Negative Gassing Insulating Oils

Introduction

The gassing properties of electrical insulating oils have emerged as popular topics for those who design, build, and operate transformers. The American Society for Testing Materials (ASTM) standard test method D2300 classifies oils as either "gas evolving" or "gas absorbing" and products that display the latter characteristic are commonly referred to in the marketplace as negative gassing oils. The deceptively simple name can lead some to incorrectly infer that negative gassing oil helps mitigate the generation of gases inside a transformer. In reality, the gassing tendency only relates to how the oil reacts when hydrogen gas is generated after the liquid surface is subjected to ionic bombardment. True understanding of negative gassing oil requires knowing how it is made, how it works, and why it is available.

History of the Standards

Professionals who design, build, and operate transformers are familiar with the standards intended to offer guidance and help ensure a level of consistent composition and performance. In North America, where the topic of negative gassing oils has received such attention, the prevailing standard from ASTM is D3487. Derived from specifications first issued in 1976, D3487 contains a series of tests related to the physical, electrical, and chemical properties of insulating oil. Additionally, many utilities rely on Doble Engineering to maintain their Transformer Oil Purchase Specification (TOPS), which includes gassing tendency as an optional test. This specification, first introduced in 1961, is distributed to Doble's clients.

The gassing tendency test method D2300 is used for all insulating oils, including non-petroleum based products. Technological advancements have allowed present day refiners to convert more of the less desirable and reactive molecules into stable naphthenic ones. These advancements have resulted in cleaner oils that more often register as gas evolving with positive values. D2300 remains in the standards today because some commercially available insulating oils test as gas absorbing with negative values due to the source crude used, blending, or the limits of the refiners' technology. ***The vast majority of insulating oil used in transformers today is derived from naphthenic crude and has been refined to a level that measures as gas evolving.***

Crude

Regardless of its source, crude oil contains thousands of different unique and individual molecules. Crude oil is grouped into one of three categories based on composition: aromatic, naphthenic, and paraffinic. The characteristics of each group determine for which finished product they are best suited. Since the mid-20th century, the dominant choice of oil used for insulating and cooling transformers has been classified as naphthenic. Naphthenic molecules contain more stable ring structures with saturated bonds than crudes classified as aromatic and paraffinic. Naphthenic oils yield products with improved thermal characteristics and low temperature qualities, making them well suited for transformer applications. Naphthenic crudes represent less than 5 percent of the known oil reserves today; however, ample supply remains to serve the transformer industry and others for generations.

History of Mineral Oil Refining

The first patent for mineral insulating liquid was issued in 1887 and the earliest recorded instances of insulating oil use in electric transformers began in the early 1890s. At that time, the options for insulating oils were as limited as the understanding around the refining and performance of them. The initial process of using distillation to separate raw crude oil into specific viscosity groups, often referred to as "cuts" or "feedstock" by refiners, was based on separation by boiling point. The distillation process has remained largely unchanged, while the technologies utilized to convert the feedstock into finished insulating oil have improved tremendously throughout the 20th century.

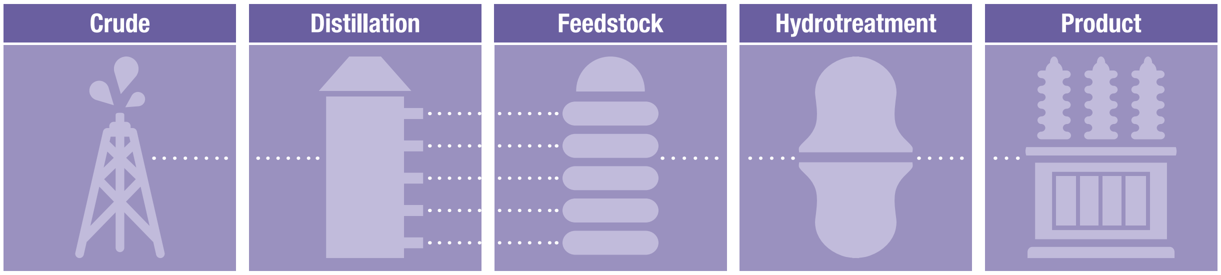

Figure 1.
Process flow of refining crude into insulating oil

In the early 1900s, the methods available for converting feedstock into viable insulating oil were primarily focused on methods of adsorption. Mainly, this involved using clay treatment, or what is often referred to as Fuller's Earth. Technically simple, the process resulted in a significant yield loss for the refiners and generated a waste material once the undesirable polar compounds had been adsorbed from the oil.

As time progressed, new methods evolved, such as treating the feedstock with acids that effectively reacted with the undesirable polar and reactive aromatic molecules to facilitate their removal from the oil. Similar to clay adsorption, acid treatment resulted in a significant yield loss for the refiner and generated a waste byproduct. The process was expensive and resulted in a highly elevated market price for insulating oils, making this an unattractive long-term solution.

An alternative method called solvent extraction gained wide acceptance because it did not generate a waste byproduct and incur a high-yield loss; however, if left untreated, the solvent extract containing reactive aromatic molecules was classified as carcinogenic. With additional refining, this material was converted into a stable product for sale. Solvent extraction remained the primary technique for producing insulating oils for decades. This method's product is very good and is still employed by a small number of refiners, but it cannot achieve the levels of refinement enabled by the current technology.

Introduced to the US market in the mid-1950s, hydrotreating offers a method that produces cleaner oil with an improved synthetic inhibitor response while maintaining yields and avoiding any waste byproducts. Adoption of hydrotreating technology was initially slow but gained real momentum by the early 1970s. Today, it is the preferred method for transforming feedstock into insulating oil. The technology relies on high pressure hydrogen and high temperature in the presence of specific catalysts to remove the reactive molecules containing sulfur and convert reactive aromatic molecules into stable naphthenic molecules. Insulating oil produced by the most modern hydrotreating units is clean and stable, and can be produced both abundantly and economically.

Determination of Gassing Tendency

Gassing tendency test method D2300 is designed to measure the tendency of an oil to either evolve or absorb hydrogen gas when subjected to electrical stress. Oils with positive test values are reported to evolve hydrogen gas which means that they are unable to absorb the hydrogen faster than the rate at which it is generated in the sample. In contrast, those oils with negative test values are determined to have ability to absorb hydrogen by chemical reaction with other insulating liquid molecules. Over time, the ability for negative gassing oil to absorb hydrogen will continue to decline to a level at which the oil would begin measuring as gas evolving. ***The term negative gassing oil is derived directly from the negative test value and has no correlation to the oils' contributions to gases being generated in the oil over time.***

Correlation to Stray Gassing

Gassing tendency should not be confused with "stray gassing," a predominant topic of research in the late 1990s that refers to the generation of gases at relatively low temperatures (90°C – 200°C) without the application of electrical stress. Stray gassing typically stabilizes with time and its cause has been attributed to several factors, including the refining process, interaction of oils with materials in the transformer, and additives like metal passivators. The seriousness of stray gassing, a common focus on gases in a transformer, and an indistinct name referencing gassing, may explain how negative gassing oil might be specified as an attempt to mitigate the generation of gases inside a transformer. ***Negative gassing oils will not prevent stray gassing from occurring, nor can it be expected to counteract it, despite the inference to the contrary.***

Gas Generation in Transformers

Gassing tendency should be differentiated from other mechanisms of gas generation in transformers. It is well known that during normal operation, various gases are generated inside transformers. Those gases include hydrogen, low molecular weight hydrocarbons, and carbon oxides. The cause for and impact of each gas is well studied and understood.

Specifically, the presence of hydrogen gas is most often associated with an event inside a transformer called partial discharge. Relative to other fault types, partial discharge is a low level energy fault usually occurring at relatively lower temperatures. It involves bombarding oil vapor found in small bubbles with ions, causing a breakdown across the bubble, with hydrogen being the major gas produced.

Gas Absorbing Chemistry

The presence of aromatic molecules and, more specifically, the complex multi-ring or poly-aromatic molecules, is the chief source of mineral insulating oil's ability to either test as gas evolving or gas absorbing. In natural ester insulating oils, the unsaturated molecules found in the triglyceride chains enable the oil to be negative gassing. The increased presence of unsaturated bonds is directly related to the reactivity of a molecule; the oil has a finite capacity to absorb hydrogen and will eventually shift from gas absorbing to gas evolving as the molecules become saturated.

Potential Impact

When hydrogen gas is produced, the gas absorbing tendency of negative gassing oils could potentially affect the prompt and accurate detection of abnormal activity via Dissolved Gas Analysis (DGA). The ASTM D2300 standard test method for measuring gassing tendency states, *"… the advantage of such insulating liquids in transformers is not well defined and there has been no quantitative relationship established between the gassing tendency as indicated by this test method and the operating performance of this equipment."* Doble TOPS adds, *"Correlation of results with equipment performance is limited at present."*

Conclusion

Regardless of the insulating oil selected, gases will be generated inside an energized transformer. Responding to market demand, consumer preferences, and despite advancements in refining technology, leading global refineries continue offering both standard and negative gassing products.

There are no correlations between gassing tendency and stray gassing or gases generated during the operation of a transformer. The only correlation is with the chemical composition of the insulating liquid. Insulating liquids that contain certain aromatics or unsaturated molecules tend to be more gas absorbing (negative gassing tendency) than insulating liquids that contain mostly saturated molecules and tend to be more gas evolving (positive gassing tendency).

We strongly encourage those involved with the selection of an insulating liquid to consult with a trusted transformer manufacturer to identify the best solutions for their applications.

HyVolt
| Dielectric Fluids

ERGON

ergonnsa.com
North & South America 601-933-3000

ergoninternational.com
EMEA +32 2 351 23 75 | Asia +65 68081547