10.1 Use the data in Table 10E.1 to set up short-run $\bar{x}$ and R charts using the DNOM approach. The nominal dimensions for each part are T_A = 100, T_B = 60, T_C = 75, and T_D = 50

	TA	TB	TC	TD					
	100	60	75	50					
					R	X1	X2	X3	X-bar
1	A	105	102	103	3	5	2	3	3.3333
2	A	101	98	100	3	1	-2	0	-0.3333
3	A	103	100	99	4	3	0	-1	0.6667
4	A	101	104	97	7	1	4	-3	0.6667
5	A	106	102	100	6	6	2	0	2.6667
6	B	57	60	59	3	-3	0	-1	-1.3333
7	B	61	64	63	3	1	4	3	2.6667
8	B	60	58	62	4	0	-2	2	0.0000
9	C	73	75	77	4	-2	0	2	0.0000
10	C	78	75	76	3	3	0	1	1.3333
11	C	77	75	74	3	2	0	-1	0.3333
12	C	75	72	79	7	0	-3	4	0.3333
13	C	74	75	77	3	-1	0	2	0.3333
14	C	73	76	75	3	-2	1	0	-0.3333
15	D	50	51	49	2	0	1	-1	0.0000
16	D	46	50	50	4	-4	0	0	-1.3333
17	D	51	46	50	5	1	-4	0	-1.0000
18	D	49	50	53	4	-1	0	3	0.6667
19	D	50	52	51	2	0	2	1	1.0000
20	D	53	51	50	3	3	1	0	1.3333

R-bar	sigmaR	Average
3.8	1.9931	0.55

R chart

UCL = D4*R/bar = 2.574*3.8 = 9.78

CL = R-bar = 3.8

LCL = D3*R/bar = 0

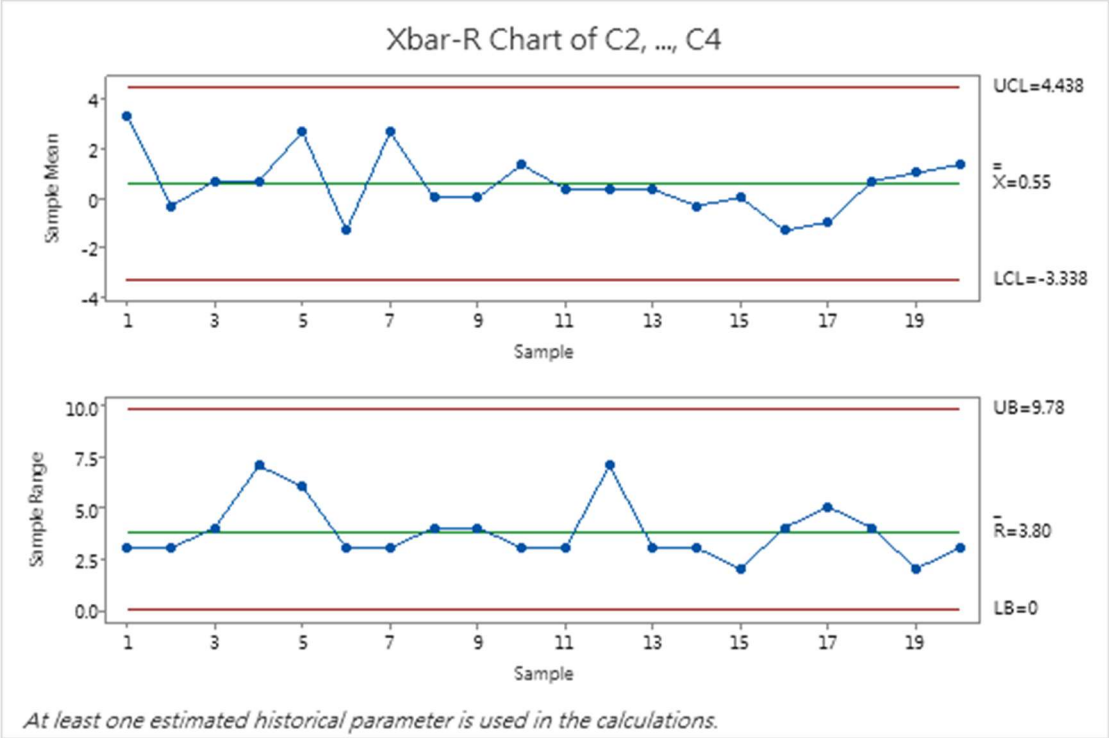
σ x-bar = R-bar / d2 = 3.8 / 1.693 = 2.245

x chart

UCL = average + A2 * R/bar = 0.55+1.023*3.8 = 4.438

CL = 0.55

LCL = average -A2 * R/bar = 0.55-1.023*3.8 = -3.338



Process is in control

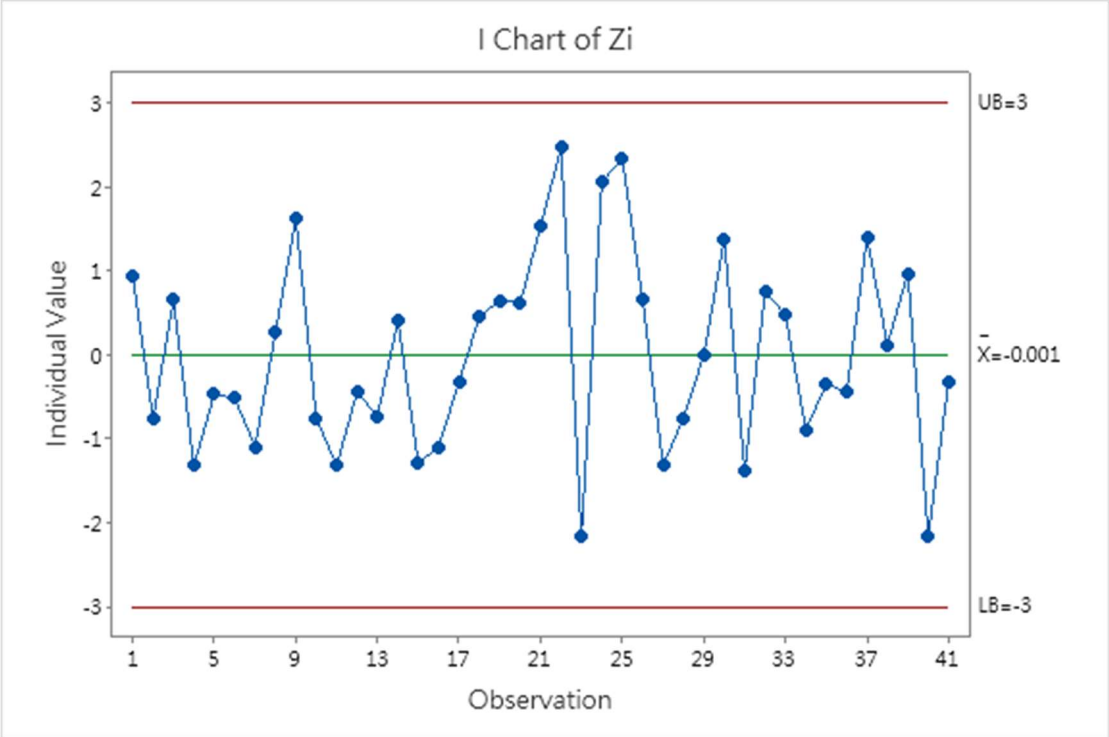
10.3 Printed circuit boards used in several different avionics devices are 100% tested for defects. The batch size for each board type is relatively small, and management wishes to establish SPC using a short-run version of the c chart. Defect data from the last two weeks of production are shown in Table 10E.2. What chart would you recommend? Set up the chart and examine the process for control.

Day	num	defects	Zi		
245	1261	16	0.9355	C1055	13.25
245	1261	10	-0.7501	C1130	64
245	1261	15	0.6546	C1261	12.67
246	1261	8	-1.3120	1385	26.63
246	1261	11	-0.4692	4610	4.67
246	1385	24	-0.5096	8611	50.13
246	1385	21	-1.0910		
247	1385	28	0.2655		
247	1385	35	1.6220		
247	1261	10	-0.7501		
248	1261	8	-1.3120		
248	8611	47	-0.4421		
248	8611	45	-0.7246		
249	8611	53	0.4054		

249	8611	41	-1.2895
249	1385	21	-1.0910
250	1385	25	-0.3159
250	1385	29	0.4593
250	1385	30	0.6530
250	4610	6	0.6155
250	4610	8	1.5409
251	4610	10	2.4664
251	4610	0	-2.1610
251	1261	20	2.0593
252	1261	21	2.3402
252	1261	15	0.6546
252	1261	8	-1.3120
252	1261	10	-0.7501
252	1130	64	0.0000
252	1130	75	1.3750
252	1130	53	-1.3750
253	1055	16	0.7555
253	1055	15	0.4808
253	1055	10	-0.8928
254	1055	12	-0.3434
254	8611	47	-0.4421
254	8611	60	1.3940
255	8611	51	0.1229
255	8611	57	0.9703
255	4610	0	-2.1610
255	4610	4	-0.3100

Statistics

Variable	num	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
defects	1055	4	0	13.25	1.38	2.75	10.00	10.50	13.50	15.75	16.00
	1130	3	0	64.00	6.35	11.00	53.00	53.00	64.00	75.00	75.00
	1261	12	0	12.67	1.33	4.62	8.00	8.50	10.50	15.75	21.00
	1385	8	0	26.63	1.70	4.81	21.00	21.75	26.50	29.75	35.00
	4610	6	0	4.67	1.69	4.13	0.00	0.00	5.00	8.50	10.00
	8611	8	0	50.13	2.25	6.36	41.00	45.50	49.00	56.00	60.00



Process in control

10.6 A sample of five units is taken from a process every half hour. It is known that the process standard deviation is in control with σ = 2.0. The $\bar{x}$ values for the last 20 samples are shown in Table 10E.5. Specifications on the product are 40 ± 8.

Sample Number	$\bar{x}$	Sample Number	$\bar{x}$
1	41.5	11	40.6
2	42.7	12	39.4
3	40.5	13	38.6
4	39.8	14	42.5
5	41.6	15	41.8
6	44.7	16	40.7
7	39.6	17	42.8
8	40.2	18	43.4
9	41.4	19	42.0
10	43.9	20	41.9

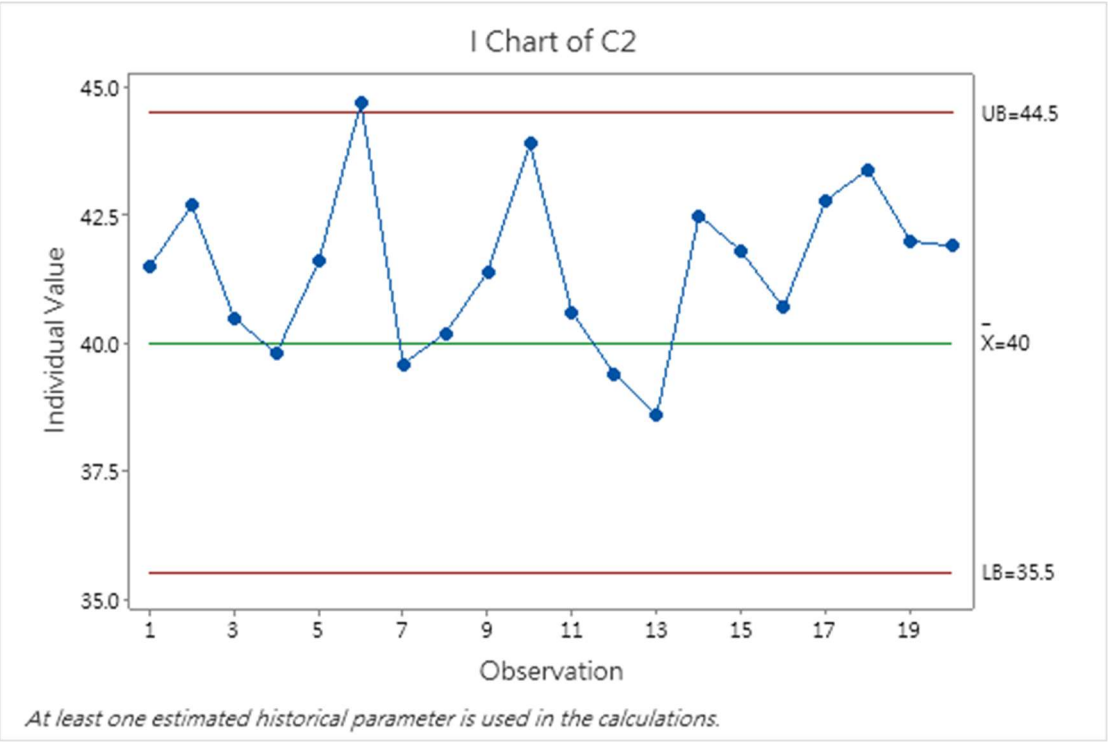
(a) Set up a modified control chart on this process. Use three-sigma limits on the chart and assume that the largest fraction nonconforming that is tolerable is 0.1%.

N = 5 δ = 0.001 Zδ = Z0.001 = 3.090

USL = 40 + 8 = 48 LSL = 40 – 8 = 32

UCL = USL – (zδ – 3$\sqrt{}$(n))σ = 48 – (3.090 – 3$\sqrt{}$(5))(2) = 44.503

LCL = LSL + (zδ - 3$\sqrt{}$(n))σ = 32 + (3.090 – 3$\sqrt{}$(5))(2) = 35.497

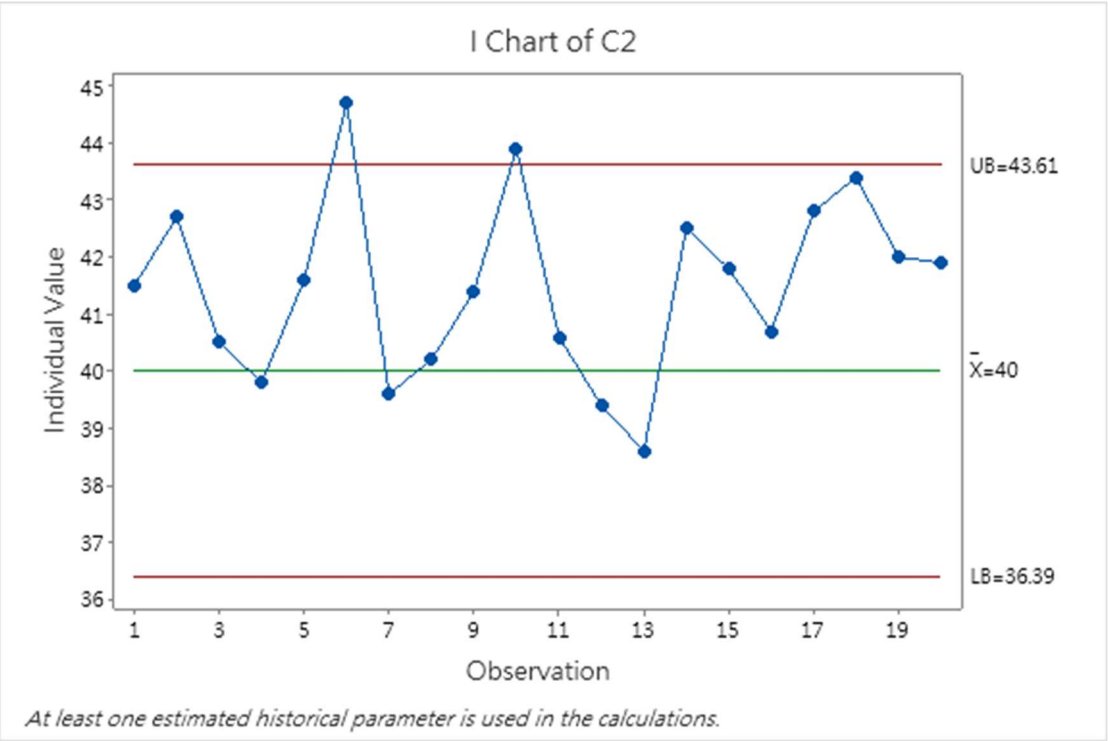


Process #6 out of control

(b) Reconstruct the chart in part (a) using two-sigma limits. Is there any difference in the analysis of the data?

UCL = USL – (zδ – 2$\sqrt{}$(n))σ = 48 – (3.090 – 2$\sqrt{}$(5))(2) = 43.61

LCL = LSL + (zδ - 2$\sqrt{}$(n))σ = 32 + (3.090 – 2$\sqrt{}$(5))(2) = 36.39



Process #10 now is out of control

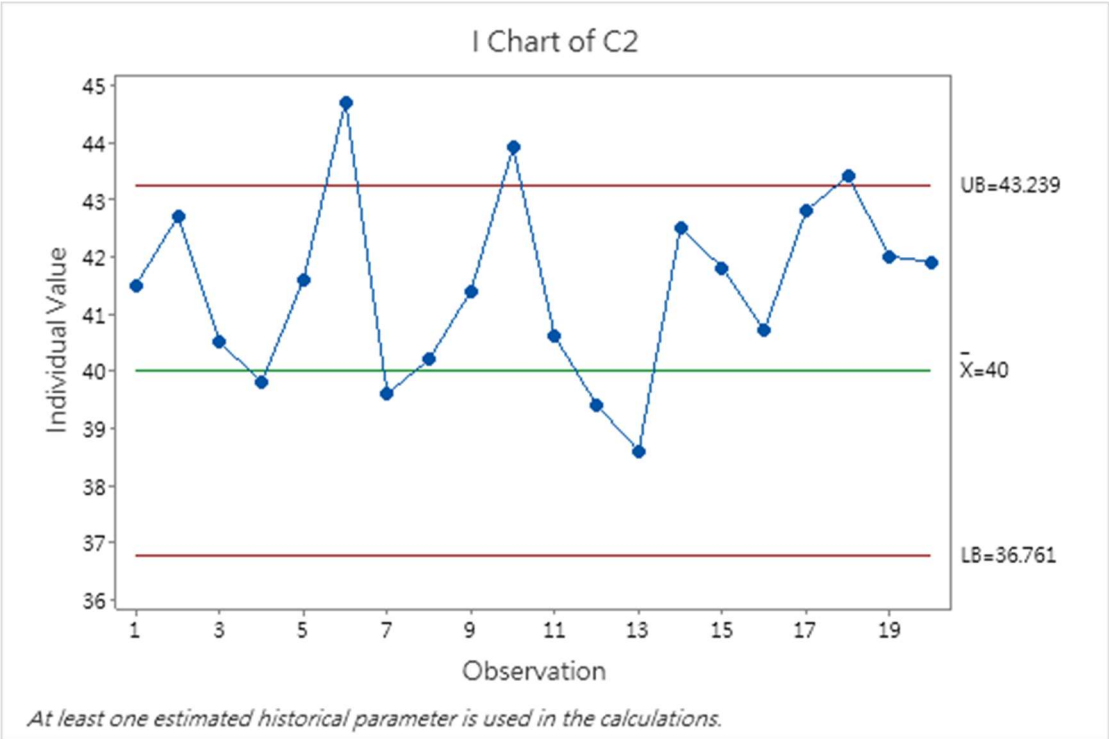
(c) Suppose that if the true process fraction nonconforming is 5%, we would like to detect this condition with probability 0.95. Construct the corresponding acceptance control chart.

γ = 0.05 Zγ = Z0.05 = 1.645

1- β = 0.95 Zβ = Z0.05 = 1.645

UCL = USL – (zγ – Zβ$\sqrt{}$(n))σ = 48 – (1.645 – 1.645$\sqrt{}$(5))(2) =43.239

LCL = LSL + (zγ - Zβ$\sqrt{}$(n))σ = 32 + (1.645 – 1.645$\sqrt{}$(5))(2) = 36.761



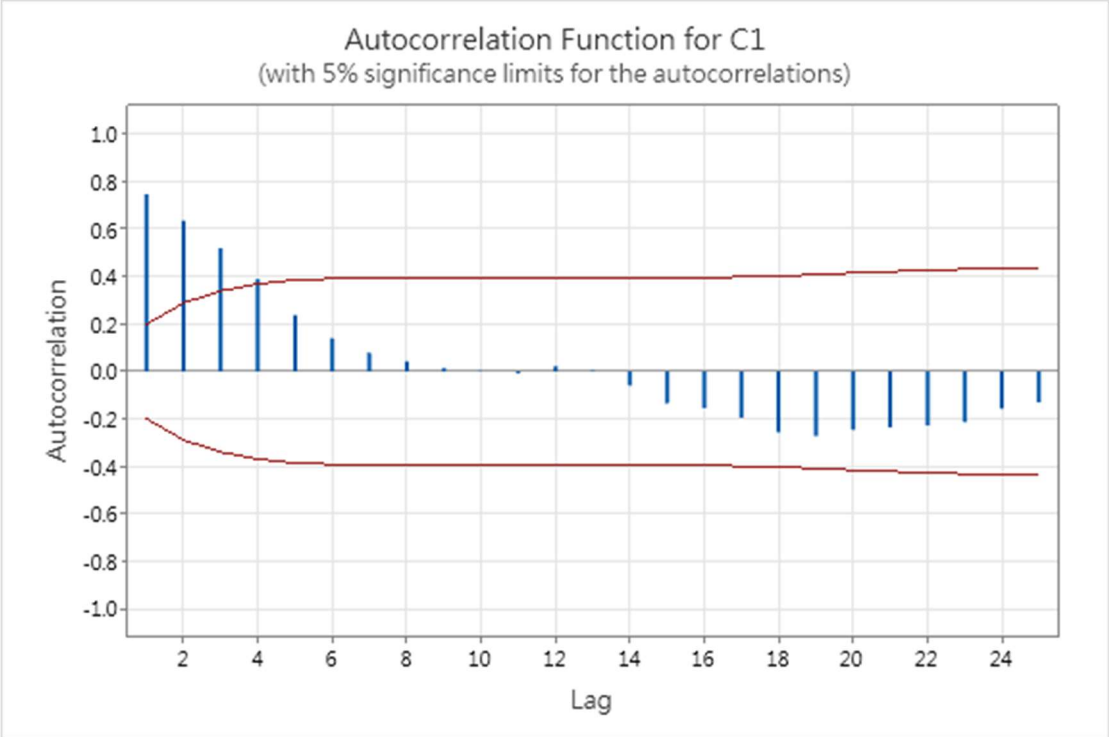
Process #18 also out of control

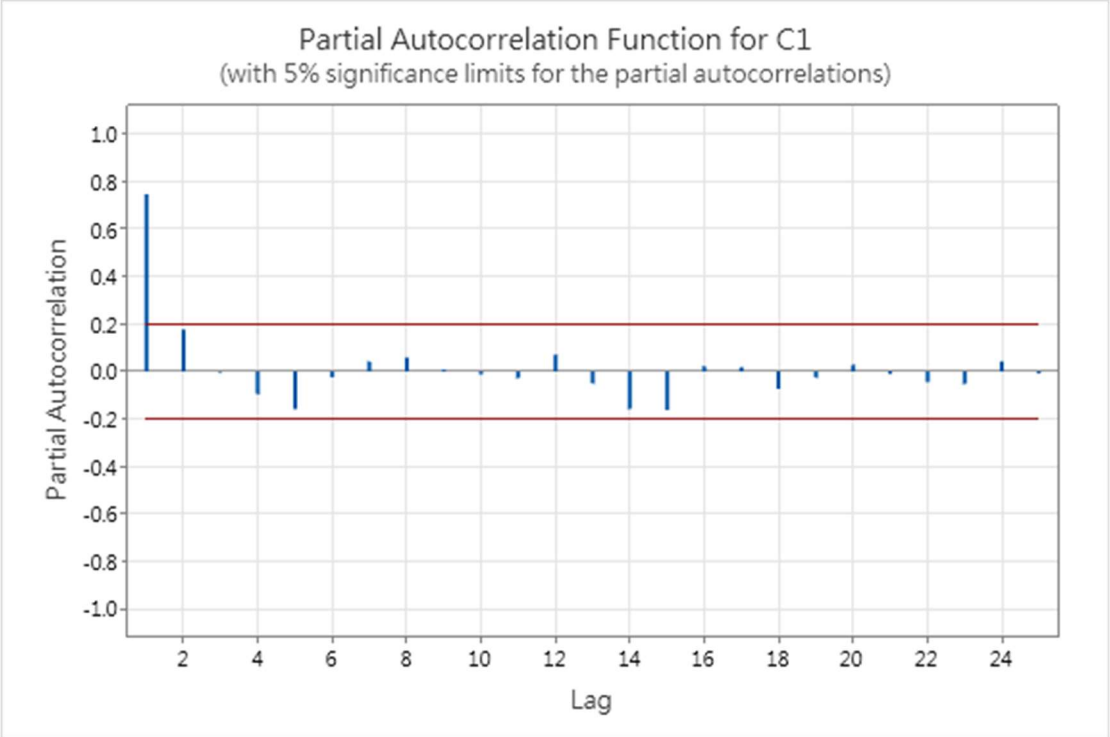
10.11 The data shown in Table 10E.6 are concentration readings from a chemical process, made every 30 minutes (read down, then across from left to right).

Chemical Process Concentration Readings

204	190	208	207	200
202	196	209	204	202
201	199	209	201	202
202	203	206	197	207
197	199	200	189	206
201	207	203	189	211
198	204	202	196	205
188	207	195	193	210
195	209	196	193	210
189	205	203	198	198
195	202	196	194	194
192	200	197	198	192
196	208	197	199	189
194	214	203	204	188
196	205	205	200	189
199	211	194	203	194
197	212	199	200	194
197	214	201	197	198
192	210	198	196	196
195	208	202	202	200

(a) Calculate the sample autocorrelation function and provide an interpretation.



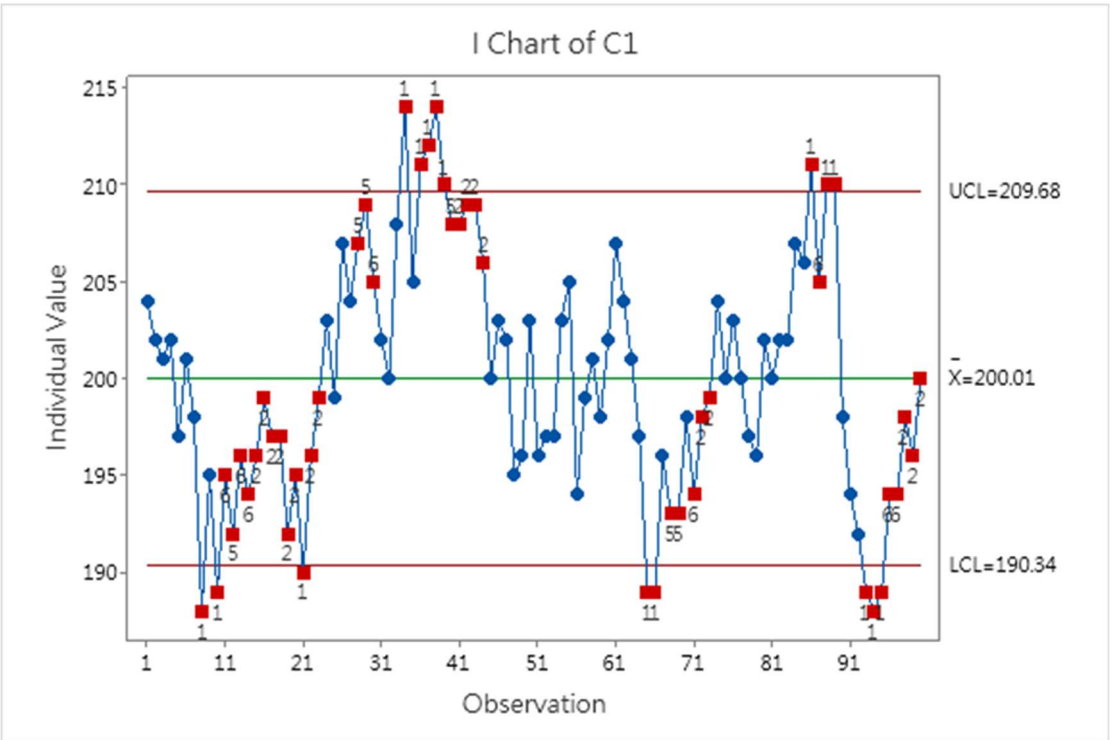


ACFs 的 decaying sine wave 還有 PACFs lag1 的尖峰

Suggest an autogressive process of order 1

(b) Construct an individuals control chart with the standard deviation estimated using the moving range method. Provide an interpretation of this control chart.

$\hat{\sigma} = \overline{MR}/d2 = 3.64/1.128$



TEST 1. One point more than 3.00 standard deviations from center line.

Test Failed at points: 8, 10, 21, 34, 36, 37, 38, 39, 65, 66, 86, 88, 89, 93, 94, 95

TEST 2. 9 points in a row on same side of center line.

Test Failed at points: 15, 16, 17, 18, 19, 20, 21, 22, 23, 41, 42, 43, 44, 72, 73, 98, 99, 100

TEST 5. 2 out of 3 points more than 2 standard deviations from center line (on one side of CL).

Test Failed at points: 10, 12, 21, 28, 29, 34, 36, 37, 38, 39, 40, 41, 42, 43, 66, 68, 69, 86, 88, 89, 93, 94, 95

TEST 6. 4 out of 5 points more than 1 standard deviation from center line (on one side of CL).

Test Failed at points: 11, 12, 13, 14, 15, 22, 29, 30, 36, 37, 38, 39, 40, 41, 42, 43, 44, 68, 69, 71, 87, 88, 89, 94, 95, 96, 97, 99

TEST 8. 8 points in a row more than 1 standard deviation from center line (above and below CL).

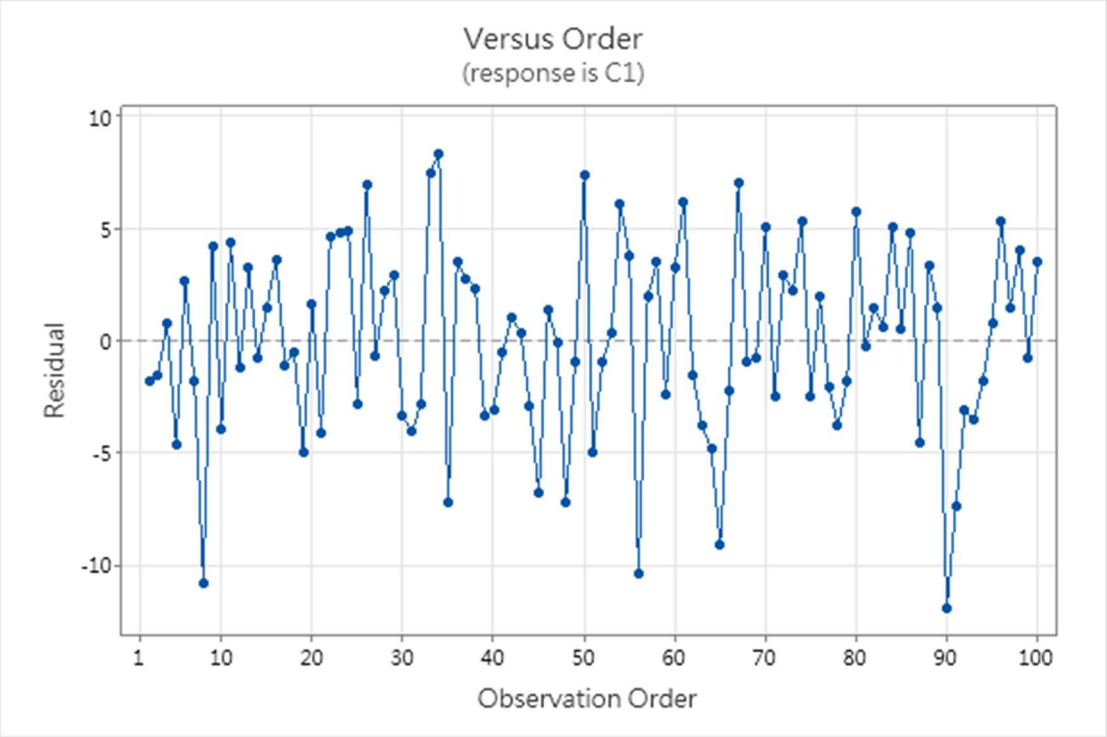
Test Failed at points: 15, 40, 41, 42, 43, 44

The process is out of control, very few observation is near the mean.

(c) Fit a first-order autoregressive model $x_t = \xi + \phi x_{t-1} + \varepsilon_t$ to the data. Set up an individuals control chart on the residuals from this model. Interpret this chart.

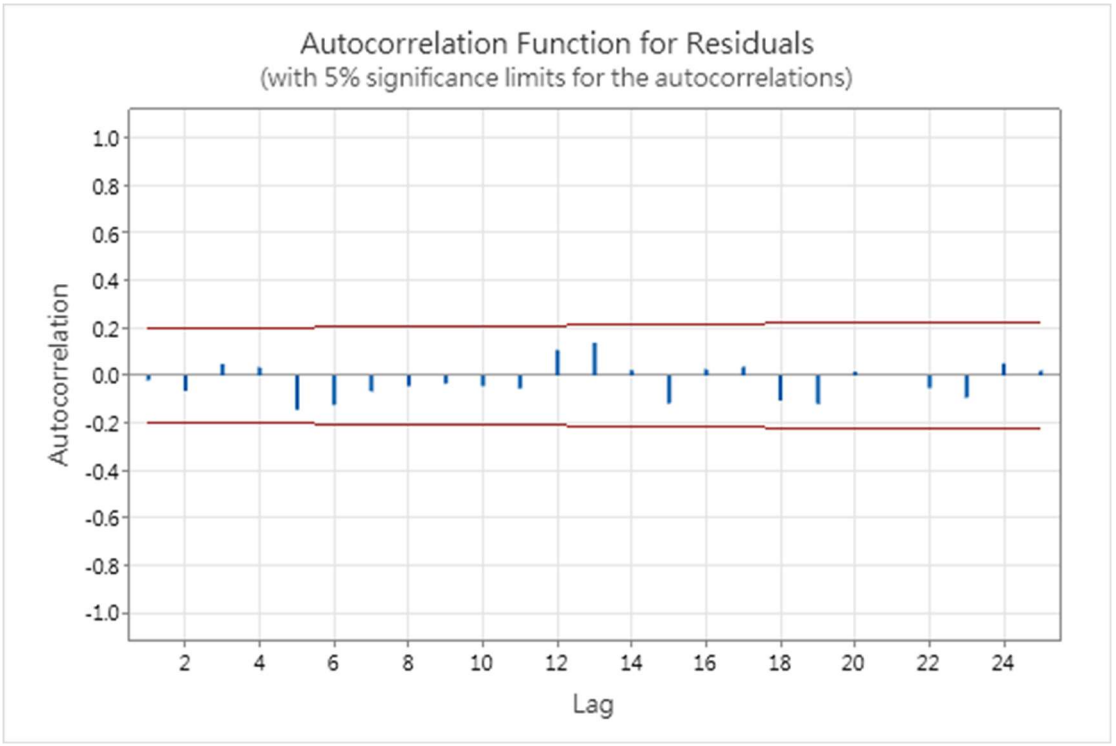
Final Estimates of Parameters

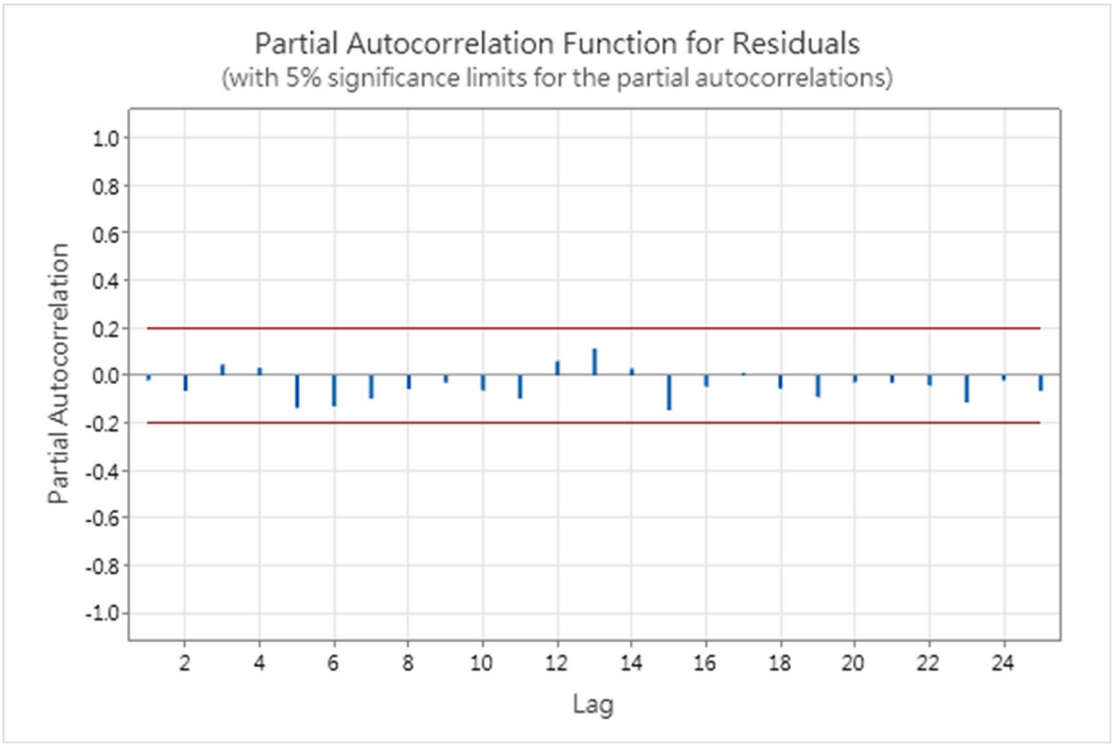
Type	Coef	SE Coef	T-Value	P-Value
AR 1	0.7493	0.0669	11.20	0.000
Constant	50.173	0.415	120.76	0.000
Mean	200.12	1.66		

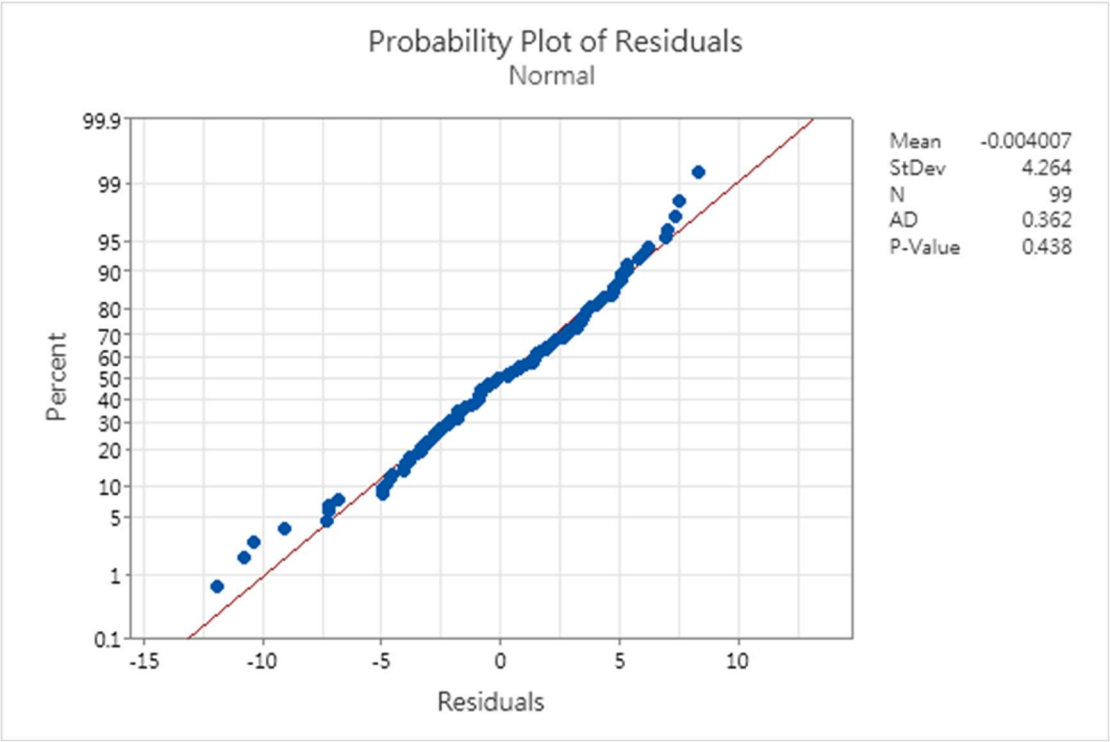


The process is in control

(d) Are the residuals from the model in part (c) uncorrelated? Does this have any impact on your interpretation of the control chart from part (c)?


Autocorrelation Function for Residuals
(with 5% significance limits for the autocorrelations)
Autocorrelation
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
2
4
6
8
10
12
14
16
18
20
22
24
Lag


Partial Autocorrelation Function for Residuals
(with 5% significance limits for the partial autocorrelations)
Partial Autocorrelation
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
2
4
6
8
10
12
14
16
18
20
22
24
Lag



The residuals are normal and uncorrelated