

Availability:
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Master Document: **Capability Study**

Standard No.: **GS-0007** Revision level: **C** Release date: 2010-04-27

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Local Edition:

Language:

Author:

Process owners:

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Approved by : Date:

Most recent change history:

Revision	Description of Change
B to C	Updated to reflect changes to GS-0004E; also changed term 'DPM' to 'PPM'

Changes in relation to previous issue are written with red, alternatively for figures and tables with a red frame around

Capability Study

1 SCOPE AND FIELD OF APPLICATION

The examination of process capability shall, typically, be conducted in connection with

- purchase of new machines;
- selection of tools, machines or processes;
- establishment of process control;
- problems with processes or products.

2 DEFINITIONS

A capability study is used to determine if the production process is likely to meet the specification requirements. The indices for estimating process capability are Pp, Ppk and Cp, Cpk as defined below.

Question: In the past we referred to Cp & Cpk using the formulas shown for Pp and Ppk. What has changed?

Answer: There is not 100% agreement on the definitions of Cp, Cpk and Pp, Ppk. However over time the definitions shown in this document have become predominant. This brings our nomenclature in line with that of the majority of our customers, national and international standards, and major software packages (Minitab, etc.)

Notations:

USL = Upper Specification Limit

LSL = Lower Specification Limit

d_2 = Statistical correction factor

n = Number of articles or observed values in a sample or subgroup

R = Range ($X_{\max} - X_{\min}$)

s = Standard variation of observed values in a sample or subgroup

$$s = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}}$$

Relation between s and R is:

$$s = \frac{R}{d_{2(n)}}$$

(For R and d_2 see relevant literature)

X_i = The actual observation

\bar{X} = Mean value of all observations in sample or subgroup

$$\bar{X} = \text{average} = \frac{\sum_i^n X_i}{n}$$

2.1 Pp, Ppk (Process performance)

This sometimes referred to as “Short Term capability” or “initial process capability” and, because demonstrated statistical stability is not required, process shifts may occur over time. Thus the defect predictions are only valid in the short term.

Requirements: Samples are normally distributed. Statistical corrections (transformations) should be made for non-normal distributions. For processes, which significantly exceed required minimums but are not normally distributed, transformations are not required.

$$P_p = \frac{USL - LSL}{6s}$$

$$P_{pk} = \min\left(\frac{USL - \bar{X}}{3s}, \frac{\bar{X} - LSL}{3s}\right)$$

Question: Why, for a process that is not statistically stable, is it necessary to meet both the Pp & Ppk Requirement?

Answer: Mean Shifts (process shifts) are expected for all processes, which are not stable. The standard assumption that we will use is that processes will shift +/- 1.5 s.

For **Key** characteristics the Pp minimum of **1.83** allows a mean shift of +/- 1.5 s, while still performing at the required **PPM** levels.

If a capability study yielded a Pp = **1.6** and a Ppk of **1.4**, the long term performance would fall below the required **PPM** levels after a +/- 1.5 s shift.

2.2 Cp, Cpk (Process capability)

Sometimes referred to as “Long Term” capability because (due to the requirement of demonstrating and maintaining statistical control of the process) the defect rate predicted by the indices will be valid for the long term.

Requirements: Process is considered normally distributed *and* demonstrated to be in a state of statistical control. A state of statistical control exists when a process is performing as consistently as it can perform.

$$C_p = \frac{USL - LSL}{6s}$$

$$C_{pk} = \min\left(\frac{USL - \bar{X}}{3s}, \frac{\bar{X} - LSL}{3s}\right)$$

Question: Why, for processes which are statistically stable, is it only necessary to meet the Cpk requirement?

Answer: A process which is maintained to be statistically stable does not undergo process shifts of +/- 1.5 s. Therefore if a process has a Cp = 1.8 and a Cpk = 1.6, the required **PPM** levels will be achieved.

Capability Study

3 PROCEDURE

3.1 Preparation

- Study size: 30 – 50 pieces.
- Determine the features to be studied. All **Key Features** must demonstrate capability. **Safety features must either demonstrate capability and verification of stability or be error-proofed.**
- Determine if Gage R&R is acceptable: Know and minimize measurement system variation for all measurements.

3.2 Determine Study Format

If process is demonstrated – through the use of control chart methods – to be statistically stable, use Cp, Cpk.

If process has not been demonstrated to be statistically stable, use Pp, Ppk.

3.3 Collect the Data

Collect and number consecutive samples from a single process stream.

If possible, use only 1 person to take all measurements (minimize reproducibility error)

It is preferable to use a measurement “expert” instead of an operator (minimize repeatability errors)

Retain samples until analysis is complete. It is acceptable to re-measure any parts which appear to be outliers.

3.4 Perform the Calculations

Perform the Capability Calculations using the Equations above.

For processes shown to be statistically stable using control charts

$$s = \frac{\bar{R}}{d2}$$

Cp, Cpk

For processes not statistically stable

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

Pp, Ppk

Capability Study

3.5 Interpreting the Results

Table 1. Requirements for processes which **HAVE NOT** demonstrated statistical stability

$s = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}}$	Both conditions met		PPM Level
	Pp (min)	Ppk (min)	
Key Features	≥ 1.83	≥ 1.33	33
Standard features	≥ 1	≥ 1	2700

Table 2. Requirements for processes which **HAVE** demonstrated statistical stability

$s = \frac{\bar{R}}{d_2}$	Cpk (min)	PPM Level
Key Features	≥ 1.33	33
Standard features	≥ 1	2700

Features or characteristics, which do not meet the Capability Index minimums shown, must have a Control Plan (process controls) capable of ensuring the PPM level specified.

3.6 Making Improvements

Always review Gage R&R as a first step in investigating or improving any capability index. For distributions, which are non-normal, once a physical understanding of the cause of the non-normality is understood, transformation to more appropriate statistical models will often improve the capability.

CHANGE HISTORY:

Date	Revision	Description of Change
2007-02-20	A to B	Removed conflict between section 2.2 and table in section 3.5. Changed process owners to quality leaders.
2009-07-16	B to C	Changed all DPM references to PPM; removed references to “Critical” features; and added reference to “Safety” features.