DTC

Daemisch Transformer Consult

On line drying as indispensable part of Life time strength conservation of power transformers

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Daemisch Transformer Consulting
On-Line drying

Abstract

Why Transformer drying?

In order to keep the water-driven deterioration as low as possible, the water content in a transformer should be kept between 1-2% average in cellulose.

It is important not to reduce the moisture under 1% in order to avoid overdrying effects.

Over 2% of water accelerates the ageing process.

A correct working system must be able to fulfil these specifications in a clearly controllable manner

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Abstract

Even, if on-line drying can be regarded today as a standard process, a “state of art procedure”, a lot of “counterindications” remain.

The reason being a great deal of insecurity about the results, correct application, and last not least the choice of acceptable methods.

It must be conceded that some bad experiences have been reported also, where the results were may be insufficient or where even serious accidents occurred.

Abstract

The reasons for that situation are typically as follows:

-wrong process
-misunderstanding of the physics
-misunderstanding of the chemistry

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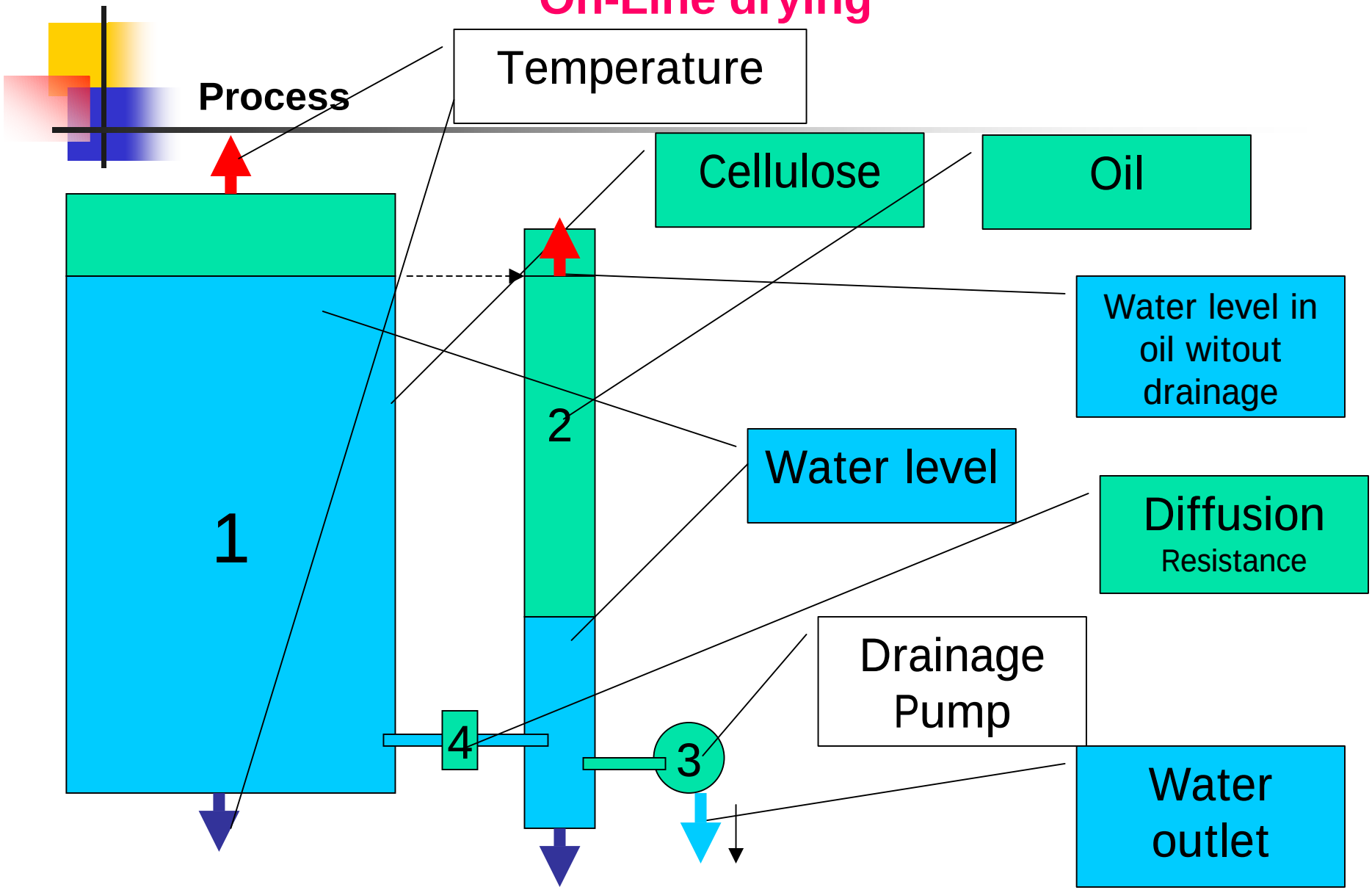

Process

The previous foil shows the basic process:

Caution: We are talking about about dissolved water!!!!!

“1” is the cellulose, this “container” is in relation to the No. “2” oil container 100/1.
Between “1” and “2” there is normally an equilibrium, depending of the “movement” of “1” by temperature (background of the equilibrium curves like Nielsen, Oomen, etc.) If the cellulose is colder than oil, all the water moves back into cellulose.

The movement of water between cellulose and oil is slowed down by the diffusion ”resistance” “4” to 50-200 ml/day.

The “drainage pump” “3” keeps the water level in “2” low, therefore the water will be drained from the cellulose.

Systems in use

Passive driers:

The difference between “filter” and “absorption” must be clearly understood.

Therefore, a **“filter”** will not work to remove dissolved water from oil. The filter can only retain particles or droplets bigger than the filter mesh. So, water in oil filters will only retain free water in droplet form!

A “**absorbent”** will take over dissolved water and retain it up to a certain level.

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Systems in use

Passive driers:

-**cellulose filters**

cellulose filters are useless, filters can only retain free water (in droplets) not dissolved water.

only temperature controlled systems can work to always keep the temperature below the transformer temperature.

-**molecular sieves**

molecular sieves can absorb water and are therefore useful for drying purposes. The material used must be proofed, i.e. there must be no side effects such as absorbing of the necessary oil contents like inhibitors, aromatics, etc.

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Systems in use

Active driers:

-**Streamline filtering = oil destruction**

These machines are basically designed for treatment of new oil for filling or refilling after a repair. They are not designed for transformer drying. At least for security reasons, they should not be used On-Line. The necessarily long treatment with internal overheating of oil and the loss of the aromatics will result in an unacceptable oil deterioration

-**Regeneration machines = misuse**

even if molecular sieves are used, they can absorb water. Such devices have been designed for other purposes, mostly we can see apparent drying results. Since the MS used in such machines are designed for regeneration, obviously the inhibitors and other required oil contents will be filtered out. The oil quality will be destroyed without reinhibition, and the results will be adverse.

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Systems in use

Active driers

Apparent drying results by regeneration:
Before

Measured values	water	BDV	neutralisation	Oil temp
	50 ppm (KF)	60 kV	0.3mg koh/g	50°C

Calculated water content by Piper, Oomen etc about 4-5 %

After 6 regeneration cycles, waiting period of several weeks

Measured values	water	BDV	neutralisation	Oil temp
	20 ppm (KF)	60 kV	0.001 mg koh/g	50°C

Calculated water content by Piper, Oomen etc. about 2-3 %

Result: Reduction of water content by 2 %

Measured by FDS before and after = about 2.5 % Result: none!!!
The apparent 2 % result by the misinterpretation of KF in aged oils!!

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Systems in use

Moderate vacuum separation of emulsion by freezing

All vacuum based systems produce an emulsion in the first stage. Emitting the outlet of such a machine into free air means loosing oil contents. The separation is normally done as in classical streamline filter machines, by heat (over 100°C). This means a loss of oil quality, which can be typically observed in oil frequently treated by such machines.

Therefore, the solution must be systems which leave the complete oil content and clearly separate the water.

The experience with such system shows long term favourable results.

The additional feature of such systems is that the oxygen content will be kept low also, and therefore the conservation will be completed by minimizing of the accelerator oxygen.

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Systems in use

Summary of the systems used:

- **Passive driers on cellulose basis** are not normally effective, they must prove their absorption capacity
- **Passive driers on molecular sieve base** are effective, but it must be proven that the oil quality and long term stability are not affected
- **active driers on streamline** filter base are normally not acceptable
- **active drying by regeneration** plants is not effective and constitutes a misuse of such plants.
- **active driers by moderate vacuum** and maintaining the oil quality are a proven technology, which, together with gas conditioning, yields an optimized conservating effect

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OFF-LINE versus ON-LINE

1. The use of **Streamline filtering or Regeneration Plants for OFF-Line drying** is useless and a waste of money! Since only the oil can be dried, a truly useful result is physically impossible!
2. **Low frequency oil spray or combination** is effective, a certain loss of DP factor seems unavoidable. The costs including the out-of-service costs are high. No long-term conservation.
3. **Vacuum Heat process** (sometimes with injection of Nitrogen) as above, highly aggressive on DP. No long-term conservation
4. **Passive driers** (effective ones) are to be used for improvement of BDV and short term improvement of reliable service.
5. **Suitable active driers with gas conditioning** are the most cost effective solution with a proven long term conservation result.

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OFF-LINE vers ON-LINE

System	Conserv. effect	Inicial costs	Service Costs	Consumables
Streaml. Filter	adverse	high	n. a.	n.a.
Regen. plant	adverse*	high	n.a.	n.a.
Pass. Filter	medium	low	high	high
LFH/Oil spray	low	high	n.a.	n.a
Vacuum /Heat	adverse	high	n.a.	n.a.
Mod. vacuum	high	medium	low	none

*** Regeneration plants used as driers. The original use for cleaning oil and transformer of ageing products is a correct highly appreciated process for conservation**

OFF-LINE vers ON-LINE

Resume:

Before applying any method, the long/middle/short term targets must be defined in order to select the method for the individual case.

In many cases a mixture of more of one method must be applied in order to optimize the technical and economical result!

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FAQ`s

-**Clamping pressure affected?** This point has not been finally clarified for OFF-line systems. The results in the literature cannot clearly evaluated. For ON-line systems, no adverse effects are known. In every case is there the recommendation to stop drying at 1.5-2%

-**Overdrying possible?** It is highly important to avoid total or partial overdrying in all processes. Especially OFF-line systems must prove how they avoid that. A result of overdrying is loss of PD. On-Line systems must also show control of drying.

On-Line drying

FAQ`s

- **Influence on DGA?** Only passive driers on cellulose base have no influence on the gas contents. All other systems will influence the gas contents in a certain way way. If it is known how the influence is working the data can be corrected and the continuity of the DGA history can be maintained.

  After OFF-line treatments it is highly recommended to document the recovery of the gas contents , preferably via On-Line gas monitoring

  ON Line systems must leave a residual gas content of 20-30%. Together with the N_2 Reference the continuity of the DGA history can be clearly maintained.

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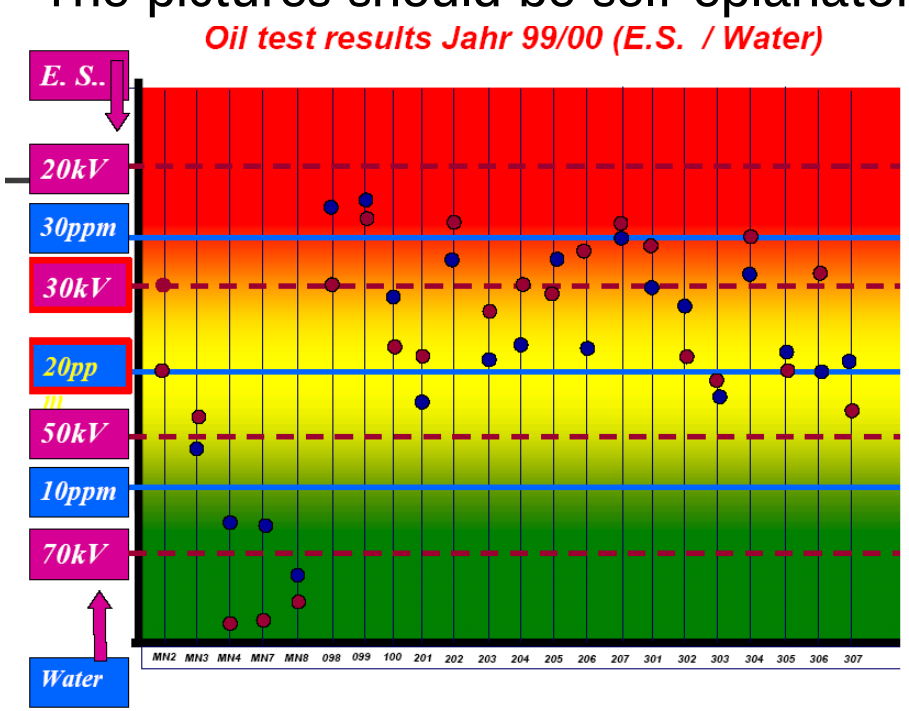
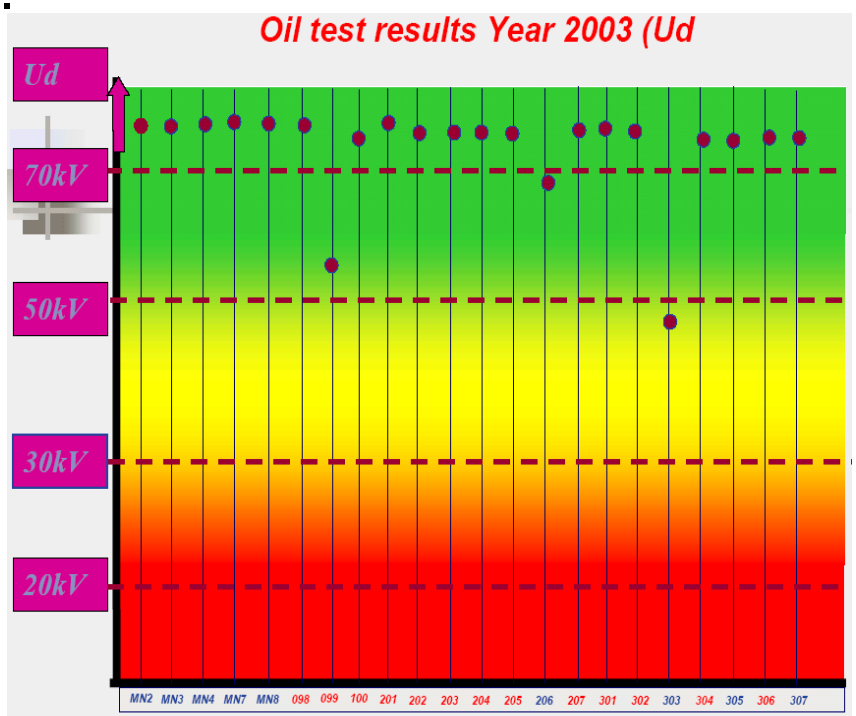
FAQ`s

Are On-Line systems able to dry transformers effectively?

The pictures should be self-eplanatory.





After 2-3 years the BDV of most transformers is > 70kV

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Economic issue

Correctly used and well planned, the application of conservational technologies in transformer population management is an extremely economical procedure! Larger populations show a profit of more than 6.5 M Euros over a 5-year calculation period!

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Economic issue aluminium plant

€

Zinsertrag	80.000	86.400	93.312	100.777	108.839	469.328
Ergebnis	-24.000	-27.600	-30.688	-33.223	-35.161	-150.672
Ergebnis	-166.667	-216.667	-236.667	-246.667	-256.667	-1.123.333
Differenz	-142.667	-189.067	-205.979	-213.444	-221.506	-972.661

Cost result with Conservation

Cost result new transformer

Cost result 1 Trans conservation

Profit 8 transformers with conservation in 5 years

Kosten / Nutzen / Summe

972.000€ Neuer Trafo

- 150.000€ Alter Trafo

822.000€ x 8 =

6.576.000

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Economic issues of generator Transformer

Generator Transformer

Reinvestment costs, conservatively calculated:	6 Mio €
Residual lifetime strength:	< 50%
Residual useable lifetime	< 5 years
Total costs inc. shut-down, planning etc.	> 7 M €
Capital costs/year (5% interest rate)	350 000€

Conservation Costs:

Regeneration, water/gas conditioning, On-line Gas Monitoring, no shut down	< 300 000€
Residual lifetime 10 Years (conservatively estimated 5X 350 000)	**3,5 Mio €**
Result:	**3,2 Mio €**

Remarks: All data are sets are calculated very conservatively. In reality the cost advantages are much higher.

Conclusion

The three pillars of transformer conservation:

-Water reduction
- Regeneration
- Gas conditioning

Using these three processes correctly yields a clearly cost-effective procedure to ensure:

Reliability of service
Competitive costs of energy
Security
Improved Ecology, conserving resources
Finally political correctness!!!!!

Contact

For questions or more information please contact:

Worldwide: www.transformer-consulting.com

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