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Edition 3.0 2019-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Specifications for the re-use of sulphur hexafluoride (SF_6) and its mixtures in electrical equipment

Spécifications pour la réutilisation de l'hexafluorure de soufre (SF_6) et des mélanges contenant du SF_6 dans le matériel électrique

IEC 60480:2019-04(en-fr)

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INTERNATIONAL
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SPECIFICATIONS FOR THE RE-USE OF SULPHUR HEXAFLUORIDE (SF_6) AND ITS MIXTURES IN ELECTRICAL EQUIPMENT

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International Standard IEC 60480 has been prepared by IEC technical committee 10: Fluids for electrotechnical applications.

This third edition cancels and replaces the second edition, published in 2004. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- specifications for the re-use of SF_6 have been confirmed;
- specifications for the re-use of SF_6 mixtures, namely SF_6/N_2 and SF_6/CF_4 mixtures are included;
- as a result of a new repartition of annexes in IEC 60376, IEC 60480 and IEC 62271-4, this new edition now contains the following five annexes:
  - Annex A: Description of methods of analysis (on-site and laboratory);
  - Annex B: By–products of SF_6 and its mixtures;

– Annex C: Procedure for evaluating the potential effects on health from by-products of SF_6 and its mixtures;

– Annex D: Reclaiming recommendations.

– Annex E: Cryogenic reclaiming of SF_6;

The text of this International Standard is based on the following documents:

FDIS	Report on voting
10/1075/FDIS	10/1080/RVD

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,
- replaced by a revised edition, or
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SPECIFICATIONS FOR THE RE-USE OF SULPHUR HEXAFLUORIDE (SF_6) AND ITS MIXTURES IN ELECTRICAL EQUIPMENT

1 Scope

This document provides criteria for the re-use of sulphur hexafluoride (SF_6) and its mixtures after recovery and reclaiming from electrical equipment (e.g. for maintenance, at the end-of-life).

Sulphur hexafluoride (SF_6), nitrogen (N_2) and carbon tetrafluoride (CF_4), are gases commonly used for electrical equipment. Taking into account environmental concerns, particular attention is paid to re-use criteria for SF_6 and its mixtures with N_2 and CF_4 for its use in electrical equipment. Procedures for recovering and reclaiming used SF_6 and its mixtures are outside the scope of this document and are described in IEC 62271-4.

This document provides several annexes on the description of the different methods of analysis, on by-products, on the procedure for evaluating the potential health effects from by-products, on cryogenic reclaiming of SF_6, and on reclaiming recommendations.

Storage, transportation and disposal of SF_6 and its mixtures are outside the scope of this document and are covered by IEC 62271-4. Procedures to determine SF_6 leakages are described in IEC 60068-2-17 [4][1].

For the purposes of this document, the complementary gases used in SF_6 mixtures will be limited to N_2 or CF_4.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-192, *International Electrotechnical Vocabulary – Part 192: Dependability* (available at http://www.electropedia.org)

IEC 60050-212, *International Electrotechnical Vocabulary – Part 212: Electrical insulating solids, liquids and gases* (available at http://www.electropedia.org)

IEC 60050-441, *International Electrotechnical Vocabulary – Part 441: Switchgear, controlgear and fuses* (available at http://www.electropedia.org)

IEC 60050-826, *International Electrotechnical Vocabulary – Part 826: Electrical installations* (available at http://www.electropedia.org)

IEC 62271-4:2013, *High-voltage switchgear and controlgear – Part 4: Handling procedures for sulphur hexafluoride (SF_6) and its mixtures*

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1 Numbers in square brackets refer to the bibliography.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-192, IEC 60050-212, IEC 60050-441 and IEC 60050-826, and the following apply.

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

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

3.1
electrical equipment
item used for such purposes as generation, conversion, transmission, distribution or utilization of electrical energy, such as electric machines, transformers, switchgear and controlgear, measuring instruments, protective devices, wiring systems, current-using equipment, insulated bushings, surge arresters

[SOURCE: IEC 60050-826:2004, 826-16-01, modified – "insulated bushings, surge arresters" has been added.]

3.2
container
vessel (cylinder) suitable for the containment of pressurized gases either in gaseous or liquid phase, according to local and/or international safety and transportation regulations

3.3
used sulphur hexafluoride
SF_6 which has been introduced into electrical equipment

3.4
reclaiming
process of contaminants removal from an insulating liquid or gas

3.5
recovery
process of transferring gas from electrical equipment to an alternate container

3.6
SF_6 mixture
gas mixture formed by SF_6 and a complementary gas, typically N_2 or CF_4

3.7
contaminant
foreign substance or material in an insulating liquid or gas which usually has a deleterious effect on one or more properties

[SOURCE: IEC 60050-212:2010, 212-17-27, modified – "or solid" has been deleted.]

3.8
by-products
contaminants which are formed by the degradation of SF_6 and its mixtures by electrical arcs or sparks

3.9
ambient air
normal atmosphere surrounding the equipment

[SOURCE: IEC 60079-29-2:2015, 3.1.1]

4 Contaminants and their sources

4.1 General

SF_6 recovered from electrical equipment in operation contains several kinds of contaminants. Contaminants in recovered SF_6 come both from gas handling and from use.

Table 1 summarizes the main contaminants and their sources. Additional information is available in Annex B.

Table 1 – SF_6 contaminants

SF_6 situation and use	Origin	Possible contaminant
Handling and in service	Leaks and incomplete evacuation Desorption	For pure SF_6: Air, oil, H_2O For SF_6 mixtures: Air, oil, H_2O, N_2, CF_4
Insulating function	Partial discharges (e.g. corona) and low energy flashovers and sparkovers	Gaseous by-products: HF, SO_2, SOF_2, SOF_4, SO_2F_2 For SF_6 mixtures: HF, SO_2, SOF_2, SOF_4, SO_2F_2, NO_x, NF_X
Switching equipment	Switching arc erosion	Gaseous by-products: HF, SO_2, SOF_2, SOF_4, SO_2F_2, SF_4, CF_4, WF_6 Solid by-products: Metal dusts, particles, AlF_3, FeF_3, WO_3, CuF_2 For SF_6 mixtures: HF, SO_2, SOF_2, SOF_4, SO_2F_2, NO_x, NF_X
	Mechanical erosion	Metal dusts, particles
Internal arc	Melting and decomposition of materials	Gaseous by-products: HF, SO_2, SOF_2, SOF_4, SO_2F_2, SF_4, CF_4, WF_6 Solid by-products: Metal dusts, particles, AlF_3, FeF_3, WO_3, CuF_2 For SF_6 mixtures: HF, SO_2, SOF_2, SOF_4, SO_2F_2, NO_x, NF_X

4.2 Contaminants from handling and use

Filling and recovering gas leads to the additional contamination with ambient air and water (humidity).

Moisture desorbs from internal surfaces of the equipment and from polymeric parts. Oil from handling equipment (pumps and compressors) may also be inadvertently introduced.

When using gas mixtures, the possibility of cross contamination shall be considered (contaminating one gas mixture by another).

4.3 SF_6 by-products in equipment that only have an insulating function

The essential process is the decomposition of SF_6 by partial discharges (e.g. corona) and low energy flashovers and sparkovers. The immediate products are fragments of SF_6, such as SF_5, SF_4 and F, combining with O_2 and H_2O to form compounds, mainly HF, SO_2, SOF_2, SOF_4 and SO_2F_2. Due to low energy of the partial discharges, flashovers or sparkovers, the accumulated quantities of these compounds are usually negligible.

4.4 SF_6 by-products in switching equipment

During current interruption, the existence of high temperature arcs leads to the formation of by-products of SF_6, vaporized electrode metal, polymeric materials and contaminants. In addition, chemical reactions take place among the products formed (see Table 1).

The quantity of these by-products depends on the number of operations, the cumulative short circuit current, the design of equipment and the use of adsorbers (solid adsorbents).

Switching equipment may also contain particles and metal dust coming from the rubbing of contacts.

4.5 SF_6 by-products from internal arcs

The occurrence of an internal arc is extremely rare. The expected contaminants in SF_6 in faulted equipment are similar to those normally found in switching equipment. The difference lies in the quantity of compounds, which create a potential toxic risk (see Clause 9). In addition, significant vaporization of metallic material occurs and creates additional reaction products such as dust.

4.6 SF_6 mixtures specific by-products

For SF_6 mixtures, the usual SF_6 by-products mentioned in Table 1 and specific mixture by-products, such as nitrogen oxide(s) and nitrogen fluoride(s) for SF_6/N_2 and fluorocarbon(s) for SF_6/CF_4, are produced. The quantities depend on the mixture composition, contaminants and energy introduced. For typical SF_6 mixtures, the gas decomposition rates are not expected to exceed those for SF_6.

Within the by-products generated in mixtures, SF_6 by-products are generally predominant in terms of quantity and toxicity. Safety procedures related to the presence of the usual SF_6 by-products shall also apply in applications with SF_6 mixtures.

5 Specifications for re-use of SF_6

Table 2 – Specifications for re-use of SF_6

Substance[a]	Concentration
SF_6	> 97 % volume
Air and/or CF_4	< 30 000 µl/l (i.e. 3 % volume)
H_2O	< 200 µl/l (i.e. 200 ppmv)
Mineral oil	< 10 mg/kg [b] (i.e. 10 ppmw)
Acidity	< 50 µl/l total (i.e. 50 ppmv) or 12 µl/l (i.e. 12 ppmv) for (SO_2+SOF_2) or 25 µl/l (i.e. 25 ppmv) HF
Key ppmv = part per million by volume ppmw = part per million by weight [a] H_2S and CO have been considered irrelevant due to lack of valuable data. [b] If gas handling equipment (pump, compressor) containing oil is used, it may be necessary to measure the oil content of the SF_6. If all equipment in contact with the SF_6 is oil-free, then it is not necessary to measure the oil content.	

For the determination of total acidity, the sum of all acidic compounds is reported as one value. Alternatively, total acidity can be measured in terms of (SO_2 + SOF_2) or in terms of HF with a limit value of 12 µl/l and 25 µl/l respectively.

6 Specifications for re-use of SF_6 mixtures

Table 3 – Specifications for re-use of SF_6/N_2 mixtures

Substance	Concentration
N_2	As per OEM specifications
SF_6 percentage	±5 % volume of the specified percentage [a]
Air and CF_4	< 30 000 µl/l (i.e. 3 % volume) [a]
H_2O	< 200 µl/l (.i.e. 200 ppmv)
Mineral oil	< 10 mg/kg [b] (i.e. 10 ppmw)
Total acidity	< 50 µl/l total (i.e. 50 ppmv) or 12 µl/l (i.e. 12 ppmv) for (SO_2+SOF_2) or 25 µl/l (i.e. 25 ppmv) HF
Storage conditions	
Shall comply with IEC 62271-4:2013, Clause J.7 in order to prevent liquefaction of SF_6.	
Key ppmv = part per million by volume ppmw = part per million by weight [a] Or unless otherwise specified by the original equipment manufacturer (OEM). [b] If gas handling equipment (pump, compressor) containing oil is used, it may be necessary to measure the oil content of the SF_6. If all equipment in contact with the SF_6 is oil-free, then it is not necessary to measure the oil content.	

Table 4 – Specifications for re-use of SF_6/CF_4 mixtures

Substance	Concentration
CF_4	As per OEM specifications
SF_6 percentage	±5 % volume of the specified percentage [a]
Air and N_2	< 30 000 µl/l (i.e. 3% volume) [a]
H_2O	< 200 µl/l (.i.e. 200 ppmv)
Mineral oil	< 10 mg/kg [b] (i.e. 10 ppmw)
Total acidity	< 50 µl/l total (i.e. 50 ppmv) or 12 µl/l (i.e. 12 ppmv) for (SO_2+SOF_2) or 25 µl/l (i.e. 25 ppmv) HF
Storage conditions	
Shall comply with IEC 62271-4:2013, Clause J.7 in order to prevent liquefaction of SF_6.	
Key ppmv = part per million by volume ppmw = par per million by weight [a] Or unless otherwise specified by the original equipment manufacturer (OEM). [b] If gas handling equipment (pump, compressor) containing oil is used, it may be necessary to measure the oil content of the SF_6. If all equipment in contact with the SF_6 is oil-free, then it is not necessary to measure the oil content.	

7 Reclaiming of SF_6 and SF_6 mixtures

7.1 Feasibility and process

The quality of reclaimed SF_6 shall meet the requirements of this document.

All occurring contaminants are formed in normal operation and can generally be eliminated on-site. Table 5 lists methods recommended for removing the contaminants as given in Table 1.

Table 5 – General contaminants and methods for their removal

Contaminant	Humidity (water vapour)	Gaseous by-products	Solid by-products	Air, N_2, CF_4	Mineral oil
Removal method	Adsorption with molecular sieve	Adsorption with activated aluminium oxide	Retaining with solid filters	Separation by cryogenic process or membrane filtration	Adsorption with activated charcoal filter
For SF_6 and its mixtures, these gaseous contaminants cannot be removed easily on-site. In each situation, an evaluation of the reclaiming options should be done to determine if the SF_6 and its mixture could be reclaimed on-site.					

Various types of adsorbent materials are available to remove contaminants from SF_6 gas (see Table 6).

Table 6 – Typical adsorbents for various SF_6 contaminants

Adsorbent	**Contaminants removed**
Molecular sieve 4A	Water, SO_2, SOF_2, SF_4
Molecular sieve 13X	Water, SO_2, SOF_2, SF_4 (also adsorbs some SF_6)
Activated aluminium oxide	Water, SO_2, SOF_2, SF_4, HF
Soda lime (CaO-NaOH)	Water, SO_2F_2, HF
Activated charcoal	Oil vapour

If the results of the gas analysis exceed the specifications for re-use of SF_6 and its mixtures given in Table 2, Table 3 or Table 4, a decision regarding the reclaiming method has to be made depending on the level and type of contamination. In general, re-purifying the gas on-site with a service device plus a separation device will be the most favourable way. However, if re-use is not possible, reclaiming by the gas manufacturer or disposal will be necessary. In this case, the gas shall be sent to the SF_6 manufacturer or reclaimer.

Figure 1 defines the selection procedure to determine the best use of SF_6 after recovery for potential treatment.

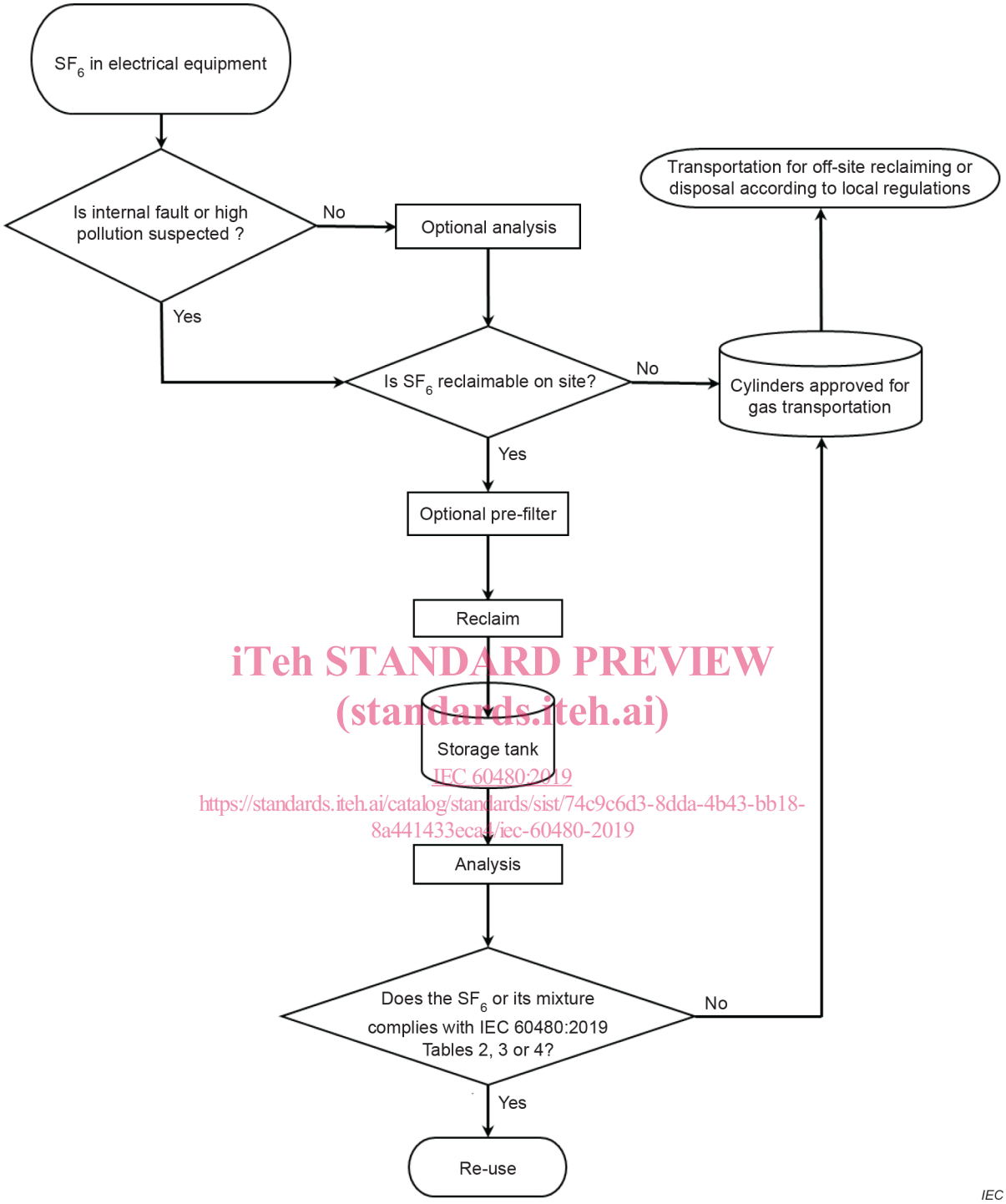

Figure 1 – Decision flow chart for recovered SF_6

- For contaminants of water or by-products, the question of whether the SF_6 is reclaimable on-site depends only on the performance of the filters available. The addition of external pre-filters may be required to increase the efficiency of the reclaiming process. If the SF_6 is not reclaimable on-site, then it shall be returned to the SF_6 manufacturer or sent to a reclaiming or disposal company.
- The case of contamination with air, N_2 and/or CF_4 shall be considered separately.
- For non-mixed SF_6, if the concentration of air and/or CF_4 exceeds the maximum acceptable contaminant level as given in Table 2, and if the container from which the sample has been taken contains liquid SF_6, then transfer SF_6 from the gas phase into a second container. The transfer should be continued until a sample from the first reservoir satisfies the maximum acceptable level. The contents of the second container cannot be