



SLOVENSKI STANDARD
oSIST prEN IEC 61203:2023
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Sintetični estri - Smernice za vzdrževanje in uporabo v električni opremi

Synthetic esters - Guidelines for maintenance and use in electrical equipment

Synthetische organische Ester für elektrotechnische Zwecke - Leitlinie zur Wartung von Transformator-Estern in Betriebsmitteln

Esters organiques de synthèse à usages àlectriques - Guide de maintenance des esters pour transformateurs dans les matériels

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NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SYNTHETIC ESTERS –
GUIDELINES FOR MAINTENANCE AND USE IN ELECTRICAL EQUIPMENT**
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This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication 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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

The National Committees are requested to note that for this publication the stability date is 20XX.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

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1 INTRODUCTION

2 Synthetic esters are increasingly being used in transformers and electrical equipment employed in
3 electrical power generation, transmission, distribution and industrial applications.

4 Synthetic esters are used in transformers over a wide range of voltage classes. These may be sealed or
5 free breathing. Synthetic esters should only be used in transformers where the internal insulation system
6 has been designed to run with these liquids, given the different electrical performance of synthetic ester
7 as compared to mineral oil. Refilling mixtures are not covered in the Normative part of this standard.
8 See Annexe B for more information. When in doubt, contact the transformer or liquid manufacturer for
9 more information.

10 Monitoring and maintaining liquid quality is essential to ensure the reliable operation of synthetic ester
11 filled electrical equipment. Codes of practice for this purpose have been established by electrical power
12 authorities, power companies and industries in many countries. A review of current experience reveals a
13 wide variation of procedures and criteria. It is possible, however, to compare the value and significance of
14 standardized liquid tests and to recommend uniform criteria for the evaluation of test data.

15 If a certain amount of liquid deterioration (by degradation or contamination) is exceeded, there is
16 inevitably some erosion of safety margins and the question of the risk of premature failure should be
17 considered. While the quantification of the risk can be very difficult, a first step involves the identification
18 of potential effects of increased deterioration. The philosophy underlying this standard is to furnish users
19 with as broad a base of understanding of liquid quality deterioration as is available, so that they can make
20 informed decisions on inspection and maintenance practices.

21 Synthetic esters are, by most regulations, deemed to be regulated and/or controlled waste. If spills occur,
22 the user shall refer to the regulations applicable to their specific location and requirements set by their
23 local authorities.

24 This International Standard, while technically sound, is mainly intended to serve as a common basis for
25 the preparation of more specific and complete codes of practice by users in the light of local
26 circumstances. Sound engineering judgement will have to be exerted in seeking the best compromise
27 between technical requirements and economic factors.

28 Although there is significant experience going back more than 40 years that experience has been mostly
29 limited to the use of synthetic esters at distribution voltages, typically up to 72.5kV. Experience in large
30 power transformers is increasing, but is currently limited to a smaller number of recently installed units.
31 While the collection of operating data allows for development of this standard, care shall be used when
32 applying the recommended values in particular at voltages at or above 72.5kV.

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

36 The synthetic esters which are the subject of this document shall be handled in compliance with local
37 regulations and supplier's safety datasheets.

38 This document is applicable to synthetic esters, chemicals and used sample containers. The disposal of
39 these items should be carried out according to local regulations regarding their impact on the
40 environment.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SYNTHETIC ESTERS – GUIDELINES FOR MAINTENANCE AND USE IN ELECTRICAL EQUIPMENT

48 1 Scope

49 This document provides procedures and supervision that are required for the use and maintenance of
50 synthetic esters in transformers and other electrical equipment.

51 This document is applicable to synthetic esters, originally supplied conforming to IEC 61099 and other
52 applicable Standards in transformers, switchgear and electrical apparatus where liquid sampling is
53 practical and where the normal operating conditions specified in the equipment specifications apply.

54 This document is also intended to assist the power equipment operator to evaluate the condition of the
55 synthetic ester and maintain it in a serviceable condition. It also provides a common basis for the
56 preparation of more specific and complete local codes of practice.

57 The document includes recommendations on tests and evaluation procedures and outlines methods for
58 reconditioning and reclaiming the liquid, when necessary.

59

60 2 Normative references

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

64 IEC 60156, *Insulating liquids – Determination of the breakdown voltage at power frequency – Test
65 method*

66 IEC 60247, *Insulating liquids – Measurement of relative permittivity, dielectric dissipation factor ($\tan \delta$)
67 and d.c. resistivity*

68 IEC 60475, *Method of sampling liquid dielectrics*

69 IEC 60567, *Oil-filled electrical equipment - Sampling of gases and analysis of free and dissolved gases -
70 Guidance*

71 IEC 60599, *Mineral oil-filled electrical equipment in service - Guidance on the interpretation of dissolved
72 and free gases analysis*

73 IEC 60666, *Detection and determination of specified additives in mineral insulating oils*

74 IEC 60814, *Insulating liquids – Oil-impregnated paper and pressboard – Determination of water by
75 automatic coulometric Karl Fischer titration*

76 IEC 60970, *Insulating liquids – Methods for counting and sizing particles*

77 IEC 61099, *Insulating liquids - Specifications for unused synthetic organic esters for electrical purposes*

78 IEC 61125, *Unused hydrocarbon based insulating liquids – Test methods for evaluating the oxidation
79 stability*

- 80 IEC 61619, *Insulating liquids – Contamination by polychlorinated biphenyls (PCBs) – Method of*
81 *determination by capillary column gas chromatography*
- 82 IEC 62021-3, *Insulating liquids – Determination of acidity – Part 3: Test methods for non-mineral*
83 *insulating oils*
- 84 IEC 62961 - *Insulating liquids – Test methods for the determination of interfacial tension of insulating*
85 *liquids - Determination with the ring method*
- 86 ISO 2049, *Petroleum products – Determination of colour (ASTM scale)*
- 87 ISO 2211, *Liquid chemical products — Measurement of colour in Hazen units (platinum-cobalt scale)*
- 88 ISO 2592, *Petroleum products - Determination of flash and fire points - Cleveland open cup method*
- 89 ISO 3016, *Petroleum products – Determination of pour point*
- 90 ISO 3104, *Petroleum products – Transparent and opaque liquids – Determination of kinematic viscosity*
91 *and calculation of dynamic viscosity*
- 92 ISO 3675, *Crude petroleum and liquid petroleum products -- Laboratory determination of density*
93 *-- Hydrometer method*
- 94 ISO 4406, *Hydraulic liquid power – Liquids – Method for coding the level of contamination by solid*
95 *particles*
- 96 ISO 5661, *Petroleum products — Hydrocarbon liquids — Determination of refractive index*
- 97 ISO 12185, *Crude Petroleum and Petroleum Products - Determination of Density - Oscillating U-Tube*
98 *Method*
- 99 ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*
- 100 ASTM D97, *Standard Test Method for Pour Point of Petroleum Products*
- 101 ASTM D1500, *Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)*
- 102 ASTM D1524, *Standard Test Method for Visual Examination of Used Electrical Insulating Liquids in the*
103 *Field*
- 104 ASTM D2129, *Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt*
105 *Scale)*
- 106 ASTM D3455, *Standard Test Methods for Compatibility of Construction Material with Electrical Insulating*
107 *Oil of Petroleum Origin*
- 108 ASTM D4052, *Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital*
109 *Density Meter*
- 110 ASTM D5950, *Standard Test Method for Pour Point of Petroleum Products (Automatic Tilt Method)*
- 111 ASTM D6922, *Standard Test Method for Determination of Homogeneity and Miscibility in Automotive*
112 *Engine Oils*
- 113 ASTM D7042, *Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger*
114 *Viscometer (and the Calculation of Kinematic Viscosity)*
- 115 ASTM D7155, *Standard Practice for Evaluating Compatibility of Mixtures of Turbine Lubricating Oils.*
- 116 ASTM D7752, *Standard Practice for Evaluating Compatibility of Mixtures of Hydraulic Liquids*

117 DIN 51423, *Testing of mineral oils - Part 2: Measurement of the relative refractive index with the Abbe-*
118 *refractometer*

119 3 Terms and definitions

120 For the purposes of this document, the following terms and definitions apply.

121 ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- 122 - IEC Electropedia: available at <http://www.electropedia.org/>
- 123 - ISO Online browsing platform: available at <http://www.iso.org.obp>

124

125 Note 1 to entry: ASTM and IEEE terminology are available at:

- 126 - ASTM D2864: Standard Terminology Relating to Electrical Insulating Liquids and Gases [9]
- 127 - IEEE C57.12.80 Standard Terminology for Power and Distribution Transformers [10]

128

129 3.1 Local regulations

130 Regulations pertinent to the particular process in the country concerned

131 Note 1 to Entry: These regulations may be defined by local, regional, or national legislation or even by the owner or operator of the
132 equipment itself. They are always to be considered as the most stringent of any combination thereof. It is the responsibility of each
133 user of this standard to familiarize themselves with the regulations applicable to their situation. These regulations refer to
134 operational, environmental or health and safety issues. A detailed risk assessment will usually be required.

135

136 3.2 Routine tests (Group 1)

137 Minimum tests required to monitor the liquid and to ensure that it is suitable for continued service

138 Note 1 to Entry: If the results obtained from these tests do not exceed recommended action limits usually no further
139 tests are considered necessary until the next regular period for inspection but, under certain perceived conditions,
140 complementary tests may be deemed prudent.

141 3.3 Complementary tests (Group 2)

142 Additional tests, which may be performed to obtain further specific information about the quality of the
143 synthetic ester, and may be performed to assist in the evaluation of the synthetic ester for continued use
144 in service

145 3.4 Special investigative tests (Group 3)

146 Tests performed mainly to determine the suitability of the synthetic ester for the type of equipment in use
147 and to ensure compliance with environmental and operational considerations

148

149 4 Categories of equipment

150 In order to take into account, the different user requirements, equipment has been placed in various
151 categories as shown in Table 1 below.

152 **Table 1 - Categories of equipment**

Category	Transformers and Reactors
Category A	Power transformers / reactors with a nominal system voltage above 170 kV. Also, power transformers of any rated voltage where continuity of supply is vital and similar equipment for special applications operating under onerous conditions.
Category B	Power transformers / reactors with a nominal system voltage above 72,5 kV and up to and including 170 kV (other than those in Category A).
Category C	Power transformers / reactors for MV/LV application e.g. nominal system voltages up to and including 72,5 kV (distribution transformers) and traction transformers (other than those in Category A).
	Instrument Protection Transformers
Category D	<i>Instrument / protection transformers with a nominal system voltage above 170 kV.</i>

Category E	Instrument / protection transformers with a nominal system voltage up to and including 170 kV.
Tap-changers	
Category F	Diverter tanks of On-Load Tap-Changers (OLTC), including combined selector/diverter tanks.
<p>Note 1 Separated selector tanks of on-load tap-changers belong to the same category as the associated transformer.</p> <p>Note 2 Regardless of size or voltage, a risk assessment may justify condition-monitoring techniques usually appropriate to a higher classification.</p> <p>Note 3 For practical and economic reasons, some electrical utilities may decide that their small transformers up to 1 MVA and 36 kV are not included in this classification. Routine monitoring programmes may not be considered economical for this type of equipment. Where a monitoring programme is required for these transformers, the guidelines given for category C should be adequate.</p> <p>Note 4 Due to the very limited number of actual applications, recommended limits are not yet available for Categories D and E. Therefore, these categories are here reported only for IEC 60422 consistency and possibly limits will be added at the next revision if feedback will exist.</p> <p>Note: For Category F, limit values are specified for breakdown voltage (BDV) and water content only. For other parameters relevant to the tap-changer liquid, values may be adopted from the category as the associated transformer, and may also be applicable to vacuum type tap changers.</p>	

153

154 5 In-service synthetic ester diagnostic tests

155 Many tests may be applied to in-service synthetic esters in electrical equipment. The tests listed in Table
 156 2 are considered sufficient to determine whether the condition of the in-service synthetic ester is
 157 adequate for continued operation and to suggest the type of corrective action required, if needed. When
 158 more than one test method is reported, the reference method is the first one listed and it is also reported
 159 in paragraph 9. In case of dispute this method shall be used.

160 Note The tests are not listed in order of priority within a grouping.

161

Table 2 – Diagnostic tests for in-service synthetic esters

	Property	Sub-clause	Method
Group 1 – Routine Tests	Colour	9.2	ISO2049
	Appearance (Visual assessment)		Clear, free from sediment and suspended matter
	Breakdown voltage	9.3	IEC 60156
	Water content	9.1	IEC 60814
	Acidity (neutralization number)	9.5	IEC 62021-3
Group 2 – Complementary Tests	Dielectric dissipation factor (DDF)	9.6	IEC 60247
	Fire point	9.7	ISO 2592 (ref method) or ASTM D92
	Interfacial tension (IFT)	9.8	IEC 62961
	Density	9.9	ISO 12185 (ref method) ISO 3675 or ASTM D7042
	Additives (antioxidant) content	9.11	IEC 60666

Group 3 – Special Investigative Tests (informative)	Pour point	9.10	ISO 3016 (reference method) manual method ASTM D97 or automated tilt method ASTM D 5950
	Viscosity	9.4	ISO 3104 (ref method) or ASTM D7042
	Particles - identification - counting and sizing	9.12	IEC 60970B IEC 60970A
	Liquid Compatibility and miscibility	9.13	ASTM D7752 or D7155 and ASTM D6922
	Refractive Index	9.15	DIN 51423-1 or ISO 5661 (ref method)

162

163

164 6 Evaluation of synthetic esters in new equipment

165 A substantial proportion of electrical equipment is supplied to the final user already filled with synthetic
 166 ester. In these cases, as the synthetic ester has already come into contact with insulating and other
 167 materials, it can no longer be considered as “unused synthetic ester” as defined in IEC 61099. Therefore,
 168 its properties shall be regarded as those applicable to a synthetic ester in new equipment prior to
 169 energisation. Synthetic ester properties for new equipment shall be appropriate to the category and
 170 functions of the transformers and reactors (see Table 3).

171 Note As the characteristics of the synthetic ester in new equipment prior to energization are an integral part of that
 172 equipment design, the user may request these characteristics to be better than the minimum standards suggested in
 173 Table 3, which are based on the experience of many years of operating practice.

174

175 **Table 3 - Recommended limits for Synthetic esters properties after filling in new**
 176 **electrical equipment prior to first energization**

Property	Highest voltage for equipment Um (kV)		
	≤ 72,5 kV	72,5 < Um ≤ 170 kV	> 170 kV
Appearance	Clear, free from sediment matter		
Colour	ISO 2049, ASTM D 1500 max 1 (ISO 2211 Max. 300 Hazen)		
Breakdown voltage (kV)	Min 55	Min 60	Min 60
Water content (mg/kg) ^a	Max 200	Max 150	Max 100
Acidity (mg KOH/g)	Max 0.08		
Dielectric dissipation factor at 90 °C	Max 0,1		
Fire point (°C)	≥ 300		
Particles	See section 9.13		
PCB content (mg/kg)	Manufacturers shall declare their product does not contain PCB according to local regulation		