

Transformer Insulating Fluids Testing

The purpose of a power transformer is to alter the voltage from that of a distribution rating, to a lower utilization level. Power transformers are usually the most vital link in most industrial and commercial electrical systems, and are among the most reliable components in the system. Because they are so reliable, coupled with the lack of movement, noise, or other signs of action, they are subject to general disregard and neglect.

Because a transformer failure is usually of a very serious nature, requiring extensive repair (or replacement) and long down times, regular maintenance procedures are the best assurance for continued high reliability. For maintenance purposes, transformers may be divided into two general categories based on their insulating medium and construction. The categories are liquid-filled type and dry type. In general, measurement of the dielectric value and/or resistance of the insulation are the major maintenance tests for all transformers.

Liquid-filled transformers have their core and coils immersed in a fluid. The purpose of the fluid is to act as the insulating medium, and to transfer heat away from the windings. The most common types of fluids in use are Hydrocarbon Insulating Fluid, Poly-Chlorinated Biphenyl (PCB), and Dielectric Silicone. PCB is subject to very strict environmental controls. These fluids are all subject to deterioration and contamination that can effectively reduce their insulating qualities. Air, moisture, dirt, and conductive particulate are the major causes of degradation of insulating fluid quality.

Many tests have been developed to determine the condition of transformers and their insulating fluids. The following tests are recommended as the "minimum required to determine the suitability for continued use".

Dielectric Breakdown Test

The Dielectric Breakdown Test measures the ability of an insulating liquid to withstand electrical stress up to the point of failure. It reveals the voltage at which a breakdown will occur. Moisture, dirt, and conductive particulate contamination will cause failure below acceptable levels. The minimum acceptable breakdown value is never less than 1 kV for each kV of Primary Rating. The base minimum requirement is 22 kV for Hydrocarbon Insulating Fluids and 25 kV for PCBs and Silicones.

Acid Neutralization Test

The Acid Neutralization of the fluid is a measure of how much it has oxidized and thus deteriorated, and how great is the propensity to form sludge and sediment. Acidity is measured by a neutralization number which represents the milligrams of potassium hydroxide required to neutralize the acid in one gram of oil. Acidity in PCB can indicate chemical reaction with organic insulation. Oxidized fluid will allow interior components to rust. The maximum permissible acid neutralization values are 0.3 for Hydrocarbon Insulating Fluids, 0.1 for PCBs, and 0.2 for Dielectric Silicones.

Sediment Test

The oxygen in air, combined with the heat developed during normal operation, will result in the formation of acids in insulating fluids. These acids create sludges or sediments. The sludge/sediment settles on the horizontal surfaces of the windings and at the bottom of the tank. They interfere with the transformer's ability to dissipate heat and can reduce the "flashover" value of the insulating surfaces. Sediment is either present or not present.

Interfacial Tension Test

The Interfacial Tension Test is a measurement of the forces of attraction between molecules of the insulating fluid and water, and is used to detect oil-soluble polar contaminants and oxidation products. It is expressed in millinewtons per meter (mN/m). The minimum acceptable rating is 24 for Hydrocarbon or PCBs. This test is not performed for Dielectric Silicones.

Parts Per Million Moisture Test

Moisture is the most dangerous contaminant. As little as ten parts per million by volume can reduce the dielectric strength of insulating fluid below its minimum acceptable value. It may also be absorbed by the solid insulation and reduce its dielectric value. The maximum acceptable rating is 26 for Hydrocarbons or PCBs, and 100 for Silicone.

Color and Visual Particulate Test

The Color and Visual Particulate Test of the fluid is a measure of how much sludge, dirt, and particulate contamination exists in suspension. Color is measured by visually comparing the light transmitted through the fluid with a standard color scale. New oil is clear. Silicone is colorless. Dark Oil, PCB, or Silicone is contaminated. The maximum acceptable color number is 3 for Hydrocarbon, 2 for PCBs, and .5 for Silicone.

If an insulating fluid tests below these values, the necessary steps to replace or to improve the fluid quality by filtering or addition of neutralizing agents should be performed immediately. Testing for PCB contamination is required prior to disposal, reclamation, and/or filtering of insulating fluids unless confirmation of previously performed testing for contamination can be provided.

United States regulations require that electrical apparatus and electrical insulating fluids containing PCBs be handled and disposed of through the use of specific procedures. The procedure to be used for a particular apparatus or quantity of insulating fluid is determined by the PCB content of the fluid. Separate and dedicated equipment is used for handling PCBs to avoid contamination of non-PCB equipment and insulating fluids.

Dissolved Gas Testing

Hydrocarbon oils and silicones are used as insulating fluids because of their high dielectric strength, heat transfer properties, and chemical stability. Under normal operating conditions, very little decomposition of the dielectric fluid occurs. However, when either a thermal or electric fault does occur, dielectric fluid and solid insulation will partially decompose and produce various gases. These fault gases are soluble in the dielectric fluid.

Dissolved Gas Analysis (DGA) is widely accepted as the most reliable tool for the earliest detection of thermal (overheating) and incipient faults (arcing and/or corona) in transformers and load tap changers. DGA testing is recommended initially at the start of the maintenance program, and annually thereafter, or at any time unusual conditions occur. These conditions include:

- A transformer has been found to have a high-recorded temperature on its temperature gauge.
- An infrared thermography inspection reveals a “hot spot” at a bushing or tap changer.
- Electrical testing indicates a breakdown of the insulating fluid or insulations.
- A transformer has been overloaded or subjected to unusual electrical stresses.
- A transformer is not providing quality power.

The kinds and amounts of gases produced are indicative of their cause (corona, thermal effects, sparking, or electric arcing). The results are reported in Parts-Per-Million (PPM) by volume. The following are the 6 combustible gases that are considered:

Hydrogen (H ₂)	Corona or low energy electrical discharges
Acetylene (C ₂ H ₂)	High energy arcing
Ethylene (C ₂ H ₄)	Severe localized overheating or low energy arcing
Ethane (C ₂ H ₆)	General overheating
Methane (CH ₄)	Corona or overheating
Carbon Monoxide (CO)	Cellulose overheating

Hydrogen, Ethylene, Ethane, Acetylene and Methane are each indicative of extreme operating conditions or incipient failure. The presence of Hydrogen, Ethane, and Methane may indicate sparking or tracking at the low-voltage bushing connections. The presence of Ethylene and Acetylene may indicate that arcing is occurring at the tap changer or high voltage bushing connections. The total volume of combustible gasses is considered, as are the ratios of the various gases (DGA Roger’s Ratio) to each other.

In addition to the above, Carbon Dioxide (CO₂) is considered, and the ratio of CO₂ to CO (Cellulose Insulation) is evaluated to understand the condition of the cellulose components (woods and papers). Nitrogen (N₂), and Oxygen (O₂) are also considered.