

A step ahead in the bulk separation of gas-liquid mixtures

The new Schoepentoeter* Plus

In many industrial applications, the separation of gas from liquid in mixed-phase streams plays an important role in the performance of the whole plant. Effective operation is becoming ever more critical in order to produce high-quality final products from the available feedstock, which is of decreasing quality. Sulzer Chemtech and Shell* Global Solutions have jointly developed a feed inlet device able to cope with the most severe applications.

In the hydrocarbon industry—i.e., oil refineries, petrochemical plants, gas plants, and exploration and production facilities—it is often necessary to separate gas from liquid at a certain stage of an operation or process. The operating conditions of the mixed phases and the requirements for separation efficiency may vary widely. Therefore, special care should be taken in selecting the most appropriate device to match the specific duty.

For a bulk gas-liquid separation, where generally not more than 95% of

the liquid must be removed from the gas stream, the Schoepentoeter* [1] has proven to be one of the most effective devices available on the market. The Schoepentoeter is a Shell* proprietary feed inlet vane device commonly used for introducing gas-liquid mixtures into distillation columns or gas-liquid separators. The Schoepentoeter has two main functions:

- To separate the liquid from the gas and
- To distribute the vapor in the gas compartment of the column.

The Schoepentoeter accomplishes these objectives by slicing up the mixed-phase feed into a series of flat jets by means of properly distributed and oriented vanes. The jets dissipate a large part of the kinetic energy due to the vanes so that the vapor enters the gas compartment of the column in a smooth and uniform manner. The vanes also provide the mixed-phase feed with centrifugal acceleration to promote and/or enhance the separation of the liquid from the vapor—otherwise possible only by gravitational force.

In a refinery, separation of gas from liquid in mixed-phase streams plays an important role.



* Schoepentoeter and Shell are trademarks owned by Shell.

For any given duty, the Schoepentoeter allows for a considerably smaller feed entry section of the vessel, thus a reduction of the total column's height and costs.

Process design parameters

The main design parameters for a Schoepentoeter are the sizing of the feed inlet nozzle, the flow parameter, and the column load factor. These factors are important in predicting the efficiency of the Schoepentoeter.

The sizing of the feed inlet nozzle of a vessel equipped with a Schoepentoeter should be based on the maximum flow rate, including the design margin. The internal nozzle diameter may be taken to be equal to that of the upstream feed piping to the vessel, provided that the maximum momentum criterion is satisfied. In some applications where the gas density is very low—e.g., in refinery vacuum towers—the velocity of the gas at the feed inlet nozzle should be somewhat lower than the critical velocity of the gas—the speed of sound of the gas mixture—to prevent choking or damage due to vibrations. The flow parameter is used to characterize the type of gas-liquid mixture entering the vessel or the relative importance of the liquid load approaching the feed inlet device. It is proportional to the ratio of the liquid mass flow to gas mass flow.

Additionally, the performance of the Schoepentoeter—in particular, the separation efficiency—is greatly affected by the column load factor, also known as the capacity factor. This factor is proportional to the volume flow of the gas to the cross section of the tower.

Separation efficiency

The separation efficiency of a feed inlet device for gas-liquid mixtures is normally defined by the ratio of the liquid flow rate separated from the gas stream and the liquid flow rate originally contained in the mixed-phase stream.

For a Schoepentoeter, the separation efficiency can be expressed as a function of the nozzle's and columns's diameters, the column load factor, the flow parameter, and the ratio of the surface tension of the liquid compared with the surface tension of water.

Mechanical design parameters

The Schoepentoeter shall be designed to comply with and satisfy the following mechanical requirements and criteria:

- It shall support a maximum operating load over the feed inlet nozzle of 15000 Pa.
- It shall withstand its own weight plus the weight of the fluid at process conditions.
- The downward or upward deflection under operating loads shall not exceed 1% of the nozzle diameter or 15 mm, whichever is larger.
- The tilt of the Schoepentoeter shall not exceed 1% of the column diameter or 15 mm, whichever is smaller.
- Thermal expansion during normal operation and transient conditions, e.g., start-up/shutdown, shall be also considered.
- For mega-sized Schoepentoeter devices, i.e., those with nozzle diameter >3 meters and length >9 meters, additional detailed mechanical strength calculations and vibration calculations shall be performed.

There are cases, e.g., refinery vacuum tower revamps or flare system knockout drums, in which the Schoepentoeter is subject to loads even heavier than those mentioned above. Therefore, some additional measures shall be taken to avoid vane tips being bent or broken, e.g., using thicker material or employing stiffening strips at the back of long, unsupported vane tips.

Established performance

In most of the cases, the conventional Schoepentoeter has been proven to provide very good performance, and even to exceed optimistic expectations.

There are indeed only a few applications, e.g., refinery vacuum towers, where the separation efficiency was measured to be lower than expected.

Those measurements may have occurred because the liquid, separated by the vane, is not conveyed. Rather, it leaves the vane in a shape of a thin curtain, which, on its way to the bottom section of the tower, is subject to the upward momentum of the ascending vapor. A portion of the separated liquid (entrainment) may be carried to the feed



1 The conventional Schoepentoeter is one of the most effective devices available on the market for a bulk gas-liquid separation, where generally no more than 95% of the liquid needs to be removed from the gas stream.

entry zone of the tower. Therefore, the resultant separation efficiency may be lower than expected, especially under severe operating conditions—e.g., when the inlet nozzle momentum is above 7000–8000 Pa or column load factor is above 0.09 m/s—conditions commonly encountered in refinery vacuum towers.

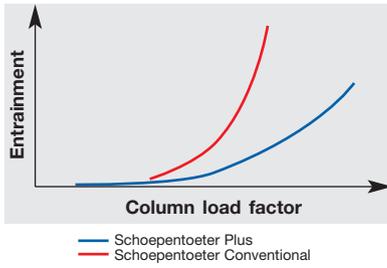
Research and development

Extensive research and development work was completed in the form of experimental tests and computational fluid dynamics analysis at the Sulzer Chemtech pilot plant in Winterthur and at the Shell Technology Center in Amsterdam 2.

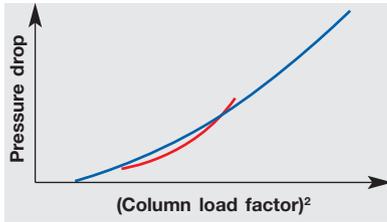
2 Several experiments were carried out at the Sulzer Chemtech pilot plant in Winterthur and at the Shell Technology Center in Amsterdam. The picture shows a pilot column in operation.



3 The tests were performed at different column load factors and flow parameters. At higher column load factors, the entrainment of the Schoepentoeter Plus is even less than one-third of the conventional one.



4 The improvement is achieved without any significant increase in the pressure drop.



The aim of the study was to optimize the separation efficiency without compromising the hydraulic capacity, in particular, the pressure drop through the feed nozzle and the Schoepentoeter itself. The idea was to design a feature that would collect the separated liquid in a way to counterbalance the upward momentum of the ascending vapor. Several types of advanced vanes were tested. The goal was achieved by modifying the back end of the vane from a straight and flat vertical plate to a sloped and curling plate—the so-called catching rim.

The catching rim collects the separated liquid and conveys it into a rivulet heavy enough to win the upward momentum of the ascending vapor and reach the bottom section of the tower, thus minimizing the entrainment. The tests were performed at different capacity factors and flow parameters 3.

At low column load factors, no major difference was measured: both the

devices performed sufficiently. At higher capacity factors, typically encountered in several industrial columns, the separation efficiency of the Schoepentoeter Plus was consistently higher than the conventional one: the entrainment was even less than one-third for values typically encountered in several industrial columns. The improvement was achieved without any significant increase in the pressure drop 4.

A new correlation for the prediction of the entrainment was developed by analytical regression of the experimental data, which considers the effect of the new vanes.

A new tool has been engineered to manufacture the catching rim. It will be available at all of Sulzer's major sites by the end of 2010.

Computational fluid dynamics study

Within the last decade, CFD has reached such maturity that it is now considered an indispensable analysis and design tool in a wide range of industrial applications, including for feed entry sections of distillation towers or gas-liquid separators. Therefore, a CFD study was performed to check the efficiency of the feed inlet device in terms of vapor distribution. For this scope, the flash zone of a refinery vacuum tower was modeled and analyzed with both the devices. The following operating conditions were set:

- a feed inlet nozzle momentum of 6370 Pa;
- a column load factor of 0.097 m/s;
- a collector tray with a 30% open area above the Schoepentoeter; and
- a combined bed of Mellapak™ 125X and Mellagrid™ 64X structured packings above the collector tray.

The vertical vapor velocities (y-axis in the picture) over the horizontal plane were checked at different tower elevations, in particular, underneath the combined bed of Mellagrid and Mellapak in the wash section 5. The different colors correspond to different vapor velocities, the blue and the red being the lowest and the highest values respectively. There is no significant difference between the two devices: the vapor distribution efficiency is good for both the distributors.

Fields of application

In general, the Schoepentoeter Plus could be used in all applications suitable for a conventional device, e.g., separation in oil and gas upstream units or distillation in the oil and gas downstream plants. However, this article mainly focuses on the second application.

Oil and gas downstream

There are cases where there is no need for the Schoepentoeter Plus, e.g., when the inlet device is used for a single-phase stream and no significant benefit in distribution efficiency would be achieved. The higher cost of the Plus version makes the conventional one more attractive.

The best candidates for installation of the Schoepentoeter Plus are vacuum towers, crude distillation main fractionators, and hydrocracking main fractionators in oil refineries, where the separation efficiency of vapor from liquid plays a significant role in the performance of the units.

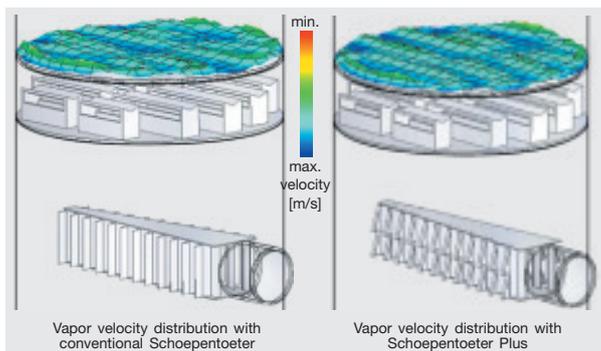
Case study: vacuum tower revamp

The column is located at a major European refinery. The main duty of the tower is the recovery of light and heavy vacuum gas oil—LVGO and HVGO respectively—from the long residue coming from the primary distillation of the crude oil. The feed, preheated up to 400–420 °C and partially vaporized, accesses the flash zone of the column through the feed inlet device, which performs a bulk separation of the liquid from the vapor as well as a vapor distribution in the gas compartment of the column.

The liquid drops down to the stripping section for the ultimate recovery of the light hydrocarbons and, finally, is drawn off as short residue from the bottom of the tower. The vapor phase is fractionated into light and heavy vacuum gas oil in the upper sections. The LVGO is drawn off at the top section of the tower; a pump-around circuit provides the column with the duty necessary to condense the relevant vapors coming from the section below.

The HVGO is generally the first useful side cut above the flash zone. A pump-around provides the column with the

5 The different colors correspond to different vapor velocities. There is no significant difference between the two devices: the vapor distribution efficiency is fine for both the distributors.



duty necessary to condense the right amount of vapors coming from the wash section. A portion of the condensate—the wash oil—is pumped back to the bed below to control the quality of the drawn-off product. Among other factors—e.g., feed composition, wash section configuration, and operating parameters—the quality of the HVGO may also be affected by the separation efficiency of the feed inlet device.

Concerns at the existing tower

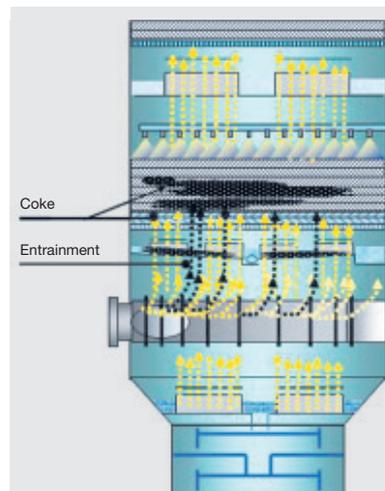
The flash zone of this column was originally equipped with a conventional Schoepentoeter. Since the separation efficiency was lower than expected, the liquid carryover to the wash section (entrainment), which was made of the heaviest hydrocarbons and should, indeed, have followed the short residue at the bottom of the tower, was higher than expected. As consequence, the slop wax flow rate (generally an unwanted product) was consistently higher than foreseen.

In the attempt to maximize the yield of the HVGO while minimizing the slop wax production, the wash oil was substantially reduced—even below the minimum—causing a deterioration of the wash bed performance:

- Bad quality of HVGO: a high Conradson carbon residue (CCR) and metal content with negative impact on the downstream fluid catalytic cracking (FCC) unit. These results led to lower liquid yields and higher catalyst make-up rate than expected.
- Coking up of the wash bed: higher pressure drop and less recovery of distillates; this effect led to shorter plant run length, unexpected shutdown, thus reduced plant utilization factor, and increased maintenance costs [6].

Tower modifications

After an in-depth investigation and detailed analysis of the tower performance, Sulzer decided to replace the existing conventional Schoepentoeter with the Plus version. The wash bed was replaced due to coke formation, and the existing combination of Mellagrid and Mellapak was kept. In addition, the two pump-around beds were replaced with the same type of packing within the scheduled maintenance program of the unit, during the overall turnaround of the refinery. All the other tower internals were retained [7]. The tower has recently been started up. A detailed plant survey at maximum throughput is expected by the end of the year.



[6] The coke in the wash bed leads to a higher pressure drop and lower recovery of distillates. This effect results in shorter plant run length, unexpected shutdown, thus reduced plant utilization, and increased maintenance costs.

Increased separation efficiency

The Schoepentoeter Plus provides the hydrocarbon industries with a great tool with which to improve the bulk separation efficiency of gas-liquid mixtures. The main fields of application are the refinery towers in vacuum distillation units, crude distillation units, and hydrocracking plants.

The best fit is the revamp of vessels equipped with radial feed inlet devices; in new columns, the higher cost of the Schoepentoeter Plus may make the conventional one more attractive, provided that the performance requirements are not excessively high.



[7] Schoepentoeter Plus for a European refinery vacuum tower (top), front end view (bottom left), enhanced vane with catching rim (bottom right).

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