

27.11.2020

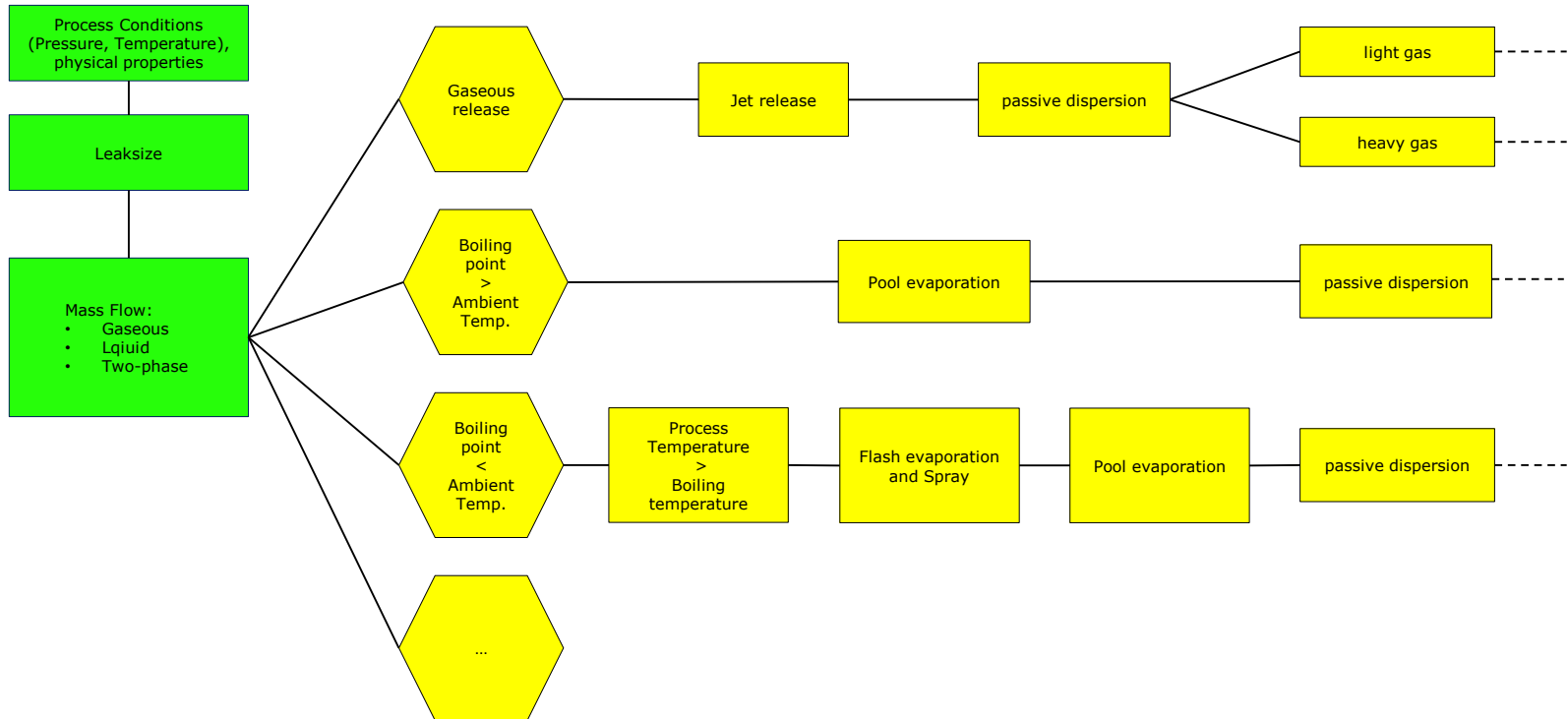
**HAZARD ASSESSMENT AND REALITY – OR - THE
DIFFERENCE BETWEEN THEORY AND PRACTICE IS
GREATER IN PRACTICE THAN IN THEORY.**

Abdel Karim Habib

Hazard Assessment and Reality

- Hazard Assessment needs models to predict what would happen in case of an accident
- For each hazard different Scenarios are possible -> Which one is representing the real case
- For each Scenario different models are suitable -> Each model gives different results
- Models exist in varying complexity: from empirical up to CFD Codes
- How do I match reality and model best?
- How are models validated?
- Are experimental data “the absolute truth”?

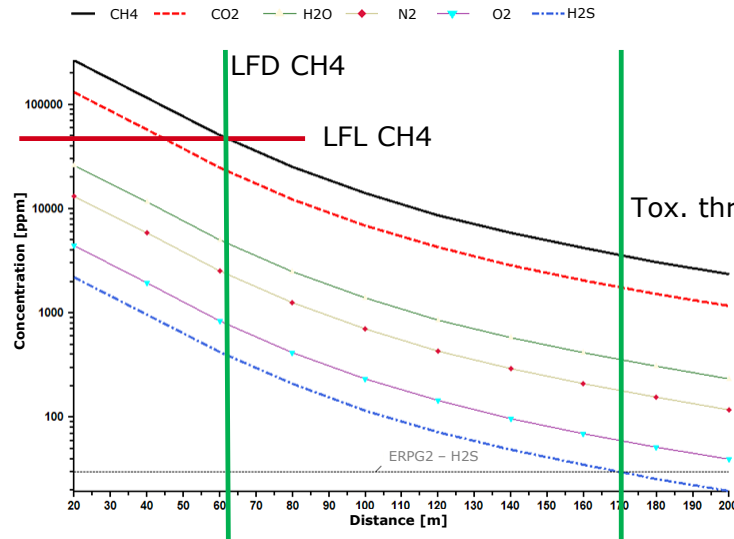
Hazard Assessment Scenarios



Hazard Assessment Scenarios

- Always check if the chosen scenario is either leading to the desired result (e.g. the Lower Flammability Distance is required) or if it is suitable to find the most adverse effect (maybe several Scenarios have to be compared)

Biogas release with
75 Vol.% Methane
and 0,5 Vol.% H₂S



**Toxic Hazard >
Flammable Hazard?**

- Mass flows through orifices can be calculated as follows:

$$\dot{m} = A_c \Psi K_{dg} \sqrt{\frac{2p_0^2}{RTz}}$$

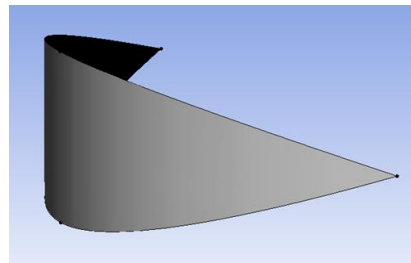
- The mass flow is proportional to the discharge coefficient K_{dg} , which is known for a lot of components (e.g. Safety Valves, round orifices...) but not for all kinds of orifices!
- E.g. Biogasplants, flexible inflatable fabric Biogas holder:
 - Following the german guidelines KAS-18 and KAS-32 : a leak area of 0,6 m² and a discharge coefficient of 1 should be used when assessing the hazards of a biogas plant

Mass flow through an orifice

- To determine the discharge coefficient 32 experiments, with leak areas form 0,05 m² up to 0,45 m² have been carried out at BAM-TTS in 2018.

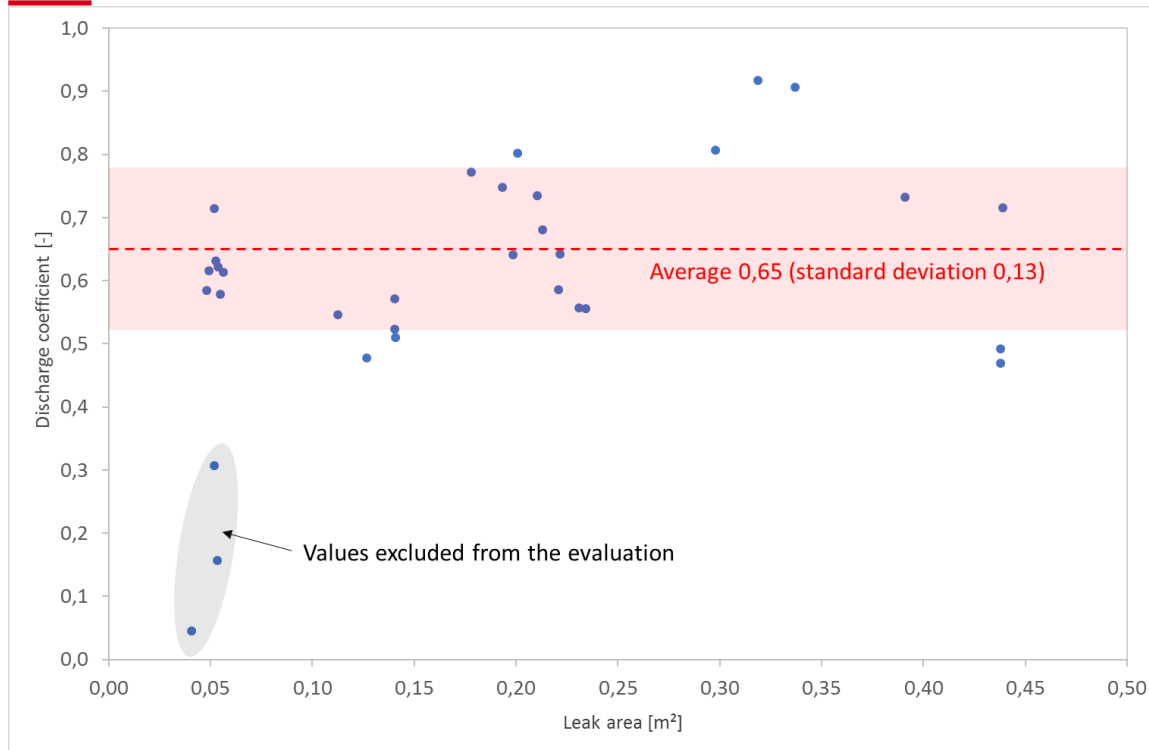


- The leak area had to be determined via a CAD reproduction of the leak.



Uncertainties in the Determination of the leak area result in uncertainties for the discharge coefficient

Mass flow through an orifice

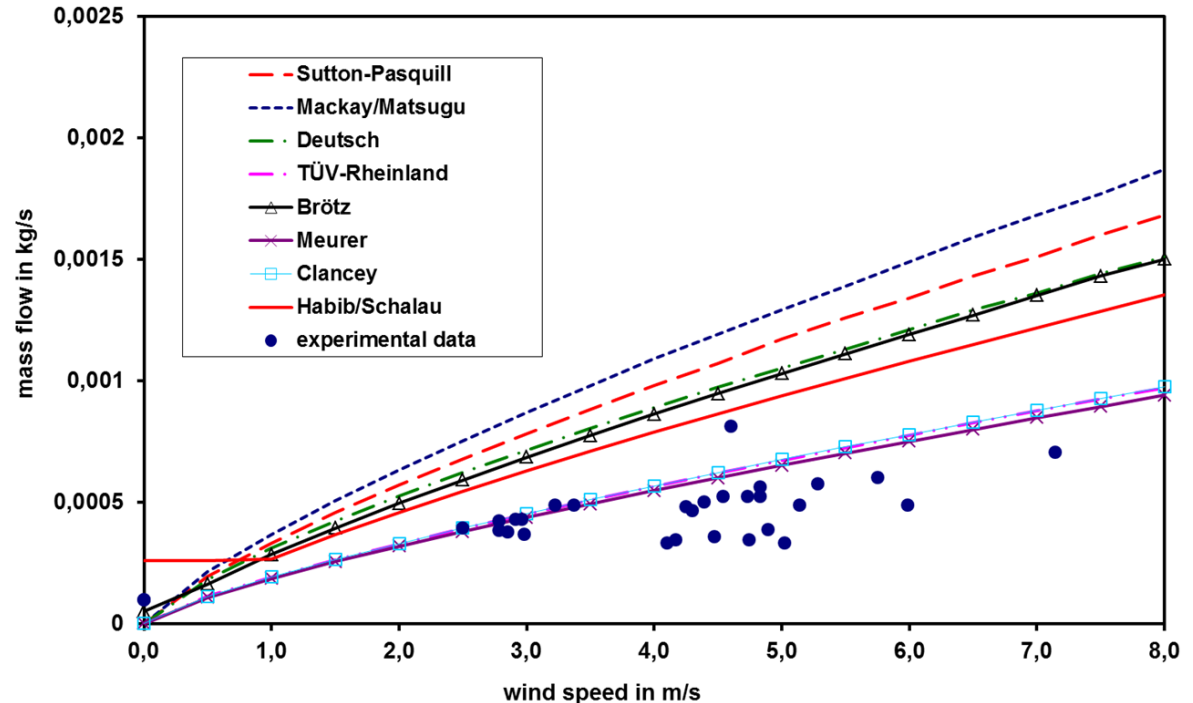


Measured discharge coefficients range from 0,45 up to 0,9 with an average of 0,65.

A discharge coefficient of 1 seems too high.

Mass flow from an evaporating pool

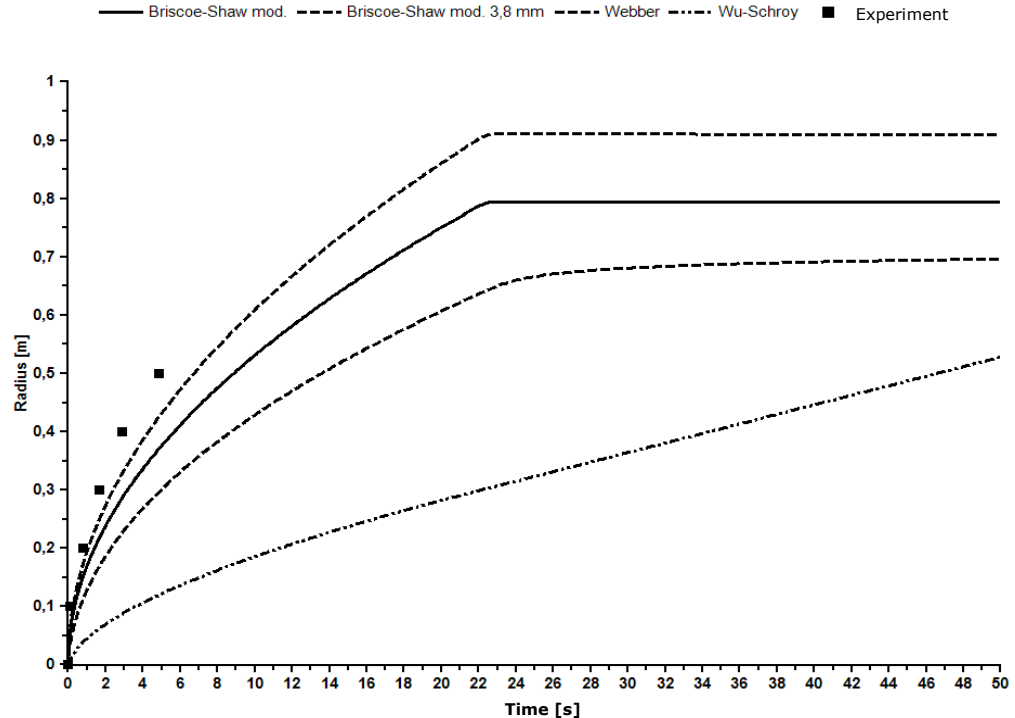
- Pool evaporation models calculate the evaporating mass flow of a stationary pool.
- The pool size and temperature are assumed to be constant.
- The calculated mass flow strongly depends on the model chosen.



From: Thesis of A. Habib, 2010, BAM

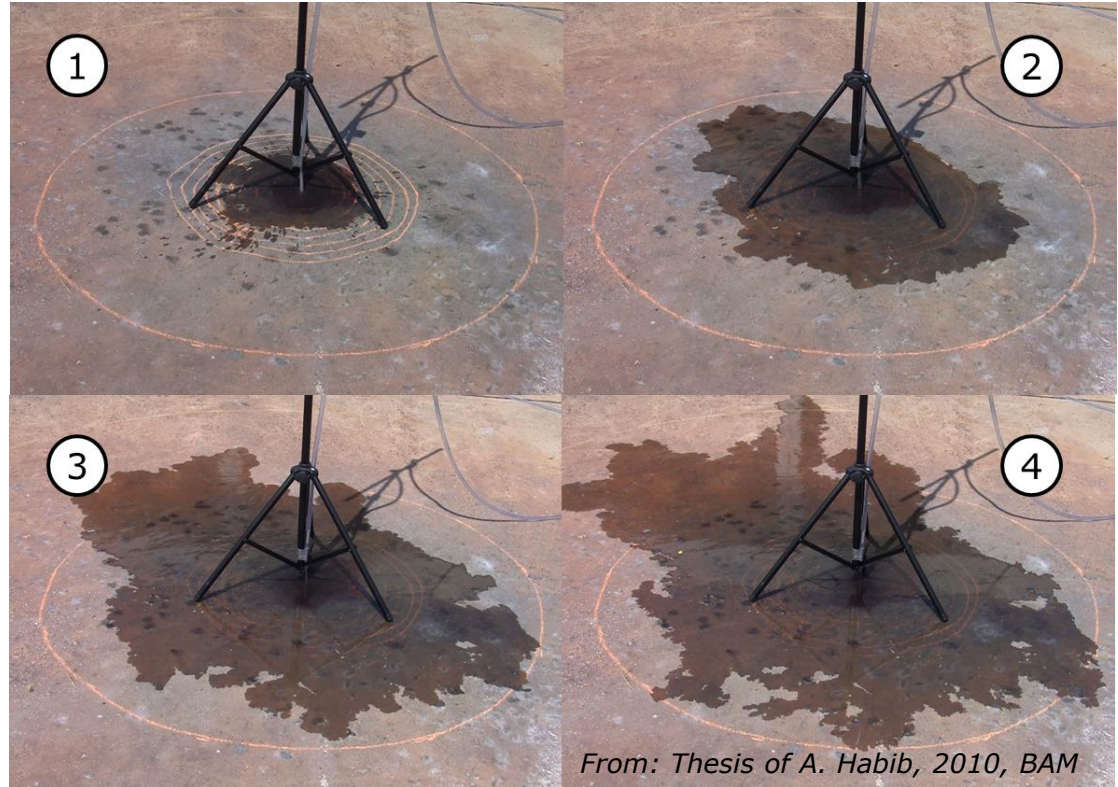
Mass flow from an evaporating pool

- Pool evaporation in reality depends on the transient pool size.
- Models for calculating the spreading of a liquid pool can show a good agreement with experimental values.



Mass flow from an evaporating pool

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- The models assume a circular spreading of the pool...
 - ...the experiments do not show that behaviour. The pool area had to be estimated via image processing and an equivalent radius was calculated!



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- Jet Flame models (as well as Jet release models) are designed for „small“ circular orifices and „high“ pressures. Are they suitable for non circular big openings at low pressures?
 - For Biogas plants hazard assessment , a jet flame has to be considered:
 - Release through a 0,6 m² hole with a discharge coefficient of 1 and an overpressure of 5 mbar!
 - Are the models available, able to predict the jet flame correctly?

Biogas release – Jet flame modelling

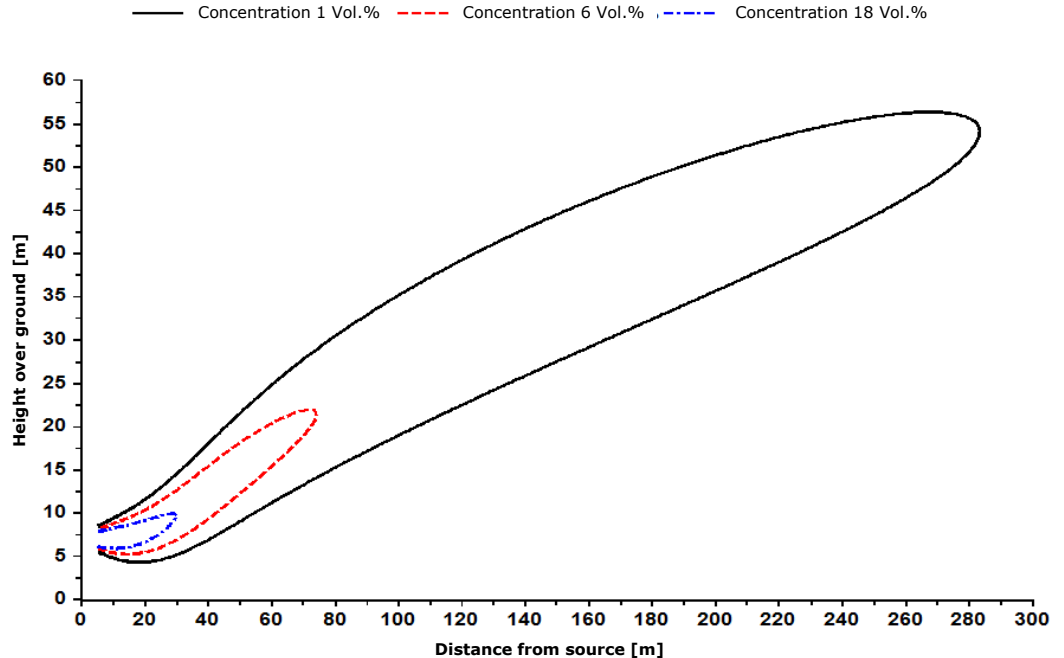
Model predictions:

Jet release:

60 m to LFL and 280 m to
1 Vol.%

Jet flame:

The jet Flame length is
calculated with 68 m,
oriented mainly
horizontally with a slight
angle upwards.



Biogas release – Jet flame in reality

Reality shows a totally different behaviour compared to the model predictions.

-> Models are designed for high pressure / small opening. The considered case is beyond the limitations of the models!



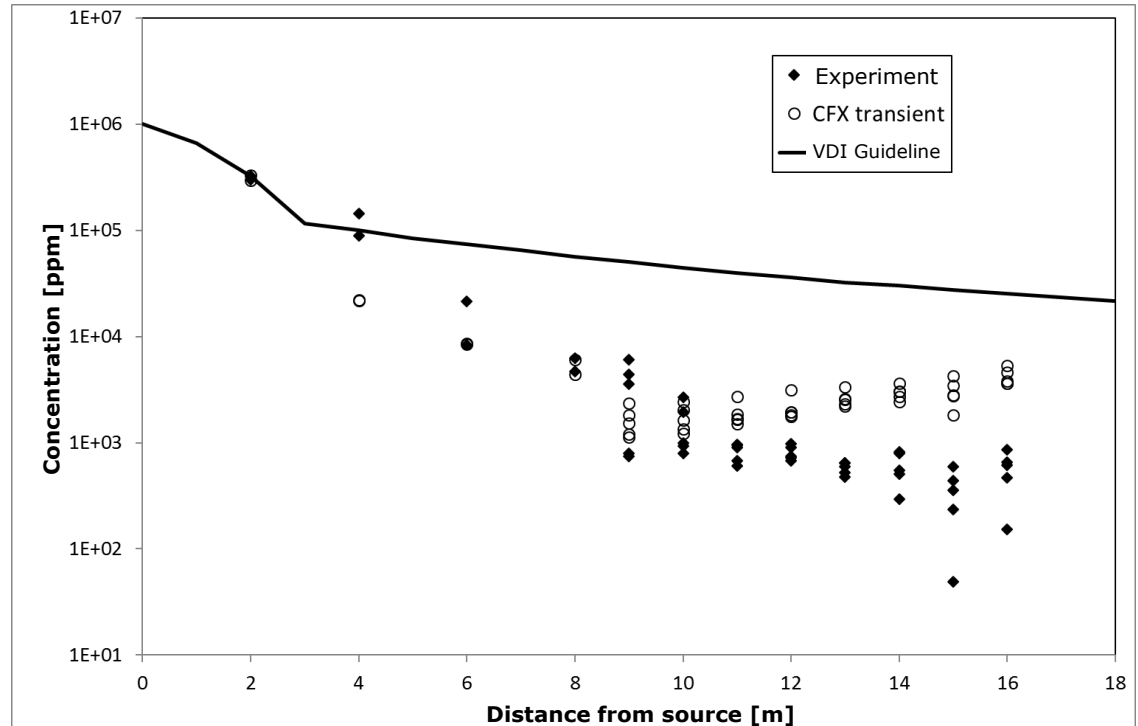
BAM-TTS 2018

Heavy gas dispersion – simple models vs. CFD

Experiments on the release and dispersion of r134a at BAM-TTS in 2011-2013:

VDI Guideline 3783 gives conservative values!

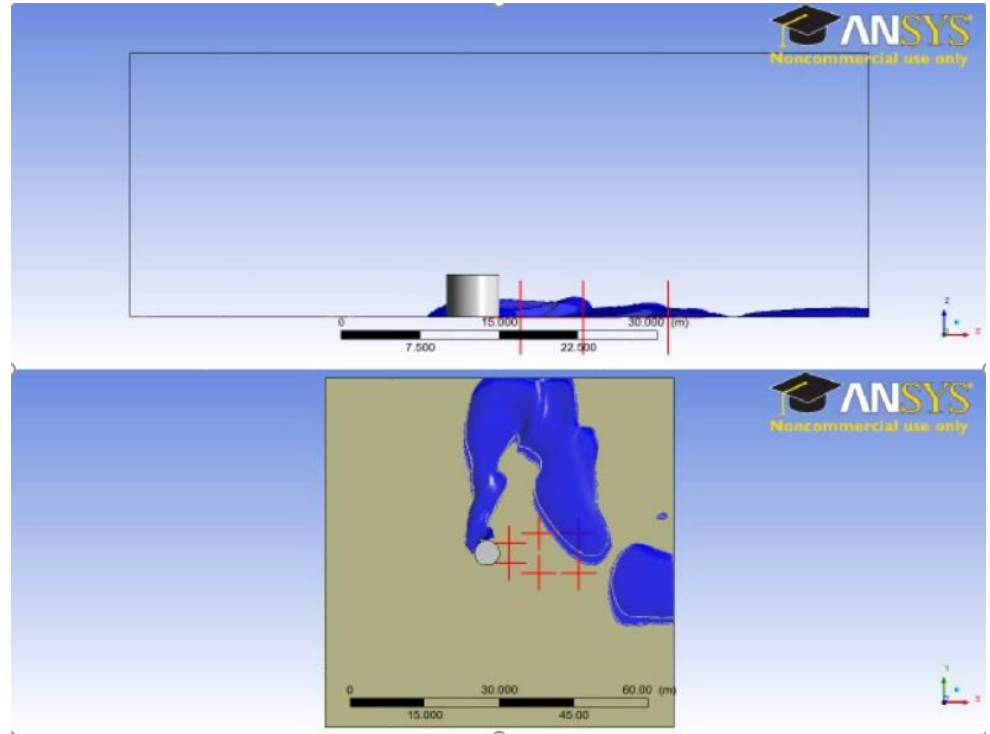
Only CFD can provide additional information on the curve characteristic of the experimental values!



Heavy gas dispersion – simple models vs. CFD

Experiments on the release and dispersion of r134a:

CFD model includes transient windspeed and direction during the experiments, as well as a „sensor model“ to account for the t_{90} time of the sensors used!



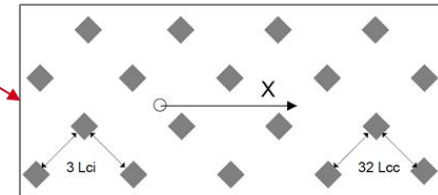
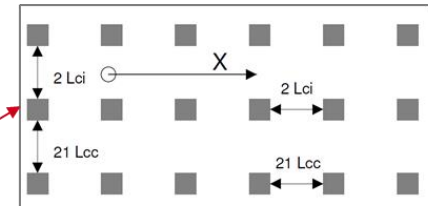
Heavy gas dispersion – simple models vs. CFD

- VDI Guideline 3783 Part 2 for the calculation of heavy gas dispersion.
- Based on Wind Tunnel experiment statistics.
- 26 generic setups called dispersion areas were investigated

Problem:
How to match
model and reality?

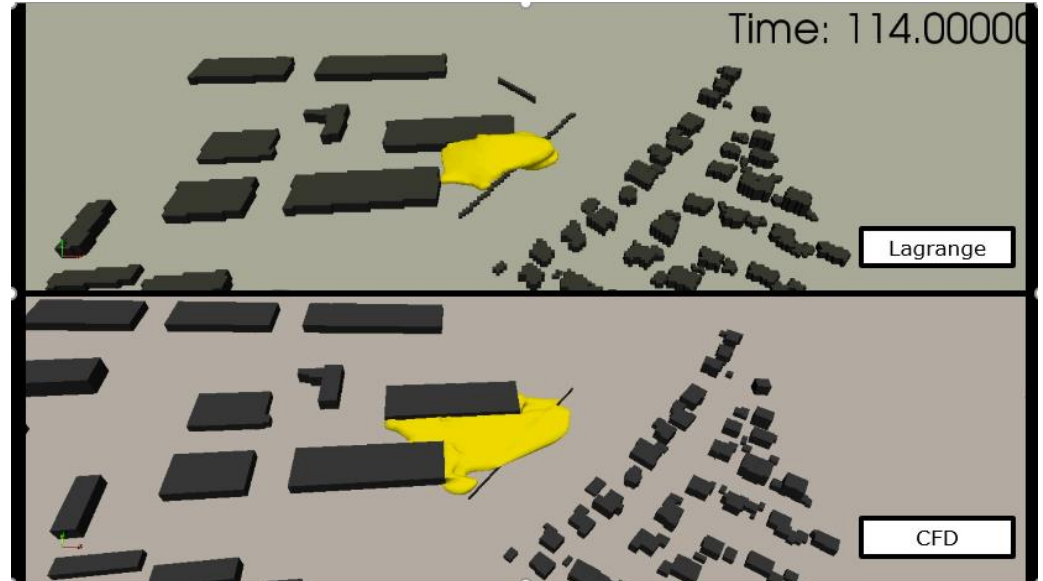


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Heavy gas dispersion – simple models vs. CFD

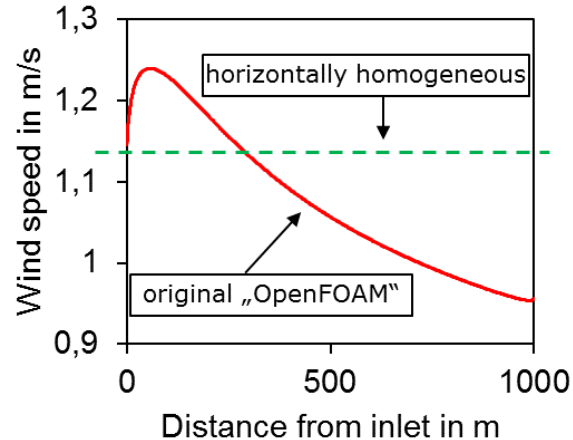
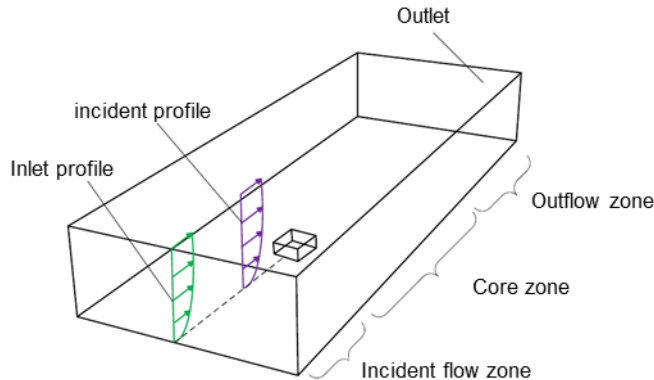
- Higher order models (lagrangian or Euler/Euler) are able to represent reality a lot better.
- But while simple models are able to give a result within seconds (max. minutes) the computational effort significantly increases with the order of the model.
- In this example, the lagrangian model required hours and the CFD models days to finish
- Especially for CFD the requirements concerning the boundary conditions are often so high, that using CFD is not recommended, for a „single shot“



From: Thesis of S. Schalau, BAM

CFD – the panacea?

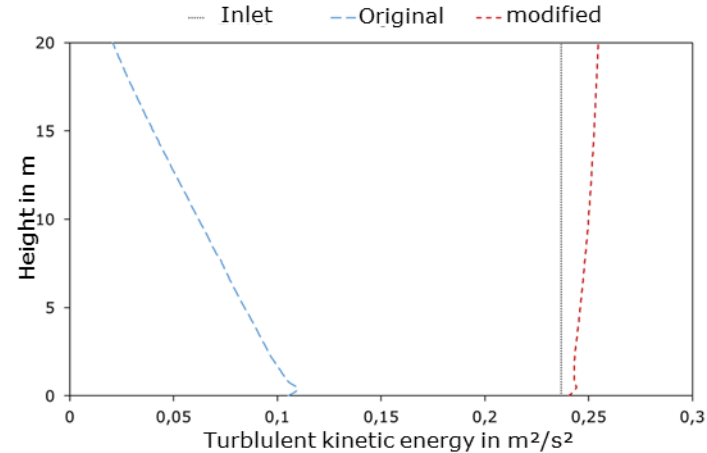
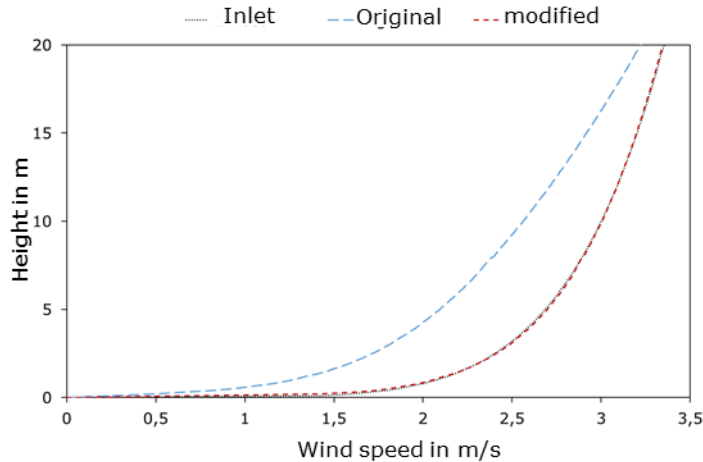
- Although CFD is able to give more precise insight in physico-chemical processes than simpler models, it is to note that it requires a considerably higher effort in defining the scenario and computational power.
- CFD has the ability of providing „high definiton“ results...but only with „high definition“ input, e.g. Wind profile, wind speed and direction, transient mass flow, etc.



From: Thesis of S. Schalaus, BAM

CFD – the panacea?

- Even with a deep knowledge of the boundary conditions in reality it is not necessarily possible to achieve a good result with standard CFD methods.
- The code often has to be modified, to asses for the required phenomenon
- E.g. the gas dispersion is mainly dependent on the wind field, wich should be of atmospheric type, and stable throughout the domain

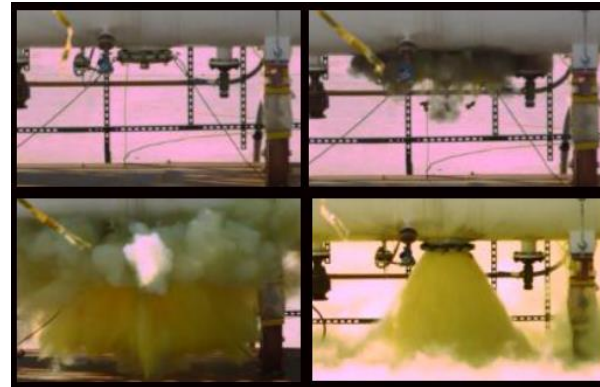


From: Thesis of S. Schalau, BAM

CFD – the panacea?

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- Although complex problems can be solved using CFD, we can be confronted with scenarios so complex, that even CFD won't help getting a „one step solution“
 - E.g. JackRabbit II (JR II) - Chlorine release Tests:
 - High momentum **jet release downward** -> requires very high spatial and time resolution in CFD
 - Momentum driven lateral dispersion -> requires high spatial and time resolution in CFD
 - Passive dispersion with the wind **over 11 km** -> requires low spatial and time resolution in CFD
 - Here we encounter a problem of Scale: high res. near field for the momentum driven part and low res. far field for the long distance
 - With „classical“ models, parts of the scenario can not be modeled e.g. downward jet impinging on the ground, momentum driven lateral dispersion!

CFD – the panacea?

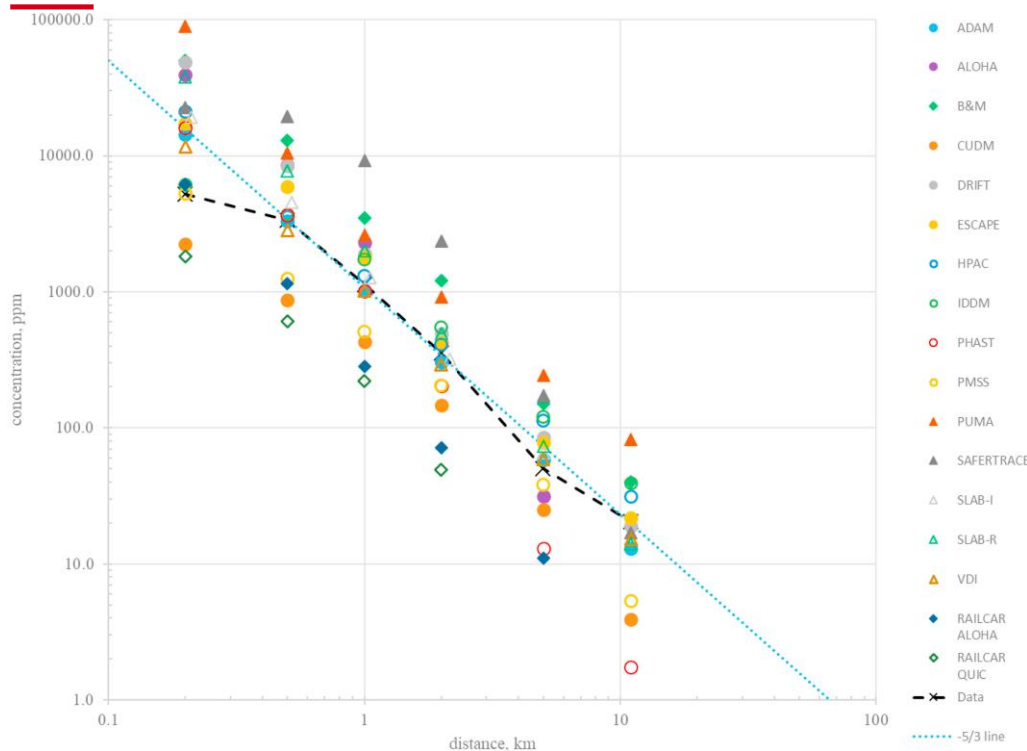


*Pictures from:
Jack Rabbitt II-
Update and
Impacts, Shannon
Fox, DHS, 2019*

CFD – the panacea?

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- Although calculating the JR II releases with CFD is a challenge and will not work as a „one shot“ calculation, and although the scenario seems too complex for simpler models: the **VDI Guideline 3783 is able to give acceptable results for the far field dispersion**
 - The release scenario was ignored and the formed passive cloud of 120 m x 120 m taken as a source term.
 - ! The atmospheric boundary conditions for each trial were not measured during the release, but extrapolated from long term on site atmospheric measurements conducted some time before the trials !
 - > Could be a problem when using CFD, as the exact boundary conditions are unknown!

Heavy gas dispersion – JR II and the VDI Guideline 3783

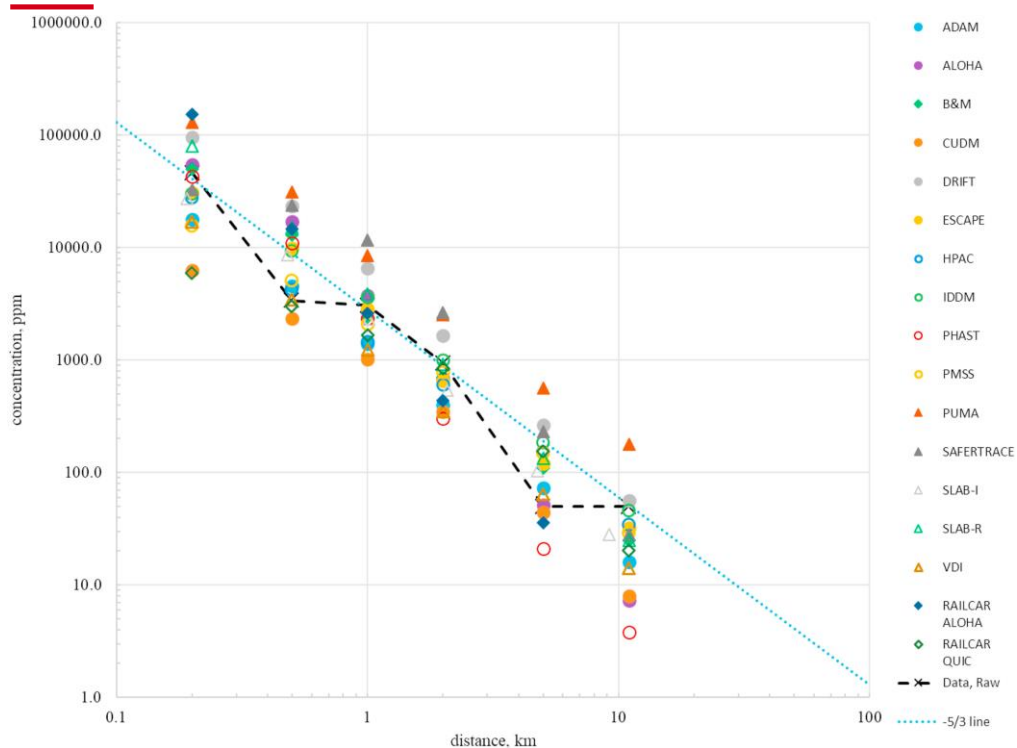


Trial 1 of JR II experiments.

Taken from:

Mazzola et al. - Results of comparisons of the predictions of 17 dense gas dispersion models with observations from the Jack Rabbit II chlorine field experiment - Atmospheric Environment 244 - 2021

Heavy gas dispersion – JR II and the VDI Guideline 3783

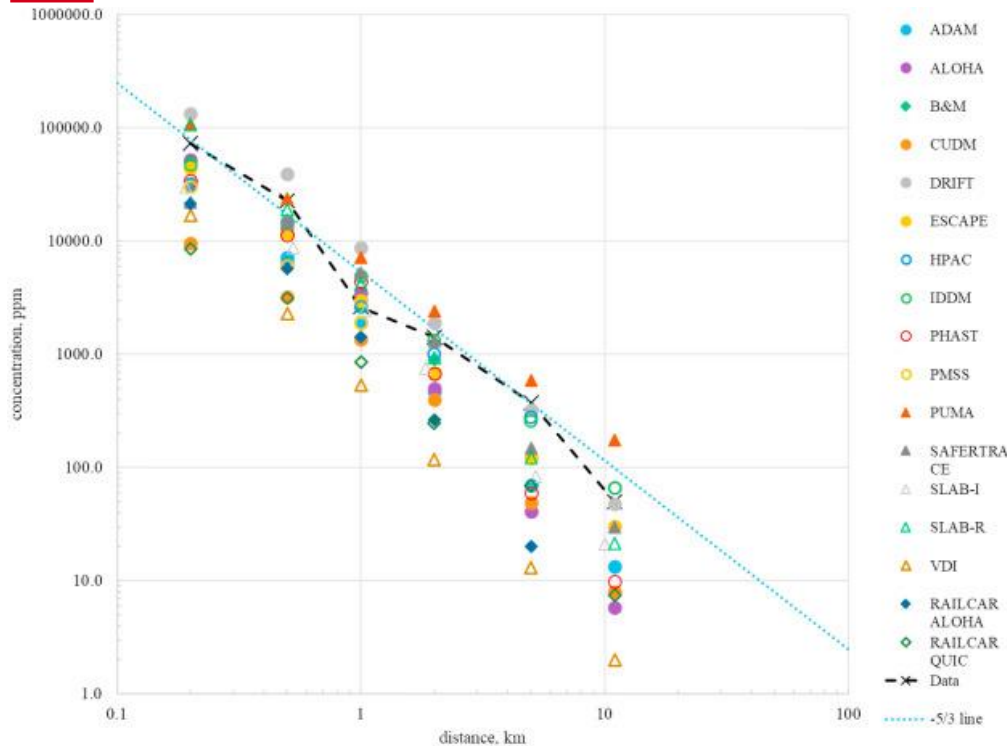


Trial 6 of JR II experiments.

Taken from:

Mazzola et al. - Results of comparisons of the predictions of 17 dense gas dispersion models with observations from the Jack Rabbit II chlorine field experiment - Atmospheric Environment 244 - 2021

Heavy gas dispersion – JR II and the VDI Guideline 3783



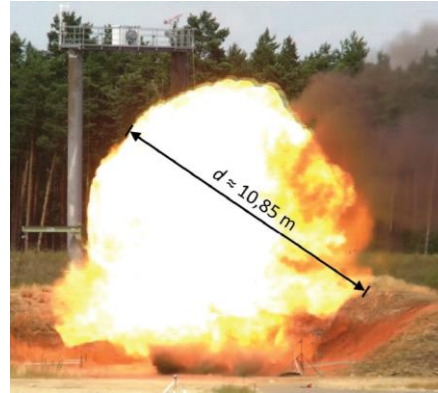
Trial 7 of JR II experiments.

Taken from:

Mazzola et al. - Results of comparisons of the predictions of 17 dense gas dispersion models with observations from the Jack Rabbit II chlorine field experiment - Atmospheric Environment 244 - 2021

Heat radiation

- Heat radiation models for burning gas clouds, assume that the gas cloud is of spherical shape, and the ignition occurs in the center of the cloud
- Deformation of the cloud, heterogenous mixture or an ignition at a random location can not be investigated
- The estimated emitted radiation is always a stationary value



**BAM-TTS, Project CoFi-ABV*

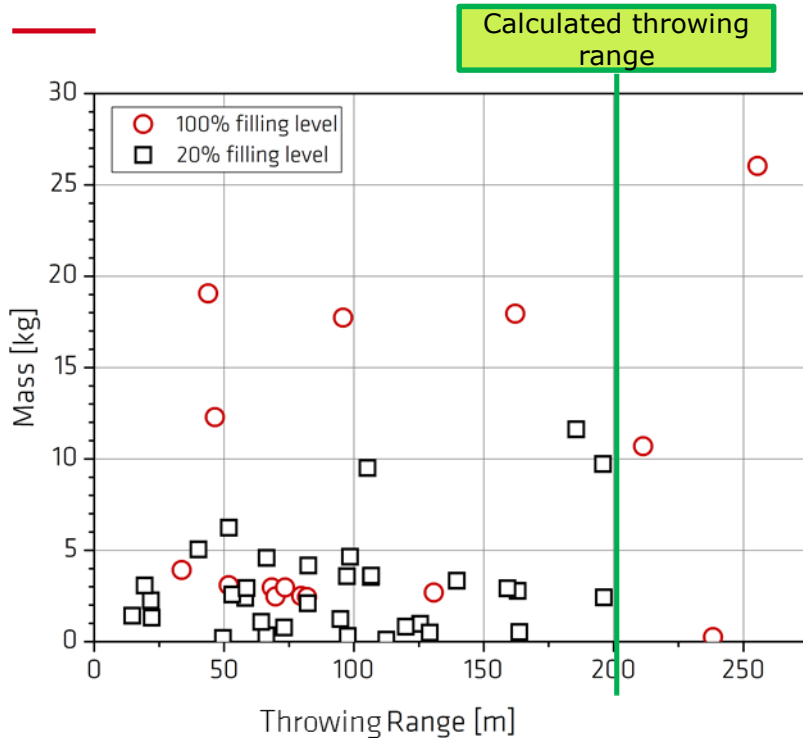


Lack of experimental values for model development or validation!

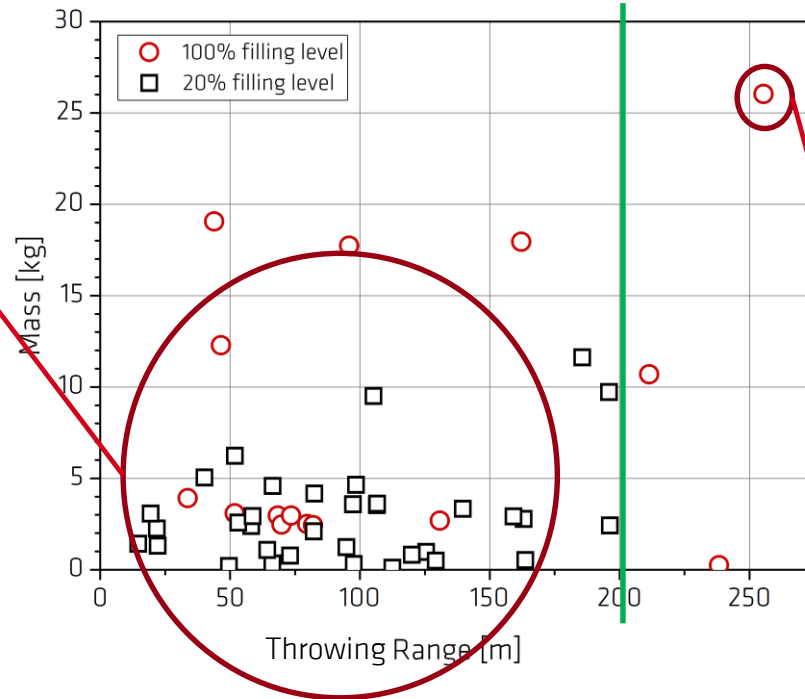
Throwing range of fragments

- When dealing with pressurized gas cylinders or gas tanks, the burts of the vessel is one of the hazards to be assessed. Besides adverse effects from a burning gas cloud or a bleve, the hazard coming from vessel fragments has to be assessed.
- Existing models predict the throwing range based on the assumption of each fragment as a ballistic body. Aerodynamic properties of the fragments due to their shape can not be taken into account. Except for generic basic shapes, that are implemented in the models.

Throwing range of fragments



Throwing range of fragments



Throwing range of fragments



„Rocketing“ Gas Tank, being propelled by it's gas content like a rocket.

**BAM-TTS, Project CoFi-ABV*

Throwing range of fragments



„Rocketing“ Gas Tank, being propelled by it's gas content like a rocket.

**BAM-TTS, Project CoFi-ABV*

Throwing range of fragments



Track of the rocketing gas tank

„Rocketing“ Gas Tank, being propelled by its gas content like a rocket.

**BAM-TTS, Project CoFi-ABV*

Throwing range of fragments



„Frisbeeing“ Gas Tank, fragment increasing it's throwing range due to rotation.

**BAM-TTS, Project CoFi-ABV*

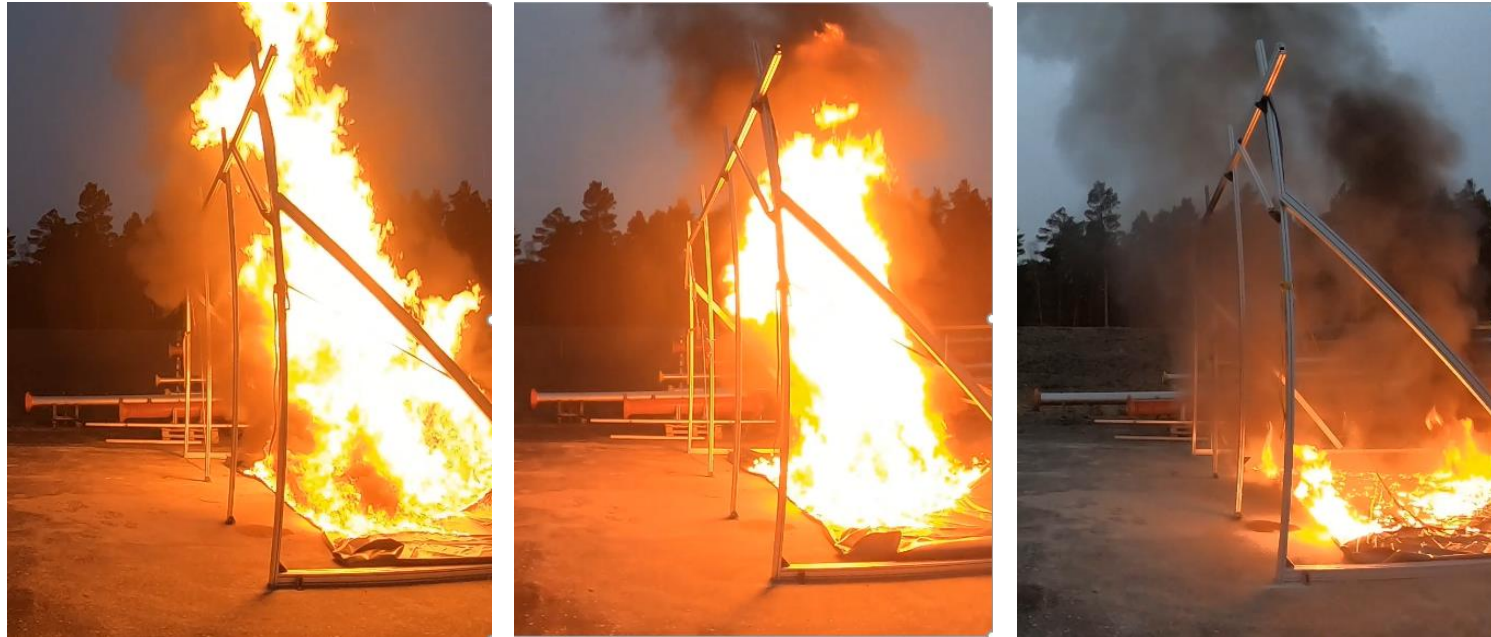
Hazard Assessment and Reality

– or - The difference between theory and practice is greater in practice than in theory.

The most exciting phrase to hear in science [...] is not "Eureka!" but "That's funny ..."
- Isaac Asimov -

- Hazard assessment is a challenging field
- The definition of the Scenario to be considered is the most crucial moment in Hazard assessment
- A thorough documentation is mandatory due to the multitude of available models and settings
- When ranging models from "empiric/simple" up to "highly sophisticated/CFD" it should be understood as a range of "Quality" but simply a range of "effort" – Often the "simple/empiric" models give more reliable results than CFD!
- When documenting experiments, document everything and not only the outcomes

Hazard assessment and reality



The inflatable fabric biogas holder was qualified as „hardly inflammable” or even „non-flammable”

27.11.2020

THANK YOU FOR YOUR ATTENTION!

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