Petrochemical Pilot Plants: A Historical Perspective

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The age of petroleum refining and petrochemicals was ushered in by World War II, more than 30 years after the discipline of chemical engineering was established, including the founding of AIChE. A look back at pilot equipment from the 1940's through today reveals ostensibly little change in physical equipment comprising a majority of the unit operations being piloted. Rather, it is the control and data acquisition systems along with analytical methods which "date" a given pilot plant, more so than changes in the gross physical design of unit operations. The range of scales of pilot plants has also remained similar over time.

Underlying the external similarities have been incremental improvements in internals for mass and heat transfer, as well as marked improvements in catalysts and sorbents, and many other aspects of chemical engineering discipline. Control systems have evolved significantly over time, with movement from analog to digital, and toward electronic vs. pneumatic or electro-mechanical control devices, reducing need for operator monitoring and intervention, enabling remote monitoring, and making virtually all data accessible retroactively. A progression of improvements in fluid flow and physical property metering and measurement devices has enabled smaller-scale pilot units to be considered, though scale up considerations for unit operations are often the limiting consideration preventing extensive scale-down.

An evolution in analytical chemistry, combined with advances in process modeling and simulation with shared physical property databases, has revolutionized pilot "scope", if not size. Prior to widespread use of gas and liquid chromatography (ca. 1960), the distillation column was perhaps the most important analytical tool. Much of the pilot effort was designed to produce distillation cuts to characterize compositions and yields. Today, compositions can be fully detailed via analysis of less than a milliliter of sample, and process simulators can often predict separations without requiring extensive piloting of fine distillations. These trends also offer an opportunity to decrease pilot scale and costs, relative to the requirements of previous decades.

Advances and wide-spread availability of process modeling and simulation software have led to reduced emphasis on semi-empirical scale-up based on dimensionless groups, in lieu of full development of a rigorous process model with detailed reaction kinetics and separations. The pilot has in many cases become a means to calibrate the model, including explicit sensitivity to scaling. The model can then be used to examine optimal parameter spaces and operability, reducing the number of pilot runs required relative to past operating practice.

Despite the above trends, which could allow smaller and less comprehensive pilot programs to be considered or the pilot-stage to be skipped outright, pilots and demonstration plants of today (2008) are often conducted at the same scales as those of past generations. Part of the purpose of a pilot plant is to reveal that which is not anticipated or known – the so-called "unknown unknowns". That which is "unknown" at the laboratory scale may be revealed at the appropriate pilot scale, a phenomenon which leads to conducting pilots at approximately the same scale as those which have been successful in past commercializations. Risk tolerance is also reduced as margins for refining and petrochemicals are diminished due to strong global competition. Despite advances in chemical engineering science and fundamentals over the past 60+ years, primary objectives and reasons for pilots and demonstration plants including selection of appropriate size and scale, have thus remained largely unchanged.[1]

Reference

1. H. Hoog, W. B. Hawes, and J. J. Leendertse (Royal Dutch Shell), “Pilot Plants and Semi-Commercial Units”, *Chemical Engineering Practice* (Cremer & Davies), Vol-1, 255-404 (1956).