Do's & Don'ts for Screening Process Factors

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Maximizing this educational opportunity

Welcome everyone! To make the most from this webinar:

- Attendees on mute
- Chat addressed afterward
- Send further questions to mark@statease.com

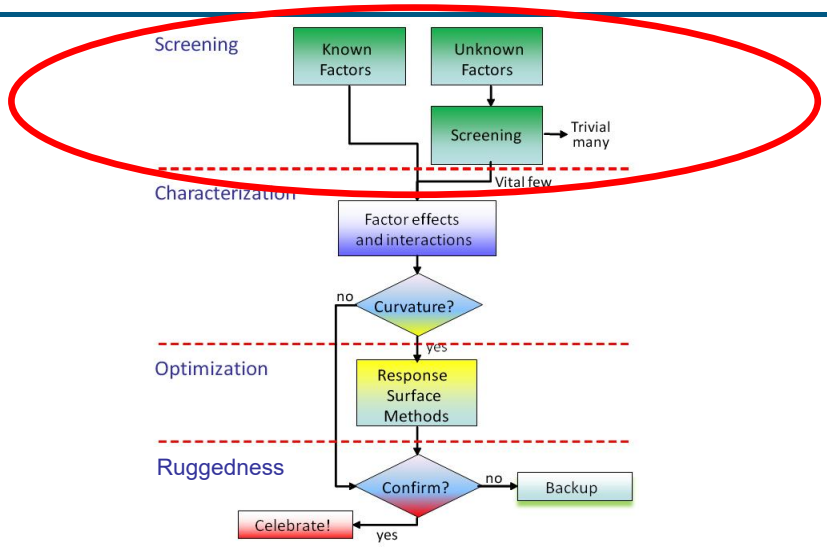
PS Presentation posted to www.statease.com/webinars/

Please press the raise-hand button if you are with me.

This Webinar: What's In It for You

- How, if done properly, design of experiments (DOE) provides huge process improvements via small screening studies. Do!
- Why low-resolution two-level designs—standard (2^{k-p}) or Plackett-Burmans (PBs)—should be avoided. Don't!
- What can be done to follow up on PBs and their like after being deployed for a quick process fix. Do *(if you must)*!
- Choosing a resolution IV design from the start to clearly reveal vital main effects. Do *(it right the first time)*!
- Enlightenment on the fine line of reliable screening at a minimum number of experimental runs.

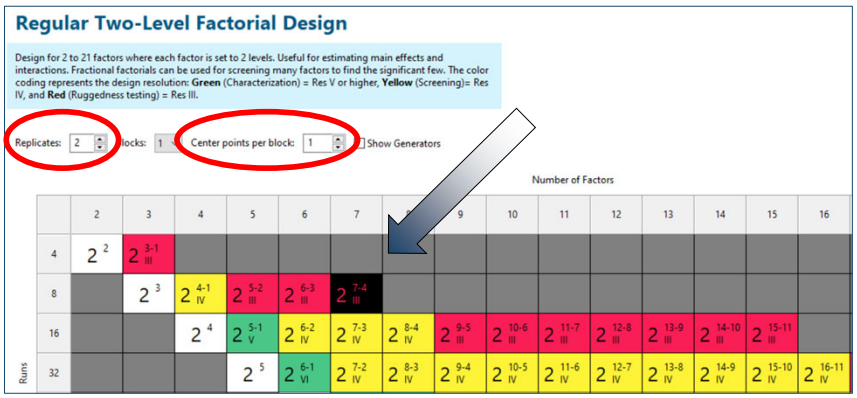
SCO strategy—tried and true



Common “don’t” for screening: Standard Res III

Compounded by replicating and adding 1 center point

Recently a pharma process developer asked me to try making sense from the results of this 2^{k-p} “screening” experiment on 7 factors (time, temp, etc.) thought to affect product yield and purity.



Advice for wayward experiment-designer *(1/2)*

Designing it right the first time

- Doing only 1 center point is not effective. Either do none (best for screening) or 4 CPs, particularly if the design is meant for characterization, that is, a res V or higher--green or white (full).
- Rather than do a res III red ruggedness design for 7 factors in 8 runs and then replicating this to 16 runs, you would have been far better off going to the unreplicated res IV yellow screening design for 7 factors in 16 runs—gaining resolution while preserving 2-rep power.

In SE360, build 1-rep design starting with 1 CP (see warning) then none.
View aliases. Check power for 3/1.8 delta/sigma.
Go back and increase reps to 2. Note same aliasing. Power increased.
Re-do with 1-rep for 16-run yellow Res IV. Better aliasing. Power good too.

Advice to wayward experiment-designer *(2/2)*
How to salvage the design for intended screening

- To get a far clearer idea of which factors (and possibly interactions) affect your reaction, add (to current res III) a block of foldover runs via Design Tools, Augment Design. This builds res to IV. ☺

Rebuild original 2-rep design with 1 CP.
Do complete foldover and view aliases.
View design in std order. See 'mirroring' of levels.
PS Delete dups in 2nd block and view aliases—still good!

- If in any doubt, ask for StatHelp before doing your next DOE. But go ahead and ask afterward if botched. We will be gentle. ;)
- Organize a Modern DOE workshop for you and your colleagues. Then you will know better!

Another "don't" for screening: Plackett-Burman
Compounded by replicating and adding 1 center point

Plackett-Burmans (PBs), being run in multiples of 4 provide more options than the regular (standard) two-level designs. PBs work well for ruggedness testing per my 2021 webinar*—my favorite being the 12-run design that can handle up to 11 factors.

NIST's "Engineering Statistics Handbook" recommends that PBs be *"used for screening experiments because… main effects are, in general, heavily confounded with two-factor interactions."* In other words, these are Res III designs! Even so, searching "Plackett-Burman" and "screening" brings up hundreds of thousands of hits. However (as I will demonstrate):

If any factors interact, PB designs do not serve well for screening.

*View at www.statease.com/webinars/doe-for-ruggedness-testing/

**See www.itl.nist.gov/div898/handbook/pri/section3/pri335.htm

The problem with Plackett-Burmans: Interactions 'smearing' out on main effects

Stat-Ease software provides 2^{k-p} gap-filling PBs for 12 to 48 runs. These designs feature partial aliasing of main effects (MEs) with two-factor interactions (2FIs). For example (as you will see), in the 12-run design, every ME gets aliased by plus-or-minus one-third of 45 2FIs. Thus, when one or more 2FIs create a large effect, they get misapplied to multiple main effects or completely lost by being 'smeared out'.

For example, let's see what would happen by redoing a full two-level factorial from Montgomery's *Design and Analysis of Experiments* as a Plackett-Burman design (using the same model and standard deviation to simulate the results).

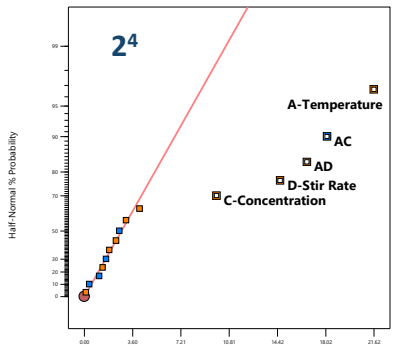
Open Tutorial Data "Filtration Rate". Show design. Fit model.
Open a second SE360 Do same for "Filtration Rate PB". Compare.

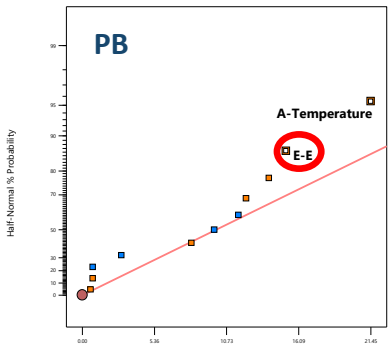
The problem with Plackett-Burmans: Interactions 'smearing' out on main effects

The model (coded) from the 16-run full factorial (2^4) is:

Filtration rate = 70.1 + 10.8A + 4.9C + 7.3D − 9.1AC + 8.3AD

The 12-run PB founders on the 'dummy' factor **E** (= −0.333AC+0.333AD).
It barely IDs factor A (p=0.045) if at all. *This is a fail for screening.*





Folding over a PB to increase its Res to IV

This botched screening situation can be salvaged by adding a second block of 12 runs, bringing the total to 24 runs. In this case, it seems to work, but keep in mind that, though MEs now come clear, the subset of 2FI's that get estimated will each be partially aliased with 36 other 2FIs. Thus, another block of runs is needed to nail down the 2FIs.

Fold over "Filtration Rate PB" and simulate results for the 2nd block.
Right click and open the sim to show how it got created.
Then view the effects compared to the 16-run full factorial.
Finish up with Evaluation, Ignoring 4FIs, of aliasing for 2FIs.

Resolution IV designs for screening (Do!)

To clearly reveal vital main effects with no troublesome aliasing by 2FIs (full or partial), select (in order of my preference):

- Res IV regular two-level (yellow) or
- Mini-Run Screen (9 factors or more, for sure) or
- Definitive screening design (if you hope to achieve a short-cut to optimization by running 3 levels of each factor).

Case study for screening 6 factors
Spin coater: Description*

Process engineers at a "fab" must gain better control over the photoresist thickness to bare silicon wafers by their spin coaters. They start by screening 6 factors in a 16 run resolution IV design:

A. Spin speed, 6650 to 7350 rpm
B. Acceleration rate, 5 to 20 rpm/sec
C. Volume of resist, 3 to 5 cc
D. Spin time, 6 to 14 sec
E. Resist supplier, Vendor A or B
F. Exhaust pressure, Cover off or on

As we will see, this experiment uncovered some interactions that then got resolved via an 8-run semifold.

*Adapted from problem 8.26 of Montgomery's *Design and Analysis of Experiments*

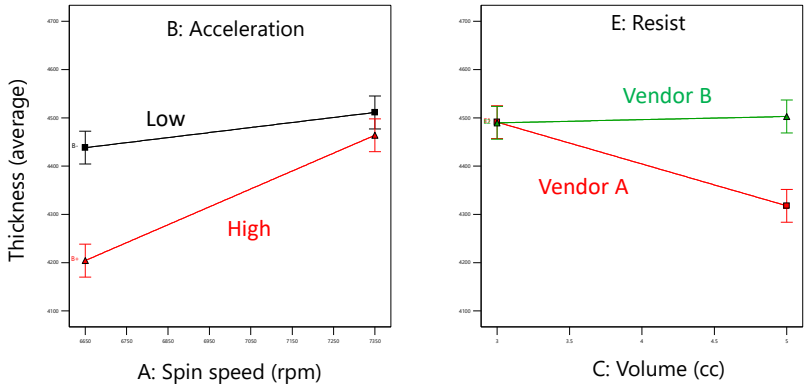
Case study for screening 6 factors
Spin coater: Analysis

As you will see, this screening design (well done at resolution IV) reveals not only main effects, but an interaction. But be careful, Stat-Ease software arbitrarily labels aliased effects with the one at the smallest degree coming first in alphabetical order. Although the numerical coefficient remains the same for aliased 2FIs, they create quite different interaction patterns due to being tilted by their differing parents.

Open "Thickness", rebuild it, reopen, model with default for interaction: AB.
Set up a second model and change the interaction to its alias: CE.
Compare the two interactions.
Display the coded model.
Note differing MEs.

Case study for screening 6 factors
Spin coater: Aliased 2FIs (AB left = CE right)

Either interaction seems possible to the engineers, and both include active parent factors (main effects). This can be resolved via a semifoldover (*a full foldover will not work and waste runs*).



Case study for screening 6 factors
Spin coater: Semifoldover

Show what happens with complete foldover—no improvement in resolution. Then do semifold per original EDME slides—half the runs and success for resolving the 2FIs. Right click on CE to see that it's now aliased only with 3FIs. It's not AB! Copy out the interaction plot.

- Spin coater (thickness) 16-run screen (must re-create from semifolded file) to start
- Show what happens with complete foldover—no improvement
- Do the semifold and then open the file with responses.

Foldover Options (copy from EDME 6-6 ppt)

Conclusions

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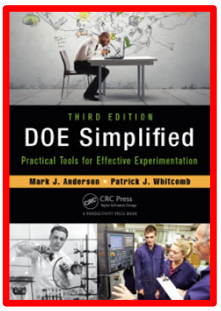
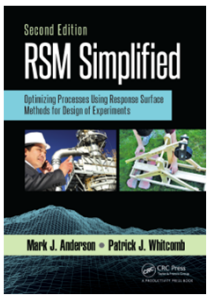
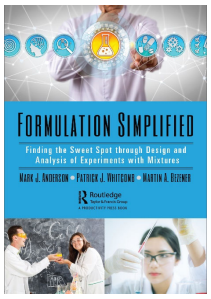
Mission accomplished?

References
*DOE/RSM/Formulation Simplified Series**







**Anderson, et al, Taylor & Francis, Productivity Press, New York, NY.*

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