Strategies for Improvement of Process Control

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National Manufacturing Week

March 2000

Presentation Objectives

- Expand the concept of process control beyond the present SPC paradigm
- Provide a broad range of tools and strategies to help you improve control of your processes.

Outline

- The Ball Rollers
- Quality Goals
- Defining Process Control
- Process Performance Analysis
- Control Methods
- Process Control Strategy
- Summary
- Questions & Answers

The Ball Rollers

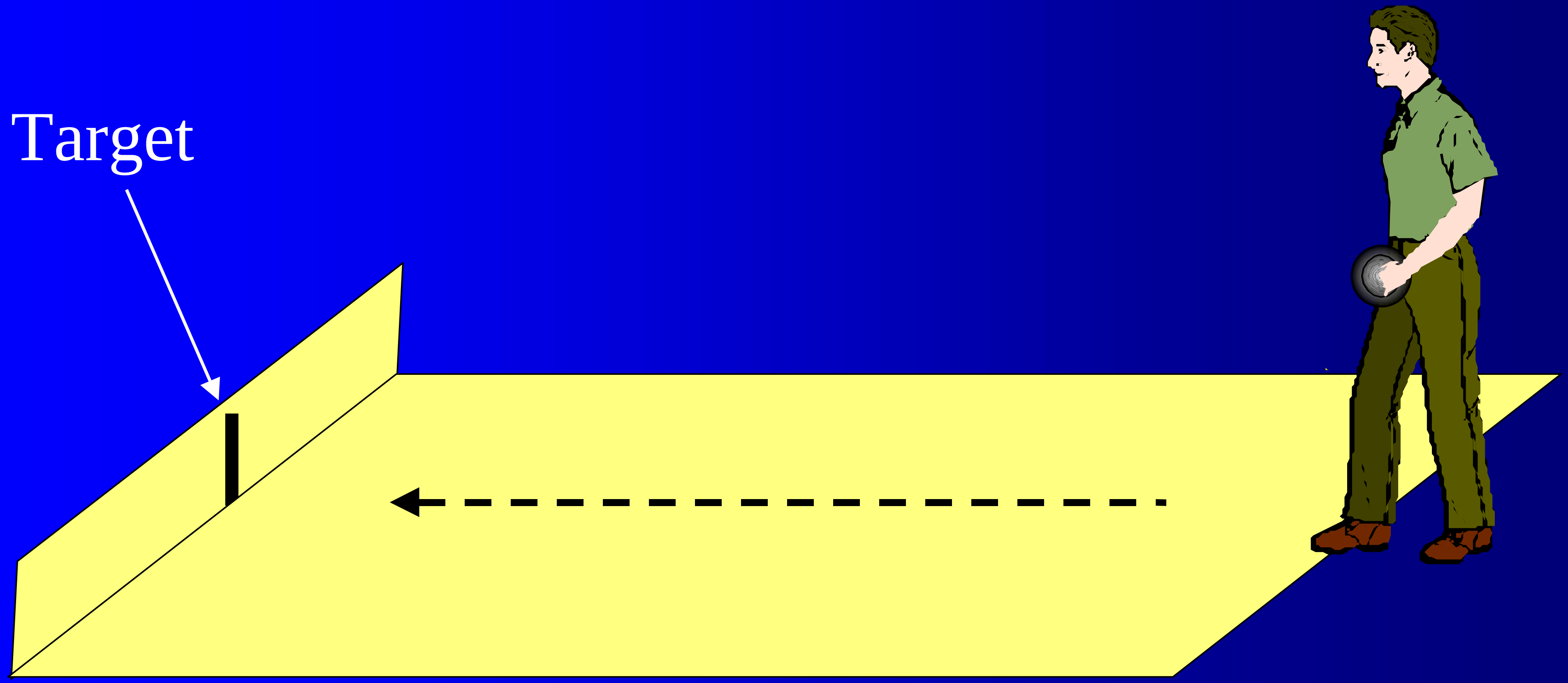
A Fictional Story (?)

The Ball Rollers: Job Description

- Roll 4-inch balls across the floor and strike a mark on the wall 12 feet from the rolling position

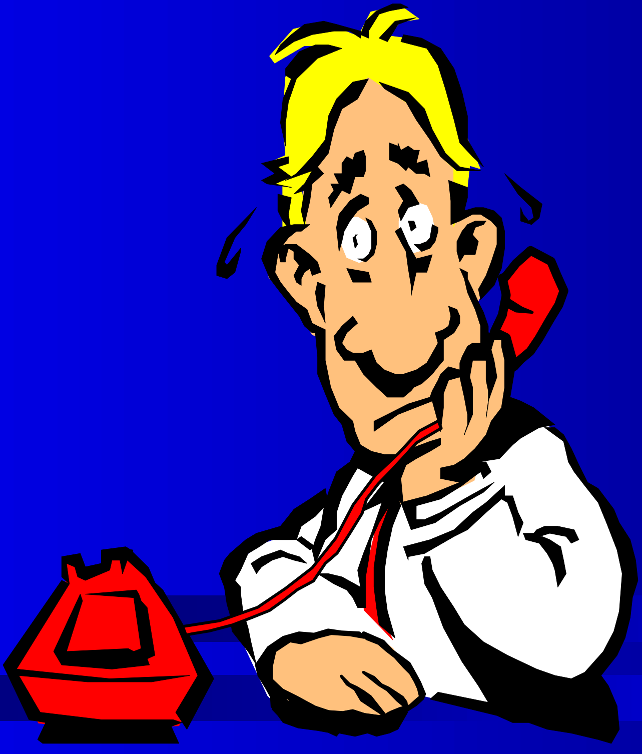
- Customer needs require the balls to hit within ± 2.00 inches of the target, with optimum at target.

The Ball Rollers



The Ball Rollers: Customer Complaints

- Customers have been complaining of seeing deviations 3-4 inches from target!



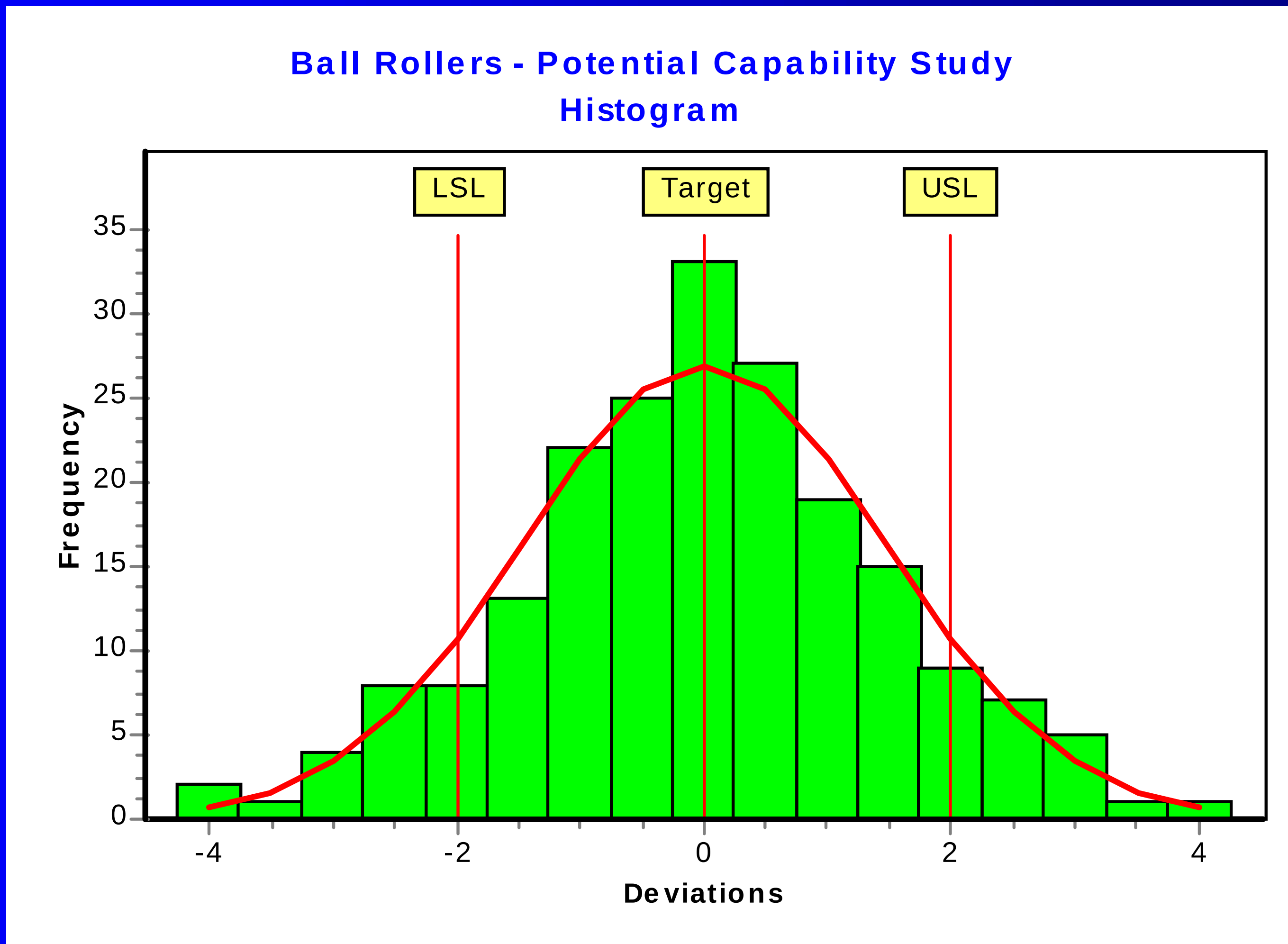
The Ball Rollers: Quality Facilitator Called In

- The four operators form a team
- Operators are given SPC training
- Training done on calipers used to measure deviations
- Gauge studies conducted to obtain R&R
- Process potential study conducted
  - Each operator rolls 50 balls with measurements taken.

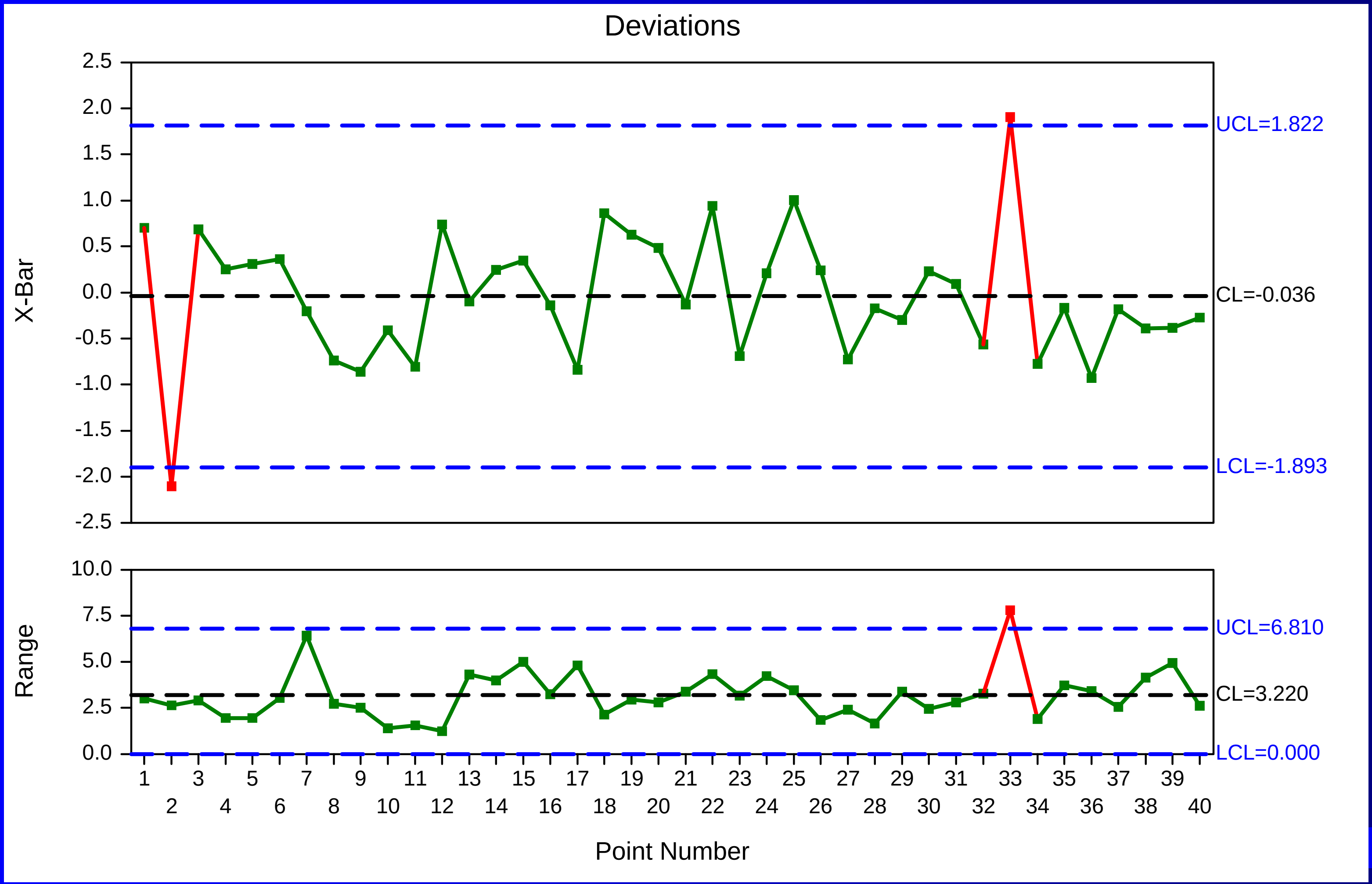
The Ball Rollers: Potential Capability Study

- Consecutive observations appear to be in control for each operator
- Tests for normality show distributions may be approximated by the normal distribution
- Levene test for differences in variation show Curly to have lower variation
- Post hoc from Oneway ANOVA shows Larry to have a slight bias to the right
- More training, procedures updated, potential study repeated . . .

The Ball Rollers: Potential Capability Study



The Ball Rollers: X-Bar and R Charts



The Ball Rollers: Performance Problems

- Potential Capability does not look good
- Long-term Control charts show instability
- The Team is stumped

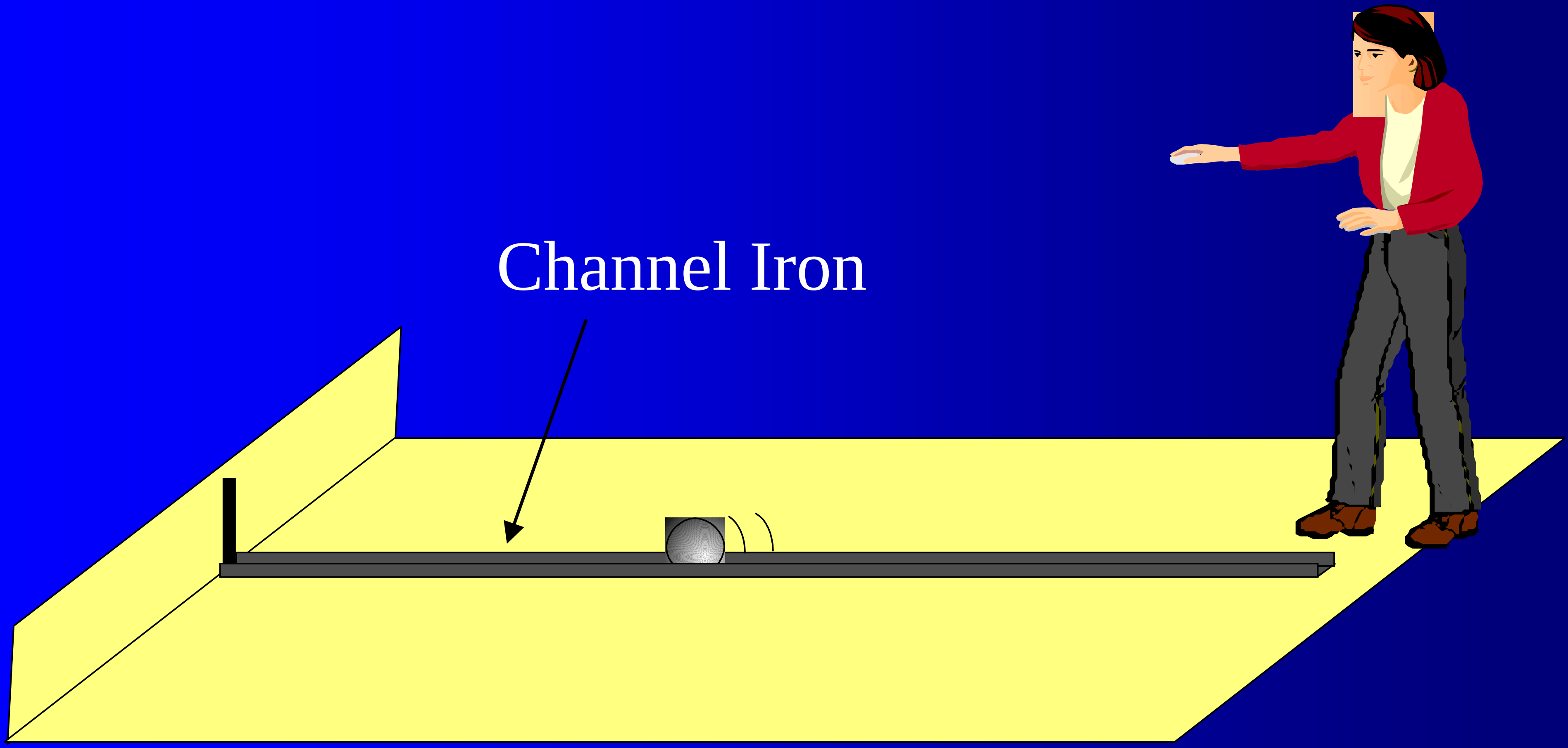
- Team Meeting Called
- They invite Mary from the maintenance department.

The Ball Rollers: Performance is not Good

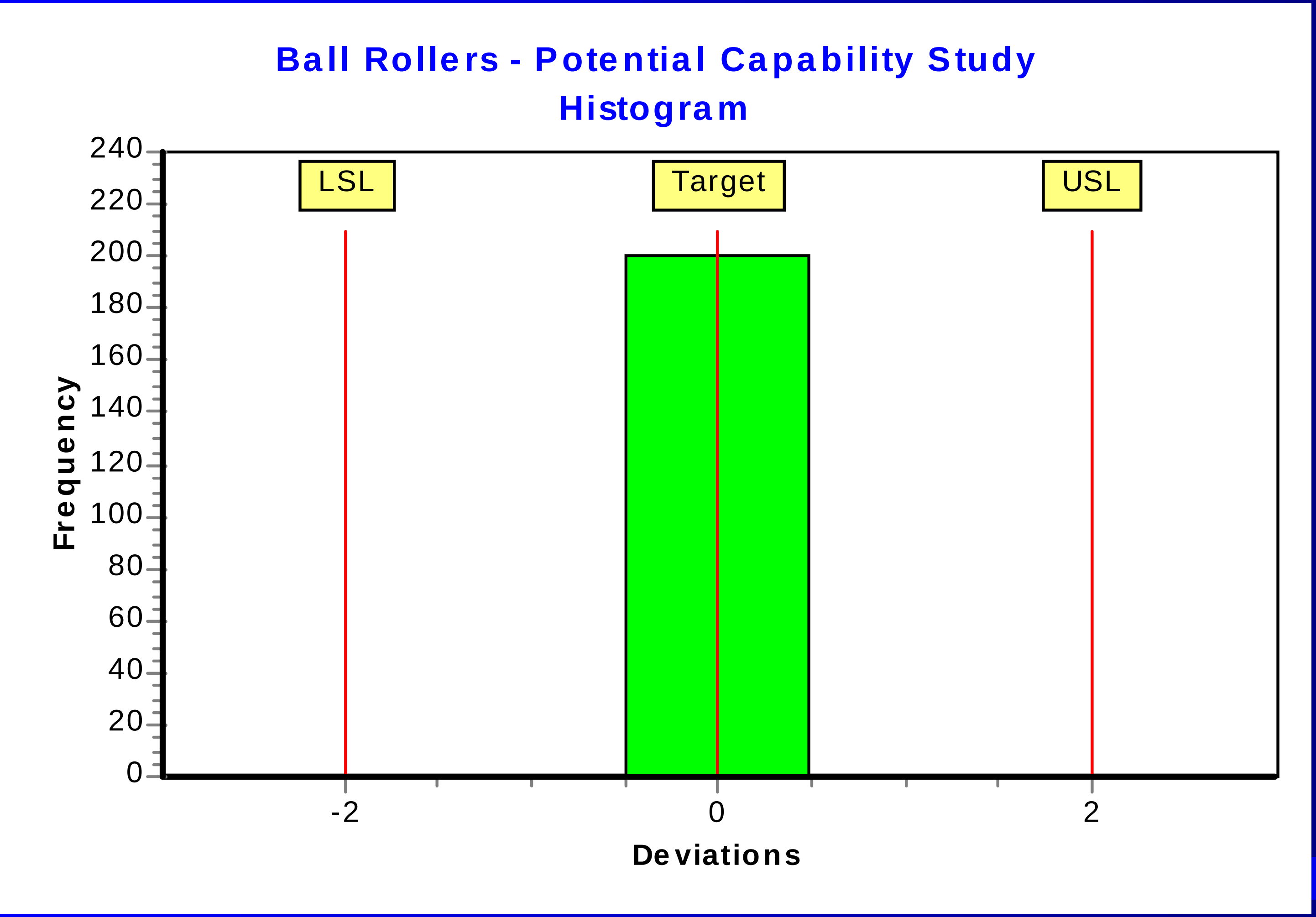
- After explaining to the situation to Mary, who did not attend SPC training, she says,

  "I'll fix it tomorrow."

The Ball Rollers
Mary's Fix



Ball Rollers
New Potential Study



Ball Rollers Conclusion

- Operator Moe returns the calipers
- The control charts are given back to Skippy, the quality facilitator
- The customers remark on the vast improvement in quality.

Ball Rollers

Just a funny story?

Or

Typical results of limited thinking about possible control methods

Quality Goals

Quality Goals Include

1) Eliminating nonconformance

2) Minimizing variation around appropriate targets

3) Doing so at minimum cost

Defining Process Control

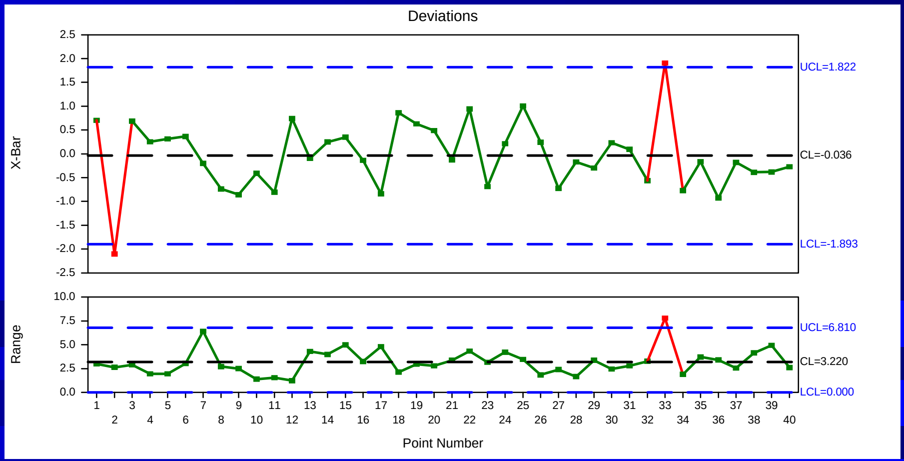
Defining Process Control

- Walter Shewhart (1931) wrote,

  "...a phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future."

Process Control in Traditional SPC

- Processes are said to be “in-control” or “out-of-control” based upon observed patterns on a control chart
- This is a narrow view of process control

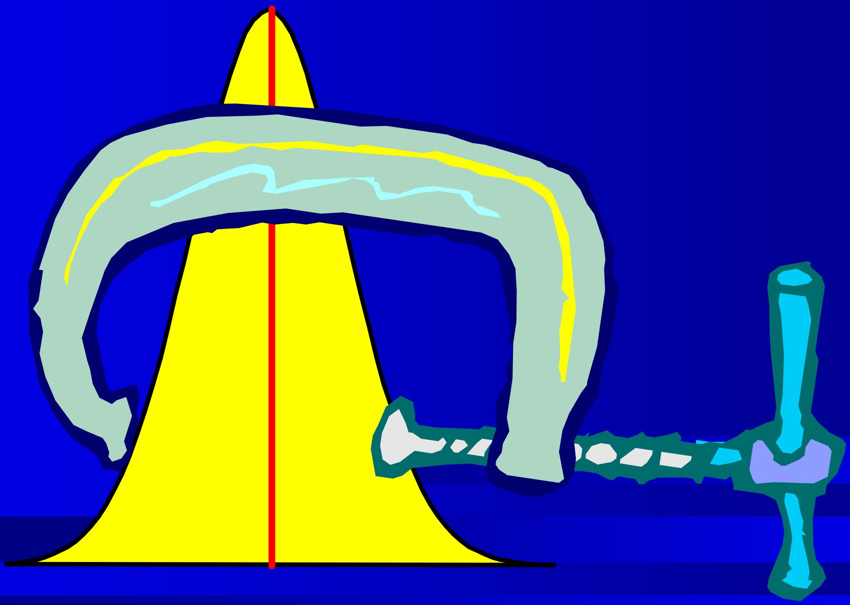


Random House Webster's Definitions of Control

1. to exercise restraint or direction over; dominate, regulate, or command;
2. to hold in check; curb: to control one's emotions;
3. to prevent the flourishing or spread of: to control a forest fire;
4. check or restraint: My anger was under control;
5. prevention of the flourishing or spread of something undesirable: rodent control.

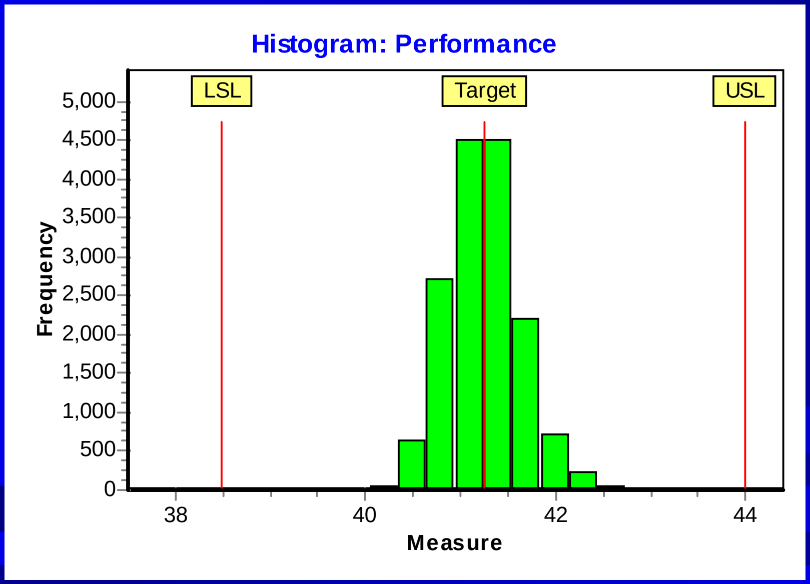
A New Definition for Process Control

- Process control is the ability to constrain variation and prevent nonconformance over time



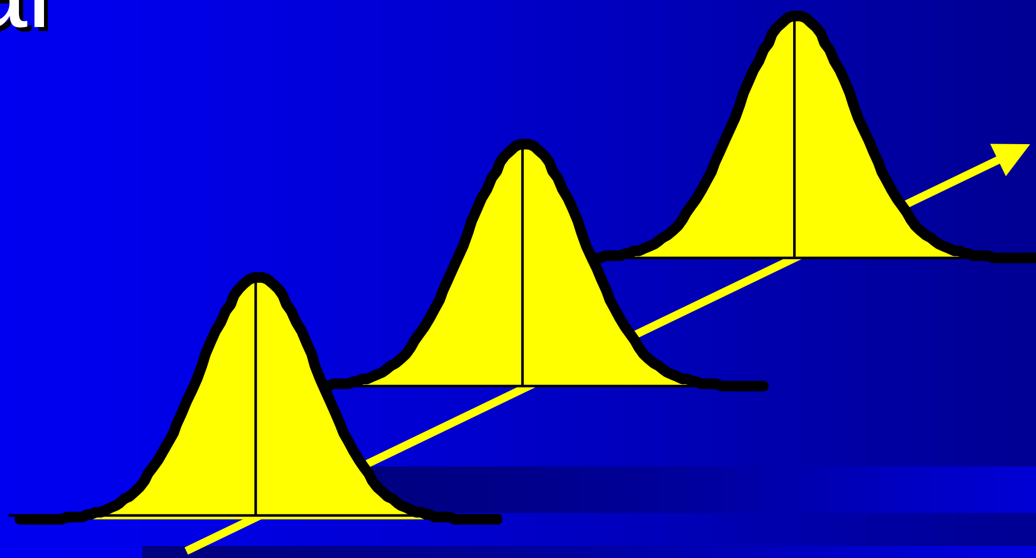
Process Control

- The level of control is demonstrated through the evaluation of long-term process performance



Process Control

- Statistical control is not the goal: achieving conformance and minimal variation over time, at minimal cost, is the goal



Process Control

- Is Mary's process in a state of "Statistical Control?"

- Does it matter?

Process Performance Analysis

Process Performance Analysis

- Tells you how well your control systems are working
- Tells you what you need to work on
- Tells you what you don’t need to work on.

Process Performance Analysis

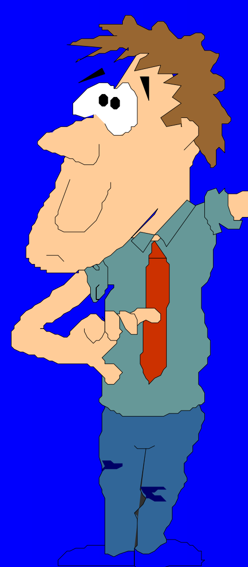
- Uses data collected over long periods of time across all sources of variation
  - 1 month minimum, 3 months preferred
- Typically, data are collected at end-of-line
- Attributes:
  - assess total outgoing nonconforming rates
- Variables:
  - assess total outgoing variation.

Process Performance: Attributes Data

- Outgoing nonconforming rate is used to evaluate attribute performance

Process Performance: Variables Data

$$P_{pm} = \frac{USL - LSL}{6\sqrt{\dfrac{\sum (X-T)^2}{n-1}}} = \frac{USL - LSL}{6\sqrt{s^2 + \dfrac{n}{n-1}(\bar{X}-T)^2}}$$



P_{pm} will improve as:

- Process is brought into better stability
- Differences in tooling, setup, operators, machines, and material are reduced
- Process brought on target
- Inherent process variation reduced.

For More Information on Process Performance Analysis

- See 1998 ASQ Congress paper:

"Performance Analysis for Process Improvement"

Available at:
http://www.mvpprograms.com/html/ppa.html

Control Methods

Control Methods

- Control methods are the means used to achieve a level of process control
- Optimal control methods deliver a desired level of control at minimal cost
- Control methods are countermeasures against sources of variation or process changes.

Control Methods Can Do the Following

- Eliminate nonconformance
- Reduce the probability of nonconformance
- Constrain or minimize variation
- Minimize the effects of nonconformance or excess variation.

Control Methods Include

- Prevention Methods

  and

- Detection and Reaction Methods

Control Methods

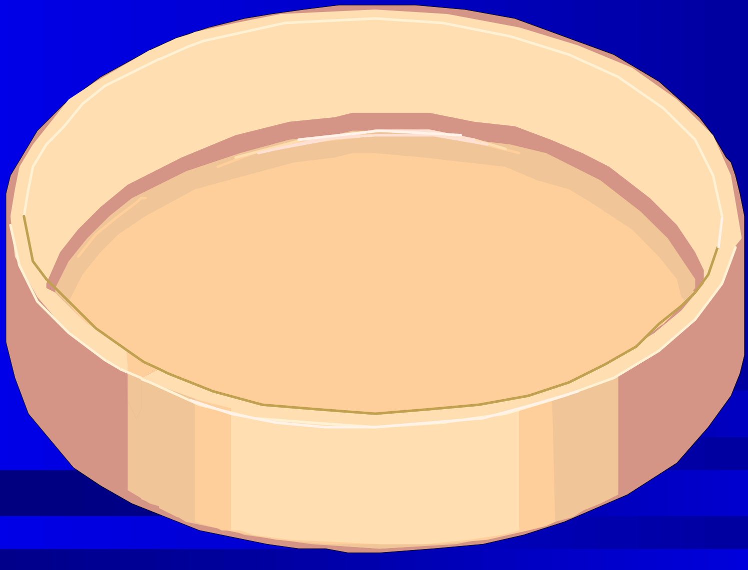
- Robust Product and Process Design
- Mistake-Proofing
- Automatic Control Systems
- Adjustment Charts
- Standardized Operations
- Reliability Methods

Robust Product and Process Design

- Involves designing products and processes that prevent or minimize the effects of process variation and environmental conditions
- The most preferred method of process control
- Controls process without human intervention or investigation.

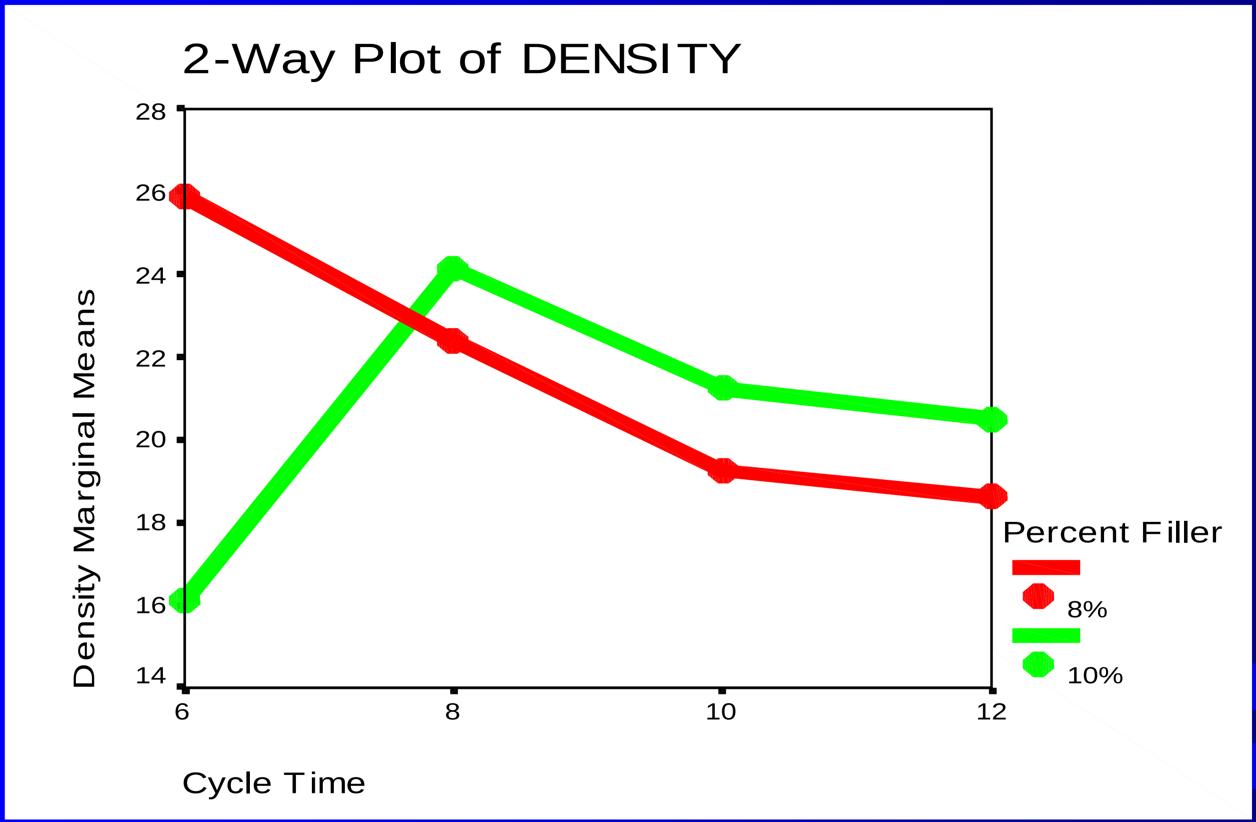
Robust Product Design: Lid Example

- Changing a Lid radius eliminated a tight operating window, between the occurrence of two types of nonconformities, and eliminated both problems



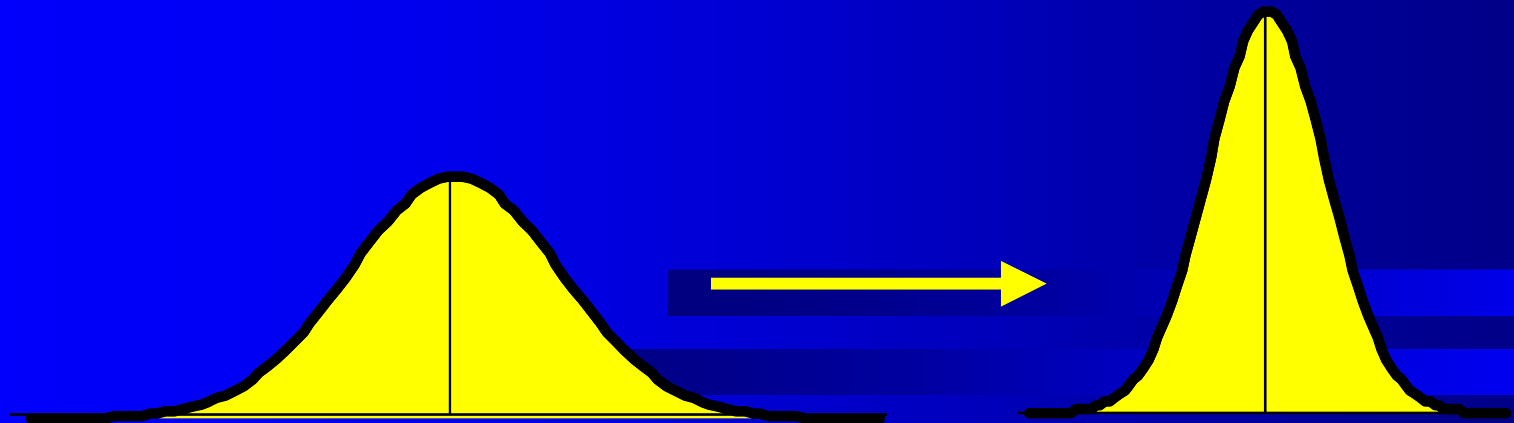
Robust Process Design: Molding Example

- Cycle Time changes affect robustness of Density to changes in Percent Filler



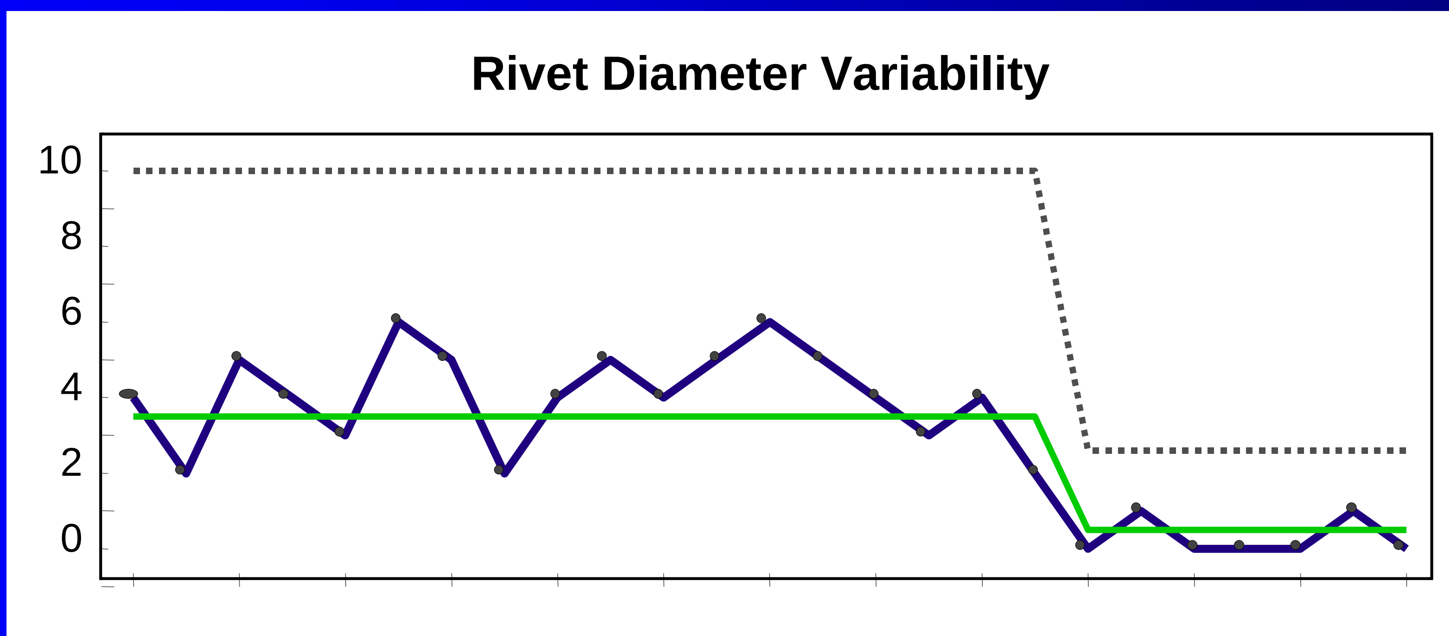
Robust Process Design: Setting Changes

- Although not widely known, changing process settings or configuration can often change inherent process variability
  - Speeds, Temperatures, Pressures, Tool Designs, Materials, Coolants, etc.



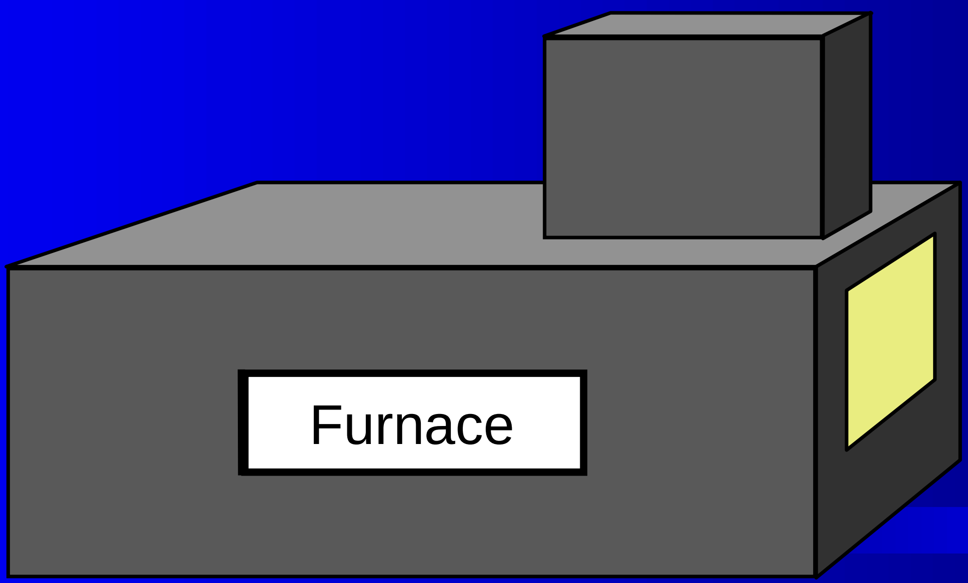
Robust Process Design: Rivet Example

- Changing spin motor speed reduced Rivet Head Diameter variation 40%



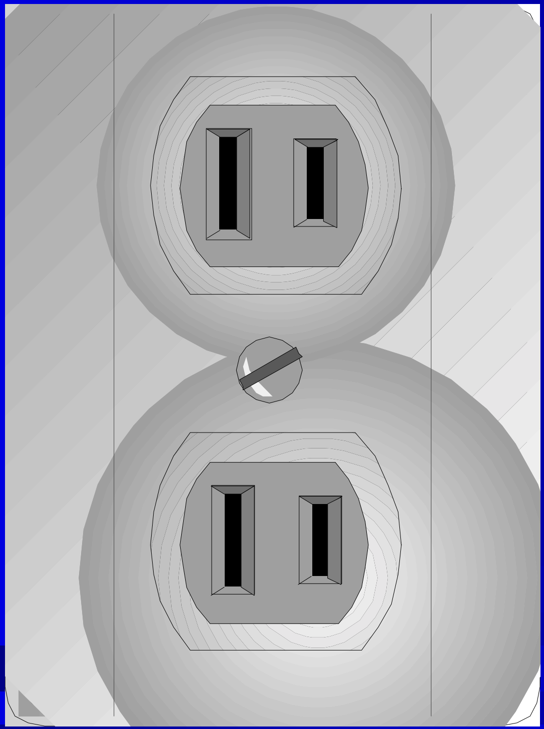
Robust Process Design: Furnace Example

- Changing the part stacking configuration reduced hardness variation in a Heat Treat Furnace



Mistake-Proofing

- Called “Poke-Yoke” in Japan
- A form of Robust Design



Mistake-Proofing Includes

- Methods to prevent an incorrect operation
  - Addresses problems at the source
- Methods to warn or call attention to problems
- 100% evaluation.

Mistake-Proofing: Examples

- Sensors which detect improper setup
- Jigs which hold parts only in the correct position
- Switches which render a machine inoperable without all needed settings
- Boxes and Labels which are color coded to prevent mixing
- Counters which ensure all parts are included before an operation is complete.

Mistake-Proofing

- For more information see:
  - *Zero Quality Control: Source Inspection and the Poka-Yoke System*
    Shigeo Shingo
  - *Poka-Yoke: Improving Product Quality by Preventing Defects*
    NKS/Factory Magazine

Automatic Control Systems

- Systems, often electronic, which measure product or process variables and automatically adjust processes
- Useful where incoming material or environmental variation is inherent to the system
- May use feedback or feed-forward control.

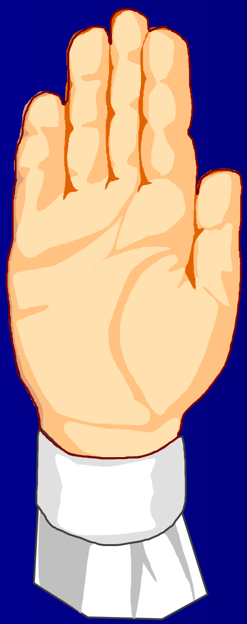
Automatic Control Systems: Examples

- Thermostat in a home
- Cruise control in an automobile
- Load control system in a rolling mill
- Mixing control system in a chemical plant
- Automatic control of grinding depth on a grinding process
- Fan-tail on a windmill to automatically face the windmill into the wind.

Automatic Control Systems

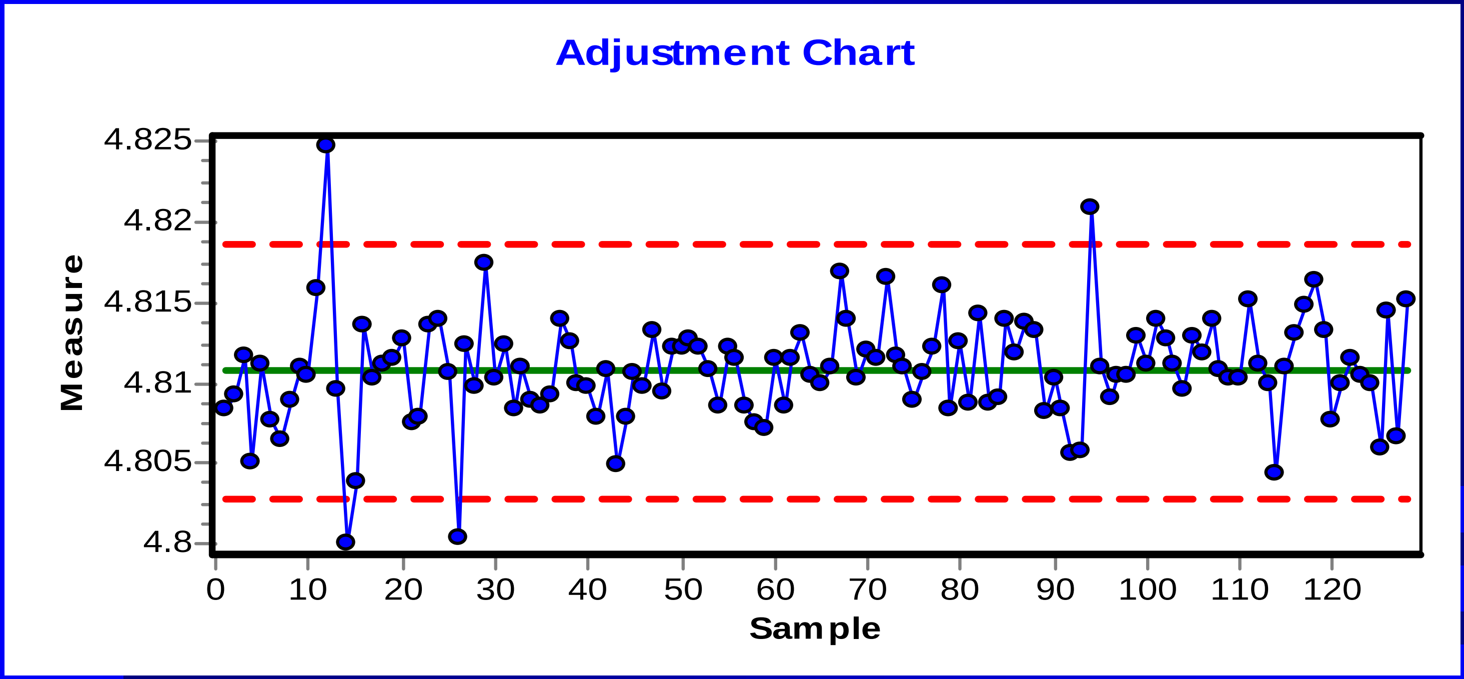
- Warning:

  These systems can be sub-optimized, control system settings are critical to minimize variation



Adjustment Charts

- Paper “Automatic” Control Systems
- Often look like Statistical Process Control charts



Control Charts

- Control charts are not control methods, they are tools for process study

- Control charts provide diagnostic information on when process changes occur, allowing the causes to be discovered, so countermeasures (or control methods) may be implemented.

Control Charts vs. Adjustment Charts

- Control charts try to minimize errors of signaling false changes and not signaling real changes

- Adjustment charts try to minimize product or process variation.

Control Charts vs. Adjustment Charts

- Control charts are to detect shifts in otherwise stable processes
- Adjustment charts are to signal needed adjustments in assumed unstable processes
- If adjustment is the only intent, control charts are inappropriate.

Adjustment Charts

- Optimum adjustment limits are most likely not ±3 standard errors as found on a control chart

- The adjustment strategy must be determined with care - how much and when do you adjust?

Adjustment Charts

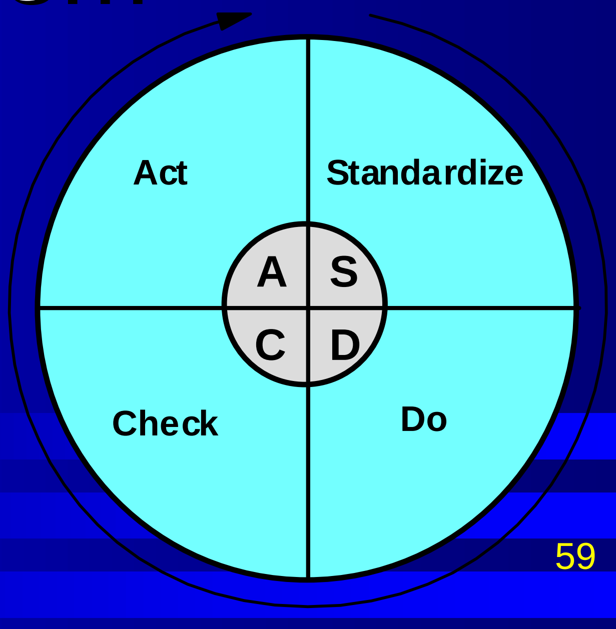
- For more information see:

  - *Statistical Quality Control by Monitoring and Feedback Adjustment*

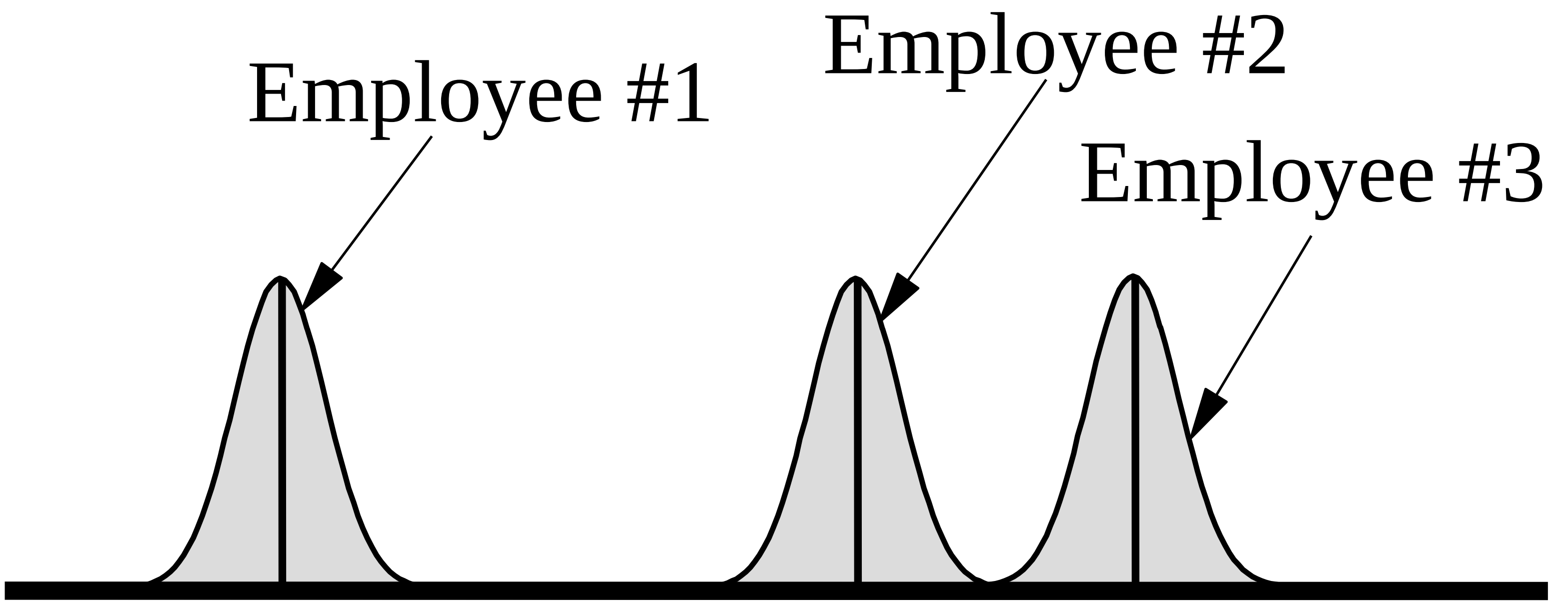
    George Box & Alberto Luceno

Standardized Operations

- Standardization minimizes variation in materials, methods, equipment, and people
- Eliminates potential problem conditions
- Minimizes variation in output.



Non-Standardized Work Instructions



Three excellent employees, with combined mediocre output!

Standardized Operations

Standardized operations are a "state" not a "document"

Reliability Methods

- Include a wide range of tools and techniques
- Once stability is achieved, process failures can still occur through deterioration and breakdown of equipment
- Equipment failure is often the root-cause of nonconformance and excessive variability.

Process Control Strategy

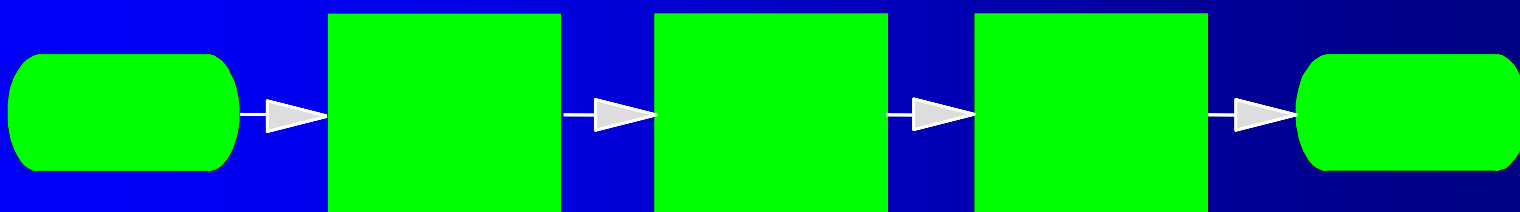
Process Control Strategy

- The following strategy may be used to systematically analyze processes and develop control methods

- This strategy combines elements of Control Plans, Process Failure Mode and Effects Analysis, and Root-Cause Analysis.

Step 1) Process Blocks

- Construct a high level process flow diagram which identifies the major process operations or “blocks”



Step 2) Output Characteristics

- Identify product output characteristics
  - Label each characteristic in terms of a deficiency: either a negative attribute or excess variation
- This is a comprehensive list of anything that can go wrong in the product
  - No customer complaint or scrapped product should occur for something not on this list.

Step 2) Output Characteristics (Cont.)

- Examples
  - Voids
  - Cracks
  - Excess variation in flatness
  - Excess variation in diameter

Step 3) Priority

- Identify characteristic contributions to complaints, scrap, and outgoing nonconforming levels
  - May start with a High, Medium, Low scale or data from Pareto charts
  - Use this information for prioritization.

Step 4) Causes

- For each characteristic determine the principle causes in a causal chain
  - Capture 3-5 levels, three for the first pass

Example

Mold Flash

caused by Pellet Placement,

caused by Timing Error,

caused by Worn Pulley

Step 5) Cause Frequency

- Identify frequency of problem causes
  - May be done initially using a High, Medium, and Low scale
  - May be used for prioritization
  - Check sheets may be generated to obtain actual data.

Step 6) Detection and Reaction

- Identify detection and reaction methods for the problem and problem causes
  - Important if problems cannot be prevented
  - Not required at all levels
  - Noting the level that detection is available will be useful
  - Reaction methods are the actions taken when the problem or cause occurs
  - Can be manual or automatic.

Step 7) Prevention

- Identify the prevention methods for problem causes
  - These are the means used to prevent, minimize the occurrence, or reduce the effect of the causes
  - Prevention method categories may include: product, process, and tooling design; operating parameters; work instructions; materials; and preventive maintenance.

Step 8) Effectiveness and Execution

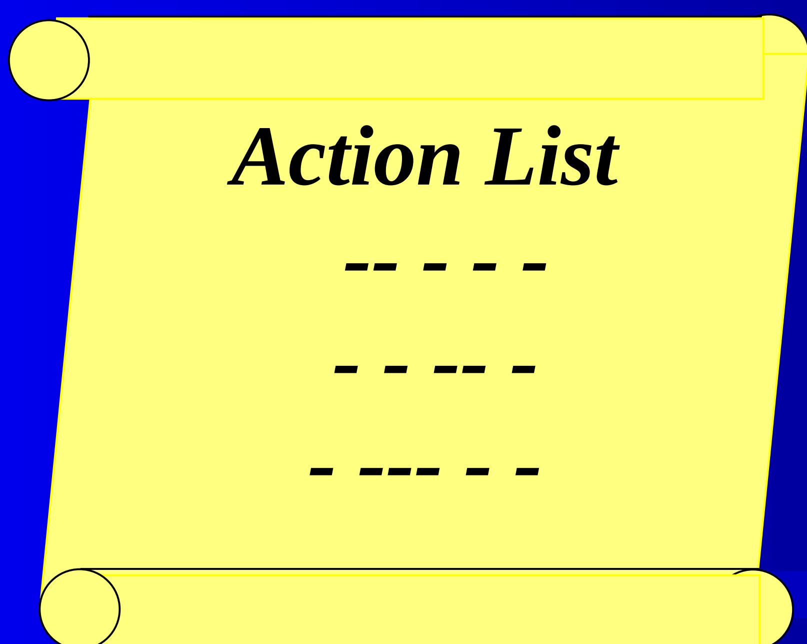
- Identify “effectiveness” and “execution” of the current control methods
  - Use a Low, Medium, High scale
  - Effectiveness refers to how well the methods work
  - Execution refers to how well the methods are actually carried out
  - Data collection will yield objective data.

Step 9) Potential Controls

- Record potential control methods or improvements
  - These may be past methods employed or new ideas.

Step 10) Action Items

- List action items and develop action plans



Process Control Strategy Summary Information

- Process Block
- Characteristic
- Priority
- Causes
  - Level 1 Cause
  - Level 2 Cause
  - Level 3 Cause
- Frequency
- Detection Method
- Detection Reaction
- Prevention Method
- Effectiveness
- Execution
- Potential Controls
- Actions

Process Control Strategy

- The strategy is dynamic
- Continuous effort will improve the control methods used
- Problem solving efforts should result in updating the control strategy
- Your control technology will be documented with this strategy.

Summary

Summary

- Remember the quality goals
- Define control as the ability to constrain variation and prevent nonconformance over time
- Use process performance measures
- Consider a broad range of methods to control processes
- Use a systematic process control strategy.

Questions

Further Questions: E-mail

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The End