HOW SAFE IS SAFE ENOUGH?

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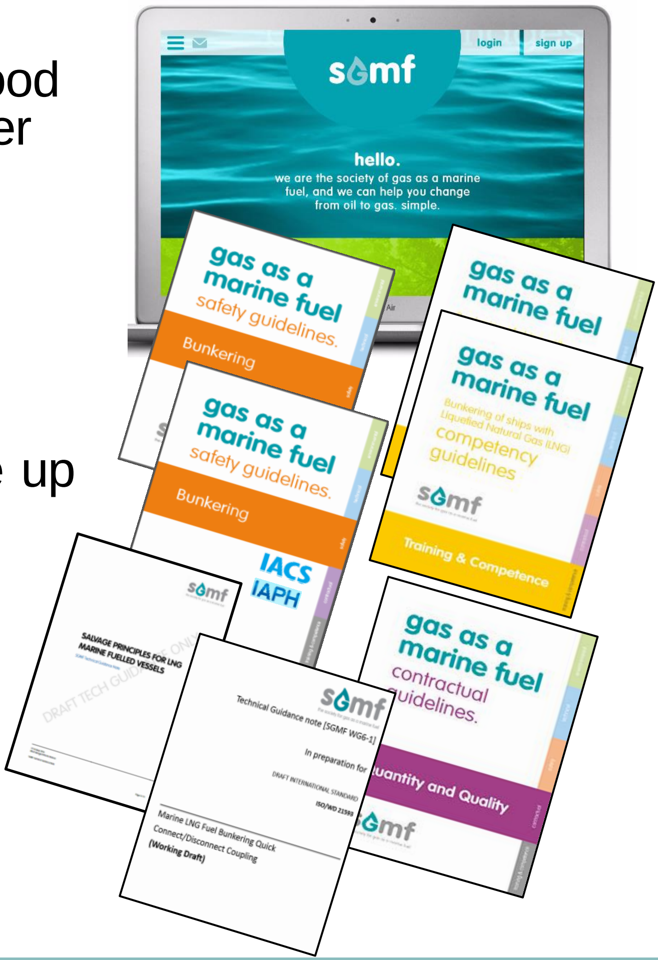
Who are SGMF?

- SGMF is the Society for Gas as a Marine Fuel
- Membership based NGO aiming to develop good practice for ships designed and operating under the IGF code and the onshore and offshore services that support them
- London based secretariat
- 115 members (end September 2017)

- Guidance is provided by working groups made up from SGMF's membership supported, when required, by industry experts

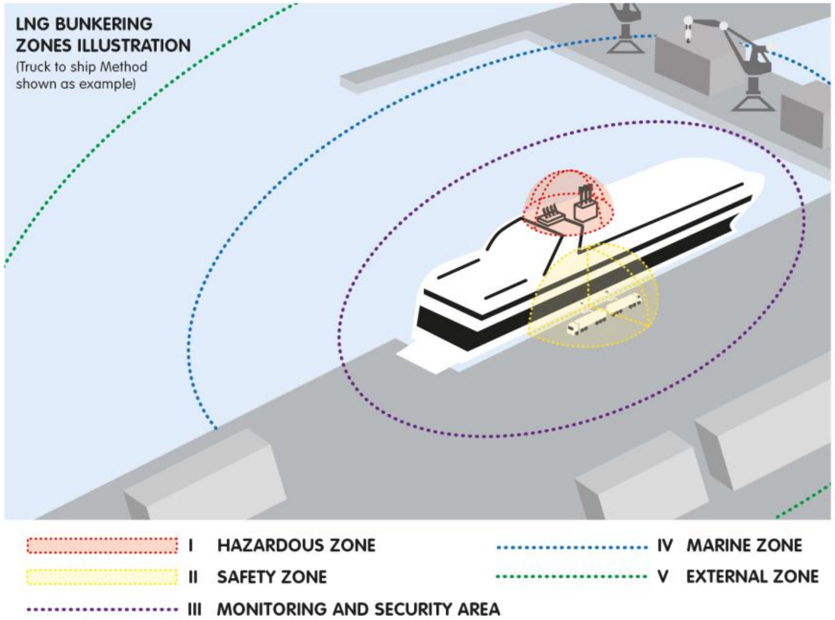
- This presentation covers the work done by Working Group 2 on Control Zones for LNG bunkering

https://www.sgmf.info/



Zones & Areas

- Hazardous zones
  - Where gas might be present at all times
- Safety zone
  - Where gas may be present during bunkering from a leak or failure
  - Place where activities need to be controlled
- Monitoring & security area
  - Space around safety zone to protect control measures
- Maritime exclusion zone
  - Keep other vessels sufficiently distant to avoid collisions and hydrodynamic effects impacting moorings
- External zone (in some jurisdictions)
  - Distance to a defined risk contour, typically to protect the public



* Truck to ship bunkering method shown as the example
** Hazardous zone around the ship/truck manifold(s) and truck relief valve not shown for clarity
*** Relative sizes and distances are for illustration purposes only

Safety Zone

- Any leak during bunkering will impact the safety zone
- Access to and activities within the safety must be managed

- Activities in the safety zone must be authorised
- Authorisation = risk assessment and mitigation to acceptable levels

What is the worst case scenario?

There is little evidence (so far) to determine a “worst case” scenario

Three hazard scenarios:

1. Event only impacts on the safety zone
   - Hazard remains within the safety zone and is therefore limited in consequence

SAFETY ZONE

2. Event potentially impacts outside the safety zone but can be controlled to the safety zone by the PIC
   - High consequence, very low frequency events, that take time to develop
   - Events need immediate attention but can be prevented from escalating

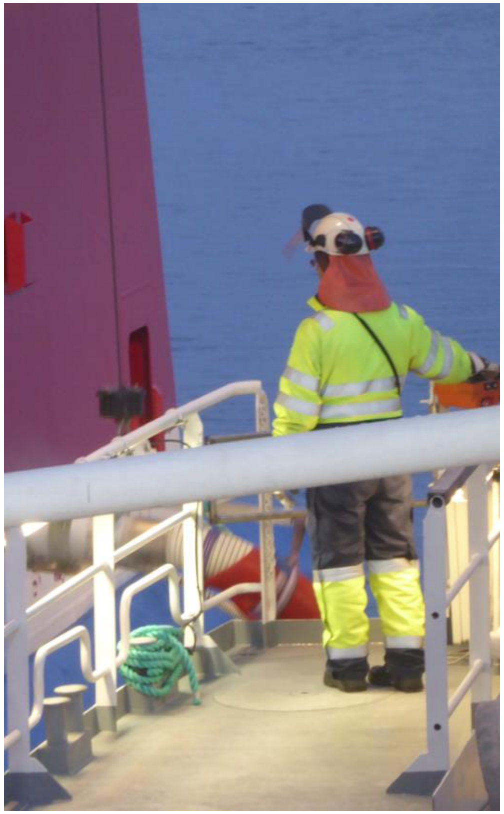
SAFETY ZONE

3. Event is uncontrollable and impacts outside the safety zone
   - Impacts mitigated by probability of occurrence

EXTERNAL ZONE

What does/should happen in the safety zone?

- Flanges and connectors leak frequently during connection and cooldown
- Hoses leak before failure
  - An immediate guillotine failure does not appear credible
  - Dry break coupling required by the IGF code prevents over extension failure scenario
- PIC controls the safety zone so can intervene at the early stages of a hazardous event
  - Flow can be stopped and connections tightened
  - Hose leaks can be stopped/controlled before rupture
  - Inventory loss can be minimised
  - Intervention increases the time available for effective emergency response



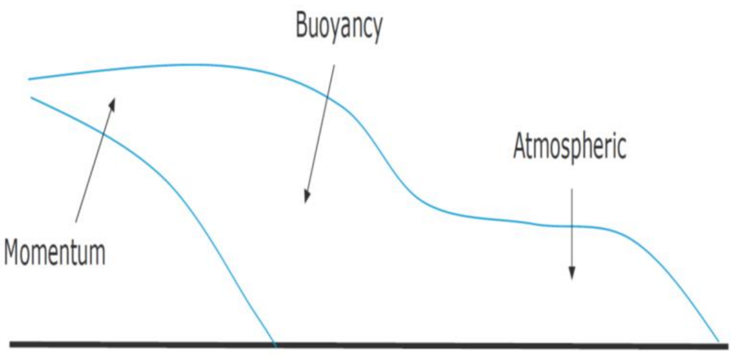
Controlling event

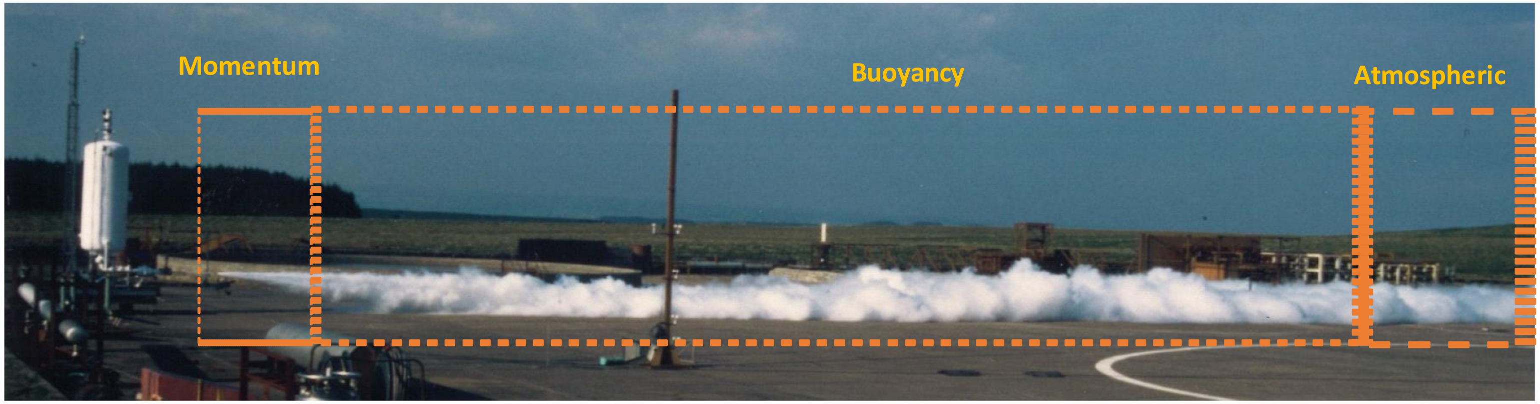
- Dispersion of gas from a LNG/vapour leak to the lower flammable limit is hazardous to the largest distance
- On ignition this will become a flash fire which burns back to the leak source
- This therefore defines the safety zone

- Pool and jet (torch) fires are catastrophic to anything in their immediate vicinity but are relatively compact
- Unless in an extensive, congested area, explosion (deflagrations) effects are very localised

Physics of gas dispersion - 1

- Gas dispersion depends on 3 factors
  - Momentum from the pressure/velocity behind the leak
  - Buoyancy of the material compared to the atmosphere
  - Atmospheric effects





Physics of gas dispersion

- Vertical (upwards) release

- Horizontal release

- Vertical (downwards)/pool release

- Other angles

SGMF consequence model - BASIL

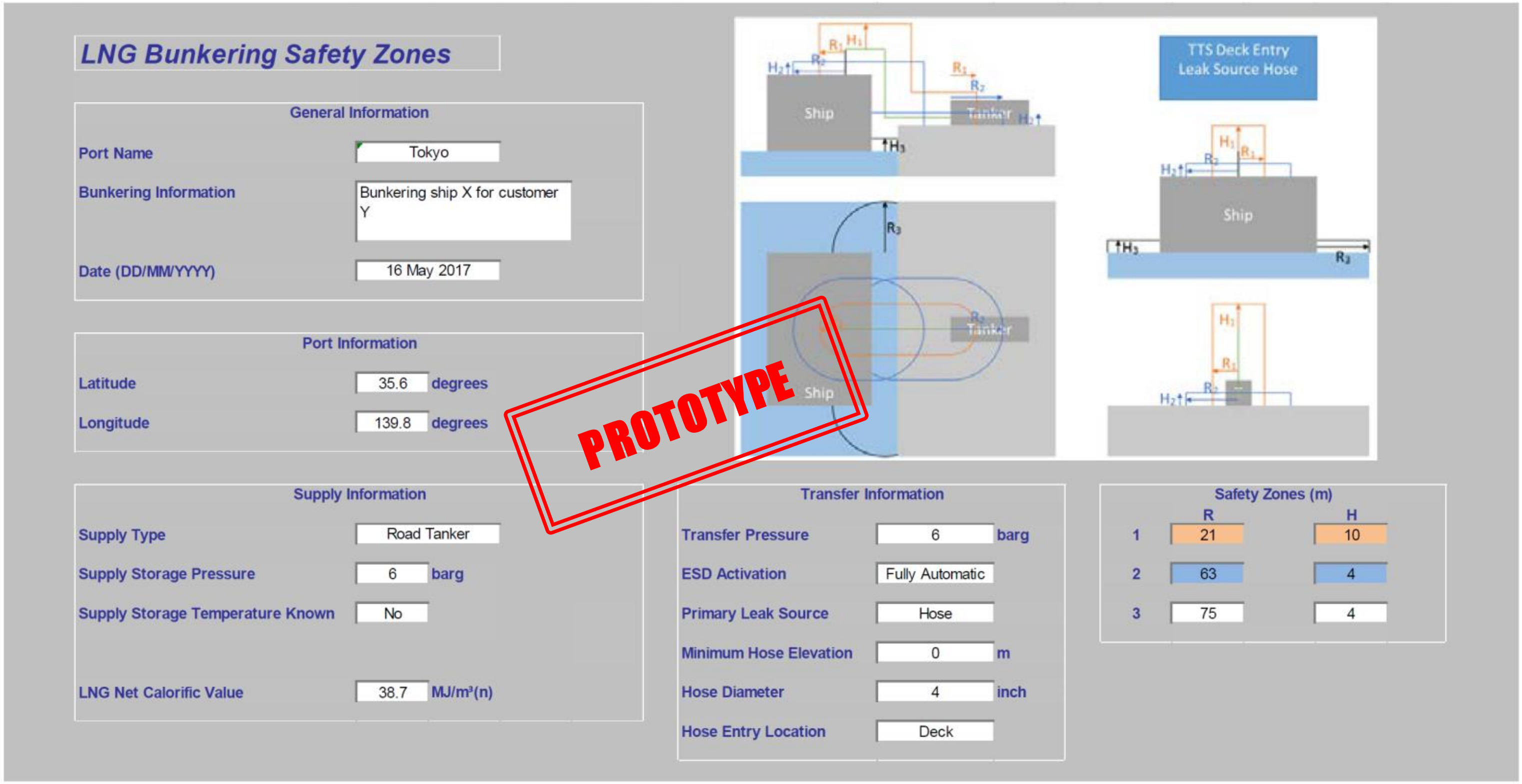
- DNV GL, under contract to SGMF, have created a bunkering incident consequence model based on gas dispersion
- Model predicts, using scientific and repeatable methodologies, the maximum distance to the flammable boundary (LFL)

- Distance to LFL is a function of
  - Hole size
  - LNG quality
  - Transfer temperature, pressure & flowrate
  - Local atmospheric conditions

- Model is deliberately conservative

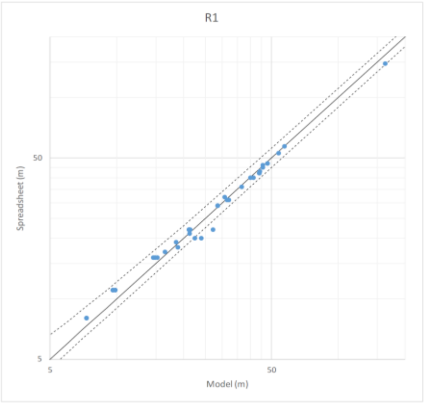
BASIL example

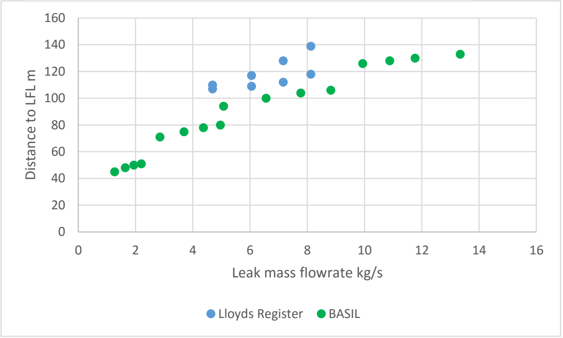
- User enters key operational data for the LNG bunkering
- BASIL interpolates in 8 dimensions across 1.4 million data points

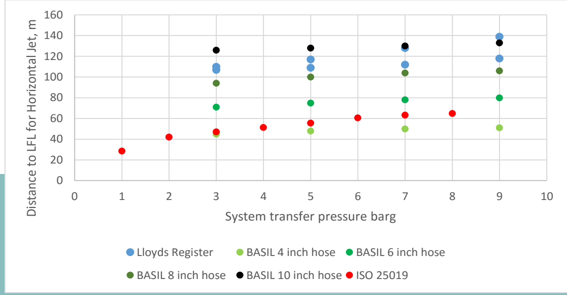


Validation

- The interpolations have been validated against
  - Detailed gas dispersion models derived from full scale experiments on LNG and other cryogens at DNV GL's Spadeadam test site in the UK
- The interpolations have been compared against models used by other industry specialists
  - In ISO 20519
  - Motorship 2016 Lloyds Register paper
- Accuracy is consistently within +/- 10%
  - Infrequent, larger inaccuracies mainly result from the simplistic assumptions made by the model on LNG composition







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Learning points

- Gas clouds are not hemispherical – they are hemi-ellipsoidal
- Different phenomena result in different mitigations:
  - Gas clouds produced by high/medium momentum leaks reach their maximum size within a few seconds
  - Low momentum releases form pools and are dominated by atmospheric effects which happen slowly and grow with time
  - ESD system (primarily leak detection) effectiveness depends on the leak scenario
  - System inventory (hose length, etc) has a limited impact as the gas cloud reaches its maximum dimension while gas is flowing prior to isolation
- A hose lying on the ground can only entrain air from above and the side limiting dispersion
  - Raise hose off the ground (30 cm / 1 foot +)
- Mass flow (hole size, pressure and flow) is the most important parameter
  - Without control measures safety distances can be large

Control measures

- LNG flow, pressure and temperature are set by commercial requirements

- Leak magnitude depends on the hole size
- What hole size should be used?
  - Flange and valve leaks well understood and hole size distribution available based on experience
  - Similar data on hoses absent: 8 – 10% of hose area often used

- What effects hole size?
- Handling and connection procedures and practices
  - Inspection of flanges, gaskets and hoses prior to use
  - Mechanical handling and bend limiters used on larger (>= 6 inch) hoses
- Cooldown rates and leak checking procedures
- Maintenance and storage procedures
  - Careful storage, use and maintenance should extend hose (fatigue) life and reduce the probability of failure
- Construction technology
  - Quick connectors vs flanges
  - Can double wall hoses leak? Is the failure scenario now a smaller leak from a flange?
- Training and professionalism of personnel involved

The next 3 months

- Convert “worst case” consequences into a risk based process that can be implemented
- Use “expected” hole size as the risk parameter

- Define leak (hole) size based on operating/maintenance practices
  - Recommend flange leak sizes
  - One hose hole size (eg 10% of hose area) may not be realistic for all scenarios

- Provide guidance to regulators and industry participants on how hole size should be selected
  - Publish!
  - “Risked” consequence model will be made available via the SGMF portal – free to members and as a service to others

Summary

- The SGMF working group has brought together representatives of all industry stakeholders to produce a shared solution
- A physics based consequence model has been produced which allows all the key parameters in LNG bunkering to be investigated
- The consequence model is conservative – design and operating practices are being examined to calibrate ("risk") the model (simultaneously encouraging good practice)
- The final model will be made available to the whole industry to encourage consistency and define minimum standards

we sea change, do you?

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