

FE 483 FOOD OPERATION LABORATORY

DOUBLE-PIPE HEAT EXCHANGER

PURPOSE

To demonstrate the working principles of a double heat exchanger operating under parallel and counter flow conditions.

THEORY

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions.

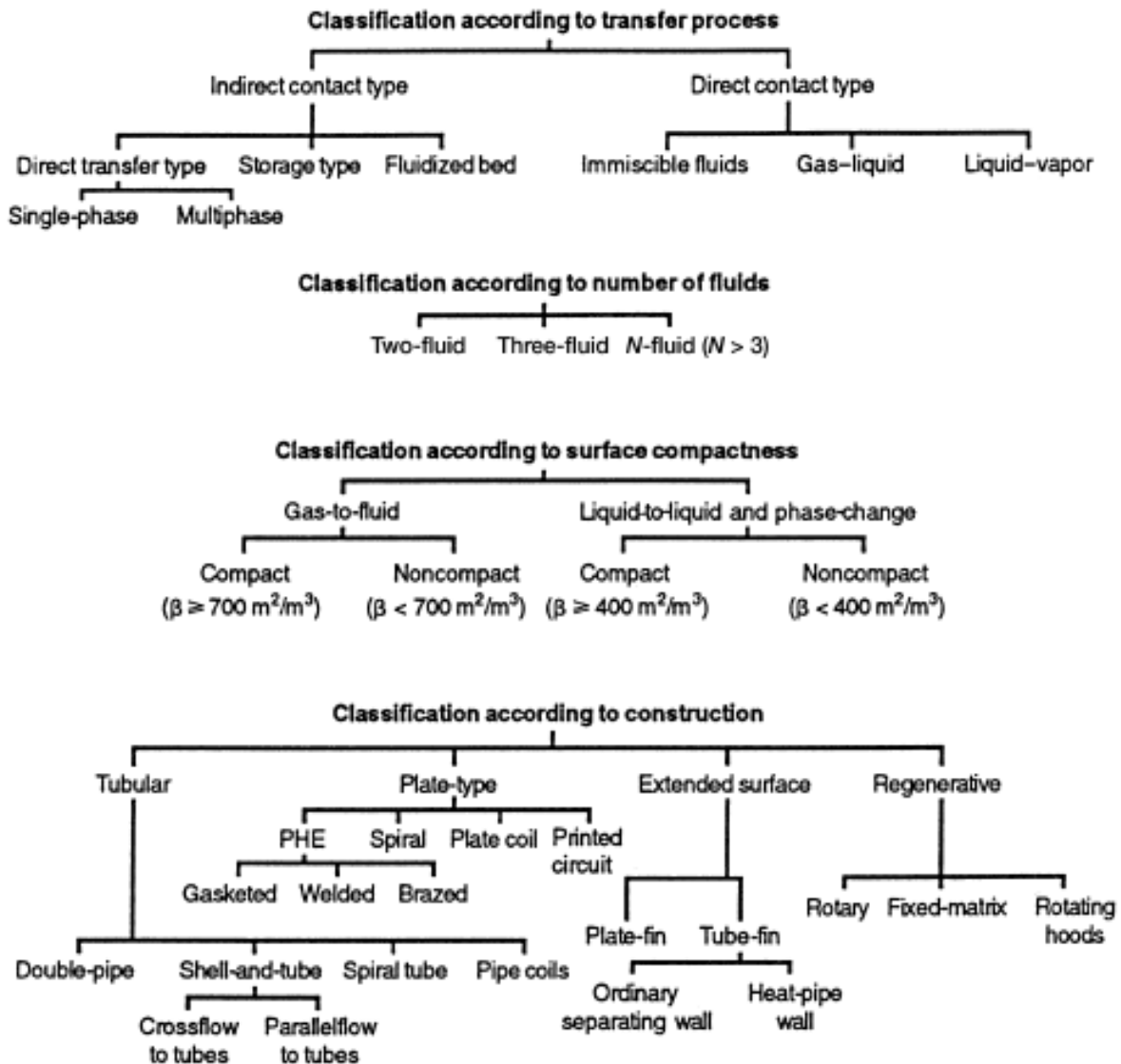


Figure 1. Classification of heat exchangers

Double-pipe heat exchanger (DHE) is one of the simplest types of heat exchangers. It is called a double-pipe exchanger because one fluid flows inside a pipe and the other fluid flows between that

pipe and another pipe that surrounds the first. Double pipe heat exchangers are also known as hairpin, jacketed pipe, jacketed U-tube and concentric pipe. The simplest form of double heat exchanger is a single pipe placed concentrically inside a larger pipe. The inner pipe can be plain or have longitudinal fins attached to increase the surface available for heat transfer. Flow in a double-pipe heat exchanger can be co-current or counter-current. There are two flow configurations: co-current is when the flow of the two streams is in the same direction, counter current is when the flow of the streams is in opposite directions. In double-pipe heat exchanger a hot process fluid flowing through the inner pipe transfers its heat to cooling water flowing in the outer pipe. The system is in steady state until conditions change, such as flow rate or inlet temperature. These changes in conditions cause the temperature distribution to change with time until a new steady state is reached. The new steady state will be observed once the inlet and outlet temperatures for the process and coolant fluid become stable. In reality, the temperatures will never be completely stable, but with large enough changes in inlet temperatures or flow rates a relative steady state can be experimentally observed.

Table 1. Advantages and disadvantages of DHE

Advantages	Disadvantages
Suited to high pressure applications.	Limited to low heat duties requiring surface areas less than 47 m ²
Standardization, simplifies maintenance, servicing and stocking of parts.	Flow pattern is strictly counter flow; there is no cross flow.
Flexibility, units can be added or removed as required.	As units are added on the possibility of leakage increases because of the number of connections increases.
Modular type construction.	

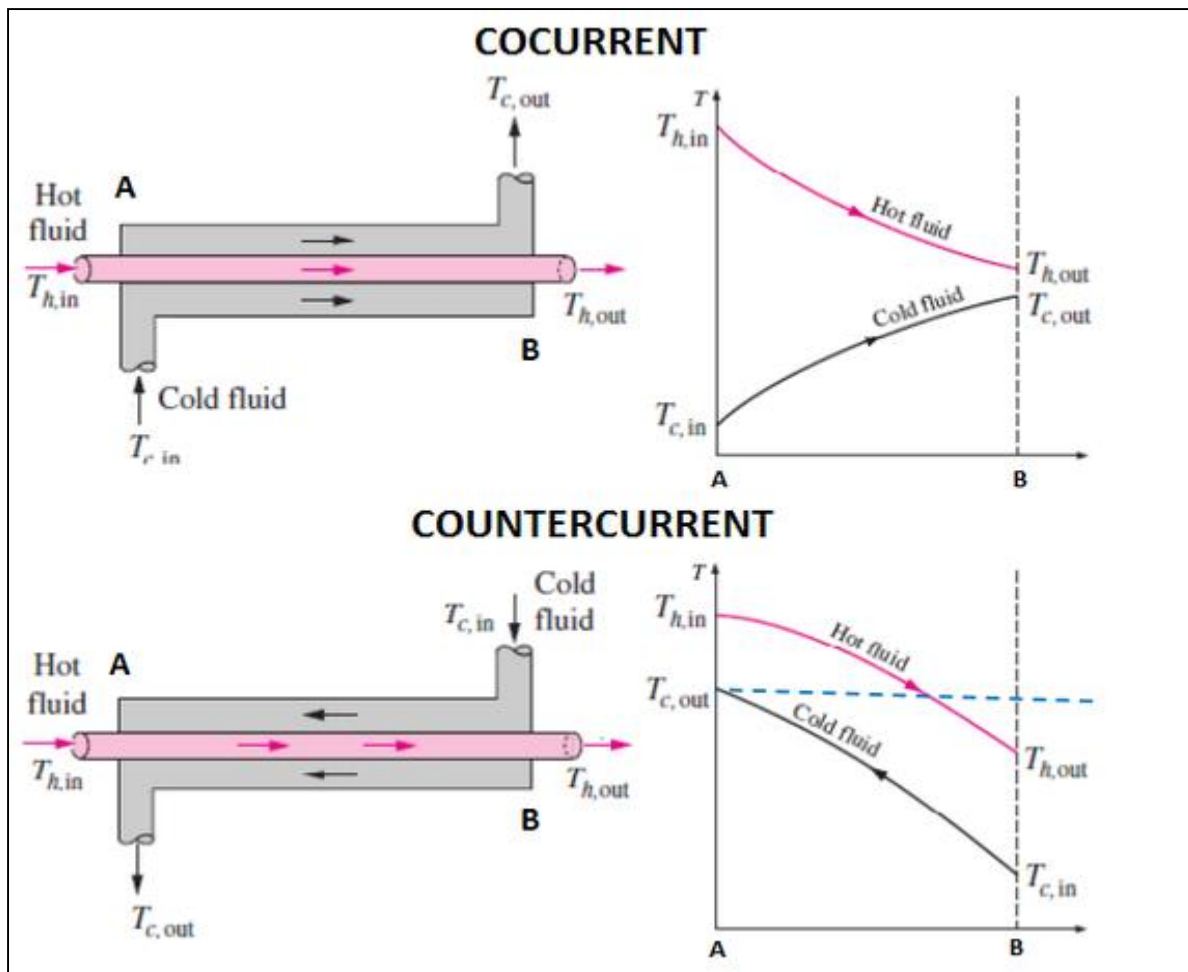


Figure 2. Counter flow verses parallel flow in DHE

PROCEDURE

The working principle of a DHE will be explained on the apparatus. Experiment will be conducted according to the runs seen in Table 2. Temperature measurements for each run will be written in Table 3.

Table 2. Runs of the experiment

Runs	Flow type	$T_{Hin} (^{\circ}C)$	Flow rate of hot fluid (L/min)	Flow rate of cold fluid (L/min)
1	parallel flow	60	2	1
2	parallel flow	60	3	1
3	parallel flow	60	2	2
4	parallel flow	70	2	1

Runs	Flow type	T _{Hin} (°C)	Flow rate of hot fluid (L/min)	Flow rate of cold fluid (L/min)
5	counter flow	60	2	1
6	counter flow	60	3	1
7	counter flow	60	2	2
8	counter flow	70	2	1

RESULTS, CALCULATIONS and REPORTING

1. Do all calculations by using the data in Table 3 and formulas written below. Then, fill the Table 4.

Table 3. Data of the measurements

Runs	T _{Hin} (°C)	T _{Hmid} (°C)	T _{Hout} (°C)	T _{Cin} (°C)	T _{Cmid} (°C)	T _{Cout} (°C)
1						
2						
3						
4						
Runs	T _{Hin} (°C)	T _{Hmid} (°C)	T _{Hout} (°C)	T _{Cin} (°C)	T _{Cmid} (°C)	T _{Cout} (°C)
5						
6						
7						
8						

$$\text{Heat power emitted} = Q_H \cdot \rho_H \cdot c_{pH} \cdot (T_{Hin} - T_{Hout})$$

$$\text{Heat power absorbed} = Q_C \cdot \rho_C \cdot c_{pC} \cdot (T_{Cin} - T_{Cout})$$

$$\text{Heat power lost} = (\text{Heat power emitted} - \text{Heat power absorbed})$$

$$\text{Efficiency} = (\text{Heat power absorbed} / \text{Heat power emitted}) \cdot 100$$

$$\Delta t_m = (\Delta t_1 - \Delta t_2) / \log (\Delta t_1 / \Delta t_2)$$

$$U = \text{Heat power absorbed} / (\text{Heat transmission area} \cdot \Delta t_m)$$

Table 4. Results of the calculations

Runs	Power emitted (W)	Power absorbed (W)	Power lost (W)	Efficiency (%)	Δt_m (°C)	U (W/m ² °C)
1						
2						
3						
4						
Runs	Power emitted (W)	Power absorbed (W)	Power lost (W)	Efficiency (%)	Δt_m (°C)	U (W/m ² °C)
5						
6						
7						
8						

2. Write a detailed operating procedure that has:

- A. a sketch of the apparatus, with the valves labeled,
- B. a description of which valves to open and close to set countercurrent flow, and which valves to adjust to change flow rates in counter flow,
- C. a description of valves to open and close to set parallel flow, and which valves to adjust to flow rates in parallel flow.

3. Sketch the expected temperature profiles for counter and parallel flow types.

Note: Read the related pages for theory and calculations in Geankoplis book (Chapter 4.9).