## *CAPIEL*
# *Frequently asked Questions (FAQ) and Answers on $SF_6$*

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| 1 | What is $SF_6$? | It is a colourless, odourless, chemically neutral, and inert gas, non-inflammable and 5 times heavier than air, not toxic and not ozone depleting. More detailed information is given in IEC 60376 [6] and IEC 61634 [8] or by gas manufacturers (e.g. www.solvay-fluor.com) |
| 2 | Where is $SF_6$ used? | The following applications are known:<br>For sound insulation in windows, in vehicle tyres, for magnesium casting in the automotive industry, as insulating and arc extinguishing medium in electric power equipment, for manufacturing of semi-conductors, in tandem-particle accelerators, in electron microscopes, as tracer-gas in mining, in x-ray material examination equipment, as purification and protection gas for aluminium and magnesium casting, in sport shoes, medical examinations, in military aircraft radar systems and other military applications. |
| 3 | Is $SF_6$ a health hazard? | Pure $SF_6$ is physiologically completely harmless for humans and animals; it's even used in medical diagnostic. Due to its weight it might displace the oxygen in the air, if large quantities are concentrating in deeper and non ventilated places. Legislation for chemicals does not categorise SF6 as a hazardous material. |
| 4 | Is $SF_6$ harmful for the environment? | It has no ecotoxic potential, it does not deplete ozone. Due to its high global warming potential of 22.200 (*) it may contribute to the man made greenhouse-effect, if it is released into the atmosphere. However in electrical switchgear the $SF_6$ gas is always used in gas-tight compartments, greatly minimising leakage. This make the real impact on greenhouse effect negligible<br><br>(*) According to the 3rd Assessment Report of UNFCCC. Previous accepted value was 23.900 |
| 5 | What is the overall contribution of $SF_6$ used in the electrical equipment to the greenhouse effect? | Less than 0,1 % ( see CAPIEL[1] ESA[2] [1])<br>http://www.capiel-electric.com/home.asp?op=publicats<br>and CIGRE http://www.CIGRE-sc23b3.org/ $SF_6$/)<br>In an Ecofys study the contribution to the greenhouse effect in Europe is estimated to 0.05 % [9]. |
| 6 | How wide is the use of $SF_6$ in transmission and distribution switchgear applications ? | $SF_6$ insulated switchgear is currently used world-wide. It is estimated that an average of about 80 % of HV equipment manufactured now has an $SF_6$ content. |

[1] CAPIEL: Coordinating Committee fort he Associations of Manufacturers of Industrial Electrical Switchgear and Controlgear in the European Union
[2] Environment Sustainability Approach, Part D: http://www.capiel-electric.com

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| 7 | Why is $SF_6$ used in electric power equipment? | Because of its outstanding electrical, physical and chemical properties enabling significant benefits for the electricity supply network:<br>it insulates 2.5 times better than air (N2),<br>over 100 times better arc quenching capability than air ($N_2$),<br>better heat dissipation than air;<br><br>In addition to this, LCA studies have proven that the use of $SF_6$ technology in the electrical distribution switchgear equipment results in lower overall direct and indirect environmental impacts compared to air-insulated switchyards [2] |
| 8 | What are the benefits of high and medium voltage $SF_6$-switchgear? | There is a significant number of benefits, as follows:<br><br>***Local operator safety***<br><br>$SF_6$-insulated switchgear makes a substantial contribution to reduce the accident risk.<br><br>The total enclosure of all live parts in earthed metal enclosures provides immanent protection against electric shock and minimises the risks associated with human errors<br><br>The high-grade switchgear remains hermetically sealed for its whole service life.<br><br>***Very high operational reliability***<br><br>It offers a great operational reliability because inside the enclosed gas compartments the primary conductors have complete protection against all external effects.<br><br>The minimal use of synthetics reduces the fire load.<br><br>The $SF_6$ insulation ensures complete freedom from oxidation for the contacts and screwed joints, which means that there is no gradual reduction in the current carrying capacity of the equipment as it ages.<br><br>There is no reduction in insulation capacity due to external factors.<br><br>***Important contribution to the security of supply***<br><br>Total enclosure also means that the equipment is almost completely independent from the environment. $SF_6$-insulated switchgear can also be used under difficult climatic conditions, for example:<br><br>In humid areas with frequent condensations from temperature changes, and even in places with flooding potential.<br><br>Where the reliability of the insulation might otherwise suffer from contamination, e.g. dust from industry or agriculture or saline deposits in coastal areas. Gas-insulated switchgear completely eliminates this possibility throughout the whole service life of an installation. |

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| | | In contrast to air insulation, whose insulating capacity reduces with increasing altitude, $SF_6$-insulated switchgear retains its full insulating capacity regardless of height above sea level. So larger and more costly special designs, or equipment with higher insulation ratings - and therefore more costly - are avoided<br><br>***Small space requirement***<br><br>Due to the high dielectric strength of the gas, the switchgear is compact with space requirements minimised.<br><br>The excellent safety and low space requirement of $SF_6$ switchgear allows it to be sited directly in conurbations and close to load centres, such as city centres, industrial manufacturing plants and commercial areas.<br><br>Therefore, this fulfils one of the basic essentials of power distribution, namely that substations should be placed as close as possible to load centres in order to keep transmission losses to a minimum, to conserve resources and to minimise costs.<br><br>Major savings in building, land and transport costs can be achieved throughout the whole process chain.<br><br>In several cases $SF_6$ switchgear is the only possible solution: for wind power plants (offshore), in caverns, for large generator circuit-breakers, and for extensions of existing installations.<br><br>This often allows existing buildings use to be extended where switchgear replacement or extension to meet load growth is needed.<br><br>***Excellent economical and ecological features***<br><br>• Distinct economic benefits come from:<br>– the long service life<br>– minimal maintenance expenditure thanks to maintenance-free, gas-tight enclosures<br>– reduced costs for land, buildings, transport and commissioning.<br>– maximum operational reliability as a prerequisite for the remote control and automation of power networks<br><br>• Ecological and economic benefits arise from:<br>- Minimum transmission losses as a result of placing equipment close to load centres.<br>- Reduced primary energy consumption and emissions contribute to economically optimised power supply systems.<br>- And the long service life of $SF_6$ switchgear also contributes to the conservation of resources.<br><br>• Aesthetic and ecological benefits for rural and city landscapes:<br>- Because $SF_6$ installations are compact, need minimum maintenance, have extraordinarily high |

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| | | availability and are independent from climatic impacts. They offer not only major ecological and economic advantages but can also be integrated seamlessly in any landscape or architecture of towns, cities or countryside<br>- Reclamation of areas previously taken up by conventional substations. |
| 9 | Is there any alternative to $SF_6$ in switchgear for high and medium voltage? | From the LCA point of view no technically and economically viable alternative exists with an equivalent set of properties described above and the same degree of safety and reliability.<br><br>”A combination of extraordinary electrical, physical, chemical and thermal properties makes $SF_6$ a unique and indispensable material in electric power equipment for which there is no functionally equivalent substitute.” (Quotation from a CIGRE[3] Report) [3] |
| 10 | Why not insulate or switch with nitrogen? | The experiences and calculations using N2 or other gases show that these alternatives are neither economically nor technically comparable because they are less suitable for their application in electrical equipment:<br>***Insulation capacity***<br>dielectric strength is lower than with $SF_6$<br>To compensate this would mean increase of e.g. gas pressure, clearances and creepage distances thus resulting in larger dimensions and increased use of resources<br>***Thermal conductivity***<br>lower heat dissipation would mean either lower load carrying capacity (at same dimensions) or increased dimensions and use of resources (copper, space, etc.)<br>***Switching capacity***<br>$SF_6$ has an inherently higher arc-quenching capability due to its thermal and electrical properties.<br>In particular for transformer substations (RMU) $SF_6$ – in contrast to all other arc-quenching media – enables the use of simple and hence very cost-effective switchgear (switch disconnectors). Thus contributing to economical electricity supply and benefit to the public. |
| 11 | What are the different applications in electrical power equipment using $SF_6$? | GIS (Gas Insulated Switchgear for medium and high voltage), CBs (Circuit Breaker), Power transformers , VT (Voltage Transformer), CT (Current transformer), RMU (Ring Main Unit), assemblies of HV devices and GIL (Gas insulated lines), Capacitors etc. |
| 12 | What is the difference between high-voltage (HV) and medium-voltage (MV) GIS regarding $SF_6$? | Basically there is no difference as both applications use the $SF_6$ in gas-tight compartments with negligible leakage rates. In general the MV (up to 52 kV) use pressures close to atmospheric pressure in sealed |

[3] CIGRE: International Council on Large Electric Systems

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| 13 | What is the difference between closed and sealed pressure systems? | Closed systems may be refilled, while sealed are not requiring any refilling for the expected life.<br>According to IEC 62271-1 (former IEC 60694) [5]<br>• Closed pressure system for gas:<br>volume which is replenished only periodically by manual connection to an external gas source (example of closed pressure systems are $SF_6$ single pressure circuit-breakers).<br>• Sealed pressure system:<br>volume for which no further gas or vacuum processing is required during its expected operating life (examples of sealed pressure systems are tubes of vacuum circuit-breakers in MV switchyards or some $SF_6$ circuit-breakers; sealed pressure systems are completely assembled and tested in the factory). |
| 14 | What are the main commitments of the voluntary actions/agreements of manufacturers and users concerning $SF_6$ handling? | Both, switchgear manufacturers and users are committed to a continuous improvement in reduction of emission rates as well as monitoring and annual reporting. |
| 15 | How is the effectiveness of voluntary actions verified? | The production processes of MV and HV switchgear in Western Europe have been improved so to reduce the specific emission rates of about 2/3 from1995 to 2003). Ecofys determined for the same period an emission reduction of 40 %. This improvement is substantiated by systematic application of comprehensive monitoring methodologies and intensive personnel training. According to the study already 70 % of potential measures are realised. |
| 16 | What are the user's obligations for monitoring $SF_6$ –data of medium voltage switchgear? | As far as sealed pressure systems (sealed for life)are concerned the users do not normally need to either monitor or report emissions. Therefore they only have to assure that the disposal and the end of life is carried out by a qualified entity, in accordance with available national rules. |
| 17 | How is proper handling of $SF_6$ ensured during the closed loop process from cradle to grave? | Compliance with processes described in national and international standards and recommendations.<br>• Development: IEC 60376 (new $SF_6$, technical grade $SF_6$) [6], IEC 60480 (used $SF_6$) [7], CIGRE report 276, 2005 "Practical $SF_6$ Handling Instructions" [11],<br>• Manufacturing: Manufacturer's internal instructions, design- and routine-test principles; IEC 62271 series for high-voltage and medium-voltage switchgear apparatus/devices<br>• Installation, erection, commissioning : IEC 61634 (handling $SF_6$) [8], IEC 60376 (new $SF_6$, technical graded $SF_6$) [6], IEC 60480 (used $SF_6$) ]7]; CIGRE report |

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| | | 276, 2005 "Practical $SF_6$ Handling Instructions" [11],<br>• Leakage in service: IEC 60376 (new $SF_6$, technical graded $SF_6$), IEC 60480 (used $SF_6$), CIGRE 2002 ("$SF_6$ in the Electric Industry") [10]<br>• Repair work and maintenance: IEC 61634 (handling $SF_6$), CIGRE 1991 (handling of $SF_6$), CIGRE report 276, 2005 "Practical $SF_6$ Handling Instructions" [11], CIGRE report 163, 2000 (Guide for $SF_6$ gas mixtures)<br>• End of life, recycling: IEC 61634, CIGRE 2003 ($SF_6$ recycling guide) [15] |
| 18 | How is the proper end-of-life treatment of $SF_6$-switchgear ensured? | Following internationally acknowledged instructions (i.e. according to IEC 60~~0~~1634, CIGRE 2003 $SF_6$ Recycling Guide) [15]. |
| 19 | What are the user's obligations when taking $SF_6$-switchgear out of service? | To make sure that the $SF_6$ is handled by a qualified entity or by qualified personnel according to IEC 61634 subclause 4.3.1. and according to IEC 60480 subclause 10.3.1. |
| 20 | How is used $SF_6$-gas treated or disposed? | It is normally re-used after proper filtering. In some special cases disposal of the gas is necessary. Appropriate detailed information can be found in IEC 61634 (handling $SF_6$), IEC 60480 (used $SF_6$); CIGRE guide for the preparation of customised "Practical $SF_6$ Handling Instructions" [11] |
| 21 | In some European countries bans on $SF_6$-switchgear have been proposed. Where are legal bans implemented? | There are no legal bans implemented. In political discussions reduced use of $SF_6$ in some applications was proposed which are not related to the electrical industry. In the past some proposals of this kind concerning electrical switchgear came up due to insufficient knowledge on how the electrical industry is using $SF_6$. Once this was clarified and the benefits given by this technology were explained, the proposals were withdrawn.<br>. |
| 22 | In Germany the government discussed a ban on $SF_6$-switchgear. When will this be implemented? | The ban on MV- and part of HV-switchgear was just a proposed action mentioned in the so called 'Policy Paper' of the Environmental Ministry, released end of September 2002. It was declared a discussion paper calling for an open discussion with all stakeholders. Meanwhile the political bodies in Germany recognised the voluntary agreement of the manufacturers and users of electrical switchgear > 1 kV [16]. The authorities clearly indicated that there will be no ban in German legislation.<br>The users decide in individual cases on AIS or GIS installation taking into account technical, economical and ecological criteria. Furthermore LCA-studies concerning electricity supply using $SF_6$ technology and concerning MV switchgear prove that with respect to the GHG[4] effect and other criteria there are advantages rather than disadvantages of GIS, compared to AIS[5]. |

[4] GHG: greenhouse gas
[5] AIS: air-insulated switchgear

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| 23 | It was said Sweden and Spain recently also banned $SF_6$-switchgear. Is that true? | No. This is incorrect. |
| 24 | What is the present status on legislative measures in European Commission? | At present at EU level, the draft Fluorinated Gas Regulation is under discussion. The current wording of the draft considers a number of items of interest for the electrical industry: reporting obligations, training of personnel and end of life handling. No ban is foreseen for electrical equipment. |
| 25 | What does the European switchgear industry undertake to prevent bans, use restrictions, or potential additional administrative burden to the users of $SF_6$-switchgear during the current legislation process? | Complying with Voluntary Agreements and the adequate measures. |
| 26 | Can we use vacuum as insulation medium? | Vacuum technology is already in use for switching purposes in the MV range. In the case of a small volume, a vacuum can be relatively easy maintained, which is essential to assure the performance of the switching device. Application of vacuum as insulating medium in a larger volume is electro physically and technically much more demanding, economically exceeding difficult, and practically not realisable. |
| 27 | How can the user supervise the $SF_6$ quality? | The sealed for life MV equipment does not require $SF_6$ quality checks.<br>For other HV equipment Annex B of IEC 60480 describes different methods of analysis applicable for closed pressure systems (on-site and in laboratory). |
| 28 | What about ageing process of $SF_6$ gas? Is replenishment of gas needed after approximately 20 years? | It is generally not necessary because the gas quality than is in line with the values given in IEC 60480 Table 2 "Maximum acceptable impurity levels" (applicable for closed pressure systems).<br><br>For MV sealed for life equipment no replenishment is necessary, because of the unique qualities of $SF_6$ under normal operating conditions no degradation occurs. |
| 29 | How much $SF_6$ (quantified in kg) can escape due to "normal" leakage? | This depends on the filling quantity, which depends on the rating and design of the equipment (volume and pressure). For HV switchgear the emission factor ranges from about 0.1% per year to 0,5% (0,5% per year is the maximum acceptable leakage rate according to IEC 62271-203)<br>For sealed for life MV equipment a range below 0,1 % per year is common. For example, a 3 kg filling quantity (RMU) results in a calculated loss of 3 g per year. |
| 30 | How high is the MAC (Maximum allowable working environment | It is generally recommended that the maximum concentration of $SF_6$ in the working environment should be |

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| | concentration) for pure $SF_6$ in the substation and how hazardous is pure $SF_6$? | kept lower than 1000 µl/l [4]. This is the value accepted for a full time (8 h/day, 5 day/week) work schedule. This value is not related to toxicity, but an established limit for all non-toxic gases which are not normally present in the atmosphere.<br>Therefore, this limit does not mean that higher $SF_6$ concentrations pose any toxic hazard. According to Clause 7.1 of IEC 60480: "In principle, a mixture of 20% of oxygen and 80% $SF_6$ can be inhaled without adverse effect. Concentrations above 20% would cause suffocation due to lack of oxygen. |
| 31 | What decomposition products are created in the case of internal arc faults, and in what quantities? | Gaseous and dusty by-products will be generated. See IEC 60480, Table 1 and/or CIGRE Report Electra 1991 ("Handling of $SF_6$ and its decomposition products in GIS", Table 2 "Rough characterisation of the major decomposition products resulting from different sources"). The decomposition products depend on the type of equipment and its service history; the quantities depend on energy (voltage, current, time) and the type of the equipment. |
| 32 | How hazardous are the decomposition products? | See IEC 61634, Annex C: "Release of $SF_6$ from switchgear and control gear – potential effects on health". In this Annex a calculation method is given to evaluate the amount of by-products with toxic characteristics generated under different conditions. It is, then, possible to evaluate potential toxic hazard taking into account the volume of the switchgear room. Calculations show that, in practice, only in case of an internal arc with a massive emission of heavily arced gas a real hazard is created. Evacuation and ventilation is therefore compulsory in such an event. |
| 33 | What has to be done after an arc fault in the switchgear? | In such accidental cases caution must be taken. If the encapsulation has been damaged some compounds with toxic characteristics may be present, generated not only from decomposition of $SF_6$ but also from other sources (e.g. burning paintings, vapours of copper, etc) can be present. Therefore, in all cases, evacuation of the switchgear room is the first measure to be taken irrespective the switchgear contains $SF_6$ or not. See IEC 61634 [8] sub-clause 5.3: "Abnormal release due to internal fault". |
| 34 | Does a (passive or active) ventilation system have to be installed in the switchgear room or cable basement? | Buildings containing $SF_6$-filled indoor equipment should be provided with ventilation; natural ventilation would normally be adequate to prevent the accumulation of $SF_6$ released due to leakage (see IEC 61634, sub-clause 3.4: "Safety of personnel" and IEC 61936-1) [12]. Type and extent of required measures depend upon location of the room, the accessibility, and the ratio of gas to room volume. |
| 35 | What do I have to do when a GIS installation is damaged (for example hole drilled in encapsulation or transport damage such as a panel | Appropriate corrective action should be to deal with the leakage. If the equipment is in service and the leakage is high, it must be de-energised, in accordance with the organisation's operational procedures. Loss of gas must |

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| | dropped and cast resin broken) and $SF_6$ escapes or when my GIS develops an abnormal leak? | be minimised by following the organisation's procedures and using the services/recommendations of the manufacturer or qualified service organisation as appropriate. The technical integrity of the equipment will need to be verified after such an occurrence and appropriate corrective actions taken by authorised personnel before refilling of equipment or placing in service. |
| 36 | Under which conditions needs $SF_6$ gas in gas-insulated switchgear to be replaced? Which are the parameters to be checked e.g. (concentration, dew point, decomposition products) and what are the related acceptable limits? | Normally the gas remains until disassembly. During a maintenance operation requiring the evacuation of the gas, it should be analysed. Guidance on how to proceed then is given in IEC 60480 |
| 37 | How do I evacuate and fill the system? | See IEC 61634, CIGRE Report 2004 ("Practical $SF_6$ handling instructions"). Please, refer also to the instruction manual of your equipment.<br>The work should be done in conjunction with the manufacturer or qualified service company in cases where an organisation's own personnel is not trained appropriately. |
| 38 | How much $SF_6$ gas is in my switchgear? Where do I find this information? | On the nameplate or in the operating manual.<br>For older equipment please ask your manufacturer. |
| 39 | Does SF6 have to be disposed of when moist? | No, it is possible to dry the gas; moisture can be reduced to acceptable levels by adsorption; material such as alumina, soda lime, molecular sieves or mixtures thereof are suitable for this purpose (see also IEC 61634, Annex B.3: "Measures for the removal of SF6 decomposition products"). Maximum tolerable moisture levels for re-use can be taken from IEC 60480, Annex A. |
| 40 | What do I have to do when I came in contact with decomposed $SF_6$? | See IEC 61634 [8], Annex E: "General safety recommendations, equipment for personal protection and first aid". Normally only trained and qualified personnel should deal with this and hence be aware of the necessary precautions and actions. |
| 41 | What environmental and safety at work aspects have to be taken into account? | See IEC 61634 [8], clause 4: "Handling of used $SF_6$". |
| 42 | What has to be done when decomposed $SF_6$ escapes into the environment? | See IEC 61634 [8], sub-clause 4.3: "Working with used $SF_6$". |
| 43 | How is $SF_6$ to be transported and shipped? | See IEC 60480 [7], chapter 10.6: "Storage and transportation of used $SF_6$". |
| 44 | What has to be observed for cleaning of the switchgear room after an internal fault with emission of decomposed gas? | See IEC 61634 [8], sub-clause 5.3/5.3.3 "Abnormal release due to internal fault"/"Indoor installations", and national requirements. |

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| 45 | What substances can be created by chemical reactions with decomposition products in the worst case? Is the generation of prussic acid or hydrogen fluoride possible? | See IEC 60480 [7], Table 1 ("Origin of $SF_6$ impurities") and/or CIGRE Report Electra 1991 ("Handling of $SF_6$ and its decomposition products in GIS", Table 2 "Rough characterisation of the major decomposition products resulting from different sources"); the decomposition products depend on type of the equipment and its service history. |

[1] CAPIEL is the Coordinating Committee for the Associations of Manufacturers of Industrial Electrical Switchgear and Controlgear in the European Union: Environmental Sustainability Approach (ESA) is available from the national member associations and manufacturers

[2] Solvay Germany, 1999: Urban power supply using $SF_6$ technology, Life cycle assessment on behalf of ABB, PreussenElektra Netz, RWE Energie, Siemens, Solvay Fluor und Derivate

Solvay et al., 2003, - Solvay Management Support: : $SF_6$-GIS technology for energy distribution – medium voltage, Life cycle assessment on behalf of ABB, AREVA T&D, EnBW Regional, e.on Hanse, RWE, Siemens and Solvay Fluor und Derivate

[3] $SF_6$ and the global atmosphere: ELECTRA No. 164, February 1996, page 120-131

[4] TRGS 900, Technische Regeln für Gefahrstoffe

[5] IEC 62271-1 / IEC 60694 Common specifications for high-voltage switchgear and controlgear standards

[6] IEC 60376 Specification and acceptance of new sulphur hexafluoride

[7] *I*EC 60480 Guidelines for the checking and treatment of sulphur hexafluoride ($SF_6$) taken from electrical equipment and specification for its re-use

[8] IEC 61634 High-voltage switchgear and controlgear - Use and handling of sulphur hexafluoride ($SF_6$) in high-voltage switchgear and controlgear

[9] ECOFYS, Sina Wartmann, Dr. Jochen Harnisch, June 2005, “Reductions of $SF_6$ Emissions from High and Medium Voltage Equipment in Europe”

[10] $SF_6$ in the Electric Industry, Status 2000, (CIGRE Study Committee No.23) P. O'Connel et al, ELECTRA No. 200, February 2002, pp 16-25

[11] CIGRE-report 276, 2005: Guide for the preparation of customised "Practical $SF_6$ Handling Instructions". A short version appears in August 2005 in ELECTRA.

[12] IEC 61936-1 Power installations exceeding 1 kV a.c. - Part 1: Common rules

[13] Handling of $SF_6$ and its decomposition products in gas insulated switchgear (GIS), CIGRE Working Group 23-03, ELECTRA No. 136, June 1991, p. 69

[15] CIGRE-report 234, 2003: $SF_6$ recycling guide.

[16] Solvay, VIK, VDN, ZVEI: „Selbstverpflichtung der $SF_6$-Produzenten, Hersteller und Betreiber von elektrischen Betriebsmitteln > 1kV zur elektrischen Energieübertragung und –verteilung in der Bundesrepublik Deutschland zu $SF_6$ als Isolier- und Löschgas“, Mai 2005, www.sf6-energietechnik.de