NovAcec Services

How to dry your transformer

The dangers of moisture in a transformers

Water is the enemy of a transformer for different reasons. Not only **it will decrease the voltage the insulation fluid can withstand**, but also **it will deteriorate (age) the solid insulation** in a transformer. On top of that, a high moisture content might "boil" and create dangerous vapor bubbles that can cause an electrical breakdown in a transformer!

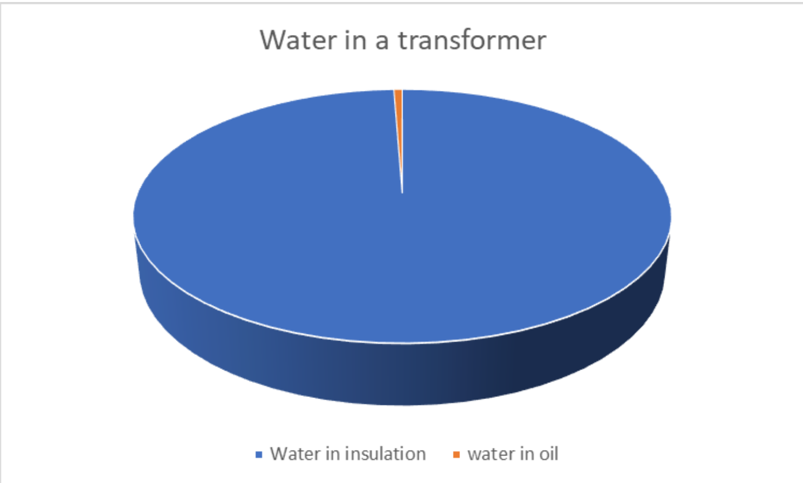
For more information on the effects and dangers of water in a transformer we refer to our documents on the topic:

Flyer Allowable moisture content in a transformer.pdf

Flyer Moisture in transformers v1.5.pdf

> **"Moisture will decrease the voltage the insulation fluid can withstand and it will deteriorate (age) the solid insulation"**

Moisture in insulation

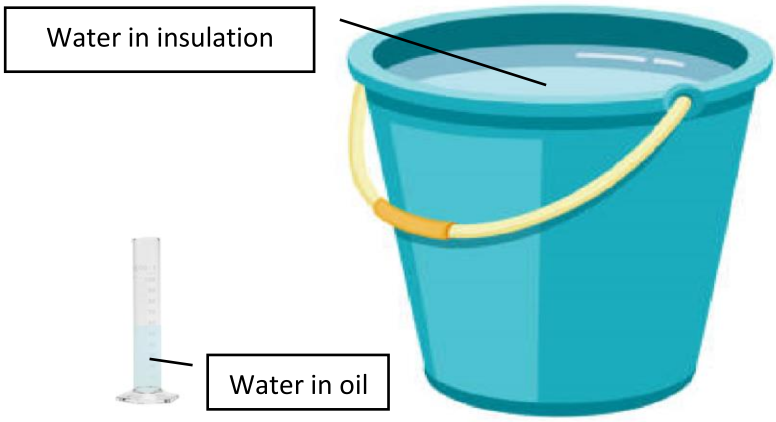


Water is not evenly distributed in a transformer. Although there will be a kind of equilibrium for water in the different materials in a transformer, this equilibrium is not leading to equal amounts of water in the insulating materials. As a result, the amount of water in solid insulation is much higher than in the insulating oil.

And thus, about 99,5% of the water in a transformer is in the solid insulation and only about 0.5% is in the oil! As an example, a transformer containing 10 liter of water will have 9,94 liter water in its solid insulation and only 60 ml (milliliter) in its oil!

On top of that, the equilibrium is strongly temperature dependent. However, since there is only a very small amount of water in the oil, a shift due to temperature changes will hardly have influence on the solid insulation. A small change of moisture however will have a big change on the water content in the oil.

For instance, a transformer with 30000 kg of oil, 3000 kg of solid (cellulose) insulation and 60,36 liter of water will contain 2% of water in the solid insulation and 12ppm of water in the oil at 50°C. If the temperature changes, a small amount of the water will migrate from solid insulation into oil and vice versa.



	Moisture content		Moisture content change from 50°C [%]	
Temperature [°C]	in solid insulation [%]	in oil [ppm]	in solid insulation	in oil
20	2,010	2,1	0,5	-82,1
40	2,005	7,0	0,25	-41,6
60	1,992	19,9	-0,4	65,8
80	1,962	50,3	-1,9	318,9
100	1,900	112,9	-5	841,2

From the situation above, it is clear that **the vast amount of water in a transformer is in the solid insulation and that this amount does not change much with temperature**.

The amount of moisture in the oil however changes dramatically with temperature. When heating up, moisture will migrate from solid insulation to oil and moisture will migrate back from oil to solid insulation when cooling down.

> **"The vast amount (> 99%) of water in a transformer is in the solid insulation and this amount does not change much with temperature"**

“The amount of moisture in the oil however changes dramatically with temperature”

Kinetics of exchange

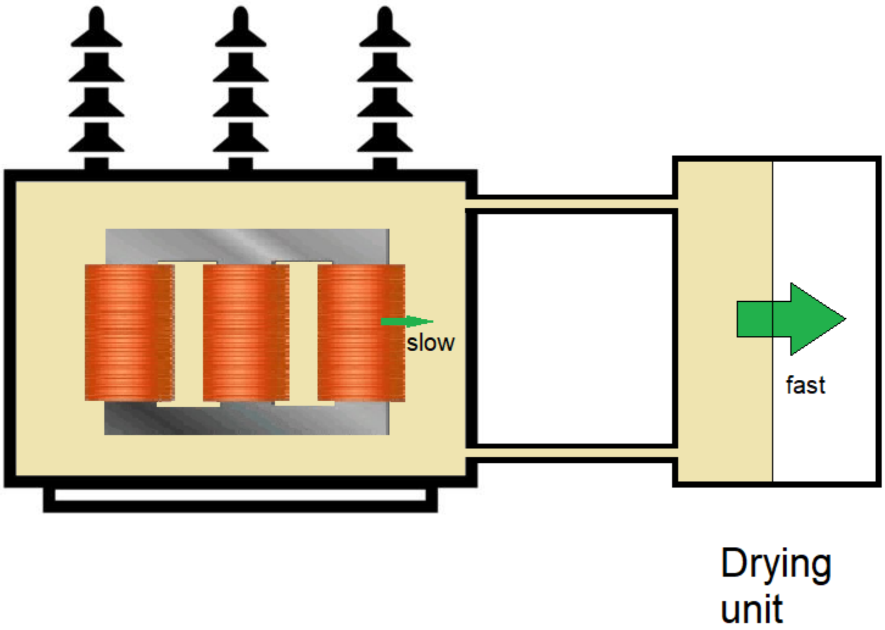
Due to the fact that the exchange of water between oil and solid insulation is very slow (and stro,g temperature dependent), a high amount of water can remain in the oil when a transformer cools down.

This can be very dangerous since high moisture in oil at low temperature can dramatically lower the breakdown voltage o insulating oil and lead to a dangerous situation (see Allowable moisture content in a transformer.docx)!

This slow diffusion process also is important if one wants to dry out a transformer. Indeed, the efficiency of a drying depends on the slowest process in the chain. In this case this is the diffusion of the moisture through the cellulose fibers of the solid insulation. Indeed, once the water is out of the solid insulation, it is easily transported to the drying machine by pumping the oil thorough the machine. Also the removal of the moisture out of the oil is very fast (due to several mechanisms).

The result is that long term drying is necessary for a good drying of the insulation.

“… long term drying is necessary for a good drying of the insulation.”



Drying proces

Several methods exist to dry transformers onsite, but there are only three basic techniques to do it online.

Nearly all the systems on the market will remove water and particles

The main differences are:

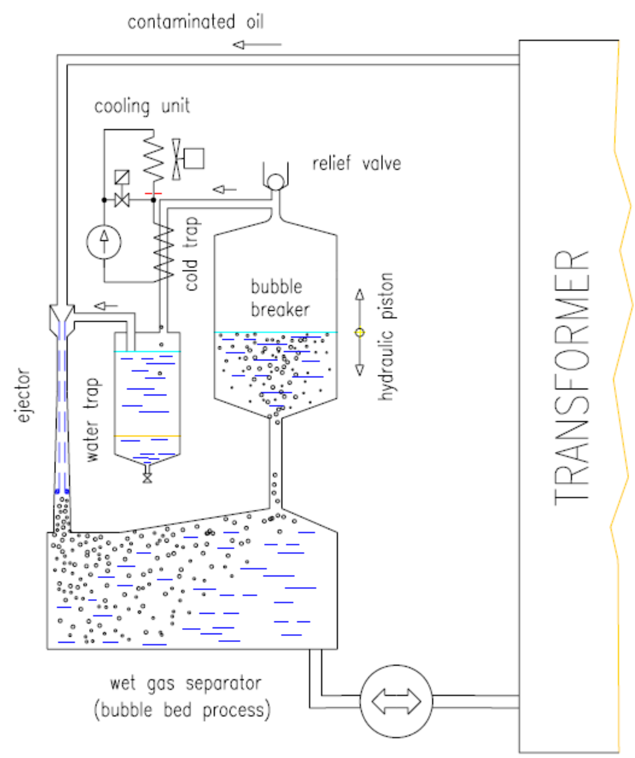
	Partial vacuum degassing	High vacuum degassing	Resin filtering
Removed water	**removed water visible and can be accurately measured (volumetrically + efficiency proved)**	Removed water to be calculated based on water measurements = uncertainty	Removed water to be calculated based on water measurements = uncertainty!
Influence on oil	**Oil unchanged (even inhibited oil)**	• **not for inhibited oils (will be removed!)** • **removal of light hydrocarbons possible! (viscosity!)**	**Oil unchanged (even inhibited oil)**
removal of fingerprint gases	partial removal (increase of gases can be detected, but at lower levels)	**full removal**	**no removal of fingerprint gases**
regeneration	No regeneration cost	No regeneration cost	High regeneration costs expecially with large transformers and/or high moisture content
Energy-cost	high operational costs (energy!) with cool transformer (to be heated to optimum temperature!)	**Very high operational costs (energy!) with cool transformer (to be heated!)**	Low energy-cost
Overdrying[1]	**Not possible**	**possible**	Unlikely + can be controlled
Purchase price	**high**	**Very high**	**low**
other	**Needs more than 2,5% of gas (air) in oil to operate !**	Operation without supervision not sure	**manual changing of cartridges**

From the above, it is clear that partial vacuum degassing and resin filtering are the best ways to fundamentally dry a transformer online. Both methods can be used in different types of transformers, but **the resin filtering is more suited to be used with small transformers with relatively low moisture content, while the partial vacuum degassing is more suited to be used with larger transformers and transformers with higher moisture content.**

[1] Overdrying can be dangerous for a wet transformers since it could lead to clampings getting loose due to crimp during intense drying!

Principles of operation

Partial vacuum degassing (Altmann Vacuum separator VS-06)



Oil contaminated with water is pumped into the device and is locally adjusted to an optimum temperature. Since the driving force for diffusion of water from oil to the gas bubbles should be as high as possible, the vacuum and optimal temperature are essential. On top of that, also a large interfacial area is essential for efficient separation. The large interfacial area is formed by creating bubbles. To produce bubbles with a large interfacial area (bubble bed), the hot oil is mixed under vacuum via an ejector with the gas (previously separated from oil). The intense diffusion of moisture from oil into the bubbles is also enhanced by minimizing the partial pressure of water vapour in the bubbles. This is achieved by sub-cooling the carrier gas to condense and freeze-out all traces of moisture prior to mixing the gas with the wet oil. Dissolved gases and vapours diffuse into bubbles which are then agglomerated, collected and broken. The water vapour then is collected as ice in the cold trap, periodically defrosted and collected as a liquid in the water trap.

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Water absorbing filtering

The on-line drying of transformers can also be conducted based on absorption principle. The wet oil from the transformer then is forced into columns filled with molecular sieve 3A. Water dissolved in the oil will get trapped by the molecular sieve and the oil will be dry and filtered at the outlet and pumped back into the transformer.

The on-line drying process continues till the whole absorption capacity of columns is exhausted (columns has then to be replaced) or the amount of water in the transformer is reduced to a requested level.

An example of this principle is the ADT mini from Altmann.