

PROCESS CAPABILITY

CAPABILITY IS ACTUAL PERFORMANCE vs COMPONENT SPECIFICATION

STAGES IN CAPABILITY STUDY

1. The process must be under statistical control.

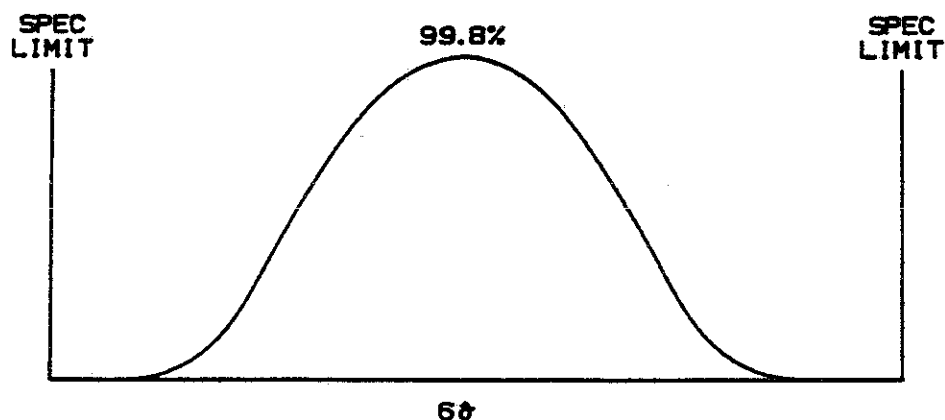
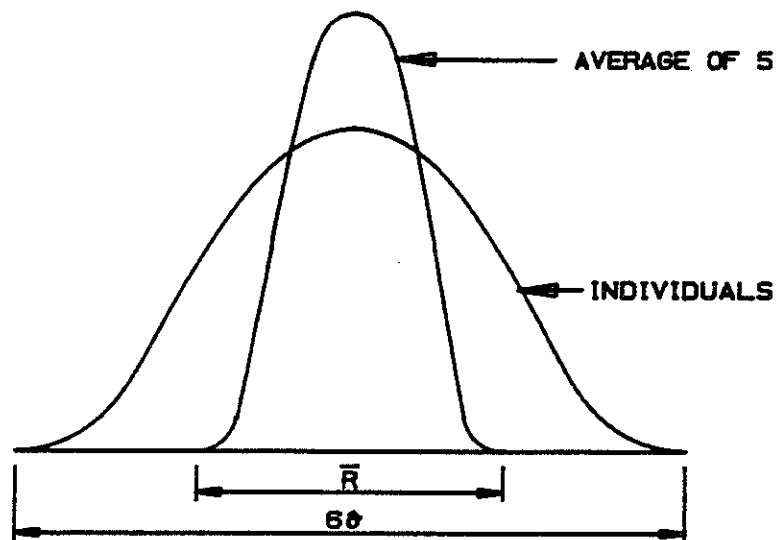
This means that the output from the process is normally distributed and stable with time.

2. A measure of the spread or variability of the process is determined, in this case the standard deviation ($\hat{\sigma}$).

$\bar{R}$, the average range for a sample of 5 is known.

Convert $\bar{R}$ (when $n = 5$) to $\hat{\sigma}$ (when $n = 1$) by using the relationship:

$$\hat{\sigma} = \frac{\bar{R}}{d_2} = \frac{\bar{R}}{2.33} \quad (\text{For sample of 5})$$



3. Calculate the CAPABILITY INDICES for the process.

$$\text{Index } C_p = \frac{\text{Total specification tolerance}}{6\hat{\sigma}}$$

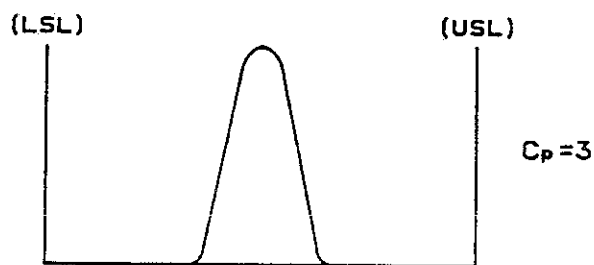
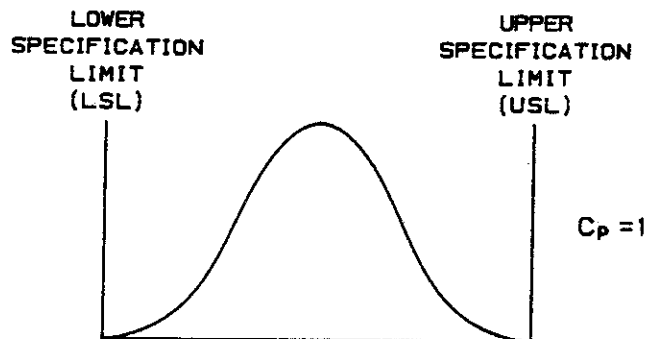
This indicates the spread of the process.

Index C_{pk} = smallest of

$$\frac{\text{Upper specification limit} - \bar{\bar{X}}}{3\hat{\sigma}} \text{ or } \frac{\bar{\bar{X}} - \text{Lower specification limit}}{3\hat{\sigma}}$$

This indicates the process setting as well as spread.

PROCESS CAPABILITY INDICES



20

1

2

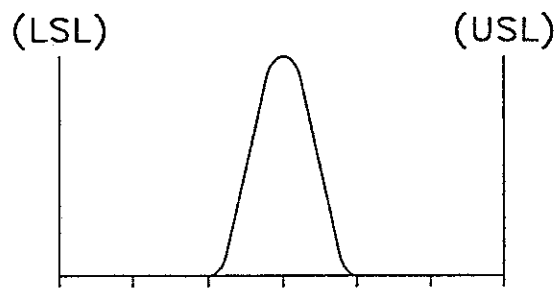
3

4

5

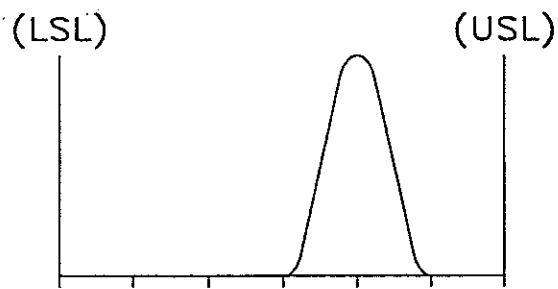
6

7



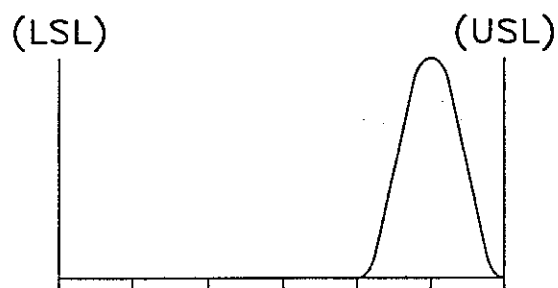
$$C_p = 3$$

$$C_{pk} = 3$$



$$C_p = 3$$

$$C_{pk} = 2$$



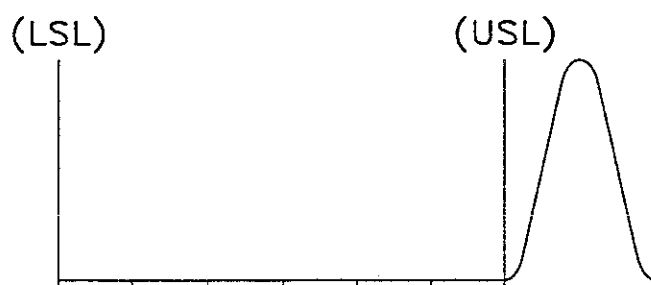
$$C_p = 3$$

$$C_{pk} = 1$$



$$C_p = 3$$

$$C_{pk} = 0$$

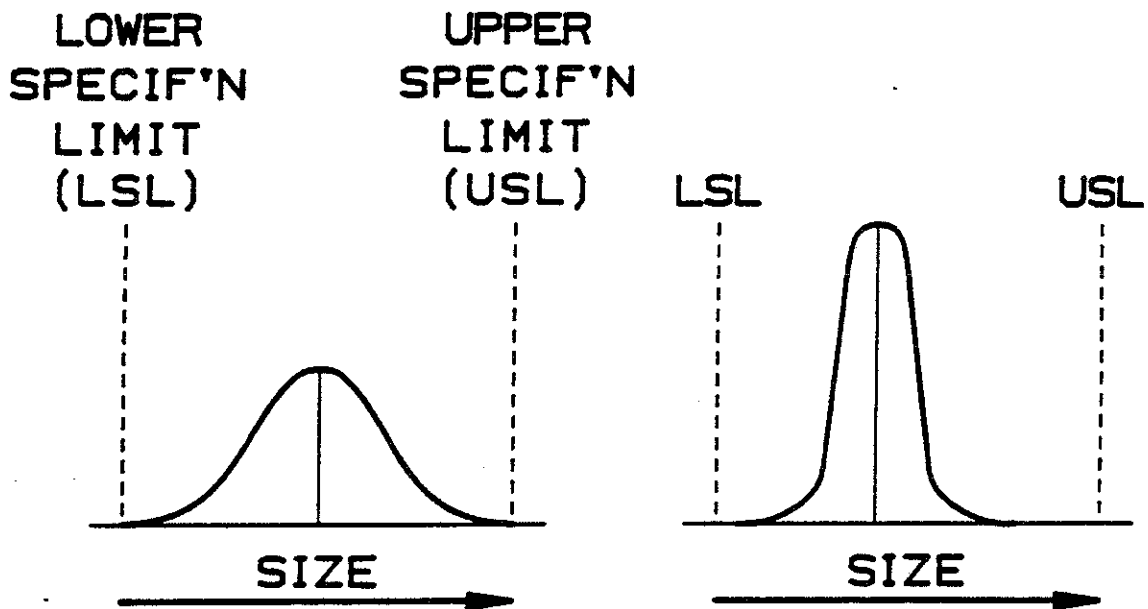


$$C_p = 3$$

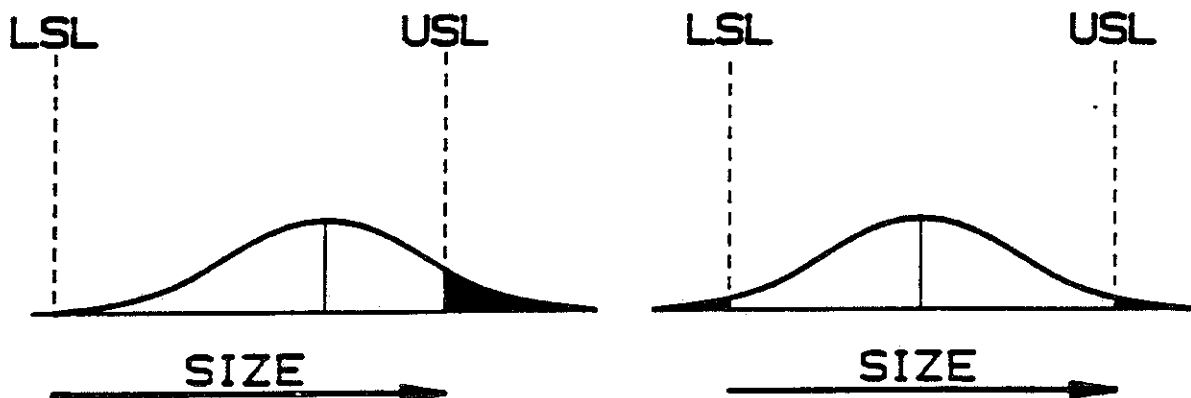
$$C_{pk} = -1$$

PROCESS CAPABILITY

CAPABLE PROCESSES
[VIRTUALLY ALL OUTPUT IS
IS WITHIN THE SPECIFICATIONS]

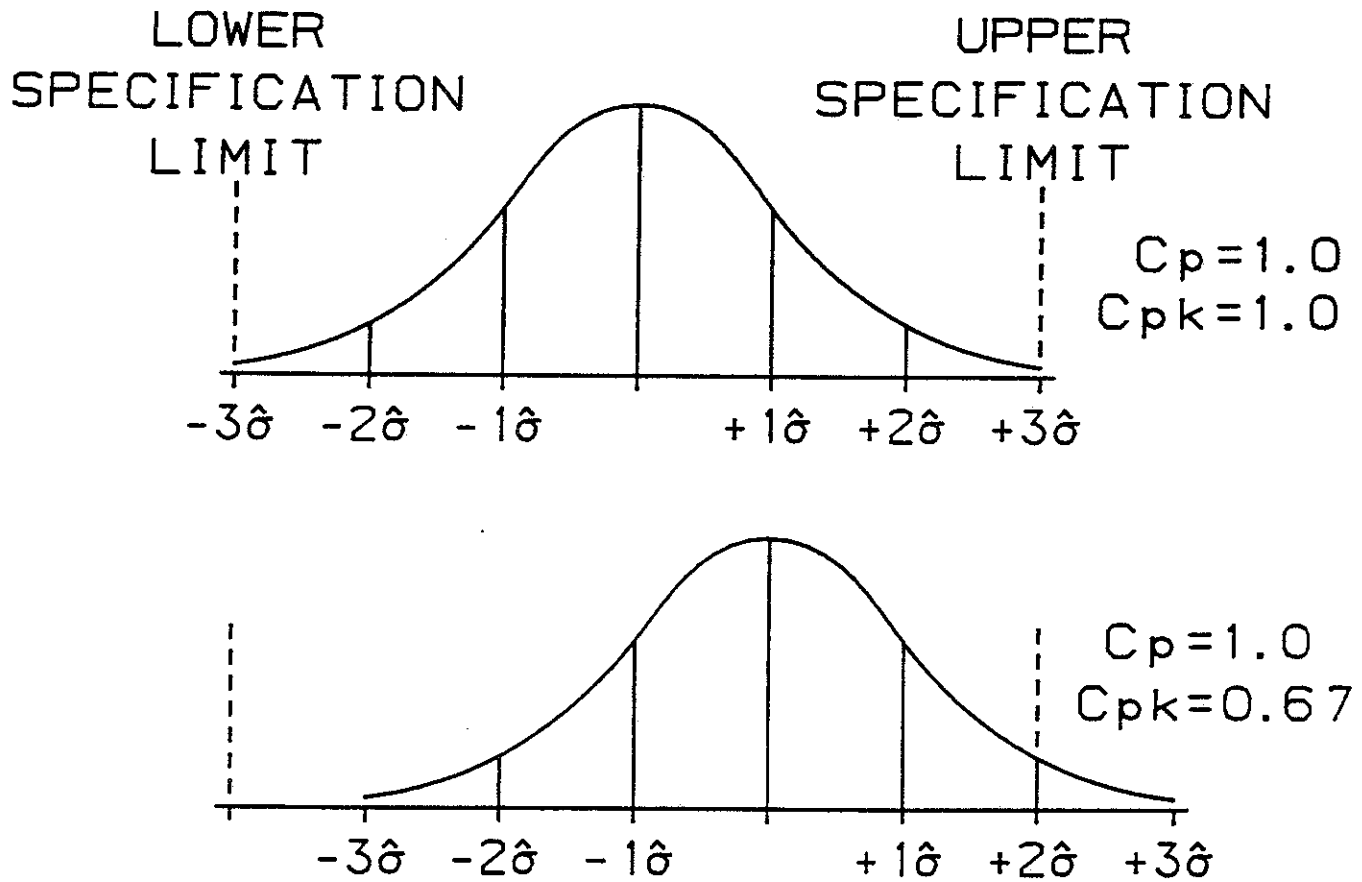


NON-CAPABLE PROCESSES
[OUTPUT IS PRODUCED BEYOND
ONE OR BOTH SPECIFICATIONS]



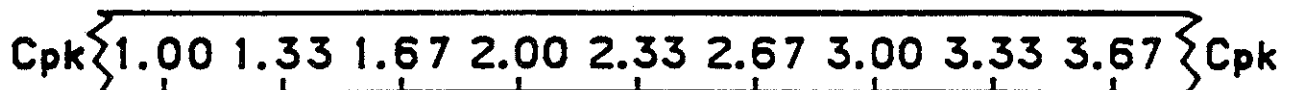


PROCESS CAPABILITY INDICES



4. Analysis. The minimum requirement is a process capability index of 1. The aim is to increase the index year by year.

CAPABILITY INDEX



1

2

3

4

PROCESS CAPABILITY - EXAMPLE

From previous calculations $\bar{\bar{X}} = 10.16, \bar{R} = 6.35$ ($n = 5$)

The process was found to be under control.

The process specification is given as 10 ± 8 i.e. 18 to 2.

Analysis:-

First the standard deviation must be found:-

$$\hat{\sigma} = \frac{\bar{R}}{2.33} = \frac{6.35}{2.33} = 2.73$$

$$C_p = \frac{\text{Total specification tolerance}}{6\hat{\sigma}} = \frac{16}{6 \times 2.73} = 0.98$$

Since this is below one, the specification is not yet being met.

$$C_{pk} = \frac{\text{Upper spec. limit} - \bar{\bar{X}}}{3\hat{\sigma}} = \frac{18 - 10.16}{3 \times 2.73} = 0.96$$

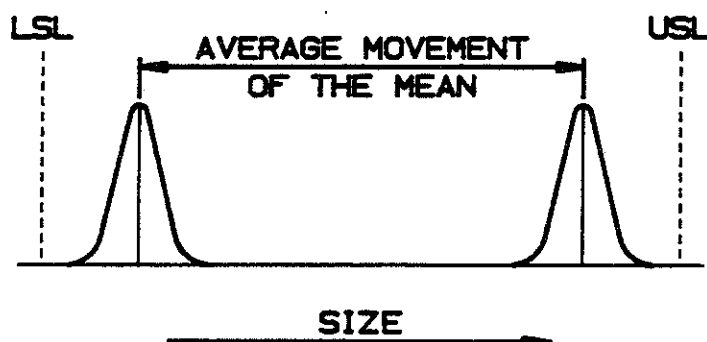
$$\text{or } = \frac{\bar{\bar{X}} - \text{Lower spec. limit}}{3\hat{\sigma}} = \frac{10.16 - 2}{3 \times 2.73} = 1.0$$

Minimum is 0.96, the process is set off centre - 10.16 instead of 10.0.



SPECIAL CASE

CAPABLE PROCESSES WITH MOVING MEAN



Where it is necessary, usually for technical and productivity reasons, to allow the process mean to drift, this must be allowed for.

Control limits for the average chart are:-

$$UCL_{\bar{X}} = \bar{\bar{X}} + 0.58 \bar{R} + \frac{\text{Average movement of mean}}{2}$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - 0.58 \bar{R} - \frac{\text{Average movement of mean}}{2}$$

Control can be monitored with diagonal limits.

The range chart is the same as for standard applications.

The process capability indices are then determined from:

$$C_p = \frac{\text{Total specified tolerance} - \text{average movement of the mean}}{6\hat{\sigma}}$$

C_{pk} = Minimum of:

$$\frac{\text{Upper specified limit} - \bar{\bar{X}} - \frac{\text{Average movement of the mean}}{2}}{3\hat{\sigma}}$$

$$\text{and } \frac{\bar{\bar{X}} - \text{Lower specified limit} - \frac{\text{average movement of the mean}}{2}}{3\hat{\sigma}}$$

For this type of process an index of less than 1.0 could indicate that an excessive movement of the mean is being allowed.

DATA SHEET

Tables of Constants and Formulae

$\bar{X}$ and R Charts *				
Subgroup Size n	Chart for Averages ($\bar{X}$)	Chart for Ranges (R)		
	Factors for Control Limits	Divisors for Estimate of Standard Deviation	Factors for Control Limits	
	A ₂	d ₂	D ₃	D ₄
2	1.880	1.128	—	3.267
3	1.023	1.693	—	2.574
4	0.729	2.059	—	2.282
5	0.577	2.326	—	2.114
6	0.483	2.534	—	2.004
7	0.419	2.704	0.076	1.924
8	0.373	2.847	0.136	1.864
9	0.337	2.970	0.184	1.816
10	0.308	3.078	0.223	1.777

$$UCL\bar{X}, LCL\bar{X} = \bar{\bar{X}} \pm A_2\bar{R}$$

$$UCLR = D_4\bar{R}$$

$$LCLR = D_3\bar{R}$$

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

2000

1000

500

250

100

Work Sheet 8

PROCESS CAPABILITY

1. Analyse the control chart on the attached sheet to check the stability and control of the process.

Is the average chart in control - YES / NO _____

Is the range chart in control - YES / NO _____

2. Determine the standard deviation of the process and the process capability indices C_p and C_{pk} .

3. Comment on the ability of the process to meet the desired specifications and the setting of the process mean.

2000

1000

1000

1000

1000

SPEC 75 ± 5

n = 5

