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Smoke Gas Toxicity

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Previous Research

- Study on smoke production, development and toxicity in bus fires
- Project duration 2009-2013
- Research project by BAM, the Federal Material Research Institute, financed by BASt
- Recommendations for the upgrade of the fire safety requirements for bus interior materials
  - Burning behavior
  - **Smoke gas toxicity**
  - Technical assistance systems (e.g. fire detectors)

- General conclusion of the researchers: alignment of vehicle standards to rail standards necessary!

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Accidentology

- **Approximately 75% of all bus fires start in engine compartment**
- Approximately 85% of busses were driving while fire started
- Mostly city busses (60%)
- Fatalities typically from catastrophic bus fires

- Study leaves open how often accidents contributed to the fire or to the injuries

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Improved Standards: Modifications to UN R118, UN R107

- Fire sensor in engine compartment

  (eff. 31.12.2012/31.12.2013)
- Burning behavior internal materials (cables)

  (eff. 9.12.2015/9.12.2015)
- Fire extinguisher system in engine compartment

  (eff. 10.6.2018/10.6.2019)
- Burning behavior internal materials (fire speed, test direction)

  (eff. 26.7.2017/26.7.2020)
- Emergency exits

  (eff. 10.6.2018/10.6.2020)

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Smoke Gas Toxicity – Rail Standards

Carbon Dioxide	Carbon Monoxide	Hydrogen Bromide	Hydrogen Chloride
Hydrogen Cyanide	Hydrogen Fluoride	Nitrous Gases	Sulphur Dioxide

$$CIT = 0{,}0805 \cdot \sum_{i=1}^{8} \frac{c_i}{C_i}$$

$c_i = concentration\ of\ the\ smoke\ component\ i\ in\ the\ chamber\ after\ 4\ or\ 8\ minutes\ respectively\ (mgm^{-3})$

$C_i = reference\ concentration\ of\ the\ smoke\ component\ i\ (mgm^{-3})$

Figure 12 – Formula for calculating the CIT-value according to the EN 45545-2

Smoke gas component	CO_2	CO	HBr	HCl	HCN	HF	NO_x	SO_2
Reference concentration	72000	1380	99	75	55	25	38	262

Conventional Index of Toxicity –
„Average Toxicity?“

Threshold Values For CIT Calculation And Their Meaning

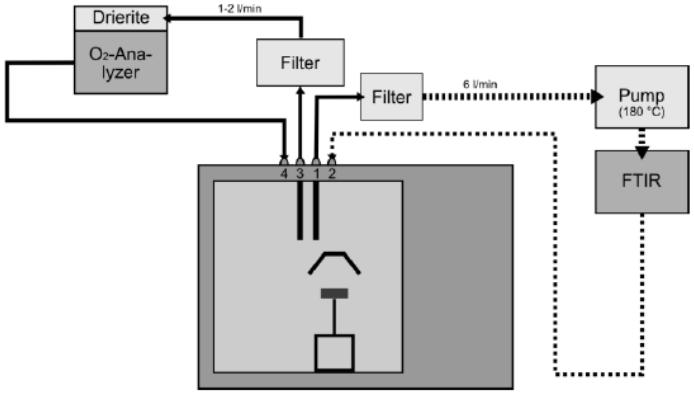
Smoke gas component	CO_2	CO	HBr	HCl	HCN	HF	NO_x	SO_2
Reference concentration	72000	1380	99	75	55	25	38	262

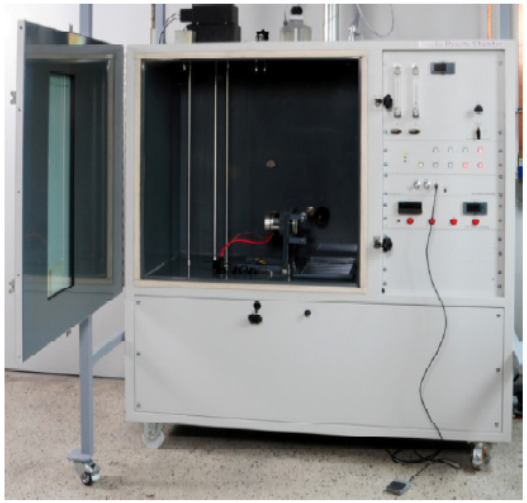
- CO_2: 80000 ppm → Unconsciousness, **short-termed death**
- CO: 1380 ppm → Headaches in 20 min, **fatal within 1-2 hours**
- HBr: 99 ppm → Hard incapacitating impact on escape after 10 min
- HCl: 50 ppm → breathes stopped by lung irritation
- HCN: 100 ppm → **Fatal after almost 1 hour**
- HF: 24 ppm → Hard incapacitating imacpt on escape after 1 hour
- NOX: 50 ppm → Strong irritation on respiratory tract and eyes
- SO_2: 100 ppm → **Life-threatening**

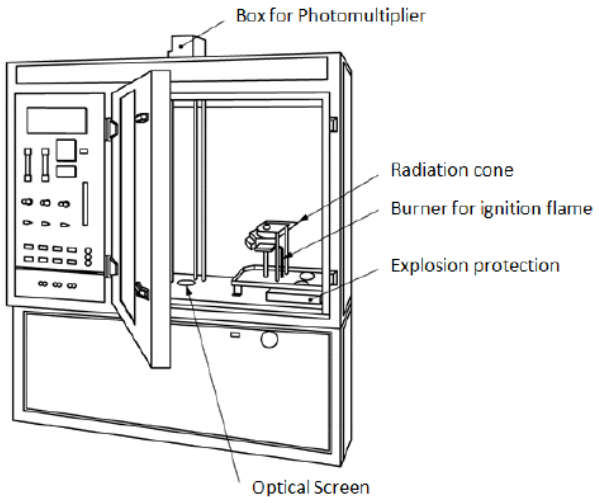
CIT = 0.64: all values at threshold

Experiments

- Body insulation
- Floor covering
- Side panel
- Ceiling (seats, gangways)
- Foam of seats







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Results

- CIT: „Conventional Index for Toxicity“
- CIT = 0.64 if all components approach the specified reference concentration

	4 min – CIT OK?	8 min – CIT OK?	Individual concentrations
Body insulation	Ok	Ok	Ok
Floor covering	Not Ok	Not Ok	Toxic HCl
Side panel	Ok	Ok	4 min: Fatal ~ 10 min 8 min: Fatal << 10 min
GRP part	Ok	Ok	8 min: Fatal 30-60 min
Ceiling seat	Not Ok	Not Ok	Toxic HCl
Ceiling gangway	Not Ok	Not Ok	Toxic HCl
Foam of seats	Ok	Ok	Ok

?

HCN

Results (2)

Material (material requirement)		Components of CIT-value								CIT-value		
		CO_2 [ppm]	CO [ppm]	SO_2 [ppm]	NO_x [ppm]	HBr [ppm]	HCl [ppm]	HF [ppm]	HCN [ppm]	Calculated CIT_G	HL1 (EN 45545)	HL2 (EN 45545)
IMO MSC 61(67) Annex 1, Part 2		-	*1450*	*120*	*350*	*600*	*600*	*600*	*140*	-	-	-
ABD 00031 (Airbus)		-	*1000*	*100*	*100*	-	*150*	*100*	*150*			
BSS 7239 (Boeing)		-	*3500*	*100*	*100*	-	*500*	*200*	*150*	-	-	-
SMP 800-C (Bombardier)		*90000*	*3500*	*100*	*100*	*100*	*500*	*100*	*100*	-	-	-
First symptoms of intoxication		*20000*	*200*	*4*	*10*	*22*	*5*	*10*	*18*			
Lethal concentrations		*80000*	*1000*	*100*	*100*	*120*	*50*	*44*	*100*			
Body insulation (R1)	4 min	5900	99	5	73	0	1	0	36	0		
	8 min	6900	168	25	54	0	3	4	52			
Floor covering (R9)	4 min	7500	793	0	31	0	4050	2	3	6,[illegible]		
	8 min	100	931	0	8	0	3572	4	5	5,8	1,2	0,9
Side panel (R1)	4 min	3600	1076	80	0	1	0	0	167	0,4	1,2	0,9
	8 min	4400	2004	41	1	0	0	0	245	0,6	1,2	0,9
GRP part (R1)	4 min	19800	682	0	0	4	0	0	10	0,1	1,2	0,9
	8 min	35700	1122	0	0	7	2	0	16	0,2	1,2	0,9
Ceiling over seats (R1)		900	668	0	87	0	1013	1	39	1,9	1,2	0,9
		700	967	0	97	1	923	0	40	1,8	1,2	0,9
Ceiling over gangways (R1)	4 min	16500	762	52	111	0	1528	3	33	2,[illegible]		
	8 min	20000	984	40	149	0	1385	0	40	2,[illegible]		
Foam of seats (R20)	4 min	14200	23	1	82	0	0	0	5	0,[illegible]		
	8 min	15800	53	0	74	0	1	0	7	0,2	1,2	0,9

~30-60 min

~30-60 min

>> 10 min

<< 10 min

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Conclusion – Smoke Gas Toxicity

- In general CIT and individual toxic concentrations in line
- In one case, the Hydrogen Cyanide concentration approaches values for fatality (and CO after 30-60 minutes)
  - after 10 min (4 min burning test)
  - less than 10 min (8 min burning test)
- In another case, CO is fatal after ~ 30 – 60 min

- At this stage, it is still unclear whether the CIT value is a good criterion for bus materials
- ***What is a good criterion for smoke gas toxicity on busses?***
- ***Is a new criterion needed?***
- ***Is a tailored test for the bus sector more appropriate?***

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Upcoming Research

Identification of appropriate criterion to limit smoke gas toxicity in busses

→ Identification of smoke gas toxicity from current materials
→ Identification of relevant materials
→ Identification of relevant smoke gas components
→ Definition of a simplified test procedure
→ Derivation of threshold values for simplified test procedure

Project will last 10 month, has not started as of now. Input from BMFE still possible. Intermediate results could be provided to BMFE.

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Recent Severe Fire (July 2017)

- Bus (2013) **impacts** stationary truck with **60-70 km/h** impact speed
- Damaged tank, pneumatic reservoir contribute to quick fire spread, 18 fatalities,
- Vehicle **fully compliant** with regulations applicable at that time, i.e. **NOT** equipped with AEBS!

- Today's AEBS: - 20 km/h on stationary tgt.
- German proposal to increase requirements (GRVA)
  - No impact up to 70 km/h
  - Impact ≤25 km/h from 80 km/h
  - Impact ≤40 km/h from 90 km/h
  - Impact ≤55 km/h from 100 km/h
  - Impact ≤65 km/h from 110 km/h

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Summary

- Bus fires typically start in the engine compartment (>75%)
- Bus fire safety has been improved
- Improved standards not all effective as of now (for new busses!)

- Smoke gas toxicity not yet limited
- Criterion for smoke gas toxicity under investigation

- Severe bus fires typically after severe accidents
- Improvement of AEBS → *German proposal at GRVA*
- Improvement of crash safety → *GRSP activities*
- *High potential to address catastrophic bus fires with additional measures!*

Thank you for your attention!

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