Lecture #30

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Chapter 10

Bring text to class!!

Roll Mill Process Case Study

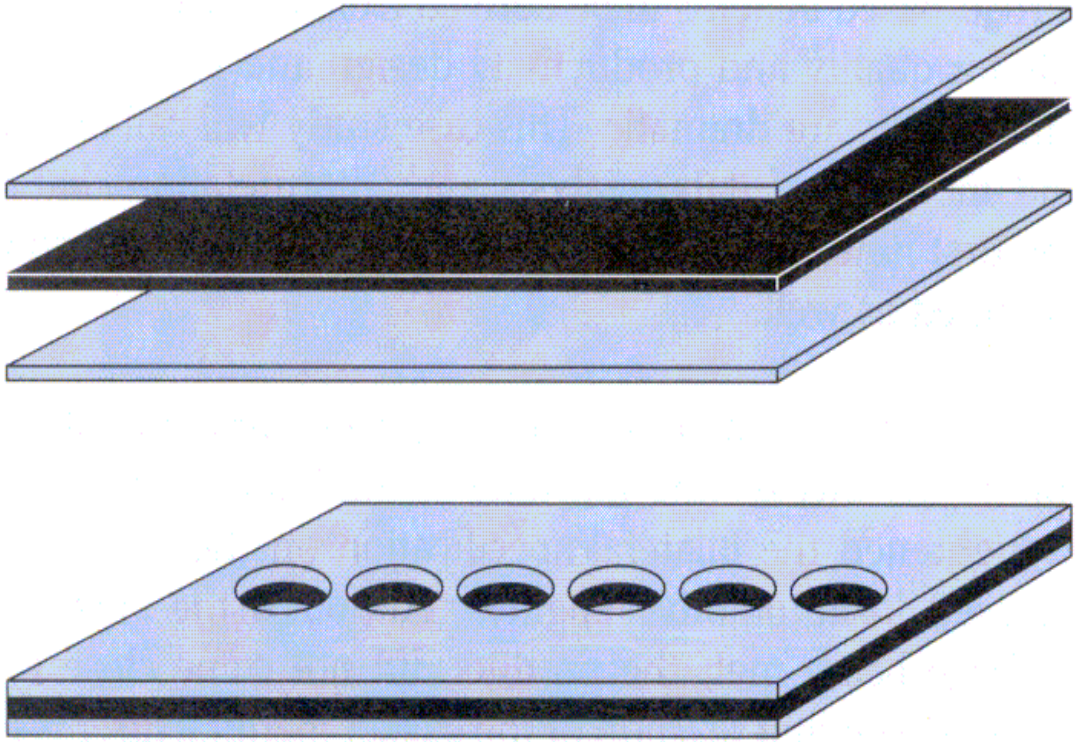


Figure 10.1 The Product: A Hard Gasket of Three-Piece Construction for Automotive Applications

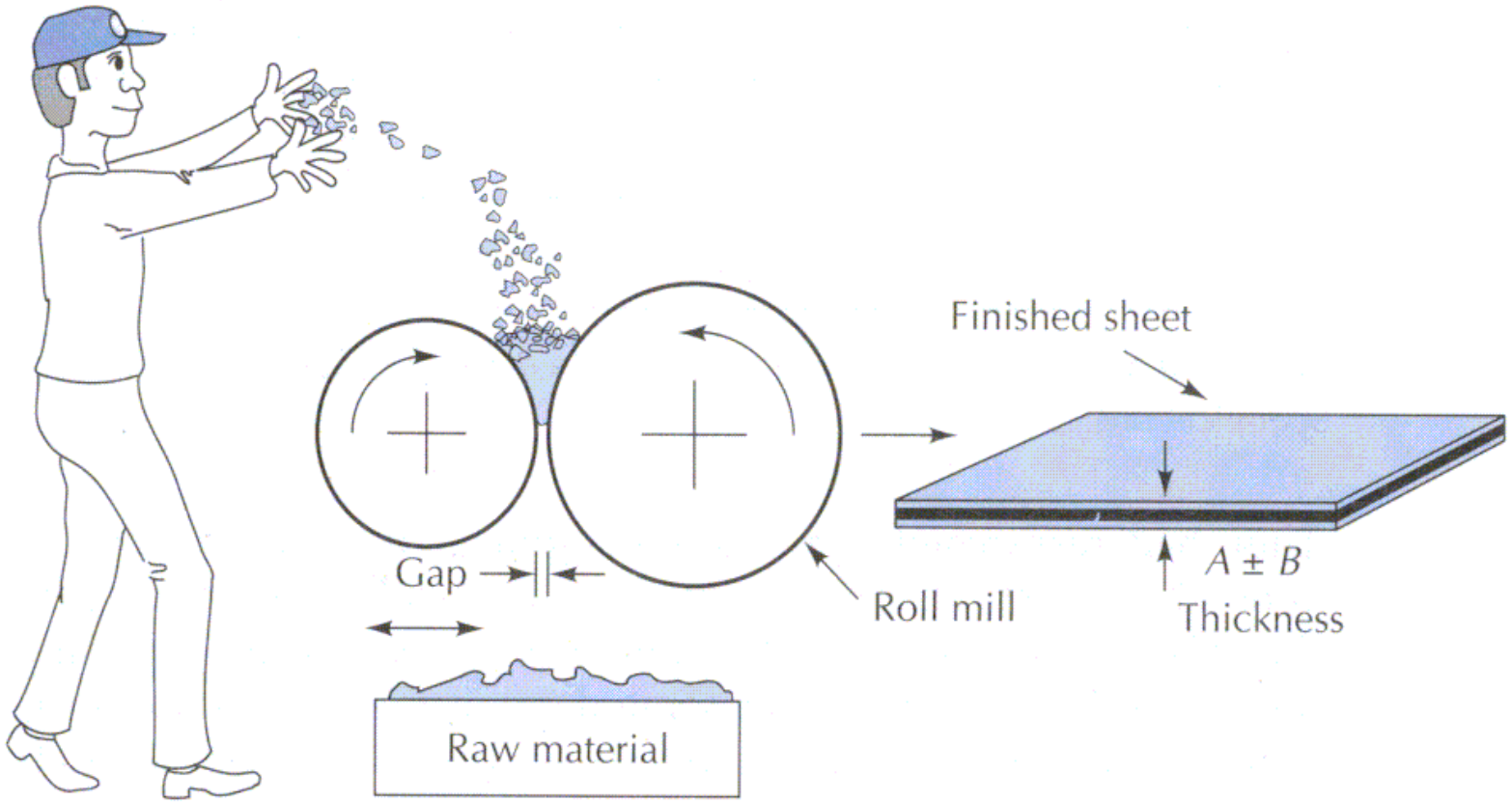


Figure 10.2 The Process: Roll Mill for the Manufacture of Soft Gasket Material

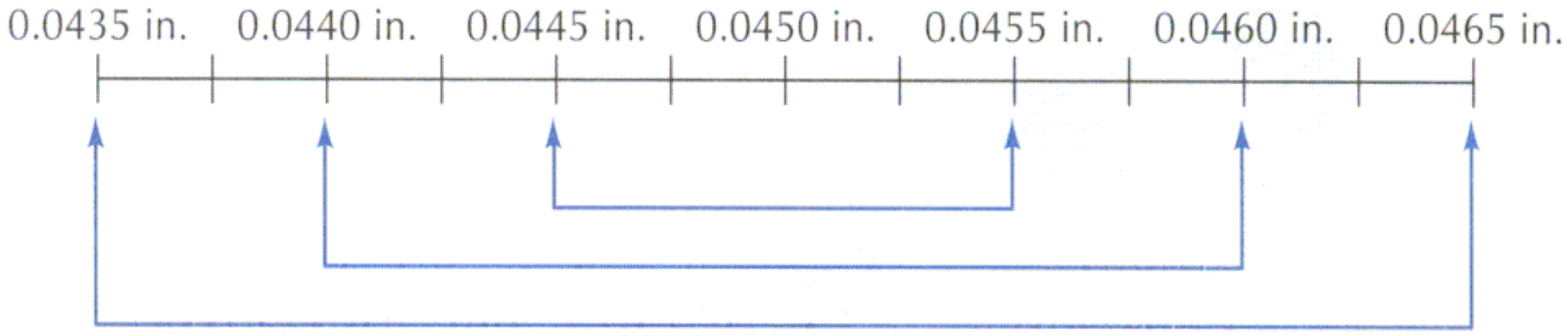


Figure 10.3 Selective Assembly Process Used to Assemble Hard Gaskets That Meet the Specifications

TABLE 10.1 Measurements of Sheet Thickness

Sheet	Thickness (in.)	Sheet	Thickness (in.)	Sheet	Thickness (in.)	Sheet	Thickness (in.)
1	0.0440	19	0.0472	37	0.0459	55	0.0425
2	0.0446	20	0.0477	38	0.0468	56	0.0442
3	0.0437	21	0.0452	39	0.0452	57	0.0432
4	0.0438	22	0.0457	40	0.0456	58	0.0429
5	0.0425	23	0.0459	41	0.0471	59	0.0447
6	0.0443	24	0.0472	42	0.0450	60	0.0450
7	0.0453	25	0.0464	43	0.0472	61	0.0443
8	0.0428	26	0.0457	44	0.0465	62	0.0441
9	0.0433	27	0.0447	45	0.0461	63	0.0450
10	0.0451	28	0.0451	46	0.0462	64	0.0443
11	0.0441	29	0.0447	47	0.0463	65	0.0423
12	0.0434	30	0.0457	48	0.0471	66	0.0447
13	0.0459	31	0.0456	49	0.0427	67	0.0429
14	0.0466	32	0.0455	50	0.0437	68	0.0427
15	0.0476	33	0.0445	51	0.0445	69	0.0464
16	0.0449	34	0.0448	52	0.0431	70	0.0448
17	0.0471	35	0.0423	53	0.0448	71	0.0451
18	0.0451	36	0.0442	54	0.0429	72	0.0428

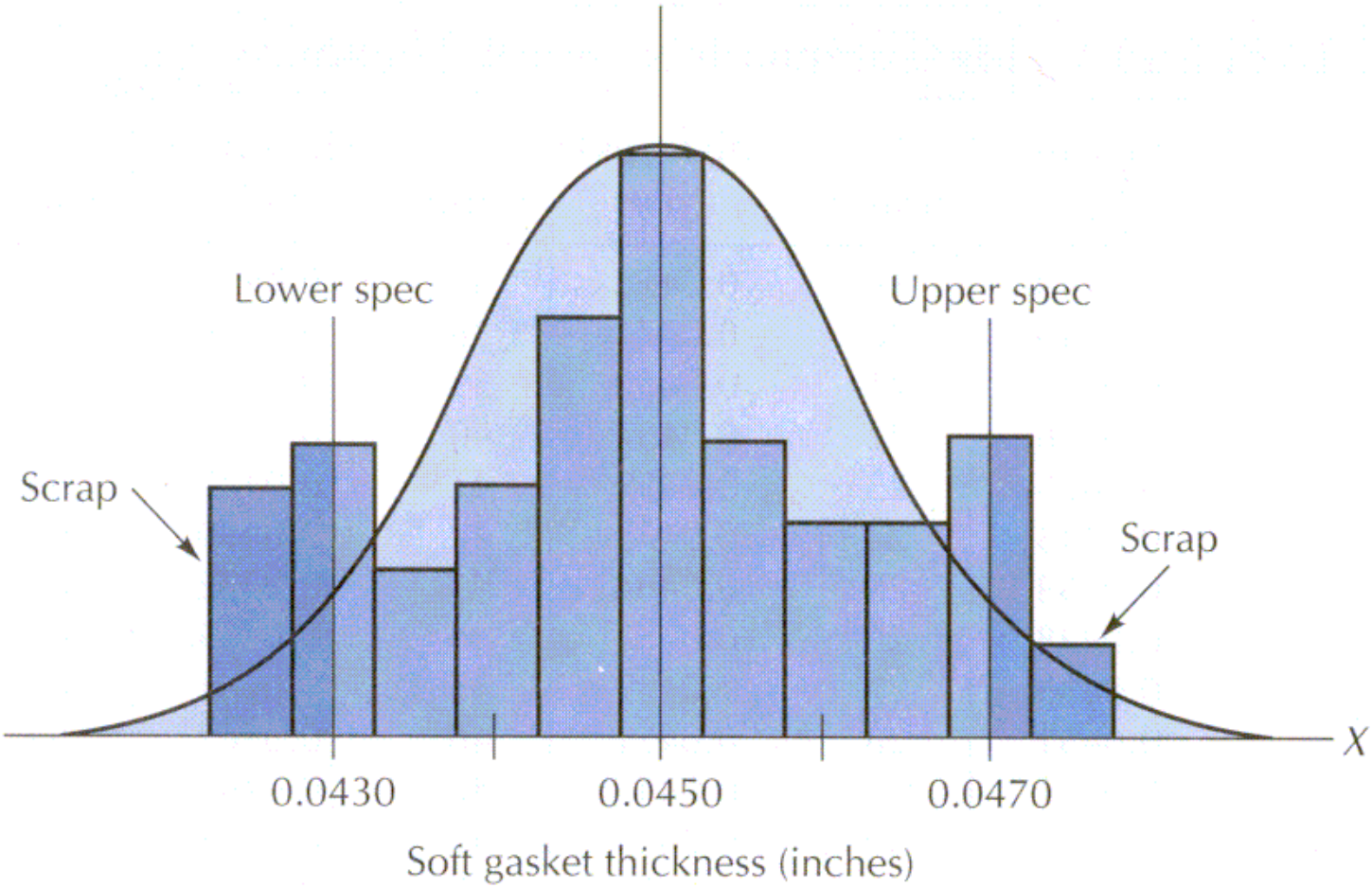
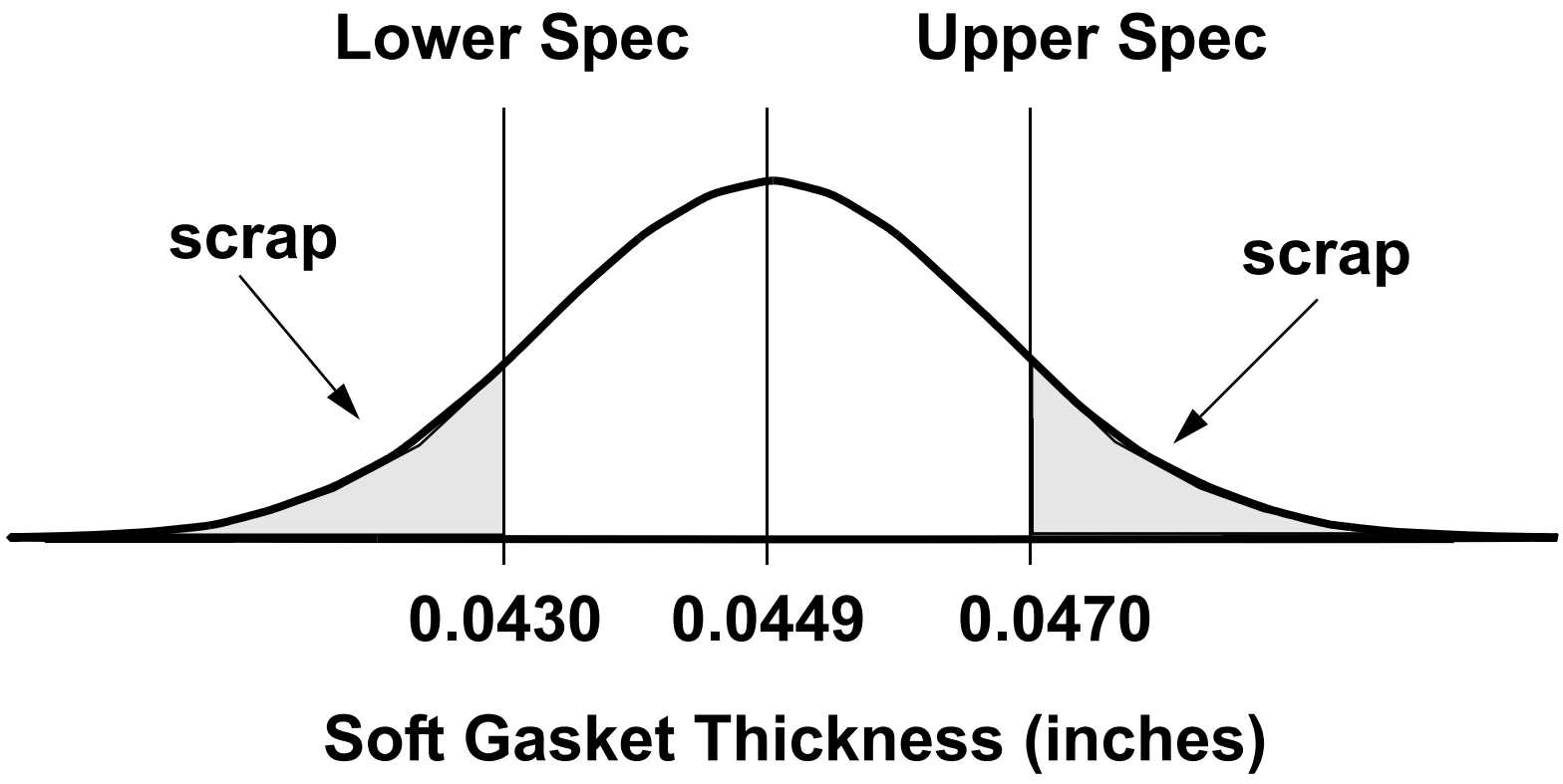


Figure 10.4 Histogram of Data from Initial Process Capability Study

72 sheets

X-double-bar = 0.0449 s_x = 0.0014



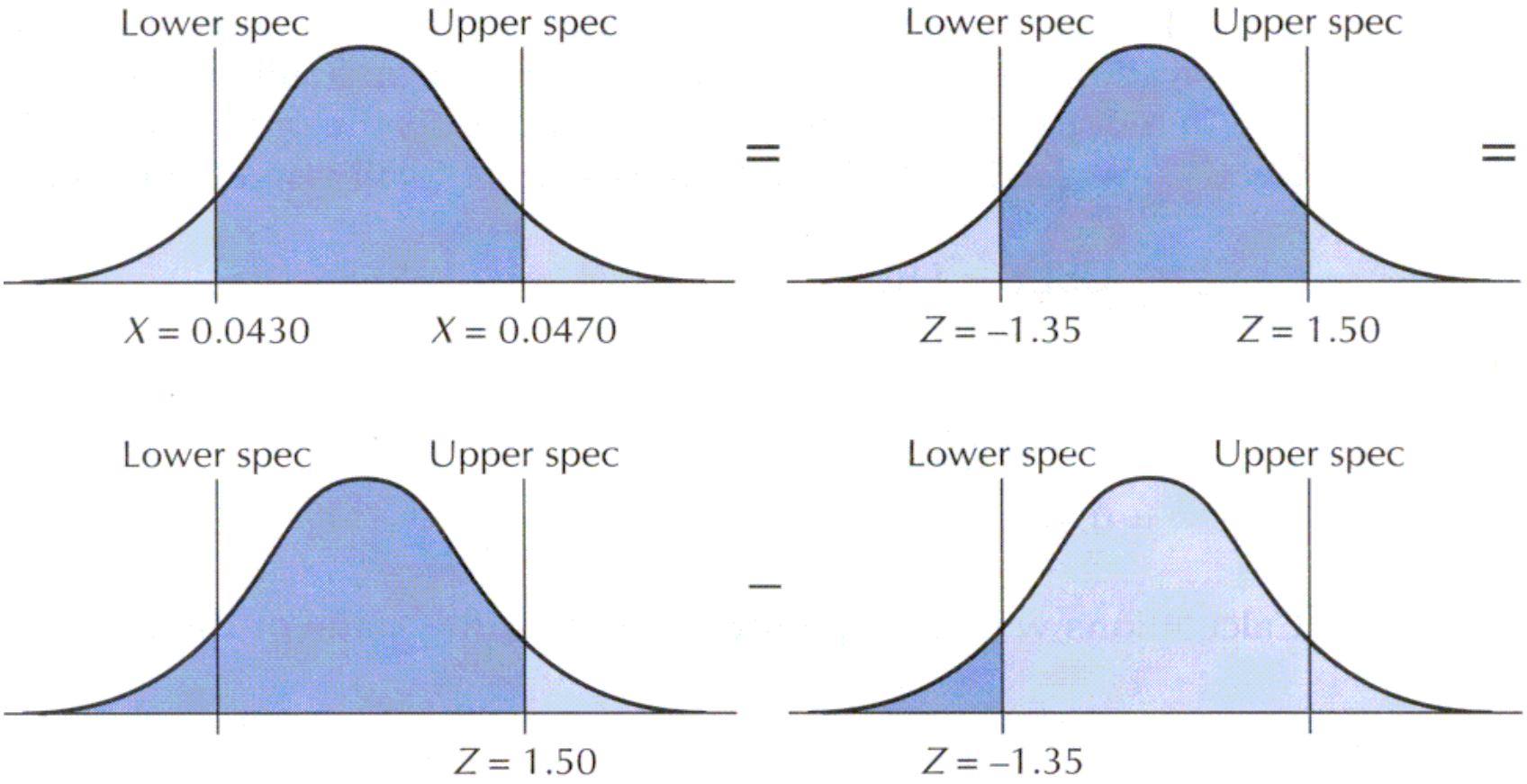
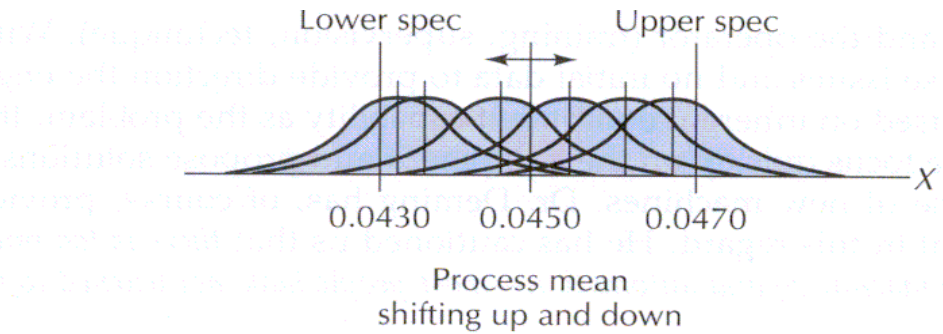


Figure 10.6 Graphical Representation of the Z Transformation and Probability Calculation

Cap. = 84.6% **C_p = 0.477** **C_{pk} = 0.45**

Progress to Date

1. Product Control Way of Thinking
2. Tunnel Vision of the Engineers
3. Selective Assembly Process
4. Statistical Process Control / Process Capability Relationship



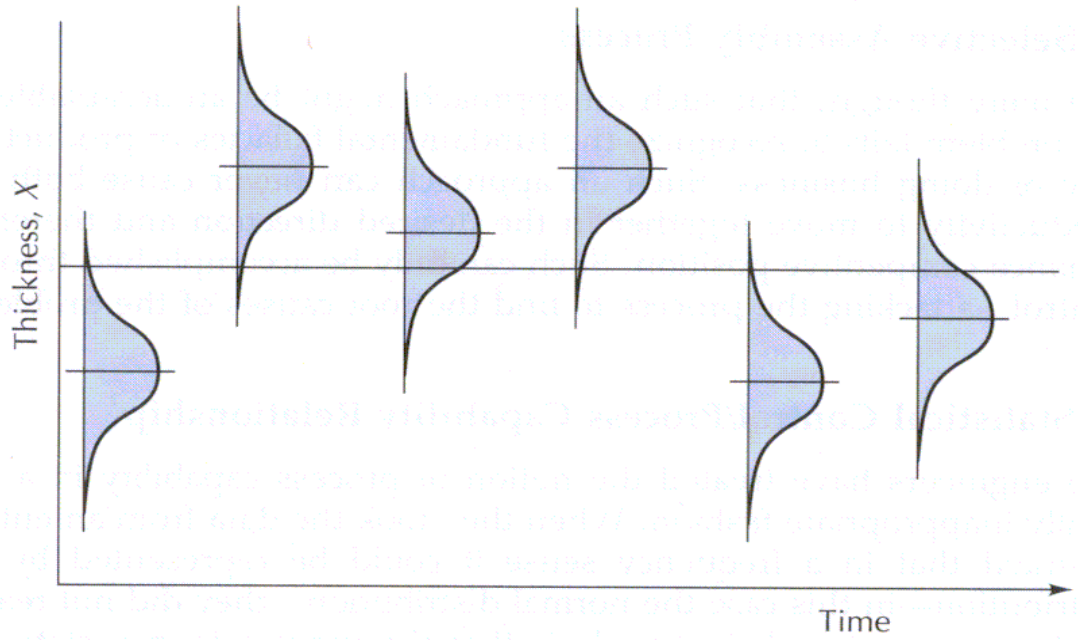


Figure 10.7 Time Behavior of a Process That Is Changing Mean Level in a Sporadic Fashion

Process Adjustment History (Fig. 10.8)

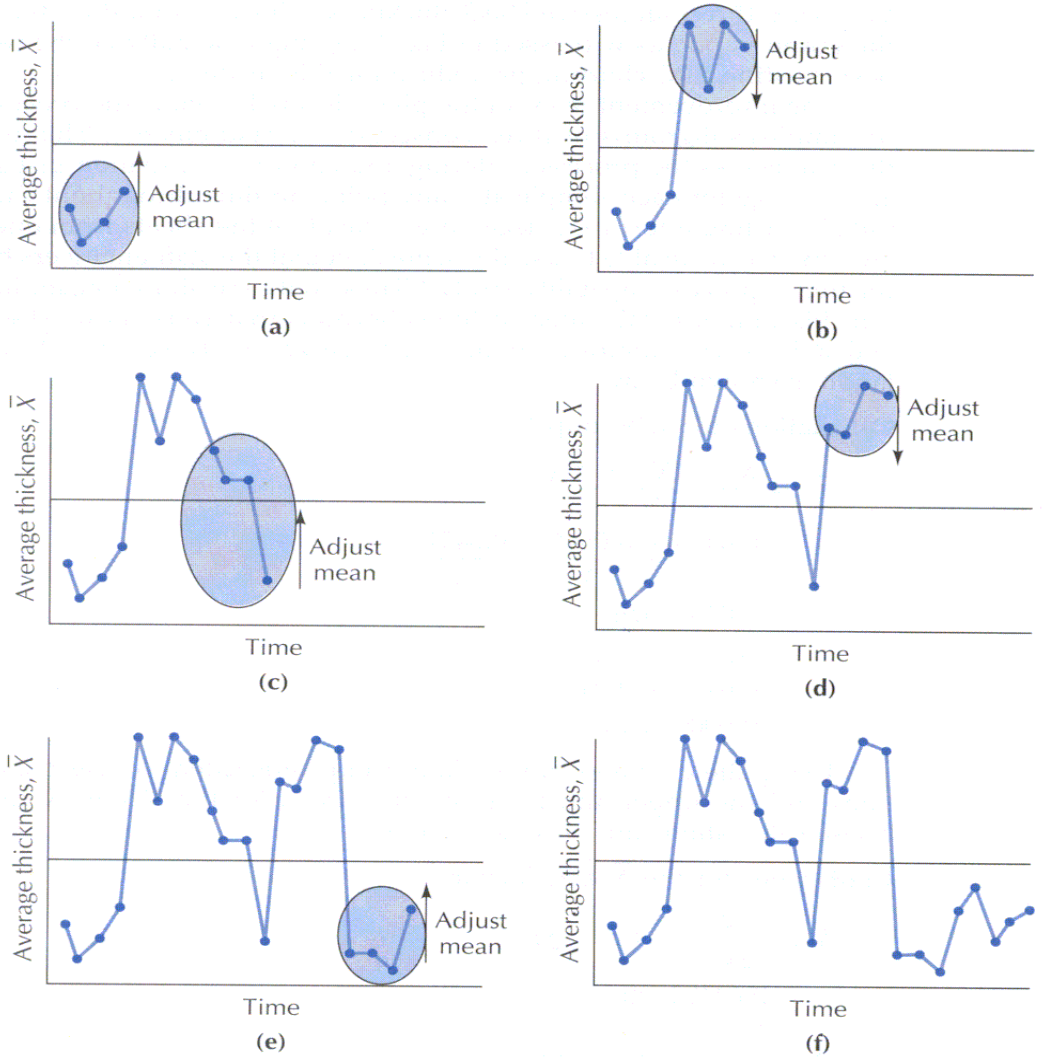


TABLE 10.2 Original Data Grouped into Subgroups of Size $n = 3$ (inches)

Subgroup	X_1	X_2	X_3	$\overline{X}$	R
1	0.0440	0.0446	0.0437	0.0441	0.0009
2	0.0438	0.0425	0.0443	0.0435	0.0018
3	0.0453	0.0428	0.0433	0.0438	0.0025
4	0.0451	0.0441	0.0434	0.0442	0.0017
5	0.0459	0.0466	0.0476	0.0467	0.0017
6	0.0449	0.0471	0.0451	0.0457	0.0022
7	0.0472	0.0477	0.0452	0.0467	0.0025
8	0.0457	0.0459	0.0472	0.0463	0.0015
9	0.0464	0.0457	0.0447	0.0456	0.0017
10	0.0451	0.0447	0.0457	0.0452	0.0010
11	0.0456	0.0455	0.0445	0.0452	0.0011
12	0.0448	0.0423	0.0442	0.0438	0.0025
13	0.0459	0.0468	0.0452	0.0460	0.0016
14	0.0456	0.0471	0.0450	0.0459	0.0021
15	0.0472	0.0465	0.0461	0.0466	0.0011
16	0.0462	0.0463	0.0471	0.0465	0.0009
17	0.0427	0.0437	0.0445	0.0436	0.0018
18	0.0431	0.0448	0.0429	0.0436	0.0019
19	0.0425	0.0442	0.0432	0.0433	0.0017
20	0.0429	0.0447	0.0450	0.0442	0.0021
21	0.0443	0.0441	0.0450	0.0445	0.0009
22	0.0443	0.0423	0.0447	0.0438	0.0024
23	0.0429	0.0427	0.0464	0.0440	0.0037
24	0.0448	0.0451	0.0428	0.0442	0.0023

X-bar & R Charts (Fig. 10.9)

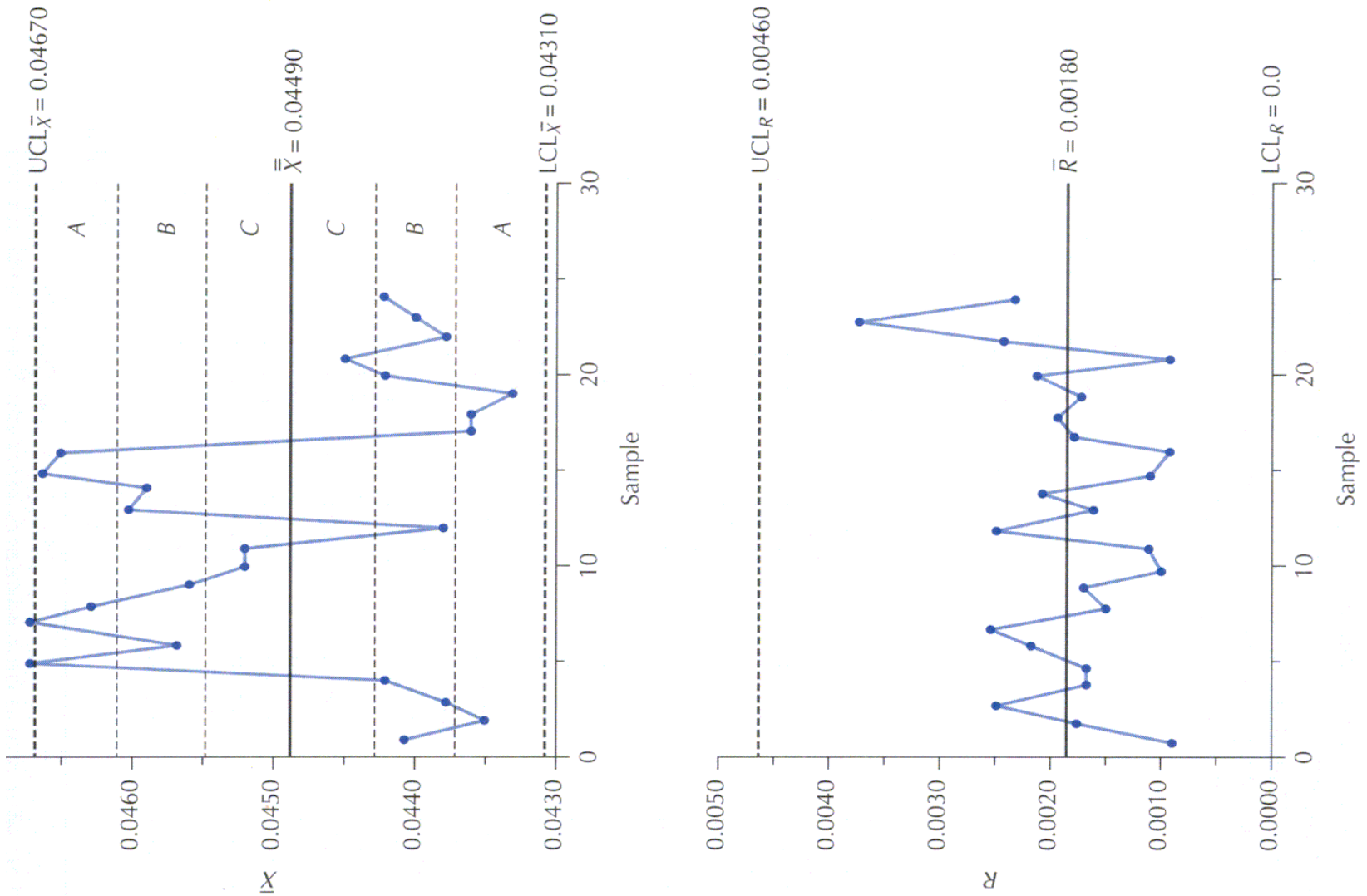


TABLE 10.3 Zone Violations from Fig. 10.10, $\bar{X}$ Chart

Subgroup	Rule(s) Violated
4	1. Four out of five in zone *B* or beyond
5	1. Extreme point
7	1. Extreme point
	2. Two out of three in zone *A* or beyond
8	1. Two out of three in zone *A* or beyond
	2. Four out of five in zone *B* or beyond
	3. Eight in a row outside zone *C*
9	1. Eight in a row outside zone *C*
	2. Four out of five in zone *B* or beyond.
16	1. Two out of three in zone *A* or beyond
	2. Four out of five in zone *B* or beyond
18	1. Two out of three in zone *A* or beyond
19	1. Two out of three in zone *A* or beyond
	2. Eight in a row outside zone *C*
20	1. Four out of five in zone *B* or beyond
	2. Eight in a row outside zone *C*
22	1. Four out of five in zone *B* or beyond
23	1. Four out of five in zone *B* or beyond
24	1. Four out of five in zone *B* or beyond
	2. Run of eight below the centerline

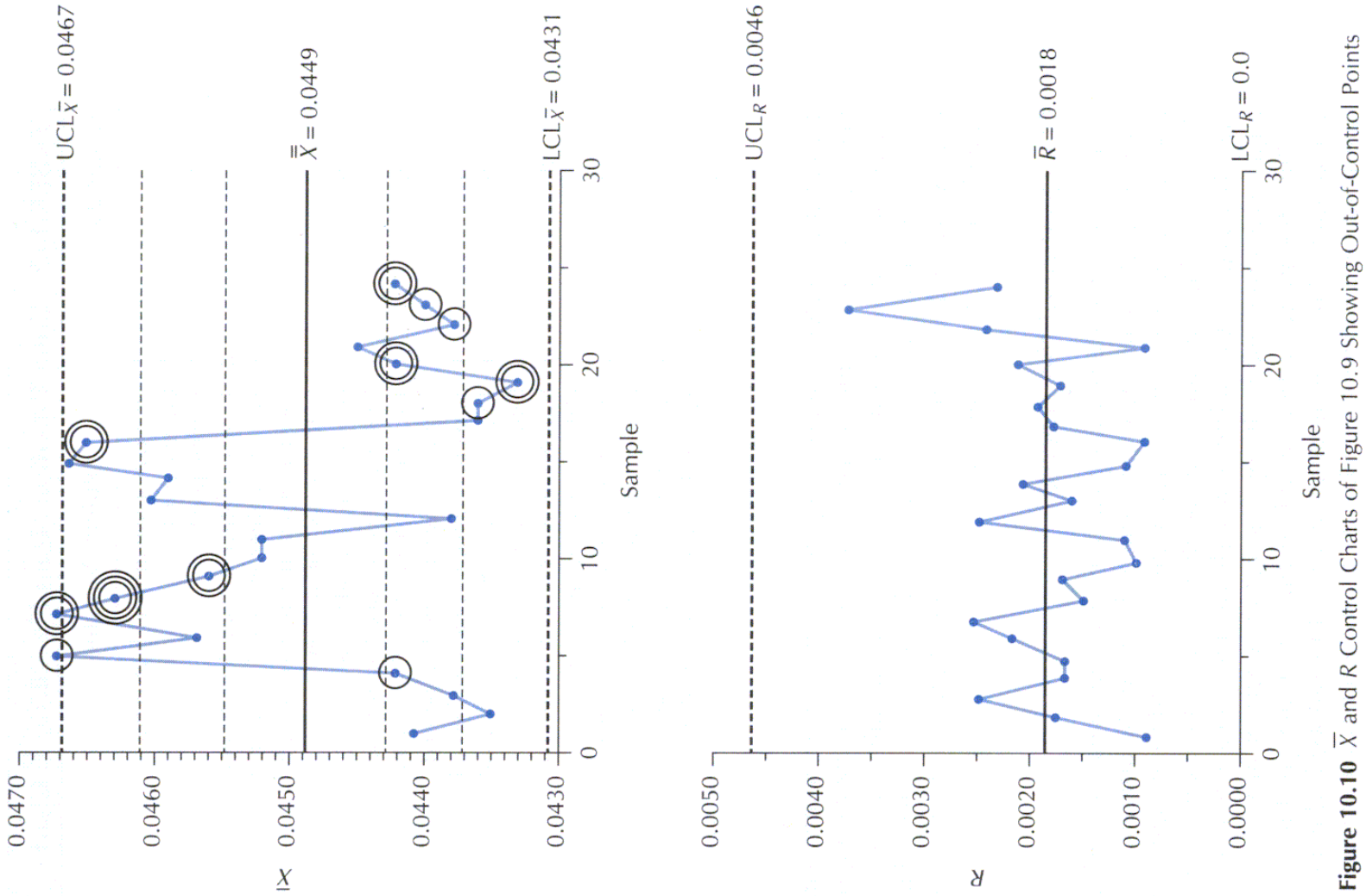


Figure 10.10 $\bar{X}$ and R Control Charts of Figure 10.9 Showing Out-of-Control Points

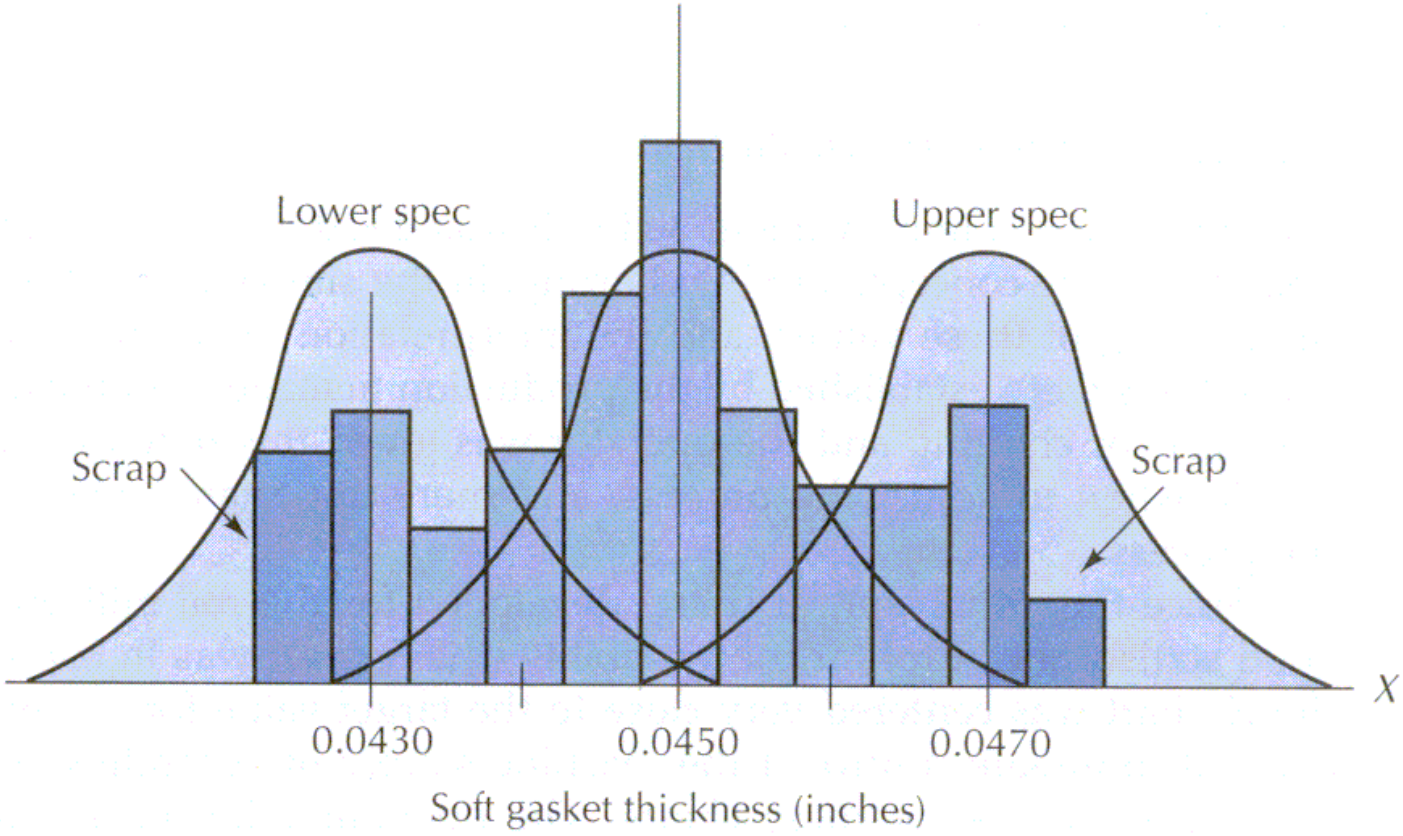


Figure 10.11 Consequences of Overcontrol on Process Performance

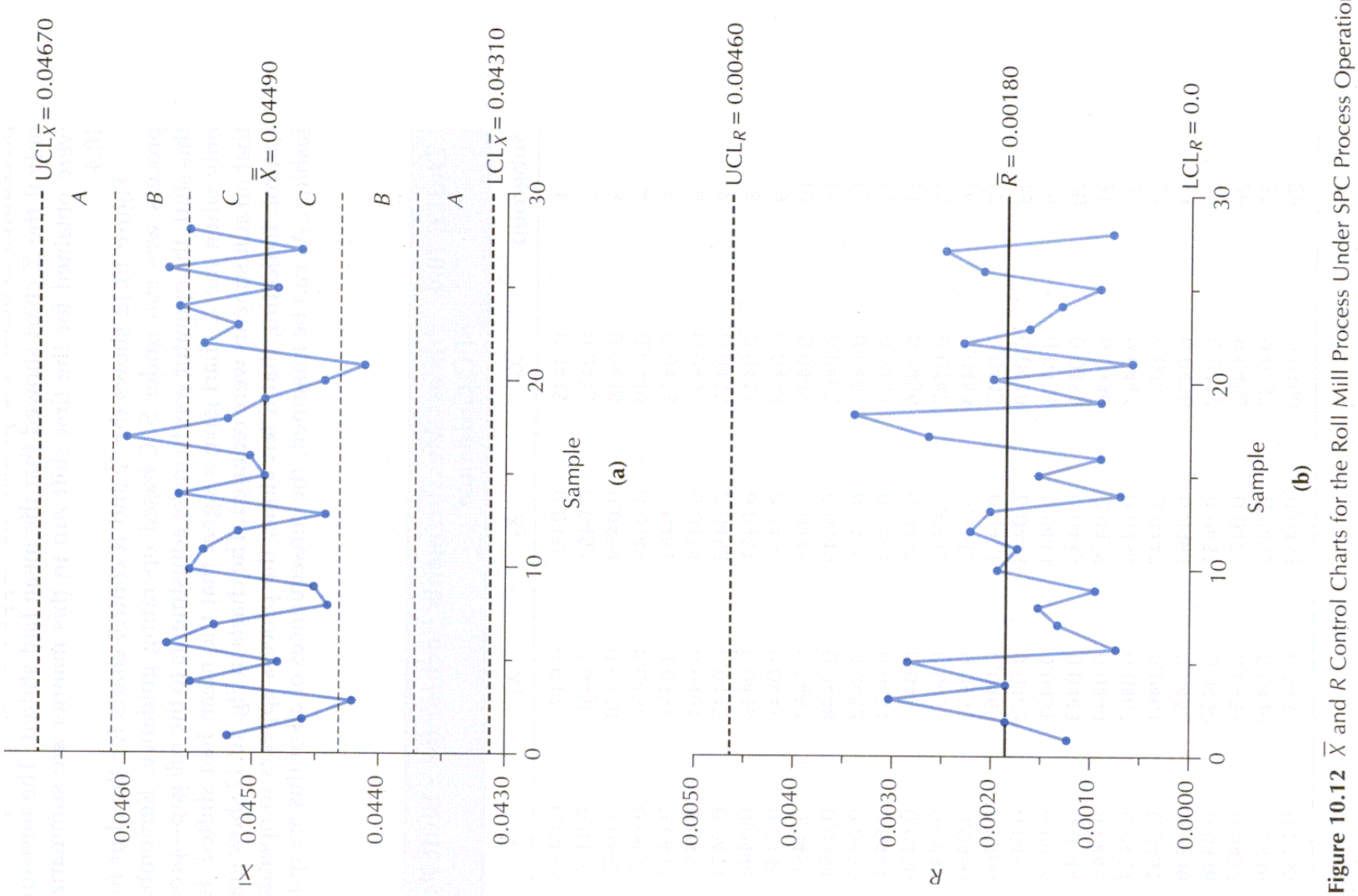


Figure 10.12 $\bar{X}$ and R Control Charts for the Roll Mill Process Under SPC Process Operation

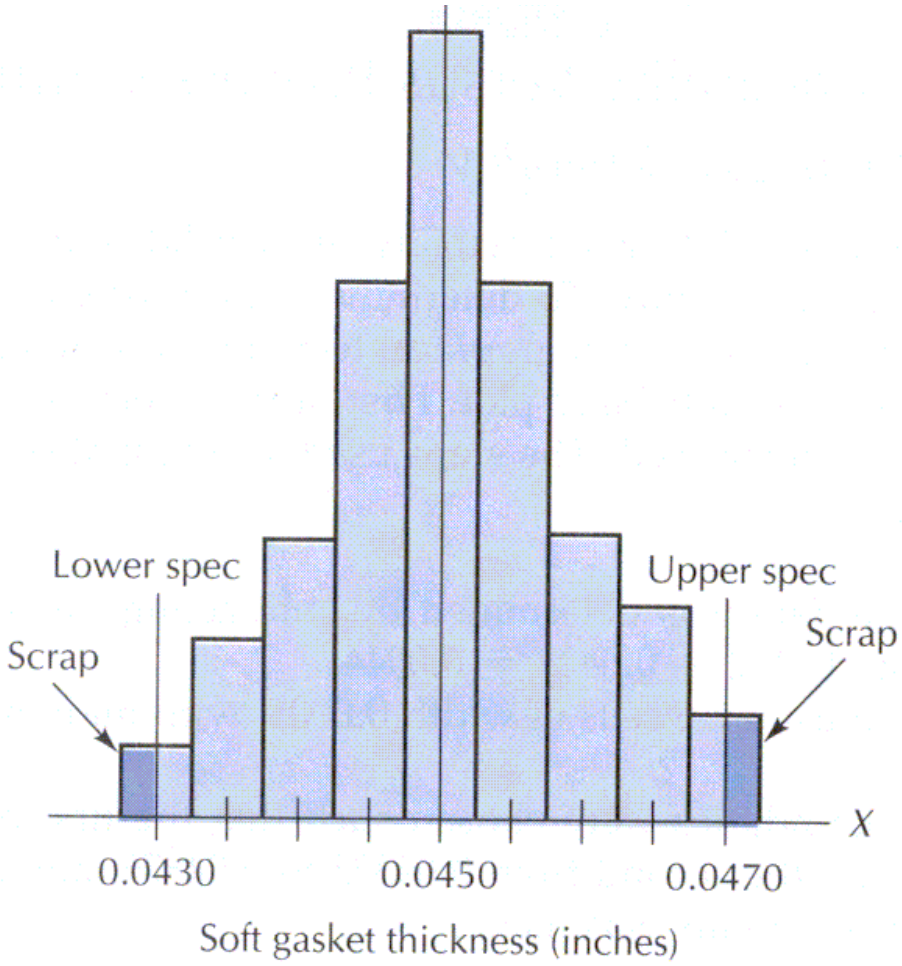


Figure 10.13 Histogram of the Gasket Measurements in Table 10.4

TABLE 10.5 Data for Normal Probability Plot of Fig. 10.14

Order	Measure-ment	Estimated Cumulative Probability (%)	Order	Measure-ment	Estimated Cumulative Probability (%)
1	0.0428	2	16	0.0450	52
2	0.0433	5	17	0.0451	55
3	0.0435	8	18	0.0451	58
4	0.0436	12	19	0.0453	62
5	0.0437	15	20	0.0454	65
6	0.0441	18	21	0.0455	68
7	0.0443	22	22	0.0455	72
8	0.0445	25	23	0.0455	75
9	0.0445	28	24	0.0457	78
10	0.0445	32	25	0.0458	82
11	0.0448	35	26	0.0459	85
12	0.0449	38	27	0.0461	88
13	0.0449	42	28	0.0461	92
14	0.0449	45	29	0.0467	95
15	0.0450	48	30	0.0468	98

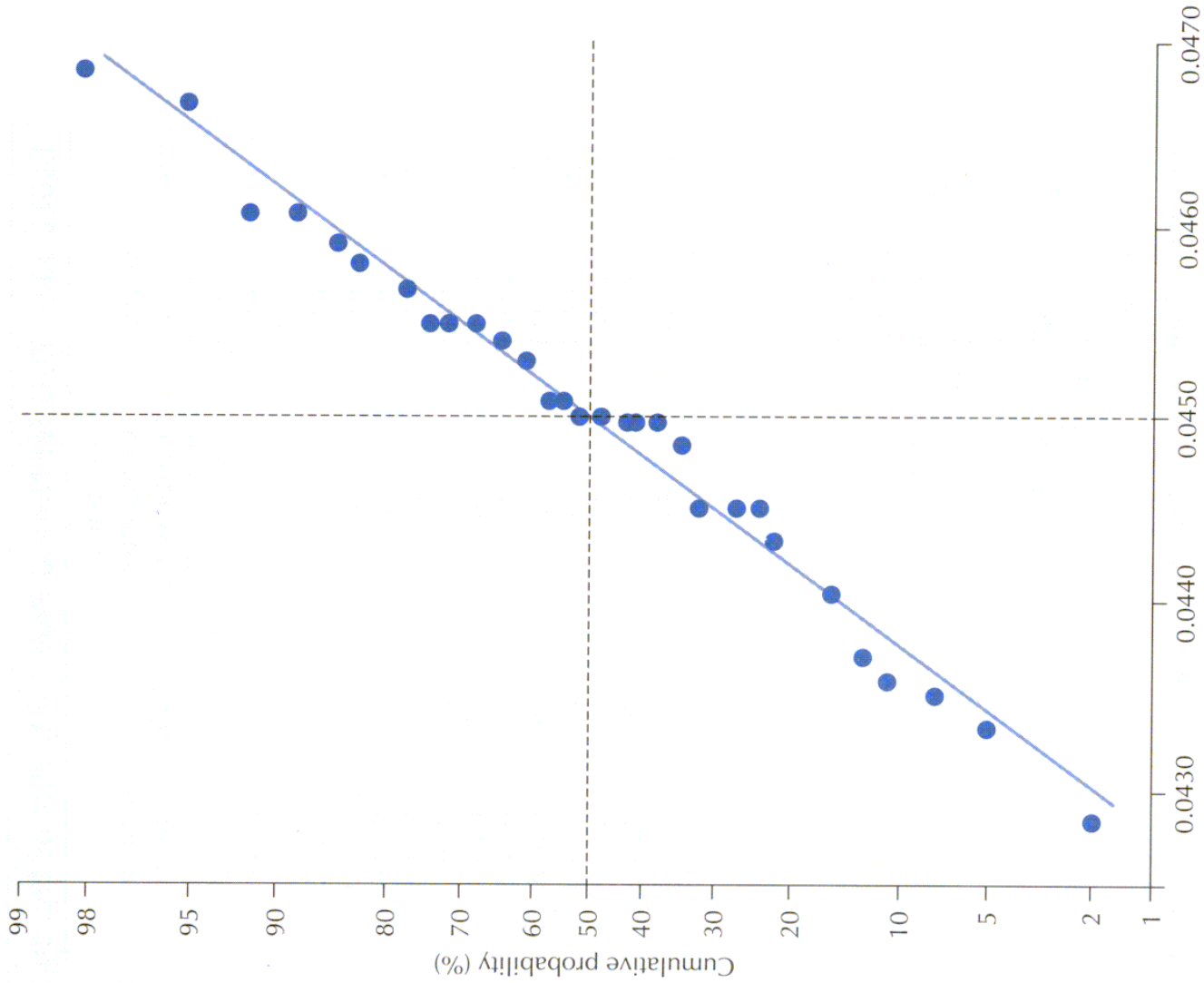


Figure 10.14 Normal Probability Plot Based on the Data of Table 10.5

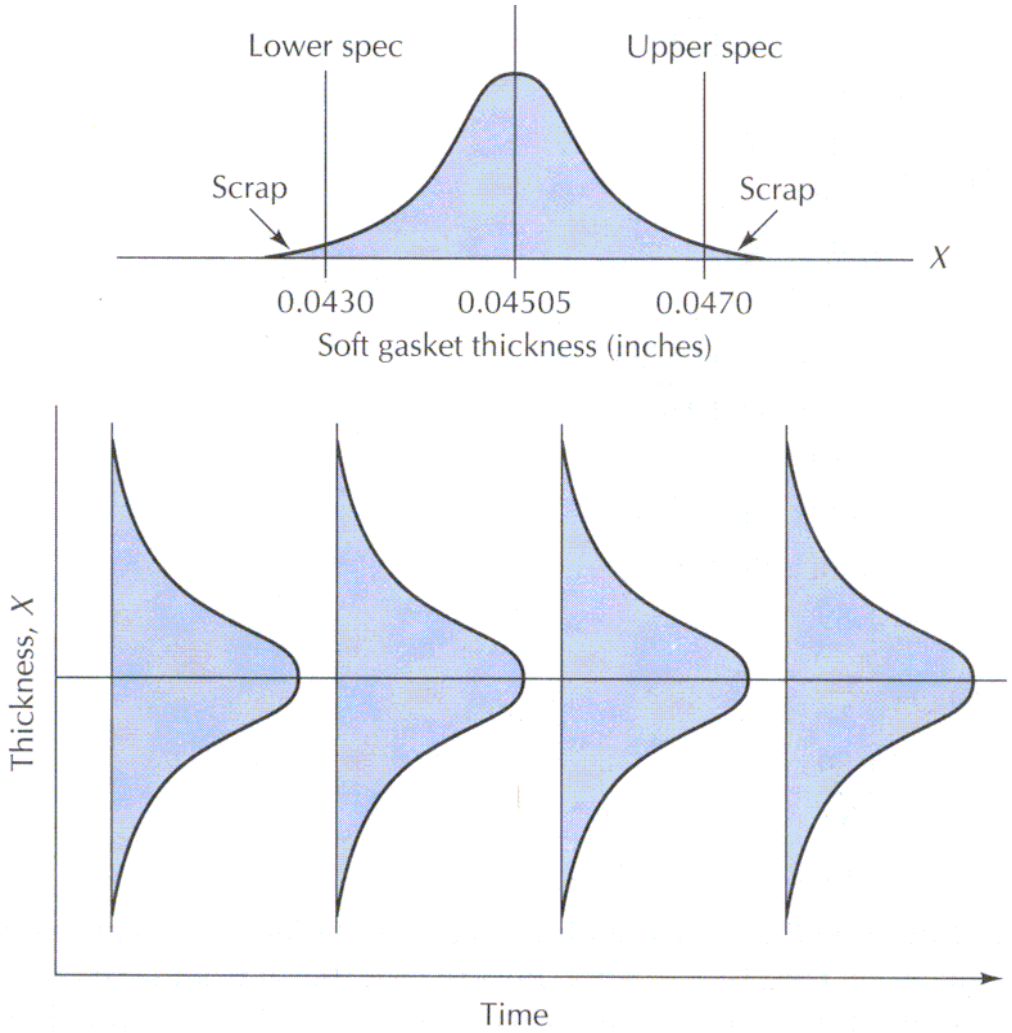


Figure 10.15 Process Capability Analysis Based on the Process Data of Table 10.4

84 sheets

Xdbar = 0.04505
Sig-x = 0.00103

Cap = 94.7%
C_p = 0.645
C_{pk} = 0.63

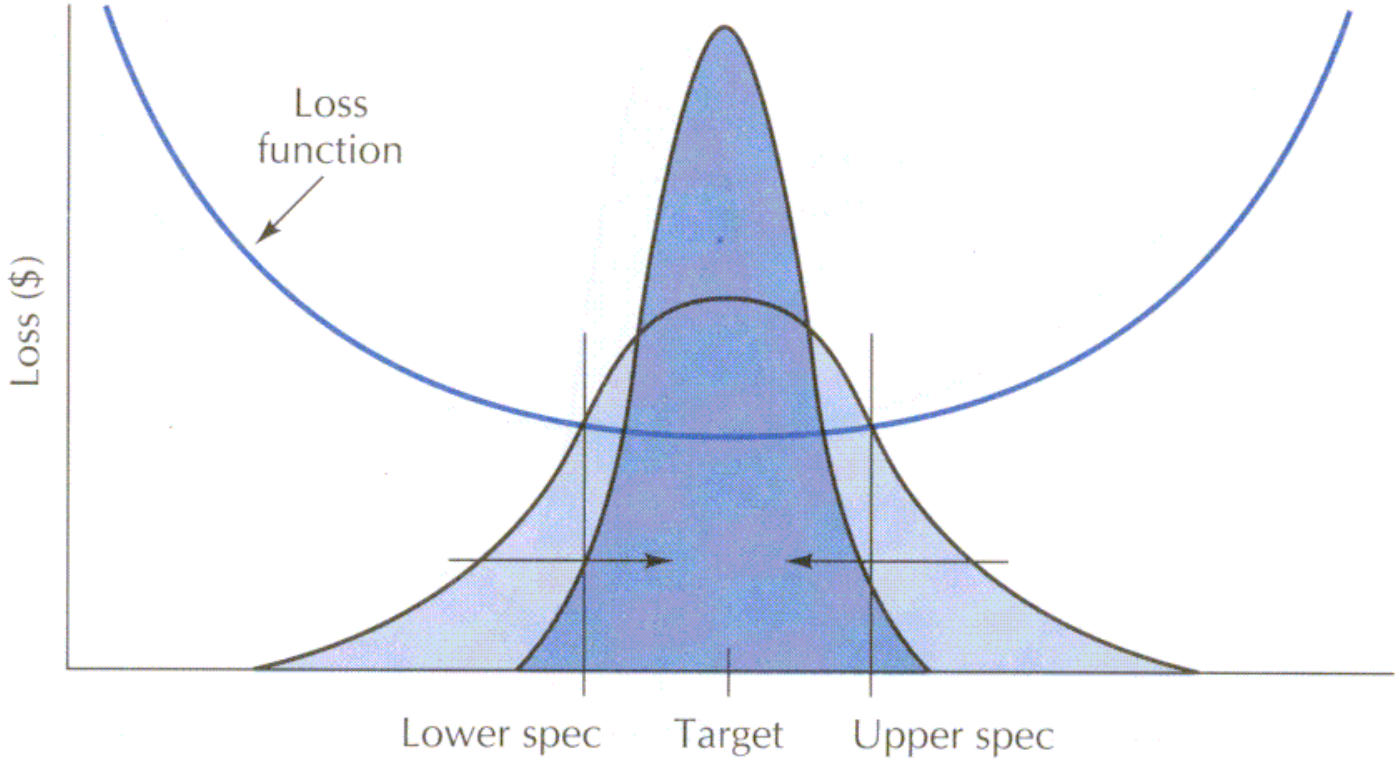


Figure 10.16 Loss Function View of Quality/Variability Relationship

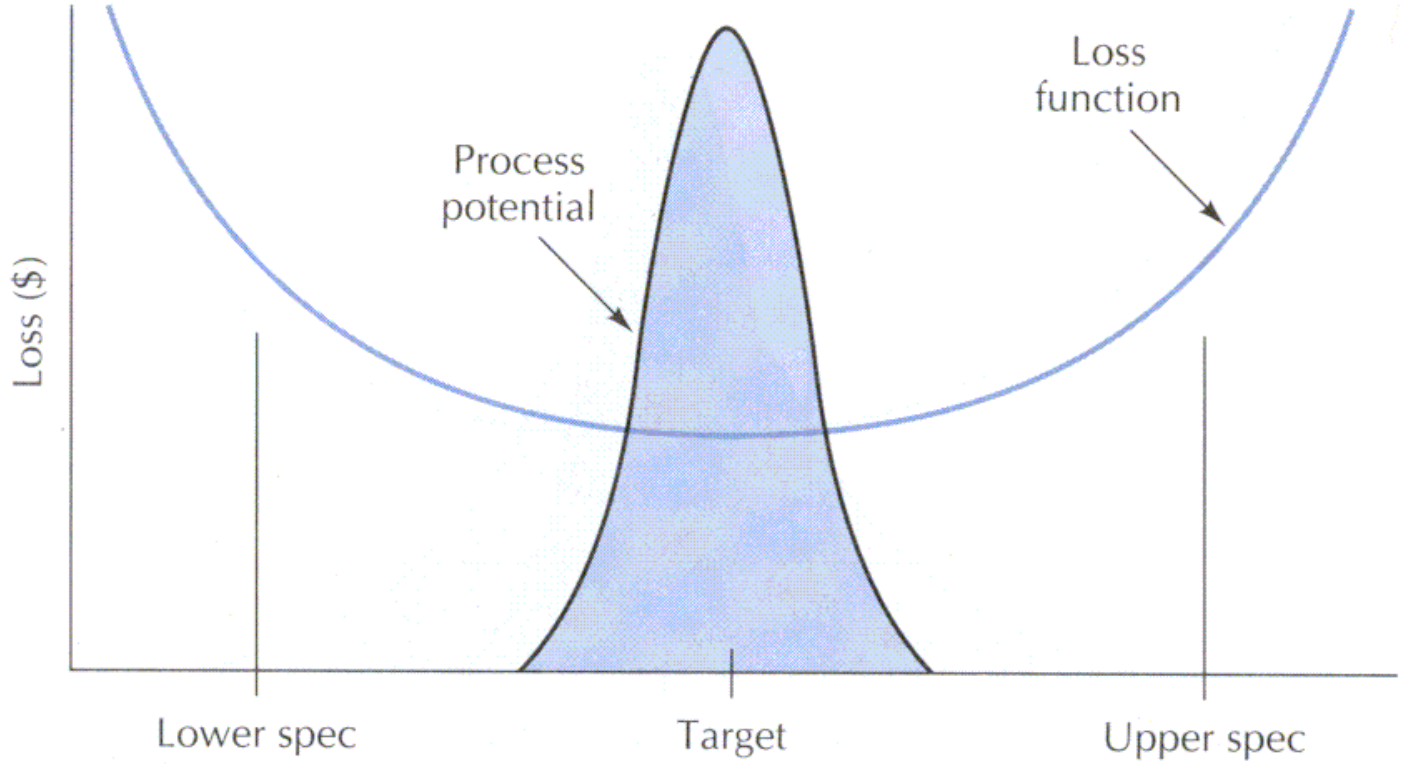


Figure 10.17 Loss If Process Is in a State of Statistical Control Centered at the Nominal

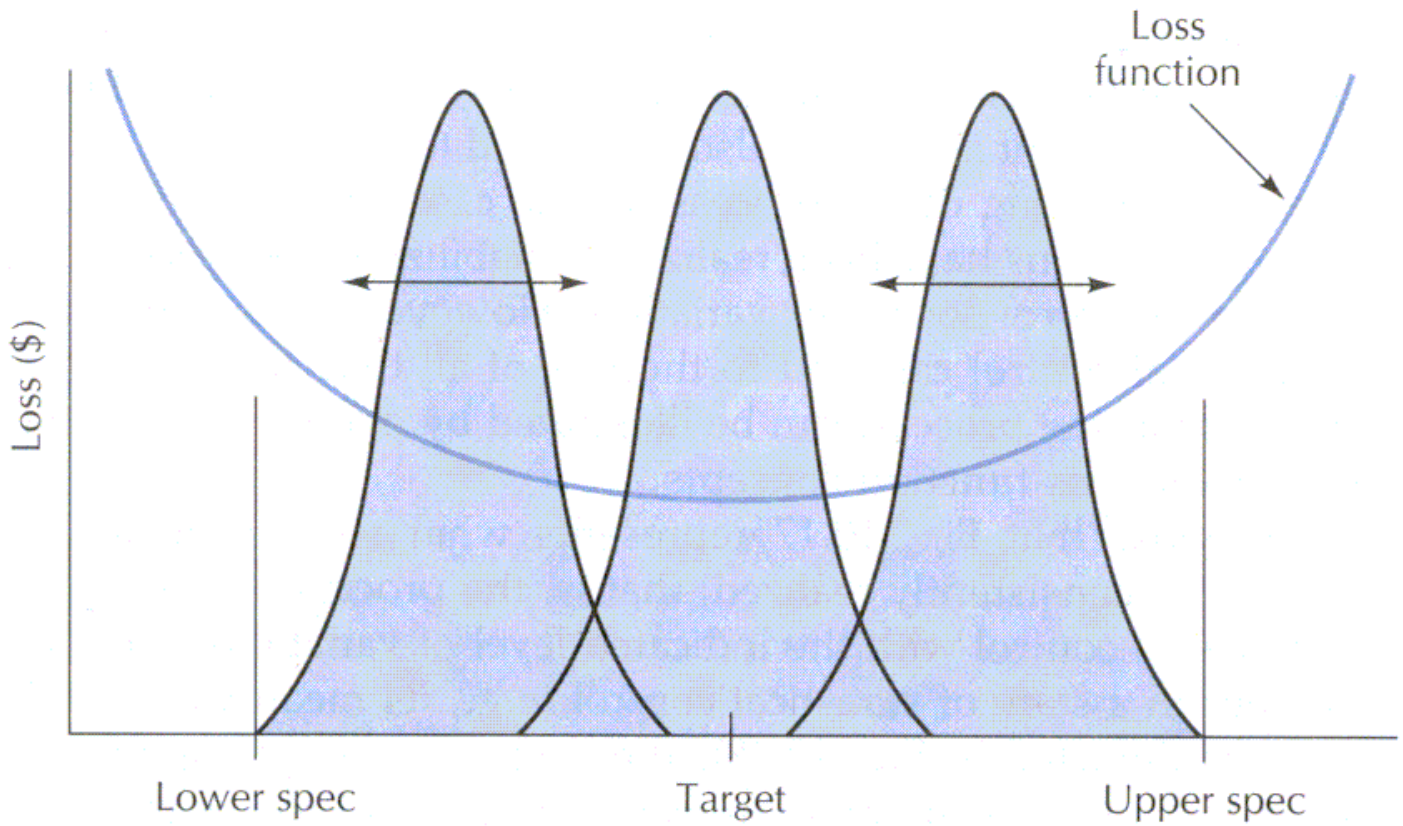


Figure 10.18 Behavior of Process If Statistical Control Is Not Maintained

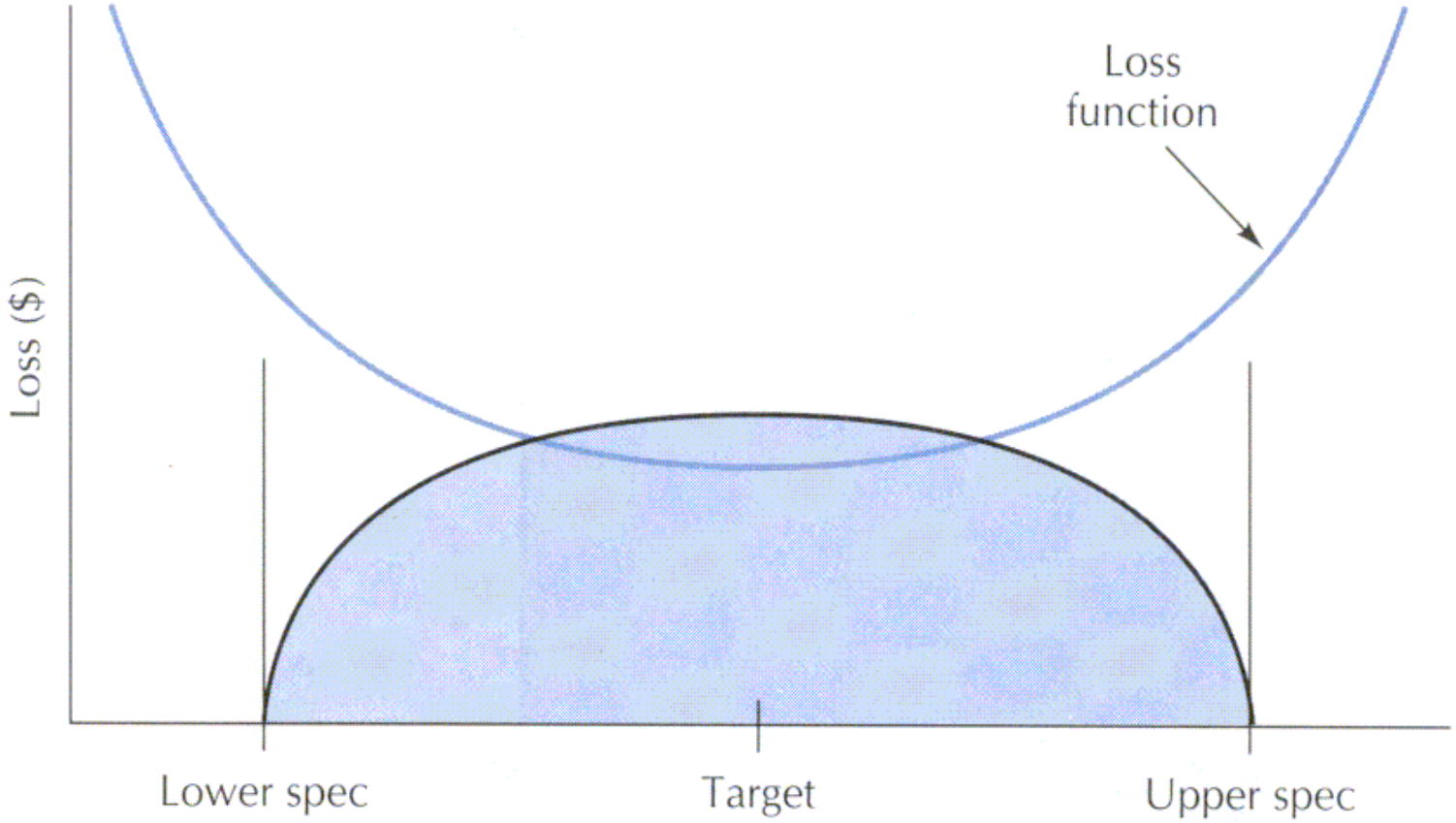


Figure 10.19 Loss If Statistical Control Is Not Maintained

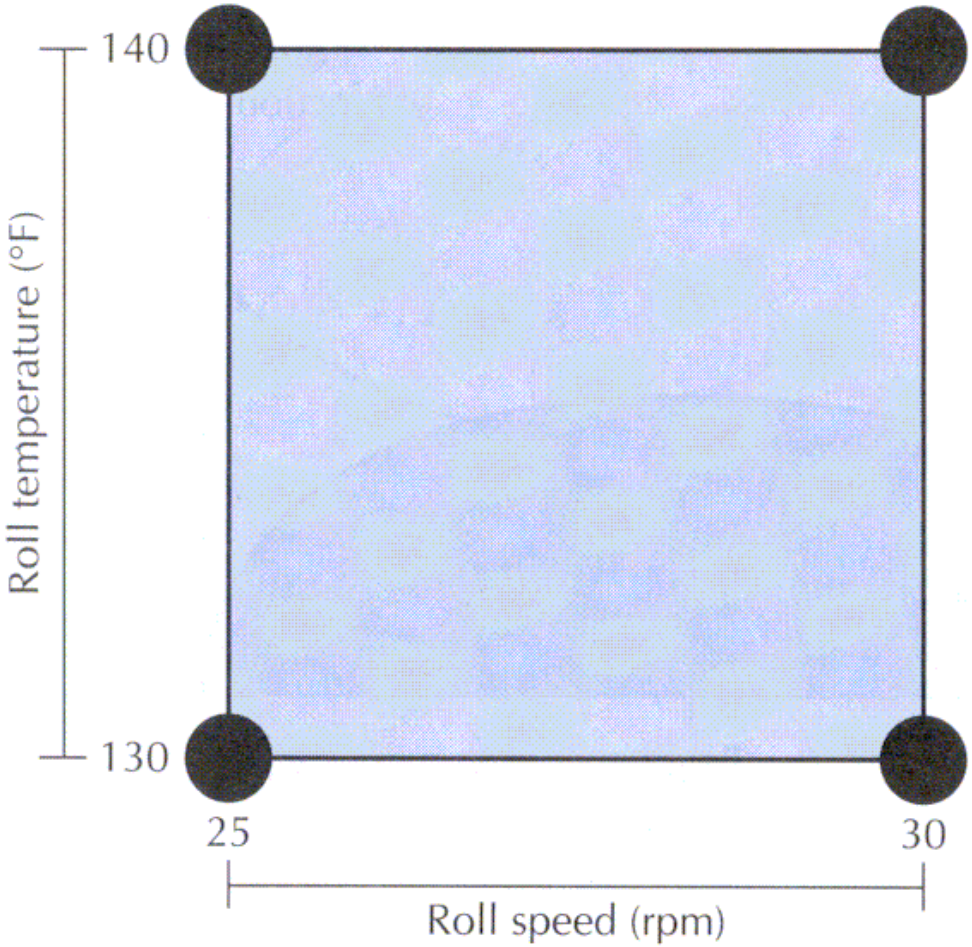


Figure 10.20 Two-Level Factorial Design to Study Roll Mill Process

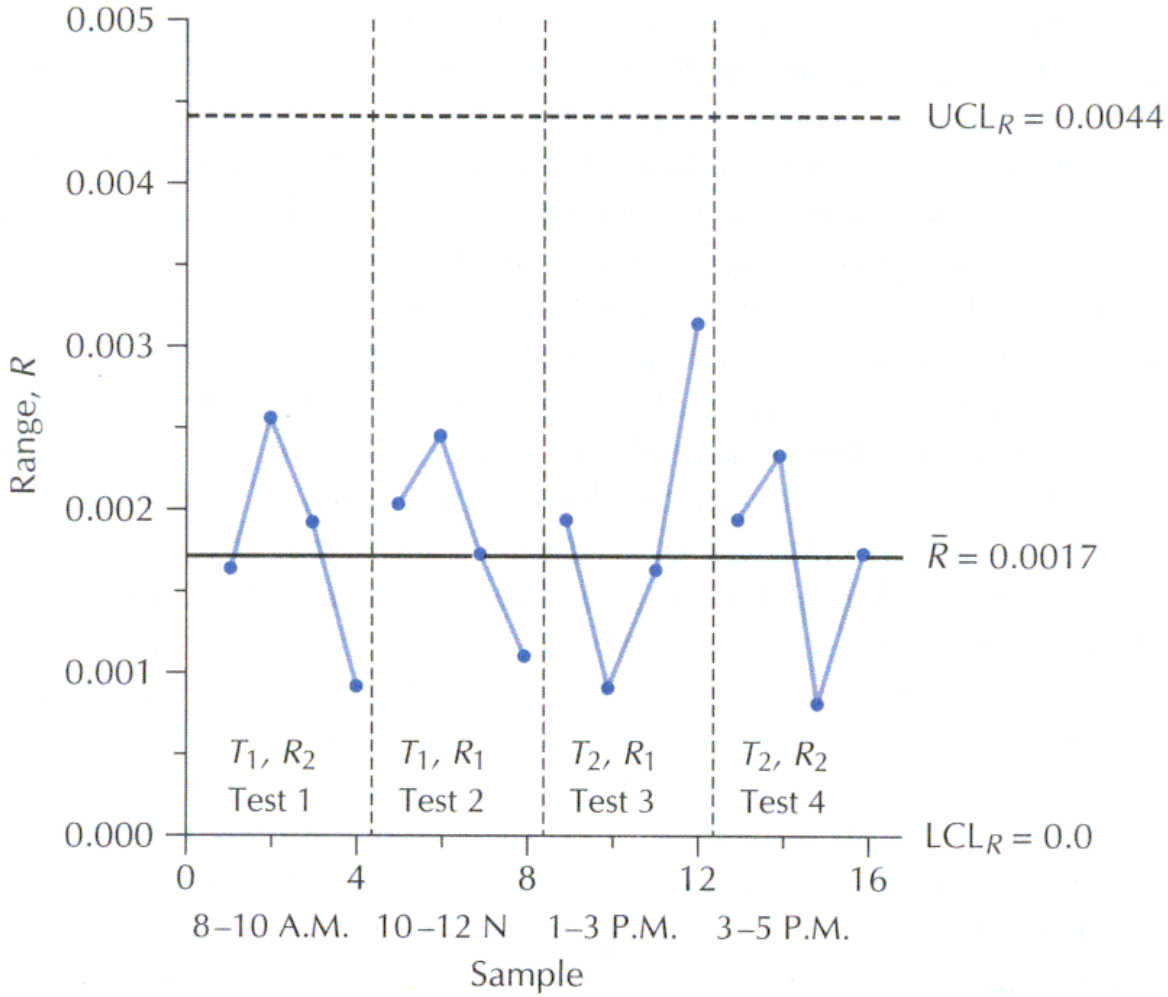


Figure 10.21 Range Chart for the Process over the Period of the Factorial Experiment

Taking Another Look at the Process

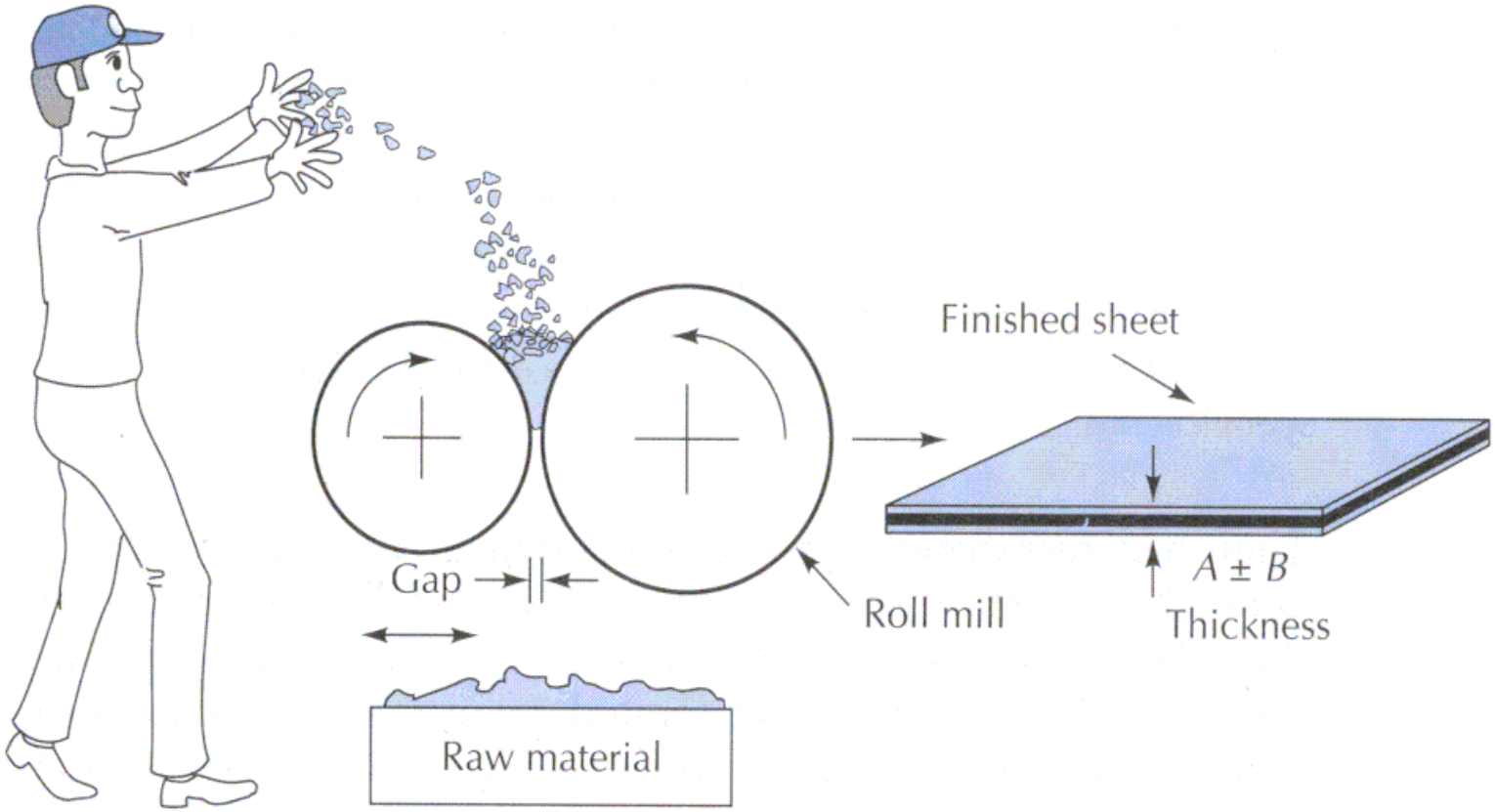
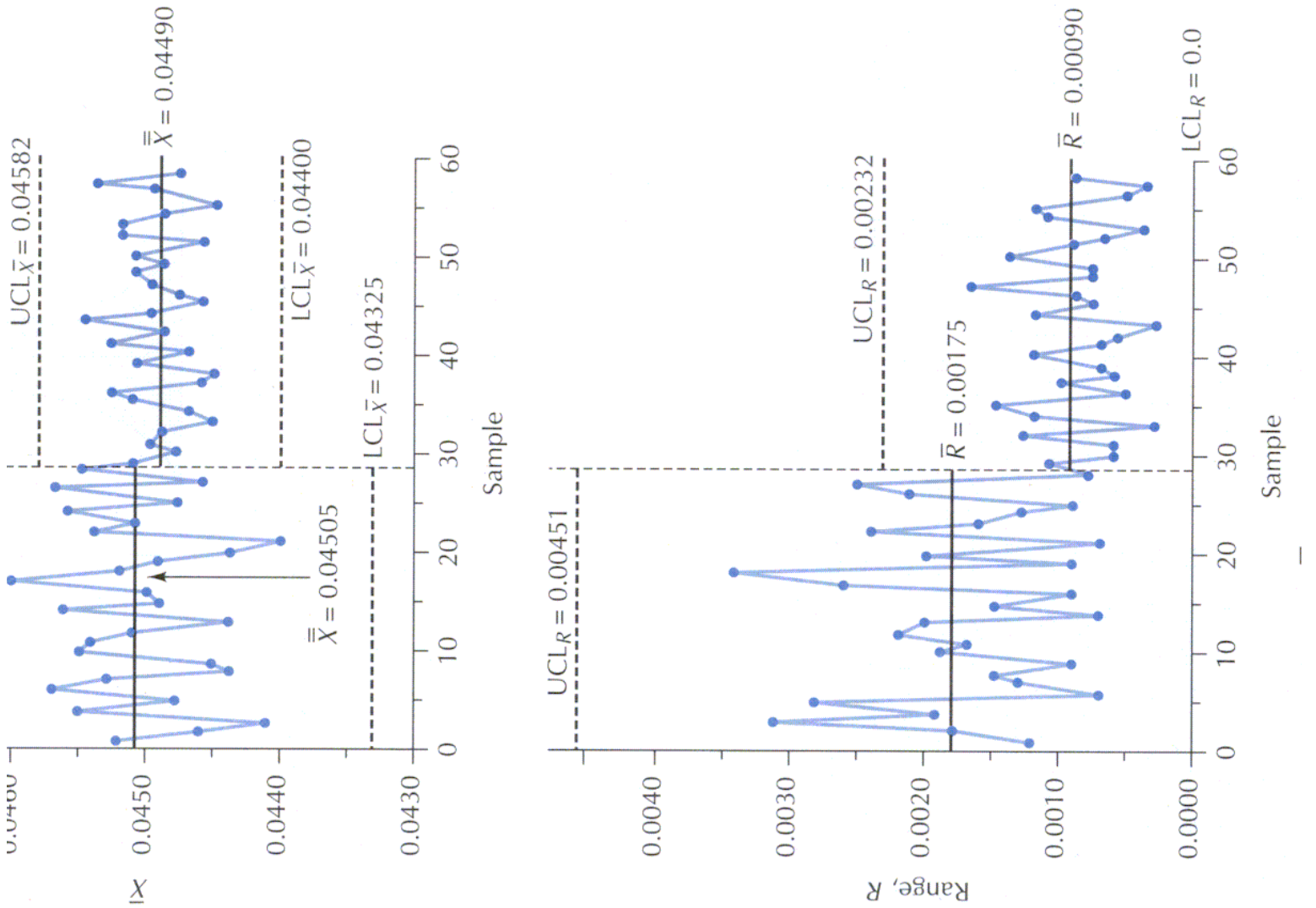


Figure 10.2 The Process: Roll Mill for the Manufacture of Soft Gasket Material

30 samples of size 3 (Fig. 10-22)



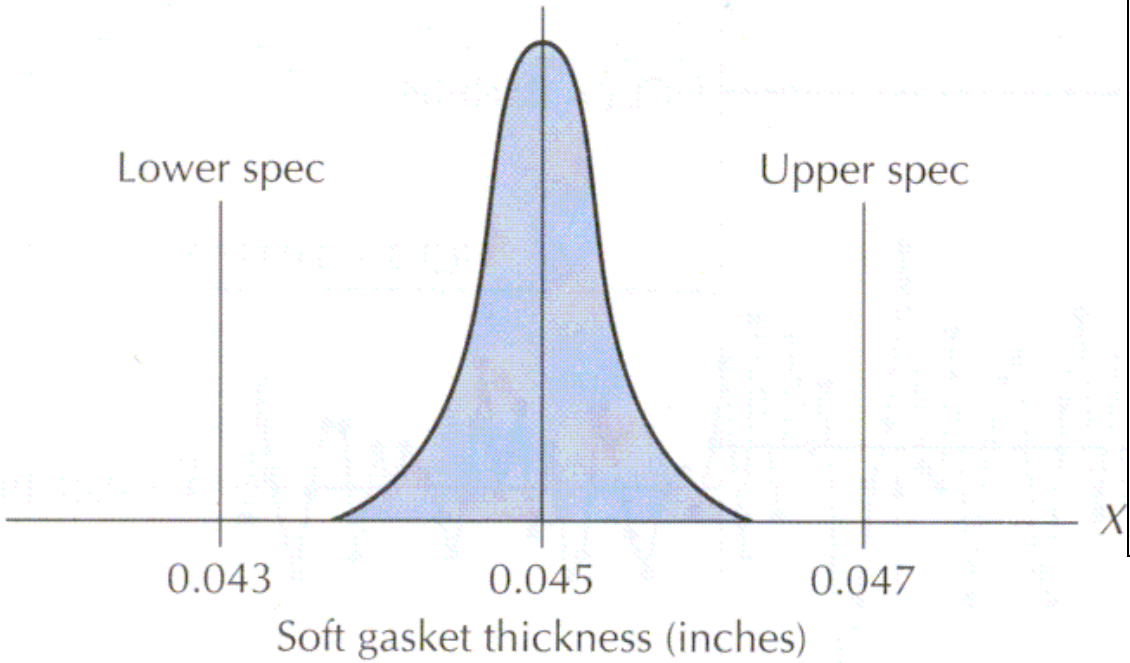


Figure 10.23 Process Capability After Material Metering Was Put into Effect

90 sheets

Xdbar = 0.04490
Sig-x = 0.00053

Cap > 99.9%
C_p = 1.253
C_{pk} = 1.19

Revisiting the Use of DOE

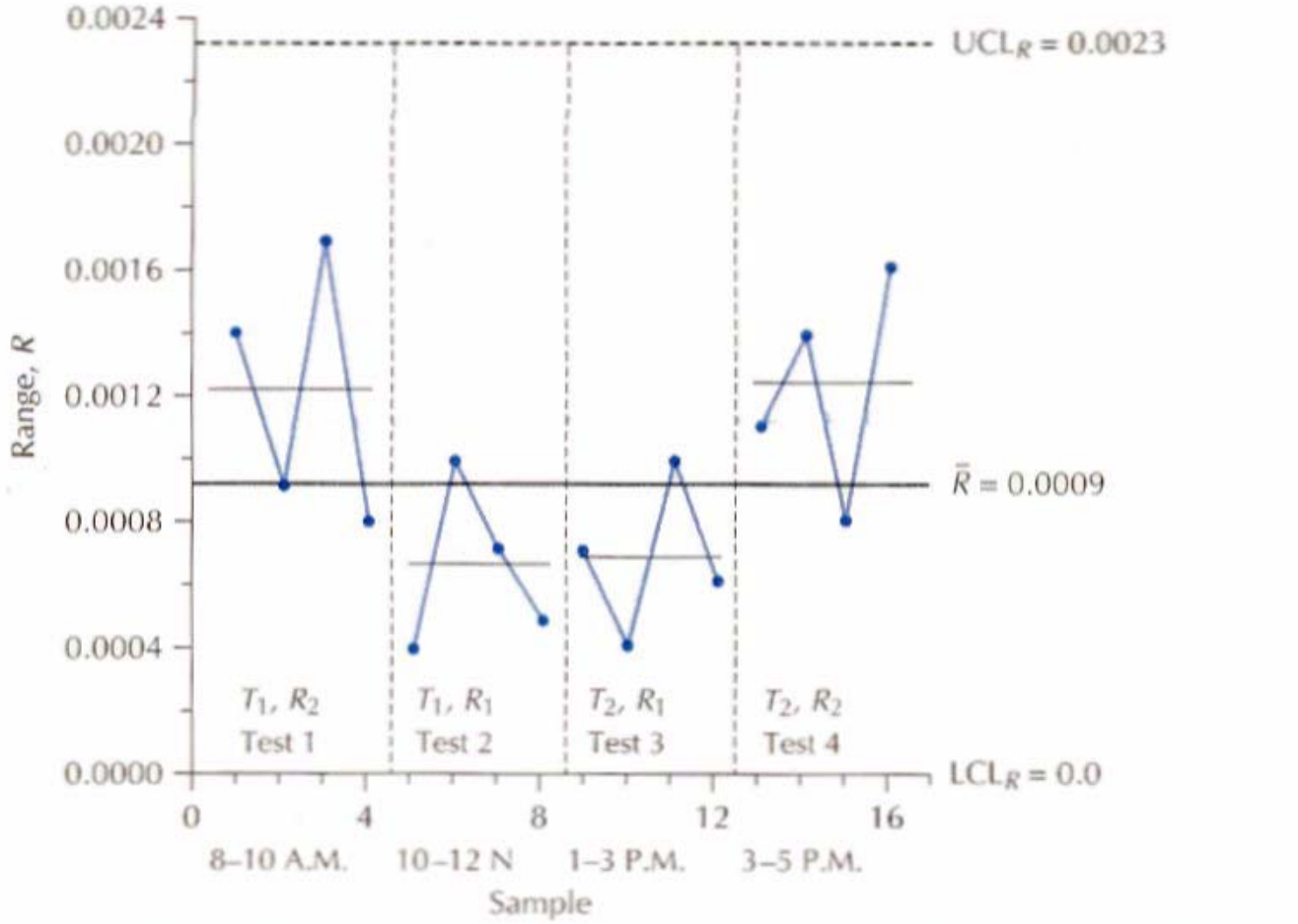
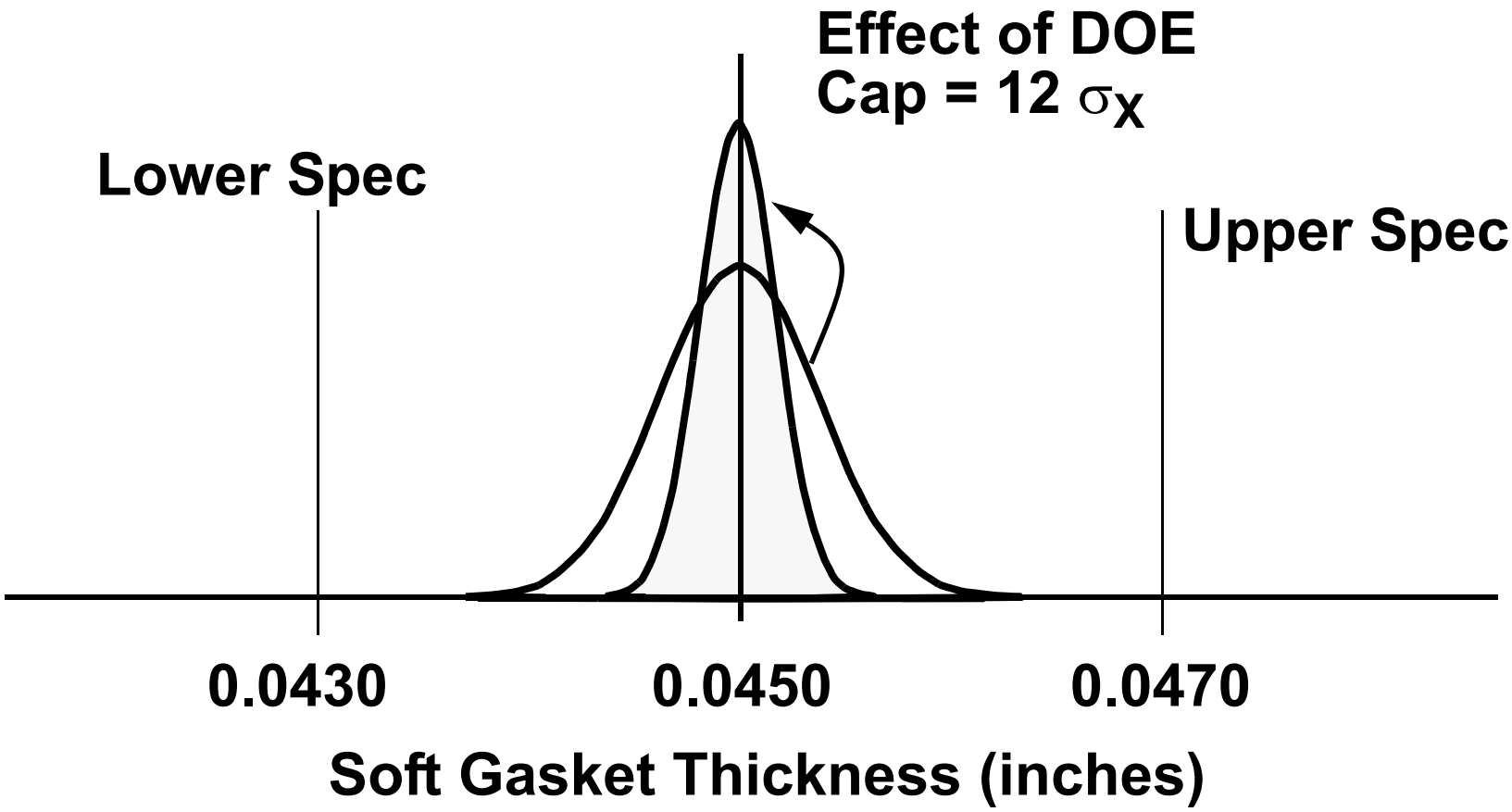


Figure 10.24 Results of the Repeated Factorial Experiment After Process Material Metering Was Initiated

Capability after DOE Study



A Postscript