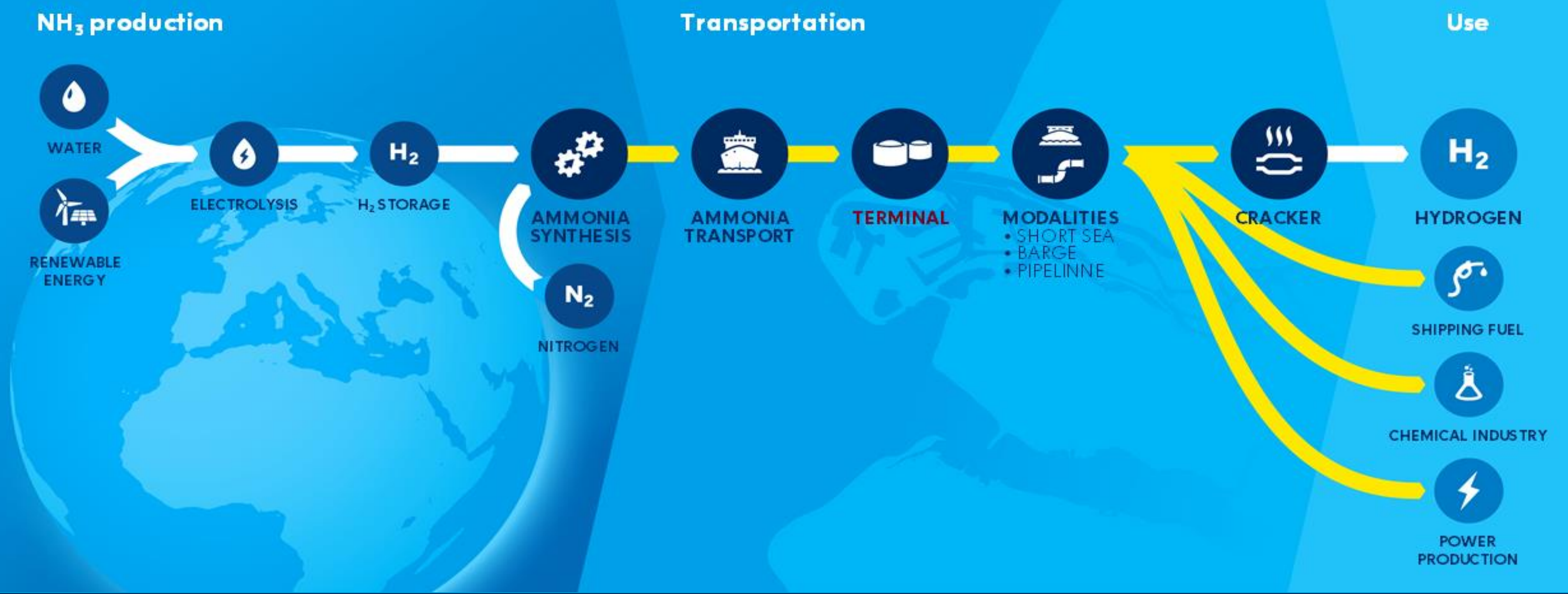
Revisions to PGS12



Chiel Deij

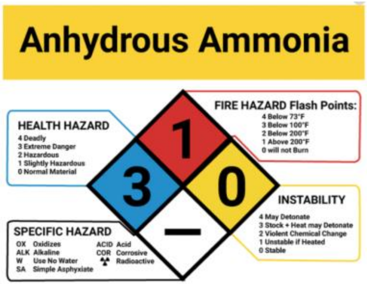
Sr. Consultant Ammonia, OCI

Agenda

- Introduction/Agenda
- Ammonia Properties
- Introduction into PGS12
- PGS12 Revision Process
- Changes in PGS12
- Global Impact of new PGS12
- Forum / Questions

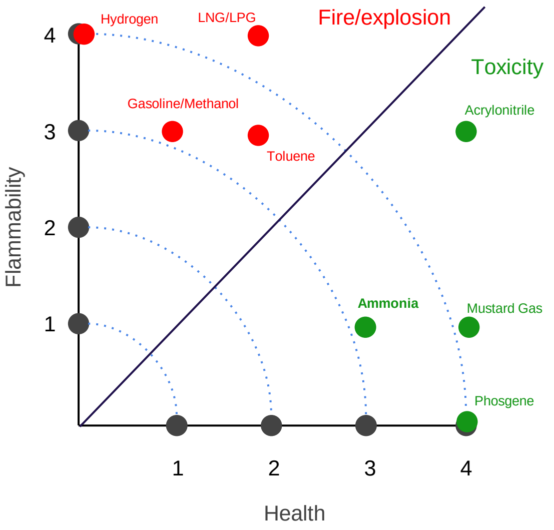
Courtesy of: Geldof

Ammonia NFPA rating, toxicity limits compared



	NH_3		CO_2	Toluene	Acrylonitrile
IDL (Immediate danger limit)	300 ppm	*versus* →	50 000 ppm	500 ppm	85 ppm
STEL (Short term exposure limit)	35 ppm	*versus* →	30 000 ppm	150 ppm	10 ppm

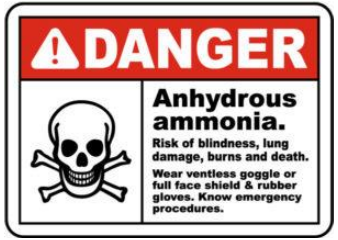
NFPA comparison plot for several substances



Main Takeaway

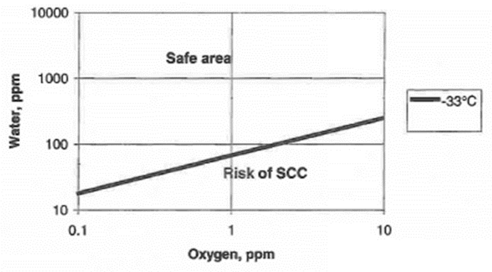
The fertilizer industry has been storing and transporting ammonia for **many decades** in a safe way. Most of their knowledge, experience and lessons learnt is covered in documents developed by the **European Fertilizer Manufacturer Association** (EFMA).

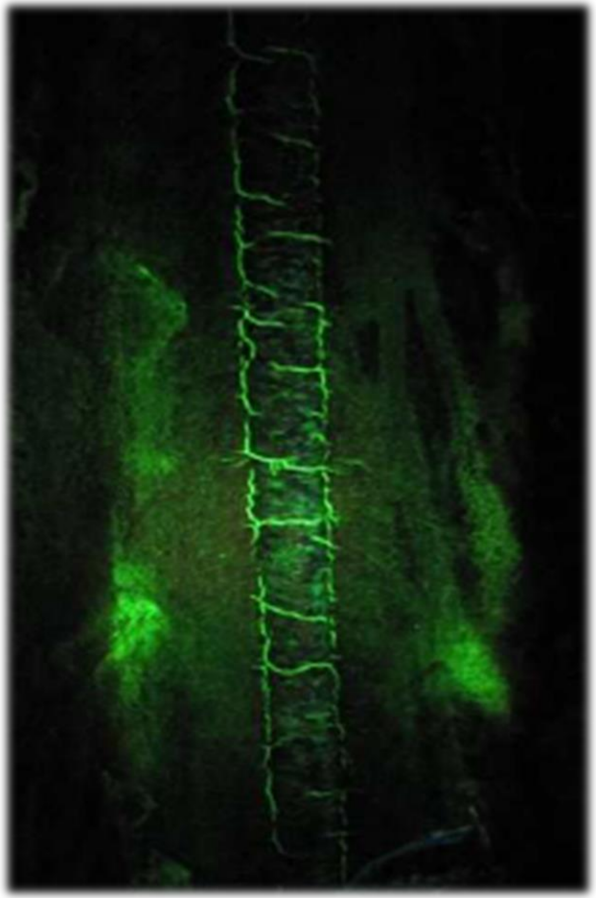
The main risks come with the **upscaling** of the supply chain of ammonia as an energy carrier. In this case, ammonia can no longer be regarded as a **specialty chemical**, but as a **commodity chemical.**



Stress Corrosion Cracking (SCC)

- Stress corrosion cracking in ammonia involves **crack initiation** by active dissolution of small amounts of iron along slip steps in small local areas where bare metal is exposed by disturbance of the oxide layer **due to local plastic deformation**.
- Cracking usually occurs only **in the welds**, where residual stresses from welding on top of operational stresses can result in local yielding; sometimes extending into the **heat affected zone**.
- The cracks **can grow** by local dissolution of the metal along slip steps. Ammonia SCC is an **anodic dissolution process** driven by potential difference between the bare metal at the crack tip and the oxide covered metal in the outer part of the crack or outside the crack.
- In general, SCC is **initiated by oxygen** and **inhibited by water**.
  Water content 0,2-0,5%wt (2000-5000ppm)
  Analysis of oxygen content is in liquid ammonia is rather difficult to perform.



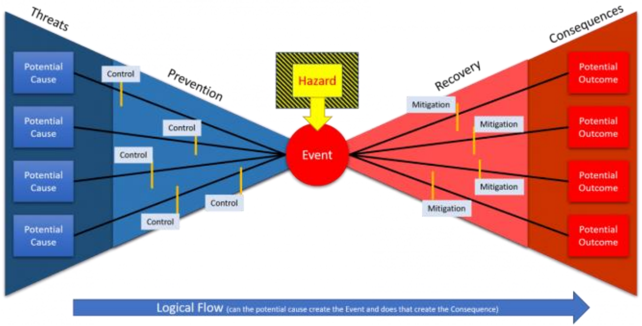


Introduction into PGS12

PGS: Publication Series on Hazardous Substances

About PGS12:

- **Ammonia specific** Storage and Handling Guidelines
- Developed and maintained by the **NEN institute** (Dutch Normalisation Institute)
- In the Netherlands it is a **legal requirement**
- Applicable in the **Netherlands** but also being used **as reference** abroad
- Describes **Best Available Techniques** (BAT)
- Uses the **bow-tie** risk management methodology:
  scenarios, objectives and mitigating measures



- An imposed mitigating measure may be replaced with another measure,
  when this results in the same risk level (NL: '**Gelijkwaardigheidsbeginsel**', ENG: '**Principle of equivalence**').

Revision Process | Incentive

The existing PGS12 version 2014 raised the following questions

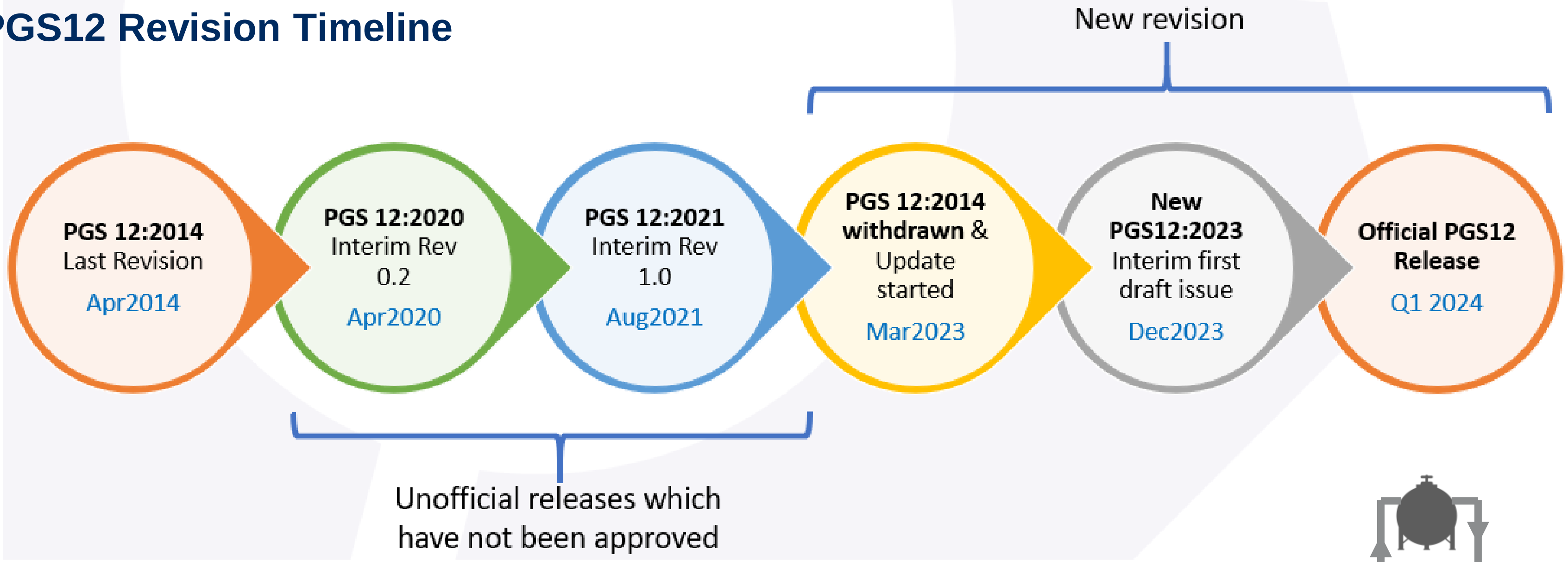
- Does the PGS-12 cover the large quantities stored and handled for the energy transition?
- Is the current industrial QRA risk profile of ammonia installation acceptable?
- Are group risk and domino effects considered for permitting?
- Will tanks and storage facilities limit the development of other new industries, such as methanol/ethanol storage or Hydrogen Cracking?
- Does the PGS-12 ensure NEW Energy players inexperienced with ammonia can operate safely?

Answer: The previous PGS-12:2014 did not cover all risks related to **large scale** storage in a storage terminal environment.

Action: With **10-15 ammonia initiatives** in the Rijnmond area and the Province of Zeeland, an **urgent request** emerged to revise the PGS12.

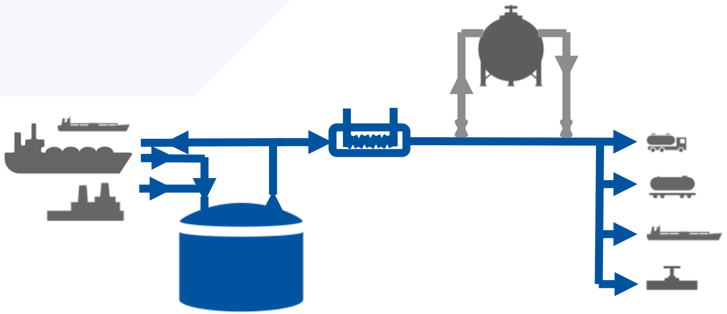
Revision Process | Timeline & Scope

PGS12 Revision Timeline



Phasing

Phase 1: New terminals & refrigerated tanks
Phase 2: Existing terminals & tanks
Phase 3: Pressurised storage of ‘warm ammonia’



Revision Process | Involved Parties

WORK GROUP

Industry Representatives
Yara
Vopak
OCI Nitrogen
Proton Ventures

Authorities
DCMR (Environmental Protection Agency of Rijnmond Region)
Rijkswaterstaat (Ministry of Infrastructure and Water Management)

Emergency Responders
Fire Department
VR-RR (Safety Region Rotterdam Rijnmond)
VRZ (Safety Region Province of Zeeland)

BI-WEEKLY MEETINGS

INDUSTRY OPEN FORUM

Organised by VOTOB (Tank Storage) and VNCI (Chemical Industry).
Provides an opportunity for industry to express concerns and individual opinions.
These concerns, opinions and issues are brought back into the discussion of the PGS12 work group in a consolidated manner.

Tank Design Philosophy

What we are aiming for is to design and build a tank that once commissioned and operational, does not need intrusive inspection (out of service) for the next ±30 years. Similar to a LNG or LPG tank. Is this achievable?

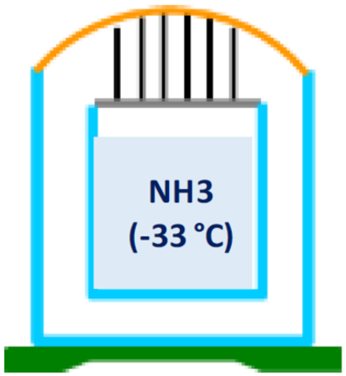
Design philosophy in the Netherlands:

1. Tank lifetime >50 years
2. Full containment
3. Correct material selection, in relation to Stress Corrosion Cracking (SCC)
4. Using the correct insulation material and method
5. Developing in-service-inspection methods, such as robot inspections
6. Lowest failure rate of 10^{-8}
    - Tank is protected against external impact
    - Eliminate bottom or shell penetrations.

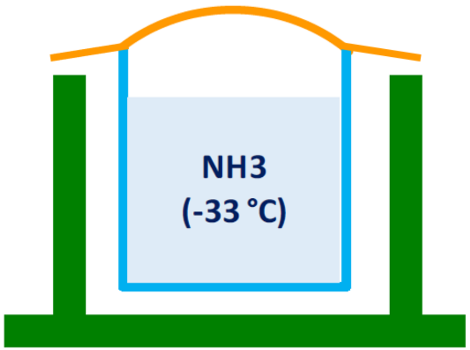
BASF Antwerp (Courtesy of: Willemen Groep)

Storage Concepts for Refrigerated Gas (Simple Version)

Double containment (DC) versus Full Containment (FC)

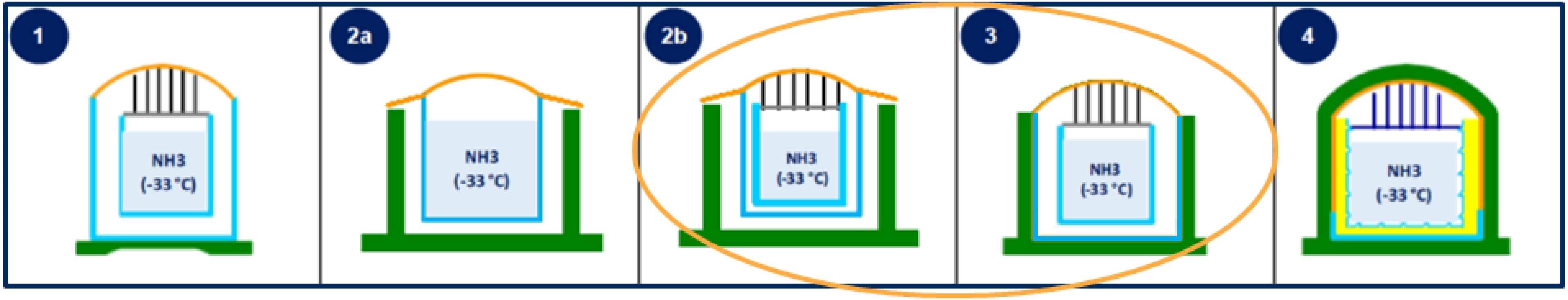


Full Containment
'Cup in tank'
Vapours are contained when primary containment fails.



Double Containment
'Tank in Cup'
Vapours are emitted when primary containment fails.

Storage Concepts for Refrigerated Gas (Expanded Version)



Conclusion

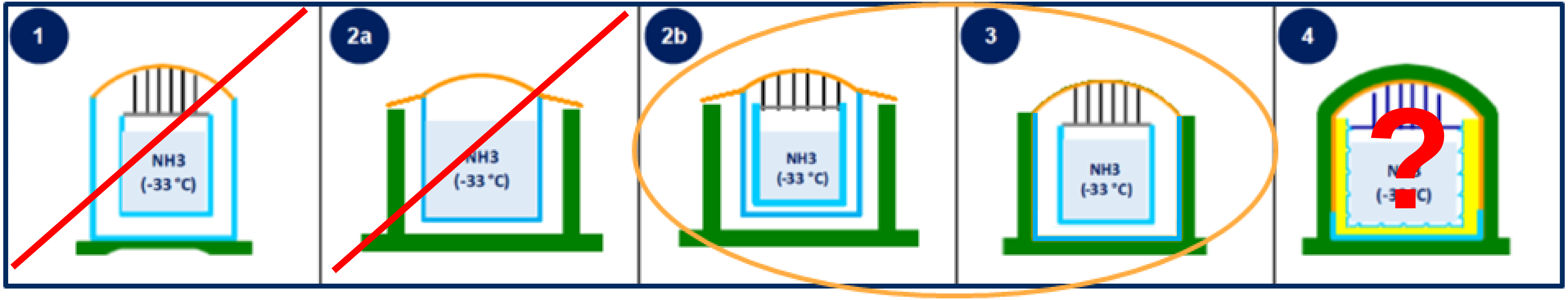
In the Netherlands, we will only build **full containment tanks** with a protective concrete **'blast-wall'** to protect the tank against exterior impact.

Main reasoning behind this:

1. Ammonia tanks will be built in **densely populated areas**;
2. Netherlands has clearly defined **failure rates** for single and double wall tanks, consolidated in the "Handleiding Risicoberekeningen Bevi v4.3".
   This clearly states a failure rate for a steel/steel tank (not protected against impact from external projectiles) of 10^{-6} versus a concrete/steel tank of 10^{-8}.
   With this input, the **QRA** will *not* meet the requirements with a steel/steel tank in the Netherlands.
3. **Benchmark** with surrounding countries (a.o. Germany, Denmark, France, Spain, Belgium).
4. Agreed upon with industry forum with regards to **'level playing field'** for all companies developing ammonia projects in the Netherlands.
5. **Societal discussion.**

Changes in PGS12 | Storage Concept

Storage Concepts for Refrigerated Gas (Expanded Version)



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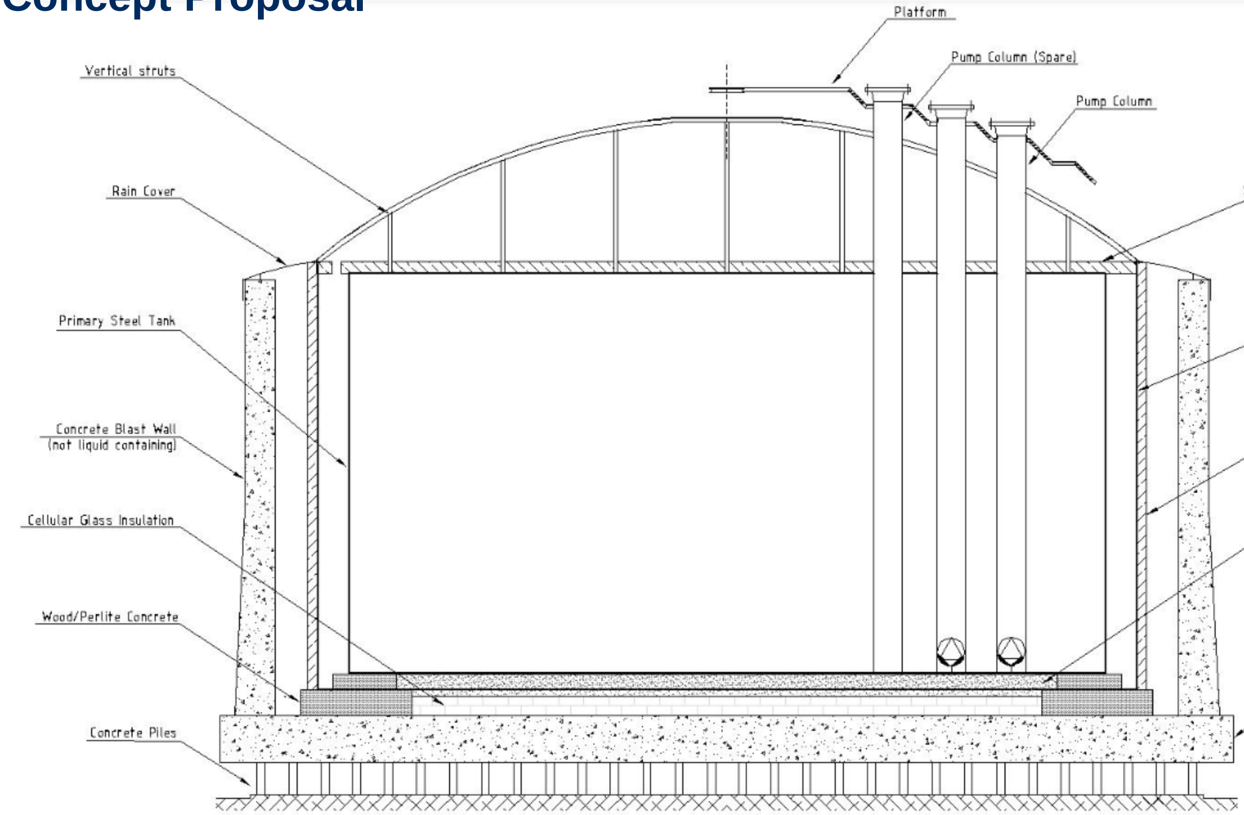
Changes in PGS12 | Storage Concept

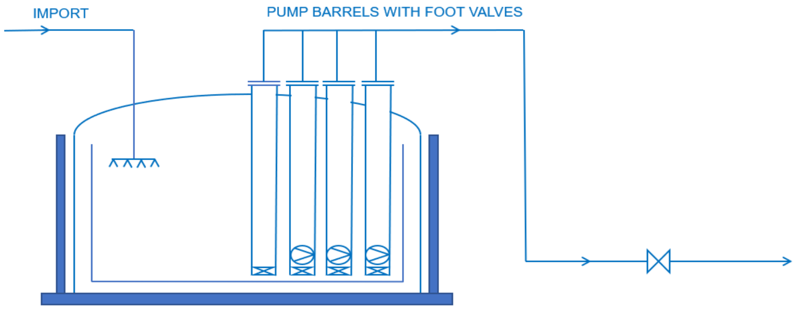
Tank Concept Proposal



Changes in PGS12 | Pump Configuration

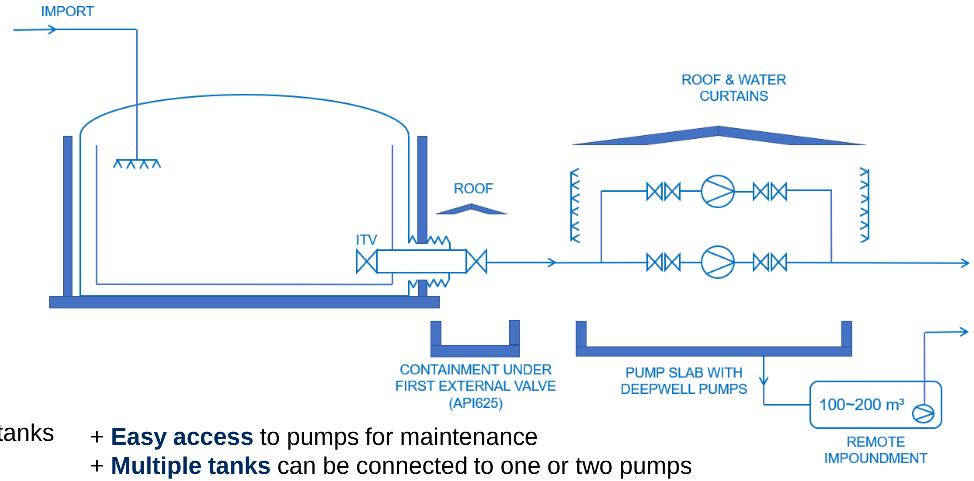
PGS12

In-Tank Pumps versus External Pumps (process risk vs personal risk)



+ Lowest Process risk, no **physical connection** between inner and outer tanks
+ No **additional equipment** required, increasing MTBF
+ Follows the **design philosophy** to increase OOS intervals.

- Retracting a pump for maintenance comes with **personal risks**
- External **booster pump** might still be needed to increase pressure
- Each tank requires its **own set of pumps** (incl redundancy)
- **Availability** of in-tank ammonia pumps on the market
- Potential problems with **failing foot valve**
- Requires solid design of **umbilical cords** for E&I cabling



+ **Easy access** to pumps for maintenance
+ **Multiple tanks** can be connected to one or two pumps
+ Can facilitate **large flowrates** for loading a VLAC

- Increased **process risk**
- Thermal overload can lead to **loss of both containments** (Rostock incident 2005)
- **Additional equipment** (ITV & expansion joint) is needed, decreasing MTBF
- Design of the pump pit includes **significant civil and mechanical works**.
- Does not follow the **design philosophy** of increased OOS intervals.

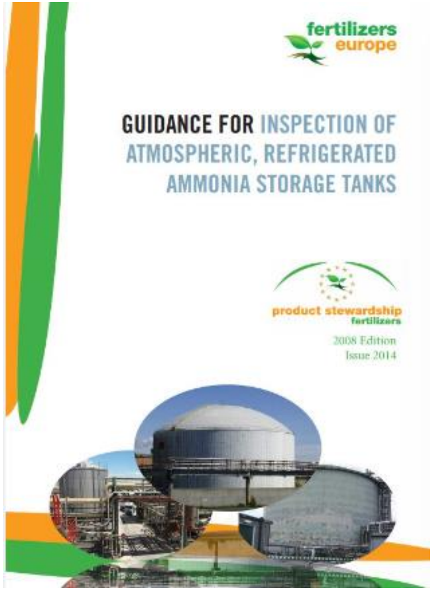
Statement: In-tank pumps are the industry standard for LNG, so why not for ammonia?

Changes in PGS12 | Inspections

In-service inspections

- Using **robot crawlers** in the annular (e.g. Force Technology, Denmark).
- Non-intrusive inspection of the inner tank **6 years and 12 years** after commissioning. Subsequent inspection invtervals are based on **RBI** following the EFMA Guidance.
- (Development of **permanent AET-sensoring** of inner tank is pending).

Courtesy of: FORCE Technology



Changes in PGS12 | Inspections

Additional requirements

- Pipeline **segmentation**; to avoid large quantities LOPC;
- Temperature safeguarding on tank inlet / jetty line; to avoid **thermal overload** of the tank;
- Specific design for **heat exchanger** to avoid leakage of ammonia to the environment;
- Accessible **air-gap foundation**.
- Stainless steel piping.
- No vapors connected during loading, no vapors back to the storage tank (avoid Oxygen in storage tank!)

Courtesy of: Paresa

Global Impact of the new PGS12

Can the new PGS12 be applied globally?

Considerations:

1. PGS12 has been developed specifically for the **Netherlands**,
   where **import** terminals will be built in **densely populated areas**.
2. In other countries local stakeholders and societies could be underrepresented.
3. PGS12 is not an independent document. It is an integral part of other PGS documents such as PGS3, PGS13, PGS29 as well as other Dutch permitting legislation, making it challenging to introduce into other countries.

Will it be a benchmark code for other countries to adopt?

Definitely! It contains throughout BAT technology.
It gives guidance to, and reasoning behind safe tank and terminal design.
It describes scenarios, consequences, objectives and mitigating measures.

Ammonia Codes should be centralised similar to the API and NEN-EN,
and be focused solely on the ammonia industry, with its own standards, materials and procedures.

The upcoming EN-14620 Part 7 will give non-location specific requirements for the design
and construction of tank systems for the storage of liquefied ammonia.

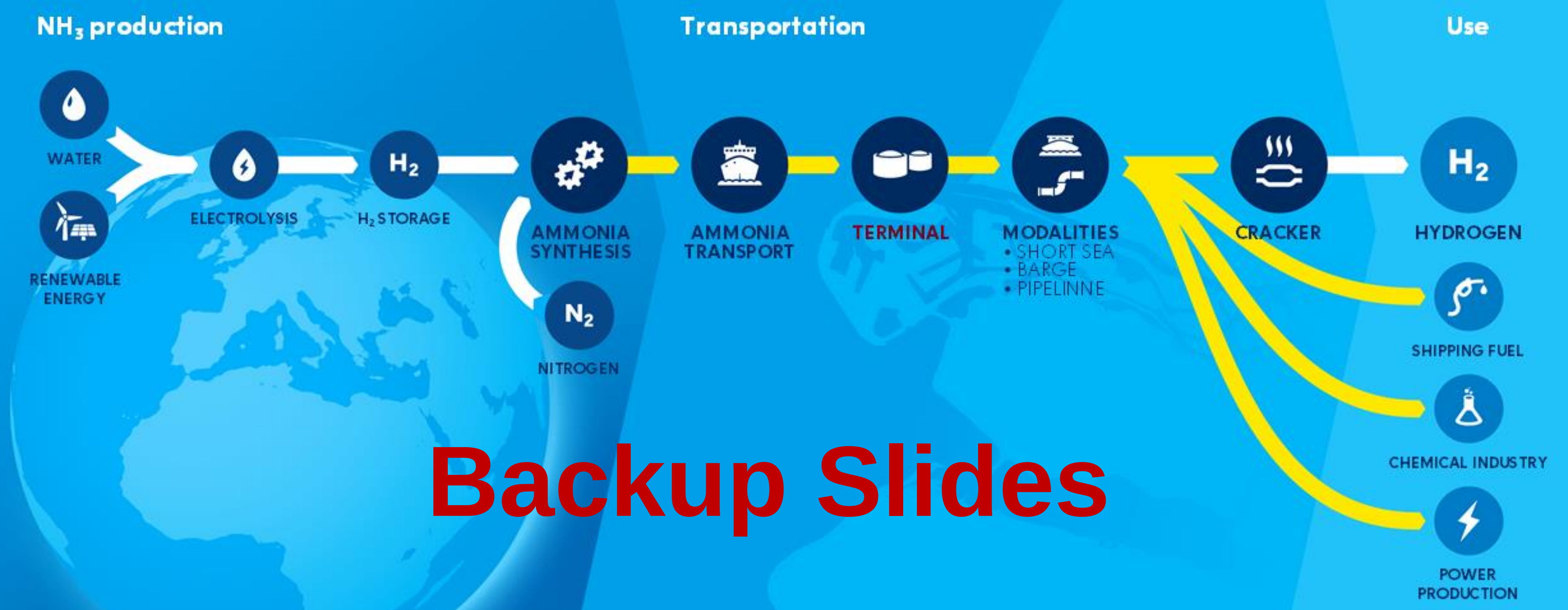
Thank you for your attention

"As engineers and industry leaders, our resolute mission is to develop the ultimate and safest ammonia storage terminals, advancing the energy transition."

Answering your questions today:

George Dodoros	(Business Development Director, Proton Ventures)
Stefano de Cillis	(Chief Technology Officer, Proton Ventures)
Chiel Deij	(Senior Consultant Ammonia, OCI Nitrogen)
Wim Versteele	(Transition Manager, Yara Sluiskil)
Jochem Langeveld	(Senior Project Manager Environmental Permitting, DCMR)
Martin Reuvers	(Senior Engineer, Vopak)

Backup Slides



Backup Slides

International Codes and Standards

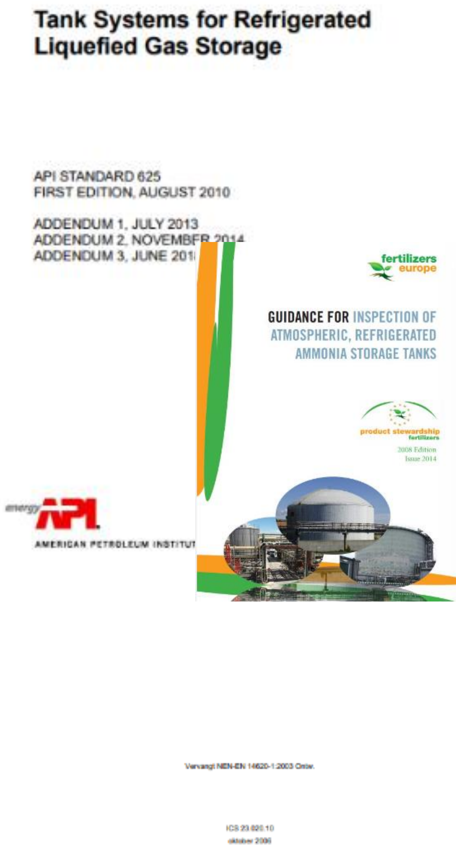
API 620/625 Design and Construction of Large, Welded, Low pressure Storage Tank
- Appendix R: specific requirements for temperatures down to -52,5 °C
- Appendix Q: specific requirements for temperatures down to -167 °C

DIN 4119 and **BS 7777**
- Allow lower thickness for the shell plates
- Higher requirements on the steel quality

EEMUA 147 (1986-2016): Recommendations for refrigerated liquefied gas storage tanks

EN 14620 : applicable as from 2007 in the EU
- Part 1: general
- Part 2: metallic components
- Part 3: concrete components
- Part 4: insulation components
- Part 5: testing, drying, purging and cool-down
- Pending Part 6 (liquid oxygen, liquid nitrogen or liquid argon)
- Pending Part 7 (liquid ammonia, expected 2025)

European Fertilizer Manufacturers Association (EFMA)
- Guidance for inspection of atmospheric, refrigerated ammonia storage tanks (2008 Edition, Issue 2014)
- Until now, this is one of the few documents specifically written for ammonia storage



In-Tank Pumps

Contacted In-Tank Pump manufacturers:

- **Ebara:**
  in operation: 900 m^3/hr
  now available: 1800 m^3/hr

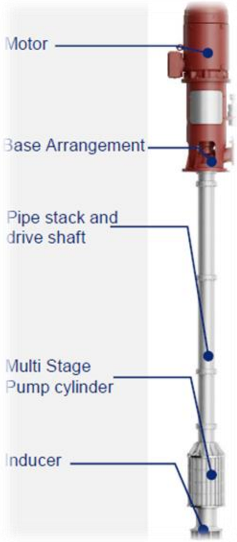
- **Hermetic:**
  up to ±1000 m^3/hr

- **Svanehoj:**
  Long-shaft pump available up to 1000 m^3/hr

- **Nikkiso:**
  Announced their ±1500 m^3/hr ammonia pump at GasTech 2023

Hermetic

Nikkiso



Svanehoj

Ebara

Tank Failure Rates (Netherlands)

Handleiding Risicoberekeningen Bevi versie 4.3 – Module C, 1 januari 2021, pag.44

Steel / steel

Tabel 18 Scenario's voor atmosferische opslagtanks met een beschermend buitenomhulsel

	Frequentie (per jaar)
1. Instantaan falen van primaire container en buitenomhulsel; vrijkomen van de gehele inhoud	5×10^{-7}
2. Instantaan falen van primaire container; vrijkomen van de gehele inhoud in het intacte buitenomhulsel	5×10^{-7}
3. Falen van primaire container en buitenomhulsel; vrijkomen van de gehele inhoud in 10 min. in een continue en constante stroom	5×10^{-7}
4. Falen van primaire container; vrijkomen van de gehele inhoud in 10 min. in een continue en constante stroom in het intacte buitenomhulsel	5×10^{-7}
5. Falen van primaire container; continu vrijkomen uit een gat met een effectieve diameter van 10 mm in het intacte buitenomhulsel	1×10^{-4}

10^{-6}

Concrete / Steel

Tabel 20 Scenario's voor volledig omsloten atmosferische opslagtanks

	Frequentie (per jaar)
1. Instantaan falen van primaire en secundaire container; vrijkomen van de gehele inhoud	1×10^{-8}

Backup Slides | Tank Failure Rates

PGS12

Tank Failure Rates (Belgium)

Failure mode	Failure frequency [/tank year]	
Tank type	FC1	FC2
Primary vessel material (liquid-tight)	Metal	Metal
Material of secondary vessel, incl. roof (liquid- and vapour-tight)	Metal	Concrete
Rupture of the entire tank system releasing 100% of its contents	5.0 10^{-7}	-
"Rupture" of the entire tank system releasing 10% of its contents	-	5.0 10^{-9}
Full release in 10 minutes of entire tank system releasing 100% of its contents	5.0 10^{-7}	-
"Release in 10 minutes" of the entire tank system releasing 10% of its contents		5.0 10^{-9}

FC1: 10^{-6}

FC2: 10^{-8}

Backup Slides | Opportunities

Opportunities or Technology Improvements

1. In-Tank pumps with higher capacity >2500 m^3/hr;

2. In-line water and oxygen analyzers;

3. Permanent AET-sensors on inner tank;

4. Sluice system on top of pump barrels to reduce risk when retracting the pump;

5. Hybrid tanks for LNG and NH_3; Membrane tanks;

6. …