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colour inside

Oil-filled electrical equipment – Sampling of free gases and analysis of free and dissolved gases in mineral oils and other insulating liquids – Guidance

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

OIL-FILLED ELECTRICAL EQUIPMENT – SAMPLING OF FREE GASES AND ANALYSIS OF FREE AND DISSOLVED GASES IN MINERAL OILS AND OTHER INSULATING LIQUIDS – GUIDANCE

FOREWORD

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This commented version (CMV) of the official standard IEC 60567:2023 edition 5.0 allows the user to identify the changes made to the previous IEC 60567:2011 edition 4.0. Furthermore, comments from IEC TC 10 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 60567 has been prepared by IEC technical committee 10: Fluids for electrotechnical applications. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2011. This edition constitutes a technical revision. **1**

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

a) a new normative Annex F relating to DGA analysis of insulating liquids other than mineral oils (esters and silicones) has been added;
b) Clause 4 to Clause 11 and informative Annex A to Annex E remain devoted to mineral oils;
c) two new mercury-free gas extraction methods are described in Annex B (low pressure vacuum extraction and mechanical oscillation).

The text of this International Standard is based on the following documents:

Draft	Report on voting
10/1207/FDIS	10/1211/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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INTRODUCTION

Gases ~~may~~ can be formed in oil-filled electrical equipment due to natural ageing but also, to a much greater extent, as a result of faults.

Operation with a fault ~~may~~ can seriously damage the equipment, and it is valuable to be able to detect the fault at an early stage of development.

Where a fault is not severe, the gases formed will normally dissolve in the oil, with a small proportion eventually diffusing from the liquid into any gas phase above it. Extracting dissolved gas from a sample of the oil and determining the amount and composition of this gas is a means of detecting such faults, and the type and severity of any fault ~~may~~ can often be inferred from the composition of the gas and the rate at which it is formed.

In the case of a sufficiently severe fault, free gas will pass through the oil and collect in the gas-collecting (Buchholz) relay if fitted; if necessary, this gas may be analysed to assist in determining the type of fault that has generated it. The composition of gases within the bubbles changes as they move through the oil towards the gas-collecting relay.

This can be put to good use, as information on the rate of gas production ~~may~~ can often be inferred by comparing the composition of the free gases collected with the concentrations remaining dissolved in the liquid.

The interpretation of the gas analyses is the subject of IEC 60599.

These techniques are valuable at all stages in the life of oil-filled equipment. During acceptance tests on transformers in the factory, comparison of gas-in-oil analyses before, during and after a heat run test can show if any hot-spots are present, and similarly analysis after dielectric testing can add to information regarding the presence of partial discharges or sparking. During operation in the field, the periodic removal of an oil sample and analysis of the gas content serve to monitor the condition of transformers and other oil-filled equipment.

The importance of these techniques has led to the preparation of this document, to the procedures used for the sampling, from oil-filled electrical equipment, of gases and oils containing gases, and for subsequent analysis.

NOTE Methods described in this document apply to insulating oils, since experience to date has been almost entirely with such oils. The methods ~~may~~ can also be applied to other insulating liquids, in some cases with modifications.

General caution, health, safety and environmental protection

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

The insulating oils which are the subject of this document should be handled with due regard to personal hygiene. Direct contact with the eyes ~~may~~ can 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 document involve the use of processes that ~~could~~ can lead to a hazardous situation. Attention is drawn to the relevant standard for guidance.

Mercury presents an environmental and health hazard. Any spillage should immediately be removed and be properly disposed of. ~~Consult local regulations~~ Regulatory requirements for mercury use and handling can apply. Mercury-free methods may be requested in some countries.

Environment

WARNING – This document is applicable to insulating oils, chemicals and used sample containers.

Attention is drawn to the fact that, at the time of writing of this document, many insulating oils in service are known to be contaminated to some degree by polychlorinated biphenyls (PCBs). If this is the case, safety countermeasures should be taken to avoid risks to workers, the public and the environment during the life of the equipment, by strictly controlling spills and emissions. Disposal or decontamination of these oils ~~should be carried out strictly according to local regulations~~ can be subject to regulatory requirements. Every precaution should be taken to prevent the release of any type of insulating oil into the environment, including those partially biodegradable with time.

OIL-FILLED ELECTRICAL EQUIPMENT – SAMPLING OF FREE GASES AND ANALYSIS OF FREE AND DISSOLVED GASES IN MINERAL OILS AND OTHER INSULATING LIQUIDS – GUIDANCE

1 Scope

This document deals with the techniques for sampling free gases from gas-collecting relays from power transformers. Three methods of sampling free gases are described.

The techniques for sampling oil from oil-filled equipment such as power and instrument transformers, reactors, bushings, oil-filled cables and oil-filled tank-type capacitors are no longer covered by this document, but are instead described in IEC 60475:~~2011~~2022, 4.2.

Before analysing the gases dissolved in oil, they are first extracted from the oil. Three basic methods are described, one using extraction by vacuum (Toepler and partial degassing), another by displacement of the dissolved gases by bubbling the carrier gas through the oil sample (stripping) and the last one by partition of gases between the oil sample and a small volume of the carrier gas (headspace). The gases are analysed quantitatively after extraction by gas chromatography; a method of analysis is described. Free gases from gas-collecting relays are analysed without preliminary treatment.

The preferred method for ensuring the performance of the gas extraction and analysis equipment, considered together as a single system, is to degas samples of oil prepared in the laboratory and containing known concentrations of gases ("gas-in-oil standards") and quantitatively analyse the gases extracted. Two methods of preparing gas-in-oil standards are described.

For daily calibration checks of the chromatograph, it is convenient to use a standard gas mixture containing a suitable known amount of each of the gas components to be in a similar ratio to the common ratios of the gases extracted from transformer oils.

The techniques described take account, on the one hand, of the problems peculiar to analyses associated with acceptance testing in the factory, where gas contents of oil are generally very low and, on the other hand, of the problems imposed by monitoring equipment in the field, where transport of samples ~~may~~ can be by un-pressurized air freight and where considerable differences in ambient temperature ~~may~~ can exist between the plant and the examining laboratory.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60296, *Fluids for electrotechnical applications – ~~Unused Mineral insulating oils for transformers and switchgear~~ Mineral insulating oils for electrical equipment*

IEC 60475:~~2011~~2022, *Method of sampling insulating liquids*

~~IEC 60599, *Mineral oil-impregnated electrical equipment in service – Guide to the interpretation of dissolved and free gases analysis*~~

~~ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*~~

ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results – Part 1: General principles and definitions*

~~ASTM D2780, *Standard Test Method for Solubility of Fixed Gases in Liquids*~~

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Edition 5.0 2023-12

INTERNATIONAL STANDARD

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Oil-filled electrical equipment – Sampling of free gases and analysis of free and dissolved gases in mineral oils and other insulating liquids – Guidance

Matériels électriques immergés – Échantillonnage de gaz libres et analyse des gaz libres et dissous dans les huiles minérales et d'autres liquides isolants – Recommandations



IEC 60567:2023-12(en-fr)

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Operation with a fault can seriously damage the equipment, and it is valuable to be able to detect the fault at an early stage of development.

Where a fault is not severe, the gases formed will normally dissolve in the oil, with a small proportion eventually diffusing from the liquid into any gas phase above it. Extracting dissolved gas from a sample of the oil and determining the amount and composition of this gas is a means of detecting such faults, and the type and severity of any fault can often be inferred from the composition of the gas and the rate at which it is formed.

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Mercury presents an environmental and health hazard. Any spillage should immediately be removed and be properly disposed of. Regulatory requirements for mercury use and handling can apply. Mercury-free methods may be requested in some countries.

Environment

WARNING – This document is applicable to insulating oils, chemicals and used sample containers.

Attention is drawn to the fact that, at the time of writing of this document, many insulating oils in service are known to be contaminated to some degree by polychlorinated biphenyls (PCBs). If this is the case, safety countermeasures should be taken to avoid risks to workers, the public and the environment during the life of the equipment, by strictly controlling spills and emissions. Disposal or decontamination of these oils can be subject to regulatory requirements. Every precaution should be taken to prevent the release of any type of insulating oil into the environment, including those partially biodegradable with time.

OIL-FILLED ELECTRICAL EQUIPMENT – SAMPLING OF FREE GASES AND ANALYSIS OF FREE AND DISSOLVED GASES IN MINERAL OILS AND OTHER INSULATING LIQUIDS – GUIDANCE

1 Scope

This document deals with the techniques for sampling free gases from gas-collecting relays from power transformers. Three methods of sampling free gases are described.

The techniques for sampling oil from oil-filled equipment such as power and instrument transformers, reactors, bushings, oil-filled cables and oil-filled tank-type capacitors are no longer covered by this document, but are instead described in IEC 60475:2022, 4.2.

Before analysing the gases dissolved in oil, they are first extracted from the oil. Three basic methods are described, one using extraction by vacuum (Toepler and partial degassing), another by displacement of the dissolved gases by bubbling the carrier gas through the oil sample (stripping) and the last one by partition of gases between the oil sample and a small volume of the carrier gas (headspace). The gases are analysed quantitatively after extraction by gas chromatography; a method of analysis is described. Free gases from gas-collecting relays are analysed without preliminary treatment.

The preferred method for ensuring the performance of the gas extraction and analysis equipment, considered together as a single system, is to degas samples of oil prepared in the laboratory and containing known concentrations of gases ("gas-in-oil standards") and quantitatively analyse the gases extracted. Two methods of preparing gas-in-oil standards are described.

For daily calibration checks of the chromatograph, it is convenient to use a standard gas mixture containing a suitable known amount of each of the gas components to be in a similar ratio to the common ratios of the gases extracted from transformer oils.

The techniques described take account, on the one hand, of the problems peculiar to analyses associated with acceptance testing in the factory, where gas contents of oil are generally very low and, on the other hand, of the problems imposed by monitoring equipment in the field, where transport of samples can be by un-pressurized air freight and where considerable differences in ambient temperature can exist between the plant and the examining laboratory.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60296, *Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment*

IEC 60475:2022, *Method of sampling insulating liquids*

ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results – Part 1: General principles and definitions*

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MATÉRIELS ÉLECTRIQUES IMMERGÉS – ÉCHANTILLONNAGE DE GAZ LIBRES ET ANALYSE DES GAZ LIBRES ET DISSOUS DANS LES HUILES MINÉRALES ET D'AUTRES LIQUIDES ISOLANTS – RECOMMANDATIONS

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L'IEC 60567 a été établie par le comité d'études 10 de l'IEC: Fluides pour applications électrotechniques. Il s'agit d'une Norme internationale.

Cette cinquième édition annule et remplace la quatrième édition parue en 2011. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) une nouvelle Annexe F normative concernant l'analyse AGD des liquides isolants autres que les huiles minérales (esters et silicones) a été ajoutée;
b) les Articles 4 à 11 et les Annexe A à Annexe E informatives restent consacrés aux huiles minérales;
c) deux nouvelles méthodes d'extraction de gaz sans mercure sont décrites à l'Annexe B (extraction sous vide à basse pression et oscillation mécanique).

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
10/1207/FDIS	10/1211/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

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INTRODUCTION

Les processus naturels de vieillissement dans les matériels électriques immergés dans l'huile forment des gaz, mais il peut s'en produire beaucoup plus en cas de défauts.

Le fonctionnement en présence de défauts peut sérieusement endommager les matériels, et il est important de pouvoir détecter ces défauts au tout début de leur apparition.

Si ces défauts ne sont pas importants, les gaz formés se dissolvent normalement dans l'huile et diffusent éventuellement, dans une faible proportion, du liquide dans toute la phase gazeuse au-dessus du liquide. L'extraction des gaz dissous à partir d'un échantillon d'huile et la détermination de leur teneur et de leur composition sont des moyens de détecter de tels défauts. Le type et la sévérité de tout type de défaut peuvent alors souvent être déduits à partir de la composition des gaz et de leur vitesse de formation.

Dans le cas de défauts suffisamment importants, les gaz libres traversent l'huile et sont recueillis au relais de protection (Buchholz), le cas échéant; en cas de nécessité, ces gaz peuvent être analysés pour déterminer le type de défaut qui les a créés. Au fur et à mesure du déplacement des bulles dans l'huile vers le relais de protection, la composition des gaz dans ces bulles varie.

Cela peut être utilisé à bon escient, puisque les informations concernant la vitesse de formation des gaz peuvent souvent être déduites en comparant la composition des gaz libres recueillis à la concentration des gaz qui restent dissous dans le liquide.

L'interprétation de l'analyse des gaz fait l'objet de l'IEC 60599.

À tous les stades de la vie des matériels immergés dans l'huile, ces techniques sont précieuses. Lors des essais de réception des transformateurs en usine, la comparaison des analyses de gaz dissous dans l'huile avant, pendant et après un essai d'échauffement peut révéler la présence de points chauds; de même, après les essais électriques, les analyses peuvent fournir des informations complémentaires concernant la présence de décharges partielles ou disruptives. Lors du fonctionnement sur site, des prélèvements périodiques d'échantillons d'huile, pour l'analyse des teneurs en gaz, servent à surveiller l'état des transformateurs et autres matériels immergés dans l'huile.

L'importance de ces techniques a conduit à l'établissement du présent document, qui donne les modes opératoires utilisés pour l'échantillonnage des gaz et de l'huile contenant des gaz dans les matériels électriques immergés dans l'huile, pour les analyses ultérieures.

NOTE Les méthodes décrites dans le présent document s'appliquent aux huiles isolantes, car l'expérience, à ce jour, a presque entièrement été obtenue sur de telles huiles. Ces méthodes peuvent également être appliquées à d'autres liquides isolants, sous réserves de modifications éventuelles.

Précautions générales, protection de la santé, de la sécurité et de l'environnement

AVERTISSEMENT – Le présent document ne prétend pas couvrir tous les problèmes de sécurité liés à son utilisation. Il incombe à l'utilisateur du présent document d'établir, avant de l'utiliser, des pratiques d'hygiène et de sécurité appropriées et de déterminer l'applicabilité des restrictions réglementaires.

Il convient de manipuler les huiles isolantes dont traite le présent document en respectant l'hygiène personnelle. Un contact direct avec les yeux peut provoquer une irritation. En cas de contact oculaire, il convient d'effectuer un lavage avec une grande quantité d'eau courante propre et de consulter un médecin. Certains des essais spécifiés dans le présent document impliquent l'emploi de procédés qui peuvent conduire à une situation dangereuse. Les recommandations des normes correspondantes sont prises en compte.

Le mercure présente un risque pour l'environnement et pour la santé. Il convient de nettoyer et d'éliminer immédiatement tout déversement de façon appropriée. Des exigences réglementaires concernant l'utilisation et la manipulation du mercure peuvent s'appliquer. Des méthodes qui n'utilisent pas de mercure peuvent être exigées dans certains pays.

Environnement

AVERTISSEMENT – Le présent document s'applique aux huiles isolantes, aux produits chimiques et aux récipients d'échantillons usagés.

L'attention est attirée sur le fait que, au moment de la rédaction du présent document, de nombreuses huiles isolantes en service sont connues pour être contaminées dans une certaine mesure par des polychlorobiphényles (PCB). Si tel est le cas, il convient de prendre des contre-mesures de sécurité afin d'éviter les risques pour les travailleurs, le public et l'environnement au cours de la durée de vie du matériel, en contrôlant rigoureusement les débordements et les émissions. L'élimination ou la décontamination de ces huiles peut être soumise à des exigences réglementaires. Il convient de prendre toutes les précautions afin d'empêcher le déversement de tout type d'huile isolante dans l'environnement, y compris celles qui sont partiellement biodégradables dans le temps.

MATÉRIELS ÉLECTRIQUES IMMERGÉS – ÉCHANTILLONNAGE DE GAZ LIBRES ET ANALYSE DES GAZ LIBRES ET DISSOUS DANS LES HUILES MINÉRALES ET D'AUTRES LIQUIDES ISOLANTS – RECOMMANDATIONS

1 Domaine d'application

Le présent document traite des techniques d'échantillonnage de gaz libres au niveau des relais de protection des transformateurs de puissance. Trois méthodes d'échantillonnage des gaz libres sont décrites.

Les techniques d'échantillonnage de l'huile dans les matériels immergés dans l'huile, tels que les transformateurs de puissance et de mesure, les bobines d'inductances, les traversées de transformateurs, les câbles à huile fluide et les condensateurs de puissance ne sont plus couverts par le présent document, mais se trouvent dorénavant dans l'IEC 60475:2022, 4.2.

Avant d'analyser les gaz dissous dans l'huile, ils sont en premier lieu extraits de l'huile. Trois méthodes de base sont décrites, l'une utilisant l'extraction sous vide (Toepler et dégazage partiel), une autre par déplacement des gaz dissous par barbotage d'un gaz vecteur dans l'échantillon d'huile (entraînement) et la dernière par partition des gaz entre l'échantillon d'huile et un faible volume du gaz vecteur (espace de tête). Après extraction, l'analyse quantitative des gaz s'effectue par chromatographie en phase gazeuse; une méthode d'analyse est décrite. Les gaz libres prélevés au niveau des relais de protection sont analysés sans traitement préalable.

La méthode préférentielle pour assurer le fonctionnement des matériels d'extraction des gaz et d'analyse, étudiés ensemble comme un seul et même système, consiste à extraire les gaz d'échantillons d'huile préparés au laboratoire qui contiennent des concentrations en gaz connues ("étalons de gaz dissous dans l'huile") et qui sont analysés quantitativement. Deux méthodes sont décrites pour l'obtention d'étalons de gaz dissous dans l'huile.

Lors de vérifications quotidiennes de l'étalonnage du chromatographe, il est commode d'utiliser un mélange de gaz étalons dont les teneurs en chacun des composants sont connues et appropriées, et dans un rapport similaire aux teneurs habituelles des gaz extraits des huiles des transformateurs.

Les techniques décrites tiennent compte, d'une part, des problèmes spécifiques à l'analyse liés aux essais de réception en usine, pour lesquels les teneurs en gaz sont généralement très faibles, et, d'autre part, des problèmes rencontrés dans la surveillance du matériel sur site, le transport des échantillons pouvant se faire par fret aérien non pressurisé et des différences importantes de températures pouvant exister entre le site de prélèvement et le laboratoire d'analyse.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60296, *Fluides pour applications électrotechniques – Huiles minérales isolantes pour matériel électrique*

IEC 60475:2022, *Méthode d'échantillonnage des liquides isolants*

ISO 5725-1, *Exactitude (justesse et fidélité) des résultats et méthodes de mesure – Partie 1: Principes généraux et définitions*