World's first ship driven by liquid hydrogen
Preliminary safety considerations

Bergen 06.03.2019

About Norled

- 1 000 employees
- Turnover NOK 2 billions
- 80 vessels
- Transport of 8 million cars and over 18 mill pax annually
- Operations from the Oslo Fjord to Troms County in Norway
- Operation of 23 ferry and express boat contracts, about 50 different services

Initiating zero emission ship operations

1st December 2015 the Norwegian Parliament made a decision to support actions enabling all Norwegian car ferries and high speed passenger vessels to utilise low or zero emission energy systems onboard.

MF Ampere had since early in 2015 proved that this technology was possible and this ferry has now sailed a distance equal to six times around equator in 4 years.

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

IMO INTERNATIONAL MARITIME ORGANIZATION

RESOLUTION MEPC.304(72)
(adopted on 13 April 2018)

INITIAL IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS

Norwegian Centres of Expertise
NCE Maritime CleanTech

Grønt Kystfartsprogram

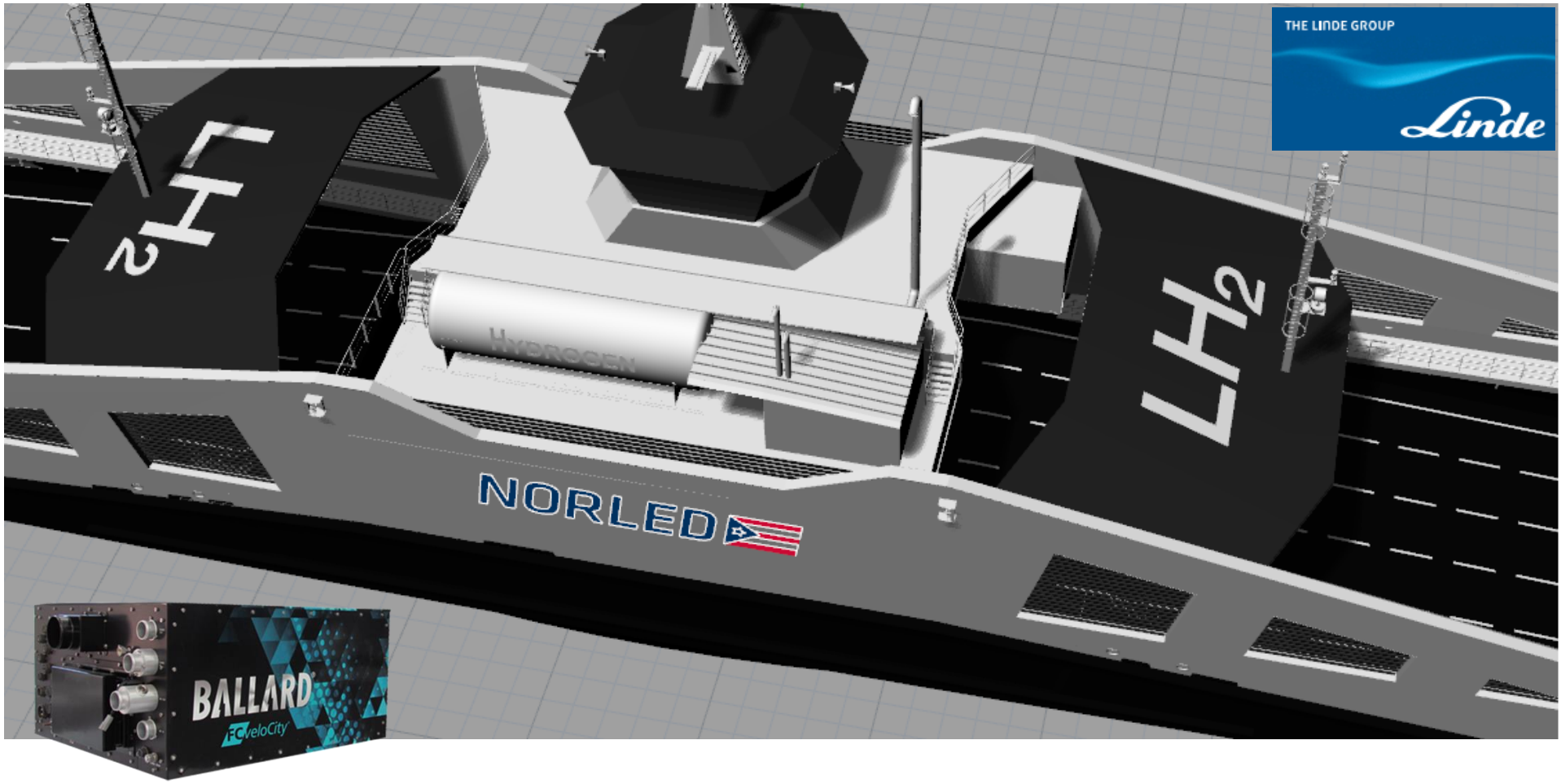
World's first ship driven by LH_2

Hjelmeland-Nesvik-Skipavik route

Length	82.40 m	Car capacity	80
Beam	16.75 m	Truck capacity	10
Draught	2.8 m	Passenger capacity	299

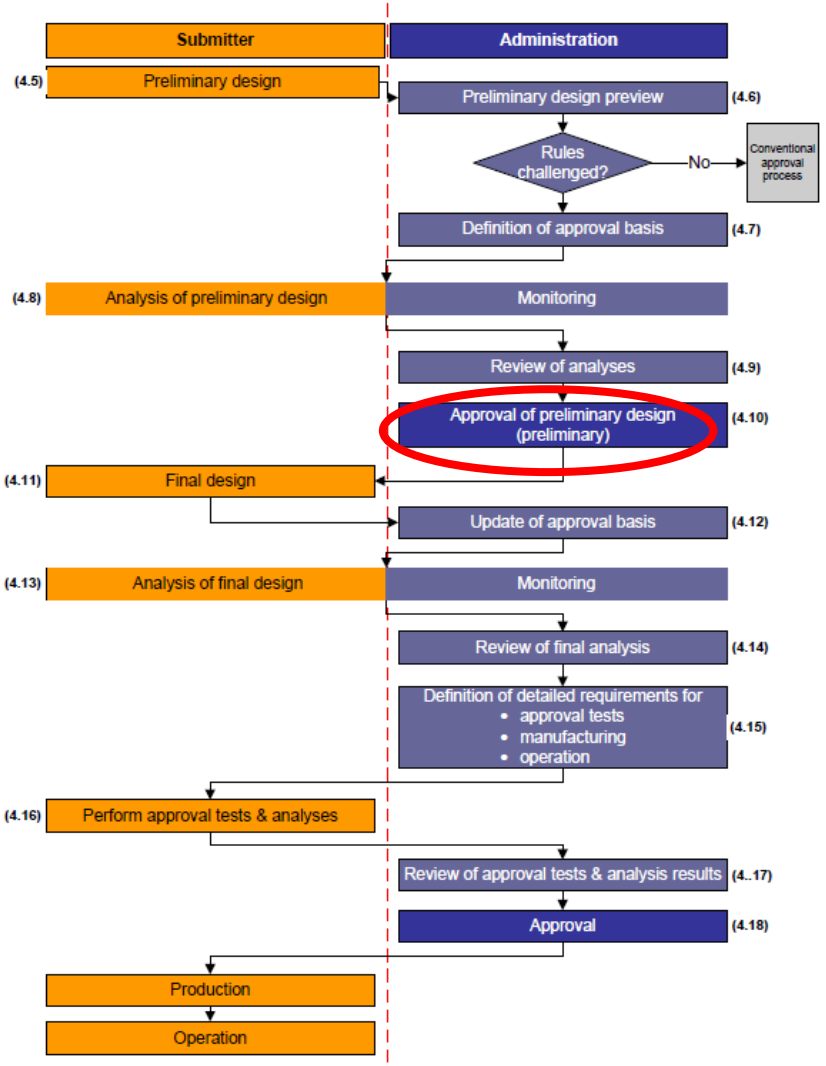
LMG80-DEH2

Hydrogen arrangement

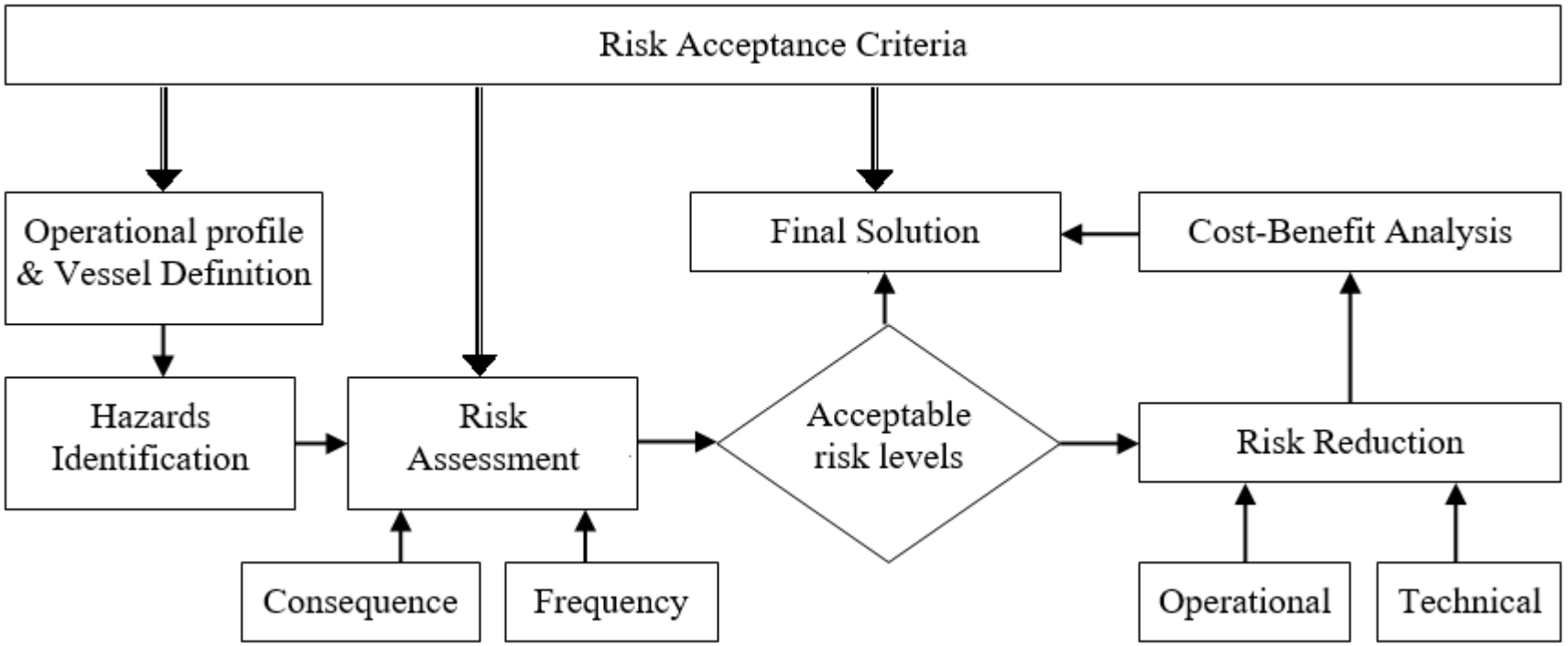


Risk-based approach (IMO Circ. 1455)

- A well-known method for the development of ship designs where risks shall be as low as reasonable practicable (ALARP)
- Utilized by LMG Marin and Gexcon for the development and construction of the LNG-driven gas ferries (Halhjem-Sandvikvåg) in 2004-2006, which become the basis for rules development for such ferries
- The aim for Norled, assisted by LMG and Gexcon, is to prove that the hydrogen-driven ferry is as safe as diesel-driven ferries – an equivalent risk level
- Approval in principle received from DNVGL and NMA



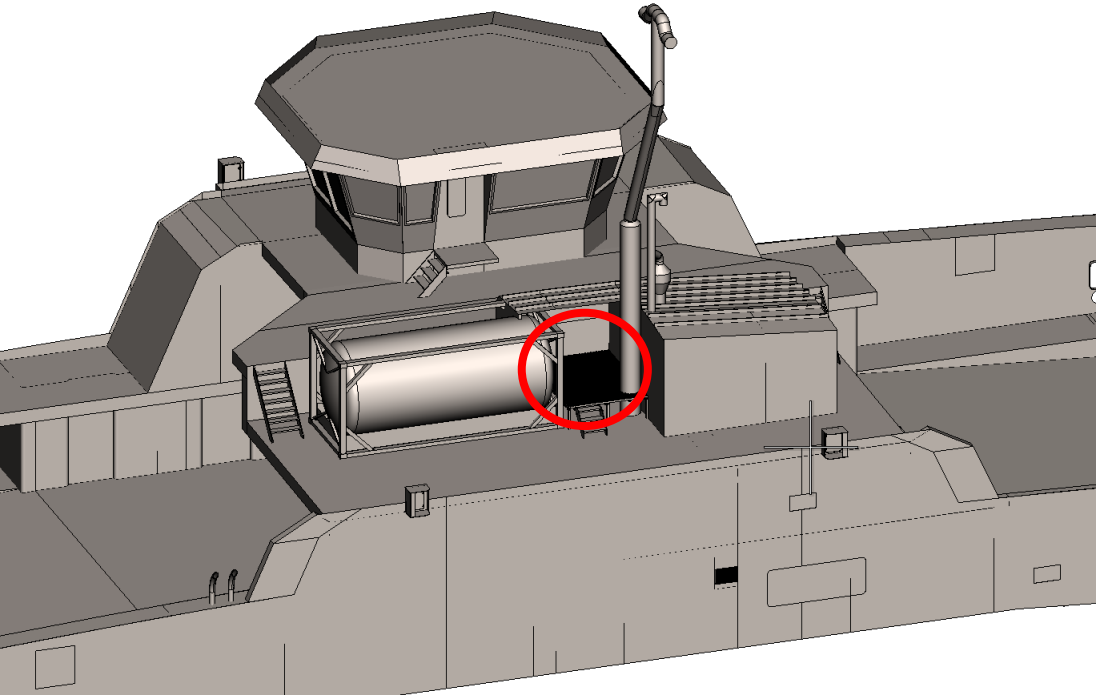
Risk-based ship design

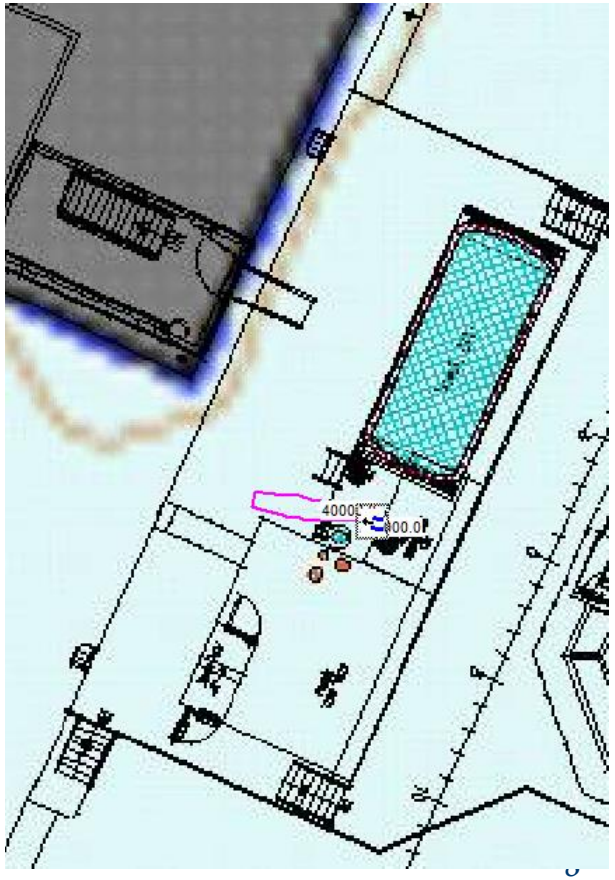


- Results in an improved overall design
- Little extra costs if conducted as an integral part of the design process
- Currently limited risk (frequency) data available for ships

Scenario – LH2 pipe leakage

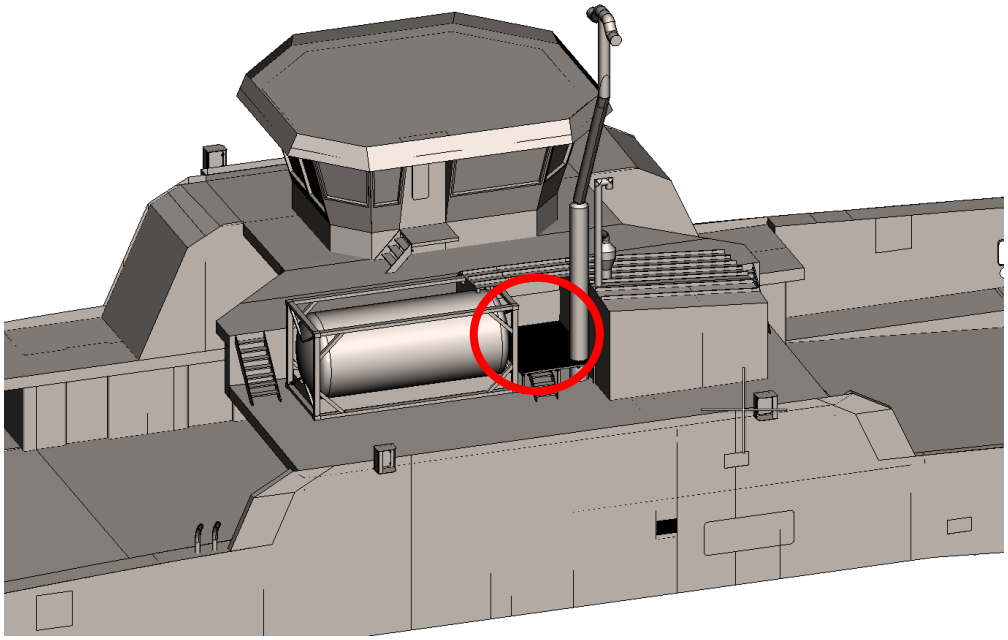
- Rupture of 3 meter 10 mm LH_2 pipe
- All liquid released within 7.5 seconds
- Leak rate: 2 g/s
- Plume length: 3 m
- If ignited: Minor flash fire (dangerous to nearby personnel, but unlikely to cause escalation).



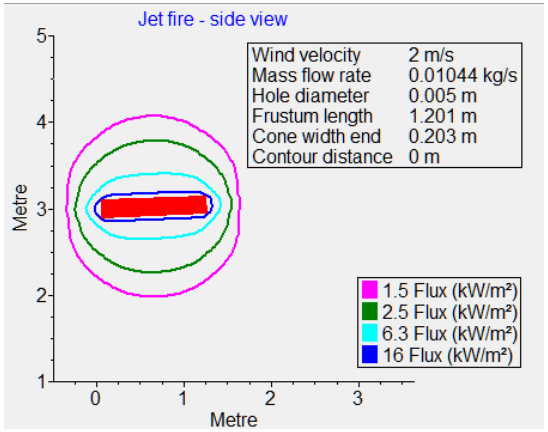


Scenario – gas phase hydrogen pipe leakage

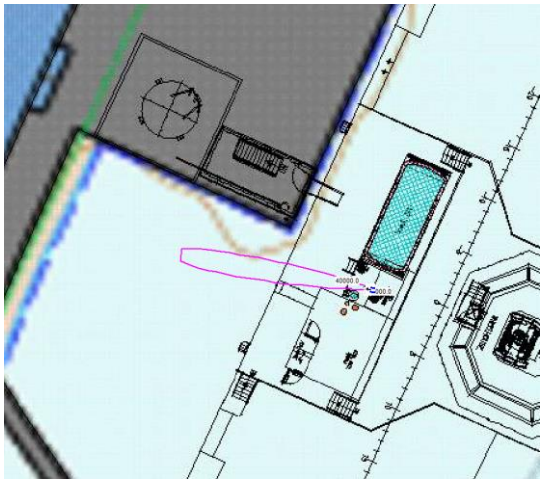
- Rupture of 10 mm H_2 gas pipe
- Conservative case: Assuming gas is close to boiling point (more dense/higher leak rate)
- Leak rate: 54 g/s
- Plume length: 12 m
- Jet fire hazard distance: 3.5 m



Fire radiation

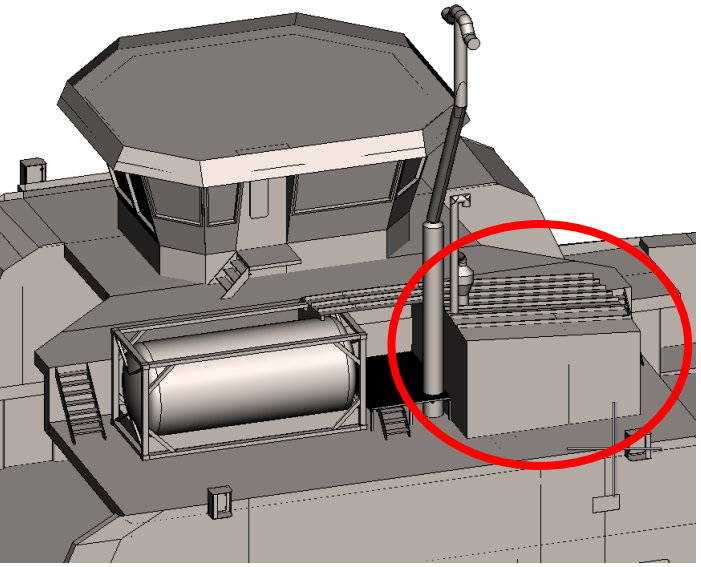


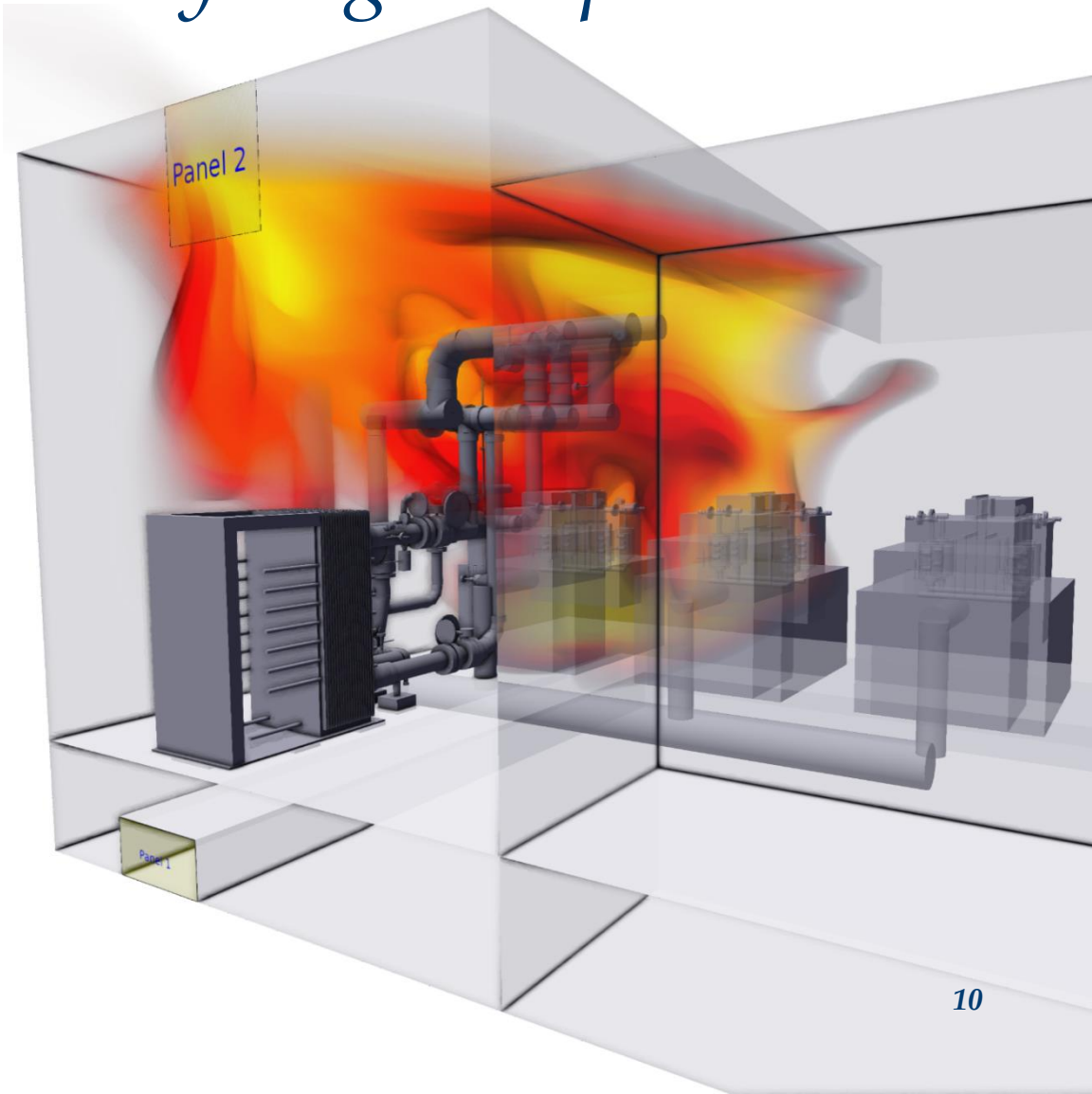
Flammable gas



Scenario – FC room hydrogen explosion

- 1 minute undetected leak
- Assumed no ventilation
- 83 g H_2 – 3 m^3 gas cloud
- Peak pressure 0.55 bar
- Possible mitigation:
  - Pressure relief panels
  - Gas detection/shutdown
  - Ventilation
  - Wall design

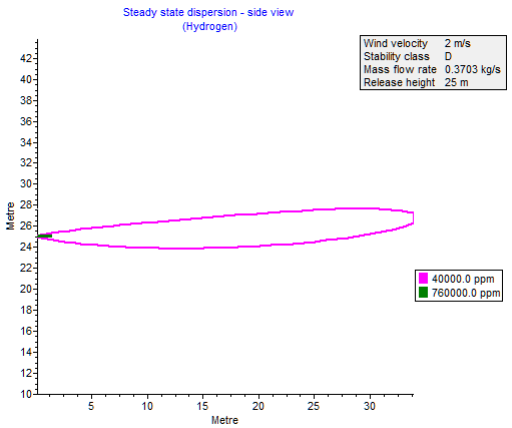




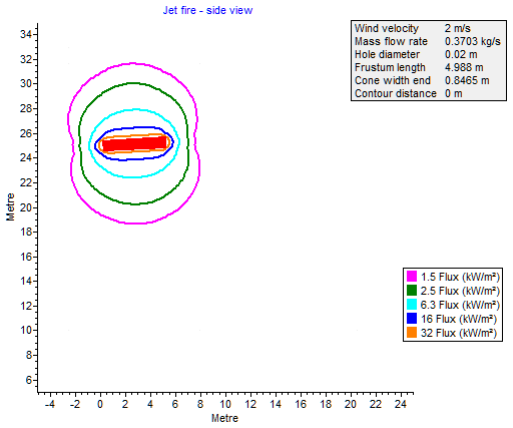
Scenario – vent mast hydrogen dispersion

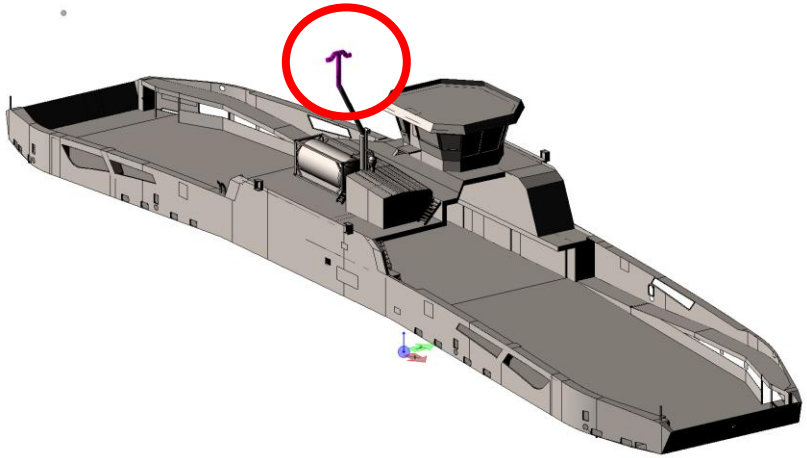
- High pressure vent (6 barg)
- 20 mm vent at 25 m height
- Flammable gas reaches 35 meters horizontally
- Gas is never brought toward ground
- If ignited, radiation contours would be limited to at the lowest 18 meter above ground

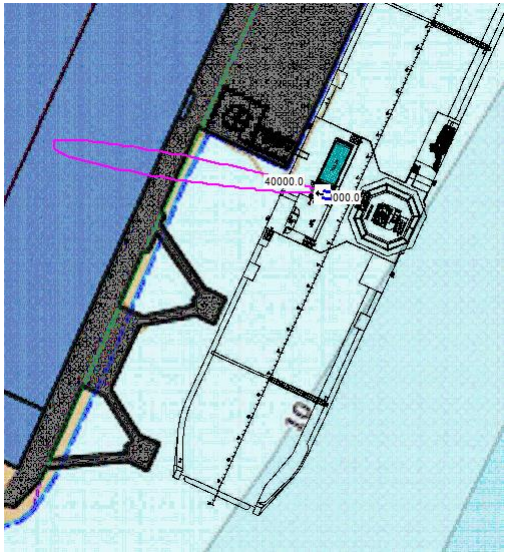
Flammable gas

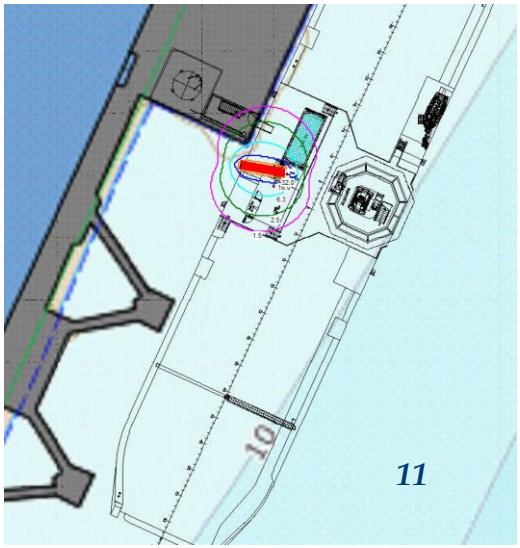


Fire









Some discussion points

- Initial risk analysis work started with AIP received from DNVGL and NMA
- Selected (dimensioning) consequence scenarios analysed, frequency data limited
- Much analysis work remains
- Aiming to be just as safe as existing diesel-driven ships
- Norled also focuses on risks during the bunkering operations towards DSB

Thank you for the attention

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