

Are you ready for **MARPOL?**

The shipping and refinery business is facing a new reality



As the International Maritime Organization (IMO) has decided to implement the MARPOL Annex VI, all ships must globally reduce their emissions of sulfur by 86% before 2020.

This fact is bound to have a huge impact on the shipping as well as the refinery industry. But exactly what will happen? What options are there? What are the opportunities? Who will seize them? And how?

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For the refinery industry

Upgrade heavy fuel oil to meet MARPOL regulations

Atmospheric Residue De-Sulfurization (ARDS)

The introduction of new MARPOL regulations is expected to have a major impact on demand patterns in our industry. While this will present challenges to refineries, it will also create opportunities for those companies who optimize assets.

Upgrade now

To help refineries process products that will comply with MARPOL by 2020, we offer a straight-forward solution: An Atmospheric Residue De-sulfurization (ARDS) unit for upgrading high-sulfur heavy fuel oil into low-sulfur fuel oil.

These units convert atmospheric residue into higher-value products by reducing the content of sulfur, nitrogen, carbon residue and asphaltenes as well as metals. As an added benefit, they also achieve a moderate conversion of residues into distillate products.

Meeting shifts in demand

The ARDS unit will give you the edge you need in an evolving marketplace. It will position your refinery to meet the growing demand for low-sulfur fuel oil. Or give you the flexibility to export the low-sulfur output for further processing into high-value products in resid fluid catalytic cracking (RFCC) units in or outside the refinery.

Striking the perfect balance

We have been providing catalysts to fixed bed hydrotreating units since the early 1980's. This has given us considerable design experience with a wide range of heavy feedstocks like shale oil, coke oven tar, tall oil and heavy coker gas oils.

More specifically, we have not only learned what is required operationally to achieve satisfactory catalyst activity. We've gained important insights into which measures need to be in place to prevent high deactivation and pressure drop in fixed bed catalyst systems.

Ultimately, the key to proper fixed-bed resid design is optimal catalyst loading.

Units are typically loaded with at least three different kinds of catalysts:

1. An HDM catalyst with high activity for metals removal
2. An HDS catalyst for removing sulfur, nitrogen and other heteroatoms
3. A transition catalyst in-between

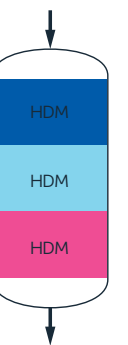
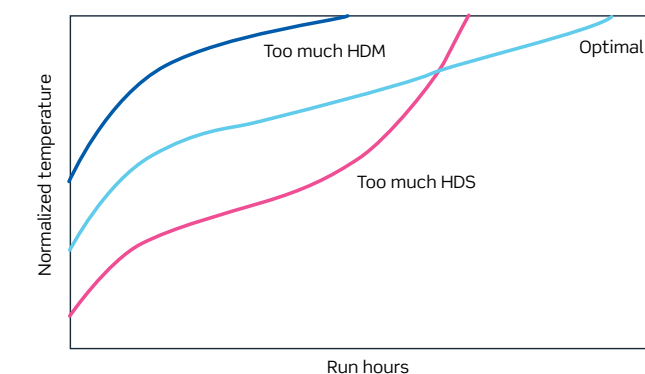
We make it a priority to know your process objectives, and then match them with a tailored catalyst system.

Let's talk about how we can help you

- Determine the margin-enhancing value you can expect by deploying ARDS in your refinery
- Discover most profitable market destination for the products (fuel oil, coker stock or other)
- Optimize unit design and catalyst loading

For more information please contact:

Jens Valdemar Thomsen
Senior Licensing Manager
jth@topsoe.com



A lower cost option for **increasing** capacity

Crude overflash hydrocracking

One approach to reducing the dependency on the fuel oil market has been to revamp or install more conversion capacity in refineries. Such projects have been an extremely cost-effective way for a refinery to shift its product slate.

The International Maritime Organization has announced a global sulfur cap of 0.5% on marine fuels starting January 1, 2020. This has put small and simple refineries at a comparative disadvantage relative to larger competitors as they face a disproportionate rise in compliance costs. We think that this will have significant implications for both operations and capital investment decisions.

Integrate and save

One of the most effective ways to adapt while reducing investment costs is to maximize use of existing equipment and to optimize operations.

That's why we developed a process to help simple skimming refineries without a vacuum distillation unit to integrate a conversion unit to help keep costs down. The unit is designed to be integrated with the crude unit or diesel hydrotreater.

The unit's feed is part of the crude tower overflash stream, which is already drawn from the crude tower to measure tower performance.

The technology provides some significant positive features to boost capacity and manage a shifting feedstock slate.

What's in it for you?

- No crude tower revamp
- Low capital cost vacuum column section
- Low capital cost hydrocracker
- No fired heater required, thus no emission trouble
- A fraction of low value fuel oil is converted to high value products

Talk to us. We're here to help

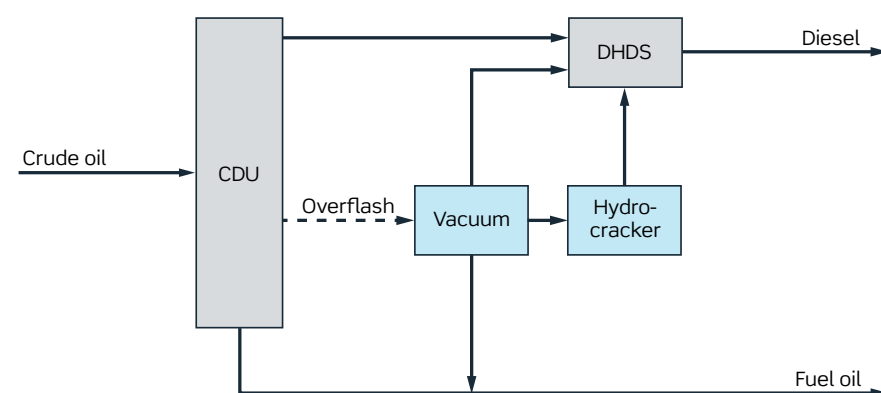
Topsoe has deep experience with designing and building solutions that help refineries unlock value depending on their specific processing goals. We can help by studying your plant to determine the feasibility of adding extra conversion capacity and feedstock slate flexibility to your plant.

These are just a few of the areas worth investigating before you invest in new equipment and processes:

- Cost-benefit analysis
- Plot availability
- Hydrogen and sulfur balances within the refinery
- Emission loads
- Retrofit requirement within the refinery

For more information please contact:

Jens Valdemar Thomsen
Senior Licensing Manager
jth@topsoe.com



Make the **most** of what you have

Feed stream management

In the not-so distant past, crude oil prices were hitting records everyday worldwide as downstream operators saw their margins decrease.

Some refineries in Europe were forced to shut down. Others were acquired by companies with highly developed upstream operations. Those refineries that survived implemented operational optimization programs in a search for "quick wins" and wise capital investment decisions.

Among other processes, middle distillate hydroprocessing units became the target for improvements.

Today, the industry is abuzz with talk about a possible uplift in margins that will be driven by the new MARPOL regulations.

Unlock your potential

As a world leader in hydroprocessing catalyst and technology, Topsoe is positioned to help refineries address this emerging challenge by unlocking their full competitive potential.

Our solutions will help you optimize feed pool management for hydroprocessing. Given the implications of tougher bunker fuel legislation, our detailed knowledge of oil treatment and associated hydrogen and sulfur issues become particularly relevant.

We work along with our customers' LP and finance departments to make sure that process adjustments lead to financial performance improvements.

Let's help you meet MARPOL 2020 requirements

You need a robust plan for successfully competing in today's volatile market.

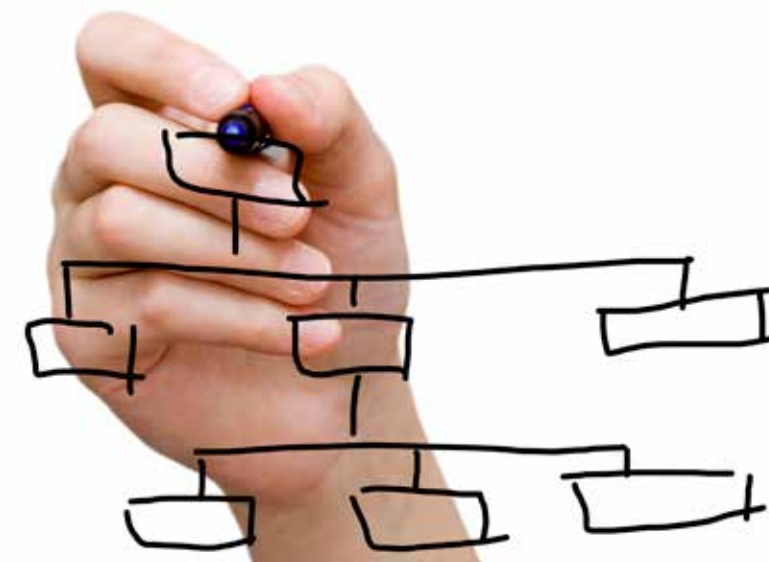
The best plans start with an initial study and evaluation of your stream management potential. In the face of new regulations, some of the questions you may want to explore include:

- How can you meet MARPOL specifications and keep diesel hydrotreaters profitable?
- How can you contend with the changing feedstock slate and increasingly stringent environmental standards?

- How can refineries balance heavy oil, hydrogen and sulfur treatment?
- Which low sulfur stream should you use for blending?
- How to balance ULSD production with MARPOL specifications?

For more information please contact:

Maria Mitina
Group Manager
mvm@topsoe.com



A bold shift into high value products

Slurry technology

Thanks to MARPOL, refineries have more incentive than ever to exit the bunker fuel market and shift their production to lucrative products such as gasoline, jet fuel and diesel.

Slurry technology represents an excellent opportunity. While it is the most expensive option for refineries, it offers the highest rates of conversion and a way to produce more premium grade products that command higher prices.

Unmatched high-end processing

ENI's Slurry Technology (EST), together with Topsoe's downstream upgrading technology, enable both existing as well as grassroots refineries to convert any kind of heavy residue to any kind of high-value transportation fuels. It is a proven technology for converting residue oil into high value products. Moreover, thanks to its extremely high feedstock flexibility, EST can even be applied to very low quality crude oils such as heavy and extra heavy oils and tar sands.

Several processes are available for converting residues into lighter products. These processes typically fall into two categories: 1) carbon rejection in form of delayed coking or 2) hydrogen addition with a catalytic process that adds hydrogen to improve product yield and quality.

Highest conversion rate possible

Today, the hydrogen addition route is likely to be more attractive given its high conversion (i.e. >95%), high diesel

selectivity and Euro V grade product output. Hydrocracking solutions like fixed-bed and ebullated bed technologies suffer from feedstock quality limitations as well as problems related to residue stability that limit the maximum conversion achievable. These conventional processes produce only modest conversion and as a result, produce a significant amount of low value fuel oil. Slurry technology solution allows refiners to mitigate low value fuel production.

The heart of the process is a slurry reactor that hydrocracks heavy feed into lighter products in the presence of the slurry molybdenum based catalyst. Intermediate products from the slurry section, which are quite challenging, are processed in VGO and diesel upgraders to produce the final products. The VGO and diesel upgrader configurations (i.e. VGO hydrotreater, mild hydrocracker, once through or full conversion hydrocracker, diesel hydrotreater) may vary and depend on the desired product slate.

Benefit from our experience

ENI and Topsoe offer an integrated solution for fully converting all classes of residue feedstocks. These include turning vacuum residue, visbreaker tar, pitch, clarified oil and pyrolysis oil into a variety of high quality distillate products.

We have vast experience in hydroprocessing of the products from the EST process. We have been involved in every phase of projects,

pilot plant testing of products to operating industrial units. Thanks to our experience, we are poised to tailor hydroprocessing catalysts and technology solutions for upgrading slurry hydrocracker products into a range of high quality products such as LPG, naphtha, kerosene/ATF, Euro V grade diesel and lube base feedstock.

Let's join forces and conduct a study to evaluate the broader implications of deploying slurry technology integrated with VGO and diesel upgraders. We could examine areas such as:

Lowering sulfur fuel oil production while maximizing the distillates production

- Eliminating fuel oil production while maximizing the distillates production
- Meeting additional hydrogen demand which will be required to upgrade the heavy oil
- Handling increased sulfur production, as well as offer additional capacity

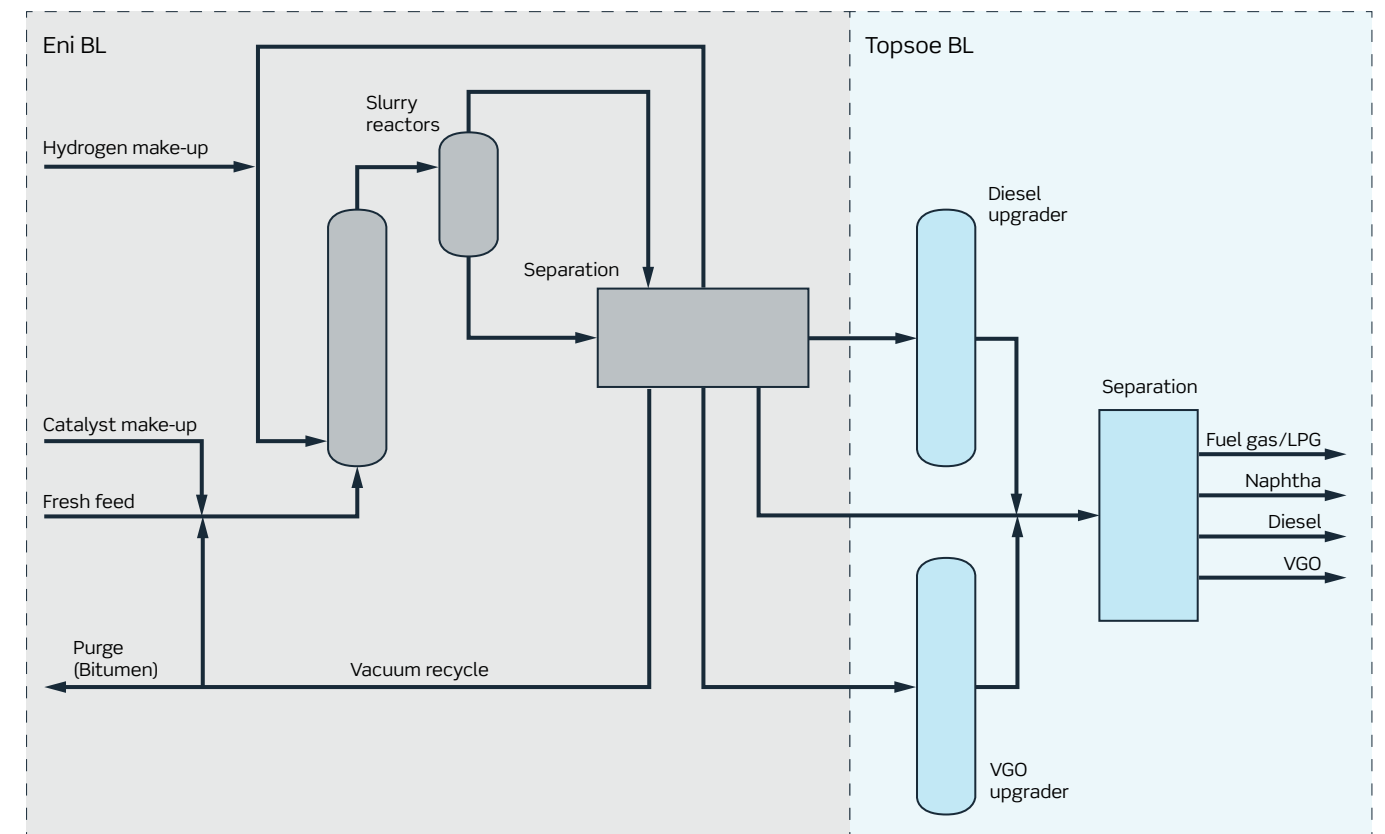
Profit from us

What kind of returns can you expect from an investment in our slurry process technology?

For more information please contact:

Morten Krogh Johansen

Senior Licensing Manager
mkj@topsoe.com



Slurry technology flow diagram

A **low** CAPEX path to **higher** profitability

Delayed coking

MARPOL regulations are creating uncertainty about how best to invest in conversion capacity to comply or shift production to more profitable products.

Adding a delayed coking unit to refinery operations offer a straight-forward way to comply with tougher MARPOL-mandated sulfur legislation by moving away from bunker fuel.

Delayed coking is an attractive solution because it allows refineries to upgrade their fuel oil pool to value products such as diesel, gasoline and jet. This will position refineries to become more competitive as the industry tilts towards a higher refining margin environment. Better yet, delayed cokers offer a low CAPEX solution.

Understand your challenges

Before upgrading or revamping assets, refiners need to understand its impact on product balances and other units. What will be the impact of a delayed coker unit on product balances? What will be the ramifications for other hydroprocessing units? Will they need to be checked or revamped to process new feeds and increase capacity and utilization?

Another challenge is determining the most profitable way to off-load the solid coke. Its value depends on its quality. Usually the lowest quality pet coke is used as fuel in plants where sulfur oxides can be trapped and converted to a high quality sulfuric acid or sulfur. Topsoe offers hydrotreating catalyst and technologies for all coker

fractions, enabling refineries to meet product specifications at a low cost and with higher profits. For each application, we match the optimum configuration with your feedstock and processing objectives.

Talk to us

To assist refiners, we offer support studies for the introduction of a delayed coker. Our experience has taught us that a solution must be customized, and should be researched to better understand your operations and marketplace.

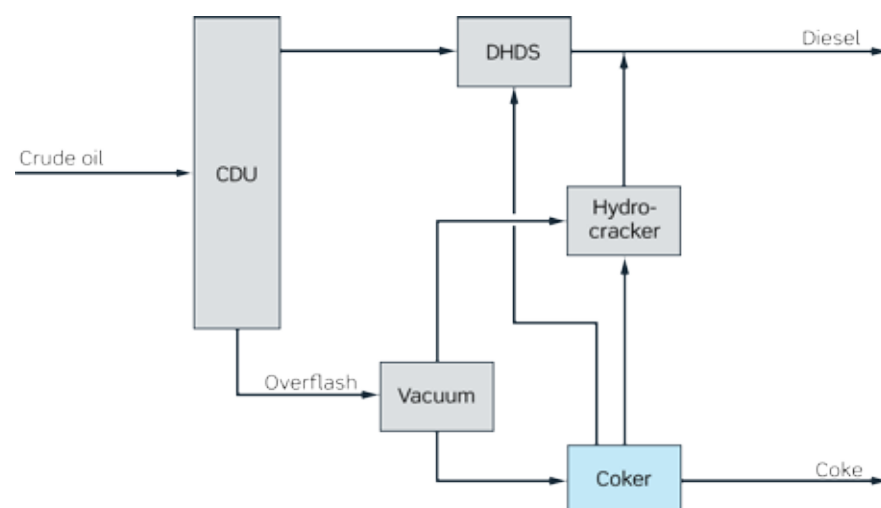
- Yields
- Cost-benefit analysis
- Catalyst implication in downstream treatment
- Operation optimization towards unit integration

- Retrofit of downstream existing hydroprocessing units
- Possibilities for off-load of coke
- What is the implication of the H₂ requirement and the H₂S discharge?
- Insights to Shipping and Engine industries

Understanding your business is the key to configuring an optimized delayed coking set-up.

For more information please contact:

Jesper Gottlieb
Licensing Manager
jego@topsoe.com



A **cleaner** alternative to bunker fuel oil

Conversion to methanol production

The MARPOL legislation on bunker fuel for 2020 requires that sulfur emissions can be no higher than 0.5 wt% of the fuel used. Within these parameters, methanol is emerging as an alternative to bunker fuel because it's clean and contains no sulfur or NOx and is soot-free.

The road less travelled

Methanol is attractive because it can be used for a variety of applications as seen below. It gives refineries an opportunity to diversify their portfolio of higher value products. Refineries may want to consider the methanol production route if they are seeking a strategic drive into chemicals to escape the commoditization of product segments such as diesel, jet and gasoline.

Following a trend

The global trend towards greater use of green power may accelerate a move towards methanol. After all, a methanol platform meets several needs and bunker fuel is a potential source for large quantities.

Methanol is a viable alternative to conventional chemicals, including PP, PE and various aromatic intermediates. The diversity of downstream products can make this scenario compelling in the future.

Tailored approach

Topsoe is a leader in methanol production technology, including units for producing only methanol as well as units co-producing methanol and ammonia. We make a difference by tailoring methanol production platforms to match the processing objectives of your operations. Many customers benefit from this tailored approach.

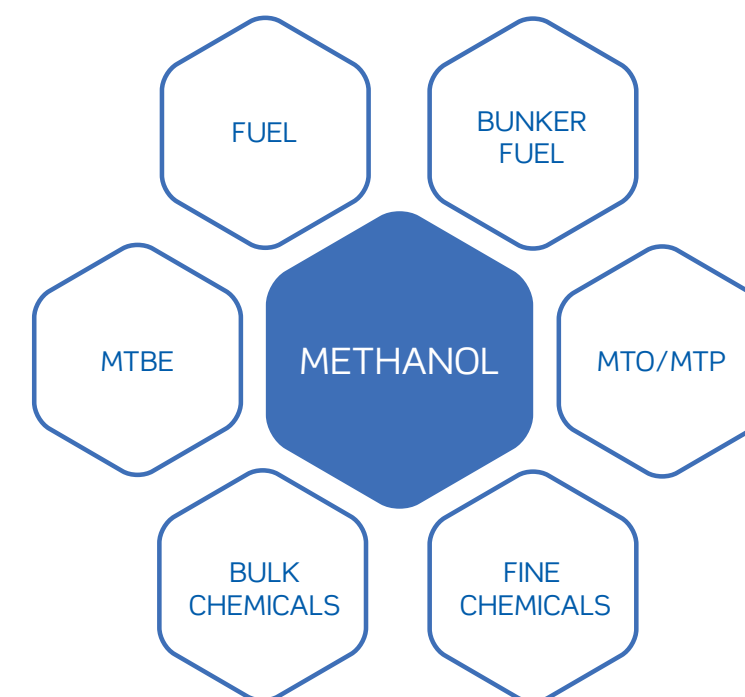
To find out how you can benefit from this tailored approach, our design and engineering team can explore the feasibility of methanol production for your company by conducting a study that can form the basis for your decisions. Study topics include:

- Value proposition
- Cost benefit analysis
- Methanol unit integration within an existing refinery
- Evaluation of downstream unit's application
- Plot issues

That input helps us to define what we need to aim for when developing methanol production concepts and designs. And it means that customers cannot only adopt leading-edge solutions from a highly experienced specialist in methanol, but they also receive a solution that is tailored to achieve their strategic goals.

For more information please contact:

Hans Christian Ferdinandsen
Senior Proposal Manager
hcn@topsoe.com



Handling **increasing** amounts of H₂S

Sulfur Management

In the race to achieve more and deeper desulfurization of fuel oil and other refinery products, the challenges faced by refineries are many. For some, the issue is capacity. Existing H₂S gas treatment facilities such as Claus plants may not have sufficient capacity to treat additional H₂S gas. In other cases, refiners need to increase sulfur removal efficiency to comply with environmental regulations.

We've got answers today

Topsoe's Wet gas Sulfuric Acid (WSA) technology was developed for H₂S gas treatment as well as Claus tail gas applications.

Our compact WSA process converts H₂S into concentrated sulfuric acid, which can then be used by the refinery itself or be marketed for use by companies such as fertilizer producers.

A major advantage of WSA technology is that it exports about three times more energy than a Claus plant. The energy is available in the form of superheated high-pressure steam that's suitable for use in steam turbines.

WSA technology easily accepts ammonia, e.g. in SWS gas, and hydrocarbons, and many oil refineries worldwide have already adopted WSA technology to treat H₂S gas.

Three ways to boost H₂S gas processing capacity

Supplement Claus plants with WSA to treat extra H₂S gas

Additional H₂S gas can be directed to a WSA plant to produce sulfuric acid and generate a significant amount of steam. A WSA plant typically takes up less space than a Claus plant, so limited space in refineries shouldn't be a problem. You can see a flow diagram of a typical WSA plant Fig. 1.

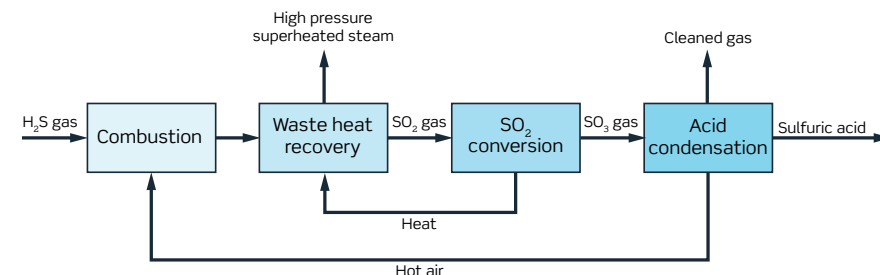


Fig. 1: Typical WSA plant

Treat H₂S and tail gas simultaneously

Here's an elegant solution for simultaneously treating H₂S gas and tail gas to increase overall sulfur removal efficiency and capacity. Configure a WSA plant to achieve both. Assume that after installation of additional HDS capacity, an additional 50% of H₂S gas is generated. The problem is that the existing Claus plant can't handle the extra load. A simple solution is to direct the additional H₂S gas to a WSA plant that also treats the tail gas from the existing Claus plants. As a result, you can realize a combined

Treat Claus tail gas

In cases of insufficient sulfur removal rates in Claus plants, a WSA plant can be installed to treat tail gases. Almost all sulfur will still be available as elemental sulfur, while a smaller portion will be processed into concentrated sulfuric acid.

Burning high-sulfur residual oil and petcoke

What if a refinery determines that desulfurization of all fuel oil isn't a viable option? What do you do with the high-sulfur residue from the refinery that cannot easily be sold?

One possibility is to burn the residue to generate steam, heat and power for the refinery or nearby consumers.

The sulfur dioxide (SO₂) rich flue gas from the combustion can be treated in a Topsoe SNOX™ plant. It converts SO₂ into concentrated sulfuric acid. In contrast to other flue gas cleaning methods, SNOX™ operates without consuming absorption materials and without producing liquid or solid waste that would require handling and disposal.

Unlike other flue gas cleaning methods, the economics of SNOX™ gets better the more sulfur content there is in the fuel. At the same time, a boiler supplied with SNOX™ flue gas cleaning is more energy efficient, with a 5-7% higher production of energy than a boiler outfitted with conventional flue gas treatment technologies.

The resulting lower carbon footprint (less CO₂ per kWh of energy produced) and the absence of waste benefit both the climate and environment: It may generate carbon credits too. The SNOX™ process is a variant of the WSA process. This is illustrated in Fig. 3, along with an upstream boiler.

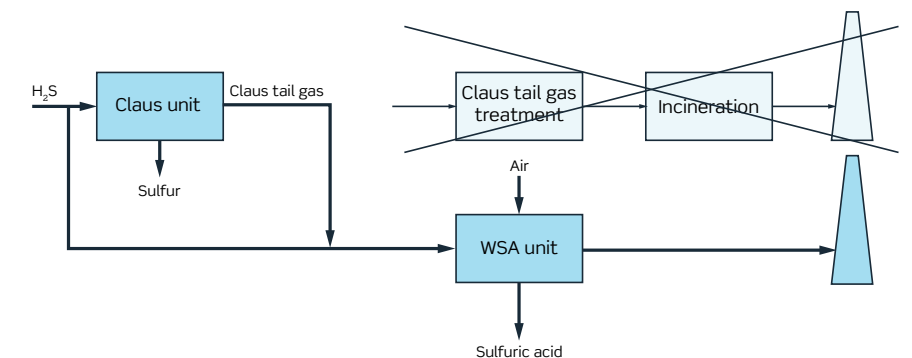


Fig. 2: Sulfuric acid in the WSA plant

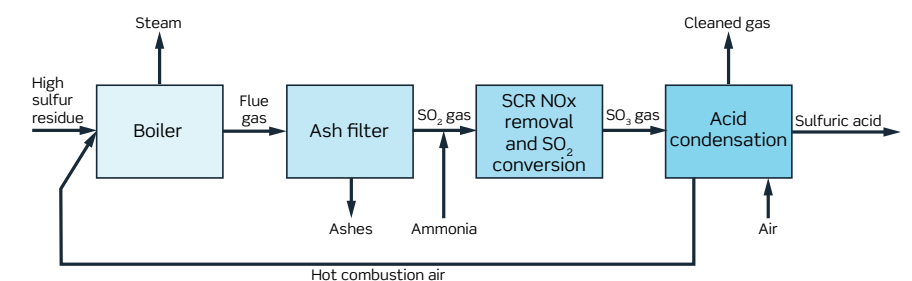


Fig. 3: SNOX™ process

Studies and answers

We recommend initiating a project by conducting a study to gain insights into how different technologies will perform at a customer's facility and to discover which solutions are best.

Relevant topics for investigation could include:

- Cost benefit analysis
- Plot issues

- Integration with upstream and parallel units
- Emissions control
- Tolerances for waste stream feeds

For more information please contact:

Frands Erling Jensen
Senior Licensing Manager
fej@topsoe.com

A cost **effective** way to convert sulfur compounds from oils

Hydrogen technology – Steam reforming hydrocarbons

Treating fuel oils to meet the strict MARPOL sulfur regulations 2020 will require hydrogen. It is by far the most economical way to convert the sulfur compounds found in oil. When this organic sulfur is converted to H_2S , it can be processed into commercial grade sulfuric acid or elemental sulfur.

Special expertise

Treating fuel oils with hydrogen requires specialist knowledge because it involves a risk of significant side reactions. For this reason, both the hydrogen consumption rate and purity specification must be carefully monitored and controlled.

Cost effective solutions

Topsoe offers a range of cost effective and safe technologies for hydrogen production based on steam reforming of hydrocarbons.

We use cutting edge research from our R&D teams as well as our field-proven experience with catalysts and designs to continuously improve the integration of new catalysts with technologies.

Hydrogen technologies for new plants and revamps

Our hydrogen technologies work for new plants and revamps alike. They offer:

- High on-stream, safe and reliable availability
- Low maintenance and upfront investment costs
- Exceptional energy efficiency

- Feedstock flexibility
- Customized designs
- Minimum manpower requirements
- Patented Load Temperature and Management System (LTMS)

Purpose-Designed Platforms

We have four technology platforms for the production of hydrogen. The platform you choose will depend on a variety of parameters, including capacity required, if export of steam is needed or not, the plot size available and on-site construction time.

Small footprint. Greater capacity

The Haldor Topsoe Exchange Reformer (HTER) is a heat exchange steam reformer in which the reaction heat is provided by hot process gas.

The HTER is used in hydrogen plants and configured with a radiant wall steam reformer for additional capacity. The HTER utilizes a bayonet tube for optimal utilization of heat transfer areas. Hot steam reformer effluent is used as heating medium because high pressure enables an effective heat transfer. An integrated HTER unit reduces fuel consumption and steam production and can increase capacity up to 20-30%. This makes HTER ideal for both capacity revamps and new units where factors such as low steam export and compactness are important.

Speed up erection time with skid mounting

Our Convection Reformer (HTCR) is a heat exchange steam reformer in which process gas is heated primarily by flue gas. An HTCR unit is compact

in size and well-suited for new hydrogen units and revamps that increase the capacity of existing plants.

It consists of a number of bayonet reformer tubes contained in a refractory-lined vessel. The heat from the flue gas is transferred to the process gas inside the bayonet reformer tubes, resulting in low feedstock consumption and, importantly, zero steam export. An HTCR unit is often skid-mounted to minimize erection time and on site costs.

More than 30 plants with capacities ranging from 5,000 to 30,000 Nm^3/h (4.5 to 27 MMSCFD) have chosen HTCR.

The industry benchmark for high capacity radiant wall steam reforming

Topsoe's radiant wall steam reformer consists of several catalyst tubes in a single line in one or two fired boxes with burners placed at the walls at several elevations.

The burner flames are directed towards the furnace wall to eliminate any risk of flames striking catalyst tubes. This enables full control over the temperature profile along the entire catalyst tube length. This allows the radiant wall steam reformer to operate at low steam-to-carbon ratios, and for the high average heat fluxes to be unmatched at high outlet temperatures.



More than 250 Topsoe radiant wall steam reformers are operational today

Low hydrocarbon consumption. Little to zero steam export

The Topsoe Bayonet Reformer (TBR) combines the principle of convection heat transfer known from HTCR and radiant heat transfer known from the radiant wall steam reformer.

TBR provides hydrogen production with low hydrocarbon consumption and little or no steam export.

It consists of bayonet reformer tubes in a furnace box heated by radiant wall burners. Improved heat utilization in combination with high average heat flux in the TBR tubes significantly reduces the size and capital cost of the hydrogen plant.





The combination of high-energy efficiency and low steam export results in a uniquely low production of carbon dioxide per unit of hydrogen in the TBR.

Let's discover the best solution possible

It can be hard to know the difference between solutions that are simply feasible — and those optimized to your operations. That's why we recommend conducting a study to provide substantial insights into how different technologies will perform at your facility and which solutions are best. We just have to be aware of the different types of operations and feedstocks that you use, and to collect data about them. They can also help clarify, for example,

if the plot area needed for a revamp or a new unit is adequate. In addition, they will help define the scope of revamps for increasing or changing the feedstock for existing units.

Let's take a deeper dive

Perhaps you have concerns about costs, access to technology and how best to integrate new hardware into your facility. Whatever your challenges, contact us for insights that will help you to deliver a value-adding project.

For more information please contact:

Tim Lyng Sønderby
Senior Proposal Engineer
tlys@topsoe.com

For the shipping industry



Are you MARPOL ready?

NOx reduction

On January 1, 2016, a new era for the marine NOx emission reduction industry began. As the first in the world, the US coast became an IMO Tier III NOx Emission Control Area (NECA).

NECAs will expand around the world in the near future, raising the bar for shipping companies as more than 50% of all new ocean-going vessels will be required to have NOx reduction equipment to be compliant.

The challenge of compliance, solved

Despite the challenging outlook for the shipping industry as a whole, there are actions companies can take to protect their position.

One is the adoption of Selective Catalytic Reduction (SCR), a technology proven to effectively reduce NOx from marine vessels. Yet only on a few thousand marine engines are equipped with SCR today. That may be set to change, as MARPOL makes it more relevant than ever.

Helping leading companies stay ahead

Topsoe introduced the first Tier III compliant SCRs in 1988. Since then, we have further refined the technology to optimize integration with marine boilers and scrubbers.

This has enabled problem-free SCR operation, even on heavy fuel oil (HFO) and with SCR positioned before or after the turbo charger.

Create the future

We expect that several types of fuel will be used many years ahead, and that the industry will adopt even greater integration of SCR technologies with engines, boilers and scrubbers.

Towards this end, we are actively involved in a concerted effort to combine engines and SCR with particle reduction technologies into compact solutions that will have a significant impact on air quality on sea and in coastal areas. That being said, we recognize that the integration of such different processes will require close collaboration between multidisciplinary teams.

Our R&D teams are already innovating around the clock in partnership with a diversity of engineering disciplines and external partners.

Our ambition is to begin similar studies with interested clients. To learn more, why not contact us today?

For more information please contact:

Henrik Trolle
Sales Manager
htj@topsoe.com



Deal **efficiently** with soot from heavy fuel oil

Soot and particulate removal

Shipping, unlike land-based transportation, has not been subject to strict environmental regulations. It isn't simply a question of whether or not companies were prepared to pay for technology improvements to reduce emissions. In fact, the technology was simply not available.

Things are about to change

Ships using heavy fuel oil (HFO) emit harmful black emissions of particulate matter (PM), including soot and NOx. These are known to cause severe health hazards and contribute to global warming.

Unfortunately, without operational technology, removing particulate pollutants was technically infeasible. This has now changed.

Sail ahead with HFO with ultra-low emissions

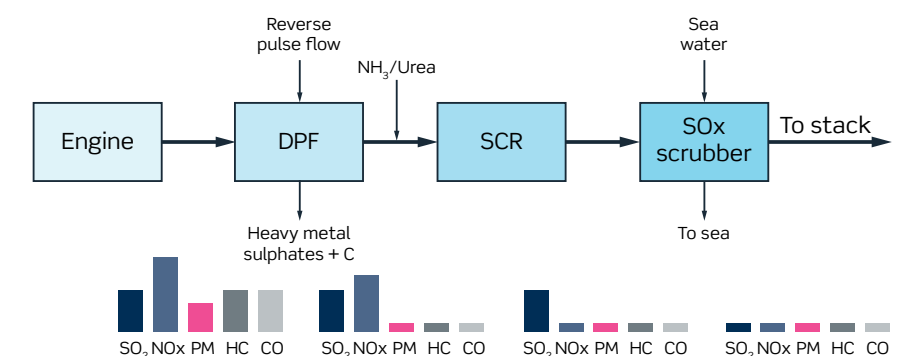
Topsoe and our Italian partner Ecospray have launched a groundbreaking PM/soot filtration process technology that tackles this problem. One combined unit significantly reduces all harmful emissions from marine vessels.

The technology houses our patented BMC-101 catalyzed filter coating that passively combusts soot trapped in the filter at 350° – 420°C together with the frequent reverse flow of formed metal sulfate ash. Once installed aboard ships using HFO, the process eliminates up to 95% of soot emissions, along with poisonous hydrocarbons (PAHs) and a wide range of heavy metals including vanadium, iron, nickel, silicon and sodium.

Synergy with scrubbers

Removal of soot and heavy metal ash from a marine engine using HFO has a significant synergy with the SOx scrubber, as it can be operated in open flow mode. Soot, PAHs and

heavy metals are removed upstream from the scrubber in compliance with IMO regulations. A full marine exhaust system is shown in the illustration below.



Proven seaworthy

The technology has been installed on a new-build cruise ship, the AIDA Prima, since June 2016. The ship is partly fueled with HFO and partly with marine diesel oil and has a two 4-stroke 12 MW diesel electric engine.

Profit from our experience

To find out whether or not our patented PM & soot filtration process technologies are right for your company. We could start by exploring:

- Soot and NOx removal together with scrubbers

- Possibilities for soot removal in and around harbors
- Retrofit design in existing ships

Let's talk about your expectations for efficient soot and particulate removal.

For more information please contact:

Henrik Trolle
Sales Manager
htj@topsoe.com

Haldor Topsoe is a world leader in catalysis and surface science. We are committed to helping our customers achieve optimal performance. We enable our customers to get the most out of their processes and products, using the least possible energy and resources, in the most responsible way. This focus on our customers' performance, backed by our reputation for reliability, makes sure we add the most value to our customers and the world.



Get in touch today
www.topsoe.com/MARPOL

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