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

I. Vela, C. Knaust, A. Rogge, K.-D. Wehrstedt
Federal Institute for Materials Research and Testing (BAM)
Unter den Eichen 87, 12205 Berlin
iris.vela@bam.de
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Outline

- Introduction to fire science at BAM
- Industrial fire accidents – effects
- BAM recent research
- BAM contribution to HORIZON 2020
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
BAM: fire science

Interdisciplinary research
Dimensions from nm to 100 m
Experiment and Simulation

Chemical Safety Engineering
Combustible Dusts

Pool Fires
Fire Engineering

Containment Systems

Full Scale Testing
Standardisation

Simulation

Fire Testing

Coatings

Nanotechnology

Analytical Chemistry

Gas Analysis

Thermal Analysis

Polymer Science

Microscopy
Fire accidents - effects

- Technical
  - fire
  - explosion
  - emissions
  - damage
  - dispersion

- Economic
  - loss of goods
  - supply shortfall
  - loss of insurability
  - cost of incidence response

- Societal
  - loss of acceptance
  - supply shortfall
  - infuriation
  - NIMBY

2012 | warehouse in Hannover
2012 | warehouse in Hagen

iNTeg-Risk Deliverable T1.3.2, BAM
U. Krause, University of Magdeburg
Industrial system – safety requirements

• 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

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

Determination of safety distances

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

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

Dimension: 40 m x 40 m x 6 m
Openings: 2 Tore (2 m x 2 m), 4 Light bands (10 m x 1 m)

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
Fires in industrial buildings

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

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

Fire in industrial building – the complex structure
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
BAM
Airport fire

- 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
  \((\text{CO}_2, \text{CO}, \text{HCN}, \text{O}, \text{soot})\)

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
Large scale storage of hazardous materials

• 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
  - mathematical analysis.

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

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

- 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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Explosive substances of chemical Industries

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

<table>
<thead>
<tr>
<th>Storage Group</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Mass explosion, with or without heavy fragments.</td>
</tr>
<tr>
<td>1.2</td>
<td>Explosions, but no mass explosion, with or without heavy fragments.</td>
</tr>
<tr>
<td>1.3/1a</td>
<td>Mass fire.</td>
</tr>
<tr>
<td>Ib</td>
<td>Fires, the intensity of which range between mass and ordinary fires.</td>
</tr>
<tr>
<td>II</td>
<td>Ordinary fire.</td>
</tr>
<tr>
<td>1.4/III</td>
<td>Only for organic peroxides according to UVV; it is not possible to initiate a fire (e.g. stable dispersions in water)</td>
</tr>
</tbody>
</table>

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

Large scale fire tests with 5 tons TBPB (left) and 5 tons TBPEH
Laboratory scale tests on pool fires

- 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
Large scale fire tests on liquid and solid fuels

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

H. Chun, Dissertation
BAM

K.-D. Wehrstedt
BAM
Multiple fires

Safety distances from multiple hydrocarbon and peroxide pool fires
- Experiments and numerical modeling

Observed:
- Flame merging (depending on distance D between pools)
- Increased thermal radiation in comparison with a single pool fire
- Increased safety distance in comparison with a single pool fire

Kerosene pool fires

DTBP pool fires

S. Schälike, Dissertation
BAM
University of Duisburg-Essen
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

BAM contribution to the HORIZON 2020
Thank you for your attention!

BAM Federal Institute for Materials Research and Testing

Contact details:
A. Rogge  
andreas.rogge@bam.de  

C. Knaust  
christian.knaust@bam.de  

K.-D. Wehrstedt  
klaus-dieter.wehrstedt@bam.de  

I. Vela  
iris.vela@bam.de  

http://www.bam.de/