H2 readiness

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ENERGY IS US

?

Kraftwerk Reisholz nach der Explosion im Jahre 1920

Source: google

- 29 November 1920: Founding of a working group, which later became the "Association of Large Boiler Owners" in Leuna after a serious boiler explosion at the Reissholz power plant in Düsseldorf with 27 deaths.
- 1924: First guideline published
- 1957: Founding of the KRAFTWERKSSCHULE for the training of power plant foremen
- 2025:418 members from 33 countries with an installed capacity of 296.000MW

H2 readiness?

Experiences with Hydrogen

„Hindenburg Trauma“

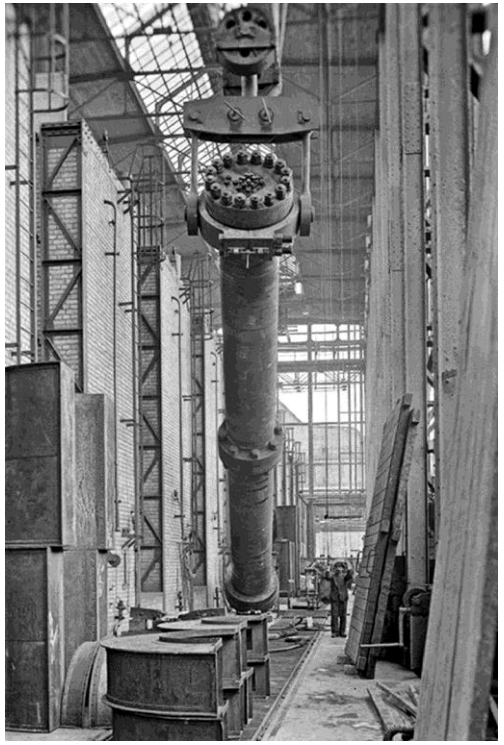
Source: google

→ Hydrogen burns above the leakage point!

Experiences with Hydrogen

Ammonia Synthesis

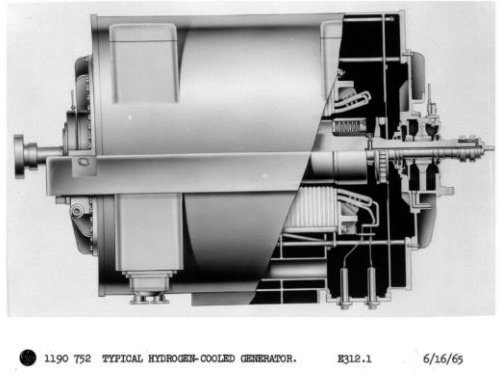
BASF: Ammonia-Reactor 1913
200 bar!



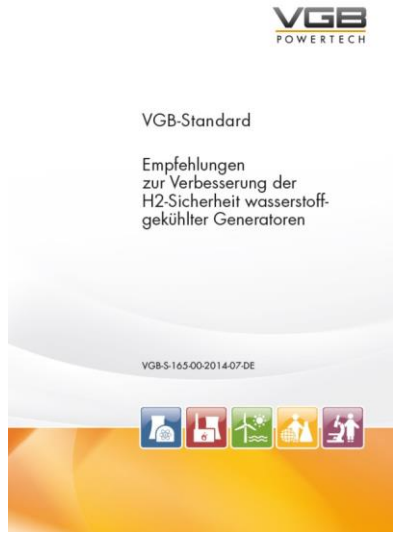
Source: BASF SE

H2 Cooled Turbo-Generators in Germany from the Early 1950s to Today

(First installation: 1937 Dayton Power amp Light Co. in Dayton, Ohio
OEM: General Electric, 31.25 MVA, 60Hz)



Source: google



Source
vgbe (2015)

H2 Properties - Highlights

- High thermal conductivity leads to very low ignition energy.
- Very low density and viscosity:
  - → high leakage rate even with small leaks
  - → different dispersion compared to CH4
  - → escape from the Earth‘s atmosphere
- Flame hat little radiant heat → effect on component life
- Inverse Joule-Thomson Effect → H2 warms upon expansion (a little)
- High diffusion coefficient
  - → good mixing even with short mixing paths

$$\frac{v_1}{v_2} = \sqrt{M_2/M_1}$$

What Does H2 Ready Mean? VGBE ENERGY IS US definition:

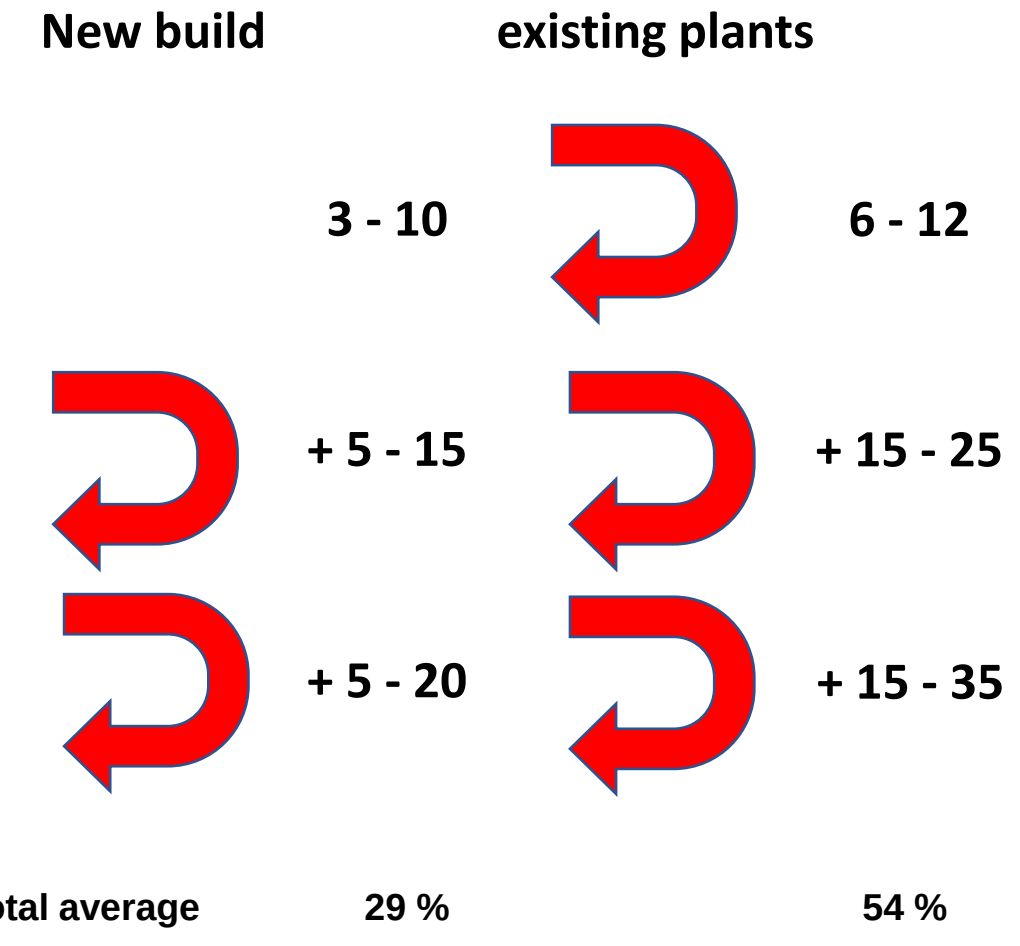
- H2 ready means 100% H2 over the lifecycle of the machine.
- Possibly in various retrofit steps.
- All gas mixtures from 100% natural gas to 100% H2 can be burned.
- Valid for new and existing plants.
- Also applies to other H2-based energy carriers, e.g., ammonia.
- Current gas turbine technology is also suitable for H2 combustion, except for the combustion system and auxiliary systems.

Proposed Development Stages

H2 readiness levels

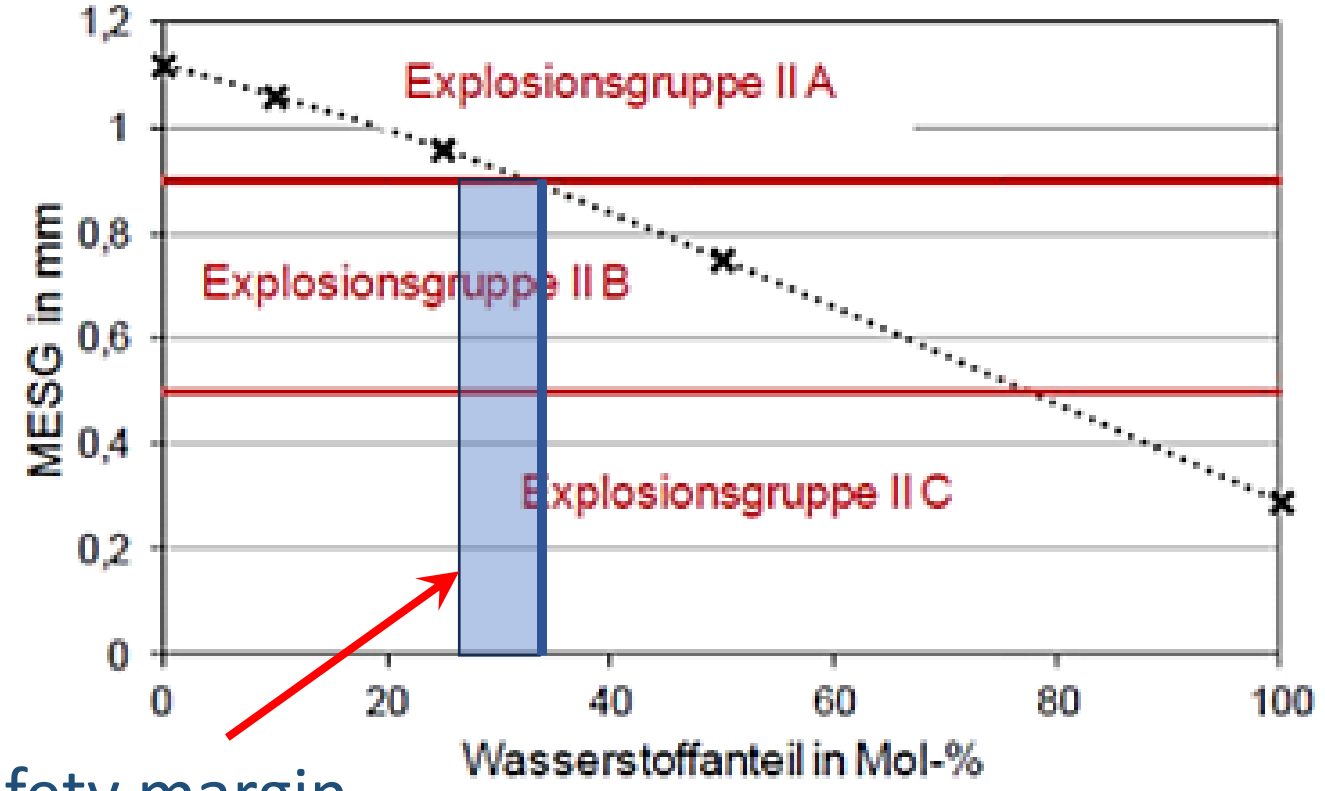
- Level 0: NG only
- Level 1: 6% H2 TFC
- Level 2: 25% H2 TFC
- Level 3: 100% H2 TFC

Additional cost an retrofitting effort in % of the GT
Costs are additive



Explosion Group (of fuel gas)

- Change of explosion group is driver for:
  - → considerations of explotion protection (incl. HRSG)
  - → changes in periphery (sensors, lighting, …)



Safety margin

Measured values from PTB

Source: SCHRÖDER, V. 2016, Abschlussbericht zum Forschungsvorhaben 2539, Sicherheitstechnische Eigenschaften von Erdgas-Wasserstoff Gemischen, BAM, Berlin

Materials

- In general, not all used materials are suitable for H2 → embrittlement
  - Depends on H2 partial pressure, but gas pipes made of 316 & 316L are
- Elastomers: "explosive decompression" due to embedded hydrogen
- No standards in Europe for H2 high-pressure applications
- No standards for testing materials in H2 applications
  - Effect on pressure cycle service life still unclear

Source: google

→ vgbe technical program: “Materials Safety in the Hydrogen Economy”

→Testing methods

→Life cycle concepts

→…

- Currently available are API 617 and API 941

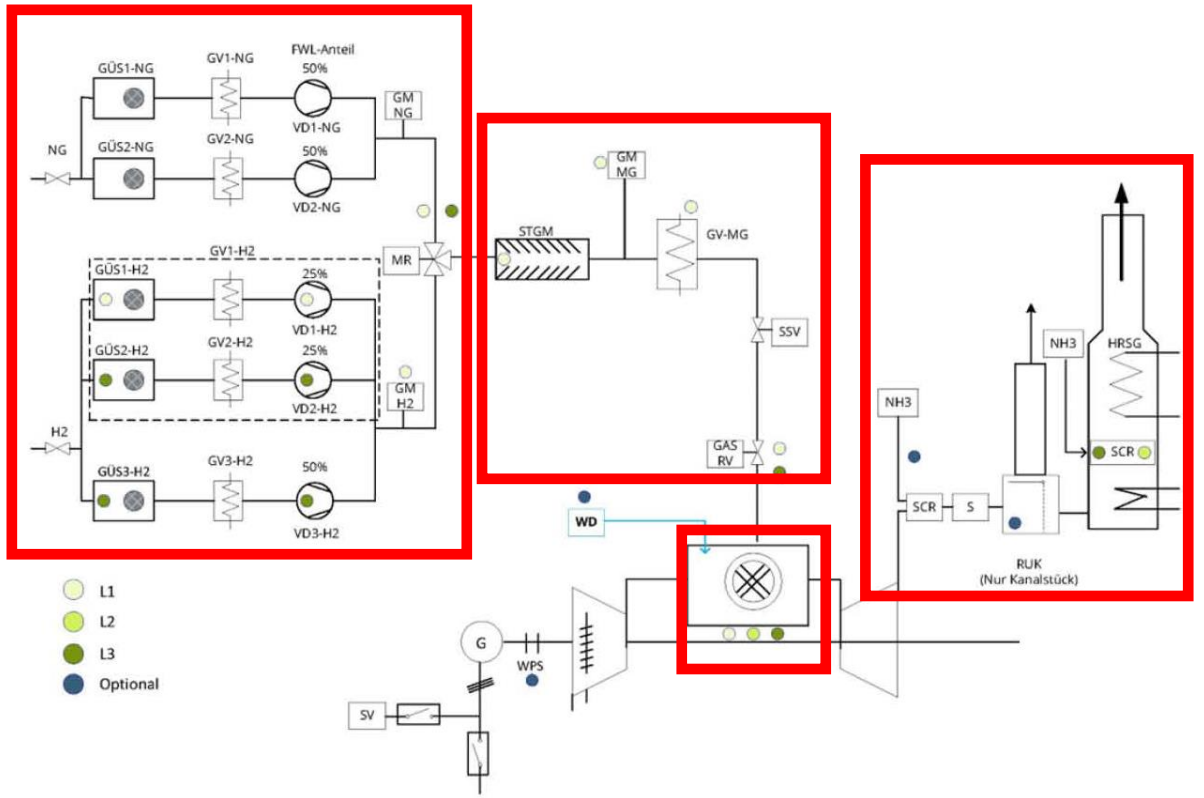
Example: hydrogen-induced stress corrosion cracking

Source: Wikipedia

Overview of technical requirements for H2 readiness for GTA subsystems according to VGBE ENERGY IS US factsheet

Subsystems considered:

- Gas supply
- Fuel gas system between gas feed, compressor, mixer, fuel gas block to fuel quick-closing valve
- Combustion system and gas turbine
- Exhaust system, including HRSG
- Control and protection system
- Fire and explosion protection
- Retrofitting of existing systems
- approval procedures, emissions, etc.



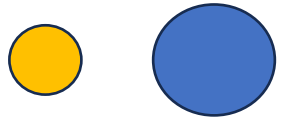
Examples:

- Level 1 (6% H2 TFC):
  - Checking whether materials and seals are suitable
  - Installation of mixing “skid” and fast gas chromatograph
  - Adaption of control system
- Level 2 (25% H2 TFC):
  - Adapted burner technology (f.e. installation of flashback extinguishing system)
    - NOx catalyst needed?
  - Flame detectors
  - Explosion protection measures, incl. adaption of venting enclosure and HRSG
  - Adaptation diameters fuel gas pipes and valves, incl. bleed and safety valves
- Level 3 (100% H2):
  - New combustor / burner technology

Gas supply system

- Generally from approx. 25vol% H2 change of explosion group
  → Effects on explosion protection, etc.

- 3,3 times the volume
  → diameter of piping and valves x1,8



- Preheating is not mandatory and above 200°C is not advisable due to increased diffusion (Joule-Thomsen effect: 100 → 20 bar: +3K)

- Valuable information: ISO/TR 15916 “Basic considerations for the safety of hydrogen systems

Summary

- Materials is a challenge in high-pressure H2 applications, but there is experience in the chemical industry and power plant technology.
- In the future, GTAs must be able to burn mixtures between 100% natural gas and 100% hydrogen to be hydrogen ready.
- A development of combustion systems with low NOx emissions is to be expected.
- With a constant combustion heat output and constant air mass flow, there is no increase in the turbine inlet temperature. Performance and efficiency increase slightly.
- The water vapor content in the exhaust gas increases only moderately from about 4 to 7% (mass).

papers

- https://www.vgbe.energy/en/?jet_download=a602a7abf476ddc4c8b5dea8bed047a2506f3a5b

- https://www.vgbe.energy/en/?jet_download=c27e206dba054173d43e4201a2bec5a5d0a839b6