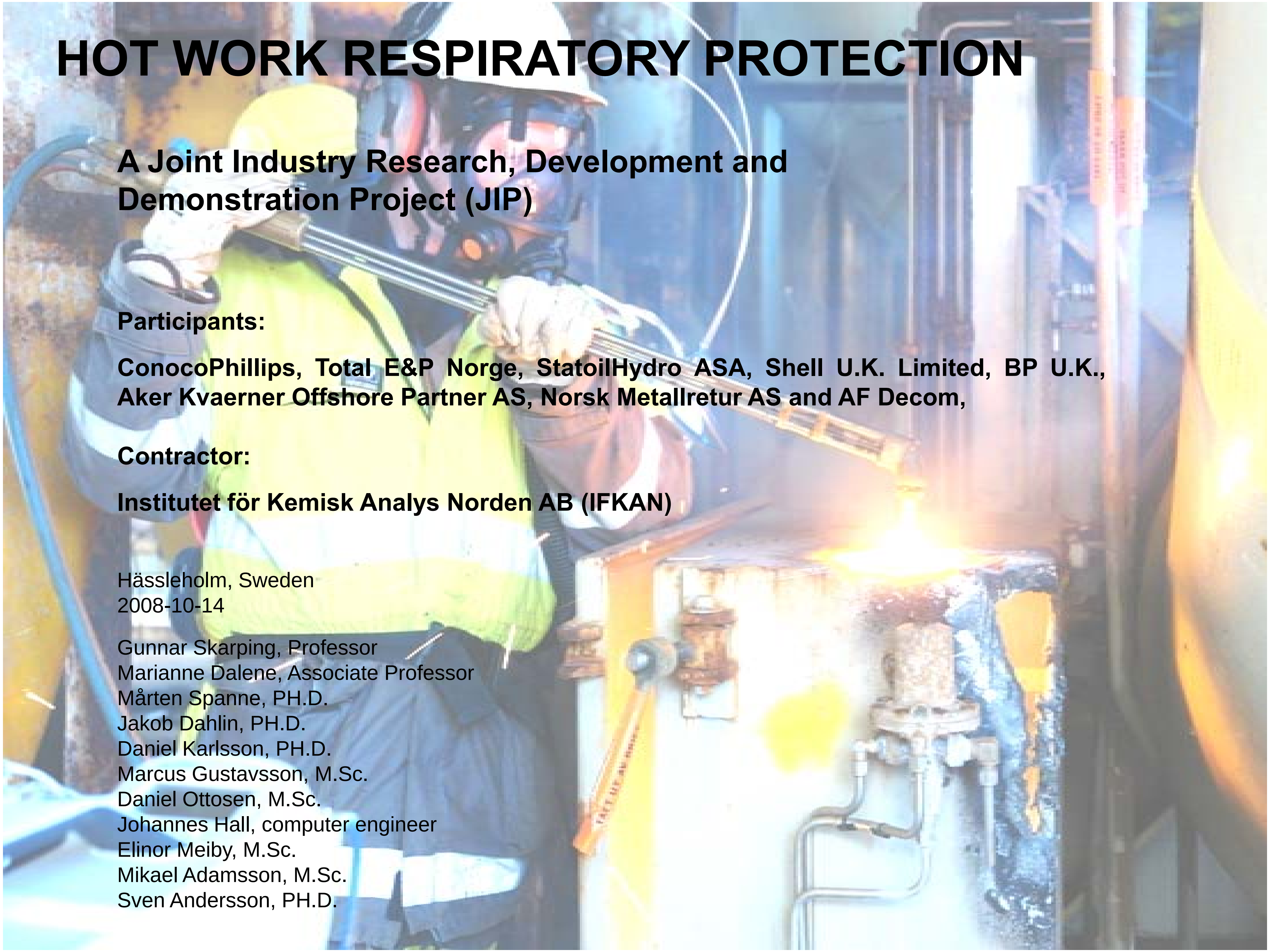

HOT WORK RESPIRATORY PROTECTION

A Joint Industry Research, Development and Demonstration Project (JIP)

Participants:

ConocoPhillips, Total E&P Norge, StatoilHydro ASA, Shell U.K. Limited, BP U.K., Aker Kvaerner Offshore Partner AS, Norsk Metallretur AS and AF Decom,

Contractor:

Institutet för Kemisk Analys Norden AB (IFKAN)

Hässleholm, Sweden
2008-10-14

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Sven Andersson, PH.D.

The project

Institutet För Kemisk Analys Norden AB

EVALUATION OF REPRESENTATIVE RESPIRATORY PROTECTION DEVICES USED IN THE NORTH SEA

EDUCATIONAL PACKAGE

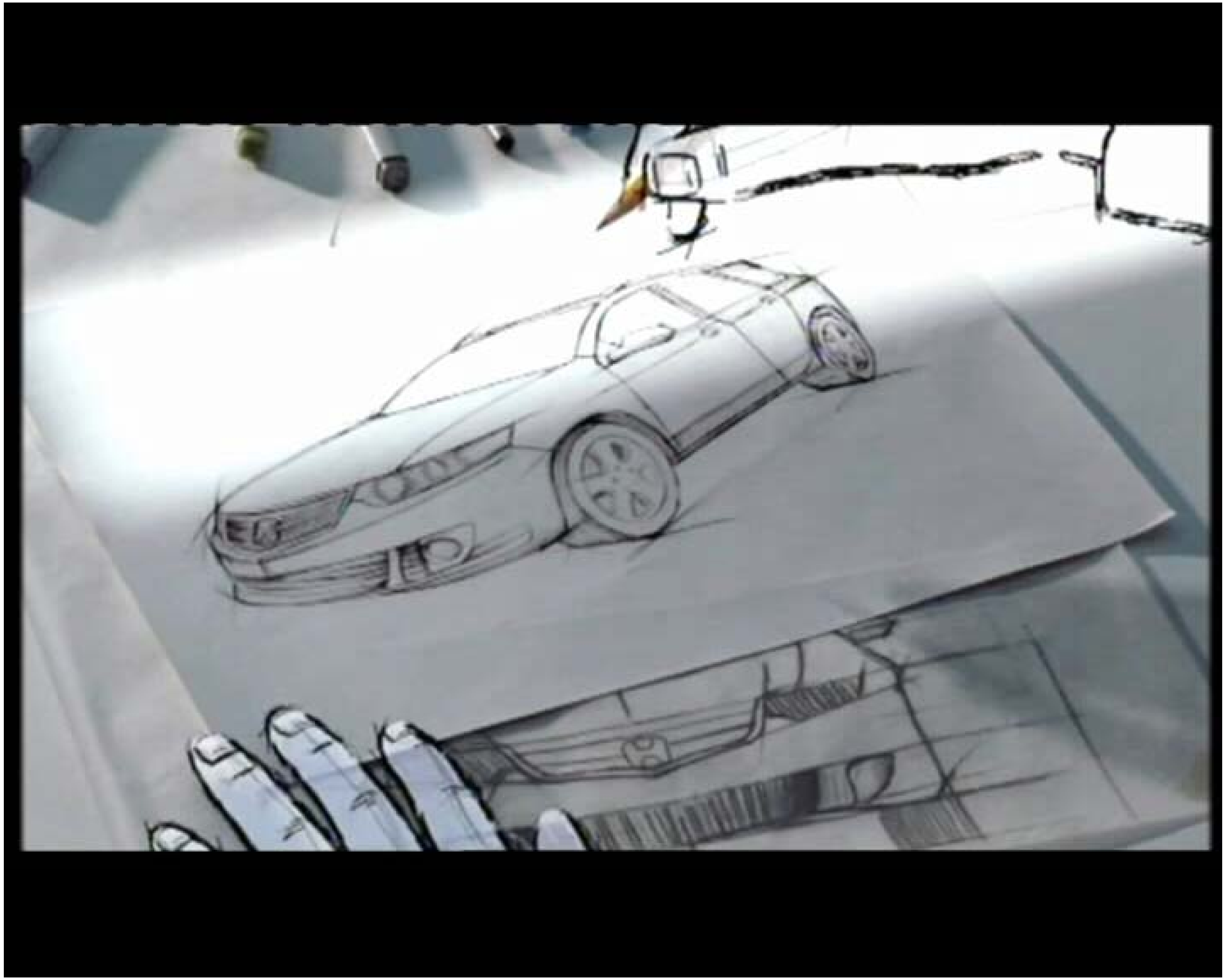
EMISSIONS FROM HOT WORK IN COATED METAL PARTS

EVALUATION /QUALIFICATION OF DRY SAMPLER FOR ISOCYANATES

DEVELOPMENT OF A DIRECT READING ISOCYANATE INSTRUMENT

DISPERSION

EVALUATIONS FOR IMPROVEMENT OF RESPIRATORS
QUESTIONNAIRE
INDUCTION



Scope

- Test chamber **performance comparison** of respirators already in use under work and weather conditions similar to those at North Sea offshore installations and onshore decommissioning sites
- **Field test** of the 3 best performing respirators
- User interviews and questionnaire

→ problem identification and presentation of suggestions for **improvement**

Tested respirators

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Air supply	Number of models
Negative pressure filter	4
Fan assisted filter	5
Compressed air system	3

Face piece	Number of models
Half mask	4
Full face mask	4
Visor	4

In total, 12 different respirator systems were tested.

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Various respirator types

3M 7501-7503,
negative pressure half-face mask.

SR 100
negative pressure half-face mask.

3M 6700-6900
negative pressure full-face mask.

Scott ProCap
fan assisted respirator with visor.

Sundström SR 200 with SR 500
fan assisted respirator with full-face mask.

Malina Safety Clean air Chemical
fan assisted respirator with visor.

Various respirator types

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Sundström SR 540 with SR 500
fan assisted respirator with visor.

3M 7907S
compressed air fed respirator with full-face mask.

3M 4279
disposable negative pressure half-face mask.

Sundström SR307 with SR200
compressed air fed respirator with full-face mask.

3M 6100-6300 with S200,
compressed air fed respirator with half-face mask.

3M HT-701 with Jupiter Turbo
fan assisted respirator with visor.

It was easy in the beginning

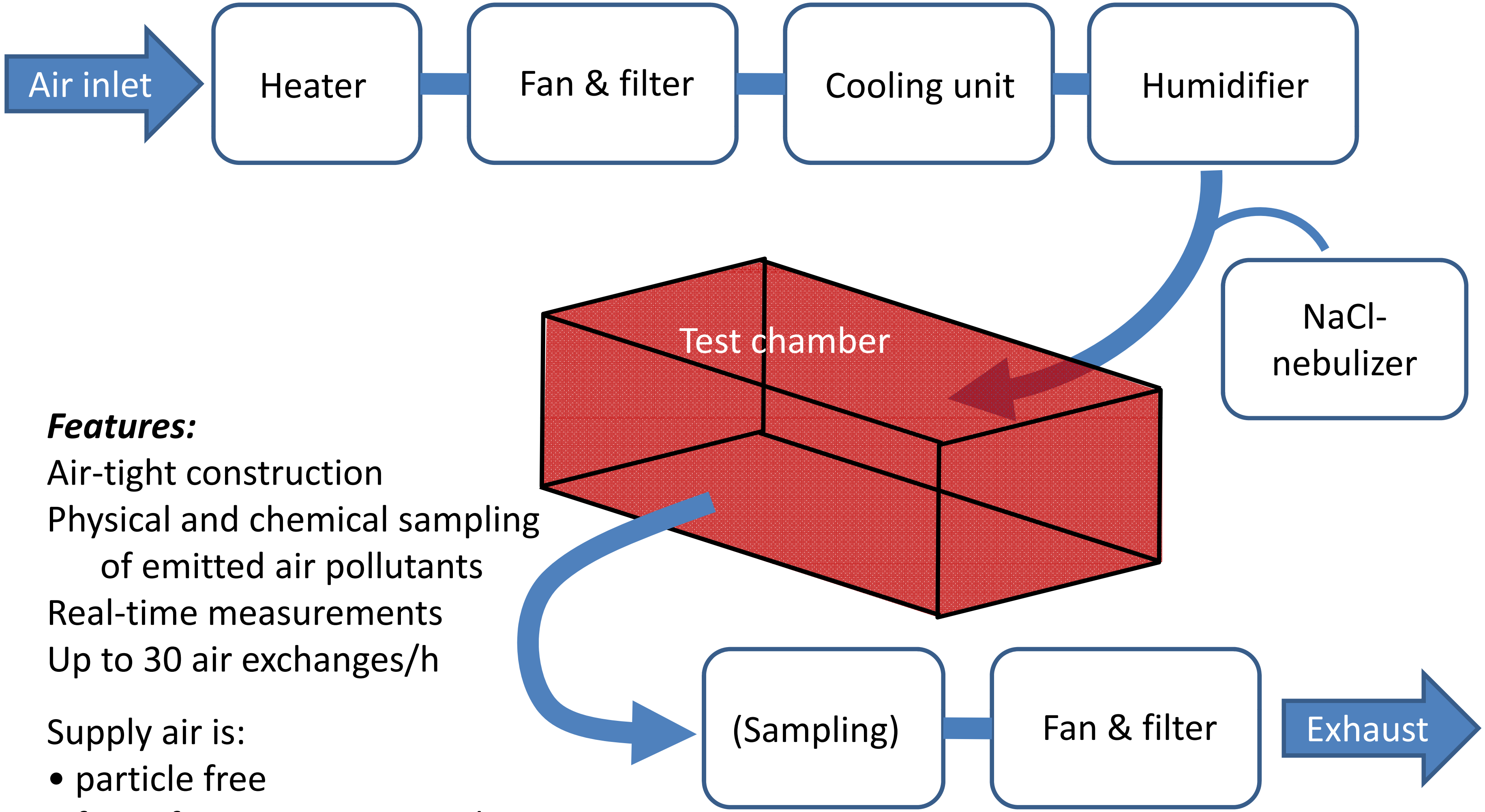
but…


Wenaas

"Hot work" in the North Sea offshore industry:

- Great variation of work tasks
- Medium workload (no running!)
- Diverse but mainly cold weather conditions
- Extremely high concentrations, during short periods, of unknown mixture of air pollutants

The Hässleholm emission/exposure test facility



Features:
Air-tight construction
Physical and chemical sampling
of emitted air pollutants
Real-time measurements
Up to 30 air exchanges/h

Supply air is:
- particle free
- free of organic compounds
- humidity regulated (30 - >95 % RH)
- temperature regulated (5 - 30°C)

Chamber size: approx. 3 x 2.5 meters

Test procedure - definition and sources

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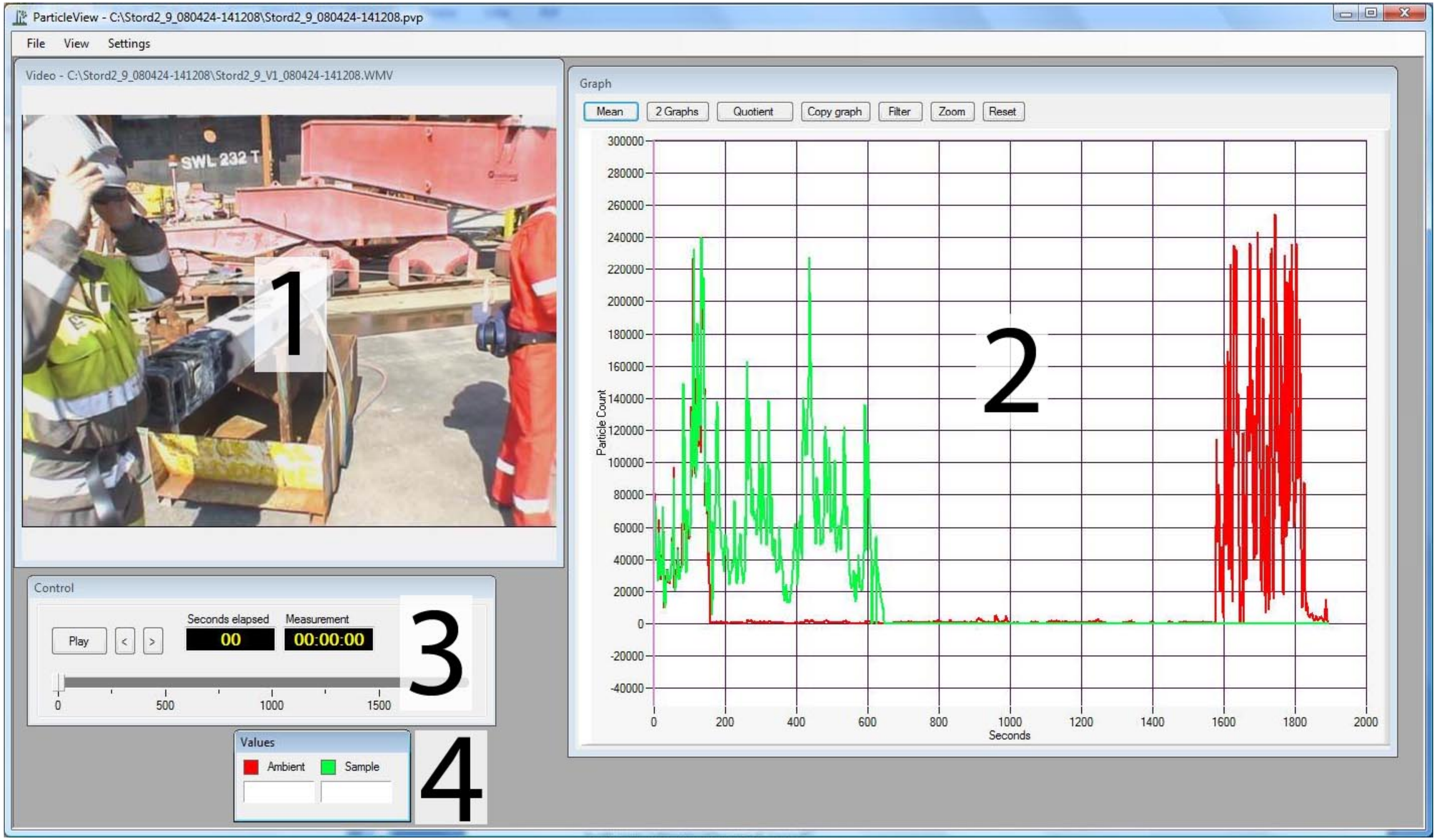
1. Normal breathing	40 s (fit test according to OSHA 29CFR1910.134)
2. Deep breathing	40 s
3. Head side to side	40 s
4. Head up and down	40 s
5. Talking	40 s
6. Grimace	15 s
7. Bending over	40 s
8. Normal breathing	40 s ➡ *Fit test time: 4:55*
9. Walking	3 min (level @ 4.0 km/h; EN13274-2:2001, 6.7 Table 1:9)
10. Talking while walking	2 min (reading text)
11. Moving objects	4 min
12. Cutting	7 min (simulating, 240 mm/min)
13. Walking	3 min (level @ 4.0 km/h)
14. Talking while walking	2 min (reading text)
15. Normal breathing	40 s
16. Deep breathing	40 s
17. Head side to side	40 s
18. Head up and down	40 s
19. Talking	40 s
20. Grimace	15 s
21. Bending over	40 s
22. Normal breathing	40 s

Total test time: about 1 h

Conditions: **5°, 15° or 25°C, 80 % RH**.

ParticleView software



The main screen of ParticleView consists of four elements:

1) Video window, **2)** Graph window, **3)** Playback Control and **4)** Data Values

Leaks

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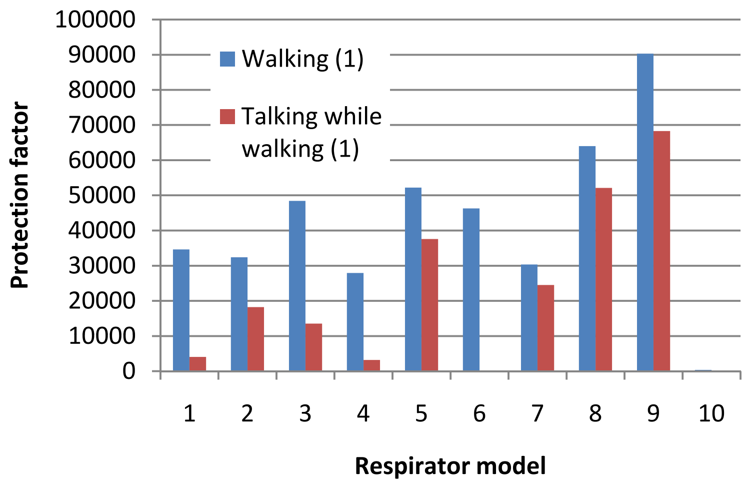
General observations:

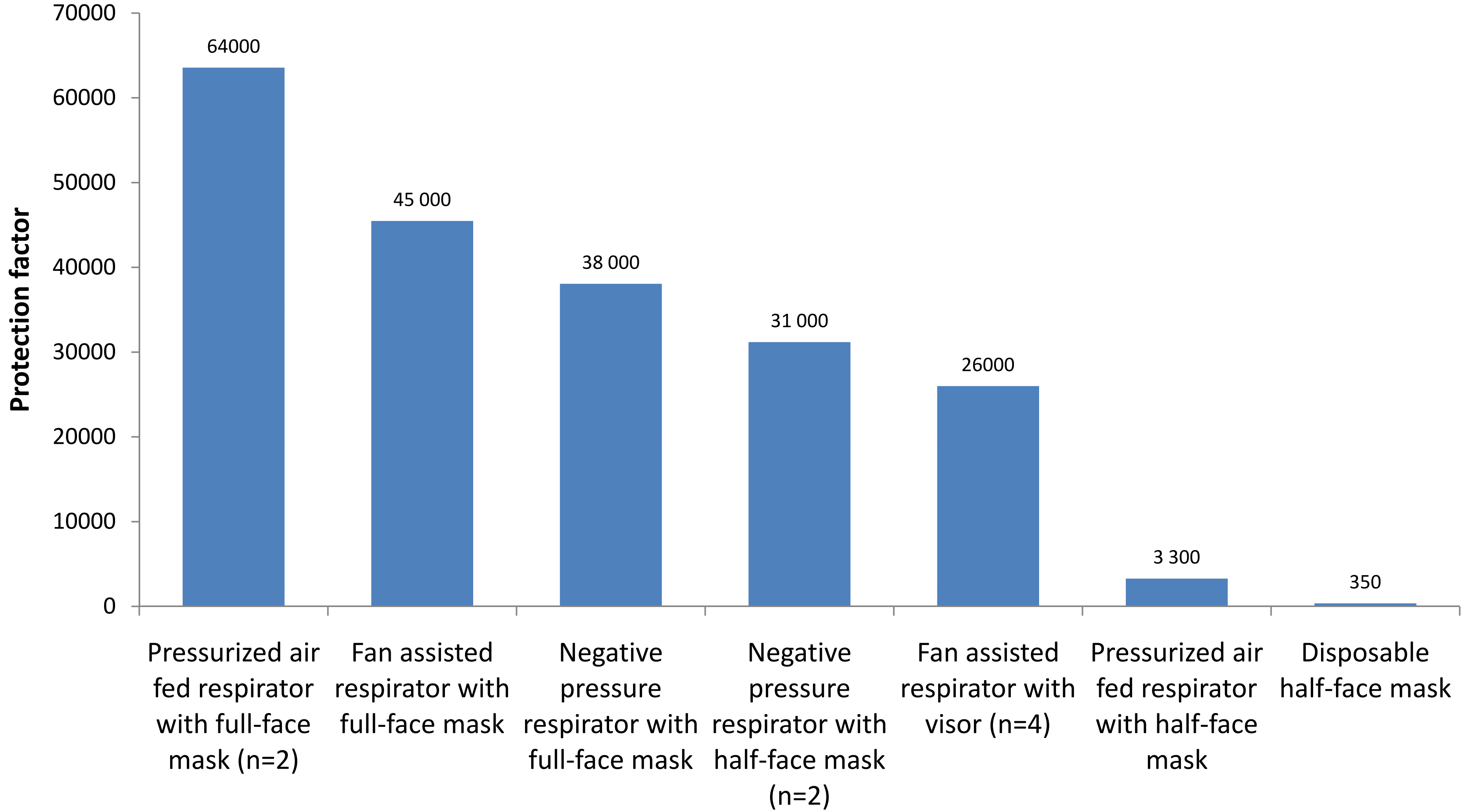
- We have seen no indications that the filter or fan unit should leak particles or other air pollutants.
- Leaks that are detected in these studies comes from failures in the mask/visor unit.

Comparison average protection factors for activities "walking" and "talking while walking"

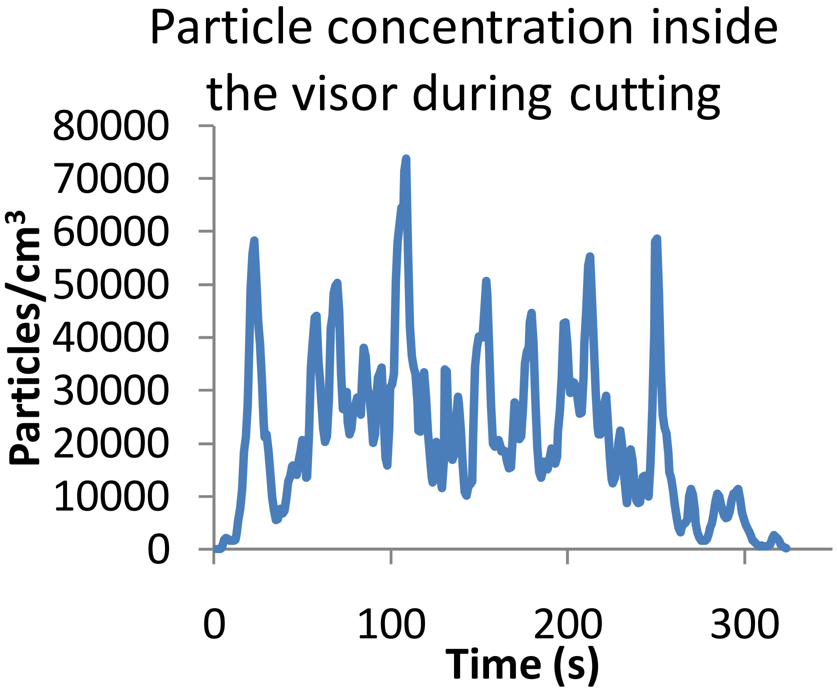


PPEtest_74_short

Average protection factor for the different respirator types from all tests



Cutting operation and a graph displaying the measured particle concentration during cutting inside the respirator



Conclusions

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- A test procedure that in addition to standard fit tests also includes activities related to hot work has been used to test 12 respirators commonly used in the North Sea petroleum industry. As expected, compressed air fed respirators had the highest protection factors. Respirators were found to be more prone to leak during certain movements or activities – especially during walking while talking. Beard growth and a cold mask will influence the performance of the respirator negatively.

- Three respirators from different producers were tested by three workers in a site test. During fit testing one fan assisted visor failed for one test person. This demonstrates the need for an objective quantitative fit test for each worker before a new respirator is used and also testing at regular intervals. Biomarkers were found to be an effective method to identify workers' exposure when oxygen/acetylene cutting in coated metal parts was performed.

- Comments from the users have been compiled from the questionnaire to recommend improvements of respirators.

Manufacturers of PPE

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The project group will invite manufacturers of respirators to discuss test results and suggested improvements

The project

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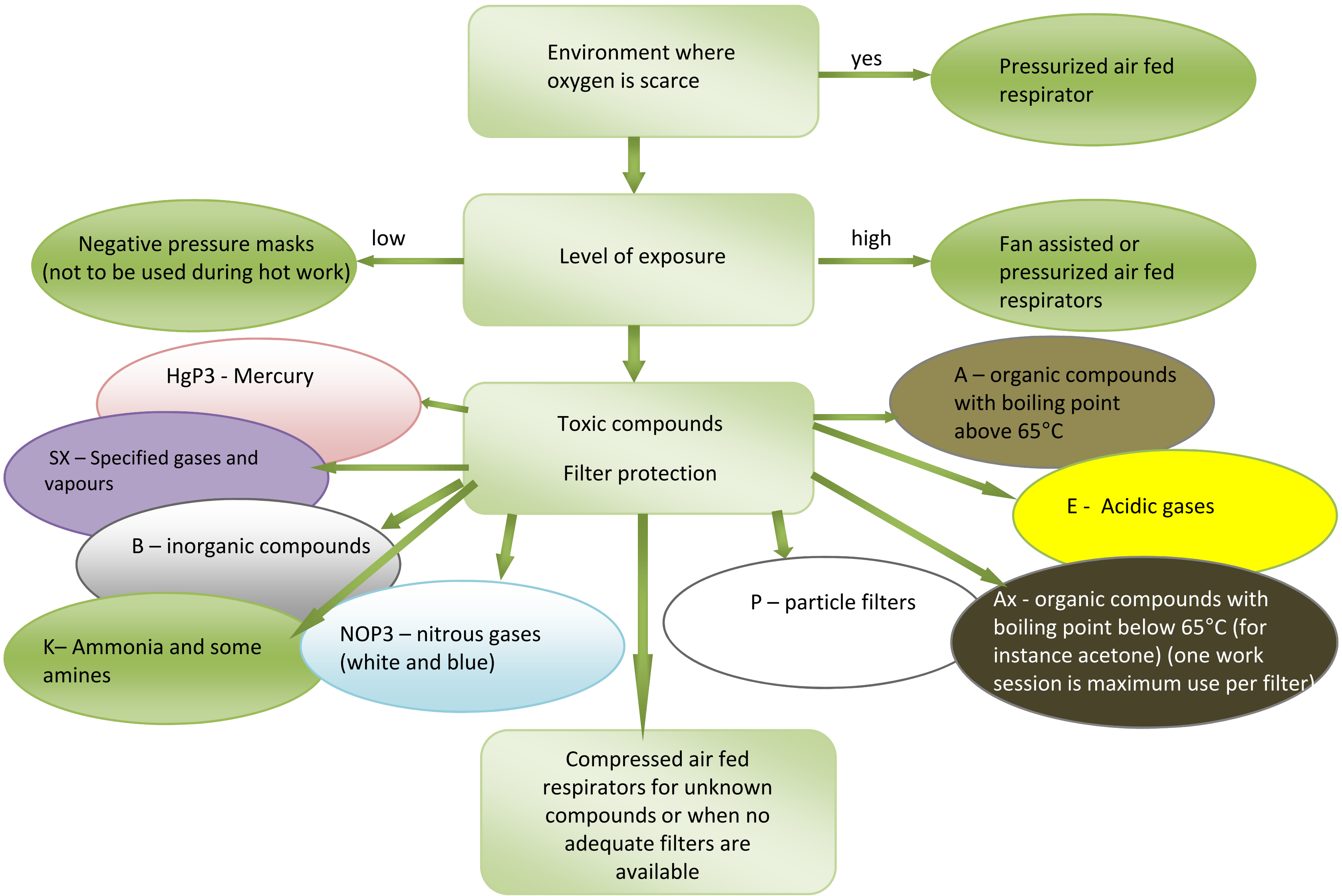
Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
	X	X	X	X

Procedure for choosing proper respiratory protection



Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
	X	X	X	X

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Procedure for maintenance of respirators

- Exchange of filters (check with manufacturer for filter life-cycle)
  - System to ensure that filters are exchanged before expiration
- Setting of air flow (compressed air fed and fan assisted respirators)
- Control of respiratory protection performance
  - How often?
  - How is control of leakage carried out regularly?
- Cleaning procedure
  - Performed by the user or by dedicated personnel?

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

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Do's and don'ts

Do

- Keep the respirator on at the work site after hot work – air pollutants can remain in enclosed spaces for long periods of time (hours) afterwards
- Use appropriate filters for the actual working situation – what toxic compounds can be expected?
- Clean your respirator on a regular basis
- Exchange filters according to the manufacturer's instructions
- Take into consideration that the protection factor is impaired during certain movements – especially for visors
- Increase the air flow during hard work to maintain positive pressure inside the mask at all times – especially for visors
- Always try to minimize the risk of exposure

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

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Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
x	x	x	x	x

Dispersion of air pollutants

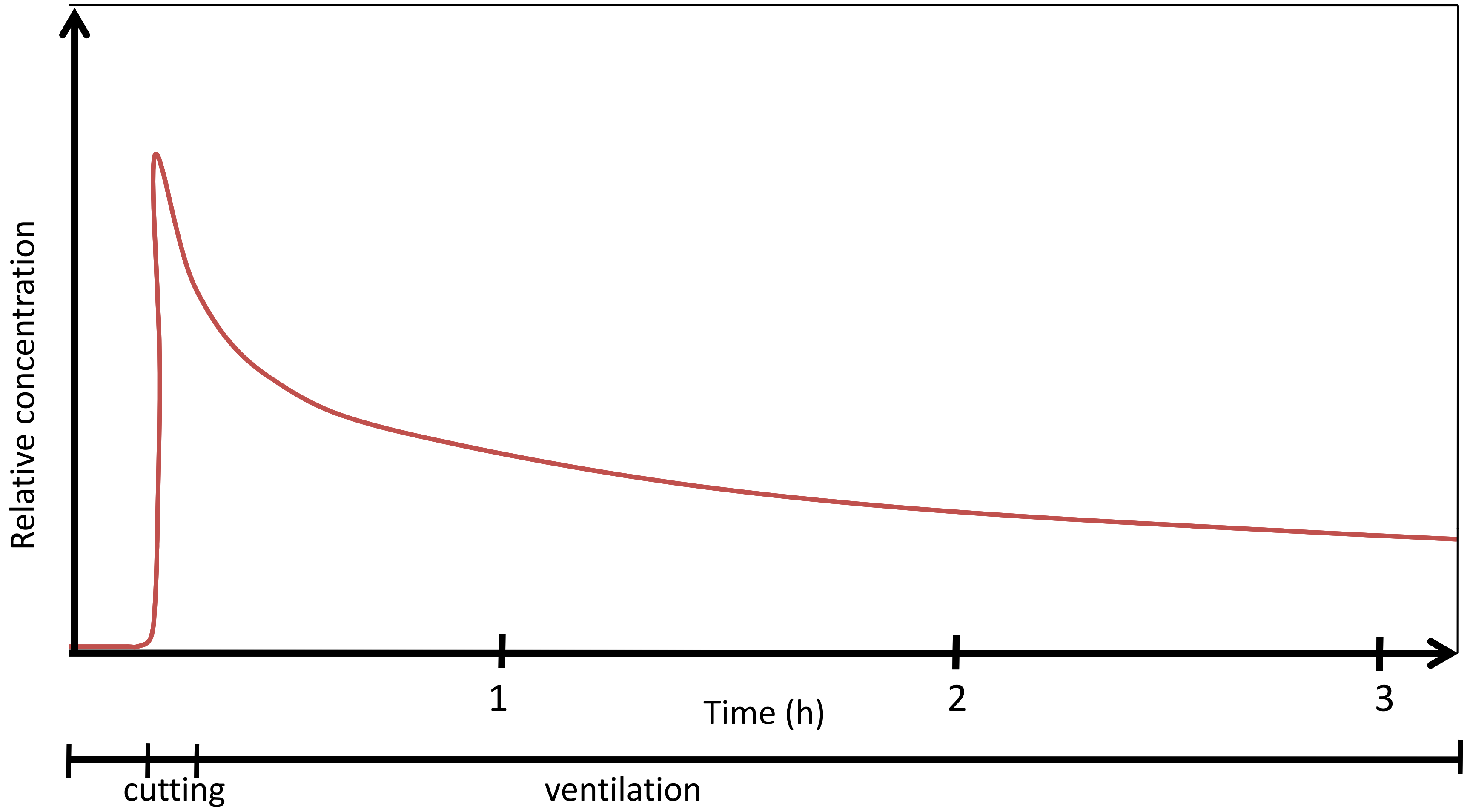

Figure 3. The concentration of aerosols in an enclosed space during and after hot work. The hot work was carried out for 2 minutes. Considerable concentrations of aerosols could still be detected 3 hours after the cutting.

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

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Leaks during movements

During fit tests, certain movements have been detected that more often lead to leakage of the respirator than others.

Examples of such activities are:

- Moving objects
- Talking while walking

Activities relevant for the worker's work situation must be included in the fit test.

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

Leaks during movements

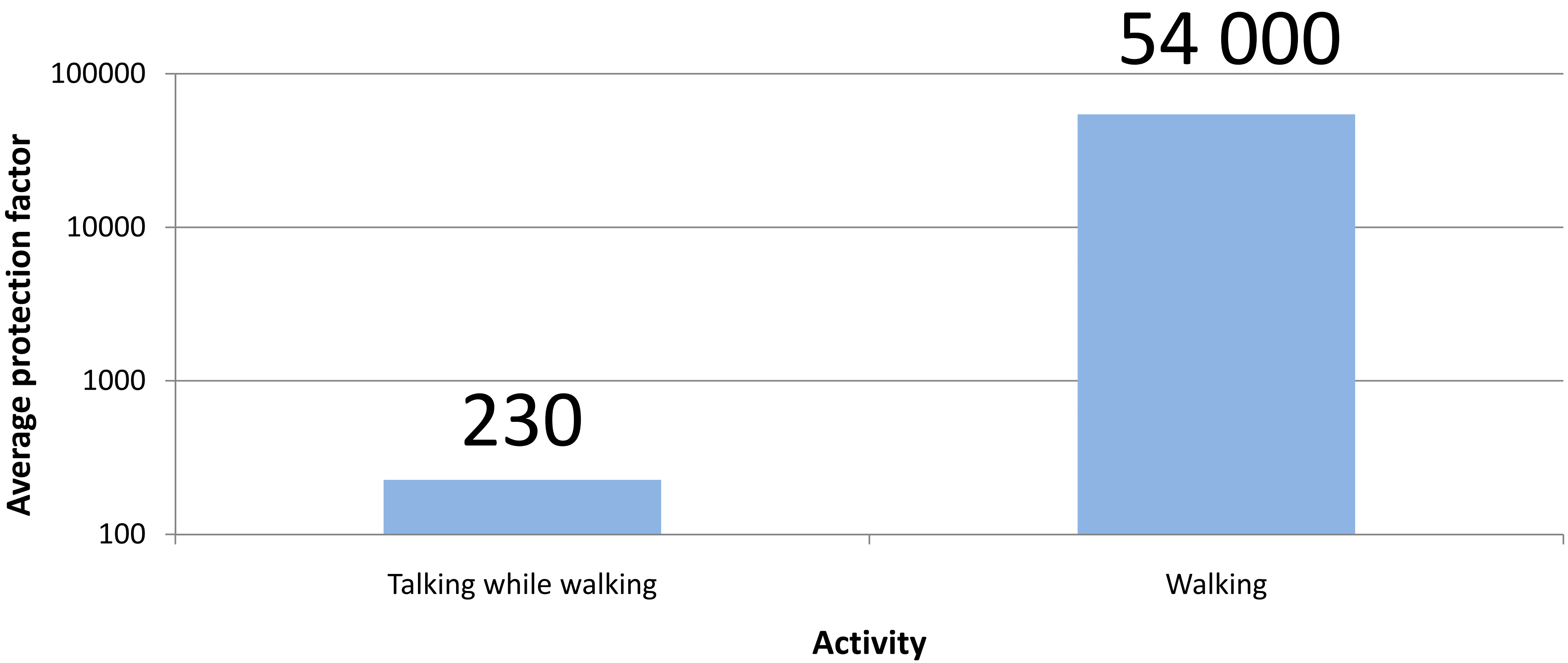

Figure 4. Protection factors for a fan assisted respirator with visor during two activities of the fit test. The protection factor of the visor is significantly lower during the activity ”Talking while walking” as compared to “walking”. Note that the Y-axis is logarithmic to better demonstrate the differences between the respirators.

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

Respiratory protection has a greater tendency to leak during certain movements

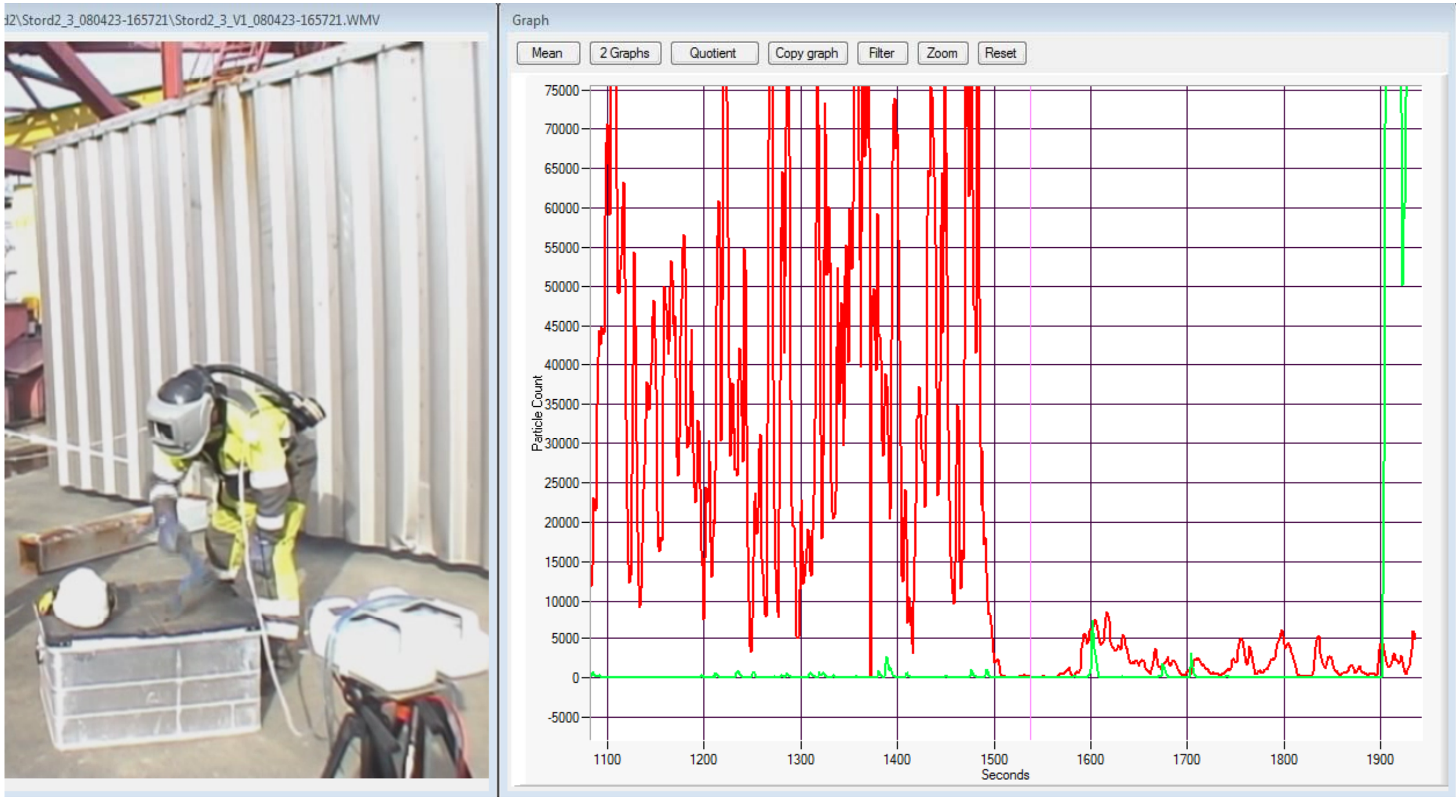

Figure 5. ”Moving object” during a fit test leads to leakage. The graph shows the particle concentration outside (red) and inside (green) the respirator during the fit test. Peaks for the green line shows leakage during this activity.

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

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- Always try to minimize the risk of exposure

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

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Do not

- Don’t wear the mask when not shaved.
- Don’t use negative pressure masks in environments with high exposure
- Don’t assume that all masks fit all wearers
- Don’t work with a cold mask

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

The protection factor for negative pressure respirators is influenced by beard growth

Figure 6. Protection factor for one test person with different beard length, using a negative pressure respirator.

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

Do not

- Don’t wear the mask when not shaved
- Don’t use negative pressure masks in environments with high exposure
- Don’t assume that all masks fit all wearers
- Don’t work with a cold mask

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

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- Don’t work with a cold mask

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

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Fit test

Individual face shape influence whether a respirator fits – a respirator with bad fitting are more likely to leak

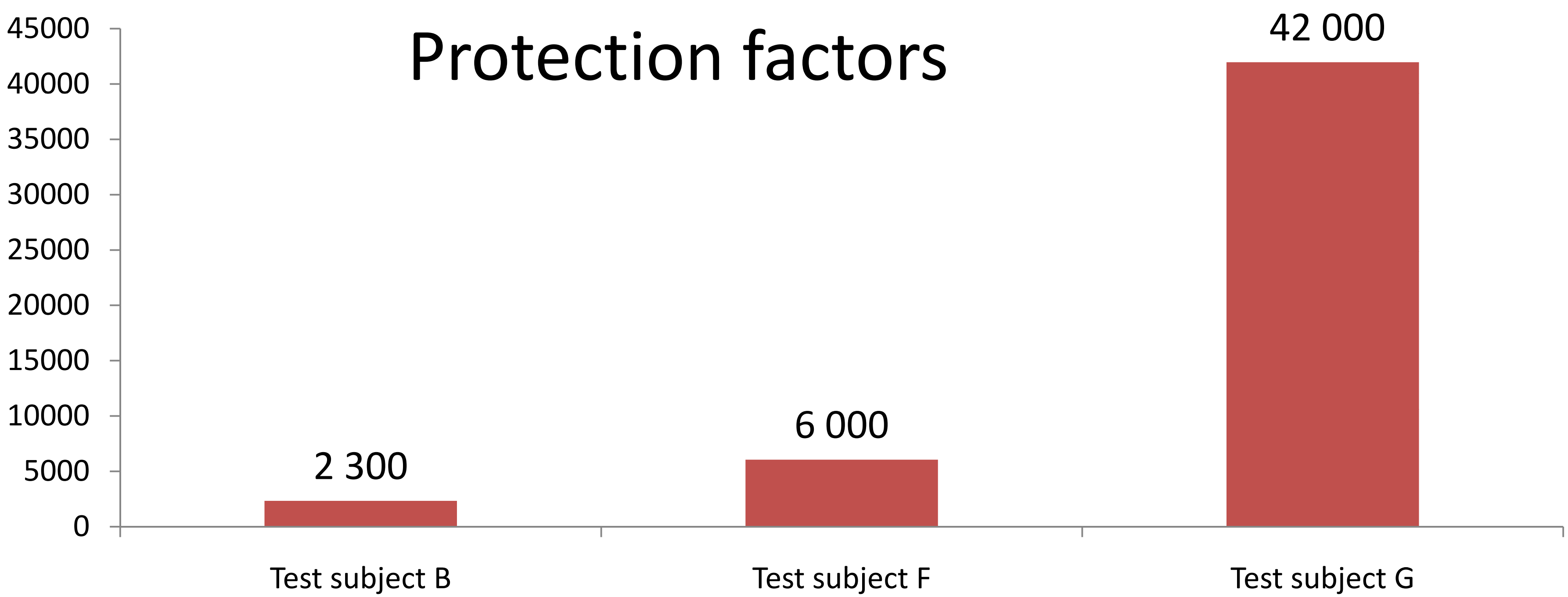

Figure 7. Variation in protection factor during the activity “Talking clearly” during the fit test for three test persons while testing a negative pressure half-face mask.

Workers	Team leader	Executive personnel	HMS personnel	Quality assurance personnel
X	X	X	X	X

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Fit test

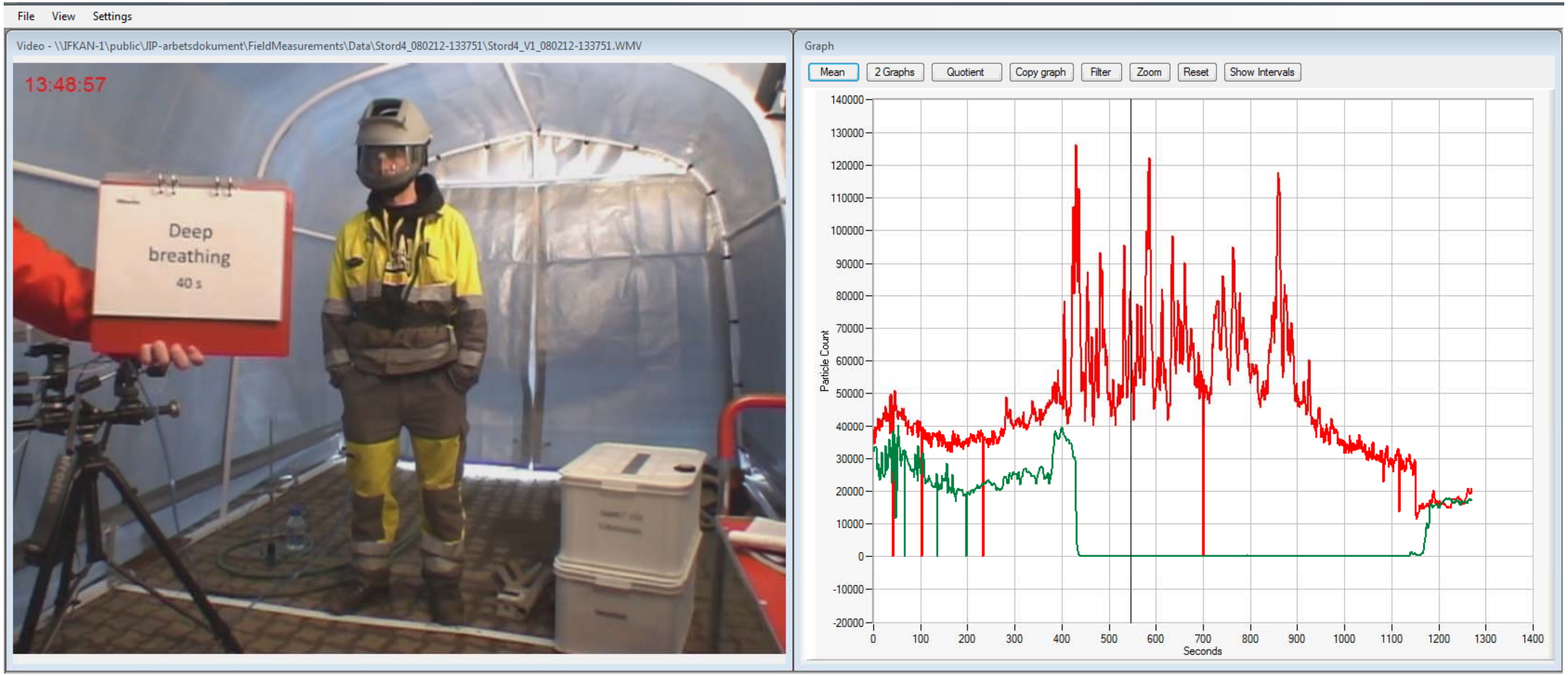

Figure 8. Fit test – ”Deep breathing”. The graph to the right shows the particle concentration, which is monitored inside (green line) and outside (red line) the respirator in combination with the fit test.

Fit test

- Validates that the respirator provides efficient protection for the individual
  - Ideally a fit test should be performed every time a respirator is used
  - A fit test should be performed when the user obtains a new respirator to validate that it fits the user (facial dimensions)
- Relevant fit test regarding the work task for the user should be carried out

Fit test

- The fit test ensure that the respirator provides efficient protection for the individual
- A fit test should involve movements similar to those in the work task that shall be performed
- The fit test should be performed regularly and every time a new respirator is used

Conclusions

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- Based on the information in this educational package an interactive learning program in Norwegian and English is in progress (MINTRA & IFKAN).

The project

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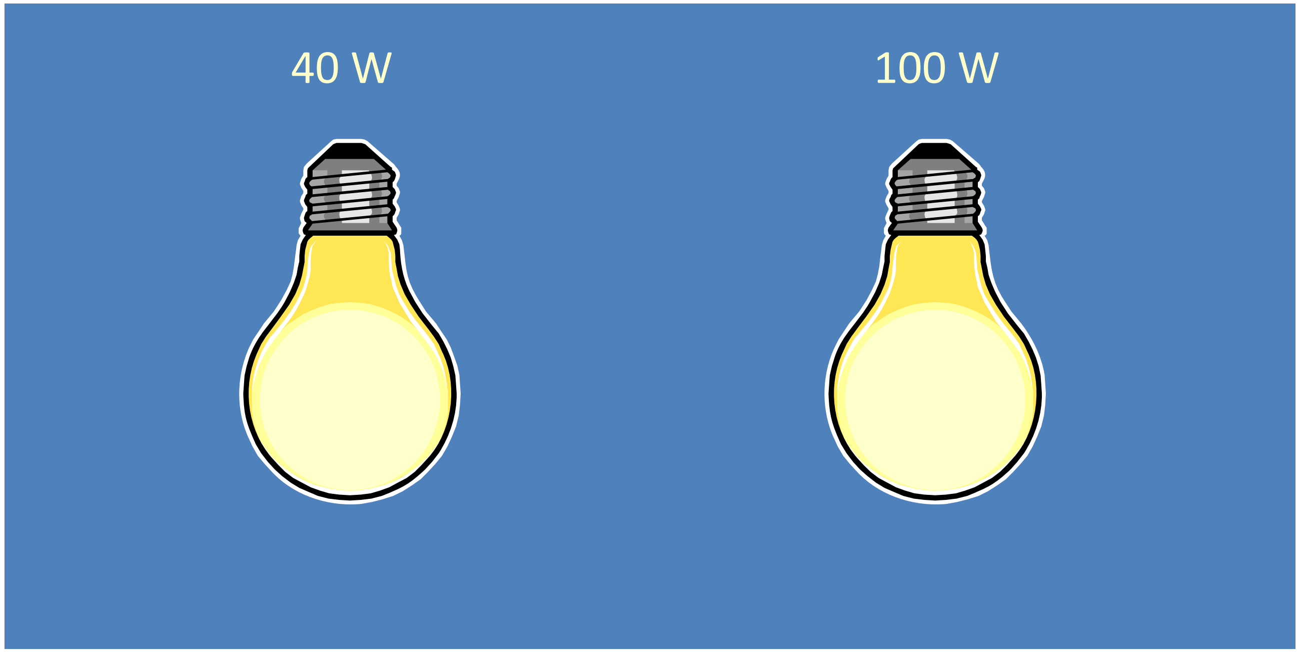
Source strength

$$\dot{m} = \frac{\dot{C}_t \cdot Q}{1 - e^{-\frac{Q}{V}\cdot t}}$$

m = mass produced/time unit
C_t = maximum concentration of the substance
Q = volumetric flow through the room where the source is located
V = volume of the room
t = production time



Source strength

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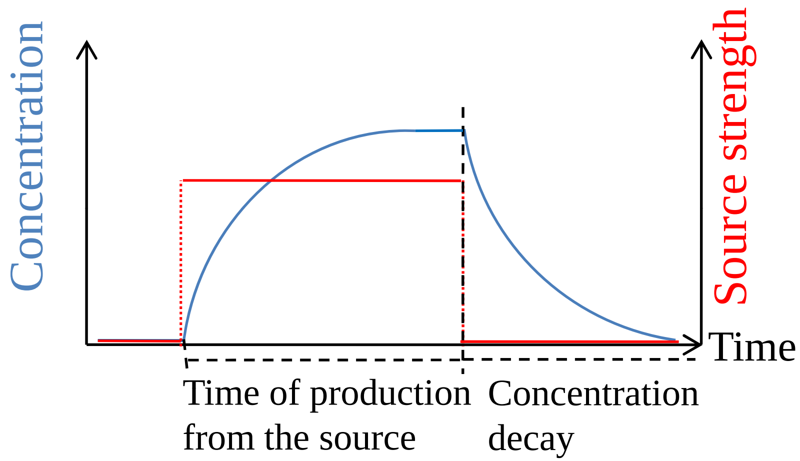


A graph showing how the concentration varies with time during an operation that produces an airborne contaminant inside a well mixed ventilated room.

OELs

Norwegian OEL's for nitric oxides and mercury:

	Adm. norm	Takverdie
NO_2	--	2 ppm
NO	25 ppm	--
Hg (inorganic)	50 µg/m^3	--

British WEL's for nitric oxides and mercury:

	LTEL (8 h)	STEL (15 min)
NO_2	3 ppm	5 ppm
NO	25 ppm	35 ppm
Hg (inorganic)	25 µg/m^3	--

Source strength measurements
- Air sampling

- **Impinger sampling, toluene-DBA**
- **Isocyanates:** isocyanic acid (ICA), methyl isocyanate (MIC), ethyl isocyanate (EIC), propyl isocyanate (PIC), phenyl isocyanate (PhI), hexamethylene diisocyanate (HDI), toluene diisocyanate (TDI), isophorone diisocyanate (IPDI), methylenediphenyl diisocyanate (MDI)
- **Diamines:** hexamethylene diamine (HDA), toluene diamine (TDA), methylene diphenyl diamine (MDA)
- **Aminoisocyanates:** hexamethylene aminoisocyanate (HAI), toluene aminoisocyanate (TAI), methylene diphenyl aminoisocyanate (MAI)
- **Organic Acid Anhydrides:** maleic anhydride (MA), phthalic anhydride (PA), tetrahydro phthalic anhydride (TA), *cis*-hexahydro phthalic anhydride (HA)
- **Impinger sampling, 5 mM H_2SO_4**
- **Small amines:** ethanolamine (EOA), diethylamine (DEA), dimethylethylamine (DMEA), aniline (ANL), triethylamine (TEA), diethanolamine (DOA), triethanolamine (TOA)
- **Impinger sampling, EtOH**
- **Tinorganic compounds:** Tricyclohexyltin (TCHT), di-n-butyltin (DBT), di-n-octyltin (DOT), triphenyltin (TFT), tributyltin (TriBT), monooctyltin (MOT), butyltin (BTT), tetra-n-butyltin (TetraBT)
- **Sorbent tube, DNPH**
- **Aldehydes:** formaldehyde (FAL), acetaldehyde (AAL), propionaldehyde (PAL)
- **Filter sampling**
- **Metals:** As, Ca, Cd, Co, Cr, (Cr(VI) separate filter), Cu, Fe, Mn, Mo, Ni, Pb, V, Zn
- **Mercury sampling on carbon sorbent tubes**

Particle size distribution during thermal oxygen cutting

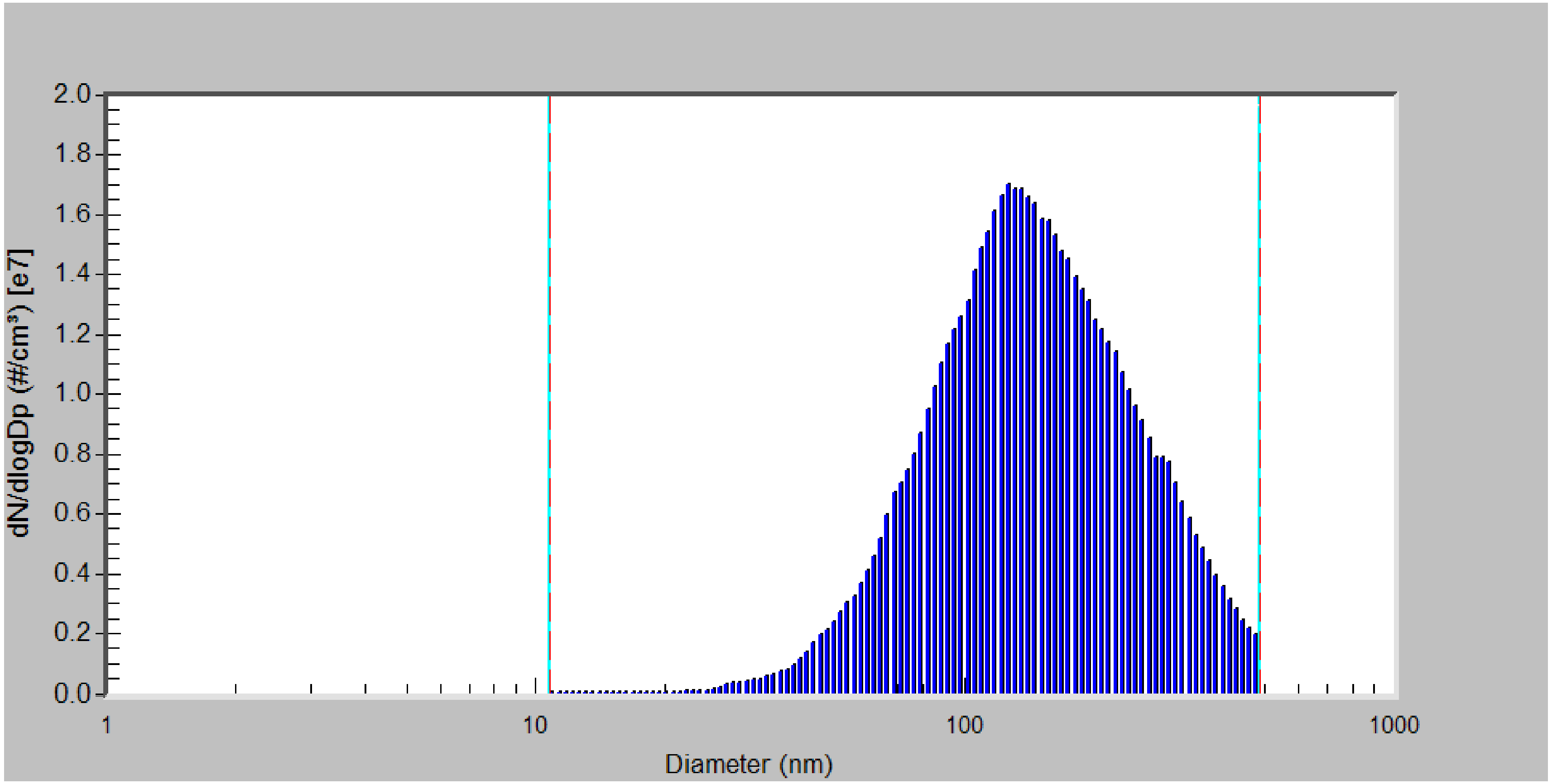
Measured with a scanning mobility particle sizer (SMPS)

Example from sample A2:

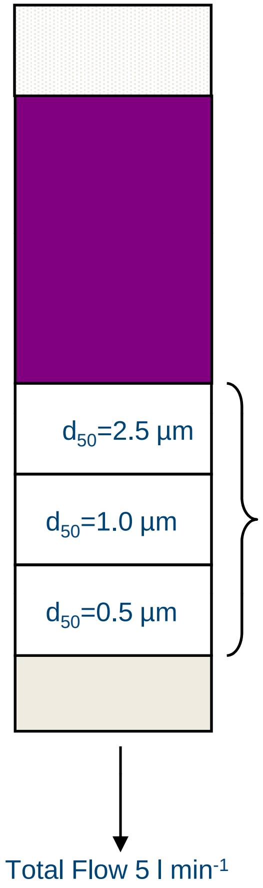
Geometric mean diameter for number distribution: 143 nm

Total number concentration: 9.7×10^6 particles/cm^3

Total mass concentration: 55 mg/m^3 (assuming a density of 1.2 g/cm^3)



Fractionated Sampling



Preselector

Denuder

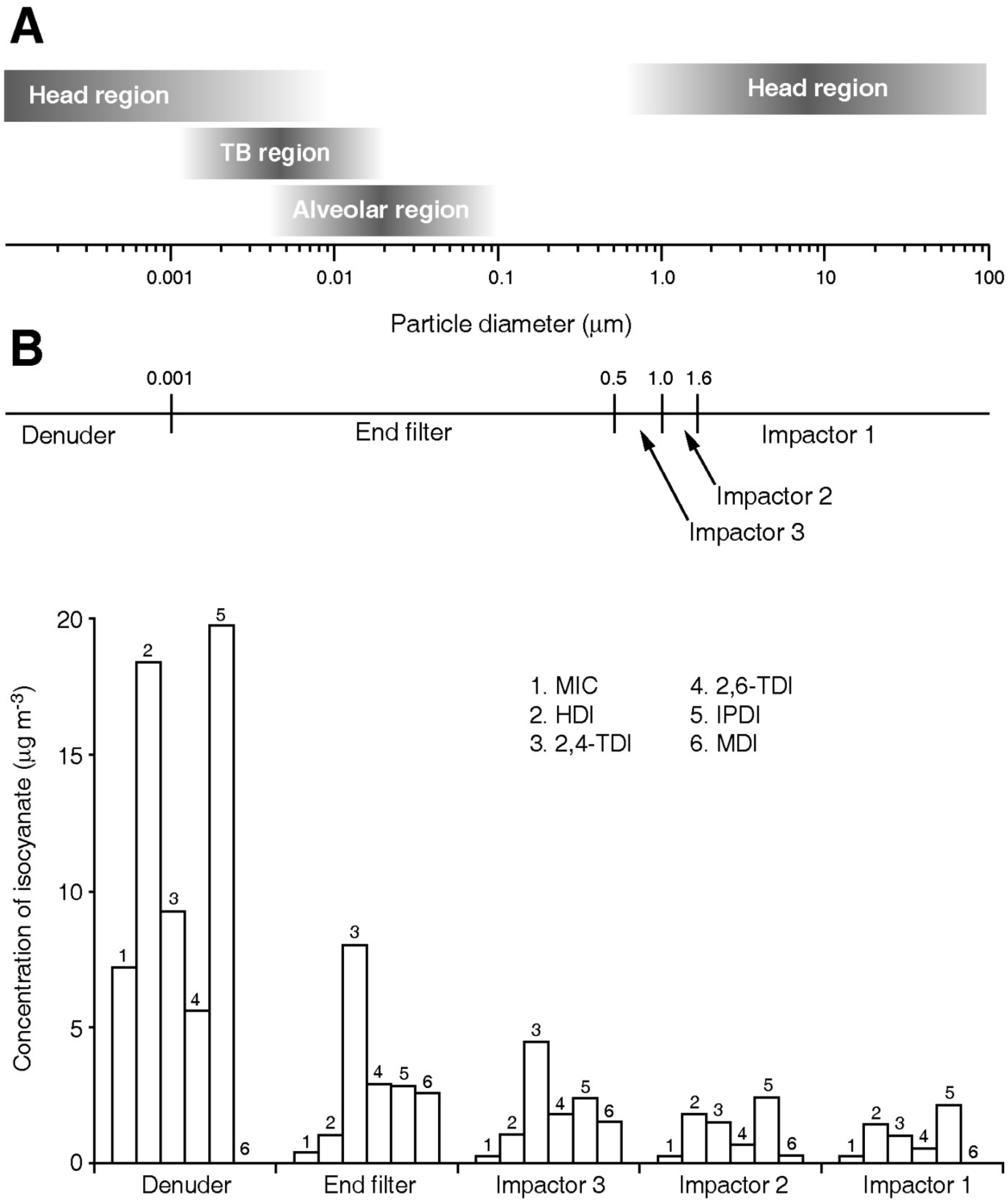
Gaseous Isocyanates

Impaction Stages

Particle-bound Isocyanates

Filter

Small Particles



1. Multi-channel denuder made of a bundle of small rolls of glass fiber filter (length = 90 mm, total diameter = 35 mm)

2. Single orifice impaction stage with a diameter of 2.0 mm (d50 approx. 1.6 µm)

3. Second impaction stage with a diameter of 1.5 mm (d50 approx. 1.0 µm)

4. Third impaction stage with a diameter of 1.0 mm (d50 approx. 0.5 µm)

5. Final end filter.

Thermal degradation of PUR-coating

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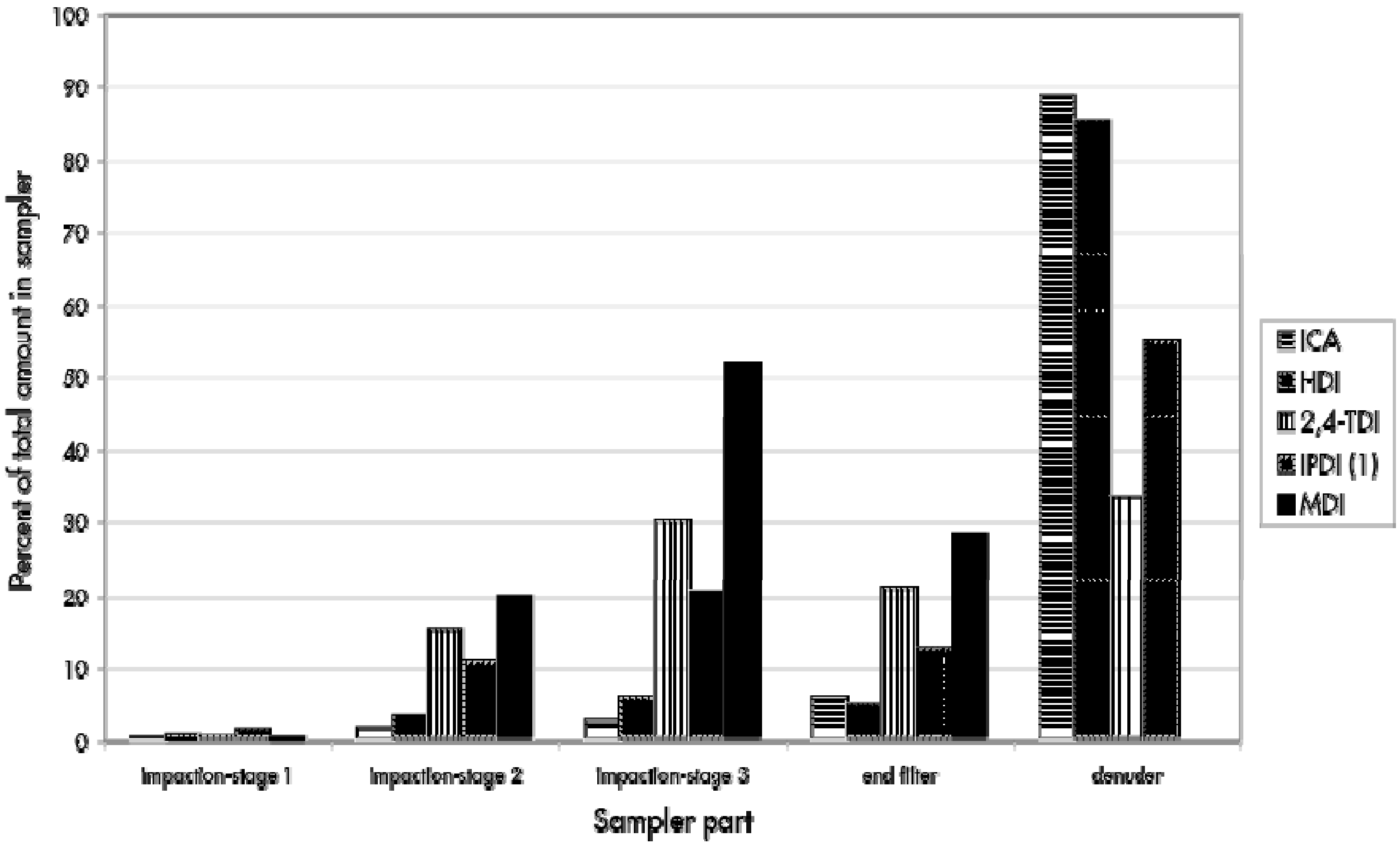


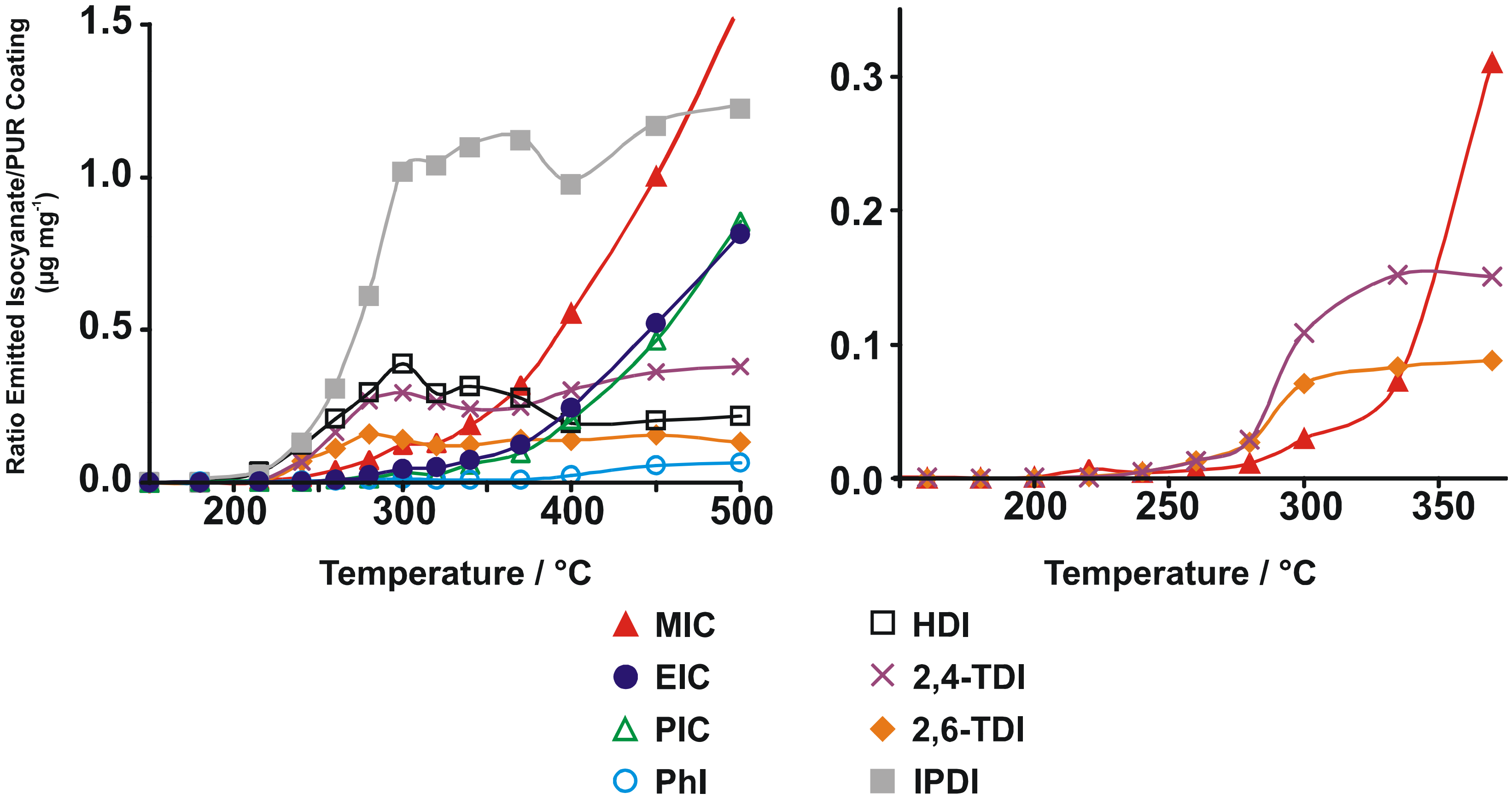
Total air levels: ICA 830 µg/m³, HDI 96 µg/m³, 2,4-TDI 45 µg/m³, IPDI (1) 70 µg/m³, MDI 20 µg/m³

Table 15. Date: 2005 07 03; Operation: Gas cutting in red water pipes: Location: TCP2 pump room.

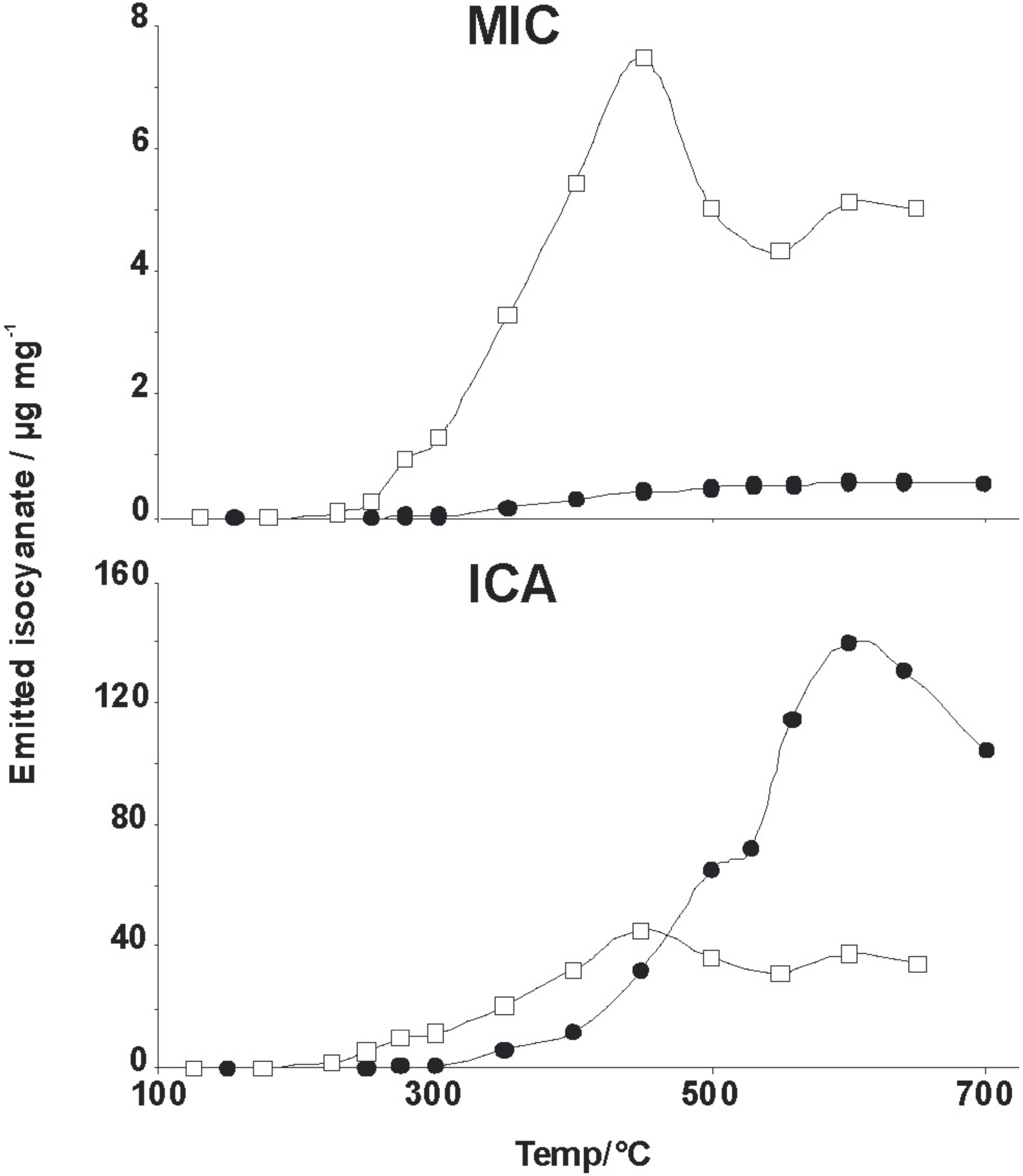
Frigg 2005 07 03									
Sampling place	Sample	µg/m3				% of OEL			
		ICA	HDI	FA		ICA	HDI	Σ isoc.	FA
1 m fr cut spot	EasySampler 50	-	52.3	na			224	224	
1 m fr cut spot	EasySampler 51	2.7	-	na		46		46	
1 m fr cut spot	DNP50	na	na	134					33
1 m fr cut spot	DNP51*	na	na	77					19
3 m fr cut spot	EasySampler 52	13.5	4.7	na		225	20	245	
3 m fr cut spot	EasySampler 53	3.4	-	na		57		57	
3 m fr cut spot	DNP52	na	na	31					8
3 m fr cut spot	DNP53	na	na	23					6
5 m above cut spot	EasySampler 54	14.1	1.2	na		235	5	240	
5 m above cut spot	EasySampler 55	15.5	-	na		258		258	
5 m above cut spot	DNP54	na	na	24					6
5 m above cut spot	DNP55*	na	na	9*					3*
1 m fr cut spot	EasySampler 56	2.9	33.5	na		49	144	193	
1 m fr cut spot	EasySampler 57	1.4	-	na		24		24	
1 m fr cut spot	DNP56	na	na	101					25
1 m fr cut spot	DNP57*	na	na	-*					*
3 m fr cut spot	EasySampler 58	-	-	na				0	
3 m fr cut spot	EasySampler 59	0.6	33.5	na		9	143	153	
3 m fr cut spot	DNP58	na	na	21					5
3 m fr cut spot	DNP59	na	na	39					10
5 m above cut spot	EasySampler 60	16.5	1.3	na		275	5	281	
5 m above cut spot	EasySampler 61	10.5	2.6	na		175	11	186	
5 m above cut spot	DNP60*	na	na	-*					*
5 m above cut spot	DNP61*	na	na	-*					*

*Pump faliure

Emission of isocyanates from two different types of PUR coatings. Weighted amounts (about 10 mg) of coating removed from a car metal sheet were thermally decomposed in a tube furnace.



Thermal degradation of phenol-formaldehyde-urea resins, bakelite and mineral wool



Source strength

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Deliverables

Comparisons with regards to emission can be performed for:

- different coatings
- different work operations/procedures
- different work tools

Enhance the choice of proper respiratory protection equipment

Conclusions

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- In order to compare different work operations and materials a controlled environment is needed. This was made possible by measuring the source strength during the experiments in the climate chamber with simultaneous sampling of a number of organic compounds, metals and sampling with direct reading instruments for nitric oxide (NO), nitrous oxide (NO_2), mercury vapour and particle concentration and size distribution.

- The metals found in the coating and rust samples taken from the different metal parts tested, were also found in the air samples taken during thermal cutting. Examples of metals found in the emissions were mercury, arsenic, chromium and lead.

- The impactor samples showed that the particles generated during acetylene/oxygen cutting was small (d_a<2 µm), i.e. are respirable and that the particles generated during plasma cutting on the stainless steel pipe were even smaller.

- The sedimentation samples showed that the metal particles generated during the cutting could be transported away from the cutting spot before settling onto the horizontal surfaces. Samples of clothing were also analyzed regarding metals and these showed that the metals emitted during the work operation were deposited on the clothes as well.

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EVALUATION OF REPRESENTATIVE RESPIRATORY PROTECTION DEVICES USED IN THE NORTH SEA

EDUCATIONAL PACKAGE

EMISSIONS FROM HOT WORK IN COATED METAL PARTS

EVALUATION /QUALIFICATION OF DRY SAMPLER FOR ISOCYANATES

DEVELOPMENT OF A DIRECT READING ISOCYANATE INSTRUMENT

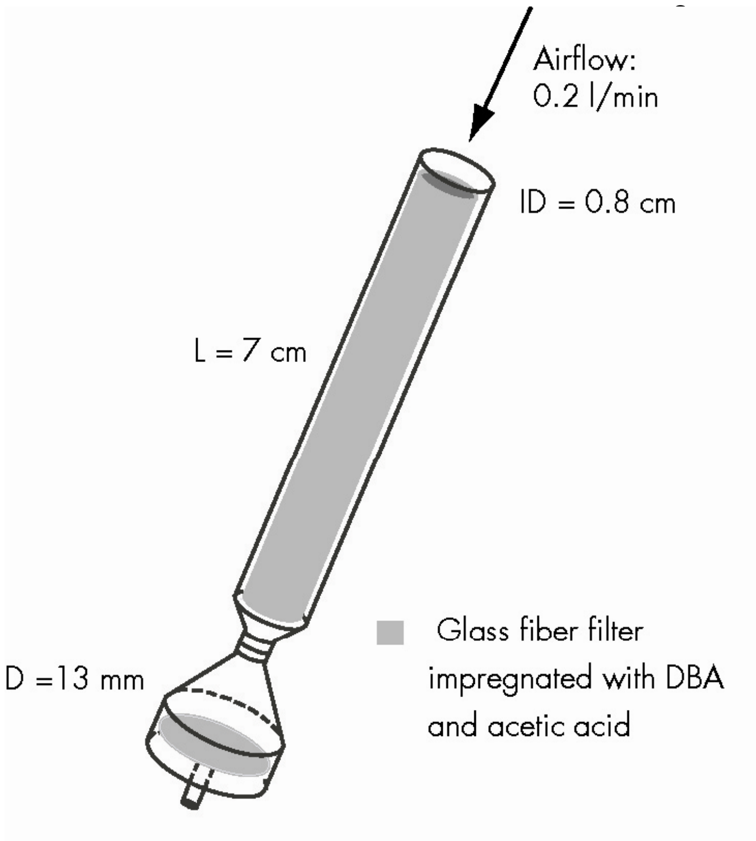
DISPERSION

EVALUATIONS FOR IMPROVEMENT OF RESPIRATORS

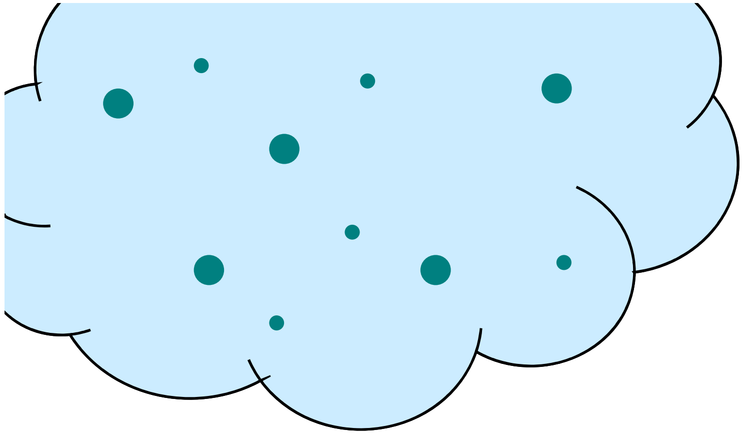
QUESTIONNAIRE

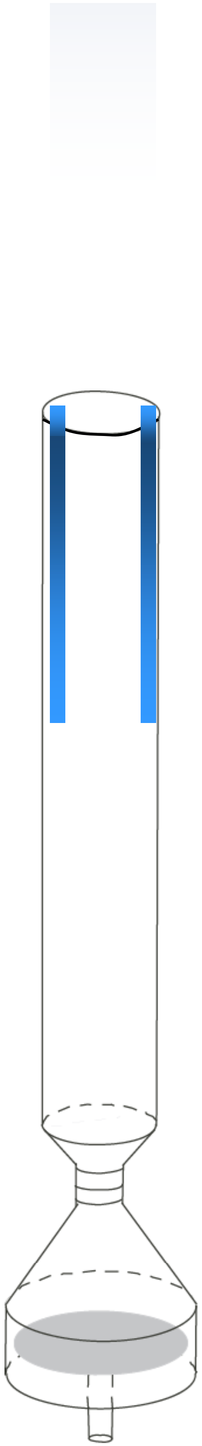
INDUCTION

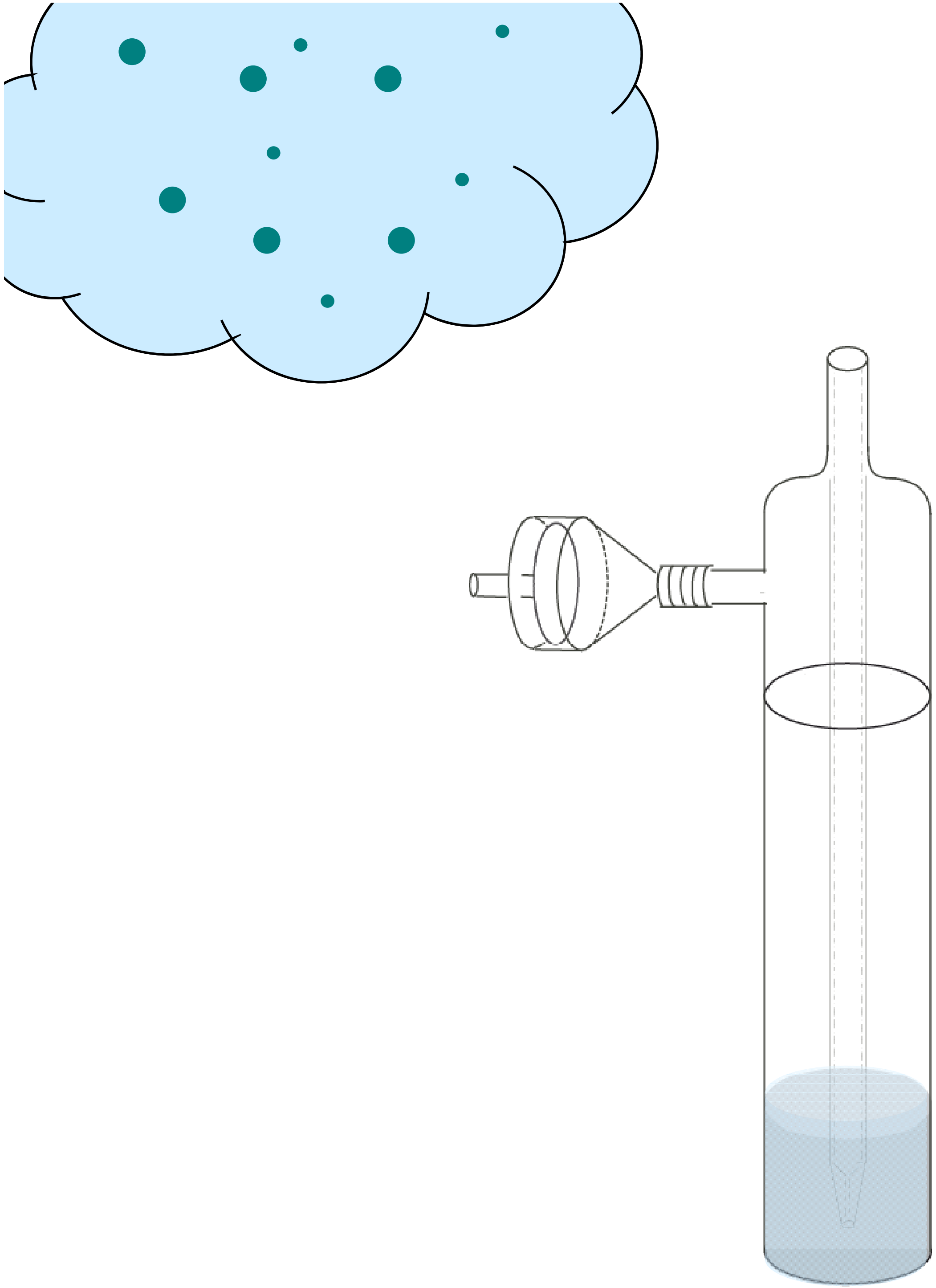
Solvent-free sampler - principle



- Collection of both gas and particle phase isocyanates
- Continuous refreshing of DBA on the end-filter
- DBA amount sufficient for > 8 h sampling
- Field extraction not necessary







Conclusions

The EasySampler has been shown to be a convenient alternative to impinger-filter sampling of isocyanates in air.

Several important benefits using this dry sampler are: easy handling in the field, easy transport to the laboratory and storage possibilities up to 15 days before analysis.

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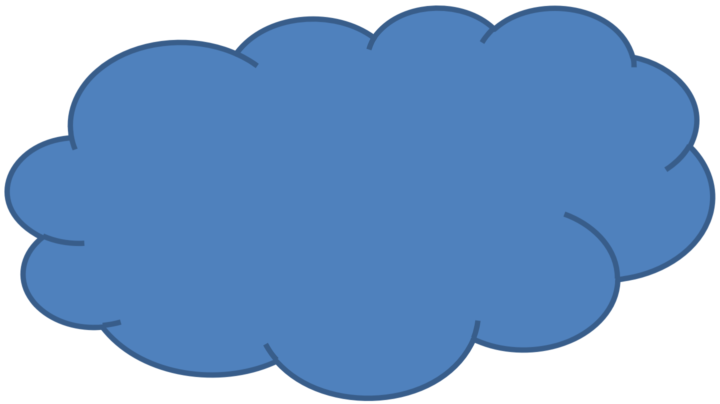
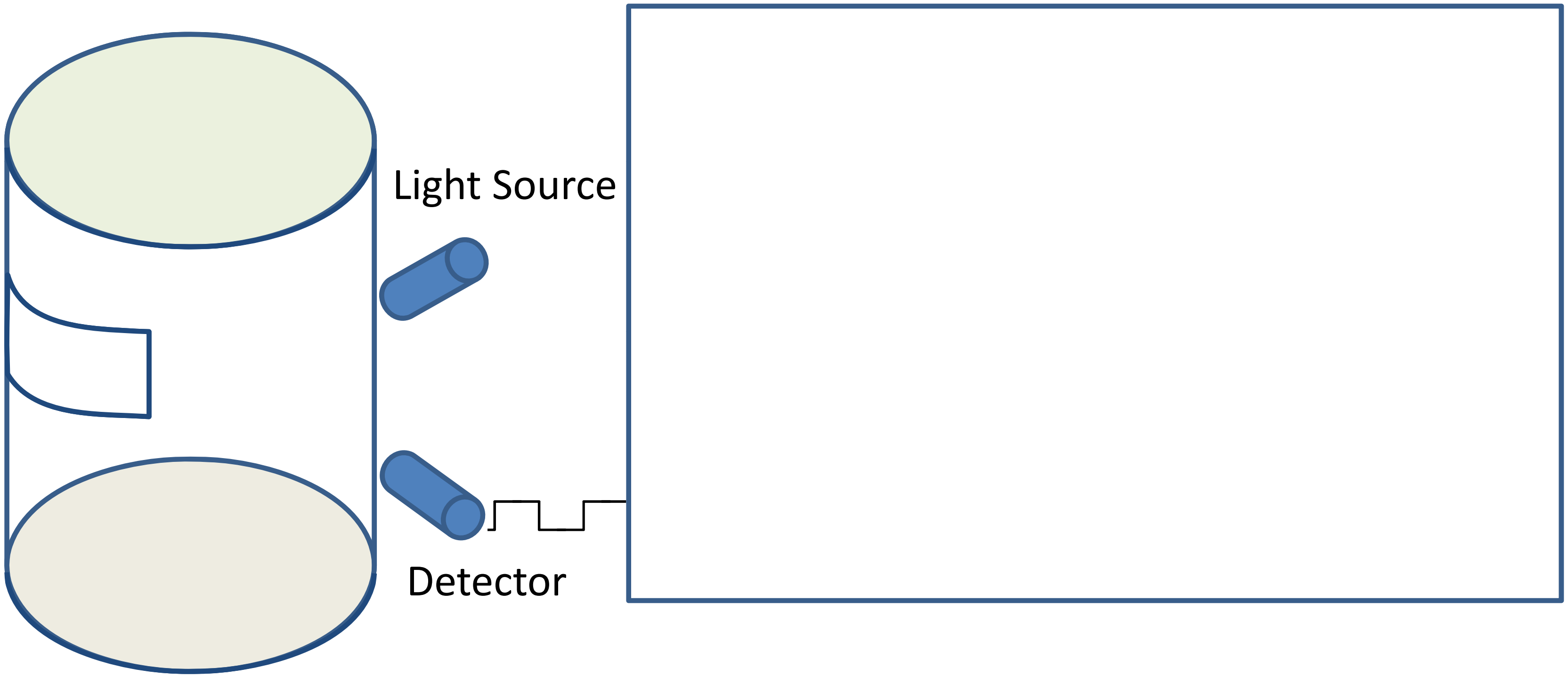
Direct reading instrument for isocyanates:





Conclusions

The direct reading instrument is able to measure concentrations of isocyanates in air, including monoisocyanates, such as isocyanic acid (ICA) and methyl isocyanate (MIC). However, the direct reading instrument needs further development to be commercially available.

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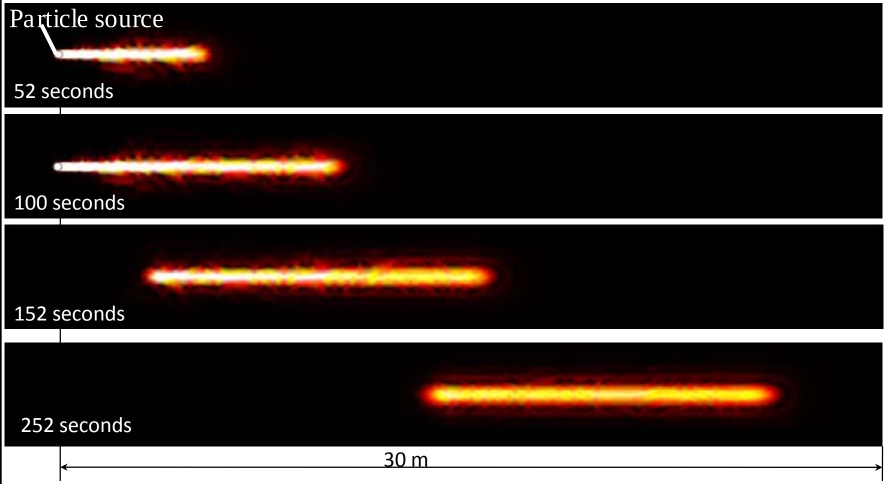
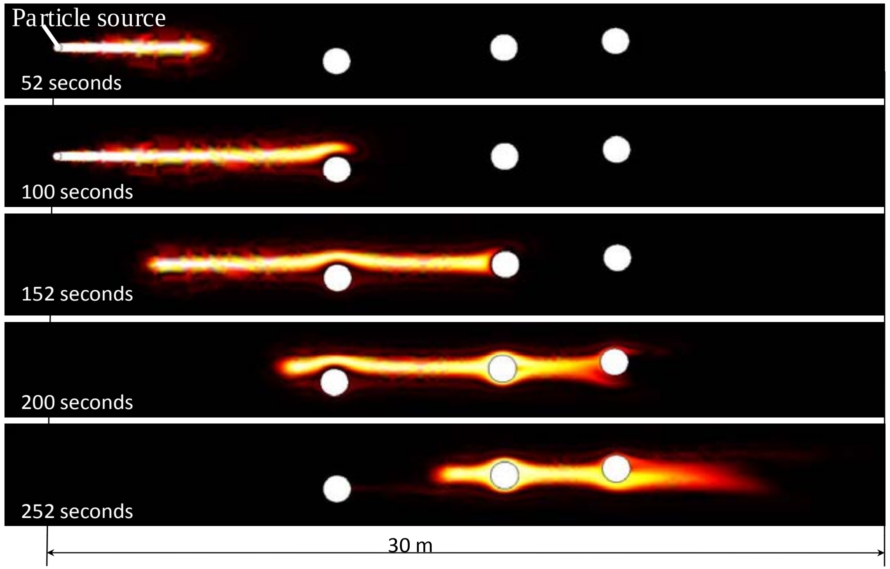
Computer simulated model - Dispersion

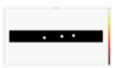


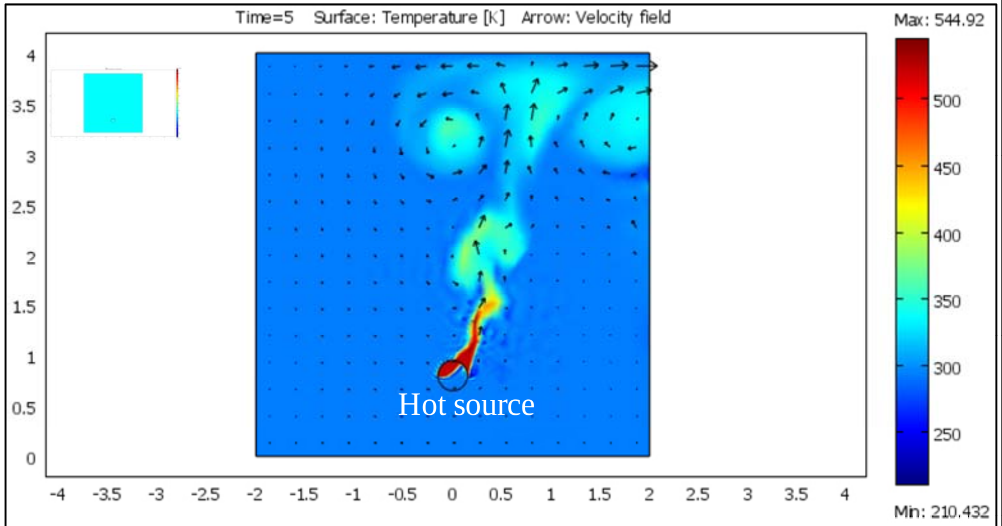
-The two images to the left show a particle cloud being emitted and propagating over time in a corridor, as seen from above.

- The top image shows a simulation of the dispersion in an empty corridor, no significant dispersion occurs.

- The bottom image shows a simulation of the dispersion, but with obstacles inside the corridor. Some dispersion occurs, which leads to a dilution of the particle concentration.



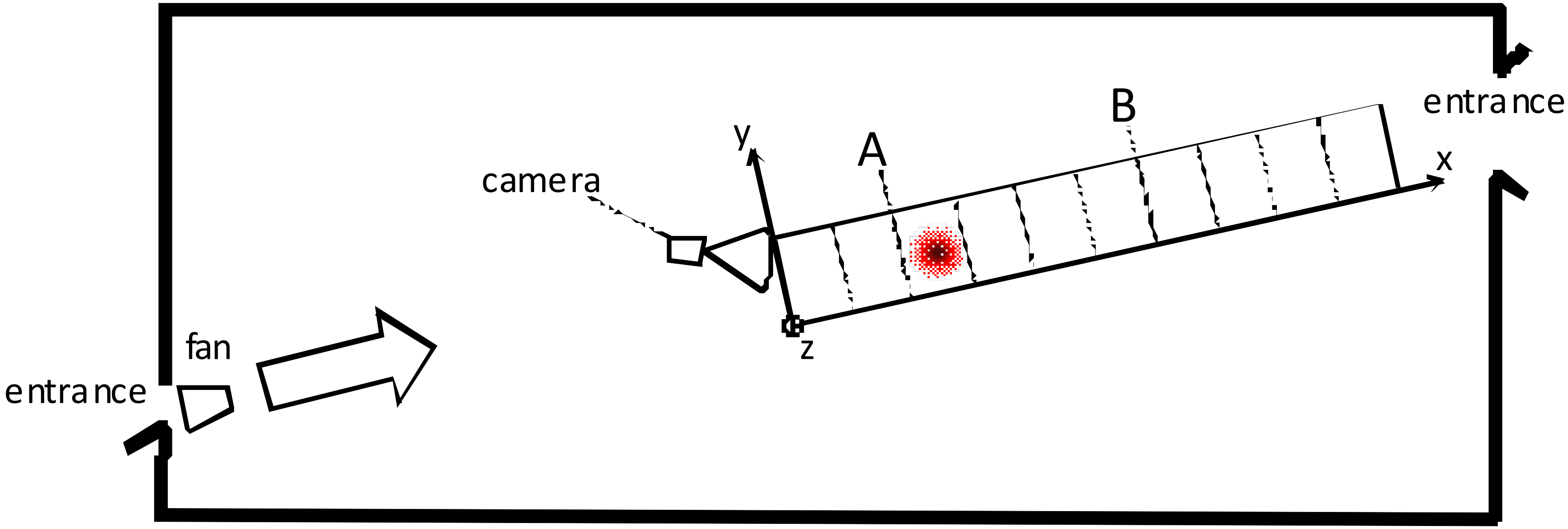




- A hot source, such as thermal cutting, causes movements in the surrounding air as the heat rises upwards.

-The image above shows a side view of heat dispersion and air velocity induced by a hot source.

-The arrows indicate the direction and the size of the air movements.



Schematic view of the test site. The corridor sections at A and B were later closed off with tarpaulin to create a closed room. The emission source is marked with a red dot.

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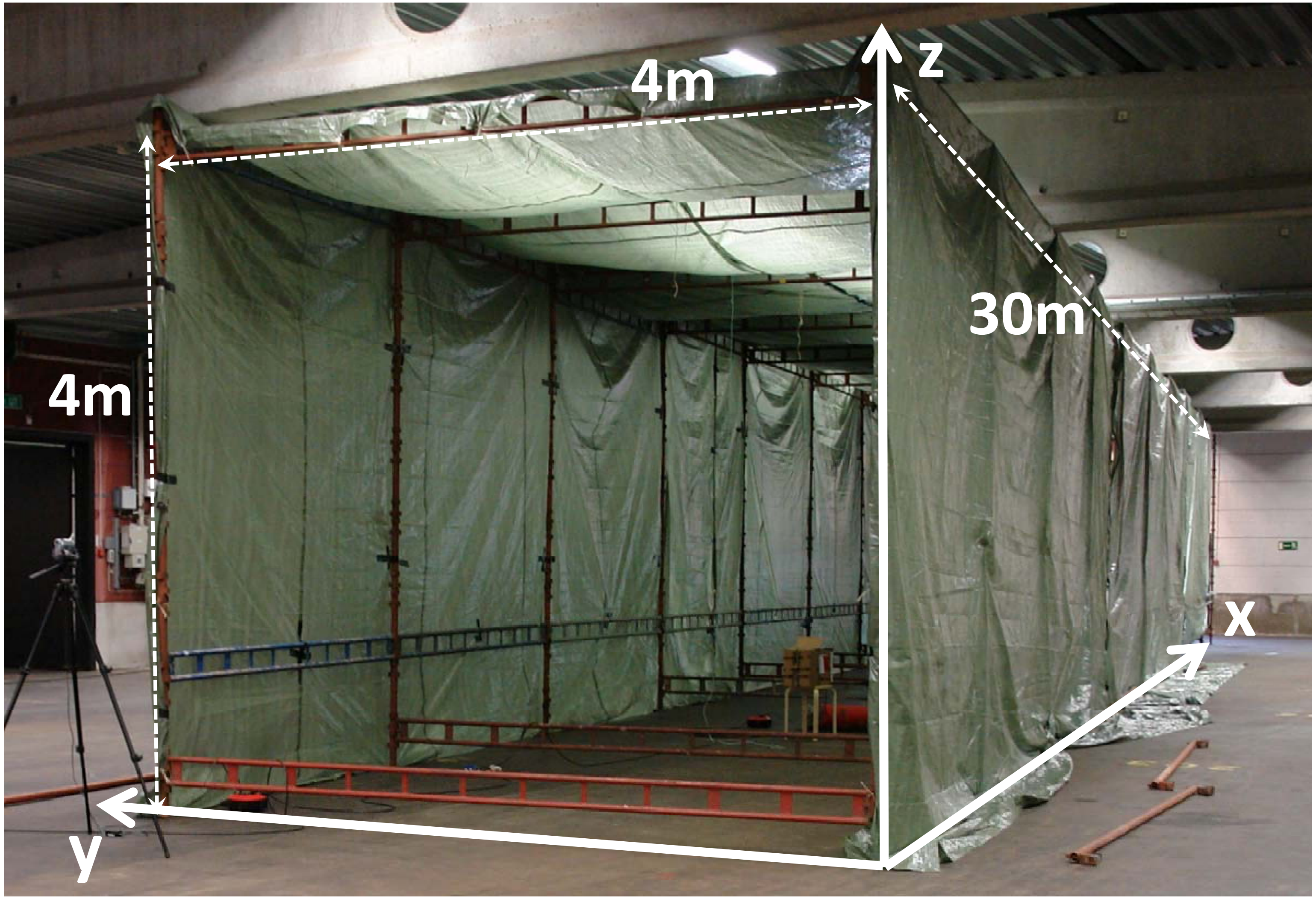
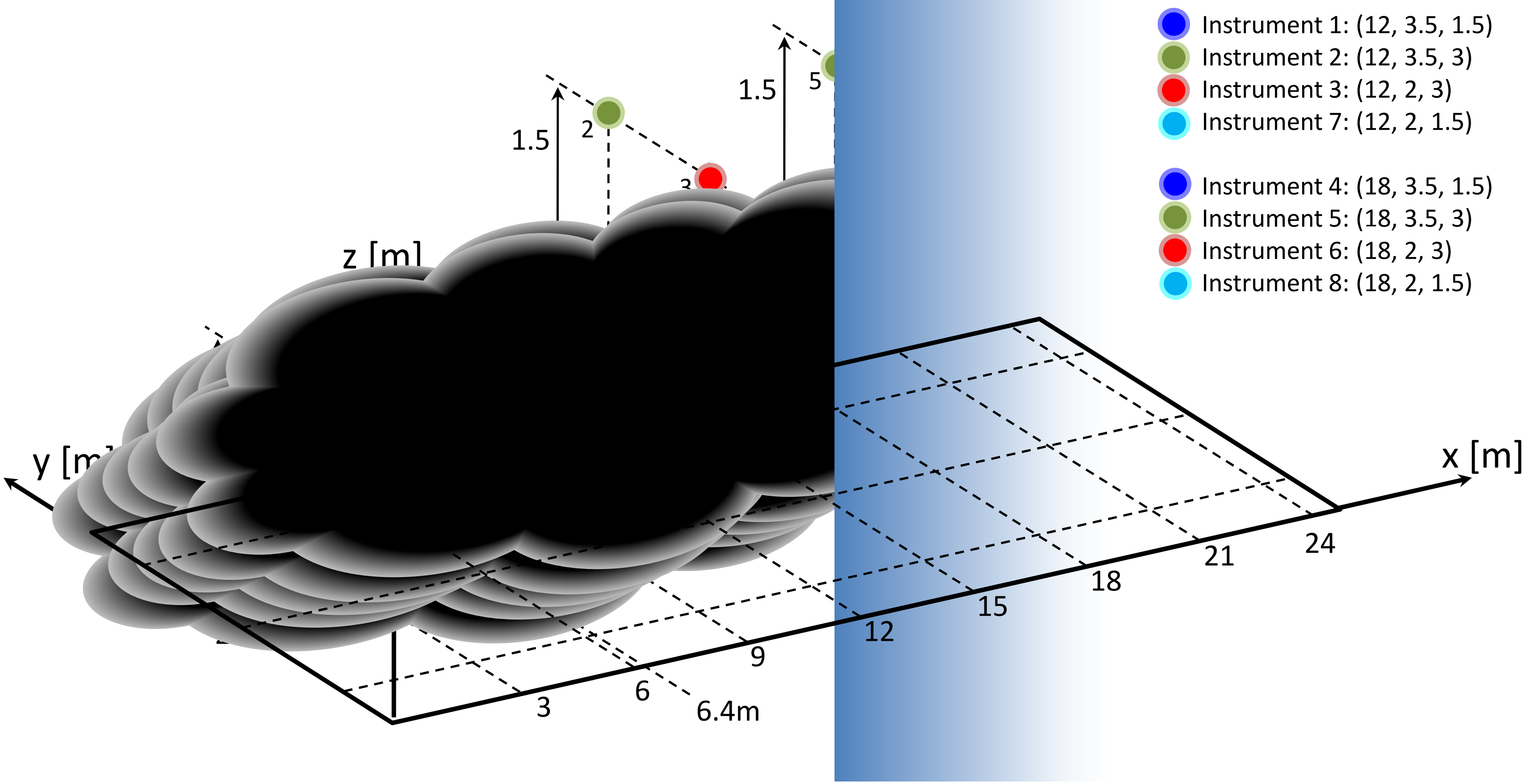


Picture of the 30-m corridor with its reference coordinate system. A 30 m corridor was built out of HAKI® scaffolding. Its cross-section was 4m x 4m and each section was 3m long. The scaffolding was covered by a light tarpaulin.

Setup 2 - Investigation of two cross-sections with laminar flow through the corridor.

In Setup 2 the industrial fan was powered off. Since the fan had been powered on
shortly before this test, there was a laminar flow measure
along the x-axis. The cutting was performed between *t* = 2



Conclusions

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The simulation model for the closed room showed similar results compared to the experimental findings, while for the corridor, there were larger discrepancies. The computer model and the real life particle measurements both showed that there will be no exposure upstream from the thermal cutting spot. It can also be concluded that at a high wind speed, the larger turbulence will result in a greater dispersion of the plume.

To establish criteria for boundary zones from this limited study is not realistic. However, the study suggests that with enough time and resources, it seems possible to establish a computer model for boundary zones using empirical data from a number of experiments of some typical cases. There will still be a need for knowledge of the wind direction, wind speed and turbulence and the geometries of the work sites.