Control Chart for Range

SESSION 4

Structure

4.1 INTRODUCTION

Prerequisite

- Lab Sessions 1, 3 and 6 of MSTL-001 (Basic Statistics Lab).
- Lab Session 2 of MSTL-002 (Industrial Statistics Lab).
- Unit 2 of MSTE-001 (Industrial Statistics-I).

In Lab Sessions 1 to 3, you have learnt about the $\bar{X}$-chart which is used to control the process mean. We have discussed in Sec. 2.5 of Unit 2 of MSTE-001(Industrial Statistics-I) that process variability also affects the product quality. When variation in the production process is high, that is, the produced items have a wider range of values of the quality characteristics, the quality of the product is assumed to be poor. So we must reduce the process variability to improve the quality of the product. We use control chart for range (R-chart) and control chart for standard deviation (S-chart) to **control the process variability**.

R-chart is more widely used in quality control than the S-chart because in quality control, we generally use samples of sizes less than 10. We know that for $n \leq 10$, range and standard deviation reflect almost the same information about the variability. Range is easier to calculate and interpret as compared to standard deviation.

The underlying logic and basic form of R-chart are similar to the $\bar{X}$-chart. The primary difference between $\bar{X}$ and R-chart is that instead of plotting the sample means and monitoring their variation, we plot the **sample range** and monitor the **variation of sample ranges**. In this lab session, you will learn how to **construct R-chart** in MS Excel 2007. We shall explain the construction of **S-chart** in the next lab session.

Objectives

After performing the activities of this session, you should be able to:

- prepare spreadsheet in MS Excel 2007;
- determine the control limits for control chart for range;
- construct the control chart for range;
- obtain the revised control limits for control charts for range and mean; and
- interpret the control charts.

4.2 PROBLEM DESCRIPTION

Suppose a bulb manufacturing company wants to check whether the variation in the life of bulbs produced by a particular machine is due to chance causes or assignable causes. For this purpose, a quality control inspector at this company selects 35 samples, each of size 5, and measures the life of each bulb (in hours).

Table 1: Life of bulbs

Sample Number	Life of Bulbs (in hours)				
	Obs. 1	Obs. 2	Obs. 3	Obs. 4	Obs. 5
1	1152	650	1090	708	1065
2	688	540	1074	598	1049
3	876	1342	1187	1214	1162
4	725	1070	847	1128	822
5	900	846	1254	904	1229
6	1080	790	871	848	846
7	952	1087	1126	1145	1101
8	741	986	578	1044	837
9	1005	1244	1140	1302	1115
10	1494	1005	614	1063	575
11	1200	870	859	928	834
12	745	964	1050	1022	1025
13	926	1172	1200	1230	1175
14	781	876	981	934	956
15	1120	1350	750	1408	725
16	880	975	768	1033	743
17	1138	636	1076	694	1051
18	674	526	1060	584	1035
19	862	1328	1173	1200	1148
20	711	1056	833	1114	808
21	886	832	1240	890	1215
22	1066	776	857	834	832
23	938	1073	1112	1131	1087
24	727	972	564	1030	823
25	991	1230	1126	1288	1101
26	1227	991	600	1049	561
27	1186	856	845	914	820
28	731	950	1036	1008	1011
29	912	1158	1186	1216	1161
30	1124	862	967	920	942
31	1106	1336	578	1490	711
32	866	961	754	1019	729
33	1124	622	1062	680	1037
34	660	658	1046	784	1021
35	848	1314	1159	1186	1134

The quality control inspector of the company has to construct a control chart for range and mean to infer whether the production variability is under control or not. If it is out-of-control, he/she computes the revised control limits.

Therefore, the problem for this session is to construct the control charts for range and mean for the data given in Table 1.

4.3 PROCEDURE FOR THE CONSTRUCTION OF R-CHART

You have already learnt all the formulae for calculating control limits for R-chart and the method to draw R-chart manually in Sec. 2.5 of Unit 2 of MSTE-001. So here we focus on the main steps involved in the construction of R-chart for the data given in Table 1:

When the value of σ is known

Step 1: The control limits for R-chart for known σ are given by

- ✓ Centre line (CL) $= d_2\sigma$ ...(1)
- ✓ Upper control limit (UCL) $= D_2\sigma$ ...(2)
- ✓ Lower control limit (LCL) $= D_1\sigma$ ...(3)

where d_2, D_1 and D_2 are constants and depend on the size of the sample. These constants have been tabulated for various sample sizes in the Appendix given at the end of this lab course.

Step 2: To construct the R-chart, we take sample number on the X-axis and sample range R on the Y-axis and plot the value of sample range for each sample against the sample number. The consecutive sample points are joined by line segments.

Step 3: Interpretation of the R-chart.

When the value of σ is unknown

In practice, the value of σ is not known. Therefore, it is estimated from the samples which are taken when the process is assumed to be under control. In R-chart, σ is estimated by sample range (R).

Step 1-2: The first two steps are the same as Steps 4 and 5 of Sec. 2.3 of Lab Session 2.

Step 3: The control limits for R-chart when σ is estimated by $\bar{R}/d_2$ are given by

- ✓ Centre line (CL) $= \bar{R}$ ...(4)
- ✓ Upper control limit (UCL) $= D_4\bar{R}$ ...(5)
- ✓ Lower control limit (LCL) $= D_3\bar{R}$ ...(6)

where D_3 and D_4 are constants and depend on the size of the sample. These constants have been tabulated for various sample sizes in the Appendix given at the end of this lab course.

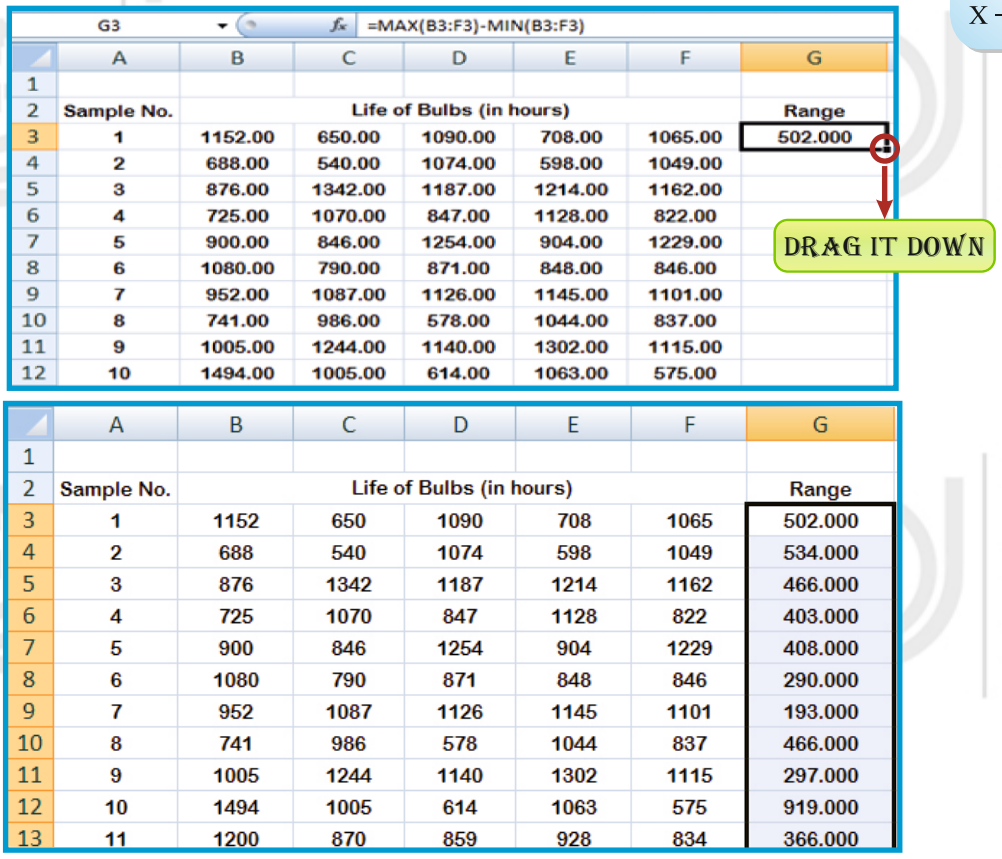
Step 4: Interpretation of the R-chart.

4.4 STEPS INVOLVED IN THE CONSTRUCTION OF R-CHART IN EXCEL 2007

In order to calculate the control limits of R-chart and to plot the control chart in Excel 2007 for the given data, we follow the steps given below:

Generally, in order to judge whether the process is in control, we use $\bar{X}$ and R-charts together. We first control the process variability and so we analyse the R-chart prior to the $\bar{X}$ - chart.

Step 1: We enter the given data in Excel Sheet and calculate range for the first sample by typing "=Max(B3:F3)-Min(B3:F3)" in Cell G3. After that, we drag down Cell G3 up to Cell G37 as shown in Fig. 4.1.



	A	B	C	D	E	F	G
1							
2	Sample No.			Life of Bulbs (in hours)			Range
3	1	1152.00	650.00	1090.00	708.00	1065.00	502.000
4	2	688.00	540.00	1074.00	598.00	1049.00	
5	3	876.00	1342.00	1187.00	1214.00	1162.00	
6	4	725.00	1070.00	847.00	1128.00	822.00	
7	5	900.00	846.00	1254.00	904.00	1229.00	
8	6	1080.00	790.00	871.00	848.00	846.00	
9	7	952.00	1087.00	1126.00	1145.00	1101.00	
10	8	741.00	986.00	578.00	1044.00	837.00	
11	9	1005.00	1244.00	1140.00	1302.00	1115.00	
12	10	1494.00	1005.00	614.00	1063.00	575.00	

	A	B	C	D	E	F	G
1							
2	Sample No.			Life of Bulbs (in hours)			Range
3	1	1152	650	1090	708	1065	502.000
4	2	688	540	1074	598	1049	534.000
5	3	876	1342	1187	1214	1162	466.000
6	4	725	1070	847	1128	822	403.000
7	5	900	846	1254	904	1229	408.000
8	6	1080	790	871	848	846	290.000
9	7	952	1087	1126	1145	1101	193.000
10	8	741	986	578	1044	837	466.000
11	9	1005	1244	1140	1302	1115	297.000
12	10	1494	1005	614	1063	575	919.000
13	11	1200	870	859	928	834	366.000

Fig. 4.1

Step 2: In Cell G38, we compute the average range ($\bar{R}$) by typing "=Average(G3:G37)" and click on ***Enter*** key as shown in Fig. 4.2.

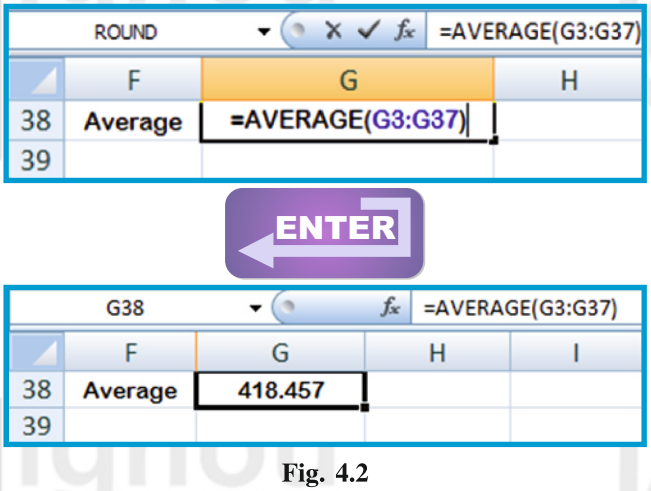


Fig. 4.2

Step 3: Next we type the values of k and n in Cells G40 and G41, respectively. We also have to type the values of D_3 and D_4 for n = 5 in Cell G42 and G43, respectively, as shown in Fig. 4.3. We take them from the Appendix given at the end of this lab course.

	D	E	F	G
40			k	35
41			n	5
42	D_3 Value from Table (for n=5)			0
43	D_4 Value from Table (for n=5)			2.114

Fig. 4.3

Step 4: We recall the method for computing the centre line and both control limits described in Lab Sessions 1-3. Here we use Columns H, I and J for putting the values of centre line, upper and lower control limits, respectively. We calculate these values as follows:

The formula with dollar sign ($) is used for an absolute reference.

i) The centre line is given in equation (4) and $\bar{R}$ is given in Cell G38 (see Fig. 4.2). So we type "=$G$38" in Cell H3 to find the centre line as shown in Fig. 4.4a.

ii) We use equation (5) for the upper control limit. The values of D_4 and $\bar{R}$ are given in Cells G43 and G38, respectively (see Figs. 4.2 and 4.3). We type "=$G$43*$G$38" in Cell I3 as shown in Fig. 4.4b.

iii) Similarly, we calculate the lower control limit from equation (6) and type "=$G$43*$G$38" in Cell J3 as shown in Fig. 4.4c.

(a)

H3 fx =$G$38

	H	I	J	K
1	Control Limits			
2	Centre Line	UCL	LCL	
3	418.457			
4				

(b)

I3 fx =$G$43*$G$38

	I	J	K	L
1	ntrol Limits			
2	UCL	LCL		
3	884.618			
4				

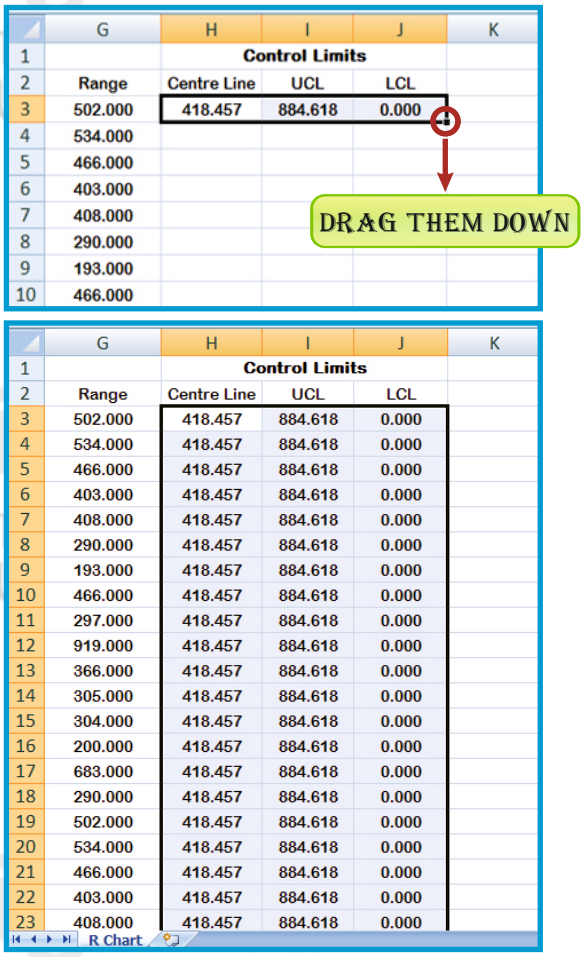
(c)

J3 fx =$G$42*$G$38

	J	K	L	M
1	s			
2	LCL			
3	0.000			
4				

Fig. 4.4

Step 5: For plotting control limits using Excel, we first select Cells H3:J3 and drag them down up to Row 37 as shown in Fig. 4.5.



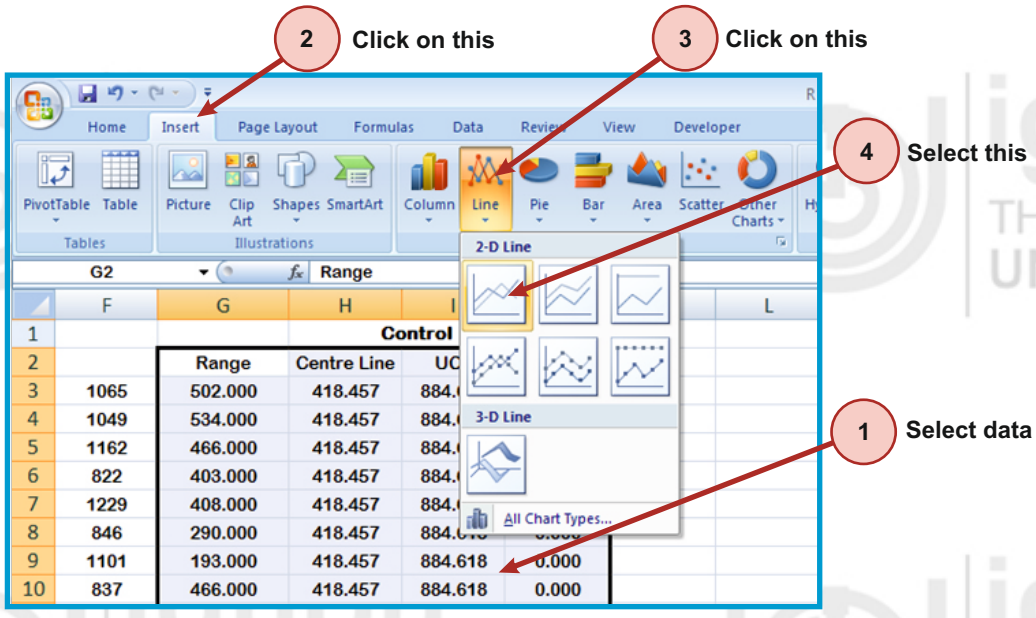
	G	H	I	J	K
1		Control Limits			
2	Range	Centre Line	UCL	LCL	
3	502.000	418.457	884.618	0.000	
4	534.000	418.457	884.618	0.000	
5	466.000	418.457	884.618	0.000	
6	403.000	418.457	884.618	0.000	
7	408.000	418.457	884.618	0.000	
8	290.000	418.457	884.618	0.000	
9	193.000	418.457	884.618	0.000	
10	466.000	418.457	884.618	0.000	
11	297.000	418.457	884.618	0.000	
12	919.000	418.457	884.618	0.000	
13	366.000	418.457	884.618	0.000	
14	305.000	418.457	884.618	0.000	
15	304.000	418.457	884.618	0.000	
16	200.000	418.457	884.618	0.000	
17	683.000	418.457	884.618	0.000	
18	290.000	418.457	884.618	0.000	
19	502.000	418.457	884.618	0.000	
20	534.000	418.457	884.618	0.000	
21	466.000	418.457	884.618	0.000	
22	403.000	418.457	884.618	0.000	
23	408.000	418.457	884.618	0.000	

R Chart

Fig. 4.5

Step 6: For plotting the R-chart in Excel 2007, we refer to Fig. 4.6. It means that we

1. select Cells G2:J37,
2. click on the ***Insert*** tab,
3. select the ***Line*** option, and
4. choose the chart subtype.



	F	G	H	I	L
1			Control		
2		Range	Centre Line	UC	
3	1065	502.000	418.457	884.	
4	1049	534.000	418.457	884.	
5	1162	466.000	418.457	884.	
6	822	403.000	418.457	884.	
7	1229	408.000	418.457	884.	
8	846	290.000	418.457	884.	
9	1101	193.000	418.457	884.618	0.000
10	837	466.000	418.457	884.618	0.000

Fig. 4.6

Step 7: We find that Columns H, I and J will provide horizontal lines on the chart representing the centre line, UCL and LCL, respectively. Column G will provide the ranges for 35 samples on the chart. We format the chart as explained in Sec. 1.4 of Lab Session 1. Thus, we obtain the R-chart shown in Fig. 4.7.

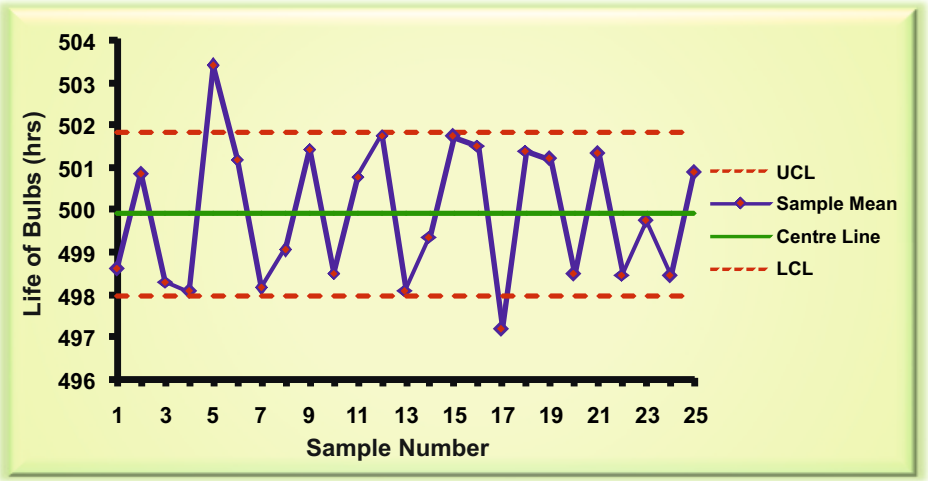


Fig. 4.7

Interpretation

Note from Fig. 4.7 that two points corresponding to Samples 10 and 31 lie outside the UCL. So the control chart indicates that the process is **not under statistical control**. Some **assignable causes** are present in the process. To bring the process under statistical control, it is necessary to investigate the assignable causes and take corrective action to eliminate them.

4.5 REVISED R-CHART

After eliminating the assignable causes from the process, we revise the control chart of Fig.4.7 by deleting out-of-control samples. For this purpose, we obtain the revised control limits for the R-chart using only the remaining samples as explained below:

Step 1: For revised limits for R-chart, we first calculate new $\bar{R}$ as follows:

$$\bar{R}_{new} = \frac{\sum_{i=1}^{k} R_i - \sum_{j=1}^{d} R_j}{k-d} \quad \cdots(7)$$

where $\sum_{j=1}^{d} R_j$ – sum of the ranges of discarded samples, and

d – number of discarded samples.

Step 2: After finding the new $\bar{R}$, we reconstruct the centre line and control limits by replacing $\bar{R}$ by $\bar{R}_{new}$ as follows:

- ✓ Centre line (CL) $= \bar{R}_{new}$ …(8)
- ✓ Upper control limit (UCL) $= D_4\bar{R}_{new}$ …(9)
- ✓ Lower control limit (LCL) $= D_3\bar{R}_{new}$ …(10)

Step 3: Interpretation of the R-chart.

Steps in Excel

The main steps for calculating the revised centre line and control limits for the R-chart in Excel 2007 for the remaining samples are as follows:

Step 1: We highlight the samples outside the control limits, i.e., the 10th and 31st samples, with light orange colour (Fig. 4.8).

	A	B	C	D	E	F	G	H	I	J
1								Control Limits		
2	Sample No.	Life of Bulbs (in hours)					Range	Centre Line	UCL	LCL
3	1	1152	650	1090	708	1065	502.000	418.457	884.618	0.000
4	2	688	540	1074	598	1049	534.000	418.457	884.618	0.000
5	3	876	1342	1187	1214	1162	466.000	418.457	884.618	0.000
6	4	725	1070	847	1128	822	403.000	418.457	884.618	0.000
7	5	900	846	1254	904	1229	408.000	418.457	884.618	0.000
8	6	1080	790	871	848	846	290.000	418.457	884.618	0.000
9	7	952	1087	1126	1145	1101	193.000	418.457	884.618	0.000
10	8	741	986	578	1044	837	466.000	418.457	884.618	0.000
11	9	1005	1244	1140	1302	1115	297.000	418.457	884.618	0.000
12	10	1494	1005	614	1063	575	919.000	418.457	884.618	0.000
13	11	1200	870	859	928	834	366.000	418.457	884.618	0.000
14	12	745	964	1050	1022	1025	305.000	418.457	884.618	0.000
15	13	926	1172	1200	1230	1175	304.000	418.457	884.618	0.000
16	14	781	876	981	934	956	200.000	418.457	884.618	0.000
17	15	1120	1350	750	1408	725	683.000	418.457	884.618	0.000
18	16	880	975	768	1033	743	290.000	418.457	884.618	0.000
19	17	1138	636	1076	694	1051	502.000	418.457	884.618	0.000
20	18	674	526	1060	584	1035	534.000	418.457	884.618	0.000
21	19	862	1328	1173	1200	1148	466.000	418.457	884.618	0.000

	A	B	C	D	E	F	G	H	I	J
31	29	912.00	1158.00	1186.00	1216.00	1161.00	304.000	418.457	884.618	0.000
32	30	1124.00	862.00	967.00	920.00	942.00	262.000	418.457	884.618	0.000
33	31	1106.00	1336.00	578.00	1490.00	711.00	912.000	418.457	884.618	0.000
34	32	866.00	961.00	754.00	1019.00	729.00	290.000	418.457	884.618	0.000
35	33	1124.00	622.00	1062.00	680.00	1037.00	502.000	418.457	884.618	0.000
36	34	660.00	658.00	1046.00	784.00	1021.00	388.000	418.457	884.618	0.000
37	35	848.00	1314.00	1159.00	1186.00	1134.00	466.000	418.457	884.618	0.000

Fig. 4.8

Step 2: We have two samples outside the UCL, so we put d = 2 in Cell G44 as shown in Fig. 4.9.

	D	E	F	G
40			k	35
41			n	5
42		D_3 Value from Table (for n=5)		0
43		D_4 Value from Table (for n=5)		2.114
44			d	2

Fig. 4.9

Step 3: For calculating the value of $\bar{R}_{new}$ given in equation (7), we type "=(Sum(N3:N37)-N12-N33)/(G40-G44)" in Cell G39 and then press ***Enter***. We get the value of revised $\bar{R}$ i.e., $\bar{R}_{new}$ as shown in Fig. 4.10.

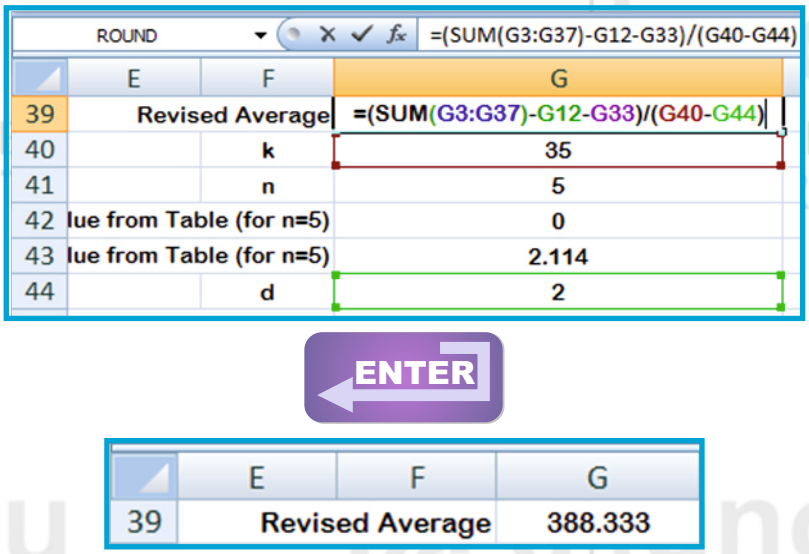


Fig. 4.10

Step 4: We now calculate the revised centre line, upper and lower control limits as discussed in Step 4 of Sec. 4.3. Here we use Columns K, L and M for putting the values of the revised centre line, upper and lower control limits, respectively.

The formula with dollar sign ($) is used for an absolute reference.

i) The revised centre line is given by equation (8). The value of $\bar{R}_{new}$ is given in Cell G39 (see Fig. 4.10). So we type "=$G$39" in Cell K3 to find the centre line as shown in Fig. 4.11a.

ii) The upper control limit is given by equation (9). The values of D_4 and $\bar{R}_{new}$ are given in Cells G43 and G39, respectively (see Fig. 4.10). So we type "=$G$43*$G$39" in Cell L3 as shown in Fig. 4.11b.

iii) Similarly, we calculate the lower control limit given by equation (10) by typing "=$G$42*$G$39" in Cell M3 as shown in Fig. 4.11c.

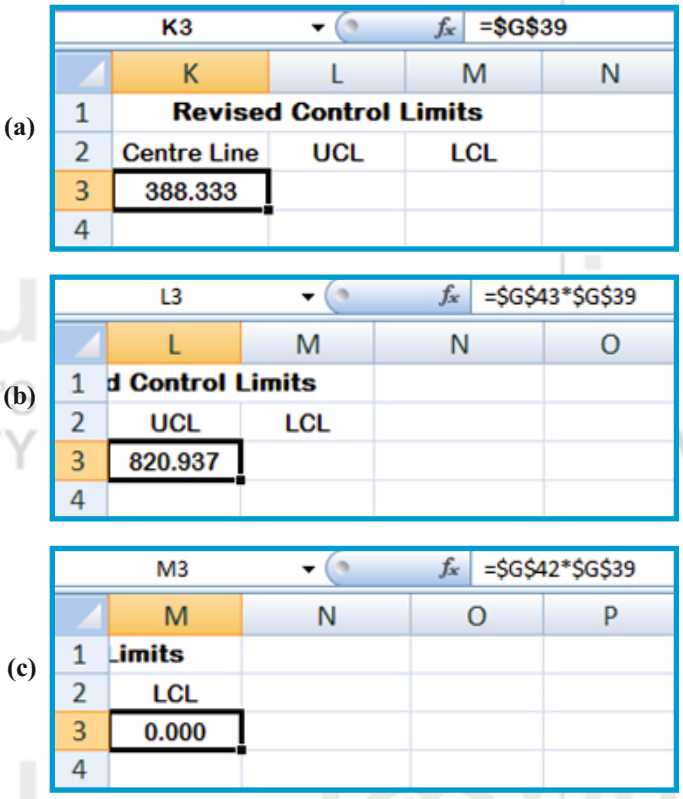
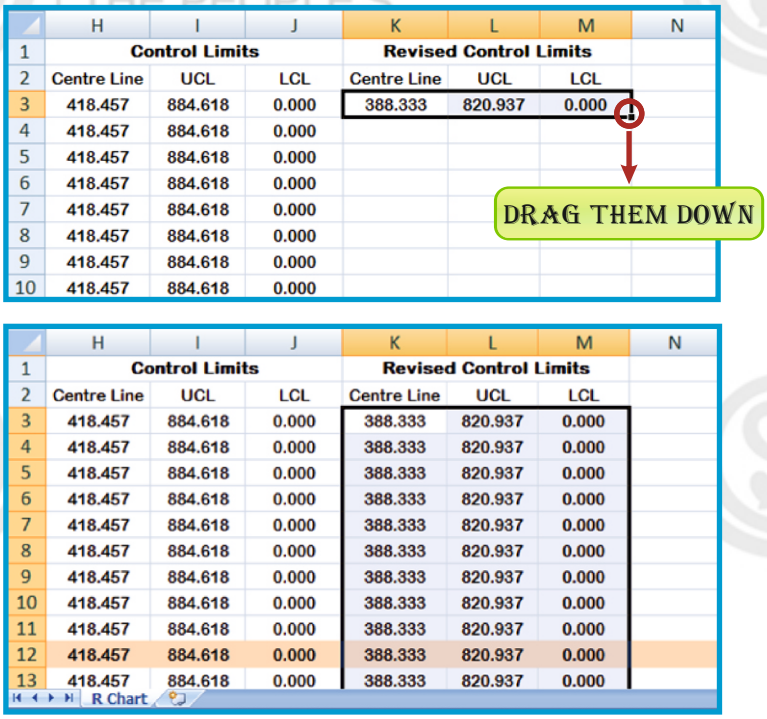


Fig. 4.11

Step 5: For plotting control limits on the chart using Excel, we first select Cells K3:M3 and drag them down up to Row 37 as shown in Fig. 4.12.



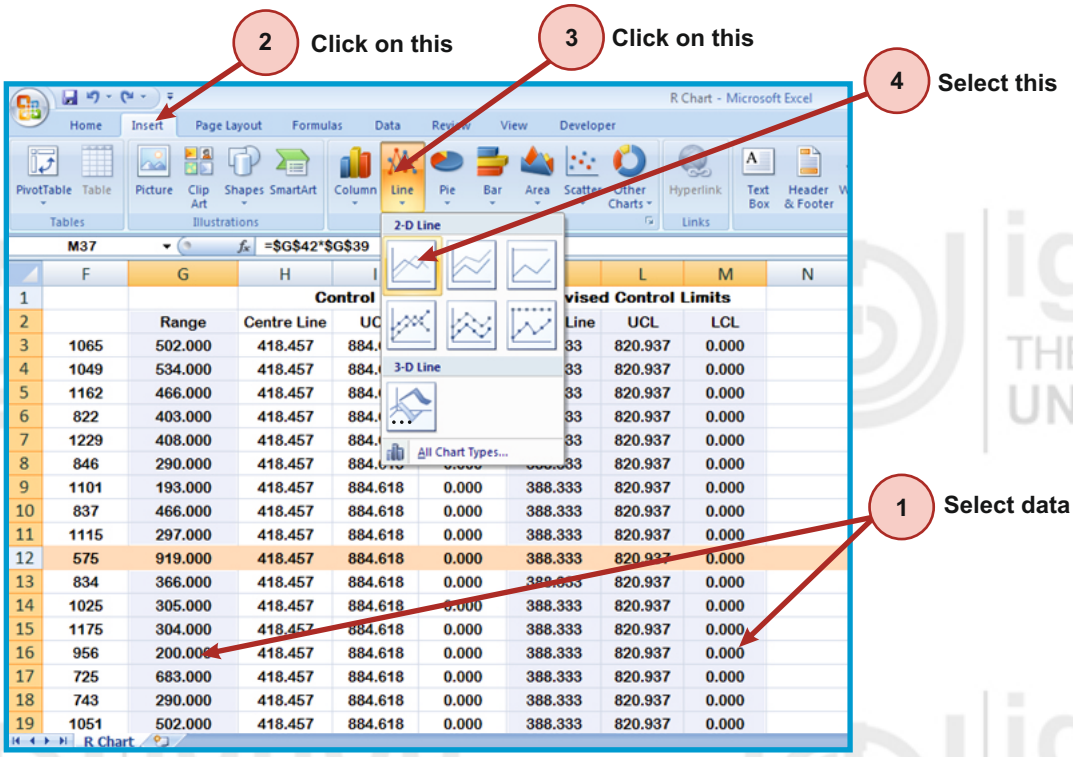
	H	I	J	K	L	M	N
1		Control Limits			Revised Control Limits		
2	Centre Line	UCL	LCL	Centre Line	UCL	LCL	
3	418.457	884.618	0.000	388.333	820.937	0.000	
4	418.457	884.618	0.000				
5	418.457	884.618	0.000				
6	418.457	884.618	0.000				
7	418.457	884.618	0.000				
8	418.457	884.618	0.000				
9	418.457	884.618	0.000				
10	418.457	884.618	0.000				

	H	I	J	K	L	M	N
1		Control Limits			Revised Control Limits		
2	Centre Line	UCL	LCL	Centre Line	UCL	LCL	
3	418.457	884.618	0.000	388.333	820.937	0.000	
4	418.457	884.618	0.000	388.333	820.937	0.000	
5	418.457	884.618	0.000	388.333	820.937	0.000	
6	418.457	884.618	0.000	388.333	820.937	0.000	
7	418.457	884.618	0.000	388.333	820.937	0.000	
8	418.457	884.618	0.000	388.333	820.937	0.000	
9	418.457	884.618	0.000	388.333	820.937	0.000	
10	418.457	884.618	0.000	388.333	820.937	0.000	
11	418.457	884.618	0.000	388.333	820.937	0.000	
12	418.457	884.618	0.000	388.333	820.937	0.000	
13	418.457	884.618	0.000	388.333	820.937	0.000	

Fig. 4.12

Step 5: For plotting the R-chart in Excel 2007, we refer to Fig. 4.13. It means that we

1. select Cells G2:G11, G13:G32, G34:G37, K2:M11, K13:M32 and K34:M37 by holding *Ctrl* key,
2. click on the *Insert* tab,
3. select the *Line* option, and
4. choose the chart subtype.



	F	G	H	I	J	K	L	M	N
1			Control				vised Control Limits		
2		Range	Centre Line	UC			Line	UCL	LCL
3	1065	502.000	418.457	884.			33	820.937	0.000
4	1049	534.000	418.457	884.			33	820.937	0.000
5	1162	466.000	418.457	884.			33	820.937	0.000
6	822	403.000	418.457	884.			33	820.937	0.000
7	1229	408.000	418.457	884.			33	820.937	0.000
8	846	290.000	418.457				33	820.937	0.000
9	1101	193.000	418.457	884.618	0.000	388.333		820.937	0.000
10	837	466.000	418.457	884.618	0.000	388.333		820.937	0.000
11	1115	297.000	418.457	884.618	0.000	388.333		820.937	0.000
12	575	919.000	418.457	884.618	0.000	388.333		820.937	0.000
13	834	366.000	418.457	884.618	0.000	388.333		820.937	0.000
14	1025	305.000	418.457	884.618	0.000	388.333		820.937	0.000
15	1175	304.000	418.457	884.618	0.000	388.333		820.937	0.000
16	956	200.000	418.457	884.618	0.000	388.333		820.937	0.000
17	725	683.000	418.457	884.618	0.000	388.333		820.937	0.000
18	743	290.000	418.457	884.618	0.000	388.333		820.937	0.000
19	1051	502.000	418.457	884.618	0.000	388.333		820.937	0.000

Fig. 4.13

Step 7: We format and change the horizontal axis as discussed in Steps 9 and 10 of Sec. 2.5 of Lab Session 2. The resulting R-chart is shown in Fig. 4.14.

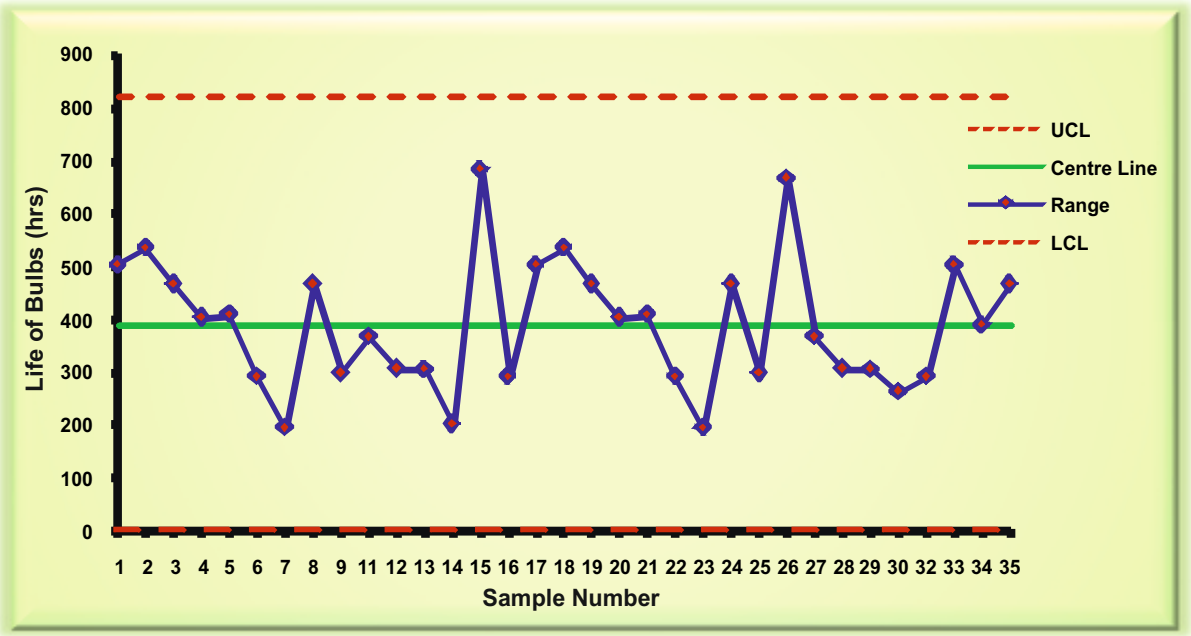


Fig. 4.14

If one or more points lie outside the revised control limits, we calculate the revised control limits of R-chart again. This continues until the process comes under control.

Interpretation

The revised R-chart shown in Fig. 4.14 indicates that all points lie within the control limits. So the process is under statistical control with respect to process variability.

Activity 1

You can also determine the revised control limits using another approach. For this purpose, follow the steps given below:

- ✓ Select Cells A2:F11, A13:F32 and A34:F37.
- ✓ Choose Cell A46 or any other cell and paste the values. You can also use a separate Excel sheet where you can paste these values.
- ✓ Repeat all the steps given in Sec. 4.4.

It will give you the same results as you have obtained in Sec. 4.5.

So far you have learnt how to control the process variability using the R-chart. We shall now study the process mean. For this, we calculate the control limits of the $\overline{X}$-chart using the remaining samples.

4.6 REVISED $\bar{X}$-CHART

We have already controlled the process variability using R-chart in Sec. 4.5 after eliminating the assignable causes present in the process. We now have to control the process mean. Here we use $\bar{R}_{new}$ to estimate the process variability. We calculate $\bar{\bar{X}}_{new}$ by deleting the out-of-control points. We compute the revised control limits for the $\bar{X}$-chart as explained in Sec. 2.5 of Lab Session 2.

Step 1: For the revised limits for $\bar{X}$-chart, we calculate new $\bar{\bar{X}}$ and new $\bar{R}$ as follows:

$$\bar{\bar{X}}_{new} = \frac{\sum_{i=1}^{k} \bar{X}_i - \sum_{j=1}^{d} \bar{X}_j}{k-d} \quad ...(11)$$

and $$\bar{R}_{new} = \frac{\sum_{i=1}^{k} R_i - \sum_{j=1}^{d} R_j}{k-d} \quad ...(12)$$

where $\sum_{j=1}^{d} \bar{X}_j$ – sum of the averages of discarded samples,

d – number of discarded samples, and

$\sum_{j=1}^{d} R_j$ – sum of the ranges of discarded samples.

Step 2: Then we reconstruct the centre line and control limits of the chart by replacing $\bar{\bar{X}}$ by $\bar{\bar{X}}_{new}$ and $\bar{R}$ by $\bar{R}_{new}$ as follows:

- ✓ Centre line = $\bar{\bar{X}}_{new}$ ...(13)
- ✓ Upper control limit (UCL) = $\bar{\bar{X}}_{new} + A_2\bar{R}_{new}$ ...(14)
- ✓ Lower control limit (UCL) = $\bar{\bar{X}}_{new} - A_2\bar{R}_{new}$ ...(15)

Step 3: Interpretation of the $\bar{X}$-chart.

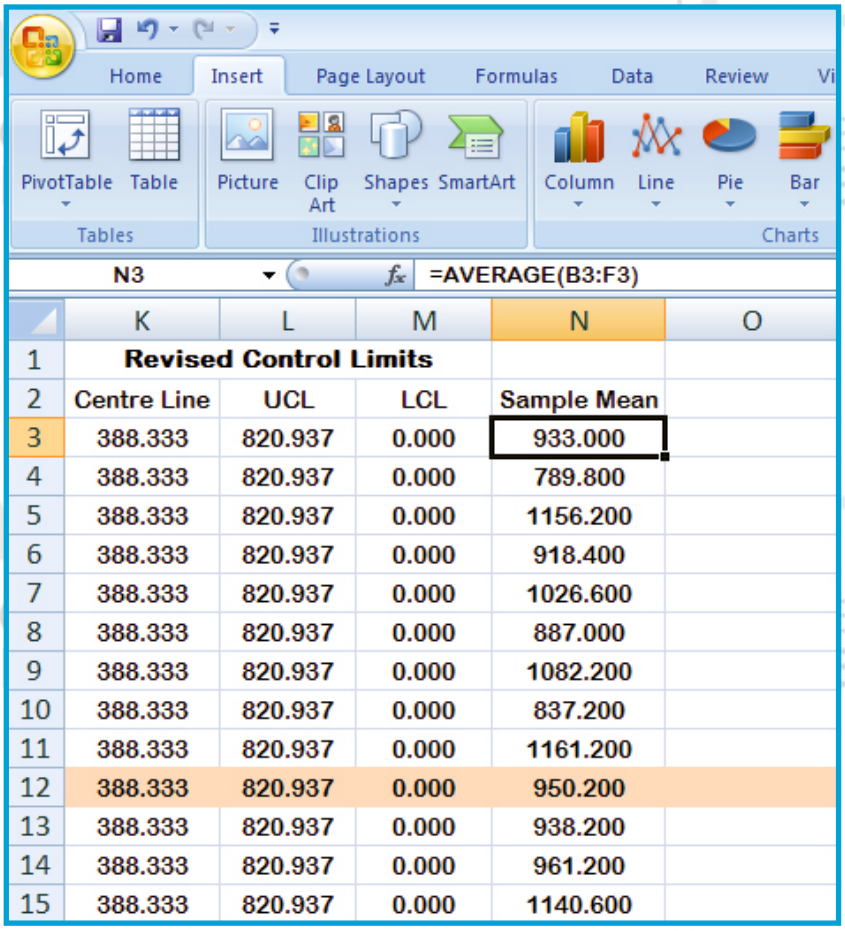
If R-chart indicates that the process variability is out-of-control, we first control the process variability by investigating the assignable causes and take corrective action to eliminate them. Then we analyse $\bar{X}$- chart. because when R-chart is brought to control, many assignable causes for $\bar{X}$-chart are also eliminated.

If R-chart indicates that the process variability is under control but the $\bar{X}$-chart indicates that the average of the process is out-of-control, we continue to use the same R-chart and revise the centre line and control limits of the $\bar{X}$-chart by eliminating these points.

Steps in Excel

The main steps for calculating the revised centre line and control limits for the $\bar{X}$-chart in Excel 2007 using the remaining samples are as follows:

Step 1: We compute the sample means for all given samples in Cells N3:N37 as explained in Steps 1-5 of Sec. 1.4 of Lab Session 1. The output is shown in Fig. 4.15.



	K	L	M	N	O
1	Revised Control Limits				
2	Centre Line	UCL	LCL	Sample Mean	
3	388.333	820.937	0.000	933.000	
4	388.333	820.937	0.000	789.800	
5	388.333	820.937	0.000	1156.200	
6	388.333	820.937	0.000	918.400	
7	388.333	820.937	0.000	1026.600	
8	388.333	820.937	0.000	887.000	
9	388.333	820.937	0.000	1082.200	
10	388.333	820.937	0.000	837.200	
11	388.333	820.937	0.000	1161.200	
12	388.333	820.937	0.000	950.200	
13	388.333	820.937	0.000	938.200	
14	388.333	820.937	0.000	961.200	
15	388.333	820.937	0.000	1140.600	

Fig. 4.15

Step 2: We calculate $\bar{\bar{X}}_{new}$ by typing "=(Sum(N3:N37)-N12-N33)/(G40-G44)" in Cell N38 (Fig. 4.16).

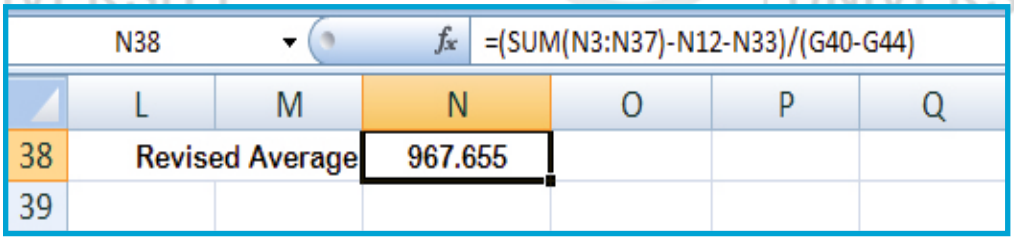


Fig. 4.16

Step 3: We already have the value of d = 2 in Cell G44 (see Fig. 4.9). We now type the value of A_2 for n = 5 in Cell G45 (Fig. 4.17).

	D	E	F	G
44			d	2
45	A_2 Value from Table (for n=5)			0.577

Fig. 4.17

Step 4: We compute the centre line, UCL and LCL in Columns O, P and Q, respectively, as explained in Sec. 2.5 of Lab Session 2 (Fig. 4.18).

	O	P	Q
1	Control Limits		
2	Centre Line	UCL	LCL
3	967.655	1191.723	743.586
4	967.655	1191.723	743.586
5	967.655	1191.723	743.586
6	967.655	1191.723	743.586
7	967.655	1191.723	743.586
8	967.655	1191.723	743.586
9	967.655	1191.723	743.586
10	967.655	1191.723	743.586
11	967.655	1191.723	743.586
12	967.655	1191.723	743.586
13	967.655	1191.723	743.586
14	967.655	1191.723	743.586
15	967.655	1191.723	743.586
16	967.655	1191.723	743.586
17	967.655	1191.723	743.586
18	967.655	1191.723	743.586
19	967.655	1191.723	743.586
20	967.655	1191.723	743.586
21	967.655	1191.723	743.586
22	967.655	1191.723	743.586
23	967.655	1191.723	743.586

R Chart

Fig. 4.18

Step 5: To plot the $\bar{X}$-chart, we

1. select Cells N2:Q11, N13:Q32 and N34:Q37 by holding *Ctrl* key,
2. click on the *Insert* tab,
3. select the *Line* option, and
4. choose the chart subtype.

We format the chart as explained in Sec. 1.4 of Lab Session 1. The resulting control chart is shown in Fig. 4.19.

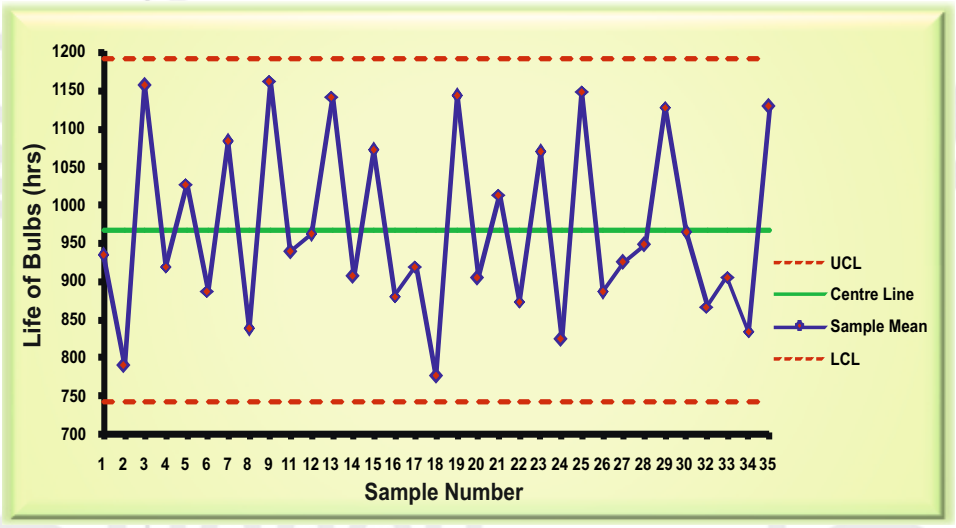


Fig. 4.19

Interpretation

Note from Fig. 4.19 that no point lies outside the control limits of the revised $\overline{X}$-chart. This indicates that the process mean is under control. Hence, we may conclude that the process is under statistical control with respect to the process variability and process mean.

Now, you can try the following exercises to revise the R-chart and $\overline{X}$-chart which are used to control the process variability and mean, respectively.

Activity 2

Construct the control charts for range with the help of MS Excel 2007 and interpret the results for

A1) Example 5 given in Unit 2 of MSTE-001.

A2) Exercise E10 given in Unit 2 of MSTE-001.

Match the results with the manual calculation done in Unit 2 of MSTE-001

Continuous Assessment 4

Consider a problem related to a process which maintains the quality of bottling procedure. Suppose a fruit juice manufacturing company uses automatic machines to fill 500 ml juice bottles. A quality control inspector at the company collects 25 samples each of four observations at different times and measures the volume of each filled bottle. The data is given in Table 2.

Table 2: Volume of fruit juice in the filled bottles

Sample	Volume of Juice per bottle (in ml)			Number
	Obs. 1	Obs. 2	Obs. 3	Obs. 4
1	497.32	500.62	498.68	497.82
2	504.76	500.00	498.32	500.32
3	499.24	497.18	498.12	498.68
4	499.26	496.32	498.88	497.82
5	498.32	500.62	499.56	500.12
6	499.12	500.32	499.38	500.94
7	499.34	498.32	497.32	497.62
8	499.38	498.12	500.62	498.12
9	499.26	498.38	500.68	500.38
10	498.60	497.62	499.25	498.56
11	499.44	500.00	501.32	499.38

Sample	Volume of Juice per bottle (in ml)			Number
	Obs. 1	Obs. 2	Obs. 3	Obs. 4
12	498.26	500.32	500.76	499.68
13	497.32	498.50	497.18	499.38
14	499.56	498.00	498.76	501.12
15	500.24	500.32	499.12	499.25
16	500.76	500.50	499.68	498.12
17	500.65	497.82	494.06	496.25
18	499.12	500.26	500.44	498.76
19	499.50	500.50	499.56	500.76
20	497.50	498.82	499.76	497.82
21	499.44	500.62	500.00	501.26
22	499.38	498.38	497.56	498.56
23	501.56	499.56	498.00	499.82
24	498.32	497.32	499.56	498.62
25	499.50	500.12	498.50	500.38

Develop the $\overline{X}$ and R-charts to check whether the process of bottling is under control or out-of-control. Also plot the revised control chart, if necessary.

Home Work: Do It Yourself

1) Follow the steps explained in Secs. 4.4, 4.5 and 4.6 to construct the control charts for the data of Table 1. Use a different format for the control charts. Take their screenshots and keep them in your record book.

2) Develop the spreadsheet for the exercise "Continuous Assessment 4" as explained in this lab session. Take screenshots of the final spreadsheet and the charts.

3) **Do not forget** to keep the screenshots in your record book as these will contribute to your continuous assessment in the Laboratory.