Lecture #33

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Chapter 11
Control Charts for Individuals

- **Ordinarily we want to take samples of size 4-6 from a process -- then chart the X-bars & Rs.**

- **Sometimes it may seem attractive to not take samples & instead just work with individuals. Too much effort, too costly, why bother??**

- **Don't fall into the trap & take the easy way out. When we work with just individuals we lose chart sensitivity and are left with no way to estimate the process (common cause) variability.**

Are there circumstances when a control chart for individuals is appropriate?? ----- YES!!

- Sometimes it makes no sense to make several measurements of a process (form a rational sample)
  - Oven temperature
  - Airborne particulate count
  - Accounts receivable
  - Machine downtime

- Characteristics from many of these phenomena don't differ substantially in time & space

- Values only differ due to measurement/reading errors

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X and R$_m$ Charts

Rm: Moving Range -- determine this by considering windows of X's'

Samp #	1	2	3	4	5	6	7	8	9	10
X	12	15	13	12	14	18	13	16	15	12

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Constructing the Charts

$$\bar{X} = \frac{\sum\limits_{i=1}^{k} X_i}{k}$$

$$\bar{R}_m = \frac{\sum\limits_{i=1}^{k-n+1} R_{mi}}{k-n+1}$$ **n is the artificial sample size**

Plot the Xs and Rms using standard conventions

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Constructing the Charts

Centerlines: use $\bar{X}$ and $\bar{R}m$

Control Limits for the Rm (moving range) chart:

From Appendix Table A.2 use D_3 & D_4 for sample size n

$$LCL_R = D_3 \cdot \bar{R}_m$$

$$UCL_R = D_4 \cdot \bar{R}_m$$

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Control Limits for the X chart:

1st step -- use $\overline{\text{Rm}}$ to estimate σ_x.

$$\hat{\sigma}_x = \overline{R}_m / d_2 \quad \text{Table A.2 } d_2 \text{ for sample size n}$$

Then use this estimate to get limits for X chart.

$$LCL_X = \overline{X} - 3\hat{\sigma}_x$$

$$UCL_X = \overline{X} + 3\hat{\sigma}_x$$

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Case Study: White Millbase Dispersion Process

Automotive paint plant -- batch processing of white millbase.

Process begins by charging sand grinder premix tank with resin, pigment, and other additives. Premix agitated. Small portion of slurry pumped thru sand grinder. Grinder output checked for fineness & gloss.

Batch may require adjustments (pigment/resin additions) to achieve acceptable gloss. Batches require too many adjustments (adjustment/test takes 4 hours).

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Quality Characteristic: Weight/Gallon

Overcharge of pigment (high density): too heavy
Overcharge of resin (low density): too light

Wts. from 30 consecutive batches recorded

Artificial sample size of 2 used.

See Table 11.1

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$$\overline{X} = 14.311$$

$$\overline{R}_m = 0.294$$

$d_2 = 1.128$ for n=2, so estimate of σ_X is

$$0.294 \, / \, 1.128 = 0.261$$

$$LCL_R = 0 \cdot 0.294 = 0$$

$$UCL_R = 3.27 \cdot 0.294 = 0.963$$

$$LCL_X = 14.311 - 3(0.261) = 13.528$$
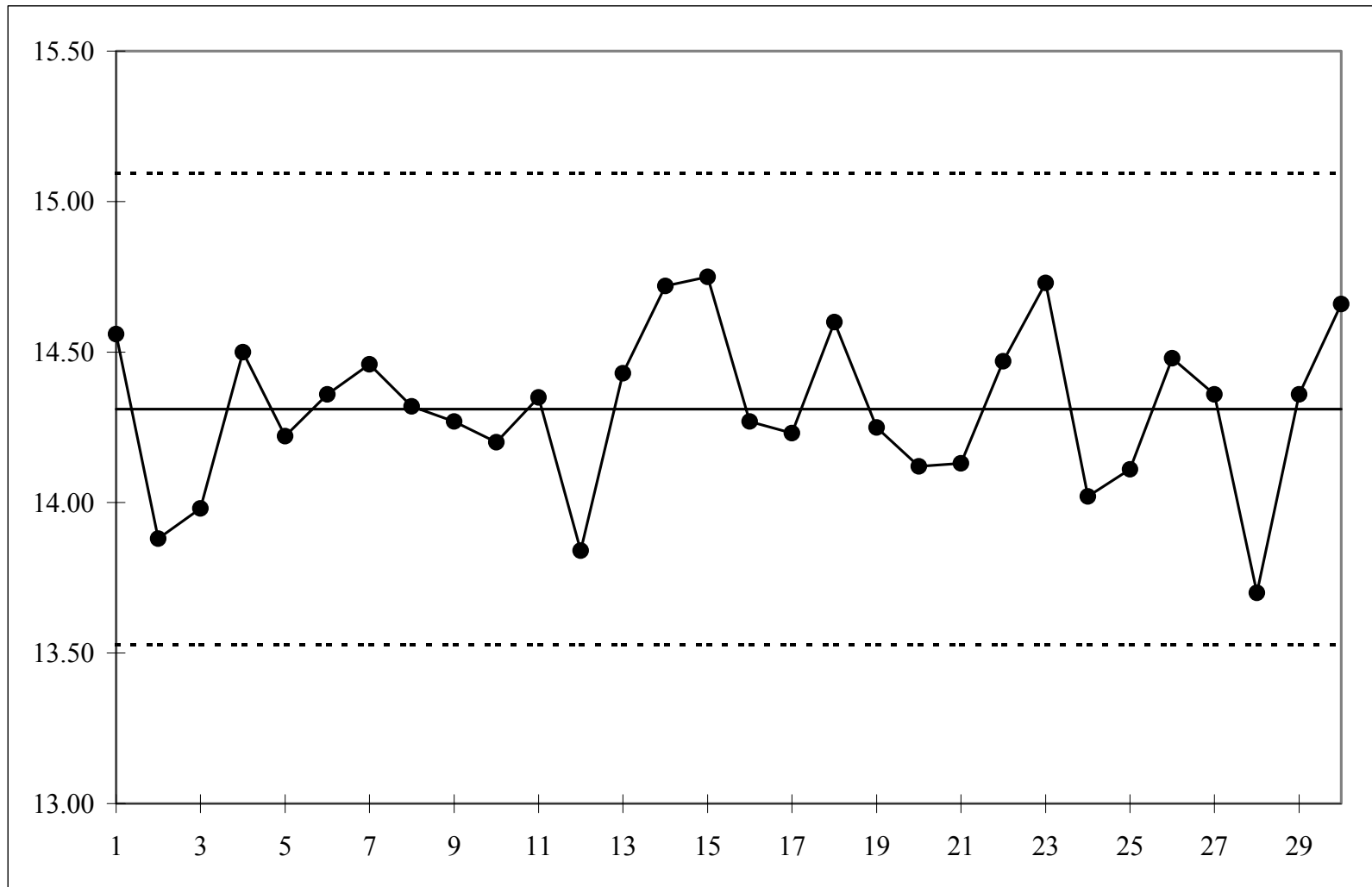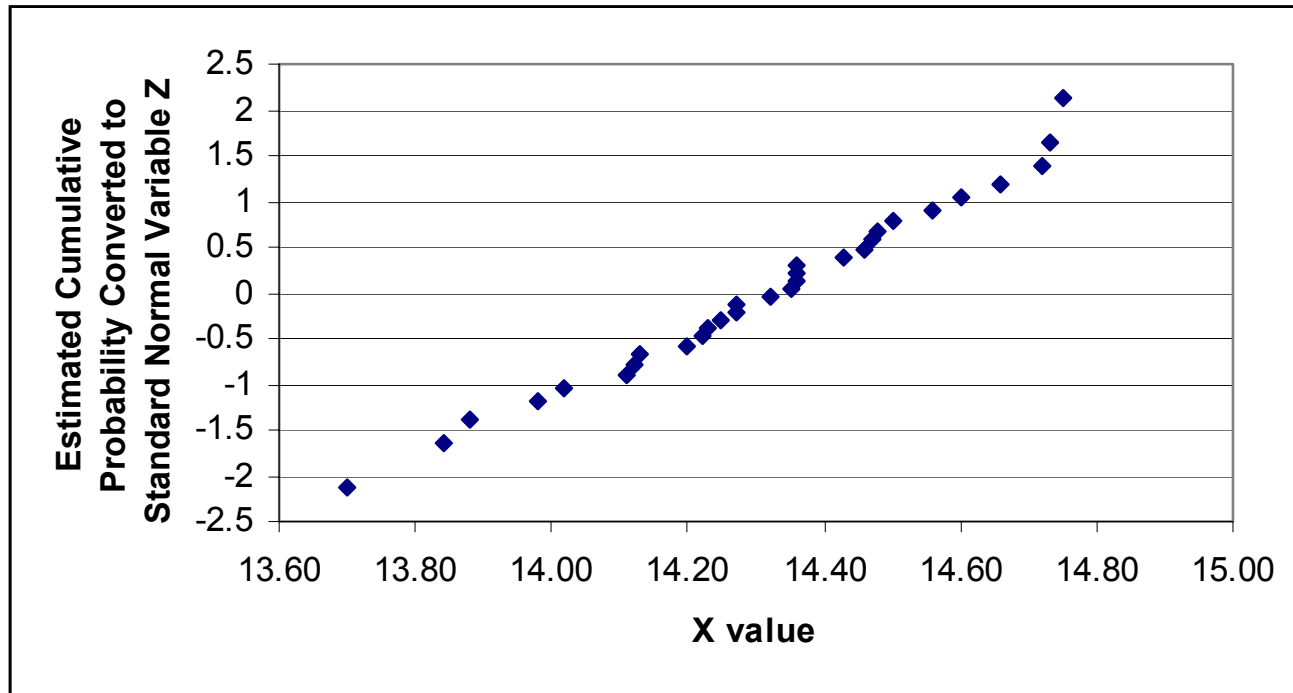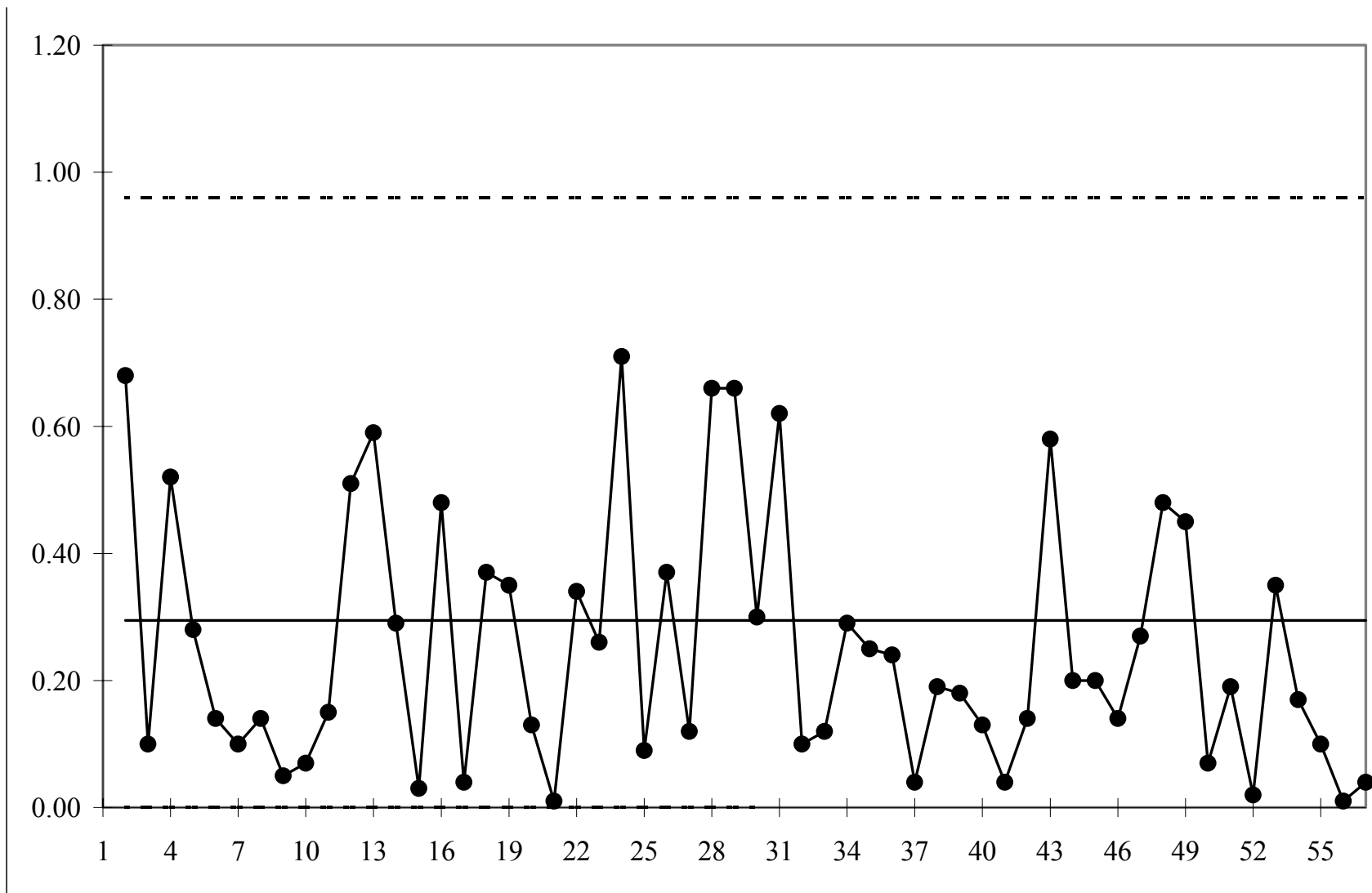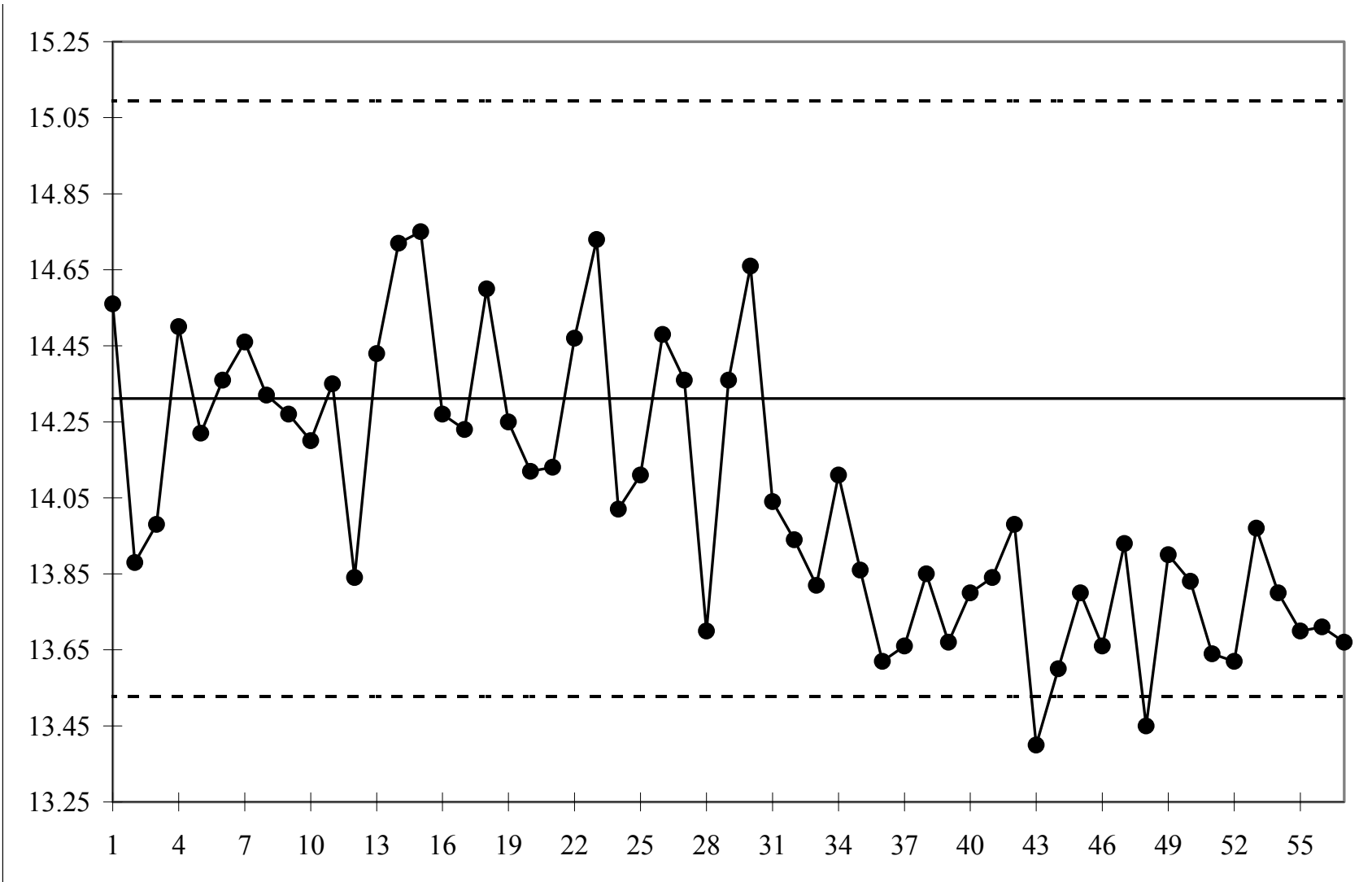
$$UCL_X = 14.311 + 3(0.361) = 15.094$$

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1.20

1.00

0.80

0.60

0.40

0.20

0.00

1   3   5   7   9   11   13   15   17   19   21   23   25   27   29

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Chart Interpretation

- **Generally can only use 4 of the rules on both X and Rm charts since no guarantee that Xs are normal.**

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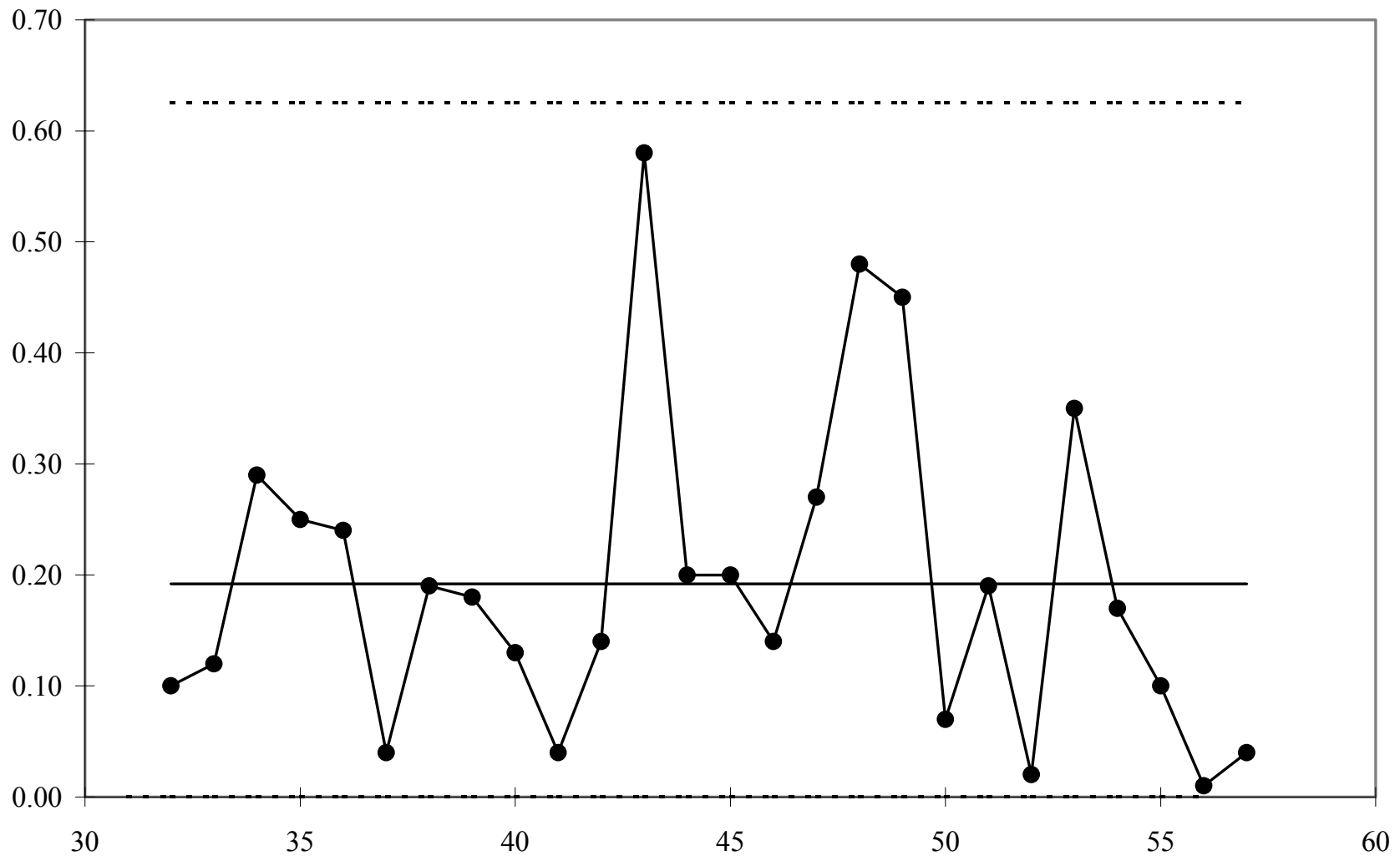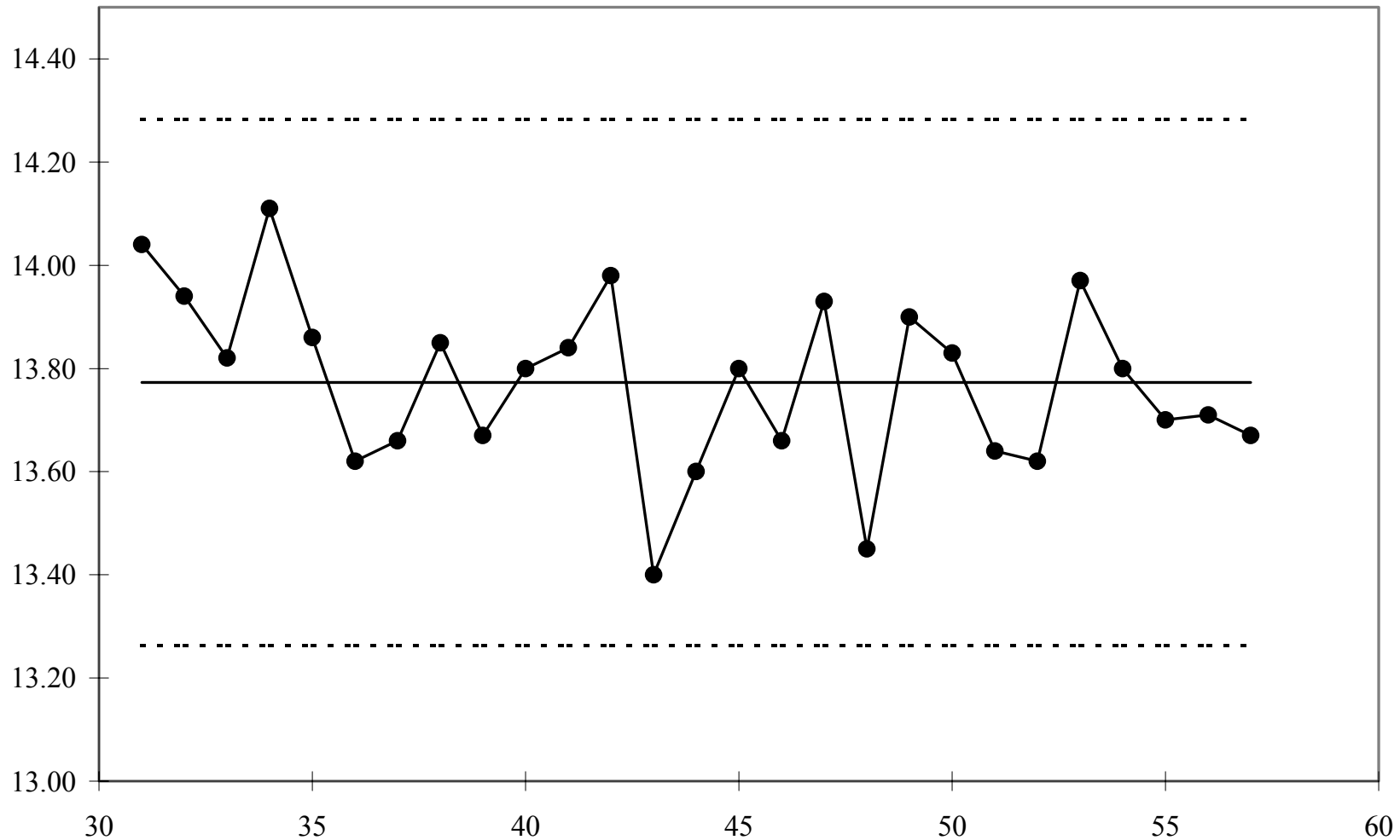**Michigan Technological University**

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- Since X's look normal -- can use all 8 rules.

- Charts show no statistical signals -- process is in control

- Only common causes present -- but, variability is way too high.

- Study team re-examined process. Cause & effect diagram constructed.

- Better method needed to help selecting amount of pigment to add. Batch adjustment chart established based upon experimental study. Single ash test used with chart to ascertain amount of pigment to add.

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- **Plenty of evidence that system has changed.**

- **Process variability reduced**

- **Process mean reduced and now very close to target value.**

- **Re-chart only most recent data (after use of batch adjustment chart begins)**

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Conclusion

- **Process is in control**

- **System has been changed -- level of common cause variability has been reduced.**

- **Average pigment level lowered by 2% -- Big $$$ saved**

- **First gloss check often met specs -- Big hours saved**

- **Batch-to-batch variation reduced by 1/3**

- **Similar approach can be applied to other processes**