Pilot Plant Fabrication: Inspiration to Operation Guidance

Eliminating surprises in the process

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Introduction

Bringing new products to market quickly is a business imperative in virtually every industry. A methodical approach that minimizes process and product quality risks in developing new technologies is also critical. To that end, pilot plants play an essential role in transforming R&D concepts into commercially viable processes for chemicals, catalysts, fuels and other products.

Although the overall design-build-test-operate cycle for pilot plants follows similar steps for most technologies, these can be unfamiliar and even daunting to those who haven't been through the process before.

This article provides insight into the pilot plant development cycle, with the goal of understanding the process for companies that are seeking a design and fabrication services provider to help them develop and commercialize technologies. This article assumes that the company has established proof-of-concept at the bench scale and is now ready to scale-up.

Scope

Pilot plants are necessary to minimize risk encountered when developing new and unproven technologies. The distinguishing characteristic of a pilot plant is that its main "product" usually is data – not a large volume of physical goods. These data include engineering design information for the commercial plant, impact of operating parameters on process efficiency and product quality, feedstock qualification, development of safe operating procedures, and assessment of capital and operating costs. Consequently, pilot plants must be more robust and flexible than their commercial manufacturing counterparts. Pilot plants are built to withstand extremes in process conditions, since optimal manufacturing temperatures, pressures and other elements of the process have not yet been established.

What this means for the pilot plant "owner" is that the scope of the project is more extensive than if the unit was built only for physical goods production. Economies of scale, extra instrumentation, more flexible process configuration and conservative construction philosophy all lead to relatively higher costs for these development units. Many organizations that have never designed, built or operated this type of custom equipment often underestimate the cost of the unit, even though they recognize the importance and value of their pilot plant. The goal is to find the balance between building a pilot plant that is sufficiently large and flexible, yet is no more complex and costly than required to meet your objectives.

The fabricator's engineers can work with you to assess the purpose, size, operational flexibility, and the extent of automation and analytical equipment required to meet your project goals. A fabricator's experience, ingenuity and understanding of the chemistry that is the foundation of the process being tested can make a big difference in this regard. These competencies, as well as commercialization experience, are advantageous to have at hand when implementing a vital tool for advancing your technology.

Engineering Study

Before the first component is bought or weld is made, an engineering study should be done. Determining the depth of the study is a first step in this part of the project. The more detailed the

study, the more accurate the cost estimate for the pilot plant will be. A fairly cursory, preliminary study can yield a +/- 50% "budget estimate," which can help you make a go/no-go decision for the project, or decide to commit funds for a deeper study. The more extensive study, which can narrow the cost variance to about 10%, will enable appropriate allocation of funds and ensure that all the parties involved – the owner, fabricator and any subcontractors – understand their role, the schedule and the deliverables.

A thorough study calls for significant effort on the part of the designer/fabricator. It is not uncommon for the engineering study to represent up to 10% of the total project cost. The benefits of investing in this effort include lowering project risk and costs through: tightening the project scope, identifying all major equipment, projecting labor costs, enacting preliminary safety and operations reviews, and developing a critical path schedule. This study provides the information necessary to make sound decisions about the pilot plant project and, consequently, the pace of technology development.

A prime consideration in the design and operation of the pilot plant is safety. Because the unit will likely be used to define operational limits during the process of technology development, the design needs to incorporate redundant safety systems and eventually enable the overall system to "fail safely." Operator safety is of the utmost importance, and means going beyond the normal practice of addressing safety regulations relevant to the facility where the unit will operate and any industry regulatory mandates.

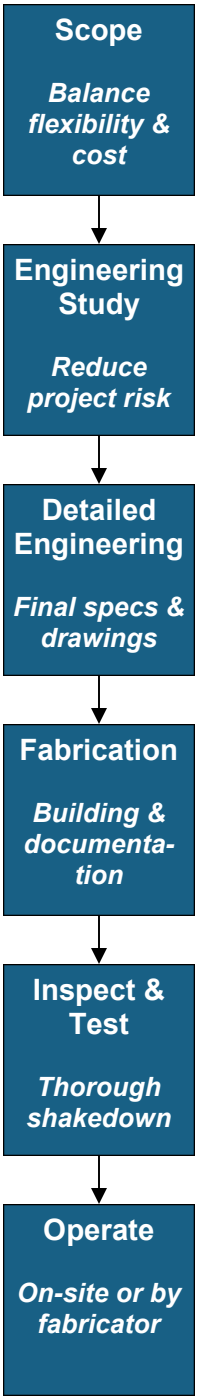
Keep in mind that it's not only the conditions inside the processing system that matter. Units that are being fabricated in the process of scaling for "real world" systems that might run in the heat of the Texas summer or cold of the Canadian winter call for considering the effect of extreme environments. That will enable the service provider to determine a parts list with components that can tolerate the all operating conditions and to build a pilot plant that will more effectively provide the data and product you need to asses and refine your process. By utilizing all the tools available, relying on your fabricator's experience, and anticipating your needs in the "real world" system, you can advance toward commercialization and minimize the need for changing the system during fabrication.

Detailed Engineering

Once the scope of the project is finalized and the engineering study is complete, the project is ready for detailed engineering and fabrication. Detailed engineering involves sizing and specifying equipment (including materials of construction, instrumentation, service requirements, etc.), creating detailed process designs, and identifying the precise layout of the equipment. This is a major part of the process. At this stage, the owner's involvement is often reduced, since the major part of the effort at this stage is for the engineers to turn the scope and results of the engineering study into final specifications and drawings.

A detailed engineering study provides everything needed to fabricate, including:

- Project schedule
- Process flow diagrams
- Block flow diagrams



- Calculations
- Process & instrumentation drawings (P& IDs)
- Specifications and drawings for all equipment (process, mechanical, structural, piping, electrical and instrument)
- Control philosophy and automation
- Safety systems

Fabrication

With all the essential, up-front engineering finished, fabrication can begin. At this stage in the process, it is best to not introduce change orders. Change orders are generated when deviations from the scope of work are required during fabrication – which even includes *removing* components from the system. Considering that most projects are meticulously planned as a step-by-step series of tasks with deadlines, it's easy to understand how modifications significant enough to warrant a change order will increase cost and time of fabrication.

During fabrication, documentation on the system and its operation are created. Final documentation includes:

- As-built version of all the review documents
- P&IDs
- Equipment layout
- Process bill of materials including instruments (specifying tag, manufacturer, model, basic size or connection, basic materials, design pressure/temperature, calibration, special notes
- Equipment data sheets
- PSVs (pressure safety valves)
- Designer notes
- Equipment vendor technical and maintenance manuals
- Material certifications
- Pressure vessel certifications

Multiple copies of the documentation are usually provided and frequently include electronic copies.

Inspection & Testing

During fabrication, individual components will be tested for functionality and their ability to meet operational conditions, for example leak checking of pressurized systems. But, ultimately, the complete system needs to go through a shakedown. Inert gases and simulating fluids can be used to run the unit at a series of conditions, so that the system is tested at the flows, pressures and temperatures that the unit will see during normal operation.

Several layers of testing are important during checkout. First, the unit should be tested for completeness, meaning that all the process, electrical, instrumental and computer materials and components that were included in the bill of materials and design are present, meet their specifications and are properly tagged. The system needs to be tested for mechanical functionality and leaks; pumps, valves and other components also undergo a functional test to verify the performance of the equipment and associated instruments. All the controls also will be tested during the functional test. Finally, all safety systems must be activated to ensure that the unit "fails safely."

Operation
Once the pilot plant is fabricated and tested, the next step is operation. There are three options for operations:

1. Delivery of the pilot plant to the owner's site for installation and start-up
2. Brief operation by a contractor before delivery
3. Long-term operation by a contractor

Option 1 is most typical. Most owners want to start operations themselves, as they have already operated the process at smaller scale and may have proprietary procedures or chemicals that they want to maintain as secret.

Options 2 and 3 can be extremely valuable to the customer. Experienced operators can run the pilot plant for the customer, both to ensure that the unit is operating as expected, under "real world" conditions, and to optimize the process. The fabricator can train the owner's operators during this time as well, while using collected data to determine if final equipment changes are required. Using the fabricator as operator also can be valuable if the owner does not want to increase staff, or has limited experience with pilot plant operations.

Summary and Conclusions
While new methods for simulating the behavior of complex processes have been and continue to be developed, nothing can substitute for the knowledge gained through actual operations. Just like commercialization, pilot plant fabrication and operation is a step-by-step procedure that calls for both experience and creativity. The pilot plant is a critical vehicle for technology development, a tool to help ensure that your innovation enables your company to succeed.

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About Continental Technologies
Continental Technologies designs, builds, installs and can operate processing equipment for technology development and scale-up. The company specializes in pilot plants for fuels, catalysts, chemicals, polymers and solids development and production.