

## Fact Sheet Technology

**Subject:** Bergius 1: 1924 – 1945

**Rev:** April 2006

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## Bergius-Pier Process (1)

### 1. History in brief

Three major preconditions had to be established for the commercial use of any hydrogenation technology:

- ◇ Suitability of equipments to handle high pressure and temperature
- ◇ Availability of molecular Hydrogen
- ◇ Availability of Catalysts

The first Hydrogenation technology established was the Ammonia Synthesis based on the research work of F. Haber at the University of Karlsruhe in 1910. Carl Bosch built the first commercial plant with operating temperatures of above 300 °C and pressure ranges between 200 and 1.000 bars in 1914 at the Oppau site of the Badische Anilin und Soda-Fabrik ("BASF").

Based on these commercial scale experiences and the research results of F. Bergius (University of Hannover, 1913), BASF started to work on the technical commercialization of the high pressure hydrogenation of heavy hydrocarbons. With new poison resistant catalysts developed, Matthias Pier of BASF started in 1924 the specific development of the hydrogenation of coal, tar and heavy oil. The developments were made on process related issues like catalyst type as well as on mechanical/equipment design, e.g. development of the standard "9 m<sup>3</sup> Reactor" with a diameter of 1000mm and a length of 18m.

On June 18, 1926 it was approved to build the first commercial plant for the liquefaction of lignite coal at the Leuna site. On April 1, 1927 this plant was started-up. Until the general shut down in 1945 an overall of 12 plants were built and operated all over Germany with a total capacity of 3,850,000 t/year, which was the main source for Germany's fuel supply at that time. Table 1 shows the main data of the 12 hydrogenation plants.

Site	Feed	Process Pressure		Capacity t/year
		Liquid Phase	Gas Phase	
		[bar]	[bar]	
Leuna	Lignite Coal Tar	200	200	600.000
Böhlen	Lignite Coal Tar	300	300	240.000
Magdeburg	Lignite Coal Tar	300	300	230.000
Zeitz	Lignite Coal Tar	300	300	300.000
Wesseling	Lignite Coal	700	300	200.000
Brüx	Lignite Coal Tar	300	300	400.000
Gelsenkirchen Scholven	Hard Coal	300	300	200.000
Gelsenkirchen Horst	Hard Coal	700	300	350.000
Blechhammer	Hard Coal	700	300	500.000
Bottrop	Hard Coal	700	700	180.000
Lützkendorf	Vacuum Residue Tar	700	700	50.000
Pölitz	Hard Coal Vacuum Residue Tar	700	300	600.000

Tab. 1: Hydrogenation Plants in Germany 1927 - 1945

## 2. Technology - 1<sup>st</sup> development, 1924 - 1945

### 2.1 Overall Process

#### Process characteristics:

- ◇ Hydrogen partial pressure above 200 bar (400 bar for Hard Coal)
- ◇ Process pressures up to 700 bar
- ◇ Cracking and Hydrogenation in one step in the “Liquid Phase” bubble column reactor
- ◇ Further treatment of Syncrude in Hydrotreater /-cracker (“Gas Phase”) step
- ◇ Complete separation of “Liquid Phase” and “Gas Phase”
- ◇ Mechanical and thermal work up of the hydrogenation residue

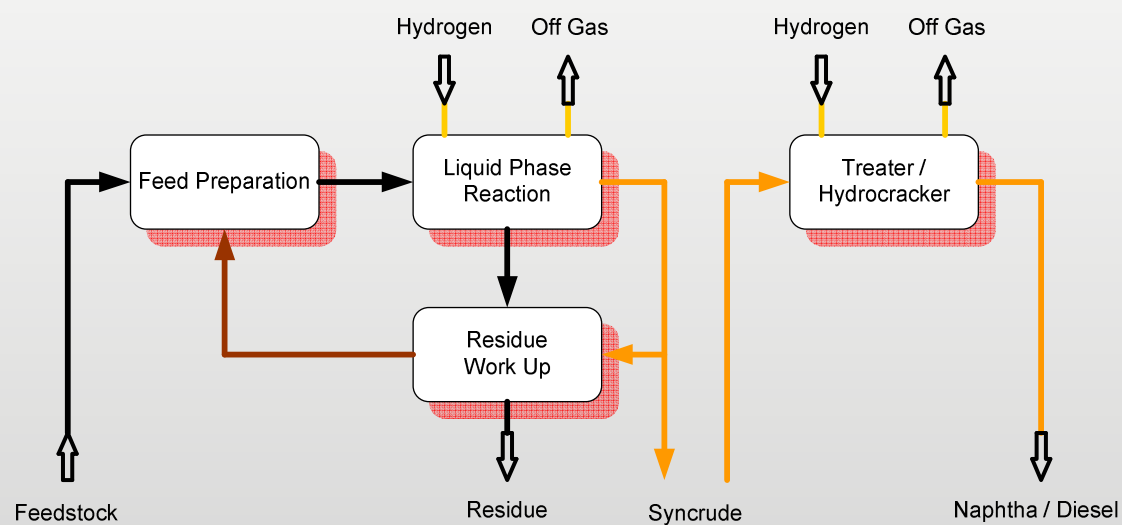


Fig. 1: Block Diagram Bergius-Pier 1<sup>st</sup> development status

#### Objectives:

- ◇ Flexibility in feedstocks:
  - ⇒ Hard Coal (bituminous and sub-bituminous coals)
  - ⇒ Lignite coal
  - ⇒ Tar
  - ⇒ Vacuum Residues from Refinery
- ◇ High oil yields (in coal mode) respectively conversion rates (in oil mode):
  - ⇒ >50% oil yield for coal
  - ⇒ >85% conversion for Tar and Vacuum Residue
- ◇ One process configuration for different feedstocks

#### Disadvantages:

- ◇ Two separate high pressure recycle gas loops which required depressurization with consecutive additional pressurization of Syncrude
- ◇ Poor specific throughput in the Liquid Phase due to high oil recycle to the Feed Preparation
- ◇ High level of asphaltenes in the Liquid Phase

## 2.2 Feed preparation of the first development 1924-1945

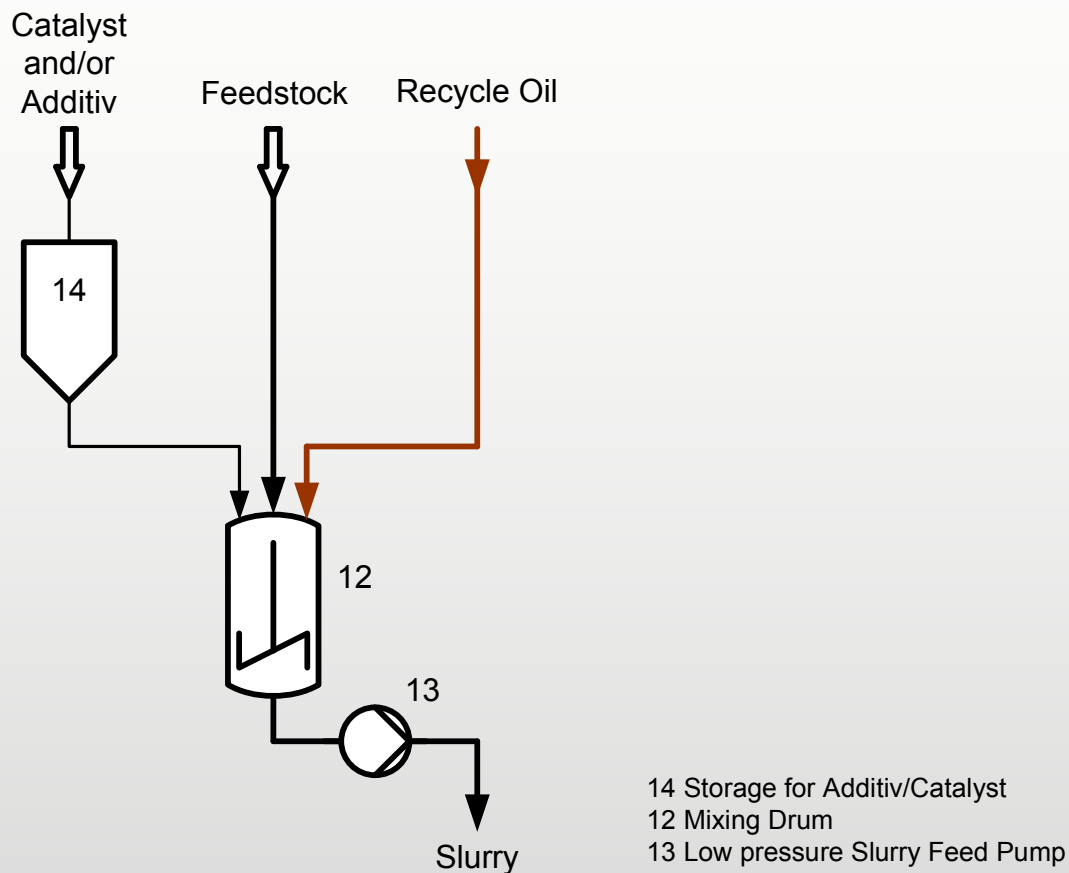


Fig.2: Feed Preparation scheme

All necessary liquids and solids for the “Liquid Phase” process step were mixed to Slurry (12) and fed to the high pressure part (13). In those plants using coal as feedstock an upstream grinding and drying unit was installed.

The use of catalyst and/or additive depends on the feedstock and pressure of the plant. The normal pressure for Lignite Coal, Tar and other lighter feed stocks was 300bar and for hard coal typically 700bar, with one exception at the Leuna plant, which was designed for 200bar. The typical catalysts (14) and additives were Tin, Chlorine, Iron Oxide, Sodium Sulphide, Coke Dust, Iron Sulphate and Molybdenum Acid.

Recycle oil as the solvent for the slurry preparation was derived from the residue work up unit, containing about 6% solids and high level of asphaltene.

### 2.3 Liquid Phase reaction section, first development 1924-1945

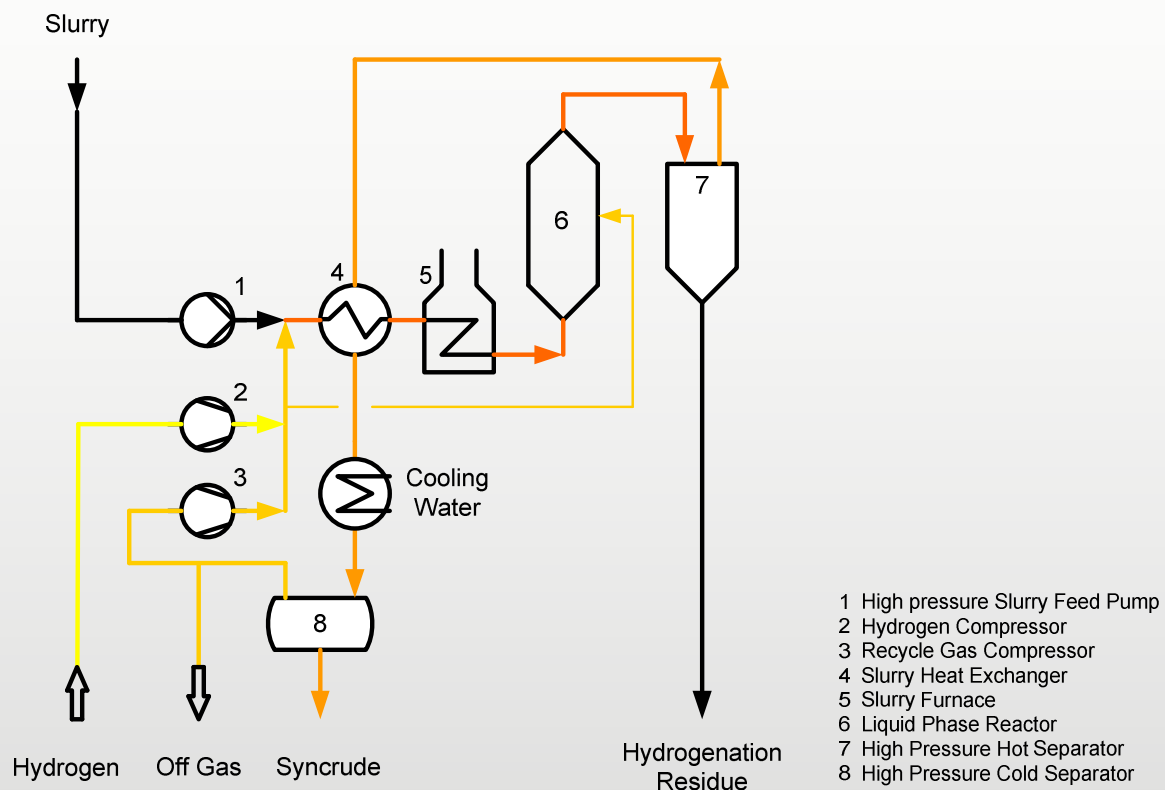


Fig. 3: Liquid Phase

The slurry coming from the feed preparation, was pressurized by special plunger pumps (1) to 300 or 700bar. The pressurized slurry was mixed with hydrogen (2) and recycle gas (3). Heating up of this three phase flow was done in two steps. The first step was done in a battery of 2 to 4 slurry heat exchangers (4) and the second peak preheating was achieved by the slurry furnace (5). The Liquid Phase reaction takes place at process temperatures of 460 °C - 485 °C.

A cascade of 3 to 4 Liquid Phase Reactors (6) converted the heavy feedstock in Gas, Naphtha, Diesel and VGO. As the overall reaction is exothermic, the temperature control was done by injection of recycle gas to adjust an isothermal profile.

The high pressure hot separator (7) split the product of the Liquid Phase reactor (6) into hydrogenation residue (unconverted Feedstock, solids, coke and some heavy VGO) and vaporous Syncrude (mixture of Naphtha, Diesel and VGO) with recycle gas. The cut point was in the range of 420 °C. The hydrogenation residue was send via the bottom outlet to the Residue Work Up Unit.

Condensation of the vaporous Syncrude and cooling down of the recycle gas was achieved by heat exchange with the feed in the slurry heat exchangers (4) and finally by water cooling. The high pressure cold separator (8) collected the Syncrude, process and injection water.

Parts of the remaining recycle gas were purged as off gas for pressure control. Most of the recycle gas was routed - after passing a washing section - to the recycle gas compressor (3).

## 2.4 Residue Work Up Unit, first development 1924-1945

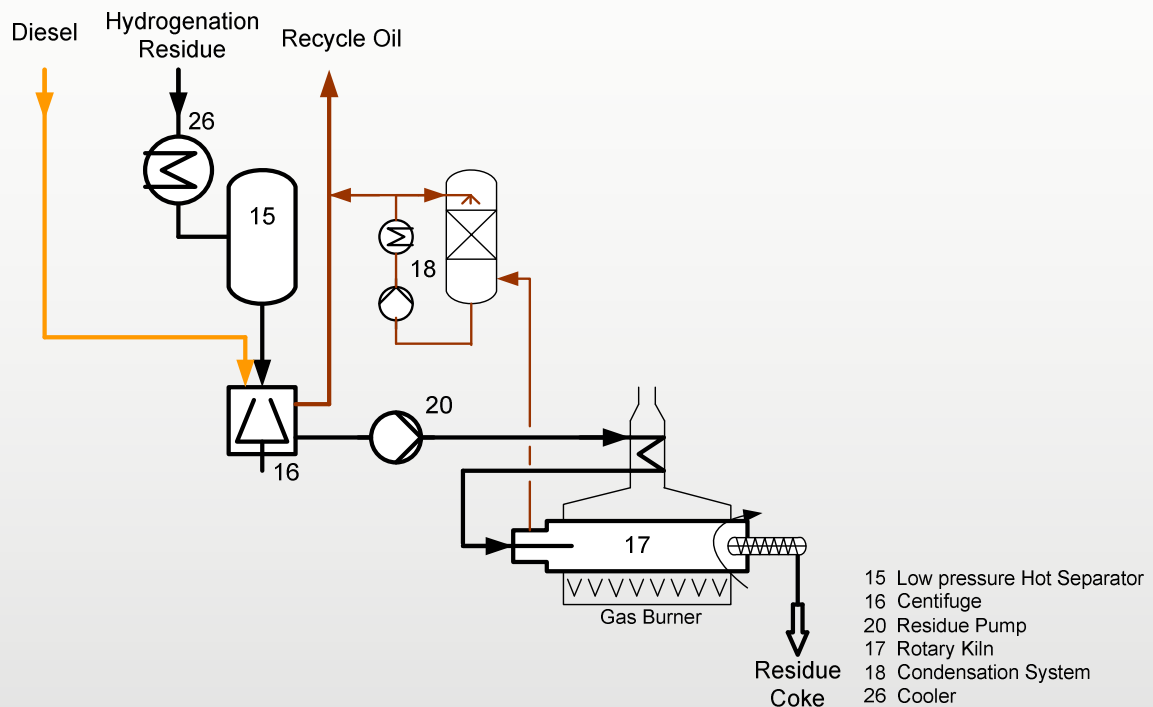


Fig.4: Residue Work Up

The hydrogenation residue coming from the high pressure hot separator (7) was depressurized after cooling (26) to below 200 °C in the low pressure hot separator (15).

This residue was mixed with a middle distillate fraction and was fed to a centrifuge (16). The washing step with lighter oil was necessary to operate the centrifuges properly. The recycle oil from the centrifuges had had a solid concentration of 2 to 12% with a high amount of asphaltenes.

The remaining residue with solid concentrations of about 40% was pumped (20) and preheated fed into a rotary kiln (17) to produce residue coke.

Vapours coming from the Rotary Kiln were condensed (18) and send together with recycle oil from the centrifuge to the Feed Preparation Unit. A minor part of this oil was also used as flushing oil.

2.5 Hydrotreater, Hydrocracker, first development 1924-1945

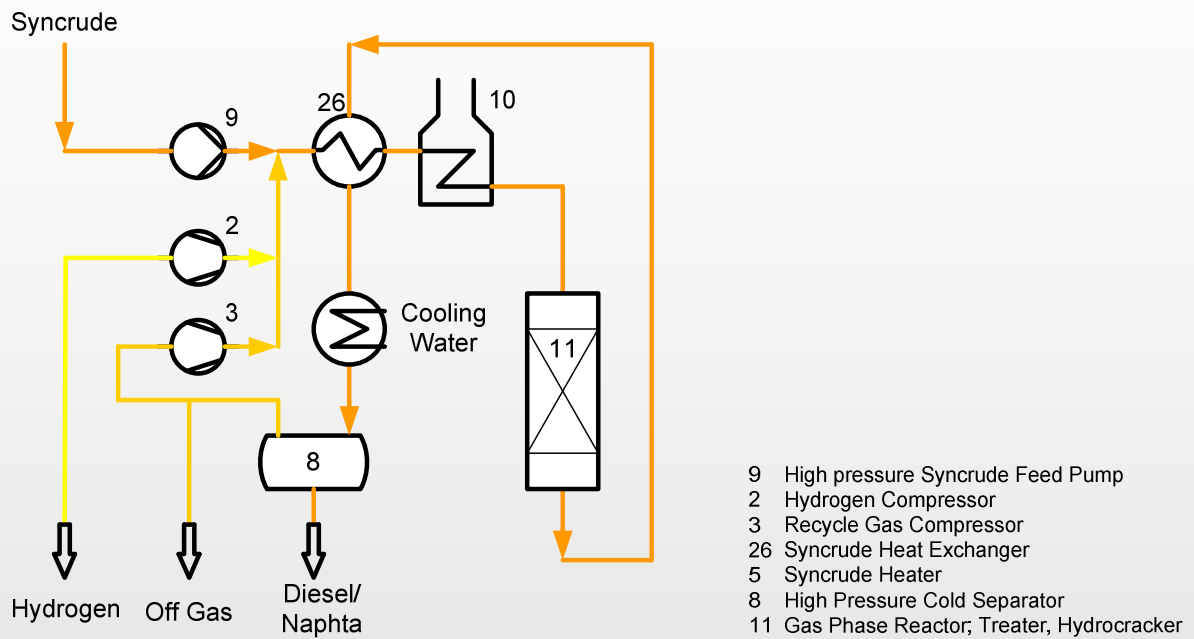


Fig.5: Gas Phase section

The development of the Gas Phase reactor system is a separate chapter and is not part of this information. Figure 5 shows the general arrangement.

2.6 Original drawings, first development 1924-1945

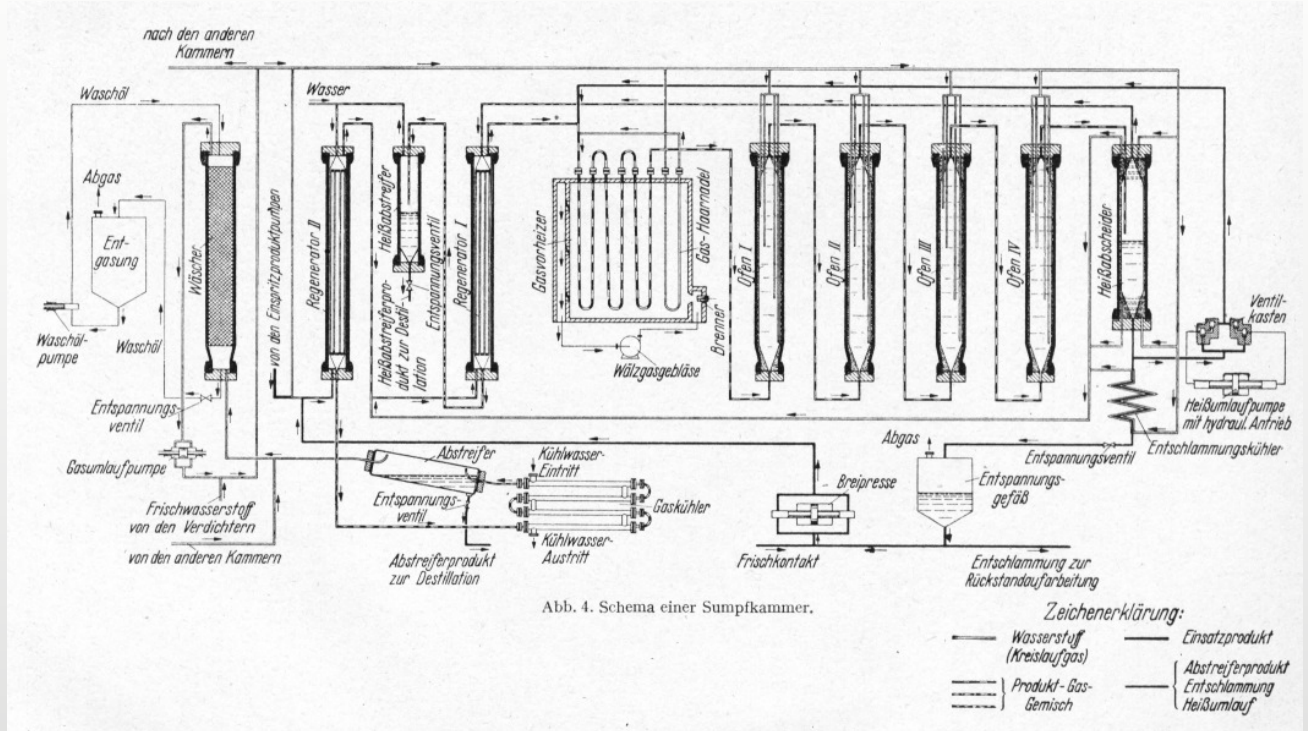


Fig.6: Liquid Phase reaction section

Source:  
 Die katalytische Druckhydrierung von Kohlen Teeren und Mineralölen  
 (Das I.G.-Verfahren von Matthias Pier)  
 Dr. Walter Krönig, Springer Verlag 1950