Computing the control limits for the R chart, we have

$$\begin{aligned}\text{UCL} &= \bar{R}D_4 \\ &= 0.0575(2.574) \\ &\approx 0.1480 \\ \text{LCL} &= \bar{R}D_3 \\ &= 0.0575(0) \\ &= 0 \\ \text{Centerline} &= \bar{R} = 0.0575.\end{aligned}$$

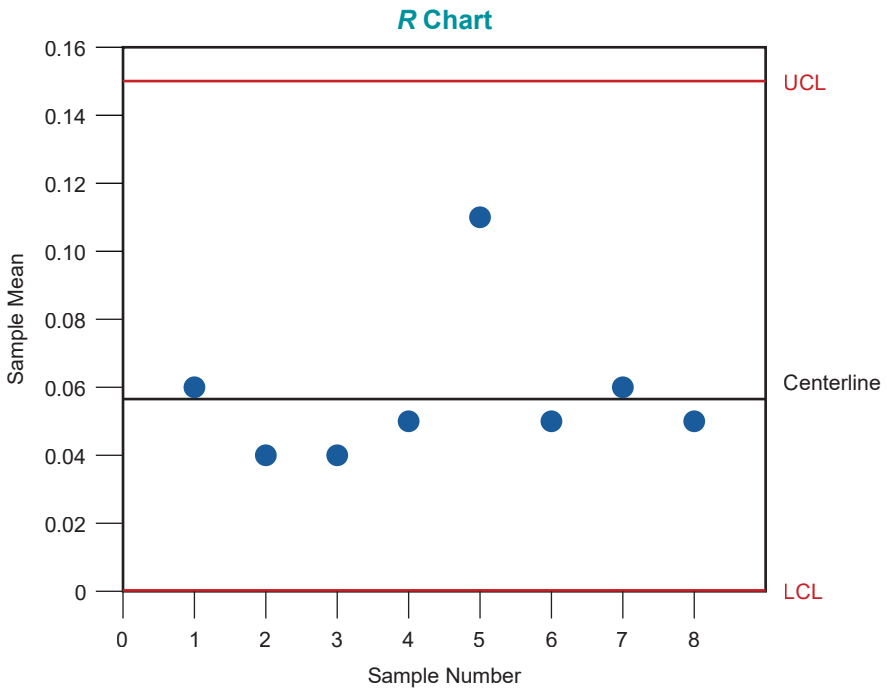

Figure 18.3.4

Examining the $\bar{x}$ chart and R chart, one can see that both the process mean and variability are within the control limits. That is, each of the sample means and sample ranges falls within the control limits of the $\bar{x}$ chart and R chart, respectively, indicating that the process is in control.

18.3 Exercises

Basic Concepts

1. How are control charts associated with hypothesis testing? Identify the null and alternative hypotheses that can be tested using control charts.
2. What is an $\bar{x}$ chart?
3. What is an R chart?
4. What does the Central Limit Theorem have to do with statistical quality control?
5. What is a common interval used to measure in-control and out-of-control processes? What is the probability that random variation would cause a sample statistic to fall outside this interval?

6. How are the upper and lower control limits for an $\bar{x}$ chart calculated if the process mean and standard deviation are known?

7. How do the calculations for the control limits change for an $\bar{x}$ chart when the process mean and standard deviation are unknown?

8. When studying a control chart, how do you determine if the process is out of control?

9. Consider the process in Example 17.1. Give an example of something that might cause this process to be out of control.

10. Why do managers study $\bar{x}$ charts and R charts together?

Exercises

11. An automobile manufacturer requires the fuel injections to be adjusted so that its cars get an average of 30 miles per gallon with a standard deviation of 3 miles per gallon over a long period of time. Calculate the upper and lower control limits for an $\bar{x}$ chart if the quality control department starts sampling 64 cars each day during the month.

12. A pharmaceutical manufacturer requires the average active ingredient of allergy pills to be 0.03 grams, with a standard deviation of 0.002 grams. An FDA inspector inspects 10 batches of 100 pills and finds the following sample means.

0.032 0.028 0.031 0.032 0.026 0.027 0.030 0.033 0.034 0.026

a. Determine which batches, if any, are out of control using an $\bar{x}$ chart.

b. Does the process appear to be in statistical control? Explain.

13. A manufacturer of auto windows employs a constant quality control technique where the thickness of glass is checked every hour. A perfect piece of glass will have a thickness of 4 mm. From past experience, it is known that the standard deviation of thickness is 0.25 mm. The result of one shift's production is given in the following table.

Glass Thickness (mm)

Sample	Observations					Sample	Observations				
1	4	3	4	2	4	9	5	4	3	2	5
2	5	3	5	4	2	10	4	4	4	4	4
3	3	3	3	3	4	11	1	6	4	4	2
4	4	5	5	4	5	12	3	3	4	5	4
5	4	2	2	3	2	13	4	4	5	6	5
6	4	5	2	5	4	14	3	2	5	4	2
7	3	5	4	4	5	15	3	3	3	2	1
8	2	4	4	4	3	16	4	4	4	5	3

a. Construct an $\bar{x}$ chart for these data.

b. Construct an R chart for these data.

c. According to the $\bar{x}$ chart constructed in part **a.**, which samples, if any, are out of control?

d. According to the R chart constructed in part **b.**, which samples, if any, are out of control?

14. Princeton Manufacturing produces air conditioning units designed to maintain 45 degrees. Samples of 10 units are taken to monitor the process, and it is found that the units are maintaining 45 degrees as designed. The mean of the sample ranges is found to be 2 degrees.

a. Find the UCL, LCL, and centerline for the $\bar{x}$ chart.

b. Find the UCL, LCL, and centerline for the R chart.

15. A trucking company tries to deliver its freight in 24 hours. Ten samples of 20 customers are taken with the following sample means.

22.6 24.5 24.1 23.8 25.3 25.0 23.8 23.6 23.0 25.2

The average range for these deliveries is 5.8 hours.

a. Compute the 3σ control limits for the mean delivery time. Which samples, if any, are out of control?

b. Compute the 3σ control limits for the process range.

16. Natural Life produces a variety of natural food products. The quality control department samples one cereal to ensure proper net weight. In the past when taking samples of 15 boxes, the average range was 0.45 ounces. Find the upper and lower control limits for an R chart.

17. A paper products manufacturer makes 60-inch cores that are later cut into smaller lengths in the production of bathroom tissue. To monitor the production and to make sure the cores are acceptable for the cutting state, a sample of 25 cores is taken each hour of the day. Along with the core length, the range of the core length is recorded for each sample (as shown in the following table). Determine the upper and lower control limits for an R chart and indicate which samples, if any, are out of control.

Core Lengths

Sample Number	Sample Range	Sample Number	Sample Range
1	0.10	13	0.19
2	0.20	14	0.08
3	0.22	15	0.10
4	0.08	16	0.07
5	0.06	17	0.16
6	0.23	18	0.19
7	0.20	19	0.21
8	0.09	20	0.14
9	0.25	21	0.16
10	0.17	22	0.19
11	0.14	23	0.12
12	0.18	24	0.13

18. A manufacturer of small electric motors has a model that draws 1300 watts when working properly. To ensure conformity with this standard, samples of 20 motors are taken each hour during the day shift. Along with the average wattage, the range of wattage is recorded for each sample (as shown in the following table). Determine the upper and lower control limits for an R chart and indicate which samples, if any, are out of control.

Electric Motor Wattage

Sample Number	Sample Range	Sample Number	Sample Range
1	8.8	5	4.1
2	12.2	6	9.6
3	11.6	7	8.8
4	8.0	8	5.3