POLITECNICO DI TORINO

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Modelling and monitoring gas dispersion in an oil&gas platform: project definition and design of a validation experiment

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Outline

1. Framework of the activity
2. Background
3. The theoretical approach: Hybrid CFD simulations
4. The experimental setup for validation
5. Follow up and conclusions

Framework of the activity 1/2

- The Seadog Laboratory @ Politecnico di Torino aggregates expertise of **three** Departments (Energy, Environment, Land and Infrastructure Engineering, Applied Science and Technology).
- Seadog stands for **Safety & Environmental Analysis Division for Oil & Gas**
- The Laboratory is being supported by the Italian Ministry of Economic Development's Directorate General for Safety - National Mining Office for Hydrocarbons and Georesources.

Framework of the activity 2/2

- Among the research projects financed:

→ **Development of innovative models for the simulation of accidental scenarios with an experimental validation**

- Research carried out by the Seadog DENERG, with the support of the Mechanical and Aerospace Engineering Department
- Experimental validation in collaboration with Environment Park S.p.A.

Background

- Risk assessment on oil&gas platforms:
  - Identification of hazard scenarios (e.g. gas releases from pressurised equipment ruptures)
  - Evaluation of frequencies and **consequences**
- To evaluate these consequences: 2 possible approaches
  - Semi-empirical → fast and too conservative
  - CFD → accurate and high computational load

→ Proposed alternative approach: **HYBRID**

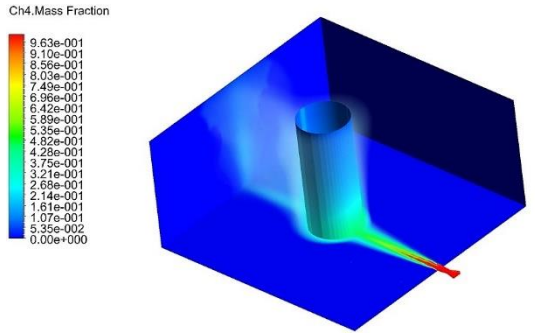
  - Accurate yet acceptable computational load

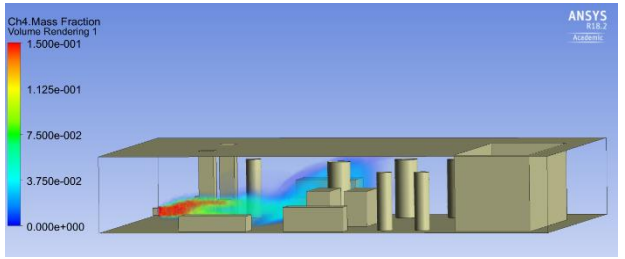
Hybrid approach: source box + dispersion

The gas release phenomenon from a rupture is split in two phases:

- Supersonic release
- Dispersion

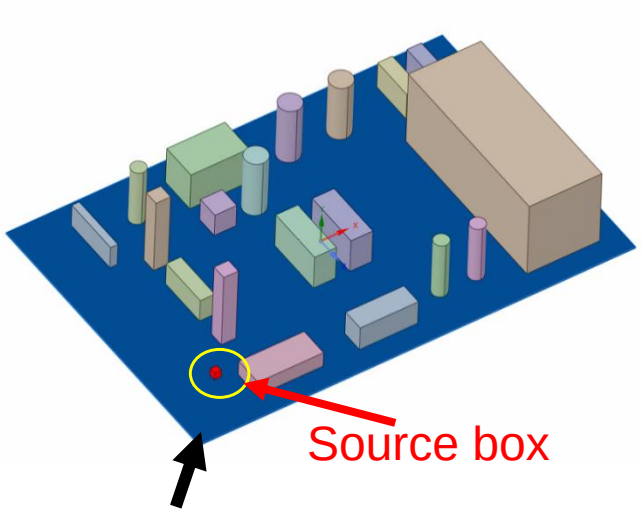
- The **supersonic release** is simulated within a domain (source box) that contains the phenomenon until the velocity of the gas is ≈ wind velocity (same order of magnitude)
- The **dispersion phase** is simulated after the release phase is completed
- Coupling between the two simulations through **velocity and concentration** distribution



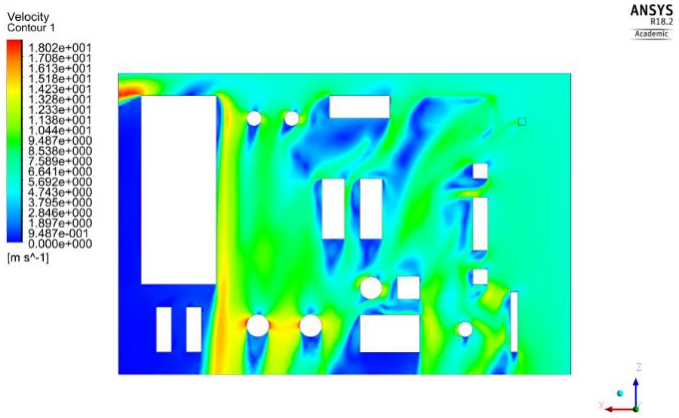


CFD simulations boundary conditions

- Domain: production deck of a representative Italian platform
  - 30x20 m deck dimensions
  - Floor and roof plated
- Ambient conditions: wind velocity = 6 m/s

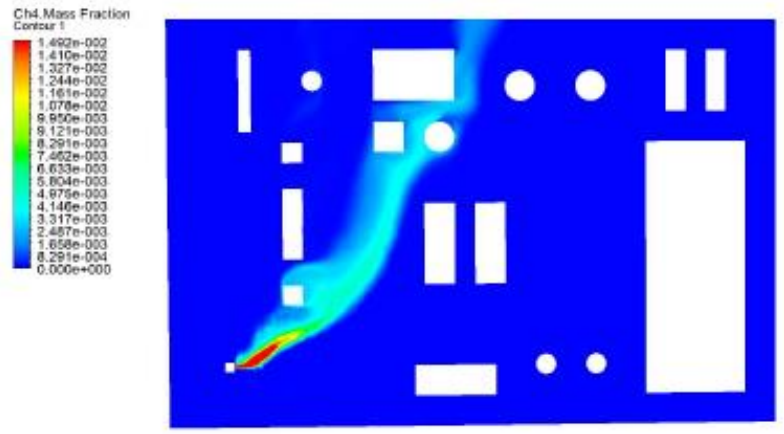


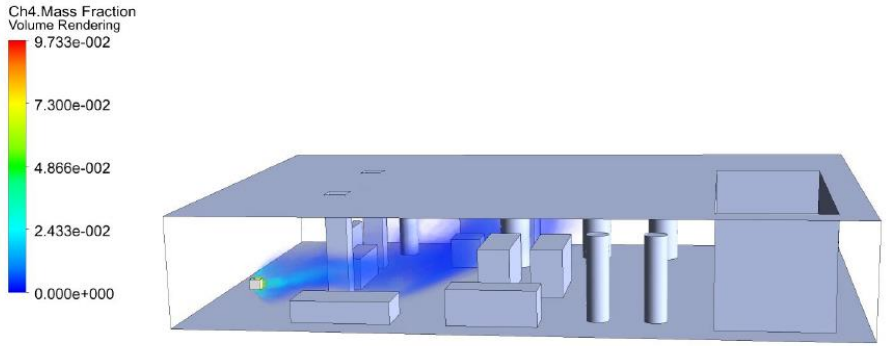
v_{wind} = 6 m/s from NW



CFD results

- Concentration and velocity of the gas released within the source box are input data to the dispersion model.
- Preliminary test performed: grid independence
- The simulations allow evaluating:
  - volume of the flammable cloud and zones reached
  - concentration of the gas
- Further tests:
  - sensitivity to the input data (concentration, size and position of the source box, wind speed)



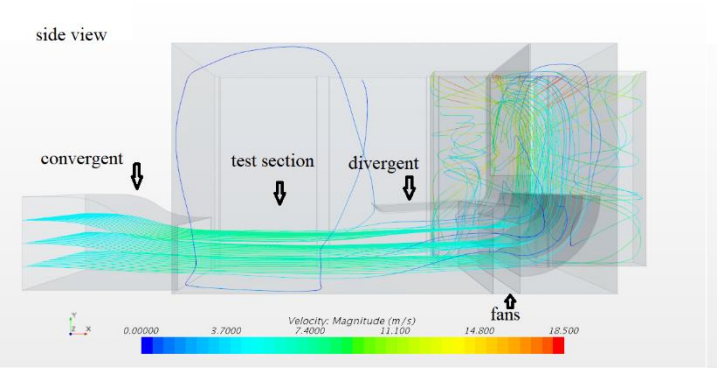


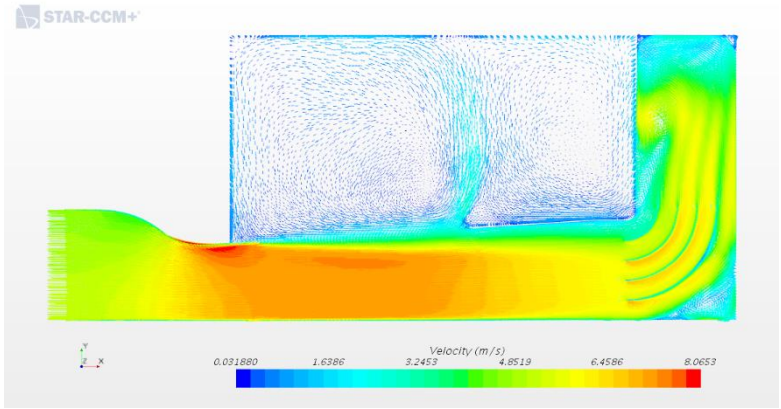
The experimental facility

- The validation of the proposed CFD hybrid approach passes through an experimental setup and campaign
- Steps - design and realisation of:
  - A wind tunnel to recreate the appropriate ambient conditions
  - A scaled mock-up of platform
  - A gas release assembly
  - A sensors network (including safety sensing and alarm system)
- Location of the experimental facility: Environment Park premises (Torino, IT), in a 16m x 8m x 9m room (+ control room)

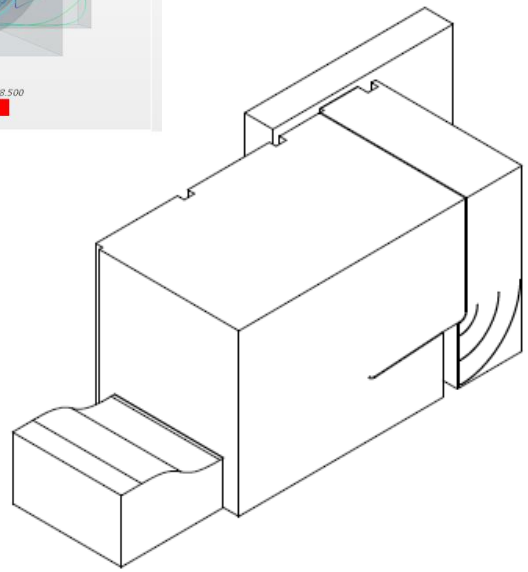
Wind tunnel

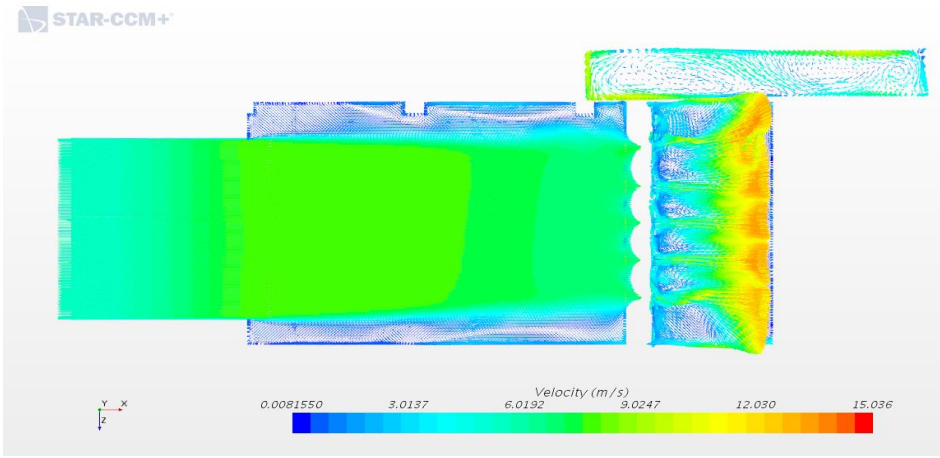
- The wind tunnel has been designed to create a stable wind flow in a range of velocities of up to 6 m/s





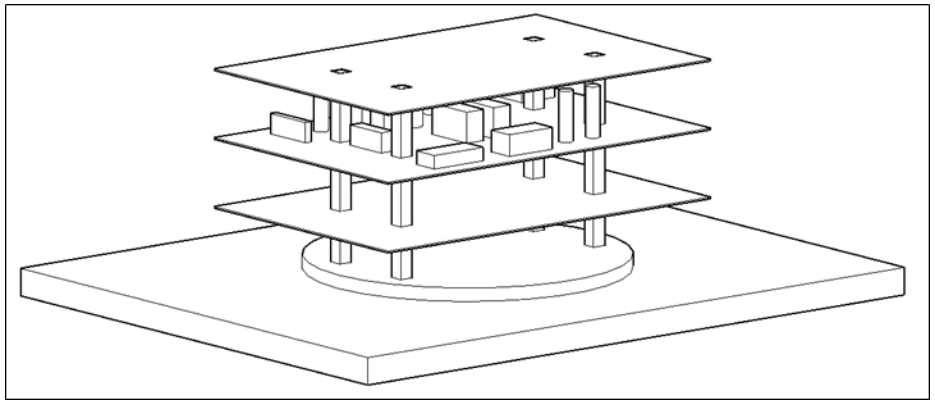
- 10 fans in 2 rows
- Power available for fans: 70 kW





Scaled mock-up platform

- Scale of the mock-up: 1:10
- Deck dimensions: 3m x 2m
- Interdeck: 0,5 m
- Total Height: about 2 m



- Possibility to rotate in order to simulate more wind directions
- Obstacles distribution simulating a real production deck
- Each floor is plated (conservative setup)
- The legs will host the jacks to lift the decks (to optimise the position w.r.t. the wind flow field)
- The obstacles will be fixed to the deck although revolving

Gas release setup

- **Selection of the mixture**
  - For safety reasons, the actual released gas, natural gas, cannot be used at 100% concentration
  - Tracer requirements:
    - economic
    - easily measurable
    - non-toxic
    - non-allergenic
    - non-flammable
    - same molecular mass of the CH_4
    - not absorbable by the laboratory surfaces
    - not one of the main air constituents

→ **Best option for technical similarity: Neon**

→ **but…too expensive**

→ **2,2% CH_4 / air mixture is chosen**

(after tests at real and scaled release pressure)

Gas release setup – first case study setup

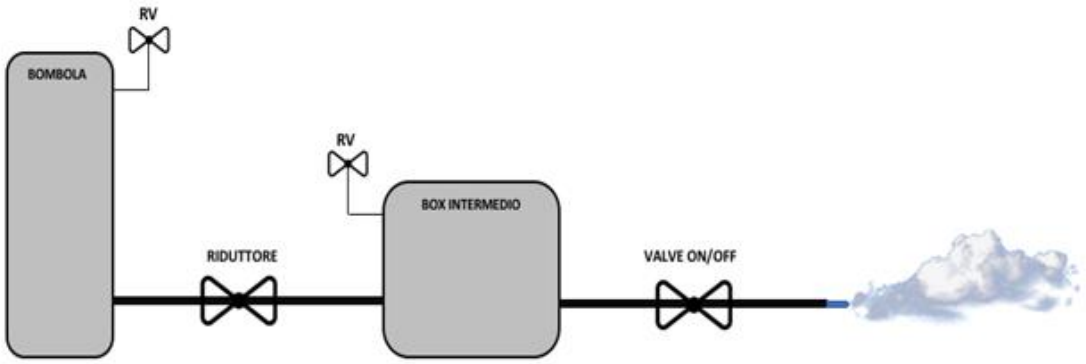
- The source box is scaled too: nozzle + obstacle in one assembly
- Release features
  - Diameter rupture: from literature small/medium rupture diameters are more frequent, but high release flow rates are more easily scalable in the setup, so first setup is
    - **30 mm real scale rupture → 9,5 mm scaled rupture**
  - Release pressures: a set of pressures will be considered according to operating pressures in equipment
    - **65 bar real scale pressure → 6,5 bar scaled pressure**
    - **When proposing the scaled release setup, the similarity parameter that must be kept constant in critical conditions is the dimensionless momentum flux**

Scaled supply line

2 options:

1. The gas mixture can be supplied either via a supply line starting with a pre-mixed cylinder (@2,2% CH_4 concentration)

→ An assembly that allows constant pressure release is needed



2. or via a mixing valve installed on a line supplied with compressed air and CH_4 separately

Sensors and alarms

- Concentration and velocity sensors are needed
- Installed into the obstacles to minimise fluid-dynamic perturbation
- Available concentration sensors have long response times

→ **difficult to catch transients**

- Velocity sensors are big

→ **few obstacles can host them**

- Options: Wired or Wireless?
- Safety sensors and alarm setup to be installed in the wind tunnel

Follow up and conclusions

- A new hybrid approach to accidental gas release simulation in oil&gas platforms has been proposed
- It is time to validate it experimentally
- A complete laboratory setup has been designed with
  - Wind tunnel
  - Scaled platform mock up with sensors
  - Gas supply line
- Experimental campaign will start as soon as the laboratory is operating in Torino (stay tuned…)

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Thank you for your attention

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SEADOG DENERG laboratory

Bibliography

[1] Vivalda C., Gerboni R., Carpignano A.. "A practical approach to risk-based gas monitoring system design for oil and gas offshore platforms", proceedings of the Probabilistic Safety Assessment and Management Congress (PSAM 14), Los Angeles (USA), 2018.

[2] Carpignano A.; Corti T.; Uggenti A. C.; Gerboni R.. "Modelling of a supersonic accidental release in Oil&Gas offshore: Characterization of a source box", GEAM Geoingegneria Ambientale e Mineraria. Vol. 152:3, pp. 58-64 (2017)

[3] Impalà M., Uggenti A.C., Gerboni R., "Models and Tools for the simulation of exhaust dispersion in oil & gas offshore platforms", proceedings of the European Safety and Reliability conference (ESREL 2016), Glasgow, 2016

[4] Uggenti A.C., Carpignano A., Savoldi L., Zanino R., Ganci F., "Perspective and criticalities of CFD modelling for the analysis of offshore accident scenarios", proceedings of the European Safety and Reliability conference (ESREL 2016), Glasgow, 2016