Application Approaches

Successful conductivity measurements may be made for most any aqueous based ionic solution, included among these are commonly encountered acids, bases, and salts. These ionic measurements may be displayed in units of measure denoting conductivity e.g. most typically microsiemens per centimeter (^S/cm) which are equivalent to micromhos), or millisiemens per centimeter (mS/cm., which are equivalent to millimhos), (Note - 1 millisiemen = 1000 microsiemens).

If desired, the conductivity value(s) may also in many instances be converted to percent concentration (or, g/l = grams per liter, ppt = parts per thousand, ppm = parts per million, etc.). Measurements of conductivity converted to percent concentration are typically most successful for binary solutions, i.e. for a solution of water, and one other primary conductivity contributor. (e.g. one of the most commonly encountered solutions in Industry is NaOH … water which contributes negligible conductivity when compared to the primary conductivity contributor sodium hydroxide). A percent concentration measurement of a binary solution is feasible because most ionic solutions exhibit a typical bell shaped curve relative to conductivity vs. percent concentration, at a specific temperature (see example of NaOH curve @ 25 C, and 100 C, below).

The curve shape is different for each ionic solution (i.e. NaCl is different from NaOH, etc.), and since the conductivity of ionic solutions typically increases with temperature, the curve shape itself changes with temperature (e.g. NaOH curves). Conductivity curves thus most typically display a front slope of increasing conductivity vs. concentration, a 'top, or flat portion' where there is little differentiation between point, and a back slope of decreasing conductivity vs. concentration (note – the concentration from the back slope of a curve is written in reverse, e.g. 99.5 to 93 % H2SO4, because the lower conductivity is equivalent to the higher percent concentration).

For those most commonly encountered solutions where the conductivity vs. concentration is well established, a standard curve has been defined, and offered. The Foxboro co. provides > twenty different standard curve sets in our 870ITEC Intelligent Transmitter, and the 875EC Communicator. Most, but not all of these standard curves are comprised of data found on the front slope of the relevant bell curves. Notable exceptions are (e.g.) high concentration sulfuric acid (e.g. 99.5 to 93 % H2SO4), and Anhydrous hydrofluoric acid (> 90 % HF).

Although standard curves support the most commonly encountered solutions, there are numerous applications where the measurements desired fall outside the norm …, either greater than typical concentrations (e.g. 50 to 26 % NaOH), or at temperatures that are higher (or lower) than standard curves support. In these instances Custom curve sets may be the answer.

Custom curve sets, if feasible, are comprised of conductivity vs. concentration data at a specific process temperature (e.g. see Table xx), and a custom temperature compensation curve (e.g. see Table yy).

The first order of business is to determine if the (e.g.) percent concentration range desired is feasible. To do this it is most helpful to review a conductivity curve of the binary process solution in question, at varying temperatures. Conductivity curves for most solutions encountered are most often a variation of the typical bell curve.

Example -

It is not practical to make a percent concentration measurement on both sides of a conductivity curve. If this were attempted, it is possible (and likely) that a single conductivity could equate to two distinctly different concentrations. For this reason both standard, and Custom, curves are limited to either the front, or back slope (see also dual curve approaches with 870ITEC and 875EC).

Foxboro provides a standard curve of (e.g.) 0 to 10 % Oleum (front side of the curve, and linear), and another standard curve of 42 to 18 % Oleum (back side of the Oleum curve …, and linear, *and* written in reverse, since the higher concentration would then be the *lower* conductivity) @ a 65 C (149 F) Reference temperature.

IF it were desired to measure a higher concentration Oleum than the 42 – 18 % curve provided would support (e.g. 65 % Oleum), then a Custom curve set would be required.

Custom curve – Conductivity vs. Concentration @ a Reference Temperature.

Using the example of a desired 65 % Oleum measurement, and because a 'range' is required, a Custom curve range of (e.g.) 70 to 60 % Oleum might be selected, *and* this would be at some Reference temperature which is often the most typical process Temperature. This curve, once defined, will provide a linear slope so there is differentiation between percent concentration points. That is, 70 % Oleum will have distinct conductivity (at Ref. Temp…. e.g. 65 C), and 68 % would have a measurable and repeatable higher conductivity, as would 66 %, 64%, etc.

IF a percent vs. conductivity relationship such as this can be established (either by Literature data, or on-line measurements, and / or Lab determinations), then a measurement may be feasible.

Custom Curve - Temperature Compensation

Using the same example of a desired 65 % Oleum measurement (above), and presuming the Reference Temp. is (e.g.) 65 C (149 F), then a typical concentration must be selected (often the most critical control point) and the conductivity of it measured in usually even step, precisely controlled temperature increments (most often this would be a concentration ~ 70 % of the defined range. Thus, if the range were "0 to 10", a conc. of '7' would be typically be taken …, in the above example this might be 63 % Oleum …, however, if (e.g.) 65 % were the most critical concentration, then *that* would be used).

If the Process Temperature were known to vary from (e.g.) 100 F to 170 F, then at minimum the conductivity of the selected percent concentration would be measured at (e.g.) 90 F, through 180 F in ten degree increments.

The accuracy of the temperature compensation curve is related to the precision of the measurements, *and* the number of relevant data points. A Temperature compensation "curve" of two points, e.g. 90 F and 180 F would provide expectedly limited 'compensation'.

Once both the Conductivity vs. Concentration, and the Temperature Compensation curves have been defined on-site (to capture any known, or unknown process variables), and entered into the Intelligent Transmitter / Communicator, then process measurements can begin …, presuming the correct (material compatible, etc.) sensor has been selected / installed !

Questions related to this may be directed to Kevin Quackenbush @ Foxboro … Jquacken@foxboro.com.