

## Scale Up, Small-scale Feasibility Studies, Tests and Testing

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### Introduction

The small scale is easy to design and operate. Design and process limitations are not apparent and are not recognized. The large scale is much more difficult. Limitations become obvious and significant. Inability to scale up shows. Failure of pilot plant studies shows and failure to commercialize happens.

Procedures are the backbone of any process, yet frequently the process itself can be improved upon. The entire process may require consideration, or one component of the process can be altered to improve the whole. In the case where one component is selected to be improved, many times it is helpful to use a small-scale feasibility study to demonstrate the proof of the principle of the improvement. This can be done relatively inexpensively and can serve as evidence that a scaled-up test would be beneficial.

Frequently the design and process procedures can be improved. Design is changed by retrofits. Many times, small-scale studies with some testing are useful. Such studies can be done inexpensively and can serve as evidence that a scaled-up test would be beneficial.

### Process Development Tests and Product Development Tests

There are the regular process development and product development tests. They are usually directed at obtaining data, debugging and modifications of the process or product. They may result in process and equipment redesign and retrofits. Such tests relieve the plant from testing and permits experienced development personnel to work on problems.

These tests may go by many different names.

- Scoping Study
- Feasibility
- One and Two Point Investigations
- Proof of Principle
- Optimization
- Confirmation of Information

### The name describes the test

Optimum sloppiness is a rapid comparison of options to quickly eliminate inefficient options. It is a very good general approach and should always be considered. After all, you really do not want to study inefficiencies.

Scoping studies is a wise choice. These are also small quick studies to accomplish verification. Scoping studies can be expanded to feasibility studies to see if "things" actually work. Flow visualization studies and side by side design comparisons should be routine.

Before any physical testing takes place, solutions must be researched. Engineers often spend much of their time researching the task at hand. Has this problem been encountered before in the production facility,

and what were the steps taken to fix it? Did those solutions work?

Problems are never completely solved. Solutions are forgotten. Problems return. History is important and often repeats itself. As a result, the plant historian, if you have one, is very important. Hopefully a record was made about any previous attempts at a "fix" and this information is still available.

If those previous attempts did not fix the problem, perhaps they can give insight into the potential success of the current proposed solution. If no such history is available, it is certainly recommended that details of this attempted solution be preserved. Even if the current problem is fixed, something similar may arise elsewhere in the facility in the future. If no prior history exists, the vendor that originally supplied the tank may be able to provide ideas on the feasibility of the solution.

Allocca [1] illustrated an excellent example of one and two point investigations. In the study, nine different static mixers were evaluated using just two data points for each static mixer, eighteen experimental runs in all. Inefficient static mixers were eliminated from further study, leaving two static mixers to choose from.

Geometry is often the most important design variable. Unfortunately the process is forced into one piece of equipment and other equipment is not studied. Limited equipment studies limit scale up outcomes.

### Testing, Testing Equipment and Communications

#### Scaling objectives, testing suggestions and testing concerns overlap each other

Laboratory personnel should be given guidance as to what data and information are needed for scale up. Plant engineers should help select laboratory equipment, more so than they are doing now. Mishaps will occur if this is not done. In one case, an engineer was asked to scale up a biological process that was done in the lab using a shaker table. The engineer subsequently quit since the environment in a shaker table was difficult to scale up.

Equipment selection should be for easy scale up. Experiments should be performed in scalable systems. Equipment used in experimentation and piloting should resemble actual plant equipment.

Communications is very important between plant, pilot plant and laboratory. It would be wise to have the laboratory and plant personnel

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eat lunch together on a regular basis.

### Poor communication example

The lab had finished an investigation into a new process they were quite satisfied with themselves at this point. Everyone involved in the project felt that the process could go directly to the plant, by passing scale up process. At startup, everything went well. The process control measurements indicated exactly like they were supposed to do. However, no product came out of the tank.

Upon inspection of the reactor, the operators found the product balled up on the impeller. The reactor volume was 10,000 gallons. Upon talking to the lab, the plant personnel found that this happened to the lab reactor all the time. The lab solution was to pick up the reactor and shake it.

This example points to: 1) poor communications and 2) procedures in the lab may not exist in the plant.

### Process mishaps and mistakes

Chris Columbus sailed in three ships, not one, for various reasons for this. One might have been that he figured he would lose two ships on the voyage and he would be on the third. You want to make mistakes. The learning curve is much steeper for a mistake than that of success. Costs of mistakes in pilot plant studies are low. Costs of mistakes in commercial units are high. You should make the big mistakes in pilot studies. Don't make big mistakes in plant. Remember you can learn from your mistakes.

Different successes do not really matter all that much when that one failure shuts down your plant. Chris Columbus would hardly be known if he drowned during his first voyage across the Atlantic.

### Examples of simple tests or "Go or No Go" tests

Often it is useful to develop simple tests to help in processing. These are "Go or No Go." The following serve as examples of such tests.

- Capillary Suction Test in Filtration
- Plugging tests of a Bingham Plastic for Yield Point
- Plate Glass Foam Test

The Capillary Suction Test uses a test tube filled with material to be filtered. This test tube is inverted on blotting paper. The liquid filtrate soaks in the paper to form a liquid front. Filtration difficulty is determined by timing this moisture front as it moves.

Yield point can be estimated by plugging a tube to material. The yield point can be determined by pressurizing one end of the tube. As the material begins to move, the pressure is recorded and the yield point determined from a force balance.

A foam meter can be constructed using two glass plates separated by a gap. Liquid is placed between the plate and gas is bubbled up from below the liquid. The foam characteristics can then be studied.

### Testing example

Cosmetics companies develop lotions all the time in large batch tanks. Due to the viscosity of the product, significant air entrainment occurs. Unfortunately, the aerated material cannot be bottled with such high air concentration. As a result, a significant amount of time is required for the air to leave that tank. Time (days) is added to the procedure to allow the air to leave the lotion.

The process needs review. Obviously, if the lotion was made in such a way that air was prevented from entraining in the lotion, then the time for the air to leave the lotion can be removed from the procedure, e.g., days could be removed from the procedure.

One potential design solution is to have a floating surface baffle on top of the liquid. This reduces the amount of air entraining into the product, reducing the wait time for bottling.

A quick test was set up for this paper to see if a surface baffle could reduce air entrainment. The results are shown in Figures 1 and 2. Figure 1 shows an agitated tank with water without a surface baffle. A significant amount of air entrainment occurs. Figure 2 shows the same conditions with a surface baffle and substantially less air entrainment. The fluid was water at room temperature. The diameter of the tank was about 1 foot with 4 wall baffles.

The decision to add a surface baffle is not that simple as this test. More testing, designs and changes in procedures will be needed. Cleaning of surface baffles would also have to be addressed. Processing in a completing filled tank may also minimize air entrainment.

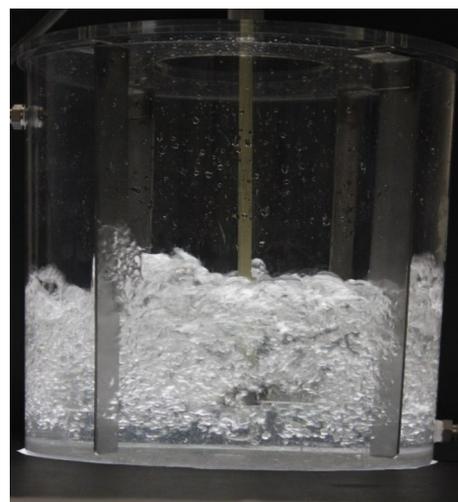


Figure 1: Significant Air Entrainment without Surface Baffles.

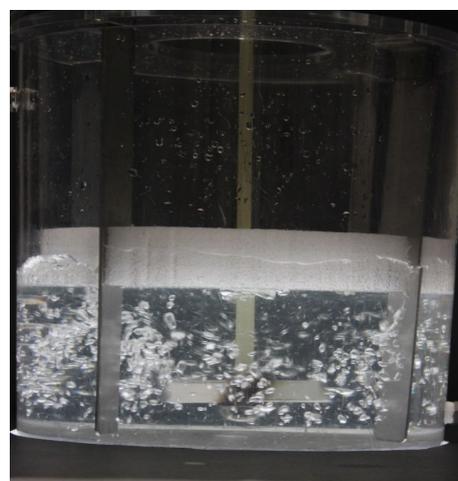


Figure 2: Surface Baffles with Significantly surface baffles.

This test was a simple “proof of principle”, “feasibility test” or “scoping study” using a side-by-side comparison of two different designs.

### **Testing at the small scale and/or large scale**

Pilot plants testing at the small scale is fine. However, full scale tests on existing equipment are recommended. The full scale is the right size where no scaling involved. However, large scale testing is inflexible, has a limited range and costly.

Some testing can only be done at the large scale. Testing for fouling at the plant scale and in the plant environment can only be done at the large scale since fouling is likely not scalable.

Testing by vendors is possible and should be included. Full scale tests should be done with plant personnel that are familiar with the current unit, its operation, its advantages, and its downsides. Full scale tests can also be done without disruption to production.

### **Optimizations**

Optimization comes next. Just as some processes are not scalable, some optimizations are not scalable. Many optimizations can only be accomplished on the large scale.

### **Reference**

1. Allocca P (1980) The Variation Coefficient as a Function of Length for Various Static Mixer Elements. 73rd AIChE Annual Meeting, Nov 1980.