ONSET OF THERMOACOUSTIC OSCILLATIONS IN FLEXIBLE TRANSFER LINES FOR LIQUID HELIIUM

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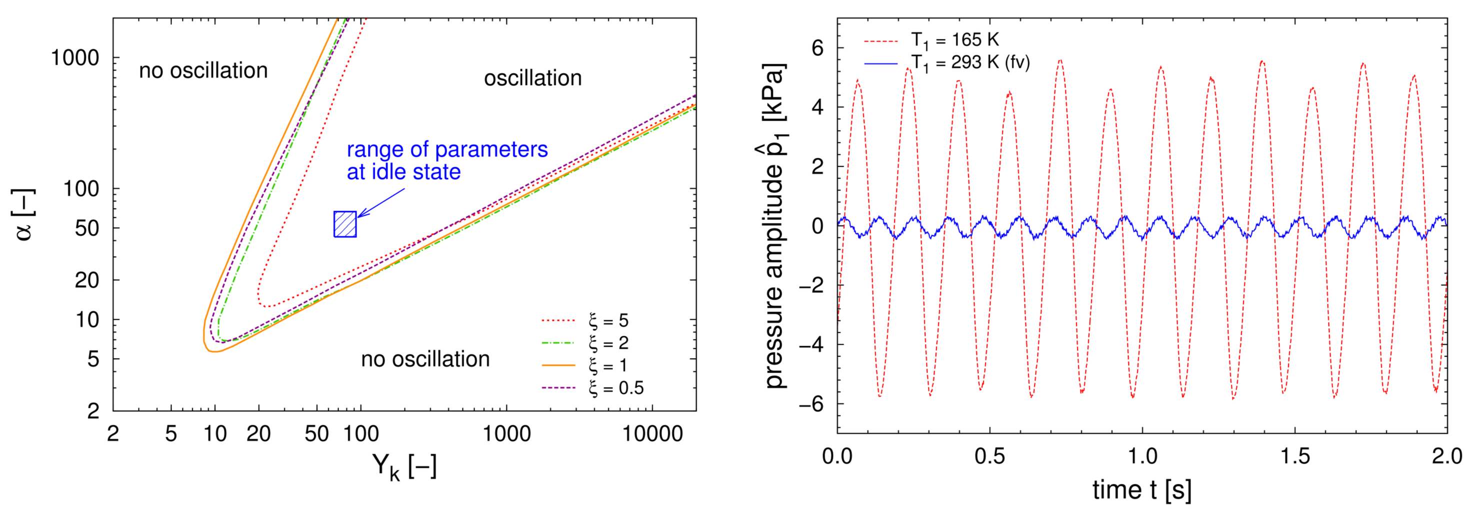
MOTIVATION

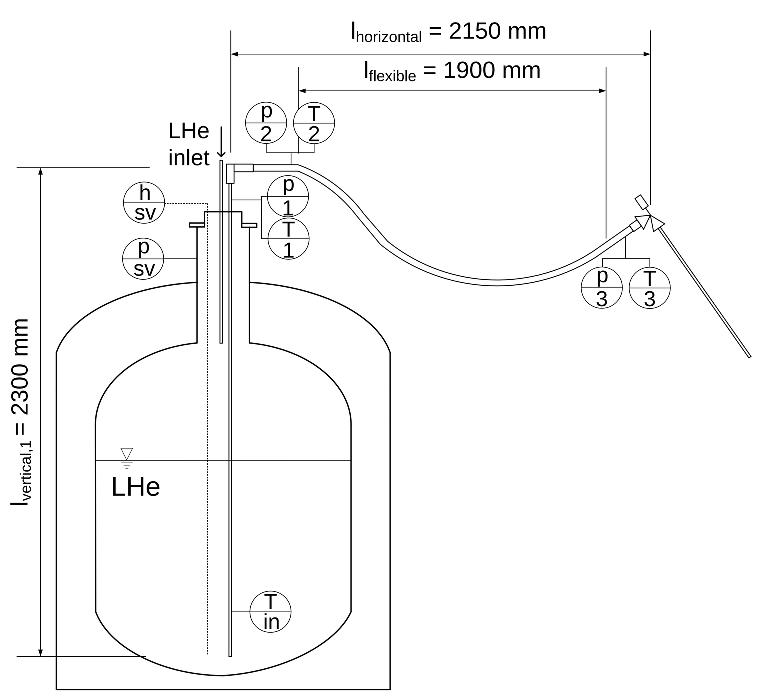
Thermoacoustic oscillations are observed in an idle LHe transfer line, leading to increased evaporation rates and critical pressure levels in the considered storage vessel.



(a) (b)

Figure 1: (a) Stability limit according to Rott; (b) Measured pressure amplitudes for different temperatures T_1 indicating a low and a high amplitude oscillation mode.

EXPERIMENTAL SET UP



The experimental transfer line features temperature and pressure sensors. The error of the pressure sensor is ±0.1% full scale (80 kPa_g) and the temperature sensor error is ±0.25 K (DT-670A). An optional, steady opened foot valve can be applied to the transfer line inlet.

Figure 2: Scheme of the decant station equipped with the experimental transfer line.

RESULTS

ONSET OF THERMOACOUSTIC OSCILLATIONS

The transfer line warms up rather quick after the transfer of LHe is finished. At a temperature ratio $\alpha_1 = T_1/T_c \cong 25$ a low amplitude oscillation is observed. At $\alpha_1 \cong 55$ an amplification from $\hat{p}_1 = 0.5$ to 2.8 is observed. The maximum amplitude is determined to be $\hat{p}_1 = 5.6$ kPa.

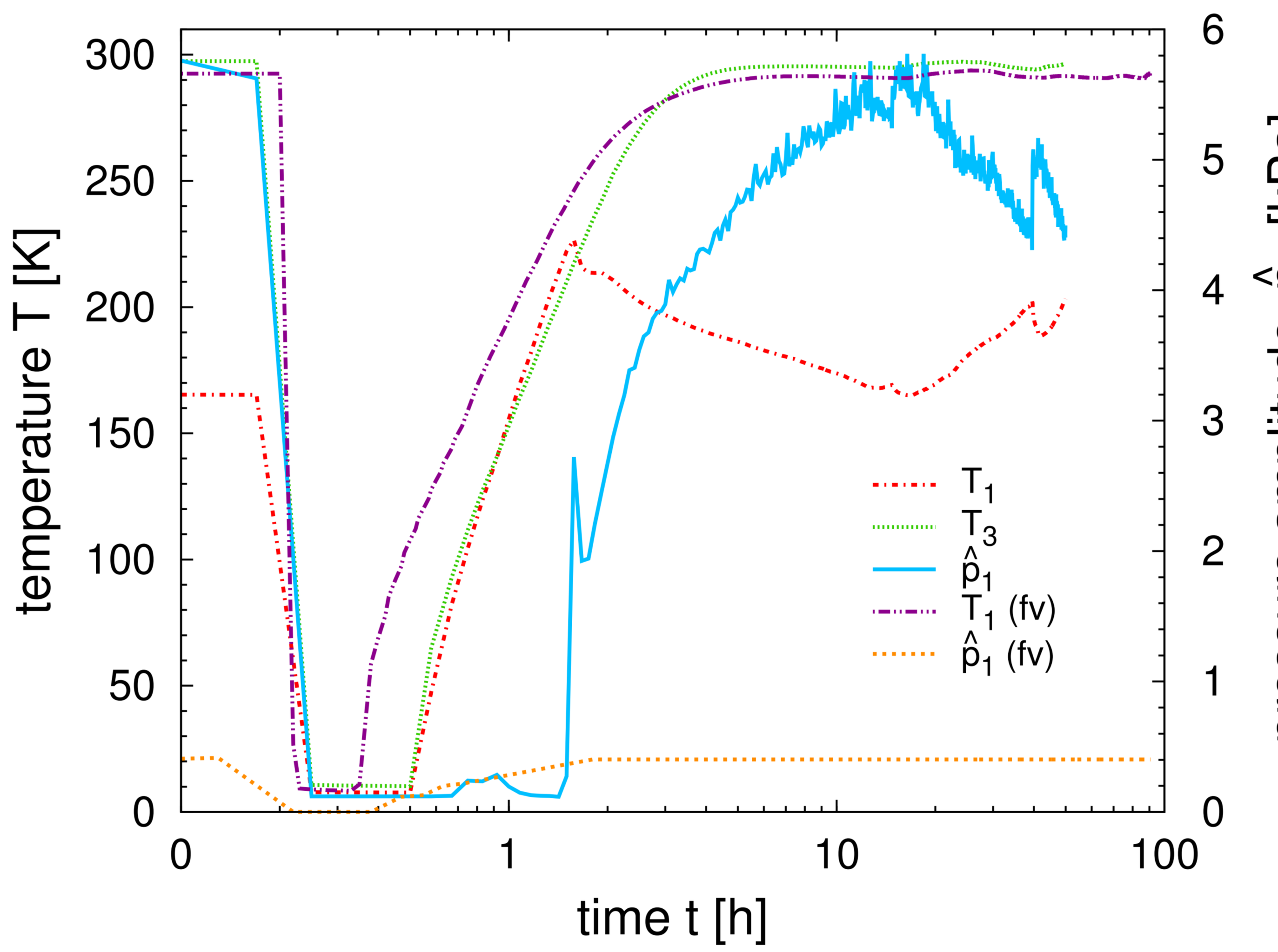
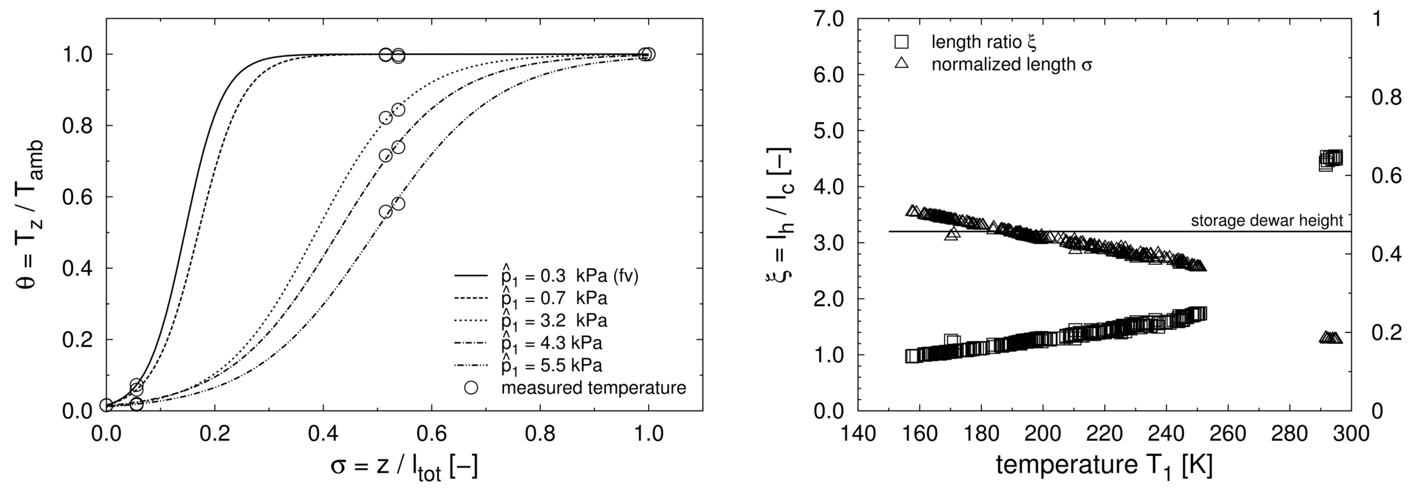


Figure 3: Time-referenced values of temperature and pressure amplitude indicating the onset of thermoacoustic oscillations after transfer of liquid helium.

TEMPERATURE PROFILE

According to Rott and Luck et al. the temperature profile is approximated by a s-shaped function. For that purpose a logistic distribution $\theta = \left(1 + exp\left(-\frac{\sigma_z - \sigma_c}{\beta}\right)\right)^{-1}$ is used.



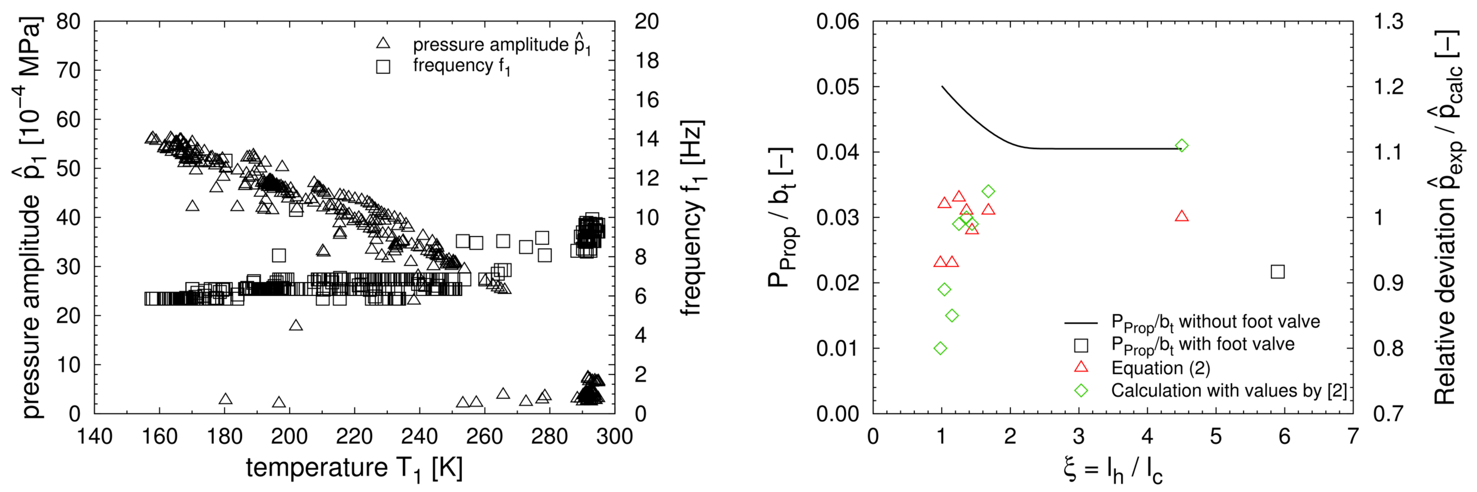
(a) (b)

Figure 4: (a) Approximated temperature profiles using a logistic distribution; (b) Derived cold length and dimensionless position of boundary between cold and warm length.

ESTIMATION OF AMPLITUDE AND FREQUENCY

In the calculation of the amplitude the oscillating system is considered as a system of one mass, one spring and one turbulent damper. Thereby the cold gas column is the oscillating mass and the warm one acts as a spring. According to Luck et al. the pressure amplitude is:

$\hat{p} = \frac{3\,\pi\,V_{wg}\,k^3\,r^2}{4\,A^3\,\omega^3\,\eta_{cg}\,l^2} \cdot \frac{P_{Prop}}{b_t}$ with P_{prop} / b_t being a specific ratio for each oscillating system that is derived from dedicated experiments. The frequency given by Fig. 5 [Rott, 1973] corresponds to experiments. For oscillations with high amplitudes it gives 6 to 7 Hz and 9 Hz for the low one .



(a) (b)

Figure 5: (a) Measured pressure amplitudes and frequencies as a function of temperature T_1; (b) Specific value of P_{prop} / b_t and the resulting relative deviation.

HEAT LEAK

	High amplitude	Low amplitude	Storage vessel only
Heat leak Q_{tot} [W]	22.5	14.9	12
Evaporation rate [l_{LHe}/h]	2.6	1.1	1.0

CONCLUSION

Thermoacoustic oscillations are a severe problem concerning the safety and efficiency of storage vessels at decant stations. An opened foot valve at the inlet prevents an amplification of the low amplitude oscillation. The corresponding heat leak is close to that of the examined vessel. Published correlations allow good estimations of amplitude and frequency using cold gas properties.

REFERENCES

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