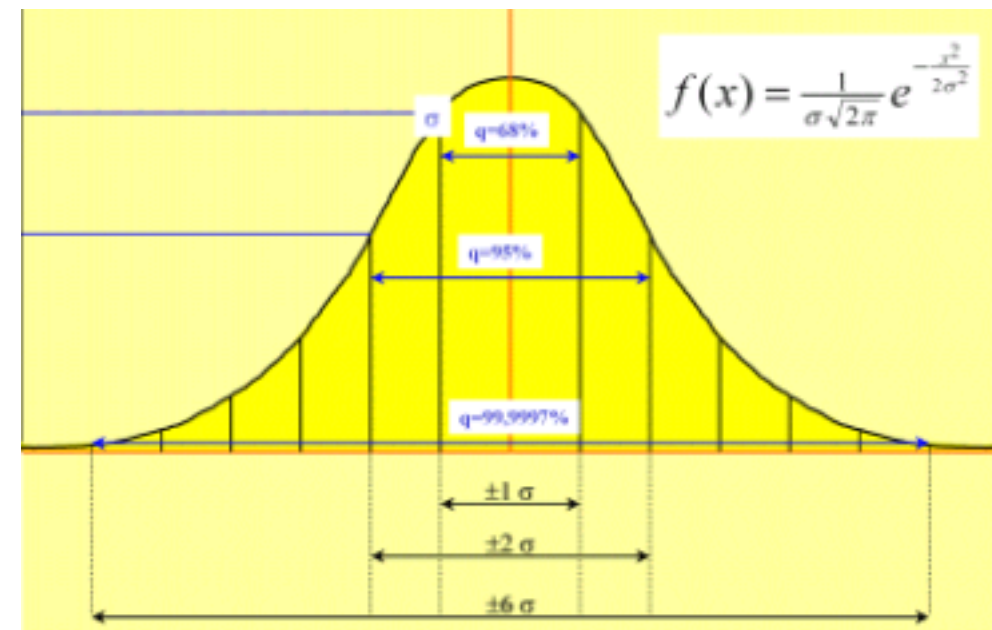
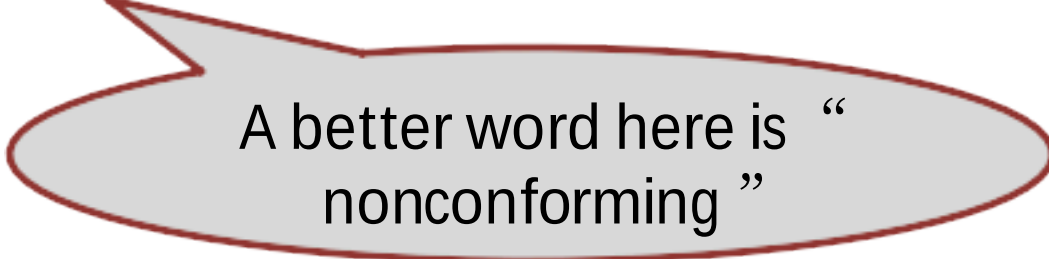


CH-4: CONTROL CHARTS FOR VARIABLES



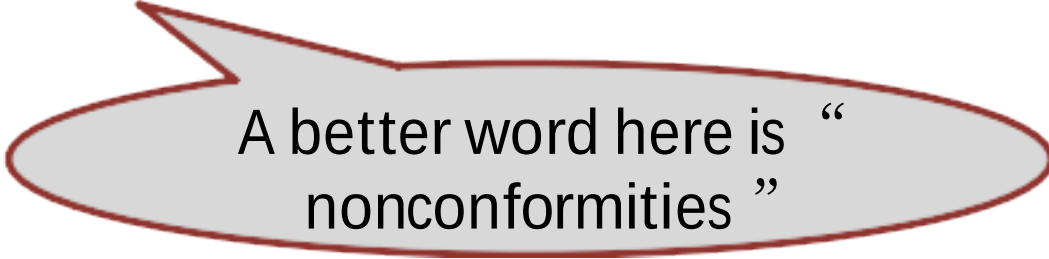
Control Charts for Attribute Data

- Here, you are counting something
- The number of defective units in a batch of units
- OR -



A better word here is “nonconforming”

- The number of defects on one unit



A better word here is “nonconformities”

- For attribute data, you draw one chart or the other (not both)

p Charts and c Charts

- When monitoring the number of nonconforming units in a batch of units, you plot a p chart
- When monitoring the number of nonconformities on one (always one) unit, you plot a c chart
- Consequently, for attribute data, you only plot one of these charts

Control Charts for Attributes

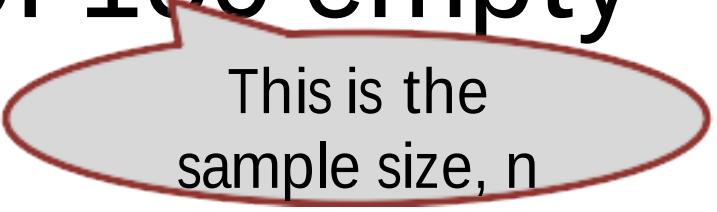
- Although the distribution of sample information follows a binomial distribution, that distribution can be approximated by a normal distribution with a
 - mean of $\bar{p}$
 - standard deviation of $\sqrt{\frac{\bar{p}(1 - \bar{p})}{n}}$
- The 3σ control limits are

$$\text{UCL} = \bar{p} + 3\sqrt{\frac{\bar{p}(1 - \bar{p})}{n}}$$

$$\text{LCL} = \bar{p} - 3\sqrt{\frac{\bar{p}(1 - \bar{p})}{n}}$$

p Chart Example-1

- There are 20 samples of 150 empty coffee cans
- Note that we get much larger samples for p charts (150, here)
- That's a total of $(20)(150) = 3000$ cans



This is the
sample size, n

p Chart Example

Sample	Bad cans	Proportion	
1	7	$7/150 = .047$	Call this p_1
2	4	$4/150 = .027$	Call this p_2
3	1	$1/150 = .007$	Call this p_3
⋮			
20	<u>2</u>	$2/150 = .013$	Call this p_{20}
	96		

We will plot these
in the p chart

p Chart Example

- Find the overall proportion of bad cans

- This is $\bar{p}$

- $\bar{p} = \frac{96}{(20)(150)} = \frac{96}{3000} = .032$

This is the center line for the p chart

- $$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = .032 + 3\sqrt{\frac{(.032)(.968)}{150}} = .075$$

- $$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = .032 - 3\sqrt{\frac{(.032)(.968)}{150}} = -.011$$

p Chart Example

- Since the LCL is negative, it is inactive and can be ignored
- This is because **it is impossible to get a proportion of bad cans that is negative**
- Next, plot the 20 proportions
- This is your p chart (shown on the next slide)

p Chart for Coffee Can Example

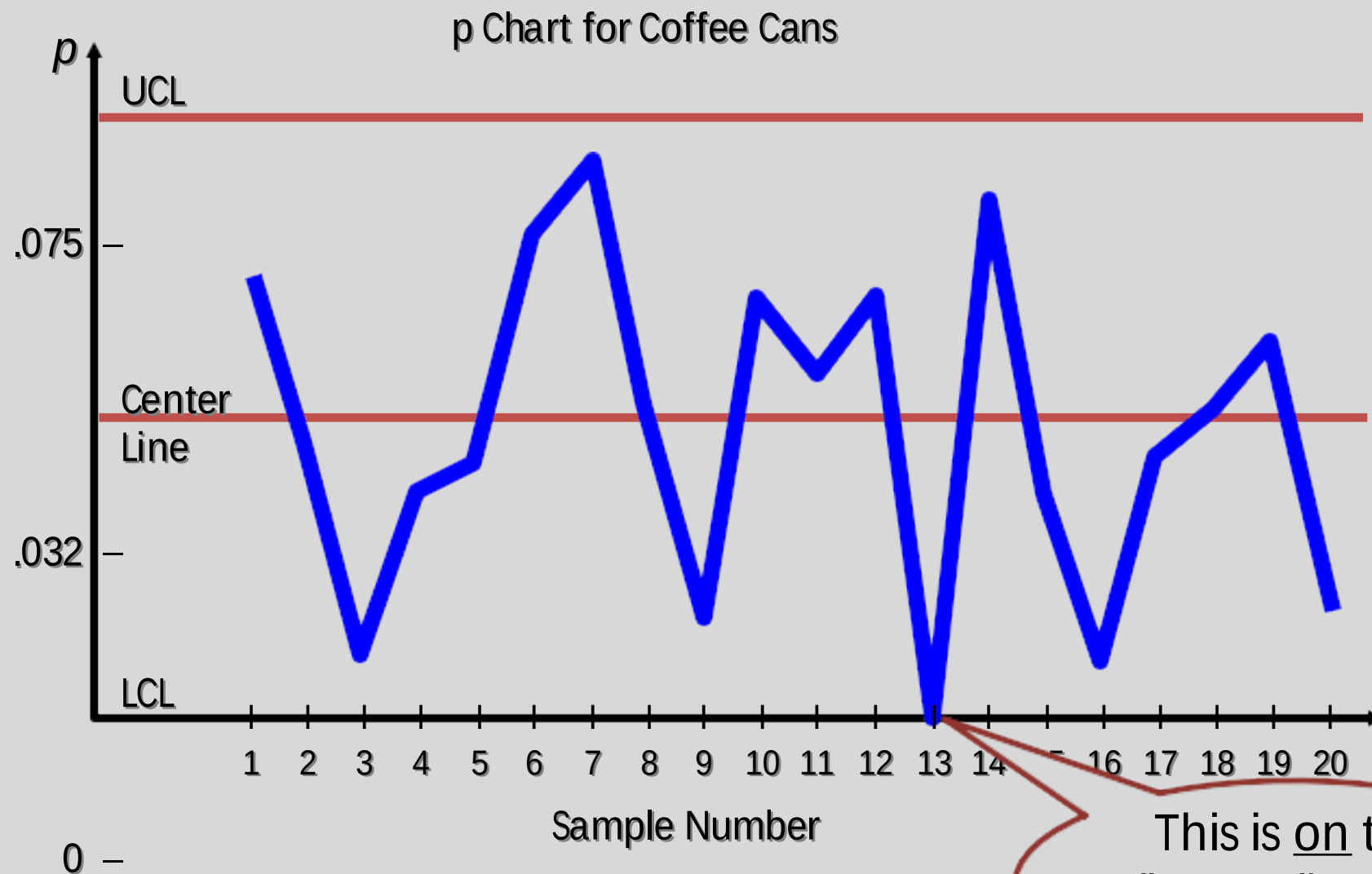


Figure 9.18

Example

- Each sample consists of 150 empty coffee cans

Sample	Bad cans	Proportion
1	5	$5/150 = .033$
2	2	$2/150 = .013$
3	11	$11/150 = .073$
4	6	$6/150 = .040$
5	8	$8/150 = .053$

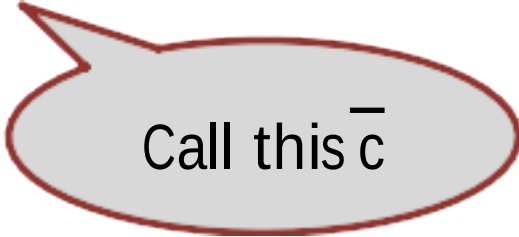
All are below UCL = .075
So far, you're okay

c Charts

- For a c chart, you are always looking at one unit and counting the number of
 - scratches
 - blemishes
 - loose bolts
 - missing rivets, etc.
- The c chart is based on the Poisson distribution

Example of a c Chart

- In an automotive plant, you are looking at 25 newly painted door panels (one at a time) and counting the number of paint blemishes
- Call the number of blemishes $c_1, c_2, \dots; c_{25}$
- Average these values and you get, say $48/25 = 1.92$
- On the average, there were 1.92 blemishes per door panel



Call this $\bar{c}$

Constructing a c Chart

- The center line of the c chart is $\bar{c}$
- For the Poisson distribution, the mean and variance of this random variable are the same
- Consequently, the standard deviation is the square root of the mean
- As a result, for the c chart

$$UCL = \bar{c} + 3\sqrt{\bar{c}}$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}}$$

Example of a c Chart

- Using the door panels example,
The center line is $\bar{c} = 1.92$
The upper control limit = $1.92 + 3\sqrt{1.92} = 6.08$
The lower control limit = $1.92 - 3\sqrt{1.92} = -2.24$
- Since the LCL is negative, it is inactive and can be ignored since you can't have a negative number of paint blemishes
- Next, plot the 25 c values- this is your c chart

Door Panels Example

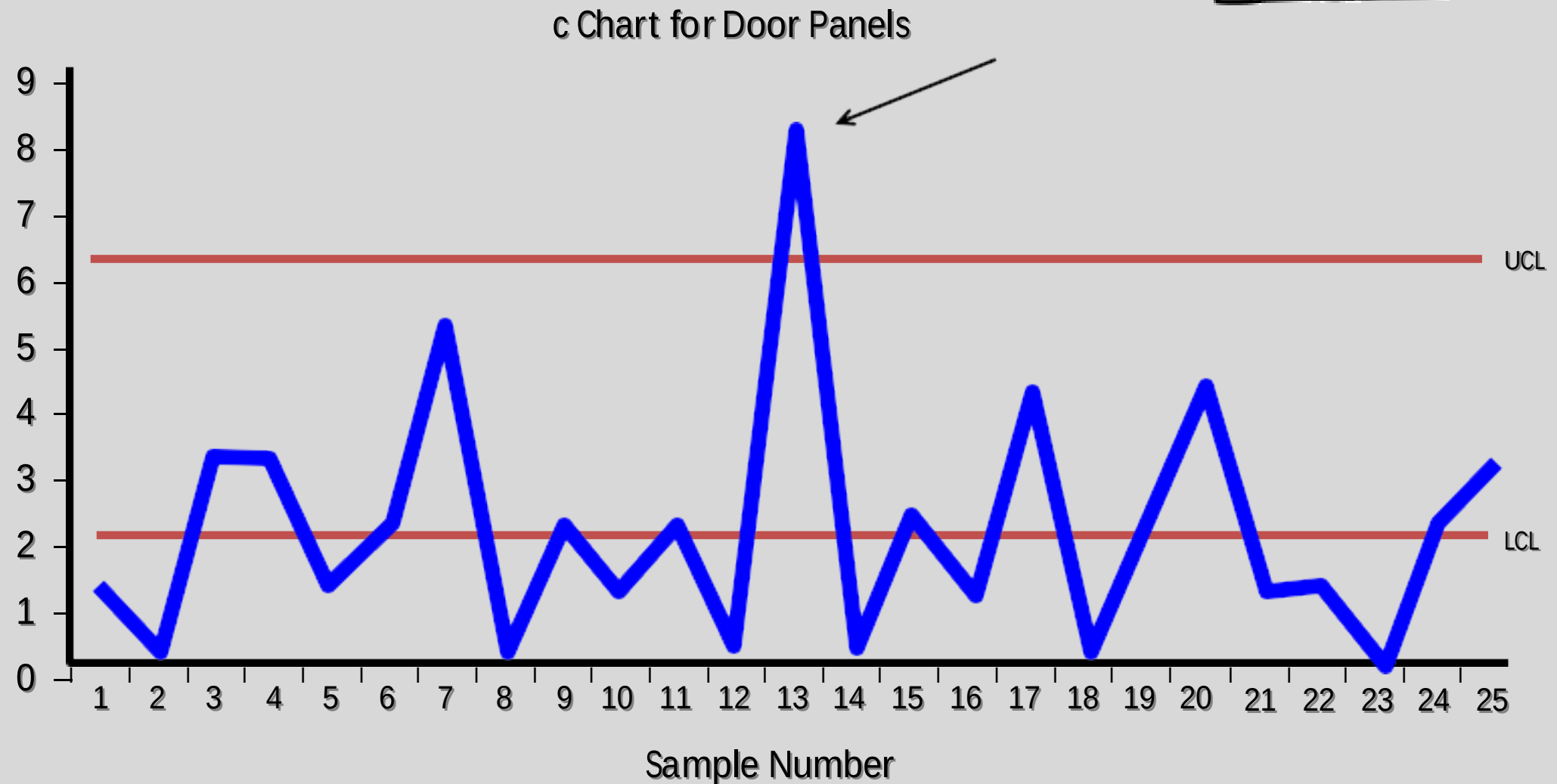
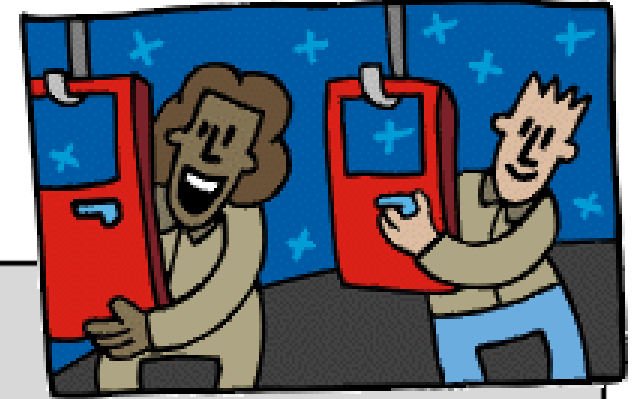


Figure 9.20