Principles of Chemical Engineering

Heat Transfer

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Syllabus Contents

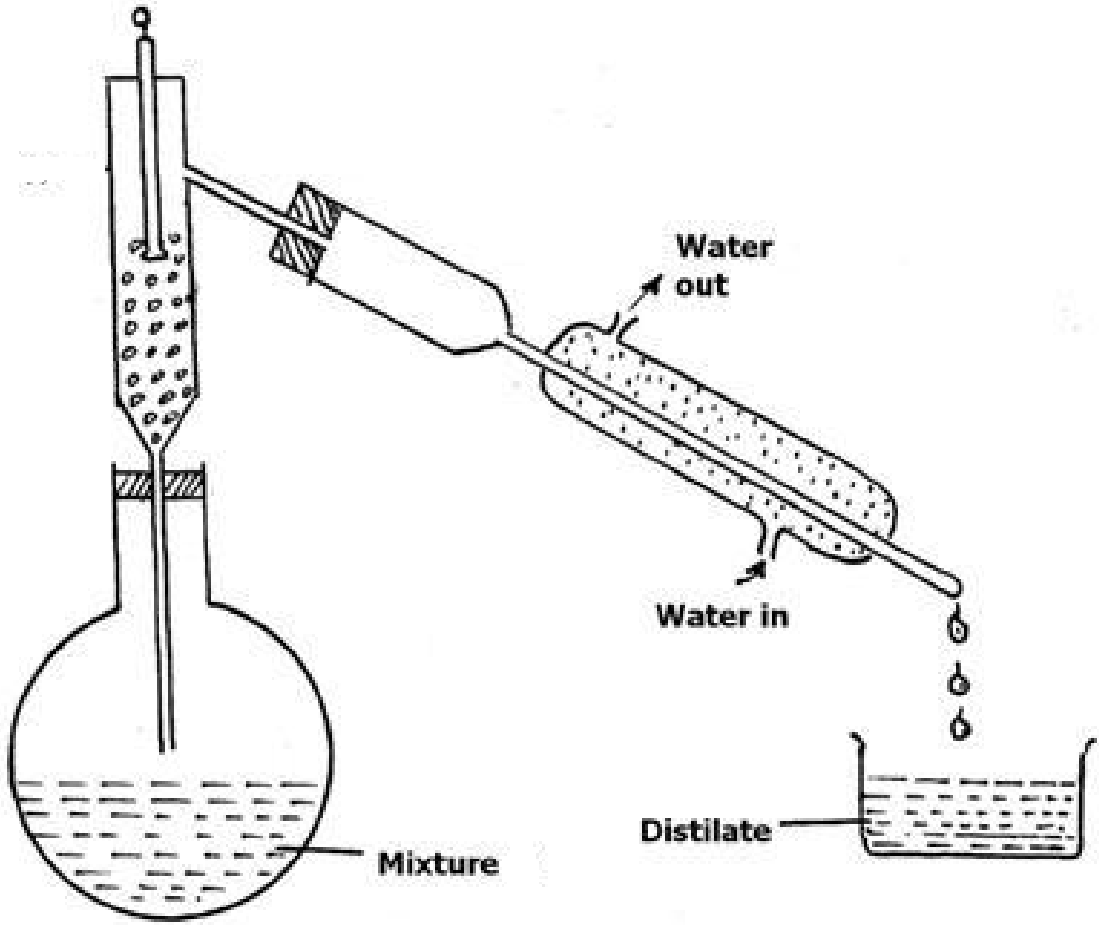
Flow arrangement in heat exchangers - Variation of Fluid temperature in heat exchangers

Objectives

- To understand the variation of temperature of a fluid along the length of its travel in a heat exchanger.
- To understand the role of flow arrangement of fluids in a heat exchanger.

Heat Exchanger

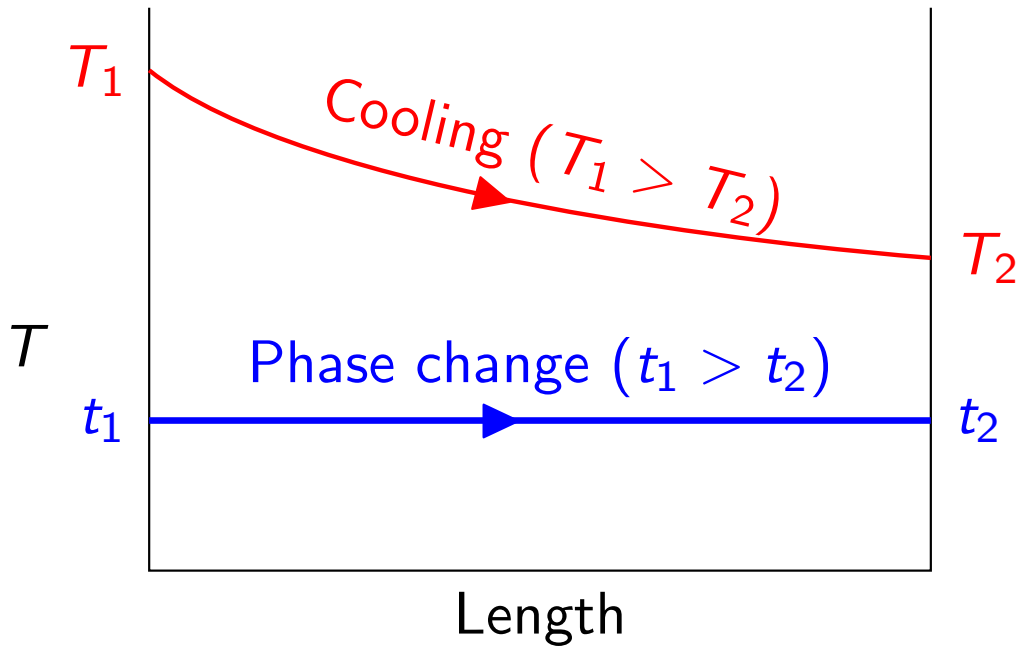
A heat exchanger is a device that allows heat from one fluid to pass to another fluid with a solid surface separating them.



Temperature Profile of a Fluid

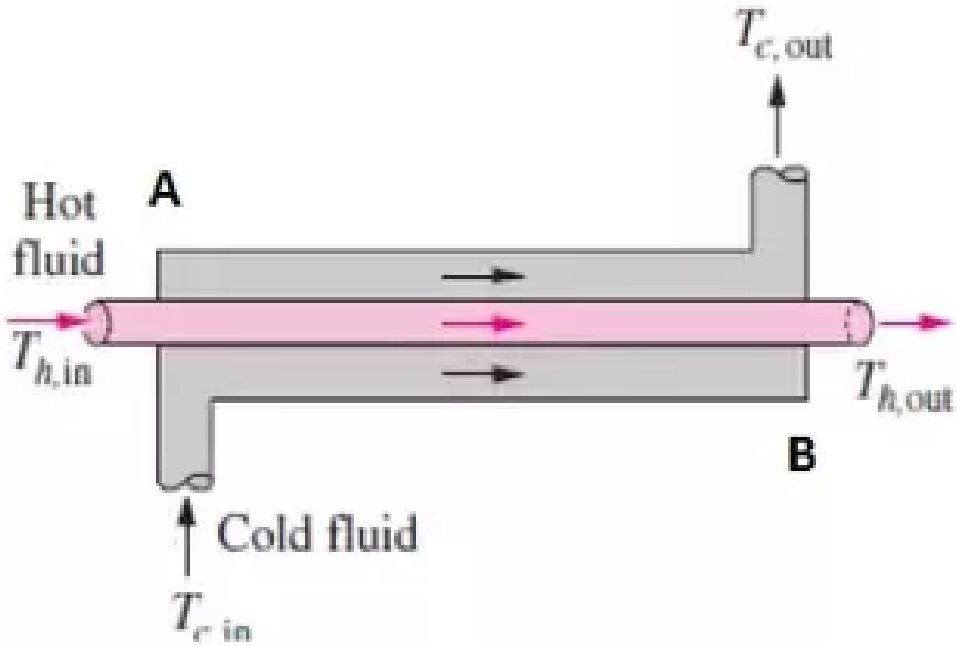
Variation of temperature of a fluid along the length of a heat exchanger is called as the temperature profile of a fluid.

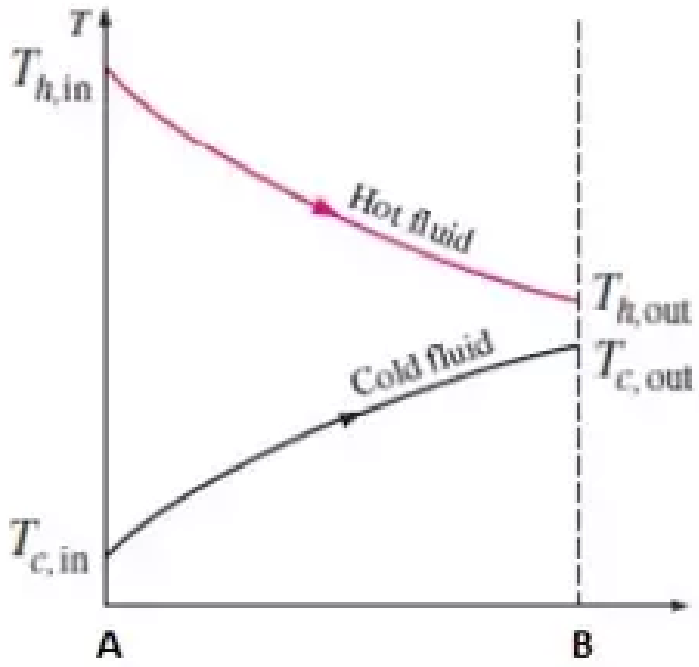
- For a fluid that is getting cooled down, it's temperature decreses along the length. For a fluid that is getting heated up, it's temperature increses along the length.
- For a fluid undergoing phase change (such as boiling, or condensation), there is no change of temperature along its length.



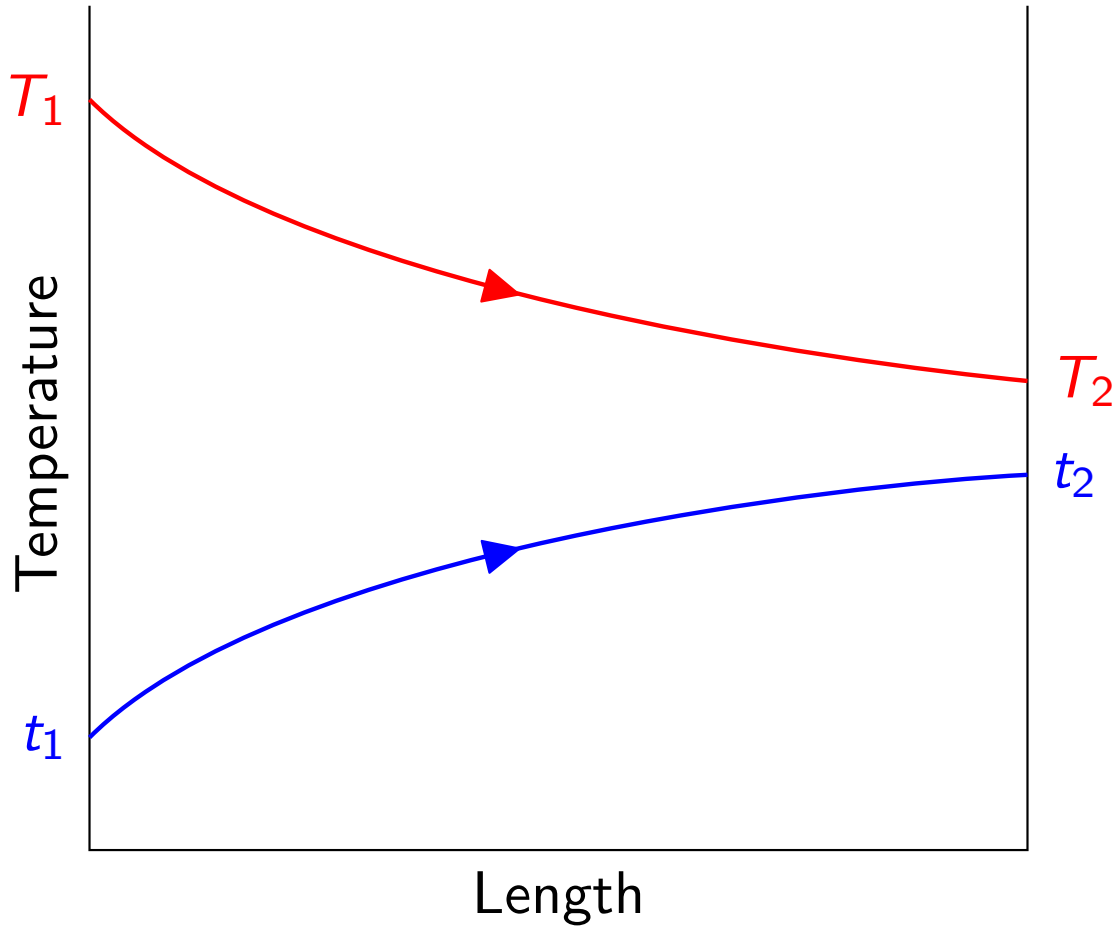
Temperature Profiles

Co-Current Flow





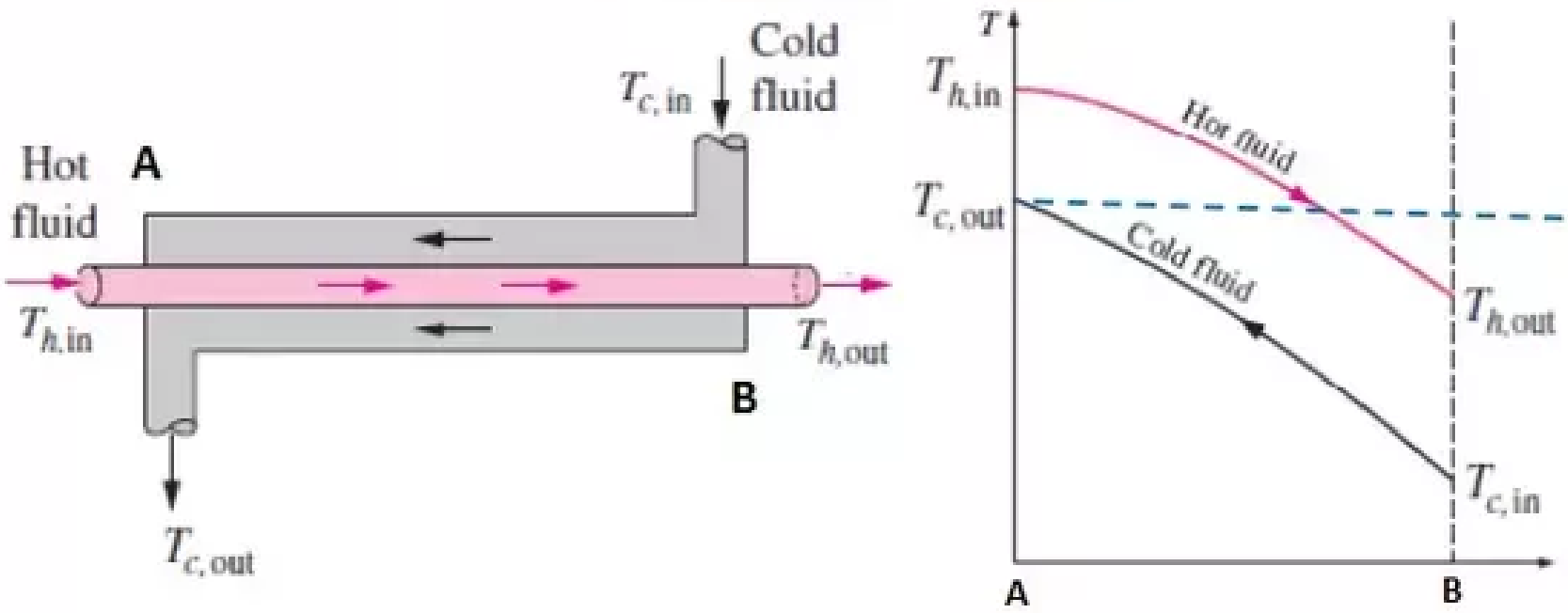
$T_{c,out}$, cannot exceed $T_{h,out}$.



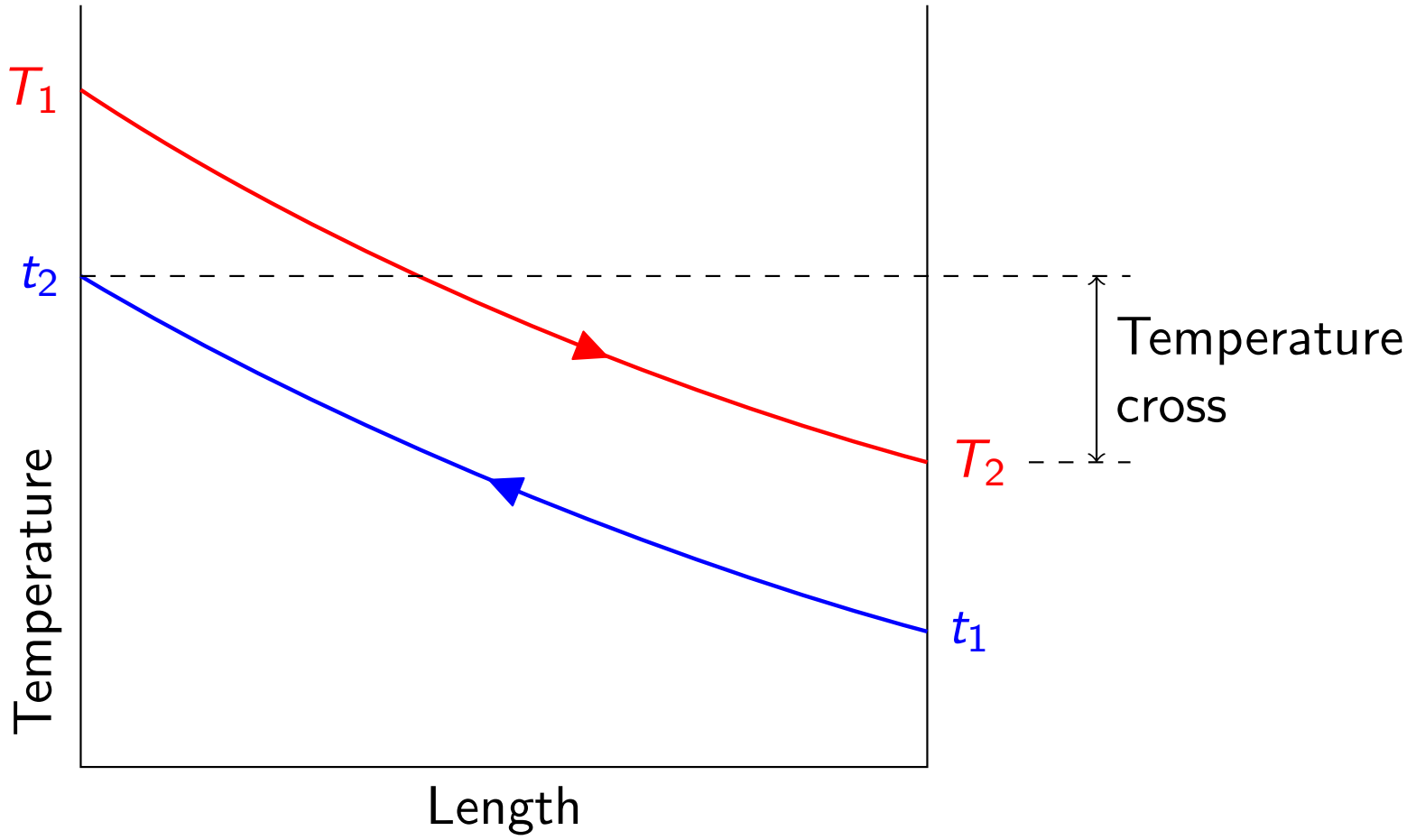
Cocurrent flow

Temperature Profiles

Counter-Current Flow

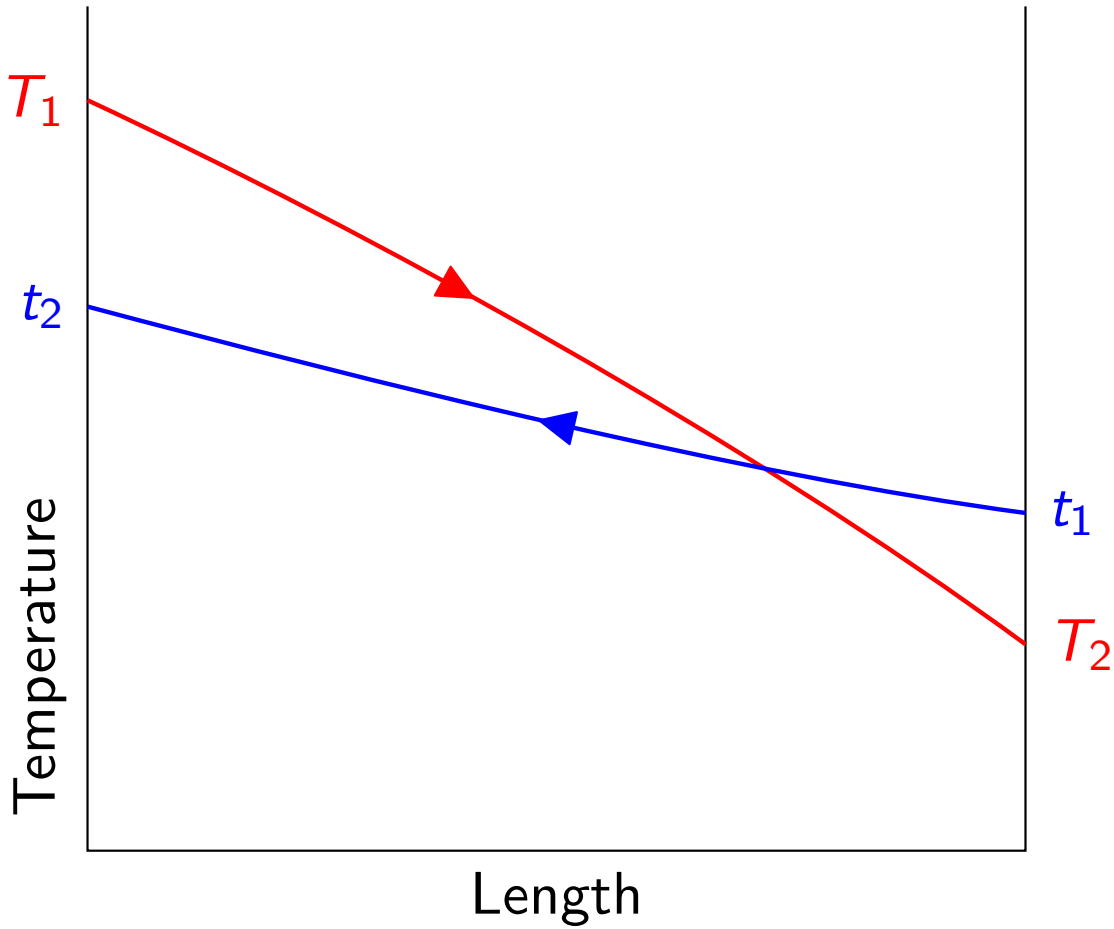


$T_{c,out}$, out can exceed $T_{h,out}$.



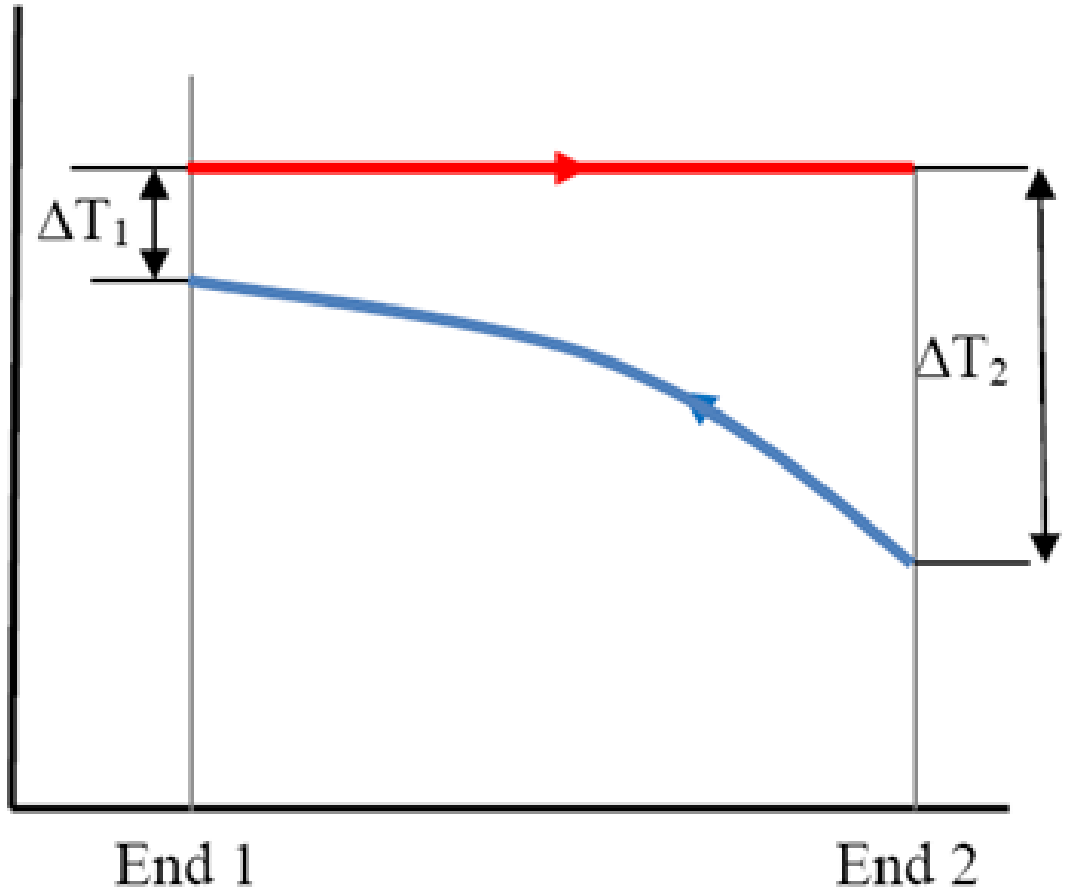
Countercurrent flow

Thermodynamic Violation!



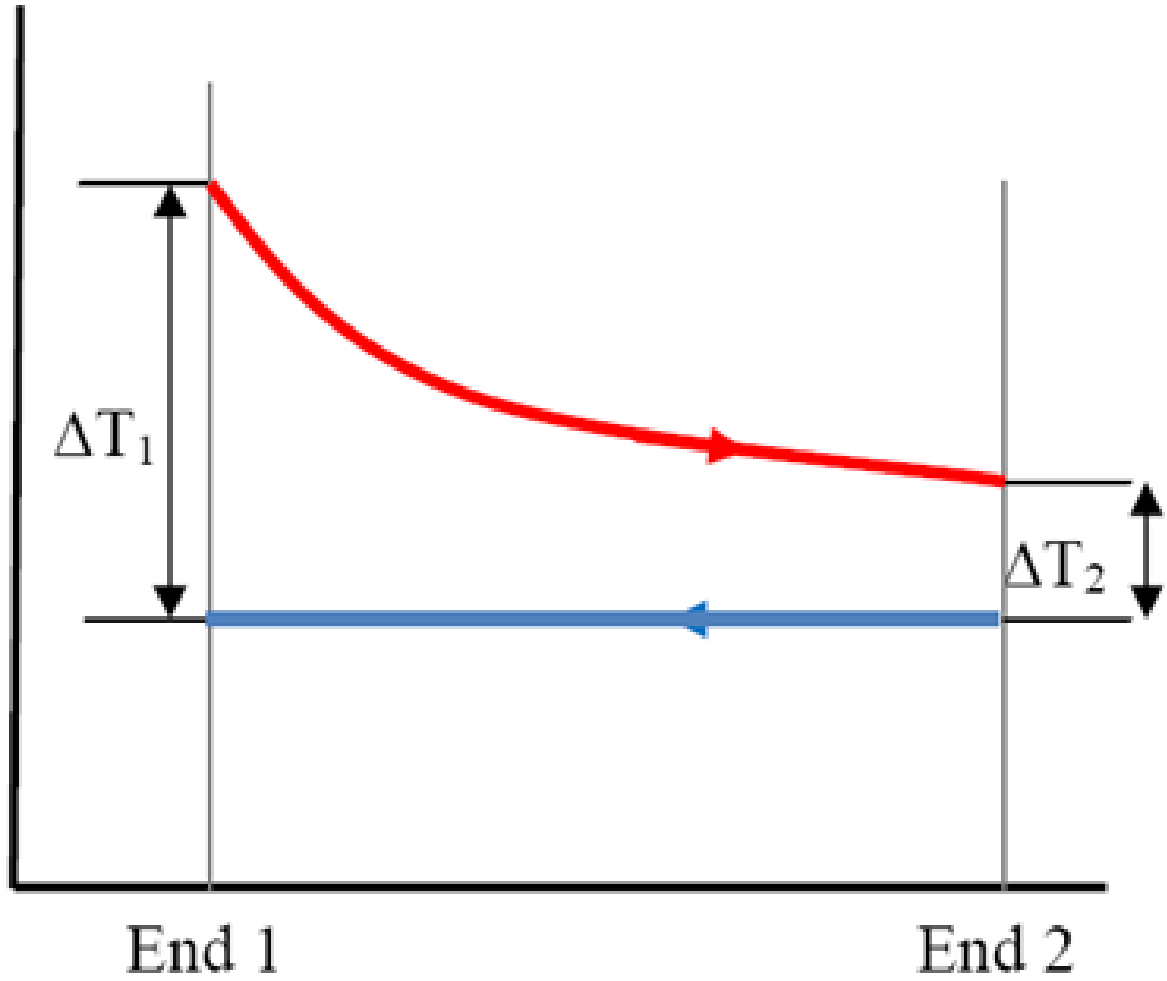
Temperature Profiles with Phase Change

Condenser

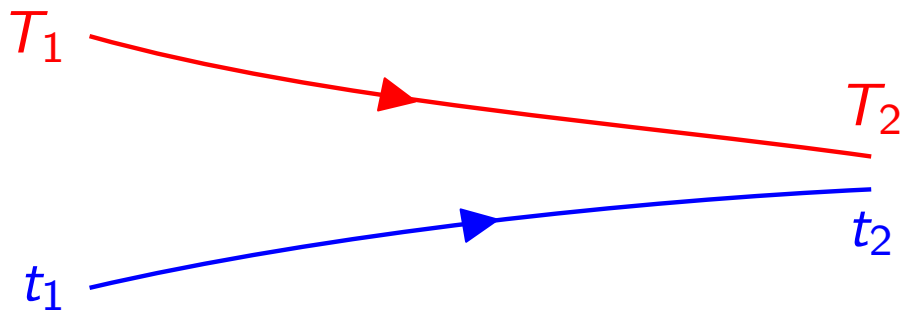


Temperature Profiles with Phase Change

Boiler

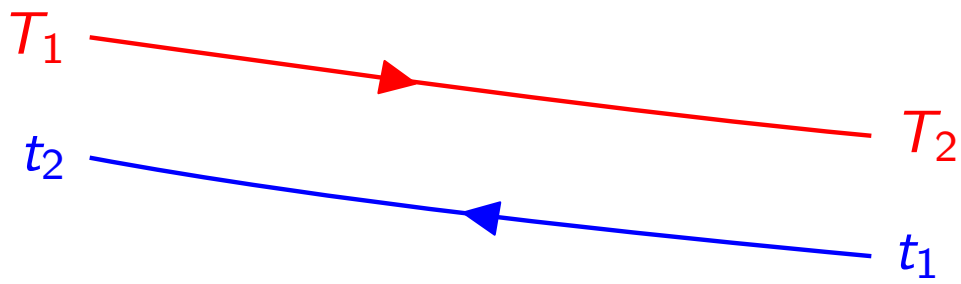


Cocurrent Arrangement



- With cocurrent flow, the wall temperatures throughout the exchanger will be more uniform than with other flow patterns.
- When the goal is to end up with two fluids that have a relatively insignificant temperature gap, a parallel flow may be the ideal solution.
- The dramatic temperature difference at the inlet can cause thermal stress, which may result in vibrations that lead to equipment damage.

Countercurrent Arrangement



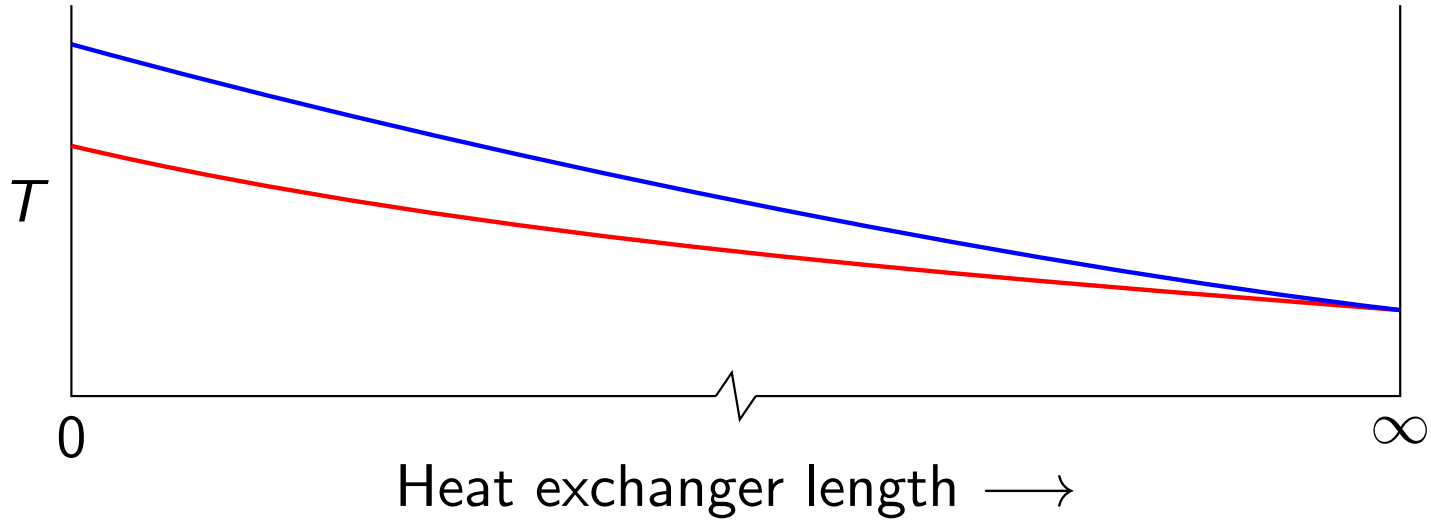
- This flow pattern allows for the greatest temperature change between fluids. The cold-fluid can reach the hottest temperature of the hot-fluid since it exits at the end where the hot-fluid enters.
- Since the temperature difference is more consistent, the heat exchange rate is also more consistent throughout the exchanger.

Comparison between Co-current and Counter-current

- Since higher mean ΔT between the fluids is possible with countercurrent, this arrangement leads to the requirement of reduced heat exchanger size in comparison to cocurrent.
- To achieve greater heat recovery, a counter-current design is preferred to that of a co-current design.
- If we want to ensure that the temperature of the cold fluid never exceeds a particular temperature, then co-current exchanger designs are advantageous.
- Suppose one of the two interacting fluids is undergoing a phase change due to the heat transfer (e.g.: condensation of saturated steam), then both designs are identical.

Quiz

1. Refrigerant circulating in the household refrigerator changes it state from superheated vapor to saturated liquid upon passing through condenser coils by exchanging its heat with the ambient air. Draw the temperature profiles for the refrigerant and the ambient air.
2. Temperature profile for a infinitely long heat exchanger is given below.



What is the nature of flow of fluids? i.e., cocurrent / countercurrent ?