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Modeling of Methane Tank Depressurization in Cold Weather

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MOTIVATION

Non-metallic tanks are used in industry to store and transfer gases such as methane. As the tanks are emptied, properties of the gas within the tank change. At low temperatures, liquid condensation can form and the tank lining can reach a critically low temperature, causing fracture to the tank wall. This study was conducted to see if during cold-weather operation liquification of methane occurs, and to determine if the gas temperature becomes low enough to endanger the polymer tank (200 K).

METHOD AND PROCEDURES

- Aspen Plus utilized for starting properties and steady state values
  - Method: Soave-Redlich-Kwong
  - Vessel Heat Transfer:
    - Specific Heat Capacity: 850 J/kg-K
    - W/ Environment: 10 W/sqm-K
    - W/ Wetted Wall: 19.33 W/sqm-K
  - Vessel Geometry:
    - Head Type: Hemispherical
    - Equipment Mass: 2444 kg
    - Length: 8.56 m
    - Diameter: 1.08 m
- Aspen Plus Dynamics utilized for dynamic simulation

Full Tank				
Temperature: 288 K		Pressure: 250 Bar		
Temperatures Examined (K)				
263	253	243	233	223
Mass Flows Examined (kg/s)				
0.3	0.119	0.064		

Table 1. Properties of full vessel and temperatures examined.

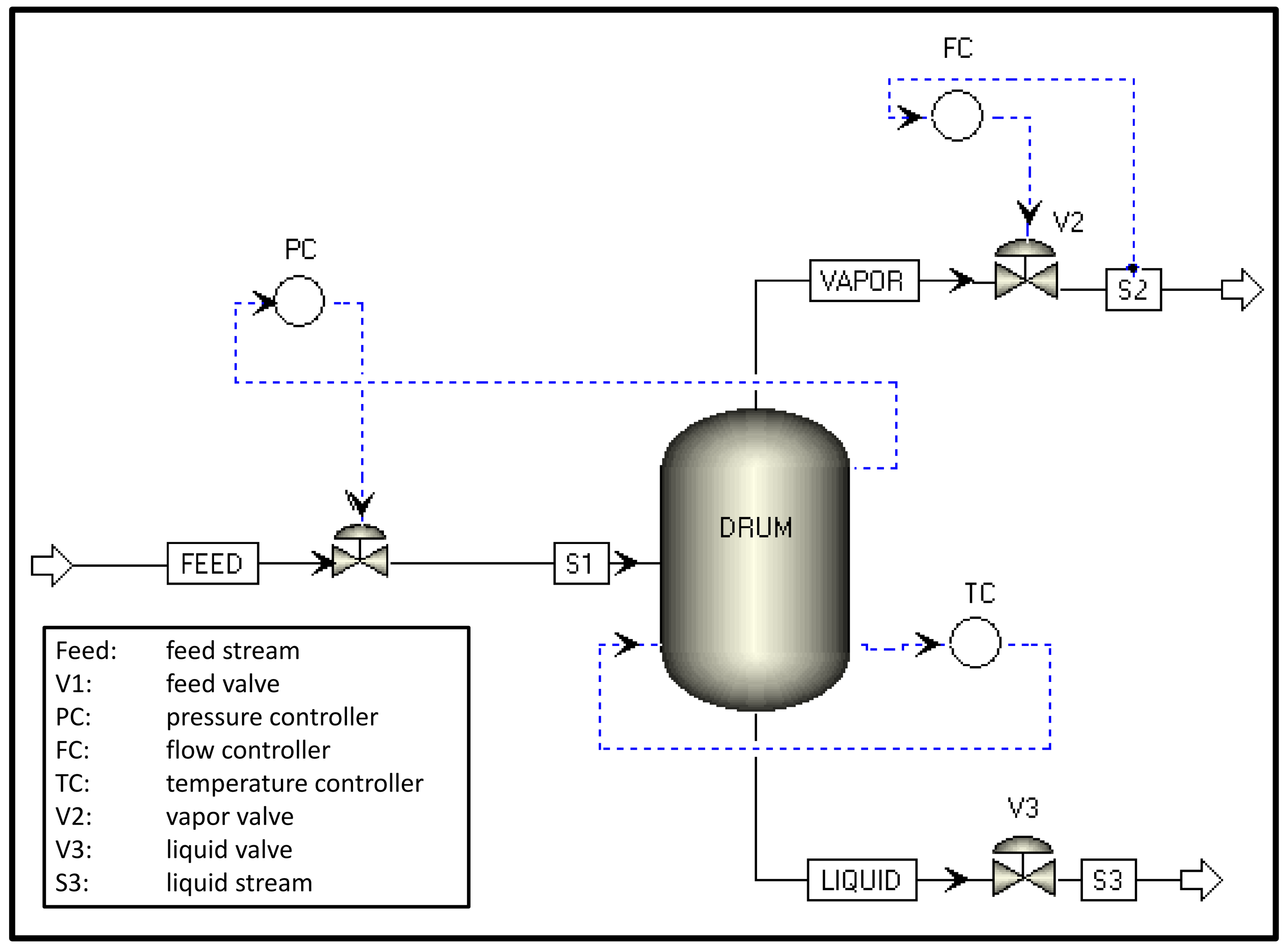

Figure 1. Flowsheet used in Aspen Plus Dynamics.

RESULTS

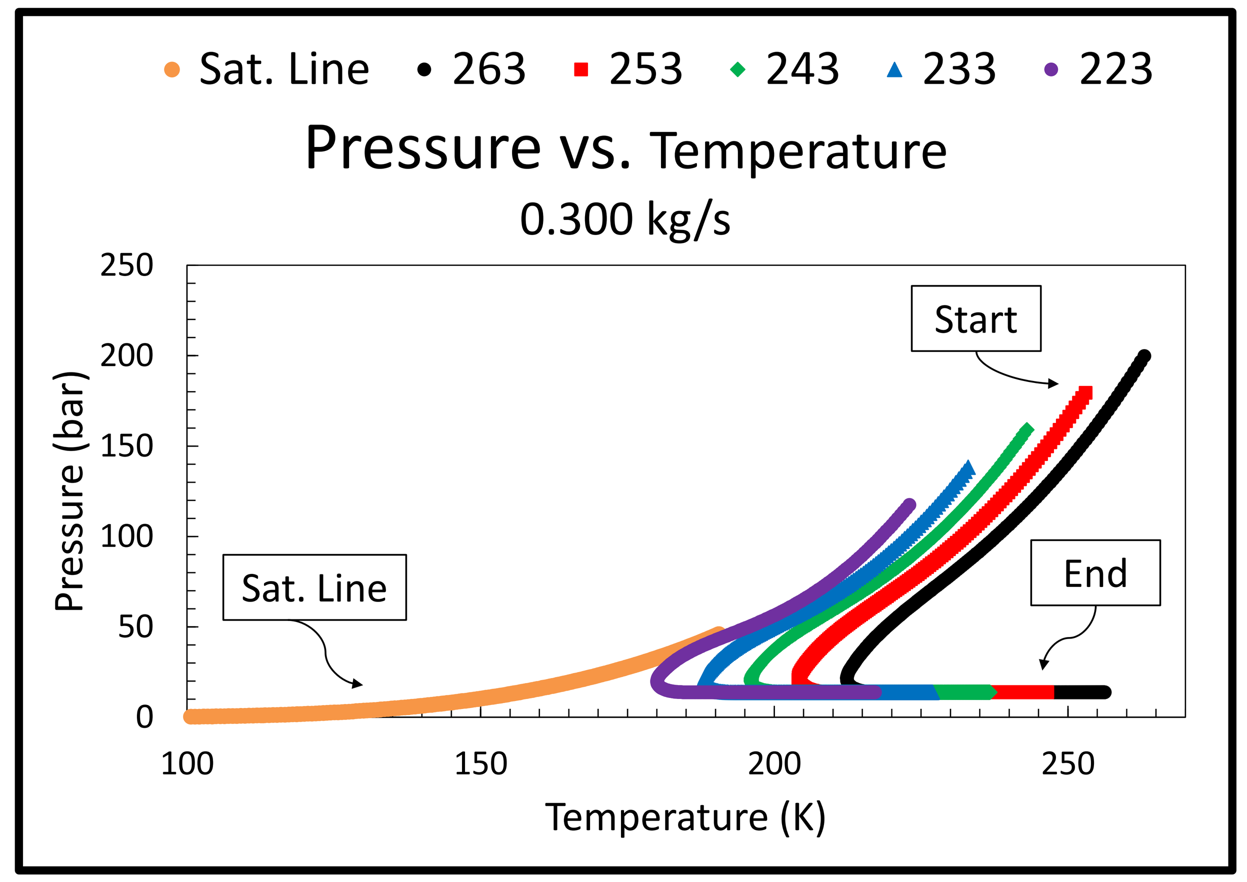

Figure 2. Temperature versus time for 0.300 kg/s mass flow.

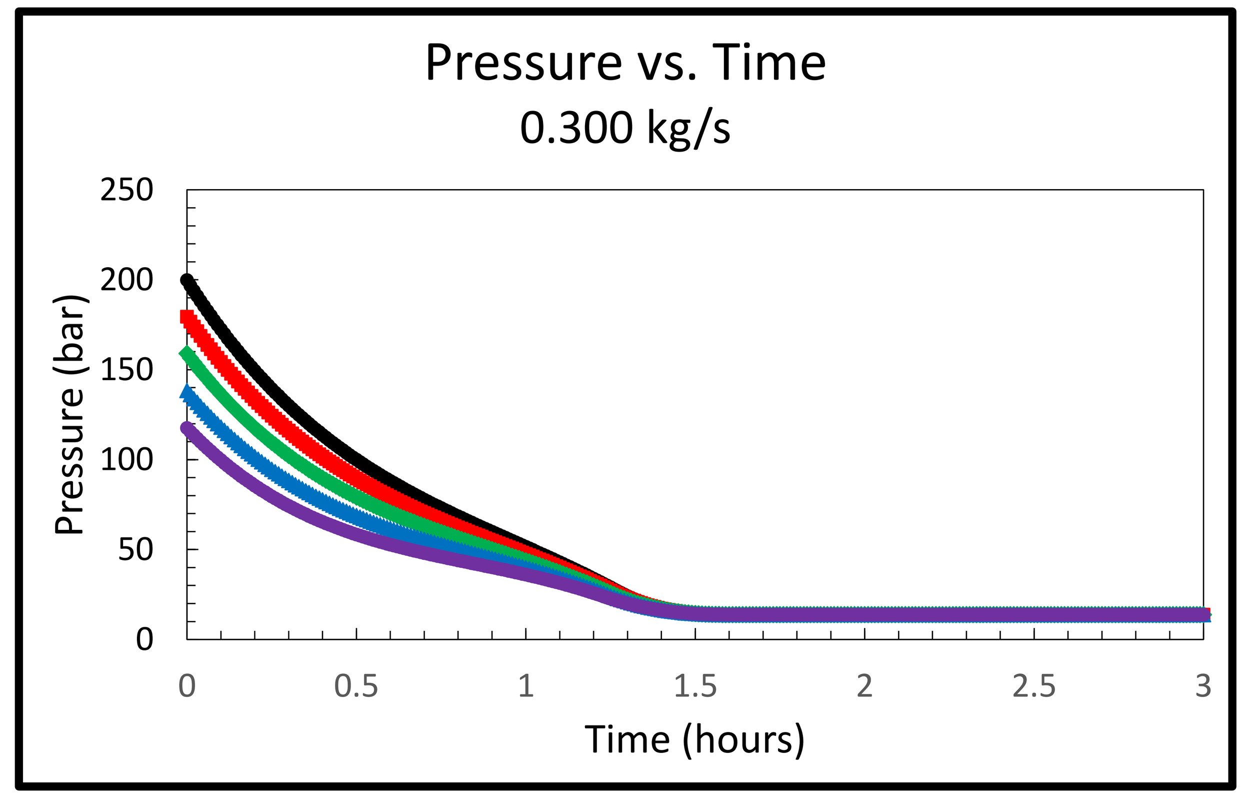

Figure 3. Pressure versus time for 0.300 kg/s mass flow.

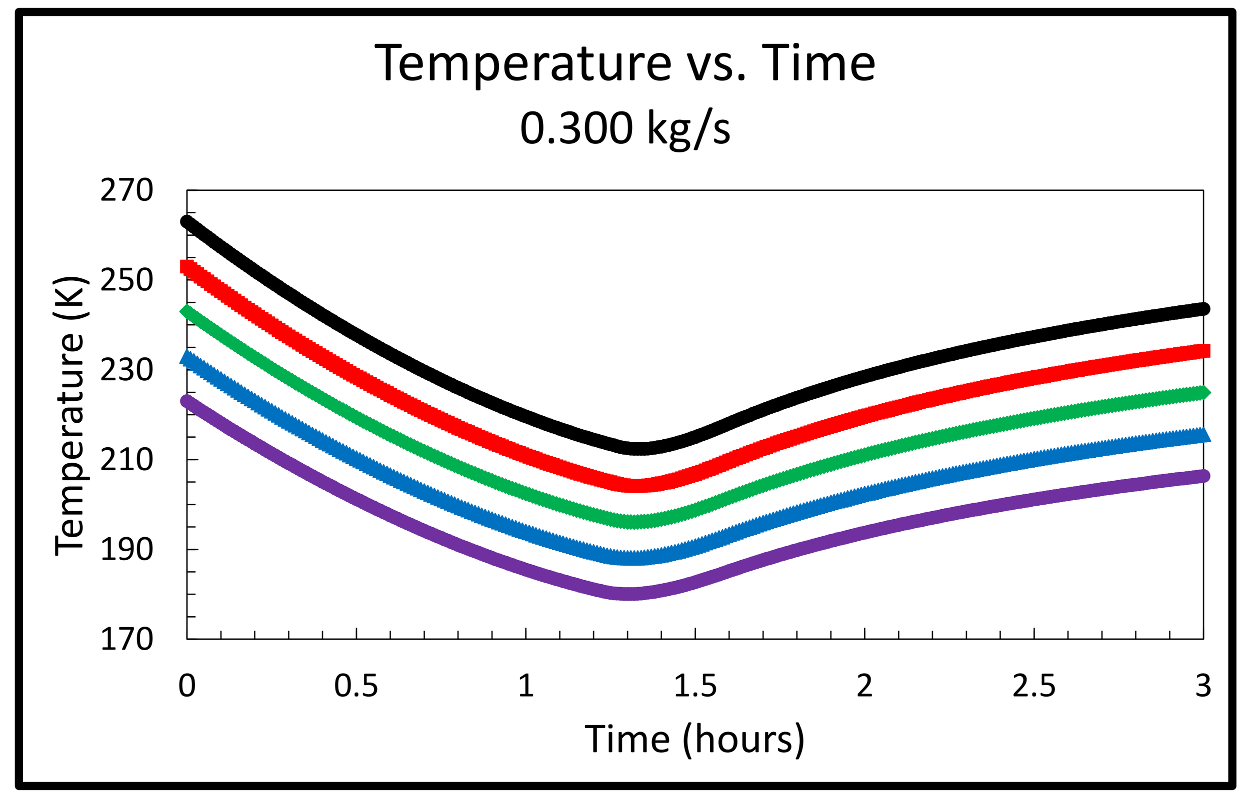

Figure 4. Temperature versus time for 0.300 kg/s mass flow.

PROCESS INFORMATION

- When the vessel valve opens, the temperature and pressure of the methane is initially at the starting conditions.
- As time progresses, the pressure in the vessel decreases, causing a decrease in the pressure of the methane.
- Additionally, the decrease in pressure causes a decrease in the temperature of the methane. This can be seen by following any starting temperature line.
- At approx. 1.35 hours, the pressure inside the vessel reaches the outlet pressure of the valve, indicated by the horizontal pressure lines. At this point, mass can no longer leave the vessel and the valve is shut.
- After closing the valve, the vessel remains at the outlet pressure.
- In Figure 3, at approx. 1.35 hours, the lowest temperature is reached. After the valve is closed, the vessel continues to exchange heat with its surroundings and the temperature within the vessel increases.

CONCLUSIONS

- For all starting temperatures and all mass flow rates, the temperature and pressure of the methane follow the same trend. Namely, the pressure and temperature of the methane decrease until the pressure reaches the outlet pressure.
- For all starting temperatures and all mass flow rates, when the valve is closed, the vessel remains at the outlet pressure and the temperature of the methane increases until it reaches the temperature of its surroundings.
- For the mass flow rate of 0.300 kg/s, the methane liquefied at the starting condition of 223 K. Additionally, the starting condition of 233 K brought the methane close to liquification.
- At mass flow rates below 0.300 kg/s, the methane did not reach saturation conditions.
- At the mass flow rate of 0.300 kg/s, the methane reached and exceeded the danger temperature (200 K) for the tank wall at the starting conditions of 243, 233, and 223 K.
- At high mass flow rates, the methane will become a mixture. Therefore, the vessel valve should be closed before this time to maintain vapor state.

ACKNOWLEDGEMENTS

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