# Maintenance-Free dehydrating breather for Power Transformers and Industrial application


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*Abstract*— **Power transformers are complex and critical components of the power transmission and distribution system. Continuous extension of operating times, combined with ever-growing current density levels exerted on power transformers, have resulted in ever-increasing quality and reliability demands and reduction of life cycle costs of transformers and there accessories. To this effect finding simple, practical solutions is frequently required when transformers in operation are to be ugraded and retrofitted. Besides that the useful life of transformers is described in general by the lifespan of the oil paper-insulation system, because with loss of the mechanical stability of the oil paper-insulation the risk of a dielectric failure and with it of an entire failure of the transformer exists. Besides the *temperature* factor of influence (known since Montsinger) *humidity* has been recognized – based on investigations during the last years - increasingly as important catalyst for theageing process of transformers. To guarantee a very high useful life of a transformer, it´s therefore the basic purpose, to decrease this ageing catalyst or to avoid his influence a priori.**


## I. Introduction

It is well known that moisture continues to be a major cause of problems in transformers and a limitation to their operation. Particularly problematic is excessive moisture in transformers systems, as it affects both solid and liquid insulation with the water in each being interrelated. The insulation system in power transfomers degrades under normal operating conditions, in particular with higher temperature, higher moisture and oxidation. The life of transformer is significant influenced by the condition of solid insulation. Currently degradation of insulation [Fig.1] in a transformer is monitored by sampling the oil and analysing for dissolved gases furan content and by examining the change in the degree of polimerisation. Reason is the admission of moisture in the transformer-oil by the contact with the inhaled air inside the transformer oil-compartement. From cost or accessibility reasons poorly serviced conventional breathers are often the reason that the oil takes up moisture from the air. To avoid this process an optimized drying of the inhaled air of the transformer is indispensable.

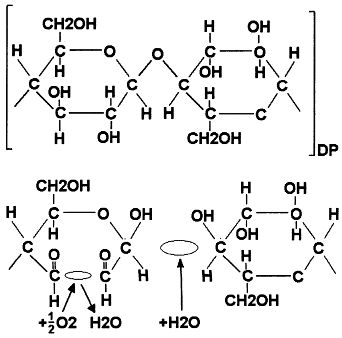

Fig. 1 Depolimerization process, forced by water

## II. Types of water in oil

Water can exist in serveral different states within the transformer. There are three basic types of water found associated with transformer oil:

- dissolved water is hydrogen bonded to the hydrocarbon molecules of which oil is composed
- emulsified water is supersaturated in solution but has not yet totally separated from oil. It usually gives oil milky appearance
- free water is also supersaturated in solution but in a high enough concentration to form water droplets and separate from oil.

In most cases, when one is analyzing or discussing the amount of water in oil, dissolved water is being referred to as emulsified and free water is visually apparent.

## III. What does it mean: Water in Oil (ppm)?

The detection of water in oil performed in the laboratories is most often performed by an analytical technique called Karl Fischer titration decribed in ASTM Test Method D1533 or IEC Method 60814. Both methods are very comparable and involve a coulometric titration technique involving the reduction of an iodine-containing reagent. The methods are used to determine the amount of water in an oil sample on a weight-to-weight (mg/kg) basis or what is commonly known as ppm (parts per million).

## IV. What does it mean: Solubility of Water in Oil?

The concepts of solubility and relative saturation can sometimes be difficult to understand. Solubility is defined as the total amount of water that can be dissolved in the oil at a specific temperature. The solubility of water is not constant in oil but changes due to temperature. As the temperature increases, the amount of water that can be dissolved in oil also increases. The increase is not linear but exponential in function. The table shown [Table1] lists the calculated solubility limits for oil at various temperatures. These levels are the greatest amount of water that can be dissolved at the temperatures listed. If the concentration of water in oil is higher than shown for that specific temperature then the oil is supersaturated with water, and free or emulsified water could exist.The solubility for mineral oil can nearly be calculated using *equation 1*

$$\log \mathbf{So} = -1567/\mathbf{K} + 7{,}0895$$

**So** = solubility of water in mineral oil
**K** = temperature in Kelvin (°C + 273)

## V. What means Relative Saturation (RS) of Water in Oil?

Relative Saturation (RS) is the actual amount of water measured in the oil in relation to the solubility level at that temperature. Relative saturation, expressed in units of percent, is the concentration of water (Wc) in the oil relative to the solubility (So) or concentration of water the oil can hold at the measurement temperature, as shown in *equation 2*

$$\mathbf{RS} = \mathbf{Wc} \,/\, \mathbf{So}\ (100\%)$$

For example, a sample of oil was taken for determination of the water content. The temperature of the oil at the time of sampling was 62°C. The laboratory performed the analysis and determined the water content to be 11 ppm. From equation 1, it is calculated that the solubility level at 62°C is 259 ppm. As discussed previously, relative saturation is the actual measured value compared to the solubility value. In this case it is 11 ppm divided by 259 ppm resulting in a relative saturation of 4,25 percent.

| Oil Temperature | Water Content in Oil, ppm |
|---|---|
| 0°C | 22 |
| 10°C | 36 |
| 20°C | 55 |
| 30°C | 83 |
| 40°C | 121 |
| 50°C | 173 |
| 60°C | 242 |
| 70°C | 331 |
| 80°C | 446 |
| 90°C | 592 |
| 100°C | 772 |

Table1 Water solubility in mineral oil as a function of temperature

## VI. Meaning for the Transformer System

Water does not remain at the same concentration in insulations but, rather, it is continuously migrating between the solid and liquid insulation. Most of the water in a transformer system resides in the solid insulation (paper and pressboard) and not in the oil. As temperature increases the water is forced from paper into oil.

## VII. Potential Solution to avoid inhaled humidity

In December 2001 MESSKO GmbH installed on a 350 MVA transformer at the RWE substation in Dauersberg/Germany MTraB® Maintenance-Free Dehydrating Breather [Fig.2] for testing purposes and in order to collect field experience. Up to now these installed breathers are operating perfectly.The installation of a maintenance free breather may solve the needs like:

- No frequent changing of saturated silica-gel; avoidance of humidified inhaled air
- Self-monitoring and remote control system
- No pollution and disposal problems
- Easy retrofit solution

Fig. 2 MTraB, maintenance free breather


Fig. 3 Comparative measurements at a power transformer with a measuring flange for conventional dehydrating breathers (MESSKO, Oberusel)

When the oil conservator suctions in air (e.g., due to the reduced load), the air flows through a sintered metal filter to the inside of the device. The filtered air flows through a desiccant chamber filled with colorless, moisture adsorbing pellets and is dehydrated. The dehydrated air rises further via the pipe in the oil conservator. The relative humidity will be measured with a moisture sensor which is mounted in the connection flange of the breather. This relative humidity is a saturation indicator of the desiccant. When a pre-defined moisture value is exceeded the desiccant is baked out by heating elements mounted in the desiccant chamber. During this baking process, the temperature is also monitored by a temperature sensor mounted in the connection flange. The water vapor created by the baking process condenses by convection in the dehydrating breather on the bottom metal flange. The condensed water exits the device through the sintered metal filter. No maintenance is required for replacement and regeneration of the desiccant.

Baking out of the maintenance-free dehydrating breather releases approx. 250 ml of water, which is drained through the sintered metal filter.

## VIII. MATERIAL PROPERTIES OF THE DESICANT

The chemical structure of the silica gel with its hydrophobic properties enables polar bonding, i.e. absorption of water, up to a certain quantity.The higher the humidity concentration gradient at the silica gel contact surface, the higher the dehumidification capacity.

Fig. 4 Drying agent, colorless

**Grain size 2 - 5 mm, without colour indicator** with white, semi-transparent appearance, bulk density approx. 750 g/l. The spherical shape enables better aeration. This is an advantage if silica gel is to be used with a layer thickness of more than 2 cm; internal surface: 800 $m^2/g$

Adsorption characteristics in percent by weight (at 25 °C):
Δ r.h. = 20% / 11 percent by weight
Δ r.h. = 40% / 20 percent by weight
Δ r.h. = 80% / 34 percent by weight

In the MTraB DB200 air passes the silca gel in radial direction through a 12 times greater area compared with a conventional dehydrating breather:

- 0.1508 m² Outer cylinder surface of MTraB DB200
- 0.0125 m² Circular area of a conventional dehydrating breather

In combination with the adsorption properties of the silica gel (type E) used in the MTraB the resulting degree of dryness is at least as good as that of a conventional dehydrating breather of size L3.

## IX. COMPARATIVE MEASUREMENTS WITH CONVENTIONAL DEHYDRATING BREATHERS

Comparative measurements [Fig.3] were carried out with a measuring flange at conventional dehydrating breathers equipped with the same sensors as a maintenance-free dehydrating breather, using a 350 MVA mains coupling transformer.

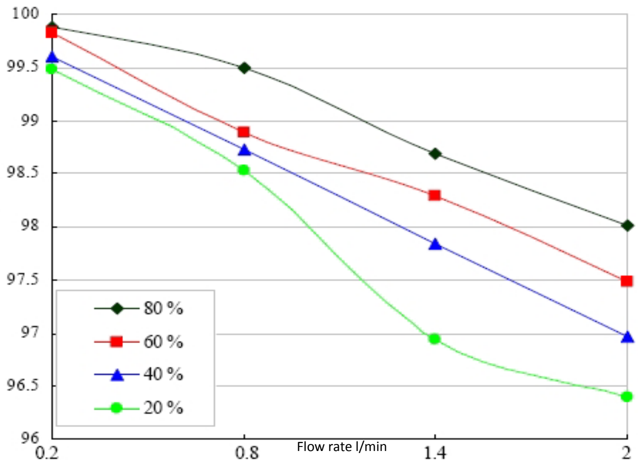


*Fig. 5* ***Conventional Breather*** *Degree of dryness as a function of the air speed for different initial humidity values (measurements IEH, TU Stuttgart)*

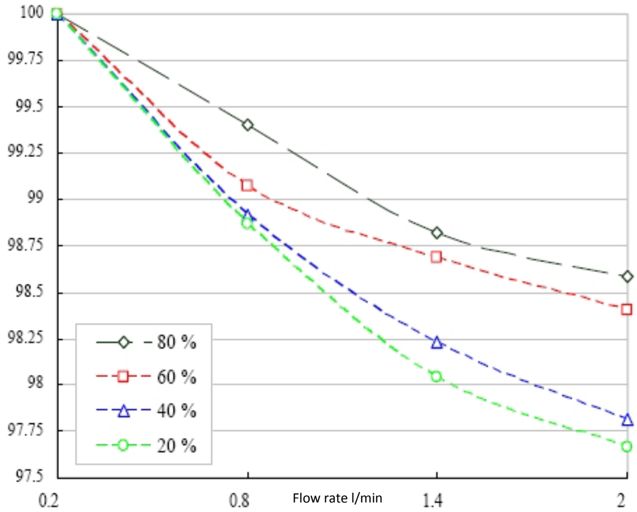


*Fig. 6* ***Maintenance Free Breather*** *Degree of dryness as a function of the air speed for different initial humidity values (measurements IEH, TU Stuttgart)*

Comparative measurements carried out at the University of Stuttgart indicated a higher degree of dryness than a conventional dehydrating breather. Good measurement results were also achieved at the MESSKO test rig.

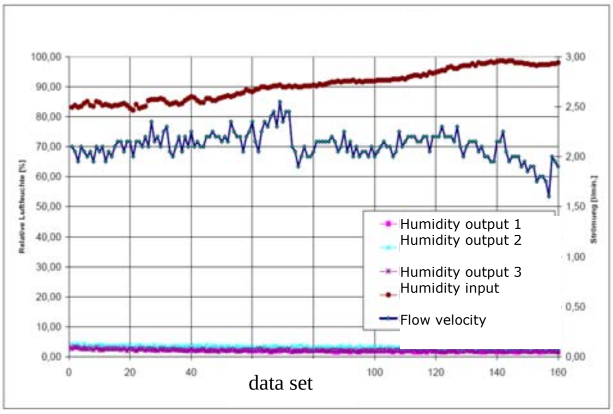


*Fig. 7* ***Maintenance Free Breather*** *Drying capacity of MTraB at an air flow rate of 2l/min (measurements Messko test rig, Oberursel)*

## X. Water absorption capacity of silica gel

Because in the MTraB the air is dehumidified in axial direction, the quantity of water that is picked up is slight lower than in a conventional dehydrating breather if the flow velocity exceeds 1 m/s, although it is better if the velocity is less than 1 m/s. Due to the larger contact area for the incoming air this somewhat poorer water absorption behaviour has no negative effect on the degree of dryness of the air (Fig 8 and 9)

This characteristic can be attributed to the higher adsorption capability of silica gel at high humidity differential between incoming and exiting air.

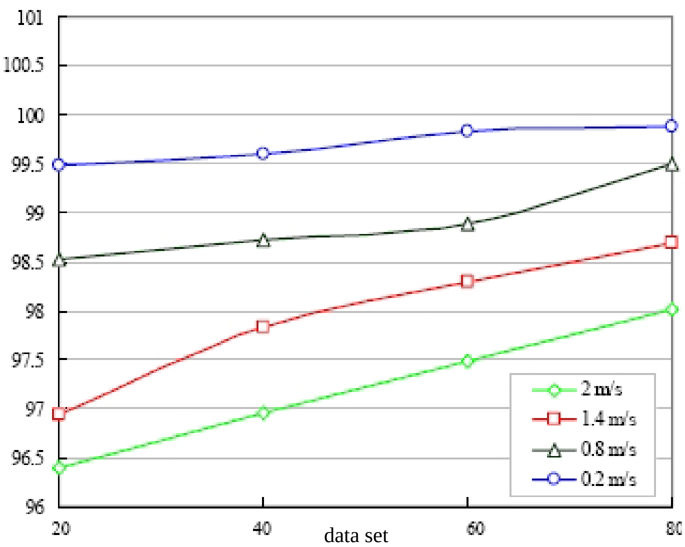


*Fig. 8* ***Conventional Breather*** *Water absorption capacity at different flow velocities as a function of relativ humidity (measurements IEH, TU Stuttgart)*

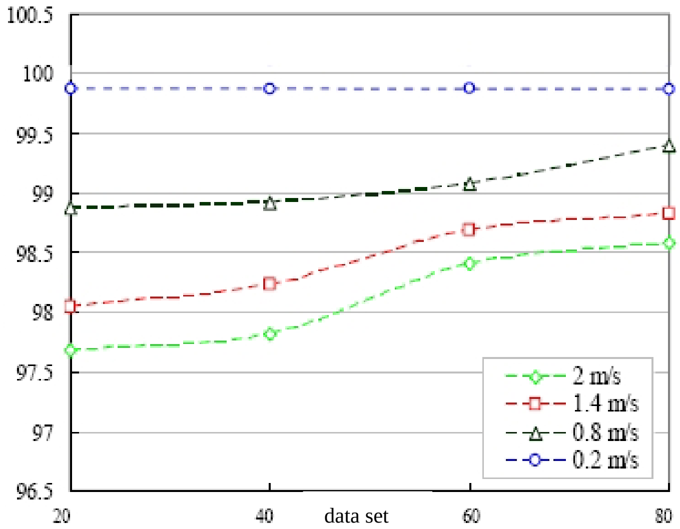


*Fig. 9* ***Maintenance Free Breather*** *Water absorption capacity at different flow velocities as a function of relativ humidity (measurements IEH, TU Stuttgart)*

## XI. Conclusion

Humidity plays a key role in the aging process of achievement transformers near the oil-temperature. Hence, purpose is to reduce the moisture absorption by the contact of the insulation-oil with the inhaled air clearly.

The new development of maintenance-free dehydrating breathers (type MTraB®) offer the perfect solution to this problems. With the operating times of transformers in power supply networks and industrial processes growing ever longer, introduction of theses breathers will on the one hand reduce the "contamination" of oil with moisture and on the other hand provide a marked reduction in lifetime costs.

Comparative measurements carried out at University of Stuttgart and MESSKO relating to the drying performance of conventional and maintenance-free dehydrating breathers indicated no significant differences in a real transformer environment. No negative attributes relating to the application of maintenance-free dehydrating breathers were found. Incoming air this somewhat poorer water absorption behaviour has no negative effect on the degree of dryness of the air.

## References


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