When Should We Compute New Limits?

How to use the limits to track the process.

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Last month in "Exact Answers to the Wrong Questions" we looked at how we can compute useful limits with as few as six to ten values. In this column I would like to consider the question of how to use the limits on a process behavior chart to understand the underlying process. In order to do this we need to answer the related question of "When should we compute new limits?"

This question about computing new limits usually takes one of two forms. Most often it has to do with "When do we need to update the limits of a continuing chart?" Occasionally it has to do with "When do we need to polish the limits that we have just computed?" I will discuss both of these issues in this column.

Updating Limits on a Continuing Chart

Three-sigma limits computed in the proper manner are robust. (For an explanation of the right and wrong ways of computing limits see my columns for January and February of 2010.) Correctly computed limits will usually detect signals of exceptional variation *even though the exceptional variation is part of the computation*. This ability to get good limits from bad data minimizes the need to polish the limits. However, from time to time, it is necessary and appropriate to update your limits.

Ultimately the answer to the question of when to compute new limits requires both judgment and process knowledge. You should always seek to use the limits to characterize the current process in a realistic manner. As guidance to making this decision a colleague of mine, Perry Regier, found the following set of questions to be helpful.

1. Does the process display a distinctly different kind of behavior than in the past?

   Any of the traditional signals of a change, such as a point outside the limits, or a run that satisfies one of the Western Electric zone-tests, may be interpreted as a signal of a process change. No additional test or analysis is needed.

2. Is the reason for this change in behavior known?

   If the change coincides with a known and deliberate change in the process inputs, then you can use the chart to characterize the effect of the known change. If the change is a spontaneous change that corresponds to no known changes, then you can be reasonably certain that there are important, yet unknown, cause-and-effect relationships that affect your process. These are called assignable causes of exceptional variation.

3. Is the new process behavior desirable?

   Reduced process variation is desirable. Operating closer to a target value is desirable. Increased variation, operating further from the target, and a process average that is moving around will create excess costs and are therefore undesirable.

4. Is it intended and expected that the new behavior will continue?

   The intent of this question is to determine if the process change was spontaneous or deliberate. Spontaneous improvement is rare. Spontaneous deterioration is common. Either way, when the changes are spontaneous, you need to find out the cause.

With these four questions Perry Regier defined a filter to use when deciding whether to update the limits. When the answer to all four questions is yes, then it is appropriate to revise the limits based on data collected since the time when the process change.

If the answer to Question One is no, and the limits are based on 10 to 20 values (or 10 to 20 subgroups), then there should be no need for new limits. (If the limits are based on fewer data and there is no evidence of a process change, then updating the limits as new data become available is recommended.)

If the answer to Question Two is no, then the computation of new limits will not help. You should be looking for the assignable cause of the change in the process instead of tinkering with the limits.

If the answer to Question Three is no, then you will need to identify the assignable cause of the undesirable behavior if you hope to keep it from continuing to haunt your process. Computing new limits will not prevent the undesirable process behavior.

If the answer to Question Four is no, then you are admitting that your process has multiple personality disorder, and the only cure for this disease is to find the assignable causes of the process changes. Once again, tinkering with the limits misses the point.

Remember, the objective is to take the right action on the process. No credit is given for finding the "right numbers."

Thus, one occasion for recalculating limits is when a deliberate change has been made in the process. Here it is logical to collect data following the change and use these new data to compute new limits. The difference, if any between the new and old limits will characterize the effect of the deliberate process change.

Sometimes, when using process behavior charts, the feedback provided by the charts will allow each step to be done with slightly less variation. The cumulative effect of these reductions in variation will often be a dramatic improvement downstream. In cases such as this, while there may not be a single dramatic process change, there may still be a need to update your limits. Perry Regier's four-question-filter works in this case as well.

While the Perry's four-question-filter provides one way to answer the question of when to update your limits, there are other times when a revision of the limits is appropriate. In particular, the charts essentially make a comparison between the current time period and the baseline time period. In effect, the questions asked by the charts are framed by your choice of a baseline period. Over time, your baseline time period will age, and at some point it may cease to adequately characterize your current process. Since we usually do not want to compare our current operation with a baseline period that is ancient history, we will need to periodically use a new baseline period to compute limits that reflect what our process is currently doing. Judgment is required to determine how often this might be appropriate.

For example, while it might make sense with some processes to compute limits each month for use with the next month's data, in most cases this will be an example of excessive updating. At the other extreme, limits from sometime in the 1990s are unlikely to reflect how your process is currently operating. The choice of a rational frequency for updating the limits is a matter of process knowledge, judgment, and listening to the process.

Polishing the Limits

While the correct computations are robust to signals on the average chart, and fairly robust to signals on a chart for individual values, the computations can be corrupted by signals on the range chart. Specifically, range values that are far above the upper range limit will tend to inflate both the average range and the limits on all the charts. However, in most cases, this is not a problem.

Nine times out of ten, when you have points above the upper limit on a range chart, you will also have signals of process changes on the average chart or the chart for individual values. Polishing the limits will tend to remove the inflation from the average range and tighten up the limits. This may result in more points falling outside the limits on both parts of the chart but it will seldom change the story told by the chart.

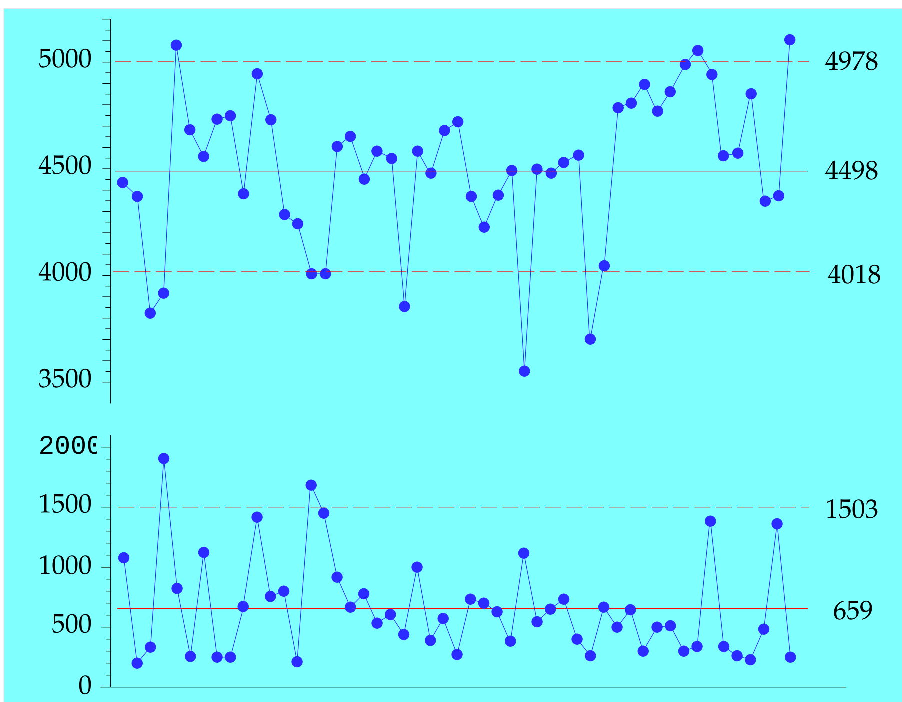

Figure 1: Resistivity Data with Original Limits

In Figure 1 we have an example that comes from page 21 of Shewhart's *Economic Control of Quality of Manufactured Product*. The 204 data were arranged into 51 subgroups of size 4 according to the order of production. The grand average was 4498, and the average range was 659. The limits are:

$$\text{Grand Average} \pm A_2 \text{ Average Range} = 4498 \pm 0.729 * 659 = 4018 \text{ to } 4978$$
$$\text{and} \quad D_4 \text{ Average Range} = 2.282 * 659 = 1503$$

Figure 1 shows 10 averages and 2 ranges outside the resulting limits. This is sufficient to tell us that this process is subject to assignable causes of exceptional variation.

One way to polish these limits is to polish the computation of the average range. If we delete the two large ranges from this computation we find a new average range of 612. This gives an upper range limit of 1396. Now we find two more ranges above this new limit. Upon deleting these we get a new average range of 577. This gives a new upper range limit of 1317. Two more ranges fall above this value. Upon deleting these two ranges we get a fourth average range value of 542. This gives a new upper range limit of 1237. No additional ranges fall above this limit, so at this point we are finished polishing the average range. Using this latest value for the average range we end up with the limits shown in Figure 2.

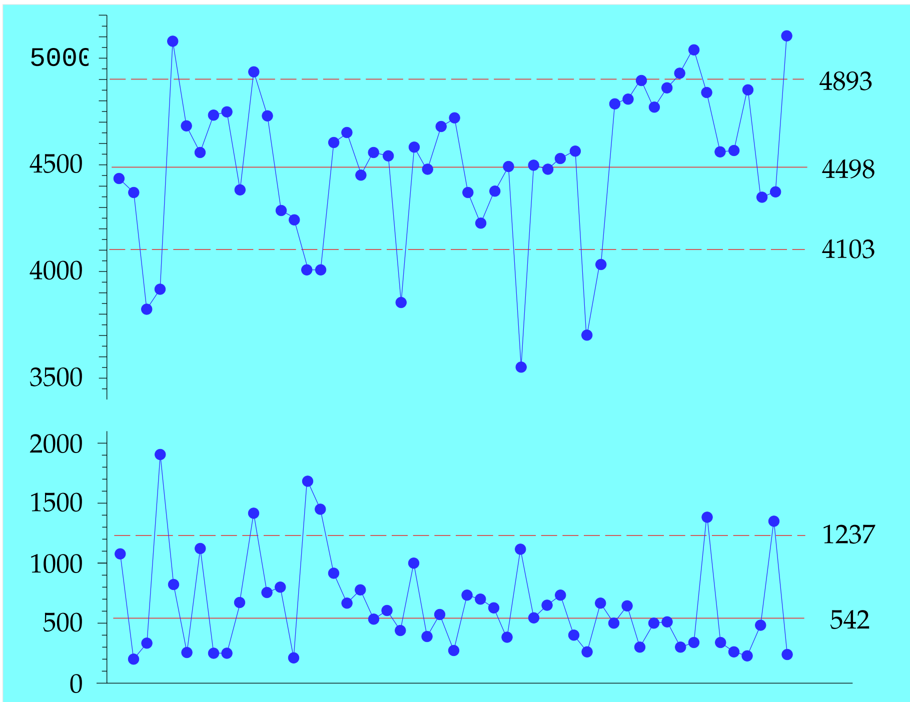

Figure 2: Resistivity Data with Limits Based on Revised Average Range

Now that we have polished our limits we find 13 averages and 6 ranges outside the limits. The new limits are only 82% as wide as the original limits. These limits provide a slightly better approximation to what this process has the potential to do. Unfortunately, until such a time as the assignable causes have been found and made part of the set of controlled factors for this process, this process will continue to operate at less than its full potential.

Some people do not like the delete-and-revise method of polishing the limits because the deletion of some of the data seems slightly suspect. For these, a second method of polishing the data is available. This method uses all of the data, requires only one iteration, and usually ends up with limits that are similar to those obtained from the delete-and-revise approach. This method consists of using the median range instead of using the average range to find the limits.

The median of the 51 subgroup ranges for the data of Figure 1 is 570. This median range and the grand average of 4498 result in the limits shown in Figure 3:

$$\text{Grand Average} \pm A_4 \text{ Median Range} = 4498 \pm 0.758 * 570 = 4066 \text{ to } 4930$$
$$\text{and} \quad D_6 \text{ Median Range} = 2.375 * 570 = 1354$$

These limits are 90% as wide as the limits in Figure 1. Here we find 12 averages and 6 ranges outside the limits. So, once again, we find that this process is subject to assignable causes of exceptional variation.

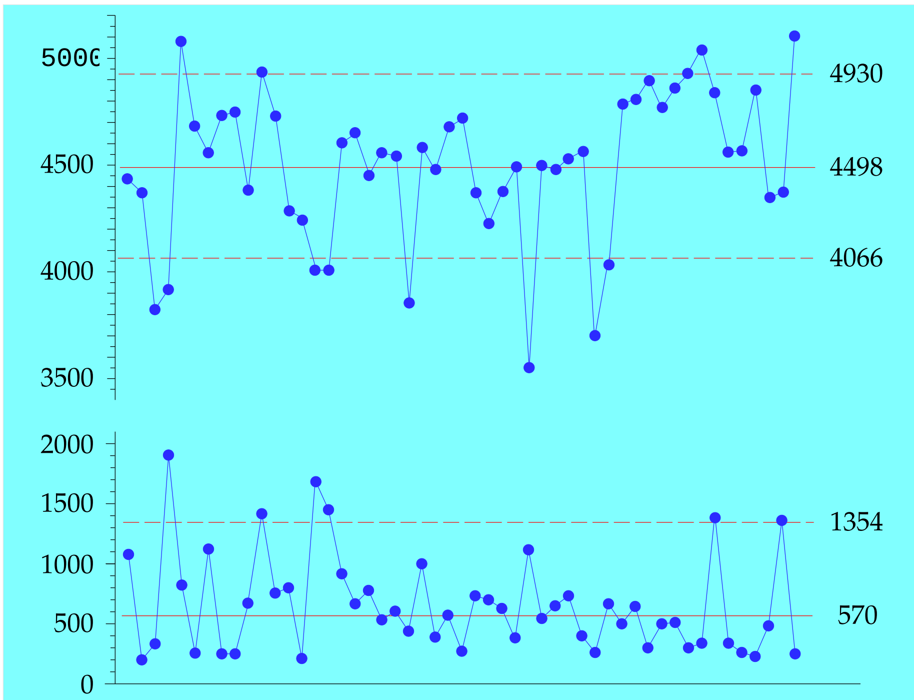

Figure 3: Resistivity Data with Limits Based on the Median Range

So, what have we gained by polishing the limits? We added some small signals to the signals we already had, and we slightly improved our approximation of what the process can be made to do, but we have made no real progress in improving this process. Before you set out to polish your computed limits it is best to stop and ask if such revision is necessary. The objective of the process behavior chart is to provide insight into the process, not practice in arithmetic. If your chart already shows some points outside the limits, the proper course of action is to look for the assignable causes associated with these signals. Revising the limits may give you more points outside the limits, but if you are NOT using the signals you already have, why do you need more signals? Revision of the chart limits will, in effect, make the chart more sensitive. Before you do this, you should ask if it isn't already sensitive enough.

Instead of polishing the limits, it is better to work on finding the assignable causes for signals which have already been identified by the chart. As you find these assignable causes and make them part of the set of controlled factors for the process you will, as a matter of course, collect new data. Whenever this happens you should also routinely compute new limits following each change.

Using the limits in Figure 1, they searched until they found the assignable causes. They then took steps to prevent this exceptional variation from showing up in their process.

Subsequently they collected the data on the right side of the chart in Figure 4. Now the Grand Average is 4418, the Average Range is 367, and the limits for this revised process are only 56% as wide as the original limits. By finding the assignable causes and making them part of the set of controlled factors for this process they not only got rid of the outlying points, but they substantially reduced the process variation as a whole. At this point there is no evidence of any additional assignable causes of exceptional variation in this process.

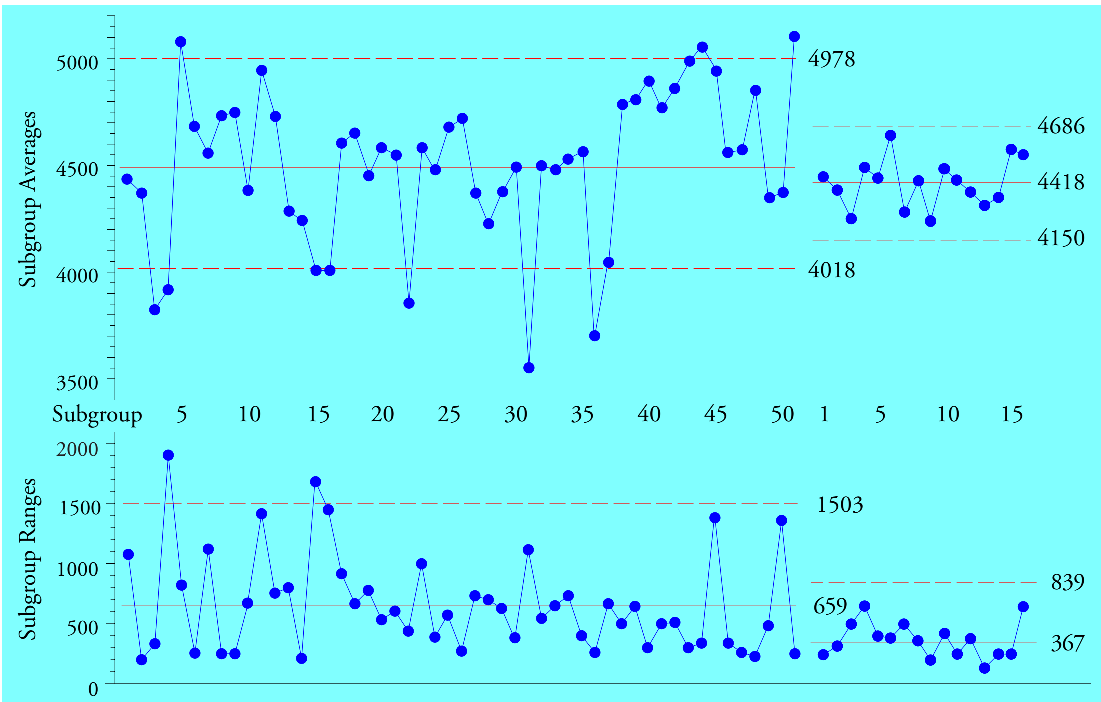

Figure 4: Resistivity Data Before and After Discovery of Assignable Cause

Thus, if you are going to look for assignable causes, and make them part of the set of controlled factors for your process, it is not imperative that your initial limits identify *all* of the assignable causes. Rather, they just need to identify enough of the signals of exceptional variation to allow you to get started by finding *some* of the assignable causes. This means that as long as you have points outside the limits, polishing the limits is a moot point. Compare the polished limits in Figures 2 and 3 with the limits for the improved process in Figure 4.

Summary

While there is a need to periodically update the limits on a process behavior chart, this should not be much of a problem as long as the charts are being used to find the assignable causes of exceptional variation and actions are taken to make these assignable causes part of the set of controlled factors for your process. As these changes are made to your process you will naturally be computing new limits.

On the other hand, the practice of automatically recomputing limits every time a point is added to the chart is unnecessary at best and may be misleading on occasion. Likewise, always using the last 30 points or the last 30 subgroups as some software does ignores the fact that the baseline period frames the questions asked by the charts. The choice of baseline period is always a matter of judgment requiring knowledge of the context for the data.

As Bill Scherkenbach says, the only reason to collect data is to take action. In between collecting the data and taking action on the process you will have to analyze the data in some manner. The process behavior chart provides the simplest way to gain the insight needed to take the right action on your process. The computations are merely a means to this end. Do not get so caught up in the computational cycle that you forget to take action.