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Power transformers –
Part 14: Design and application of liquid-immersed power transformers using high-temperature insulation materials

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ELECTROTECHNICAL
COMMISSION

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 60076-14, which is a technical specification, has been prepared by IEC technical committee 14: Power transformers.

This second edition cancels and replaces the first edition published in 2004. It is a technical revision.

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

- additional clarification added to the introduction;
- addition of an introduction to the ageing and lifetime of insulation materials;
- enhancement of insulation system descriptions;
- clarification of temperature rise limits and the addition of overload temperature limits.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
14/591A/DTS	14/600/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

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

A list of all parts of the IEC 60076 series can be found, under the general title *Power transformers*, on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

The average temperature rise in liquid-immersed transformer windings has for several tens of years been limited to 65/70 K and the top oil temperature rise to 60 K, as specified in IEC 60076-2.

Winding conductors in these transformers have historically been insulated with cellulosic paper or enamel. Other solid insulation materials have also been cellulose-based products. The insulation liquid has, for the most part been mineral insulating oil. These materials are still dominant.

Consequently, most of the accumulated experience of transformers in service is based on these insulation materials and these temperature limits. In some cases, space or weight limitations require the designer to reduce the transformer dimensions with higher temperature rises as a consequence. The application of insulation materials (both solid and liquid) with better ageing properties at elevated temperatures than the traditional ones is necessary in order to provide an acceptable life expectancy. High-temperature solid insulation materials have also occasionally been used only in certain parts of the windings where high temperature has been expected.

Recent temperature measurements by means of fibre-optics have indicated that the hot-spot temperature may sometimes be higher than predicted, and in certain cases considerably higher. This has created concern regarding higher rate of ageing than expected. The measurements have provided knowledge regarding where the hot-spots are situated and where high-temperature materials might be applied.

High-temperature insulation, from enamel and tape wrap for conductors, to spacer and mechanical support materials are already used in power, distribution, mobile, locomotive and rectifier transformers. Class K liquids, with a fire point greater than 300 °C are suitable for temperatures higher than mineral insulating oil and have been used for decades. Their use and range of application is increasing rapidly. For many years, manufacturers have met the needs of special applications by designing transformers using high-temperature materials to achieve lower weight, higher power density, improved fire safety or increased life.

The purpose of this technical specification is to begin the process of standardizing the development of liquid-immersed transformers that use high-temperature insulation. As a system, the solid insulation may encompass a broad range of materials with varying degrees of thermal capability. The insulating and cooling liquids also vary substantially from mineral oil to any of a number of new class K liquids that also have a broad range of thermal capability.

The liquid and solid insulation materials found in any standard type of modern liquid-immersed transformer compose an insulation system that has evolved and developed over more than 100 years. Accordingly, the rules and guidelines for application are also robust and rather well developed. In contrast, high-temperature insulation materials and applications for transformers that use these materials are relatively new in both development and application.

It should not therefore be surprising that much of the information is neither well developed nor completely understood. However, it is important to establish and maintain a document that provides a starting point for discussion between the manufacturer and the user. It is expected that this technical specification would be updated regularly as development progresses.

This document is not intended to stand alone, but rather builds on the wealth of information and guidelines documented in the other parts of the IEC 60076 series. Accordingly, this document follows two guiding principles. The first principle is that liquid-immersed transformers are well known and are well defined in other parts of this series and therefore, the details of these transformers are not repeated in this technical specification, except where reference has value, or where repetition is considered appropriate for purposes of emphasis or comparison.

The second principle is that the usual liquid-immersed transformer, insulated with kraft paper, pressboard, wood, mineral oil and many other commonly used materials operating at established temperature limits, are well known and considered normal or conventional. All other insulation materials, either solid or liquid that have a thermal capability higher than the materials used in this well known system of insulation materials are considered high-temperature.

Consequently, this “standard” or “normal” insulation system is defined as the “conventional” insulation system for comparison purposes and these normal thermal limits are presented for reference to illustrate the differences between other higher-temperature systems. Commonly used solid and liquid insulations are also tabulated in a general way to allow easy comparison of typical properties and to demonstrate the added range and capabilities of relatively unfamiliar materials.

This technical specification addresses loading, overloading, testing and accessories in the same manner. Only selected information for the “conventional” transformers is included for comparison purposes or for emphasis. All other references are directed to the appropriate IEC document.

POWER TRANSFORMERS –

Part 14: Design and application of liquid-immersed power transformers using high-temperature insulation materials

1 Scope

This part of IEC 60076 provides specification, design, testing and loading information for use by both the manufacturer and user of liquid-immersed power transformers employing either high-temperature insulation or combinations of high-temperature and conventional insulation.

It is applicable to:

- power transformers designed in accordance with IEC 60076-1,
- convertor transformers designed to IEC 61378 series,
- arc furnace transformers,

and covers the use of various liquid and solid insulation combinations.

Whilst standards for traction transformers fall under the authority of IEC technical committee 9, this part of IEC 60076, however, may be applicable as a guideline for the use of high-temperature insulation materials in traction transformers.

2 Normative references

The following referenced documents are 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 60076-1:1993, *Power transformers – Part 1: General*

IEC 60076-2, *Power transformers – Part 2: Temperature rise*

IEC 60076-3, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-5, *Power transformers – Part 5: Ability to withstand short-circuit*

IEC 60076-7:2005, *Power transformers – Part 7: Loading guide for oil-immersed power transformers*

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60216-1, *Electrical insulating materials – Properties of thermal endurance – Part 1: Ageing procedures and evaluation of test results*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60317 (all parts), *Specifications for particular types of winding wires*

IEC 60554-3 (all parts), *Specification for cellulosic papers for electrical purposes – Part 3: Specifications for individual materials*

IEC 60641-3 (all parts), *Pressboard and presspaper for electrical purposes – Part 3: Specifications for individual materials*

IEC 60674-3 (all parts), *Plastic films for electrical purposes – Part 3: Specifications for individual materials*

IEC 60819-3 (all parts), *Non-cellulosic papers for electrical purposes – Part 3: Specifications for individual materials*

IEC 60836, *Specifications for unused silicone insulating liquids for electrotechnical purposes*

IEC 60851-4, *Winding wires – Test methods – Part 4: Chemical properties*

IEC 60867, *Insulating liquids – Specifications for unused liquids based on synthetic aromatic hydrocarbons*

IEC 60893-3 (all parts), *Insulating materials – Industrial rigid laminated sheets based on thermosetting resins for electrical purposes – Part 3: Specifications for individual materials*

IEC 61099, *Specifications for unused synthetic organic esters for electrical purposes*

IEC 61100, *Classification of insulating liquids according to fire-point and net calorific value*

IEC 61212-3 (all parts), *Insulating materials – Industrial rigid round laminated tubes and rods based on thermosetting resins for electrical purposes – Part 3: Specifications for individual materials*

IEC 61378-1, *Convertor transformers – Part 1: Transformers for industrial applications*

IEC 61629-1, *Aramid pressboard for electrical purposes – Part 1: Definitions, designations and general requirements*

ISO 2592, *Determination of flash and fire points – Cleveland open cup method*

ISO 2719, *Determination of flash-point – Pensky-Martens closed cup method*