Safety Challenges

Ammonia as Marine Fuel

Dr Paul Davies

Global Head of Technology, Risk Assessment
Technical Policy Group, Lloyd’s Register

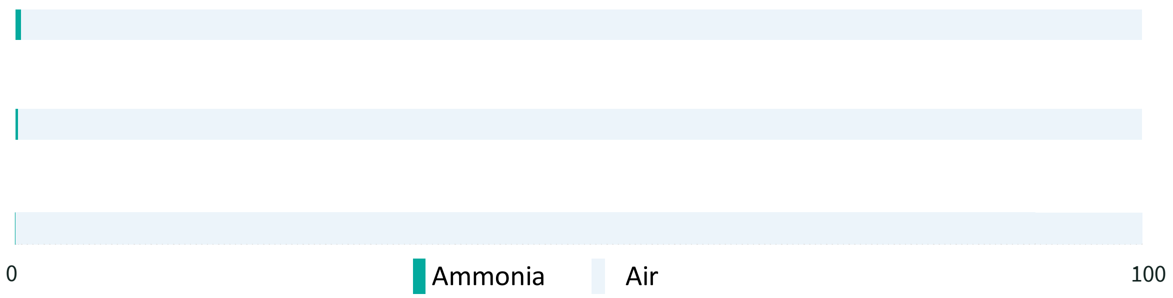
MariNH3 Annual Conference – 28 June 2023

Why are there safety challenges?

– Toxicity

Ammonia is toxic at very low concentrations in air

- 0.5% could be fatal within minutes
- 0.25% could be fatal within 15 minutes
- 0.07% could cause immediate injury



Ammonia is toxic to aquatic life

- an immediate danger if released to the sea
  - readily dissolves in water - non-toxic at 50% water content or more - a single spill can be considered as non-persistent

Ref: Public Health England. 2015. Ammonia, Toxicological Overview; and Ammonia, Incident Management.

Why are there safety challenges?

– Individual Risk

of fatality per year from accidents

- All Causes
  excl. ammonia as fuel, all ranks, all vessel types [1,2]
  - approx. 1 in 10,000
- Ammonia as Fuel
  all ranks, cargo ships [3]
  - approx. 1 in 10,000
- All Causes + Ammonia as Fuel
  - approx. 2 in 10,000

Ref: HSE (2001), Reducing Risks, Protecting People – HSE's decision-making process. C100. IMO (2018), Revised Guidelines for Formal Safety Assessment (FSA) for Use in the IMO Rule-Making Process. MSC-MEPC.2/Circ.12/Rev 2, Appendix 5.

[1] *Roberts S E et al. (2014), Fatal accidents and injuries among merchant seafarers worldwide. Occupational Medicine 2014; 64:259-266.2.*

[2] *European Maritime Safety Agency (2022). Annual Overview of Marine Casualties and Incidents 2022. Ares (2022) 8241169 – 29/11/2022.*

[3] *Franks, A.P. & Graugaard, C. (2022). Quantitative Risk Assessment of Ammonia Fuelled Vessels. RINA Scaling Decarbonisation Solutions: Reducing Emissions by 2030 Conference.*

Why are there safety challenges?

REQUIREMENT

– Safety, equivalent to traditional fuel

Does equivalent mean equal?

- without many years of experience, given an accident it might be easy to say that an equivalent level of risk had not been provided
- 'equivalent' cannot mean equal, it must mean in the region of what can be 'accepted', otherwise we cannot move forward with fuels such as hydrogen & ammonia
  – hydrogen & ammonia present new/increased major accident hazards

Ref: IGF Code 3.2.1

Why are there safety challenges?

– Societal (Group) Risk

	Annual Frequency of N Fatalities or Less					
	1 in 10,000		1 in 100,000		1 in 1 million	
	Acceptable	Tolerable	Acceptable	Tolerable	Acceptable	Tolerable
USA	1	3	1	10	3	30
Australia	1	10	2	45	10	200
Denmark / Neth.	3	/	10	/	30	/
Hong Kong	1	10	1	90	10	1,000
Belgium	10	/	30	/	100	/
UK	1	100	10	1,000	100	10,000

- it is very different losing one seafarer in a single accident, to say losing ten or more
- individual risk can be acceptable and at the same time group risk can be unacceptable
  individual risk may be low but that is no comfort if tens or hundreds of passengers are lost in a single accident

Ref: RA-RBC Guidance. Societal Risk - Societal Risk in High Hazard Industries. Davies, P.A., Lloyd's Register, 2011.

Why are there safety challenges?

REQUIREMENTS

– Risk, limited to a minimum by design

What is a minimum?

- given an accident, it might be easy to say risk was not limited to a minimum by design
  – the likelihood of failure and/or consequences of failure were not limited to a minimum by design

– Risk, eliminated where possible or *mitigated as necessary*

What is possible? When is 'mitigated as necessary' achieved?

- what is possible and when *mitigated as necessary* has been achieved is open to argument, and given an accident, it might be easy to say risks could have been eliminated or mitigated further

Ref: IGF Code 3.2.2 & IGF Code 4.2.3

Why are there safety challenges?

– Risk Assessment

Provides insight not definitive answers!   Helps identify safeguards

- different individuals & groups, applying the same approaches are likely to determine different results – and this is difficult to reconcile because there is no single right answer
- little to no operational experience
- poor data input on equipment failures and subsequent consequences (for ammonia/hydrogen as fuel for ships) – mainly from other industries & for different substances
- large uncertainties as to what could happen & how best this should be modelled (little experimental data to support assumptions)

What can be done today to meet safety challenges?

– Inherently Safer Design

0. Eliminate the hazard – unfortunately, in this case, the fuel is the hazard!

1. **Reduce** the severity and scale of **consequences**
   e.g. minimise the quantity of fuel stored & present within equipment & pipework
   smaller the quantity, the shorter the duration of a potential release
   -reduced dispersion distance -reduced likelihood of ignition -shorter fire duration -less damaging fire/explosion

2. **Reduce** the **likelihood** of accidents (leaks)
   e.g. minimise the number of equipment items, instruments & connections
   limits the number of potential leak sources so reducing the chance of an accident

3. **Protect life** from potential accidents
   e.g. separate individuals as far away as possible from ammonia sources (via distance/physical barriers)
   limits the potential to be harmed given an accident

What can be done <u>today</u> to meet safety challenges?

– Inherently Safer Design

A simple mind-set:

- *simplify your design so it has fewer equipment items & 'add-on' safeguards*
  - this will require less supervision & intervention
- *less supervision & intervention translates to a lower chance of an accident*
  - there are fewer parts that can fail and fewer chances for human error to cause an accident

What you don't have can't fail

And what you don't fit costs you nothing & needs no maintenance

What can be done today to meet safety challenges?

– Meaningful Protection

For new/novel designs minimising risk requires more than meeting scant prescription, subjective attainment of high-level safety goals, and basing decisions on risk assessments – we have no operational experience, much uncertainty, and accidents can and do happen

Meaningful Protection

protection that might be reasonably expected

That is, given an accident it can be shown that all obvious, simple, practical and cost-effective protections were adopted in addition to those expected by regulation and identified by risk assessment

What can be done today to meet safety challenges?

– Meaningful Protection, *for ammonia-as-fuel, ensure*

1. likelihood of releases minimised
   e.g. minimal number of equipment items and connections
2. detection of releases initiates prompt emergency actions, recovery & protection
   e.g. gas detection initiates venting/ventilation and mustering of crew to safe locations
3. release quantity minimised
   e.g. flow sensors initiate closure of isolation valves
4. releases safely contained or dispersed
   e.g. double-walled pipework, venting to a safe location
5. likelihood of igniting releases minimised
   e.g. elimination of ignition sources, ex-rated equipment, hazardous area zoning
6. protection and mitigation provided against toxic impact, fires/explosions
   e.g. gas detection initiates closure of ventilation in the ship's accommodation space; fire-fighting

Meaningful Protection

protection that might be reasonably expected

That is, given an accident it can be shown that all obvious, simple, practical and cost-effective protections were adopted in addition to those expected by regulation and identified by risk assessment

Conclusion

– Ammonia as fuel presents safety challenges, but these challenges can be met

through…

- good research and engineering

and application of…

- Risk Assessment
- Inherently Safer Design
- Meaningful Protection

Thank you

Contact details:

paul.davies@lr.org