



**The Revision of IEC 60296 –
Fluids for electrotechnical
applications –
mineral insulating oils for
electrical equipment – Ed 5**

Introduction

The International Electrotechnical Commission (IEC) establishes international standards for all electrical, electronic, and related technologies. IEC 60296 covers the standard specifications for mineral insulating oils. HyVolt I and HyVolt III are produced to meet these specifications. The first edition of 60296 was developed in 1969 with an amendment in 1972. The second edition was approved in 1982 with an amendment in 1986. The third edition was approved in 2003 and the fourth in 2012. These standards are generally revised and updated every ten years or so depending on the state of the industry. For example, the fourth edition was mainly concerned about the issue of corrosive sulfur and the detection of dibenzyl disulfide (DBDS).

The first four editions of 60296 contained the specifications for “unused” mineral insulating oils. The use of the word “unused” prevented recycled or re-refined mineral insulating oils from being compliant with the scope of the standard. In the context of the IEC, recycled or re-refined mineral insulating oils are mineral insulating oils which have been used in electrical equipment, removed from that equipment, treated by various means off-site (as opposed to on-site reclamation processes), and offered for sale as a mineral insulation oil. In addition, these oils will have “originally been supplied in compliance with a recognized unused mineral insulating oil specification.” The inclusion of the provisions of being previously used in electrical equipment and having been originally compliant with an unused mineral insulating oil specification was an effort to distinguish recycled or re-refined mineral insulating oils from the more generic recycled or re-refined mineral oils produced for other industries, such as passenger car motor oil.

There were two ways to address this issue so that recycled or re-refined mineral insulating oils would be covered by a standard specification. The first was to just remove the word “unused” and allow any mineral oils, however produced, to comply with the standard. The second was to issue a separate specification standard that specifically covered recycled or re-refined mineral insulating oils.

Originally, the second way was chosen and in March 2014, IEC 62701 was approved. It covered the fluids for electrotechnical applications — recycled mineral insulating oils for transformers and switchgear. As a request of recycled mineral insulating oil suppliers to avoid setting their product apart from the other mineral insulating oils arguing that their product met the same technical specifications. In May 2015, the standard was withdrawn. In February 2016, the Standardization Management Board (SMB) instructed Technical Committee 10 (TC10), fluids for electrotechnical applications, to revise 60296 so that it covered all mineral oils irrespective of their source. There could, however, be a requirement for the declaration of the provenance of the oils without bias to the alternatives. This disclosure and labeling requirement would allow the purchaser/user to specify the source of the oil.

IEC TC10 formed Maintenance Team 38 (MT38) in 2016 to revise 60296. The MT met twice a year from 2017 through 2019. There were 49 experts from 22 countries. In addition, a separate group was formed under the auspices of CIGRE, WG D1.70, since IEC does not engage in research. The WG D1.70 performed research and conducted round robin testing (RRT) to validate the requirement set forth in 60296. MT38 culminated in the publication of IEC 60296:2020 Edition 5 on June 26, 2020.

1) SIGNIFICANT REVISIONS OR ADDITIONS

a) Scope

The scope is very specific in what is covered and what is not:

Comparison of Scopes Between Edition 4 and Edition 5

| Edition 4 | Edition 5 |
|------------------------------------|--|
| For unused mineral insulating oils | For unused and recycled mineral insulating oils |
| Recycle oils are beyond the scope | This document does not differentiate between the methods used to recycle mineral insulating oils |
| | Recycled oils are produced from oils previously used as mineral insulating oils in electrical equipment and will have originally been supplied in compliance with a recognized unused mineral insulating oil specification |
| | Oils treated on-site are not within the scope |

b) Definitions of Unused and Recycled

3.8

unused mineral insulating oil (V)

mineral insulating oil, obtained by refining, modifying and/or blending of petroleum products and other hydrocarbons and that has **not been used in, nor been in contact with electrical equipment** or other equipment not required for manufacture, storage or transport

Note 1 to entry: In some countries, unused mineral oil is described as virgin oil.

Note 2 to entry: The manufacturer and supplier of unused mineral insulating oil shall take reasonable precautions to ensure that there is no contamination with polychlorinated biphenyls or terphenyls (PCB, PCT) or other contaminants.

3.9

recycled mineral insulating oil (R)

mineral insulating oil **previously used in electrical equipment** that has been subjected to re-refining or reclaiming (regeneration) after removal from the electrical equipment

Note 1 to entry: Any blend of unused and recycled oils is to be considered as recycled.

Note 2 to entry: The characteristics of recycled oil are heavily dependent on the oil from which it was recycled, the original refining technique, the service history and the type of recycling process.

Note 3 to entry: Natural or added antioxidants originally present in the oil might have been depleted in service or removed by the recycling process. The oxidation stability therefore needs to be restored/improved and is usually achieved by the addition of an oxidation inhibitor.

Note 4 to entry: Such recycled oils are often produced from mixtures of mineral insulating oils of different origins. The manufacturer and supplier of recycled mineral insulating oil shall take reasonable precautions to ensure that there is no contamination with polychlorinated biphenyls or terphenyls (PCB, PCT) or other contaminants.

3.10 reclaimed mineral insulating oil regenerated mineral insulating oil

recycled mineral insulating oil used in electrical equipment, which has been subjected, after removal from the electrical equipment, to chemical and physical processing to reduce soluble and insoluble contaminants

3.11 re-refined mineral insulating oil

recycled mineral insulating oil used in electrical equipment that has been removed from service and subjected to an off-site treatment similar to that used for the production of unused mineral insulating oil from virgin feedstock, in order to reduce the level of undesired compounds

Note 1 to entry: Such re-refined oils are often produced from mixtures of mineral insulating oils of different origins including processes such as distillation and hydrogenation.

c) Oils Types – Type A and Type B

i) 60296:2012, Edition 4

In 60296:2012, there was one specification table, Table 2 – General Specifications. It contained limits for two classes of mineral insulating oils, transformers and low temperature switchgear oil. The transformer oil was sub-divided into three groups depending on the antioxidant (inhibitor) content.

- (1) Uninhibited oils contained no detectable amounts of synthetic antioxidants. They rely on natural antioxidants native to crude oil.
- (2) Trace inhibited oils contain less than 0.08% synthetic antioxidant, such as butylated hydroxytoluene (BHT).
- (3) Inhibited oils contain between 0.08 and 0.40% synthetic antioxidant.

The performance of each group of transformer oil is determined by IEC 61125, the test method of oxidation stability. Each group has the same limits for total acidity (max 1.2 mg KOH/g), sludge (max 0.8%), and DDF (max 0.500) but the test time is different for each group, 164 hours for uninhibited, 332 hours for trace inhibited, and 500 hours for inhibited.

There is a fourth group of transformer oil, not in Table 2, but in Clause 7.1, for special applications. This describes mineral insulating oils of higher oxidation stability and lower sulfur content. The oxidation test conditions are the same as the inhibited oils, but the limits are lower, total acidity (max 0.3 mg KOH/g), sludge (max 0.05%), and DDF (max 0.050). Plus, the total sulfur content, prior to the oxidation test, had a limit of max 0.05%.

ii) 60296:2020, Edition 5

There were major changes in 60296:2020. The tables for general specifications still include both classes of mineral insulating oils, transformers and low temperature switchgear oil, but the groups were rearranged with the introduction of Type A and Type B mineral insulating oils. The specifications described in Edition 4, Clause 7.1 and Table 2, were converted into Table 3 and Table 4, respectively, in Edition 5. In addition, properties for which there were “no general requirement” were removed from the table.

The special applications from Clause 7.1 were incorporated into a new Table 3 – General Specifications, Type A (fully inhibited high grade oils). This table includes three new specifications.

- (1) Color, ISO 2049 – L0.5 (less than 0.5)
- (2) Interfacial Tension (IFT), IEC 62961 – Min 43 mN/m
- (3) Stray gassing under thermo-oxidative stress, Clause A.4 (oil saturated with air in the presence of copper) – Non-stray gassing, < 50 µl/l hydrogen and < 50 µl/l methane and < 50 µl/l ethane

Table 2 of Edition 4 essentially became Table 4 – General specifications, Type B (uninhibited and inhibited standard grade oils). This table includes two new specifications.

- (1) Color, ISO 2049 – Max 1.5
- (2) Interfacial Tension (IFT), IEC 62961 – Min 40 mN/m

d) Labelling

In 60296:2012, the labelling requirements were simple: U for uninhibited, T for trace inhibited, and I for inhibited. 60296:2020 introduces a four-letter labelling system. The first letter describes the class of equipment: T for transformer and S for switchgear. The second letter describes the provenance of the mineral oils: V for unused (or virgin) and R for recycled. The third letter describes the Type of oil: A for specification Type A and B for specification Type B. The fourth letter describes the antioxidant level: I for inhibited, U for uninhibited, and T for trace inhibited.

For example, an inhibited high-grade recycled oil for transformers would be labelled as: **TRAI**. A trace inhibited recycled oil for switchgear would be labelled as: **SRBT**.

This allows the customer to be exact in their description of the oil they are purchasing. They could ask for just a Type A fully inhibited high grade oil (virgin or recycled) or they could specify either TVAI or TRAI, for either a virgin or recycled oil, respectively.

e) Stray Gassing

Stray gassing is a complicated subject; even the definition is not universal.

ASTM D7150 defines stray gassing as the production of gases in an insulating liquid due to heating, contamination, or in combination. It describes the gassing characteristics due to thermal stress at 120°C of insulating liquids and without the influence of other electrical apparatus materials or electrical stresses. That is, just the oil by itself.

CIGRE Technical Brochure 296 defines thermal stray gassing as the formation of gases from insulating mineral oils heated at relatively low temperatures (90-200°C). It is not gassing tendency (under gas-phase electrical discharge) or as a result of catalytic reactions on metal surfaces or paints. That is, just the oil by itself.

In 60296:2020 Edition 5, it is defined as stray gassing under thermo-oxidative stress; the development of gases in an insulating liquid in-service under temperatures considered usual for normal operating conditions, due to its constituents and not connected to an internal fault in the electrical equipment.

Both D7150 and CIGRE Technical Brochure 296 define stray gassing of the mineral oil by itself, without any other components or electrical stress. It is an inherent property of the mineral oil. 60296:2020 defines stray gassing in relation to the electrical equipment since stray gassing is actually seen in operating transformers.

In order to more closely mimic an operating temperature, the stray gassing procedure in 60296:2020 Annex A, Clause A.4, Procedure A, uses air saturated oil in the presence of copper. The temperature of 105°C more accurately mimics the temperature in an operating transformer and higher temperatures could lead to different reactions not normally seen in a transformer. Three gasses are monitored, hydrogen, methane, and ethane. The specification limits were set at < 50 µl/l for any of the three gasses for Type A oils. The inhibited Type A oils easily passed the limits (< 50 µl/l). It was found that Type B oils all exhibited stray gassing significantly higher than 50 µl/l for at least one of the gases. Due to variability, it was not possible to set limits for Type B oils.

It should be noted that Annex A includes testing with air saturated oil without copper and with nitrogen saturated oil with and without copper. Only the more severe conditions of air saturated oil with copper provided the best differentiation.

Test Conditions for Stray Gassing

| | D7150 | CIGRE TB 296 | 60296:2020 |
|---------------|--------------|---------------------|-------------------|
| Air | Yes | Yes | Yes |
| Nitrogen | Yes | Yes | No* |
| Temperature | 120°C | 120°C | 105°C |
| Time, Hours | 164 | 16 and 164 | 48 |
| Glass Syringe | Yes | Yes | Yes |
| Copper | No | No | Yes* |

* 60296:2020 provided examples using nitrogen and without copper; however, only air saturated oil in the presence copper was used in the specification.

f) Disclosure of Additives

The disclosure of additives changed from “the supplier shall declare the **generic type** of all additives” in Edition 4 to “the supplier shall declare the **chemical family and function** of all additives” in Edition 5. The disclosure of the “concentrations in the cases of **inhibitors** and passivators” in Edition 4 was changed to “concentrations in the cases of **antioxidants** and passivators” in Edition 5. The change from inhibitors to antioxidants lines up with the updated definitions of antioxidants and inhibitors in Edition 5.

g) Definitions of Antioxidants vs Inhibitors

The terms antioxidants and inhibitors are often used interchangeably. In Edition 4, **antioxidant additives** are additives that improve oxidation stability. They are sub-divided into (1) **inhibitors** of the phenolic or amine type, (2) **other antioxidants** of the sulfur or phosphorus type, and (3) passivators which may also improve oxidation stability.

In Edition 5, the term **antioxidant additive** was clarified as **antioxidant oxidation inhibitor** of the phenolic type. The previous amine types were moved from **inhibitors** and are now included within the **other antioxidant additive** of the sulfur and phosphorus type. The terminology on passivators remained essentially constant.

h) Compatibility and Miscibility

The clause on miscibility in Edition 4 was expanded to include miscibility and compatibility in Edition 5. In Edition 4, it simply stated that unused oils of the same class, same group, same LCSET, and containing the same types of additives are considered to be miscible and compatible with each other.

In Edition 5, the discussion is expanded. All mineral insulating oils are physically miscible with each other; however, there could be compatibility issues with the additives. Here it is stated that mineral insulating oils of the same class and type, same group, same LCSET, and containing the same types of additives are considered to be compatible with each other in mixtures **up to 10%** with no need for additional testing. If the oils are of different class, type, group, LCSET, type of additives or above 10%, the mixture shall be classified and tested according to this standard.

SUMMARY

1. Both unused and recycled mineral insulating oils are covered in the scope in Edition 5.
2. Definitions are given for unused and recycled mineral insulating oils.
3. The table format changed from one table in Edition 4 to two tables in Edition 5.
4. Special application inhibited oils were moved from Clause 7.1 in Edition 4 to Table 3 in Edition 5.
5. Table 2 in Edition 4 became Table 4 in Edition 5.
6. The oils are divided into two types, Type A — fully inhibited high grade oils and Type B — uninhibited and inhibited standard grade oils.
7. New specifications of color, IFT, and stray gassing were included for Type A oils.
8. New specifications of color and IFT were included for Type B oils.
9. Specifications with “no general requirement” were removed from the specifications.
10. There is an expanded labelling requirement to indicate the provenance of the oil.
11. A new test method and requirements for stray gassing for Type A oils were introduced.
12. Disclosure of additives is more specific.
13. Definitions of antioxidants and inhibitors were expanded.
14. Compatibility and miscibility section was expanded.

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