INVESTIGATING THE CAUSES OF FIRE
2ND INTERNATIONAL WORKSHOP

ISTITUTO SUPERIORE ANTINCENDI
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An LPG explosion scenario reconstruction based on CFD simulations

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- CFD analyses using FLACS code
  - Explosion feedback loop
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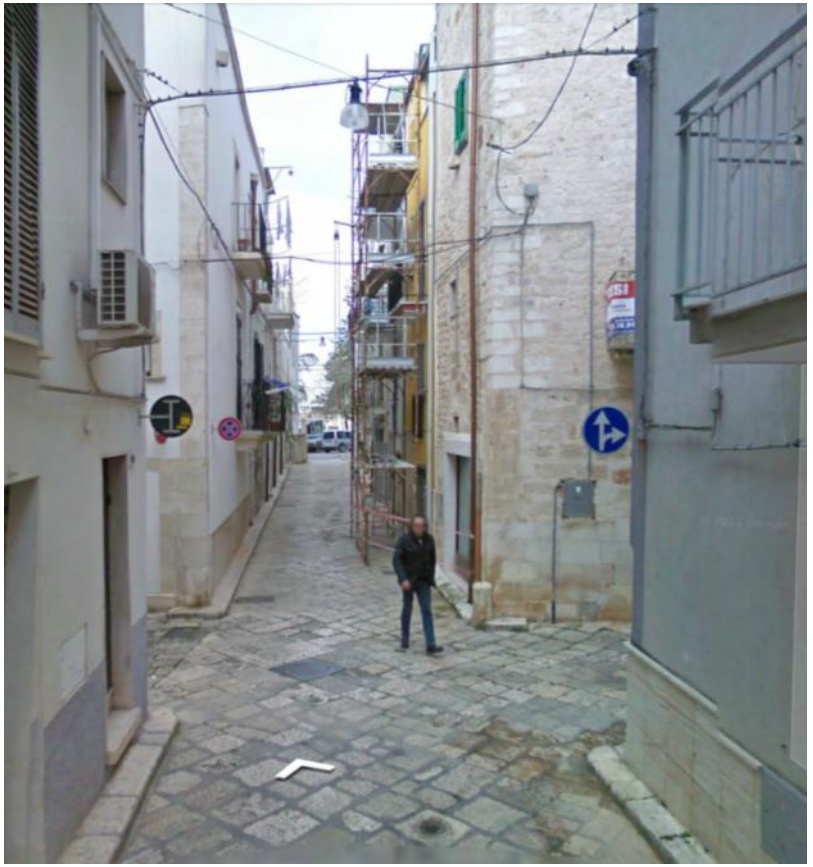
Site description

- Terraced houses masonry buildings, including 3 flats (41, 42, 44), each one three m height and 4x6.5 m area storeys
- Volume of the central flat (hosting the leak): 234m^3



Site description

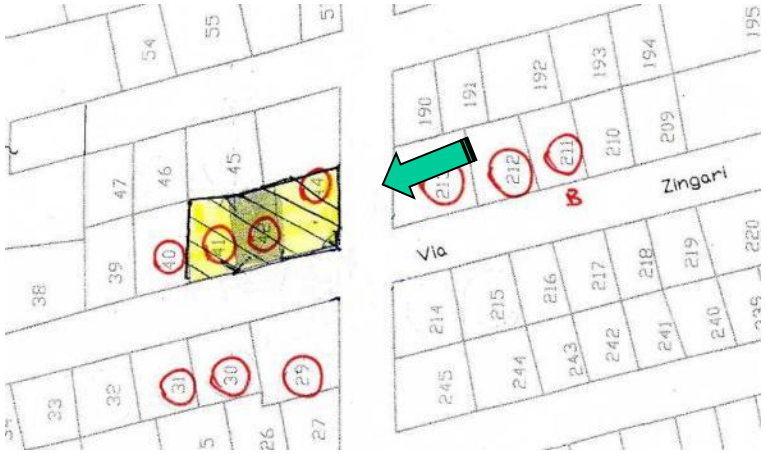
- Terraced houses masonry buildings, including 3 flats (41, 42, 44), each one three m height and 4x6.5 m area storeys
- Volume of the central flat (hosting the leak): 234m^3

Blast event description

- Blast occurred on 7 June 2012
- Gas leak from a 15kg LPG transportable refillable cylinder (bottle) was detected
- 3 fatalities
- Collapse of a part of the masonry buildings including 3 flats 41, 42 and 44

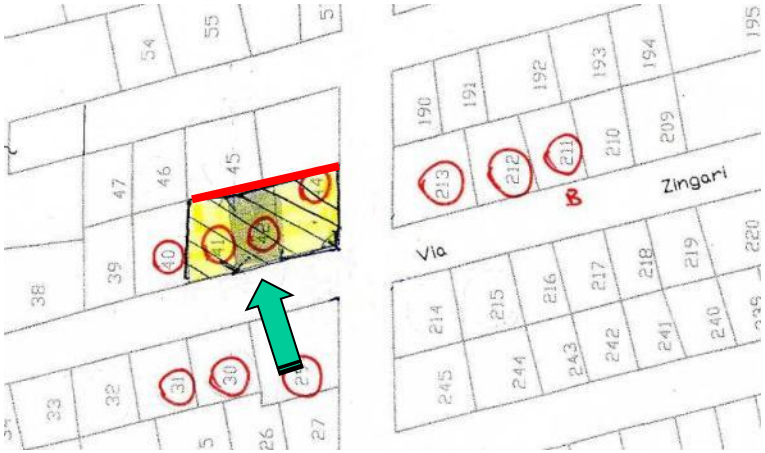
Blast event description

- Gas mixture 30% propane, 70% butane (top concentration 3.5%)
- Mixture expanded n.c. volume 7.5m^3
- Worst case gas cloud volume 214m^3
- Volume of the central flat (hosting the leak): 216m^3



Blast event description

- Structural damages on rear wall of adjacent buildings (45)



Blast event description

- Structural damages on side wall of lateral building (40)

Blast event description

- Structural damages on front wall of opposite building (29)

CFD analyses using FLACS code

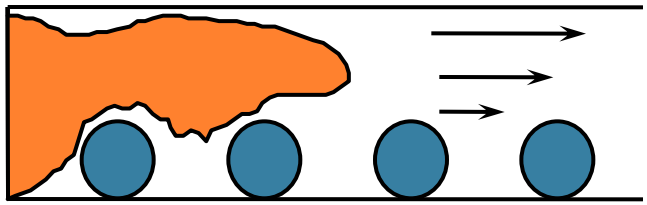
Geometrical modeling:

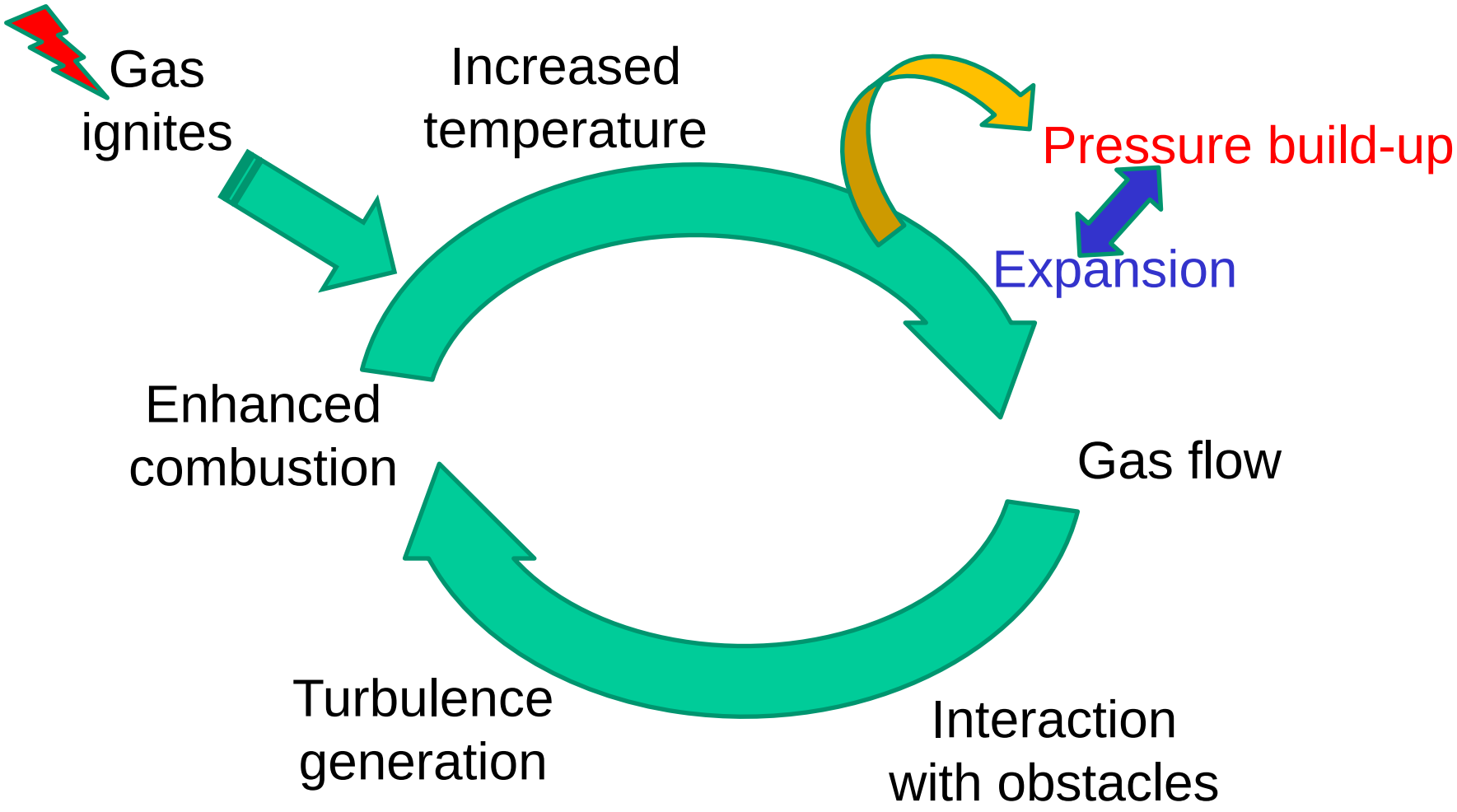
- Main volumes
- Weak structural elements (walls, slabs, windows)
- ”Domestic congestion”

Sensitivity analyses – investigated aspects:

- gas cloud extension and position
- ignition location
- domestic congestion
- windows-doors-walls lateral pressure withstand capability

Explosion feedback loop

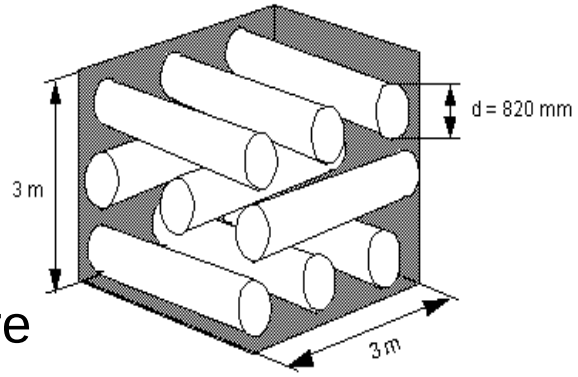


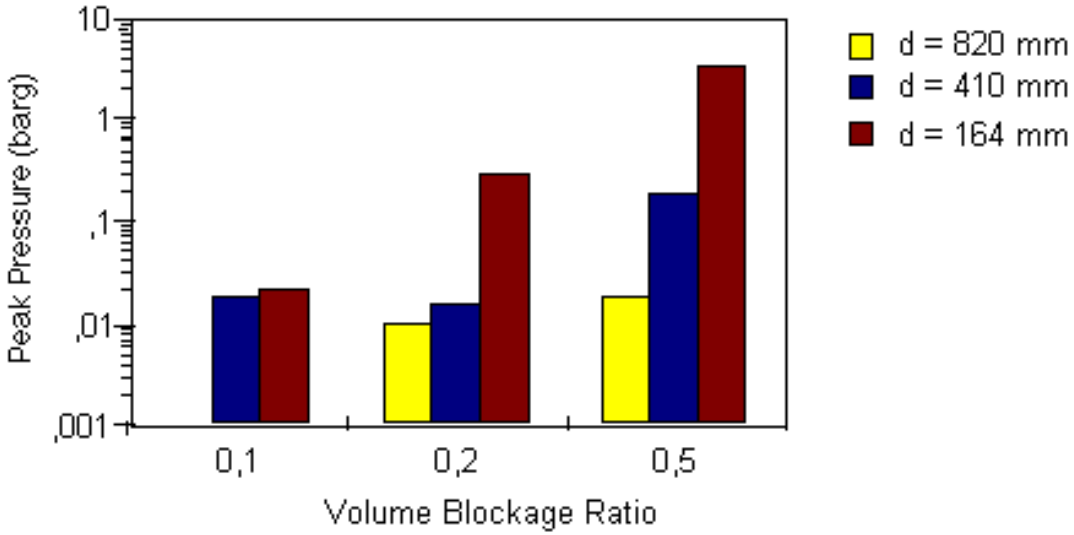


Explosion feedback loop

- The combustion process is strongly influenced by congestion degree

EXAMPLE:
CMR 3D-Corner tests
Total volume 27m^3
VBR=50%
Propane stoich. mixture



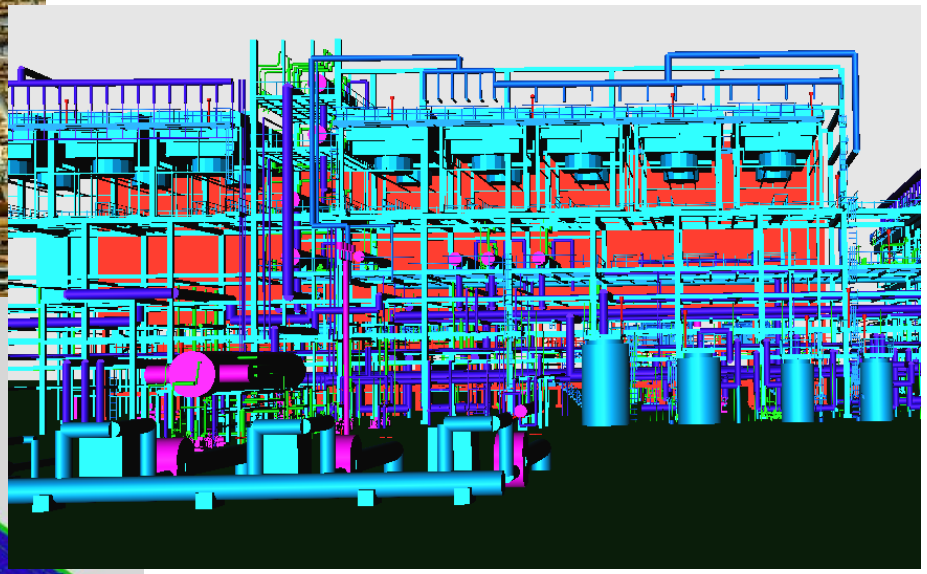


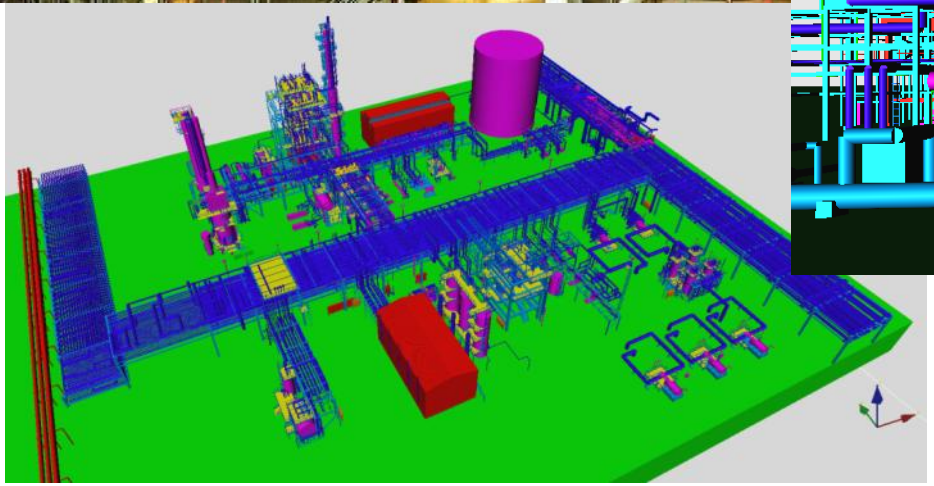
3x3x3 820mm pipes

15x15x15 164mm pipes

Congestion modelling

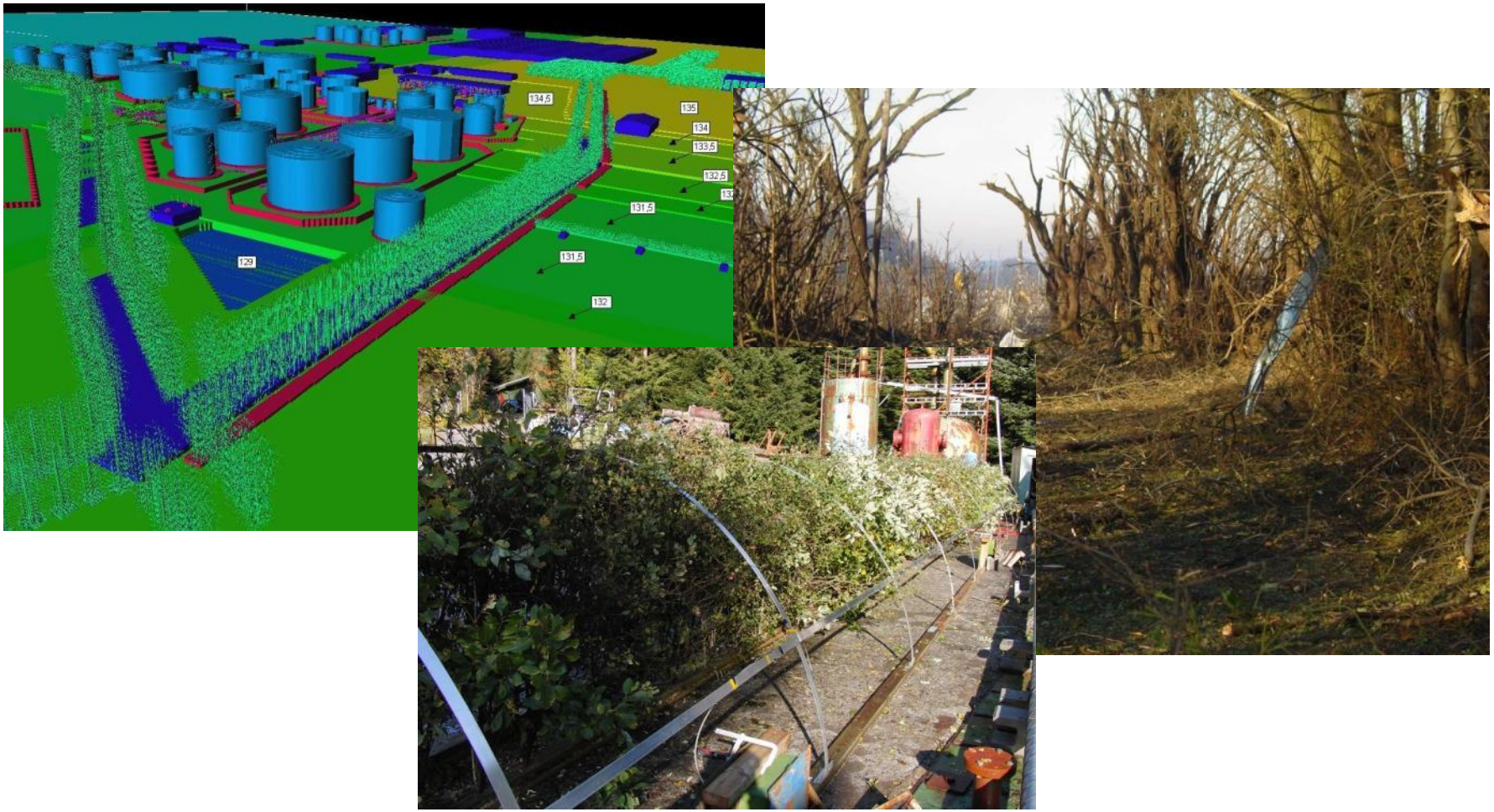
Flame propagation is strongly affected by interference with objects.
Modelling the geometrical congestion plays a crucial role in CFD analyses.





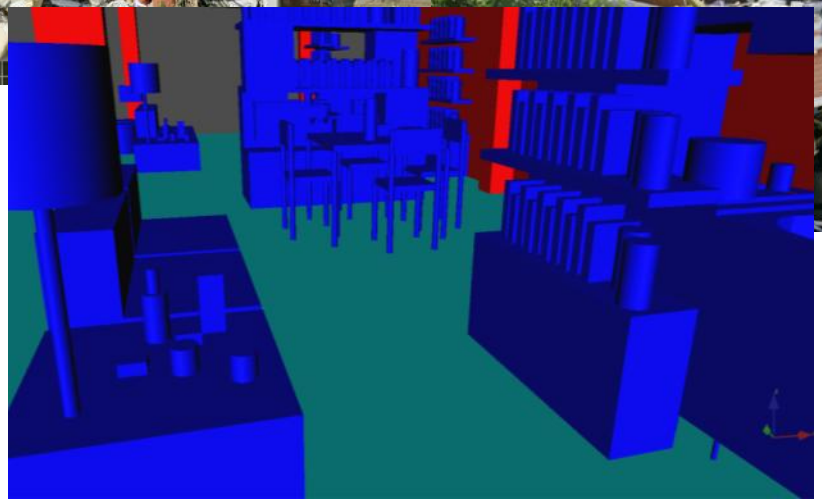
Congestion modelling

Flame propagation is strongly affected by interference with objects.
Modelling the geometrical congestion plays a crucial role in CFD analyses.



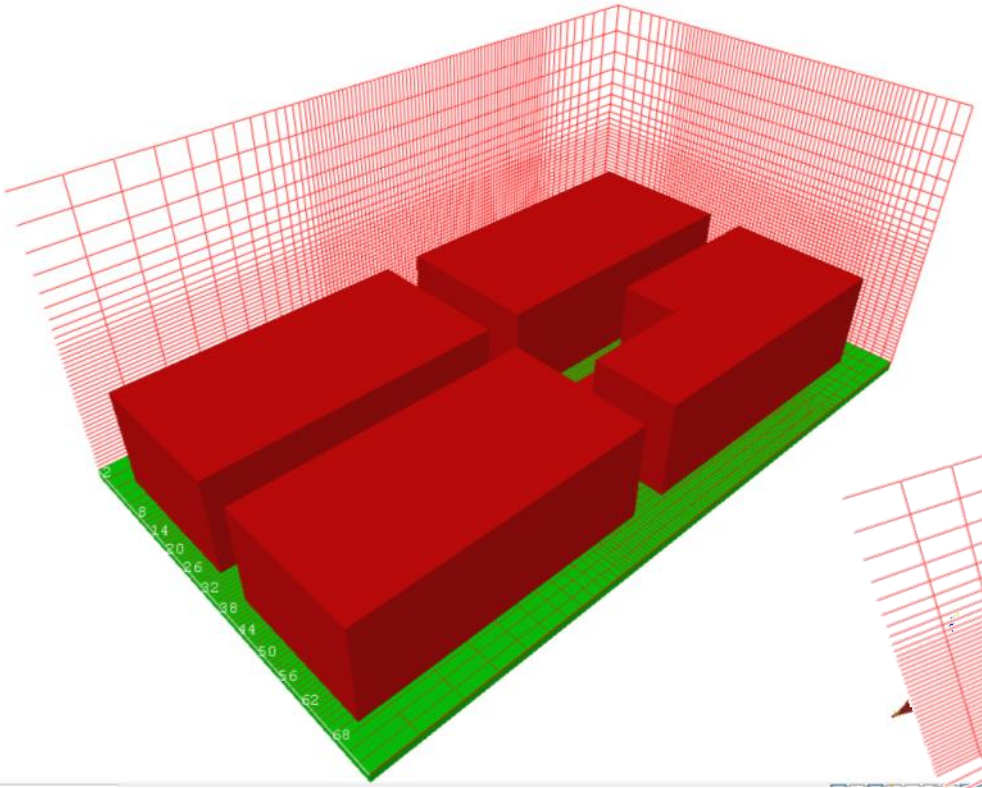
Congestion modelling

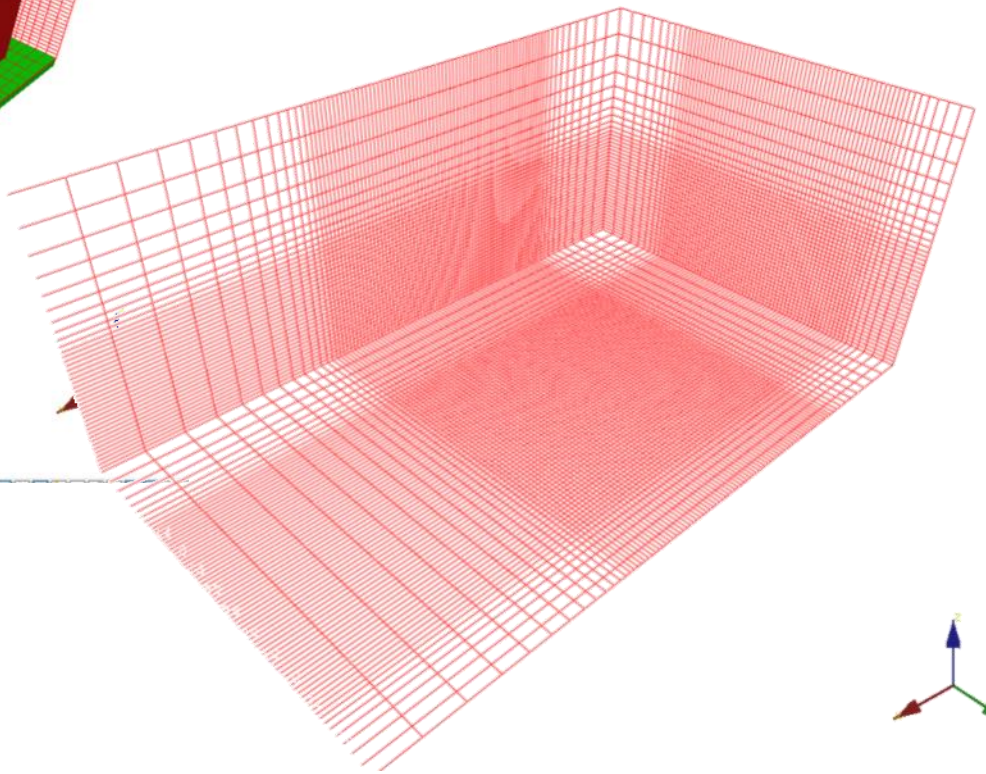
”domestic congestion” can have an effect on the combustion process due to enhanced turbulence induced in explosion scenarios in civil buildings



Geometrical model

3D geometrical model and computational grid

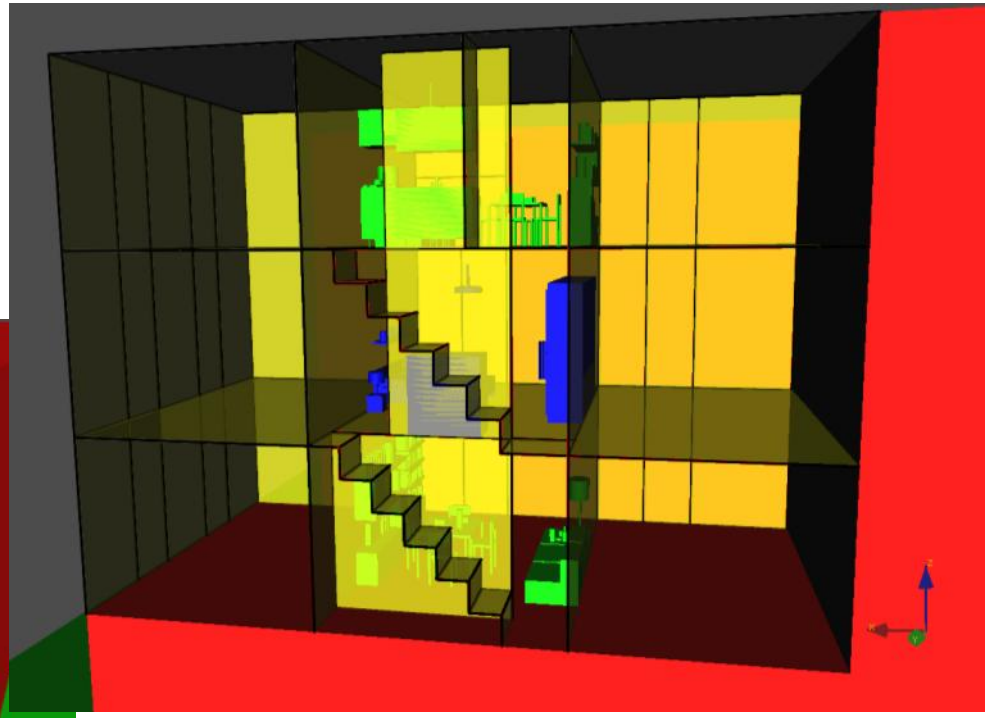


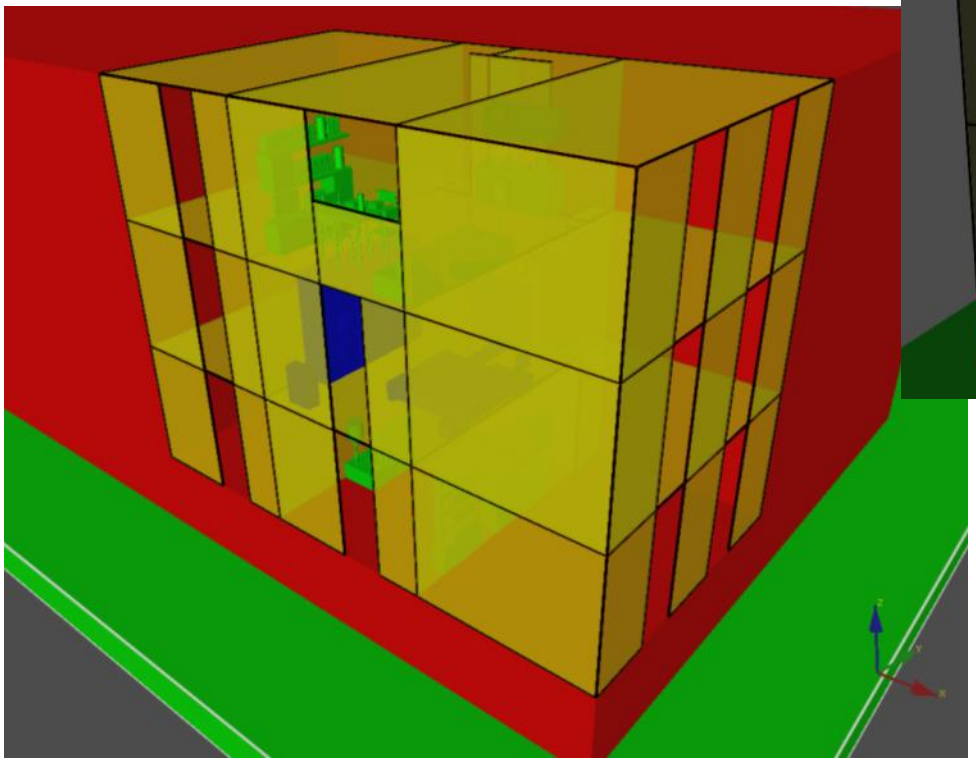


Geometrical model

3D geometrical model

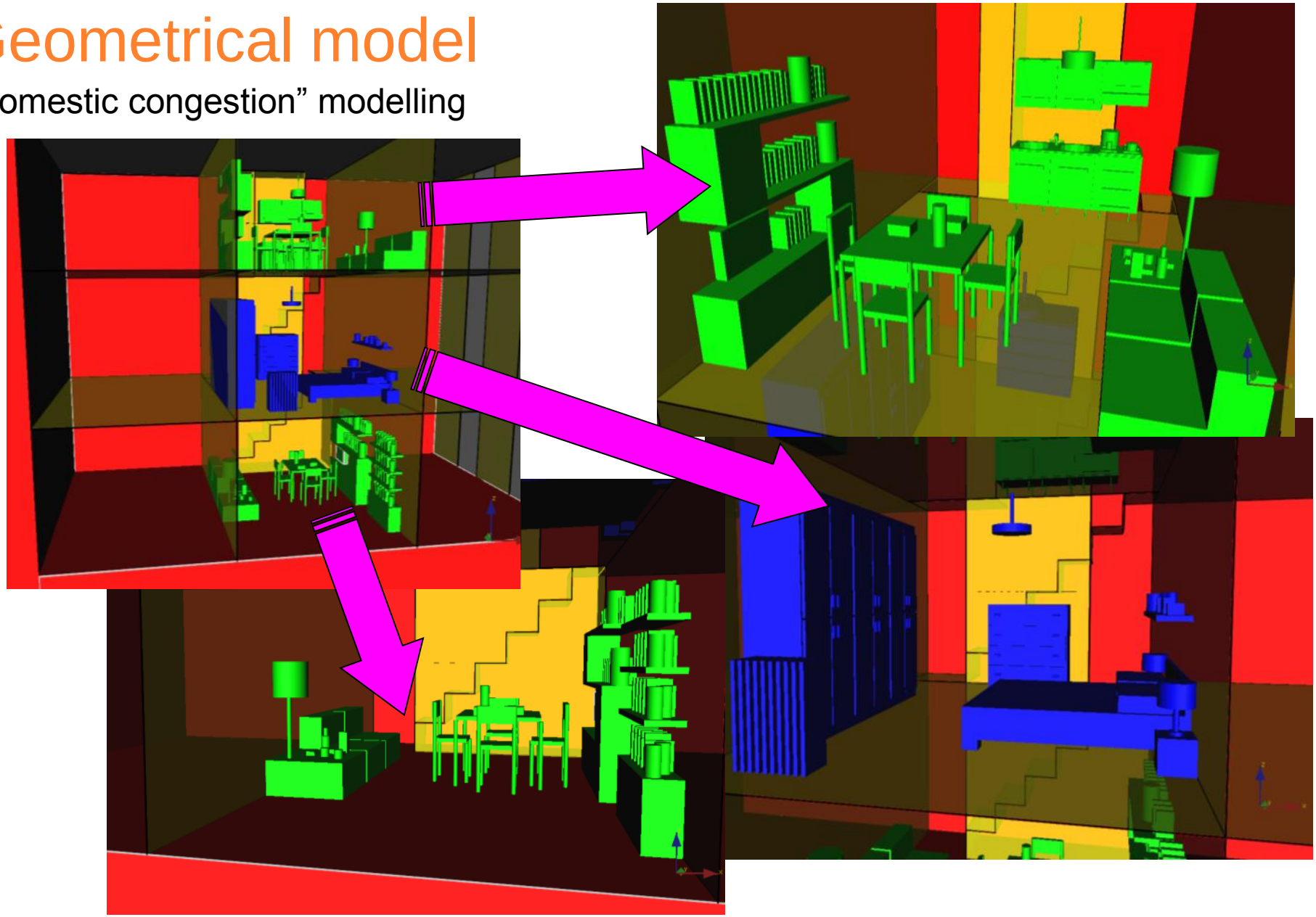
internal and external walls, as well as windows, stairs and slabs, are modelled by means of ”blast resistant panels” – i.e. elements having a predefined withstand pressure load capability and mass.





Geometrical model

”domestic congestion” modelling



Scenarios set-up

Sensitivity analyses – considered configurations and assigned indexes:

GAS CLOUD (m)		Position			Dimension		
		x	y	z	x	y	z
1	4X5.5X3 (P2)	0	0	8	4	5.5	3
2	4X5.5X3 (P1)	0	0	5	4	5.5	3
3	4X6.5X6 (P2+P1+stair)	0	0	5	4	6.5	6
4	4X6.5X9 (P2+P1+P0+stair)	0	0	2	4	6.5	9

IGNITION POSITION (m)		x	y	z
1	refrigerator	2.1	5.4	8.1
2	bedroom	2.1	5.4	6.1
3	first floor	2.1	5.4	3.1

P0 wall (bar)	
1	0.02
2	0.04
3	0.08

P0 facade (bar)	
1	0.02
2	0.04
3	0.08

P0 slab (bar)	
1	0.025
2	0.05
3	0.1

P0 window (bar) & Domestic congestion		
0	0.001	no
1	0.01	no
2	0.015	no
3	0.02	no
9	0.015	yes

Scenarios set-up

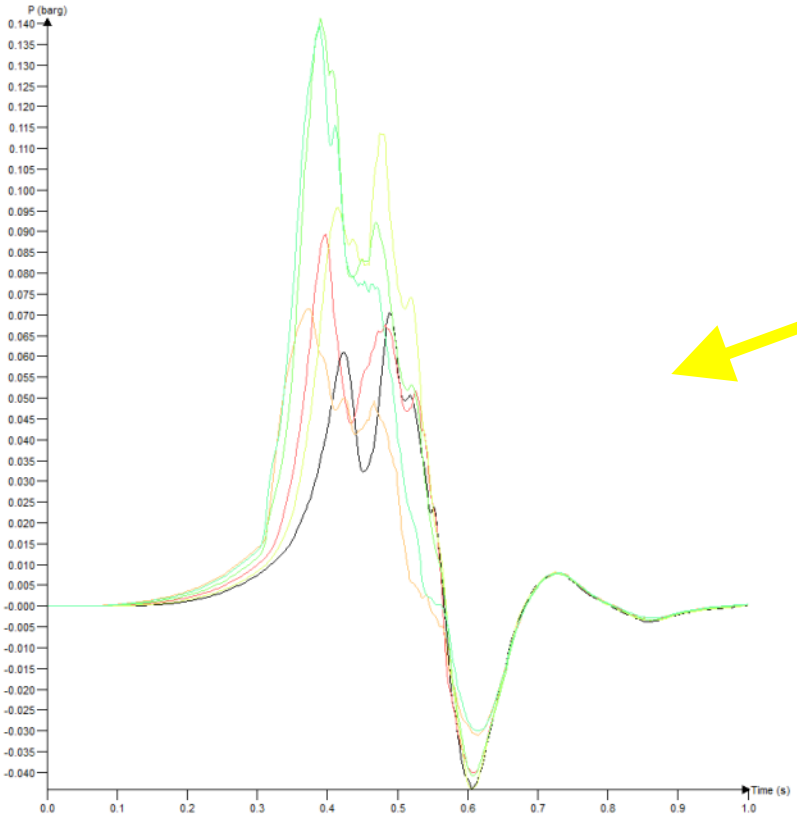
Scenarios definition

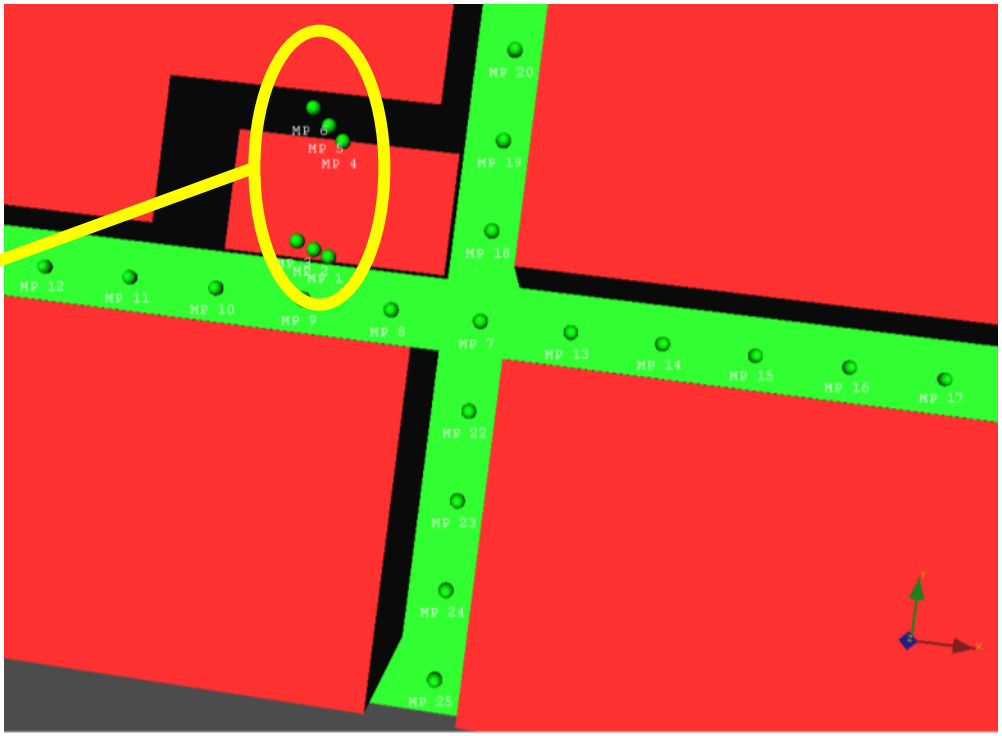
JOB name	GAS CLOUD SIZE	IGNITION POSITION	P0 WALL	p0 FACADE	P0 SLAB	P0 WINDOW	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
a	1	1	2	2	2	0	112220	4X5.5X3 (P2)	refrigerator	0.04	0.04	0.05	0.001	no
b	1	1	2	2	2	2	112222	4X5.5X3 (P2)	refrigerator	0.04	0.04	0.05	0.015	no
c	2	2	2	2	2	0	222220	4X5.5X3 (P1)	bedroom	0.04	0.04	0.05	0.001	no
d	2	2	2	2	2	2	222222	4X5.5X3 (P1)	bedroom	0.04	0.04	0.05	0.015	no
e	3	1	2	2	2	2	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
f	3	2	2	2	2	2	322222	4X6.5X6 (P2+P1+stair)	bedroom	0.04	0.04	0.05	0.015	no
g	4	1	2	2	2	2	412222	4X6.5X9 (P2+P1+P0+stair)	refrigerator	0.04	0.04	0.05	0.015	no
h	4	2	2	2	2	2	422222	4X6.5X9 (P2+P1+P0+stair)	bedroom	0.04	0.04	0.05	0.015	no
i	4	3	2	2	2	2	432222	4X6.5X9 (P2+P1+P0+stair)	first floor	0.04	0.04	0.05	0.015	no
j	3	1	1	1	1	2	311112	4X6.5X6 (P2+P1+stair)	refrigerator	0.02	0.02	0.025	0.015	no
k	3	1	3	3	3	2	313332	4X6.5X6 (P2+P1+stair)	refrigerator	0.08	0.08	0.1	0.015	no
l	3	1	2	2	2	9	312229	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	yes
m	4	1	2	2	2	9	412229	4X6.5X9 (P2+P1+P0+stair)	refrigerator	0.04	0.04	0.05	0.015	yes

FLACS analyses

Typical results – Pressure time histories on preselected internal locations

Local Pressure

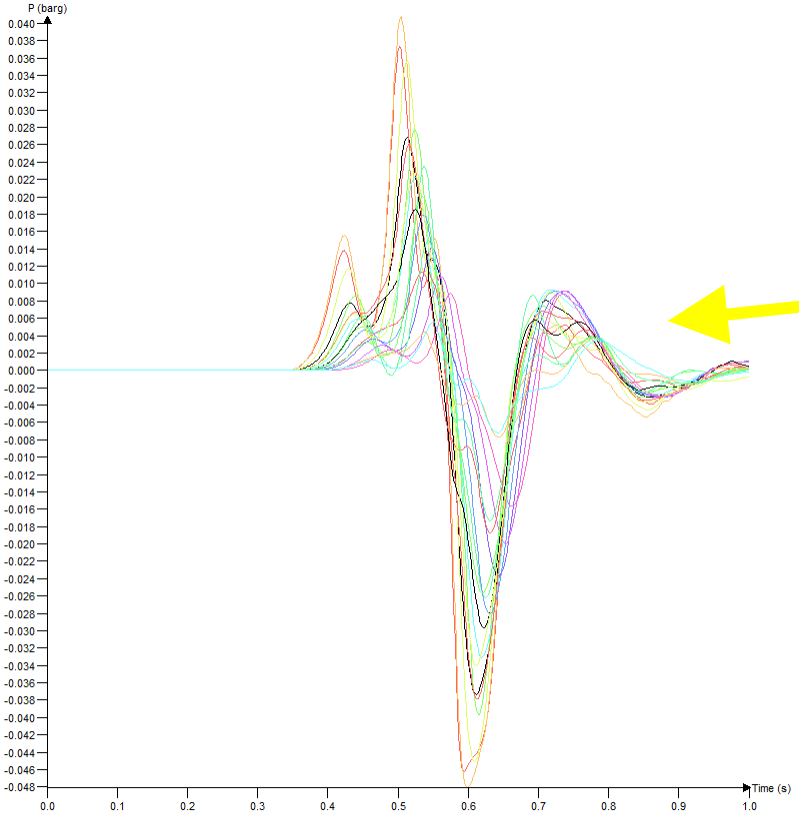


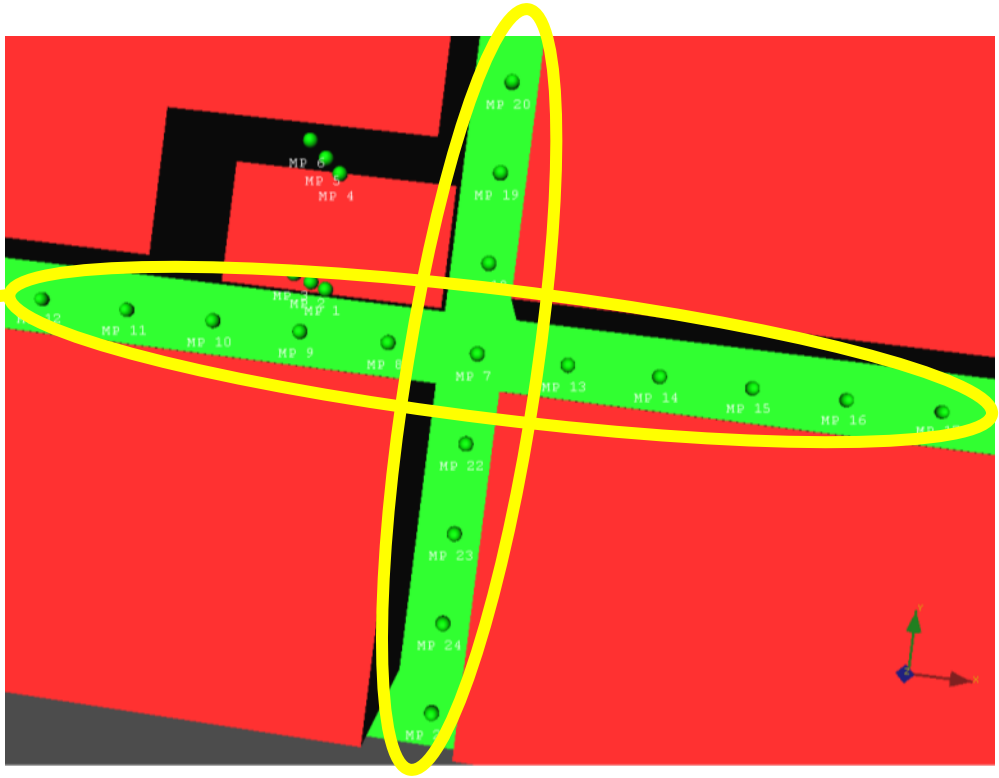


FLACS analyses

Typical results – Pressure time histories on preselected external locations

Local Pressure





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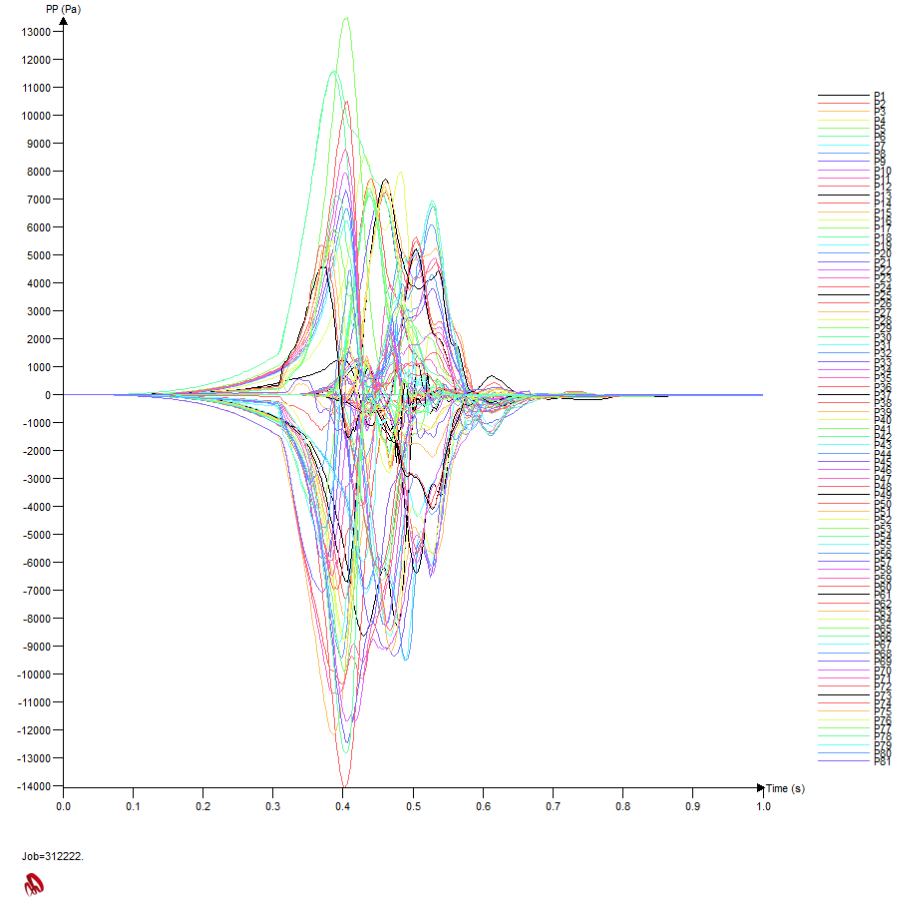
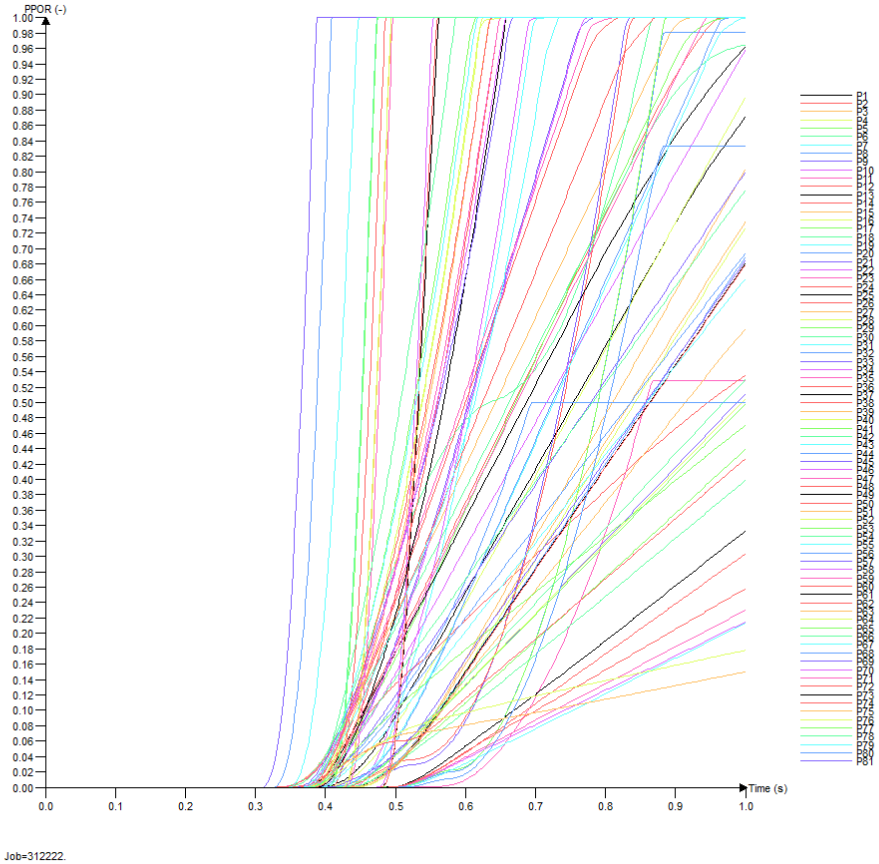
FLACS analyses

Typical results – Time histories on panels

Average Pressure on panels



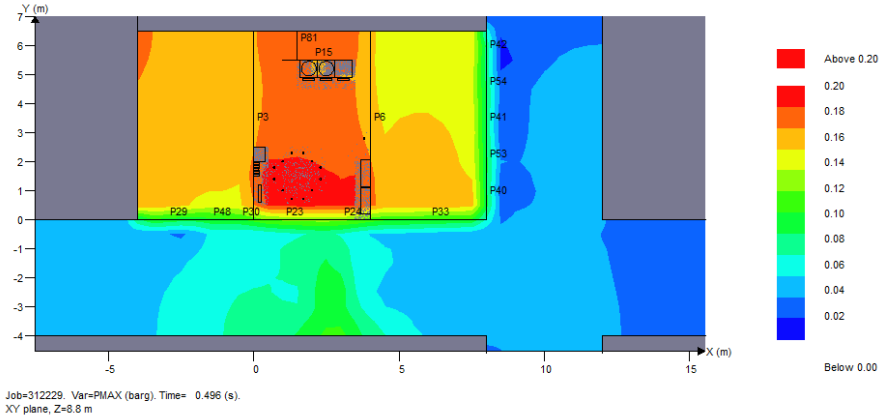
Panel porosities (opening/failure evolution)



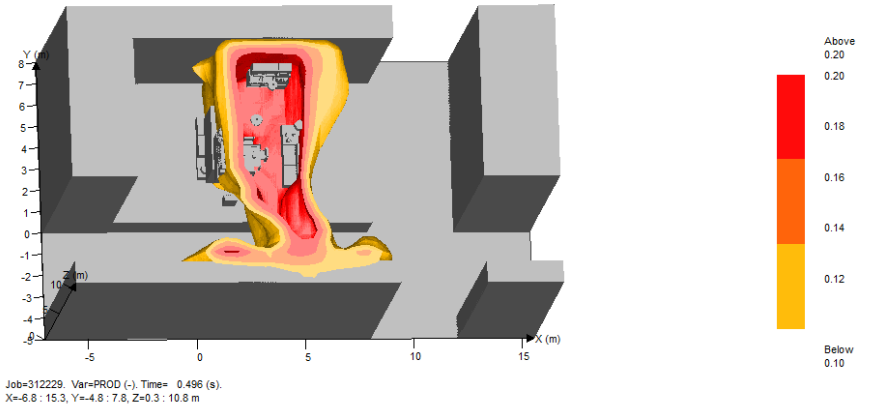
FLACS analyses

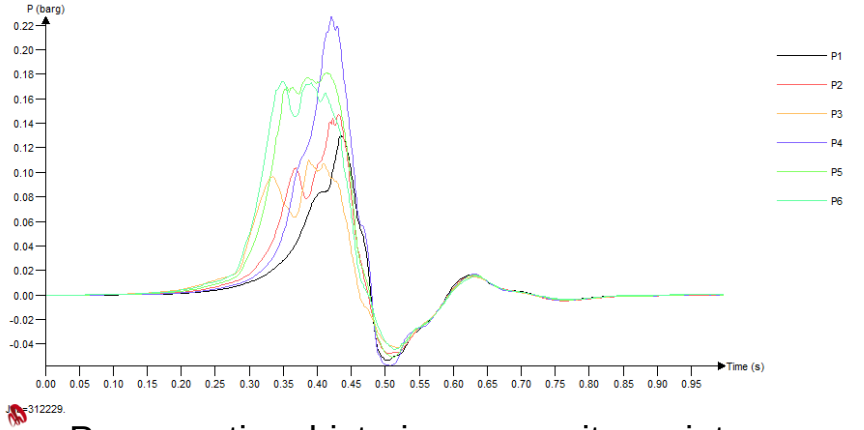
Typical results – 2D and Volume Contours

Pressure envelope

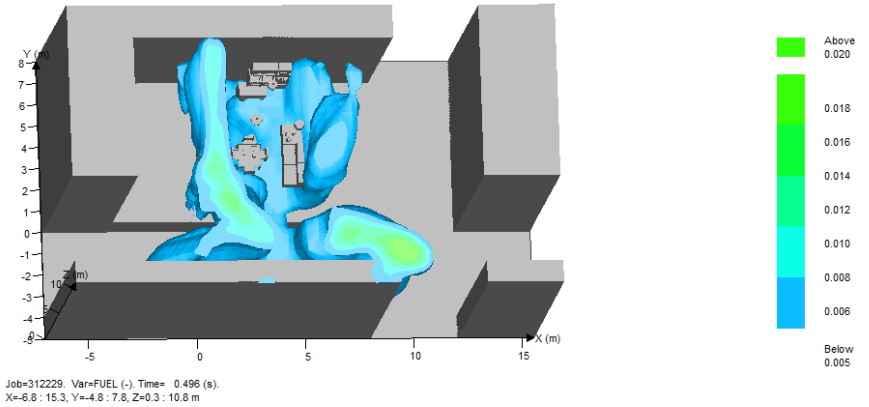


Flame propagation





Pressure time histories on monitor points

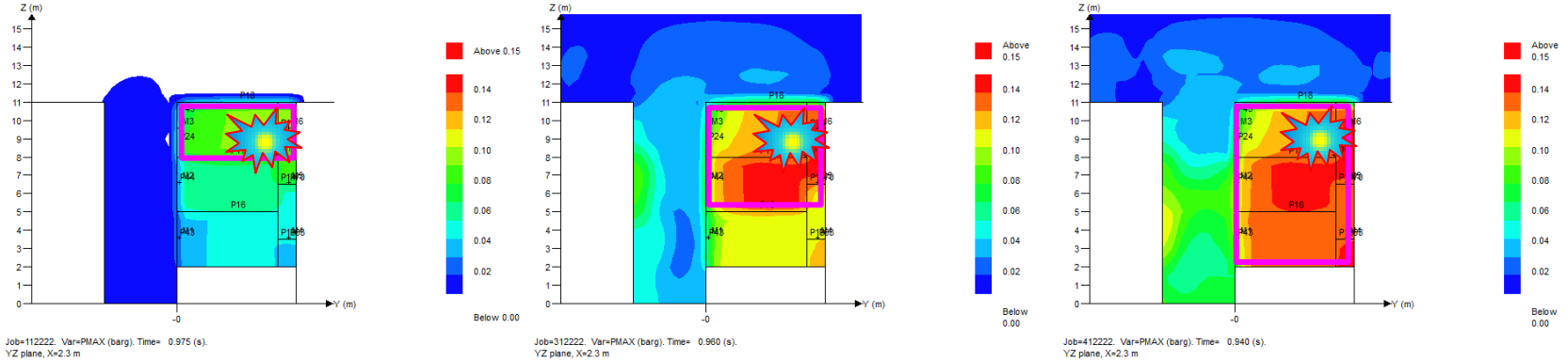


Fuel distribution (gas cloud)

FLACS analyses

Results: effect of gas cloud position and size – pressure envelope

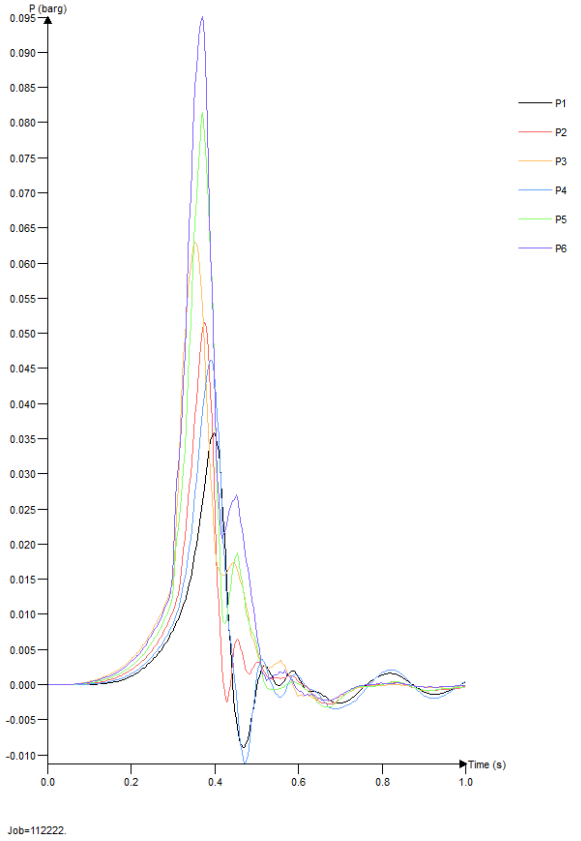
JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
b	112222	4X5.5X3 (P2)	refrigerator	0.04	0.04	0.05	0.015	no
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
g	412222	4X6.5X9 (P2+P1+P0+stair)	refrigerator	0.04	0.04	0.05	0.015	no

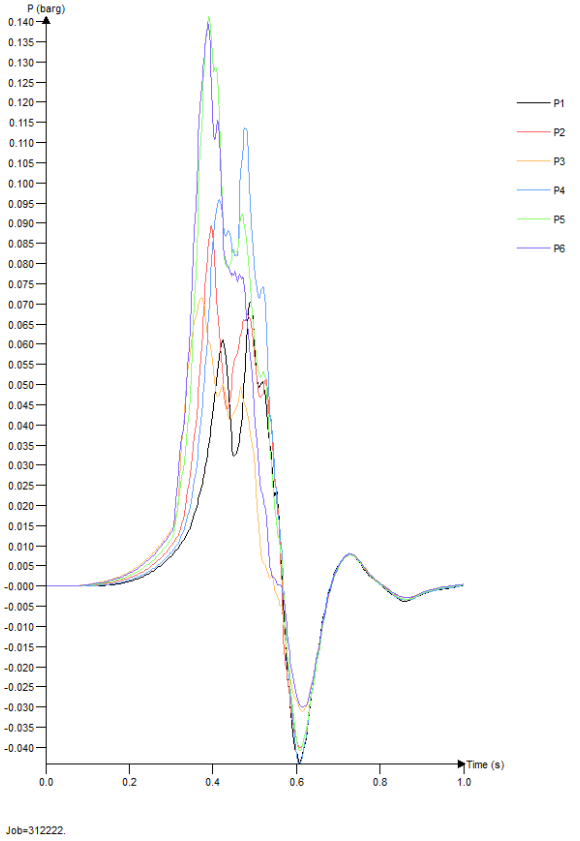


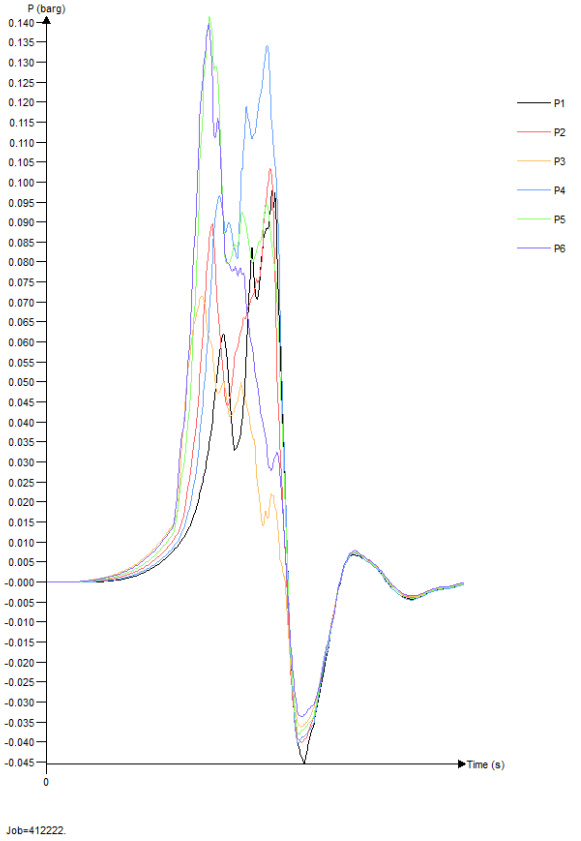
FLACS analyses

Results: effect of gas cloud position and size – pressure time histories

JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
b	112222	4X5.5X3 (P2)	refrigerator	0.04	0.04	0.05	0.015	no
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
g	412222	4X6.5X9 (P2+P1+P0+stair)	refrigerator	0.04	0.04	0.05	0.015	no



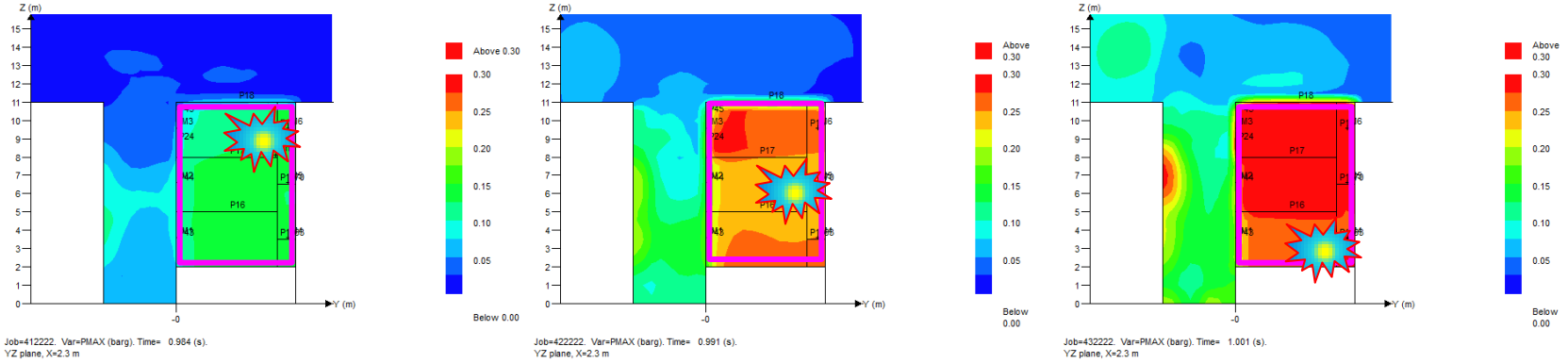


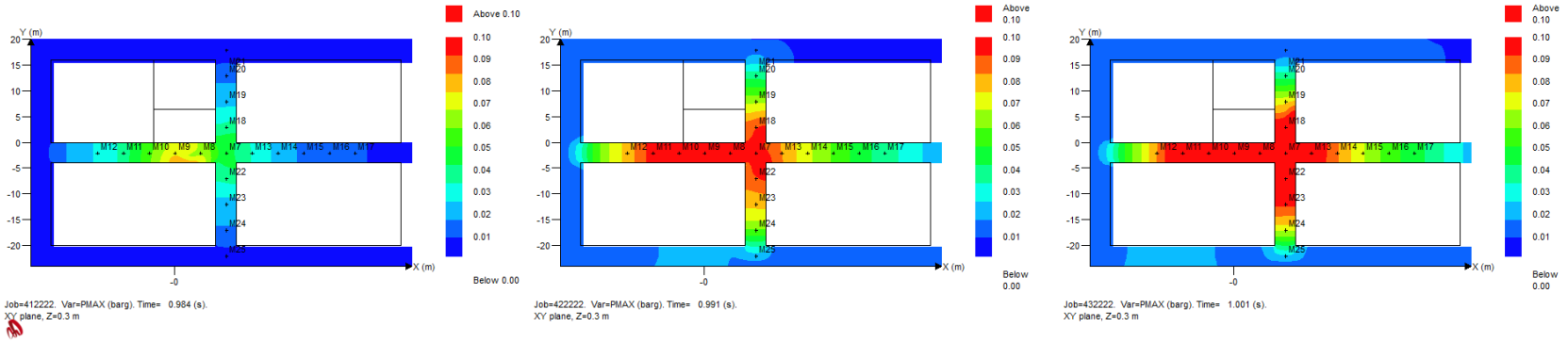


FLACS analyses

Results: effect of ignition location – pressure envelope

JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
g	412222	4X6.5X9 (P2+P1+P0+stair)	refrigerator	0.04	0.04	0.05	0.015	no
h	422222	4X6.5X9 (P2+P1+P0+stair)	bedroom	0.04	0.04	0.05	0.015	no
i	432222	4X6.5X9 (P2+P1+P0+stair)	first floor	0.04	0.04	0.05	0.015	no

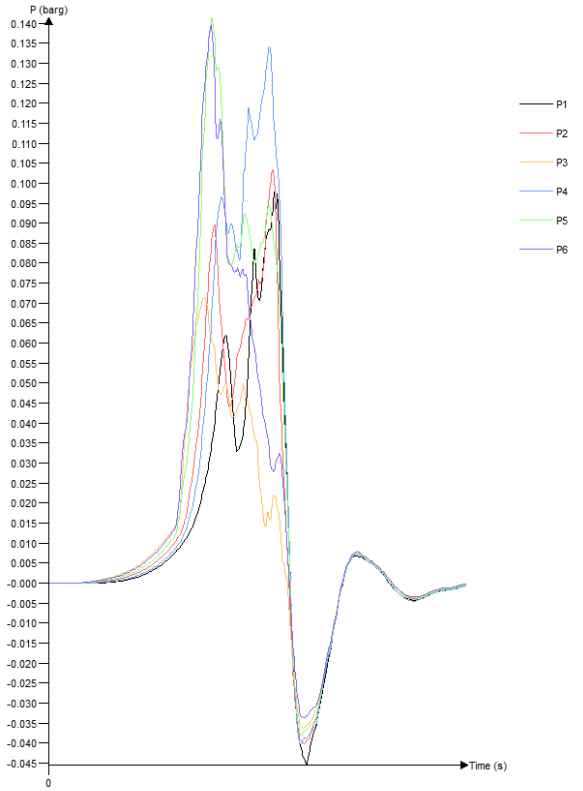




FLACS analyses

Results: effect of ignition location – pressure time histories

JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
g	412222	4X6.5X9 (P2+P1+P0+stair)	refrigerator	0.04	0.04	0.05	0.015	no
h	422222	4X6.5X9 (P2+P1+P0+stair)	bedroom	0.04	0.04	0.05	0.015	no
i	432222	4X6.5X9 (P2+P1+P0+stair)	first floor	0.04	0.04	0.05	0.015	no



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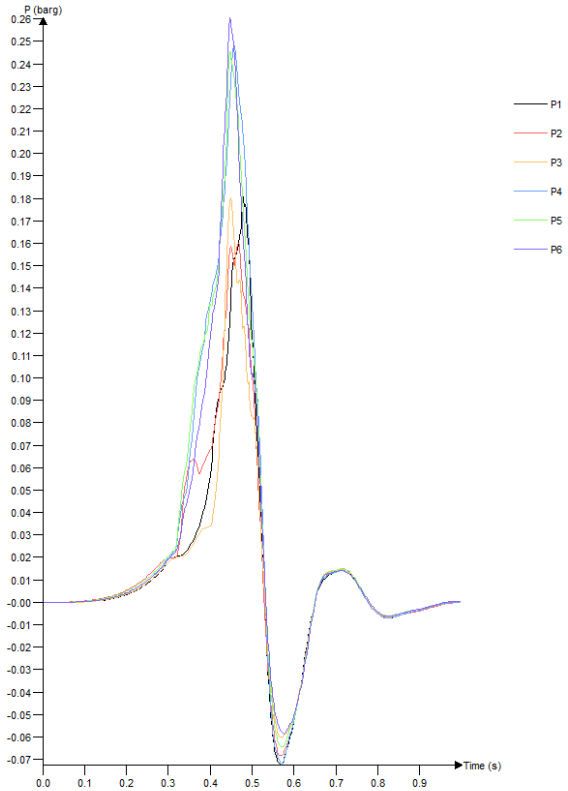

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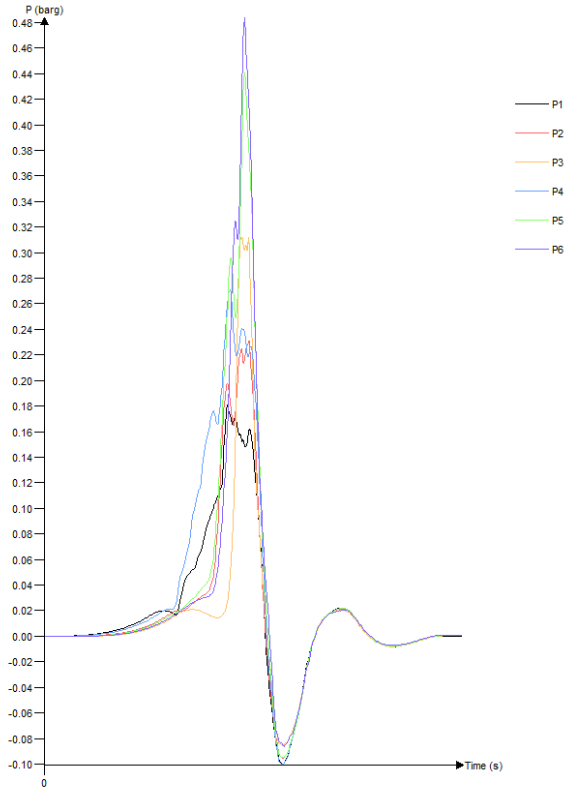

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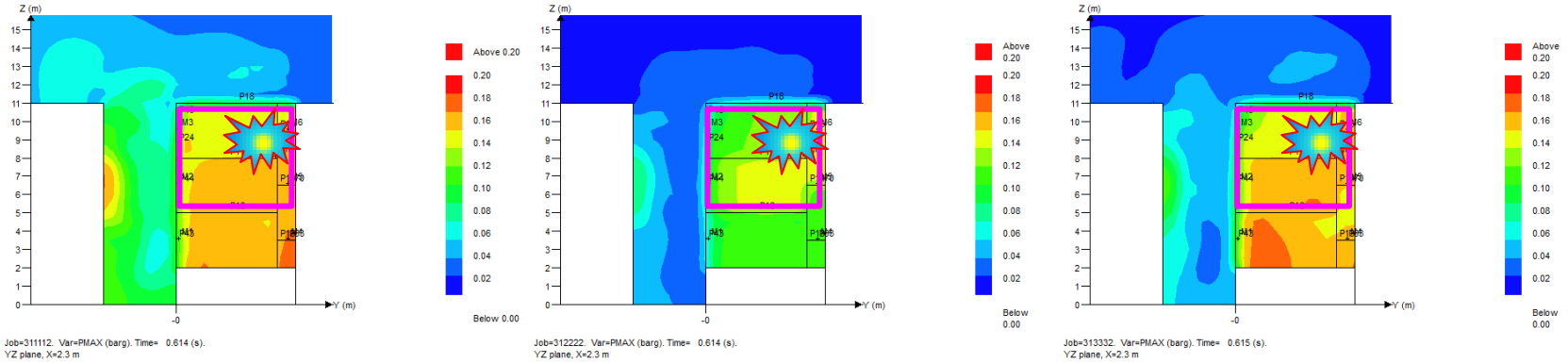
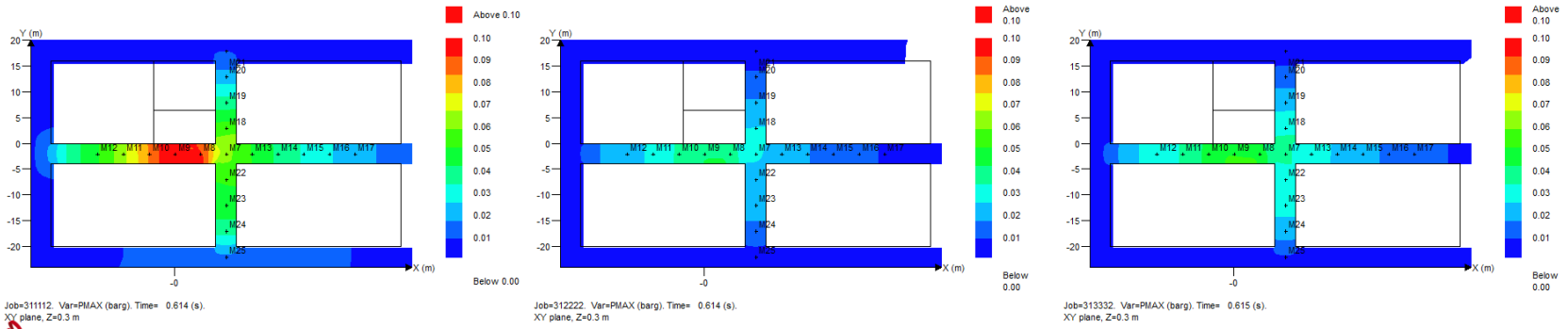
FLACS analyses

Results: effect of structural elements bearing capacity – pressure envelope

JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
j	311112	4X6.5X6 (P2+P1+stair)	refrigerator	0.02	0.02	0.025	0.015	no
k	313332	4X6.5X6 (P2+P1+stair)	refrigerator	0.08	0.08	0.1	0.015	no

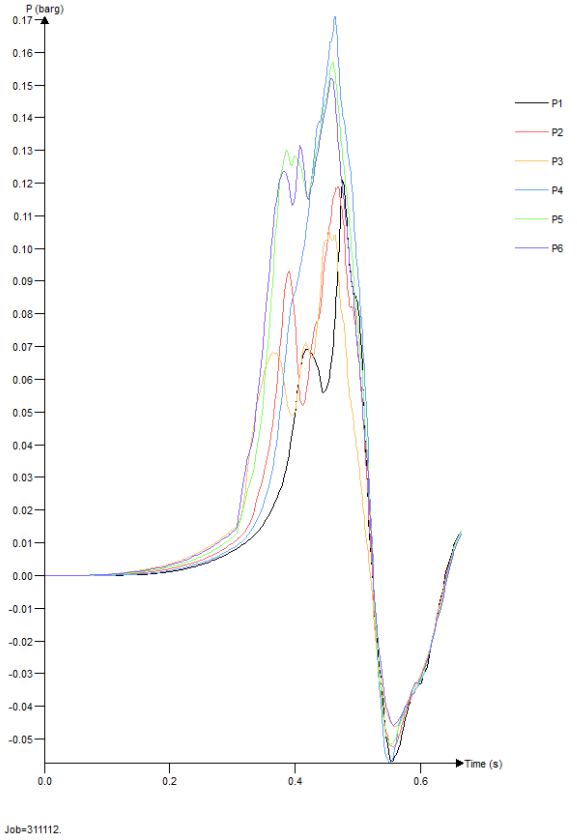


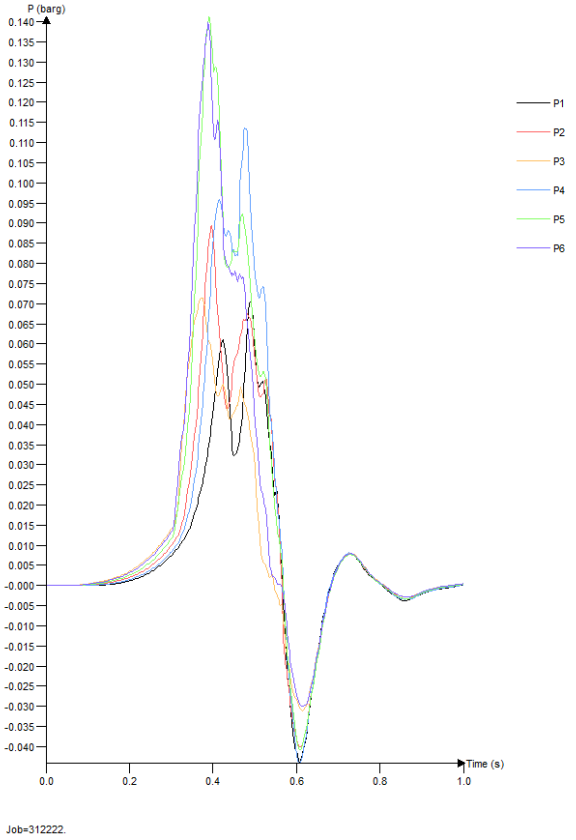


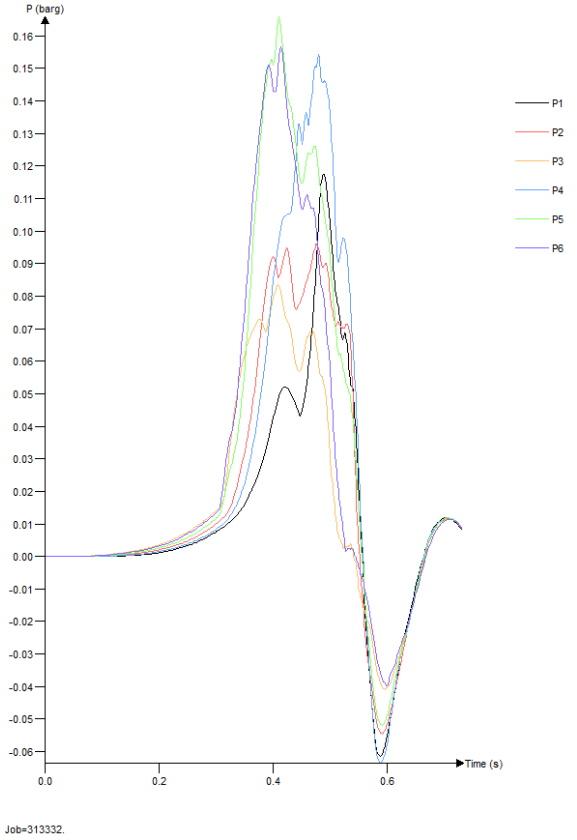
FLACS analyses

Results: effect of structural elements bearing capacity – pressure time histories

JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
j	311112	4X6.5X6 (P2+P1+stair)	refrigerator	0.02	0.02	0.025	0.015	no
k	313332	4X6.5X6 (P2+P1+stair)	refrigerator	0.08	0.08	0.1	0.015	no



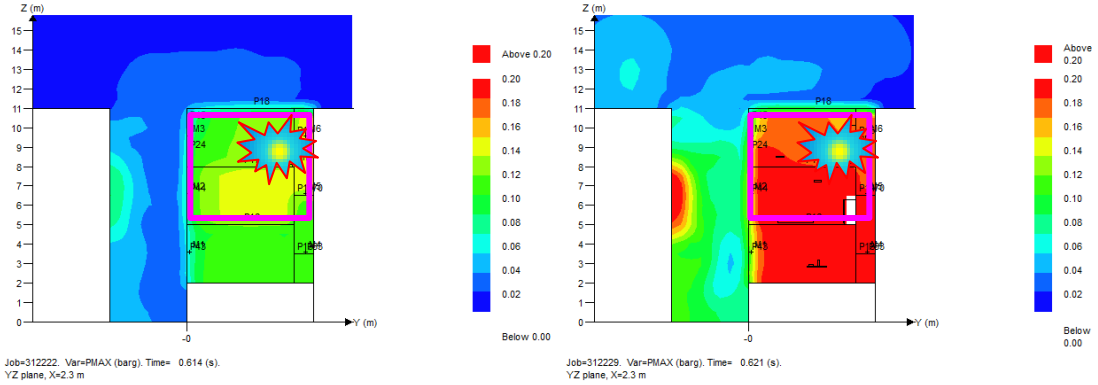


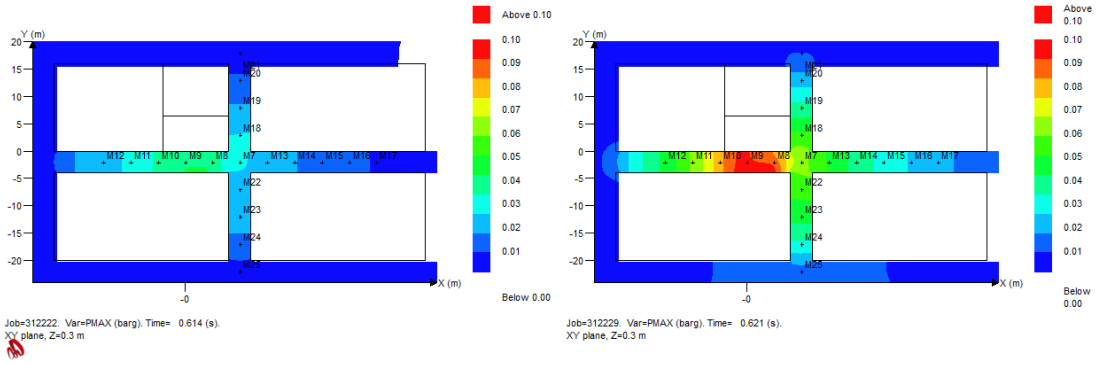


FLACS analyses

Results: effect of domestic congestion – pressure envelope

JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
l	312229	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	yes

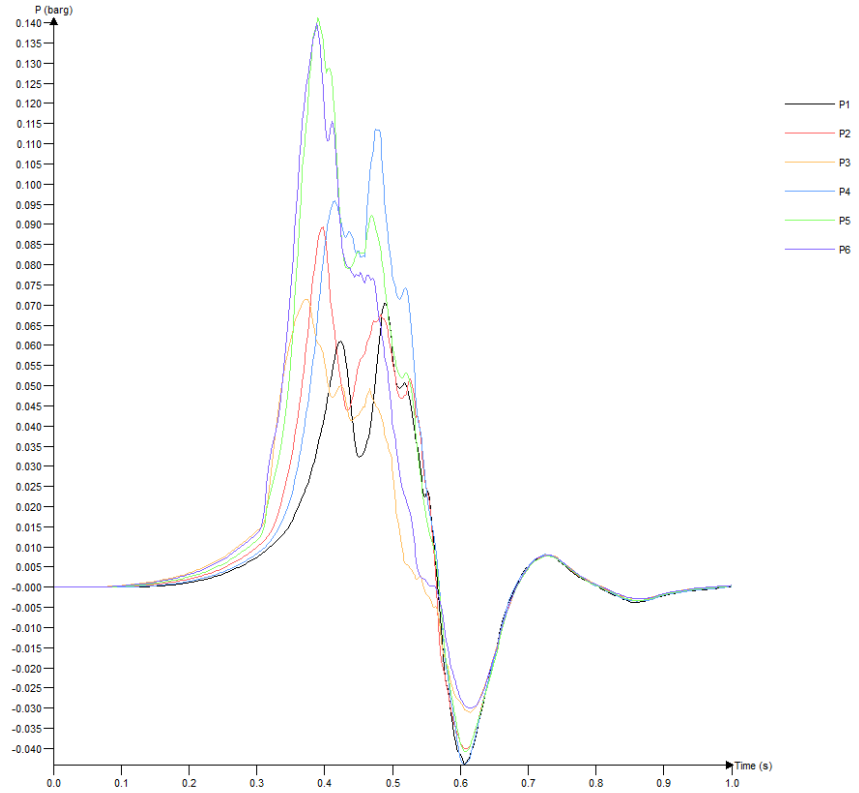


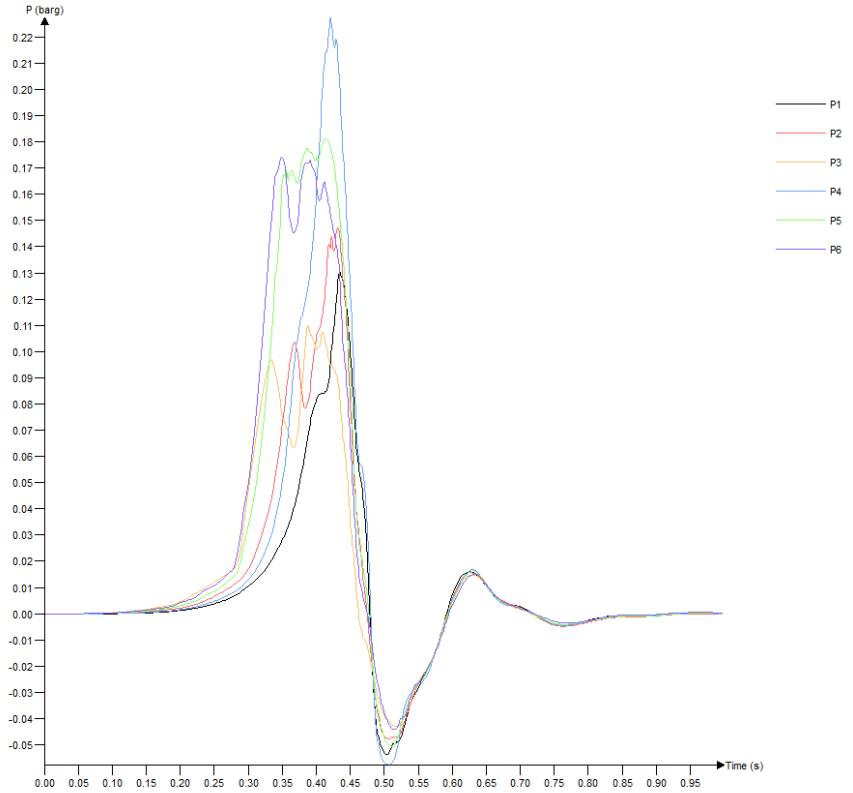


FLACS analyses

Results: effect of domestic congestion – pressure time histories

JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
l	312229	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	yes

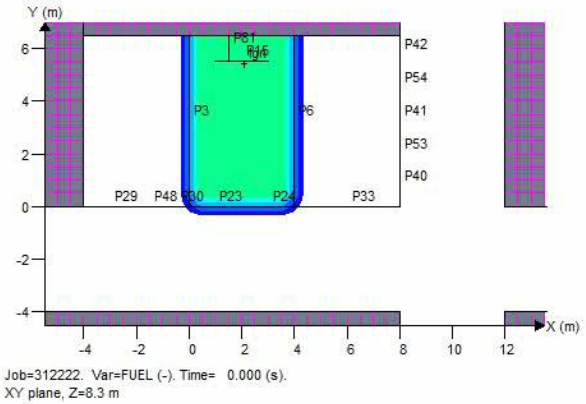


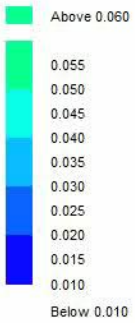


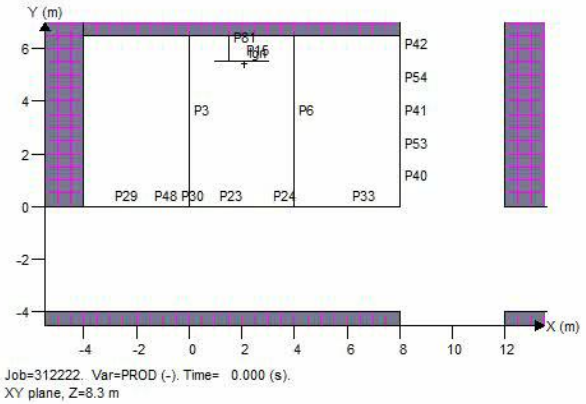
FLACS analyses

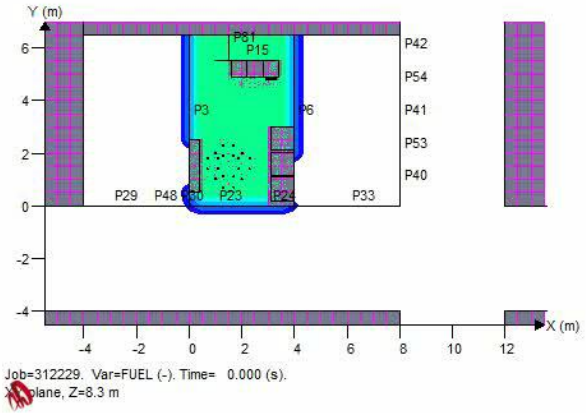
Results: effect of domestic congestion – Fuel & flame propagation

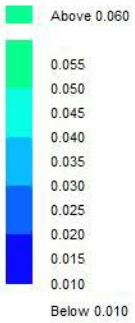
JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
l	312229	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	yes

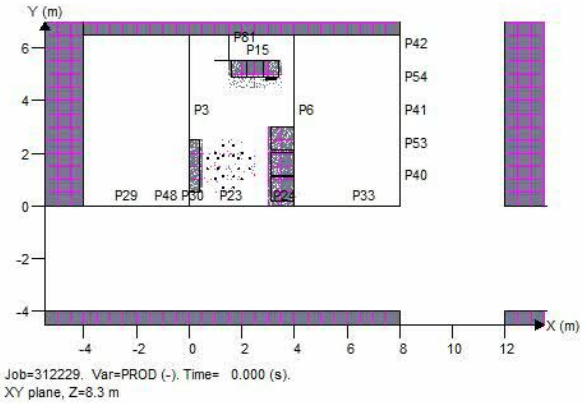








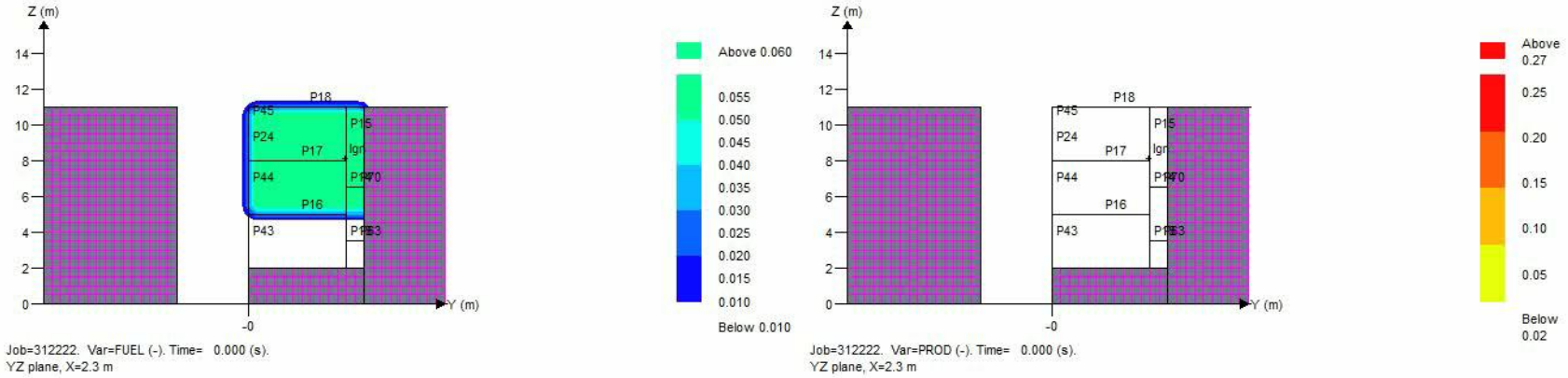




FLACS analyses

Results: effect of domestic congestion – Fuel & flame propagation

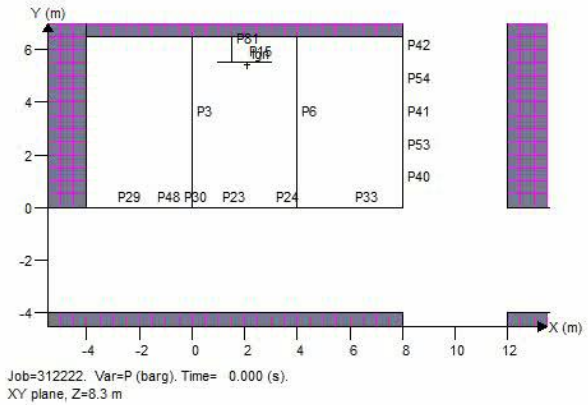
JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
l	312229	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	yes

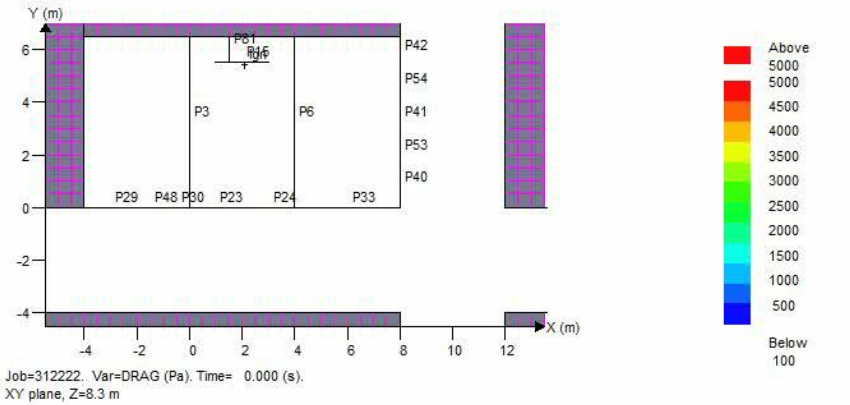


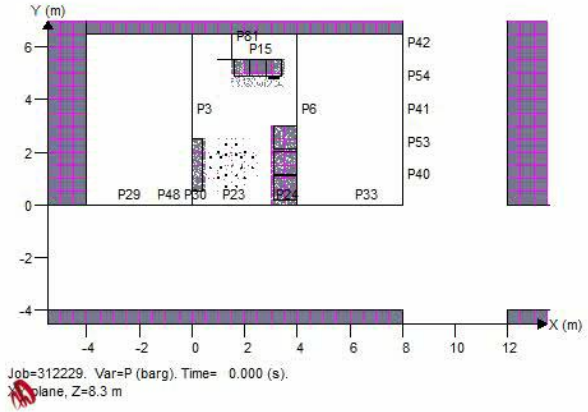
FLACS analyses

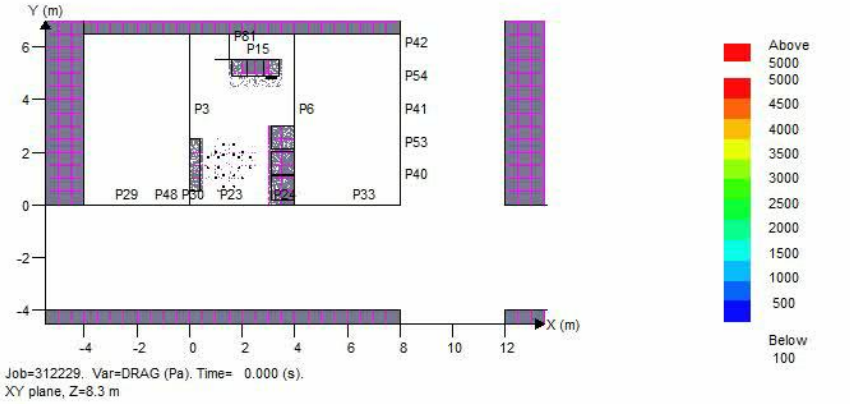
Results: effect of domestic congestion – Pressure and drag (dynamic pressure)

JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
l	312229	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	yes





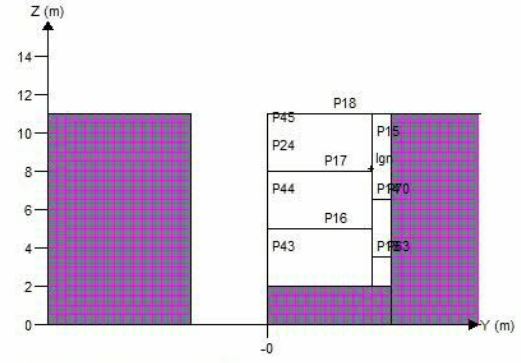


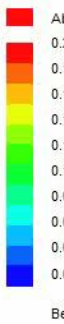


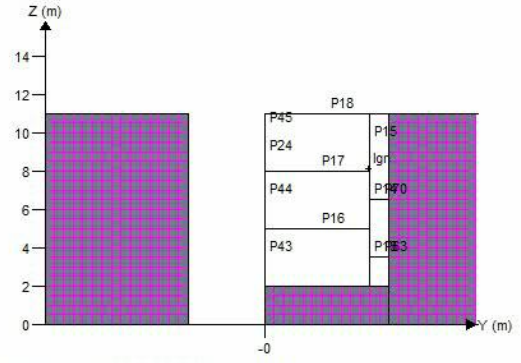
FLACS analyses

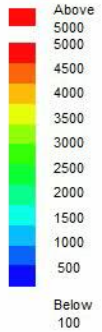
Results: effect of domestic congestion – Pressure and drag (dynamic pressure)

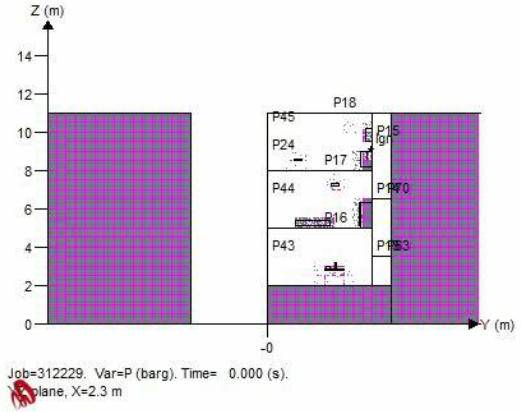
JOB name	JOB label	gas cloud size	ignition position	p0 wall	p0 facade	p0 slab	p0 window	domestic congestion
e	312222	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	no
l	312229	4X6.5X6 (P2+P1+stair)	refrigerator	0.04	0.04	0.05	0.015	yes

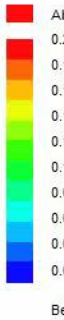


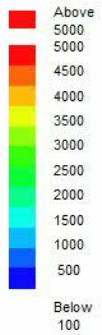












Conclusions

- The use of advencad CFD tools (i.e. FLACS) allows to take into account for real scenario parameters such gas cloud size, ignition source and congestion degree, as well as geometry.

- In accident investigation applications, the use of CFD tools permits to assess the sensitivity of the parameters defining the accident scenario, and to identify the most credible values according to the real damage experienced.

  - ✓ Domestic congestion
  - ✓ Gas cloud position and size
  - ✓ Ignition position
  - ✓ Structural elements bearing capacity

- Further aims of simulations:
  - Forecast (new building design)
  - Research and development (new techiques and materials)

…thank you

cmr Gexcon