

Monitoring and maintenance guide for mineral insulating oils in electrical equipment

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Committees responsible for this British Standard

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- Chemical Industries Association
- Electricity Association
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Foreword

This British Standard has been prepared by Technical Committee GEL/10. It is based on IEC 60422 published by the International Electrotechnical Commission (IEC). It supersedes BS 5730:1979, which is withdrawn.

CAUTION (Health and Safety). This British Standard calls for the use of substances and procedures that may be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage. In particular, attention is drawn to the following hazards (this list is not exhaustive).

- Prolonged exposure to the insulating oils described in this standard can cause skin sensitization, so it is essential that oils are handled with due regard to personal hygiene.

- The methods described in the standard employ flammable solvents.

CAUTION (Environmental). The insulating oils described in this standard have low biodegradability and can present an environmental hazard if not disposed of correctly. The methods described in this standard can give rise to waste chemicals, contaminated containers and oil contaminated solids which can also present an environmental hazard if not disposed of correctly.

Annex A is normative.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 27 and a back cover.

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Introduction

Monitoring and maintaining oil quality is essential in ensuring the reliable operation of oil-filled electrical equipment. Codes of practice for this purpose have been established by electrical power authorities and power companies in many countries.

A review of current experience reveals a wide variation of procedures and criteria. It is possible, however, to compare the value and significance of standardized oil tests and to recommend uniform criteria for the evaluation of test data.

Much greater difficulties exist in deciding frequency of testing and permissible oil degradation levels which are acceptable for all applications of insulating oil in relation to differences in operating policies, reliability requirements and types of electrical system. For example, large power companies will normally find uneconomical the full application of these recommendations to distribution transformers and tend to accept a higher failure risk. Conversely, the industrial user whose activities depend on the reliability of his power supply, may wish to institute more frequent and stricter controls of oil quality as a means of guarding against power failures.

If a certain amount of oil deterioration is exceeded, there is some erosion of safety margins and the question of the risk of premature failure has to be considered. While the quantification of the risk can be very difficult, a first step involves the identification of potential effects of increased deterioration. The philosophy underlying this guide is to furnish users with as broad a base of understanding of oil quality deterioration as is available, so that they can make informed decisions on inspection and maintenance practices.

The guidelines given in this standard, while technically sound, are mainly intended to serve as a common basis for the preparation of more specific and complete codes of practice by users in the light of local circumstances. Sound engineering judgement will have to be exerted in seeking the best compromise between technical requirements and economic factors.

Reference should also be made to instructions from the equipment manufacturer.

1 Scope

This British Standard gives guidance on the monitoring and maintenance of the quality of the insulating oil in electrical equipment.

This standard is applicable to mineral insulating oils, originally conforming to BS 148, in transformers, switchgear and similar electrical apparatus where oil sampling is reasonably practicable and where the normal operating conditions specified in the equipment specifications apply.

The purpose of this standard is to assist the power equipment operator in evaluating the condition of oil in equipment and in maintaining the oil in a serviceable condition. To this end, the standard gives recommendations on standardized tests and evaluation procedures and outlines methods for reconditioning and reclaiming oil.

NOTE It is recognized that the oil in certain types of equipment may contain dissolved gases and furanic compounds, the analysis of which may be useful in assessing the condition of the insulation system. The methods of analysis are given in BS EN 60567, BS EN 60599 and BS EN 61198. The interpretation of the results with respect to plant condition monitoring is outside the scope of the standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text constitute provisions of this British Standard. For dated references subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 148, *Specification for unused and reclaimed mineral insulating oils for transformers and switchgear.*

BS 171, *Specification for power transformers.*

BS 1752, *Specification for laboratory sintered or fritted filters, including porosity grading.*

BS 2000-15, *Methods of test for petroleum and its products — Petroleum products — Part 15: Determination of pour point.*

BS 2000-196:1997, *Methods of test for petroleum and its products — Petroleum products — Part 196: Determination of colour (ASTM scale).*

BS 5263, *Method of sampling liquid dielectrics.*

BS 5737, *Method for the measurement of relative permittivity, dielectric dissipation factor and d.c. resistivity of insulating liquids.*

BS 5984, *Method for detection and determination of specified anti-oxidant additives in insulating oils.*

BS 6522, *Methods for determination of percentage water saturation of insulating oil.*

BS EN 22719, *Methods of test for petroleum and its products — Petroleum products and lubricants — Determination of flash point — Pensky-Martens closed cup method.*

BS EN 60156, *Insulating liquids — Determination of the breakdown voltage at power frequency — Test method.*

BS EN 60567, *Guide for the sampling of gases and of oil from oil-filled electrical equipment and for the analysis of free and dissolved gases.*

BS EN 60599, *Mineral oil impregnated electrical equipment in service — Guide to the interpretation of dissolved and free gases analysis.*

BS EN 60814, *Insulating liquids — Oil-impregnated paper and pressboard — Determination of water by automatic coulometric Karl Fischer titration.*

BS EN 61125:1993, *Unused hydrocarbon-based insulating liquids — Test methods for the evaluation of oxidation stability.*

BS EN 61198, *Mineral insulating oils — Methods for the determination of 2-furfural and related compounds.*

BS EN 61619, *Insulating liquids — Contamination by polychlorinated biphenyls (PCBs) — Method of determination by capillary column gas chromatography.*

BS EN ISO 3104, *Methods of test for petroleum and its products — Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity.*

BS EN ISO 3675, *Crude petroleum and liquid petroleum products — Laboratory determination of density or relative density — Hydrometer method.*

ISO 6295, *Petroleum products — Mineral oils — Determination of interfacial tension of oil against water — Ring method.*

3 Properties and deterioration of oil

The reliable performance of mineral insulating oil in an insulation system depends upon certain basic oil characteristics which can affect the overall performance of the electrical equipment.

In order to accomplish its multiple role of dielectric, heat-transfer agent and arc-quencher, the oil needs to possess certain basic properties, in particular:

- high dielectric strength to withstand the electric stresses imposed in service;
- sufficiently low viscosity so that its ability to circulate and transfer heat is not impaired;
- adequate low-temperature properties down to the lowest temperature expected at the installation site;
- resistance to oxidation to ensure long life in service.

Mineral oil in service is subject to deterioration due to the conditions of use. In many applications, insulating oil is in contact with air and therefore subject to oxidation. Such reactions are accelerated by elevated temperatures. The presence of metals, organo-metallic compounds or both may act as oxidation promoters.

Change in colour, formation of acidic compounds and, at an advanced stage of oxidation, precipitation properties may be impaired.

In addition to oxidation products, many other undesirable contaminants, including water, solid particles and oil-soluble polar compounds can accumulate in the oil during service and alter its properties.

The presence of such contaminants and any deterioration product of an oil is indicated by a change of one or more properties as described in clause 4.

Deterioration of main plant equipment materials can also be indicated by changes in oil properties. Such deterioration can interfere with the proper functioning of the electrical equipment and shorten its working life.

4 Oil tests and their significance

4.1 General

A large number of tests can be applied to mineral insulating oils in electrical equipment. The tests listed in Table 1 and discussed in 4.2 to 4.17 are considered to be sufficient to determine whether the oil condition is adequate for continued operation and to suggest the type of corrective action required, where applicable. The tests are not listed in order of priority.

Table 1 — Tests for mineral insulating oils

Property	Subclause	Method
Colour and appearance	4.2	BS 2000-196
Odour	4.2	—
Breakdown voltage	4.3	BS EN 60156
Water content	4.4	BS EN 60814
Neutralization value (acidity)	4.5	BS 148
Sediment and sludge	4.6	Annex A
Dielectric dissipation factor and resistivity	4.7	BS 5737
Interfacial tension ^a	4.8	ISO 6295
Oxidation stability ^a	4.14	BS EN 61125:1993, method C
Dissolved gas content ^a	4.9	BS EN 60567
Cellulose degradation products (furanic compounds) ^a	4.15	BS EN 61198
Flash-point ^a	4.10	BS EN 22719
Compatibility ^b	4.16	BS EN 61125:1993, method C
Pour-point ^b	4.11	BS 2000-15
Density ^b	4.12	BS EN ISO 3675
Viscosity ^b	4.13	BS EN ISO 3104
Inhibitor content ^c	4.14	BS 5984
Polychlorinated biphenyls (PCBs)	4.17	BS EN 61619
NOTE See note to clause 1.		
^a Only needed under special circumstances, see applicable subclause.		
^b Not essential, but can be used to establish type identification.		
^c Restricted to inhibited oils.		

4.2 Colour, appearance and odour

The colour of an insulating oil is determined in transmitted light and is expressed by a numerical value based on comparison with a series of colour standards, as described in BS 2000-196. It is not a critical property, but it may be useful for comparative evaluation. A rapidly increasing or a high colour number may be an indication of oil deterioration or contamination.

Besides colour, the appearance of oil may show cloudiness or sediments which may indicate the presence of free water, insoluble sludge, carbon, fibres, dirt, or other contaminants.

If the oil has an acrid or unusual odour, consideration should be given to carrying out further tests.

4.3 Breakdown voltage

Breakdown voltage is a measure of the ability of an oil to withstand electric stress.

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

breakdown voltage value can indicate that one or more of these are present. However, a high breakdown voltage does not necessarily indicate the absence of all contaminants.

4.4 Water content

Water can originate from the atmosphere or be produced by the deterioration of insulating materials. At comparatively low water content, the water remains in solution and does not alter the appearance of the oil. Therefore dissolved water needs to be detected by chemical methods.

Dissolved water may, in certain circumstances, affect the electrical properties of the oil. The solubility of water in transformer oil increases with temperature and neutralization value (see 4.5 and Figure 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 electric strength and resistivity and an increased dielectric dissipation factor.

In a transformer the total mass of water is distributed between the paper and the oil such that the bulk of the water is in the paper. Small changes in temperature significantly modify the dissolved water content of the oil but only slightly modify the water content of the paper.

In the case of transformers, the measured water content should be corrected to 20 °C. This can be done by multiplying the measured water content by the relevant correction factor as shown in Figure 2.

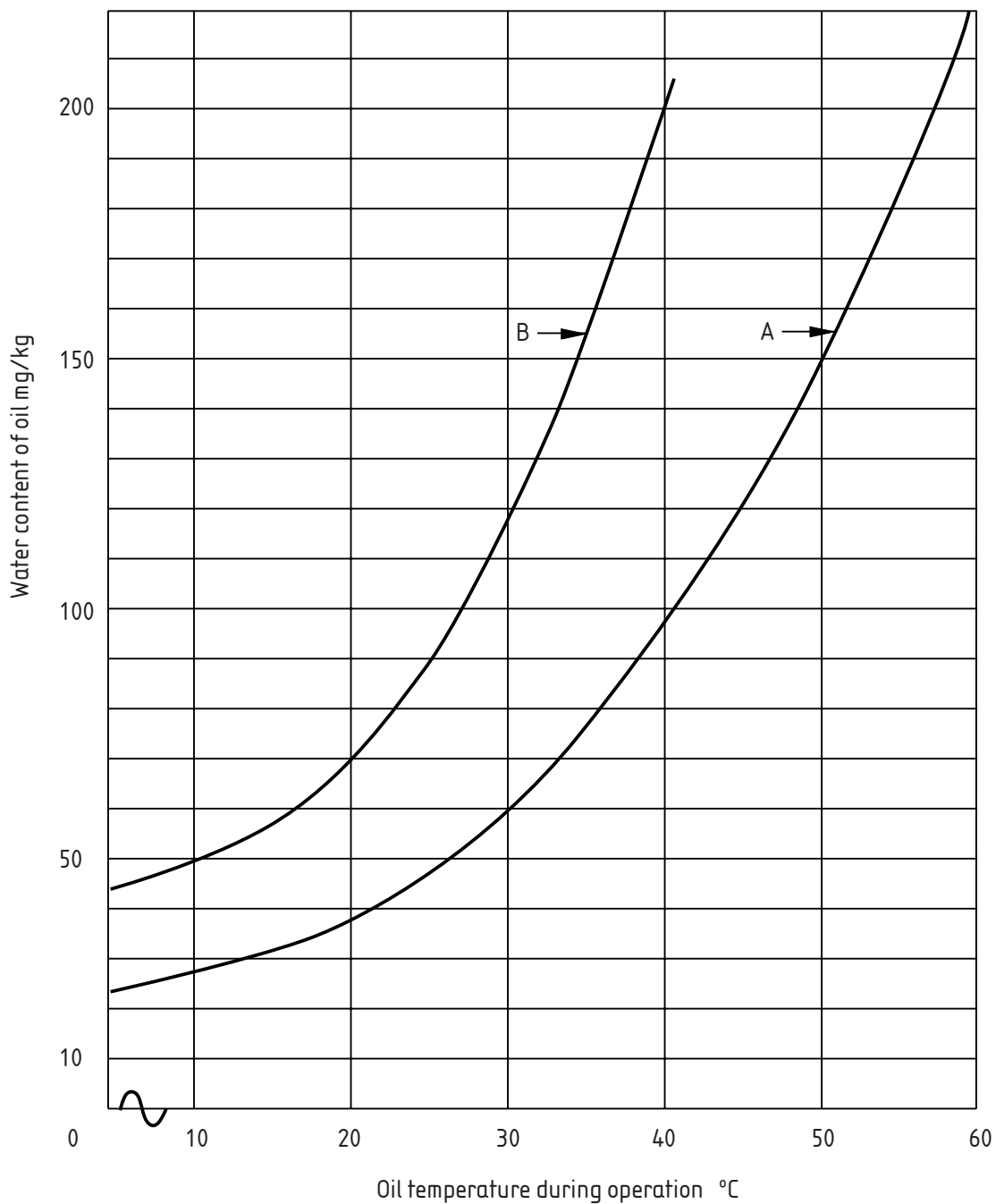
EXAMPLE

Measured dissolved water content	10 mg/kg
Temperature of sample	40 °C
Multiplication factor (from Figure 2)	0.45
Corrected dissolved water content	(10 × 0.45) 4.5 mg/kg

The limiting values for water content which are recommended in Table 6 are intended to control the water content in cellulosic insulation, including insulating paper, within acceptable limits and are related to normal (oil) operating temperatures of 40 °C to 60 °C. For consistency, oil temperature should be measured from the oil stream as the sample is being taken.

Where significant amounts of paper are not present, such as in switches, tap changers and diverters, temperature has a relatively small effect on the measured amount of dissolved water in the oil (expressed in milligrams of water per kilogram of oil). In these cases the correction to 20 °C is not valid and how close the oil is to saturation with water is a more important parameter. Instruments are available to measure the relative water saturation of the oil. This information can also be useful when paper is present.

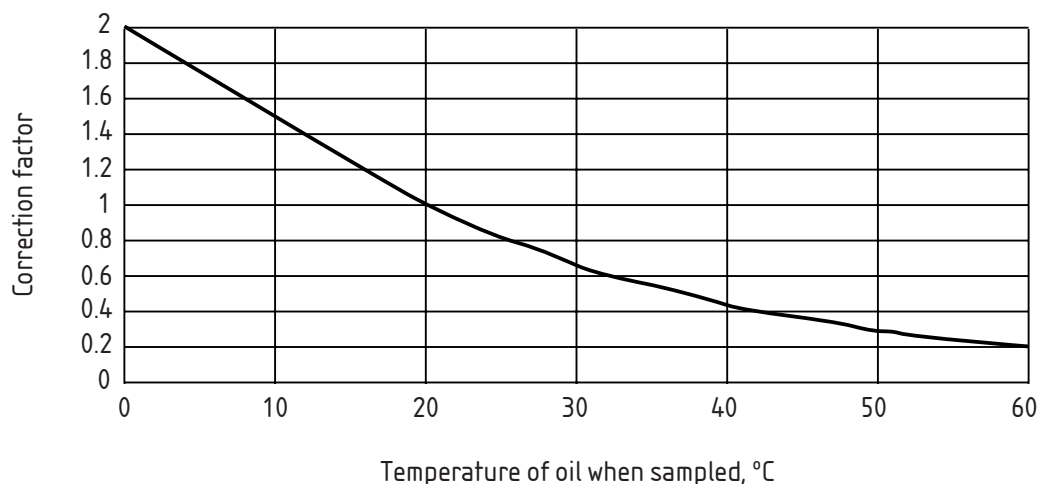
High water content accelerates the chemical deterioration of insulating paper and is indicative of undesirable operating conditions. Using a graphical method, it is possible to obtain, at a given temperature, an estimate of the water content of the paper from the measured water saturation level of the oil, assuming equilibrium conditions. A method for determining the percentage water saturation of insulating oil at temperatures up to 60 °C is given in BS 6522.



Curve A: Saturation water content in unused oil

Curve B: Typical saturation water content in oxidized oil with a neutralization value of 0.3 mg KOH/g

Figure 1 — Example of the variation in saturation water content with oil temperature for insulating oil conforming to BS 148



NOTE Where significant amounts of paper are not present, such as in switches, tap changers and diverters, temperature has a relatively small effect on the measured amount of dissolved water in the oil. In these cases the correction to 20 °C is not valid (see 4.4).

Figure 2 — Example of factors to correct the measured water content of oil to 20 °C in the presence of paper insulation

4.5 Neutralization value (acidity)

The neutralization value of an oil is a measure of the acidic constituents or contaminants in the oil.

The neutralization value 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.

4.6 Sediment and sludge

This test distinguishes between sediment and sludge.

Sediment is insoluble material present in the oil.

Sediment includes:

- a) insoluble oxidation or degradation products of solid or liquid insulating materials;
- b) solid products arising from the conditions of service of the equipment; carbon, metal, metallic oxides;
- c) fibres, and other foreign matter, of diverse origins.

Sludge is polymerized oxidation products of solid and liquid insulating material. Sludge is soluble in oil up to a certain limit. At sludge levels above this the sludge comes out of solution, contributing an additional component to the sediment.

The presence of sediment and sludge may change the electrical properties of the oil, and in addition, deposits may hinder heat-exchange, thus encouraging deterioration of the insulating materials.

4.7 Dielectric dissipation factor (DDF) and resistivity

These parameters are very sensitive to the presence in the oil of soluble polar contaminants, ageing products or colloids. Changes in the levels of the contaminants can be monitored by measurement of these parameters even when contamination is so slight as to be near the limit of chemical detection.

Acceptable limits for these parameters depend largely upon the type of apparatus and application. However, high values of the dielectric dissipation factor may deleteriously effect the power factor and/or the insulation resistance of the electrical equipment.