Corrosion & Low-Carbon Energies

DE LA RECHERCHE À L'INDUSTRIE

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WCO Webinar «Corrosion in low-carbon energies»

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What exactly are we talking about?

Low-carbon energies, as proposed by the Intergovernmental Panel on Climate Change (IPCC) of United Nations

- Renewables energies
- Nuclear energy
- Carbon capture and storage

Green energies, as described in media

- Environmentally friendly (“clean”)
- Sustainable
- Renewable

Green corrosion ?

- Green chemistry
- Sustainable
- Environmental issues

ERIKA (1999) “result of structural weakness caused by corrosion”

Mississippi Bridge, Minneapolis, August 1, 2007, 13 fatal structural weakness caused by corrosion

Green Power =  +  +  **Low carbon energies**

SYNOPSIS

- Introduction “Low carbon energies & Green power”
- **Green chemistry principles & corrosion**
  - Declination of the 12 principles
- **Green energies & corrosion**
  - Green technologies & materials
- **Conclusive remarks**

The 12 principles of Green Chemistry

1. Prevention of waste & pollution
2. **Atoms economy**
3. Less hazardous conditions
4. Design safer chemicals
5. Benin solvents
6. **Design for energy efficiency**
7. Use of renewable feedstocks
8. Reduce derivatives
9. **Catalysis**
10. Design for innocuous degradation
11. Pollution prevention
12. Safer for accident prevention

From P.T. Anastas & J.C Warner, “Green Chemistry: theory & practice, 1998, Oxford University Press, New-York, USA & S. Sarrade, La chimie d’une planète durable, Editions Le Pommier, 2011.

Principle 2…

Atoms economy: economy of “raw materials”

Illustration – extension of exploitation time of industrial equipements

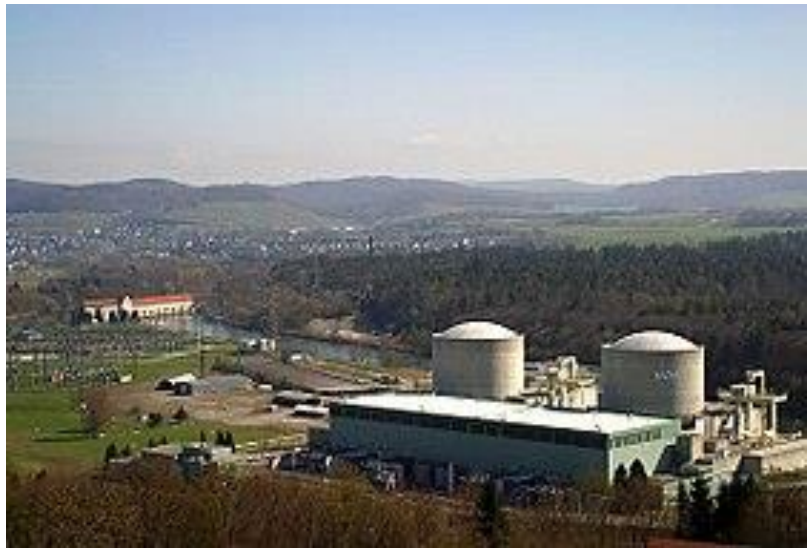
Initial nuclear power plants were planned for 30 years, new ones are planned for 60 years of operation and the exploitation of some old ones have been extended to 60 years or more, one reason being a very good corrosion resistance of the alloys.

Atoms economy:

7 000 tonnes for the confinement building,

550 tonnes for the steam generator,

330 to 510 tonnes for the vessel, ….



Beznau nuclear power plant (1969, 365 Mwe, initially planned for 40 years, the oldest nuclear power plant in operation today in Europe)

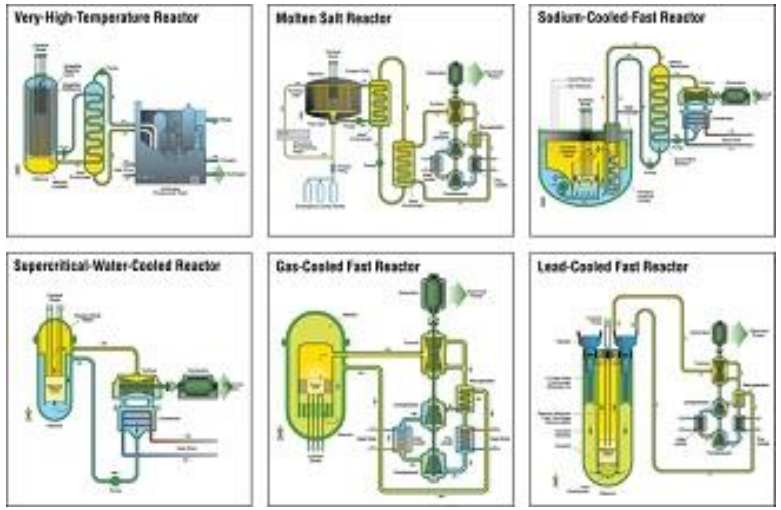
Principle 6…

Design for energy efficiency

Illustration – Efficiency of electricity production

Thermal electricity generation process is limited by the Carnot efficiency = $(T_{source} - T_{sink}) / T_{source}$.
High temperatures of T_{source} lead to a better efficiency, but corrosion is thermally activated.

A supercritical coal plant in Germany achieves thermal efficiency of 46%



Six nuclear energy systems for further development

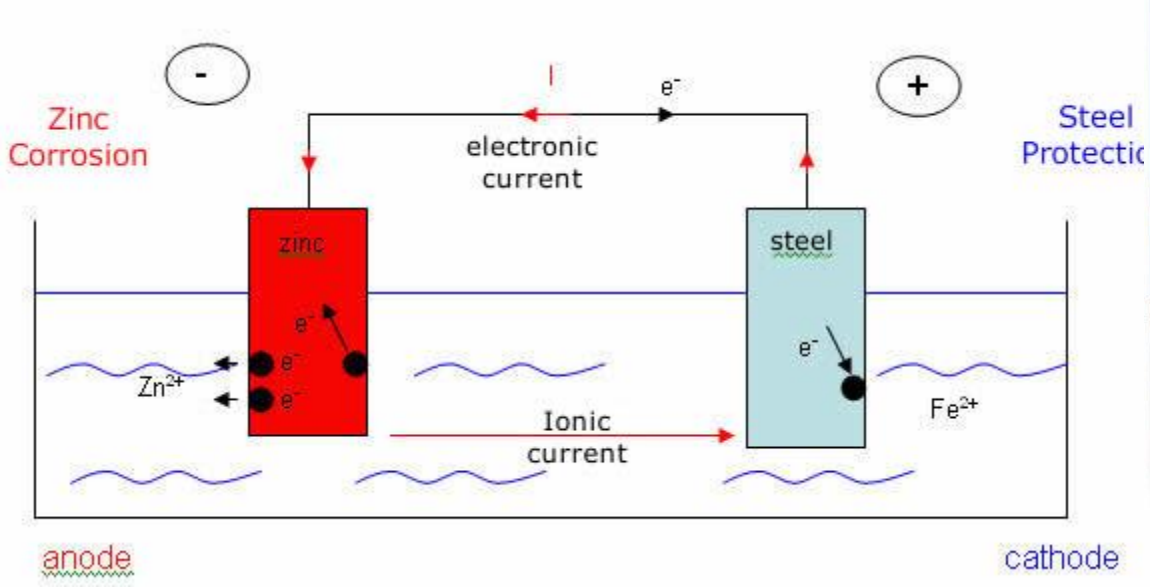
https://www.gen-4.org
https://www.oecd.org/officialdocuments/

Challenges:

- Thermally resistant alloys
- High temperature corrosion

Catalysis

Illustration – cathodic protection



Impressed Current Cathodic Protection (ICCP) for Offshore Wind

- Anodic reaction is increased on the « anode »
- Cathodic reaction is increased on the « cathode », the metal to protect
- To avoid cationic metallic pollution, imposed current has to be favorised

Intermediate comments

Corrosion follows the 12 principles of “green chemistry”

Design, inhibitors, coatings, monitoring, modelling…

Application & development of corrosion knowledge in corrosion is also needed for the development of green energy technologies

Atmospheric corrosion & protection

Seawater corrosion & protection

Geothermal energy

Development of supercritical technologies (water & CO_2)

Corrosion of pipes in $SCCO_2$ storage system
from G. Schmitt, White paper, WCO, 2009

Application & development of corrosion knowledge for sea water turbine (near & off shore)

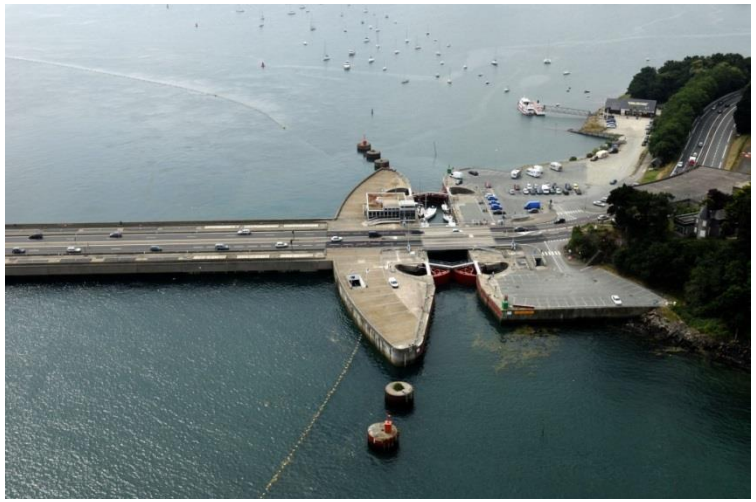
Sub seawater turbines are destroyed by corrosion

Les hydroliennes de Paimpol-Bréhat attaquées par la corrosion

ENERGIE & ENVIRONNEMENT | ENERGIES RENOUVELABLES | HYDROLIEN | NAVAL | EOLIEN | EDF
PAR BAPTISTE CESSIEUX PUBLIÉ LE 10/11/2017 À 10H42

La corrosion a attaqué les deux hydroliennes du site d'essai de Paimpol-Brehat. Celles-ci ont été retirées de l'eau en mai et juillet dernier. Immergées en 2014, ces deux prototypes n'ont jamais atteint l'un de leurs objectifs : produire de l'électricité pour 3000 foyers. Explications.

En mai et juillet dernier, les deux hydroliennes du site d'essai de **Paimpol-Brehat** ont été retirées de l'eau. Malgré leurs raccordements au réseau, les machines qui avaient été immergées en 2014 n'ont jamais atteint l'un de leurs objectifs : produire de

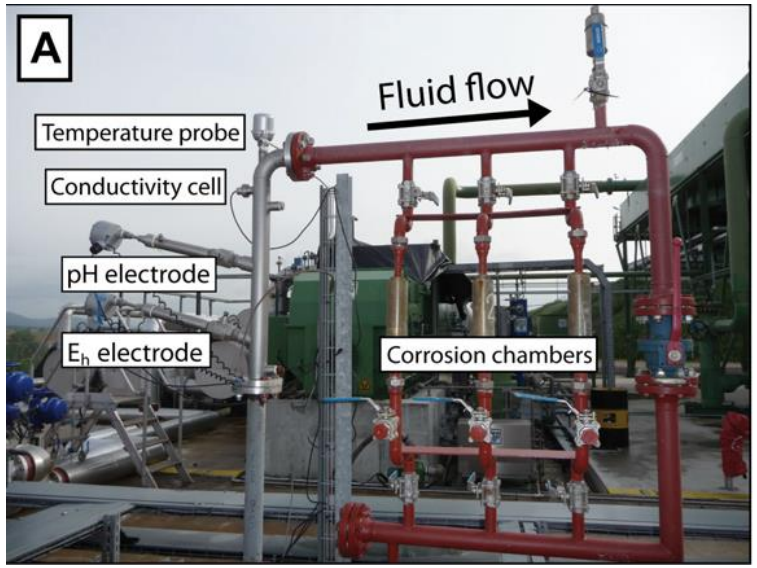


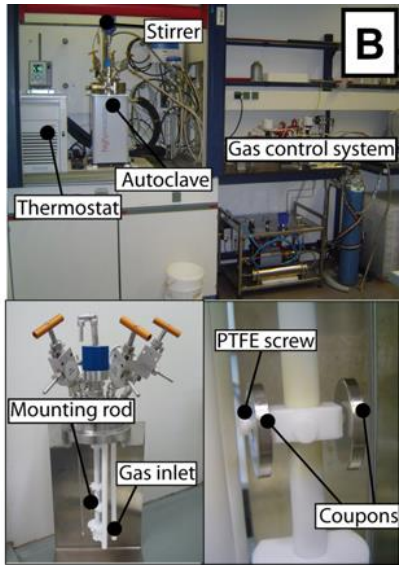
TIDAL ENERGY: Since 1966 a plant built across the estuary of the La Rance River in Brittany, France, produces around 500 GWh/year (turbines blades in titanium, all metallic parts are catholically protected by imposed current since the beginning)

Main issues: seawater corrosion, including corrosion-erosion phenomena

Geothermal energy

- **Geothermal energy is already well developed in some countries (Island, Philippines, …).**
- **Brine chemistry is the key point for corrosion resistance**
  - Some have low salt content "General corrosion rates in the geothermal district heating systems in Iceland are generally low, of the magnitude 1 µm/y. The reason is high pH (9.5), low-conductivity (200 µS/cm) and negligible dissolved oxygen", *from S. Richter, L.R. Hilbert, R.I. Thorarinsdottir, Corrosion Science 48 (2006) 1770–1778.*
  - But often, many brines are very corrosive environments (temperature, sulfur, high salt concentrations including chlorides, …). Corrosion investigation and monitoring are then needed to select the alloys.





Monitoring system used for to a better understanding of corrosion and scaling in an operating geothermal power plant (Soultz-sous-Forêts, France), *from N. Mundhenk & al., Corrosion Science 70 (2013) 17–28.*

Conclusive remarks & future events

Becoming green, energies need to pay more and more attention to corrosion issues

- To raise awareness of corrosion and corrosion control
- To identify international best practices
- To develop knowledge

2020: WCO workshops and forum on "Green Power & corrosion"

- ❑ **Forum during next NACE CORROSION** (March 17th, Houston, USA) postponed June 16th -?
- ❑ **Workshop during the 21st ICC** in Sao Paulo (Brazil), on May 10th-14th, 2020, postponed December 14th – 18th
- ❑ **Workshop during Eurocorr 2020** in Brussels (September 6th – 10th, 2020) - ?
- ❑ **Workshop in China** (12th – 13th November 2020)
- ❑ Other meetings under discussion in Australia, Bolivia…

Objective : a white paper for United Nations in 2021

WEBINAR «CORROSION and LOW CARBON ENERGIES »

- *Damien Féron (CEA, France)* Corrosion and low-carbon energies
- *Raul R. Rebak (GE, USA)* Environmental Degradation of Light Water Reactor Fuel Rods in the Entire Fuel Cycle
- *Digby D. Macdonald (University of California at Berkeley, USA)* Corrosion issues in Fusion Reactors
- *Gareth Hinds (NPL, UK)* Cost reduction of water electrolysers via insights into anode current collector corrosion
- *Ralph Bässler (BAM, Germany)* Corrosive CO_2-stream components, Challenging for materials to be used in CC(U)s applications
- *Polina Volovitch (ENSCP, France)* Corrosion & solar panels

Thank you for your attention

THE WORLD CORROSION ORGANIZATION

April 24th – Corrosion Awareness Day

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