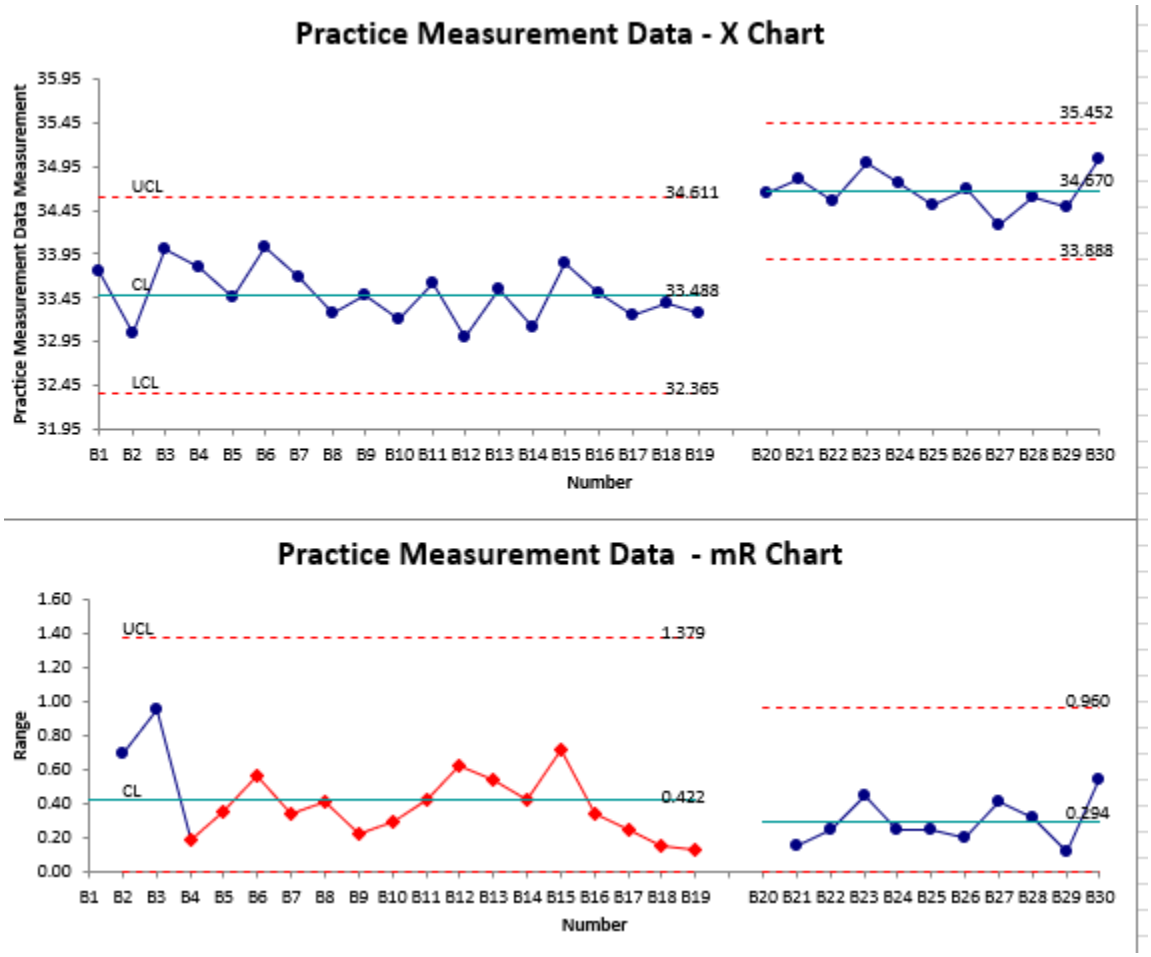
Control Chart White Paper

By Jay Arthur

QIMacros®

Control Chart White Paper



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Control Chart White Paper

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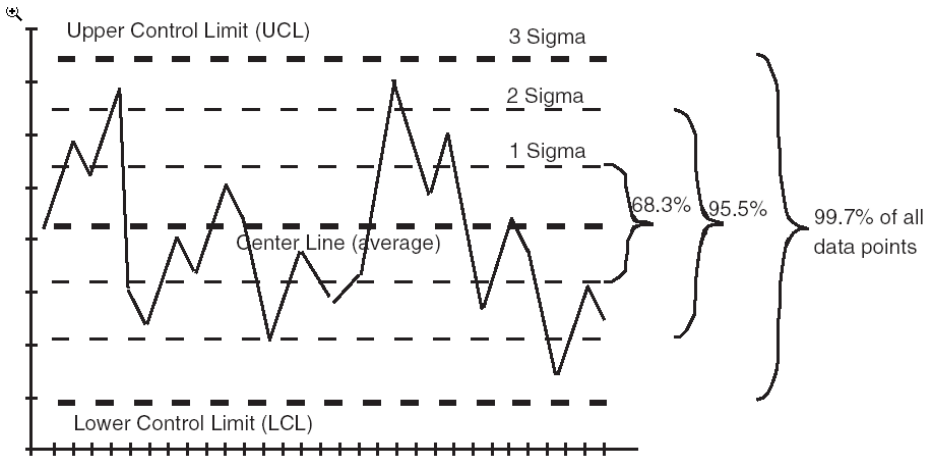
What Is a Control Chart?

A control chart is a line graph of your data with average and sigma lines to determine stability. The average and sigma lines (±1, 2 and 3 sigma) are calculated from the data. The Upper Control Limit (UCL) is the +3 sigma line and the Lower Control Limit (LCL) is the -3 sigma line. Approximately 99.7% of all data points will fall between these two limits.

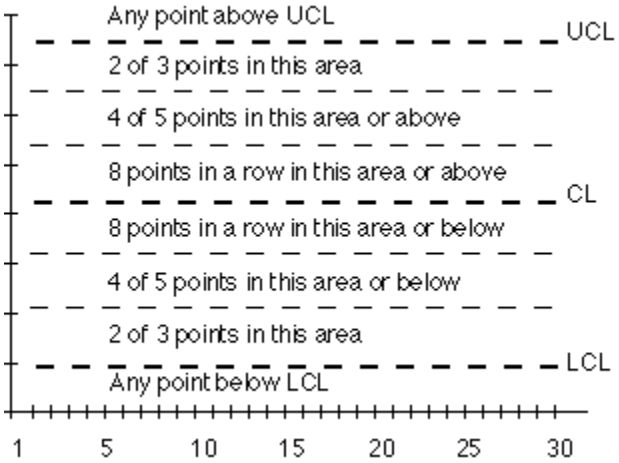


What Does a Control Chart Tell You?

A control chart will tell you whether your process is stable or unstable. A stable process produces PREDICTABLE RESULTS CONSISTENTLY. Processes that are "out of control" need to be stabilized before they can be improved.

Stability Analysis

The QI Macros for Excel SPC Software identifies unstable points or trends for you and highlights them in red. Unstable conditions include the following:



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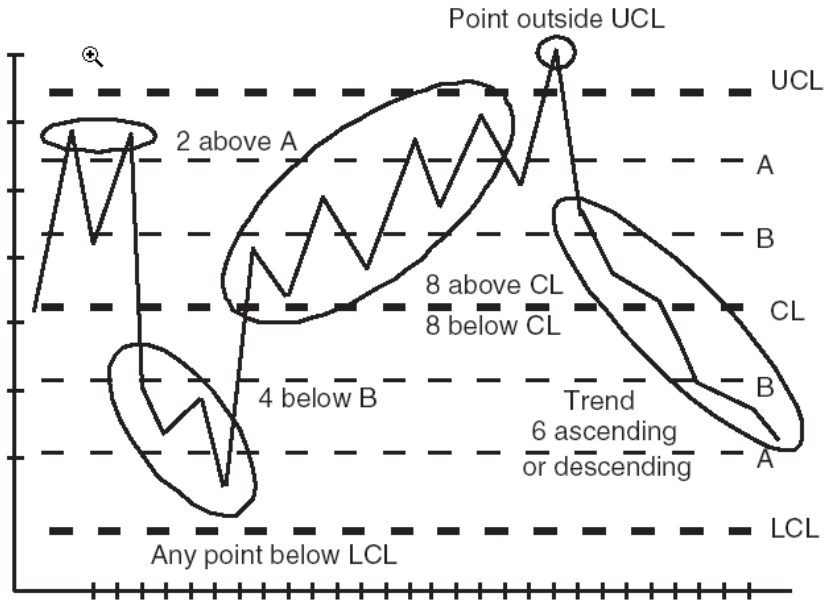
QI Macros lets you select from a variety of rules. The default is Montgomery. Healthcare uses special rules that can be selected from the Control Chart Rules Menu.

Control Chart Rules	n (point	Westgard	Nelson-Juran	AIAG	Montgomery	Western Electric	Healthcare
1. Points above UCL or Below LCL	1	1	1	1	1	1	1
2. Zone A *n* of *n* + 1 points above/below 2 sigma	2	2	2	2	2	2	2
3. Zone B *n* of *n* + 1 points above/below 1 sigma	4		4	4	4	4	
4. *n* points in a row above or below center line	8	8	9	7	8	8	8
5. Trends of *n* points in a row increasing or decreasing	6	7	6	6	6		6
6. Zone C - *n* points in a row inside Zone C (hugging)	15		15	15	15		15
7. *n* points in a row alternating up and down	14		14	14	14		
8. Zone C - *n* points in a row outside Zone C	8		8	8	8		
9. Zone B n points above/below 1sigma; 2 points one above, one below 2sigma		4					

There are two different causes of variation:

- **Common causes** of variation happen all the time, every day. Getting from your home to school or work takes varying amounts of time because of traffic or transportation delays.
- **Special causes** require immediate analysis to eliminate the root cause of variation. A blizzard, a traffic accident, a chemical spill or other freak occurrence would be a special cause of variation in your commute.

Any point outside the upper or lower control limits is a clear example of a special cause. The other forms of special cause variation are called "runs." Trends, cycling up and down, or "hugging" the center line or limits are special forms of a run.



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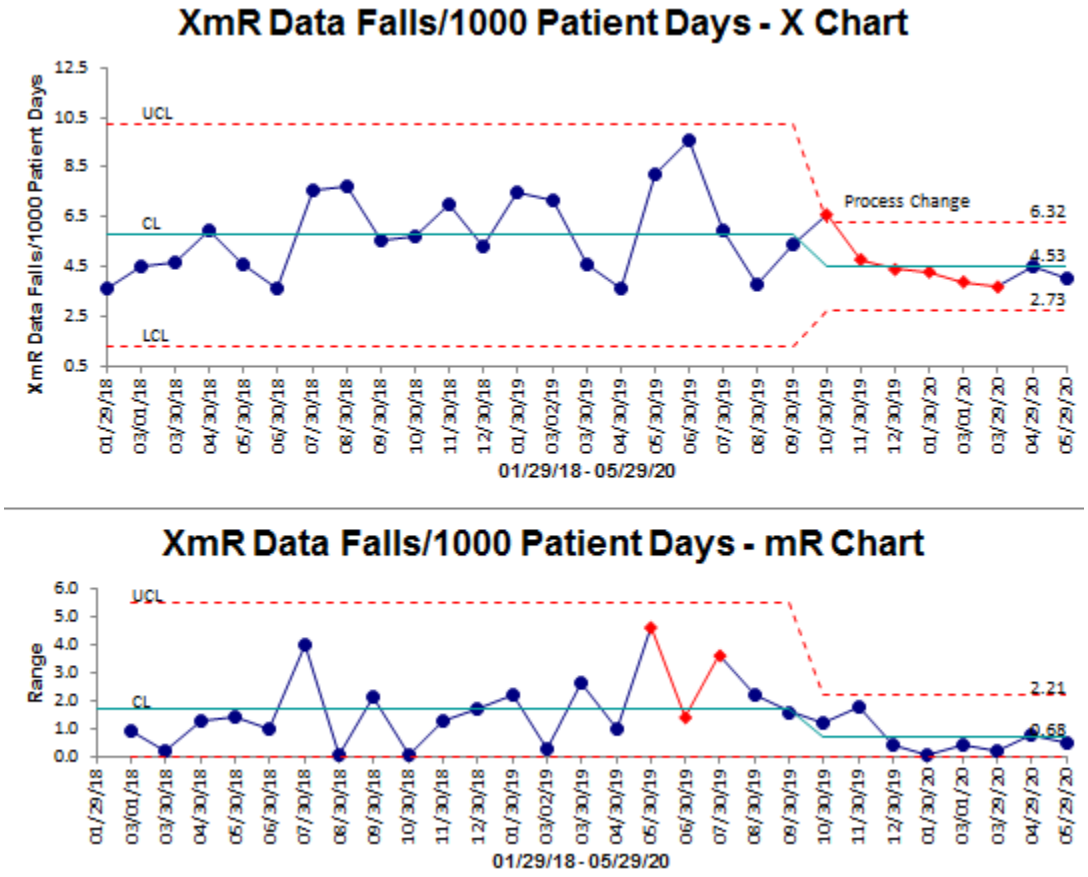
Recalculating Control Chart Limits to Show Process Changes

Generally, you can use QI Macros Chart Menu to fix control limits using your first 20 to 25 data points and then use those limits to evaluate the rest of your data. If you have a process change, you should recalculate your control limits beginning with data after the process change occurred.

Use QI Macros Process Change Wizard to recalculate limits to show the success of process improvement efforts. Success is shown by the change in the average or center line and the reduced variation (difference between the UCL and LCL). In the following example, the process improvements reduced patient falls per 1000 patient days from 5.84 to 4.27 and significantly reduced variation as evidenced by the distance between the UCL and LCL.



Using Control Charts to Compare Data from Different Processes

You can also use control charts to compare different processes side by side. If you are in healthcare, you could compare data for several different doctors, hospitals, floors, etc.

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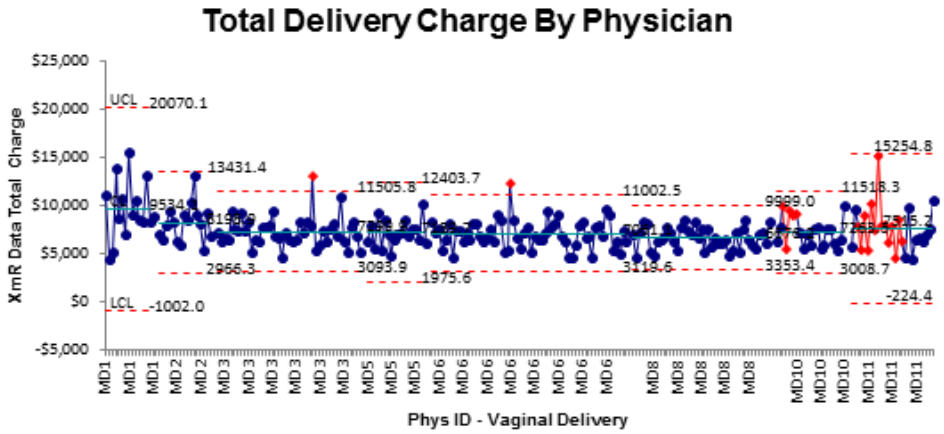
If you are in manufacturing, you could compare data from different machines, lots, batches, etc.

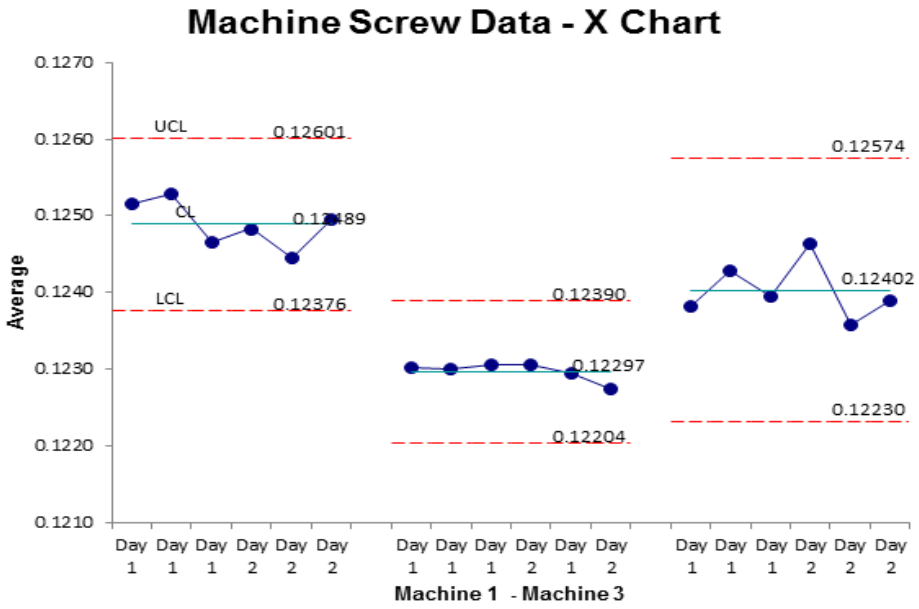


In the following example we used data taken from a case study on the government's statistics website: http://www.itl.nist.gov/div898/handbook/ppc/section5/ppc521.htm

The essence of the case study is that:

- A machine shop has **three** automatic screw machines that produce various parts.
- The shop has enough capital to **replace one** of the machines.
- The quality control department has been asked to conduct a study and make a recommendation as to which machine should be replaced.

If you run side by side control charts you can see that Machine 3 has the most variation (greatest distance between UCL and LCL). Based on this analysis you would replace machine 3.



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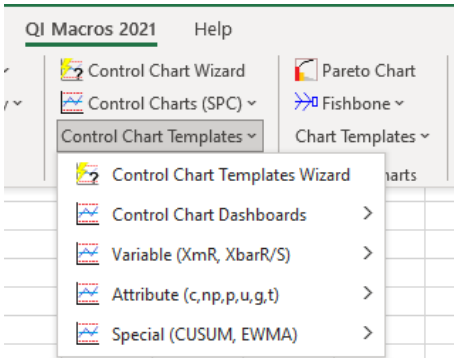
Which Control Chart Should I Use?

One area that many people struggle with is choosing the right control chart. The right chart is based on the type of data, attribute (counted) or variable (measured), and the sample size.

The QI Macros Control Chart Wizard and Control Chart Template Wizard can analyze your data and select the right control chart for you. Simply click and drag over your data to select it and then select Control Chart Wizard from the QI Macros Menu. The wizard can select the right chart and only needs to ask one question when it is trying to determine between a p and u chart.



If you want to understand how to choose the right chart, here are some tips:

These are the most common control charts in healthcare:

Number	Control Chart	Examples
Decimals (3.4, 87%, $2.45) One per day, month	XmR	• Time (door-to-balloon time) • Ratios (e.g., falls per 1000 patient days, infection rate per 1000 patient days) • Patient Satisfaction (%) • Financial Data (e.g., Denied Insurance Claims)
integers (1,3,5) numerator denominator	p/u chart	• c-sections/deliveries • returns/surgeries • readmissions/discharges • Adverse Drug Events/doses

Integers
Days or counts
	g Chart	• time or procedures between Never Events
		  ○ retained foreign objects
		  ○ adverse events
		  ○ wrong side surgeries

integers (1,3,5) No denominator	c Chart	• Injuries, needle sticks
Decimals Multiple per day	XbarS	• Patient Length of Stay (LOS) • Turnaround times for Lab/imaging

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For attribute (i.e., integer or counted defects) data use np, p, c and u charts:

- If you are counting defective items (e.g., incorrect orders)
  - use a np chart if the sample size is constant
  - use a p chart if the sample size varies
- If you are counting the number of defects (e.g., number of errors on an order)
  - use a c chart if the sample size is large or not available
  - use a u chart if the sample size varies
- If you are using a ratio of defects/period (e.g., patient falls/1000 patient days) use the XmR chart

For variable or measured data (i.e., decimal) such as time, cost, length, weight, etc. use XmR, XbarR, and XbarS Charts:

- If the sample size is one, use an XmR chart
- If the sample size is 2-5, use an XbarR chart
- If the sample size is 6-25, use an XbarS chart

When working with data in Excel, follow a simple strategy for selecting the right chart based on the *format* of the data itself. There are three formats to look for:

1. A single row/column.
2. Two rows/columns with a numerator and a denominator.
3. Two or more rows/columns containing multiple observations from each sample.

They look like this:

	A	B
1		Injuries
2	01/01/20	1
3	01/15/20	3
4	01/29/20	0
5	02/12/20	7
6	02/26/20	2
7	03/11/20	0

	A	B	C
1	Sample Number	Defects	Sample Size
2	S1	12	100
3	S2	8	80
4	S3	6	80
5	S4	9	100
6	S5	13	110
7	S6	12	110

	A	B	C
1	Sample Number	Obs 1	Obs 2
2	S1	74.030	74.002
3	S2	73.995	73.992
4	S3	73.988	74.024
5	S4	74.002	73.996
6	S5	73.992	74.007
7	S6	74.009	73.994

Single Row/Column

If you only have a single row/column of data, there are only three charts you can use:

- c chart (attribute or counted data) – It's always an integer (e.g., 1,2,3,4,5)
- XmR chart (variable or measured data) – It usually has decimal places (e.g., 33.75)
- XmR Trend chart for variable data that increases (e.g., rising costs due to inflation)

So, which one should you choose? If you're counting indivisible things like defects, people, cars, or injuries, then choose the c chart. If you're measuring things like time, length, weight, or volume, choose the XmR chart.

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The data looks like the following:

c Chart	XmR chart	XmR Trend
defects, people, cars, injuries	time, money, length, weight, or volume	Increasing or decreasing time, money, length, weight, or volume

	A	B
1		Injuries
2	01/01/20	1
3	01/15/20	3
4	01/29/20	0
5	02/12/20	7
6	02/26/20	2
7	03/11/20	0

	Number	Measurement
1		
2	B1	33.75
3	B2	33.05
4	B3	34.00
5	B4	33.81
6	B5	33.46
7	B6	34.02

	A	B
1		Fixed Costs $(000)
2	Jan	324.3
3	Feb	325.6
4	Mar	330.2
5	Apr	334.2
6	May	338.4
7	Jun	335.4

Look for these patterns in the data and then select the chart.

Two Rows/Columns

If the data has a numerator and a denominator that varies (e.g., defects/batch, errors/transactions), then you will want to use the:

- p chart (one defect maximum per piece)
- u chart (one or more defects per piece)

How can you tell which one to use? Ask yourself: "Can this widget have more than one defect?" If yes, use the u chart, otherwise use the p chart.

p Chart	u Chart
Defective items per batch	Defects per item

	A	B	C
1	Sample Number	Defects	Sample Size
2	S1	12	100
3	S2	8	80
4	S3	6	80
5	S4	9	100
6	S5	13	110
7	S6	12	110

	A	B	C
1	Roll Number	Nonconformities in Dyed Cloth	50 Sq Meters
2	R1	14	10
3	R2	12	8
4	R3	20	13
5	R4	11	10
6	R5	7	9.5
7	R6	10	10
8	R7	21	12

	E	F	G
		ED Returns within 72 Hours	ED Pts/100
M		17	41.78
A		26	43.89
M		13	39.86
J		16	40.03
A		24	38.07
S		27	43.43
O		19	39.21

Sometimes, as in the u chart example above, you can have more defects than samples. This is another clue. Look for these patterns in the data and then select the chart.

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Two or More Rows/Columns of Variable Data

Service industries such as healthcare don't use the XbarR or XbarS charts very often. They are mainly used in manufacturing. If you have two or more rows or columns of variable data (time, weight, length, width, diameter, or volume) then you can choose one of three charts:

- XbarR (Average and Range, 2-5 rows/columns per sample)
- XMedianR (Median and Range, 2-5 rows/columns per sample)
- XbarS (Average and Standard Deviation, 6-50 rows/columns per sample)

Your data should look like this:

	A	B	C	D	E	F
1	Sample Number	Obs 1	Obs 2	Obs 3	Obs 4	Obs 5
2	S1	74.030	74.002	74.019	73.992	74.008
3	S2	73.995	73.992	74.001	74.011	74.004
4	S3	73.988	74.024	74.021	74.005	74.002
5	S4	74.002	73.996	73.993	74.015	74.009
6	S5	73.992	74.007	74.015	73.989	74.014
7	S6	74.009	73.994	73.997	73.985	73.993
8	S7	73.995	74.006	73.994	74.000	74.005

	A	B	C	D	E	F
1		LOS Pt1	Pt2	Pt3	Pt4	Pt5
2	Jan-19	25	22	35	23	24
3	Feb-19	25	22	35	23	24
4	Mar-19	45	36	34	32	40
5	Apr-19	34	32	40	35	67
6	May-19	25	22	35	23	24
7	Jun-19	25	22	35	23	24
8	Jul-19	45	36	34	32	40

You can run the XbarR, XMedianR or XbarS on this data. Xbar uses the average as the measure of central tendency. The XMedianR uses the median. If you have more than five samples per period, then the XbarS will probably be the most robust chart for your needs.

You can also use the XbarR or XbarS if your data has a varying number of samples per period:

Sample Number	Obs 1	Obs 2	Obs 3	Obs 4	Obs 5
S1	74.03	74.002	74.019	73.992	74.008
S2	73.995	73.992	74.001		
S3	73.988	74.024	74.021	74.005	74.002
S4	74.002	73.996	73.993	74.015	74.009
S5	73.992	74.007	74.015	73.989	74.014
S6	74.009	73.994	73.997	73.985	
S7	73.995	74.006	73.994	74	

Look for these patterns in your data and then select the chart.

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The np Chart

There's one chart left to last because I rarely find situations where it applies. The np chart is like the p chart except that the sample sizes are constant. The data looks like this:

	A	B	C
1	Sample Number	Sample Size = 50	Nonconforming Cans
2	S1	50	12
3	S2	50	15
4	S3	50	8
5	S4	50	10
6	S5	50	4

Again, look for these patterns in your data and then select the chart.

Summary

So, just recognizing patterns in your data can make it easier to pick the right control chart.

Rows/Columns	Attribute (integers)	Variable (decimals)
1	c chart np chart	XmR chart XmR Trend
2	p chart u chart	
2 or more		XbarR XMedianR XbarS

Why Are There So Many Charts?

Understanding Standard Deviation and Control Charts

Many people ask: "Why aren't my upper and lower control limits (UCL, LCL) calculated as: $\mu \pm 3\sigma$ (where μ is the mean and σ is the standard deviation)?" This formula works for the Levey Jennings chart but not others because the underlying distribution is different. To answer this question, you have to understand some key, underlying statistics: variation, standard deviation, sampling and populations.

Variance ($stdev^2$) is the average of the square of **the distance between each point in a total population (N) and the mean (μ)**.

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If your data is spread over a wider range, you have a larger variance and standard deviation. If the data is centered around the average, you have a smaller variance and standard deviation.

Standard deviation (stdev or σ) is the square root of the variance and it can be estimated using the average range (Rbar) between samples ($Rbar/d_2$) when the number of subgroups is 2-10, or using standard deviation $Sbar/c_4$ when n>10.
Rbar = Rave = $\Sigma R_i/n$ Sbar = Average(stdev) = $\Sigma \sigma_i/n$
d_2 and c_4 are constants based on the sample size.

Sampling: Early users of SPC found that it cost too much to evaluate every item in the total population. To reduce the cost of measuring everything, they had to find a way to evaluate a small sample and make inferences from it about the total population.

Understanding Control Chart Limits

Ask yourself this question: "If a simple formula using the mean and standard deviation would work for any data, why are there so many different control charts?"
The short answer: to save money by measuring small samples, not the entire population.

Long answer: When using small samples or varying populations, the simple formula using the mean and standard deviation just doesn't work, because you don't know the average, μ, or sigma of the total population, only μ or sigma of your sample.

Why are there so many control charts?
Because you have to estimate μ and sigma using the average and range of your samples.

In variable charts the XmR uses a sample size of 1, XbarR (2-10) and XbarS (11-25). These small samples may be taken from lots of 1,000 or more.

In attribute charts the c and np chart use small samples and "fixed" populations; the u and p charts have varying populations. So, you have to adjust the formulas to compensate for the varying samples and populations.

To reduce the cost of inspection at Western Electric in the 1930s, Dr. Walter S. Shewhart developed a set of formulas and constants to compensate for these variations in sample size and population. That's why they are sometimes called Shewhart Control Charts.

Reference: You can find these in *any book* on statistical process control (e.g., Introduction to Statistical Process Control, Montgomery, Wiley, 2001, pgs. 207-265).

So, stop worrying about the formulas. Start monitoring your process using the charts.

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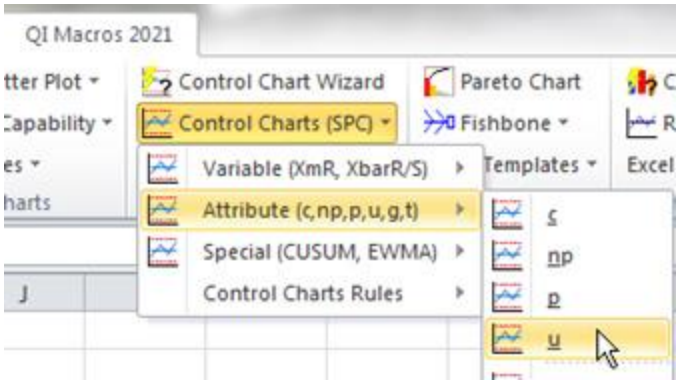
Creating Control Charts with QI Macros

There are two different ways to create most charts in the QI Macros. One is by selecting your data and then running a macro from the QI Macros Menu. The second is by using the QI Macros templates.

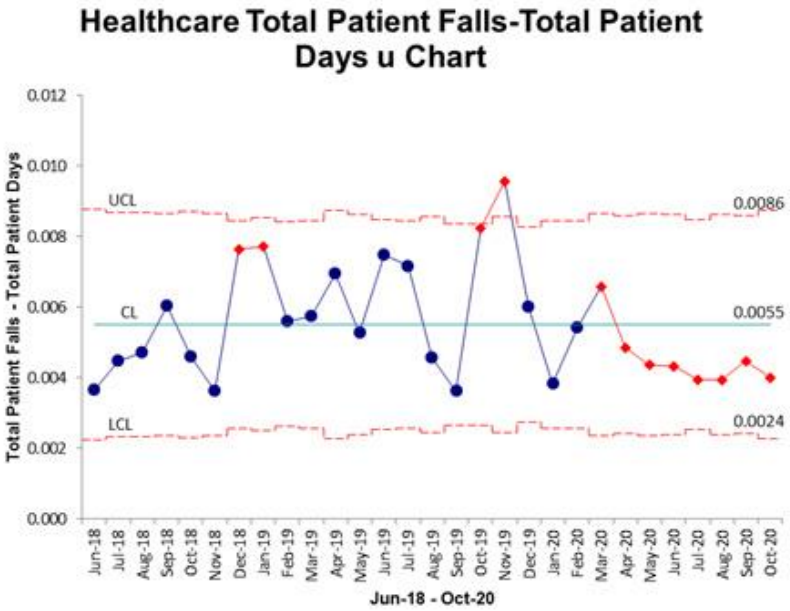
Create a Chart Using a Macro

To create a chart using a macro from the QI Macros Menu:

1. Just select the data to graph (using the mouse to click and drag).
2. Then, using the QI Macros menu, select the chart you want to graph.



If you don't know which chart to use, select your data and choose the Control Chart Wizard in the QI Macros. The QI Macros will do the math and draw the graph for you. The control chart macros will run stability analysis on your data and turn any unstable points or conditions red.



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If the labels and data are not adjacent, you can use the control key function in Excel (select the first set of data, press down on the control key (CTRL), and then select the second range of data.)

	A	B	C	D	E
1	Month	C-Sections	Total Deliveries	Total Patient Falls	Total Patient Days
2	Jul-98	65	370	17	4658
3	Aug-98	64	383	22	4909
4	Sep-98	77	446	23	4886
5	Oct-98	59	454	30	4970
6	Nov-98	64	463	22	4780
7	Dec-98	74	431	18	4973
8	Jan-99	72	443	44	5762
9	Feb-99	67	451	42	5441
10	Mar-99	59	433	33	5893

Data Input and Format Tips

When you select the data you want to graph, you can select the associated labels as well (e.g., Jan, Feb, Mar, etc.) The QI Macros will use the labels to create part of your chart (e.g., title, axis name, legend). Make sure you follow these rules when inputting your data.

1. **Labels should be formatted as text**. If your labels are numbers (e.g., 1,2,3) you need to make them text so that Excel doesn't treat them as part of your data. To do this, you will need to put text in front of them. Some examples are: Sample1, S1, Lot1, L1. If you just want the 1 to show then you will need to put an apostrophe ' in front of each number to change it from data to text (e.g., '1, '2, '3 etc.) ***Note:*** *just using the format function in Excel does NOT work.*
2. **Data should be formatted as numbers**. Your data must be numeric AND formatted as a number for the macros to perform the necessary calculations. If you have "data" that is left justified or looks like 001, 002, 003 then it is formatted as text and the macro will not run.

   Tip: Data exported from Microsoft Access is often in text format. To change it to numeric: 1) import the data to Excel, 2) put the number 1 in a blank cell, 3) Edit-Copy the cell with the 1 in it, 4) select the imported text data, and 5) choose Edit-Paste Special/Multiply to multiply every imported cell by 1 which will convert them to numeric data.
3. **Select the right number of columns**. Each chart requires a certain number of columns of data to run properly. They are:
   - 1 column: Pareto, Pie, Run, C chart, np chart, XmR chart
   - 1 or more columns: Line, Bar, Histogram
   - 2 columns: Scatter, u chart, p chart
   - 2 or more columns: Box & Whisker, Multivari, XbarR and XbarS

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4. **Beware of "hidden" rows or columns.** If you select columns A:F, but B and C are hidden, the QI Macros will use all five columns including the hidden ones. To select columns that are not adjacent to each other use the control key.
5. **The QI Macros and the statistical tools work best when data is organized in columns, not rows.** So, for an XbarR chart, you might have Sample1, Sample2, ... Sample5 across the top, and then lot numbers or dates down the left-hand side. The macros will work if your data is laid out horizontally in rows instead of in columns, but vertical columns is the preferred method.
6. **Decimal places**. To get the correct number of decimal places, format your data as Numeric (1-6 decimal places) vs General (which has no precision).

Sample Test Data
xThe QI Macros for Excel installs test data on your PC in My Documents\QI Macros Test Data. Use this data to practice with the charts and to determine the best way to format the data before you run a macro.

Selecting Your Data Correctly

We have tried to mistake-proof the QI Macros, but we have to make certain assumptions about the data you select before running a chart. One assumption is that you have no more than one row of headings and one column of labels. **If you have two rows of headings or two columns of labels, BE CAREFUL**. QI Macros eliminates extra rows or columns of headings.

Tips for selecting your data:

- Don't select the whole column or row, just the data and associated labels you want to graph.
- Make sure you only select one row and one column of labels.

Control Chart Limits

Control chart limits are based on the average of your data. Therefore, when the average changes, your control limits will change as well. Generally, you should use the first 20 to 25 points of data to calculate the average and the baseline control limits. Future data points should be evaluated against the baseline. You should only recalculate the average and corresponding control limits when you have a process change.

How Control Chart Limits are Calculated in the QI Macros

When you select data and then run a control chart using the QI Macros Menu, QI Macros will use ALL your data points to calculate the average. The average field is then used to calculate the 1 and 2 sigma lines and the upper and lower control limits. If you have 14 points it will use 14 points, if you have 26 points it will use 26 points, if you have 50 points it will use 50 points, etc.

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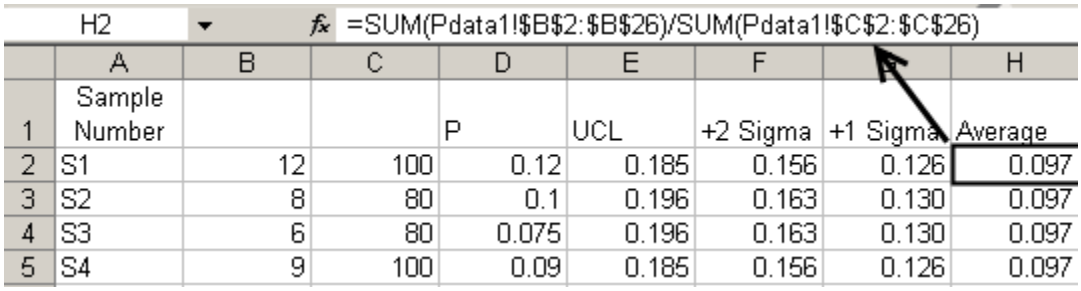
To view which points are used to calculate your average, simply click on the data sheet created by the QI Macros (e.g., pdata1) and then click on the first cell under the cell labeled "Average". You can determine the data used in the average formula in one of two ways.

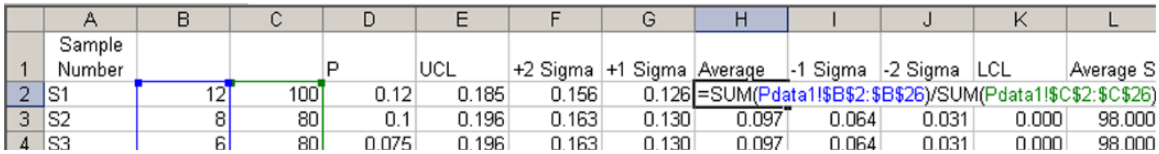
1. View the formula in Excel's formula bar. This will show the range of data that is used to calculate the average. In the following example, we clicked on cell H2 and noted that the average is calculated using cells B2 to B26 and C2 to C26.



H2 =SUM(Pdata1!$B$2:$B$26)/SUM(Pdata1!$C$2:$C$26)

	A	B	C	D	E	F	G	H
1	Sample Number			P	UCL	+2 Sigma	+1 Sigma	Average
2	S1	12	100	0.12	0.185	0.156	0.126	0.097
3	S2	8	80	0.1	0.196	0.163	0.130	0.097
4	S3	6	80	0.075	0.196	0.163	0.130	0.097
5	S4	9	100	0.09	0.185	0.156	0.126	0.097

2. Depending on the chart, these formulas can be hard to read. **Another way to determine the cells used to calculate the average is to use the F2 function key.** The function keys are located at the top of your keyboard. When you click on a cell and then the F2 function key, Excel will highlight the cells used in the formula for that cell. In the example below, Excel draws a border line around cells B2 to B26 and C2 to C26.

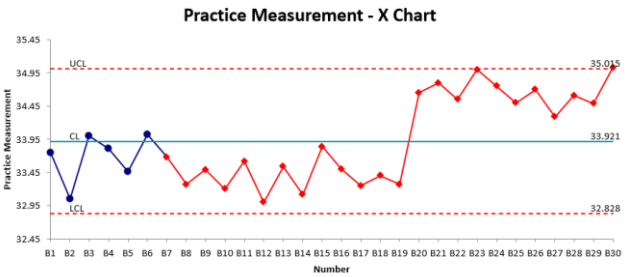


	A	B	C	D	E	F	G	H	I	J	K	L
1	Sample Number			P	UCL	+2 Sigma	+1 Sigma	Average	-1 Sigma	-2 Sigma	LCL	Average S
2	S1	12	100	0.12	0.185	0.156	0.126	=SUM(Pdata1!$B$2:$B$26)/SUM(Pdata1!$C$2:$C$26)				
3	S2	8	80	0.1	0.196	0.163	0.130	0.097	0.064	0.031	0.000	98.000
4	S3	6	80	0.075	0.196	0.163	0.130	0.097	0.064	0.031	0.000	98.000

Changing Control Chart Limits After Running a Chart

Often, after stabilizing a process, you will want to "lock" the control limits. Then you'll be able to easily compare current performance with past performance. Doing this with the QI Macros Chart Menu is easy.

Let's say you've run an XmR chart using our data:



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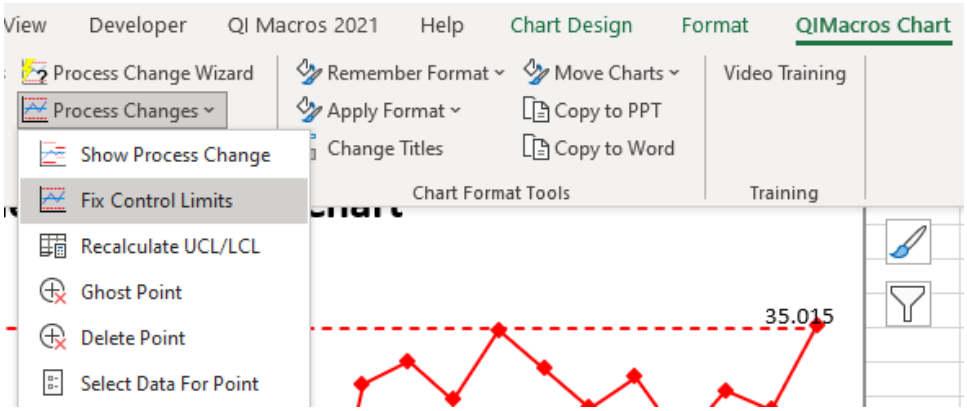
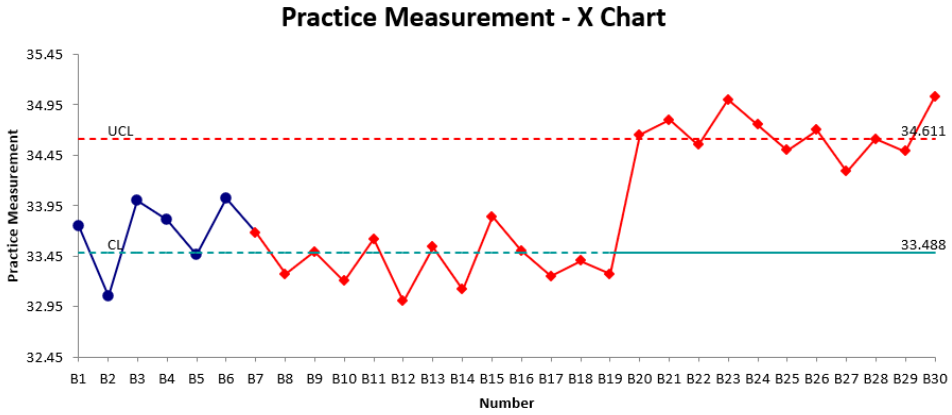
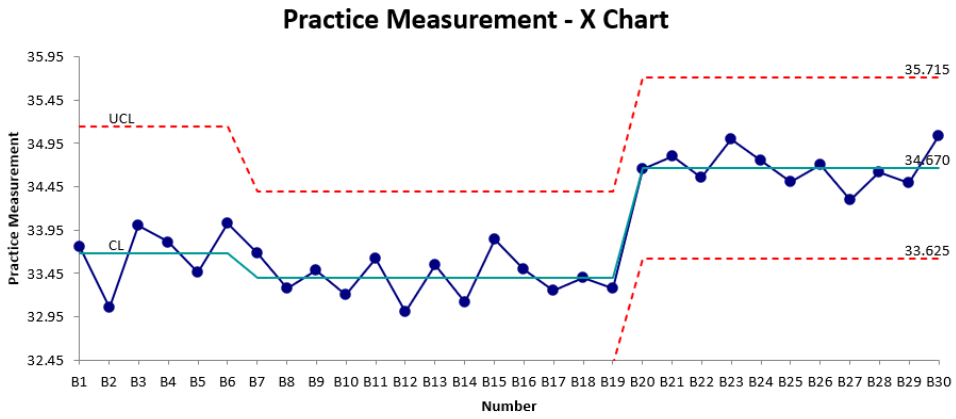
Since there are 30 data points, all 30 were used to calculate the control limits. But what if you wanted to only use the first 19 points as the data points that represent your process performance? Just click on the 19th point to select it and use Fix Limits under the QI Macros Chart Menu to change the formulas:





You could also use the Process Change Wizard to automatically identify all changes. The revised chart will look like this:



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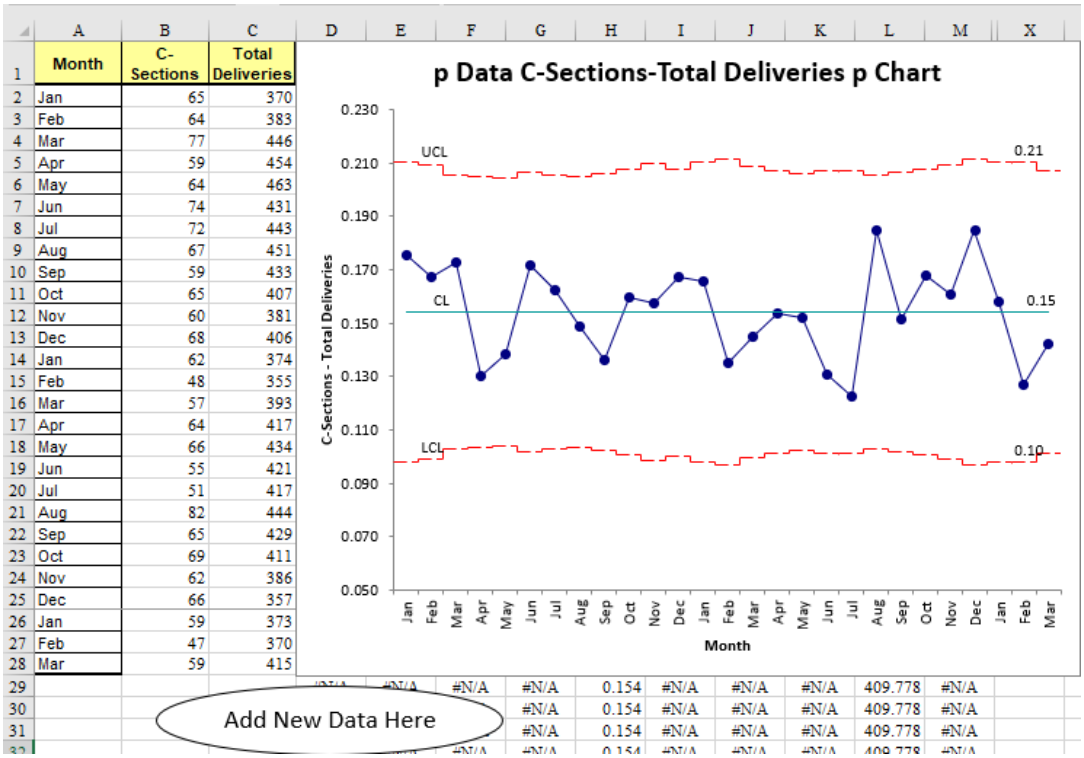
Adding Data to Existing Charts

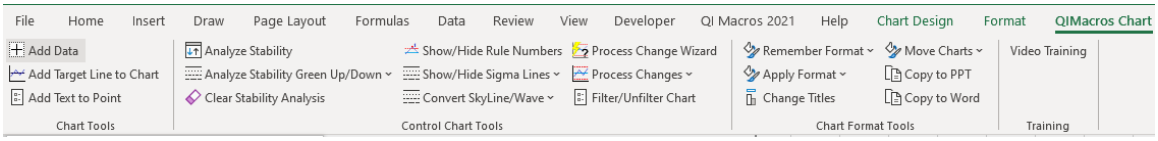
When you run a macro, you end up with the chart and data spreadsheet where all the calculations are performed. To add data to an existing chart:

1. Add the new data and labels in the rows under your old data.



If necessary, use Edit/Copy and Edit/Paste to copy any formulas down to the new rows.

2. Click on the chart. Then click on the QI Macros Chart Menu and select "Add Data".



3. Input the number of rows of data you just added to the intermediate spreadsheet and click OK. This function will change the "source data range" of the chart and will update the chart to display your new data.

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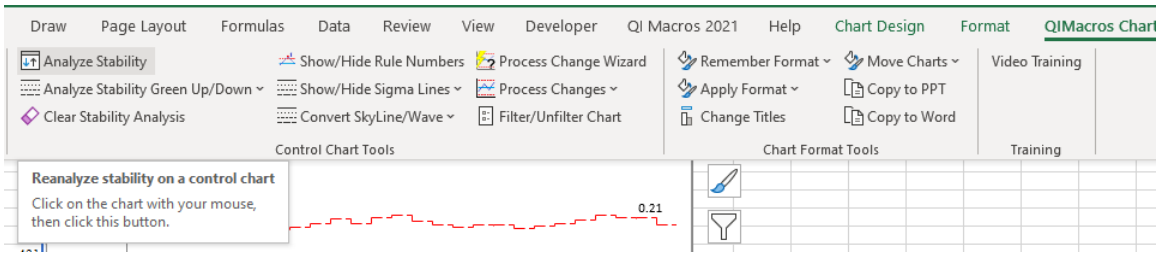
Re-Analyzing Stability

To re-run stability analysis on the chart. Click on the chart. Use the QI Macros Chart Menu to select "Analyze Stability". The QI Macros will rerun stability analysis on your old and new data.



Recalculating Control Chart Limits to Include New Data

When you run a chart from the QI Macros Menu and then add data to the existing chart, the control limits DO NOT recalculate. If you want the control limits to recalculate using your new data, there are two options.

1. You might consider using one of the QI Macros control chart *templates*. These are set up to take 50 data points and the control limits will recalculate every time you add new data. Click on Control Chart Templates to access these.
2. Use the Show Process Change function to recalculate the control limits. To do this, click on the chart and then select Recalculate UCL/LCL from the Chart Menu.

Delete a Point from a Control Chart

To delete a point from a control chart:

1. Click on the chart.
2. Click on the point you want to delete.
3. Click on the QI Macros Chart Menu and select Delete Point.
4. Rerun stability analysis without the deleted point.

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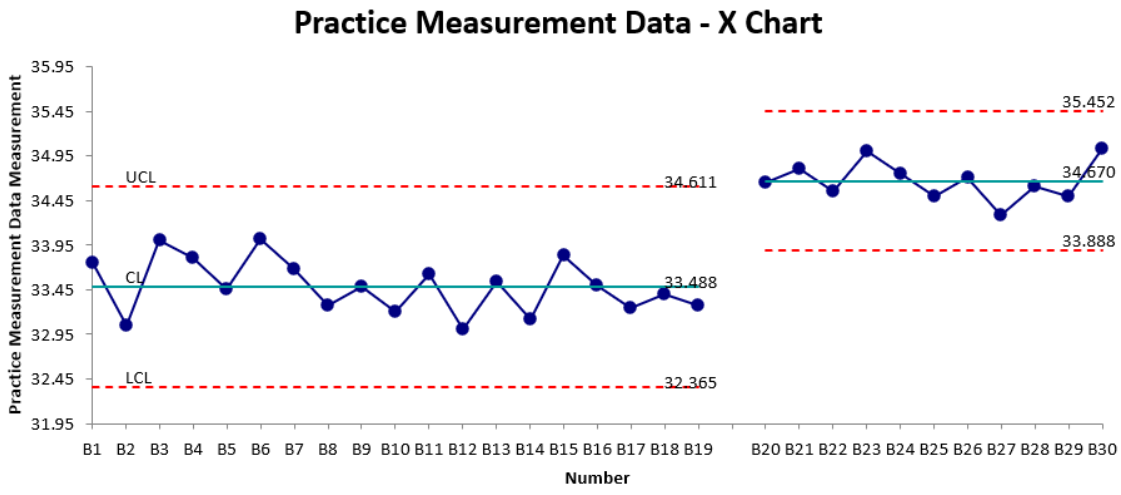
Show Process Change on a Control Chart

Before You Run a Chart

To calculate two or more sets of control limits on new charts simply leave a blank row between the data points where you want the limits to change.

	A	B	C
1	Number	Measurement	
2	B1	33.75	
3	B2	33.05	
4	B3	34.00	
5	B4	33.81	
6	B5	33.46	
7	B6	34.02	
8	B7	33.68	
9	B8	33.27	
10	B9	33.49	
11	B10	33.20	
12	B11	33.62	
13	B12	33.00	
14	B13	33.54	
15	B14	33.12	
16	B15	33.84	
17	B16	33.50	
18	B17	33.25	
19	B18	33.40	
20	B19	33.27	
21			Additional Data
22	B20	34.65	
23	B21	34.80	

Select the data including the blank row(s) and run the chart. You should get a chart with two or more sets of control limits.



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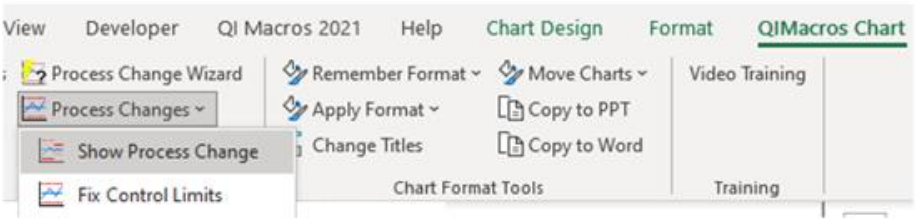
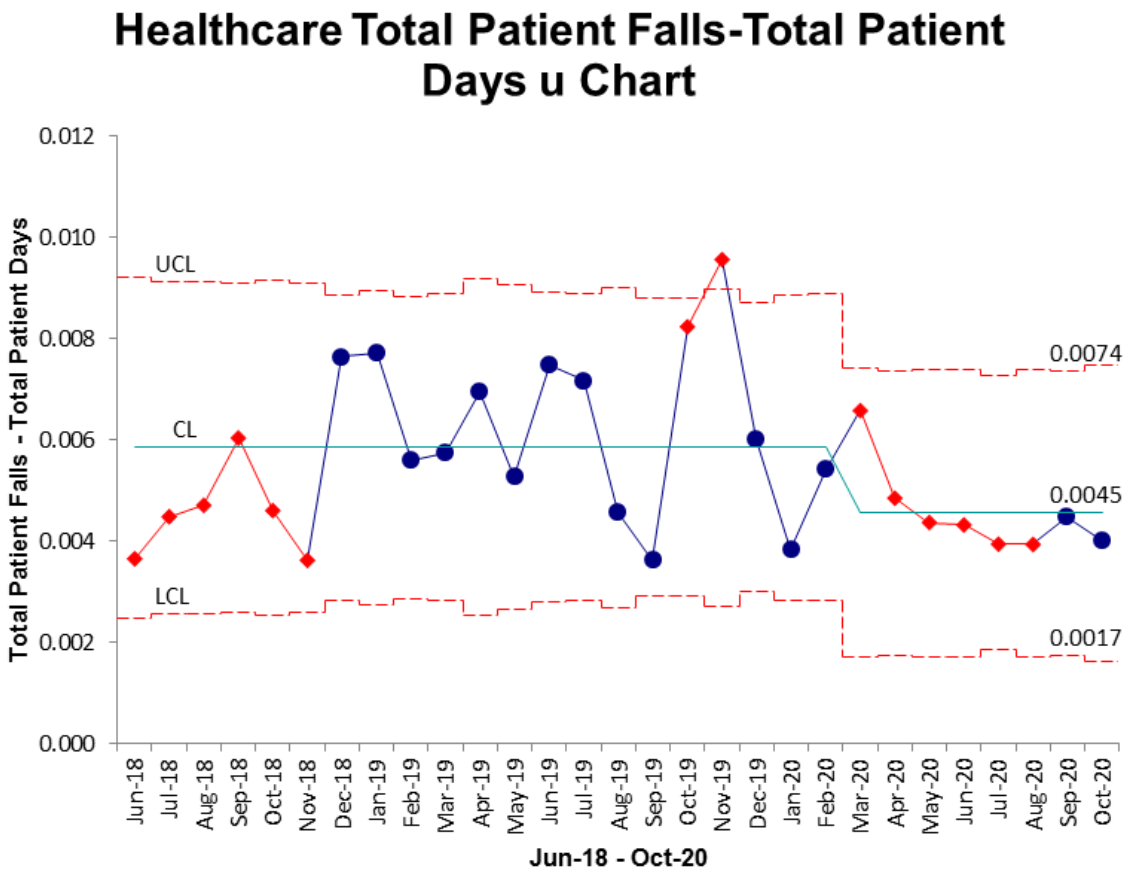
After You Run a Chart

Go to the chart and click on the first data point where the process change occurred. **Note**: The first time you click on the point, Excel will select the whole line. Click on the point a second time to get just the point. If you have done this correctly, Excel will highlight your point and the point before it.

Click on the QI Macros Chart Menu and select Show Process Change:



The macros will calculate a new set of control limits starting at the data point you selected. The macros will also update the UCL, Average and LCL labels to reflect the second set of control limits. **Note:** You can do this more than once on the same chart.



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Don't forget to rerun stability analysis using the new control limits. Click on the chart sheet. Use the QI Macros Chart Menu to select "Analyze Stability". QI Macros will rerun stability analysis using the new control limits.

Compare Different Process on the Same Chart

As previously indicated, adding a blank row to your data before you run a control chart will calculate two different sets of control limits? One set will be calculated using the data before the blank row and the second set will be calculated using the data after the blank row.

This functionality is most commonly used to show a process change on a control chart. However, many customers use it to compare two different processes side by side. If you are in healthcare, you could compare data for several different doctors, hospitals, floors, etc. If you are in manufacturing, you could compare data from different machines, lots, batches etc.

You might start with data that looks like this.:

	A	B	C	D	E
1	**Day**	**Shi**	**Machine 1**	**Machine 2**	**Machine 3**
2	1	Day	92.6	90.5	81.6
3	1	Swing	88.7	90.6	82.8
4	2	Day	91.8	96.3	88.9
5	2	Swing	87.0	87.6	84.0
6	3	Day	90.5	89.4	82.8
7	3	Swing	93.7	88.4	88.7
8	4	Day	90.5	89.7	84.1
9	4	Swing	92.5	91.2	80.9
10	5	Day	89.6	92.3	87.4
11	5	Swing	93.3	88.8	90.2
12	6	Day	95.3	95.9	86.4
13	6	Swing	93.2	91.2	91.0
14	7	Day	90.4	90.2	81.1
15	7	Swing	91.9	92.6	90.7
16	8	Day	93.9	87.2	83.3
17	8	Swing	94.2	89.6	89.0
18	9	Day	92.3	85.6	81.0
19	9	Swing	92.5	98.9	80.9
20	10	Day	91.5	92.1	88.1
21	10	Swing	89.9	87.6	81.3
22	11	Day	94.6	90.5	88.4
23	11	Swing	90.1	87.0	83.7
24	12	Day	96.6	87.8	90.2
25	12	Swing	93.4	85.5	85.4

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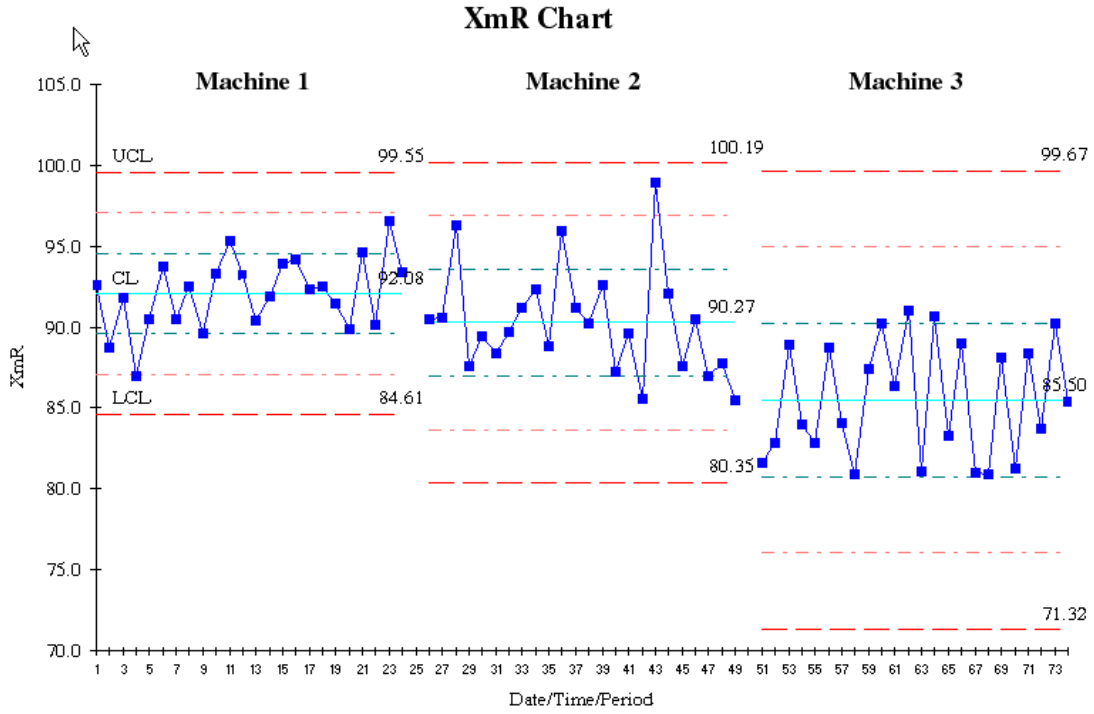
Use Excel's cut and paste functions to reorganize your data. Move the machine 2 and machine 3 data below the machine 1 data in the **same** column. Leave a blank row between the data for each machine. In the example below, C25 is the last value for machine 1 then we leave a blank row and paste machine 2's data starting in C27.

	A	B	C
19	9	Swing	92.5
20	10	Day	91.5
21	10	Swing	89.9
22	11	Day	94.6
23	11	Swing	90.1
24	12	Day	96.6
25	12	Swing	93.4
26			
27			90.5
28			90.6
29			96.3
30			87.6
31			89.4

Now select the data and run an XmR chart. Use the text box tool to label the data for each machine.



These side-by-side charts make it much easier to compare machines. You can easily see that the average yield for machine 3 is lower than machines 1 and 2. You can also tell how much wider the control limits are for machine 3. This means there is much more variation in the yields for machine 3.

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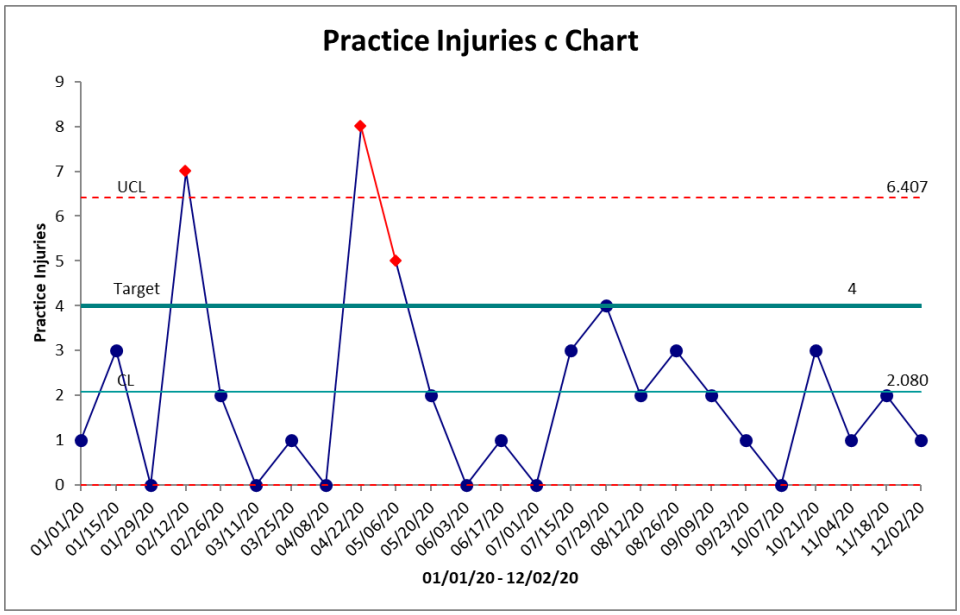
Add Target or Goal Lines to Control Charts

Remember control limits are calculated from your data. However, you can also show a target or goal line on your control chart in one of two ways:

1. Use Excel's drawing tools to simply draw a target line on your existing control chart. Then use Excel's drawing tools to add a text box to label the line. Note: If you add data to the chart you may need to re-synch up the line.
2. Add target line to the chart.
    - Click on the chart
    - Select Add Target Line to Chart from QI Macros Chart Menu.



Creating a Chart with a QI Macros Template

You can also create charts with QI Macros Templates. These templates are especially helpful if you have non-quality department personnel (e.g.: at nursing stations or on the shop floor) who will be inputting data, or you don't have enough data (you're starting to collect the data).

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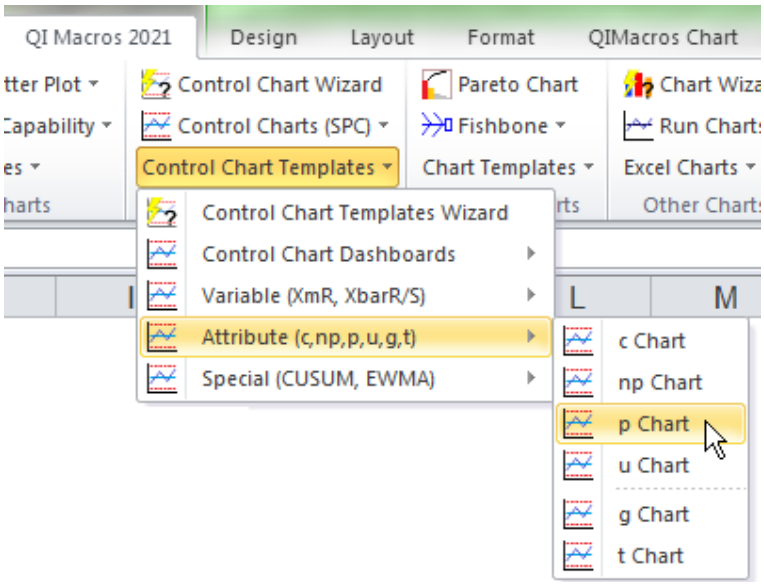
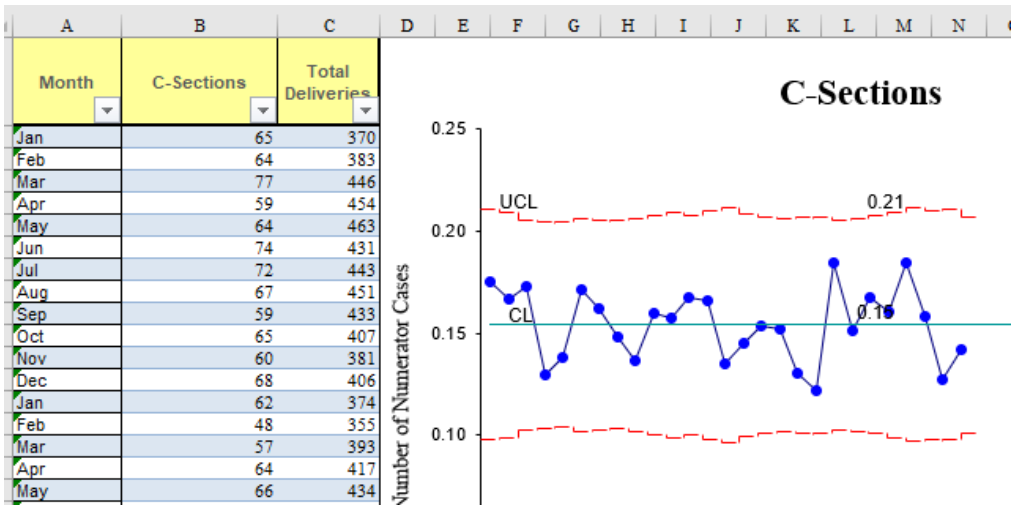
To create a chart using a template:

1. Click on the QI Macros menu, Control Chart Templates, then the chart you want.



2. The input areas for all the templates are shaded yellow. Either input your data directly into the template, cut and paste it from another Excel spreadsheet, or set the template input cells equal to cells in other spreadsheets.



3. As you input data, the chart will populate to the right. The X chart templates also display a histogram, probability plot and scatter plot.

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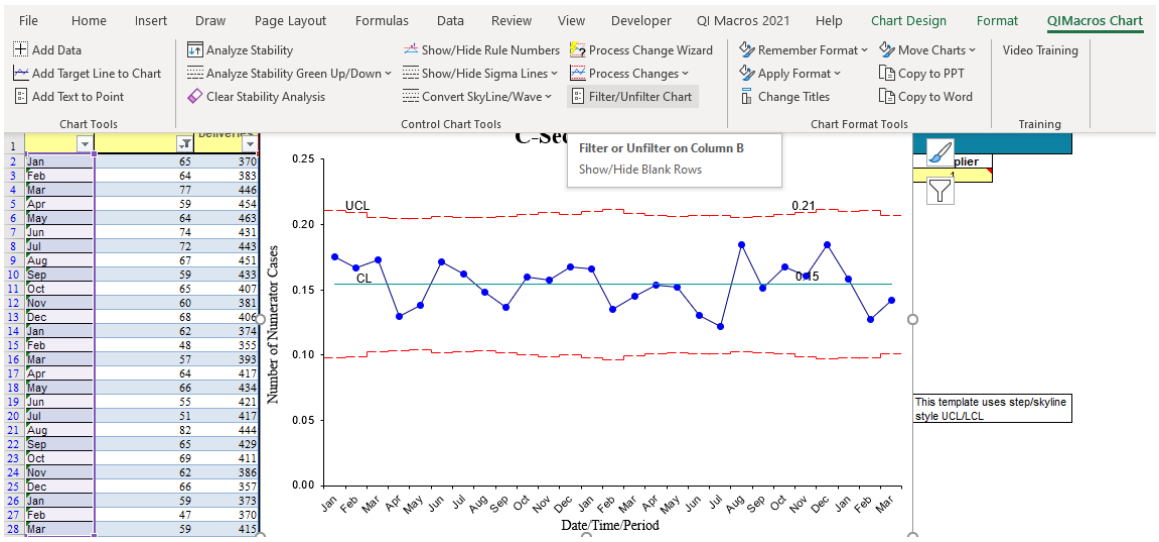
Choosing Which Points to Plot

Each template defaults to 50 data points. If you have fewer than 50 points and only want to show the points with data, click on the chart and use the QI Macros Chart Menu. Select Filter/Unfilter Chart to plot only the points with data.



Adding New Data

Control Chart templates are set up to take 50 data points. To add data to a template:

1. Make sure the data is unfiltered so that all input rows are visible.
2. Simply input data into the next blank row. The chart will expand to include the next data points.
3. Re-run stability analysis whenever you have added new data by clicking on the chart and then clicking on the QI Macros Chart Menu. Select Analyze Stability to run stability analysis on your data. Any unstable point or condition will turn red.

Analyzing Stability

To run stability analysis on a chart created using a control chart template click on the chart, click on the QI Macros Chart Menu, and select Analyze Stability.

Delete a Point from a Control Chart Template

To delete a point on a control chart template simply delete that point or row from the input area.

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Formulas

If you have QI Macros, you don't need to know the formulas. Just focus on the charts and what they tell you. If you want to know the formulas, they are provided here for your reference.

Control Chart Constants

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	n	A	A2 for Ave	A2 for Median	A3		c4	1/c4		B3	B4	B5	B6		d2	1/d2		d3	D3	D4	E2	E3	Efficiency of Median	Fractional Factorial
2	2	2.121	1.881	1.881	2.659		0.798	1.253		0.000	3.2670	0.000	2.606		1.128	0.564		0.853	0.000	3.267	2.659	3.760	1	0.5
3	3	1.732	1.023	1.187	1.954		0.886	1.128		0.000	2.5680	0.000	2.276		1.693	0.847		0.888	0.000	2.574	1.772	3.385	0.743	1.5
4	4	1.500	0.729	0.796	1.628		0.921	1.085		0.000	2.2660	0.000	2.088		2.059	1.030		0.880	0.000	2.282	1.457	3.256	0.838	2.5
5	5	1.342	0.577	0.691	1.427		0.940	1.064		0.000	2.0890	0.000	1.964		2.326	1.163		0.864	0.000	2.114	1.290	3.192	0.697	3.5
6	6	1.225	0.483	0.549	1.287		0.952	1.051		0.030	1.9700	0.029	1.874		2.534	1.267		0.848	0.000	2.004	1.184	3.153	0.776	4.5
7	7	1.134	0.419	0.509	1.182		0.959	1.042		0.118	1.8820	0.113	1.806		2.704	1.352		0.833	0.076	1.924	1.109	3.127	0.679	5.5
8	8	1.061	0.373	0.432	1.099		0.965	1.036		0.185	1.8150	0.179	1.751		2.847	1.424		0.820	0.136	1.864	1.054	3.109	0.743	6.5
9	9	1.000	0.337	0.412	1.032		0.969	1.032		0.239	1.7610	0.232	1.707		2.970	1.485		0.808	0.184	1.816	1.010	3.095	0.669	7.5
10	10	0.949	0.308	0.362	0.975		0.973	1.028		0.284	1.7160	0.276	1.669		3.078	1.539		0.797	0.223	1.777	0.975	3.084	0.723	8.5
11	11	0.905	0.285	0.350	0.927		0.975	1.025		0.321	1.6790	0.313	1.637		3.173	1.587		0.787	0.256	1.744	0.945	3.076	0.663	9.5
12	12	0.866	0.266	0.316	0.886		0.978	1.023		0.354	1.6460	0.346	1.310		3.258	1.629		0.778	0.283	1.717	0.921	3.069	0.709	10.5
13	13	0.832	0.249	0.307	0.850		0.979	1.021		0.382	1.6180	0.374	1.585		3.336	1.668		0.770	0.307	1.693	0.899	3.063	0.659	11.5
14	14	0.802	0.235	0.281	0.817		0.981	1.019		0.406	1.5940	0.399	1.563		3.407	1.704		0.763	0.328	1.672	0.881	3.058	0.699	12.5
15	15	0.775	0.223	0.275	0.789		0.982	1.018		0.428	1.5720	0.421	1.544		3.472	1.736		0.756	0.347	1.653	0.864	3.054	0.656	13.5
16	16	0.750	0.212	0.255	0.763		0.983	1.017		0.448	1.5520	0.440	1.526		3.532	1.766		0.750	0.363	1.637	0.849	3.050	0.692	14.5
17	17	0.728	0.203	0.251	0.739		0.985	1.016		0.466	1.5340	0.458	1.511		3.588	1.794		0.744	0.378	1.622	0.836	3.047	0.653	15.5
18	18	0.707	0.194	0.235	0.718		0.985	1.015		0.482	1.5180	0.475	1.496		3.640	1.820		0.739	0.391	1.608	0.824	3.044	0.686	16.5
19	19	0.688	0.187	0.231	0.698		0.986	1.014		0.497	1.5030	0.490	1.483		3.689	1.845		0.733	0.403	1.597	0.813	3.042	0.651	17.5
20	20	0.671	0.180	0.218	0.680		0.987	1.013		0.510	1.4900	0.504	1.470		3.735	1.868		0.729	0.415	1.585	0.803	3.040	0.681	18.5
21	21	0.655	0.173	0.217	0.663		0.988	1.013		0.523	1.4770	0.516	1.459		3.778	1.889		0.724	0.425	1.575	0.794	3.038	0.637	19.5
22	22	0.640	0.167	0.210	0.647		0.988	1.012		0.534	1.4660	0.528	1.448		3.819	1.910		0.720	0.434	1.566	0.786	3.036	0.637	20.5
23	23	0.626	0.162	0.203	0.633		0.989	1.011		0.545	1.4550	0.839	1.438		3.858	1.929		0.716	0.443	1.557	0.778	3.034	0.637	21.5
24	24	0.612	0.157	0.197	0.619		0.989	1.011		0.555	1.4450	0.549	1.429		3.895	1.948		0.712	0.410	1.548	0.770	3.033	0.637	22.5
25	25	0.600	0.153	0.191	0.606		0.990	1.010		0.565	1.4350	0.559	1.420		3.931	1.966		0.708	0.459	1.541	0.763	3.031	0.637	23.5

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