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Subject: Alternative options: Reconditioned & Recycled versus Virgin SF6 gas

With the expected changes in policies and regulations at state level regulatory agencies, SF_6 gas reporting and the continued move towards SF_6 gas emissions reduction continues to be a challenge.

Furthermore, as new alternatives are being reviewed by utilities and Gas Insulated Equipment (GIE) users, alternatives with lower global warming potential (GWP) must be considered. One of these alternatives is exactly what we have been using all along; however, user practices must be changed to ensure global and local reduction of emissions.

The recently updated Intergovernmental Panel on Climate Change (ipcc) document, 2019 Refinement of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, states that an estimate of 0.03kg (~0.066lbs) to 0.08kg (~0.18lbs) of SF_6 gas is emitted to the atmosphere per every 1kg (~2.2lbs) of SF_6 gas produced. This is illustrated on the table found in the document in Chapter 3, Volume 3, page 3.28 as follows:

TABLE 3.28A (NEW)
TIER 1 DEFAULT EMISSION FACTORS FOR FLUOROCHEMICAL PRODUCTION

Fluorochemical Produced	Emission Factor for each Emitted GHG (kg fluorinated GHG emissions/kg fluorochemical produced)	Uncertainty for default emission factor for fluorochemical production
SF_6	0.03 (SF_6)[a] 0.08 (SF_6)[b]	±50% (0.015 to 0.045) ±50% (0.04 to 0.12)
NF_3	0.02 (NF_3)[c] 0.03 (N_2O)[d] 0.01 (CF_4)[d]	±50% (0.01 to 0.03) ±50% (0.015 to 0.045) ±50% (0.005 to 0.015)
All other fluorochemicals	0.04 (see Table 3.28B for composition of emitted mass)[e]	-98% to +470% (0.001 to 0.2)[f]

Source:

[a] O'Connell, 2002.

[b] Suizu, 1999.

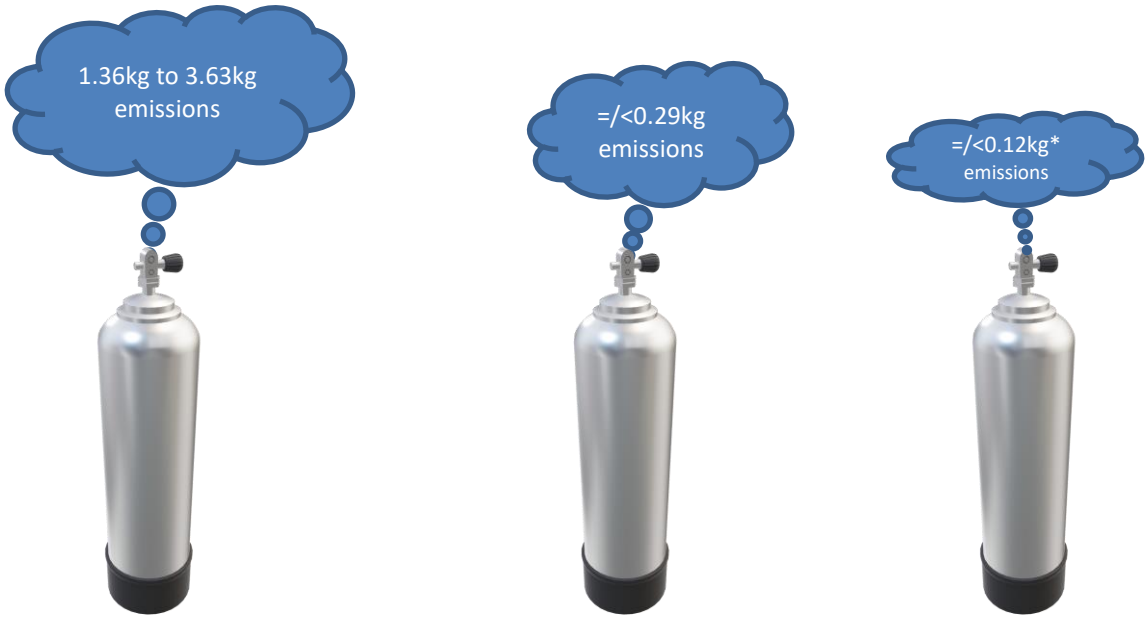
[c] Fthenakis, 2010.

[d] Tasaka, 2004; 2007.

[e] As described further in Annex 3A.1 of this Volume, the default emission factor was estimated using data from the US EPA Greenhouse Gas Reporting Program (US EPA, 2017a; 2017b). Briefly, under the Greenhouse Gas Reporting Program, fluorinated GHG emissions are reported annually on a facility basis and include facilities with and without abatement. Depending on the year, 14 to 16 fluorochemical production facilities have reported under the Program. Facilities that abate their emissions report their level of abatement for each process as a range. To develop emission factors on an uncontrolled basis, the pre-abatement emissions of each facility were estimated using the arithmetic averages of the abatement ranges reported by that facility for its processes. Then, for each facility, this estimate was divided by the total quantity of fluorinated gases produced or transformed by that facility to obtain an uncontrolled emission factor for that facility and year. This was done for all six years for which the US EPA had data at the time the factor was developed. For each facility, the emission factors for each year were then averaged over the six years of reporting, and the resulting facility averages were averaged to obtain the default factor above. Because the reporting U.S. facilities use multiple manufacturing methods to produce a wide array of fluorochemicals,[3] averaging the facility-specific emission factors is expected to provide a default emission factor that is applicable where the manufacturing method is unknown, as is often the case in a Tier 1 calculation.

[f] As noted above, emission rates from different manufacturing methods can vary widely, a pattern seen in the variation of the emission factors across the facilities reporting to the U.S. Greenhouse Gas Reporting Program. This variation (summarized here as a 95-percent confidence interval around the arithmetic mean) provides a first order estimate of the uncertainty of the default Tier 1 emission factor. Thus, the default emission factor is broadly applicable, but it is also highly uncertain due to the inherent variability of emission rates across manufacturing methods and produced fluorochemicals.

Using this reference as stated, extrapolating the weights of delivered virgin SF_6 gas, reconditioned SF_6 gas and recycled SF_6 gas to a weight of 45.36kg (100lbs), we can determine the following emission rates as illustrated in the diagram below:



45.36kg of Virgin SF_6 Gas delivered (1)

45.36kg of SF_6 Gas reconditioned (2)

45.36kg of SF_6 Gas recycled (3)

(1) Virgin SF_6 Gas, which is batch tested (analyzed) to be at a purity of 99.9%, delivered into North America

(2) Reconditioned SF_6 Gas, which is analyzed to be at a purity of 95% and is reconditioned using DILO SF_6 gas separation processor and the DILO SF_6 gas handling procedures that limit emissions, to a reconditioned purity of =/>99.0%

(3) Recycled SF6 Gas, which is analyzed to be at a purity of =/>97% and is recycled using the applicable DILO recovery system and the DILO SF6 gas handling procedures that limit emissions.

Illustration expressed in a table

Weight of SF_6 Gas	Type of SF_6 Gas	Emission dependent of process
45.36kg (100lbs)	Virgin SF_6 Gas	1.36kg (2.0lbs) to 3.63kg (8.0lbs)
45.36kg (100lbs)	Reconditioned (95% to =/>99.0% Purity)	=/<0.29kg(0.64lbs)
45.36kg (100lbs)	Recycled (97% Purity)	=/<0.12kg (0.05lbs)*

*0.12kg (0.05lbs) emissions can be less and are dependent on handling processes and practices.

The document goes on to further state, "*In addition to the compounds being intentionally produced, a variety of fluorinated GHG by-products can be emitted from fluorochemical manufacturing processes. Emissions of these other fluorinated GHGs can exceed emissions of the compound being intentionally produced.*"

In summary, other GHGs that are either produced or used during the manufacturing process are emitted to the atmosphere as part of the SF_6 manufacturing process. Due to the processes and potential mitigation used, it is difficult to specifically determine the exact amount of additional GHGs emitted.

It is estimated that a representative chemical composition of the emitted mass can be determined per the following table:

TABLE 3.28B (NEW)
REPRESENTATIVE CHEMICAL COMPOSITION OF THE EMITTED MASS

Fluorinated GHG emitted	Percentage emitted (% of unweighted tonne)[a]
HFC-134a	18
PFC-14 (Perfluoromethane)	18
Perfluorocyclobutane	13
HFC-32	11
HFC-125	11
HFC-23	11
HFC-143a	7
PFC-116 (Perfluoroethane)	5
PFC-218 (Perfluoropropane)	4
PFC-5-1-14 (Perfluorohexane, FC 72)	3

Source:

[a] To derive this composition, six years of US EPA GHGRP data were sorted, and the chemical species with the highest estimated uncontrolled emissions (in metric tonne) were identified. The weighted average GWP of these emissions is the same as the weighted average GWP of the uncontrolled emissions (other than very low-GWP emissions) estimated for fluorinated gas producers that report to the US EPA.[4] More discussion on the development of the default emissions factor and the representative chemical composition is provided in Annex 3A.1.

It is imperative to recognize that SF_6 gas is currently the best insulator and arc quenching medium for GIE. It has been tried and tested through real time experience and history that SF_6 gas can perform at all the applicable voltage levels and current ratings as well as in extreme temperature applications. In some cases, the integration of heaters and/or mixed gas applications is required.

Furthermore, as SF_6 gas GIE design continues to evolve and reconditioned and recycled SF_6 gas becomes more available, re-using SF_6 gas is not only environmentally friendly but also economical.

Utilities currently utilizing reconditioned and recycled SF_6 gas can provide further references to the effectiveness of the gas in GIE that have been in service for a number of years without incident due to the use of reconditioned and/or recycled SF_6 gas.

References:

DILO Company Inc. – Reconditioning and recycled SF_6 gas processes

DILO GmbH - SF_6 gas Separation device

EPA & ipcc, 2019 Refinement of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol3.html