Merrell Robert Fenske (1904-1971)

A few years ago an enthusiastic A-level student told me that they were going to study chemical engineering. After all, he argued to me, it was simply chemistry, but on a larger, more industrially relevant scale. I reminded him of that flippant remark that chemistry is simply physics scaled up. Sure you need physics to understand it, but chemistry involves a different way of thinking. Chemical engineering in turn, require another step in thinking, a change which happened early in the 20th century.

Among those who contributed to this shift was Merrell Fenske a chemist born in Michigan City, a town in Northern Indiana in the plains of the mid-West. Almost nothing is known of his family, although he had at least one sibling since two nieces still lived in his hometown when he died. He travelled a two hundred miles south to study chemistry at a small private liberal arts school, DePauw University in 1919 with a Rector Scholarship. When he graduated, he moved to the East coast to study industrial chemistry at MIT in Boston.

In the 1920's MIT was *the* place to study chemical engineering, a subject being revolutionized by Warren K Lewis and his friend and colleague Arthur D Little. Rather than thinking of industrial processes in terms of the chemical reactions and their details, they broke down industrial transformations into "unit processes": heat transfer, fluid flow, combustion, filtration, distillation etc. In other words, the chemistry was mattered little provided one knew the key physical parameters governing a particular operation. The1923 textbook that Lewis co-authored with colleagues William Walker and William McAdams, was filled with flow-charts and partial derivatives rather chemical equations, and would become a cornerstone of chemical engineering thinking.

As he worked on a wide range of problems. Lewis attracted a strong group of young scientists including the Norwegian chemist, Per Frolich, whose short career at MIT was nothing short of meteoric, rising from a doctorate in chemical engineering in 1925 to associate professor four years later. When Fenske arrived at MIT in 1925, Lewis set him to work with Frolich, with whom he studied the catalytic conversion of syngas into alcohols, publishing six paper in the space of two years. When Fenske graduated in 1929 he moved to Penn State to set up a new industrially funded laboratory in petroleum engineering. But Frolich too moved on to a position at Standard Oil (today's Exxon) of which he would eventually become research director.

At the time, the automobile industry was expanding rapidly, and Pennsylvania was still a significant producer of crude oil, sixty years after the state's original oil rush. Motor car engines were becoming faster and more powerful, thanks to ever higher compression ratios. But this brought with it an insidious problem – the higher the pressure in the engine, the higher the risk of a spontaneous explosion during compression, "knocking", that at the very least caused a characteristic pinging sound, and at its worst risked destroying the engine altogether. In 1922 Thomas Midgely at General Motors discovered that addition of tetraethyl lead to gasoline largely eliminated the problem of knocking. In 1924, General Motors and Standard Oil set up the Ethyl Corporation to make the additive in spite of a growing number of reports of lead poisoning among workers.

But the causes of knocking were poorly understood, especially in relation to the composition of the fuel. Fenske's objective was to find ways to separate Pennsylvania crude oil – a highly desirable feedstock, low in sulfur – into fractions in the hopes of investigating the relationship between knocking and composition. Fenske's first paper shows the scale of his ambition. He did a preliminary rough distillation of Pennsylvania crude, and then transferred nine gallons of the product into a still with an electrically heated iron fractionating column almost 11 meters high. The column was filled with alternating layers of Raschig rings (see CK13 Sept 2008) and steel "jack chain". Over a period of 45 hours he distilled fractions boiling from 43 to 204 ˚C, each of which he then tested as a fuel using an engine provided by the Ethyl Corporation. The standard test involved measuring the degree of "knocking" of the motor as a function of the volume of tetraethyl lead added to a gallon of fuel.

His fractionation column was not just a random choice. Fenske was developing the theory of fractionation to establish the best strategy for the construction of the most efficient stills. He based his study in part on Warren's pioneering work at MIT but also that of the Bristol-based chemist Sidney Young. Young is forgotten today, but it was he who discovered that addition of benzene to an alcohol still caused the "breaking" of the water-ethanol azeotrope and allowing the isolation of absolute alcohol.

Fenske derived an equation that established the number of theoretical plates required to separate two volatile compounds by fractionation under idealized conditions, a relation widely used today. Working with a pair of graduate students, Fenske tested his relation by successfully separating the isomers of isobutylene which boil only 3.3 ˚C apart.

Then the work of fractionating the crude began. Well before the advent of chromatography, they detailed the chemical composition of each fraction that came off their column, and identified the many hydrocarbon isomers that they isolated. But alongside this work they also looked in detail at the influence of the packing materials inside the column. They compared the performance of glass rings, with metal chains, metal staples, segments of wire in ziz-zag segments, flat C-shaped rings, and short lengths of helical spring wire. The differences between the materials were substantial, with the helices coming out on top. Better still, the helices tangled nicely allowing the fractionating column to be unpacked very quickly when needed.

They soon found that they could build a 100 theoretical plate fractionating tower 13 m high with a 60 cm glass column simply by replacing metal rings with the new helices. A short patent suggested that such helices could be made of virtually any material, depending on the chemical circumstances under which they would be used.

Fenske never lost his interest in chemistry and distillation, but applied his equation more widely to liquid-liquid extraction; during the war he contributed to the development of isotope separation methods for the Manhattan project. His helices have never disappeared from chemical catalogues.

To my surprise, I happened to meet the engineering student after he'd graduated with a first glass degree. He was very happy with his choice. But, he added, "I don't think I saw a single chemical equation during the whole my degree". Chemistry vs engineering. Take your pick.

References:
C. O. Tongberg, S. Lawrowski , M. R. Fenske, *Ind. Eng. Chem*., **1937**, *29*, 957.
MR Fenske, US Patent US 2,135,703 (1936)

FIG. 1.

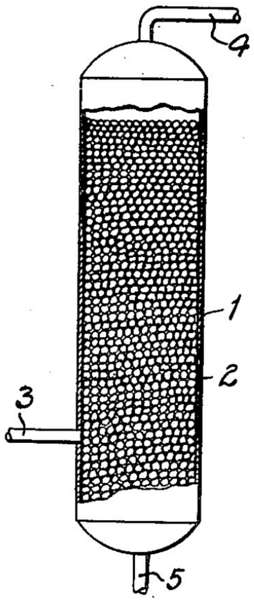

FIG. 2.

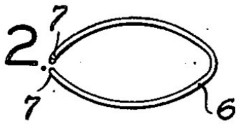

FIG. 3.

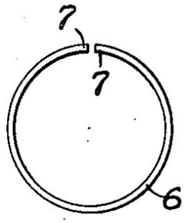

FIG. 4.