Electrical Insulating Liquids

New Mineral Insulating Liquids of Advanced Performance

Presentation Elements

Insulating Liquid Types

Petroleum Insulating Liquids History

Mineral Transformer Oil Standards

Naphthenic Insulation Oil Production

Mineral Transformer Oil Types

Storage of Transformer Oil

Recycled Mineral Oil

Insulating Liquid Types and Applications

Liquid	Equipment
Petroleum Oil	All Types
Synthetic Hydrocarbons	Cables, Capacitors
Askarels	Transformers, Capacitors, Switchgear
Halogenated Hydrocarbons	Electronics
Silicones	Transformers
Silicate Esters	Electronics
Natural Esters	Transformers
Synthetic Esters	Transformers
Mixed Liquids	Cables, Capacitors

PCB's started use in the 1930's but production was banned in the USA in 1976 and later in other nations in 1986.

Petroleum Insulating Oil

Petroleum oil is the most common liquid used as insulating oil

Petroleum oils have been used to insulate and cool transformers since the late nineteenth century.[1]

The primary types used have been naphthenic and paraffinic

- Naphthenic being saturated ring structures
- Paraffinic being straight chain or branched straight chains

Historical Properties Desired[1]

- High electric strength, impulse strength and resistivity
- Low dielectric strength dissipation factor
- High or low permittivity, depending on the intended use
- High specific heat and thermal conductivity
- Excellent chemical stability and gas absorbing properties
- Good low temperature flow properties and low viscosity
- Low volatility and high flash point
- Low solvent power
- Low density
- Good arc quenching properties
- Be non-flammable and non-toxic
- Be cheap and easily available

Transformer Oil Standards

Standards are the specifications needed for good performance and to purchase oil

Prior to formal standards, oil quality was determined by transformer manufacturers or users

International standards undergo review and debate from international committees

Most original standards were developed around uninhibited oils.

Doble TOPS was written specifically for uninhibited oil per Doble research conducted from 1954 to 1961.[2]

Historical Standards Startup:

BS 148	1923
Doble TOPS	1961
IEC 296	1969
ASTM D3487	1976
IEC 60296	2003

Transformer Oil Standards

The need for standards was recognized long ago

For unused oil IEC 60296 replaced IEC 296 in 2003

BS 148 merged into IEC 60296 in 2009

The current BS 148 contains specifications for reclaimed mineral insulating oil

IEC 60296 is currently being rewritten to include recycled mineral insulating oil

ASTM D3487 is a standard for unused oil and reissued in 2016

ASTM is currently writing a standard for recycled mineral insulating oil

Current Transformer Oil Standards

Some transformer oil standards used today are country or company specific while others are international

IEC 60296	International
ASTM D 3487	International
Doble TOPS	Doble Engineering Specific
CSA C50-2008	Canadian National
AS 1767.1-1999	Australian National
JIS C2320-1993	Japan National
Eskom 32-406	South African National
NMX-J-123-ANCE	Mexico National

All of these standards have specifications for Inhibited and Uninhibited insulating oil

Manufacture

Early refining processes included:

- **Solvent extraction**
- **Acid treating**
- **Clay filtration**

Solvent extraction, acid treating and clay filtration leave natural inhibitors for producing uninhibited oil

Early uninhibited oil didn't always work when inhibitor was added

Manufacture

Hydrogenation is used to produce most transformer today

- Hydro-treating – Catalytic cleaning of oil by infusing hydrogen
- Hydro-cracking – Catalytic cracking oil molecules in hydrogen

Hydrogenation was first made commercially viable in the USA during the 40's and 50's

Germany used hydrogenation to make fuel during WWII

Hydrogenation removes most natural inhibitors

Synthetic inhibitors are needed for transformer oil

Natural inhibitor streams can be added to make uninhibited product

Hydrogenation also reduces the volume of aromatics

- This gives the oil positive gassing tendency

Naphthenic Crude Selection

Crude is low wax or wax free naphthenic

It must be available in ample supply

Naphthenic crudes make up less than 5% of the world's crudes

They are usually heavier than paraffinic crudes used to make fuel

Traditional naphthenic crudes are from Venezuela, West Louisiana, East Texas and North Sea

New fields recently found in Brazil, West Africa and Australia

Manufacture – Crude Fractionation

The first step to processing crude products is refining

Crude is cut into individual fractions by distillation

Processing after fractionation depends on the refinery

Transformer oil is produced from a specific fraction that meets the required specifications

Most naphthenic transformer oil producers make little fuel products

- They are considered specialty or niche market producers

Crude Fractionation

Fractionation allows refiners to separate crude into different temperature blocks.

Each with different molecular weight, viscosity, chemistry and sulfur levels.

These serve as feed stocks (FS) for other processes.

Manufacture – Hydro-treating

The primary process for refining naphthenic insulating oil is high pressure hydro-treating

Hydro-cracking is not used in the production of naphthenic insulating oils

Mineral Transformer Oil Types

Uninhibited transformer oil has no synthetic inhibitors added

Trace inhibited transformer oil has 0.0 to 0.08 wt. % inhibitor by ASTM and IEC

Inhibited transformer oil:

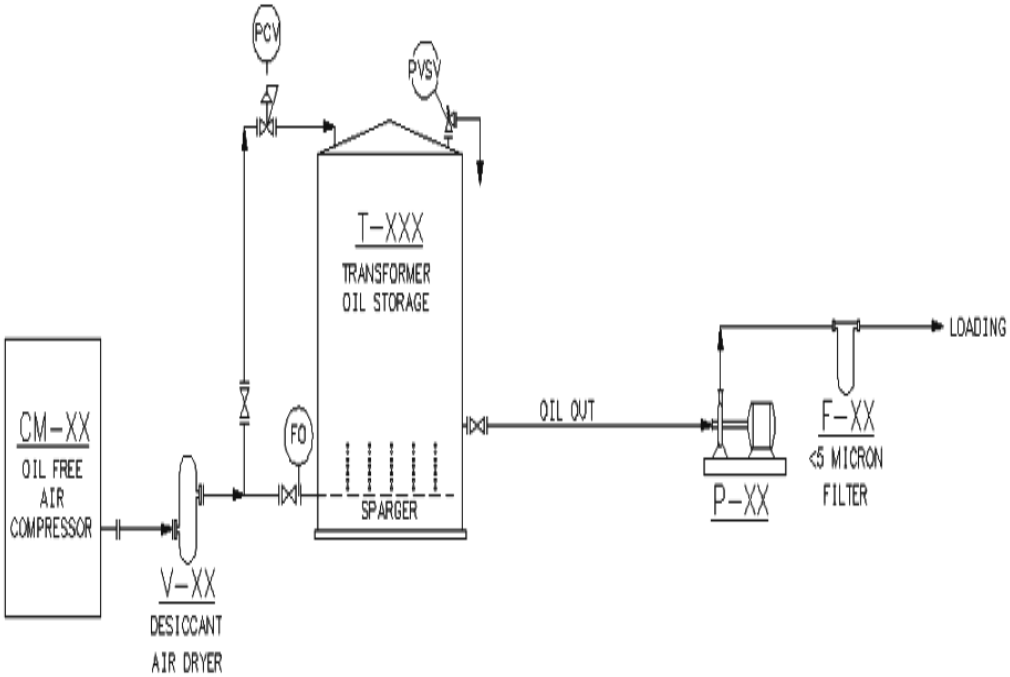
- **0.30 wt.% anti-oxidant max. for ASTM**
- **0.08 to 0.40 wt.% anti-oxidant max. for IEC.**

Anti-oxidant performance is enhanced after removal of natural contaminants

There are applications where inhibited or uninhibited is specified

High stress, extended life transformers prefer inhibited oils

Transformer Oil Storage and Handling



Hydro-treating and Chemistry Impacts

Refiners produce base oils that become transformer oil

Hydro-treating uses heat, pressure, hydrogen and catalyst

- Produces no hazardous by-products

Hydro-treating removes oxygen, sulfur, nitrogen and aromatics

- Helps them pass today's environmental and toxicological requirements
- Makes very clean products

Hydro-treating removes natural inhibitors

- Reduces the ability to produce uninhibited transformer oil

Cleaner base oils improve synthetic inhibitor (DBPC; DBP) response

Inhibited oils are preferred in most power transformers

Hydro-treating completely removes corrosive sulfur

Recycled Transformer Oil

Current IEC Activity to address the lack of a standard

The Standards Management Board (SMB) has directed IEC TC 10 to write recycled oil into the current IEC 60296 Standard for Unused oil per the following decision:

> With Decision 155/27 (Document SMB/5800/DL – 2016-02—23). The SMB confirmed Decision 153/15[….]. SMB instructs TC 10 to revise IEC 60296 so that it becomes a standard for mineral insulating oil (irrespective of their source). The standard should include requirements for declaration of the provenance of the oils without bias to the alternatives. The user / purchaser may then make any preference declared in their purchasing process.

If / When this occurs recycled oil could be sold alongside unused oil

Maintenance Team 38 (MT38) has been formed in IEC to perform the work mandated by SMB

Recycled Transformer Oil

Current ASTM Activity to address the lack of a standard:

- ASTM D27 Committee first decided that re-refined oil was cleaner and should not be treated the same as reconditioned and reclaimed.
  - D27 decided to write standard specifications for re-refined oil and handle reconditioned and reclaimed oil using IEEE Guidance.
- ASTM D27 Committee was surveyed following the May 2015 meeting seeking input as to where re-refined specifications should reside.
  - Should re-refined oil specifications be part of the existing unused oil standard ASTM D3487?
  - Should re-refined oil specifications exist within a separate standard?

The majority vote from D27 membership was to write re-refined oil specifications into a separate standard and keep ASTM D3487 as an unused oil standard.

A D27 Task Group has been assigned to write the re-refined oil standard

Future Mineral Insulating Oil

Oil will continue to be primarily naphthenic and paraffinic

Products will be much cleaner due to better processing

Totally uninhibited oils will be hard to find

Trace inhibited applications might go away

Fully inhibited applications will increase

Inspection testing will become more rigorous

Transformers will be larger but contain less oil
Will demand more robust oil

Oil in-service life will get longer

References

1. Wilson, A.C.M (1980) Insulating Liquids: Their Uses, Manufacturing and Properties
2. Doble Engineering Company (1995), Doble Tested: Frank C. Doble and Doble Engineering Company

THANK YOU!