

## The Future FCCU – Gasoline Machine or Petrochemical Unit?

a report by

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For years the terms ‘fluid catalytic cracking’ (FCC) and ‘petrochemicals’ have been synonymous with production of propylene. Indeed, the much-abused term ‘petrochemical-FCC’ is defined by some FCC licensors as a unit that produces >10 wt.% propylene from vacuum gas oil feedstock.

Consider for a moment that the number of operating units that qualify for the title of petrochemical-FCC under this definition can be counted on the fingers of both hands and, further, that if Chinese units are excluded, there is only a single true petrochemical-FCC operating today outside China (TPI in Thailand). At this point one begins to wonder what all the fuss is actually about.

With the context of the global propylene market, however, this is represented by small quantities of propylene from many FCC units (FCCUs). Overall around 33% of total global propylene supply is sourced from FCCUs, which is equivalent to around 22 million tons of propylene. This production of propylene should be set in context to the global gasoline market, which is currently sized at over 880 million tons.

With propylene prices averaging in the long term around 1.9 times premium gasoline – and on occasions considerably higher – there must be considerable barriers to exploiting the FCCU further as a producer of petrochemicals.

These facts beg several questions:

- Why are petrochemical-FCCs today so rare?
- What are the obstacles to using the FCCU as a petrochemical producer?
- In what new ways can the FCCU be exploited as a petrochemical producer?

This article will look at the present state of the art of the FCCU-based petrochemical complex as represented by a recent project; the future plans for enhanced levels of petrochemical production from FCCUs; and the possible long-term goal of a ‘fully petrochemical FCCU’. In short, we believe that the

FCCU has remained a gasoline machine for too long, and that the full range of possibilities represented by this unit has yet to be exploited.

### The Problem (and One Solution)

With the development of modern zeolite catalysts, and following Mobil’s use of ZSM-5 zeolite (starting in 1983), which converts gasoline range olefins into light olefins, the methods to produce high volumes of propylene from FCCUs have long been known:

- Increasing the riser temperature reduces gasoline production and enhances the production of olefinic LPG, dry gas and coke.
- Addition of ZSM-5 additive reduces gasoline production and increases olefinic LPG production.

Both processes tend to denude the gasoline of olefins and paraffins, especially the C7+ gasoline cut. Hence, the increase in olefin production comes at the expense of gasoline volume. Also, as the gasoline becomes depleted in paraffins and olefins, its octane number increases (desirable) and its density increases (undesirable). Both phenomena are due to the concentration of aromatics in the gasoline as paraffins and olefins are depleted.

ZSM-5 has another desirable characteristic in that it promotes the isomerisation of olefins to branched olefins. These in turn form branched paraffins by hydrogen transfer reactions. Branched paraffins have good octane numbers and are desirable in the gasoline product. Hence, from a gasoline blending perspective, there are advantages in not overcracking the gasoline when using ZSM-5 so as to ensure a high level of branched paraffins in the gasoline cut.

The extreme position of high propylene production (>10 wt%) is therefore found to be generally undesirable by refiners because the highly cracked gasoline has an unacceptably high density (being predominantly aromatics and naphthenes) and is deficient in paraffins. By contrast, many refiners choose to operate with modest levels of ZSM-5 in a mode where the mild depletion of gasoline volume



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is offset by the increases in gasoline octane due to isomerisation/hydrogen transfer reactions and mild concentration of aromatic species. This corresponds to propylene yields in the 5–10 wt.% range.

In all of the above we ignore any other capacity constraints refiners may face: for example, FCCU reactor/main fractionator capacity, wet gas handling, or the ability to valorise the additional C4 and C3 olefins produced (e.g. by alkylation or propylene recovery). Grassroots projects do not suffer from these constraints, which are all too real for existing operations.

Jacobs Consultancy was involved recently in a project in which it sought to optimise the petrochemical yield from an FCCU that was originally designed for gasoline production, albeit with a relatively high propylene yield.

The Sohar RFCC in Oman has recently commenced operations. This is a 75 kbpd FCC operating on Oman Export Blend residue. The FCC was designed to produce 8.5wt.% propylene with the FCC gasoline being routed to gasoline blending. At the outset of the study, the Sohar Refinery Company ('SRC'), a grassroots project, was in construction, being roughly 20 months away from start-up. Because the SRC was project financed it was clear that any new project would have to be minimally invasive of the original project, since the project loan was secured on this operation; therefore, lenders would require that the cash flows from the original project were not put at risk. For this reason, no major alteration to the original refinery process units or refinery operations could be considered.

The C7-C10+ gasoline from the Sohar FCC has an aromatics content of almost 50 vol.% density of 0.8, research octane number (RON) of 94 and motor octane number (MON) of 82 and aromatics content of almost 50 vol.%. In Europe premium gasoline can have a maximum aromatics content of 35 vol.%, maximum density of 0.775, and minimum RON and MON of 95 and 85 respectively. Hence, it can be seen that the C7+ FCC gasoline from this unit is not a particularly attractive blending component. Recalling that this unit operates at 8.5wt% propylene yield, if the FCC moved to a more severe petrochemical-FCC mode of operation, the C7+ gasoline would become even higher in aromatics content, although its density, RON and MON would also improve somewhat.

Viewing this stream from a petrochemical rather than gasoline blending viewpoint, it becomes apparent that the issues that make it less attractive for gasoline blending – density and aromaticity –

are, in contrast, attractive features for the production of aromatics. The removal of this stream from the refinery gasoline pool and its conversion to high-value aromatics thus became the focus of Jacobs' work. (It is also possible to blend FCC C7+ gasoline into kerosene to a limited extent, though its smoke point is poor. In some areas, for example parts of Europe, this represents an alternative option for use of this stream.) From this idea emerged the concept for the use of the C7+ FCC gasoline as a petrochemical feedstock.

Key to the success of this scheme is the ability to upgrade heavy aromatics (C10+) to xylenes with modern metal-promoted transalkylation catalysts. The viability of this project, however, also hinged on minimal interference with the refinery. The proposed processing scheme plans to re-use one of the FCC gasoline hydrotreaters; other than this change there is no alternation to refinery processing units and, importantly, the proposed changes do not create stranded assets on the refinery.

It is notable that the refinery makes a small volume gain from the addition of the aromatics project. Principally this comes from a reduction in gasoline density due to the removal of the dense C7+ FCC gasoline from the gasoline pool. Other than the reduction in regular gasoline production and the elimination of full-range naphtha sales, the refinery balance is largely unaffected. For these reasons, the banks providing the project loan to SRC approved the changes necessary for the aromatics project (now called Aromatics Oman Limited ('AOL')) to proceed.

The US\$1.6 billion AOL project achieved financial close in mid-2006, prior to the start-up of the SRC refinery, which is currently underway in the fourth quarter of 2006. Process technology was licensed from Axens. The engineering, procurement and construction (EPC) is being undertaken by GS E&C and LG International of Korea under an LSTK contract. The project sponsors are Oman Oil Company (80%) and LG International of Korea (20%). The key features of the AOL project are:

- world's largest single train PX plant (though even larger units are now in design);
- over 50% of reformer feed is RFCC gasoline;
- heavy reformer feed (boiling range 98–190°C) gives high yield of C9 and C10 aromatics;
- over 60% of xylenes from transalkylation; and
- closely integrated to the SRC refinery for feedstock supply and disposal of by-products. ■

*A longer version of this article containing figures can be found in the Reference Section on the website supporting this briefing ([www.touchoilandgas.com](http://www.touchoilandgas.com)).*