The Uniqueness of the Pilot Scale

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I recall a talk given by an invited speaker that I attended during my post-graduate work during a break from slaving away in the lab doing kinetic experiments related to a new commercial hydrogenation catalyst. The speaker boasted about how rich we chemical engineers were with meaningful mathematical models for the processes we worked with: “With computing power becoming cheaper every year, and with the wealth of steady-state models at our disposal, I see a day when our simulators are so powerful that the pilot plant will become a thing of the past.” Even just starting my career, I was skeptical of such a grandiose statement, knowing just how difficult it is to obtain meaningful kinetic data under industrially significant conditions and how pivotal that data is to designing a commercial plant that actually works. Twenty-five years later, having developed technology from the bench through pilot and onto the commercial scale across the full breadth of the chemical process industry for Zeton Inc., I am just as sure that pilot plants are here to stay and will very much be a part of our future.

With that said, pilot plants are a significant investment (significantly larger than the investment required for a simulation or lab test rig), so the process technology developer or owner and the designer/fabricator of a new pilot-plant facility are faced with some difficult technical choices to give their project the best chance of success and best outcome for their R&D investment. Schedule savings in the design, manufacture, and commissioning of the pilot plant or in a rapid completion of the experimental program can be very beneficial. On the other hand, oversights in the pilot work may kill the entire program outright, rendering the entire R&D effort to that point a total waste.

To maintain a good balance between cost savings and well-conceived planning, the first thing to think about is what a pilot plant is. A pilot plant is a processing system that operates at a scale intermediate between the laboratory and the commercial scale. In many instances, laboratory testing is done batchwise whereas pilot plants generally operate in the same mode as commercial operations as continuous processes (often with one or more recycle streams). However, even when pilot plants and commercial plants are both designed for continuous operation, viewing a pilot plant as a commercial plant in miniature can lead to some incorrect design assumptions.

Different Products = Different Design Requirements

A full-scale commercial plant's goal is to generate tonnes per hour of product of suitable quality. The pilot plant has an entirely different product; it is designed to generate process knowledge and understanding in the form of both experimental data and operational observations and to do so in an economical and timely fashion. This is a key difference, one that makes the pilot scale a unique undertaking, and one that must be kept clearly in focus during all parts of the design process.

It is helpful to compare and contrast the pilot and commercial scales in terms of objectives and design factors arising from these objectives, as detailed in Table 1 below.

Table 1. Comparison of Commercial and Pilot-Scale Operations

Table 1 — Comparison of commercial and pilot scale operations

Factor	Commercial Scale	**Pilot Scale**
Key Objectives	Continuous generation of on-spec product(s)	• Process knowledge and understanding • Operational observations • Scale-up data
Scale	Tonnes per hour	Kilograms per hour
Operation	Continuous, maximizing up-time	Continuous campaigns lasting up to several weeks
Design Life	Tens of years	Between one and ten years
Maintenance	During operation, as much as possible	Between campaigns
Operational Mode	Steady state	Chasing steady state
Data Acquisition and Control	As needed to maintain steady state	To obtain steady state and the necessary process data for scale-up
Operating	Commercially optimal	Beyond commercially optimal

Temperature and Pressure	conditions	conditions (to establish optimum)
Design Points	Single	Multiple
Flowsheets	Single, fixed	Frequently multiple, variable
Source of Design Data	Pilot plant	Laboratory data and simulations, experience
Capital Project Timescale	Several years	One year
Need for Operational Flexibility	Modest	Considerable

A pilot plant will have different design data sources, objectives, scales, lifespan, operational conditions, and products than a commercial operation and should therefore have a separate, distinct design and project execution approach. Starting from the perspective that the pilot plant has a different set of objectives and a different set of operational conditions will help keep the design process on track.