PGS 12 AMMONIA

New BAT document on ammonia storage
in the Netherlands

milieudienst
Rijnmond

PERSONAL INTRODUCTION

JOCHEM
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SENIOR PROJECT MANAGER ENVIRONMENTAL PERMITTING

Working at the DCMR Environmental Protection Agency for the Port of Rotterdam Area and Port of Vlissingen.

- MSc Chemical Engineering
- Member of PGS 12 Working group
- 20 years of experience in environmental permitting

AGENDA

DCMR milieudienst Rijnmond

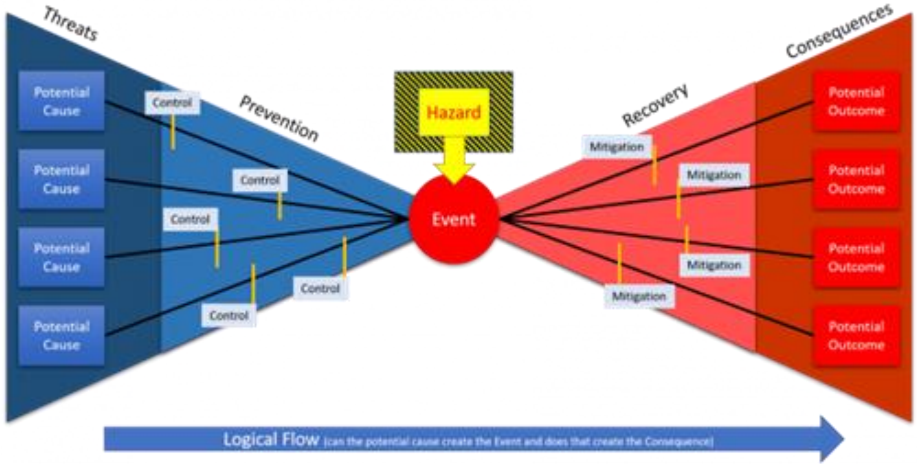
- PGS 12 timeline & proces
- Phasing PGS12
- Changes in storage concept
- BAT cold ammonia storage
- Pump configuration
- In-Service Inspections
- BAT warm ammonia storage
- PGS 12 in Permits & Opportunity's for development

INTRODUCTION INTO PGS 12

PGS: PUBLICATION SERIES ON HAZARDOUS SUBSTANCES

About PGS 12:

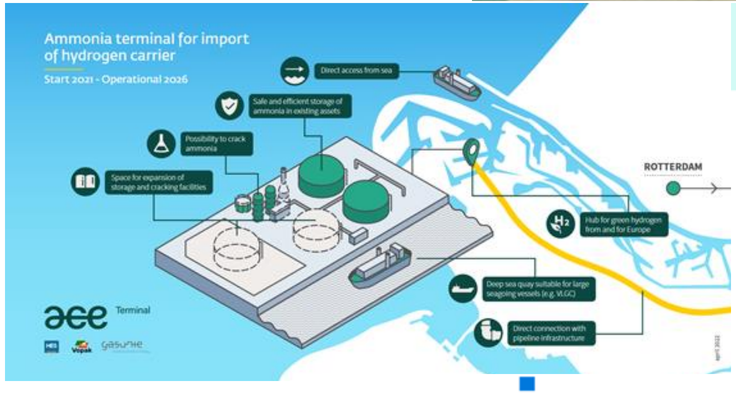
- **Ammonia specific** Storage and Handling Guidelines
- Developed and maintained by the **NEN institute** (Dutch Normalisation Institute)
- In the **Netherlands** it is a legal requirement
- Describes **Best Available Techniques** (BAT)
- Uses the **bow-tie** risk management methodology: scenarios, objectives and mitigating measures
- An imposed mititgating measures may be replaced with another measure, when this results in the same risk level (NL: **Gelijkwaardigheidsbeginsel**, ENG **Principle of equivalance**)



INCENTIVES FOR REVISION PGS 12

VARIOUS AMMONIA STORAGE INITIATIVES

- Multiple initiatives for Ammonia storage and handling
- Last version PGS 12 from 2014
- New and bigger Storage Tanks 50/60 kton instead of 20 kton excisting
- Need for BAT describing the new reality of ammonia import terminals
- Industry support for revision



April 6, 2023

Advario enters the Port of Rotterdam to develop a new, future-focused energy storage terminal

Joint Press Release
September 12, 2022

Uniper and Vesta to cooperate on developing a green Ammonia terminal site in the Netherlands

- **Important step towards Uniper's goal to achieve carbon neutrality**
- **Already existing terminal capacity in Vlissingen to be refurbished and expanded**
- **Green Ammonia hub to enable and boost future hydrogen capability and availability**
- **Further strengthening Europe's long-term sustainable security of supply**

REVISION PROCESS INVOLVED PARTIES

DCMR milieudienst Rijnmond

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.

TIMELINE PGS 12

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End 2022
START AMMONIA TEAM
Various Ammonia Project are announced in Rotterdam and Vlissingen

April 2023
TOR PGS12 FASE 1&2
Cryogenic storage ammonia

Nov 2023
DRAFT VERSION FASE 1
Public consultation of fase 1 PGS 12 on the new build of cryogenic Ammonia storage tanks

June 2024
TOR PGS12 FASE 3
Pressurized Storage of Ammonia

July 2024
FINAL VERSION PGS12 FASE 1
New Build of Cryogenic Ammonia Storage tanks

Dec 2024
DRAFT PGS12 FASE 2&3
Pressurized and excisting Cryogenic storage ammonia

Feb 2025
PUBLIC CONSULTATION FASE 2&3
Pressurized and excisting Cryogenic storage ammonia

Today

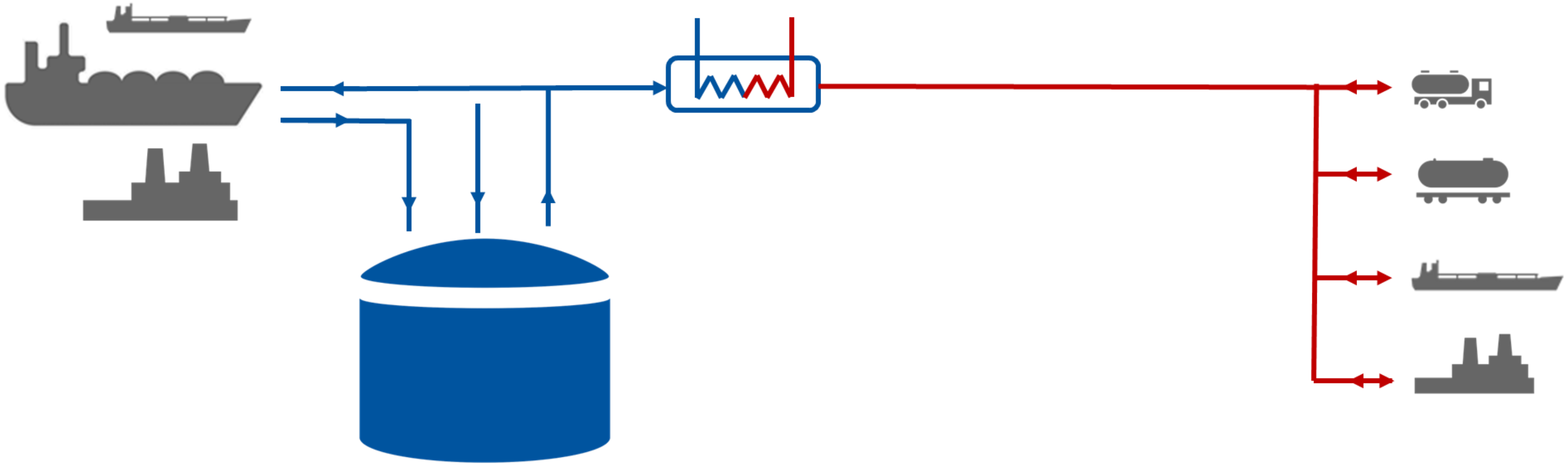
June 2025
FINAL VERSION PGS12
Complete new PGS12

PHASING PGS 12

Phase 1: New terminals & refrigerated tanks

Phase 2: Existing terminals & tanks

Phase 3: Pressurised storage of ‘warm ammonia’



PHASING PGS 12

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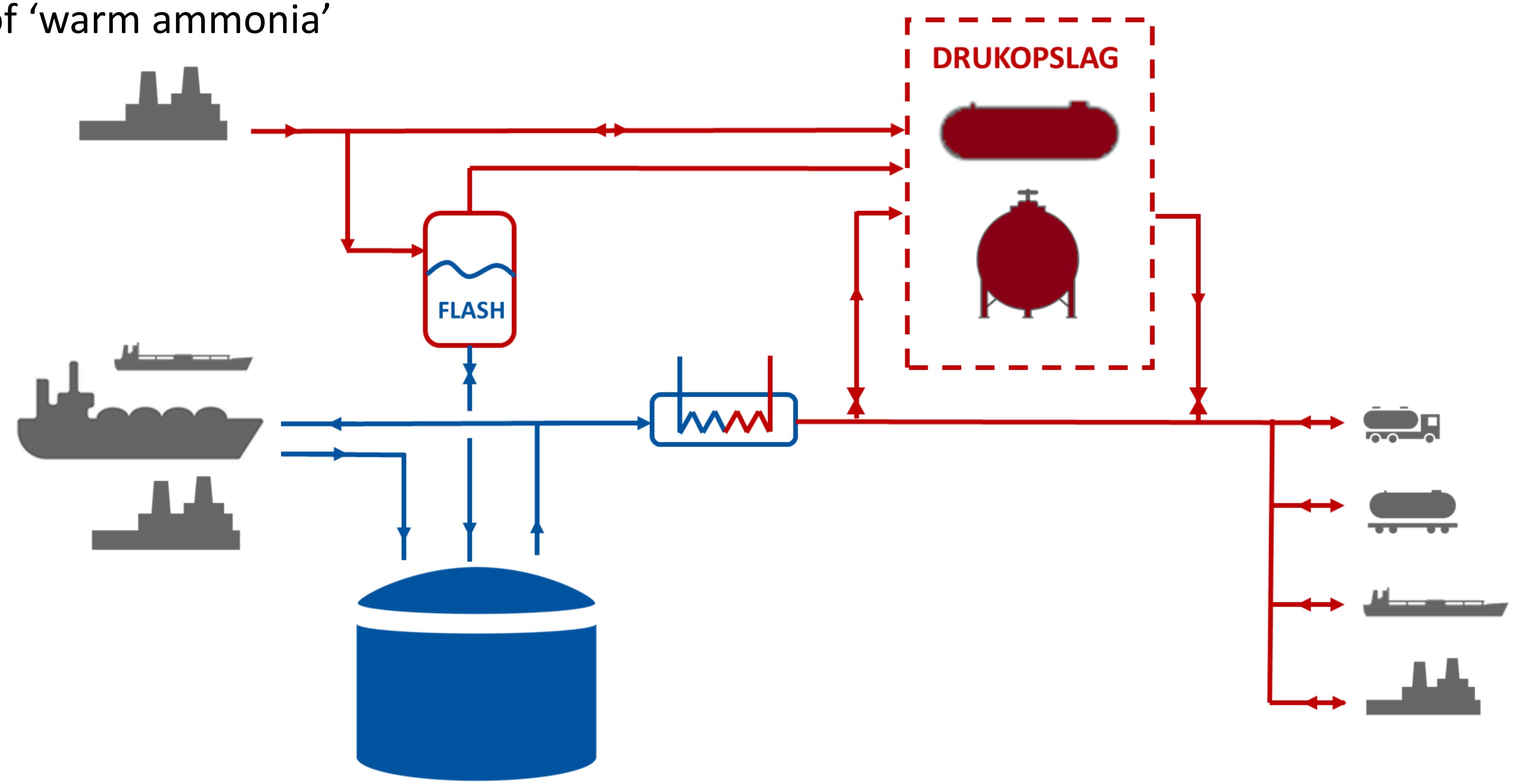
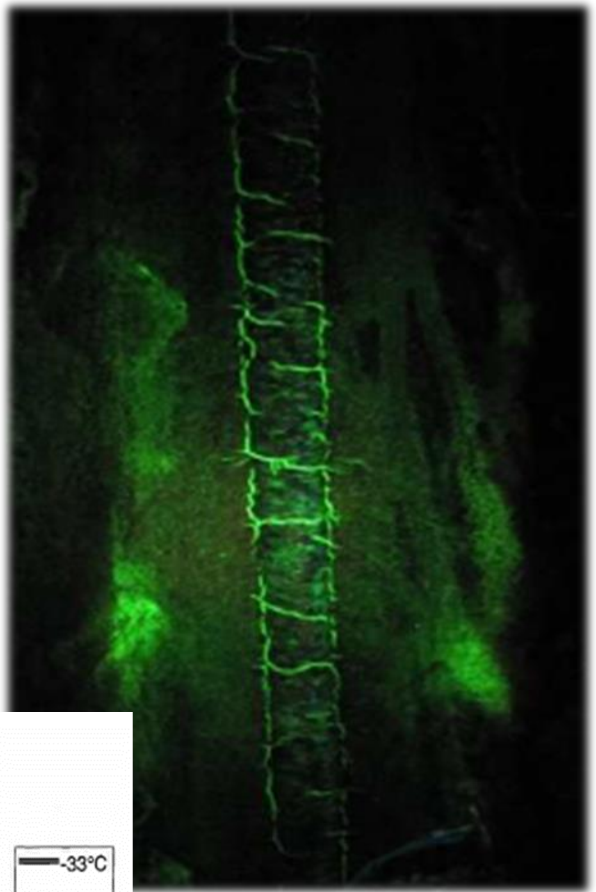
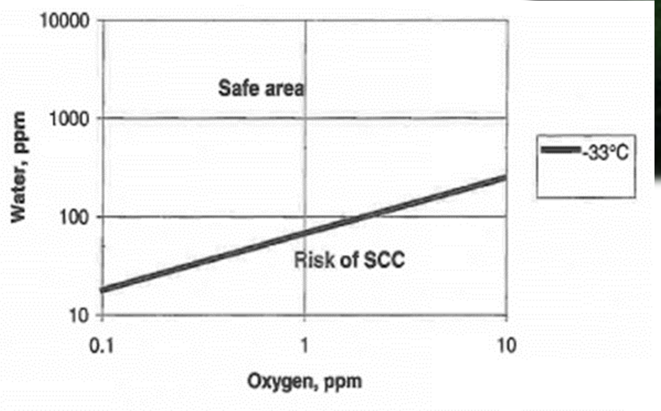


STRESS CORROSION CRACKING

STRESS CORSOSION CRACKING (SCC)



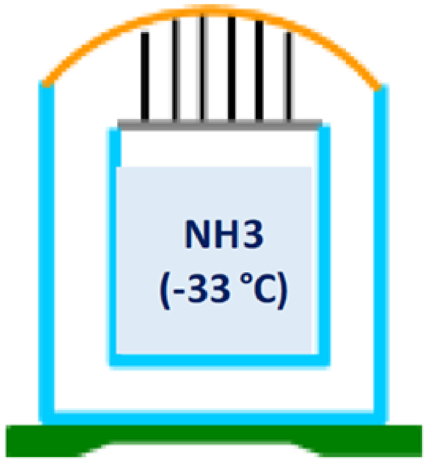
- Stress corrosion cracking in ammonia involves **crack initiation** by active dissolution of small amounts of iron along slip steps in small local areas where bare metal is exposed by disturbance of the oxide layer **due to local plastic deformation**
- Cracking usually occurs only **in the welds**, 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.

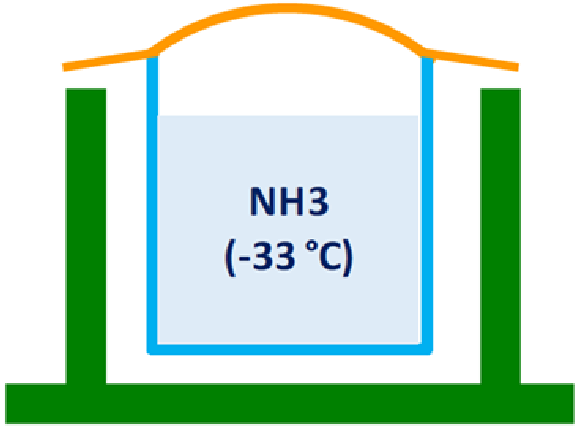


CHANGES IN STORAGE CONCEPT

STORAGE CONCEPTS FOR REFRIGERATED GAS (SIMPLE VERSION)

DOUBLE CONTAINMENT (DC) VERSUS FULL CONTAINMENT (FC)





FULL CONTAINMENT

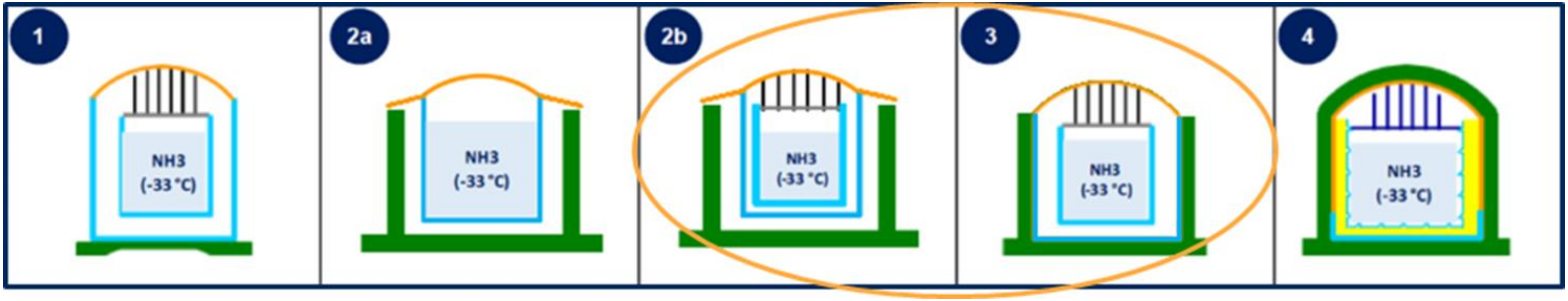
'Cup in tank'
Vapours are contained when primary containment fails.

DOUBLE CONTAINMENT

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

CHANGES IN STORAGE CONCEPT

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 external impact.

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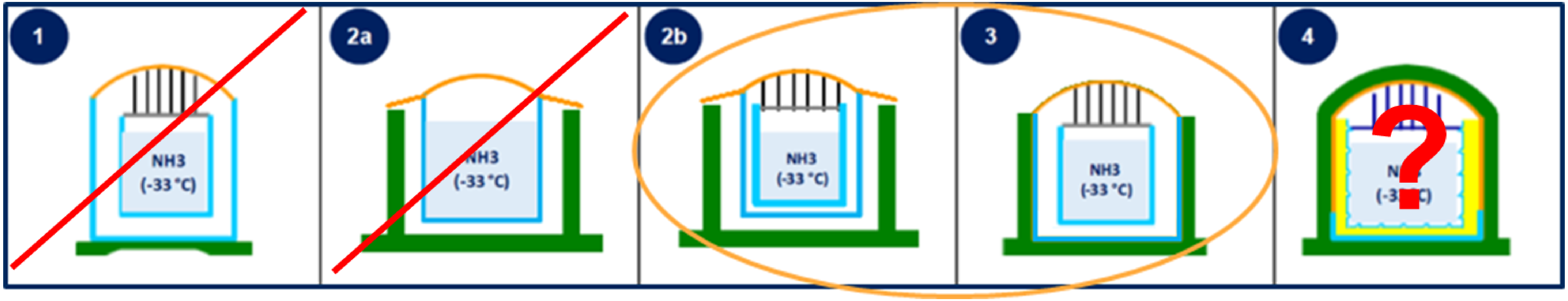


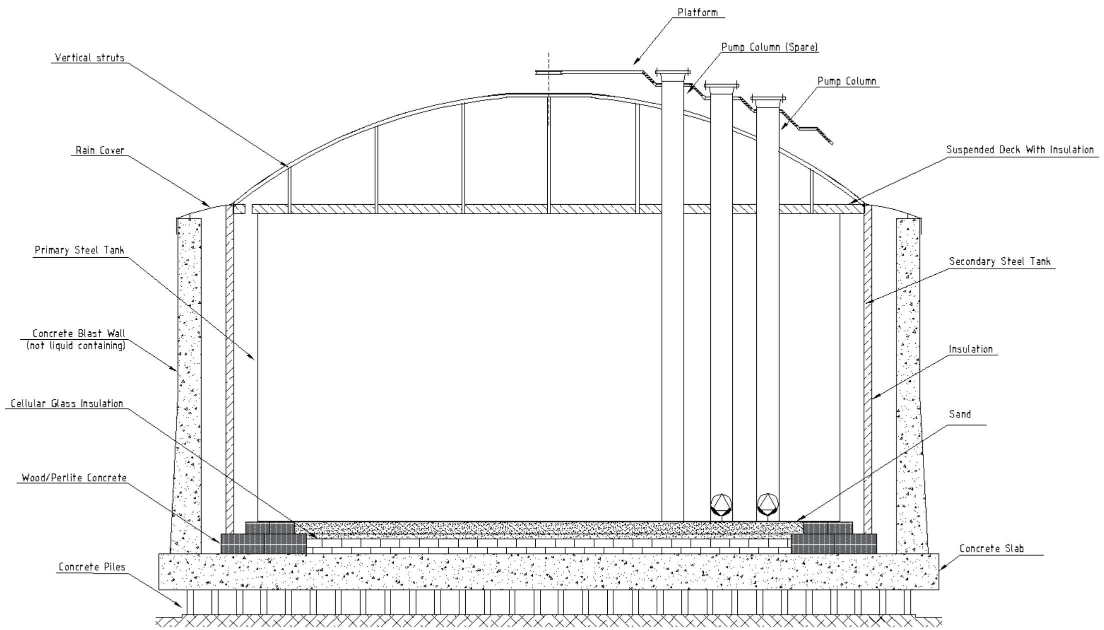
CONCLUSION

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

BAT FOR COLD AMMONIA

AMMONIA STORAGE

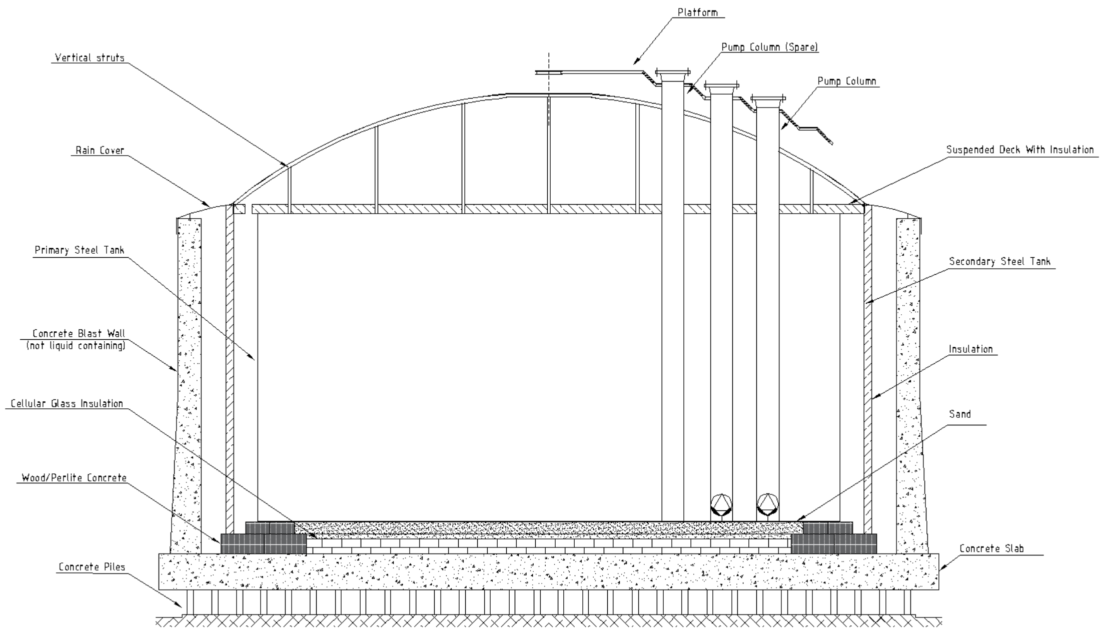
1. Min. expected lifetime 50 years
2. Full Containment Tank (Failure Rate 10^{-8}
3. Concrete protection wall against externa
   impact
   - Explosion
   - Small air plane
   - Heat load
4. No wall or bottom penetrations
5. Internal pumps
6. Air-gap fundation
7. No insulation in annular space



BAT FOR COLD AMMONIA

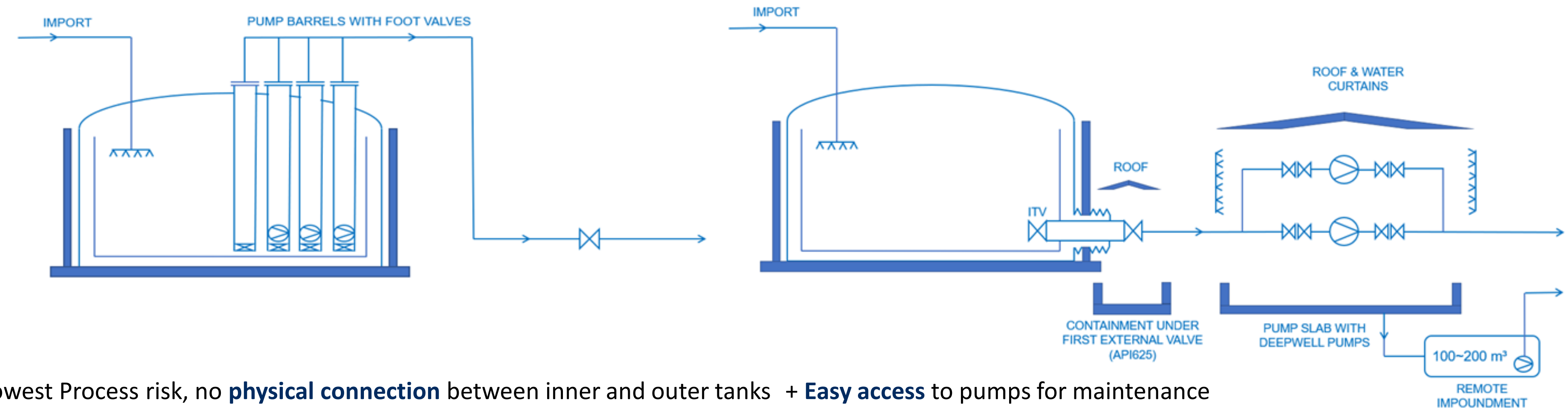
TO REDUCES THE RISK ON SCC

- Avoid exposure to Oxgen
- No Return Vapours to tank or BOG
- Focus on In-service inspections
- Avoid Out of service inspections
- No isolation in annulaire space



PUMP CONFIGURATION

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

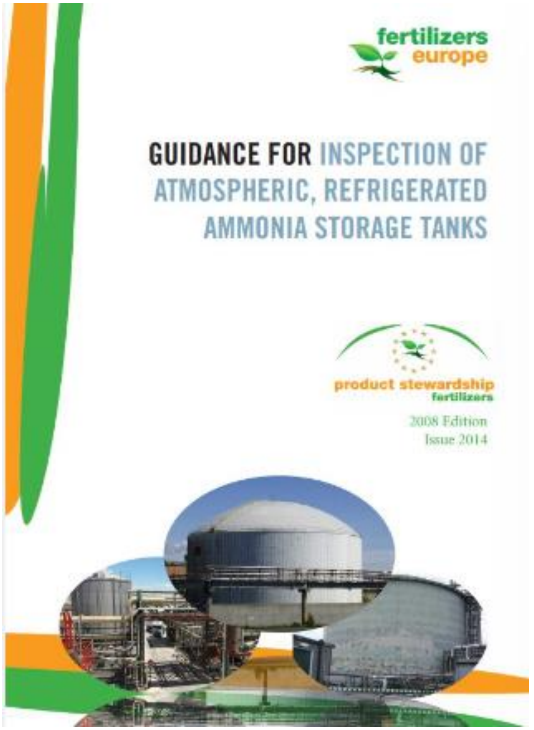
- Increased **process risk**
- Thermal overload can lead to **loss of both containments** (Rostock incident 2005)
- **Additional equipment** (ITV & expansion joint) is needed, decreasing MTBF
- Design of the pump pit includes **significant civil and mechanical works**.
- Does not follow the **design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

IN-TANK PUMPS ARE INDUSTRIAL STANDARD FOR LNG, WHY NOT FOR AMMONIA

IN-SERVICE INSPECTIONS

WHY IN-SERVICE INSPECTIONS

- Disadvantages of Out of service inspections
  - Warming Up and cooling down the tank introduces the risk off stress in the material of the tank
  - Introduction of oxygen atmosphere
  - Incidents during commissioning en decommissioning Rostock incident 2005
  - Operational down time of several weeks
  - Need of a spare tank to stay operational
  - RBI inspection method following EFMA Guidance
  - Inspection intervals every 6 or 12 years

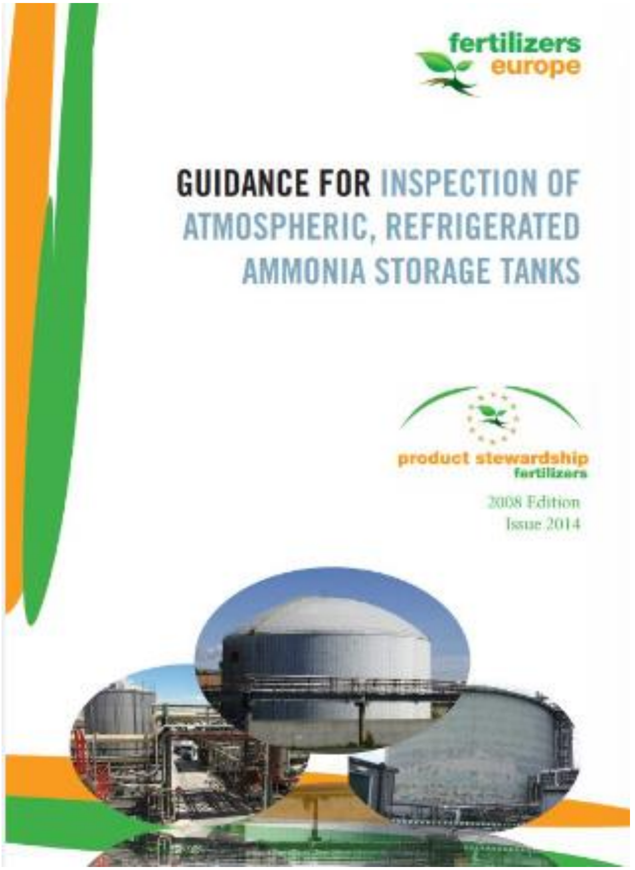


IN-SERVICE INSPECTIONS

IN-SERVICE INSPECTIONS

- Using robot crawlers in the annular (e.g. Force Technology, Denmark).
- Prepare the design of the tank for in-service inspection
  - Accessible annular space
  - Annular space free from insulation
- Non-intrusive inspection of the inner tank 6 years and 12 years after commissioning. Subsequent inspection intervals are based on RBI following the EFMA Guidance.
- (Development of permanent AET-sensoring of inner tank is pending).

Courtesy of: FORCE Technology



COFFEE BREAK 10 MIN MAX

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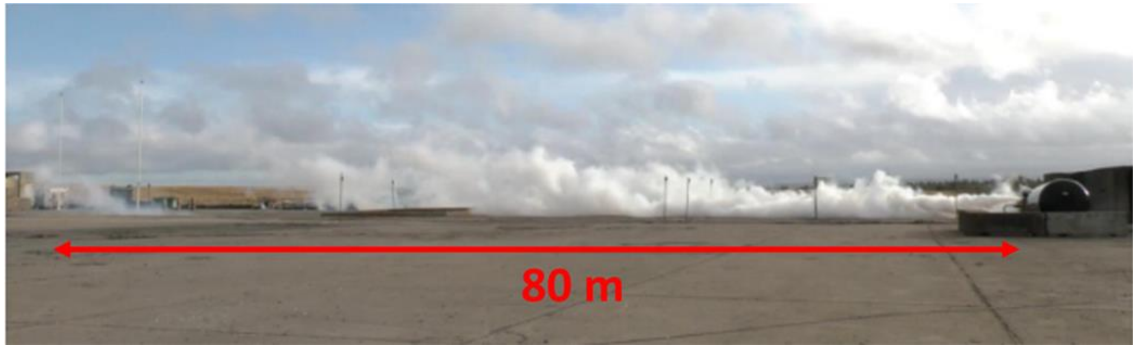
WARM AND COLD AMMONIA

Storage (kton)	Temp (°C)	Max pool (m^2)	Toxic effect zone (m)	1% letal F1,5 (m)	Failure frequency
60	-33,4	100.000	4950	4250	$1\ 10^{-8}$
50	-33,4	100.000	4850	4150	$1\ 10^{-8}$
30	-33,4	100.000	4750	3950	$1\ 10^{-8}$
15	-33,4	100.000	4700	3700	$1\ 10^{-8}$
4	9,8	1.000	5300	4400	$1\ 10^{-6}$
2	9,8	1.000	4300	3250	$1\ 10^{-6}$
1,2	9,8	1.000	3280	3030	$1\ 10^{-6}$
1	9,8	1.000	3000	2300	$1\ 10^{-6}$
0,8	9,8	1.000	2710	2540	$1\ 10^{-6}$

BAT FOR WARM AMMONIA

AMMONIA STORAGE UNDER PRESSURE

- Higher temperature; higher risk on SCC
- Additional risk of Jetspray
- Skirt around storage tank to reduce jetspray effects



Red Squirrel Tests: Air Products ammonia field experiments

Yara, Le Havre

BAT FOR WARM AMMONIA

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AMMONIA STORAGE UNDER PRESSURE

- Monitoring on temperature and oxygen level in the tank
- Safe by design:
  - Design pressure 20 bar
  - Full vacuüm
  - Design temperature min -33 °C max 50 °C
  - Max volume 1000 ton p/tank
  - Two storage tank per Seveso facility (2*1000 ton NH_3)

Pressure/ Temperature	**Condition Gas phase**				**Pressure/ Temperature**
	No discharge from gas phase, for example only liquid bottom discharge	Frequent discharge from gas phase	Continues discharge from gas phase		
>6 barg >13,87 °C	**1**	**4**	**7**	High NH_3 temperature leads to condensation (water free) on the inside of the pressure storage. High risk of SCC.	>6 barg >13,87 °C
3-6 barg -1,79-13,87 °C	**2**	**5**	**8**	Medium NH_3 temperature leads to condensation (water free) on the inside of the pressure storage. Medium risk of SCC.	3-6 barg -1,79-13,87 °C
0-3 barg -33,4 - -1,79 °C	**3**	**6**	**9**	Low NH_3 temperature leads to condensation on the outside of the pressure storage. Low risk of SCC.	0-3 barg -33,4- -1,79 °C
	Potential O_2 accumulation in gas phase. High risk on SCC	Potential O_2 frequently discharged. Medium risk on SCC	Potential O_2 directly discharged. Low risk on SCC	**Risk**	

PGS12 IN PERMITS

- OCI expansion with an 60 kton ammonia tank

HOST PROJECT IN ESBJERG

- Ammonia production and storage 2*15 kton Ammonia
- Contacts with Danish Government
- Exchange on info about PGS12
- 7 principles on BAT for Ammonia storage implemented

B Indretning og drift

Virksomheden må være i drift døgnet rundt alle årets dage.

Ammoniaktanke

I forbindelse med sagsbehandlingen af HØST-projektet har Miljøstyrelsen været i kontakt med de norske og hollandske myndigheder i forhold til erfaringsudveksling vedr. regulering af større ammoniaktanke. De hollandske myndigheder er pt. i gang med en opdatering af deres guideline i forhold BAT for indretning af store tankoplag af ammoniak ved atmosfærisk tryk. Guidelinen er baseret på den nyeste viden på området.

Miljøstyrelsen har i forbindelse med ansøgningsprocessen bedt CIP redegøre for designet af ammoniaktankene i HØST-projektet i relation til udkastet til den hollandske guideline for Best Practice for opbygning af ammoniak-tanke (afsnit 7.6.1.1) i forhold til miljø og risiko/sikkerhed.

CIP har oplyst, at den producerede ammoniak vil blive opbevaret i to tanke hver indeholdende 15.000 tons ammoniak (2 x 22.500 m³), hvor det opbevares på væskeform ved ca. -33 °C ved atmosfærisk tryk. Ammoniaktankene er udført som dobbelttanke med inder- og ydertanke. Mellemrummet mellem de to tanke vil rumme ammoniakgas og er sensorovervåget, således at en potentiel lækage af flydende ammoniak fra indertanken til hulrummet detekteres.

Herudover har CIP bekræftet, at de overordnede retningslinjer i guidelinen kan imødekommes og vil blive fulgt i detaljeret design af ammoniaktankene.

Guidelinens overordnede retningslinjer er:

1. Opbevaringstankens levetid mindst 50 år (Storage tank lifespan at least 50 years)

Vurder

2. Fuld opbevaringstank til indeslutning (Full containment storage tank)
3. Opbevaringstank med en beton ydervæg (Storage tank with a concrete outer wall)
4. Ingen gennemtrængninger gennem væg og bund af tank (No penetrations through wall and bottom)
5. Interne pumper (Internal pumps)
6. Fundament på bunker (Foundation on piles)
7. Isolering helst ikke i det ringformede rum mellem indre og ydre tank (Insulation preferably not in the annular space between inner and outer tank)

enst
ond

OPPORTUNITY'S FOR DEVELOPMENT

- In-Tank pumps with higher capacity >2500 m^3/hr
- In-line water and oxygen analyzers for liquid ammonia
- Permanent AET sensors system on the inner tank
- Sluice system on top of the pump barrels to reduce risks when retracting In-Tank pumps
- In-service inspection of the inner tank from the liquid ammonia phase

QUESTIONS?

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DCMR milieudienst Rijnmond

IN-TANK PUMPS

IN-TANK PUMPS

- 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

Hermetic

Nikkiso

Svanehoj

Ebara

DUTCH VISION ON HYDROGEN CARRIERS

GENERAL

- Role for LH2 and LOHC’s
- Also for MeOH en syntetic CH4 (sustainable CO2)
- Short term: stimulation of hyrogen carriers
- Mid term: more selection on specific carriers depending on developments

SPECIAL CHAPTER ON AMMONIA

- Ammonia seen as a first mover
- Ammonia use or cracking in Sea Ports and as far as possible from Urban areas
- Transport by pipeline or schip
- Transport by train and road is not preferred, only back up solution and only via Betuweroute

TANK FAILURE RATES

TANK FAILURE RATES FLEMISCH GOVERNMENT

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		$5.0\ 10^{-9}$

10^{-6}

10^{-8}

TANK FAILURE RATES

TANK FAILURE RATES NETHERLANDS

REKENVOORSCHRIFT OMGEVINGSVEILIGHEID MODULE I BASISVOORSCHRIFTEN JAN 2025 PARAGRAAF 3.6.3

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}

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}

AMMONIA TEAM

DCMR

Every two weeks an update on developments in general on Ammonia and the different projects.

- Permitting officers
- External Safety experts
- Environmental Impact assessment experts
- Legal advisors
- Inspection officers

FIRE BRIGADE

- VRR Rotterdam
- VRZ Zeeland