# Considerations Relating to the Effectiveness of the Float Installed Inside the Conservatory of Oil to Electrical Power Transformers

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*Abstract* - **Protection of the electroinsulating oil against oxidation, constitutes one aspect investigated to increase safety in the operation of the electric power transformers. Oxidation is a chemical reaction between transformer oil and oxygen. This reaction is influenced by: temperature, humidity, catalytic action of metals (especially copper), sunlight (especially ultraviolet radiation), electromagnetic field and products of impregnation incompletely polymerized. From the aspects of safety, continuity of service, and of efficient, low-cost maintenance it is desirable to monitor the condition of the insulating oil by testing and to take remedial measure before the oil reaches a point of determination beyond each failure of equipment can be expected. The condition of the oil and the load conditions should determine whether in annual, biannual or more frequent schedule should be followed. Normally acidity, IFT, power factor and dielectric tests should be done on oil in major electrical equipment at least once a year. The surface of the electro-insulating oil in contact with air was reduced by constructing oil conservatory. Installing of the float inside the conservatory is intended to cover the oil and thus to limit at the maximum the contact with the air. An experimental stand, built in the Laboratory EMAD of the University "Stefan cel Mare" of Suceava, is presented in this.**

**Keywords -** *transformer, electoinsulating oil, safety in exloatation*

## I. Introduction

The electroinsulating oils into operation not preserve their properties unlimited. They change slowly or rapidly, due to the phenomenon of oxidation.

Oxidation is actually a chemical reaction between transformer oil and oxygen. This reaction is influenced by: temperature, humidity, catalytic action of metals, sunlight (especially ultraviolet radiation), electromagnetic field [1] and products of impregnation incompletely polymerized, so:

-first cycle of reaction leads to the oxidation products soluble, such as acids;

-the second cycle of reaction is characterized by the fact that the oxidation soluble products is transformed into insoluble compounds (waxes, resins, etc.) and forming mud (schlamm).

Insoluble deposits on the transformer windings are disturbing in that it prevents normal discharge of heat released. Another high-risk is that the acids attack the cellulose-based insulation and the result of the aging process loses its elasticity and became vulnerable to mechanical forces (example of forces electrodynamics of short-circuit). As a result in conductor insulation short-circuit can occur which cause serious damage of the transformer, see Fig 1.

Research of the causes, that leading to a rise in the phenomenon of oxidation of the electroinsulating oil, have shown that this process occurs at maximum intensity in the conservatory of electrical transformers. The fact appears justified given that the area of contact with the atmospheric oxygen is maximum in the conservatory of oil, where the oil in the presence of oxygen and moisture oxidizes strong [2].

The products of oxidation descend in the transformer tank (see Fig. 2), where it attack the hopelessly insulation (insulation of windings in particular made cellulose-based).

The conservatory or the expansion vessel is a container, that communicates with the vat through a pipe and serving to the location of the oil level oscillations and decrease the surface contact with air in transformer oil.

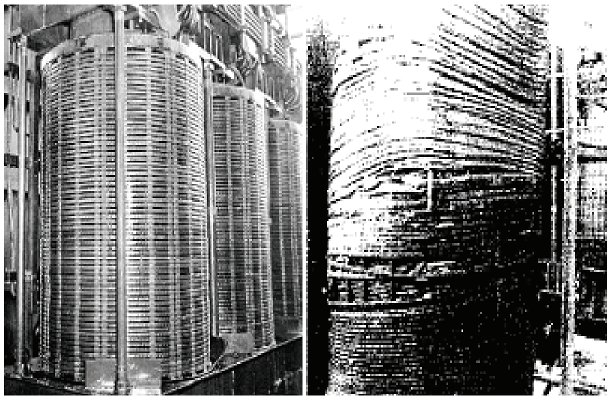


Fig. 1. Damages caused in a power tansformer with electroinsulation oil: a) Healthy insulation; b) Faulty insulation due to a short circuit [3]

The use of a mineral oil, as insulating liquid, in a transformer, was patented [4], for the first time in the USA, in 1887. First, use, in a three-phase transformer, dates from 1892. At the beginning, they were from the category of paraffinic oils. The first conservatories of oil for power transformers were built in 1918.

Today, the electric transformers with power exceeding 20 kVA inclusive, are endowed with oil conservatory.

By using a conservatory, the surface of the heated oil, in contact with the ambient air, is reduced to about 20%; In addition, the conservatory of oil isn't subject to variations in temperature so large as in the tank.

Absorption of moisture and oil aging are in this case greatly reduced. To determine the approximate capacity of the conservatory, it is based on the assumption that the difference between the maximum oil temperature during the summer and minimum temperature in winter can reach about 100 ° C. The coefficient of thermal expansion of the oil being 0,0007 will result in a variation in volume of 0,0007 • 100 = 0,07, i.e. 7%. Taking into account that at the lowest temperature must remain the least oil in conservatory, and that in some cases there may occur a difference in temperature and higher than expected (for example in case of overloading) take conservatory capacity equal to 10% of the volume of oil in transformer [5].

The oil volume of transformer is estimated with the relationship (1)

$$V_u = V_{cv} + V_{ur} - \left(V_w + V_m\right) \quad (1)$$

Where:

$V_u$ , the oil volume of transformer;

$V_{cv}$ , the volume of the tank;

$V_{ur}$ , the volume of oil in the cooling elements;

$V_w$ , the volume of the windings;

$V_m$ , the volume of the magnet circuits.

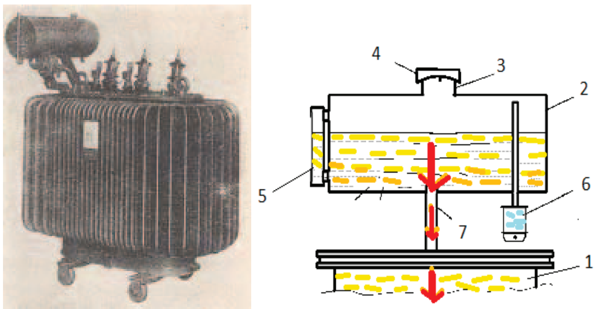



Fig. 2. Conservatory of oil: a) overview; b) Scheme of priciple: 1-tub; 2-oil conservatory; 3-hole filling with oil; 4-cap; 5-level indicator; 6-silica gel filter; 7-connecting pipe [6].

## II. Conservatory with elastic membrane

Transformer oil on oxidizes over time, and the substances, which formed, are very harmful [6]. That's why it seeks to avoid the contact of the oil with atmospheric air, reinforcing the elastic expansion vessels. Sometimes it introduces a mattress of nitrogen on top of the oil, for the same purpose. Lately, instead of rubber membranes are used modern plastics, achievement of the expansion bags is only of plastic.

Polyester membrane type Mustbalance (MTB), Fig. 3 a is inserted into the conservatory through the window of inspection, placed at the end of the conservatory [7]. Schema of principle is shown in the Fig. 3 b. Somme explanations: check the air pressure in the MBT 7, to be 10 kPa (0.1 bar). If not, the pressure increases at the fill and closes the fill valve air 3.

Open the ventilation valve 4, on both ends of the conservatory. Opens the valve 6, between the conservatory and tank and pump more oil in the conservatory. Pumping speed needs to be slow, so that the pressure in the MBT 7, does not exceed 13kPa (0,13 bar). Stops pumping when oil starts to come out of the vent valve and close the aeration screws.

Adjust pressure within the MBT 7, to normal by opening the plug of the flange or from the fill valve with air 3 and remove the pressure hose. Reopen the valve 6, between the conservative and the tank, and continue filling with oil until the oil level indicator 5, show the correct value according to the temperature of the transformer. The advantages are excellent mechanical properties (tensile strength tear > 18 daN), temperature resistance (-40 ° C + 120 ° C), resistance to ageing (up to 10 years) and prevents condensation.

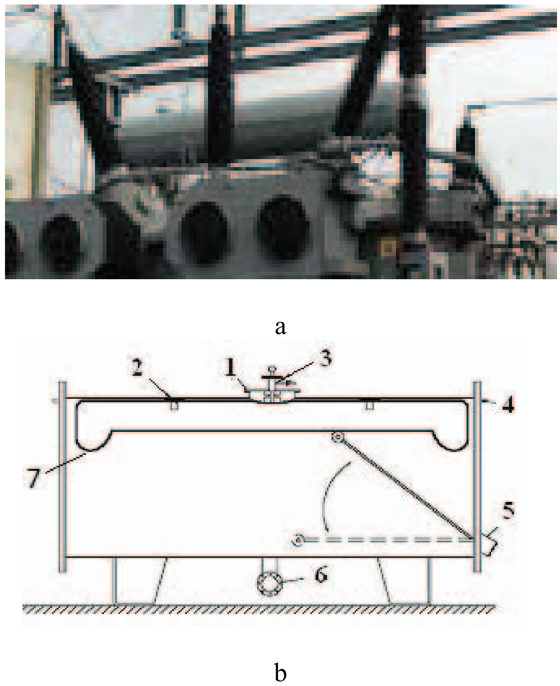



Fig. 3. Conservatory of oil with polyester membrane type Mustbalance: a) Overview; b) Schema of principle: 1-cap; 2-hooks; 3-valve filler; 4-valve vent; 5-level indicator with float (maximum closing position of the membrane); 6-valve of the tank and conservatory; 7-MTB membrane type Mustbalance, coated with high-quality elastomer (nitrile) to resist contact with the transformer oil without degrading it (insert into conservatory) [7]

## III. Stand for study the oil conservatories

The invention [8]. relates to a stand for the study of chemical processes, that accompany the oxidation reaction of electroinsulating oil, content in the conservatory that is mounted on the electric power transformer, for takeover expansion in the volume of oil content in the transformer tank.

*The coefficient of volume expansion* $\alpha_V$ defines the variation of density $\rho_t$ according to temperature, thus:

$$\rho_t = \rho_{t_0}\alpha_V\left(t - t_0\right) \quad (1)$$

For mineral oils, $\alpha_V$ is depending on the density according to the relationship:

$$\alpha_V = (234 - 194 \cdot \rho_{15})x10^{-5} \qquad (2)$$

where: $\alpha_V$ varies between 7 and 9 x $10^{-4}$.

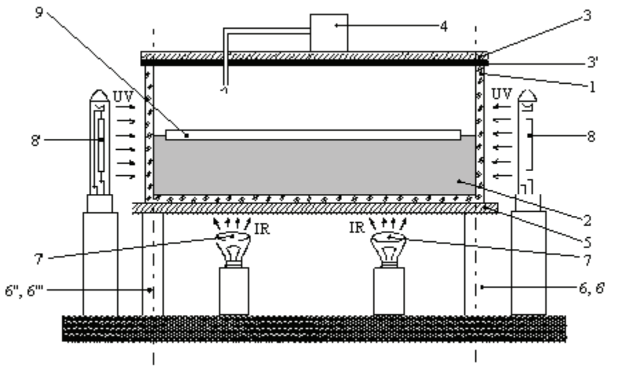



Fig. 4. Stand for studying the oil conservatories: a) Overview; b) principled Scheme of prinsiple: 1-glass jar; 2-sample of oil; 3-cap; 3 '-gland; 4-device for adjusting the humidity; 5-metal plate; 6, 6 supported vertical ; 7, 7 '-infrared lamps; 8, 8 '-lamps with ultraviolet radiation; 9-float with silica gel [8]

Stand for studying the oil conservatory (see Fig. 4), composed mainly of a box transparent container, made of glass walls, in which is found a quantity of oil 2, subject to test and which is airtight enclosed by a cap 3, paired with a sealing gasket 3 ', on which is fixed a device 4, for adjusting the controlled humidity, inside the conservatory, as well as for the measurement of relative humidity. The dish box 1, is fixed on a metal plate 5, supported on some vertical racks 6, 6’, 6", 6"’, which is found under the action of heat, generated by two lamps 7 and 7', infrared. In order to speed up oxidation reaction, stand, is provided with two lamps 8 and 8 ', with ultraviolet radiation, placed in the sides of the glass box conservatory 1. In the scope to model exactly, operating conditions, metal plate 5, is heated through the flow of infrared radiation coming from the lamps 7 and 7 '. The walls of glass of the conservatory are meant to facilitate the observation of the evolution of oil color. On the surface of the bath oil of the conservatory, is placed a float 9, with the possibility of equipping with substance, designed to influence the evolution of oxidation reaction (silica gel with small porosity).

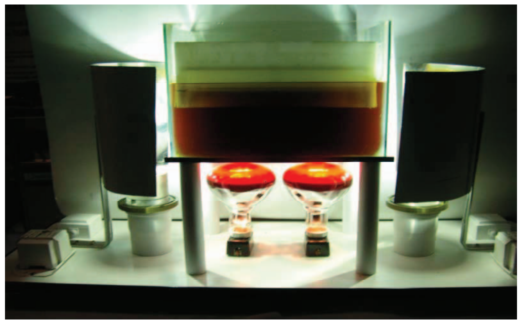
## IV. THE EFFECTIVENESS OF THE FLOAT INSTALLED INSIDE THE CONSERVATORY OF OIL

For to study the behavior electroinsulating oil of the conservatories that are placed on the electrical power transformers, in connection with the application for patent of invention A/00452 to 21.05.2010 [8],

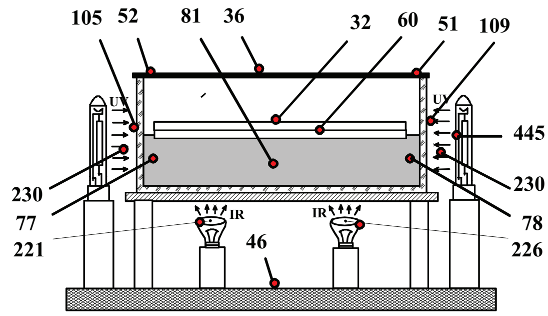
I conducted an experiment in the Laboratory EMAD, University "Stefan cel Mare" of Suceava, in two steps, for to study the behavior electroinsulating oil of the conservatories that are placed on the electrical power transformers, in connection with the application for patent of invention A/00452 to 21.05.2010 [8].

In the first stage, we covered the oil tank with a float of plastic material, resistant to chemical action of electroinsulating (see Fig. 5 a). Quantity 9.5 l of oil, electroinsulating from exploitation was heated with infrared radiation IR and has been exposed at ultraviolet radiation UV.

Temperatures measured at different points of the stand are presented in Fig. 5 b. At the end of the first stage fuel tank was emptied and cleaned.

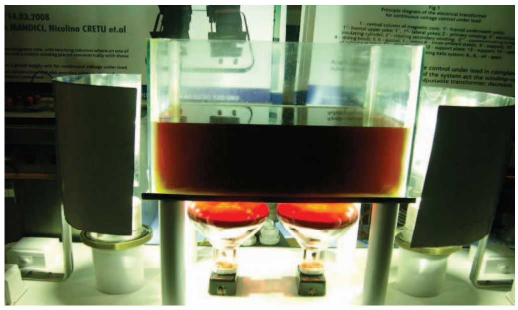


a




b

Fig. 5. Stand with float for studying the oil conservatories with float [8]: a) Overview; b) Prinsiple scheme: 31 at 445*C- temperatures measured at different points



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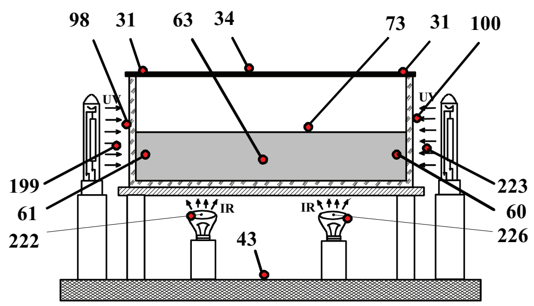
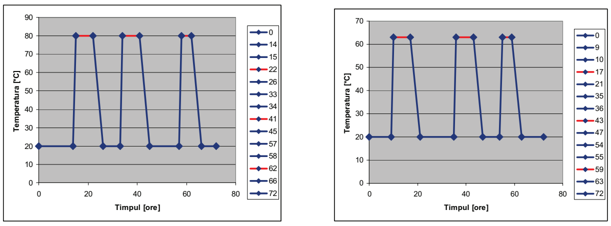



b

Fig. 6. Stand for studying the oil conservatories whithout float [8]: a) Overview; b) Principle scheme: 31 at 226 *C- temperatures measured at different points

In the second stage, another quantity of 9.5 l of electroinsulating, oil of the same class, were introduced in the transparent tank, of the stand and was heated with infrared radiation IR, simultaneously has been exposed at the ultraviolet radiation UV. The particularity of this stage consisted in removing the float on the surface of the oil from the tank, so that a larger amount of atmospheric air, came into contact with the oil, which allowed direct contact of the oil with the oxygen and the atmospheric humidity (see Fig. 6 a). Temperatures measured at different points of the stand are presented in Fig. 6 b.

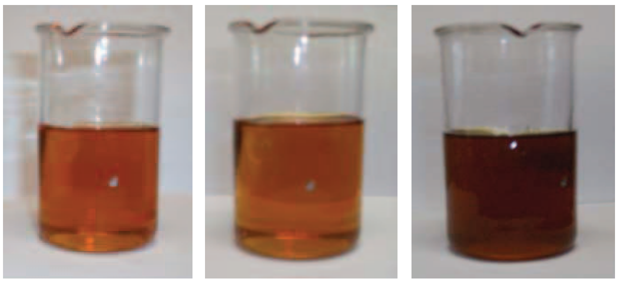
The experiment was carried out over a period of 72 hours, for each stage (time total 142 h), by connecting and disconnecting the stand to the power supply voltage, according to the schedule "in the teeth of the saw" presented in the Fig. 7 a –version with float and in Fig. 7 b - version without float.




a b

Fig. 7. The graph of the experiment “in the teeth of saw”: a) version with float; b) Version without float

*Comments* - In regards to color of the electroinsulating oil, subjected to the experiment, can say the following: from the original color brown of the Fig. 8 a, is a slight modification, to the color grey, to the oil sample after first round (with float), Fig. 8 b and a change to the black color of the oil at the end of the second stage (no float), Fig. 8 c.



a b c

Fig. 8. Samples of electroinsulating oil: a) The oil form exploitation-brown color; b) The oil after stage with float-grey color; c) The oil after the stage without float-black color

These aspects of color, highlight a stronger degradation of oil in the absence of the float, which confirm the theory concerning the accelerated aging of the oils in exploitation at the time when they come into contact with the atmospheric air.

Also, we can say that the ultraviolet radiations UR, reflecting the role to accelerate the oxidation reaction.

In terms of acidity index, the results are presented in Table.1 and in Fig. 9. It is observed, the same beneficial influence of the float, in order to maintain the quality of electroinsulating oil.

TABLE I.
ACDITY INDEX

| Time [hours] | $I_A$ with float [mgKOH/g] | $I_A$ without float [mgKOH/g] |
|---|---|---|
| 0 h | 0,5 | 0,5 |
| 24 h | 0,55 | 0,6 |
| 48 h | 0,60 | 0,7 |
| 72 h | 0,65 | 0,8 |

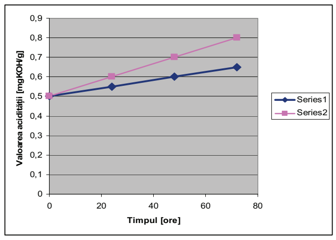
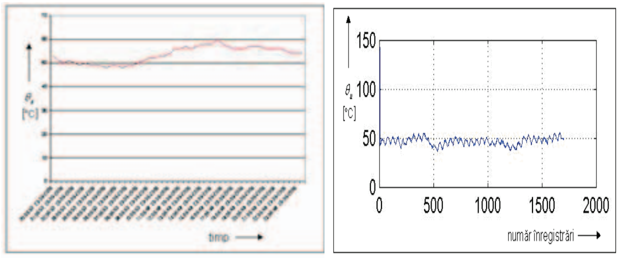



Fig. 9. The variation of acidity index: Series 1-stage with float; Series 2-stage without float




a b

Fig. 10. The variation of temperature of oil in the power transformer in exploitation: a) During a day; b) During one month [9]

## V. CONCLUSIONS

The following conclusions are listed:

1. The experiment, performed on the stand for checking the conservatory of oil, simulate very good the conditions in which can be found in oil into the electrical power transformers of in use. Thus, the values of the temperature of the oil in exploitation, according to some recent measurements [9], presented in Fig. 10 a and Fig. 10 b, are comparable with those obtained experimentally in the laboratory on the stand, with patent application [8], presented in Fig. 7 a and Fig. 7 b.

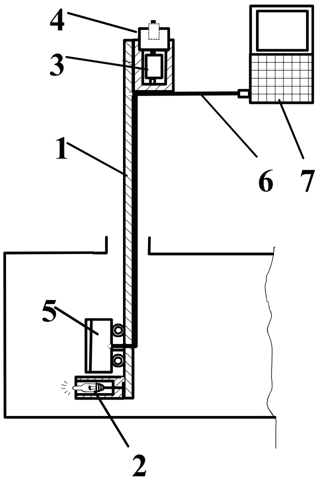
2. As following of the results obtained, it can be said that the use of the float bring a positive contribution to maintaining oil quality in conservatories of the electrical power transformers in exploitation. Using the float in exploitation, will be made after that will be analyzed the phenomena that occur in the liquid-solid interface [10] and other [13], [14].

3. Using the float, in the exploitation of the electrical power transformers, will be made after it will be filled with silica gel of small porosity, in order to stop the oxidation reaction of electroinsulating oil [11].

4. In the absence of the float, change color from brown to black and acidity index increased by 12%, show the

degradation of oil, due to contact with the oxygen in atmospheric air. So, give the opportunity to build of the devices for checking the internal surfaces of the oil conservatory [12], which may be affected by rust.

a




b

c

Fig. 11. Device for checking the inner surface (webcam) [108]: a) Using the device to check the inner surfaces of conservatory of a transformer MT; b) Scheme of principle: 1 - flexible rod; 2 - lamp lighting with magnifying glass; 3 - electric battery; 4 – switch; 5 - live camera (webcam); 6 – cable; c) Image of rust spots

In Fig. 11 a it gives an example of using the device to practice, in order to check the inner surfaces of conservatory, of a transformer for MT and in Fig. 11 c give the image some rust spots, found inside the conservatory it examined, obtained with the help of this device, built in the laboratory EMAD of the University "Stefan cel Mare" Suceava.

The device for checking the interior areas (see Fig. 11 b), according to the invention [12] is composed of a flexible rod 1, at the end of which, for the purpose of lighting the inner surfaces of the conservatory verified, is fitted with a magnifying glass, powered with a battery 3, controlled by an on/off switch 4. To the same end of the rod 1 is placed a video camera, which takes the image of the inner surface of the Conservatory, and transmit it via a USB cable 6, on the screen of a laptop 7.

With this device you can detect, rust stains, arising within the oil mains, during operation power transformers, knew that the oxidation of metallic surfaces, the maximum is upon contact with the air and moisture, cumulative conditions, which are found only in conservatory and less oil in vats of power transformers. The device for checking the inner surfaces can be used in repair workshops for transformers, but also as mobile field kit by the team of electricians.

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