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FCC Catalysts with Mesoporous Zeolite Yield Higher Quality Products

Drop-in Replacement for Current FCC Catalysts Allow for Higher Volumes of Low Quality Feeds and Higher Riser Temperatures While Increasing Product Quality and Less Light Gases and Coke

Barry Speronello, Javier Garcia-Martinez and Allen Hansen, Rive Technology, Inc.
Ruizhong Hu,Grace Davison Refining Technologies

Rive Technology and Grace Davison in partnership are commercializing advanced fluid catalytic cracking (FCC) catalyst technology that significantly increases the yield of transportation fuels per barrel of crude oil. Rive's Molecular Highway™ technology makes traditional zeolite catalysts more capable of cracking large hydrocarbon molecules, and allows valuable primary cracked products, like gasoline and diesel molecules, to more readily escape the catalyst before they are overcracked to less valuable light gases and coke. This new catalyst is a drop-in replacement for current catalysts and will enable refiners to increase throughput and profitability without capital investment.

Since the introduction of zeolite-based catalytic cracking in the 1960s, zeolite-Y has been the active ingredient of choice. It's relatively stable at the high temperatures within the FCC unit (up to about 1400°F) and very efficient at catalyzing the cracking of smaller FCC feed molecules that can enter through its micropores, (with pore mouths of about 0.7 nm.). However, many feed molecules are too large to enter Y-zeolite micropores and must first pre-crack less selectively either thermally or outside of the zeolite before entering the zeolite crystals. Similarly, larger gasoline and LCO product molecules are a tight fit within zeolite pores and can take a relatively long time to leave the zeolite crystal. During that relatively long stay within the micropores, such valuable products can be recracked (overcracked) to less valuable gases and coke.

Rive™ zeolite technology was invented at MIT in the early 2000s by Garcia-Martinez and Ying.[1] It improves on zeolite-Y by creating a network of intermediate sized (2 - 6 nm) mesoporous "molecular highways" throughout the crystals of zeolite-Y. These "molecular highways" admit and pre-crack even the largest feed molecules, while also channeling product gasoline and diesel molecules safely out of the zeolite.

Mesopores in Rive™ zeolite can be clearly seen in transmission electron microscope (TEM) images. The size and volume of mesopores created in Y-zeolite can be controlled over a fairly wide range with Cont. page 2

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Rive's Molecular Highway™ technology. **Figure 1** shows a pore size distribution typical of that used for catalytic cracking. The graph compares the cumulative pore volumes of both Rive™ Y-zeolite and conventional Y-zeolite as a function of pore diameter, and it shows that both types contain a large volume of micropores at <20 Å (<2 nm) diameter. In addition, however, Rive™ zeolite also contains about 0.15 cc/gm of larger pores in a very narrow range at about 40 Å in size. These 40 Å (4 nm.), "meso" sized pores are unique to Rive™ zeolite and are the key to achieving the superior cracking yields that will be described in further detail. The catalytic impact of these zeolite mesopores complements matrix porosity that has been fine-tuned by FCC catalyst manufacturers over the past 50 years of zeolite based FCC catalysts.

Initial screening experiments for catalytic cracking of VGO were done by Dr. Garcia-Martinez to compare the cracking yields of powdered pure mesoporous ultrastable Y-zeolite (USY) with pure conventional USY in a fluid bed microactivity test unit at the National Center for Upgrading Technology (NCUT) in Devon, Alberta, Canada, and the results showed greatly improved yields with the mesoporous material.

Figure 2 shows a yield comparison of zeolites steamed for 4 hours at 1450 °F and 100% steam. At equal 70 wt% conversion, mesoporous USY increased gasoline yield 10% relative from 42% to 47%, increased distillate (LCO) yield by 20% relative, and decreased coke yield by 20% relative! These selectivity improvements were a dramatic confirmation of the benefits of zeolite mesoporosity for improving large-molecule cracking and reducing loss of gasoline to coke and gases.

Since that time Rive Technology has focused its efforts on capturing that magnitude of improved performance (i.e., uplift) in formulated FCC catalysts. Initial work focused on formulations using relatively inert silica sol matrices with testing being done at the Chemical Processing Engineering Research Institute (CPERI), Thessaloniki, Greece. A range of formulations was tested. ACE test results were obtained for one preferred formulation after steaming for four hours at 1450 °F and 100% steam with feed properties listed in **Table 1**. While the feed used for this study had a relatively low CCR and 90% boiling point, its low API gravity and high Ca show that it is relatively aromatic and difficult to crack.

Gasoline yield vs. conversion were compared for a

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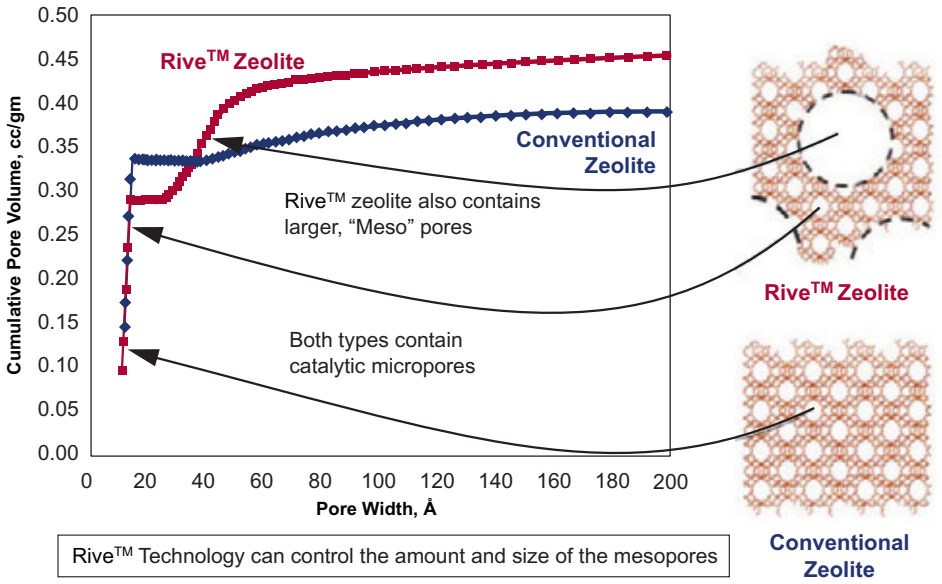
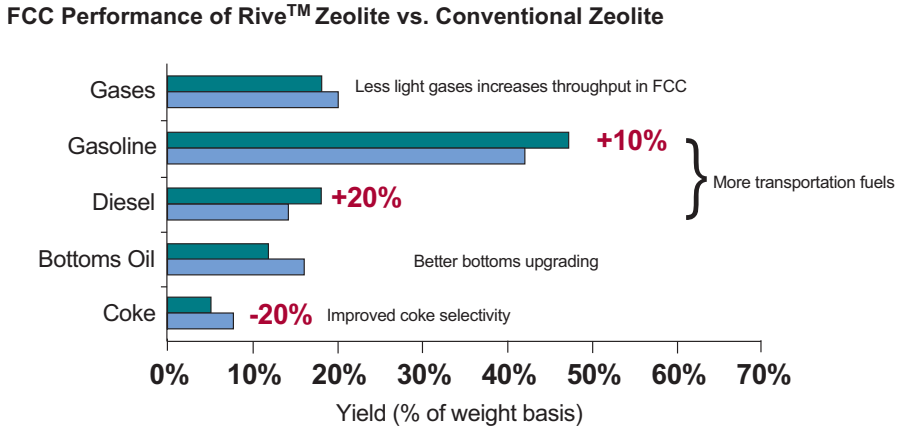


Figure 1. Argon Adsorption showing 40 Angstrom (Å) mesopores created in Y-zeolite.



Note: Experiments performed using zeolite powder in MAT test after steaming at 1450°F / 4 hours

Figure 2. Mesoporous Rive™ USY zeolite showed greatly improved cracking yields compared to standard USY.

Table 1. CPERI feedstock properties used in comparisons of gasoline, coke and LCO yields of silica sol matrix FCC catalysts containing Rive™ and conventional zeolites when cracking in an ACE unit.

°API	19.6
CCR	0.29%
Sulfur	2.39%
IBP	577 °F
50%	831 °F
95%	1000 °F
Kwatson	11.63
Ca	25.75

catalyst containing Rive™ zeolite to a catalyst containing conventional zeolite. The zeolites were processed to have the same steamed crystal unit cell size and the catalysts had the same zeolite contents and matrix formulations. This comparison shows that the benefits of Rive™ zeolite mesoporosity translate well from pure zeolite powders to catalysts. In this case the uplift was about 3.0 percentage points (about 6% relative) compared to the catalyst made using conventional zeolite.

Similarly, comparison of the coke yields of the two catalysts shows that the catalyst having Rive™ zeolite made about 1.0 percentage point (15% relative) less coke than the catalyst containing conventional zeolite. LCO yields were similar for the two catalysts, though, so the advantage in bottoms cracking seen with the pure powders was diminished when mesoporous zeolite was formulated into a silica sol matrix and used to crack this relatively challenging aromatic gas oil feedstock.

The first commercial catalyst formulations containing Rive™ mesoporous zeolite were developed based on ACE testing using paraffinic vacuum gas oil. Controls for these tests were alumina-matrix commercial catalysts A (moderate rare earth) and B (high rare earth). Both equilibrium catalyst and lab deactivated fresh catalysts were used in the comparisons.

Selectivity matches were excellent when comparing selectivities vs. conversion (and conversion vs. cat/oil ratio) for the equilibrium and lab deactivated versions of commercial catalyst A. The deactivation conditions used for this comparison (8 hrs/1450 °F/100% steam) were somewhat less severe than that experienced in the FCCU.

In a comparison of a steamed GRX™ formulation containing a moderate rare earth mesoporous Rive™ zeolite with lab steamed commercial catalyst A, the two catalysts were substantially equal in activity, yielding similar conversions at equal cat/oil ratios. There was also little difference in gasoline selectivity between the two. There was, however, a significant benefit in bottoms upgrading and coke selectivity for the catalyst containing mesoporous Rive™ zeolite. At constant 3.0% coke, the mesoporous Rive™ zeolite catalyst produced 1/3 lower bottoms relative to the catalyst containing conventional zeolite (5% vs. nearly 8%).

A similar type of comparison for was prepared for GRX™ and conventional zeolite-containing alumina matrix catalysts, but at higher rare earth content. Again, catalyst activities were equal, but at the higher rare earth level there was a significant gasoline yield advantage for the catalyst with mesoporous Rive™ zeolite, along with improved bottoms cracking and coke selectivity.

Overall, Rive™ mesoporous zeolites in different catalyst formulations tested to-date have consistently showed selectivity benefits in one form or another in all tests. The degree of benefit has varied depending upon the overall formulation, and the feedstock used for the test, but directionally performance benefits in bottoms upgrading, gasoline yield, coke selectivity and/or olefinicity have consistently been demonstrated.

Catalyst formulation work is continuing with the objective of achieving the level of selectivity improvement seen with pure zeolite powders. As of today, comparing the catalytic results achieved with pure powdered zeolites with those from formulated catalysts, we estimate that these excellent first improvements have the potential to double when the full potential of the technology is realized.

Economic Value

Because of the complex inter-relationship between different units in a refinery and with economic factors like crude pricing and the value spread between feed and cracked products, it is challenging to relate catalyst performance to refinery value. Rive Technology has used industry-standard AspenTech PIMS and KBC Profimatics modeling tools to bridge the gap between lab test results and economic value to the refiner.[2,3]

At the beginning of the analytical process, ACE testing data measured at either CPERI or Grace Davison is processed using either Profimatics FCC-SIM™ process simulation software, or a proprietary kinetic model developed by Rive Technology to produce catalyst performance factors that, in turn, are converted to Profimatics catalyst factors. Shift vectors generated with Profimatics are then input to a PIMS model of a standard reference refinery and the operation is optimized. Sensitivity analyses have been run on variables such as crude or product pricing, the value spread between feedstocks and products, and different operating limits.

To ensure that crude costs and refinery product pricing data are input into the PIMS model in a consistent manner, correlations were developed based on historic data. We found that the historic cost of each crude and the price for each refinery product could be predicted well using linear functions of the prevailing 3-2-1 crack spread and the cost of West Texas Intermediate crude (WTI). Therefore, for any projected WTI cost and crack spread, the price of each crude and each product could be setup systematically in the model.

The hypothetical reference refinery for this process has a 150,000 bpd crude capacity with a 42,000 bpd FCC unit. It has both sour and sweet crude stills. Refinery constraints include:

- Sweet crude is at rate limit (sour crude rate is usually not a limit, but can be set if desired)
- Naphtha hydrotreater is feed limited (i.e. reformer naphtha feed treater)
- FCC is coke limited
- Hydrocracker is at rate limit
- Coker is at rate limit
- Product blending specs

Catalyst factors and shift vectors for the example analysis are based on the GRX™/commercial catalyst comparison previously summarized where alumina matrix catalyst formulation containing mesoporous Rive™ zeolite matched the activity and had improved selectivity vs. commercial alumina matrix catalyst containing conventional zeolite. Crude price is set at $75/bbl for West Texas Intermediate (WTI) based on the two year average spot price

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March 2009 thru February 2011. The crack spread is assumed to be $10/bbl; which is consistent with long range projections from the Energy Information Administration (EIA).

Table 2 shows the PIMS estimates for two operating cases. In Case 1 crude rates were allowed to float within the unit constraints of the reference refinery. In Case 2 crude rates were constrained to the levels optimized for the base catalyst case. Case 1 shows that increased economic value results from the following factors:

1. The combination of improved coke selectivity and reduced gas selectivity for the GRX™ catalyst with Rive™ mesoporous zeolite allows both the quality of the feed to the FCC unit to be reduced and a 17 °F increase in reactor top temperature while keeping within the FCCU coke limit:
   - Coker distillate is rerouted from the FCC to the distillate hydrotreater, which augments and improves diesel blending stock and makes the FCCU feed heavier
   - Sweet crude train is limited, but to make up diverted FCCU feed and to provide more blendstock for higher quality products coming from the FCCU, more sour crude is run. Naphtha cut point is decreased to stay within the reformer naphtha pretreater feed limit, thereby swinging more material to kero (jet)
   - FCCU feed rate decreases 1.8%, and feed quality is reduced
   - Increased riser top temperature results in increased FCCU conversion and also increases the octane and olefin content of the cracked products. Negative value bottoms fall 15%.
2. Feed to the alkylation unit increases as a result of greater olefins from the FCCU and together with the increased octane from the FCCU, total octane barrels is sustained
3. Added jet from crude allows more FCC hydrotreated heavy naphtha to be blended into diesel instead of jet
4. Hydrocracker is at its maximum feedrate, but the unit is able to shift yields to more naphtha and less distillate due to increased diesel from both FCC hydrotreated heavy naphtha and coker distillate
5. Reformer pretreater is limited, but 2.1% more reformate is produced due to more hydrocracker naphtha production (which does not need to go through the constrained pretreater).

Table 2. Incremental value of improved catalytic selectivity from GRX™ FCC catalyst. All data shown are relative to base case (not shown).

Parameter	Case 1: Optimized Crude Rates	Case 2: Crude Rates Constrained To Base Case
Refinery Throughput	+5.3 vol%	N/A
Refinery Profitability	+0.79 $/bbl crude	+0.47 $/bbl crude
Refinery Products:		
LPG	+0.3 vol% of crude	+0.2 vol% of crude
Gasoline	+1.0 vol% of crude	+0.3 vol% of crude
Distillates	+3.8 vol% of crude	+2.7 vol% of crude
Fuel Oil	+0.3 vol% of crude	-2.6 vol% of crude
FCC Riser Temperature	+17°F	+11°F
FCC Rate	-1.8 vol% of crude	-2.0 vol% of crude
FCC Yields:		
Conversion	+3.8 wt%	+4.4 wt%
Gas	+0.6 wt%	+0.6 wt%
C3 + C4 Olefins	+1.2 wt%	+1.2 wt%
C3 + C4 Non-olefins	+1.6 wt%	+1.7 wt%
Gasoline	+0.2 wt%	+0.8 wt%
Distillate	-2.2 wt%	-2.4 wt%
Bottoms	-1.6 wt%	-2.0 wt%
Coke (constant max coke rate constraint)	+0.2 wt%	+0.1 wt%

The net result of these changes, shown in Table 2, is a 5.3% increase in refinery throughput with 1.0% coming in gasoline and 3.8% in distillates. The net value of these improvements is $0.79/bbl ($118,000/day, or $43,000,000/yr).

Case 2 in Table 2 focuses on the value to the FCCU alone by constraining the refinery feed rate to base case levels. Consequently, the spillover value to other units is diminished, but there is still an increase in overall distillate and gasoline yields of 3.0% of the crude rate, and the FCCU experiences a 2.0 wt% drop in bottoms yield. Increased gasoline octane and olefins yields also help sustain octane-barrels.

The values in Table 2 are based upon a crude price of $75/bbl and a crack spread of $10/bbl. **Figure 3** (on page 5) shows the impact of changes to these values on the increased profitability of Case 1. It plots the value uplift in $/bbl of crude vs. crack spread ($5/bbl to $15/bbl), and it displays three lines representing WTI crude prices of $63/bbl, $75/bbl, and $87/bbl. This range represents the 10% and 90% points in the distribution of monthly running average WTI prices since March 2009.[4,5]

The graph shows that value uplift due to the improved selectivity of GRX™ catalyst containing mesoporous Rive™ zeolite increases nearly linearly with crack spread and roughly the same with increases in crude price. It is highly profitable in all combinations within the explored range. Even under the least favorable condition of $63/bbl crude price and $5/bbl crack spread, the uplift is worth $0.52/bbl crude (ca. $28,000,000/yr). At the most favorable conditions the value uplift is $1.04/bbl crude, or ca. $57 million per year.

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While not shown, sensitivity analysis also indicates that the value uplift due to improved FCC catalyst selectivity is approximately linear with refinery size.

Commercialization

Manufacturing of the first FCC catalyst from this joint program between Grace Davison and Rive Technology is now moving from the pilot scale to full commercial production. Thousands of pounds of Rive™ Y zeolite have been produced at the pilot plant of Grace's Curtis Bay, MD manufacturing facility, and, as can be seen from **Figure 4**, its performance matches that of smaller scale materials made in Rive's Princeton NJ laboratory. Figure 4 compares two catalysts made using the same formulation and rare earth level, but one catalyst contained Rive™ zeolite that was processed in the laboratory and the other contained Rive™ zeolite that was produced in the pilot plant.

Figure 4 shows that catalyst made with pilot plant Rive™ zeolite was more active and had equal selectivity compared to catalyst made using lab-produced Rive™ zeolite. Continuous calcination at the tech center allowed for more uniform stabilization of the zeolite which, in turn, produced a more crystalline and more hydrothermally stable product. At equal zeolite content the pilot plant catalyst had a steamed zeolite surface area of 190 m^2/gm compared to 160 m^2/gm for the catalyst with lab produced zeolite. Consequently, the pilot plant catalyst had about 25% higher activity (i.e., pilot plant zeolite catalyst achieved 75% conversion at 5.5 cat/oil vs. 7 cat/oil for the lab catalyst).

Otherwise, the two catalysts were identical. Figure 4 shows that there were no differences in either the gasoline, LCO, or coke selectivities of the two catalysts. ■

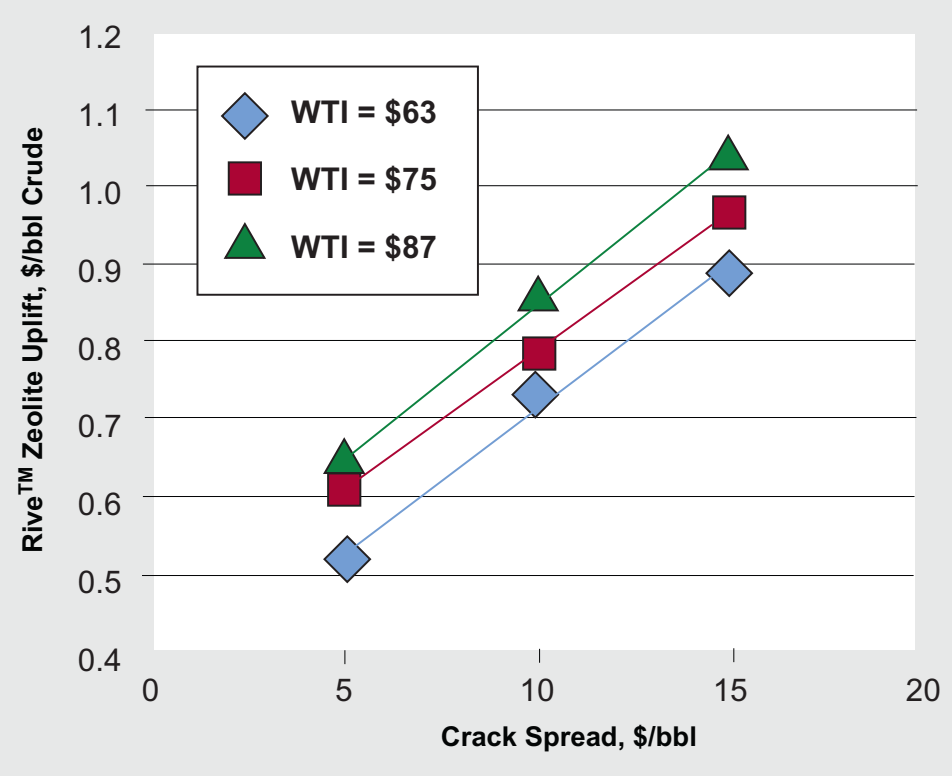

Figure 3. Improved profitability from FCC catalyst containing Rive™ mesoporous zeolite as a function of crude cost and crack spread.

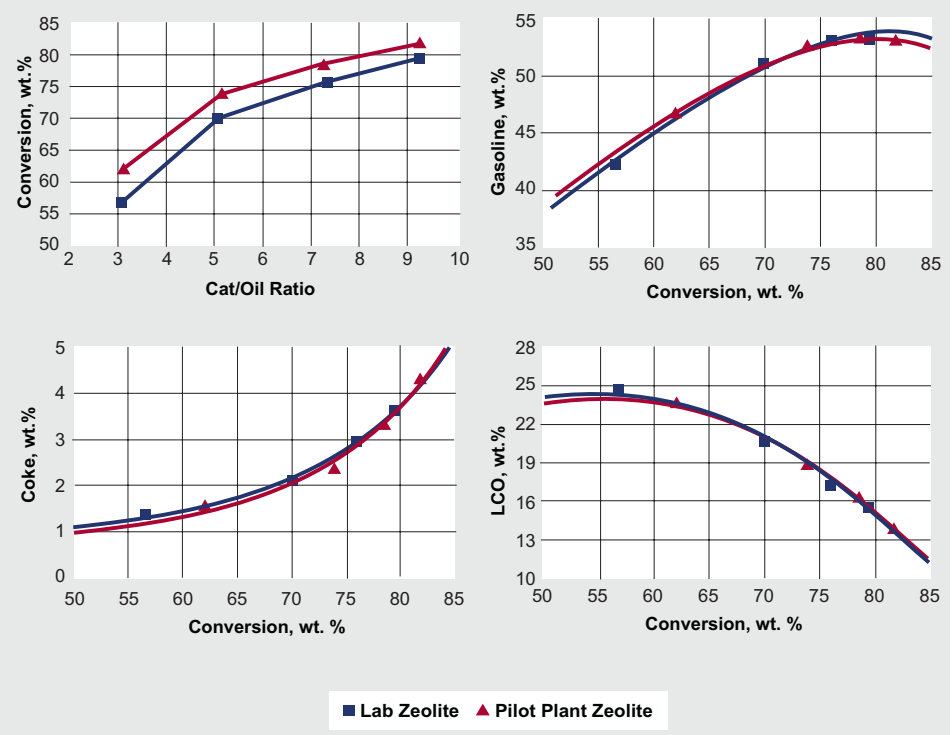

Figure 4. Scale-up of Rive Zeolite™ manufacturing process at the Grace Davison technology center produced excellent quality.

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The Authors

- **Barry Speronello**, Ph.D., is research fellow, Rive Technology, Inc. (barry.speronello@rivetechnology.com).
- **Javier Garcia-Martinez**, Ph.D., is co-founder, Rive Technology, Inc. He is also a professor of inorganic chemistry at the University of Alicante in Spain (Javier@rivetechnology.com).
- **Allen Hansen**, is process modeling engineer, Rive Technology, Inc. (allen.hansen@clinchain.com)
- **Ruizhong Hu**, Ph.D., is manager of research and tech support, Grace Davison Refining Technologies (ruizhong.hu@grace.com).

PROCESS OPERATIONS

Independent Catalyst Testing

George Hoekstra, Hoekstra Trading, LLC

Hoekstra Trading LLC

George Hoekstra

The rapid expansion of hydrotreating catalyst for ULSD production has opened a market for independent catalyst testing, such as for the testing of different brands of Type II, CoMo-based catalyst. Cost-sharing of catalyst testing among refiners is a cost-effective method for providing complete test data and catalyst ratings. More importantly, results are available for immediate delivery. A 12-day test duration with full analytical work-up using standardized protocols provides the opportunity to test different generations of competitive catalysts side-by-side, thus simplifying catalyst selection.

Simplify Catalyst Selection

Within each brand of catalysts, there are many different formulations and options, including:

- CoMo vs NiMo
- Fresh or regenerated
- Refurbished
- High pressure or low pressure
- Performance or value
- Single bed or stacked bed
- Cylindrical or quadrilobe
- High density or low density, etc.

With 20 or more brands of diesel hydrotreating (DHT) catalyst currently on the market, over 100 different options can easily be generated, thus complicating the selection process. Moreover, there are many performance claims surrounding these options. Some of these claims are strong and others are weak, but they are usually based on the suppliers own data.

Efforts by refiners to consolidate vendor-supplied data results in information lacking a common frame of reference and no methodology for validating the supplier's claims. Sorting through performance and product claims from catalyst suppliers can be challenging for independent refiners with "tight" resources. To be sure, many of these supplier claims are backed up by very good data. However, the lack of a common frame of reference adds up to a bewildering array of choices for refinery engineers.

Competitive Analysis

Analysis of every catalyst suppliers' product information is necessary to initiate an objective selection process. There are dozens of reports available at any given time from the suppliers that contain product data of catalysts that are being considered for commercial use. These reports combined with catalyst testing results are included in a competitive product analysis for refiners. For example, combining information on commercially available CoMo-based catalysts with cross-vendor testing on a common test track can optimize the selection process.

Recent independent testing conducted at the CEPRI Solutions, LTD labs in Thessaloniki, Greece of different generations of Type II CoMo catalyst yielded some surprising results.[1] These results provided new insights that changed the refiner's view of the catalyst at the processing objectives and operating conditions specific to their facility's configuration. This first-year test program was launched in May 2009 when Hoekstra Trading (www.hoekstratrading.com) sent out "questionnaires" to 15 different independent refiners. The request described the plan to test DHT catalyst samples supplied by the refiner.

Initially, a few of these refiners contacted were very interested and submitted samples that were tested in the summer 2009 pilot plant run. Consequently, finding refiners that were willing to pay for this type of service and detailed report ($50,000 for independent refiners and $75,000 for refiners with capacities over 1.0 million bpd) showed there was in interest in independent catalyst testing. Another winter 2009 pilot plant run of catalyst samples submitted by additional refiners validated there was potential growth in the market for independent catalyst testing on a common test track. These pilot plant tests typically involve 12-day runs of up to eight different catalysts with full analytical work-up.

Editor's Note: The Chemical Process Engineering Research Institute (CEPRI) in Thessaloniki, Greece includes several pilot plants for testing hydrotreating catalysts. Additional information can be obtained by contacting George Hoekstra at Hoekstra Trading LLC (George.hoekstra@hoekstrading.com or +1 630 330-8159). ■

Editor, Rene Gonzalez,
Refinery Operations
PO Box 11283
Spring, TX. 77391 USA
Mobile: +1 713-449-5817
Office: +1 281-257-0582
Fax: +1 281-686-5846
editor@refineryoperations.com

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inquiry@nemesismediagroup.com

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INDUSTRY NEWS

PetroChina Increasing Fuel Output

PetroChina Co., Asia's biggest company by market value, will benefit from higher oil and gas production this year as government controls on diesel and gasoline prices lead to refining losses, analysts said.

The Beijing-based company said recently first-quarter profit rose 14% from a year earlier to 37 billion yuan ($5.7 billion). The earnings missed the median forecast of 38.4 billion yuan in a Bloomberg survey of five analysts, after fuel price increases lagged behind crude oil costs.

Refining losses reached 6.1 billion yuan in the first three months after the government raised fuel prices by less than 6.0% while New York crude averaged 20% higher from a year earlier. That was offset by increased production of oil and natural gas, which is set to rise after PetroChina made its biggest overseas acquisition.

Net income at PetroChina may climb 20% to 166.9 billion yuan in 2011, according to a mean estimate of 17 analysts compiled by Bloomberg. The government is allowed to adjust oil-product prices when crude costs change more than 4.0% over 22 working days. China last raised gasoline and diesel prices by as much as 5.8% on April 7, its second increase this year, after crude hit a 30-month high.

Exploration and production accounted for 78% of PetroChina's 2010 operating income and refining and marketing had a 12% share.

Oil refining gained 16% to 250.1 million barrels in the first quarter. PetroChina is planning to increase fuel output to meet demand from farmers and help supply the world's biggest car market. China's economy expanded 9.7% in the first three months, beating a median forecast in a Bloomberg survey of economists for growth of 9.4%. The country's fuel demand may rise 8.0% this year, the National Energy Administration said on April 22.

The Chinese energy producer wants half its oil and gas output to come from overseas by 2020, Chairman Jiang Jiemin said in an interview last year. Less than a 10th of production now comes from abroad. PetroChina was overtaken by Apple Inc. as the world's most valuable company after Exxon Mobil Corp. last year. ■

Smaller Chinese Refining Facilities Face Closures

About 80% of independent refineries in China face the risk of closure before 2013 under the recently-released Guidance Catalog for Adjustment of Industrial Structure (2011). According to the guidance catalog, which will take effect June 1, China will shut crude distillate units (CDUs) with annual capacity less than 2.0 million mt by the end of 2013.

At the end of 2010, refining capacities of Chinese independent refineries aggregated 110 million mt per year, about 80% of which is contributed by CDUs under 2.0 million mt per year, according to data compiled by "C1" based in China. Only seven independent refineries with annual capacities totaling 22.5 million mt are equipped with CDUs of higher capacities.

Small independent refineries may have to expand capacities for survival, market sources pointed out. They could also choose to be merged or acquired by state-owned enterprises for access to capital and feedstock, according to sources researched by C1. Or, they could switch to bitumen or chemical production, the sources also denoted.

However, local governments may not execute the Cont. page 8

elimination policy when focusing on economic growth, some market sources believed. In addition, "there currently is no special governmental department in charge of phasing out small and obsolete refining facilities in China," said a refinery source. It has been well publicized in the trade press that state-owned oil giants are expected to launch massive new refining projects in 2013. ■

New South African Refinery Will be Largest in the Continent

The Mthombo Crude Oil Refinery project to be located in the Coega Industrial Development Zone near Port Elizabeth in the Eastern Cape of South Africa is an initiative taken by the state owned PetroSA to meet South Africa's demand for refined oils. The refinery will process 400,000 bpd of crude oil and will be the largest in the continent.

The project aims to meet the growing demand for refined oil, which is outstripping the country's current refining capacity of 700,000 bpd. It is estimated that by 2015 the nation will import an additional 1.5 billion litres of fuel a year. The existing aging refineries are on average 40-50 years old. Moreover, the technologies used by these refineries do not meet global emissions standards. Hence, the investments made to expand their refining capacities may prove commercially non-viable.

The FEED study for the PetroSA approved project is currently being carried out and is scheduled to be completed in early 2012. The construction is scheduled to commence in 2012 upon final approval. Completion is expected by 2015 and commissioning in 2016.

As the project was conceived during a period of economic boom, it was estimated to cost $11 billion. It will now cost 25% less ($9 billion) due to the reduction in construction costs triggered by the global economic crisis.

The Mthombo refinery will be designed on a stand-alone and self-sustainable philosophy. It will be designed to process heavy sour crude oil with 90% conversion capability. The products will meet the global emission standards of Euro V, which will enable the plant to access global markets. It will also help in the upgrading of the plant without further investments when the country adopts global emission standards.

The plant is being designed to consume less water for cooling purposes by using advanced air cooling methods. It will also discharge less effluent and wastes by using internally recycled water. It will have a flexible production system to process diesel and petrol to meet seasonal and market changes.

The refinery will have a partial conversion hydrocracker, a fluid catalytic cracking unit, delayed coker, residue solvent de-asphalting unit, and conventional top of continuous catalytic reformer and a naptha isomerization unit. The Mthombo refinery will also feature an 800MW power plant to generate electricity using petroleum coke as the energy source. It is envisaged that around 200MW of the power will be consumed by the refinery and the rest will be transmitted to the national grid.

Once built, it will be the biggest in Africa and provide a national security of supply for South Africa's future fuel requirements. National demand for refined fuels already exceeds South Africa's refining capacity and the demand is set to increase further: Diesel consumption is forecast to grow at 6.0% and petrol at 2.0% per annum between 2011 and 2020. ■

Kuwait Ready to Launch $15 Billion Project

Kuwait may relaunch plans for a fourth oil refinery after scrapping a tender to build it earlier this year following parliamentary opposition, a deputy prime minister was quoted as saying. In March, Kuwait scrapped the tender for the $15 billion refinery after several parliament deputies said there had been violations in awarding contracts.

"The past differences over the refinery were not about the project as such," said Sheikh Ahmad al-Fahad al-Sabah, deputy prime minister for economic affairs, quoted by the state news agency KUNA in late April. They (differences) were about mechanisms such as cost-plus, etc," Sheikh Ahmad said, adding that there had been "misunderstandings about the mechanisms." He did not elaborate. In a cost-plus contract, the contractor charges the client for manpower and materials, and then adds on its profit margin. Sheikh Ahmad said the project could be realised after legal and regulatory reviews, KUNA said.

In March, the state oil company KNPC said it had informed companies that were awarded contracts to build the 615,000 bpd refinery that the tender was cancelled, adding this did not mean the project would be dropped. ■

Petronas Meg-Refinery Project Scheduled for 2016 Completion

Malaysia's state-run Petronas will build a $20 billion integrated refinery and petrochemicals complex, Malaysia's largest-single investment, that will boost the country's total refining capacity by half as it looks to meet Asian demand for specialty chemicals, as reported by the Reuters news agency on May 13.

The 300,000 bpd

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refinery in southern Johor state bordering Singapore, is expected to be commissioned by end-2016 and will take Malaysia's oil refining capacity to 935,300 bpd, coming at a time of growing production capacity from India, China and South Korea.

"This commitment to an ambitious expansion in its downstream production capacity assuredly signifies the depth of Petronas' ambitions to capture the opportunities Asia's dynamic energy and chemical markets are expected to provide," Prime Minister Najib Razak said at the project's launch.

Petronas Chief Executive Shamsul Azhar Abbas said the complex, to be named the Refinery and Petrochemicals Integrated Development (RAPID), would meet an expected surge in demand for specialty chemicals in Asia, the main market for the products, while complementing Singapore's energy business.

"As far as the market is concerned, the whole Asian region is going to be short of high specialty products, so this is meant for the region," Shamsul told reporters after the launch.

The project would expand Petronas' petrochemicals business and spur growth of Malaysia's downstream oil and gas sector, he said. "More than 80% of the products are new products because we have not gone into full specialty product development," Shamsul added. Neighboring Singapore aims to rule Asia's expanding specialty chemicals sector, part of the $395 billion global market, but faces a challenge from China, which is set to increase capacity and reduce imports. Growth for Asia in this sector is seen at 10-15%, versus 2-3% in the United States and Europe, analysts said. ■

Royal Dutch Shell Reports Higher Refining Profits

Europe's largest oil company, Royal Dutch Shell Plc (RDSA) recently reported profit from refining in the first quarter 2011 surged 112% from a year earlier because of higher utilization rates at some of its plants amid rising prices for oil-products and chemicals.

Downstream earnings excluding identified items rose to $1.65 billion compared with $778 million a year ago. Including identified items, the earnings were 57% higher at $1.17 billion, said the company, which is based in The Hague. Earnings reflected higher margins and "higher refinery intake volumes, due to lower planned and unplanned maintenance activities," according to the statement. The volume of oil processed by its refineries increased 1.0% to 3.03 million bpd in the quarter, Shell said. ■

Ongoing Operational Problems with PDVSA Refinery Network

A second partial stoppage in a week occurred on Thursday, May 12 at the Amuay refinery, Venezuela's biggest refinery, which came back online days ago after electrical faults paralyzed an FCC unit and most operations there on May 6. An oil trader who deals with PDVSA estimated it would take at least a week to resume full operations at the refineries.

According to information obtained from the May 12 Dow Jones Newswire, exports from South America's biggest crude producer have declined in recent years, in part because PDVSA refinery network has suffered repeated power faults, accidents and planned stoppages for maintenance.

Oil Minister Rafael Ramirez told reporters PDVSA hoped to have both refineries restarted by the end of the week. He said the installations had inventories to last 15 days. Workers at the site said Thursday's problems appeared to have been caused by a power cut at Genevapca, the electrical plant that supplies the refineries and surrounding areas. Ramirez said the power plant was being restarted. Amuay and Cardon are part of the Paraguana Refining Center (CRP), one of the biggest oil refinery complexes in the world.

"We're monitoring the situation, but it is still an emergency," said one worker at Amuay. "Everything lost power, from the administrative building to the docks", he added, as quoted in the Dow Jones May 12 newswire. The loading and unloading of about six tankers at the CRP docks was continuing, he said, but with minimal staff because PDVSA moved most workers out of the area as a safety measure. ■

SPRC FCC Revamp

Foster Wheeler AG announced in early May that a subsidiary in its Global Engineering and Construction Group has been awarded a contract by Star Petroleum Refining Company Limited (SPRC) for front-end engineering design (FEED) for the Residue Fluidized Catalytic Cracking Unit (RFCCU) Revamp Turnaround and Inspection Project at its refinery at Map Ta Phut in Thailand. The objective of the project is to revamp the RFCCU to improve on-stream reliability together with environmental and performance improvements. Foster Wheeler will carry out the FEED for this major revamp, including licensor selection, and will also work with SPRC to evaluate the existing RFCCU maintenance and reliability philosophies with a view to identifying any changes that may be needed in the future to retain the continuous improvement of on-stream performance. The FEED is expected to be completed by the first quarter of 2012. ■

Deep Cut Vacuum Project at Thai Oil Refinery

Foster Wheeler AG announced on May 11 that a subsidiary in its Global Engineering and Construction Group has been awarded a contract by Thai Oil Public Company Limited for the basic design engineering package and engineering, procurement and construction management (EPCm) services for the Emission Improvement and PSA-3 project at Thai Oil's refinery at Sriracha in Thailand.

The project's objectives are to give the refinery greater flexibility in the crudes it can process, specifically to enable the refinery to process higher sulfur crudes, to upgrade fuel oil to more valuable end products and to meet new sulfur oxides (SOx) emissions regulations coming into force in Thailand.

Residue production will be reduced through the application of deep cut vacuum technology, which helps mitigate the effects of heavier crude slates. In addition, new sour gas handling facilities will be installed, including a sulfur recovery unit (SRU) and a tail gas treatment unit (TGTU), and hydrogen production capacity will be expanded by installation of a new pressure swing adsorption (PSA) unit. Foster Wheeler's scope also includes a significant element of revamp work. The project is expected to be completed during the first quarter of 2013. ■

Sohar Refinery Expansion Project Includes 74,000 bpd Hydrocracker

Oman Refineries and Petrochemicals Company (ORPC) will use ISOCRACKING technology from Chevron Lummus Global (CLG) at the heart of its Sohar Refinery Expansion Project to boost margins and increase production.

The Sohar hydrocracking facility in Oman will process almost 74,000 bpd of vacuum gas oil (VGO) and light cycle oil (LCO). The investment will enable Sohar Refinery to increase its naphtha production for its petrochemicals complex and produce high quality ultra-low sulfur diesel and kerosene. CLG's hydrocracking technology was selected by ORPC after a thorough analysis showed it offered the best overall economics by a well-proven process scheme.

ORPC is the leading Omani producer and distributor of refined products in Oman. The Sohar refinery is the largest in the country with a CDU capacity of 116,000 bpd. It is located about 220 km northwest of the capital Muscat. ■

Safety Instrumented Systems for BPs North American Refineries

HIMA, a leading provider of safety-certified automation and control equipment, recently announced a five-year agreement between HIMA Americas, Inc. and BP Products North America, Inc. to provide its Safety Instrumented Systems (SIS) and Functional Safety Services to BP's five North American refineries. The agreement is based on HIMA's TÜV-certified HIMax safety platform, its SILworX configuration, programming and diagnostic software suite and associated Functional Safety and Engineering services, which under the agreement will be available to all five of BP's North American refineries.

The HIMA safety systems will strengthen BP's ongoing safety focus with leading edge safety technology and services, by allowing BP to implement the highest level of safety integrity, with the flexibility to update, maintain or modify the systems without interrupting their protective functions or production operations. The HIMA safety systems will also help BP to standardize safety design, implementation methodology and compliance documentation, which will help to enhance its safety infrastructure by creating an efficient model that can be easily replicated. ■

Unplanned Maintenance Affects 1st Quarter Earnings

U.S. refiner ConocoPhillips (COP) is blaming unplanned maintenance on a hit to first quarter 2011 (1Q2011) profit, following U.S. refiner Valero (VLO) as reported by Dow Jones newswire in late April. Both companies' overall earnings fell short of analysts' expectations. COP's Jim Mulva says refining earnings would have been some $50M above the $480M reported "if we had operated our U.S. downstream at planned levels." That gap is still less than what some analysts say COP's refining profit missed their estimates by. ■

Comperj Refinery/Petrochemical Timeline

Petrobras will use natural gas from the pre-salt fields as fuel and feedstock in the new refinery/petrochemical complex in Rio de Janeiro (Comperj), which is being built in Itaborai. The first refinery is expected to go into operation in late 2013. The petrochemical plant should start operating between late 2016 and early 2017 in collaboration with Braskem. About 15 million cubic meters of natural gas daily from pre-salt will be used as a feedstock in the Comperj petrochemical plant, where it will be transformed into products such as propylene, butadiene, benzene, polyethylene and polypropylene. ■

GES+ Contract to Support Saudi Aramco's Capital Program

SNC-Lavalin recently announced that it has been selected, together with its local Saudi Arabian 50/50 joint venture partner, The Zuhair Fayez Partnership, by the Kingdom of Saudi Arabia's state-owned oil company, Saudi Aramco, to perform general engineering and project management services (GES+) under a five-year reimbursable contract.

Under the contract, SNC-Lavalin and The Zuhair Fayez Partnership will perform Front-End Engineering & Design (FEED) and select detailed engineering, as well as project management services to support the execution of Saudi Aramco's capital program. These projects include oil and gas production and processing facilities, both on and offshore, infrastructure projects, refining and petrochemical facilities. This work will be executed out of the Joint Venture offices in Al-Khobar, Saudi Arabia. ■

IPIC Project in UAE Continuing at Lesser Capacity

International Petroleum Investment Company (IPIC) plans to build a refinery in Fujariah, UAE to serve the global market. The refinery was expected to have a capacity of 500,000 bpd plus a petrochemical complex. However, the facility was downgraded to a capacity of 200,000 bpd and the petrochemical complex was discarded. Feedstock will be supplied from Abu Dhabi's Upper Zakum Field. ■

Valero Norco, Louisiana Hydrocracker Project

The 250,000 bpd Valero Norco, Louisiana turnaround maintenance to the facility's FCCU and alkylation unit will be completed by mid-May, the company noted on April 26. The hydrocracker project will be completed in late 2013, the company said. In addition, the upgrading project to build a new diesel hydrotreater unit has been extended to fourth quarter of 2012. Also, Valero's 325,000 bpd Port Arthur hydrocracker project will be completed in late 2012. ■

Downstream Technology of the Year Awarded to FCC Catalyst Supplier

Grace Davison, an operating segment of W. R. Grace & Co. has won the Downstream Technology of the Year Award at the Middle East Downstream Week 2011 conference. The prize was awarded in recognition of the impact that its NEKTOR™ fluid cracking catalysts have had in helping refiners upgrade the bottom of the oil barrel into transportation fuels, to meet worldwide demand for gasoline and diesel .

Shawn A. Abrams, Vice President and General Manager, Grace Davison Refining Technologies, commented, "We are pleased to accept this award, which recognizes Grace's long-term commitment to the research and development of innovative products that meet the continuing challenges of the global petroleum refining industry."

"The NEKTOR™ catalyst allows refiners to process additional feed or heavier feed in their FCC unit through the use of a highly functionalized matrix and a hydrothermally stable and metals-tolerant zeolite. NEKTOR™ catalysts can also allow refiners to upgrade more of their feedstock to valuable transportation fuels," said André Lanning, Director Marketing and Business Development, Grace Davison Refining Technologies. ■

EDITORIALLY SPEAKING

What to Do with Underutilized Hydrotreaters

Various hydrotreating configurations are used throughout the refining industry to remove more than 90% of all the contaminants from the 200 or so different types of crudes currently on the market. These contaminants, if not removed from the petroleum fractions as they travel through the refinery processing units, can have detrimental effects on the equipment, catalysts (e.g., FCC catalysts) and finished product.

Hydrotreating in refineries is typically done prior to processes such as fluid catalytic cracking so that the catalyst is not contaminated by untreated feedstock. However, more hydrotreating capacity will be needed "in the field" or at bitumen upgrading facilities.

Hydrotreating capacity has expanded to upgrade middle-distillate petroleum fractions into finished kerosene, diesel fuel, and heating fuel oils. Nonetheless, it has been reported that with more refiners planning on processing bitumen based feeds and other low API gravity feeds, that a significant portion of hydrotreating capacity in some regions, such as the US Midwest, are too "underpowered" to convert the kerosene cut from synthetic crude oils into a good quality jet fuel. Some designers have noted that what may be needed is to upgrade underutilized hydrotreaters to operate in the 800 psi range for kerosene hydrotreating service.

In addition hydrotreating the increasing yield of LCO from bitumen feeds means that higher volumes of aromatics (e.g., mon-aromatics, tri-aromatics and olefins) need to be saturated. This is one reason why there has been a noticeable shift in the severity of hydrotreating required to achieve product quality objectives. For example, typical VGO-based FCC units require at least 12.2 wt% H_2 content in the feed entering the FCC riser/reactor.

There are obviously quite a wide variety of hydrotreating processes and hydrotreating catalysts available to refiners depending upon the feedstock available. The choices can be confusing and time consuming for process engineers tasked with making the proper selection as noted by George Hoekstra (www.hoekstratrading.com) in the Process Operations article in this issue of *Refinery Operations*.

Hydrotreating can be used to improve the burning characteristics of distillates such as kerosene for jet fuel. Hydrotreatment of a kerosene fraction can convert aromatics into naphthenes, which are cleaner-burning compounds. In lube-oil hydrotreating, the objective (e.g., mild lube hydrotreating) is to saturate olefins and improve color, odor and acid nature of the oil. Mild lube hydrotreating also may be used following solvent processing. Operating temperatures are usually below 600 °F and operating pressures below 800 psi. Severe lube hydrotreating at temperatures in the 600 -750 °F range and hydrogen pressures up to 2,900 psi, is capable of saturating aromatic rings, along with sulfur and nitrogen removal, to impart specific properties not achieved at mild conditions.

Hydrotreating also can be employed to improve the quality of pyrolysis gasoline (pygas), a by-product from the manufacture of ethylene. Traditionally, the outlet for pygas has been motor gasoline blending, a suitable route in view of its high octane number. However, only small portions can be blended untreated owing to the unacceptable odor, color, and gum-forming tendencies of this material.

Another area that may predicate the need for higher-than-expected hydrotreating and downstream sulfur recovery capacity is with those refiners that have added thermal conversion capacity, such as with delayed cokers. Naphtha by-products from cokers have low octane, high olefins content as well as high levels of unstable diolefins and sulfur requiring hydrotreating.

Rene Gonzalez, Editor
Refinery Operations

With the shift in the global heavy crude market, many refiners are gravitating to the processing of heavier crudes to conserve feed costs. However, experience with processing these crudes has been surprisingly low. For example, Chinese and Indian refiners are beginning to encounter the process challenges that US refiners faced in the 1980s with Venezuelan heavy crudes (e.g., Merey crudes, BCF-17, etc.). At the same time, US refiners in the Midwest and the Gulf Coast are running into problems of their own with Canadian crudes that are now being processed in higher volumes. To be sure, the installation of more residue hydrocracking and solvent deasphalting capacity to handle the increased amount of heavy residues and the general shift to heavier crudes is expected to increase coker naphtha production, of which requires well designed hydrotreating configurations.

As much as has been written about hydrotreating (and linked process assets) over the past generation, we can expect to see an infusion of new information related to the these global changes in the way refiners operate their refineries with underutilized hydrotreaters playing a big role in the improvement of product quality. ■

CALENDAR OF EVENTS

MAY

24-27, *NPRA Reliability & Maintenance Conference & Exhibition*, NPRA, Denver, Colorado, +1 202 457 0480 www.npra.org.

JUNE

13-14, *The Global Catalyst Technology Forum*, Euro Petroleum Consultants, Dubrovnik, Croatia, +44 (0) 20 7357 8394 www.europetro.com

15-16, *9th International Bottom of the Barrel Technology Conference*, Euro Petroleum Consultants, Dubrovnik, Croatia, +44 (0) 20 7357 8394
www.europetro.com.

OCTOBER

9-12, *NPRA Q&A and Technology Forum,* San Antonio, Texas, +1 292 457 0480,
www.npra.org.

NOVEMBER

Nov. 29 – Dec. 1, ERTC 16th Annual Meeting, Barcelona, Spain, +44 (0) 207 484 9700, conf@gtforum.com, www.gtforum.com.