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Addressing Hydrogen Supply Constraints and Catalyst Disposal in Hydrotreating Operations

With limited hydrogen availability for desulfurization of diesel, specific criteria will influence optimization of hydrogen consumption "trade-offs" between the FCC pretreater and ULSD hydrotreating units. Important criteria are the catalytic options for achieving the desired balance of consumption.

Greg Rosinski, Advanced Refining Technologies (ART)

For any given feed, hydrogen consumption is a function of hydrogen partial pressure, LHSV, H_2/oil ratio and catalyst. For the most part, the first three variables are fixed for a given unit, since throughput reduction is not an economical choice. Thus, catalyst selection is one of the few constraints which refiners are willing to consider.

Catalyst Selection vs H_2 Consumption Trade-Off

Cobalt-molybdenum (CoMo) based catalysts have lower hydrogen consumption than nickel-molybdenum (NiMo) based catalysts due to lower aromatic saturation activity. At equivalent product sulfur, using all CoMo catalyst in the FCC pretreater will lower hydrogen consumption with a longer cycle in terms of HDS activity, but at the cost of lower FCC conversion and higher LCO yields. Using all NiMo catalyst in the FCC pretreater will result in higher FCC gasoline yields and lower LCO yields due to higher PNA saturation, but a shorter cycle life in terms of HDS activity.

With regards to the ULSD units, if the unit is high pressure, using a NiMo catalyst will result in higher aromatic and PNA saturation. This may be beneficial if cetane upgrade is desired. However, there may be a diminishing return on hydrogen for the incremental cetane upgrade over a CoMo catalyst.

ART can help optimize both FCC pretreater and ULSD performance based upon the refiners needs, including hydrogen consumption, cetane uplift and cold flow properties. ART provides the ApART and SmART staged catalyst systems for FCC pretreat and ULSD applications, respectively. We have helped many refiners manage hydrogen consumption in both units by using staged catalyst systems utilizing NiMo, CoMo and NiCoMo catalysts optimized to enhance HDS, HDN or HDPNA activity for a given feedstock. Furthermore, ART's relationship with Grace Davison can further enhance the unit optimization to include the FCC unit as well as the FCC pretreater and the ULSD unit.

Spent HDT Catalyst Handling

Spent hydroprocessing catalyst is pyrophoric due to small particulates of iron sulfide (FeS) scale that are present, so care must be taken to minimize exposure of spent catalyst to air. In addition, spent sulfided catalyst has some coke on it and it will slowly oxidize in air. If the spent catalyst is exposed to air, it will slowly heat up, and if iron sulfide is present it will combust, which may ignite the coke or other residual hydrocarbon on the catalyst.

The key to this procedure is to have competent and experienced personnel performing the

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required tasks. The reactor must be thoroughly swept of hydrocarbons, and a nitrogen purge should be kept on the reactor at all times. During the unloading, the screener and the dump nozzle should be continuously purged.

The containers that will hold the catalyst during unloading should be blanketed with nitrogen or have dry ice placed inside until ready for loading. The containers should not be open to the atmosphere. The loading should be done under inert conditions with experienced personnel. When preparing your procedure, make sure to involve your refinery EH&S group and give careful consideration to all aspects or the process to ensure you take all the precautions necessary. ■

Editor's note: *This article is based on Greg Rosinski's responses to the October 2011 NPRA Q&A Questions #19 and #14 (www.npra.org):*

#19. With limited hydrogen availability for desulfurization of diesel, what criteria influence the optimization of hydrogen consumption between the FCC pretreater and ULSD units? What catalytic options exist to achieve the desired balance of consumption?

#14. Have you successfully dumped, screened and reloaded spent hydrotreating or hydrocracking catalyst without regeneration during a turnaround? Can you share any best practices during this operation to avoid problems on restart?

The Author

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PROCESS OPERATIONS

Global Natural Gas Processing Regains Momentum

Driven by surging natural gas consumption in Asia and the United States, global use of the form of fossil fuel rebounded 7.4% from its 2009 slump to hit a record 111.9 trillion cubic feet in 2010, according to a new *Vital Signs Online* report from the Worldwatch Institute. This increase puts natural gas's share of total energy consumption at 23.8%, a reflection of new pipelines and natural gas terminals in many countries.

The world's largest incremental increase in natural gas use occurred in the United States, where low prices triggered a 1.3 trillion-cubic-feet increase to 24.1 trillion cubic feet, just over one-fifth of global natural gas consumption. But the Asia Pacific region experienced the strongest growth as a share of 2009 consumption levels, with China, India, South Korea, and Taiwan all experiencing demand growth of over 20%. China, which surpassed Japan in 2009 to become Asia's largest natural gas consumer, by and large led the region's growth spurt by consuming 3.9 trillion cubic feet, or 3.4 % of world usage.

The former Soviet Union, which experienced the largest regional decline in natural gas consumption in 2009, saw its demand bounce back by 6.8% in 2010. Russia, the world's second largest natural gas consumer, single-handedly accounted for 70% of regional growth. In the European Union, natural gas consumption increased by 7.4%. However, the EU's share of global natural gas consumption is on the decline. The Middle East, which is home to some of the richest natural gas resources in the world but lacks the proper infrastructure to facilitate much domestic consumption, saw a 6.2% rise in natural gas demand.

Natural gas producers have responded to this revived demand with a 7.3% boost in production. The United States maintained its position as the leading source of natural gas, accounting for just under one-fifth of the world's total production in 2010. In Russia, which holds nearly a quarter of the world's proved natural gas reserves, production jumped 11.6%. In the Middle East, growth in production of natural gas far outstripped that of consumption, rising by a full 13.2%. Last year, Qatar and Iran alone accounted for 29.4% of global proved reserves.

Reenergized global gas demand drove average prices up from their 2009 lows in nearly all markets. According to one index, the U.S. saw a 13% price increase over 2009 levels. Prices remained the highest in Asia, where consumption increased most rapidly between 2009 and 2010. The European Union, where prices fell 6%, proved to be the exception to this trend, thanks to an excess of liquid natural gas originally intended for U.S. markets.

Two major developments this year have significantly affected the stability of global natural gas markets. The political unrest brought about by the "Arab Spring" slowed production in a number of gas-producing countries in North Africa. Additionally, the disaster at Japan's Fukushima Daiichi nuclear plant has led countries around the world to reconsider their dependence on nuclear power. "Natural gas is likely to play a major role in filling the gap left by idled and phased out nuclear plants," write report authors Saya

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Kitasei and Ayodeji Adebola. "The unanticipated spike in public opposition to nuclear power can only increase global natural gas demand in the coming decade." Further highlights from the study:

- The share of global natural gas trade represented by liquified natural gas (LNG) surpassed 30% in 2010 for the first time on record
- Russia maintained its status as the world's leading exporter of natural gas, accounting for 27.5% of global pipeline trade
- Gas flaring, or the burning of excess gas, is on the decline in Nigeria but remains a substantial environmental threat in many countries around the world. It is estimated that 5% of global natural gas production is flared annually. ■

INDUSTRY NEWS

Chevron Phillips Chemical to Build New Ethylene Plant in Texas

The Shaw Group Inc. announced December 14 it has been awarded a contract by Chevron Phillips Chemical Company LP (Chevron Phillips Chemical) to license its proprietary technology and provide a process design package for a 1.5 Mtpy grassroots ethylene plant located at Chevron Phillips Chemical's existing Cedar Bayou Plant in Baytown, Texas. It will be designed to use economical supplies of ethane feedstock derived from increased shale gas production.

"This project represents a significant change in the ethylene marketplace as no U.S. plants have been added in approximately ten years," said James Glass, president of Shaw's Energy & Chemicals Group. "The selection of Shaw's technology for this project followed an evaluation of the top ethylene licensors in the world. Our robust Ultra Selective Conversion(R) furnace and recovery system and 70 years of experience in designing and/or building more than 120 grassroots ethylene units were key factors."

As part of the project, Chevron Phillips Chemical plans to construct two new polyethylene facilities, each with an annual capacity of 500,000

metric tons annually. The new polyethylene units would be located either at the Cedar Bayou facility or a site nearby the Chevron Phillips Chemical Sweeny facility in Old Ocean, Texas, the company said. The project will create approximately 400 direct jobs and 10,000 engineering and construction jobs, the company said. The company expects to pick a final site in the first quarter of 2012. ■

Editor's note: The development of shale gas resources could save manufacturers $11.6 billion in energy costs and create an estimated 1 million jobs for the sector by 2025, according to a PricewaterhouseCoopers report released December 14.

Toyo-Canada Awarded EDS Work of Oil Sands Refinery Project

Toyo Engineering Canada Ltd. (Toyo-Canada), a Canadian subsidiary of Toyo Engineering Corporation, Japan has been awarded a contract by North West Redwater Partnership (NWR) a joint venture between North West Upgrading Inc. and Canadian Natural Resources Limited to provide EDS (engineering design specification) work for a heavy oil upgrading and refining complex in Sturgeon County, Alberta. This EDS work is scheduled to be completed in August, 2012.

NWR project targets to build a heavy oil upgrading and refining complex in three phases with a total capacity of 150,000 bpsd. This complex will process bitumen extracted from oil sands producing naphtha, diesel oil and other petroleum products. The project is divided into several units, and TOYO will provide engineering services for the sulfur recovery unit, light ends recovery unit, sour water stripper unit and amine treatment unit. ■

Contract Awarded for Heavy Crude Oil Upgrader

JGC Corporation announced December 6 that it has been awarded a contract by PDVSA Petroleo S. A. for the detailed engineering, procurement support and construction management services associated with constructing a 210,000 bpd heavy crude oil upgrading facilities at the Puerto La Cruz oil refinery. JGC will undertake the project as leader of a consortium including Chiyoda Corp. and INELECTRA, a Venezuelan engineering company. This is the first project in the world to commercially employ the HDH Plus heavy crude oil cracking process technology developed independently by PDVSA. The French Petroleum Institute (IFP) along with AXENS of France have recently signed a cooperation agreement to work in the Puerto La Cruz refinery as well as the El Palito refinery to optimize the HDH Plus technology with the aim of achieving higher conversion of heavy and extra-heavy crude. The total PDVSA investment for the Puerto La Cruz facility located 300 km east of Caracas is estimated at approximately $5.0 billion. ■

Status of BP Whiting Refinery Project

BP has invested several billion dollars to modernize its Whiting refinery in Northwest Indiana (USA). This is the biggest private sector investment in Indiana history. As of December 2011, the Whiting Refinery Modernization Project is about two-thirds complete. Construction began at the refinery in May of 2008, after necessary permits were issued. BP is essentially complete with all engineering and module fabrication activities and is nearing completion of all underground infrastructure construction that is required for the modernization project. Above ground heavy mechanical construction is in full swing for a new gas oil hydrotreater and sulfur recovery complex. A new highly automated coker will replace the existing coker, and the facility's crude distillation unit is being reconfigured to process heavier crudes, helping to replace some of the light sweet crude that is becoming more difficult to source. ■

Sicilian Refinery Integration Expected to be completed by 2014

Esso Italiana, an Exxon Corporation affiliate, recently announced an agreement to integrate and rationalize its refinery in Augusta (Sicily) with the adjacent AGIP Petroli refinery at Priolo. When complete, this initiative will create a highly efficient refining complex, combining a crude processing capacity of approximately 240,000 bpd with large-scale chemicals, lubricants and power generating capacity. The complex will rank among the most efficient refineries in Western Europe.

The integration and related interconnections of these two existing sites are expected to be completed within two years. During this period the production cycle of the two sites will remain substantially unchanged. In addition to Augusta, Esso Italiana is the operator and 75% owner of the 250,000 bpd Trecate refinery near Milan. ■

Current State of Russian Refining Industry

According to the Russian government decree of December 2008, production of Euro-2 gasoline must cease on December 31, 2011; of Euro-4 fuel – on December 31, 2014. Similarly, production of Class 2 and 3 diesel fuels is to cease on December 31, 2011 and production of Class 4 diesel fuel is to cease on December 31, 2014. There are 27 large refineries and over 50 mini-refineries operating in the country. Important challenges facing the Russian refining industry include high depreciation level of capital assets (over 80%), low quality of yielded oil products and use of energy-intensive technologies. Most of these facilities were installed more than 50 years ago and for strategic reasons were placed far away from marine terminals and foreign consumers.

To address these challenges, major Russian oil companies, such as Lukoil are placing a significant focus on their refining segment in order to reduce exposure to the high price volatility of the oil market and improve competitiveness by producing and selling high quality products. Lukoil's seven refineries can utilize 60% of its oil production and is prioritizing introduction of European quality standards at all of its plants.

An example of the company's modernization strategy is the upgrading of Lukoil-Nizhegorodnefteorgsintez' refinery, which only recently had a Nelson Complexity Index (NCI) of only 3.6. During the first stage that was completed in 2010, gasoline production levels were increased, reaching Euro-4 standard levels. The second stage of the modernization process to be completed in 2012 will expand capacity expansion up to 20 million tons of oil per year (Mtpy). The company plans to install a new primary 8.0 Mtpy distillation unit (AVT-8) while decommissioning two old units (AVT-1 and AVT-2). The gasoline reforming unit L35/11-300 will be converted to a 440,000 tpy isomerization unit. Lukoil also plans to invest in a new 2.6 Mtpy distillate hydrotreater and a 0.6 Mtpy reformer. With the launch of the FCC complex, Nizhegorodsky refinery will produce 2.5-3 Mtpy of gasoline in full compliance with the Euro-4 standard (10 ppm sulfur content), while the diesel fuel quality would rise to Euro-5 standard.

The third stage (2012–2017) includes installation of delayed coking and a secondary gas oil hydrotreater. ■

Iraq Pursuing Basra Refinery Rehabilitation Study

The Shaw Group Inc. recently announced it has been awarded a contract by the South Refineries Company, which is part of the Republic of Iraq's Ministry of Oil, to provide a feasibility study for the rehabilitation of its 140,000 bpd refinery in Basra, Iraq. The study will assess the current condition of the refinery and estimate the engineering, equipment supply and construction services required to improve its operation.

The study is funded by the United States Trade and Development Agency (USTDA) through a grant to the South Refineries Company. This is the first grant the agency has provided directly to an Iraqi grantee, marking the USTDA's support of Iraq's long-term economic development.

In Iraq, Shaw is currently conducting feasibility studies and front end engineering and design (FEED) for two grassroots 150,000 bpd refineries near the cities of Maissan and Kirkuk, for the Republic of Iraq's Ministry of Oil. The FEED work includes all process units, offsite facilities and utilities for both refineries. Through an FCC alliance, Shaw, with its partner, Axens, are providing a process design package for a 30,000 bpd RFCC unit at Midland Refineries Company's refinery in Daura. ■

Indonesia to Build Three More Refineries

To catch up with growing demands for oil-based fuels, Indonesia needs to build at least three more refineries, each with the capacity to produce 250,000 bpd, the Energy and Mineral Resources Ministry says, according to a December 16 report in *The Jakarta Post*. The ministry's director general for oil and gas, Evita Herawati Legowo, said in Jakarta on December 15 that the three refineries would be built in Balongan in West Java, Banten and Tuban in East Java. "Currently, the total processing capacity of our refineries is 1.15 million bpd. They produced refined fuel of 76,000 bpd last year. Our fuel demand in 2010 was 1.06 million bpd, thus there was a deficit of 388,000 bpd," she told a discussion session at the Indonesian Chamber of Commerce.

She predicted that in 2015, the demand for fuel in the country would increase to 1.29 million bpd, with an assumption that fuel consumption would grow 4% per year. However, the production would only slightly increase to 677,000 bpd even with the operation of a small scale refinery in Musi Banyuasin in South Sumatra, she revealed. "So there is still a deficit of 617,000 bpd," Evita explained. The Balongan refinery was the last refinery built in the country in 1994.

With significant investment from Kuwait Petroleum, the capacity of the Balongan refinery will be expanded from the current 200,000 bpd to 325,000 bpd. The expanded refinery is scheduled to begin operating in its full capacity in 2017. ■

Jet Fuel Demand to Outpace Diesel Demand

According to a new World Energy Council (WEC) study ("Global Transport Scenarios 2050") and noted in a December 8 *Bloomberg News* agency business report, jet fuel consumption will grow at a faster rate than diesel worldwide through 2050, while demand for gasoline will decline in a "radical change" for the transport sector, The use of jet fuel may double by 2050 compared with last year, the London-based researcher said in its "Global Transport Scenarios 2050" report. Diesel and fuel oil use are forecast to climb 46%, while gasoline demand is expected to drop 63% in the next four decades, based on WEC's Tollway scenario, which assumes government intervention to stimulate alternative technologies and public transport.

"Global transport will remain heavily dependent on fossil fuels with a strong rise in demand for diesel, fuel oil and jet fuel compared to gasoline," Ayed Al-Qahtani, a senior project manager for the report, said in an e-mailed statement. Rising diesel consumption is largely driven by demand from the heavy transport, agriculture, and mining sectors, WEC said. ■

EDITORIALLY SPEAKING

Catalyst Business Profitability

Rene Gonzalez, Editor
Refinery Operations

Refinery catalyst demand continues to be influenced by volume growth in hydroprocessing catalysts, and increased refined product output in the Africa/Mideast and Asia/Pacific regions. Global efforts to reduce air pollution by lowering sulfur content in motor vehicle fuels will continue to boost catalyst loadings, as will the ongoing shift toward heavier grades of crude oil (which have higher sulfur and metals levels), and the development of unconventional petroleum resources such as Canadian bitumens. In the Africa/Mideast and Asia/Pacific regions, growing motor fuel demand due to the rapid expansion of the motor vehicle fleet will lead to some growth in new refinery construction and expanded refined product output.

Despite an industry slowdown that has forced cancellation of projects in the refining and petrochemical sectors of the energy industry, some refiners will continue with expansion plans based on long-term trends to match refinery product profiles with a global market for higher diesel and jet fuel consumption and significantly reduced fuel oil demand.

Currently, refinery expansions and upgrades moving forward are focused on upgrading a facility's capability to process heavy and sour crudes and meet ULSD requirements beyond 2012. For example, new units at the BP Whiting refinery in the state of Indiana (USA) that are expected to come on-line in 2012 will increase the refinery's ability to process cheaper heavy Canadian bitumen based feedstocks.

While significant amounts of hydrotreating catalyst will be required to supply the hydrotreater's reactors, delayed coking capacity will be increased significantly in order to demetallize coker gas oil feeds to hydroprocessing units. To be sure, the onus on hydrotreating higher volumes of heavy coker gas oils will require significant attention on the hydrogen requirements and compressor constraints. Of course, even with the latest guard bed technology installed in hydrotreaters and mild hydrocrackers, the level of metals contaminants is high enough in crude feeds to justify financing delayed coking unit upgrades. In addition, many of those refiners expanding diesel production will improve their crude unit/vacuum distillation units at the front end of the refinery to help expand the potential capacity of downstream FCC and hydroprocessing units.

Many oil companies continue to announce projects to boost diesel production as worldwide demand for diesel continues to increase annually. For example, there is an estimated 48.9 million tons per annum shortage of diesel forecasted for Europe by 2015. Despite the global economic downturn the fundamentals of certain planned and "borderline" projects still stack up in consideration of projected increases in refined product demand in non-OECD countries.

As credit markets improve and financing becomes available, more projects will go forward simply because there is still millions of barrels of heavy crude that need to be extracted and processed. Moreover, the surprising resurgence of onshore oil and gas production in the continental United States is beginning to reshape the global oil industry in ways that could not have been imagined as recently as last summer. ■

Calendar of Events

JANUARY

30-31, *2012 GE Oil & Gas Meeti*ng, Florence, Italy, GE Oil & Gas, +39 055 0949 1831, annual.meeting@ge.com, oilandgasannualmeeting.com.

MARCH

11-13, *NPRA Annual Meeting*, National Petrochemical and Refiners Association (NPRA), San Diego, California, USA, +1 202 457 0480, www.npra.org.

13-16, *European Fuels Conference 13th Annual Meeting 2012*, The Energy Exchange, Paris, www.theenergyexchange.co.uk

MAY

16-17, *NPRA National Occupational & Process Safety Conference & Exhibition*, NPRA, San Antonio, Texas, USA, +1 202 457 0480, www.npra.org.

22-25, *NPRA Reliability & Maintenance Conference & Exhibition*, NPRA, San Antonio, Texas, USA, +1 202 457 0480, www.npra.org.

AUGUST

21-22, *NPRA Cat Cracker Seminar*, NPRA, Houston, Texas, USA, +1 202 457 0480, www.npra.org.