Electrical Insulating Oil A.K.A Transformer Oil

Introduction

Electrical insulating oils were developed and first used late in the 19th century. Nearly all load bearing transformers in the electric power delivery systems, around the world are filled with some type of this liquid. The liquid functions both as an electrical insulation; suppressing corona and arcing and to serve as a coolant. Today, there is on the order of a billion liters of these petroleum-based insulating oils in use, in transformers, high voltage capacitors, switch gears and circuit breakers in the entire world.

Transformer oil, or insulating oil, is usually a highly-refined mineral oil that is stable at high temperatures and has excellent electrical insulating properties.

The oil helps cool the transformer. Because it also provides part of the electrical insulation between internal live parts, transformer oil must remain stable at high temperatures for an extended period. To improve cooling of large power transformers, the oil-filled tank may have external radiators through which the oil circulates by natural convection. Very large or high-power transformers (with capacities of thousands of KVA) may also have cooling fans, oil pumps, and even oil-to-water heat exchangers.

Large, high voltage transformers undergo prolonged drying processes, using electrical self-heating, the application of a vacuum, or both to ensure that the transformer is completely free of water vapor before the cooling oil is introduced. This helps prevent corona formation and subsequent electrical breakdown under load.

Oil filled transformers with a conservator (an oil tank above the transformer) tend to be equipped with Buchholz relays.

These are safety devices that detect the build up of gases (such as acetylene) inside the transformer (a side effect of corona or an electric arc in the windings) and switch off the transformer. Transformers without conservators are usually equipped with sudden pressure relays, which perform a similar function as the Buchholz relay.

Large transformers for indoor use must either be of the dry type, that is, containing no liquid, or use a less-flammable liquid.

Well into the 1970s, polychlorinated biphenyls (PCBs) were often used as a dielectric fluid since they are not flammable. They are toxic, and under incomplete combustion, can form highly toxic products such as furan.
Starting in the early 1970s, concerns about the toxicity of PCBs have led to their banning in many countries.

Today, non-toxic, stable silicon-based or fluorinated hydrocarbons are used, where the added expense of a fire-resistant liquid offsets additional building cost for a transformer vault.

Combustion-resistant vegetable oil-based dielectric coolant and synthetic pentaerythritol tetra fatty acid (C7, C8) esters are also becoming increasingly common as alternatives to naphthenic mineral oil. Esters are non-toxic to aquatic life, readily biodegradable, and have a lower volatility and a higher flash point than mineral oil.

**Transformer Oil Testing**

Transformers in electric power distribution and transmission systems are expected to function reliably and efficiently and to do so this for many years. The quality of the oil in a transformer plays an important role in performing this function. Mineral oils used in electrical apparatus are specified to have certain characteristics which permit realizable performance for many years.

Transformer oils are subject to electrical and mechanical stresses while a transformer is in operation. In addition there are contaminations caused due to chemical interactions with windings and other solid insulations, catalyzed by high operating temperature. As a result the original chemical properties of transformer oil changes gradually, rendering it ineffective for its intended purpose after many years.

Hence this oil has to be periodically tested to ascertain its basic electrical properties, and make sure it is suitable for further use or necessary actions like filtration/regeneration has to be done. These tests can be divided into:

1. Dissolved gas analysis (DGA)
2. Furan analysis
3. PCB analysis
4. General electrical & physical tests:
   - Color & Appearance
   - Breakdown Voltage
   - Water Content
   - Acidity (Neutralization Value)
   - Dielectric Dissipation Factor
   - Resistivity
   - Sediments & Sludge
   - Interfacial Tension
   - Flash Point
   - Pour Point
   - Density
   - Kinematic Viscosity

The details of conducting these tests are available in standards such as IEC 60296:2003, ASTM D3487:2008, MS 2322:2010 and BS 148:1998, and testing can be done by any of the methods.
The Furan and DGA tests are specifically not for determining the quality of transformer oil, but for determining any abnormalities in the internal windings of the transformer or the paper insulation of the transformer, which cannot be otherwise detected without a complete overhaul of the transformer. Suggested intervals for this test are:

- General and physical tests - bi-yearly
- Dissolved gas analysis - yearly
- Furan testing - once every 2 years, subject to the transformer being in operation for min 5 years.

**Compatibility Of The Oils**

As a rule of thumb, new transformer oils conforming to the same specification and class are compatible with each other. For example, transformer oils from different manufacturers meeting the same IEC 60296 grades can be considered as fully compatible with each other.

**Mixing Of Transformer Oils**

New transformer oils can be mixed with each other irrespective of the source, provided that they satisfy the same standard. This is clarified in all international standards, including IEC 60296, standard as extracted below:

“**Mineral insulating oils complying with the requirements of this standard, of the same class and containing no additive (see 3.4), are considered to be compatible with one another and can be mixed in any proportion. This does not apply to oils containing additives. Where the user wishes to mix such oils, a check is recommended to be made to ensure that the mixture meets the requirements of this standard**”

Inhibited oils can be mixed with each other provided they contain the same inhibitor and the content of the inhibitor in the mixture satisfies the requirements.

**Storage and Handling**

Quality and life of transformer oils depends a great deal on the adherence to prescribed norms while in storage and during handling. The nature of the oils is that they are hygroscopic and have a high tendency to readily absorb moisture.

A high level of caution is demanded to maintain the quality of transformer oils because or their high sensitive to even minute contamination such as water, polar compounds and other conducting materials.

Field staff storing and handing transformer oils need to be trained and fully aware of the sensitivity of the products and the precautions to be taken.