Simply

Step-by-Step

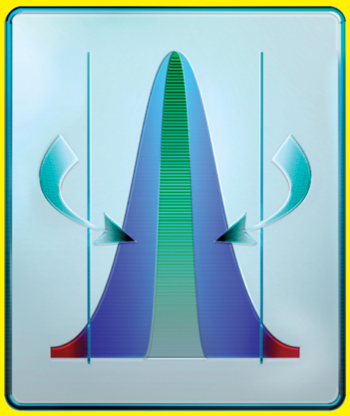
Machine/Process Capability Study

A Five-Stage Methodology for Characterizing Processes

Mario Perez-Wilson

Follow this step-by-step approach at your own pace, and teach yourself how to conduct a Machine and Process Capability Study.

You will be improving processes right away!



Machine/Process Capability Study

- A Five Stage Methodology For Characterizing Processes -

Mario Perez-Wilson
President
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"Machine/Process Capability Study"

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in-house training seminars, and
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MACHINE/PROCESS CAPABILITY STUDY

First Published	1989
Second Edition	1994
Third Edition	1999
Fourth Edition	2004
Fifth Edition	2012
Sixth Edition	2014

Current Printing (last digit)
20 19 18 17 16 15 14 13 12

PRINTED IN THE UNITED STATES OF AMERICA

ISBN 1-883237-10-6

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Foreword

In recent years, American industry has made some progress in product design through techniques such as the design of experiments. Products have been made more "robust" against "noise" and environmental factors through parameter design and tolerance design. Yet, the process that produces the product is often treated as a stepchild. Development engineers do not feel responsible for the process. They relegate that to the process engineer, who, in turn, is heavily dependent on the supplier of the equipment used in the process. And all of them use arbitrary process specifications, antiquated procedures and hit-and-miss experiences in determining process parameters. The result is confusion, finger-pointing, low yields and the high cost of poor quality.

A cooking analogy can be used to describe the chaos in production processes. The task is to bake a cake. But imagine the quality of the cake if the cook had no recipe, no knowledge of the ingredients or their respective quantities! Yet industry moves along blithely with little knowledge of which are the important process variables that must be tighly controlled and which are the unimportant variables where costs can be substantially reduced. In short, poor process characterization and optimization are of epidemic proportions in industry.

To this pall of darkness, Mario Perez-Wilson, with his book on "Machine/Process Capability Study," brings a beacon of light. He carefully orchestrates a step-by-step methodology--process delineation; metrology characterization; process capability determination; optimization; and control. It is a landmark book that fills a gaping void in manufacturing. He utilizes a series of powerful problem-solving tools, spanning different approaches to the design of experiments. He captures the techniques of repeatability and reproducibility in order to assure the accuracy and capability of instrumentation. He marshals the disciplines of statistical experimentation and evolutionary optimization. And he is able to weave these separate and independent strands into a robust cloth that can be used by the novice and the veteran, by the line worker and the professional, by individual contributors and managers.

American industry will do well to pay particular heed to Mario Perez-Wilson's "recipe" in its quest to restore its manufacturing leadership in the world.

Keki R. Bhote
Senior Corporate Consultant
Quality and Productivity Improvement
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Preface

The purpose of this book is to serve as a single source of reference to those individuals who are involved in the implementation of statistical methods (Statistical Process Control, and Design of Experiments) in manufacturing. It presents a standard methodology for conducting machine and process capability studies. The methodology has been designed to prove industry with a standard approach for studying processes, and enable them to produce within specifications.

The Machine/Process Capability Study methodology, M/PCpS, presents the steps necessary to achieve process capability in sequential order. It is divided into five progressive stages: 1) Process Delineation, 2) Metrology Characterization, 3) Capability Determination, 4) Optimization, and 5) Control. Prior to introducing each stage, necessary background information is presented. This information usually consists of problem solving tools and/or statistical techniques. Each stage is then thoroughly explained and broken down into further steps. Each step is then defined and described in detail using a "real world" manufacturing process example.

An attempt was made to illustrate the complete methodology using the same manufacturing process example. However, to simplify the explanation of certain steps a different manufacturing process was utilized. The manufacturing process operation selected to demonstrate the methodology is the Wafer Sizing operation done on silicon wafers in the semiconductor industry. Other areas of the methodology have been demonstrated using a Printed Wiring Board (PWB) wave soldering system, a fuze assembly operation, and an electronic component manufacturing process.

The methodology utilizes many techniques and problem solving tools that are usually covered independently. In the methodology, these tools and techniques have been incorporated in sequential order of execution, and integrated into one logical approach for optimizing manufacturing processes and machines. Some of the techniques are: Design of Experiments (Full Factorial Design and Fractional Factorial Designs), Analysis of Variance, Yates Algorithm, Pareto Diagrams, Concentration Diagrams, Ishikawa Diagrams, Control Chart, PosiTrol Plans, Pre-control, etc.

The book is divided into ten sections. The first section describes the author's derivation of the Machine/Process Capability Study methodology. It also suggests how the methodology should be implemented in a manufacturing environment. Sections two through eight present the five stages of the M/PCpS

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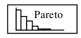
methodology in order of execution. The basic format is an introduction and a description of the tools and techniques necessary to understand the section, followed by a step by step description of the M/PCpS stage, each with an example. Within each section, the pages describing the tools and techniques are characterized by an icon [

] at the top right-hand corner of the page. The pages describing the methodology have "**M/PCpS**" in its place. Section nine presents all the standard worksheets (forms) used for guiding the user through the methodology and for complete documentation of the study. Finally, section ten contains a complete example of a M/PCpS study.

To the academic reviewers of this book, I must confess that this book is not for you, but rather for the individuals (engineers, managers and practitioners) in the manufacturing world struggling to find a method for reducing variation in their processes.

It has been my intention to provide a standard methodology that industry could adopt as an operating procedure for studying and optimizing manufacturing processes. It is my personal belief (as my years of experience in applying this methodology have proven to me) that this methodology, if followed thoroughly, will inevitably reduce the major sources of processes variation, increase the quality of your products, and speed up the successful optimization of your manufacturing processes. The United States' competitive edge in manufacturing is currently at a disadvantage against our Asian competitors. We are in an economic war, and it is time to "buckle up", apply first gear, conduct smart statistical experimentation and optimization, and win this economic war.

Mario Perez-Wilson
Kowloon, Hong Kong , December 10, 1988

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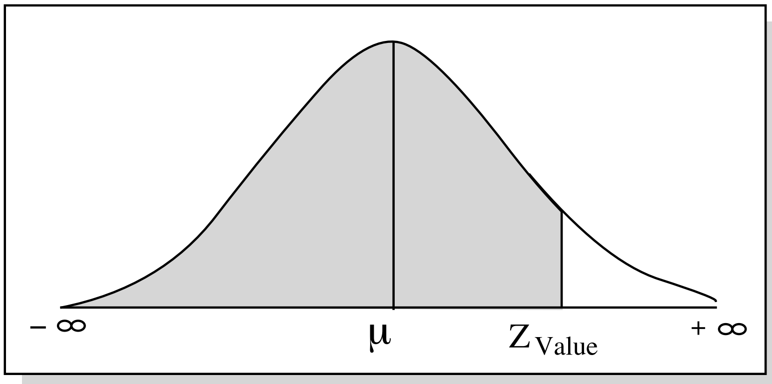
Standard Normal Distribution

The cumulative normal distribution table gives the area under the curve from minus infinity to the z-score or z value chosen.



Percent of product that falls below the USL = 45 comes from the Table:

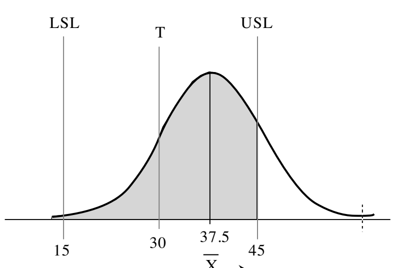
0.83147

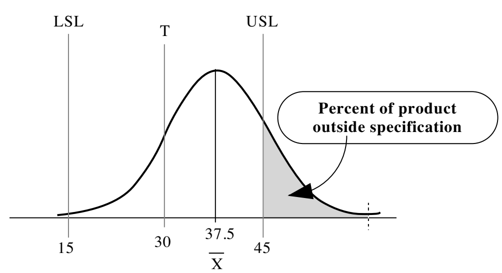
100 x 0.83147 = 83.147 %

Percent of product that falls ouside the USL = 45 is equal to:

1 - 0.83147 = 0.16853

100 x 0.16853 = 16.853 %





Cumulative Normal Distribution

Z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	Z
0.0	0.500 00	0.503 99	0.507 98	0.511 97	0.515 95	0.519 94	0.523 92	0.527 90	0.531 88	0.535 86	0.0
0.1	0.539 83	0.543 79	0.547 76	0.551 72	0.555 67	0.559 62	0.563 56	0.567 49	0.571 42	0.575 34	0.1
0.2	0.579 26	0.583 17	0.587 06	0.590 95	0.594 83	0.598 71	0.602 57	0.606 42	0.610 26	0.614 09	0.2
0.3	0.617 91	0.621 72	0.625 51	0.629 30	0.633 07	0.636 83	0.640 58	0.644 31	0.648 03	0.651 73	0.3
0.4	0.655 42	0.659 10	0.662 76	0.666 40	0.670 03	0.673 64	0.677 24	0.680 82	0.684 38	0.687 93	0.4
0.5	0.691 46	0.694 97	0.698 47	0.701 94	0.705 40	0.708 84	0.712 26	0.715 66	0.719 04	0.722 40	0.5
0.6	0.725 75	0.729 07	0.732 37	0.735 65	0.738 91	0.742 15	0.745 37	0.748 57	0.751 75	0.754 90	0.6
0.7	0.758 03	0.761 15	0.764 24	0.767 30	0.770 35	0.773 37	0.776 37	0.779 35	0.782 30	0.785 23	0.7
0.8	0.788 14	0.791 03	0.793 89	0.796 73	0.799 54	0.802 34	0.805 10	0.807 85	0.810 57	0.813 27	0.8
0.9	0.815 94	0.818 59	0.821 21	0.823 81	0.826 39	0.828 94	0.831 47	0.833 97	0.836 46	0.838 91	0.9
1.0	0.841 34	0.843 75	0.846 13	0.848 49	0.850 83	0.853 14	0.855 43	0.857 69	0.859 93	0.862 14	1.0
1.1	0.864 33	0.866 50	0.868 64	0.870 76	0.872 85	0.874 93	0.876 97	0.879 00	0.881 00	0.882 97	1.1
1.2	0.884 93	0.886 86	0.888 77	0.890 65	0.892 51	0.894 35	0.896 16	0.897 96	0.899 73	0.901 47	1.2
1.3	0.903 20	[illegible]	[illegible]	[illegible]	[illegible]	0.911 49	[illegible]	[illegible]	[illegible]	[illegible]	1.3

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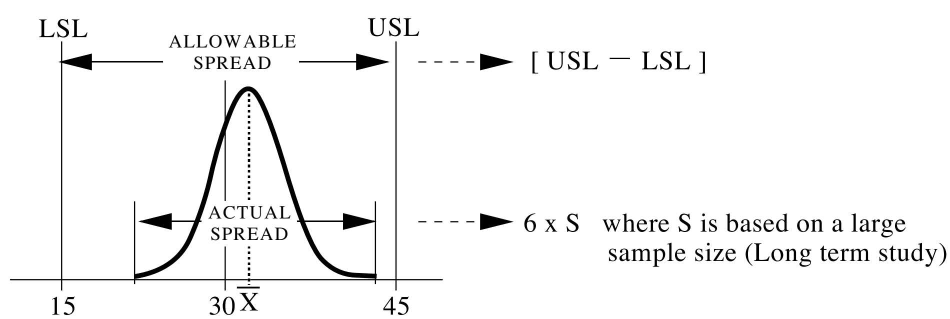
Machine/Process Potential, (Cp)

The Cp is a process potential index that measures the potential of capability of a machine or process. The Cp is the ratio of the *allowable spread* over the *actual spread*. The allowable spread is the range or tolerance of the specification, and is calculated by subtracting the lower specification limit from the upper specification limit. The actual spread is the spread from data collected from the machine or process and is calculated by multiplying 6 times the standard deviation, S, of the data.

A high value of Cp does not guarantee that the process is capable of producing product within specification. Furthermore, the whole distribution of the process, might not overlap with the specification range. The process potential does not measure the location of the average of the actual spread with respect to the center (target) of the allowable spread, it only compares their widths. The capability index, Cpk, measures the degree of centering of the actual process spread with respect to the allowable spread.

The Cp may only be calculated when two sided specifications are available. Numerical properties such as addition and averages, cannot be applied to the Cp because it is a unitless index and would not yield meaningful information.

$$Cp = \frac{\text{Allowable Spread}}{\text{Actual Spread}} \Rightarrow \frac{\text{Engineering Specification or what engineer judgment establishes as allowable for that machine or process.}}{\text{The spread from the data collected from the machine or process.}} \Rightarrow \frac{\text{What the customer WANTS.}}{\text{What the customer GETS.}}$$



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Machine or Process Potential

Formula:

$$Cp = \frac{USL - LSL}{8 \times S} \quad \text{(Short Term Study)}$$

$$Cp = \frac{USL - LSL}{6 \times S} \quad \text{(Long Term Study)}$$

where,

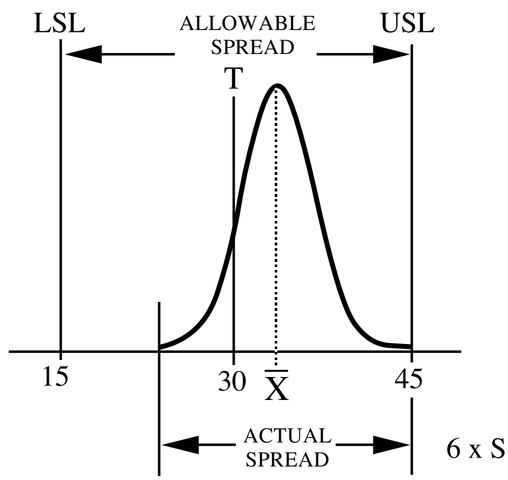
S = standard deviation of the actual process
LSL = lower specification limit
USL = upper specification limit.

Actual Process Data:

Mean, $\overline{X}$: 34

Standard Deviation, S: 3.75

$$\mathbf{Cp = \frac{45 - 15}{6 \times 3.75} = \frac{30}{22.5} = 1.33}$$

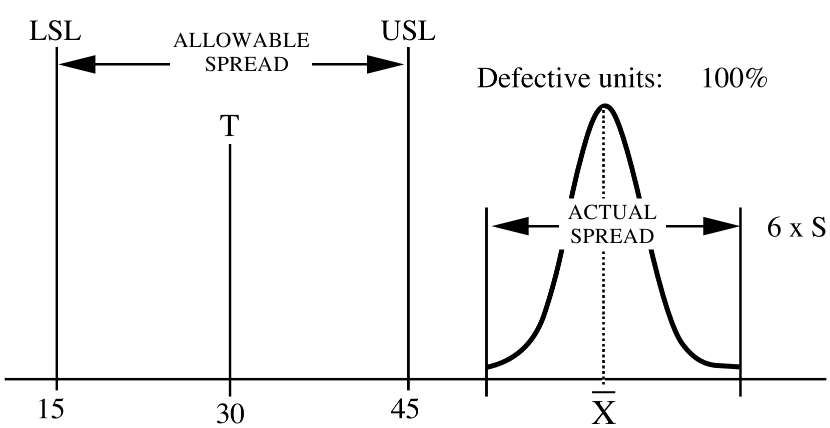


Actual Process Data:

Mean, $\overline{X}$: 60

Standard Deviation, S: 3.75

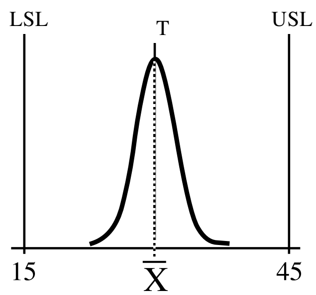
$$\mathbf{Cp = \frac{45 - 15}{6 \times 3.75} = \frac{30}{22.5} = 1.33}$$



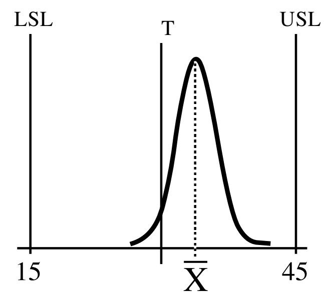
Machine or Process Capability, (Cpk)

The Cpk is a machine or process capability index that measures the ability of a machine or process to produce product within specification. The Cpk is the ratio of the distance between the actual process average and the closest specification limit over three times the standard deviation of the actual process. The capability index measures the degree of centering of the actual process spread with respect to the allowable spread. When the actual process average is outside the specification limits, then the Cpk defaults to zero.

$$Cpk = \left\{ \text{Smallest of: } \frac{\overline{X} - LSL}{3 \times S} \; ; \; \frac{USL - \overline{X}}{3 \times S} \right\}$$



Distribution Mean is centered
to the Target of the Specification



Distribution Mean is NOT centered
to the Target of the Specification

A machine or process is referred to as being capable when its Cpk has a minimum value of one, and process stability has been proven. A Cpk equal to one implies that at least 99.73% of the product is within specifications limits, provided that the process is stable. Stability of the process can be proven through the use of a control chart. Once the process data is plotted on a control chart, the process can be regarded as being stable only if it exhibits statistical control. Statistical control is exhibited when the points plotted do not extend beyond the upper and lower control limits, and also by the absence of non-random patterns or trends within the control limits.

The Cpk can be calculated for both single-sided or double-sided specifications. Numerical properties such as addition and averages cannot be applied to the Cpk because it is a unitless index and would not yield meaningful information.

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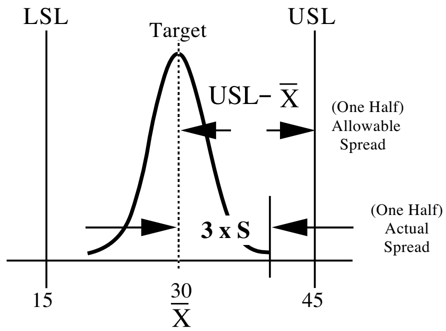
Let's assume that a product characteristic has a specification of 30 $\pm$ 15. The target of the specification becomes 30 and the tolerance is equal to two times 15 or 30. Let's calculate Cpk for different distribution means and standard deviations.



Specification: 30 $\pm$ 15 (Target: 30; Tolerance: $\pm$ 15)

Actual Process Data:

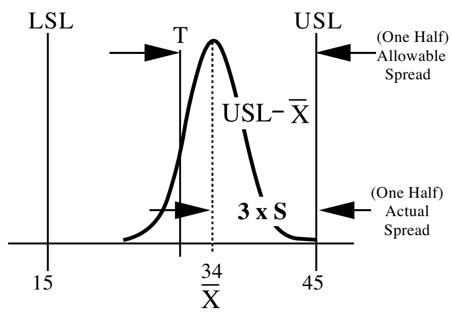
$\overline{X} = 30$

S = 3.75

$$\mathbf{Cpk} = \frac{45 - 30}{3 \times 3.75} = \frac{15}{11.25} = 1.33$$

Defective units : 64 Parts per million

In the example below, the sampling distribution is not centered with the target (T) of the specification. The standard deviation is small enough that if the distribution was centered, the process capability, Cpk, would be equal to the process potential, Cp.



Actual Process Data:

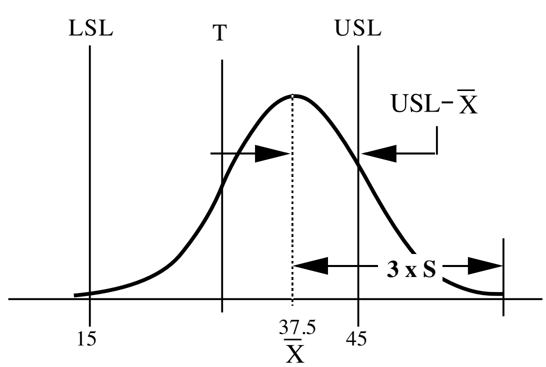
$\overline{X} = 34$

S = 3.75

$$\mathbf{Cpk} = \frac{45 - 34}{3 \times 3.75} = \frac{11}{11.25} = 0.98$$

$$Cp = \frac{45 - 15}{6 \times 3.75} = \frac{30}{22.5} = 1.33$$

In the next example, the sampling distribution is not centered with the target, T, of the specification. The standard deviation is very large and even if the distribution were centered, the process would still not be capable. The process potential is less than 1.0, which indicates that centering the distribution would not make the process capable. To make this process capable, the standard deviation has to be reduced.



Actual Process Data:

$\overline{X} = 37.5$

S = 7.82

$$\mathbf{Cpk} = \frac{45 - 37.5}{3 \times 7.82} = \frac{7.5}{23.46} = 0.32$$

$$Cp = \frac{45 - 15}{6 \times 7.82} = \frac{30}{46.92} = 0.639$$

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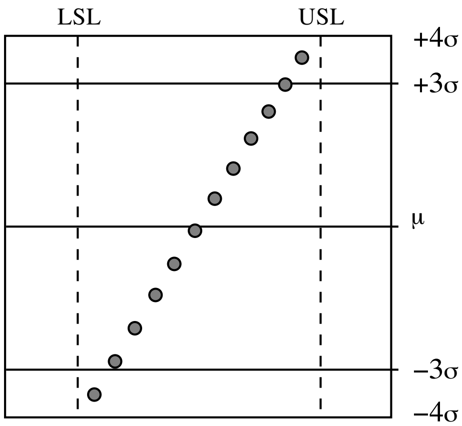
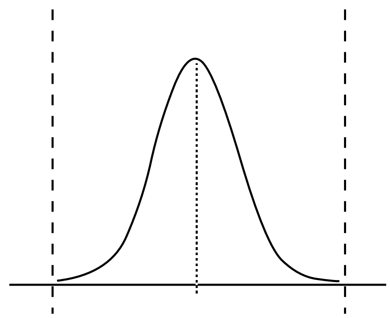
Machine Capability

Interpretations of the Normal Probability Paper plots.

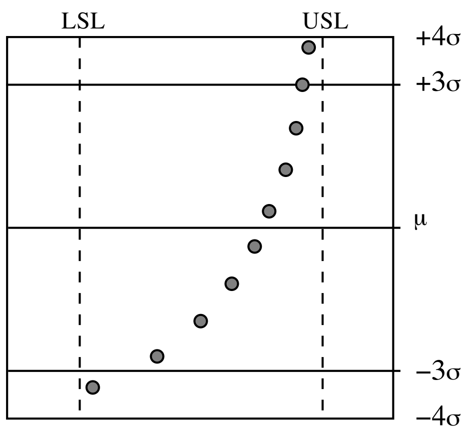
Capable Machine/Process



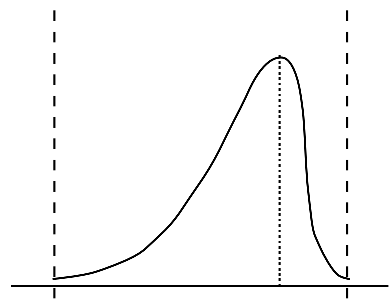
Normal Distributed (Symmetrical)



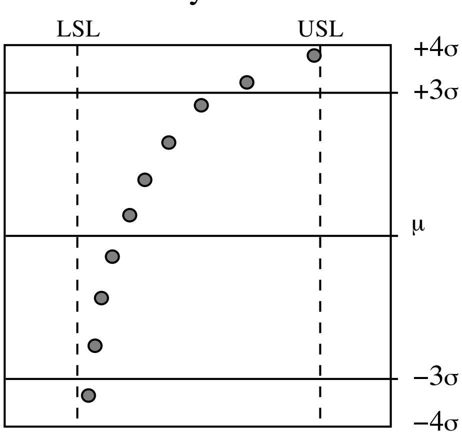
Negatively Skewed



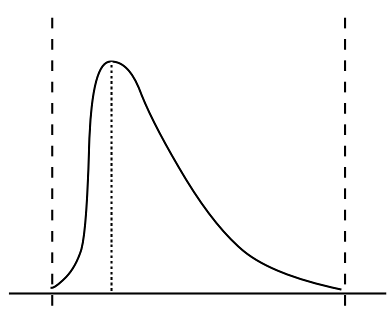
Negatively Skewed



Positively Skewed



Positively Skewed



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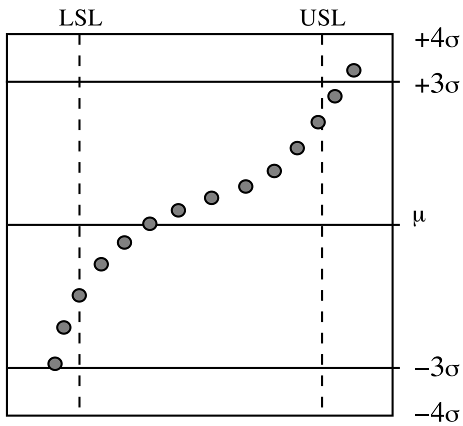
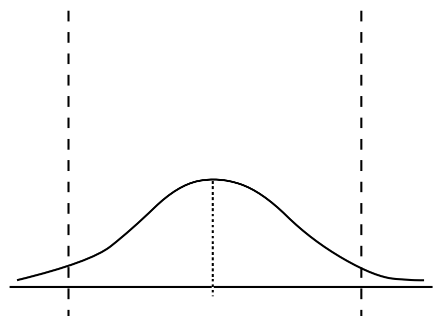
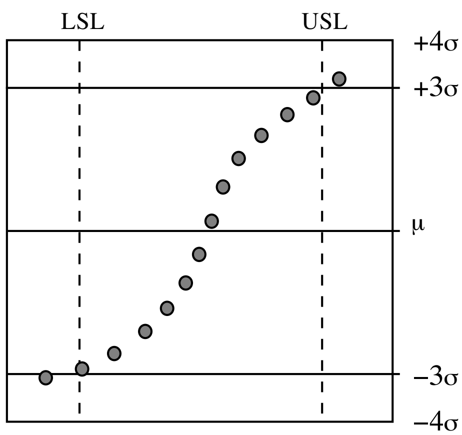
Platykurtic
(Kurtosis << 3.0)



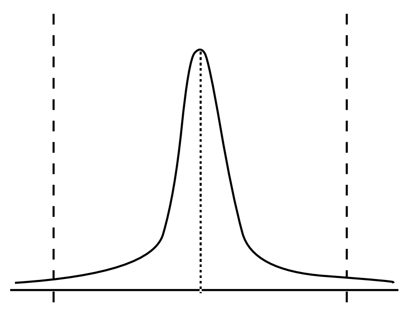
Flat Distribution



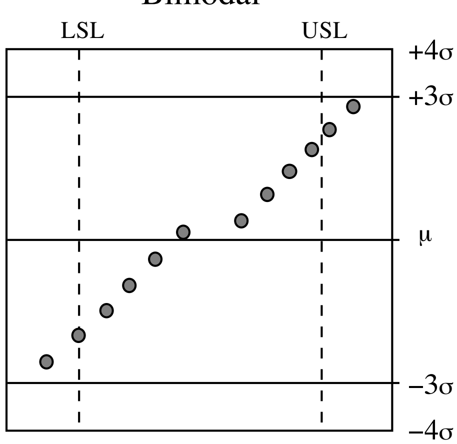
Leptokurtic
(Kurtosis >> 3.0)



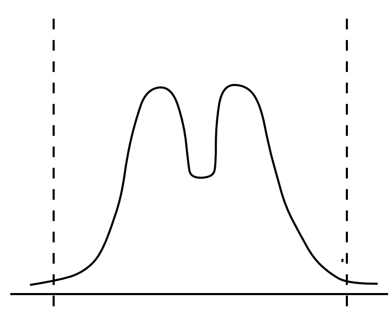
Peaked Distribution



Non-Capable Machine/Process
Bimodal



Bimodal Distribution



The Taguchi Orthogonal Array L27 (3^{13-11}) design.

Treatment Combination or Run	Rotational Speed of Holder	1st Cutter Spin Speed	Interaction between A & B (Linear)	Interaction between A & B (Quadratic)	2nd Cutter Spin Speed	1st Cutter Polish Time	2nd Cutter Polish Time	1st Cutter z Rate	2nd Cutter z Rate	Grinding Force	1st Cutter Abrasive Co…	2nd Cutter Abra…	1st Cutte…
1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	1	1	1	1	1	1	1	1	1
3	0	0	0	0	2	2	2	2	2	2	2	2	2
4	0	1	1	1	0	0	0	1	1	1	2	2	2
5	0	1	1	1	1	1	1	2	2	2	0	0	0
6	0	1	1	1	2	2	2	0	0	0	1	1	1
7	0	2	2	2	0	0	0	2	2	2	1	1	1
8	0	2	2	2	1	1	1	0	0	0	2	2	2
9	0	2	2	2	2	2	2	1	1	1	0	0	0
10	1	0	1	2	0	1	2	0	1	2	0	1	2
11	1	0	1	2	1	2	0	1	2	0	1	2	0
12	1	0	1	2	2	0	1	2	0	1	2	0	1
13	1	1	2	0	0	1	2	1	2	0	2	0	1
14	1	1	2	0	1	2	0	2	0	1	0	1	2
15	1	1	2	0	2	0	1	0	1	2	1	2	0
16	1	2	0	1	0	1	2	2	0	1	1	2	0
17	1	2	0	1	1	2	0	0	1	2	2	0	1
18	1	2	0	1	2	0	1	1	2	0	0	1	2
19	2	0	2	1	0	2	1	0	2	1	0	2	1
20	2	0	2	1	1	0	2	1	0	2	1	0	2
21	2	0	2	1	2	1	0	2	1	0	2	1	0
22	2	1	0	2	0	2	1	1	0	2	2	1	0
23	2	1	0	2	1	0	2	2	1	0	0	2	1
24	2	1	0	2	2	1	0	0	2	1	1	0	2
25	2	2	1	0	0	2	1	2	1	0	1	0	2
26	2	2	1	0	1	0	2	0	2	1	2	1	0
27	2	2	1	0	2	1	0	1	0	2	0	2	1
→ (run 27)	**450 rpm**	**4000 rpm**			**2100 rpm**	**4 sec**	**0 sec**	**5µm/sec**	**1µm/sec**	**2500 psi**	**320**	**6/9**	**10 µm/se…**

Level for each experimental factor in run # 27.

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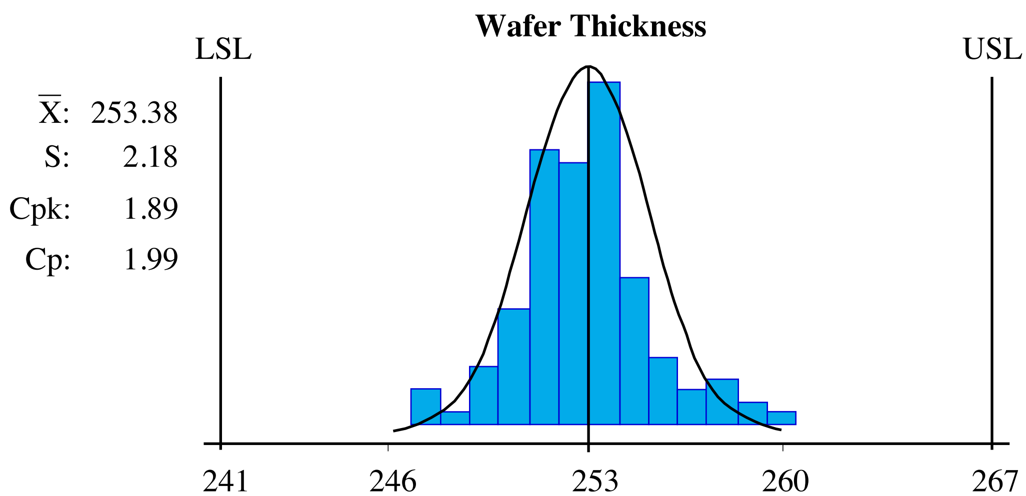
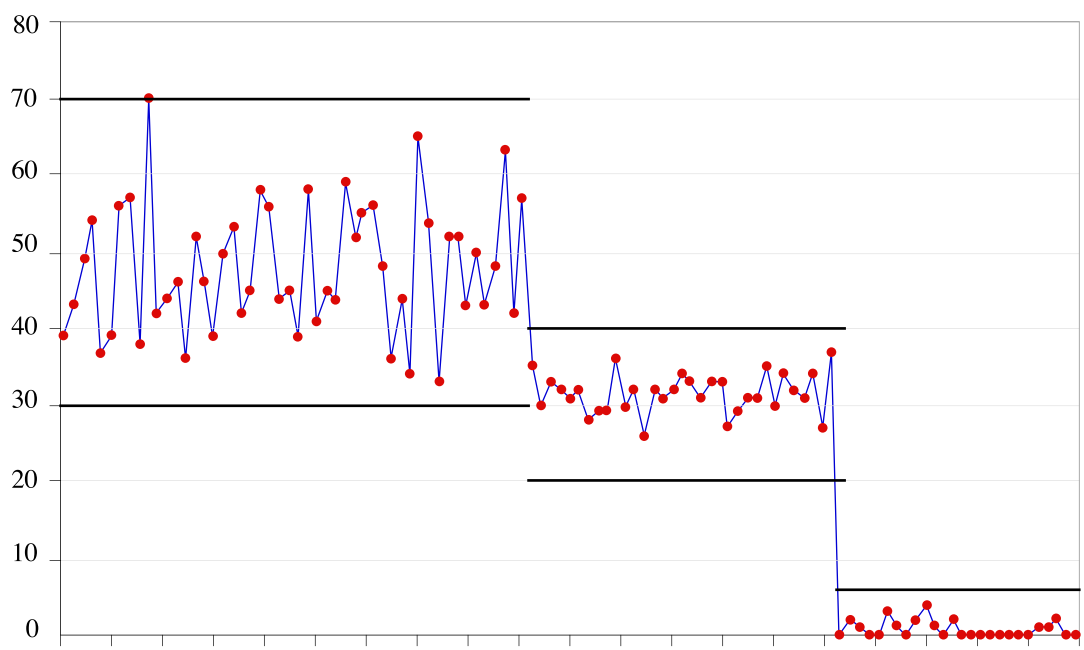
Example 3.- "Guggenheim" Wafer Sizing

At the culmination of the stage of Control, the wafer thickness process capability index was Cpk=1.89 and its process potential index was Cp=1.99.



For wafer strength, the process potential index was further improved by experimenting with cutter grit sizes and water flow rates during grinding. The final experimental results lowered the number of cracks/wafer to an average of 0.769 and a standard deviation of 1.107; thus making the wafer very strong.



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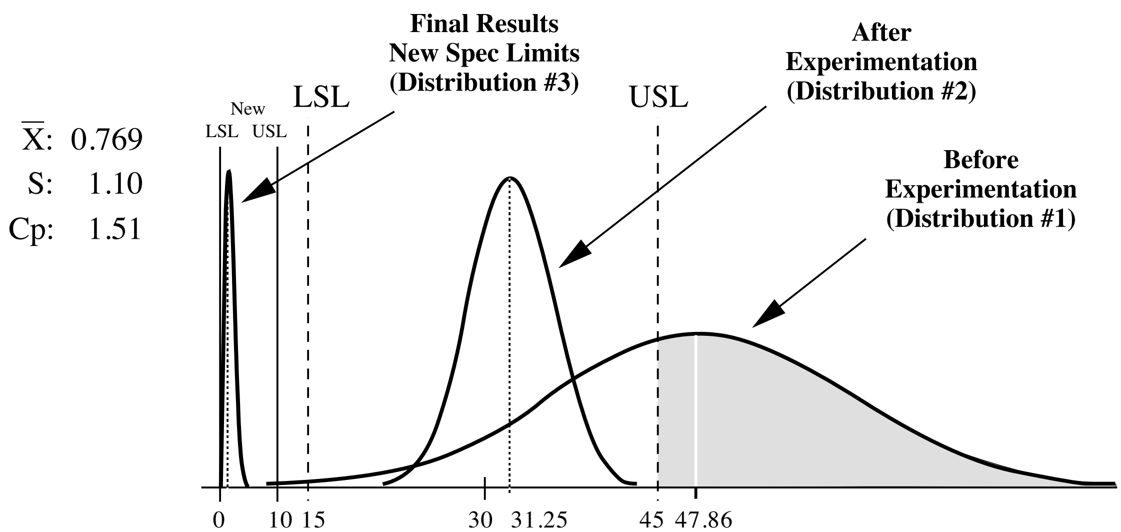
The specification limits were changed from 30 ± 15 cracks/wafer, to a lower specification limit of 0, and an upper specification limit of 10 cracks/wafer. The standard deviation was reduced from 8.42 to 1.107, far exceeding the ± Six Sigma goal performance capability. The "Guggenheim" wafer grinder achieved best-in-class status, and the wafer breakage yields were improved from 80.8% to 92.7%. An overall savings of $714,000 a year.

Wafer Strength Pre and Post Improvements



Bond Pad Corrosion Program	MACHINE/PROCESS CAPABILITY STUDY	Study # *012503*
Plasma Etch M/PCpS Team Responsible Person	C&E CROSS-REFERENCE TABLE	Date *5-20-94*
		Operation ***Etching***
		Equip # ***T-903***
		Page *3* of *26*

MACHINE/PROCESS

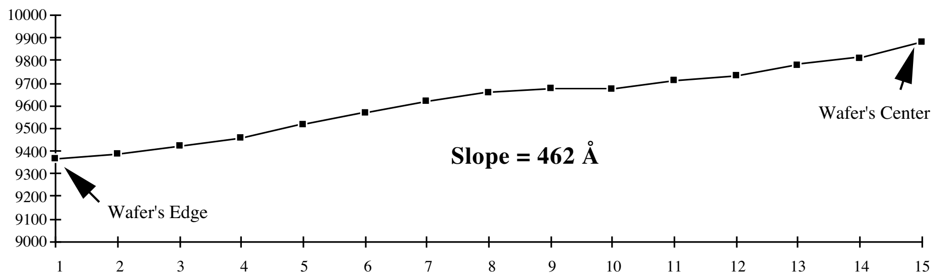
RANK-ORDER: ■ Yes ☐ No

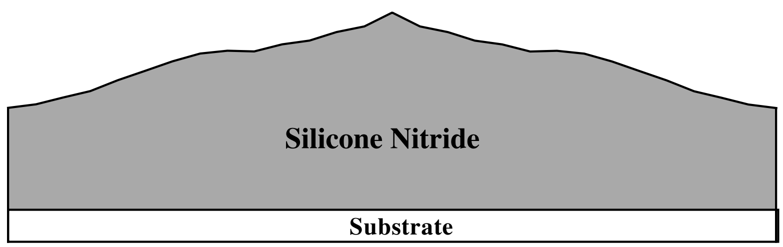
DEPENDENT → / INDEPENDENT ↓	*Etch Rate*	*Uniformity*	*Selectivity*	*End Point Consistency*				TOTAL	LEVEL OF INDEPENDENT
Pressure	**24**	**22**	**15**	**20**				**81**	
N_2	**24**	**20**	**12**	**10**				**66**	
SF_6	**22**	**22**	**4**	**10**				**58**	
CHF_3	**20**	**18**	**9**	**8**				**54**	
T.S. Upper Electrode	**7**	**5**		**7**				**19**	
T.S. Bottom Electrode	**9**	**8**	**13**	**9**				**36**	
T.S. Chamber	**12**	**8**	**4**	**12**				**36**	
P.S. Throttle Valve	**19**	**13**	**3**	**19**				**54**	
P.S. Pump System	**19**	**13**	**3**	**19**				**54**	
P.S. Transducer Accuracy	**19**	**12**	**3**	**19**				**53**	
P.S. Chamber Vacuum Integ.	**18**	**13**	**3**	**19**				**53**	
E.S. Detector				**18**				**18**	
E.S. High Voltage				**18**				**18**	
E.S. Wave Length				**18**				**18**	
E.S. Gain				**18**				**18**	
E.S. Window				**10**				**10**	
E.S. Cleanliness				**10**				**10**	
B.C.S. Clamping Spring	**11**	**15**	**5**	**11**				**42**	
B.C.S. He Flow Pressure	**9**	**12**	**4**	**9**				**34**	
B.C.S. Wafer Placement	**2**	**10**	**1**	**2**				**15**	
B.C.S. Wafer Flatness	**2**	**10**	**1**	**2**				**15**	
P.S. Matching Efficiency	**21**	**10**	**12**	**21**				**64**	
P.S. Phase Splitter	**20**	**10**	**12**	**21**				**63**	
P.S. RF Power	**22**	**10**	**13**	**22**				**67**	
Gas Flow Consistency	**20**	**14**	**15**	**20**				**69**	
Gap Parallelism	**16**	**20**	**3**	**16**				**54**	
Gap Spacing Accuracy	**16**	**20**	**4**	**10**				**50**	
Shower Head	**13**	**18**	**3**	**8**				**42**	
Environment									
Manpower	**17**	**4**	**2**	**1**				**24**	
Wafer Thickness	**18**	**8**	**13**	**3**				**42**	

Bond Pad Corrosion Program	MACHINE/PROCESS CAPABILITY STUDY	Study #	***012503***
		Date	***5-20-95***
Plasma Etch M/PCpS Team Responsible Person	DRAWING	Operation	***Etching***
		Equip #	***T-903***
		Page ***10*** of ***26***	

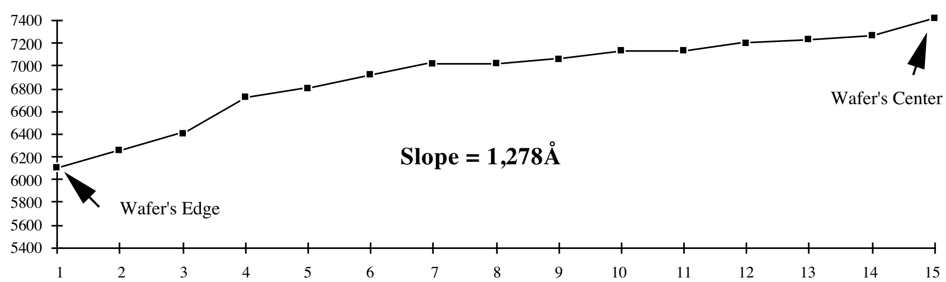
DRAWING

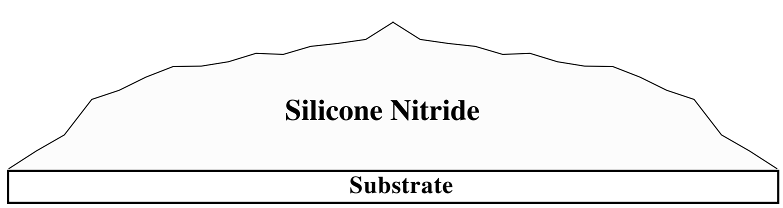
Within Wafer Thickness Uniformity (Edge to Center Thickness of Silicone Nitride from Metalization - from 30 Wafers' Average)





Within Wafer Thickness Uniformity (Edge to Center Thickness after Plasma Etching - From 30 Wafers' Average)

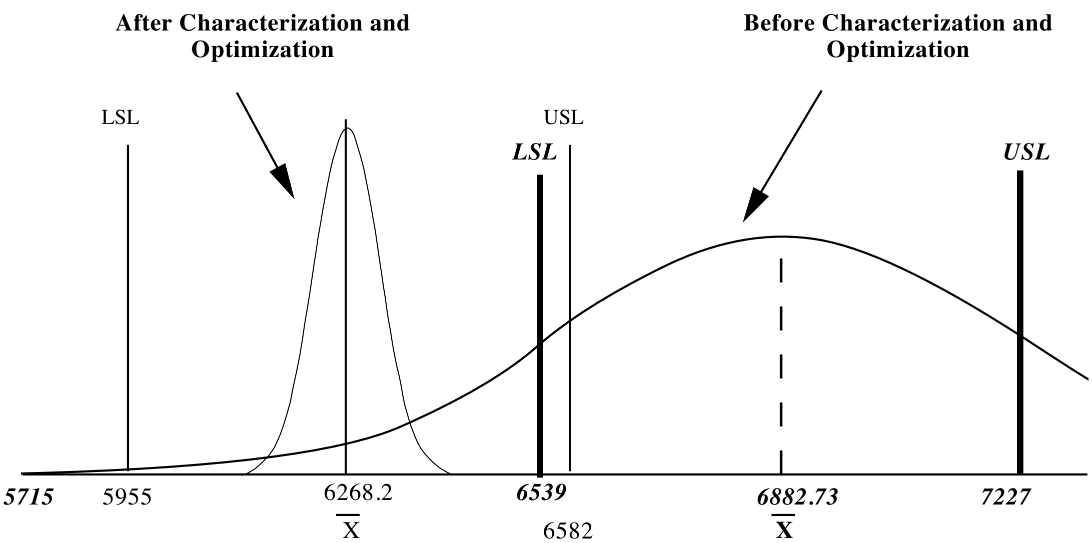




Bond Pad Corrosion Program	MACHINE/PROCESS CAPABILITY STUDY	Study #	*012503*
		Date	*5-20-95*
Plasma Etch M/PCpS Team Responsible Person	DRAWING	Operation	*Etching*
		Equip #	*T-903*
		Page *25* of *26*	

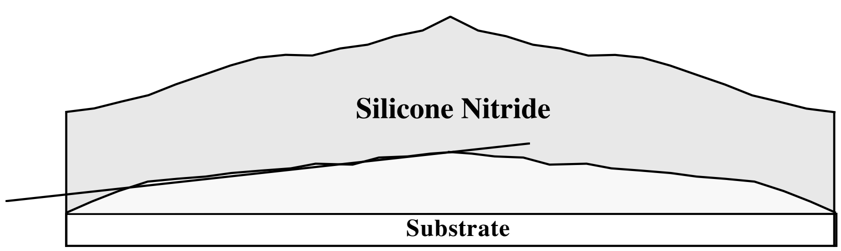
DRAWING

Final Results after Characterization



$\overline{X}$ = 6268.2
R = 230
S = 50.24
Cp = 1.56
Cpk = 1.56

$\overline{X}$ = 6882.73
R = 1209
S = 389.32
Cp = 0.22
Cpk = 0.22



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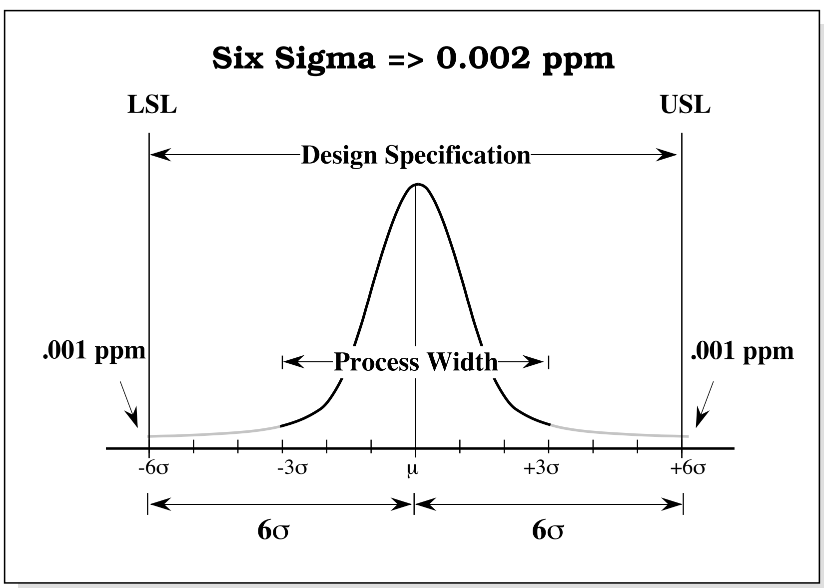
Six Sigma or + Six Sigma

Six Sigma is an optimized level of performance approaching zero-defects in a process producing a product, service or transaction. It indicates achievement and maintenance of world-class performance.

Motorola, on Thursday, January 15, 1987, defined Six Sigma as having plus or minus six sigmas (±6s) or standard deviations within specification limits. In other words, given a particular product characteristic, which has a design specification, that design specification has an upper specification limit, USL, and a lower specification limit, LSL, these two limits demarcated a design tolerance. Motorola held the design tolerance to be such, that it should allow to fit twelve (±6) sigmas or twice the process variation.

Theoretically, under the above stated condition, a process would have Cp=2, Cpk=2, in-process yield around 99.9999998%, and a defective rate below 0.002 parts-per-million (PPM). For all practical purposes, + Six Sigma implies zero-defects.

What is the objective of + Six Sigma? To reduce the process variation, such that twelve standard deviations will fit within specification limits, and to center the mean in the middle of the specification limits.



Six Sigma or plus or minus six sigma within specification limits.

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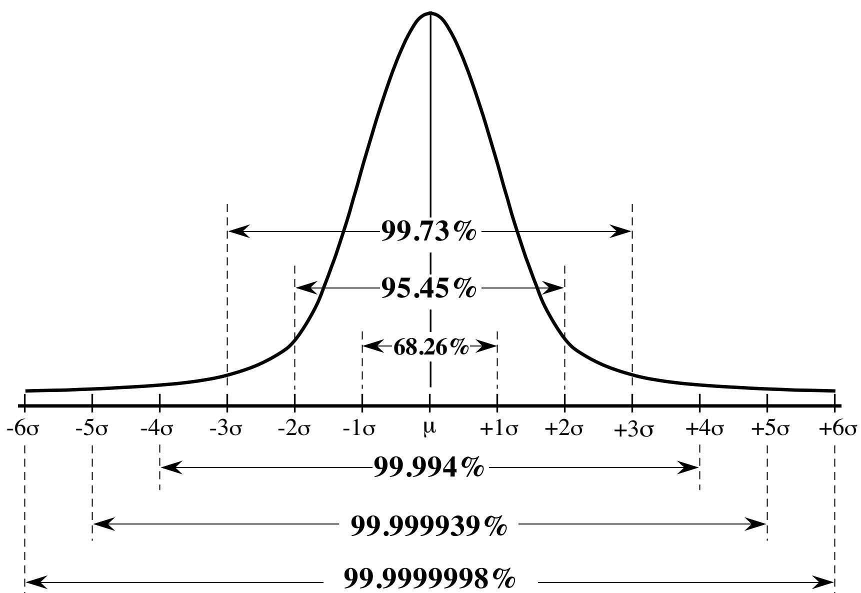
Areas under Normal Curve



Sigma Level (± xσ)	Cp	Cpk	PPM
[± 1σ] ~ One Sigma	0.33	0.33	317,320
[± 2σ] ~ Two Sigma	0.67	0.67	45,500
[± 3σ] ~ Three Sigma	1.0	1.0	2,700
[± 4σ] ~ Four Sigma	1.33	1.33	63.5
[± 4.5σ] ~ Four and a half Sigma	1.50	1.50	6.9
[± 5σ] ~ Five Sigma	1.67	1.67	0.6
[± 6σ] ~ Six Sigma	2.0	2.0	0.002

[Assumptions: Normality, Stability and Distribution centered.]

Yields, sigmas, Cp, Cpk and PPM levels when ± sigmas coincide with specification limits.

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About the Author

Mario Perez-Wilson is the founder and CEO of Advanced Systems Consultants and author of nine books: Machine/Process Capability Study - A Five Stage Methodology for Characterizing Manufacturing Processes, Multi-Vari Chart and Analysis, Design of Experiments, The Total Control Methodology - A Preventive Approach for Total Control during Production, Six Sigma - Understanding the Concept, Implications and Challenges, Positrol Plans and Logs, ANOVA - Analysis of Variance for Simple and Complex Experiments, PCB Process Characterization - Applying M/PCpS to the PCB Industry and Gauge R&R Studies - For Destructive and Non-destructive Testing.

Mr. Perez-Wilson has over 23 years of industrial experience in engineering, quality and process improvement and has served at the executive level as Corporate Vice President of Quality for Flextronics International. He holds a B.S. degree in Industrial Engineering from the University of Arizona and Global Leadership from the Thunderbird School of Global Management. He was awarded the "Da N To Tsu" (Japanese for "Best of the Best") award from the Rochester Institute of Technology in the QED 90 Symposium.

One of the original architects of Six Sigma, he served as a Division Statistical Methods Engineering Manager at Motorola. During his tenure, he institutionalized and standardized the application of statistical methods in Motorola's worldwide manufacturing, production and engineering operations. His M/PCpS™ Methodology for characterizing processes has received global recognition and has become the standard in the achievement of Six Sigma.

Mr. Perez-Wilson has conducted seminars for over 18,000 individuals in Brazil, Belgium, People's Republic of China, Germany, Hong Kong, India, Japan, Korea, Malaysia, Mexico, Philippines, Singapore, Sweden, Taiwan, and the United States, and is currently listed in The International Who's Who in Quality.

Some of the companies that have implemented Mr. Perez-Wilson's methodologies are: ADFlex Solutions, AMD, Alphatec U.S.A., Allied Signal Aerospace, Anadigics, Arvin Industries, Arvin North America Automotive, Arvin Ride Controls, Astron, Bausch & Lomb, Burr-Brown, Carsem, Chartered Semiconductor, Connector Service Corp., Conexant, CRC Industries, Crystalline Materials, CTI Cryogenics, Duracell, EG&G, Federal Reserve Bank of New York, Fiberite IBI, Flextronics, General Electric, Guidant, Hewlett-Packard, Indy Electronics, Intel, Korea Electronic Company, Legris, Los Alamos National Laboratory, LSI Logic, Lucas/Nova Sensors, Maremont Exhaust Products, Martin Marietta Astronautics, Mitsubishi Silicon America, Motorola Inc., Multek, Olin Interconnect Technologies, Pacesetter, Peavey Electronics, Philips, Rodel, Ryobi, Sandia National Laboratories, Semi-Alloys, Shimano, Sikorsky Aircraft, Vitelic (Hong Kong), Wavetek and Zimmer.

Comments From Our Customers

"Good, practical approach to tackling difficult manufacturing problems. Good class notes, and straightforward, concise approach."

Stephen V. Crowder
Senior Member Technical Staff
Sandia National Labs

"The industry would do very well if people and companies would make a deep commitment to the M/PCpS methodology"

Pat Friend
Sales Engineer
Panasonic Factory Automation

"Great format. Simplistic approach from start to finish of a complex problem -Machine/Process Capability. Good explanation of not only how but with capability studies done in real life. Both theoretical and practical approaches in one. A class that all production, engineering and managers should take."

John Reitter
Thin Films Engineering Supervisor
LSI Logic Corporation

"The real genius of the Machine/Process Capability Study course is that it ties together and organizes all the tools for process improvement. I've taken many courses on S.P.C. and process improvement that have presented one piece of the puzzle, but none of the courses have put it all together as well as what Mario does in the Machine/Process Capability course. This is by far the best training course I have taken."

Brian Decker
Senior Quality Engineer
Martin Marietta

"M/PCpS provided an outstanding and integrated overview of practical statistical methods and a clear direction for applying the methodologies to foster a 'take control' approach in manufacturing. Education in their methods and actual application of them is now critical for American companies to 'close the gap'."

Scott P. Gucciardi
QA Engineer
Welch Allyn Corp.

"The most comprehensive methodology I have seen to date for people who are serious about improving machine/process capabilities and who are willing to work at it without looking for the proverbial short term windfall."

John Toto
Director, Quality Assurance
Semi-Alloys

"Excellent material and presentation on Machine/Process Capability. Instructor has excellent working knowledge of material"

Merv Dunn
Vice President Total Quality
Arvin Industries

"Your book is one of the easiest and useful ones I have ever seen. With your presentations and book people are gaining the knowledge to do things right from the very beginning (knowledge so much needed in the American Companies)."

Ana Ley
Etch Engineer
LSI Logic Corporation

"I have taken classes with Deming and Montgomery but this class was by far the best. Mario's approach is very simple and practical. I look forward to taking further classes with him."

David Butler
Director of Package Operations
Olin Interconnect

"An extremely structured and step-by-step methodology -very clear and simplified. A superb book to have for application as well as reference. I strongly recommend all personnel involved in production or manufacturing at all levels to attend this seminar if they are really serious about improving their product quality."

Norman Sim Boon Heng
SPC Analyst
Sundstrand Pacific (Atg) P.L.

"M/PCpS methodology is an extremely well planned, step by step course on 'how to' design, plan and complete Machine/Process Capability Studies. Most seminars that I have attended are predominately theory with very little applications. The instructor's experience and knowledge was excellent and made the seminar extremely enjoyable. Probably the BEST seminar I have ever attended - approximately ten in the last three years."

Jim Angel
Director Manufacturing Quality
Arvin NAA

"Your methodology is concise and complete. You've made a challenging subject very easy. There are no more excuses!"

Don Wright
Statistical Methods Engineer
Motorola, Inc.

"A concise and lively presentation of a set of fundamental tools and a simple application of their use to control processes.."

T.A. Wiley
Quality Engineering Manager
Allied Signal Inc. Aerospace

"Mario takes a no-nonsense approach to provide designers and manufacturers with what they need to know and use M/PCpS."

W. David Williams
Quality Assurance Engineering Manager
Sandia National Labs

"This is a very good course toward 6 Sigma quality. It is a "life statistics", I encourage all manufacturing engineers to attend this class."

Tony C. R. Tsai
R & QA Manager
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Nakkina VRK
Process/ IE Task Leader
Motorola (P) Ltd.

"M/PCpS, ... methodology is vital for U.S. to regain status and market share in world economy. This, together with concurrent engineering has potential of reducing many problems of national scope."

R.J. Tockey
MTS Division Supervisor
Sandia National Labs

"Mario Perez-Wilson brings complex manufacturing techniques and tools and outlines a simple methodology that engineers can use in their day to day activities to characterize, improve and control both simple and complex manufacturing steps. This methodology can help in the path of continuous quality improvement and in becoming a 'total quality' organization."

Divyesh Shah
Process & Product Engineering Manager
Lucas Nova Sensor

"Step by step book clearly moves you through the capability study process. Format is well documented throughout the book."

Scott Schiefer
Supplier Engineer
Western Digital

"The course goes to the heart of process improvement. This methodology is as complete as I have seen."

James A. Schue
Senior SPC Specialist
Zimmer, Inc

"The Methodology is very well structured and planned. The tools I learned are very powerful!"

Carlos A. Pinheiro
Site Coordinator (Brazil)
Multek/Flextronics

"... Mario Perez-Wilson has significantly added value by organizing these techniques into a workable methodology and demonstration how it can be applied to produce the desired results."

George Melchiorsen
Quality Engineer
Hewlett Packard

46 R75780 05/27/88 13:55:33 SSSPMAP POST

TO: Carlos Genardini (RFH920)
FR: Scott Shumway (R75780)
DA: 26 May 88 at 15:29:54
CC: Gordon Chilton (RLWK10)
Tommy George (RJNN10)
Jim Norling (RF3500)

Mario
Roger

RE: SSSP DIVISION SIX SIGMA ROADMAP AND GOALS

I HAVE JUST COMPLETED A REVIEW OF YOUR DIVISION'S SIX SIGMA ROADMAP AND SUPPORTING DETAILED ACTION PLANS AND GOALS --- AN OUTSTANDING PACKAGE. YOUR DIVISION, WITH MARIO PEREZ-WILSON'S EFFORTS IN COORDINATING THE TASK, IS TRULY IMPLEMENTING WHAT WE ARE EXPECTING OF ALL DIVISIONS IN THE SECTOR. THAT IS: APPLICATION OF THE SIX SIGMA ROADMAP AS IT APPLIES AT THE DIVISION LEVEL, GENERATION OF THE SPECIFIC ACTION PLANS AND GOALS TO SUPPORT THE STATED OBJECTIVES AND RATES OF IMPROVEMENT, AND INCORPORATION OF THESE INTO THE DIVISION FIVE YEAR PLANS.

THANKS FOR YOUR LEADERSHIP IN OUR SPS QUALITY IMPROVEMENT PROCESS.
SCOTT
EOM

Carlos.

Thanks — good job!

Jim N.

RECEIVED
JUN 8 1988
CARLOS GENARDINI

P.O. Box 5257, Scottsdale, AZ 85261, Tel: (480) 423-0081

MOTOROLA INC.

SEMICONDUCTOR PRODUCTS SECTOR
INTER-OFFICE CORRESPONDENCE

Date: October 1, 1990

To:

Paul Alonas	Theresa Maudie
Bob Anger	Theresa Monroe
Rhea Benson	Jerry Quah
John Bliss	Terry Ruehs
John Bouma	Ruth Ruiz
Rick Davis	Nick Schaefer
Mike Finecey	Brooks Scofield
Bill Grant	Ora Smith
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Mark Gabrielle	Bob Tucker
M. K. Hong	Art Velarde
Henry Leung	Dave Vowles
	Jack Walker

From: Carlos Genardini   Phone: 244-4573   Mail Drop: Z208

cc:

Jerry Baumann	Sandy Johnson
Gary Beaudin	Tom Marchetti
Kelvin Blair	Mario Perez-Wilson
Jim Cryer	Dave Stevenson
Jim Fogle	John Trice
Dave Gilbert	Dave Wise

SUBJECT: Machine Process Capability Studies
A Roadmap to Success

Several of you have completed, or are in the process of completing, work on Machine Process Capability Studies (MPCS). This proven methodology has been accepted by this Division as its approach to Six Sigma engineering of our processes and products. There are other tools that may be added to accelerate our level of accomplishment; however, the fundamental base is this methodology. I expect you to complete the work currently identified, and immediately proceed to identify the next field of study by establishing a new pareto of problems or barriers. Emphasis is to be placed on applying our engineering resources to the area of highest need. During the November Operations Review, I expect to have your management present what you have selected, the timing involved and the resources needed.

Thank you.

Carlos

Carlos Genardini

MOTOROLA INC.
Discrete & Special Technologies Group

Date:	6 February 1990	From:	Dick Bond	
To:	Bob Stuart Gary Thuftedal Mario Perez Wilson	Phone:	244-3633	M/D Z308
cc:	Carlos Genardini Don Guthrie Tim Jones Paul White Gordon Chilton			

Subj: ***Allied Signal Customer Visit Presentations on 5 February 1990***

Thank you, gentlemen, for your very professional and informative presentations to the Allied Signal management team. The material you presented really helped them get a feel for how we are using SPC and applying our quality improvement principles in the factory to achieve Six Sigma.

Another job well done by three guys who are not only recognized authorities in your respective areas, but who also exhibit a level of confidence and enthusiasm which confirms our commitment to continuous improvement and Total Customer Satisfaction.

Thanks again.

Dick Bond

DB00590:j

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