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ABOUT STAT-EASE® SOFTWARE, TRAINING, AND CONSULTING FOR DOE
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Mark's Alka-Seltzer® Experiment

I conducted this exercise with help from my daughter Katie. To demonstrate an experiment on mixtures (and because it's fun!), we blew up a plastic film canister—not just once, but over a dozen times. The explosive power was fueled by Alka-Seltzer®—an amalgam of citric acid, sodium bicarbonate (baking soda) and aspirin.

You can see the experimental apparatus pictured in Figure 1. It includes a launching tube, a container with water, the tablets, a plastic film canister (Fuji's works best), a scale, and a stopwatch.

Fig. 1: Apparatus for film-canister rocketry

My research on the internet produced many write-ups on making Alka-Seltzer "rockets." These generally recommend using only a quarter of one tablet and they advocate experimentation on the amount of water, starting by filling the canister half way. However, I quickly discovered that the tablets break apart very easily, so I found it most convenient and least variable to simply put in a whole tablet every time (a constant). It then took a steady hand to quickly snap on the top of the canister, over which Katie placed the launching tube and I prepared to press my stopwatch. After some seconds the explosion occurred, propelling the lid from the back porch to nearly the height of the roof on my two-story home. Subsequent research on this experiment indicated it would have been far less nerve-wracking to

We blew up a plastic film canister—not just once, but over a dozen times.

stick the tablet on the lid with chewing gum, put water in the container, snap on the lid, and then tip it over—shooting the canister into the air.

Before designing this experiment, I did some range finding to discover that only 4 cubic centimeters (cc) of water in the 34-cc canister would produce a very satisfactory explosion. However, it would not do to fill the container completely because the Alka-Seltzer effervesced too quickly, preventing secure placement of the lid.

After some further fiddling, I discov-

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Workshop Schedule

Experiment Design Made Easy

November 3-4, 2009: Minneapolis, MN
February 9-10, 2010: Minneapolis, MN
March 23-24, 2010: Marlborough, MA

Study the practical aspects of design of experiments (DOE). Learn about simple, but powerful, two-level factorial designs. $1295 ($1095 each, 3 or more)

Response Surface Methods for Process Optimization

December 1-2, 2009: Minneapolis, MN

Maximize profitability by discovering optimal process settings via RSM. $1295 ($1095 each, 3 or more)

Mixture Design for Optimal Formulations

October 27-28, 2009: Minneapolis, MN
March 2-3, 2010: Minneapolis, MN

Find the ideal recipes for your mixtures with high-powered statistical tools. $1295 ($1095 each, 3 or more)

DOE for DFSS: Variation by Design

November 17–18, 2009: Minneapolis, MN

Use DOE to create products and processes robust to varying conditions, and tolerance analysis to ensure your specifications are met. A must for Design for Six Sigma (DFSS). $1495 ($1195 each, 3 or more)

Designed Experiments for Life Sciences

November 10-11, 2009: Cambridge, MA
February 23-24, 2010: Minneapolis, MN

Learn how to apply DOE to Life Science problems. $1495 ($1195 each, 3 or more)

European DOE User Conference

Spring 2010: Stay tuned for more info!

PreDOE: Basic Statistics for Experimenters (Web-Based)

PreDOE is an entry-level course for those who need to go back to the basics. See *http://www.statease.com/clas_pre.html* for more information. $95

Attendance is limited to 16. Contact Elicia at 612.746.2038 or workshops@statease.com.

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Blend #	Run	Type	A: Water (cc)	B: Air (cc)	Flight time (Sec.)
1	2	Vertex	4	30	1.88
2	6	Vertex	4	30	1.87
3	4	AxialCB	8	26	1.75
4	3	Center	12	22	1.60
5	8	Center	12	22	1.72
6	5	AxialCB	16	18	1.75
7	1	Vertex	20	14	1.47
8	7	Vertex	20	14	1.53

Table 1: Results from film-canister rocket experiment

ered that a reasonable maximum of water would be 20 cc's—more than half full. I then set up a two-component mixture design that provided the extreme vertices (4 to 20 cc of water), the centroid (12 cc), and axial check blends at 8 and 16 cc's. I replicated the vertices and centroid to provide measures of pure error for testing lack of fit.

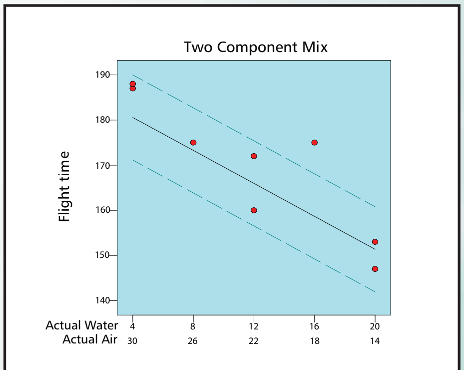

Fig. 2: Two-component mixture response plot

Just for fun, I asked several master's-level engineers, albeit not rocket scientists, but plenty smart, what they predicted. The majority guessed it would make no difference how much water—given a minimum to wet the tablet and not so full as to prevent the top snapping on. This became the null hypothesis for statistical testing—assume no effect due to changing the mix of air and water in the film canister.

Table 1 shows the results of flight time in seconds for the blends, sorted by the amount of water. Fig. 2 shows the results from a linear fit* ($p<0.01$). Now that you have seen this, do you agree with these engineers that this component makes no difference?

HEADS UP! DO NOT PICK A PRANKSTER AS YOUR ASSISTANT ROCKET SCIENTIST.

Those of you who are fans of Gary Larsen's Far Side series of cartoons may recall a classic scenario depicting a white-coated scientist putting the last nail on the nosecone of a big rocket. In the background you see his assistant sneaking up with an inflated paper bag—poised to pop it! Mark's rocketry assistant Katie discovered that enough fizz remained in the canister to precipitate a second blow up. On randomly chosen runs she would sneak up on her father while he recorded the first round's results and blast away. The only saving grace for Mark was the ready availability of Alka-Seltzer for the ensuing headache.

—Mark Anderson, mark@statease.com

*Scheffé mixture model

BLASTING OFF FROM TUCSON, ARIZONA

Fig. 3: Mighty seltzer rocket

After touring the Titan Missile Museum south of Tucson, Arizona, Mark found the toy pictured in Fig. 3 in their gift shop. This product, made by a local inventor (CSC Toys LLC), improves the aerodynamics of the seltzer-powered rocket by the addition of a nose cone and fins.

Like these film canister rockets, the thrust of the Titan missile depended on two components, albeit many orders of magnitude more powerful—a precisely controlled combination of nitrogen tetroxide (oxidizer) and hydrazine (fuel) that spontaneously ignited upon contact. This extreme exothermic chemical behavior is characterized as "hypergolic." The fuels were stable only at 58-62 degrees (F), which means that temperature control was critical.

In 1980 a worker dropped a 9-pound socket from his wrench down a silo and punctured the fuel tank. Fortunately the 8,000-pound nuclear warhead, more destructive than all the bombs exploded in all of World War II, landed harmlessly several hundred feet away. Some years later the Titans were replaced with MX "Peacekeeper" rockets that used solid fuel.

Over-Selection of Effects on the Half-Normal Plot

One of the greatest statistical tools pioneered by Cuthbert Daniel (1976) was his use of the half-normal plot to visually select effects for two-level factorials. Since these designs generally contain no replicates, there is no pure error to use as a base for statistical F-tests. The half-normal plot allows us to visually distinguish between the effects that are small (and normally distributed) versus large (and likely to be statistically significant). The subsequent ANOVA is built on this decision to split the effects into the likely "signal" versus the likely "noise." Often the split between the groups is obvious, with a clear gap between them (see Fig. 1), but sometimes it is more ambiguous and harder to decide where to "draw the line" (see Fig. 2).

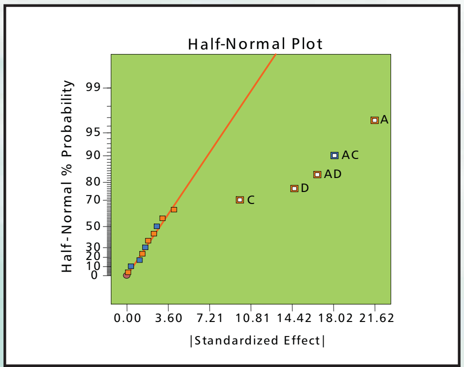

Fig. 1: A, AC, AD, D, and C stand out

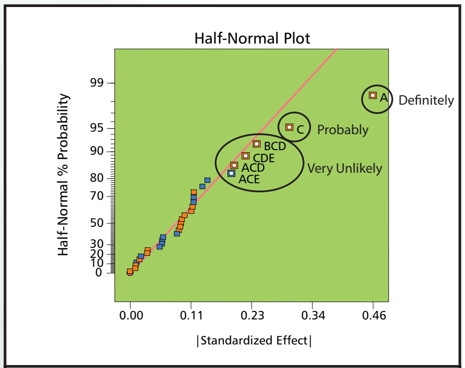

Fig. 2: Only A and C stand out

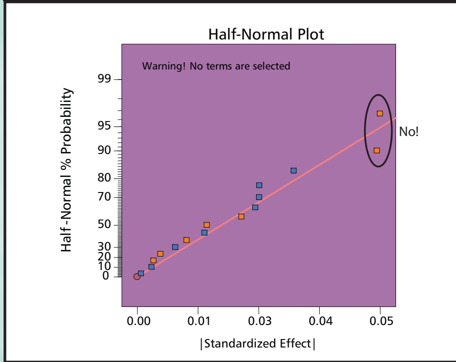

Fig. 3: Terms have the same size effect

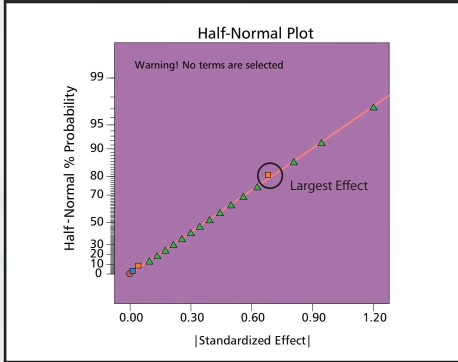

Fig. 4: Green triangles show pure error

Stat-Ease consultants recommend staying conservative when deciding which effects to call the "signal," and to be cautious about over-selecting effects. In Fig. 2, the A effect is clearly different from the other effects and should definitely be selected. The C effect is also separated from the other effects by a "gap" and is probably different, so it should also be included in the potential model terms. The next grouping consists of four three-factor interactions (3FI's). Extreme caution should be exercised here—3FI terms are very rare in most production and research settings. Also, they are "on the line," which indicates that they are likely within the normal probability curve that contains the insignificant effects. The conservative approach says that choosing A and C for the model is the best shot. Adding any other terms is most likely just chasing noise.

Hints for choosing effects:

•Split the effects into two groups—the "big" and "small" effects

•Start from the right side of the graph—where the biggest effects fall

•Look for gaps that separate big effects from the rest of the group

•STOP if you select a 3FI term—these are very unlikely to be real effects (throw them back into the noise pool)

•Don't skip a term—if a smaller effect looks like it could be significant, then all larger effects must also be included

•Effects need to "jump off" the line to be distinquishable from normal distribution.

Sometimes you have to simply accept that the changes in the factor levels did not trigger a change in the response that was larger than the normal process variation (Fig. 3). (This is actually the ideal result when the purpose of the experiment is to verify the ruggedness of a process!) Note in Fig. 3 that the far right points are straddling the straight line. These terms have virtually the same size effect. Don't select the lower one just because it is below the line.

When you are lucky enough to have replicates, the pure error is then used to help position green triangles on the half-normal plot. The triangles span the amount of error in the system and if they go out farther than the biggest effect, it is a clear indication that there are no effects that are larger than the normal process variation. No effects are significant in this case (see Fig. 4).

The half-normal plot of effects gives us a visual tool to split our effects into two groups. However, the use of the tool is a bit of an art, rather than an exact science. Combine this visual tool with both the ANOVA p-values and most importantly, your own subject matter knowledge, to determine which effects you want to put into the final prediction model.
—Shari Kraber, shari@statease.com

A Dynamic New Approach to DOE Workshops

Stat-Ease has a 25-year history of hosting premier-quality workshops on design of experiments (DOE). In the early days, workshops lasted four days. They were filled with calculations that students worked by hand in order to gain a solid grasp of fundamental concepts such as Yate's algorithm, switching between coded and actual units, etc. Being away from work and attending class was almost like a mini-vacation. You could escape the daily grind and sprinkle in a little evening relaxation!

As we all know, times have changed. In our fast-paced modern world, technology advances at an incredible rate and the amount of information available for absorption is staggering. Corporate downsizing means that you may have more duties to perform in the same amount of time. Now when you leave the office to attend class it is no longer a mini-vacation. The line between work and personal life has blurred. Blackberrys and wireless laptop connections keep you in constant contact with the office, IF you can get permission to leave at all! Evenings tend to be spent with e-mail instead of at the local baseball game.

> ***"All of the examples were great and the instructors were interactive and entertaining."***
> **—Bioassay Development Associate**

This Spring, in recognition of our changing world, Stat-Ease launched the Designed Experiments for Life Sciences (DELS) workshop—a quick TWO-DAY overview of all the DOE topics (factorials, response surfaces, and mixtures). We received an overwhelmingly positive response to both the length of the class and the content.

We listened, and as a result we are transforming all of our classes into two days of high-quality DOE content. We still shy away from making these "software" classes. Our vision remains to provide you with a solid education in design of experiments tools.

You, our tech-saavy students, now arrive in class with strong computer skills. This allows us to proceed through a variety of examples, each illustrating new DOE concepts, at a faster pace than before. Our superb instructors remain available to answer your questions, and every class is backed-up with Stat-Ease's commitment to ongoing design-building help and statistical support that workshop students can access for free. Check out the updated workshop schedule and rates on the front page of this newsletter. You'll also find them online at http://www.statease.com/clas_pub.html. We hope to see you in class soon!

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