Oxidation Ageing Alarm due to sudden variation of the O2- and CO2-level in a transformer

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1. Introduction

The Oxidation Ageing Alarm is most often induced by the sudden variation of one-shot DGA readings of the O2-level and the CO2-level in the transformer:

- O2-level sinks from the previous quasi-steady-state level 16 – 20 000 ppm at 7 – 10 000 ppm

and consequently

- CO2-level increases from 2 - 4000 ppm at 4 – 8000 ppm.

and

- during the following months another one-shot DGA reading shows a full recovery of O2- and CO2 –levels at approx. the same levels as before.

The most frequent explanation based on the standard DGA diagnostics interprets this fact as a sudden and dangerous change of the intensity of the oxidation ageing of the cellulose insulants of the transformer.

This conclusion should be regarded with the legitimate scepticism, because the main boundary conditions necessary for the mentioned process, e.g. an abrupt and a strong increase/decrease of the transformer load and the temperature is mostly not observed. The transformer load and temperature usually varies, but the average temperature of the transformer during a given period remains approx. the same.

Moreover, already the premise that the intensity of the cellulose oxidation in a transformer can simply and without any reason abruptly increase and decrease is highly questionable.

2. Flow-dynamic paradigm

The more plausible explanation of this effect offers the new paradigm based on the change of the transportation of gases in the transformer.

This paradigm consequently considers the oil content of the main tank as a capacity with:

- a continuous inflow of the O2 from the surrounding,
- a continuous consumption of O2 due to the ageing process in the cellulose
- and a continuous outflows of ageing products (CO and CO2) from the oil capacity back into the surroundings.

All gases are under normal conditions diluted in the oil and its transport is therefore performed only by the oil throughflow between the main tank and the conservator (and of course by the difusion with the surroundings) .

The new paradigm then offers quite a different and a lot more convincing explanation of a observed phenomenon.

The observed simultaneous drop / increase of the O2-level and the increase /drop of the CO and CO2-level is induced by the decreasing / increasing troughflow of oil between the main tank and the conservator, whereas the ageing intensity remains approximately the same.

For example, if the throughflow of the oil between the two tanks decreases due to small temperature difference between the oil in the main tank and the oil in the conservator, then - **by the same intensity of the oxidation aging of the cellulose -** the O2-level in the main tank **inevitably** sinks and CO a CO2-level **inevitably** rises.

Any variation of boundary conditions of the transformer which control the throughflow e.g. the deviation of the load or the surrounding temperature therefore has to:

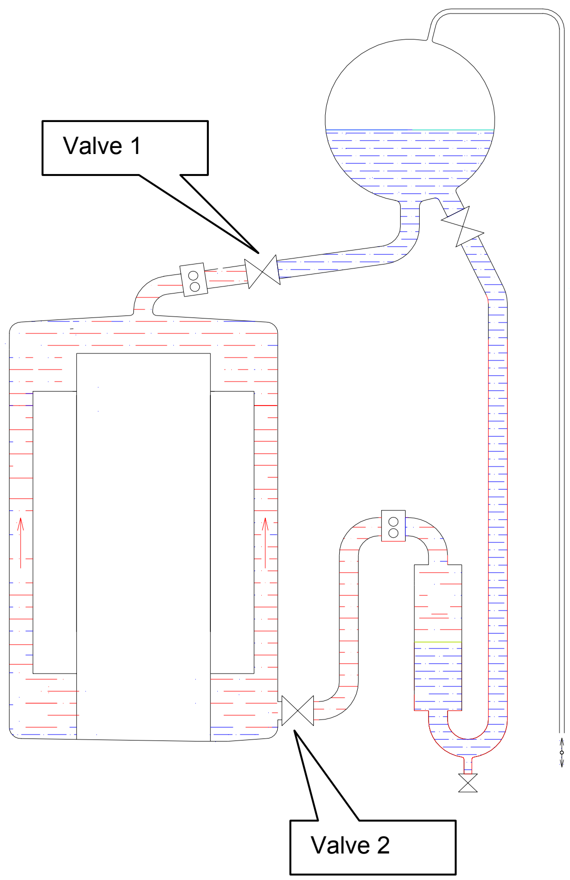
- ***immediately*** change the throughflow of the oil between the main tank and the conservator
- ***gradually*** change the DGA reading of O2 , CO and CO2-levels

The present DGA diagnostics, based on the comparison of historic change of absolute gas levels under quasi-stable conditions, cannot recognize whether the change of O2- and CO, CO2-levels corresponds to the change of the oxidation intensity or the change of the oil throughflow between the main tank and the conservator.

3. The verification of the new paradigm

The basic statement mentioned above must be of course verified by a suitable and a plausible experiment under a normal operational conditions of a transformer.

For this goal the typical oven, a highly and constantly loaded, transformer was selected , with the free oil level in the conservator provided with the continuous reading O2- and CO2-levels in the oil filling in its main tank by the on-line chromatograph TGM Gatron (See www.gatron.de)



The best demonstration of the direct relationship between the O2 and CO2 – levels in the main tank and the gas transportation between the main tank and the conservator, is given by the dynamic response of the present system to the jump-like change in the transportation of gases between the two tanks.

It can be done relatively easily in this case, because this transformer is equipped with the TRAFOSEAL II - See Fig. 1, sealing function of which can be easily switched on and off.

The TRAFOSEAL II represents here an ideal tool for our experiment – it enables a free dilatation of the oil filling (the transformer operation is not negatively affected at all), but effectively prevents mixing of the protected oil in the main tank with the oil from the conservator.

Fig. The schematic lay-out of the TRAFOSEAL II – the sealing function ON (Valve 1- closed, Valve 2 – full open)

The desired jump-like change of the gas transportation between the main tank and the conservator is then achieved by the simple opening / closing of the two slide valves:

❖ the first regime represents the normal throughflow of the oil between the main tank and the conservator - the TRAFOSEAL II is switched OFF, Valve 1 is open and Valve 2 is closed (See Fig.1) - the oil filling of the main tank directly communicates with the conservator (and with the surrounding air as well).

- the second regime simulates an effectively obstructed gas transport between the two tanks, the TRAFOSEAL is switched ON, Valve 1 is closed and Valve 2 is open (See Fig.1) - the input and output of the gases in the main tank is effectively obstructed due to strongly reduced mixing of both oils in the main tank and the conservator.

For more detailed description of the function of TRAFOSEAL II See www.ars-altmann.com\ Product Range\ TRAFOSEAL \Technical Specification.

Results of the experiment are shown at Fig. 2.

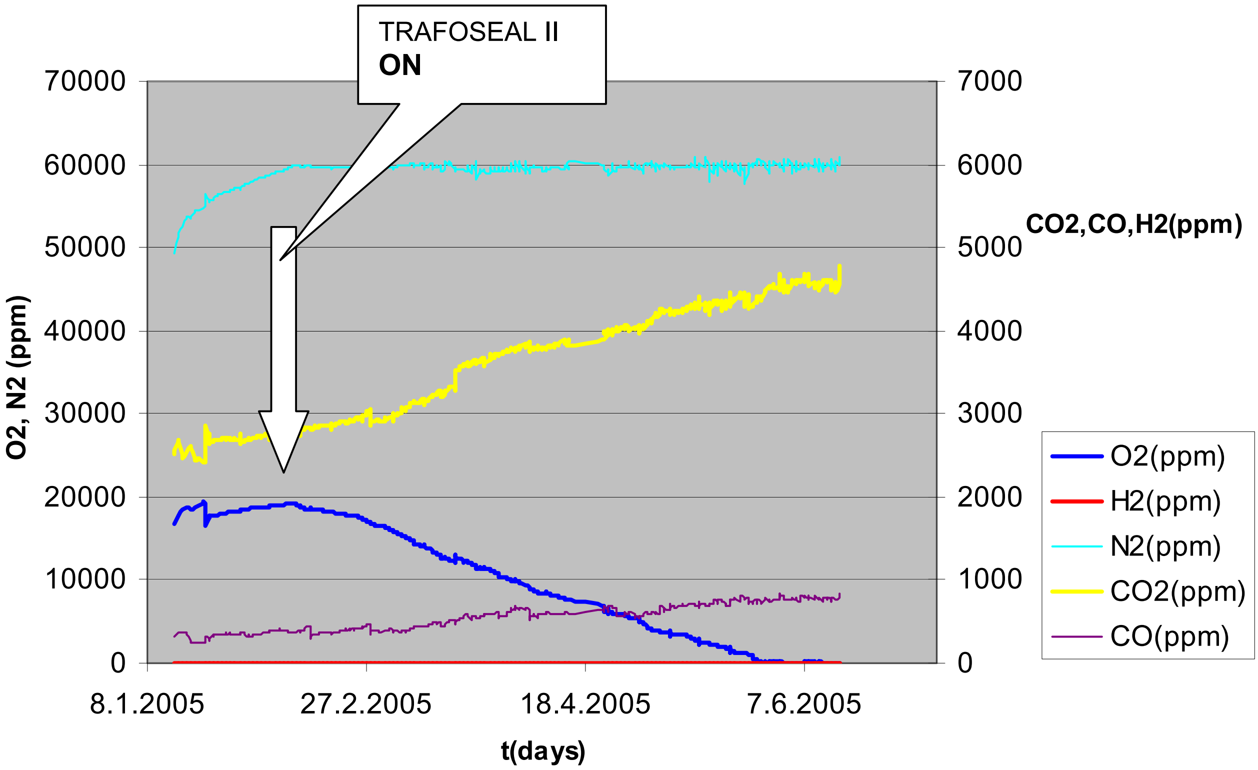


Fig.2 The on-line reading of the O2, N2, CO,CO2 and H2-levels in the main tank

The Fig.2 clearly shows the strong impact of the jump-like change in the boundary conditions evoked by switching the TRAFOSEAL II on.

The ingress of air gases into the main tank and simultaneously, the escape of ageing products from the main tank, is effectively obstructed and consequently:

- the N2-level which previously increased, is constant now (the N2 as an inert gas serves here as an ideal marker of the intensity of the transportation process between the main tank and the conservator).
- the O2-level permanently sinks - oxygen is intensively consumed in the ageing process, until the non-measurable low oxygen content in oil ($O2 \rightarrow 0$) is reached
- CO2- and CO-levels permanently grow up till the oxygen (diluted in the oil filling of the main tank) is completely consumed, then both levels remain constant.

The flow-dynamic interpretation of the experimental data is clear and simple – the **ageing process caused by the oxidation is de-facto stopped.**

This simple and plausible explanation of our experimental data must be fundamentally inconsistent with the common interpretation based on two samplings of the oil from the main tank:

- the first sampling before the TRAFOSEAL action (e.g. at 10.5 2005) gives us relatively high O2-content (20 000ppm) and relatively low CO2-content in the oil (2 800ppm)
- the second one, e.g. after cca 5 monts (at 8.5 2005), gives us an extremely low O2-content (O2 < 100ppm) and high CO2-content in the oil (over 4 500ppm).

The common DGA interpretation of the same process is then **a massive increase of a the oxidation ageing process in the cellulose.**

4. Conclusion

Our experiment clearly shows an essential drawback of the present DGA diagnostic method. This method works only with absolute levels of gases in the oil and a-priori excludes the effect of the flow dynamics in the examined system at these levels.

Two absolutely different interpretations of our experiment show how misleading the present DGA diagnostics can be:

- common DGA diagnostics obviously wrongly predicts a **massive increase of the oxidation ageing of the cellulose**

whereas

- new flow dynamic paradigm legitimately claims that the **ageing caused by oxidation of the cellulose materials is de-facto stopped**

The jump-like change of boundary conditions in our experiment is of course purposely extreme to show a not only quantitative but also qualitative discrepancy in interpretations.

The comparable obstruction of the gas transportation in the ordinary transformer (no or very weak throughflow of the oil between the main tank and the conservator) can be achieved (e.g. by the constant temperature of the oil in the main tank, the low temperature difference between the main tank and the conservator, the long tube connecting both tanks, …), but only for a relatively short time and therefore the real change in the O2-, CO- and CO2-readings is not so dramatic.

The present DGA diagnostics of the oxidation ageing reliably indicates, whether the not-desired process in the transformer exists or not, but cannot determine what amount of the specific gas [in m3 s-1 or kg s-1 units] produces an examined fault.

The present DGA diagnostics is and remains a very good first (and easily accessible) indicator of the oxidation ageing of a transformer which should give us an impulse to start a proper diagnostic method.

Generally, the plausible evaluation of faults in the transformer must be based on:

- jump-like change of boundary conditions of a transformer
- on-line reading of fault gas levels in the main tank (and in the conservator)
- quantitative evaluation of a fault by the amount of consumed and/or produced specific gas

For more information about a corresponding DGA gradient method See www.ars-altmann.com \News\ Impact of vacuum treatment on DGA.