AGEING OF A TRANSFORMER

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Is it possible to measure the ageing of a transformer?

No, maybe not. However, one can obtain a measure on the relative aging rate of the oil and the cellulose by use of the gas production rate as a result of the ageing. This is made possible by use of a Redfox degasser through which the amount of different removed gasses can be measured and calculated. As the gas content in the transformer has reached a steady-state situation the removed gasses correspond to the new production of these specific gasses. Of special interest is to determine the flow of carbon dioxide since this gas is one of the products due to chemical degradation of the oil and cellulose. Fig. 1 is illustrating the degradation.

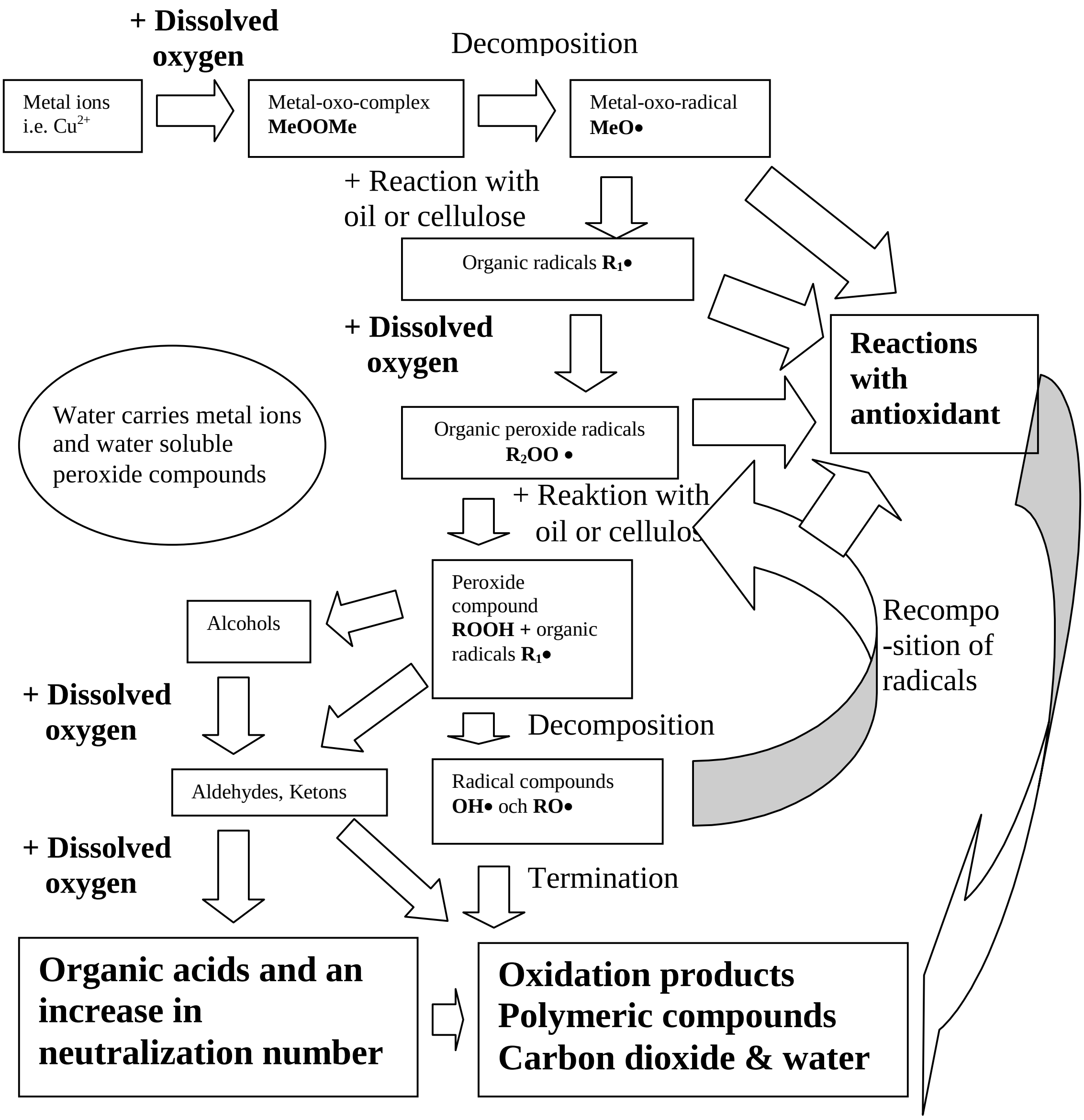

Fig. 1. An illustration of the degradation and ageing process.

The removed CO_2- flow is related to the volume of oil in the transformer and is expressed in a goodness ratio R in ppm/year. Given the fact that the production flow is measured under stationary conditions for the gas content, the ratio R can be regarded as a measure of the ageing rate. The higher the ratio, the higher the ageing rate. The ratio R can be compared with statistical numbers from IEC and Cigré, which show that 90 % of all transformers generate an amount of CO_2 between 1800-10000 ppm/year.

Godness ratio R obtained by use of Redfox C-Ty:
At 4 different transformers, after some years of degassing, we have obtained a goodness ratio between 200- 1700 ppm/year. This accounts for healthy transformers with between 10 and 50 years in operation. At additional 2 transformers from 1980´ths with thermal faults we have obtained values between 3000-3500 ppm/year.

The so far best values we have obtained on transforms at Växjö Energi AB. They installed the first Redfox under 2001 and a second under 2003. Here follows an overview of made investigation.

Transformer F7 Haga:

Year of delivery	1996
Power	120 MW
Weight of oil	32,7 tons
Closed expansion vessel	

Degassing of the transformer started about 7 years after installation. The content of gas had at that time increased to about 3 % and containing about 8500 ppm of oxygen O_2. After 27 months with continuous degassing the total gas content had decreased to 0,81% and with a oxygen content of 2300 ppm and a carbon dioxide content of 550 ppm. At the same occasion the removed gasses were collected in a bag for analysis at a laboratory. The laboratory found the following gas flows in ml/24h:

Hydrogen H_2	2,2
Oxygen O_2	300
Nitrogen N_2	770
Methan CH_4	1
Carbon oxide CO	15
Carbon dioxide CO_2	20
Ethen C_2H_4	0,6
Ethane C_2H_6	0,04
Etyn C_2H_2	0,3

The flow of nitrogen and oxygen have passed through the expansion vessel. The other gas flows have all been generated in the transformer. The generated flows for the error gasses are although slightly higher since small and here negligible flows have passed in the wrong direction, i.e. through the expansion vessel. If the content of CO_2 were about 400 ppm in the oil the negligible flow would have been zero. The goodness ration R is based on a production rate of 20 ml / 24h and that the oil volume is ~36 m^3 is then:

$$R= 20*365/36=200 \text{ ppm /year}$$

Transformer F1VM T265:

Year of delivery	1973
Power	100 MW
Weight of oil	27 tons
Open expansion vessel	

Degassing of the transformer started 22/2 – 2001 about 28 years after installation. The content of gas had at that time increased to about 10 % and containing about 23000 ppm of oxygen $O_{2.}$ After about 20 months with continuous degassing the total gas content had decreased to 1,6% and with a oxygen content of 5700 ppm and a carbon dioxide content of 370 ppm. At the same occasion the removed gasses were collected in a bag for analysis at a laboratory. The laboratory found the following gas flows in ml/24h:

Hydrogen H_2	10,4
Oxygen O_2	5230
Nitrogen N_2	11450
Methan CH_4	1,3
Carbon oxide CO	23,8
Carbon dioxide CO_2	53,5
Ethen C_2H_4	2,1
Ethane C_2H_6	0,07
Etyn C_2H_2	6,9

Of these flows, nitrogen, oxygen and a small quantity of carbon dioxide have passed through the expansion vessel. The other gas flows have all been generated in the transformer. The generated flows for the error gasses are although slightly higher since small and here negligible flows have passed in the wrong direction, i.e. through the expansion vessel. For CO_2, the situation is different since the content of CO_2 is less than 400 ppm.

A calculation of the gas exchange in the expansion vessel gives the following results:

CO is removed with 5,7 ml/24h
CO_2 is added to the oil with 3,4 ml/24h
The total amount of produced CO_2 is then 53,5-3,4 =50,1 ml/24h.

The goodness ratio R based on a production rate of 50 ml /24h and a oil volume of 30 m_3 results in:

R=50*365/30=608 ppm/year

Summary:

The calculated goodness ratios of 200 and 608 ppm /year are more than a factor 3 lower compared to the values stated by IEC and Cigré. IEC and Cigré mean that 90 % of all transformers produce CO_2 to an amount between 1700-10000 ppm/year. In fig. 2 the values of CO_2- production flow for these transformers are illustrated together with the corresponding values for transformers equipped with Redfox degasser.

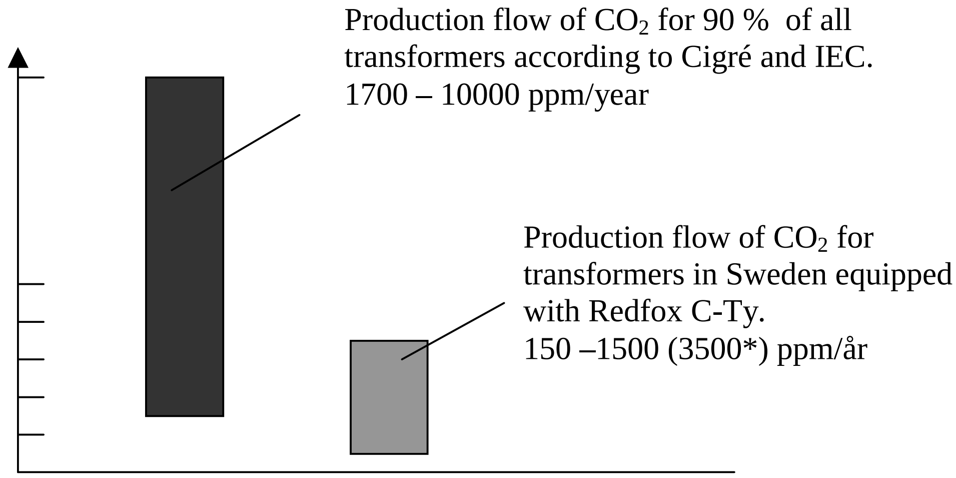

Fig. 2. Production flow of CO_2 for 90 % of all transformers according to Cigré and IEC together with production flow for transformers equipped with Redfox C-Ty.

These Cigré – values is valid for transformers with closed as well as open expansion vessel and for transformers with low as well as high temperature of operation. Oil filled power transformers will have a very low ageing rate as a result of the continuous degassing. This is according to the theory and the relation between oxygen, carbon dioxide and degradation is illustrated in Fig. 1. above.

The value of 3500 in Fig. 2. stems from two transformers with thermal problems and would not be able to operate without an active action such as continuous degassing.

This will benefit a high degree of security of operation and will is of great economical importance since the transformer will have the possibility to work for a longer period of time compared to the case if continuous degassing would not have been in operation. In addition, the calculations on the second transformer showed that the CO_2 – production rate before degassing started was 177 ml/24h. This means that the goodness ratio before degassing was 2150 ppm/year. This is a value within the interval stated by Cigré.