PERP Program – New Report Alert

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Nexant's ChemSystems Process Evaluation/Research Planning program has published a new report, ***Refinery of the Future - The Impact of Environmental Issues (02/03S11)***.

Background

The objective of this report is to consider the potential impact of environmental issues and regulations on the design and operation of petroleum refineries through year 2020.

This report focuses primarily on the United States (U.S.) regulatory regime and refinery characteristics (i.e., configured for a high proportion of gasoline production and a lower proportion of diesel production than in many other regions). There are regulations in the U.S. at the federal, state and local levels that apply to refinery operations and products. Other national and international regulatory regimes and guidelines are important to world refining, including those of the EU, Japan, the World Bank and the UN agencies. However, in defining regulatory policy impacting refineries, the U.S. regulations and standards are certainly among the toughest, and have driven the development of refining processes and operations, worldwide, for the last three decades. Also, the U.S. share of consumption of a variety of world crudes is relatively high, and it is a leading source of refining technology used around the world.

Historical Trends

The refining industry in the U.S. and throughout the world has undergone many major changes over the last two decades, including:

- Facility restructuring, with the closure of many smaller, less complex and regional refineries, and the expansion of larger, more complex refineries
- Ownership restructuring, with major mergers and acquisitions of upstream, refining, logistic and retail operations
- Refinery integration with petrochemicals facilities
- Introduction of reformulated gasoline (RFG), with reduced olefins, aromatics, sulfur and seasonal volatiles (RVP) in the United States, Europe and selectively in Asia
- Essentially complete phase-out of leaded gasoline in most of the world
- The addition of oxygenates to gasoline blends, particularly MTBE, in the U.S., Europe and elsewhere, and the more recent start of MTBE phaseout, and replacement by ethanol in the U.S.
- Reduced sulfur in gasoline, diesel, and to a lesser extent, residual fuels

- Implementation of design improvements to meet refinery site environmental regulations, especially engineering and design changes to reduce fugitive organic emissions, as well as to meet internal industry goals of pollution prevention and waste reduction.
- A shift in the average product yield slate to higher yields of gasoline and diesel, and lower production of residual fuels
- Increased production and sales of by-products such as petroleum coke and sulfur

Both fuel and facility-related regulations have increased competitive pressure on refiners in the U.S. and have caused refining costs to rise and margins to deteriorate. This economic pressure, together with regulatory impediments, has proved an effective barrier to new refinery development, so that no new grassroots refineries have been built in the U.S. for the past 20 years. Regulatory pressures on refiners in other regions vary widely, but in general are becoming more extensive as the drive to improve environmental performance becomes a key priority.

Environmental Challenges Faced

This report examines environmental issues as well as regulatory drivers to determine their potential impact on refineries, considering:

- Refinery process emissions and product-related issues that are the objects of regulation
- The various types of environmental regulations and policies that are being implemented, environmentally–related market drivers and others that are being discussed and/or that are likely to emerge in the near future
- The likely impact these regulations will have on refinery products and/or operations
- The leading refining and product technologies that can be used and are most likely to be used to comply with the regulations

The regulatory regimes faced by refiners worldwide, affecting products and operations, are complex and multi-faceted. Insofar as some of the regulations are fragmented, within the U.S. and globally, as well as among market grades and types of endusers, the challenges for refiners are made even more severe.

Other Major Factors Affecting Refining in the Future

Three other factors, interacting with and related to the different types of environmentally related drivers will affect refining now and in the future:

- Feedstock availability and quality
- Refining technology developments
- Market product requirements and volumetric trends

Refinery Feedstock

Crude oil is the primary feedstock for the refining industry. Refineries around the world use a wide range of crude oils, ranging from light and sweet to heavy and sour. U.S. refineries use both domestic and imported crude oils. Most imports of crude oils and refined products are from the Western Hemisphere (Canada, Venezuela, and other Caribbean countries), but imports from the Middle East are also significant. On average, U.S. refiners process heavier and poorer quality crudes than any other region.

There is considerable uncertainty over future global supplies of petroleum, but a consensus view agrees that:

- Total long term reserves are at or close to a peak, and the rate of discovery is definitely declining
- New resources will be increasingly more remote and geologically deep, of lower quality than today's average, and more difficult and expensive to discover and develop
- Use of alternative fuels will increase, driven either by the initiatives of developers, government policy demands, and/or consumer preferences that will become more important; this will include biofuels (ethanol, biodiesel, other esters and ethers), tar sands-derived crudes, GTL materials (Fischer-Tropsch and similar liquids derived from natural gas), as well as hydrogen from non-fossil fuel sources as a refinery feed for product treating and upgrading

Technology Developments

The primary factors that will drive refining technology development are:

- Regulations that lower sulfur levels in motor fuels (gasoline and diesel) and reduce allowed olefins, aromatics and lighter hydrocarbons in gasoline. The technologies to address these requirements are primarily various types of processes for product upgrading by hydrotreating, alkylation, and sulfur removal.
- Continued shift of product demand toward higher value products at the expense of residual fuel, resulting in growing requirements for conversion technology

Growth in Non-Petroleum Fuels

Increased demands for refined fuels to provide energy for all economic sectors (i.e., for transportation, building heating and air conditioning, industrial fuel and power, etc.) typically accompany population and economic growth worldwide, and markedly so in less developed countries. Such fuel demand growth will see more competition in the future from energy conservation, renewable energy technologies (solar, wind, hydro, biomass, etc.), and new, more efficient fuel use technologies, such as integrated gas turbine combined cycle (IGTCC) for power and cogeneration, microturbines, fuel cells, and hybrid and alternative fuel vehicles, which will tend

to reduce refined product demands. Of these, development of hybrid vehicles has the greatest potential to affect the supply/demand balance in North America.

Greenhouse gas (carbon dioxide) emissions reduction programs in various countries are expected to disfavor use of refined petroleum products and coal while favoring natural gas and renewable energy sources. In Europe, Asia and elsewhere, wind power and photovoltaics are already taking a significant share of the energy market, and both have very high growth rates, although from low base levels of demand.

Affected Products – Regulations and Solutions

The key regulatory aspects affecting fuels are:

- For gasoline:
  - Reduced olefins and aromatics
  - Oxygenate content, with phase out of MTBE in the U.S.
  - Seasonal and geography-specific volatility (RVP) limits
  - Reduced sulfur limits, in phases
  - Final phase-out of leaded gasoline in the few areas in the world where it still is available

- For diesel fuel:
  - Phased reduction of sulfur content to the level of "ultra low sulfur" in many regions to enable tailpipe controls of NOx, particulates and soot
  - Mandated or otherwise encouraged use of biodiesel in some regions, especially blended as a lubricity additive and for marine use
  - Generally more relaxed sulfur standards for off-road than for on-road diesel

- Other products:
  - Jet fuel has no significant regulatory drivers of change at this time
  - Marine fuel may face significant sulfur reduction requirements for near-shore use in the future
  - Residual fuel use is affected by requirements for reduced SOx and particulates emissions from industrial and utility boilers

- Alternative fuels competition:
  - CNG and /or LNG, biodiesel and ethanol use is being encouraged by regulations and government support programs in many regions
  - Renewable energy, including wind power, PV and biomass combustion is also being driven by regulatory programs world-wide. Through electric vehicles and other relevant transportation technologies, these developments can take some market share

Refinery Emissions – Regulations and Solutions

Refineries generate a wide range of types of emission, ranging from:

- vents and leaks of materials that range from non-toxic industrial wastes to non-toxic hydrocarbon vents
- sludge and washings
- toxic air emissions
- hazardous solid, liquid and sludge wastes

Refinery emissions of toxic, hazardous or otherwise problematic pollutants are second only to those of the chemical industry among all industrial sectors in the United States. The patterns of emissions in the U.S. are generally similar to those in other industrial economies. In non-industrial countries with less developed chemical industries the refining sector typically generates a larger percentage of total pollution.

Environmental regulations affecting refinery operations are even more complex and diverse than those affecting product specifications, and involve controls on emissions to air and water bodies, contamination of soil and groundwater, handling and disposal of hazardous wastes, emergency response, permitting, monitoring and reporting, and every aspect of the refinery facility and beyond the refinery to the handling and transportation of crude oils and products.

Many sites in the U.S. and elsewhere are integrated facilities, having both refining and petrochemical operations with common owners, and thus share impacts and strategies for compliance with regulations for both industries. Solutions to regulatory requirements can be intrinsic or direct, such as in the choice of refining processes or vent treatment technology, or secondary, as in the choice of cogeneration to reduce overall emissions in providing electricity and heat utilities at minimum net cost and with minimum environmental impact.

Conclusions

The report provides detailed conclusions about future refined product mix and quality. The future focus of technology improvements and refinery investment to accommodate the product requirements is postulated.

Refineries generally have much flexibility in adjusting to variations in crude quality and product mix, but are more constrained when they are required to make drastic changes in the quality of primary products, gasoline and diesel fuel. To respond to the challenges, the refinery of the future will likely need to add both new capacity and perhaps new parallel units in hydrotreating and distillate hydrodesulfurization. This will, in turn also require new capacity for hydrogen production and recovery as well as for expanded sulfur recovery. Alkylation and isomerization and other processes that add octane will also need to be expanded to replace olefins and aromatics, although

each of these is constrained by other demands on their raw materials within the refinery/petrochemical complexes.

To comply with local air quality regulations of NOx and particulate emissions, as well as global imperatives (but not yet regulations) on CO_2 greenhouse gas emissions, increase their energy efficiencies and thus reduce operating costs, and increase the security of their electric power supply, refineries are likely to add more capacity for cogeneration of power and heat. This will probably be through integrated gas turbine combined cycles, and further in the future, through even more efficient fuel cell-gas turbine combined cycles.

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