EQUIPPED FOR A CLEANER FUTURE

Patrick Downey, Elessent Clean Technologies, USA, introduces a sustainable solution for producing cleaner fuels.

A new age of fuel production is here with the introduction of policy changes pushing refineries to reduce emissions and ultimately achieve net zero goals. These policies include compliance and voluntary carbon markets that play an important role in driving refineries to make investments towards a more sustainable future. The carbon markets utilise tax credits that are available to refineries that can produce fuels in a more efficient and sustainable manner. One avenue to receiving carbon market tax credits is to improve energy efficiency by reducing emissions generated through utilities. This can be done by measuring and optimising utility consumption, such as fuel gas, steam, cooling water and electricity, and then converting to the equivalent amount of carbon dioxide (CO_2) emissions that were reduced. In addition to this, traditional fossil fuel feedstocks can be replaced by feedstocks made from renewable resources that are harder to process, such as vegetable oils, bioethanol, and animal fats, but that are also eligible as carbon market tax credits. As the market undergoes further energy transition and evolving policy enforcement, it will be important for the refining sector to explore more economical processes to produce fuel.

This article describes the principles of the IsoTherming® hydroprocessing technology and highlights the energy efficiency, versatility and robustness of the process. Two recent revamp case studies will be showcased that demonstrate its benefits, specifically in the areas of energy efficiency and the ability to process difficult feedstocks into Euro VI compliant fuels. In addition to this, refiners across the globe are under pressure to look for ways to comply with renewable fuels mandates. The technology is well suited to provide refiners with a cost-effective option for co-processing renewable feedstocks in the existing hydrotreater units, and is capable of managing the high heat of reaction that comes with processing these renewable components, which has proven to be a challenge to those operating hydroprocessing units with the traditional trickle bed technology. A discussion of co-processing renewable components and its impact on unit design and operation will also be presented.

Figure 1. An IsoTherming reactor in commercial service.

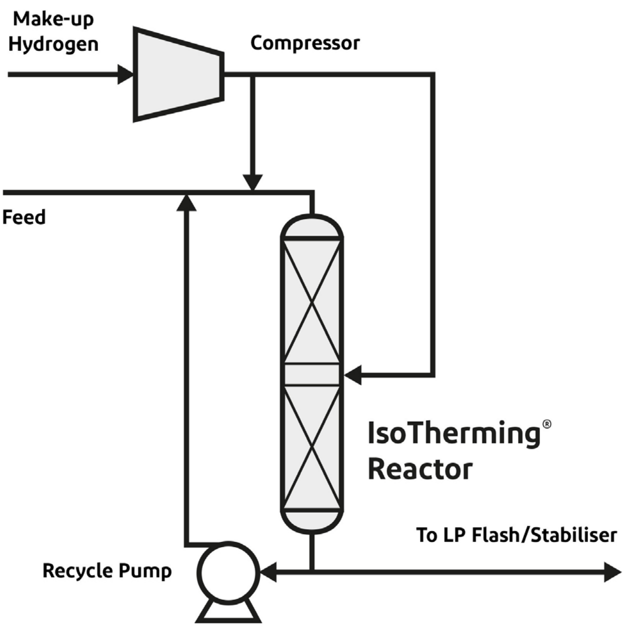

Figure 2. An IsoTherming reaction zone.

Introduction to the technology

IsoTherming hydroprocessing technology is a commercially-proven process that provides refiners worldwide with a more economical means to produce today's transportation fuels. Implementing this technology enables refiners to not only produce high-quality, low-sulfur fuels that are compliant with local environmental regulations, but also decrease energy consumption and operating costs when compared with historical trickle bed hydroprocessing technologies. The proven reliability and operational flexibility of the technology also enables refiners to meet business sustainability and social responsibility objectives.

The fundamental principle of the technology is the ability to provide the hydrogen that is necessary for chemical reactions using a liquid stream, rather than a recycle gas system. The reactor feed is saturated with hydrogen, which eliminates the need for a recycle gas compressor and amine absorber. To satisfy hydrogen requirements within the reactor, additional hydrogen can be added by means of an external liquid recycle stream and/or inter-bed hydrogen injection. Feed types that have low hydrogen demand, such as kerosene, do not require an external recycle stream to satisfy hydrogen availability requirements.

Operating the reactor liquid-full also acts as a heat sink for the exothermic reactions. Thus, the reactor operates closer to isothermal conditions, which reduces uncontrolled cracking reactions and lowers the production of light ends.

The type of hydroprocessing application, product objectives, and chemical hydrogen requirements dictate optimal reactor design considerations, such as number of catalyst beds and recycle ratio. The IsoTherming reactor design is robust and has been commercially-proven to successfully provide over 160% of design chemical hydrogen consumption, while processing fluctuating feedstocks. This flexibility offers refiners the ability to process a wide variety of feeds to maximise refinery profits.

The technology currently has 29 licenses comprised of 24 grassroots units and five revamp units. There are 16 commercial installations of the technology currently in operation. The following case studies will detail how two refineries have revamped their existing hydroprocessing units.

Case study 1

The first case study is for Refinery A, located in Western Europe. Refinery A has an existing trickle bed diesel hydrotreater that lacks a recycle gas compressor. This unit currently produces ultra-low-sulfur diesel with poor cycle length. Even at reduced throughput rates, current cycle lengths range from 12 to 14 months. An evaluation by catalyst suppliers concluded that a catalyst upgrade by itself could not achieve the desired product and operating targets due to unit constraints. Therefore, the refinery decided to evaluate the option of a unit revamp for its low-pressure diesel hydrotreater unit.

Refinery A extensively studied the revamp solution with the current trickle bed technology, and compared this to a revamp solution offered by Elessent Clean Technologies with the IsoTherming technology. A full conversion of the unit to liquid phase with this technology would provide the customer with extended cycle length, as well as a return to nameplate capacity and the ability to process cracked feedstock. A summary of the key benefits can be seen in Table 1.

Feedback from Refinery A indicated that the proposed trickle bed revamp solution was more capital cost intensive and comprised a longer list of new equipment, including a new recycle gas compressor (and associated high-pressure auxiliary equipment, such as an amine absorber and heat exchangers). Even with a new recycle gas compressor, the trickle bed technology was unable to offer the same extension in cycle length at the nameplate capacity as the IsoTherming technology, and additional catalyst volume or reduced feedstock rates were required to meet a similar cycle length.

In addition to offering a low capital cost, revamping with the IsoTherming technology provides additional operating efficiency benefits to Refinery A. The feedstock under review has very high levels of hydrogen consumption and thus a high volume of heat release. Due to the energy-efficient nature of the IsoTherming technology, coupled with this high level of heat release, the feed-fired heater is only required to operate at minimum operation rates outside of start-up conditions. Even at this minimum rate, there is surplus heat after pre-heating the feed. As such, a cost/benefit analysis was conducted, and it was deemed economical to utilise the excess heat from the reaction to produce medium-pressure steam in the unit. Table 2 quantifies the high-pressure energy savings expected post-revamp with the new technology, compared against current trickle bed operation.

Based on the assumed cost values of fuel gas and steam, the revamp would save Refinery A US$1.7 million (US$51/bbl of feedstock) annually in high-pressure utilities alone. Additional savings are also expected from low-pressure utilities.

This revamp solution is not only attractive from a capital and operating cost standpoint, but it also lowers the carbon footprint of the refinery due to the reduction in combustion of fuel gas from the fired heater. Based on the normal operating duties shown in Table 2, the reduction of 5520 tpy of CO_2 emissions is equivalent to the removal of over 1200

Table 1. Refinery A – current operation vs IsoTherming revamp

Parameter	Current	IsoTherming revamp
Capacity	149 Sm^3/hr	205 Sm^3/hr (↑ 38%)
% cracked feedstock	0%	8.1%
Feed density @ 20°C (kg/m^3)	860	909 (+49 points)
LHSV hr^{-1}	0.34	0.78
Cycle length	12 – 14 months	36 months (↑ 3x)
Recycle hydrogen	Once through	Recycle pump

Table 2. Refinery A – utility comparison: current operation vs IsoTherming revamp

Parameter	Current trickle bed	IsoTherming
Normal operating charge heater duty (million kcal/hr)	4.936	1.780
% savings	-	64%
Fuel gas (kg/hr)	414	149
Fuel gas value (US$/yr[1])	1 233 224	444 711
Steam produced (kg/hr)	-	10 281
Steam value (US$/yr[2])	-	891 035
Annual net value of utility consumption/production (US$)	1 233 224	446 324

[1] Based on a fuel gas value US$/million kcal of US$29.7
[2] Based on steam value US$/1000 kg of US$10.3

Table 3. Refinery B – current operation vs IsoTherming revamp

Parameter	Current	IsoTherming revamp
Diesel yield (wt%)	96.7	98.5
Additional diesel value (US$/yr[1])	-	701 527
Fuel gas (Gcal/hr)	10.0	6.4
Fuel gas savings (US$/yr[2])	-	1 128 325
CO_2 emissions (tpy)	21 003	13 442
CO_2 tax savings (US$/yr[3])	-	39 338
Annual net value of diesel yield/fuel gas (US$)	-	1 869 190

[1] Based on a diesel value of US$558/t, and off-gas value of US$426/t
[2] Based on 11.1 Gcal/t heating value for fuel gas, and fuel gas value of US$426/t
[3] Based on 2.58 t CO_2/t fuel gas (CO_2, SO_2, NO_X), and tax of fuel gas of US$150.50/t

light passenger vehicles annually (based on heat content of propane of 139 million Btu and 4.6 tpy of CO_2 emissions from a single light passenger vehicle). Support for the revamp of Refinery A's diesel hydrotreater unit with the new technology continues, in anticipation of a 2025 start-up date.

Case study 2

The second case study is for Refinery B, located in Eastern Europe. Refinery B has an existing trickle bed diesel hydrotreater with an approximate capacity of 229 standard m^3/hr (Sm^3/hr), which equates to 35 000 bpd. The refinery is investigating options to reach its decarbonisation targets and optimise operating expenses, while maintaining its current capacity.

Elessent Clean Technologies worked closely with Refinery B to evaluate multiple revamp scenarios geared toward its decarbonisation and sustainable operating objectives. A comparison of the final revamp conditions compared to current operation is presented in Table 3.

Based on the assumed values of diesel and fuel gas, the revamp saves Refinery B US$1.9 million (US$53/bbl of feedstock) annually from increased diesel yield, fuel gas savings and tax savings from reduced carbon footprint of the unit.

In addition to a reduction in operating expenses and carbon footprint, the revamp cost and effort from trickle bed to the IsoTherming technology was proven to be minimal. It was confirmed that the heat exchangers and air coolers supporting the existing trickle bed unit can be utilised with the new technology, with the only additional equipment required being the reactor recycle pump and proprietary IsoTherming Reactor internals.

Due to the low CAPEX required for this conversion, the calculated payback for the effort is only three years given the value provided with increased diesel yield, reduced fuel gas consumption and CO_2 tax savings. Support for the revamp of Refinery B's diesel hydrotreater unit with the technology is ongoing, as a revamp from trickle bed is anticipated in the near future.

Conclusion

The global market demand for biofuels continues to increase as mandates and renewable fuel credits are being implemented across the world. Whether mandated or not, renewable fuel production is likely on the mind of all refiners. The IsoTherming technology is well-suited to assist refiners in the production of renewable distillate range products. The liquid-full technology is capable of handling the high hydrogen consumption and temperature rise that is associated with processing lipid-based feedstocks – whether in conjunction with a petroleum-derived feedstock or in a standalone unit. It also unlocks the ability to co-process without the concern of the trickle bed's recycle gas compressor limitations. The capital cost savings, energy efficiency and sustained catalyst life highlighted in the aforementioned case studies will also be apparent in a renewable processing application.