H-Coal® and H-Coal®TS

Direct coal liquefaction to high quality distillates

The H-Coal® Process, for direct conversion of coal to high quality distillate fuels, uses HTI commercially proven ebullated-bed reactor system.

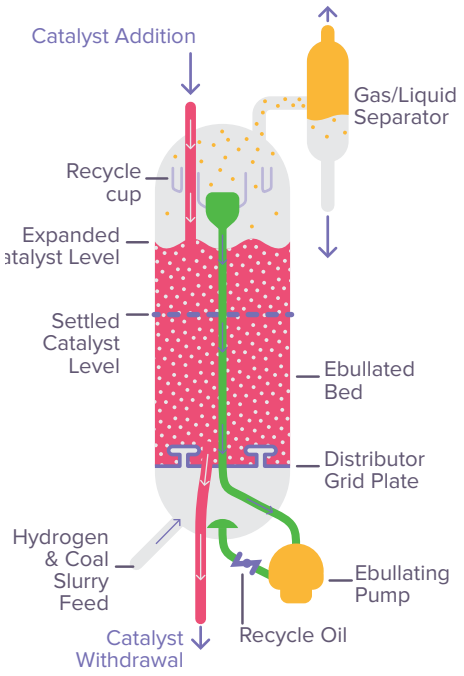

Figure 1: Ebullated-bed reactor

The ebullated-bed reactor is employed to contact hydrocarbon feedstock, hydrogen and hydro-conversion catalyst particles. The catalyst is maintained in a state of constant motion (or fluidization) by the flow of an internal liquid recycle stream provided by the ebullating pump.

The reactor is back-mixed both in terms of the reactor liquid composition and of the catalyst particles distribution. This eliminates the potential for bed plugging and/or channeling with low and constant pressure drop.

The flow of recycle oil from the ebullating pump to the reactor results in nearly isothermal operation. More importantly, fresh catalyst can be added and spent catalyst withdrawn to control the level of catalyst activity in the reactor. Finally the ebullated-bed reactor allows operating at higher severity thus achieving higher conversion.

COMMERCIAL EXPERIENCE

HTI has applied its basic engineering design expertise to the world's first commercial direct coal liquefaction plant located in Majiata, Inner Mongolia, which has been successfully started-up end 2008.

The Shenhua Group, China's largest coal company, selected us to provide the technology license of the H-Oil® unit for hydrogen donor solvent regeneration and primary upgrading of coal liquids, the basic engineering design for all direct coal liquefaction units, and the technical support services for the construction and start -up.

Figure 2: Shenhua DCL plant

Development based on H-Oil® process and proven in 200 TPD scale

One of the greatest strengths of the H-Coal® technology is the scale-up to commercial operations. The basic process flow scheme and ebullated-bed reactor are the same as in commercial H-Oil® plants.

Process development has used the same development path and the same development units. In early development, it was recognized that the ebullated-bed reactor was ideal for processing coal slurries.
Coal is crushed and pulverized to fine size particle that can easily pass up and out of the reactor with the liquid and gaseous products, while the much larger catalyst particles remain in the ebullated-bed reactor.

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The H-Coal® Process was originally developed in the 1970s and has been demonstrated on more than 30 types of coal in bench-scale pilot plants and in continuous Process Development Units (PDUs) where up to 15 barrels of clean fuels were produced daily. In the 1980s, the process was scaled up to 200 TPD at the Catlettsburg, Kentucky H-Coal® demonstration plant.

H-Coal®$_{TS}$: the next step

The need for improved yield and selectivity have led to the catalytic, two-stage coal liquefaction process (H-Coal®$_{TS}$), which yields up to five barrels of oil per ton of coal on a moisture-free basis. The two-stage process enables optimizing the operating conditions in each reactor, promoting hydrogenation reactions in the first stage at lower temperature, and hydrocracking reaction in the second stage at higher temperature.

Pulverized coal and recycle oil are mixed to provide the coal slurry feed to the process.

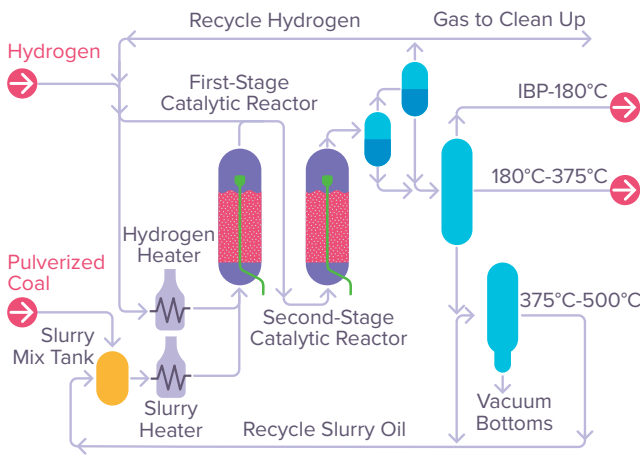

Figure 4: H-Coal®$_{TS}$ flow scheme

The coal slurry is pumped to reaction pressure, preheated, mixed with hydrogen, then fed to the first-stage ebullated-bed reactor where the coal is partially converted and the recycle oil is hydrogenated. The higher temperature second stage allows the hydrogen transfer to complete the conversion of the coal to distillates products, which are recovered by flash separation and distillation. The ash and any unconverted coal are removed at the bottom of the vacuum tower.

YIELDS, WT% MOISTURE & ASH FREE (MAF)	H-COAL®	H-Coal®$_{TS}$
C_1-C_3	11.3	8.6
C_4-525°C	51.0	77.9
Process Performance, wt% MAF		
Coal Conversion	93.7	96.8
Hydrogen Consumption	6.1	7.3
C_4-525°C (Barrels per Ton)	3.3	5.0

Table 1: H-Coal® and H-Coal®$_{TS}$ process performances

The H-Coal®$_{TS}$ reactor system is superior to other thermal or slurry based catalyst systems currently under evaluation. The ebullated-bed reactor provides:

- Increased catalyst activity due to the greater concentration of catalytic reaction sites
- Proven technology for catalyst addition and withdrawal, allowing used catalyst to be easily separated from the liquefaction reactor products
- Proven technology for catalyst reuse through reclamation, regeneration or rejuvenation
- Stable, high quality liquid products which can be upgraded to finished gasoline and diesel fuel
- Simple flow scheme leading to high unit on-stream time

With an extensive experience in refining, we can optimize the liquefied product upgrading scheme to improve products quality and adapt product yields for maximizing gasoline, diesel or aromatics. Moreover, the environmental footprint of the liquefaction unit can be reduced using carbon capture and sequestration. Up to 80% of the CO_2 can be captured.

Feedstock flexibility

A wide range of coal feeds from high-rank bituminous through lignite have been tested in the pilot units and can be processed in the H-Coal® Process.

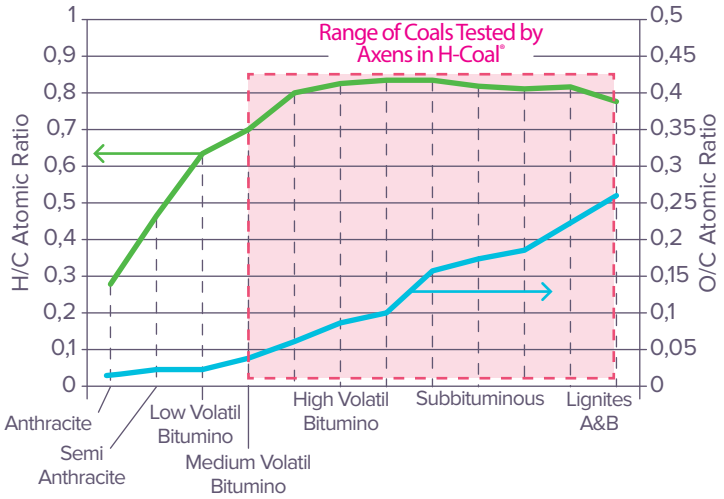

Figure 5: Coals tested in H-Coal®