# Control charts instead of poker[1]

**To control a process does not mean only to perform measurements, but also to be able to predict them within an interval being as small as possible. In order to reach this objective, one should opt for control charts, instead of playing poker with quality.**

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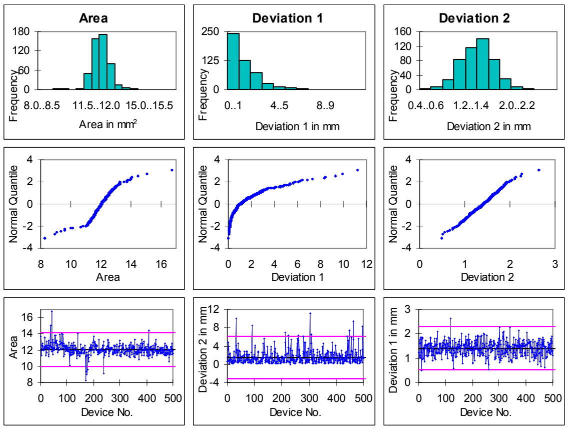


***Supervision of the radial deviation of a ray from a target value (in mm) for 500 checked X-ray tubes: histogram (top), quantile plot (middle) and control chart (bottom) for the size of the focussed points (area in mm$^2$), deviation 1 and deviation 2 (deviation value from the target in mm).***

Measurements vary, even if they are obtained under identical conditions. Potential sources of this variability are all factors that have an influence on the process measures. These are on the one hand random deviations such as unpredictable disturbances, measuring errors, etc., and, on the other hand, systematic errors such as wear, parameter changes, etc. The random deviations are process characteristics that cannot be modified, whereas the systematic errors can be reduced on purpose. A process is then under control if the random errors are known and any potential systematic errors can be corrected before their consequences appear.

The task of a control chart consists in highlighting process deviations that often constitute the cause of quality deviations or variations. The idea is to represent the measurements in the chronological order of their obtainment. In the resulting graphics, a strange value can immediately be detected. This enables early counteraction, such as the correction of various settings, before expensive products turn into refuse. If, on the contrary, control is not made systematically, then serious mistakes only become clear when the process must therefore be stopped and unnecessarily high costs have become unavoidable.

Such graphics (resp. many further statistical tools) can be produced (resp. used) by software means without difficulty, e.g. within the common Excel environment using the validated add-in EasyStat from AICOS Technologies.

## Simple but efficient

A control chart for a given measurement, like temperature, concentration, mass, length, etc., is easy to produce. One only needs two parameters, actually the mean $\mu$ and a measurement for the dispersion of the values: the standard deviation $\sigma$. Both control limits (the horizontal lines in the figure above) are obtained by calculating $LL = \mu - 3\sigma$ and $UL = \mu + 3\sigma$. If parameters $\mu$ and $\sigma$ are unknown, then they are estimated on the basis of measurements from the past or from a preliminary production phase.

Usually, the measured values are dispersed arbitrarily around the process mean $\mu$. If they follow a normal distribution, almost all values (about 99.7% of them) are between the calculated limits. The process is then statistically under control. One can easily check graphically whether the measurements are really normally distributed. The practitioner does not need to use formulae, he can obtain a so-called QQ or quantile plot just with a mouse click. He can evaluate the resulting plot with no difficulty.

The histogram for deviation 2 (see the top right figure above) shows a symmetrical distribution around the mean. The scatter plot in the quantile plot underneath more or less shows a straight line, which indicates that the values are normally distributed. The histogram of the size of the focussed points (area in mm$^2$, top left figure) looks similar. However, the points in the correspond-

[1] English version of a paper published in February 2004 in the German magazine *Process*.
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ing quantile plot build a kind of S curve instead of a straight line.

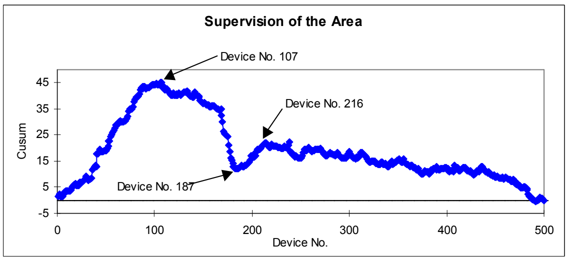
The reason for this are the extremities of the distribution, i.e., there are too many very small and very large values in comparison with a normal distribution. The human eye can better visualize systematic deviations of a scatter plot from a straight line than deviations of a histogram from a normal distribution. Therefore, when checking whether a distribution is normal, use a quantile plot instead of a histogram!

The use of a control chart with data that is obviously not normally distributed (e.g. deviation measure 1, middle column in the figure) may lead to unpleasant surprises. Since the control limits calculated then do not correspond to the data, the actual problems can be neither detected nor eliminated. In such cases, a logarithmic transformation is helpful. The quantile plot for the logarithmized data shows more or less a straight line (without figure) and the control chart is then produced for the transformed data.

The control limits calculated are not tolerance limits. The former follow from the process characteristics (position and dispersion of the measurement), the latter result from external specifications (customer specifications, adequation for the next production stage, etc.). In order to compare tolerance and control limits, so-called capability indices ($C_p$ or $C_{pk}$) can be calculated.

## Hunting drifts

Depending on the problem setting, it may be particularly important to recognize quickly and reliably any continuous drift from the process mean. For this purpose, the Cusum control chart is the best tool. This chart has a kind of memory, in the sense that not the original measurements but the cumulated sums of the deviations from a target or from the mean are represented.




***Cusum chart for the supervision of thesize of the focussed points. The cumulated deviations from the mean are represented.***

An extreme value such as the maximum in the figure enables one to discover a change of the process mean approximately at device 107. The first 107 focussed points were then almost all larger than the mean, whereas most of the following 400 were smaller (except devices 187 to 216 and a few others). In comparison, such changes are not shown clearly by the usual control chart (see bottom left figure on page 1). It is often recommended to use both control charts in parallel so as to observe both the original values and any possible trends.

### Control charts...

- *are very easy to produce,*
- *can be used when a measurement has to be controlled over a time period,*
- *make in particular sense if data (or their transformation) is normally distributed,*
- *are almost always helpful to improve the efficiency of a process.*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