The DISCHA integral tool for LH2 tank to tank transfer operations

Dr Alexandros G. Venetsanos
National Centre for Scientific Research "Demokritos" (NCSRD), Greece
venets@ipta.demokritos.gr

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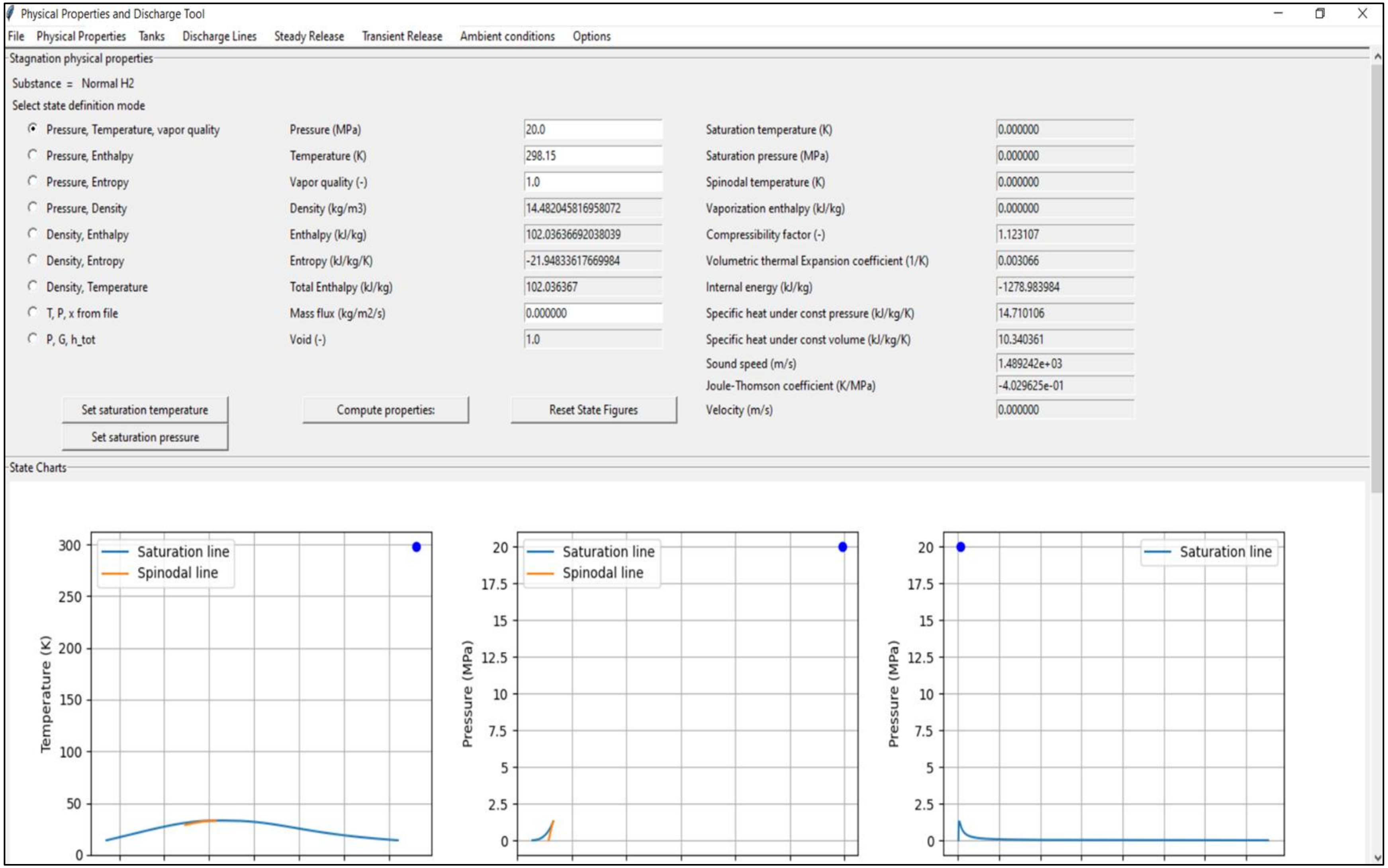
Outline

- Introduction
- Physical Models
- DISCHA validation
  - NASA no-vent LH2 tank fill experiments
- DISCHA applications
  - No vent filling of a 400 L LH2 tank

Introduction / DISCHA tool



Introduction

- DISCHA tool for
  - Physical properties at single phase and two-phase conditions
  - Discharge calculations
  - Tank to tank transfer calculations
- DISCHA development / validation within EC projects
  - NET-Tools, Webinar, 2020 (video)
  - PRESLHY_dissemination_conference, 2021 (video)
    - PRESLHY_Venetsanos.pdf
  - HyTunnel-CS_D4.4.pdf, 2022
  - ELVHYS, International Stakeholders' Seminar, 2024

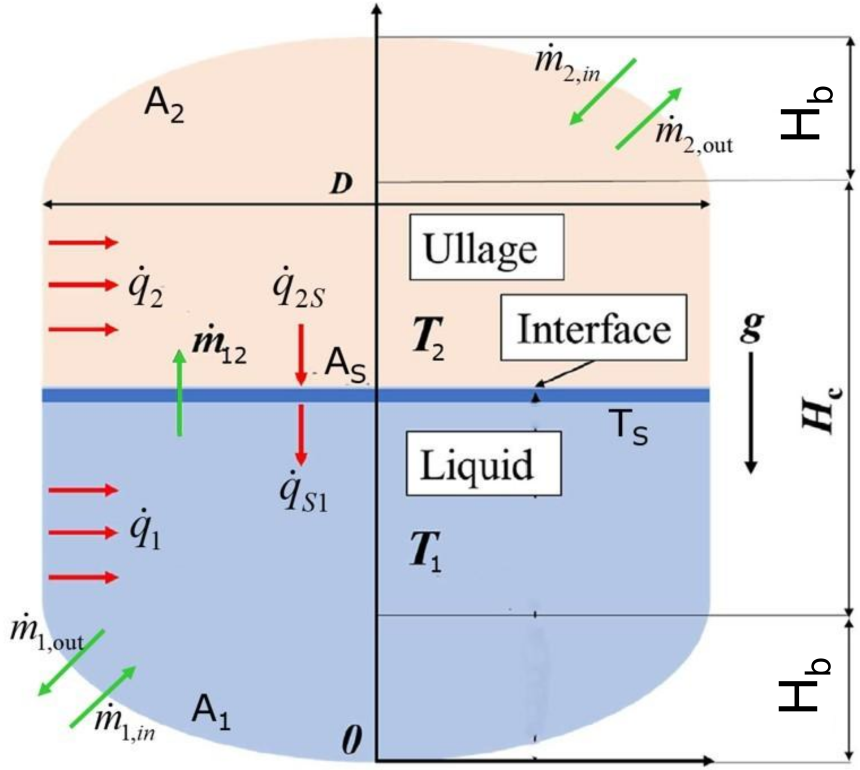
Tank modeling

2 zones

mass

volume constraint

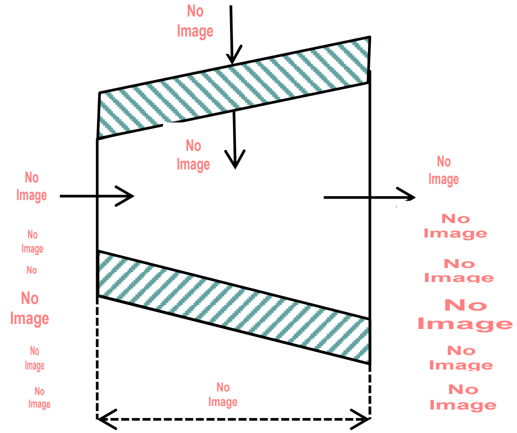
energy



1 zone

Discharge line modeling

Pipe steady state equations:



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Wall heat transfer

Friction

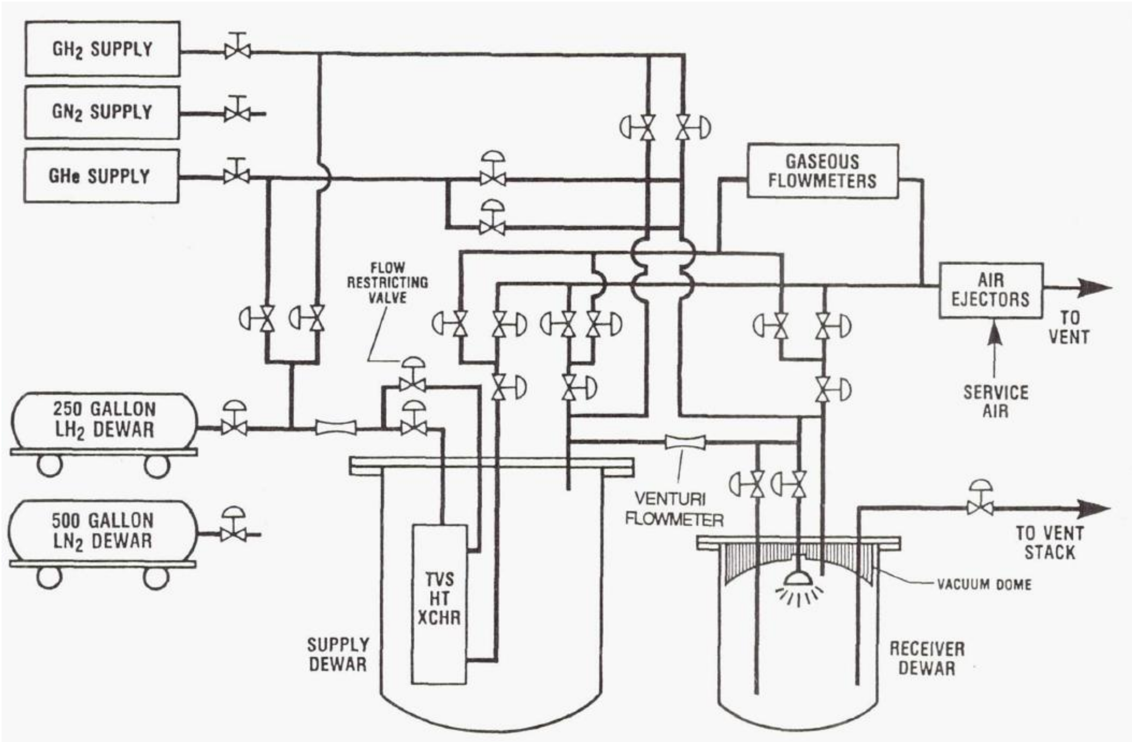
Extra resistances (fittings)

PIF (Possible-Impossible-Flow) algorithm for choked flow

Validation / No vent LH2 tank filling

- Experiments
  - @ NASA CCL-7 test rig, see (Moran et al., 1991)

Moran M.E., Nyland T.W., Driscoll S.L., Hydrogen No-Vent Fill Testing in a 1.2 Cubic Foot (34 Liter) Tank, NASA Technical Memorandum 105273, Oct. 1991

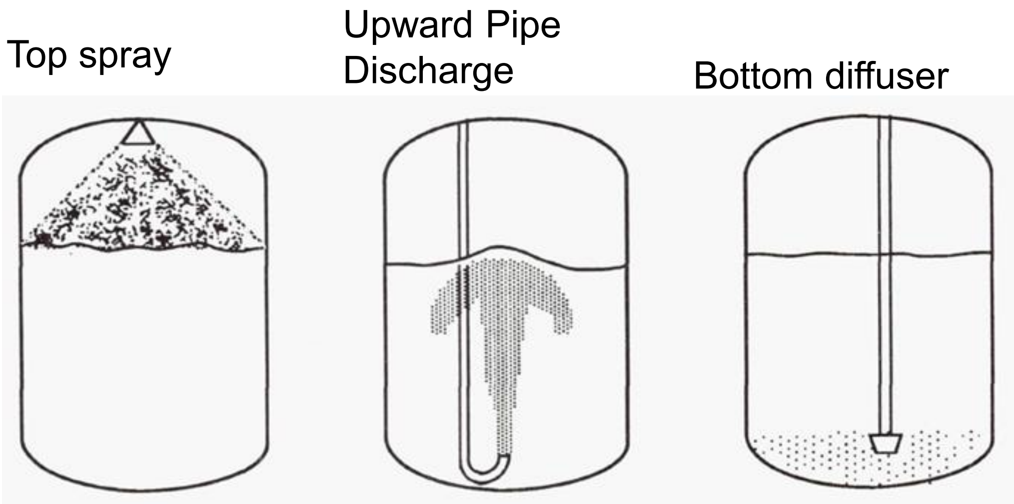


Validation / No vent LH2 tank filling

- Supply tank
  - Internal volume 306 L
  - Internal diameter 0.559 m
  - Internal height 1.372 m
- Receiver tank
  - Internal volume 34 L
  - Internal diameter 0.3175 m
  - Internal height 0.508 m
- Thermal interaction with environment
  - Vacuum jacketed stainless steel cylindrical tanks equipped with MLI within the vacuum annulus
  - The overall heat flux for all tanks was experimentally determined, and ranges between 3.2-32 W/m^2 depending on the fill level and test fluid (N2 or H2)

Validation / No vent LH2 tank filling

- 3 Fill configurations



3 fill configurations in receiver tank

Moran M.E., Nyland T.W., Driscoll S.L., Hydrogen No-Vent Fill Testing in a 1.2 Cubic Foot (34 Liter) Tank, NASA Technical Memorandum 105273, Oct. 1991

Validation / No vent LH2 tank filling

- Experimental conditions

P2 much lower than atmospheric

Top spray

Test #	P1 (Pa)	T1 (K)	P2 (Pa)	T2 (K)	MFR (g/s)	Initial liquid fill (%)
9093A	206843	17.9	26890	16.6	15.1	4.0
9094A	206843	19.2	26890	16.6	27.2	0.0
9094B	206843	19.3	24132	16.3	22.7	0.0
9094C	206843	19.2	26890	16.6	17.4	0.0

Bottom diffuser

Test #	P1 (Pa)	T1 (K)	P2 (Pa)	T2 (K)	MFR (g/s)	Initial liquid fill (%)
9088B	206843	19.5	25511	16.5	11.3	4.0
9088C	206843	19.5	20684	16.0	28.7	5.5
9081G	206843	18.5	22753	16.2	31.8	8.0
9088G	206843	18.1	23442	16.3	32.5	7.2

1: Supply tank, 2: Receiver tank

Validation / No vent LH2 tank filling

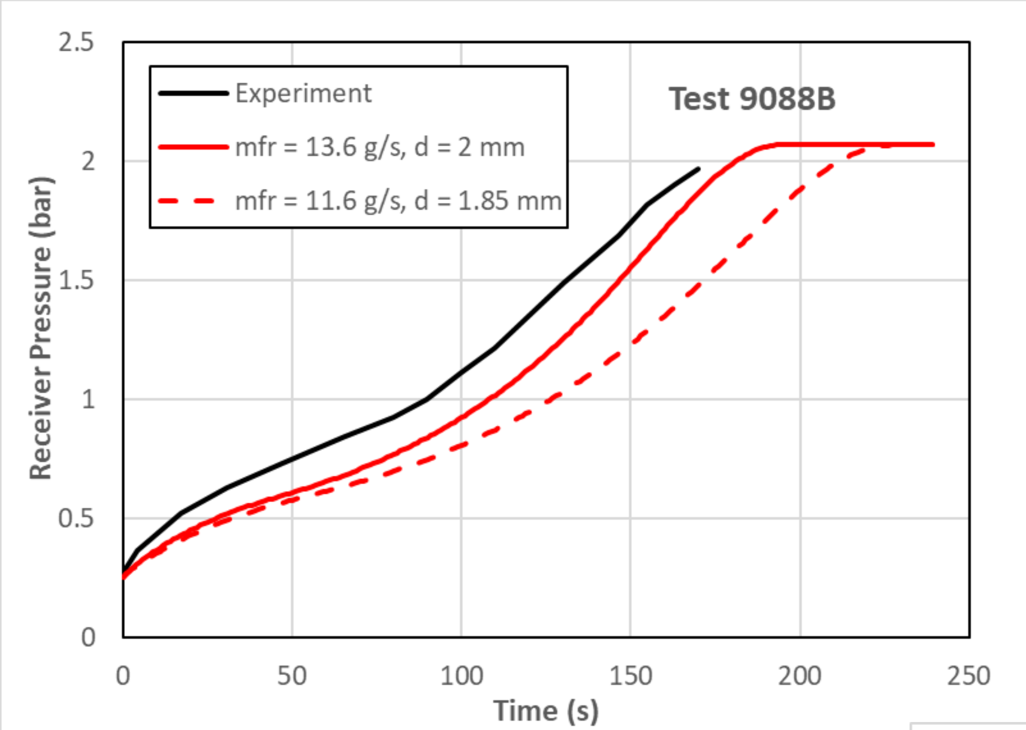
- Modelling assumptions (1/2)
  - Supply and receiver tanks taken both as ideal vertical cylinders
  - LH2 transfer from bottom of supply tank
  - Top spray assumed at top of receiver tank
  - Bottom diffuser assumed at bottom of receiver tank
  - HFE EoS for normal H2
  - No heat transfer interaction with external environment

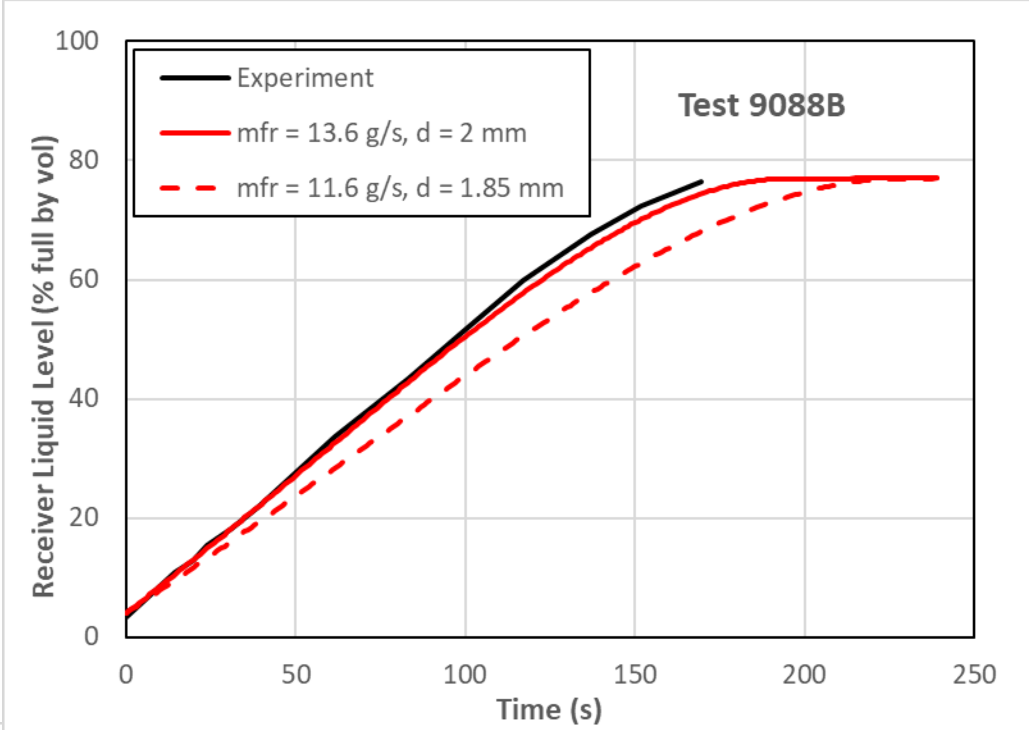
Validation / No vent LH2 tank filling

- Modelling assumptions (2/2)
  - Single zone tank model in supply tank
  - Constant pressure in supply tank = 30 PSI (206843 Pa) =>
    - Subcooled conditions in supply tank, since Tsat(30 PSI) = 23.05 K
  - Saturated initial conditions in receiver tank T2=Tsat(P2)
  - Discharge line (zero length), with internal diameter tuned to reproduce the experimentally measured mass flow rate.
  - Multizone tank model for receiver tank
    - Ullage temperature saturated or superheated
    - Liquid temperature subcooled or saturated
    - Liquid-vapor interface temperature saturated
    - Interface evaporation as in (Wang et al, 2022)

Wang H.R. et al., Modeling and thermodynamic analysis of thermal performance in self-pressurized liquid hydrogen tanks, IJHE, 47 (2022)

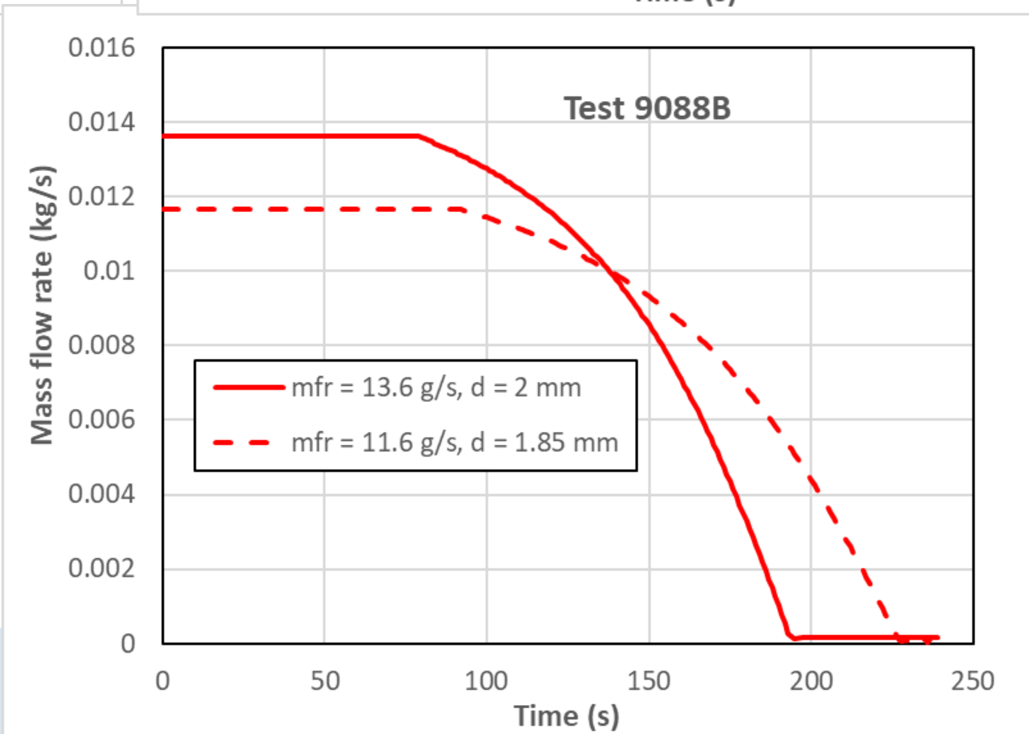
Validation / No vent LH2 tank filling



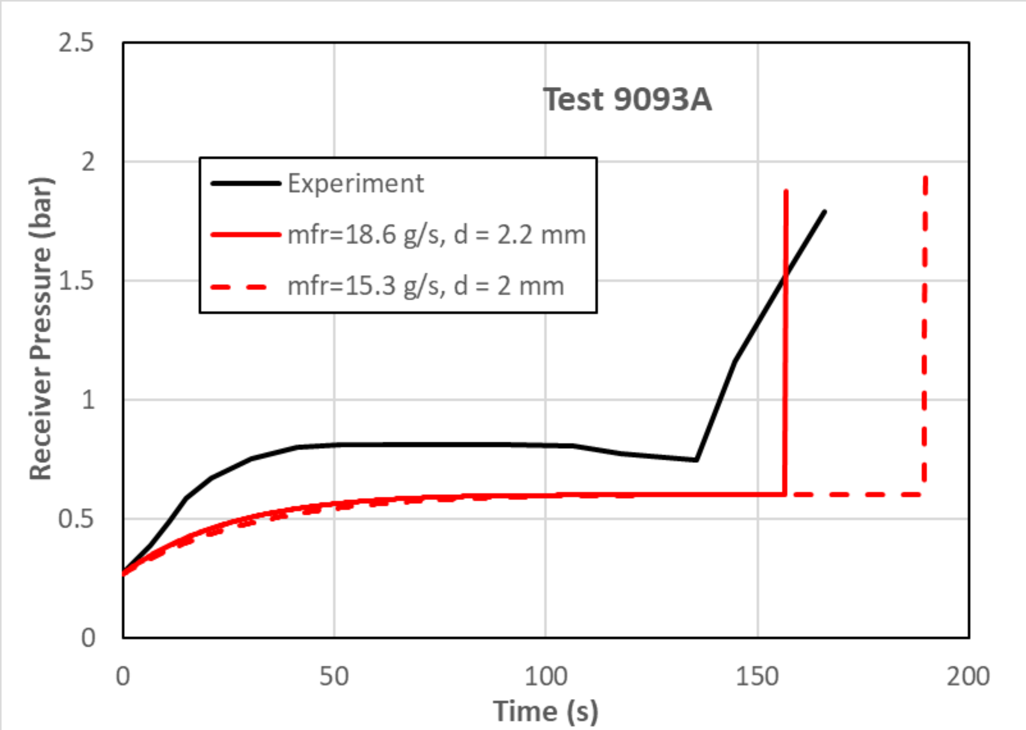


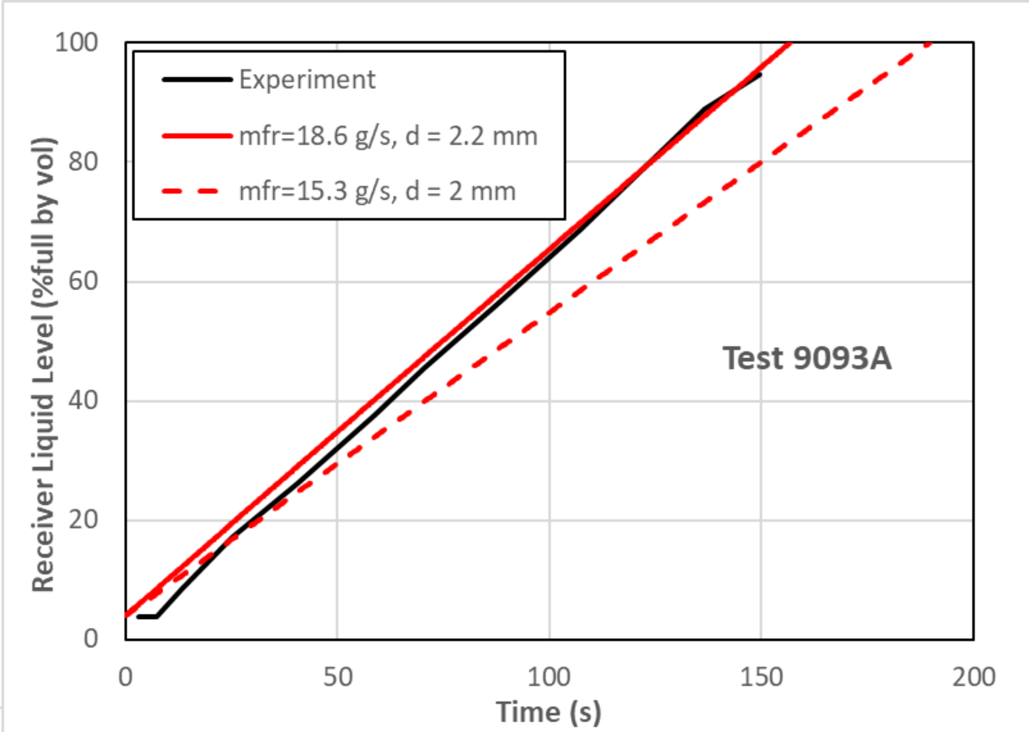
Bottom diffuser

Mfr_exp = 11.3 g/s



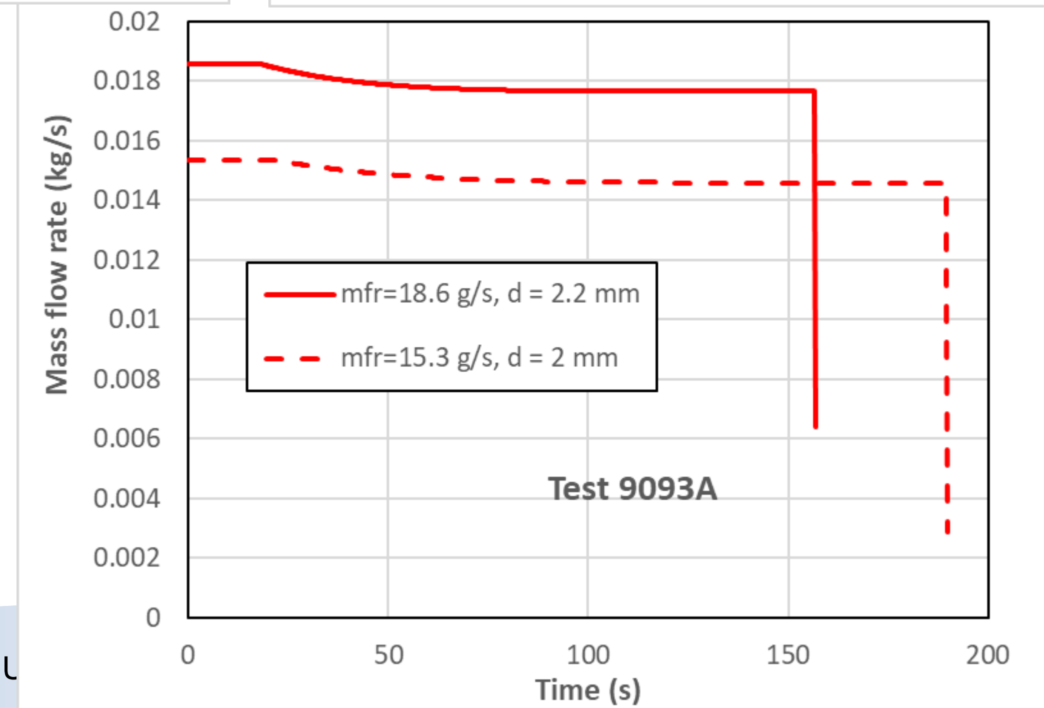
Validation / No vent LH2 tank filling





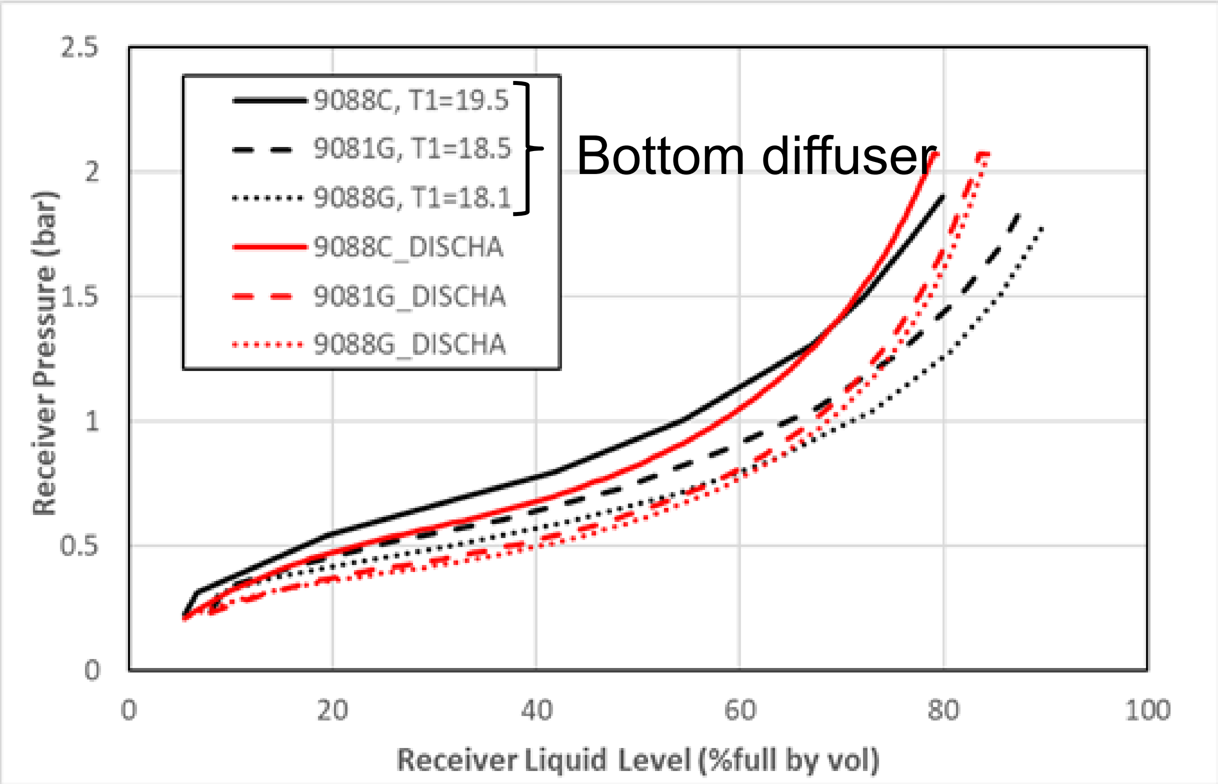
Top spray

Mfr_exp = 15.1 g/s



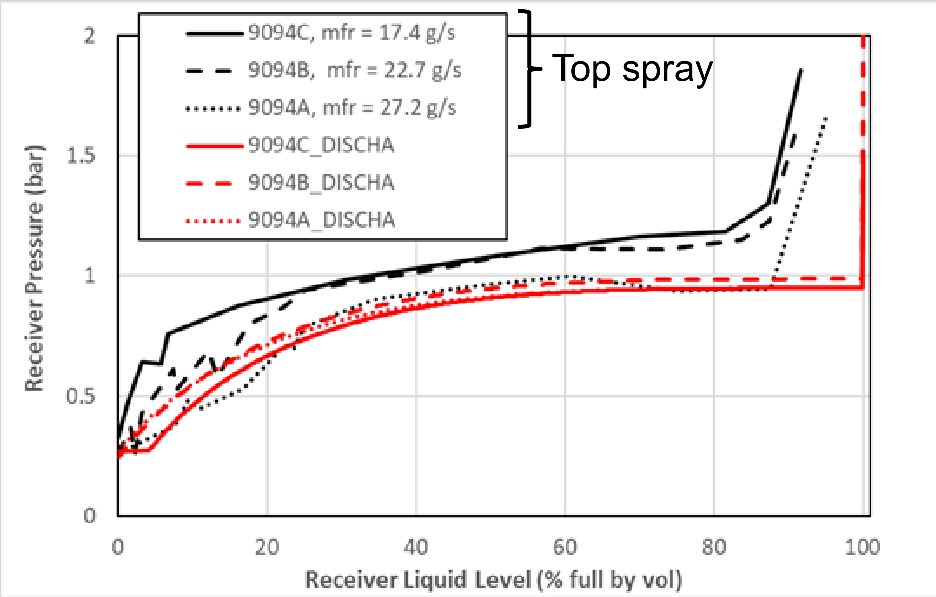
Validation / No vent LH2 tank filling

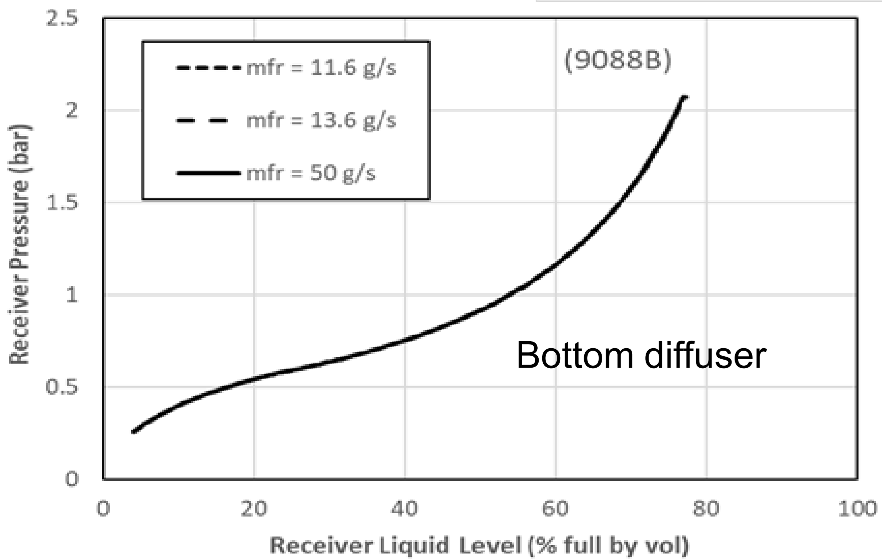
Effect of inlet temperature

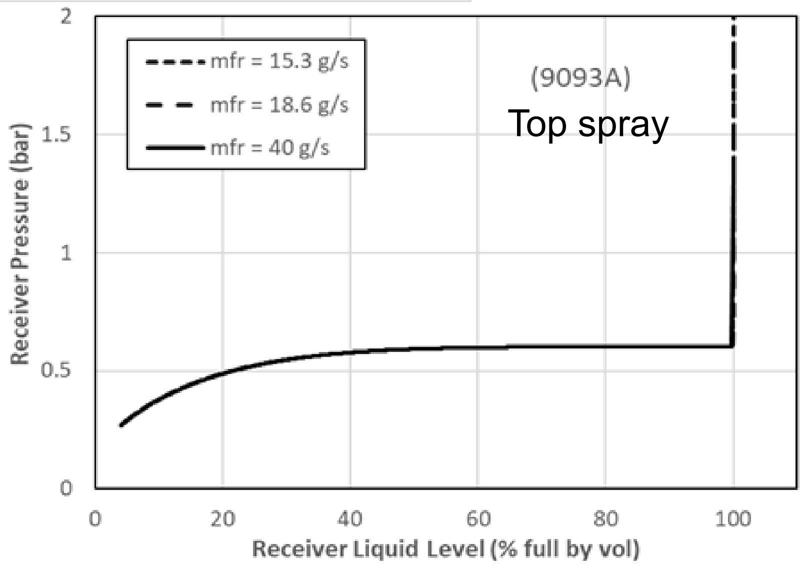


Validation / No vent LH2 tank filling

Effect of inlet liquid mass flow rate







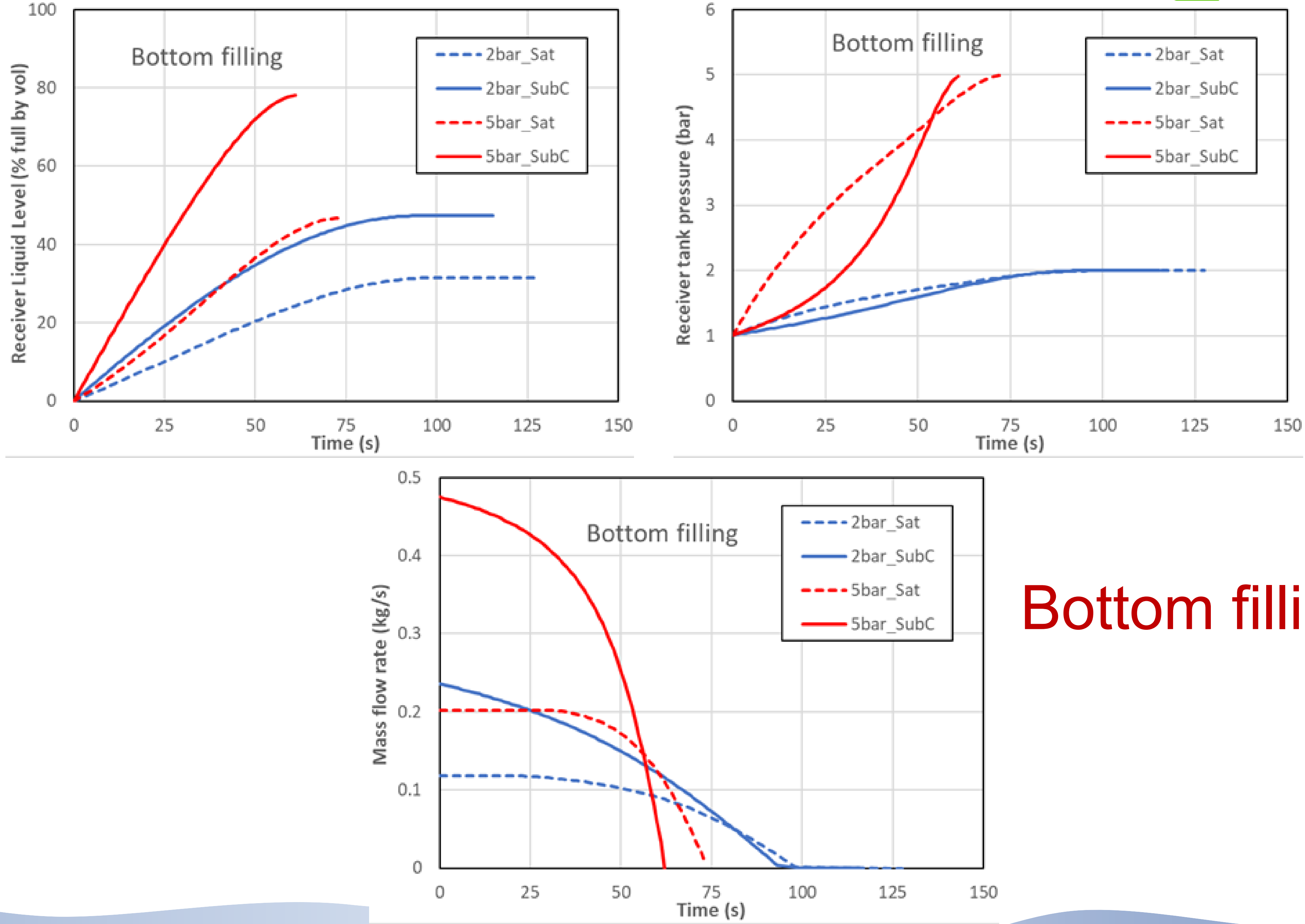
Conclusions

- DISCHA validation
  - NASA no-vent fill experiments of a 34 L receiver tank from a 306 L supply tank
    - DISCHA reproduced reasonably well the experimentally observed different behavior between top spray and bottom diffuser fillings concerning receiver tank pressure and fill level response
    - Regarding the effect of the inlet liquid temperature on the pressure vs. fill level response it was found that a lower pressure rise exists in the receiver tank as the inlet temperature is decreased in accordance with the experiments.
    - Regarding the effect of inlet liquid mass flow rate on the pressure vs. fill level response the present model shows no effect for the given conditions examined.

Application / No vent filling of a 400 L LH2 tank

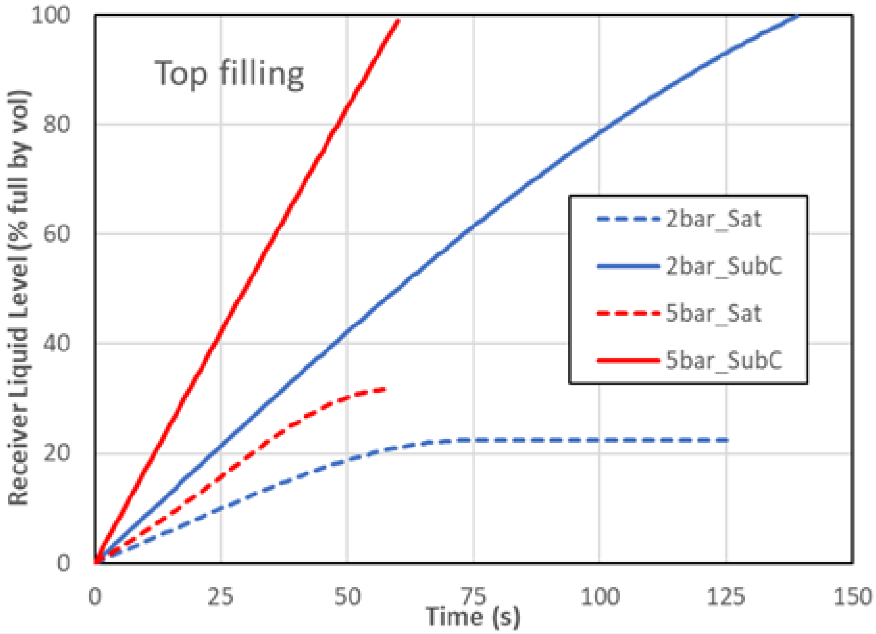
- System Components
  - Supply tank 12 m^3
  - Transfer line (30 m, 2.54 cm) + (5 cm, 10mm) nozzle
  - Receiving tank 0.4 m^3
  - All components adiabatically isolated
- Transfer Conditions
  - 2 or 5 bars, Sat LH2 or subcooled LH2 @19K in supply tank
  - 1 atm, sat GH2 initially in receiver tank
  - Bottom and top filling simulated
- Models
  - Single zone constant pressure for supply tank
  - HEM for transfer line
  - Multizone for receiving tank

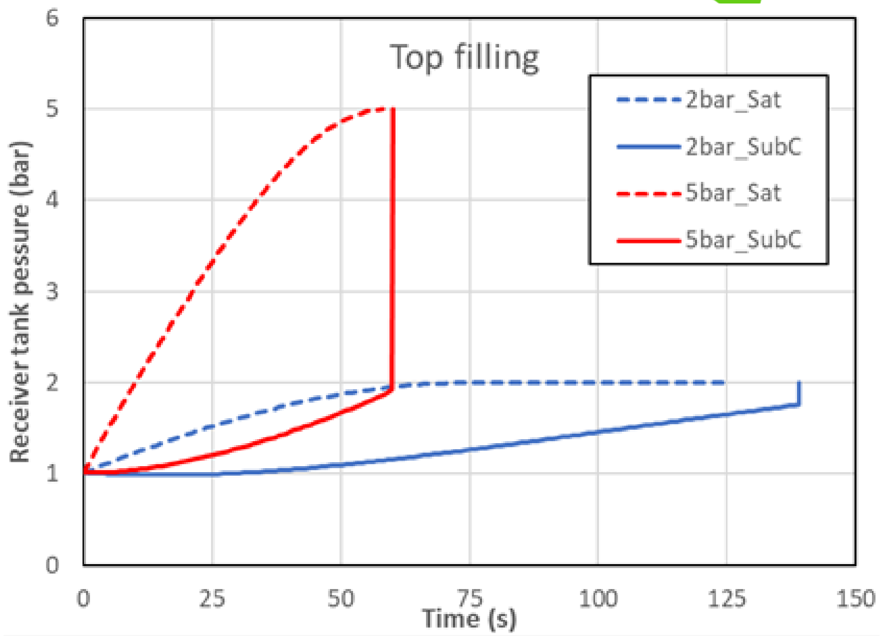
Application / No vent filling of a 400 L LH2 tank

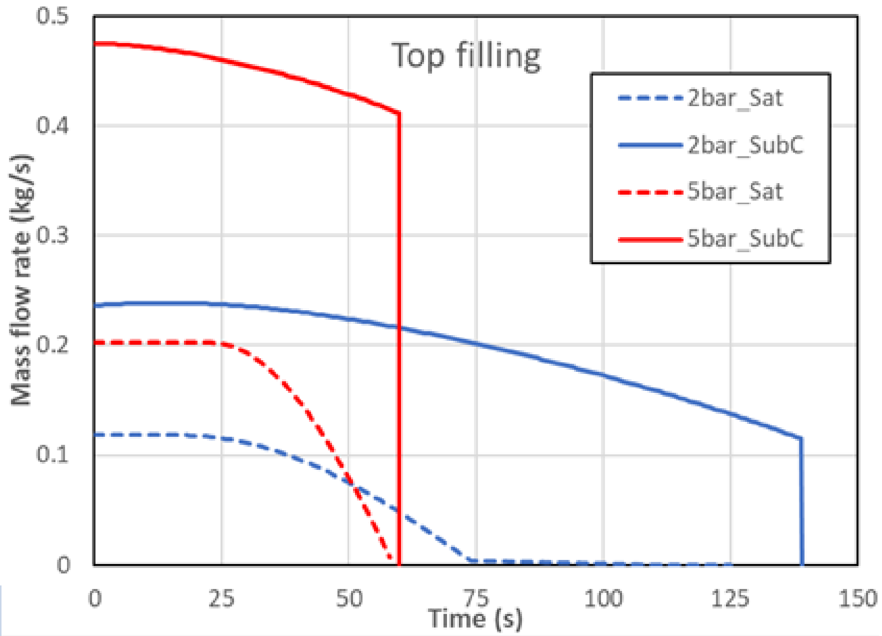


Bottom filling

Application / No vent filling of a 400 L LH2 tank







Top filling

Conclusions

- DISCHA application
  - DISCHA was applied to simulate the no-vent filling of a 400 L LH2 tank, from a 12 m^3 supply tank, through a long transfer line at various supply tank initial conditions with either bottom or top filling methods
- Findings
  - conditions exist where final filling levels can be very low
  - filling levels increase with pressure and subcooling in the supply tank
  - with subcooled conditions in the supply tank top filling is more effective than bottom filling and can achieve theoretically 100 % fills, while with saturated conditions in the supply tank bottom filling is more effective, although the achieved filling levels will remain low.

Acknowledgments

Thank you for your attention

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