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Understanding Transformer Testing

A GUIDE TO DIAGNOSTIC TESTS FOR OIL-FILLED TRANSFORMERS

[Transformer oil testing gives you insight into the true condition of your high-voltage equipment so you can make intelligent, cost-effective transformer management decisions.

This guide covers a range of tests and provides an overview of what the results may mean for your equipment.]

SDMyers ACTS 4:12

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INTRODUCTION

Since the turn of the 20th century, transformers have been filled with mineral insulating oil. The primary functions of mineral oil are to act as a **dielectric** and **insulating** material, to provide heat transfer and disperse heat, and to act as a **barrier** to protect the cellulose insulation from the damaging effects of oxygen and moisture.

A secondary function of mineral oil in transformers—and the function that we hope to demystify with this guide—is to act as a **diagnostic tool** for evaluating the solid insulation inside the transformer.

You may be familiar with the idea, "The life of the paper is the life of the transformer." A well-used phrase in the electrical reliability industry, this statement means that the condition of the cellulose insulation is, essentially, the condition of the entire unit. If the cellulose insulation fails, so does the transformer.

As transformer maintenance professionals, we look to the diagnostic function of mineral oil to learn as much as we can about a transformer. We use proven testing methods to collect data from samples, and we leverage what we know from scholarship, research, industry standards, and experience to accurately diagnose faults and to plan remediation.

This guide is an overview of these testing methods, offering a glance into the benefits and limitations of each test. Similar tests are applicable in both mineral-oil-filled and alternative-fluid-filled transformers, with alternatives including askarel, natural and synthetic esters, silicone and Wecosol. Although there is some overlap, this guide will focus on testing for mineral oil transformers.

Thank you for taking the time to educate yourself on this topic, and for trusting SDMyers as your source of information. We hope this guide sheds some light onto the value of oil testing and, most importantly, the value of diagnostic analysis as the most effective tool available for increasing the reliability of your transformer.

- The SDMyers team

TESTS

DISSOLVED GAS ANALYSIS (DGA)

ASTM D3612
Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography

DETECTS
Presence and concentration of hydrogen, oxygen, nitrogen, carbon monoxide, carbon dioxide, methane, ethane, ethylene, and acetylene.

INDICATES
Fault conditions that lead to production of fault gases.

Dissolved Gas Analysis (DGA)

The primary use of dissolved gas analysis (DGA) is as a routine monitoring oil test for electrical equipment. Incipient fault conditions—disruptions in the normal electrical and mechanical operation of electrical equipment—cause the oil to break down, generating combustible gases. The profile of those gases can be interpreted to diagnose whether fault conditions exist, and how severe those faults may be.

DGA is also used to determine the concentration of dissolved atmospheric gases (oxygen, nitrogen, and carbon dioxide) so that the operation of oil preservation systems such as conservators, continuous nitrogen systems, and nitrogen blankets can be evaluated.

DGA is used when new oil is placed in a transformer, or on newly manufactured equipment. Appropriate operation of new equipment may require an extremely low gas content in the newly installed oil—a typical specification value is 0.5% (5000 ppm) by volume of total gas dissolved in the oil. There are several methods for running this (ASTM D831, D1827, D2945), but a complete DGA by method D3612 gives the most comprehensive result. Not only does the test quantify the total gas in ppm, but it also tells which gases are present and in what quantities.

Also performed on samples drawn during factory heat runs (and sometimes during factory electrical testing), DGA can monitor the integrity of newly manufactured equipment. Similarly, most installations of new, large transformers require close monitoring by DGA during the first days, weeks, and months of operation.

KARL FISCHER MOISTURE (KF)

ASTM D1533
Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration

DETECTS
Presence and concentration of water in transformer oil.

INDICATES
Potential for further degradation of cellulose insulation.

Karl Fischer Moisture (KF)

Karl Fischer (KF) testing measures water content in transformer oil. Water content is a chemical property of new oil related to its purity. New oil leaves the refining process with very low water content, but can pick up additional moisture during storage, transfer to delivery containers or vehicles, transportation, and installation. A typical specification value for new oil, as received from the supplier, is a maximum of 25 ppm moisture.

When new oil is installed in new equipment, it is typically processed through filters, heat, and vacuum. A typical specification value for new oil leaving the processor to be filled into new equipment is a maximum of 10 ppm moisture.

Once the oil has been installed in the equipment, the moisture content of the oil in ppm no longer tells the complete story. More important values from an operational and maintenance standpoint are the percent saturation of the oil and the percent moisture by dry weight of the solid insulation. These are calculated using the moisture content of the oil in ppm and the temperature of the oil at the time of sampling. A typical specification for percent moisture by dry weight for a new unit, prior to energizing is 0.5%.

As an in-service oil test, moisture content is a critical parameter. Again, the critical values are the percent saturation and the percent moisture by dry weight calculated from the oil temperature and the moisture content in ppm reported by the Karl Fischer Titration.

LIQUID POWER FACTOR (PF)

ASTM D924
Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant)

DETECTS
The dielectric strength of insulating oil.

INDICATES
Loss of dielectric properties of liquid insulation.

Liquid Power Factor (PF)

Dissipation Factor, or Liquid Power Factor (PF), is a measure of the dielectric losses in an insulating liquid when used in an alternating current electric field.

Dissipation factor and liquid power factor are not exactly equivalent, but they vary by less than one part in a thousand up to a value of approximately 5% for the liquid power factor. They are essentially interchangeable for the values that are likely to be encountered in operating electrical equipment.

Liquid power factor is an electrical property of the oil. It relates both to the function of the oil and to its purity. Highly refined oil, free from contamination, has a very low liquid power factor. Moisture, oxidation, and contamination all serve to increase the liquid power factor. For new oil as received from a supplier, typical specification values for liquid power factor are ≤ 0.050% when measured at 25° C and 0.30% when measured at 100° C.

Liquid power factor is a particularly useful in-service tool for testing and monitoring oil because the test is sensitive to moisture, the oxidation of the oil, and contamination from outside sources. Frequently, the pattern of increase for the 25° C and 100° C values can be used to identify specific conditions of concern.

OXIDATION INHIBITOR CONTENT (DBPC)

ASTM D2668
Standard Test Method for 2,6-Ditertiary Butyl Para-Cresol and 2,6-Ditertiary Butyl Phenol in Insulating Oil by Infrared Absorption

DETECTS
Presence and concentration of oxidation inhibitor.

INDICATES
Occurrences of oxidation within the insulation.

Oxidation Inhibitor Content (DBPC)

This test measures the two compounds used as added oxidation inhibitors and reports the total content of the two compounds as total oxidation inhibitor. This is a test of the chemical properties of the oil. The test is performed on both new oil—for acceptance testing—and as a maintenance and monitoring test on in-service oil.

New oil is typically characterized as being either Type I (uninhibited), with a maximum inhibitor content of 0.08 weight percent, or Type II (inhibited), with a maximum inhibitor content of 0.30 weight percent. An appropriate specification range for acceptance of inhibited oil is 0.20 to 0.30 weight percent inhibitor.

For in-service oil, inhibitor should be replenished if the inhibitor content decreases to below 0.1% by weight. Under normal circumstances, mineral oil dielectric fluid will not generally oxidize if the inhibitor content is properly maintained.

DISSOLVED METALS (ICP)

ASTM D7151
Dissolved Metals by ICP, Standard Test Method for Determination of Elements in Insulating Oils by Inductively Coupled Plasma Atomic Emission Spectroscopy

DETECTS
Presence of copper, iron, and aluminum in transformer oil.

INDICATES
Production of metals through arcing/sparking and potential for accelerated oxidation.

Dissolved Metals (ICP)

Dissolved copper and other metals act as catalysts to promote oxidation. They also serve to elevate liquid power factor to unacceptable levels. Dissolved metals in sufficient quantity to promote aging of the oil can be removed by reclamation. Dissolved metals analysis is also useful to help diagnose fault conditions such as severe overheating or arcing/sparking indicated by other tests such as dissolved gas analysis.

Dissolved metals analysis is sometimes performed on new oil to evaluate whether refining or storage practices are resulting in elevated dissolved metals levels being introduced into the system. Since dissolved metals levels are generally measurable with brand new transformers, once energized, and tend to decrease to "none detected" levels before gradually increasing due to aging or jumping due to fault conditions, the recommendation for in-service oil is to baseline test units and then test every few years to evaluate gradual increases in metals.

If dissolved metals content is to be used to help identify a transformer fault, the abnormality will show up in the dissolved gas analysis, triggering a recommendation to perform metals analysis. Standard procedure is to test samples routinely for copper, iron, and aluminum, although many others can be run if conditions indicate a need.

FURANIC COMPOUNDS (FUR)

ASTM D5837
Standard Test Method for Furanic Compounds in Electrical Insulating Liquids by High Performance Liquid Chromatography (HPLC)

DETECTS
Furans in transformer oil.

INDICATES
Cellulose insulation damage through heat, moisture, electrical stress, or oxidation.

Furanic Compounds (FUR)

Analysis for furanic compounds (2-furaldehyde and several derivatives) in oil is a test of chemical properties. Furanic compounds are typically only present in oil because of paper degradation. It is an optional test of the composition of new oil.

On rare occasions, furanic compounds may be present in new oil because of the refining process. Since furanic compounds analysis is a diagnostic test for degradation of the solid insulation, new oil should have a negligible furanic compound content. New oil in a new transformer should be baseline tested and should have less than 20 ppb (µg/kg) of furanic compounds. Any increase in furanic compounds content, and particularly the presence of any furanic compound other than 2-furaldehyde, is an indication that the paper is being damaged by heat, moisture, electrical stress, or oxidation.

PARTICLE COUNT AND FILMING COMPOUNDS (PC/FC)

ASTM D6786
Standard Test Method for Particle Count Using Automatic Optical Particle Counters

DETECTS
Presence of particulates.

INDICATES
Possible damage from moving parts, such as a Load Tap Changer.

Particle Count and Filming Compounds (PC/FC)

This testing should be done on equipment where moving parts are in contact with insulating oil, such as in Load Tap Changers (LTCs). Following Particle Count analysis (see page 15), microscopic ferrography is used to visually identify the particles seen in the oil. Ferrous metals can be differentiated from non-ferrous types. Arcing spheres can be identified, in contrast to filming compounds (polymeric varnish that can form on electrical contacts).

This test can help identify misaligned moving parts. Cutting and shearing wear can be identified and large arcing spheres can be a sign of misaligned contacts or shorts, depending on if they are copper or iron. It is strongly recommended that a dissolved gas analysis be performed at the same time to help identify possible faults.

The microscopic ferrography part of the testing starts with the generation of a ferrogram. A ferrogram is a special microscope slide that is designed to trap particles from the oil. During the generation of the ferrogram, the slide sits over a magnetic field that will cause the ferrous particles to align with the magnetic field. As the oil flows over the slide, the particles are also distributed by size. The slide is then flushed with a fixer and dried. Once dried, the slide is examined under a microscope by a trained technician and the particles are identified. Identification of the size, shape, and composition of the particles is vital for proper interpretation of the conditions in the unit being tested.

NEUTRALIZATION NUMBER

ASTM D974
Standard Test Method for Acid and Base Number by Color-Indicator Titration

DETECTS
Relative amounts of acid/impurities.

INDICATES
The extent of oil oxidation.

Neutralization Number

Neutralization Number—either Acid Number or Base Number—is frequently determined for many different petroleum products using ASTM D974. For transformer oil, the concern is with the acid number. Impurities in new oil and in in-service oil will react with the reagent used in acid number determination (potassium hydroxide—KOH). The relative amount of these impurities is quantified as the acid number, which is sometimes referred to as "total acid number." Acid number is reported as milligrams of potassium hydroxide per gram of sample (mg KOH/g).

Acid number is a chemical property of the oil, related to its purity. Highly refined new oils have very little in the way of impurities in them and a correspondingly low acid number. A typical new oil specification is a maximum acid number of 0.015 mg KOH/g. Acid number is also a useful in-service oil test because it is a direct measure of the extent of oil oxidation. Many of the oxidation products that are formed in oil as it ages react with potassium hydroxide and are measured as a group by the acid number determination.

ASTM D974 is a manual method of titration—adding the potassium hydroxide solution to an oil sample which has had a color indicator added to it. The color indicator changes color when free potassium hydroxide is present. If there is no color change, the added potassium hydroxide reagent is reacting with aging compounds in the oil. When a color change is noted, the sample size, volume of added KOH, and concentration of the KOH added are used to calculate the acid number of the oil specimen.

Some laboratories have modified ASTM D974 to allow use of an automatic titrator. In this case, electrodes that measure pH are used instead of the color indicator. This can be an acceptable method, but instrument calibration is complex.

RELATIVE DENSITY (SPECIFIC GRAVITY)

ASTM D1298
Standard Practice for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

DETECTS
The density of the insulating liquid.

INDICATES
Oil contamination.

Relative Density (Specific Gravity)

Relative density (more commonly, specific gravity) is a direct comparison of the density (mass per volume) of an insulating liquid to water. Water has a specific gravity of 1.000; transformer oil is lighter than water, so the specific gravity is less than one. A typical specification for new oil is 0.84 to 0.91. This is a test of a physical property that relates to the oil's composition and function. Specific gravity directly affects heat transfer. Specific gravity of oil is affected by the length and structure of the hydrocarbons in the oil. Mixtures of hydrocarbons that perform as transformer dielectric liquids typically have specific gravity within a relatively narrow range.

Specific gravity is a new oil test that is also used for in-service oil. Specific gravity of oil should not change because of aging. Significant changes while in-service are an indication that the oil has been contaminated.

Other dielectric fluids have different ranges for relative density (specific gravity). The test is used for all types of new and in-service insulating liquids.

COLOR

ASTM D1500
Standard Test Method for ASTM Color.

DETECTS
The darkening of transformer fluid.

INDICATES
The need to more closely evaluate other oxidation test results.

Color

Color is a physical property of the oil. As a new oil test, a very low color is an indication of a highly refined oil and is a relative measure of the purity of the oil. A typical new oil value for color is less than 0.5 on the ASTM scale. As in-service oil ages and is oxidized, color typically increases, and the oil darkens, visibly.

Care must be taken in interpreting color results for in-service oil because there can be relatively lightly colored oils that are unacceptable for continued use and there are some darker oils that continue to provide acceptable service.

Maintenance decisions are rarely made based strictly on color, but an unacceptable color may indicate the need to more closely evaluate other test results that apply to oxidation of the oil.

VISUAL EXAMINATION

ASTM D1524
Standard Test Method for Visual Examination of Used Electrical Insulating Oils.

DETECTS
Cloudiness or particulates in the oil.

INDICATES
Possible contamination of transformer fluid.

Visual Examination

Visual examination (D1524) on either new oil or in-service oil is a pass-fail test that looks for any foreign conditions or material in the oil sample. The "passing grade," whether for new oil or in-service oil, is some variation of "clear and bright" meaning no evidence of suspended particles, cloudiness, turbidity, sediment, or any condition resulting from any contamination by solids or free water.

DIELECTRIC BREAKDOWN VOLTAGE (DISK ELECTRODES)

ASTM D877
Standard Test Method for Dielectric Breakdown Voltage Using Disk Electrodes

DETECTS
Electrical property of new oil.

INDICATES
High moisture levels and contamination in transformer oil.

Dielectric Breakdown Voltage (Disk Electrodes)

Dielectric Breakdown Voltage is an electrical property of new oil. The measurement of Dielectric Breakdown Voltage has application both to the function of new oil and to its purity.

D877 use has been reexamined by many of the standards organizations (IEEE has virtually eliminated it as a test for transformer oil in the draft revision of the acceptance and maintenance guide for mineral oil), but the test is still useful enough to justify its inclusion in both a program for accepting new oil and for evaluating oil in service.

The D877 method has two flat disk electrodes with sharp edges spaced 0.10 inches (approximately 2.54 mm) apart. D877 has limited use to measure water contamination in oil because it is not sensitive to moisture at saturation below about 60%. It is sensitive to contamination by some other materials and to the presence of particles in addition to high moisture levels. It does not do a good job of detecting oxidation decay products.

For new oil as received from a supplier, a typical specification value is a minimum of 30 kV. For evaluating in-service oil, low values indicate contamination by very high moisture levels, contamination from outside sources, or presence of conductive particles.

DIELECTRIC BREAKDOWN VOLTAGE (VDE ELECTRODES)

ASTM D1816
Standard Test Method Dielectric Breakdown Voltage Using VDE Electrodes

DETECTS
Electrical property of new oil.

INDICATES
Presence of a fault condition.

Dielectric Breakdown Voltage (VDE Electrodes)

Dielectric Breakdown Voltage is an electrical property of new oil. The measurement of Dielectric Breakdown Voltage has application both to the function of new oil and to its purity. The D1816 method has been used by many standards organizations to replace the D877 method as both a new oil test and as an in-service oil test because the VDE electrodes more closely resemble the geometry of conductors inside operating electrical equipment and because the test is much more sensitive to moisture and to cellulose particles.

There are two possible gap settings for the electrodes: 1 mm (approximately 0.04 inches) and 2 mm (approximately 0.08 inches). Typical specification values for new oil as received from a supplier are a minimum of 20 kV for a 1 mm gap and a minimum of 35 kV for a 2 mm gap. For new oil installed in new equipment and for in-service oil, the acceptable values depend on the voltage class of the equipment. A difficulty with the method is that it is also sensitive to dissolved gases, which may not present any sort of operational problem at levels that affect the test. So, while an acceptable D1816 value can be interpreted as an indication of normal operation, a questionable or unacceptable value may not automatically be interpreted as a definite sign that something is wrong; further investigation is needed.

RESISTIVITY

ASTM D1169
Standard Test Method for Specific Resistance (Resistivity)

DETECTS
The dielectric strength of insulating oil.

INDICATES
Charge-carrying contaminants.

Resistivity

Dissipation Factor, or Liquid Power Factor, is a measure of the dielectric losses in an insulating liquid when used in an alternating current electric field.

Specific Resistance (Resistivity) can be measured in the same device, but with a direct current instead of alternating current.

This is an electrical property of the oil, related to its function. High resistivity reflects a low content of charge carrying contaminants. In the U.S., it is most often run on new oil and is not as widely used as power factor. There are in-service standards for resistivity that are widely used overseas.

FLASH POINT/ FIRE POINT

ASTM D92
Standard Test Method for Flash and Fire Points

DETECTS
Electrical property of new oil.

INDICATES
The composition of the oil, specifically the presence of hydrocarbons.

Flash Point/Fire Point

Fire point and flash point are physical properties of the oil. Because the fire point and flash point are directly affected by the molecular weight and type of hydrocarbons in the oil, their measurement (particularly that of flash point) is an indication of the composition of the oil.

These tests also test the oil's function. Transformer oil must operate safely within the transformer environment. When standard design practices began to incorporate higher hot spot temperatures, the specification limit for flash point of the oil had to be increased to maintain a margin of safety. Further, the fire point of the liquid is frequently an important consideration in design of fire suppression equipment and facilities associated with liquid-filled electrical equipment.

DEGREE OF POLYMERIZATION (DP)

D4243
Standard Test Method for Measurement of Average Viscometric Degree of Polymerization of New and Aged Electrical Papers and Boards, ASTM

DETECTS
Average number of glucose monomers that make up a cellulose chain in paper insulation.

INDICATES
Weakening of cellulose insulation.

Degree of Polymerization (DP)

Paper insulation is made of cellulose, which is composed of chains of glucose monomers. The degree of polymerization (DP) test determines the average number of glucose monomers that make up such a cellulose chain in the paper sample.

The test is performed by first dissolving a measured amount of the de-oiled paper sample in a particular solvent. Then the viscosity of the solution is measured, as is the viscosity of the blank solvent. The DP of the paper is calculated from the viscosity of the dissolved paper solution, versus that of the blank solvent.

The paper in a new transformer is mechanically strong (has high tensile strength) and has a DP value of between 800 and 1200. As the paper ages, it breaks down because of heat, moisture, oxygen, and acids. As this breakdown occurs, the chains become successively shorter, and thus the DP declines, resulting in weakened paper. When the DP reaches a level of 200, it is brittle and is at the end of its useful life as defined in C57.91, the IEEE Guide for Loading Mineral-Oil-Immersed Transformers. At this level, the electrical and mechanical strength of the transformer is severely compromised.

This test is not performed very often, because of the difficulty in obtaining a paper sample from a working transformer. In addition, sampling the paper insulation would weaken the transformer at the point of sampling. Therefore, on the rare occasion that this test is performed, the sample is often from a lead, where a repair can more easily be made.

In other instances, failed units can be sampled to aid in diagnosing the cause of the failure. Much more typically, however, information about the state of aging of the paper insulation is obtained from performing furanic compounds analysis on the insulating fluid.

AGE ACID SCAVENGER

SDMyers, LLC, In-house Test Method.

DETECTS
Presence and concentration of allyl glycidyl ether (AGE).

INDICATES
Levels of AGE additive.

AGE Acid Scavenger (Perclene Fluid)

AGE is an abbreviation for a chemical whose full name is allyl glycidyl ether. (The abbreviation is usually pronounced by pronouncing the individual letters A-G-E, rather than like the word "age".) AGE is a chemical that is added to some perchloroethylene-based insulating liquids. The purpose of the AGE additive is to act as an acid scavenger when these liquids were used as retrofill fluids for Askarel transformers.

As perchloroethylene fluid ages, it breaks down and forms hydrochloric acid. The AGE additive acts to neutralize this acid, so that the acid does not react with the metals in the transformer.

Note that AGE additive applies to perchloroethylene-based retrofill fluids only. Manufacturers of original equipment perchloroethylene insulating liquids addressed the prospect of fluid breakdown and acid formation differently. (Wecosol by Westinghouse is the most frequently encountered original equipment perchloroethylene insulating liquid.) Therefore, the AGE test is appropriate for samples from former Askarel-filled transformers that were retrofilled with a perchloroethylene-based liquid (most frequently Perclene).

The AGE test determines the amount of the AGE additive that is in the fluid. The amount of sample needed for the test is small, about 5 ml. Test results are reported in custom letter format, giving the AGE concentration in ppm, together with recommendations.

POLYCHLORINATED BIPHENYLS (PCB) CONTENT

ASTM D4059
Standard Test Method for Analysis of Polychlorinated Biphenyls in Insulating Liquids by Gas Chromatography.

DETECTS
Presence of PCBs.

INDICATES
Compliance/noncompliance with environmental regulations.

Polychlorinated Biphenyls (PCB) Content

Polychlorinated biphenyls (PCBs) content in insulating liquids is a test of a chemical property. It is done primarily for purposes of complying with various environmental and regulatory requirements governing management of PCBs. New oil should be "none detected" for PCBs—the detection limit is typically specified as 2 ppm, so ND is less than this value. In-service equipment and equipment for disposal is frequently regulated according to the insulating fluid's PCBs content. Of the many PCBs analysis methods, ASTM D4059 is the most useful for measuring PCB content in electrical equipment in the United States.

CORROSIVE SULFUR

ASTM D1275B
Standard Test Method for Corrosive Sulfur.

DETECTS
Sulfur and sulfur containing compounds.

INDICATES
Corrosion.

Corrosive Sulfur

Corrosive sulfur is a chemical property of the oil, and the test for it is either pass or fail. While sulfur content relates to the composition of the oil, the presence or absence of corrosive sulfur in new oil is more appropriately considered to be a test for purity—properly refined new transformer oil should pass the corrosive sulfur test.

Free, elemental sulfur and some sulfur containing compounds in new oil will react with metals in the transformer, particularly copper and silver, which leads to corrosion of conductor, connections, and soldered or braised joints. This is foremost a new oil test—virtually all specifications in use in North America require that new oil pass the corrosive sulfur test.

There has been some use of the test for in-service oils. Where corrosion of conductor or unusual deposits of hard, black material have been noted, the test is run to determine whether corrosive sulfur from the oil is responsible. There have been some suggestions that new oil which passes a corrosive sulfur test may develop a corrosive sulfur content while in-service as certain compounds in the oil which contain tightly bound sulfur (these do not react in the corrosive sulfur test) may change chemically under thermal or electrical stress, allowing reformed corrosive sulfur compounds to react with metals.

PARTICLE COUNT DISTRIBUTION

ASTM D6786
Standard Test Method for Particle Count Using Automatic Optical Particle Counters.

DETECTS
Size and quantity of particles in transformer oil.

INDICATES
Degradation of wear parts.

Particle Count Distribution

Several interpretations of particle size and particle size distribution analysis have been applied to electrical insulating liquids. The optical method (ASTM D6786) is similar to methods used for lubricating oils and to standard methods for particle count in insulating liquids used overseas. In optical methods, an instrument is used to count and to determine the size of particles in an insulating liquid that block out light.

INTERFACIAL TENSION (IFT)

ASTM D971
Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method

DETECTS
Dissolved polar contaminants and oxidation products.

INDICATES
Precursors for formation of sludge.

Interfacial Tension (IFT)

The Interfacial Tension (IFT) test detects small amounts of dissolved polar contaminants and products of oxidation in electrical insulating oils.

The test is done by measuring the surface tension at the interface between the oil sample and distilled water. The water and the polar contaminants in the oil are attracted to each other and meet at the interface between the oil and water. The oil side of the interface becomes more polar (more water-like), causing the interfacial tension to decrease at the interface. This test provides an indication of the sludge precursors in the oil long before any sludge precipitates from the oil. Acids formed by oil oxidation also have a large effect on the IFT value, and acids are necessary for the formation of sludge.

FURTHER READING

Information on the testing standards for oil-filled transformers listed in this guide are available online. If you need more information on specific testing standards, testing processes, or the testing, diagnostic, and analytical services provided by SDMyers, please call a Transformer Specialist on **330.630.7000** or reach out to us **HERE**.

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