IEEE Standard 62 - Comments for Revision Working Group

Pages 37, 38 and 39 - Clause 6.3.12

Section 6.3.12 "Water Content" is technically incorrect for operating transformers since they are not in thermodynamic equilibrium - that is because within an operating transformer there are spatial temperature gradients and also temperatures varying with time due to load and ambient temperature changes. Therefore, for operating transformers, these dynamic parameters are improperly used as equilibrium parameters in this section. Specifically, relative humidity in oil (i.e. % water saturation in oil) can be measured but since it is a dynamic parameter then it cannot be used as an equilibrium parameter in table 7 to determine the water content of the paper. The same problem occurs in figure 11. While single location temperature and ppm water in oil parameters can be measured - these dynamic parameters cannot be used as equilibrium parameters in figure 11 to determine the moisture content of paper

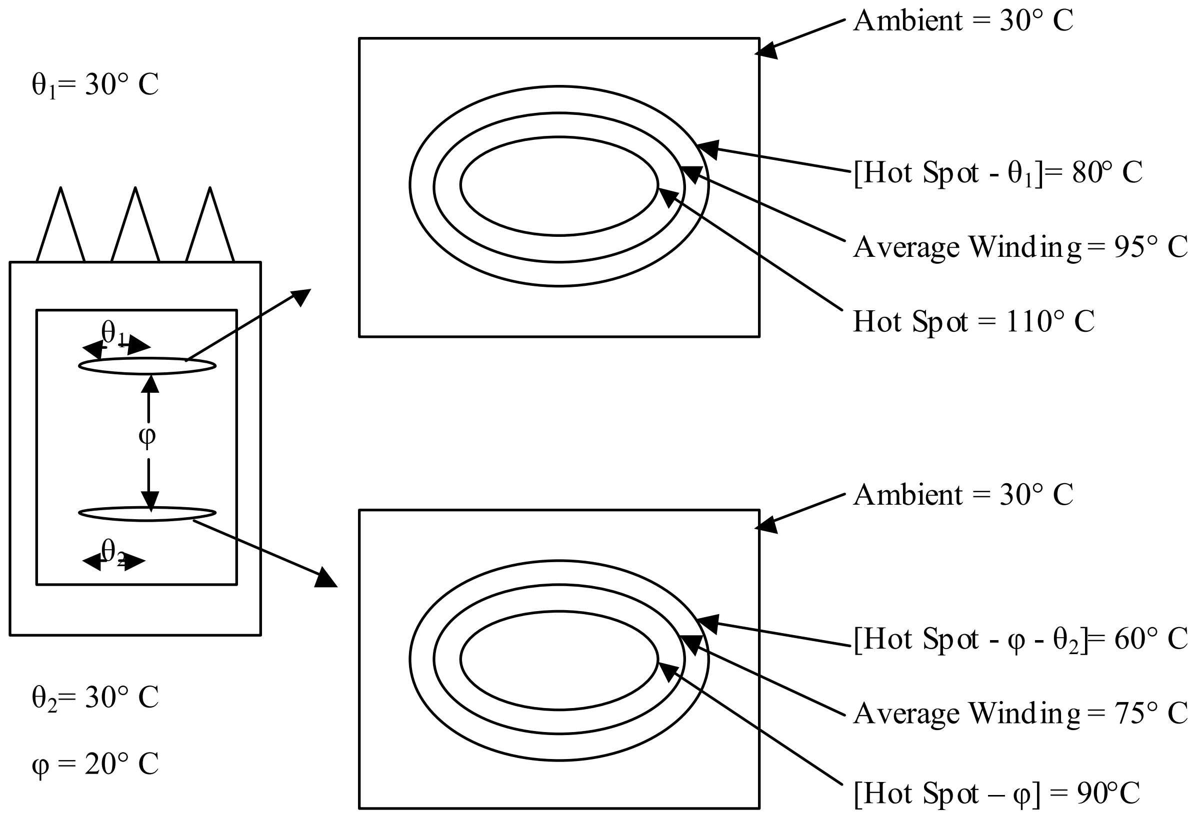
At the heart of the issue of the inability to correlate moisture in oil to moisture in paper is thermodynamics. The lack of moisture and temperature equilibrium in an operating transformer and the placement of equilibrium values into tables and graphs both give serious errors. These errors have been addressed in the PC57.106 project over the past 4 years. PDF files are presently posted on the Transformers Committee website that provides more data on this issue.

Basically, qualitative evaluation of an operating transformer gives the following conditions:

1) Temperatures and moisture concentrations vary significantly with location, and
2) Temperatures and moisture concentrations vary significantly with time, and
3) Time variation for temperature is rapid and for moisture diffusion it is slow, and
4) Solubility of moisture in oil is not the same for various transformer oils.

These first three qualitative statements can be evaluated quantitatively by using the solid insulation time constants for moisture diffusion and temperature. Work by Guidi and Fullerton (see attached paper on diffusion *Moisture Diffusion in Transformers*, Thompson) shows the moisture diffusion time constants are in the order of magnitude of weeks and months whereas typical temperature time constants from the IEEE loading guide for transformers are in the order of magnitude of hours. In addition, using Oommen's curves for a flat sheet of paper gave an approximate range of 1% to 3.5% for a temperature gradient of 40 degrees C.

Now consider the thermograph model in Figure 1 as an example. This hypothetical model serves the purpose of showing possible temperature gradients in an operating transformer that is at constant load and constant ambient conditions (temperature and wind velocity). This model also indicates that the prediction of any single moisture in paper value is invalid. While an accurate model can only be done with temperature probes, nonetheless it is clear here that moisture curves predict a range of moisture values whenever there are temperature gradients. Next, adding the conditions of changing load and ambient conditions further complicates any quantitative analysis. Finally, since the percent saturation is also dynamic parameter then serious errors result as well when placing equilibrium values in a graph or table. This revision should remove the clause or revise it to conform to IEEE PC57.106/D6 which has been submitted to RevCom for approval.



φ = (Hot Spot Temp.) – (Maximum Temp. in Horizontal Plane at bottom of Coil)

θ_1 = 2 · [(Hot Spot Temp.) – (Avg. Winding Temp at Top Coil)]

θ_2 =2 · [(Hot Spot Temp.) – (φ)] – (Avg. Winding Temp at Top Coil)

Figure 1
Model of Isothermal Lines and Temperature Gradients for Oil Filled 65° C. Rise Transformer at Constant Full Load and Constant Ambient Conditions