

Low Ranges for Sensors (NOT to be confused with Low Range Sensors!)

Now that there are low range sensors available for the applications where smaller concentrations of nitric oxide, carbon monoxide, hydrogen sulfide and other gases are to be expected, it is time to address the matter of the low ranges offered by some manufacturers.

The general configuration is a resolution of 0.1 ppm up to a level of three or four hundred parts per million, then a resolution of 1 ppm up to the maximum range of the sensor. Electronically, this is easy enough to accomplish. The two possibilities are to switch the amplification of the first stage by a factor of ten and then feed the result into the analogue/digital converter, or simply to use the standard signal and increase the resolution of the output. The method chosen will, naturally depend on the resolution of the analogue/digital converter (ADC). It is unlikely that anyone is still using an ADC with 10 bit resolution, but this would give a signal resolution using a 4000 ppm sensor of 4 ppm. A 12 bit ADC, which is probably the commonest, gives 1 ppm resolution, and a 14 bit ADC gives 0.25 ppm resolution. If this is applied to an amplifier with ten times the power, then the sensor has a measurable range of 400 ppm, and these resolutions are, of course, divided by ten, giving values that would just justify a display resolution of 0.1 ppm.

That is the theoretical explanation, which seems mathematically perfectly correct. The only factor that has not been included in the equation is the sensor itself. The sensor has not changed and has exactly the same repeatability as it had before. (It is technically incorrect to talk about *accuracy* with any sensing organ that requires calibration, although the new Standards, such as EN30759 do use accuracy now. The correct term is *repeatability*, the closeness of the agreement between the results of successive measurements of the measurand carried out under the same conditions of measurement. These sensors require calibration, meaning that they are comparing a quantity with a stored standard from calibration. The assumption is that the calibration standard is correct for measuring purposes, but it is still only a reference to an assumed quantity.)

When we add this to the fact that the manufacturers *quote* a resolution of 1 ppm for these sensors (based on filter type, electrolyte and electrode construction), it becomes ridiculous to quote a higher resolution after the inaccuracies of the amplifiers, ADC and internal calculations have all been included.

Modern sensors have a repeatability of 2 %, which is a considerable improvement on the old values of around 5 %, but still does not anyway justify using a resolution of 0.1 ppm at 400 ppm. 2 % of 400 ppm is still +/-8 ppm acceptable error, so what is the reason for showing this much better resolution? The sensors are generally far better than the manufacturers claims in this case, and a repeatability of +/-2 ppm is fairly standard with new sensors, but no more can be expected.

The resolution of an input quantity cannot be increased by processing, anything else is simply guessing a result between two known values. This should not be confused with interpolation, a mathematical procedure which estimates values of a function at positions between listed or given values. Interpolation works by fitting a "curve" (i.e. a function) to two or more given points and then applying this function to the required input. Example uses are calculating trigonometric functions from tables and audio waveform synthesis. Interpolation is thus possible between results to obtain results that were not, but could be, measured. This system is producing values that could not be measured. The information is simply not there between the points and thus cannot be interpolated.

Although this may seem like a harmless move to present results in a form pleasing to the operator, there is more to it than meets the eye. A result is being shown that cannot exist, and is therefore simply not true. If this result is being shown in a stable form, then there is some form of mathematical function producing it, since it cannot be stable in this area. A measuring instrument should show the measured values, not some value that has been calculated and might be true. Producing fictitious results is a practice that will quickly bring the whole concept of flue gas analysis into disrepute.

The only way to produce results with a higher resolution is to use a sensor with a higher resolution. These are available, and are naturally for a smaller absolute range. These sensors can only produce a limited amount of signal, since the amount of electrolyte is also very limited. The alternatives are to either build a bigger sensor, which would then no longer be compatible with existing equipment, or to limit the lifetime proportionately. Whilst this last option is possible in some cases, equipment for flue gas analysis with a number of sensors is logistically simpler if all sensors have roughly the same useful life.

The choice of sensor will depend on the range of concentrations that must be measured with the flue gas analyzer. This will dictate the resolution available in most cases and it is not possible to exceed the laws of physics or chemistry, simply because it would be convenient. Any attempt to display the results otherwise is inadvisable at best and plain dishonest at worst.