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A Control Charting Method to Judge the Performance of Feed Systems

M. Gallant, B. Newton, S. Johnson, and R. Muscato

Naval Surface Warfare Center/Indian Head Division

Indian Head, MD

Continuous Mixer and Extruder Users Group Meeting

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ARDEC, Picatinny Arsenal, NJ

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Overview

- Importance of Understanding Feeding Behavior
- Methods to Quantify Feeding Behavior
- Shortcomings of Traditional Methods
- Strengths of Charting Methods

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Conventional Wisdom

- Product Quality Direct Function of Feeder Performance
- Consistent, Accurate, Low Variance
- As Important as Screw Design
- Loss-in-Weight Choice for Solids
- Continually Ensuring Optimum Performance

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Common Methods

- Manual Catch Samples—Typically one per min. for 5-20 min.
  - Not Good for Smaller Time Intervals
  - Limited to Inert Ingredients
  - Operator Dependent
- Watch Electronic Balance using CCTV—30 sec. intervals
  - Not Good for Smaller Time Intervals
  - Operator Dependency Worse
- Data Manually Recorded and Analyzed

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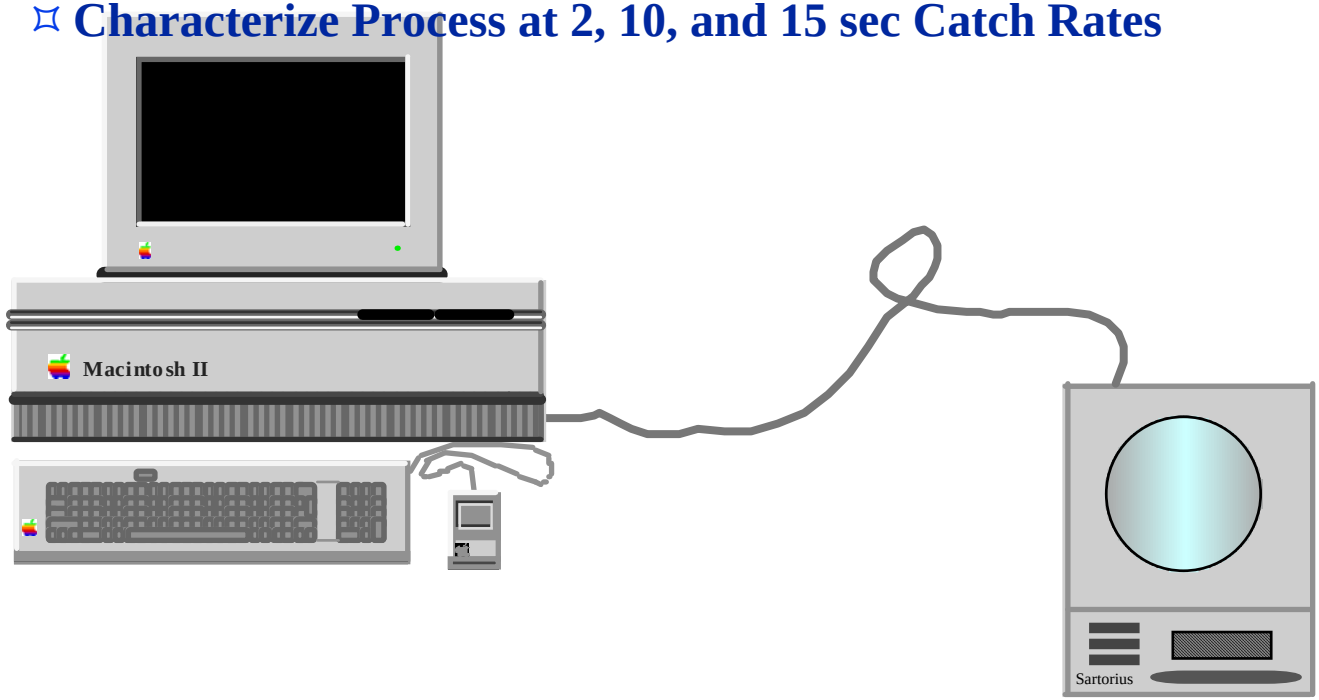
Technique Used by NSWC/Indian Head

- Computerized Data Acquisition Directly from Electronic Balance
  - Mass Delivered in 1/2 sec Intervals
  - Characterize Process at 2, 10, and 15 sec Catch Rates



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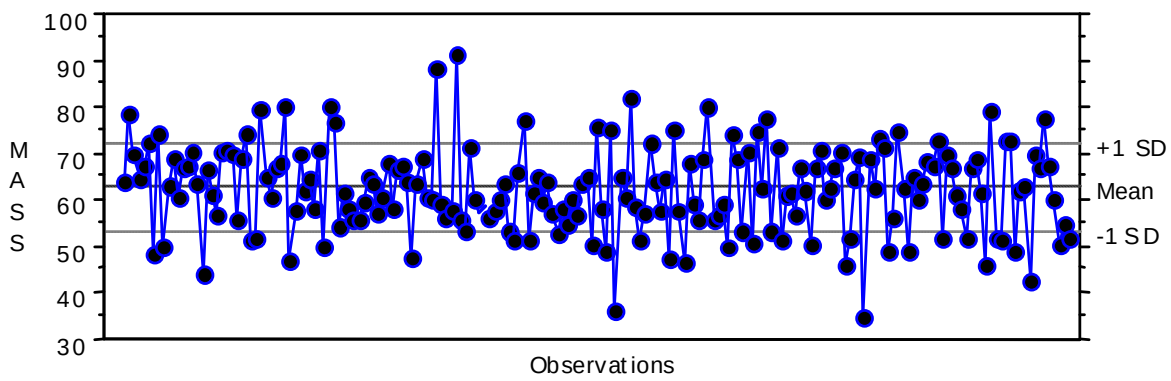
Acceptable Performance is Often Subjective

- Data from 10 sec Sampling Interval
- Is This Good or Bad?
- Is This Process in a State of Control?

$$\overline{X} = 62.9 \text{ and } \sigma = 9.39$$



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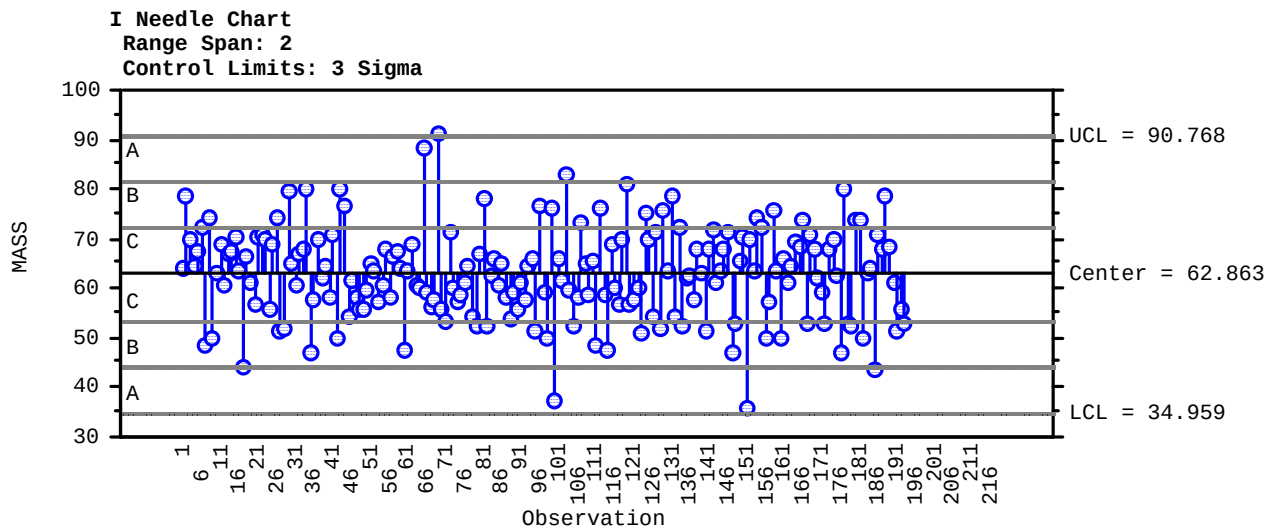
Modern Quality Control Charting

- Monitor Process Performance
  - Controlled vs. Uncontrolled Process Variance
- Define a State of Statistical Control
  - Process Drift
  - Identify Best Operating Conditions



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Application of Charting Techniques to Feeder Data

- Choice of Charting Technique
  - Nature of Measured Output
  - Degree of Sensitivity to Process Shifts
- Evolution of Charting Techniques
  - Collectively Named after Shewart
  - Reduce the Average Run Time (ARL)

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Statistical Analysis of Feeder Data

- **Direct Plotting Using Common Techniques will Lead to False Indications**
  - ***R*, *s*, and *X*-bar Charts**
- **Feeder Performance Data**
  - **Normally Distributed Bad Assumption**
  - **Data Are Not Independent**
  - **Values Are Not Randomly Occurring**
- **Autocorrelated Data**
  - **Every Value is Dependent upon Prior Neighbor(s)**
  - **Describe Process Using Time Series Analysis**
- **Residuals from Time Series Model are Normally Distributed**

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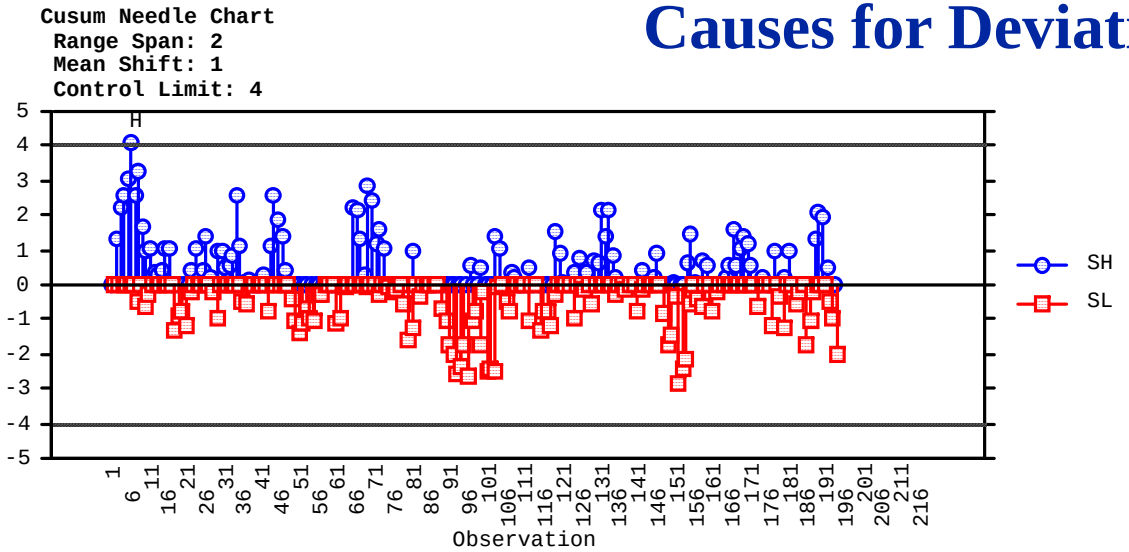
CUSUM: Cumulative Sum Charting

- Page, 1954
- Sensitive to Small Shifts in the Mean
- Chart Consists of Two Plots
  - Positive and Negative Mean Shifts
- Control Limits Set at 4 or 6 Sigma
- CUSUM Value Exceeds Control Limit-Mean Shift has Occurred
- Determine Assignable Causes for Deviations



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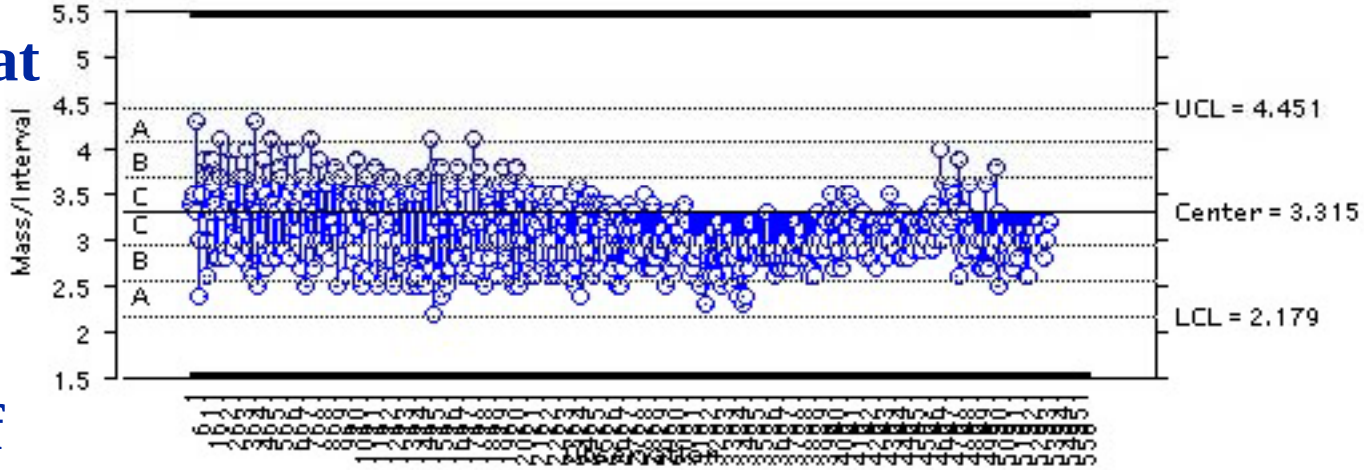
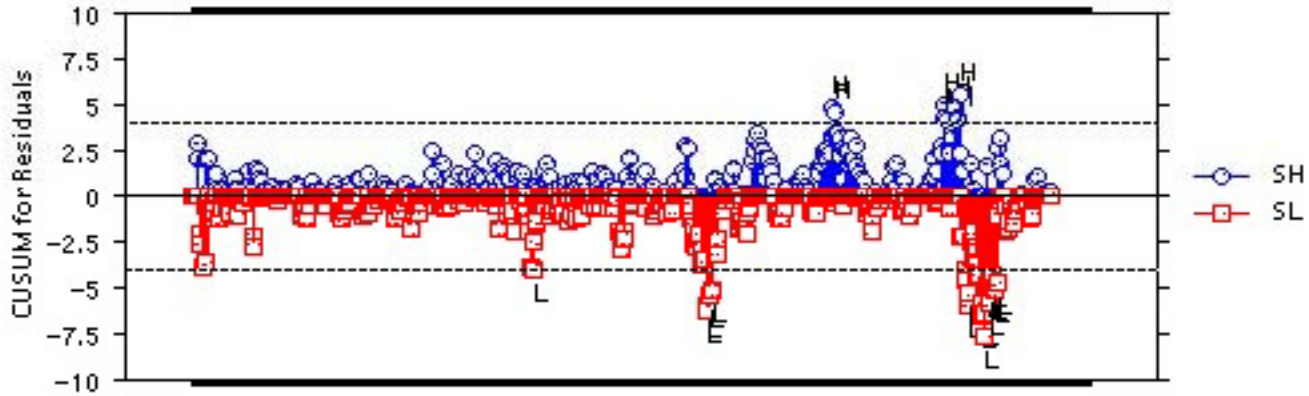
Example of CUSUM Applications

- A Feeder That Consistently Underfed a Particular Material
- Small Part of Formulation
- Full Hopper Test
- Minimum Head Height





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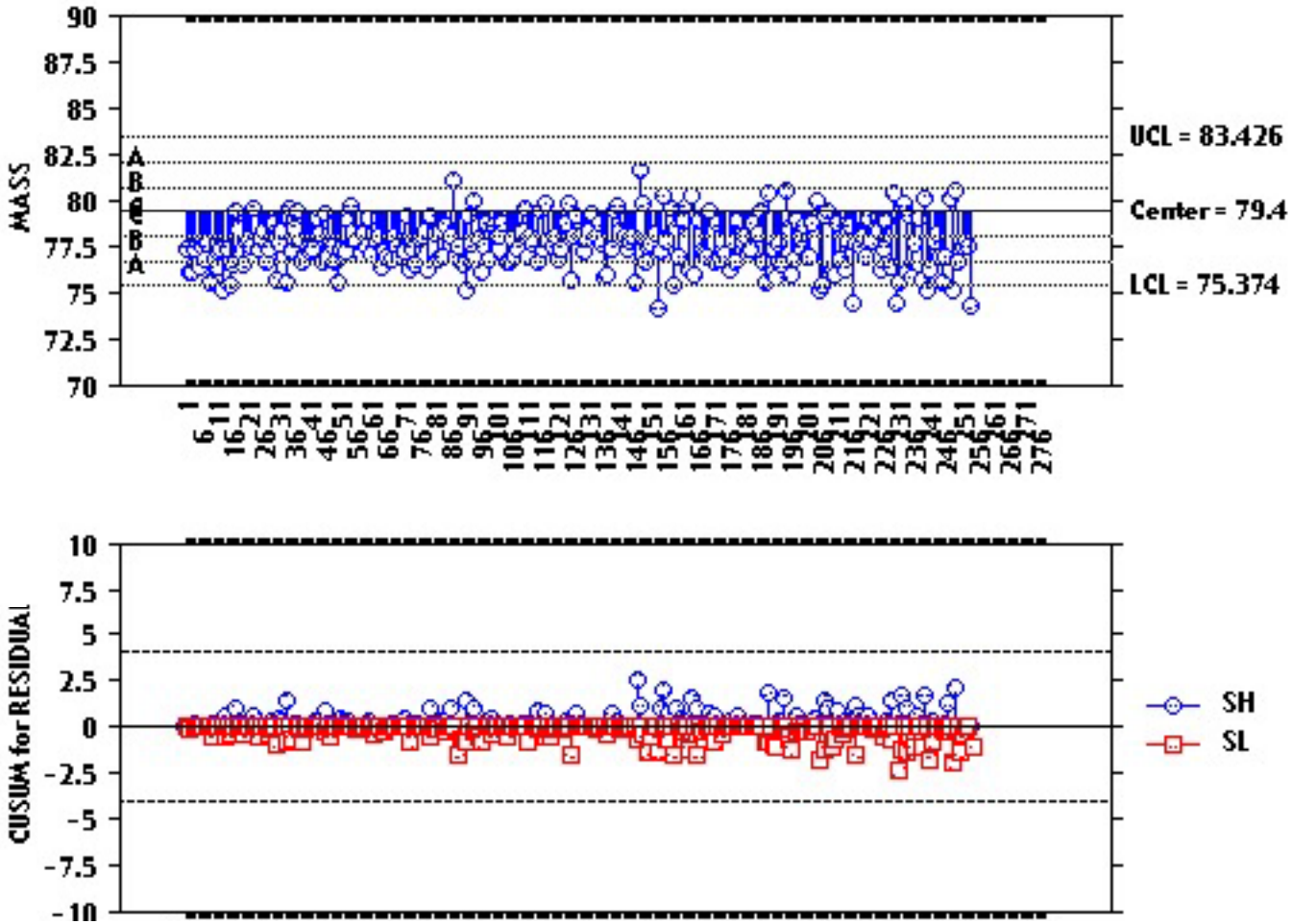
Another CUSUM Example

- Full-Up Feed Tests
- Chute & Vibration
- Dust Storm
- Material Lost
- Still in Control?



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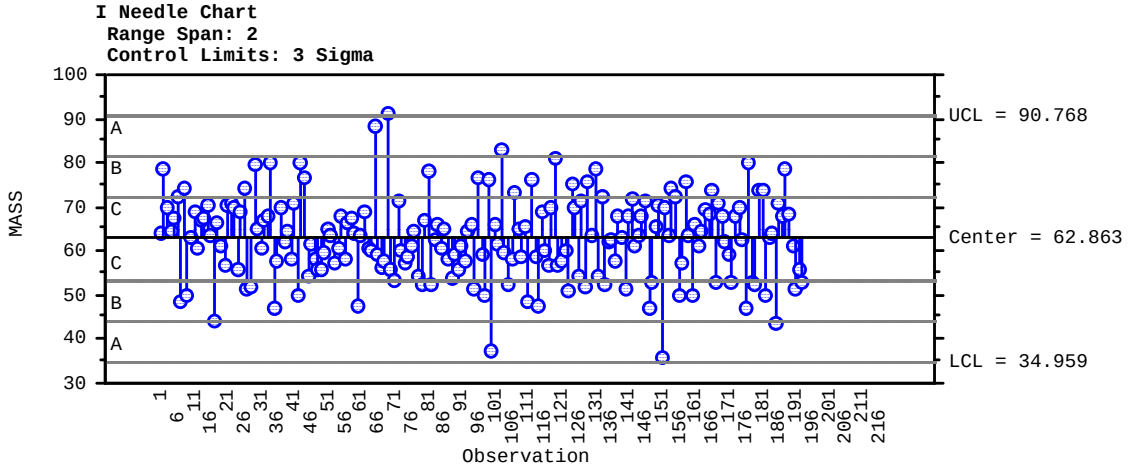
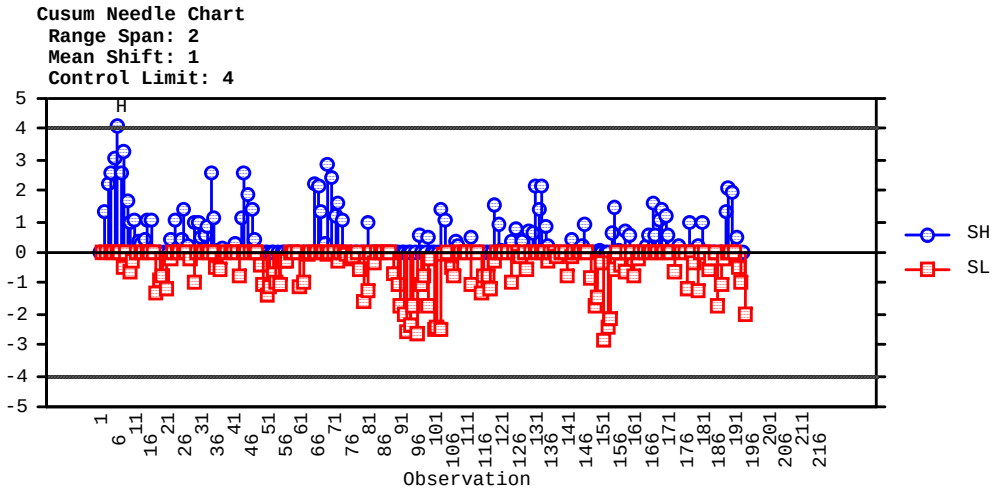
Final CUSUM Example

- Start-up Effects
- Time Until Process Achieves State of Control





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Conclusion

- Can Benefit from the Power of Control Charting Techniques
- Must Use Care in Selection and Application of Technique: Assumptions and Violations
- CUSUM Method is Well-Suited to Feeder Data
- Responsive to Variety of Effects and Disturbances