Green use of fluorocarbons in Cherenkov detectors and silicon tracker cooling systems: challenges and opportunities.

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G. Hallewell: Green FCs for Cherenkov detectors and Si tracker cooling: Sustainability session ICHEP2024 Praque 18-24 July 2024

“Green” fluorocarbons for Cherenkov detectors & silicon tracker cooling systems: challenges and opportunities

- ***Saturated fluorocarbons (PFCs, SFCs: $C_nF_{(2n+2)}$)*** chosen for optical properties as Cherenkov radiators: C_4F_{10} & CF_4 in COMPASS & LHCb RICH1&2.

- Non-conductivity, non-flammability, non-toxicity & radiation resistance ➔ ideal coolants
  - C_6F_{14} used in all LHC experiments,
  - C_3F_8 evaporatively cools ATLAS silicon tracker, TOTEM;

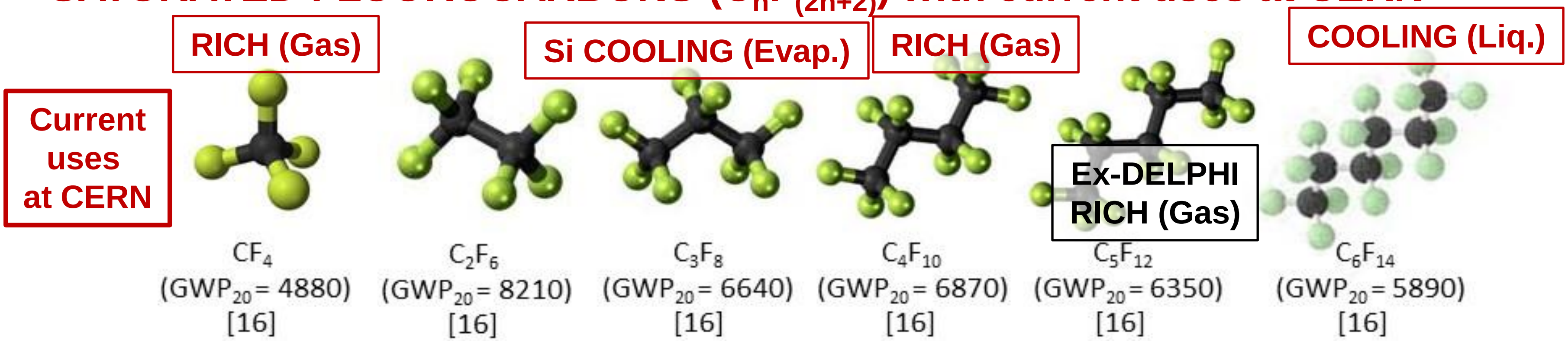
- These fluids however have high GWPs (GWP_{20} > 5000*CO_2);

- ***Fluoro-ketones ($C_nF_{2n}O$),*** while not industrialised over a wide $C_nF_{2n}O$ range, can offer similar performance at very low, or 0 GWP;

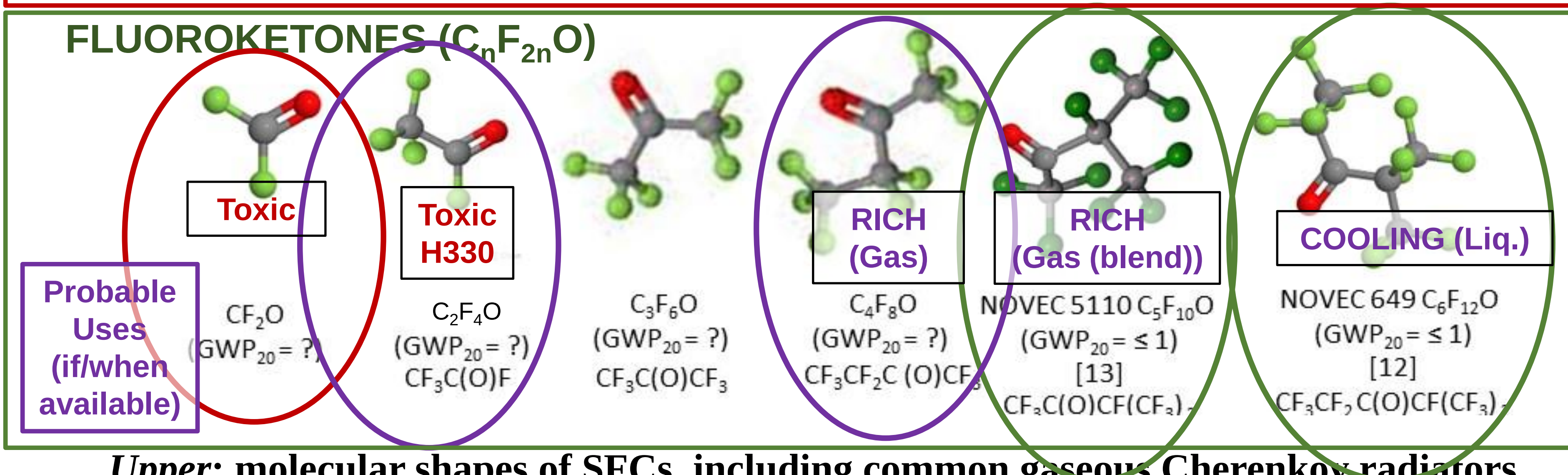
- Radiation tolerance & thermal performance of 3M NOVEC 649 (lin-$C_6F_{12}O$) sufficiently promising to be considered by CERN to replace C_6F_{14} for cooling, but acid production and materials compatibility issues to resolve;

Molecular shapes and GWP (1)

SATURATED FLUOROCARBONS ($C_nF_{(2n+2)}$) with current uses at CERN



FLUOROKETONES ($C_nF_{2n}O$)



Upper: **molecular shapes of SFCs, including common gaseous Cherenkov radiators**

Lower: **shapes of some non-cyclic $C_nF_{2n}O$ analogues**

(20-year GWPs noted where known – refs: https://link.springer.com/article/10.1140/epjp/s13360-023-04703-w**)**

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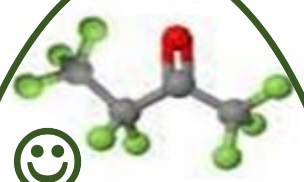
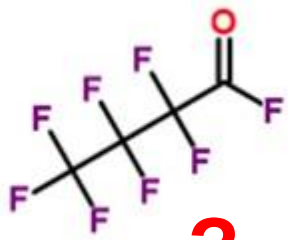
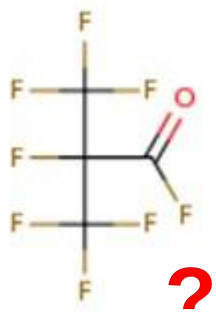
Molecular shapes and GWP (2)



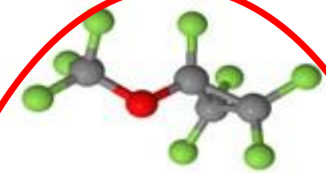


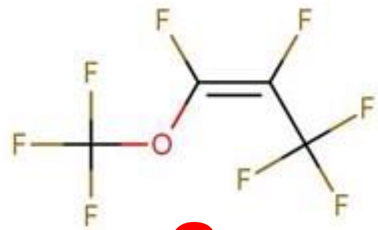
?



?

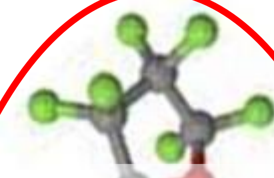
C_4F_8O
Linear & branched with Oxygen atom on external spur
(GWP_{20} = ?)



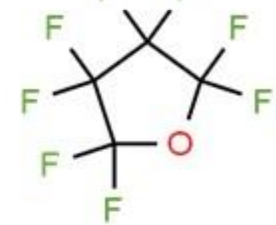


?

C_4F_8O
Linear with Oxygen atom as internal link and double carbon bonded link
(GWP_{20} = ?)



ALICE VHMPID, BTeV studies: Refractive index, UV transparancy OK (similar to C_4F_{10}), but…



High GWP!!

C_4F_8O
Cyclic
Perfluorotetrahydrofuran,
Octofluorotetrahydrofuran
(GWP_{20} = 8975) [10]

Cyclic, non-cyclic & non-cyclic double carbon-bonded C_4F_8O isomers: refs at end.

Placement of oxygen atom can also determine flammability & toxicity

From: 2021-22 CERN environmental Report report
https://doi.org/10.25325/CERN-Environment-2023-003

GROUP	GASES	tCO_2e 2021	tCO_2e 2022
Perfluorocarbons (PFCs)	CF_4, C_2F_6, C_3F_8, C_4F_{10}, C_6F_{14}	55 921	68 989
Hydrochlorofluorocarbons (HFCs)	HFC-23 (CHF_3) HFC-32 (CH_2F_2) HFC-134a ($C_2H_2F_4$) HFC-404a HFC-407c HFC-410a HFC-507	36 557	86 211
Other F-gases	SF_6, NF_3	16 838	18 355
Hydrofluoroolefins (HFO)/HFCs	R-449 R1234ze NOVEC 649	86	199
	CO_2	13 771	10 419
Total Scope 1		123 174	184 173

PFC Loss around 10-12 tonnes (particle detection and detector cooling)

GWP 23000 (SF$_6$)

GWP 0 (NOVEC 649)

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Adding some conclusion here, *in case I run out of time*:

"Green" fluorocarbons for Cherenkov detectors & silicon tracker cooling systems: challenges & opportunities

- **Saturated fluorocarbons (SFCs: $C_nF_{(2n+2)}$) chosen for optical properties as Cherenkov radiators: C_4F_{10} & CF_4 used in COMPASS & LHCb RICH1&2.**
- **Non-conductivity, non-flammability & radiation resistance ➔ ideal coolants**
  - C_6F_{14} used in all LHC experiments,
  - C_3F_8 evaporatively cools ATLAS silicon tracker, TOTEM.
- **These fluids however have high GWPs (GWP_{20} > 5000*CO_2).**
- **While not industrialised over a wide $C_nF_{2n}O$ range fluoro-ketones can offer similar performance at very low, or 0 GWP;**
- **Radiation tolerance & thermal performance of 3M NOVEC 649 (lin-$C_6F_{12}O$) sufficiently promising to be considered by CERN to replace C_6F_{14} for cooling;**
- ***Cherenkov detectors*: subject to optical testing, *lin-C_4F_8O could replace C_4F_{10}* while *lin-C_4F_8O or lin-$C_5F_{10}O$ blended with N_2 and monitored in real time by sound velocity gas analysis - could replace CF_4***
- ***SI tracker COOLING: Lighter molecules (e.g. C_2F_4O, with similar thermodynamics to C_2F_6) - would allow lower temperature, 0GWP operation than evaporative CO_2 in Si trackers operated at high luminosity: low order $C_nF_{2n}O$ toxicity a problem…***

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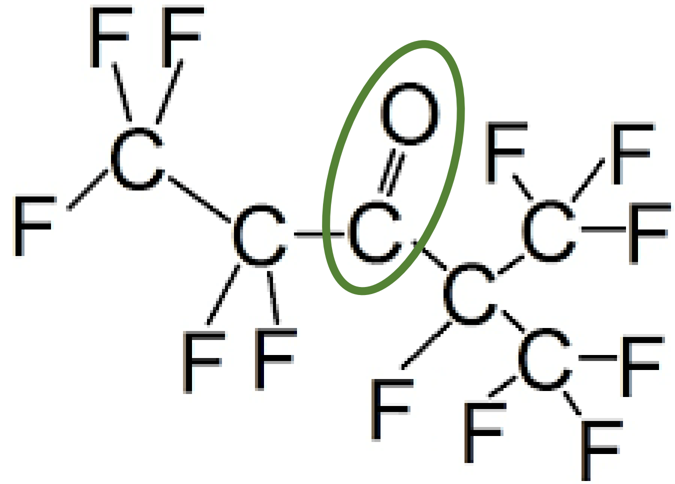
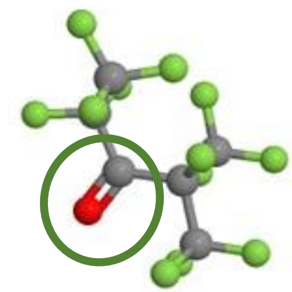
What gives NOVEC 649/1230 (lin $C_6F_{12}O$: FK-5-1-12) its low GWP?





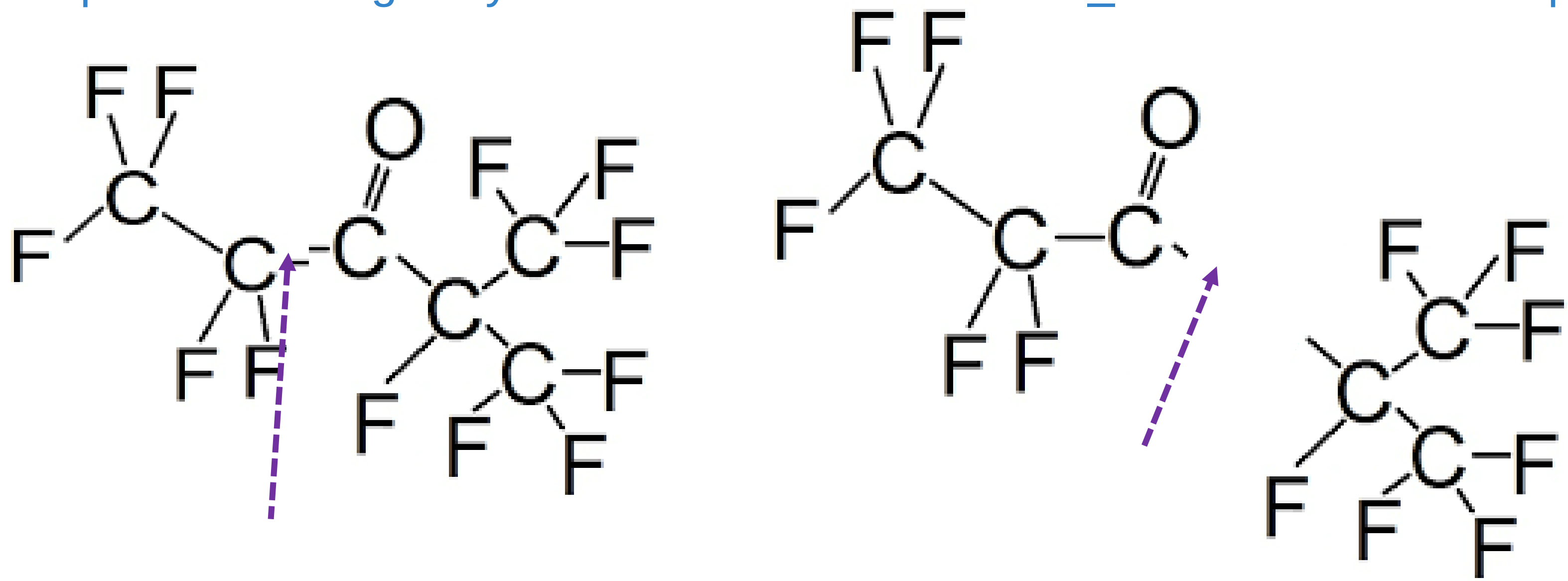
NOVEC 649 $C_6F_{12}O$
(GWP_{20} = ≤ 1)
[12]
$CF_3CF_2C(O)CF(CF_3)_2$

A: Structure!: a *double-bonded oxygen atom on a peripheral spur* of the molecule

This fluoro-ketone configuration is:
$CF_3CF_2C(O)CF(CF_3)_2$

What gives NOVEC 649/1230 (lin $C_6F_{12}O$: FK-5-1-12) its low GWP?

https://www.nist.gov/system/files/documents/el/fire_research/R0301570.pdf [15]

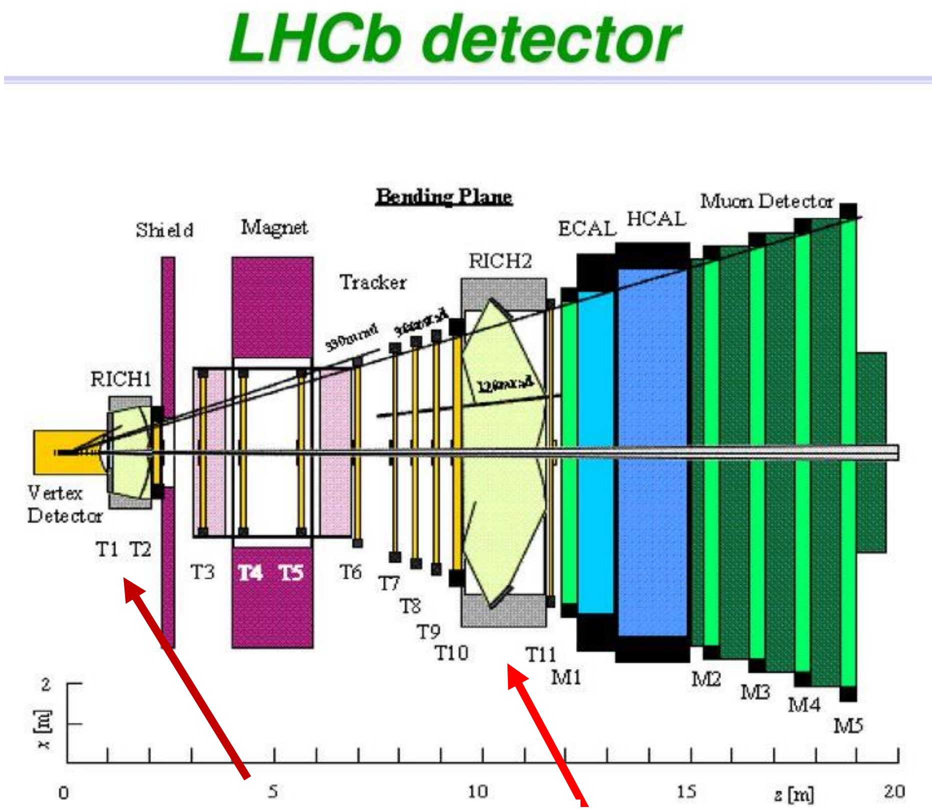


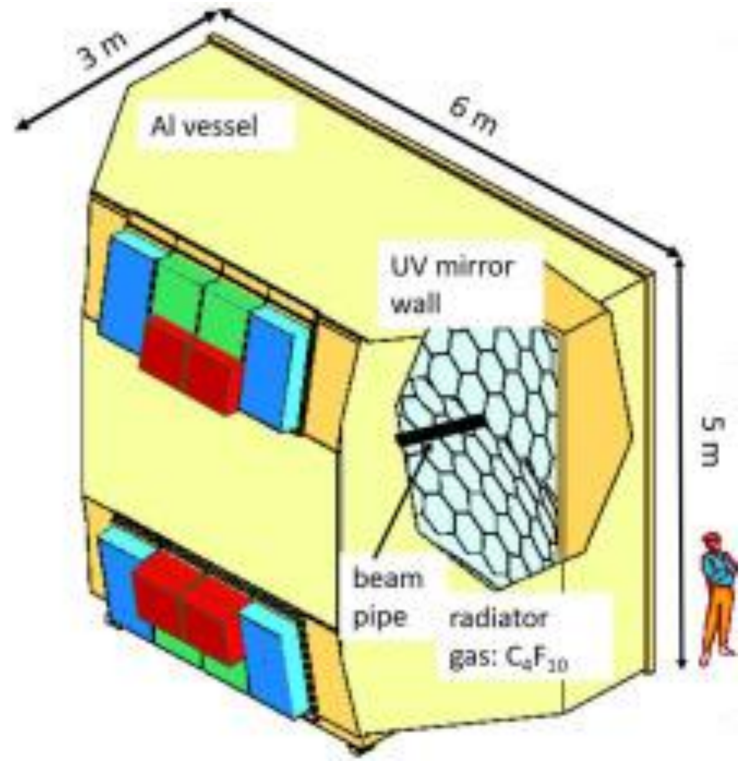
Scission by UV photons of λ ~300 nm in upper atmosphere (low P, high UV): fragments do not re-associate* into $C_nF_{(2n+2)}$ SFCs

***The Environmental Impact of CFC Replacements HFCs and HCFCs**
T. WALLINGTON et al *Environ.Sci.Technol.*1994(28)7 320A
https://doi.org/10.1021/es00056a714

The Cherenkov detector aspect

Ideally… replace SFCs with same-order GWP_0 FKs *with good UV transparency, refractivity…*





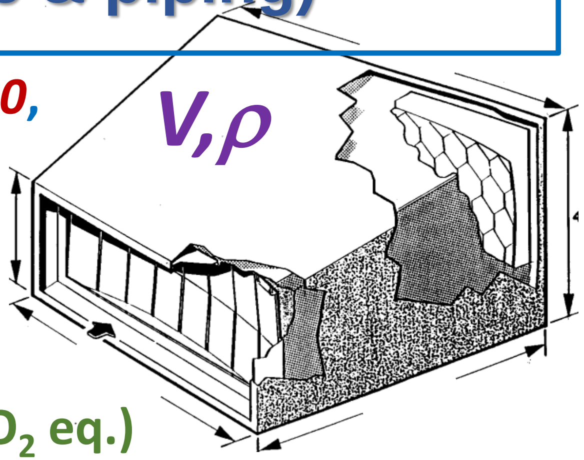
LHCb RICH 1
(4m³ lin-C_4F_8O)
GWP eqv. CO_2: 0 tonnes

LHCb RICH 2
(100 m³: CF_2O + ?)
No! CF_2O TOXIC ☹

COMPASS RICH
(100 m³ lin- C_4F_8O)
GWP eqv. CO_2: 0 tonnes

Refractive index & GWP 'load' in a Cherenkov Gas Radiator (vessel only, not including tankage & piping)

C_4F_{10} (COMPASS: 100m^3, LHCb RICH 1: 4m^3): *GWP_{20} = 4880*,
CF_4 (LHCb RICH 2: 100m^3): *GWP_{20} = 6870*



Cherenkov radiator vessel volume *V(m^3)* filled with a blend of gases of densities *ρ_i (kgm^{-3})*, fractional concentrations *w_i* & individual *GWP_i* (tonnes CO_2 eq.) has a GWP environmental "load" (& release potential) *L* given by:

$$L = \frac{V}{1000} \sum_i \left(wi \,.\, \rho_i \,.\, GWPi \right) \quad \text{(tonnes } CO_2 \text{ eq.)}$$

Corresponding radiator gas mixture refractivity given by :

$$(n-1)_{rad} = \sum_i \left(wi.\, (n-1)_i \right)$$

Can blend small concentration ω_x of (heavier) SFC or Lin-FK vapour of high refractivity *$(n\text{-}1)_x$* with ω_y of light transparent gas (N_2, Ar…) to replicate the target refractivity *$(n\text{-}1)_z$* of a lighter SFC at high concentration – for lower GWP load.

$$\omega_x = \frac{(n-1)_{z(target)} - (n-1)_y}{(n-1)_x - (n-1)_y}$$

Use real-time speed of sound to get component molar concentrations, ω_i (SoS traditionally also called "c" by acousticians to confuse things)

$$c = \sqrt{\frac{\gamma RT}{M}} \quad \gamma_m = \frac{C_{pm}}{C_{vm}} = \frac{\sum_i w_i Cp_i}{\sum_i w_i Cv_i} \quad M = \sum_i w_i M_i \quad c = \sqrt{\frac{\frac{\sum_i w_i Cp_i}{\sum_i w_i Cv_i} RT}{\sum_i w_i M_i}}$$

More details (ATLAS system): https://www.mdpi.com/2410-390X/5/1/6

Then use standard refractivity formula to get from calculated $\omega_{1,2}$

$$(n-1)_{rad} = \sum_i (wi.(n-1)_i)$$

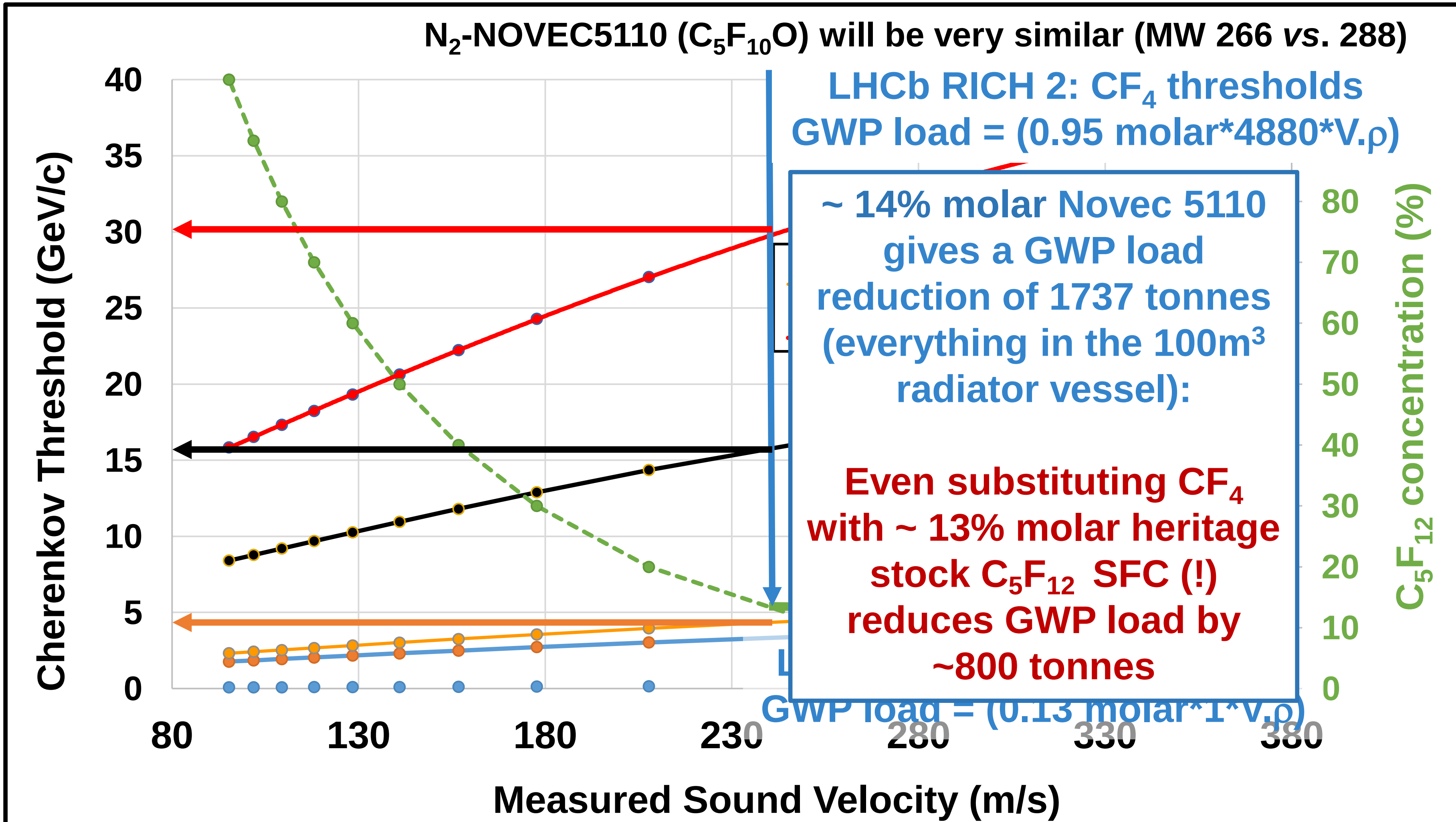
to refractive index of radiator gas blend in real-time, then standard relativistic expressions to get from n to Cherenkov γ thresholds for different particle species + $\beta = 1$ angle

Real-time measurement of *speed of sound c* takes us via the relative concentrations of the components to the *speed of light* β *and beyond!!* in the radiator gas

Eyes on the prize…(focus here on LHCb RICH2 (n-1)…)

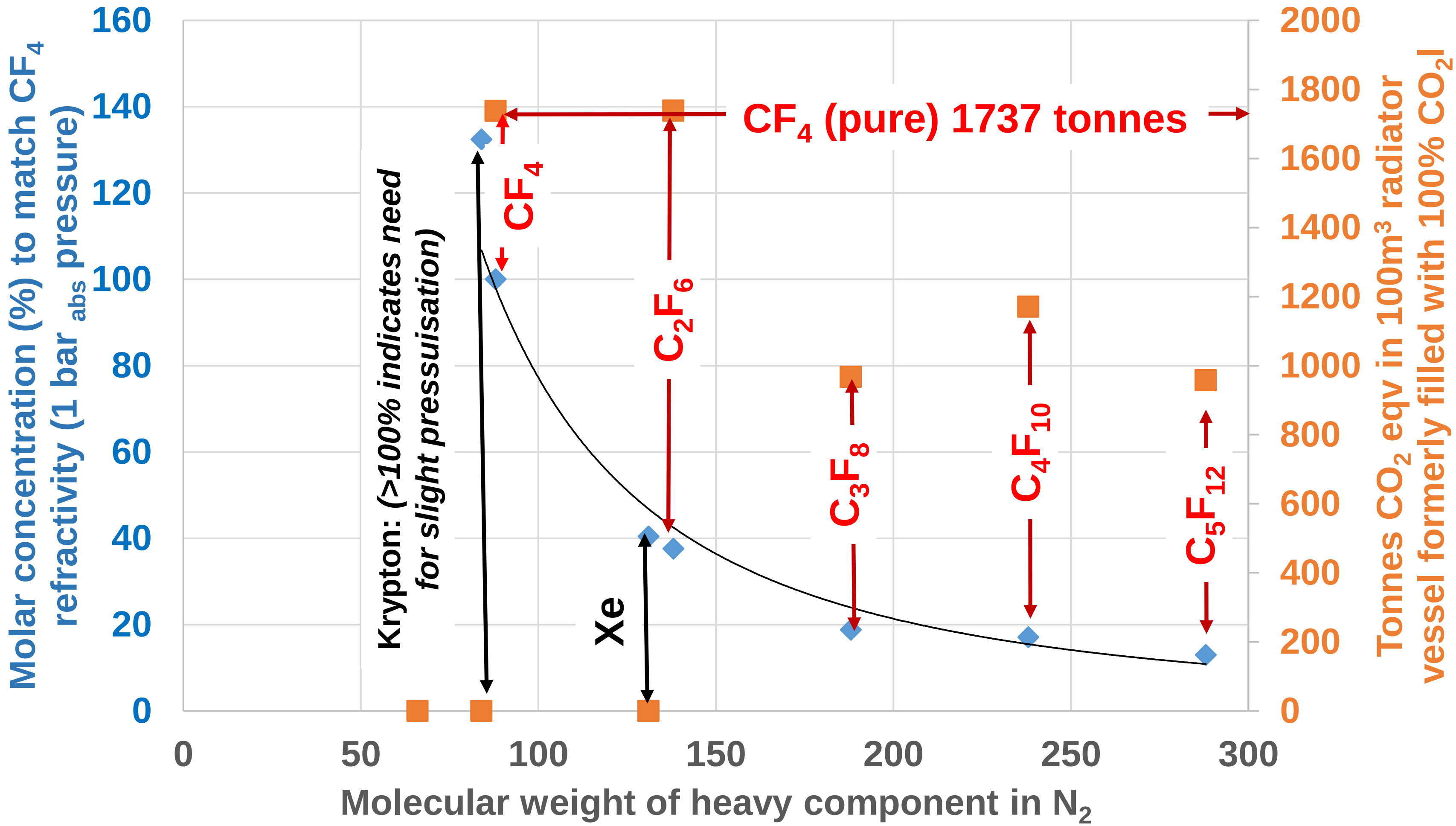
$$(488.10^{-6})_{CF4} = (\sim 1750.10^{-6})_{C5F10O} * 0.12 + (300.10^{-6})_{N2} * 0.88$$

Cherenkov threshold: *lin*-$C_5F_{10}O$ (eg: 3M NOVEC 5110)/N_2 & (heritage) C_5F_{12}/N_2 blend *and GWP load comparison with LHCb RICH2 (CF_4: 100m^3)*



Radiator volume GWP load: 100 m³ gas radiator with different mw gases blended with nitrogen to replace CF_4

(note: blends with Ar very similar: need refractivity data for linear fluoro-ketones, probably similar to SFCs)
blends with CO_2 not consdered: high CO_2 triple point temp (-56 C) ➔ thermodynamic recirculation difficulty)



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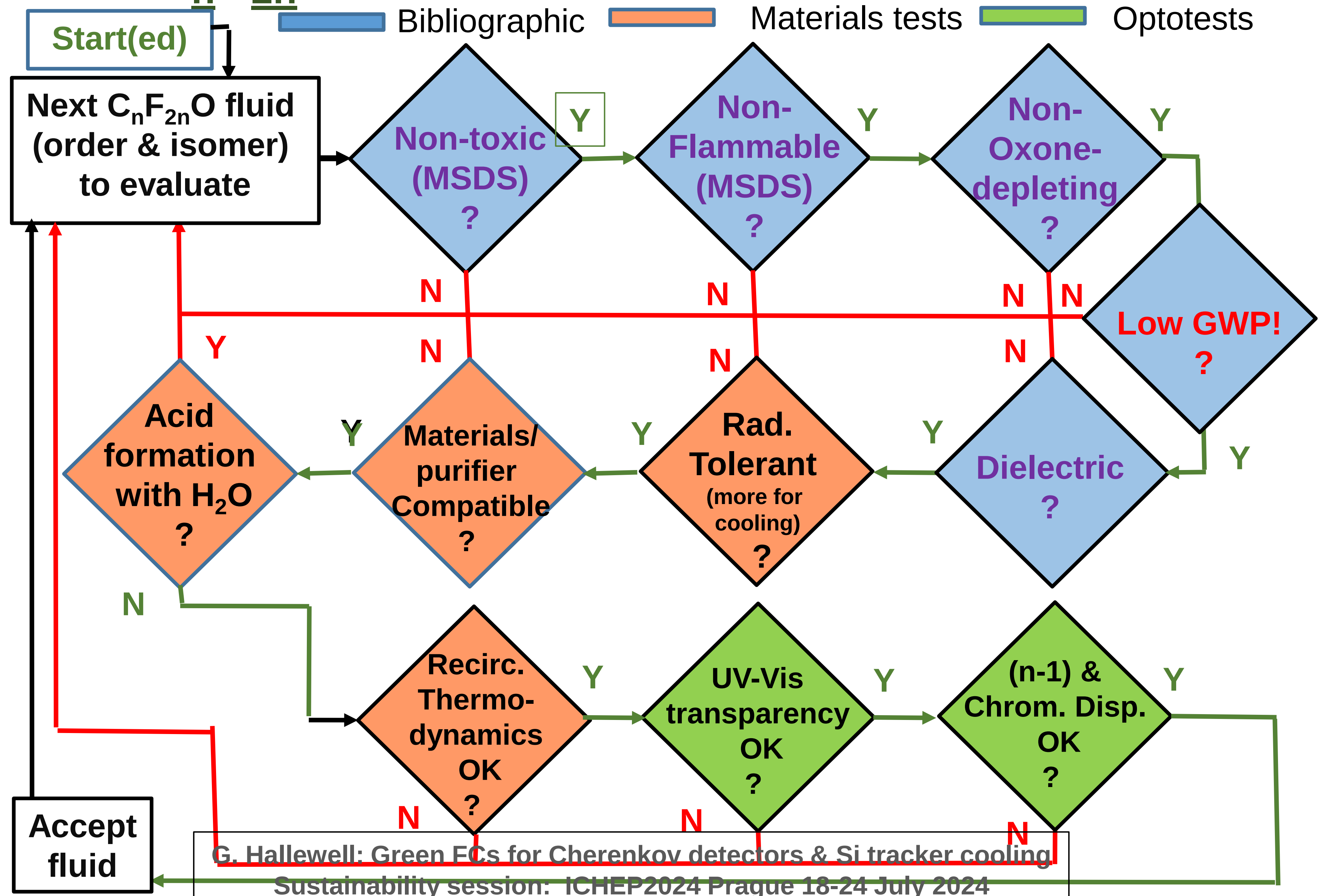
Even bigger GWP load reduction through C_4F_{10} index matching (eg here: COMPASS RICH)

Table 1: GWP loads of various SFCs and NOVEC 5110 blended with N_2 ((n-1) = 310.10^{-6}) to match refractivity of CF_4 and C_4F_{10} assumed radiator volume: 100 m^3

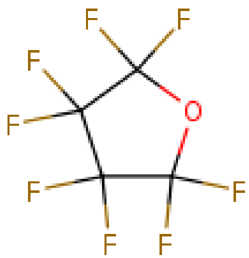
Base fluid	Base fluid density (1bar,25˚C) kgm^{-3}	Base fluid GWP (20-yr)	Component (n-1) (*10^6) (@ nm)	% Blend with N_2 to match (n-1) CF_4	GWP load ($t.CO_2$)	% Blend with N_2 to match (n-1) C_4F_{10}	GWP load ($t.CO_2$)
CF_4 LHCb RICH2 (100m^3)	**3.56 [18]**	**4880 [16]**	**488 (180-310 nm) [19]**	**100**	**1737**	**not applicable**	**n/a**
CF_2O	-			*~100*	*0*	n/a	n/a
C_2F_6	5.63 [18]	8210 [16]	793 (180-310 nm) [19]	38.1	1762	not applicable	n/a
Lin-C_2F_4O	-			-		n/a	n/a
C_3F_8	7.75 [18]	6640 [16]	1180 (250 nm) [16]	21.4	1099	not applicable	n/a
Lin-C_3F_6O	-			-		n/a	n/a
C_4F_{10} LHCb RICH1 (4m^3): COMPASS (100m^3)	**9.97 [18]**	**6870 [16]**	**1450 (250 nm) [16]**	**16.3**	**1119**	**100**	**6849**
*Lin-C_4F_8O (Non-cyclic C_4F_8O)**	*9.5 (est.)*	*Probably < 1 (NOVEC 5110 Analogy)*	*1380 @ 400nm (based on 3M PFG-3480 c-C_4F_8O [7]: linear C_4F_8O not yet measured but assumed similar)*	*18.4*	*0.18*	*112.7* (>100% would imply necessity of operating C_4F_8O at slight overpressure)*	*1.07*
C_5F_{12}	11.63 [18] (BP 30 ˚C at 1 bar)	6350 [16]	1750 (180-310nm)[19] (40 ˚C, undiluted)	13.0	957	79.3	5857
NOVEC 5110 $C_5F_{10}O$	10.7 [13] (BP 27 ˚C at 1 bar)	<1 [13]	Not yet measured: probably around 1650 by analogy with C_4F_{10} and C_4F_8O ratio	13.9	0.149	85.2	0.91

$C_nF_{2n}O$ fluid selection search criteria



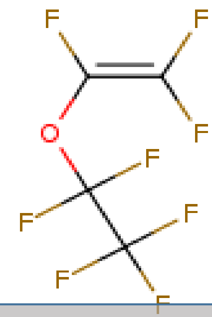
Some molecular shapes to study (or eliminate) for UVT, GWP, radiation stability & materials compatibility: example: C_4F_8O isomers,

Octafluorotetrahydrofuran
CAS: 773-14-8
H332 asphyxiant hazard

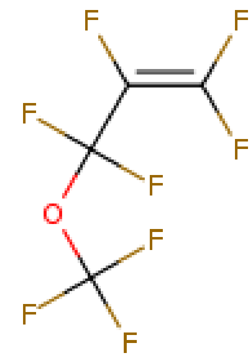


BTeV, ALICE VHMPID evaluated; good properties but high GWP

Pentafluoroethyl trifluorovinyl ether
CAS: 10493-43-3
Flammable,
H332 Inhalation toxicity Cat 4

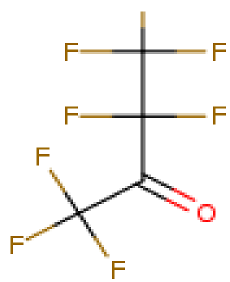


Octafluoro-3-methoxyprop-1-ene
CAS: 67641-44-5
H332 Inhalation toxicity Cat. 4

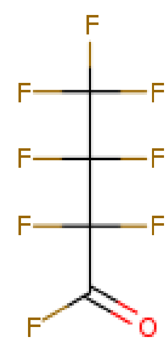


Source: https://www.synquestlabs.com

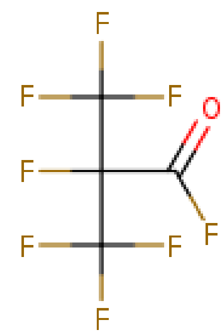
Octafluoro-2-butanone
CAS: 337-20-2
Most promising candidate? analogy with NOVEC 5110, 649 structures...



2,2,3,3,4,4,4-Heptafluorobutanoyl Fluoride **CAS**: 335-42-2
H331 Inhalation toxicity Cat. 3



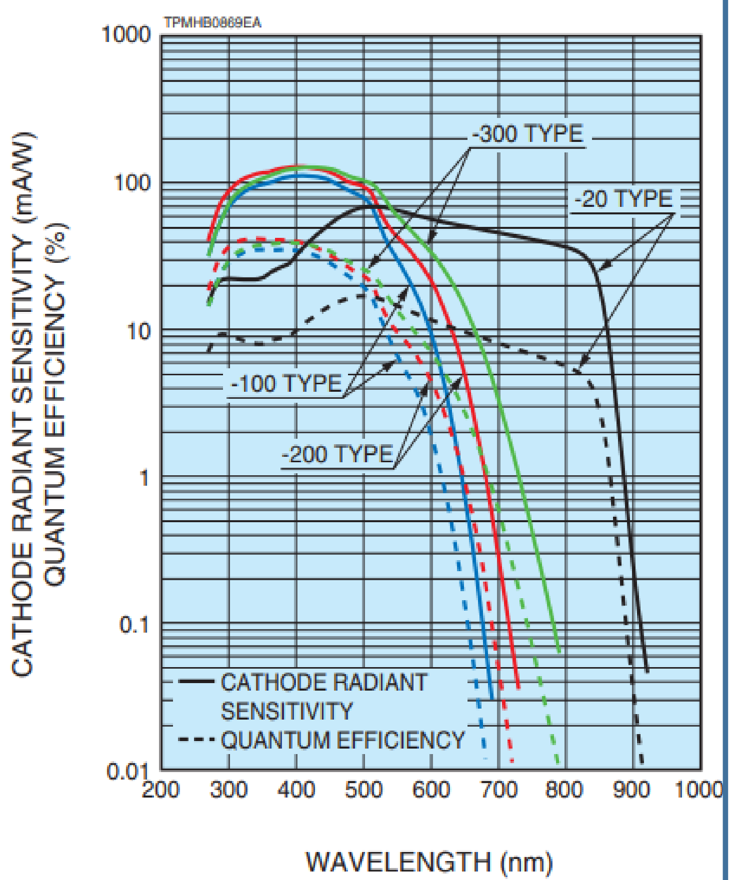
Heptafluoroisobutyryl Fluoride **CAS**: 677-84-9
H331 Inhalation toxicity Cat. 3



UV transparency, refractivity, cmhemical stability & compatibility studies needed for different $C_nF_{2n}O$ molecular shapes.

RICH detector community very competent & equipped for detailed UVT & (n-1)

Figure 1: Typical spectral response



Most probable PC spectral range in new build gas RICH detectors

T.V. Acconcia et al. / Nuclear Instruments and Methods in Physics Research A 767 (2014) 50–60

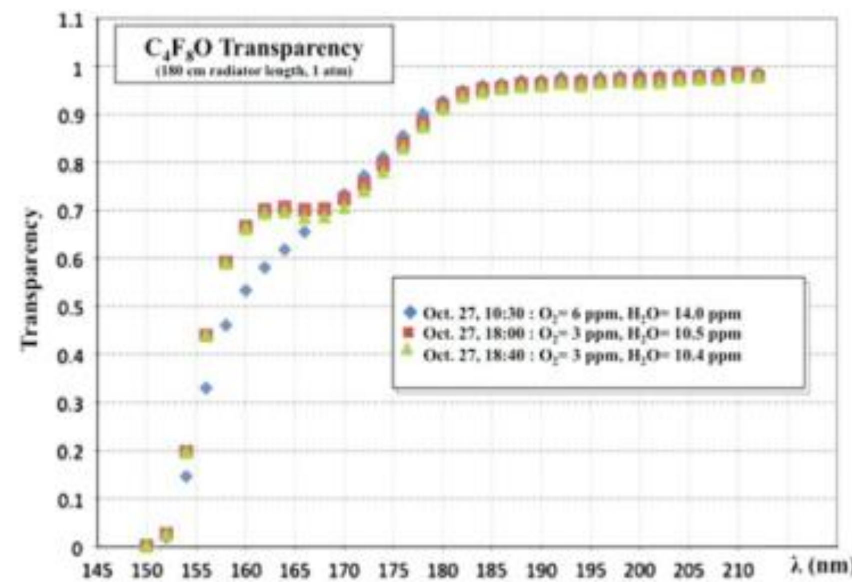


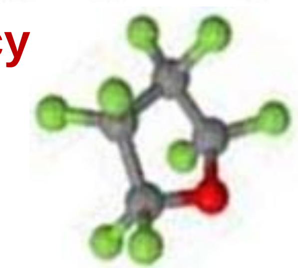
Fig. 24. Three transparency measurements of the radiator gas during the same day.

ALICE VHMPID: transparancy measurements in c-C_4F_8O

Octafluorotetrahydrofuran

CAS: 773-14-8

Synquest Inc. FL, USA



On the turning away…

The uncertain ECHA (European Chemicals Agency) route to fluorocarbon (PFC, PFAS…) prohibition

(Other people here will talk about this...Path paved with impracticalities?)

[51] ECHA/NR/23/04; https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal]

[52] ECHA Candidate List of substances of very high concern for Authorisation; https://echa.europa.eu/candidate-list-table

[53] Annex to the Annex XV restriction report proposal for restriction: Per- & polyfluoroalkyl substances (PFASs); ECHA; 22/03/2023 https://echa.europa.eu/documents/10162/d2f7fce1-b089-c4fd-1101-2601f53a07d1

[54] Per- and polyfluoroalkyl substances (PFAS); ECHA https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

Au revoir 3M… need to clarify manufacturers' attitudes (Dehon Co. (Fr), Synquest (USA), F2 (UK), various companies in China)… on future *lin*-fluoroketone ($C_nF_{2n}O$) production

Electronics industry is the driver: we just ride the coat-tails!

The Silicon tracker cooling aspect

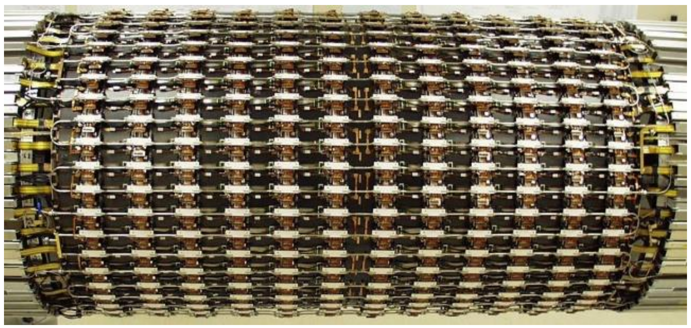
See also

https://link.springer.com/article/10.1140/epjp/s13360-023-04703-w

Examples from cooling particle physics Si trackers (ATLAS, CMS, LHCb)

Two distinct types of detector cooling geometry at HL-LHC:

(1) Tube and block 'DNA'



ATLAS barrel SCT (present)

Thermal Figure of Merit (TFM):

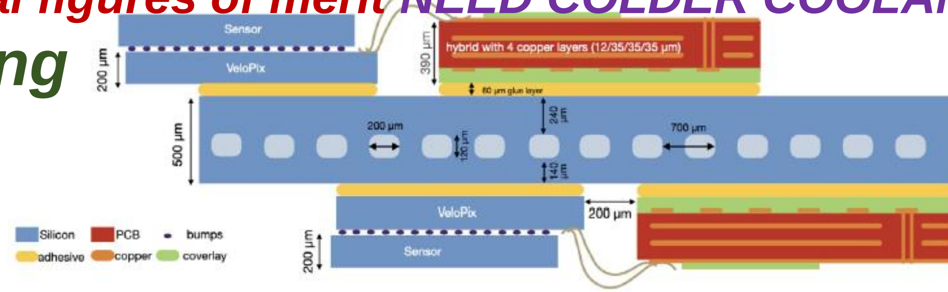
Expressed in terms of temperature difference between Si modules & coolant at given power density (units: °C cm² W⁻¹)

TFM = $((T_{(\text{Si module})} - T_{(\text{Coolant})}) / (\text{Si module power/cm}^2))$.

Lower numeric value ➔ better thermal performance.
TFMs < 4 typical in microchannel devices,
~ 20+ in some tube & block geometries.

Disadvantages: long(er) heat conduction path (more interfaces) Si ➔ cold(er) coolant: lower Thermal figures of merit NEED COLDER COOLANT!

(2) Micro-channel cooling



LHCb VELO upgrade

Advantages: shortest heat conduction path to coolant: coolant can be warmer:

Disadvantages: fraglity issues: channels etched in silicon and cover plate attached

Micro-channel cooling: the LHCb VELO upgrade

Recent mastery of evaporative CO_2 cooling in microchannels

CO_2 Evaportive cooling problems:

High triple point temperature of -56 °C

CO_2 cooling already known to be inefficient at coolant temperatures below -40 °C:

limits the lowest temperature attainable in the tubes of a tube & block cooling system:
CO_2 cooling now admitted to be insufficient for protection against radiation damage and protection against leakage current-generated thermal runaway over the whole HL-LHC envelope (2029-41):

ATLAS plans to change its inner pixel detector half way through…

A very complicated alternative trans-critical krypton evaporative cycle has been proposed

see: L. Contiero et al; Cold Krypton system for the Phase III Upgrade of the LHC, Forum on Tracking Detector Mechanics 2023, Tuebingen Germany May 31-June 2 2023

Si tracker evaporative coolingome Thermodynamic comparisons: SFCs, CO_2, Xe (F-K thermodynamics would be similar to same carbon order SFCs)

C_3F_8 won't go cold enough for HL-LHC operation, particularly in tube & block trackers →

https://link.springer.com/article/10.1140/epjp/s13360-023-04703-w

C_2F_4O would have been the ideal fluid: much cheaper than Xe, but toxic…
blend C_2F_6 with C_3F_6O?? (C_2F_6 / C_3F_8 zeotropic blends already demonstrated…)

R. Bates et al; 2015 JINST 10 P03027

On the turning away…

The uncertain ECHA (European Chemicals Agency) route to fluorocarbon (PFC, PFAS…) prohibition

(Other people here will talk about this...Path paved with impracticalities?)

[51] ECHA/NR/23/04;
https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal]
[52] ECHA Candidate List of substances of very high concern for Authorisation;
https://echa.europa.eu/candidate-list-table
[53] Annex to the Annex XV restriction report proposal for restriction: Per- & polyfluoroalkyl substances (PFASs); ECHA; 22/03/2023
https://echa.europa.eu/documents/10162/d2f7fce1-b089-c4fd-1101-2601f53a07d1
[54] Per- and polyfluoroalkyl substances (PFAS); ECHA
https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

Au revoir 3M… need to clarify manufacturers' attitudes (Dehon Co. (Fr), Synquest (USA), F2 (UK), various companies in China)…
on future *lin*-fluoroketone ($C_nF_{2n}O$) production
Electronics industry is the driver: we just ride the coat-tails!

Conclusion
(Also at beginning as I didn't think I'd get this far…)

Anyway… thanks for watching and listening:

(some references and back-up material follow
for those interested in this subject)

Also see: https://link.springer.com/article/10.1140/epjp/s13360-023-04703-w

Conclusion

- **Saturated fluorocarbons (SFCs: $C_nF_{(2n+2)}$) are chosen for their optical properties as Cherenkov radiators, with C_4F_{10} and CF_4 used in COMPASS & LHCb RICH1&2.**
- **Non-conductivity, non-flammability & radiation resistance ➔ ideal coolants with C_6F_{14} used in all LHC experiments, while C_3F_8 evaporatively cools the ATLAS silicon tracker and TOTEM.**
- **These fluids however have high GWPs (GWP_{20} > 5000*CO_2).**
- **While not industrialised over a wide $C_nF_{2n}O$ range fluoro-ketones can offer similar performance at very low, or 0 GWP;**
- **Radiation tolerance & thermal performance of 3M NOVEC 649 (lin-$C_6F_{12}O$) sufficiently promising to be considered by CERN to replace C_6F_{14} for cooling;**
- ***Cherenkov detectors*: subject to optical testing, *lin-C_4F_8O could replace C_4F_{10}* while *lin-C_4F_8O or lin-$C_5F_{10}O$ blended with N_2 and monitored in real time by sound velocity gas analysis - could replace CF_4* in RICH radiators;**
- ***SI tracker COOLING: Lighter molecules (e.g. C_2F_4O, with similar thermodynamics to C_2F_6) - would allow lower temperature, 0GWP operation than evaporative CO_2 in Si trackers operated at high luminosity: low order $C_nF_{2n}O$ toxicity a problem…***

G. Hallewell: Green FCs for Cherenkov detectors & Si tracker cooling
Sustainability session: ICHEP2024 Prague 18-24 July 2024

References and back-up material

Approaches to low-GWP fluorocarbon RICH radiator gases

.

See also:

(1) https://link.springer.com/article/10.1140/epjp/s13360-023-04703-w
(paper: EuroPhysics J. Plus, Dec 2023)

(2) https://indico.cern.ch/event/1263731/contributions/5398511/attachments/2648319/4584649/G_Hallewell_DRD4%20Rad%20Gas%20GWP%20with%20annexes%20May%2016%202023.pdf

(3) https://indico.cern.ch/event/1410802/ (DRD4 WG2 meeting 17 May 2024)

(4) https://indico.cern.ch/event/1420840/ (DRD4 WP_3.1 meeting 28 May 2024)

Cherenkov radiator and related general references (1 of 2) from https://link.springer.com/article/10.1140/epjp/s13360-023-04703-w

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Options for alternate radiators in LHCb-RICH system (including calculations by O. Ullaland); S. Easo,
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ECHA; 22/03/2023 https://echa.europa.eu/documents/10162/d2f7fce1-b089-c4fd-1101-2601f53a07d1

[54] Per- and polyfluoroalkyl substances (PFAS); ECHA https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

(5.7) SWOT analysis of cooling fluids HL-LHC

Strengths CO_2
Non-flammable, non-toxic, electrical insulator, non-ozone-depleting, radiation resistant, GWP=1

Weaknesses CO_2
High pressure circulation (60 bar) at ambient temp before cooldown to operating temp
High triple point (-56°C)

Threats CO_2
High triple point may make Si tracker operation problematic: less thermal 'headroom' after heavy irradiaton ('thermal runaway' phenomenon)

Opportunities CO_2
Extensive R&D program at CERN
Evaporative coolant of choice for ATLAS, CMS for start of HL-LHC program

Strengths xenon
Non-flammable, non-toxic, electrical insulator, non-ozone-depleting, radiation resistant, GWP=0

Weaknesses xenon
High pressure circulation (50 bar) at ambient temp before cooldown to operating temp (amost transcritical)
Extremely expensive

Threats xenon
Very difficult future procurement
(war in Ukraine)
(10^{-8} atmospheric content.)

Opportunities xenon
Could find expertise
In particle physics community for fabrication of circulators: already used in dark matter experiments

Strengths C_2F_6
Non-flammable, non-toxic, electrical insulator, non-ozone-depleting, radiation resistant

Weaknesses C_2F_6
Very high GWP
(around 6000 x CO_2)

Threats C_2F_6
Production will be phased out unless a strong motivation from semiconductor manufacture industry

Opportunities C_2F_6
Proved to decrease the operating temp of an ATLAS SCT thermal model in blend with 75% C_3F_8

Strengths $C_nF_{2n}O$
Non-flammable, non-toxic, electrical insulator, non-ozone-depleting, radiation resistant, GWP=0

Weaknesses $C_nF_{2n}O$

Threats $C_nF_{2n}O$
Large scale industrial production may depend on the phasing-out of SFCs, needs of semiconductor manufacture industry: Material compatibility needs further study.

Opportunities $C_nF_{2n}O$
Expertise in particle physics community for 3M NOVEC 649 ($C_6F_{12}O$)

The uncertain ECHA path to prohibition

(a path paved with impracticalities?)

https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal

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ECHA publishes PFAS restriction proposal

ECHA/NR/23/04

The details of the proposed restriction of around 10 000 per- and polyfluoroalkyl substances (PFASs) are now available on ECHA's website. ECHA's scientific committees will now start evaluating the proposal in terms of the risks to people and the environment, and the impacts on society.

Helsinki, 7 February 2023 – The proposal was prepared by authorities in Denmark, Germany, the Netherlands, Norway and Sweden and submitted to ECHA on 13 January 2023. It aims to reduce PFAS emissions into the environment and make products and processes safer for people.

All PFASs in the scope of the proposal are very persistent in the environment. If their releases are not minimised, people, plants and animals will be increasingly exposed, and without a restriction, such levels will be reached that have negative effects on people's health and the environment. The authorities estimate that around 4.4 million tonnes of PFASs would end up in the environment over the next 30 years unless action is taken.

Peter van der Zandt, ECHA's Director for Risk Assessment said: "This landmark proposal by the five authorities supports the ambitions of the EU's Chemicals Strategy and the Zero Pollution action plan. Now, our scientific committees will start their evaluation and opinion forming. While the evaluation of such a broad proposal with thousands of substances, and many uses, will be challenging, we are ready."

Next steps

ECHA's scientific committees for Risk Assessment (RAC) and for Socio-Economic Analysis (SEAC) will check that the proposal meets the legal requirements of REACH in their meetings in March 2023. If it does, the committees will begin their scientific evaluation of the proposal. A six-month consultation is planned to start on 22 March 2023.

RAC will form an opinion on whether the proposed restriction is appropriate in reducing the risks to people's health and the environment, while SEAC's opinion will be on the socio-economic impacts, i.e. benefits and costs to society, associated with the proposal. Both committees form their opinions based on the information in the restriction proposal and the comments received during consultations. The committees also consider advice from the Enforcement Forum on the enforceability of the proposed restriction. Once the opinions are adopted, they will be sent to the European Commission who, together with the EU Member States, will then decide on the potential restriction.

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LEGISLATION CONSULTATIONS INFORMATION ON CHEMICALS SUPPORT

ECHA > Information on Chemicals > Candidate List

Candidate List of substances of very high concern for Authorisation

(published in accordance with Article 59(10) of the REACH Regulation)

Notes:

- **Authentic version:** Only the Candidate List published on this website is deemed authentic. Companies may have immediate legal obligations following the inclusion of a substance in the Candidate List on this website including in particular Articles 7, 31 and 33 of the REACH Regulation.
- ***Numerical identifiers***: Each candidate list entry covers both anhydrous and hydrated forms of a substance. The CAS number shown in an entry is typically for the anhydrous form. Hydrated forms of the substance identified by other CAS numbers are still within the scope of the entry.
- ***Other numerical identifiers***: For those entries with "-" in the EC number and CAS number columns, a non-exhaustive inventory of EC and/or CAS Registry numbers describing substances or groups of substances considered to fall within the scope of the Candidate List entry is included, where practicably possible. This information can be accessed through the "Details" button of the selected entry.

FURTHER INFORMATION

- More information about Candidate list of Substances of Very High Concern for Authorisation
- Data on Candidate List substances in articles
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EUROPEAN CHEMICALS AGENCY

Annex to the
ANNEX XV RESTRICTION REPORT

PROPOSAL FOR A RESTRICTION

SUBSTANCE NAME(S): Per- and polyfluoroalkyl substances (PFASs)

IUPAC NAME(S): n.a.

EC NUMBER(S): n.a.

CAS NUMBER(S): n.a.

CONTACT DETAILS OF THE DOSSIER SUBMITTERS:

BAuA
Federal Institute for Occupational Safety and Health
Division 5 - Federal Office for Chemicals
Friedrich-Henkel-Weg 1-25
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Bureau REACH, National Institute for Public Health and the Environment (RIVM)
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Norwegian Environment Agency
P.O. Box 5672 Torgarden
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The Danish Environmental Protection Agency
Tolderlundsvej 5
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VERSION NUMBER: 2

DATE: 22.03.2023

P.O. Box 400, FI-00121 Helsinki, Finland | Tel. +358 9 686180 | Fax +358 9 68618210 | echa.europa.eu https://echa.europa.eu/hot-topics/perfluoroalkyl-chemicals-pfas

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- Bisphenols
- Chemicals Strategy for Sustainability
- Alternatives to animal testing
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- Biocides
- Lead
- Research to enhance protection of our health and environment

Per- and polyfluoroalkyl substances (PFAS)

Per- and polyfluoroalkyl substances (PFAS) are a large class of thousands of synthetic chemicals that are used throughout society. However, they are increasingly detected as environmental pollutants and some are linked to negative effects on human health.

They all contain carbon-fluorine bonds, which are one of the strongest chemical bonds in organic chemistry. This means that they resist degradation when used and also in the environment. Most PFAS are also easily transported in the environment covering long distances away from the source of their release.

PFAS have been frequently observed to contaminate groundwater, surface water and soil. Cleaning up polluted sites is technically difficult and costly. If releases continue, they will continue to accumulate in the environment, drinking water and food.

Latest updates

Universal PFAS restriction proposal:

- Committees for Risk Assessment and for Socio-Economic Analysis meet in June - stakeholder registration open until 9 May 2024
- Dossier Submitter's ongoing role in the PFAS restriction proposal - news from German BAuA, 15 April 2024
- Next steps for PFAS restriction proposal, 13 March 2024
- Highlights from November RAC and SEAC meetings, 7 Dec 2023
- Enforcement Forum's advice on enforceability of the proposed PFAS restriction, 8 Nov 2023
- All comments submitted to the PFAS restriction proposal now online, 2 Nov 2023

Restriction proposal on PFAS in firefighting foams:

- ECHA's committees: EU-wide PFAS ban in firefighting foams warranted, 22 June 2023

Other:

- Member States vote to restrict PFHxA in the EU, 29 February 2024
- Perfluoroheptanoic acid (PFHpA) and its salts added to Candidate List of substances of very high concern, 17 January 2023

What are PFAS and what are they used for?

What are the concerns?

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- Persistent Organic Pollutants (POPs)
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- Community Rolling Action Plan
- Harmonised classification and labelling
- Addressing substances of concern

European Commission and EU institutions

- European Green Deal: Commission proposes rules for cleaner air and water, 26 Oct 2022
- Council formally adopts further restrictions to 'forever chemicals' in waste, 24 Oct 2022
- Chemicals Strategy for Sustainability
- Commission staff working document: Poly- and perfluoroalkyl substances (PFAS)
- EFSA's PFAS draft opinion explained
- Commission welcomes provisional agreement to improve the quality of drinking water and the access to it
- Chemical pollutants –