Franz B. Ehrhardt discusses global refining – game changing trends, response strategies, and the role of technology

The petroleum refining industry has never been without substantial challenges, and it is appropriate from time to time to review the latest trends and challenges that will impact the industry.

This article will address from a strategic impact point of view two of several prevailing and emerging trends that are of adequate significance to be considered game changers, and to review how technology can and will play a role in addressing effectively the related issues.

In general, it can be safely assumed that revolutionary technology changes in fundamental thermal and hydro-treating processes in petroleum refining are not likely to emerge as game changers. All of these core processes have reached a very high level of maturity and sophistication, and improvements are more likely to emerge at the evolutionary level. The most significant and innovative refining-related improvements can be expected in the catalyst chemistry and application.

The degree of application of the many well-proven technologies, processes, and concepts, however, will change significantly as a result of several factors. These include the ever increasing share of more difficult-to-process crude oils, like heavy and extra-heavy higher sulphur, higher metals, more acidic, etc. crude oils, as well as the environmental factors of global warming and CO_2 emissions, the need for more efficient fuels, the 'aging' and the 'rust factor' of many refineries that have been in existence for fifty and more years. Also important is the shift of actual petroleum processing from consumer countries to crude oil-producing countries, and countries that promote, support, and facilitate the construction of mostly export oriented new mega-size refining industries.

The two game changers to be discussed here are the continuous increase in the production of extra heavy high sulphur crude oil and the construction of more and more mega-size, high conversion, high complexity refineries.

Significant Increase in the Share of Extra Heavy Sour Crude Oil

It is a well known fact that over time the production of heavy-sour crude oil has taken an ever increasing share of all crude produced, a trend that most certainly will continue. While a number of new reserve finds contain light sweet crudes, the presently known reserves of (extra) heavy crude oil are slightly over twice that of light crude oil. Actually, as per the most recent Annual Statistical Bulletin of OPEC, Venezuela just surpassed Saudi Arabia as the country with the largest crude oil reserves in the world, most of it being of the (extra) heavy sour grade. Canada also weighs in at a top position with the heavy grade crude oil reserves from Oil Sands.

The added challenge beyond the heavy grade is the higher sulphur content which is considered 'sour' at and above 1 percent.

Traditional refineries have been designed and built to process the light sweet crude oil that in the past was abundantly available (and much easier to extract than heavy crude). The metallurgy of the processing units and pipes in those refineries is inadequate to handle sour crude oil and they will rapidly corrode and suffer fundamental damage if exposed to crude oil with the much higher sulphur content. Therefore, the world's refining industry in general is long in sweet crude and short in sour crude capacity.

The technology and the know-how to convert refineries to heavy sour crude processing capability have been readily available for quite some time. Thus, the determining factors for a process upgrade are really outside the actual technology and processes, and are driven by economic and financial considerations. Beyond that, even if all components are favourable, to obtain the essential permits for the upgrades faces tremendous hurdles in most developed countries mainly due to government red tape and especially environmental concerns … whether justified or not!

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Another (extra) heavy crude oil processing challenge for refiners is the fact that such crude oil in the first thermal separation process step, the distillation, generates a much larger percentage of heavy ends or residual products (resids), products that usually are turned into asphalt, Bunker C, or other heavy fuel products.

Historically, there has always been a surplus of these 'heavy end' products, which, naturally, caused a very distressed price level that in reality

did not even pay for the cost of the crude feed. The increasing share of the 'heavy end' products caused by processing more and heavier crude oil, contributes further to a deterioration of the processing economics of heavy crude oil. The major benefactor of this situation, however, has been mainly the global shipping industry through the plentiful availability of very low-cost Bunker C fuel.

On the other hand, this challenging situation for the refiners can be resolved with a very attractive technology – the Delayed Coking Process. In this process the heavy ends, the residual fuel, is 'baked' under high pressure and high temperatures in a coke drum. The results are, depending on the coking technology and process actually used, liquids of 40–50 percent in the range of C5 and up, and petroleum coke (pure carbon) for the balance.

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Further hydro-treating and desulphurisation produce diesel products that provide a rather attractive value upgrade over the feedstock. The petroleum coke can be used as a feed for power plants, for cement kilns, and select further upgrades. For example, Conoco uses petroleum coke to feed a fluid bed combustion power plant at their Lake Charles refinery, a technique that now has much wider applications.

Refiners who have installed both heavy sour crude oil processing capability and substantial bottoms-upgrading capacity like hydro-crackers and especially delayed cokers are currently enjoying, and will for quite some time to come, a significant competitive advantage through very favourable incremental earnings. For example, the heavy sour processing and delayed coking pioneer among the independent refiners, Valero of the USA, has reported that their investment of $350 MM for their Texas City Coker contributed about $200 MM in 2004 alone, suggesting a pay-back period of less than two years. Many existing refineries have added delayed cokers and many new refineries incorporate them in their basic design.

New high Complexity, high Conversion Mega-size Export Refineries outside Traditional high Demand Countries

The traditional oil industry strategy has always favoured the construction of refineries in or near high finished product demand locations. This concept was primarily based on the fact that the transportation cost of crude oil to a refinery location in high demand countries was considerably lower than that of finished products to be transported from the refinery to the end-user.

Several factors have, however, initiated a trend to build mega-size, high complexity, high flexibility export refineries in crude oil-producing countries, i.e. Saudi Arabia, Kuwait, and so on, as well as in countries that actually permit, and even encourage, the construction of new refineries providing an attractive business model for strict business ventures by industry newcomers like Reliance and Essar in India.

These developments are unquestionably encouraged by the impossibility of securing the essential (mainly environmental) permits in the USA, Europe, and other developed countries. For example, the last new refinery in the USA was built 35 years ago. If I recall correctly, the last new refineries in Western Europe were built in the UK in 1968 and in 1975 in Germany. In general significant capacity expansions at existing refineries do not materialise either, due to the same permit and bureaucracy challenges.

The inability to expand the capacity to an economically viable and competitive size and to increase conversion capabilities of older and relatively small size refineries in the high-demand countries, rather effectively renders the profitability of those refineries unacceptable, especially when they try to compete with the favourable incremental economics of the new mega refineries. This situation has resulted in the disposal of many older and smaller to mid-size refineries by the major oil companies, mainly in Europe and in the USA.

Established Independent Refiners, like Valero in the USA, and independent newcomers to the industry, like Petroplus in Europe, have acquired – and will likely continue to acquire – most of those refineries and convert them to a business model of becoming economically viable through more cost-efficient operation and considerably lower O&O expenses.

The challenges to this business model, however, will be the longer-term investment needed to modernise the facilities with existing technologies and processes to remain competitive with the finished products imported from the before-mentioned mega refineries. Furthermore, the environmental challenges and the usual government red tape are likely to stall any upgrading attempt by these independent operators in the same way that they blocked the previous owners, the major oil companies, from that avenue.

Conversely, for the crude oil-producing nations (i.e. OPEC), the construction of mega refineries on their soil, and with the support of a highly facilitating government, not only provides local employment and a significant value upgrade for the crude oil stream over the net export price, it also voids the need to count the processed crude oil against their respective (OPEC) export quota, thus permitting a higher level of crude oil production.

The pure size of these mega refineries will provide highly attractive incremental economics that are further enhanced by incorporating the latest conversion and upgrading technologies into the design, including technologies that will enable the flexibility to shift the individual fuel production among products following prevailing market price swings. This

combination provides these mega refineries with significant sustainable competitive advantages that will be very challenging to overcome by the remainder of the refining industry.

It is easily conceivable that the traditional international major oil companies have detected this trend on the radar screen and that, for instance, Marathon and Conoco have made it a factor in their decision to split Downstream from Upstream into separate companies, anticipating a return to the decades of dismal financial returns from the refining and marketing business. Otherwise, one can also ask why the previously highly touted strategic benefit of full integration was ditched by these companies!

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It is also very interesting to note that with the 'downsizing' over the last two decades, the international oil majors have 'outsourced' most of the refining research and development, which together with the resulting new technologies is now in the hands of independent service companies that are only too happy to provide their services directly to the new mega refinery clientele – so rendering obsolete their need to partner with international oil companies for refining ventures.

One more comment regarding the sustainable competitive advantage of a high level of conversion and flexibility capability in the design of the latest mega refineries – while a few years ago in the second edition of the book *Petroleum Refinery Process Economics* (2000), author Robert Maples noted that US refineries rank highest in the Nelson Complexity Index, averaging 9.5, compared with Europe's at 6.5, at present, the Reliance mega refinery in India has a 14.0 index (now the highest in the world) and Essar is expected to have a 12.8 rating after completion of the present upgrade.

There is little doubt that to stay competitive, the refining industry has to rethink its prevailing business model and generate innovative applications of existing technology, processes, and know-how to compete effectively with these benchmark performers.

Conclusion

There are adequate and economically attractive technologies and processes available, especially delayed coking, to absorb and manage the increasing level of heavier and sour crude oil supplies.

While there is unquestionably a need for refineries in the high demand locations, the NIMBY (Not In My Back Yard) factor will continue to prevent such developments and hand the financial value upgrade and job opportunities to entities and countries outside Europe and the USA.

The new mega export refineries will be able to supply global markets with the full range of products that meet the most stringent specifications at prices that will severely challenge the economic viability of a large number of refineries, forcing more and more shut downs.

Until a highly innovative and revolutionary refining process like chemical hydro-carbon separation and chain manipulation at ambient temperatures is invented, the presently known and applied thermal technologies and processes can master quite capably the most challenging tasks in refining with the assistance of continually advanced catalysts.