PROTOCOL FOR HEAVY DUTY HYDROGEN REFUELING: A MODELING BENCHMARK

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ICHS International Conference on Hydrogen Safety
EDINBURGH SCOTLAND
H2 PRHYDE Protocol for heavy-duty Hydrogen refuelling
FCH Fuel Cells and Hydrogen Joint Undertaking
Horizon 2020 European Union Funding for Research & Innovation

1
Introduction

1) Introduction
Modeling software for hydrogen fillings

- Use of hydrogen in mobility uses (road transport, …) to increase
- Hydrogen Refueling Stations (HRS) needed to be safe, fast and easy-to-use
- Gaseous filling → heat generation in the vehicle tanks
- Filling protocol describes how the HRS should behave
- Development of protocol dependent on modeling

Accuracy of simplified model is very important

PRHYDE project: focus on Heavy Duty (trucks)

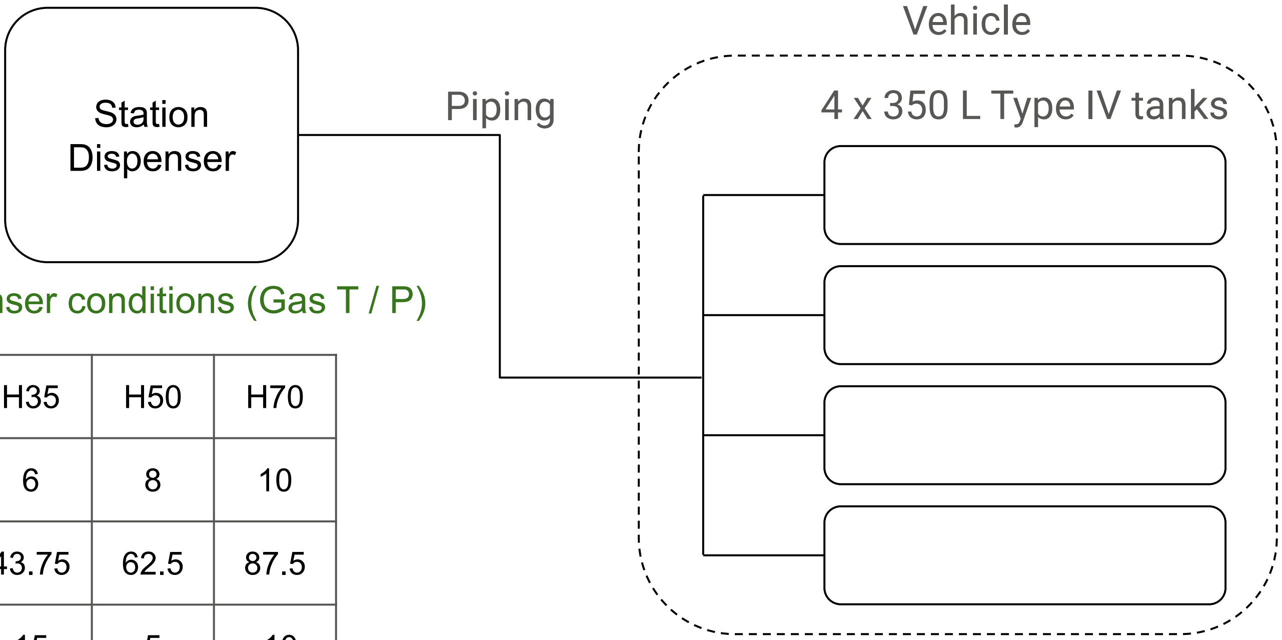
2

Modelled cases

2) Modelled cases

10 minutes filling

Tamb = 15 °C



Input Dispenser conditions (Gas T / P)

	H35	H50	H70
Initial pressure (MPa)	6	8	10
End dispenser pressure (MPa)	43.75	62.5	87.5
Dispenser temperature (°C)	15	5	-10
Reference mass flow (for pressure drop, g/s)	84	111	141

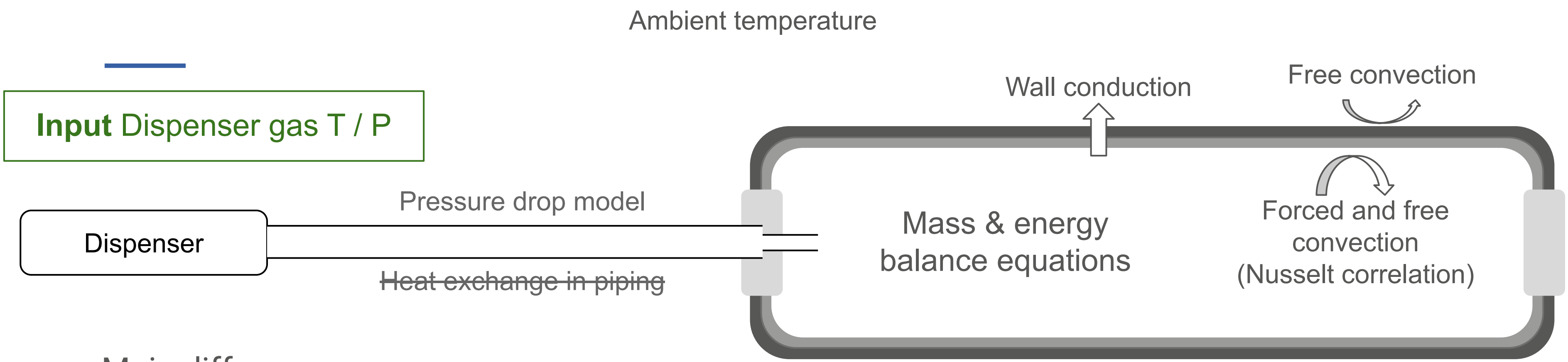
Output Tank Gas T / P

3
Models descriptions

3) Models descriptions

- **Air Liquide** SOFIL [1, 2]
- **Engie** Hyfill [3-6]
- **NREL** H2FillS [7, 8]
- **Wenger Engineering** H2-Fill [9, 10]

3) Models descriptions



4 identical tanks

Output Tank Gas T / P

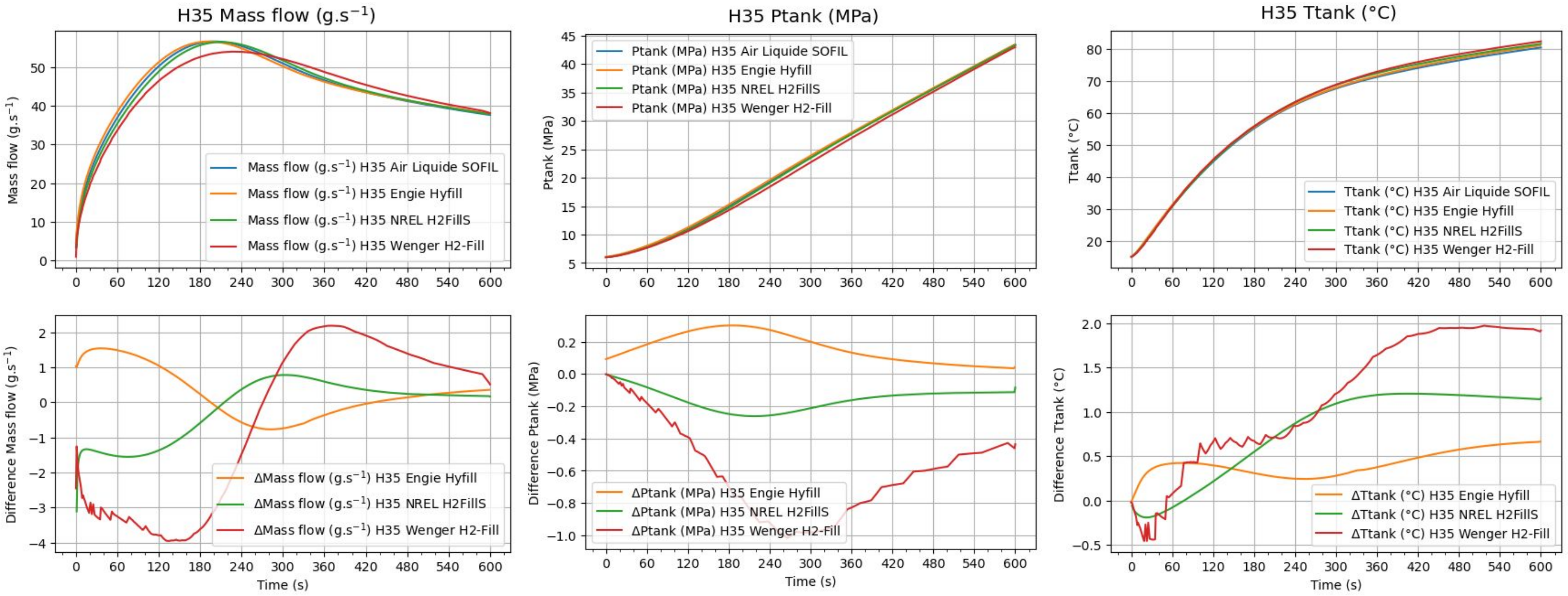
Liner
Composite
Bosses

Main differences:

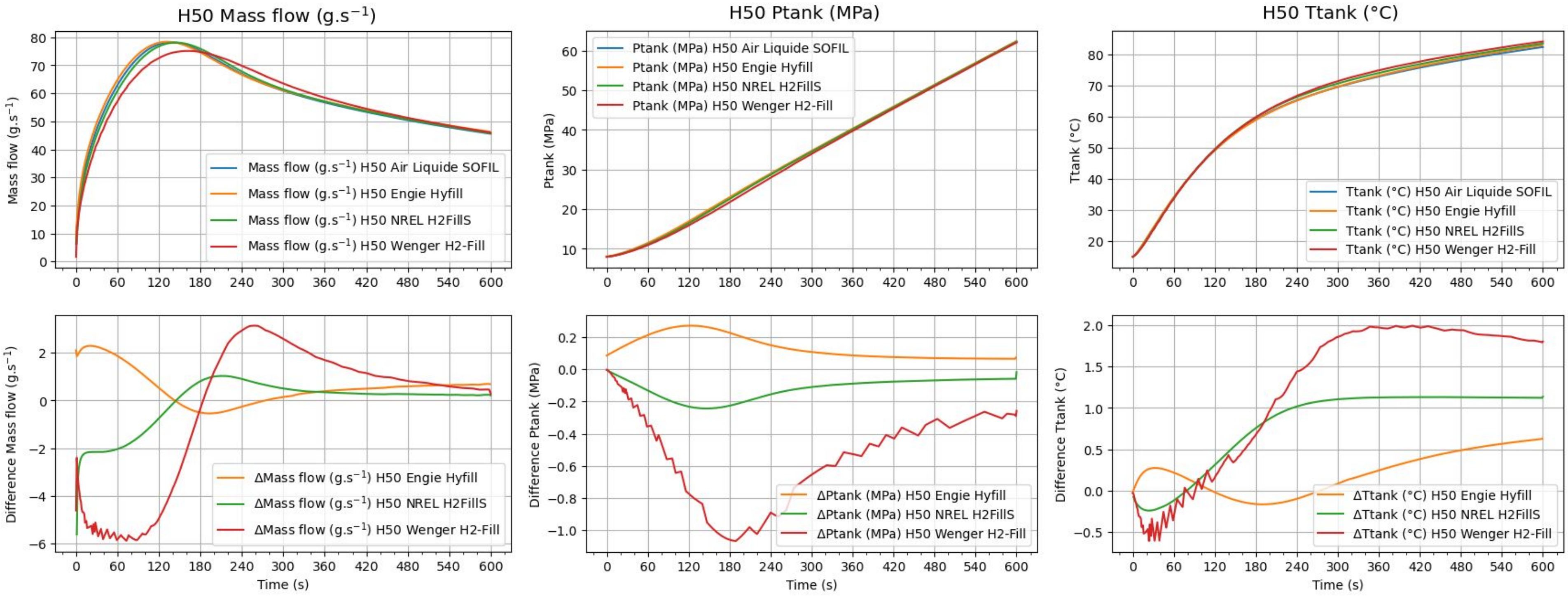
- Pressure drop models
- Real gas models
- 1D-Wall conduction (radial: Air Liquide, Engie, Wenger / cartesian: NREL)
- External heat transfer coefficient
  (fixed: Engie, NREL / Nusselt correlation: Air Liquide, Wenger)

4
Benchmark

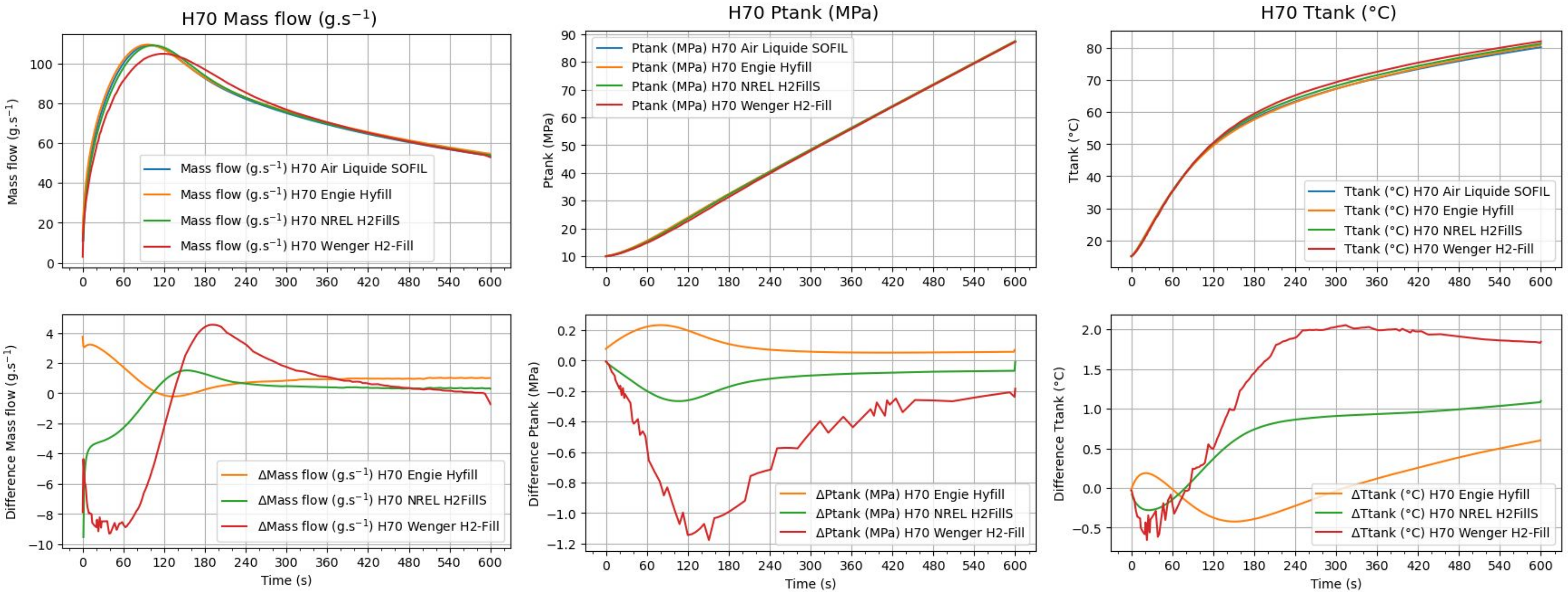
4) Benchmark - H35



4) Benchmark - H50



4) Benchmark - H70



5

Conclusion

5) Conclusion

- Very similar predictions: less than 2 °C range
- Differences:
  - Real gas equations
  - Bosses modeling
  - Simplified tank geometry implementations
  - Pressure drop formula → mass flow

Models used for protocol development in PRHYDE.

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Air Liquide

engie

WENGER Engineering GmbH

NREL Transforming ENERGY

FE FUEL

Annex

Back to presentation

A) Pressure drop models*

Air Liquide's SOFIL

Sonic flow (P1 > 2 P2)

$$\frac{dm_g}{dt} = C\, k_v P_1 \sqrt{\frac{\rho_N}{T_1}}$$

Subsonic flow (P1 ≤ 2 P2)

$$\frac{dm_g}{dt} = 2\, C\, k_v \sqrt{\frac{\rho_N\,(P_1 - P_2)P_2}{T_1}}$$

Engie's Hyfill

Sonic flow (P1 > 2 P2)

$$\frac{dm_g}{dt} = \rho_1\, N\, k_v\, Y \sqrt{\frac{P_1}{2\rho_1}} \text{ with } Y = \frac{2}{3}$$

Subsonic flow (P1 ≤ 2 P2)

$$\frac{dm_g}{dt} = \rho_1\, N\, k_v\, Y \sqrt{\frac{(P_1 - P_2)}{\rho_1}}$$

$$\text{with } Y = 1 - \frac{2}{3}\frac{P_1 - P_2}{P_1}$$

NREL's H2FillS

Sonic flow (P1 > 2 P2)

$$\dot{V} = 2930\, C_v \sqrt{\frac{(P_1 - P_2)(P_1 + P_2)}{P_1 G T_1}}$$

Subsonic flow (P1 ≤ 2 P2)

$$\dot{V} = 2538 C_v \frac{P_1}{G T_2}$$

Conversion to mass flow

$$\dot{m} = \frac{\beta \rho \dot{V}}{3600}$$

β coefficient → handle unsteady flow

* Wenger model not described

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