ENERGINET

# TURNING THE TIDE

## Navigating Water Content in Hydrogen Specifications

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# ENERGINET - HYDROGEN TRACE COMPONENTS

## Based on CEN/TS 17977.

- Growing convergence regarding trace component limits.
- Energinet departs from other quality specifications regarding maximum water content.

| Likely origin | Name | unit | Energinet Spec. |
|---|---|---|---|
| $H_2$ Generation | Carbon monoxide | ppm | ≤ 20 |
| | Carbon dioxide | ppm | ≤ 20 |
| | Ammonia | ppm | ≤ 13 |
| | Halogenated compounds | ppm | ≤ 0.05 |
| | Water | ppm | 20 ppm |
| | Oxygen | ppm<br>ppm | (≤ 1000)<br>≤ 10 |
| NG Infrastructure | Hydrocarbon DP | °C | - 2 |
| | Total sulphur | ppm | ≤ 7 |
| | Particles | mg/kg | Technically free |

Note: ppm = µmol/mol

Energinet's indicative quality and temperature specification for hydrogen (pages 11-13).



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# DESIGN CODES VS. QUALITY STANDARDS

| Standard/Code | Water limit ppm | Dew point @ 70 bar °C |
|---|---|---|
| ASME B31.12 | 20 | -21.0 |
| CEN/TS 17977 | 60 | -7.4 |

calculated with GERG-2008.

- The maximum water content is 3 times lower in ASME B31.12 compared to Hydrogen Quality Specifications!
- Conflicting requirements leads to **cross-border interoperability issues!**
- To explain the discrepancy between water content limits in design codes and quality standards and the associated risks of either choice. **The effect of water in hydrogen was investigated.**


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# WATER CONTENT IN HYDROGEN


## CONDENSATION

Avoid condensation of liquid water

## CORROSION

Reduce rate of Internal corrosion

## HYDRATES

Reduce risk of formation of hydrates

## EMBRITTELMENT

Damaging mechanisms from liquid *and/or* gaseous water (HAFCG)

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# THE EFFECT OF WATER ON MATERIALS

Does water accelerate or inhibit hydrogen embrittlement?

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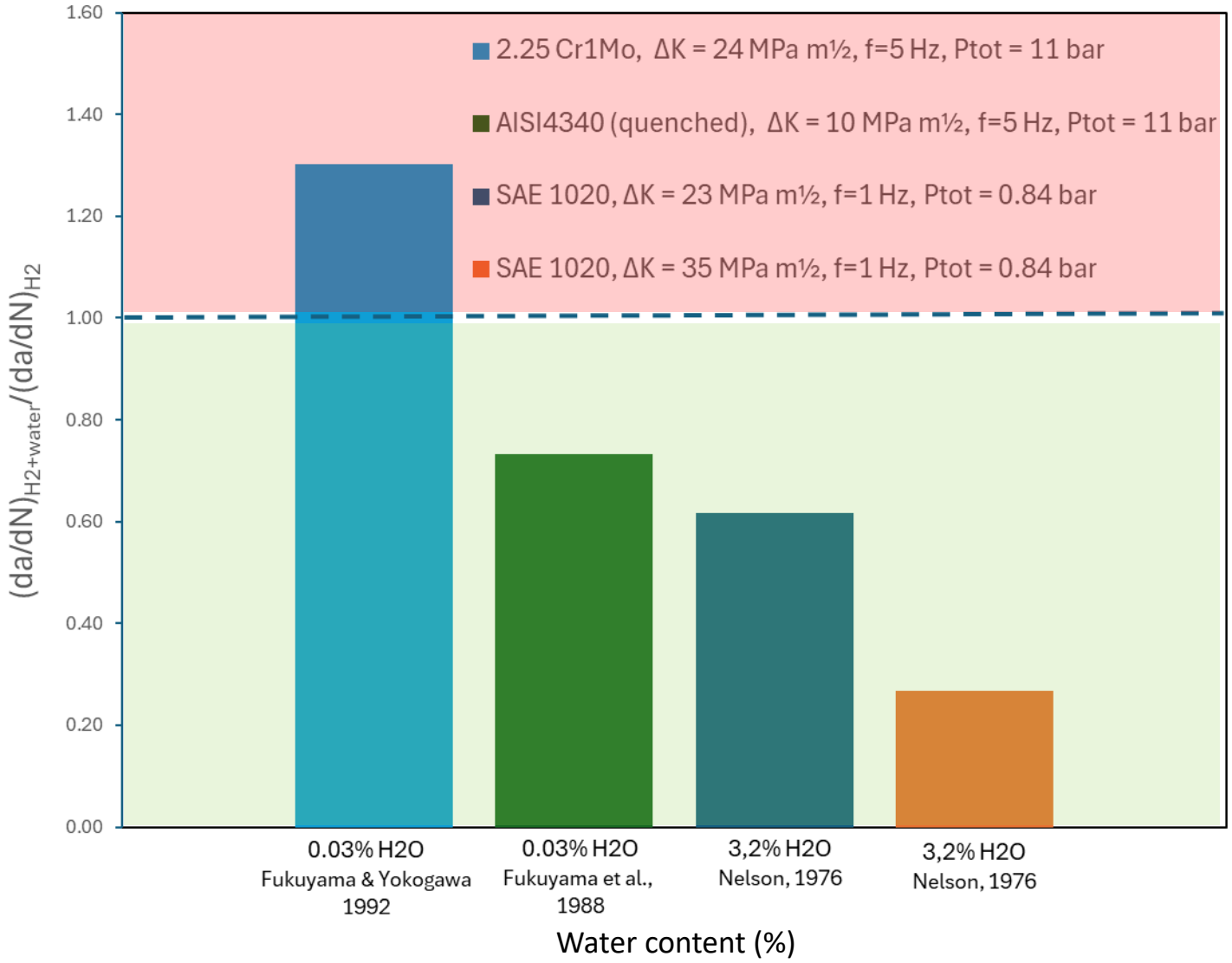
# WATER VAPOUR

- Water vapour can act as an inhibitor OR promoter of hydrogen embrittlement.
- The effect is dependent on the material and stress intensity factor.
- Insufficient studies specific to the effect of moisture have been performed.




Effect of water vapour on fatigue crack growth in hydrogen for 3 materials and various stress intensity factors (ΔK)

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# LIQUID WATER

## Condensed water films poses an integrity risk in hydrogen pipelines

A liquid water film is most likely to occur at cold spots near crevices, dead legs, welds and HAZ.

- Accelerates the rate of internal corrosion: a source of atomic hydrogen and stress. Accelerates atomic hydrogen ingress.
- Increase the **ingress of atomic hydrogen** into the material through electrochemical reactions.
- Corrosion and hydrogen embrittlement exhibit a **mutually reinforcing** relationship (HASCC).
- Acidic contaminants such as $H_2S$ and $CO_2$ further increases the risk of HASCC and SSC.


Illustration generated with AI

- **These effects are difficult to quantify** but could significantly accelerate crack initiation and HA-FCG.

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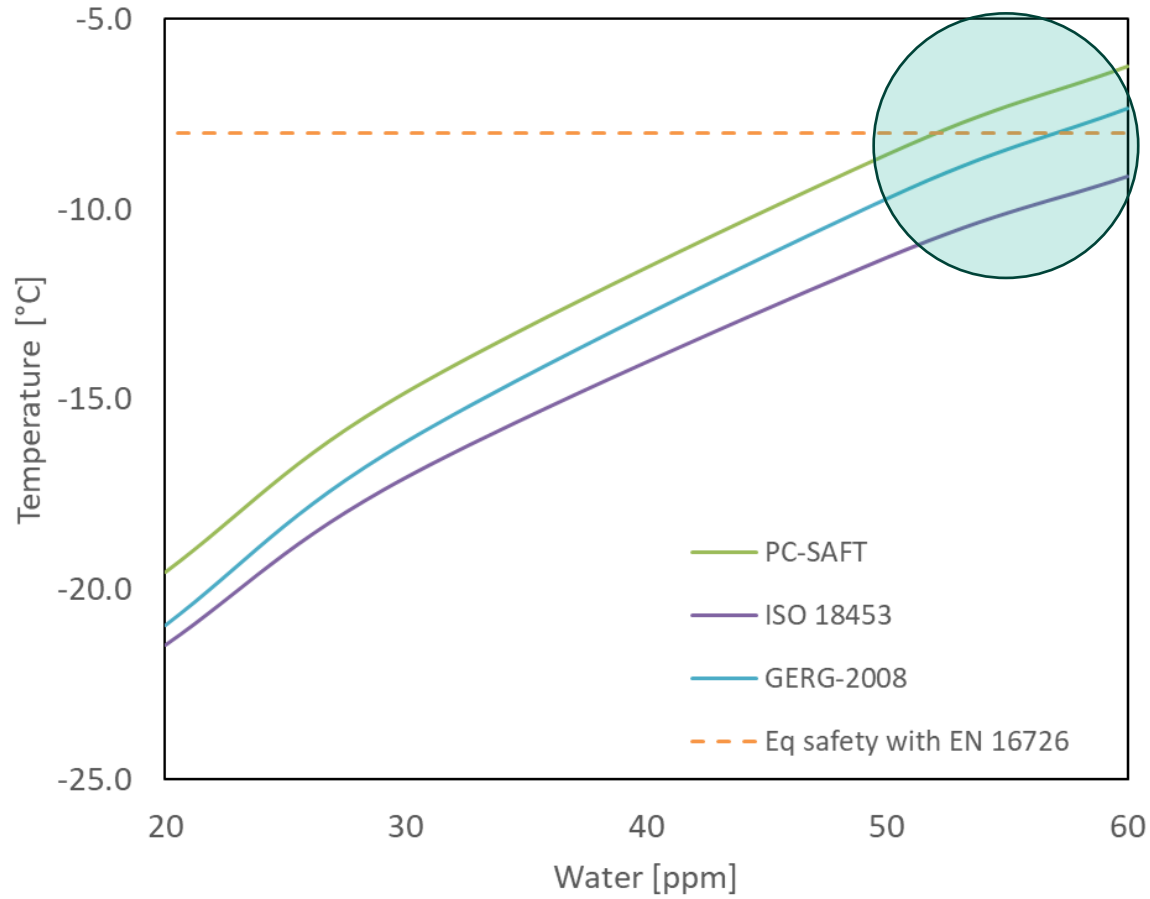
# EOS FOR WATER DEW POINT CALCULATIONS

- ✓ Equations of state for water dew point calculations are designed for natural gas.
- ✓ Different Equations of State for water dew point may vary in predictions by up to 5 °C.

Water dew point temperature at 70 bar with different models




How much do we trust the model?

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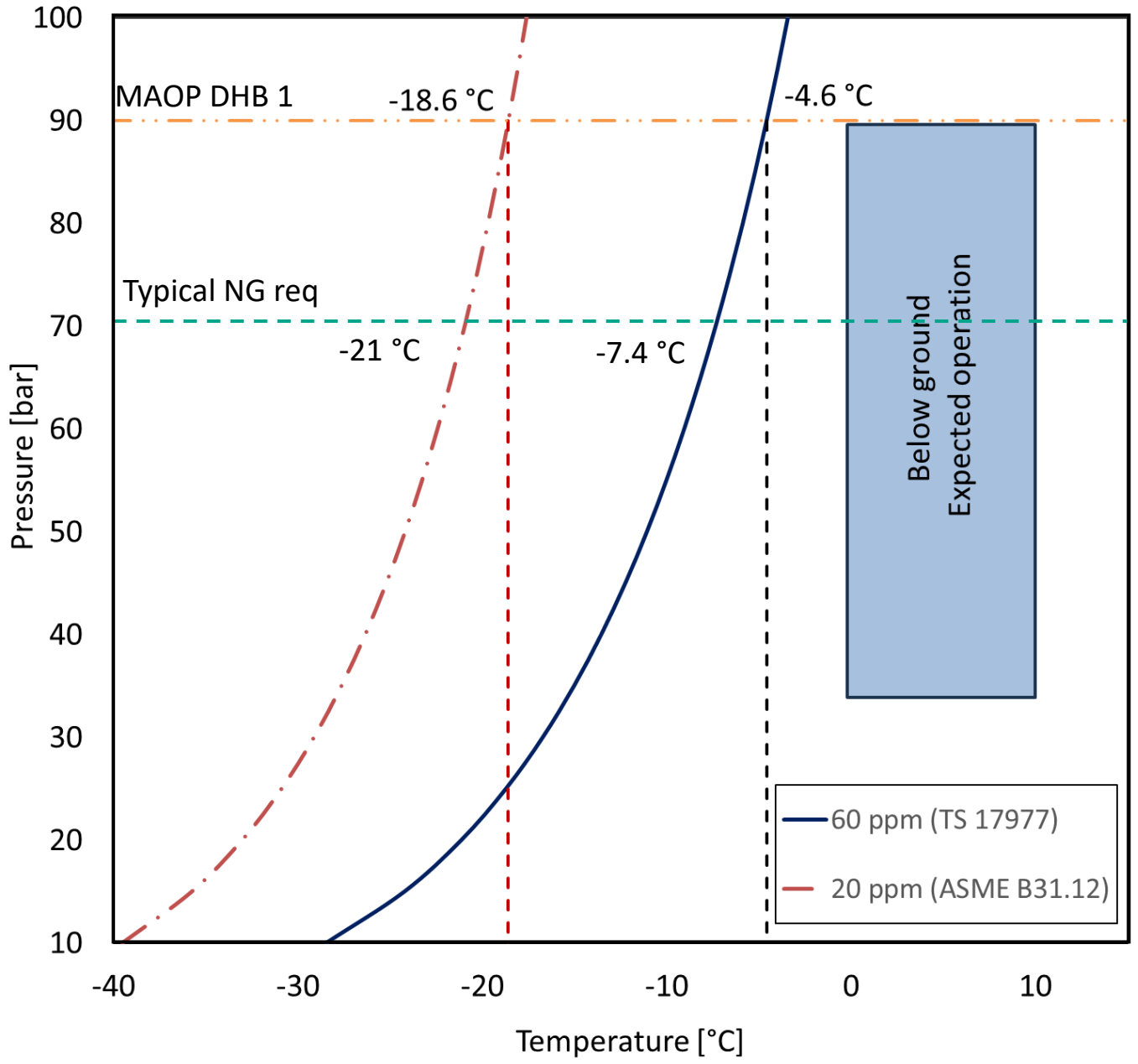
# WATER DEW POINT - PT ENVELOPE

Dew point temperatures indicated at 90 bar and 70 bar.

Expected below ground operational PT-window indicated.

Thin margin for error at MAOP of the DHB 1 with CEN/TS 17977.




Calculated using GERG-2008

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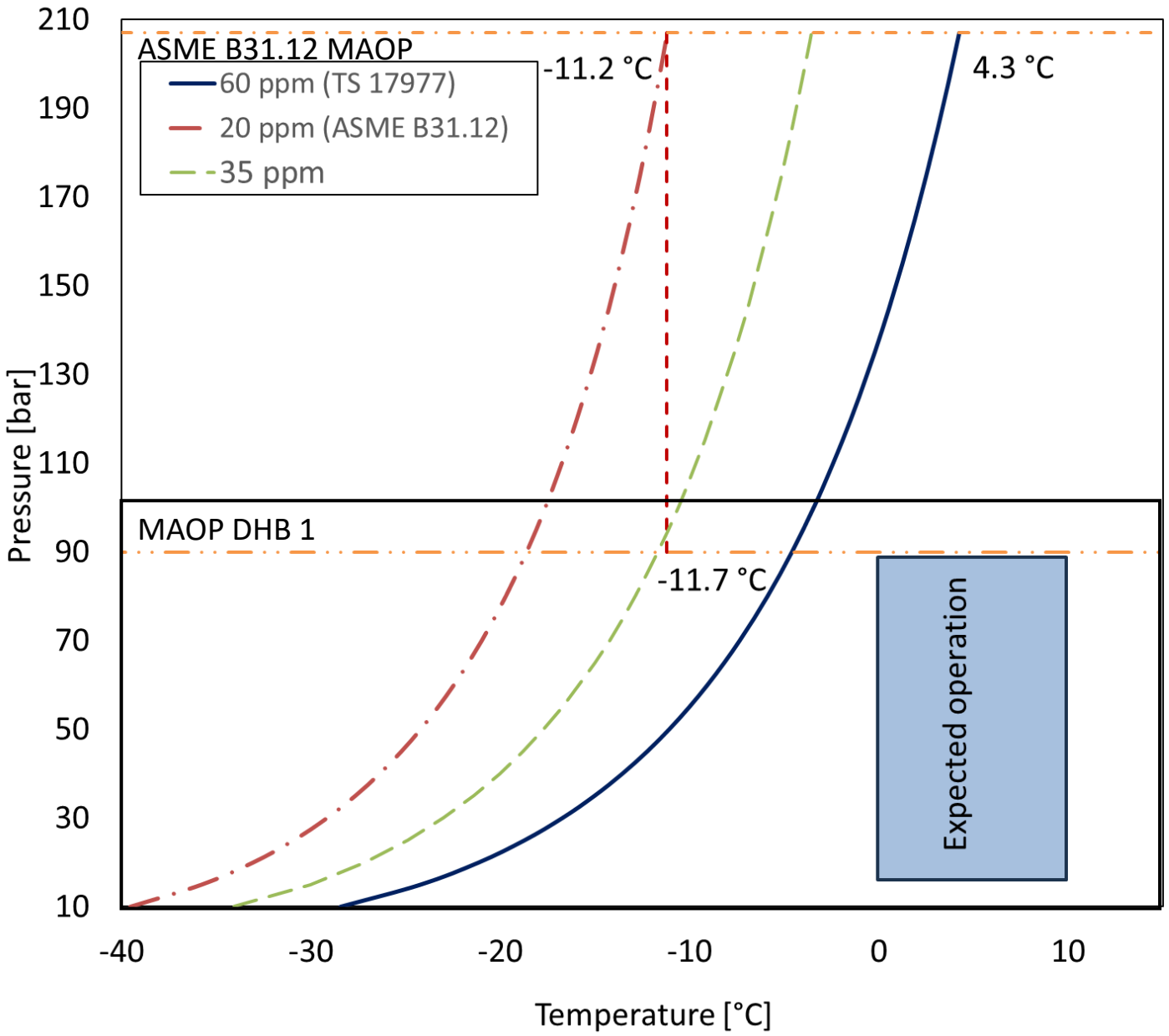
# WATER DEW POINT - PT ENVELOPE

The codes are designed for different pressure regimes!

Dew point temperature at MAOP for ASME B31.12 (≈207 barg):
**≈ -11.2 °C**

Equivalent risk of condensation at MAOP of 90 bar: c(H2O) **≈ 35 ppm**
At
MAOP of 70 bar: c(H2O) ≈ **45 ppm**




Calculated using GERG-2008

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# CONDENSATION IN HYDROGEN VS NATURAL GAS

## INCREASES RISKS

- ✓ EoS for water dew points may be inaccurate.
- ✓ Condensation may accelerate embrittlement, fatigue crack growth and/or SCC.
- ✓ Still standing gas in above ground facilities may be more prevalent than for NG due to intermitted production (electrolysis).
- ✓ Higher MAOP in part of DHB 1 than in NG.

## REDUCES RISK

- ✓ Pre-heating before pressure regulation isn't necessary, no equipment which can fail.
- ✓ Risk of gas hydrate formation is non-existent
- ✓ Water vapour sometimes inhibit embrittlement

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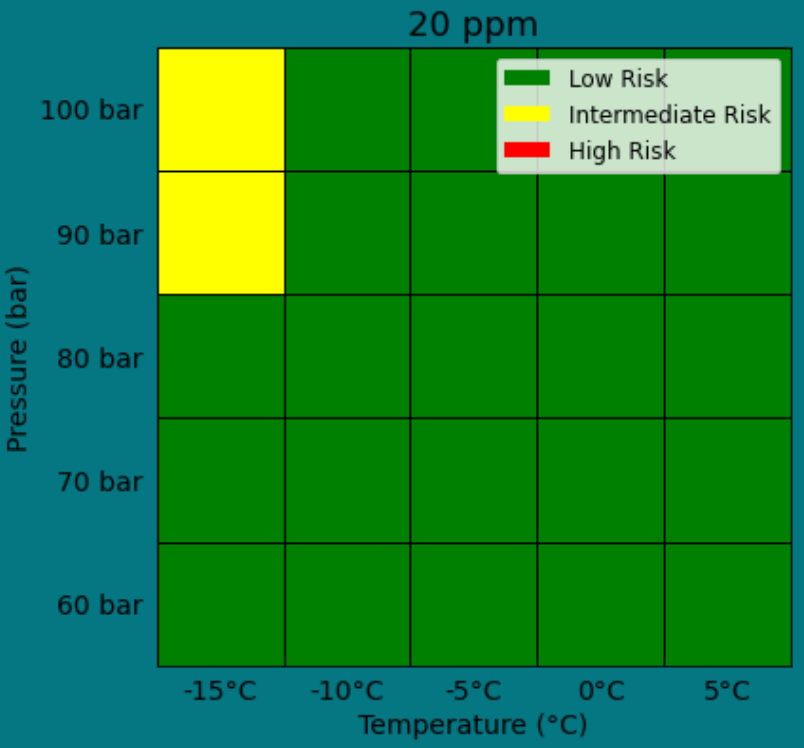
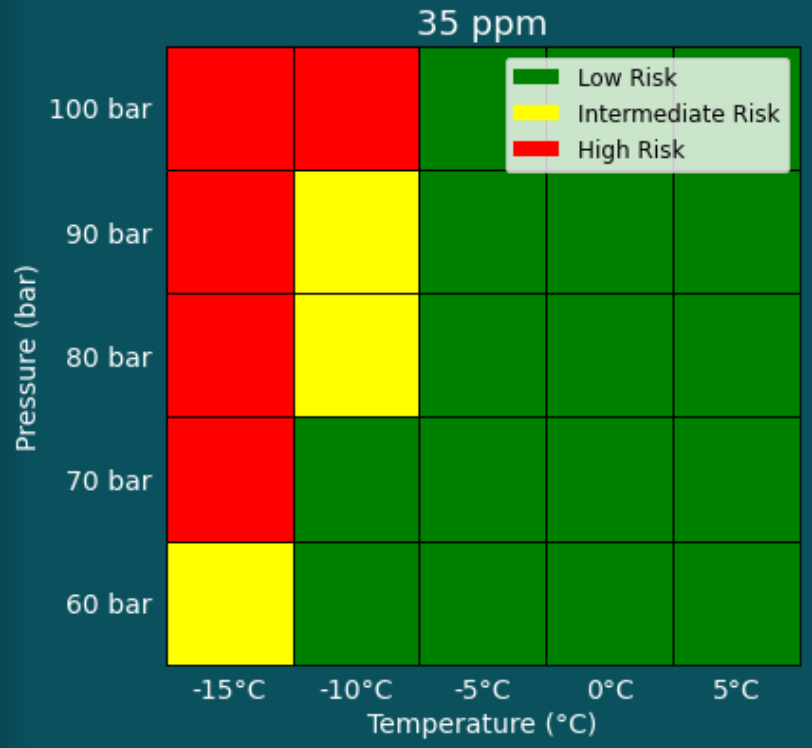
# Indicative Risk of water condensation in the DHB 1

## At specific P and T

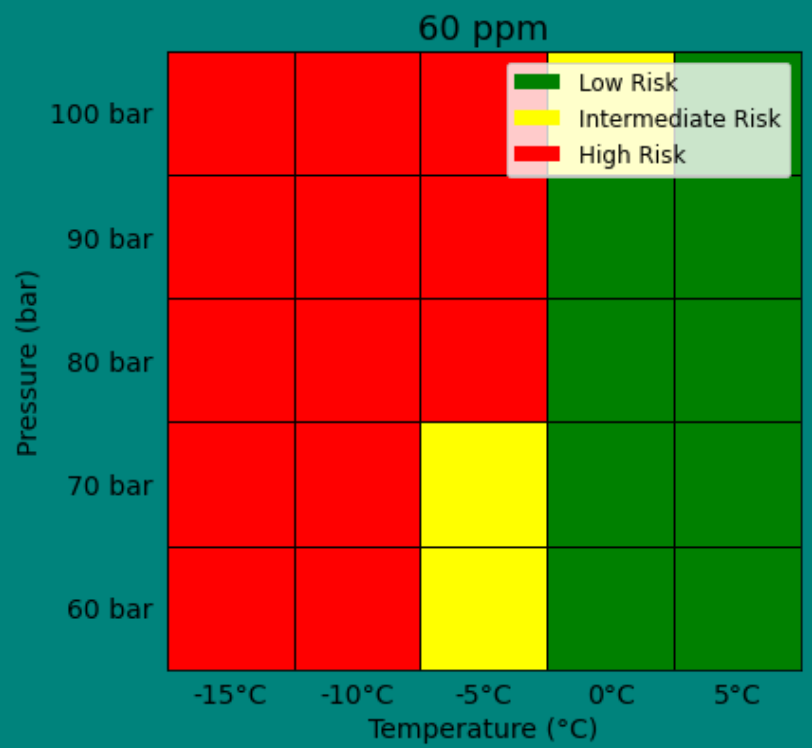
### ELIMINATING RISK




### "EQUIVALENT RISK"




### THIN MARGIN



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# CONCLUSION

**CEN/TS 17977**
**60 ppm**

- Approx. equivalent safety against condensation as in Natural gas.
- Thin margin at elevated pressures.

**”The in-between”**
**35 ppm**

- “Equivalent” condensation protection as ASME B31.12 for systems with a MAOP of 90 bar.
- Sufficient for most hydrogen networks and most climates.

**ASME B31.12**
**20 ppm**

- Applicable at high pressures in cold climates.
- Conservative end of industry practice (20-40 ppm).
- Tried and tested.

Moisture control is the compass for safe operation of hydrogen pipelines.

Careful navigation is essential to decide on the right limit

At Energinet, we’ve anchored our course to ASME B31.12, holding fast to a strict 20 ppm water limit.

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# THANK YOU FOR YOUR ATTENTION


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