Solubility of Aged Oxidised Oil

What does the Sensor actually measure?
Summary of Altmann/Bukvis 2003 equilibrium trial

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The Karl Fischer Method and Sensor Method sections will help identify exactly what water is measured in the oil by both methods. What about the increased "solubility" of oil that is aged and oxidised. What evidence is there that the sensor only measures the dissolved water, the same as in new oil - has it been independently proven ?

Water in cellulose equilibrium charts are used by utilities worldwide. The most widely quoted equilibrium chart appears to be Oommen 84. All equilibrium curves use the average transformer oil temperature (top temp + bottom temp / 2) and the water in oil ppm as the reference values. All are based on new pure oil. A recent experiment by Altmann / Bukvis (2003) set out to create their own equilibrium trial, and compare the findings.

Initially the equilibrium apparatus had new oil, and a cellulose insert at various water (%) content, to establish the oil relative saturation and ppm equilibrium values over the entire temperature range. The water in oil values (ppm) were confirmed by using both the Karl Fisher method, and, with an oil Sensor. (new oil settings).

The new oil was then completely removed from the apparatus and replaced with aged oxidised oil of 0.18NN. The water in cellulose trials were repeated using the same methods.

The findings showed two clear results.

1. The Sensor can be used in oxidised transformer oils with high accuracy as it only measures the dissolved water, not the bound water.
2. The Karl Fisher method measures both the dissolved and oxidised bound water and overstates the water in the oil, requiring oil solubility tests.

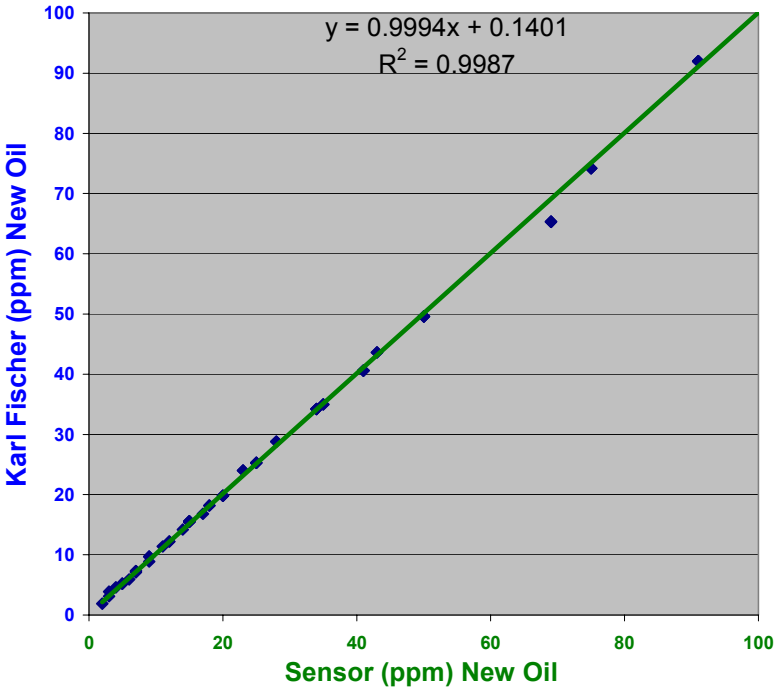
The increase in "solubility" seems to relate specifically to the oxidation by-products that are found **in** the oil. The oil itself appears not to alter in solubility. The sensor recorded virtually the same level of dissolved water in both oils during both trials. The oil is simply carrying by-products including particles and chemical compounds etc that "bind or hold water", therefore increasing its "solubility". Some of this water adsorbs and desorbs into the oil to reach equilibrium with the transformer temperature movements.

The trial confirmed that when using oil relative saturation sensors with new oil settings, the oxidised oil "solubility" does not influence the ppm calculation accuracy. Therefore ppm values from sensors can be used in new oil equilibrium charts with great accuracy.

Our own trials, including cross checking water in cellulose calculations using both the oil solubility results method and our own direct sensor values method. The water in cellulose calculation was within 0.25%. It appears that oil solubility tests do not add any value or accuracy to the diagnostic process.

For reliable accuracy I recommend

1. The Altmann/Bukvis 2003 equilibrium chart, in conjunction with,
2. Sensors (new oil settings) for accurate dissolved water in oil ppm and RS% values



Altmann / Bukvis 2003

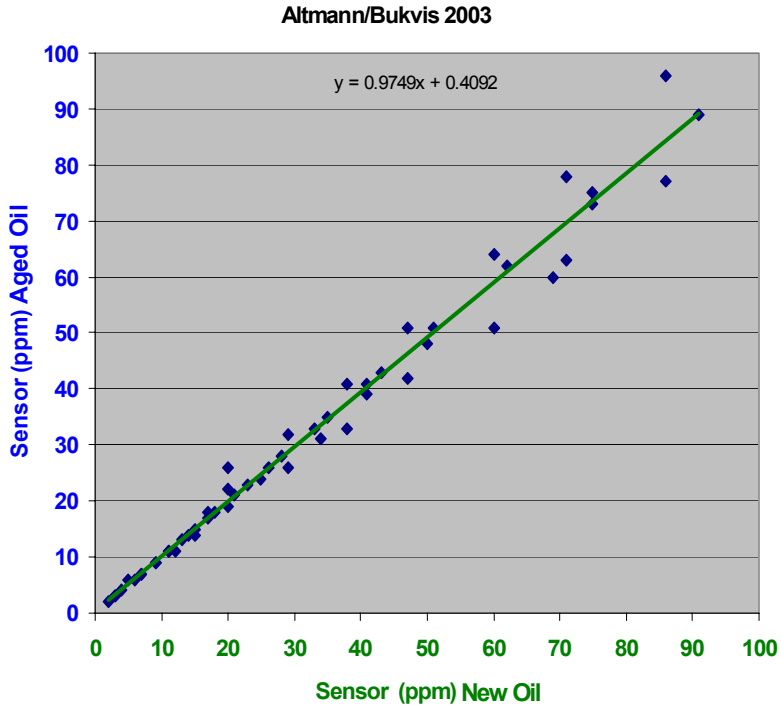
New Oil trials

Both the Sensor and Karl Fisher methods were used for measuring the ppm water in oil during the new oil trials.

They are in almost complete agreement.

The process validates the accuracy of both methods to read the dissolved water in new oil.

The new oil was removed and replaced with the aged oxidised oil 0.18NN



Oxidised Oil Trials

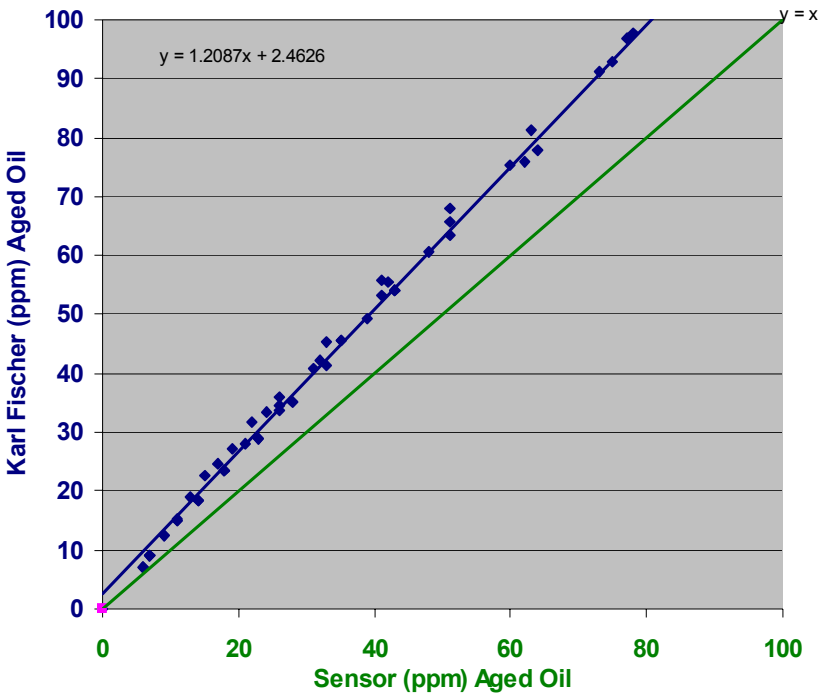
The green linear line is the Sensor new oil values from the previous trial.

The blue points are the Sensor readings during the oxidised oil (0.18NN) equilibrium trials.

The results are within a very narrow deviation band, and are very close in the ppm range that most transformers actually operate at (10ppm – 80ppm)

The trial confirms that the Sensor only measures the dissolved water in the oil, and not the bound water, no matter the age or condition.

Introducing a solubility test when the relationship is this close would only introduce more variation.



Oxidised Oil Trials

The oxidised oil was also measured for water content by the Karl Fisher method during the acid oil trial.

The green linear line is the aged oil Sensor values in the previous trial above, and is the dissolved water in the acid oil.

The blue results are the Karl Fischer values. There is an almost linear increase in bound water as the temperature and water in cellulose increases.
e.g.
KF = 50 ppm - Sensor 40 ppm
KF = 100ppm - Sensor 80 ppm

With this particular acid oil the Karl Fischer method is identifying that the bound water is about 20% of the total water.

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The Altmann/Bukvis results are the most conclusive evidence available on the accuracy of Sensors in acid transformer oil. There is nothing more accurate than equilibrium trials where all values are known to understand the water in oil.

Ing. J. Altmann has also produced some leading papers on the effects of relative saturation on oil dielectric.
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