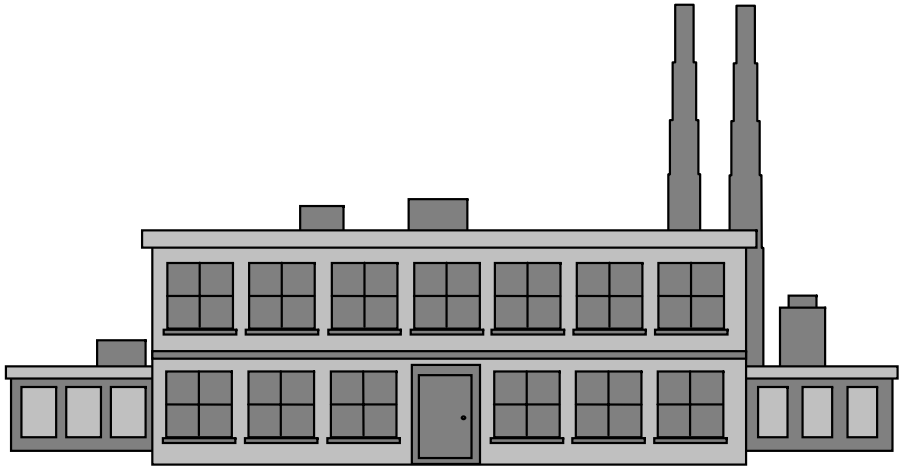
Introduction to Statistical Process Control



The assignable cause

The Control Chart

Statistical basis of the control chart

Control limits, false and true alarms and the operating characteristic function

Managing Variation over Time

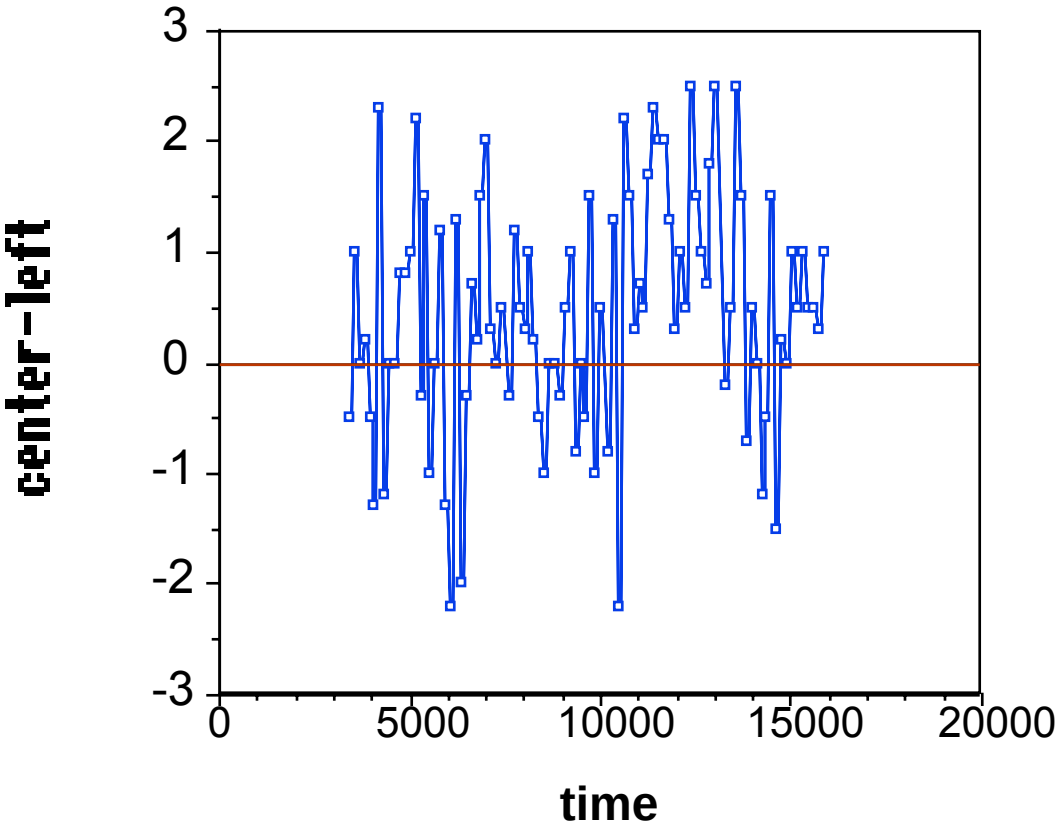
- Statistical Process Control often takes the form of a continuous Hypothesis testing.
- The idea is to detect, as quickly as possible, a significant departure from the norm.
- A significant change is often attributed to what is known as an *assignable* cause.
- An *assignable* cause is something that can be discovered and corrected at the machine level.

What is the Assignable Cause?

- An "Assignable Cause" relates to relatively strong changes, outside the random pattern of the process.
- It is "Assignable", i.e. it can be discovered and corrected at the machine level.
- Although the detection of an assignable cause can be automated, its identification and correction often requires intimate understanding of the manufacturing process.
- For example...
  - Symptom: significant yield drop.
  - Assignable Cause: leaky etcher load lock door seal.
  - Symptom: increased e-test rejections
  - Assignable Cause: probe card worn out.

Example:

Investigate furnace temp and set up a real-time alarm.



The pattern is obvious. How can we automate the alarm?

The purpose of SPC

A. Detect the presence of an assignable cause fast.

2. Minimize needles adjustment.

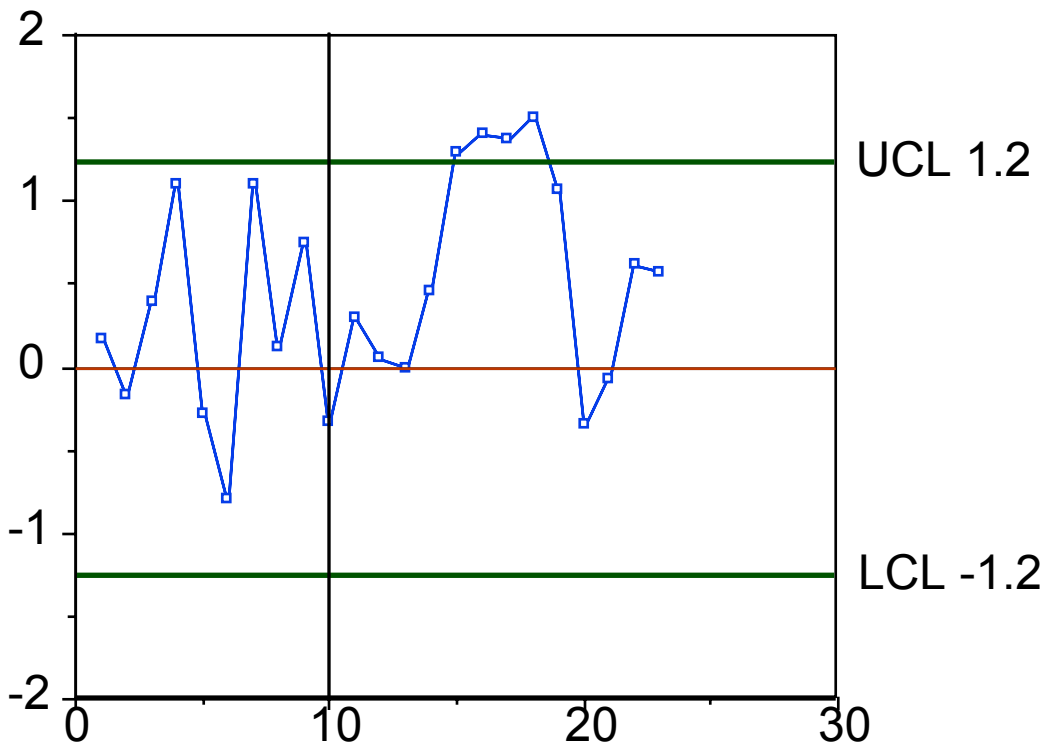
- Like Hypothesis testing
  - (A) means having low probability of type II error and
  - (B) means having low probability of type I error.

- SPC needs a probabilistic model in order to describe the process in question.

Example: Furnace temp differential (cont.)

Group points and use the average in order to plot a known (normal) statistic.

Assume that the first 10 groups of 4 are in Statistical Control. Limits are set for type I error at 0.05.



Example (cont.)

- The idea is that the average is normally distributed.
- Its standard deviation is estimated at .6333 from the first 10 groups.
- The true mean (μ) is assumed to be 0.00 (furnace temperature in control).
- There is only 5% chance that the average will plot outside the μ+/- 1.96 σ limits if the process is in control.

In general:

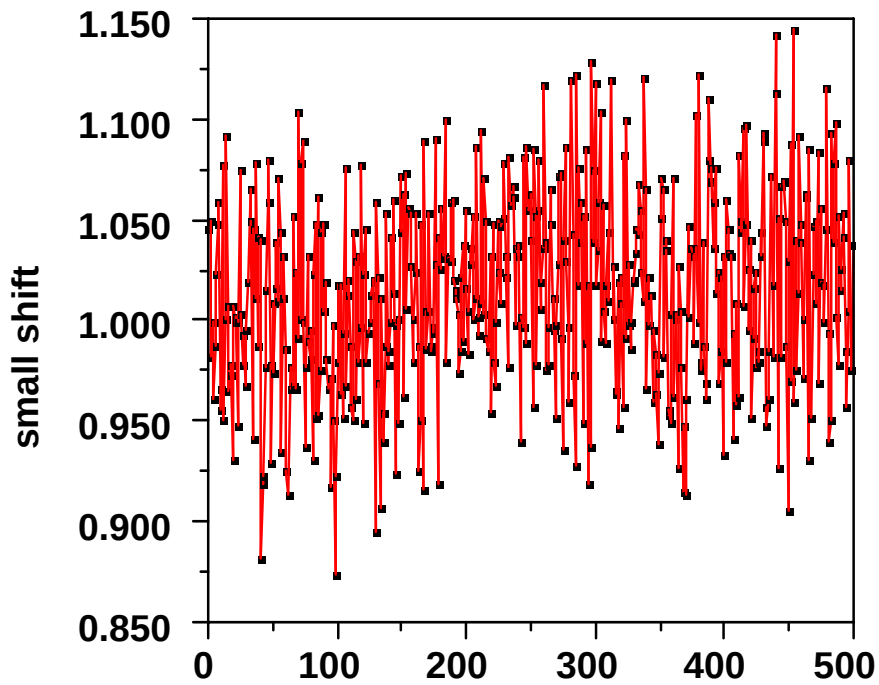
UCL = $\mu + k\,\sigma$

LCL = $\mu - k\,\sigma$

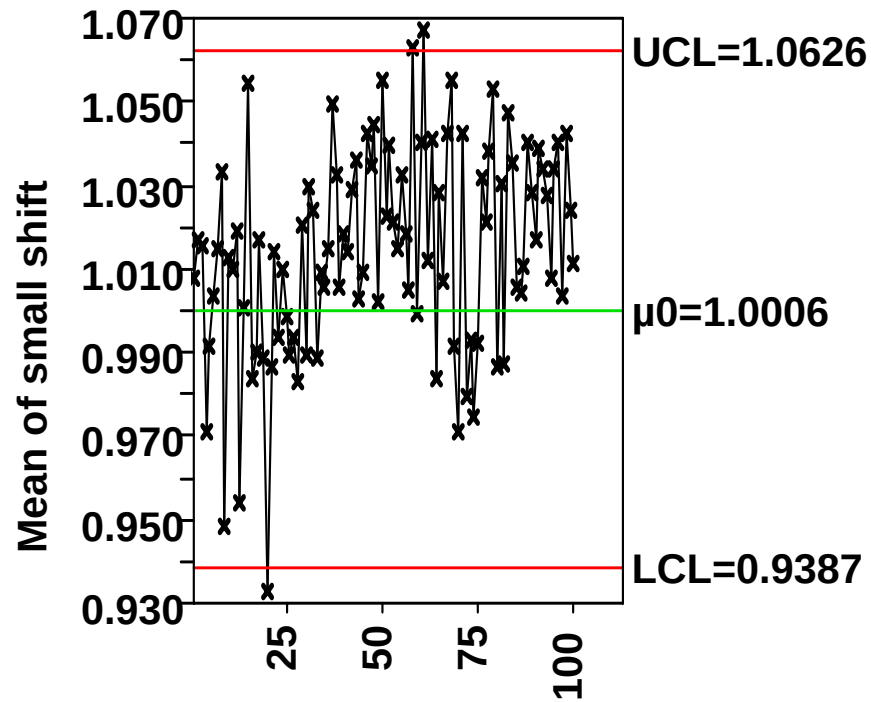
where μ and σ relate to the statistic we plot.

Another Example

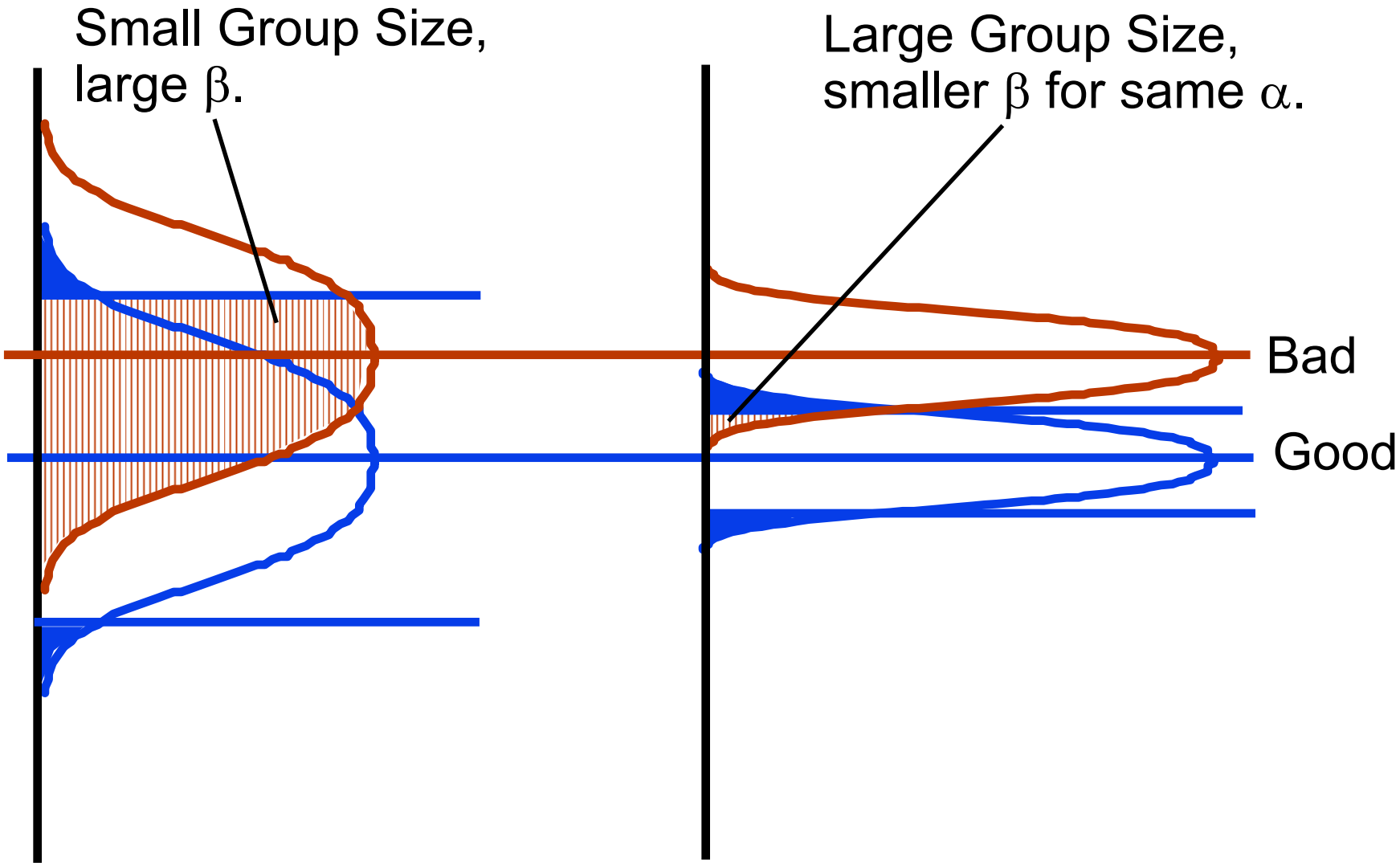
Original data



Averaged Data (n=5)



How the Grouping Helps



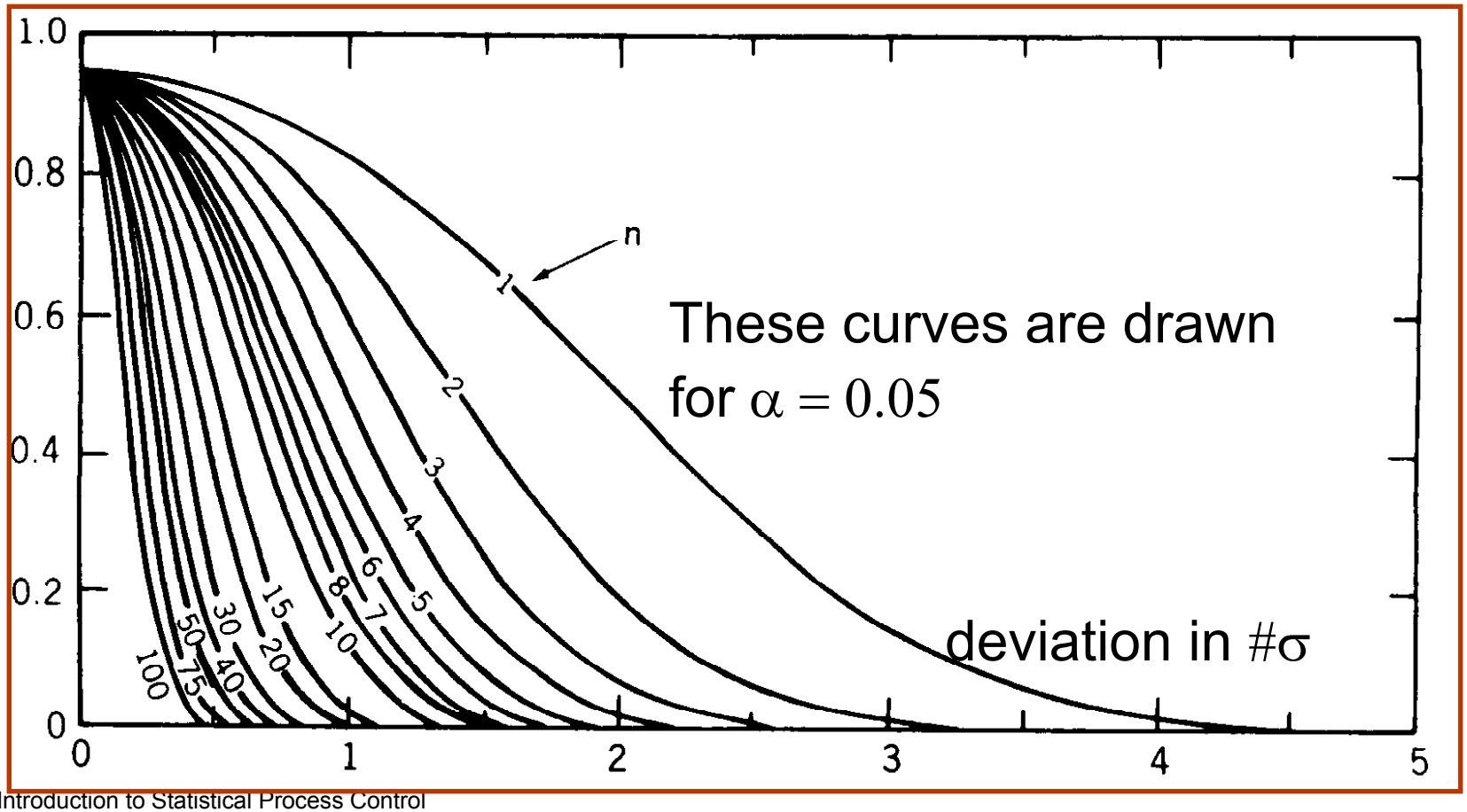
Average Run Length

- If the type I error (α) depends on the original (proper) parameter distribution and the control limits, ...
- ... the type II error (β) depends on the position of the shifted (faulty) distribution with respect to the control limits.
- The average run length (ARL) of the chart is defined as the average number of samples between alarms.
- ARL, in general, is $1/\alpha$ when the process is good and $1/(1-\beta)$ when the process is bad.

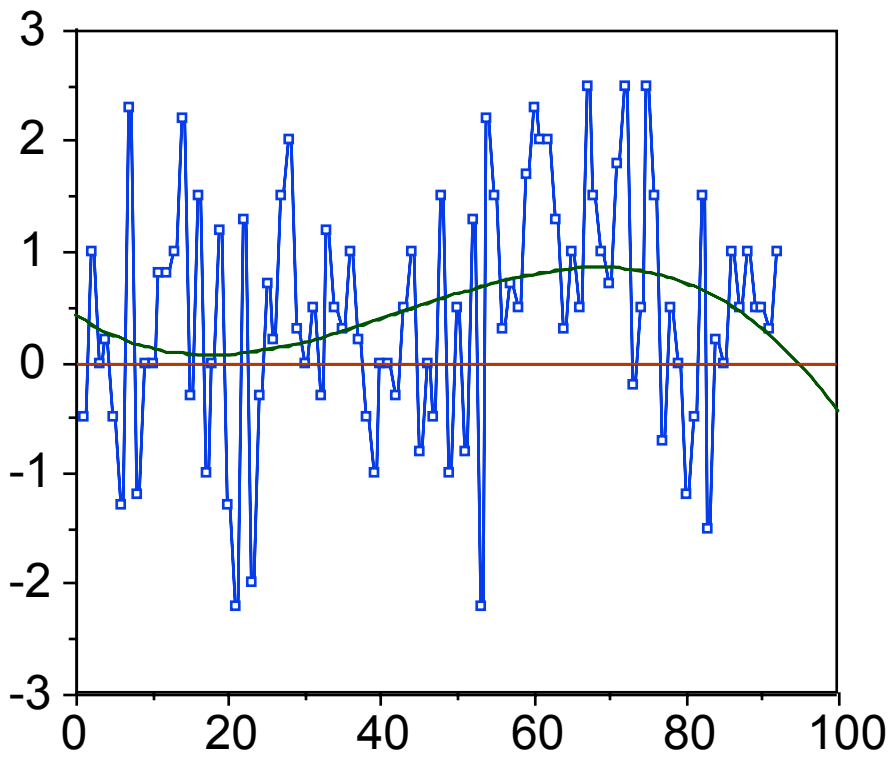
The Operating Characteristic Curve

The Operating Characteristic of the chart shows the probability of missing an alarm vs. the actual process shift.

Its shape depends on the statistic, the subgroup size and the control limits.



Pattern Analysis



Other rules exist: Western Electric, curve fitting, Fourier analysis, pattern recognition...

Example: Photoresist Coating

- During each shift, five wafers are coated with photoresist and soft-baked. Resist thickness is measured at the center of each wafer. Is the process in control?
- Questions that can be asked:

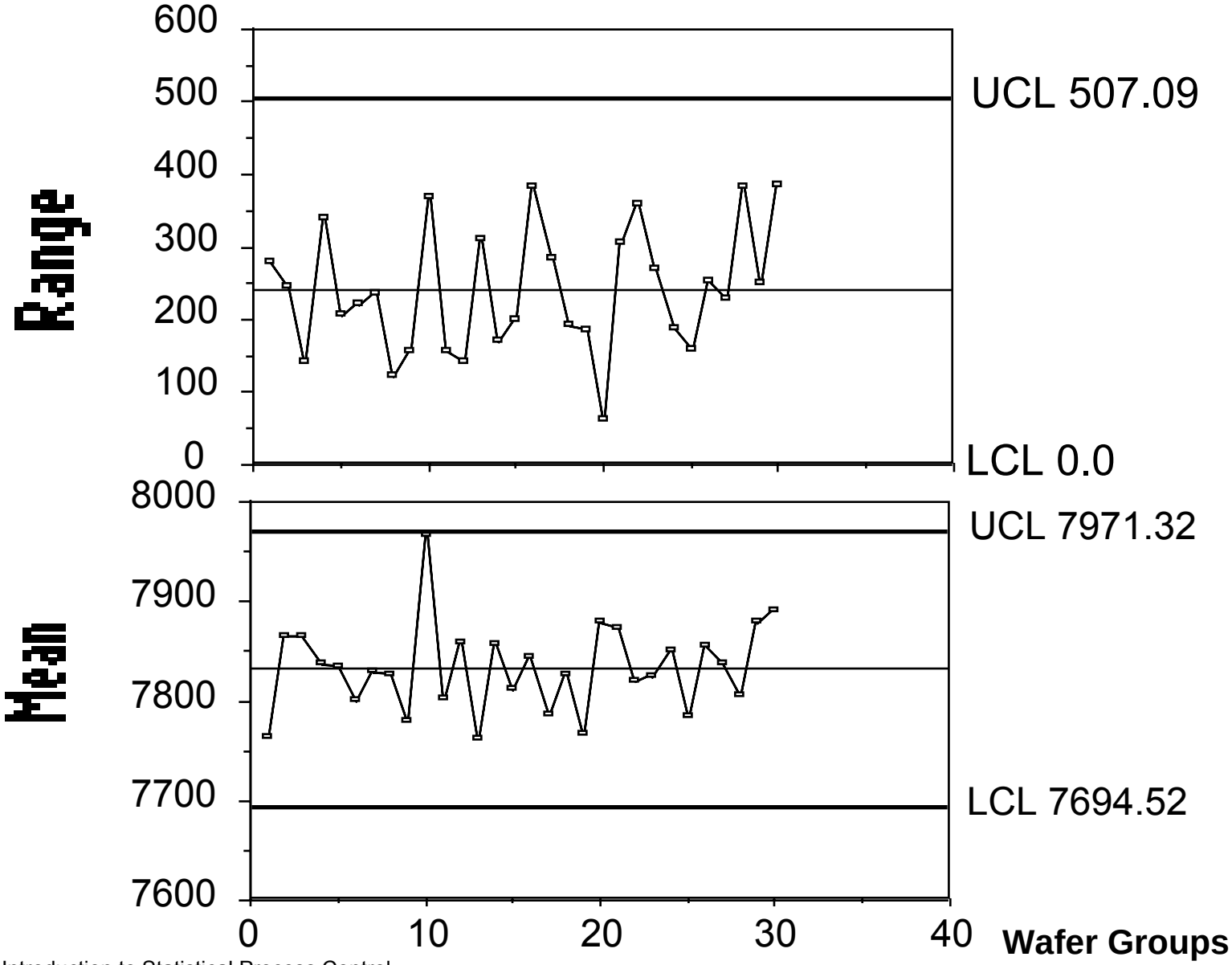
a) Is group variance "in control"?

b) Is group average "in control"?

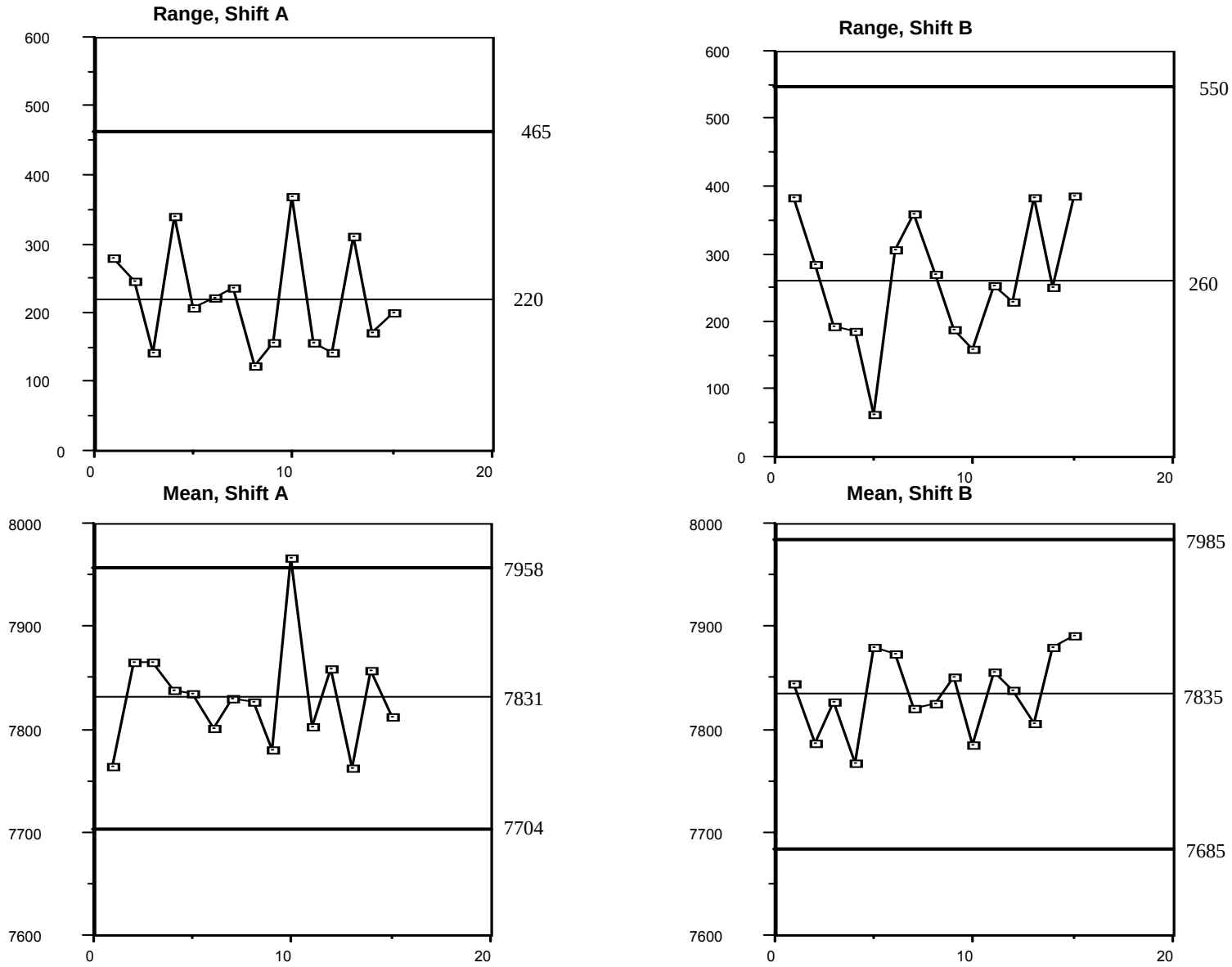
c) Is there any difference between shifts A and B?

- In general, we can group data in many different ways.

Range and $\bar{x}$ chart for all wafer groups.



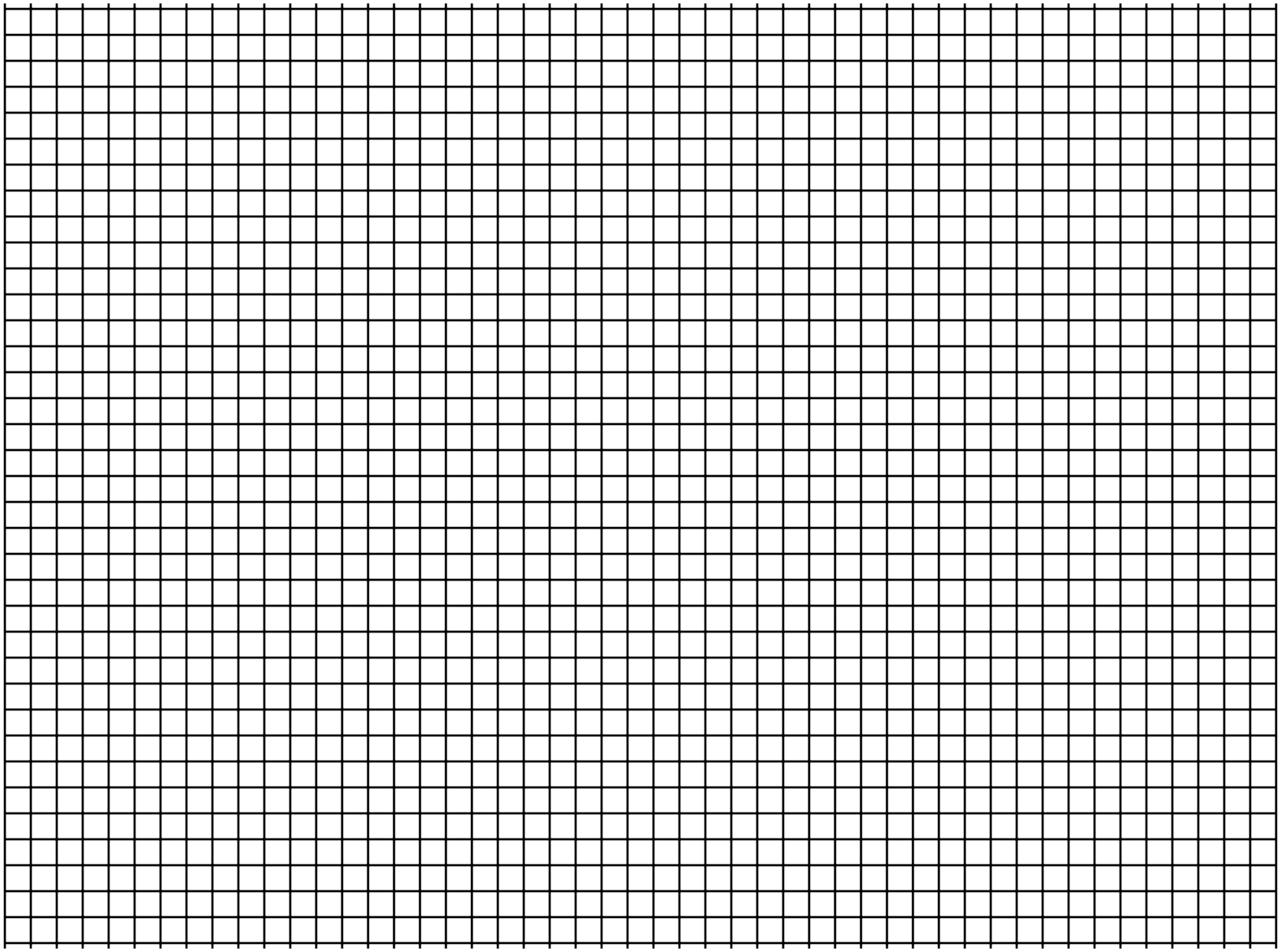
Comparing runs A and B



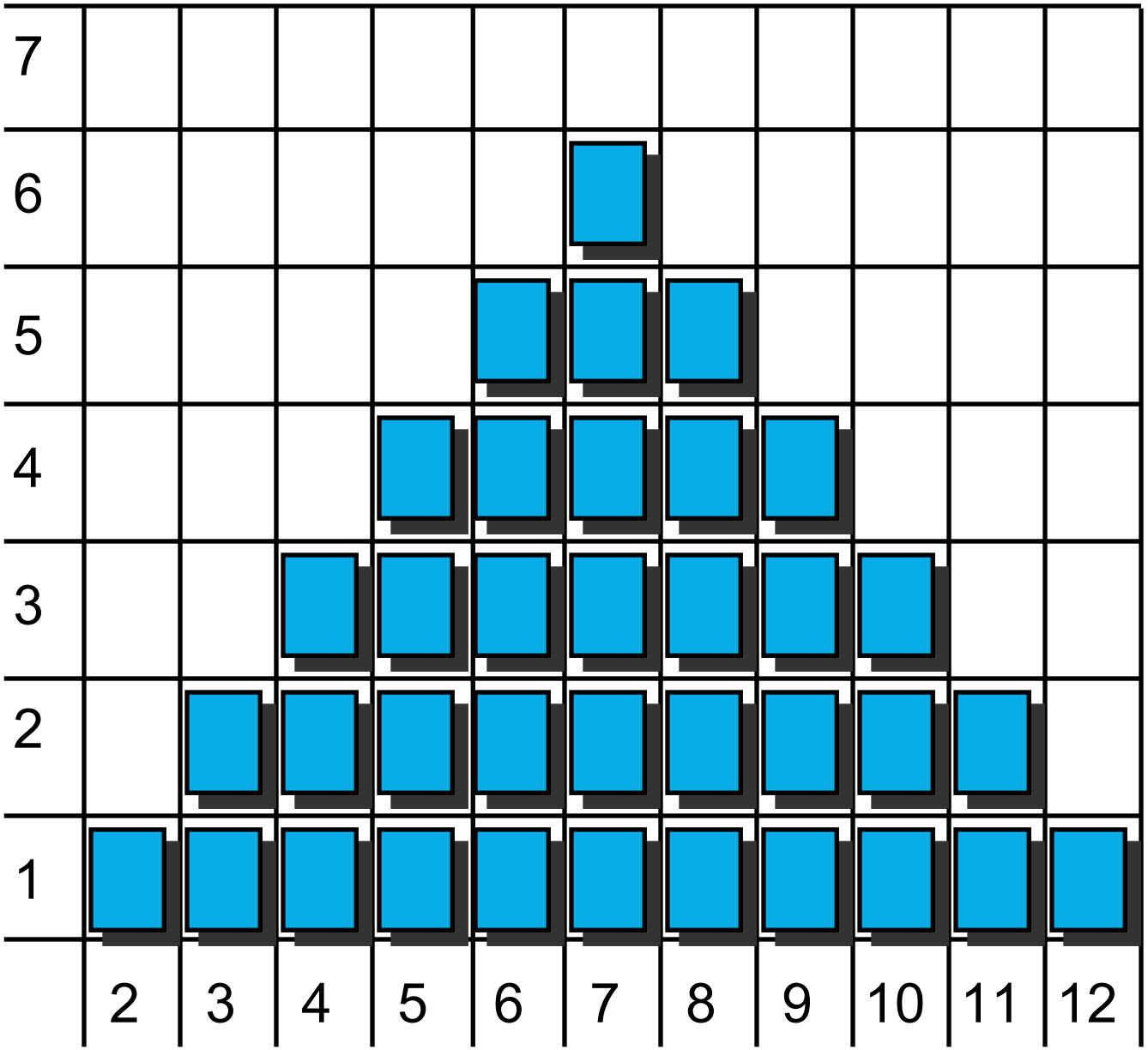
Why Use a Control Chart?

- Reduce scrap and re-work by the systematic elimination of assignable causes.
- Prevent unnecessary adjustments.
- Provide diagnostic information from the shape of the non random patterns.
- Find out what the process can do.
- Provide immediate visual feedback.
- Decide whether a process is production worthy.

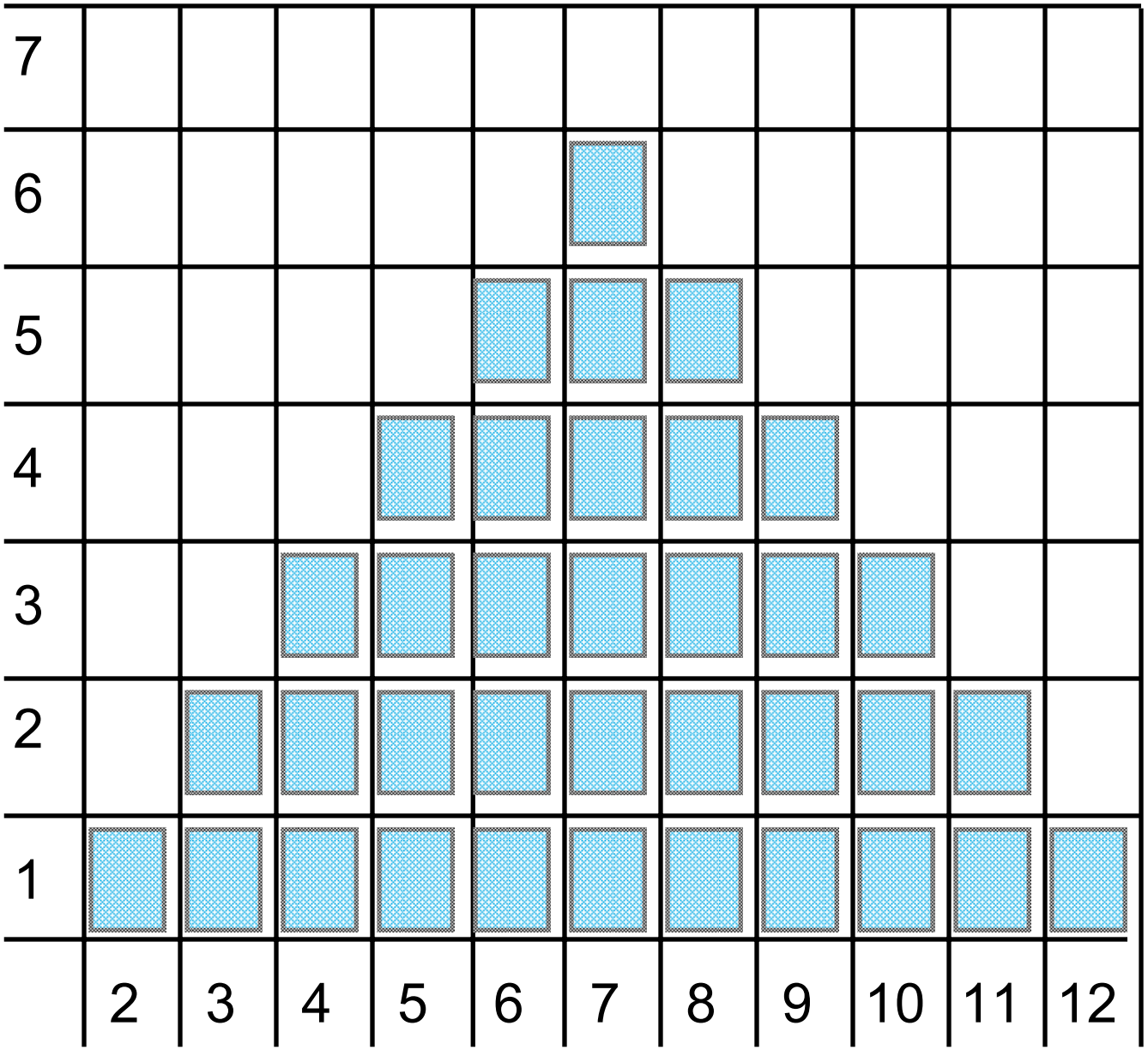
The Control Chart for Controlling Dice Production



The Reference Distribution



The Actual Histogram



In Summary

- To apply SPC we need:
- Something to measure, that relates to product/process quality.
- Samples from a baseline operation.
- A statistical “model” of the variation of the process/product.
- Some physical understanding of what the process/product is doing.