Analysis of combustion gases generated during tests to extinguish an oxygen fire with a halon fire extinguisher

Synthesis of INERIS test report (document: Ineris – 205964 – 2740277 – v0.1)

Test B4-1__Remote activation of an Air Total 74-20 halon fire extinguisher on a fire not enriched with oxygen – 10m3 test chamber.
Carried out on 8 March 2022.

The fire extinguisher was installed on a mount and activated by an operator outside the 10m3 chamber. The fire was fuelled by a piece of Hessian soaked in a cup of oil and placed in a metal enclosure.

Test conditions: the fire was not enriched by a flow of oxygen. The test chamber was not ventilated. The fire extinguisher was activated once and kept in operation until it was completely empty (approximately 15 s).

Test B4-2__Remote activation of an Air Total 74-20 halon fire extinguisher on a fire enriched with oxygen – 10m3 test chamber.
Carried out on 8 March 2022.

The equipment for extinguishing and activating the fire and the source of the fire were identical to the previous test.

Test conditions: the fire was enriched by a continuous flow of oxygen. The test chamber was ventilated (5000m3/h) after the activation of the fire extinguisher which occurred once and was kept in operation until it was completely empty (approximately 13 s).

Test B6__Remote activation of an Air Total 74-20 halon fire extinguisher on a fire enriched with oxygen – 10m3 test chamber. Carried out on 8 March 2022.

The equipment for extinguishing and activating the fire and the source of the fire were identical to the previous test.

Test conditions: the fire was enriched by a continuous flow of oxygen. The test chamber was ventilated (5000m3/h) throughout the test. The fire extinguisher was activated once and kept in operation until it was completely empty (approximately 20 s).

The concentrations of COF2 and CF4 gases and of HF, HCl and HBr acids were measured during the three tests. The values are presented in the tables below:

Summary of toxic effects

Threshold limits

The toxicity thresholds for the various gases in terms of VSTAF[1] and AEGL[2] for 10 minutes of exposure are given in Table 1. The definitions of AEGL-2 and AEGL-3 correspond to those of the irreversible effects threshold and lethal effects threshold respectively, the AEGL values being safer. The VSTAF was chosen as a priority when it existed.

For 10 minutes of exposure				
Gaz	SEI (irreversible effects threshold) [ppm]	AEGL-2 [ppm]	SEL (lethal effects threshold) [ppm]	AEGL-3 [ppm]
HF	600	95	1 123	170
HCl	240	100	1 300	620
HBr	366	100	4 108	740
COF2	ND	0.35	ND	1
CO	2 600	420	7 000	1 700
CF4	ND	ND	ND	ND
COCl2	3	0.6	10	3.6

AEGL thresholds of gases measured during the test

For halon, the INRS[3] gives a threshold value for 1 min of exposure of 4%.

[1] French acute toxicity threshold value

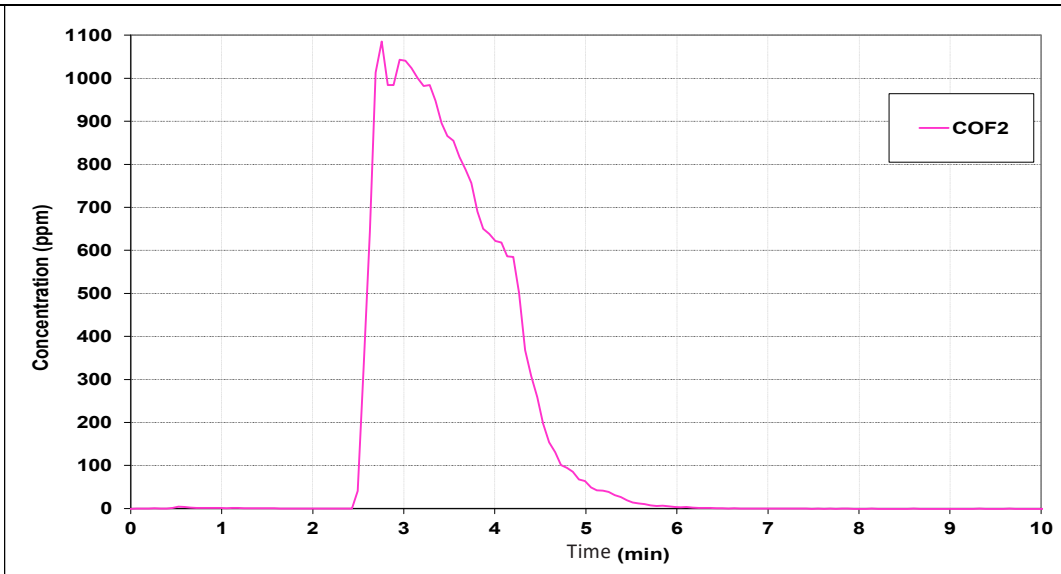
[2] Acute Exposure Guideline Level

[3] Toxicological data sheet No 165

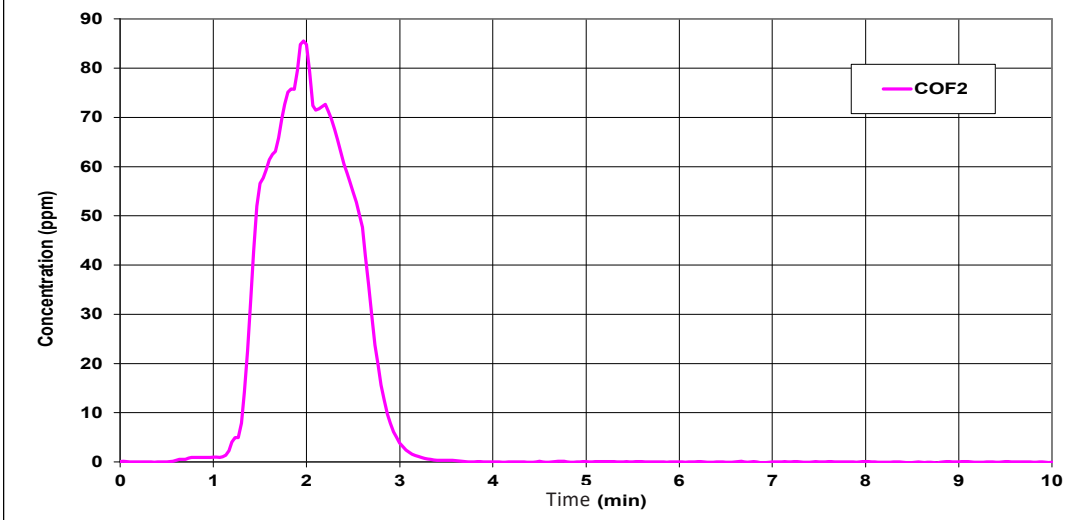
Comparison of concentrations observed and risk thresholds

COF2

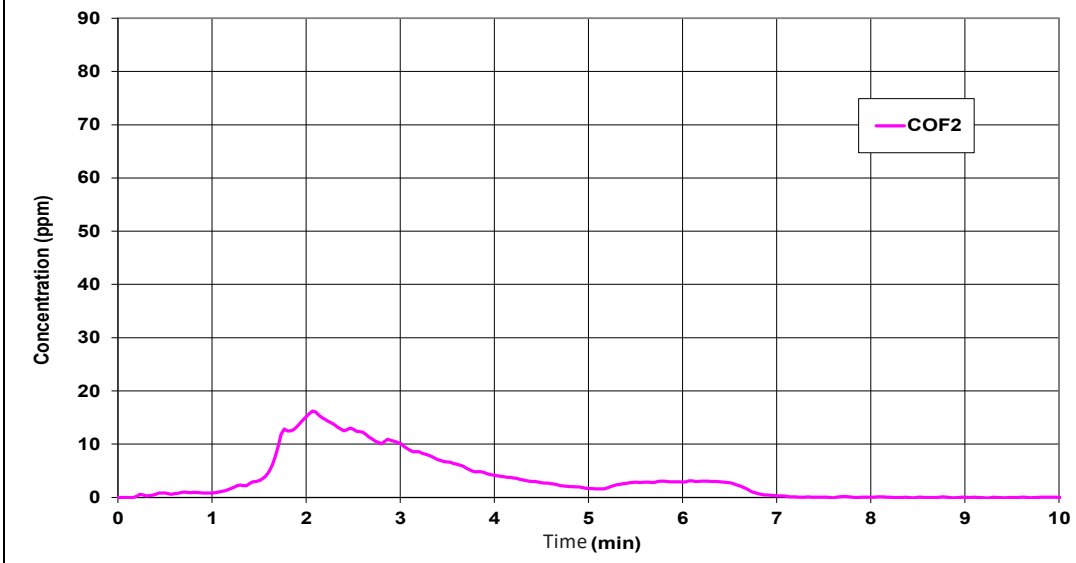
B4-2 test



B5 test



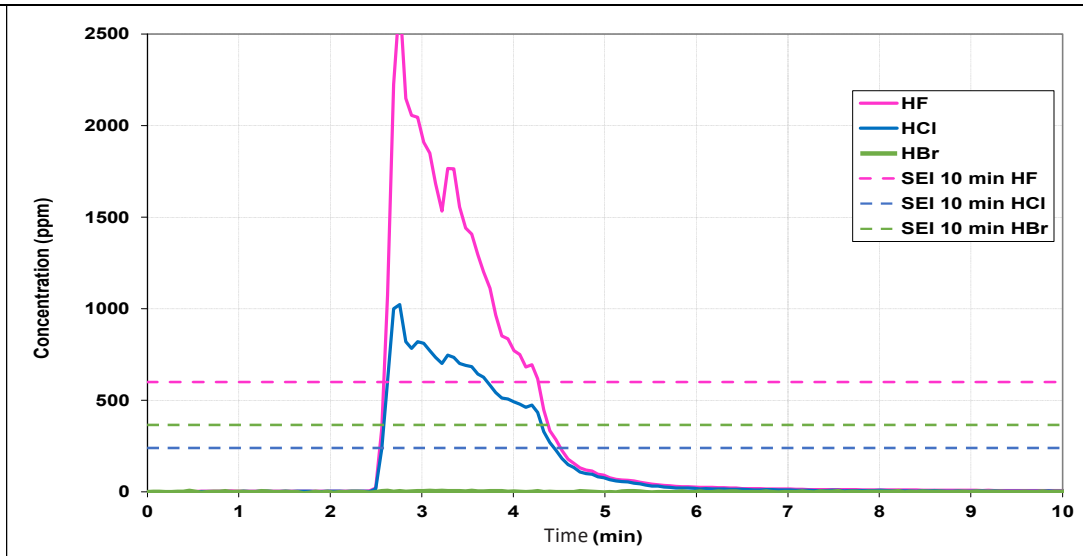
B6 test



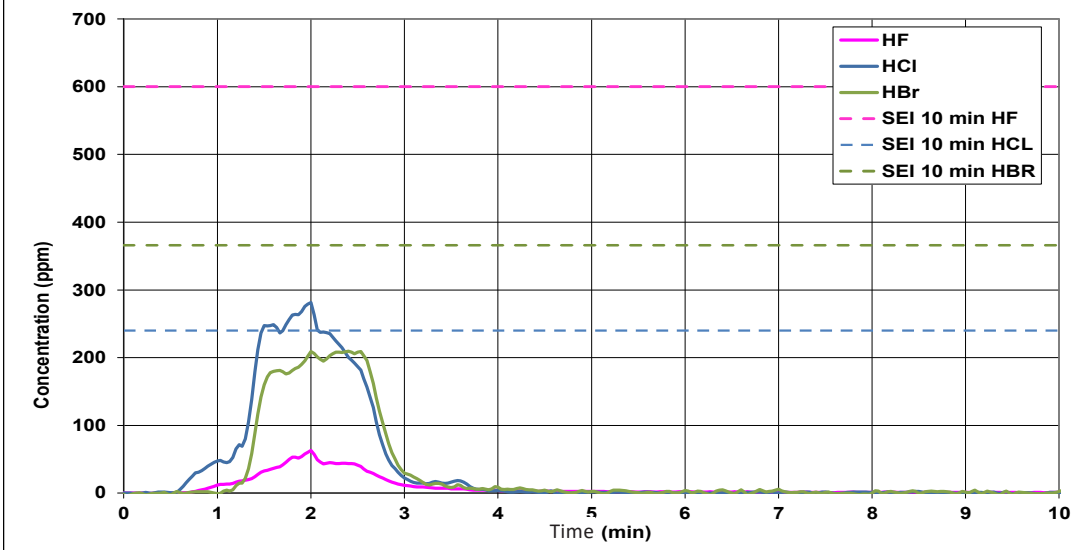
Concentration of COF2 measured during the three tests

Acids

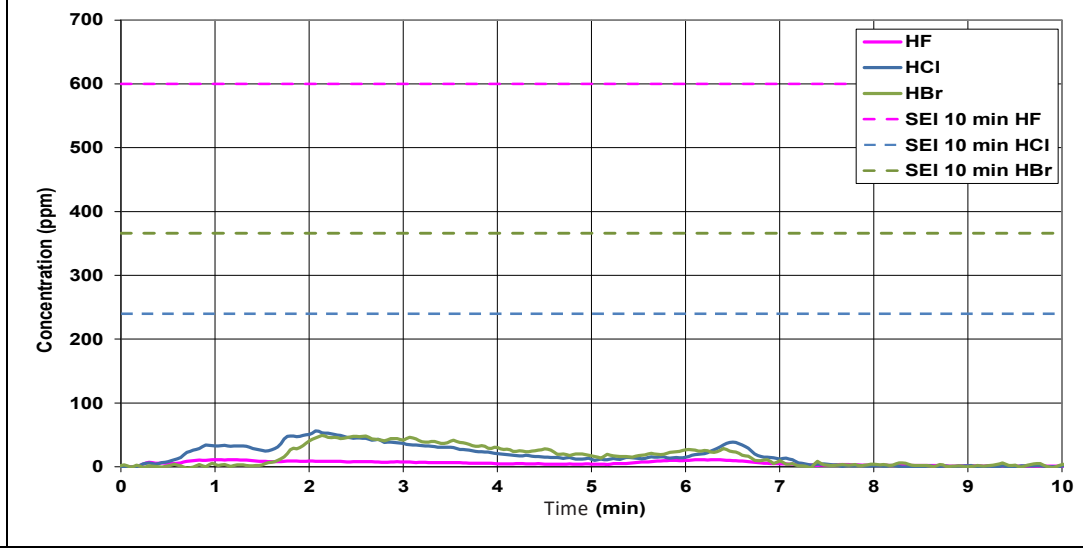
B4-2 test



B5 test

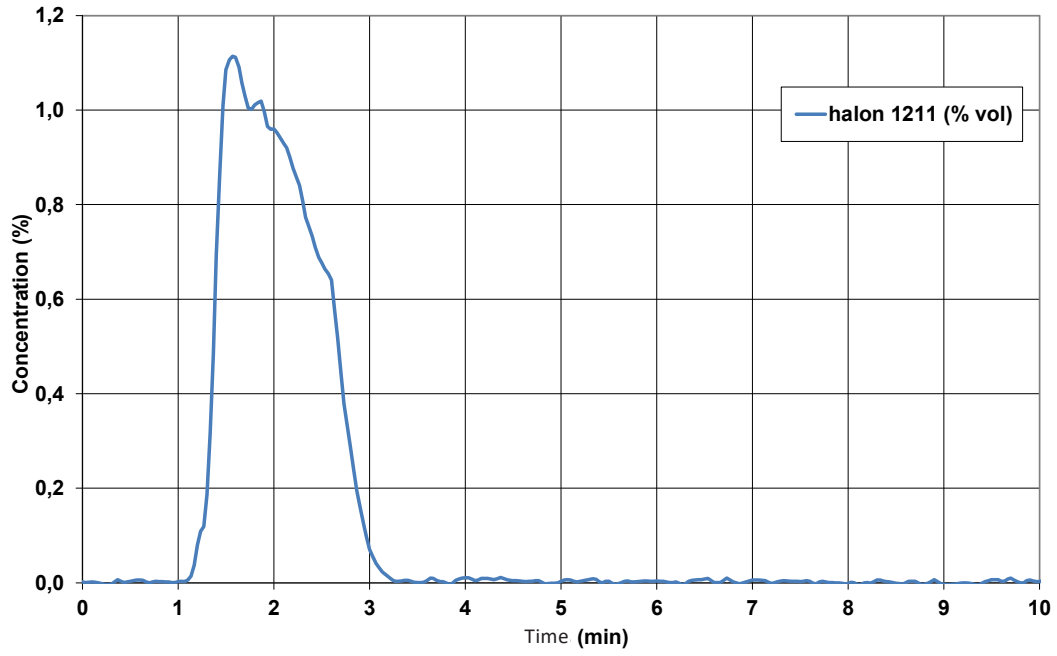
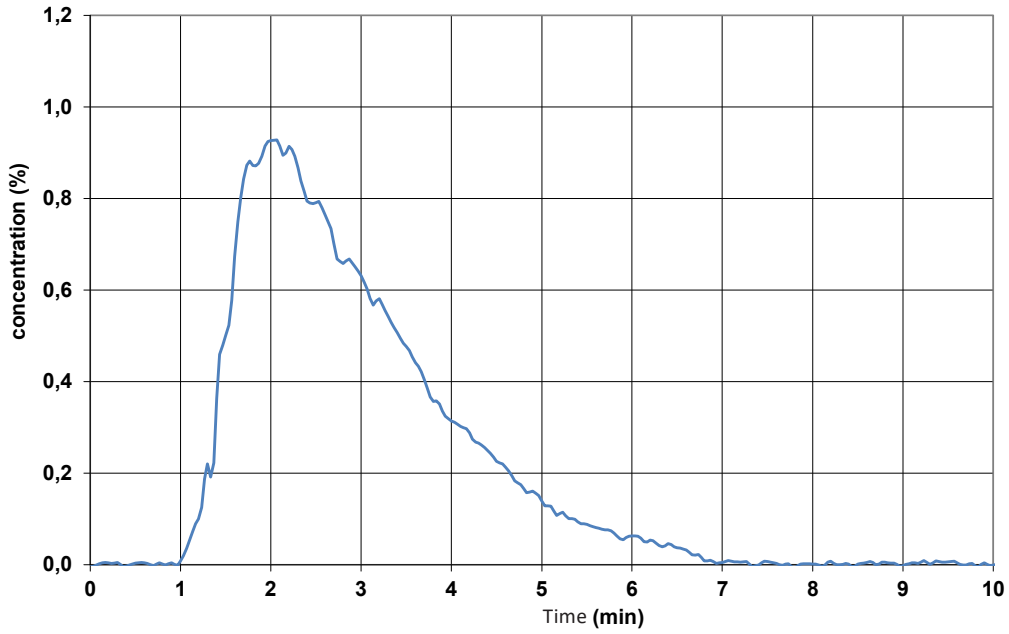


B6 test



Concentration of acids measured during the three tests (SEI = irreversible effects threshold)

Halon

B4-2 test	Measurement not made
B5 test	
B6 test	

Concentration of halon measured during the two tests

Findings:

- The concentration of COF2 exceeded the AEGL-2 threshold (equivalent to the irreversible effects threshold) in all three tests, B4-2, B5 and B6.
- The concentration of HF and HCL acids largely exceeded the irreversible effects threshold during test B4-2, mainly due to the absence of ventilation. The irreversible effects threshold for HCl was also exceeded during test B5.
- The 4% halon concentration limit was not reached during tests B5 and B6 (not measured during B4-2).

The chapter below describes the method for qualitatively comparing the gases measured against the toxicity thresholds.

Calculation of toxic dose

A toxic dose approach provides a quantitative assessment of the toxic effects caused by the fire and the action of halon, taking into account the duration of the exposure. A toxic dose is calculated using the following formula:

$$D_i = \int_{t1}^{t2} C_i(t)^{n_i}.dt$$

Where:

D_i	=	Toxic dose for gas i [-]
n_i	=	Regression parameter specific to gas i
$C_i(t)$	=	Concentration of gas i as a function of time [ppm]
dt	=	No time [min]
t1	=	Start of exposure [min]
t2	=	End of exposure [min]

In addition, in order to add up the respective toxicity of each gas, the law of additivity is applied. To do this, the sum of the doses associated with each gas is calculated as follows:

$$S_{SEI} = \sum_i \frac{D_i}{D_{SEI\_i}}$$

Where

D_{SEI_i}	=	Toxic dose at irreversible effects threshold for gas i [-]

If the sum S exceeds 1, the irreversible effect threshold is likely to be reached.

The results obtained for test B5 are presented in Table 2. The method is also used for the lethal effects.

	CO	CO2	HF	HBr	HCl	COF2	Halon
n SEI	1,99	ND	1	2	1	1	ND
n SEL	2,27		1	2	1,07	0,8	
D_{SEI} limite	62400000	ND	6000	1330000	2410	30	ND
D_{SEL} limite	5090000000	ND	11100	108000000	21200	55	
Remarque						*Note: No known value for COF2. COCL2 level is considered.*	*Note: No value for Halon. Not considered into the computation.*

	CO	CO2	HF	HBr	HCl	COF2	Halon	∑
D/D_{SEI}	0,01	ND	0,01	0,04	0,15	3,02	ND	>3.24
D/D_{SEL}	0,001	ND	0,007	0,000	0,025	0,746	ND	>0.78

Calculation of toxic dose

CONCLUSION

The results show, taking into account both the less penalising thresholds for COF_2 and omitting the halon effects, that the irreversible effects were reached given that coefficient S_{SEI} was greater than 1. Moreover, given the value obtained for the first lethal effects of 0.78, taking into account the non-penalising hypotheses, it is probable that the first lethal effects threshold was also reached.