

Coal – in Liquid Form

In 1925, **Franz Fischer** and **Hans Tropsch** at the **Kaiser Wilhelm Institute for Coal Research** in Mülheim an der Ruhr discovered how to turn coal into gasoline. Today, Fischer-Tropsch synthesis is experiencing a renaissance, as it is used to refine far more than just coal. The process can also be applied to turn natural gas, biomass and even household trash into fuel.

TEXT **ELKE MAIER**

Dwindling oil deposits are forcing scientists to be inventive. Chemists are now able to transform a wide variety of carbonaceous raw materials into high-quality liquid fuels. Some airlines are even experimenting with kerosene from household trash. The method used to bring about this transformation is neither alchemy nor is it new. It was developed more than 90 years ago at the Kaiser Wilhelm Institute for Coal Research in Mülheim an der Ruhr.

The Institute in Mülheim opened its doors for the first time on July 27, 1914. Its declared aim was to “increase the intrinsic value of coal.” The first Director was Franz Fischer – a man considered to be an “inventive mind” and a “very skillful experimenter.” Fischer had studied chemistry and completed his doctorate at the age of 22, after just four semesters. When he accepted the position in Mülheim, he was 36 years old and his research career had already been meteoric.

Initially, the Institute’s primary task was to support the German war economy by producing fuels for automobiles, tanks and airplanes. Oil was in scarce supply, but coal was plentiful. The only problem was that it had to be liquefied. Chemically, this required the following steps: First, the bonds between the hydrocarbon molecules that give the coal its stability had to be broken open. After that, the hydrocarbon chains of the liquid fuel had to be assembled.

A year earlier, in 1913, German chemist Friedrich Bergius had already found a way to do this – he even earned the Nobel Prize for it in 1931. But the Bergius process has some serious disadvantages: For one thing, it can be used to liquefy only geologically young types of coal, such as lignites, but not geologically older, hard coals that have a higher energy content. And for another, the method works only under enormous pressure, which creates technical problems.

What Franz Fischer thus had in mind was a “synthesis of oils from gases.” It all sounded quite simple in theory: The first step of his two-step process would be to heat coal dust with steam and



Putting coal into the fuel tank: Franz Fischer (left) and Hans Tropsch.

oxygen to crack all the carbon bonds and generate a mixture of carbon monoxide and hydrogen – the so-called synthesis gas. The second step was to then channel this gas over a catalyst on whose surface the molecules would link up to form complex hydrocarbons.

But as is so often the case, here, too, the devil lay in the detail – or more precisely: in the catalyst. Its task was to stimulate the otherwise far too sluggish reaction process, and also to ensure that the desired end products were created. The hunt for a suitable material resembled the

proverbial search for a needle in a haystack.

In the early 1920s, the experiments on gas synthesis were expanded. One of the scientists involved was Hans Tropsch who, according to a colleague, was an “outstandingly competent” chemist and a “master at using a slide rule for difficult calculations.” He had been recruited by Franz Fischer and entrusted with heading the “gas catalysis” department.

The scientists conducted countless screening experiments in special high-pressure devices. They tinkered with several settings at the same time, varying not only the catalyst but also the temperature and pressure, as everything taken together determined the outcome of the reaction.

It was months before the first glimmer of hope appeared. The researchers found that the apparatus held reaction mixtures that contained alcohols, aldehydes and ketones, among other things. To keep things simple, the chemists called the mixture “synthol.” The catalysts they used were iron filings that the researchers had impregnated with potassium hydroxide or rubidium hydroxide.

One member of the Institute, Carl Zerbe, did some initial road tests on a 1922 4HP NSU motorbike powered by the engine fuel they had laboriously obtained in minute amounts. “But synthol still wasn’t a high-quality fuel,” explains Matthias Haenel, professor emeritus at the Institute in Mülheim. “It still contained a lot of oxygenated compounds that cause the engine to corrode.”

So the search continued – and sorely tested the patience of the researchers. Some catalysts became inactive after only a very short time; others produced only water as their end product. The chemists had to use hammers and chisels to remove some of the catalyst charges from the pipes again, as so much carbon deposited in them.

At the beginning of 1925, a turning point finally appeared to be on the horizon. A journal containing an article by a certain Georges Patart arrived in Mülheim. In this article, their famous French colleague described how methanol – a simple compound with one carbon atom – could be synthesized with the aid of a zinc oxide catalyst. The researchers in Mülheim immediately began their attempts to cook up the experimental recipe – and succeeded on their first try. They were amazed at the “smooth, homogeneous formation of methanol on the almost unchanged white zinc oxide.”

From then on, they stuck to the catalyst described by Patart. Was it also possible to make long chain hydrocarbons in this way?

GEO, Issue 3/1983



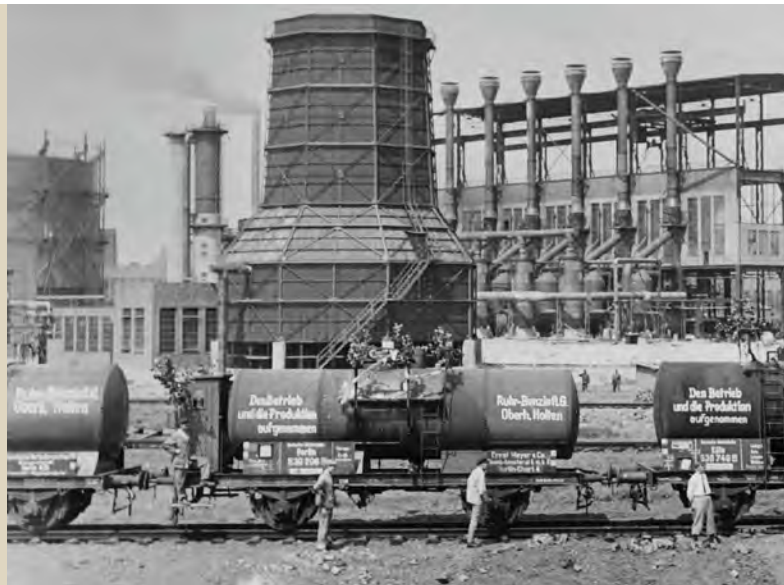
From about 2020 on – so in just 40 years – coal will play the leading role, and oil will only have a bit part.

The researchers experimented with zinc oxide, adding other chemicals they thought would be suitable. On May 25, 1925, their hunch proved to be correct: this was the day on which they first succeeded in synthesizing higher hydrocarbons at normal pressure. The philosopher’s stone turned out to be a mixture of iron and zinc oxides. It was later found that iron and cobalt catalysts are even better. On July 20, 1925, Franz Fischer and Hans Tropsch applied for a patent for their method.

The first industrial plant to operate using the process discovered in Mülheim went into operation in the mid-1930s in Oberhausen. In the early 1940s, nine German production sites were producing around 600,000 tons of liquid hydrocarbons every year. Nor were the primary products of Fischer-Tropsch synthesis used only for fuel production: they could be processed further into lubricating greases, soap or detergents, for example. It was even possible to conjure up synthetic butter.

The inventor of this synthetic edible fat was chemist Arthur Imhausen. In the Second World War, Germans fighting in the African campaign and on U-boats ate almost exclusively Imhausen’s fat. It was easy to digest, didn’t go rancid and is reported to have had quite a nice taste. Experts confirmed that the daily consumption of up to 100 grams “is harmless and causes no irritations or disorders whatsoever.” His creation was thus given the go-ahead as the first synthetic food for human consumption.

After the war, however, the Fischer-Tropsch products, and thus synthetic butter as well, were soon off the table again. The synthet-



Triumphant progress of synthetic gasoline: Wagons loaded with Fischer-Tropsch fuels wait in front of Ruhrchemie AG in Oberhausen-Holten before they set off.

ic fuels made from coal couldn’t keep up with their oil-based counterparts. The plants were dismantled. It wasn’t until the oil crisis in the 1970s that the process enjoyed a brief revival in Germany.

Franz Fischer and Hans Tropsch didn’t live to see the checkered future of their invention. Fischer retired and moved to Munich, where he twice lost all his possessions in air raids. He suffered from malnutrition and died at the age of 70 in the hunger winter of 1947. Tropsch moved from Mülheim first to Prague and later to Chicago. In 1935, illness forced him to return to Germany, where he died a short time later at the age of just 45.

After the war, the process developed by the two chemists first made waves in South Africa. The country’s policy of apartheid meant that it was subject to sanctions, and oil shipments were banned. What they had, however, were masses of coal. The government thus turned to the Fischer-Tropsch method and founded a company in 1950 that now trades under the name of South African Synthetic Oil Limited (Sasol). The company still supplies around a third of the fuel sold in the Cape, and now it processes natural gas as well as coal.

The method is now enjoying a comeback in other countries, too. “Its big advantage is that basically any carbonaceous raw material can be used in the process, so also natural gas, biomass and even household trash,” says Ferdi Schüth, Director at the Max-Planck-Institut für Kohlenforschung. “The method also delivers very pure, sulfur-free fuels.”

This fact has been exploited in Qatar, for example, where Shell commissioned Pearl GTL, the world’s largest gas-to-liquids (GTL) plant, at the end of 2011. It transforms low-priced natural gas into high-quality liquid fuel. Annual production totals around 5.6 million tons – more than nine times the amount produced in the early 1940s in all of Germany. The synthetic diesel from the desert is also available at German gas stations.

In Germany, however, it won’t be worth constructing Fischer-Tropsch plants again until the price of oil rises: “A barrel currently costs around 40 dollars, so it isn’t worth producing it with this method,” says Schüth. Yet, although it has always been possible to find new sources of oil, the day will come when oil reserves are exhausted. Then reviving the Mülheim method may be an option in Germany, as well. Whether Imhausen’s spread will also enjoy a revival, however, is questionable.