Reactor internals
- optimising catalyst performance
Cross-section of a hydroprocessing reactor

**Inlet diffuser**
Breaks down the velocity of the two phase mixture before it reaches the distribution tray.

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

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

**Hydroprocessing catalysts**
Reduce sulphur, 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 catalyst, support media, oil, etc. from SOR to EOR, while maximising the catalyst volume.

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

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

**Outlet collector**
Ensures even flow distribution in the bottom bed to achieve optimal catalyst utilisation 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. With hydroprocessing solutions from Topsøe, refiners will benefit from our extensive experience to make more effective utilisation of their hydroprocessing units.

Topsøe’s hydroprocessing technology is an integrated solution encompassing reactor internals, grading material, catalysts, process design and detailed reactor engineering. Topsøe 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.

Clients’ needs

Topsøe 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 Topsøe 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

Several hundred of Topsøe’s Vapour-Lift Tube (VLT) trays and quench mixers have been installed worldwide, giving Topsøe a reputation in the refining industry as the leading supplier of state-of-the-art reactor internals. Using our operating experience, semi-scale cold flow models, and the latest two-phase CFD modelling techniques, we have continuously improved our VLT design. This results in a number of exceptional benefits for our clients:
- maintain excellent performance over a wide range of operating variables such as liquid and vapour 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
- minimum required reactor height provides more space for catalyst in the reactor
- an unmatched number of drip points and coverage ensures improved utilisation of the catalyst, even at the reactor wall
- innovative mechanical support system for tray plates so they are less likely to warp under load as compared to traditional beam supported trays

Reactor internals – a hidden potential to optimise the process

Two-phase Computational Fluid Dynamics (CFD) simulation model of two Vapour-Lift nozzles.
The reactor internals

The liquid distribution tray and quench mixers are the most crucial elements of reactor internals design in order to ensure efficient catalyst utilisation.

Vapour-Lift distributor

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

The Topsøe VLT tray distributes the vapour and liquid evenly across the entire cross section area of the catalyst bed. These trays operate on a vapour assisted principle by which the vapour flow through the nozzles creates a pressure differential. This lifts liquid droplets from the tray and carries the liquid and the vapour up through the riser and down through the downcomer to the catalyst bed below. The vapour lift mechanism for liquid flow results in even flow distribution, because the liquid flow is not sensitive to the local liquid level at the nozzle.

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. Furthermore, the VLT is much better at handling the wide range of vapour and liquid rates encountered from start of run to end of run and during unit turndown. These variations in liquid level on the VLT tray will not significantly impact the performance. This is particularly important due to the difference in degree of feed vaporisation from start of run to end of run.

![Diagram of liquid flow distribution](image)

The operational principle of Topsøe’s VLT tray: Gas flows through the nozzles and by gravity falls onto the catalyst bed.

**Comparison of sensitivity to being ouf-of-level for bubble cap, chimney tray and first and second generation Vapour-Lift trays. The sensitivity to being out-of-level is calculated by the following formula as the measured difference in the rate of the liquid flowing from adjacent distributor points with a difference in elevation of 10 mm:**

\[
\text{Sensitivity} = \frac{F_{\text{low}} - F_{\text{high}}}{F_{\text{average}}} \times 100 \%
\]

where:

- \(F_{\text{low}}\) = liquid flow through the low distributor
- \(F_{\text{high}}\) = liquid flow through the high distributor
- \(F_{\text{average}}\) = average liquid flow
Self-cleaning nozzles

The design of Topsoe’s VLT trays includes the capacity to retain fouling material without affecting liquid and vapour 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 vapour and liquid mixed phase flow.

The quench mixer

In two-phase hydroprocessing reactors, a mixing device is required between the catalyst beds: A well-designed mixing device ensures good contact between the quench fluid and the vapour 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 non-uniformity created by a poorly-designed mixing device will result in loss of reactor efficiency.

The Topsoe Vortex-type quench mixer is a state-of-the-art design now being used extensively throughout the refining industry.
Topsøe – your partner in business optimising hydroprocessing unit performance

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).

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

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

The Topsoe refining portfolio

When working with Topsoe, 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, Topsoe has developed other related refinery technologies such as sulphur management, hydrogen production, NOx reduction (DeNOx), sulphur reduction (WSA) as well as combined reduction of NOx and SOx (SNOX™).

The Topsoe business model is unique, integrating all aspects from fundamental knowledge to practical implementation to achieve optimum industrial efficiency. By choosing Topsoe 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 catalysts. 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.