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Mechanical usage for Unused Mineral Insulating Oils for Transformers and Switchgear

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Abstract

For in-service liquid filled electric apparatus, sampling of the liquid dielectric provides a method to determine the condition of the solid and liquid insulation as well as the operating condition of the apparatus without opening or de-energizing the apparatus. This is especially important in the present utility climate, as equipment outages for out of- service testing has become very limited. Sampling provides a means to check the condition of oil in storage whether it be new or used, to determine if it complies with specifications. Sampling can also help to determine:
1) If accidental mixing of different dielectric liquids has taken place;
2) If the method of transportation contaminated the dielectric Liquid; and
3) If the handling equipment to transfer the dielectric liquid contaminated the product.

Keywords

De-energizing, Dielectric Liquid, Sampling, Photo-degradation

1. What is a Good sample

Simply put, a good sample is one that is representative of the content of the bulk liquid insulation. Since samples are usually retrieved from a drain valve or the attached sampling cock, preparation of that area is important to obtain a good sample. Cleaning the drain valve inside and out and the sampling cock is the first step in avoiding sample contamination. Cleaning the outside of the drain valve is just as important as cleaning the inside. The dirt and debris falling off the outside of the valve into the sample container during the sampling process can contaminate many samples. A lot of the contamination in the apparatus consists mostly of water and particles and over time will settle out on the bottom of the apparatus near the drain valve. This material needs to be flushed out of the system to get to the bulk liquid insulation. It is necessary to remove at least 1 to 2 liters of liquid from the drain valve, cap the drain valve, and then flush out the sampling cock before proceeding with sampling. On the occasion 2 litres are not sufficient, especially when samplings are non-energized transformer or certain OCBs and LTCs.

2. Good Sample versus Bad Sample

It is sometimes very clear to the laboratory performing the analysis on dielectric liquid that the sample was taken improperly. For example the presence of free water or foreign objects such as insects, pipe sealing tape or 2 putty are strong indicators that the drain valve was not adequately flushed out prior to sampling. Once analysis has begun and it is determined that a high of free water content coupled with a low dielectric strength with all the other test results being acceptable, then it strongly indicates that the proper sampling technique was not adhered to. It may even imply that some chemical reactions were taking place in the drain valve that was no representative of the bulk liquid installation.

3. Lab Tests Most Easily affected

As indicated previously the analytical tests most easily affected by sampling are dielectric strength and water content. This is due to the fact that the apparatus drain valves are usually at very low points in the tanks, were debris and water accumulation occurs. Water can also be present as a result of condensation that occurs in the drain valve, which is also due to the position of the drain valve on the tank. In most cases the drain valve protrudes 15 to 30 cm (6 to 12 inches) away from the main tank. From experiments performed at Double Engineering, the dielectric liquid in many of these valves varies in temperature to 10 to 15°C cooler than the bulk liquid insulation. As when oil or air has an elevated relative saturation or humidity and there is a significant cooling, condensation of water will occur marks and this is exactly what happens in a drain valve. Other analytical tests easily affected by sampling are dissolved metals, particulate metals, particle counts, dissolved gases-in-oil, and power factor. The concentration of metals, whether dissolved or in a particulate state, are especially impacted by the amount of cleaning performed on the drain valve and the amount of flushing that is performed. Debris that settles to the bottom of the apparatus and subsequently into the drain valve can consist of metal particles. In addition, just the simple fact of removing the drain-valve plug or opening the sampling cock will create particulate metals. This is due to the grinding of the surfaces between the valve body and the drain plug or sampling cock. In fact, it is becoming more apparent that that these types of samples should only be retrieved after a minimum of 2 liters of flush, and sometimes 3 to 4 liters, of dielectric liquid have been passed through the drain valve. The same is true of retrieving samples for particle count were valve debris, whether inside or outside, can severely skew the results. Of serious consequence are the debris, soot and grime that exist on the outside of the drain valve especially in industrial locations. This debris can be easily transferred to the sample bottle while the sampling process is taking place. Thus, this validates the importance of cleaning the outside of the valve prior taking the actual sample. Dissolved gas-in-oil analysis is another test impacted by sampling, drain valve components and sampling materials. When galvanic fittings (zinc coated) are used in the drain valve assembly such as the drain plug, galvanic reaction with water can cause very high levels of hydrogen to be produced. If this residue is not flushed out adequately then it will be transferred to the sample and included in the analysis, causing a level of concern that is not warranted. In addition, galvanic plumbing fitting such as nipples can have the same effect. Brass, bronze, stainless steel or black iron should be the only material used. In addition, drain valve assemblies should not be composed of dissimilar metals as corrosion can result which may end up in the sample. Debris, water and other ionic contaminants also affect the power factor test when these materials increase dielectric loss thus in turn increasing the power factor. Incompatible inorganic and organic materials from the drain valve stem packing or drain-plug sealants can also have the same effect on the power factor.

4. Science of sampling

It is important to know the reasons why the above procedures are used and how samples are affected when deviation from the written procedure occurs. Already discussed were the tests that were most affected by poor sampling but there are other factors that are extremely important to consider prior to taking a sample and these include:

I. Sample containers
II. Sampling technique
III. Sample storage and transport

I. Purpose of a Sample Container

The proper use of sample containers to retrieve and store samples is important to prevent contamination and to provide the best sample for a specific test. ASTM Practices D 923 and D 3613, the Double reference Book on Insulating Liquids and Gases, or IEC Methods and Guides 60475 and 60567 are to be consulted when choosing a sample container. Sample containers should have the following characteristics:

a) Large enough to hold the volume of liquid necessary for analysis
b) Do not impart any contamination (chemical or particles) to the sample
c) Seal the sample from external contamination
d) Shield the sample from direct sunlight to prevent photo-degradation.

This can be done either by having a dark container or by having a covering for that container. Prevent the loss or gain of gases or water when testing for these properties.

The volume of the sample is of the utmost importance, as various analytical tests require very different sample volumes. For example, a test for inhibitor content (ASTM D 2668) requires only a few millilitres of dielectric liquid whereas the test for impulse breakdown (ASTM D 3300) may require as much as two to four liters. In general it is good practice to provide the sample volume required for each test plus 10%. If unsure of the sample volume required for specific test or tests, laboratories such as the Double Materials Laboratory have reference lists that detail such information. For general oil quality tests, glass bottles, either amber or clear, function well. Amber bottles provide protection against photo-degradation while clear bottles enable visual inspection of the sample. To prevent photo degradation in clear bottles, shielding from direct sunlight by storing them in cardboard or some other type of container works well. Bottle caps must be constructed from a compatible material, which will not contaminate the sample. Bottle caps with liners composed of paper or having glue that is soluble in the dielectric liquid are not appropriate. Liners made out of foil, Teflon or polyethylenes are usually safe to use. If sealed tightly, the glass bottle is an appropriate container from which to draw a sample for water analysis. Problems however have been encountered with caps working loose over time. Glass bottles are more apt to break, if not properly protected, than other containers and they are not a suitable container for dissolved gas-in-oil analysis, as gases such as hydrogen and carbon monoxide will be lost. Metal cans have become popular because they are more resistant to breakage than glass bottles. Cans with soldered seams prepared with some fluxes will contaminate the sample and therefore welded seams are preferred. Cans made of tin, aluminium, and stainless steel have been used and are good containers especially to hold samples for oil quality tests. The use of plastic bottles has grown significantly in the past decade. Like cans, they resist breakage and shield the sample from sunlight when dark plastics are used. They are appropriate containers for samples in which oil quality tests are to be performed. Samples being tested for water should not be stored in plastic bottles as water ingress or egress can occur in just a few hours. Not all plastics are compatible with oil so selection of the construction material is important. Tests such as power factor will be affected by incompatible plastic bottles because of dissolved components transferred to the sample that will cause increases in dielectric loss. Bottles made of high density polyethylene have been found suitable and are one of the preferred sample containers when electrostatic charging tendency or furanic compound analysis is to be performed. In the case of furanic compounds, high-density polyethylene does not have the silanol groups found in glass that attracts the semi-polar furanic 5.

Compounds to the glass walls and thus remove them from the sample. Samples with a low concentration of furanic compounds are not as affected as samples with larger amounts of furanic compounds. The most appropriate container for taking samples for dissolved gas-in-oil and water content analyses and the easiest to manipulate is the ground glass syringe whose barrel and plunger have extremely tight tolerances. This type of syringe has been found to satisfactorily prevent the ingress of gases and water into the sample and in turn prevent the egress of water and dissolved gases from the sample over a period of time. Care should be taken with glass syringes to ensure the stopcock is tight and in the closed position once the sample is taken. Also the samples collected in syringes must be quickly protected from photo-degradation (degradation by light) by immediately placing them in the dark or in their shielding containers. Stainless steel cylinders may also be used but are sometimes more difficult to manipulate or to determine when all the air has been removed from the cylinder. The Metal cylinders will add significant shipping costs because of weight but are definitely more durable in transit.

II. Sampling Technique

Sampling technique involves much more than just taking the sample. It involves a more thorough knowledge of the information to be gained from taking a proper sample and includes sample site preparedness and site cleanup after sample retrieval. Some the items that are a part of sample technique are:

a. Materials used to aid in retrieval of a sample
b. Safety precautions to adhere to
c. Environmental concerns
d. Identification of the sample and Apparatus information
e. Final checks prior to sampling
f. Taking the sample (cleaning and preparation of valves)
g. Cleanup after sample has been retrieved

a. Materials Used

Whoever takes the samples must be fully prepared for most eventualities that will occur at the sample site. For example, items such as sheet plastic, plastic bags, absorbent materials, flush oil containers, and catch pans are all important materials to have to prevent or clean up liquid spillage. It must be remembered that, in order to take a proper sample, some liquid waste will be generated. Of course, bottles and syringes will be needed as sample containers and must be of sufficient size to hold the volume of dielectric liquid necessary for the desired tests. Labels are required to sufficiently and correctly identify those containers, and make-up oil and bottled nitrogen may be necessary to add oil to low volume devices to pressurize a transformer to relieve a negative pressure in order to get the dielectric liquid out of the apparatus. Tygon tubing or other compatible tubing is necessary to direct the dielectric liquid from the drain valve to the flush container, sample bottle and syringe. Tubing should only be used once and then discarded as the walls of the tubing have memory (can hold gases, water and other chemical compounds in the walls of the tubing) which can then be transferred to the next sample. Incompatible tubing such as natural rubber or PVC tubing will contaminate a sample with unwanted materials. The appropriate tools and plumbing accessories must be on-site to manipulate the drain valve in order to retrieve the sample. Personal protective equipment such as nitrile gloves is used to protect personnel from the liquid dielectric and/or polychlorinated biphenyls (PCBs). Personal protective equipment and safety practices to protect against electrical or physical hazards must also be present and observed.

b. Safety Precautions

There are several safety precautions that must be adhered to in order to secure the well-being of the equipment as well as the personnel retrieving the sample. Death is not normally associated with sample taking but it has happened when electrical hazards have not been observed. Routine and complacency often contribute to a lax adherence to safety precautions. Some of the more critical safety precautions are:

1) Make sure there is positive pressure on the electrical apparatus
2) Take into consideration the remaining volume in a low oil volume apparatus

De-energize instrument transformers before sampling Secure electrical dangers.

Make sure Occupational Safety and Health Administration (OSHA) requirements are adhered to making sure there is positive pressure on the electrical apparatus prior to sampling is the single most critical factor in assuring that the equipment survives the sampling procedure. Sampling of electrical equipment while under negative pressure will allow atmospheric air to be drawn into the equipment through the drain valve and will rise through the transformer as bubbles. These bubbles are areas of weak dielectric strength and can easily cause failure of the apparatus through flashover. Most transformers have pressure gauges that allow determination of the actual pressure. If positive or negative pressure cannot be determined, then follow the procedure in ASTM D 923 to determine the pressure condition which involves using a slug of oil in clear tubing attached to the sampling cock. If negative pressure does exist then no samples are to be drawn until that negative pressure is relieved. Sometimes this is as simple as adding dry nitrogen to the headspace of a transformer to pressurize the units or waiting until ambient temperature has increased to a sufficient degree to cause the expanding dielectric liquid to pressurize the apparatus. The remaining volume in some electrical apparatus especially OCBs, LTCs and small instrument transformers is of serious concern. Electrical components are positioned at critical distances taking into consideration that this distance is determined with liquid insulation present. If the liquid insulation level drops too low the insulation between these components is now air instead of the insulant and thus the dielectric integrity has been comprised. This is why it is important to check the liquid levels not only before sampling but after as well, in order to maintain a safe operating environment. Instrument transformers must be de-energized prior to sampling in order to secure the electrical hazards. Electrical hazards are especially prevalent in small distribution pole and pad mounted transformers. For pole transformers, these units do not usually have a sample valve so the lid of the transformer must be removed to take a sample. In addition the primary and secondary voltages terminations are extremely close to personnel. This is also true of pad mounted transformers where the secondary and sometimes primary cable or bus bar is within feet of the sample valve. Any wrong move by sample personnel and serious injury or death can result. Because of such concerns, OSHA instituted lockout/tag procedures that must be adhered to secure against such dangers.

c. Environmental Concerns

Dielectric liquid spillage as a result of sampling is a main environmental concern, as some of these liquids may still contain PCBs. The United States as well as many other countries has very strict guidelines for spill cleanup and notification of PCB materials. In the United States even one drop of liquid containing more than 50 ppm PCB is considered “improper disposal”. Even if the oil does not contain any PCBs, many states within the United States as well as other countries have regulations dealing with the release of dielectric liquids even if it is small and accidental. It is therefore easier to prevent against spillage then to cleanup after the spill has occurred. This is why many sampling personnel lay down plastic and absorbent materials under the drain valve prior to sampling and then use a catch pan to trap larger volumes of liquid.

d. Identification of the Sample and Apparatus Information

Sample identification is an extremely vital aspect of the sampling process. Many laboratories receive samples that cannot be related to a specific device. Even if the sample was taken properly, the lack of proper identification makes the sample useless and it therefore is a bad sample. When sampling personnel retrieve samples from electrical apparatus, it should be done in a prescribed sequence so nothing is forgotten. The lack of information concerning an apparatus severely limits the laboratory in its ability to provide an in-depth diagnosis. Apparatus information such as the age, type of preservation system, any previous incipient fault conditions or oil reclamation activities can alter a diagnosis.

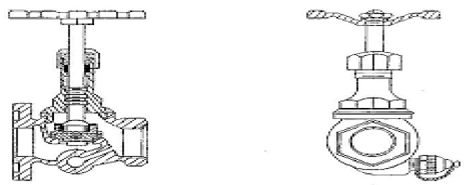

Fig 1: Oil segregator valve

Fig 2: Retroversion Oil Mixture

5. Result and Conclusion

For instance, the Double Materials Laboratory relies heavily on the type of preservation system that is part of the transformer to provide a diagnosis based on oil quality, DGA and furanic compound results. In transformers that have sealed conservator preservation system, oxygen and nitrogen values are expected to be below certain levels. If test values are above those levels, there may be several causes for this such as a breach in the bladder or diaphragm, another leak elsewhere on the transformer or a poor sampling. All these items would concern the operator of the equipment. However if no information is provided or the information is incorrect then no or an incorrect diagnosis will be provided by the laboratory. The Double 7 Materials Laboratory also uses the age and the type of preservation system of a transformer as exceedingly pertinent information when providing a diagnosis basedOn furanic compound results. The flushing procedure is very important in order to remove debris and water from the valve, in order to get a sample that reflects the bulk liquid insulation. Cast iron valves tend to retain more moisture on valve walls then do brass, bronze or stainless, so more flush liquid may be required. A good quality control check, to determine if all the water has been removed from the drain valve, is to install a portable water sensor such as the DOMINO Port Sampler onto the drain valve. In this way the water content can be monitored while flushing is taking place. Once the water sensor has reached a stable ppm value it can be assumed that all of the excess or unwanted moisture has been removed from the valve.

Rinsing a bottle several times removes any debris remaining from the bottle manufacturing process, and conditions the container to receive the sample by warming the walls of the container, so water condensation does not occur during sampling. The same is true of the syringe, where flushing and purging helps to remove any debris and moisture, coats the plunger to create an adequate seal and helps to remove air bubbles. Once the syringe is filled, any air bubbles remaining must be quickly removed. However, if gas bubbles appear after the dielectric liquid has cooled then do not release those bubbles as they are gases that have just come out of solution but still comprise the sample. Syringe samples must also be shielded from the sunlight to prevent photo-degradation of sample. When filling bottles with the dielectric-liquid sample, aeration and turbulence must be avoided. Aeration and turbulence will cause air and water to be entrained in the sample thus increasing the water content and possibly affecting some of the other properties of the oil. Glass bottles are not filled, to the very top, to avoid breakage due to the expansion or the contraction of the liquid. Metal cylinders, metal cans and plastic bottles do not suffer from this problem and therefore may be filled to overflowing and sealed.

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