Improving energy efficiency in diesel hydrodesulfurisation

Optimising heat recovery across the reactor and fractionation sections can reduce fuel consumption, emissions, and pressure drop while helping refiners make better use of existing assets. **Marcos Matsufugi and Jay Jeong, Alfa Laval,** explain.

Diesel hydrodesulfurisation (HDS) has been central to North American fuel production for nearly two decades. The US began phasing ultra-low-sulfur diesel into the highway market in 2006, while Canada introduced closely aligned requirements. Today, on-road diesel across both countries is generally limited to 15 ppm sulfur, enabling advanced exhaust aftertreatment systems to control particulate matter and nitrogen oxides effectively.

Producing compliant fuel remains technically and economically demanding. Refineries must maintain sulfur conversion as feed composition and catalyst activity change, while managing hydrogen, heater, compressor, and utility constraints. Operators must also reduce energy use and direct emissions without compromising throughput or reliability.

This is especially relevant across North America's mature refining base. Improvements will often come from modernising and debottlenecking existing units. In HDS, optimising heat recovery in the high-pressure reactor loop and low-pressure fractionation section can reduce utility demand and preserve equipment capacity, with a positive impact in the refinery's margins.

Heat recovery in the reactor loop

HDS removes sulfur by reacting sulfur-bearing molecules with hydrogen over a catalyst at elevated temperature and pressure. Feed is mixed with hydrogen-rich gas, preheated, and passed through a fired heater before entering the reactor. The effluent is then cooled and separated, with treated liquid passing to a stripper or fractionator.

The combined reactor feed/effluent exchanger is central to this process. Hot effluent leaving the reactor contains energy that is transferred to the colder feed and hydrogen mixture. Every unit of heat recovered reduces the additional duty required from the fired heater and the cooling duty required downstream.



Many HDS units use shell-and-tube exchanger trains for this service. While proven, this arrangement is not thermally efficient and is constrained by surface area, pressure drop, fouling, and plot space. Additional shells can also increase the installation CAPEX.

Thermal performance is commonly assessed by monitoring the hot-end approach temperature (HAT), the difference between the hot reactor effluent entering the exchanger and the heated feed leaving it. A smaller approach indicates greater heat recovery and a higher feed temperature at the fired-heater inlet.

Alfa Laval's Packinox is a large, welded plate heat exchanger designed for this high-pressure feed/effluent duty in HDS units. According to application data, the heat exchanger can achieve a HAT as low as 5°C (9°F), compared with approximately 30°C (54°F) for a conventional shell-and-tube train in an illustrative design. Depending on the process, the additional heat recovery reduced reactor-preheater fuel consumption and release capacity in the heater and downstream cooler. Lower pressure drop can also preserve recycle-compressor capacity. Actual results depend on the feed, operating conditions, and existing equipment.

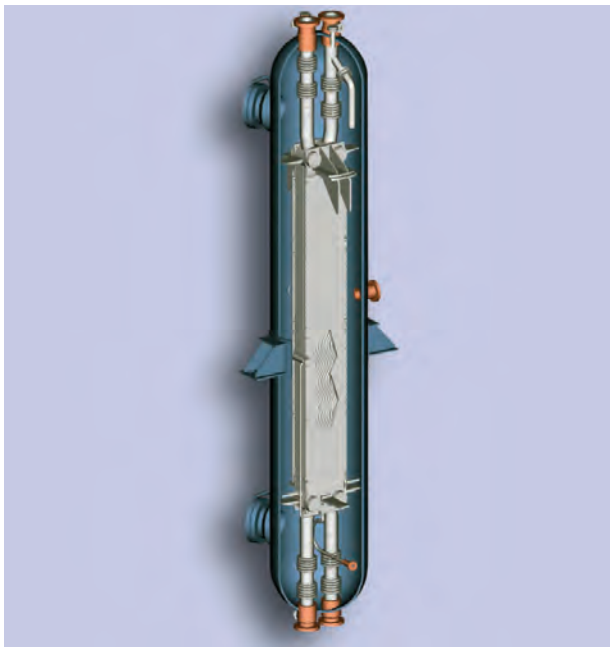


Figure 1. Packinox internal view.

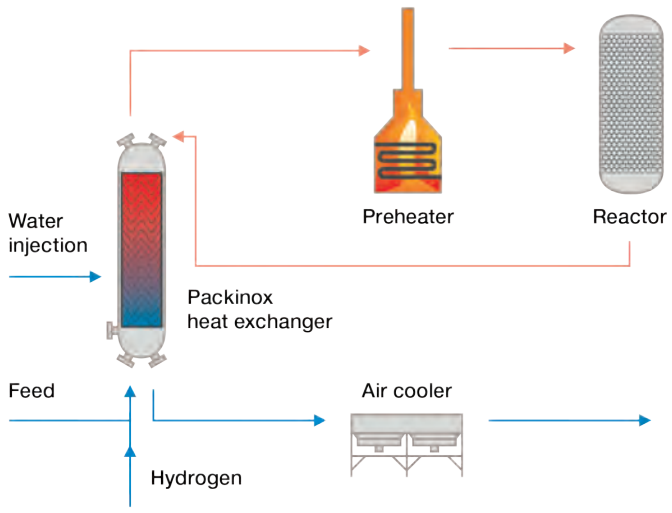


Figure 2. Packinox HDS diagram.

Fouling can affect that performance over time, particularly if ammonium salts accumulate on the effluent side of the exchanger at lower temperatures. Alfa Laval's PlateWash is an integrated cleaning system developed for Packinox in HDS services. By monitoring exchanger pressure drop, operators can identify when deposits begin to accumulate and initiate a water washing process during operation. This device allows the plates to be cleaned on-line, without stopping the unit, helping to maintain heat-transfer performance and avoid unplanned shutdowns.

Asian refinery case study

The refinery constructed two 63 000 bpd diesel hydrotreating units processing straight-run diesel blended with approximately 25 - 30% light cycle oil and light coker gas oil. Its objective was to limit CAPEX while maximising energy efficiency.

Instead of five shell-and-tube feed/effluent exchangers in each unit, the refinery installed one Packinox per train. This increased the fired-heater inlet temperature from 305°C to 350°C and reduced overall pressure drop from 18 bar to 11 bar. Furnace duty fell by approximately 80%, while compressor power consumption decreased by about 40%.

Across the two units, the reported energy saving was 15.5 MW. Using an assumed furnace efficiency of 85%, energy cost of €50/MWh and natural-gas firing, Alfa Laval calculated annual fuel and power savings of €6.8 million and avoided carbon dioxide emissions of 25 000 t.

Five years later, the refinery expanded sulfur-removal capacity by adding a second reactor to each train. With plot space restricted, it added another Packinox to each unit. Operating data showed a HAT generally between 5 - 15°C from 2007 to 2017, with limited fouling tendency and stable pressure-drop performance. The four units have accumulated between 16 and 22 years of operation.

Optimising the fractionation section

Further opportunities exist in the low-pressure stripper or fractionation section. Alfa Laval applies its Compabloc fully welded plate heat exchangers in duties including feed/bottoms interchanging, overhead condensation, product cooling, reboiling, and waste-heat recovery.

The feed/bottoms interchanger is often the first position to evaluate. Recovering heat from the hot fractionator bottoms to preheat the incoming feed reduces the load on both the final product cooler and fractionator reboiler. Maximising this duty with shell-and-tube technology may require several large exchangers, making the project costly or difficult to accommodate. A fully welded plate exchanger can accommodate temperature profile of seven to eight shell-and-tube exchangers in series configuration,