

# ECOSYSTEM FOR HYDROGEN DISPENSING AT RATES ABOVE 60 g H<sub>2</sub>/s



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## Context and Objectives

Current requirements of future road hydrogen vehicle operators are primarily determined by the fuelling speed. This concerns operators of urban and suburban bus fleets, long-haul heavy-duty vehicles, and rail passenger vehicles. The issue of high-flow fuelling is addressed by the SAE J2601-5 protocol, which enables hydrogen dispensing in the range of 60–300 g H<sub>2</sub>/s.

### The objectives of sub-project DP008 (2025–2028) are:

- ▶ To systematically summarize existing knowledge from hydrogen fuelling operations up to 60 g H<sub>2</sub>/s.
- ▶ To design and implement a set of control algorithms for the safe management of fuelling above 60 g H<sub>2</sub>/s.
- ▶ To experimentally verify the functionality of these algorithms on a mobile development platform of a dispensing device enabling high-flow fuelling, utilizing measurement technology and a testrig.

Funding Note: The results presented in this poster were obtained within the National Center for Hydrogen Mobility

## Methods

Two technological pillars:

### 1. Prototype of the mobile development platform for high-flow fuelling (Fig. 1):

- ▶ Assembly of three technological containers (K1: Compressor unit, K2: Cascade high-pressure storage 300/500 bar, K3: Cooling and dispensing device).
- ▶ Intelligent control system (Fuzzy-Neuro)
- ▶ The key innovation is adaptive control of the fuelling process.
- ▶ Fuzzy logic: Effectively works with thermodynamic uncertainty (temperature in the tank is not uniform or directly measurable at every point).
- ▶ Neural network: The system learns from each cycle and optimizes fuelling time for different tank types (buses, trucks, trains).
- ▶ Modularity: Separate control for the dispensing section and the storage management.

### 2. Testrig – mobile device for testing hydrogen refuelling stations (Fig. 2):

- ▶ Primary function is the verification of fuelling protocols.
- ▶ Equipped with four Type IV pressure cylinders with a total volume of 1400 L and an operating pressure of 350 bar.
- ▶ Triple mass verification: To achieve a tolerance of +/- 5 %, a combination of the equation of state, mass flow meter, and strain gauge weighing is used.
- ▶ Transport protection: Unique pneumatic tank fixation protects weight sensors from overload during transit.

### Design and Optimization Process:

The design of the entire system was carried out in several iterative steps, during which digital models directly influenced the final engineering solution.

#### 1. Initial simulations and cascade definition (Fig. 4):

The process began with the development of mathematical models for the filling and emptying of high-pressure storage vessels (bundles) at pressures of 300 and 500 bar. The initial simulations focused on verifying the cascade's ability to maintain a mass flow rate above 60 g H<sub>2</sub>/s at different volumes and back pressures in the vehicle tank.

lity project (TN02000007), co-funded by the Technology Agency of the Czech Republic.

The following companies are involved in the project:



### 2. Detailed 3D geometry modelling

To accurately identify pressure losses, the development moved from 1D schematics to detailed 3D modelling of the piping routes. This step made it possible to visualize the flow and identify critical bottlenecks within the piping system.

### 3. Iterative piping system optimization

The centre tube was straightened and enlarged to DN14, reducing losses in this node by more than half (Fig. 5). Simple bends replaced elbows to reduce costs while maintaining efficiency. Hoses to the Testrig tanks were enlarged to 8–10 mm to achieve target flows.

### 4. Complex system simulation and thermal management

The individual models (bundles, the dispensing unit – PA128 in Fig. 2, and the TESTRIG) were integrated into a single functional system. Simulations revealed that without active cooling, tank temperatures would reach 117.5 °C, which is unsafe. These results served as input for the cooling system design (Fig. 6).

### 5. Final validation and control

To reach a full state (SOC = 1) while respecting the 65 °C limit, dynamic fuelling protocol management via the Fuzzy-Neuro regulator is essential.

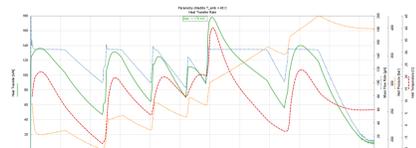


Fig. 6 | Behaviour of key variables during fuelling

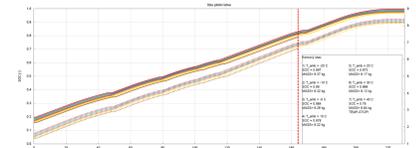


Fig. 7 | SOC simulation of the vehicle Fig. 6: Behaviour of key variables during fuelling tank cylinder

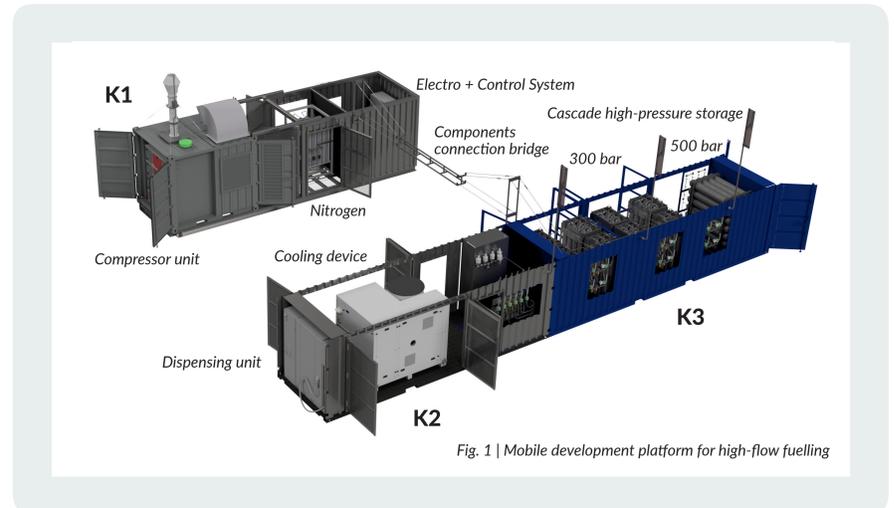


Fig. 1 | Mobile development platform for high-flow fuelling

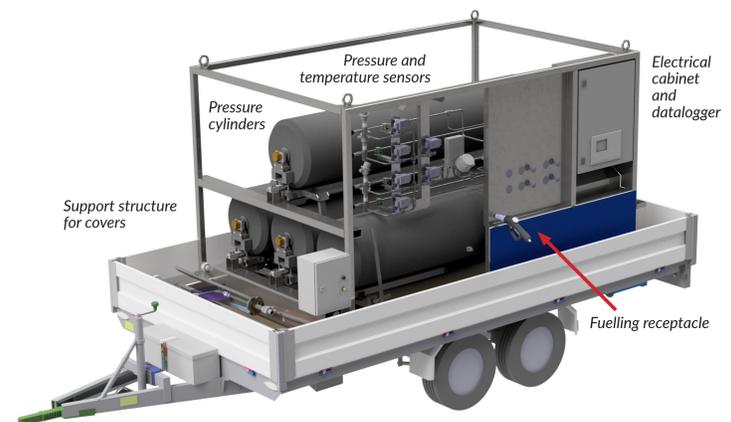


Fig. 2 | Mobile device for testing hydrogen refuelling stations

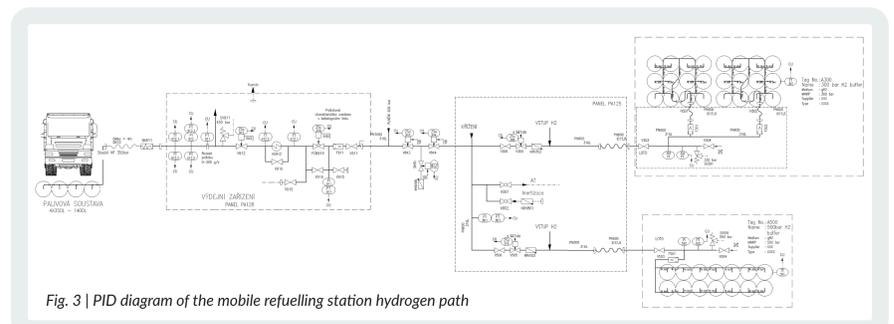


Fig. 3 | PID diagram of the mobile refuelling station hydrogen path

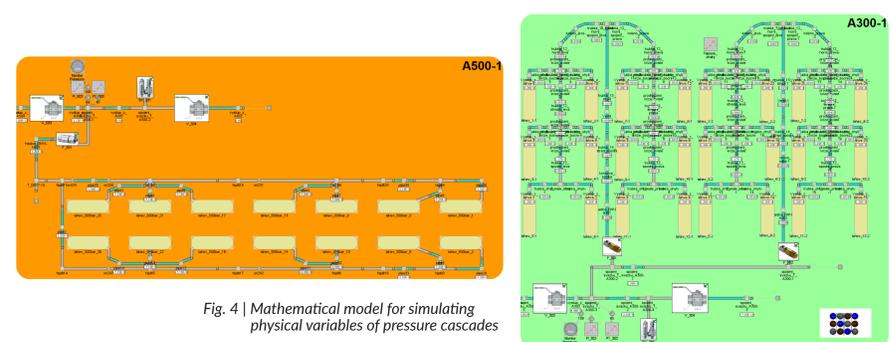


Fig. 4 | Mathematical model for simulating physical variables of pressure cascades

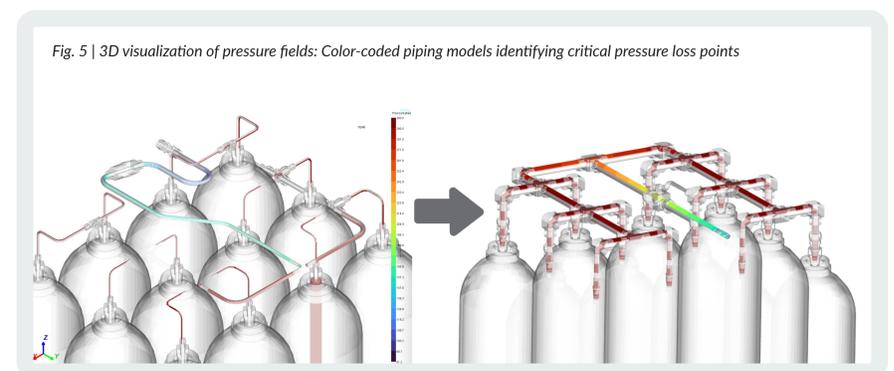


Fig. 5 | 3D visualization of pressure fields: Color-coded piping models identifying critical pressure loss points

## Planned Results & Development Platform

- ▶ Development and testing base: Results are based on the initial phase of experimental development. This is not a final commercial product for routine operation, but a mobile development platform designed as an open ecosystem for real-world data collection and validation of new technologies.
- ▶ Universal component testing: The platform is designed to allow testing of any key components for hydrogen refuelling stations (HRS), including new pressure vessels, cascade optimization, pre-cooling systems, sensors, and dispensing units.

- ▶ Simulated target parameters: The goal is to verify fuelling capability between 60 and 300 g H<sub>2</sub>/s according to the SAE J2601-5 standard.
- ▶ Verification via TESTRIG: The Testrig will serve for independent verification of fuelling protocol implementation for both newly developed and existing infrastructure components.
- ▶ Thermodynamic management: Development of algorithms to keep the tank temperature below 65 °C even at extreme fuelling rates, ensuring safety and system longevity.

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## Acknowledgements

„This project is co-financed from the state budget by the Technology agency of the Czech Republic under the Národní centra kompetence Programme.“  
“This work utilized outputs from Ekosystém plnění vodíku rychlostí přesahující 60 g H<sub>2</sub>/s (TN02000007-008) project.”

The results of the project Ekosystém plnění vodíku rychlostí přesahující 60 g H<sub>2</sub>/s (Ecosystem for hydrogen dispensing at rates above 60 g H<sub>2</sub>/s) are available online in Czech at [www.cistadoprava.cz/nahyc-m/dp008/](http://www.cistadoprava.cz/nahyc-m/dp008/)

