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Assessment of Hydrocarbon Explosion and Fire Risks

by

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The LRET Research Collegium
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Assessment of Hydrocarbon Explosion and Fire Risks in Offshore Installations: Recent Advances and Future Trends

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New Paradigm for Robust Design of Ships and Offshore ...

Various Ocean Environmental Phenomena

Traditional

- Design Formula
- Past Experience
- Deterministic
- Allowable Stress
- Mathematical Algorithm

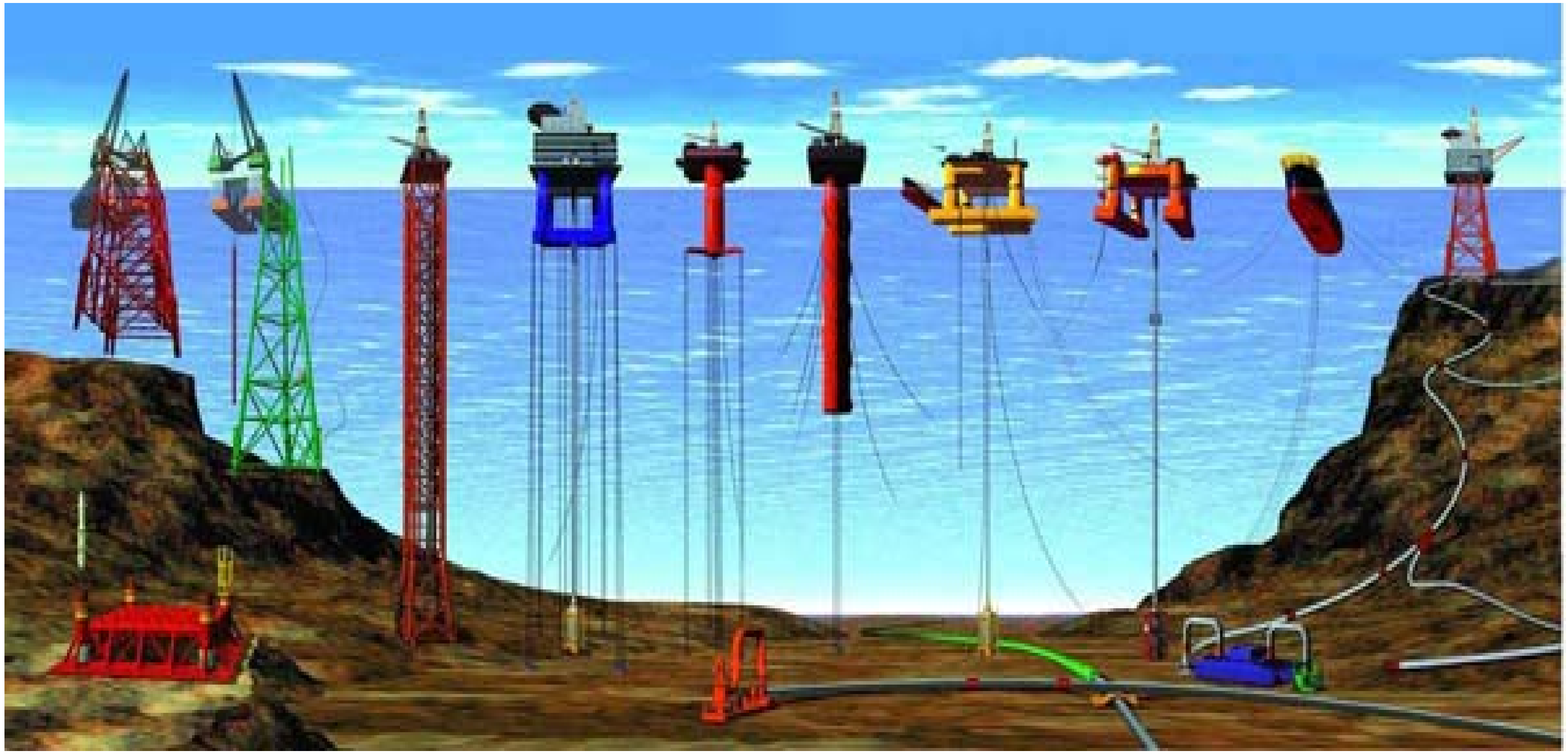
$$\sum_{i=1}^{m}\sum_{j=1}^{n}\phi\alpha\beta\gamma\lim_{x\to\infty}\frac{\zeta}{\sqrt{x^2-\varepsilon x+\eta}}\frac{n!}{r!(n-r)!}$$

Future

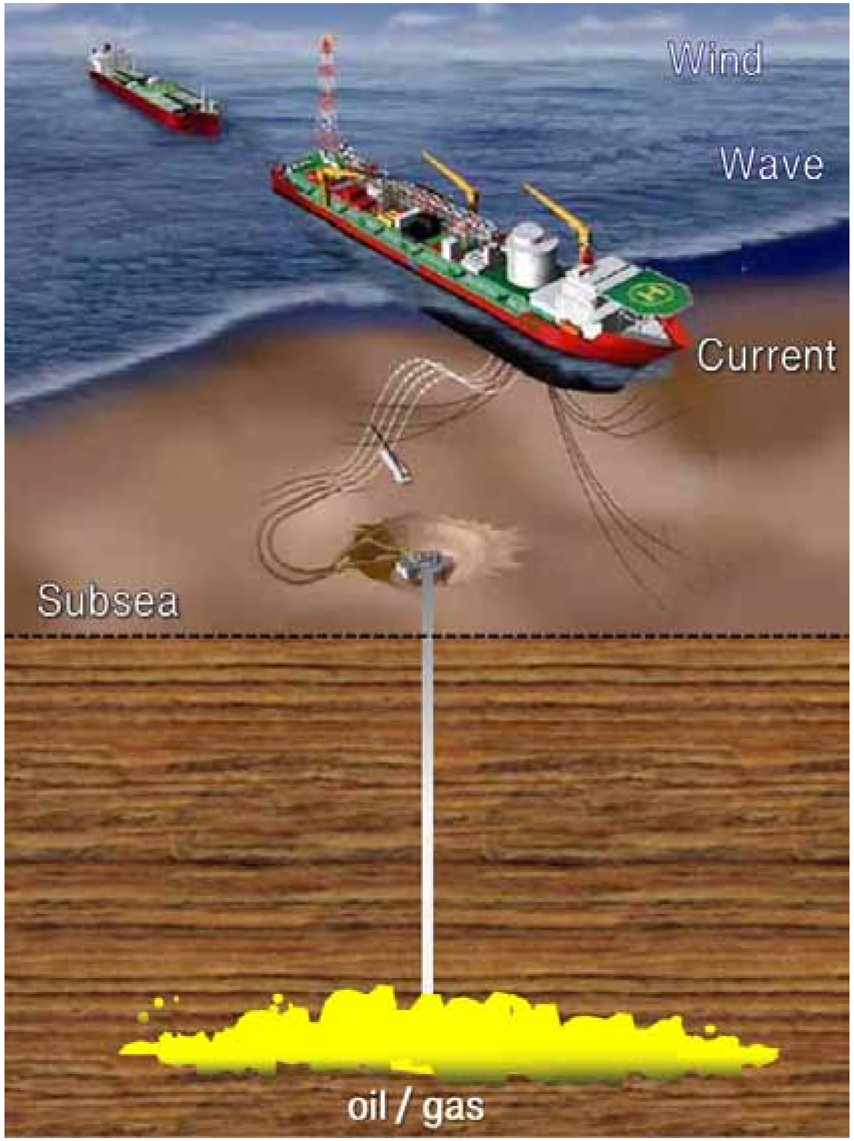
- Engineering
- First Principles
- Probabilistic
- Limit States/Risk
- Experimental Investigation

Trend in Offshore Oil & Gas Production Systems

- Fixed type in shallow waters → Floating type in deep waters
- Ship-shaped offshore unit, Semi-sub, Spar, TLP
- Pipeline infrastructure → Multiple functions such as production, storage and offloading

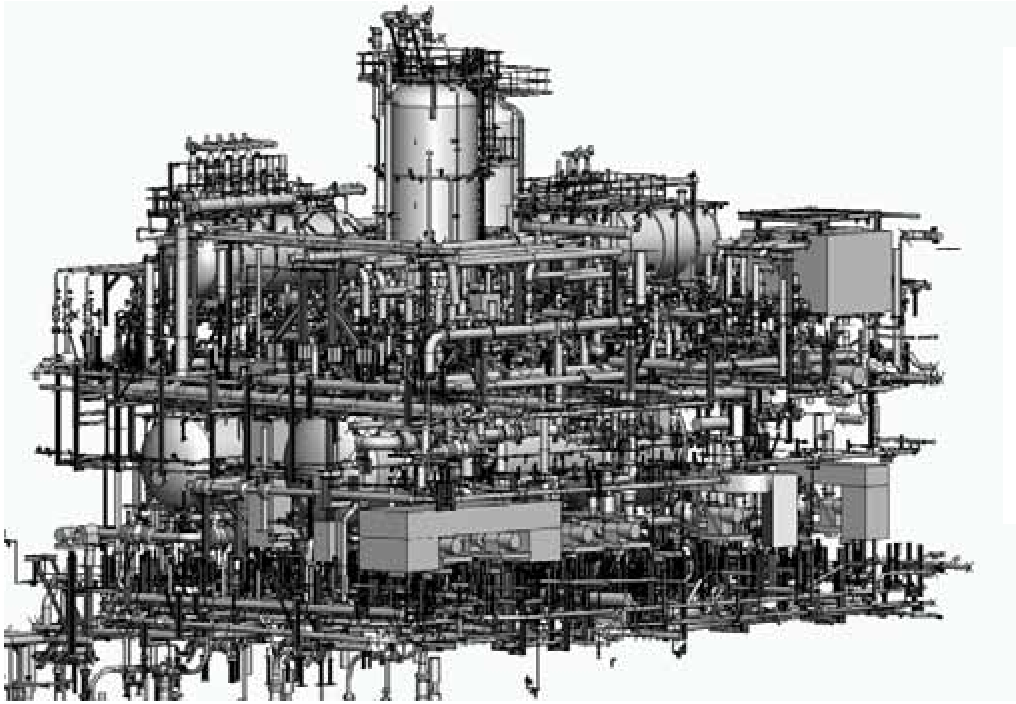


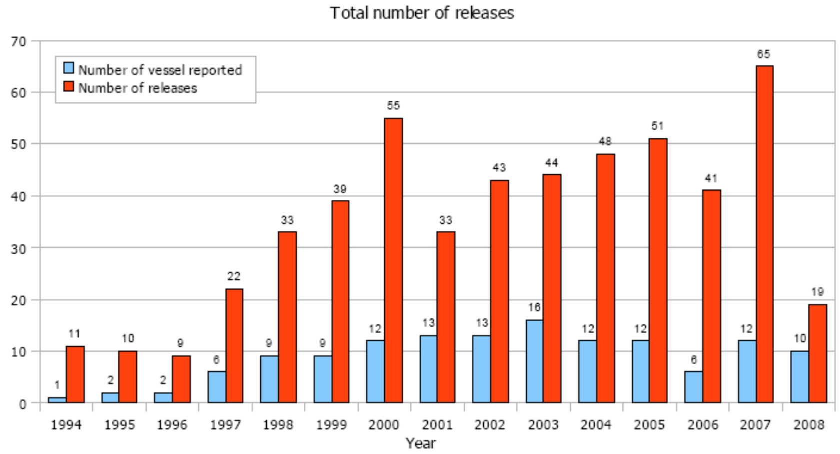
FPSO for Oil and Gas Production



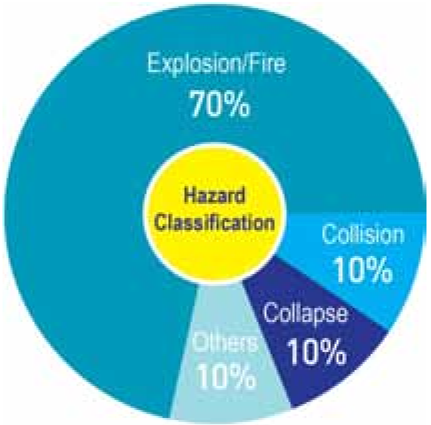
Vessel (hull), topsides (process facility), mooring, risers/flow lines, subsea, and export system

Oil/Gas Leak Resulting in Explosion and Fire





Source: HSE



Pipe Alpha Accident

- 6th July 1988, UK
- 167 people killed
- Property damage of 1.4billion US$
- Risk based engineering became mandatory since the Pipe Alpha accident

Deepwater Horizon Accident

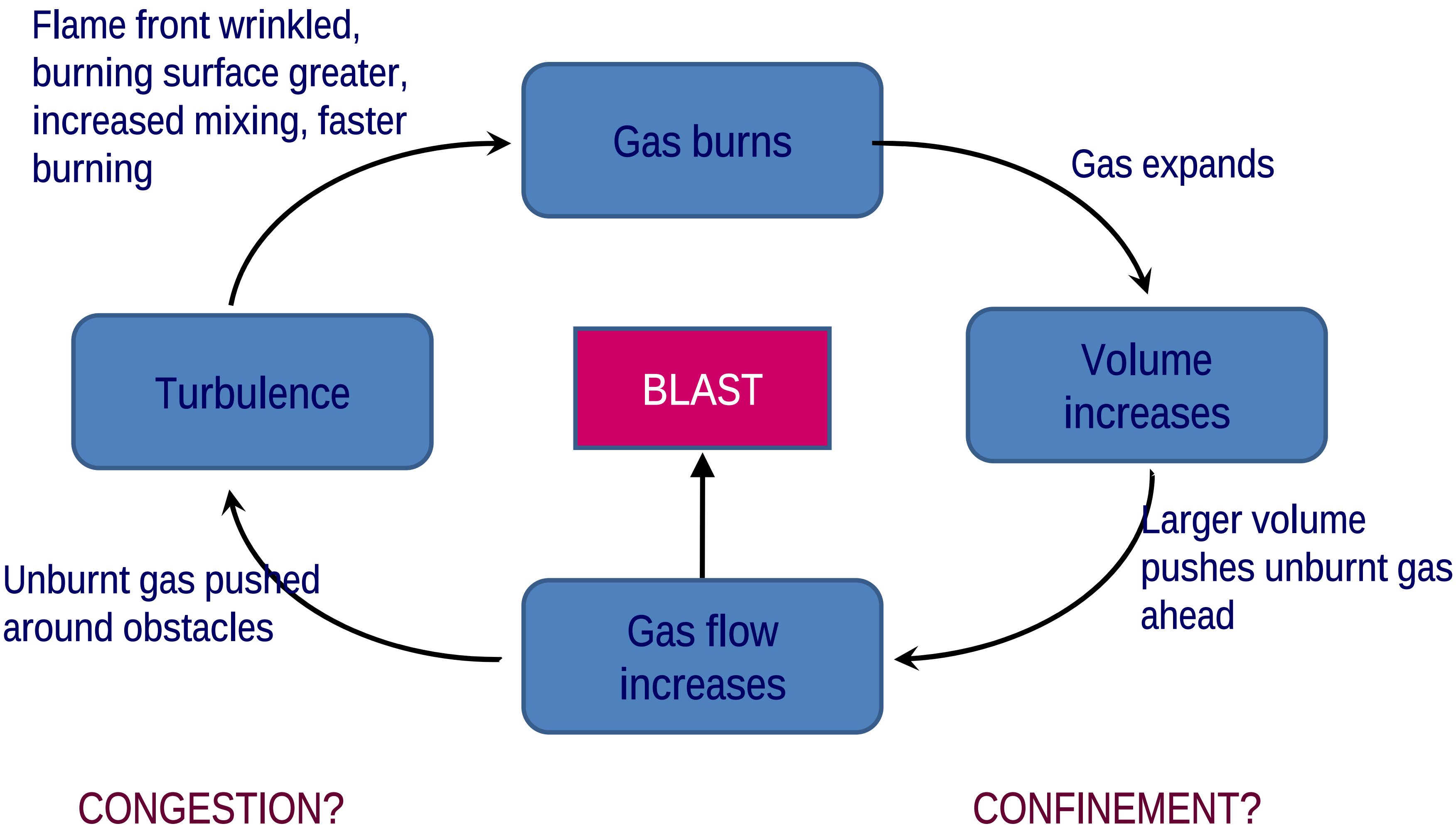
- 20^{th} April 2010, Gulf of Mexico
- 11 people killed, 17 people wounded
- Environmental damage of approx. 30 billion US$

Oil spill

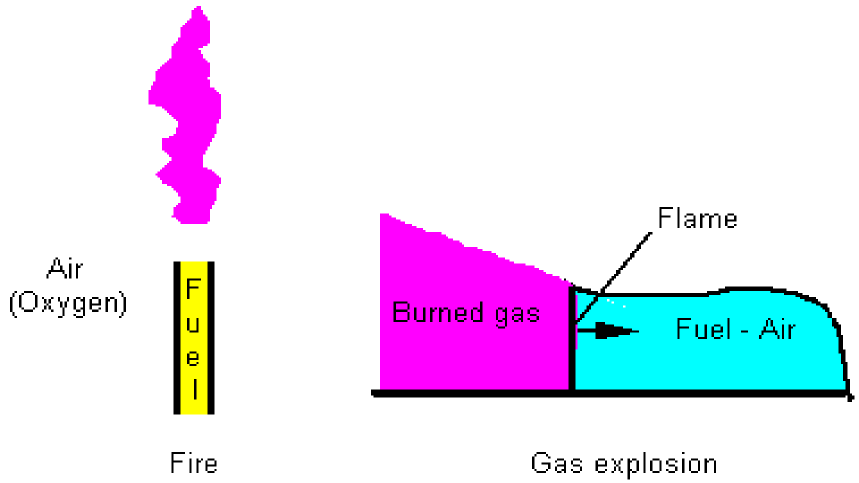
Hydrocarbon Explosions and Fires

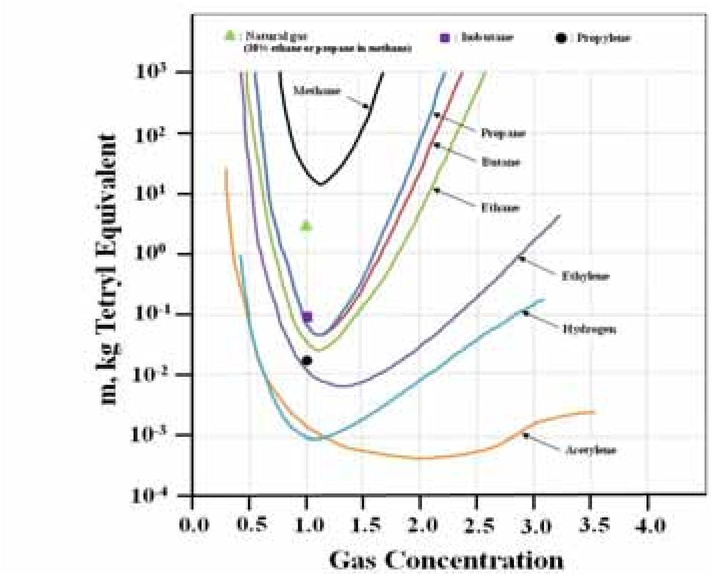
- Hydrocarbons can explode through ignition when combined with an oxidiser (usually air). Thus, when the temperature rises to the point at which hydrocarbon molecules react spontaneously to an oxidiser, combustion takes place. This hydrocarbon explosion causes a blast and a rapid increase in overpressure.
- Fire is a combustible vapour or gas that combines with an oxidiser in a combustion process that is manifested by the evolution of light, heat, and flame.
- The impact of overpressure from explosions and that of elevated temperature from fire are the primary concern in terms of the actions that result from hazards within the risk assessment and management framework.

Mechanism of Gas Explosion – Depending on Topology and Geometry



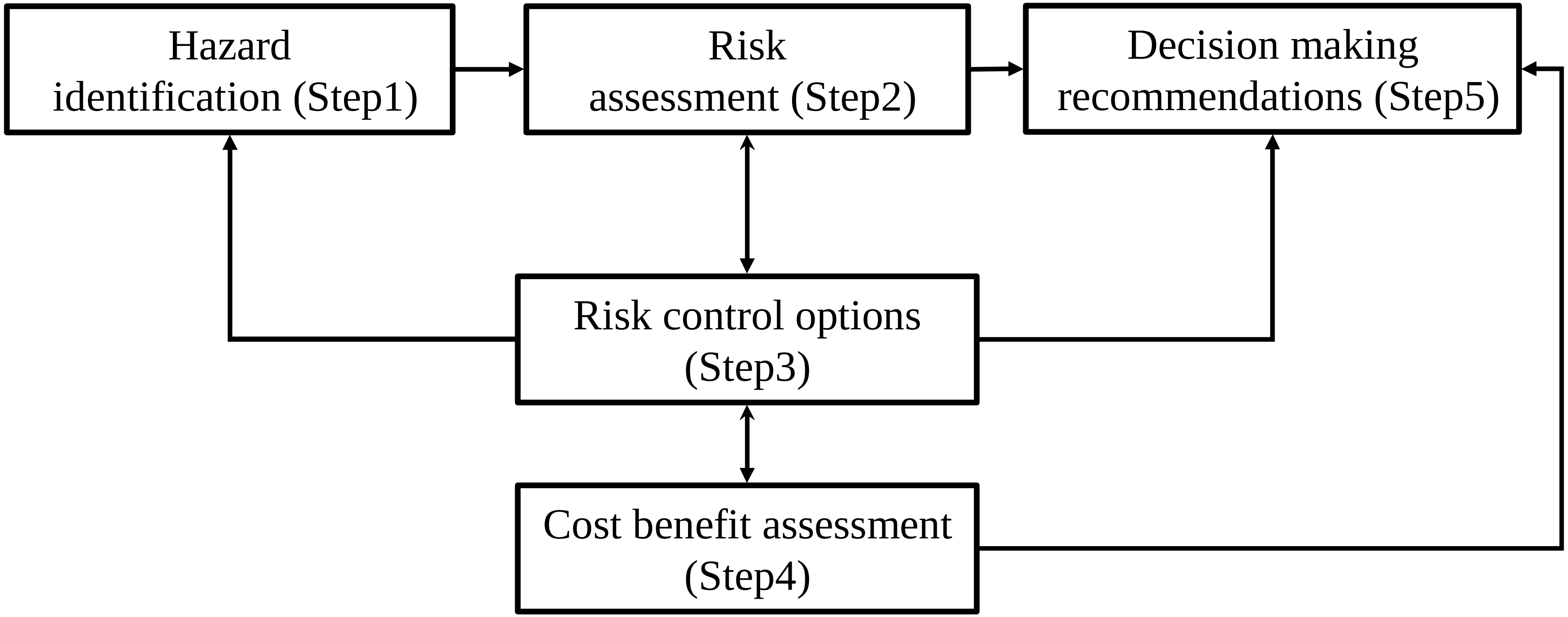
Factors Affecting Explosions and Fires





- Wind direction
- Wind speed
- Leak rate
- Leak direction
- Leak duration
- Leak position (x)
- Leak position (y)
- Leak position (z)
- Type of oil or gas (molecules)
- Concentration ratio
- Temperature of oil or gas
  (LNG Cryogenic -163 degree C)

Risk Based Design Process

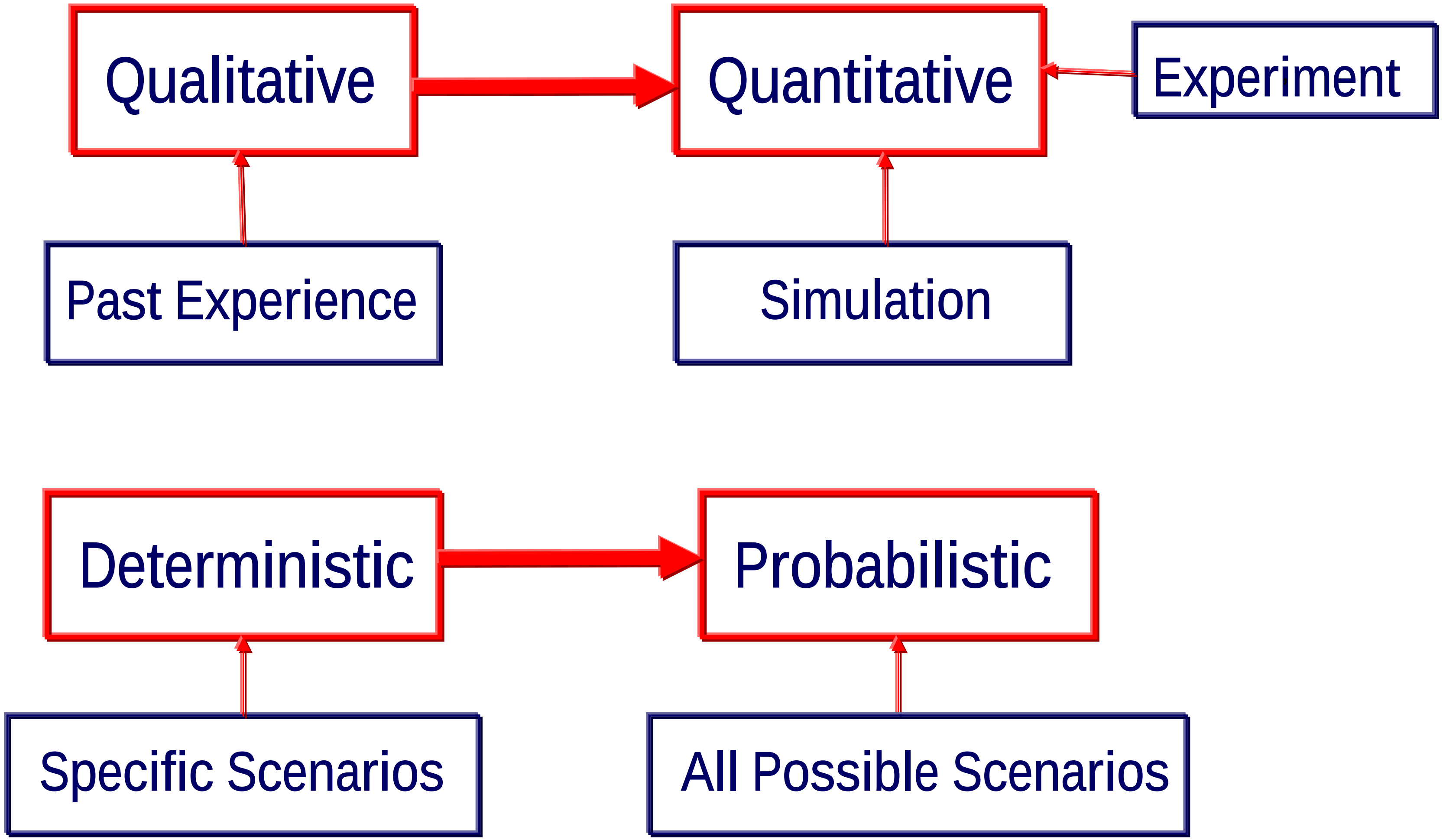


What is Risk? How to Manage Risk?

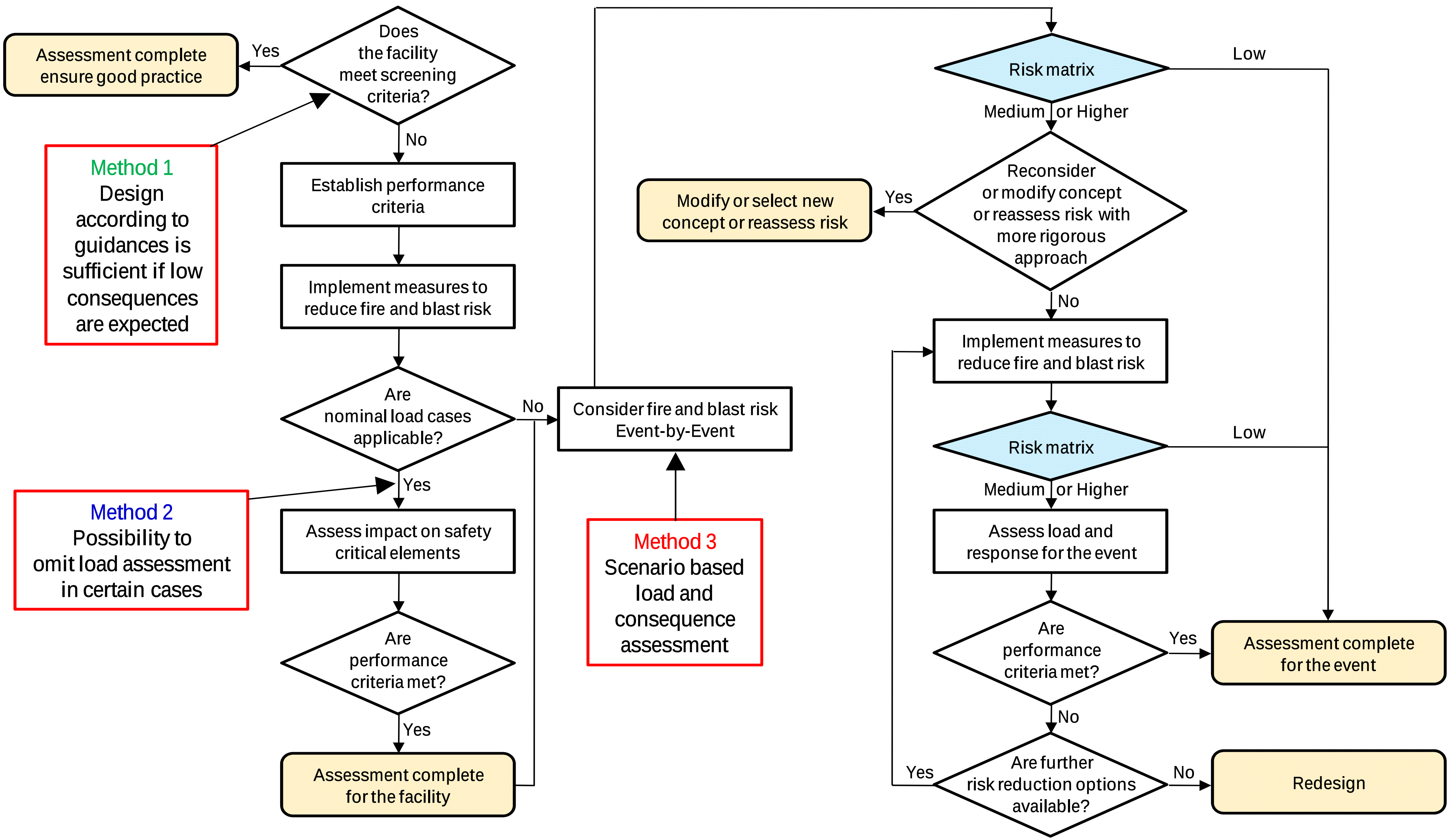
$$R = \sum_i F_i \times C_i$$

- Asset risk
  - Damage to structures and equipment
  - Duration of production delay (downtime)
- Environmental risk
  - Amount of oil that spills out of the offshore installation
- Personnel risk
  - Loss of life

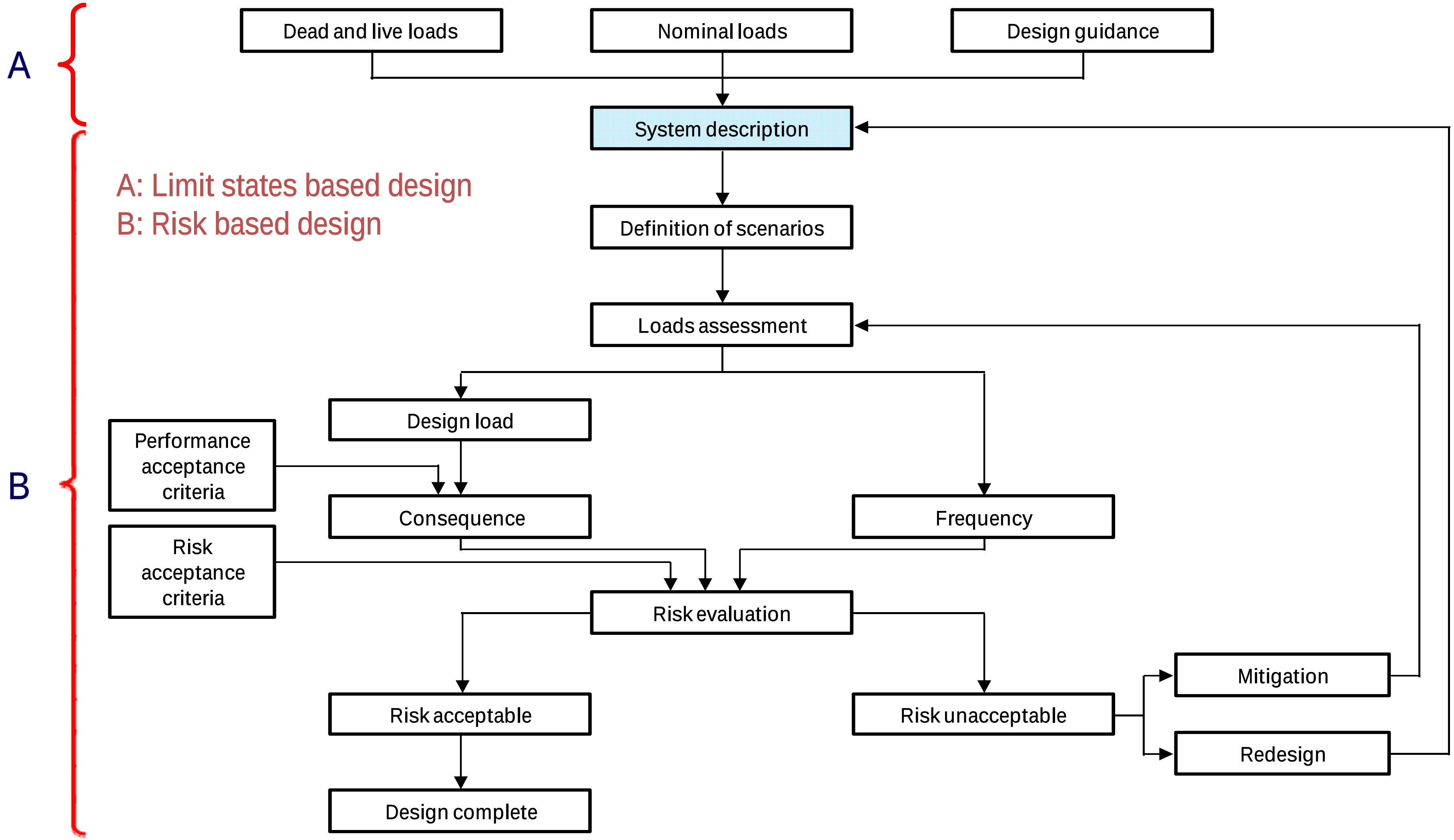
Trends in Risk Assessment



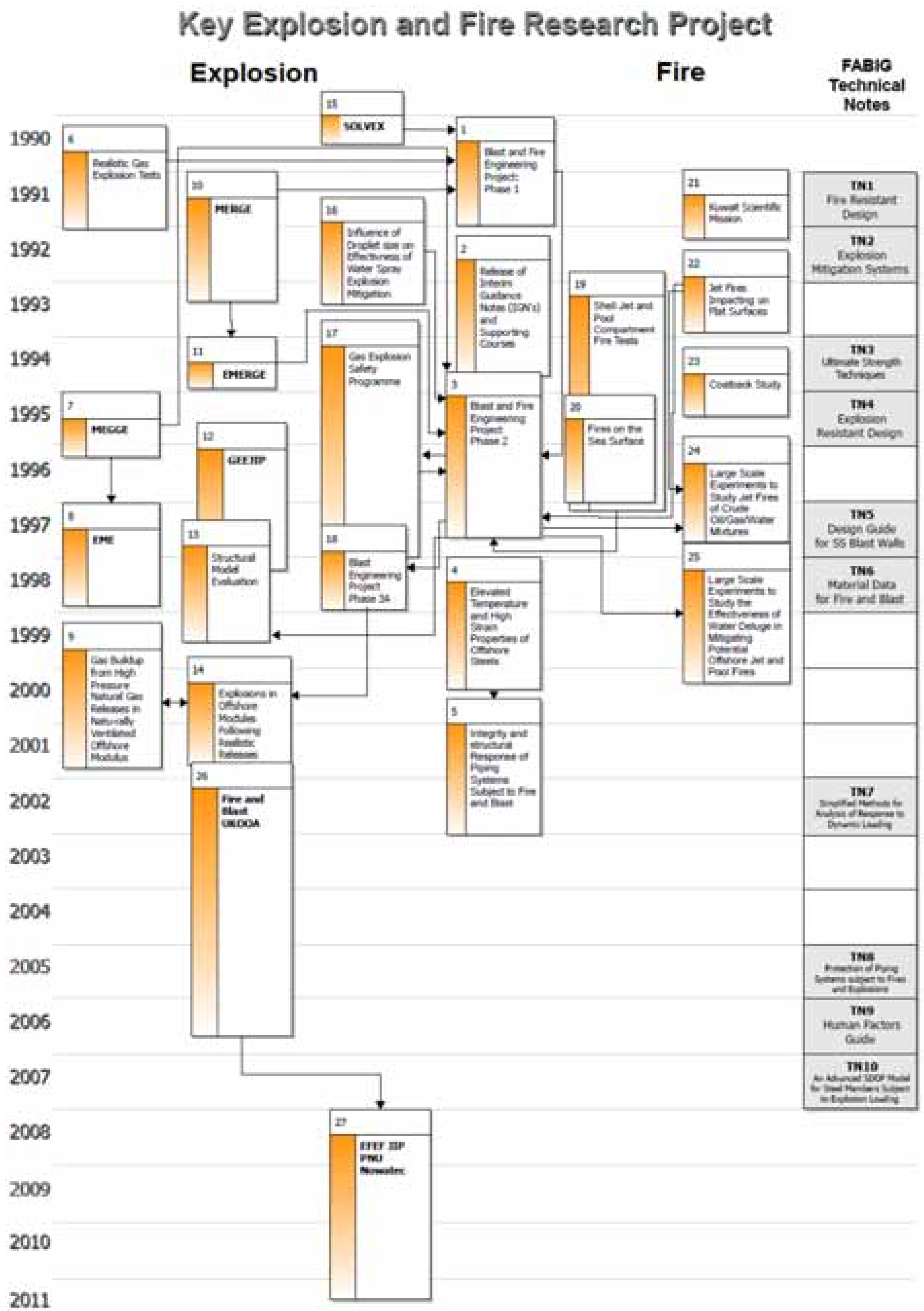
API Procedure for Risk-based Design



Simulation-based Procedure for Risk-based Design



Joint Industry Projects



EFEF JIP - 27th JIP in the World

Explosion and Fire Engineering of FPSOs

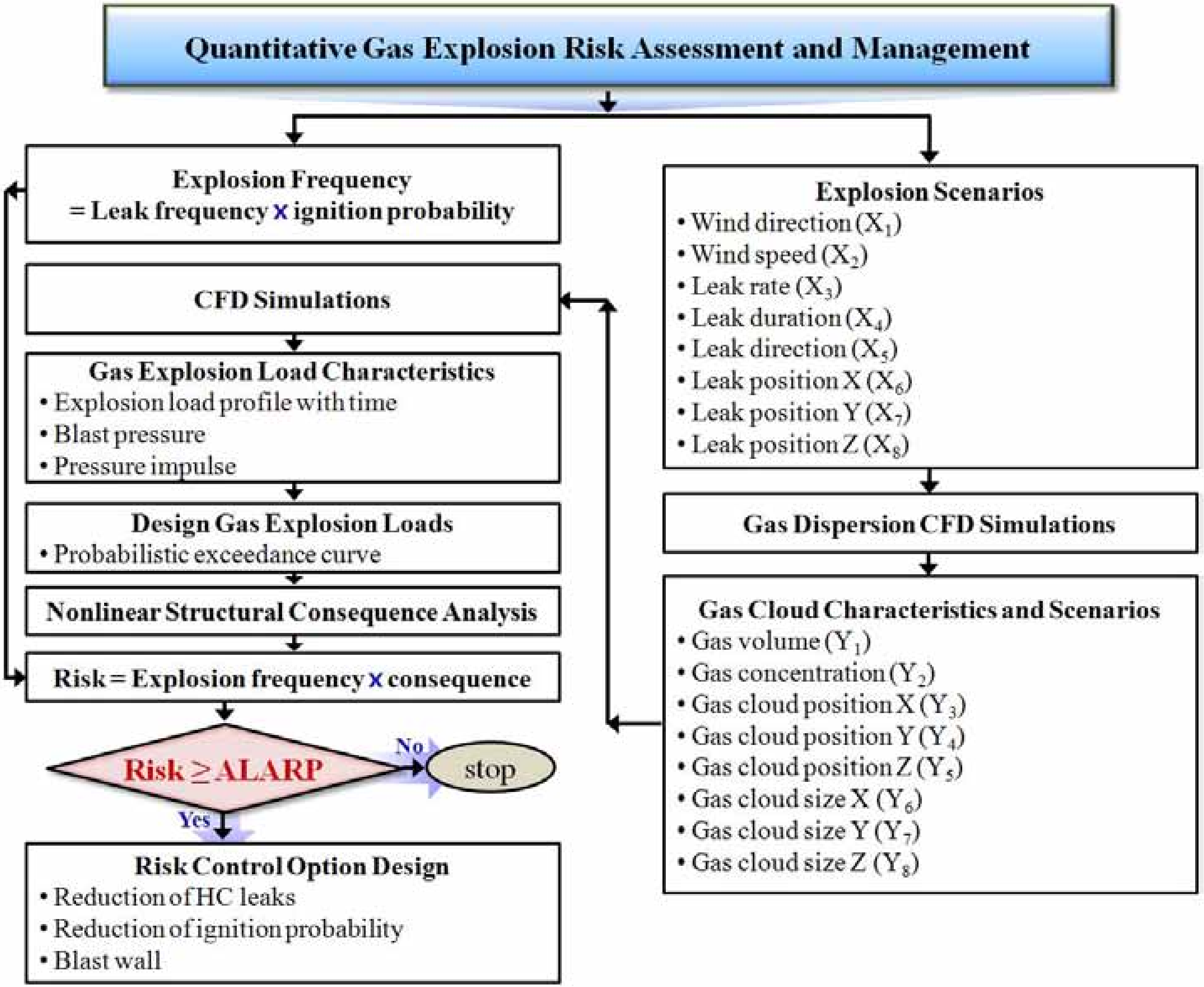
Coordinators:

- Pusan National University, Korea
- Nowatec AS, Norway

Partners:

- DSME, SHI, HHI, ABS, KR, LR
- Gexcon, CompuIT, USFOS, UK HSE, NTUA

Quantitative Gas Explosion Risk Assessment and Management (1/2)

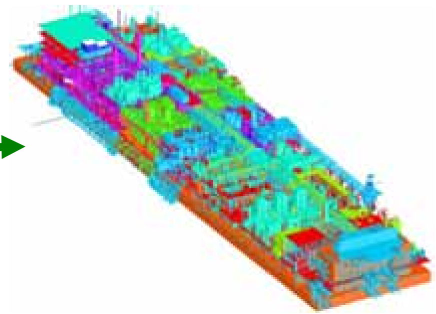


EFEF JIP Procedure for Explosion Risk Assessment and Management (2/2)

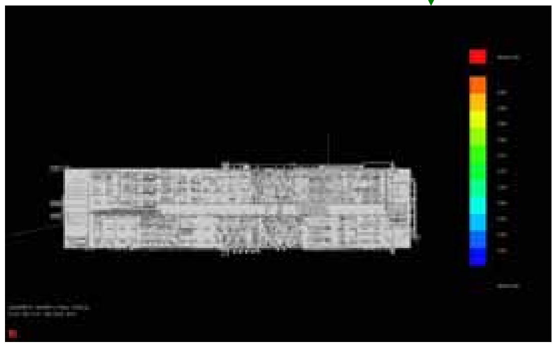
CAD model

Selection of credible scenarios involving PDF parameters of leak and environment conditions

Latin hypercube sampling technique

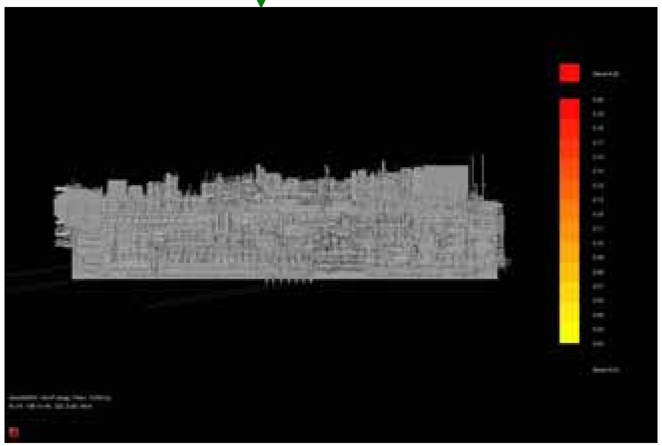


CFD model

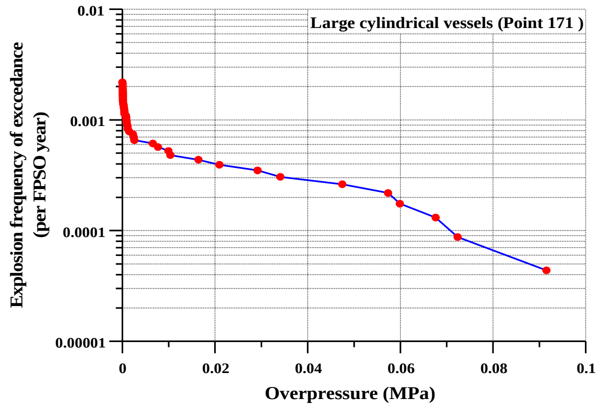


Gas dispersion analysis

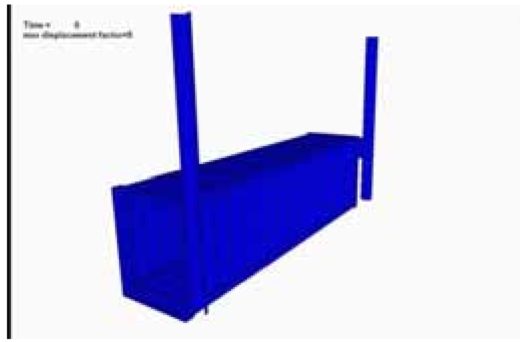
Selection of credible scenarios involving PDF parameters of gas cloud condition



Explosion CFD simulation

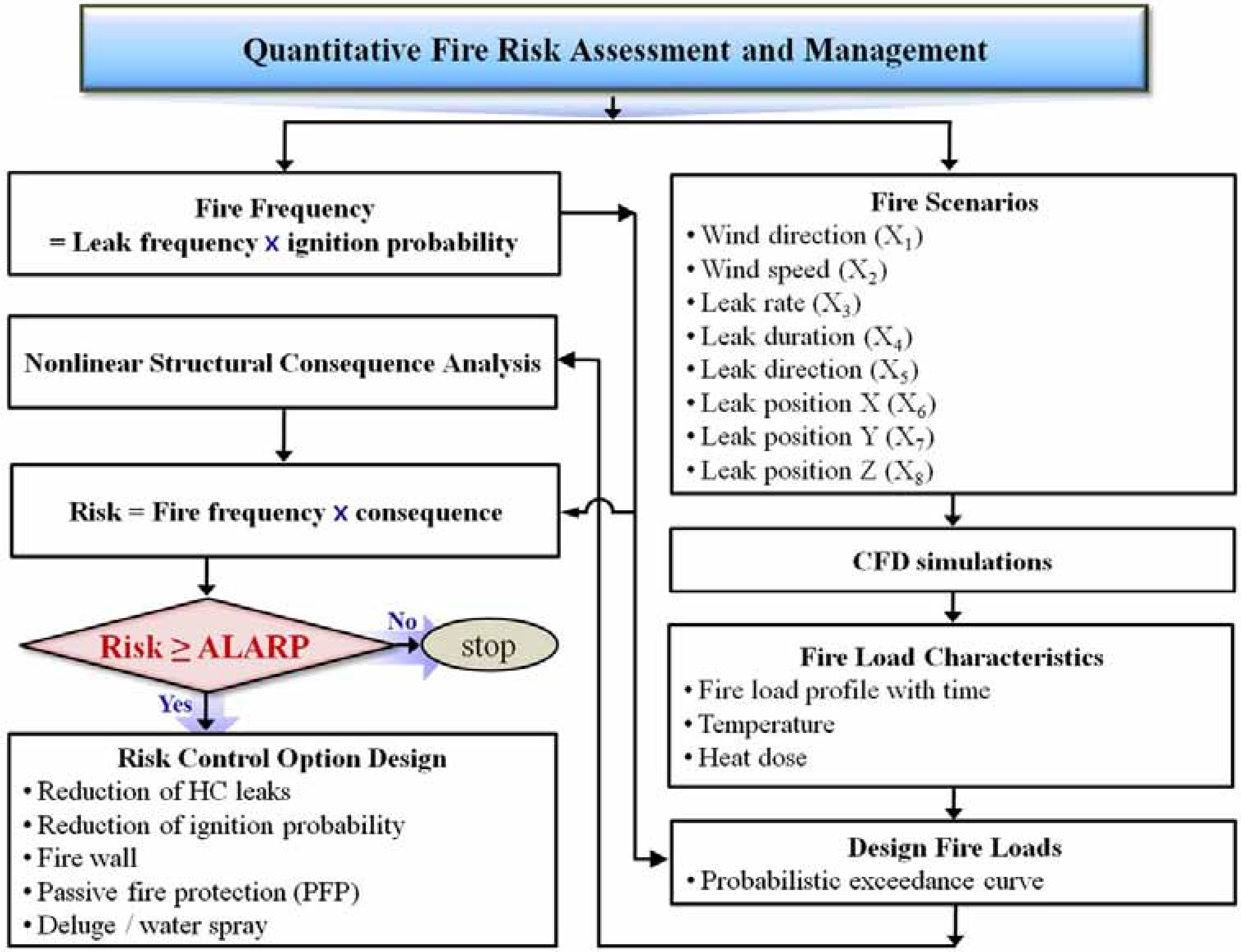


Design loads with exceedance curve



Nonlinear consequence analysis under explosion

EFEF JIP Fire Risk Assessment and Management (1/2)

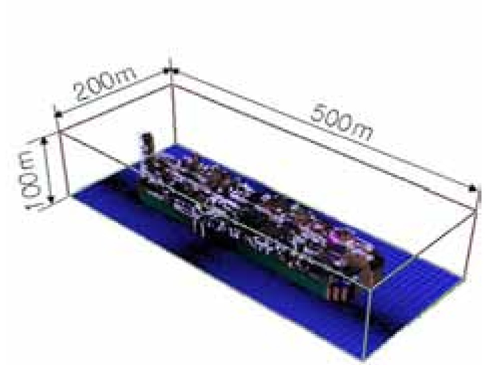


EFEF JIP Procedure for Fire Risk Assessment and Management (2/2)

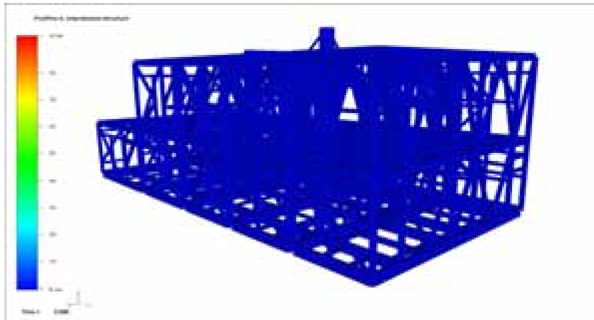
CAD model

Selection of credible scenarios involving PDF parameters of leak and environment conditions

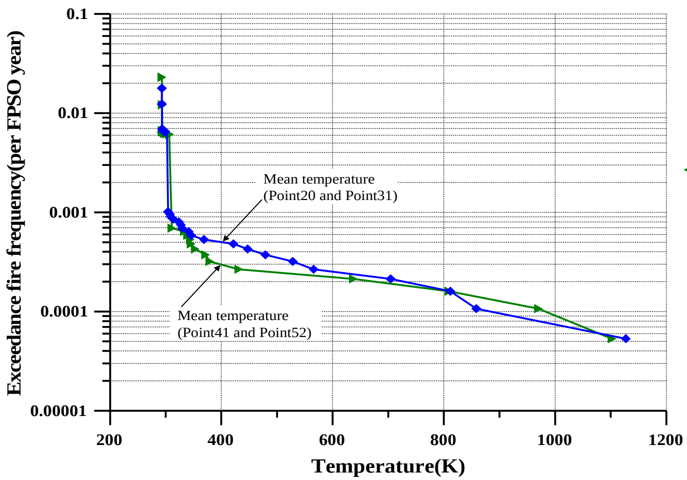
Latin hypercube sampling technique



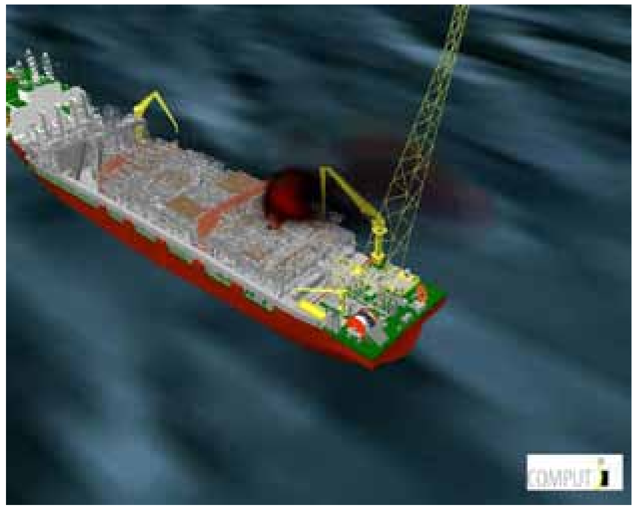
CFD model



Nonlinear consequence analysis under fire

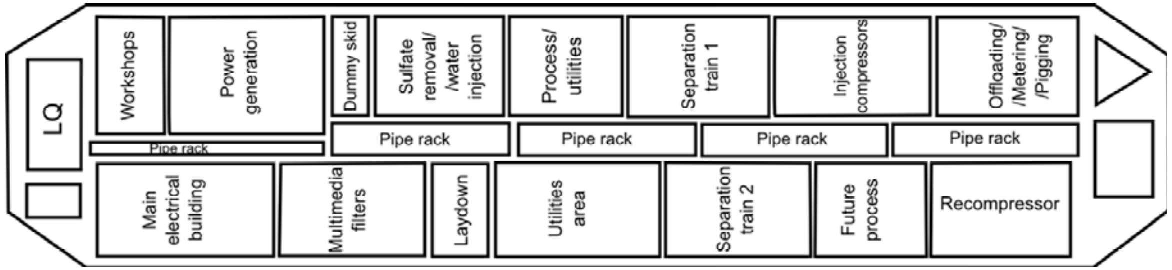


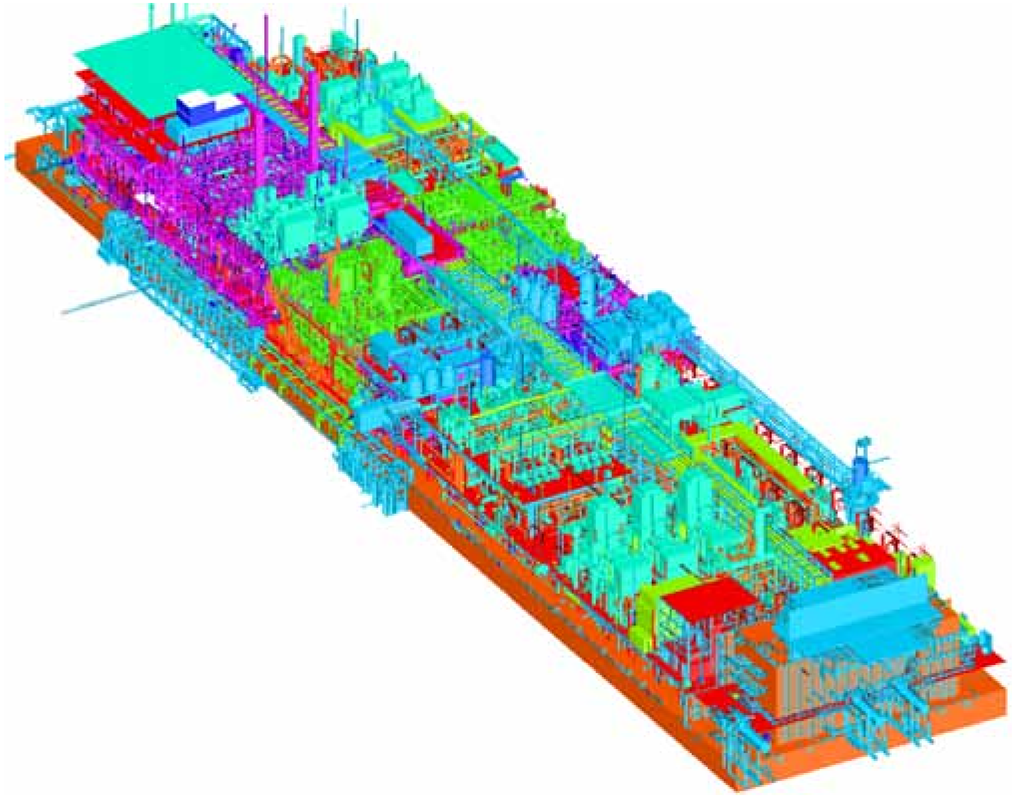
Design loads with exceedance curve



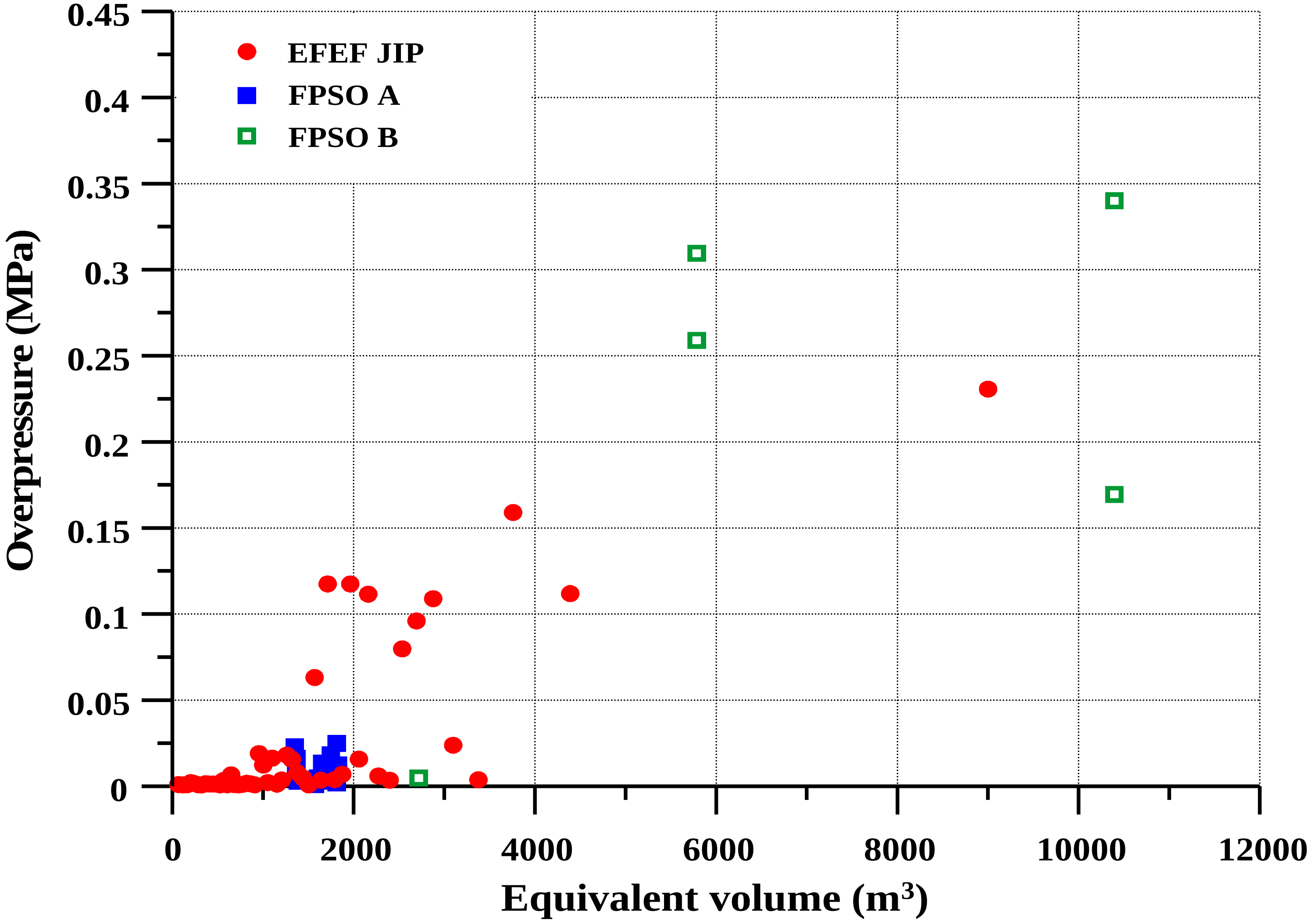
Fire CFD simulation

Applied Example: VLCC Class FPSO Topsides

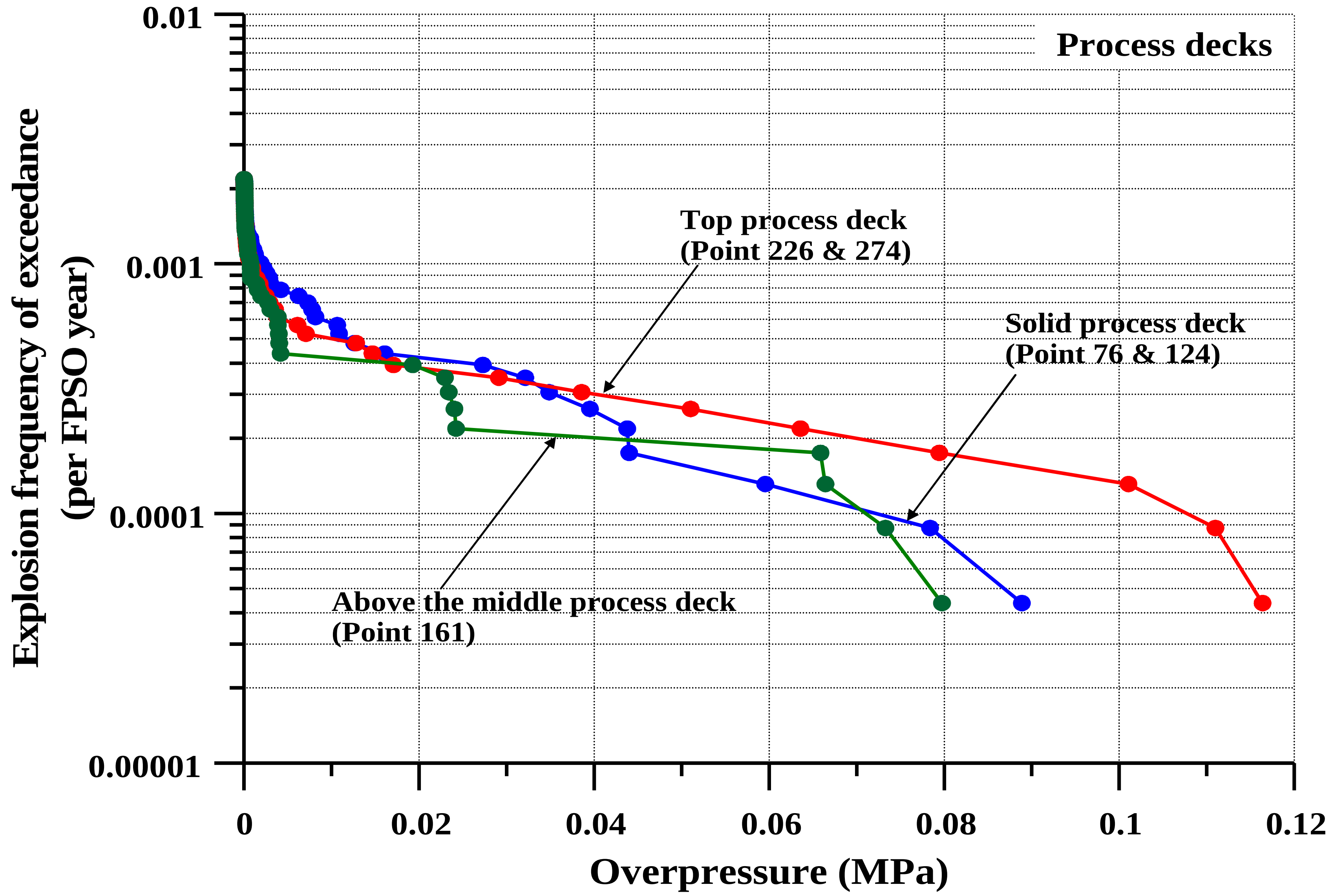




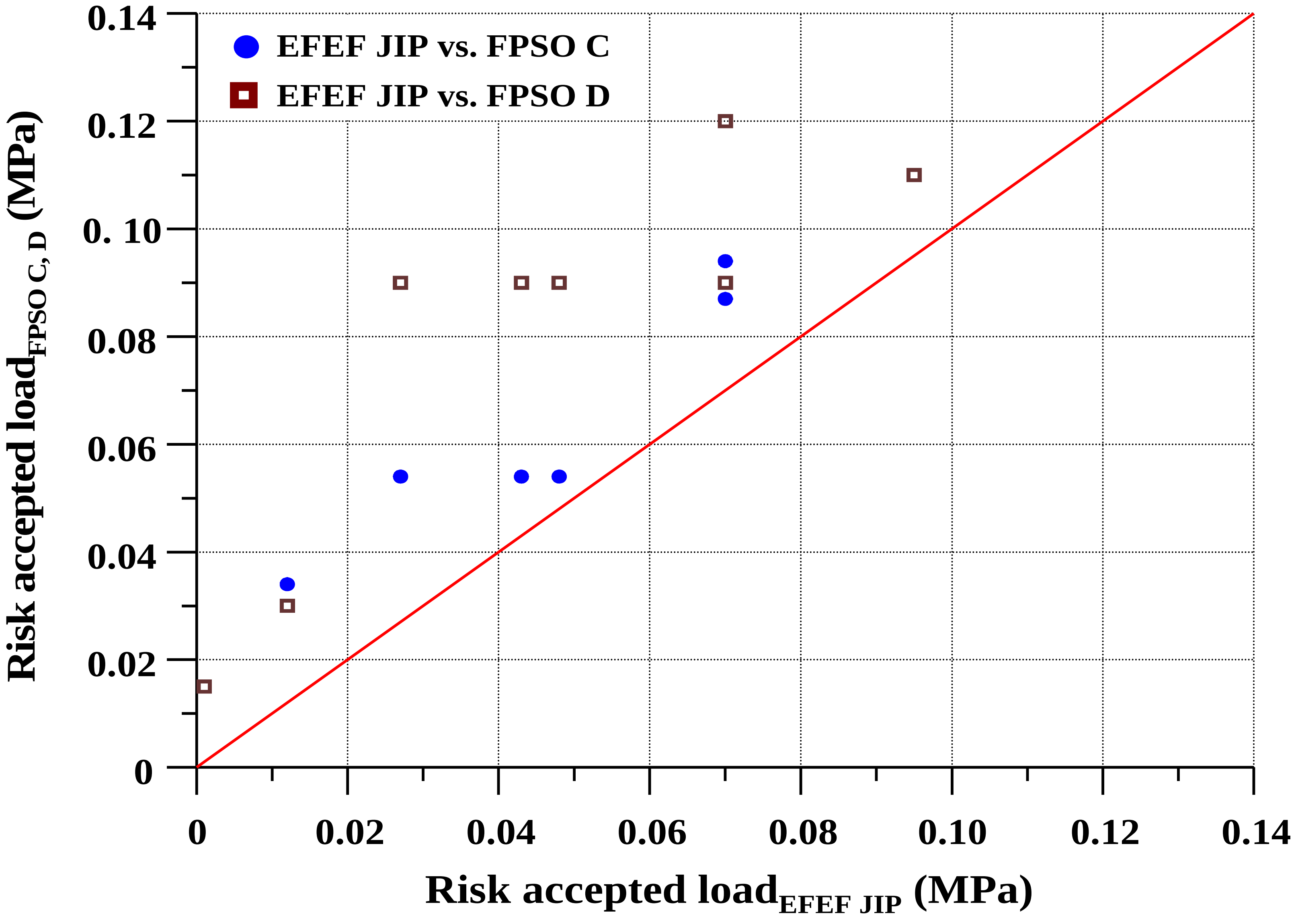
Effect of Gas Cloud Volume on Maximum Overpressure – Comparison between EFEF JIP and Existing FPSO Practices



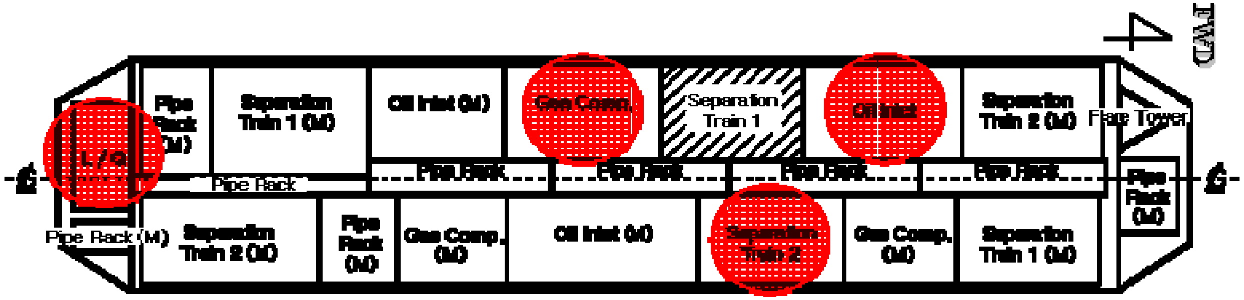
Design Explosion Loads with Exceedance Curves

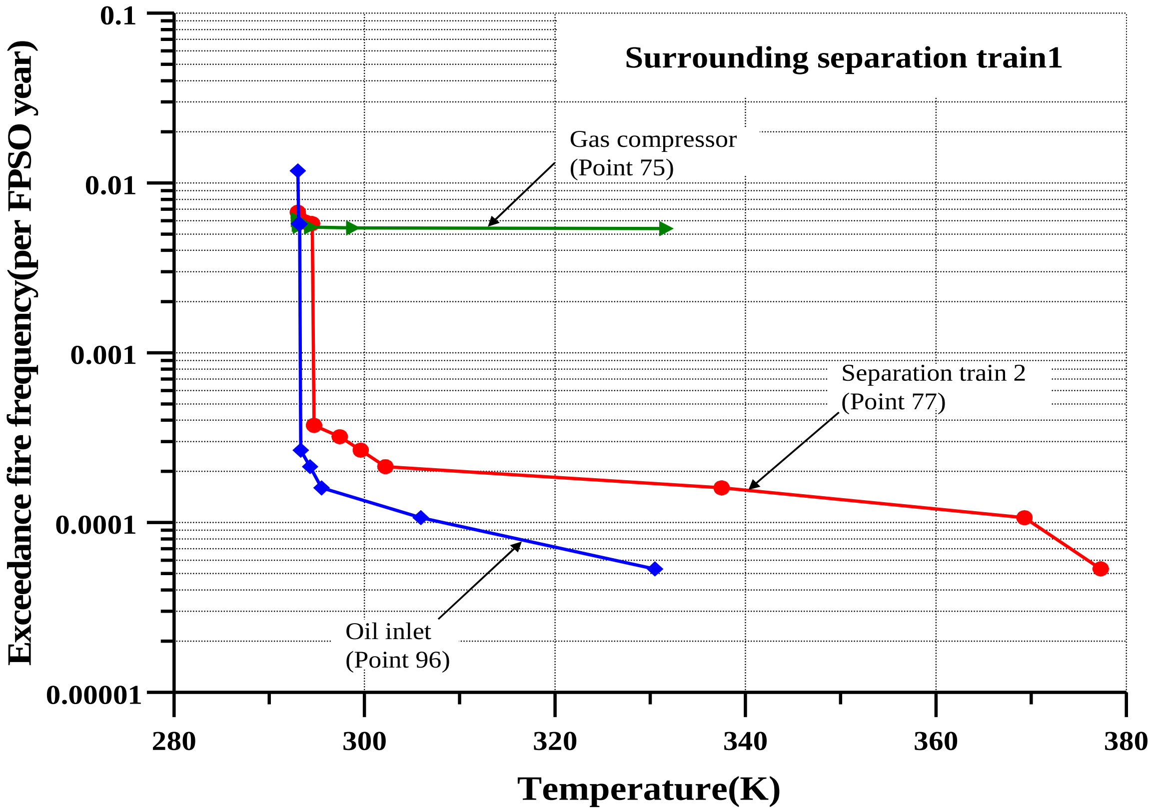


Design Explosion Loads – Comparison between EFEF JIP and Existing FPSO Practices

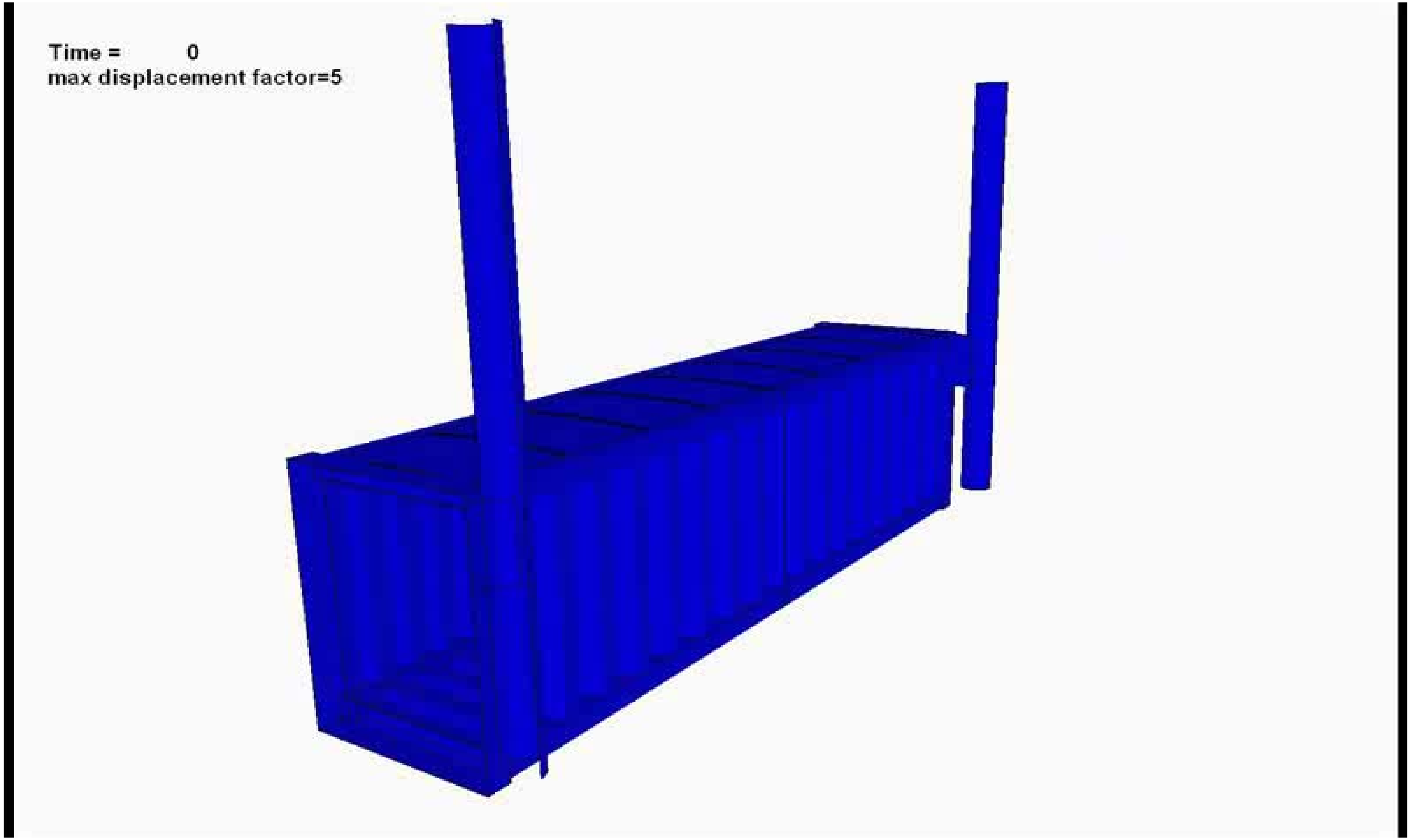


Design Fire Loads with Exceedance Curves

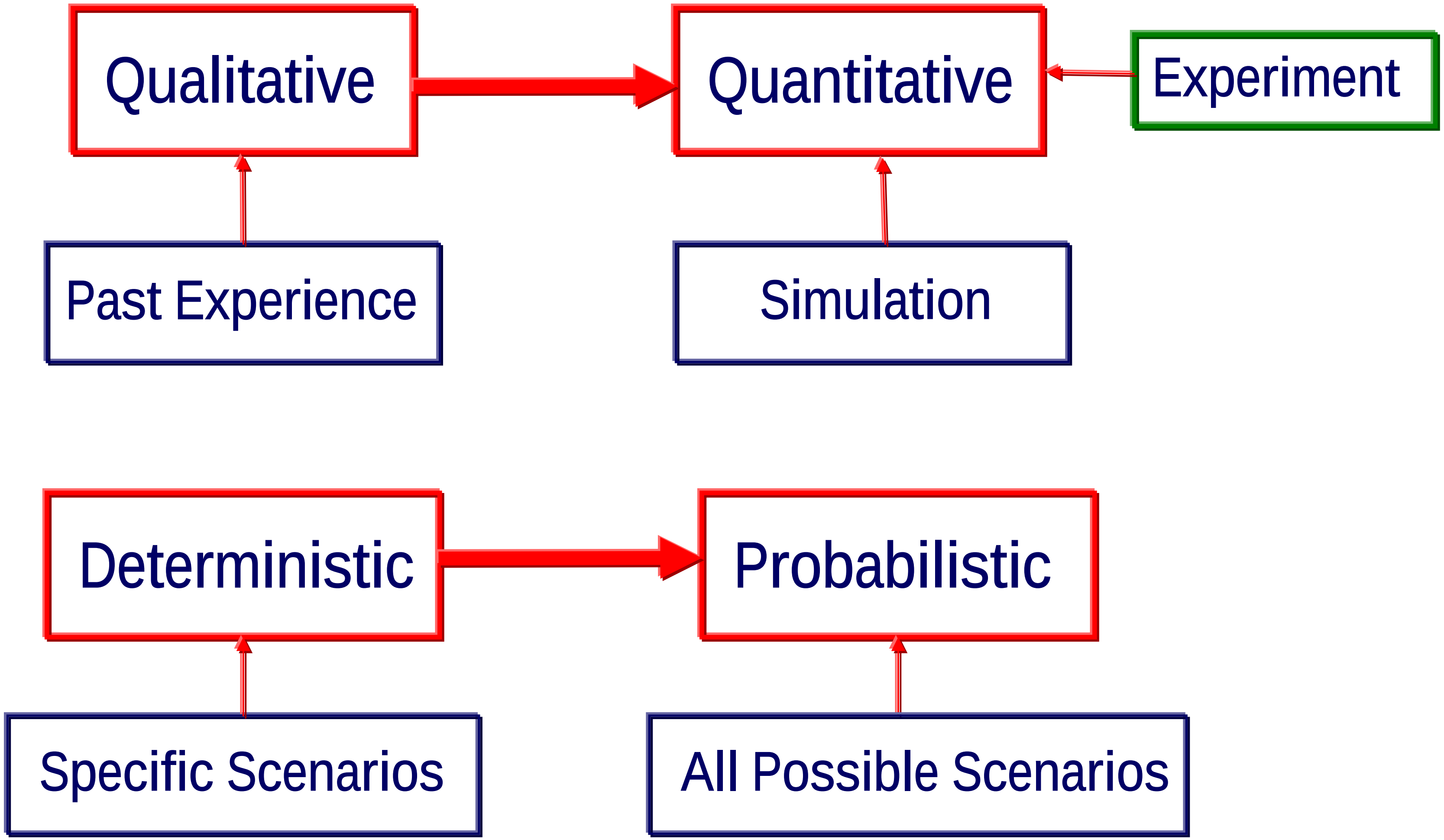




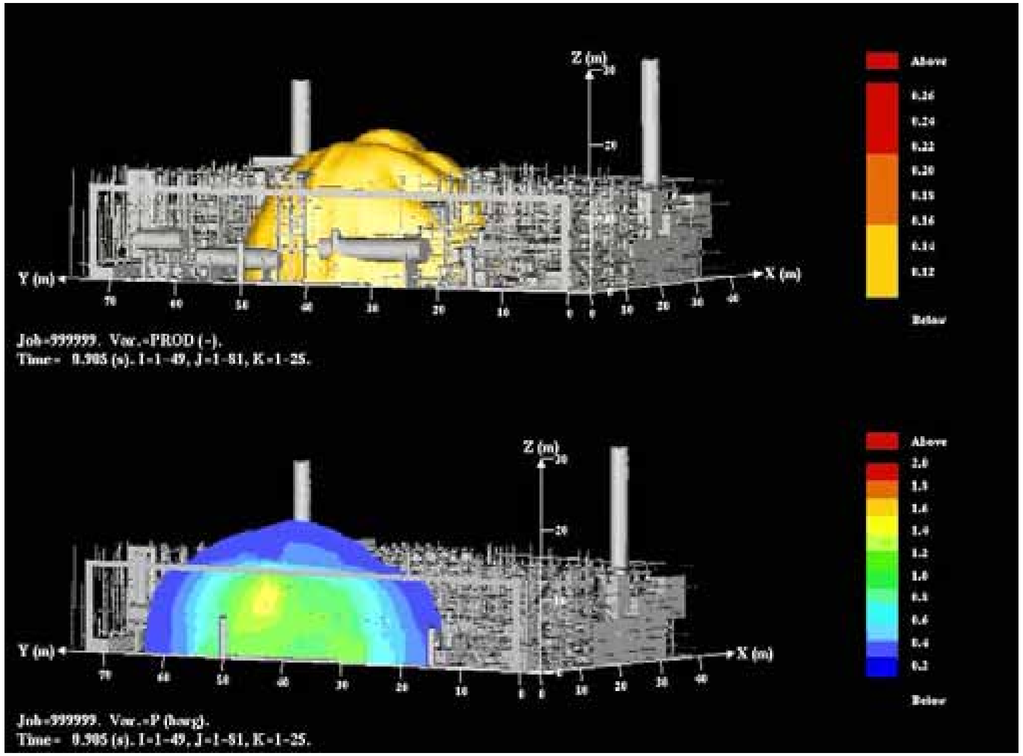
Nonlinear Structural Consequence Analysis – Escape Route

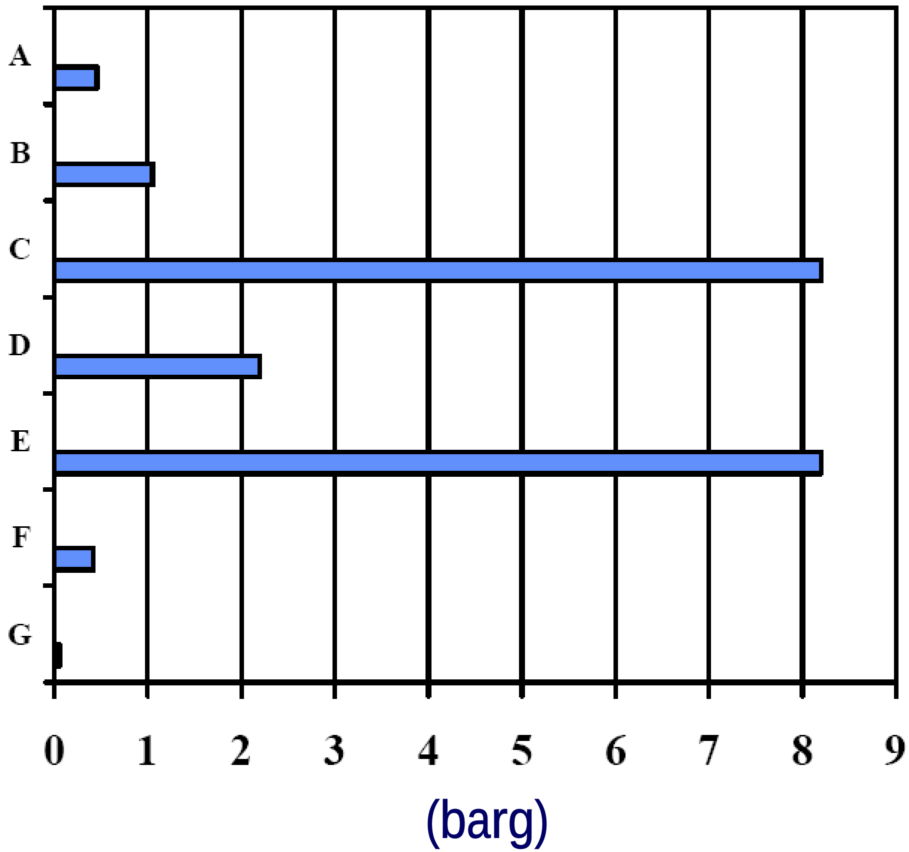


Trends in Risk Assessment



CFD Explosion Simulations





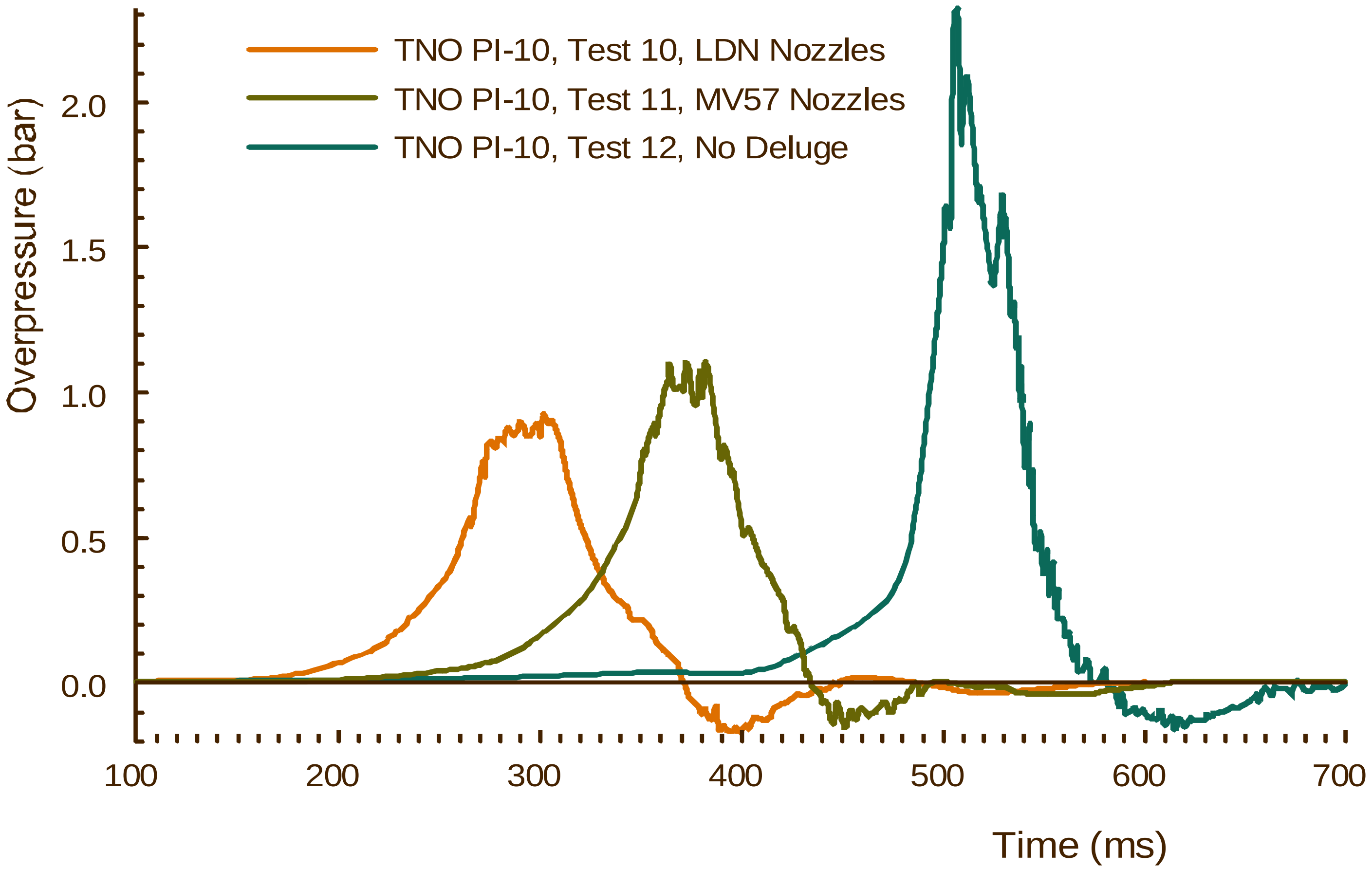
Gas Explosion Tests with or without Water Sprays (1/2)
- Importance of Risk Management

Without water sprays

With water sprays

Source: © The Steel Construction Institute, Fire and Blast Information Group

Gas Explosion Tests with or without Water Sprays (2/2)
- Importance of Risk Management



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Explosion and Fire Test Facilities under Construction in Korea