Noise Effects In Capillary Tubes Caused By Refrigerant Flow

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Refrigeration an Air Conditioning

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Thomas Tannert
Motivation

bottom-freezer appliance with remarkable noise fluctuations

- Complaints from consumer concerning noises
- Pre-testing of original appliance
- Identifying capillary tube exit as source of noise
- Build up of test setup
Flow chart of the bottom-freezer test setup

- **3/2-way valve**
- **shut off valve**
- **suction line heat exchanger**
- **roll bond evaporator (fridge)**
- **sight glass**
- **wire tube evaporator (freezer)**
- **Wrap around evaporator (freezer)**
- **dyn. pressure**
- **filter dryer**
- **wire tube condenser**
- **door frame heater**
- **microphone**

**Test setup**

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- **Flow chart of the bottom-freezer test setup**

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Acoustic study

Noise effects in freezer mode with capillary tube 2.70m / 0.65 mm (standard)
Sight glasses at inlet and outlet of capillary tube

Capillary tube flow

Capillary tube inside filter dryer

Capillary tube outlet at freezer evaporator

$t_c$, $p_c$, $t_{sat}$

$\varnothing d_i = 0.6\text{mm}$

$Q_c$, $Q_{1HX}$, $Q_0$

$t_0$, $p_0$

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Refrigerant flow at capillary tube

- capillary tube inside filter dryer
- capillary tube outlet at freezer evaporator

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Refrigerant flow pattern at capillary tube outlet

- Free jet with constant vapor mass fraction → Annular flow
- Free jet with alternating vapor mass fraction → plug flow (Taylor-bubbles)
Coincidence of alternating flow pattern and noise fluctuation at capillary tube outlet

Flow induced noise

1. Free jet with constant vapor mass fraction
2. Free jet with alternating vapor mass fraction

- Annular flow
- Plug flow

\[ \Delta L_m = 9.64 \text{ dBA} \]

Increasing noise level

Acceleration sensor

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Capillary tube flow

decreasing liquid level in capillary tube

capillary tube inlet inside filter dryer

changing flow pattern
annular flow → plug flow

capillary tube outlet at freezer evaporator
Flow induced noise

Frequency response of acceleration signal @ low and high noise level

1. Free jet with constant vapor mass fraction

2. Free jet with alternat. vapor mass fraction

- Peaks @ 284 Hz, (400 Hz), 745 Hz and broadband rising @ 2000 ± 200 Hz

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Flow induced noise

Identifying root causes for noise excitation ...

... with theoretical approach

- model:

... and validate with experimental data

- calculation approach:

\[ f = \frac{1}{\pi \cdot l} \sqrt{\frac{\kappa \cdot p}{\rho_l \cdot \left(\frac{L}{l} - 1\right)}} \]

\( \kappa = \frac{c_p}{c_v} \) @ \( t_0 \)

\( p \) saturation pressure @ \( t_0 \)

\( \rho_l \) liquid density @ \( t_0 \)

\( \approx 288 \) Hz

\( \approx 284 \) Hz

(Han et al., 2011)

from visual study

from acoustic study

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Achieved results and further investigation

- Observable **noise level fluctuation** in a bottom-freezer appliance

- Synchronously occurrence of **alternating refrigerant flow regime / pattern** and **changing frequency response** of noise at capillary tube outlet
  - **At low noise level:**
    - free jet, **constant** vapor mass fraction / **annular** flow
  - **At high noise level:**
    - free jet, **alternating** vapor mass fraction / **plug** flow (Taylor-bubbles)
    - Increasing amplitude of single frequencies + frequency bands

- Theoretical Taylor-bubbles **resonance frequency** (supported with visual data) matches the measured frequency

- Interacting of capillary tube flow and **refrigeration system dynamics**

- Developing **methods to avoid** capillary tube flow fluctuation
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