THE GENOIL HYDROCONVERSION UPGRADING SYSTEM (GHU®)
FOR HEAVY AND EXTRA HEAVY CRUDE

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Contents

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DEVELOPMENT HISTORY AND GENERAL PROCESS

Hydroprocessing of Heavy Crude Oil, Bitumen and Residues

The Hydroprocessing of residues can be done in several different types of reactors:

- Fixed bed reactors
- Ebullating bed reactors
- Slurry phase reactors

Fixed Bed Process

Fixed bed and ebullating bed systems were developed in the 1960s for the desulphurization of residues to make low-sulphur fuel oils. Additional units continue to be built, but the emphasis has shifted to the hydrotreating / hydroconversion of heavy oil and residues to gas oils and the preparation of reduced metals, reduced asphaltene FCC or other refinery feeds.

Fixed bed units account for 85% of capacity and ebullating bed units account for most of the remaining 15%. There are only four slurry phase units in operation.

The development of new and improved hydroprocessing catalytic cracking technologies has been possible due to the development of new and improved catalysts by process licensors and catalyst vendors for specific needs such as hydrodemetallization (HDM), hydrodesulphuration (HDS), hydrodenitrogenation (HDN), and hydrocracking (HYC) at elevated pressures in fixed bed, ebullating bed or slurry phase reactors.

The Genoil GHU® can be utilized to upgrade high sulphur, acidic, heavy crude, bitumen, and refinery residue streams, and for hydroprocessing naphtha, kerosene, diesel and vacuum gas oil. The Genoil processing scheme is based on a fixed bed reactor system with a reactor sequence and catalyst distribution to protect the more active hydroprocessing catalyst. The first reactors are guard reactors that can be switched on stream to remain in service if the need to change catalyst arises, containing HDM catalysts to remove metals from the feed, followed by a second main reactor using highly active HDS, or a combination of HDS and HDN beds for sulphur and nitrogen removal, and final conversion of heavier feed stock into sweet light crude or upgraded residue for utilization in the existing refinery. If the feed is of a quality wherein the HDM guard bed is not required, the entire hydroconversion process can be done through a single reactor. The unconverted residue formed after hydroprocessing through the fixed beds of the GHU® unit can be sent to a Syntheses Gas Unit, gasified, and the syntheses gas then used for hydrogen recovery to supply the Genoil GHU®, and the remaining syntheses gas used as fuel gas or to generate power and steam by adding an Integrated Gasification Configuration Cycle (IGCC) unit into the overall plant configuration.

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Using high activity hydrotreating / hydrocracking catalysts and proprietary design technology, Genoil has conducted multiple pilot plant tests on various sour, heavy crude, bitumen and residue oil feed stocks ranging from 6.5º to 17.5º API gravity. The operating conditions (pressure, temperature, space velocity) were selected to achieve a minimum one-year cycle while maintaining maximum conversion of the vacuum residue fraction of the feed. Typically, the Genoil GHU® operating conditions were substantially milder (pressure, space velocity) than other hydroprocessing processes, and the conversion of the vacuum residue fraction with the GHU® process was also much higher while avoiding precipitation of asphaltenes.

For example, shown below are the results of processing bitumen extracted from Western Canada tar sands using the GHU® technology, for a reference when upgrading heavier oils. With the addition of a distillation unit after the GHU® and using the residue to feed a syntheses gas unit, the API can be increased again from 24º to at least 34º API.

Feed and Product Properties

Bitumen Upgrading by GHU®	Feed (vol%)	Product (vol%)
Gravity, ºAPI	8.5	24.8
Sulphur, wt%	5.14	0.24
Nitrogen, wt%	0.27	0.14
C_5 Asphaltenes	17.3	1.6
C_7 Asphaltenes	12.6	1.2
CCR, wt%	12.8	2.6

Feed and Product Distillations

Cut Points	Feed (vol%)	Product (vol%)
IBP-340ºF (171ºC)	0.0	8.7
340-450ºF (171-232ºC)	2.0	11.5
450-649ºF (232-343ºC)	12.4	33.0
649-975ºF (343-524ºC)	32.3	36.7
975ºF+ (524ºC+)	53.3	10.1

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GHU® Upgrading Process Results

°API Increase	16.3
% HDS	95
% HDN	48
CCR Conversion, %	80
C_7 Asphaltenes Conversion, %	90
975°F+ (524°C+) Conversion, %	81

The Genoil GHU® Process

The GHU® complete upgrading facility has conversion rates of 70% to 90% based on the various types of feed stocks being produced: high sulphur, acidic, heavy crude, vacuum or atmospheric residue, or bitumen. The unconverted residue can be controlled by variations in temperature and pressure during the GHU® hydroconversion process. Controlling the amount of total residue being produced is done if the residue stream is to be gasified producing syntheses gas, where hydrogen is recovered and recycled to meet hydrogen consumption requirements for the GHU®. The remaining syntheses gas can be sent to fuel gas or used to produce power and steam generation through IGCC scheme.

Included in our on-going process development efforts with fixed bed reactors, we are also focusing on "on-stream" methods of catalyst replacement in the guard beds.

Some of the pilot plant runs on different feed stocks are listed below with their conversion rates:

Company	Conversion Rate
Canadian Client	80% of Bitumen Feed
U.S. Client	88% of Vacuum Residue
Eurasian Client	94% of Whole Crude

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THE GHU'S ADVANTAGE VS DELAYED COKING

	GHU® (Hydrogen Addition)	**Delayed Coking (Carbon Rejection)**
Residue Conversion	Up to 90%	70-85%
Temperatures	***Low/Medium***	High
Volume Output	100-104%	75-80%
Coke production	0%	20-25%
Desulphurization (1)	>90%	37%
Hydrotreating	Process includes hydrotreating	Needs further hydrotreating
Capital Cost	***$ 7,000 – 12,000 per barrel***	$ 8,000 – 14,000 per barrel
Equipment	Fewer Processes	More Processes
Water usage	15-20% less than Coking or Air Cooled	
Natural gas usage	Optional or None	Yes
IRR (2)	***28%***	18%

Sources:
(1) The American Oil & Gas Reporter, January 2006 / Genoil test results
(2) The American Oil & Gas Reporter, January 2006

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GHU® ADVANTAGES

- **Higher liquid yields than coking processes**
  - Output is 100 – 104% of liquid input volume versus approximately 80% of coking processes when hydrogen is supplied by other means than syntheses gas.

- **Gives refiners flexibility to process sour, acidic, heavier crude feed stocks or upgrade and recycle ATB / VTB residue back into the refinery overall process scheme producing high value product from a low value feed**

- **Capability to adjust product slate to meet increasing demand for low sulphur petroleum products, including diesel and gasoline**

- **Stability of upgraded crude produced in hydroconversion process is superior to coked products**

- **Moderate operating conditions, temperatures and pressures allowing for simple reactor design with lower CAPEX and OPEX**

- **Lower operating and capital costs per barrel investment compared to conventional hydrotreating processes**

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GHU® TECHNOLOGY DEVELOPMENT HISTORY

Starting in May 1998, Genoil (formerly CE^3 Technologies Inc.: Canadian Environmental Equipment and Engineering Technologies Inc.) researched innovative processes for the upgrading of heavy crude oils. Because heavy oil reserves account for the majority of total world oil reserves (including non-conventional oils), Genoil had realized that highly efficient processes were required to economically upgrade these heavy oils to lighter products.

To deliver the heavy oil to the market, heavy oil producers blend it with lighter oils, called condensates or diluents. This requires the implementation of an extensive infrastructure to produce the light oils and to deliver them to the heavy oil field locations. Further, this concentrated demand for light oils for blending could results in shortages and high prices.

The Genoil concept was to upgrade on-site heavy oils to lighter oils meeting pipeline specifications, eliminating the need for blending, increasing the value of the heavy oils, and having a process with economically viable capital and operating costs even for a small-scale field unit of 10,000 bpd. Of equal or greater importance was the development of a hydroconversion upgrader technology for refineries for raising the API º gravity of crude oils to refinery specifications and for recovering the refinery's heavy residuals. Reduction of sulphur, nitrogen and metals was also a similarly critical goal.

Evaluation of Emerging Technologies for Heavy Oil Upgrading

From May 1998 to January 1999, Genoil researched and evaluated emerging technologies to determine their capabilities for the upgrading of heavy oil. The initial approach was to search for the best parts of other existing technologies and, following in-house improvements, to develop a novel field and refining based upgrading process that would represent a significant advance over current practices.

Genoil evaluated two separate and distinct technologies previously developed to solve other problems in the oil industry. These technologies were the TaBoRR® process from the Western Research Institute in Laramie, WY, and the CAT process, which is typically used to make diesel fuel. Genoil spent considerable time and effort to test and analyze the technical results and economics of these processes. After nine months of research and evaluation of these processes, it was concluded that a major shift in technical practices would be required to offer an economical, yet effective, process for heavy oil upgrading.

From a technical basis, it was determined that the CAT process would not be viable for upgrading heavy oils; therefore, bench-scale experiments were not conducted with this process.

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Based on the technical merits of the TaBoRR® process (Tank Bottoms Recovery and Remediation), which is a carbon-rejection method (pyrolysis), bench-scale tests were performed using a heavy oil feed stock (12 ºAPI) to determine the potential yields and product quality. A liquid yield of 77.8 wt% was achieved with an average API gravity of 32.3º. Approximately, 13.9 wt% of the feed stock was converted to hydrocarbon gases, and the final 8.3 wt% of the original feed was produced as carbon-laden solids. However, detailed analyses indicated that a liquid yield of only 77.8 wt% limited the chances of an economic success. In addition, the liquid product was not stable (high olefin and diolefins content). Therefore, it was concluded that while the TaBoRR® process was a technical success for cracking heavy oil, it would be commercially viable only if the liquid yields could be increased.

Genoil GHU® Process Development

In September 1998, Genoil decided to develop its own heavy oil upgrading process, based on a dual approach of visbreaking and hydroprocessing, and, therefore, by adding hydrogen mass, to obtain an increase in the liquid yields. A hydrogenation process should provide more than 100% of the fresh feed volume, instead of the 75-80% of the carbon rejection processes.

To start the conceptual and preliminary design work on a hydrotreating process to upgrade heavy crude oil, Genoil acquired the Visbreaking technology from the Eadie Group and the "Bullet" technology from the Acquasol Corporation. The Eadie Visbreaking technology was developed through extensive pilot plant work conducted in the early 1990's at the Alberta Research Council. This Eadie Visbreaking technology was modified and enhanced by Genoil. The Bullet technology is a mixing device which maximizes the mass transfer between two fluids. Full dispersion of one fluid into the other fluid is achieved ("micro-molecular mixing") together with the "super-saturation" of the gas into the liquid. (Although this technology provided excellent results, Genoil has recently replaced it with an even more effective mixing technology.)

Based on these two technologies, Genoil started developing its own heavy oil upgrading process concept, with the primary goal of improving sufficiently the properties of the heavy oils to meet pipeline specifications, removing the need for diluents for transportation and to provide an advanced upgrading technology for refineries increasingly faced with the option of securing heavy feed stock and with the need to recover product residuals.

Key features of the Genoil upgrading are the addition of the hydrogen to the feed stock, and the mixing of the hydrogen with the liquid feed. To confirm this concept, Genoil constructed a laboratory scale prototype vessel together with the appropriate mixing gas/liquid devices. Then, Genoil conducted bench scale tests, at various operating conditions over a period of months, on a Cold Lake Bitumen with an API gravity between 11 and 13º. The main criteria were to achieve high liquid yields and good product stability (no olefins or diolefins). The

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original Genoil targets were to upgrade the Cold Lake Bitumen from an 11-13º API gravity to an API gravity of 19-20º without a hydrotreating catalyst, to an API gravity of 22-24º with small amounts of catalyst, and to an API gravity of 28-30º with a hydrotreating reactor (hydroconversion).

These bench scale tests confirmed that "mild" hydrocracking (once-through partial conversion with hydrogen) of the heavy oil feed stock was the way to obtain stable products. Typical visbreaking (without hydrogen) would result in an API increase of only 2-3º and in unstable products. With hydrogen addition, not only the product API could be raised further, but also the product stability was improved. The bench scale tests indicated also that addition of hydrogen limited the condensation of asphaltenes, preventing the formation of coke, allowing higher conversion levels, and resulting in higher product stability together with some desulphurization of the products.

After testing of the proprietary mixing vessel and devices, the next phase of the program was to develop a computer model to test the Genoil concept. Over three months, several simulation studies were conducted to optimize the initial design concept. The simulation results enabled the updating of the process engineering and instrumentation diagram, complete with mass balances and heat balances.

Genoil Pilot Plant

In November 1998, a Development Agreement was entered into between Renaissance Energy Ltd. (now part of Husky Energy Inc.) and Genoil by which Genoil would design and build a ten-barrel per day pilot plant to prove the new heavy oil upgrading process, and conduct demonstration tests on the Renaissance bitumen. The pilot plant had to be a fully integrated, mobile, stand-alone upgrader capable of running various types of heavy oil on a continuous basis. The target of the Renaissance test was to reduce the heavy oil viscosity to meet pipeline specifications (230 cSt @ 6ºC).

Construction of the pilot plant started in February 1999 after design work, equipment specification and procurements were completed. The construction was completed in April and the unit was moved in May to the oil field site agreed upon with Renaissance. Field connections, shake-down and start-up lasted until mid July.

The objectives of the pilot plant tests were to:

- Demonstrate the Genoil GHU® technology under field conditions
- Confirm that the mechanisms of the upgrading process worked as proposed

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- Optimize the hydrogen addition using the Bullet technology
- Produce with hydrogen addition an upgraded oil at the lowest possible temperature and pressure

- Establish the operating conditions to achieve the product specifications
- Obtain complete heat and mass balances for future design correlations
- Provide information to proceed with the scale-up of the technology to 1,000-10,000 bpd

In a series of 28 separate field tests, Genoil evaluated what improvements could be expected with this heavy Canadian bitumen feed stock (12.5 ºAPI, density of 982.6) at temperatures between 385 and 429ºC (725 and 805ºF), pressures from 3,515 to 12,125 kPa (500 to 1,725 psig), hydrogen/oil ratios between 890 and 1,780 Nm^3/m^3 (5,000 and 10,000 scf/b), without catalyst (hydrovisbreaking) and with catalyst (hydroconversion). The initial purpose of these tests was to reduce the bitumen viscosity sufficiently to meet the pipeline viscosity target without the need for diluents. A reduction in the bitumen viscosity of 75% was achieved at a moderate pressure of 5,270 kPa (750 psig). The bitumen viscosity was reduced by more than 90% at higher temperatures and pressures (427ºC, 12,120 kPa; 800ºF, 1725 psig). However, even at these conditions, the ºAPI gravity was increased only by about 2º and the sulphur reduction was less than 10%.

To improve further the quality of the upgraded oil, a high activity hydrotreating catalyst was added to the system. With such a catalyst, API gravity improvements up to 12.5º (density decrease of 78.5) were achieved together with desulphurization levels up to 92% and a viscosity reduction close to 99%. For this high severity service, the Genoil GHU® pilot plant was operated at around 12,000 kPa (1,700 psig).

Properties	**Feed**	**Hydro Visbreaking**	**Hydro Visbreaking**	**Hydro Conversion**	**Hydro Conversion**
Gravity, ºAPI	12.5	14.0	14.3	22.2	25.0
Density @15ºC	981.5	972.5	970.5	919.8	903.0
Sulphur, wt%	3.26			0.46	0.28
Viscosity, cP @20ºC	3,749	904	340	103	45
C^5 Asphaltenes, wt%	12.2			7.4	3.3
Nickel, wppm	36			18	13
Vanadium, wppm	52			25	18
Viscosity Reduction, %		76	91	97	99
Desulphurization, %				86	92
Demetallization, %				51	65
Pressure, kPa		5,270	12,125	12,000	12,000
Pressure, psig		750	1,725	1,700	1,700
Temperature, ºC (ºF)		410 (770)	427 (800)		

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GHU® Pilot Plant Test Results

In another series of tests for a major Canadian producer, Genoil evaluated what improvements could be expected with a very heavy (8.5 ºAPI, density of 1,009.9) and very sour (5.14 wt% sulphur) Canadian bitumen feed stock at pressures up to 14,050 kPa (2,000 psig), a hydrogen/oil ratio of 1,070 Nm^3/m^3 (6,000 scf/b), and a high space velocity of 0.5 $v/v.hr^{-1}$, both with a hydroprocessing catalyst (hydroconversion) and without a catalyst (hydrovisbreaking).

With this high activity hydrotreating catalyst, an API gravity improvement up to 16.3º (density decrease of 105) was achieved together with a desulphurization level up to 95%, demetallization up to 90%, and a vacuum residue (524+ºC, 975+ºF) conversion of almost 80%. These are outstanding results at such a high space velocity and reasonable operating temperatures. *The product obtained through hydroconversion was stable*, while the product from hydrovisbreaking was not stable (high bromine number).

Properties	Feed	Hydro Conversion	Hydro Visbreaking
Gravity, ºAPI	8.5	24.8	17.0
Density @15ºC	1,009.9	904.7	952.5
Sulphur, wt%	5.14	0.24	3.32
Nitrogen, wppm	2,680	1,430	3,060
Conradson Carbon, wt%	12.75	2.59	8.24
C_5 Asphaltenes, wt%	17.3	1.6	8.9
C_7 Asphaltenes, wt%	12.6	1.2	7.8
Nickel, wppm	77	8	61
Vanadium, wppm	196	18	163
Viscosity, cSt	2,399 @60ºC	10.04 @40ºC	29.85@40ºC
Residue (524+ºC), wt%	55.8	11.68	26.39
Desulphurization, %		95	35
Demetallization, %		90	18
Residue conversion, %		79	53

In 2005, Genoil conducted a series of 12 pilot plant runs for a major international oil producer, to confirm the required operating conditions to upgrade a heavy oil (bitumen) from 17.5ºAPI (density of 949.7) to a minimum of 34.0ºAPI gravity (density of 849.8), while decreasing the sulphur content from 1.22 to below 0.6 wt%. These tests were conducted at pressures between 12,000 and 12,830 kPa (1,700 and 1,825 psig), and at average catalyst temperatures between 377 and 430 ºC (710 and 806ºF). The overall catalyst space velocity was 0.40 $v/v.hr^{-1}$ for a 9 months catalyst cycle. At the previous temperatures and pressures, the desulphurization ranged from 75 to 97%, denitrogenation from 37 to 53%, metal removal from 76 to 98%, Conradson Carbon

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reduction from 47 to 87% and the pitch (535+ °C, 995+°F) conversion from 37 to 95%. *The hydrocracked products were stable at all conditions*, even with the high space velocity used in the Genoil tests versus the ones practiced in traditional hydroprocessing processes.

At the selected operating conditions	Bitumen Feed	Synthetic Crude Product
API Gravity	17.5	35.0
Specific Gravity	0.9497	0.8498
Sulphur, wt%	1.22	0.038
Metals, wppm	77	<1.5
Conradson Carbon, wt%	7.4	<1
Nitrogen, wt%	0.286	0.135
Aromatics, %	42.4	
369+C, wt% (vol %)	75.75 (77.9)	
509+C, wt% (vol %)	50.92 (51.8)	
535+C, wt% (vol %)	41.74 (42.1)	5.04 (4.23)

Summary of Distillation by Product in Upgraded Barrel of Crude:

Upgraded Crude Product Yields	**Full Range Naphtha**	**Kerosene**	**Heavy Diesel**	**Vacuum Gas Oil**	**Vacuum Residue**
TBP, C	IBP to 200	200 to 300	300 to 350	350 to 535	535+
TBP, F	IBP to 392	392 to 572	572 to 662	662 to 995	995+
Weight, %	20.18	30.89	16.45	27.44	5.04
Volume,%	22.77	31.32	16.01	25.67	4.23

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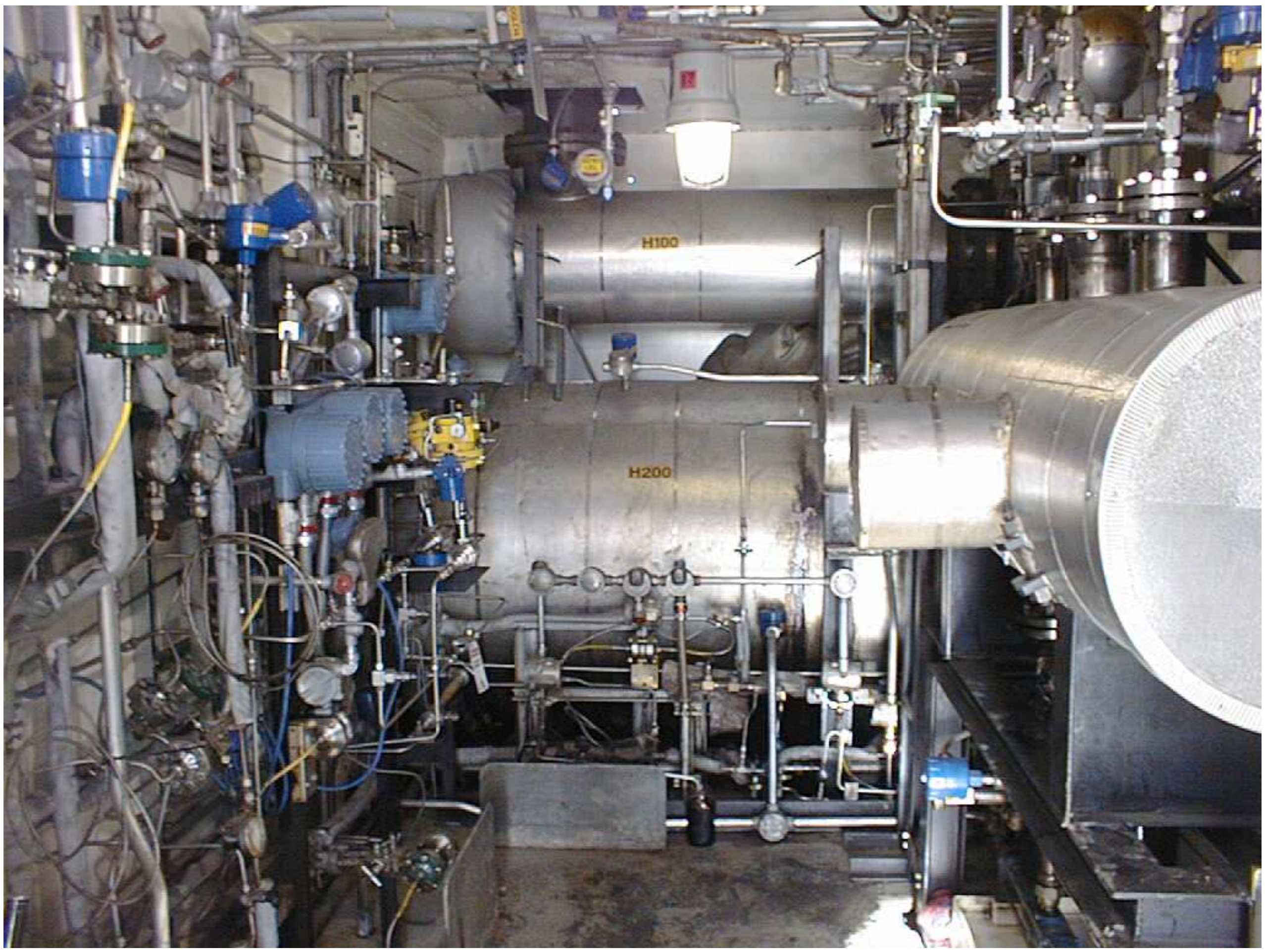
Genoil GHU® Pilot Plant



Genoil GHU® Pilot Plant

GenOIL
Clean Technology

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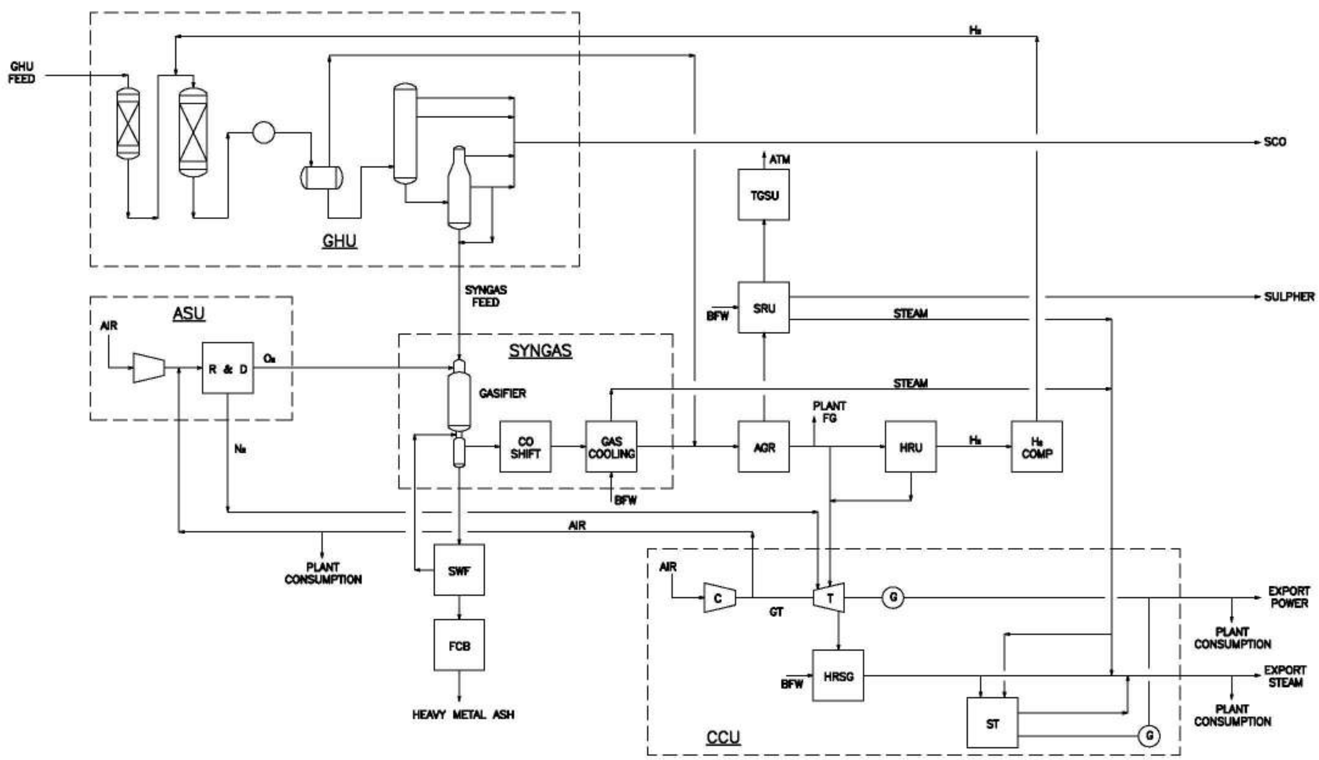
GENOIL GHU® UPGRADING FACILITY
SIMPLIFIED PROCESS FLOW DIAGRAM



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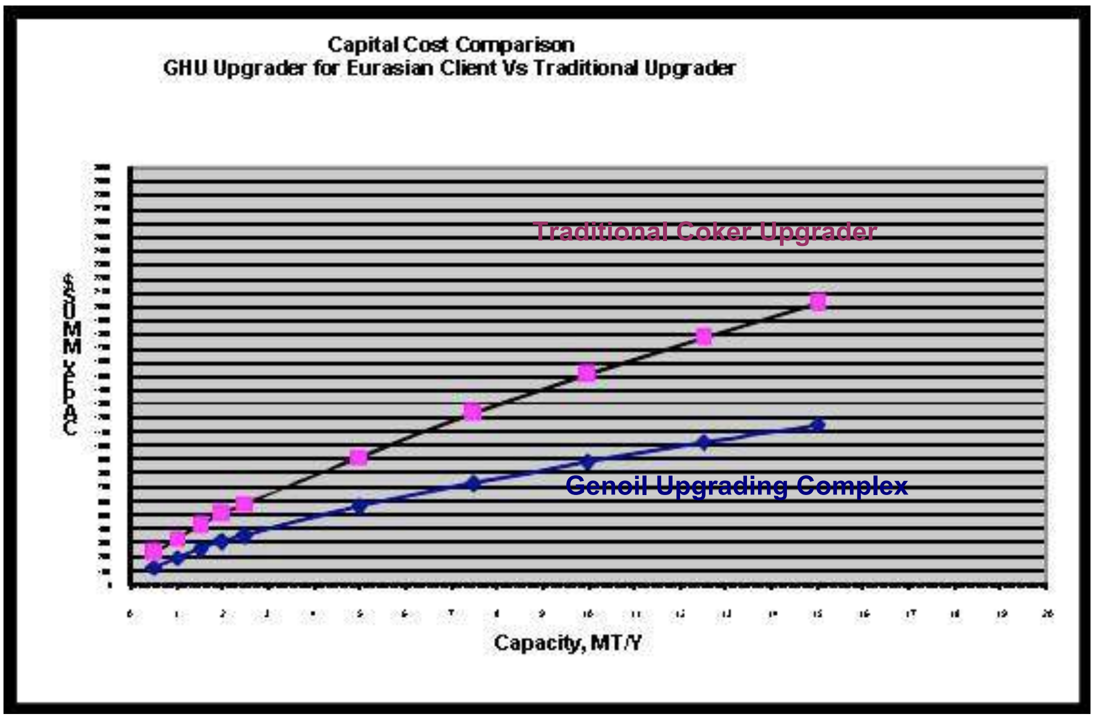
Capital Cost Comparison
Genoil GHU® Upgrader vs. Traditional Coking

The table below shows the Capital Expenditures and Unit Costs at graduated processing capacities for Genoil GHU upgrading facility versus a traditional delayed coking upgrading facility.



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MAIN FEATURES OF THE GHU® UPGRADING PROCESS

- Flexible hydroconversion process: conversion and hydrogenation in one stage.
- Upgrading process applicable to sour, acidic, heavy crude and heavy refinery feed stocks.
- Proprietary devices to mix the hydrogen and the hydrocarbon stream.
- Super-saturation of the liquid hydrocarbons with hydrogen.
- High conversion of the heavy fractions of the feed at moderate operating conditions.
- Production of stable products at high conversion levels.
- Premium sweet synthetic crude product: no penalty for density or sulphur.
- Removes the need for expensive blending diluents.
- Flexibility of operation: "dial" the conversion level and the product properties by changing the operating temperature.
- Upgrader is economical at a 10,000 bpd capacity.
- Operating costs are lower than for existing processes.