BlowView-H2: cutting-edge simulation for hydrogen tank liner optimization

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BlowView-H2: Cutting-edge Simulations for Hydrogen Tank Liner Optimization

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Peachtree City, GA , USA

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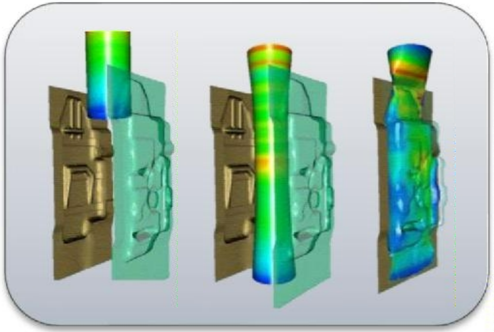
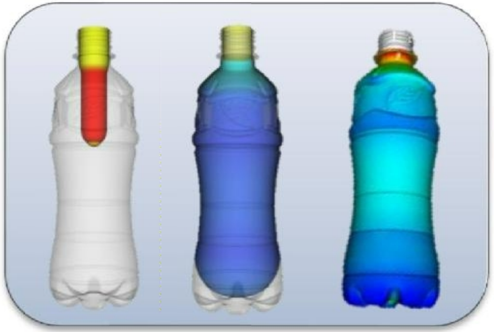
Overview

- **Introduction to NRC's BlowView simulation software**
- **Objectives of the Blow Molded Plastic Liner (BMPL) simulation study**
- **BMPL simulation & optimization results**
- **BMPL H_2 permeation model and simulation case studies:**
  - Case 1 :Isothermal Case: Constant air temperature, and constant H_2 temperature & pressure
  - Case 2: Variable H_2 temperature & pressure
  - Case 3 : Pressure/Temp Variation during the Filling and Emptying Cycle
- **Conclusion & what's next ?**

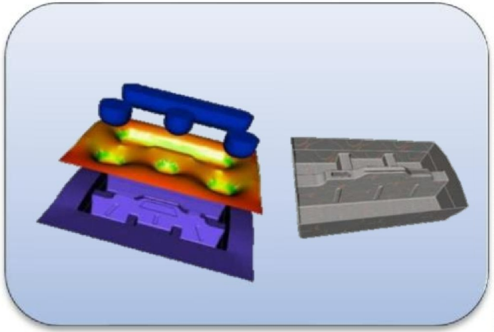
NRC’s BlowView Simulation Software



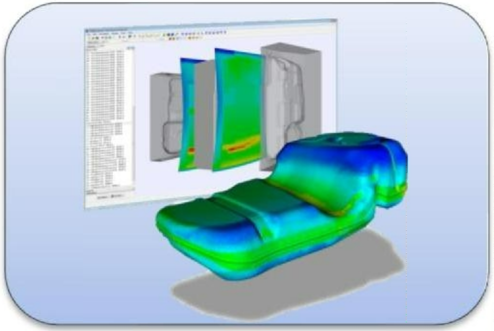
Extrusion Blow Molding



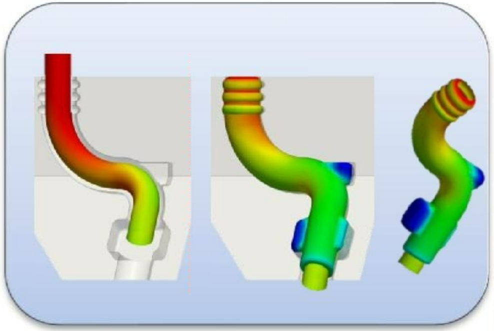
Stretch Blow Molding



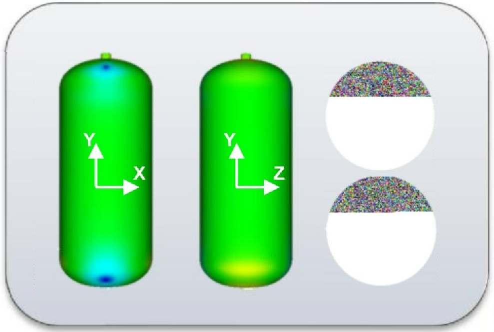
Thermoforming



Twin-Sheet EBM



Suction Blow Molding

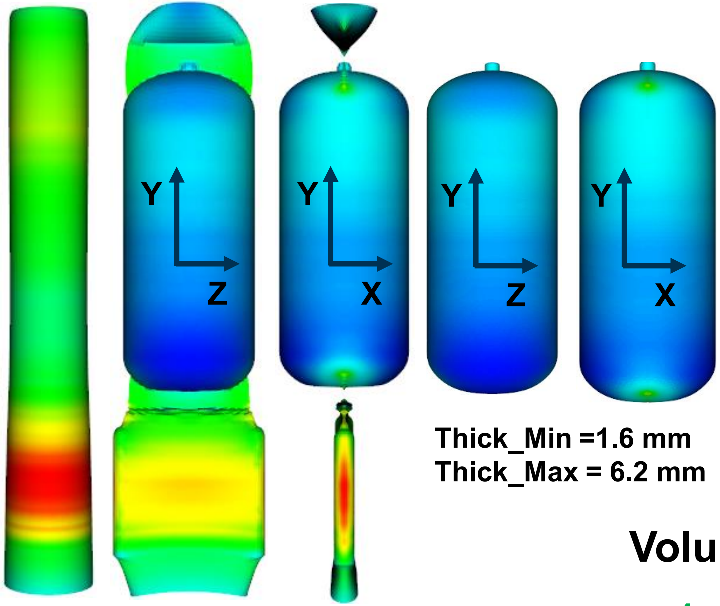


H2 Liners

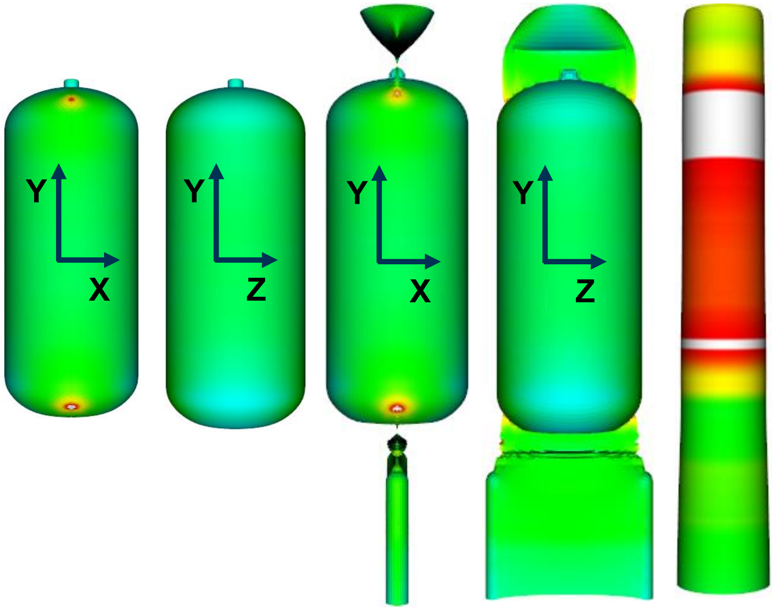
Objectives

- Simulate a BMPL provided by industrial Partner using a PA6 resin (i.e., Durethan BC550Z);
- Optimize the process parameters to enhance uniformity in liner thickness for lightweighting;
- Evaluate the permeability performance of the BMPL under variable surrounding air temperatures, and internal H_2 temperatures and pressures;
- Simulate the filling and emptying cycle to predict pressure and temperature variations within the tank, as well as across the liner and composite layer.

H2 Liner Simulation & Optimization Results

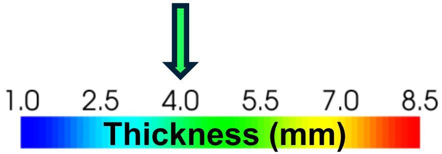


Thick_Min =1.6 mm
Thick_Max = 6.2 mm



Volume = 61 L

4 mm (Target)



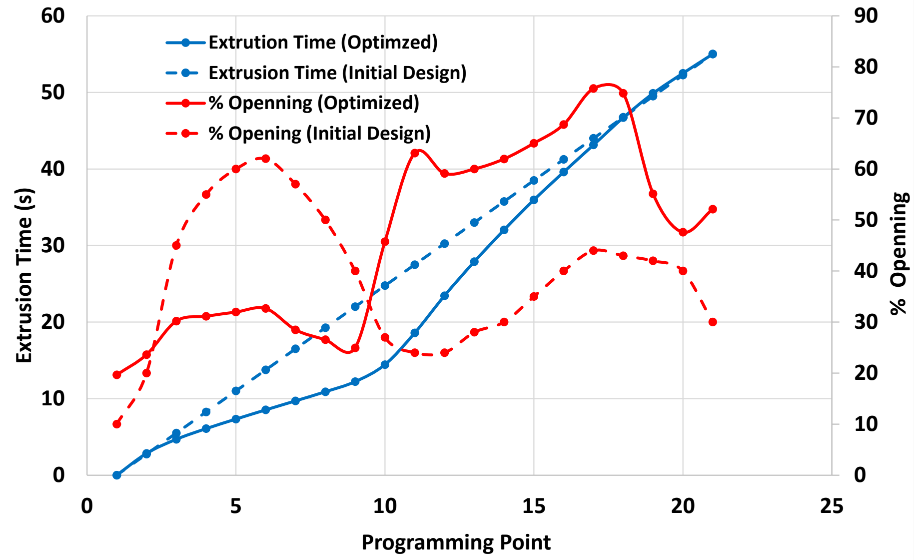
Initial Profile

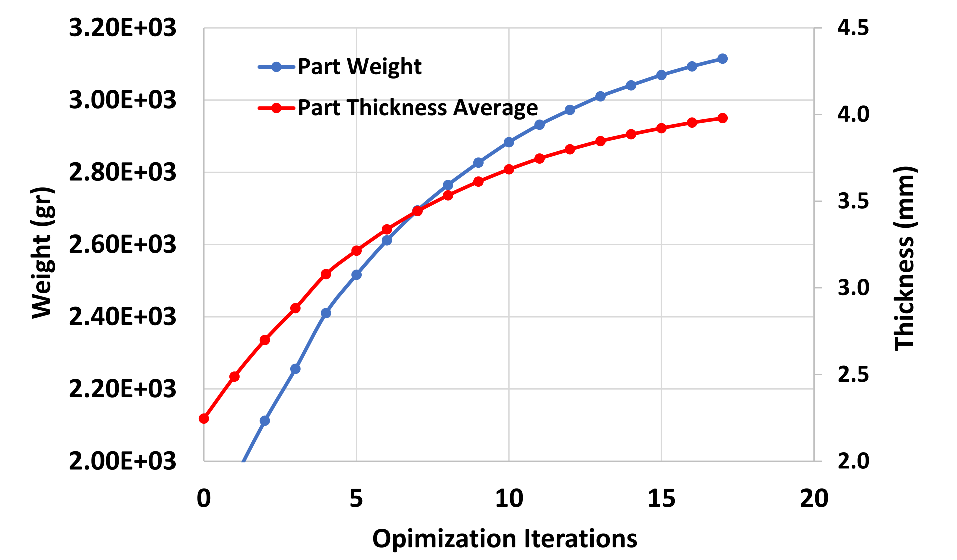
Parison Length : 1432 mm
Parison Weight : 4281 g
Part Weight : 1759 g
Average Part Thickness: 2.2 mm

Optimized Profile

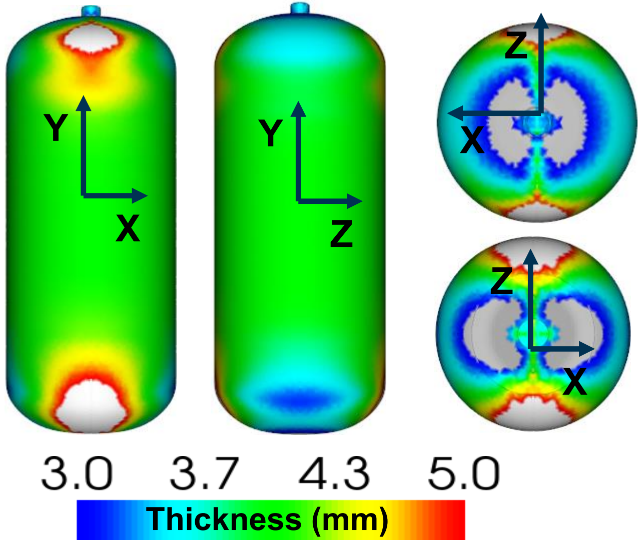
Parison Length : 1299 mm
Parison Weight : 5089 g
Part Weight : 3158 g
Average Part Thickness: **4.0 mm**

H2 Liner Simulation & Optimization Results

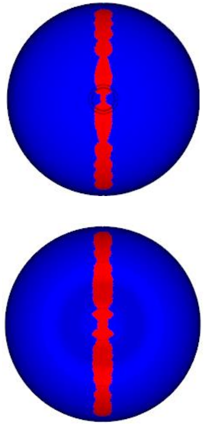




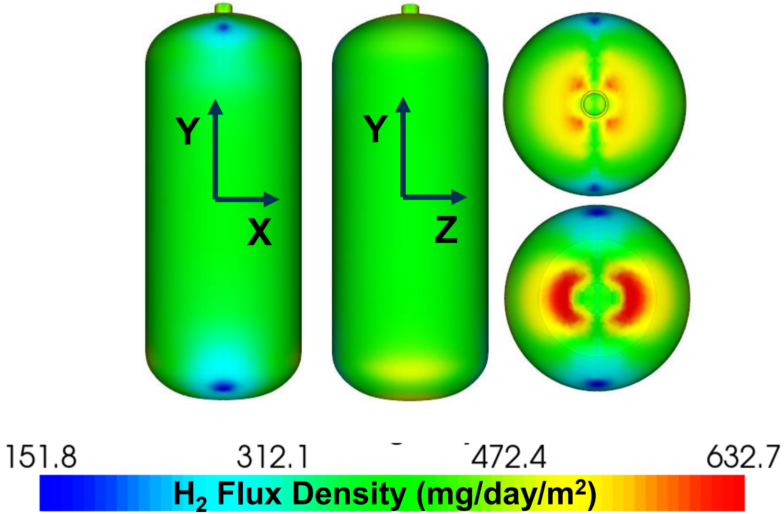
H_2 Permeability Analysis on Optimized Liner
Case 1 (Isothermal): T_{H2}= 20°C, P_{H2}= 70 MPa, T_{air}= 20°C



Part Weight : 3158 g
Part Average Thickness: 4.0 mm



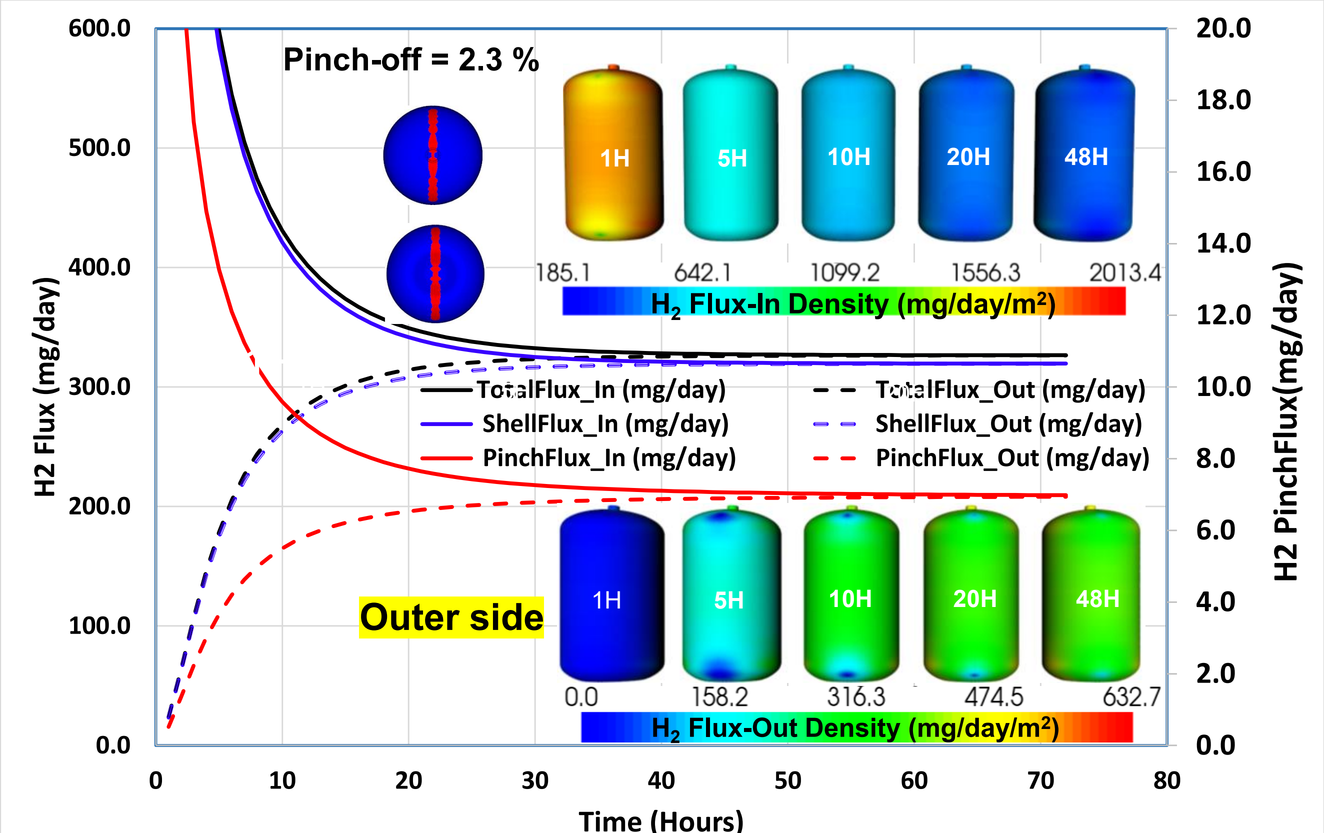
Pinch-off = 2.3 %



Shell Surface = 0.839062 m^2
Pinch-off Surface = 0.018724 m^2
H_2/Day through Shell Surface = 326.45 mg/Day
H_2/Day through Pinch-off Surface = 6.60 mg/Day
Total H_2/Day = 333.05 mg/Day = 5.17 Nml/hr/L

Note: Limit = 6 NmL/hr/L

H_2 Permeability Analysis on Optimized Liner
Case 1 (Isothermal): T_{H2}= 20°C, P_{H2}= 70 MPa, T_{air}= 20°C



H2 Permeability Analysis on Optimized Liner
Case 2 (Non-Isothermal): Time Depend P and T

Case 2:

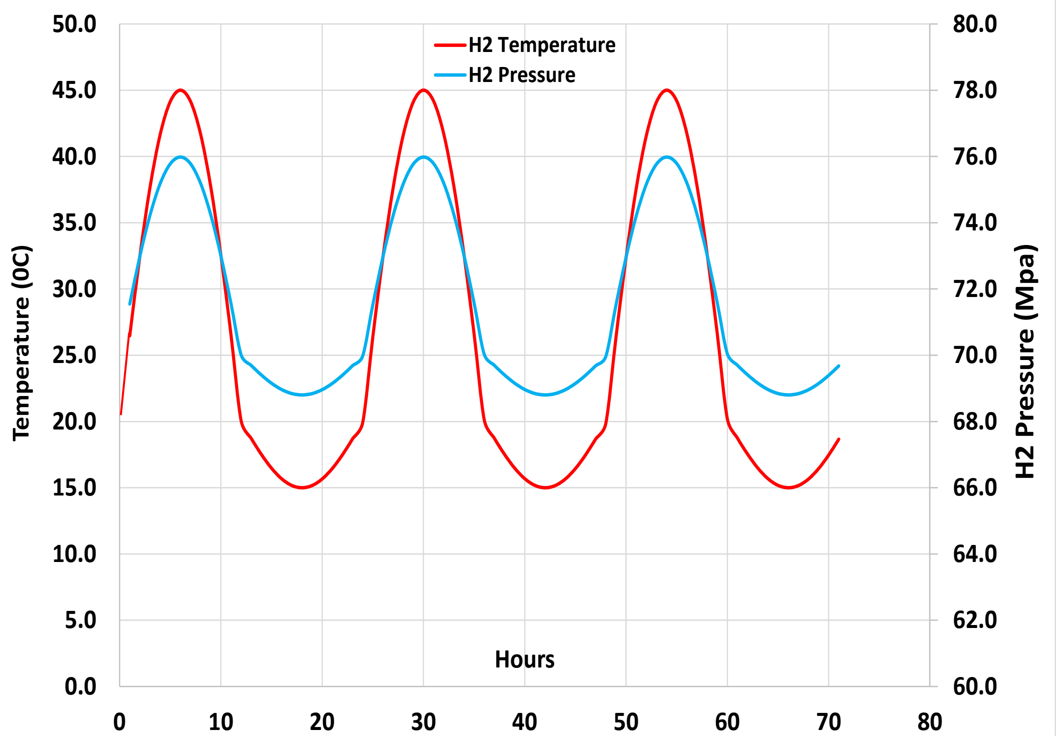
Initial liner T_Init = 20°C; P_H2 = 0.0 MPa

Inner side T_H2 = 20°C + Amp . sin(2PI/24*time);

Inner side (H2 Pressure obey to isochore transformation)

P_H2 /T_H2 = (P_H2 = 70 x 10^6) / (T_H2 = (273+ 20))

Outer side T_Air = 20°C; P_H2 = 0.0 MPa

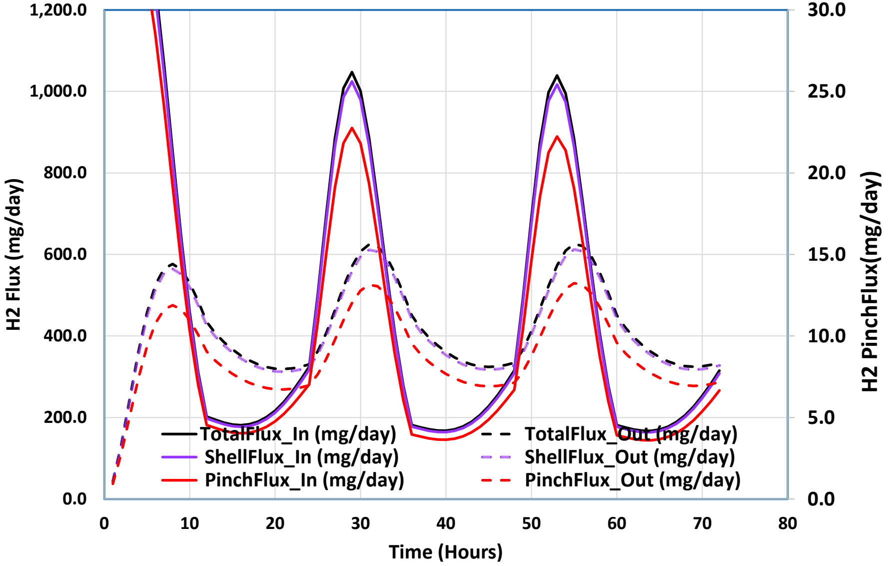


H2 Permeability Analysis on Optimized Liner
Case 2 (Non-Isothermal): Transient thermo-diffusion

T_H2 = 20°C + Amp. sin(2PI/24*time); T_Air = 20°C

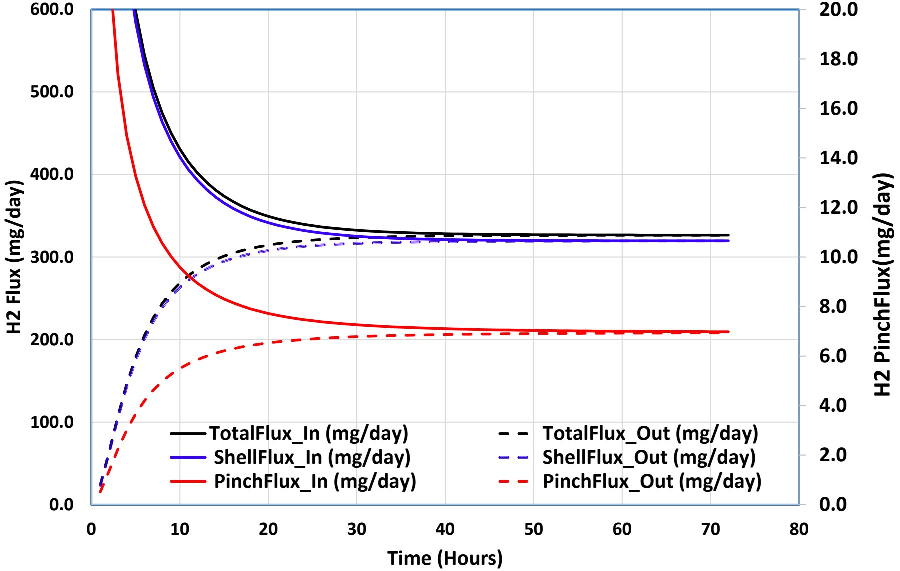
Isochore Transformation

P_H2/T_H2 = constant



Isothermal: T_H2 = 20°C & T_Air =20°C

P_H2= 70 MPa



Isothermal Transient case

H2 Permeability Analysis on Optimized Liner

Case 3: Pressure/Temp Variation during the Filling and Emptying Cycle

Filling Phase

Station Conditions

$T_{H2\_Station} = 25°C$

$P_{H2\_Station} = 90\ MPa$

Reservoir Conditions

$T_{H2\_R} = 25°C$

$P_{H2\_R} = 1\ MPa$

$V_{H2\_R} = 61\ L$

$P_{H2\_R\_Max} = 70\ MPa$ (cut-off pressure)

Emptying Phase

Reservoir Conditions

$T_{H2\_R} = 25°C$

$P_{H2\_R} = 70\ MPa$

$V_{H2\_R} = 61\ L$

EmptyingRate = 1.1 kg/hr

H2 Permeability Analysis on Optimized Liner

Case 3.1 : Pressure/Temp Variation during the Filling

Filling Phase Time = 5 min

Station Conditions

$T_{H2\_Station}$ = 25°C

$P_{H2\_Station}$ = 90 MPa

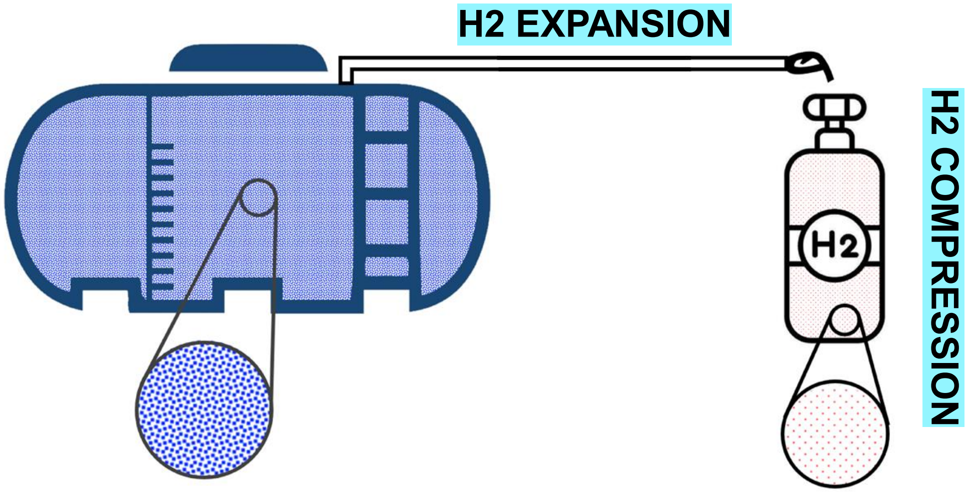
Reservoir Conditions

T_{H2_R} = 25°C

P_{H2_R} = 1 MPa

V_{H2_R} = 61 L

$P_{H2\_R\_Max}$ = 70 MPa (cut-off pressure)



Filling thermodynamic model assumptions

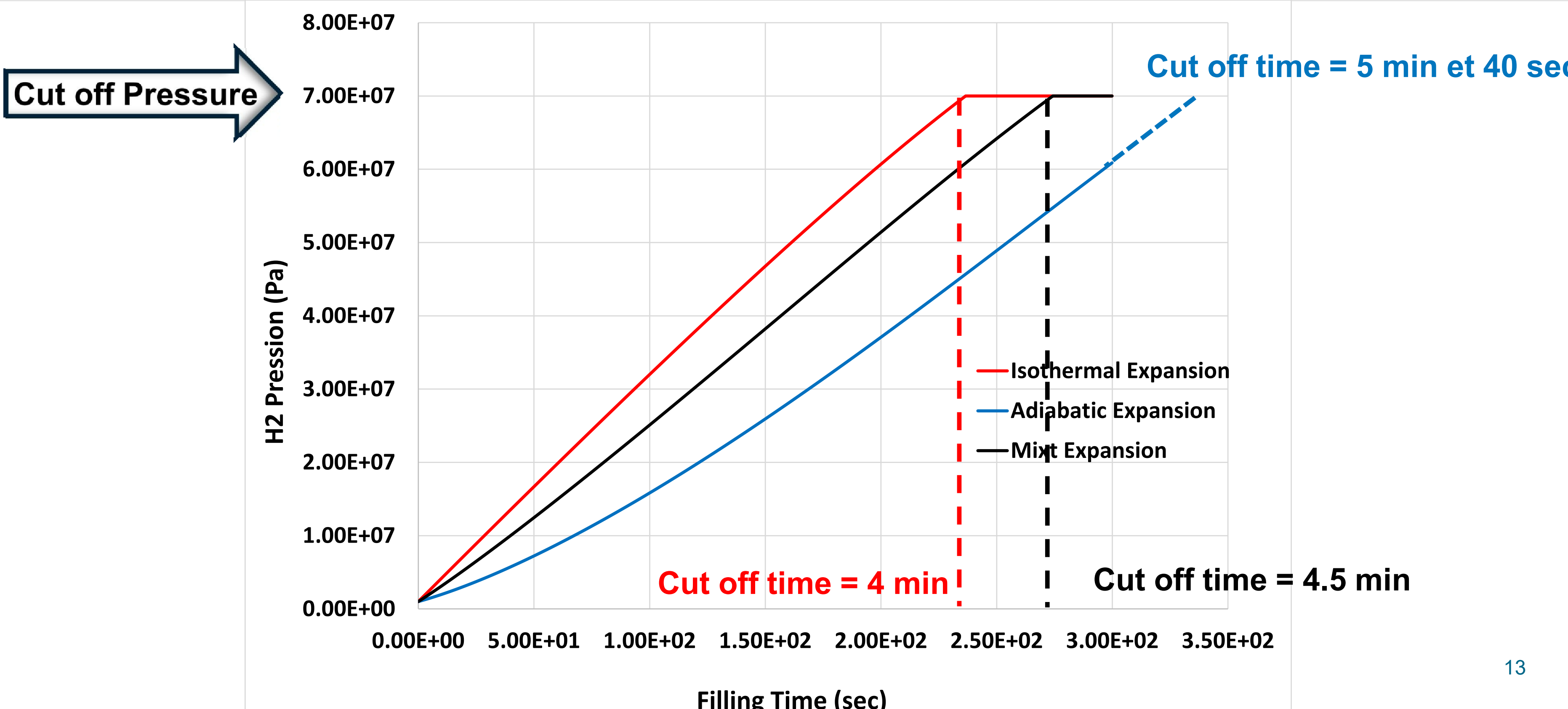
Scenario 1 : Isothermal expansion in the station supply pipe

Scenario 2 : Adiabatic expansion in the station supply pipe

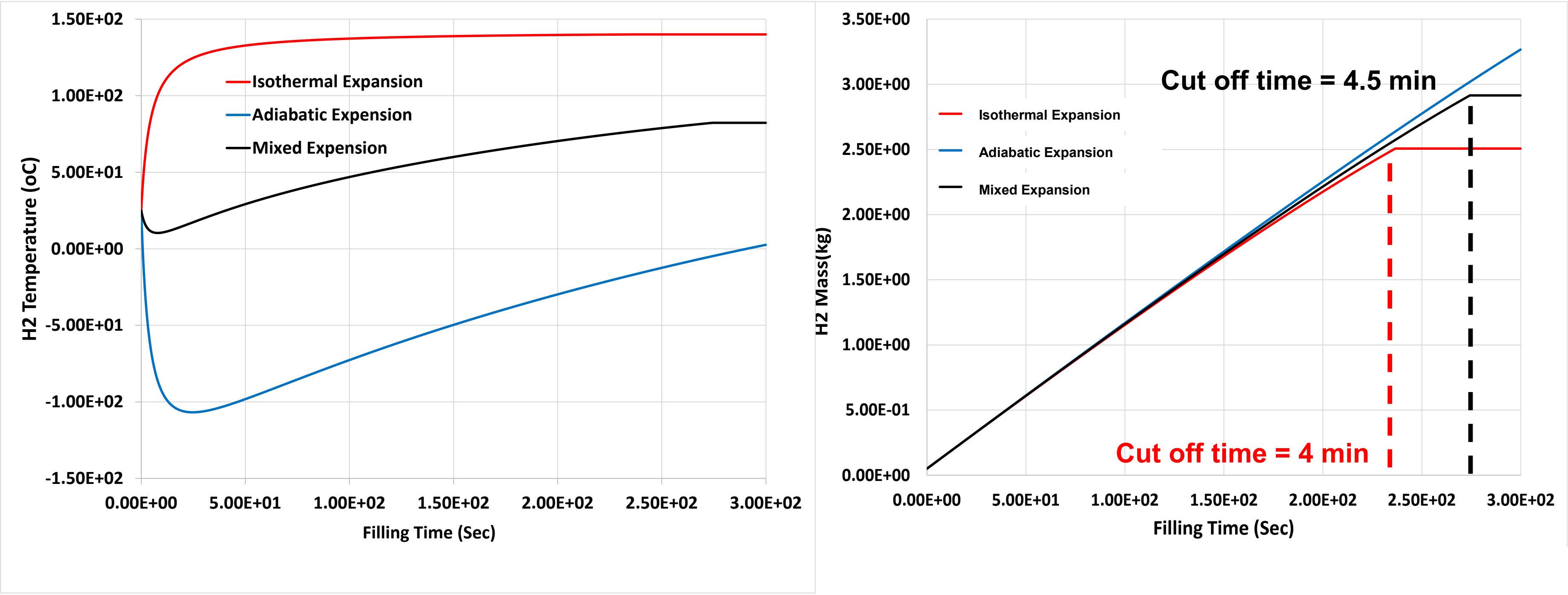
Scenario 3 : Mixed model

H2 Permeability Analysis on Optimized Liner

Case 3.1: Pressure/Temp Variation during the Filling



H2 Permeability Analysis on Optimized Liner
Case 3.1: Pressure/Temp Variation during the Filling



H2 Permeability Analysis on Optimized Liner
Case 3.2: Pressure/Temp Variation during the Emptying

Emptying Phase

Reservoir Conditions

T_{H2_R} = 25°C

P_{H2_R} = 70 MPa

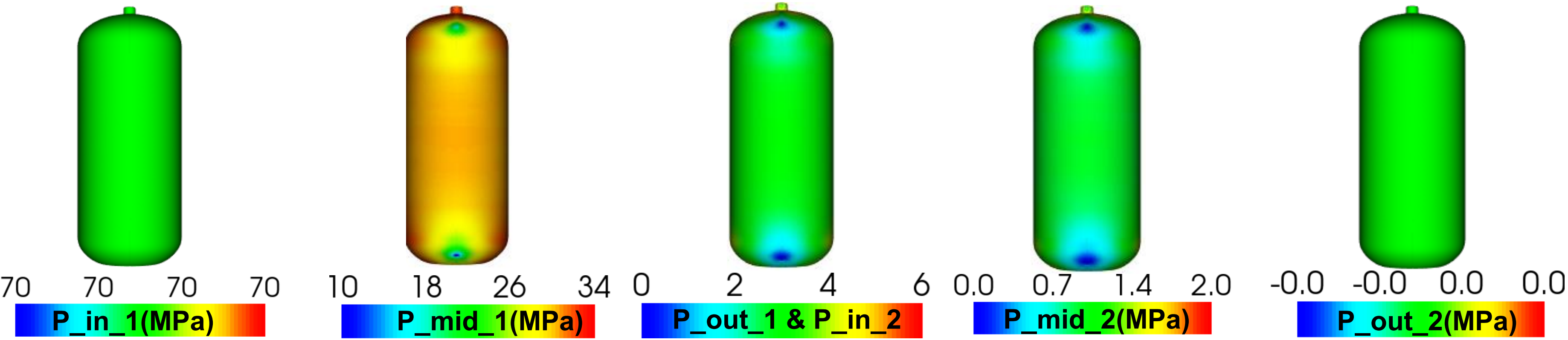
V_{H2_R} = 61 L

EmptyingRate = 1.1 kg/hr

PREDICT

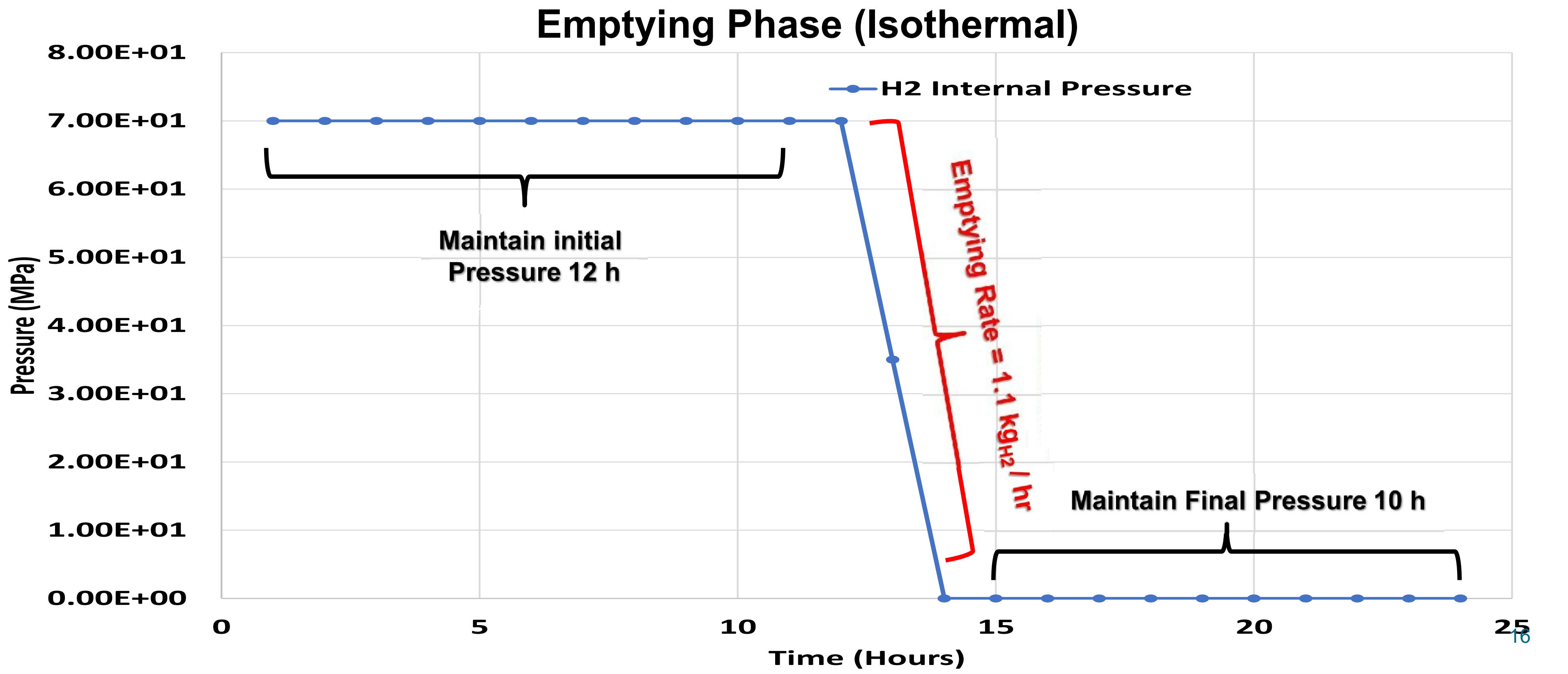
H2 Pressure Evolution:

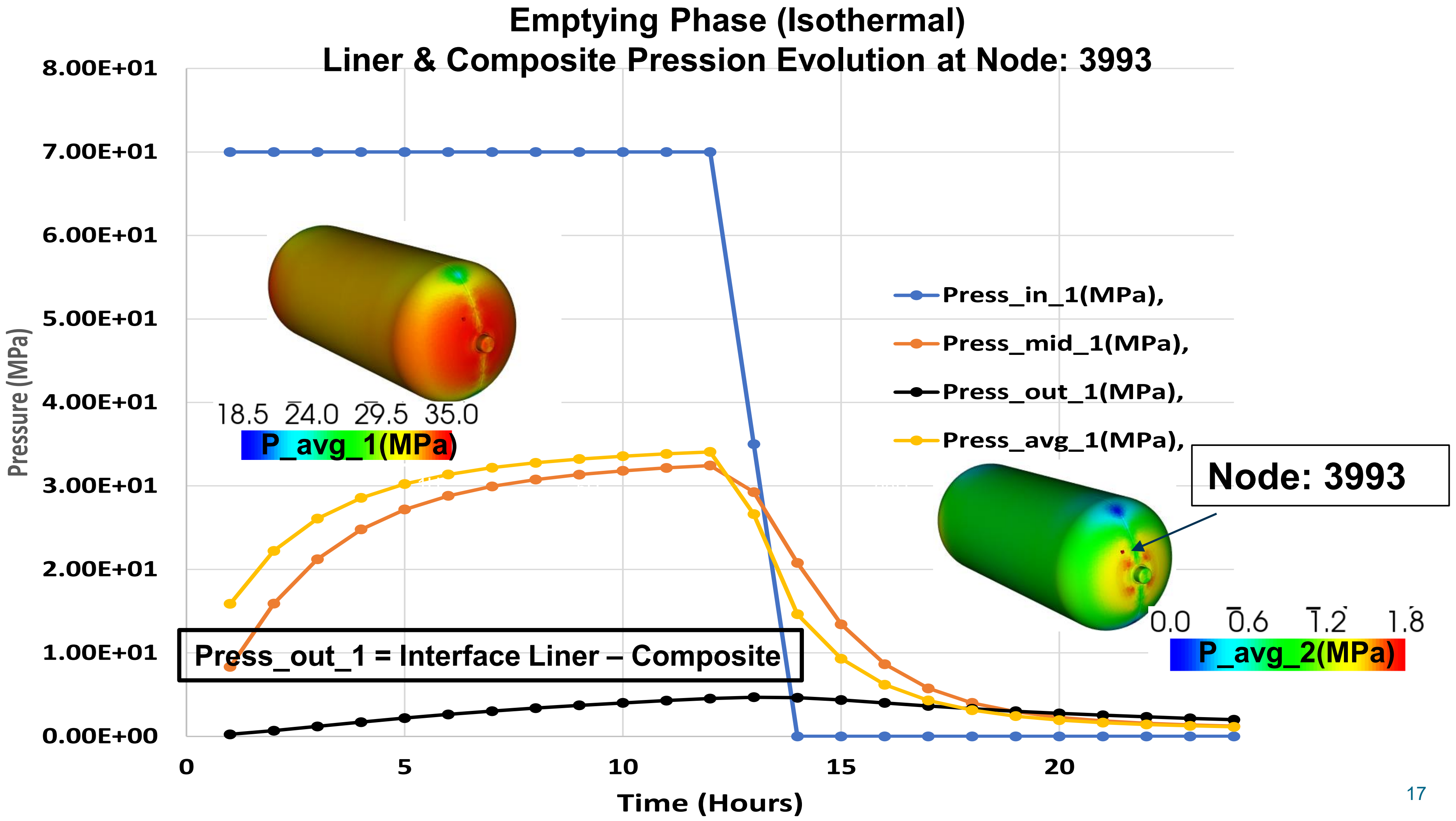
- **Inside the H2 tank**
- **Through the Liner**
- **Interface Liner - Composite**
- **Through the Composite Layer**



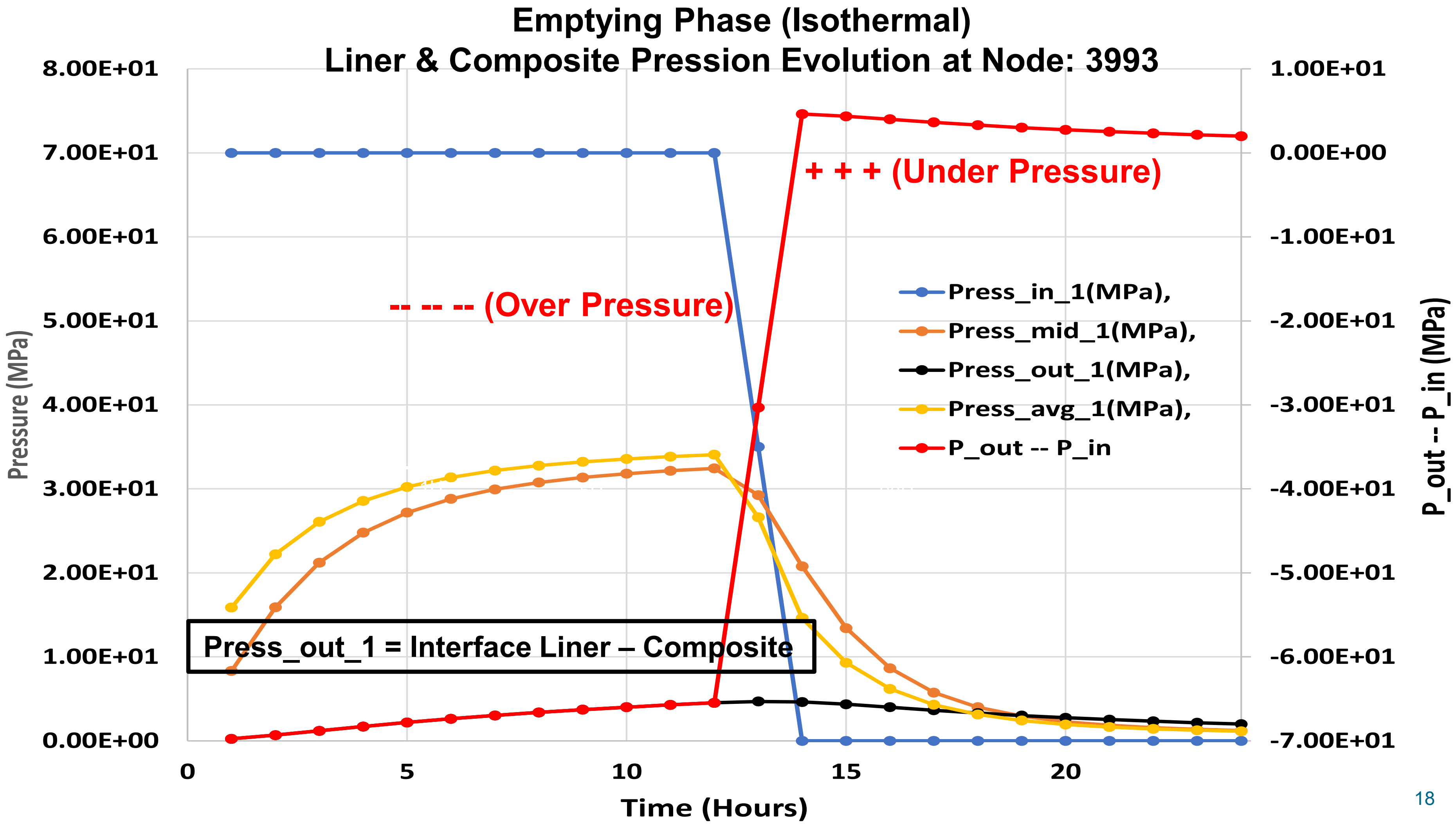
H2 Permeability Analysis on Optimized Liner

Case 3.2: Pressure/Temp Variation during the Emptying Cycle





Emptying Phase (Isothermal)
Liner & Composite Pression Evolution at Node: 3993
8.00E+01
7.00E+01
6.00E+01
5.00E+01
4.00E+01
3.00E+01
2.00E+01
1.00E+01
0.00E+00
Pressure (MPa)
0
5
10
15
20
Time (Hours)
18.5 24.0 29.5 35.0
P_avg_1(MPa)
Press_in_1(MPa),
Press_mid_1(MPa),
Press_out_1(MPa),
Press_avg_1(MPa),
Node: 3993
0.0 0.6 1.2 1.8
P_avg_2(MPa)
Press_out_1 = Interface Liner – Composite


Emptying Phase (Isothermal)
Liner & Composite Pression Evolution at Node: 3993
8.00E+01
7.00E+01
6.00E+01
5.00E+01
4.00E+01
3.00E+01
2.00E+01
1.00E+01
0.00E+00
Pressure (MPa)
1.00E+01
0.00E+00
-1.00E+01
-2.00E+01
-3.00E+01
-4.00E+01
-5.00E+01
-6.00E+01
-7.00E+01
P_out -- P_in (MPa)
+ + + (Under Pressure)
-- -- -- (Over Pressure)
Press_in_1(MPa),
Press_mid_1(MPa),
Press_out_1(MPa),
Press_avg_1(MPa),
P_out -- P_in
Press_out_1 = Interface Liner – Composite
0
5
10
15
20
Time (Hours)

Conclusion & Future Developments

- **The permeability model has been improved by integrating the energy equation and the inclusion of the temperature effect on the transport coefficients**

- **Implementation of the thermodynamic model permitting :**
  - ➢ Predict H2 temperature and pressure variations during filling and emptying cycles;
  - ➢ Predict the pressure and temperature distribution through the liner and the composite layer.

Conclusion & Future Developments

- **Additional topics that are under investigation include:**
  - ➢ Predicting the exacerbation of liner-composite layer delamination during repeated tank filling and emptying cycles.

- **Coordinate, with industrial partners, validation studies based on experimental measurements.**

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Thank you !

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