is a registered trademark of Shell.

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