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Safety assessment and risk analysis of potential fire hazards and fire development in industrial facilities

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Future Safety and Security Research in Europe
Prague, 24. - 25. 10. 2013

Outline

- Introduction to fire science at BAM

- Industrial fire accidents – effects

- BAM recent research

- BAM contribution to HORIZON 2020

BAM: safety in technology and chemistry

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Working areas

- Behaviour of structures in fire,
- Fire scenarios and fire analytics,
- Fire testing of construction materials and elements
- Large-scale industrial fires,
- Assessment of dangerous goods/substances
- Flammable bulk materials and dusts, solid fuels
- Explosive substances of chemical Industries
- Explosion dynamics
- Chemical process safety

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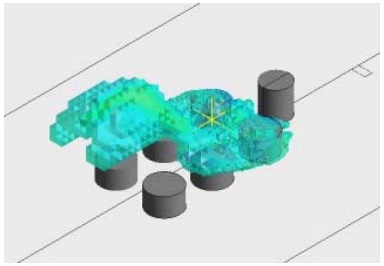
Explosion test ground

Pool fire test



Numerical simulation of fire propagation across a tank model

Fire test stand for containment systems of dangerous goods

Fire test stand B, heat input test on a 5000-l container

BAM: fire science

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Interdisciplinary research
Dimensions from nm to 100 m
Experiment and Simulation

Chemical Safety
Engineering

Combustible Dusts

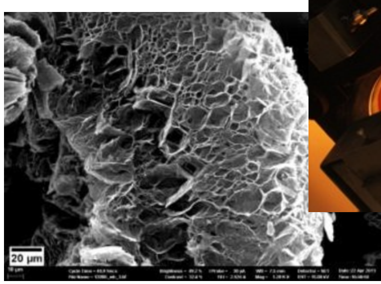
Pool Fires

Fire Engineering

Fire Testing

Coatings

Nanotechnology



Containment
Systems

Full Scale Testing

Standardisation

Simulation

Gas Analysis

Analytical Chemistry

Thermal Analysis

Polymer Science

Microscopy

B. Schartel
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Fire accidents - effects

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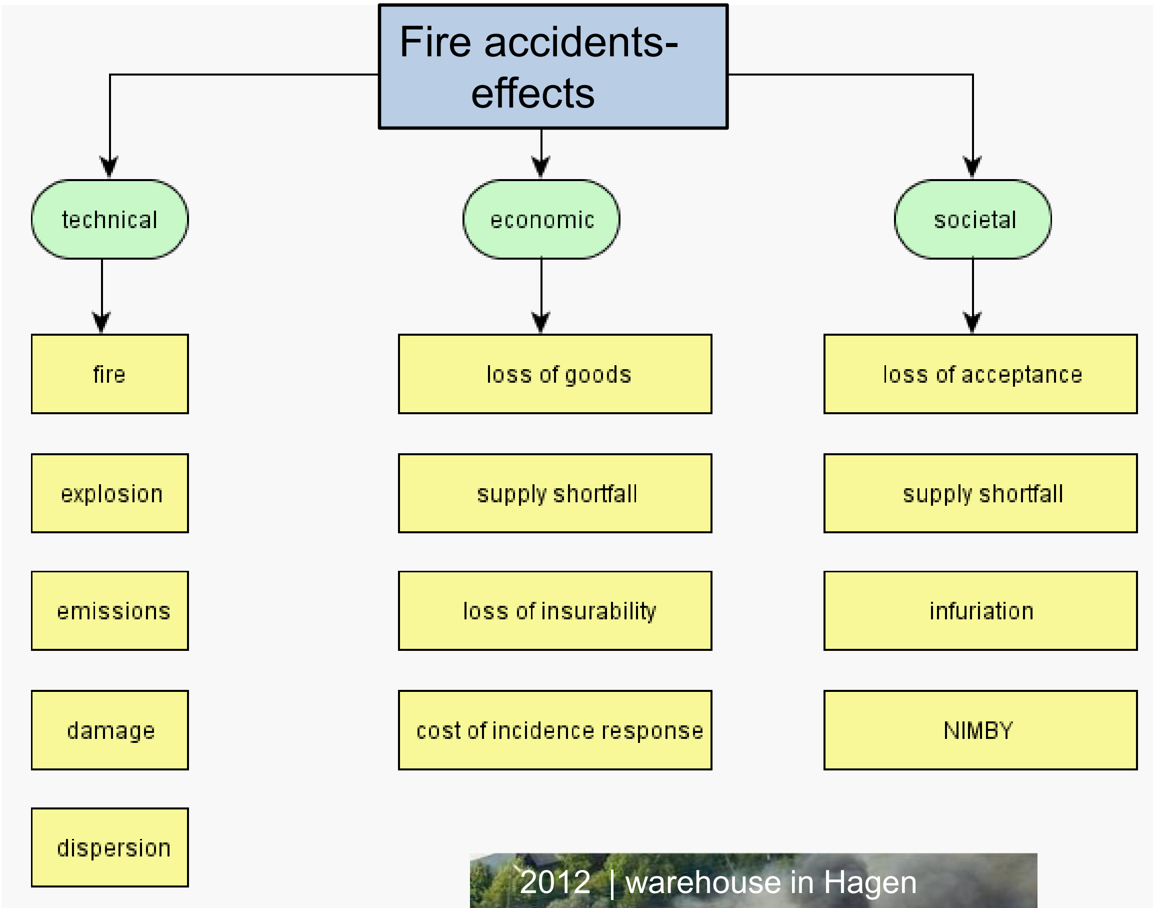

iNTeg-Risk Deliverable T1.3.2, BAM
U. Krause, University of Magdeburg

Industrial system – safety requirements

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- Fire safety regulations for design of industrial buildings and storages
  - deterministic methods and approaches
    - prescriptive methods - design of industrial buildings
    - performance base - engineering methods
    - SEVESO directives, REACH regulation

- Complex industrial system requires appropriate methodologies

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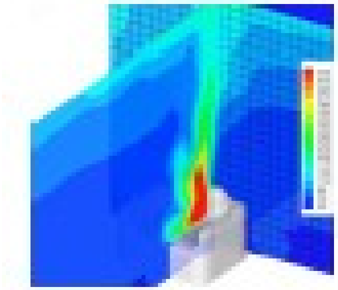
- new methods, considering coupled incidents and probabilities
- new methodologies and recommendations
- safe and economical design of industrial structures and storages

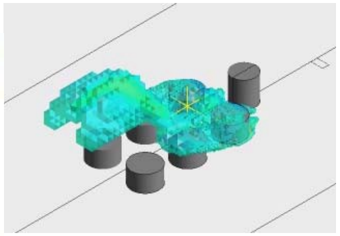

BAM recent research

Risk analyses of fire hazards and fire development in industrial buildings and storages

- Experiments and numerical simulations

- fire and smoke propagation, temperature, thermal radiation, fire toxicity
- impact of fire to the structure, stresses and strains in construction elements, load-carrying capacity of buildings





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Determination of safety distances

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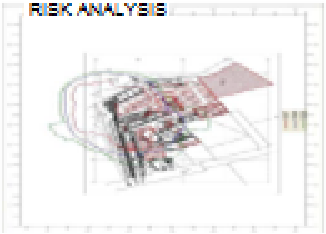
Evaluation:

Risk from fire to humans and environment

Risk from fire to industrial structures



- Design of industrial buildings and the sizing of components with respect to safety and economic efficiency

Fires in industrial buildings

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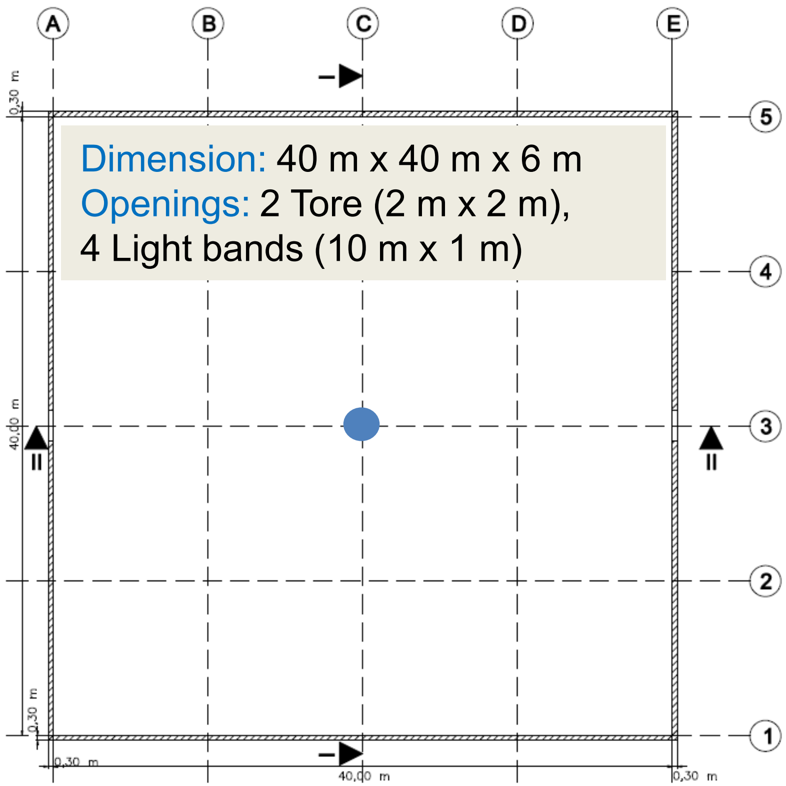
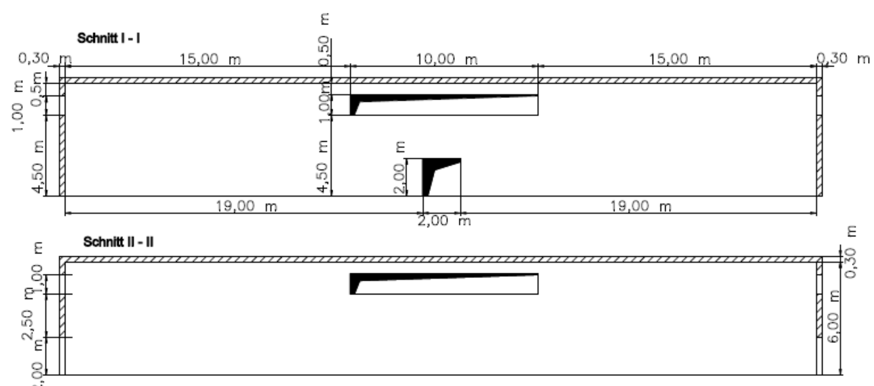
- Numerical modeling
  Determination of the gas and components temperature in an industrial building



Fire load quantity:	172,80 MJ/m²
Specific fire power:	48 KW/m²
Distribution:	uniform
Heating value:	4,8 kWh/kg
Pyrolysis rate:	10, 20, 30kg/(m² h)
Fire spread:	1 m/min



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Fires in industrial buildings

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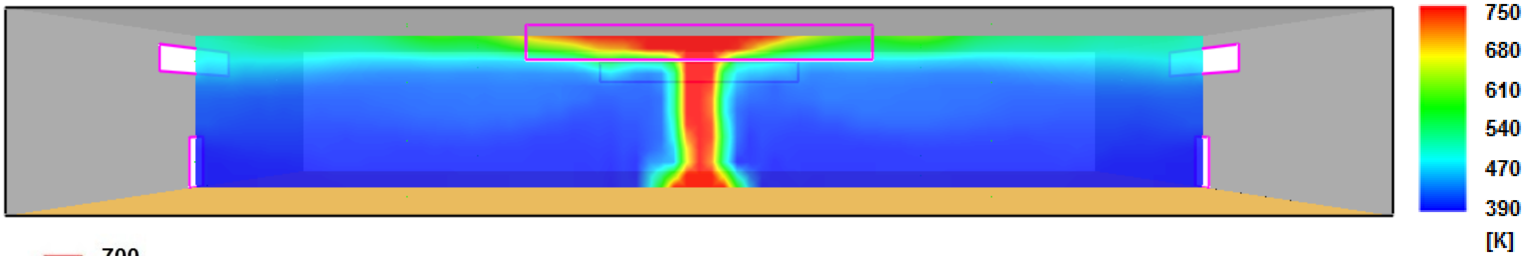
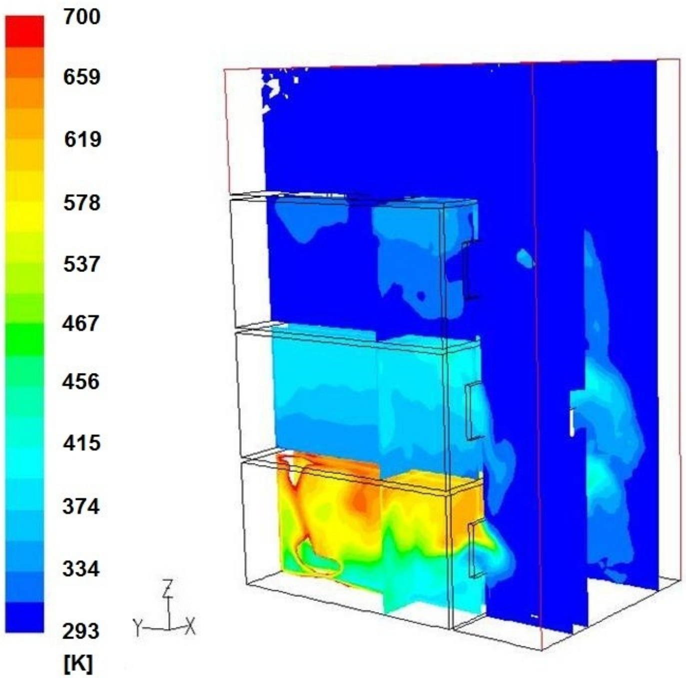
Numerical and empirical models in the fire protection engineering
- effects of mass and energy releases





Fire in industrial building – the complex structure

- Fire propagation
  - temperature distribution
  - thermal radiation
  - smoke distribution
- Load carrying capacity of construction
- Stresses and strains in construction elements
- Safety distances from the fire

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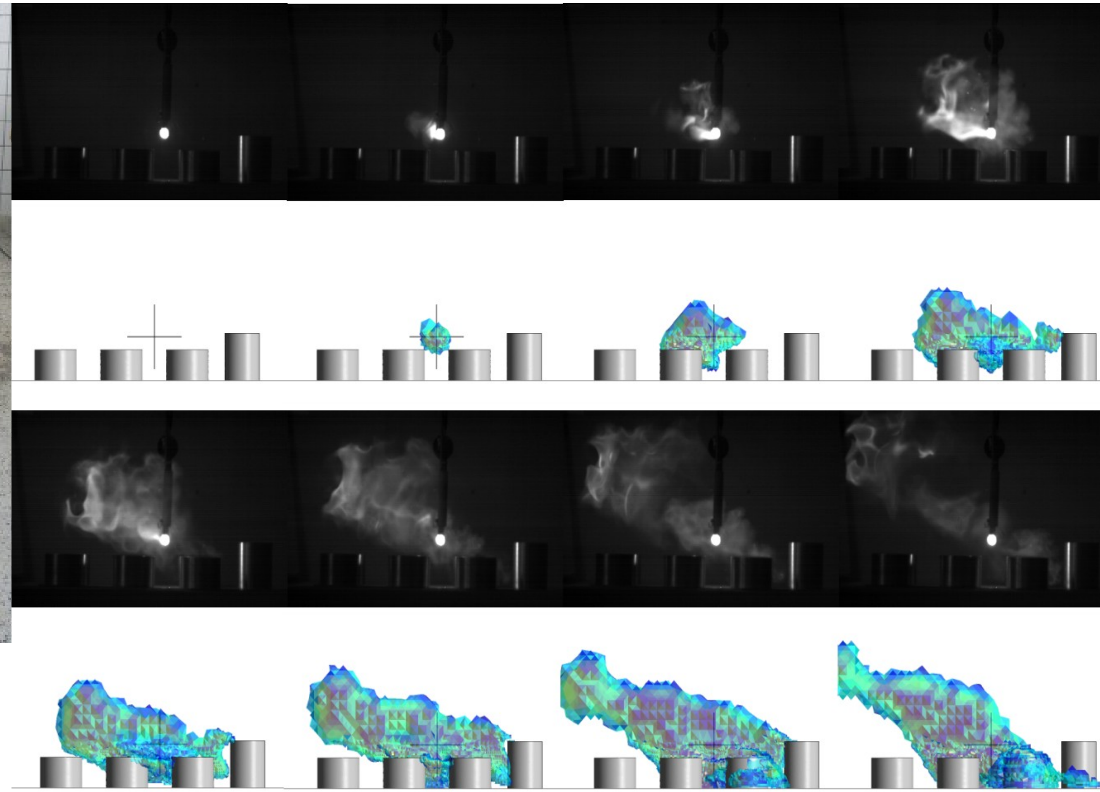
Fires in industrial plant

Fire propagation tests and numerical modeling



Fire test in wind channel with a model of industrial plant

Small scale tests: 1:200

Methan fire propagation
(low wind conditions, $v_w < 1$ m/s)

Safety distances for tanks and people
- Ignition and propagation of a methane flame
- Temperature distribution
- Thermal radiation intensity
- Pressure waves

S. Pfister, Dissertation
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Airport fire

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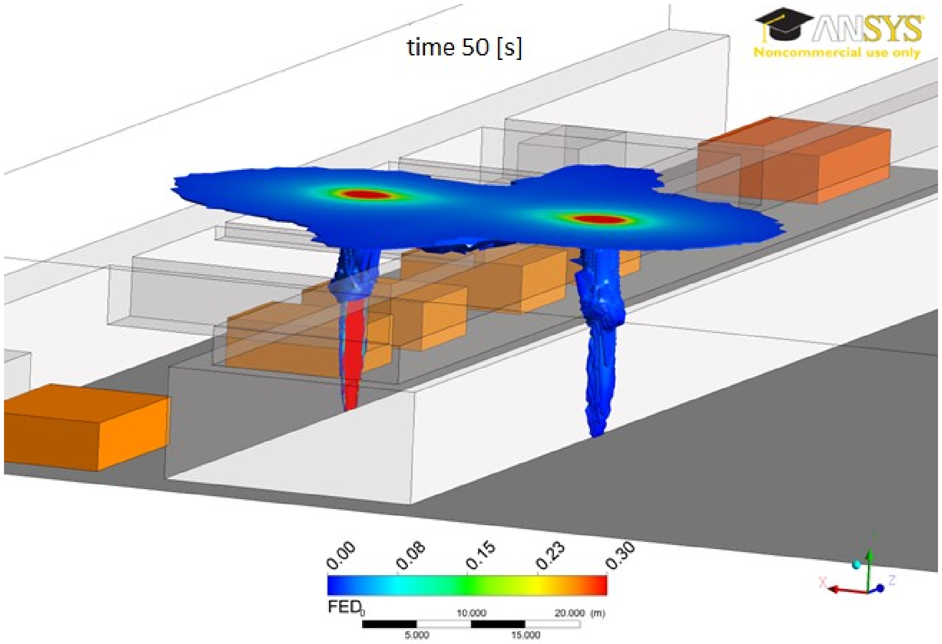
- Experiments and numerical modeling
  New model for determination of smoke propagation and toxicity
  (Fractional Effective Dose (FED) concept)



Safety distances
- Fire propagation
- Smoke propagation
- Smoke toxicity
  (CO_2, CO, HCN, O, soot)

Risk assessment:
- tenable risk
- the rescue situation for people (direction and time for evacuation)

Airport terminal
Dimension: 125 m x 20 m x 220 m

A. Löhnert, Interflam 2010
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Large scale storage of hazardous materials

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- Technological risk due to storage failure

→ emerging risk

A methodology to assess the hazard of unwanted chemical reactions

- characterisation of long-term thermal and chemical stability of the stored material, prediction of the long-term thermal stability of the deposit.

  - experimental investigation using methods of thermal analysis

  ↓

  advanced predictive model

  - mathematical analysis.

- effect of unwanted reactions on the public and on the environment (smoke and fire products emissions)

Storage of combustible wastes

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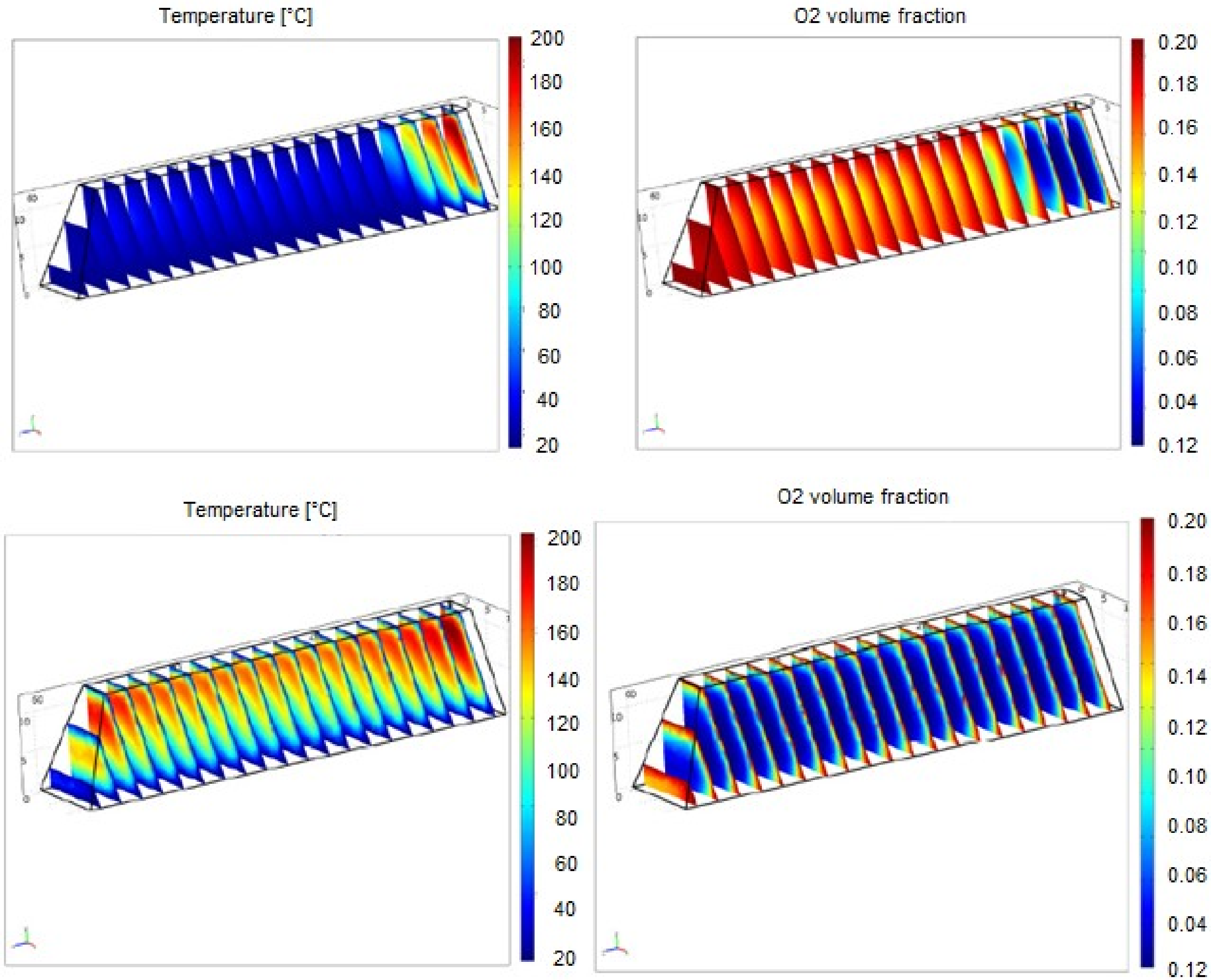
- Numerical modeling
  Fires in porous bulk materials (waste dumps, coal heaps, silos, biomass storage)



The progression of the internal fire after the self-ignition in a waste deposit

- Temperature (left) and volume fraction oxygen (right) distribution in time

after 2 years
and 138 days

after 4 years
and 303 days

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U. Krause, University of Magdeburg

Explosive substances of chemical Industries

Storage Group	Hazard
1.1	Mass explosion, with or without heavy fragments.
1.2	Explosions, but no mass explosion, with or without heavy fragments.
1.3/Ia	Mass fire.
Ib	Fires, the intensity of which range between mass and ordinary fires.
II	
1.4/III	Ordinary fire.
IV	Only for organic peroxides according to UVV; it is not possible to initiate a fire (e. g. stable dispersions in water)

The storage groups Ia, Ib, II, III and IV were introduced as shown in the table (German Explosives Act).

- Safety distances from peroxide fires
  - laboratory and large scale tests
- Development of criteria for storage groups
- Improvement of existing and establishing new standards

- German storage regulations for substances which are not used as explosives but showing “explosive properties”

Large scale fire tests with 5 tons TBPB (left) and 5 tons TBPEH

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Laboratory scale tests on pool fires

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- Experiments and numerical modeling

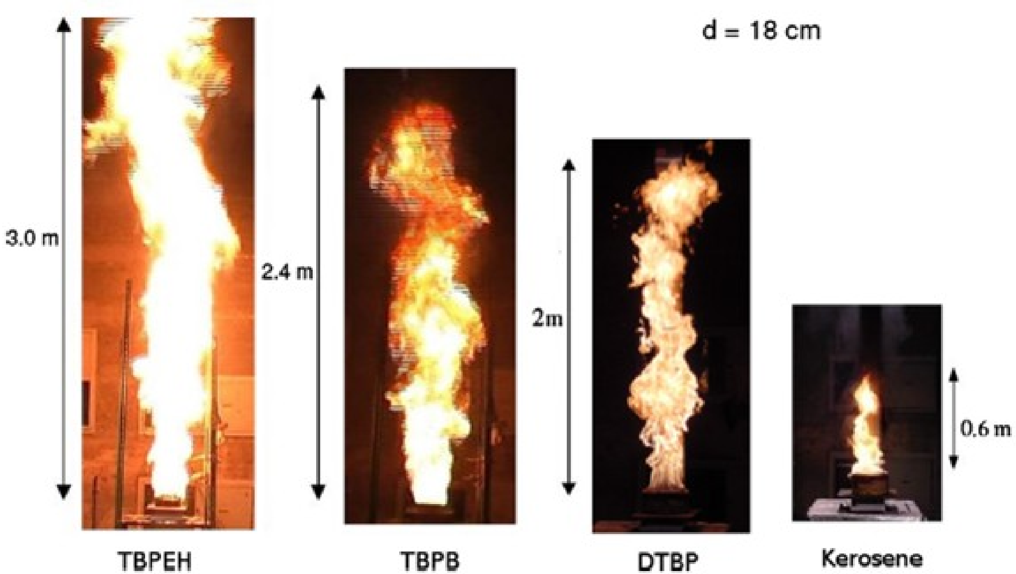
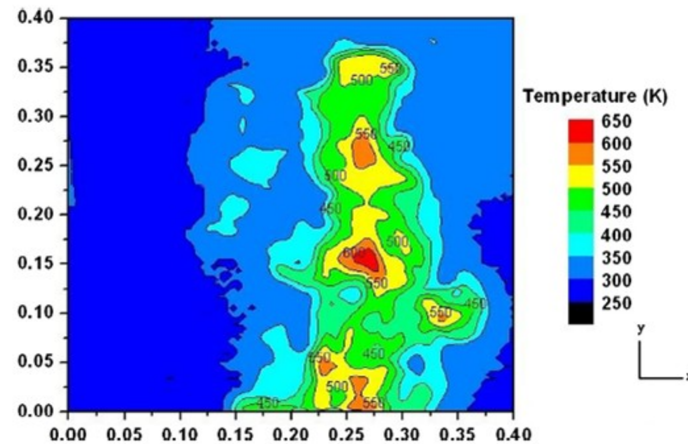


Fig. 5. Visible flame lengths of kerosene and peroxy-fuels.



Simulated flame temperature of kerosene pool fire (section above the liquid pool surface)

Measurements:
- Mass burning rate
- Temperature
- Thermal radiation
  (surface emissive power, irradiance)
- Flame height

K. B. Mishra, K.-D. Wehrstedt
Fuel 113 (2013) 158-164
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Large scale fire tests on liquid and solid fuels

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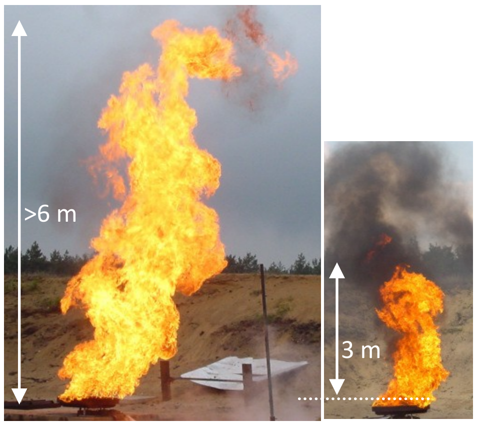
Safety distances from hydrocarbon and peroxide fires

- Experiments and numerical modeling



DTBP and kerosene pool fires (d = 1 m)


Radiometers

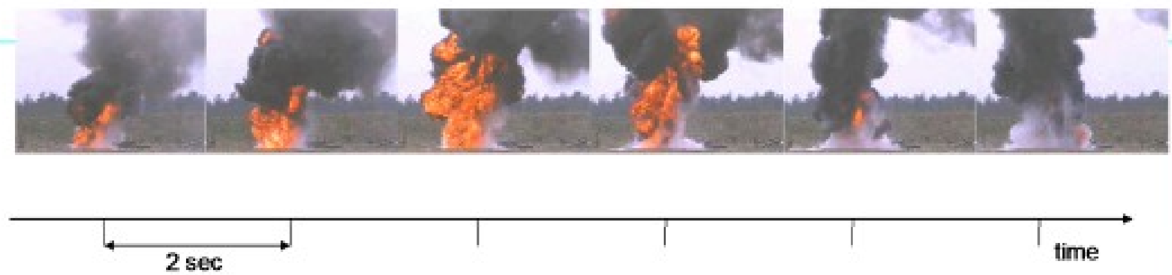
Measurements:
- Mass burning rate
- Temperature
- Thermal radiation
  (surface emissive power, irradiance)
- Flame height

Burning of Dibenzoyl peroxide with 25% water

– short sequence of a test with 5 packages each with 20 kg(100 kg)

– intensive heat radiation, pulsating burning

– height of maximum flame about 8 m



– image sequence of one pulse

H. Chun, Dissertation
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Multiple fires

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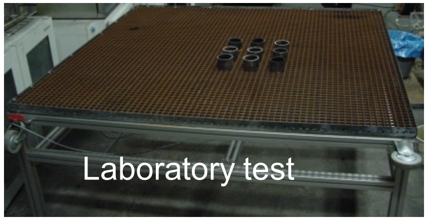
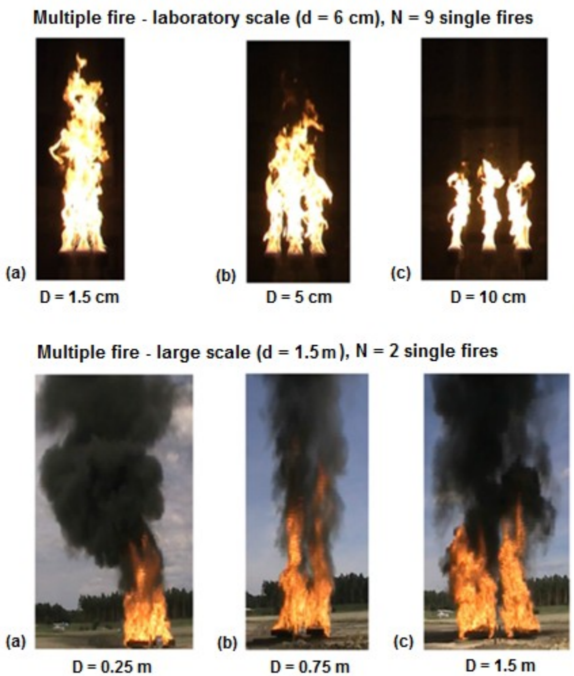
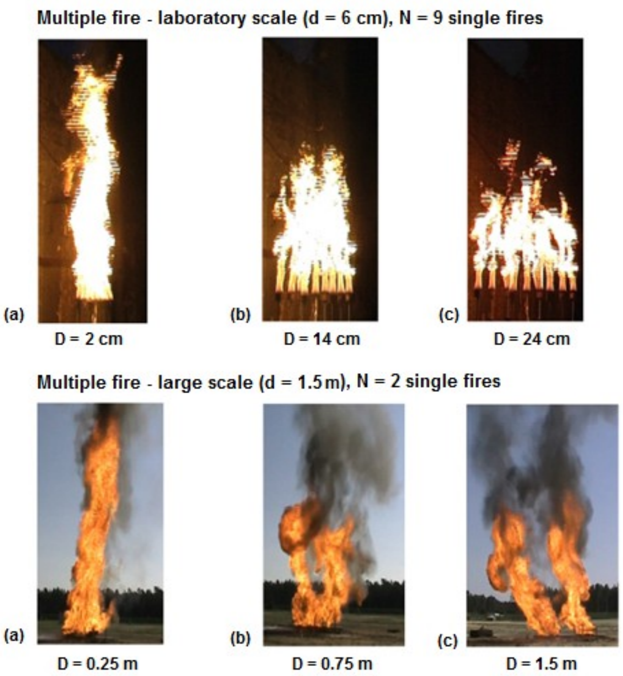
Safety distances from multiple hydrocarbon and peroxide pool fires

- Experiments and numerical modeling





Kerosene pool fires



DTBP pool fires

Observed:

Flame merging (depending on distance D between pools)

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Increased thermal radiation in comparison with a single pool fire

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Increased safety distance in comparison with a single pool fire

S. Schälike, Dissertation
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University of Duisburg-Essen

BAM contribution to the HORIZON 2020

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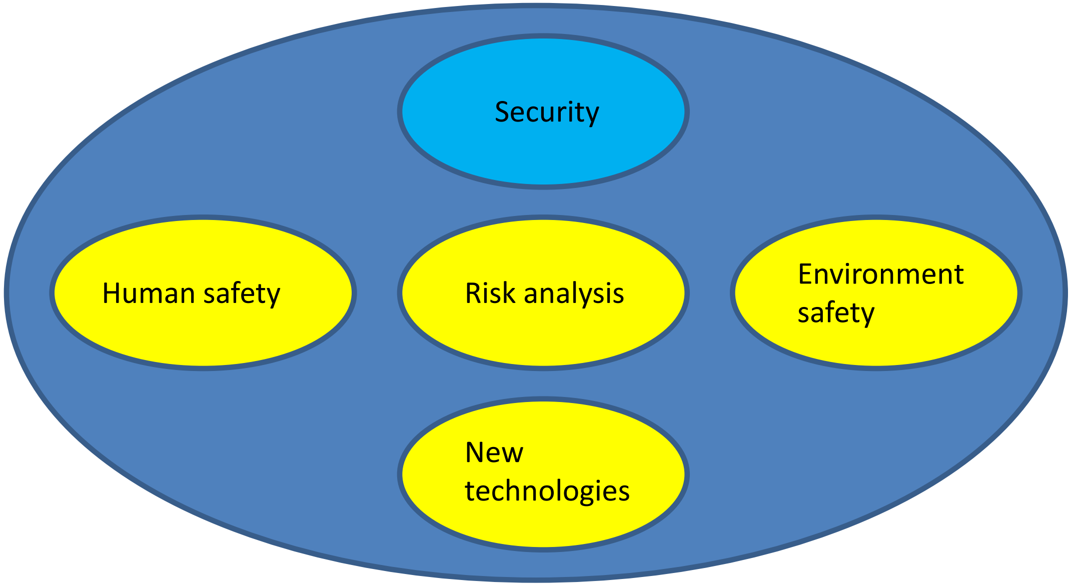
Experimental and numerical research with respect to

- Risk analysis of potential fire hazards and fire development in industrial buildings and storages
- Technical, environmental and human safety
- Safety improvements of industrial structures
- Safety assessment of road, sea and air transport



Thank you for your attention!

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