

Ammonia Storage and Handling

From Proven Practices to Future Solutions

Gas Terminals of Tomorrow



Agenda



History



Properties / specifics / design considerations



Regulations and Standards

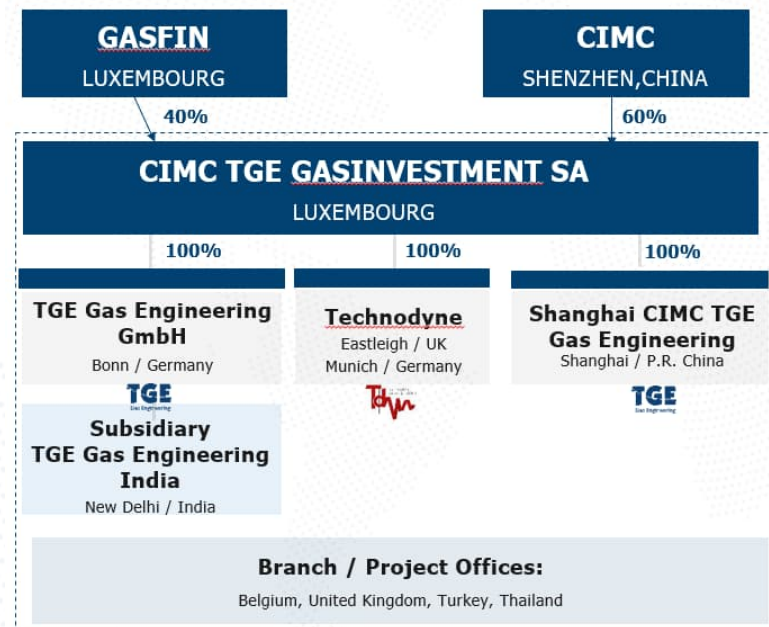


Tank concepts in discussion

History / Who we are



Founded in
1980 in
Bonn,
Germany



Services and Product Lines



Tailored contract modules as clients demand

- Technical and Commercial Feasibility Studies
- Conceptual Design
- Environmental Impact Assessment (EIA) and HAZOP
- Capital Cost (CAPEX) and Operating Cost (OPEX) Estimation
- Capital Investment and Project Financing Services
- Basic Engineering / Front End Engineering Design (FEED)
- Detailed Engineering
- Procurement
- Construction & Supervision Services
- Pre-Commissioning and Commissioning
- Start-Up / Shut Down
- Operation and Maintenance Services
- Life-Cycle Engineering Studies and Plant Life-Cycle Optimization

Terminals
for LNG



Terminals
for Petrochemicals



Logistics & Storage for
Green Energy NH_3/H_2



Logistic Solutions
for CO_2



Terminal & Storage
Retrofit and Upgrade



History of Ammonia Storage Tank Design

History of Ammonia Storage Tank Designs – Single Containment

Pressurised vessels

- Up to 1960s Ammonia was stored mainly at atmospheric temperatures in pressurised vessels (bullets and spheres)
- Bottom penetration surrounded by low bund wall
- Failure of vessel leads to total loss of inventory
- Capacity limitations



History of Ammonia Storage Tank Designs – Single Containment

TGE reference in Mazidagi, Turkey

- Owner ETI BAKIR A.S.
- 2 x 5,480 m³ pressurized spheres
- Design Code ASME VIII Div.2
- Including compression system, flares, send-out pumps
- EPC for spheres
- completed in 2018
- Pumps installed external
- Multistage canned motor pump



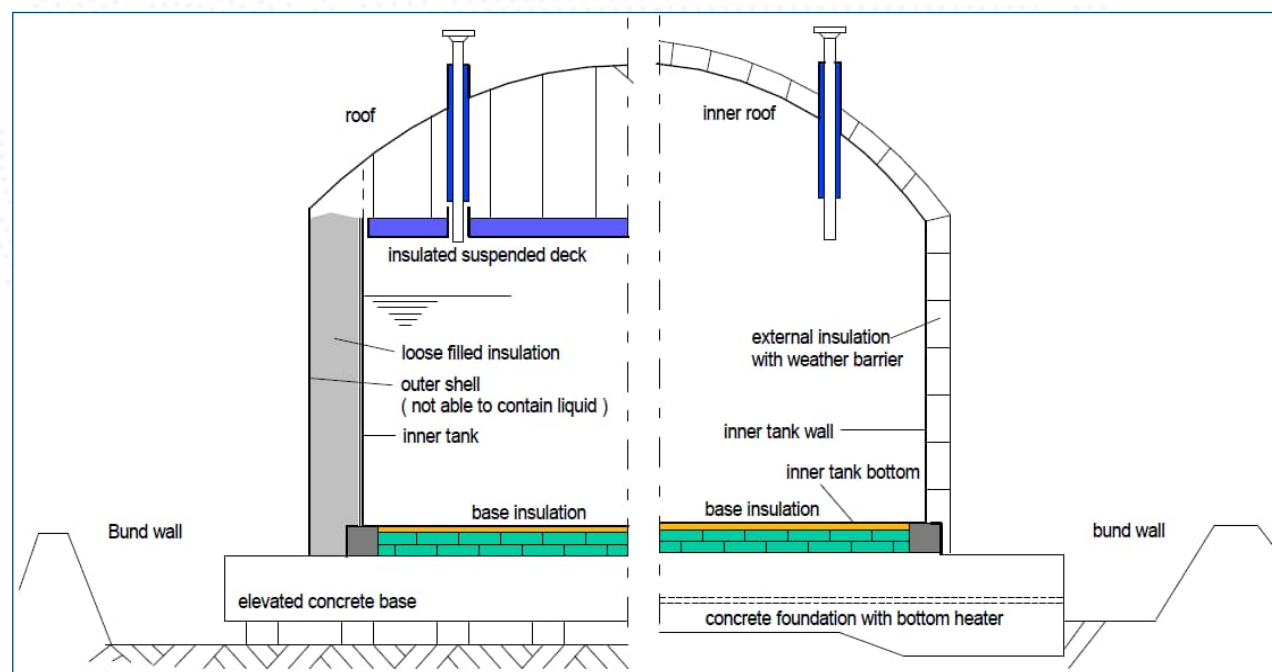
History of Ammonia Storage Tank Designs – Single Containment

Refrigerated Tanks

- Refrigerated tanks were developed to increase storage capacity starting in the 1960s
- Ammonia is stored close to atmospheric pressure at $-33\text{ }^{\circ}\text{C}$

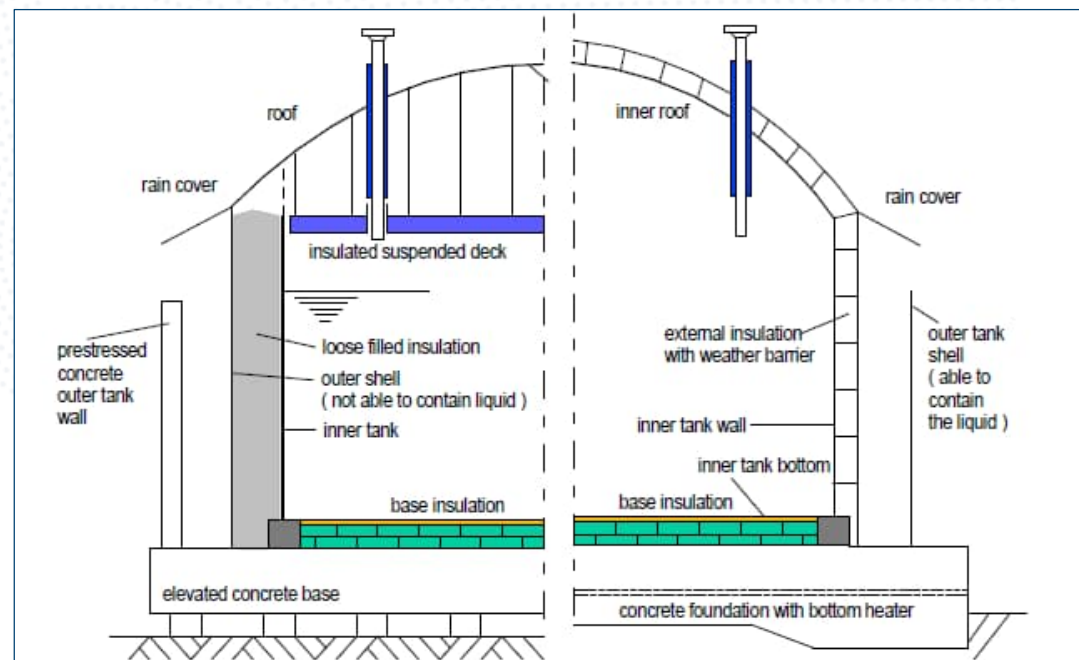
Single Containment

- One container to store the liquid / vapor product
- Bund wall surrounding the tank
- Failure of container leads to total loss of inventory which is collected within the bund wall area
- Tank bottom /side penetration to supply external pumps



History of Ammonia Storage Tank Designs – Double Containment

- Concrete or steel outer container which can contain the liquid in case of an inner tank failure
- Outer tank does not contain vapor. Failure of inner tank releases vapor cloud to atmosphere
- Tank bottom /side penetration to supply external pumps
- Additional possibility: double dome design



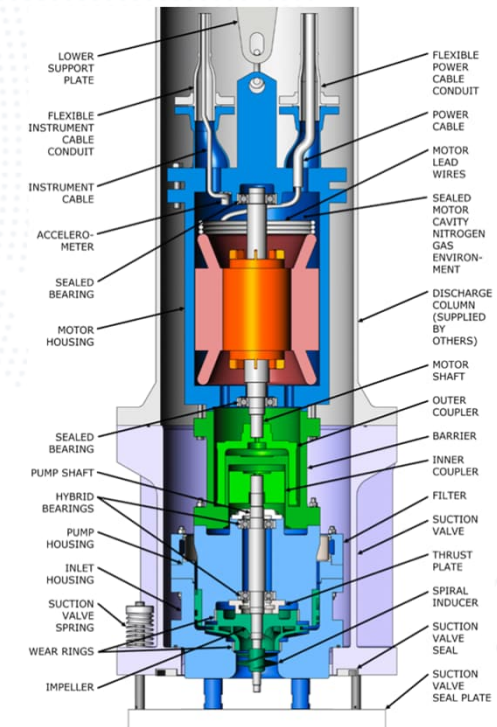
History of Ammonia Storage Tank Designs – Double Containment

TGE reference in Mailiao, Taiwan

- Owner Formosa Petrochemical Corporation
- 2 x 30,000 m³ Double Dome Tanks
 - Double dome tank with external breather tank
 - Annular space purged with nitrogen
 - Perlite insulation in annular space
- Design Code API 620
- Including ship unloading, sendout system and BOG compression package.
- EPC project completed in 1998
- In-tank pumps (prototype development by Ebara/TGE)
 - Sealed motor submerged pump with magnetic coupling
 - Copper containing parts are isolated and pressurized with nitrogen



a member of the CIMC group

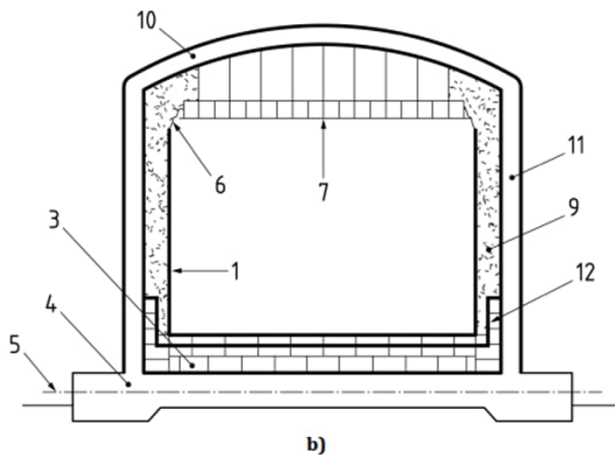
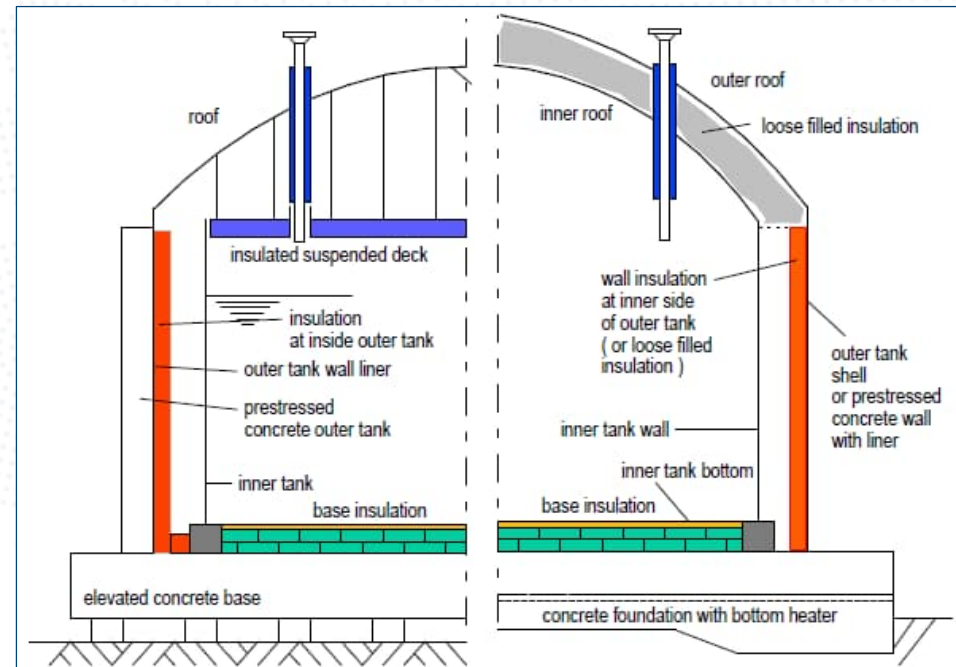


<https://www.elliott-turbo.com/industry-sustainability>

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History of Ammonia Storage Tank Designs – Full containment

- Outer container designed to retain liquid and vapor in case of an inner tank failure
- Bottom penetration for external pumps, but with actuated valves between tanks for isolation
- Failure of inner tank entirely contained with controlled vapor release only



Key

- | | | | |
|---|------------------------------------|----|--|
| 1 | primary liquid container (steel) | 7 | suspended roof (insulated) |
| 2 | secondary liquid container (steel) | 8 | roof (carbon steel) |
| 3 | load bearing insulation (bottom) | 9 | loose fill insulation |
| 4 | Foundation | 10 | concrete roof |
| 5 | foundation heating system | 11 | pre-stressed concrete secondary liquid container |
| 6 | flexible insulating seal | 12 | TPS system (if applicable) |

History of Ammonia Storage Tank Designs – Full Containment

TGE reference in Samsun Turkey

- Owner Toros Tarim Sanayi Ve Ticaret A.S.
- 15,000 MT Steel-steel Full Containment Tank
- External insulation PUF
- Design Code API 620
- External canned motor pumps (supplier Hermetic)
- Including ship unloading, sendout system and BOG compression package.
- EP+CS project completed in 2013
- Extension in 2021 to include booster pumps and sendout heater system with glycol water package



History of Ammonia Storage Tank Designs – Overview

- Several 100 ammonia tanks have been built and operated worldwide
- Typically tank sizes small to mid scale (20.000 m³ to 50.000 m³)
- Most tanks with bottom/side outlet and external pumps
- Development of tank concepts similar to other industries (LNG, petrochemical), difference is that in-tank pumps are more challenging due to properties of ammonia
- Transportation by pipeline and ship is common practice (approx. 170 converted vessels and 200 ports worldwide have infrastructure available)



Extensive experience mainly in the fertilizer and refrigeration industry

Design Considerations Ammonia

Design considerations: Toxicity & Environmental impact

- Extremely corrosive to human tissues with low toxic exposure limits
 - F&G systems with automatic activation of mitigation systems
 - Safety showers at loading areas
 - Implementation of safe havens into the design
 - Full PPE and spillage kits available at common release locations (loading bays)
- Environmental concerns - Toxicity & Eutrophication
 - Design of impounding systems at jetties
 - Segregation of stormwater drainage systems from spill collection systems
 - Treatment of collected spillages



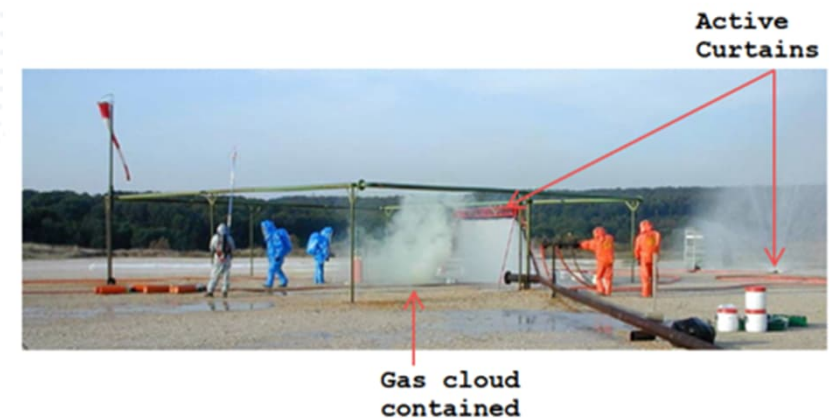
Design considerations: Dispersion and hygroscopic nature

- Lighter-than-air ammonia gas binds readily with water vapor forming ammonia hydroxide
- Resulting in heavier-than-air, visible gas clouds that are very corrosive to plant and people.



Images from "A Guide to Storage Tanks & Equipment", Gardner & Long, 2004

- Hygroscopic nature – basis for release management
 - Water curtains – stop gas cloud migration and absorbs ammonia
 - Water monitors – Used for quick dilution of corrosive ammonium hydroxide solution
 - Water scrubbers – used as part of the no-flaring concept (No NOx, but reversible reaction)



Hald, K. et al "Heavy gas dispersion by water spray curtains: A research methodology" Journal of Loss Prevention in the Process Industries, vol. 18, no. 4–6, 2005

Design considerations: Chemical compatibility

- Ammonia is corrosive
 - Dissolves copper and zinc
 - Severely corrosive to brass and bronze
 - Not compatible with nitrile, natural rubber and some plastics

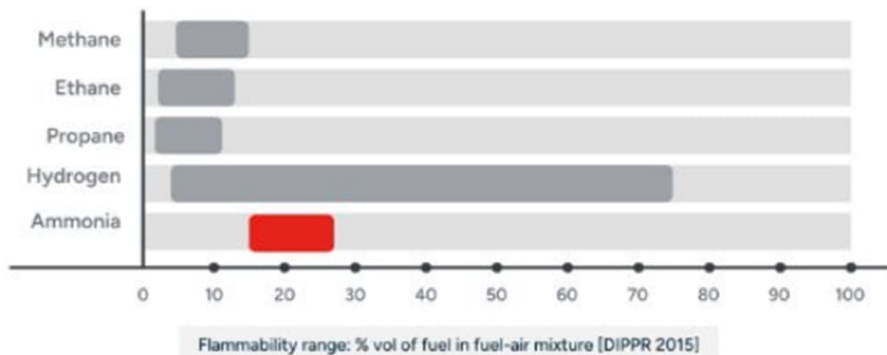
This affects the selection of:

- Tank insulation materials: typical tank insulation materials e.g. PIR, PUF not compatible
- Selection of sealing material (O-rings, gaskets)
- Electrical components: one reason in-tank pumps design is challenging
- Firefighting equipment
- PPE



Design considerations: ATEX & Flaring

- Ammonia has a low risk of fire and explosion
- ATEX ratings are critical in enclosed spaces
- Flaring requires key design changes compared to hydrocarbons
 - Toxic dispersion – elevation
 - Radiation is less of a concern
 - Assist gas is often required to keep flame stable
 - Large diameter flares – gas velocity < flame front velocity



<https://www.gexcon.com/resources/blog/ammonia-hazards/>



<https://delta-em.eu/wp-content/uploads/2017/01/15.jpg>

TGE
Gas Engineering



<https://protonventures.com/news/health-safety-and-environment-as-part-of-the-proton-ventures-ammonia-value-chain-design/>

Design considerations: SCC

- Stress Corrosion Cracking (SCC) has in the past been predominantly a concern for pressurized storage tanks
- Few documented cases in cylindric storage tanks



https://ramirezycobos.es/galerias/fotos/casos_practicos/iso45001_57.png



Design Considerations: SCC Summary

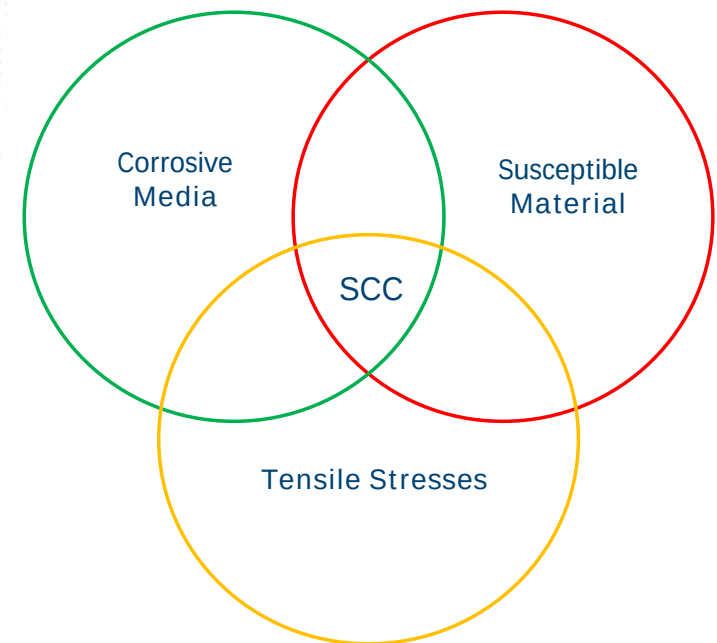
- Oxygen is main driver of SCC
- Water acts as inhibitor
- Occurrence mainly in regions with high stresses
- Commissioning and re-commissioning (inspection) most critical phase



SCC cannot be disregarded in refrigerated storage, but is manageable



Tank inspections more common in Ammonia storage tanks in comparison to other refrigerated tanks



New Design Considerations

- Site placement
 - Vicinity to hydrogen plants and other petrochemical storage
 - Big industrial ports close to urban areas
- Increasing transport and storage capacities
 - Tank capacity $\geq 80.000 \text{ m}^3$
 - Larger transfer rates
- New industries sectors – new to operators
 - Knowledge of liquefied gases, but not Ammonia
- Increasing safety awareness
- New technologies:
 - Availability of in-tank pumps
 - In-service inspection (Robotic, Acoustic emission monitoring)



- Overpressure scenario, concrete outer wall
- Development of new standards / guidelines
- Preference for full containment with in-tank pumps

Regulations and Standards

- EN 14620 part 1-6
- API 620/625

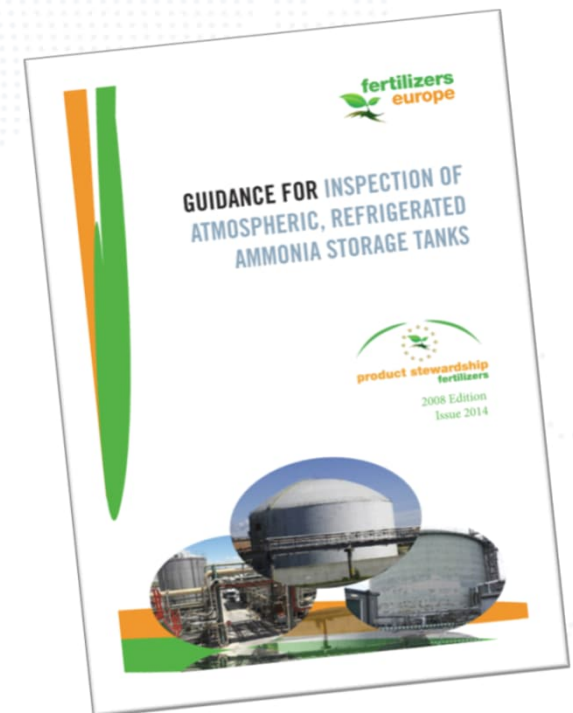


Cover refrigerated storage tanks in general including Ammonia

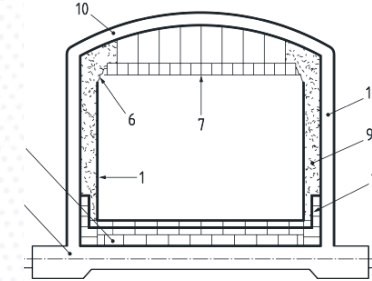
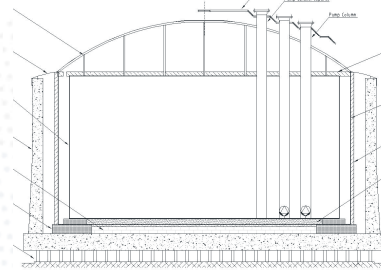
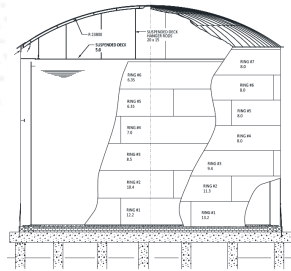
- Fertilizer Europe Guidance / BAT
- PGS 12 – Dutch legislation
 - Risk based approach specifically developed for the Netherlands
 - Can be used as guidance in other countries as hazards are the same, but risk-based outcome may differ



Specific to Ammonia



Tank concepts in discussion



	Steel/Steel	PGS-12	Steel/Concrete
Complexity	Most simple	Most complex	More complex
Structural Integrity	Lowest	Concrete wall	Highest
Roof loads	Critical	Critical	Less concern
In-tank pumps	One option	Required	Required
In service inspection	+	+	±
Insulation system	Proven	Proven	Under development

Summary – Key Takeaways

- 1 Proven practice – applied to new scale, new industries and new site locations
- 2 Ammonia properties – specific challenges to design
- 3 Regulations – a solid framework exists, but updates to reflect changing market
- 4 New developments – allow and require to rethink the design



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