HyET Hydrogen

Efficient purification & compression

Introduction HyET Hydrogen

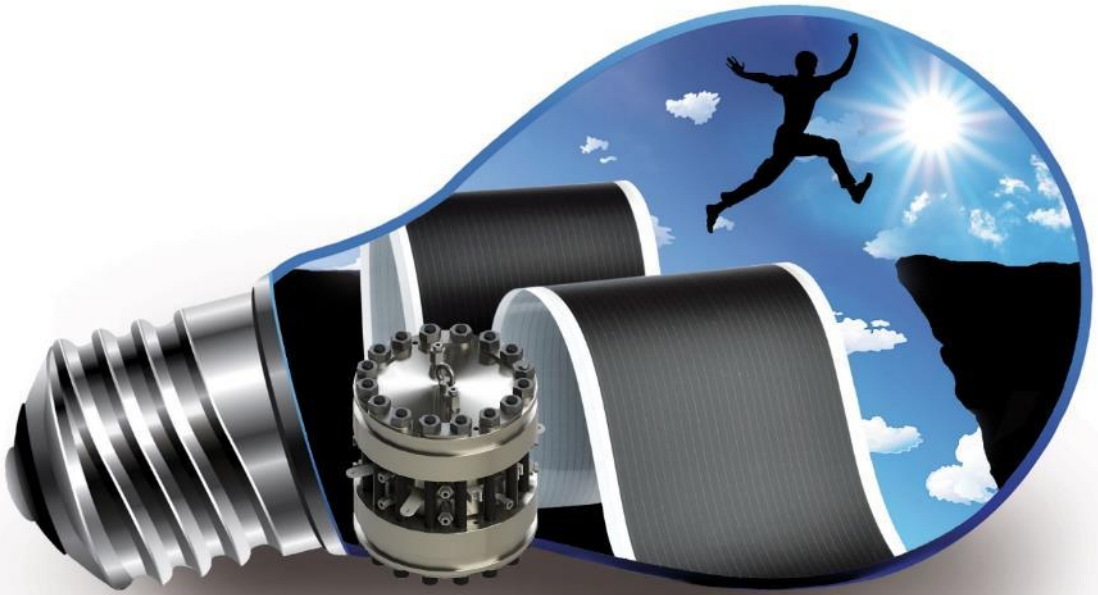
Cost-Effective Electrochemical Processing of Hydrogen

November 2022

Electrochemical Compression of Hydrogen

Electrochemical Separation of Hydrogen from Natural Gas

Optimization of hydrogen release processes



HyET High Yield Energy Technologies

HyET Hydrogen is part of the HyET group of companies

HyET Group of companies

Critical components for the renewable, distributed energy supply chain providing fossil fuel parity

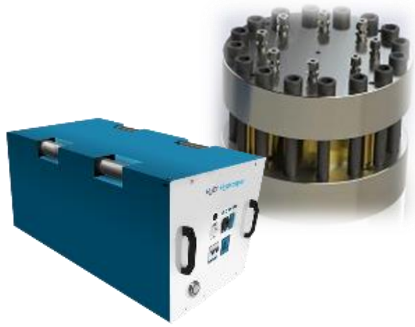
HyET Solar
Flexible lightweight solar modules

Efficient & low cost PV compensating for conversion & storage costs

HyET E-Trol
Low-cost electrolysis for hydrogen production

Low cost electrolysis at improved energy efficiency and reduced CAPEX

HyET Hydrogen
Efficient purification & compression



Reliable & low cost storage and transportation of energy

HyET NoCarbon
Decarbonizing the energy supply chain

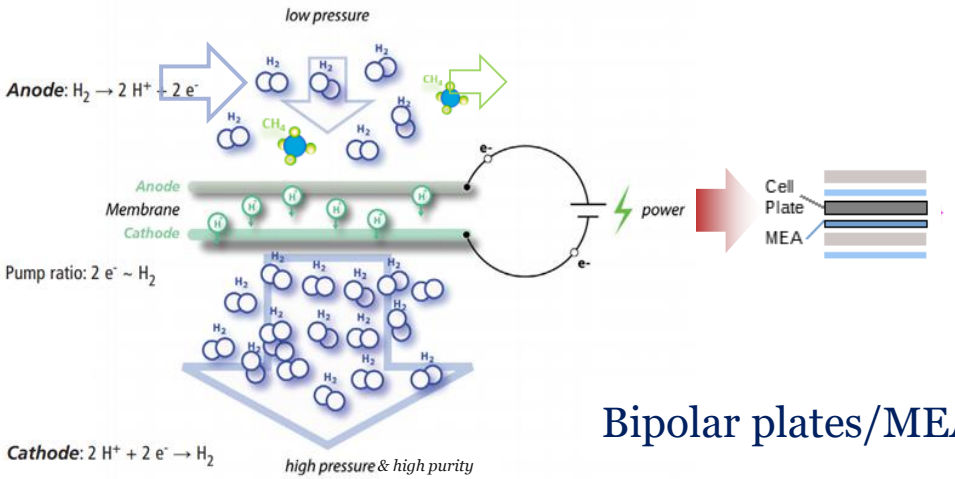
Modular membrane reactors to enable a fast energy transition. NH_3 processes, CO_2 capture & Synthetic Fuels

HyET Lithium
High energy density solid-state batteries

Roll-to-Roll production of high density solid-state Lithium ion batteries

Electrochemical H2 processing

H2 compression + purification (EHC/P)

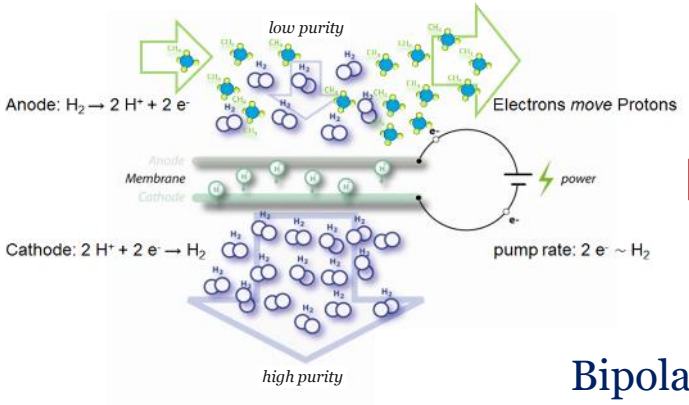


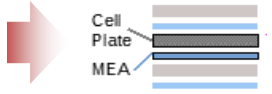
Bipolar plates/MEA

Compression/Purification Stack

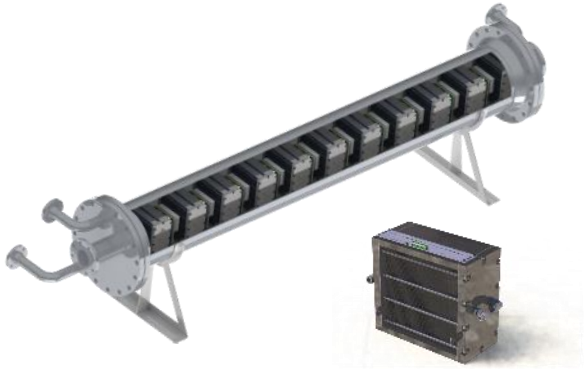
EHC/P module

H2 extraction + purification (EHE/P)





Bipolar plates/MEA



Extraction/Purification Stack

EHE/P module

Value Proposition HyET Hydrogen

Current challenge

How can we get Hydrogen to end users for an affordable price?

Compression and Purification represent the largest part of the costs in the hydrogen supply chain.

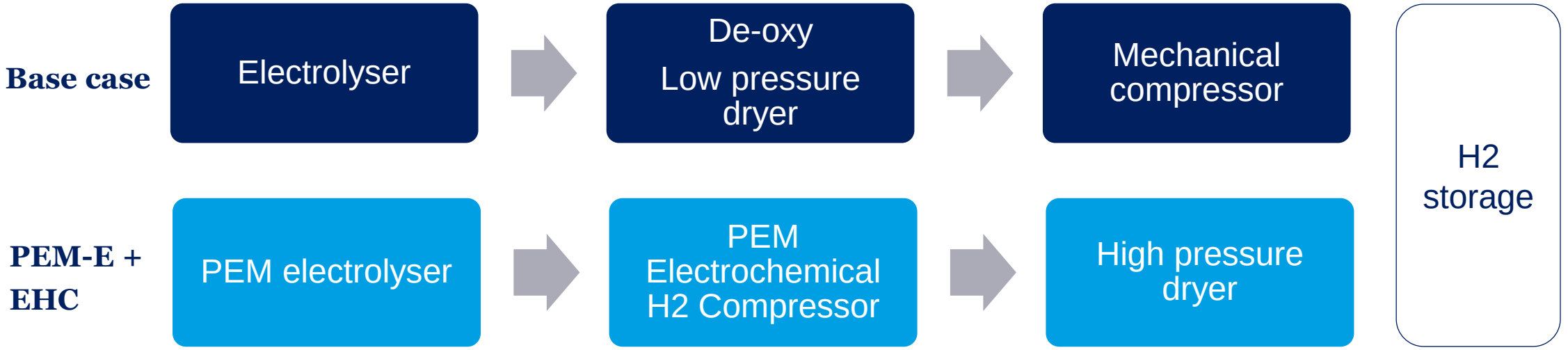
High failure rate of compressors and complexity of purification systems prompt for a novel, reliable, alternative technologies.

HyET Hydrogen deploys proprietary technology for compression, purification and extraction of Hydrogen.

Our value proposition:

- Cost effective compression of hydrogen
  - **High uptime**
  - **Flexible, 10% to 150%**
  - **100 mbar – 500 bar**
  - **No moving parts**
  - **Silent**
  - **Lowest total cost of ownership**
- Purifying Hydrogen waste streams to accelerate adoptions for Hydrogen as a fuel
- Using existing infrastructure (gas grid) for distribution of Hydrogen, selectively purify and extract the Hydrogen at the location where you need it the most

Balance-of-plant synergy of PEM-E and EHC process chain



Expected chain synergies for PEM-E / EHC combination:

- Electrolyser and compressor are PEM based; both have excellent design for dynamic, intermittent operation following renewable energy production
- Electrochemical compressor anode electrocatalyst strips trace amounts of oxygen, as is done in the de-oxy dryer used downstream of electrolysers
- Pressurized hydrogen already condenses water, reducing amount of water vapour to be removed from hydrogen flow
- Fuel cell end-use of hydrogen would even allow for “wet storage” if refuelling is “slow fill”, removing the drying process step in the chain

Therefore: project PEM-E / EHC

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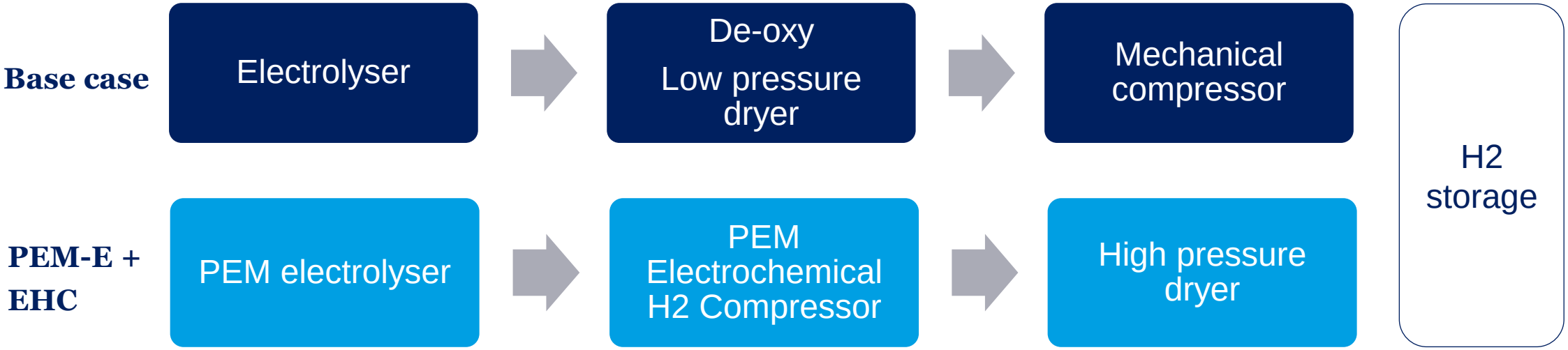
HyET Efficient Hydrogen purification & compression

Project goal

Wat zijn de operationele voordelen van het koppelen van een PEM electrolyser en elektrochemische compressor in vergelijking met de base case?

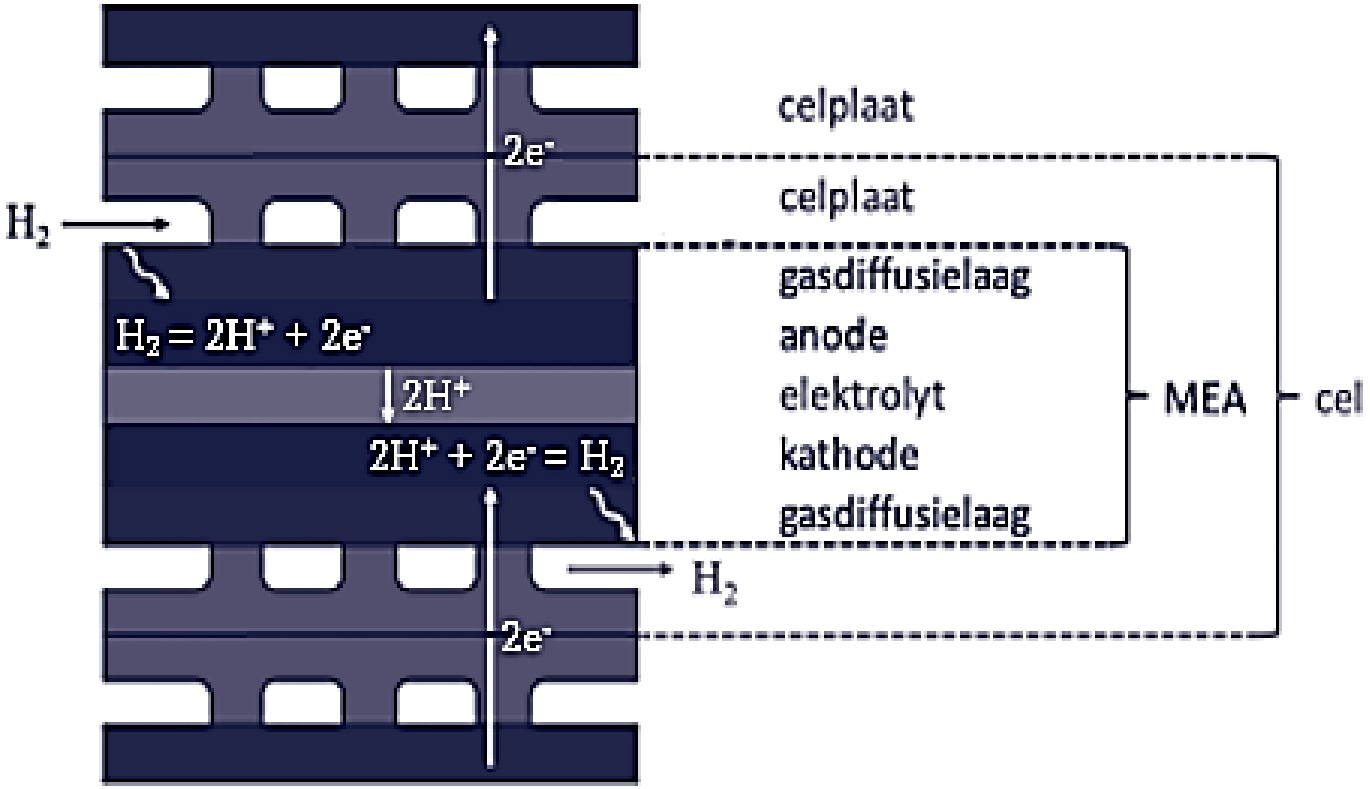


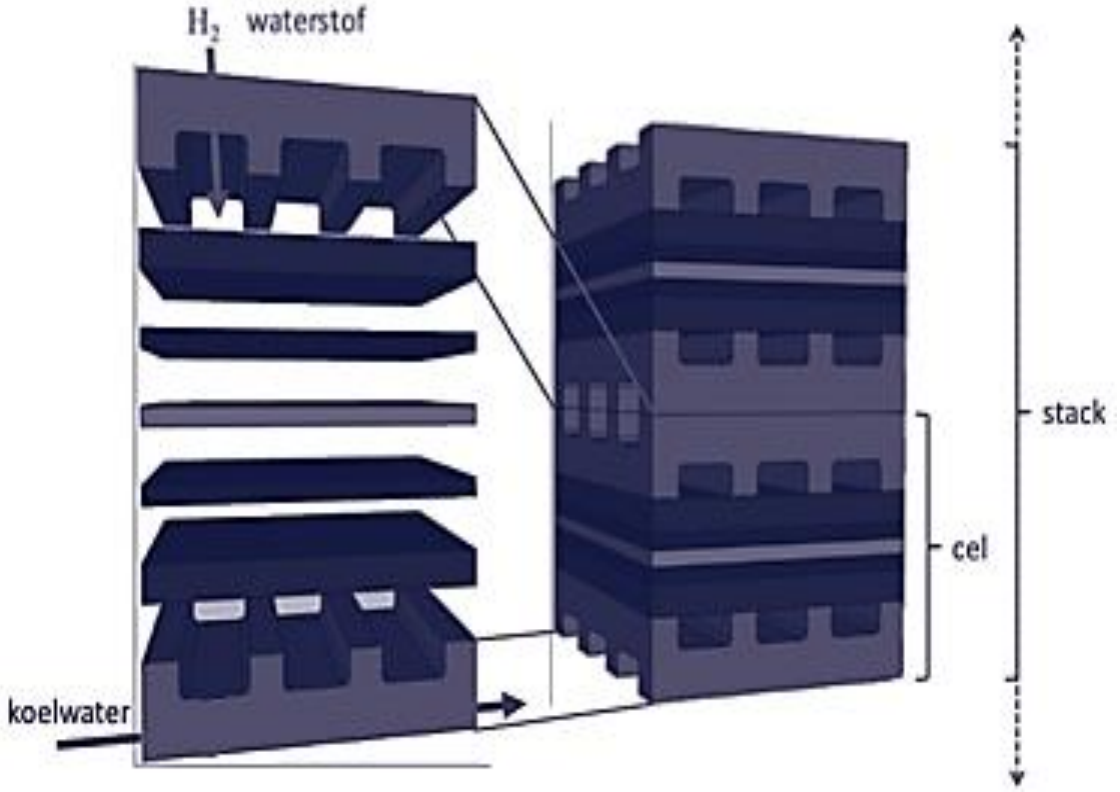
Research questions

Hoofdvraag:
Hoe kan een meetopstelling worden gemaakt waarin PEM-E en EHC aan elkaar zijn gekoppeld zodat:

- Geen vocht hoeft worden toegevoegd.
- Zo min mogelijk extern verwarmd of gekoeld hoeft te worden.
- De EHC niet volloopt met water en niet uitdroogt.

Werkingsprincipe electrochemische compressor

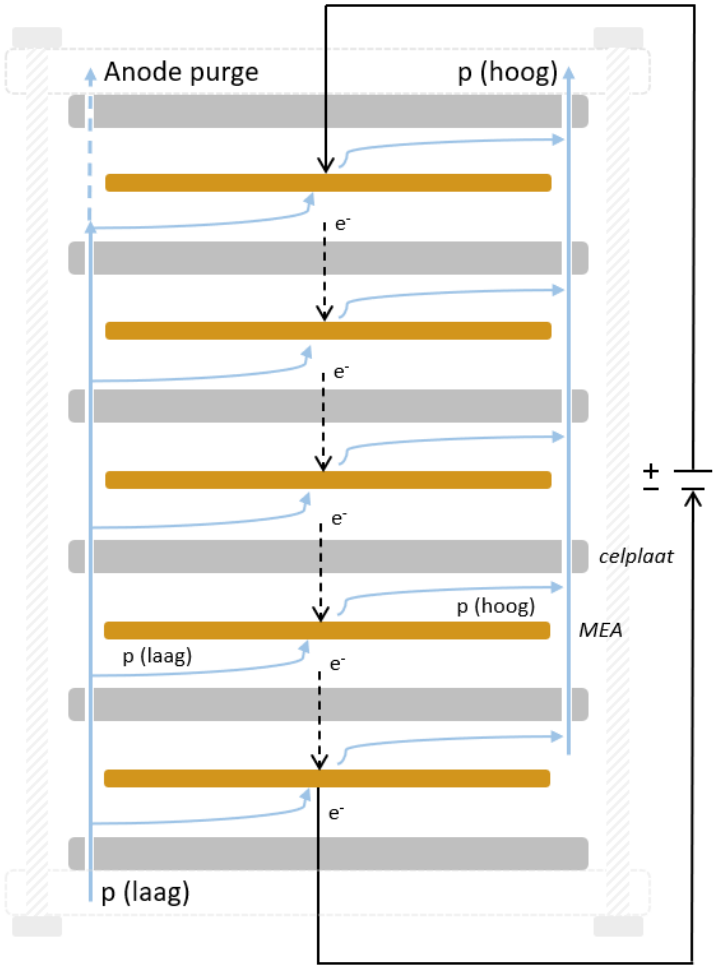




Werkingsprincipe electrochemische compressor

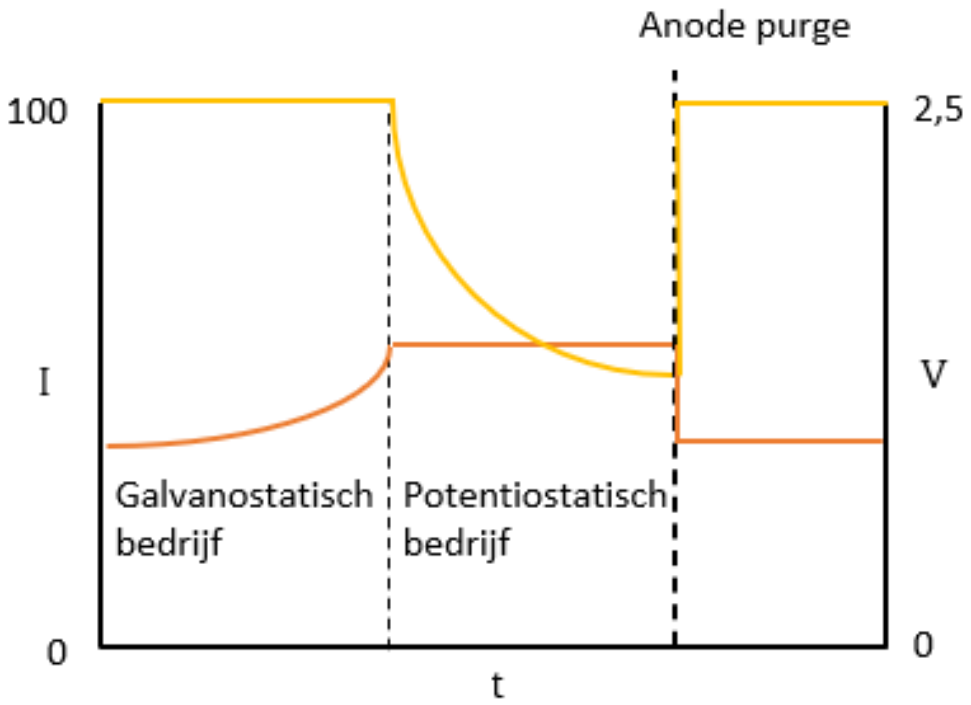
- 5 cellige stack
- Randeffecten
- Stabiliteit en betrouwbaarheid

- Gasstroom parallel
- Stroomkring serie
- Één spanningsbron en minder bekabeling



Oorzaken verminderde efficiëntie

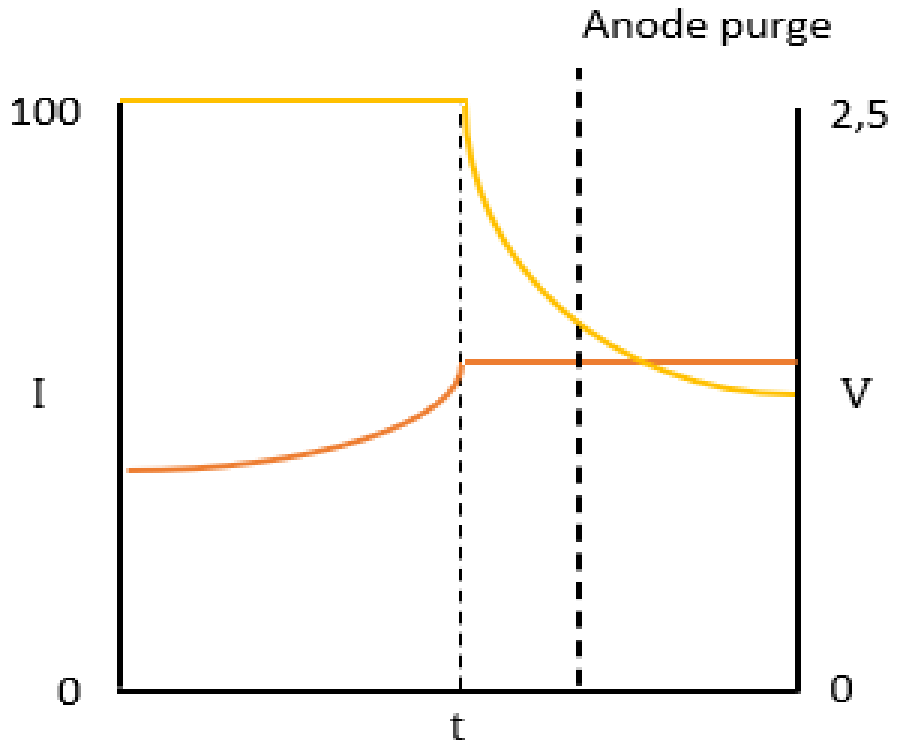
1. Overstroming



- Relatieve vochtigheid > 99%
- Vloeibaar water bedekt celoppervlak
- Oplossing: anode purge

Geel: Stroom (waterstofproductie)
Oranje: Voltage (efficiëntie)

2. Uitdroging



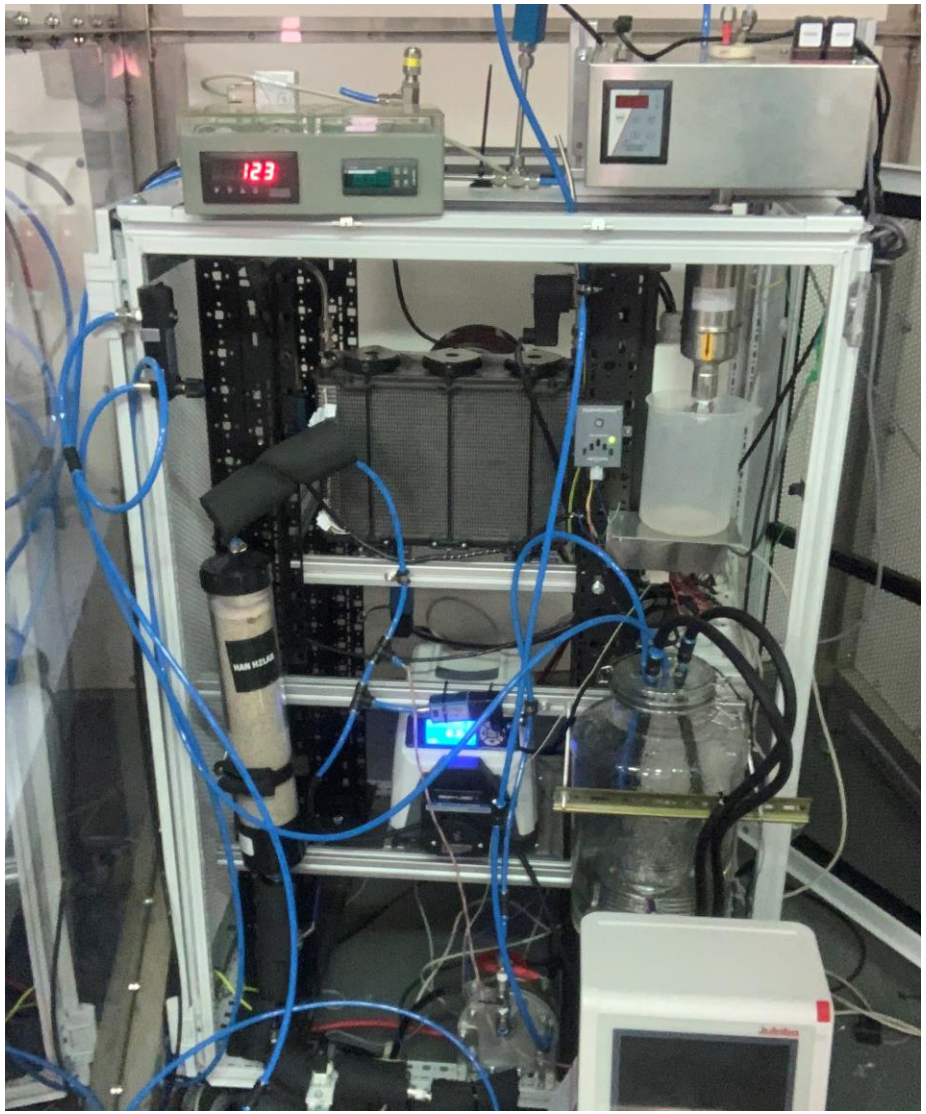
- Relatieve vochtigheid < 90%
- Anode purge werkt niet
- Oplossing: verhogen relatieve vochtigheid

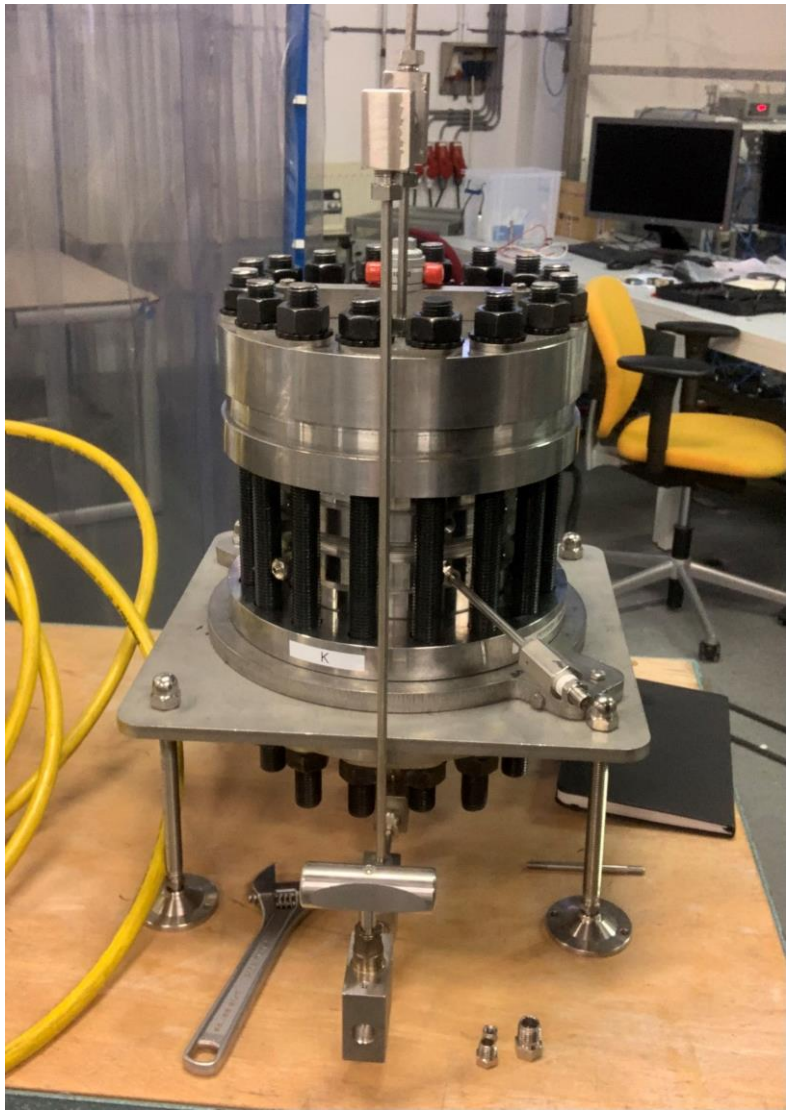
Geel: Stroom (waterstofproductie)
Oranje: Voltage (efficiëntie)

3. Toxische gassen

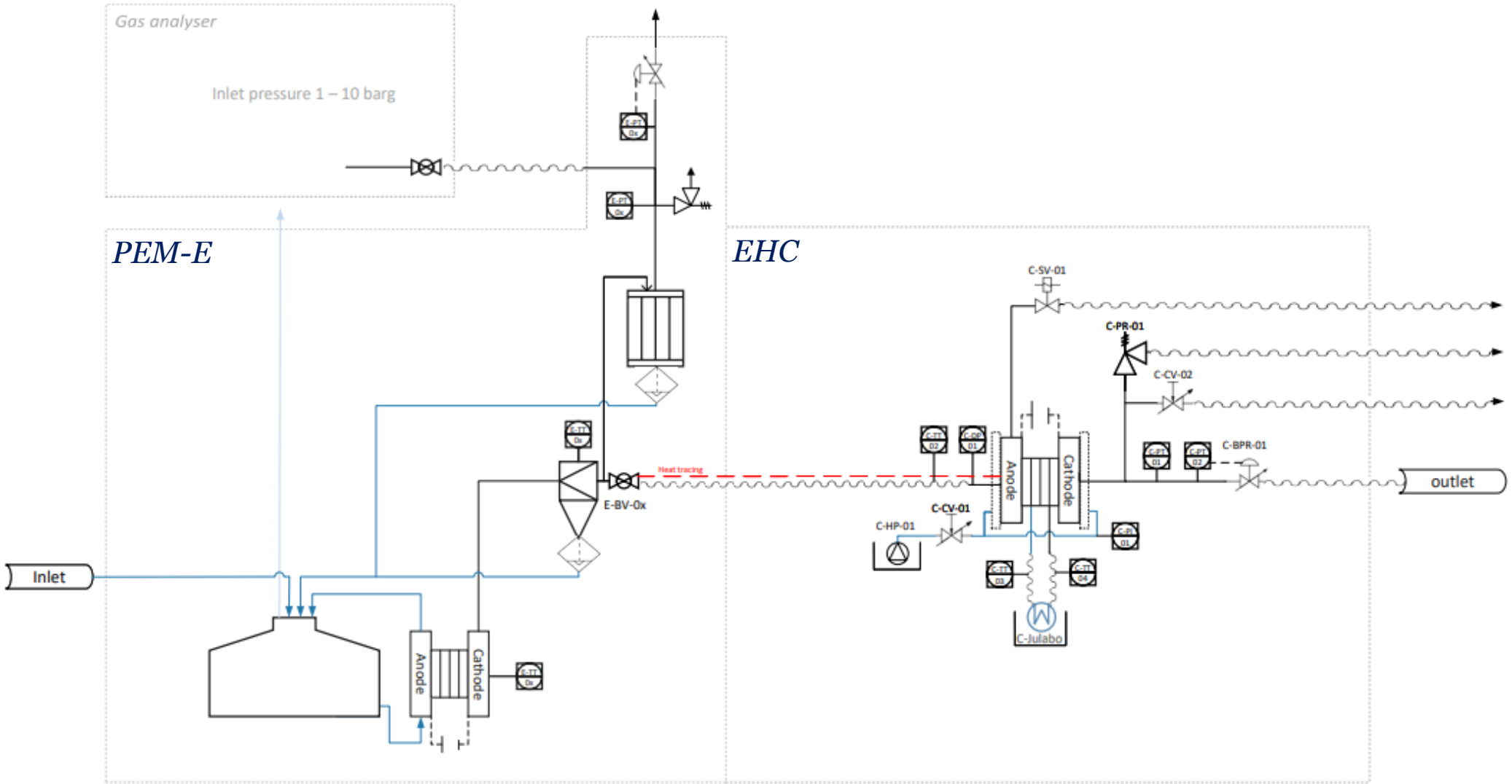
- Koolstofmonoxide sterkere binding aan katalysator
- Zwavel schadelijk voor katalysator
- Zouten zorgen voor ionen in het membraan
- Kenmerken: anode purge en bevochtigen werkt niet

Testopstelling PEM-E en EHC





Testopstelling Piping & Instrumentation Diagram



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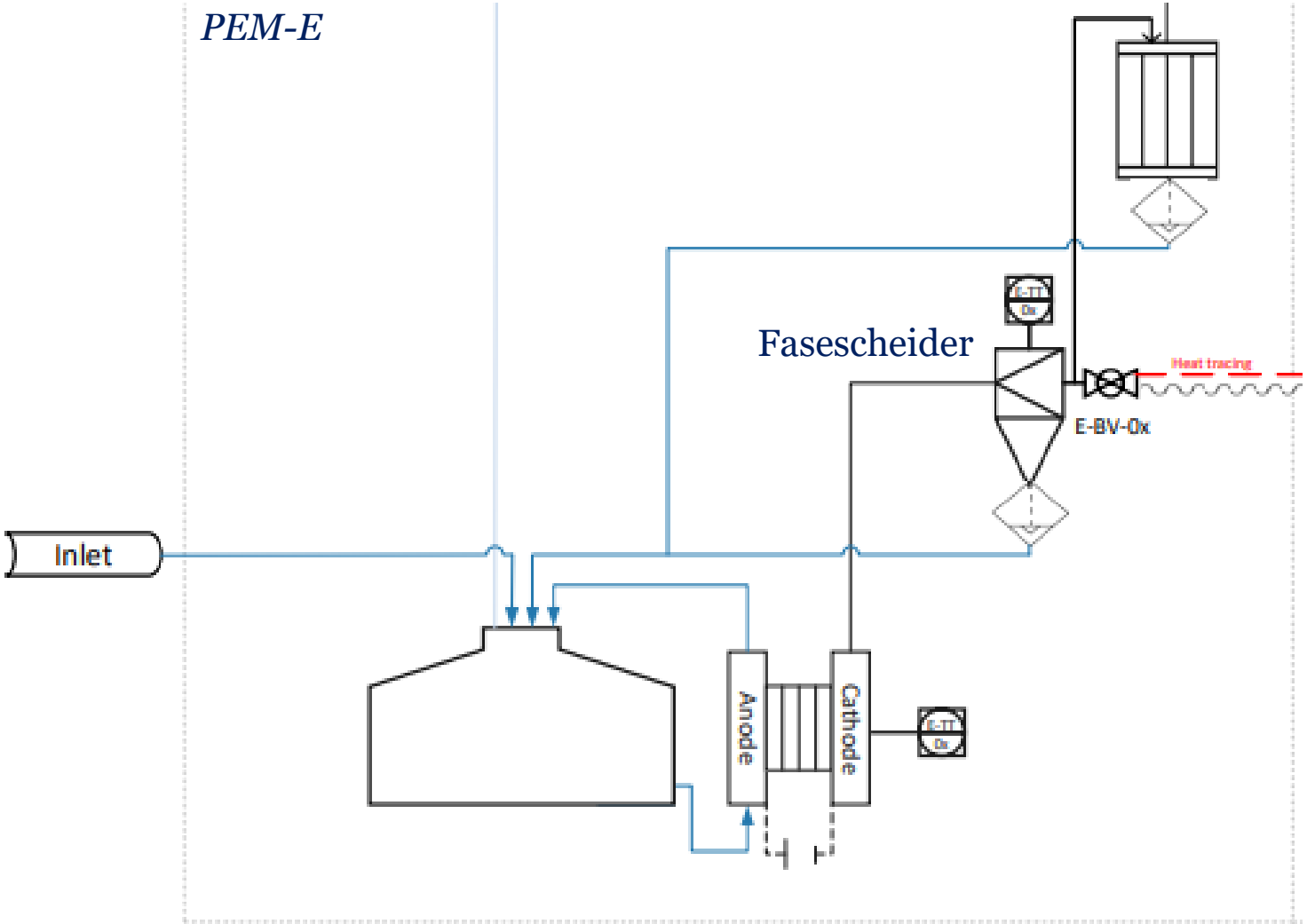
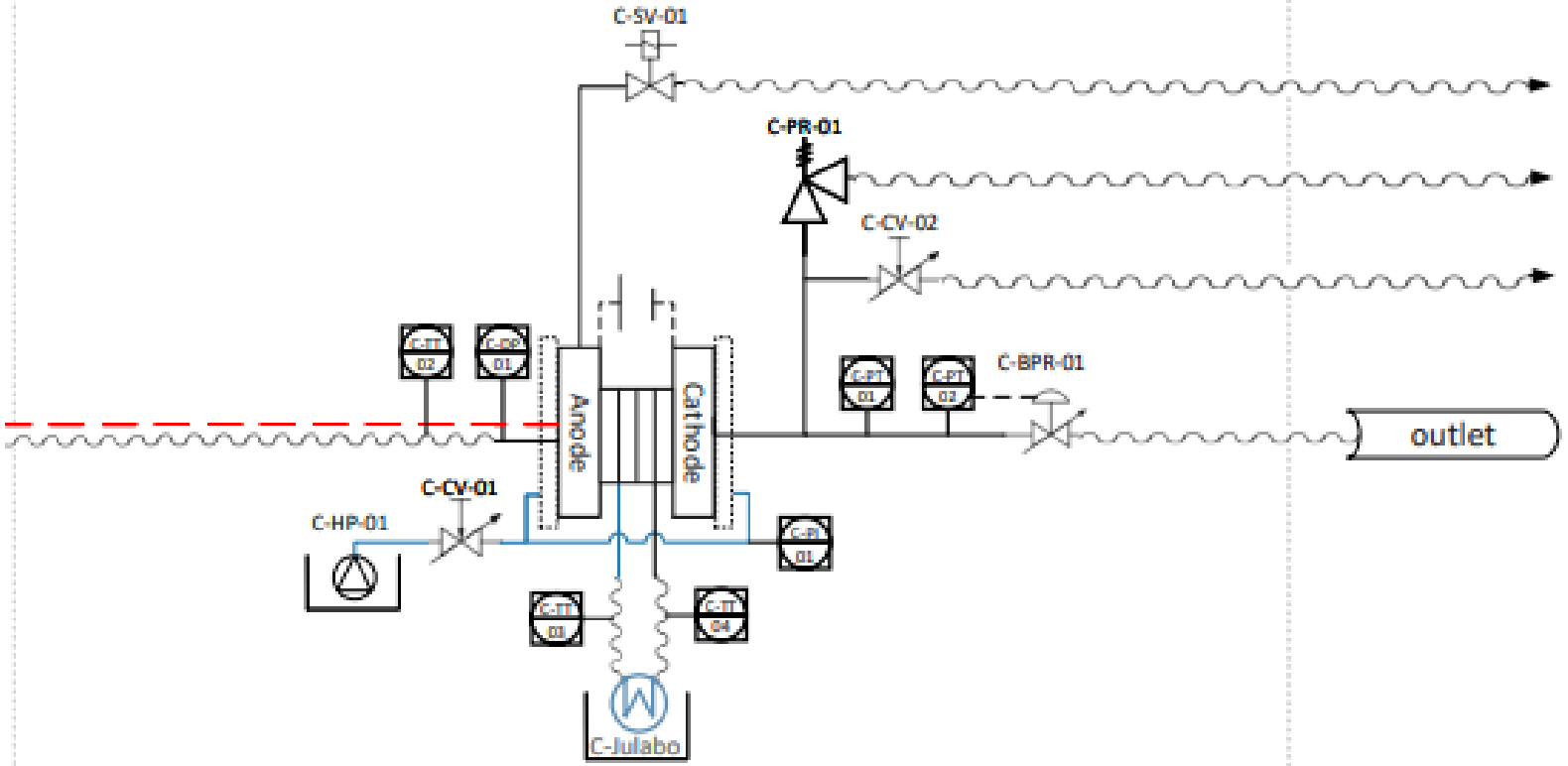


Testopstelling Piping & Instrumentation Diagram

EHC



C-SV-01, Purge klep
C-PR-01, Drukreduceer
C-CV-02, Naaldventiel
C-BPR-01, Tegendrukregelaar

Testobjectives

- De EHC bedrijven door gebruik te maken van het vochtige waterstofgas uit de PEM-E
- Onderzoeken hoe de warmte uit de PEM-E optimaal benut kan worden
- Zuurstofgehalte meten om te testen in hoeverre de EHC functioneert als deoxidator

Voordelen en uitdagingen

Voordelen

- Extern bevochtiger is niet nodig
- Aparte deoxo niet nodig
- Energieverlies minimaal

Uitdagingen

- Waterhuishouding EHC
- Op hoge druk vocht verwijderen

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