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# Introduction to ASME Code Rules on Electrochemical Cell Stacks for Electrolysis

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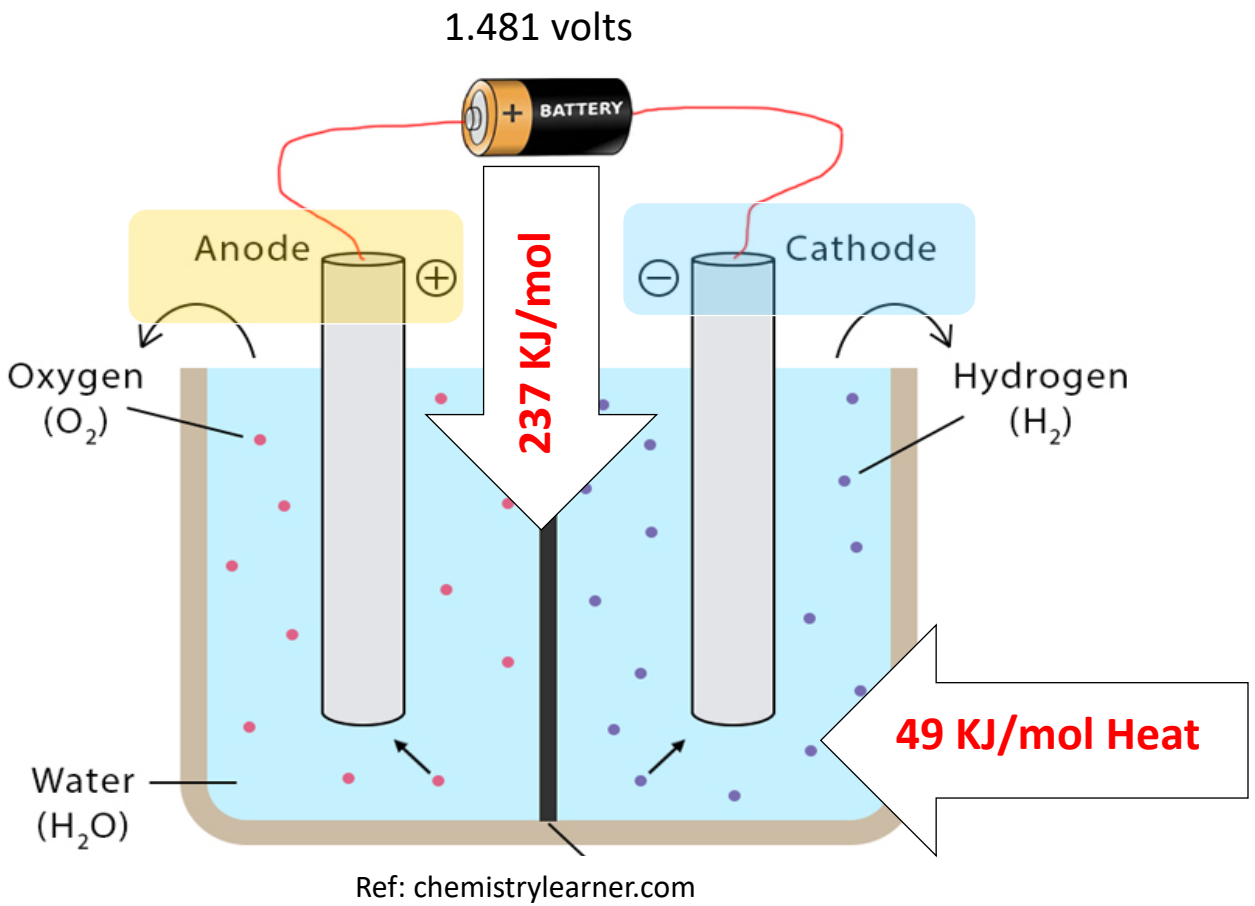
Making our world more productive

# Outlines

- Introduction to water electrolysis
- Historical development and current electrolysis technologies
  - Alkaline electrolyzers (AEL)
  - Proton exchange membrane (PEM) electrolyzers
- ASME BPVC Section VIII Code Scope and existing code rules
- Code Case 3078: new ASME Code rules on electrochemical cell stacks
- Summary

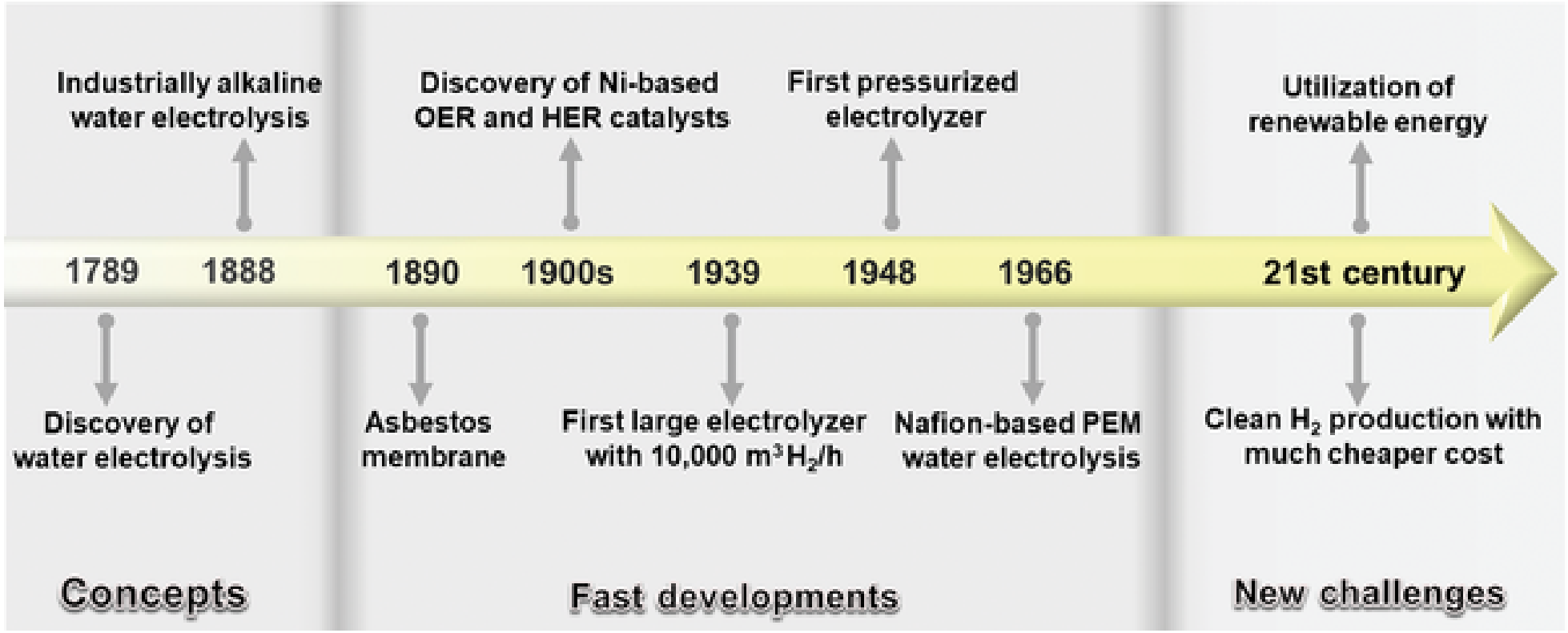
# Water Electrolysis

$H_2O$ (liquid) + 286 kJ/mol -> $H_2$ (gas) + ½ $O_2$ (gas)




Ref: chemistrylearner.com

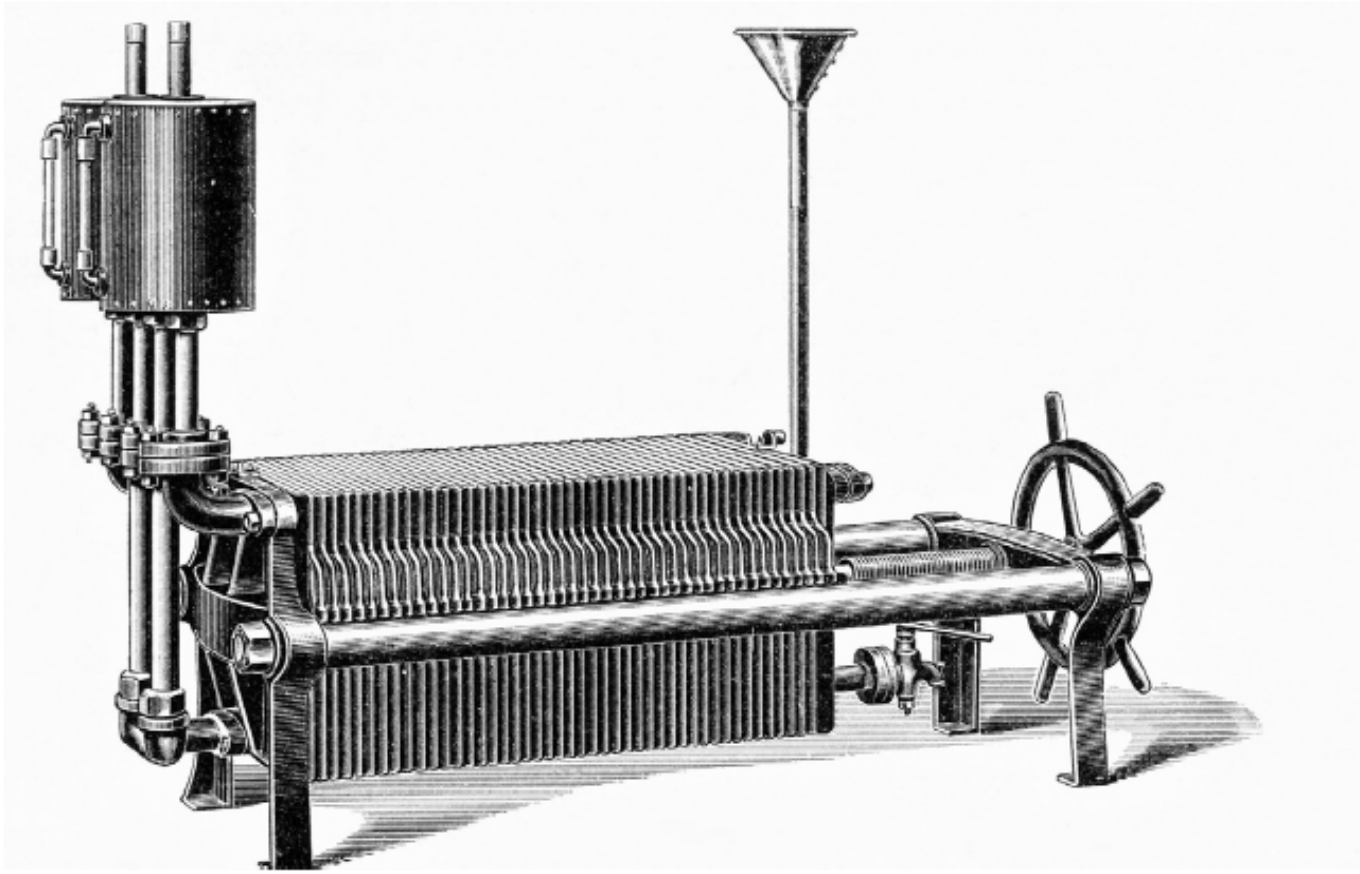
# Historic Electrolyzer Development




*Ref: Yu et al, Adv. Materials, 2021, 33, 2007100*

Water electrolysis was discovered more than 200 years ago

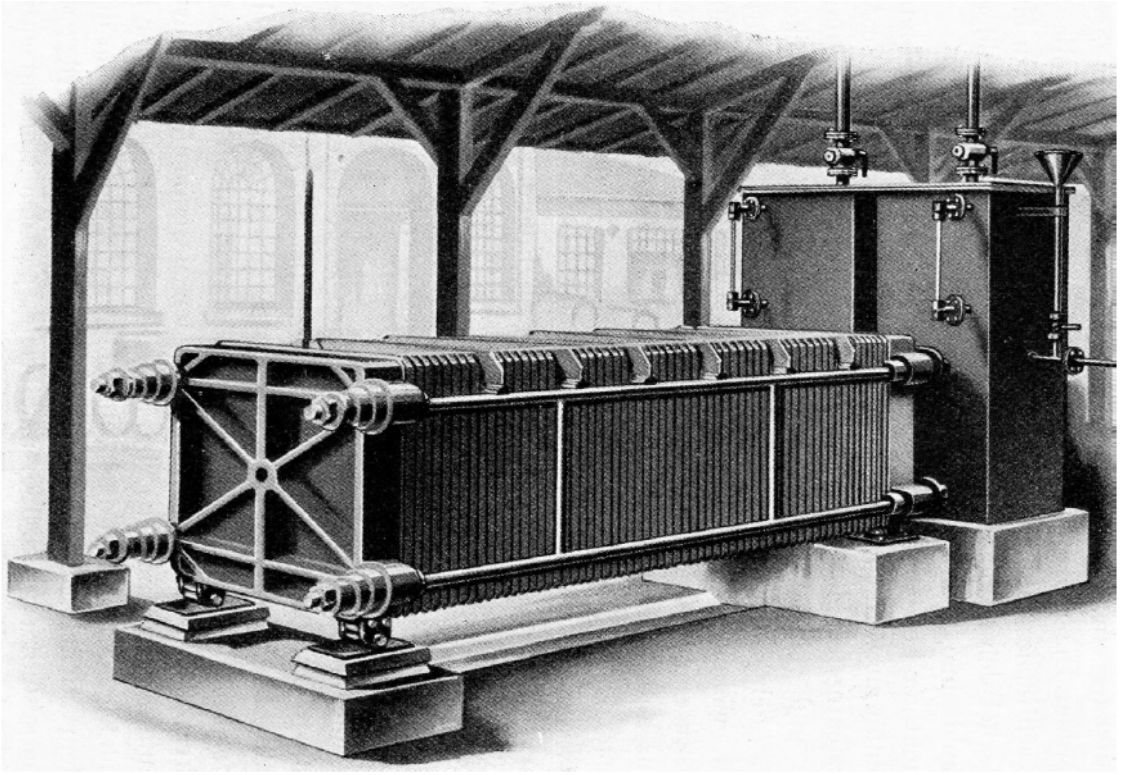
# Commercial Electrolyzers - Early Days



Ref: Smolinica, T. et al, “The History of Water Electrolysis from Its Beginnings to the Present”, in *Electrochemical Power Sources: Fundamentals, Systems, and Applications*, Elsevier 2021, Pages 83-164

1899: 44 cells diaphragm filter press alkaline electrolyzer by Schmidt (66 $Nm^3$/day)

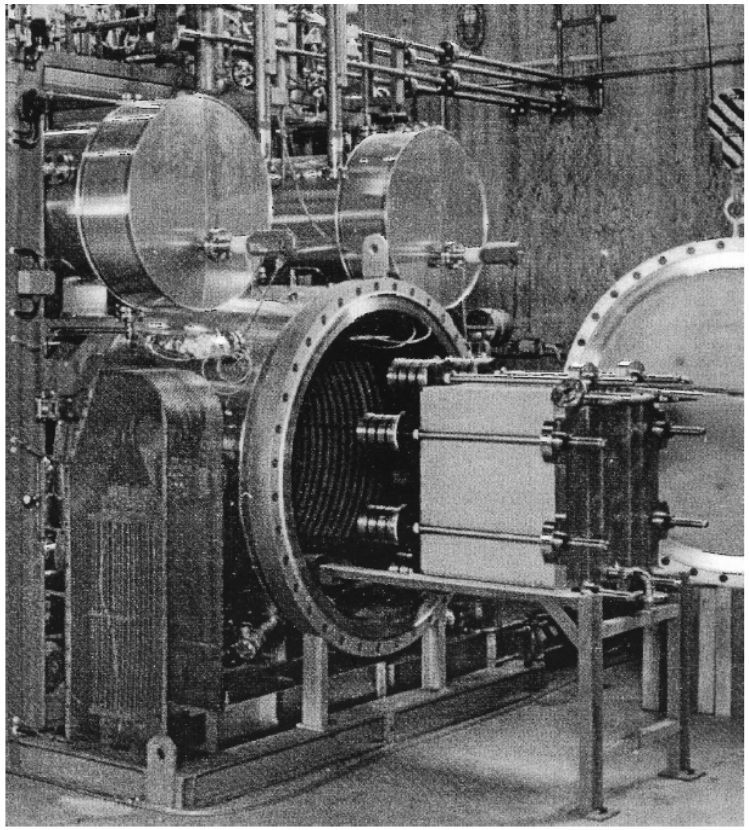
# Commercial Electrolyzers – Mid 1900s

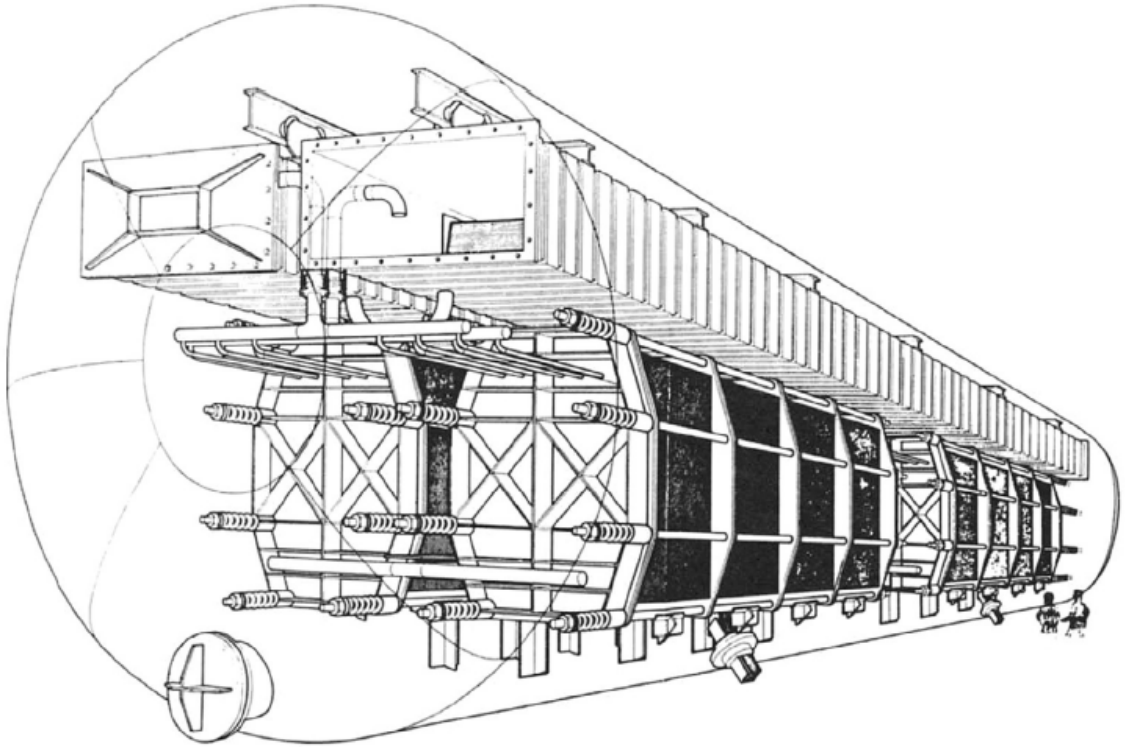


Ref: Smolinica, T. et al, "The History of Water Electrolysis from Its Beginnings to the Present", in *Electrochemical Power Sources: Fundamentals, Systems, and Applications*, Elsevier 2021, Pages 83-164

1949: 135 MW alkaline electrolyzer (27900 $Nm^3$/hour) from Norsk Hydro

# Commercial Electrolyzers – Pressurized Cells



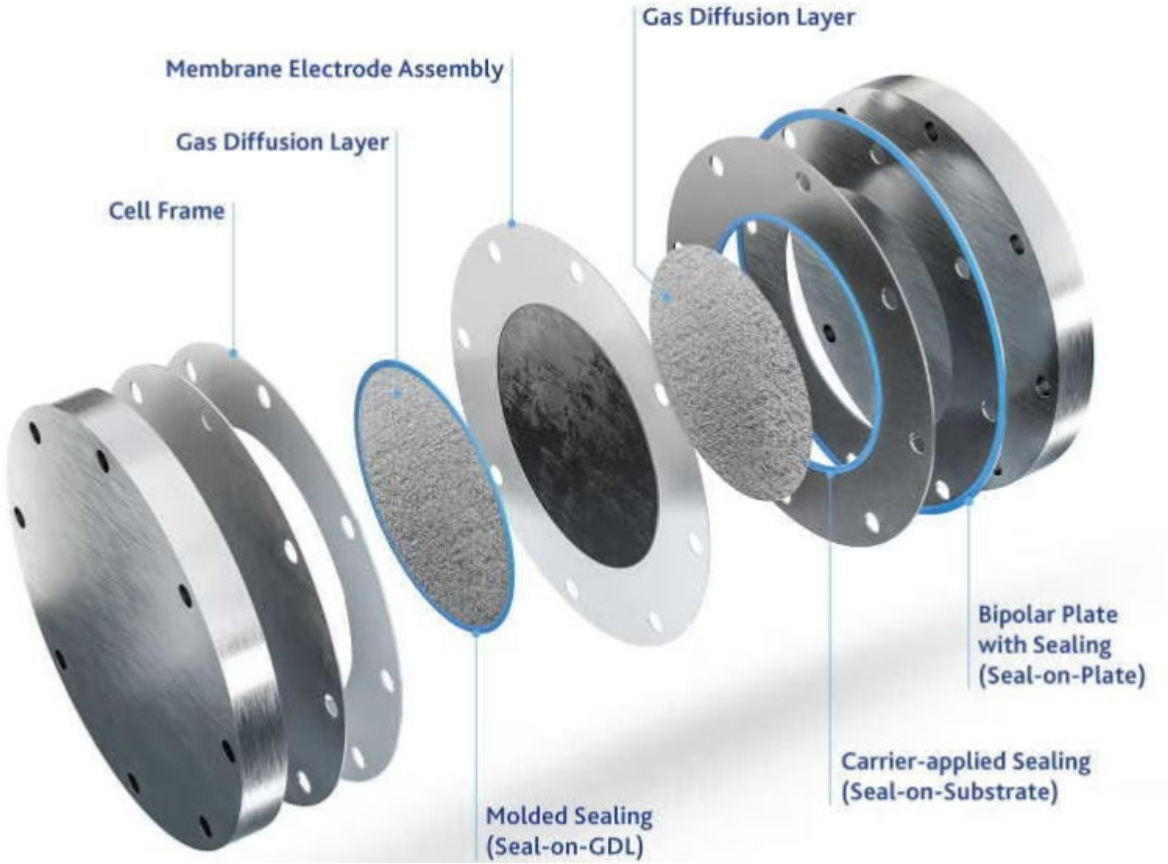


Ref: Smolinica, T. et al, "The History of Water Electrolysis from Its Beginnings to the Present", in *Electrochemical Power Sources: Fundamentals, Systems, and Applications*, Elsevier 2021, Pages 83-164

1990s: Advanced alkaline electrolyzer cells operating at 450 psi inside pressure vessel

# Proton Exchange Membrane (PEM) Electrolyzers

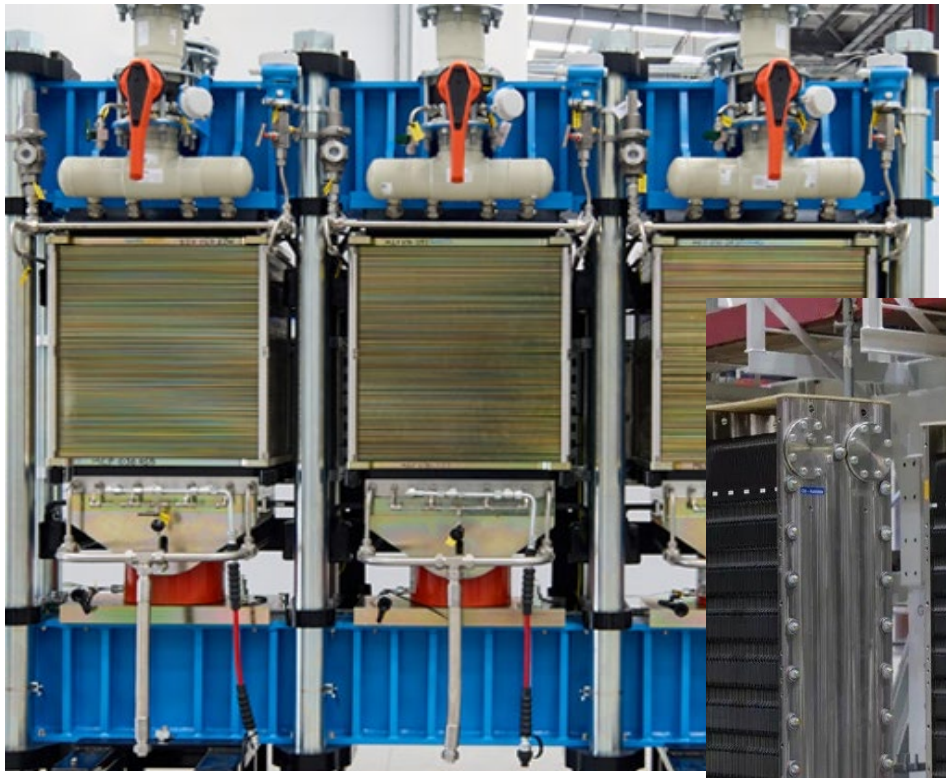
- PEM technology developed in 1960s and was used in aerospace.
- Compared with AEL, PEM offers:
  - High current density
  - High efficiency (MW range)
  - High H2 purity
  - High operating pressure
  - Compact design
  - Higher cost
  - Less durability




https://www.fst.com/corporate/newsroom/press-releases/2021/from-manufactory-to-gigafactory/

# Variety of PEM Cell Stacks

M. Hamdan, Water electrolyzer Technology: Status and Challenges, Giner ELX

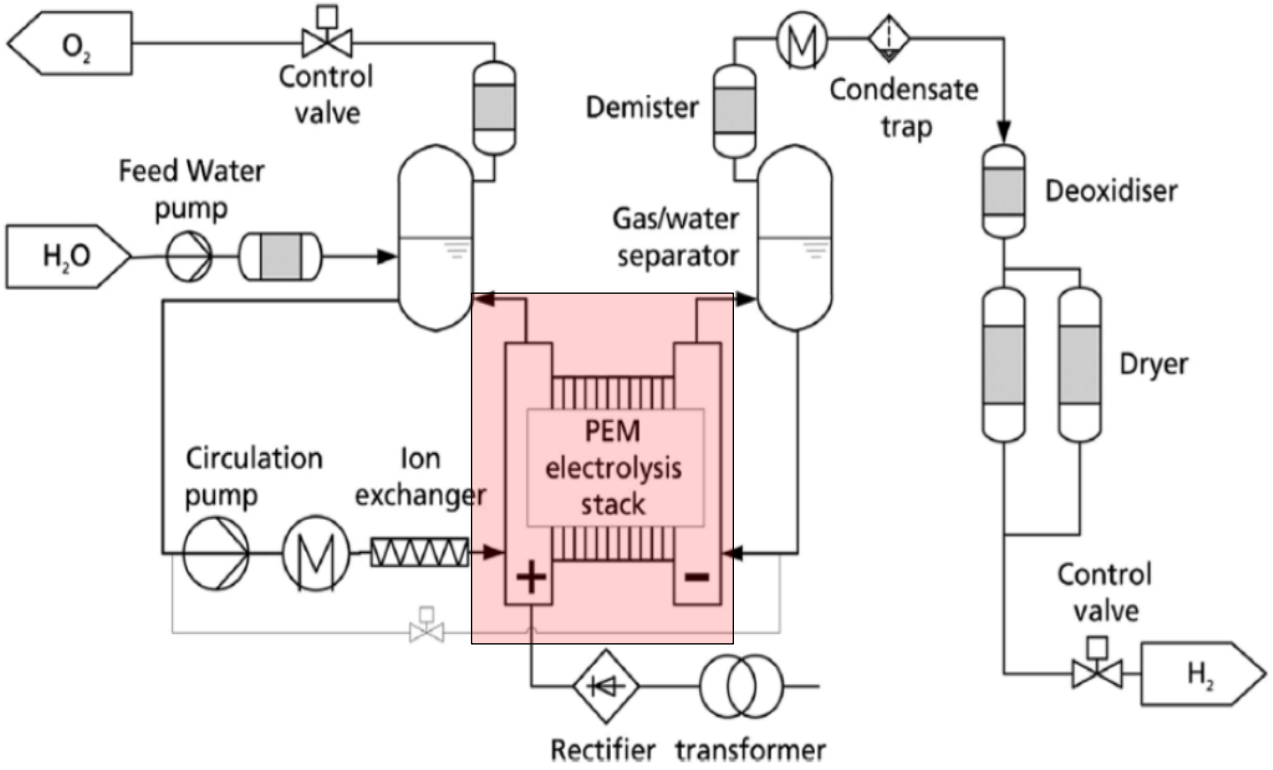


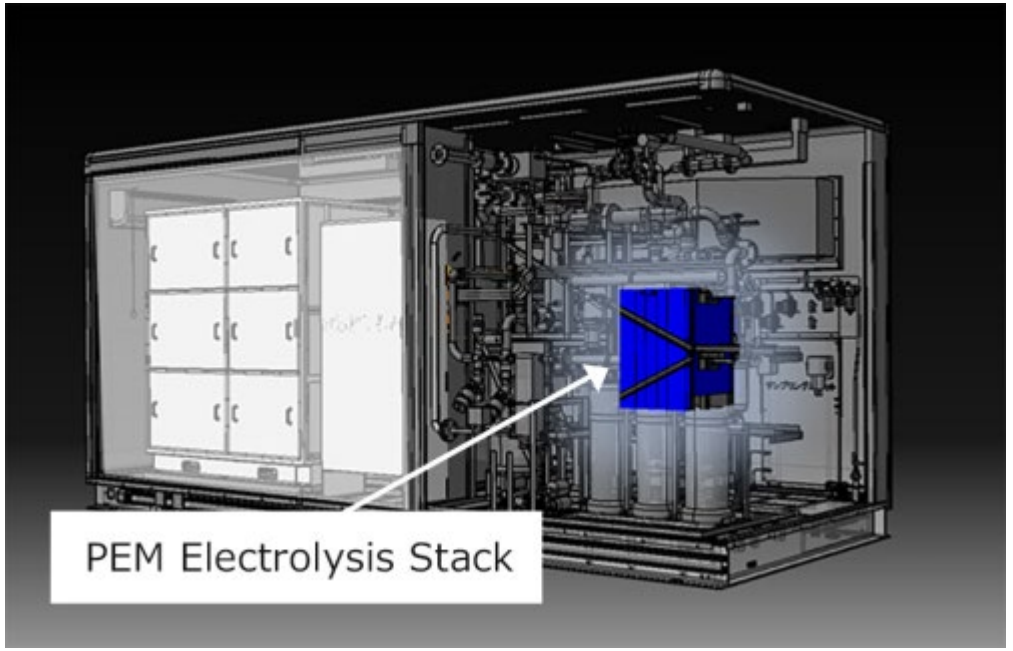
https://itm-power.com/how-it-works/pem

https://www.enlit.world/hydrogen/siemens-energy-and-air-liquide-partner-on-hydrogen-electrolyser-production/

# PEM Electrolyzer System

- The system contains the electrochemical cell stacks, piping, storage tanks, a power supply, a hydrogen and oxygen separator, pumps, water purification and other functional components.




https://www.greencarcongress.com/2023/03/20230312-toyota.html

Ref: Holst et al, "Cost Forecast for Low Temperature Electrolysis – Technology Driven Bottom Up Prognosis for PEM and Alkaline Water Electrolysis Systems", Fraunhofer Institute for Solar Energy Systems ISE, 2021

# Typical PEM Electrolyzer Cell Stack Design

- 1MW PEM stack capacity – 200 $Nm^3$/hr (40 lbs/hr) H2
- Operating pressure: 500-750 psi
- Operating temperature: 120-170 F
- ISO 22734/CSA B22734: guidelines on performance based requirements
- EU: must comply with Pressure Equipment Directive (PED 2014/68/EU) – CE marking required
- North America:
  - Ambiguity on Authority Having Jurisdiction (AHJ)
  - Lack of understanding on regulatory requirements – regulate as pressure vessels

https://engineering.airliquide.com/technologies/renewable-hydrogen

# ASME BPVC Section VIII Division 1 Scope

- Section VIII codes are the most adopted pressure vessel codes in jurisdictions in North America.
- Section III Division 1 Scope is defined in U-1(c)(2) with ten exclusions - is a Section VIII pressure vessel unless it can be claimed as the exclusions:

1) Vessels under other ASME Code Sections
2) Fired tube heaters
3) Pump or compressor components
4) Piping system
5) Piping components
6) Vessels containing water and air at certain conditions
7) Heated water tank
8) Vessels with design pressure no greater than 15 psi
9) Vessels internal dimensions no larger than 6 inches
10) Vessels for human occupancy

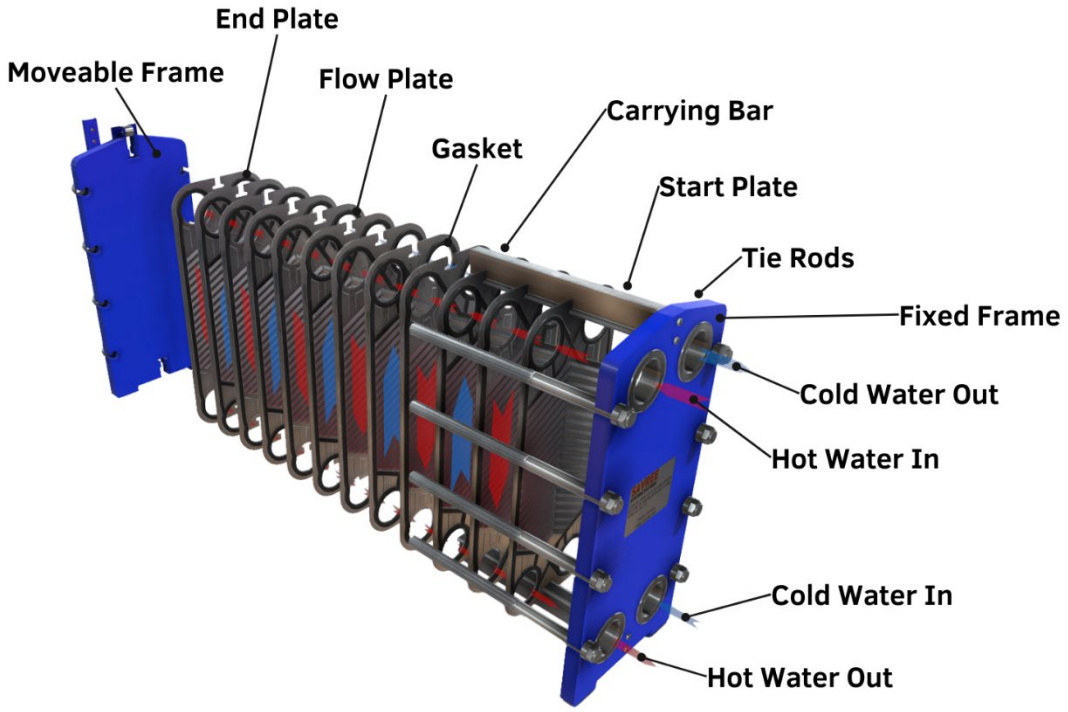
- Pressurized electrolyzer cell stacks are within the ASME BPV Section VIII code scope if the pressure and size exceeds the limits.

By current Code definition, Pressurized electrolyzer cell stacks are considered as ASME Section VIII pressure vessel

# Plate Heat Exchanger vs PEM Cell Stacks

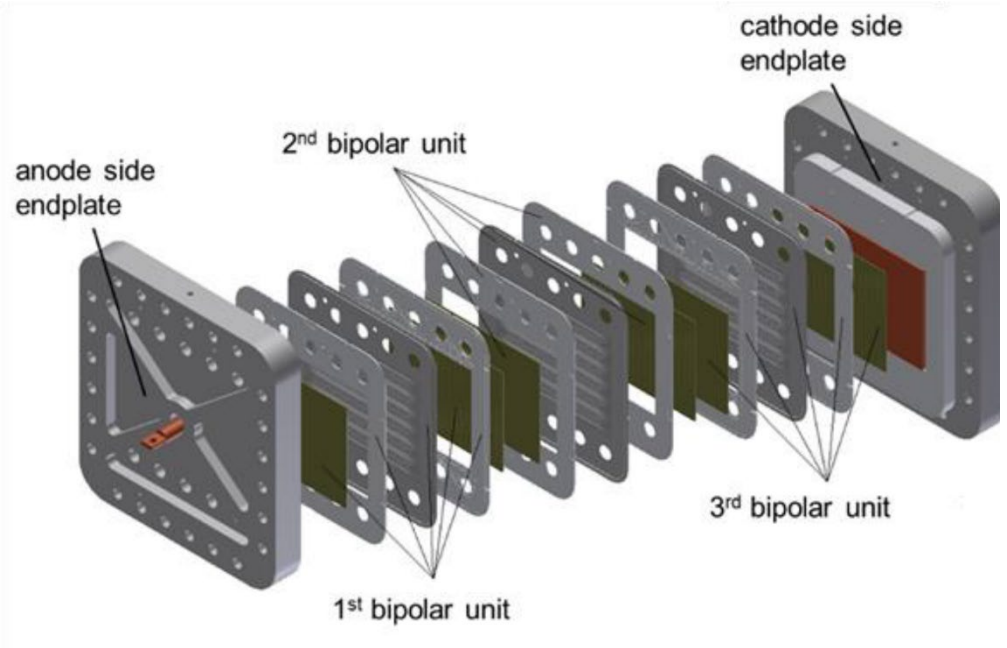
Gasketed plate heat exchangers (PHE) and electrochemical cell stacks (ECS) share many mechanical similarities: end plates, tie rods, gaskets, layered construction etc.

## Gasketed PHE




https://savree.com/en/encyclopedia/plate-heat-exchanger-phe

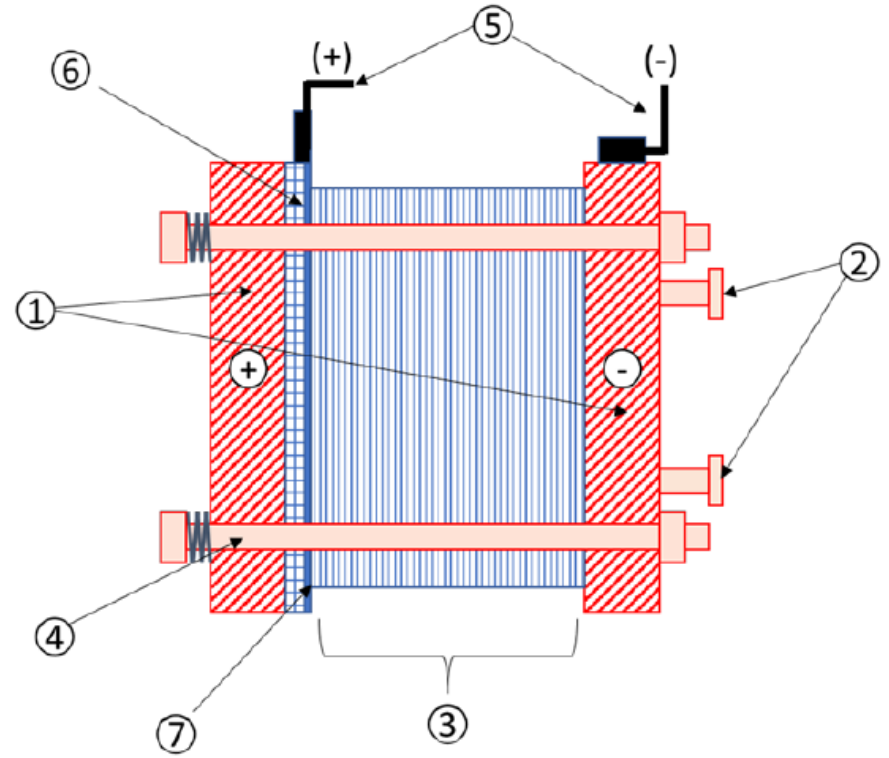
## PEM ECS




https://www.mdpi.com/1996-1073/15/10/3656

# Development of ASME Code Rules for ECS

- ECS Code boundary: all metallic pressure-retaining parts, including the endplates, bolting, and nozzles. These metallic materials shall comply with ASME material requirements.
- Recognition of non-metallic materials essential for electrolysis: dielectric plates, membrane and other internals.
- These non-metallic materials are exempted from code requirements as long as they meet ISO 22374 or ANSI/CSA B22734 type testing requirements.




ASME Code Case 3078

**ASME code boundary: metallic end plates, bolting and nozzles ASME code boundary**

**Exempted: dielectric plates, membrane and internal structures**

# Development of ASME Code Rules for ECS, Cont'd

- MAWP is determined from endplate, bolting and nozzles, similar as PHE in Appendix 45.
- Proof test or design calculation for cell pack is not required, similar as PHE in Appendix 45.
- Pressure test: hydrostatic or pneumatic test at 1.5XMAWP for 2 minutes
  - Consistent with type qualification test requirements in ISO 22734
  - Mandatory for every production unit
  - Witnessed by AI unless requirements in U-1(j) are met.
- Overpressure protection per ASME
- Certification: MDR U-1E/U-3E and mandatory compliance with ISO 22734 or ANSI/CSA B22734

# Section VIII Division 1 Code Case 3078

- ASME Section VIII Division 1 Code Case 3078 was approved in September 2023

**Approval Date: September 26, 2023**

*Code Cases will remain available for use until annulled by the applicable Standards Committee.*

**Case 3078**
**Rules for Gasketed Electrochemical Cell Stacks for Electrolysis**
**Section VIII, Division 1**

*Inquiry:* In the absence of rules covering gasketed electrochemical cell stacks in Section VIII, Division 1, what rules may be used to fabricate gasketed electrochemical cell stacks in compliance with Section VIII, Division 1?

*Reply:* It is the opinion of the Committee that the following rules may be used to fabricate gasketed electrochemical cell stacks in compliance with Section VIII, Division 1

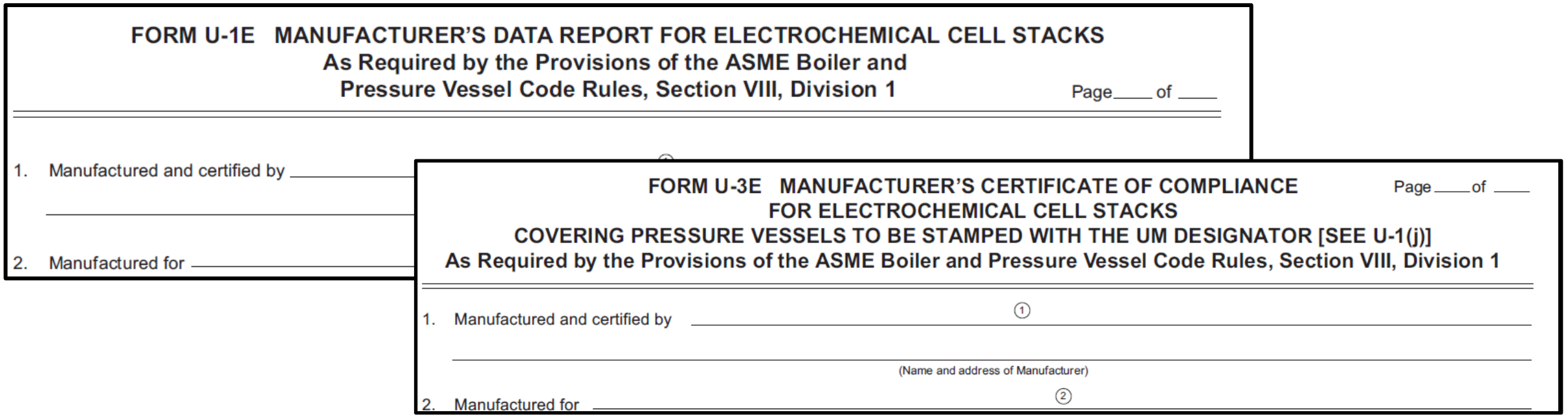
This Case does not address the process and electrical safety requirements of ECS. These requirements are commonly found in other applicable safety standards such as CSA/ANSI B22734 or ISO 22734.

## 3 MATERIALS

All pressure-containing parts shall be constructed using materials permitted by this Division except for dielectric materials, membrane materials, and other internal ECS component materials used for the purpose of electrochemical process provided that when used in ECS, they meet the type test requirements in CSA/ANSI

# Section VIII Division 1 Code Case 3078, Cont'd

- Forms U-1E and U-3E are provided in Code Case 3078
- Published code rules provide clarity on AHJ: easier for users to specify, easier for manufacturers to comply with ASME code, easier for Jurisdictions to accept product.
- An ASME Section VIII Task Group has been set up to incorporate the Code Case to a Mandatary Appendix.



FORM U-1E MANUFACTURER'S DATA REPORT FOR ELECTROCHEMICAL CELL STACKS
As Required by the Provisions of the ASME Boiler and
Pressure Vessel Code Rules, Section VIII, Division 1

Page ____ of ____

1. Manufactured and certified by _____

2. Manufactured for _____

FORM U-3E MANUFACTURER'S CERTIFICATE OF COMPLIANCE
FOR ELECTROCHEMICAL CELL STACKS
COVERING PRESSURE VESSELS TO BE STAMPED WITH THE UM DESIGNATOR [SEE U-1(j)]
As Required by the Provisions of the ASME Boiler and Pressure Vessel Code Rules, Section VIII, Division 1

Page ____ of ____

1. Manufactured and certified by ① _____

(Name and address of Manufacturer)

2. Manufactured for ② _____

# Summary

- Electrochemical cell stacks for electrolysis are considered as ASME Section VIII Division 1 pressure vessels based on current code scope.
- Code Case 3078 is developed based on existing code rules for PHE, with considerations of special materials and process used in water electrolysis.
- The Code Case provides code rules on design and construction of ASME Code compliant electrochemical cell stacks.
- The Code Case provides a  path for ECS manufacturers to comply with Jurisdiction requirements for pressure vessels.
- Incorporating CC3078 as a mandatory Appendix in Section VIII Division 1 is underway, and is expected to be in 2027 Code Edition