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Proposed Guide
for
MAINTENANCE of INSULATING OIL

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Proposed Guide ***of the*** **American Institute of Electrical Engineers**

MAINTENANCE OF INSULATING OIL

I INTRODUCTION

Certain essential properties of insulating oil, used in transformers and circuit breaking devices, must be retained in service if the oil is to reliably perform its multiple role of electrical insulating, arc quenching and heat-transfer agent.

It must have adequate dielectric strength to withstand the electrical stresses imposed in service. It must retain a sufficiently low viscosity so that its ability to circulate and transfer heat is not impaired. It must pour readily at low temperatures, and have high flash point and fire point for safety. Its dielectric losses should not become excessive. It should not be allowed to become so deteriorated or contaminated that it adversely affects other materials in the apparatus, nor should deterioration products sludge it sufficiently to impair its circulation through cooling ducts.

This guide attempts to assist the power equipment operator in his efforts to maintain his oil in serviceable condition. It recommends and standardizes oil test and evaluation procedures, methods of reconditioning and reclaiming oil when necessary, and routines for restoring oxidation resistance by additions of inhibitors.

II ECONOMIC FACTORS

In Section III of this guide, oil in service is classified on the basis of the composite evaluation of significant characteristics. Oil classified under Groups II and III is subject to reconditioning if this is economically justifiable. The alternate choice is replacement with new oil.

A review of experience and cost data obtained from many operators and users of transformers reveals a wide variation of practices and cost data involved in the reconditioning and reclaiming of oil. These differences are mostly attributable to the type of system, field inspection operations, and available laboratory and shop facilities. For example, an operator having a large number of pole type transformers installed over a large area may follow a different practice than one having large transformers in stations in a metropolitan area.

Insulating oil that falls in Group II can be reconditioned by mechanical means at a cost of from less than 1 cent per gallon where large

shop facilities are available to 5 cents per gallon for small field operations. This process of maintaining oil in satisfactory condition, is used by many operators and users of transformers.

Insulating oil that falls in Group III can be reclaimed by chemical and adsorbent means at a cost of from 10 cents to 20 cents per gallon.

In determining whether or not reconditioning and/or reclaiming of insulating oil is economically justifiable, a number of factors must be considered. Some of these factors are as follows:

1. Cost of materials.
2. Disposition of used materials.
3. Total cost of process *vs* quality of end product.
4. Equipment maintenance and amortization.
5. Cost of collection and storage of oil.
6. Labor and transportation costs.
7. Laboratory costs.
8. Cost of new oil *vs* cost of reprocessed oil.
9. Loss of oil during reprocessing.
10. Cost of inhibitors and blending process.
11. Value of used oil when used for some other purpose. (One user reports that they utilize certain amounts of this oil for fuel purposes with a value of between 7 and 10 cents per gallon.)

The economic justification of whether reconditioning and/or reclamation work is performed by company personnel or contractors must be resolved on the basis of factors applicable in each particular case.

III CLASSIFICATION OF USED INSULATING OILS

It is impossible to indicate the value of specific tests and recommended test limits for all possible existing applications of transformer oil in service. It should also be recognized that with the present state of knowledge, no one test can be used as the sole criterion of the condition of oil in service. It is possible, however, to summarize the value and importance of the current tests and to suggest methods of treatment for the oil being examined, such methods being based on current industry experience. Oils in service may be placed in the following classifications based upon the composite evaluation of significant characteristics.

GROUP I

This group contains oils which are in satisfactory condition for continued use.

GROUP II

This group contains oils which require only minor reconditioning for further service (Reconditioning is the mechanical removal of moisture and insoluble contaminants. Typical means employed are filtering and centrifuging.)

GROUP III

This group contains oils in poor condition. They should be reclaimed or disposed of depending upon economic considerations. (Reclamation involves the use of methods and processes which result in a beneficial chemical change in the oil. Typical means employed are treatments with adsorption agents, acid refining, alkali treatment, etc.)

GROUP IV

This group contains those oils in such poor condition that it is technically advisable to dispose of them.

IV OIL TESTS AND THEIR SIGNIFICANCE

There are many tests that can be applied to transformer oil as a basis for classifying oils as indicated in the foregoing. It is recommended wherever possible that tests be the latest revisions accepted as standards or tentative standards by ASTM. These tests and their significance are as follows:

Test	ASTM Designation
1. Neutralization Number.	D 664, D 974
2. Dielectric Breakdown...	D 877
3. Interfacial Tension.....	D 971
4. Power Factor.....	D 924
5. Color.....	D 155
6. Viscosity.....	D 88, D 445
7. Flash Point.....	D 92
8. Steam Emulsion.....	D 157
9. Specific Gravity.....	D 287
10. Pour Point.....	D 97
11. Resistivity.....	D 257
12. Saponification Number..	D 94
13. Gas Content.....	D 831
14. Inorganic Chlorides and Sulfates.....	D 878
15. Combined Corrosive Sulphur.....	D 1275
16. Sludge.....	D 1313, D 1314
17. Water In Insulating Oils by Extraction....	D 1315

1. Neutralization Number—D 664 and D 974

Neutralization number for used oils is in general a measure of the acidic constituents of an oil and is the milligrams of KOH required to neutralize one gram of oil. It is a measure of the oil deterioration and some types of contamination.

2. Dielectric Breakdown—D 877

The dielectric strength of an insulating oil is the average voltage gradient at which electric failure or breakdown occurs under prescribed conditions. This test is made to determine if an oil has adequate electrical strength and is not necessarily an indication of its other properties.

3. Interfacial Tension—D 971

The interfacial tension between an electrical insulating oil and water is a measure of the molecular attractive force between their unlike molecules at the interface. It is expressed in dynes per centimeter. This test provides a means of detecting soluble polar contaminants and products of deterioration.

4. Power Factor—D 924

Power factor is the ratio of the power dissipated in the oil in watts, to the product of the effective voltage and current in volt-amperes, when tested with a sinusoidal field under prescribed conditions. It is usually measured at 25C and reported as percent power factor measured at 60 cycles per second corrected to 20C. This test is an indication of the presence of contaminants or deterioration products such as water, oxidation products, metal soaps, charged colloids, etc.

5. Color—D 155

The color of an insulating oil is determined by means of transmitted light and is expressed by a numerical value based on comparison with a series of color standards. A rapidly increasing or high color number is an indication of oil deterioration or contamination or both.

6. Viscosity—D 88 and D 445

The viscosity of an oil is its resistance to uniformly continuous flow, without turbulence, inertia or other forces. The viscosity of insulating oil is usually measured by the time of flow of a given quantity of oil under controlled conditions. Viscosity is not significantly affected by oil contamination or deterioration but may be useful for identifying certain types of used insulating oils.

7. Flash Point—D 92

The flash point of oil is the temperature to which the material must be heated in order to give off sufficient vapor to form a flammable mixture with air.

A low flash point indicates the presence of hazardous, volatile, combustible contaminants in the transformer oil.

8. Steam Emulsion—D 157

In the steam emulsion test, steam is passed into the oil under prescribed conditions, and the time in seconds required for complete separation of the oil and the condensed steam is recorded as the Steam Emulsion Number (S.E. Number) of the oil.

The steam emulsion number may be of value in indicating the presence of certain undesirable impurities, but has not been widely applied to used oils.

9. Specific Gravity—D 287

The specific gravity of a transformer oil is a ratio of the weights of equal volumes of oil and water at 15.56C (60F). Specific gravity is not significant in determining quality or serviceability of a transformer oil but may be useful for type identification.

10. Pour Point—D 97

The temperature at which transformer oil will just flow under the prescribed conditions is known as the pour point.

The pour point has little significance as far as contamination or deterioration is concerned but may be useful for type identification and for determining the type of equipment in which it can be used.

11. Resistivity—D 257

The volume resistivity in ohms centimeter of an oil is the ratio of the direct potential gradient in volts per centimeter paralleling the current flow in amperes per square centimeter at a given instant of time and under prescribed conditions. A low resistivity normally indicates the presence of conductive contaminants but has not been widely applied to used oils.

12. Saponification Number—D 94

The saponification number of an oil is the number of milligrams of potassium hydroxide which are consumed by one gram of oil under prescribed conditions. The significance of this test as a measure of oil quality is questionable but is currently being re-evaluated by ASTM.

13. Gas Content—D 831

The gas content of an insulating oil may be defined as the volume of gas per 100 volumes of oil. In evaluating used oil, this test normally has little significance in determining quality or serviceability.

14. Inorganic Chlorides and Sulfates—D 878

This test indicates the presence of inorganic chlorides and sulfates by precipitation of insoluble salts by means of the usual analytical

procedures. This test generally is of little value in the examination of used insulating oils.

15. Combined Corrosive Sulphur—D 1275

This test is designed to detect the presence of free sulphur and combined corrosive sulphur by subjecting copper to contact with oil under prescribed conditions. This test indicates the possibility of corrosion resulting from the presence of either free sulphur or unstable sulphur compounds.

16. Sludge—D 1313, D 1314

The sludge value for mineral transformer oil represents the percentage of insoluble matter formed when the oil is heated and oxidized under certain prescribed conditions. These tests are applicable to new transformer oil and have no significance in determining the quality or serviceability of a used oil.

17. Water In Insulating Oils By Extraction—D 1315

Water as determined in this test includes total water in the insulating oil. The unit of measure of the water is in parts per million. The test is significant in that it will show the presence of water which may not be evident from electrical tests.

Certain other criteria which may be helpful in evaluating the quality of oils in service are listed below.

1. Visual Condition

This test indicates the presence of free water and sediment such as metal particles, insoluble sludge, carbon, dirt, etc. One method of visually examining an oil sample is to observe a representative sample in a clear glass tube or bottle. If the oil by visual examination is clear, then the appropriate tests given below should be applied to classify the oil in the proper group as initially defined above. If insoluble contaminants are present, valuable information may be obtained by filtering the oil and identifying the residue. The oil filtrate should be examined and classified in the same manner as a clear oil sample.

A method for visual condition is currently under investigation by ASTM.

2. Water

Water may be present in several forms. The presence of free water may be disclosed by visual examination in the form of separated droplets or as a cloud dispersed throughout the oil. This type of water invariably results in decreased dielectric strength which may be restored by filtration or other suitable means. Water in solution cannot be detected visually, and is normally determined by either physical or chemical methods. One such method under ASTM con-