Latest Trends In Use Of Transformer Oils

B. Koti Reddy

Electrical Engineer
HWPM India

Abstract *— Transformer oil acts as a cooling and insulating medium in transformers. This insulating oil not only fills up the pores in the fibrous insulation such as paper, but also the gaps between the turns of the winding and the spacing between the winding and the tank. The oil, in addition to functioning as a dielectric also serves as a cooling medium and also preserves the metal parts internally by submerging them. There are so many oils used in the transformers right from Mineral oil to vegetable oils. This paper highlights the latest trends in oil market by discussing advantages and disadvantages of each oil.*

Keywords *— Oil, Mineral, askarels, silicones, vegetable, coconut, soya bean, temperature, esters, palm oil.*

I. INTRODUCTION

The main purpose of using oil in a transformer is to provide electrical insulation between the various live parts and it also acts as a protective coating layer to prevent oxidation of the metal surfaces. Another important function of the oil is to enhance heat dissipation. Transformer cores and windings get heated up during operation due to various power losses. Oil takes heat away from the core and windings by the process of conduction and carries heat to the surrounding tank, which is then radiated out to the atmosphere. Transformers generate a lot of heat and the he heat has to be removed or the copper will melt and leads to failure of transformer as a whole. Since beginning mineral oil dominates the industry but there are certain disadvantages of using it. Anyone who has been involved in a transformer oil spill or leak knows the headache as well as the expense of cleanup. Today, most transformers use insulating and cooling fluids derived from petroleum crude oil. Industries have little choice but to develop extensive contingency plans and detailed procedures that require training personnel and purchasing special equipment to handle accidental spills and leaks of transformer fluid. Several recently introduced environmentally friendly fluids could be substituted in transformers thereby reducing or eliminating these elaborate procedures. Transformer oil helps in:

- Providing an arc quenching medium .

-It acts like an insulation between the windings for which cupper losses due to heating reduces.

-It reduces the humming noise created in transformer resulting in low vibration.

-The paper insulation provided on winding due to heat they melt and settle down at the bottom of the tank. The oil helps in preparing a sludge which can be easily removed at the time of cleaning.

-It's also use as an indicator where the buchholz relay senses the fault in transformer and gives a tripping signal.

All the variety of oils available in market as on date are discussed in subsequent sections.

II. MINERAL OIL

Mineral oil surrounding a transformer core-coil assembly enhances the dielectric strength of the winding and prevents oxidation of the core. Oil also picks up heat while it is in contact with the conductors and carries the heat out to the tank surface by self convection. Mineral oils have proven reliable as an insulating medium but they have disadvantages:

-Combustibility–the explosion and fire cause heavy Damage to adjacent equipment and buildings.

-Fire suppression, barrier walls, and huge or large physical separation are now a standard practice to reduce this risk.

- Environmentally unfriendly – spilled oil must be treated as toxic waste. Mineral oil that escapes into water (such as rivers) is especially harmful.
- Mineral oil is non- biodegradable.

-Shortened insulating paper life – water trapped in the paper shortens the life of the paper and the transformer. Water is minimally soluble in mineral oil.

III. ASKARELS

Beginning about 1932, a class of liquids called askarels or polychlorinated biphenyls (PCB) was used as a substitute for mineral oil where flammability was a major concern. Although these coolants were considered non-flammable, as used in electrical equipment they could decompose when exposed to electric arcs or fires to form hydrochloric acid and toxic furans and harmful to humans animals. Hence the phase-out of askerels due to their undesirable health hazards and environmental impacts led to a succession of replacement fluids in 1970s.

IV. ESTERS

Esters are a broad class of organic compounds available from agricultural products (natural esters) or chemically synthesized from organic precursors (synthetic esters).

Synthetic ester dielectric fluids have suitable dielectric properties and biodegrade much quicker than mineral oil and hydrocarbon fluids. Due to their high cost compared to other less flammable fluids, synthetic fluids are generally limited to use in traction and mobile transformers, and other specialty applications.

Synthetic esters are being used in Europe, where high-temperature capability and biodegradability are most important and their high cost can be justified, for example, in traction (railroad) transformers.

Natural Esters(Soya bean oil)

Organizations have recognized the increasing stringency of environmental regulations and liability risks involving mineral oil and Synthetic oil based transformer fluids.

Natural ester oils extracted from seed were considered as potential transformer fluids as early as the 1890s. These early ester oils offered no performance or economic benefits over mineral oil. Additionally, seed oil-based coolants oxidation resistance paled compared to mineral oil, so commercial acceptance did not materialize. Transformer manufacturers are now investigating the use of natural esters obtained from vegetable seed oils. It is possible that agricultural esters will provide the best combination of high temperature properties, stability, biodegradability, and cost as an alternative to mineral oil in distribution transformers. Modern transformers, along with suitable fluid additives and minor design modifications, can compensate for oxidation problems. Used mainly as foodstuffs, these agricultural commodity oils are also a renewable resource, unlike mineral oil-based fluids.

Based on research and development beginning in the early 1990s, natural esters have matured into suitable dielectrics with excellent fire safety properties while being non-toxic and biodegradable.

Mineral oil saturates with water at approximately 60 ppm 9Parts per million parts). Natural ester saturates at approximately 1,200 ppm, i.e. 20 times mineral oil saturation. This means that much more water will be in the ester fluid instead of the paper; thereby, extending paper life.

V. COCONUT OIL

More recently, the environmentally friendly Coconut oil has been used as a transformer oil in Sri Lanka where it is freely available at all the places there.

Properties of Coconut Oil : Coconut oil is a colourless pale brownish-yellow liquid. In temperate climates, it appears as greasy, somewhat crystalline, white too yellowish solid fat. In order to avoid problems with impurities present in Coconut oil available in the ordinary market in barrel-form, only commercially available purified coconut oil to be used in transformers. There are certain doubts regarding solidification of coconut oil and the same has been verified by M/s Lankan Transformers. M/s ABB also conducing experiments to use these oils in transformers. The break down strength in different forms of coconut oil are tested and shown in table I. At different states of oil It is seen from table that the breakdown strength of Coconut oil appears to be independent of the state of solidification. This is probably because Coconut oil solidifies without creating voids, keeping its dielectric strength unreduced. However Volume contraction at low temperatures is possible.

TBLE I
COCONUT OIL PROPERTIES

State	Break down voltage in KV at 2.5 mm gap		
Liquid	60.00	60.21	60.07
Partially Solid	59.65	59.79	60.07
Solid	60.00	58.33	60.00

Coconut oil solidifies without creating voids, keeping its dielectric strength unreduced. When exposed to heavy magnetic fields, oil with a higher unsaturated degree of fats may break but coconut oil having a very low degree of unsaturated fats, ensures consistent properties at heavy magnetic fields essential for insulating oils.

In a study 250 ml of coconut oil at room temperature (27^{o}C) was gradually cooled observing the reduction in volume. It was observed that the volume reduced to 247 ml at 10^{o}C indicating a reduction in volume of about 1.2%. This reduction in volume is not considered to be significant and the results are shown in Fig. 1.

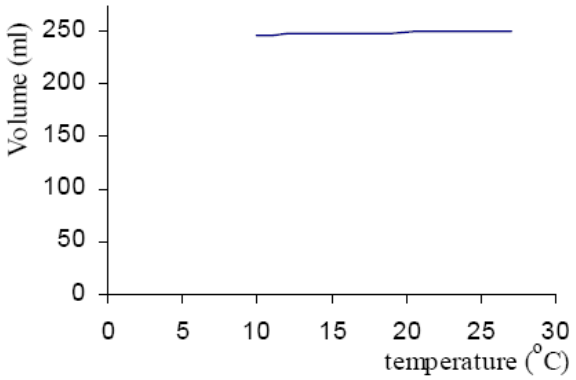

Fig. 1 Volume reduction

Hence it can be concluded that the marginal volume reduction at different temperatures is not a problem with coconut oils.

VI. PALM OIL

Studies showed that Palm kernel oil have good properties to act as insulating and cooling liquid in a transformer. It has dielectric strengths of 25 kV in its crude state compared with transformer

(mineral) oil which has a maximum dielectric strength of 50 kV and has a very high flash point 242°C. The comparison among various oils is shown in Table II. From the table it is clear that coconut oil is the best among others from break down strength point of view.

TBLE II
VARIOUS OILS PROPERTIES

Property	Mineral Oil	Silicone Oil	Synthetic Ester	Soya bean Oil	Coconut Oil	Palm Oil
BDV(KV)	50	40	43	39	60	25
Moisture Content(%)	0.15	0.1	0.1	0.2	0.1	0.19
Pour point(^{o}C)	-40	-55	-50	-1	23	15
Flash point(^{o}C)	140		270	234	225	242
Density(g/cc)	0.89	0.87	0.97	0.92	0.92	1.5
Viscosity(CST) At 40^{o}C	9.2	37	29	35	29	30

VII. CONCLUSIONS

The vegetable oils discussed are good alternatives for transformer oil. The limitations thereof are; inferior oxidative property, poorer low temperature properties, higher viscosity and higher cost to produce. They can be used in their raw form for low voltage transformer but have to be refined and purified to improve on their properties for high voltage transformers. In terms of economic costs and environmental considerations, Soya bean oil, Coconut oil and palm kernel oil appear to be viable alternatives to transformer oils and they are readily available in India, Malaysia, Sri Lanka etc.

ACKNOWLEDGMENT

The authors thank the various industrial unit heads who has allowed to gather information about their transformers and their maintenance practices.

REFERENCES

[1] IS 335-1993, New Insulating oils-specifications, by Bureau of Indian standards with updates in 1998.
[2] IS 2026-2011, Power transformers, Bureau of Indian Standards
[3] Indrajit Dasgupta, Design of Transformers Book, Tata McGraw-Hill Education, 2002.
[4] M. Wegmull Martin Heathcote(editor), J&P Transformer Book, Newnes, 2007.