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Estimating consequences of scenarios of batch operated process in production buildings.

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DSM Operations & Responsible Care
PS Conference Dordrecht, 17 may 2017

Why are we concerned?

- Flammable materials
- High temperature / high pressure
- Large volumes / flows
- Continuous process
- Most often outside building

- Flammable materials
- Exothermic reactions
- High temperature / high pressure
- Relatively small volumes
- Batch process
- Most often inside buildings

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Used for:

- HAZOP and Risk classification
- Occupational health, exposure
- Occupied building assessments
- Design of control rooms
- Layout of production buildings with occupied rooms

Examples of occupied buildings

- Control rooms
- Compressor Buildings
- Warehouses
- Offices
- Canteens
- Emergency Command Centers
- Conference rooms
- Building in a building
- Weather shelters
- Cabins at charging stations

Analyzer Buildings
Workshops
Laboratories
Classrooms
Shelter-in-place
Dressing rooms
Portable buildings
Smoke areas
Scaffolding houses
Sanitary blocks

Software tools for consequence analysis

Mostly designed for outdoor scenarios.
Theory based on outdoor scenarios for large petrochemical sites

- Source strength
- Fire and explosion
- Toxic dispersion and consequences

- DNV PHAST
- TNO Effects
- ALOHA
- Baker Risk tools for building assessments
- CFD
- Etcetera

But not many tools available for scenarios taking place inside buildings

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Scenarios & limits

	Outside building	Inside building
Explosion inside vessel	• Pressure wave • Flame length vented explosion	• Pressure wave • Flame length vented explosion
Explosion outside vessel	• Pressure wave • Flash fire	• CSTR • Assessment of building integrity • Fireball
Jet fire	• Heat radiation	• Heat radiation
Flash fire	• LFL	• LFL
Pool fire	• Heat radiation • Secondary Containment	• Heat radiation • Secondary Containment
Toxic effect	• Dispersion	• CSTR

		Overpressure (inside)	Overpressure (outside)	LEL	Heat radiation	Toxic effects
Effect on people	≥C1	30 mbar	100 mbar		6.3 kW/m^2 (fast escape possible)	1% lethality
Effect on people	≥C2	100 mbar	300 mbar	100% LEL	12.5 kW/m^2	5% lethality
Effect on building		100 -300 mbar*	100 - 300 mbar*	≥100% LEL	25-35 kW/m^2	n.a.

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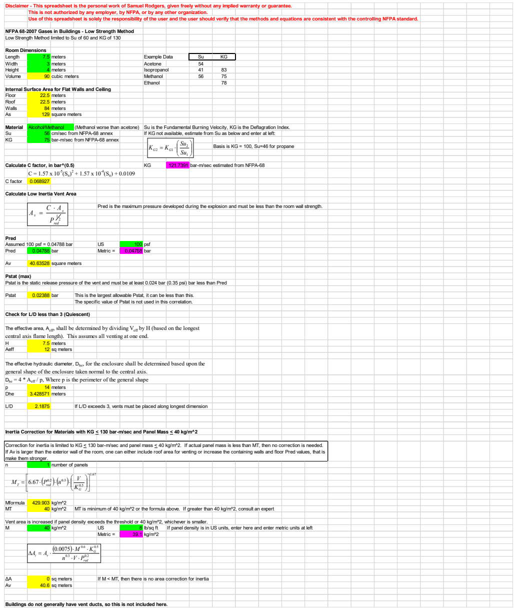
Background of calculations

- TNO: Yellow Book PGS 2
- R.J. Harris: gas explosions in buildings and heating plant
- Lees’ Loss prevention in
- ProcessNet: Statuspapier Quelltermberechnung
- Umweltbundesambt: Ermittlung und Berechnung von Störfallablaufszenarien nach Maßgabe der 3. Störfallverwaltungsvorschrift
- Others
  - Abdelkarim Habib, Bernd Schalau: Pool evaporation at higher vapor pressures

- Limited information or calculations suitable for scenarios taking place inside buildings

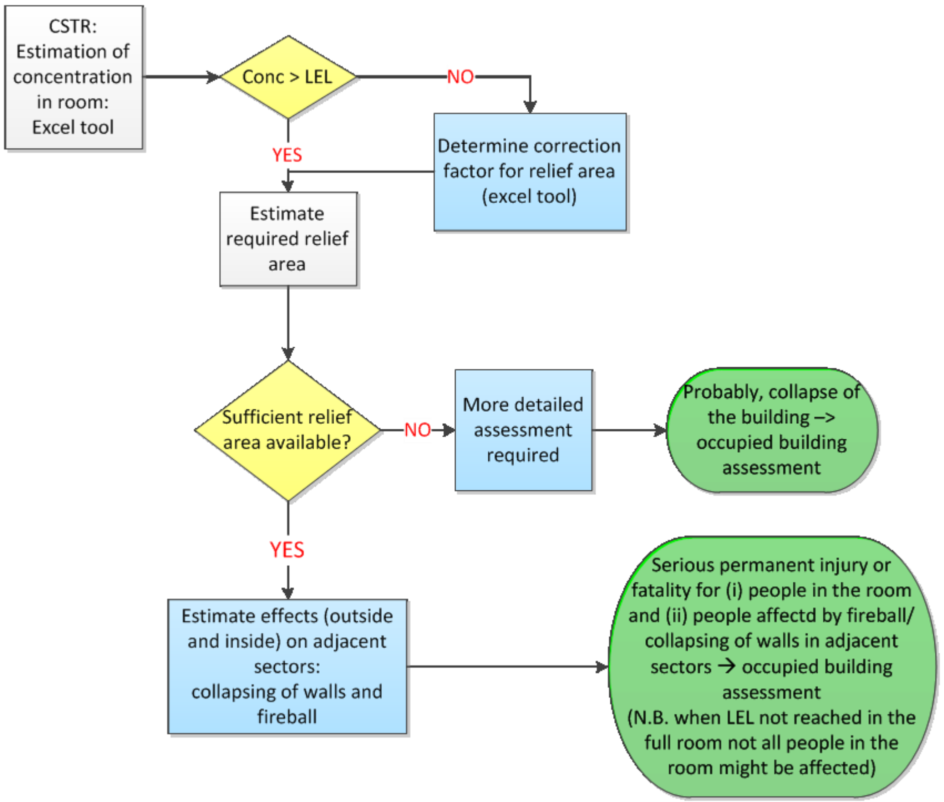
NFPA 68 2013 edition

- Standard on Explosion Protection by Deflagration Venting
- \+ Use for gas and vapor and dust explosion
- \+ Use for equipment and rooms / buildings
- \+ Excel sheet is available on internet / NFP
  - \+ NFPA 68 2012 revised 20130122
- – Physical properties needed
- – Rather complex to use



Fire and Explosion

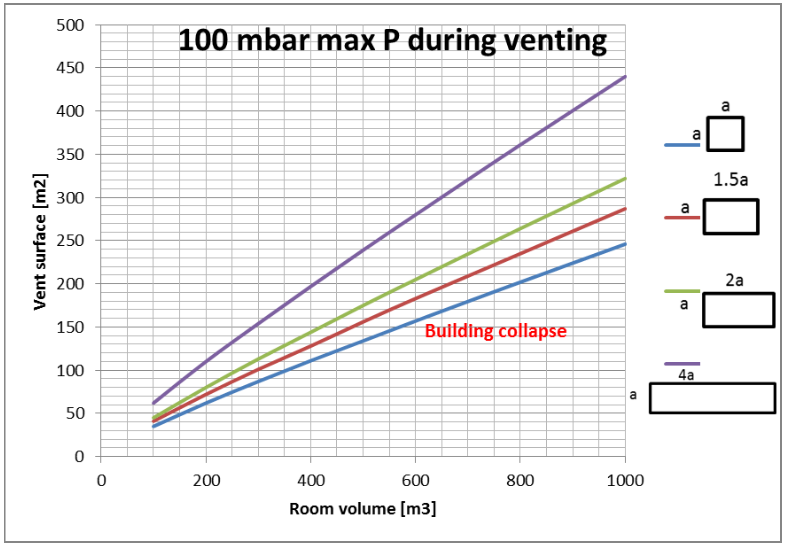
- Vessel burst:
  - Pressure wave
  - Heat radiation / flash fire
- Leakage
  - Gas or vapor release
  - Spray of liquid content
  - Pool evaporation
  - Ignition inside the building
  - Temperature and ventilation



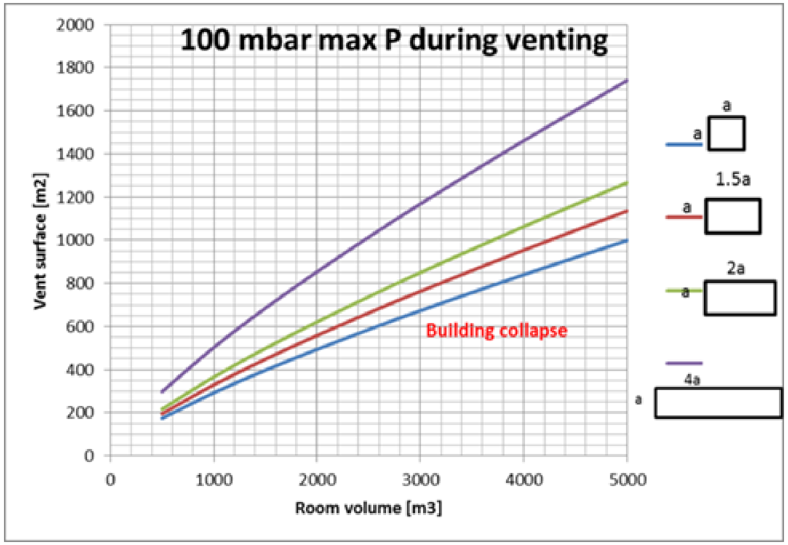
Decision tree for assessing the effects of vapor/gas explosion outside vessel indoor

Examples

Room 5m high



Room 25m high



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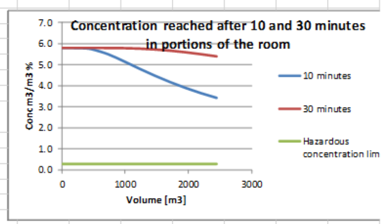
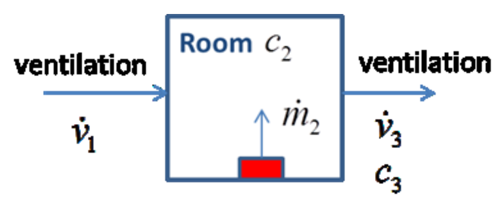
Toxic indoor

- CSTR approach: Excel Tool
  - Release of gas
  - The whole volume has the same concentration (ideally mixed)
  - Constant source and one time source
  - If Room conc > Hazardous concentration
    - Constance source:
      - Determination of time to reach Hazardous concentration
      - Determination of volume filled to Hazardous concentration after 10 and 30 minutes

Toxic indoor

FILL IN ALL BLUE FIELDS			
Constant source			
Source	0.148	kg/s	
Technical data			
Volume room	2450	m3	
Fresh air ventilation rate (Number of room exchange volumes per hour)	5	-	
Calculated fresh air input into Ventilation	12250	m3/h	
Substance properties			
Molar mass of toxic gas released	17	g/mol	
Hazardous concentration limit	0.27	% v/v	
Caclulated density	0.71	kg/m3	
Parameters/conditions			
Ambient pressure	1.013	bara	
Ambient pressure	20	°C	
Concentration above Hazardous level			
cend	0.041	kg/m3	
cend	5.80	% v/v	1
Haz conc reached in the full room within	1	min	
Fraction of steady state concentration to reach hazardous concentration	0.05	-	
Volume in which Haz. conc. after 10 min	2450	m3	
Volume in which Haz. conc. after 30 min	2450	m3	





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Toxic releases inside buildings

- Also suitable for (nitrogen) asphyxiation scenarios inside buildings
- Standard ideal (CSTR) mixing inside building calculations
- Local dispersion calculations
- Probit functions for lethality

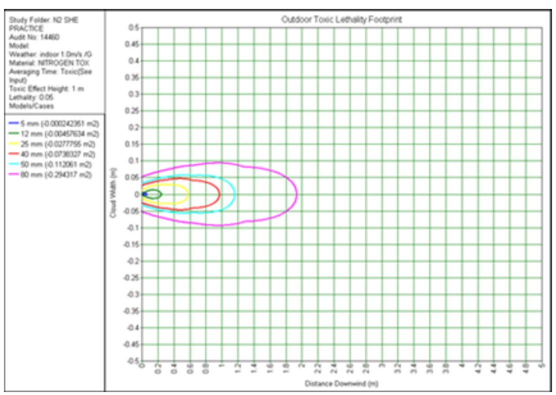
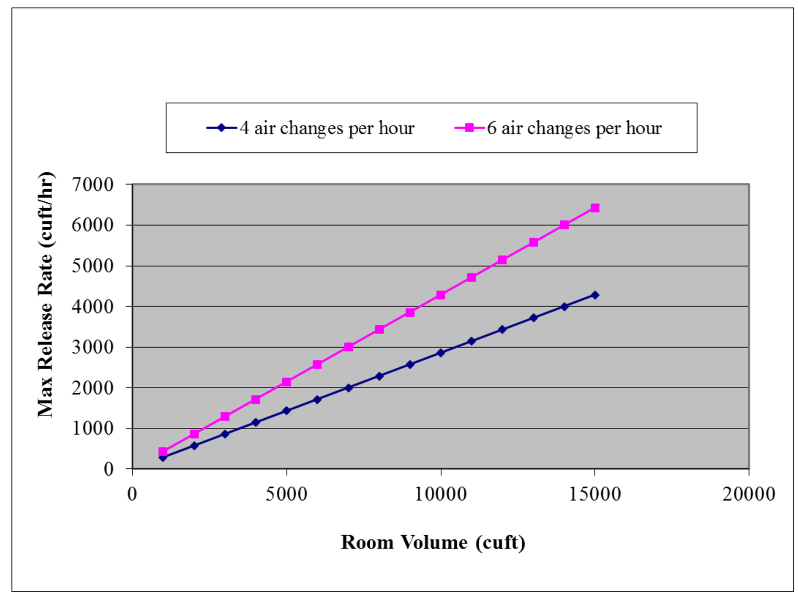
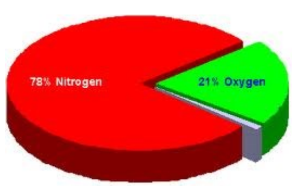
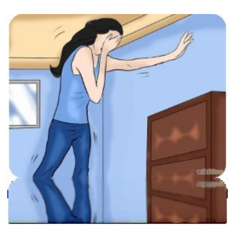


Table 8 Footprint of 5 % at 7 barg (~ 13.1% O_2).
(95% of the people in the effect area are death within 10 minutes)







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Data for calculations

- Building or room volume
- Design strength of main construction and separation walls
- Opening pressure of explosion panels, window panes, doors, light construction walls for explosion venting
- Physical properties of the hazardous materials
- Source strength
- Corrections for partly filled volumes

Conclusions

- Calculation methods are available in literature, but not always ready to use
  - Older literature information sometimes lead to conservative over – or underestimation of the effects.

- Tools, excel sheets, graphs help speeding-up and make risk classifications more reliable and uniform

- NFPA 68 suitable for explosion scenarios inside rooms / buildings and explosion venting of buildings

- Design of apps would help supporting risk classifications

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