Q & A on Moisture in Transformer Oil

A unique opportunity to answer your specific questions about Moisture in Transformer Oil Behavior

VAISALA

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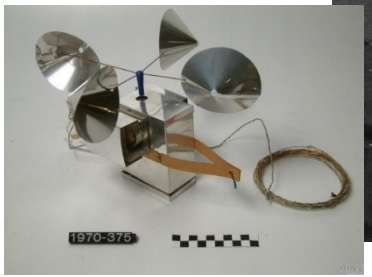
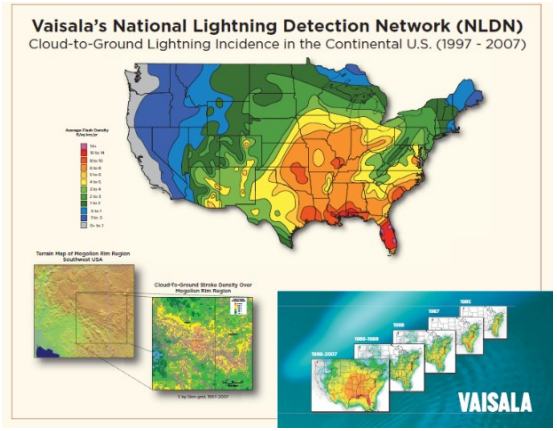
Agenda

- Vaisala Introduction
- Short Overview of Vaisala Instruments for Transformer Monitoring
- Question & Answer addressing your questions on Moisture in Transformer Oil

Vaisala Introduction



- Founded in 1936 by Dr. Vilho Vaisala
- Beginnings in weather measurement business:
  - temperature, humidity, pressure
  - later in wind speed & direction, cloud height, visibility, lightning detection...
- 1973 HUMICAP® invented - solid state, polymer based capacitive humidity sensor
- Expansion from weather → industrial applications
- Other sensing technologies followed
  - CO2, Dew point, Moisture in Oil...
- Industrial & Environmental Measurement key areas
- Sensor & Instrumentation Innovation remain our core competence
- National Lightning Detection Network (NLDN)
- Moisture in Oil Transmitters – early 1990's



MMT330 Series

- Fully configurable to user needs
  - 3 different probe options
  - compression fitting for adjustable insertion depth
  - 2, 5 or 10 m cable length
  - -40...+356 ºF
  - 580 psi pressure rating
  - Graphical display & user interface
  - Alarm relays & universal power supply
  - Power supply: 10…35VDC / 100…240 VAC
  - Battery secured data logging (4 years)
  - LAN/WLAN module option
  - Analog outputs (mA, V) + RS232/RS485
  - Modbus

MMT310 Series

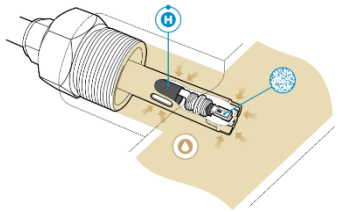
- A compact transmitter for OEM customers
  - transformer manufacturers
- Several configuration options
  - two probe options
  - 2, 5 or 10 m cable length
  - -40...+356 ºF
  - 24 VDC
  - RS232 serial & two 4…20 mA outputs

MMT162

- Compact economical transmitter for drying system OEM's
- IP66 enclosure
- Two thread options: G1/2" ISO and NPT 1/2"
- RS485 and 2 analog output channels
  - 4...20 mA, 0...20 mA, 0...1 V, 0...5 V, 0...10 V
- Handheld indicator can be used as a display to read two units simultaneously

MM70

- Handheld device ideal for quick spot-checking of oil
- Also for on-site verifying and calibrating fixed mount transmitters
- Graphical display and simple menu based user interface
- Datalogs up to 2700 points – downloadable to PC
- 13" adjustable depth probe – can be used with ball valve
- -40...+212 °F probe operating range
- 20 bar (293 psi) pressure rating



MHT410

- Moisture (%RS, aw, ppm), Hydrogen (ppm), Temperature Transmitter
- Integrated probe designed to be installed directly through a ball valve to obtain a true, representative in-situ measurement
- No pumps, sampling systems, or membranes – no moving parts of any kind
- IP66 Housing
- Operating voltage 15...30 VDC, 24 VAC
- Isolated 3 x 4... 20 mA analog outputs
  - Also isolated RS-485 with Modbus

Optimus OPT100

- Infrared (IR) based DGA
- Hydrogen H_2
- Carbon Monoxide CO
- Carbon Dioxide CO_2
- Methane CH_4
- Ethane C_2H_6
- Ethylene C_2H_4
- Acetylene C_2H_2
- Moisture
- Temperature

- Patented IR sensing and vacuum gas extraction technologies
- Hermetically sealed system contained within IP66 housing
- No gas bottles, no consumables, no regular maintenance
- < 2 hours for installation + commissioning

Q&A

VAISALA

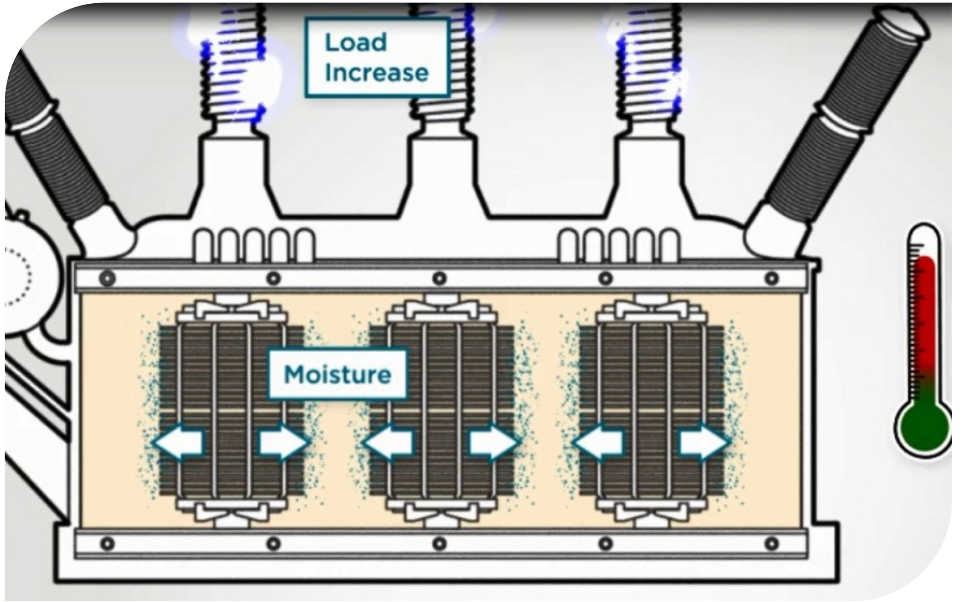
Q: How significant is ambient temperature in determining the migration of moisture between paper and oil?

A: Ambient temperature affects cooling efficiency of transformer and thus also temperature inside the transformer.

However, the winding temperature has the biggest effect on moisture migration. Higher the temperature more moisture comes into oil.

Ambient temperature is not good reference when defining paper moisture.

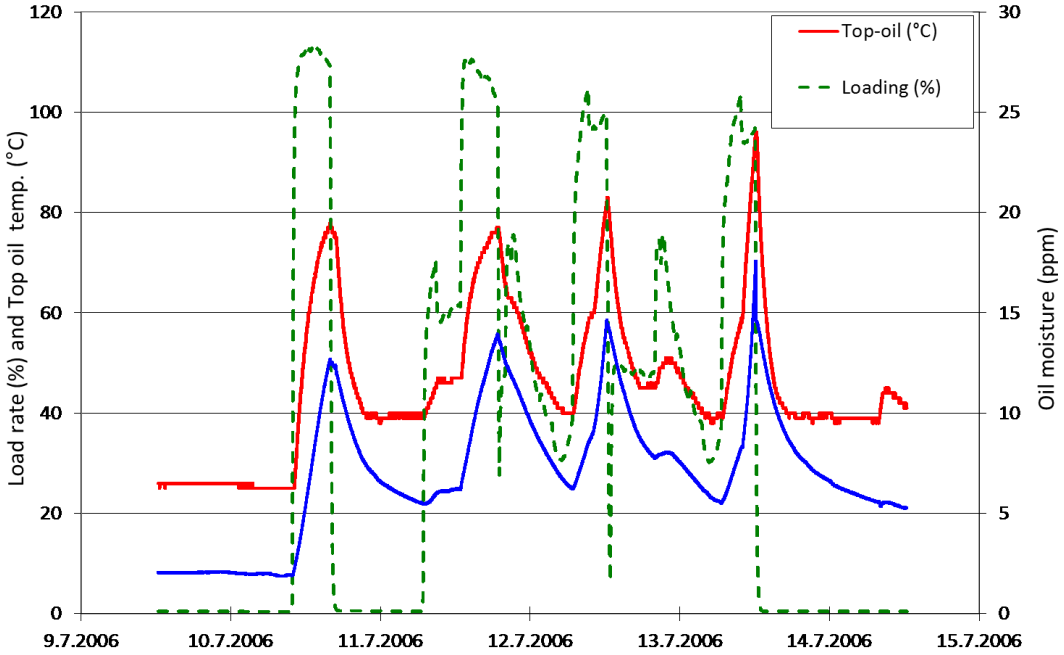
Use top oil or winding temperature.



Q: How can we monitor real time moisture transport between the cellulose paper, pressboard, wood support structures during transformer overload?

A: Online moisture monitoring in the oil circulation gives good indication on how much water is released from paper and other cellulose material surfaces.

Moisture from inner parts of paper, pressboard or wood will not move to oil.



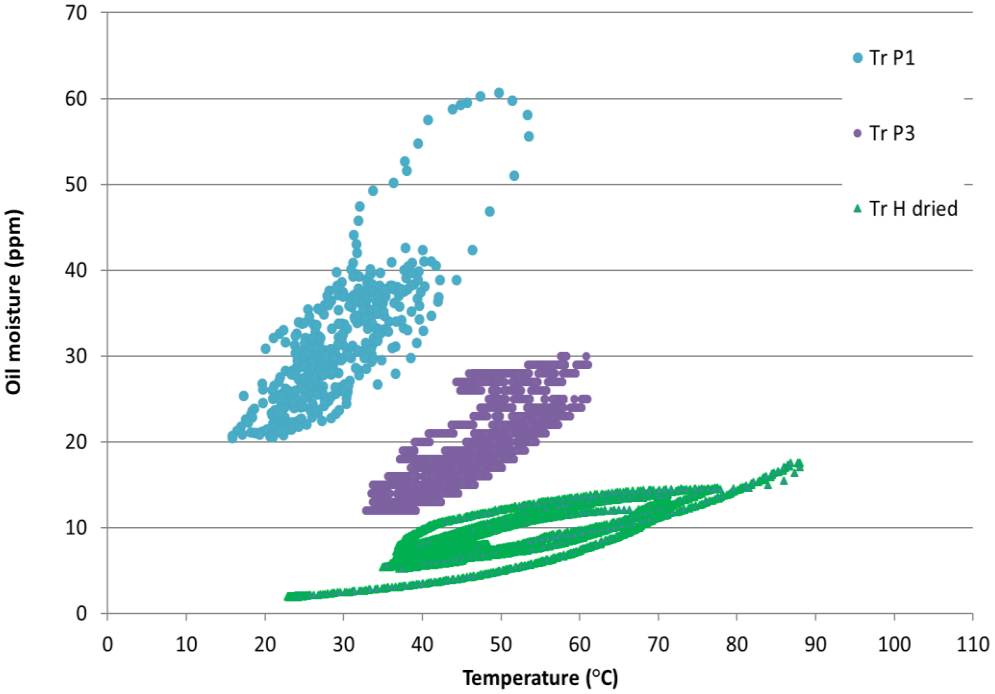
Q: Is there any consistent correlation between the top oil temperature and moisture content of the oil?

Q: Migration of moisture between paper and oil relative to temperature?

A: The higher the temperature the more moisture migrates out of paper surfaces.

However, the amount of moisture coming to oil depends on the moisture content of solid insulation.

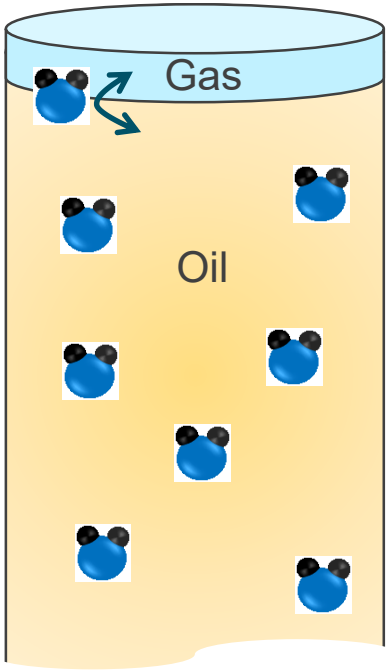
Characteristics of a specific transformer can be seen with longer time online moisture monitoring.



Q: During the transformer operation there is exchange of humidity between oil and paper, what happens in case of transformers sealed with nitrogen, the humidity can mixed with the gas? How about the real content of humidity in the oil?

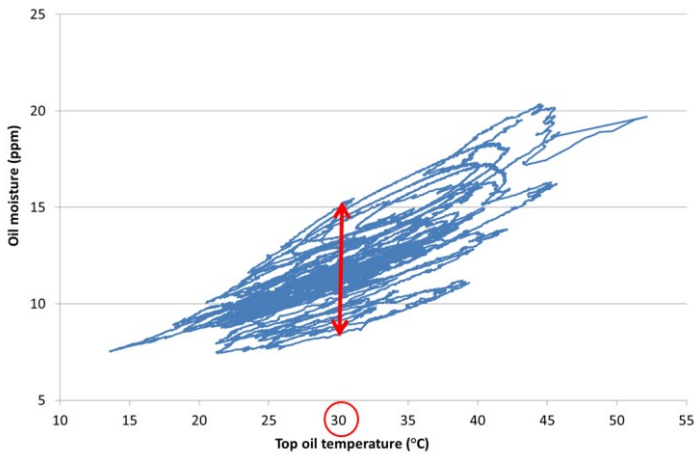
A: Some moisture will move from oil surface to the gas phase.

Diffusion of water molecules in oil is very slow, thus amount of water vapor migrating to the gas volume is negligible.



$V_{gas} << V_{oil}$

Q: Correlation between oil analysis and transformer life time?

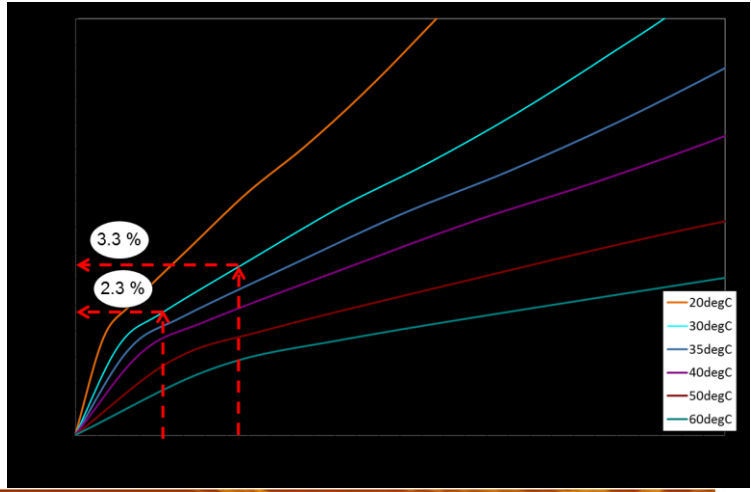


A: There is some correlation. But no direct conclusions can be made.

The quality and lifetime of insulation paper is affected by moisture, oil acidity and temperature.

Moisture, acidity and furans can be evaluated with oil analysis.

Uncertainties related to oil sampling and analysis must be taken into account.



Q: If transformer is not sealed properly, how would the oil absorb environmental moisture?

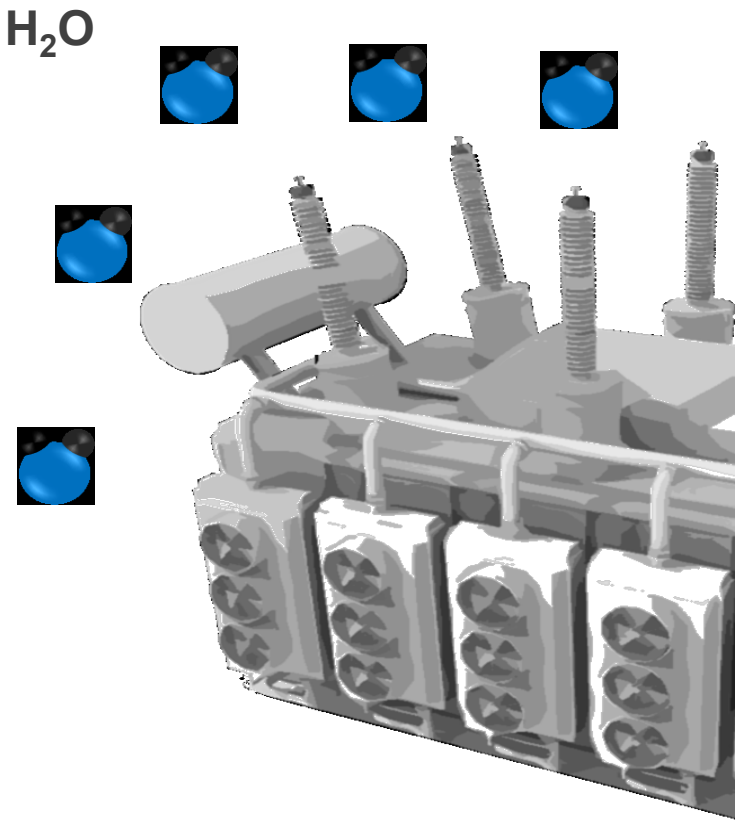
A:

Absorption of moisture when there is direct exposure of the insulation to ambient air.

Moist airflow through bad sealing if there is pressure difference.

Large amount of rainwater can be sucked into a transformer tank in case of negative pressure.

Water contamination is also possible for transformers due to free breathing.



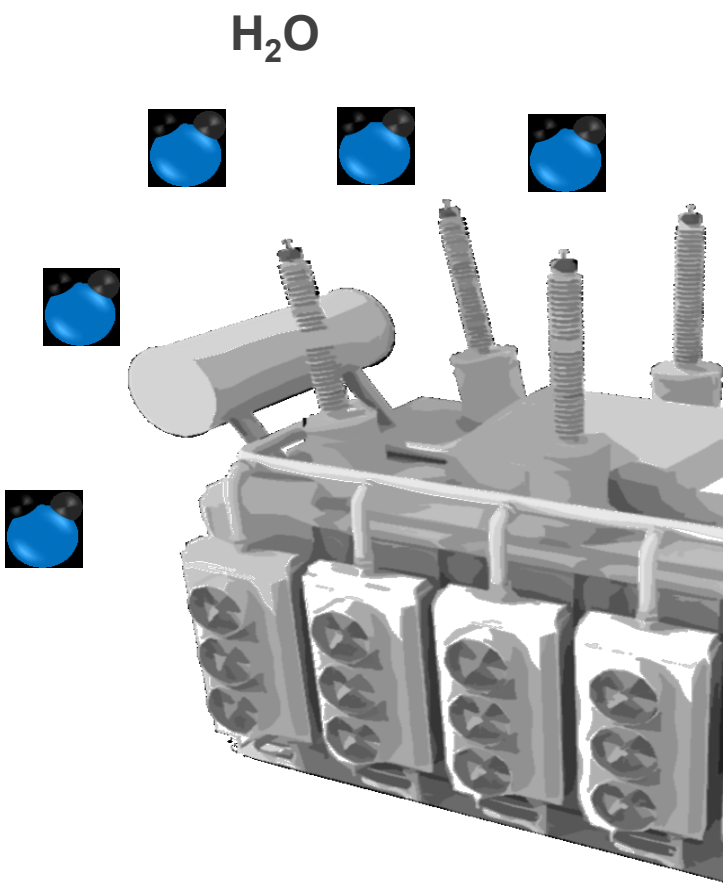
Q: What is the most effective way to keep moisture out of a transformer?

A:

Keep the sealing materials in good condition.

Keep the breathing dryers in good operating condition.

When applying open service take great care that solid insulation is protected against rain and also humid ambient air.



Q: Moisture sensor element is interchangeable and easily replaceable. How do I know the right time for replacement?

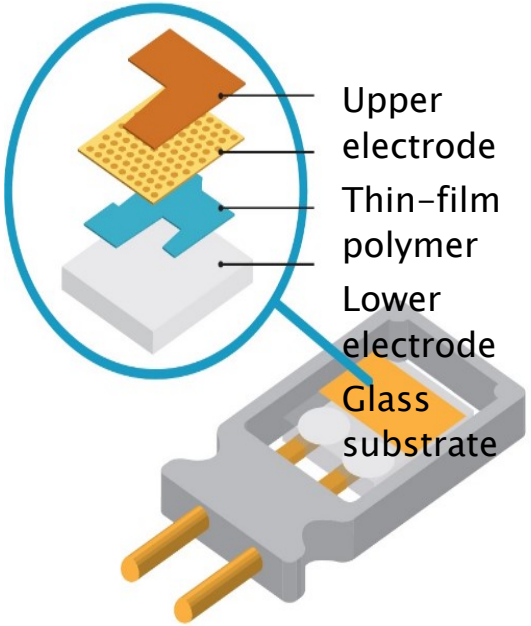
A: Most likely, the sensor element does not need to be changed. It's question of sensor stability.

In the event it becomes damaged and does need to be changed, it needs to be calibrated accurately.

Q: What is a competitive advantage of Vaisala moisture sensors?

A: Good sensitivity in very dry oil and extremely good long term stability

Also against degradation from by-products of oil.



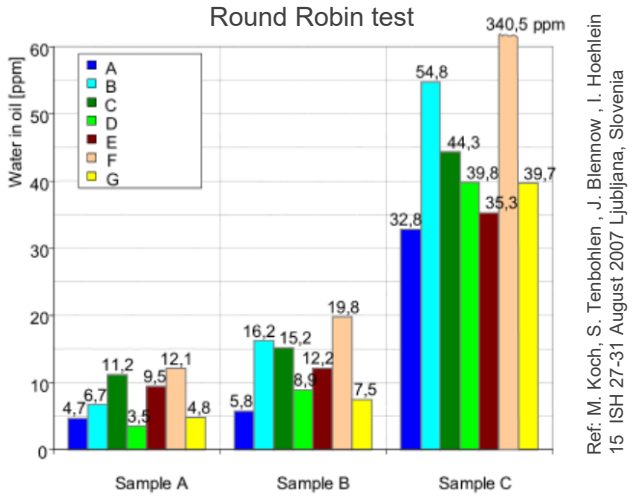
Q: We are embarking on online monitoring to measure moisture in oil. What is the expected accuracy level of online sensor compared to labs KFT method.

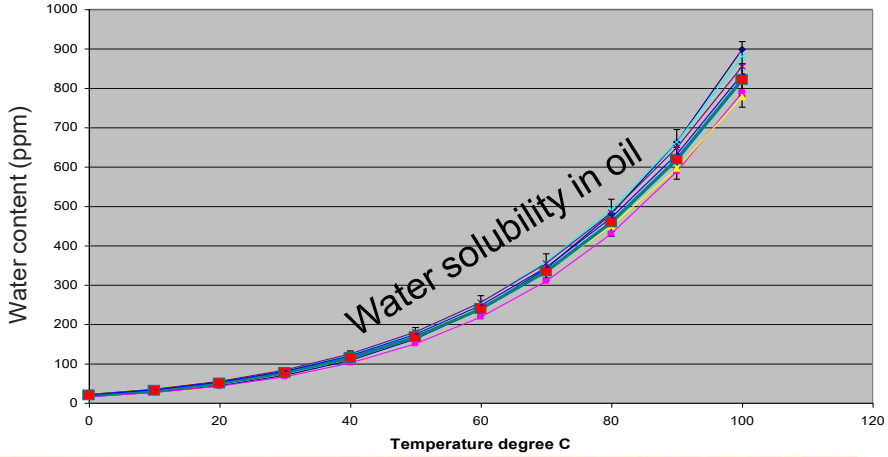
A: All methods have their uncertainty.

For laboratory analysis oil sampling is major uncertainty source.

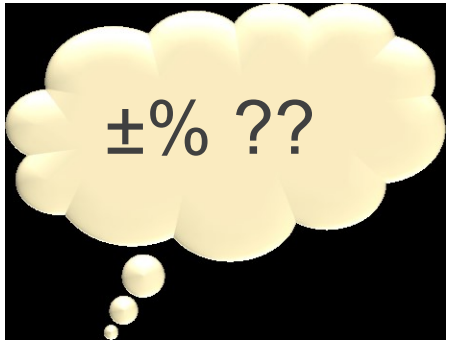
Online sensors measure %RS where ppm is calculated based on pre-defined water solubility.

Direct comparison of different methods may not be reasonable.





Q: How important is the accuracy of a moisture sensor?



A:

Accuracy including repeatability, precision, and sensitivity is important, when results are used for further analysis.

Accuracy alone may not give the true picture of the sensor performance.

Dynamics of the measurement i.e. measurement range over whole operating temperature and response time are also important.

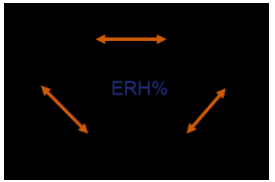
Stability (tolerance for aging and oil environment) is crucial in long term monitoring.

Q: Calibration and certification of a moisture- in-oil sensor are conducted in the air. Why not in the oil - the media where these sensors are used?

A: All reference standards, applicable to capacitive moisture sensors with traceability chain e.g. to NIST, are in gas phase.

However, in equilibrium %RH is the same in all 3 phases: solid, gas and liquid.

Governed by Henry's Law (illustration)

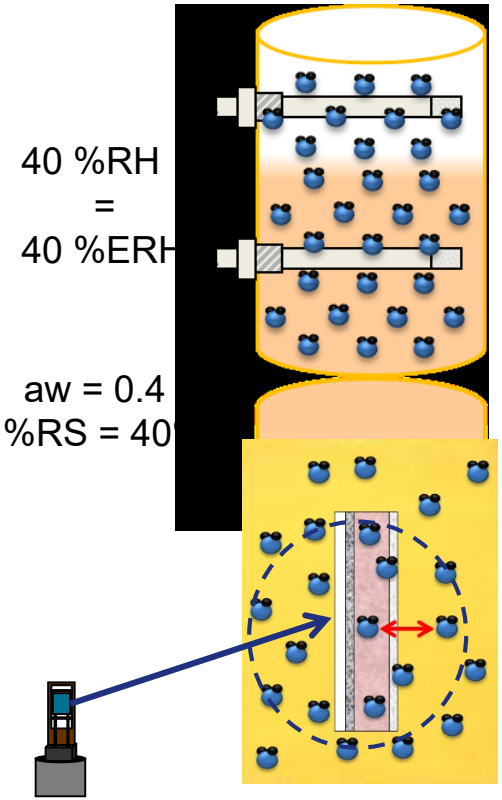


Q: How long is the calibration valid?

A: This depends on the sensor manufacturer, as not all sensors are the same. There may be significant differences in their stability.

In Vaisala, we will have sensors return for calibration after being in use for 10yrs → still within the initial specification.

Portables may need more frequent calibration.



%ERH = equilibrium relative humidity

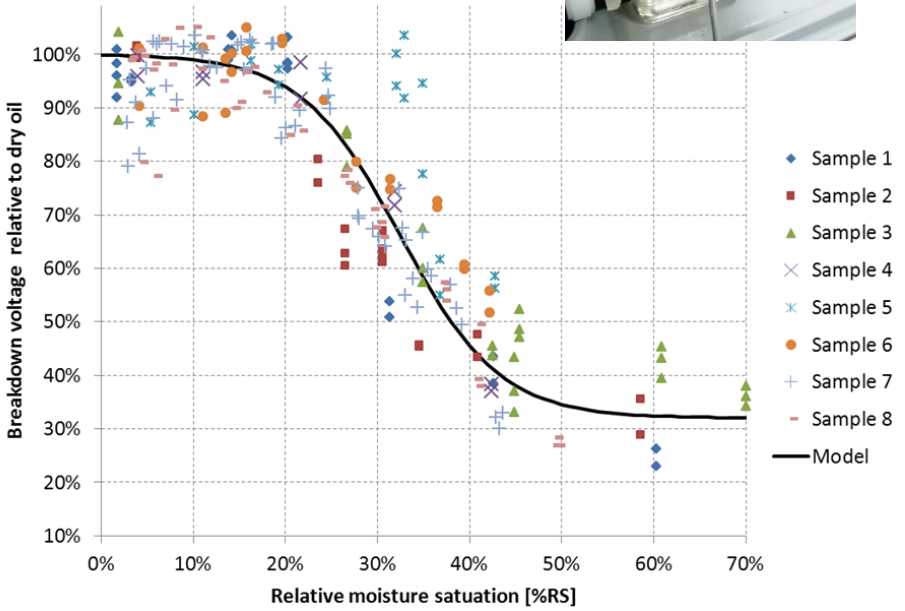
Q: How does moisture in transformer oil affect the dielectric properties of oil? How it can be controlled?

Q: What are the acceptable limits of moisture for aged oil?

Q: Criteria to adopt to trigger moisture removal actions, and what are the recommended methods?

A: Relative saturation over 20%RS, decreases dielectric strength of oil. This may be a good criteria to begin applying online drying equipment.

We cannot say what is actually acceptable limit. However, in our studies we have found out that BDV is relative to %RS and it has the same effect on both new and aged oils.

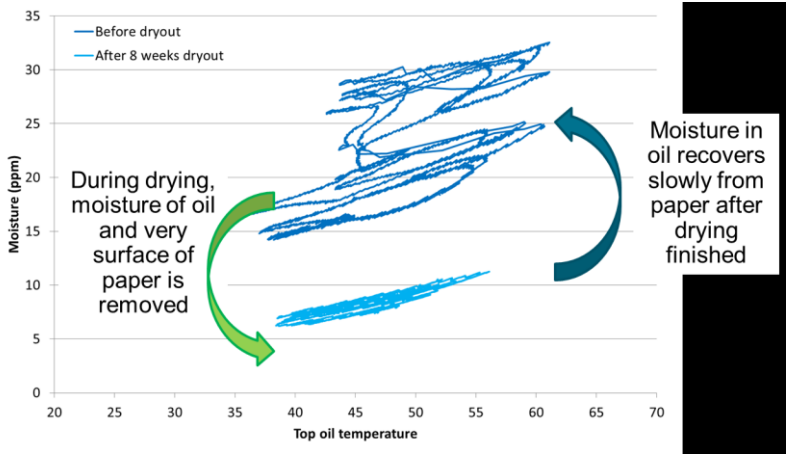


Q: What methods there are to dry in-service transformers.

Q: What is the current state of online/live oil treatment?

A: If considering only drying, and not oil regeneration, there are different types of online dryers available on the market, molecular sieve based, vacuum based and cellulose cartridges.

If applied only for a few weeks, it is only oil and the very surface of the paper that can be dried.



Q: How do you measure the water content in oil in online?

Q: Does your moisture monitoring equipment work on the transformer as well as on oil processing equipment?

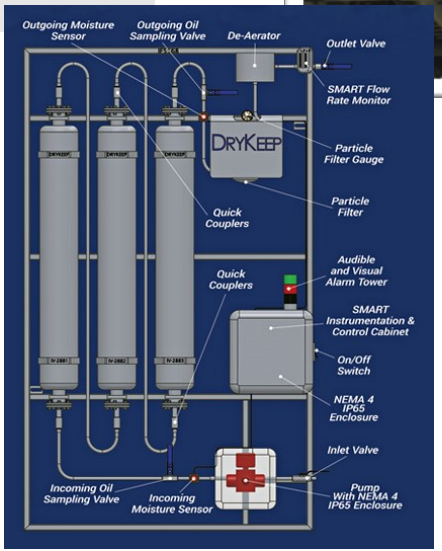
A: Vaisala has moisture sensors like the MMT330 for online transformer monitoring and the MMT162 for oil processing equipment

The sensor should be installed in a location where oil flows freely around it.

Recommended along oil cooling circulation → representative oil.

Avoid "dead-ends" and bottom of pipe bending.

If the sensor is not in representative oil the full variation in temperature and moisture may not be seen



Q: Dynamic modelling of moisture inside transformer solid insulation in cold areas?

A: This is challenging, because in practice at low temperature all water is in solid insulation. Online sensor on top oil during summer time may give rather good picture on moisture in solid insulation.

Q: I need to measure moisture in transformer oil, OFFLINE (by bleeding the oil through drain flange) with our MM70 hand held meter. What is the recommended procedure for same?

A: Measurement at drain valve/flange generally not recommended

Flush sample line/cell sufficiently to achieve representative oil sample – at least several liters

Greater oil flow through sample cell will dramatically improve sensor response time

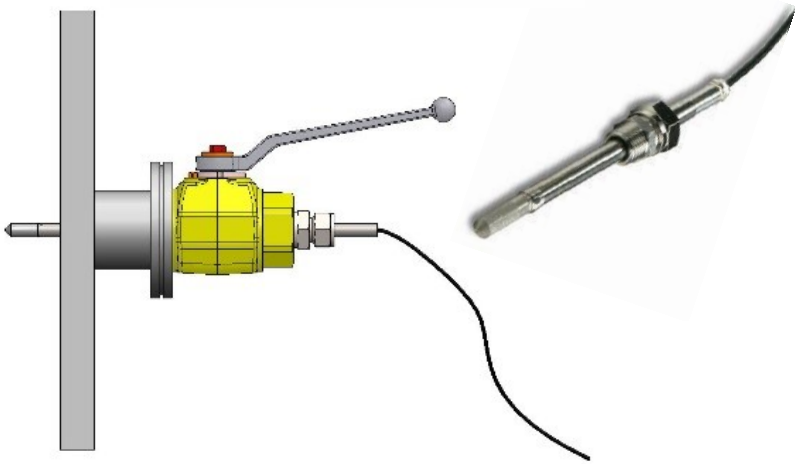
Q: What is the relationship between online moisture determination and paper moisture content determination through "dew point measurement?

A: There are calculation formulas available (e.g. Piper and Fessler eq.), which are again based on equilibrium.

In case it's question of transformer outdoors after transportation, it may not be in thermal equilibrium.

- Ambient temperature is not probably same as winding temperature.

To measure dewpoint reliably, it's best to measure directly inside tank to minimize errors caused by moisture released from sample pipes and connectors.



Thank you!

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