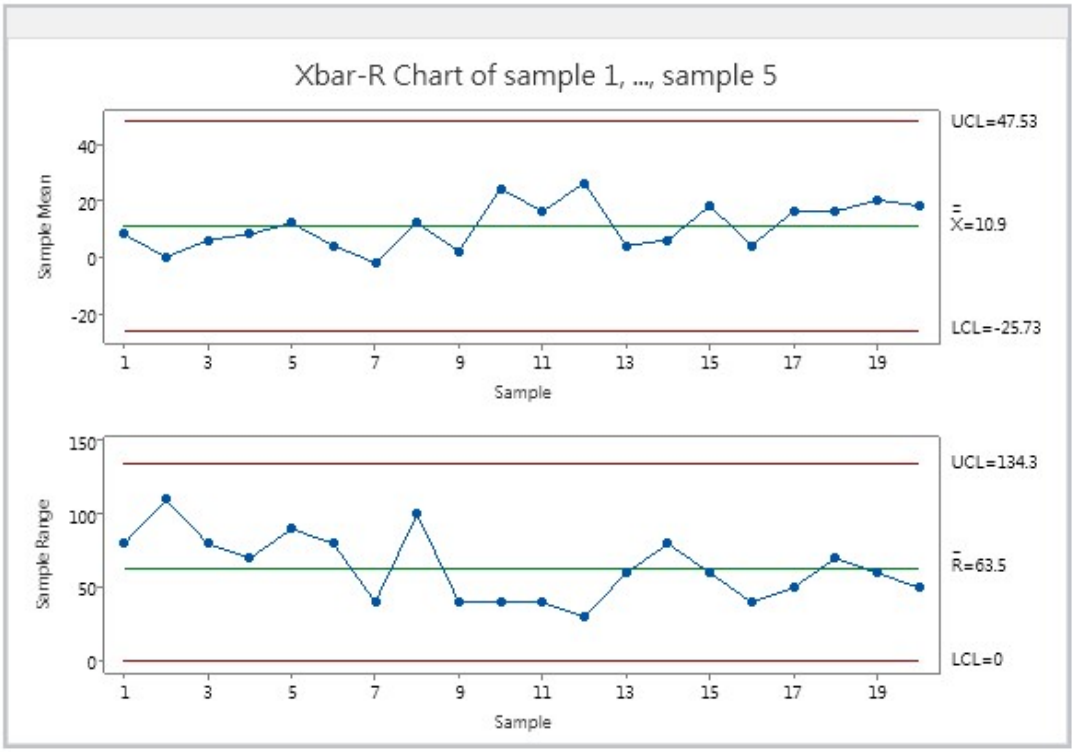
6.5. The data shown in Table 6E.2 are the deviations from nominal diameter for holes drilled in a carbon-fiber composite material used in aerospace manufacturing. The values reported are deviations from nominal in ten-thousandths of an inch.

Table 6E.2 Hole Diameter Data for Exercise 6.5

Sample Number	x_1	x_2	x_3	x_4	x_5
1	−30	+50	−20	+10	+30
2	0	+50	−60	−20	+30
3	−50	+10	+20	+30	+20
4	−10	−10	+30	−20	+50
5	+20	−40	+50	+20	+10
6	0	0	+40	−40	+20
7	0	0	+20	−20	−10
8	+70	−30	+30	−10	0
9	0	0	+20	−20	+10
10	+10	+20	+30	+10	+50
11	+40	0	+20	0	+20
12	+30	+20	+30	+10	+40
13	+30	−30	0	+10	+10
14	+30	−10	+50	−10	−30
15	+10	−10	+50	+40	0
16	0	0	+30	−10	0
17	+20	+20	+30	+30	−20
18	+10	−20	+50	+30	+10
19	+50	−10	+40	+20	0
20	+50	0	0	+30	+10

a. Set up $\bar{x}$ and R charts on the process. Is the process in statistical control?



Yes, it is in statistical control.

b. Estimate the process standard deviation using the range method.

N = 5 → d2 = 2.326

σ = $\bar{R}$ / d2 = 63.5/2.326 = 27.30009

c. If specifications are at nominal ±100, what can you say about the capability of this process? Calculate the PCR Cp.

Cp = (USL - LSL) / 6*sigma

USL = nominal + 100;

LSL = nominal – 100;

Cp = 200 / (6 * 27.3) = 1.22 > 1

Means the process is in control

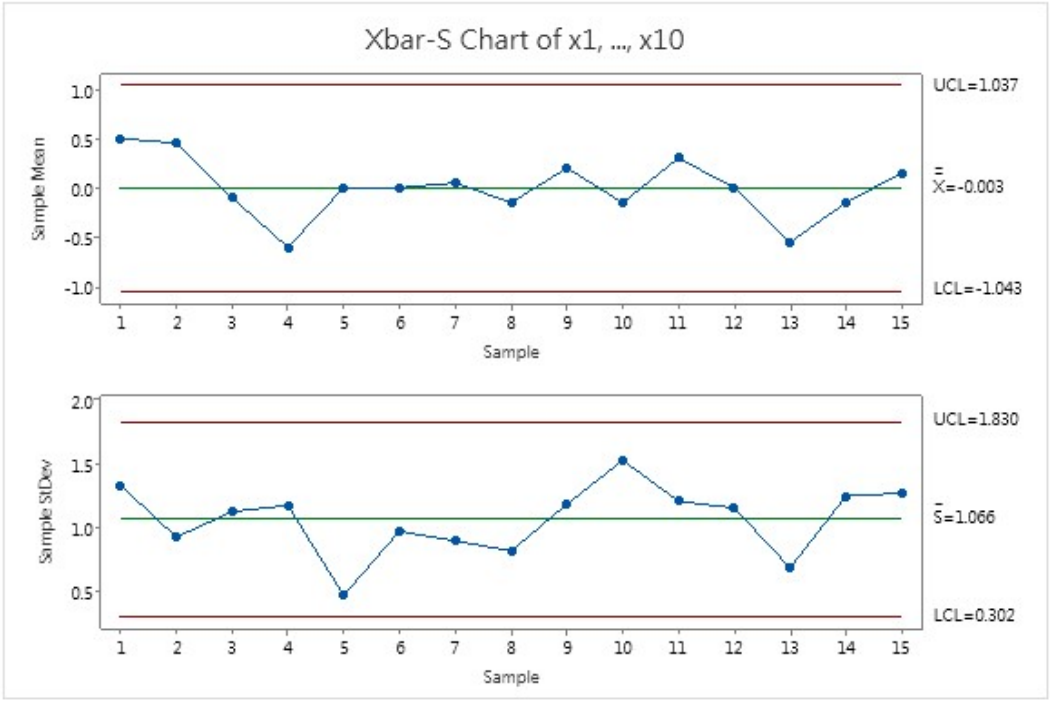
6.6. The fill volume of soft-drink beverage bottles is an important quality characteristic. The volume is measured (approximately) by placing a gauge over the crown and comparing the height of the liquid in the neck of the bottle against a coded scale.

On this scale, a reading of zero corresponds to the correct fill height. Fifteen samples of size n = 10 have been analyzed, and the fill heights are shown in Table 6E.3.

Table 6E.3 Fill Height Data for Exercise 6.6

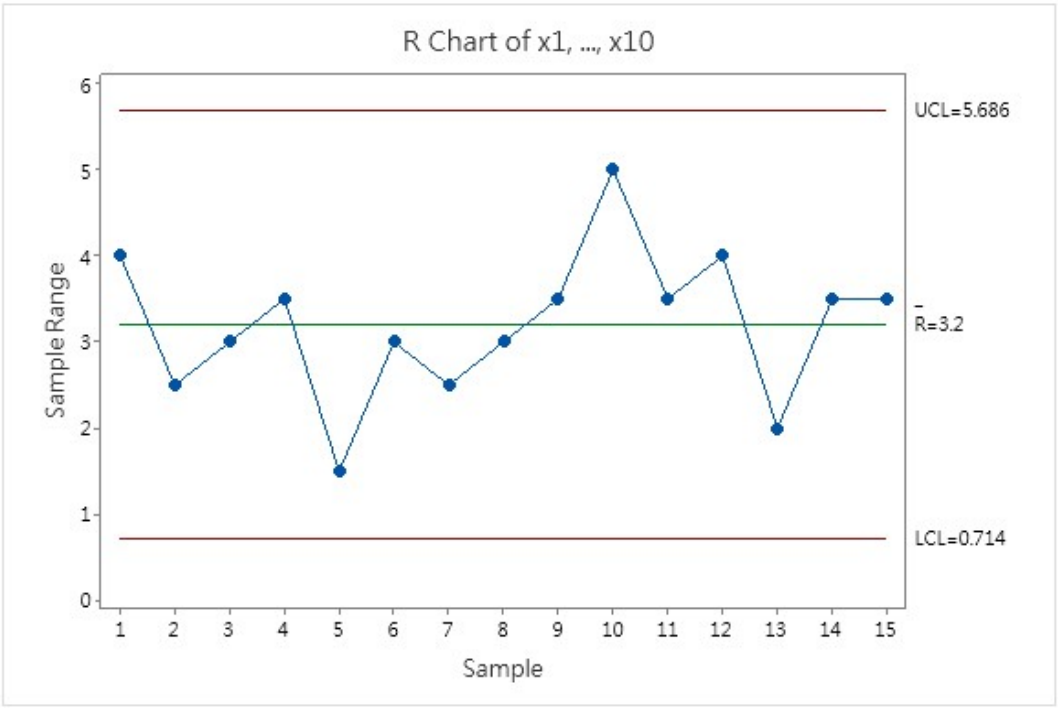
Sample Number	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
1	2.5	0.5	2.0	−1.0	1.0	−1.0	0.5	1.5	0.5	−1.5
2	0.0	0.0	0.5	1.0	1.5	1.0	−1.0	1.0	1.5	−1.0
3	1.5	1.0	1.0	−1.0	0.0	−1.5	−1.0	−1.0	1.0	−1.0
4	0.0	0.5	−2.0	0.0	−1.0	1.5	−1.5	0.0	−2.0	−1.5
5	0.0	0.0	0.0	−0.5	0.5	1.0	−0.5	−0.5	0.0	0.0
6	1.0	−0.5	0.0	0.0	0.0	0.5	−1.0	1.0	−2.0	1.0
7	1.0	−1.0	−1.0	−1.0	0.0	1.5	0.0	1.0	0.0	0.0
8	0.0	−1.5	−0.5	1.5	0.0	0.0	0.0	−1.0	0.5	−0.5
9	−2.0	−1.5	1.5	1.5	0.0	0.0	0.5	1.0	0.0	1.0
10	−0.5	3.5	0.0	−1.0	−1.5	−1.5	−1.0	−1.0	1.0	0.5
11	0.0	1.5	0.0	0.0	2.0	−1.5	0.5	−0.5	2.0	−1.0
12	0.0	−2.0	−0.5	0.0	−0.5	2.0	1.5	0.0	0.5	−1.0
13	−1.0	−0.5	−0.5	−1.0	0.0	0.5	0.5	−1.5	−1.0	−1.0
14	0.5	1.0	−1.0	−0.5	−2.0	−1.0	−1.5	0.0	1.5	1.5
15	1.0	0.0	1.5	1.5	1.0	−1.0	0.0	1.0	−2.0	−1.5

a. Set up x and s control charts on this process. Does the process exhibit statistical control? If necessary, construct revised control limits.



There is no indication of out-of-control

b. Set up an R chart, and compare it with the s chart in part (a).



No indication of out-of-control

The trends are the same in s and r chart, means there's no difference between them

c. Set up an s2 chart and compare it with the s chart in part (a)

$CL = \bar{s}^2 = (1.066)^2 = 1.136$

$\alpha = 0.01$

$UCL = (\bar{s}^2 / (n-1)) \, x^2_{\alpha/2, n-1} = (1.136/14) \, x^2_{0.005/2, 14}$

$= 0.0811683 * 31.32$

$= 2.542$

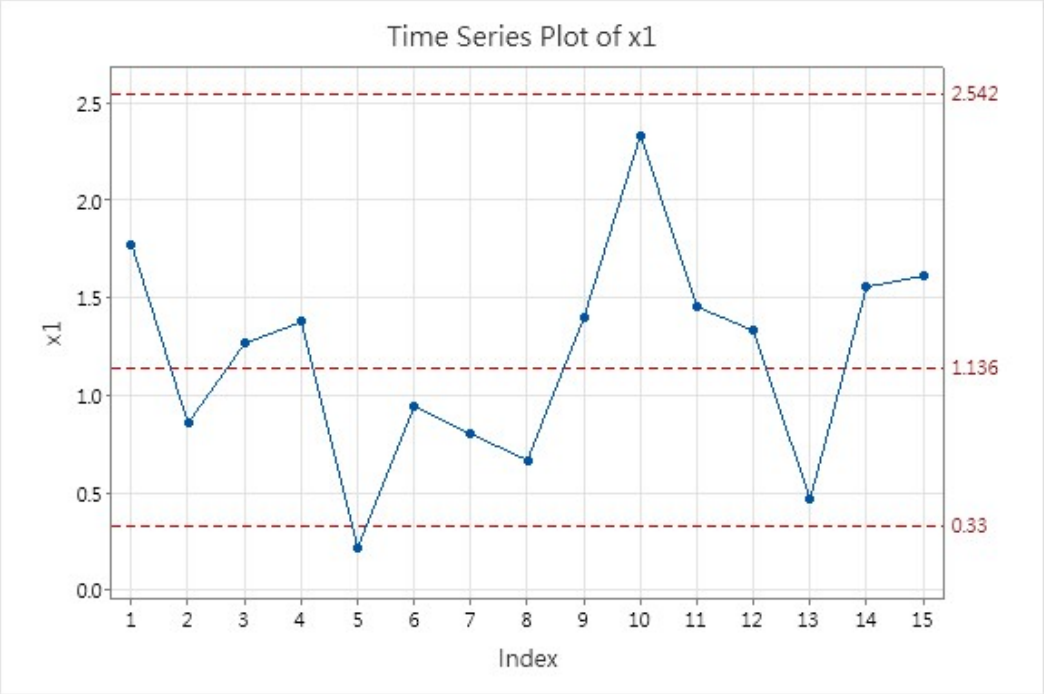
$LCL = (\bar{s}^2 / (n-1)) \, x^2_{1-\alpha/2, n-1} = (1.136/14) \, x^2_{0.995, 14}$

$= 0.0811683 * 4.07$

$= 0.33$

Statistics

Variable	Variance
x1	1.778
x2	0.858
x3	1.267
x4	1.378
x5	0.222
x6	0.944
x7	0.803
x8	0.669
x9	1.400
x10	2.336
x11	1.456
x12	1.333
x13	0.469
x14	1.558
x15	1.614



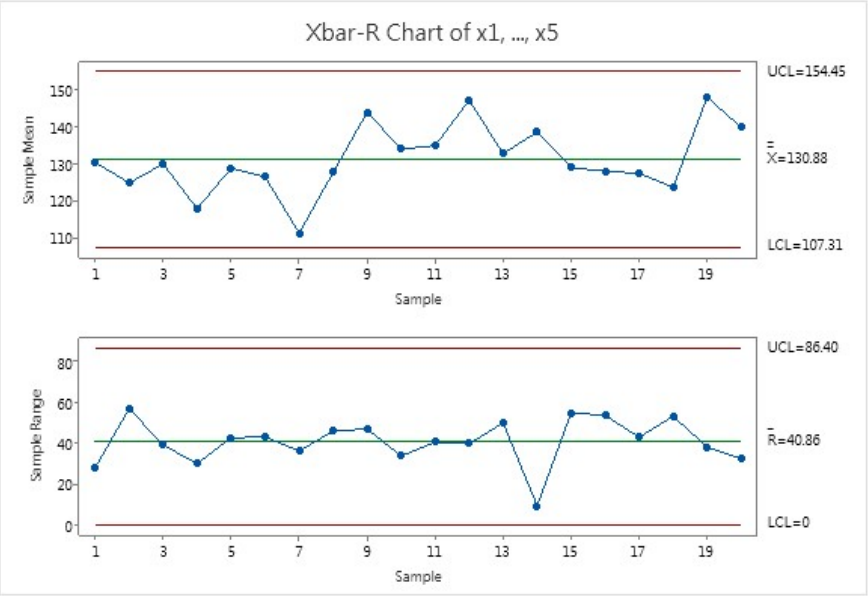
Compare to s chart, sample 5 is out of control (below LCL)

6.9. Table 6E.4 presents 20 subgroups of five measurements on the critical dimension of a part produced by a machining process.

Table 6E.4 Data for Exercise 6.9

Sample Number	x_1	x_2	x_3	x_4	x_5	$\bar{x}$	R
1	138.1	110.8	138.7	137.4	125.4	130.1	27.9
2	149.3	142.1	105.0	134.0	92.3	124.5	57.0
3	115.9	135.6	124.2	155.0	117.4	129.6	39.1
4	118.5	116.5	130.2	122.6	100.2	117.6	30.0
5	108.2	123.8	117.1	142.4	150.9	128.5	42.7
6	102.8	112.0	135.0	135.0	145.8	126.1	43.0
7	120.4	84.3	112.8	118.5	119.3	111.0	36.1
8	132.7	151.1	124.0	123.9	105.1	127.4	46.0
9	136.4	126.2	154.7	127.1	173.2	143.5	46.9
10	135.0	115.4	149.1	138.3	130.4	133.6	33.7
11	139.6	127.9	151.1	143.7	110.5	134.6	40.6
12	125.3	160.2	130.4	152.4	165.1	146.7	39.8
13	145.7	101.8	149.5	113.3	151.8	132.4	50.0
14	138.6	139.0	131.9	140.2	141.1	138.1	9.2
15	110.1	114.6	165.1	113.8	139.6	128.7	54.8
16	145.2	101.0	154.6	120.2	117.3	127.6	53.3
17	125.9	135.3	121.5	147.9	105.0	127.1	42.9
18	129.7	97.3	130.5	109.0	150.5	123.4	53.2
19	123.4	150.0	161.6	148.4	154.2	147.5	38.3
20	144.8	138.3	119.6	151.8	142.7	139.4	32.2

a. Set up x and R control charts on this process. Verify that the process is in statistical control.

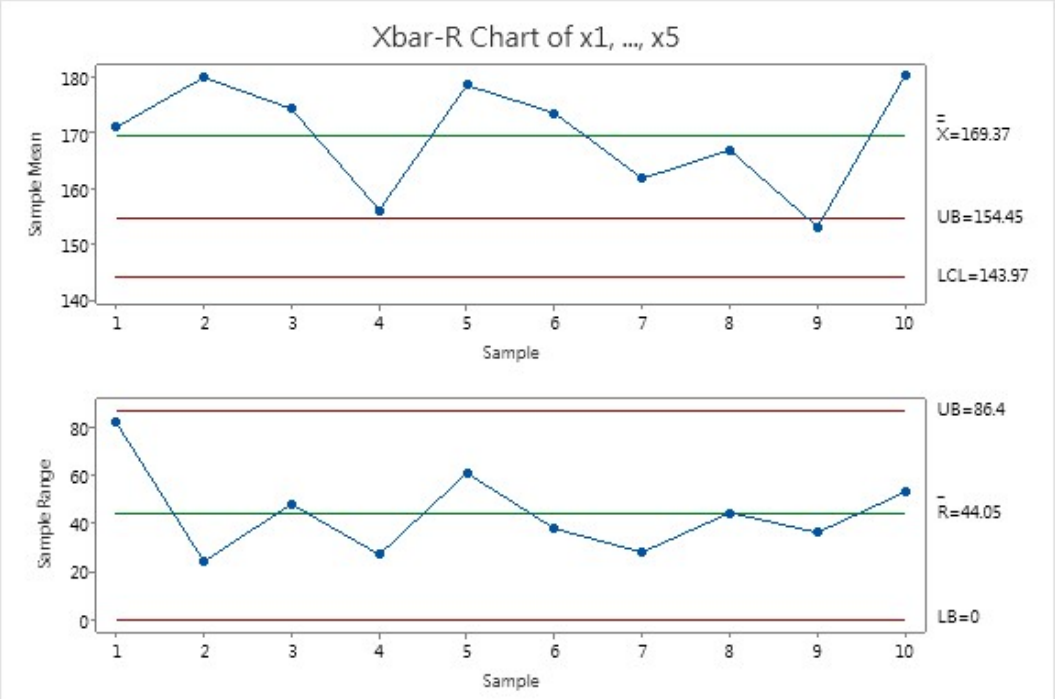


The process is in statistical control.

b. Following the establishment of control charts in part (a) above, 10 new samples in Table 6E.5 were collected. Plot the x and R values on the control chart you established in part (a) and draw conclusions.

Table 6E.5 Additional Data for Exercise 6.9, part (b)

Sample Number	x_1	x_2	x_3	x_4	x_5	$\bar{x}$	R
1	131.0	184.8	182.2	143.3	212.8	170.8	81.8
2	181.3	193.2	180.7	169.1	174.3	179.7	24.0
3	154.8	170.2	168.4	202.7	174.4	174.1	48.0
4	157.5	154.2	169.1	142.2	161.9	157.0	26.9
5	216.3	174.3	166.2	155.5	184.3	179.3	60.8
6	186.9	180.2	149.2	175.2	185.0	175.3	37.8
7	167.8	143.9	157.5	171.8	194.9	167.2	51.0
8	178.2	186.7	142.4	159.4	167.6	166.9	44.2
9	162.6	143.6	132.8	168.9	177.2	157.0	44.5
10	172.1	191.7	203.4	150.4	196.3	182.8	53.0



Out of control

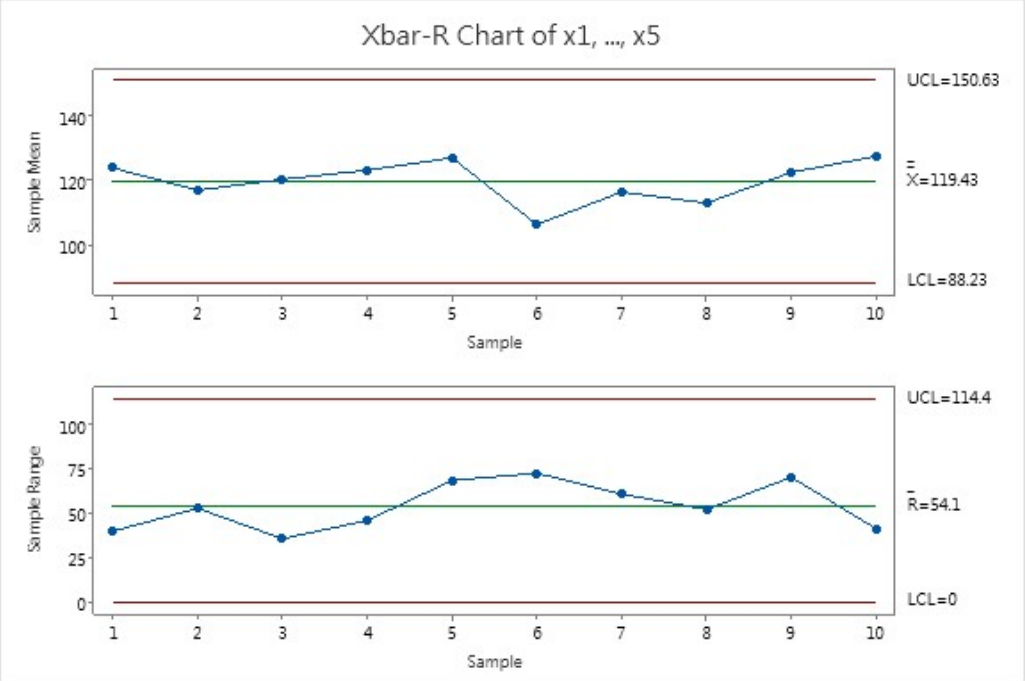
c. Suppose that the assignable cause responsible for the action signals generated in part (b) has been identified and adjustments made to the process to correct its

performance. Plot the x bar

and R values from the new subgroups shown in Table 6E.6, which were taken following the adjustment, against the control chart limits established in part (a). What are your conclusions?

Table 6E.6 New Data for Exercise 6.9, part (c)

Sample Number	x_1	x_2	x_3	x_4	x_5	$\bar{x}$	R
1	131.5	143.1	118.5	103.2	121.6	123.6	39.8
2	111.0	127.3	110.4	91.0	143.9	116.7	52.8
3	129.8	98.3	134.0	105.1	133.1	120.1	35.7
4	145.2	132.8	106.1	131.0	99.2	122.8	46.0
5	114.6	111.0	108.8	177.5	121.6	126.7	68.7
6	125.2	86.4	64.4	137.1	117.5	106.1	72.6
7	145.9	109.5	84.9	129.8	110.6	116.1	61.0
8	123.6	114.0	135.4	83.2	107.6	112.8	52.2
9	85.8	156.3	119.7	96.2	153.0	122.2	70.6
10	107.4	148.7	127.4	125.0	127.5	127.2	41.3



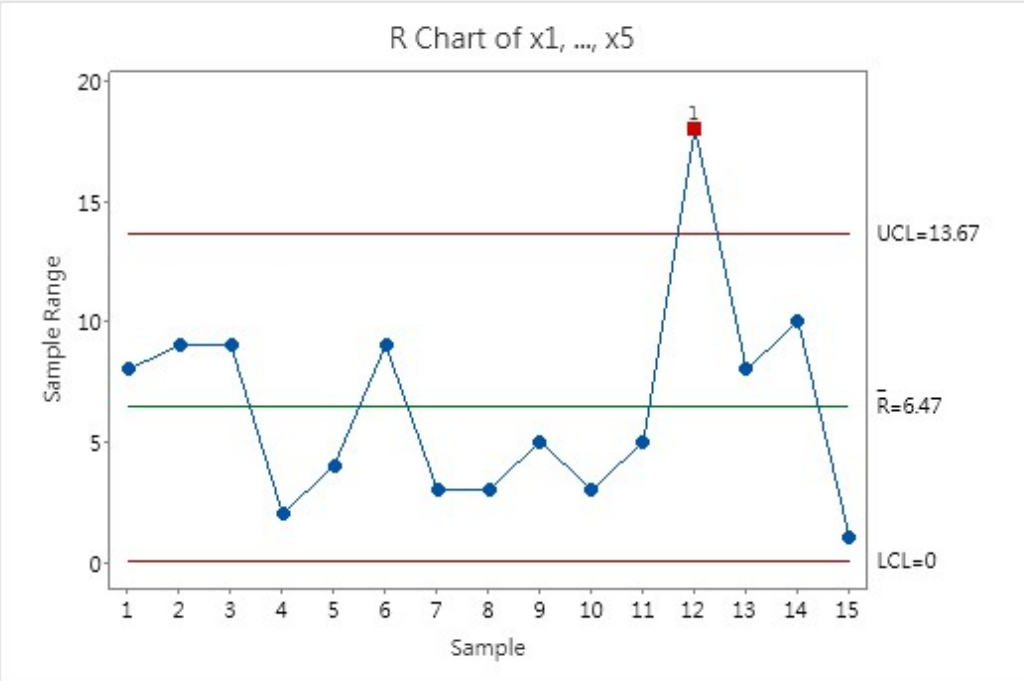
It controls better, the process is in statistical control

6.20 Specifications on a cigar lighter detent are 0.3220 and 0.3200 in. Samples of size 5 are taken every 45 min with the results shown in Table 6E.8 (measured as deviations from 0.3210 in to 0.0001 in.).

Table 6E.8 Data for Exercise 6.20

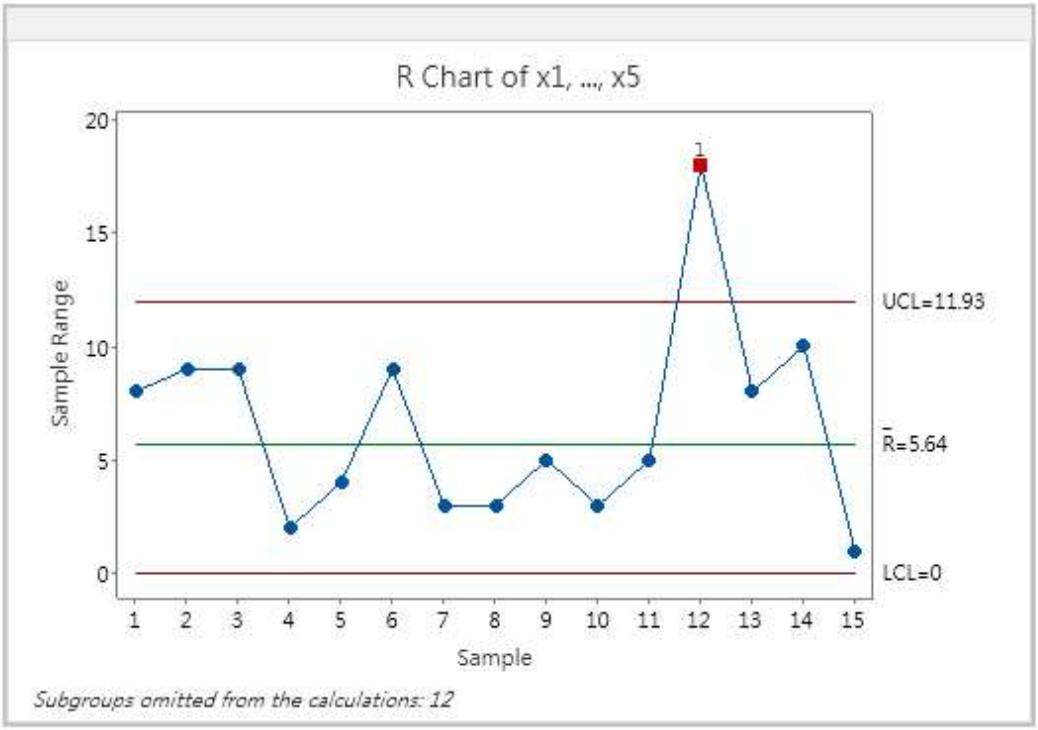
Sample Number	x_1	x_2	x_3	x_4	x_5
1	1	9	6	9	6
2	9	4	3	0	3
3	0	9	0	3	2
4	1	1	0	2	1
5	−3	0	−1	0	−4
6	−7	2	0	0	2
7	−3	−1	−1	0	−2
8	0	−2	−3	−3	−2
9	2	0	−1	−3	−1
10	0	2	−1	−1	2
11	−3	−2	−1	−1	2
12	−16	2	0	−4	−1
13	−6	−3	0	0	−8
14	−3	−5	5	0	5
15	−1	−1	−1	−2	−1

a. Set up an R chart and examine the process for statistical control.



process is not in control, sample 12 is out of control

b. What parameters would you recommend for an R chart for on-line control?



Test Results for R Chart of x1, ..., x5

TEST 1. One point more than 3.00 standard deviations from center line.
Test Failed at points: 12

Remove sample 12

c. Estimate the standard deviation of the process.

N = 5→d2 = 2.326

σ = $\bar{R}$ / d2 = 5.64 / 2.326 = 2.42

d. What is the process capability?

Cp =(USL-LSL) / 6σ = (0.322-0.32) / 6 (2.42 * 0.0001) = 1.37741