TIEMS ANNUAL CONFERENCE 2009

"Risk management starts from risk assessment and simulation"

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RISK IS THE EFFECT OF .....

- PROBABILITY OF HAZARDS
- EXPECTED DAMAGE

R = P X D

The professional assessment of P and D can lead to a proper Risk Management matrix and procedure

INTEGRATED APPROACH TO RISK

QUESTIONS FOR RISK MANAGERS

- Do I know what are the predictable effects of a primary event ? (Fire - Explosion - Toxic release)
- Do I know what kind of hazard I'm facing with?
- Do I know the predictable dispersion of toxic/nocive/flammable/explodible leakage?
- Do I have the detailed (updated) map of the site?
- How can I safely coordinate the rescue/safety teams?

STATISTICS OF FIRE AND EXPLOSIONS

- FIRES AND EXPLOSIONS ININDUSTRY
- FIRE AND EXPLOSIONS IN CIVIL BUILDINGS

ALL THESE QUESTIONS NEED TO BE ANSWERED BEFORE SUCH EVENTS HAPPEN……

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FIRES AND EXPLOSIONS IN PROCESS INDUSTRY

- **SPARKS AND FLAMES CAN LEAD TO A SEVERE EXPLOSION**

Basic Norms and Directives for the risk assessment

Dir 96/82/EC

In the light of recent industrial accidents (Toulouse, Baia Mare and Enschede) and studies on carcinogens and substances dangerous for the environment, the Seveso II Directive 96/82/EC was extended by the Directive 2003/105/EC of the European Parliament and of the Council of 16 December 2003 amending Council Directive 96/82/EC

'SEVESO' DIRECTIVE

The most important extensions of the scope of that Directive are to cover risks arising from storage and processing activities in mining, from pyrotechnic and explosive substances and from the storage of ammonium nitrate and ammonium nitrate based fertilizers. This Directive is addressed to the Member States. They shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive before 1 July 2005

AT.EX. EXPLOSIBLE ATMOSPHERES

AT.EX. 95

Dir 94/99/EC

Economic Directive

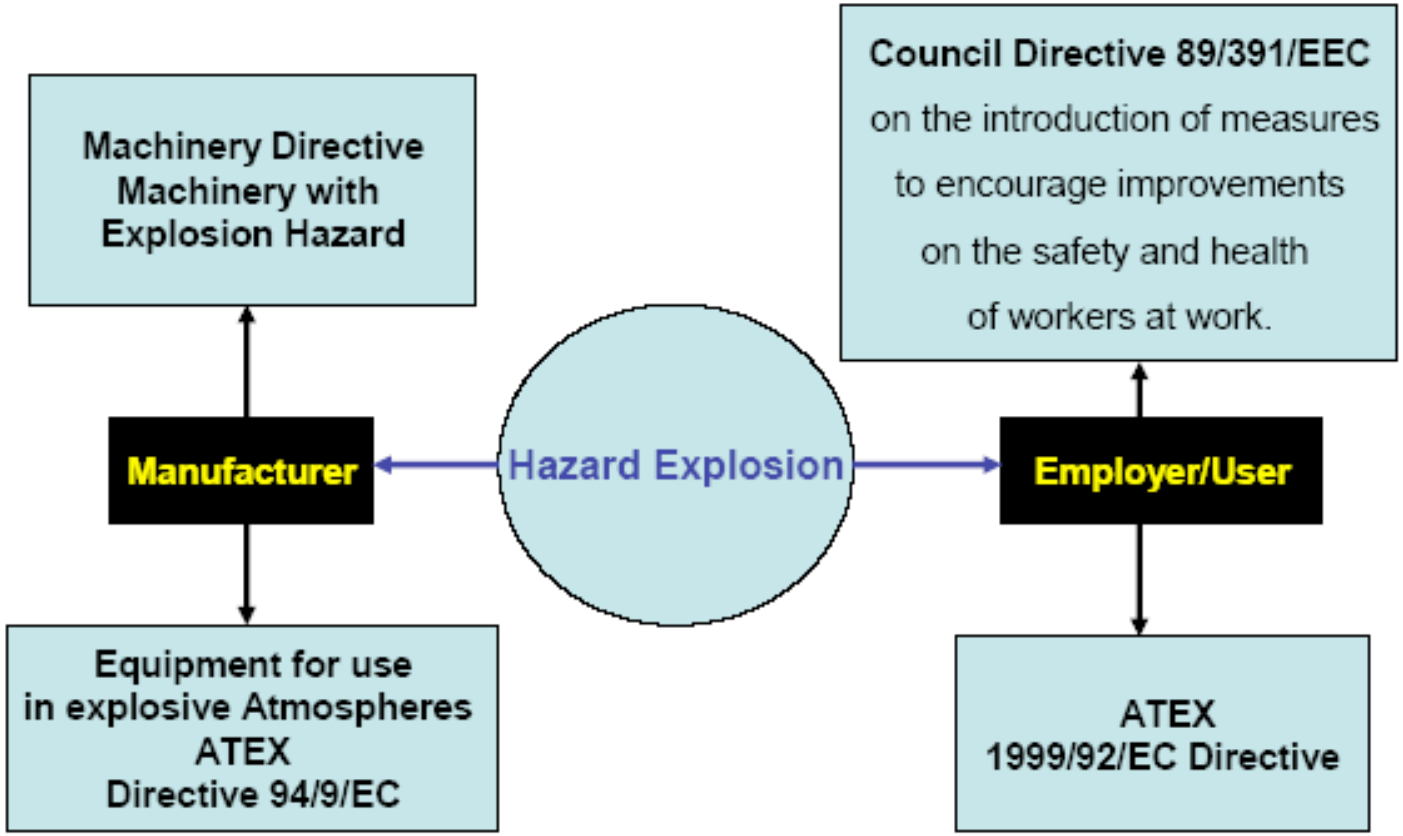
AT.EX.137

Dir 99/92/EC

Social Directive

AT.EX. EXPLOSIVE ATMOSPHERES

Requirements in the field of explosion are shown in the following scheme



MAIN STANDARDS

EN european norms

NFPA national fire protection association

FM factory mutual

+

NATIONAL STANDARDS

EXPLOSIONS IN PROCESS INDUSTRY (1)

EXPLOSIONS IN PROCESS INDUSTRY(2)

THEY ARE OFTEN INTERCONNECTED

- **EFFECT OF EXPLOSION AFTER FIRE**

MODERN APPROCH

TO

FIRE AND EXPLOSION HAZARD

IN THE

PROCESS INDUSTRY

BASIC NEEDS

Professional competence in:

- **FIRE**
- **EXPLOSION**
- **FLAMMABLE/TOXIC RELEASE**

Risk assessment, best technologies,

effects on human beings and assets, their mitigation

BUT ALSO…

…Professional competence in:

PROCESS ENGINEERING

THE RISK ASSESSMENT PROCESS

HAZARD EVALUATION

↓

PREDICTABLE EFFECTS

↓

RISK ASSESSMENT

↓

PREVENTIVE MEASURES

↓

PROTECTIVE MEASURES

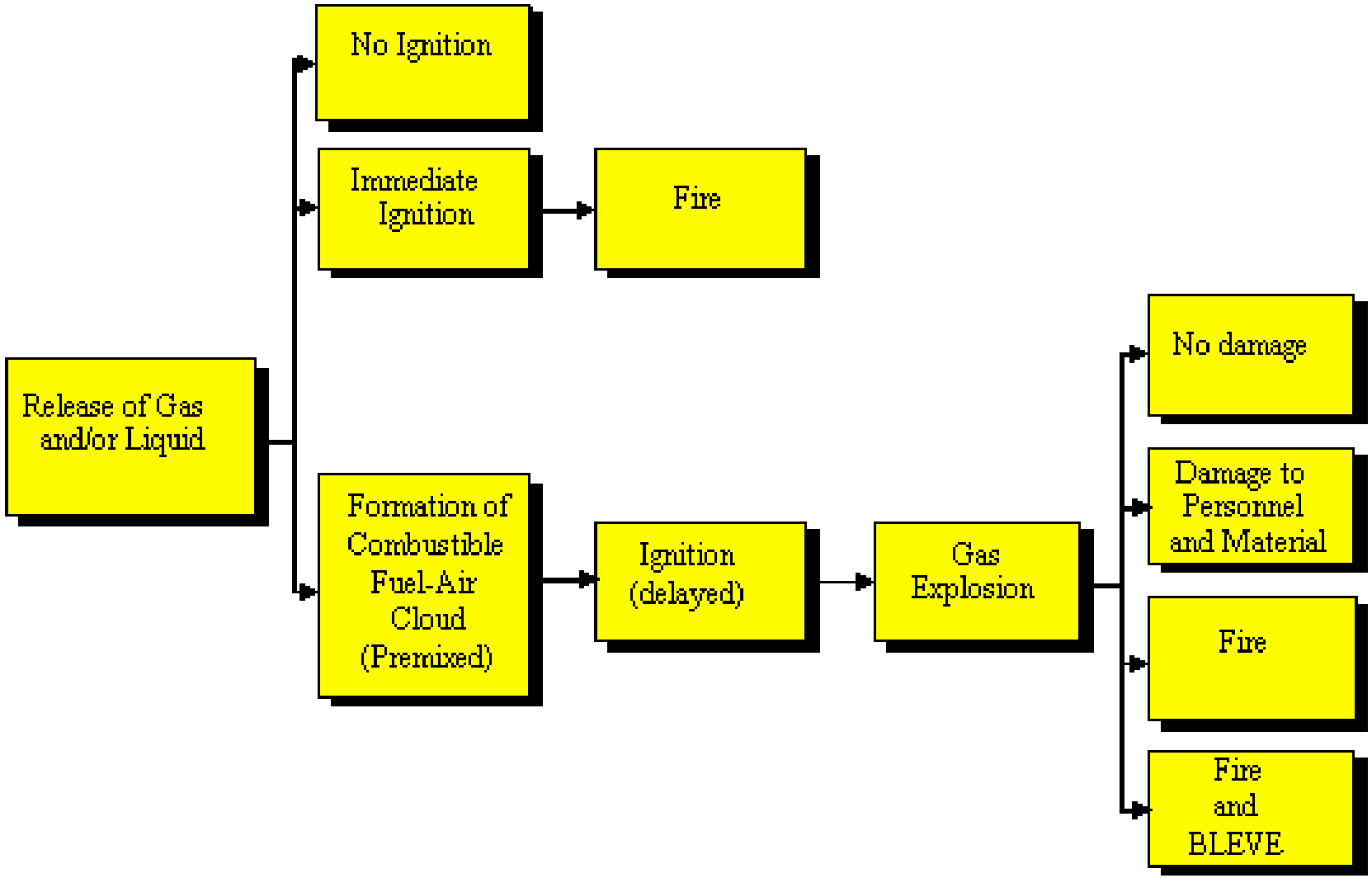
↓

PREDICTABLE EFFECTS AFTER PREV/PROT

↓

RISK MANAGEMENT

THE RISK ASSESSMENT PROCESS



FIRE - EXPLOSION

Are two exhotermic phenomena

Related to

- **material properties**
- **effective ignition sources**

HAZARD EVALUATION

- **DUSTS AND LIQUIDS MAY EXPLODE AND SPREAD FIRE**

PHYSICAL AND CHEMICAL PROPERTIES TO BE KNOWN

Product	Particle Size (avg9 µm	LEL (g/m^3)	MIT/LIT (°C)	MIE (mJ) (with/without inductance)	Pmax (bar)	Kst (barm/s)	moisture %	Expl class	resistivity (Ωm)(1)
Sugar	591,7	20	350/280	10<MIE≤30	5,9	49	2	St1	A
Wheat flour	30	60	400/320	> 30	8,4	70	13-15	St1	Mb
Cacoa 10-12%	> 10	15	530/430	>10	8,3	98	4,6	St1	M
Cacoa 20–22%	< 63	30	490/430	>1EXP5	7,3	83	2	St1	M
Maltodextrin	< 63	30	380/250	5	7,6	133	2	St1	A

PHYSICAL AND CHEMICAL PROPERTIES TO BE KNOWN

Product	Flash point ° C	Density	Range					Ignition temp °C	Volumic mass kg/m³	Molar mass kg/kmol
			LEL % vol	UEL % vol.	Boiling point °C	Vapour tension 20°C	Vapour tension 40°C			
LPG	< 0	> 1,50	2,00	9,00	-42	800 370	1 269 928	365	507	44,094
Methane	< 0	0,554	4,40	17,00	-161,4			537	415	16,04
Natural gas	< 0	0,5-0,65	3,93-6,60	13,20-17,50	< 0			482		17,85-13,734

PHYSICAL AND CHEMICAL PROPERTIES TO BE KNOWN

Product	Specific Heat at Ambient T J(kg K)	MIE (mJ)	Kg (bar m/s)	P max (bar)	Flame speed (cm/s)	Group T class
LPG	2225					IIBT2
Methane	3454	0,21	55	7.1	40	IIAT1
Natural gas		0,21	55	7.1	40	IIAT1

OTHER PROPERTIES TO BE KNOWN

MSDS

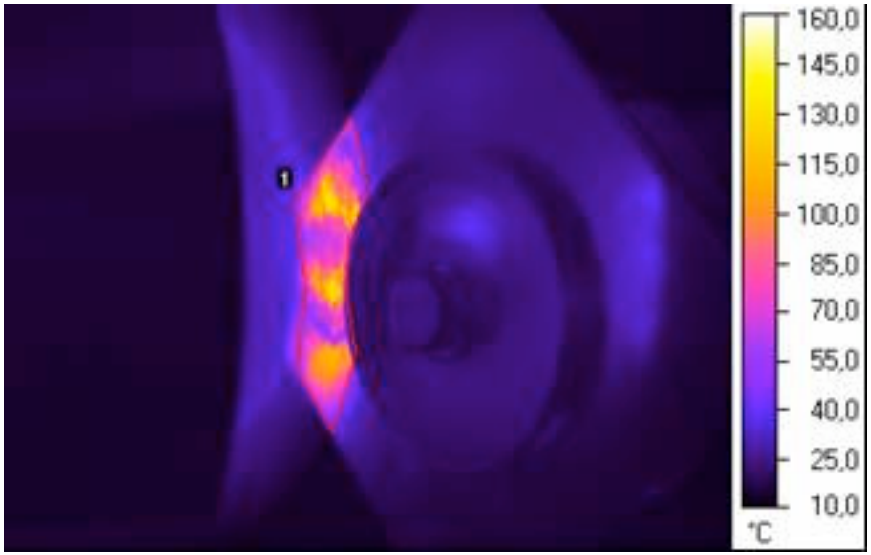
A Material Safety Data Sheet (MSDS) is a document that contains information on the potential health effects of exposure to chemicals, or other potentially dangerous substances, and on safe working procedures users should adhere to when handling chemical products.

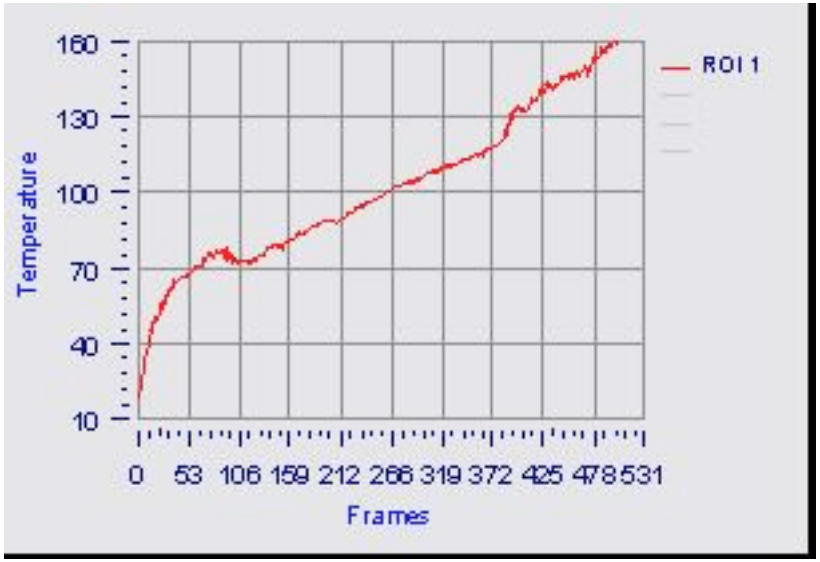
IGNITION SOURCES

Possible Ignition Sources

- Hot surfaces
- Flames and hot gases (hot particles)
- Mechanical sparks
- Electrical equipment
- Stray electric currents (e.g. from Cathodic protection systems)
- Static electricity
- Lightning
- High frequency radiation
- Optical radiation
- Ionising radiation
- Ultrasonics
- Adiabatic compression and shock waves
- Chemical reaction

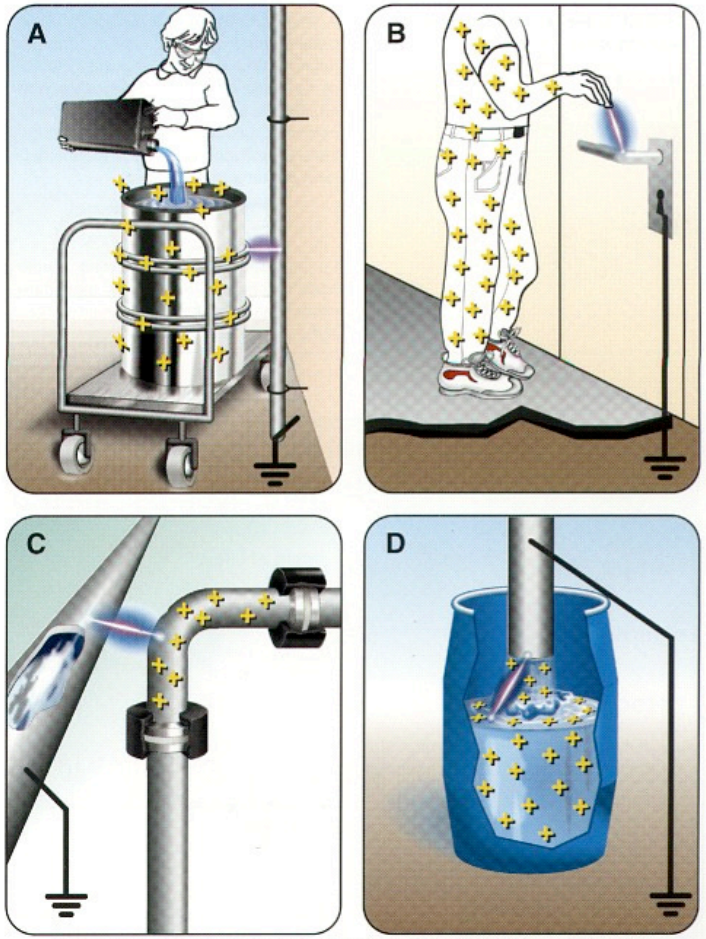
HOT SURFACES





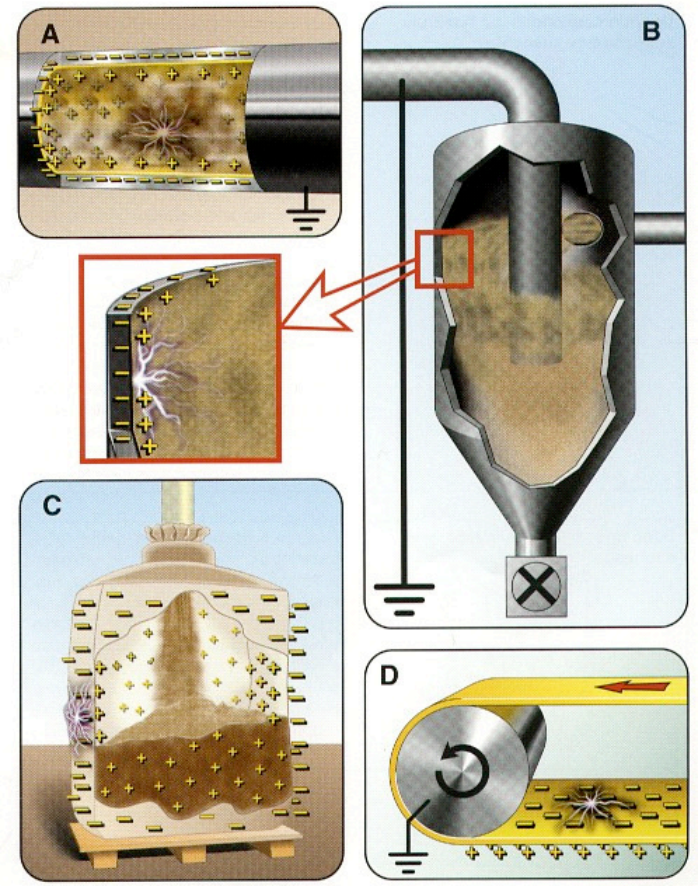
TERMOGRAPHIC SURVEY

STATIC DISCHARGE



Esempi di casi pratici di scariche disruptive – A: fusto metallico isolato da terra B: persona isolata da terra (scarpe isolanti) C: tubo a gomito isolato mediante guarnizioni D: liquido conduttore isolato mediante il fusto di plastica

STATIC DISCHARGE



Esempi pratici di scariche a pennacchio
A: in una tubazione con rivestimento interno isolante
B: in un separatore di polvere con rivestimento interno isolante
C: su un contenitore in materiale isolante
D: su un nastro trasportatore isolante che scorre veloce

IN THE PROCESS INDUSTRY, FIRE AND EXPLOSION HAZARDS MUST BE ASSESSED TOGETHER

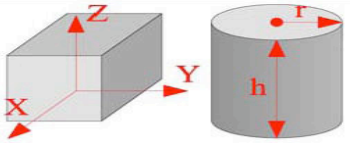
COMBINED PREVENTION AND PROTECTION

HAZARD EVALUATION

ZONING

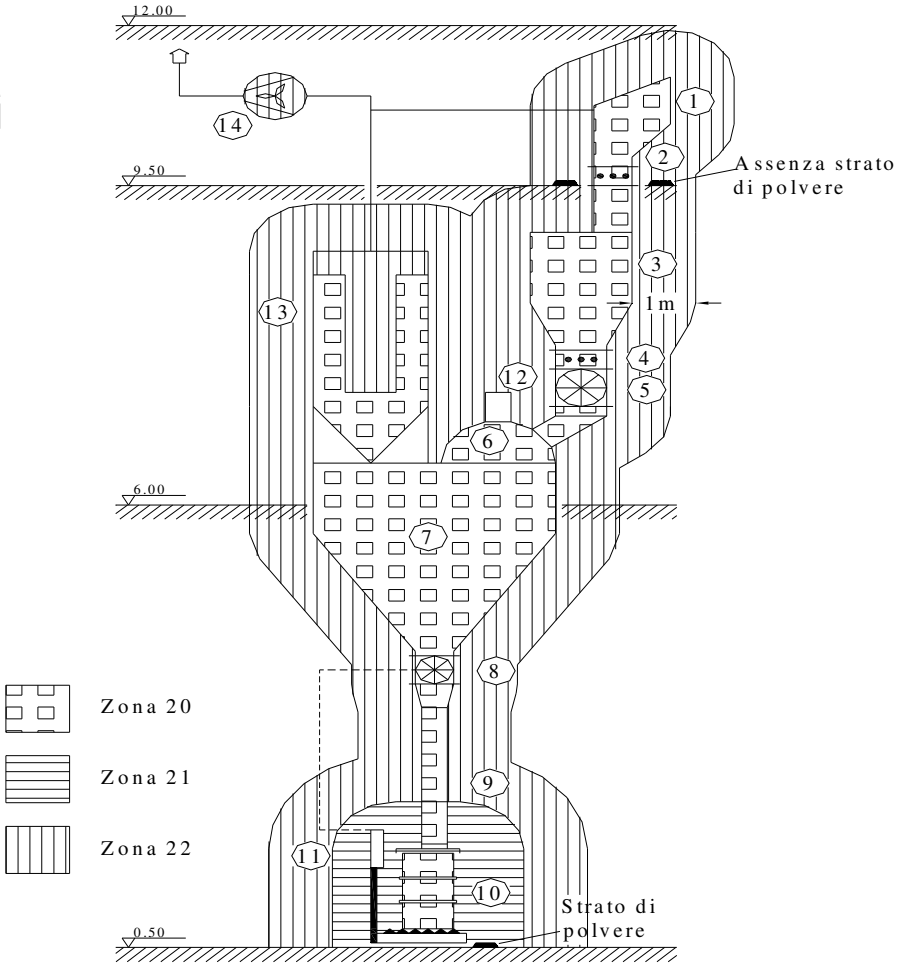
IMPIANTO:						Rif.			CP		
COMPONENTI DI IMPIANTO: *Filtro a maniche*	Grado di emissione		Condizione operativa			Parametri fisici					
SORGENTE DI EMISSIONE	primo	secondo	sovrapressione	press. atmosferica	depressione	angolo uscita α	velocità di uscita (v) m/s	distanza massima calcolata (D) m	distanza corretta per influsso vento (v^1) m/s		
Portella di ispezione o passo d'uomo		X			X	45	2	0,87	0,97		
Membrana antiscoppio											
Albero estrattore											
Portella antintasamento											
Flangia di connessione (altre parti)		X			X	45	2	0,87	0,97		
Flangia fondo vibrato											
Flange condotti											
Flangia sensore (livello-temperatura.)											
Flangiature elementi strutturali		X			X	45	2	0,87	0,97		
Tenuta albero orizzontale											
Tenuta albero verticale bassa ☐ alta ☐											
Giunto Morris											
Raccordi flessibili											
Valvola di sovrappressione											
Specola											
Collettore aria pulita		X	X(2)			0/90	15	11,7	11,9		
Tenuta albero ventilatore		X			X						
Manichella											
Temperatura ambientale max	35°C					**Velocità aria ambiente**					0,15

Estensione Zona		
	Esterno piano x-y (raggio) m	0,97
	Esterno piano y-z (altezza) m	fino a terra
	Interno m	



Note: La velocità iniziale è riferita alla fase di controlavaggio maniche
* l'ipotesi considera la rottura maniche ed il collettore a quota m 3

ZONING

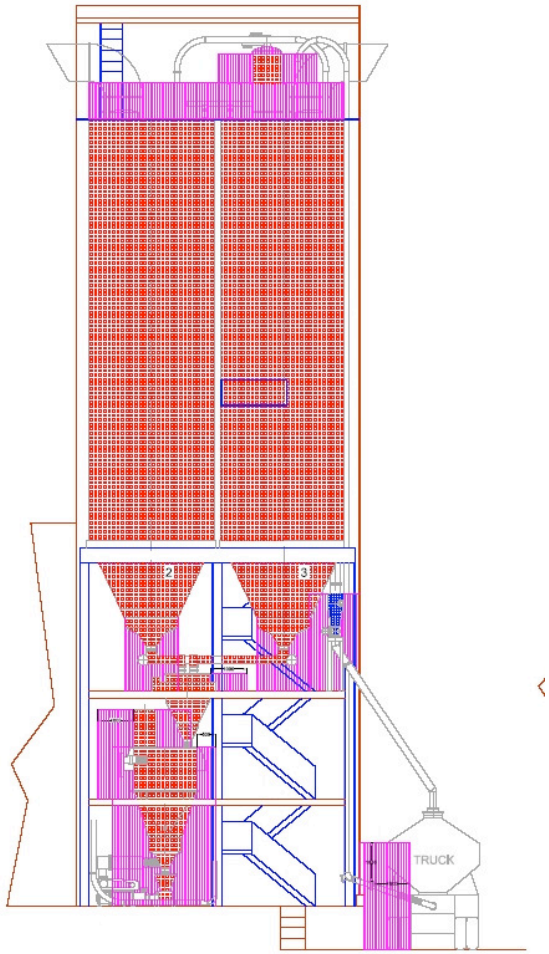


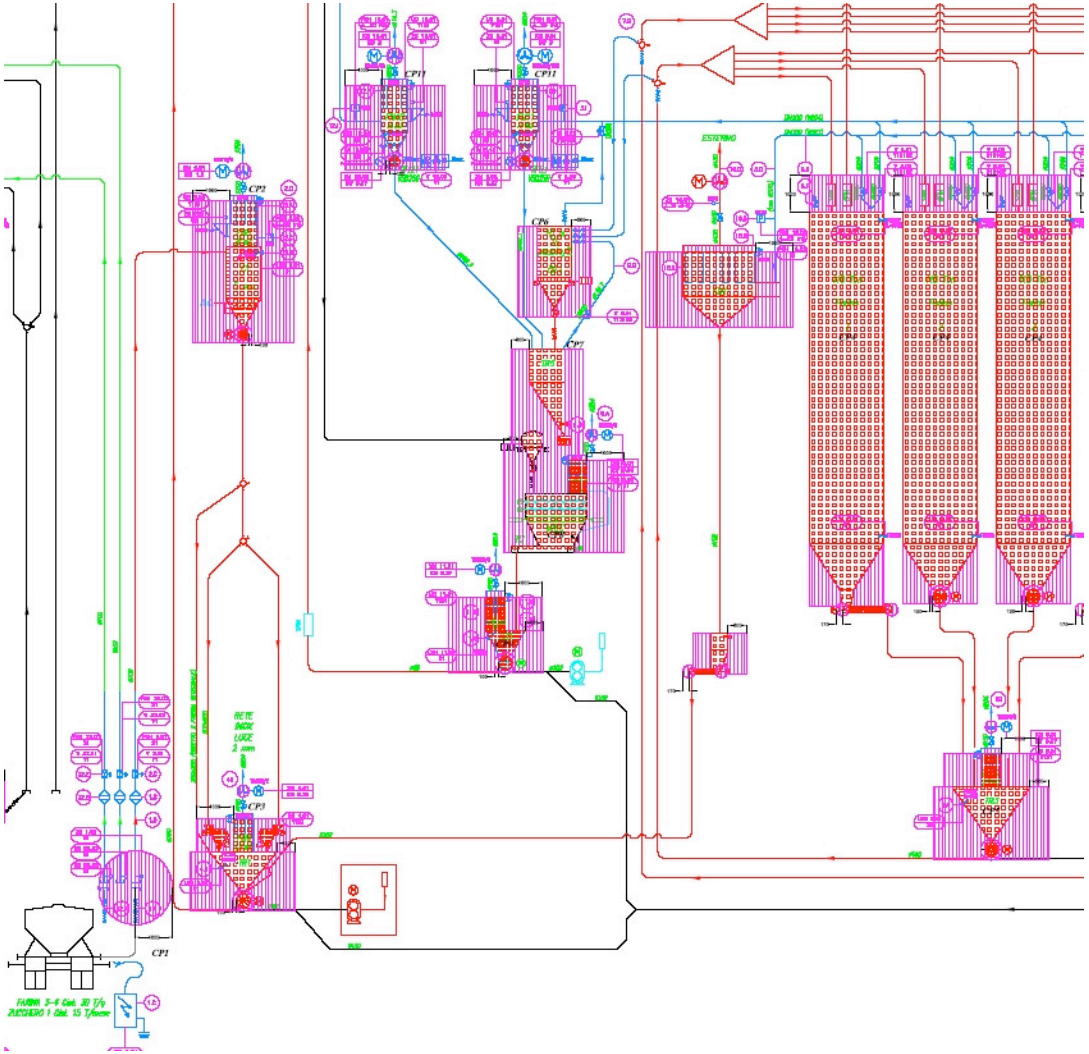
Note: accoppiamento tra 9 e 10 permette il rilascio di polvere in ambiente durante il normale funzionamento

Item	Designation
1	Tramoggia di alimentazione
2	Macinatore
3	Tramoggia alimentazione mulino
4	Deferizzatore
5	Rotocella
6	Mulino a martelli
7	Sostatore
8	Rotocella
9	Raccordo flessibile
10	Fusto
11	Bilancia
12	Prelievo aria ambiente
13	Filtro
14	Ventilatore

HAZARD EVALUATION

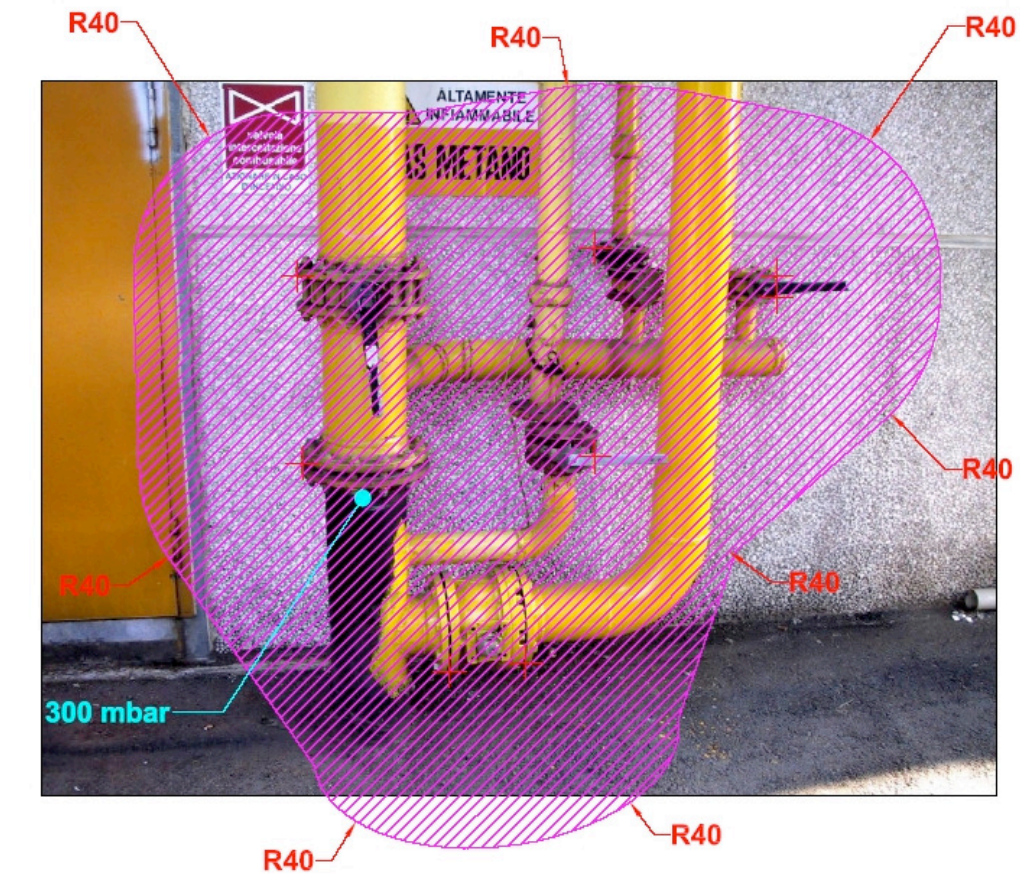
ZONING





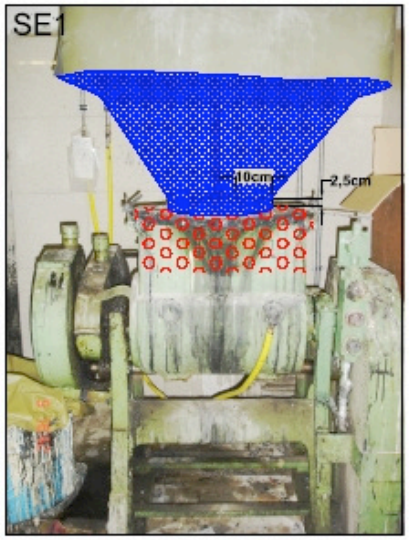
HAZARD EVALUATION

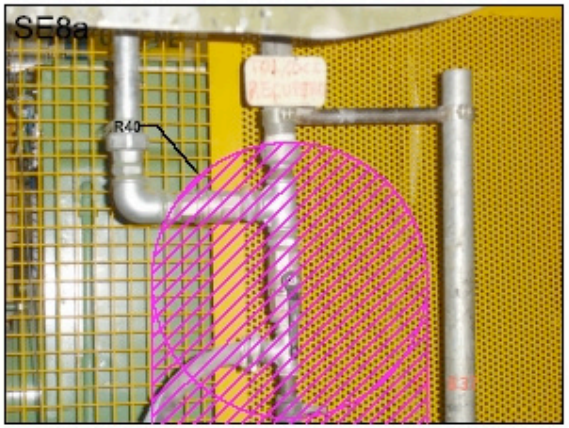
DIGITAL ZONING



HAZARD EVALUATION

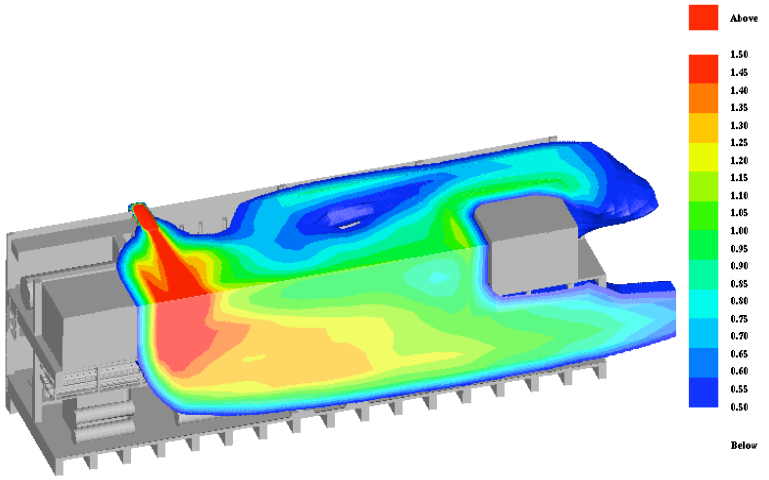
ZONING





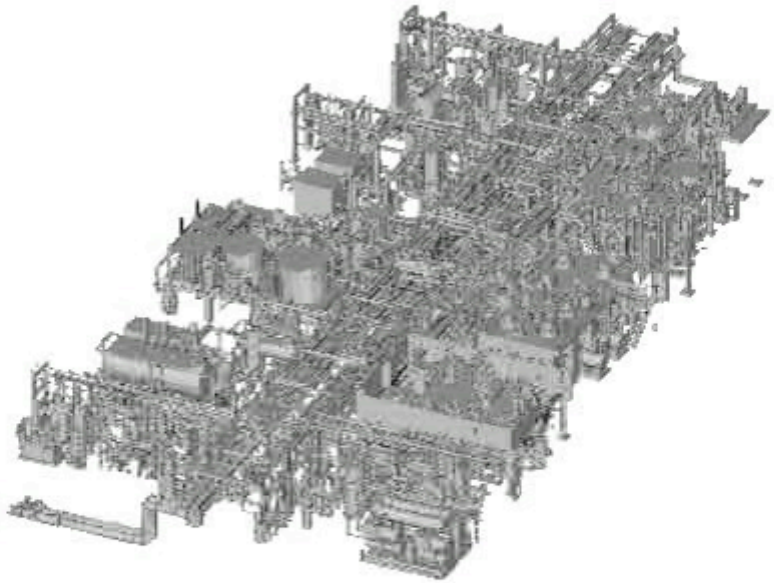
ZONING WITH SIMULATION

- Modeling of gas/dust release
- Leak source location, size, and direction
- Forced and natural ventilation conditions
- Concentration profiles at different heights
- Jet release/diffusive release
- Realistic scenario design: Ignition at any time or location during dispersion



ZONING WITH SIMUL

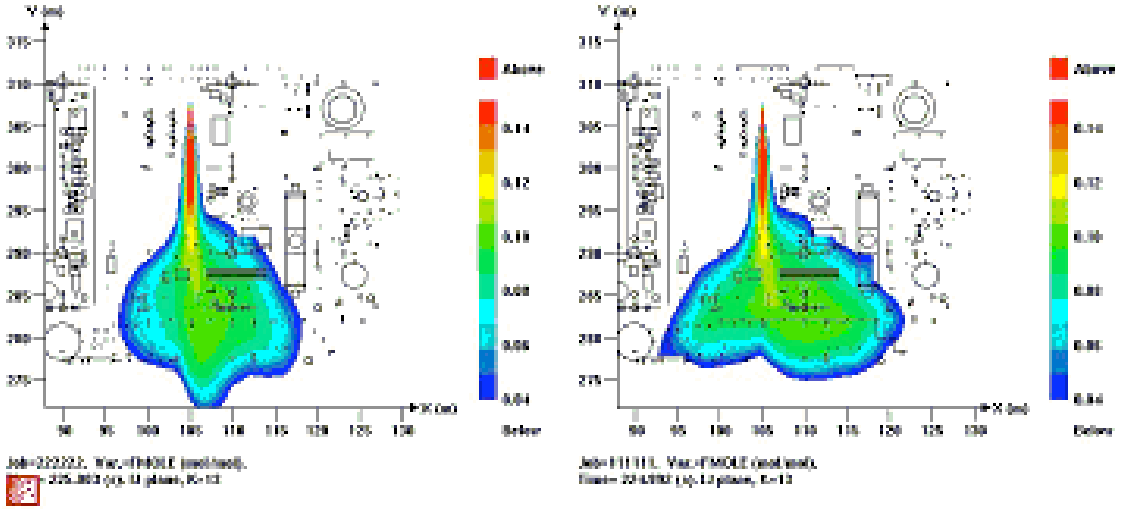
DISPERSION MODEL



Job=361717. Var=ER (-). Time= 38.966 (s).
X=-847 : -731, Y=428 : 491, Z=101 : 107 m

HAZARD EVALUATION

Ventilation Simulations



- Modeling of external wind field
- Modeling of forced/HVAC ventilation
- Louvre drag factors
- Air change rates at varying external wind conditions
- Effect of netting and other blockages
- Flow velocities in the module and through the louvre

HAZARD EVALUATION

- **DISPERSION MODEL is the simulator in the area of dispersion and ventilation.**
- **Due to the ability to represent detailed geometries with the distributed porosity concept, the dispersion capabilities have proven particularly powerful for calculating release scenarios in process areas, in which the density of objects and pipes is high. The Model has been extensively validated against large-scale realistic release and explosion tests and full-scale experiments carried out at Advantica test site Spadeadam in a 2600m3 semi-confined model of an offshore module.**

HAZARD EVALUATION

The dispersion models are very suitable for calculations of explosion cloud sizes and the use in explosion risk assessments. Recent work has been addressing the ability to simulate toxic release scenarios onshore, in which representation of terrain and turbulent wind profiles are important. Models for release and dispersion of aerosols are also under development.

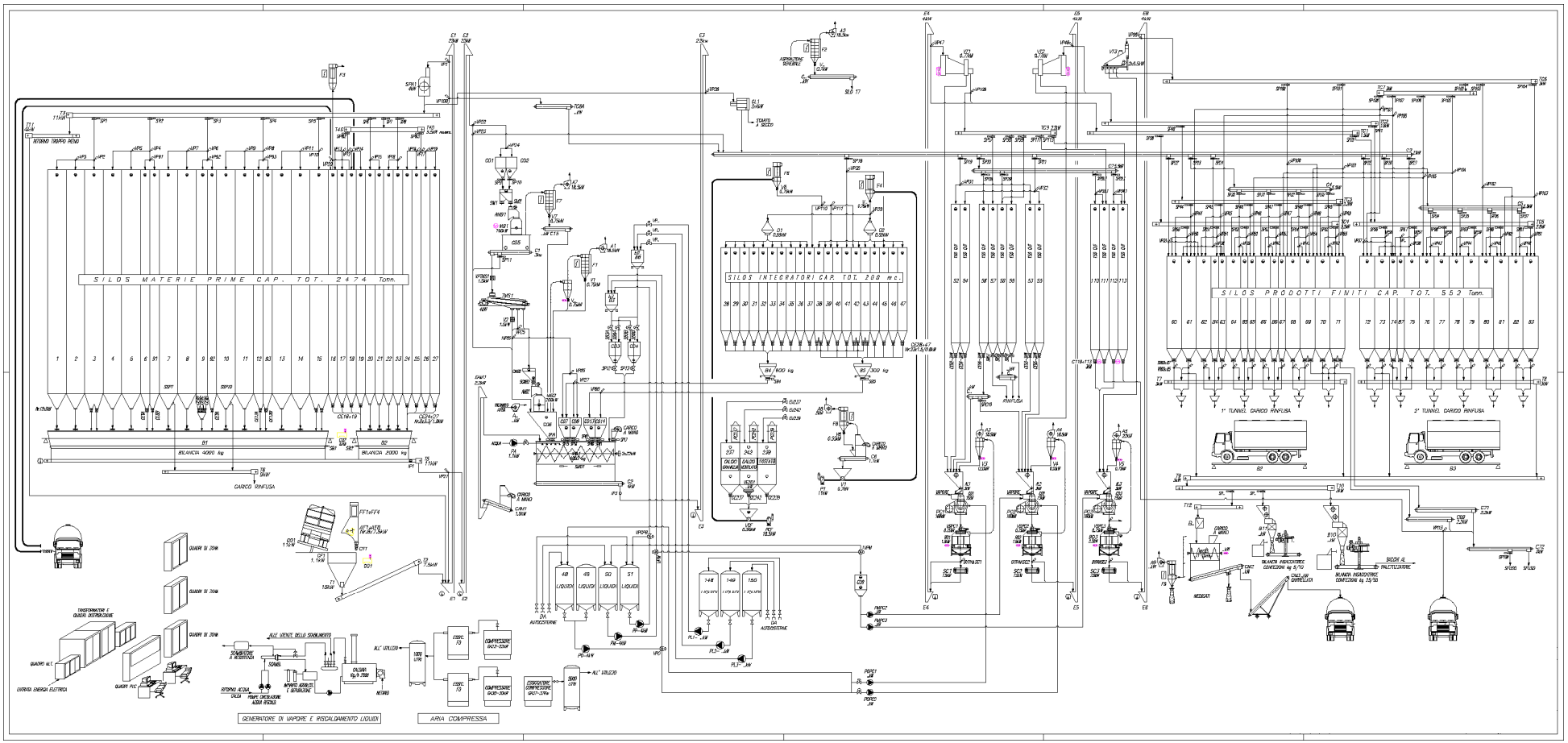
HAZARD EVALUATION

Capabilities of the simulator:

- Geometry import from CAD
- Various gases (More than 10 + user defined) and mixtures of these
- Wind boundary conditions with wind profiles
- Effect of water deluge on dispersion
- Efficient pre-processing, reasonable simulation times
- Export of gas cloud to explosion calculations (FLACS)
- Data to estimate transient ignition probabilities and cloud sizes
- Local gas concentrations and accumulated cloud estimates
- 2D and 3D field plots of various variables
- Automatic generation of mpg-videos from postprocessor
- Extensive validation (Phase 3B, Dispersion JIP, GSP, Licorefla, SMEDIS)

HAZARD EVALUATION

P&Id

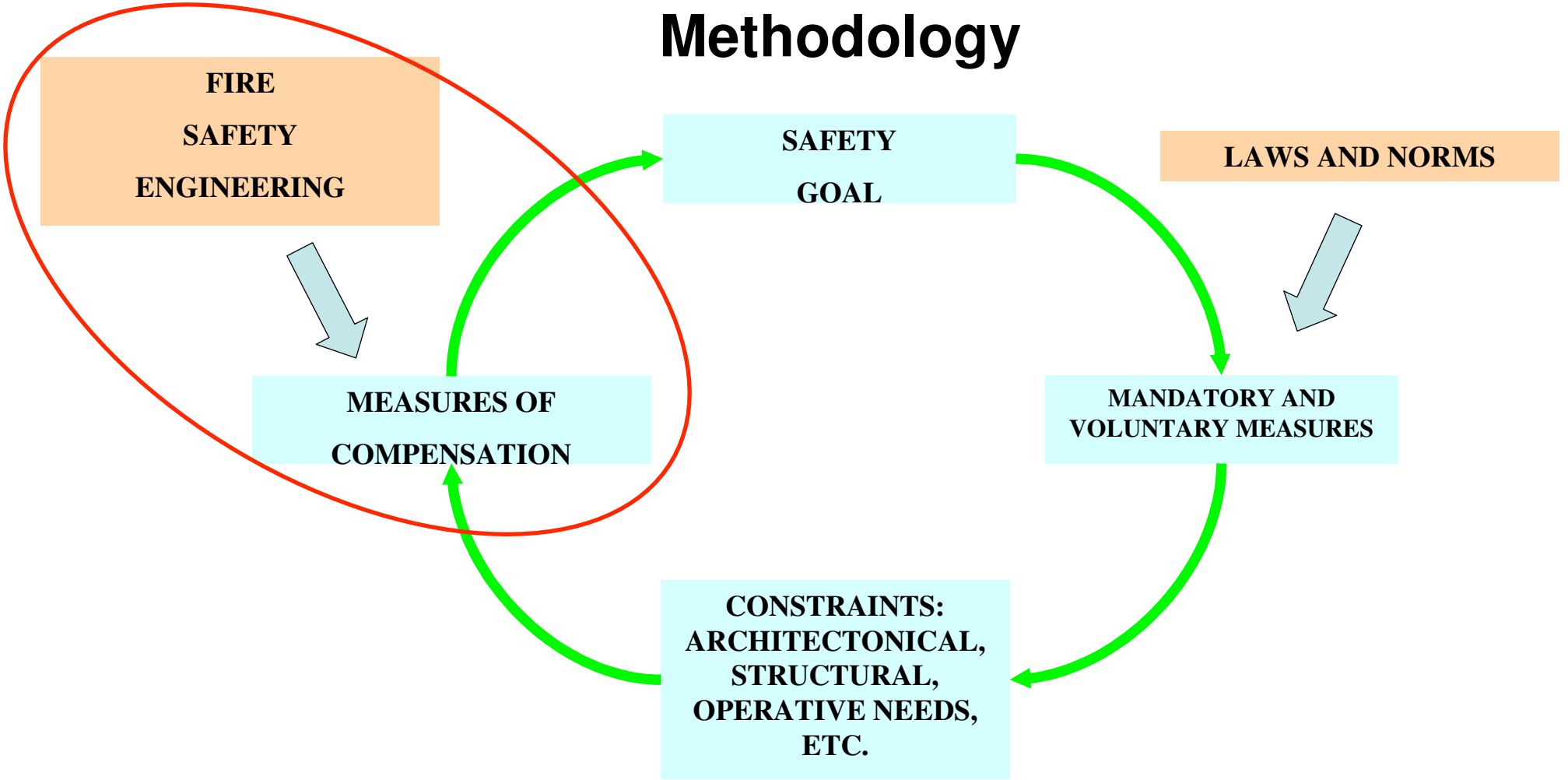


PREDICTABLE EFFECTS

- **FSE (Fire Safety Engineering)**
- **GAS EXPLOSIONS**
- **DUST EXPLOSIONS**

FSE (FIRE Safety Engineering)

Methodology



FSE – State of the art

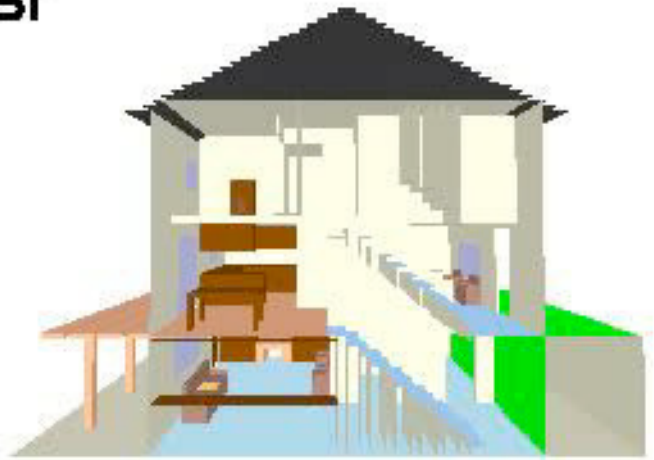
NB	TITLE	DATE PUBBL.
ISO/TR 13387-1	Fire Safety Engineering - Parte 1: applicazione dei concetti prestazionali antincendio agli obiettivi di progetto	01/10/1999
ISO/TR 13387-2	Fire Safety Engineering - Parte 2: progetto degli scenari di incendio e progetto degli incendi reali	01/10/1999
ISO/TR 13387-3	Fire Safety Engineering - Parte 3: analisi e verifica dei modelli matematici d'incendio	01/10/1999
ISO/TR 13387-4	Fire Safety Engineering - Parte 4: base e sviluppo dell'incendio e generazione degli effluenti dell'incendio	01/10/1999
ISO/TR 13387-5	Fire Safety Engineering - Parte 5: movimento degli effluenti dell'incendio	01/10/1999
ISO/TR 13387-6	Fire Safety Engineering - Parte 6: risposta strutturale e propagazione del fuoco al di là dell'ambiente di sviluppo	01/10/1999
ISO/TR 13387-7	Fire Safety Engineering - Parte 7: rilevazione, attivazione dei sistemi di spegnimento e spegnimento dell'incendio	01/10/1999
ISO/TR 13387-8	Fire Safety Engineering - Parte 8: salvaguardia della vita umana - comportamento, localizzazione e condizioni di sicurezza degli occupanti l'edificio	01/10/1999

FSE - FIELD MODEL

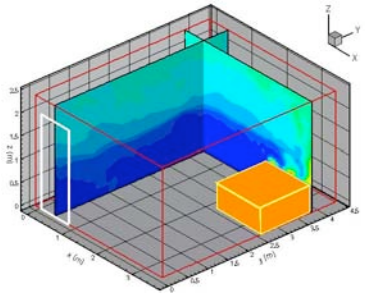
NIST

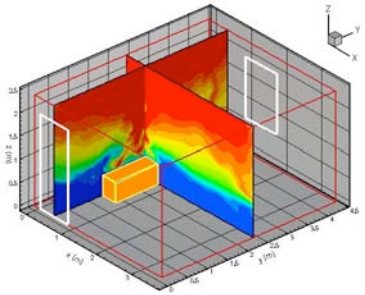
Time: 0.1

NIST



Time: 0.1





WHAT IS IT USED FOR?

OUTPUT?

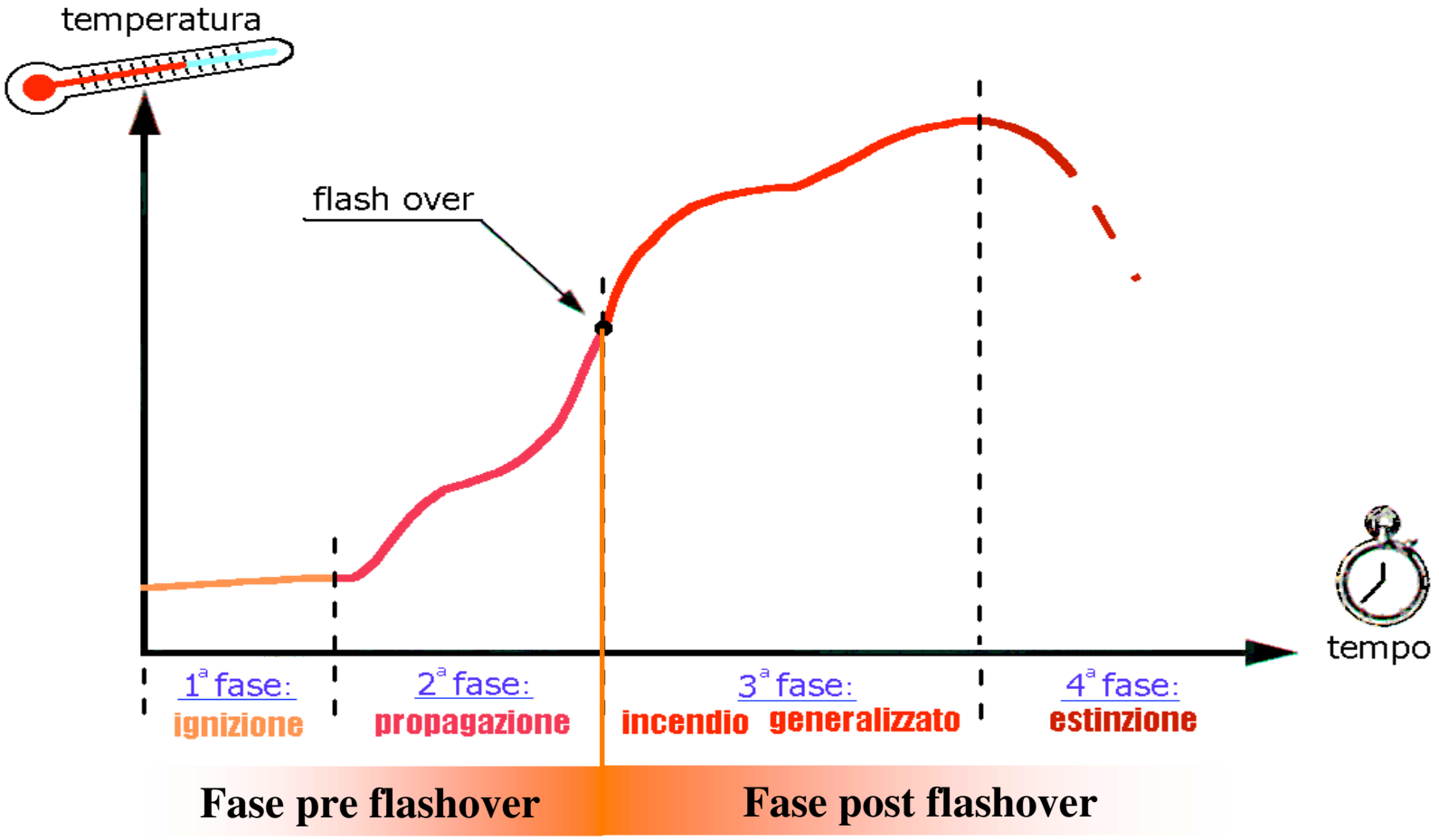
FSE - RESULTS

- **NATURAL FIRE CURVE (TEMPERATURE TIME RELATED)**
- **HEAT RELEASE RATE CURVE (HRR)**

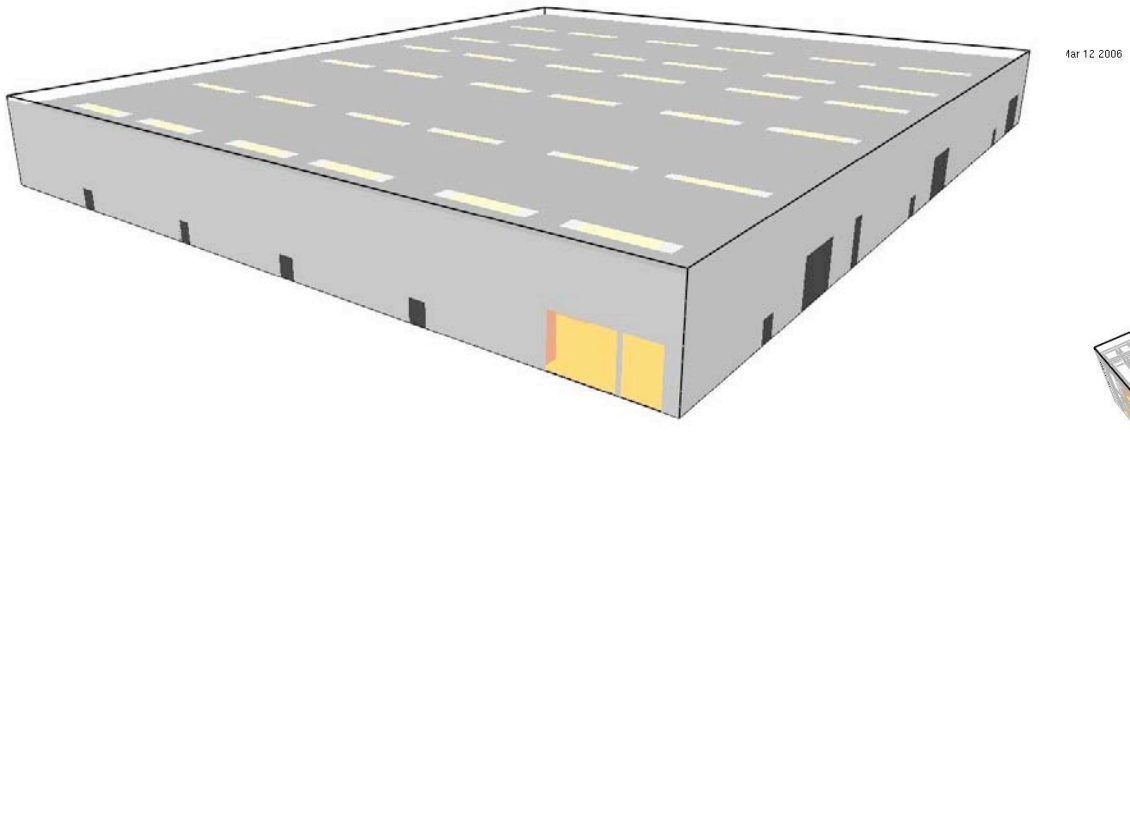
…but also…

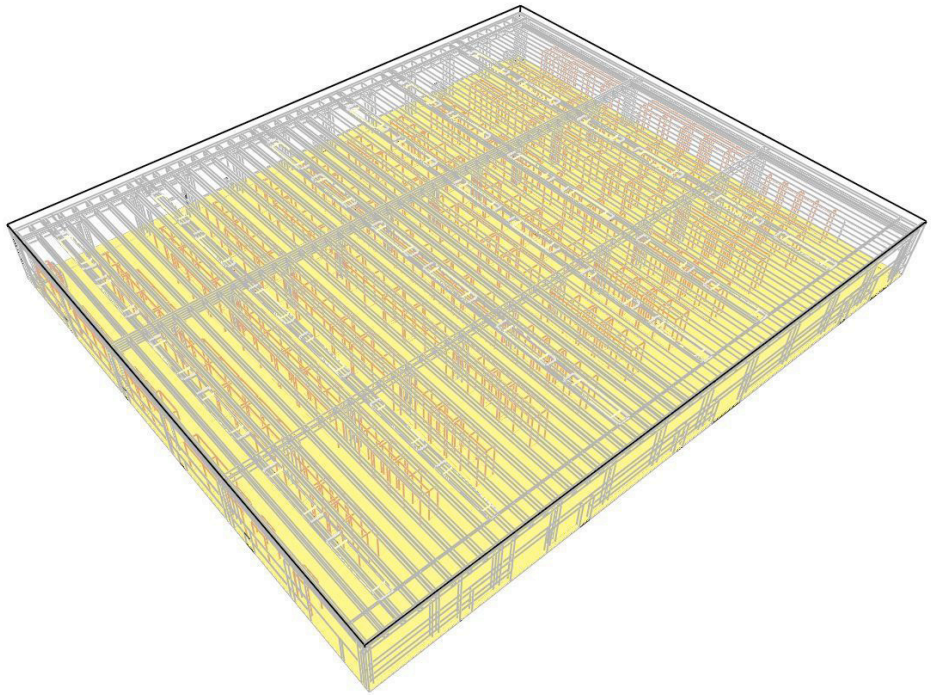
- **SMOKE HEIGHT (TIME RELATED)**
- **SAFE EGRESS TIME**
- **FIRE RATING OF BUILDING PARTS**

1. PRE FLASHOVER (ignition and propagation)
2. FLASHOVER
3. POST FLASHOVER (open fire and extinction)

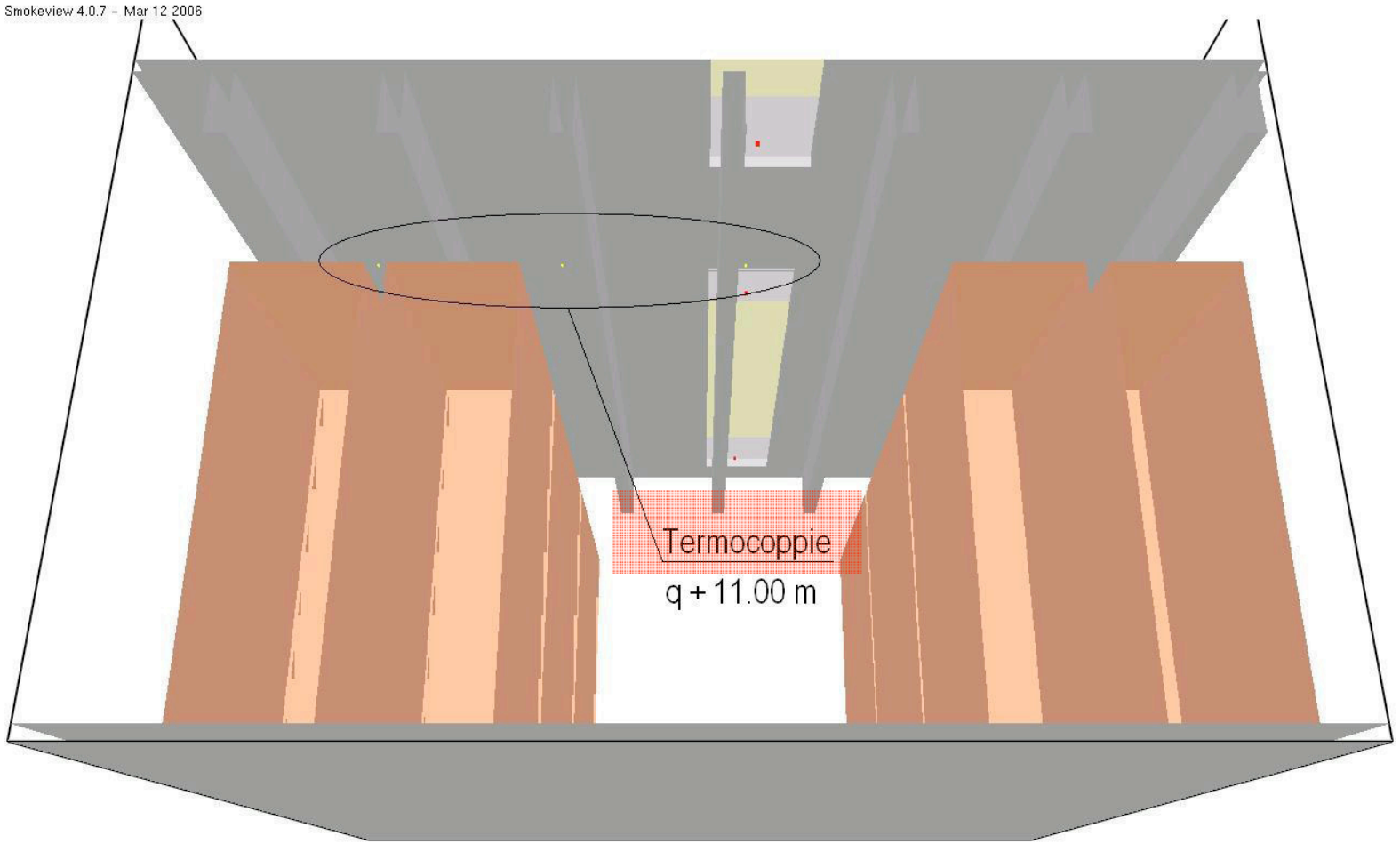


FSE - THE MODEL



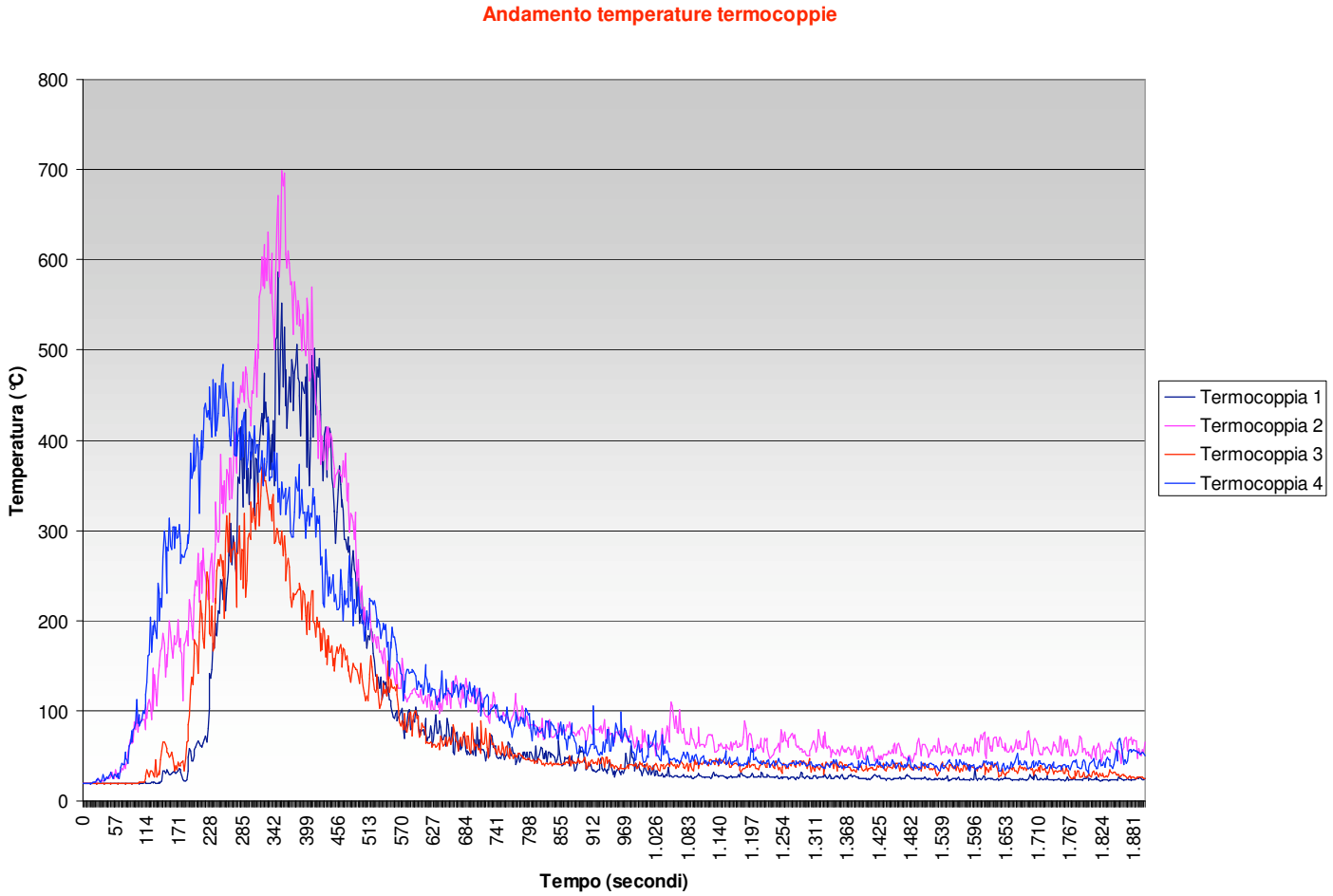


FSE - THE MODEL



NATURAL FIRE CURVE (TEMPERATURE TIME RELATED)

Fire
Of
Cellulose material



HEAT RELEASE RATE CURVE (HRR)

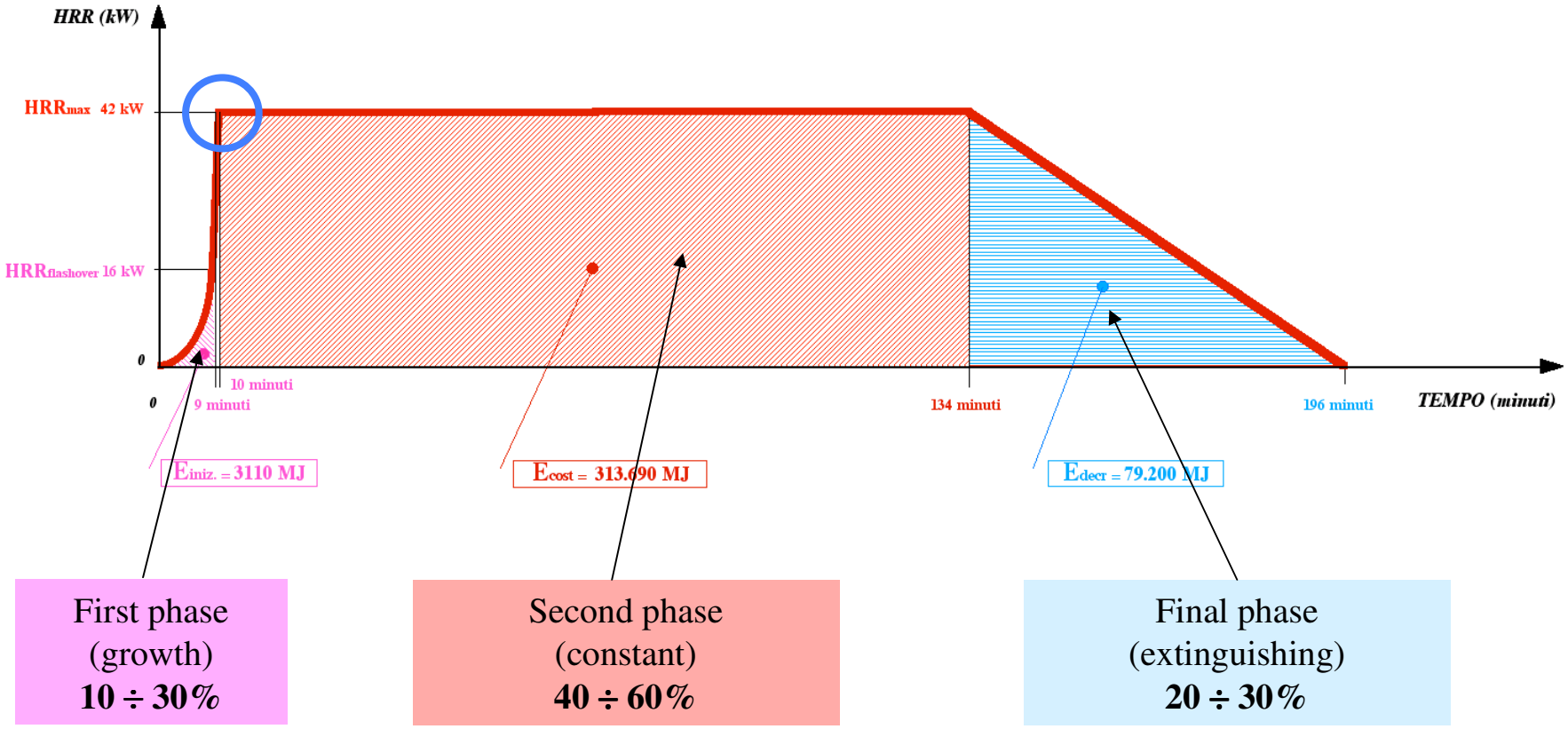
Depending on the material under combustion, the fire spreads with a different speed. Based on the time needed for a thermal heat release of ***1055 kW*** (***1000 Btu/sec***), fires are classified as follows:

SLOW GROWTH
MEDIUM GROWTH
FAST GROWTH
VERY FAST GROWTH

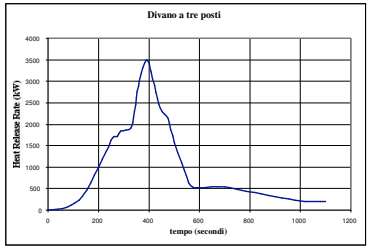
Classes:

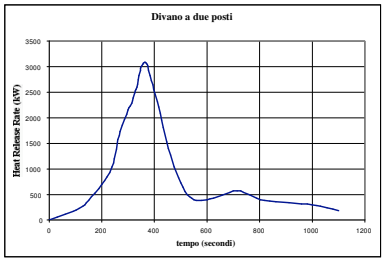
"slow growth"	if a HRR of 1055 (1000) kW is reached in 600 seconds
"medium growth"	if a HRR of 1055 (1000) kW is reached in 300 seconds
"fast growth"	if a HRR of 1055 (1000) kW is reached in 150 seconds
"very fast growth"	if a HRR of 1055 (1000) kW is reached in 75 seconds

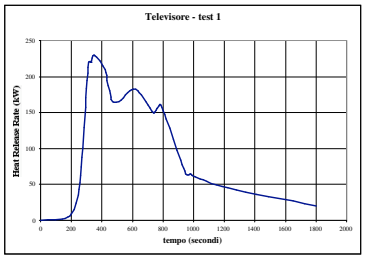
HEAT RELEASE RATE CURVE (HRR)

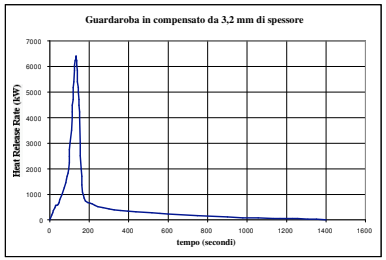


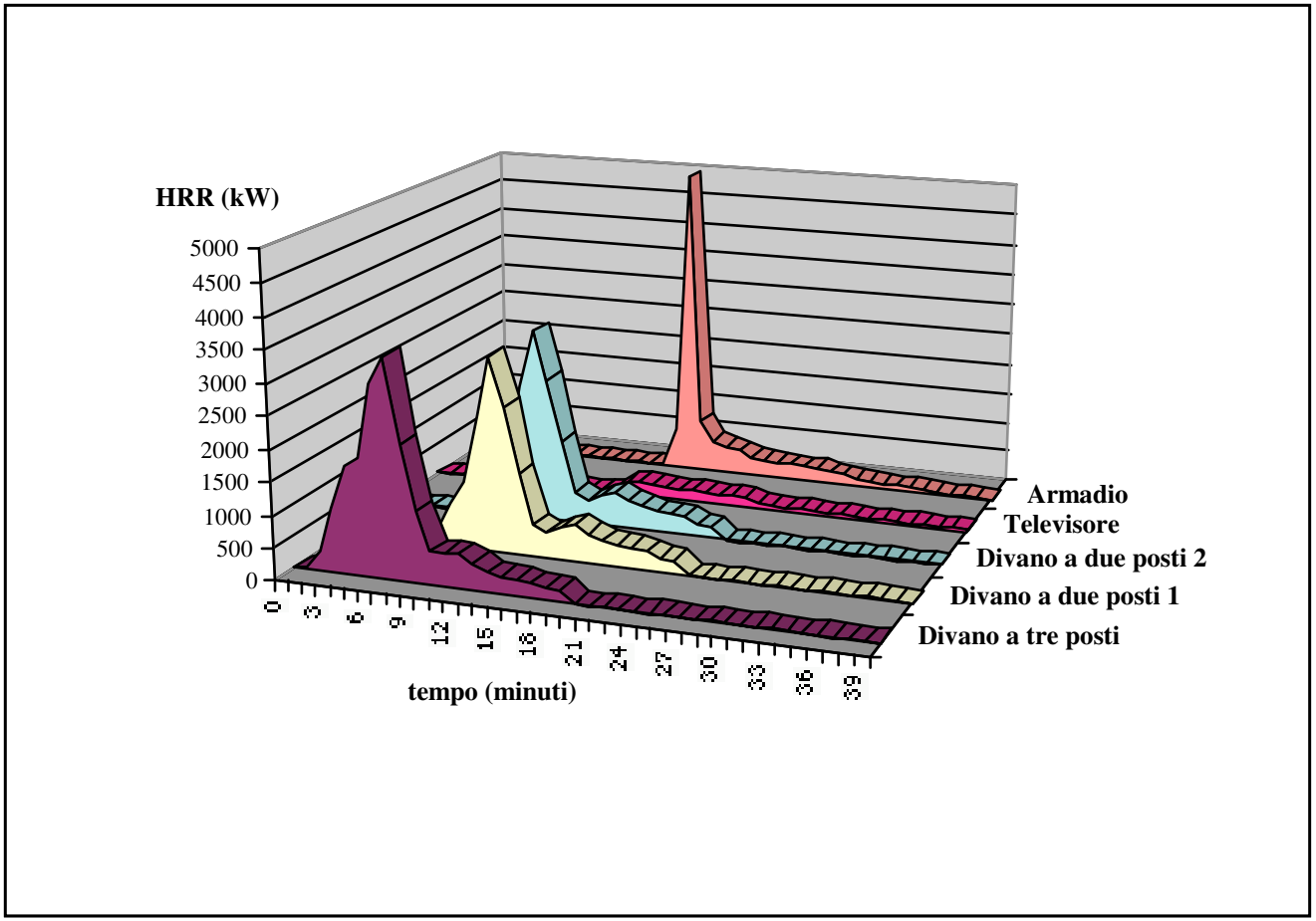
HEAT RELEASE RATE CURVE (HRR)



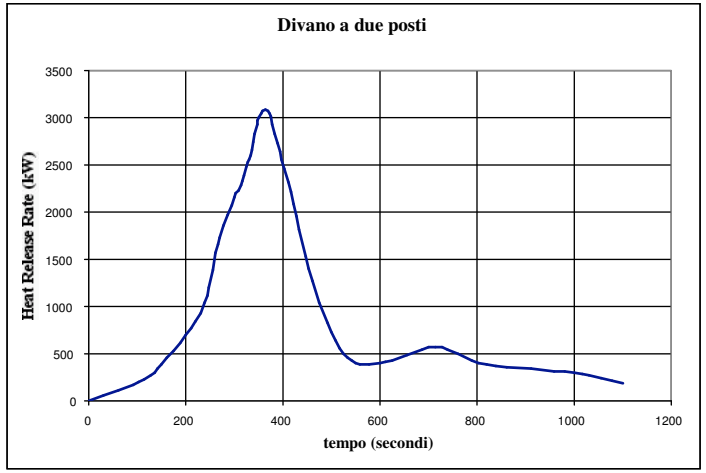


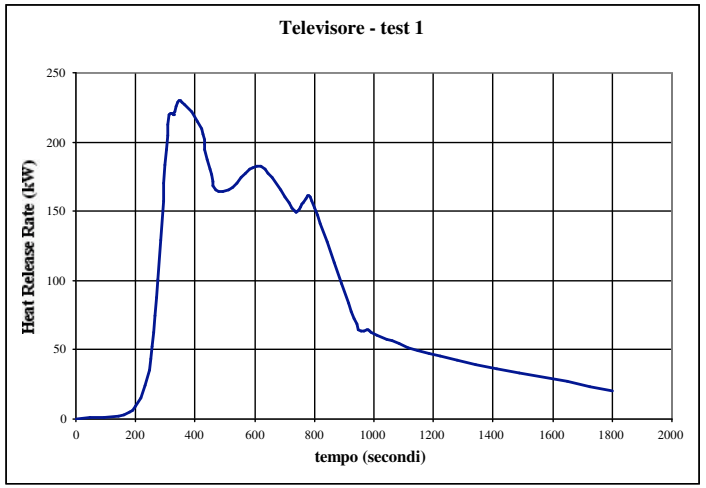


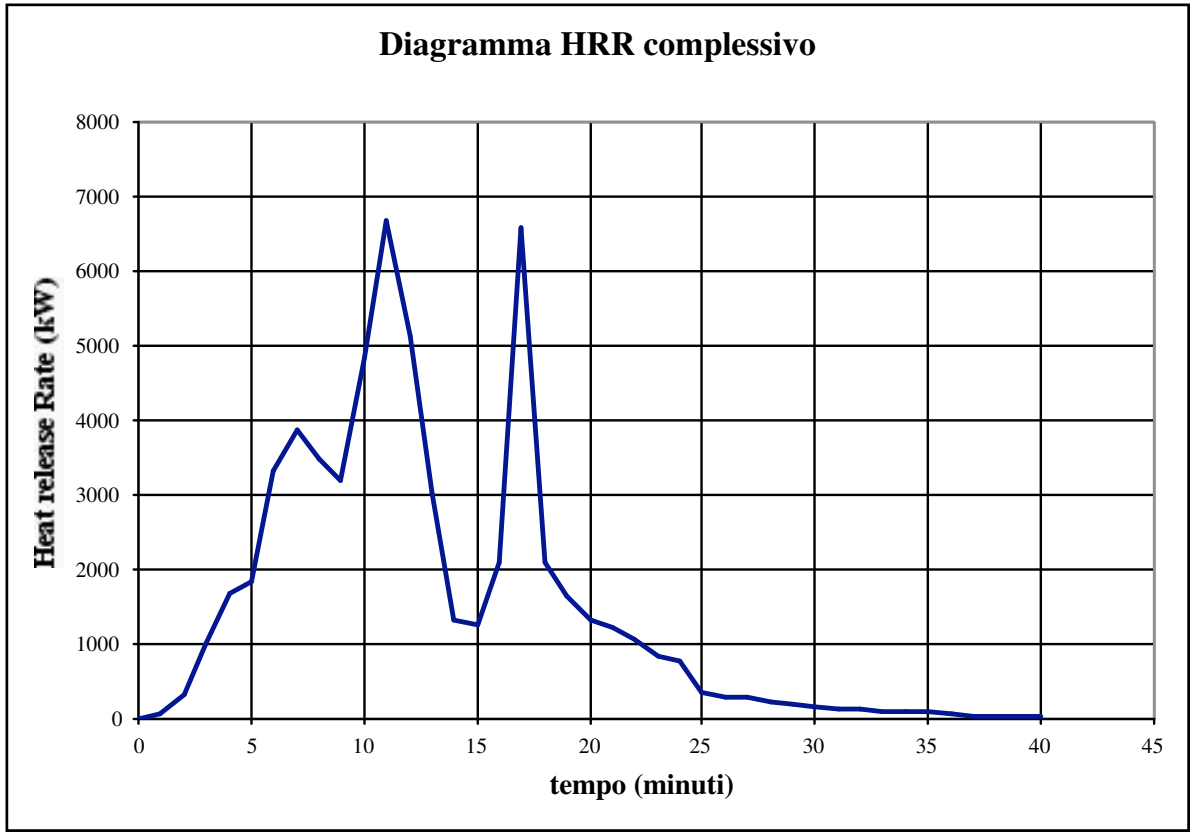




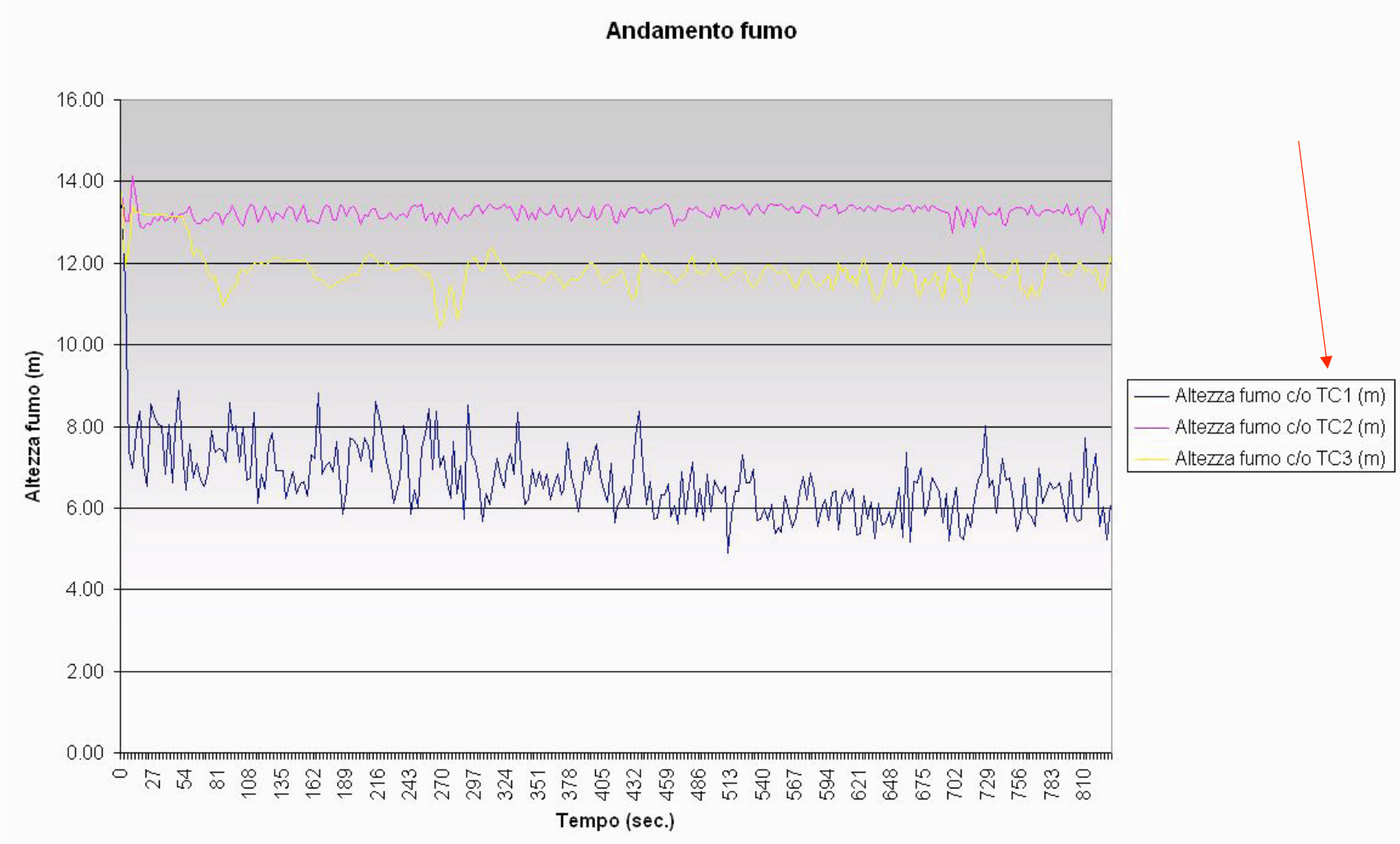
HEAT RELEASE RATE CURVE (HRR)







SMOKE HEIGHT (TIME RELATED)



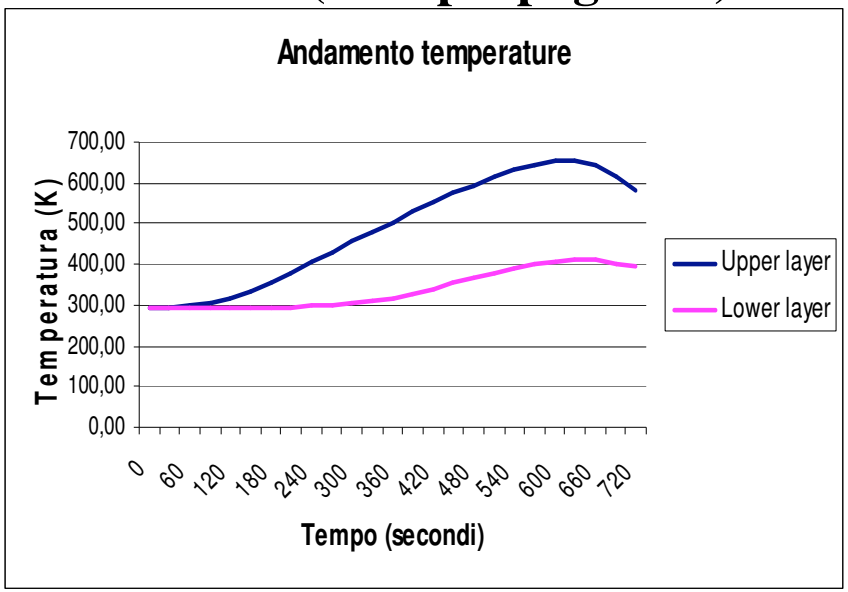
RSET (Required Safe Egress Time)

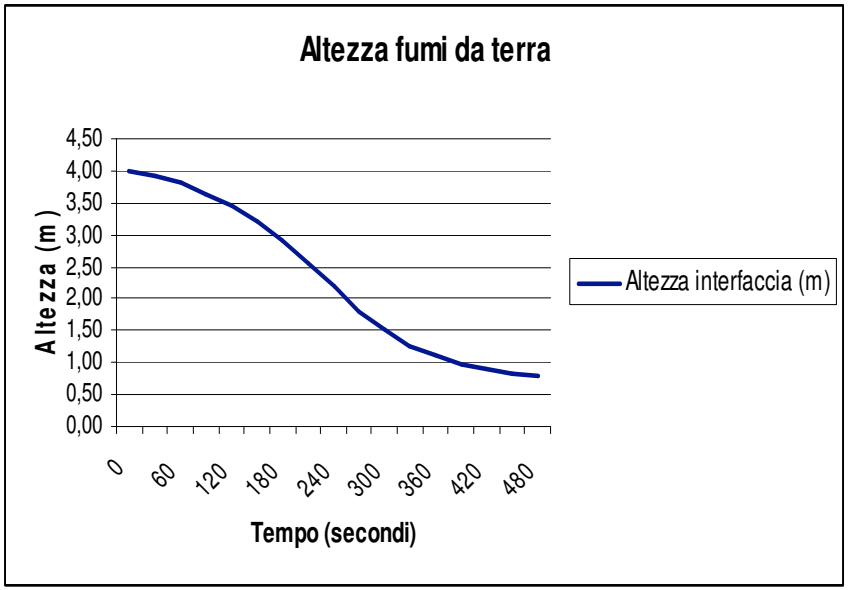
RSET

1. The time needed for the fire detection
2. The time needed to activate the fire alarm
3. The delay time to start the egress
4. The movement time for all the expected occupants to reach the safe area

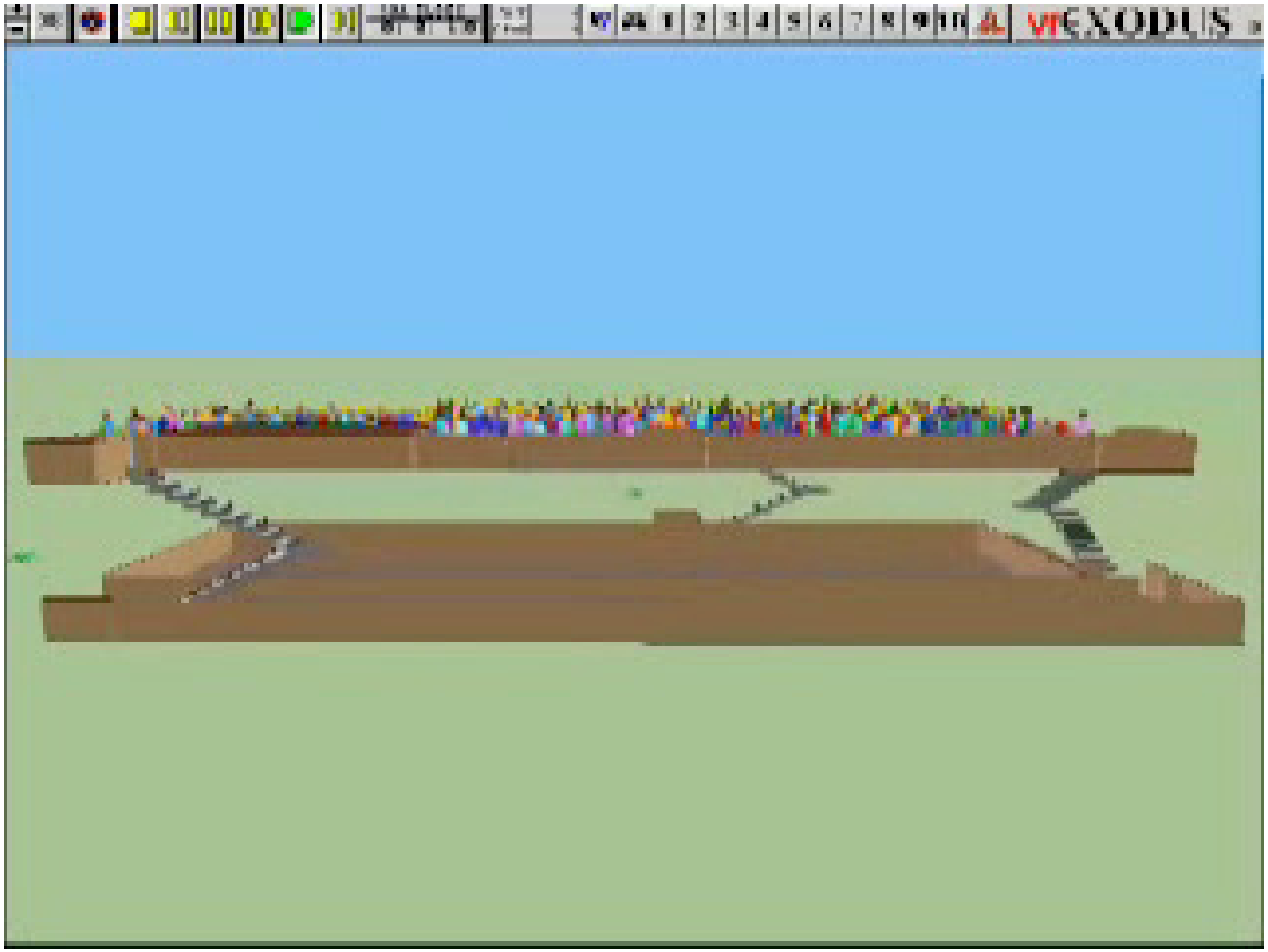
ASET (Available Safe Egress Time)

It is based on the smoke height (time related) and on the temperature behaviour (heat propagation). Must be crosschecked with the value RSET





FSE - EXAMPLE OF ASET VS RSET



FSE - EXAMPLE OF SIMULATION

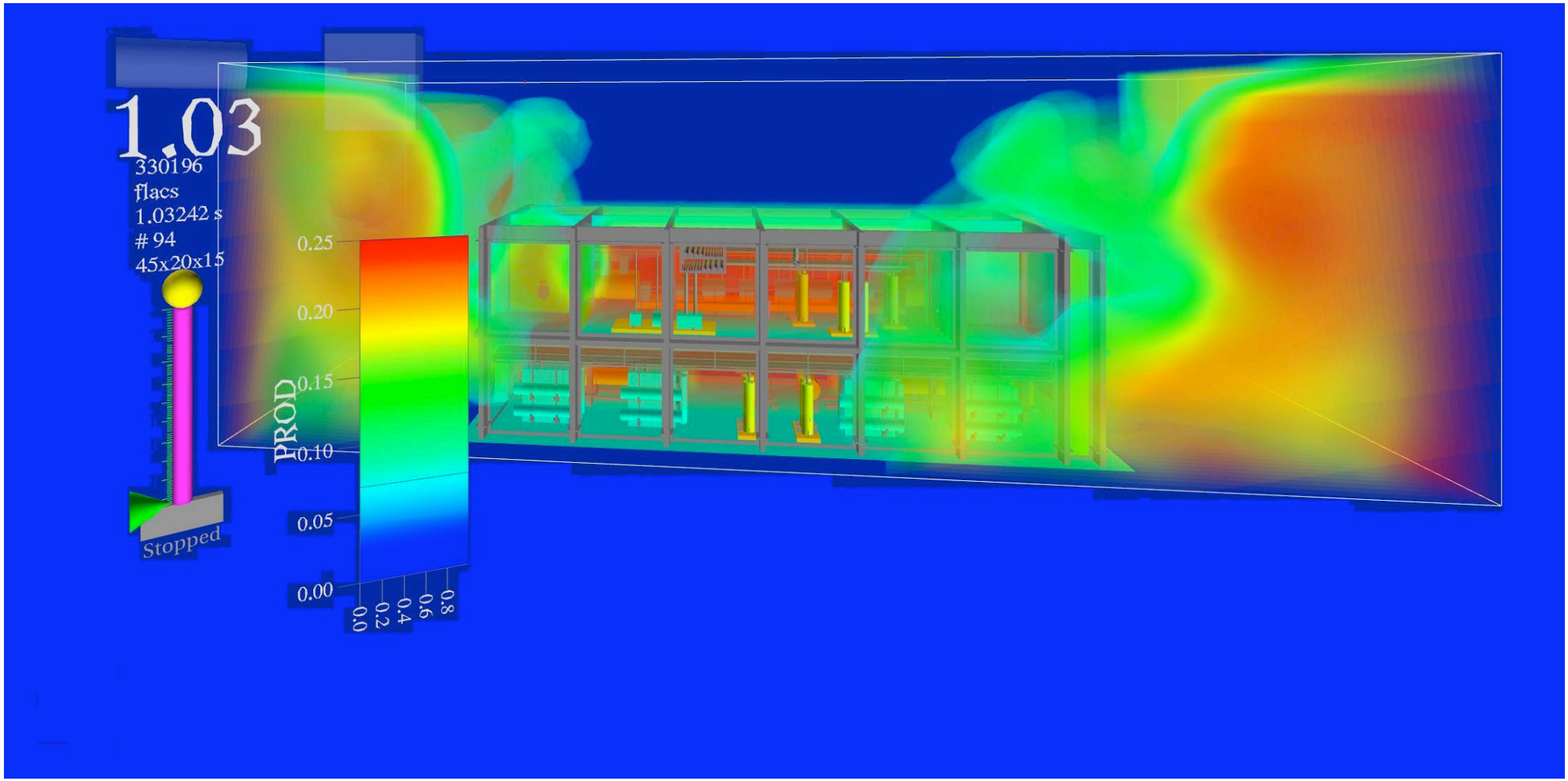
GAS EXPLOSION SIMULATION

Flame Acceleration Simulator

It is an advanced tool for the modelling of ventilation, gas dispersion, vapour cloud explosions and blast in complex process areas. It is used for the quantification and management of explosion risks in the offshore petroleum industry, onshore chemical industries, other high risk industries and urban agglomerates.

GAS EXPLOSION SIMULATIONS

GAS EXPLOSION SIMULATIONS



GAS EXPLOSION SIMULATIONS

Explosion Simulations

- Any ignition point location
- Variable gas cloud size
- Hydrocarbon gases (e.g. Methane, Ethane, Propane, Butane, and mixtures of these)
- Variation in gas concentration
- Vent panels: weight, opening mode, opening pressure
- Yielding walls: failure mode
- Effect of waterspray: nozzle type, flow rate, location
- Any type of louvered walls, angle of blades, effective openings
- Predication of blast wave strength outside the area were the explosion occurs
- Effect of inert gases; CO_2, N_2, and varying O_2 concentration

GAS EXPLOSION SIMULATIONS

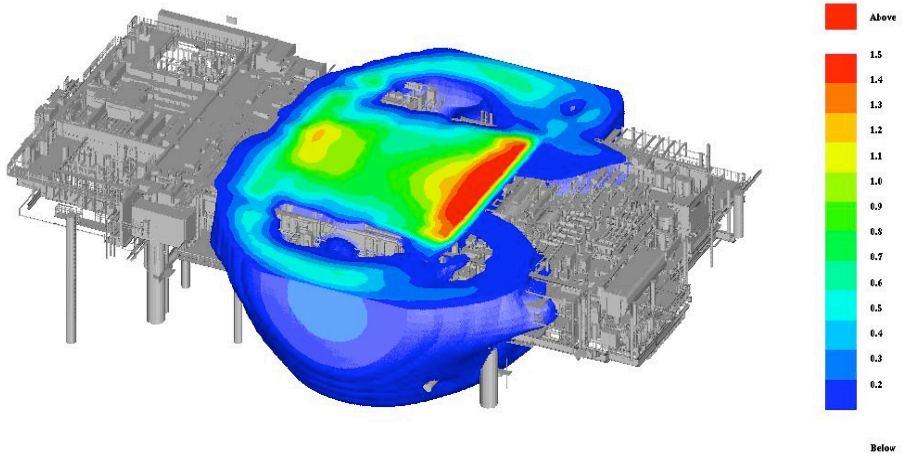
Knowledge based

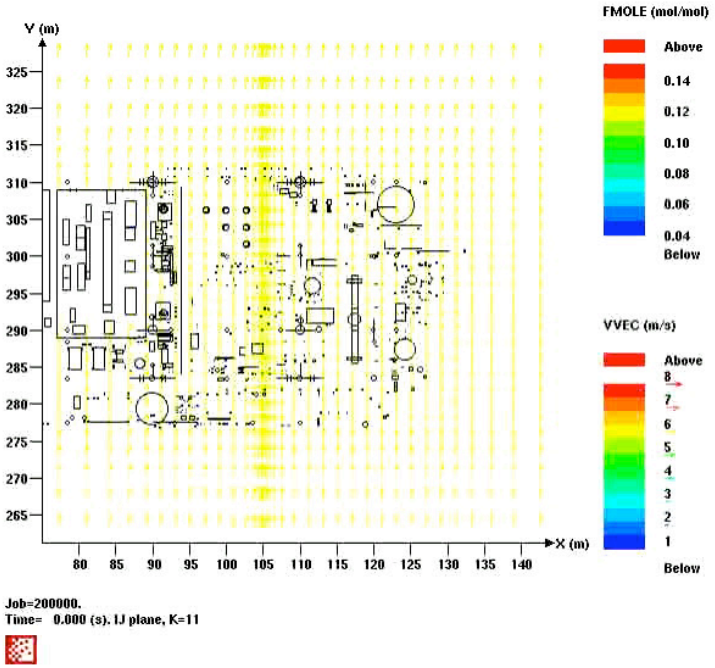
Dispersion, location of gas detection, simulations

Explosion effects, prediction, QRAs

Limitation of effects, design, lay-out, mitigation (water/gas)

Risk Management

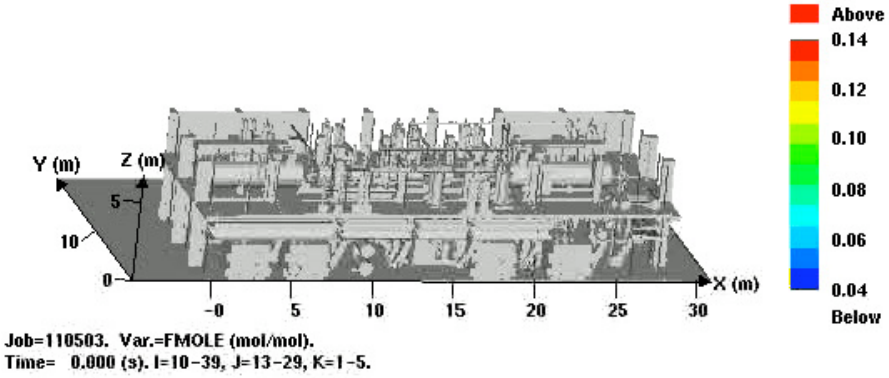


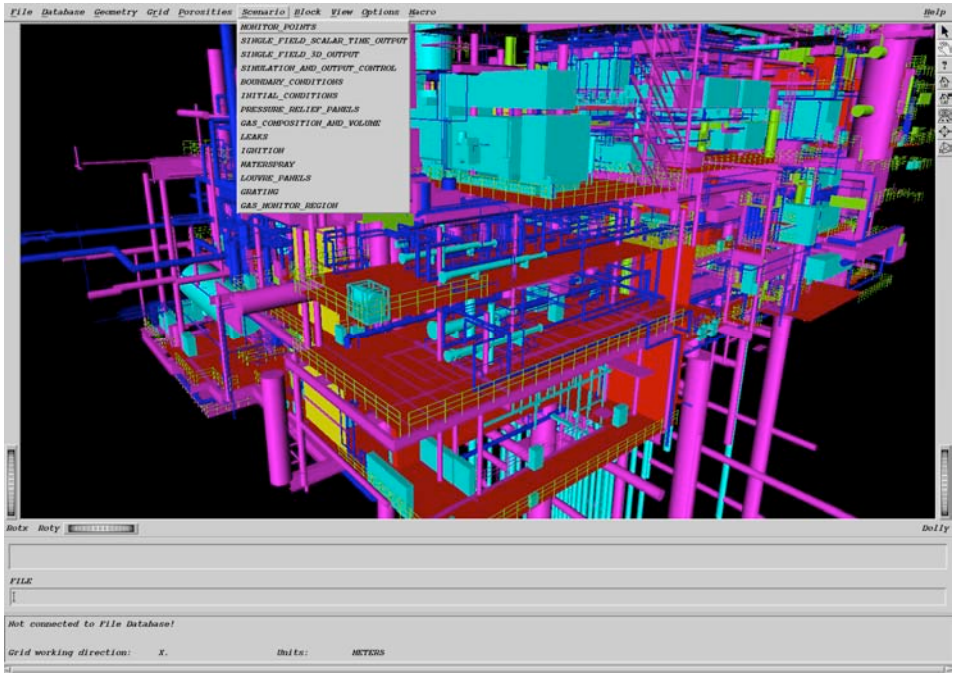


GAS EXPLOSION SIMULATIONS

Explosions require very good representation of geometry

Recent dispersion tests in geometries of "real" congestion confirmed importance of geometry representation for dispersion





GAS EXPLOSION SIMULATIONS

Any flame model (3D) will be grid dependent!

Flame models:

Beta model, force fuel equation to give specified burning velocity (S_{lam}, S_{turb})

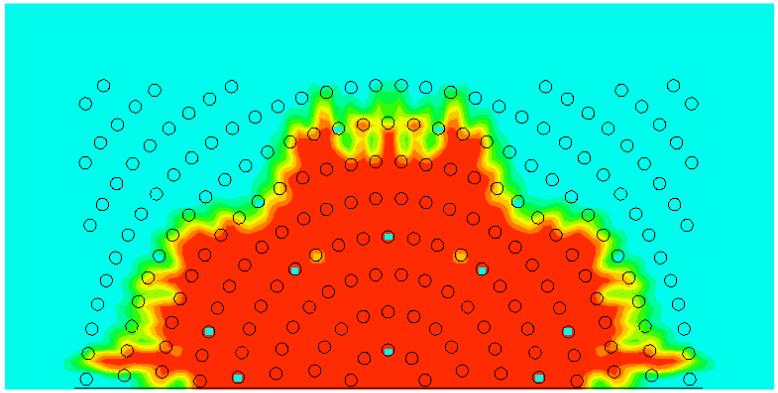
=> reaction zone has a certain thickness (3-5 control volumes)

Must be adjusted when high curvature / laminar phase (wrinkling low with thick flame)

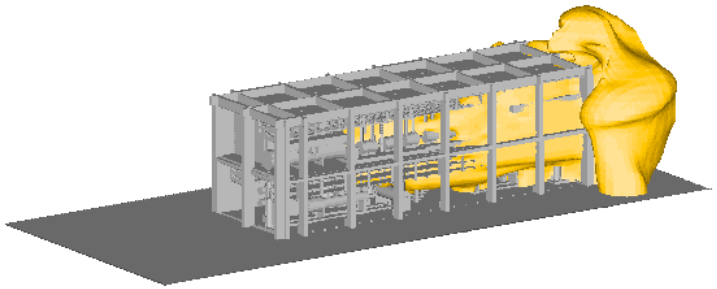
SIF model, simple interface flame (zero thickness => inside one control volume)

=> fine grid allows more wrinkling than coarse grids

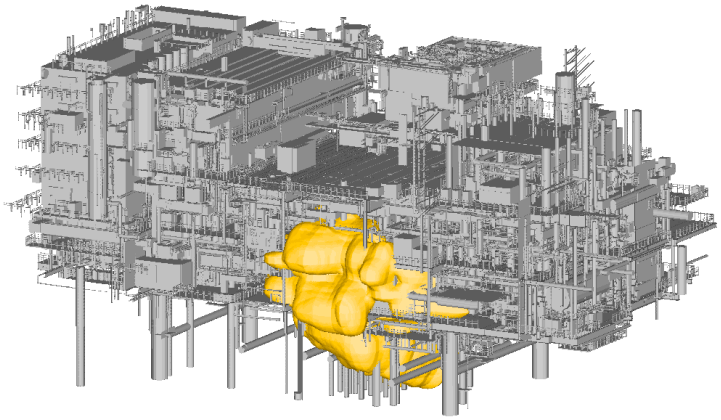
Flame area depends on grid resolution => compensation still needed

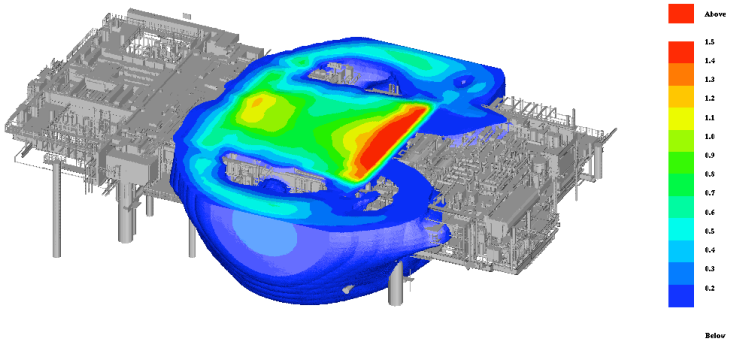


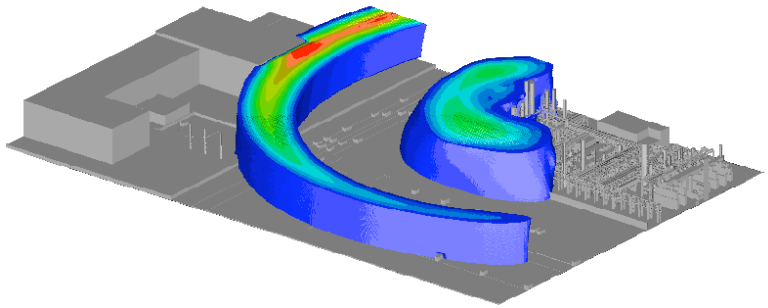
Job=340396. Var.=PROD(-).
Time=0.109973 (s). U plane, K=2



GAS EXPLOSION SIMULATIONS



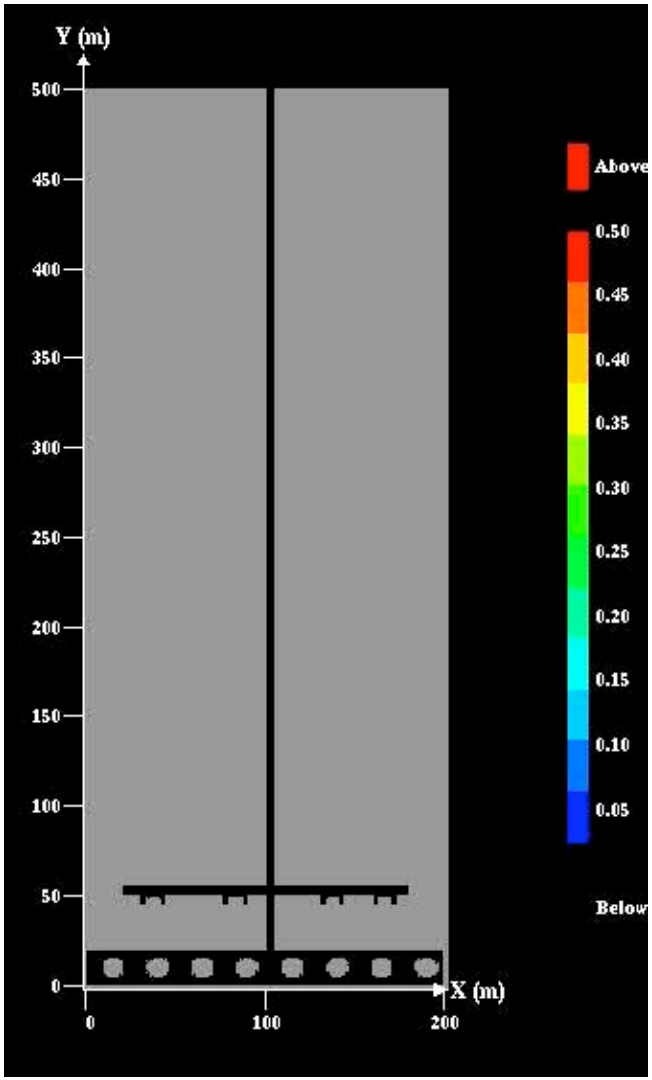


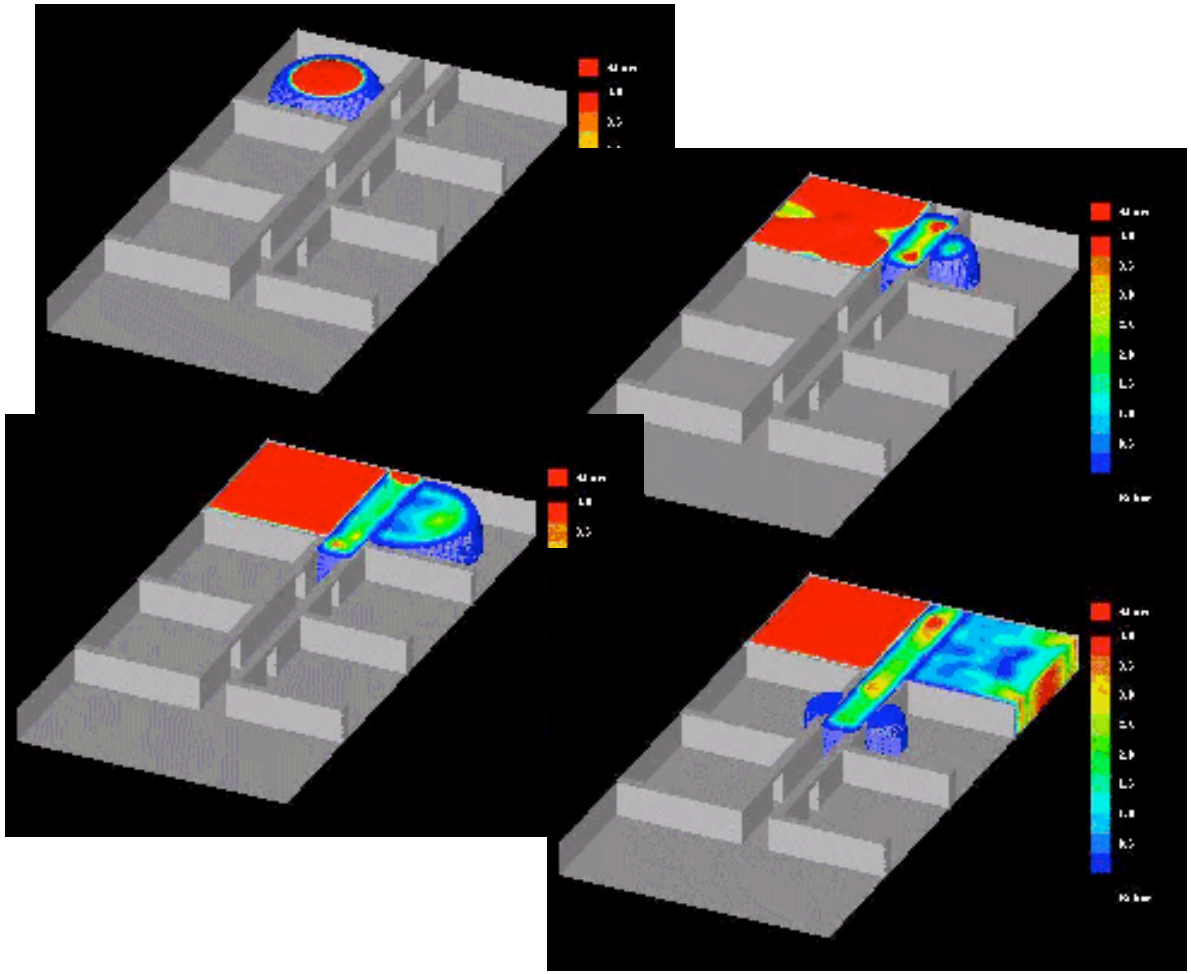


Blast wave propagation effect on buildings

GAS EXPLOSION SIMULATIONS

Explosion in tunnel systems (hydroelectric plant)

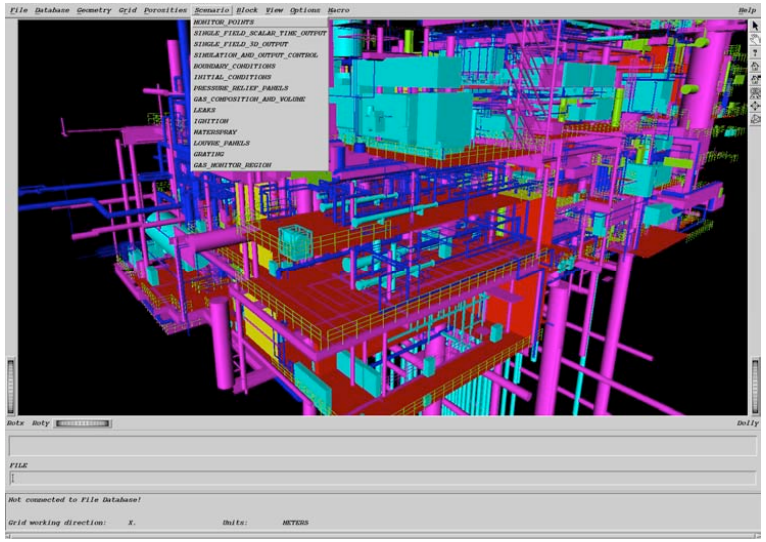




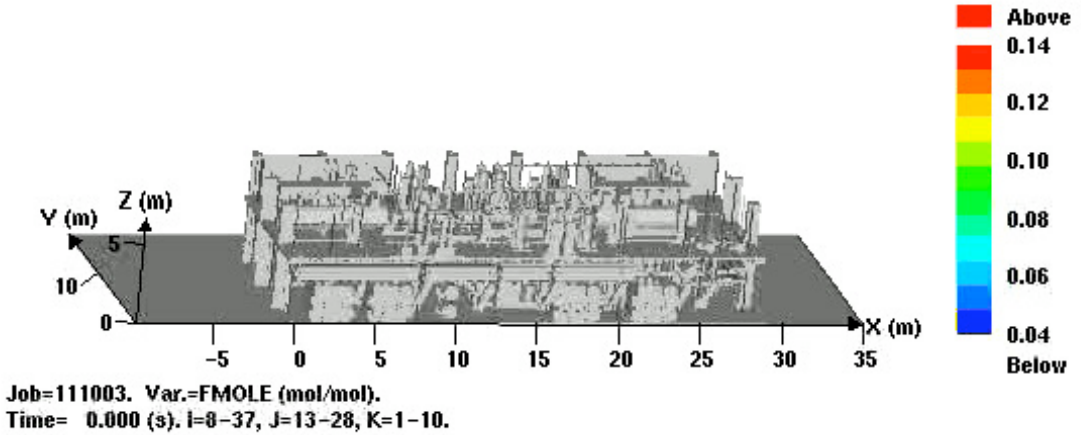
Explosives in storage facility

GAS EXPLOSION SIMULATIONS

More recent features:
3D-walk through options in preprocessor



Automatic generation of video-files (mpg)



GAS EXPLOSION SIMULATIONS

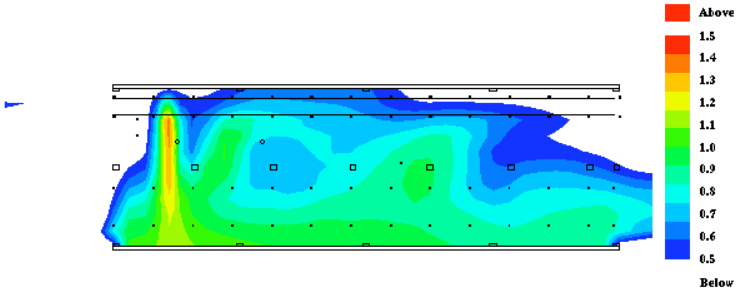
Measures for load reduction:

1 Reduce confinement

Effect on cloud formation, exposure time

Reduces explosion pressure level and duration

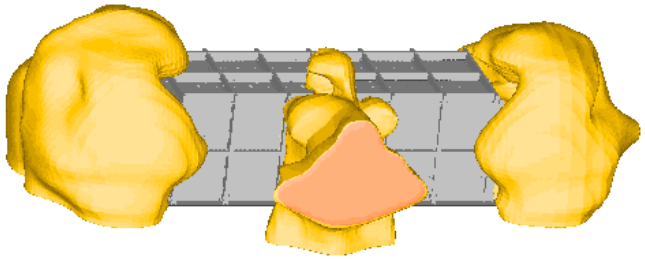
Efficiency of water deluge increases



2 Geometry changes / relocation of objects

Effect on flame acceleration

Location of frequent leak/ignition sources



3 Pressure relief panels (with inertia)

4 Water deluge

Effect increasing with scale, water amount, vent area, congestion

5 Inert gas mitigation (CO2 / N2 / Inergen)

DUST EXPLOSION SIMULATION

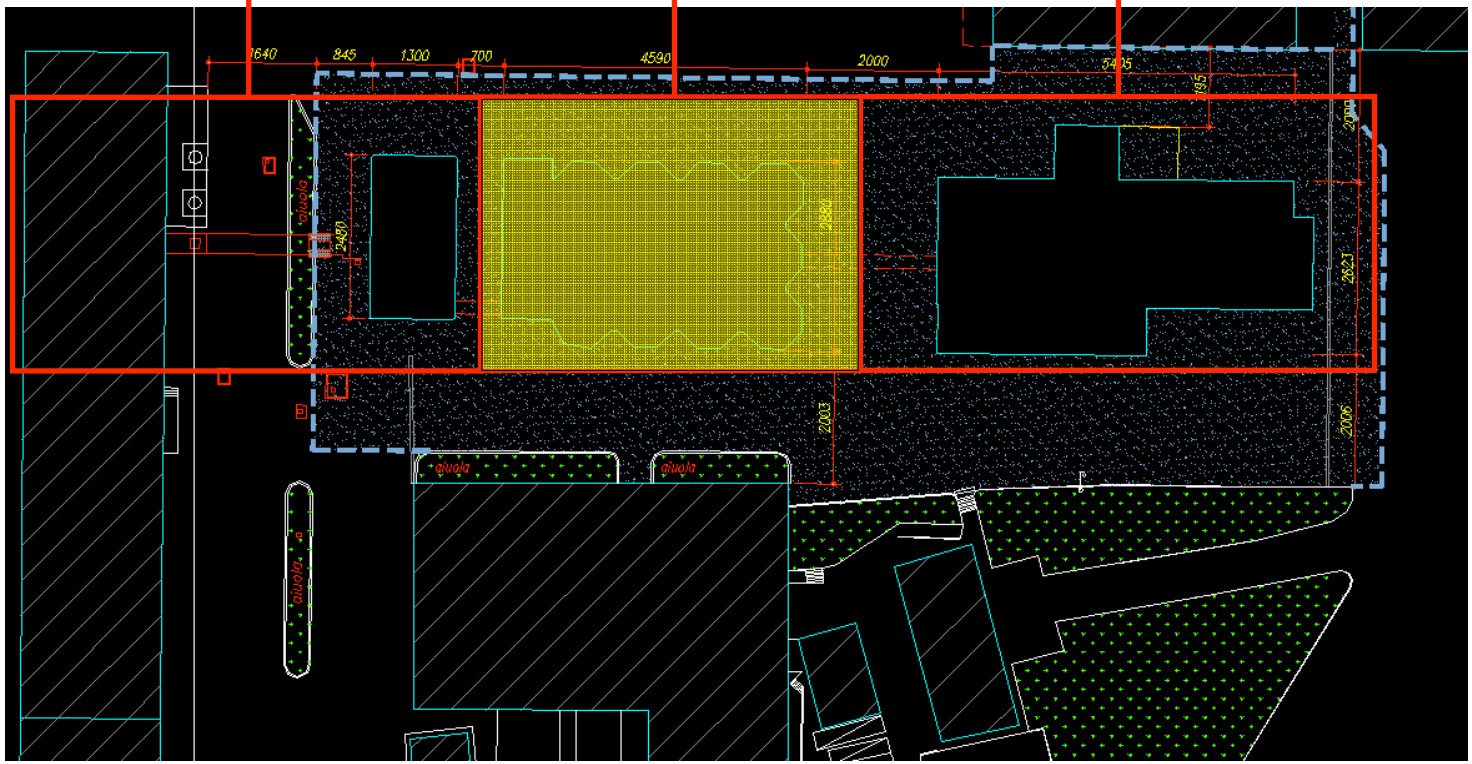
Scenario

New maize processing plant

Ship and truck unloading station

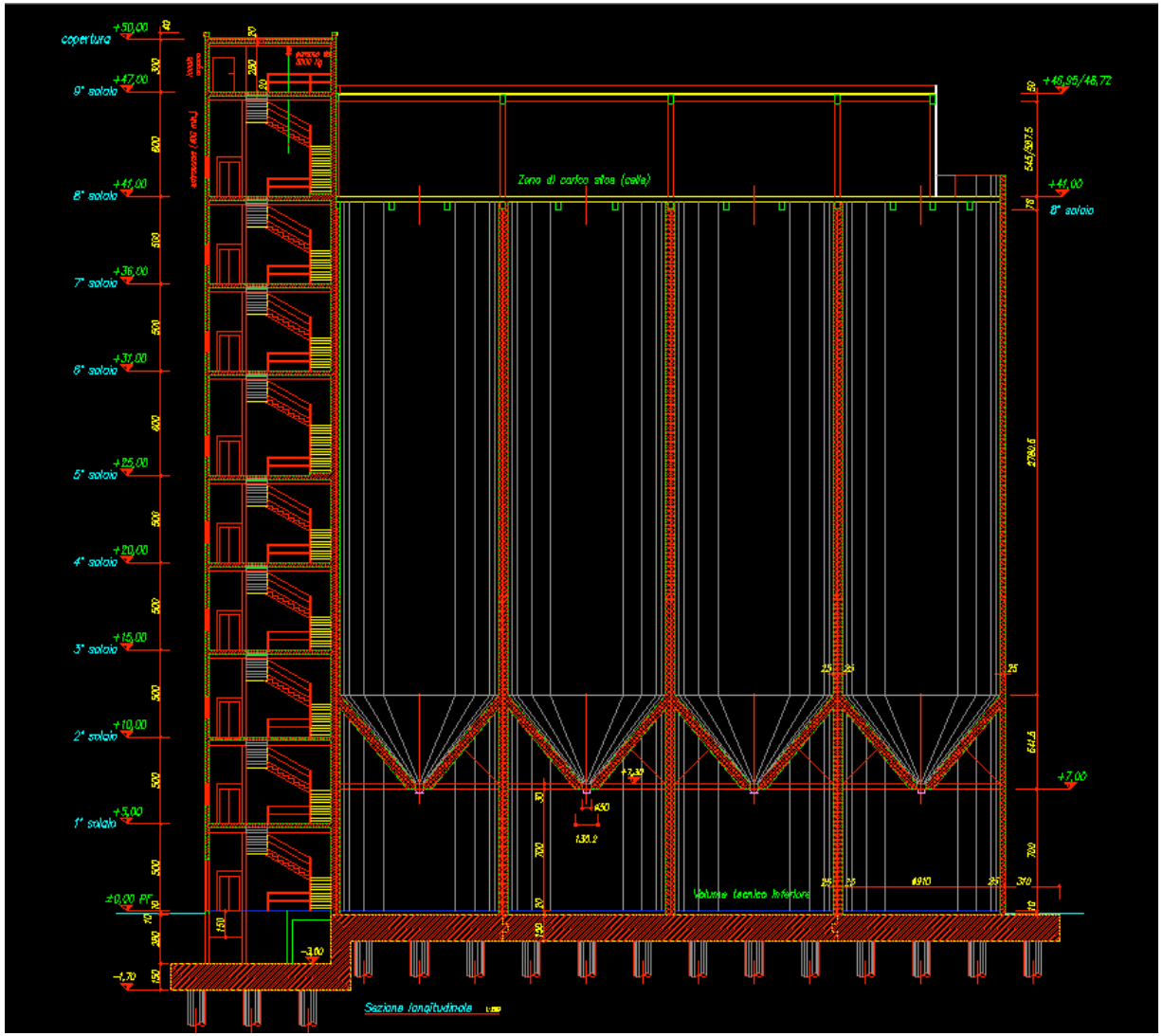
Bucket elevators and silos

Screens, hammermills, etc



Scenario

Bucket elevators and silos



Penthouse with n°2 chain conveyors

Reinforced concrete silos (AS IS)

Height: 34 m

Diameter: 9 m (large), 5 m (small)

Structural resistance:

- Upper half: 0,75 barg
- Lower half: 1 barg
- Concrete roof: 0,11 barg

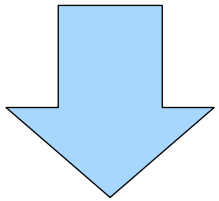
Scenario

Problem:

1. Design the protection system for the entire plant, in order to minimize the effects of dust explosion:

- Design the protection system for silos
  - Venting panels or other equipment?
  - In case venting panels are not applicable, what else the customer can do?
- Design the protection system for bucket elevators

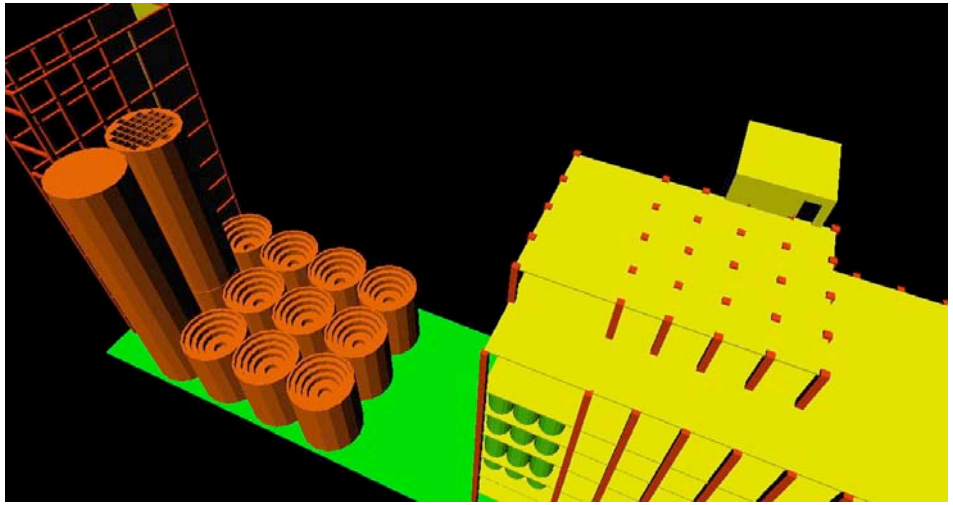
2. Calculate the predictable effects of a dust explosion on nearby buildings and modify the Risk Management (Emergency Action Plan) accordingly

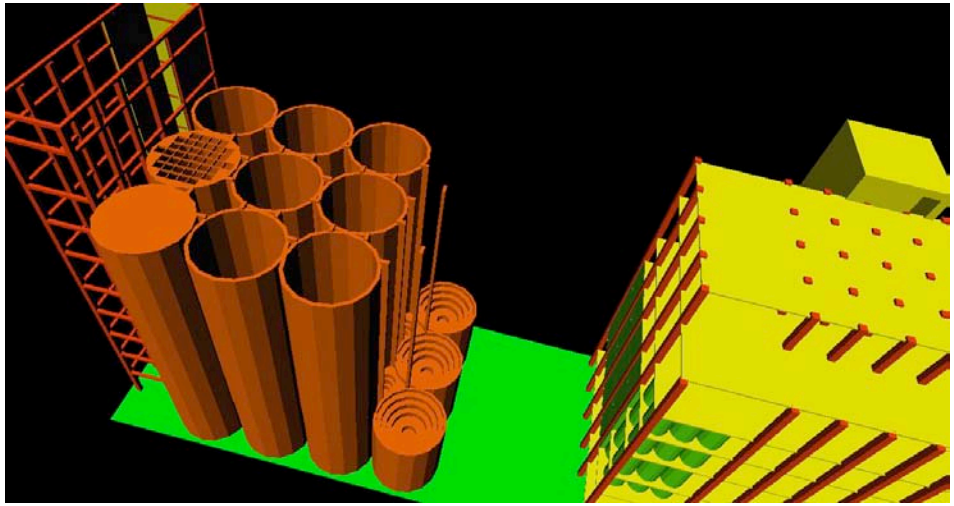


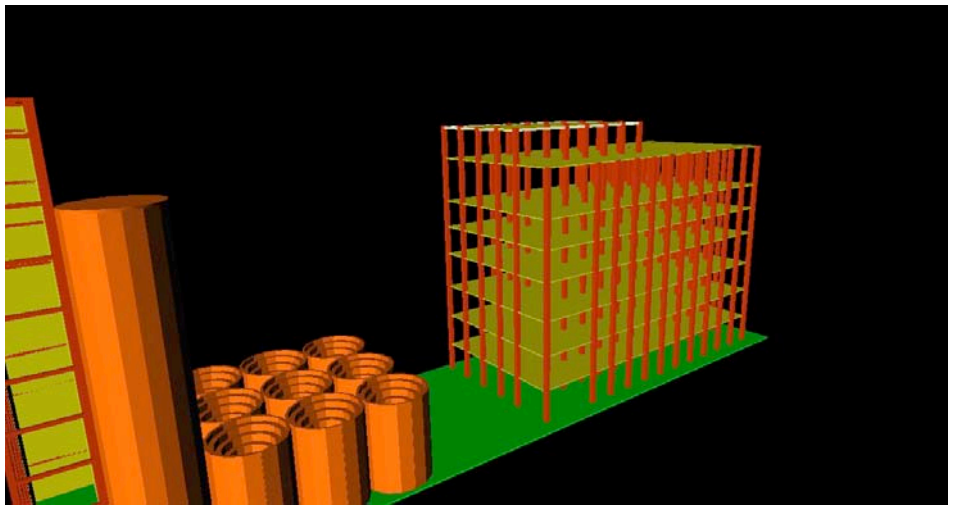
Dust Explosion Simulator Code has been used to solve these problems

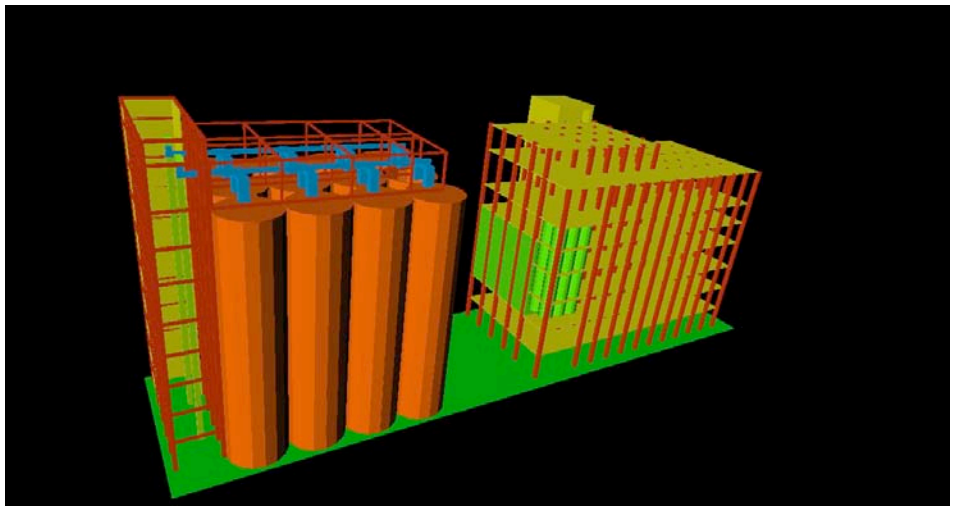
From scenario to DESC

Real geometry has been drawn into CASD



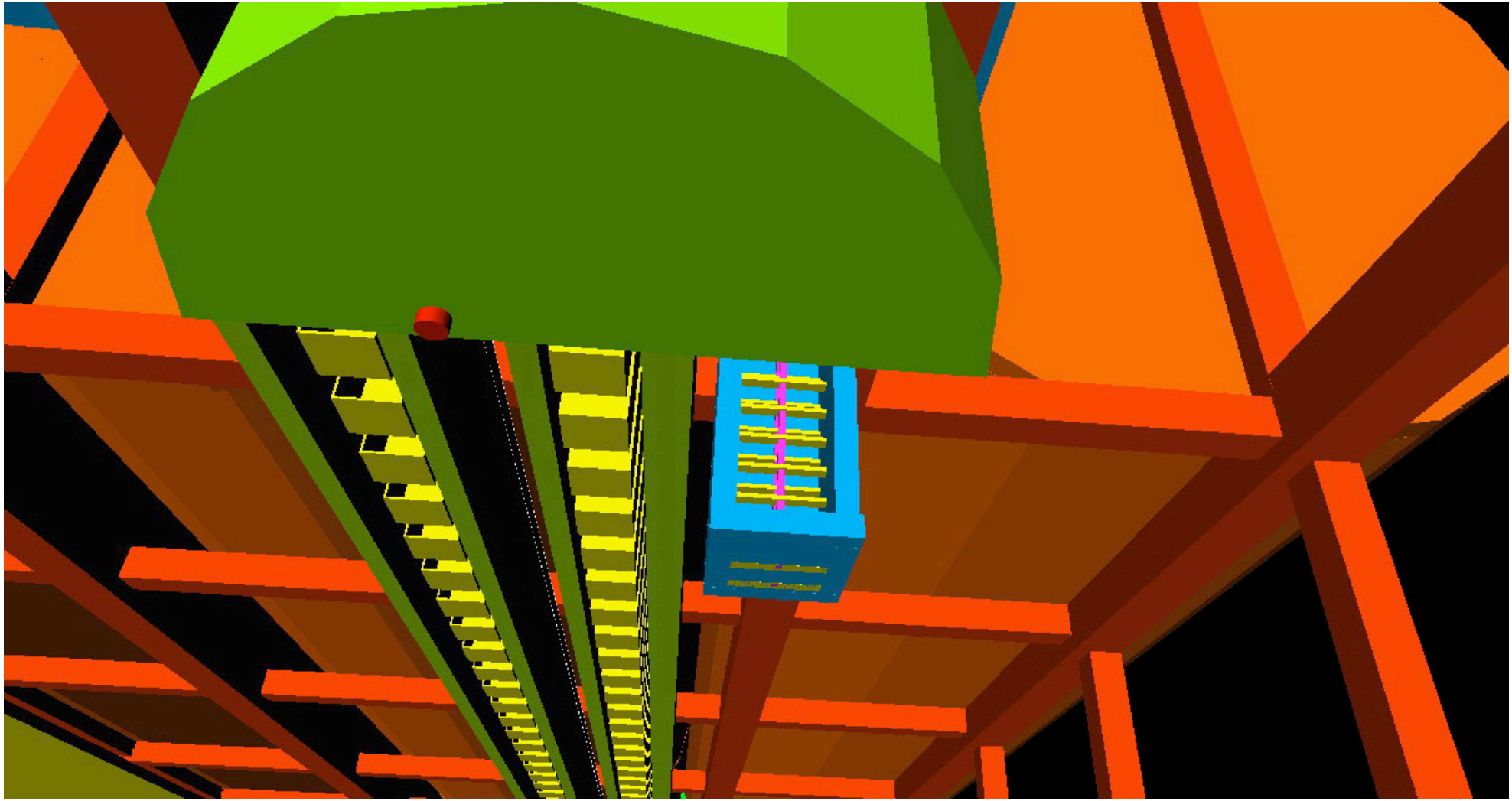






From scenario to DESC

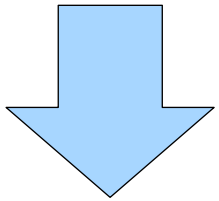
Bucket elevator



Protection system for silos

Required venting surface as been calculated according to the European Standard (EN 14491), using the following data:

- Product data (from customer):
  - Kst=112 bar*m/s
  - Pmax=8,3 bar
- Resistance (overpressure)
  - Pred=0,11 barg (concrete roof structural resistance)
- Rupture disks
  - Pstat=0,1 barg



Required venting surface = 121 m^2

Roof surface = 63,5 m^2

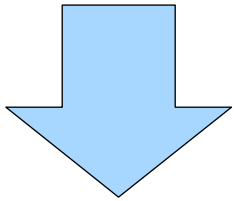
Available roof surface = 40 m^2

Protection system for silos

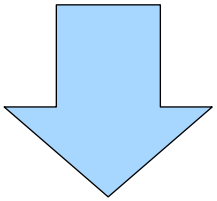
Standard venting panels are not applicable, because the available surface is not enough to

guarantee correct venting of the dust explosion.

In case silos are not correctly protected, what happens to them? Does only the roof collapse or even the cylindrical body is seriously damaged?



DESC has been used to calculate the effects of a dust explosion inside silos and on nearby building



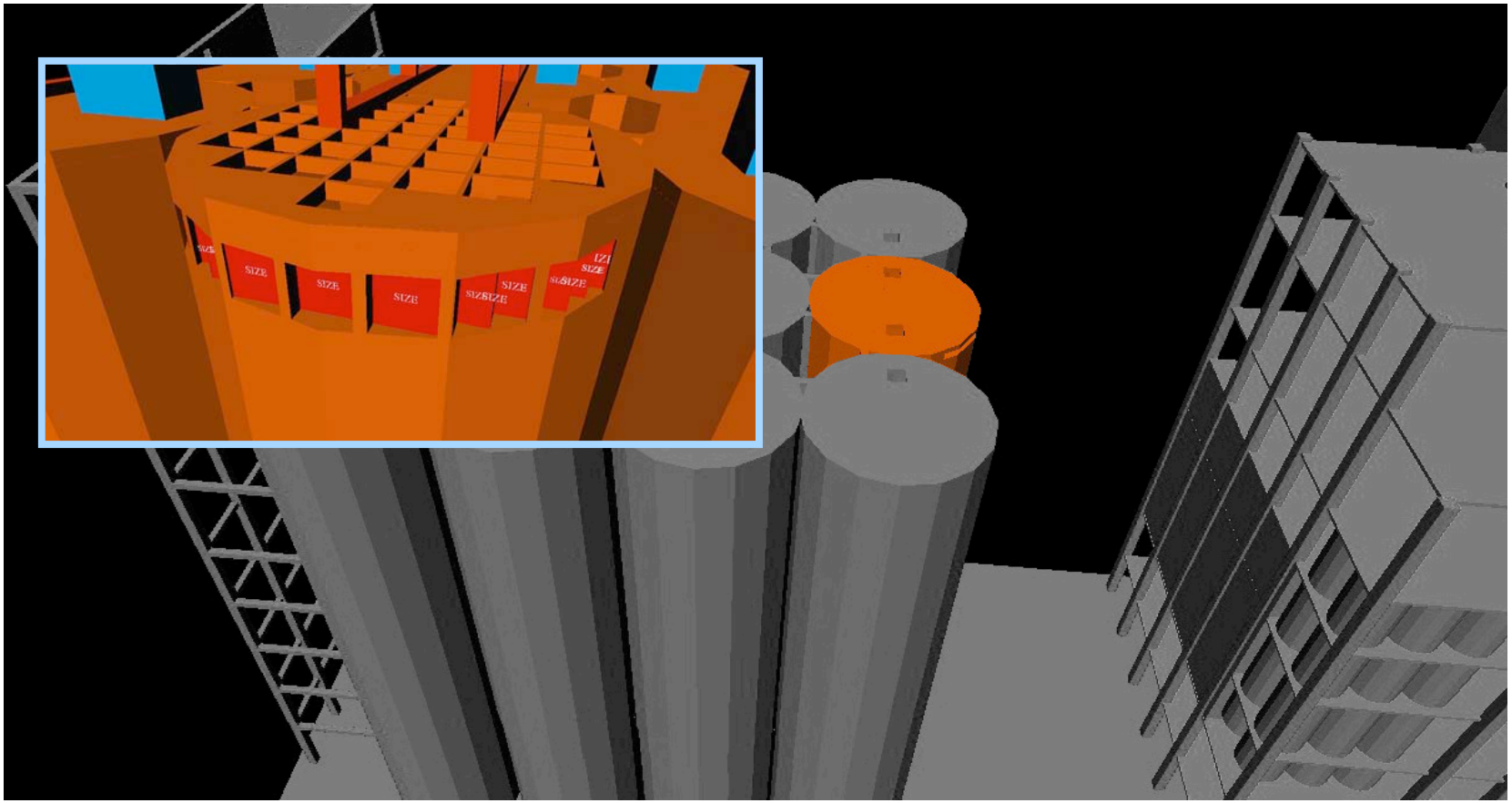
Worst case scenario has been considered:

- Silo fulfilled with **airborne** dust
- Ignition always on **bottom** of the silo

Protection system for silos – AS IS

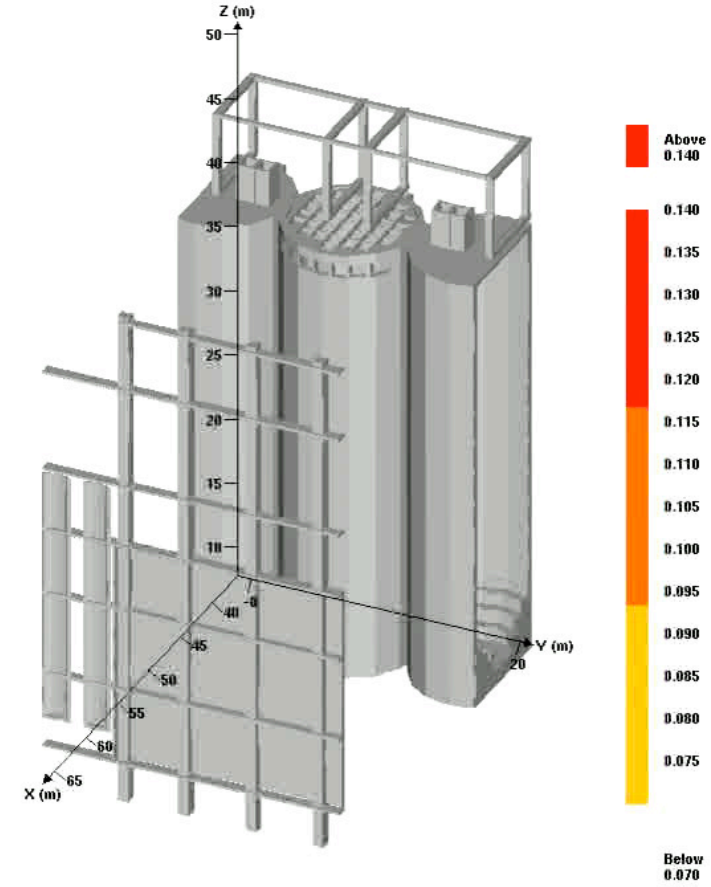
Second simulation refers to the highlighted silo below. Instead of 40x1 m^2 venting panels, there are 10 more panels on side wall of the silo.

Altough venting surface has been increased, it is still under the surface required by the EU Standard (121 m^2).

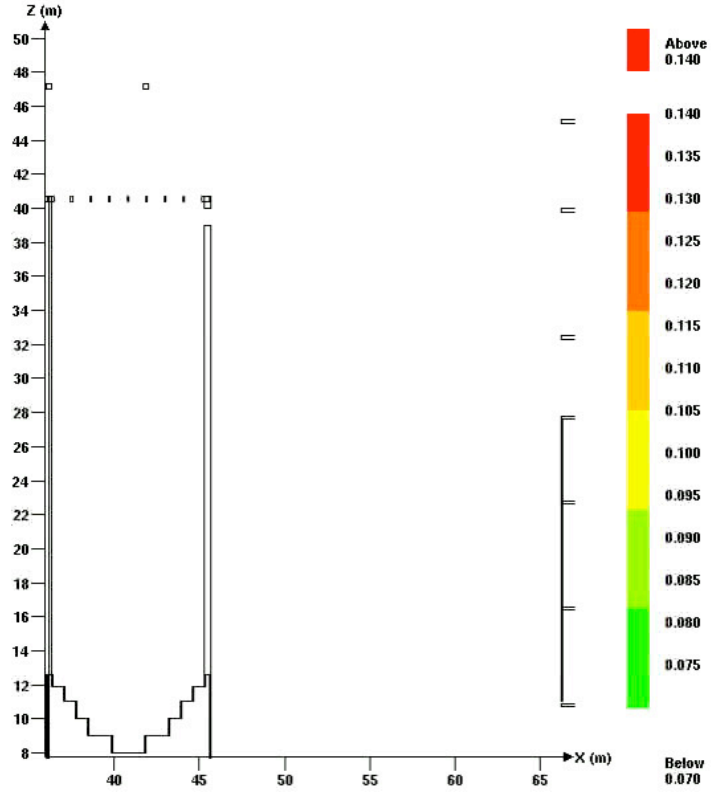


Protection system for silos – AS IS

Simulation results



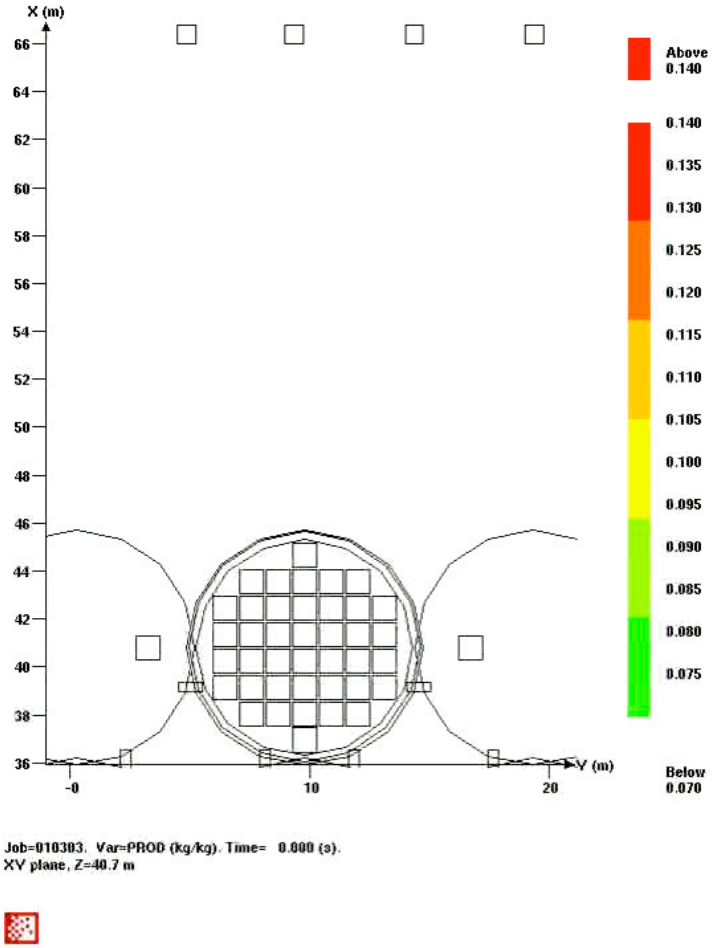
Job=010303, Var=PROD (kg/kg), Time= 0.000 (s).
X=36 : 66.8, Y=-0.9 : 20.9, Z=7.9 : 50.9 m



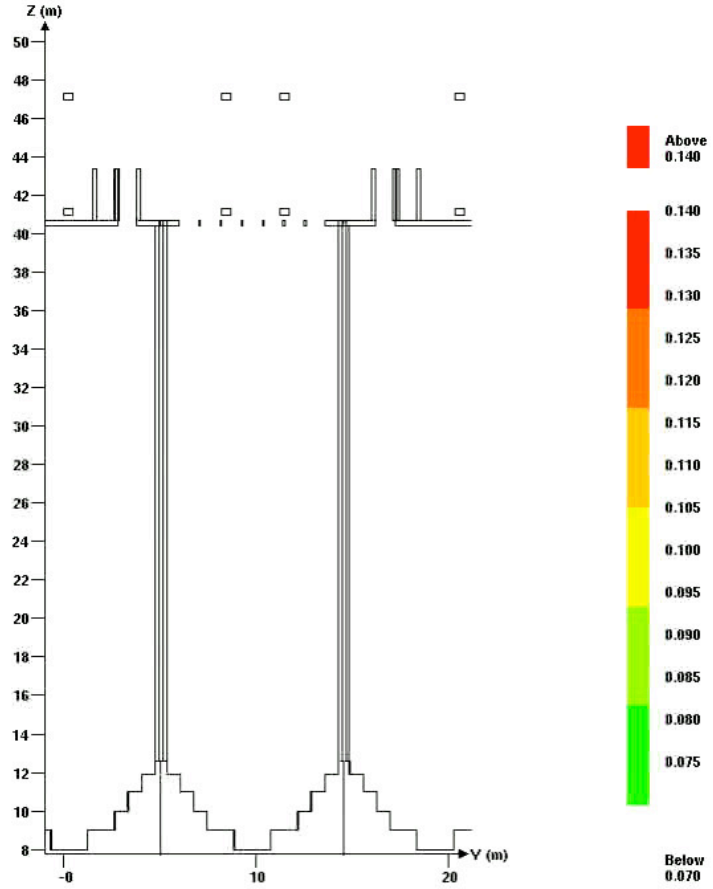
Job=010303, Var=PROD (kg/kg), Time= 0.000 (s).
XZ plane, Y=9.9 m

Protection system for silos – AS IS

Simulation results



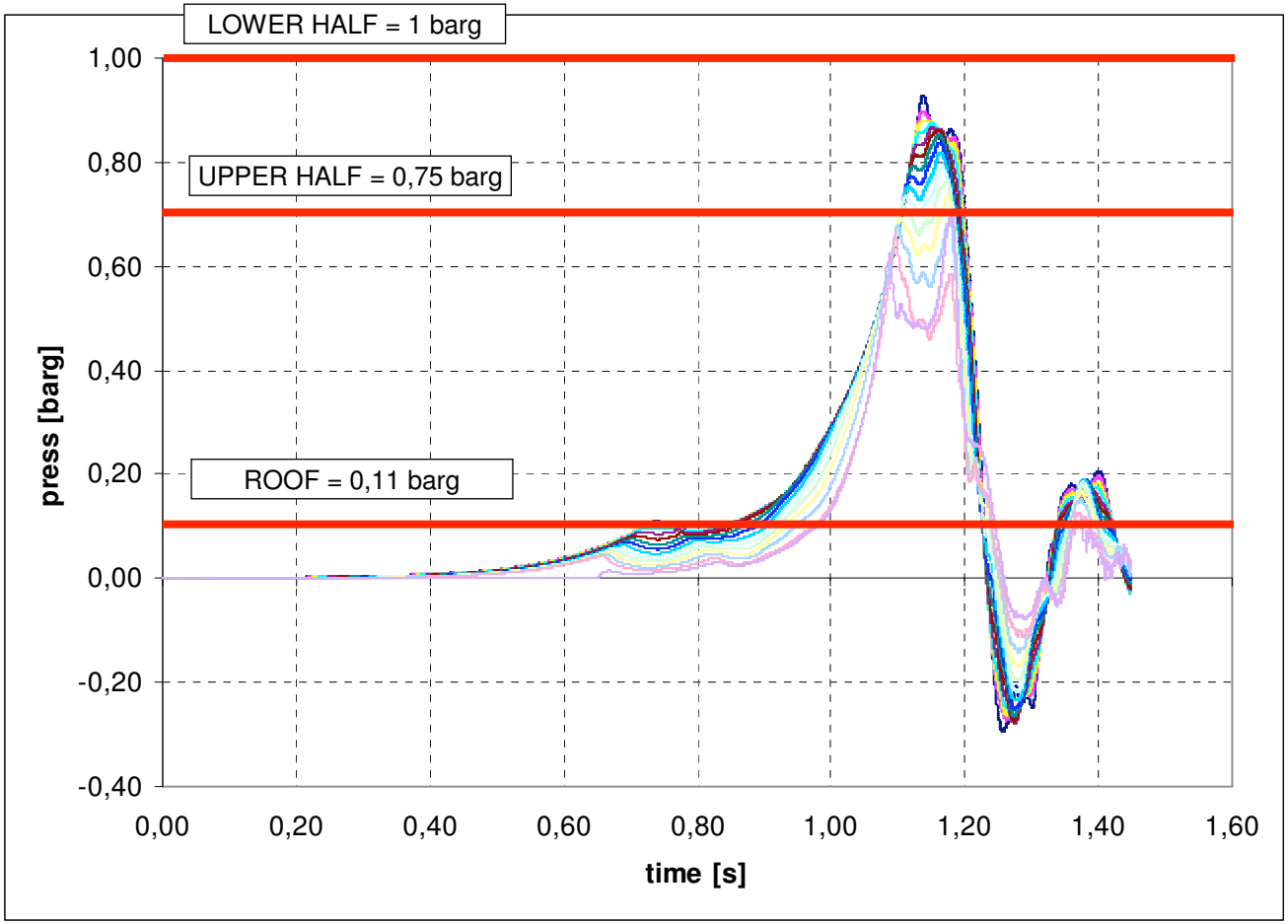
Job=010303, Var=PROD (kg/kg), Time= 0.000 (s).
XY plane, Z=40.7 m



Job=010303, Var=PROD (kg/kg), Time= 0.000 (s).
YZ plane, X=40.6 m

Protection system for silos – AS IS

Simulation results – overpressures



Monitor points are placed:

1. Along the side walls of the silo and under the roof
2. Inside the penthouse
3. Over the building in front of the silo

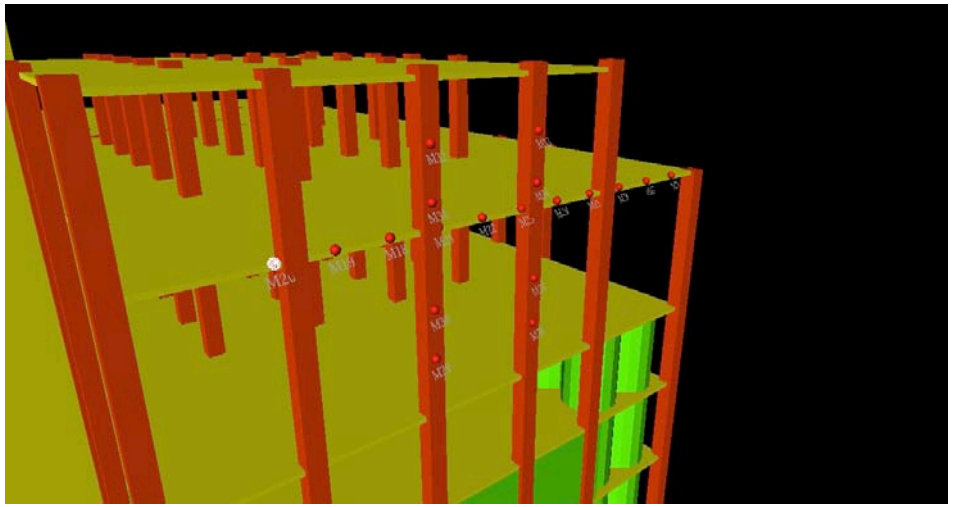
Effects:

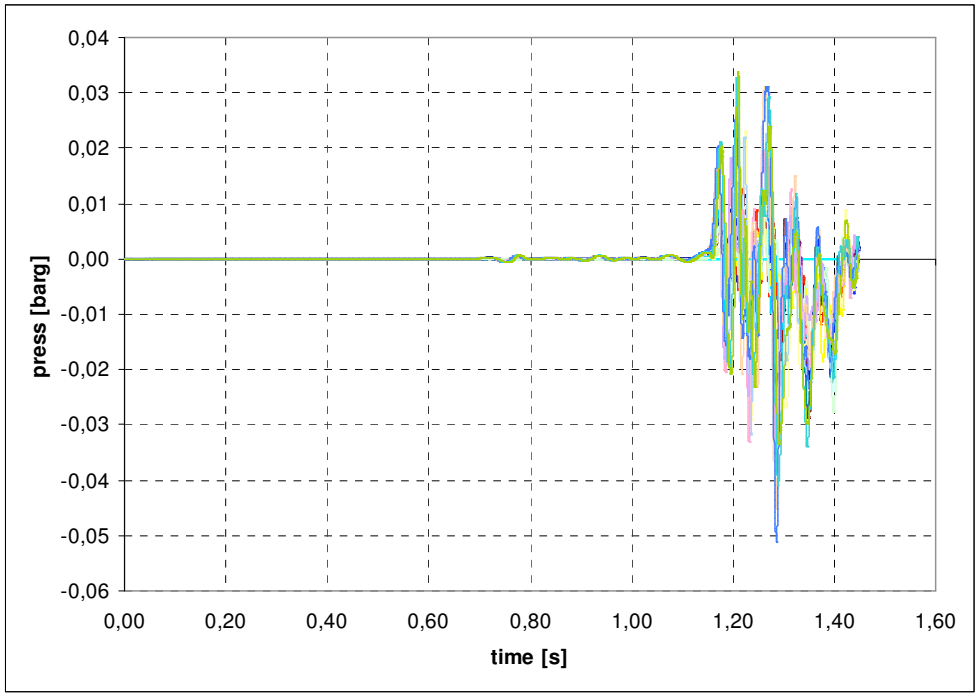
The enlarged venting surface produces lower overpressures inside the silo, but the roof and the upper half of the silo are destroyed

There are severe damages to the penthouse.

Protection system for silos – AS IS

Simulation results – overpressures





Effects on the building in front of the silo (mill):

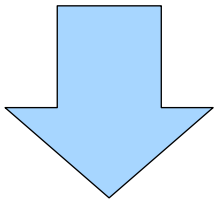
According to literature, the overpressure on the mill's walls causes:

- **Structural damages**
- **Large windows break**

New safety concept

Simulation results

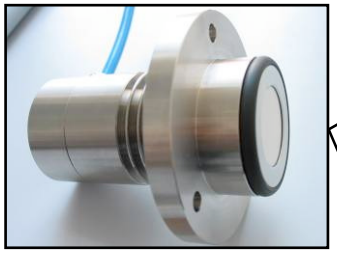
- Inadeguate venting surface causes severe damages to the silos and to the nearby buildings
- Silos can't be protected using standard venting panels (Pstat=0,1 barg)



New safety concept

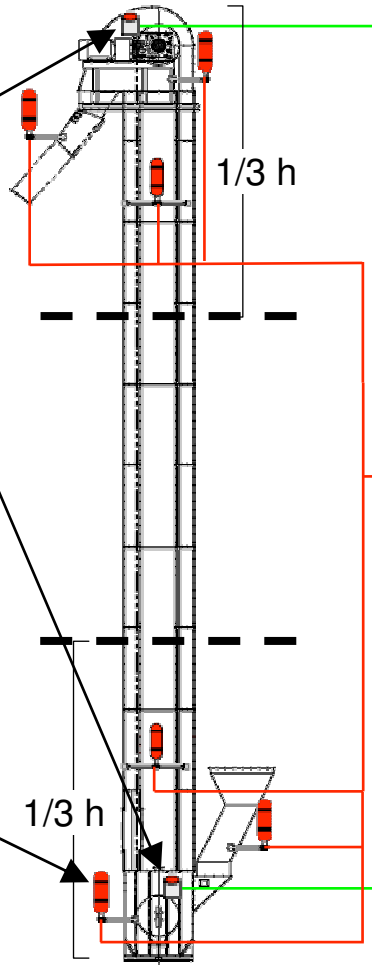
1. Reduce the probability that an ignition source enters inside silos (sparks, flames, foreign bodies coming from the unloading station, etc)
2. Implement all applicable preventive measures
3. **Explosion protection on bucket elevators**
4. **New design of the silo's roof**

Explosion protection on bucket elevator



PXD Analog Sensor

Chemical Suppressor

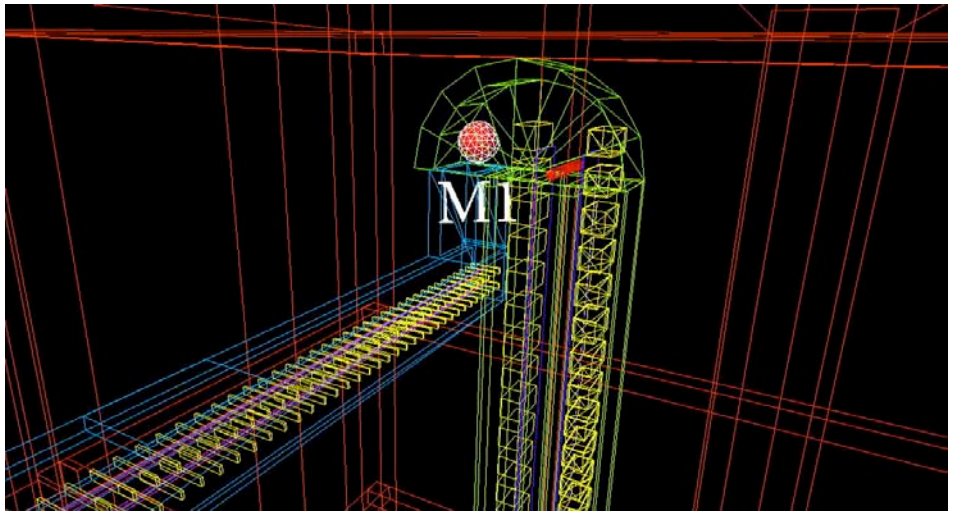


PXD sensors detect deflagration and send signal to electronic control equipment.

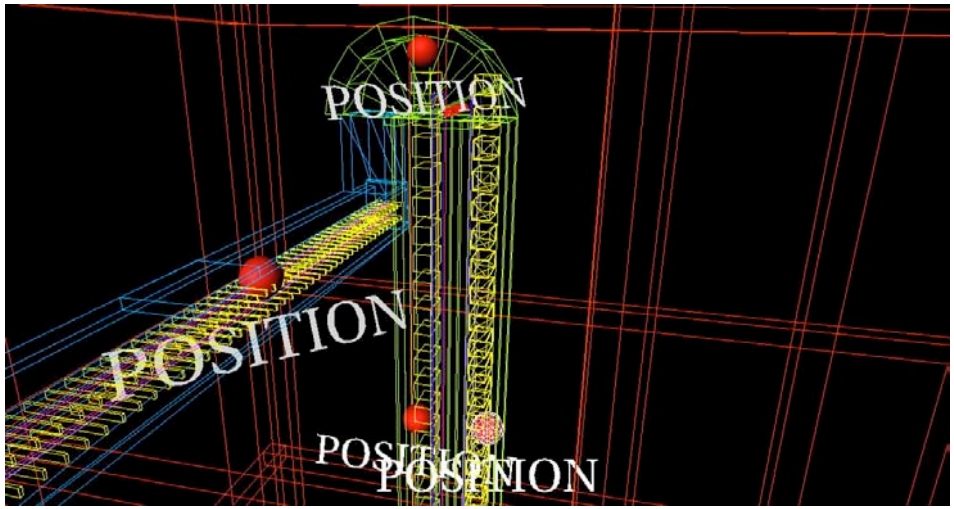
Control panel activate the suppressors to chemically cool the fire and suppress the advancing flame front mitigating pressure build up.

Control Panel

Explosion protection on bucket elevator



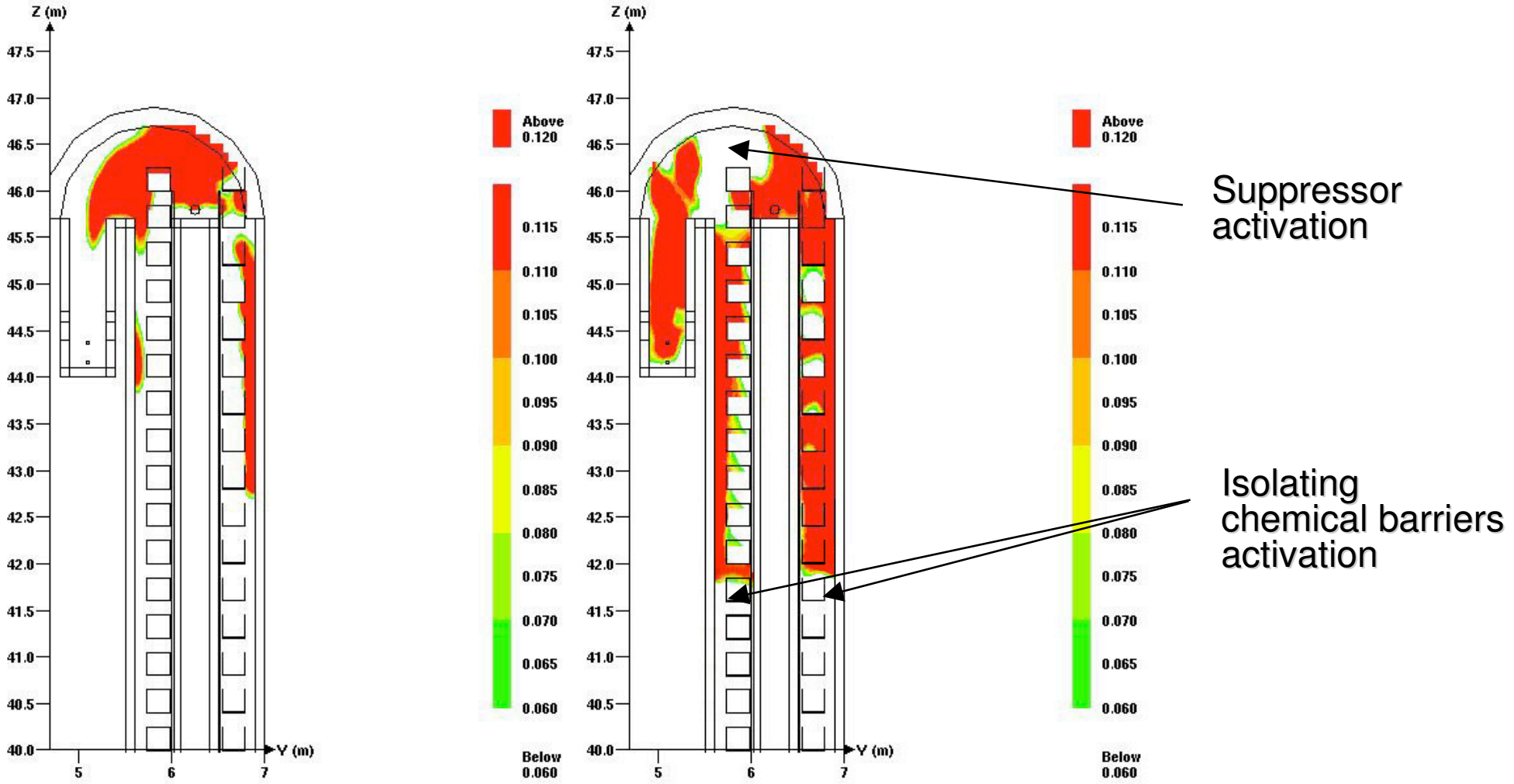
Dynamic pressure detector simulated in DESC using a monitor point



Suppressors simulated as “leaks” of dessicarb, activated by the monitor point

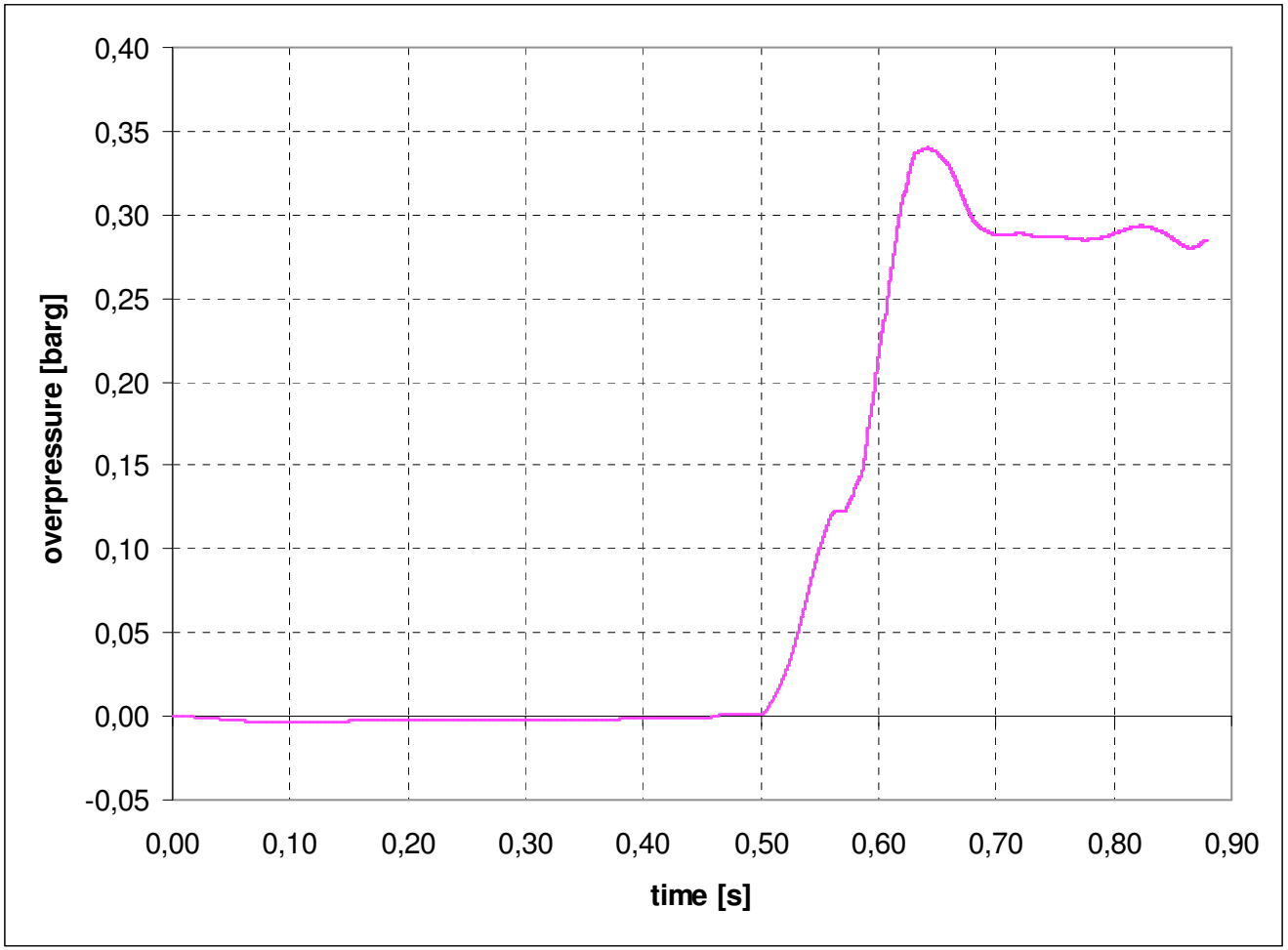
Explosion protection on bucket elevator

Simulation results



Explosion protection on bucket elevator

Simulation results – overpressures



Effects:

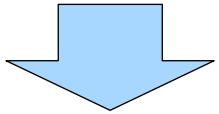
The overpressure inside bucket elevator doesn't damage it

No flame propagation to the lower part of the elevator and to the chain conveyor

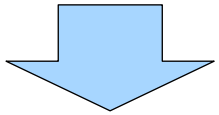
No secondary explosion inside silos

New design of the silo's roof

All the preventive and protective measures listed before are enough to reduce the explosion risk to an acceptable level.
According to the risk analysis, the safety concept suggested doesn't require protection systems for the silos.

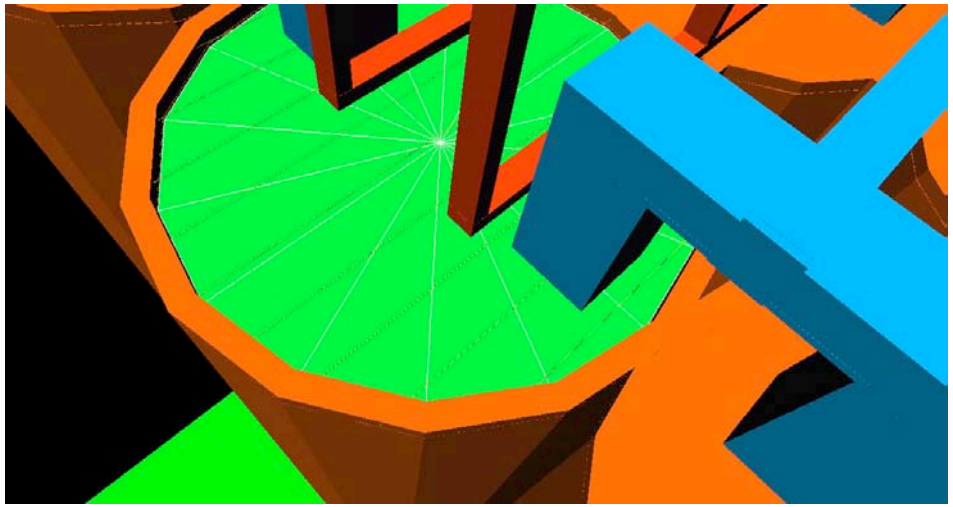


Altough the explosion risk is acceptable, we suggested to the customer to design the roof of each silo so that it behaves like a venting panel.
In other words, each roof should avoid pressure built up inside the silos over the structural limits of the walls (0,75 barg for the upper half of the silos)
How this could be done?

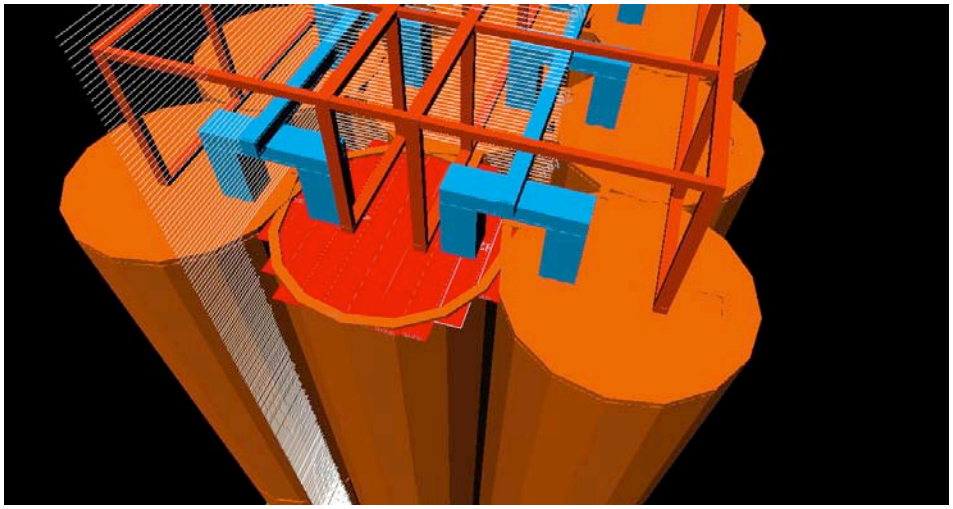


Using DESC we have designed several kind of roofs, until we found a pressure-time curve that doesn't exceed structural limits of the concrete walls
The roof will be made up of light 1 m^2 metallic panels, that break when the overpressure exceeds 0,03 barg

New design of the silo's roof



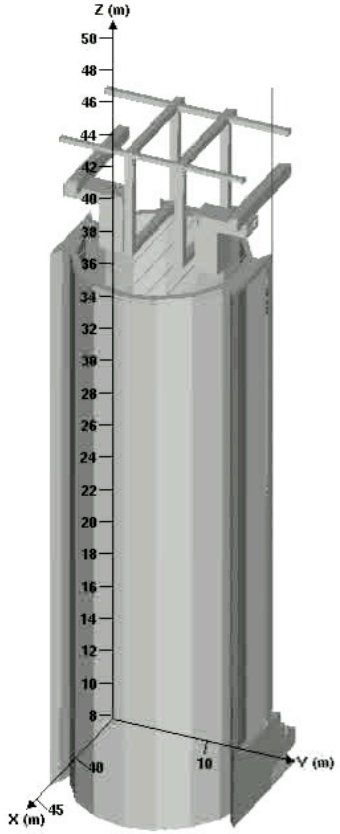
Light metallic roof made up of plates

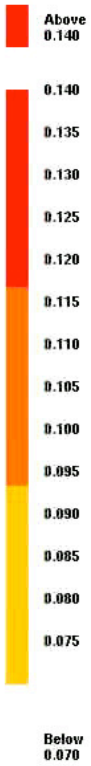


Roof simulated as venting panels (Pstat=0,03)

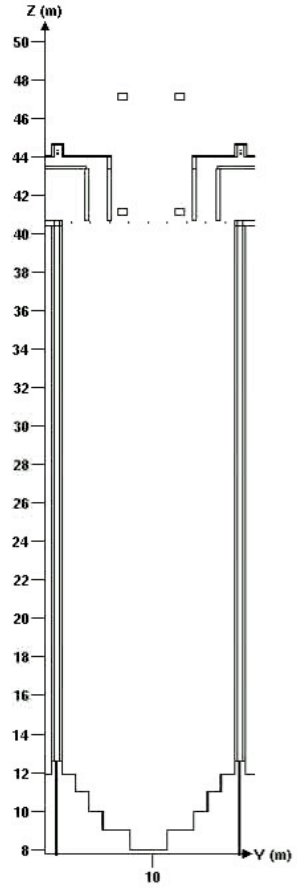
New design of the silo's roof

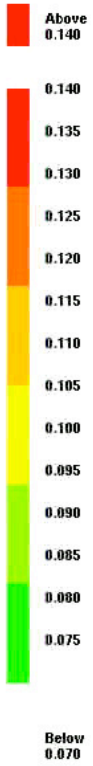
Simulation results





Job=010405. Var=PROD (kg/kg). Time= 0.000 (s).
X=35.5 : 46.1, Y=4.5 : 15.1, Z=7.9 : 50.9 m

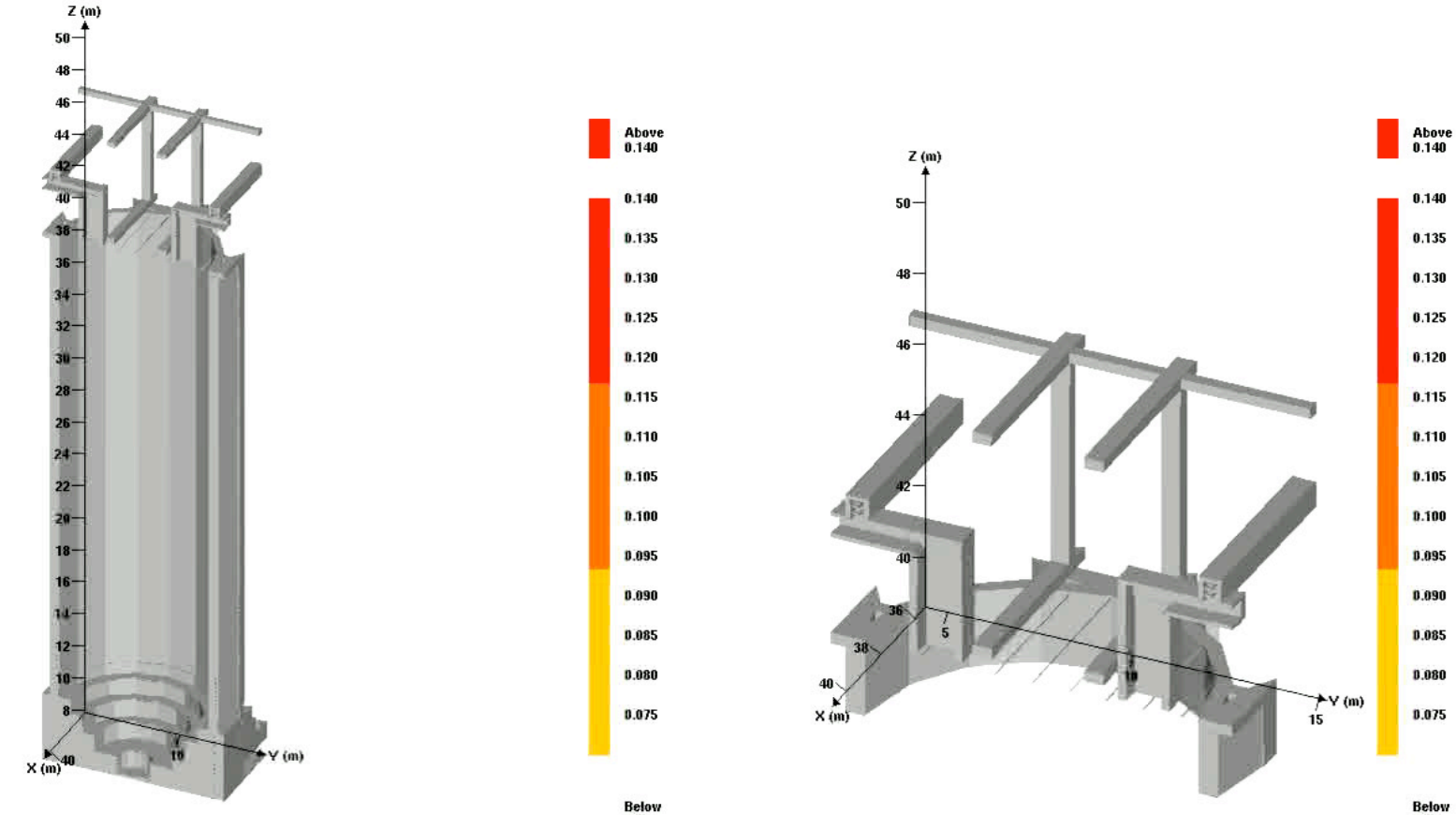




Job=010405. Var=PROD (kg/kg). Time= 0.000 (s).
YZ plane, X=40.7 m

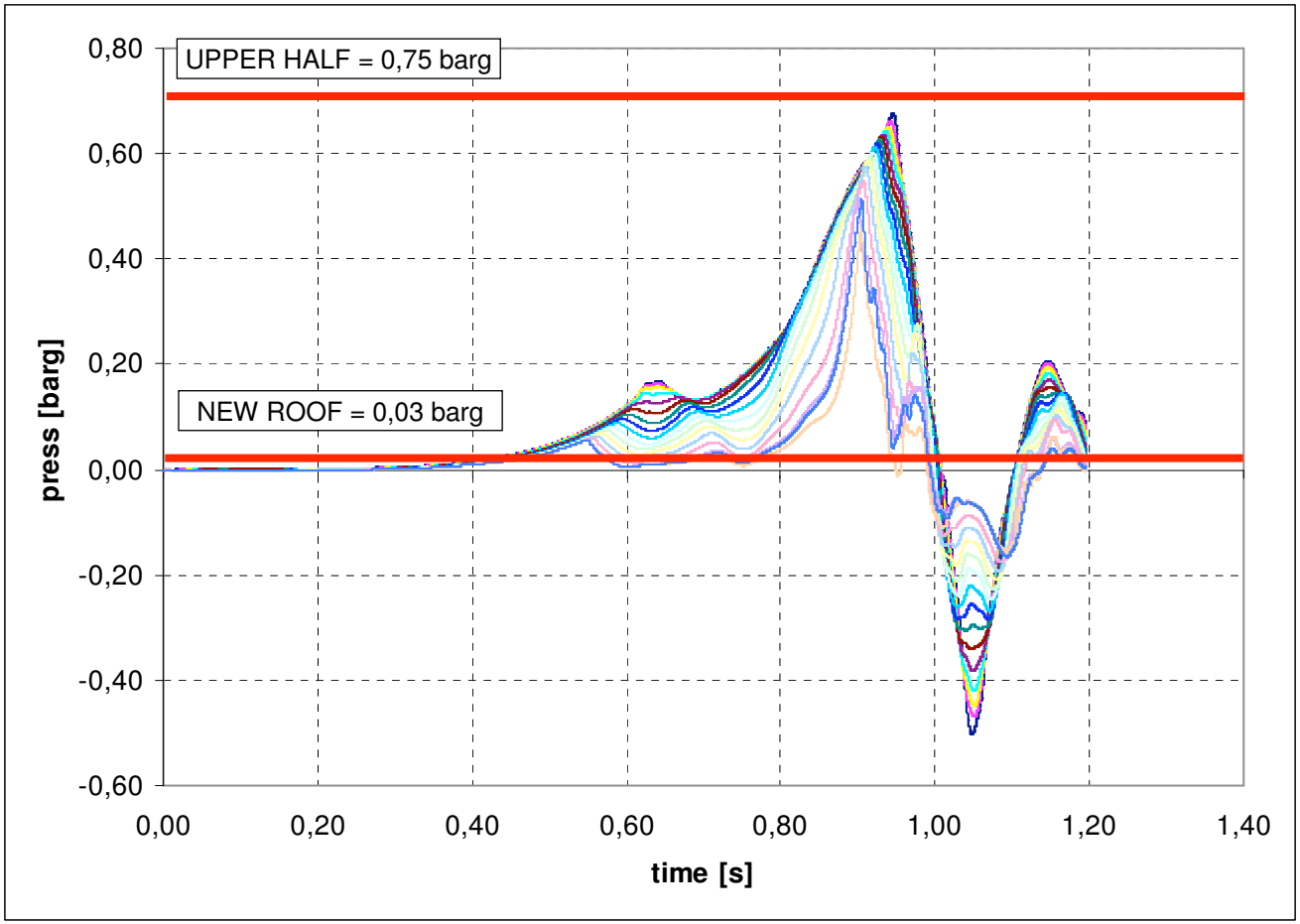
New design of the silo's roof

Simulation results



New design of the silo's roof

Simulation results – overpressures



Effects:

The new light roof arrests pressure built-up before there are severe damages to the silo's structure

The panels of the roof are projected away and fragments can hit personnel, altough the explosion should not occur because of all the preventive and protective measures discussed before

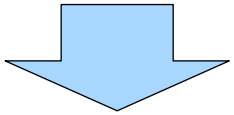
IMPACT ON THE SAFETY PLAN

WHAT ARE THE ANTICIPATED EFFECTS OF AN EXPLOSION?

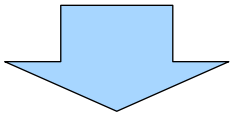
- **Overpressure** $Sd = d_{Pred \leq 0,02\ barg}$
- **Thermal radiation** $Sd = d_{I \leq 1,9\ kW/m2}$
- **Flame lenght** **(primary expl)**

New safety plan

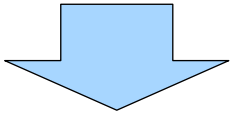
1. Workers are not allowed to work or walk on the silo roof during any loading operation



2. In case of fire inside the silos or nearby, the Fire Brigades and the Rescue Teams should not walk on the silo roof because of a risk of explosion



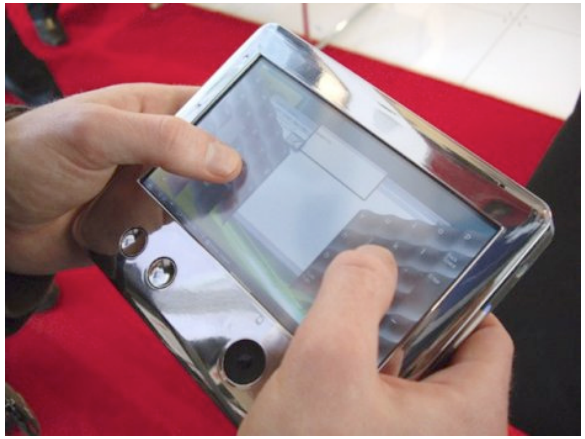
3. In case of any Fire Alarm in the plant, workers located on the silo roof should leave the area immediately, reporting to the local Safety Coordinator



4. In case of external intervention by Rescue Teams, the hazardous areas of the plant where **dust (if toxic), flames, pressure and heat radiation** could be fatal for human beings, are clearly represented; the **rescue strategy** can be quickly defined based on the actual scenario

Modern Application of Risk assessment results in the Risk Management and Disaster Recovery

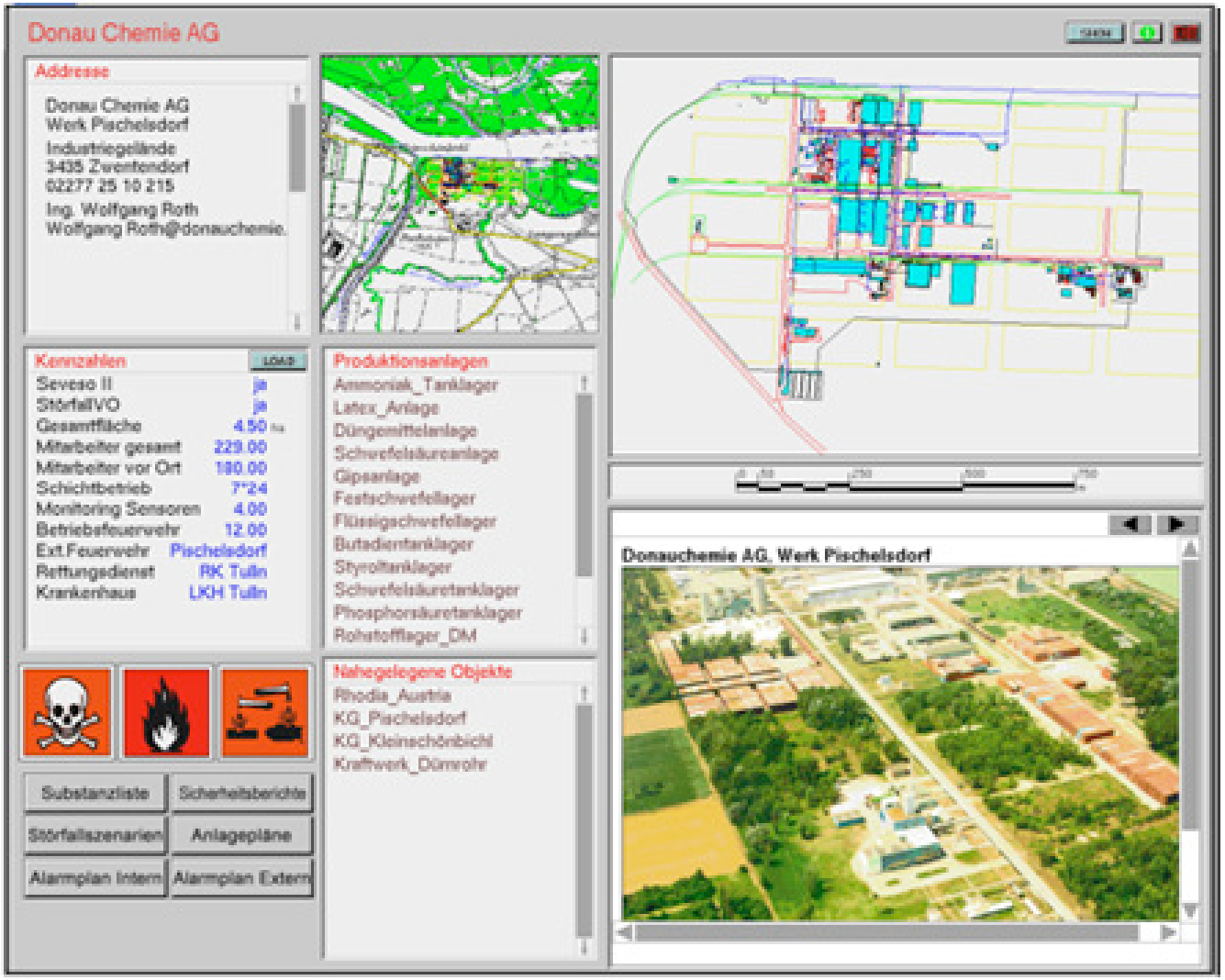
Hardware



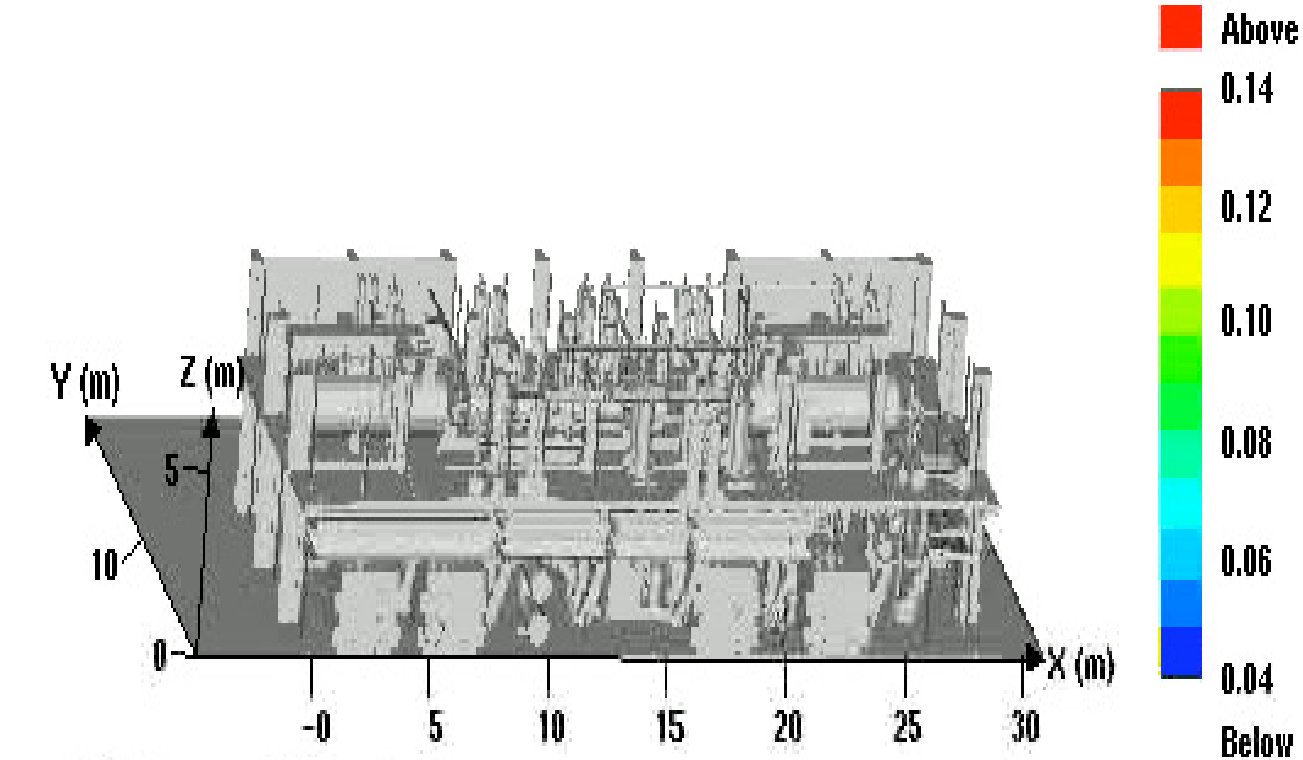
Index

- 2D/3D PLANT LAYOUT
- SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)
- 3D EFFECT REPRESENTATION
- RECOMMENDED SAFETY PROCEDURES (BASED ON THE SCENARIO)
- CRITICAL POINTS AND HAZARDOUS AREAS
- MSDS AND PROPER MEANS OF PROTECTION

2D/3D PLANT LAYOUT

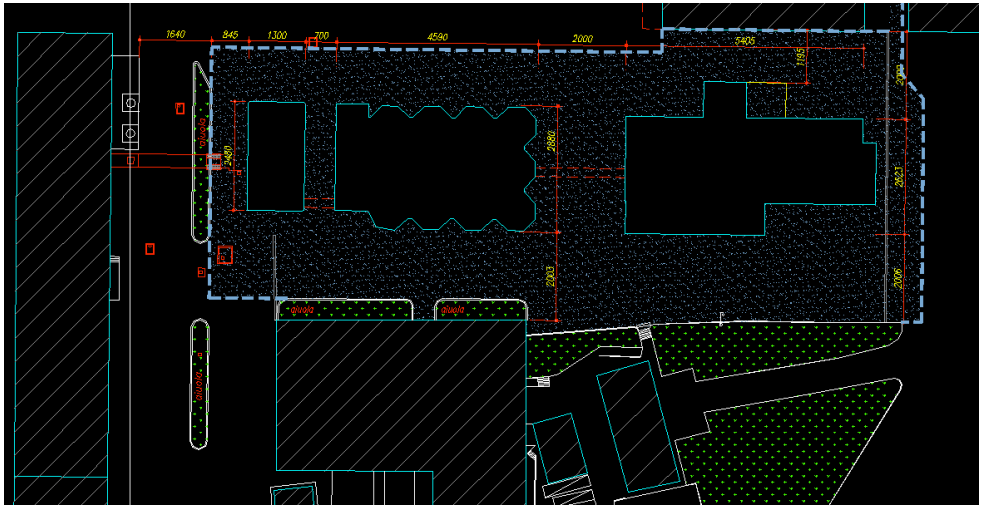


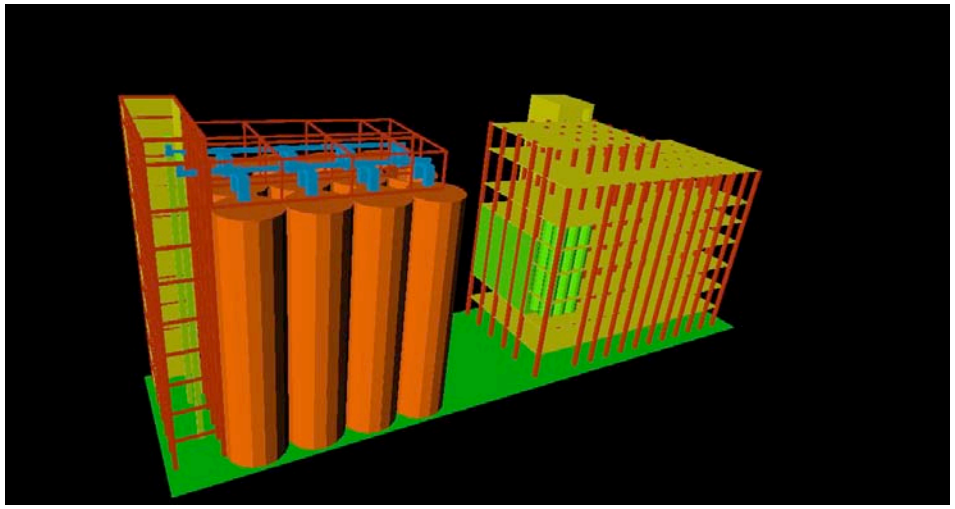
3D PLANT LAYOUT



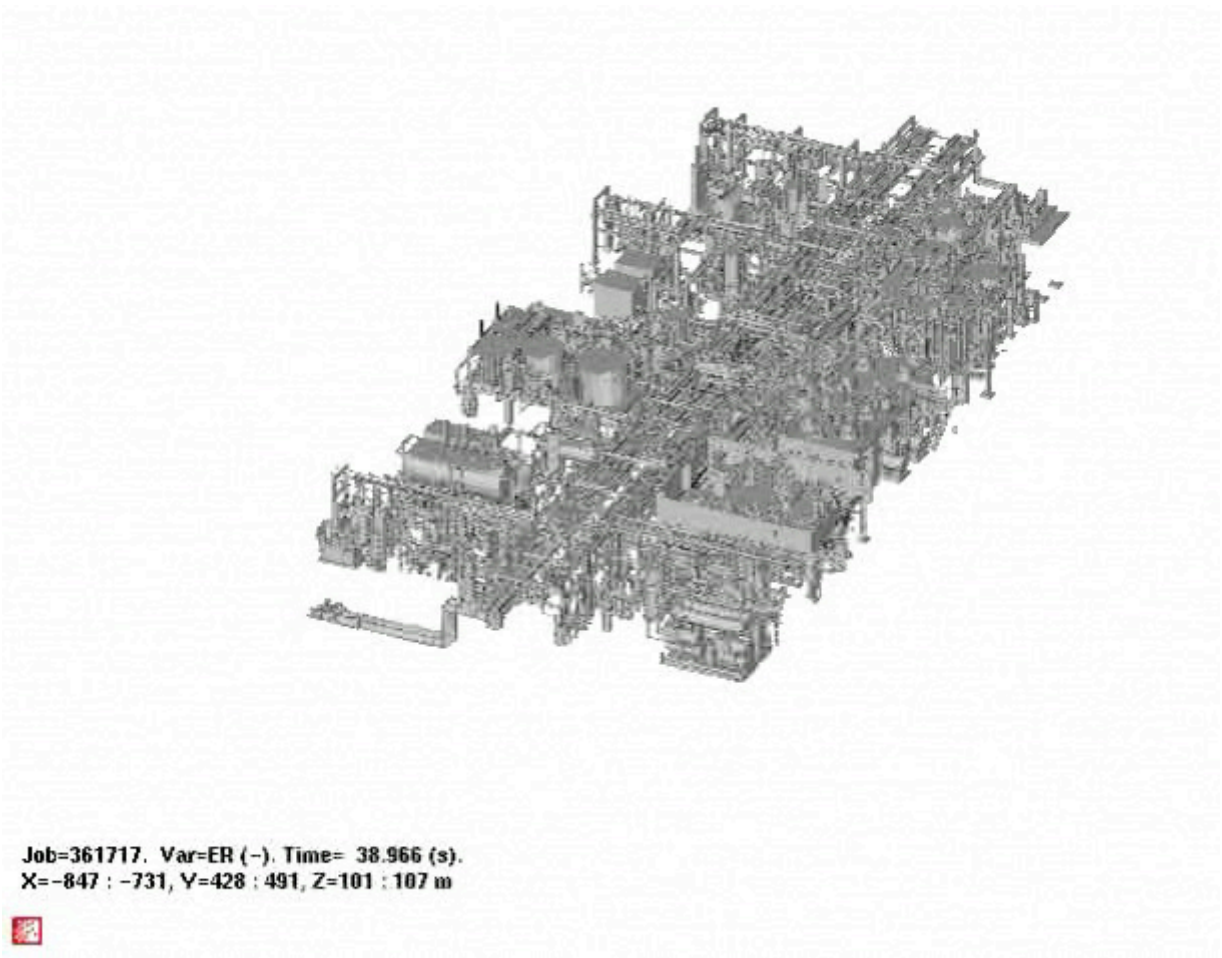
Job=110503. Var.=FMOLE (mol/mol).
Time= 0.000 (s). I=10-39, J=13-29, K=1-5.

3D PLANT LAYOUT



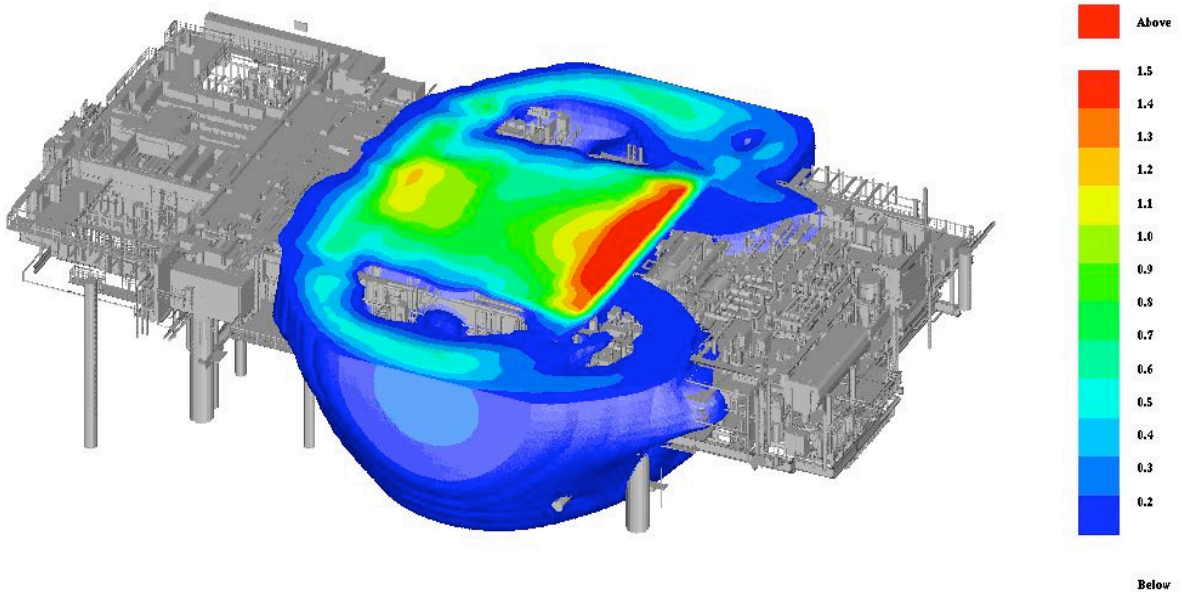


SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)



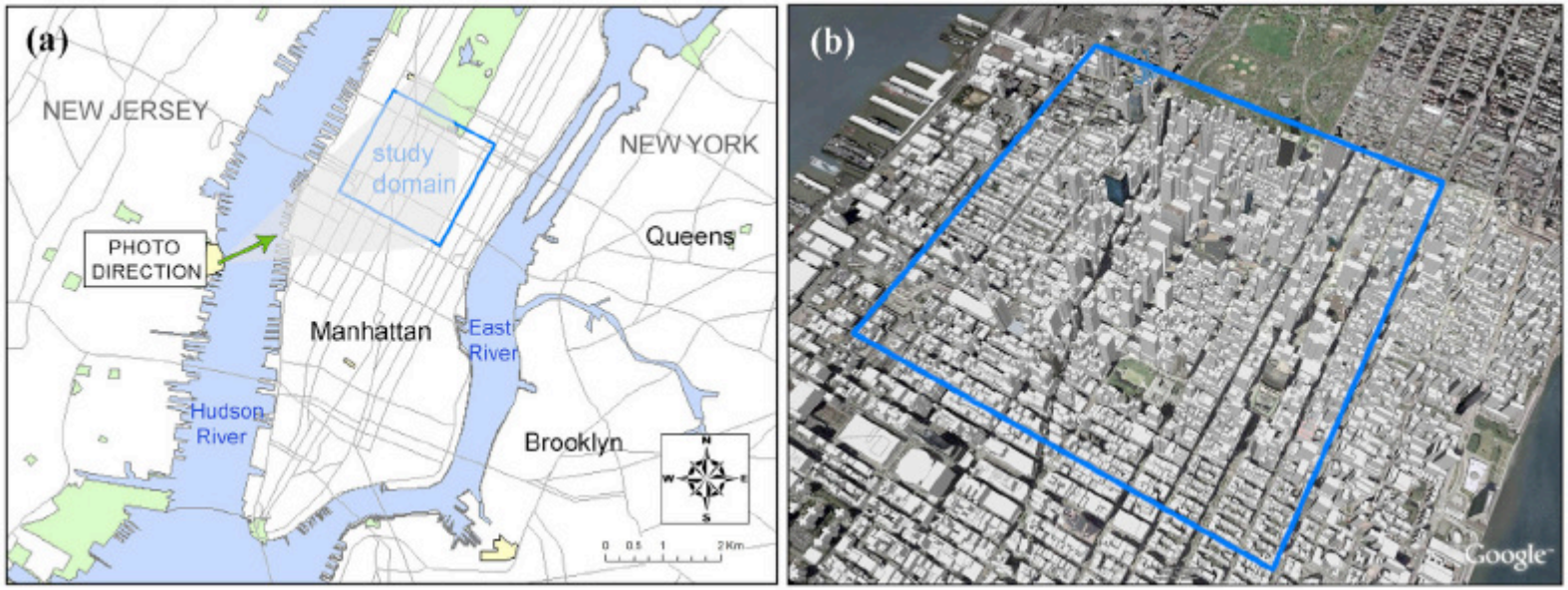
GAS DISPERSION

SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)



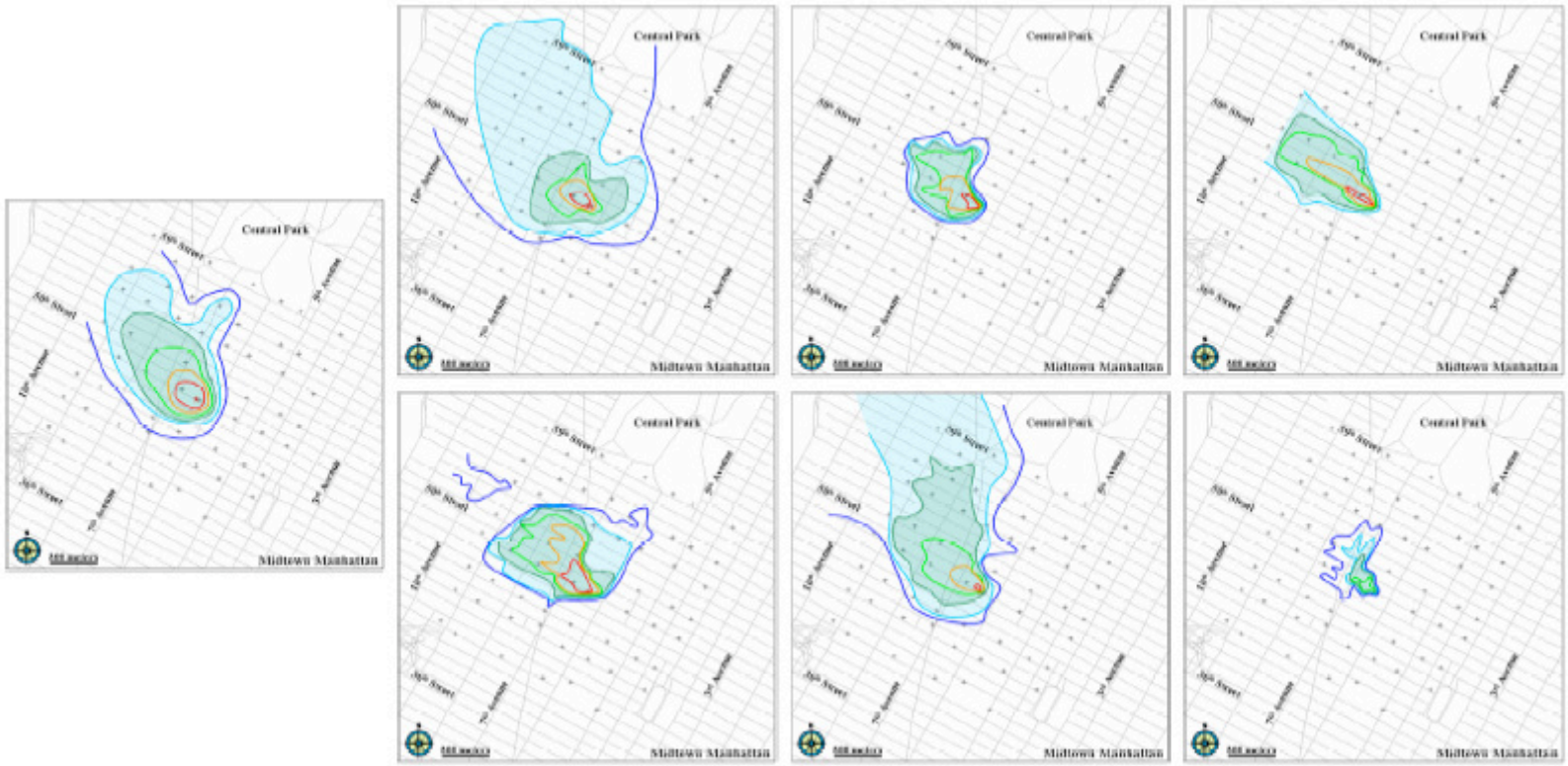
GAS DISPERSION

SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)



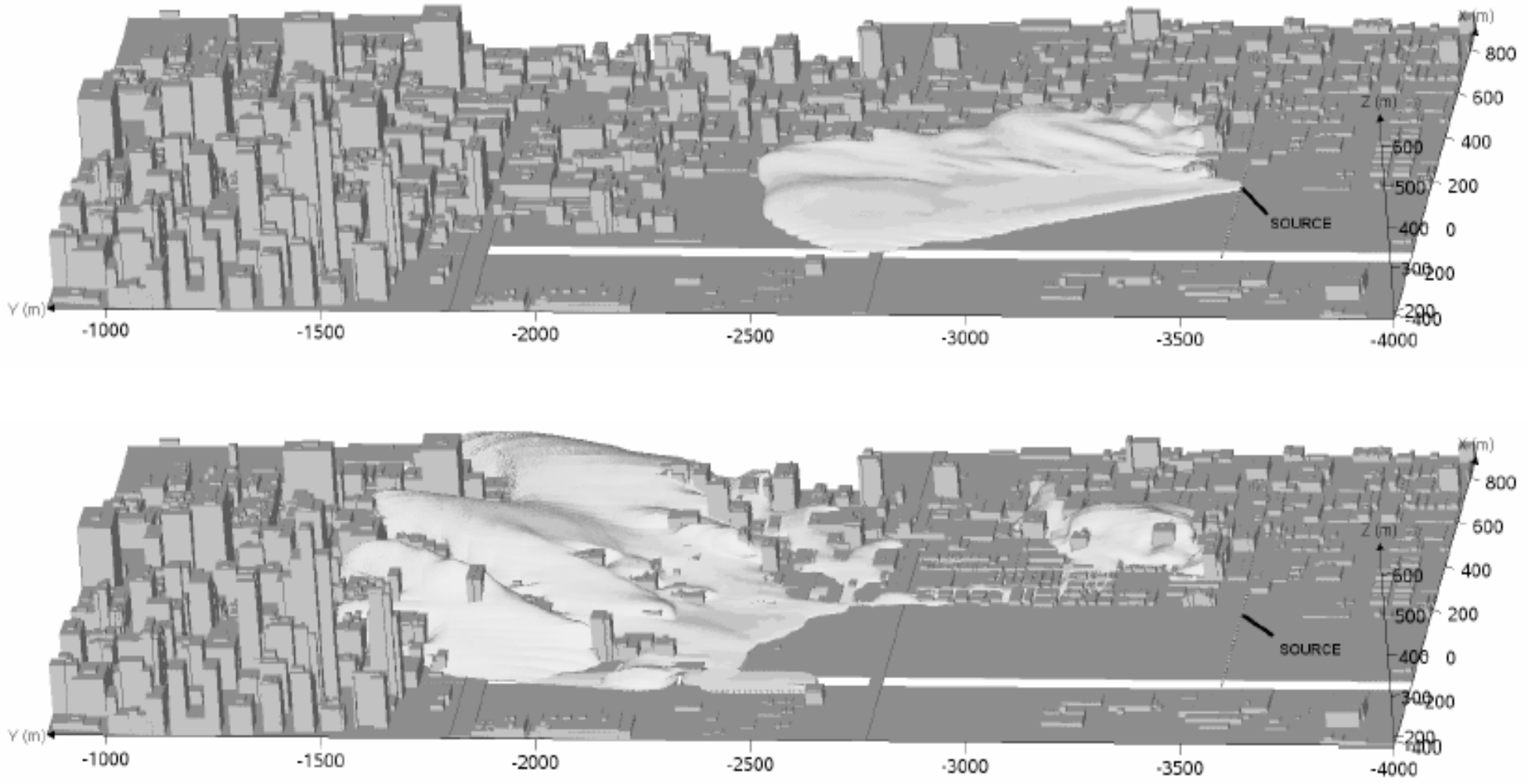
GAS DISPERSION – URBAN MODEL

SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)



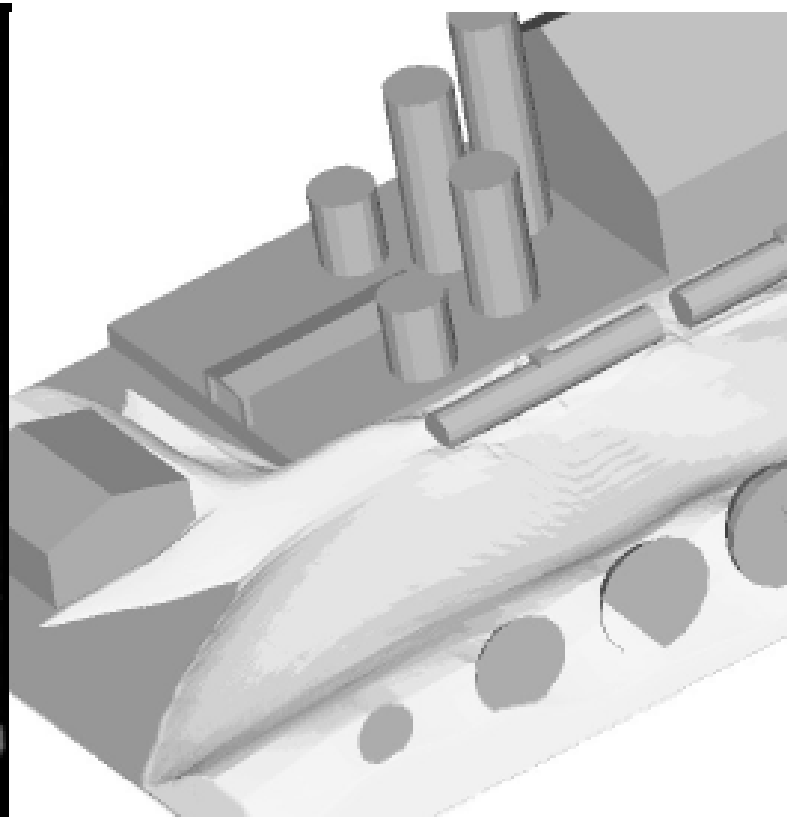
GAS DISPERSION – URBAN MODEL

SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)



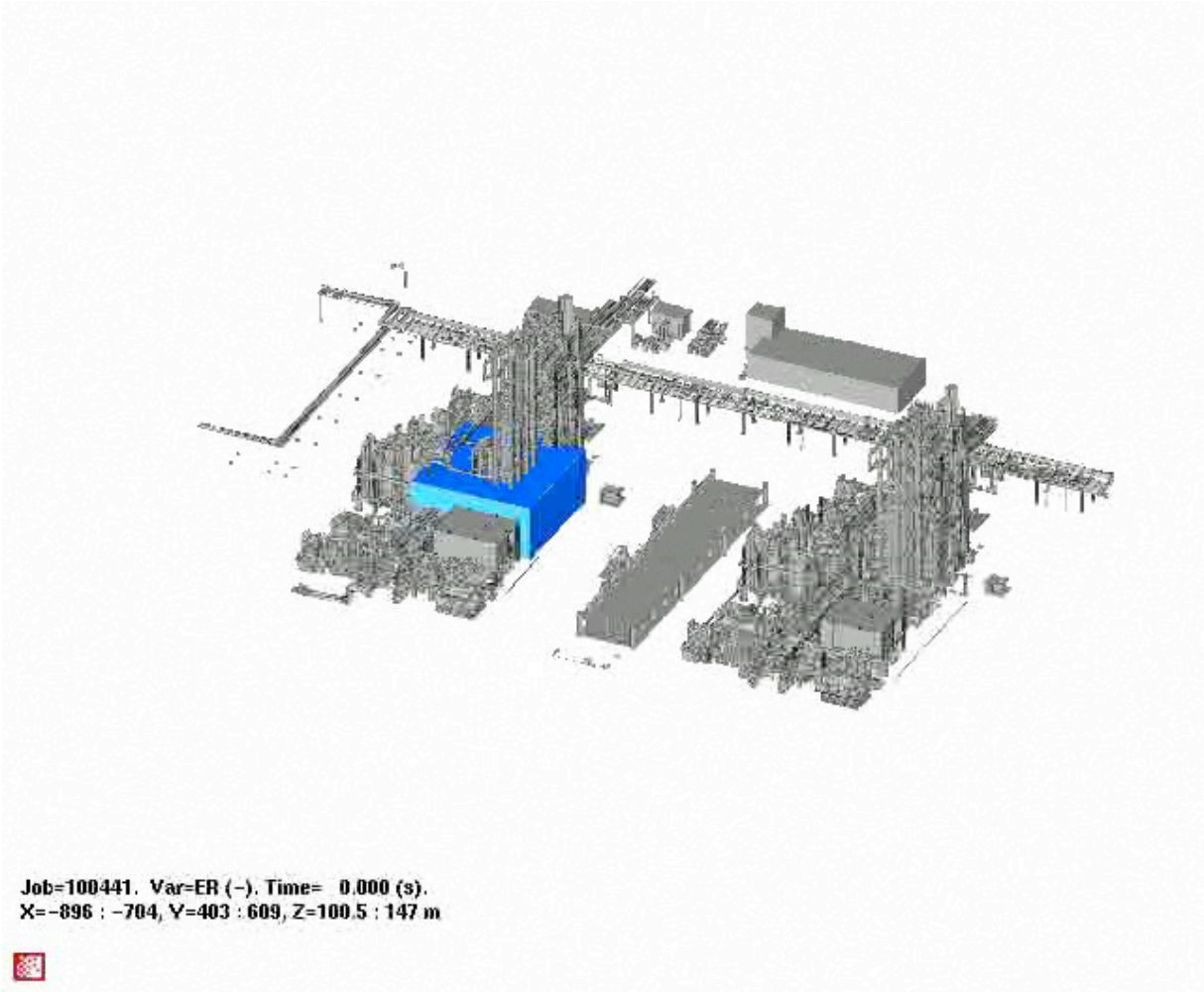
GAS DISPERSION – URBAN MODEL

SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)



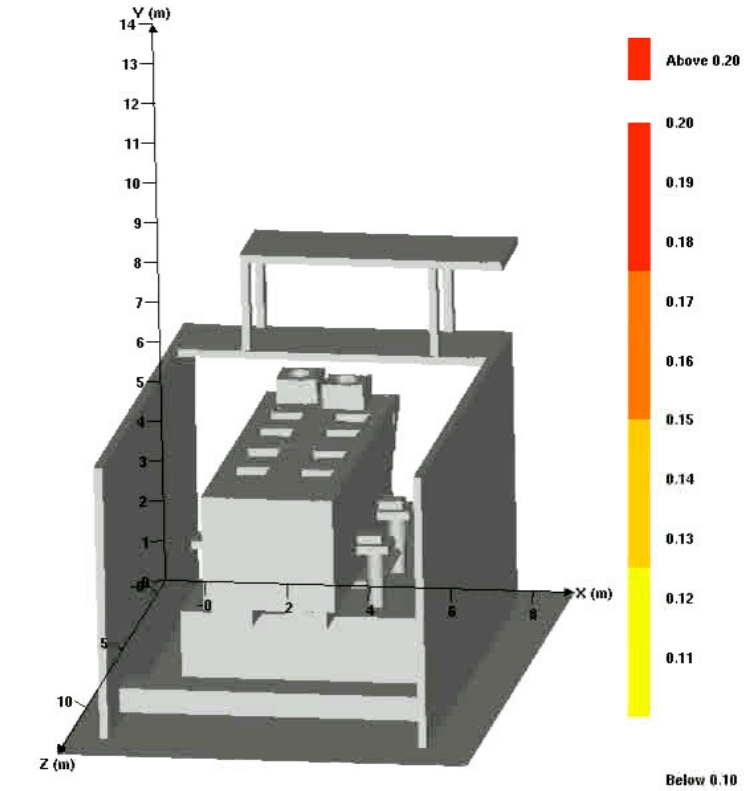
GAS DISPERSION – OTHER MODEL

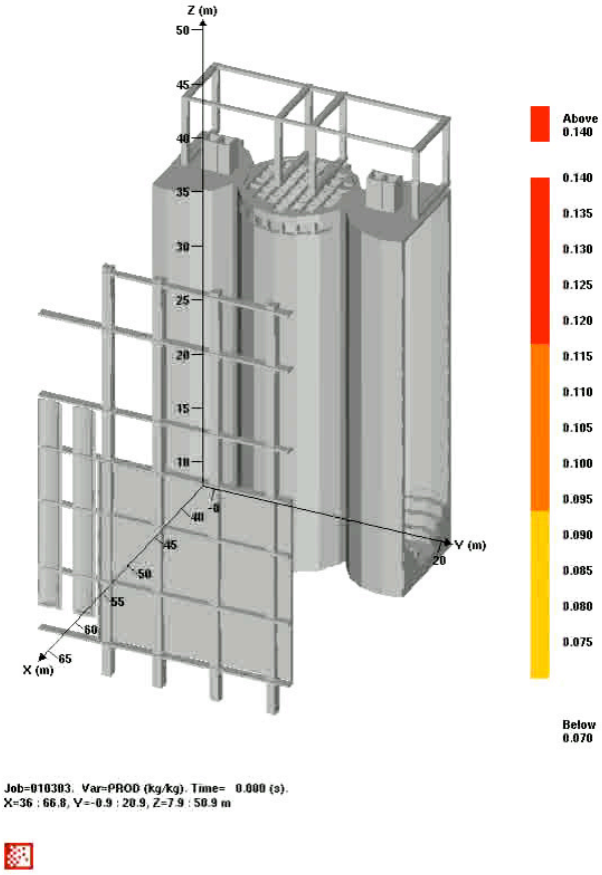
SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)



GAS EXPLOSION

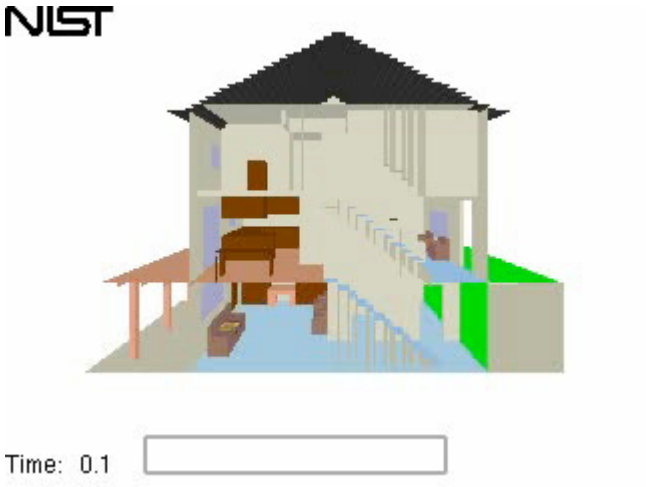
SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)

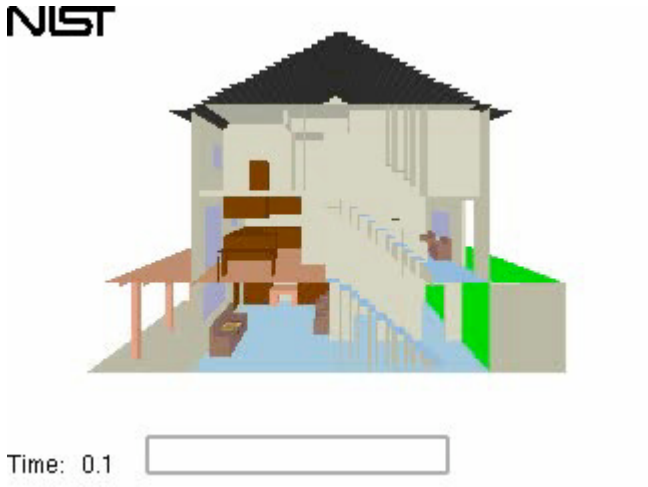




DUST EXSPLOSION

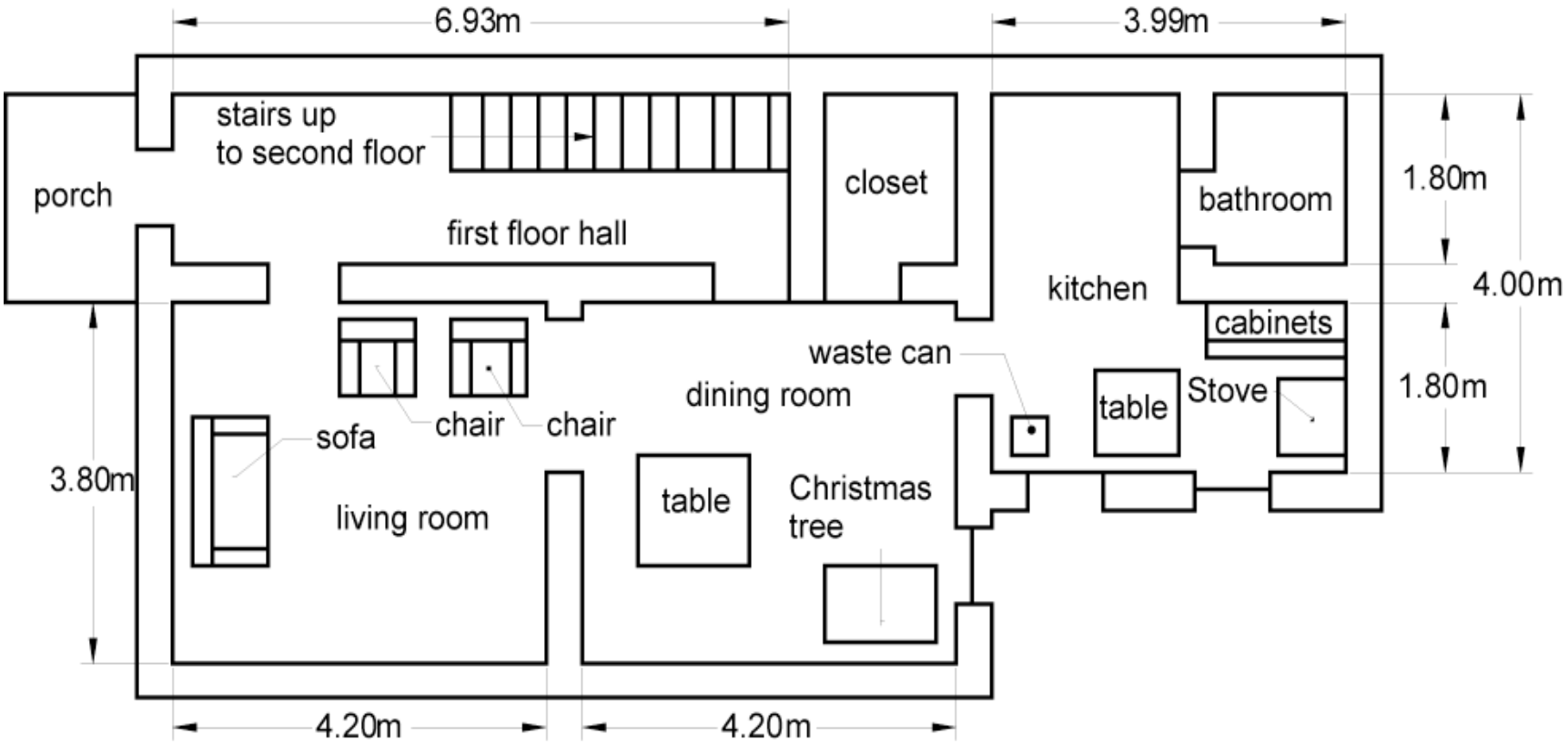
SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)





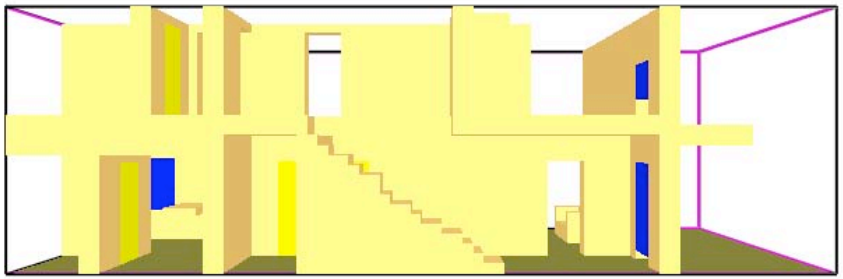
FIRE PROPAGATION

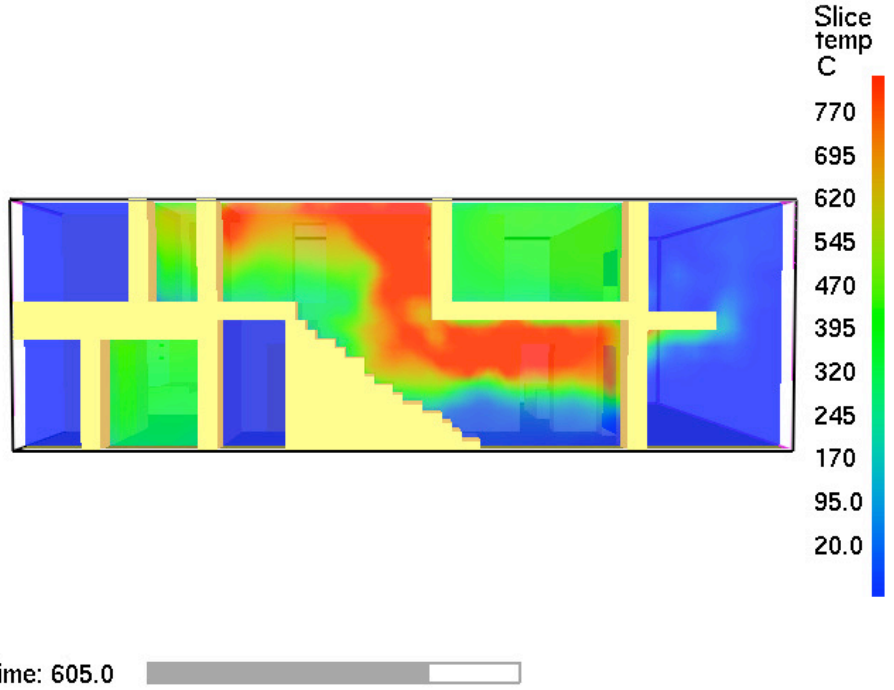
SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)



FIRE PROPAGATION

SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)





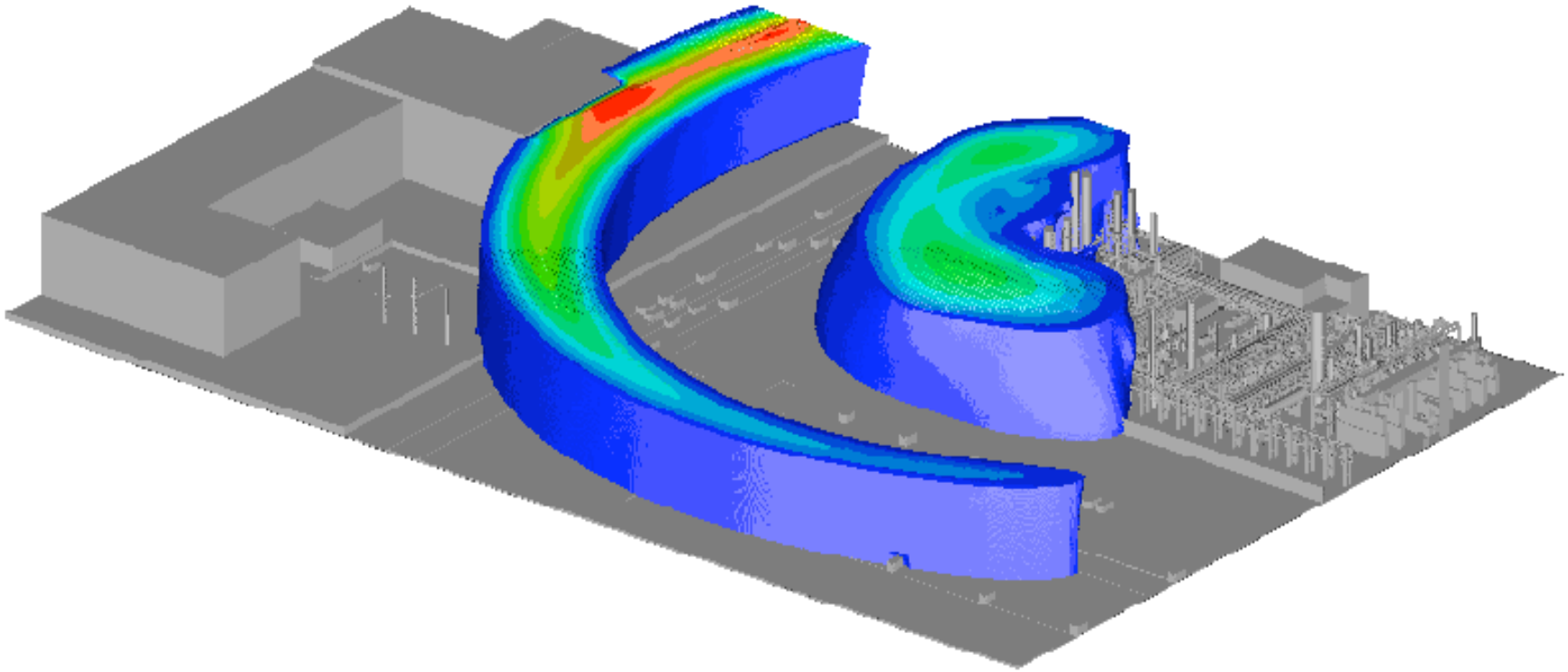
FIRE PROPAGATION

SCENARIOS (GAS/DUST DISPERSION – FIRE – EXPLOSION)

Estimated flame boundary spreading through the dining room and into the living room at approximately 8:34 AM.

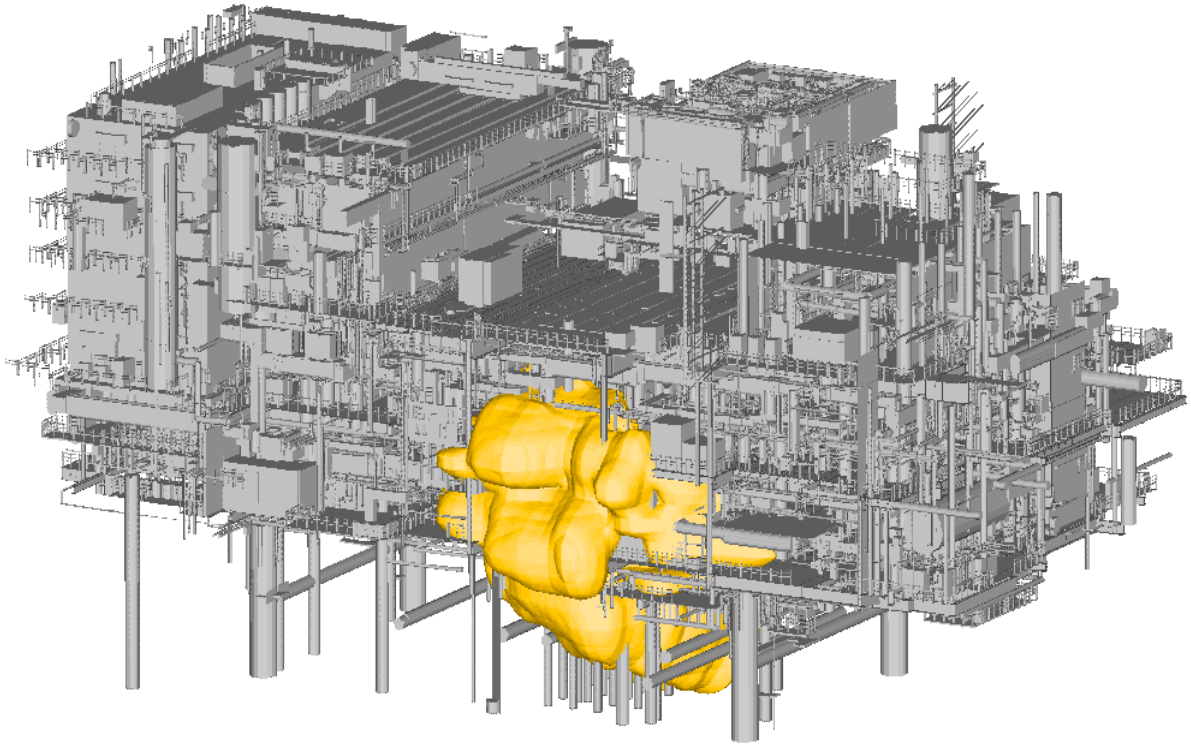
FIRE PROPAGATION

3D EFFECT REPRESENTATION



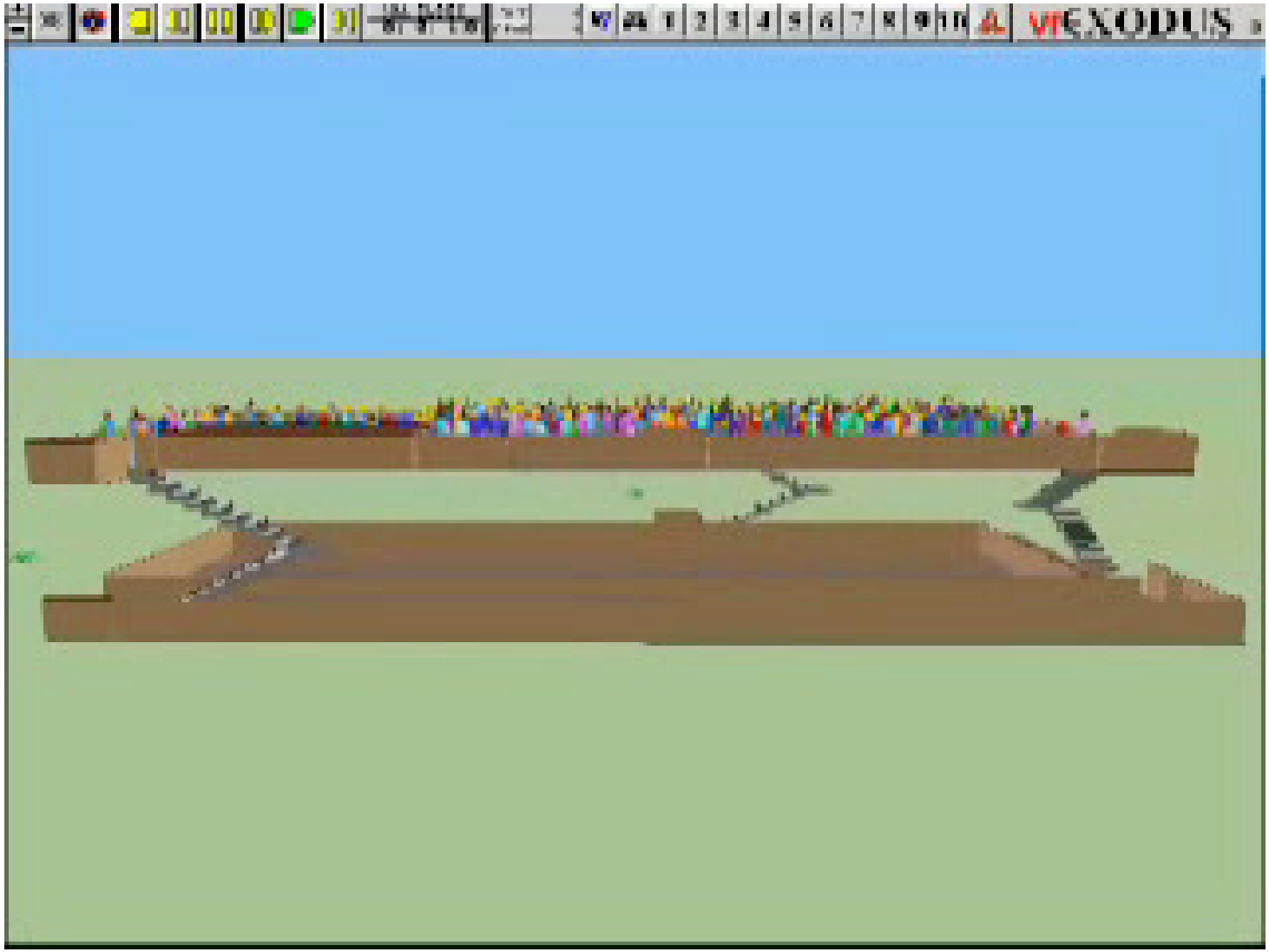
BLAST PROPAGATION

3D EFFECT REPRESENTATION



FIRE PROPAGATION

RECOMMENDED SAFETY PROCEDURES (BASED ON THE SCENARIO)

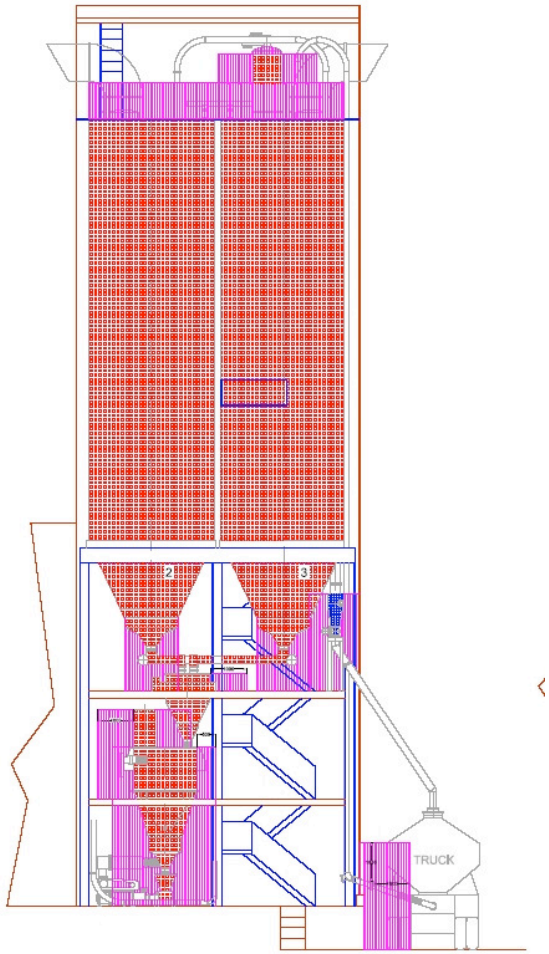


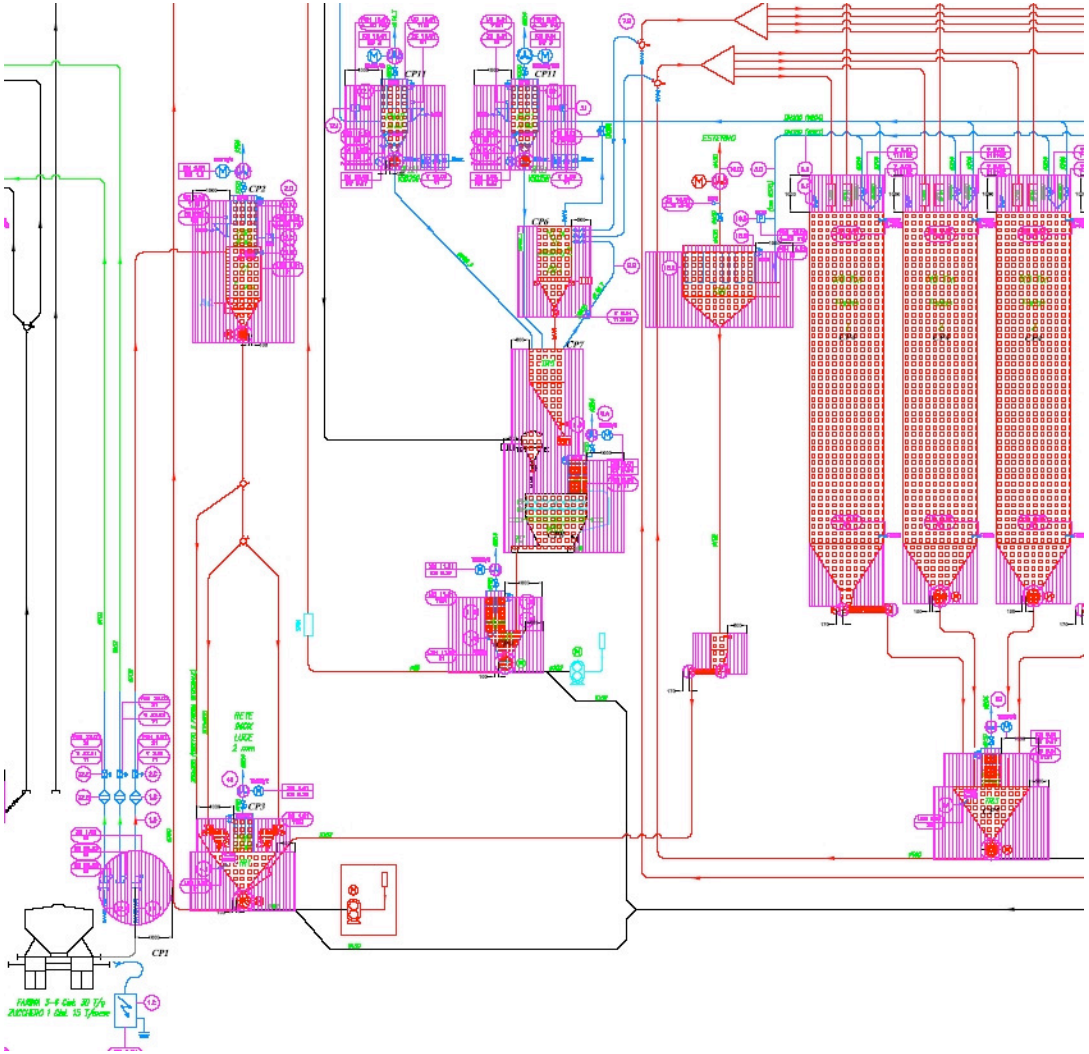
RECOMMENDED SAFETY PROCEDURES (BASED ON THE SCENARIO)

disaster recovery plan

- Organization chart showing names and positions
- Existing plan
- Staff emergency contact information
- List of suppliers and contact numbers
- List of emergency services and contact numbers
- Premises addresses and maps
- Existing evacuation procedures and fire regulations
- Health and Safety procedures
- List of professional advisers and emergency contact information
- Communication system specification

CRITICAL POINTS





CRITICAL POINTS

MSDS AND PROPER MEANS OF PROTECTION

2) COMPOSITION/INFORMATION ON INGREDIENTS

Substances with established exposure limits or classifiable as dangerous according to EC Directive 67/548 and following amendments, in concentration equal or higher than that reported in EC Directive 98/24:

Name	Conc.	CAS N°	Symbol	Risk Phrases
ε-Phthalimidoperoxyhexanoic acid	≈ 70%	128275-31-0	O , Xi , N	R 7-41-50

3) HAZARDS IDENTIFICATION

Adverse human health effects	Severe irritation to eyes, irritation to skin and respiratory system.
Environmental effects	No adverse long-term effects to the aquatic environment are foreseen, due to biodegradability and non-bioaccumulable properties of the active ingredient. The preparation may exhibit acute effects in case of massive discharge in watercourses.
Physical and chemical hazards	The active ingredient is an oxidizer; flammable aerosols may be released in case of thermal decomposition.

4) FIRST-AID MEASURES

Symptomatology following exposure

Eye contact	Severe irritation, pain, opacity of the cornea, iris injuries.
Skin contact	Redness, irritation.
Ingestion	Abdominal pain, nausea, vomit, diarrhoea; release of Oxygen in the stomach may cause dilatation with local bleeding.
Inhalation	Severe irritation of mucous membranes, cough.

First Aid Measures

Eye contact	Wash immediately and thoroughly with plenty of water for at least 15 minutes, keeping eyelids well raised. Protect the eyes with sterile gauze or a lean, dry handkerchief. Seek immediately medical advice.
Skin contact	Take off all contaminated clothing {and soak them in water}. Areas of the body that have – or are only suspected of having – come into contact with the product must be rinsed immediately with plenty of running water and soap. Seek medical advice in case of persistent pain.
Ingestion	Give 2-3 glasses of water to drink. Do not induce vomiting. Seek immediately medical advice.
Inhalation	Remove the patient from the contaminated area and make to rest in a well-ventilated area. Supply Oxygen in case of difficult breathing. Seek medical advice.

MSDS AND PROPER MEANS OF PROTECTION

5) FIRE FIGHTING MEASURES

Specific hazards	The active ingredient is an oxidizer. The preparation is not flammable, not explosive. Pressure bursts may occur due to decomposition in confined spaces.
Specific methods	Wear suitable protective clothing. In case of surrounding fire, remove the containers, if possible to do so in safe conditions. In case of impending fire, keep the containers cool by spraying with water.
Extinguishing media	Water (spay, fog, stream), CO_2, chemical powders or foam.
Protection of fire-fighters	Self-contained breathing apparatus; anti-acid clothing.

MSDS AND PROPER MEANS OF PROTECTION

8) EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure limits	Reference	ACGIH 2005
Total particulate	TLV/TWA	= 10 mg/m3
Respirable particulate	TLV/TWA	= 5 mg/m3
Engineering Measures	Ensure adequate ventilation, especially in confined areas.	

PERSONAL PROTECTIVE EQUIPMENT

Respiratory protection	Anti-dust mask. Self-contained apparatus in case of fire.
Eye protection	Safety goggles.
Hand protection	Rubber gloves.
Skin and body protection	Worksuit or rubber apron.
Hygiene measures	Do not eat, drink or smoke during handling.

END OF PRESENTATION

THANK YOU

FOR

YOUR KIND ATTENTION