THE Locomotive
Published since 1867
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Transformer Oil Testing

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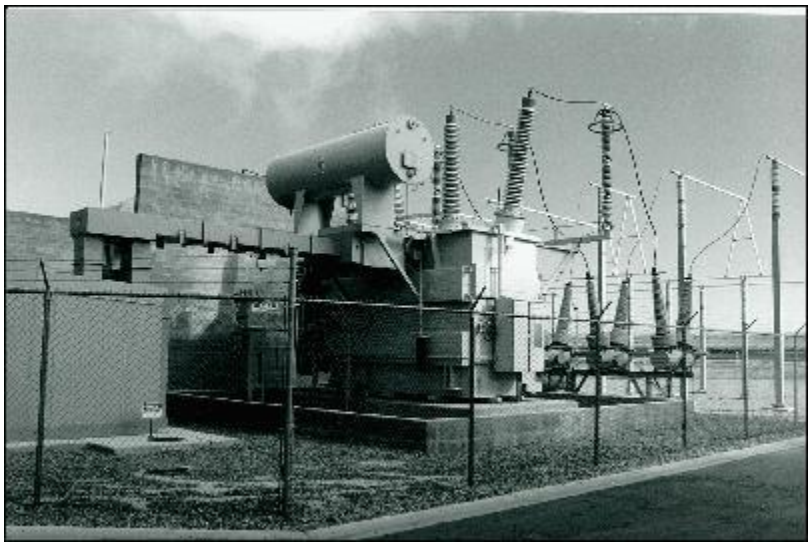

The Value Of Transformer Oil Testing

Transformer Oil Testing is a proven loss prevention technique which should be a part of any condition-based predictive maintenance program. This early warning system can allow maintenance management to identify maintenance priorities, plan work assignment schedules, arrange for outside service, and order necessary parts and materials. Hartford Steam Boiler uses test results in its Transformer Oil Gas Analyst (TOGA®) program, for instance, to diagnose transformer problems.

The transformer's fluid not only serves as a heat transfer medium, it also is part of the transformer's insulation system. It is therefore prudent to periodically perform tests on the oil to determine whether it is capable of fulfilling its role as an insulant. Some of the most common tests for transformer oil are: Dissolved Gas In Oil Analysis, screen tests, water content, metals-in-oil, and polychlorinated biphenyl (PCB) content. In this article, we will examine the value and benefits of each test.

Dissolved Gas-In-Oil Analysis

The most important test that can be done on the liquid insulation of a transformer is an annual Dissolved Gas Analysis (DGA). This test can give an early indication of abnormal behavior of the transformer. As the name implies, this test analyzes the type and quantity of gases that are dissolved in the transformer oil.

Small samples of oil are taken for this test, using a clean, moisture-free, gas-tight container — usually a ground-glass 50 ml syringe. It is very important that a DGA sample is kept air tight; otherwise the gases that are dissolved in the liquid can escape into the atmosphere, or external gases can be admitted, which would invalidate the test results.

The syringe is sent to a laboratory for gas extraction and analysis. Gases are extracted from the oil with a vacuum pump and the gases are identified using gas chromatography. The principal gases that are typically found are hydrogen, oxygen, nitrogen, carbon monoxide, carbon dioxide, methane, ethylene, ethane, and acetylene. Certain quantities and combination of these gases are indicative of: insulation overheating/overloading, liquid overheating , partial discharge (corona), or arcing in the transformer.

Insulation Overheating

The paper insulation which is normally used to insulate the windings of a transformer is a cellulose product. If a transformer becomes overloaded for any reason, the windings will generate more heat and deteriorate the cellulose insulation. A DGA test can identify an overloaded transformer by a test result showing high carbon monoxide, high carbon dioxide, and in extreme cases, even elevated methane and ethylene.

If a transformer is overloaded for a long period of time, the deteriorating condition of the cellulose will shorten the life of the transformer. When the cellulose insulation breaks down to the point where arcing starts to occur, the transformer must be taken out of service.

Insulation Liquid Overheating

Overheating of the liquid insulation is a slightly different problem in transformers. A DGA test will indicate high thermal gases (methane, ethane and ethylene) as a result of overheating of the liquid. These gases are formed from a breakdown of the liquid caused by heat. Heating may be caused by poor contacts on a tap changer, or loose connections on a bushing or a grounding strap, or circulating currents in the core due to an unintended core ground.

Actions that can be taken once a thermal gas problem is detected would depend on the severity of the problem. If conditions are not severe, the transformer should be monitored closely. If conditions gets worse, and thermal combustibles elevate, the transformer will need to be taken out of service. If the combustibles are stable and remain present, the transformer should be inspected at the next outage or downtime scheduled.

Corona

Corona is considered to be partial discharge and occurs at areas of high electrical stress, such as at sharp points along an electrical path. Partial discharge is commonly explained as being intermittent

unsustained arcs which are shot off of the conducting material like a stream of electrons. If these arcs contact solid insulating material, they can cause serious damage.

Corona is detected in a DGA by indications of elevated hydrogen. If corona is detected by a DGA test, other methods of pin-pointing the exact location of the problem can be used — a partial discharge detector can be used to detect the popping noise that a corona is making.

Arcing

Arcing is the most severe condition in a transformer because it indicates a breakdown of the insulation. The presence of acetylene is an indicator of arcing; and even low levels of this gas should cause concern. Normally, arcing occurs only after other problems surface which show up through DGA testing. However, the high energy required to produce an arc will cause all combustibles to be elevated. If the arc occurs in the area of cellulose insulation, carbon dioxide and carbon monoxide also will be elevated.

Arcing can be generated in many areas of a transformer. Insulation breakdown in the windings, from coil to coil or coil to ground, will result in arcing. A portion of the insulation may deteriorate until it can no longer contain the stress of the electrical conductor. If a winding shorts from turn to turn, or phase to phase, or phase to ground, arcing will occur and the transformer will fail. When arcing occurs in the area of the windings, the usual result is de-tanking of the transformer, and a rewind conducted. A loose connection also may cause arcing, but of greater significance would be arcing due to insulation breakdown.

Screen Testing

The "screen test" is a collection of physical, electrical and chemical tests for the transformer oil. These tests include dielectric breakdown, power factor, interfacial tension, acidity, and color. A larger quantity of oil is needed for these tests. To gather the sample, a clean, moisture free container must be used — typically a 1 liter glass bottle. Each test is an indication of how suitable the insulation liquid is for service. No single test alone will represent or indicate the true condition of the liquid. Therefore, it is suggested that they all be performed.

Dielectric Breakdown

The dielectric breakdown test is a physical test that measures the breakdown voltage of an insulation liquid. The dielectric breakdown test serves as an indicator to the presence of contaminating agents such as water, dirt, moist cellulosic fibers, and conducting particles in the insulating liquid. One or more of these items present in significant concentrations will contribute to a low dielectric breakdown value.

Interfacial Tension

The interfacial tension test of electrical insulating fluids is an indicator of the presence of polar compounds. These compounds are considered by some to be an indicator of contaminants of oxidation or deterioration of the materials of transformer construction.

Color

Determination of the color of petroleum products is used mainly for manufacturing control purposes. It is an important quality characteristic since color is readily observed by the user of the product. In some cases, the color may serve as an indication of aging and presence of contaminants. However, color is not always a reliable guide to liquid quality and should not be used as a stand-alone test for determination of contamination.

Acidity

The acidity test is used to estimate the total acid value of the transformer insulating liquid. As acid values increase, (usually due to oxidation of the oil), the insulating quality of the oil decreases. In general, acidic by-products produce increased dielectric loss, increased corrosivity, and may cause thermal difficulties attributable to insoluble components called "sludge."

Power Factor

A power factor (dissipation factor) test measures the dielectric losses in the liquid and hence the amount of energy dissipated as heat. The laboratory normally performs this test at two temperatures, 20 degrees C (68 degrees F) and 100 degrees C (212 degrees F), boiling. By testing the oil at a standard temperature, the test results can be compared to standard values.

Power factor test results can help reveal the quality and the integrity of the insulation liquid. This information can form the basis for making a judgment on whether it's suitable for a transformer to continue in service. The screen test can be used as a maintenance test for determining when a filtering or change of the transformer liquid is in need.

Additional Tests

In addition to DGA and screen testing, most transformer oil laboratories often offer other tests which are beneficial to the transformer.

Water Content

The water content test detects the moisture content in parts per million of the liquid insulation. The electrical characteristics of an insulating liquid are dramatically affected by its water content. A high water content may make a dielectric liquid unsuitable for some applications because a deterioration in properties such as dielectric breakdown voltage will occur. This test is suitable for evaluating filtration.

PCB Tests

Determination of PCBs on a percentage value, or as a parts-per-million (ppm) value, is widely available from commercial laboratories. A PCB-contaminated unit is a transformer containing more that 50 ppm of PCBs and should be treated according to Environmental Protection Agency regulations.

Metals-In-Oil

The metals-in-oil test is beneficial after a DGA finds an arcing problem. When the transformer has been detected as having a problem, a metals-in-oil test can help pinpoint the location by determining what metal is present. For instance, the test may reveal copper deposits from the winding construction.

Loss Prevention Services For HSB Customers

Many of Hartford Steam Boiler's policyholders have long recognized the benefits of transformer oil testing. As a loss prevention service, HSB provides the laboratory analysis of the insulating fluid for all insured transformers which are critical to production.

HSB provides its customers with sampling kits (for both DGA and screen tests) and documentation for drawing samples from the transformers to be tested. The insured then sends the sample to HSB's contracted laboratory, where the analysis is conducted and the results are recorded.

After the test results are entered, HSB's Transformer Oil Gas Analyst program is used to assist in checking results and diagnosing transformer problems. TOGA is an expert system, relational database and laboratory management system designed and developed several years ago by HSB engineers. If conditions are satisfactory, TOGA automatically reschedules the next DGA in 12 months; the next screen test is scheduled for every 36 months, or three years.

A baseline of data is thereby created, and with periodic measurements, small changes in the insulation system can be detected over time. Subsequent annual testing will allow HSB to trend the data for each transformer.

Those results that do not meet HSB's criteria are reviewed by one of our transformer specialists. If conditions are not satisfactory, HSB may request another test immediately, or in three months, six months, etc. A TOGA loss prevention report is prepared, and when appropriate, recommendations are offered. Of course, if the situation is critical, urgent recommendations are made by phone or fax. HSB then continues to work with the insured until the transformer condition is repaired or replaced.

Testing For Other Than HSB Insureds

HSB also commercially offers insulating oil analysis of transformers, oil circuit breakers (OCBs) and load tap changers (LTCs). HSB can manage an entire oil testing program, from scheduling to performing analysis and issuing reports. The contain trending analysis tables which are easily interpreted by

maintenance personnel. Consulting services also are provided for determining fault locations, providing assistance during internal inspections, and bringing experienced personnel into a repair situation.

Summary

Transformer oil testing is a key part of any maintenance program. An annual DGA is the most important test for liquid insulation. Analysis of gases in the oil can indicate insulation overheating/overloading, liquid overheating, partial discharge (corona), or arcing in the transformer. The screen test is a collection of additional physical, electrical and chemical tests, including: dielectric breakdown, power factor, interfacial tension, acidity and color. No single test alone will indicate the true condition of the liquid, so all the screen tests should be performed. Additional useful tests performed by transformer oil laboratories include those for water content, PCBs furanic compounds and metals-in-oil.

About the Author

Robert Turcotte joined Hartford Steam Boiler in 1992 and is manager of electrical loss control in HSB's Energy Division. He earned his Bachelor of Science degree in electrical engineering from the University of Hartford in West Hartford, Conn. Robert is an active member of The Institute of Electrical and Electronics Engineers.