The New Case For Hydrocracking

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Introduction

For decades hydrocracking failed to achieve lofty predictions made in the mid-1960s about this new and highly versatile refining process.

In this presentation we will examine:

- The early history of the hydrocracking process;
- Reasons why the process failed to supplant the FCC as once thought; and,
- Why today's refining environment has finally made hydrocracking a preferred conversion technology.

Early History

Commercialization of the hydrocracking process is attributed to I. G Farben in Germany in 1927 as part of that country's efforts to produce transportation fuels from coal and lignite.

In the late 1920s and early 1930s, Esso Research and Engineering (ER&E) worked with I.G. Farben to apply the process to heavy oils and bring the technology to the U.S.

However, there was little interest in hydrocracking until the late 1950s and "ground zero" for hydrocracking research and development was in California.

Why California?

California has always been "unique" relative to the rest of the U.S. and the differences extended to the refining industry.

- California's indigenous crude oil supply was much more naphthenic and much higher in nitrogen content than mid-continent and imported Middle Eastern crude oils process by most other U.S. refiners in the 1950s and 1960s.
- Smog became an issue and in 1959 Los Angeles County instituted a maximum bromine number of 30 for gasoline which significantly limited olefin content. The state later adopted this rule for all California gasoline.
- Rapidly growing demand for gasoline in the 1950s and 1960s created an imbalance with the typical supply balance of gasoline & distillate produced by California refineries.

As a result, an alternative to the FCC, which struggled to obtain high conversion of California gas oil and produced high bromine number gasoline, was needed and hydrocracking was seen as the answer.

The First Demonstration Units

Several process technology and major oil companies began working to commercialize hydrocracking of various feedstocks and several small demonstrations units were built.

- UOP and Standard Oil of California (SoCal) jointly developed the Isomax process and installed a 1,000 bpd Isomax unit at the SoCal refinery in Richmond, CA in 1959.
- Gulf and Houdry jointly developed the H-G hydrocracking process and installed a 6,500 bpd unit at the Gulf refinery in Philadelphia, PA in 1962.
- Hydrocarbon Research (HRI) developed the H-Oil process and together with Cities Service Oil Co. installed a 2,500 bpd unit designed to hydrocrack resids at Cities' Lake Charles, LA refinery in 1963.
- ER&E and Unocal jointly developed the Unicracking-JHC process and installed a 15,600 bpd unit at Unocal's Wilmington, CA refinery in 1964.

The 1960s – Hydrocracking's "Golden Age"

The 1960s was a decade of growth and innovation for the U.S. and hydrocracking became the "hot, new" refining technology.

According to the *Oil & Gas Journal*, 25 hydrocrackers were installed in U.S. refineries by early 1967 and another 12 were scheduled to come on-stream by the end of 1968.

To no one's surprise, 40% of this initial hydrocracking capacity was installed in California refineries.

What might be a surprise to the newer generation of refiners is that 30% of that capacity was earmarked for converting distillate barrels into gasoline!

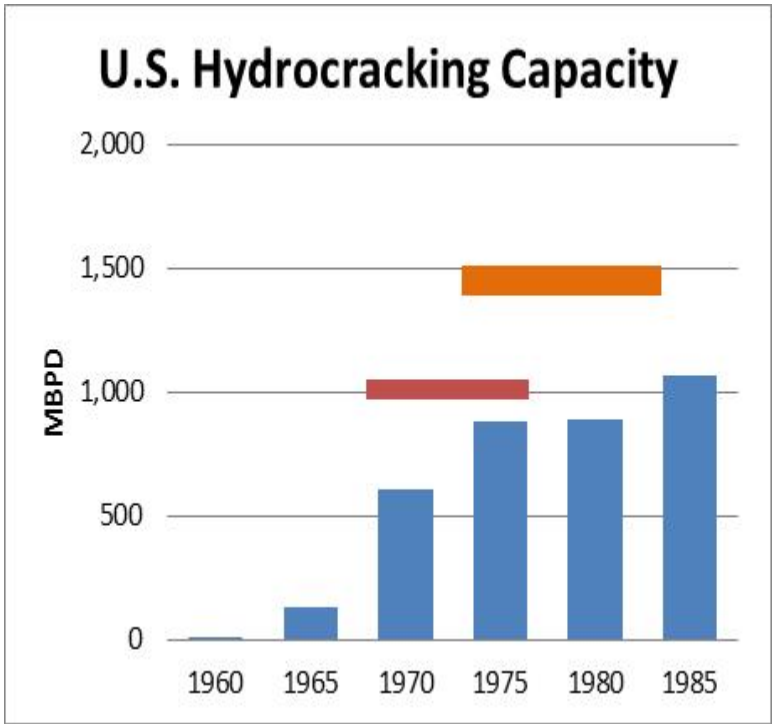
The Great Expectations Go Unfulfilled

The rapid rise of hydrocracking, its feedstock versatility and ability to achieve very high conversion created expectations that the process would quickly overtake the FCC as the preferred conversion process, if not supplant the FCC outright.

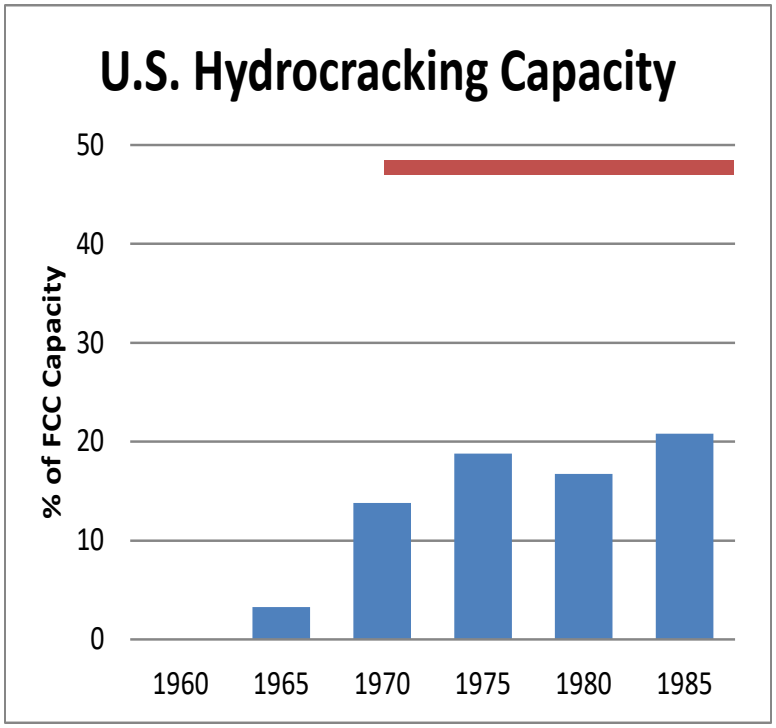
- The December 1965 edition of *Hydrocarbon Processing* boldly stated that total U.S. hydrocracking capacity would exceed 1 million bpd by 1970 and approach 50% of total FCC capacity.
- A 1967 technical manual on hydrocracking published by the *Oil & Gas Journal* proclaimed that total U.S. hydrocracking capacity would reach 1.4 -1.5 million bpd by 1975.

Both predictions would prove far from correct.

Actual U.S Hydrocracking Capacity



Data Source: Oil & Gas Journal Refining Survey
Hydrocarbon Processing Prediction
Oil & Gas Journal Prediction



Data Source: Oil & Gas Journal Refining Survey
Hydrocarbon Processing Prediction

Hydrocracking's "Glass Ceiling"

There are several reasons for the equally dramatic halt in hydrocracking additions in the U.S.

- Numerous advances in FCC catalyst & technology during the 1960s, 1970s, and 1980s.
- Hydrocracking's relatively high investment cost versus FCC.
- Shifting product demand.

While the relative maturity of the U.S. refining industry might be seen as a cause for the abrupt slowdown in hydrocracking additions, we don't find that to be the case:

- From 1970 to 1980, FCC capacity grew by 930 MBPD compared to 285 MBPD for Hydrocracking
- For 1975-1980, FCC growth was 627 MBPD to HCU's 8 MBPD

FCC Catalyst Advances

The most important advance in FCC catalysis was the introduction of zeolites in the mid-1960s.

- Dramatically increased conversion & reduced slurry recycle rates
- Quickly adopted – going from zero market share in January 1964 to 77% in only 3 years according to the *Oil & Gas Journal*.

Later catalyst advances would include:

- Metals passivation additives
- Combustion promotors
- New catalyst formulations to increase FCC gasoline octane
- High matrix formulations to enhance bottoms cracking and reduce slurry yields
- ZSM-5 additives to increase octane and light olefin yield

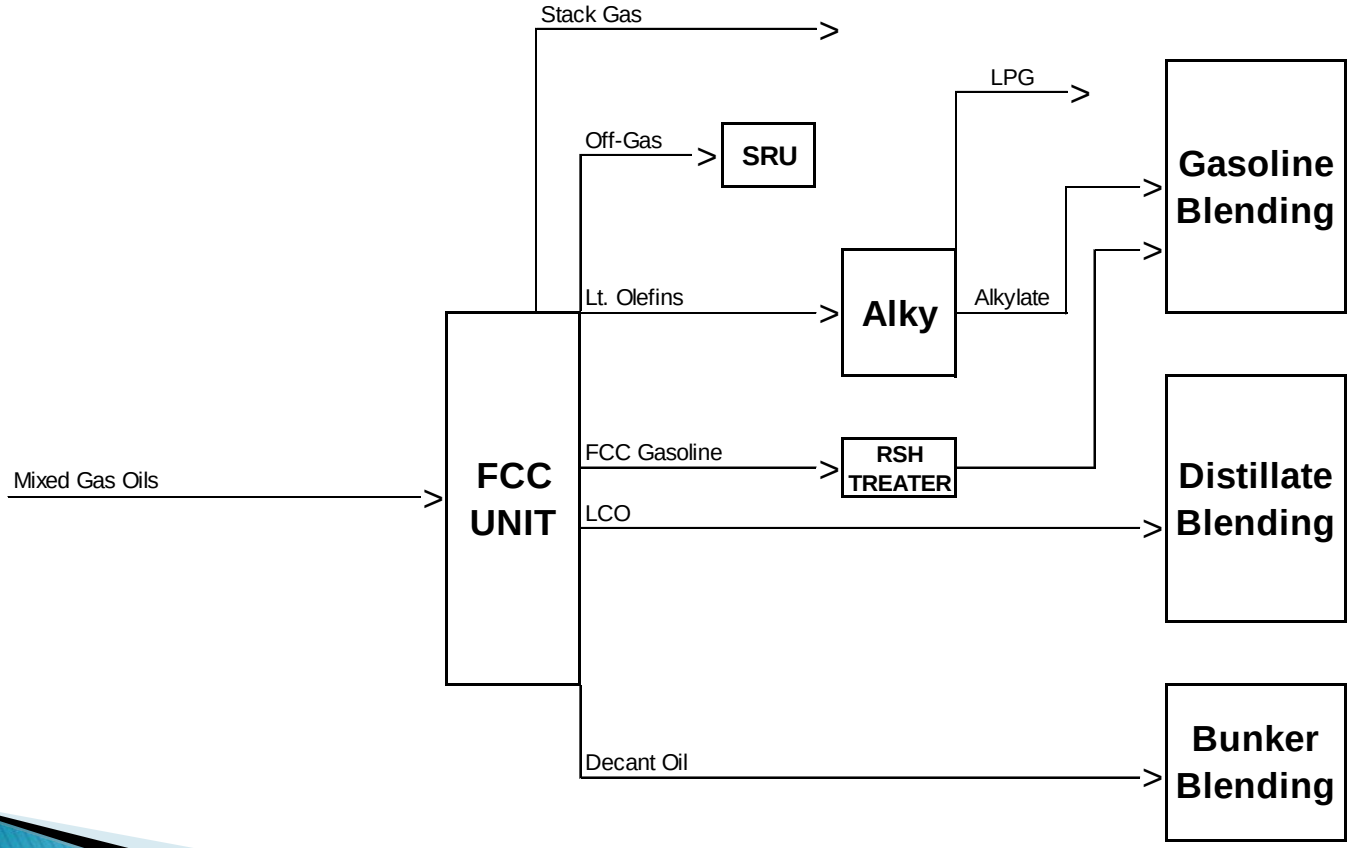
FCC Technology Advances

A number of advances in FCC technology were also introduced to improve performance and allow "dirtier" feedstocks including:

- Riser cracking
- Sophisticated feed nozzles
- Catalyst coolers
- Riser termination devices
- Two-stage regeneration

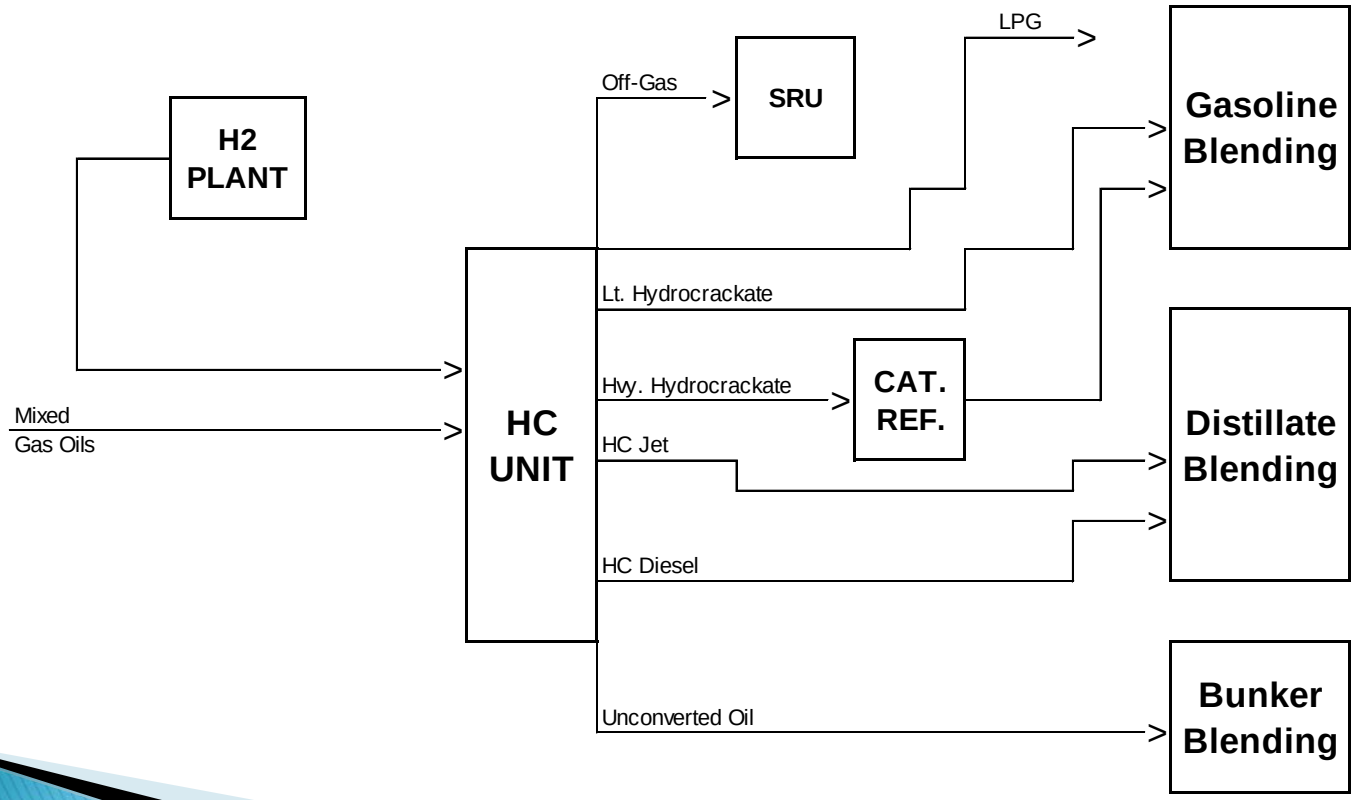
Hydrocracking's High Investment Cost

Looking back to the 1970s and 1980s, it is easy to see why FCC units, which could produce mostly finished blendstocks, enjoyed an investment cost advantage over hydrocrackers.



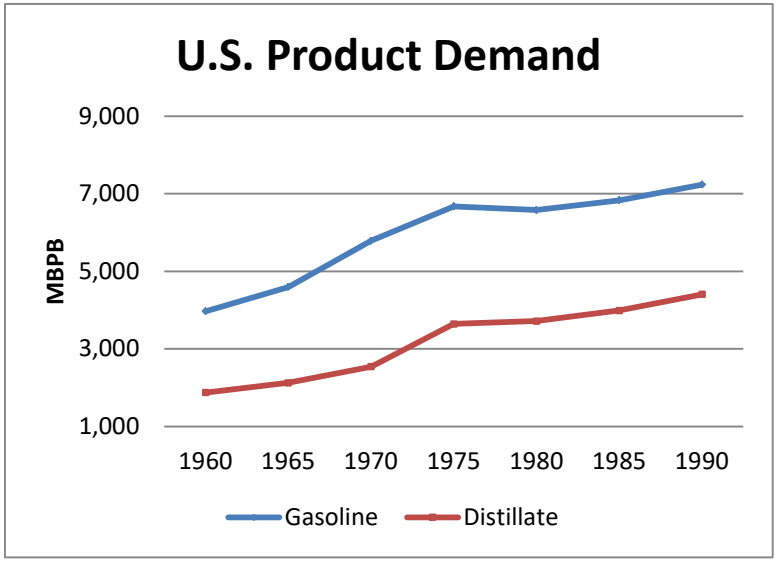
Hydrocracking's High Investment cont.

A hydrocracking complex in a light sour refinery would cost approximately 20% more than a similarly-sized FCC complex and 40% more in a light sweet refinery.

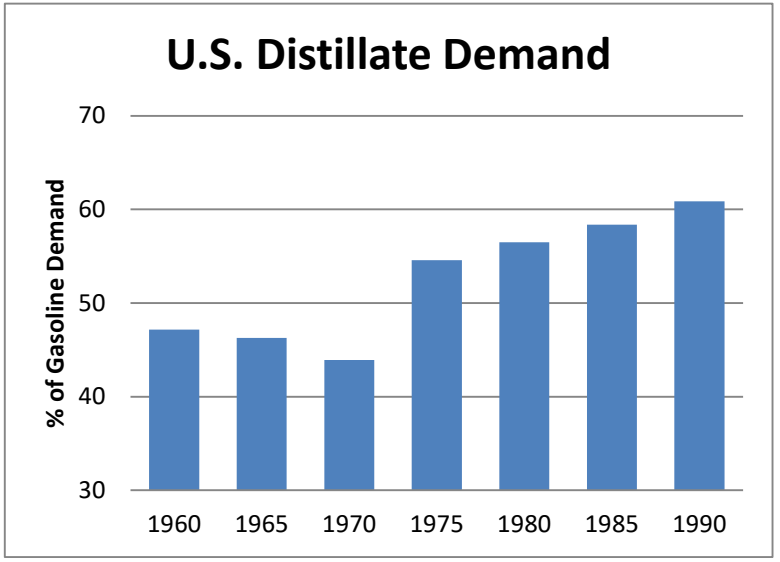


Shifting U.S. Product Demand

The increased demand for gasoline relative to distillate which spurred hydrocracking additions in the 1960s reversed in the 1970s reducing the need to hydrocrack distillates.



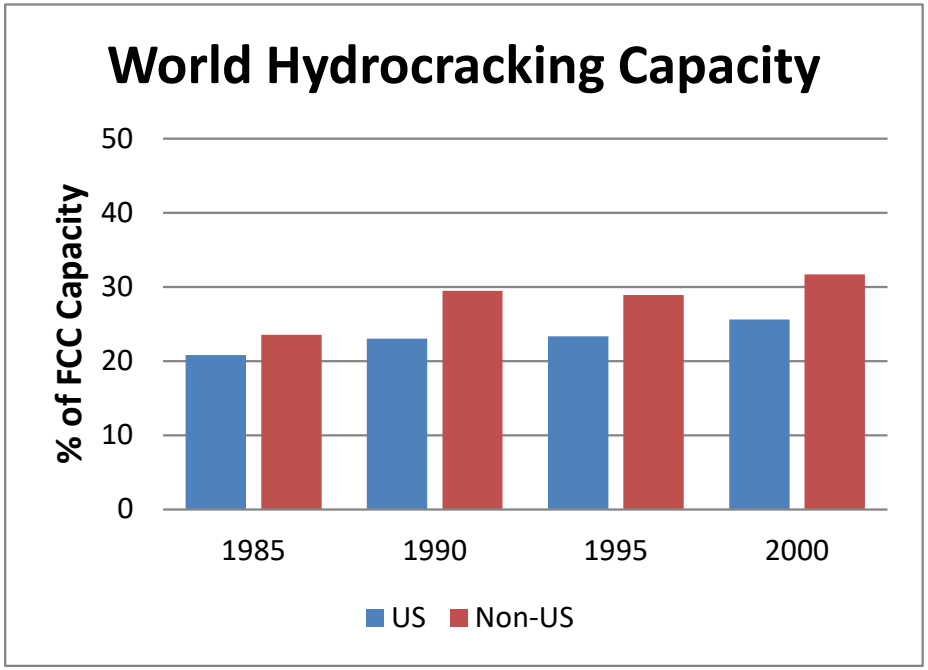
Data Source: EIA Petroleum Supply Annual



Data Source: EIA Petroleum Supply Annual

Non-U.S. Refineries

Up through 2000, the rest of the world was a bit more favorable toward hydrocracking, but capacity relative to FCC capacity was not much different from the U.S.



Data Source: Oil & Gas Journal Refining Survey

The “Clean “ Fuels Era – 2000 & Beyond

The start of the “clean” fuels era, initially in Europe and the U.S. represented a seismic shift in the relationship between FCC and hydrocracking.

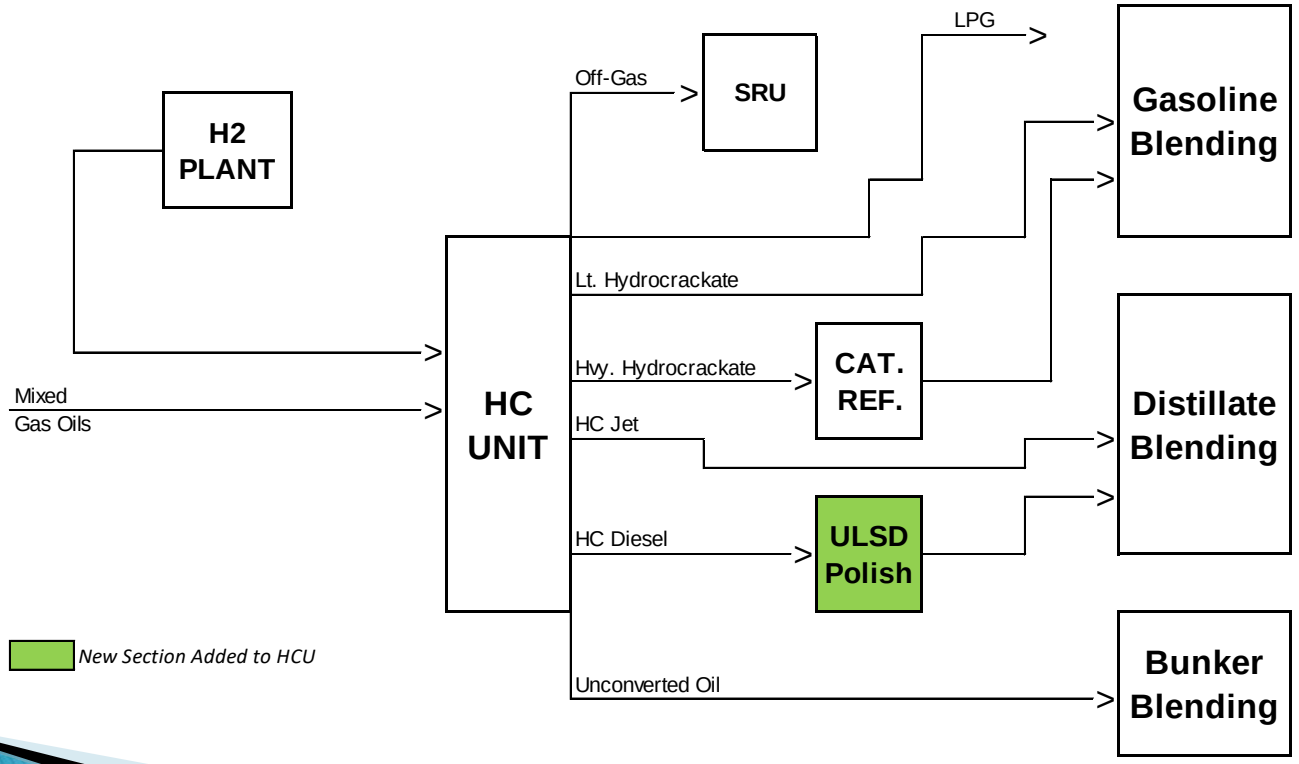
The push for ultra-low sulfur fuels in Europe (Euro I-V) and the U.S. (Tier II and III) triggered the need for additional hydrodesulfurization within refineries in those countries beginning in the 2000-2005 period.

Soon after, other countries began to lower gasoline & diesel sulfur levels to combat urban smog and MARPOL is now set to dramatically lower bunker fuel sulfur in 2020.

As a result, the investment cost advantage FCCs once enjoyed over hydrocracking has all but disappeared.

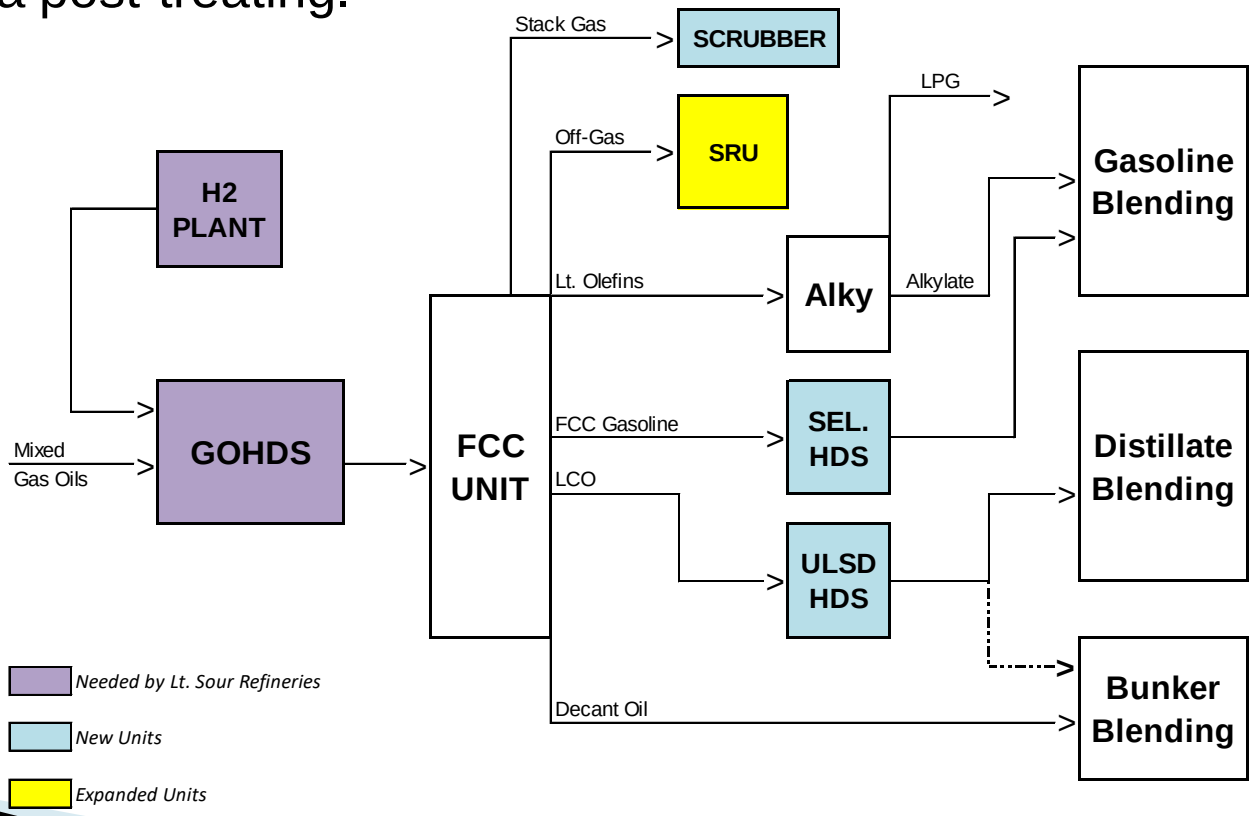
“Clean” Fuels Hydrocracking Complex

A hydrocracking complex for the “clean” fuels era is remarkably similar to the previous era facility with perhaps the only significant addition being a diesel “polishing” unit to achieve ULS quality.



“Clean” Fuels FCC Complex

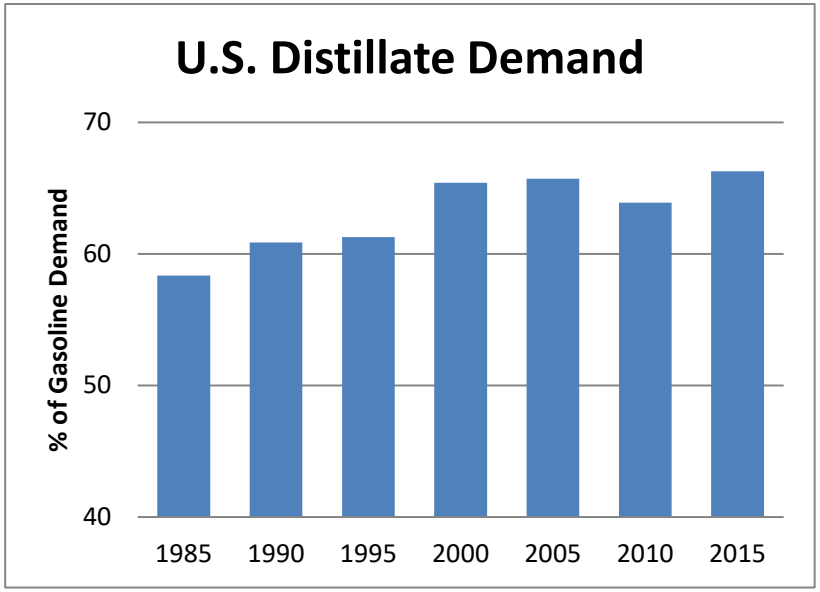
In contrast, a “clean” fuels FCC complex requires much more investment than its predecessor, with Lt. Sour refineries perhaps needing FCC feed pre-treating in addition to FCC naphtha post-treating.



Dieselization Favors Hydrocracking

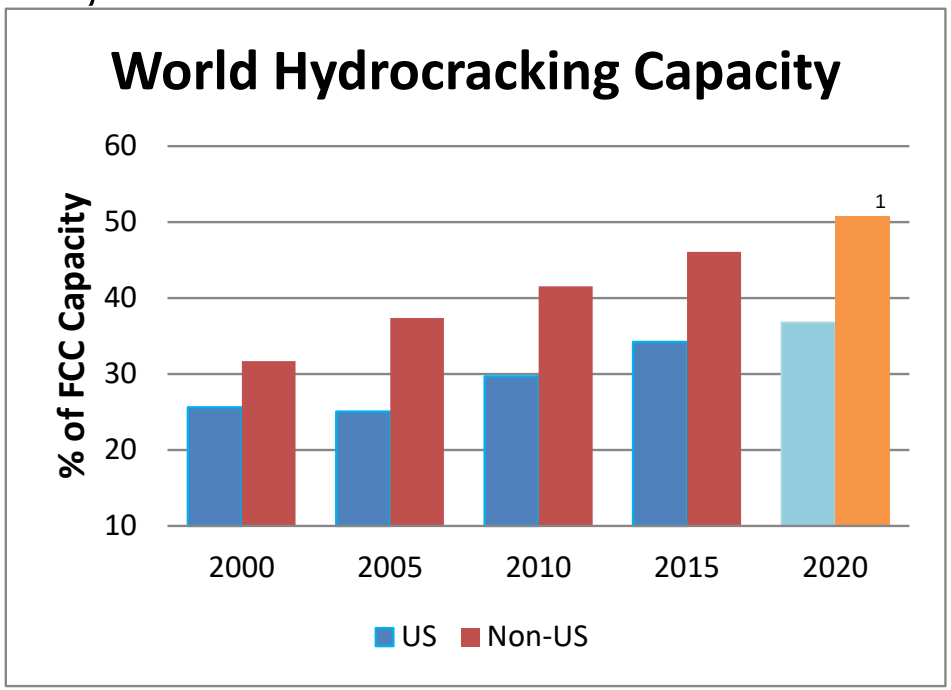
The push within much of the world for using diesel in place of gasoline for light duty vehicles has increased distillate demand to the point where its supply is tight and new hydrocrackers that can maximize distillate yield are favored over new FCCs.

While dieselization is not as popular in the U.S., especially since the VW debacle, we have still seen a gradual increase in domestic distillate demand relative to gasoline.



Hydrocracking Is On The Rise

The combination of ULS fuels and, to a lesser degree dieselization, has hydrocracking capacity back on the rise, even in the U.S.



Data Source: Oil & Gas Journal Refining Survey

1. 2020 is based upon a TM&C forecast of capacity additions

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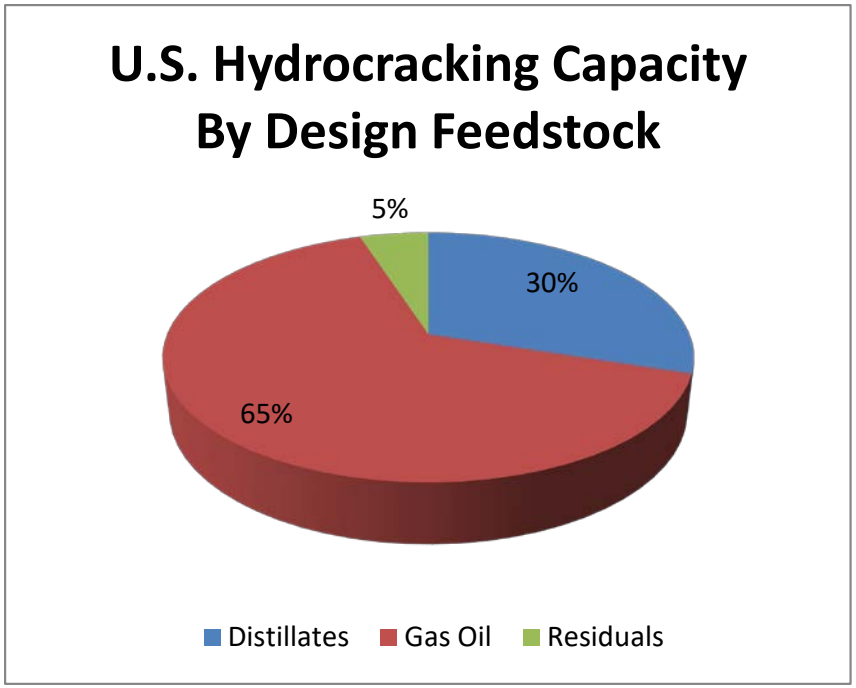
Distillate Hydrocracking

Surprisingly, there remains a significant portion of U.S. hydrocracking capacity configured for distillate cracking.

While LCO, and in some instances heavy diesel hydrocracking may be needed for cetane and cold flow improvement, there is a good chance that some of this capacity is either under utilized or being operated for only sulfur reduction.



Data Source: EIA, Capacity of Operable Petroleum Refineries, 1/1/15

FCCs Still Have a Major Role in Refining

FCC units still retain certain advantages over hydrocrackers

- Can better handle “dirty”, heavier feeds
- FCCs are still preferred when crude oil feedstock has “crackable” bottoms
- Lt. olefins needed for petrochemical feedstocks
- Large amount of existing FCC capacity
- In the U.S., alkylate is desirable for CARBOB and RFG blends

FCCs Still Have a Major Role cont.

Certain synergies exists between the two technologies

- Refinery isobutane balance
- LCO destruction
- Refinery hydrogen balance

Most conversion refineries with hydrocrackers also have FCCs

- U.S. HCU-only conversion refineries; 5 out of 98 (5%)
- Non-U.S. HCU-only conversion refineries; 43 of 276 (15%)

Conclusions

ULS fuels specifications have largely erased the cost advantages FCCs once held vs. hydrocracking;

Dieselization further advantages hydrocracking relative to the FCC, but some countries are starting to reconsider political emphasis on diesel over gasoline

New hydrocracking capacity additions will outpace FCC capacity additions; *TM&C forecasts 1,037 Mbpd new hydrocracking vs. 742 Mbpd new FCC through 2021*

FCCs still retain some advantages over hydrocrackers; and,

The most competitive refineries going forward will possess both technologies.

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