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**REFINING
GAS PROCESSING
PETROCHEMICALS**

**ENHANCED ENERGY RECOVERY
FOR CRUDE PREHEATING**

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Enhanced energy recovery for crude preheating

Replacing shell and tube heat exchangers with a compact welded exchanger increased heat transfer efficiency and reduced fouling issues in a crude unit

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The Preem refinery in Lysekil is a modern refinery of high complexity, located on the west coast of Sweden. In 2010, the company conducted a refinery-wide energy analysis study, covering among other process units a 11 million t/y integrated atmospheric and vacuum distillation unit, with two parallel trains for crude preheating. This study concluded that by increasing the recovery of energy from the column bottom reflux into crude, Preem would not only improve the energy efficiency by preheating the crude to a higher temperature before the furnace, but would also offload the top section of the distillation column and thereby reduce the overhead pressure drop. This latter parameter means that the refiner could reduce the flash zone pressure in the column and thereby increase the yield of heavy gasoil over light vacuum gasoil, a more valuable product that would increase the refinery's profitability.

The original shell and tube heat exchanger was designed to

preheat crude from 189°C to 208°C, recovering 8.5 MW from the bottom reflux. The heat transfer area was 308 m², the diameter was 950 mm, and the tube length was 7315 mm.

The new heat recovery service would instead recover 21.2 MW from the bottom reflux, preheating the crude from 192°C to 234°C.

As in all other refineries, the Preem crude preheat train does not have a lot of plot space available for adding/increasing heat transfer area for more energy recovery. Instead, the refiner decided to go for an unconventional heat transfer solution, using a high efficiency compact welded plate heat exchanger called Compabloc.

In Preem Lysekil refinery, Compabloc exchangers had already been in service as lean/rich amine interchangers in the amine regenerator system and sulphur recovery unit since 2006 and 2008 respectively. Because the exchangers were performing well, Preem had no doubts other than to use the same

technology for this revamp of the crude preheat train.

As the Compabloc exchanger would recover so much more energy from the bottom reflux into the crude, one downstream shell and tube heat exchanger could be removed from the preheat train, and the new Compabloc with a plot space of 2.0m x 2.0m was installed in its place (see Figures 1 to 3).

In addition, another of the downstream services, recovering energy from heavy vacuum gasoil into crude in two shell and tube exchangers in series, could be moved to the preheat train A, providing additional preheating in this line.

Finally, in order to maximise the reliability of the new preheat train design, the original shell and tube heat exchanger recovering energy from the bottom reflux for crude preheating was kept on standby for the new Compabloc exchanger.

The Compabloc exchanger was installed at the end of 2013 and, since the beginning of 2014, it has been operating at full capacity. In

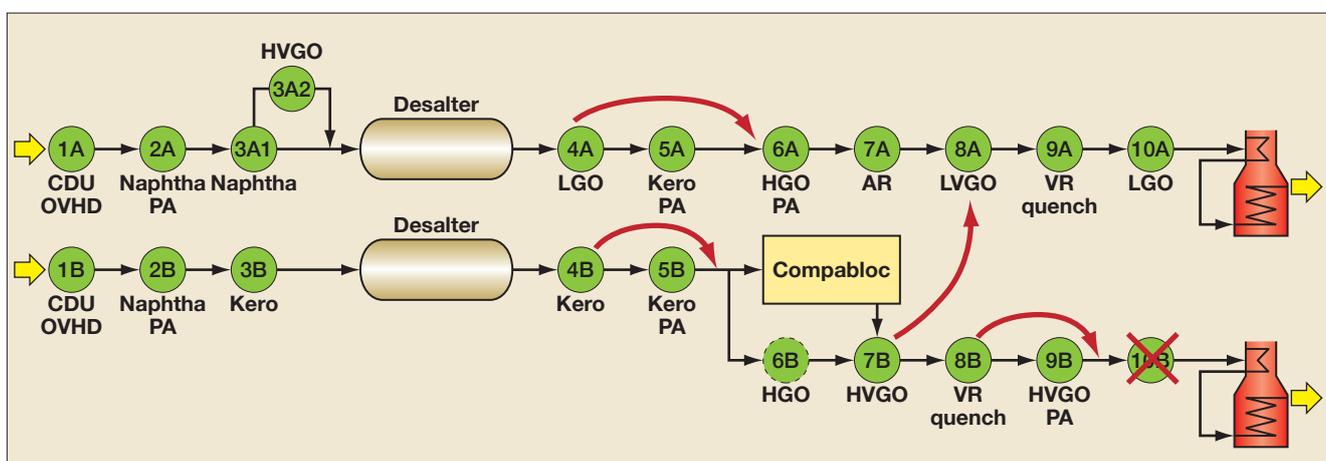


Figure 1 Modifications to crude preheat trains A&B post desalters

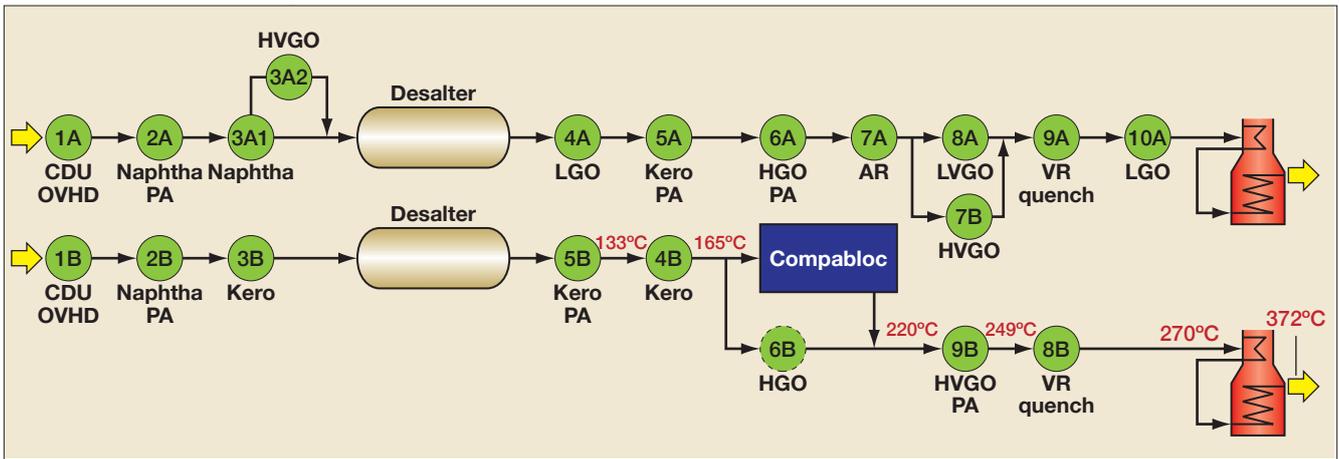


Figure 2 Layout of crude preheat trains A&B post desalters after revamp

February 2017, it was taken out of service for a first internal inspection, as per Preem's safety regulations.

Looking at the average operating data for these first 34 months of operation, it can be seen that the performance is very stable without any tendency to fouling.

Table 1 shows that the average operating performance in terms of heat duty and logarithmic mean temperature difference (LMTD) is very similar to expected design values. The crude outlet temperature is 10°C lower than design values,

which can be explained by the lower crude inlet temperature, the lower bottom reflux to crude flow ratio and the overall lower flow rates, reducing the heat transfer efficiency of the exchanger slightly.

During the period when the Compabloc was taken out of service for inspection, the original shell and tube heat exchanger was put back into service. This was another improvement made to the pre-heat train during the revamp. By installing the new exchanger with block valves on both sides, it can

easily be taken out of operation for cleaning or inspection, without having to interrupt the operation of the plant.

Figure 4 shows the fouling tendency of the shell and tube exchanger in comparison to the fouling tendency of the Compabloc exchanger, when in operation.

Fouling in crude heat exchangers is very much related to crude temperature and crude shear stress in the heat transfer channel. The higher the crude temperature, the higher the fouling tendency, and the higher the shear stress in the heat transfer channels, the lower the fouling tendency.

As Figure 4 shows, the Compabloc exchanger suffers less from fouling than the original shell and tube heat exchanger, even though the crude outlet temperature from the latter was more than 20°C lower than from the Compabloc exchanger and the shell and tube exchanger operated with a slightly higher (5%) crude flow rate.

The lower fouling tendency of the Compabloc exchanger was also confirmed during internal inspection of the heat transfer channels, when Preem was expecting to find more fouling material.

In summary, the main advantages of the new exchanger in the Preem crude preheat train are:

- High heat transfer efficiency: one Compabloc replaced four shell and tube exchangers and provided in total 7 MW more than the original exchangers.
- Compact design: one Compabloc recovering 21.2 MW into crude pre-

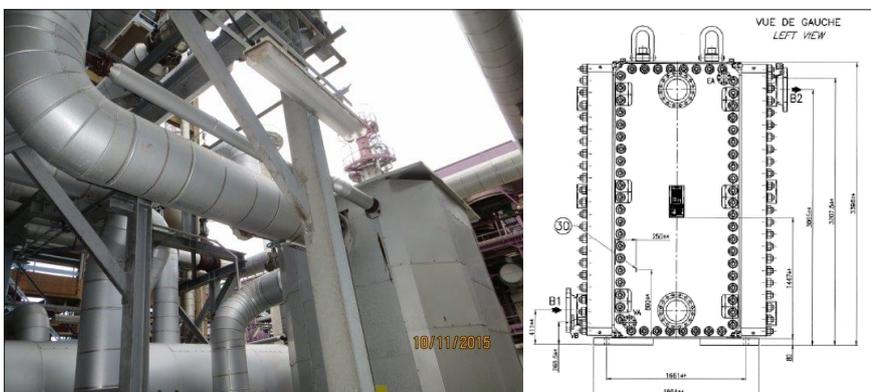


Figure 3 Compabloc installed in Preem's CDU preheat train B, and outer dimensions as per the drawing

Design data vs average operating data

	Design	Operating (Apr 2014 – Feb 2017)
Bottom reflux flow, kg/h	484 645	401 016* (455.7)
Crude flow, kg/h	696 763	604 620* (671.8)
TG in/out temp, °C	265/207	264.6/191.8
Crude in/out temp, °C	192/234	170.8/224.3
Heat duty,** MW	21.2	22.5
LMTD, °C	21.4	29.6

* Mass flow rates are calculated based on measured volumetric flows (m³/h, in brackets) and fluid density at 15°C.
 ** Heat duty is calculated based on operating data and fluid specific heat at average operating temperature.

Table 1

Welded plate heat exchangers

The design of Alfa Laval's Compabloc heat exchanger makes it capable of operating at high temperatures with a wide range of aggressive media and under high pressure (up to 400°C and 42 bar).

The exchanger delivers three to five times higher heat transfer efficiency (per surface area) than a shell and tube exchanger and can handle temperature approaches (the temperature difference between hot and cold fluid) as low as 3-5°C, which allows for maximum energy recovery. The high shear stress in the heat transfer channels also results in significantly less fouling, which means the Compabloc can typically operate three times as long between maintenance/cleaning operations.

The compactness of the plate exchanger means that it can normally be installed even where plot space is limited. A maximum 15m² plot space, including service space, is required for 850m² of heat transfer surface, equivalent to 4000m² of shell and tube heat transfer area.

Today there are more than 1000 Compabloc exchangers installed in atmospheric and vacuum distillation units and more than 25 preheat trains where every single heat exchanger is of this type.

heating could fit into a plot space of only 2m x 2m. In addition, no service space was needed to pull out the tube bundle. Only a service area of 1m around the exchanger is required to remove the panels with a normal crane.

- Reduced cost: increased energy recovery of 7 MW means reduced fuel consumption in the fired heater for an annual cost saving of \$2.2 million and CO₂ emissions reduced by 14 600 t/y.
- Reduced fouling tendency: meaning that the energy efficiency is more constant over time, and the

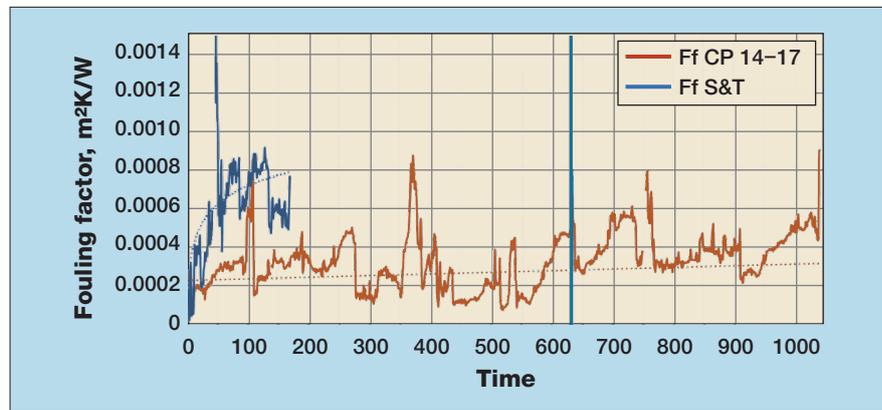


Figure 4 Fouling trend in Compabloc vs original shell and tube exchanger during inspection

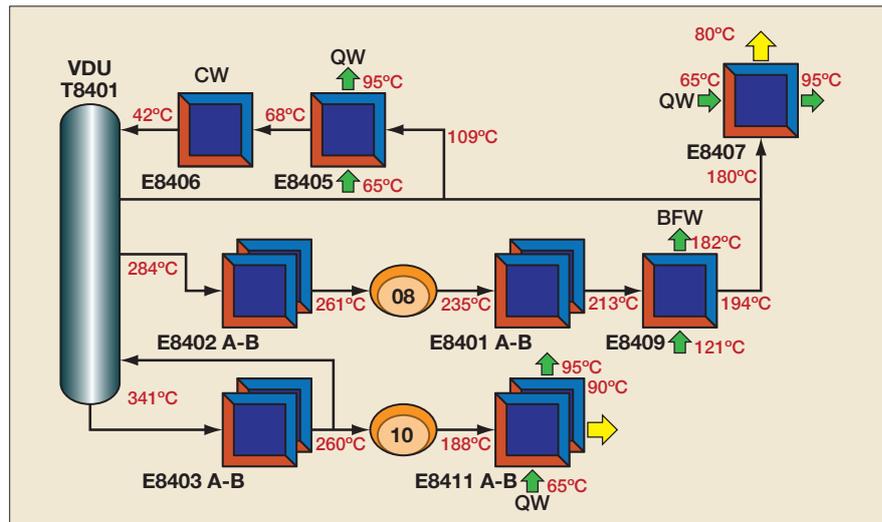


Figure 5 Layout of Preem's new VDU

cost of maintenance and cleaning is reduced.

Based on its experience with Compabloc welded plate heat exchanger technology in this crude preheating service, Preem has also decided to use the technology in greenfield projects.

In the second half of 2018, Preem will start up a new grassroots vacuum distillation unit with a capacity of 1.75 million t/y. In this process, all heat exchangers in the preheat train plus one boiler feed water (BFW) preheater and four cooling water (QW/CW) exchangers will be Compabloc heat exchangers, mean-

ing a total of 12 new units in total. For all the preheat train services, there is 100% spare capacity, while for all other services single exchangers will be used (see Figure 5).

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