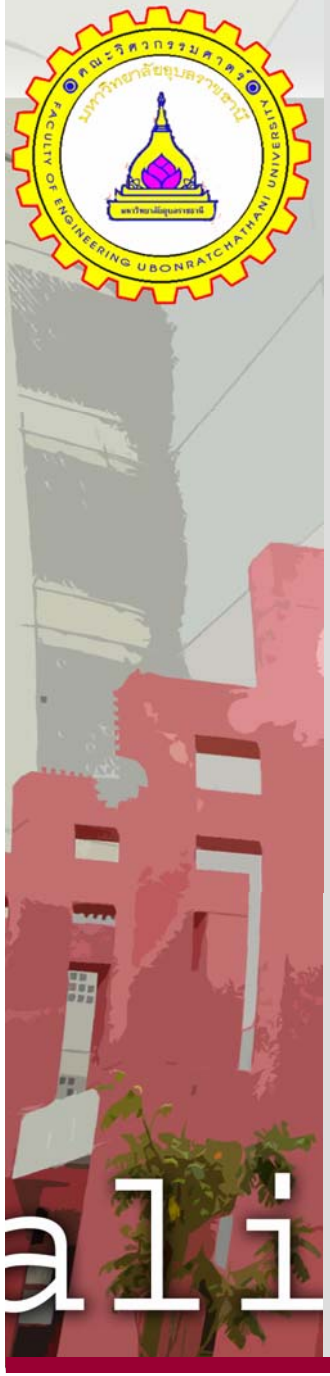
Chapter 5 (continue)

Additional SPC Techniques for Variables



Introduction

- Last chapter: Long production runs of discrete parts
- This chapter:
  - **Continuous and batch processes,**
  - **short run and**
  - **gage control**

Continuous and Batch Processes

- ex the paper making process

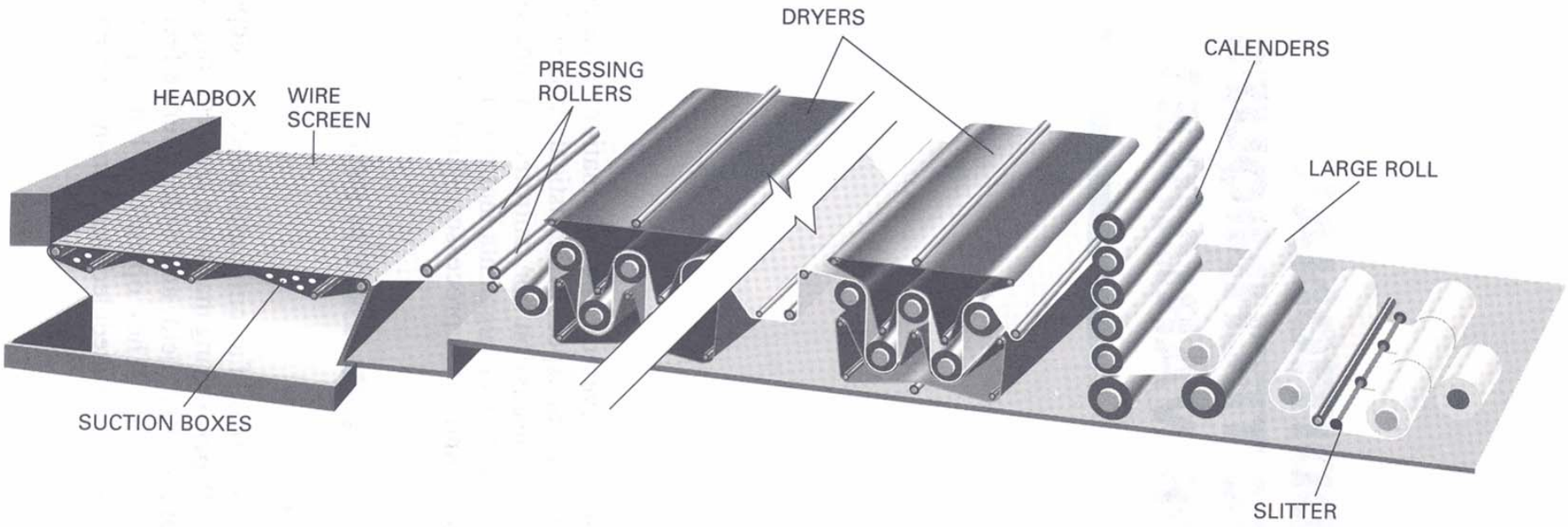


FIGURE 5-1 Paper-making machine. (Adapted from *The New Book of Knowledge*, 1969 edition. Copyright 1969 by Grolier Incorporated. Reprinted by permission.)

Statistical process control (SPC) on the web

- In the machine direction (md)
- Or cross-machine direction (cd)

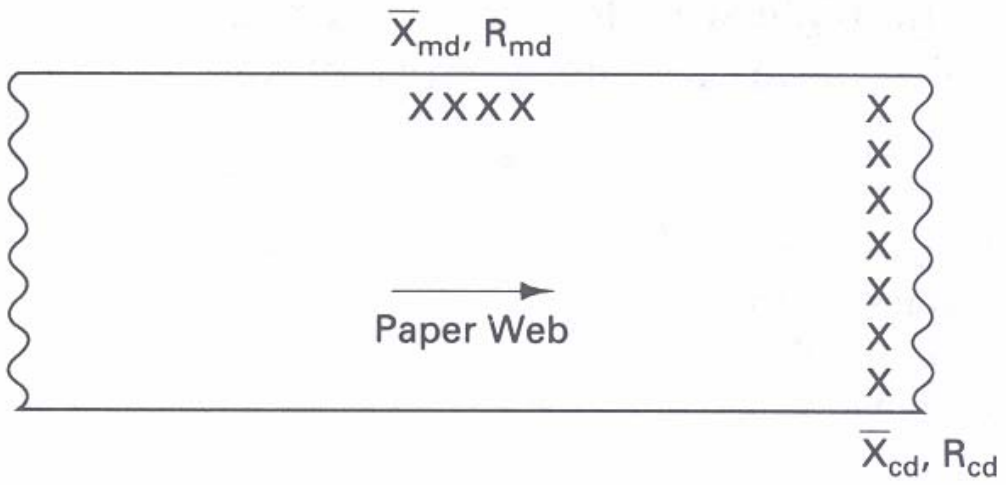
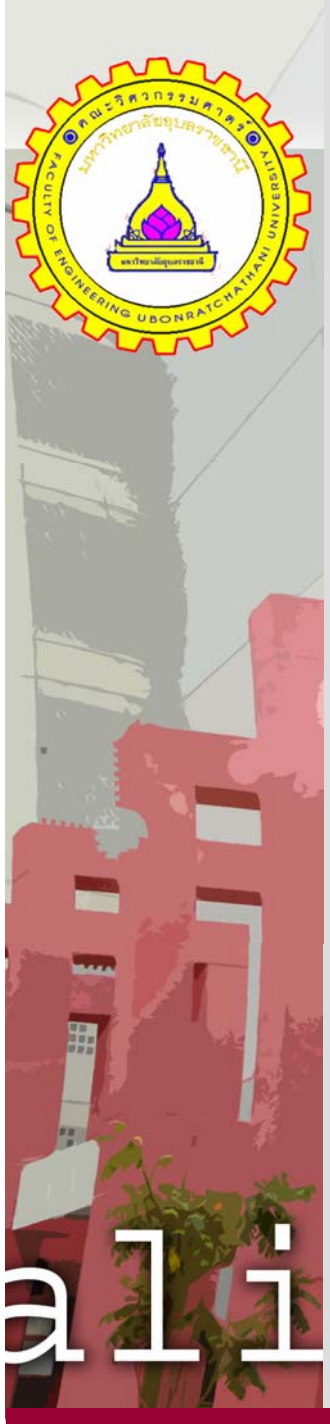


FIGURE 5-2 Paper web and observed valves for md and cd control charts.



Group Chart

- This type of control chart eliminates the need for a chart for each stream. A single chart controls all the stream; however, it does not eliminate the need for measurements at each stream.
- Data are collected in the same manner as outlined in Chapter 4.
  - **25 subgroups for each stream**
  - **Calculated the central line and control limits**

Out-of-Control Situation

- Any out-of-control situation would call for corrective action.
- We have out-of-control situation when the same stream gives the highest or lowest value ***r*** time in succession.

TABLE 5-1 Suggested *r* Values for the Number of Streams.

NUMBER OF STREAMS	*r*
2	9
3	7
4	6
5–6	5
7–10	4
11–27	3
Over 27	2

Example problem

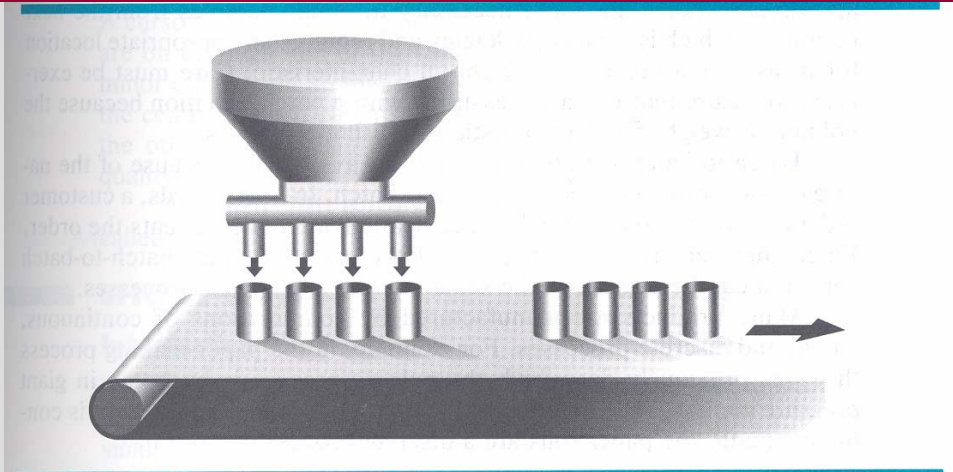


FIGURE 5-3 Example of multiple streams: a four-spindle filling machine.

Assume a four-spindle filling machine as shown in Figure 5-3 and a subgroup size of 3. Determine the number of subgroups needed to establish the central lines and control limits. Also determine the number of time in succession one of the spindles can be plotted before an out-of-control situation occurs.

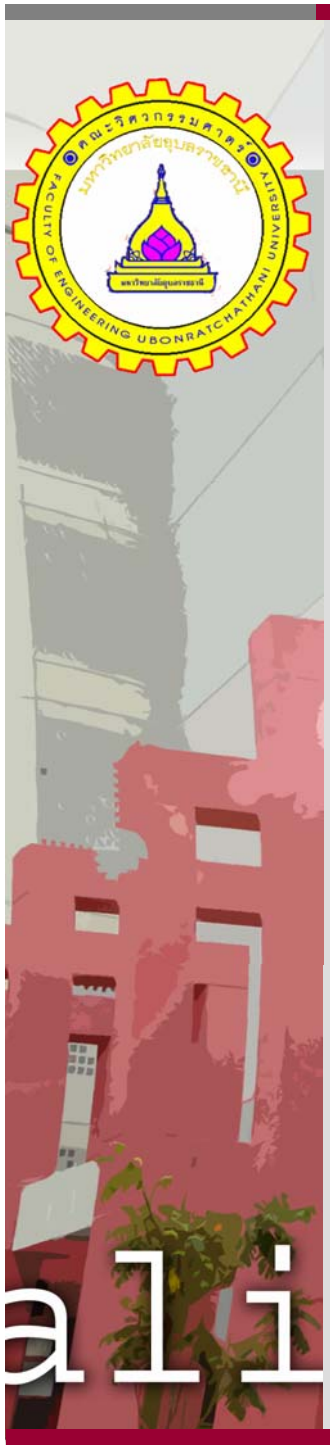
25 per spindle x 4 spindle = 100 subgroups of 3 each

From the table,

$r = 6$

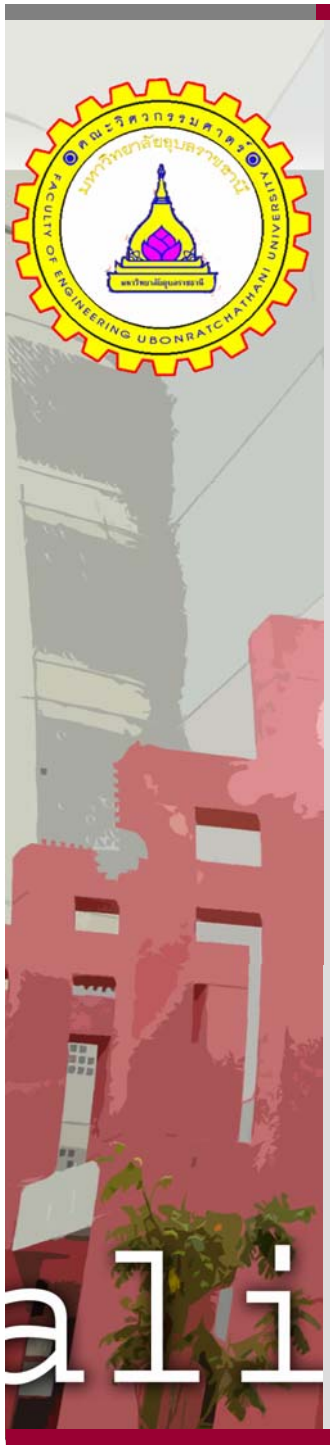
TABLE 5-1 Suggested r Values for the Number of Streams.

NUMBER OF STREAMS	r
2	9
3	7
4	6
5–6	5
7–10	4
11–27	3
Over 27	2



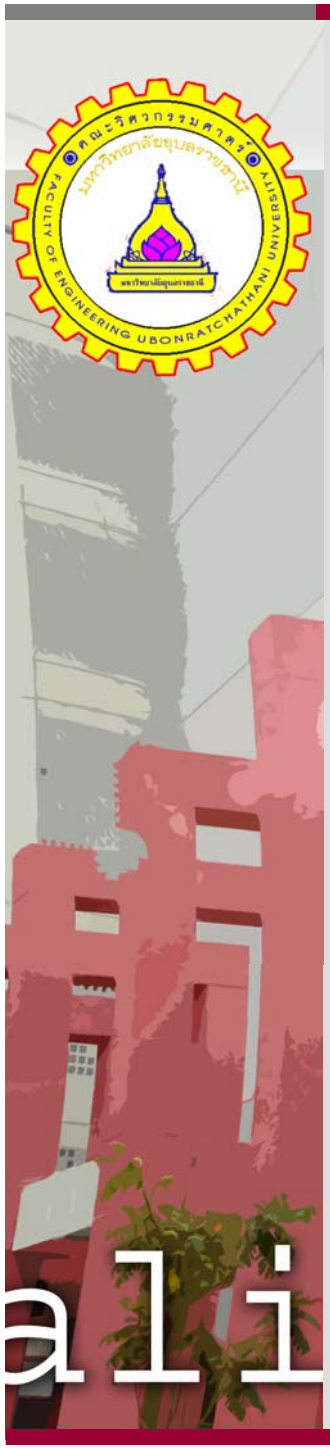
Batch Processes

- Ex paint, adhesives, soft drink, bread, soup, iron, etc.
- SPC of batches has two forms: within batch variation and between batch variation.



Within batch variation

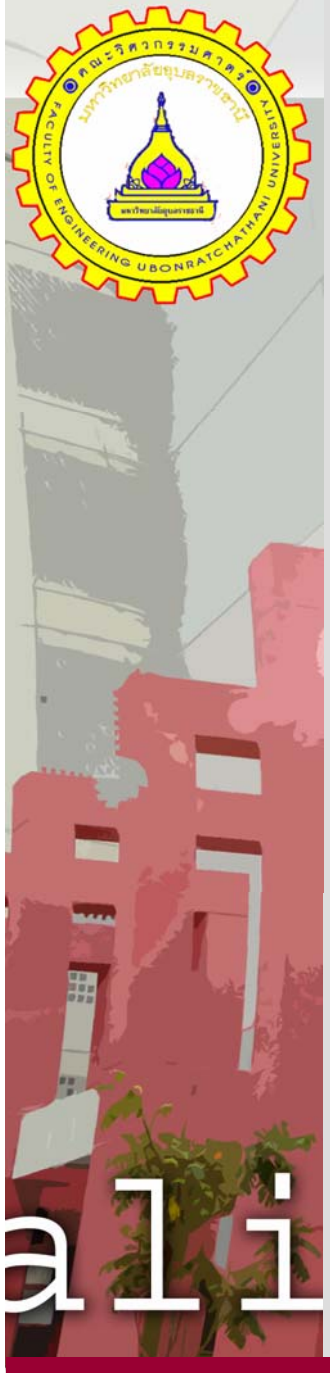
- Within batch variation can be very minimal for many liquids that are under agitation, heat, pressure, or any combination thereof.
- Only one observed value of a particular quality characteristic can be obtained.
- X and R chart for individual would be appropriate SPC technique.
- Each batch in a series of batches would be plotted on the control chart.



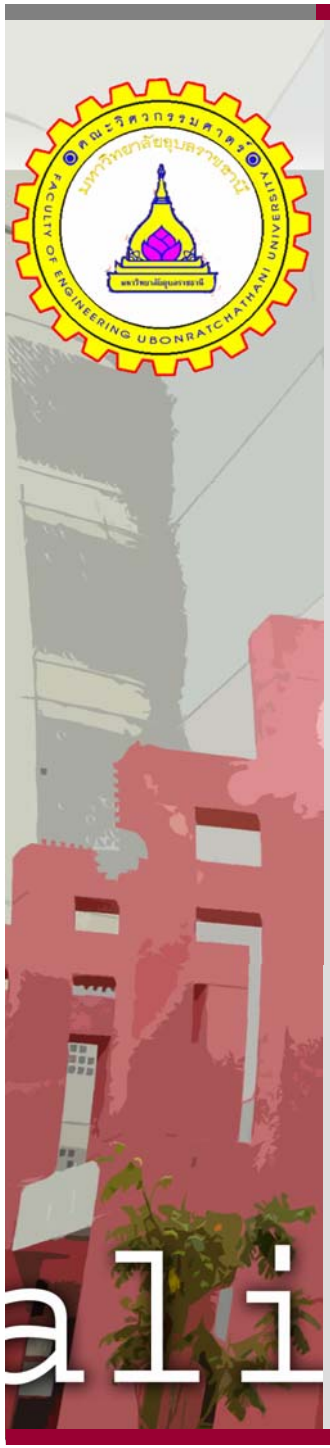
- Some liquid products such as soup will exhibit within batch variation. Observed values (sample) need to be obtained at different locations within the batch.
- $\bar{X}$ and R chart are appropriate

Batch-to-batch variation

- Batch-to-batch variation can be charted in the same manner as discrete processes.



Many products are manufactured by combinations of continuous, batch, and discrete processes. For example, in the paper-making process, the pulping process is by batch; the paper making process is continuous; and, the paper rolls are discrete process.



Batch Chart

- Many processing plants are designed to produce a few basic products to customer specifications. While the ingredients and process are essentially the same, the specifications will change with each customer's batch.

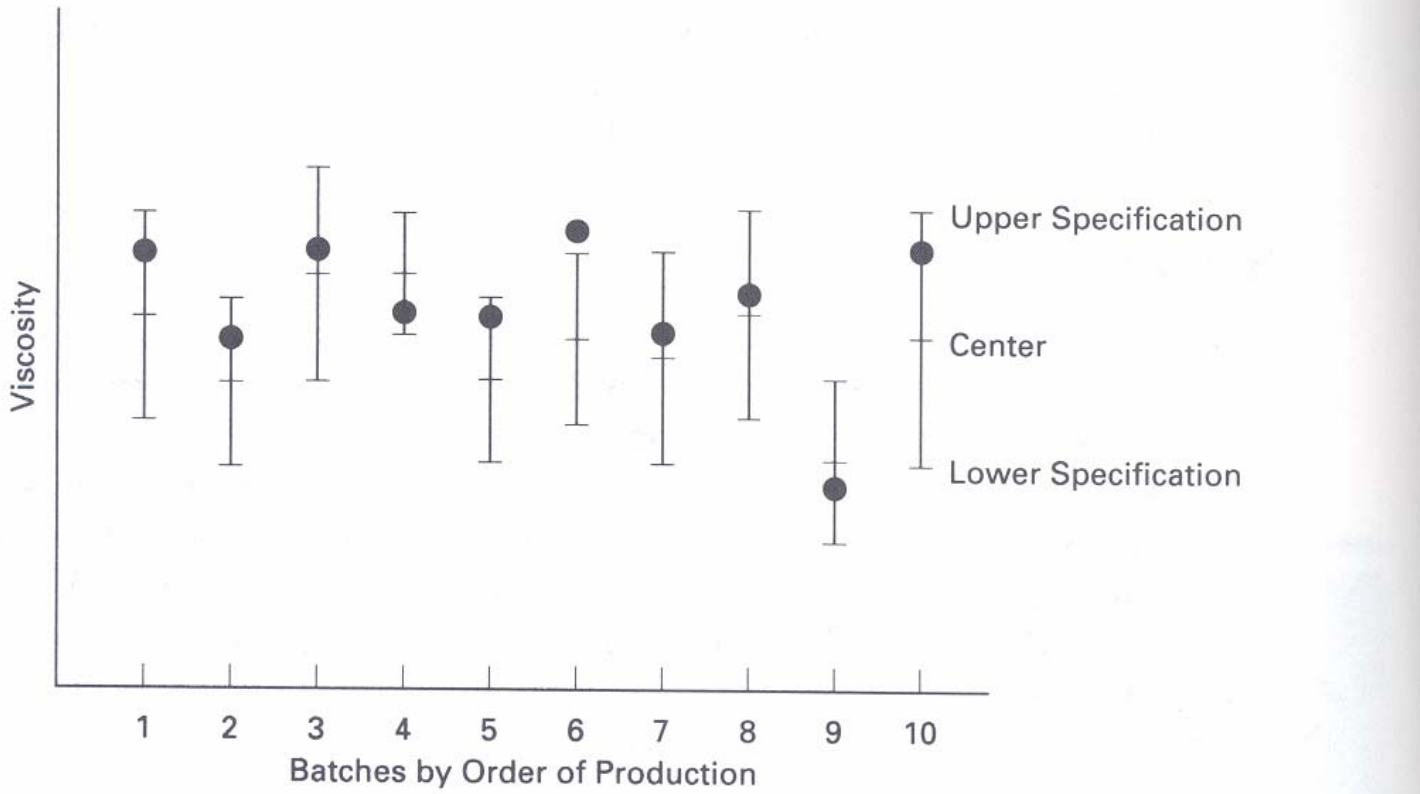


FIGURE 5-4 **Batch chart for different batches with different specifications.**

- 8 out of 10 plotted points are on the high end of the specification.
- Provide information for effective quality improvement.

Short Run SPC

- In many processes, the run is completed before the central line and control limits can be calculated.
- Possible solution to this problem are basing the chart on specification, precontrol, deviation chart, $\bar{Z}$ and W charts, and Z and W charts.

Specification Chart

- The central line and the control limits are established using the specification.
- Assume that the specifications call for 25.00 ± 0.12 mm. Then the central line, $\bar{X}_0 = 25.00$. The difference between the upper specification and the lower specification (USL-LSL) is 0.24 mm, which is the spread of the process under the case II situation (Cp = 1.00).

- Thus,

$$C_p = \frac{USL - LSL}{6\sigma}$$

$$\sigma = \frac{USL - LSL}{6C_p}$$

$$\sigma = \frac{25.12 - 24.88}{6(1)}$$

$$\sigma = 0.04$$

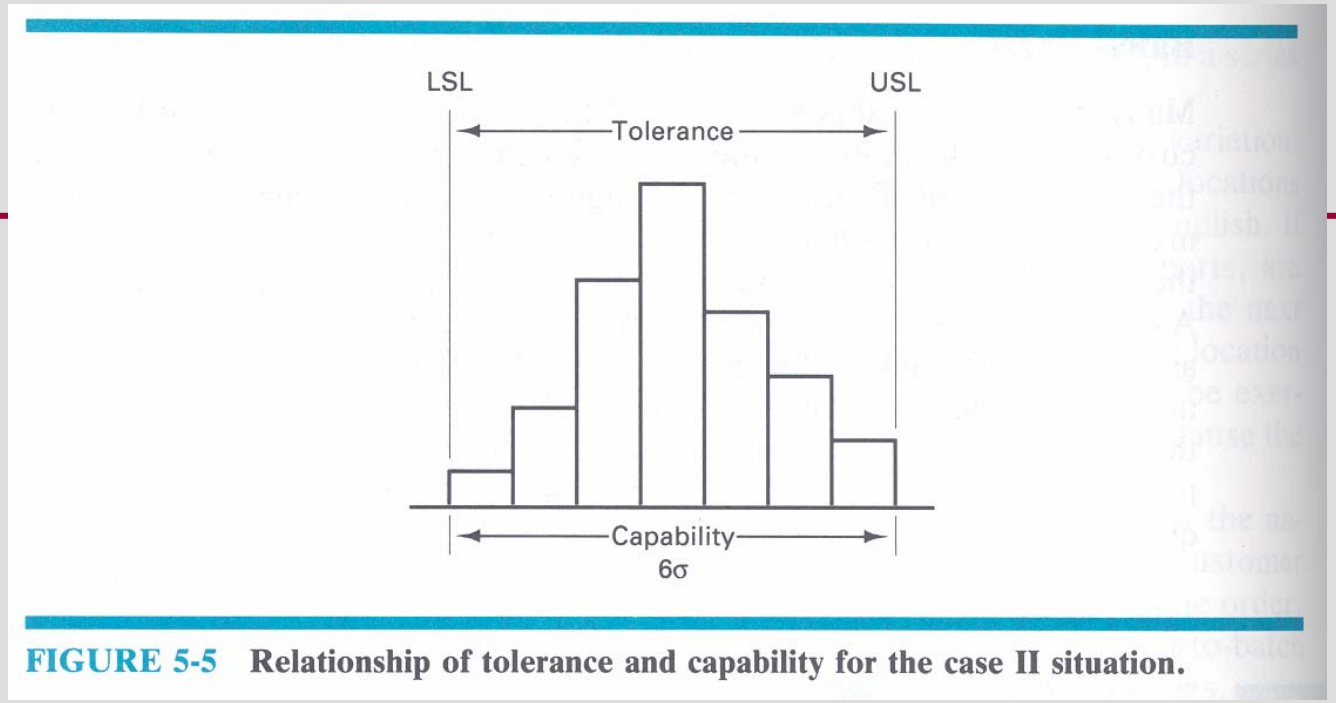


FIGURE 5-5 Relationship of tolerance and capability for the case II situation.

- Thus, for n = 4

$$URL_{\bar{X}} = \bar{\bar{X}} + A\sigma = 25.00 + 1.500(0.04) = 25.06$$

$$LRL_{\bar{X}} = \bar{\bar{X}} - A\sigma = 25.00 - 1.500(0.04) = 24.94$$

$$R_\sigma = d_2\sigma = (2.059)(0.04) = 0.08$$

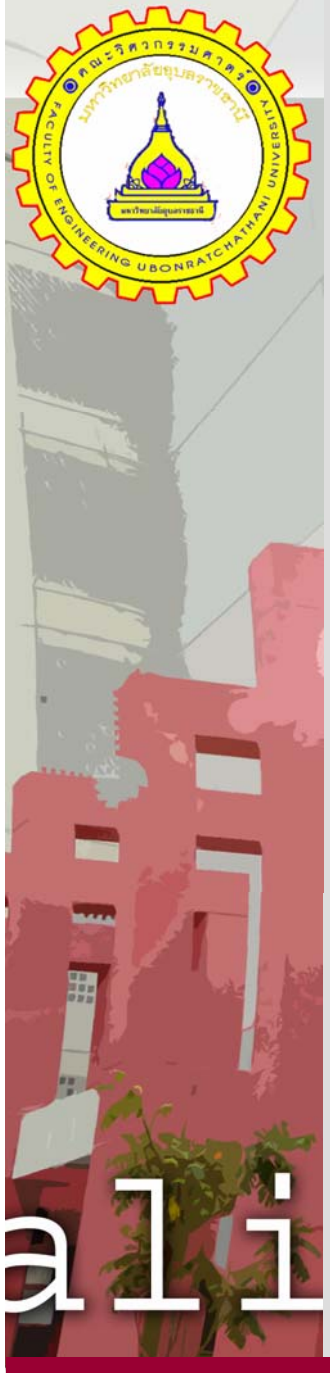
$$URL_R = D_2\sigma = (4.698)(0.04) = 0.19$$

$$LRL_R = D_1\sigma = (0)(0.04) = 0$$

Problem

- จงคำนวณหา Central line and limits สำหรับ การผลิตแบบ short production run ที่จะผลิตเสร็จใน 3 ชั่วโมง และ specification คือ 25.0±0.3 เมื่อ n=4

  และ Cp=1.33



Precontrol

$\bar{X}$ and R chart มีข้อเสียดังนี้

- On short runs, กระบวนการผลิตเสร็จสิ้นก่อนที่พนักงานจะมีเวลาคำนวณ the limits
- พนักงานไม่มีเวลา หรือ ไม่สามารถคำนวณได้
- พนักงานสับสนระหว่าง specification and control limits โดยเฉพาะเมื่อเกิดกรณีที่กระบวนการผลิต out-of-control แต่ไม่มีของเสียเกิดขึ้น

Precontrol สามารถกำจัดข้อเสียเหล่านี้ได้

- ขั้นแรกคือ ต้องแน่ใจว่ากระบวนการผลิตมี process capability น้อยกว่า specification ดังนั้น capability index, Cp, ต้องไม่น้อยกว่า 1 ($Cp \geq 1$)
- จากนั้น สร้าง precontrol line ซึ่งจะแบ่ง tolerance ออกเป็น 5 zone.

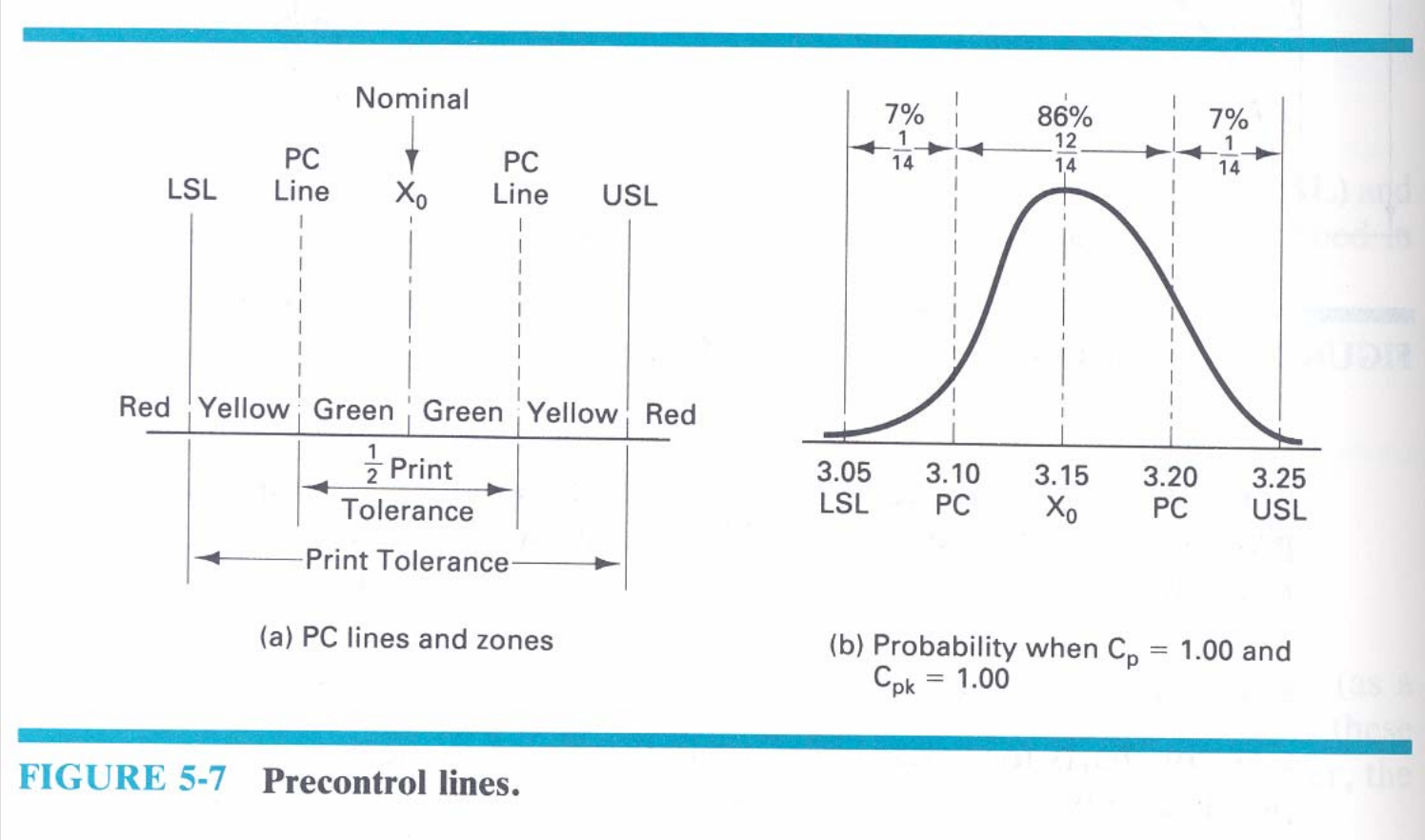
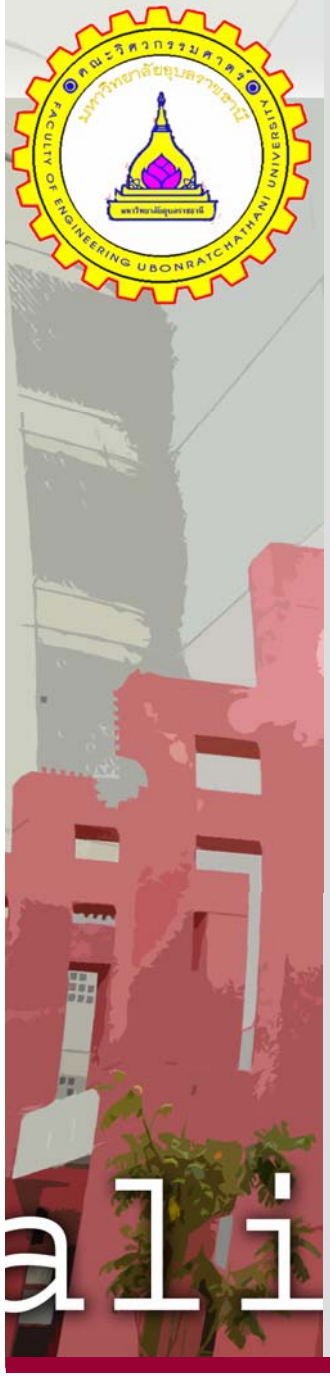


FIGURE 5-7 **Precontrol lines.**

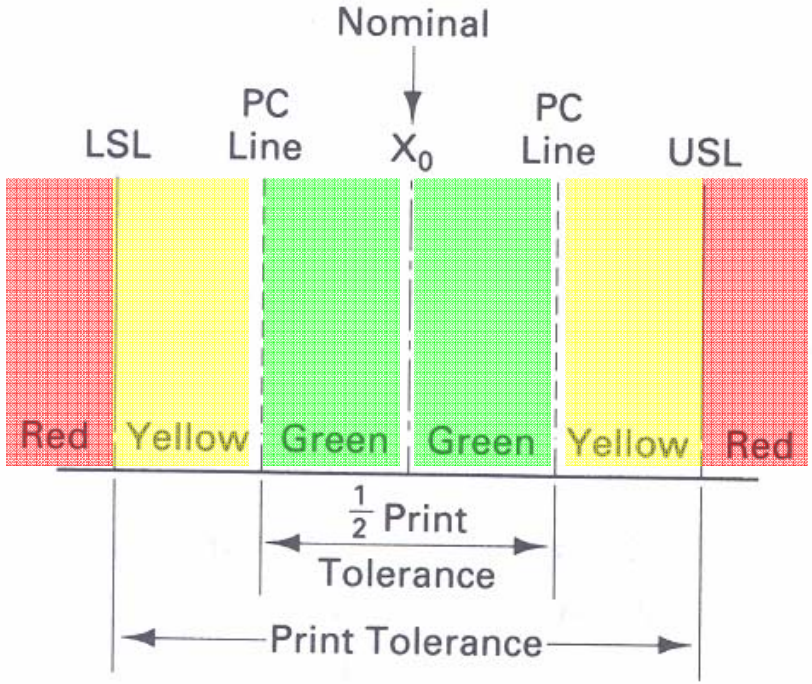


For a specification of 3.15 ± 0.10 mm.

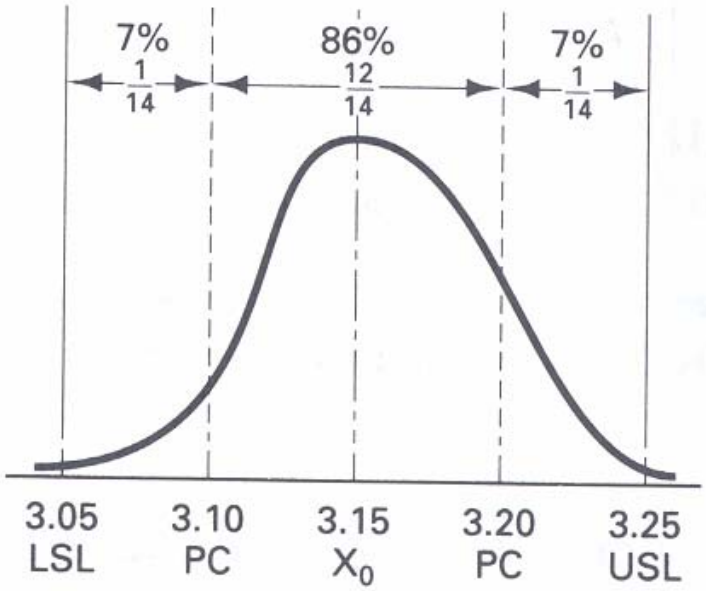
The calculations are

1. Divide tolerance by 4: 0.20/4 = 0.05
2. Add value to lower specification, 3.05: PC = 3.05+0.05 = 3.10
3. Subtract value from upper specification, 3.25: PC = 3.25 – 0.05 = 3.20

Thus, the two PC lines are located at 3.10 and 3.20 mm.



(a) PC lines and zones



(b) Probability when $C_p = 1.00$ and $C_{pk} = 1.00$

FIGURE 5-7 **Precontrol lines.**

The Precontrol Procedure

- has two stages; start-up and run.

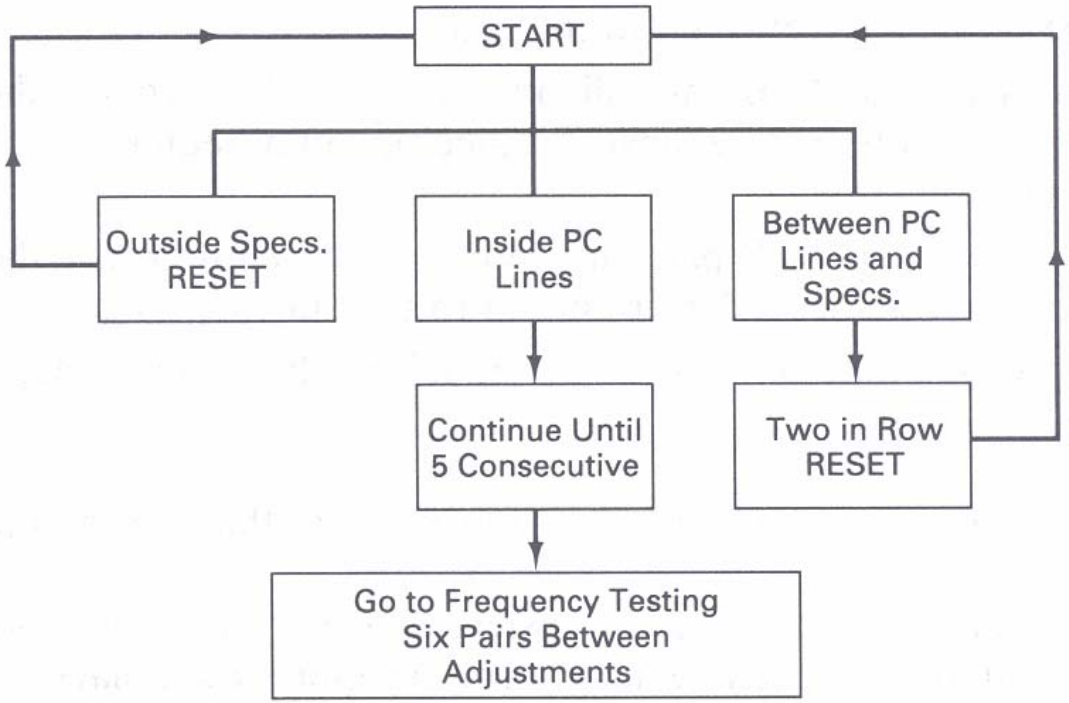


FIGURE 5-8 Precontrol procedure.

TABLE 5-2 Frequency of Measuring.

TIME BETWEEN ADJUSTMENTS, HOURS	TIME BETWEEN MEASUREMENT, MINUTES
1	10
2	20
3	30
4	40
.	.
.	.
.	.

The decision rules for the measured pairs.

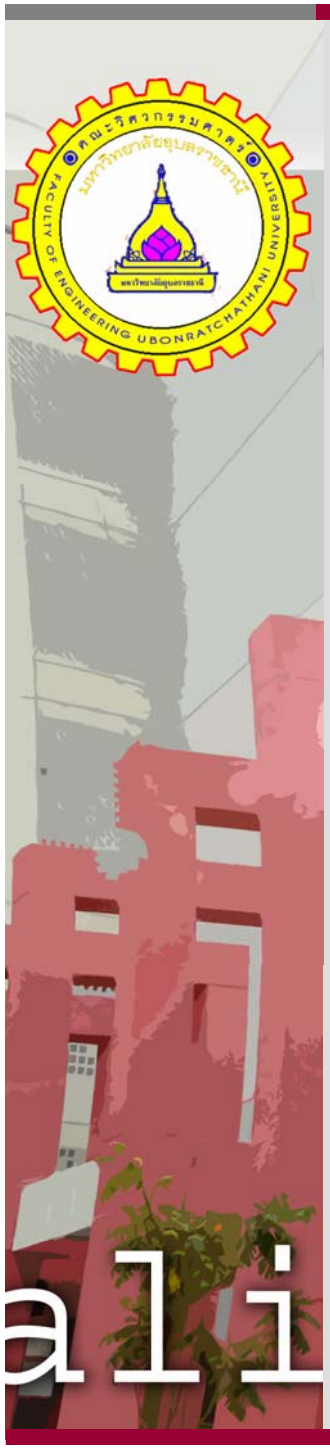
Decision	Color Zones: Red	Yellow	Green	Yellow	Red	Probability
Stop, Go to Start-up	A				A	nil nil
Stop, Get Help		A B		B A		1/14 * 1/14 = 1/196 1/14 * 1/14 = 1/196
Adjust, Go to Start-up		A, B		A, B		1/14 * 1/14 = 1/196 1/14 * 1/14 = 1/196
Continue		A B	A, B B A A B	B A		12/14 * 12/14 = 144/196 1/14 * 12/14 = 12/196 1/14 * 12/14 = 12/196 12/14 * 1/14 = 12/196 12/14 * 1/14 = 12/196
		LSL	PC X_0 PC		USL	Total = 196/196

Nominal (Target)

FIGURE 5-9 **Run decision and probability.**

Advantage of Precontrol

1. It is applicable to short production runs as well as long production runs.
2. No recording, calculating, or plotting of data is involved. A precontrol chart can be used if the consumer desires statistical evidence of process control.
3. It is applicable to start up so the process is centered on the target.



4. It work directly with the tolerance rather than easily misunderstood control limits.
5. It is applicable to attributes.
6. It is simple to understand, so training is very easy.

- It is only monitoring technique. Control charts are used for problem solving.

Problem

- จงคำนวณหา PC line สำหรับกระบวนการผลิตที่มีค่า nominal = 32.0^{o} และค่า tolerance คือ ± 1.0^{o}c?
- ถ้ากระบวนการผลิตต้องถูกปรับทุกๆ 3 ชั่วโมง ควรเก็บข้อมูลอย่างไร
- จงคำนวณหาความน่าจะเป็นที่ข้อมูลจะอยู่ใน zone สี เขียว เมื่อ Cp = 1

Deviation Chart

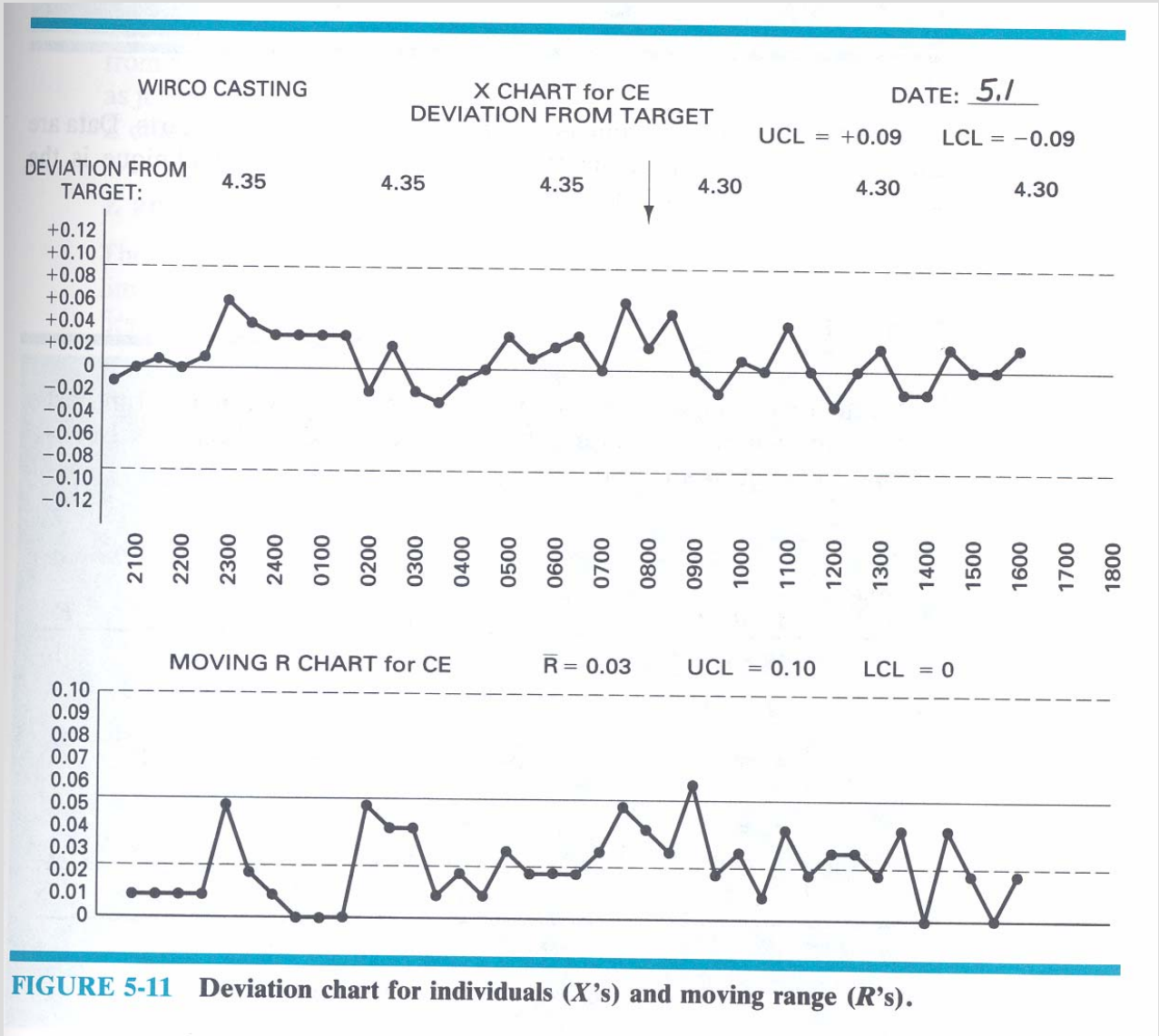


FIGURE 5-11 Deviation chart for individuals (X's) and moving range (R's).

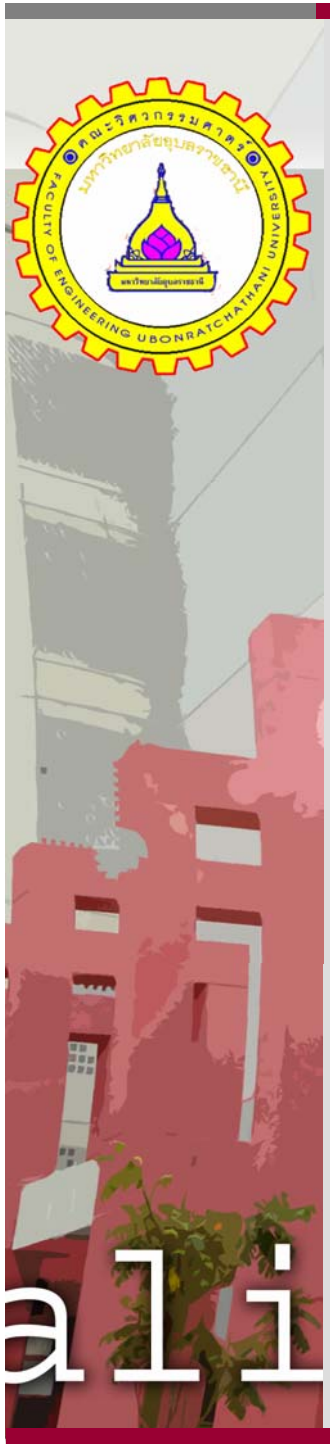
Analysis of Variance (ANOVA)

$$\frac{\bar{R}_{Process}}{\bar{R}_{Total}} \leq 1.3$$

Where

$\bar{R}_{Process}$ = average range of the process

$\bar{R}_{Total}$ = average range for all of the processes



Example Problem

The average range for all of the iron melt processes with different CE target is 0.03. For the process with a targeted CE value of 4.30, the average range is 0.026. Can this process use the deviation technique? What about the process for a targeted CE value of 4.40 with an average range of 0.038?

Example Problem

A lathe turns rough diameters between 5 mm and 50 mm and runs last less than two hours. Material and depth of cut do not change. Determine the central line and control limits. Data are

SUB-GROUP	TARGET	X_1	X_2	X_3	X_4	$\bar{X}$	R
1	28.500	0	+.005	−.005	0	0	.010
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
15	45.000	0	−.005	0	−.005	−.0025	.005
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
25	17.000	+.005	0	0	+.005	+.0025	.005
					Σ	+.020	.175

$\overline{Z}$ and W Chart

ใช้เมื่อ variation มีค่ามาก (จาก rule of thumb) การคำนวณหา central line และ control limits นั้นคำนวณโดยวิธีที่กล่าวมาแล้วสำหรับ ***R*** chart

Gage Control

Observed Value = True Value + Measurement Error

Thus,

Total variation = Product Variation + Measurement Variation

- repeatability
- reproducibility

GR&R (Gage Repeatability and Reproducibility)

Average and Range by Automobile Industry Action Group

- **Data Collection – ทดลองแบบสุ่ม ด้วยชิ้นงาน 10 ชิ้น และ พนักงาน 2 หรือ 3 คน ทดสอบชิ้นละ 2 หรือ 3 ครั้ง**
  - พนักงาน #1: ทดสอบ #1: 4 7 5 9 1 6 2 10 8 3
  - พนักงาน#1: ทดสอบ #2: 2 8 6 4 3 7 9 10 1 5
  - …

อาจใช้ตารางเลขสุ่มเพื่อจัดลำดับในการทดสอบ

Average and Range by Automobile Industry Action Group

- **Calculations**

1. คำนวณ average และ Range ของแต่ละชิ้นงานที่ทดสอบโดยพนักงานแต่ละคน
2. จะได้ $\bar{R}_a, \bar{R}_b, \bar{R}_c, \bar{\bar{X}}_a, \bar{\bar{X}}_b, \bar{\bar{X}}_c$
3. คำนวณ $\bar{\bar{R}}$ และ $\bar{\bar{X}}_{Diff}$ เมื่อ $\bar{\bar{X}}_{Diff} = \bar{\bar{X}}_{Max} - \bar{\bar{X}}_{Min}$
4. $UCL_R = D_4 \bar{\bar{R}}$ และ ศ$CL_R = D_3$ R discard any Rang that is out of control

Average and Range by Automobile Industry Action Group

- **Calculations**

1. คำนวณ average และ Range ของแต่ละชิ้นงานที่ทดสอบโดยพนักงานแต่ละคน
2. จะได้ $\overline{R}_a, \overline{R}_b, \overline{R}_c, \overline{\overline{X}}_a, \overline{\overline{X}}_b, \overline{\overline{X}}_c$
3. คำนวณ $\overline{\overline{R}}$ และ $\overline{\overline{X}}_{Diff}$ เมื่อ $\overline{\overline{X}}_{Diff} = \overline{\overline{X}}_{Max} - \overline{\overline{X}}_{Min}$
4. $UCL_R = D_4 \overline{\overline{R}}$ และ ศ$CL_R = D_3 \overline{\overline{R}}$ discard any Rang that is out of control
5. คำนวณ X ของแต่ละชิ้น และ $R_p = \overline{\overline{X}}_{max} - \overline{\overline{X}}_{min}$

Average and Range by Automobile Industry Action Group

- **Analysis the Result**

1. **Repeatability**

$$EV = k_1 \bar{\bar{R}}$$

เมื่อ EV คือ Equipment Variation (repeatability)

k_1 = 4.56 for 2 trial และ = 3.05 for 3 trial

2. **Reproducibility**

$$AV = SQRT\{(k_2 \bar{\bar{X}}_{Diff})^2 - EV^2/n\ r)^2\ \}$$

เมื่อ AV คือ Appraser Variation (reproducibility)

k_1 = 3. 65 for 2 Operators และ = 2.70 for 3 Operators

n = number of part r = number of trial

Average and Range by Automobile Industry Action Group

- **Analysis the Result**

3. **Repeatability and Reproducibility**

$R\&R = Sqrt(EV^2 + AV^2)$

4. **Part Variation** **$PV = k_3 R_p$**

เมื่อ R_p = Range of the part average

k_3 = ขึ้นอยู่กับจำนวนชิ้นส่วน

Part	2	3	4	5	6	7	8	9	10
k_3	3.65	2.70	2.30	2.08	1.93	1.82	1.74	1.67	1.62

Average and Range by Automobile Industry Action Group

- **Analysis the Result**

5. **Total Variation**

$$TV = \text{sqrt}(R\&R^2 + PV^2)$$

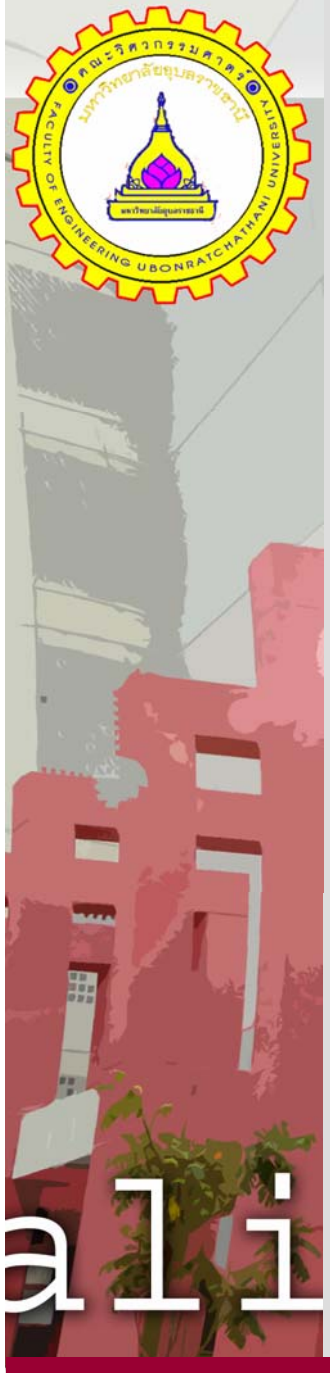
6. **คำนวณเปอร์เซ็นต์**

%EV = 100(EV/TV)

%AV = 100(AV/TV)

%R&R = 100(R&R /TV)

%PV = 100(PV/TV)



Evaluation

- If repeatability is large compared to reproducibility

1. The gage needs maintenance
2. There is excessive within part variation

- If reproducibility is large compared to repeatability

1. The operator need to be better trained
2. Calibration on the gage are not legible

Guideline for accept GR&R

- Under 10% error – Gage system is satisfactory
- 10% to 30% error – may be acceptable
- Over 30% error - Gage system is not satisfactory

  Identify the causes and take corrective action

ตัวอย่าง

- 2 appraiser
- 5 parts
- 3 trials

	PART NUMBER				
	1	2	3	4	5
Apprasier A					
Trial 1	0.34	0.5	0.42	0.44	0.26
Trial 2	0.42	0.56	0.46	0.48	0.3
Trial 3	0.38	0.48	0.4	0.38	0.28
Xbar	**0.38**	**0.51**	**0.43**	**0.43**	**0.28**
R	**0.08**	**0.08**	**0.06**	**0.1**	**0.04**
Apprasier B					
Trial 1	0.28	0.54	0.38	0.43	0.31
Trial 2	0.32	0.48	0.42	0.44	0.28
Trial 3	0.24	0.44	0.34	0.4	0.36
Xbar	**0.28**	**0.49**	**0.38**	**0.43**	**0.31**
R	**0.08**	**0.1**	**0.08**	**0.06**	**0.08**