Hydrogen production through electrolysis – process safety

Nationaal Congres Waterstofveiligheid

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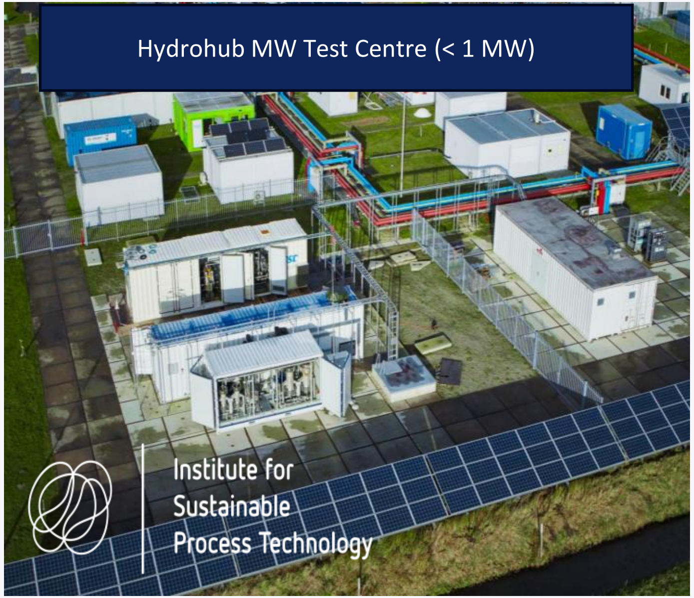
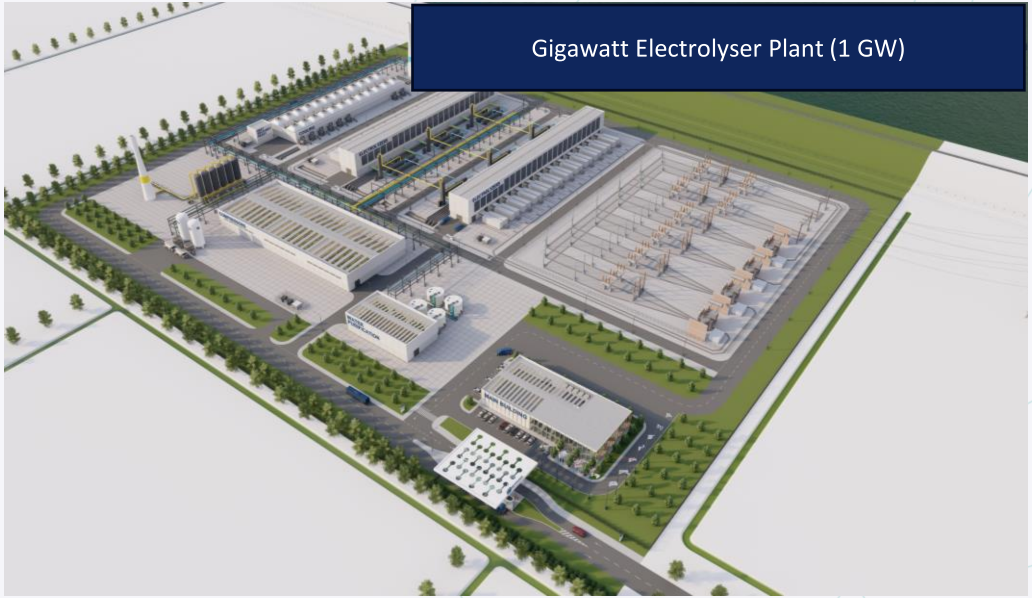
ISPT

- **Institute for Sustainable Process Technology**
- **Open innovation platform**
- **>180 partners from industry and universities**
- **Projects contributing to**
  - **Energy transition**
  - **Materials transition**
  - **Agrifood transitions**
- **Cooperation in trust-based environment**

Electrolysis plant



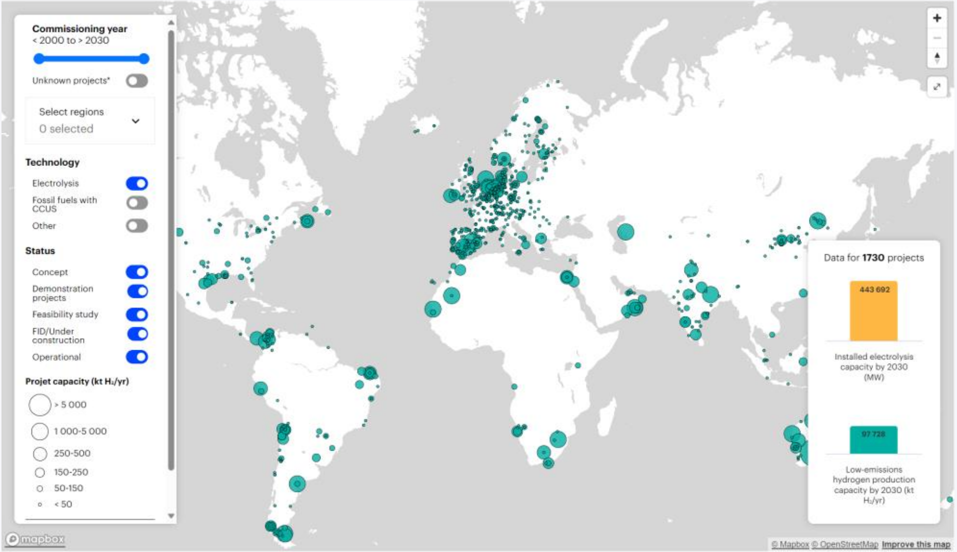
Hydrohub MW Test Centre (< 1 MW)

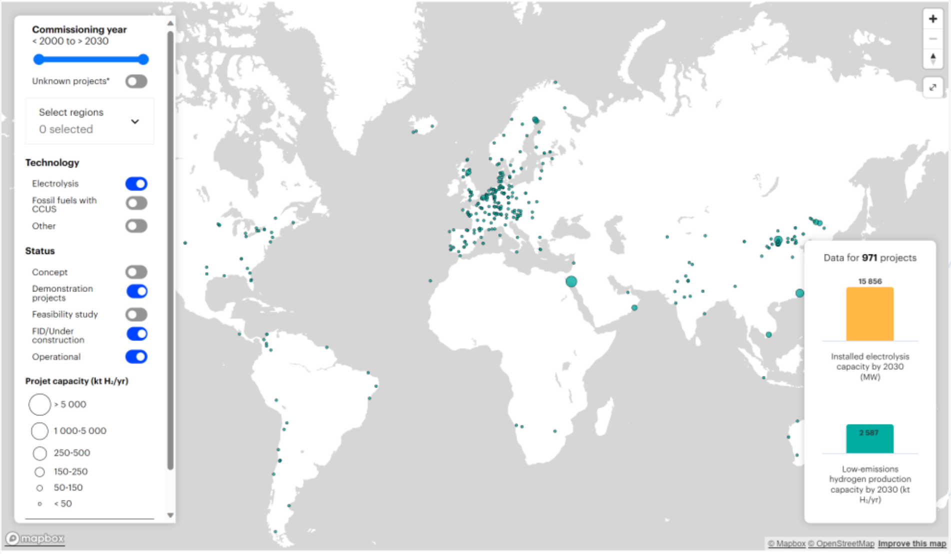


Gigawatt Electrolyser Plant (1 GW)

Mentimeter1: How many electrolysis projects are in development worldwide?

Worldwide hydrogen development





Hydrogen production projects interactive map – Data Tools - IEA

Key challengers:

1. Reliable and affordable supply chain
2. Infrastructure in place
3. Stable and clear policy
4. Green Hydrogen Market

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What is your focus?

- PEM and Alkaline Water Electrolysis, low/high P, diff P
- Large industrial scale, multi stack/module
- Process safety (qualitative/ quantitive)
- Fire &explosion hazard, scenario's of H_2/O_2 mixtures, Low L, high S
- Frequencies, probabilities and consequences
- Delayed ignition
- Vapour cloud explosions, Deflagration to Detonation Transition (DDT)
- Shrapnel, domino
- Credible scenario's
- Inherent safe design

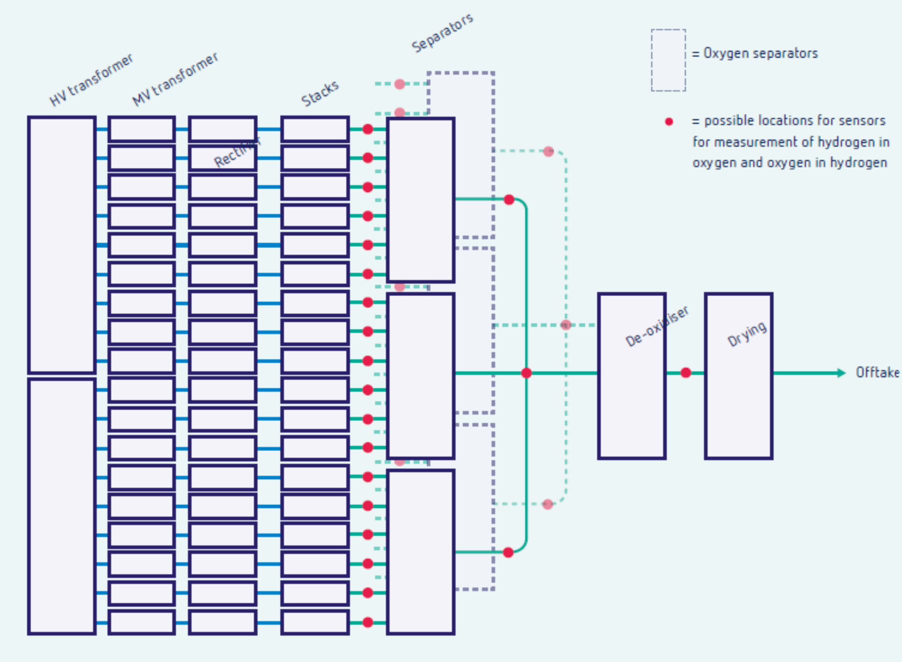

Figure 20: Possible locations of gas analysers

Mentimeter2: Which challenge or focus are there for you regarding safety?

Objective H_2 Safety 1 Project

- Understanding the fire and explosion risks with large scale electrolysers
- Developing consistent and objective risk assessment methods
- Gathering knowledge towards new inherent safety concepts
- Creating awareness
- Reducing risks to society
- What is level of understanding, eg competent authorities?

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Partners in H_2 Safety 1 Project

HyCC

Ørsted

Shell

YARA

DNV

Royal HaskoningDHV
Enhancing Society Together

TNO

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We also would like to thank the following technology providers for their valuable input and feedback:
Green Hydrogen Systems, Hystar, John Cockerill, McPhy, PERIC, Plug Power, ThyssenKrupp-Nucera

Main conclusions

- The process/chemical industry has well-established tools to assess the safety of processes involving hydrogen, including GW-scale electrolyser plants.
- However, there is a lack of historical and validated data on failure frequencies, probability of failure on demand and probability of ignition at GW scale.
- In addition, data and corresponding models on deflagration and detonation are not as well developed for hydrogen as they are for hydrocarbon systems.
- This will meanwhile require a conservative approach in assumptions and models for the design and operation of upcoming large-scale deployments.
- Sharing of experiences, failure data and incidents is needed

DOWNLOAD ...

Safety Aspects of Green Hydrogen Production on Industrial Scale

Download your free copy

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ISPT H_2 Safety2 Project on Standardisation

- May 2023 to end of 2024
- ISO22734 not adequate, revision now in Committee Draft Phase by WG 34 of ISO TC 197
- Process safety study
- Initiation National Technical Agreement (NTA) on process safety aspects for electrolysers
- Follow-up and input to ISO TC197

*: subcontractor ISPT

Ammonia Pipeline Safety Study

Industry is in control to transport ammonia in a safe and cost-effective way.

- The goal is to increase the level of **understanding of safety aspects**, mitigations and residual risks regarding design, operation and maintenance of ammonia transport in pipelines with large volumes and over large distances.
- The anticipated result is to show if and -if so- **how ammonia pipeline transport can be done safely** as part of a sustainable value chain. The results will support decision-making by authorities for policy making and industries for strategic investments.

fluxys · gasunie · Shell · OCI Global · Koole Terminals · equinor · aramco · EnBW · Port of Rotterdam

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Wouter Blom

3 – April - 2024

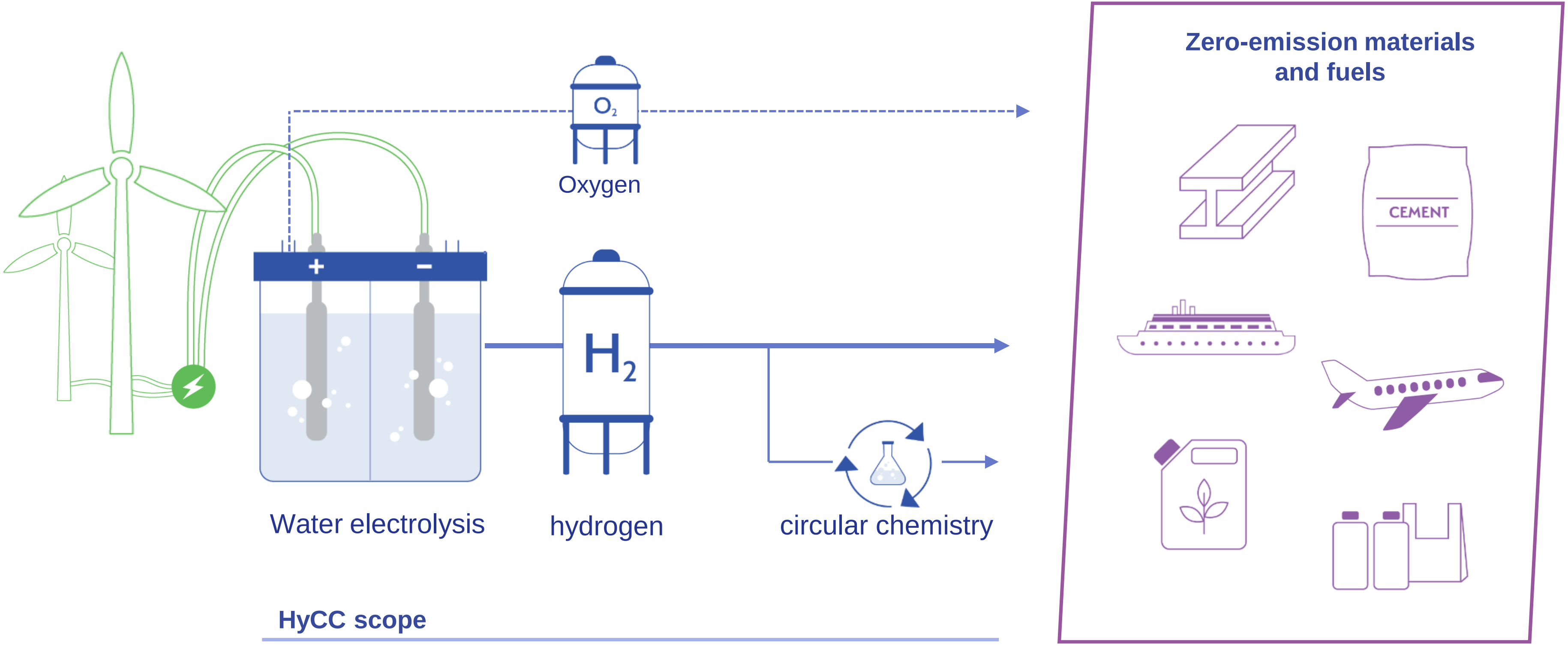
Enabling emission-free industries

Our Vision & Mission

To enable the full **decarbonization of industry** and the transition to a truly circular economy, by supplying safe, reliable and affordable **green hydrogen** supplies and circular **chemistry solutions**

HyCC

Towards a zero-carbon future



Hydrogen technology in early stages of development and different TRL levels

Atmospheric alkaline


TKUhde (Nucera)


AKC


NEL

Pressurized alkaline


McPhy


PERIC


John Cockerill


Hydrogen-Pro

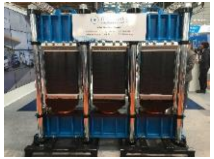

Green
Hydrogen Systems


Sunfire

PEM
(atmospheric and pressurized)


Siemens


Plug power


ITM


Cummins

Other Technologies


SOEC: Haldor Topsoe


AEM: Enapter

Mentimeter3:
What are the largest hazards in a water electrolysis plant?

The main hazards in the Water Electrolysis

1. O_2 and H_2 mixing in equipment

- Confined vapor clouds explosions, resulting in brittle fracture and fragments, followed by jet fires

Managed by:

- Hold-up (pressure & volume)
- Instrumental safeguarding
- Mechanical Safeguarding
- Compartments
- Safe siting

2. H_2 leakages and large holdup / storage

- Jet fires
- Confined vapor clouds (by accumulation in a building)

Managed by:

- Standard design measures
  - Hold-up & pressure
  - Compartments
  - Safe siting
  - Mechanical Safeguarding
  - Instrumental detection / safeguarding

3. Caustic leakages and sprays

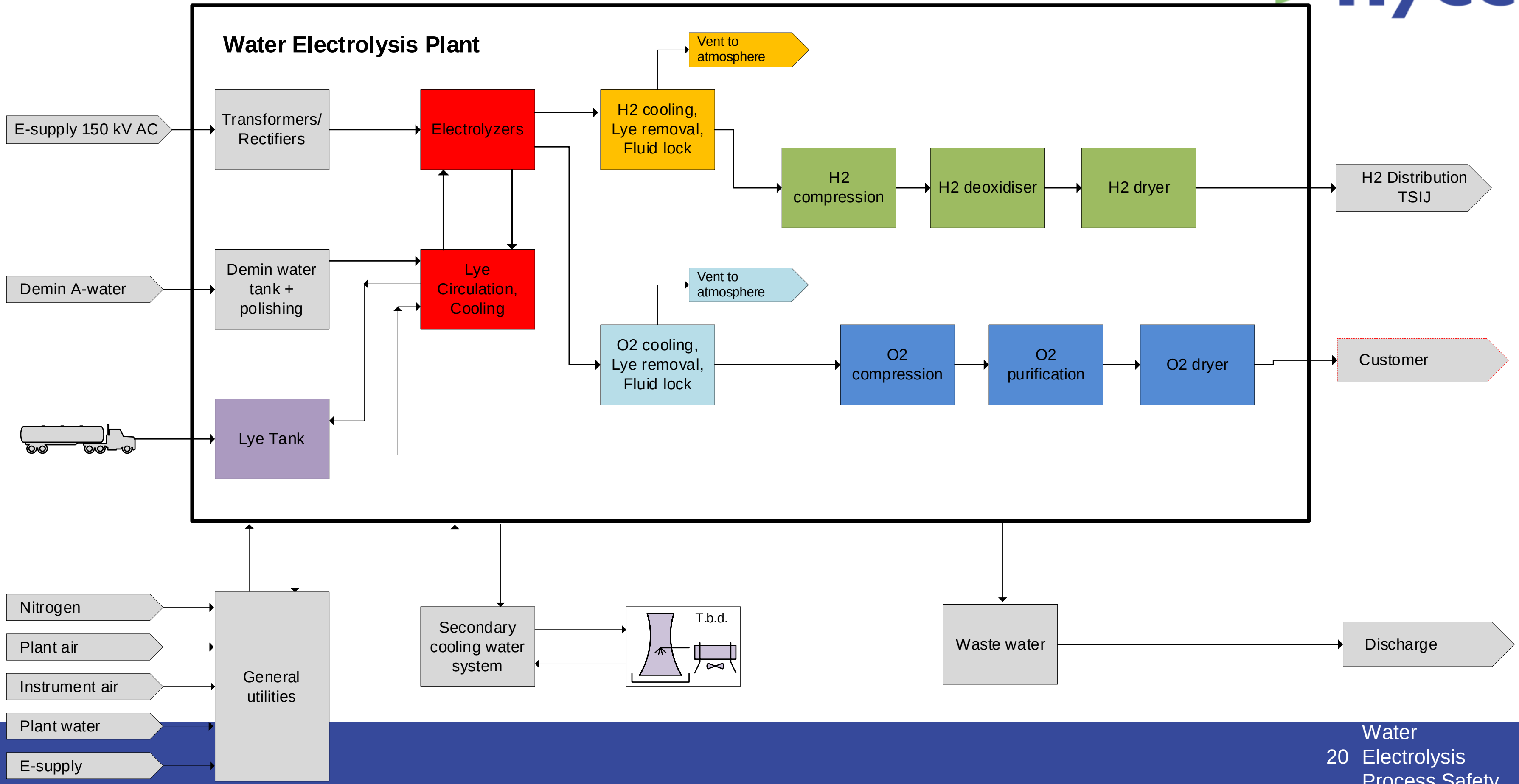
4. Oxygen promoted fire (materials & greases)

5. Electric Shock / Magnetic Fields

6. Thermal Burns from hot equipment

7. Nitrogen suffocation

Where are the hazards in the process?



H_2-O_2 explosion Ilford, UK, 1975

Event: Explosion of O_2-lye separator of Zdansky-Lonza pressurized alkaline electrolyzer
Severity: One operator killed by hot caustic burns; building and electrolyzer damaged
Cause: Sludge silting up lye supply ➔ corrosion + small explosions in electrolyzer ➔ whole in diaphragm ➔ H_2 transport into O_2 drum ➔ explosion of the O_2-lye separator.
Learnings: monitor gas quality continuously & interlock with safety system (alarm, trip); maintain and monitor plant operation and condition frequently and regularly

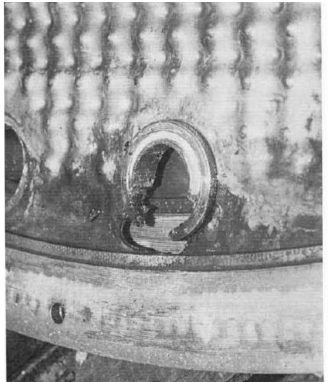

Corrosion/erosion caused a hole in bipolar (Goffer) plate

Fig 4 Perforated goffer plate

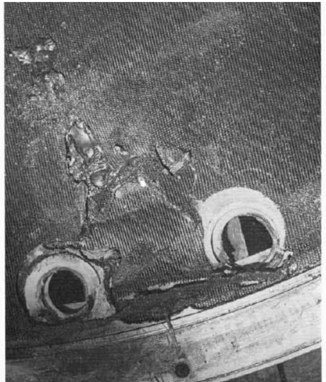

Smaller explosions damaged separator (diafragm)

Fig 5 Cell 16/3 showing damage to electrodes and asbestos separator

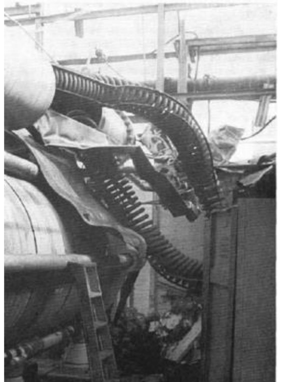
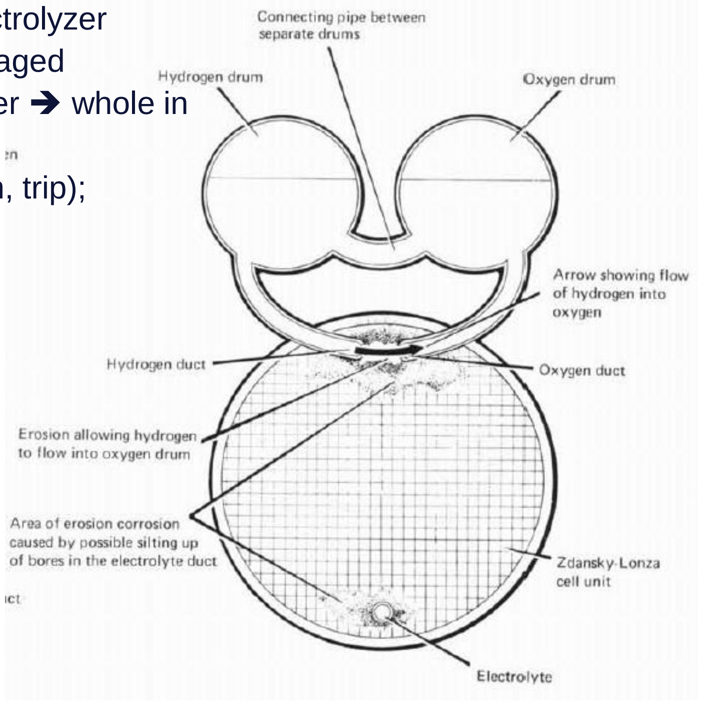

Exploded O_2-separator tank

Fig 2 Electrolytor showing cell block and oxygen separating drum with cooling coil



Ref 1. The explosion at Laporte Industries Ltd Ilford, 5 April 175, by HM Factory Inspectorate, ISBM 0118803336

H_2-air explosion China, 1992

<u>Event</u>: explosion of two H_2 receivers (8.68 long x 1.12 m diameter, 6.9 Mpa) in a water electrolysis plant
<u>Severity</u>: two people killed, eight-teen injured by fragments, extensive blast damage ~100 m radius, 275 kg TNT equivalent
<u>Cause</u>: during ~ 20hrs after restart, all gas supplied to H_2 receivers was air!
<u>Learnings</u>: be sure that inertization is complete (measure gas quality) before starting compression and/or electrolysis process

H_2-O_2 explosion Gangneung, South Korea, 2019

Event: explosion of compressed hydrogen storage tank from a facility containing fuel cells and water electrolysis processes
Severity: two people killed, six injured, damage of several buildings
Cause: oxygen entered hydrogen storage tank, spark caused explosion
Learnings: not known in detail, no detailed report available

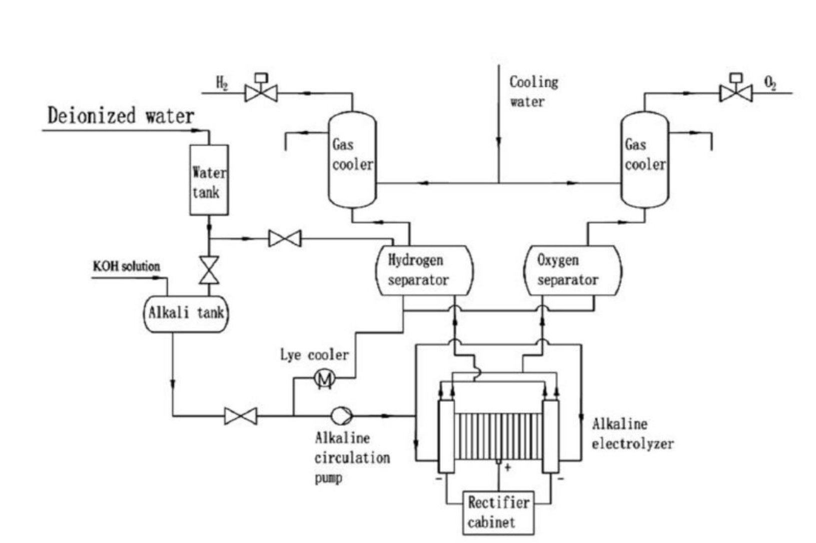
https://www.koreatimes.co.kr/www/nation/2019/05/281_269400.html

Mentimeter4:
What is required to avoid incidents from happening in the future?

When developing new installations, we need to work together to ensure safety

- **Understanding of the risks**
  - And acknowledgement of the knowledge gaps: ignition probabilities, DDT, …
- **Design and safety review processes, tools and methodologies**
  - No compromise when designing an installation, when uncertain be on the safe side
  - Detailed modelling to verify assumptions, even when costly
- **Industry wide design & safety standards**
  - Traditional standards like EIGA for hydrogen and oxygen (or equivalent) as well as new ones for water electrolysis like the ISO standards.
  - Programs like JIP, ISPT SAFER, work with industry partners and suppliers to develop the right standards.
- **Standard operating procedures for the operation of water electrolysis plants**
  - Suppliers should work towards high quality operating procedures, they will need help of established operators to develop this.
- **Sharing of near miss / incident learnings across the business**
  - It is crucial to learnings to keep each other safe. We will not be fully developed from day 1.

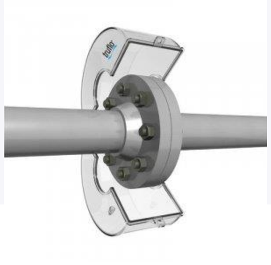
Problems with implementing safety in electrolysers



- Lack of knowledge on specific fire and explosion hazard scenarios
- Little experience with change of base load to flexible operation and maintenance and new generations of electrolysers in general
- New risks introduced from single units to large scale multi-modular
- Lack of a common understanding and standardised risk and design approach
- Limited data available on failure frequencies, probability of failure on demand and probability of ignition.
- Worst case, maximum effect -> high costs
- Delay in permitting
- Underestimating of risks

A fundamantally safe design focusses on eliminating and reducing the hazards

Inherent	Passive	Active	Procedural
Eliminating the possibility of H_2 explosions all together	Avoid people hazards by e.g. thick steel to contain risks or caustic shields that protect people against leakages	Implement controls, alarms, safety instrumented systems, and mitigating systems	Use policies, operating procedures, training, emergency response to prevent incidents or to minimize the effects of an incident.



Mentimeter5:
How large is the gap between where we are and where we need to be?

Where do we store learnings from near misses and incidents?

- FCH 2 JU conducted a workshop on the safety of electrolysis
- ARIA database is a database on overview of accidents/incidents in France
- HIAD 2.0 database
- Eurochlor incident reports

We have some scattered over industry as hydrogen is produced by various methods (SMR, Chlor-Alkali, Waterelectrolysis) and is utilized even more diversely.

How should we centralize these learnings?

Mentimeter6:
How / where should we centralize the learnings from water electrolysis near misses and incidents?

Thank you

HyCC