COLD SEPARATION CHALLENGES *Resolved*

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At a petroleum refinery in South Asia, the diesel hydrotreating (DHT) process removes sulfur, nitrogen, halides, oxygenates, and metal compounds from diesel feedstock, thereby reducing sulfur oxide (SO_X) and nitrogen oxide (NO_X) emissions during diesel engine combustion.

Operating under medium pressure and moderate temperature, the feed is mixed with hydrogen and passed over a catalyst in the DHT reactor. In this process, sulfur is converted into hydrogen sulfide. The excess hydrogen exiting the reactor is compressed and recycled back into the feed stream.

Post-reaction, the reactor effluent undergoes partial cooling and quenching through water injection. Air-fin coolers then condense the evaporated water and hydrocarbons, yielding a hydrogen-rich gas phase. This produces a three-phase mixture that is directed to the cold separator, where vapour, liquid water, and liquid hydrocarbons are separated.

Separated water is routed to a sour water recovery unit, where hydrogen sulfide and ammonia are removed. The hydrogen-rich gas from the cold separator moves to the recycle gas unit and amine unit for further processing. Figure 1 provides an overview of the reactor and three phase separators.

Challenges with existing cold separator performance

The original design of the cold separator incorporated a parallel plate coalescer, manufactured by a local vendor, to facilitate the separation of hydrocarbon and water phases. Figure 2 illustrates the arrangement of the parallel plate coalescer. In practice, however, the system exhibited suboptimal performance, resulting in significant water carryover into downstream units together with the hydrocarbon stream entering the heat exchangers. This carryover led to severe scaling and corrosion within the heat exchangers, alongside increased maintenance requirements and elevated operating costs.

To assess the limitations, Koch-Glitsch evaluated the existing cold separator arrangement equipped with a parallel-plate coalescer by analysing its flow rate, phase-separation efficiency, residence time, and internal velocities. The parallel plate coalescer consisted of a series of parallel plates inclined at 30 - 45° and installed inside the separator vessel. As water droplets rise by buoyancy or fall by gravity, they encounter these plates, which promote coalescence and enhance phase separation.

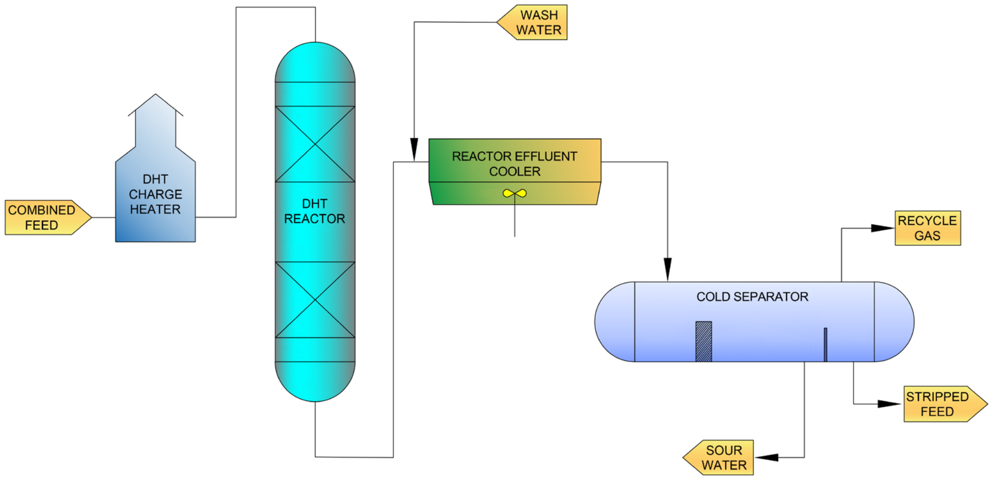

Figure 1. Overview of the DHT unit.

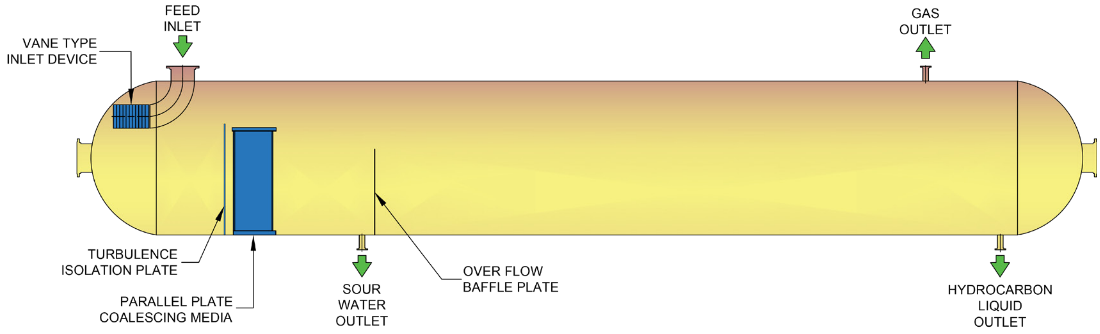

Figure 2. Cold separator arrangement before revamp.

Parallel plate coalescers operate most effectively when the density difference between the aqueous and hydrocarbon phases exceeds 300 - 400 kg/m^3, and when the hydrocarbon stream contains only minimal amounts of finely dispersed water droplets.

In this case, the density difference was approximately 180 kg/m^3, which is significantly lower than the ideal range. Additionally, the feed entering the separator was expected to contain fine water droplets. Very small droplets (<5 µm) have low settling velocities and often do not remain in the separator long enough to be effectively captured by the parallel plate, frequently bypassing the coalescer altogether. Because of their minute size and high stability in the hydrocarbon phase, these droplets tend to follow the bulk fluid streamlines rather than settling out. As a result, they escape the intended coalescence mechanism, pass through the separator with the hydrocarbon stream, and contribute to downstream water carryover. This ineffective phase separation not only reduces the efficiency of the coalescer but also exacerbates operational issues such as scaling, corrosion, and increased maintenance in downstream equipment.

The estimated residence time of the hydrocarbon phase in the existing arrangement was less than 4 min., which is insufficient for effective phase separation. Consequently, the parallel plate coalescers configuration failed to achieve the desired water-hydrocarbon separation in the cold separator. The analysis indicated that the short residence time within the vessel was a primary factor contributing to poor phase separation and water carryover. Extending the residence time was identified as a potential solution for improving separation efficiency.

As part of an initial evaluation, separation performance was improved by repositioning the partition baffle away from the parallel plate coalescer, thereby creating a larger settling zone for the aqueous phase. This modification increased the residence time by around 4 min. and resulted in a noticeable reduction in water carryover – from 12 000 ppmv to 4000 ppmv in the hydrocarbon phase. Table 1 illustrates that the baffle plate rearrangement substantially reduced water carryover, confirming that increased residence time enhanced phase separation efficiency. While this adjustment provided measurable benefits, it was considered a preliminary measure with limited scope.

To further minimise water carryover in the hydrocarbon phase, the upstream water injection rate was reduced to less than half of its original value. This adjustment successfully lowered the water carryover in the hydrocarbon phase to nearly one fifth of the previous level. However, the reduced injection rate raised concerns regarding salt deposition downstream. Consequently, the water injection was restored to its original level to ensure adequate salt dissolution at the injection point. Despite these corrective measures, water carryover persisted as a significant issue. A comprehensive evaluation of the cold separator's performance was therefore undertaken, analysing key parameters such as vessel sizing, flow rates, and the coalescing media. The assessment revealed that the existing parallel plate coalescer was inefficient for phase separation, prompting consideration of alternative options to enhance separation effectiveness.

Table 1. **First modification effectiveness**

Parameter	Existing equipment	After modification (baffle plate)
Vessel diameter	3.3 m	3.3 m
Coalescing media	Parallel plate	Parallel plate with longer settling zone
Pressure drop across media	<2 mbar	<2 mbar
Water carryover at hydrocarbon outlet	12 000 ppmv	4000 ppmv

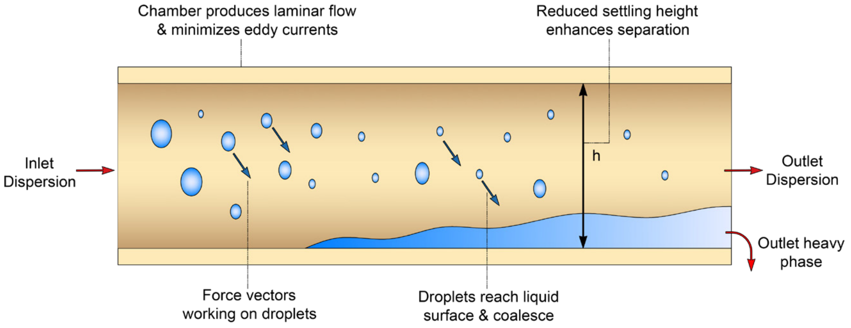

Figure 3. Working of KY-FLEX liquid-liquid coalescing media.

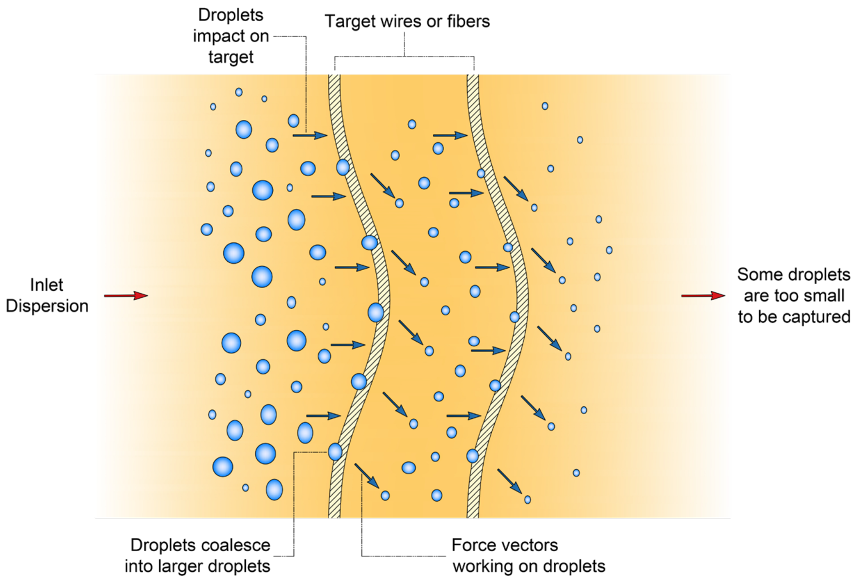

Figure 4. Working of KY-MESH liquid-liquid coalescing media.

Considerations for coalescer selection

The selection of an appropriate coalescer is critical for the efficient separation of immiscible liquids such as hydrocarbon liquid and water. Key design considerations include fluid properties – density difference, viscosity, and interfacial tension – as well as droplet size distribution, which is strongly influenced by upstream equipment. Operating conditions such as temperature and pressure further affect fluid behaviour and separation efficiency. Accurate sizing requires evaluation of flow rates for both continuous and dispersed phases, together with sufficient residence time to promote effective coalescence. Contaminant loading and fouling potential also influence maintenance frequency and long-term reliability. In addition, practical aspects such as installation constraints, cost, and environmental compliance must be addressed to ensure sustainable operation.

The existing parallel plate coalescer separator relied primarily on the density difference between the hydrocarbon and aqueous phases to achieve separation. In the cold separator, this density difference was approximately 180 kg/m^3, which proved inadequate for effective disengagement and gravitational settling of fine water droplets. Furthermore, the dispersed phase accounted for less than 10% of the total stream, further limiting separation efficiency.

To address these limitations, alternative solutions were evaluated with the objective of maintaining laminar flow and minimising the travel distance required for dispersed droplets to reach the interface,

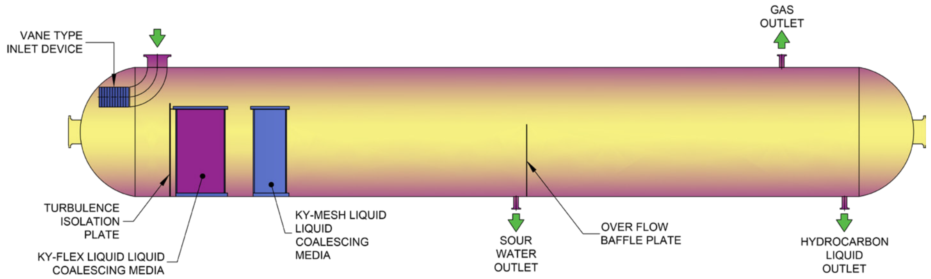

Figure 5. Cold separator arrangement after revamp.

Table 2. Comparison of modification effectiveness

Parameter	Original parallel plate	Parallel plate with adjusted baffle	KY-MESH and KY-FLEX media
Vessel diameter	3.3 m	3.3 m	3.3 m
Coalescing media	Parallel plate	Parallel plate with longer settling zone	KY-MESH and KY-FLEX liquid-liquid coalescing media
Pressure drop across media	<2 mbar	<2 mbar	< 5 mbar
Water carryover at hydrocarbon outlet	12 000 ppmv	4000 ppmv	< 15 ppmv

thereby accelerating coalescence. Among these, the KY-FLEX® liquid-liquid coalescing media was assessed for its ability to enhance hydrocarbon-water separation. The media operates by facilitating the rise of hydrocarbon droplets in the aqueous phase to the hydrocarbon-water interface, while simultaneously promoting the settling of water droplets in the hydrocarbon phase. Figure 3 illustrates the working principle of the KY-FLEX liquid-liquid coalescing media.

Given the relatively low-density difference between the hydrocarbon and aqueous phases, along with the presence of a smaller dispersed phase, the liquid-liquid coalescing media was identified as an effective option for bulk phase separation. It promotes the disengagement of immiscible liquids under such conditions; however, very fine droplets are not efficiently captured by this media alone. To address this limitation, a downstream stage incorporating KY-MESH liquid-liquid coalescing media was evaluated.

KY-MESH liquid-liquid coalescing media, composed of wire mesh, provides a high surface area with numerous collision sites where fine droplets can aggregate, coalesce into larger droplets, and subsequently settle more readily. Figure 4 illustrates the working principle of the product. The integration of KY-FLEX and KY-MESH liquid-liquid coalescing media thus offers a complementary solution: KY-FLEX liquid-liquid coalescing media effectively manages bulk phase separation, while KY-MESH liquid-liquid coalescing media captures and removes finer dispersed droplets that would otherwise bypass the primary stage.

The solution also considered the use of turbulence isolation plate which ensures a quiescent flow regime within the separator, preventing turbulent mixing of phases and enabling the downstream KY-FLEX liquid-liquid coalescing media and KY-MESH liquid-liquid coalescing media to operate under optimal conditions. The combined arrangement provided a technically robust solution, justified by the need to address both bulk separation and fine droplet removal, thereby improving overall phase separation performance in the cold separator.

A solution combining both products, together with a turbulence isolation plate, was implemented to enhance phase separation efficiency. Figure 5 provides details of the arrangement. The solution was installed in the existing cold separator with only minor modifications, utilising welded tower attachments. In addition, the partition baffle height was reduced to minimise interference with the feed inlet and to prevent re-entrainment, thereby improving separation performance. Following installation, the vessel demonstrated a significant improvement, with water carryover at the hydrocarbon outlet reduced to below 15 ppm. Table 2 presents the detailed performance results after installation of both products.

Conclusion

The performance of cold separators and coalescing vessels is critical to protecting downstream equipment, minimising corrosion and scaling, and preventing unplanned shutdowns. Achieving reliable separation efficiency requires careful consideration of fluid properties, operating conditions, and equipment design, supported by proven coalescing technologies.

In this study, the integration of KY-FLEX liquid-liquid coalescing media for bulk phase separation and KY-MESH liquid-liquid coalescing media for fine droplet removal, together with a turbulence isolation plate, provided a robust solution to the limitations of conventional parallel plate coalescer. The implemented modifications – including optimised residence time and improved flow regime – resulted in a substantial reduction in water carryover and enhanced overall phase separation performance.

This outcome demonstrates that combining advanced coalescing media with thoughtful vessel internals design can significantly improve process reliability and operational continuity under challenging service conditions. Leveraging subject matter expertise and adopting field proven solutions remain essential for ensuring dependable, efficient, and sustainable operation in refinery applications.

Note

KY-FLEX® liquid-liquid coalescing media is a trademark owned or licensed to Koch-Glitsch, LP.