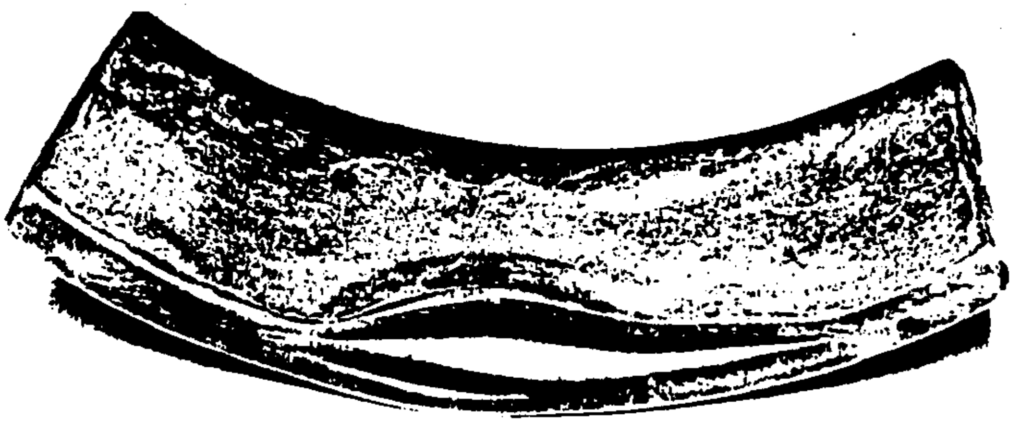
HYDROGEN EFFECTS

Hydrogen can degrade metals by:

- **hydrogen blistering;**
- **hydrogen embrittlement;**
- **decarburization;**
- **hydrogen attack.**

Blistering

Hydrogen enters the Lattice of a metal diffuses to voids, creates high internal stresses → blisters . . .



Cross section of a carbon steel plate removed from a petroleum process stream showing a large hydrogen blister. Exposure time: 2 years.

Blistering may occur during exposure to:

- **hydrocarbon;**
- **electroplating solutions;**
- **chemical process streams;**
- **pickling solutions;**
- **H-containing contaminants during welding;**
- **general corrosive environments.**

Embrittlement

Similar to blistering . . . hydrogen enters metal lattice . . .

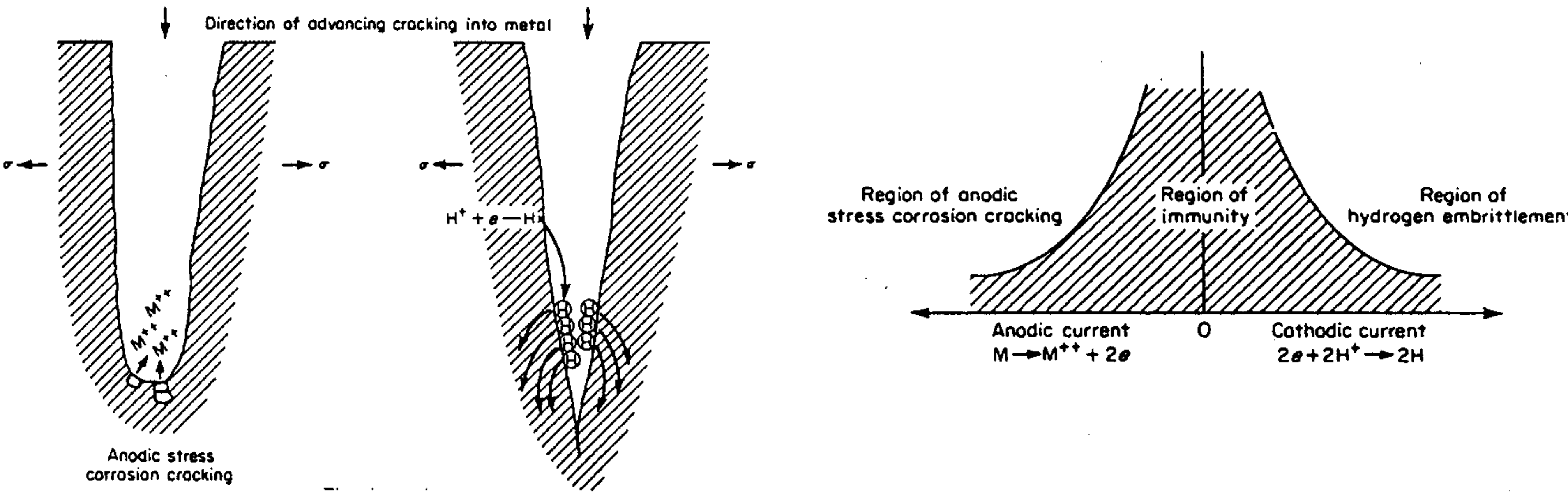
BUT . . . interaction with metal lattice different.

High-strength (and more brittle) steels are susceptible.

H-embrittlement different from SCC in nature of cracks . . .

- **stress-corrosion cracks usually propagate anodically;**

hydrogen-embrittled cracks occur under cathodic conditions . . .



Hydrogen
embrittlement

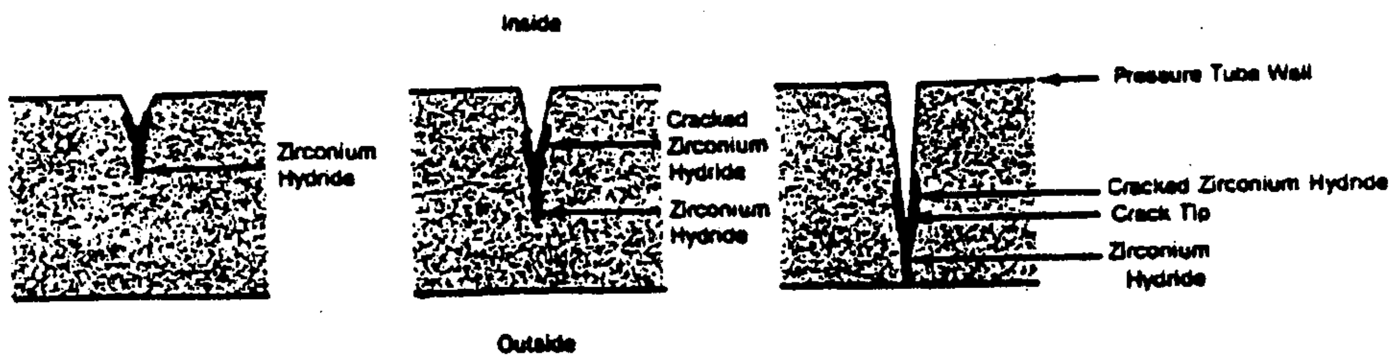
Schematic differentiation of anodic cracking and cathodically sensitive embrittlement.

Hydride-forming metal are susceptible to H- embrittlement . . .

e.g., Zr-alloy pressur tubes (in CANDUs) and fuel sheathing (in all water-cooled reactors) pick up hydrogen (or deuterium in heavy water) by general corrosion. The hydrogen (D) migrates through the metal lattice to cool regions and to regions of high tensile stress - can precipitate as separate phase - zirconium hydride.

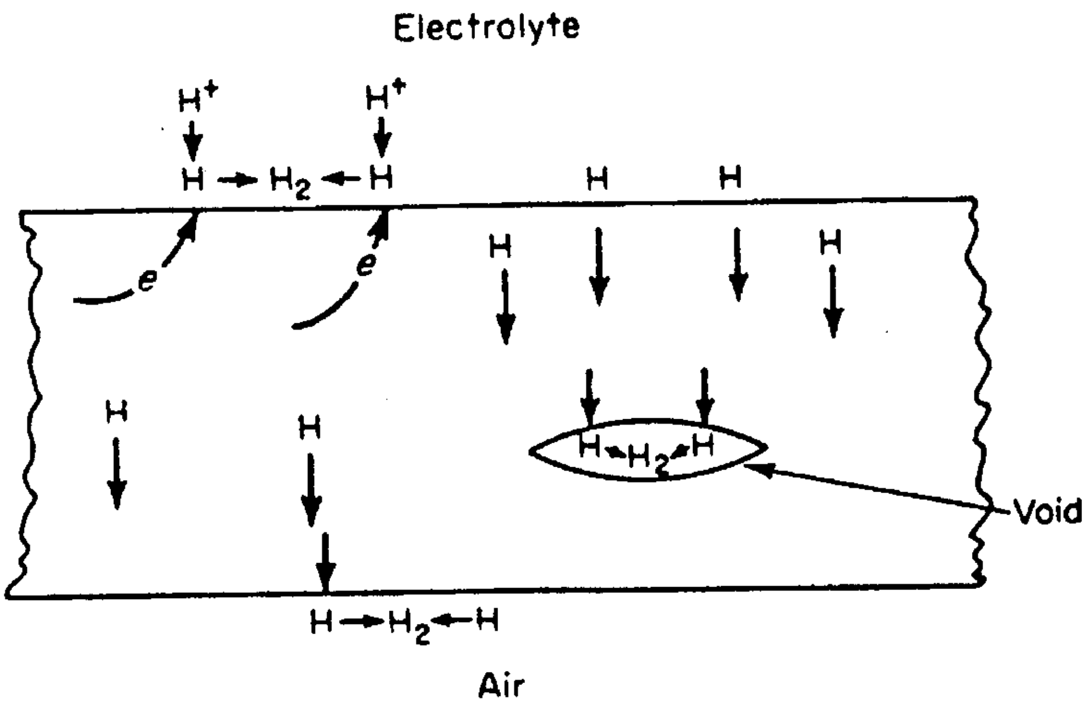
These hydrides are <u>themselves</u> brittle, and crack, and the crack can propagate through the material, with more hydride progressively precipitating at the crack tip.

<u>N.B</u>. Enough hydride can precipitate to form a "<u>hydride</u>" blister . . . c.f. "<u>hydrogen</u>" blister.



Representation of the Growth of a Crack Through Failure of Zirconium Hydride that Precipitates at Crack Tips

<u>N.B</u>. The mechanism of hydrogen uptake by metals must involve



Schematic illustration showing the mechanism of hydrogen blistering.

BUT . . . remember that molecular hydrogen may absorb and dissociate on metal surfaces.

Decarburization and Hydrogen Attack

High temperature process - C or carbide in steels can react with gaseous hydrogen . . .

$$C + 2H_2 \rightarrow CH_4$$

Note that the reaction con occur with atomic H in the metal lattice . . .

$$C + 4H \rightarrow CH_4$$

May crack the steel from high internal pressure.

May cause loss of strength as C disappears.

PREVENTION

Blistering

- Use steels with few or no voids;
- Use coatings;
- Use inhibitors;
- Remove impurities that can promote hydrogen evoution . . .
  S^{-2} (particularly bad), As, CN^{-}, ect.
- Use different materials (Ni-base alloys have low diffusion rates for hydrogen).

Embrittlement

- Reduce corrosion rate (inhibitors, coatings, ect.);
- Change electroplating process to minimize H effects (voltage, current density, bath composition, ect.);
- Bake material to remove H;
- Minimize residual stresses;
- Use less susceptible material;
- Maintain clean conditions during welding.