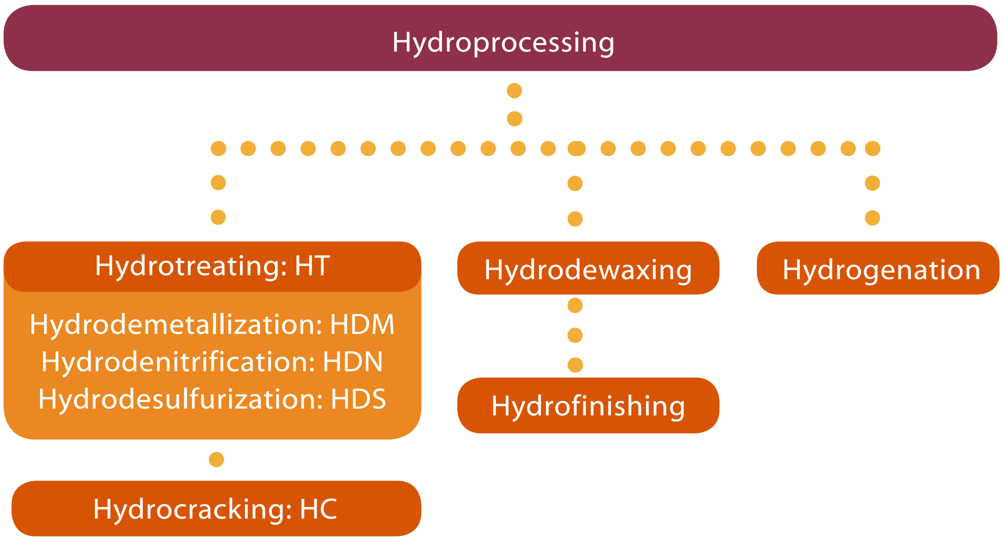
HYDROPROCESSING PILOT PLANTS

Modern petroleum refining operations have to meet tight specifications in terms of sulfur and nitrogen levels, olefin and aromatic content and heavy metals such as vanadium and arsenic.

Over the last half century, a variety of hydroprocessing technologies have been developed to enable refiners to meet the continuous tightening specifications imposed upon the industry. All hydroprocessing technologies consume hydrogen and typically convert heavy oil fractions into lighter and more valuable products.

Hydroprocessing – the use of hydrogen to convert crude oil and other feedstocks into higher value products. Pilot plants are used to optimize the process and develop/test new catalysts.



HYDROTREATING (HT)

This technology removes undesirable materials from petroleum feedstocks by selectively reacting these streams with hydrogen in a catalyst bed at elevated temperatures and pressures.

Hydrodemetallization (HDM):

This process removes metals out of petroleum crudes. Generally, nickel and vanadium are present in crudes that may also contain silicon, lead and arsenic. These metals are poisonous for downstream operations and must be removed by hydrocleaving. The cleaved metals are deposited on the sacrificial catalysts that must be periodically replaced.

Hydrodenitrification (HDN):

This process catalytically removes nitrogen out of the petroleum crude. There are two broad categories of nitrogen compounds -- basic nitrogen associated with six-member rings and neutral nitrogen associated with five-member rings. The inherent complexity of nitrogen compounds makes denitrification a difficult proposition. The NH3 that is generated must be subsequently removed.

Hydrodesulfurization (HDS):

This technology is the most common hydrotreating reaction. Sulfur containing hydrocarbons come in a large variety of forms and the desulfurization ability varies from one feedstock to another. For example, straight run naphthas can be almost completely desulfurized, whereas heavier materials such as resids can only be desulfurized down to a 50-70% level. Hydrodesulfurization produces H2S which must be subsequently removed.

HYDROCRACKING (HC)

Hydrocracking can increase the yield of gasoline components and also creates a 25% gain in volume.

Hydrocracking is the most severe form of hydrotreating. In this process, the feedstock oil flows over a high activity catalyst at temperatures >650°F and pressures >1,000 psig.

Hydrocracking can increase the yield of gasoline components and also creates a 25% gain in volume. The cracking/ hydrogenation combination results in products whose average gravity is lower than the feed. Hydrocracking produces high quality gasoline (jet fuel and diesel fuel) from heavy gas oils.

Hydrocracking is simple. It is cat cracking in the presence of hydrogen. The hydrogen and the catalyst are complementary in several ways. First, the catalyst causes cracking which needs heat to keep it going. This step is an endothermic process. On the other hand, as the cracking proceeds, the hydrogen saturates (fills out) the molecules – an exothermic process that gives off the heat to keep the process going.

Another way in which the hydrogen and catalyst are complementary has to do with the formation of isoparaffins. Cracking forms olefins, which can join together to form normal paraffins. Hydrogenation rapidly fills out all the double bonds, thus forming isoparaffins that prevent the reversion to less desirable molecules -- isoparaffins have higher octane numbers than normal paraffins.

Typical hydrogen consumption is about 2,500 scf/bbl. After the hydrocarbon leaves the first stage reactor, it is cooled and liquefied and run through a hydrogen separator. The hydrogen is recycled into the feed. The typical hydrogen recycle rate is between 5,000-7,000 scf/bbl. The liquid is charged into a fractionator. Depending on the products desired (gasoline components, jet fuel and gas oil), the fractionator is run to cut out the bottoms which are again mixed with the hydrogen stream and charged into the second stage reactor. Since this material has already been subjected to some hydrogenation, cracking and reforming in the first stage, the operation of the second stage is more severe in terms of higher temperatures and pressures.

Typical examples of hydroprocessing catalysts are shown in the table below.

COMPONENT	HYDROTREATING	HYDROCRACKING		
Active Metal Catalyst	MoS_2	MoS_2	WS_2	Pd/Pt
Promoters	Ni/Co	Ni/Co		
Support	γ-alumina ← Increasing amount			
Acidic Support	H-Y....ZSM....SAPO zeolites Increasing amount →			

HYDRODEWAXING – HYDROFINISHING

Hydrodewaxing

This process involves the fixed bed catalytic hydrogenation of gas oils to produce motor base oils and lubricating oils. One route is to selectively hydrocrack the paraffinic (waxy) components in the feedstock. The preferred modern option is to catalytically hydroisomerize the molecular structure of the wax into C20+ isoparaffins. These isoparaffins have a high viscosity index, low pour points and oxidation resistance.

Hydrofinishing

This process is used to adjust the color and stability of motor base oils and lubricating oils. The technology completely removes aromatics, oxygenates and unsaturated molecules from the feedstock -- typically responsible for both the brown color and instability. One route for hydrofinishing is to use a classical desulfurization catalyst at low severity operating conditions. The other route uses noble metal catalysts that claim excellent oxidation stability and superior color. This option operates at lower pressures and smaller reactor volumes.

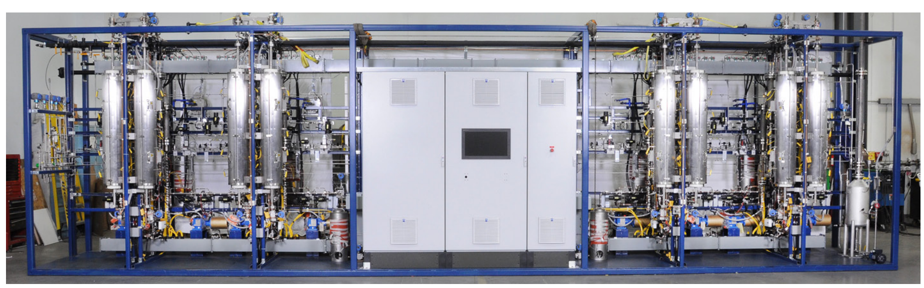
HYDROGENATION

Hydrogenation generally defines a process in which the feedstock is reacted with hydrogen in the presence of a raney nickel, palladium or platinum catalyst. The most common application of this process is to reduce or saturate organic compounds such as the hydrogenation of unsaturated fats to make saturated fat products. Most hydrogenation processes use gaseous hydrogen, but some involve the alternative sources of hydrogen – these processes are called transfer hydrogenations.

Background in Hydroprocessing

- Eight hydrocracker/hydrotreater pilot plants for the Research Institute of Petroleum Processing (RIPP), Sinopec. These systems are still being operated at the Beijing R&D Center.
- Four reactor molten salt based hydrotreater (all four reactors are in the same molten salt bath) that enable high speed analysis of catalytic performance.
- Four independent single reactors in molten salt baths -- four independent trains, especially important for maintaining isothermality in highly exothermic hydrocracking reactions.
- Four hydrocracker demonstration plants equipped with simulated adiabatic electric furnaces.
- Ebulliating bed hydrotreaters for coal hydro liquefaction and bitumen upgrading -- at pressures up to 5,000 psig.
- Supercritical water (SC) hydrotreater. This unit used SC water to enhance the kinetics of hydrodesulfurization and hydrodemetallization.
- Dual reactor multi-zone adiabatic hydroprocessing unit.
- Gradientless Spectrum reactor with a static basket for hydroprocessing catalyst evaluation.
- Orinoco crude Ore-emulsion hydroprocessing demonstration plant for demetallization and desulfurization.
- Hydrocracking of heavy tar sands to make lighter feedstocks.
- Ultra-low sulfur diesel (ULSD) demonstration plant.
- Sorbitol hydrocracker for converting sorbitols into polyol based materials. This technology was the genesis of the new bio-refining industry that is rapidly emerging in the US.

Two Recent Hydroprocessing Units made by Unitel



If you are interested in learning more about **Hydroprocessing System Pilot Plants & Demo Plants**, please contact Unitel Technologies:

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