Medium scale LNG-related experiments and CFD simulation of water curtain

Tomasz Olewski, Subramanya Nayak, Omar Basha and Simon Waldram
Ras Laffan, (North East)
- LNG

Doha (East)
- Capital

Mesaieed (South East)
- Downstream processing

Dukhan (West)
- Oil
Education City

- Headquarters of Qatar Foundation
- 2500-acre campus
- Participating universities
  - Texas A&M University at Qatar (Engineering)
  - Virginia Commonwealth University Qatar (Art & Design)
  - Weill Cornell Medical College (Medicine)
  - Carnegie Mellon University Qatar (Business studies & IT)
  - Georgetown University (Foreign Service, Diplomacy)
  - Northwestern University (Media & Communications)
- Schools, Science and Technology Park, International Conference Centre
- Located in Doha, Qatar
1. Public safety consequences of a terrorist attack on a tanker carrying liquified natural gas need clarification.
2. Public safety consequences of a liquified natural gas spill need clarification.

Expert panel ranking of research needs:

1. Large fire phenomena ✅
2. Cascading failure
3. Large scale spill testing on water ✅
4. Large scale fire testing
5. Comprehensive modeling: interaction of physical processes ✅
6. Risk tolerability assessments
7. Vulnerability of containment systems (hole size)
8. Mitigation techniques ✅
9. Effect of sea water coming in as LNG flows out
10. Impact of wind, weather and waves ✅
LNG Safety: Advancing the Science and Technology

- BP Gas Marketing: September 2008 – August 2013, $3M
- LNG spills on land and water
- Heat transfer and vaporization
- Dispersion of dense gas
- Warming in air until the LNG vapor become buoyant
- Ignition and fire
- Mitigation: high expansion foam, water curtain,
  Foamglas®, turbulence inducing vapor fences

- Cirrus, PHAST, FLUENT, CFX and FLACS
Ras Laffan Industrial City (RLIC)

Qatargas
RasGas
Dolphin Energy
Oryx GTL
Pearl GTL
Condensate refinery
Power generation
Sulfur plant
Port
NFPA 59A, 2009 Edition

“Standard for the production, storage, and handling of liquified natural gas (LNG)”

5.3.3.6.: “.... In the event of an LNG spill..... the average concentration of methane in air of 50% of the lower flammable limit does not extend beyond the property line,

........... with a model that is acceptable for use by the authority having jurisdiction that has been evaluated by an independent body ..........

Fire protection research foundation, contracts with HSL:

Evaluating Vapor Dispersion Models for Safety Analysis of LNG Facilities
Dr M.J. Ivings, Dr S.F. Jagger, Dr C.J. Lea and Dr D.M. Webber

The anatomy of a water curtain

Weather conditions
Water supply: temperature and flow rate

Air entrainment mixing and warming

Buoyant vapor

Cold / dense vapor

Wind

LNG Spill

AVI
WMV
Ras Laffan
Emergency and Safety College (RLESC)
Data acquisition system

16 air thermocouples

solar radiometer

3 ultrasonic anemometers

2 water turbine flow meters
2 pressure transducers

weather station

DAQ
Calibration of sensors: evaluation of response times

Thermocouples

Response time evaluation
First-Order Dynamic Response

Radiation from bulb at diff. distances
Experimental setup

- Pole to measure water fan height
- Ultrasonic anemometer
- Thermocouples
- Wind tunnel
- Water line and pipe
- Nozzle head
- Location of colored smoke
- Wind tunnel
Water curtain dimensions

Little effect of nozzle size

Curtain dimensions change becomes insignificant

Water flow rate, m$^3$/min $^{-1}$

Dimensions, m

- Radius (large head)
- Height (large head)
- Radius (small head)
- Height (small head)
Horizontal wind velocity

Test no. 6 - no obstacle

+ SI-01

- SI-02

- SI-03

Wind horizontal velocity, m/s

Test no. 12 - small fan nozzle

+ SI-01

- SI-02

- SI-03

Wind horizontal velocity, m/s

blue points – before water (upstream)
red and green – behind water curtain

120° spread
wind direction change behind water curtain

WIND
Water velocity and porosity

Porosity = f ("Radius")
Velocity = f ("Radius")

- half-ellipse
- continuity eq.
- constant fan width
- size of the nozzle neglected
Water curtains and FLACS model

Porosity = f (Radius)
Velocity = f (Radius)
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