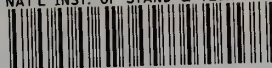


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David A. Leep and Richard J. Van Brunt

Electrosystems Division
Center for Electronic and Electrical Engineering
National Bureau of Standards
U.S. Department of Commerce
Washington, DC 20234

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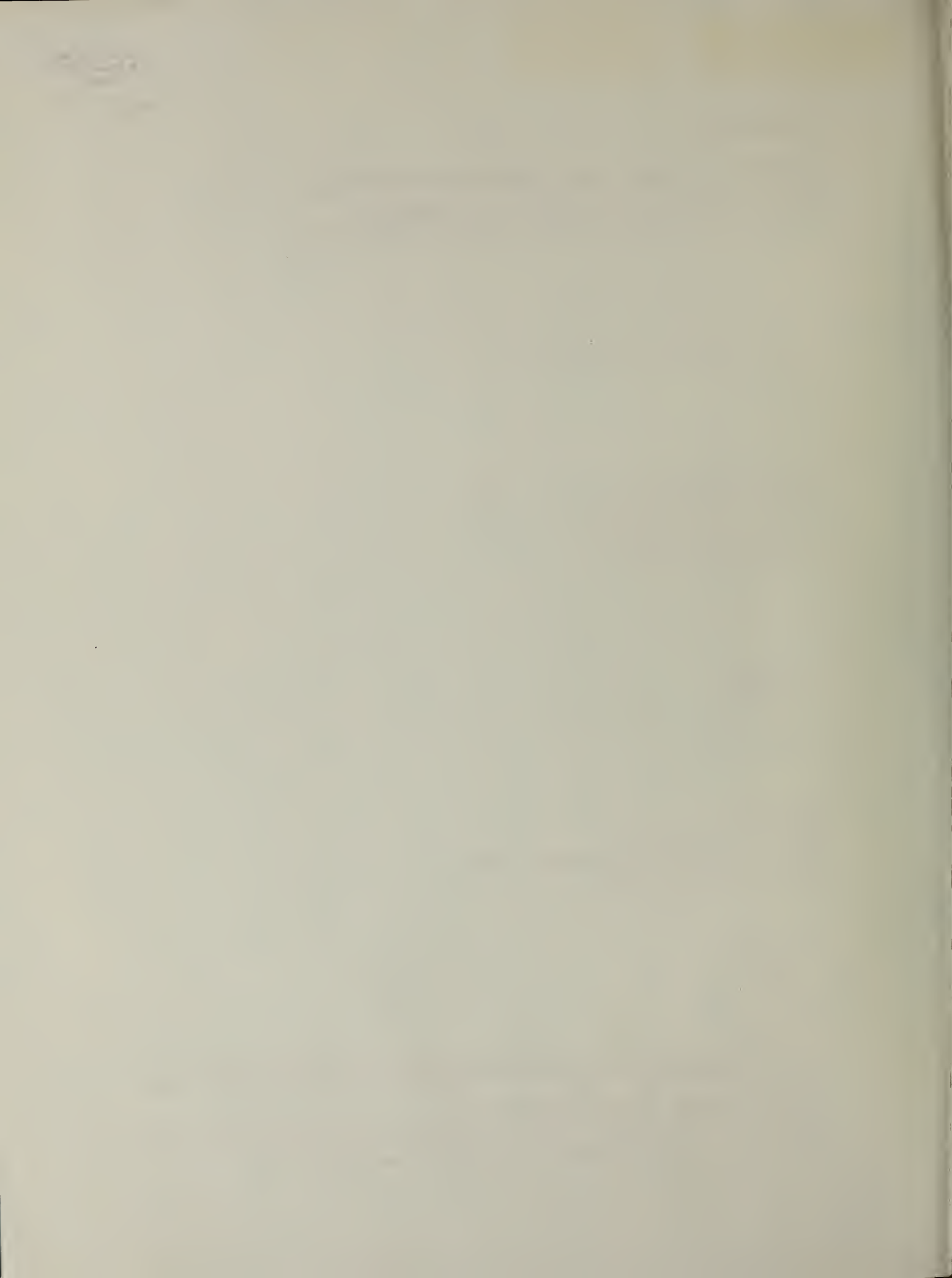
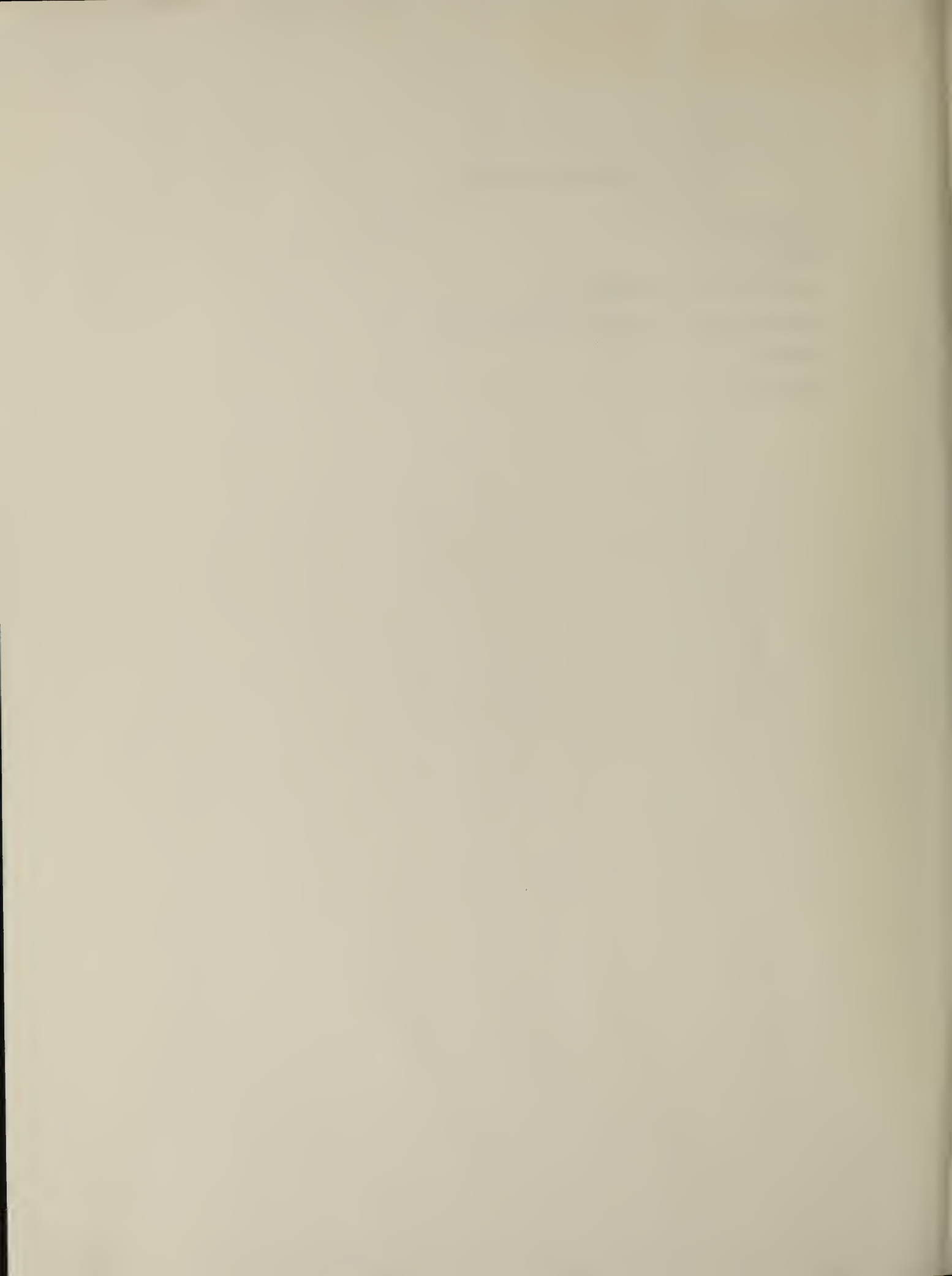


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Safety Considerations for Handling SF₆
Used in Electrical Equipment

Prepared by

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This report has been prepared for the benefit of those within the National Bureau of Standards who must use gaseous sulfur hexafluoride for electrical insulation. The information presented herein has been gathered from the National Institute of Occupational Safety and Health's Registry of Toxic Effects of Chemical Substances and from other sources believed to be reliable, but this information is not the result of any critical data evaluation or testing activity of NBS. The publication, reprinting, reproduction, or open-literature listing of this report either in whole or in part, is not authorized unless permission is obtained from the Office of the Director, National Bureau of Standards, Washington, D.C. 20234.



I. INTRODUCTION

The purpose of this report is to introduce laboratory workers at the National Bureau of Standards to the hazards associated with use of sulfur hexafluoride (SF_6) in electrical equipment and to recommend precautions that should be taken to insure safety in handling of this gas. This report is not concerned with other uses of SF_6 or its mixtures with other gases.

Compressed gaseous SF_6 is a common electrical insulant in various types of high voltage electrical apparatus such as circuit breakers, power transformers, capacitors and bushings. Occasionally it is necessary to vent or otherwise expel this gas from equipment in order to perform routine maintenance or repairs. There also exists the possibility that an SF_6 -containing vessel will accidentally develop leaks resulting in release of significant quantities of gas into the laboratory environment. One should thus be aware of the possible dangers of exposing oneself to SF_6 , particularly if the equipment involved is known to have experienced an electrical failure which might have caused decomposition of a significant portion of the gas.

Under normal atmospheric conditions at room temperature, SF_6 is an inert, chemically stable gas and is not by itself considered to be toxic. However, some of its decomposition products which might, for example, result from electrical arcing in the gas are known to be highly reactive and toxic. It is not the purpose of this report to provide detailed information about the toxicity of all possible SF_6 decomposition products. Some information concerning the more common gaseous by-products is given in the Appendix. More information can be obtained from the references cited.

II. PURE SF₆

Sulfur hexafluoride in the pure state is not considered dangerous to life unless it accumulates to such a degree that it displaces necessary oxygen for a sufficient length of time to interfere with normal respiratory functions. This could occur only in situations where SF₆ is released into an enclosure or depression having poor ventilation. Because it is five times more dense than air SF₆ will, if leaked into a low area of little circulation, tend to settle upon displacing air. The danger of asphyxiation from SF₆ which has displaced air is enhanced by the fact that this gas is odorless and colorless.

Laboratory tests¹ have shown that animals exhibit no ill effects upon prolonged breathing of an atmosphere containing 20% O₂ and 80% SF₆, i.e., an atmosphere in which naturally occurring N₂ is replaced by SF₆. Nevertheless, the Occupational Safety and Health Administration (OSHA) regulations² limit occupational exposure to SF₆ in air to a time-weighted average (TWA) of 1000 ppm by volume.

Not only is SF₆ nontoxic, but it is also chemically inert and does not decompose under normal atmospheric conditions. Moreover, it is chemically stable with respect to most common laboratory materials even at red heat. Although SF₆ is nonflammable in air, it will react readily if heated or sparked with H₂ or H₂S, but since these gases, if present, are considerably more hazardous than SF₆, it is unlikely that a situation would exist where these gases would accidentally mix in the laboratory environment. Mixtures of SF₆ and H₂, for example are potentially explosive and require special precautions in handling which are not covered here.

III. CONTAMINATED OR DECOMPOSED SF₆

It is known that if SF₆ (particularly SF₆ contaminated by air, moisture or hydrocarbon containing materials like oil) is thermally decomposed, a variety of toxic by-products can be produced depending on the environment in which the gas exists. This can happen, for example, in an electrical arc or when the gas has been subjected to continuous corona discharges. The toxic by-products that represent the greatest immediate hazards are, of course, those that exist in the gaseous state under normal conditions, and can, therefore, be released into the atmosphere of the laboratory in the event of a rupture or intentional opening of an SF₆-containing vessel. The noxious gaseous by-products of chief concern are^{1,5-7} the oxyfluorides SOF₂, SO₂F₂, SOF₄ and HF and SO₂. All of these with the exception of SO₂F₂ have strong odors and thus provide adequate warning of their presence. It should be noted, however, that SO₂F₂ is much less toxic than the other gases and, when formed from SF₆ under arcs, is always accompanied by the others. Tests indicate that of the oxyfluorides resulting from decomposition of SF₆ in an arc, the most prevalent is usually SOF₂, which has a prominent rotten-egg odor.

Toxic, lower valence, sulfur fluorides such as SF₄, S₂F₂, and S₂F₁₀ as well as free fluorine, although often formed in initial decomposition of SF₆⁷, tend to react among themselves or with moisture to form SF₆, oxyfluorides, SO₂ and HF. Of these SF₄ is usually generated in greatest abundance and could escape into the laboratory at a sufficient rate to be harmful. This gas also has a disagreeable odor which permits its presence to be easily sensed. The Appendix contains toxicity information obtained from Ref's 1-4 on some of the gaseous decomposition products mentioned above.

In addition to being toxic some of these gases such as SO_2 , HF and SF_4 are known to be very reactive or corrosive and may, for example, readily attack insulating materials. This can lead to production of other toxic gaseous or solid compounds. If tungsten or silicon are present in the apparatus one can expect production of gaseous WF_6 and SiF_4 . Presence of carbon or hydrocarbons like PTFE (polytetrafluorethylene) can yield CF_4 , CO or CO_2 , although of these only CO is considered harmful. If arcing occurs along or near polyethylene or epoxy or phenolic resins, one can also expect formation of CS_2 , COS, or COF_2 ⁵. Most metal fluorides which might be formed in electrical apparatus, such as those of aluminum or copper are solids under normal conditions and are thus unlikely to represent an immediate hazard. However, when cleaning or repairing SF_6 -containing equipment, care should be taken to remove powders and other solid deposits that might be formed so as to avoid possible inhalation of these.

IV. RECOMMENDATIONS FOR SAFE HANDLING OF SF_6

Although SF_6 is not considered a toxic substance there are conditions under which improper handling of this gas can be hazardous to one's health. Based on the information given above we recommend that the following precautions be taken in working with SF_6 :

1. Avoid unnecessary exposure to this gas at concentrations greater than specified by OSHA regulations.
2. Vessels containing SF_6 should never be vented directly into an enclosure or room with poor ventilation.
3. A hose or other arrangement should be used in venting SF_6 to carry the gas either outside of the building or into a venting system or fume hood.

4. If possible, vessels containing pressurized SF₆ should be equipped with pressure gauges that should be checked regularly to determine possible existence of leaks. This is important not only because leaking gas may be hazardous but also because insulating quality of gas decreases with decreasing pressure, thus increasing the risk of electrical breakdown.
5. If an SF₆ containing vessel is known to be leaking, it should if at all possible be placed in a well ventilated area preferably outside the building, and one should be alert for obnoxious odors (pungent, like H₂S or SO₂) which would indicate the presence of toxic decomposition products, primarily SOF₂.
6. In the extreme case of an electrical fault leading to rupture of an SF₆-containing vessel, one should leave the room immediately and report this as an emergency. Re-entry should not be attempted without proper respiratory equipment as long as obnoxious odors persist. In cleaning up damaged equipment containing contaminated SF₆ resulting from electrical failure it is essential that all decomposed gas be removed preferably by dumping gas into a fume hood or gas cart with a pump or blower. The dust-like metallic fluorides should be removed using a well filtered vacuum cleaner, and finally the vessel should be wiped clean with rags. Those performing this task should protect not only their lungs but also their skin leaving no parts of their body exposed, e.g., they should have sleeves and pants legs taped, wear gloves, etc.
7. It is possible to filter out toxic SOF₂, SO₂F₂, SOF₄, SF₄, SO₂ and HF from SF₆ by flowing the gas through activated charcoal or alumina filters. The effectiveness of such filtering depends on the selection and conditioning of the filters, details of which are not included

here. Such filters may be useful with SF₆-insulated equipment in which arcs are to be expected during normal operation, e.g., spark gaps or circuit breakers. Most commercially available equipment of this type are already provided with activated alumina absorbers to help remove decomposition products.

It should be noted that these recommendations are believed to conform to current practices recommended by industrial users and manufacturers of SF₆ for electrical insulation.

V. APPENDIX

The toxicity data summarized below are reproduced from Ref. 4, in which references to the primary data sources may be found. Brief definitions of the standard abbreviations for inhalation toxicity of gases in air are given below.

LC₅₀ = lethal concentration reported to kill 50% of test population

LCLo = lowest concentration reported to have caused death of humans or test animals.

TLV = threshold limit value, the maximum deemed tolerable for daily 8-hr. exposure

TWA = time-weighted average

ppm = parts per million by volume

SF₆ : OSHA standard TWA = 1000 ppm

TLV = 1000 ppm

SOF₂ : LCLo (mouse) = 260 ppm/1 hr

LCLo (rabbit) = 1000 ppm/1 hr

NIOSH-recommended standard TWA = 2.5 mg/m³

SO_2F_2 : LCLo (mouse) = 1200 ppm/1 hr
LCLo (rabbit) = 5000 ppm/1 hr
LC₅₀ (rat) = 3020 ppm/ 1 hr
OSHA standard TWA = 5 ppm
TLV = 5 ppm

SF_4 : LCLo (rat) - 19 ppm/4 hr
TLV = 0.1 ppm

S_2F_{10} : LCLo (rat) = 1780 ppm/1 hr
LCLo (mouse) = 130 mg/m³/10 min
OSHA standard TWA = 250 µg/m³
TLV = 0.025 ppm

SOF_4 : [No quantitative information available, but believed on the basis of information given in Ref. 1 to be similar in toxicity to SF_4 .]

SO_2 : LCLo (mouse) = 6000 ppm/5 hr
LCLo (frog) = 1 ppm/15 min
OSHA standard TWA = 5 ppm
TLV = 5 ppm

One could qualitatively describe the odors of these gases as follows:

SOF_2 like rotten eggs; SF_4 , SOF_4 , SO_2 acrid; and SF_6 , SO_2F_2 , S_2F_{10} odorless.

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