NAME : PORTAL	GROUP REF. : A3
COUNTRY : FRANCE	PREF. SUBJECT :PS2
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Possible harmonisation of C4-FN mixtures?

Question Q13: A variety of C4-FN based mixtures (with and without oxygen) and composition ratios (some even undisclosed) is reported. With every manufacturer having its "proprietary gas" could "inter-operability" be realized? Can specialist predict whether a "one-gas-fits-all" solution is waiting at the horizon or at what time horizon convergence of various technologies can be expected?

C4-FN based mixtures / why different mixtures?

Over the last years, different ratios of C4-FN/O_2/CO_2 have been introduced as alternatives to SF_6 for electrical switchgear. With SF_6, the only degree of freedom for switchgear designers was the gas pressure. Now to accommodate different applications and use (new product or retrofit/retrofill of existing assets) additional degrees of freedom with ratios of the different mixture component were available to further optimize the design.
This has enabled to design products of the same size as SF_6 equipment with C4-FN mixtures.

As all the applications have yet not been covered it seems too early to freeze ratios. For instance:

- HV retrofilling of existing SF_6 assets might require higher ratio (20%) of fluoronitrile[1] than the ones usually implemented in new assets (3 to 6%).
- MV load break switch[2] application requiring 10 to 15% C4-FN

Anyhow for new equipment convergence is on the way and some manufacturers have been working to limit the number of variants. For instance, regarding the O_2 content and optimum of 13% of O_2 was identified[3] to improve the short circuit current capability.

Could the mixtures based on C4-FN be jointly defined?

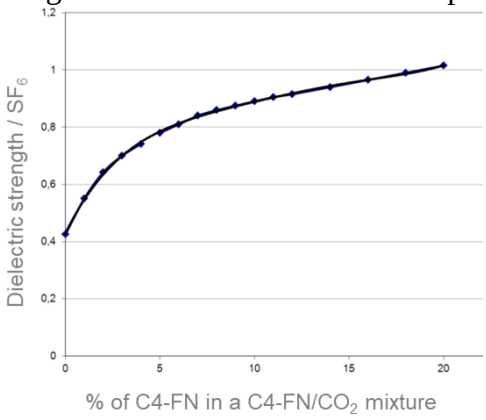
To reduce further the number of variants, a joint definition by several manufacturers would be needed, anyhow it remains a challenge as:

- Optimum in design could depend on the manufacturer
- Changing ratio of some compound for the ones who have already developed a solution could lead to re-design and re-type-test
- Co-development between OEM would require sharing information between competitors

Then to limit the definition of new mixtures, newcomers in the field of alternatives could select already proposed mixture by other OEM

Inter-operability of gas mixtures?

The concept of inter-operability for gas in switchgear would require one design to work with several gas mixtures. C4-FN being the main driver of dielectric strength it is not likely that using any C4-FN mixtures could be used in any type of switchgear. Indeed, each switchgear design have been validated with a specific mixture and amount of C4-FN.



Anyhow, as far as site operations are concerned it is important to highlight that all C4-FN mixtures can be operated with the same tools (gas carts, gas analysers).

Last regarding inter-operability, if anticipated at the design stage it is possible to define high voltage switchgear that will be compatible with several type of gases. For instance, last generation of 362/420 kV GIL[4] can be operated with either SF_6 or a C4-FN mixture.

One-gas-fits-all? By when?

Step by step harmonisation of C4-FN gas mixtures is coming for new developed equipment. Manufacturers having a long experience in C4-FN have been already through this process of reducing the number of available mixtures.
But, as C4-FN mixtures are extending their use to a wider range of applications to enable SF_6 phase-out, it is not likely that a single type of mixture will exist in the coming years.
For instance:

- Recent retrofit applications[5] with N_2 instead of $C0_2$ have demonstrated interesting capability for retrofilling existing SF_6 GIL without gasket change.
- Application in MV voltage is having specific needs
- Application outside electrical switchgear (e-beam and others)

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[1] L. Loizou et al., "Technical Viability of Retro-filling C3F7CN/CO2 Gas Mixtures in SF6-designed Gas Insulated Lines and Busbars at Transmission Voltages", IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 35, NO. 5, OCTOBER 2020
[2] A. Laso et al, "Design Considerations for Implementing SF6 Alternatives for Distribution Switchgear Applications with Focus on Toxicity and Load Break Performance," in CIGRE Paper A3-10136, Paris, 2022.
[3] J. Ozil et al, "Return of experience of the SF6-free solution by the use of Fluoronitrile gas mixture and progress on coverage of full range of transmission equipment," in CIGRE Paper A3-117R, Paris, 2021.
[4] https://www.gegridsolutions.com/press/gepress/ge-dual-gil.htm
[5] L. Chen et al., "Application of SF6 Alternatives for Retro-filling Existing Equipment", in CIGRE Paper A3-10103, Paris, 2022.