

Measurement of the average viscometric degree of polymerization of new and aged electric papers

Committees responsible for this British Standard

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- British Ceramic Research Ltd.
- British Industrial Ceramic Manufacturers' Association
- Electrical and Electronic Insulation Association (BEAMA Ltd.)
- Electricity Association
- Federation of the Electronics Industry
- Rotating Electrical Machines Association (BEAMA Ltd.)
- Transmission and Distribution Association (BEAMA Ltd.)

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National foreword

This British Standard has been prepared by Technical Committee GEL/15. It is identical with IEC 450:1974 *Measurement of the average viscometric degree of polymerization of new and aged electrical papers*, published by the International Electrotechnical Commission (IEC).

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.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 9 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Introduction

This specification has been prepared as the result of work carried out by the Working Group "Paper-Oil" of C.I.G.R.E. Study Committee "Insulating Oils". It is based on the experimental procedure described in the French Specification AFNOR NF T 12 005.

To obtain values of the degree of polymerization which are reproducible in different laboratories, the requirements of the present test procedure shall be observed in all respects. However, it may be found that the sample is not satisfactorily dissolved after the preferred solution time of 2 h, in such a case this time may be increased up to a maximum of 18 h.

For a sample of aged paper, there is little risk that this increase of solution time will cause further significant degradation.

1 Object of specification

This specification describes a standard method for determining the average viscometric degree of polymerization (abbreviated $\overline{DP}_v$) of new or aged electrical papers. The determination is made by measuring the intrinsic viscosity of a solution of the paper in an appropriate solvent.

The degree of polymerization (or the degree of condensation) of a particular cellulose molecule is the number of anhydrous- β -glucose monomers, $C_6H_{10}O_5$, in the cellulose molecule.

Within a sample of paper, all the cellulose molecules do not have the same degree of polymerization so that the mean value measured by viscometric methods is not necessarily the same as that which may be obtained by, for instance, osmotic or ultracentrifuging methods.

2 Field of application

This specification may be applied to all papers made from "pure" (unmodified) cellulose, as used in transformer, cable or capacitor manufacture. It applies to new or aged papers. For information, Appendix D shows an example of statistical distribution of $\overline{DP}_v$ values for new papers intended for the insulation of transformers, together with information relative to cable and capacitor papers. Nevertheless, where evaluating the decomposition stage of aged papers, care should always be taken to use, as a reference, the $\overline{DP}_v$ value of a new paper of the very same origin, $\overline{DP}_v$ of new papers being a function of their specific gravity and of their manufacturing process.

The methods described can also be used for the determination of the intrinsic viscosity of solutions of chemically modified papers, provided that these dissolve completely in the selected solvent. The method described shall be used with caution when it is applied to loaded papers.

3 Principle

The method used is to measure the specific viscosity¹⁾ of a solution of the paper in cupriethylene-diamine. From this measurement the intrinsic viscosity of the solution is deduced, and from this the degree of polymerization is easily calculated.

The specific viscosity η_s is defined by:

$$\eta_s = \frac{\text{viscosity of paper solution} - \text{viscosity of solvent}}{\text{viscosity of solvent}}$$

The intrinsic viscosity $[\eta]$ is defined by:

$$\lim_{c \rightarrow 0} \left[\frac{\eta_s}{c} \right]$$

where c is the concentration of the solution.

The average viscometric degree of polymerization $\overline{DP}_v$ (the ratio of the mean molecular mass indicated viscometrically to the molecular mass of the monomeric unit is related to the intrinsic viscosity $[\eta]$ by the equation:

$$[\eta] = K \cdot \overline{DP}_v^\alpha$$

K and α being characteristic coefficients of the polymer-solvent system (paper, cupriethylene diamine) and of the monomer.

The intrinsic viscosity $[\eta]$ is calculated from the specific viscosity η_s and the concentration c by Martin's empirical formula:

$$\eta_s = [\eta] \cdot c \cdot 10^{k \cdot [\eta] \cdot c}$$

¹⁾ Solutions of cellulose are non-Newtonian fluids (their viscosity decreases as the flow velocity increases — sometimes known as "structural viscosity"). Although the viscosity of dilute solutions varies only slightly with the gradient of the velocity modulus, it is necessary to comply strictly with the conditions laid down in this specification to ensure maximum accuracy (the gradient of the velocity modulus shall not exceed 300 to 500 s⁻¹).