Cross-section of a hydroprocessing reactor

**Inlet diffuser**
Reduces the energy of the two-phase mixture before it reaches the distribution tray.

**Scale catcher**
The scale catcher will collect the fines, scales, inorganic rust, etc. and avoid plugging of the distributor tray and the catalyst bed below.

**Top liquid distribution tray**
Ensures optimum distribution of liquid and vapor over the entire catalyst bed.

**Graded catalyst bed**
Reduces pressure drop build-up during operation.

**Hydroprocessing catalysts**
Reduces sulfur, nitrogen, metals and aromatics of petroleum fractions by hydrotreating and boiling range shift by hydrocracking.

**Catalyst support beams and grids**
Designed to support the weight of the catalyst, support media, oil, etc. from SOR to EOR, while maximizing the catalyst volume.

**Vortex quench mixer**
Ensures efficient heat and mass transfer between the cold quench gas, vapor and liquid effluent from the upper catalyst bed.

**Liquid redistribution tray**
Ensures equal redistribution of liquid and vapor over the entire catalyst bed.

**Rough cut distributor**
Reduces the energy of the two-phase mixture before it reaches the redistribution tray.

**Outlet collector**
Ensures even flow distribution in the bottom bed to achieve optimal catalyst utilization and prevents catalyst migration.
Efficient hydroprocessing solutions

In a world with tight product specifications and ever more difficult feedstocks to process, efficiency losses due to imperfect reactor performance cannot be tolerated. Topsoe’s hydroprocessing solutions will help refiners benefit from our extensive experience in obtaining a more effective utilization of their hydroprocessing units.

Topsoe’s hydroprocessing technology is an integrated solution, encompassing reactor internals, grading material, catalyst, process design and detailed reactor engineering. Topsoe reactor internals include liquid distribution trays, quench mixers as well as inlet diffusers, catalyst support beams, grids and outlet collectors. With this extensive product portfolio, our clients only have to deal with one company. We call it single-source responsibility.

Client’s needs

Topsoe assists clients in all aspects of hydroprocessing technology, including:

- catalyst and reactor internals replacement
- revamp of an existing unit
- design of a grassroots hydroprocessing unit

Many refiners have installed Topsoe internals in existing reactors. Our “in-house” design can be tailor-made to fit any reactor configuration. The internals can be installed using existing support structures, be attached to other internals or even hung from the inlet flange.

Exceptional client benefits

More than 600 of Topsoe’s Vapor-Lift Tube (VLT) trays, quench mixers and catalyst supports have been installed worldwide, giving Topsoe a reputation in the refining industry as the leading supplier of state-of-the-art reactor internals. Using our operating experience, small-scale cold flow models and the latest two-phase CFD modelling techniques, we are continuously improving our reactor internals design. This has resulted in a number of exceptional benefits for our clients:

- excellent performance over a wide range of operating variables such as liquid and vapor loads
- superior performance also when tray is not perfectly level during operation
- self-cleaning nozzles require less maintenance and thereby improve performance
- easy and fast installation to save time during turnarounds
- minimum required height provides more space for the catalyst in the reactor
- an unmatched number of drip points and coverage ensures improved utilization of the catalyst, even at the reactor wall
- improved safety through significant reduced risk of hot spots
- innovative mechanical support system for tray plates, making them less likely to warp under load as compared to traditional beam supported trays
- quick release manway design
- designed to be installed with no welding

Reactor internals – a hidden potential for process optimization
The reactor internals

Uniform feed distribution over the catalyst from start of run (SOR) to end of run (EOR) is the key to achieve optimal catalyst performance as well as to reach the increasingly tighter product specs combined with tougher feeds. Therefore, the liquid distribution trays and quench mixers are the most crucial elements of the reactor internals design.

Even distribution extends the catalyst lifetime and the ability to meet product specs. The costs associated with inefficient unit performance and shorter cycle length are often not acknowledged. The gains achieved from improved performance and longer cycle length make a change of reactor internals a very profitable investment.

Scale catcher

When the feed contains fines, scales, inorganic matter, rust etc., it is recommended to install a scale catcher above the top distributor tray to prevent pressure drop and maldistribution.

The scale catcher will collect the fines, scales etc. before distribution in the reactor. This way, plugging of the catalyst bed leading to maldistribution is minimized. Topsoe has also prevented recurrent pressure drop problems by revamping reactors with scale catchers. Thus, unit cycle length and performance have been improved significantly.

Installing a scale catcher can reduce the amount of top grading material needed and increase the active catalyst volume.

Vapor-Lift distributor

Topsoe’s VLT tray has a number of unique features created through in-house development combined with industrial experience:

The Topsoe VLT tray distributes the vapor and liquid evenly across the entire cross section area of the catalyst bed. These trays operate on a vapor assisted principle by which the vapor flows through a vertical slot on the side of the VLT and creates a pressure differential. This lifts liquid droplets from the tray and carries the liquid and the vapor up through the riser and down through the inner tube to the catalyst bed below. The vapor lift mechanism for liquid flow results in even flow distribution, because the liquid flow is not sensitive to the local liquid level on the tray.

In contrast to the VLT tray, a chimney tray achieves liquid flow by means of gravity. Thus, the flow through a chimney depends greatly on the liquid level at the chimney.
The VLT trays exhibit much lower sensitivity to being out of level than other designs. Low sensitivity to tray levelness is crucial, as tests have shown that 2.5% sensitivity corresponds to 5% additional catalyst needed or 0.5°C higher temperature, whereas 20% sensitivity corresponds to 50% additional catalyst needed or 5°C higher temperature!

Furthermore, the VLT handles the wide range of vapor and liquid rates encountered from start of run to end of run and during unit turndown. These variations in the liquid level on the VLT tray will not impact performance. This is particularly important due to the difference in degree of feed vaporization from SOR to EOR.

The liquid level on the tray will automatically be adjusted to reach about halfway up the slot before the gas pulls liquid through the riser. The VLT is a self-adjusting tray able to operate perfectly at a large range of operating conditions.

In recent years, Topsøe has further developed the VLT tray concept into the Topsøe Box VLT.

The Topsøe Box VLT is self-supported, thereby rendering support beams obsolete and diminishing tray deflexion. The lack of support beams allows increased catalyst loading and thereby higher efficiency.

Self-cleaning nozzles

The design of Topsøe’s VLT trays includes the capacity to retain fouling material without affecting liquid and vapor distribution and thereby catalyst performance. The slotted nozzles are self-cleaning: by design, the velocities through the slots do not allow fouling materials to settle in the slot and thus always provide enough cross-sectional area to ensure that the flow paths are kept clear for the vapor and liquid mixed phase flow.

The Topsøe quick release system

Topsøe reactor internals are easy to install, maintain and dismantle during turnaround. In order to reduce downtime during turnarounds, Topsøe supplies a reactor internals system, incorporating a quick release system for the The Box VLT tray manway sections and the Topsøe Quench sections.
Topsøe quick release system

The quick release system ensures that the manway sections are locked firmly against the gaskets. The system is operated with a manual handle and without tools. No nuts and bolts are used, as these most likely ceases after some time in service. Industrial feedback and tests have shown that manway access time for opening and closing the manways is as short as five minutes for the Box VLT tray. In inert gas condition, the opening and closing operation can easily be carried out by one person. This is significantly shorter compared to other reactor internals where manway opening and closing time is often three-four hours or more, due to bolting, wedge pins and other types of fasteners. As a result, Topsøe reactor internals offer a significant reduction of downtime for catalyst replacement.

The quench mixer

In two-phase hydroprocessing reactors, a mixing device is often required between the catalyst beds: a well-designed mixing device ensures good contact between the quench fluid and the vapor and liquid effluent from the catalyst bed above.

This results in efficient heat and mass transfer with uniform composition and an even temperature profile in the bed below. Any nonuniformity created by a poorly designed mixing device will result in loss of reactor efficiency.

The Topsøe Vortex type quench mixer is a state-of-the-art design, now being used extensively throughout the refining industry.
The Topsøe approach to quality

Each VLT tray and quench mixer is custom designed based on a detailed technical review with our clients to ensure an optimal design to meet or exceed the required performance and specifications.

The reactor internals are manufactured only in certified shops, where Topsøe’s mechanical engineers will inspect the reactor internals throughout the fabrication process. This inspection includes PMI testing (Positive Materials Identification), pre-assembly and reactor mock-up.

The reactor internals are preassembled in the fabrication shop, and all dimensions are checked against the design to ensure a perfect fit and to avoid field installation problems.

Topsøe’s mechanical engineers will be on site to assist our clients with the installation of the reactor internals.

Continued improvement

Extensive collaboration between Topsøe’s engineering disciplines, Research and Development and industrial feedback ensures fast implementation of new ideas and design features for constant improvement of our technology.

Topsøe’s product portfolio includes catalyst, licensing of technology, hardware supply, engineering of processing units and technical service. Proprietary knowledge in these areas makes Topsøe a valuable business partner for our clients.

The Topsøe refining portfolio

When working with Topsøe, you will benefit not only from our long-term involvement in the refining industry, but also from our broad scope of supply. In addition to our technology and catalysts for hydrocracking and hydrotreating, Topsøe has developed other related refinery technologies such as sulfur management, hydrogen production, NO\textsubscript{x} reduction (DeNO\textsubscript{x}), sulfur reduction (WSA) as well as combined reduction of NO\textsubscript{x} and SO\textsubscript{x} (SNO\textsubscript{x}).

The Topsøe business model is unique, integrating all aspects from fundamental knowledge to practical implementation to achieve optimum industrial efficiency. By choosing Topsøe reactor internals, clients will have a competent and reliable partner for today and for the future.
The information and recommendations have been prepared by Topsøe specialists having a thorough knowledge of the hardware. However, any operation instructions should be considered to be of a general nature and we cannot assume any liability for upsets or damage of the customer’s plants or personnel. Nothing herein is to be construed as recommending any practice or any product in violation of any patent, law or regulation.