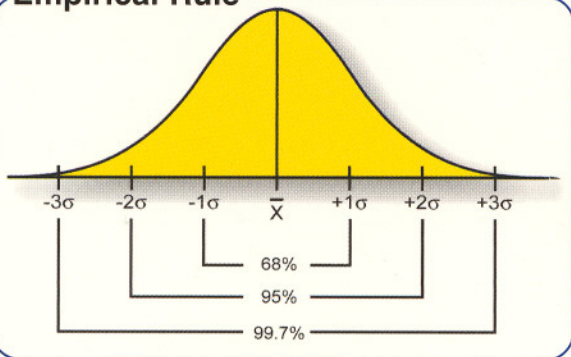
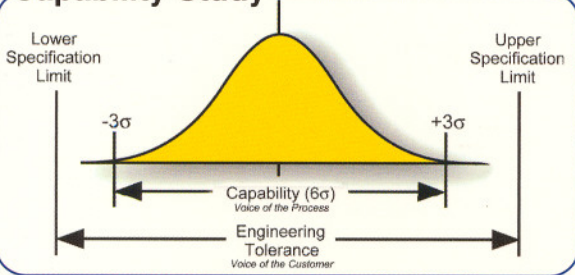


Empirical Rule



Capability Study



Capability Formulas

$$P_{pl} = \frac{\bar{X} - LSL}{3s} \quad C_{pl} = \frac{\hat{\mu} - LSL}{3\hat{\sigma}}$$

$$P_{pu} = \frac{USL - \bar{X}}{3s} \quad C_{pu} = \frac{USL - \hat{\mu}}{3\hat{\sigma}}$$

$$P_p = \frac{USL - LSL}{6s} \quad C_p = \frac{USL - LSL}{6\hat{\sigma}}$$

$$\bar{X} = \frac{\sum X}{n}$$

$$s = \sqrt{\frac{\sum (X_i - \bar{X})^2}{N-1}}$$

$$\hat{\sigma} = \frac{\bar{R}}{d_2}$$

$$\hat{\mu} = \text{Estimated population mean}$$

Control Chart Formulas

Variables Control Charts

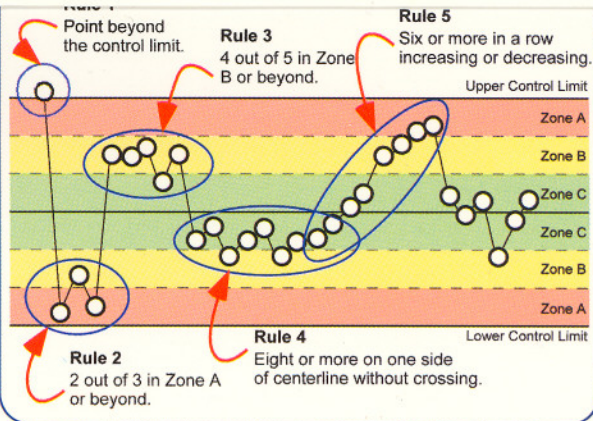
Chart Type	Centerline	Control Limits	Estimate of Sigma
\bar{X} and R	$\bar{\bar{X}} = \frac{\sum \bar{X}}{k}$ $\bar{R} = \frac{\sum R}{k}$	$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 \bar{R}$ $LCL_{\bar{X}} = \bar{\bar{X}} - A_2 \bar{R}$ $UCL_R = D_4 \bar{R}$ $LCL_R = D_3 \bar{R}$	\bar{R}/d_2
IX and MR	$\bar{IX} = \frac{\sum IX}{k}$ $\bar{MR} = \frac{\sum MR}{k-1}$	$UCL_{IX} = \bar{IX} + A_2 \bar{MR}$ $LCL_{IX} = \bar{IX} - A_2 \bar{MR}$ $UCL_{MR} = D_4 \bar{MR}$ $LCL_{MR} = 0$	\bar{MR}/d_2
\bar{X} and s	$\bar{\bar{X}} = \frac{\sum \bar{X}}{k}$ $\bar{s} = \frac{\sum s}{k}$	$UCL_{\bar{X}} = \bar{\bar{X}} + A_3 \bar{s}$ $LCL_{\bar{X}} = \bar{\bar{X}} - A_3 \bar{s}$ $UCL_s = B_4 \bar{s}$ $LCL_s = B_3 \bar{s}$	\bar{s}/c_4

Attribute Control Charts

Chart Type	Centerline	Control Limits	Estimate of Sigma
p	$\bar{p} = \frac{\sum p}{k}$	$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ $LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$	$\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$
np	$n\bar{p} = \frac{\sum np}{k}$	$UCL_{np} = n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$ $LCL_{np} = n\bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})}$	$\sqrt{n\bar{p}(1-\bar{p})}$
c	$\bar{c} = \frac{\sum c}{k}$	$UCL_c = \bar{c} + 3\sqrt{\bar{c}}$ $LCL_c = \bar{c} - 3\sqrt{\bar{c}}$	$\sqrt{\bar{c}}$
u	$\bar{u} = \frac{\sum u}{k}$	$UCL_u = \bar{u} + 3\sqrt{\bar{u}/n}$ $LCL_u = \bar{u} - 3\sqrt{\bar{u}/n}$	$\sqrt{\bar{u}/n}$

Calculated Capability Ratio	P _p Fallout (both sides combined)	P _{pk} Fallout (one side only)
0.50	133,620	66,810
0.60	71,860	35,930
0.70	35,730	17,865
0.80	16,396	8,198
0.90	6,934	3,467
1.00	2,700	1,350
1.10	966	483
1.20	318	159
1.30	96	48
1.40	26	13
1.50	7	3
1.60	2	1
1.70	0.340	0.170
1.80	0.060	0.030
1.90	0.012	0.006
2.00	0.002	0.001

Fallout rates expressed in PPM (parts per million)



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Control Chart Constants

\bar{X} and R Control Charts					\bar{X} and S Control Charts				
n	A ₂	D ₃	D ₄	d ₂	n	A ₃	B ₃	B ₄	c ₄
1	2.660	-	-	-	10	0.975	0.284	1.716	0.9727
2	1.880	0	3.267	1.128	11	0.927	0.321	1.679	0.9754
3	1.023	0	2.574	1.693	12	0.886	0.354	1.646	0.9776
4	0.729	0	2.282	2.059	13	0.850	0.382	1.618	0.9794
5	0.577	0	2.114	2.326	14	0.817	0.406	1.594	0.9810
6	0.483	0	2.004	2.534	15	0.789	0.428	1.572	0.9823
7	0.419	0.076	1.924	2.704	16	0.763	0.448	1.552	0.9835
8	0.373	0.136	1.864	2.847	17	0.739	0.466	1.534	0.9845
9	0.337	0.184	1.816	2.970	18	0.718	0.482	1.518	0.9854
10	0.308	0.223	1.777	3.078	19	0.698	0.497	1.503	0.9862
11	0.285	0.256	1.744	3.173	20	0.680	0.510	1.490	0.9869
12	0.266	0.283	1.717	3.258	21	0.663	0.523	1.477	0.9876
					22	0.647	0.534	1.466	0.9882
					23	0.633	0.545	1.455	0.9887
					24	0.619	0.555	1.445	0.9892
					25	0.606	0.565	1.435	0.9896