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Indian Standard

CODE OF PRACTICE FOR ELECTRICAL MAINTENANCE AND SUPERVISION OF MINERAL INSULATING OIL IN EQUIPMENT

(Third Revision)

1 SCOPE

1.1 This standard deals with maintenance and supervision of mineral insulating oils complying with the requirements of IS 335 and IS 12463 in transformers, switchgears, and similar electrical apparatus where oil sampling is practicable and where the normal operating conditions specified for the equipment are observed.

NOTE — Recommendations for oil used in hermetically sealed and low volume equipment are excluded from this code because such equipment is not designed for the process of routine oil sampling.

2 REFERENCES

2.1 The Indian Standards given in Annex D are necessary adjuncts to this standard.

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Electric Strength (Break Down Voltage)

The voltage at which the oil breaks down when subjected to an ac electric field with a continuously increasing voltage contained in specified apparatus. The voltage is expressed in kV.

3.2 Flash Point

The temperature at which the oil gives off so much of vapour that this vapour, when mixed with air, forms a ignitable mixture and gives a momentary flash on application of pilot flame under the prescribed conditions.

3.3 Precipitable Sludge

Oil deterioration products or contaminants or both, which are insoluble after dilution of the oil with *n*-heptane but are soluble in the solvent mixture of equal parts of toluene, acetone and alcohol under prescribed conditions.

3.4 Sediment

Any substance which is insoluble after dilution of the oil with *n*-heptane and also insoluble in the solvent mixture of equal parts of toluene, acetone and alcohol under prescribed conditions.

3.5 Neutralization Value (Total Acidity)

It is the measure of free organic and inorganic acids present together in the oil. It is expressed in terms of the number of milligrams of potassium hydroxide required to neutralize the total free acids in one gram of the oil.

3.6 Specific Resistance (Resistivity)

It is the ratio of the dc potential gradient in volts per centimeter paralleling the current flow within the specimens to the current density in amperes per square centimeters at a given instant of time and under prescribed conditions. This is numerically equal to the resistance between opposite faces of a centimeter cube of the liquid. It is expressed in ohm-centimeter.

3.7 Dielectric Dissipation Factor (Tangent Delta)

It is the tangent of the angle (delta) by which the phase difference between applied voltage and resulting current deviates from $\pi/2$ radian when the dielectric of the capacitor consists exclusively of the insulating oil.

3.8 Interfacial Tension

It is a force necessary to detach a planar ring of platinum wire from the surface of the liquid of higher surface tension that is upward from the water-oil surface. It is expressed in N/m.

3.9 Reconditioning

This is a process to eliminate, by physical means only, solid particles from the oil and to decrease the water content to acceptable level.

3.10 Reclaiming

This is a process to eliminate from the used oil, all contaminants, insoluble and dissolved, to obtain an oil with characteristics similar to those of a new oil.

4 OIL DETERIORATION AND RECOMMENDED TESTS

4.1 In service, insulating oils are subjected to normal deterioration due to the conditions of use. For example, in many applications the oil is in contact with air. It is, therefore, subjected to oxidation reactions accelerated by temperature and presence of catalysts (solid iron and copper, dissolved metallic compounds). As a result, the oil darkens in colour and its acidity begins to increase. There will be a simultaneous change in the electrical characteristics, such as, fall in resistivity values and/or an increase in the dielectric dissipation factor. In the advanced stages of oxidation, sludge formation may also occur.

4.2 In certain special cases, other changes in the characteristics of the oil may be a sign of abnormal deterioration of certain other materials used in construction of the equipment. All these changes may have effect on both solid and liquid insulating materials and interfere with the proper functioning of the equipment, shorten its working life and in some cases increase in no load losses.

4.3 The development of an odour and a change in colour, although not being of a decisive nature, may on comparison, give useful indication about the trend of changes in the oil.

The following contaminants may be found in insulating oils in service:

a) Water : Its presence is determined by Karl Fischer method

b) Sediment and precipitable sludge : These are determined by method given in Annex 'A'

c) Polar substances : Their presence is determined by fall in values of dielectric dissipation factor, specific resistance and interfacial tension properties

d) Acids : Their presence is determined by neutralization value

e) Dissolved gases : These can be determined by gas chromatography

f) Light hydrocarbons : These can be determined by flash point test

The presence of these contaminants or any kind of deterioration of an oil is made evident by changes in any one or more of the properties covered by these tests. The details of test methods (a) to (f) as above are covered in **7.0**.

5 SAMPLING OF OIL FROM EQUIPMENT

5.1 Every effort should be made to ensure that samples are representative of the insulating oil in equipment. Experience indicates that oil is sometimes rejected unjustifiably because inadequate care has been taken during sampling.

5.2 It is strongly recommended that the procedures and precautions outlined in IS 6855 are closely followed. Sampling for the determination of low moisture content and analysis of dissolved gases, sampling as per IS 9434 shall be followed. The oil sampled should be stored safely in a dark place.

5.3 Sampling from equipment should preferably be carried out while the equipment is operating normally or very shortly after de-energization. This requirement is particularly necessary when water content, or characteristics dependent on it, are to be checked and in these cases the temperature of the oil at the time of sampling should be recorded.

5.4 Where available, manufacturer's instructions should be followed. This is especially required with certain type of equipment, such as instrument transformers, in view of the limited oil volume as well as specific design.

5.5 Oil samples (1or 2 litres depending on the number and type of tests needed) are normally drawn from the sampling valve or bottom valve at least, observing the following general rules :

- Ensure that sampling is done by an experienced person.
- Sampling outdoors in rain, fog, snowfall or strong wind should be avoided. However if sampling is inevitable in such conditions special precautions shall be taken to ensure that ambient conditions do not influence the characteristics of the sample. Sampling under high humidity is to be avoided. Preferably sampling should be carried out when the humidity is less than 50 percent.
- Use, only dry and clean containers, such as amber coloured glass bottles or seamless metal containers of stainless steel. Plastic containers can be used provided their suitability has been proved. Clear glass bottles should be provided with opaque covers.
- Run off sufficient quantity of oil to remove any contaminants that may have accumulated at the sampling orifice.
- Rinse the containers with the oil being sampled.
- Fill the containers, if possible allowing the liquid

being sampled to flow against the side of the containers, thus avoiding trapped air.

- Ensure that each container is filled to about 95 percent of its capacity.
- After sampling, carefully close the sampling valve.
- Label the samples, including at least the following details :
  a) Equipment identification,
  b) Sampling point,
  c) Temperature of oil, and
  d) Date of sampling.
- A minimum of 1 litre and maximum of 2.5 litres oil depending on number of tests needed shall be sampled and stored in a dark place if clear glass bottles have been used.

6 INSPECTION OF SAMPLE

6.1 Visual inspection and odour give useful information, for example :

a) Cloudiness in oil may be due to suspended moisture or sediments such as iron-oxide or sludge. Undissolved water present in oil may be determined by crackle test (**7.3**).

However total moisture content can be determined from water content test (Table 1).

b) Acid smell indicates the presence of volatile acids which can cause corrosion. This may render oil unsuitable for treatment at site.

c) Colour can indicate different stages oil quality under ageing:

Pale yellow	:	Good oils
Yellow	:	Proposition 'A' oils
Bright yellow	:	Marginal oils
Amber	:	Bad oils
Brown	:	Very bad oils
Dark brown	:	Extremely bad oils
Black	:	Oils in disastrous condition

(Dark brown colour indicates dissolved asphaltenes and green colour indicates presence of copper compounds.)

Inferences drawn from the above mentioned visual inspection can be used as screening tests at site and also at the laboratory after receipt of samples for evaluation. The information shall be noted for record purposes, as it is valuable to decide the periodicity of laboratory tests given in Table 2. However, when the laboratory tests are contemplated for the sample, crackle test or any other test is not warranted.

NOTE — S D Myer *et al* have proposed determination of quality index calculated as ratio of Interfacial tension in dynes to Neutralization value in mg KOH/g of oil. This index can also be employed in field by determining both the properties at field.

7 SIGNIFICANCE OF TESTS AND TEST METHODS

There are a large number of tests that can be applied to oil delivered in equipment or oil from equipment in service but the following tests are believed to be sufficient to determine whether the oil condition is adequate for continued operation and suggest the type of corrective action required:

Property	*Method*
Appearance	IS 335
Electric strength	IS 6792
Water content	IS 13567
Neutralization value	IS 1448 [P : 2]
Sediment and sludge	Annex 'A'
Dielectric dissipation factor	IS 6262
Resistivity	IS 6103
Interfacial tension [1]	IS 6104
Oxidation stability [1]	Annex C of IS 335 IS 12422 as applicable
Total gas content	IS 9434
Pour point [2]	IS 1448 [P : 10]
Density [2]	IS 1448 [P : 16]
Flash point	IS 1448 [P : 21]
Viscosity [2]	IS 1448 [P : 25]
Inhibitor content [3]	IS 13631

Remark : *See* Note under **1**.

7.1 Appearance

The appearance of oil may show cloudiness or sediments which may indicate the presence of free water, insoluble sludge, carbon, fibres, dirt, etc.

7.2 Breakdown Voltage

The breakdown voltage is of importance as a measure of the suitability of an oil to withstand electric stress.

Dry and clean oil exhibits an inherently high breakdown voltage. Free water and solid particles, the

[1] Only under special circumstances.

[2] Not essential, but can be used to establish type of oil.

[3] Restricted to inhibited oils.

latter particularly in combination with high levels of dissolved water, tend to migrate to regions of high electric stress and reduce breakdown voltage dramatically. The measurement of breakdown voltage, therefore serves primarily to indicate the presence of contaminants such as water or conducting particles, one or more of which can be present when low breakdown voltage values are found by test. However, a high breakdown voltage does not indicate the absence of contaminants.

7.3 Water Content

Water may originate from the atmosphere or be produced by the deterioration insulating materials. At comparatively low water content, the water remains in solution and does not alter the appearance of the oil. Dissolved water shall therefore be detected by chemical or physical methods.

Dissolved water may or may not affect the electrical properties of the oil. The solubility of water in transformer oil increases with increasing temperature and neutralization value (*see* Fig. 1). Above a certain water content (The saturation Water content), all the water cannot remain in solution and free water may be seen in the form of cloudiness or water droplets; free water invariably results in decreased dielectric strength and resistivity and increased dielectric dissipation factor.

In a transformer, the total water content is distributed between the paper and the oil in a ratio that is predominantly in favour of the paper. Small changes in temperature significantly modify the water content of the oil but only slightly that of paper.

Using graphs which may be found in the literature, it is possible to obtain at a given temperature the water content of the paper from the measured water content of the oil assuming equilibrium conditions. The limiting values for water content which are recommended in Table 2 are intended to control the water content in cellulosic insulation within acceptable values and are related to normal operating oil temperatures over 40 to 60°C.

High water content accelerates the chemical deterioration of insulating paper and is indicative of undesirable operating conditions or maintenance requiring correction. Crackle test may be used as a field test for detecting free moisture.

7.4 Neutralization Value

The neutralization value of an oil is a measure of the acidic constituents or contaminants in the oil. Its value, negligible in an unused oil, increases as a result of oxidative ageing and is used as a general guide for determining when an oil should be replaced or reclaimed, provided suitable rejection limits have been established and confirmation is received from other tests.

For quickly determining the total acidity of insulating oils in service, a portable acidity testing kit has also been devised with which test for acidity of oils can be determined at site with ease. The details of the portable kit is given in Annex C.

7.5 Sediment and Sludge

This test distinguishes between sediment and total sludge that is oil insoluble sludge plus sludge which is precipitated by adding heptane).

Solid matter comprises insoluble oxidation or degradation products of insulating materials, fibres of various origins, carbon, metallic oxides, etc, arising from the conditions of service of the equipment. The presence of solid particles may reduce the electric strength of the oil and, in addition, deposits may hinder heat transfer, thus promoting further deterioration of insulation.

Sludge consists of products formed at an advanced stage of oxidation and is forewarning of sludge deposits in the equipment.

7.6 Dielectric Dissipation Factor (DDF) and Resistivity

These characteristics are very sensitive to the presence in the oil of soluble polar contaminants, ageing products or colloids. Changes may be motivated even when contamination is so slight as to be undetectable by chemical methods.

Acceptable limits for these characteristics depend largely upon the type of apparatus and application. However, high values of dissipation factor may influence the power factor and/or the insulation resistance of transformer windings.

There is generally a relationship between DDF and resistivity at elevated temperature with resistivity decreasing as DDF increases. It is normally not required to conduct both tests on the same oil.

Useful additional information can be obtained by measuring resistivity or DDF at both ambient and at higher temperature such as 90°C. A satisfactory result at 90°C coupled with an unsatisfactory value at lower temperature is an indication of the presence of water or degradation products precipitable in the cold but

generally at a tolerable level. Unsatisfactory results at both temperatures indicate a greater extent of contamination and that it may not be possible to restore the oil to a satisfactory level by reconditioning.

7.7 Interfacial Tension

The interfacial tension between oil and water provides a means of detecting soluble polar contaminants and products of deterioration. This characteristics changes fairly rapidly during the initial stages of ageing but levels off when deterioration is still moderate. For this reason, results are rather difficult to interpret in terms of oil maintenance. However, oils with interfacial values at or near the minimum limit value specified in Table 2 should be further investigated (*see* Fig. 2).

7.8 Total Gas Content

For most applications of mineral insulating oil, the determination of total dissolved gas content normally has little significance for assessing the quality and serviceability of the oil. However, for certain types of EHV equipment, a maximum gas content is some times specified when filling apparatus or in service. Gas-in-oil analysis for the detection of incipient faults is dealt within IS 9434 and IS 10593.

7.9 Flash Point

A low flash point is an indication of the presence of volatile combustible products in the oil.

Prolonged exposure of the oil to very high temperature under fault conditions may produce sufficient quantities of low molecular weight hydrocarbons to cause a lowering of the flash point of the oil.

7.10 Pour Point

Pour point is a measure of the ability of the oil to flow at low temperature. There is no evidence to suggest that the property is affected by oil deterioration. Changes in pour point may normally be interpreted as the result of topping-up with a different type of oil.

7.11 Density

Density is not significant in determining the quality of an oil but may be useful for type identification or to suggest marked compositional changes. In cold climates density may be pertinent in determining the suitability for use, for examples ice crystals formed from separated water, may float on oil of high density and lead to flash over on subsequent melting.

7.12 Viscosity

Viscosity is a controlling factor in the dissipation of heat. Ageing and oxidation of the oil tend to increase viscosity but the effect is not discernible at the deterioration levels considered in this guide. Viscosity measurements may be useful for oil type identification.

7.13 Inhibitor Content and Oxidation Stability

Inhibited oils deteriorate more slowly than uninhibited oils so long as active inhibitor is present and the oil still has inhibitor response. For a given oil/inhibitor pair, the induction period is generally proportional to the active inhibitor content and dependent on the presence of oxidation promoter.

The degree of protection provided by the oxidation inhibitor is a function of base oil chemistry and inhibitor concentration. The determination of residual inhibitor in service-aged inhibited oil assesses the rate of inhibitor depletion.

The oxidation test for unused inhibited oil (*see* IS 12463) enables the induction period of an oil to be easily measured by means of the determination of volatile acids developed. This test, applied to a used oil previously tested will indicate to what extent the induction period has been reduced.

7.14 Polar Substances

These are oil-soluble compounds resulting from oxidation of the oil itself, or from the solution in the oil of external contaminants or materials used in the construction of the equipment.

Measurements of dissipation factor and to a least extent, resistivity and interfacial tension of the oil enable such contaminants to be detected and periodically assessed.

A comparison of the rate of change of neutralization value with that of one of these three characteristics namely, dissipation factor, resistivity, and interfacial tension gives, to some extent, an indication of the deterioration of the oil. For example, a high value of dissipation factor associated with a low neutralization value may some time be considered as an indication of oil contamination other than that of oil origin.

8 CATEGORIES OF EQUIPMENT

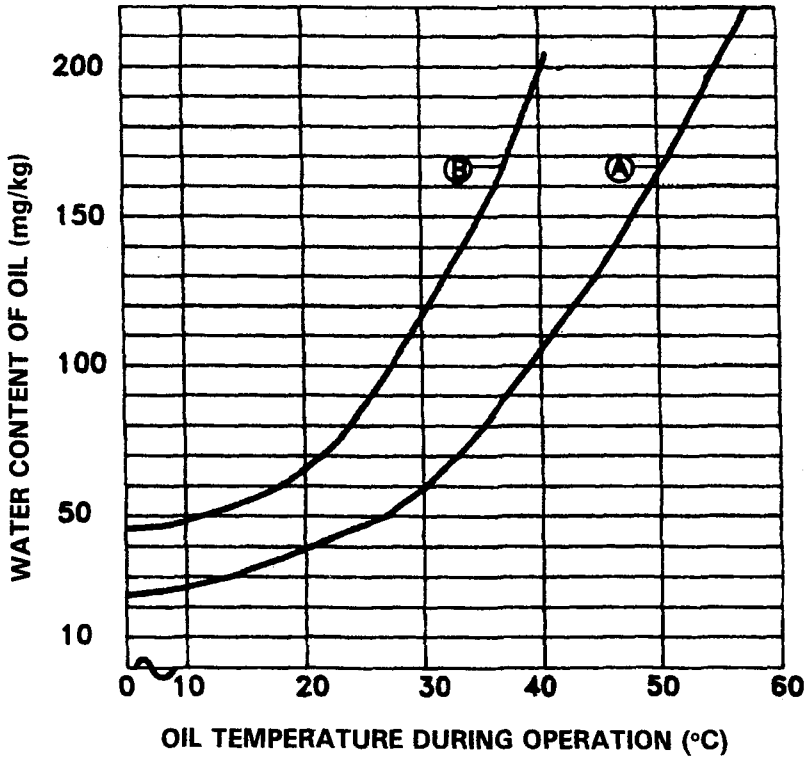
In order to take account of different user requirements, equipment has been placed in various categories as follows :

Category O :

Power transformers with a system highest voltage above 420 kV.

Category A:

Power transformers with a system voltage above 170 kV and up to 420 kV. Also power transformers of any



Curve 'A' : Saturation Content of Water in Unused Oil
Curve 'B' : Saturation Content of Water in Used Oil

FIG. 1 EFFECT OF TEMPERATURE ON SOLUBILITY OF WATER CONTENT IN INSULATING OILS

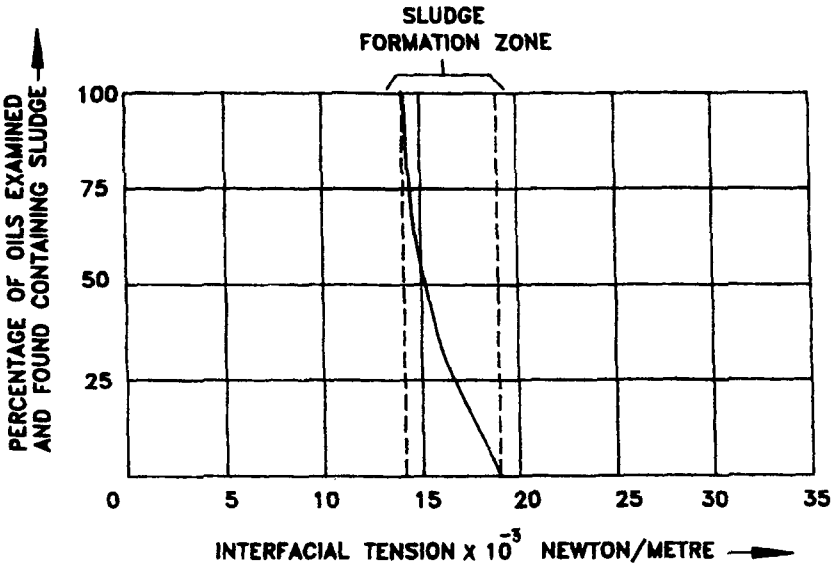


FIG. 2 PRESENCE OF SLUDGE IN OILS RELATED TO INTERFACIAL TENSION VALUES AT AN AMBIENT TEMPERATURE OF 27°C

rated voltage where continuity of supply is vital and similar equipment for special applications operating under onerous conditions.

Category B:

Power transformers with a system highest voltage above 72.5 kV and up to 170 kV (other than those in category A).

Category C:

Power transformers with a system highest voltage up to 72.5 kV (other than those in category A), oil filled switches, a.c. metal enclosed switch gear and control gear.

Category D:

Instrument transformers with a system highest voltage above 170 kV.

Category E:

Instrument transformers with highest voltage up to 170 kV.

Category F:

Diverter tanks of on-load tap changers.

Category G:

Oil filled circuit breakers.

NOTES

1 Separated selector tanks of on-load tap changers belong to the same category as the associated transformer.

2 Oil impregnated paper bushings and other hermetically sealed equipment may be placed in category D if a routine monitoring programme is desired. Any tests considered necessary would be specialized in nature and require separate consideration. Refer to manufacturerís instructions.

3 Small transformers up to 1 MVA and 36 kV are not included in this classification. Routine monitoring programme is considered uneconomical for this type of equipment. Where a monitoring programme is required for these transformers, the guidelines given for Category C should be adequate.

9 EVALUATION OF NEW INSULATING OIL IN NEW EQUIPMENT

A substantial proportion of mineral oil is supplied to the final user already filled into electrical apparatus and it is commonly recognized that certain properties which reflect the presence of dissolved contaminants may differ from those accepted for unused oil, that is oil which has not been in contact with insulation and construction materials. The extent of changes may vary with type of equipment due to the different types material and ratios of liquid-to-solid insulation, and should be kept within acceptable limits through proper oil processing techniques and careful selection of materials.

In addition, other oil properties, such as breakdown voltage and water content should be adequate to the category and functions of the equipment.

The characteristics of oil in new equipment are integral parts of the equipment design for which the manufacturer has final responsibility. However, user may require these characteristics to be definitely better than minimum standards for reliable service. The characteristics listed in Table 1 are representative of good operating practice and are recommended as basis for agreement.

10 EVALUATION OF USED OIL

10.1 Frequency of Examination of Oils in Service

It is impossible to lay down general rule for the frequency of examination of oils in service which will be applicable to all possible situations that might be encountered.

The optimum interval will depend on the type, function, power, construction and service conditions of the equipment. A compromise shall often be found between economic factors and reliability requirements.

By way of a guide, a suggested frequency of tests suitable for different types of equipment is given in Table 2. However, oil preservation systems designed to control exposure of oil to atmosphere may permit less frequent testing.

Generally, check measurements can be carried out on the basis of the following criteria, which apply particularly to transformer oils :

- Check characteristics periodically, at intervals as suggested in Table 2, unless otherwise defined by the manufacturer.
- If possible, check at more frequent intervals characteristics that are determinable at site.
- Heavily loaded transformers may require more frequent testing.
- Increase frequency of examination where any of the significant properties approaches the limit recommended for continued service.

10.2 Testing Procedures

The venue of testing and the number and types of tests that can be carried out on a given sample of oil may vary depending on local circumstances and economic consideration.

Oil in service will vary widely in the extent of degradation and the degree of contamination.

In general no one test can be used as the sole criterion of the condition of the oil sample.

Evaluation of condition should be preferably based on the composite evaluation of significant characteristics determined in properly equipped laboratories. However, some users find it advantageous to make field screening test.

10.2.1 *Field Screening Test*

Field tests are usually limited to visual inspection (colour and appearance), breakdown voltage and, with some approximation, neutralization value. These tests can sometimes be used classification of service-aged oils in accordance with **10.3**, though, more often, field tests are made to identify oil samples requiring laboratory evaluation.

Experience has shown that breakdown voltage tests made on site often produce results that are more reliable than those obtained in the laboratory following long-distance transportation and prolonged storage of oil samples. Portable dielectric test sets have been available for a long time and have proved quite satisfactory.

10.2.2 *Laboratory Tests*

The complete examination scheme includes all the tests listed in **7**. Along with the evaluation of the general condition of the oil, consideration of all results together often enables the cause of degradation or the source of a contaminant to be recognized, so that the appropriate action can be taken to ensure the reliable operation of the equipment.

Quite often, laboratory testing merely seeks to establish the continued serviceability of the oil. The following tests are believed to suffice to meet this objective:

- Interfacial tension
- Breakdown voltage
- Flash point
- Dielectric dissipation factor
- Specific resistance
- Neutralization value
- Water content
- Sediments and sludge

NOTES

1 In order to assess the continued serviceability of the oil, water content tests, while desirable in all cases, becomes particularly necessary when the breakdown voltage approaches the rejection level.

2 Regarding oil in switchgear, it may be sufficient to check breakdown voltage either periodically or after a given number of operations.

10.3 Classification of Oils in Service

It is virtually impossible to set hard and fast rules for the evaluation of oil in service or even to recommend test limits for all possible applications of insulating oil in service.

According to current industrial experience, oils in service can be placed in the following classification based on the evaluation of significant properties and/or their ability to be restored to the characteristics desired.

Group 1 :

This group contains oils that are in satisfactory condition for continued use. Oils with property values laid in Table 2, for the appropriate category of equipment, are considered to belong this group. It should be understood that these limits are indicative only. With the exception of breakdown voltage, one or more properties outside the limits indicated do not require immediate action although, in the long run, the condition can result in accelerated deterioration and shortened equipment life. In interpreting the data, account has to be taken of various factors such as : conditions of use, age of equipment and general progression of oil characteristics.

Group 2 :

This group contains oils that require reconditioning for further service. This condition will be usually indicated by higher water content and lower breakdown voltage while all other criteria are still satisfactory. (Sometimes dielectric dissipation factor and specific resistance may not be satisfactory under this condition).

The oil may have a cloudy or dirty appearance. The appropriate treatment consists of removal of moisture and insoluble matter by mechanical means. Treatment must be adequate to result in values of water content and breakdown voltage to those given in Table 1 where applicable. However, it should be appreciated that excessive water in oil be indicative of an undesirable condition of the solid insulation which also requires correction.

Group 3 :

This group contains oils in poor condition that it can restore satisfactory properties only after reclaiming. This condition will usually be indicated by evidence of soluble or precipitable sludge and values of neutralization value and/or dielectric dissipation factor in excess of those indicated in Table 2. Insulating oils in this group should either be reclaimed or replaced depending on economic considerations.

Group 4 :

This group contains oils, in such poor state that it is technically advisable to dispose of them. Usually many properties will be unsatisfactory.

10.4 Corrective Action

The action to be taken is detailed in Table 2. The following recommendations should also be noted :

a) Where a test result is outside the recommended limits, compare it with previous results and, if appropriate, obtain a fresh sample for confirmation before any other action is suggested.

b) As a general rule, several characteristics will have to be unfavourable in order to justify its use However, if the breakdown voltage is below the limits given, irrespective of the values of the other characteristics, action as detailed in Table 2 is essential.

c) If rapid deterioration or acceleration in the process of deterioration is observed, institute more frequent tests and inform the manufacturer of the equipment.

11 MUTUAL COMPATIBILITY OF MINERAL INSULATING OILS

Topping-up should preferably be with unused insulating oil conforming to IS 335 or IS 12463. Under no circumstances should the properties of the oil added be worse than those of the in-tank oil.

Unused oils complying with IS 335, of the same class and containing no additives, are onsidered compatible with each other and can be mixed, in any proportion. Field experience indicates that no problems are normally encountered when fresh oil is added in small percentage, say less than 5 percent, to Group 1 used oils, though larger additions to heavily aged oil may cause sludge to precipitate.

Experience is very limited regarding the use of oil containing pour point depressants as make up fluid for naturally low pour point oils. However, extensive laboratory investigations suggest that no significant deterioration of low temperature behaviour is likely to occur.

However, when substantial quantities of service-aged oils or of fresh and used oils are to be mixed, it is good practice to perform laboratory tests to determine if the properties of the blended oil are still satisfactory. Compatibility tests are particularly required in the case of oils containing additives.

The main characteristics, including oxidation stability and measurement of dissipation factor after ageing, are determined on a mixture of the component oils. The ratio of this mixture should be the same as that effectively chosen in practice or, if this is not known, a 50-50 ratio is used.

The results obtained on the composite should not be less favourable than those of the worst individual oil.

Reference to the oil supplier or the equipment supplier is recommended if any doubts concerning compatibility arise.

12 HANDLING AND STORAGE

To ensure satisfactory service, the utmost care in handling oil is essential. Drums used transport and storage should be kept under cover. In practice owing to contamination in the containers, difficulty may be experienced in maintaining the purity of the oil when it is transferred from one vessel to another, and once a vessel or drum has been filled with moist oil it is extremely difficult to clean. Drums should be clearly marked to indicate whether they are for clean or for dirty oil and should be reserved for the type indicated.

When oil is stored in drums, these should be placed in such a position that there is a head of oil on the stopper or plug to prevent the entry of water during storage. However, it is recognized that storage of oil in drums is not always satisfactory, particularly when oil is stored in drums which have been bent or otherwise damaged in transit or storage, and the transfer of oil from such containers to electrical equipment should normally be through a suitable treatment plant.

In substations with fixed oil-handling equipment the pipe work from the clean oil tanks to the electrical apparatus should be kept clean and free from moisture. Where portable oil handling equipment is used, flexible pipe work and hand pumps should be carefully inspected to ensure that they are free from dirt and water, and should be flushed with clean oil before use. If the clean oil is from drums, it should have been recently tested, and the filling orifices of the drums should be clean. Hoses used for clean oil and dirty oil should be clearly marked and provided with plugs for sealing the ends when not in use.

For any specific problems, reference may be made to equipment manufacturer's instructions.

13 TREATMENT

13.1 Reconditioning

13.1.1 *General Considerations*

This is a process which eliminates, by physical means only, solid particles from the oil and decreases water content to acceptable level.

The physical means that are used for removing water and solids from oil include several types of filtration, centrifuging and vacuum dehydration techniques.

If vacuum treatment is not employed it is advisable to limit the temperature to 60°C. Vacuum is employed a higher temperature may be advantageous. If vacuum is employed, the initial boiling-point of that oil should not be exceeded, to avoid undue loss of lighter fractions. If this information is not available, it is recommended that the oil should not be vacuum treated at temperature over 70°C (*see* Note).

If it is desired to reduce sludge or free water, cold treatment may be appropriate.

Filters deal efficiently with solid impurities, but are generally capable of removing small quantities of water such as may be found in oil from equipment housed in buildings. Where relatively large quantities of water are present, most of it can, and shall, be drained away before filtration of the oil.

Centrifugal separators are, in general, satisfactory for removing free water from oil and can in any case deal also with any finely divided solid impurities.

If oil is purified hot, its viscosity is reduced and the throughput with certain types of purifiers is greater. On the other hand, sludge and free water are more soluble in hot oil than in cold, therefore, more effectively removed by cold treatment. Dissolved and suspended water is effectively removed by hot vacuum treatment.

If the oil contains solid matter, it is advisable to pass through some kind of filter processing under vacuum.

NOTE — Processing inhibited oil under vacuum and at elevated temperatures may cause partial loss of oxidation inhibitors; the common inhibitors, 2,6-di-tertiary- butyl-paracresol and 2,6-di-teritiary-butyl-phenol, are more volatile than mineral insulating oil. The selectivity for removal of water and air in preference to loss of inhibitor and oil is improved by use of a low processing temperature.

Conditions that have been found satisfactory for most inhibited /uninhibited mineral oil processing are :

Temperature	*Pressure*
°C	Pa
40	5
50	10
60	20
70	40
80	100

13.1.2 *Reconditioning Equipment*

13.1.2.1 *Filters*

These are generally based on the principle of forcing oil under pressure through absorbing material such as paper or other filter media. Filters of this type are preferentially used in removing contaminants in suspension (The filter medium should be capable of removing particles larger than a nominal 10 µm). These devices do not de-gas the oil.

The water-removing ability of a filter is dependent upon the dryness and quantity of the filter medium. When filtering oil containing water, the water content of the filter medium rapidly comes into equilibrium with water content of the oil. A continuous indication of the water content of the out going oil is useful to monitor the efficiency of the process.

Care should be taken that paper filters are of the correct grade to ensure that no fibres are shed by them.

13.1.2.2 *Centrifuges*

In general, a centrifuge can handle a much greater concentration of contaminants than can a conventional filter but cannot remove some of the solid contaminants as completely as a filter.

Consequently, the centrifuge is generally found in use for rough bulk cleaning where large amounts of contaminated oil are to be handled.

Frequently the output of the centrifuge is put through a filter for the final clean-up.

13.1.2.3 *Vacuum dehydrators*

The vacuum dehydrator is an efficient means of reducing the gas and water content of mineral insulating oil to very low levels.

There are two types vacuum dehydrators; both function at elevated temperature. In one method the treatment is accomplished by spraying the oil into a vacuum chamber; in the other the oil flows in thin layers over a series of baffles inside a vacuum chamber. In both types the objective is to expose maximum surface and minimum thickness of oil to the vacuum.

In addition to removing water, vacuum dehydration will degas the oil and remove the more volatile acids.

13.1.3 *Application to Electrical Equipment*

13.1.3.1 *Direct purification*

The oil is passed through a purifier and then stored in suitable clean containers. When the electrical equipment is to be refilled the oil is passed through the

purifier again, and then directly into the equipment. This method should be used for switchgear. It is suitable, too, for small transformers but care is needed to ensure that the core, the windings, the interior of the tank and other oil-containing compartments are thoroughly cleaned. The oil-containing compartments of all equipment should also be well cleaned, by means of oil from the purifier.

13.1.3.2 *Purification by circulation*

The oil is circulated through the purifier, being taken from the bottom of the tank of the electrical equipment and re-delivered to the top. The return delivery should be made smoothly and horizontally at or near the top oil level to avoid, as far as possible, mixing cleaned oil with oil which has not yet passed through the purifier. The circulation method is particularly useful for removing suspended contaminants, but all adhering contaminants will not necessarily be removed.

Experience has shown that it is generally necessary to pass the total volume of oil through the purifier not less than three times, and equipment of appropriate capacity should be chosen with this in mind. The final number of cycles will depend on the degree of contamination, and it is essential that the process be continued until a sample taken from the bottom of the electrical equipment, after the oil has been allowed to settle for a few hours, passes the breakdown voltage test.

The circulation should be performed with the electrical equipment disconnected from the power source, and this is essential when using a purifier which aerates the oil. In all cases, and especially when aeration has occurred, the oil should be allowed to stand for some time in accordance with the manufacturer's instructions before the equipment is re-energized.

Another technique is sometimes used for transformers, in which oil is continuously circulated during normal service through an adsorbent, such as molecular sieve, thus keeping both oil and windings dry and removing many oil oxidation products: this is a specialized method not further considered in this guide.

13.2 Reclaiming

This is a process which eliminates soluble and insoluble contaminants from the oil by chemical and adsorption means in addition to mechanical means, in order to restore properties as close as possible to the original values.

Reclaiming is a process often performed by an oil refiner but, since in some countries reclaiming is performed by the user on site, some guidance is given in Annex B.

13.3 Re-refining

This is treatment that makes use of primary refining processes that may include distillation and acid, caustic, solvent, clay or hydrogen treatment and other physical and chemical means to produce an oil with oil characteristics complying with IS 335.

Re-refining should be performed by an oil refiner and such a process is outside the scope of this guide.

14 REPLACEMENT OF OIL

14.1 Replacement of Oil in Transformers Rated Below 72.5 kV and in Switchgear and Associated Equipment

A small extra quantity of oil is needed to rinse the interior of the tank and the immersed parts. It is essential that the tank and the surfaces of conductors and insulators be kept free from fibres. Such fibres are readily introduced by the use of unsatisfactory cleaning materials during plant maintenance; in practice the only efficient and permissible materials are plastic wipers and chamois leathers. It is also essential that the tank and other surfaces be kept free from moisture.

There should be as little aeration as possible during the filling of tanks and, as far as possible, the end of the delivery pipe should be held below the surface of the oil in order to avoid splashing: alternatively, the tanks should be filled from the bottom. There should be a standing period of not less than 12 h to allow de-aeration before commissioning transformers (one hour may be adequate for switchgear).

14.2 Replacement of All in Transformers Rated 72.5 kV and Above

Reference should be made to the equipment manufacturer.

15 HYGIENE AND ENVIRONMENTAL PRECAUTIONS

The oils with which this code of practice is concerned are mineral hydrocarbon (petroleum) oils.

Although no special risks are involved in the handling and use of mineral insulating oils, attention is drawn to the need for personal hygiene (washing of skin and clothing which has come into contact with oil) by those working with these products.

When mineral oil has to be disposed off, certain precautions are necessary to avoid risk of environmental pollution, and legal requirements may apply. Normally, if the precautions and regulations applicable to the handling and disposal of industrial and other lubricants (for example automobile crank-case drainings) are applied to mineral insulating oils, no problems should arise.

Table 1 Recommended Limits of Unused Mineral Oil Filled in New Power Transformer

(*Clauses* 6.1 *and* 10.3)

Property	Highest Voltage of Equipment (kV)		
	<72.5	72.5 to 170	>170
Appearance	Clear, free form sediment and suspended matter		
Density at 29.5°C (g/cm³), *Max*	0.89	0.89	0.89
Viscosity at 27°C (cSt), *Max*	27	27	27
Flash point, (°C), *Min*	140	140	140
Pour point, (°C), *Max*	−6	−6	−6
Neutralization value (mg KOH/g), *Max*	0.03	0.03	0.03
Water content (ppm), (*see* Note 1), *Max*	20	15	10
Interfacial tension (mN/m), *Min*	35	35	35
Dielectric dissipation factor at 90°C and 40 Hz to 60 Hz (*see* Note 2), *Max*	0.015	0.015	0.010
Resistivity (90°C) × 10^{12} (ohm-cm), *Min*	6	6	6
Breakdown voltage (kV), *Min*	40	50	60
Oxidation stability of uninhibited oil			
i) Neutralization value (mg KOH/g), *Max*	0.4	0.4	0.4
ii) Sludge (percent by mass), *Max*	0.1	0.1	0.1
Oxidation stability for inhibited oil			
Induction period (hours)	Similar values as before filling		

NOTES

1 For use in transformers under 72.5 kV class; the maximum water content should be agreed between supplier and user depending upon local circumstance.

2 Higher dielectric dissipation factor values may indicate excessive contamination or the misapplication of solid materials used in manufacture and should be investigated.

Table 2 Application and Interpretation of Tests

(*Clauses* 7.3, 7.7, 10.1, 10.3 *and* 10.4)

Property (Unit) (1)	Test Venue F = field L = laboratory (2)	Category of Equipment (3)	Frequency of Tests (4)	Recommended Action Limits (5)	Action (6)	Notes (7)
Appearance	L or F	O,A,B,C,D,E	In conjunction with other quantitative tests	Clear, without visible contamination	As dictated by other tests	
Breakdown voltage	L or F	O,A,B,C,D, E,F,G	O,A,B–After filling or refilling prior to energizing–then yearly C.D.E– After filling or refilling prior to energizing– then yearly F–After filling or refilling prior to energizing– then every four years or 70 000 operations whichever the lower or manufacturer's instructions. G–Refer to manufacturer's specifications (*see* **9.2.2**, Note 2)	O,A,D: >50 kV B, E : >40 kV C : >30 kV G : >20 kV F a) Tap changer of neutral end tap changer O,A,B,C, transformer 25 kV b) Single phase or connected tap c) Changer O,A,B, transformers:>40 kV d) C transformers e) > 30 kV	Recondition oil or alternatively, if more economical or other tests dictate replace oil	Refer to 10.3 and 10.4

Table 2 *(Concluded)*

Property (Unit) (1)	Test Venue F = field L = laboratory (2)	Category of Equipment (3)	Frequency of Tests (4)	Recommended Action Limits (5)	Action (6)	Notes (7)
Water content	L	O,A,B,C,D,E	O,A– After filling or refilling prior to energizing–then after three and 12 months, subsequently in conjunction with dissolved gas analysis B,D,E–After filling or refilling prior to energizing–then after 12 months, subsequently every one year or in conjunction with dissolved gas analysis. Not a routine test: only when break down voltage approaches the rejection level	O,A,D: ≤ 20 PPM B : ≤ 40 PPM E : ≤ 30 PPM C : ≤ No free moisture at room temperature	Check source of water and consider reconditioning	1. The given values are applicable only where acidity does not exceed 0.1 mg KOHg 2. For variation of water content of (IS 335) transformer oil with oil temperature and acid value. *See* Fig. 1
Neutralization value	L	O,A,B,C,D, E,F,G	Yearly	O,A,B,C,D,E, *Max* 0.3 mg KOH/g	Replace or reclaim oil	Perform tests more frequently when neutralization value exceeds 0.2 mg KOH/g
Sediment and sludge	L	O,A,B,C,D,E	Routine test–yearly	No sediment or precipitable sludge should be detected, results below 0.02 percent by mass may be neglected	Where sediment is detected, recondition oil. Alternatively if more economic, or other tests dictate, replace oil. Where precipitable sludge is detected consider replacing or reclaiming existing oil	
Resistivity	L	O,A,B,C,D,E C,E–Routine test–yearly	After filling or refilling prior to energizing–then yearly	At 20°C, *Min* 1×10^{12} ohm-cm 0.1×10^{12} ohm-cm At 90°C, *Min* 1 Gohm- m	Investigate	
Dielectric dissipation factor at 90°C and 40 to 60 Hz	L	O,A,B,C,D,E C,E–Routine test–yearly	After filling or refilling prior to energizing–then yearly	O,A,D, *Max* 0.2 B,C, *Max* 1.0 E, *Max* 0.3	Investigate	Comply with manufacturers instructions if other frequency and limit are recommended
Interfacial tension	L	O,A,B,C,D,E	O,A,B,C,D,E– After filling or refilling prior to energizing– then yearly	O,A,B,C,D,E *Min.*: 15 mN/m	Investigate	
Gas content	L	O,A,B,C,D,E	–	–	–	Comply with manufacturer instructions
Flash point	L	O,A,B,C,D,E	Yearly	O,A,B,C,D,E, *Max* decrease 15°c	Replace oil, equipment may require inspection	

ANNEX A

(*Clause* 4.3)

DETERMINATION OF SEDIMENT AND SLUDGE

This method covers the determination of sediment and of precipitable sludge in used insulating oils.

NOTES — For the purpose of this guide, sediment is any substance which is insoluble after dilution of the oil with *n*-heptane and which is insoluble in solvent mixture mentioned in **A-1**.

For the purpose of this guide, perceptible sludge is oil deterioration products or contaminants, or both, which are insoluble after dilution of the oil with *n*-heptane under prescribed conditions but which are soluble in the solvent mixture mentioned in **A-1**.

A-1 PROCEDURE

Thoroughly agitate the sample of used oil in the original container until any sediment is homogeneously suspended in the oil.

Weigh approximately 10 g of oil to the nearest 0.1 g into a stoppered conical flask and introduce a volume of *n*-heptane corresponding to 10 ml for each gram of oil taken.

Thoroughly mix the sample and solvent and allow the mixture to stand in the glass flask, in the dark, for 18 to 24 h .

If a solid deposit is observable filter the solution through a tared sintered glass crucible of Grade P10 porosity with the assistance of vacuum; rinse the flask with fresh *n*-heptane to ensure complete transfer of the precipitate to the crucible. Wash the crucible and precipitate with *n*-heptane until free from oil.

Allow any *n*-heptane to evaporate and then dry the crucible in an oven at 100 to 110°C for 1 h. Cool the crucible in a desiccator and then weigh it. Calculate the increase in mass of the crucible as a percentage of the mass of oil taken. Denote this value, representing the total of insoluble material such as sediment and perceptible sludge, as A.

Dissolve the sludge in the crucible by treatment with the minimum quantity of a mixture of equal parts of toluene, acetone and alcohol (either ethanol or *iso*-propanol may be used, 95 percent being satisfactory in either case), at approximately 50°C, until no more will dissolve, and collect the washings in an accurately tared flask. Distill off the solvent; visual examination of the flask content at this stage will show whether any precipitable sludge was present in the oil.

If a quantitative value is required dry the flask in an oven at 100 to 110°C for 1 h. Cool the flask in a desiccator and then weigh it. Calculate the mass of residue in the flask as a percentage of the mass of oil taken. Denote this value as B.

The difference A-B, if any, will represent sediment in the oil.

ANNEX B

(*Clause* 13.2)

GENERAL GUIDANCE FOR OIL RECLAIMING

B-1 GENERAL CONSIDERATIONS

This is a process which eliminates, by chemical and adsorbent means, the acidic and colloidal contaminants and products of oil deterioration from the oil to obtain an oil with many characteristics similar to those of a new product.

B-2 ADSORBENT PROCESS

Fuller's earth, a naturally occurring clay with a fairly high surface activity, is the material most frequently used for reclaiming oils and is the least expensive. It may be used in its original state, except for drying, crushing, and sizing, or it may be calcined, water-washed, steam-treated, or acid-treated. The processed clays are more active but also more expensive. Activated alumina is an adsorbent for impurities found in oil. It is mechanically more stable, and may be reactivated.

In general, reclaiming is done in accordance with one of two methods:

a) Percolation through coarse clay using either gravity or pressure to force the oil through the clay, or

b) Contact at an elevated temperature with finely divided clay.

B-2.1 Percolation by Pressure

Pressure percolation is similar to gravity percolation in general principle except that the oil is forced through the clay by a pump. Pressure percolators are commercially available and vary in mechanical detail, but all have a chamber to hold a container such as a bag or cartridge filled with clay. The chamber is so designed that oil is admitted around the outside of the clay pack and must pass through a certain amount of clay before leaving the chamber.

These machines are capable of processing large volumes of oil in a relatively short time. They accomplish this by forcing the oil through a comparatively shallow depth of clay at a pressure of about 400 kN/m^2 resulting in a short contact time. Since the amount of clay is relatively small with respect to the amount of oil, frequent changes of clay are required.

Specially treated clays are sometimes used for increased efficiency. The output is a graded one for the same reasons that apply to the gravity percolation output (*see* **B-2.2**), and the same control tests are used periodically.

An advantage of such machines is that they may be brought to the job and used directly on the apparatus whose oil is to be reclaimed. They have been used on energized equipment to a limited extent, and such use will increase when proper safety procedures have been developed.

B-2.2 Percolation by Gravity

Gravity percolation makes use of gravity or the hydrostatic head of a column of oil to force the oil through a column of clay. A typical gravity-percolation system, shown schematically in Fig. B1, consists of three tanks on different levels. The upper tank is used as a dirty-oil reservoir, the middle tank as the filter containing Fuller's earth (24 mesh/cm to 32 mesh/cm), and the lower tank as a blending chamber for the filtered oil.

The middle tank is equipped with a strainer type bottom covered by canvas or filter cloth supporting a 2 m bed of clay. A float valve controls the flow of oil from the dirty-oil storage tank above so that a constant head of about 5 m to the filter plate is provided. Once the process is started it continues in operation with very little attention other than periodic sampling. Tests for interfacial tension or acidity are used regularly to control the process.

The output of gravity percolation is a graded one starting with water-white over treated oil and ending with oil in approximately the same condition as before treatment. To obtain a uniform product, blending is necessary in the third tank in the series. Some convenient mechanical means of agitating the oil in this tank is essential.

It has been proved that the undesirable characteristics of the over treated oil that first comes through the earth are offset in the blending process.

By this method, the oil can be treated to any desired degree. The flow rate of such a method is slow, being about 400 litres per hour per square meter of filter bed area for an installation such as the one described above. This slow flow rate results in a relatively long contact time which makes for efficient use of the clay.

B-2.3 Contact Process

The contact process for reclaiming oil makes use of 77 mesh/cm to 96 mesh/cm Fuller's earth and relatively high operating temperatures usually 60 to 70°C.

This process makes the most efficient use of the earth and produces a uniform product. The degree of reclaiming depends on the amount of earth used which is determined by an analysis of the deteriorated oil.

In typical commercial apparatus, oil is introduced into a heated mixing chamber as a measured amount of earth is fed in through a hopper. The mixture is stirred as heat is applied and the process continues until the desired temperature is reached. This operation requires about half an hour. The oil is then dropped into a tank before it is pumped through a filter especially built to accommodate the earth. Much of the oil ordinarily retained in the earth is extracted by the application of compressed air to the filter. A semi-automatic type of apparatus is on the market which recharges itself and operates until the filter becomes filled with clay.

This type of apparatus does not lend itself to the treatment of oil in transformers under load as operating on the batch principle, it withdraws oil from the apparatus and does not return the oil for 45 min. Also it should not be used to process oil containing 2,6-ditertiary-butyl-paracresol if it is desired to retain the inhibitor in the oil, as this additive when catalyzed by clay, begins to decompose at 100°C.

B-2.4 Choice of Methods

The choice of reclamation methods that will prove the most practical and economical for a given system depends upon the geographical characteristics of the power system, the existing facilities available for application of such work, and the facts concerning the various types of reclaiming equipment and methods previously described.

For example, on a compact system with large quantities

of damaged oil or on a system where oil reconditioning has been done in the past at a central location, the gravity-percolation method of reclaiming has many advantages in requiring a minimum amount of new equipment, attention and labour.

On a system where the oils requiring attention are widely scattered in location, service outages are difficult to obtain, and spare equipment is at a premium, some type of portable pressure percolator may be preferred for reclaiming in the field by recirculating the oil in the equipment. The possibility of recirculation with the equipment alive may be considered in such cases, with due regard to safety measures.

Irrespective of the type of clay used, two adjuncts should also be incorporated with the treater:

a) The oil should be put through some device for removing free water before it contacts clay in order to prevent water from wetting the clay.

b) Water will cause at least partial and possibly complete blocking of the clay, thus making it necessary to discard that batch of clay. The oil coming out of the clay treater should be put through some kind of foolproof completely automatic dehydrator equipped with positive means and safeguards for preventing any water from being present in the finished product. This is particularly true when recirculating the oil in a transformer and absolutely essential if the reclai-ming is done when the transformer is energized.

B-3 OTHER RECLAIMING METHODS

B-3.1 Reclaiming by Trisodium Phosphate

The trisodium phosphate/activated Fuller's earth method (*see* Fig. B2) consists in agitating a mixture of oil and trisodium phosphate solution maintained at 80°C for 1 h and then allowing the mixture to separate. Most of the spent phosphate solution is drained from the tank, the balance is washed from the oil with a water spray, and the oil is then decanted through a centrifuge and a heater to another tank, where 77 mesh/cm activated Fuller's earth is added and the mixture agitated. This agitation with clay is allowed to settle out overnight. The oil is again washed with hot water, decanted through a centrifuge, and then dehydrated by passage through a dehydrator or filter.

The process is described as economical and capable of yielding a uniform product by varying the amounts of reclaiming agents as determined by the analysis of the deteriorated oil. The method may be more economical than reclaiming with clay alone for large quantities of badly deteriorated oil.

B-3.2 Reclaiming by Activated Carbon Sodium Silicate

This method is capable of variation to meet the requirements of different grades of service-aged oil under favourable conditions, this process is a continuous one. The method consists of the following basic treatments:

- An activated carbon treatment in which 2 percent by mass of activated carbon is used.
- A treatment involving 30 percent by volume of a 2 percent by mass sodium silicate solution.
- A clay treatment in which 2 percent by mass of activated Fuller's earth is used.

The oil is heated to 85°C and is maintained at this temperature until the final filtering operation is reached.

The first step consists of a treatment by agitation with activated carbon in cases where the acid rating of the oil is 0.5 mg KOH/g or over. This step is necessary to prevent subsequent emulsification of acid oil with the sodium silicate solution where the acid value is low, this process may be omitted.

The oil is next decanted through a filter to a second tank where it is paddle-stirred with the sodium silicate solution. It is then run through a centrifuge and the silicate solution discarded.

The oil is now run into a reaction tank with clay added through a hopper. The resulting mixture is agitated, allowed to settle and then cleaned by passing through a second centrifuge. The oil is then run into a receiving tank and allowed to cool. Finally it is filtered and run into storage tanks.

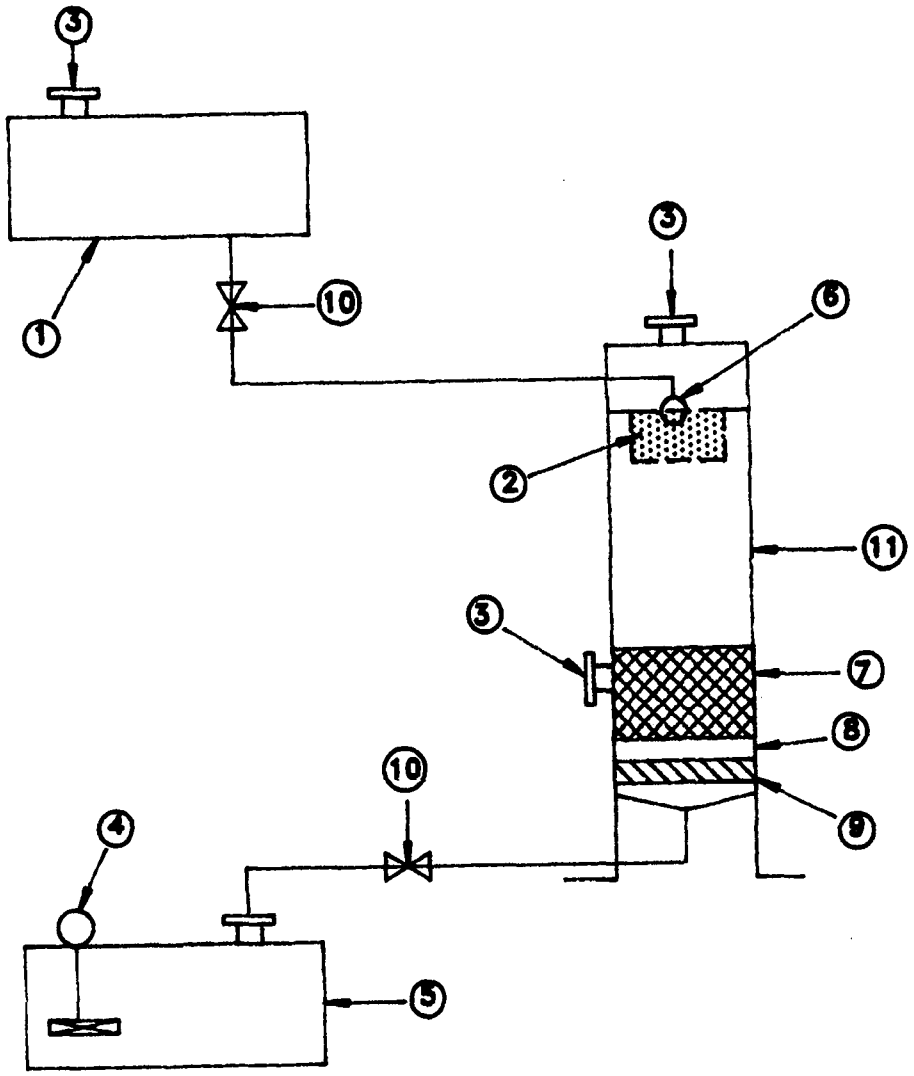
When used without activated carbon, the process is continuous with an output of 570 litres per hour. When the activated-carbon treatment is necessary the process becomes a batch process with an output of 1 900 litres per day. As both clay and activated-carbon retain about 60 percent of their weight of oil, the process should be run with a minimum of these materials. Oil in fair condition shows satisfactory characteristics when treated with activated carbon and clay; 1 percent of the oil volume of either material is normally sufficient.

B-3.3 Percolation by Thermo-Siphon Bypass on In-Service Transformer

Good oil which is deteriorating slowly may be held in safe operating condition by applying a special bypass earth filter to the individual transformer. The oil is forced through the filter by the action of the heat generated by the apparatus and the heat dissipated by the filter. As the actuating force is small, the filters

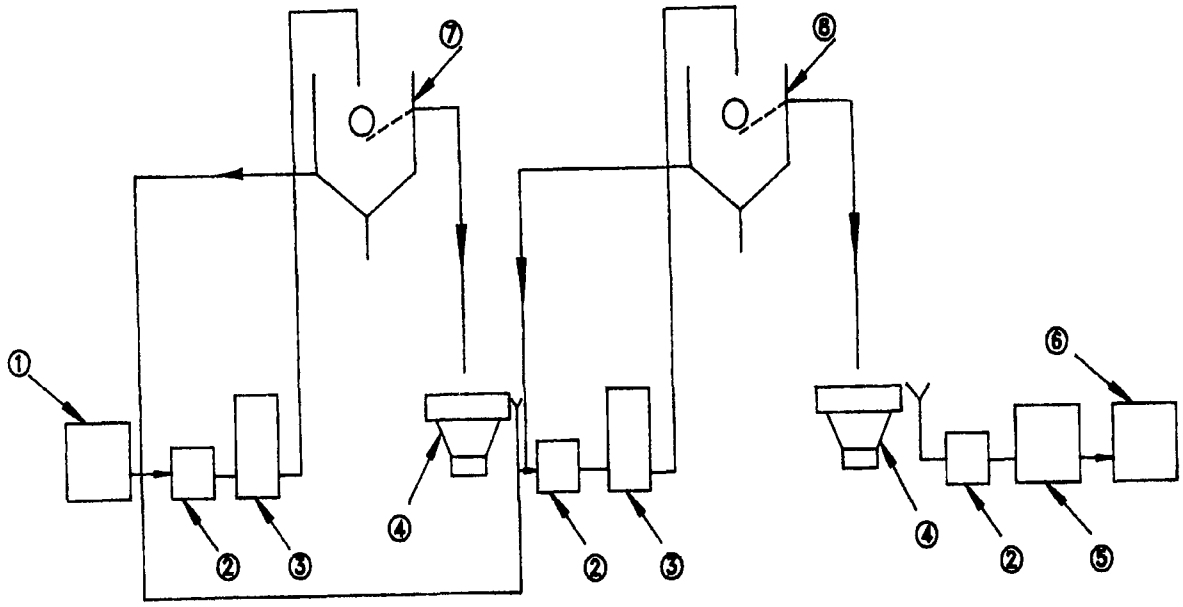
must be loosely packed coarse activated alumina or 0.66 mesh/cm Fuller's earth is employed, and the apparatus operates without attention during the active life of the adsorbent.

The bypass method of maintaining oil in usable condition has certain definite limitations. On standby transformers or on circuit breakers it is inoperative as the heat necessary to its operation is not constantly available. The operation of bypass filters might also be termed very 'gentle' as little force is available to drive the oil through even a coarse filter bed. There is also the possibility that fine particles of the earth may leak through the system into the processed oil.



1. Used oil storage tank
2. Oil
3. Manhole
4. Stirrer
5. Clean oil mixing and storage tank
6. Float valve
7. Clay bed
8. Filter cloth
9. Support grid
10. Valve
11. Fuller's earth filter

FIG. B1 SCHEMATIC DIAGRAM OF GRAVITY—PERCOLATION RECLAIMING APPARATUS



1. Used oil storage tank
2. Pump
3. Heater
4. Centrifuge
5. Filterpress
6. Clean oil storage tank
7. Process oil tank No. 1
8. Process oil tank No. 2

FIG. B2 SCHEMATIC DIAGRAM OF TRISODIUM PHOSPHATE/FULLER'S RECLAIMING APPARATUS

ANNEX C

(*Clause* 7.4)

PORTABLE KIT TEST METHOD

C-0 This is a simple, rapid and yet sensitive method for determining the total acidity of insulating oils.

C-1 PRINCIPLE

C-1.1 The total acidity of oil is expressed as neutralization number which is defined in as the number of milligrams of potassium hydroxide required to neutralize completely acids present in one gram of the oil.

C-1.2 It is well known that all acids produced by oxidation of mineral oils are soluble in alcohol and can be extracted from the oil by it.

C-1.3 If these extracted acids are treated with a fixed quantity of suitable alkali, the resulting mixture would be acidic, neutral or alkaline depending upon the amount of acids present.

For example, if the total acidity of an oil is 0.5 and to the extracted acids some alkali is added which just neutralizes the acids, the resulting solution would be neutral or have *p*H value of 7.

If the same amount of alkali is added to an oil of total acidity greater than 0.5 the resulting solution would be acidic or have a *p*H value between 0 and 6 depending on the amount of acid left un-neutralized.

Similarly, if the total acidity is less than 0.5 the resulting solution would be alkaline or have a *p*H value between 8 and 14, depending on the amount of alkali left behind.

C-1.4 This change in *p*H values may be sensitively determined by use of standard indicators.

Thus, if the quantity of alkali is so adjusted that it neutralizes 0.5 total acidity exactly oils having a total acidity of less than 0.5 would be in the alkaline range and those with total acidity above 0.5 in the acid range.

C-1.5 It has been found experimentally that sodium carbonate (anhydrous) is the most suitable alkali, as its solutions do not change concentration rapidly in contact with atmosphere, and universal indicator is a good indicator, as this gives different colours at different *p*H values which may be easily determined visually.

C-1.6 Thus, with use of appropriate reagents the total acidity can be determined colorimetrically.

C-2 PROCEDURE

A 1.1 ml of portion of the insulating oil (approximately 1 g) to be tested is accurately pipetted into a clean dry test tube. To this added 1 ml of rectified spirit (ethyl alcohol) and mixture is gently shaken.

One millilitre of solution of 0.085 N sodium carbonate is then added.

After shaking the test tube again, five drops of universal indicator are added.

The resulting mixture develops a colour depending on the *p*H value of the mixture.

Oils having total acidity of 0.5 total acidity of 0 to 0.5 shall show transition colours from prussian blue to yellow, whereas those having total acidity 0.5 and above shall show a change from yellow to vermilion.

Plate 1 gives the colours obtained by using this test on oils having neutralization value (total acidity) ranging from 0 to 10.

C-3 PORTABLE TEST KIT

C-3.1 This kit consists of a box containing the following:

a) Two polyethene bottles containing 100 ml each alcohol and sodium carbonate solution of 0.008 5 N concentration;

b) An indicator bottle containing universal indicator;

c) Four clean glass test tubes;

d) Three graduated droppers, with neutralization number values; and

e) Instructions booklet.

C-4 PREPARATION OF SODIUM CARBONATE SOLUTION

This solution is prepared by dissolving 0.118 3 g of anhydrous sodium carbonate in 250 ml of distilled water. 1.0 ml of this solution has just enough alkali to neutralize the acids extracted from an oil with an acid number of 0.5.

Sodium carbonate solution should be prepared carefully taking the necessary precautions as used in such procedures. This solution has a life of three to four months after which it must be discarded and fresh one shall be made.

C-5 PRECAUTIONS

C-5.1 The test tubes and pipettes used for the test should be absolutely clean and dry. It is best to wash them with soap and hot water followed by a final rinse with distilled water. The use of chromic acid for cleaning is also recommended where possible, but traces of the acid must be completely washed off before drying the glassware.

C-5.2 Rectified spirit used shall be of good quality conforming to IS 323. Commercial spirit (methylated) should not be used. Where possible, the use of ethyl alcohol A R grade is recommended.

C-5.3 While conducting the tests, the test tube should be gently shaken to mix the solutions and not closed with the thumb and vigorously agitated. This may lead to contamination of the solution.

C-5.4 The same pipette can be used for a number of oils provided it is thoroughly rinsed with oil to be tested before pipetting it.

ANNEX D

(*Clause* 2.1)

LIST OF REFFRED INDIAN STANDARDS

IS No.	*Title*	*IS No.*	*Title*
323 : 1959	Rectified spirits	[P : 21] : 1990	Flash point (closed) by Pensky-Martens apparatus (*third revision*)
335 : 1993	New insulating oils (*fourth revision*)	[P : 25] : 1976	Determination of kinematic and dynamic viscosity (*first revision*)
1448	Methods of test for petroleum and its products:	6103 : 1971	Methods of test for specific resistance (resistivity) of electrical insulating liquids
[P : 2] : 1967	Acidity		
[P : 10] : 1970	Cloud point and pour point		
[P : 16] : 1990	Density of crude petroleum and liquid petroleum products by hydrometer method (*third revision*)	6104 : 1971	Methods of test for interfacial tension of oil against water by the ring method

IS No.	*Title*
6262 : 1972	Methods of test for power factor and dielectrical constant of electrical insulating liquids
6792 : 1992	Method for determination of electric strength of insulating oils (*first revision*)
9434 : 1992	Guide for sampling and analysis of free and dissolved gases and oil from oil-filled electric equipment (*first revision*)
10593 : 1992	Method of evaluating the analysis of gases in oil-filled electric equipment in service (*first revision*)
12422 : 1988	Test method for oxidation stability of inhibited mineral insulating oils
12463 : 1988	Inhibited mineral insulating oils
13567 : 1992	Determination of water in insulating liquids and in oil-impregnated paper and press board by automatic coulometric Karl Fisher titration–Method of test
13631 : 1993	Method of test for detection and determination of antioxidant additives in insulating oils

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BUREAU OF INDIAN STANDARDS

Headquarters :

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002
Telephones : 2323 01 31, 2323 33 75, 2323 94 02

Telegrams : Manaksanstha
(Common to all offices)

Regional Offices :		Telephone
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Eastern	: 1/14 C.I.T. Scheme VII M, V. I. P. Road, Kankurgachi, KOLKATA 700 054	2337 84 99, 2337 85 61, 2337 86 26, 2337 91 20
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