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*Glen Netherwood, **MiC Quality***

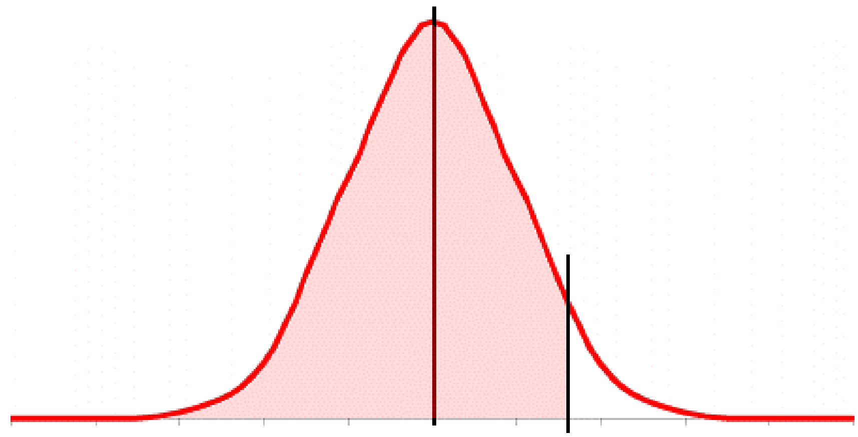
CONTENTS

APPENDICES

USEFUL STATISTICAL MEASURES

MEASURE	DESCRIPTION	FORMULA	EXCEL FUNCTION
Mean/ Average	The sum of the sample values divided by the sample size. The sample statistic $\bar{x}$ is an unbiased estimate of the population mean μ.	$\bar{x} = \frac{\sum_{i=1}^{i=n} x_i}{n}$	**=AVERAGE(data_range)**
Median	The middle value after the sample values have been sorted into order by magnitude. If there are an even number of values in the sample, the average of the two middle values.		**=MEDIAN(data_range)**
Mode	The most common value in the sample.		**=MODE(data_range)**
Range	The difference between the largest and smallest values in the sample.		**=MAX(data_range) - MIN(data_range)**
Variance	An estimate of the variation or dispersion of the process from which the sample was drawn. The sample statistic 's^2' is an unbiased estimator of the population parameter σ^2.	$s^2 = \frac{\sum_{i=1}^{i=n}\left(x_i - \bar{x}\right)^2}{n-1}$	**=VAR(data_range)**
Standard Deviation	The square root of the variance. Often preferred as a measure of process variation. The sample statistic 's' is an estimator of the population parameter 'σ' This method of calculating the standard deviation is known as the Root Mean Square Error (RMSE) method.	$s = \sqrt{\frac{\sum_{i=1}^{i=n}\left(x_i - \bar{x}\right)^2}{n-1}}$	**=STDEV(data_range)**

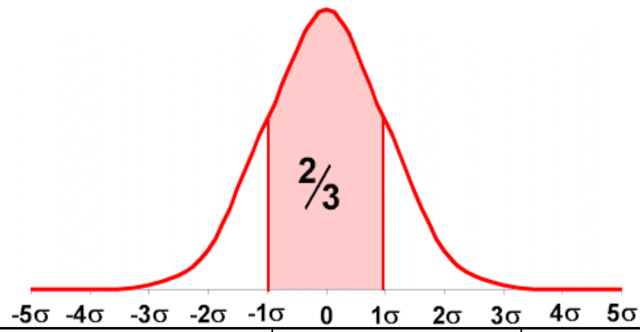
NORMAL DISTRIBUTION

DESCRIPTION	The output of many types of processes can be represented by the normal distribution. The normal distribution is often used to estimate the proportion of process output that will lie within a specific range of values (for example, the proportion of the process output that will be within specification). The normal distribution shape results from the 'common cause' variation in a process. It can be used to reveal the presence of 'special causes'.
DISTRIBUTION	
EXCEL FUNCTION	The proportion of the process output smaller than 'X' can be found in Excel using: **=NORMDIST (X, Mean, Standard Deviation, TRUE)**
TABLES	The proportion of the process output smaller than 'X' can be also found from Normal Distribution Tables (see **Appendix 2**).
Z-SCORE FORMULA	The z-score is calculated from: $z = \frac{x - \mu}{\sigma}$ 'μ' process mean, estimated from the sample mean '$\bar{x}$' 'σ' process standard deviation, estimated from the sample standard deviation 's'
EXAMPLE	A process produces bars with a mean length of 50mm and a standard deviation of 5, what proportion of the bars will be shorter than 64mm? **Answer:** The z-score is 2.80. From tables find that 0.9974 (99.74%) of the bars will be shorter than 64mm.

USEFUL VALUES FROM THE NORMAL DISTRIBUTION

DISTRIBUTION

About **two thirds** of the process output lie within one standard deviation either side of the process mean. Other values to remember:



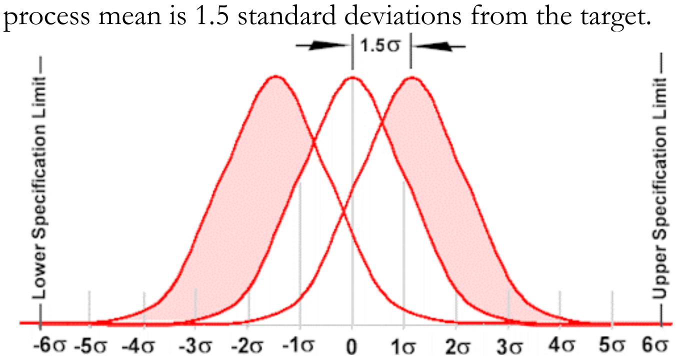
VALUES

Standard Deviations either side of the mean	Approximate amount	Exact amount
±1	two-thirds	68.27%
±2	95%	95.45%
±3	99.7%	99.73%

SIX SIGMA 'SIGMA VALUES'

SIX SIGMA

The '**six sigma**' approach uses the '**sigma value**' to measure the number of **DPMO** (Defects per Million Opportunities). The calculation assumes that the process mean is 1.5 standard deviations from the target.

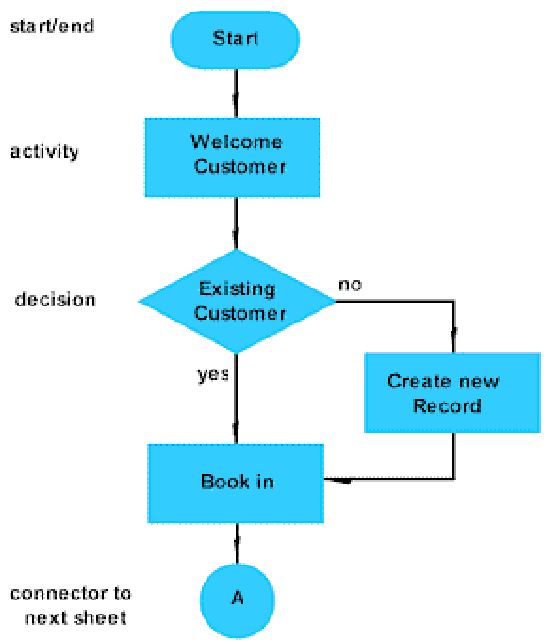


VALUES

(**ppm** – parts per million)

Sigma Level	Yield (%)	Defective ppm
1	30.23	697700
2	69.13	308700
3	93.32	66810
4	99.3790	6210
5	99.97670	233
6	**99.9999660**	**3.4**

FLOW CHARTS

CHART TYPE	Flow Chart
PROCESS PERSPECTIVE	A process is defined as a series of activities aimed at the conversion of inputs into value added outputs  Activities in organizations, whether administrative transactions activities or production activities can be modeled as 'processes'.
FLOW CHART	A chart that shows the steps in a process. Preparing a flow chart should be one of the first steps in a process improvement activity. The flow chart should be based on close observation of what actually happens, and should not omit any steps.
EXAMPLE	

CHECK SHEETS & CAUSE AND EFFECT DIAGRAMS

Check Sheet

DESCRIPTION

A method for collecting data from a process; for example, data on the frequency and types of defects.

EXAMPLE

The example shows a check sheet used to record types of paint defects on an automotive part.

Paint Date	Shift Booth	Color/Spoiler Type	Quantity Accept	Quantity Reject	Pinholes	Dirt	Fibre	Clearcoat	Run	Solvent Boil	Mottled	Fried	Fisheye
20/7	D2	XR Silver	9	3	/	/			/				
20/7	D3	XR White	10	2		//							
20/7	A2	DF Blue	14	1		/							
20/7	D1	DF Silver	11	4		/			///				
21/7	A3	JR Red	9	3	/	/			/				
22/7	D1	DF Blue	14	2		//							
23/7	A2	XR White	12	3		//				/			

CHART TYPE

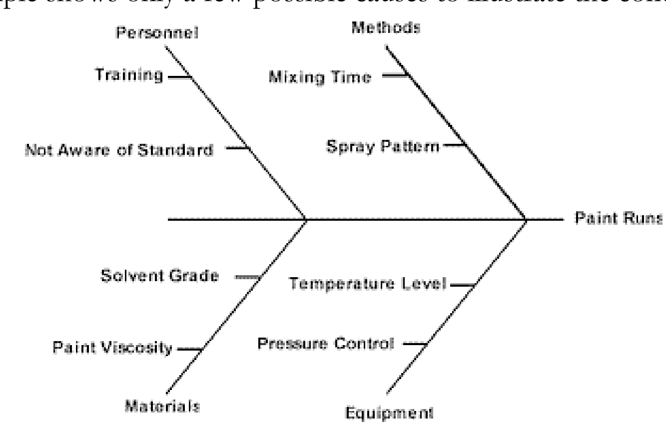
Cause and Effect Diagrams

DESCRIPTION

Also called Ishikawa or Fishbone diagrams. A method for categorizing possible causes of a problem.

EXAMPLE

The example shows only a few possible causes to illustrate the concept:



Histograms and Pareto Charts

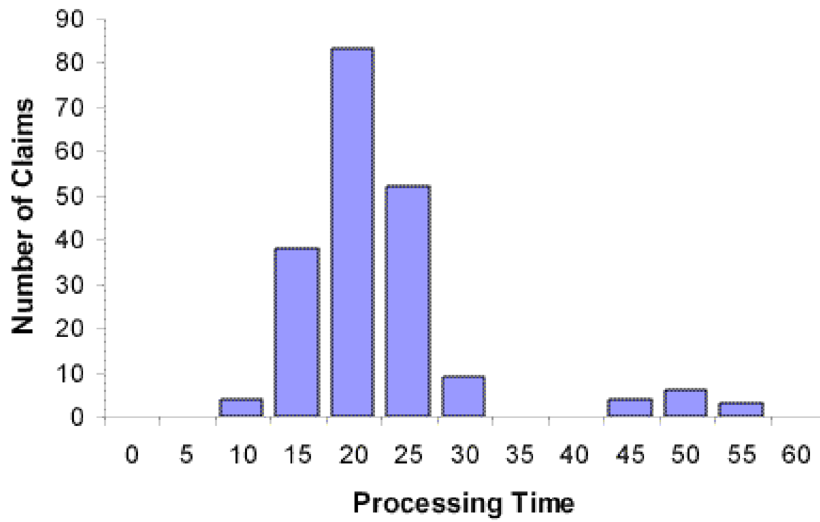
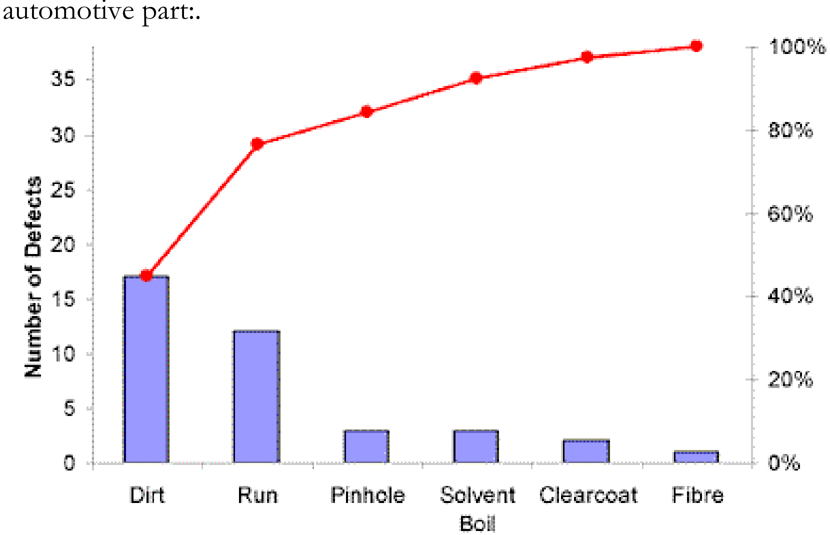
CHART TYPE	**Frequency Histogram**
DESCRIPTION	A useful way to represent the distribution of a set of data.
EXAMPLE	The example shows processing time for insurance claims. 

CHART TYPE	**Pareto Chart**
DESCRIPTION	Used to sort the 'significant few' from the 'trivial many'. Often combines a sorted histogram and a cumulative graph.
CHART EXAMPLE	The example shows the frequency of occurrence of types of paint defects on an automotive part:. 

STEM AND LEAF PLOTS

CHART TYPE	**Stem and Leaf Plots**
DESCRIPTION	Stem and Leaf Plots are similar to histograms, but retain some, or all, of the original data values.
EXAMPLE	The following values:

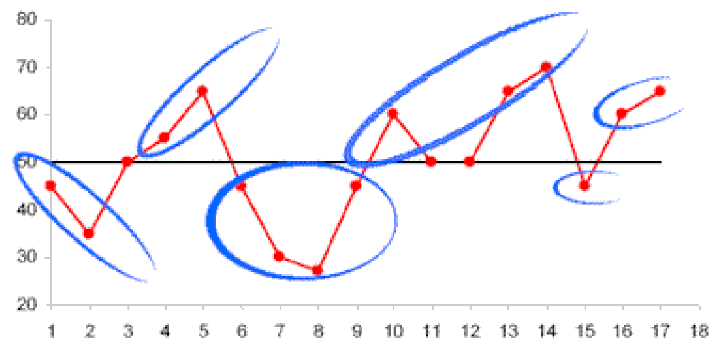
38	10	60	90	88
96	1	41	86	14
25	5	3	16	22
2	29	34	55	36
37	36	91	47	43

Would form a stem and leaf plot:

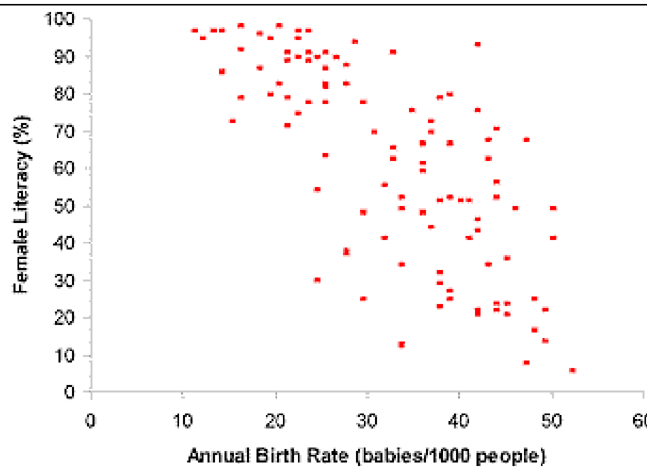
Frequency	Stem	Leaves
5	0	12345
3	1	046
3	2	259
5	3	46678
3	4	137
1	5	5
1	6	0
0	7	
2	8	68
3	9	116
0	10	

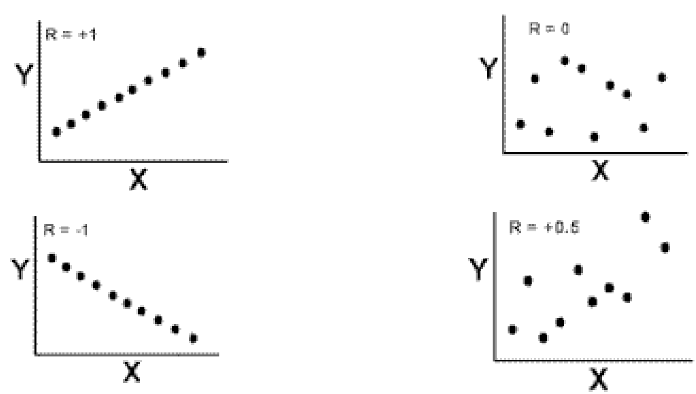
There are two values with a stem of '8', the values 86 and 88. These go into the row with stem '8'; the leaves are '6' and '8'.

Run Charts

CHART TYPE	Run Charts
DESCRIPTION	Charts that plot data in time sequence and so identify patterns that suggest 'special causes'. The center line of a run chart is the median. A run is one or more consecutive points on the same side of the median. The run stops when it crosses the median. Points on the median do not stop a run, but are not counted in the run.
EXAMPLE	
TESTS	**Test 1: The number of runs** The number of runs is checked against the table in Appendix 3. **Test 2: Too many points in a run** • less than 20 useful observations, 7 or more points • 20 or more useful observations, 8 or more points "Useful observations" exclude points on the median line. **Test 3: Trend** An unusually long sequence of consecutive points either ascending or descending: <table><tr><th>Total Number of Points</th><th>Consecutive Ascending or Descending Points</th></tr><tr><td>5 to 8</td><td>5 or more</td></tr><tr><td>9 to 20</td><td>6 or more</td></tr><tr><td>more than 20</td><td>7 or more</td></tr></table> Count points on the median, but ignore points that repeat the preceding value. **Test 4: Zig-Zag** Fourteen or more consecutive points alternatively up and down.

Scatter Graphs & Correlation

CHART TYPE	**Scatter Graphs**
DESCRIPTION	Scatter graph are used to explore associations between two variables. They are normally used when the data form natural pairs, and where there are many pairs. Standard X-Y graphs are normally used to explore a causal relationship between X and Y; typically X is varied systematically and the effect on Y measured.
EXAMPLE	
COMMENTS	Female Literacy and Birth Rate are associated, but there is not necessarily a causal relationship.

	Correlation
DESCRIPTION	Correlation is a measure of the strength of the relationship between the input and the output of a process. Correlation is measured by the 'Pearson Product Moment Correlation', known as 'R'. The value of 'R' varies from +1 to –1.
EXAMPLES	
COMMENTS	An R value of + 1 is perfect correlation. Values between –0.5 and + 0.5 show weak relationships.

CUSUM CHARTS

CHART TYPE	Cusum Charts

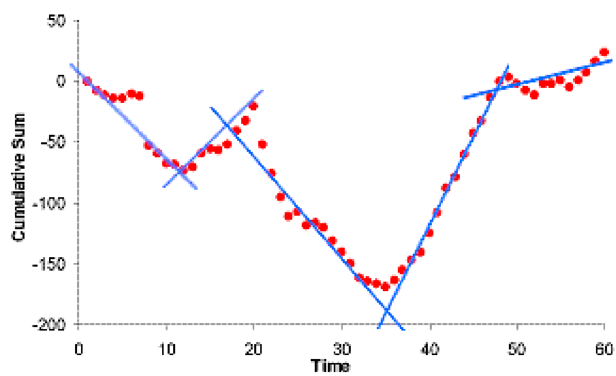
DESCRIPTION

Cusum charts plot the cumulative deviation from a specified value. The example uses a specified value of 190:

	Data	Difference	Calculations	Cumulative Sum
1			0	
2	189	-1	0 + -1 = -1	-1
3	183	-7	-1 + -7 = -8	-8
4	192	+2	-8 + 2	-6

The advantage of the cusum chart is that is very sensitive to long-term, small changes to the process mean.

EXAMPLE

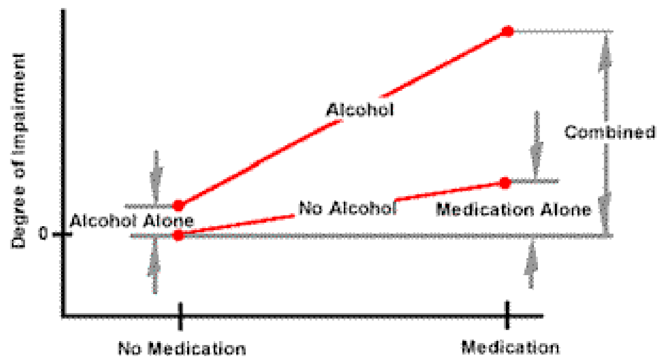


COMMENTS

The intersections of the lines represent the turning points. Thus a 'special cause' has affected the process at each of the four turning points in the example chart.

For long-term monitoring of processes a variation on the basic cusum chart known as the 'tabular cusum chart' is preferable. The tabular cusum chart allows for the small variations in the process mean that are acceptable and unavoidable in most processes.

INTERACTIONS

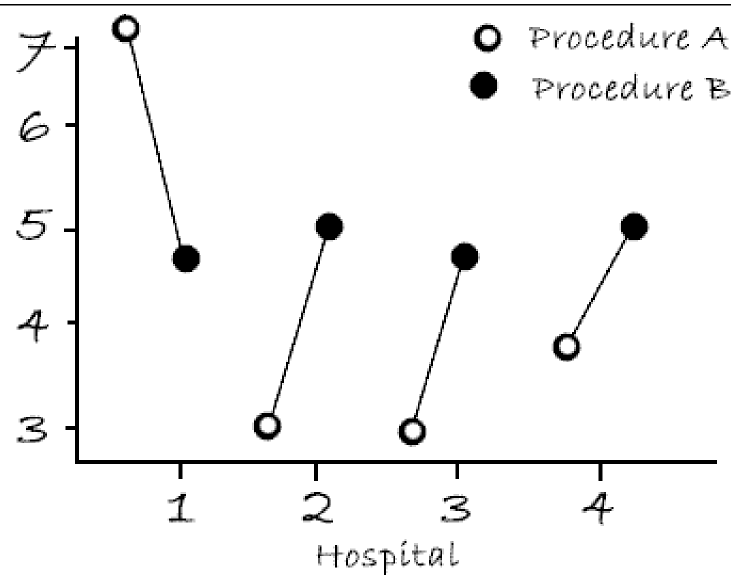
Interactions	
DESCRIPTION	Where a process has several inputs, interactions may exist between the inputs. This means that the effect of one input depends on the value of one or more of the other inputs.
EXAMPLE	
COMMENTS	Some medications interact with alcohol. If a person has either the medication or a moderate amount of alcohol their judgment is not significantly affected. If they combine the two, the effect is substantial. The Design of Experiments (DOE) is the most effective method for analyzing processes that have multiple inputs, particularly if there may be interactions between the inputs.

MULTI-VARI CHARTS

CHART TYPE	Multi-Vari Charts
DESCRIPTION	Multi-vari charts are a graphical method used to show the effect of more than one input variable on the output, including any interaction between the input variables. This is illustrated by an example. The table shows the Average Length of Stay (LOS) for two procedures, 'A' and 'B' at four different hospitals.

Hospital	Procedure	LOS
1	A	7.25
1	B	4.75
2	A	3.00
2	B	5.00
3	A	3.00
3	B	4.75
4	A	3.75
4	B	5.00

EXAMPLE

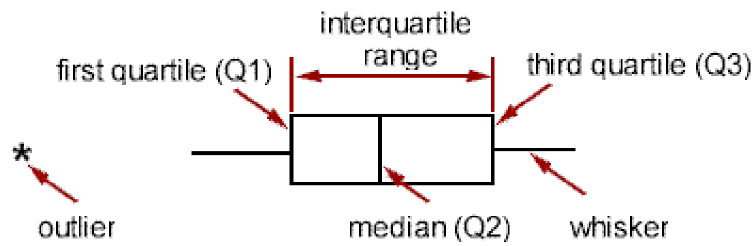
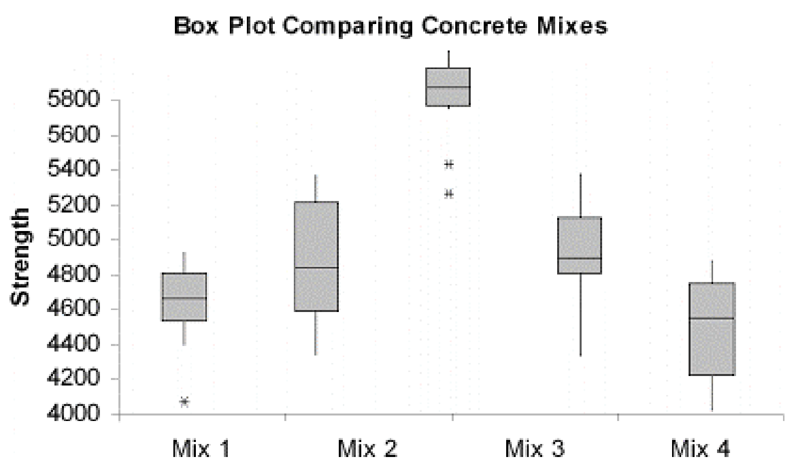


COMMENTS

The chart clearly shows that Procedure A at Hospital 1 is the odd one out.

Multi-vari charts can show the effects of more than two input variables. If there were three input variables, there would be a separate chart for each level of the third variable.

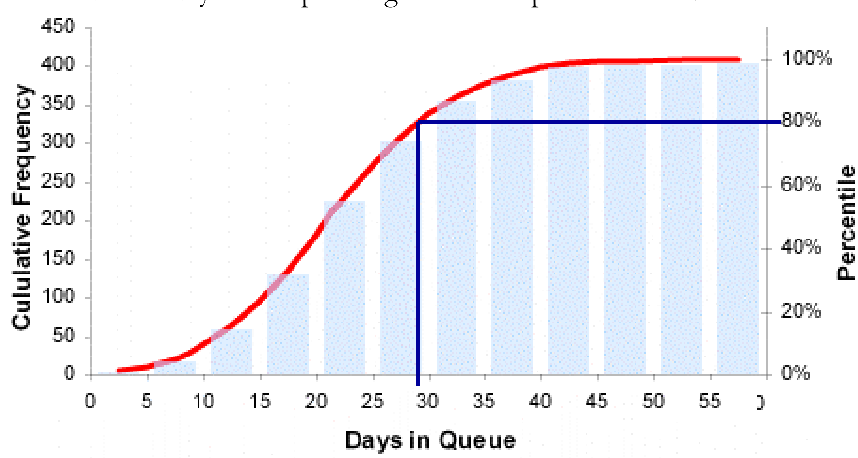
Box Plots

CHART TYPE	Box Plot
DESCRIPTION	A graphical method for representing a data set.  • **outliers** are smaller than $Q1 - 1.5 \times (Q3 - Q1)$ or greater than $Q3 + 1.5 \times (Q3 - Q1)$ • **whiskers** are the largest and smallest data values that are not outliers
EXAMPLE	The example shows a box plot used to compare the strength of five mixes of concrete: 

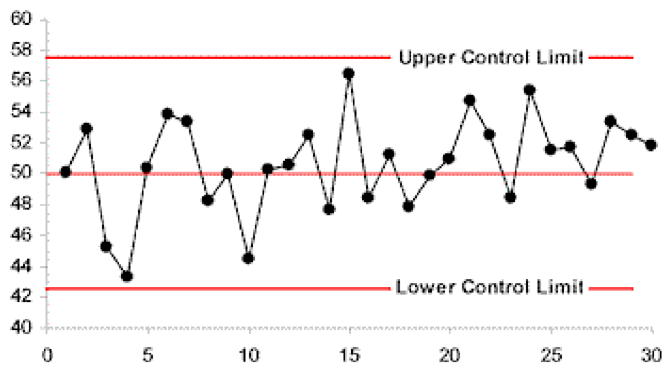
GROUPED DATA

MEASURE	DESCRIPTION	FORMULA
Mean of Grouped Data	Used where data are collected in ranges of values, rather than individual values (e.g., census data). The number of individual data values would typically be large.	$\bar{x} = \frac{\sum_{j=1}^{k} f_j M_j}{n}$ **f_j** - frequency for group 'j' **M_j** - midpoint of the range (smallest + largest)/2 **n** - the total number of samples **k** - the number of groups
Standard Deviation of Grouped Data		$s = \sqrt{\frac{\sum_{j=1}^{k} f_j \left(M_j - \bar{x}\right)^2}{n-1}}$

PERCENTILES

DESCRIPTION	Percentiles show the cumulative frequency and are often associated with grouped data.
EXAMPLE	The chart shows how a frequency '**ogive**' is created from grouped data (displayed as a cumulative histogram). It also shows, as an example, how the number of days corresponding to the 80^{th} percentile is obtained. 

CONTROL CHARTS

CHART TYPE	Control Charts
DESCRIPTION	Control charts are used to monitor processes. They are introduced after a state of 'statistical control' has been achieved. The purpose of control charts is to achieve timely identification of 'special causes' entering the process. There are many types of control charts, and control charts are used to monitor both variables and attributes. For comprehensive coverage see the **MiC Quality Statistical Process Control** and **Advanced SPC** courses at www.micquality.com
EXAMPLE	
COMMENTS	The control limits are usually located at three standard deviations from the mean. Three standard deviations are selected because it is a reasonable compromise between the probability of a 'Type I Error' and a 'Type II Error'. In healthcare some experts advocate using two standard deviations.
WESTERN ELECTRIC RULES	Various patterns are used to signify a 'special cause'. The 'Western Electric' rules are often used. **Rule 1:** A single point outside the three sigma control limits, on either side. **Rule 2:** Any two of the last three points outside the two sigma line, on the same side **Rule 3:** Any four of the last five points outside the one sigma line, on the same side **Rule 4:** Eight consecutive points on the same side of the center line **Rule 5:** Six consecutive points trending either up or down **Rule 6:** Fourteen consecutive points alternating up and down
COMMENTS	In addition about two thirds of the points should be within the one standard deviation of the mean, and about 95% within 2 standard deviations.

Range and Standard Deviation

DESCRIPTION

The process standard deviation can be estimated by calculating the average range of a number of samples, each of size '**n**', and dividing by a constant.

n >= 15

If the number of samples is **greater than about 15**:

$$s = \frac{\overline{R}}{d_2}$$

Values of d_2:

n	2	3	4	5	6	7	8	9	10	11	12	13	14	15
d_2	1.128	1.693	2.059	2.326	2.534	2.704	2.847	2.970	3.078	3.173	3.259	3.336	3.407	3.472

n < 15

If the number of samples is **less than 15**:

$$s = \frac{\overline{R}}{d_2^*}$$

Values of d_2^* are tabulated in **Appendix 1.**

NOTE

d_2^* is mainly used in Measurement Systems Analysis/ Gage R&R Studies where the number of samples is unavoidably small. In other applications at least 30 samples are normally used for reliable results.

EXAMPLE

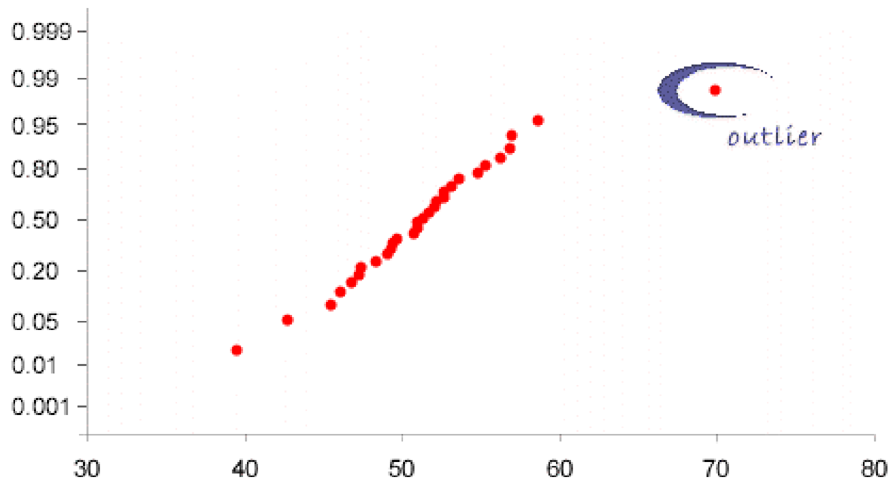
Thirty samples, each containing five items are taken from a process. The average range of the thirty samples is 5 mm. Estimate the standard deviation of the process.

Answer:
The value of d_2 is 2.326, the standard deviation is 2.15

NORMAL PROBABILITY PLOTS

CHART TYPE	**Normal Probability Plot**
DESCRIPTION	A type of graph used to check if a sample conforms to a normal distribution, or to identify values that do not conform to a normal distribution (outliers).

EXAMPLE



The 'y' scale of the normal probability plot is non-linear. It can be created using special graph paper or can be created in Excel using the function '=NORMSINV' as a transform as follows:

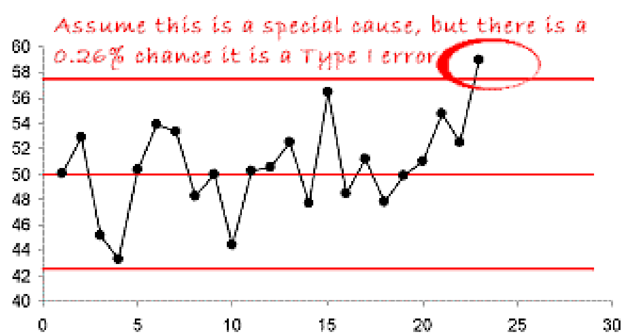
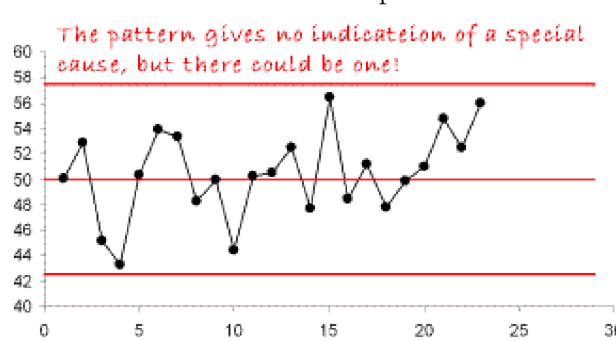
Index	Fi	Y	Ordered Data (x)
i	$F_i = \frac{i-0.5}{n}$	=NORMSINV(F_i)	x_i

Index values run from 1 through n, where n is the number of values in the sample.

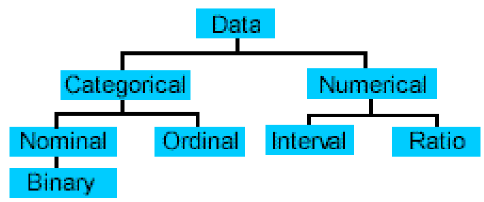
Sampling Methods

Sampling Types	
Sampling	Inferential statistics is used to draw conclusions about a population based on a relatively small sample. The conclusions are only meaningful if the sample is representative of the population.
Simple Random Sampling	In a simple random sample, the sampling is carried out in a way that ensures that every member of the population has an equal chance of being selected. This can be done by numbering each item in the population, and then picking numbers from a hat, as in a lottery. An easier approach is to use a computer to generate random numbers.
Stratified Sampling	This involves splitting the population into categories and then taking a random sample from each category. The size of the samples are proportional to the size of the category. Suppose a company wants to carry out a survey of employee satisfaction. A simple random sample would select employees at random. A stratified sample might select employees proportionally from each department, and level of management. In a small mixed gender group it may be appropriate to ensure that males and females are proportionally represented.
Convenience Sampling	A simple random sample is often impractical because some items are difficult to access, for example in products that are palletized. Sampling from the easy to access items may be acceptable if there is evidence that they are representative of the remainder of the batch.
Sample Homogeneity	In some types of test the sample is taken from an area that may not be homogeneous, for example a 500 gram sample of soil may represent 10 acres of land. In this case sub-samples are taken from over the area and thoroughly mixed to make sure it is representative of the plot.

IMPORTANT STATISTICAL CONCEPTS

Important Statistical Concepts	
Inferential and Descriptive Statistics	**Descriptive** (enumerative) statistics are used to summarize and describe important features of the data, such as the centering, spread or normality. **Inferential** (analytical) statistics uses information obtained from a sample to draw conclusions (make inferences) about the population as a whole.
Common and Special Cause Variation	**Common cause** variation refers to the many small factors, many of which will not have been identified, that contribute to process variation. If only common cause variation is present the process response will conform to a normal distribution. **Special cause** variation results from identifiable factors that have a significant effect on the process, larger than the common cause variation. Special causes can be identified and should, where possible, be eliminated.
Statistical Control	A process is in **statistical control** when only common cause variation is present, and when the statistical properties of the distribution do not vary with time.
Type I and Type II Errors	In the context of control charts, a **Type I Error** occurs when the patterns on the control chart indicate that the process is not in a state of statistical control, but in reality the process is in control:  A **Type II Error** occurs when the process is not in a state of statistical control, but no evidence of this has shown up on the control chart: 

MEASUREMENT SCALES

Measurement Scales	
DESCRIPTION	When you collect sample data you use a 'Measurement Scale'. The choice of scale affects the amount of information you will get from the data, and the mathematical operations that you can use with it. There are four types of measurement scale, nominal, ordinal, interval and ratio.
Taxonomy	
Nominal (Attribute)	This is the most basic measurement scale. Data are placed into categories that cannot be sorted into a logical order. An example would be marital status: single, married, divorced. Nominal data are also known as 'attribute data'. ***arithmetic:*** *equal to* ***statistical:*** *mode*
Ordinal	Data are sorted into categories. The categories can be placed into a logical order, but the intervals between the categories are undefined. Often used for order of preference. ***arithmetic:*** *comparison (equal to, greater than, less than)* ***statistical:*** *median, mode*
Interval	Items are placed on a scale, with intervals that can be measured numerically. The numerical scale can be linear or non-linear (e.g. logarithmic). Zero does not mean the absence of the entity. Rating customer satisfaction on a scale of 1 to 10 would be an example of an interval scale. The Fahrenheit or Centigrade temperature scales are also interval scales because zero does not imply an absence of temperature. ***arithmetic:*** *comparison, addition, subtraction* ***NOT*** *multiplication, division.* ***statistical:*** *mean, median, variance*
Ratio	Similar to an interval scale with the additional constraint that zero means the absence of the entity. Length or weights are measured on a ratio scale. ***arithmetic:*** *comparison addition, subtraction, multiplication, division* ***statistical:*** *mean, median, variance*

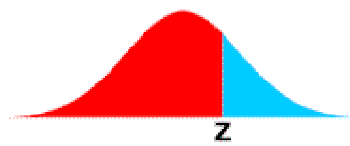
APPENDICES

APPENDIX 1: VALUES OF d_2 AND d_2^*

	Size of Sample (n)													
# Samples (k)	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	1.414	1.912	2.239	2.481	2.673	2.830	2.963	3.078	3.179	3.269	3.350	3.424	3.491	3.553
2	1.2879	1.805	2.151	2.405	2.604	2.768	2.906	3.025	3.129	3.221	3.305	3.380	3.449	3.513
3	1.231	1.769	2.120	2.379	2.581	2.747	2.886	3.006	3.112	3.205	3.289	3.366	3.435	3.499
4	1.206	1.750	2.105	2.366	2.570	2.736	2.877	2.997	3.103	3.197	3.282	3.358	3.428	3.492
5	1.191	1.739	2.096	2.358	2.563	2.730	2.871	2.992	3.098	3.192	3.277	3.354	3.424	3.488
6	1.181	1.731	2.090	2.353	2.558	2.726	2.867	2.988	3.095	3.189	3.274	3.351	3.421	3.486
7	1.173	1.726	2.085	2.349	2.555	2.723	2.864	2.986	3.092	3.187	3.272	3.349	3.419	3.484
8	1.168	1.721	2.082	2.346	2.552	2.720	2.862	2.984	3.090	3.185	3.270	3.347	3.417	3.482
9	1.164	1.718	2.080	2.344	2.550	2.719	2.860	2.982	3.089	3.184	3.269	3.346	3.416	3.481
10	1.160	1.716	2.077	2.342	2.549	2.717	2.859	2.981	3.088	3.183	3.268	3.345	3.415	3.480
11	1.157	1.714	2.076	2.340	2.547	2.716	2.858	2.980	3.087	3.182	3.267	3.344	3.415	3.479
12	1.155	1.712	2.074	2.3439	2.546	2.715	2.857	2.979	3.086	3.181	3.266	3.343	3.414	3.479
13	1.153	1.710	2.073	2.338	2.545	2.714	2.856	2.978	3.085	3.180	3.266	3.343	3.413	3.478
14	1.151	1.709	2.072	2.337	2.545	2.714	2.856	2.978	3.085	3.180	3.265	3.342	3.413	3.478
15	1.150	1.708	2.071	2.337	2.544	2.713	2.855	2.977	3.084	3.179	3.265	3.342	3.412	3.477
d_2	**1.128**	**1.693**	**2.059**	**2.326**	**2.534**	**2.704**	**2.847**	**2.970**	**3.078**	**3.173**	**3.259**	**3.336**	**3.407**	**3.472**

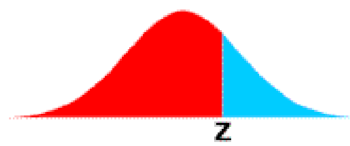
Duncan A. J (1986), Quality Control and Industrial Statistics Appendix D3

APPENDIX 2:
NORMAL DISTRIBUTION TABLES



Z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.40	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
-3.30	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
-3.20	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
-3.10	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
-3.00	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.90	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.80	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.70	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.60	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.50	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.40	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.30	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.20	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.10	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.00	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.90	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.80	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.70	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.60	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.50	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.40	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.30	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.20	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.10	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.00	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.90	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.80	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.70	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.60	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.50	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.40	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.30	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.20	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.10	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.00	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641

Appendix 2:
Normal Distribution Tables continued



Z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.00	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.10	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.20	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.30	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.40	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.50	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.60	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.70	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.80	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.90	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.00	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.10	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.20	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.30	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.40	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.50	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.60	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.70	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.80	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.90	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.00	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.10	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.20	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.30	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.40	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.50	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.60	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.70	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.80	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.90	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.00	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.10	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.20	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.30	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.40	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

Appendix 3: Limits on Runs for Run Charts

Number of Points not on Median	Lower Limit	Upper Limit	Number of Points not on Median	Lower Limit	Upper Limit
10	3	8	34	12	23
11	3	9	35	13	23
12	3	10	36	13	24
13	4	10	37	13	25
14	4	11	38	14	25
15	4	12	39	14	26
16	5	12	40	15	26
17	5	13	41	16	26
18	6	13	42	16	27
19	6	14	43	17	27
20	6	14	44	17	28
21	7	15	45	17	29
22	7	16	46	17	30
23	8	16	47	18	30
24	8	17	48	18	31
25	9	17	49	19	31
26	9	18	50	19	32
27	9	19	60	24	37
28	10	19	70	28	43
29	10	20	80	33	48
30	11	20	90	37	54
31	11	21	100	42	59
32	11	22	110	46	65
33	11	22	120	51	70

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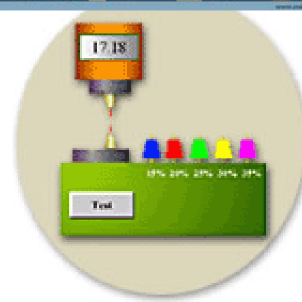
(see previous page for more information)



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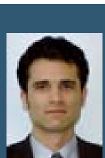

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