GUIDE FOR THE PURIFICATION OF INSULATING OIL

by
I.A.R. Gray-Transformer Chemistry Services

INTRODUCTION

The purpose of this guide is to further oil conservation by providing information for the purification of used insulating oils by chemical and mechanical means, making them suitable for reuse as insulating fluids.

DEFINITIONS

DRYING METHOD can be considered as any process that reduces and maintains at a low level the material's water vapour pressure.

PURIFICATION or RECONDITIONING of insulating oil is the process of removing moisture, dissolved combustible gas and particulate matter, as determined by oil and transformers' tests.

REGENERATION or RECLAIMING of insulating oil is the process of removal of contaminants and products of degradation such as polar, acidic or colloidal material, as determined by oil and transformer tests.

SCOPE

The scope of this guide covers mineral insulating oil commonly defined as transformer oil and description of the various purification procedures.
The other procedures of transformer dehydration will be covered but not in detail. All drying methods share a common objective - the removal of free and dissolved moisture from the cellulose paper, as well as the insulating oil.
Note: The oil decay products (especially acids and sludge's) will not be discussed, as these are removed by a process of regeneration.

The guide covers a transformer that is free from contamination by external sources ie bad gasketing, cracked insulation, a loose manhole cover, a ruptured explosion diaphragm, etc.

Note: The Dielectric Breakdown test will only detect free water, dirt and conductive particles. If the leaks are repaired, it is quite easy to dry out the oil and remove particulate matter, but it is altogether another matter to dehydrate the windings. After a short period following the initial treatment the moisture can be almost at the level of its initial condition, but the transformer should be free of particle contamination for a longer period ie 5 years plus.

Authorities now agree that careless sampling and testing technique has been the source of 99 percent of"bad" dielectric readings

CORRECTIVE MAINTENANCE PROCEDURES FOR OIL-INSULATED TRANSFORMERS

INTRODUCTION

When predictive maintenance (Transformer and oil tests) has disclosed a serious problem of moisture, combustible gas and/or oil decay products, certain corrective (Preventative) maintenance procedures should be followed. (See Tables page 6 for oil test limits)

See flow chart of basic transformer field maintenance procedures. (See Figure 2)

Water trapped in oil impregnated cellulose materials, indicated by increased water content (and/or de-energised winding power factor and other electrical tests), requires some form of dehydration of the transformer's insulation system. The drying procedures can only reduce the rate of loss of mechanical strength but never regain that which has been lost through neglect.

The removal of dissolved combustible gases, determined by the technique of gas in oil analysis by gas chromatography, generally requires unit repair and degasification.

DEHYDRATION OF TRANSFORMERS

Significant factors concerning the choice of drying method include the type of transformers, ambient and operating temperatures, time limitations, thickness of the insulation pieces, and the vapour pressure of moisture in the surrounding atmosphere.

Moisture removal can be can be accomplished by several methods using various combinations of factors. The two general categories of drying, involves the use of heat /or vacuum performed using factory repair shop or field methods-either, power off or power on. (Table 2)

Even with all its benefits, improper drying can result in damage to the transformer insulation.

The comparisons of oil treatment practices are given in Table 3.

Note: The Filter Press and Centrifuge tend to aerate the oil, which leads to more rapid decay due to oxidation and are therefor unsatisfactory for the use on transformers.

The universal demand for higher quality control has resulted in the Heat-vacuum with Coalescing filters being the preferred process.

THE BONUS OF DEGASIFICATION

The primary advantage for dehydration of oil with high vacuum in contrast to heat alone lies in a side effect-degasification-which simultaneously occurs. This does not occur with other methods of water removal.

The value of a high degree of dehydration and degasification at the factory or in the field, prior to energising brings these benefits:

* Minises partial discharge (corona) effect from inadequate oil impregnation.
* Removal of unwanted oxygen.
* Removal of combustible gases.
* Extremely dry oil.

Drying Efficiency

The efficiency of dehydration regardless of method depends on a number of factors, including the oil temperature and the degree of vacuum pulled. The challenge is to use a system that avoids use of excessive temperature, which promotes degradation of the cellulose, yet brings about the removal of the maximum degree of moisture from the insulation.

For efficient dryout, vacuum in excess of the equilibrium values is required. The drying operation occurs when the oil-cellulose equilibrium condition is disturbed favorably.

Other factors that determine the efficiency of water removal include, initial water content in the oil and in the cellulose, oil film thickness, time of exposure to vacuum and accelerators, such as agitation.

In the case of just wet oil, or wet oil and wet windings, a couple of recirculations of the oil through a vacuum dehydration system will dry the oil. The dry oil will be contaminated by the wet windings as they seek equilibrium condition, repeating this cycle many times can correct the situation.

Note: Above 50 ppm(ASTM 1533) of water in transformer oil definitely indicates the paper insulation is loaded with water.

TRANSFORMER OIL PURIFICATION SPECIFICATION.

When predictive maintenance (Transformer and oil tests) has disclosed a serious problem of moisture, combustible gas and/or oil decay products, and on site purification is the chosen procedure the following steps are suggested:

1. Suitable competent contractors are identified.
Note: Membership of the Electrical Contractors Association should be a prerequisite and Workers Compensation mandatory.

2. The transformer oil test results should be supplied to the contractor, and the cost of purification should be based on the standard for finished product, a transformer oil reading:

* TOTAL WATER CONTENT	: Maximum 10 ppm (mg/Kg)	ASTM D-1533
* DIELECTRIC STRENGTH	: Minimum 70 kV	IEC 156
* TOTAL GAS CONTENT	: Maximum 1.0 percent	ASTM D-2945 or
* INDIVIDUAL COMBUSTIBLE GAS	: Maximum 1 vpm	ASTM D-2945

Note: The sample must be drawn from inlet of the purification process i.e. condition of oil from the transformer. If the sample is drawn from the outlet, this just indicates the efficiency of the purification plant.

3. The Flow diagram of the process should be supplied by the contractor before concluding the contract.

SAFETY CONSIDERATIONS

Concern for static charges when transformer oil flows through pipes or tanks must be emphasised. The explosive mixture of oil vapours and air that may be present is also cause for concern. Proper grounding of all devices is essential. No smoking or open flames should be permitted. Fire extinguishers, preferably the carbon dioxide (CO_2) type should be available nearby before beginning any dry out procedure.

Power on purification should not be attempted without gas-in-oil analysis, as further damage is likely, if an internal fault is occurring. The other consideration is the combustible gas generated by the internal fault will be exhausted via the vacuum process resulting in an explosive situation.

Adequate grounding of the processing equipment to station grounding.

Staying clear of energised conductors.

ENERGISED PROCESSING.

The following particular safety features should be built into the processing equipment system for energisied purification:

Liquid level detectors and controls to ensure that current carrying internal components will not be exposed to the atmosphere. These controls should be designed to maintain a constant oil level in both the transformer and the process equipment.

Automatic heat regulation to maintain the oil at a temperature to prevent damage to the insulating properties.

Alarm devices to signal when pressure, temperature and oil levels deviate from prescribed limits.

Filters at the discharge of all pumps to catch metal cuttings that might be released from the pump impellers and gears.

Design that ensures that vacuum is drawn only in the process equipment and not in the transformer.

Instrumentation for monitoring flow rates to provide an evaluation of the process efficiency.

Note: Energisied purification should not be attempted on an oil that contains water in excess of 50 ppm(mg/Kg) and an Electric Strength of less than 24 kV.

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TRANSFORMER OIL STANDARD

	IN SERVICE	PURIFICATION	REGENERATION
Water (mg/Kg) (ASTM 1533)	20-30 max	10 max	10 max
Electric Strength (kV) (IEC 156)	30-50 min	70 min	70 min
Acidity(mg/KOH/g oil) (IEC 296)	0.20 max	N/A	0.20 max
InterfacialTension(mN/m) (ASTM D971)	15 max	N/A	35 min
Oil Quality Index	160	N/A	300 min
Dissolved Gas (ASTMD-2945)	Refer to Note 3	1.0% max	1.0% max

NOTE 1: Transformer oils that contains acidity in the range 0.21-0.60(mg KOH/g oil) have a 72 % probability of containing sludge.

NOTE 2: The 20 ppm water in oil is Recommended Limit, the 30 ppm is the Maximum Limit. Maintaining the water content in the insulating oil at the recommended limit of 20 (ppm), insures that insulating paper contains less than 2 % moisture (Absolute upper limit of acceptability).

TRANSFORMER PAPER INSULATION DATA

	Results by Percentage
0.5 %	Well dried transformer
1.5 %	Will pass tests and perform to design
2.0 %	Total upper limit
3.0 %	Paper fibres in oil
4.5 %	Flashover at 90° C.
7.0 %	Flashover at 50° C.
8.0 %	Flashover at 20° C.
>8.0 %	Who Knows ?

NOTE 3: Dissolved Gas analysis is a valuable technique for detecting and identifying fault occurring within transformers and reactors. Heat, and /or electrical discharges occurring inside the unit lead to the decomposition (breakdown) of the insulating oil and other insulating materials (paper, barrier board, resins, etc). Slow generation of gas may allow absorption into the oil whereas a sudden large release will not dissolve in the oil and this will cause the Buchholz relay to activate.

The Dissolved Gas analysis can only be done by suitably equipped laboratories providing this service.

CAUTION: Interpreting the gas analysis results is not an exact science, mainly because of the influence of many transformer designs. It should therefore only be performed by transformer specialists.

SUMMARY OF INSULATION DRYING PRACTICES[1-2]

Processing Site	Heat (Removal of Major Portion of Water)		Heat and Vacuum (Final Removal of water and Degasification)	
	Power Off	Power On	Power Off	Power On
Factory and Repair Shop Methods	Oven	-	Traditional heat (90°C) and vacuum	-
	Elevated temperature	-	Combinations with heat, such as hot oil and short circuit	-
	Dry air(80°C-100°c)	-	Vapor phase	
			Hot oil spray and vacuum	
Field Pracitce	Short circuit(95°C) (core type units)	Natural draft	Dry ice cold trap and high vacuum	Oil conditioner (Purivac)
	Forced hot air(90°C) (shell type units)	Dry air (6 months-1 year)	Water vapour trap and high vacuum	Oil degasification (Keene Bowser)
	Circulating hot oil through external heater(85°C)	Portable dry air supply	Oil cycling and high vacuum	External mounted dehydrator
	Oil-immersed resistor (85°C)	Dry air circulation Use of silica gel(1-2 years)	Hot spray(80°C) and high vacuum	Stationary Installation
			Vapor phase	Hot oil reclaimer
				Mini-oil purifier

[1] Heat only for older units without full vacuum bracing capacity.
[2] Vacuum only for units with high ambient temperature.

COMPARING OIL TREATMENT PRACTICES

Oil Reclamation Method	Types of Contamination Removed: Soild	Free Water	Soluble Water	Air and Gas	Acids, Sludge, etc Volatile	Other
Reconditioning						
Mechanical Filter(Blotter or Filter Press)	Yes	Yes	Partial	No	No	No
Centrifuge	Yes	Yes	No	No	No	No
Coalescing Filter	Yes	Yes	No	No	No	No
Precipitation/Setting	Yes	Yes	No	No	No	No
Vacuum Dehydration	No	Yes	Yes	Yes	Most	No
Reclaiming						
Contact Process	Yes	Yes	Yes	No	Yes	Yes
Percolation by Pressure	Yes	Yes	Partial	No	Yes	Yes
Percolation by Gravity	Yes	Yes	Partail	No	Yes	Yes
Activated carbon-Silicate Process	Yes	No	No	No	Yes	Yes
Trisodium Phosphate	Yes	No	No	No	Yes	Yes
Oil Reclamation Systems						
Stationary	Yes	Yes	Yes	Yes	Yes	No
Moblie On-Site	Yes	Yes	Yes	Yes	Yes	Yes
Mini-Oil Reclaimer	Yes	Yes	Yes	Yes Partial	Yes	Yes limited