STATISTICAL DESIGN OF EXPERIMENTS FOR QUALITY IMPROVEMENT OF FERTILIZER PRODUCTS

Mark J. Anderson (Consulting Engineer, Stat-Ease Corp., 612-378-9449, mark@statease.com)
P. K. Bhattacharjee (Chief Engineer, U. S. Agrichemical Corp.),
Patrick J. Whitcomb (Consulting Engineer, Stat-Ease Corp.))

ABSTRACT

Statistical tools, especially design of experiments (DOE), provide the means for quality improvement of DiAmmonium Phosphate (DAP) and related fertilizer products. Depletion of high-grade phosphate ores in Florida and elsewhere makes it increasingly difficult to meet customer specifications for nitrogen content of DAP. Urea or ammonia can be used as nitrogen supplements, but this adds cost to the final product. This paper lays out a special form of DOE, called two-level factorial design, which can be used to maximize nitrogen content in DAP, and make it less susceptible to impurities in lower-grade phosphates.

PROBLEMS OF THE PROCESS ENGINEER

Here's a list of typical problems we face as process engineers, particularly those of us who work in a mature chemical line:

- Raw material costs are increasing and/or quality is decreasing
- Competitors are cutting product prices
- Profit margins are declining

To solve these problems, we need to get together and identify causes for poor yields quality. An exhaustive list might include dozens of potential variables - many more than we could possibly investigate. Some of these variables can't be controlled: we can at least record their values. Other variables won't be given much priority: we should try to hold these at fixed levels. Still, we're likely to be left with many possible control factors, more than we can deal with one at a time. These can most efficiently be investigated via design of experiments (DOE).

The basics of DOE are well-documented (1). To illustrate the application of DOE to chemical engineering, we will look at phosphate fertilizer production. The case study shows how we can make breakthrough improvements with a simple DOE called two-level factorial design. By restricting the tests to only two levels, we minimize the number of experiments, yet the contrast between levels gives us the necessary driving force for process improvement. Fortunately, software makes it easy to set up and analyze two-level DOEs (2,3). However, like any powerful tool, the more we know about DOE, the better we'll do, so it pays to learn what we can about the statistical aspects.

CASE STUDY

Phosphate fertilizer is produced by combining phosphoric acid with ammonia in a slurry reactor. The end product is DiAmmonium phosphate (DAP) in granular form. Customers desire nitrogen contents of 18 per cent or better, but this can be difficult to achieve in the presence of raw material impurities, especially calcium, iron, aluminum and magnesium. The latter three contaminants are