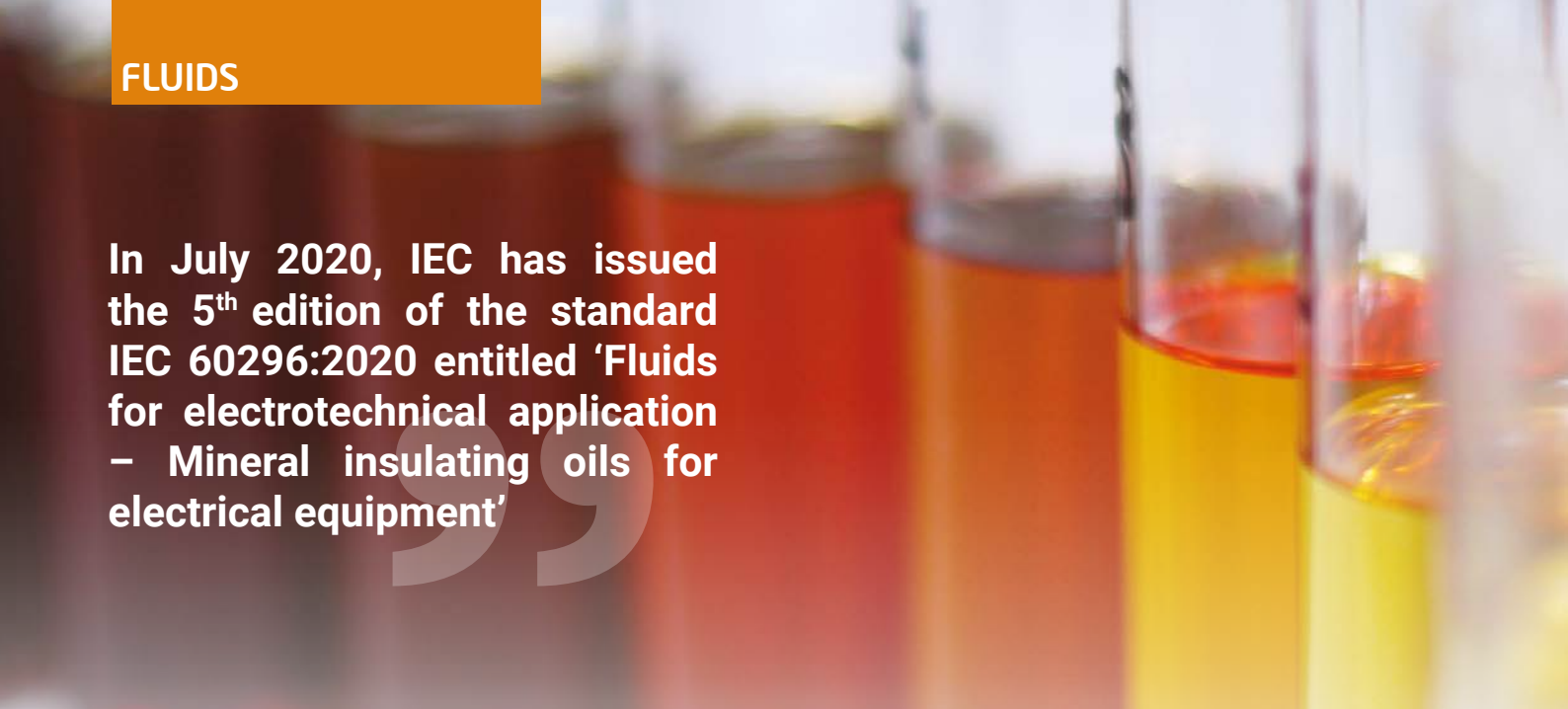

In July 2020, IEC has issued the 5th edition of the standard IEC 60296:2020 entitled 'Fluids for electrotechnical application – Mineral insulating oils for electrical equipment'

IEC 60296 (Ed. 5) – a standard for classification of mineral insulating oil on performance and not on the origin

1. Introduction

TIn July 2020, the 5th edition of IEC 60296 has been published (Fig. 1). The title of the standard is as follows: Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment.

ABSTRACT

The revision of the standard IEC 60296, Ed. 4.0 resulting in IEC 60296, Ed. 5.0 had three main aims: to set up a standard based on the performance of mineral insulating oil and not on the origin, to distinguish between good and bad mineral insulating oils, and to protect the user providing adequate testing parameters. In addition, there are several exciting news and changes in the new version of the standard compared to the previous versions.

KEYWORDS

classification, mineral insulating oils, performance

IEC 60296 is one of the oldest (first edition 1969) and most developed specifications on insulating liquids. The developing on the oil market and the environmental issues require high knowledge from the users and more possibilities to assure the right quality of a certain brand.

2. History

The FDIS (Final Draft International Standard) of the standard IEC62701 *Rerefined and reclaimed mineral insulating oils for transformers and switchgear* was approved in September 2013. Part of the industry saw discrimination of reprocessed oils in respect of unused ones. SMB (Standardization Management Board) withdrew IEC 62701.

SMB instructed TC 10 (Technical committee Fluids for Electrotechnical Application) to revise IEC 60296 so that it becomes a standard for mineral insulating oils irrespective of their source. The standard shall include requirements for declaration of the provenance of the oils without bias to the origin. The user / purchaser may then make any preference declared in their purchasing process.

As a consequence, MT 38 has been established in TC 10 with the following task – to revise IEC 60296 so that it becomes a standard for mineral insulating oils, irrespective of their source.

Mrs. Ivanka Atanasova-Höhlein has been nominated as MT 38 convenor.

In this article, the convenor presents her personal point of view on IEC 60296 5th edition. Some of the points are not new. Nevertheless, they will be mentioned in order to elucidate their meaning. New items will be explicitly marked.

For the first time we have a standard which is based only on performance, not on the origin. Nevertheless, it must be clear that the described properties are those that have turned out to be important in the course of time. A standard reflects the state-of-the-art practices and

is adaptive in case of damages and accidents caused by the material described. Raw materials such as crude oil and specially processed oil such as transformer oil are short resources and must be economically used. This is not just a temporary statement but substantial necessity for mankind survival. Present methods for oil processing have been developed using adsorption methods, such as the ones in the case of reclaiming (regeneration), and mild hydrogenation, as in case of re-refined oils. Chemical engineering and technology are further developing and able to rejuvenate already aged transformer oils. The properties of such oils shall not differ from those of unused transformer oils.

3. Classification in classes for labelling (New, Part 5.1.4 of IEC 60296)

Regarding labelling mineral insulating oils can be:

Unused mineral oil (V for „virgin")

- Mineral insulating oil, obtained by refining, modifying and / or blending petroleum products and other hydrocarbons (e.g., from gas source); such oil has not been used in, nor has it been in contact with electrical equipment or other equipment not required for manufacture, storage, or transport

Recycled mineral oil (R)

- Mineral oil previously used in electrical equipment that has been subjected to re-refining or reclaiming (regeneration) after removal from the electrical equipment
- It is important that in its „first life" the oil has been used for the same purposes and also that the reprocessing takes part after removal from the electrical equipment. This is important since an oil reprocessing within equipment will also be influenced by the other materials experienced the ageing.

Recycled mineral oils are:

- Reclaimed (regenerated) – recycled mineral insulating oil subjected to chemical and physical processing to reduce soluble and insoluble contaminants

A new standard IEC 60296 (Ed. 5) reflects the state-of-the-art practices and is adaptive in case of damages and accidents caused by the material described

- Re-refined – recycled mineral insulating oil, subjected to a process similar to that used for the production of unused mineral oil

Both oil groups unused and recycled can be uninhibited (U), trace inhibited (T), or inhibited (I). The classification is based on the quantity of the oxidation inhibitor, which is defined as di-t-butyl-p-cresol (DBPC) or di-t-butyl-phenol (DBP).

4. Classification in classes for application (Part 5.1.1 of IEC 60296)

According to IEC 60296 (Ed. 5), there are two classes for application:

- Transformer oils (T)
- Low-temperature switchgear oils (S)

5. Classification on performance – Two types – A and B (New, Part 5.1.1. of IEC 60296)

Within the transformer oils, two groups of oils are defined: Type A (Table 1) and Type B (Table 2).

- Type A insulating oils are fully inhibited (I) and deliver higher oxidation stability than Type B.
- Type B insulating oils can be uninhibited (U), trace inhibited (T), or fully inhibited (I), deliver good resistance to oil degradation, and provide good oxidation stability.

In Table 1 and Table 2, the most important functional properties are listed. These are the properties where limit values are necessary and available.


IEC

IEC 60296

Edition 5.0 2020-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment

Fluides pour applications électrotechniques – Huiles minérales isolantes pour matériel électrique

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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Figure 1. Screenshot from the IEC website

Table 1 – General specifications, Type A (fully inhibited high-grade oils)

Property	Test method	Limits	
		Transformer oil	Low-temperature switchgear oils
1 – Function			
Viscosity at 40 °C	ISO 3104 a or ASTM D7042	Max. 12 mm^2/s	Max. 3,5 mm^2/s
Viscosity at –30 °C [b]	ISO 3104 a or ASTM D7042	Max. 1800 mm^2/s	–
Viscosity at –40 °C [c]	IEC 61868	–	Max. 400 mm^2/s
Pour point	ISO 3016	Max. – 40 °C	Max. – 60 °C
Water content	IEC 60814	Max. 30 mg/kg [d] / 40 mg/kg [e]	
Breakdown voltage	IEC 60156	Min. 30 kV / 70 kV [f]	
Density at 20 °C	ISO 12185 a or ISO 3675 or ASTM D7042	Max. 895 kg/m^3	
DDF at 90 °C	IEC 60247 a or IEC 61620	Max. 0,005	
2 – Refining / stability			
Colour	ISO 2049	L0,5 (less than 0,5)	
Appearance	–	Clear, free from sediment and suspended matter	
Acidity	IEC 62021-2 a or IEC 62021-1	Max. 0,01 mg KOH/g	
Interfacial tension	IEC 62961 a or ASTM D971	Min. 43 mN/m	
Total sulphur content	ISO 14596 a or ISO 8754	Max. 0,05 %	
Corrosive sulphur	DIN 51353	Not corrosive	
Potentially corrosive sulphur	IEC 62535	Not corrosive	
DBDS	IEC 62697-1	Not detectable (< 5 mg/kg)	
Inhibitors of IEC 60666	IEC 60666	(I) Inhibited oil: 0,08 % to 0,40 %	
Metal passivator additives of IEC 60666	IEC 60666	Not detectable (< 5 mg/kg), or as agreed upon with the purchaser	
Other additives		See [g]	
2-furfural and related compounds content	IEC 61198	Not detectable (< 0,05 mg/kg) for each individual compound	
Stray gassing under thermo-oxidative stress	Procedure oil saturated with air in the presence of copper	Non stray gassing:	
		< 50 µl/l of hydrogen (H_2) and < 50 µl/l methane CH_4) and < 50 µl/l ethane (C_2H_6)	
3 – Performance			
Oxidation stability	IEC 61125: Test duration (I) Inhibited oil: 500 h	For oils with other antioxidant additives and metal passivator additives	
– Total acidity [h]	4.8.4 of IEC 61125:2018	Max. 0,3 mg KOH/g	
– Sludge [h]	4.8.1 of IEC 61125:2018	Max. 0,05 %	
– DDF at 90 °C [h]	4.8.5 of IEC 61125:2018	Max. 0,050	
4 – Health, safety and environment (HSE) i			
Flash point	ISO 2719	Min. 135 °C	Min. 100 °C
PCA content [j]	IP 346	< 3 %	
PCB content	IEC 61619	Not detectable (< 2 mg/kg)	

[a] Reference method
[b] This is the standard LCSET for a transformer oil and can be modified depending on the climatic condition of each country. Pour point should be minimum 10 °C below LCSET.
[c] Standard LCSET for low temperature switchgear oil
[d] For bulk supply
[e] For delivery in drums and IBC
[f] After laboratory treatment
[g] The supplier shall declare the chemical family and function of all additives, and the concentrations in the cases of inhibitors, antioxidants and passivators.
[h] At the end of oxidation stability tests
[i] In some countries there can be additional requirements, e.g., REACH in the EU.
[j] Some individual PAH compounds can be determined by EN 16143.

Table 2. General specifications, Type B (uninhibited and inhibited standard grade oils)

Property	Test method	Limits	
		Transformer oil	Low-temperature switchgear oils
1 – Function			
Viscosity at 40 °C	ISO 3104 [a] or ASTM D7042	Max. 12 mm^2/s	Max. 3,5 mm^2/s
Viscosity at –30 °C [b]	ISO 3104 [a] or ASTM D7042	Max. 1,800 mm^2/s	–
Viscosity at –40 °C [c]	IEC 61868	–	Max. 400 mm^2/s
Pour point	ISO 3016	Max. –40 °C	Max. – 60 °C
Water content	IEC 60814	Max. 30 mg/kg [d] / 40 mg/kg [e]	
Breakdown voltage	IEC 60156	Min. 30 kV/70 kV [f]	
Density at 20 °C	ISO 12185 [a] or ISO 3675 or ASTM D7042	Max. 895 kg/m^3	
DDF at 90 °C	IEC 60247 [a] or IEC 61620	Max. 0,005	
2 – Refining / stability			
Colour	ISO 2049	Max. 1,5	
Appearance	–	Clear, free from sediment and suspended matter	
Acidity	IEC 62021-2 [a] or 62021-1	Max. 0,01 mg KOH/g	
Interfacial tension	IEC 62961 [a] or ASTM D971	Min. 40 mN/m	
Corrosive sulphur	DIN 51353	Not corrosive	
Potentially corrosive sulphur	IEC 62535	Not corrosive	
DBDS	IEC 62697-1	Not detectable (< 5 mg/kg)	
Inhibitors of IEC 60666	IEC 60666	Uninhibited (U): not detectable (< 0,01 %) Trace inhibited (T): ≥ 0,01 < 0,08 % Inhibited oil (I): 0,08 % to 0,40 %	
Metal passivator additives of IEC 60666	IEC 60666	Not detectable (< 5 mg/kg), or as agreed upon with the purchaser	
Other additives		See [g]	
2-furfural and related compounds content	IEC 61198	Not detectable (< 0,05 mg/kg) for each individual compound[h]	
3 – Performance			
Oxidation stability	IEC 61125 Test duration [i] (U) Uninhibited oil: 164 h (T) Trace inhibited oil: 332 h (I) Inhibited oil: 500 h	FFor oils with other antioxidant additives and metal passivator additives	
– Total acidity [j]	4.8.4 of IEC 61125:2018	max. 1,2 mg KOH/g	
– Sludge [j]	4.8.1 of IEC 61125:2018	max. 0,8 %	
– DDF at 90 °C [j]	4.8.5 of IEC 61125:2018	max. 0,500	
4 – Health, safety and environment (HSE)[k]			
Flash point	ISO 2719	Min. 135 °C	Min. 100 °C
PCA content[l]	IP 346	< 3 %	
PCB content	IEC 61619	Not detectable (< 2 mg/kg)	

- Stray gassing under thermo-oxidative stress is not included as a normative test for Type-B mineral oils, because there has been insufficient data to determine the appropriate limits. The requirement for a stray gassing test, as well as the limit values, if stipulated, can be negotiated between the user and supplier.
[a] Reference method
[b] This is the standard LCSET for a transformer oil and can be modified depending on the climatic condition of each country. Pour point should be minimum 10 °C below LCSET.
[c] Standard LCSET for low temperature switchgear oil
[d] For bulk supply
[e] For delivery in drums and IBC
[f] After laboratory treatment
[g] The supplier shall declare the function and chemical family of all additives and the concentrations in the cases of inhibitors antioxidants and passivators.
[h] In agreement with the customer, oils with a higher furfural content can be delivered, when these values do not jeopardise the application.
[i] In some countries there can be lower requirements for oxidation stability.
[j] At the end of oxidation stability tests
[k] In some countries there can be additional requirements, e.g., REACH in the EU.
[l] Some individual PAH compounds can be determined by EN 16143.

Table 3. Meaning of the identifying letter codes in the ordering designation of mineral oil according to IEC 60296

First letter = equipment	**T** – transformer	**S** – switchgear	
Second letter = declaration	**V** – unused (virgin)	**R** – recycled	
Third letter = type	**A** – specification type A	**B** – specification type B	
Fourth letter = antioxidant	**I** – inhibited	**U** – uninhibited	**T** – trace inhibited

Example 1. For order for inhibited high grade recycled oil for transformers: **TRAI**.
Example 2. For order for uninhibited unused oil for transformers: **TVBU**.
Example 3. For order for inhibited high-grade unused oil for switchgear: **SVAI**.
Example 4. For order for trace inhibited recycled oil for switchgear: **SRBT**.

The standard is applicable to specifications and test methods for unused and off-site recycled mineral insulating oils in the delivered state

6. Coding matrix (New, Part 5.1.4. of IEC 60296)

Since there are several possibilities – unused and recycled oils, transformer and switchgear oils, uninhibited, trace inhibited, inhibited – they can be summarised as shown in Table 3. This table also reflects the labelling and ordering designation.

The ordering designation shall follow the order: Equipment / Declaration / Type / Antioxidant.

In case of non-standard specification, e.g., for lowest cold start energising temperature (LCSET), pour point etc., this shall be declared separately.

7. Lowest cold start energising temperature (LCSET) (Revised, Part 6.1. of IEC 60296)

LCSET shall be – 30 °C unless otherwise specified. If a different LCSET is specified it shall be chosen from the values shown in Table 4.

8. New properties for the mineral insulating oils group A – Stray gassing (New, Annex A of IEC 60296)

Stray gassing under thermo-oxidative stress (usually called stray gassing), describes the development of gases in an insulating liquid in-service under temperatures considered usual for normal operating conditions [3], due to its constituents and not connected to an internal fault in the electrical equipment. Various kinds of gassing have been observed, for example producing hydrogen, methane, ethane, or a combination of these gases. Stray gassing is accelerated by oxygen content and copper availability as well as by the temperature. Nevertheless, it has been observed both in open breathing and sealed equipment.

Stray gassing can be caused by different reasons, such as refining or additives. The definition used in IEC 60296 for stray gassing does not include the influence of incompatible materials on the gassing of oil. In reality, however, outgassing of paints or some types of cross-linked polyethylene (XLPE), as well as other incompatible materials, can contribute to gas formation not related to internal faults. The method used in this document and described in Annex A does not consider this, since the compatibility of materials is a responsibility of the equipment manufacturer.

Dissolved gas analysis (DGA) was developed long ago as a tool recognising faulty conditions in liquid insulated electrical equipment. The most common evaluation schemes, however, may not distinguish between this kind of stray gassing and certain kinds of fault and therefore can lead to misinterpretation.

It is, therefore, useful to have a method characterising the stray gassing behaviour (under thermo-oxidative stress) of a certain oil. In practice, gas due to stray gassing only has not been proven to be harmful to the equipment, and it usually levels off with time. The proposed method provides useful information to help users differentiate between genuine fault conditions in electrical equipment and stray gassing due to thermo-oxidative stress. This characterisation should be considered when users select oil for equipment so that it forms part of the supporting information when DGA is done.

The method used in this document is described in Annex A of IEC 60296 (Ed. 5). It implements a temperature of 105 °C, which is the highest permissible top oil temperature at normal cyclic loading according to IEC 60076-7 [3] for the duration of 48 h (it has been shown that longer incubation times do not increase the significance of results) in the presence of copper (copper enhances the radical formation and is a metal used for the windings in the majority of electrical equipment).

The incubation at 105 °C can be carried out with air or nitrogen saturated oil with and without the presence of copper. Testing under all these conditions can be beneficial for qualifying a new oil.

The results of the round robin test (RRT) showed that the most severe condition for gas formation is under air saturated oil in the presence of copper. The limits reported in Table 1 are based on the testing under this condition.

9. Miscibility and compatibility (New, Part 5.3. of IEC 60296)

According to IEC 60296 (Ed. 5), mineral oils are generally considered miscible and compatible if the characteristics of their mixture are not less favourable than those of the worst individual oil.

Within the transformer insulating oils, two new groups are defined – Type A and Type B – based on their performance

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