C2Po1D-06: Modeling of Condensation in the Presence of Noncondensables in GFSSP

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MOTIVATION

A reliable condensation model accurately predicts condensation rates.

When a noncondensable gas (often He) is present, modeling of temperature and concentration gradients is more difficult, and uncertainty in condensation rates is increased.

Aerospace applications of interest include:

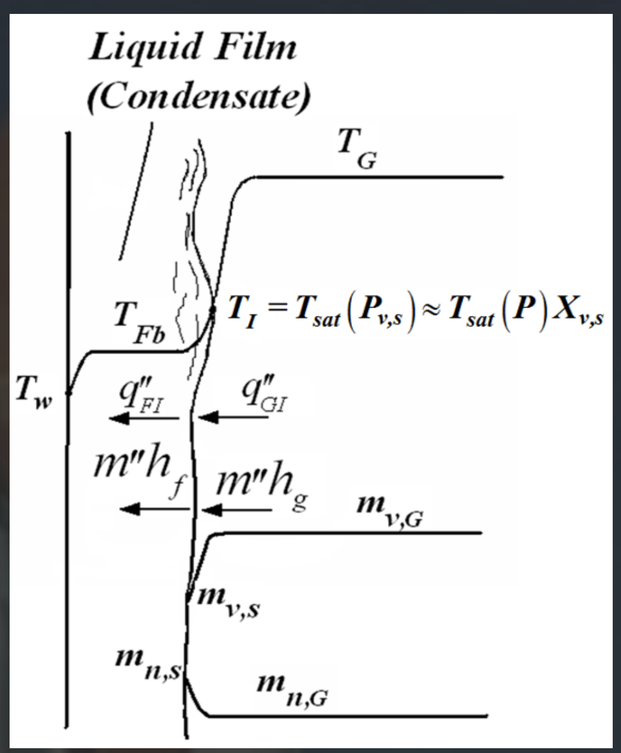
1. Tank pressurization processes using He (Ullage collapse considerations)
2. In-situ resource utilization (ISRU)
3. Moisture removal (on board ISS, non-cryogenic)

OBJECTIVES

Equip NASA's Generalized Fluid System Simulation Program (GFSSP) with the Couette Flow Film Model to predict condensation in the presence of noncondensables.

Validate predictive model against available test data.

APPROACH



Schematic of temperature and species concentration profiles during condensation in the presence of a noncondensable. [1]

$$T_{\mathrm{I}} = T_{\mathrm{sat}}(X_{\mathrm{v,s}} P)$$

$$\dot{h}_{\mathrm{GI}}(\bar{T}_{\mathrm{G}} - T_{\mathrm{I}}) - \dot{h}_{\mathrm{FI}}(T_{\mathrm{I}} - \bar{T}_{\mathrm{F}}) + m^{"} \boldsymbol{h}_{\mathrm{fg}} = 0$$

$$m^{"} = -K_{\mathrm{GI}} \ln \frac{1 - m_{\mathrm{v,G}}}{1 - m_{\mathrm{v,s}}}$$

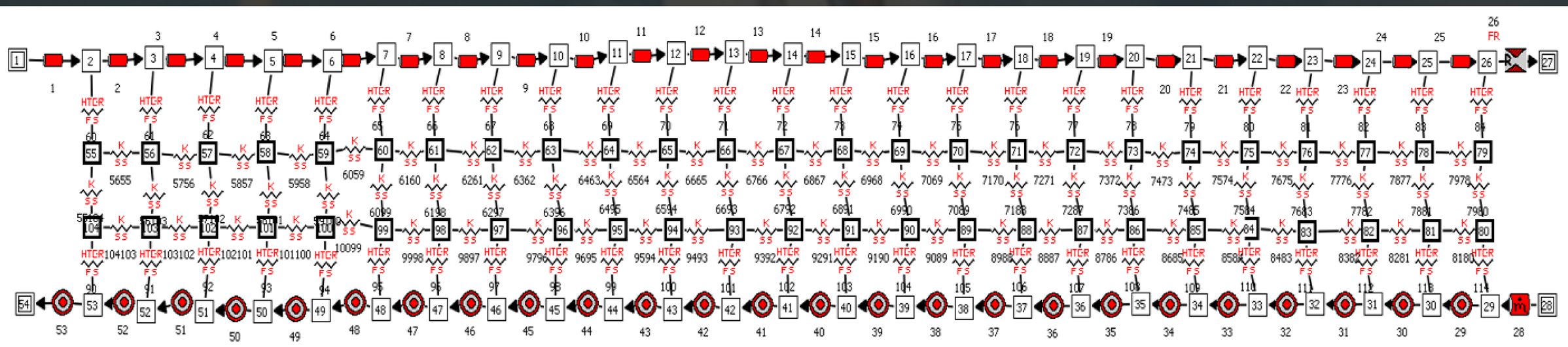
$$m_{\mathrm{v,s}} = \frac{X_{\mathrm{v,s}} M_{\mathrm{v}}}{X_{\mathrm{v,s}} M_{\mathrm{v}} + (1 - X_{\mathrm{v,s}}) M_{\mathrm{n}}}$$

$$\dot{h}_{\mathrm{GI}} = \frac{-m^{"} C_{Pv}}{\exp\left(\frac{-m^{"} C_{Pv}}{h_{\mathrm{GI}}}\right) - 1}$$

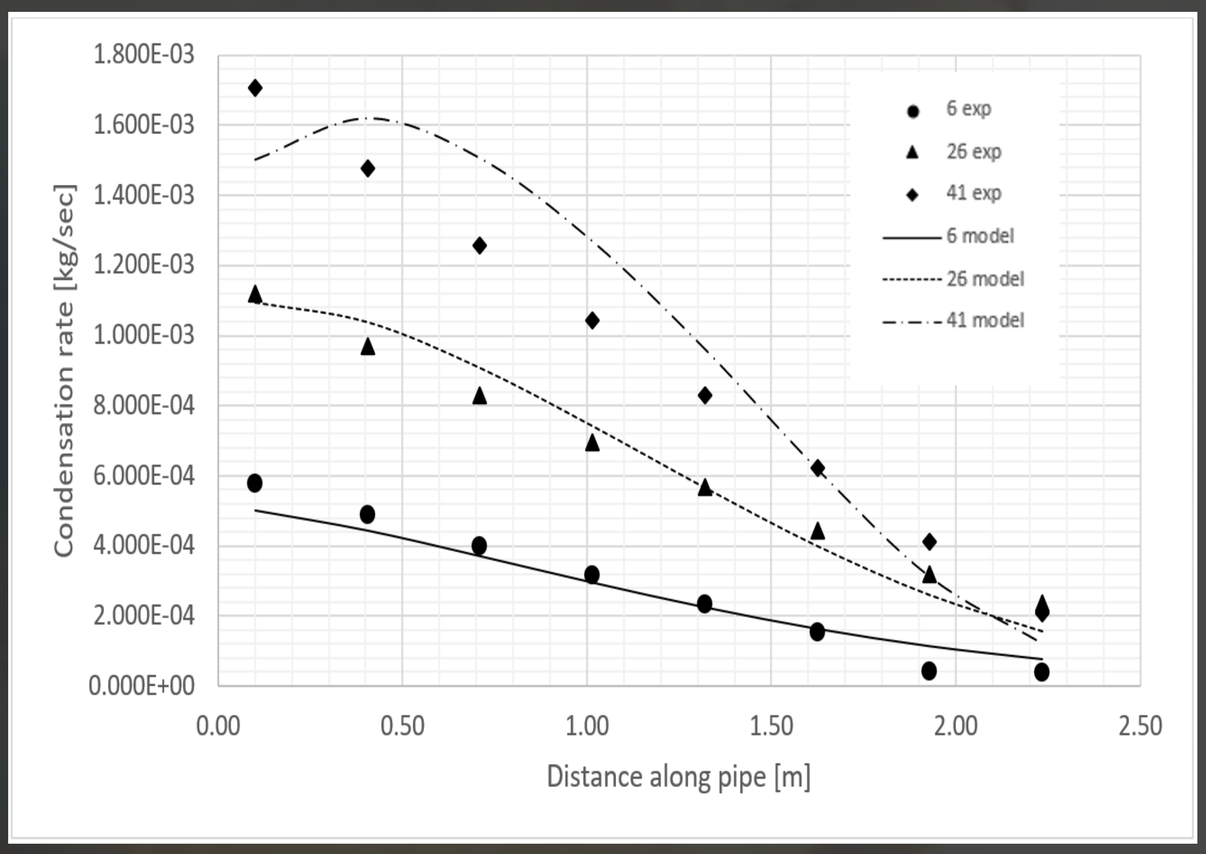
$$\dot{h}_{\mathrm{FI}} = \frac{m^{"} C_{PF}}{\exp\left(\frac{m^{"} C_{PF}}{h_{\mathrm{FI}}}\right) - 1}$$

List of the six model equations to be solved. Unknowns: $T_{\mathrm{I}}, m_{\mathrm{v,s}}, X_{\mathrm{v,s}}, m^{"}, \dot{h}_{\mathrm{GI}}$, and $\dot{h}_{\mathrm{FI}}$

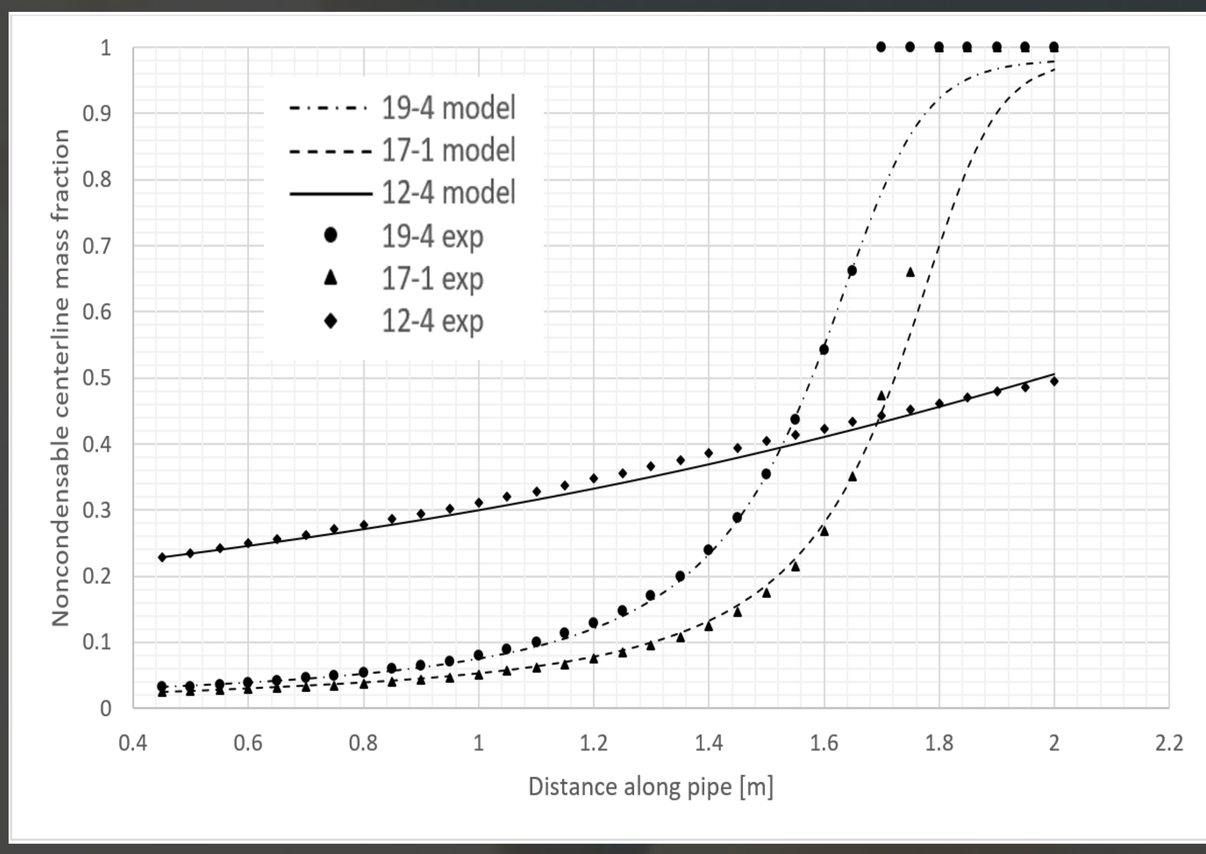
GFSSP MODEL



RESULTS



Air-steam mixture condensation rate vs. distance
Test data: Siddique [2]



Air-steam mixture noncondensable mass fractions vs. distance
Test data: Ogg [3]

CONCLUSIONS

1) The Couette flow film (stagnant film) model has been developed and coded for GFSSP
2) The GFSSP model performs well when compared to the two air-steam experimental data sets analyzed

REFERENCES

[1] Ghiaasiaan, S.M. *Two-Phase Flow, Boiling and Condensation in Conventional and Miniature Systems.* 2nd ed. Cambridge University Press, Cambridge, United Kingdom, 2017.

[2] Siddique, M., "The Effects of Noncondensable Gases on Steam Condensation under Forced Convection Conditions," PhD Thesis, Massachusetts Institute of Technology, Department of Nuclear Engineering, Cambridge, Massachusetts, 1992.

[3] Ogg, D.G., "Vertical Downflow Condensation Heat Transfer in Gas-Steam Mixtures," MS Thesis, University of California, Department of Nuclear Engineering, Berkeley, CA, 1991.