This is a ***Free Preview*** of actual seminar **Handout** materials (Notes) and presentation **Slides** used in the training seminars offered by **Nutek, Inc**.

If you are planning to get an **appreciation and develop understanding** of the subject matter, read the Notes (*First of the available files*).

Should you wish to **self-study and learn how to apply the technique**, consider purchasing both Notes and Slides when available.

Recommended Self-study steps:

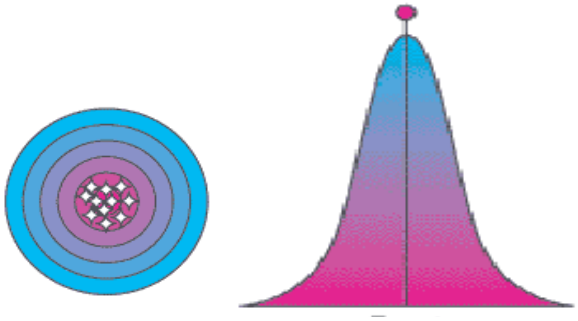
- *Review Notes first.*
- *Use Slides as more focused study. Review Notes to clarify concepts.*
- *Review examples and carry out exercises presented.*

To train a group of people at your facility, visit our web sites to explore options and details: http://nutek-us.com/wp-sem.html

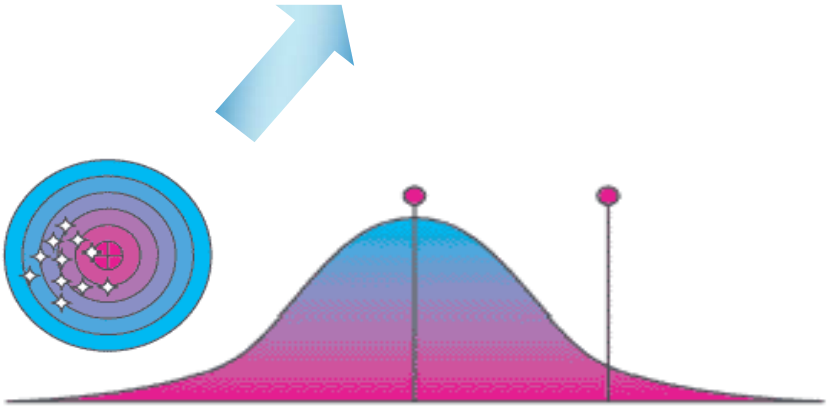
Nutek, Inc.
3829 Quarton Road, Suite 102
Bloomfield Hills, Michigan 48302, USA.
Tel: 1-248-540-4827, E-mail: Support@Nutek-us.com
Web site: http://nutek-us.com/wp-sem.html

Seminar Handout - Preview Notes

DOE-I Basic Design of Experiments



Target



Mean Target

Nutek, Inc.
Quality Engineering Seminar and Software
Bloomfield Hills, MI, USA. www.Nutek-us.com

DOE-I Basic **Design of Experiments**

Presented
By

Nutek, Inc.
3829 Quarton Road
Bloomfield Hills, Michigan 48302, USA.
Phone and Fax: 248-540-4827
Web Site: http://nutek-us.com , E-mail: Support@Nutek-US.com

Course Overview

Design of Experiment (DOE) is a powerful statistical technique for improving product/process designs and solving production problems. A standardized version of the DOE, as forwarded by Dr. Genichi Taguchi**,** allows one to easily learn and apply the technique product design optimization and production problem investigation. Since its introduction in the U.S.A. in early 1980's, the Taguchi approach of DOE has been the popular product and process improvement tool in the hands of the engineering and scientific professionals.

This seminar will cover topics such as: *Orthogonal arrays, Main effects, Interactions, Mixed levels, Experiment planning,* etc. Participants in this seminar learn concepts with practice problems and hands-on exercise. The goal of the seminar discussion will be to prepare the attendees for immediate application of the experimental design principles to solving production problems and optimizing existing product and process designs. The afternoon of the third day of the class will be dedicated to demonstrating how Qualitek-4 software may be used to easily accomplish experiment design and analysis tasks.

Outline

- Overviews

Standard Experiment Designs

- Basic principles of DOE and orthogonal arrays experiments
- Simple example showing experiment planning, design, and analysis of results
- Experiment planning steps

Interaction Studies

- Understanding interactions
- Scopes of interaction studies and its effect on experiment design
- Designing experiment to study interaction & Effect of interaction on the conduct of experiment
- Analyses for presence and significance of interaction
- Corrective actions for significant interactions

Mixed Level Factor Design

- Upgrading & Downgrading column levels
- Scopes of array modifications
- Factor level compatibility requirements & Combination designs

Design and Analysis Tasks using Software

- Experiment designs
- Analysis tasks

Principal Instructor's Background

Ranjit K. Roy, Ph.D., P.E. (Mechanical Engineering, president of NUTEK, INC.), is an internationally known consultant and trainer specializing in the Taguchi approach of quality improvement. Dr. Roy has achieved recognition for his down-to-earth style of teaching of the Taguchi experimental design technique to industrial practitioners. Based on his experience with a large number of application case studies, Dr. Roy teaches several application-oriented training seminars on quality engineering topics.

Dr. Roy began his career with The Burroughs Corporation following the completion of graduate studies in engineering at the University of Missouri-Rolla in 1972. He then worked for General Motors Corp. (1976-1987) assuming various engineering responsibilities, his last position being that of reliability manager. While at GM, he consulted on a large number of documented Taguchi case studies of significant cost savings.

Dr. Roy established his own consulting company, Nutek, Inc. in 1987 and currently offers consulting, training, and application workshops in the use of design of experiments using the Taguchi approach. He is the author of A PRIMER ON THE TAGUCHI METHOD - published by the Society of Manufacturing Engineers in Dearborn, Michigan and of Design of Experiments Using the Taguchi Approach: 16 Steps to Product and Process Improvement published (January 2001) by John Wiley & Sons, New York. He is a fellow of the American Society for Quality and an adjunct professor at Oakland University, Rochester, Michigan.

SEMINAR SCHEDULE

Design of Experiments Using Taguchi Approach

DOE- I

- **Introduction**
  - The Taguchi Approach to Quality Engineering
  - Concept of Loss Function
  - Basic Experimental Designs

- **Designs with Interactions**
  - Application Examples
  - Basic Analysis

- **Designs with Mixed Levels and Interactions**
  - Column Upgrading
  - Column Degrading
  - Combination Design

DOE-II • **Robust Design Principles**
  - Noise Factors and Outer Array Designs
  - S/N Ratio Analysis

- **Learning ANOVA through Solved Problems**
  - Computation of Cost Benefits Using LOSS FUNCTION
  - Manufacturer and Supplier Tolerances
  - Brainstorming for Taguchi Case Studies

- Design and Analysis Using Computer Software
- Group Reviews
- Computer Software (Qualitek-4) Capabilities

- **Dynamic Systems**

- Class Project Applications
- Project Presentations

General Reference

Taguchi, Genichi: *System of Experimental Design*, UNIPUB Kraus Intl. Publications, White Plains, New York, 1987
Roy, Ranjit: *Design of Experiments Using the Taguchi Approach: 16 Steps to Product and Process Improvement*, John Wiley & Sons; ISBN: 0471361011

INTERNET: For general subject references (Taguchi + Seminar + Software + Consulting + Case Studies + Application Tips), try search engines like **Yahoo, Lycos, Google**, etc. For Nutek products, services, and application examples, visit:

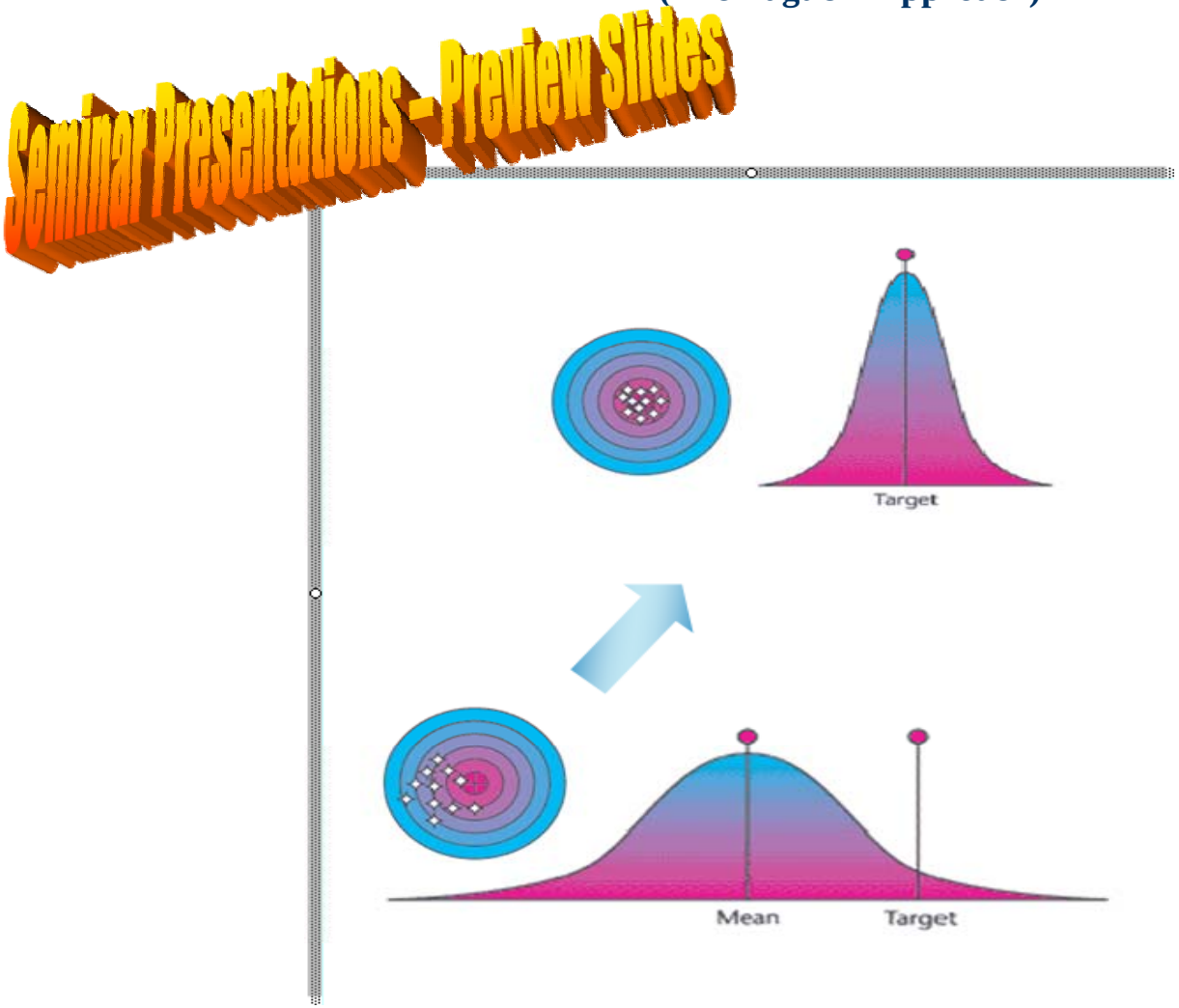
http://www.nutek-us.com
http://www.rkry.com/wp-sem.html http://www.nutek-us.com/wp-sps.html
http://www.nutek-us.com/wp-s4d.html http://www.nutek-us.com/wp-q4w.html

Table of Contents

Continued……..

DOE-I Basic Design of Experiments

(The Taguchi Approach)



by

Ranjit K. Roy

Nutek

Expected Participant Benefits

Ref. Page N/A

- Learn how to apply DOE/Taguchi technique and how to benefit from it in your production and engineering activities.
- Understand key concepts in DOE and Robust designs.
- Learn application of advance concepts:
  - *Mixed level factor designs*
  - *Interaction studies*
  - *Simultaneously studying multiple criteria of evaluations*
- Know how to work together as teams and plan experiments based on consensus decisions.

Group and Individual Exercises (2-day course)

Class Activities

- Practice Problems & Group Exercises
- Solve problems together. Earn 1 credit when you solve yourself, but get 5 credits when you help your partners/neighbors understand and solve it.
- Do problems 1A – 4B by hand calculations (use calculators as needed).

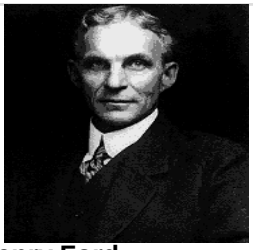
Overview Slide Contents

Things you should learn from discussions in this module:

* Where DOE fits into quality improvement efforts.
* How is Taguchi approach relates to DOE
* What did Dr. Genechi Taguchi introduce that is new?
* How is quality defined by Taguchi and what is the approach to achieve performance improvement?

Quality & Cost Improvement - Lean Manufacturing History (Timeline)

Eli Whitney
1765 – 1825, was an American inventor and manufacturer who is credited with creating the first cotton gin in 1793.
• Interchangeable parts



Henry Ford
•Assembly Line
•Flow Lines
•Manufacturing Strategy



Eiji Toyoda Taichi Ohno Shigeo Shingo
•Just in Time and Toyota Production System
•Stockless Production
•World Class Manufacturing

Civil War

WW-I

WW-II

1850 1875 1900 1920 1940 1960 1980 2000

Fredrick Taylor
• Standardized work time study & work standards
• Worker/management dichotomy

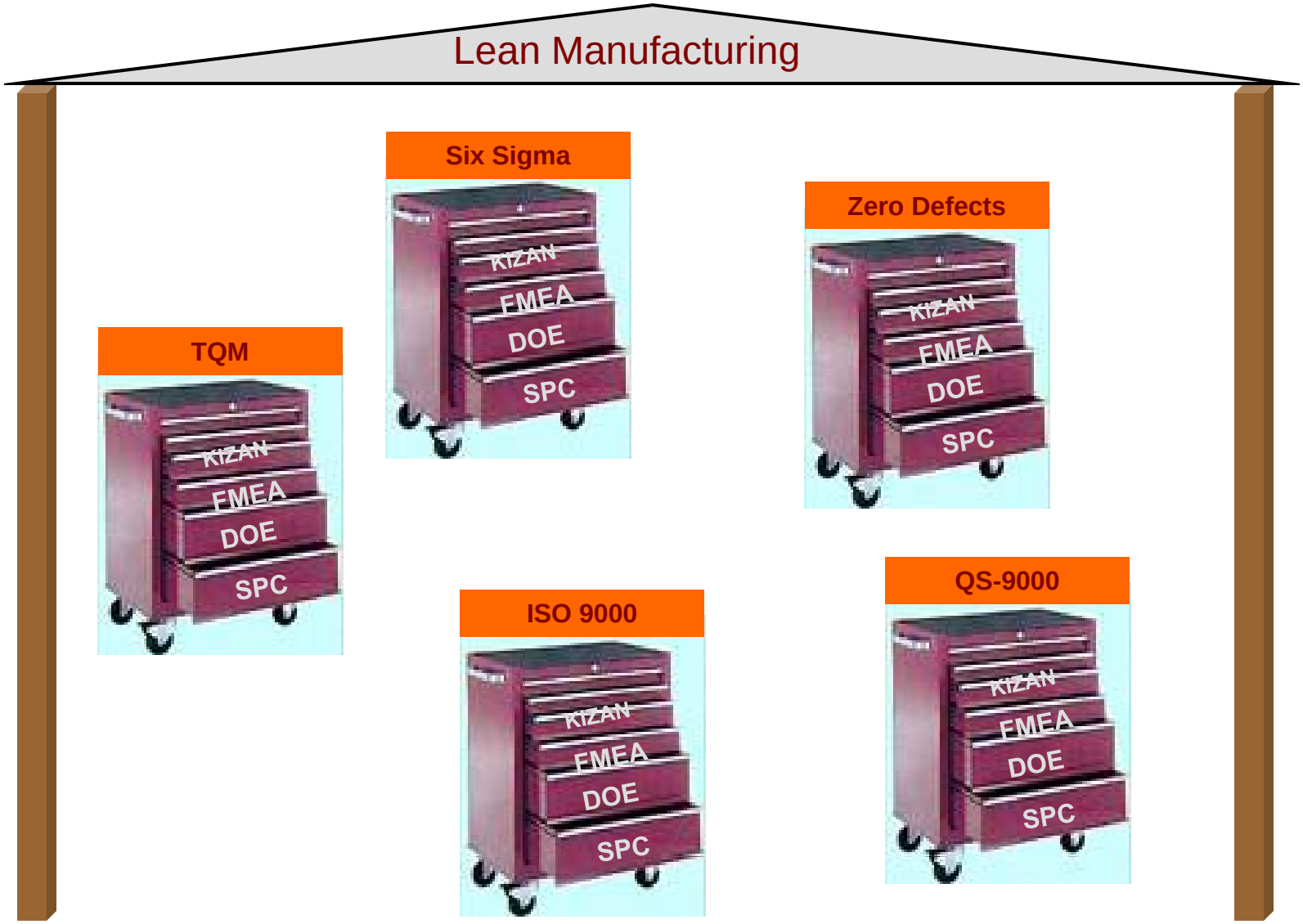

Frank & Lilian Gilbreth
•Process Chart
•Motion Study




Edward Deming **Joseph Juran** **Genichi Taguchi** **Kaoru Ishikawa**

•TQM, SPC, Taguchi Methods, Fishbone Diagram ….

Tools and Techniques for Quality Improvement



Source of Topic Titles

What is DOE

Design of Experiments (DOE)

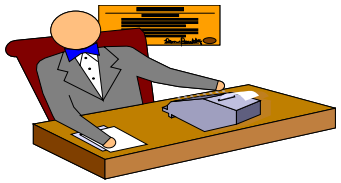
Using The Taguchi Approach

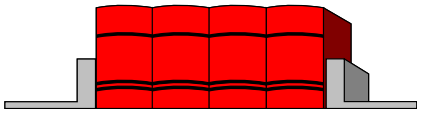
Who is Taguchi

What is it used for?
How do we apply it?

Who is Taguchi?

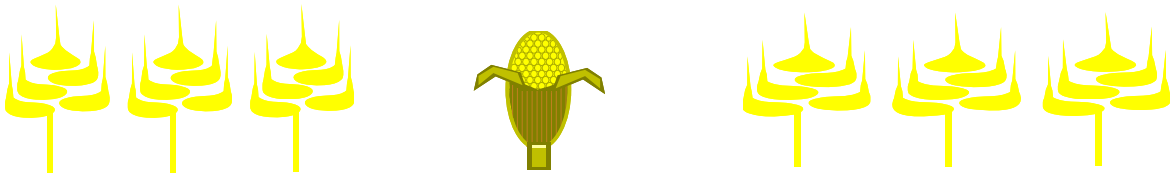
- Genechi Taguchi was born in Japan in 1924.
- Worked with Electronic Communication Laboratory (ECL) of Nippon Telephone and Telegraph Co.(1949 - 61).
- Major contribution has been to standardize and simplify the use of the DESIGN OF EXPERIMENTS techniques.
- Published many books and papers on the subject.





What is the Design of Experiment Technique?

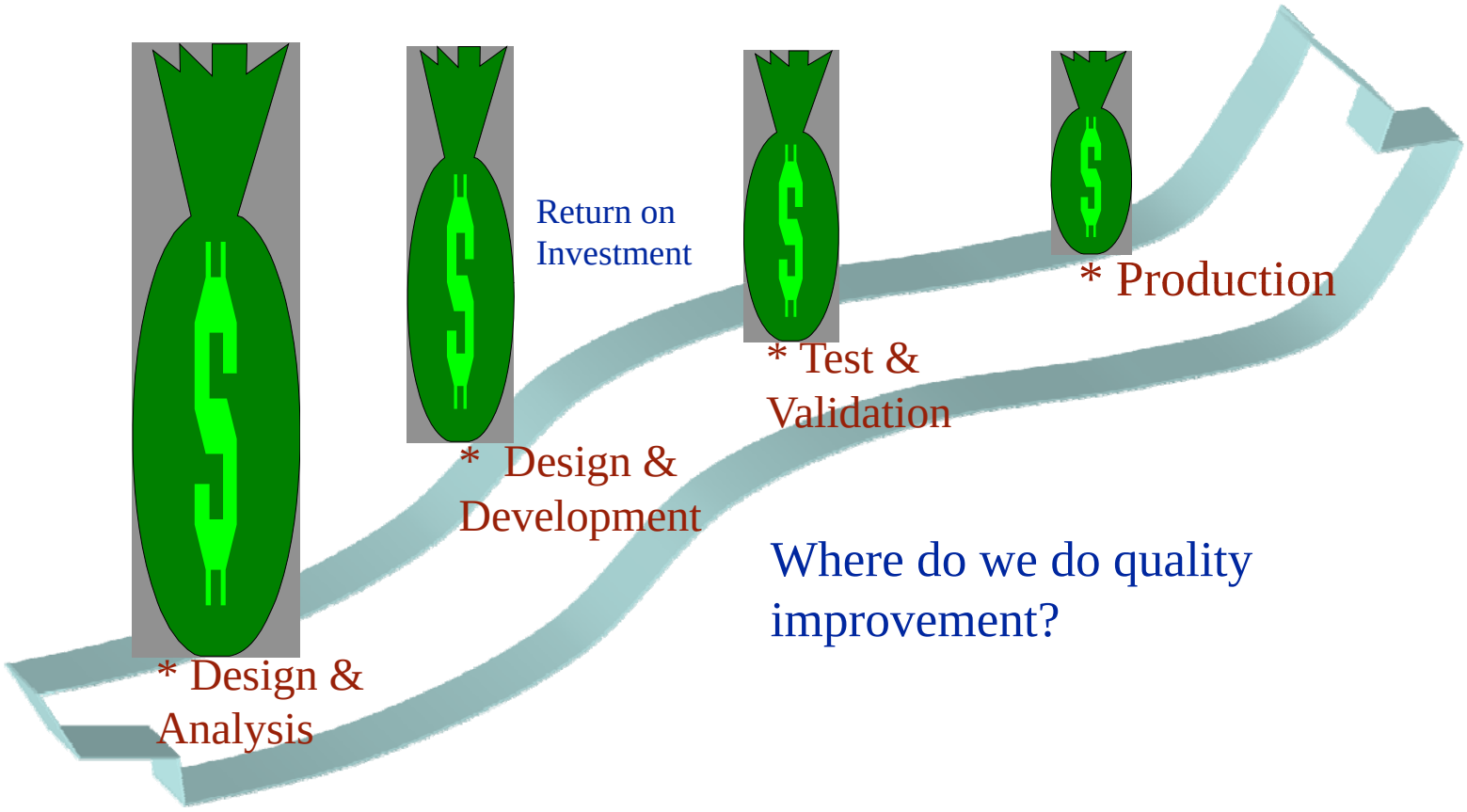
- It all began with R. A. Fisher in England back in 1920's.
- Fisher wanted to find out how much rain, sunshine, fertilizer, and water produce the best crop.
- Design Of Experiments (DOE):
  - statistical technique
  - studies effects of multiple variables simultaneously
  - determines the factor combination for optimum result



What's New? Philosophy !

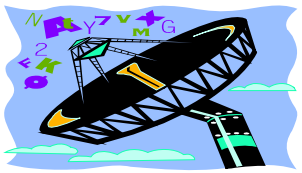
- DO IT UP-FRONT:
  - Return on investment higher in design
  - The best way is to build quality into the design
- DO IT IN DESIGN. DESIGN QUALITY IN:
  - Does not replace quality activities in production
  - Must not forget to do quality in design

Product Engineering Roadmap (Opportunities for Building Quality)



Background of Genechi Taguchi

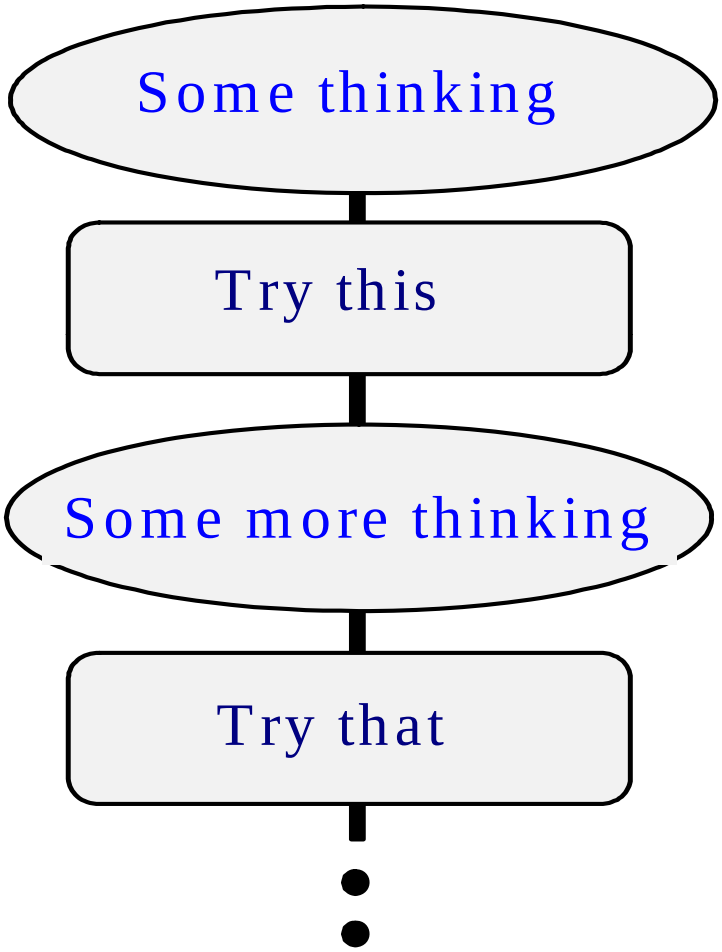
- Dr. Taguchi started his work in the early 1940's
- Joined ECL to head the research department
- Research focussed primarily on combining engineering and statistical methods to improve cost and quality
- Is Executive Director of American Supplier Institute in Dearborn, Michigan
- His method was introduced here in the U.S.A in 1980
- Most major manufacturing companies use it to improve quality of product and process designs



What's New? Discipline!

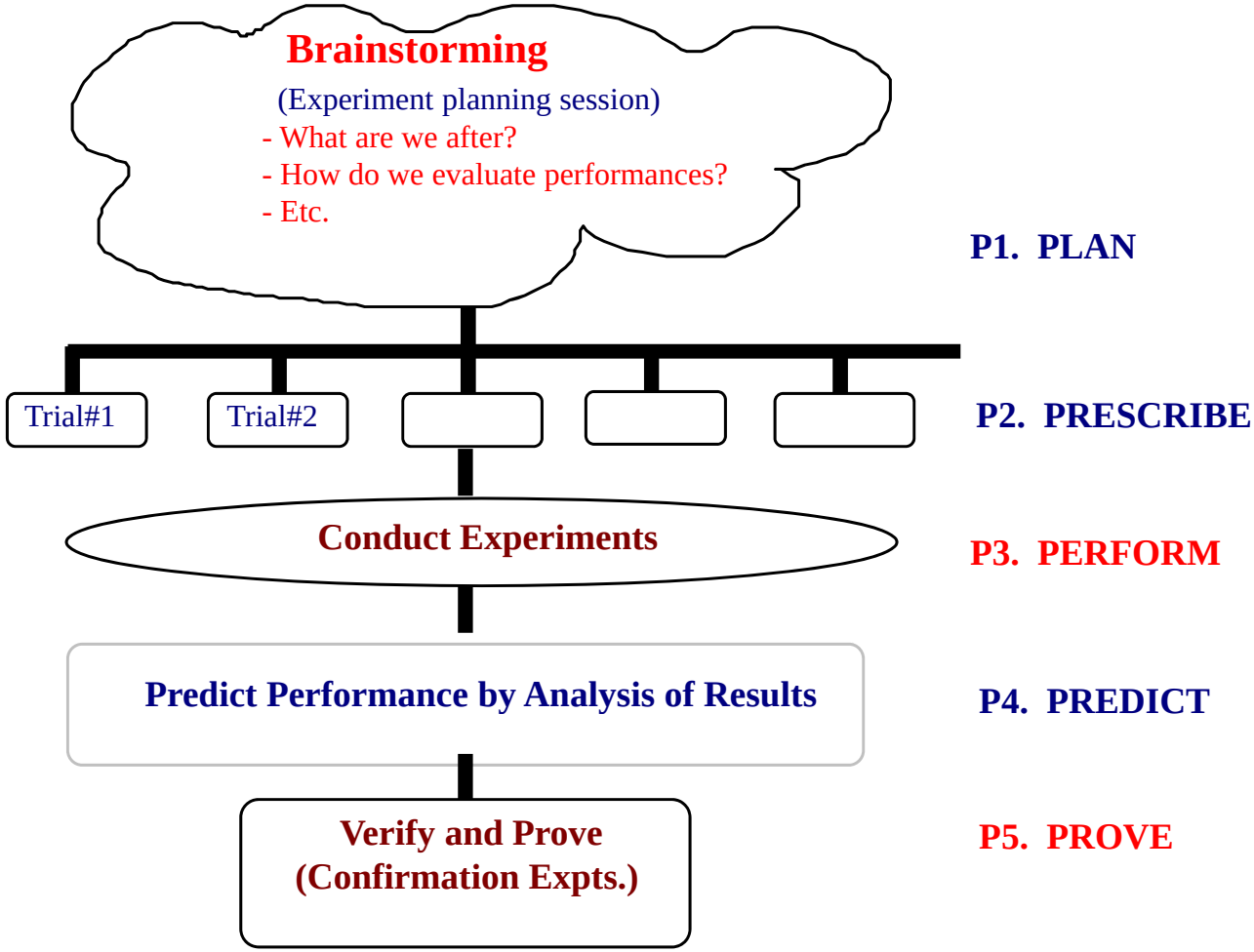
- BRAINSTORMING: Plan experiments and follow through.
- TEAM WORK: Work as a team and not alone.
- CONSENSUS DECISIONS: Make decisions democratically as a team. Avoid expert based decisions.
- COMPLETE ALL EXPERIMENTS planned before making any conclusions.
- RUN CONFIRMATION EXPERIMENTS.

Typical Old Approach (Series Process)



Five-Phase Application Process

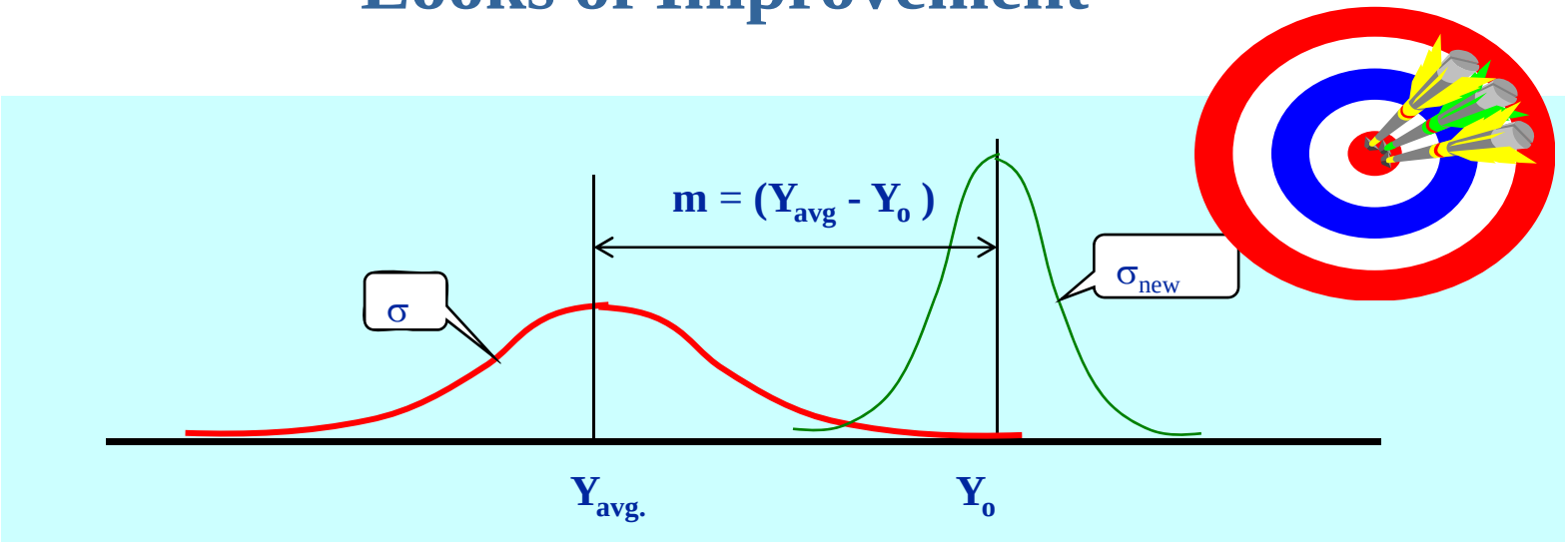
Application phases (5-P's)



What's New? Definition of Quality

- CONSISTENCY OF PERFORMANCE: Quality may be viewed in terms of consistency of performance. To be consistent is to BE LIKE THE GOOD ONE'S ALL THE TIME.
- REDUCED VARIATION AROUND THE TARGET: Quality of performance can be measured in terms of variations around the target.

Looks of Improvement



Improve Performance = Reduce σ and / or Reduce **m**

Figure 1: Performance Before Experimental Study

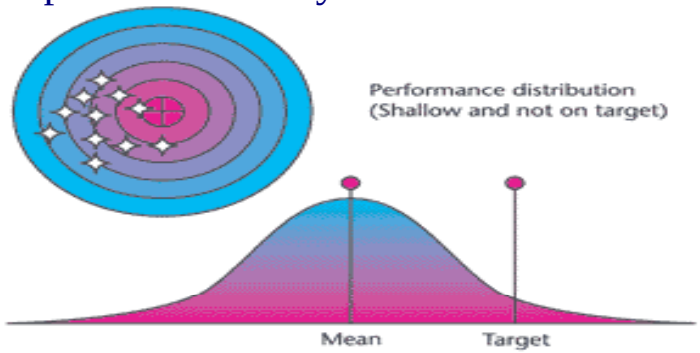
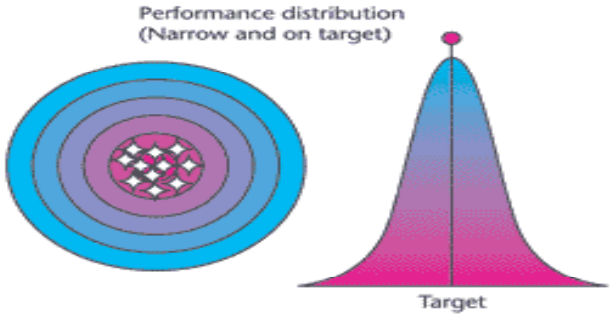
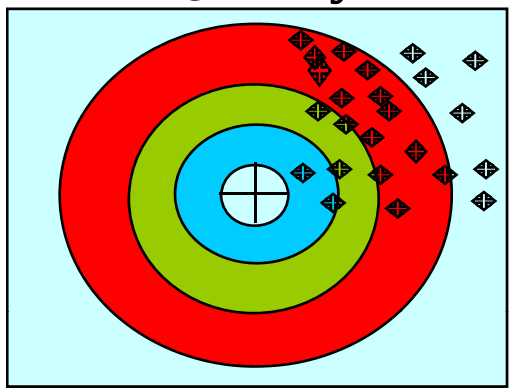


Figure 2: Performance After Study

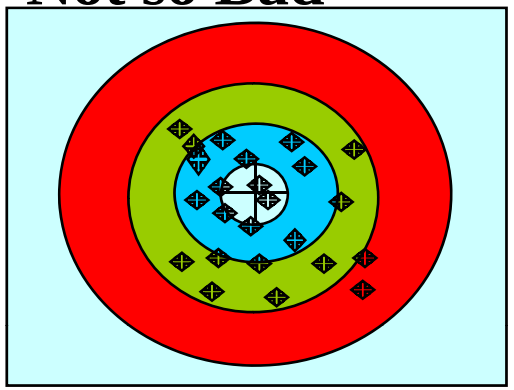


Being on Target Most of the Time

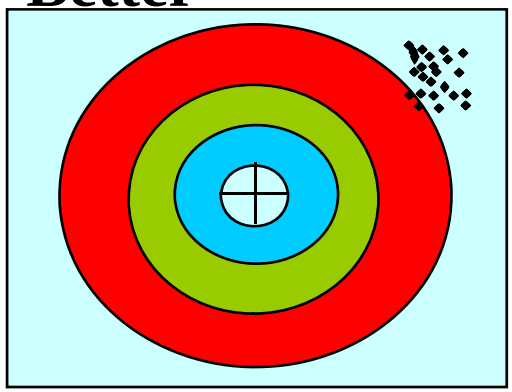
Poor Quality



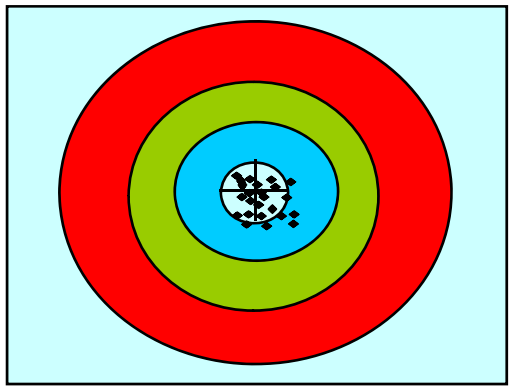
Not so Bad



Better



Most Desirable



What's New? Loss Function!

- MEASURING COST OF QUALITY:
  - Cost of quality extends far beyond rejection at the production
  - Lack of quality causes a loss to the society.
- LOSS FUNCTION : A formula to quantify the amount of loss based on deviation from the target performance.

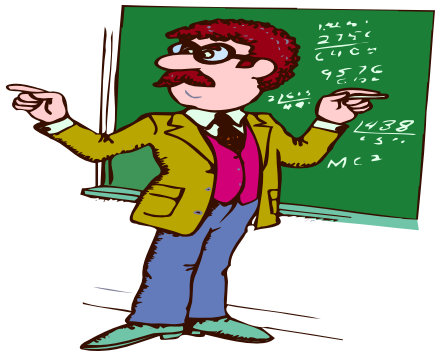
$$L = K (y - y_0)^2$$

What's New? Simpler and Standardized DOE.

- APPLICATION STEPS: Steps for applications are clearly defined.
- EXPERIMENT DESIGNS: Experiments are designed using special orthogonal arrays.
- ANALYSIS OF RESULTS: Analysis and conclusions follow standard guidelines.

DOE - the Taguchi Approach - Seminar Contents

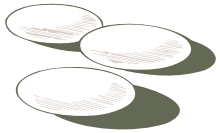
- PARAMETER DESIGN: Taguchi approach generally refers to the parameter design phase of the three quality engineering activities (SYSTEM DESIGN, PARAMETER DESIGN and TOLERANCE DESIGN) proposed by Taguchi.
- Off-line Quality Control
- Quality Loss Function
- Signal To Noise Ratio(s/n) For Analysis
- Reduced Variability, a Measure Of Quality

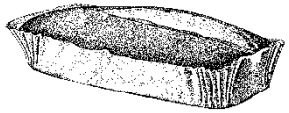


How Does DOE Technique Work?

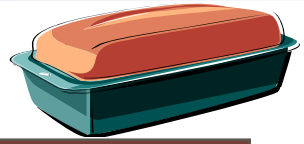
EXAMPLE APPLICATION

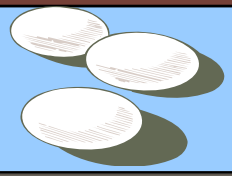
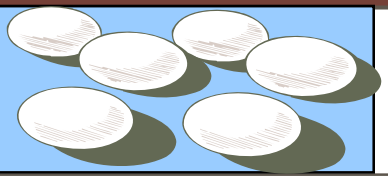
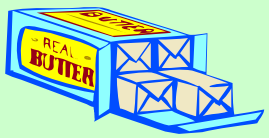
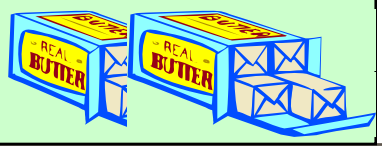
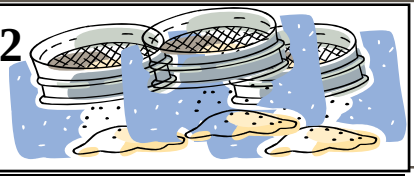
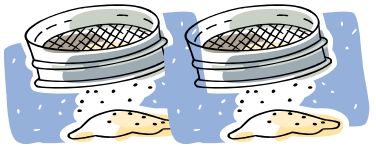
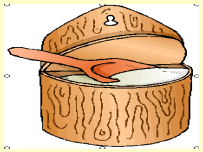
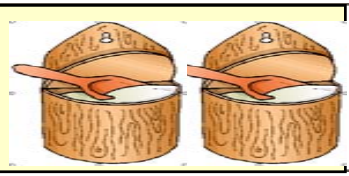
- It is an experimental technique that determines the solution with minimum effort.
- In a POUND CAKE baking process with 5 ingredients, and with options to take HIGH and LOW values of each, it can determine the recipe with only 8 experiments.
- Full factorial calls for 32 experiments. Taguchi approach requires only 8



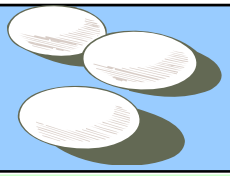
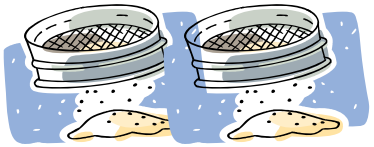
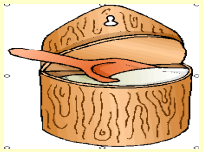
Ingredients for Baking Pound Cake

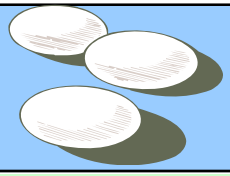
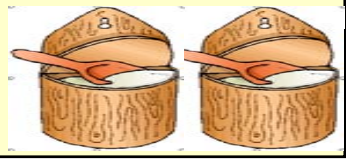


Factors	Level-1	Level-2
A: Egg	A1 	A2 
B: Butter	B1 	B2 
C: Milk	C1 	C2 
D: Flour	D2 	D1 
E: Sugar	E1 	E2 

FIVE factors at TWO levels each make $2^5 = 32$ separate recipes (experimental condition) of the cake.

Experimental Conditions

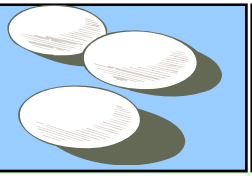
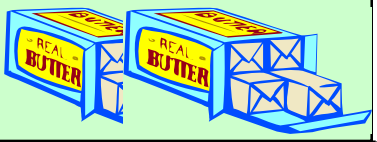
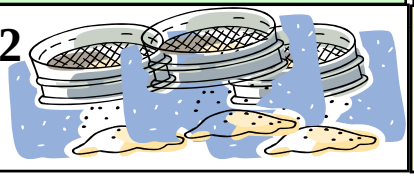
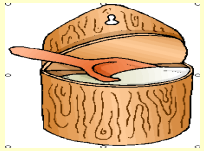
A1 	**B1** 	**C1** 
Condition #1	**D1** 	**E1** 

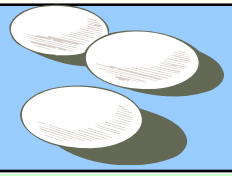
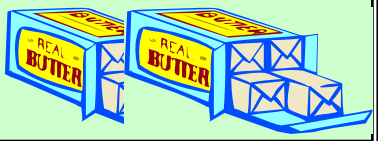
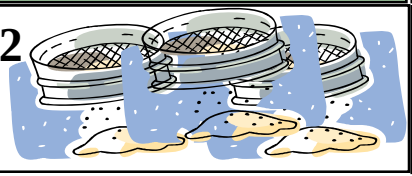
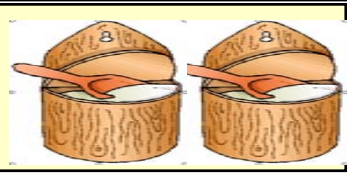
A1 	**B1** 	**C1** 
Condition #2	**D1** 	**E2** 

Experimental Conditions

Condition # 9 through 30 . . . . .

Experimental Conditions

A2 	**B2** 	**C2** 
Condition #31	**D2** 	**E1** 

A2 	**B2** 	**C2** 
Condition #32	**D2** 	**E2** 

Experimental Trial Conditions by L-8 Orthogonal Array

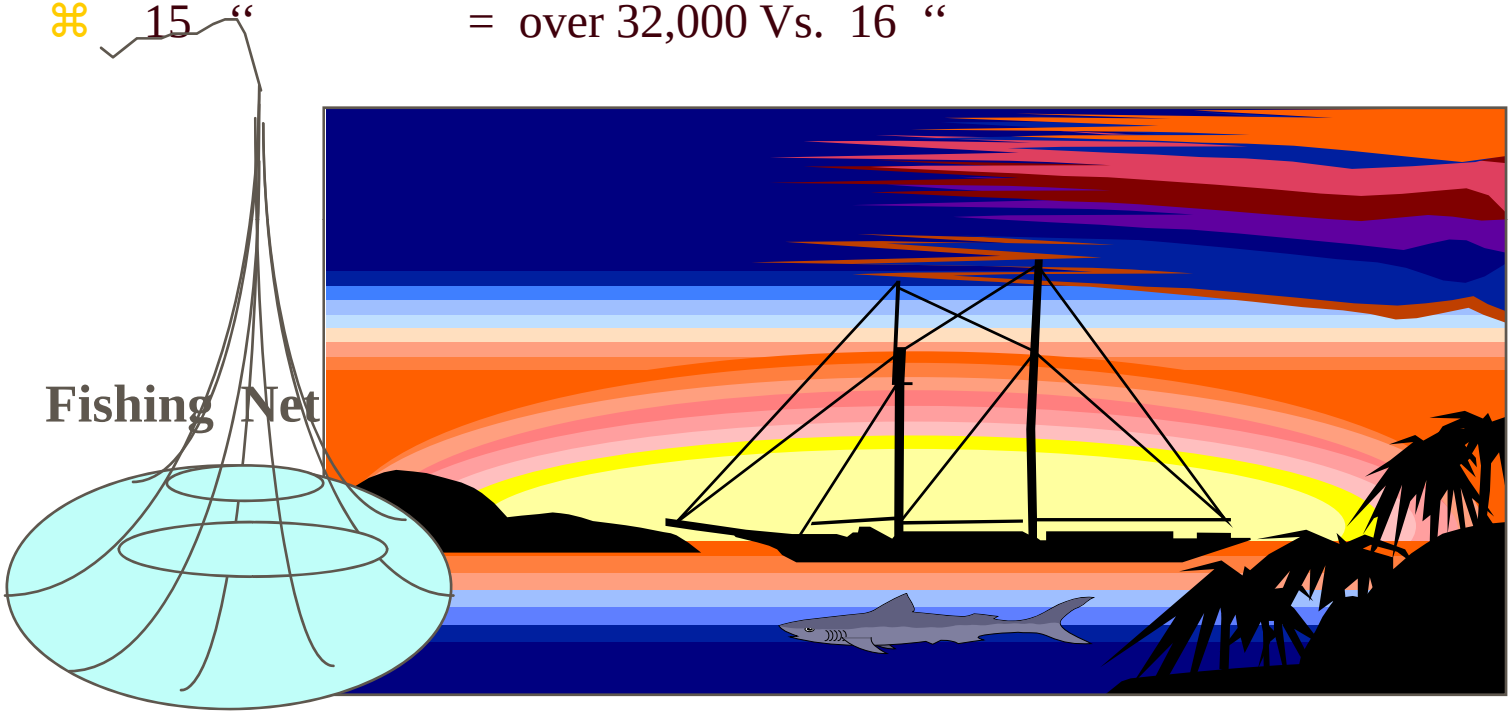
Trial#	A	B	C	D	E	-	-
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Experiment Design Using L-8 Array

Trial					
1	A1	B1	C1	D1	E1
2	A1	B1	C1	D2	E2
3	A1	B2	C2	D1	E1
4	A1	B2	C2	D2	E2
5	A2	B1	C2	D1	E2
6	A2	B1	C2	D2	E1
7	A2	B2	C1	D1	E2
8	A2	B2	C1	D2	E1

Orthogonal Array - a Fish Finder

- 3 2-L factors = 8 Vs. 4 Taguchi expts.
- 7 " " = 128 Vs. 8 Expts.
- 15 " = over 32,000 Vs. 16 "



Example Case Study (Production Problem Solving)

I. Experiment Planning

Project Title - Clutch Plate Rust Inhibition Process Optimization Study (CsEx-05)

The Clutch plate is one of the many precision components used in the automotive transmission assembly. The part is about 12 inches in diameter and is made from 1/8-inch thick mild steel.

Objective & Result - Reduce Rusts and Sticky

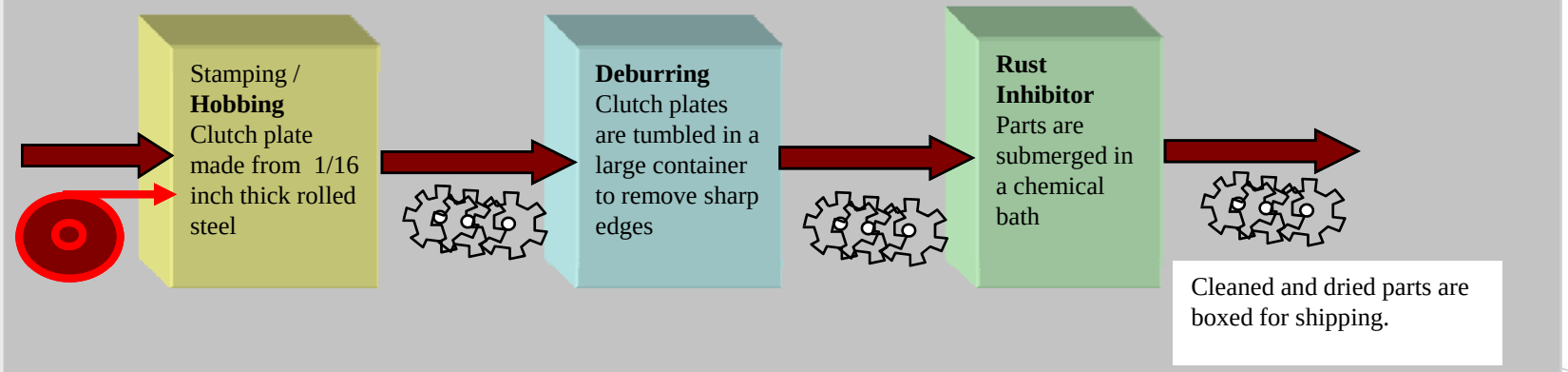
(a) Sticky Parts – During the assembly process, parts were found to be stuck together with one or more parts.

(b) Rust Spots – Operators involved in the assembly reported unusually higher rust spots on the clutch during certain period in the year.

Factors and Level Descriptions

Rust inhibitor process parameters was the area of study.

Figure 1. Clutch Plate Fabrication Process



Example Case Study (Production Problem Solving)

I. Experiment Planning

Project Title - Adhesive Bonding of Car Window Bracket

An assembly plant of certain luxury car vehicle experienced frequent failure of one of the bonded plastic bracket for power window mechanism.The cause of the failure was identified to be inadequate strength of the adhesive used for the bor[illegible]

Objective & Result - Increase Bonding Strength

Bonding tensile (pull) strength were going to be measured in three axial directions. Minimum force requirements were available from standards set earlier.

Quality Characteristics - *Bigger is better* (B)

Factors and Level Descriptions

Bracket design, Type of adhesive, Cleaning method, Priming time, Curing temperature, etc.

II. Experiment Design & Results

Six different process parameters were quickly studied by experiments designed using an L-8 array.

DOE/Taguchi Approach, Part I & Part II