

PILOT PLANTS — PART 2:

Don't Apply Commercial-Plant Specifications to Pilot Plants



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Save time and money by using equipment and procedures appropriate for the requirements of a demonstration-scale plant.

IT MAY BE TEMPTING TO DESIGN AND BUILD a pilot or demonstration plant using the same specifications as for a full-scale commercial facility. However, doing so can add to the cost and schedule of the project. It can also have a severe impact on the quality and operability of the pilot plant, and may, in the extreme case, cause the project to be abandoned.

Often, the uniqueness of pilot plants and factors such as cost, space minimization, time restrictions and pilot-plant life are not carefully considered. Furthermore, dated plant specifications will often prohibit the use of new instrumentation and equipment technology, which is unfortunate since pilot plants are an excellent way to test these advances.

This article emphasizes the need to focus on the unique requirements of the pilot plant, and it provides some specific guidance and examples related to vessel constructions, instrument installation and utilities.

The principle of keeping it simple is very important in a pilot plant. While it is easier at the beginning to blindly pass on specifications, don't be lured into that trap.

Instead, consider industry-accepted codes, standards and practices, and, where necessary, supplement these with pilot-scale-appropriate specifications or guidance rules for the most critical parts.

It is imperative to keep the operational life of the plant in focus. Why choose 20-plus-year methods or materials for a 2-yr development plant, or specify off-shore methods for an indoor pilot plant?

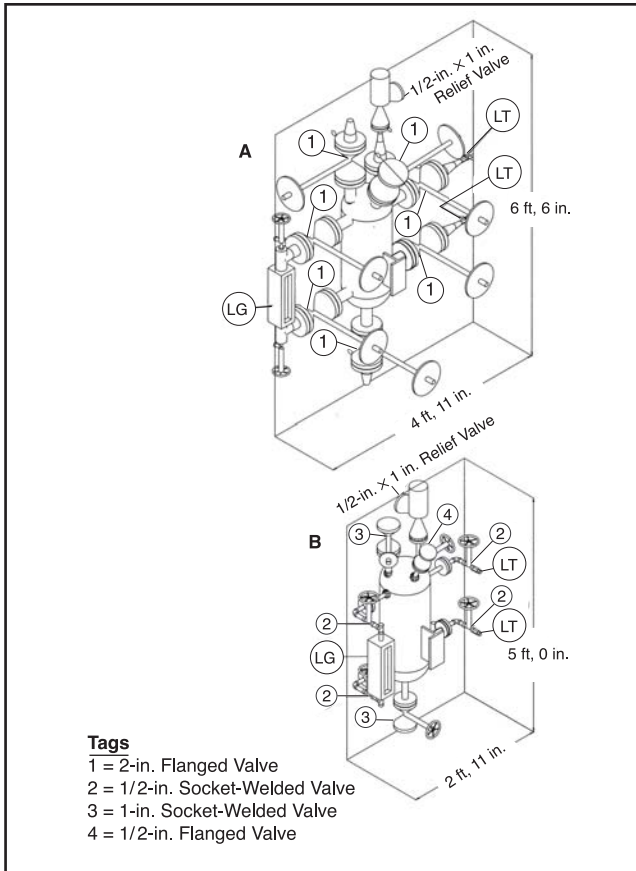
Rely on the experience and expertise of the designer/fabricator. How has it been done successfully in the past? And, it is very important to allow creativity in design and novel approaches to be considered.

Is space an issue for your pilot plant? Do you intend to change or add equipment or instruments during the life of the pilot plant? Real estate is often at a premium, hence smaller is better, and every added item, no matter how trivial, will add to the needed space or result in a very cluttered pilot plant that is difficult to maintain.

Example 1: Minimum nozzle size

A plant specification required that all nozzles on a 10-in.-dia. vessel (designed for 185°C and 145 psig) be a minimum of 2 in. Figure 1A shows the vessel as constructed per the specification. It has 8 nozzles, which were required to be NPS 2-in. with 2-in. flanged isolation valves.

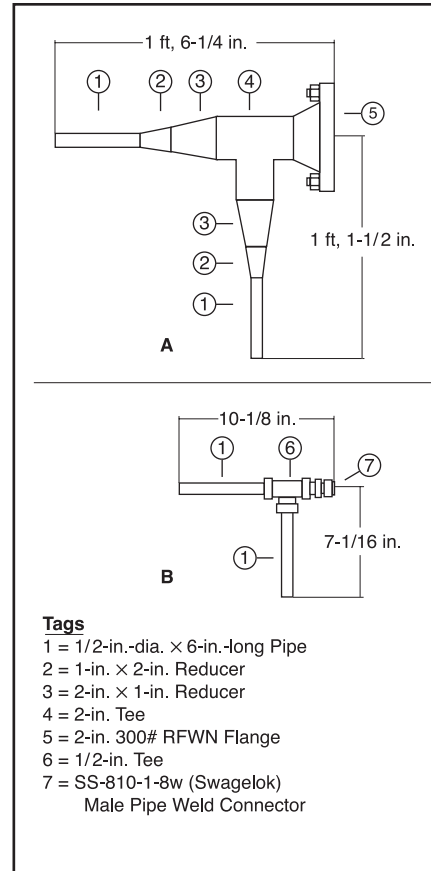
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■ Figure 1. Relaxing minimum nozzle size can reduce space, labor requirements and costs.

Figure 1B is an alternative vessel design that maintains the pipe specifications and isolation valves. The figures are drawn to the same scale, illustrating that the overall length and height of the space required for this vessel and its instruments can be reduced by 2 ft and 1-1/2 ft, respectively. This is a significant space savings for a modular pilot plant with structural skids measuring 12 ft (L) × 10 ft (W) × 10 ft (H).

If the nozzle size and isolation valve sizes are allowed to be a combination of 1 in. and 1/2-in., as shown in Figure 1B, then accessibility for operation, maintenance and/or any later modifications can be significantly improved. The savings in labor is more difficult to quantify, but considering the handling, mounting and fabrication of a lighter vessel, it is clear that the labor and schedule can also be reduced considerably. The difference in weight between the original 2-in. nozzles and the combination of 1-in. and 1/2-in. nozzles is about 44 lbs; as the shell and head weigh 110 lb, this translates into an overall vessel weight reduction of about 35%.



■ Figure 2. Thermocouple connections can often be made smaller.

threaded valves instead of 1/2-in. socket welded valves. However, this would require many exemptions to the pipe and vessel specifications.

Example 2: Smaller thermocouple connections

A specification that requires 2-in. flanged thermowells for temperature measurements may be practical for a large plant, but it is highly impractical for a pilot plant. Figure 2A shows a typical detail from big-plant specifications. Figure 2B illustrates an alternative design that consists of a 1/8-in. thermocouple inside a 1/4-in. tubing thermowell, inside 1/2-in. piping, installed using a tube-swage fitting. In this example, all components are made of carbon steel, except SS-810-8W, which is stainless steel.

The Figure 2A design requires seven welds, while the Figure 2B configuration requires only three. The table on the next page lists the components in each system. The overall material cost for the Figure 2A design is triple that of the Figure 2B design, and the labor cost is double. The temperature element and thermowell in Figure 2A weighs

The total savings in material cost is about \$3,115 (vessel \$383, valves \$2,157, instruments \$575) [all in U.S. dollars]. This particular project has over 20 vessels where this recommendation can be applied, which means a total savings of over \$62,300. In addition, weeks can be trimmed from the project schedule simply by relaxing just this one specification.

Additional savings can be realized by using 1/2-in. threaded couplings for instrument connections and

Table. Components required for two thermocouple systems.

| Item | Description | Quantity on Figure 2A | Quantity on Figure 2B |
|------|---|-----------------------|-----------------------|
| 2 | 1-in. × 1/2-in. reducer | 2 | 0 |
| 3 | 2-in. × 1-in. reducer | 2 | 0 |
| 4 | 2-in. Tee | 1 | 0 |
| 5 | 2-in. 300# RFWN flange | 1 | 0 |
| 6 | 1/2-in. Tee | 0 | 1 |
| 7 | SS-810-8W | 0 | 1 |
| 8 | 2-in., 300# flanged thermowell + thermocouple | 1 | 0 |
| 9 | 1/4-in. thermowell with thermocouple | 0 | 1 |

14 lb, while the one in Figure 2B weighs 2 lb, which leads to an estimated saving of \$400 per TE/TW combination. A pilot plant with 50 TE/TWs would realize a savings of \$20,000, not including the benefits of saving space and handling of a lighter instrument.

Example 3: Material certifications

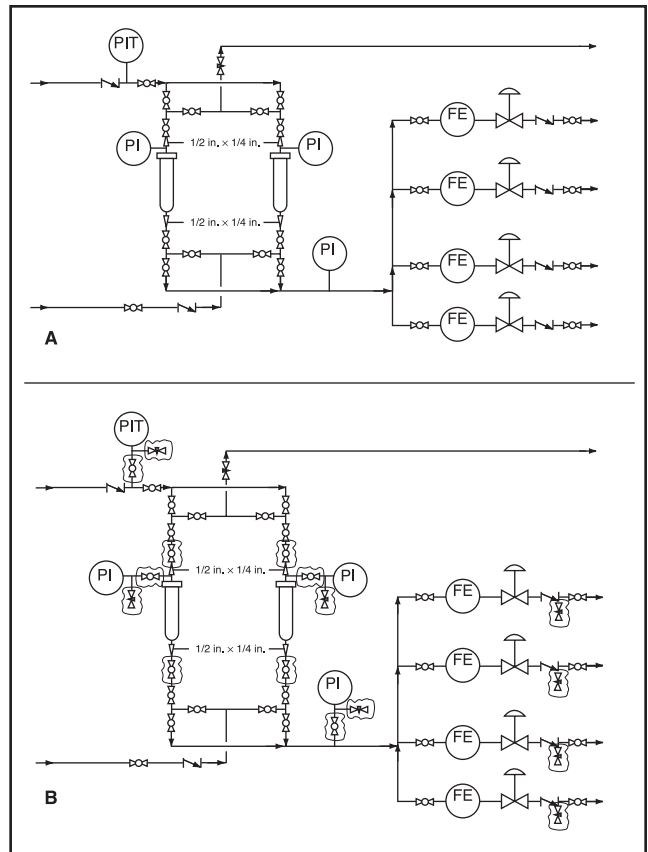
This pilot plant (which had an intended life of 2 yr) was to be constructed for installation within a refinery. The R&D group did not negotiate with the refinery group for clearance to allow pilot plant specifications to apply, so the pilot plant was designed and constructed to refinery specifications.

The large-plant specifications required 100% positive material identification (PMI) on all fittings, welds and equipment. This project was on a very tight schedule (approximately 8 wk for construction), and the 100%-PMI specification added 2 wk to the schedule and \$10,000 to the budget.

An alternative would have been to accept material test certifications (mill certification) for all items, institute quality control procedures on the incoming materials, and perform 10% PMI on these items.

Example 4: Operating mode and life cycle considerations

What is the life cycle and operating mode of your pilot plant? Is it necessary or even allowable to continue operation during maintenance and/or replacement of instrumentation or equipment, or will a shutdown be required? When a shutdown is required, block-and-bleed valves on instruments and double-block valves and bypasses around control valves are typically installed in a full-size plant. But in a pilot plant, these will add unnecessary cost and complexity without adding value. It is extremely important to remember that every item added increases the cost of fabrication and testing, procurement and engineering



■ Figure 3. Operating mode and life cycle considerations.

specification/selection labor. Hence, the elimination of unnecessary components can result in significant reductions in the cost and improved delivery and start-up time for a pilot plant.

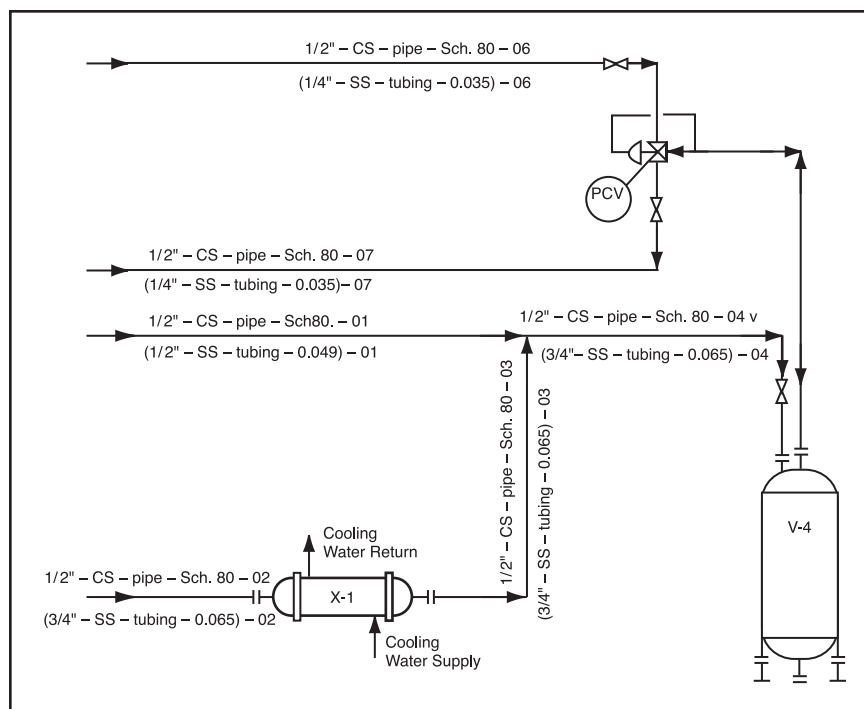
The plant in this example is not intended for operation 24/7 and the lines are tubing between 1/2-in. and 1/4-in. With block-and-bleed valves and isolation valves on pressure gauges, the valve count is 44. Twenty of these, costing \$2,000 and requiring close to double the labor for fabrication, could be eliminated, as shown by the revision clouds in Figure 3B.

The project had 23 P&IDs that were far more complex. Including block-and-bleed and isolation valves would double the total number of valves as well as the labor, significantly increase the space required, and lengthen the schedule by 12.5%.

Example 5: Tubing instead of piping

Who is operating the plant? Do you need to design a pilot plant so that operators can stand on nozzles or piping? If the answer is yes, then this must be addressed during the design of the plant.

In many cases, tubing can be a viable alternative to pip-



■ Figure 4. Tubing may be a viable alternative to piping.

ing. If tubing can provide an adequate flow area, significant savings on design, procurement, labor and installation costs can be realized.

Figure 4 is a portion of a P&ID for a tank and a shell-and-tube heat exchanger. The design flowrate for Line 01 is 275 lb/h, the fluid density (ρ) is 61.7 lb/ft³ and viscosity (μ) is 0.5 cP. If 1/2-in. Sch. 80 pipe is used, the pressure drop would be 0.3 psi/100 ft, while in 1/2-in., 0.049-in.-wall-thickness tubing, $\Delta P = 1.3$ psi/100 ft. In Line 02, ΔP in 1/2-in. Sch 80 pipe would be 0.03 psi/100 ft, while the tubing $\Delta P = 1.1$ psi/100 ft. The sizing criterion for Line 05 is that the tank needs to be emptied every 8 h, *i.e.*, 375 gal in 30 min; this cannot be done in tubing and requires 1-1/2-in. Sch. 80 pipe. In all, six of seven lines (Lines 01, 02, 03, 04, 06 and 07) can be constructed out of tubing instead of welded pipe, eliminating the need to generate eight isometrics and perform pipe stress analysis. The material cost for the piping is double the tubing cost, and the tubing does not require elaborate pipe supports. The labor for welded pipe is triple that for tubing. The overall savings for the design and fabrication and the reduced schedule for these six lines is estimated at approximately \$5,000. Additional savings on instrumentation are also possible.

It is worth noting that there is greater flexibility with tubing, as it is much easier to make modifications, add equipment or instruments, and perform repairs and maintenance.

Example 6: Tubing material

The common plant specification that requires stainless steel tubing to be used for instrument air lines does not make sense for a pilot plant.

This pilot plant has approximately 50 control valves, 40 solenoid valves and 32 air regulators. In stainless steel, they cost \$3,100, versus \$500 in brass. The labor for stainless steel is three times that for brass, since brass tubing is much easier to work with. In addition, control valves come as a standard vendor product with brass fittings, which would have to be removed and replaced with stainless steel ones.

Some facilities have allowed plastic tubing for air lines in pilot plants. During the HAZOP analysis, it was determined that a fire would cause the plastic air-line tubing to melt, thus assuring the fail position of the valves.

Recommendations

These examples are just a few simple specifications that can have significant impacts on a pilot plant's costs, space requirements and schedule. The following conclusions can be drawn from these examples:

1. Keep it simple.
2. Keep in focus the intended operation and life of the pilot or demonstration plant.
3. Review large-plant specifications at the beginning and decide whether they are applicable for the pilot or demonstration plant.
4. Take advantage of the expertise of others.
5. Allow for creativity in design and approach. CEP

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