
## ABSTRACT

There is a large number of national and international standards covering various aspects of transformer insulating fluids such as specifications, sampling techniques, testing procedures, maintenance, diagnostics, and so on. The present paper summarises available standards and technical brochures related to the above aspects of the insulating fluid for an immediate reference to the user



## KEYWORDS

fluids, liquids, standards, transformer oil

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# Standards relevant to transformers – Part VIII

## Insulating liquids

### 1. Introduction

Insulating fluids in combination with solids have been used in transformers for more than a century. Insulating fluid in a transformer serves multipurpose roles such as an insulating medium, enhancing the insulation properties of solid insulating materials like kraft paper, carrying away the heat from copper and core to cooler, and, more importantly, as a condition monitoring information carrier.

Mineral oils have dominated as an insulating fluid for many decades. However, new fluids with different molecular structures are also presently used.

There is a large number of national and international standards covering various aspects of transformer insulating fluids such as specifications, sampling techniques, testing procedures, maintenance, diagnostics, and so on. CIGRE also has published several technical brochures on similar topics.

The present paper summarises available standards and technical brochures related to the above aspects of the insulating fluid for an immediate reference to the user.

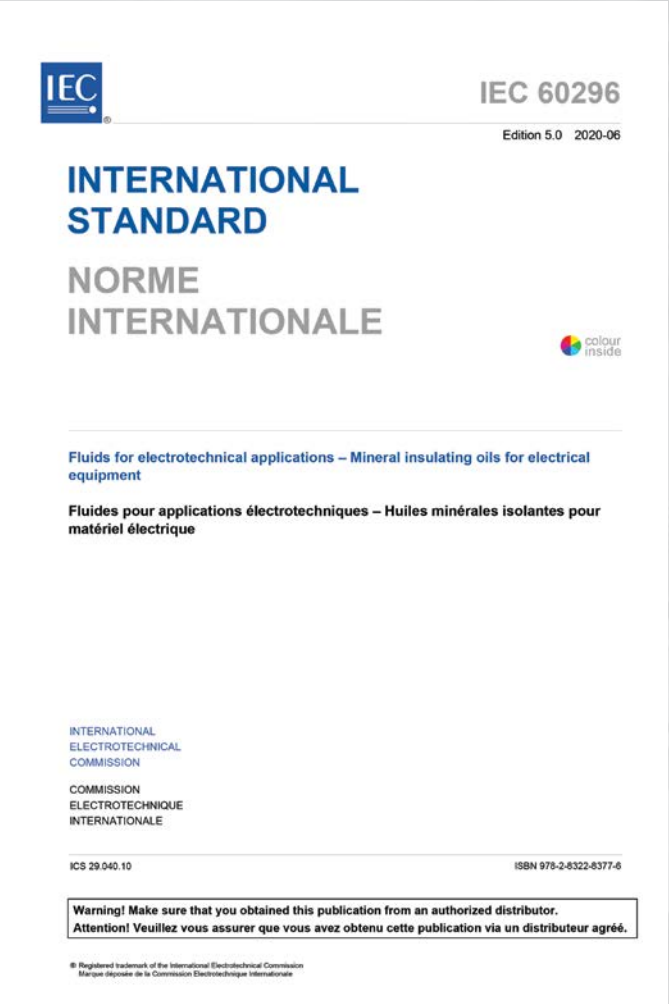
### 2. Standards

| Subject | IEC Standard / CIGRE TB | ANSI / IEEE standard | Indian standard |
|---|---|---|---|
| Mineral oil – specifications | 60296 Ed 5.0 – 2020 (2012) | ASTM D3487-16 | IS 335 – 2018 (effective 2019-04-30) |
| Mineral oil – inhibited | | | IS 12463 (superseded by IS335 – 2018) |
| Mineral oil – recycled oil | 62701 Ed 1.0 – 2014 (withdrawn) | BS 148 – 2020 (2009) | |
| Functional requirements of insulating liquids for use in power transformers | TR 60076-26: 2020 | | |
| Silicone oil specifications | 60836 Ed 3.0 – 2015 (2005) | ASTM D4652-20 | |
| Natural ester fluid | 62770 Ed 1.0 – 2013 | ASTM D6871-17 | IS:16659 – 2017 |

| Subject | IEC Standard / CIGRE TB | ANSI / IEEE standard | Indian standard |
|---|---|---|---|
| Synthetic organic ester oil specifications | 61099 Ed 2.0 – 2010 (1993) | | IS:16081 – 2013 |
| Synthetic aromatic oil specifications | 60867 Ed 2.0 1993 – (1986) | | |
| High molecular weight hydrocarbons | | ASTM D 52222 | |
| Dielectric performance of insulating fluids | CIGRE TB 856 – 2021 – Dielectric performance of insulating liquids for transformers | | |
| Sampling of insulating liquids | 60475 Ed 5.0 – 2022 (2011, 1974) | ASTM D923-15 | 6855 – 2017 |
| Liquid sampling for DGA | (60567 – 2011) | (ASTM D3613-98 – withdrawn) | |
| Breakdown voltage | 60156 Ed 3.0 – 2018 (1995) | ASTM D1816-12 | IS 2026 (Part 2): 2010 / IEC 60076-2 (1993) |
| Partial discharge inception voltage – test procedure | 6792 (dual with IEC 60156) | | |
| Viscosity | ISO 3104 | C57.12.90 - 2010 (2010) | IS 2026 (Part 2): 2010 / IEC 60076-2 (1993) |
| Pour point | ISO 3016 | | IS1448 (Part 10) – 2015 |
| Flash point | ISO 2719 (by PMCC) | | IS1448 (Part 10) – 2015 |
| Flash and fire point | ISO 2592 (by COC) | | |
| Density | ISO 3675 (hydrometer method)<br>ISO 12185 (oscillating U-tube method) | | 1448 (Part 16) – 2014 |
| Dielectric dissipation factor along with permittivity and resistivity | 60247 Ed 3.0 – 2004 (1978) | | 6262 – 1971 |
| Dielectric dissipation factor –by conductance and capacitance | 61620 Ed 1.0 – 1998 | | 16086 – 2013 (by C&C method) |
| Particle count | 60970 Ed 2.0 – 2007 (1989) | | 13236 – 2013 |
| Appearance | 60296 Ed 5.0 – 2020 (2012) | ASTM D1524-15 | IS 335 – 2018 (effective 2019-04-30) |
| Colour in Hazen units | ISO2211 | ASTM D1500-12 | |
| Acidity | 62021-1 Ed 1.0 – 2003 | | 1448 (Part 2) – 2007 |
| Interfacial tension | 62961 Ed 1.0 – 2018<br>EN 14210 | ASTM D971-20 | 6104 – 1971 |

| Subject | IEC Standard / CIGRE TB | ANSI / IEEE standard | Indian standard |
|---|---|---|---|
| Total sulphur content | ISO EN 14596 | ASTM D4294-21 | |
| Corrosive sulphur | DIN 51353 | ASTM D 1275 B-15 | |
| Potential corrosive sulphur | 62535 Ed 1.0 – 2008 | | 16310 – 2017 |
| DBDS (dibenzyl disulphide) content | 62697-1 Ed 1.0 – 2012 | | 16497 (Part 1) – 2017 |
| Metal passivator additives | 60666 Ed 2.0 – 2010 (1979) | | 13631 – 2017 (dual with IEC 60666) |
| Oxidation inhibitor content | 60666 Ed 2.0 – 2010 (1979) | | 13631 – 2017 (dual with IEC 60666) |
| Oil oxidation stability | 61125 Ed 2.0 – 2018 (1992) | ASTM D2440-13<br>ASTM D2112-15 | 12422 – 2017 (dual with IEC 61125) |
| Oil oxidation characteristics of mineral oil | | ASTM D1904 (obsolete) | |
| 2-furfural content | 61198 Ed 1.0 – 1993<br>CIGRE TB 494 – 2012 | ASTM D 5837-15 | 15668 (dual with IEC 61198) |
| Interpretation of furfural and $CO_2$ for paper aging | TR 62874 – 2015 | | |
| Methanol and ethanol – quantitative determination | TR 63025 – 2021<br>CIGRE TB 850 – 2021 | ASTM D8086-20 | |
| Water content in oil | 60814 Ed 2.0 – 1997 (1985) | ASTM D1533-12 | 13567 – 2018 (dual with IEC 60814) |
| Gas content in oil | | ASTM D 2945 (withdrawn) | |
| PCA content, % | IP346 | | |
| PCB content | 61619 Ed 1.0 – 1997 | | 16082 – 2013 (dual with IEC 61619) |
| DGA – interpretation of results | 60599 Ed 4.0 – 2022 (2015)<br>CIGRE TB 296-2006; TB 771-2019 – Advances in DGA interpretation | C57.104 – 2019 (2008) | |
| DGA – bushing oil | TS 61464 Ed 1.0 – 1998<br>60599 Ed 3.0 – 2015 – Section A.5 | C57.152 – 2013 – Annexure B | |

| Subject | IEC Standard / CIGRE TB | ANSI / IEEE standard | Indian standard |
|---|---|---|---|
| DGA – OLTC oil | 60599 Ed 3.0 – 2015 – Section A.7<br>CIGRE TB 443 – 2010 – DGA in OLTC and non-mineral oils | C57.139 – 2015 | |
| DGA – during factory test | 61181 Ed 2.0 – 2007 + Amendment 1 – 2012 | C57.130 – 2015 | IS:16085: 2013 (dual with IEC 61181) |
| DGA – sampling of gases | 60567 Ed 4.0 – 2011 (2005) | ASTM D3305 (withdrawn) | |
| DGA of oil – test method | | ASTM D 3612-11 (02) | |
| Testing for combustible gases in gas space using portable meters | | ASTM D3284-05 | |
| DGA – silicone oil-filled transformers | | C57.146 – 2005 | |
| DGA – synthetic and natural-ester-filled transformers | CIGRE TB 443 – 2010<br>DGA in non-mineral oils and OLTC | C 57.155 – 2014 | IS: 16785: 2018 |
| Fire hazard testing – assessing fire hazards of insulating liquids | 60695-1-40 Ed 1.0 – 2013 | | |
| Test method for gases of insulating liquids under thermal stress | | ASTM D7150-13 | |
| Reclamation of oil | | C57.637 – 2015 | |
| Mineral oil maintenance | 60422 Ed 4.0 – 2013 (2005) | C57.106 – 2015 (2006) | |
| Silicon oil maintenance | 60944 Ed 1.0 – 1988 | C57.111 – 1989 | |
| Synthetic organic ester maintenance | 61203 Ed 1.0 – 1992 | | IS:16099 – 2013 |
| Natural ester fluid maintenance | 62975 Ed 1.0 – 2021<br>CIGRE TB 436 – 2010<br>Experience in service with new insulating liquids | C57.147 – 2008 | |
| High molecular weight hydrocarbon fluid maintenance | | C57.121 – 1998 | |
| Gassing tendency | IEC 60628 Ed 2.0 – 1985 (1978) | | |
| Stray gassing | CIGRE TB 296 | ASTM D7150 | |
| Electrostatic charging tendency | CIGRE TB 170 | | |
| Foaming test | ISO 6247 | | |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IEC 60296

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Fluides pour applications électrotechniques – Huiles minérales isolantes pour matériel électrique

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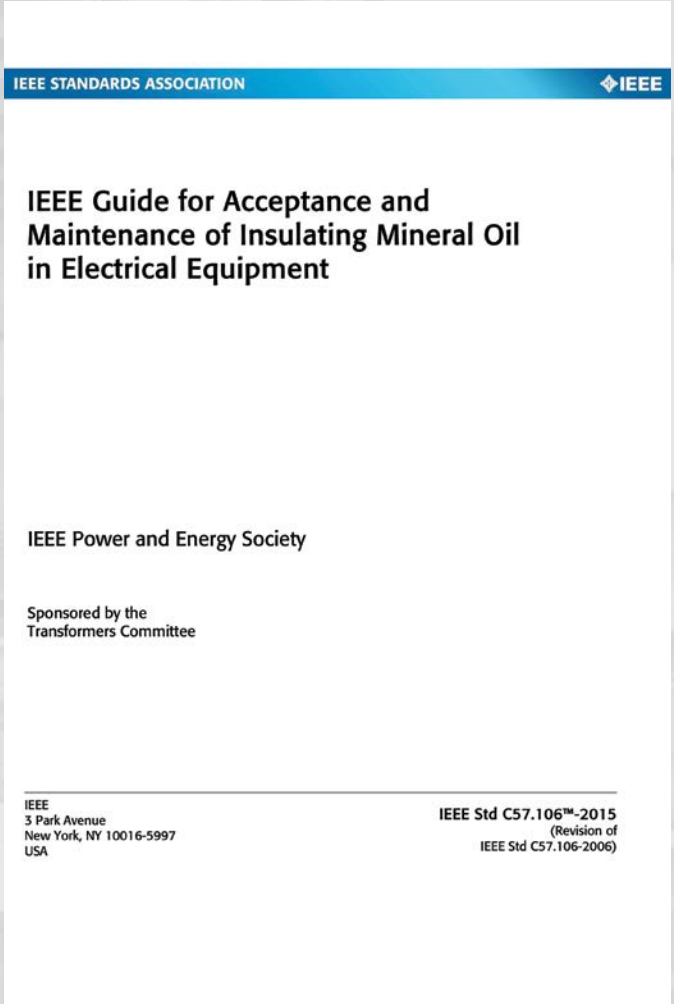
IEEE STANDARDS ASSOCIATION

IEEE

IEEE Guide for Acceptance and Maintenance of Insulating Mineral Oil in Electrical Equipment

IEEE Power and Energy Society

Sponsored by the Transformers Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std C57.106™-2015
(Revision of
IEEE Std C57.106-2006)

**DGA is a widely used diagnostic method for oil transformers and is covered by various international and national standards as well as technical brochures**

## 3. Conclusion

The insulating liquid is an important part of the transformer. This paper has summarised various international / national standards covering transformer insulating fluids as a ready-reference to transformer designers and users.

## Authors


**P. Ramachandran** started his career in the transformer industry in 1966 at TELK, Kerala, a Hitachi Joint venture, in India. He worked with ABB India during 1999-2020. He has more than 50 years of experience in the design and engineering of power products, including power transformers, bushings, and tap-changers. He received a Bachelor of Science Degree in Electrical Engineering from the University of Kerala, India, and a Master of Business Administration Degree from Cochin University, India. He is a Fellow of the Institution of Engineers (India), and he represented India in CIGRE Study Committee A2 for transformers during 2002 – 2010.

**A. S. Jhala** started his professional career with T&R India Limited Ahmedabad in 2005 and is now Deputy General Manager. He has been associated with various functions during his career viz. Testing, Designs and Technology Development. He was actively involved with several development projects including establishment and institutionalizing licensed technology for 765 kV transformers and 400 / 765 kV shunt reactors. He has been associated with Bureau of Indian Standards (BIS) responsible for standardisation activities in India, Central Board of Irrigation and Power (CBIP) and Indian Electrical and Electronics Manufacturers Association (IEEMA). He is also on the board of Managing committee of Electrical Research and Development Association (ERDA). He has contributed about 30 technical papers in national / international seminars.