When to Use Tightened Specifications

How to ship conforming product

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In "Tightened 100% Inspection" we found that the excess costs associated with tightened specification limits are generally prohibitive. Here we consider the question "Under what conditions can we use tightened specifications without incurring undue excess costs?"

My previous column considered 1052 different combinations of process capability, intraclass correlation, and tightened specification limits. Of these, only 46 combinations even came close to being economically feasible. Moreover, these 46 only worked when the regular specification limits already shipped more than 98.5% conforming product. So tightened specification limits are economical only when very small amounts of conforming product are found near the specifications. The economic burden of rejecting good product makes tightened specifications impractical for use when the specifications cut through the bulk of the histogram. This article will consider what happens with larger capability and performance indexes where the specifications fall in the extreme tails of the histogram.

When a process is operated predictably with both capability indexes in excess of 1.10 there is very little chance of nonconforming product. Here the predictable operation of the process will remove the need for inspection and so there will be little need for tightened specifications. The measurements taken to continue to operate the process in a predictable manner will also suffice to guarantee the conformity of the product produced.

However, when a process is operated unpredictably the process characteristics can change in a moment. Even if such a process has wide specifications, there can still be a need to know if a specific value is inside or outside the specifications. And this is the situation where tightened specification limits can prove useful.

When a process is operated unpredictably and yet has the bulk of its values comfortably within the specifications, so that there are relatively few values near the specifications, we can use tightened specification limits without incurring the economic penalties discussed in the previous article. Here we can use tightened specifications to judge the likelihood of conformity for each value that falls near a specification.

AN EXAMPLE

A production process produces five batches each day. Since batches are well stirred it is reasonable to characterize each batch using its final test value. The specification for the key component of these batches is 700 ± 70. In this plant they characterize each day's production using daily performance indexes as shown in Figure 1.

Day	Final Test Values					P_p	P_{pk}
1	720	712	688	690	690	1.57	1.57
2	692	688	684	688	678	4.41	3.53
3	680	692	682	702	704	2.11	1.87
4	680	682	696	686	678	3.27	2.54
5	685	671	683	671	687	2.99	2.11
6	637	645	639	653	687	1.14	0.36
7	723	721	727	723	723	10.65	7.09
8	713	723	721	731	725	3.57	2.42
9	715	727	727	727	727	4.35	2.82
10	722	716	714	716	722	6.24	4.63
11	727	721	731	725	735	4.32	2.60
12	724	720	718	718	736	3.09	2.06
13	705	705	715	724	752	1.20	0.85
14	745	755	745	769	749	2.32	0.58

Figure 1: Final Test Values for 70 Batches

All performance indexes are descriptions of the past. They summarize the location and dispersion of the data relative to the specifications. Here the performance ratios vary from 1.14 to 10.65, which suggests that there is plenty of elbow room for this process within the specifications. The centered performance ratios for eleven of these days vary from 1.57 to 7.09, which suggests that on these days the process location is comfortably within the specifications. The other three days have centered performance ratios that fall below 1.00, which suggests a potential for nonconforming batches on these days.

Since this industry is regulated and the penalties of shipping a nonconforming batch are severe, the producer wants to be sure the batches are conforming before shipping them. While all of the values in Figure 1 fall within the customer specifications of 630 to 770, the producer wants to take the uncertainties due to measurement error into account before certifying each batch as conforming. This is what tightened specifications allow us to do.

TIGHTENED SPECIFICATIONS

The appropriate increment for creating tightened specification limits is the probable error of a measurement. This value is 0.675 $SD(E)$ where $SD(E)$ is the standard deviation of the measurement system, (also known as repeatability or test-retest error). The probable error is used for creating tightened specification limits because it is the median error of a measurement, and as such it defines the effective resolution of the measurement system.

When an observation falls *less* than one probable error inside the watershed specifications the product can only be said to have a 63% chance of conformity.

When an observation falls more than one probable error inside the watershed specifications the product has more than an 85% chance of conformity.

When an observation falls more than two probable errors inside the watershed specifications the product has more than a 96% chance of conformity.

When an observation falls more than three probable errors inside the watershed specifications the product has more than a 99% chance of conformity.

And when an observation falls more than four probable errors inside the watershed specifications the product has more than a 99.9% chance of conformity.

For more information see "Where Do Manufacturing Specifications Come From?" ***Quality Digest***, July 6, 2010.

For our example, samples from several batches were split and tested in duplicate. The differences between these paired tests averaged 3.68 units. This average range value results in an estimate of the standard deviation of measurement error of 3.26 units. This in turn gives a probable error of 2.20 units. While these measurements were recorded to the nearest whole number, they will err by ± 2 units or more at least half the time.

With watershed specs of 629.5 and 770.5 we find 85% manufacturing specs of 631.7 and 768.3, which become 632 to 768 in practice.

96% manufacturing specs are 633.9 and 766.1, which become 634 to 766 in practice.

99% manufacturing specs are 636.1 and 763.9, which become 637 to 763 in practice.

And 99.9% manufacturing specs are 638.3 and 761.7, which become 639 to 761 in practice.

When we look at the three days with centered performance ratios that are less than 1.00 we find the following. Day 6 had a centered performance ratio of 0.36. The batch values were 637, 645, 639, 653, and 687. So, allowing for measurement error, the first batch can be said to have at least a 99% chance of conformity, while the remaining four batches from day 6 have at least a 99.9% chance of conformity.

Day 13 had a centered performance ratio of 0.85. The batch values were 705, 705, 715, 724, and 752. So all of these batches can be said to have at least a 99.9% chance of conformity.

Day 14 had a centered performance ratio of 0.58. The batch values were

745, 755, 745, 769, and 749. Four of these batches fall below the upper 99.9% specification of 761, and can be said to have at least a 99.9% chance of conformity. The remaining batch had a test value of 769. Allowing for the effects of measurement error, this batch can only be said to have a 63% chance of conformity.

COMMENTARY

Daily performance indexes based on only five values will have 4 degrees of freedom. This means that a 90% interval estimate for each day's performance ratio will vary by about ±55%. Moreover, a 90% interval estimate for each day's centered performance ratio will vary by –70% to +120%. These uncertainties make the computation of performance indexes based on five values a practice that cannot be recommended. Yet, as in this example, I occasionally encounter this triumph of computation over common sense. How much simpler it would be to directly compare the batch values with the tightened manufacturing specifications. Indeed, as seen in Figure 2, a running record of the batch values plotted against the manufacturing specifications would immediately show the conformity of each batch along with the unpredictable operation of the process.

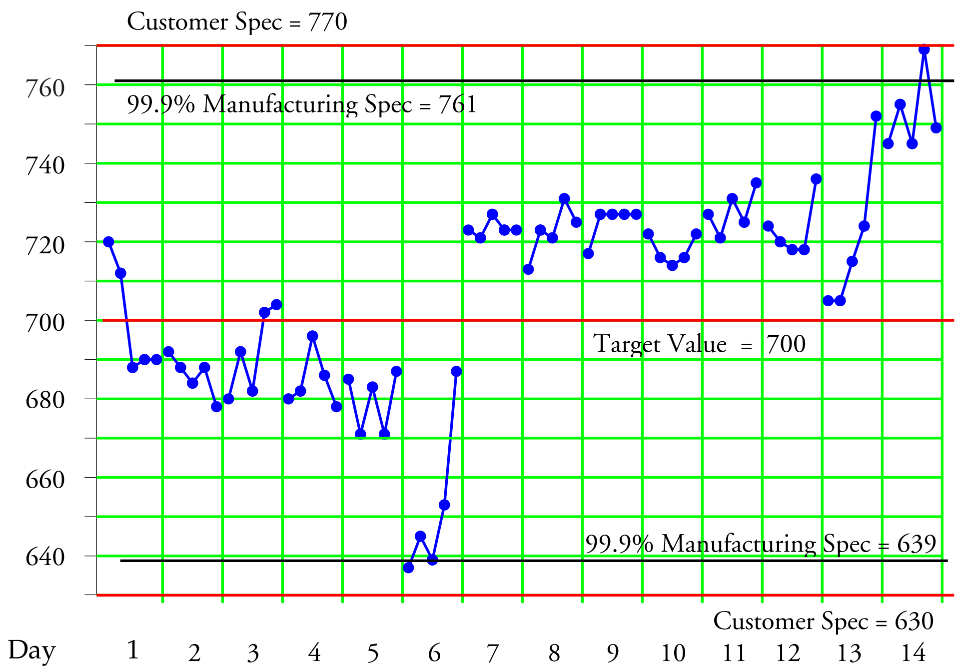

Figure 2: A Process Operating Under the Influence

As Figure 2 makes abundantly clear, this process is operating under the influence of some input that is not being properly controlled. Yes, they have been lucky so far in that all but two of these batches fell safely within the manufacturing specifications. But what will happen when the uncontrolled input takes the process on walkabout outside the specification limits? With process changes like those Figure 2, the only questions are "When will they go outside the specs?" and "Why will it be a surprise when they do so?"

SUMMARY

The economic losses associated with rejecting good product proscribe the use of tightened specification when there are substantial amounts of conforming product near the specifications. However, when operating unpredictably with wide specifications, the use of tightened manufacturing specifications can remove the uncertainties due to measurement error from the question of conformity. So while tightened specifications are no panacea, there are situations where they do have a useful role to play.