NEW HEAT EXCHANGER MODELS FOR 2-PHASE COOLING

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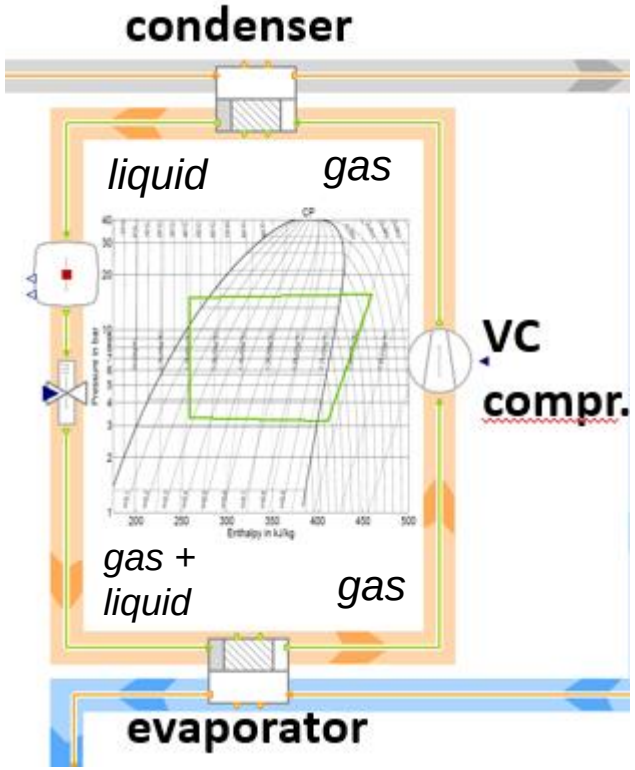
Motivation

Vapor cycle Cooling

Condensation of Refrigerant

cooling channel



1 Medium
2 Phases

Evaporation of Refrigerant

air + water

Condensation of humid air

Air Cooling

cooling channel

air + water

humid air in fresh air channel

Condensation of humid air

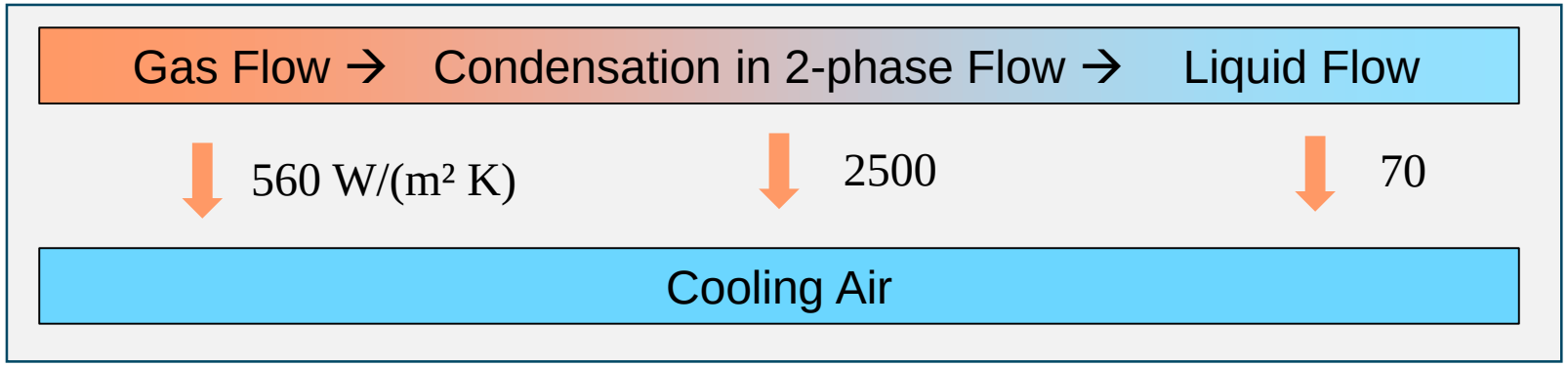
2 Media: Dry Air + Water
Water in 2 Phases

humid air in fresh air channel

Heat Transfer Coefficients during Phase Transitions

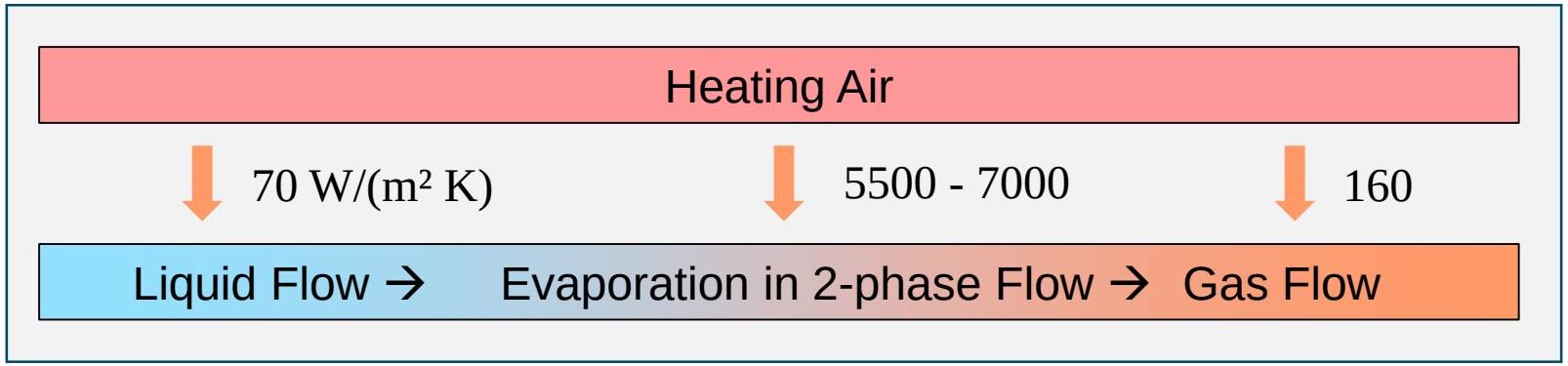
Modeling Approach:

Condenser:



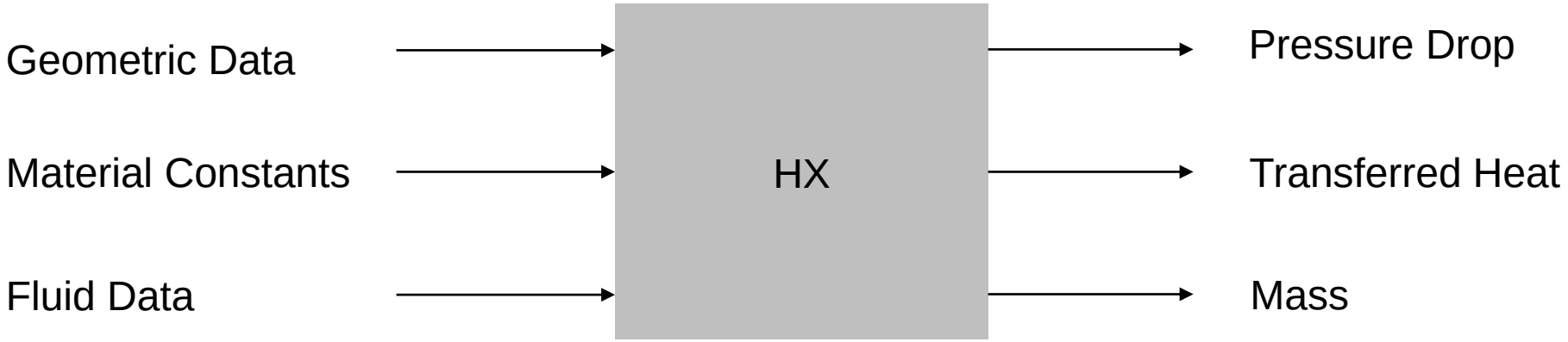
Nußelt's Waterfilm Theory

Evaporator:



Empiric Transition due to Chen

Way of New Approach



Material Coefficients
instead of
Empirical Parameters

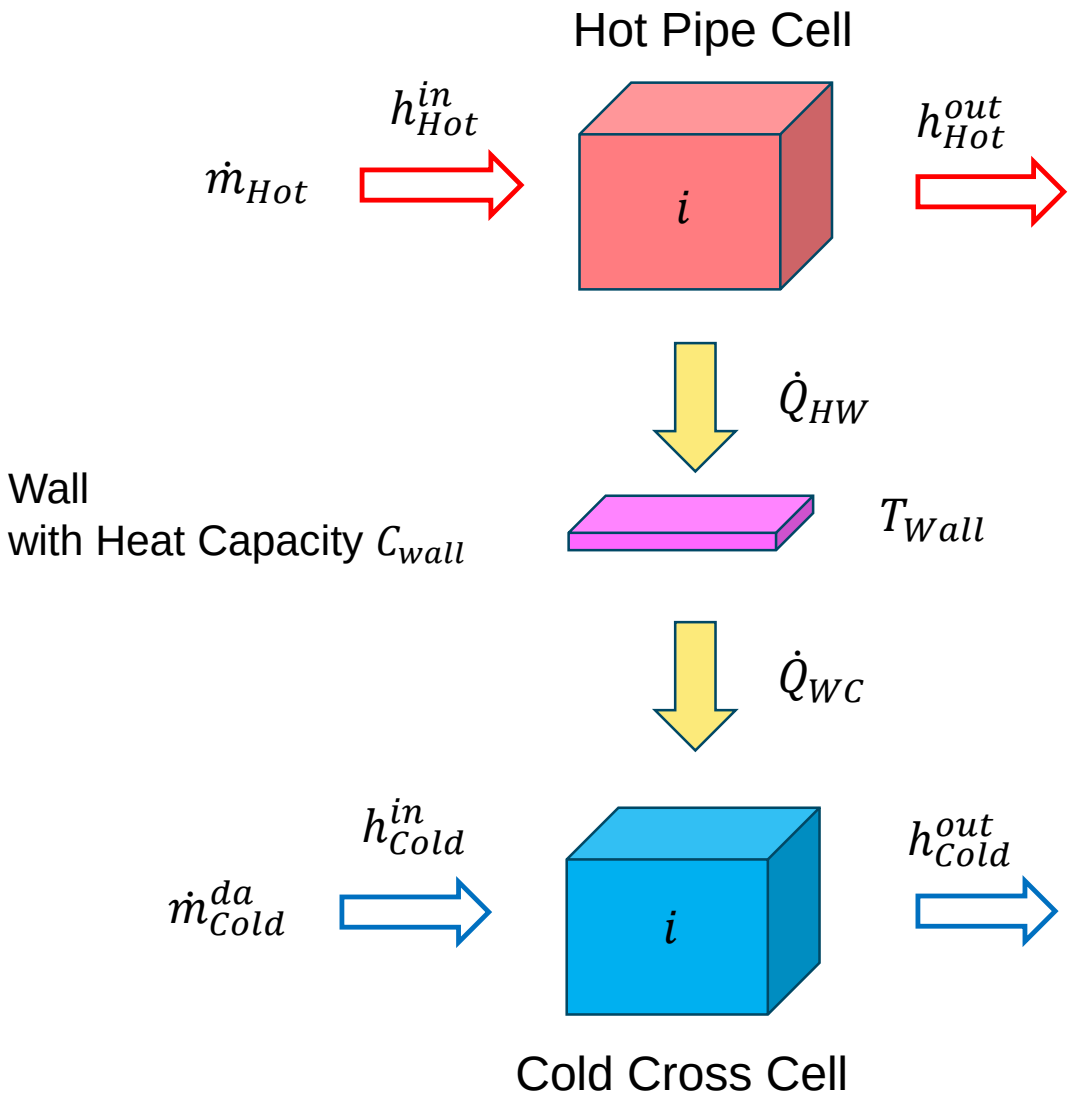
Modeling of Physical Processes:

Material Transport
Heat Transport
Phase Change (Condensation, Evaporation)

Discretization:

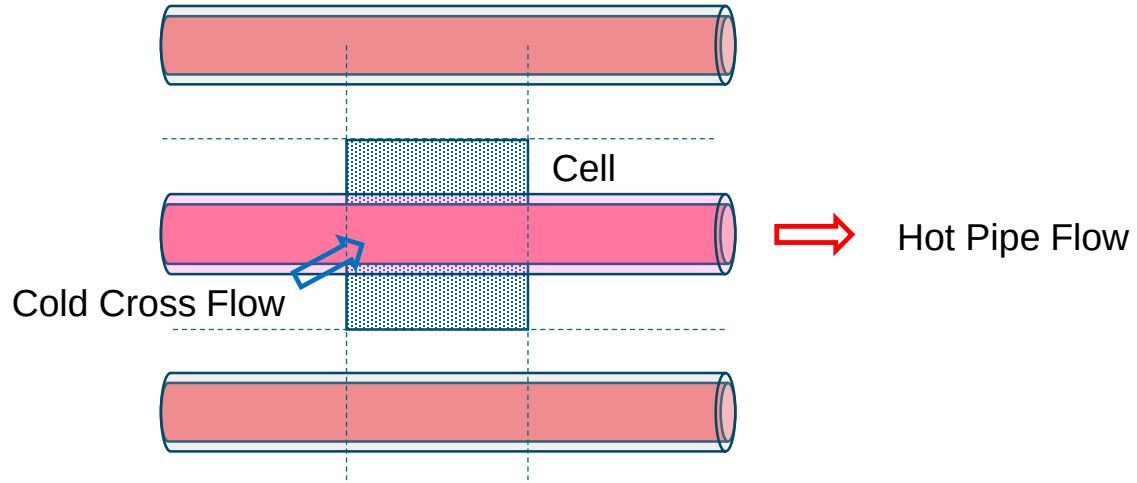
1 Type of Process per Cell

Discretization and Separation of Hot and Cold Channel



Idea:
Tin of wall has very high thermal conduction.

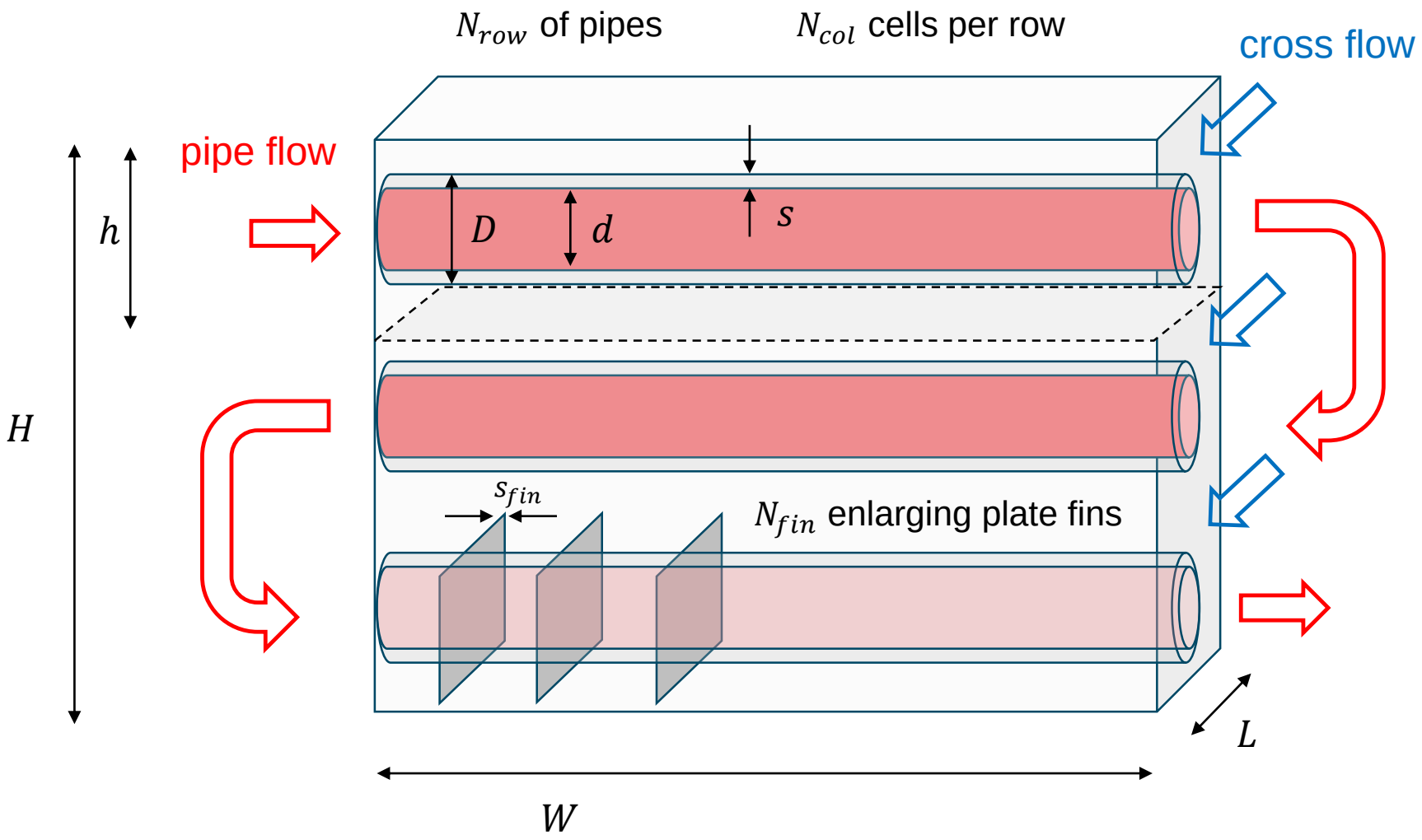
➔ Wall takes temperature very fast +
single wall temperature for each cell



Possible Structures of Heat Exchangers:

- Cross Flow
- Counter Flow
- Parallel Flow

Building a Cross Flow Heat Exchanger with Cell Elements



Geometric Data:

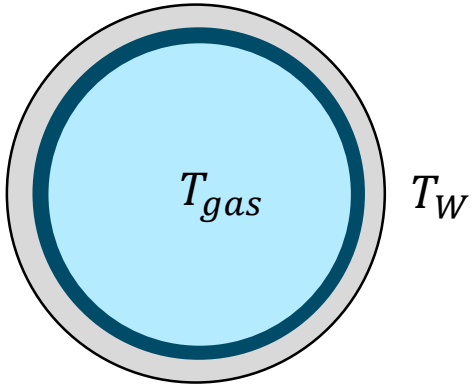
H	height
W	width
L	length
N_{row}	number of rows
N_{col}	number of cells per row
N_{fin}	number of fins per row
d	inner pipe diameter
s	thickness pipe wall
s_{fin}	thickness of fins

$$N_{cell} = N_{row} \cdot N_{col}$$

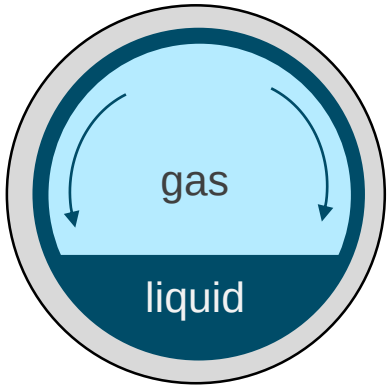
Film Condensation in Horizontal Condenser Tube

$T_W < T_{vap}^{sat} < T_{gas}$

$T_{liq} = T_{vap}^{sat}$



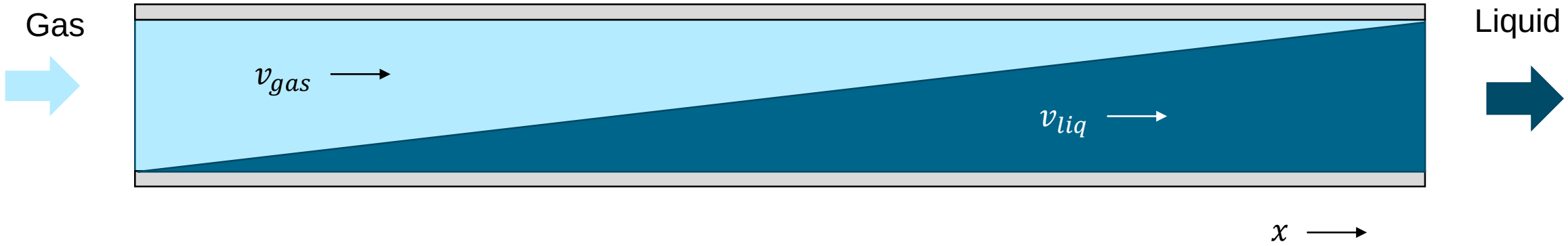
Film around a tube



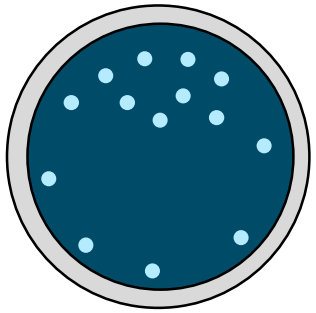
Film flows to the bottom and fills the bottom

Film thickness δ determines the heat transfer rate

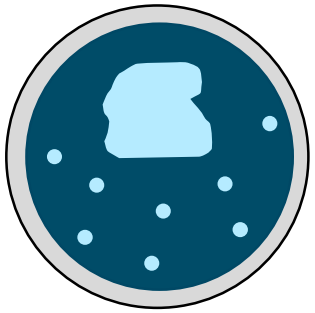
$$\dot{Q}_{cond} = \lambda_{liq} \frac{T_F^{sat} - T_W}{\delta} A_{wall}$$



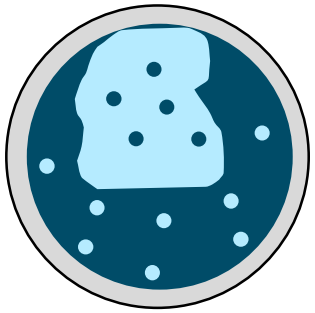
Process of Evaporation in a Horizontal Tube



Bubble Flow
(Blasenströmung)

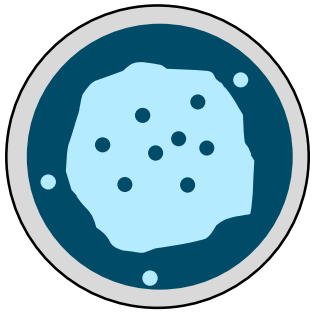


Plug Flow
(Pfropfenströmung)



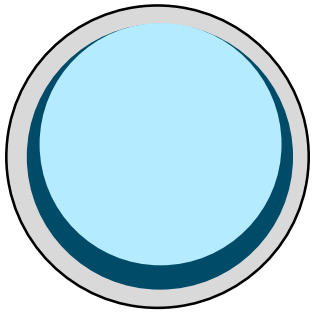
Slug Flow
(Schwallströmung)

Stratified Flow
(Schichtenströmung)

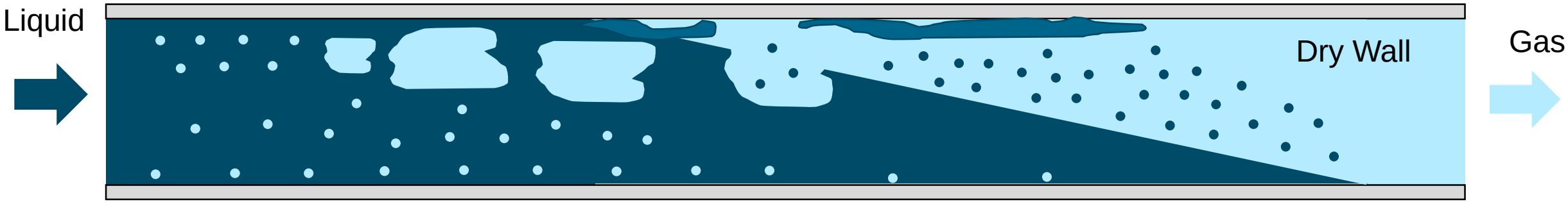


Annular Flow
(Ringströmung)

Wavy Flow
(Wellenströmung)



Spray Flow
(Sprühströmung)

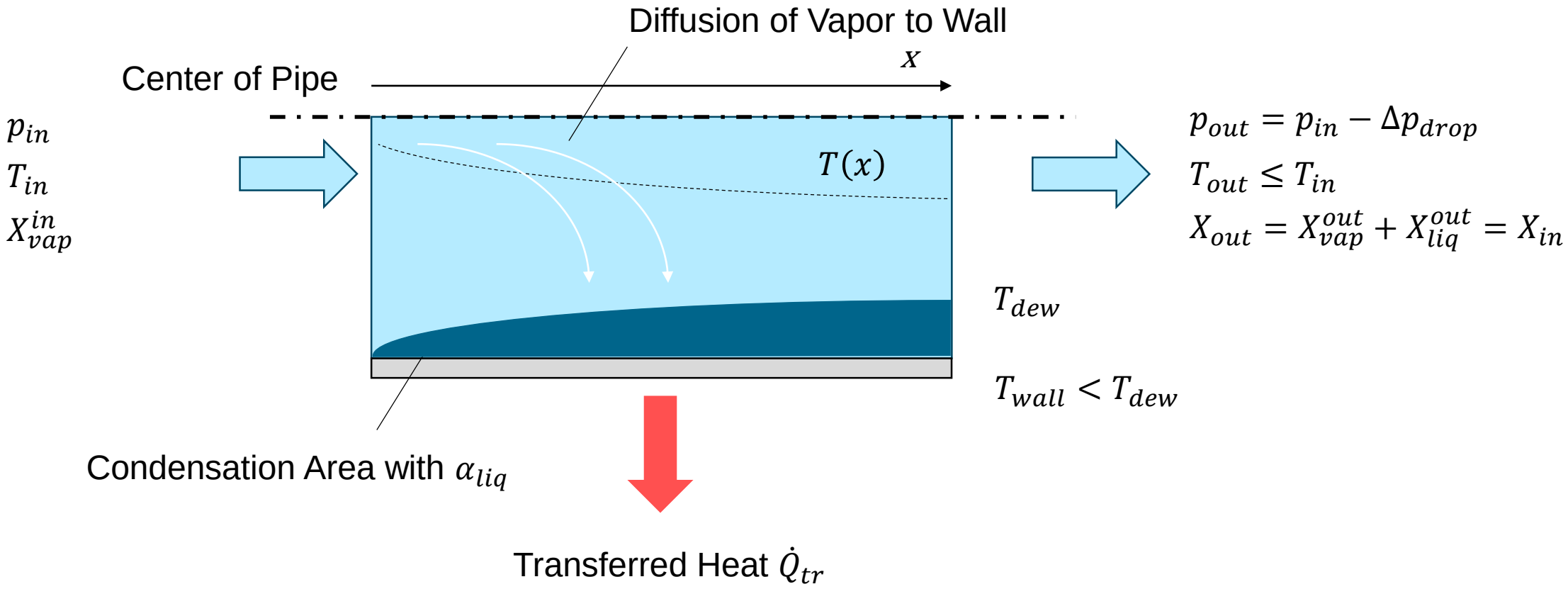


Subcooled Boiling
(unterkühltes Sieden)

Bulk Boiling
(Blasensieden)

Flow Boiling
(Strömungssieden)

Condensation of Humid Air



Solved Problems

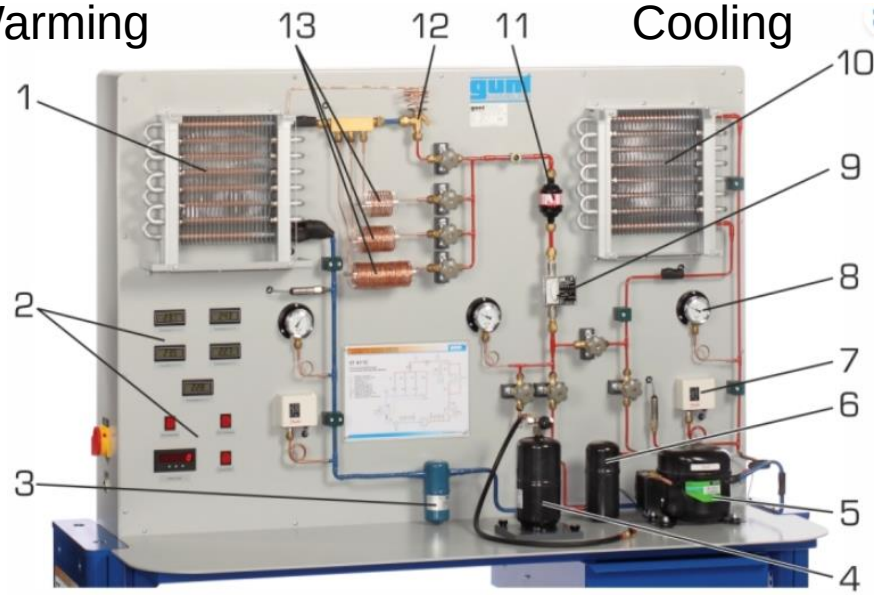
- Good Guess of Heat Transfer Coefficients
- Heat Transfer Coefficients vary with Phase State
- Free geometric Sizing
- Mass Calculation

Literature

Validation

Refrigerant:
Condensation and Evaporation:
Temperature and Enthalpy Deviations < 5%

Test Rig



Invitation for Beta-Testing

Use public Library

nieweber/ThermofluidStream at physicalApproachHEX (github.com)

with Package HeatExchangersPhysical

THANKS FOR YOUR ATTENTION!