chemical week

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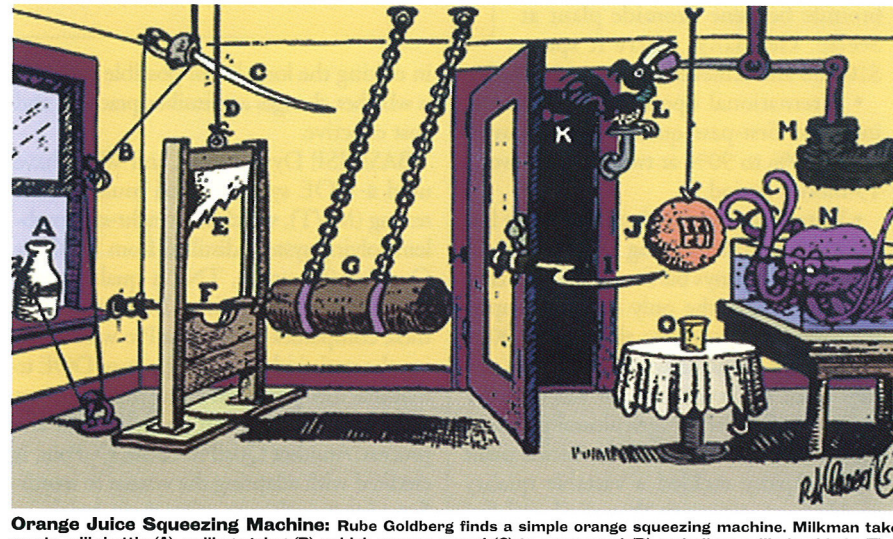
Rapid Adjustment

Statistical Attack on Manufacturing

DOES SPIKE (K) NECESSARILY HAVE to stab "prune hawk" (L) to drop the diver's boot (M) onto a sleeping octopus (N)? What if we reduce the number of sharp metal objects (C,E,I,K), shorten the chain on the battering ram (G), and use a younger octopus (N)? What efficiencies would we discover by making minor changes to these key variables and eliminating unnecessary steps?

Cartoonist Rube Goldberg, whose "inventions" lampooned the industrial age tendency to overcomplication, might have applauded that line of questioning. These days chemical companies interested in achieving significant savings in manufacturing processes with minimal capital investment are asking the same kinds of questions. A statistical exercise called design of experiment (DOE), developed at about the time Goldberg's cartoons gained fame in the 1920s, has taken hold in manufacturing quality regimes in recent years. DOE, a method of identifying the most significant variables in a process and testing adaptations to these variables simultaneously, is much faster than the typical trial-and-error approach of testing process variables in isolation. It is now, thanks to personal computers, a practical tool in a manufacturing facility.

Companies working on "six sigma" quality programs—broad ranging regimes that target a defect level of 3.4 per million (*CW, Oct. 8, 1997, p. 33*)—may be incorporating DOE. AlliedSignal, a forerunner in six sigma, considers DOE "one of our most advanced tools" for reaching the goal, according to Gary Hansell, v.p./six sigma for specialty chemicals at Allied. Other companies, such as Dow, that have not declared six sigma as a goal are beginning to rely heavily on DOE. It is still perceived by many as a prohibitively complicated statistical tool, but as success stories proliferate, its use spreads. Recent successes include:



Orange Juice Squeezing Machine: Rube Goldberg finds a simple orange squeezing machine. Milkman takes empty milk bottle (A), pulling string (B), which causes sword (C) to sever cord (D) and allow guillotine blade (E) to drop and cut rope (F) which releases battering ram (G). Ram bumps against open door (H), causing it to close. Grass sickle (I) cuts a slice off end of orange (J)—at the same time spike (K) stabs "prune hawk" (L) he opens his mouth to yell in agony, thereby releasing prune and allowing diver's boot (M) to drop and step on sleeping octopus (N). Octopus awakens in a rage and, seeing diver's face which is painted on orange, attacks it and crushes it with tentacles, thereby causing all the juice in the orange to run into a glass (O). Later on you can use the log to build a log cabin where you can raise your son to be President like Abraham Lincoln.

• BASF's pigments plant in Huntington, WV has eliminated grit in finished product by adding a temperature control system, adjusting pH, and changing the temperature in a filtration phase. Production process success rate increased from 85% to 95%, equating to "several millions of dollars worth of sellable material." Waste disposal costs were cut by $750,000/year.

• At its Rensselaer, NY dyestuffs plant, BASF swithched from using ice in a cooling phase to using a standard heat exchanger. The successful experiment, which defied standard engineering principles, eliminated the cost of making the ice and freed up 25%-30% of the reactor space during the cooling process.

• Dyno Nobel has used DOE to reduce particulate levels in emissions at its Louisiana, MO plant. Plume opacity was reduced

from 45% to 5% shortly before state regulation went into effect that require opacity levels under 40%. The company reduced waste at a dynamite plant at Carthage, MS by improving physical characteristics of ammonium nitrate; at Port Ewen, NY it achieved a 15% scrap rate reduction in the manufacture of detonator caps. By adjusting the space between cap components and the particle size of powder explosives, Dyno says it saved "tens of thousands of dollars" in scrap and customer service costs.

• AlliedSignal has increased purity, which was already in the high 90% range, by 3% and yield by 25% at its Geismar, LA chlorine products plant. The project, which Hansell says "essentially cost us nothing," generated $18 million in savings and improved yield. It also offset a $4-million investment in larger pipes and reactors. The company achieved similar results at a 4-bromile benzene bromide plant at Seelze, Germany, where it spent $10,000 and achieved savings of $300,000.

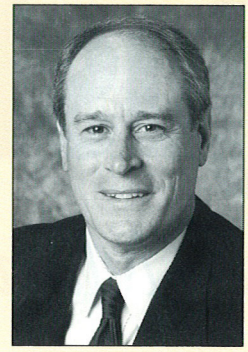
• International Specialty Products has increased first-pass quality from an average of 60% to 90% at two facilities over a 15-month period.

• Witco has saved $10 million since last September implementing DOE at various sites. The company's bill for training and consulting services, the only costs for implementing DOE, came to about $180,000.

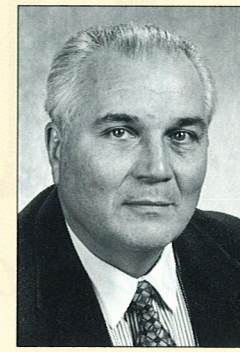
• DuPont has achieved $10 million in savings from an investment of less than $1 million at four of its agricultural products facilities. At its LaPort, IN herbicide plant the company tackled a variable quality problem on a process that produced five grades of herbicide; it now produces one high-quality grade.

In each of these cases, teams of engineers, plant operators, and business administrators compiled lists of all possible changes that might result in improvement. Using the principles of DOE, long lists were shortened and experiments were designed to test three or more key variables simultaneously. Tests were performed on-line or in a laboratory. Results prescribed system adjustments that ranged from installing process control systems to simply turning a few knobs.

BASF's pigments project is a typical example of how DOE works. Michael Hinton, manager/technology development and quality control at Huntington, says about 30 people worked on the project. The group identified 93 process variables that could be changed and whittled the list down to 32. Of these, 23 were used in multiple variations in 24 test batches. The final experiment tested seven variables in eight batch runs. Ultimately, the adjustments to the system keyed on temperature, the order of introduction of raw materials, and heat-up rates. According to Hinton, the principal criteria in editing the long list of possible variables is whether changes are feasible, practical, and cost effective.



Hansell: An advanced tool.



Mueller: Prepare for resistance.

BASF, ISP, Dyno Nobel, and Witco have used a DOE system called multivariable testing (MVT), which is an eight-step problem-solving system distilled from DOE by QualPro (Knoxville, TN), a quality management consulting firm. Management at these companies credit QualPro with catering the statistical analysis aspects of DOE to manufacturing in such a way that engineers and plant workers can participate in the process. Another QualPro client, DuPont, is credited with adapting the system to manufacturing as well as to research analysis.

"DuPont is a discovery and a manufacturing company, and this technique plays strong in both fields," say Timothy Read, senior consultant at DuPont's quality management technology (QMT) center. QMT developed the concept of DOE and introduced it within DuPont in 1965. It has since consulted other companies on its use. According to Read, DOE is useful "throughout the product life cycle." DuPont applies it in product and process development, plant startup, and process improvement and control. It has hired QualPro to consult on the last because of MVT's focus on manufacturing, Read says.

"Sometimes the reaction I get to DOE in manufacturing is that it takes a large block of production time," says Patrick Meehan, manager/QMT. He says testing one variable to achieve a quick fix is more appealing to the "production mentality." However, he says, investing the time in a DOE process usually results in a better long-term correction to a system. DOE's analytical process produces information about the system that cannot be attained intuitively, Meehan adds. Joel Wommack, director of global operations for DuPont Agricultural Products, agrees. "You get subtle effects [through DOE] that you might not otherwise have appreciated."

At AlliedSignal, which has developed its own methods for DOE, experiments are sometimes run in laboratories without interrupting the manufacturing process. Plant engineers and operators collect information on the system, relaying it to laboratory engineers who run multivariable experiments. Plans for system adjustments, based on the results of the laboratory tests, are delivered to the on-site operators. Hansell says the teamwork necessary to do the job has been fostered by its six sigma work, which has saved Allied $1.5 billion companywide.

Andrew Mueller, executive v.p./operations at ISP, says it is wrong to play down the difficulty in getting plant staff and engineers to go along with DOE. "It's hard to get the plant people to cooperate" because of the likelihood that processes will be interrupted or changed, he says. Engineers are usually resistant to any challenges to the conventional engineering methods upon which their PhDs are based. DOE, "when used properly, breaks down myths and destroys paradigms," which accounts for the difficulty some companies have in pursuing it, says Mueller.

Art Hammer, CEO of QualPro, says other companies have held off on DOE because of failure in past attempts to apply statistical analysis to manufacturing design.

Sources agree that manufacturers need to make better use of statistics. According to Meehan, university education in the U.S. does not prepare engineers for statistical work. The gap adds to the training needed to implement DOE, which Meehan says is comparable only to safety training. Most larger companies, however, have been working on team building for manufacturing management for years. Hansell says the six sigma program at Allied will bring the organization up to speed on DOE training by next year. By then everyone in the company is expected to be a "green belt" in six-sigma, which borrows its merit system from the martial arts. —RICK MULLIN