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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Mineral oil-filled electrical equipment – Application of dissolved gas analysis (DGA) to factory tests on electrical equipment

Matériels électriques imprégnés d'huile minérale – Application de l'analyse des gaz dissous (AGD) lors d'essais en usine de matériels électriques

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FOREWORD

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This consolidated version of IEC 61181 consists of the second edition (2007) [documents 10/675/FDIS and 10/688/RVD] and its amendment 1 (2012) [documents 10/881/FDIS and 10/886/RVD]. It bears the edition number 2.1.

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience. A vertical line in the margin shows where the base publication has been modified by amendment 1. Additions and deletions are displayed in red, with deletions being struck through.

International Standard IEC 61181 has been prepared by IEC technical committee 10: Fluids for electrotechnical applications.

This edition includes the following significant technical changes with respect to the previous edition:

a) the specific procedures used during factory tests (sampling location, sampling frequency, gas extraction and chromatographic analysis in the laboratory) are described in more detail;

b) information is provided in Annex A concerning the residual gas contents recommended before thermal tests on power transformers, typical gas values observed during the tests and cases where gas formation during the tests was followed by problems in the transformers;

c) typical values observed during chopped lightning-impulse tests on instrument transformers are indicated in Annex B.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

IEC technical committee 10, responsible for IEC 61181, has prepared guidelines for performing DGA measurements during factory testing on equipment filled with mineral insulating oil in order to ensure consistency in the industry and improve the confidence with which the results will be used.

DGA is used routinely as a standard quality control procedure during and after factory tests on electrical equipment, for example during temperature-rise and chopped lightning-impulse tests, to indicate that a design meets specified requirements. Due to the small quantities of gases generated during factory tests, specific requirements are necessary for the sampling and analysis of oil samples and the interpretation of results.

Acceptance criteria are beyond the scope of TC 10. Attention is drawn, however, to the fact that the guidelines issued by CIGRE in 1993-1995 [1][1] do not apply any more to transformers manufactured today, the design of which having been improved. Examples of values actually observed today are indicated in Annexes A and B.

[1] Figures in square brackets refer to the bibliography.

MINERAL OIL-FILLED ELECTRICAL EQUIPMENT – APPLICATION OF DISSOLVED GAS ANALYSIS (DGA) TO FACTORY TESTS ON ELECTRICAL EQUIPMENT

1 Scope

This International Standard specifies oil-sampling procedures, analysis requirements and procedures, and recommends sensitivity, repeatability and accuracy criteria for the application of dissolved gas analysis (DGA) to factory testing of new power transformers, reactors and instrument transformers filled with mineral insulating oil when DGA testing has been specified.

The most effective and useful application of DGA techniques to factory testing is during the performance of long-term tests, typically temperature-rise (heat run) and overloading tests on power transformers and reactors, also impulse tests on instrument transformers. DGA may also be valuable for over-excitation tests run over an extended period of time.

Experience with DGA results, before and after short-time dielectric tests, indicates that DGA is normally less sensitive than electrical and acoustic methods for detecting partial discharges. However, DGA will indicate when these partial discharges become harmful to the insulation and may be detected by inspection [2].

2 Normative references

The following referenced document is indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60567: *Guide for the sampling of gases and of oil from oil-filled electrical equipment and for the analysis of free and dissolved gases*~~

IEC 60475:2011, *Method of sampling insulating liquids*

IEC 60567:2011, *Oil-filled electrical equipment – Sampling of gases and analysis of free and dissolved gases – Guidance*

3 General caution, health, safety and environmental protection

This standard does not purport to address all the safety problems associated with its use. It is the responsibility of the user of the standard to establish appropriate health and safety practices and determine the applicability of regulatory limitations prior to use.

The mineral insulating oils which are the subject of this standard should be handled with due regard to personal hygiene. Direct contact with the eyes may cause irritation. In the case of eye contact, irrigation with copious quantities of clean running water should be carried out and medical advice sought. Some of the tests specified in this standard involve the use of processes that could lead to a hazardous situation. Attention is drawn to the relevant standard for guidance.

This standard is applicable to mineral insulating oils and used sample containers, the disposal or decontamination of which must be done according to local regulations. Every precaution should be taken to prevent release of mineral oil into the environment.

4 Oil sampling

4.1 General

Sampling of oil shall be carried out using apparatus and methods complying with IEC ~~60567~~ 60475:2011.

It is recommended that samples be taken by qualified personnel, trained to operate in accordance with IEC ~~60567~~ 60475:2011.

Samples shall be taken in duplicate (test sample and spare sample).

4.2 Sample containers

The most appropriate container is a gas-tight glass syringe of suitable capacity and fitted with a three-way sampling cock. For storage and transportation, stainless steel caps may also be used.

Alternative sample containers conforming to IEC ~~60567~~ 60475:2011 are acceptable.

4.3 Sampling location

Oil samples shall be representative of the bulk of the oil in the equipment. In power transformers, oil samples shall be taken from the main oil stream (e.g. at the ground level of the pipes circulating the oil through the radiators, when the pump is in operation, or using a metal pipe to bring the oil from the top oil valve to the ground). Points outside the main oil stream (e.g. from the bottom valve of the tank) shall be disregarded. For instrument transformers, follow the indications of manufacturers.

When using syringes, draining of at least 2 l of oil is recommended before sampling (when using bottles, twice the volume of the bottle or 5 l). When using bottles, a piece of oil-compatible tubing should be used from the oil valve to the bottom of the bottle, and the bottle filled with oil from the bottom up.

NOTE These provisions are not applicable to electrical equipment of small oil volume.

4.4 Sampling frequency

4.4.1 Thermal tests on power transformers

Irrespective of the type and duration of the test, oil samples for DGA shall be taken before the test begins and after the conclusion of the test.

Intermediate samples may be taken during the test depending on its duration and nature as they may be essential to improve the precision of the data and the reliability of their evaluation. Practices to that respect vary widely, and it is left to the user to decide the number of samples to be taken.

Oil sampling at the followings stages of the thermal tests has been found useful:

- after filling the transformer with degassed oil (for quality control of the drying and filling process);
- one day to one week later, depending on the transformer (when impregnation of oil in paper is completed);
- before start of thermal test;
- every 2 h during the tests, or at different test intervals depending on test duration and transformer design;
- at the end of test only;

– 24 h or more after the test is completed (to allow for equilibrium to be completed);
– some users recommend analysis of the duplicate and intermediate samples only if found necessary later.

If the cooling system of the unit under test includes oil pumps, they should be operated 2 h before the first oil sample is taken and kept running until the last oil sample is taken, except for any period the test conditions require the pumps to be turned off.

NOTE In the case of dielectric tests on power transformers, oil sampling may be performed:

– before first HV test.
– after all dielectric tests.

4.4.2 Impulse tests on instrument transformers

An oil sample shall be taken before the chopped lightning-impulse test. A second oil sample shall be taken 72 h after the test to assure the diffusion of the small quantities of gas generated during the test.

NOTE 1 During dielectric tests, the oil in an instrument transformer is virtually stationary and even convective movement is restricted. Consequently, the diffusion of small quantities of gas generated to the sampling point may take a considerable time. It is essential that the manufacturer and purchaser reach an agreement on the time the last sample should be taken.

NOTE 2 Between the beginning and the end of impulse tests, instrument transformers should not be subjected to other tests.

4.5 Sample labelling

Oil samples should be properly labelled before dispatch to the laboratory with the following minimum information:

– identification of equipment;
– date and time of sampling;
– nature of factory test;
– sampling point;
– top oil temperature.

4.6 Sample storage

To prevent oxidation, the samples shall be shielded from direct light by wrapping the container in aluminium foil or by storing in an opaque enclosure.

4.7 Disposal of waste oil

Waste oil shall be disposed of according to local regulations.

5 Factors affecting gassing rate during thermal tests

Gas measurements are used to detect the effect of abnormal temperatures in windings, leads, magnetic circuit, structural elements, or from abnormal leakage flux. The design of these transformer parts therefore has an influence on gas production rate. Other important design aspects that may affect production rate are:

– oil to cellulose mass ratio: if there is less oil to absorb the gas produced, higher gassing rates will be observed;
– paper type or quality (thermally upgraded or not, Nomex);
– oil type or brand (stray gassing tendency);
– in some transformers: paints, glues, stainless steel and other materials;

– cooling method and cooling efficiency;
– test duration.

Gassing rate is strongly dependent on temperature and air content. It should be noted that there is always some gassing, although very low, during all thermal tests.

Oxygen concentration is normally low since the oil is initially degassed. Sometimes the oil can be oxygenated to a given range of concentrations, such as 8 000 µl/l to 12 000 µl/l, to increase gas formation. In case of a nitrogen-cushioned transformer, considerable amounts of gases may diffuse from the oil.

6 Dissolved gas extraction and analysis

Gases dissolved in oil should be extracted and analysed by gas chromatography in accordance with IEC 60567:2011, with the detection limits of the overall determination indicated in Table 1.

Table 1 – Required detection limits for factory tests

Gas	Concentrations	
	µl/l	µmol/l
Hydrogen	2	0,08
Hydrocarbons	0,1	0,004
Carbon monoxide	5	0,2
Carbon dioxide	10	0,4
Oxygen	500	21
Nitrogen	2000	84

Oil samples should be analysed as soon as possible after being taken and in no case later than seven days afterwards.

The recommended methods of gas extraction for factory tests, as indicated in IEC 60567:2011, are the Toepler and partial degassing methods, including their Mercury Free versions, since they allow a higher gas extraction efficiency at the low gas concentration levels observed during factory tests. Head space may be used if a sufficient sensitivity and accuracy can be reached.

When using partial degassing, the following adaptations for factory tests are recommended:

– use a gas burette of smaller volume;
– run a blank (with no oil injected) to check for vacuum leaks in the extraction system;
– use an extraction system dedicated to factory tests (to avoid contamination by routine oil samples containing high levels of fault gases);
– if this is not possible, perform a full extraction procedure on a sample of degassed oil before running the factory test samples;
– if a better precision is desired, use a larger volume of oil (e.g., a 50 ml or 100 ml syringe).

When using Toepler method, the following adaptations are recommended:

– if it is known before gas extraction that the oil used has been well degassed (total volume < 1 %), introduce a measured volume (e.g. 1 ml to 2 ml) of argon into the oil syringe (to increase the precision on the reading of the total gas measured in the burette);
– if after gas extraction the extracted gas volume is too small for precise quantification, introduce e.g. 1 ml or 1,5 ml of argon to the extracted gas, so that there is sufficient gas volume to carry out the analysis;
– alternatively, when the total gas volume is too small to obtain a reading on the burette, lower the mercury level and take a reading at reduced pressure, then correct to atmospheric pressure;
– flush with air then put under vacuum (to decontaminate the extraction system from previous analyses). A full extraction procedure on a sample of degassed oil may also be used where the apparatus may be contaminated from routine samples;
– an alternative procedure consists in increasing the volume of oil used (typically, twice the amount used for routine analysis).

The use of high sensitivity capillary columns, as in example 2 of Table ~~3~~ 4 of IEC 60567:2011 is recommended.

In addition to adequate sensitivity levels, a very good repeatability r is necessary to prevent misinterpretation of results. Consequently, it is essential for all samples to be analysed by the same laboratory, by highly-trained qualified personnel, and within a short period of time. It is also recommended that the laboratory repeatability be regularly monitored. A required criteria for repeatability at low gas concentrations, as indicated in IEC 60567:2011, is:

$$r \leq S$$

where S is the required detection limit.

The objective of the DGA determinations is the detection of very small differences between oil samples. A calculated difference is significant only if it is larger than the repeatability (for analyses performed within a short period of time, e.g., one day), or than the reproducibility or by default the accuracy (for analyses performed over a longer period of time), as indicated in 9.3 of IEC 60567:2011.

The required accuracy, deduced from round robin tests performed by IEC TC 10 at low gas levels (1 µl/l to 3 µl/l of the hydrocarbons, 2,5 µl/l of H_2, 5 µl/l of CO and 40 µl/l of CO_2), is ±44 %.

7 Report

The report should include the following information:

– testing laboratory;
– identification of equipment tested;
– sampling location;
– DGA results on each sample, in µl/l or µmol/l (total volume of gas, oxygen and nitrogen may conveniently be expressed in percent of oil volume);
– rate of generation of gases in µl/l/h.