

As part of the **CANDHY** project, an extensive experimental campaign has been conducted to assess the compatibility of new and vintage non-steel materials with hydrogen-enriched environments. The campaign covers interlaboratory and individual testing across the full range of materials, test methods, and hydrogen blends defined within the project scope. All experiments were carried out at a gas pressure of 16 bar, representative of operating conditions in natural gas distribution networks.

The testing programme comprises two main categories:

- Dynamic loading tests: Slow Strain Rate Testing (SSRT), Fracture Toughness (FT), and Fatigue Crack Growth (FCG).
- Static load-controlled tests: Constant Tension CT-WOL and C-ring methods conducted in hydrogen for 1000 hours.

This approach allows evaluating hydrogen embrittlement susceptibility under both conditions where the material is continuously deforming (rising load) and conditions where the load is held constant. The campaign evaluates the influence of several key factors: hydrogen concentration (100% H₂ vs. 20% H₂ + 80% CH₄ blend), the presence of stress concentrators (cracks or notches), microstructural characteristics, and the effect of material age (new vs. vintage).

Although the experimental campaign is still ongoing, some key preliminary conclusions can already be drawn.

Microstructure governs embrittlement in cast irons:

For ductile cast iron materials, microstructure is the main factor affecting hydrogen embrittlement susceptibility. A higher pearlite fraction is associated with a greater loss of ductility and fracture toughness. The type of graphite (nodular vs flake) also plays an important role. Cast irons with a high percentage of nodular graphite and very little pearlite showed almost no loss in plastic strain, suggesting that nodular graphite can act as a hydrogen sink, capturing hydrogen atoms and delaying embrittlement.

Material age does not influence embrittlement:

The age of the material (new vs. vintage) does not, by itself, affect hydrogen embrittlement susceptibility, as long as service-related defects are excluded. Vintage ductile cast irons with significantly higher nodular graphite content, demonstrated greater resistance to hydrogen embrittlement than new cast iron with lower nodular graphite content, confirming that the microstructure rather than age is the relevant variable.

Higher hydrogen partial pressure increases embrittlement:

Both SSRT and Fracture Toughness results confirm a clear trend: fracture resistance decreases as the partial pressure of hydrogen increases. Consequently, the embrittlement ratios measured for the 20% H₂ blend (relative to N₂ baseline) are slightly lower than those measured in 100% H₂, but the difference is modest. This is an important finding for network operators considering hydrogen blending, as it indicates that even partial hydrogen addition reduces material performance.

Fatigue crack growth is accelerated in hydrogen:

Preliminary FCG results indicate that crack propagation rates in pure hydrogen at 16 bar can be up to an order of magnitude higher than in air. Consequently, components subjected to cyclic loading in hydrogen-blended networks may experience reduced fatigue life.

Brass shows negligible embrittlement under the test conditions:

The 60Cu/38Zn/2Pb brass material exhibited very low sensitivity to hydrogen embrittlement, with negligible loss in fracture toughness (approximately 7% in 100% H₂ at 16 bar, and nearly 0% in the 20% H₂ blend).

Static vs. dynamic loading:

The data collected so far indicate that the degree of embrittlement depends on the loading condition. In the CANDHY experimental campaign, rising-load tests (SSRT, FT and FCG) consistently produced higher embrittlement indices than constant-load (constant displacement) tests (CT-WOL, C-ring). In this sense constant-load tests, which allow for significantly longer exposure durations, should be complemented with rising-load tests to contribute to a more comprehensive evaluation of material behaviour.

These results are of particular interest because most published research on hydrogen embrittlement in the gas network context has focused on carbon steel pipelines and on hydrogen introduced by electrochemical charging in laboratory settings. Little is known about how gaseous hydrogen under pressure affects the non-ferrous materials (cast iron and copper alloys, principally) that make up much of the distribution network.

The CANDHY experimental campaign addresses this gap. By testing non-steel materials under realistic gaseous hydrogen conditions, at pressures relevant to distribution networks, and across both static and dynamic loading regimes.

Finally, CANDHY results will be made available in a public database, contributing to the development of material selection criteria for hydrogen-blended gas networks.