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How to Detect and Overcome BAD Data

Graphical 'tricks of the trade' to salvage outstanding results from real-life experiments

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Maximizing this educational opportunity

Welcome everyone! To make the most from this webinar:

- Attendees on mute
- Chat discussed afterwards as time allows
- Address 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.

Frequently Asked Question

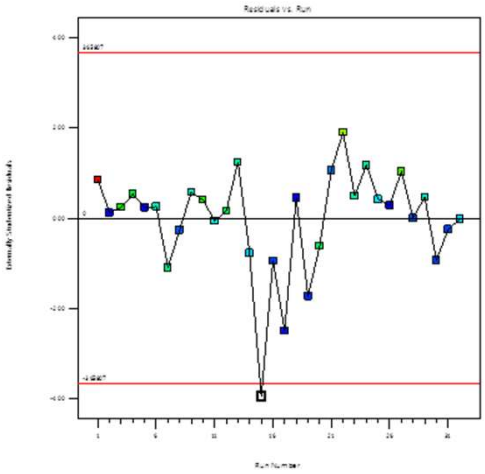
Sent: Wednesday, October 21, 2020 8:38 AM

Hello Mark,

Could I please have your opinion on this (I am a beginner on DOE). I have an outlier in my model, in this scenario, what would someone do.

Is the model still valid.

Thanks for your help



1. Thorny issues (stuff happens)
2. False outlier alarm—Type I error *(bearing life)*
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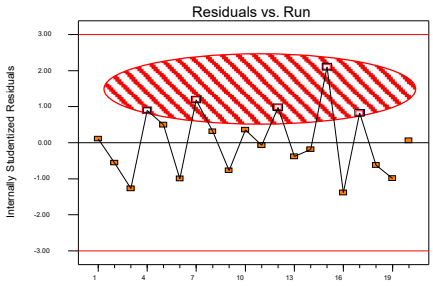
4. Conclusion

Thorny Issues! *(1 of 2)*

How to maintain reasonable balance between two types of errors:

1. Focusing on data that vary only due to common causes, thus introducing bias. (False Positive.)

   Examples:
   + cold fusion [keeping only the highs],
   *– Pig's Eye treatment [keeping only the lows].**

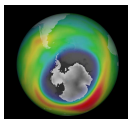


*Source:
James J. Anderson
—Mark's father.

Thorny Issues! *(2 of 2)*

How to maintain reasonable balance between two types of errors (continued):

2. Overlooking true (special cause) outlier(s) (False Negative.) Thus:
   - Obscuring real effects (*case later*) or
   - Drawing false conclusions and/or
   - Losing chance in future to:
     - ✓ Prevent failure (*ex. ozone hole**) or
     - ✓ Reproduce breakthrough improvements ('Eurekas' such as 3M Postit Notes®).



**"When the first measurements were taken the drop in ozone levels in the stratosphere was so dramatic that at first the scientists thought their instruments were faulty."*
www.theozonehole.com/ozoneholehistory.htm

"Stuff" Happens!

- Typographical erors (*Tip: type data from top, proof from bottom*)
- Breakdowns in equipment
- Mistakes by operators
  "Mark, Regarding the odd result: We had an accident in the lab and one of the techs caught on fire." –Myra (software user)
- Non-representative samples
- Bad measurements
- Unknown lurking variables that appear only intermittently

Has "stuff" like this ever happened to you?

Two Types of Error

"Stuff" does not always happen! (Only sometimes.)

Outlier(s)?		What you think:	
		"No"	***"Yes"***
Truth:	***No***	OK☺	Type I Error *False Alarm*
	Yes	Type II Error *Failure to detect*	OK☺

Let's look at two case studies illustrating the two error types.

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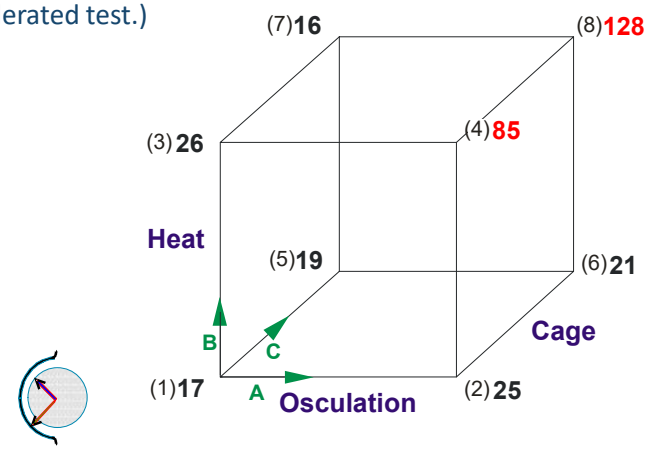
Box's Bearing-Life Case

Box's protégé makes bearing **breakthrough** that saves his company from bankruptcy, but is it too good to be true? (Results in hours from accelerated test.)

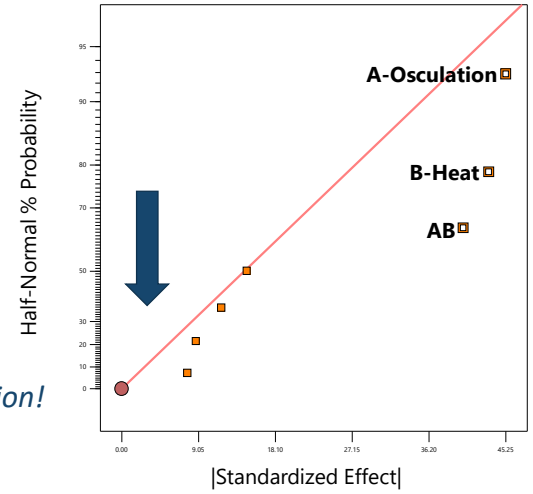


First Sign of Trouble

Half-Normal Plot Misaligned

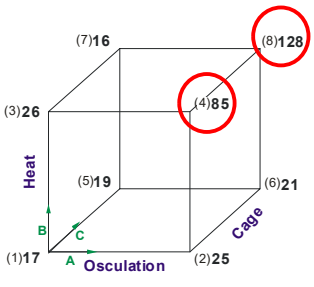
Near-zero effects do not align to the origin.

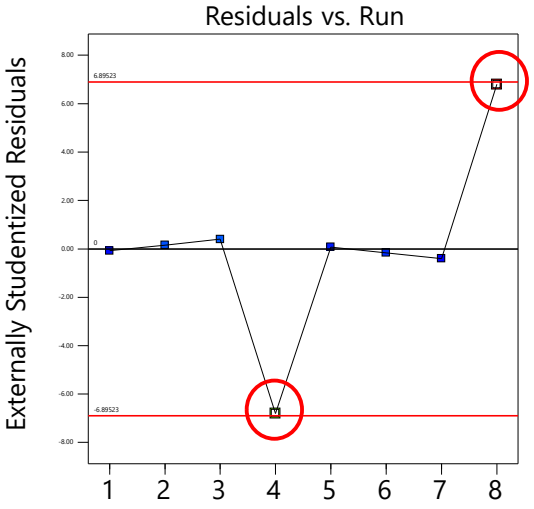
Proceed with caution!



Apparent Outliers on Run Chart

Toss the outliers?
Note these are the two best results. Sad.



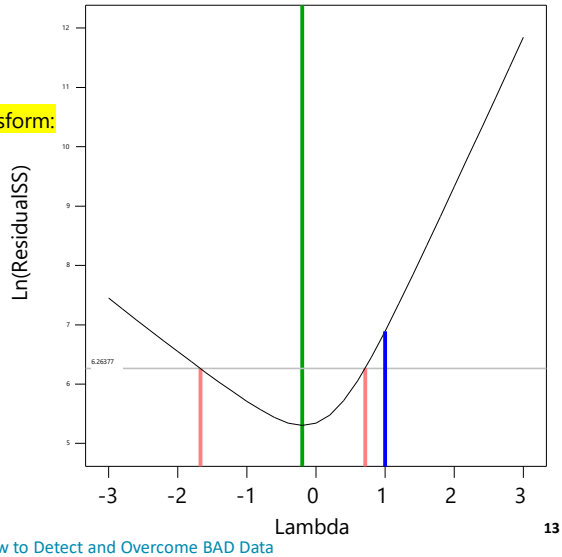


Box-Cox Plot Saves the Data!

Life

Current Lambda = 1

Recommended transform:
Log
(Lambda = 0)



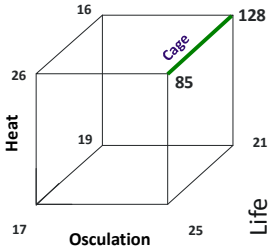
Diagnostics Reveal the Problem
False Alarm (Type 1 Error) on Outliers

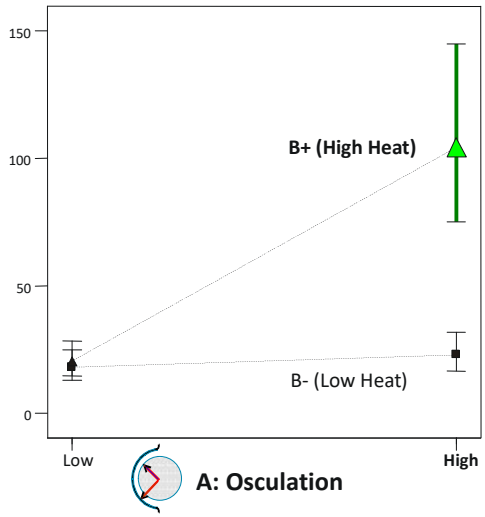
Design-Expert makes it easy to set up this experiment design, model the results and analyze them statistically—including diagnosing the residuals, which in this case proves to be of vital importance. The key comes from the Box-Cox plot, which advises re-analyzing in log scale. Let's see via show and tell how all the responses now fit (no outliers!).

Bearings

"Nature goes her own way and all that seems an exception is really according to order."
-- Goethe

Bearing Case (after log transformation): Interaction Plot (the happy ending!)





Notice how LSD bar widens at break-through life (green). Thus increase from 85 to 125 with cheaper cage may not hold. But still a big win!

*The rest of the story** DOE Saves the Company

Swedish SKF, inventors of the rolling bearing (1919), nearly went of business in the 1970's due to Japanese competition. Led by Christer Hellstrand, they abandoned one factor at a time (OFAT) for multifactor DOE. As a result, SKF improved bearing life ten-fold from 41 million to 400 million revolutions at reduced cost.**

"Christer showed them how they could test two additional factors 'for free' – without increasing the number of runs and without reducing the accuracy of their estimate of the cage effect."

-George Box, *Improving Almost Anything: Ideas and Essays*

*("Breaking the Boundaries," *Design Engineering*, Feb 2000, pp 37-38.)
**(US Patent 4227754 www.freepatentsonline.com/4227754.pdf)

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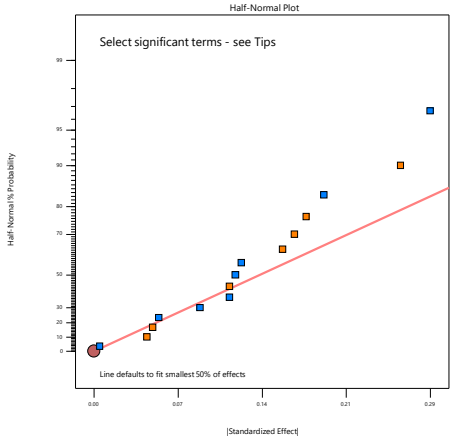
Die-Casting Dilemma

Defect rates on die-cast aluminum disk-drive housing drop ten-fold from 50% to 5%, but is it real or just chance?

Not looking good—nothing stands out, but do not give up yet. This response, being a 0 – 1 fraction, often does better being transformed.

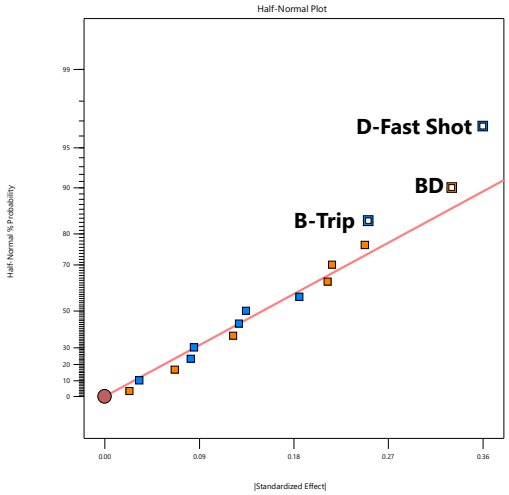
Try the appropriate transformation—the arcsine square root.



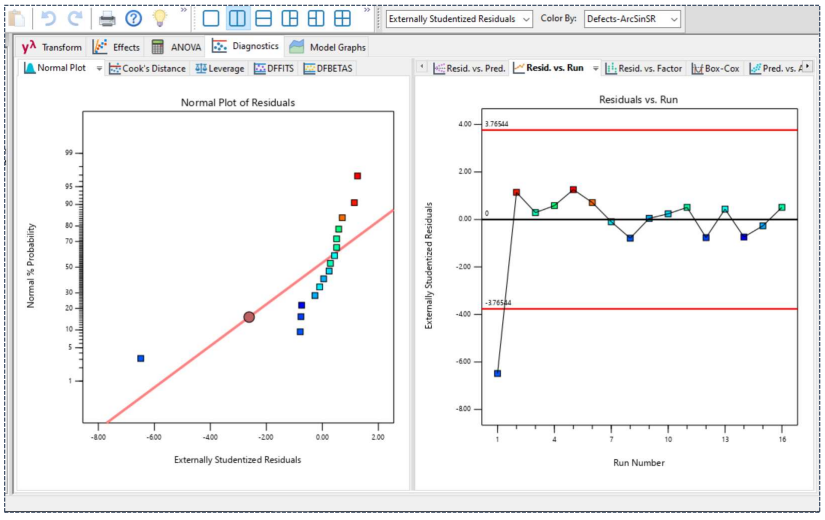
Die-Casting Case
Transformed

All effects still line up: arcsine square root no help. ☹

But don't give up yet – pick one or more of the biggest main effects and/or two-factor interactions. Then look for outliers.



Dual Diagnostic View
Outlier Revealed!



Diagnostics Reveal the Problem
Failure to detect an outlier—Type II error

The die-casting engineer, Dave DeVowe, called the foreman who confessed to overlooking run 1 until after a weekend shutdown, thus causing the result to be non-representative of the main block.

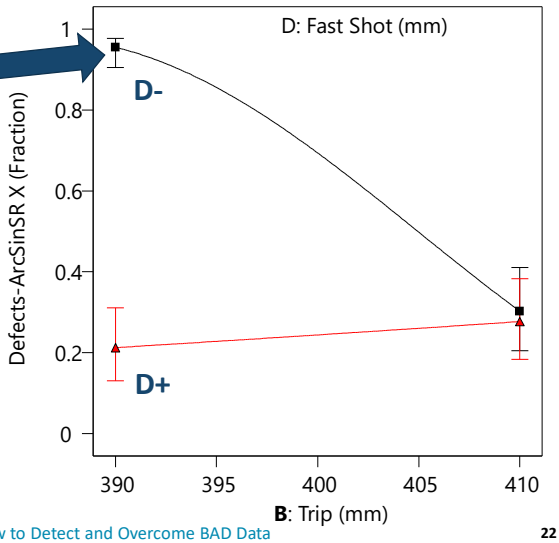
Lesson learned: Do not give up if nothing stands out on the half-normal plot, pick one or more of the biggest main effects and/or two-factor interactions. Then look for outliers.

Let's see the real picture emerge after ignoring the special-caused outliers.

Die-casting

Interaction plot (run #1 ignored)
The happy ending!

Answer now obvious: Do not run both B & D low. If possible, push lower on B and/or build up more power via replication to see if this significantly reduces defects further. For now this remains TBD.



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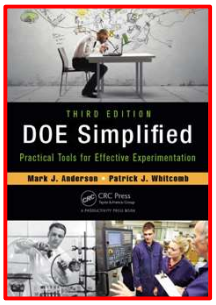
Conclusion

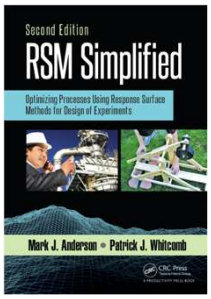
- This talk dealt with thorny issues that confront every experimenter: How to handle bad data.
- Design-Expert software provides graphical tools that make it easy to diagnose what is wrong—damaging outliers and/or a need for transformation.
- Two case studies demonstrated the value of these diagnostics, one that illustrated a Type 1 error—a false outlier alarm, and the other showing a Type 2 error—not detecting a real outlier.
- Always do diagnostics. They will save you a great deal of embarrassment by incorrect interpretation of experimental results, or the opportunity lost by letting bad data obscure a breakthrough discovery.

Reference*

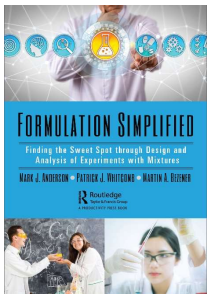
3rd edition 2015



2nd edition 2016



1st edition 2018



** Taylor & Francis/CRC/ Productivity Press New York, NY.*

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Despite BAD data!

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