

You Did What?! Surprising Experiments, Surprising Results: Entertaining and Unusual Experiments

RS-ASQ Dinner Meeting
January 16, 2008
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You Did What?! Surprising Experiments, Surprising Results: Entertaining and Unusual Experiments

- ◆ 20 years teaching experimental design at RIT, 25 years consulting on it
- ◆ Surprising ideas for experiments and a number of unusual results
- ◆ Funny, surprising, sad, lessons
- ◆ Background in experimental design - not needed here
- ◆ From beer and popcorn to fancy state-of-the-art equipment at Fortune 100 corporations (fully coded, with names changed to protect the guilty).

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Joiner Triangle



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Quality Sophistication Levels—Scientific Approach

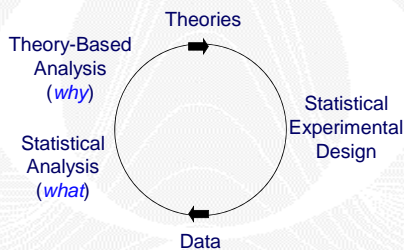
1. 100% Inspection of Product, all along the process—test and retest
2. Retrospective Observational Studies
3. Prospective Observation Studies
4. Sampling Inspection
5. Traditional SPC
6. Simple SPC Extensions
7. Simple Measurement-System Studies
8. Simple (1FAT) Experiments
9. Passive Experiments
 - ◆ Carefully planned studies on the process as is
 - ◆ ANOVA, ANOVA/SPC, Components of Variance, Multi-vari
10. Active Experiments
 - ◆ Carefully planned studies, *making intentional process changes*
 - ◆ 2^k -P, Box Behnken, Plackett-Burman, OMED, CCD, Robust Exper'n

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Basis of Experimentation



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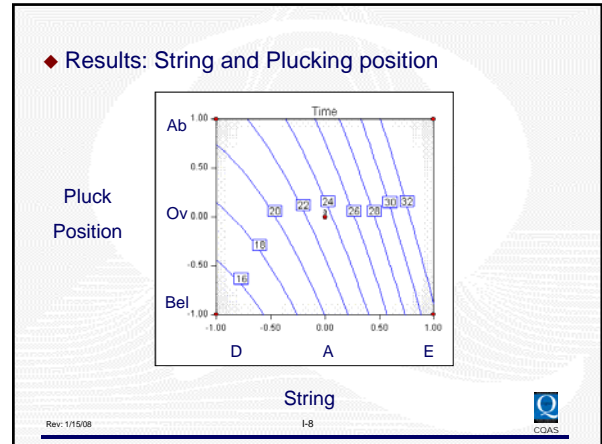
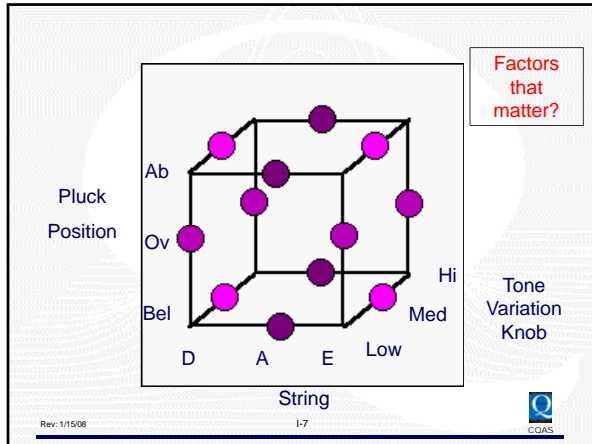
Bass Guitar (Kurt)

- ◆ Produce longest sounding note.
- ◆ Response: length of note (seconds)
- ◆ Factors
 - string plucked (D, A, E)
 - tone variation knob (high, medium, low)
 - plucking position of note (above, over, below the pick-up)
- ◆ Design
 - Randomized, blinded plucker and measurer
 - Box-Behnken, 15 runs

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Spaghetti Sauce (Tom)

Factors that matter?

◆ Background

◆ Original design: 2^{5-2}

◆ Modified design: 2^{11-7}

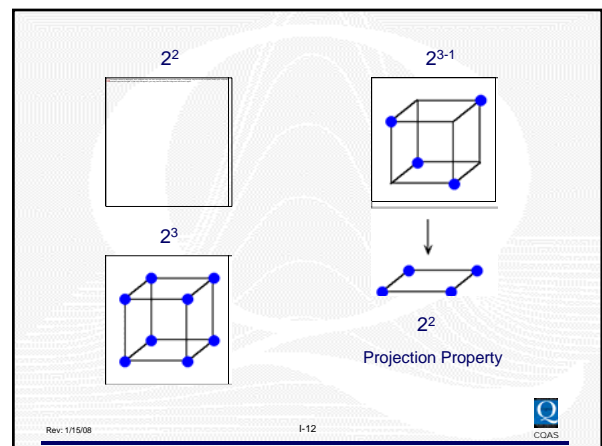
◆ Examples of factors (A, B, C, D, ...):

<ul style="list-style-type: none"> Paste/NoPaste Pork (1 lb) / no Pork Whole Tomatoes / Puree 	<ul style="list-style-type: none"> Fresh Basil / Dry Basil Bay Leaf / No Bay Leaf 4 Cloves Garlic / 2 Cloves Garlic 	<ul style="list-style-type: none"> Cook 3 hr / 2hr Browned Meat / Raw Meat
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A	B	C	D	E	F	G	H	J	K	L	Husb	Wife
+	-	-	+	+	+	+	-	-	-	-	0.00	1
+	+	-	-	+	+	+	+	-	-	-	5.50	3
-	-	+	+	+	+	+	-	-	-	-	2.00	7
-	+	+	+	+	+	+	+	-	-	-	3.50	4
+	-	+	+	+	+	+	-	-	-	-	7.75	4
+	+	+	+	+	+	+	-	-	-	-	9.50	5
-	-	+	+	+	+	+	+	-	-	-	9.25	3
-	+	+	+	+	+	+	-	-	-	-	8.00	7
-	-	-	+	+	+	+	+	-	-	-	2.00	2
-	+	-	+	+	+	+	-	-	-	-	4.00	5
+	+	-	-	+	+	+	+	-	-	-	6.00	3
+	+	+	+	-	-	+	+	-	-	-	4.00	3
-	-	-	+	+	+	+	+	-	-	-	9.25	7
-	+	+	+	+	+	+	-	-	-	-	5.50	2
+	+	+	+	+	+	+	-	-	-	-	5.50	7
+	+	+	+	+	+	+	+	+	+	+	6.00	8

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- ◆ Only one factor, D, was active!
- ◆ Clearly so only for husband!

Measurement Difficulties??

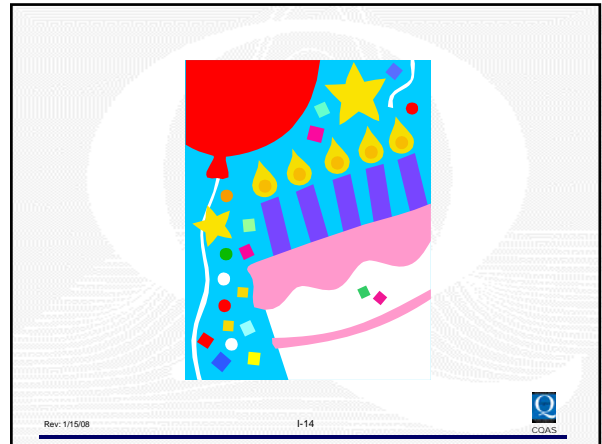
D

Wife's Scores

D

Husband's Scores

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The Best-Tasting Chocolate Chip Cookies (Jennifer & Elaine)

- ◆ Eight factors, each at two levels

<ul style="list-style-type: none"> • A Butter/Marg • B Lgt/Drk Brown Sugar • C +/- refrigerated 	<ul style="list-style-type: none"> • D +/- vanilla • E egg/egg substitute • F Jenn/Elaine oven 	<ul style="list-style-type: none"> • G white/whole wheat flour • H milk/semi-sweet chips
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- ◆ Treatment Designs??
- ◆ Use 2^{8-4} –16 batches? Use Plackett-Burman –12 batches? Example of first 3 batches:

Batch	A	B	C	D	E	F	G	H
1	+	-	-	-	+	-	+	+
2	+	+	-	-	-	+	+	-
3	-	-	+	-	+	+	+	-

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- ◆ How to measure??
- ◆ Test in pairs. All possible pairs.
- ◆ Example: if 4 batches, need to test 6 pairs (give example...)

- ◆ So either $(16\text{-choose-}2)=120$ or $(12\text{-choose-}2)=66$. Use 66
- ◆ How??
 - 1 person—66 pairs?
 - 66 people—1 pair?
 - Minimum # of pairs for one person to test all 12 cookies = 6. 66 pairs total. Possible to split up among 11 people so each person tastes all 12 cookies, and the total # test all 66 pairs? Yes!
- ◆ Analysis. Use as response (for batch X) the number of times X was preferred.

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Pairings and Preferences of 2 of the 11 people

	Person 10	Person 11
	(1 11)	(1, 12)
	(2 10)	(2 11)
	(3 7)	(3 5)
	(4 8)	(4 6)
	(5 9)	(5 4)
	(6 12)	(6 10)

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Batch#	Total
1	7
2	6
3	7
4	7
5	2
6	5
7	5
8	4
9	1
10	6
11	8
12	8

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◆ Results. Two factors are active. Which ones?

• A Butter/Marg	• D +/- vanilla	• G white/ whole wheat flour
• B Lgt/Drk Brown Sugar	• E egg/ egg substitute	• H milk/ semi-sweet chips
• C +/- refrigerated	• F Jenn/Elaine oven	

	Egg Type		Flour	
	White	Whole	White	Wheat
Whole	7, 8, 9	7, 5, 6		
Substitute	6, 7, 5	2, 4, 1		

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Brake Rotor Experiment

- ◆ Metallic pads instead of asbestos used for rotors
- ◆ Problems
 - Lots of “squealing”
 - Pulsating motion
 - Wore out faster, had to be turned more often.
- ◆ Proposed metallurgical changes to rotors.
 - Use different kind of iron, change some chemistries.
 - Reduce hardness spec tolerance by 50%.
 - Theory: these would solve problems.
- ◆ Result: high level of scrap due to tolerance change.

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9	Passive Experiments
	• Carefully planned studies on the process as is
	◆ ANOVA, ANOVA/SPC, Components of Variance, Multi-vari
10	Active Experiments
	• Carefully planned studies, making intentional process changes
	◆ 2 ⁿ , Box Behnken, Plackett-Burman, OME, CCD, Robust Exper'n

- ◆ After this, many traditional studies were done.
- ◆ Metallurgical experts conclusions made...
- ◆ Problem: required \$7M in capital, and still only a theory.
- ◆ Decided to run *Active Experiment*. Brainstorming → 2⁹⁻⁴
 - But problems here. Couldn't run many conditions.
- ◆ So, decided to run designed *Passive Experiment*.
 - 1 day/ 5 points in time / 3 consecutive molds / each 8 cavities / measure Brinell hardness at 4 sites, 90° apart.
 - 5 x 3 x 8 x 4 = 480 readings

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Time	Sample	Cavity
8:00 AM	1	1 2 3 4 5 6 7 8
	2	○ ○ ○ ○ ○ ○ ○ ○
	3	○ ○ ○ ○ ○ ○ ○ ○
10:00 AM	1	Each of these corresponds to a rotor that was made.
	2	
	3	
12:00 N	1	etc
	2	
	3	
2:00 P.M.	1	This blow-up of the rotor shows the four positions that were measured on each rotor
	2	
	3	
4:00 PM	1	○ ○ ○ ○ ○ ○ ○ ○
	2	○ ○ ○ ○ ○ ○ ○ ○
	3	○ ○ ○ ○ ○ ○ ○ ○

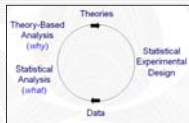
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◆ Analysis (Statistical → *Theory-Based*)

- variation within a part → *Inoculant Type*
- difference in 8 castings from same mold → *Pour Basin Size*
- When *Copper* added at lunch, or when *Sand Compactability* was high, got good results.
- **Letting the data talk to you**



- ◆ So, set up a 2⁴, to reduce hardness variation and center it.

◆ Results.

- Current conditions poor: hardness too soft, and variation high.
- Change in conditions → \$1M/year savings in scrap.

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Guns! Guns! Guns!

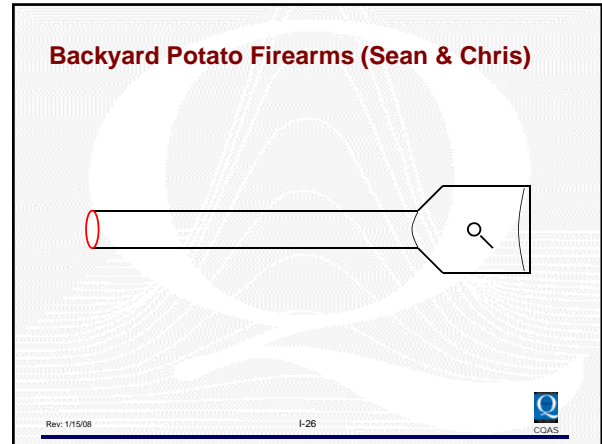
Optimal Operation of a Super-Soaker Water Gun (Alvin)

- ◆ Claim by supplier: 50 feet
- ◆ Optimal result: 20 feet!

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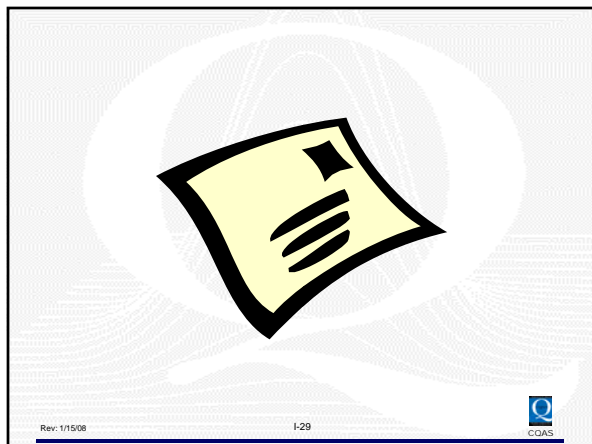
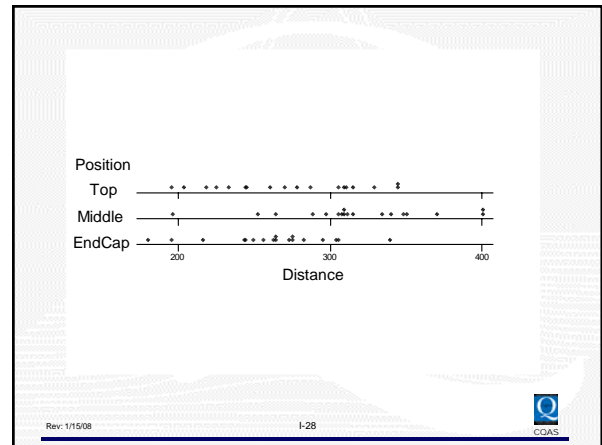


◆ Design. A 3^3 , 5 reps, CRD.

<p>◆ Sparker position</p> <ul style="list-style-type: none"> • end-cap (bottom) • middle • top (of firing chamber) 	<p>◆ Hair spray brands</p> <ul style="list-style-type: none"> • AquaNet Extra Super Hold • Style Unscented Super Hold • Rave Micro Spray Megahold 	<p>◆ Hairspray amounts</p> <ul style="list-style-type: none"> • 2 seconds • 3 seconds • 4 seconds
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◆ Reduced to 2 reps
◆ Active factors?

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Efficient Postal Mailing of Standard Business Letters (John)

- ◆ Postal Service claim: prepare letter within guidelines
- ◆ Guidelines followed throughout study except for certain factors
- ◆ Factors?
 - Label: handwritten/typed
 - Stamp type: affixed/metered
 - Zip code: included/excluded
 - Period of day: morning/afternoon
- ◆ Design 2^4 , run in 3 blocks, 1 week apart. N=48 letters mailed
- ◆ Which factors mattered?

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		Rep/Zip					
		1		3		2	
Label	Hand	No	Yes	No	Yes	No	Yes
Typed							

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		Rep/Zip					
		1		3		2	
Label	Hand	No	Yes	No	Yes	No	Yes
		6	4				
		7	7				
		6	7				
		6	4				
Typed		4	2				
		7	2				
		4	2				
		4	2				

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		Rep/Zip					
		1		3		2	
Label	Hand	No	Yes	No	Yes	No	Yes
		6	4	4	2		
		7	7	4	2		
		6	7	4	2		
		6	4	4	2		
Typed		4	2	4	2		
		7	2	6	2		
		4	2	4	2		
		4	2	4	2		

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		Rep/Zip					
		1		3		2	
Label	Hand	No	Yes	No	Yes	No	Yes
		6	4	4	2	5	5
		7	7	4	2	5	5
		6	7	4	2	5	5
		6	4	4	2	5	5
Typed		4	2	4	2	5	5
		7	2	6	2	5	5
		4	2	4	2	5	5
		4	2	4	2	5	5

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Felting Knitted or Woven Fabric (Nancy)

- ◆ Felting—process of
 - treating a knitted or woven fabric
 - under conditions of moisture, heat, and agitation
 - so the fibers interlock

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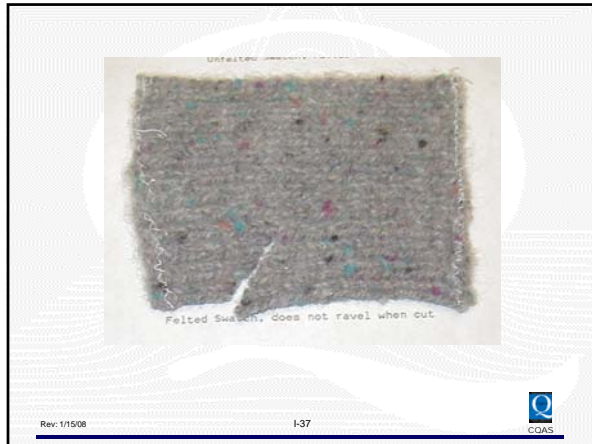
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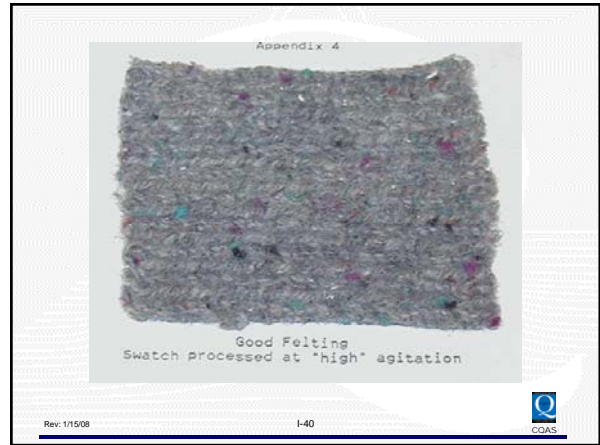


- ◆ Idea. Enhance desirable attributes of original fiber while producing a dense, yet workable material.
- ◆ Here 100% wool used. Idea—enhance water repellency and warmth. Also, want it not to ravel when cut—ideal for sewing
- ◆ Knot swatches, then treat in a 2⁴

◆Knitting tension	◆Agitation	◆Wash time	◆Wash temp
•Low	•Gentle	•6 min	•Warm
•High	•Regular	•12 min	•Hot

Factors that matter?

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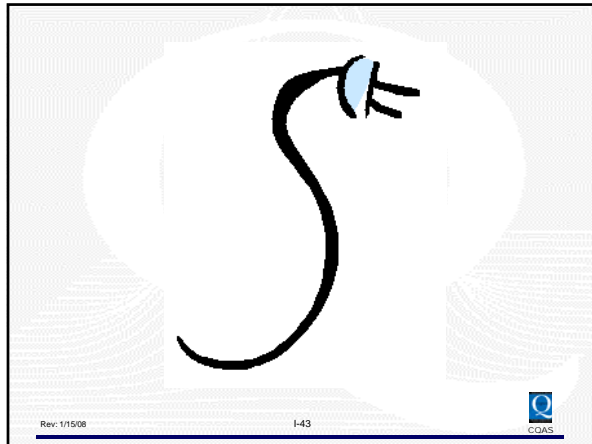
Luminescent Properties of Pickles (Jan)

- ◆ Objective. Find how to yield the brightest pickle
- ◆ Factors?

Brand	Flavor	Salinity	Temperature	Moistness
• Vlasic	• Polish Dill	• Standard	• Refrig	• Soak
• Tops	• Kosher Dill	• Reduced	• Room	• Leave out overnight

- ◆ Design. 2⁵⁻¹, CRD.

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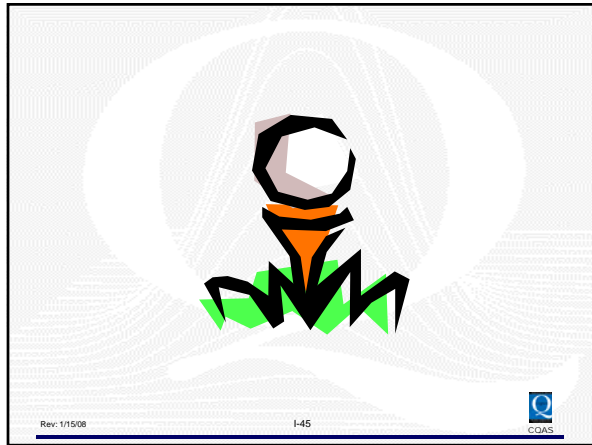


- ◆ Connect each sample to a 120V outlet
- ◆ Measure intensity with a photometer, subtracting out ambient light
- ◆ Results
- ◆ Factors can vary intensity from about 0.25 to 5.00 footcndl $\times 10^{-2}$

Salinity

Moist

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Justification for a New Set of Golf Clubs (Joe)

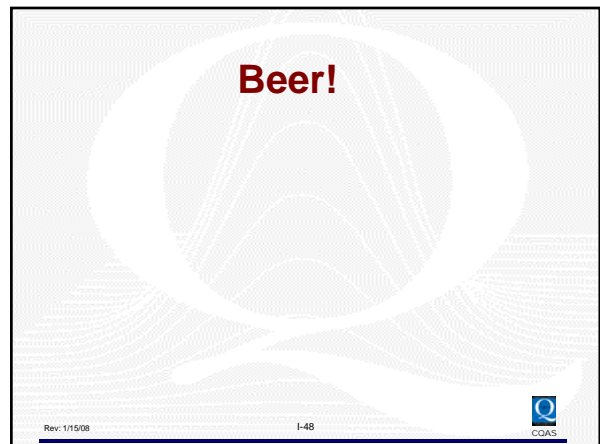
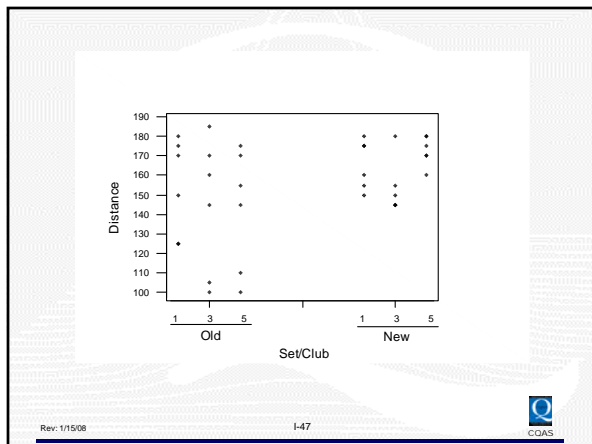
- ◆ Factors?

Set • 1-Old • 2-New	Club • 1-Wood • 3-Wood • 5-Wood	Swing Group • 1-6 When swings were done	Order • 1-6 Order of two treatment factors within swing group
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- ◆ Treatment design (Set x Club) 2 x 3. Error control is Latin Square

Swing	Order					
	1	2	3	4	5	6
1	1/3	2/5	1/1	1/5	2/1	2/3
2	1/1	1/5	2/1	2/3	1/3	2/5
3	1/5	2/1	2/3	1/3	2/5	1/1
4	2/5	1/1	1/5	2/1	2/3	1/3
5	2/1	2/3	1/3	2/5	1/1	1/5
6	2/3	1/3	2/5	1/1	1/5	2/1

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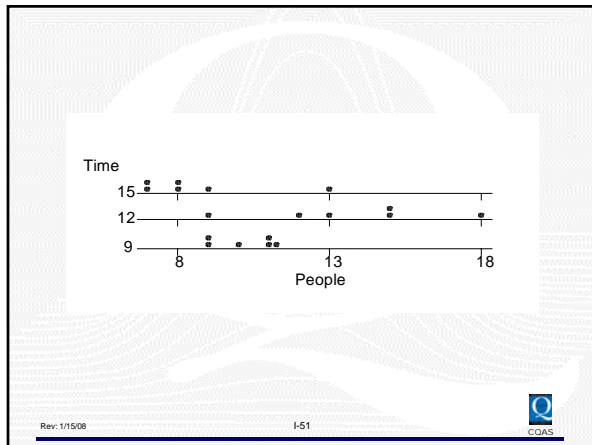


The Old Double-Nickel Trick (Ken)

- Idea. Place two bright and shiny nickels in the middle of a hallway and observe how many people pass by before one hones in for the kill.
- Factors. Which mattered?

Day	Time	Location
• 1-6	• 9 AM • 12 N • 3 PM	• 1. Liberal Arts • 2. Engineering • 3. SAU

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- Overall
 - Well Planned, Well Thought Out
 - Experimental Conditions ("Treatment Design")
 - Structure
 - Balance
 - Many factors simultaneously
 - Protection ("Error Control")
 - Randomization
 - Blocking
 - Replication
 - Blinding
- Rev: 1/15/08 I-52

- General Notes
 - Methods of Measurement
 - Passive, then Active, Experimentation
 - PC - Politely Cynical. Theory versus Data
 - Graphical Presentation of Results
- Rev: 1/15/08 I-53

Experiment!

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