# A Comparative Study of Drying Processes for Removing Moisture from Transformer Coil Insulation

***Rushikesh.R.Kulkarni*[1]*, M.T.Siddiqui*[2]*, and Avinash.P.Paranjape*[3]**
***[1]PG Student, [2]Assitant Professor, [3]Aassociate Professor***
***[2]Department of mechanical engineering, PES college of engineering,***
***[1,3]Department of electrical engineering, PES College of engineering,***
***Aurangabad, Maharashtra, India.***
***[1]rushikesh7kulkarni@gmail.com***
***[2]mohd.tareq.siddiqui@gmail.com***
***[3]app1911@pescoe.ac.in***

**Abstract: Moisture removal is the key concern about transformer performance. Traditionally, we are using paper and oil insulating systems both have 8 to 10% of moisture content but these systems have changing moisture levels as per different operating conditions. These variations in the conditions make the transformer very difficult to achieve its optimal operating performance. These conditions directly affect electric strength, resistivity, and strength of solid insulation. This eventually speeds up the deterioration of insulation.**

**This paper presents a comparison of various techniques employed to reduce moisture levels during manufacturing stages. These methods are Hot Air Circulation (HAC), Hot oil spry (HOS), Hot oil circulation (HOC), Conventional vacuum drying (CVD) and Vapour phase drying (VPD). Using conventional monitoring procedures, it is complicated to establish the removal of residual moisture concentration throughout the insulation. The solvent vapor phase drying process is one of the most significant processes during the production and maintenance for large oil immersed power transformer. The vacuum drying method is preferred over other conventional methods due to use of a vacuum which improves the efficiency of moisture reduction.**

**Keywords: Transformer insulation, polarization index (PI), vacuum, moisture.**

## I INTRODUCTION

Large power transformer plays an important role in power transmission and transformation system. Solid Insulation of a transformer is the key aspect which does affect the reliability of transformer [1]. It reduces the electric strength and resistivity of the oil and accelerates the deterioration of solid insulation. A moisture removing from the solid insulation is the important process in transformer manufacturing. With the rapid development of the power system in India difficulty in the drying of the power transformer is increases and higher quality equipment are required. In the transformer industry, the drying process is done regularly as part of the production process [4].

In Power Transformers, there is always a persistent concern for moisture management, especially for the aging units. Drying technology is applied to the stage of production and continuous efforts are made to maintain the dryness. According to the IEEE® Std 62 – 1995[1] the moisture content in solid insulation was defined as follows:

Dry Insulation 0 – 2%
Wet Insulation 2 – 4%
Very Wet Insulation 4.5%+

In the more recent IEEE Std C57.106 – 2002[2] the permissible moisture level in the paper is inferred from values of water content in oil, assuming thermal stability and moisture equilibrium between paper and oil:

| **Transformer rated voltage** | **Maximum water content in oil ppm** | | | **Equivalent water content in paper** |
|---|---|---|---|---|
| | 50°C | 60°C | 70°C | |
| Up to 69kV | 27 | 35 | 55 | 3% |
| 69 to 230kV | 12 | 20 | 30 | 2% |
| 230kV and above | 10 | 12 | 15 | 1.25% |

Moisture is found in different parts of solid insulation. Water in the oil and the insulation reduce dielectric strength of both [7]. The value of Polarisation Index (PI) is used to confirm the moisture extraction [1]. Fig.1 shows the effect of moisture content on impulse voltage strength of oil and solid insulation [2-6]. Fig.2 shows the influence of moisture on ageing time of paper [6].

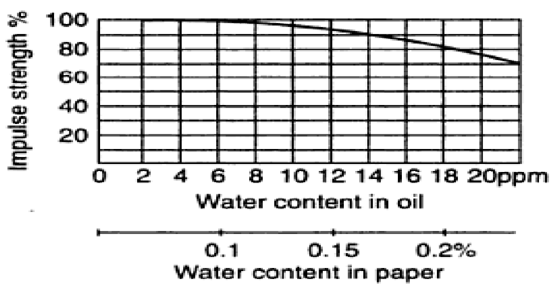


Fig.1- Effect of moisture content on the impulse voltage withstand strength of oil and paper[6]

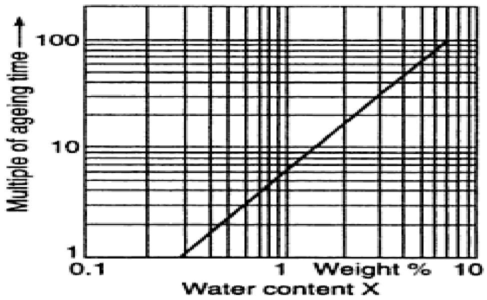


Fig.2- Influence of moisture on ageing time of paper[6]

## II. PRINCIPLES OF DRYING

Drying out of the transformer is accomplished by creating a pressure difference between water vapour around the insulation and water vapor in that insulation. Vapour pressure in the insulation is enhancing by heating the solid insulation and vapour pressure around the insulation is decrease by creating a vacuum. Fig.3 shows pressure versus temperature and humidity graph, from which it is seen that 20 degrees Celsius increasing temperature increase the internal pressure More than 100%. It is to obtain high processing temperatures consistent with an insulation type and aging properties. Effective drying also depends on the diffusion coefficient of the solid insulation. [5]

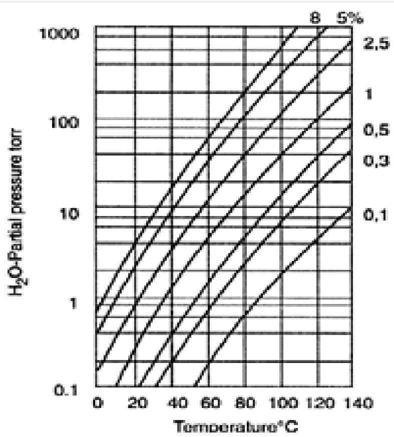


Fig.3- Pressure versus temperature and humidity graph [6]

**A). Drying time**: The drying time of the insulation increases gradually with the operating voltage and size of the transformer. Greater the drying time, the higher the partial discharge inception voltage [5].

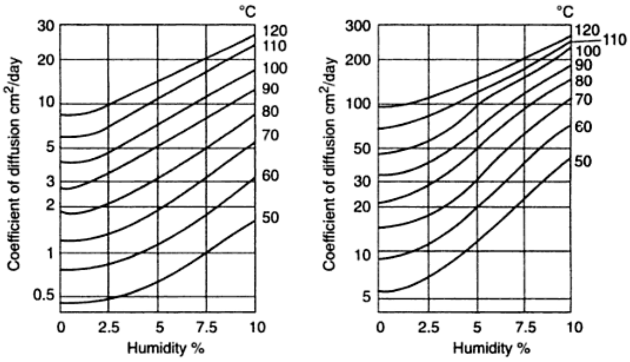


Fig.4- Diffusion coefficient of low-density oil-free press board at different drying temperatures [6]

## III. TECHNOLOGIES FOR TRANSFORMER DRYING

For removing the moisture from solid insulation of power transformer need a combination of heat and vacuum. Technologies can be used on improving the condition of the solid insulation. Varies types of technologies for drying are Hot Air Circulation (HAC), autoclaving or Hot oil spry (HOS), Hot oil circulation (HOL), vacuum drying (VD) and vapor phase drying (VPD).

### A). Hot Air Circulation (HAC)

During manufacturing of transformer drying out of the core-coil assembly is an important aspect. This should be done to remove the moisture. To removing this moisture the transformer core coil assembly put into the oven up to 36 hours (shown in Fig.5 and Fig.6). The oven temperature set to 120 °C is used to heat the core-coil assembly of transformer [6]. Throughout the process, the temperature inside the oven should be kept at a definite value. A solid insulation limit of temperature is 125°C recommended. This method is used for a distribution transformer [9].

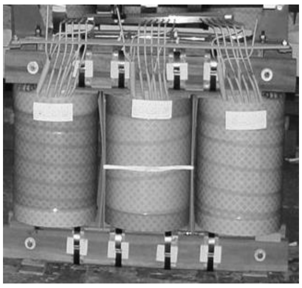

Fig.5- Core coil assembly [7]


Fig.6- Transformer oven [7]

## B). Hot oil spry (HOS)

After draining the transformer oil from the tank, the spray nozzle is installed at manhole and flanges (shown in Fig.7). Hot oil is sprayed over the core-coil assembly, along with the simultaneous application of vacuum evacuated by vacuum pump unit to a pressure range of 5 mbar [9]. The core-coil assembly is heated up and moisture evaporates. However, due to the design of the core-type transformers, uniform heating of the entire transformer might be difficult due to the presence of press-plates and shielding. In case of shell type transformer, this method is very useful. The spared oil is recycling after drying and degassing. In this method, drying time are so long. This method is used for drying power transformer in the field.

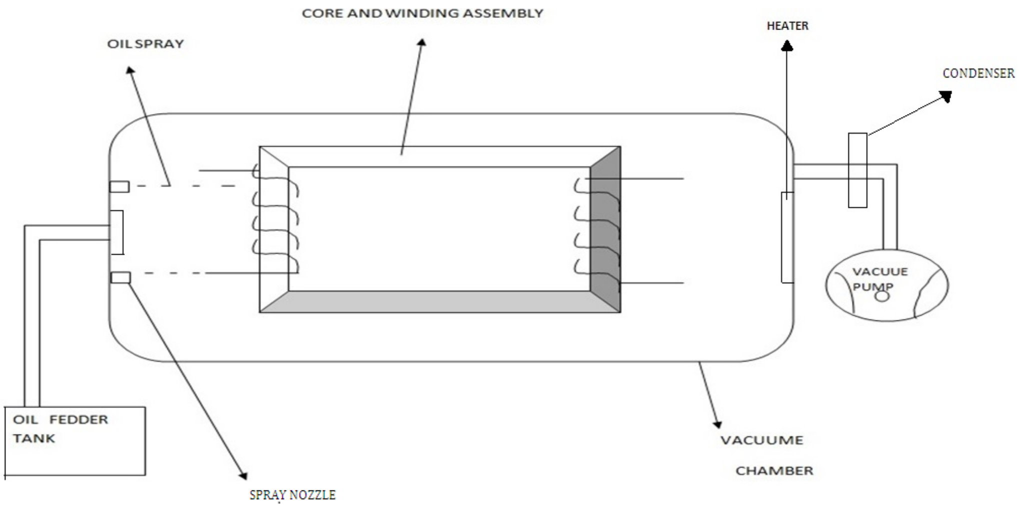


Fig.7- Hot oil spray

## C). Hot oil circulation (HOC)

In this method, the solid insulation is drying by hot oil circulation. This process is done either by oil purification or reclamation (shown in Fig.8). The oil treatment plant increases the oil temperature to about 60-80 degree Celsius, which is then circulating through transformers tank. The vacuum is created by using a vacuum pump so that the hot oil circulation will evaporate the water [9]. Repetition of the heating cycle is depending upon the amount of water content in the solid insulation the size and the voltage level of the transformer. Drying times for Hot Oil Circulation were calculated by Almendros-Ibaez et al. based on simulations [10].

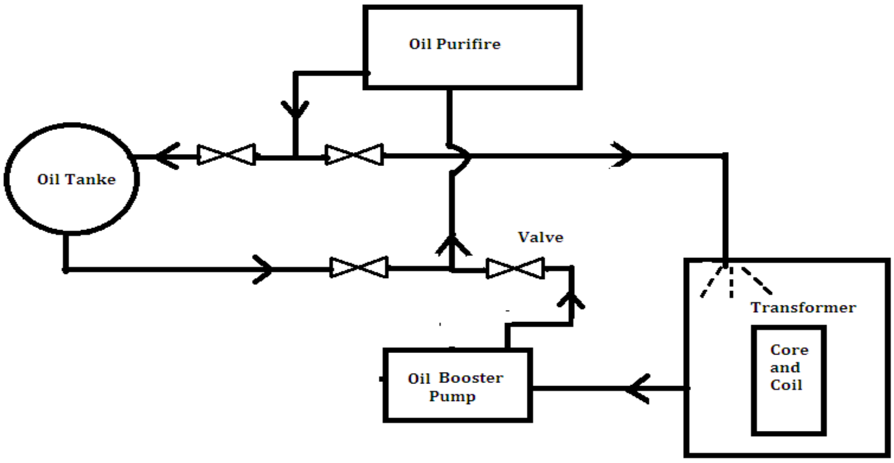


Fig.8 -Hot oil circulation

**D). Conventional vacuum drying (CVD)**:

In this process, the core-coil assembly is kept in a vacuum chamber where it is heated to 100 degree Celsius by using electrical heaters and then the vacuum is evacuated by using a vacuum pump (shown in Fig.9). Heating time is reduced due to the high level of vacuum. Level of vacuum is depending upon solid insulation and the voltage level of the transformer. A vacuum level corresponding to an absolute pressure as Low as 1.33 Pa or 0.01 Torr can be obtained [1-6]. To maintain the transformer active part (core coil assembly) temperature to the specific value the pressure is increased to the atmospheric level (760 torr) by injecting hot dry air at intervals during the first few hours. During the vacuum drying, the water content in the solid insulation is an escape in the form of vapour due to the application of vacuum pump and collected through a condenser in the form of water and this quantity of water is recorded at regular interval [8].

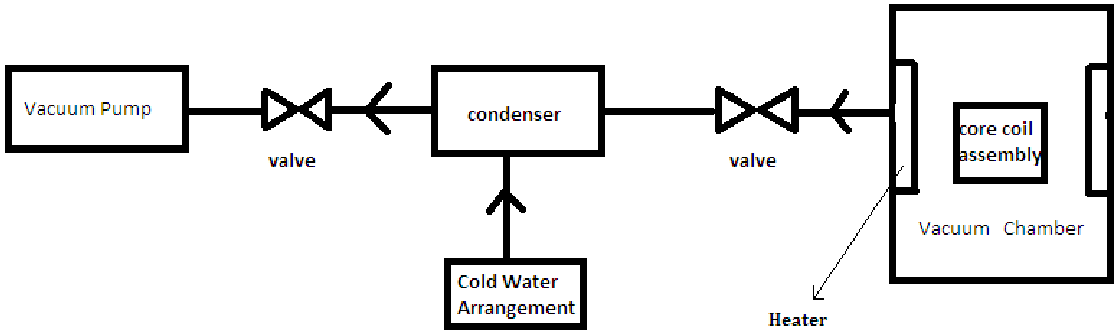


Fig.9- Schematic block digs of CVD

**E). Vapour phase drying (VPD):**

Vapour phase drying is a recent and more efficient method of a drying as compared to CVD [4]. The vacuum chamber is evacuated by using the vacuum pump. The low viscosity solvent liquid like kerosene is adopted as a heat career with a high flash point instead of air. The kerosene solved vaporized into the solvent vapour by using the electric heater and passed over the core-coil assembly place inside the vacuum chamber for drying (shown in Fig.10). The kerosene vapour at high temperature enters vacuum chamber and condenses when it strikes the transformer body at a low temperature and collected back in the form of liquid solvent which will be sent into the evaporator and will be recalculated [5]. The moisture present in the solid insulation will eliminate from heat due to the evaporation phase changes. Thus VPD consists of vacuum system chamber, heating system, kerosene vaporization system, condensation system, and solvent feedback and control arrangement. By Alternating vacuum process and heat process, we can increase the drying rate of power transformer [6].

The main difference between the conventional vacuum drying (CVD) and vapor phase drying (VPD) is that later process design arrangement is more complex and many more control for the central stages of the cycle. The cycle usually consists of an intermediate pressure reducing cycle followed by the vacuum cycle. The pressure reducing cycle allows the extraction of moisture and the vacuum cycle helps to heat up the active part and evaporate the moisture from inside the solid insulation [8].

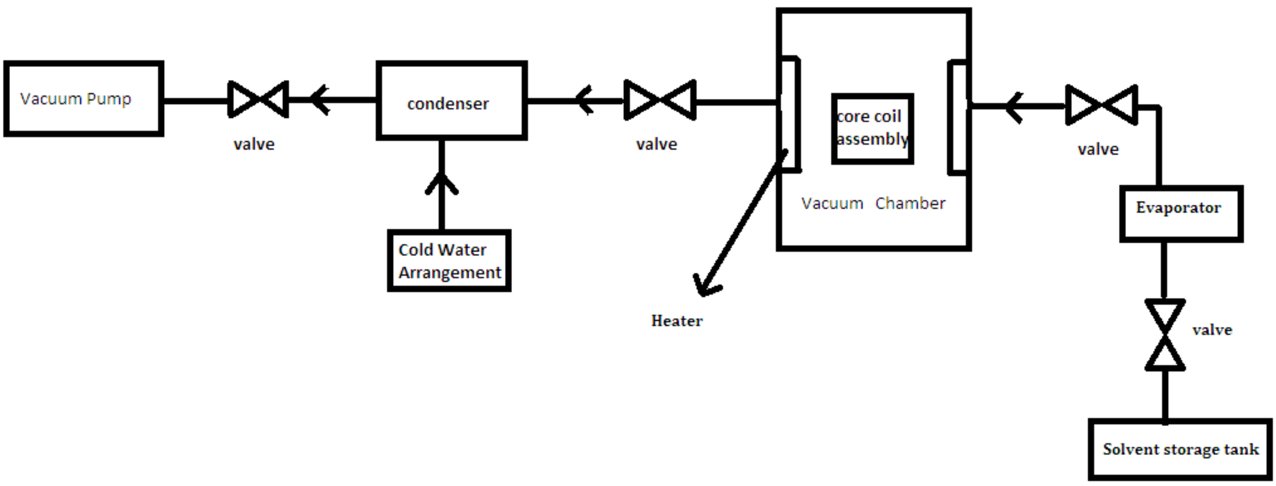


Fig.10- Schematic block dia. of VPD

## IV. CONCLUSION

Water in transformers can be found in varies parts of the insulation system. It can build up in solid insulation, be dissolved in oil, or be found in the form of liquid water at the core or bottom of a transformer. Accurate measurement of moisture present in the transformer coil insulation using drying technologies is very much necessary to increase the lifespan of a transformer. A transformer drying technique aimed at improving the oil and paper insulation conditions by removing moisture content from the transformer coil insulation.

## REFERENCES


[1] Prof. Ajay Bangar, Prof. Rajan Sharma, Prof. H.P.Tripathi & Anand Bhanpurkar, ―"Comparative Analysis of Moisture Removing Processes from Transformer which are Used to Increase its Efficiency", Volume 12 Issue 5 Version 1.0 Year 2012 J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] IEEE Std 62-1995, IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus – Part 1: Oil Filled Power Transformers, Regulators and Reactors K. Elissa, "Title of paper if known," unpublished

[3] IEEE Std C57.106, Guide for Acceptance and Maintenance of Insulating Oil Equipment

[4] Stefan Zabeschek, Helmut Strzala. "Drying of high voltage power transformer in the field with a mobile vapor phase drying equipment"

[5] Ehringshausen, Germany: HEDRICH Vacuum Systems, 2007M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[6] BHEL; "Transformer"; McGraw Hill Publishing Company Limited (ISBN 9780070483156); 2003.

[7] J&P Transformer Handbook, Martin J Heatchote, 12th Edition

[8] Chetan Sawant,Mukund Nalawade,and Nikhil Choudhary,―Experimental Analysis of Vapour Phase Drying System International Engineering Research Journal Special Edition PGCON-MECH-2017

[9] Ramamoorthi P Venkatasubramanian, " Experimental Assessment of Oil Regeneration Technique for Transformer Life Extension"A thesis submitted to The University of Manchester for the degree of MASTER OF PHILOSOPHY,2015

[10] J. Almendros-Ibaez, J. C. Burgos, and B. Garcia, "Transformer field drying procedures: a theoretical analysis," IEEE Transactions on Power Delivery, vol. 24, pp. 1978-1