Design-Expert® 7 is released—see page 3!

stat teaser

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Struggle for Power vs. Resolution vs. Simplicity in an ASTM Standard

While teaching an in-house Experiment Design Made Easy workshop some years ago in Connecticut, the company's quality control manager gave me a copy of the ASTM (American Society for Testing and Materials) Standard E1169 for Ruggedness Testing. It specified a resolution III two-level factorial design with seven factors in eight runs, which confounds main effects (ME) with two-factor interactions (2FI).

That is OK because one assumes that the system being tested will indeed be rugged, that is, it will not be significantly affected by any of the factors applied to it. However, what the QC guy questioned was the E1169 protocol that the Resolution III design be fully replicated for a total of 16 runs. This makes sense from the perspective of keeping it simple statistically (KISS) by making it easy to calculate variability from the pooled standard deviations of replicate runs.

> "Everything should be made as simple as possible, but not one bit simpler."
> Albert Einstein

Also, it's obvious that doubling the runs increases the power of the ruggedness test for detecting a given effect. On the other hand, by doing a whole new set of eight runs with opposite levels, called a "foldover," the Resolution improves to IV. Thus, one can have power and resolution also, like having your cake and eating it too.

About one year ago, I happened to see

Mark's Experiment

an announcement in ASTM's Standardization News that they would be convening a meeting to review their E1169 standard. I e-mailed ASTM about how they could improve their protocol of ruggedness testing and the next thing I knew I was on the committee for revising it! (Lesson learned — n ever suggest improvements unless one is prepared to help implement them.) It's been interesting to meet via the internet every few weeks using ASTM's set-up with Microsoft Live Meeting, for which I was elected as host.

I have been very impressed with the dedication of all the committee members, but particularly the chairperson, Stan Shulman of the National Institute for Occupational Safety and Health (NIOSH) and Neil Ullman, a fellow of ASTM and a past chairman of their Committee E11 on Quality and Statistics.

At a DOE seminar sponsored by the University of Wisconsin a decade ago, I heard George Box say that "Running a resolution III design is like kicking your television to make it work." However, I suppose that for purposes of ruggedness testing it makes sense to not only kick the TV, but also throw things at it and generally heap as much abuse as you think the exterior and insides will withstand under the normal condi-

—*Continued on page 2.*

—*Continued from page 1.*

tions of a family household. The beauty of a two-level factorial design is that it specifies combinations of factors that really put a system to the test.

For example, consider this case study that I searched out on the internet and passed along to Neil, who then talked the experimenter, Jeff Simpson of NDC Nitinol Devices & Components (a Johnson & Johnson company), into joining our E1169 committee. (To see a fascinating web portal, check out www.nitinol.com, where you can learn more about nitinol materials.) Jeff followed ASTM E1169 to the letter by replicating a 7-factor in 8-run Plackett-Burman design over two blocks.* (I will make no attempt to describe the application; suffice it to say that ideally none of the factors tested should change the response significantly and/or enough to be important as a practical matter.)

What I found interesting is that after the first block, nothing stood out as being significant as shown in the half-normal plot of effects pictured in Figure 1. (Note: All figures come from version 7 of Design-Expert® software. To produce Figure 1, I went to the design layout, highlighted the second block of runs, and set row status to ignore.)

After the second block it became clear from Figures 2a and 2b that the anneal temperature does change significantly as a result of the factors tested, thus failing the test for ruggedness (assuming the observed effects are of practical importance).

Although effect F looks to be a bit off the line of near-zero effects interlaced with error estimates from replicated runs, it may be non-significant as evidenced by where its bar falls on the Pareto chart below the Bonferroni limit (a conservative, multiple pairwise test).

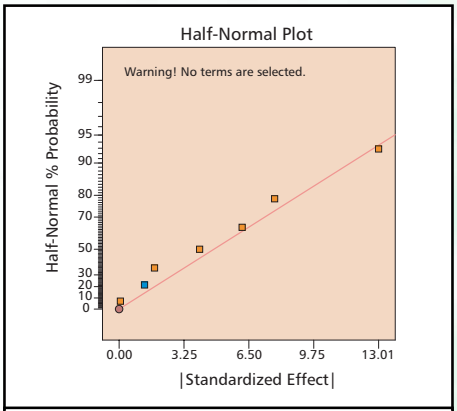


Figure 1: Half-normal plot of effects from block 1 of nitinol ruggedness test

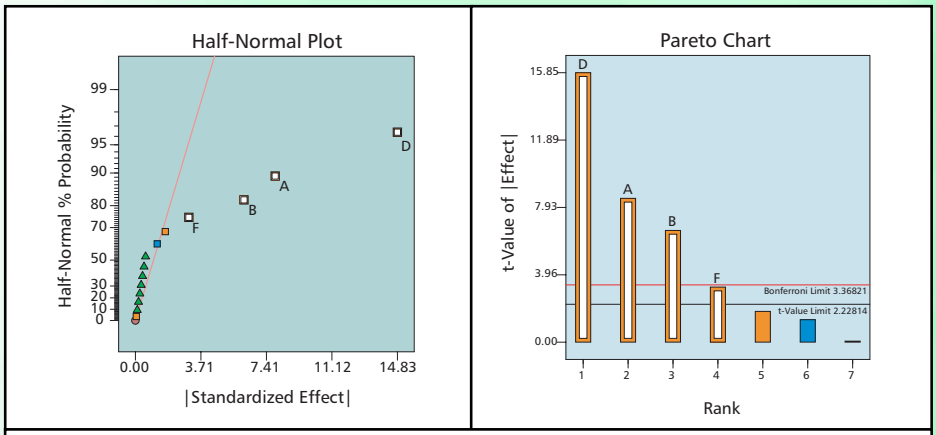
Nonetheless, there's no denying the effect of factor D and likely A and B as well. However, keep in mind that by replicating this Resolution III Plackett-Burman design for 7 factors in 8 runs (same would apply for the standard 2^{7-4} design), these main effects are aliased with potential two-factor interactions, which Stat-Ease® DOE software reveals in its evaluation:

[A] = A - BF - CD - EG
[B] = B - AF - CG - DE
[D] = D - AC - BE - FG
[F] = F - AB - CE - DG

For example, is the main effect of F really -AB? Or, perhaps the effect labeled as [A] could be -BF. This is why I felt compelled to get involved in revising E1169: Rather than replicating the initial block of runs, by doing a foldover the power would be preserved, with the added benefit of enhanced resolution to level IV, that is, main effects cleared of aliased 2FI's. The advantage of this alternative approach can be easily seen by simply deleting the second block of runs from Simpson's nitinol test and then via Stat-Ease software's design tools, augmenting the design by the advised method of foldover, which adds a new block with all levels opposite the first. Here are the results from the design evaluation:

[Block 1] = Block 1 - ABF - ACD - AEG - BCG - BDE - CEF - DFG
[Block 2] = Block 2 + ABF + ACD + AEG + BCG + BDE + CEF + DFG
[A] = A + BCE + BDG + CFG + DEF
[B] = B + ACE + ADG + CDF + EFG
[D] = D + ABG + AEF + BCF + CEG
[F] = F + ACG + ADE + BCD + BEG
[G] = G + ABD + ACF + BEF + CDE

With no loss in power, by folding over the original eight ruggedness test runs (rather than simply replicating them), the ruggedness tester de-aliases main effects from potential two-factor inter-



Figures 2a,b: Half-Normal and Pareto plots of effects from the entire nitinol ruggedness test

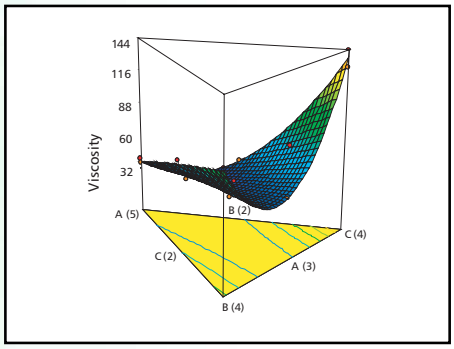
—*Continued on page 3.*

Stat-Ease® Releases Design-Expert 7!

Stat-Ease is proud to announce the release of Design-Expert® 7 (DX7). Five years in the making, this major release includes dozens of new features including design creation tools, enhanced design augmentation ability, analysis capabilities, diagnostics capabilities, updated graphics, an improved user interface, more options for design evaluation, expanded help, and new import/export tools.

Whether you already use Design-Expert software or are looking at it for the first time, we are sure you will be impressed with this new release. Try it free for 45 days by downloading the fully-functional trial version at **http://www.statease.com/soft_ftp.html**. Here are some highlights of the features you will find in Version 7:

1. *Pareto chart of effects:* Quickly see the vital few effects relative to the trivial many from two-level factorial experiments.
2. *"Min-Run Res IV" (two-level factorial) designs for 5 to 50 factors:* Use a minimum number of runs to screen main effects.
3. *"Min-Run Res V" designs for 6 to 31 factors:* Resolve two-factor interactions (2FI's) with a minimum number of runs.
4. *Two-level fractional factorials for up to 21 factors:* Accomodate more factors than ever-before possible.
5. *Full-color contour and 3D surface plots:* Graduated or banded colorization adds life to reports and presentations.
6. *New "Color By" option:* Color-code points on graphs according to the level of another factor—a great way to incorporate another piece of information into a graph.
7. *"Screen tips":* Press the new tips button for enlightenment on the current screen—this is especially helpful for novice users.
8. *3D surface plots for categorical factors:* See colored bars towering above others where effects are the greatest.
9. *On plots of effects simply draw a box around the ones you want selected for your model:* This is much easier than clicking each one with your mouse.
10. *Central composite designs (CCD's) are now available for up to 30 factors and 8 blocks:* This represents a significant expansion in RSM capability.
11. *CCD's based on Min-Run Res V fractional-factorial core:* Take advantage of a much more efficient design for larger numbers of factors.
12. *Box-Behnken designs expanded up to 21 factors:* This popular RSM previously was limited to certain numbers of factors, but that's no longer the case.
13. *Crosshairs window:* Predict your response at any place in the response surface plot.
14. *Magnification feature:* Incredible tool for expanding a mixture graph that is originally a small sliver and difficult to interpret.
15. *Mixture-in-mixture designs:* Develop sophisticated experiments for immiscible liquids or multilayer films involving separate formulations that may interact.
16. *Add blocks D-optimally:* This will be especially useful for mixture designs, which previously could not be blocked automatically.
17. *Data Points on 3D graphs:* See 'lollipops' protruding from surfaces where actual responses were collected.



18. *Row(s) in the design layout are highlighted when point(s) are selected on diagnostics:* The highlighting feature makes identification of problematic data much easier.
19. *Numerical optimization solutions are now carried over to graphical optimization and point prediction:* Explore the results of the numerical optimization on other screens.
20. *Right-click on any response cell and "ignore" it:* Previously one had to ignore an entire row in the design matrix, even though the other responses may have good data.

For more information and to see a complete list of the new features in Design-Expert, Version 7, please visit **http://www.statease.com**. To place an order, fill out the form on page 4 and mail it to us or fax it (1.612.378.2152) for faster service. You may also order online. Give DX7 a try!

—Continued from page 2.

actions. Does this not make a whole lot more sense as a strategy of experimentation? Evidently the committee for revising the E1169 Ruggedness Testing standard agreed with me, because the foldover technique will be put to ballot for a vote by the members. At the moment, some dispute remains over the value of using the half-normal plot of effects as opposed to simply relying on statistical tables, but I am hopeful that the use of graphics can be encouraged. After all, one graph is worth a thousand numbers (with apologies to Confucius).

Mark Anderson, mark@statease.com
* Data e-mailed upon request.

Place your order now for Design-Expert® 7

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