Acoustically Enhanced Condensation in Saturated Liquid-Vapor Flow

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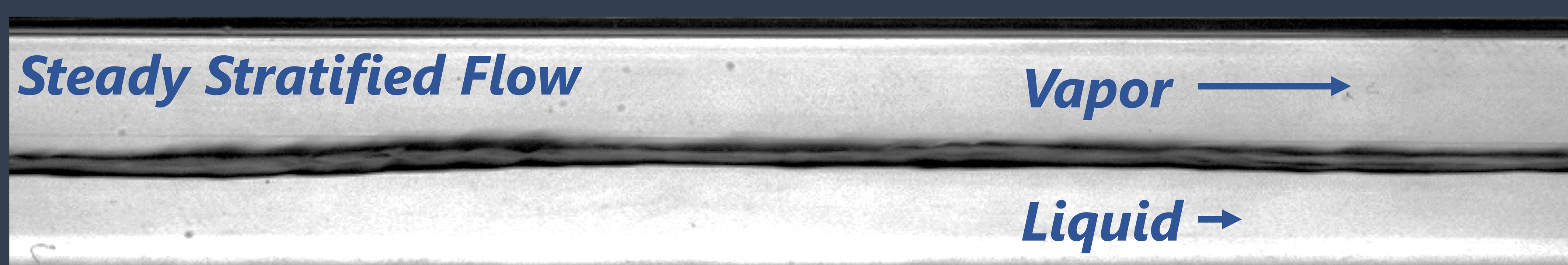
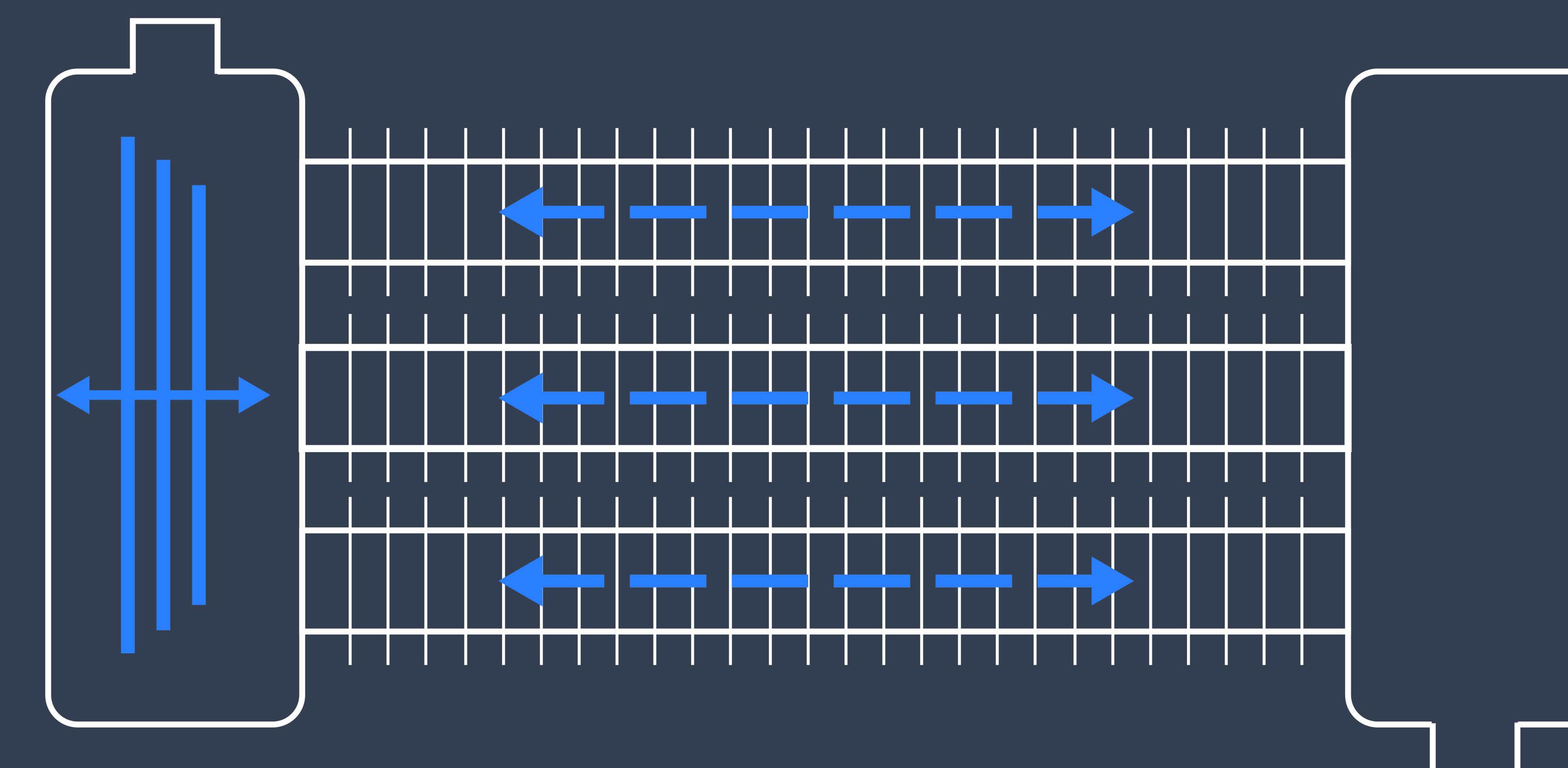
A saturated mixture of refrigerant (R134a) liquid and vapor flows horizontally in a tube simulating air-cooled condenser tubes. Under steady operation, the condensed liquid accumulates at the bottom of the tube, resulting in a stratified two-phase flow regime with a smooth liquid interface and decreased heat transfer to the tube walls.

The insulating effects of the slow-moving liquid layer are overcome by inducing ***Helmholtz resonance*** within the tube using ***low-frequency acoustic actuation*** coupled to the vapor flow to excite interfacial liquid-vapor shear instabilities. The forced interface oscillations induce the formation of high-amplitude surface waves accompanied by streamwise velocity fluctuations that are larger than the mean flow velocity and entrain both liquid and vapor leading to ***finely dispersed two-phase flow***.



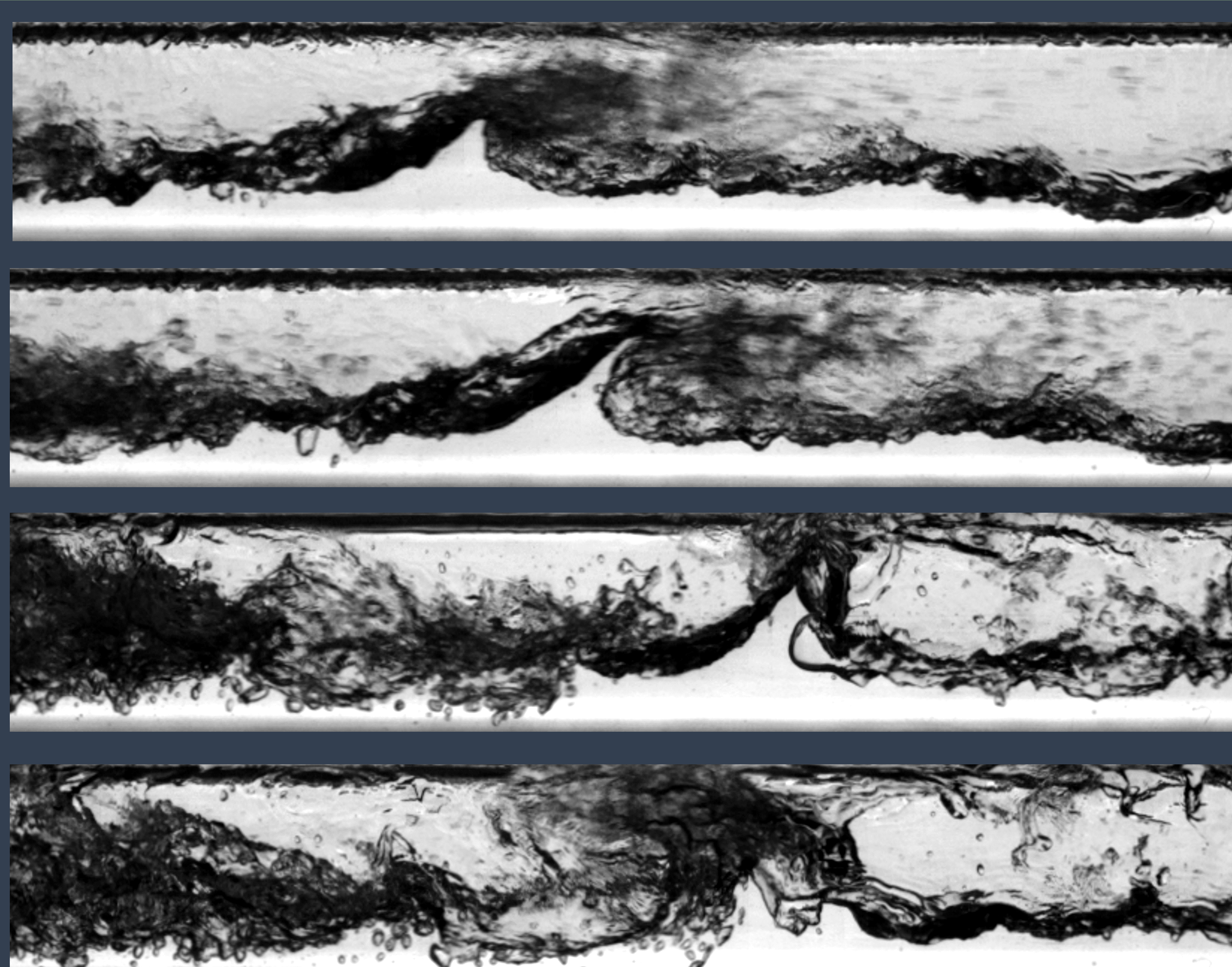
The interfacial oscillations are forced by leveraging an acoustic resonance that can be driven within common heat exchanger designs by using Helmholtz resonance determined by the large volumes of the front and rear headers and the connecting heat exchanger tubes. Acoustic waves introduced at the inlet or outlet headers propagate through the tubes and are reflected at the opposite header forming the pulsatile flow depicted in the images below.

Air-cooled condenser with header driver



Temporal Evolution of Helmholtz Actuation (f = 6.5 Hz, T = 154 msec)

Low Amplitude: Forced Interfacial Wave Formation



Time *(from TDC)*

0.000*T*

0.163*T*

0.326*T*

0.489*T*

High Amplitude: Liquid Entrainment and Complete Phase Mixing