Testing Hydrogen admixture for Gas Applications

Welcome to the 2nd THyGA Workshop

Presenters: Lisa Blanchard, Laurent Briottet, CEA, Fr

Host and Moderation: Johannes Schaffert, Gas- und Wärme-Institut Essen (GWI), Ger
schaffert@gwi-essen.de

Project Coordination: Patrick Milin, ENGIE, Fr
patrick.milin@engie.com

The THyGA project has received funding from the Fuel Cells and Hydrogen Joint Undertaking under grant agreement No. 874983. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

ORGANIZATION OF TODAY'S WORKSHOP – CODE OF CONDUCT

- We are glad you could make it!
- Please keep your microphones muted when not needed
- Audience video should also be disabled during the presentations
- Calling-in per telephone is possible – the number can be found in your calendar invitation

ORGANIZATION OF TODAY'S WORKSHOP – CODE OF CONDUCT

- **This workshop will be interactive**. Nevertheless, with 300 registered participants we need to streamline the agenda and focus discussion.
- Therefore, **please feel free to make a posting in the chat any time** if you have a question and/or use the raise-hand tool, if you see it (not always the case)
- Johannes will read the questions or announce your questions and unmute your microphones so you can speak to each other in person.
- Optional (if chat function does not work): You can **send questions** to schaffert@gwi-essen.de and patrick.milin@engie.com at any time.
- All questions that remain open today will not be forgotten, promised.

ORGANIZATION OF TODAY'S WORKSHOP – AGENDA

Agenda of today's THyGA Webinar on Hydrogen & Material Science	**10h**
Welcome to the meeting, rules for today, number and spectrum of attendees	Johannes Schaffert
Introduction by the THyGA Project	Johannes Schaffert
Hydrogen embrittlement	Lisa Blanchard and Laurent Briottet
➢ Discussion on embrittlement	Johannes, Lisa, Laurent
Hydrogen permeation and leakage	Lisa Blanchard and Laurent Briottet
Presentation of the WP3 test on leakage	Lisa Blanchard and Laurent Briottet
➢ Questions and open Discussion	Johannes, Lisa, Laurent
End of meeting	**12h**

THE THYGA PROJECT & CONSORTIUM

The project has been created by 9 partners to answer the Horizon 2020 call FCH-04-3-2019.

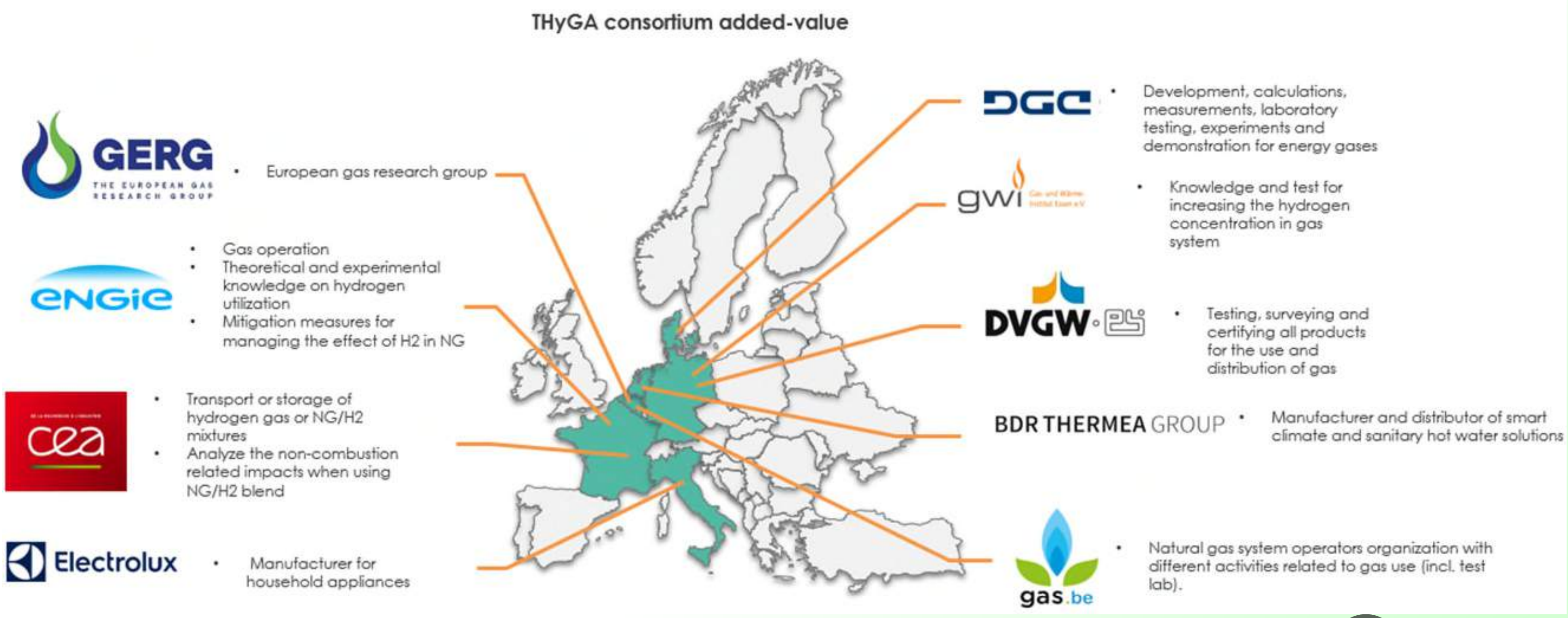
- *"Research is required to identify and verify the impacts of … H2NG blends on the combustion characteristics … of appliances together with the potential impacts on appliance safety, efficiency, lifetime and environmental performance (e.g. NOx emissions)."*
- *Low, medium and high hydrogen concentrations in natural gas should be investigated:*
    - *Low = <10% Vol.*
    - *Medium = 10-30% Vol.*
    - *High = 30-60% Vol.*

The Project focus lies on testing. Up to 100 tests are planned, including various heating, cooking, catering, CHP, FC, ... appliances.

Project period: 2020-2022

project budget: 2,5M€.

visit: https://thyga-project.eu/



OBJECTIVES OF THE PROJECT

- THyGA project (Testing Hydrogen Admixtures for Gas Appliances) sets out to develop and communicate a detailed understanding of the technical impact of blends of natural gas and hydrogen on end use applications, specifically in the domestic and commercial sector.
  - Screening and segmenting the portfolio of appliance technologies in the domestic and commercial sectors and assessing the impact of hydrogen admixtures.
  - Testing up to 100 commercial and residential gas appliances to provide a generic protocol that can be adapted for virtually any appliance.

- To go further, the project consortium will identify and recommend appropriate codes and standards that should be modified or adapted to answer the needs, and develop a strategy for addressing the challenges for new and existing appliances.
  - Developing a validated certification protocol for different levels of H2 in natural gas
  - Making recommendations for manufacturers, decision makers and end-users along the gas value chain for appliance design, manufacture and certification.

THyGA

STRUCTURE AND INTERACTION WITH ADVISORY PANEL

WP2 – Status of gas utilization technologies

Segmentation and inventory of the gas utilization technologies in Europe

X

Impact of hydrogen admixture on combustion processes

→

Test program
&
Selection of the appliances to be tested

WP1 – Project management
General coordination, WP coordination and relation to FCH 2 JU

WP3 – Experimental work
What happens on the field with H2 injection ?
Generic test protocol (safety, efficiency, emissions, comfort)

***Tests on ~100 appliances** for domestic and commercial end use (short and long term)*

WP4 – Standardization
How can we certify an appliance according to H2 rate in NG?
Development of test procedures including definition of test gases
Validation through tests

WP5 – Recommendations for mitigation measures
How can we increase the acceptable H2 rate?
Identification of mitigation measures to increase H2 rate
Validation through tests

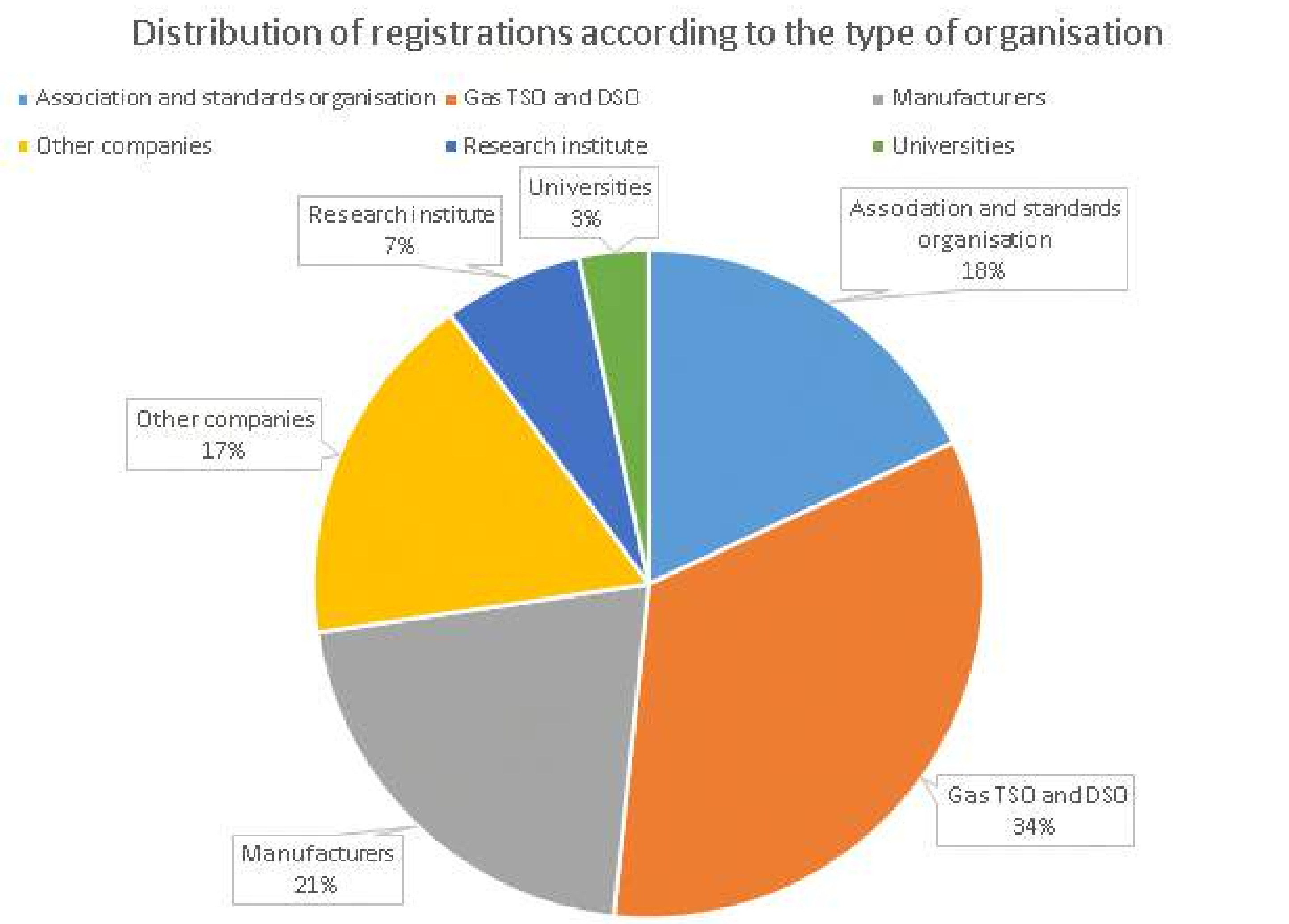
Advisory Panel group
The objective is to ensure a constant challenge of the processed results and a great opportunity for a wide dissemination/communication plan to share results.

« market and dissemination »
Associations, DSO, academia

« Technology»
Manufacturers (appliances, burners, controls, sensors)

WP6 – Communication, dissemination and exploitation
dissemination to stakeholders, press, workshops, etc.
Green H2 admixture roadmap from the end-user point of view

TODAY'S WORKSHOP – SPECTRUM OF PARTICIPANTS



Non-combustion related impact of introducing hydrogen admixture in gas network distribution

Webinar on material science, 26th of October 2020

L. Blanchard, L. Briottet

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OUTLINE

- HYDROGEN EMBRITTLEMENT (HE)
  - Context and definition of HE
  - Observation of HE (at room temperature and in gas environment) and mechanisms
  - Materials evaluation toward HE
  - Influencing factors
  - Impact of HE on the materials used in gas distribution network
  - Standards
- NON-EMBRITTLEMENT CONCERNS
  - Chemical compatibility
  - Permeation and leakage
- LEAKAGE TEST

BACKGROUND – DISTINCTION BETWEEN CORROSION AND HE

CORROSION ≠ HYDROGEN EMBRITTLEMENT

- Corrosion definition by the ISO 8044 :

" Physicochemical interaction between a metallic material and its environment that results in changes in the properties of the metal, and that may lead to significant impairment of the function of the metal, the environment or the technical system, of which these form a part. "

- Can apply to:
  - Metallic materials;
  - Concrete;
  - Minerals;
  - Polymers

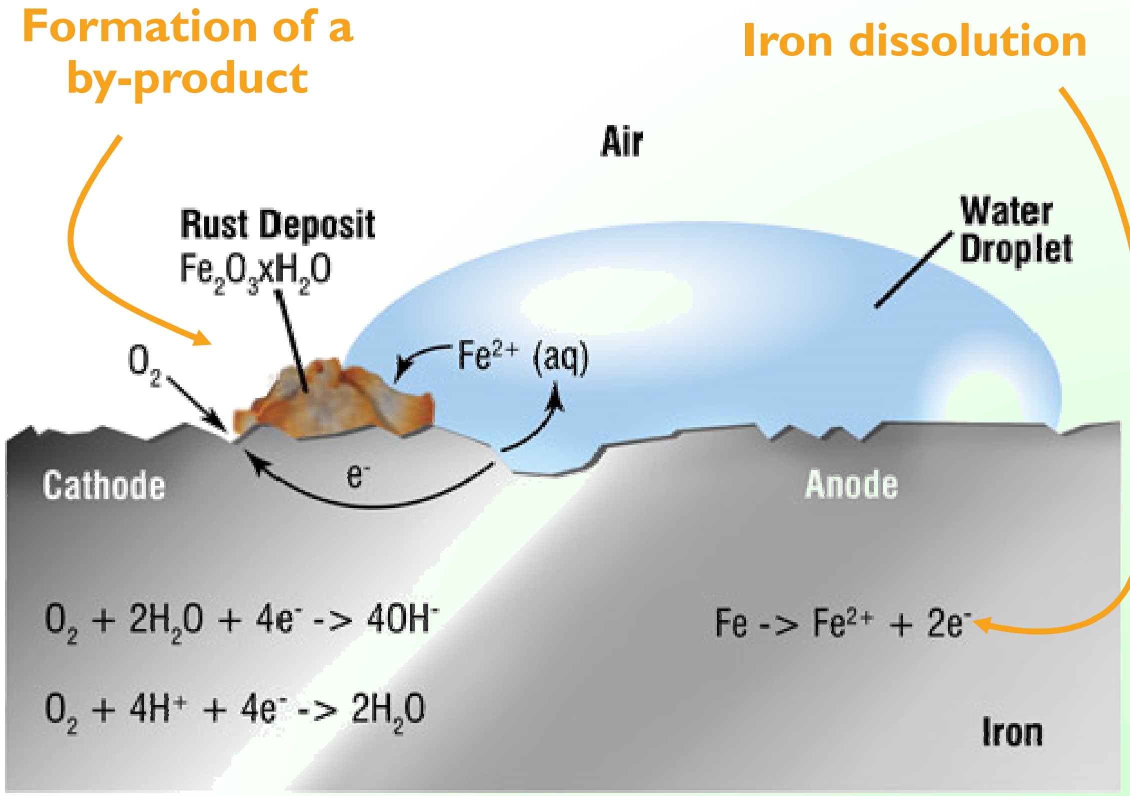
www.corrosionpedia.com

BACKGROUND – DISTINCTION BETWEEN CORROSION AND HE

- **Wet corrosion**
  - Electrochemical attack occuring in the presence of a fluid containing oxygen
  - Electrochemical mechanism
  - Metal dissolution and formation of deposit

- **Dry corrosion**
  - Chemical attack occuring in the presence of a reactif
  - Absorption mechanism
  - Metal dissolution and formation of a superficial oxyde layer

- Example of ferrous corrosion in aqueous medium:

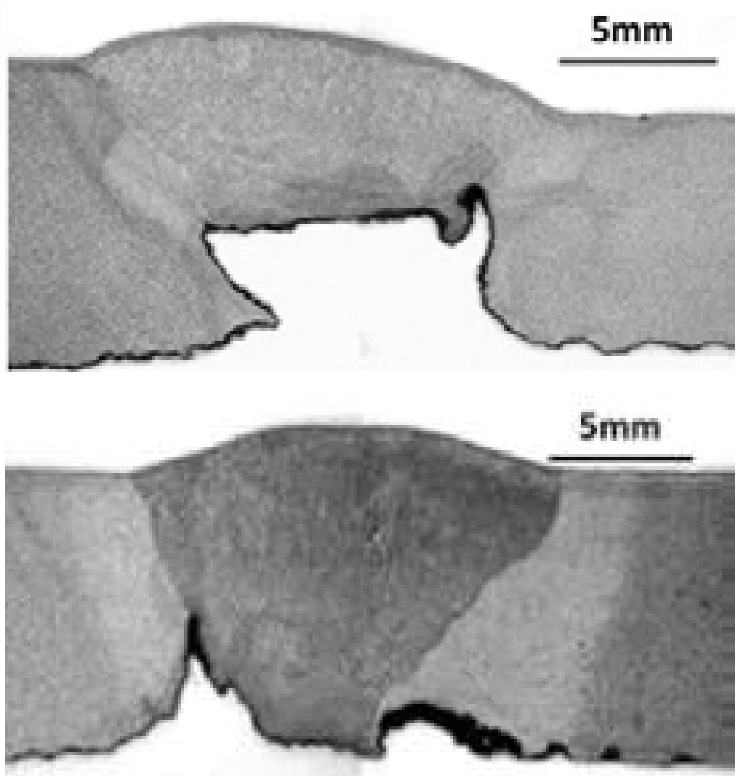


www.machinerylubrication.com/Read/29116/inhibiting-rust-corrosion

BACKGROUND – DISTINCTION BETWEEN CORROSION AND HE

CORROSION CRACKING

Corrosion of gas pipeline welds due to welding imperfections.



Alloy dissolution

HYDROGEN CRACKING

Cracking in duplex stainless steel shielded metal arc (SMA) weld due to hydrogen ingress during the process

Embrittlement of the alloy

A Guide to Failure Analysis for the Oil and Gas Industry,Alber Sadek, 2016

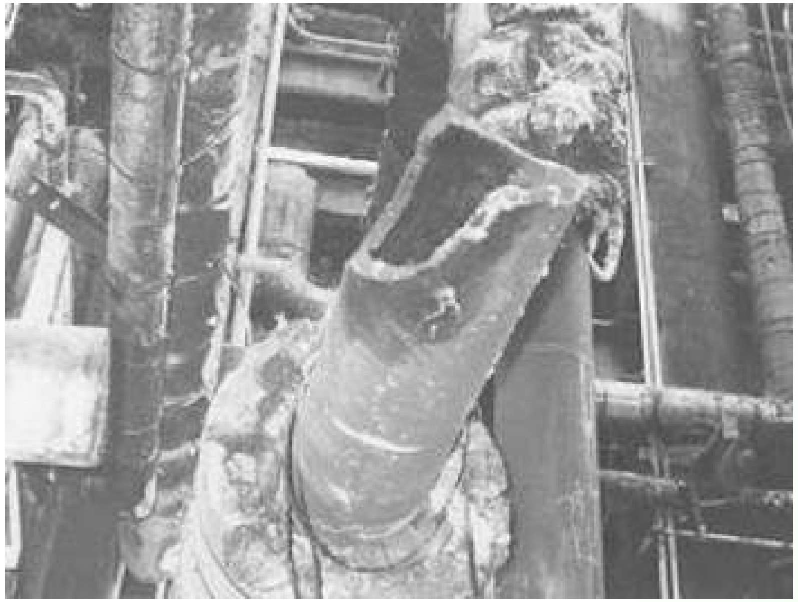
Hydrogen Cracking of Ferritic-Austenitic Stainless Steel Weld Metal, A. J. Leonard, 2000

CONTEXT

San Francisco–Oakland Bay Bridge, 2013

SFOBB rods failure, H.E. Townsend et al., 2015

Chemical plant, 2001



Failure of piping by hydrogen attack, TG. Kim, 2002

Oil field, 2006

Garn west failure, S. Huizinga et al., 2006

HYDROGEN EMBRITTLEMENT - MECHANISMS

HE
(Hydrogen embrittlement)

HTHA
(High temperature hydrogen attack)
400-500°C and ~100 bar

HIC
(Hydrogen induced cracking)
In the presence of H_2S

HE
Room temperature and
gaseous environment (H_2)

Hydrides cracking
(Phase transformation)
Zirconium and titanium alloys

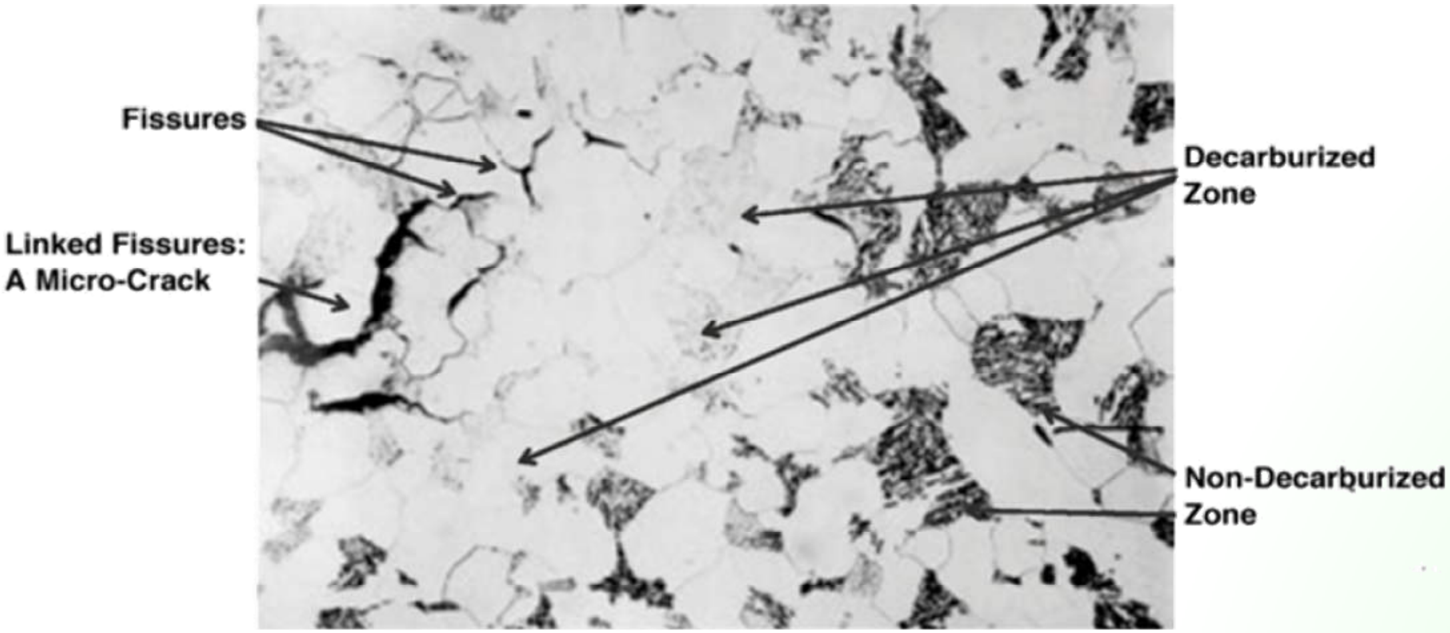
HEDE
(Hydrogen induced decohesion)

AIDE/HELP
(Hydrogen induces local
plasticity)

HESIV
(Hydrogen enhanced
stress-induced vacancy)

HIGH TEMPERATURE (400-500°C) HIGH PRESSURE (~100 BAR)

- High temperature hydrogen attack (HTHA)



API RP 941, 2016

Hydrogen reacts with the carbon in solution:

<u>External decarburization</u>

- Decrease in hardness and increase in ductility;

→ Minor impact

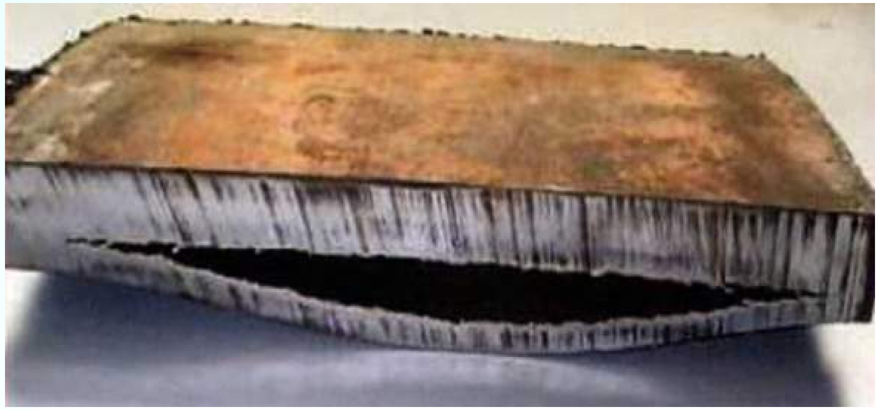
<u>Internal decarburization</u>

- Formation of methane
- Accumulation in the microstructure
- Development of voids coalescence and substantial deterioration of mechanical properties

→ **Failure**

HYDROGEN INDUCED CRACKING – H_2S ENVIRONMENT

- HIC: Hydrogen Induced Cracking



whatispiping.com/sour-experiences-HIC

Surface blistering

Detailed mechanism of surface blistering in sour environment, Crolet, 2001

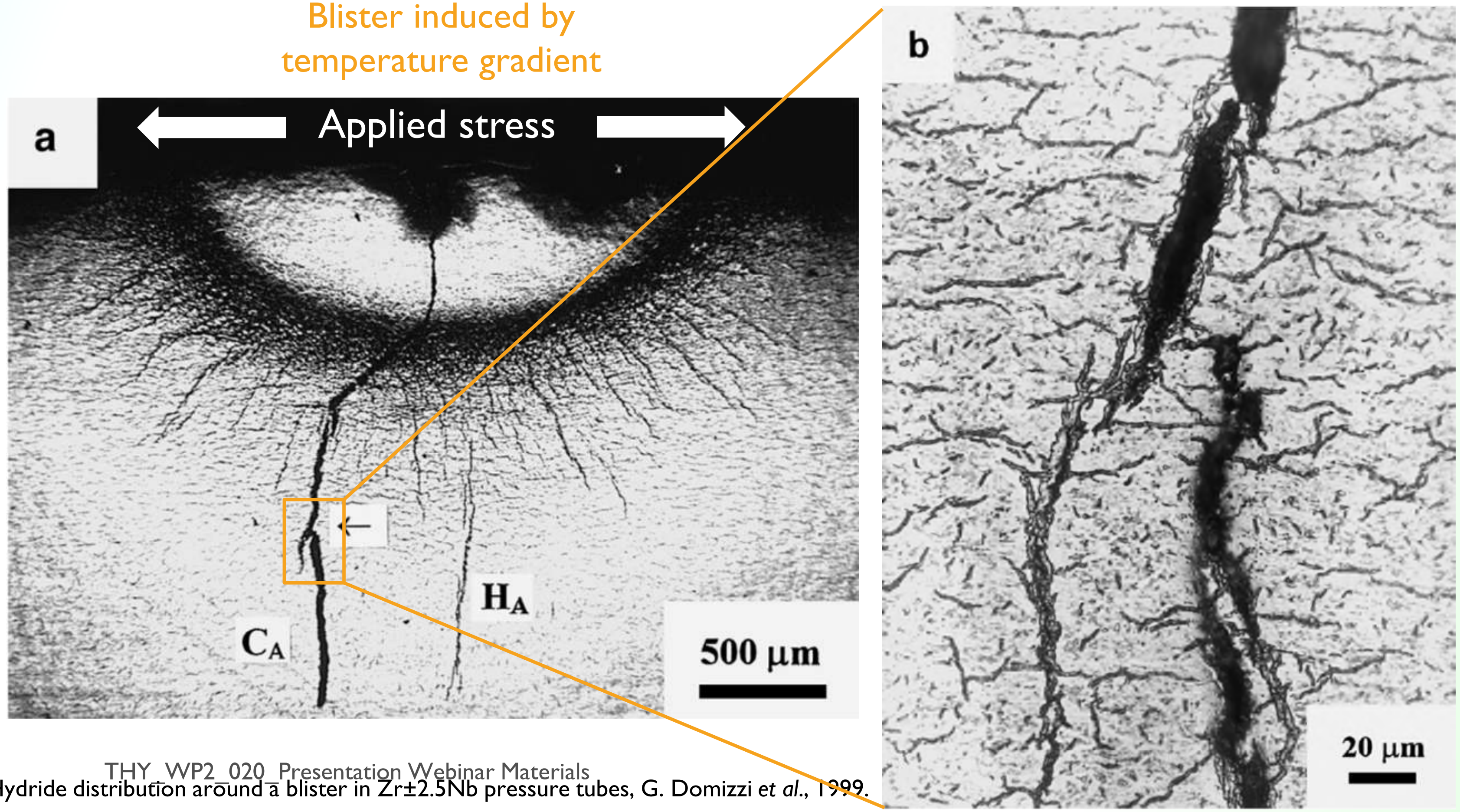
1. In sour environment: H_2S facilitates hydrogen to get into the material.
2. Hydrogen adsorbed into the material is recombined as H_2 gas.
3. Pressure accumulates in the microstructure and inducing the formation of blisters.

FORMATION OF HYDRIDES INDUCING EMBRITTLEMENT (ZR AND TI ALLOYS)

- Formation of hydrides inducing embrittlement in zirconium alloy

Blister induced by temperature gradient

Hydrides distribution

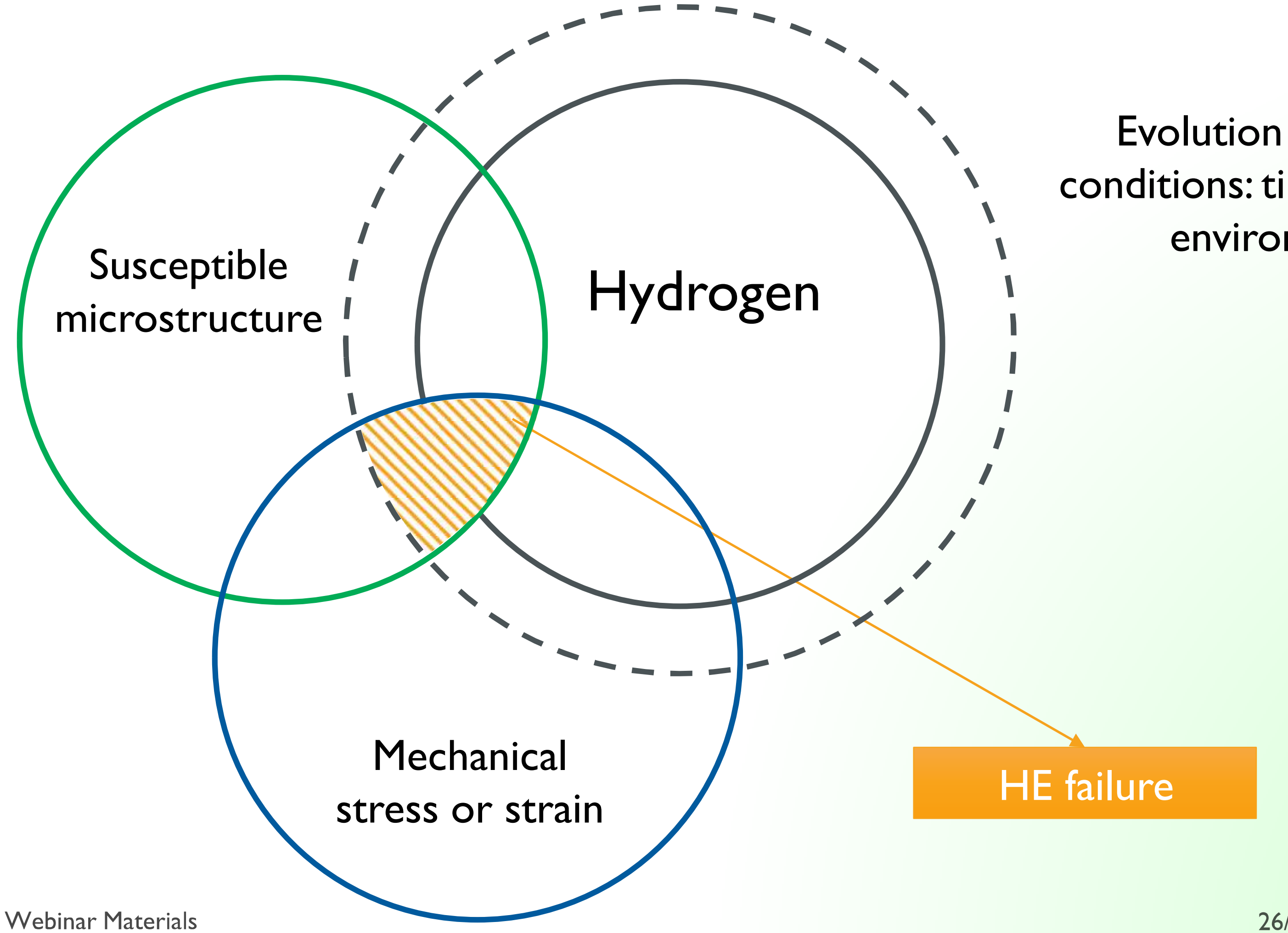


Hydride distribution around a blister in Zr±2.5Nb pressure tubes, G. Domizzi *et al.*, 1999.

1. Failure of the blister in the direction normal to the applied stress
2. Crack propagation through the base material embrittled by the hydrides formation. Crack propagates at the interface ZrH_x / Zr
3. Ductile propagation through the base metal non embrittled by hydrides formation

HYDROGEN EMBRITTLEMENT – ~RT AND GASEOUS ENVIRONMENT

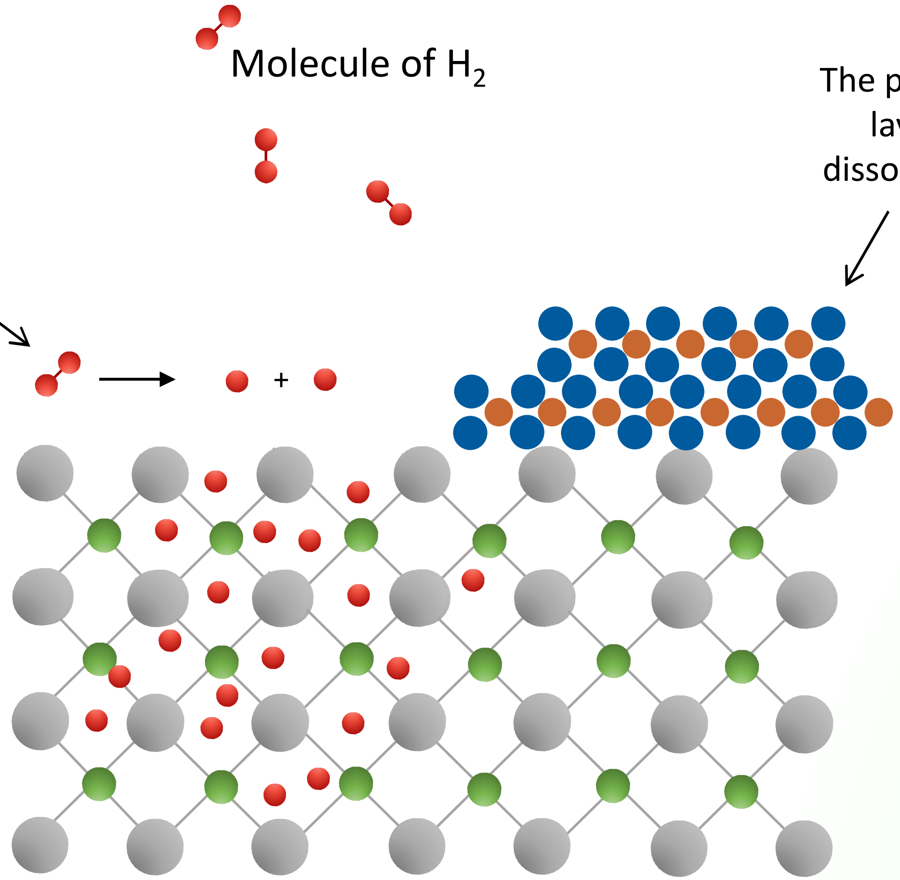
Crystallographic microstructure, grain size, phases, dislocation density, precipitates, etc.



Evolution with charging conditions: time, temperature, environment, etc.

BACKGROUND - HYDROGEN ENTRY IN THE METAL

Hydrogen dissociates at the metal surface
$H_2 \rightarrow 2H^+ + 2e^-$



The presence of an oxyde layer may hinder H dissociation and/or entry

Hydrogen get adsorbed in the first atomic layer

Hydrogen get absorbed in the microstructure

Solubility of hydrogen in the material (Sievert's law) :

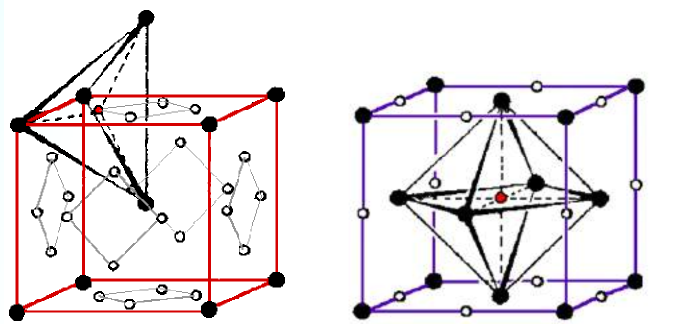
$$C_H = K_H \, P_{H2}^{\,½}$$

C_H – hydrogen concentration
P_{H2} – hydrogen partial pressure
K_H – Sievert's constant

BACKGROUND - HYDROGEN TRANSPORT IN THE METAL LATTICE

1. Hydrogen diffusion and solubility

Tetragonal sites   Octahedral sites



BCC (ferritic steels)   FCC (austenitic steels, Al, Cu)

Hydrogen diffusion in steels:

Ferritic : 10^{-8} - 10^{-9} $m^2.s^{-1}$

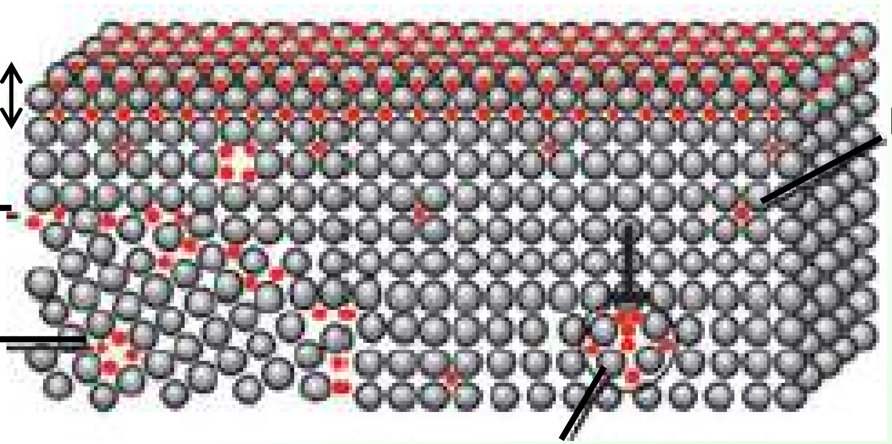
Austenitic : ~10^{-16} $m^2.s^{-1}$

Hydrogen solubility in steels :

Ferritic : ~ 0,5 $molH_2.m^{-3}.MPa^{-1/2}$

Austenitic : ~ 70 $molH_2.m^{-3}.MPa^{-1/2}$

2. Hydrogen trapping in the metal lattice



A. Pundt et al. 2006.

3. Influence of stress and strain

Hydrostatic stress gradient → induces hydrogen diffusion

Hydrostatic stress → induces higher hydrogen solubility

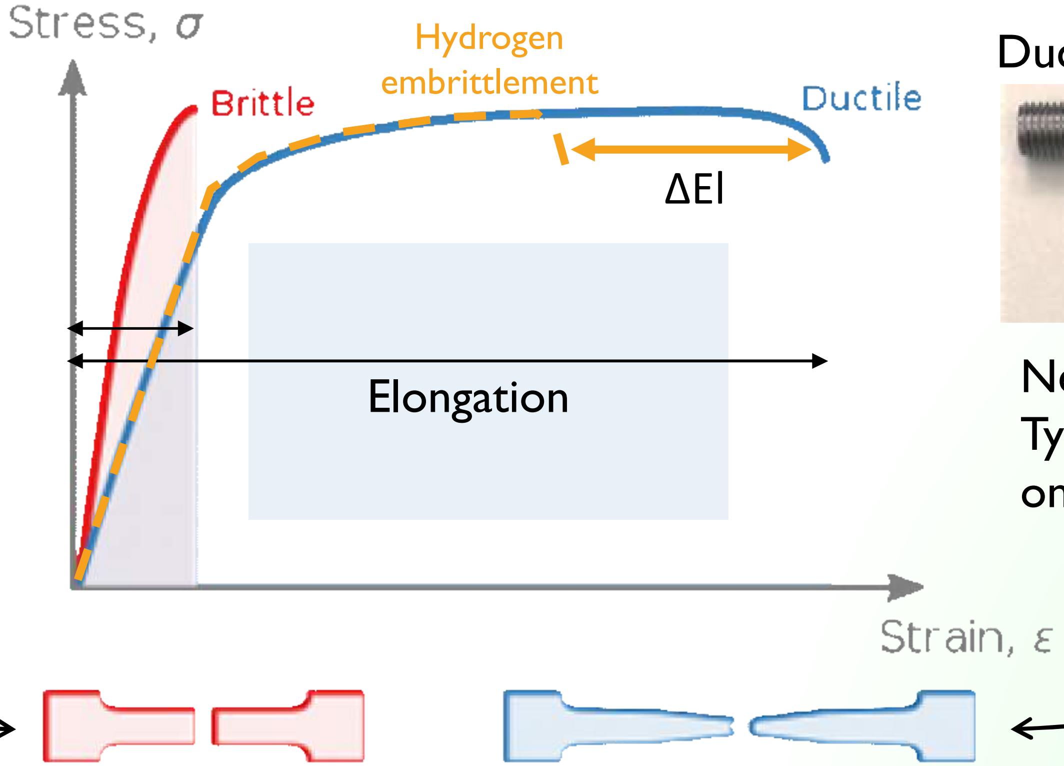
Dislocation → H trapping and diffusion

BACKGROUND – DUCTILITY IN METAL

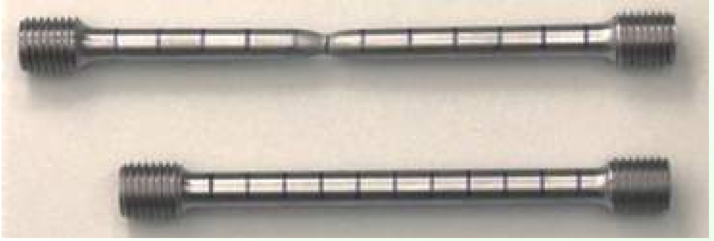
Tensile curves: comparison brittle to ductile materials

Brittle failure

Absence of necking
Secondary cracks
Cleavage



Ductile failure



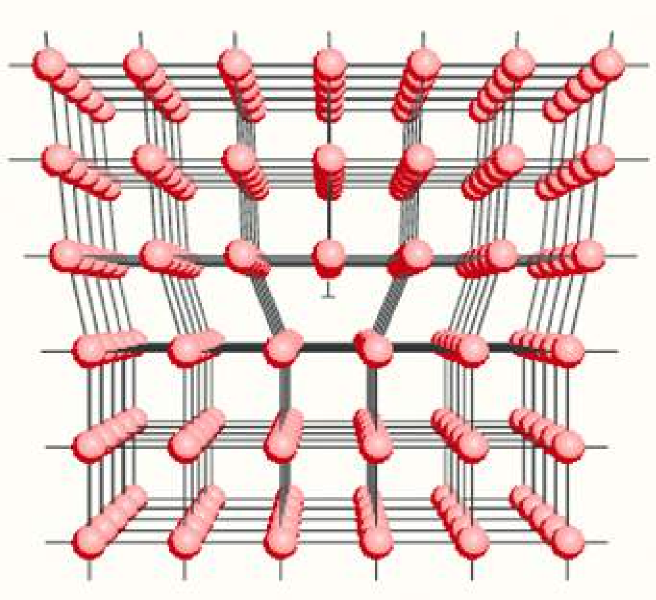
Necking
Typical ductile features on the fracture faces

Hydrogen embrittlement → decrease of the total elongation and necking

BACKGROUND – DISLOCATIONS

Dislocations:

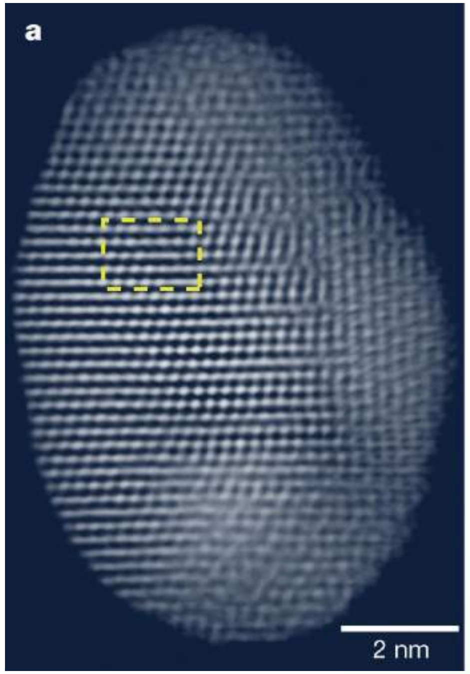
Linear defect enabling plastic deformation in metals

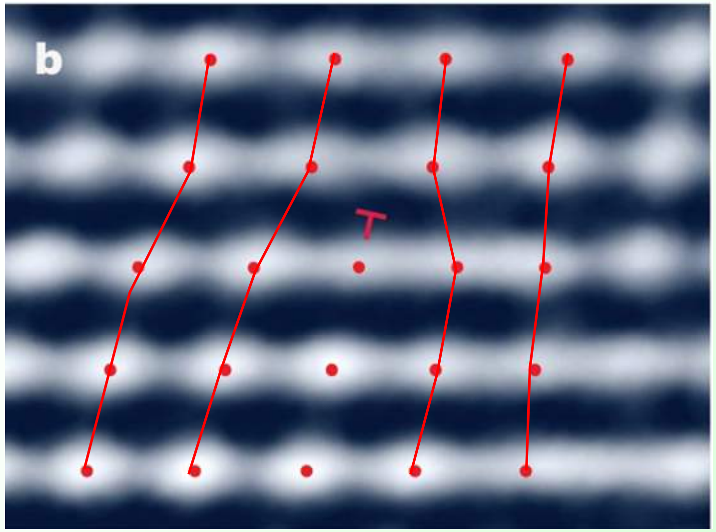


J. McNally, 2013

Edge dislocation in a crystal lattice

Observation of the 3D core structure of an edge dislocation at atomic resolution.





C.C. Chen, 2013

View of an edge dislocation using transmission electronic microscope (TEM).

HYDROGEN EMBRITTLEMENT - MECHANISMS

HE
(Hydrogen embrittlement)

HTHA
(High temperature hydrogen attack)
400-500°C and ~100 bar

HIC
(Hydrogen induced cracking)
In the presence of H_2S

HE
Room temperature and gaseous environment (H_2)

Hydrides cracking
(Phase transformation)
Zirconium and titanium alloys

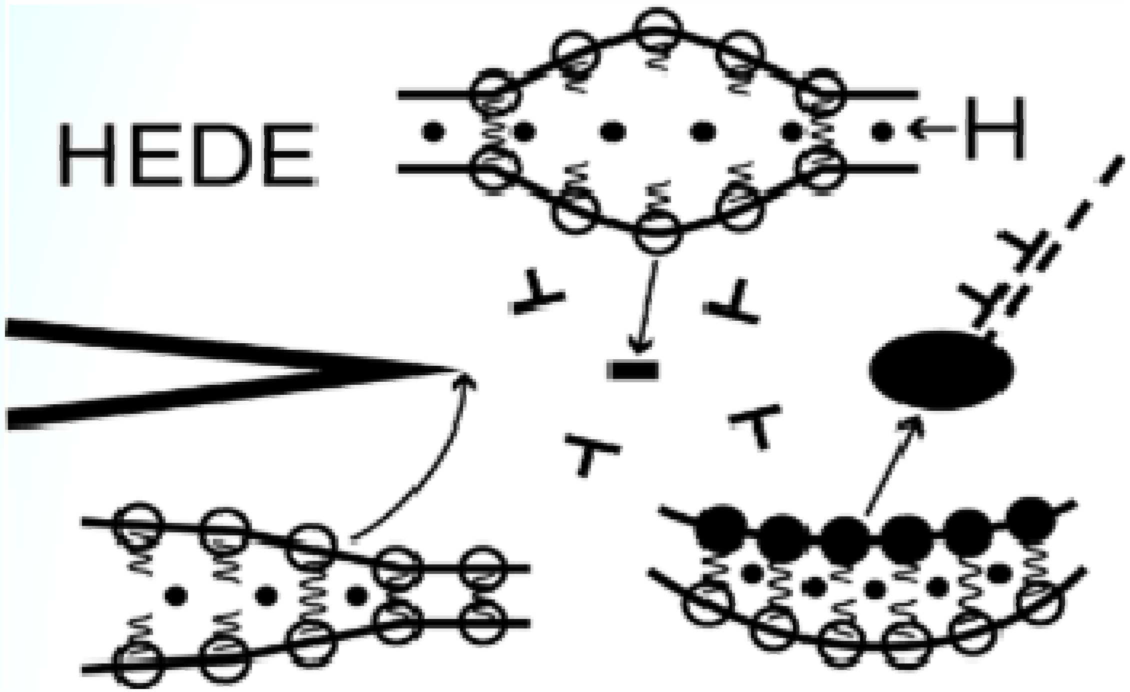
HEDE
(Hydrogen induced decohesion)

AIDE/HELP
(Hydrogen induces local plasticity)

HESIV
(Hydrogen enhanced stress-induced vacancy)

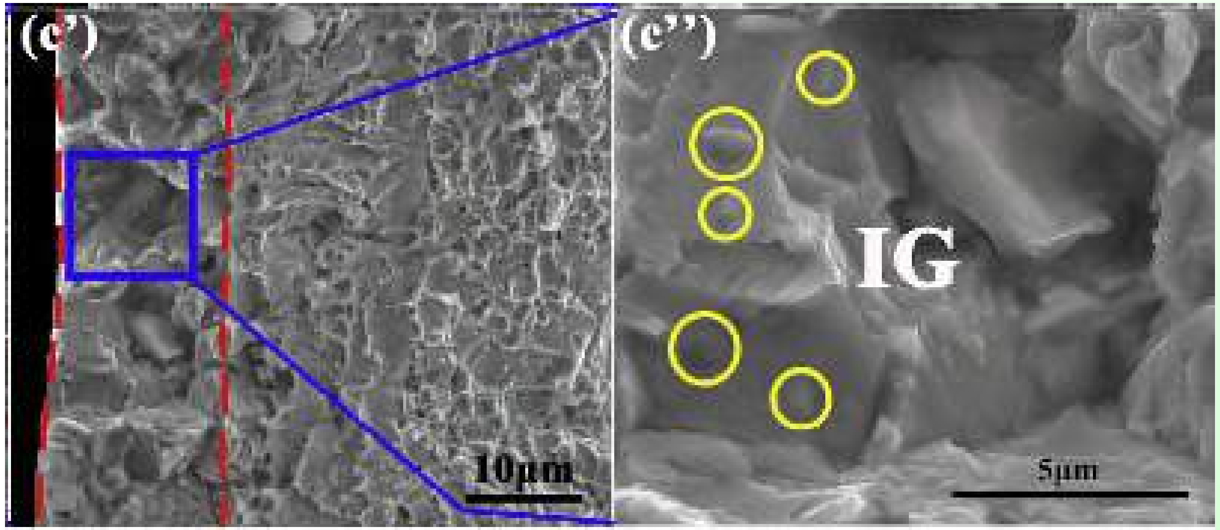
HYDROGEN ENHANCED DECOHESION (HEDE)

- Hydrogen weakens the atomic cohesive bond between atoms, grain boundaries, matrix/precipitates interfaces.



Hydrogen embrittlement (HE) phenomena and mechanisms, Lynch, 2011

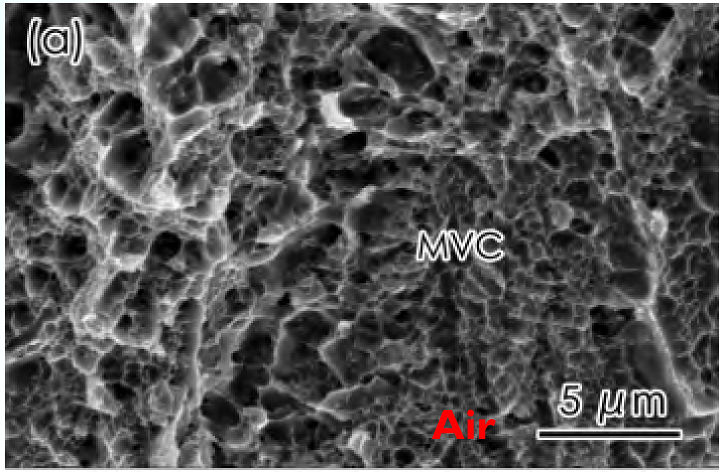
Intergranular or cleavage features on the fracture faces

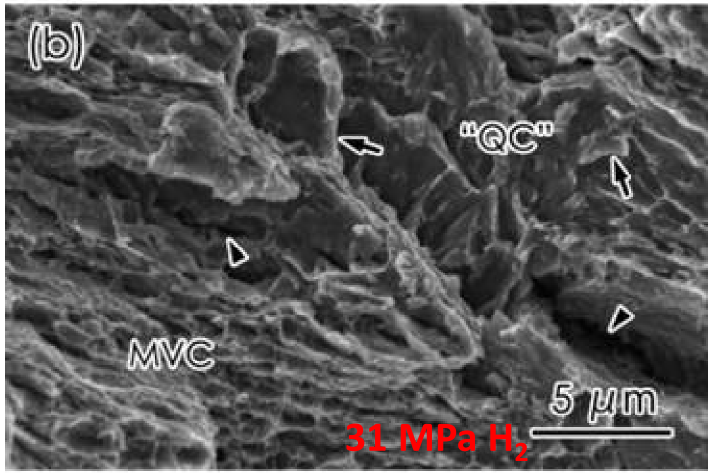


Tensile mechanical properties and fracture behaviors of nickel-based superalloy 718 in the presence of hydrogen, X. Li, 2018.

INTERACTION HYDROGEN PLASTICITY – MACROSCOPICAL OBSERVATION

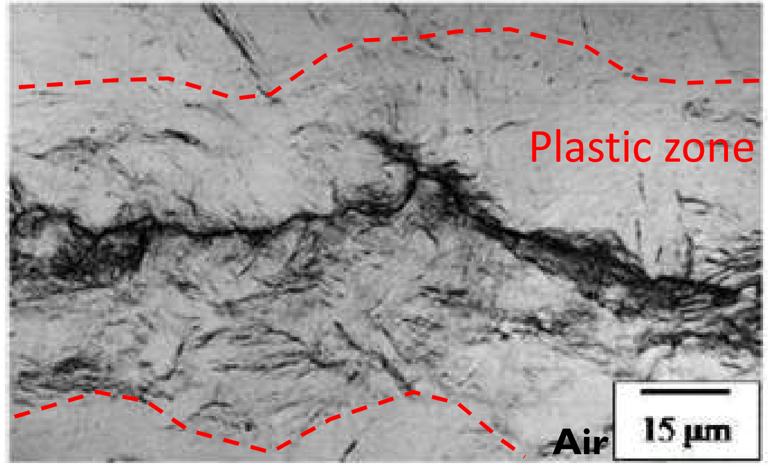
Fracture surfaces of Steel-B550

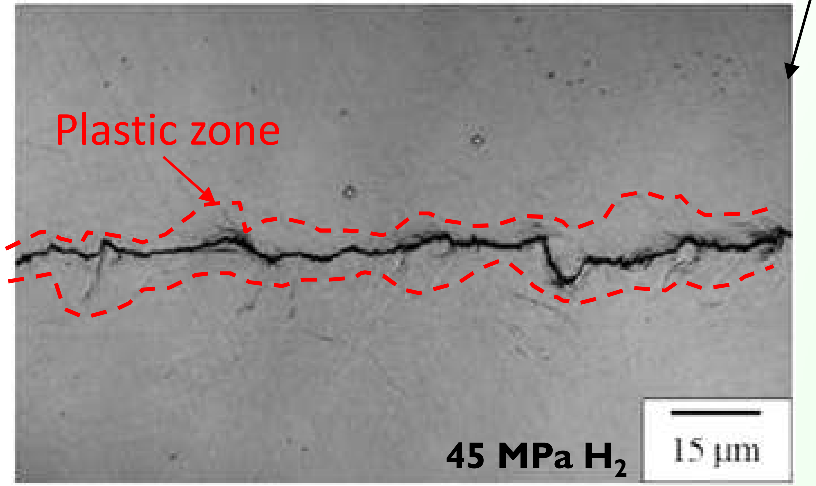




Nagao, 2014

Ni-Cr-Mo <steel





Macadre 2010

Identical stress concentration applied

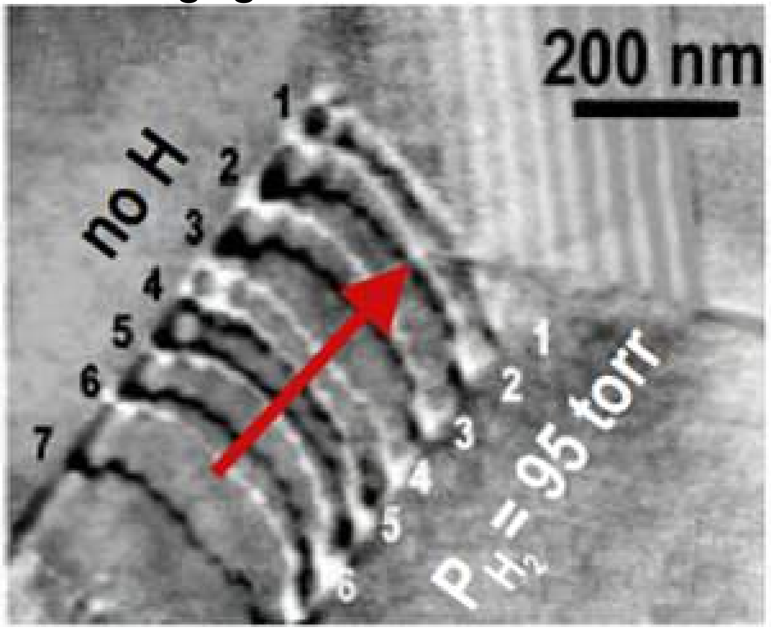
➡ Loss of ductility induced by local plasticity

INTERACTION HYDROGEN PLASTICITY - DISLOCATIONS

- **Interaction hydrogen/dislocations**

Hydrogen promotes dislocation shielding

TEM imaging

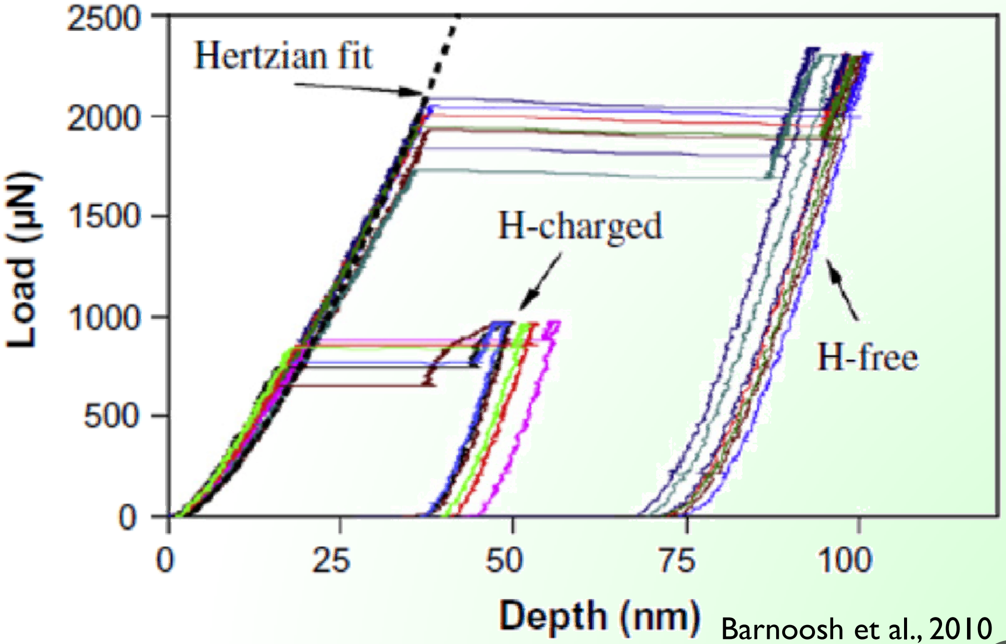


Ferreira et al., 1998

Accumulation of dislocations create high stresses in the microstructure

Hydrogen promotes dislocation emission

Nano indentation test

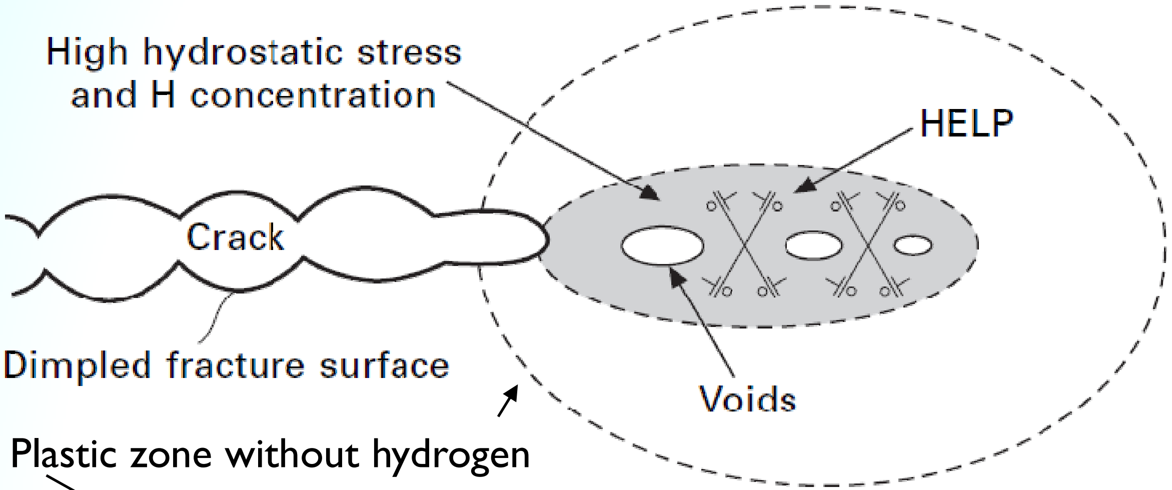


Barnoosh et al., 2010

INTERACTION HYDROGEN PLASTICITY - EMBRITTLEMENT MECHANISMS

- **Hydrogen Enhanced Localised Plasticity (HELP)**

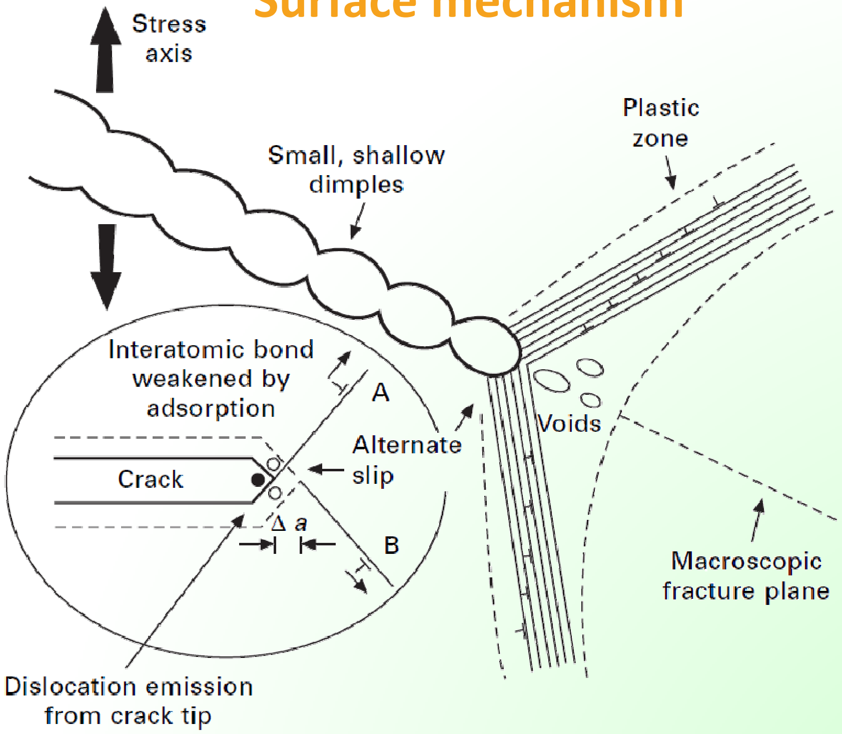
Volume mechanism



Plastic zone without hydrogen
→ Less strain localisation
→ More crack blunting
→ Higher overall strain for micro-void coalescence
→ Deeper dimples

- **Adsorption Induced Dislocations Emission (AIDE)**

Surface mechanism



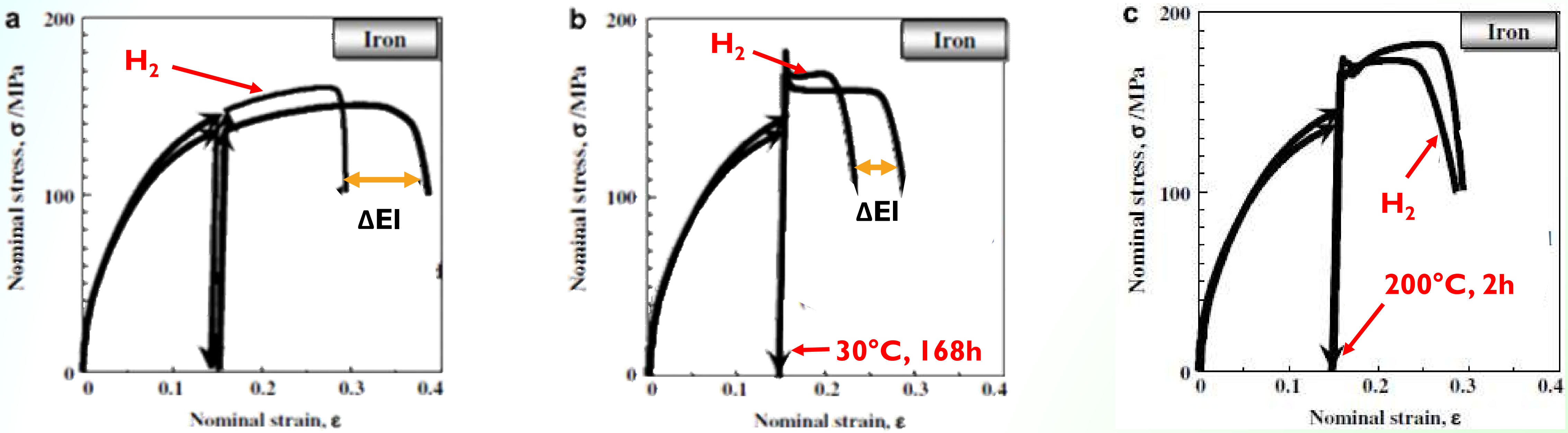
Hydrogen embrittlement (HE) phenomena and mechanisms, Lynch, 2011

Mechanisms based on hydrogen promoting local plasticity

INTERACTION HYDROGEN VACANCIES

- Hydrogen-enhanced stress-induced vacancy (HESIV)

Takai 2008



Test 1:

- Tensile test in H_2 and air

➔ Embrittlement

Test 2 (interupted):

- H_2 desorption
- Vacancy density remains constant

➔ Embrittlement

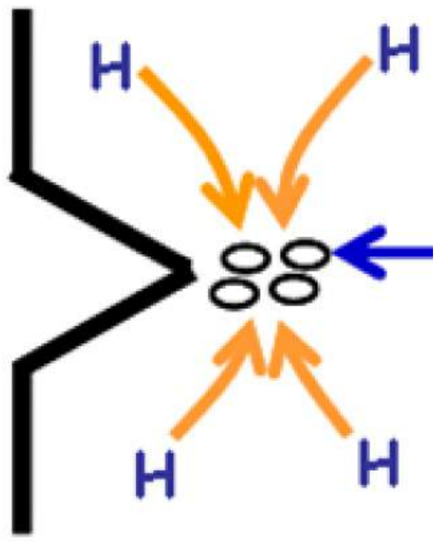
Test 3 (interupted):

- H_2 desorption
- Decrease of vacancy density

➔ **No embrittlement**

HYDROGEN EMBRITTLEMENT - DEFINITION

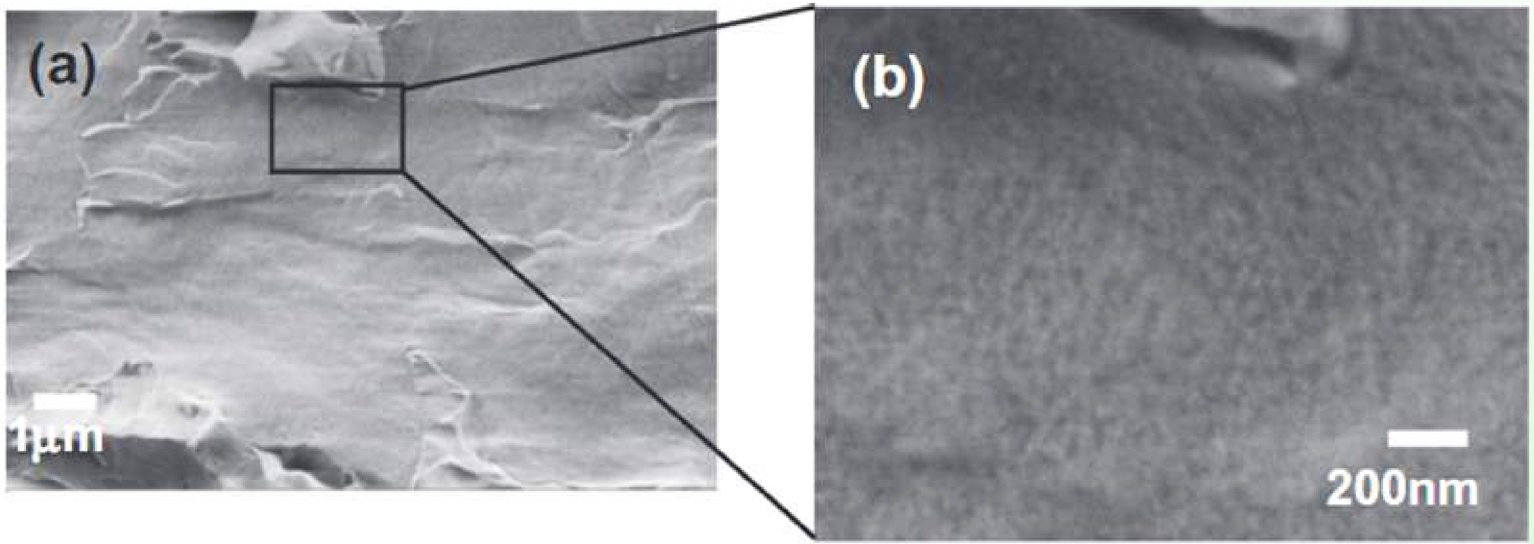
- Hydrogen-enhanced stress-induced vacancy (HESIV)



Nagumo, 2004; Naguma, 2008; Takai 2008

X60 tested in 21 MPa H_2

Nano-scale dimples on hydrogen embrittled quasi-brittle facets



Neeraj, 2012

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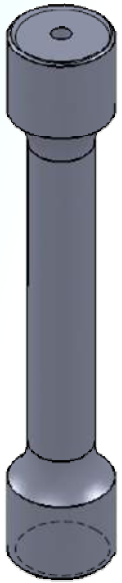
EVALUATION OF HE– MECHANICAL TESTING

σ, ε

Continuum mechanic
(smooth and notched speciemen)



Monotone/cyclic
stress/strain

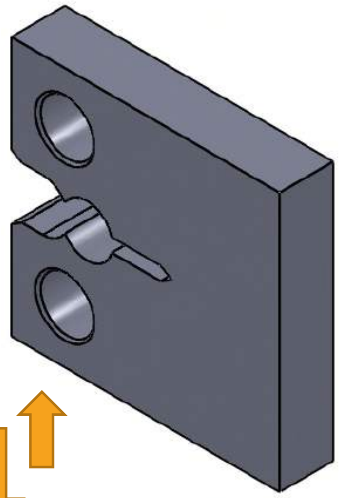
- σ, ε

Tensile properties

Fatigue properties

σ, ε Monotone/cyclic
stress/strain

Fracture mechanic
(crack)



- σ, ε

Toughness properties: energy required for the crack to extend (J, N/mm and K_{IC})

Fatigue crack growth rate

Resistance to crack propagation
→ remaining life of service components

EVALUATION OF HE– MECHANICAL TESTING

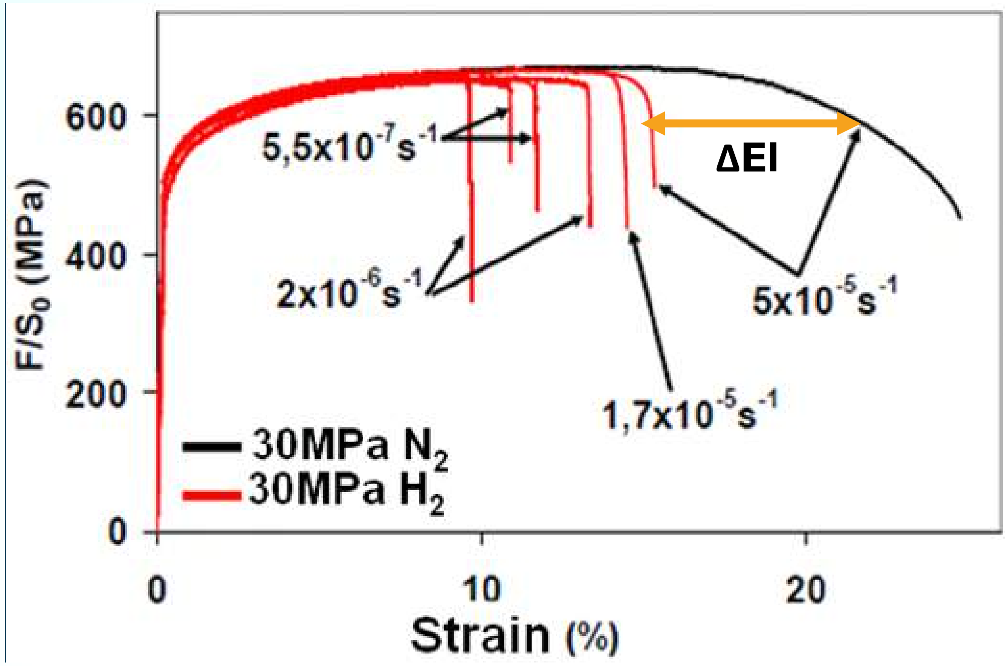
- **In-situ testing in hydrogen gas environment**

CEA/LITEN equipment

MECHANICAL TESTING – EXAMPLE/OBSERVATION

Tensile test

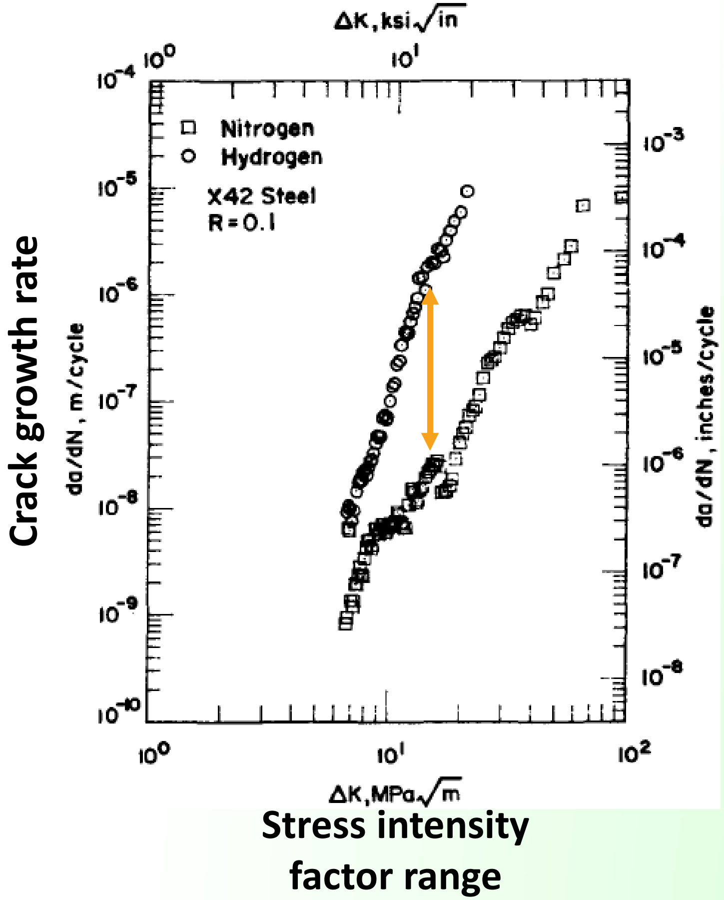
Evidence of X80 embrittlement in 30 MPa H_2



Briottet, IJHE, 2012

Fatigue crack growth rate

X42 pipeline steel in 6.9 MPa N_2 and 6.9 MPa H_2



Increase of fatigue crack growth rate in hydrogen

Cialone et al., 1985

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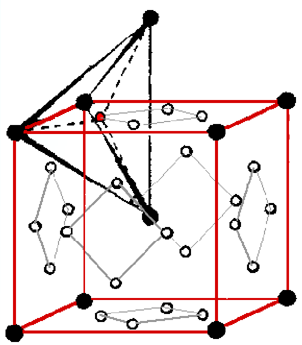
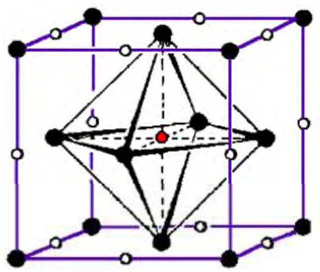
INFLUENCING FACTORS - MICROSTRUCTURE

Tetragonal sites



BCC
(ferritic steels)

Octahedral sites



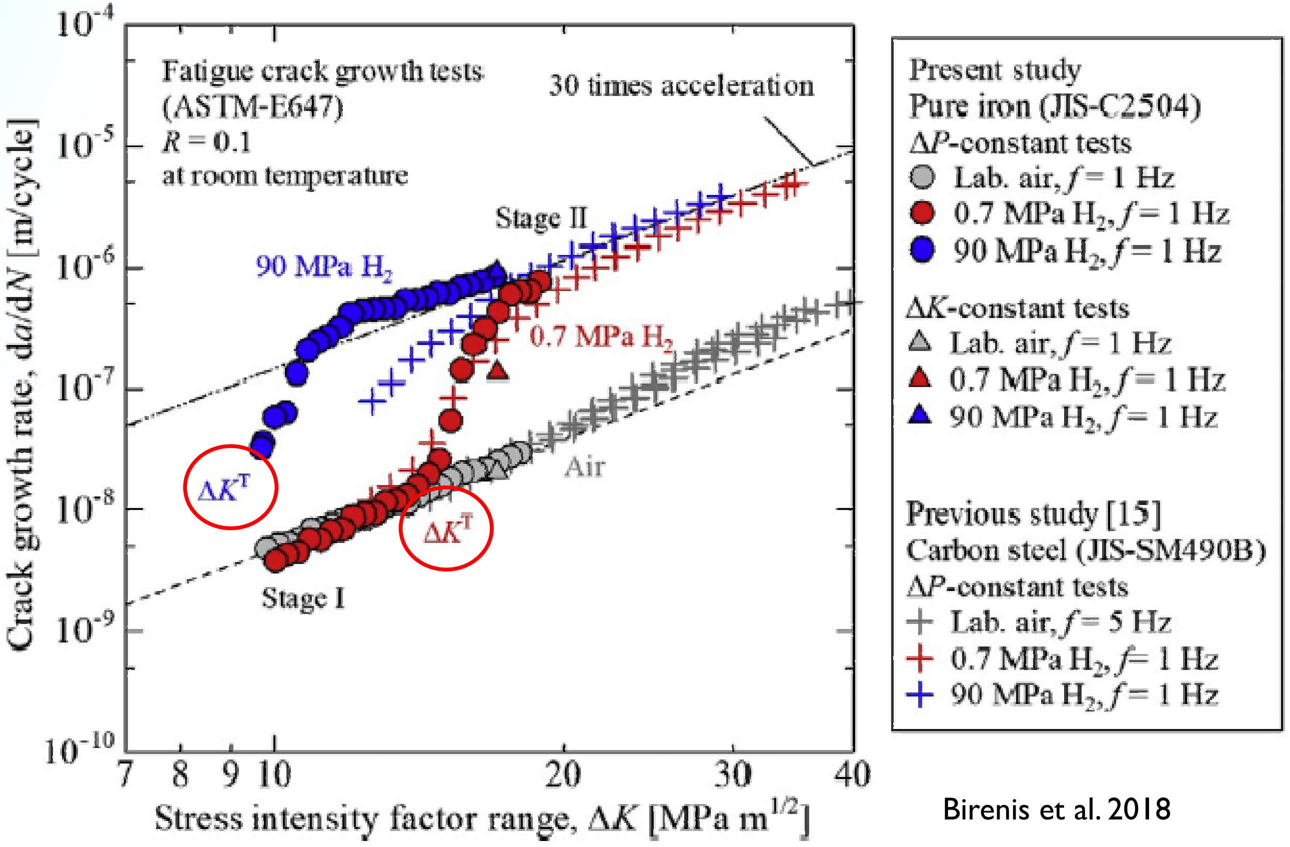
FCC
(austenitic steels, Al, Co)

Ex: Steels

<table>
<tr><th>Most susceptible microstructure</th><th colspan="3">Order of increasing the resistance to HE</th><th>Less susceptible microstructure</th><th>References</th></tr>
<tr><td>Martensitic materials</td><td colspan="3">Ferritic materials</td><td>Stable austenitic alloys</td><td>(Barthelemy, 2006)</td></tr>
<tr><td colspan="2">Ferritic/perlitic</td><td colspan="3">Tempered bainite</td><td>(Brass et al., 2000)</td></tr>
<tr><td>Martensite</td><td>Bainite</td><td>Perlite</td><td>Tempered bainite</td><td>Tempered martensite</td><td>(“FD E29-649 Bouteilles à gaz transportables - fragilisation par l’hydrogène des aciers,” 2016)</td></tr>
</table>

HYDROGEN EMBRITTLEMENT – HYDROGEN PARTIAL PRESSURE

Fatigue crack growth testing



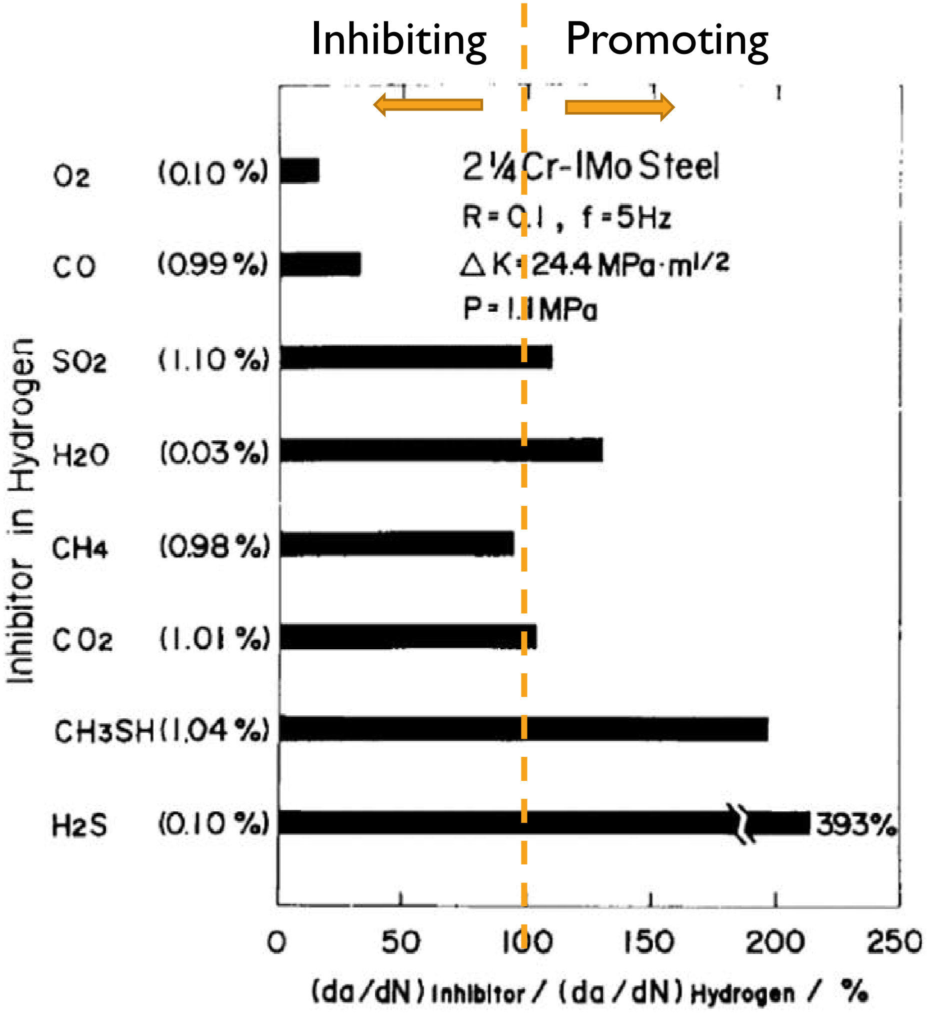
Birenis et al. 2018

- ΔK^T from which fatigue crack growth rate increases
- ΔK^T is pressure dependent
- Same increase in fatigue crack growth rate at 0,7 MPa and 90 MPa.

INFLUENCING FACTORS - IMPURITIES

- Fatigue crack growth tests

Ratio $\frac{(da/dn)inhibitor}{(da/dn)hydrogen}$ (%)



O_2, CO inhibit HE

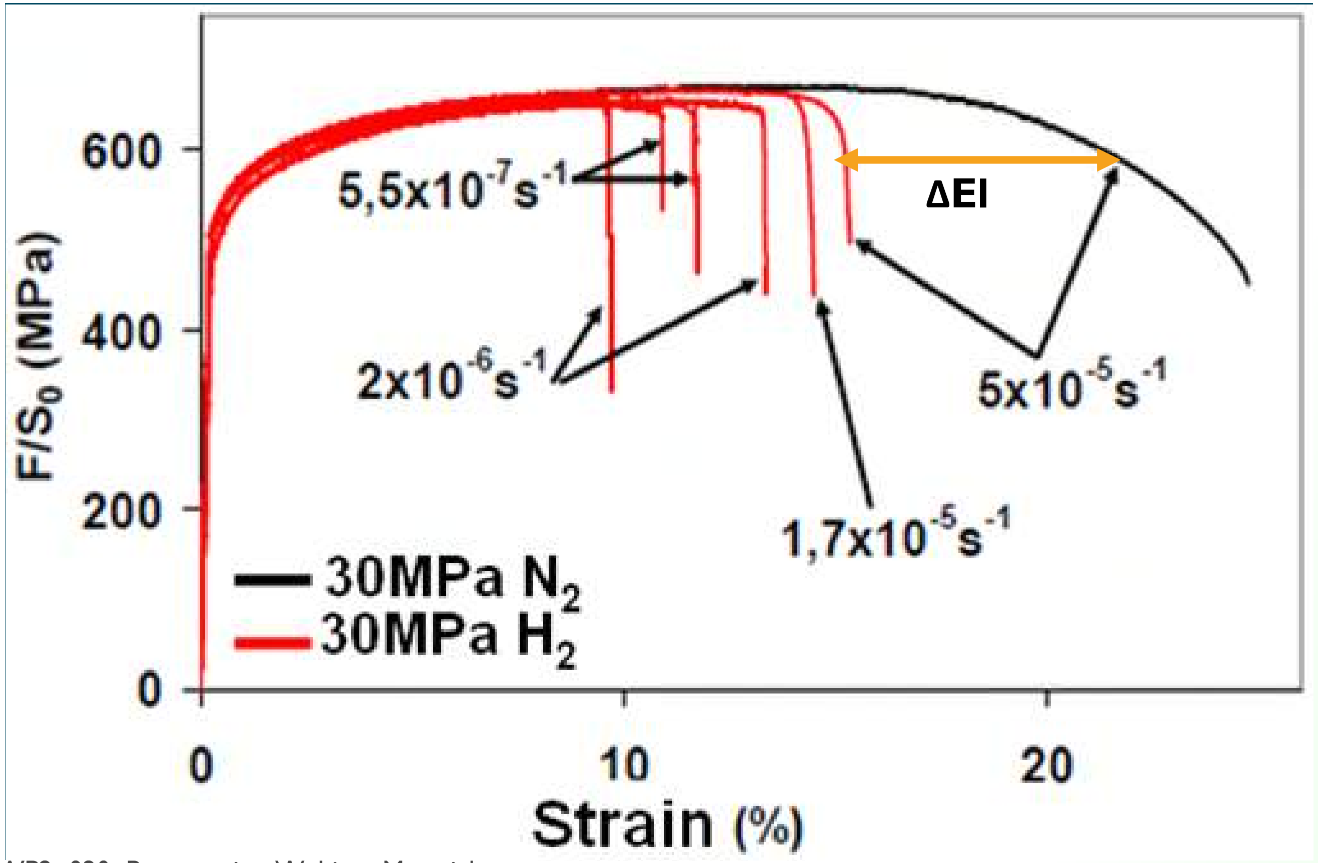
Water vapour : may increase or decrease sensitivity depending of the steel grade

H_2S strongly increases HE susceptibility

Fukuyama, 1990

INFLUENCING FACTORS – LOADING RATE

Tensile testing of a X80 at different loading rates

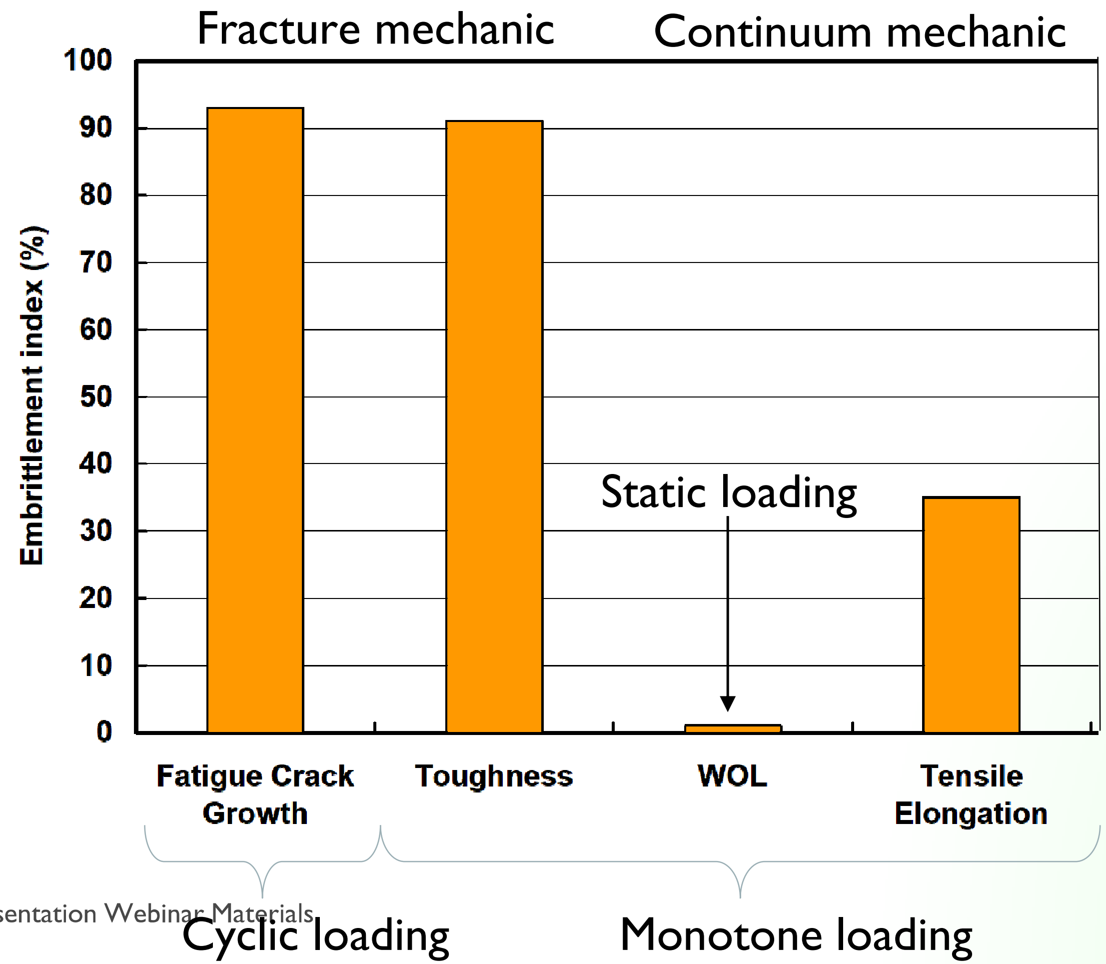


Briottet, IJHE, 2012

HE susceptibility increases as the loading rate decreases

INFLUENCING FACTORS – TESTING CONDITIONS

Comparison of HE susceptibility measured using different mechanical tests on a X80



300 bar H_2

Influence of the loading mode and the presence of a crack to quantify HE susceptibility of a material

Briottet, IJHE, 2012

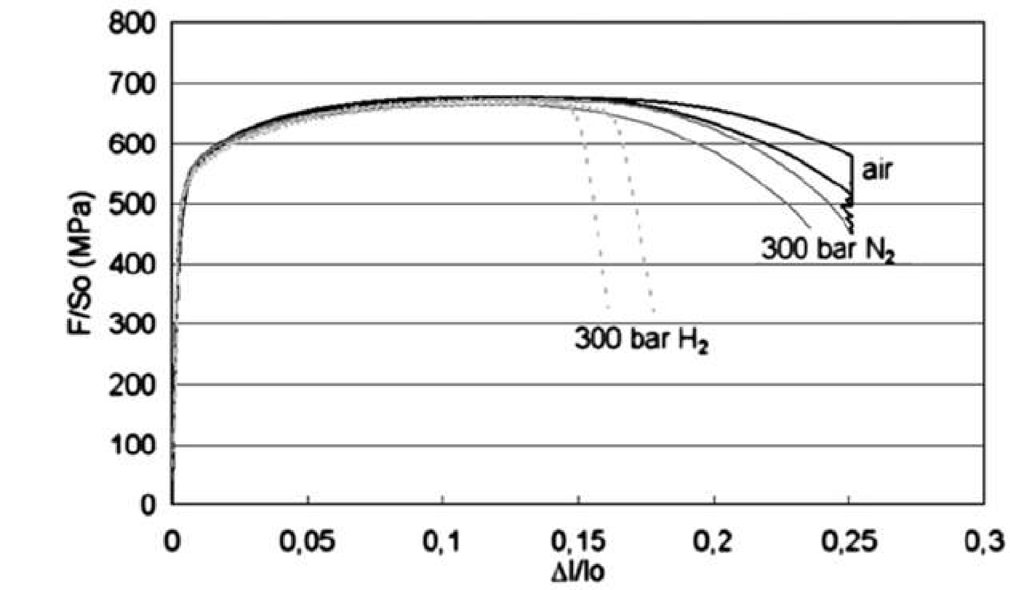
OUTLINE

- HYDROGEN EMBRITTLEMENT (HE)
  - Context and definition of HE
  - Observation of HE (at room temperature and in gas environment) and mechanisms
  - Evaluation of HE
  - Influencing factors
  - Impact of HE on the materials used in gas distribution network
    - Carbon steels
    - Stainless steels
    - Copper and copper alloys
    - Aluminium alloy
    - Brass
  - Standards
- NON-EMBRITTLEMENT CONCERNS
  - Chemical compatibility
  - Permeation and leakage
- LEAKAGE TEST

HYDROGEN EMBRITTLEMENT – CARBON STEELS

Tensile properties

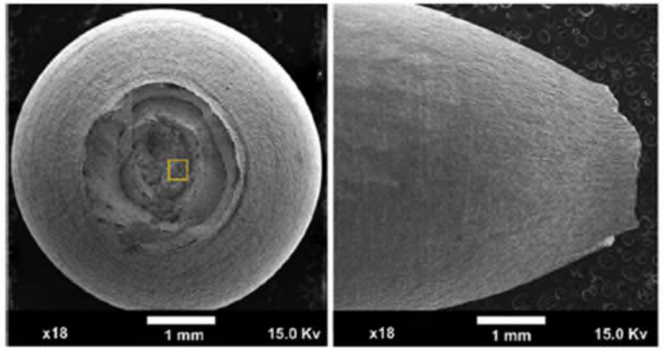
Tensile test results of X80 steel



Briottet et al., 2012

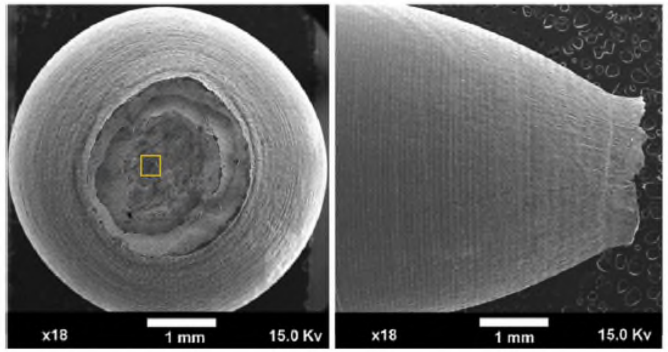
Fractography of a X70 pipeline steel tested

Air

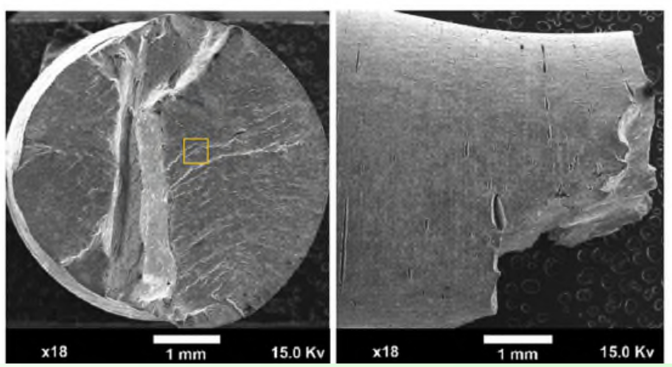


Nguyen et al., 2020

100 bar gas mixture with 1% H_2 → P_{H2} = 1 bar



P_{H2} = 100 bar



No HE observed at P_H = 1bar

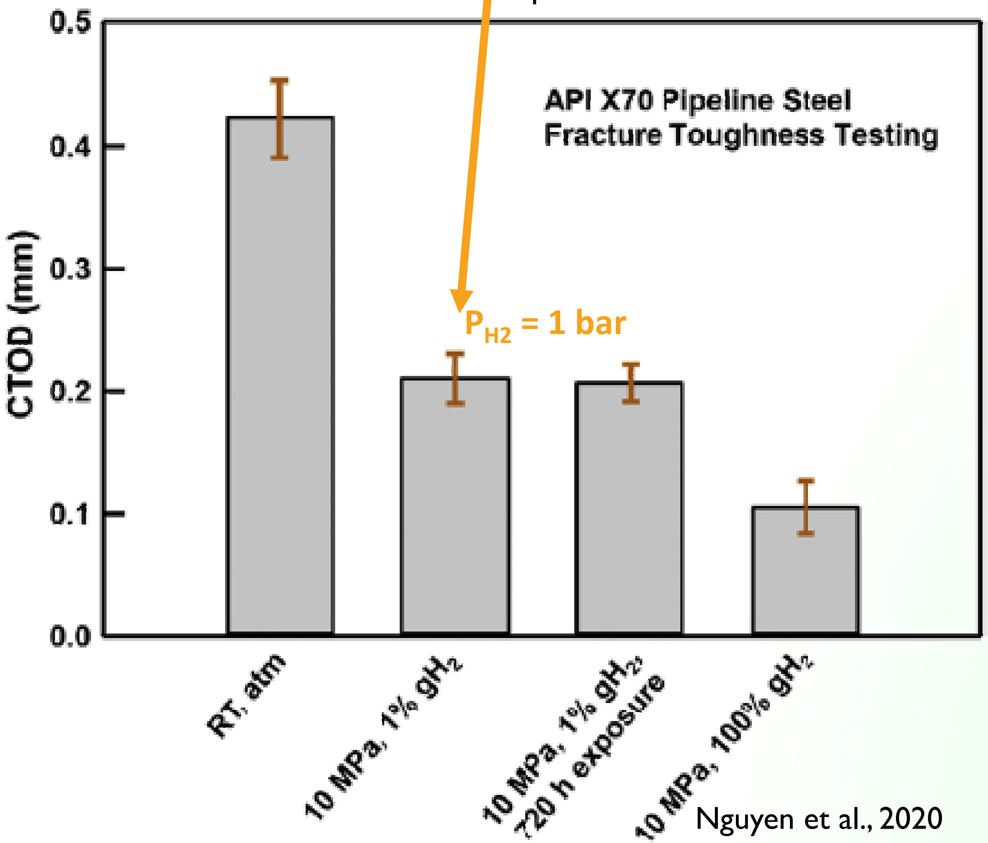
HE observed at P_H = 100bar: No necking, development of secondary cracks, quasi-cleavage

HYDROGEN EMBRITTLEMENT – CARBON STEELS

Toughness testing of a X70 steel

→ Evaluation of the HE resistance to a monotone loading in the presence of a defect.

Influence of hydrogen in the presence of a crack

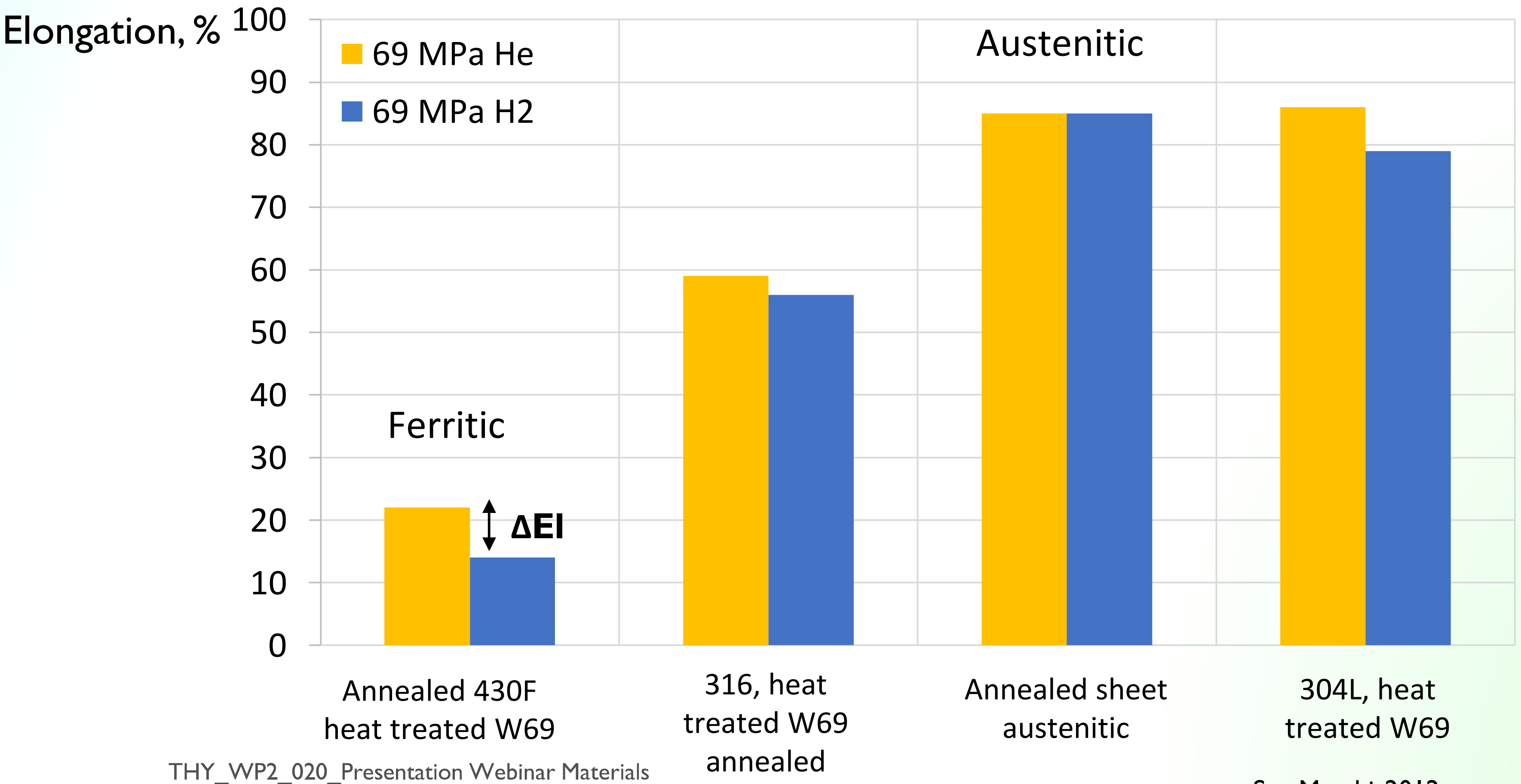


Nguyen et al., 2020

HE of the X70 from P_H = 1bar in the presence of a crack.

STAINLESS STEELS

Tensile testing on ferritic and austenitic stainless steels in He and H_2 gas environments ($0{,}4 \times 10^{-4}$ mm.s^{-1})

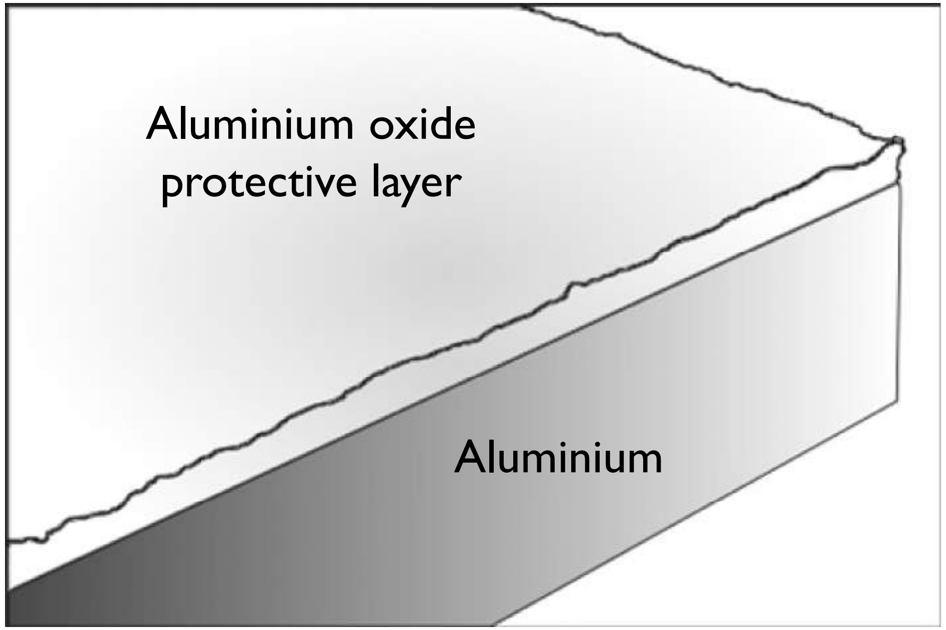


San Marchi, 2012

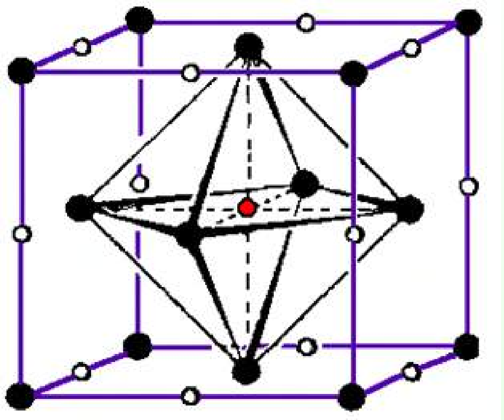
Austenite SS have better resistance to HE than ferritic SS

ALUMINIUM ALLOYS

Formation of stable oxide film in all reducing environments
→ impedes hydrogen ingress



FCC microstructure



→ low hydrogen diffusion properties

Al alloys in dry hydrogen are not susceptible to HE

Hydrogen embrittlement and aging of natural gas distribution network in the presence of hydrogen

- Objective: To evaluate the effect of hydrogen embrittlement on five alloys identified according to their propensity to be present on the gas network and the potentiality of their mechanical properties to be affected by hydrogen.

- Description of the test:
  - Embrittlement testing
  - Among the five alloys
    - Brass CW617N and brass CW614N
    - Zamak (pressure regulator)
    - Copper (tubing)
  - Three gas blends were used for the test: natural gas (NG), NG+6%vol.H_2, NG+ 20%vol.H_2

- Conclusions:
  - Brass CW617N, brass CW614N, copper and zamak : **no significant susceptibility to HE**
  - Zamak, copper and brass CW617N : **no hydrogen susceptibility**
  - Brass CW614N: low hydrogen effect, but stayed non-significant and do not constitute a risk in terms of security in the service conditions.

STANDARDS

Existing standards for hydrogen storage and transport (high pressure):

ISO 11114-4: “*Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Tests methods for selecting metallic materials resistant to hydrogen embrittlement*”

ASME B31.12-2019: “*Hydrogen piping and pipelines*”

ASME BPVC: Section VIII – “*Rules for construction of pressure vessels division 3 –Alternative rules for construction of high pressure vessels*”

HYDROGEN EMBRITTLEMENT – CONCLUSION AND QUESTIONS

- HE is a concerned for many industries;
- Different proposed mechanisms but no link between mechanism and components design-life prediction;
- Susceptibility of main alloys used in gas distribution network:

  Carbon steels > Ferritic stainless steels > Austenitic stainless steel ~ Aluminium ~ Brass ~ Copper

- In the context of gas distribution network: $\mathbf{P_{H2} < 1.03}$ **bar; limited mechanical loading, limited stress concentration ?**

  → No high HE susceptibility is expected in those conditions

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CHEMICAL COMPATIBILITY

- Corrosion or selective dissolution at room temperature in dry hydrogen gas environment.

In dry hydrogen environment, hydrogen is not a concern for corrosion of metallic materials

→Focus on polymers (Polyethylen (PE))

CHEMICAL COMPATIBILITY OF PE

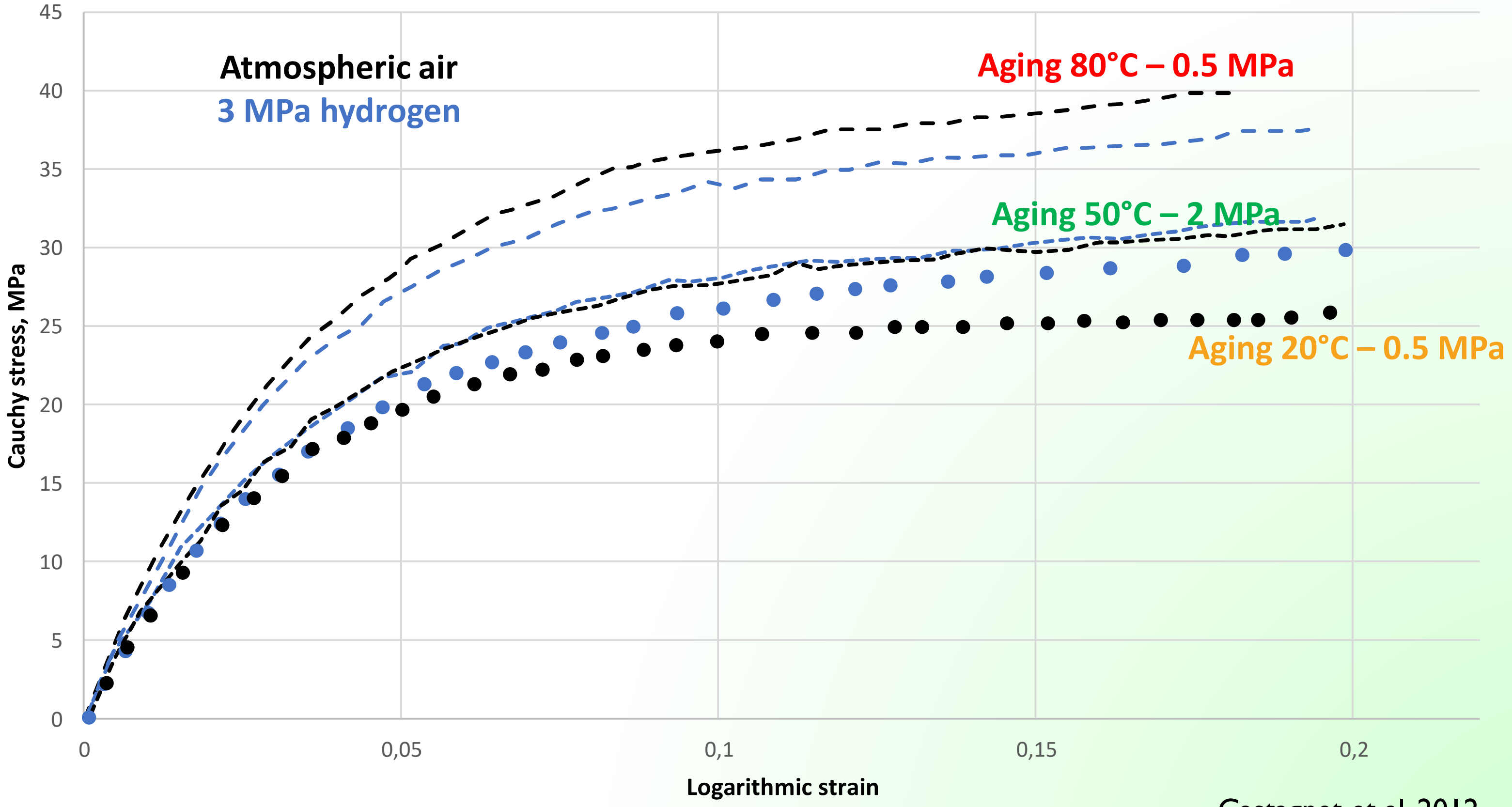
Testing of resistance to hydrogen exposure of PE

Phase 1: Aging for 13 months

Temperature, °C	Pressure, MPa
80°C	P_{H2} = 0.5 MPa
	P_{Air} = 0.5 MPa
50°C	P_{H2} = 2 MPa
	P_{Air} = 2 MPa
20°C	P_{H2} = 0.5 MPa
	P_{Air} = 0.5 MPa

Phase 2: Tensile testing :

- Aged in air = in Pair = 0.1 MPa
- Aged in H_2 = in P_{H2} = 3 MPa



Castagnet et al. 2012

No chemical interaction

No hydrogen influence on mechanical properties

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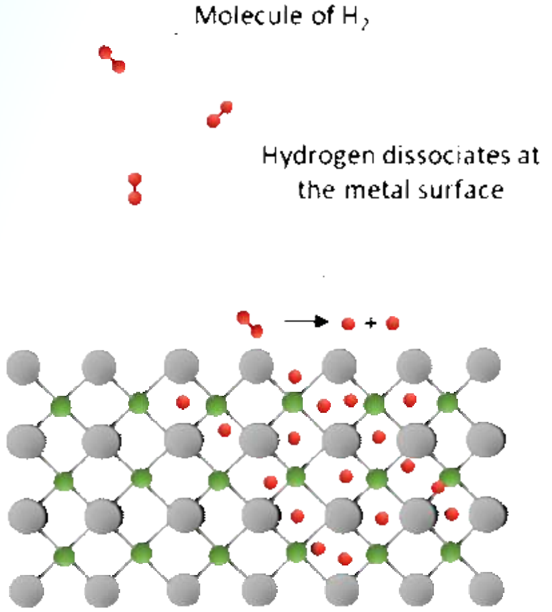
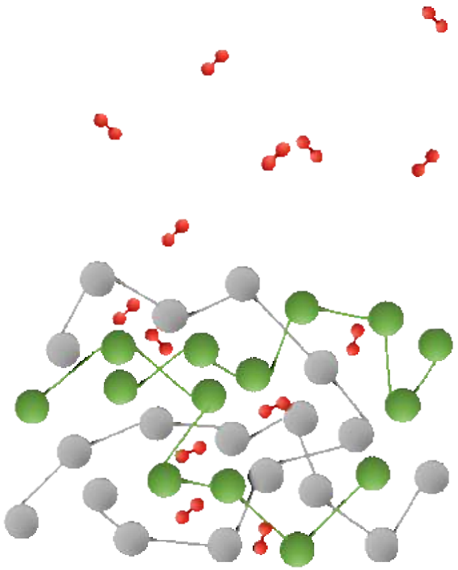
HYDROGEN PERMEATION AND LEAKAGE

PERMEATION



Hydrogen is adsorbed at the metal surface and absorbed in the bulk material where it diffuses as a proton.

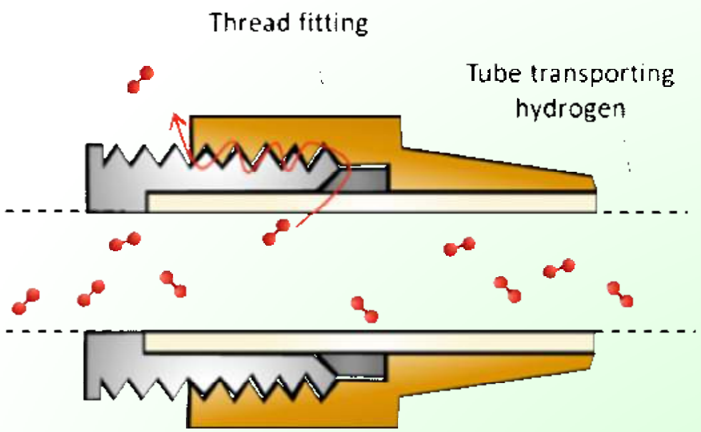
METAL



Dihydrogen penetrates at in the plastic material without dissociation

POLYMER

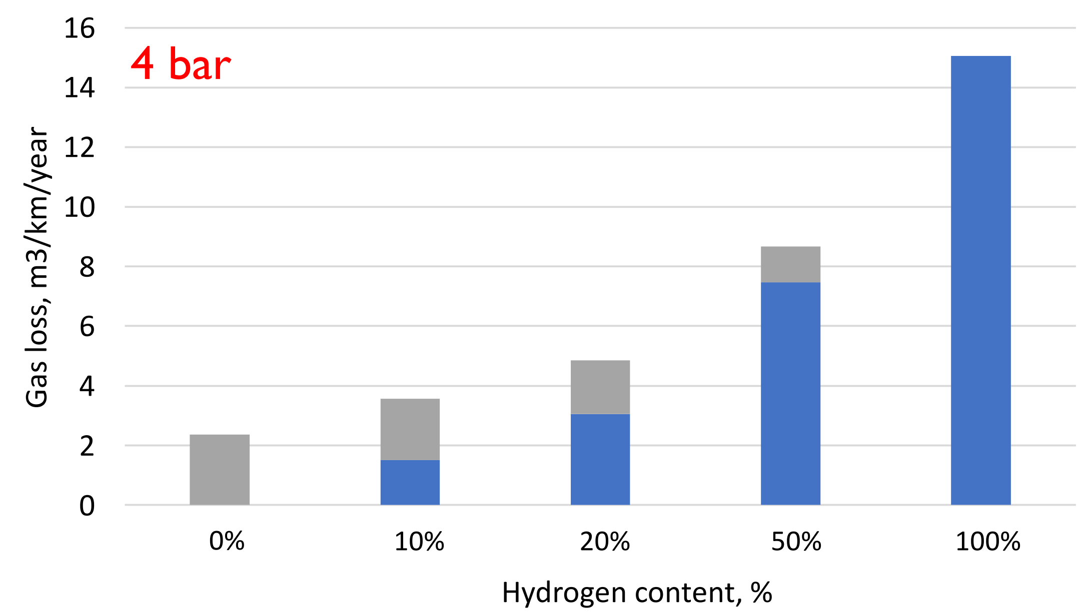
LEAKAGE

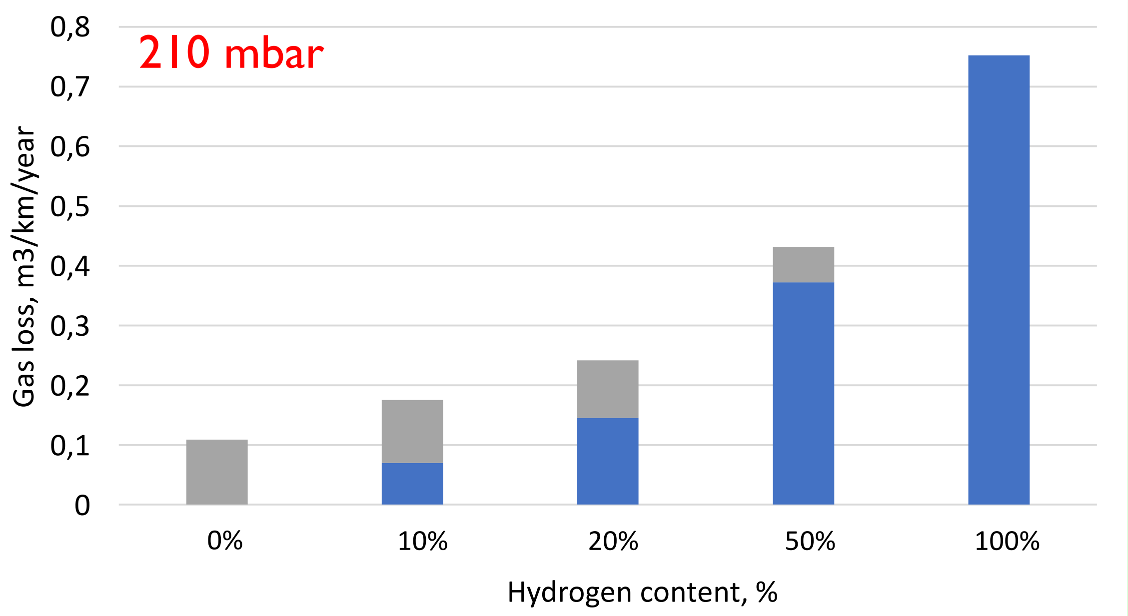


HYDROGEN PERMEATION IN PE – NATURALHY PROJECT

- NATURALHY : Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues

Permeation on main materials used on the US gas network distribution (~4 bar) and service (~200mbar)





Increase of gas loss with the hydrogen content
Incubation time for methane to permeate – not for hydrogen
Economical point of view H gas losses at low operating pressure not problem

HYDROGEN LEAKAGE PROPERTIES

- Hydrogen leakage is a concern
- Leak characteristics of hydrogen, methane and propane (Leader et al., 2001).

	Hydrogen, H_2	Methane, CH_4	Propane, C_3H_8	Helium, He
Density, Kg,m^{-3}	0.0838	0.6512	1.870	0.1634
Viscosity, g.cm^{-1}.s^{-1} × 10^{-5}	8.9	11.7	8.0	19.6
Relative flow rates, volumetric: Subsonic flow • Laminar flow • Turbulent flow Sonic flow	 1 1 1	 0.77 0.35 0.34	 1.11 0.21 0.20	 1 1

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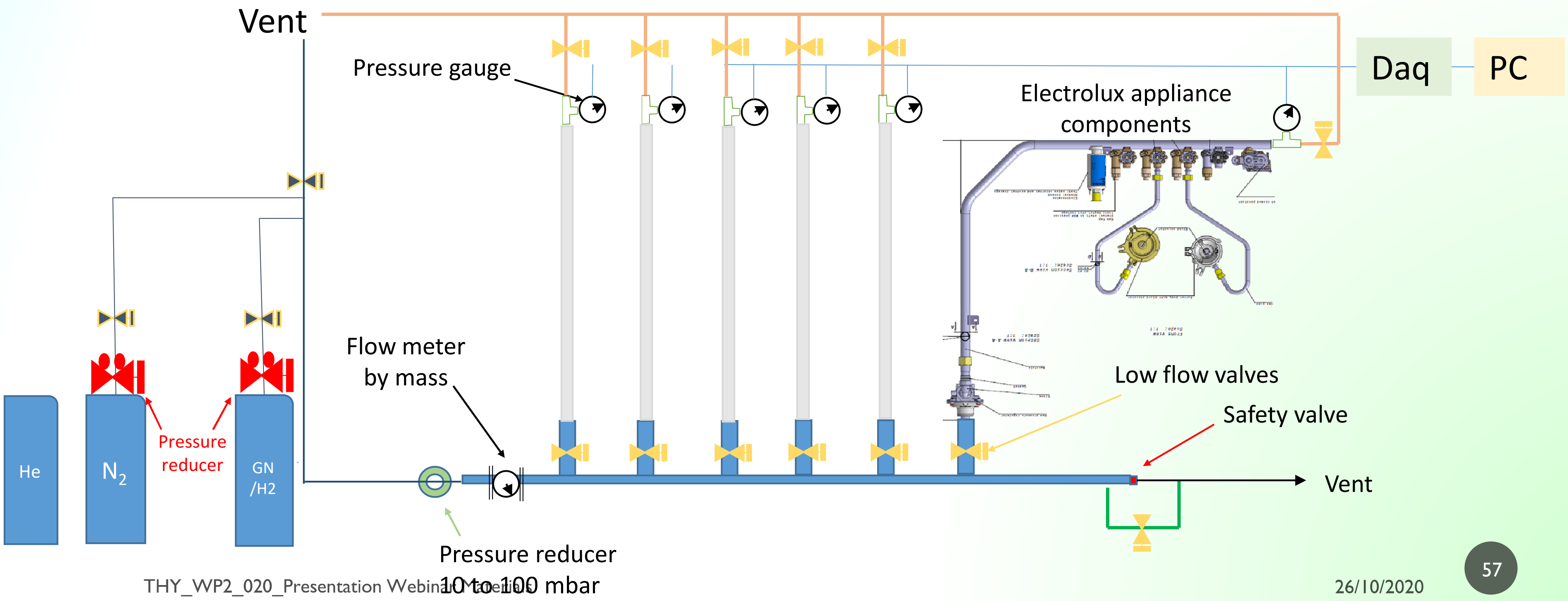
TIGHTNESS TEST OF GAS NETWORK DISTRIBUTION COMPONENTS

- **Objective:** To evaluate the tightness of the components located on the gas line within the building from Germany, Denmark, Belgium and France to the mixture $CH_4 + H_2$.



TIGHTNESS TEST OF GAS NETWORK DISTRIBUTION COMPONENTS

Testing procedure

Static testing
Measure of the **pressure drop** within closed lines
(several months)

Dynamic testing
Measure of the **gas flow** in each line alternatively to impose a constant pressure
(several hours)

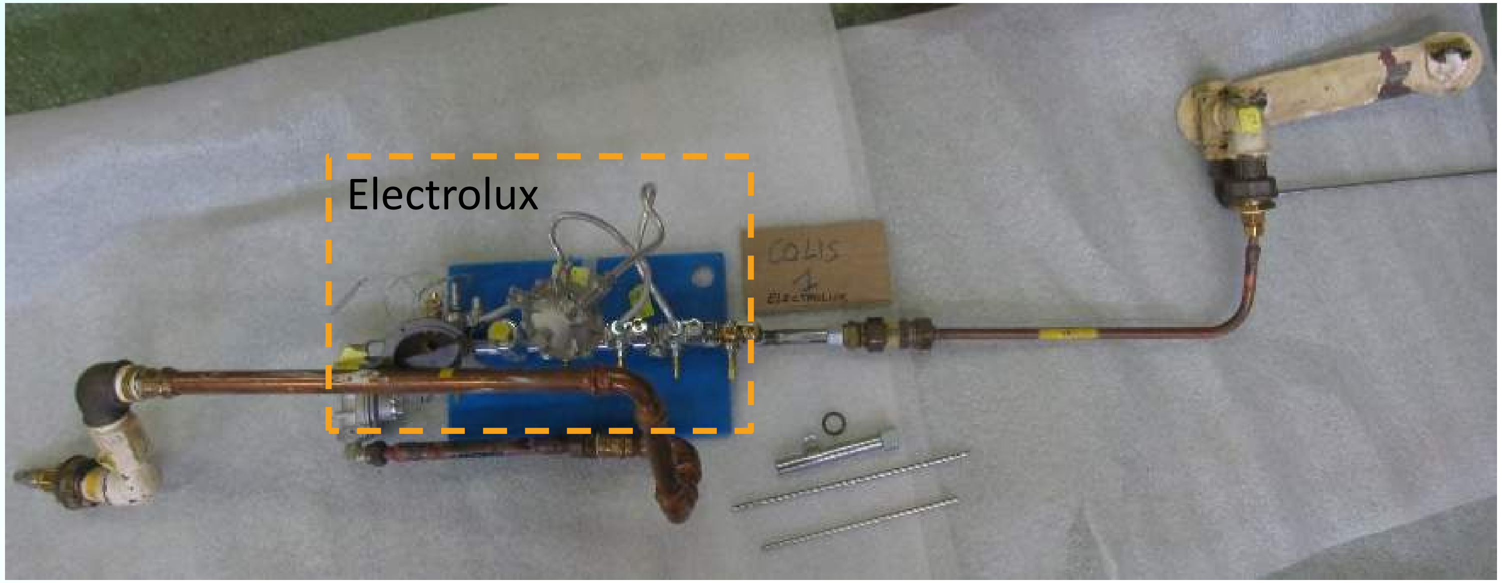
- Test parameters:
  - Gas mixture: 40%CH_4 + 60%H_2
  - Temperature: RT
  - Pressure: 30 mbar

Components sourcing

- DGC (Danish gas technology centre)
- BDR Therma group
- Electrolux
- GWI (Gas- und Wärme-Institut Essen) (Germany)
- DVGW.EBI (German Technical and Scientific Association for Gas and Water)

TIGHTNESS TEST PRESENTATION OF THE LINES AND COMPONENTS

Electrolux and DGC line



GWI, DVGW.EBI and DGC line

Materials in the Electrolux gas circuit:
Aluminium (burner, pipe, pressure regulator)
Brass (gas thermostat)
Aluminized iron (manifold)

Materials in the DGC:
Iron, copper, brass

Materials in the line:
Steel, stainless steel, copper, brass

TIGHTNESS TEST OF GAS NETWORK DISTRIBUTION COMPONENTS

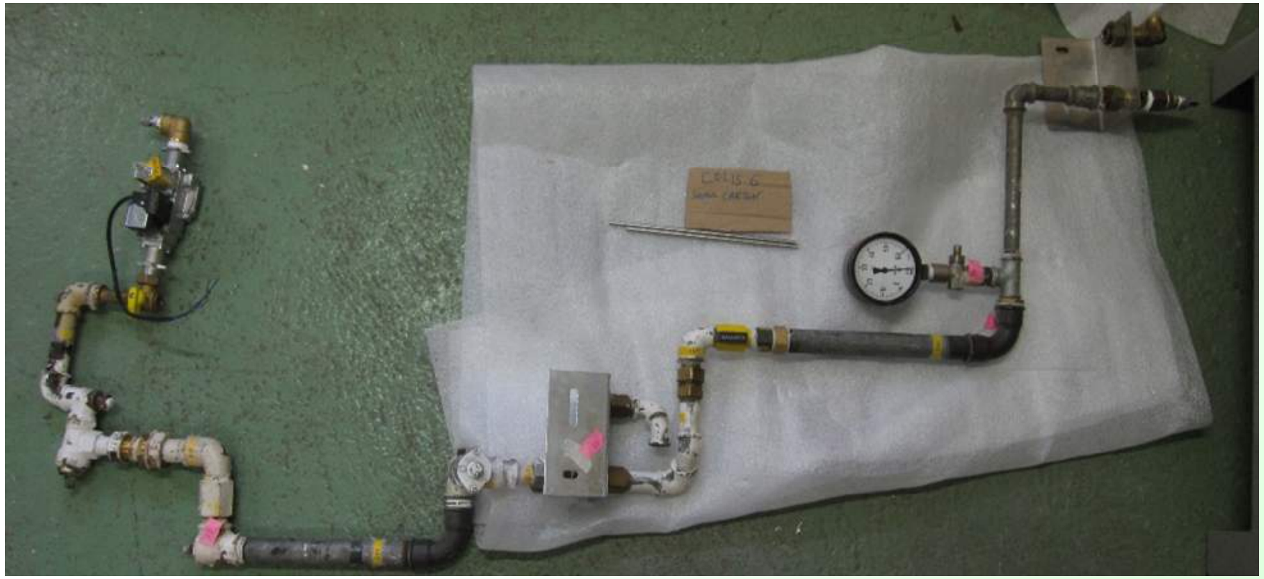
GWI, DVGW.EBI and DGC lines

Gas meters tubing and valves made of steel, copper, brass and stainless steel.

THyGA

TIGHTNESS TEST OF GAS NETWORK DISTRIBUTION COMPONENTS

GWI, DVGW.EBI and DGC lines



Gas meter, tubing, pressure valves made of steel, copper, brass and stainless steel.

QUESTIONS

Thank you for your attention

Link to THyGA project:

https://thyga-project.eu/

Link to the state of the art on the "Non-combustion impact of hydrogen admixture material compatibility":

https://thyga-project.eu/deliverable-d2-4-non-combustion-related-impact-of-hydrogen-admixture-material-compatibility/