Heat Exchangers

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목차

생물들의 열교환 방법

<거대한 귀를 가진 코끼리>

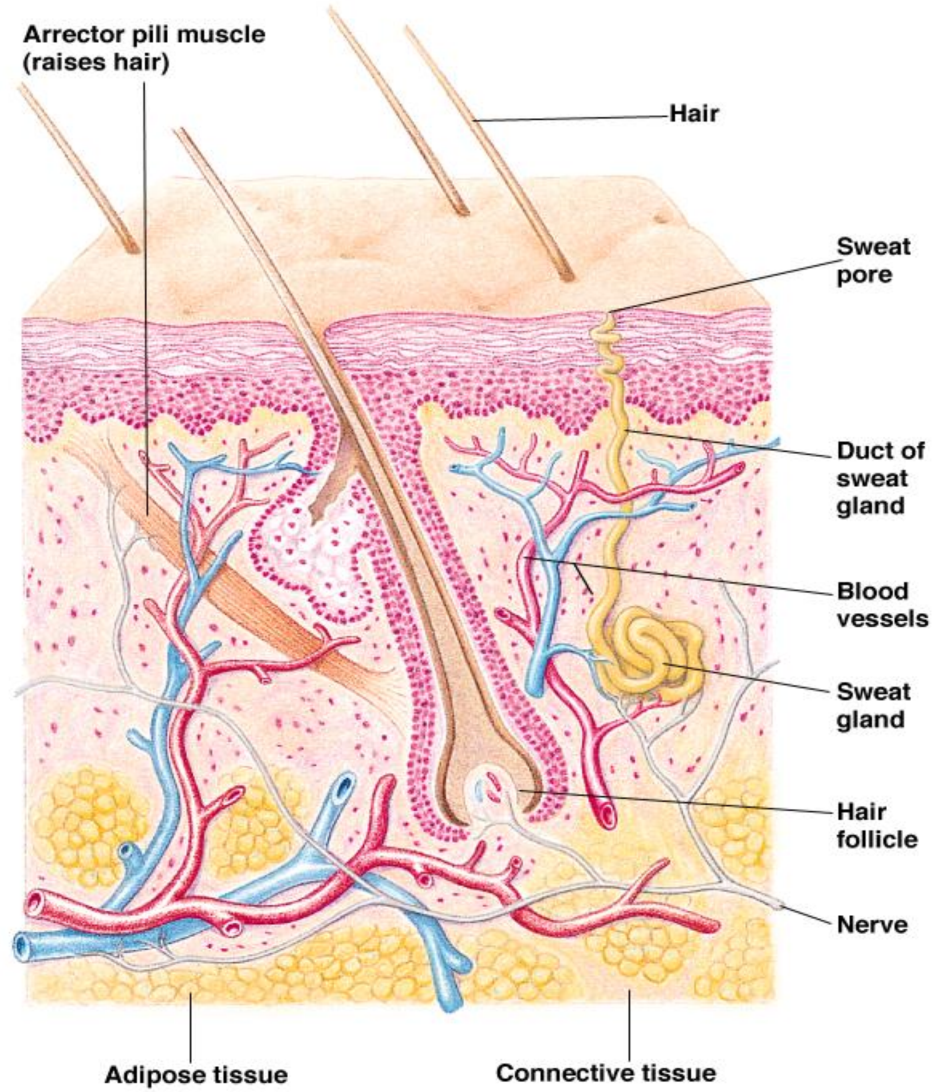
<스테고사우루스>

<디메트로돈>

<범고래>

생물들의 열교환 방법

< 온 도 변 화 의 보 호 막 인 나 무 껍 질 >

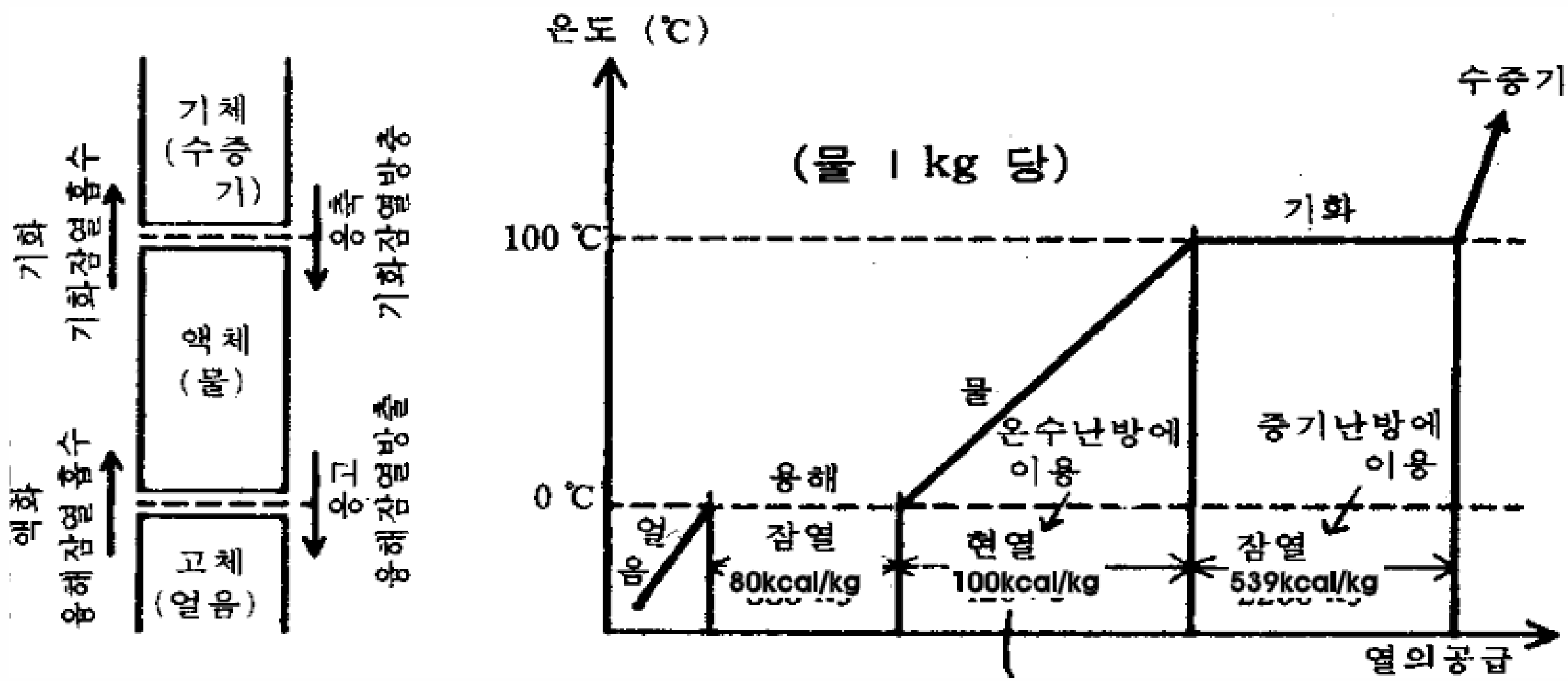


< 인 간 의 피 부 조 직 >

열의종류

- 현열(Sensible heat)
  - 온도계로 측정할 수 있는 열
  - 물질의 온도 변화시 상태(고체, 액체, 기체) 변화없이 흡수되거나 방출된 열

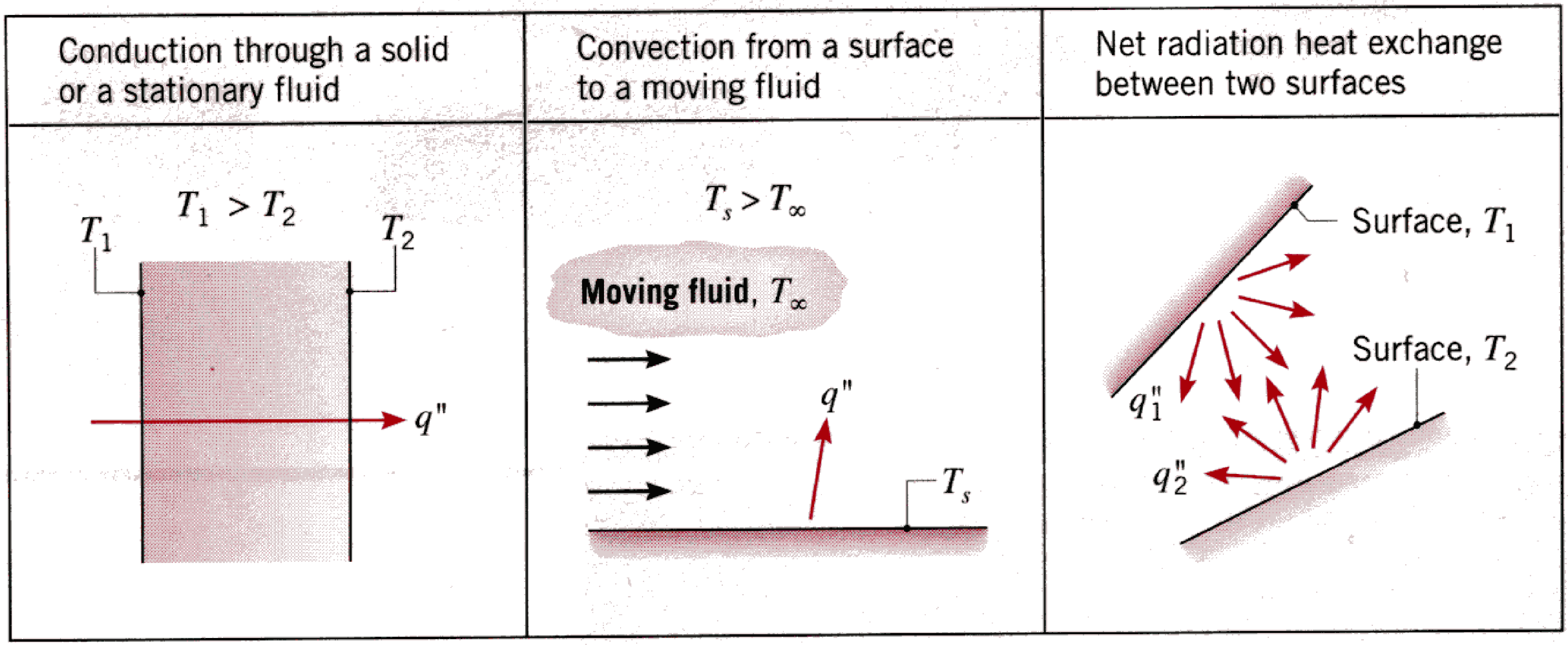
- 잠열(Latent heat)
  - 온도계로 측정할 수 없는 열
  - 물질의 상태(고체, 액체, 기체) 변화시 온도 변화없이 흡수되거나 방출된 열
  - 건물에서 잠열의 활용 : 증발냉각
  - 땀(물)이증발하면 많은열(증발잠열)을 피부로부터 빼앗아 피부가냉각됨



물의 상태 변화

열이동 메커니즘

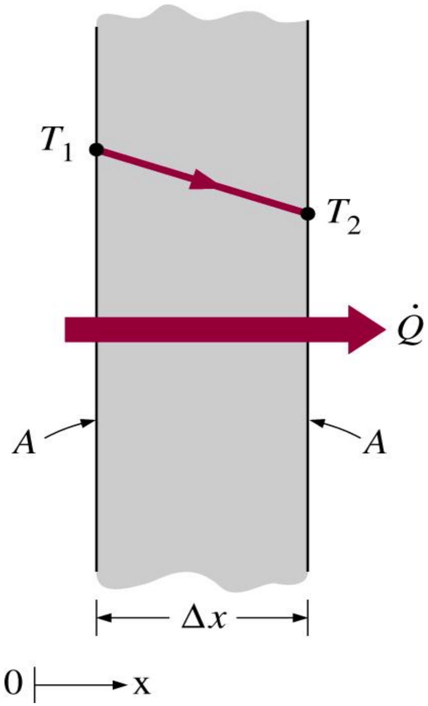
열은 전도, 대류, 복사의 세가지 방법으로 전달된다. 모든 열전달 형태는 온도차가 있어야 가능하며 높은 온도에서 낮은 온도의 물체로 전달된다.

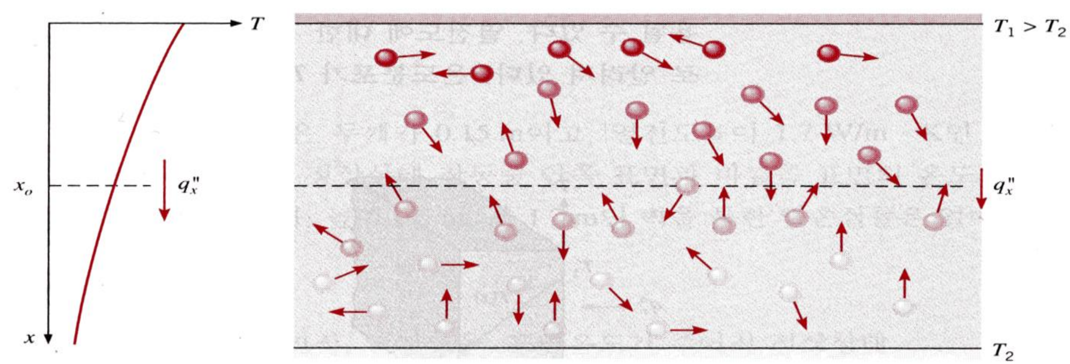


전도(Conduction)

- 입자간의 상호작용에 의해 보다 에너지가 많은 입자에서 적은 입자로 에너지가 전달되는 현상
- 고체, 액체, 기체에서 모두 발생
- 기체와 액체에서의 전도는 분자들이 임의적으로 움직이는 과정에서 이들의 충돌과 확산에 의함
- 고체의 경우 격자 내부 분자의 진동과 자유전자의 에너지 전달에 의함

  ex.) 따뜻한 방안에 있는 깡통 속의 차가운 음료-전도에 의해 음료수가 실내온도로 데워짐
- 물체의 기하학적 형상, 두께, 재질, 온도차 등에 영향

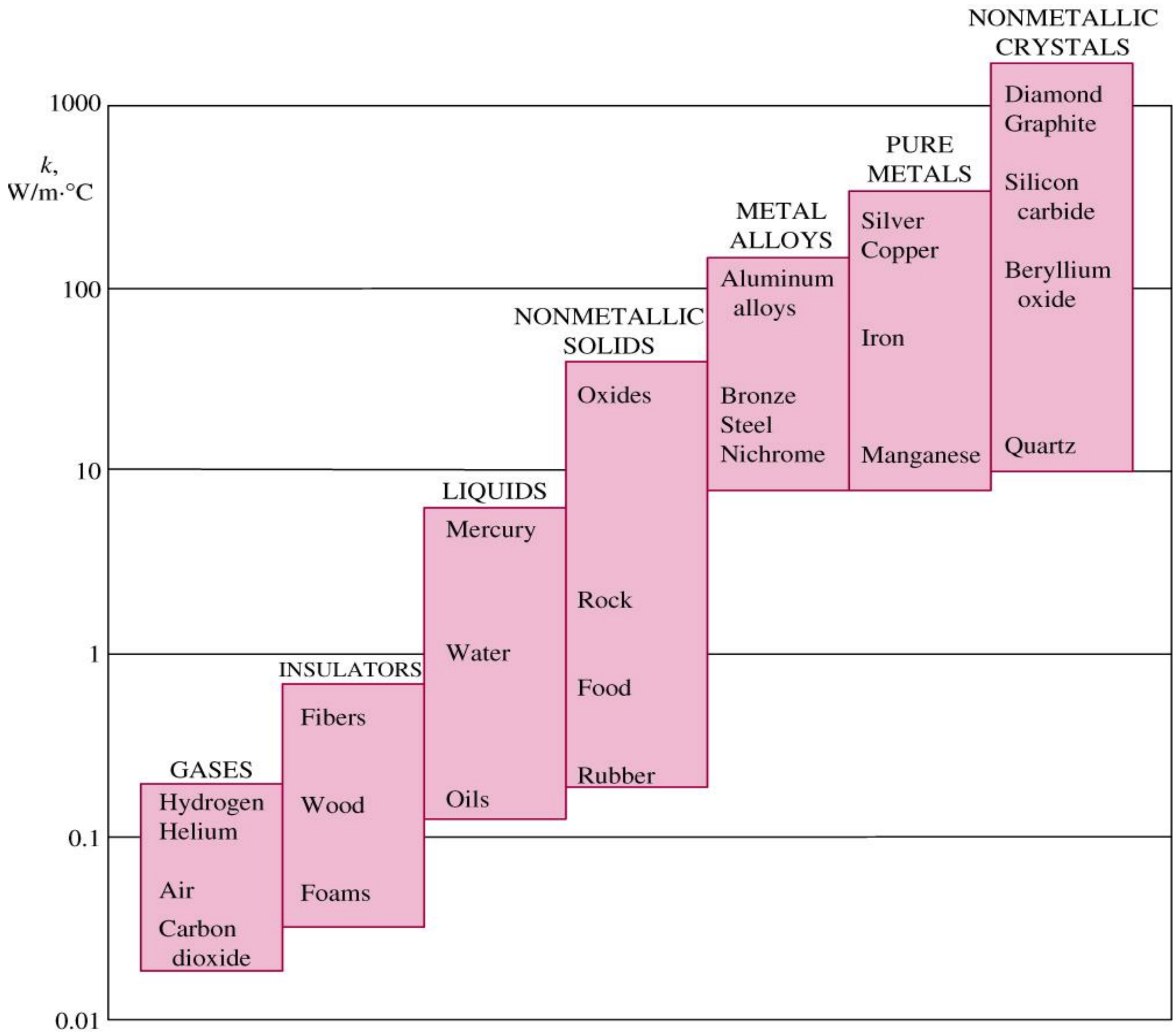




$$\text{전도열전달율} \propto \frac{(\text{면적})(\text{온도차})}{\text{두께}}$$

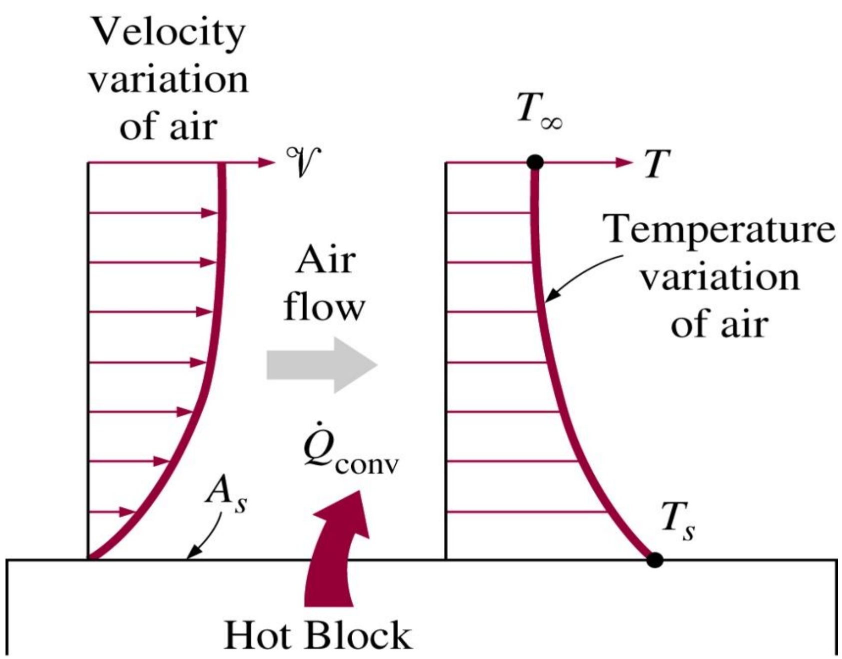
$$Q_{cond} = -kA\frac{dT}{dx} \qquad (\mathrm{W}) \quad \leftarrow \quad \text{Fourier의 열전도법칙}$$

실온에서 다양한 물질의 열전도도 범위



대류(Convection)

- 유체 입자 자체의 움직임에 의한 열전달
- 유체와 고체의 면에서 유체의 운동에 의해 열이 이동 하는 것
- 대류의 종류: 자연대류(**natural convection**), 강제대류(**forced convection**)



$$\dot{Q}_{convection} = hA(T_s - T_\infty)$$

h=대류열전달계수, **W/㎡℃,**

A=대류열전달이 발생하는 면적,

T_s=물체 표면온도,

T_∞=표면에서 충분히 멀리 떨어진 곳에서의 유체온도

대류(Convection) 열전달의 종류

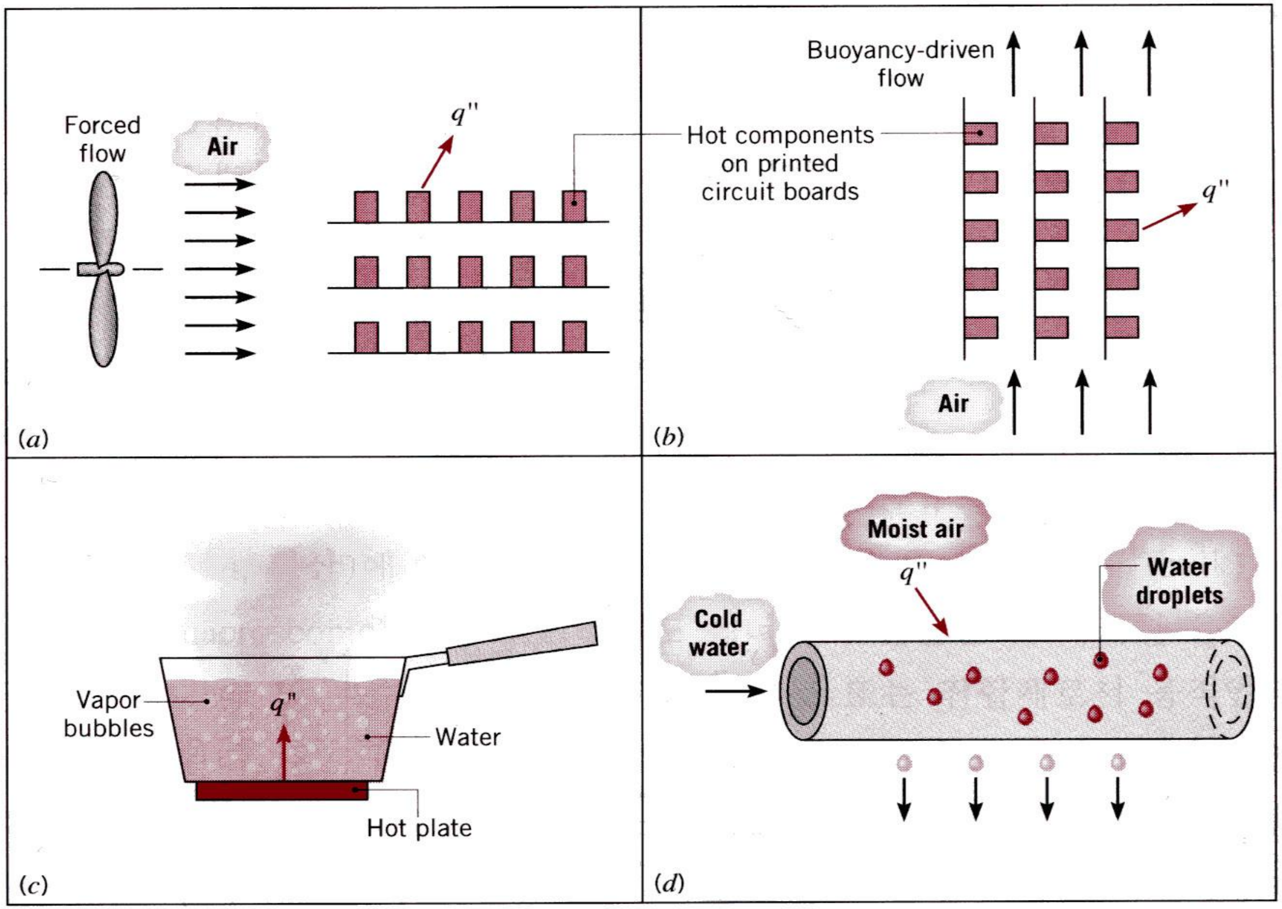
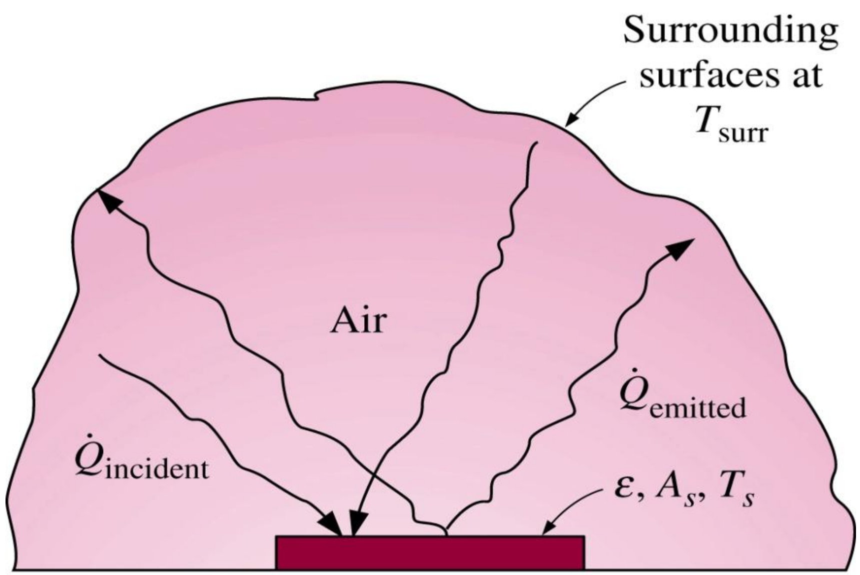


그림 1.5 대류 열전달 과정. (*a*) 강제대류, (*b*) 자연대류, (*c*) 비등, (*d*) 응축

복사(Radiation)

- 유한한 온도(절대온도 **0 K** 이상)의 모든 표면이 전자기파의 방식으로 에너지를 방출함에 의해서 발생하는 열전달(절대온도4승에 비례하는전자파 방사)
- 전도, 대류와 달리 중간에 열전달 매질이 없는 경우(진공상태 등)에도 서로 다른 온도의 표면간에는복사에 의한 열전달 발생(예, 태양으로부터 지구로의 복사 열전달)
- 유한한 온도의 모든 표면은 복사에너지를 지속적으로 방출, 흡수함
- 온도가 높을수록 복사에너지의 흡수량보다 방출량이 많아 열을 잃게됨



$$\dot{Q}_{rad} = \varepsilon\sigma A_s(T_s^4 - T_{surr}^4)$$

Stefan-Boltzmann 법칙

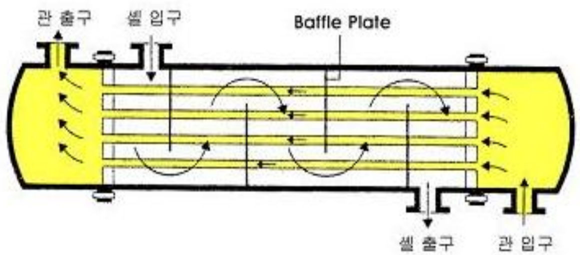
- 절대온도 T_s인 표면에서 방출하는 최대 복사율

$$Q_{emit,\ max} = \sigma A T_s^4 \qquad \text{(W)}$$

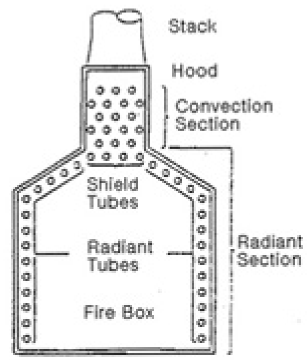
$\sigma = 5.67\times10^{-8}\, W/m^2K^4$, Stefan-Boltzmann 상수

열교환기란?

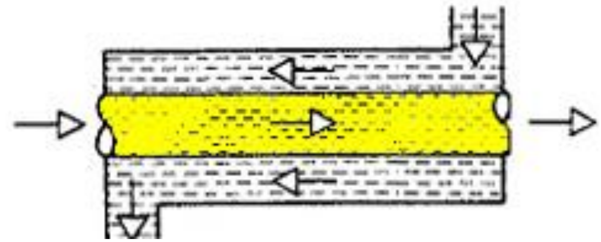
냉동 및 공기조화에 널리 사용되며, 한 유체의 흐름에서 고체표면을 통과하여 또 다른 유체흐름으로 에너지를 전달하는 장치



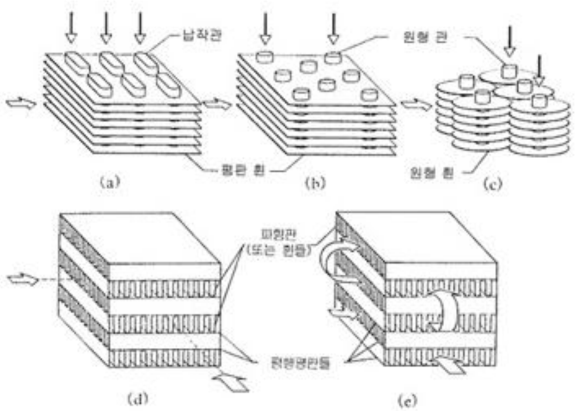
원통다관식(Shell &Tube)



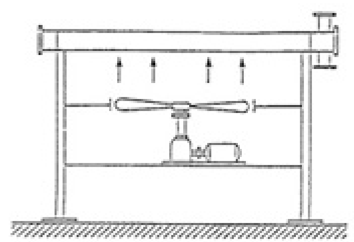
가열로(Fired Heater)



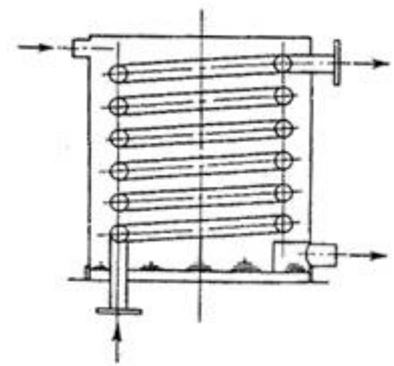
이중관식(Double Pipe Type)



평판형(Plate Type)



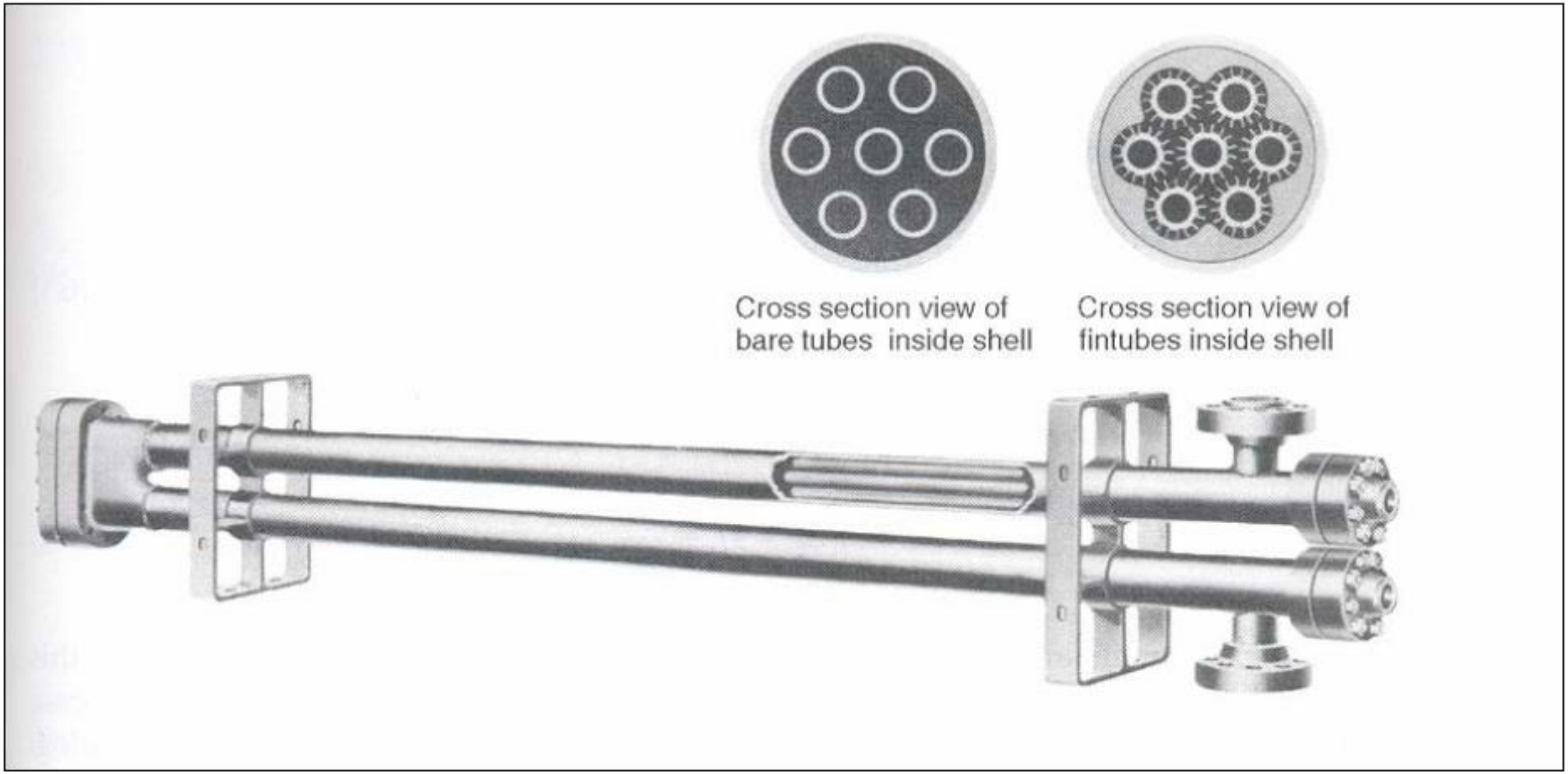
공냉식 냉각기(Air Cooler)



코일식(Coil Type)

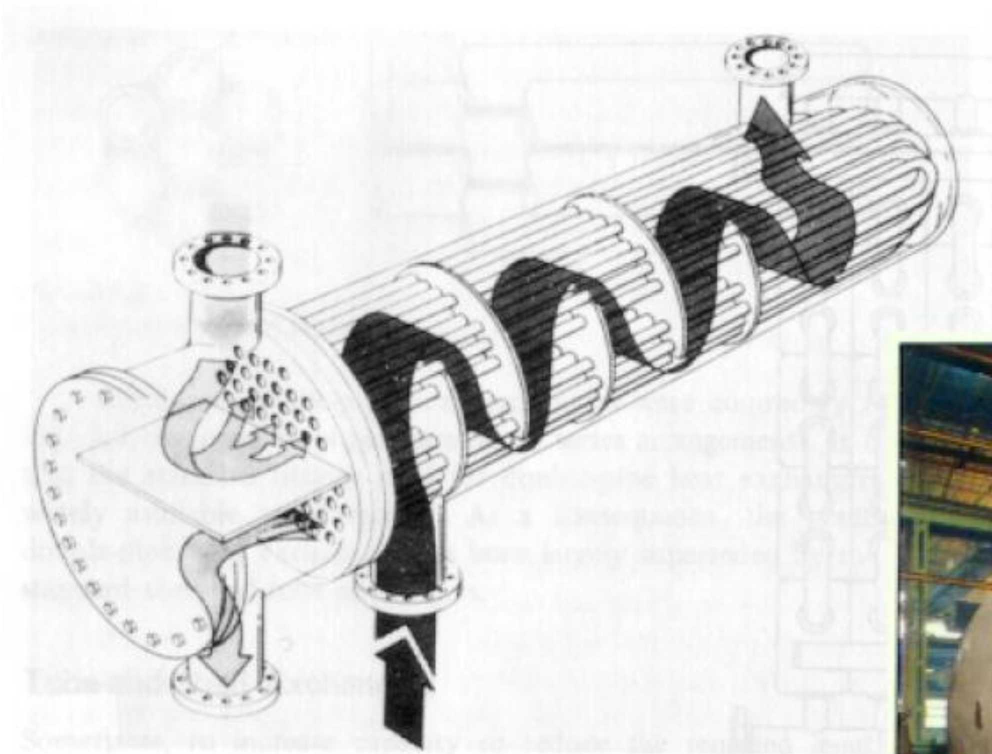
열교환기의 종류

Tubular HEX/Double Pipe



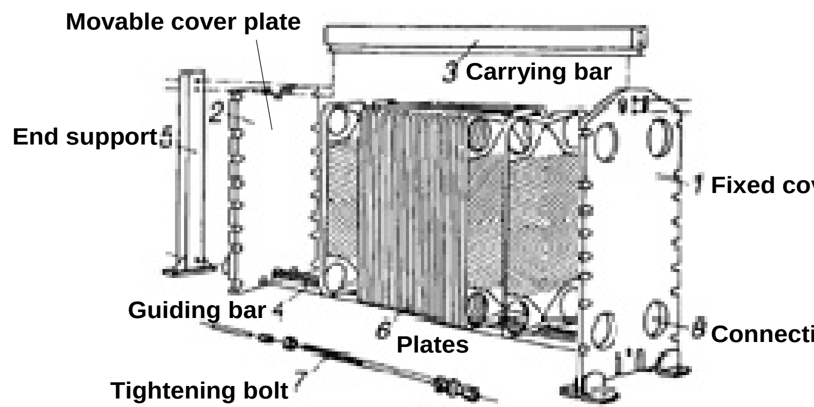
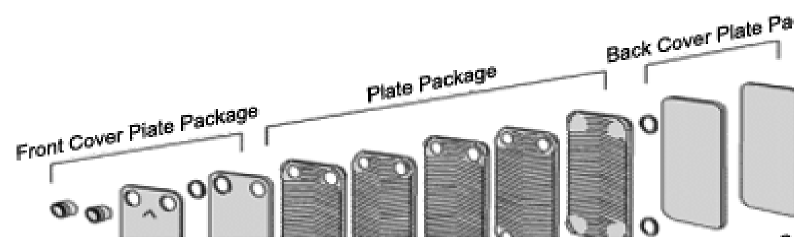
열교환기의 종류

Tubular HEX/Shell and Tube



열교환기의 종류

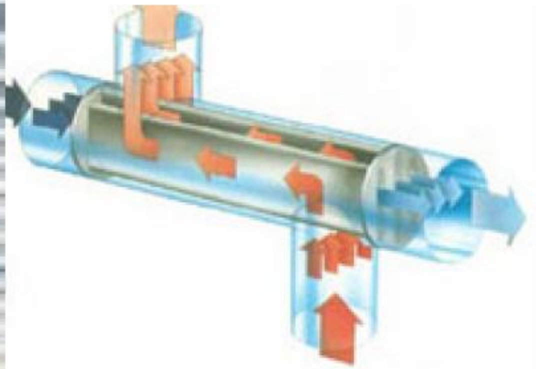
Plate HEX

PHE Type	Sample	Structure
Gasket		
Brazed		

열교환기의 종류

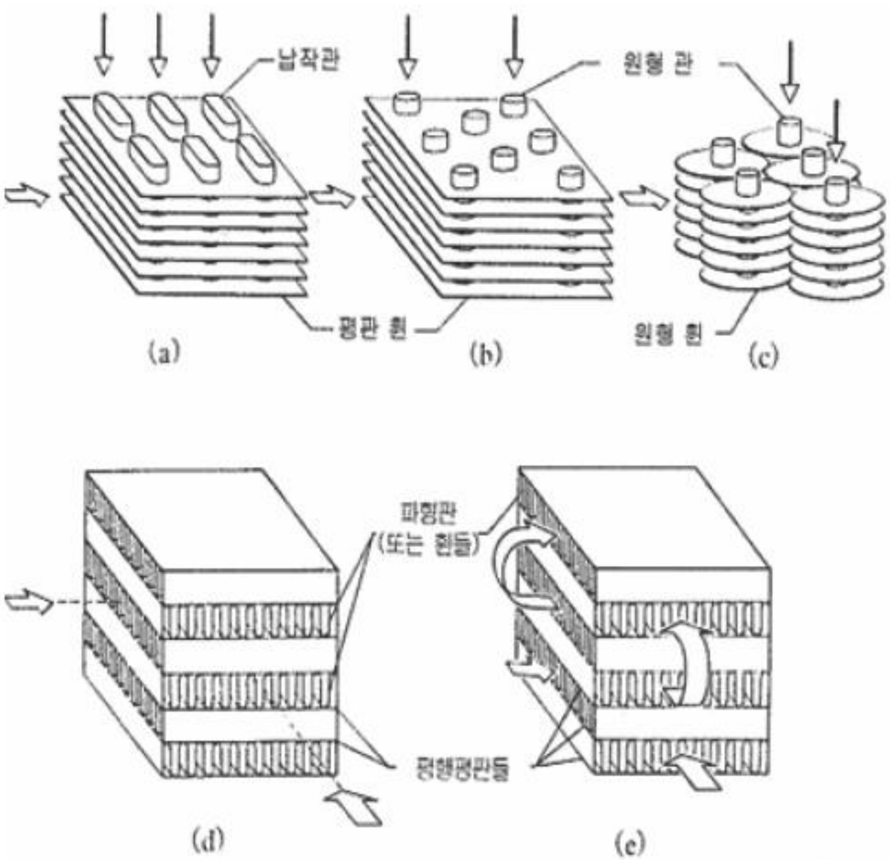
Plate HEX/Spiral

Plate HEX/Lamella



열교환기의 종류

Extended Surface HEX/Plate Fin



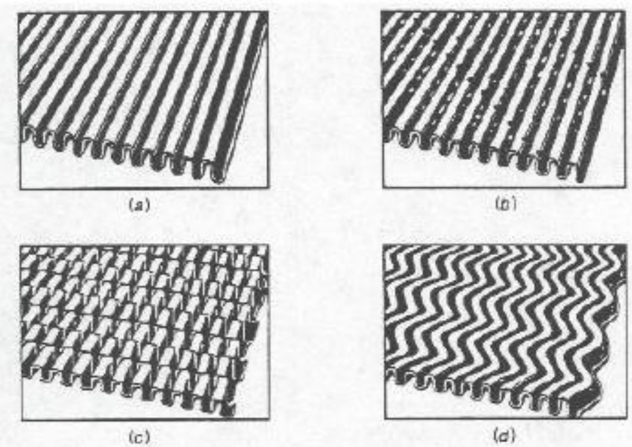
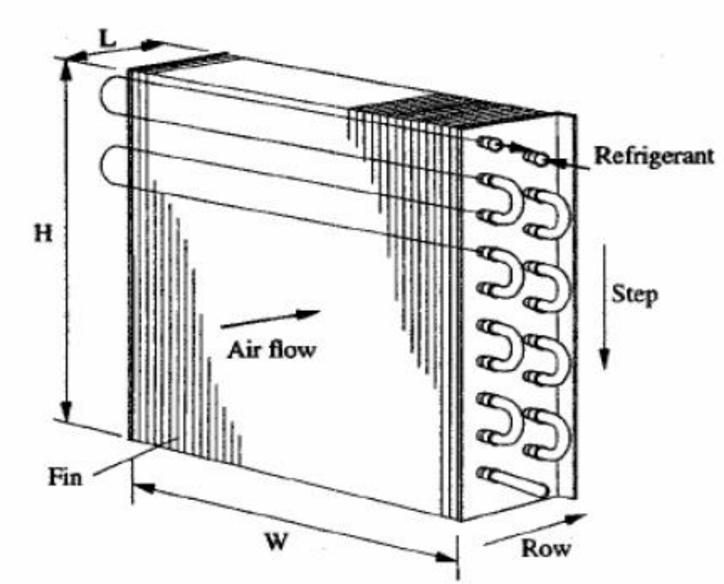
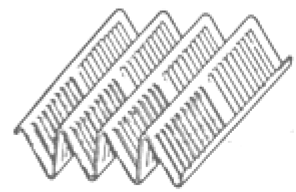


Figure 1.18 Fin types in plate-fin exchangers: (a) plain, (b) perforated, (c) serrated, (d) herringbone (*adapted from Ref. 4*)

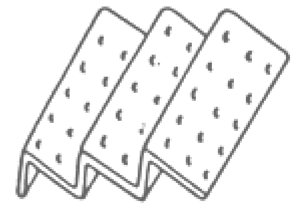
열교환기의 종류

Extended Surface HEX/Tube Fin

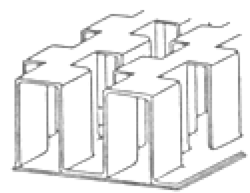




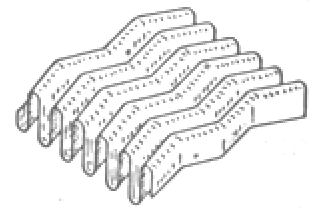
Louver



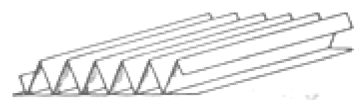
Perforate



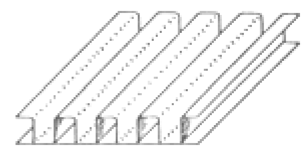
Offset strip fin



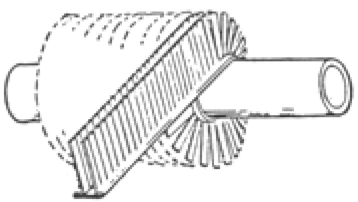
Wavy



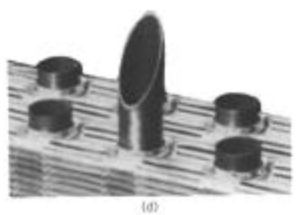
Triangular



Rectangular



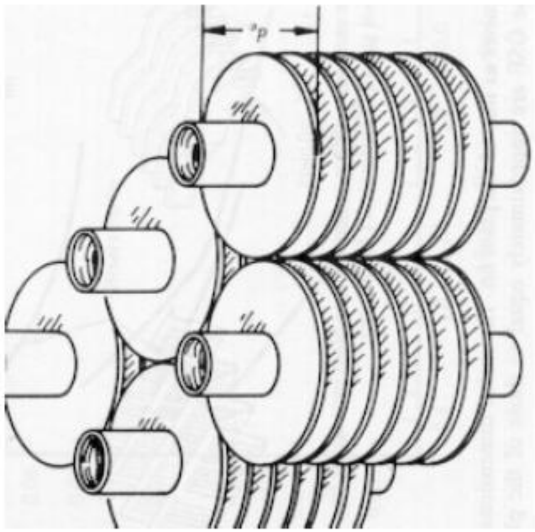
Spine fin

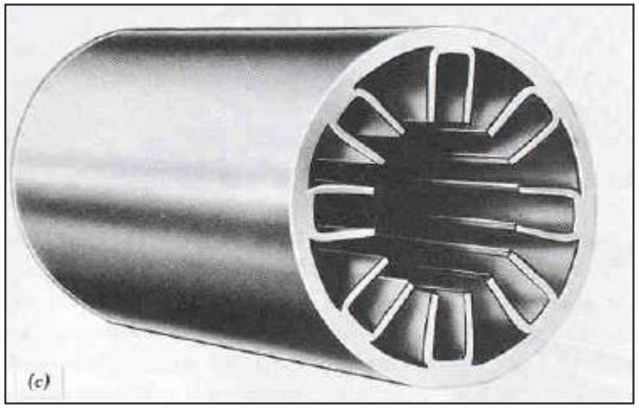


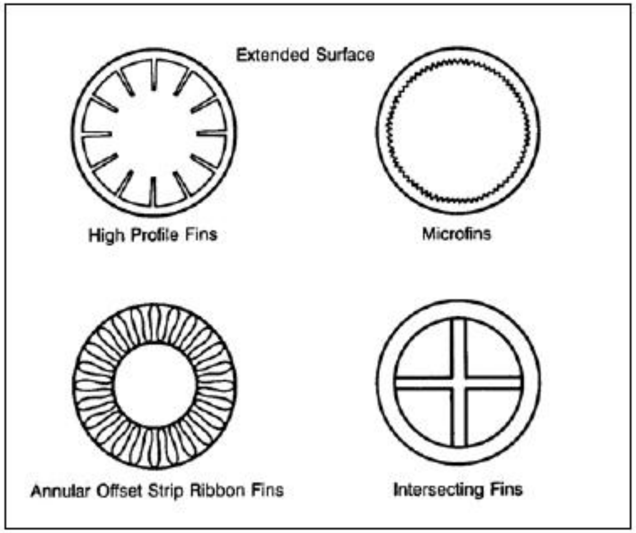
Convex louver

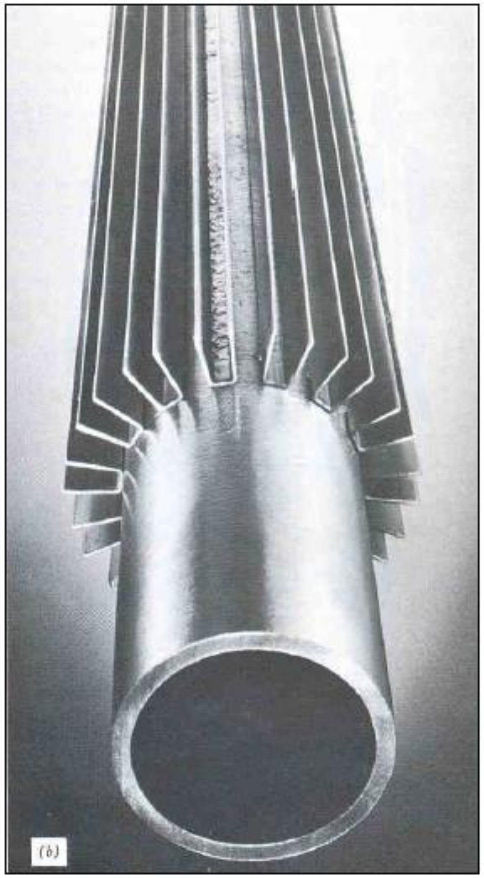
열교환기의 종류

Extended Surface HEX/Tube Fin

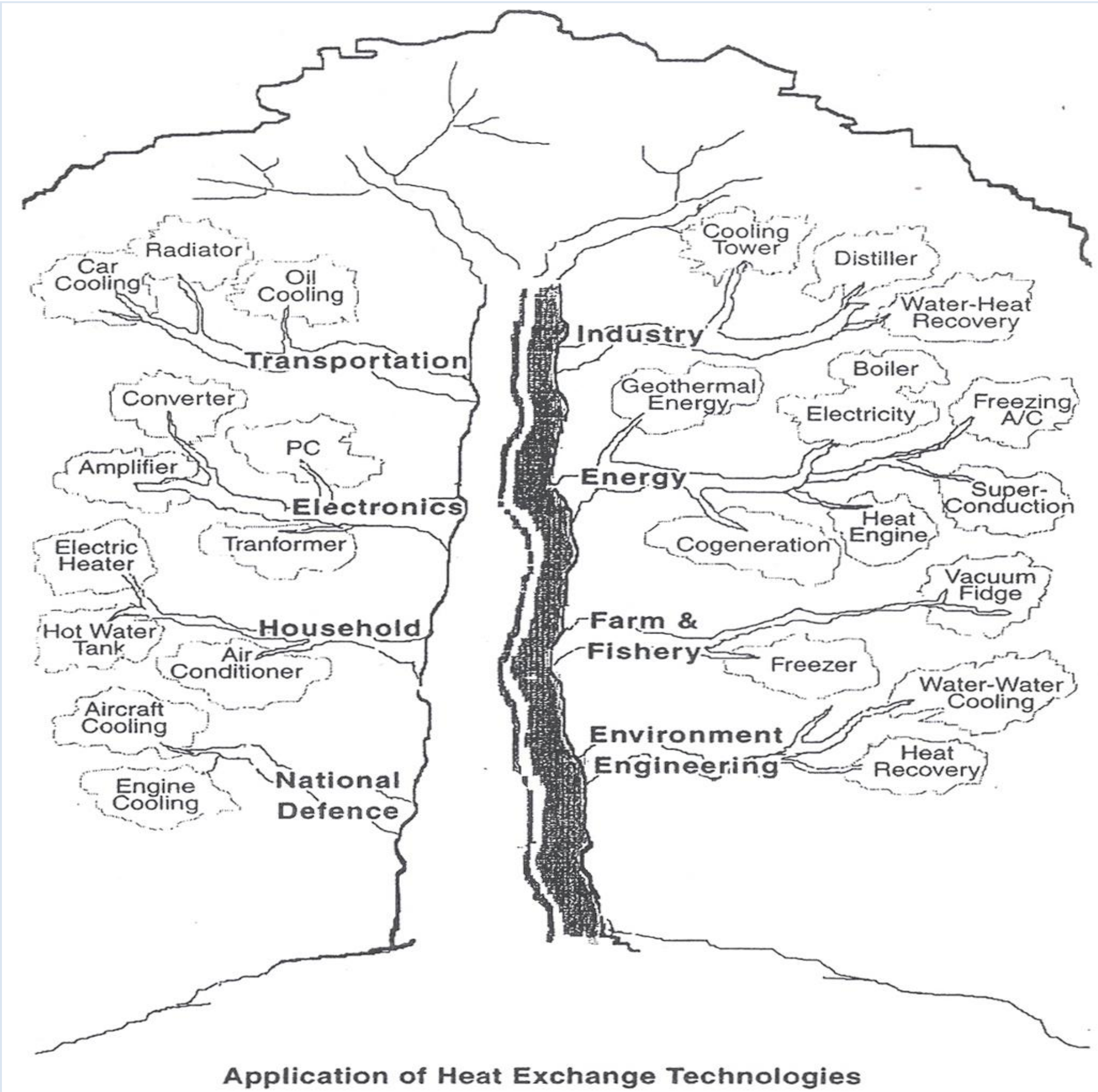








열교환기의 용도


Radiator
Car Cooling
Oil Cooling
Transportation
Converter
PC
Amplifier
Electronics
Electric Heater
Tranformer
Hot Water Tank
Household
Air Conditioner
Aircraft Cooling
Engine Cooling
National Defence
Cooling Tower
Distiller
Water-Heat Recovery
Industry
Boiler
Geothermal Energy
Electricity
Freezing A/C
Energy
Super-Conduction
Heat Engine
Cogeneration
Vacuum Fidge
Farm & Fishery
Freezer
Water-Water Cooling
Environment Engineering
Heat Recovery
Application of Heat Exchange Technologies


for Refrigerator Car

열교환기의 설계기준

1. 요구되는 열전달량

2. 가격

3. 크기(또는 무게) : 설치상의 문제나 공간상의 제약을 고려

4. 압력강하특성 : Pump 동력, 송풍기 동력

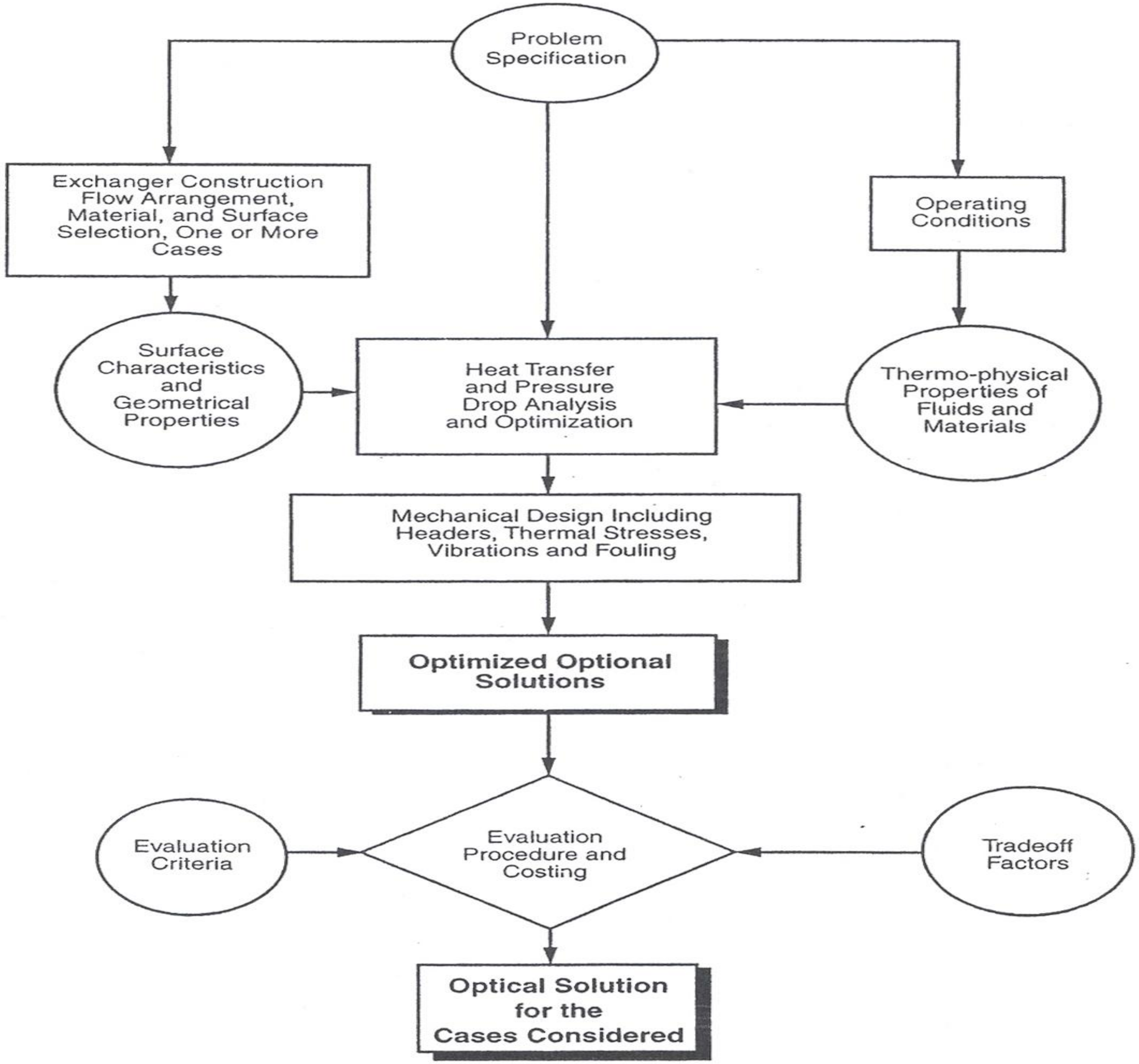
5. 기계적 응력 : 운전시, 시동시 , 운전 정지시, 그리고 사고로 인한
작업 중지시 발생하는 기계적 응력을 견디어야함

6. 정비가능 : 설비의 다른 부분을 건드리지 않고서도 정비가 가능 하도록 설계

선정(selection) : 열교환기에서의 유동 형태와 기하학적인 형상을 선택하는 과정
예) 핀-관 열교환기에서 핀의 종류
핀-관의 배열 등

견적(rating) : 열교환기가 선정된 후 주어진 두 유체사이에 열전달과
압력강하를 결정하는 계산 과정

열교환기의 설계


Problem Specification
Exchanger Construction Flow Arrangement, Material, and Surface Selection, One or More Cases
Operating Conditions
Surface Characteristics and Geometrical Properties
Heat Transfer and Pressure Drop Analysis and Optimization
Thermo-physical Properties of Fluids and Materials
Mechanical Design Including Headers, Thermal Stresses, Vibrations and Fouling
Optimized Optional Solutions
Evaluation Criteria
Evaluation Procedure and Costing
Tradeoff Factors
Optical Solution for the Cases Considered

열교환기의 유동 형태

A heat exchanger is classified according to the flow direction of the hot and cold fluid streams and the number of passes made by each fluid as it travels through the heat exchanger.

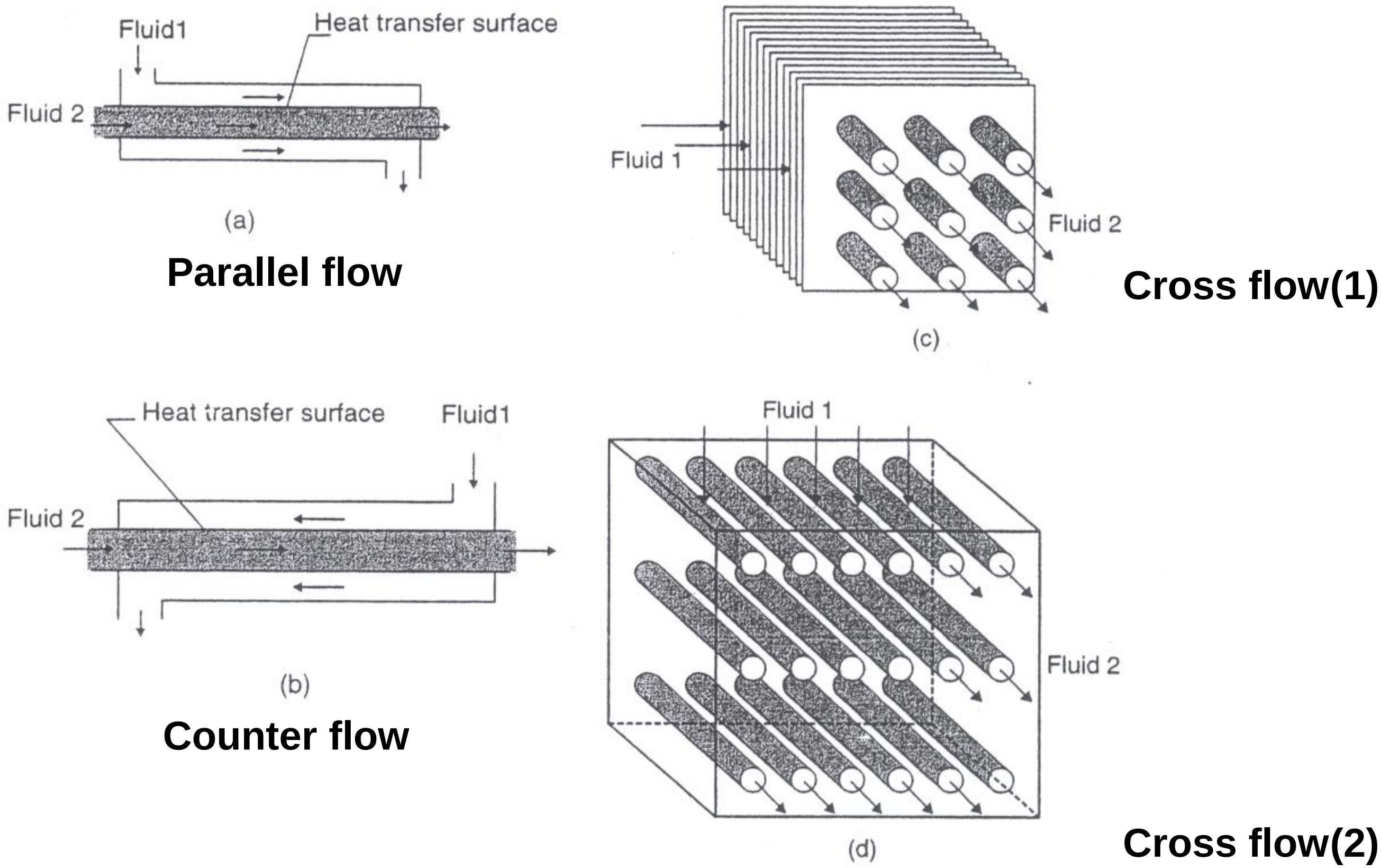
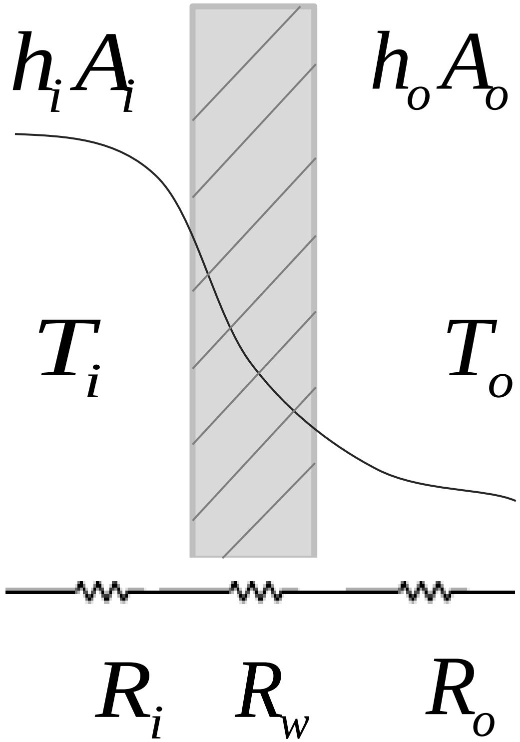


FIGURE 2.1
Heat exchanger classification according to flow arrangements.

총괄열전달계수

총괄열전달계수는 두 유체들 사이의 열전달에 대한 전체 열저항으로 정의



$$Q = UA(T_i - T_o)$$

$$R = \frac{1}{UA} = \frac{1}{h_i A_i} + \frac{t}{kA_m} + \frac{1}{h_o A_o}$$

※ 외측에 핀이 달린 경우

$$\frac{1}{UA} = \frac{1}{h_i A_i} + \frac{t}{kA_m} + \frac{1}{\eta_0 h_0 A_0}$$

$$\eta_0 = 1 - \frac{A_f}{A_0}(1-\eta)$$

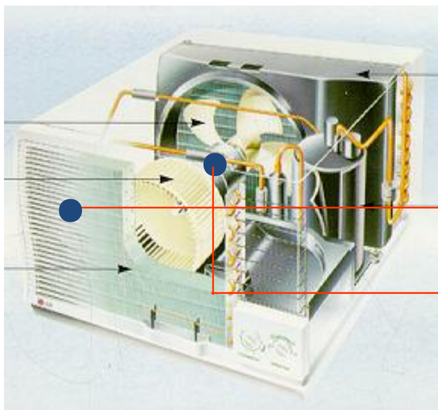
열교환기 해석방법 : LMTD & ε −NTU

열교환기 해석하는 방법은 **LMTD(Log-mean temperature difference,로그평균온도차)와 ε-NTU(Effectivness-number of transfer units, 유용도-NTU법)방법이 있음.**
열교환기 해석에서 유체의 입구온도와 출구온도가 주어지면 **LMTD** 방법, 단지 유체의 입구온도만 주어지면 **ε-NTU**방법을 사용하는 것이 바람직함.

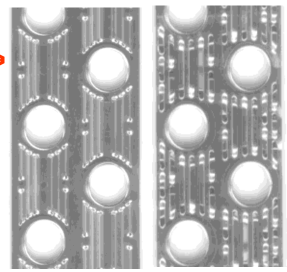
LMTD	ε−NTU
$Q = UAF\Delta T_{lm,cf}$	$Q = \varepsilon C_{\min}(T_{h1} - T_{c1})$
$LMTD = \Delta T_{lm,cf} = \dfrac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}$	$\varepsilon = \dfrac{C_h(T_{h1} - T_{h2})}{C_{\min}(T_{h1} - T_{c1})} = \dfrac{C_c(T_{c2} - T_{c1})}{C_{\min}(T_{h1} - T_{c1})}$
$\Delta T_1 = T_{h1} - T_{c2}, \Delta T_2 = T_{h2} - T_{c1}$ $P = \dfrac{T_{c2} - T_{c1}}{T_{h1} - T_{c1}}, R = \dfrac{T_{h1} - T_{h2}}{T_{c2} - T_{c1}}$	$C^* = \dfrac{C_{\min}}{C_{\max}} = \dfrac{(\dot{m}c_p)_{\min}}{(\dot{m}c_p)_{\max}}$ $\mathrm{NTU} = \dfrac{UA}{C_{\min}} = \dfrac{1}{C_{\min}} \int_A U dA$
F = ϕ (P, R, flow arrangement)	ε = ϕ (NTU, C*, flow arrangement)

열교환기의 성능향상 기술

High Efficiency



High Efficiency Fin



Grooved Tube

$$Q = UA\Delta T_m$$

$$Q = \frac{UA}{L} L\Delta T_m$$

L/UA is the overall thermal resistance, per unit tube length

$$\frac{L}{UA} = R = \frac{L}{\eta_1 h_1 A_1} + \frac{Lt_w}{k_w A_m} + \frac{L}{\eta_2 h_2 A_2}$$

The reduced L/UA may be used for one of three objectives

- Size reduction
- Increased UA
- Reduced pumping power for fixed heat duty

열교환기의 성능향상 기술

Bergles et al. have identified 13 enhancement techniques.

Table 1.1 Summary of References on Enhancement Techniques as of November 1983

	Single-Phase Natural Convection	Single-Phase Forced Convection	Pool Boiling	Forced-Convection Boiling	Condensation	Mass Transfer
Passive Techniques (No External Power Required)						
Treated surfaces	—	—	149	17	53	+
Rough surfaces	7	418	62	65	65	29
Extended surface	23	416	75	53	175	33
Displaced enhancement devices	+	59	4	17	6	15
Swirl flow devices	+	140	—	83	17	10
Coiled tubes	+	142	—	50	6	9
Surface tension devices	30	—	12	1	—	+
Additives for liquids	3	22	61	37	—	6
Additives for gases	+	211	—	—	5	0
Active Techniques (External Power Required)						
Mechanical aids	16	60	30	7	23	18
Surface vibration	52	30	11	2	9	11
Fluid vibration	44	127	15	5	2	39
Electric or magnetic fields	50	53	37	10	22	22
Injection or suction	6	25	7	1	6	2
Jet impingement	—	17	2	1	—	2
Compound techniques	2	50	4	4	4	2

Note: — Not applicable; + no citations located.

Source: Bergles and Webb (1985).

열교환기의 성능향상 기술

Coated surfaces

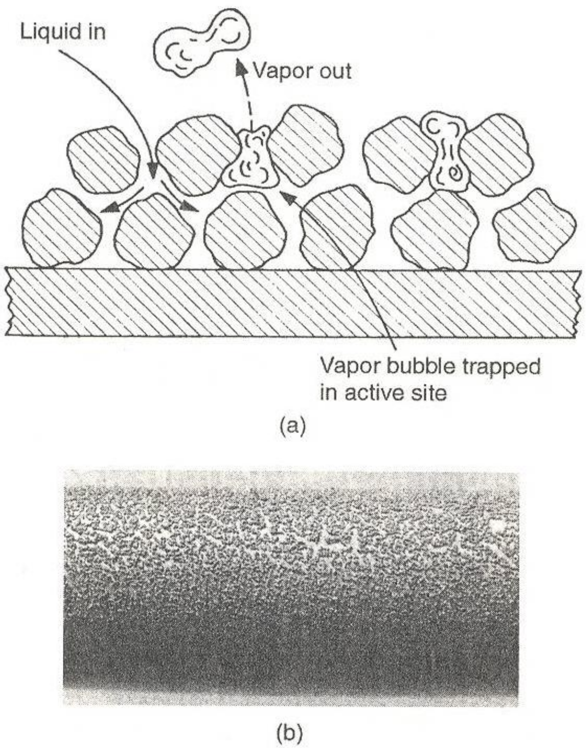


Figure 1.1 (a) Illustration of cross section of porous boiling surface, (Courtesy of UOP Corporation, Tonawanda, NY.) (b) Attached particles used for film condensation.

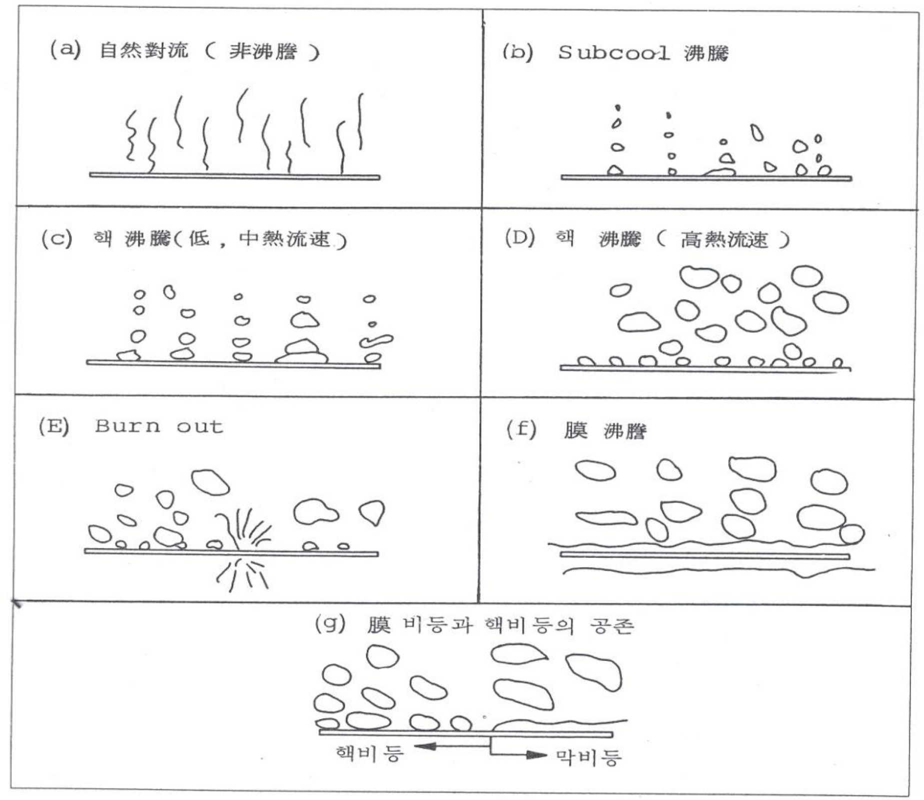
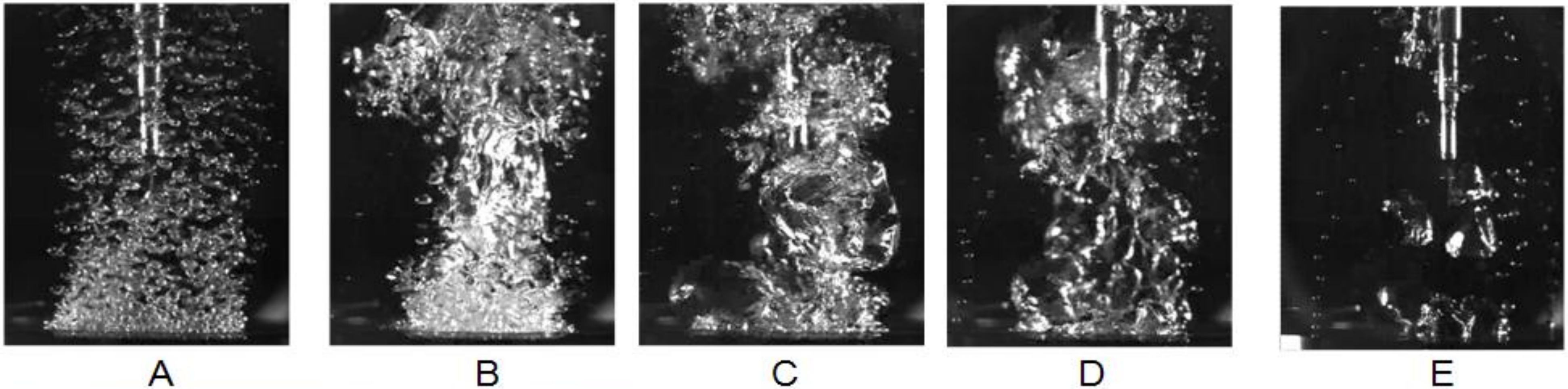
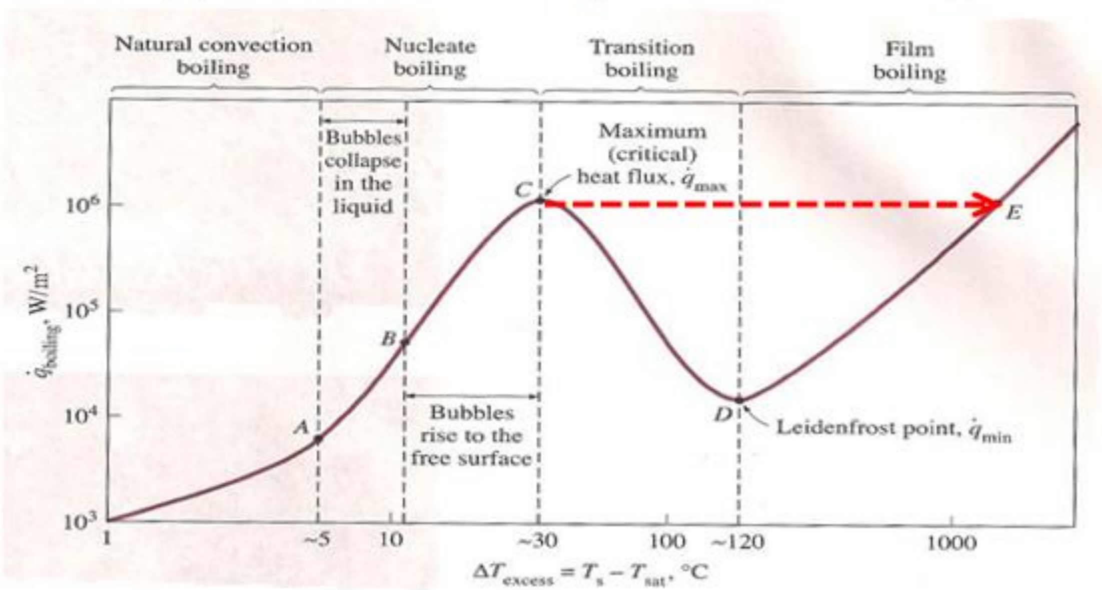


그림 (2.6 - 1) 沸騰의 種類

열교환기의 성능향상 기술

Pool boiling phenomenon





A : Low heat flux nucleate pool boiling

B: Developed nucleate pool boiling

C: Critical nucleate boiling

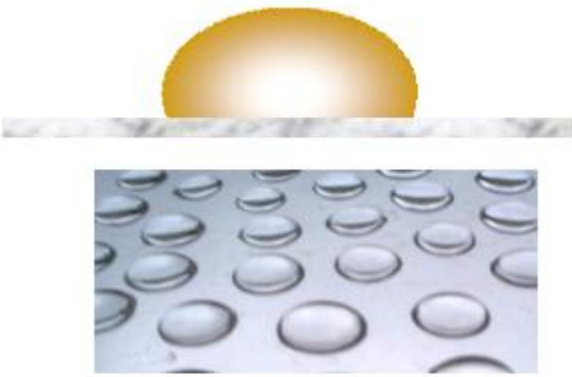
D: Transition boiling

E: Film boiling

열교환기의 성능향상 기술

Coated surfaces

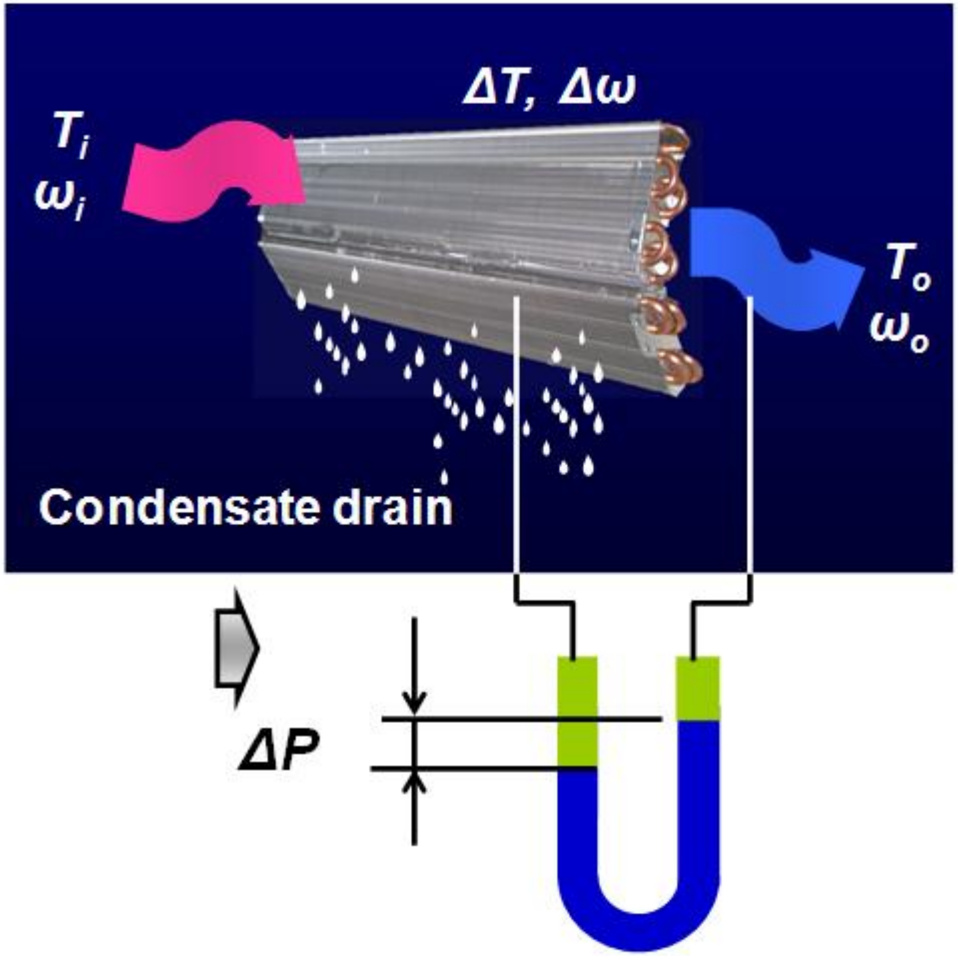
Hydrophobic surface



Dropwise condensation

Hydrophilic surface

Filmwise condensation



열교환기의 성능향상 기술

Extended surfaces

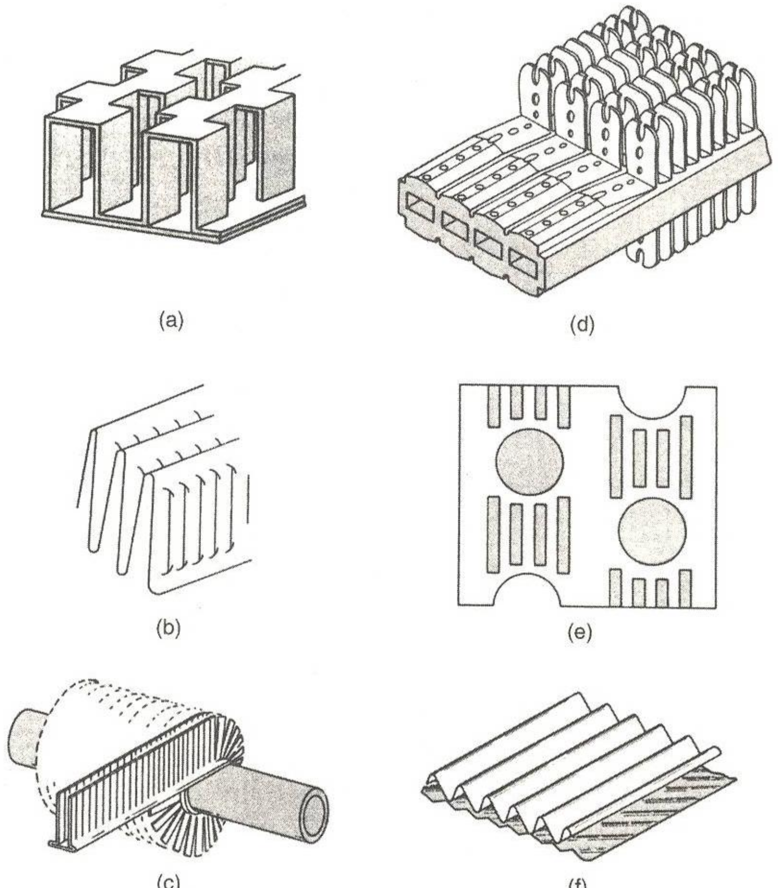


Figure 1.3 Enhanced surfaces for gases. (a) Offset strip fins used in plate-fin heat exchanger, (b) louvered fins used in automotive heat exchangers, (c) segmented fins for circular tubes, (d) integral aluminum strip-finned tube, (e) louvered tube-and-plate fin, (f) corrugated plates used in rotary regenerators. (From Webb and Bergles [1984].)

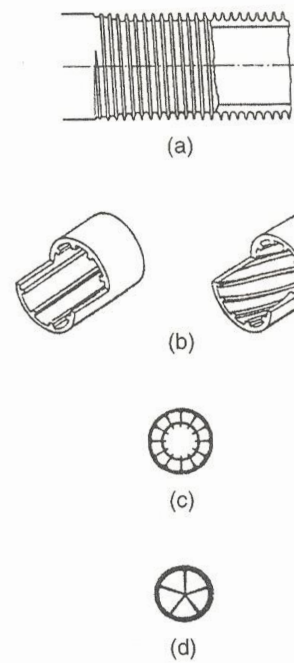


Figure 1.4 (a) Integral fins on outer tube surface, (b) internally finned tubes (axial and helical fins), (c) cross sections of multiply internally finned tubes, (d) tube with aluminum star insert.

열교환기의 성능향상 기술

Rough surfaces

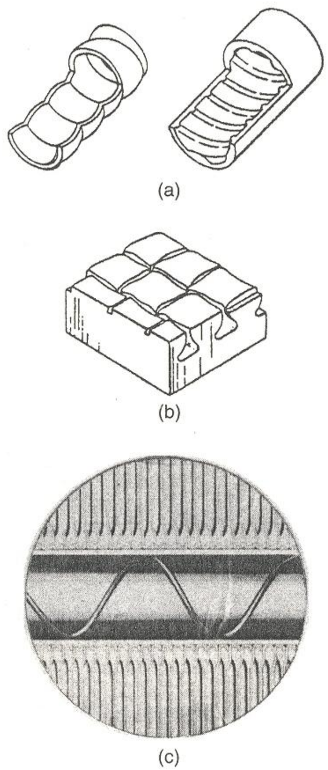


Figure 1.2 (a) Tube-side roughness for single-phase or two-phase flow, (b) "rough" surface for nucleate boiling, (c) wire-coil insert.

Displaced insert

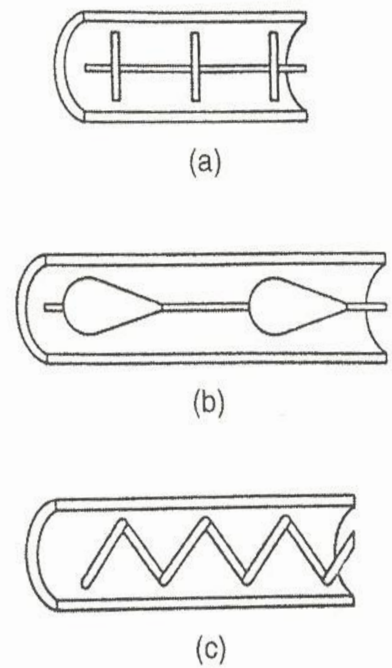


Figure 1.5 (a) Spaced disk devices, (b) spaced streamline-shaped insert devices, (c) displaced wire-coil insert. (From Webb [1987].)

열교환기의 성능향상 기술

Swirl flow

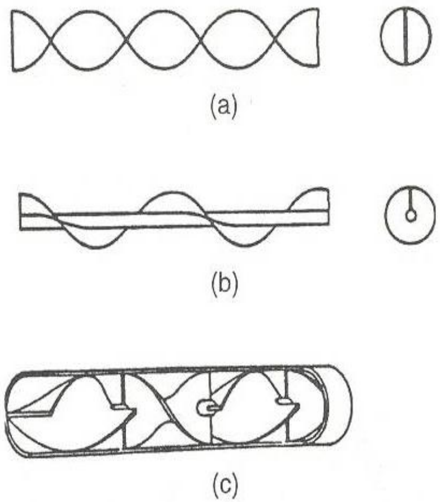


Figure 1.6 Three types of swirl flow inserts: (a) twisted-tape insert, (b) helical vane insert, (c) static mixer.

Coiled flow

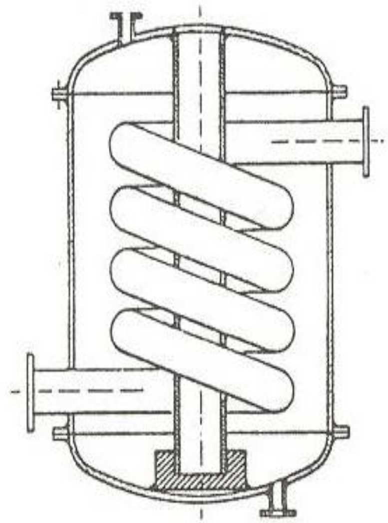
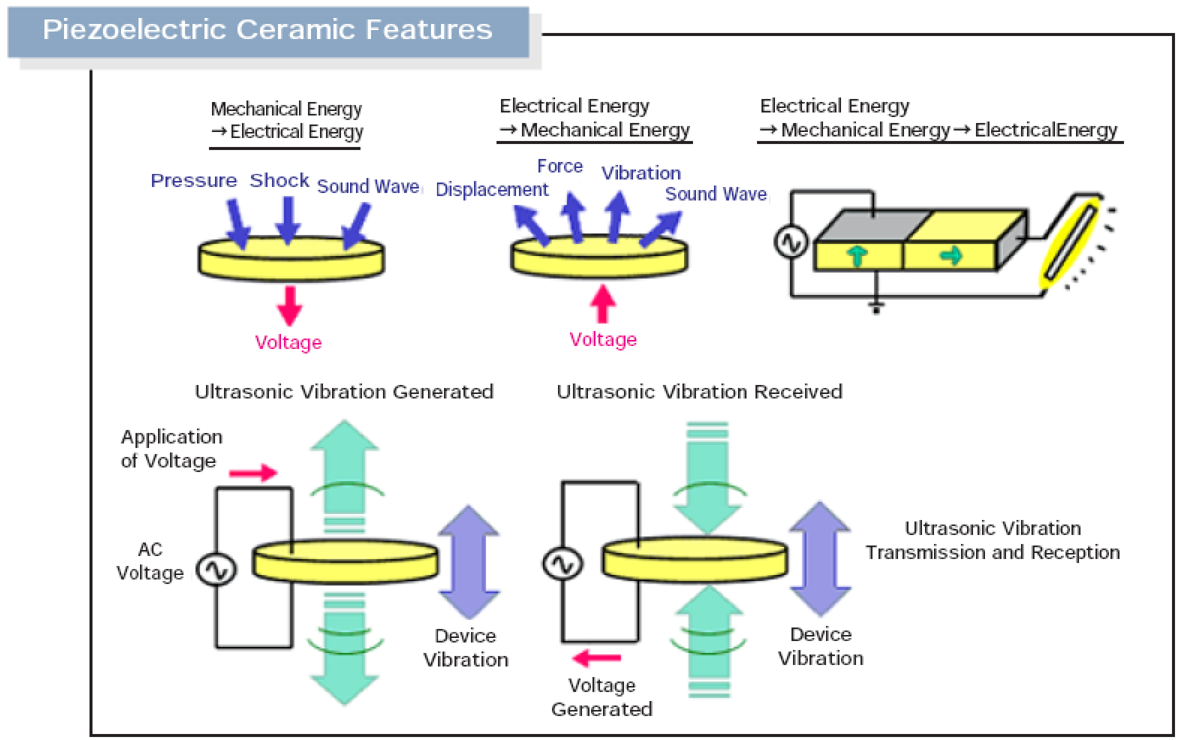


Figure 1.7 Helically coiled tube heat exchanger. (From Bergles and Webb [1985]. With permission.)

열교환기의 성능향상 기술

Active Techniques

- Mechanical aids
- Surface vibration
- Fluid vibration
- Electrostatic fields
- Injection
- Suction
- Jet impingement



Finned-tube HEX 개요

- **Finned-tube heat exchangers have been used for heat exchanger between gases and liquids (single or two phase) for many years.**
- **The gas-side heat transfer coefficient is typically much smaller than the tube-side value, it is important to increase the air-side hA value.**

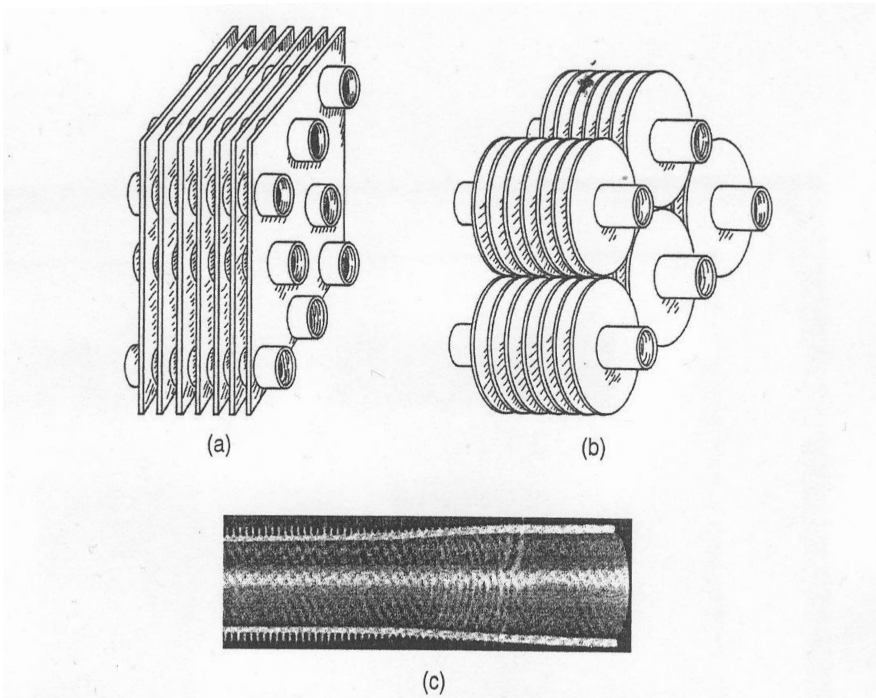
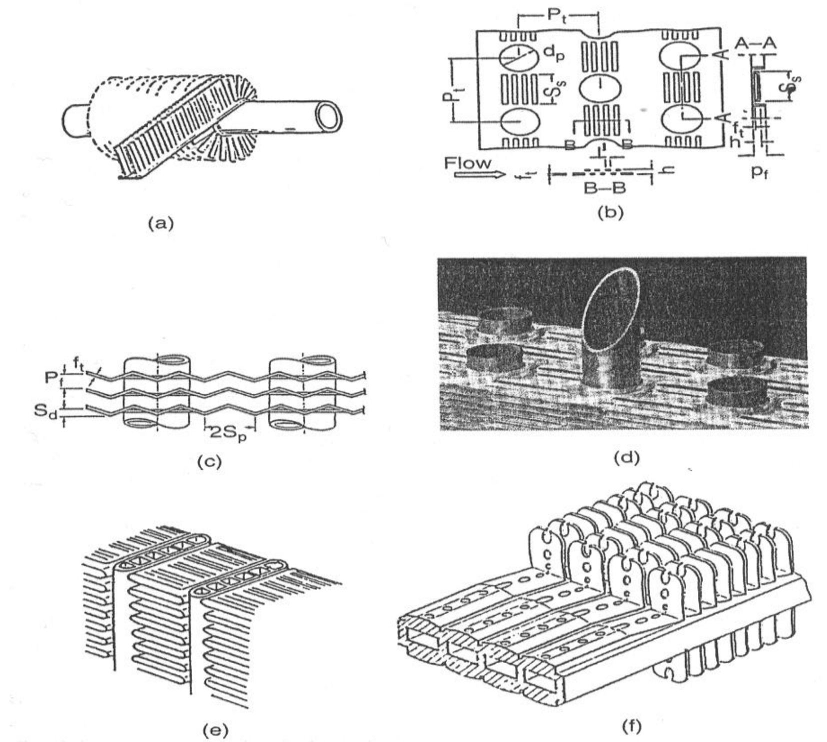


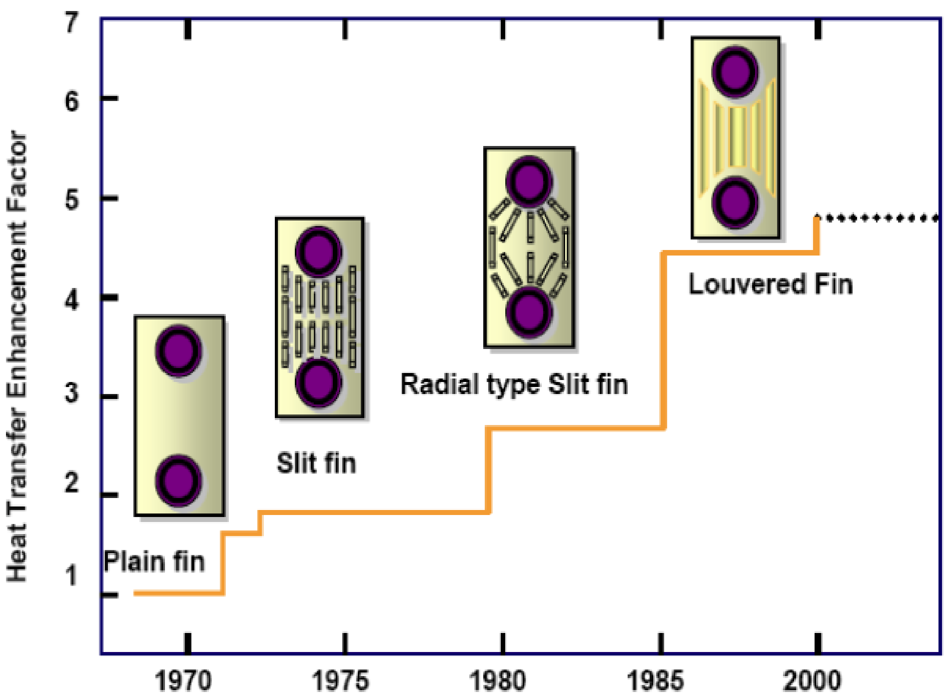
Figure 6.1 Finned tube geometries used with circular tubes: (a) plate fin-and-tube used for gases, (b) individually finned tube having high fins, used for gases. (From Webb [1987]) (c) Low, integral-fin tube.



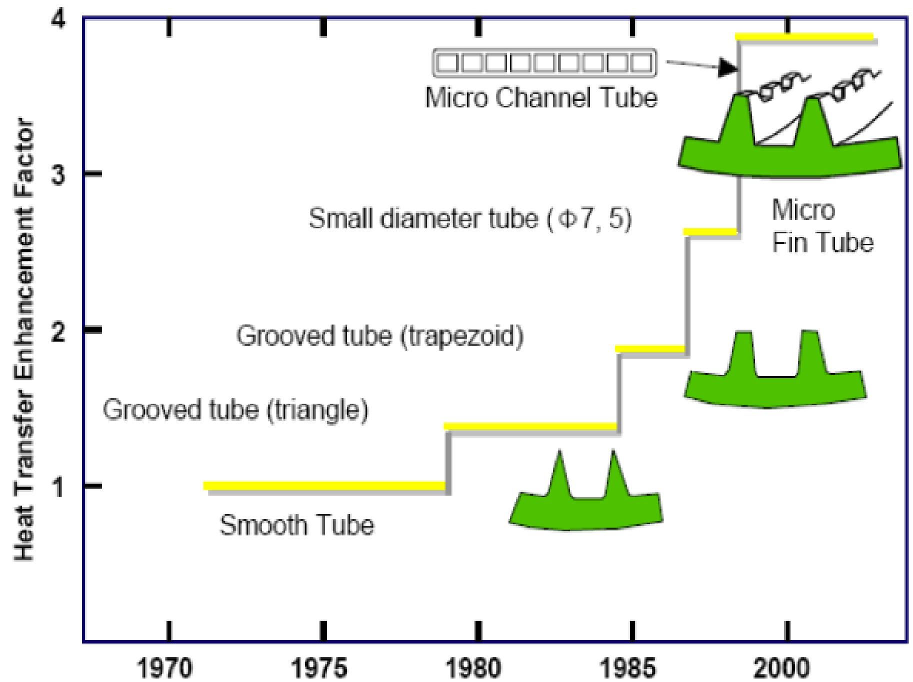
e 6.2 Air-side geometries used in finned tube heat exchangers: (a) spine-fin, (b) slit type (
fins, (d) convex louver fin, (e) Louver fins brazed to extruded aluminum tube, (f) interrupt
egral to extruded aluminum tube.

Finned-tube HEX의 Trend

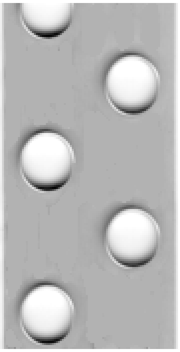
Air-side heat transfer



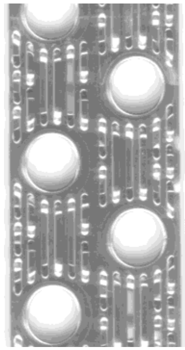
Refrigerant-side heat transfer



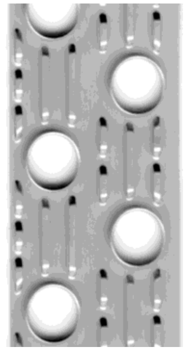
Finned-tube HEX의 Fin 형상별 성능



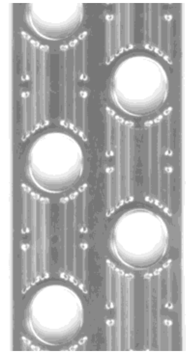
Plain fin



Slit fin

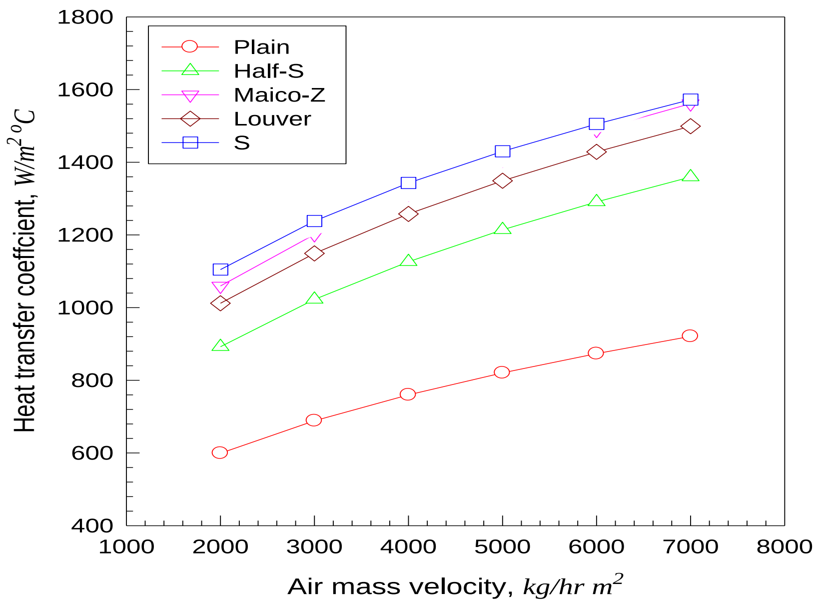


Half-Slit fin

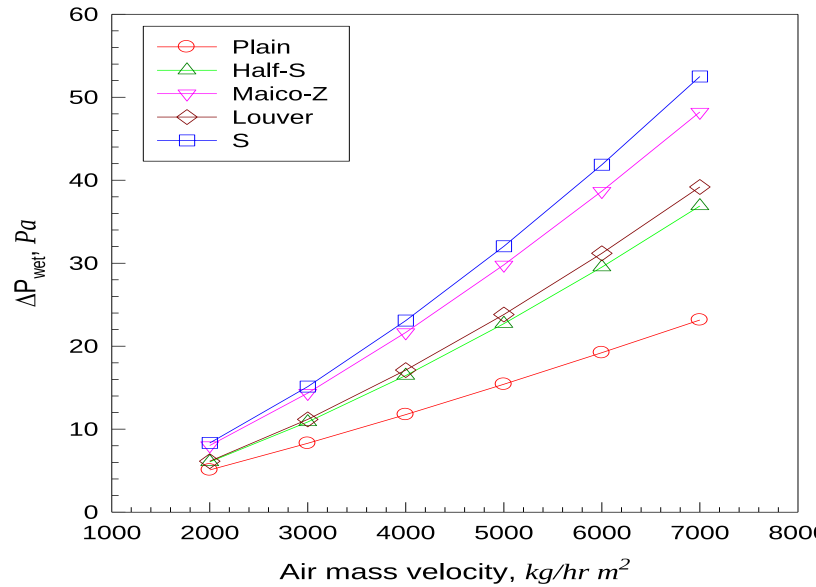


Louver fin

Heat transfer coefficient



Pressure drop



성능 무차원화 방법 (j, f factor)

$$j = St \cdot \Pr^{2/3} = \frac{h_o}{\rho_a \cdot C_{pa} \cdot V_{max}} \cdot \Pr^{2/3}$$

$$\Pr = \frac{\nu_a}{\alpha_a}$$

$$V_{max} = \frac{A_{fr}}{A_c} \cdot V_a$$

$$h_o = \frac{1}{\eta_o A_o}\left[\frac{1}{UA} - \frac{1}{h_i A_i} - \frac{\delta_t}{k_t A_t}\right]^{-1}$$

$$h_i = \frac{Nu_{Dh} \cdot K_w}{D_h}$$

$$UA = \frac{Q_a}{\Delta T_{LMTD}} = Q_a \Big/ \left[\frac{\Delta T_{out} - \Delta T_{in}}{\ln(\Delta T_{out} / \Delta T_{in})}\right]$$

$$\eta_o = 1 - \frac{A_f}{A_o}(1 - \eta_f)$$

$$Nu_{Dh} = \frac{(\frac{f}{8}) \cdot (\mathrm{Re}_{Dh} - 1000) \cdot \Pr}{1 + 12.7(\frac{f}{8})^{1/2} \cdot (\Pr^{2/3} - 1)} \quad at(3000 \le \mathrm{Re}_{Dh} \le 10^6)$$

$$f = (0.79 \ln(\mathrm{Re}_{Dh}) - 1.64)^{-2}$$

$$\Pr = \frac{\nu_w}{\alpha_w}$$

$$\mathrm{Re}_{Dh} = \frac{V_m \cdot D_h}{\upsilon_w}$$

$$\eta_f = \frac{\tanh(ml)}{ml}$$

$$m = \left\{\frac{2h_o}{k_f \cdot \delta_f}(1 + \frac{\delta_f}{F_d})\right\}^{1/2}$$

$$l = \frac{H}{2} - \delta_f$$

$$f = \frac{\Delta P \cdot D_h}{2\rho_a \cdot (V_{max})^2 \cdot L}$$

$$V_{max} = \frac{A_{fr}}{A_c} V_a$$

성능 무차원화 방법 (j, f factor)

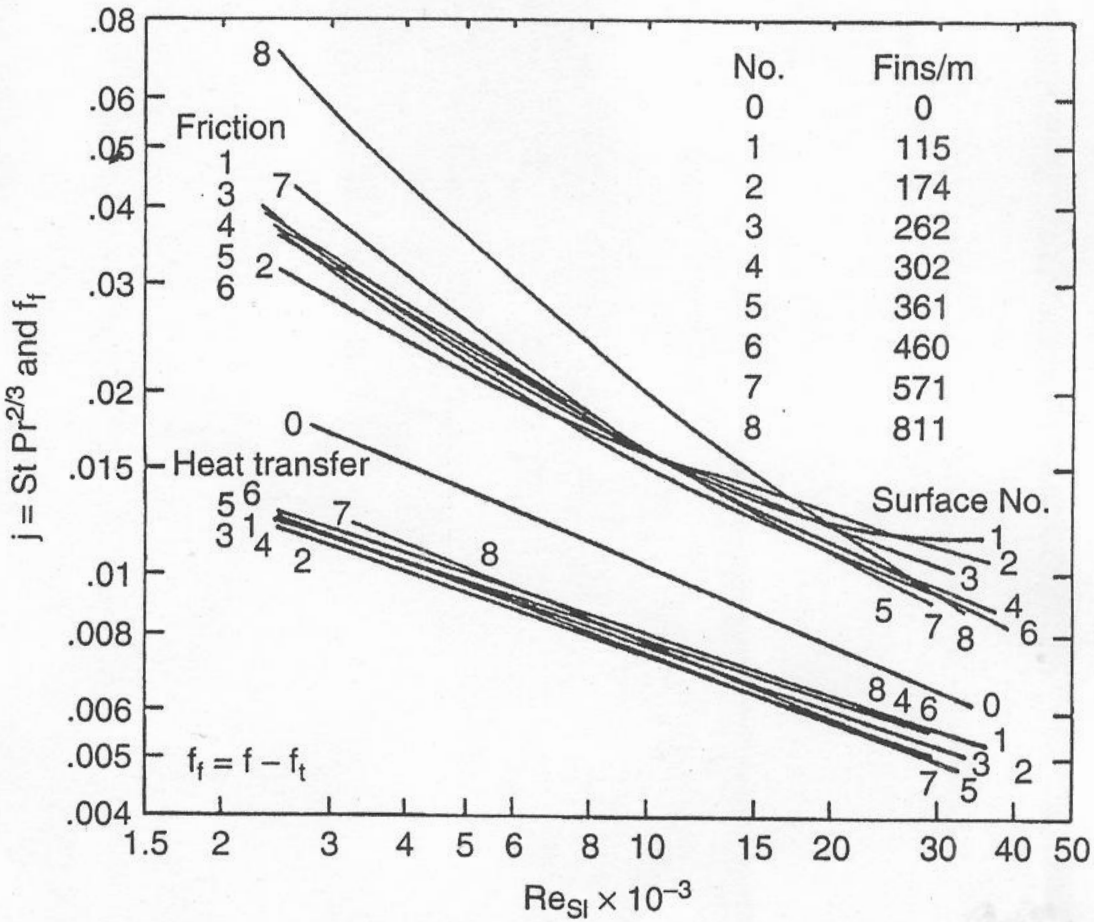


Figure 6.4 Plot of the *j* factor and the fin friction vs. Re_{SI}.

Finned-tube HEX의 Design flow

▶ **Design Flow**

Fin & tube design	Heat transfer Co. Pressure drop (air)	Pressure drop (Ref.) System Evaluation	Detailed Design for Mass production
• Numerical analysis • Surface characteristics • Geometrical properties	• Heat transfer Co. • Pressure drop (air) • Evaluation	• Pressure drop (Ref.) • Cycle Simulation	• Detaled design • Press die design • Tube • Facility

Index for evaluating heat exchanger

Initial cost analysis

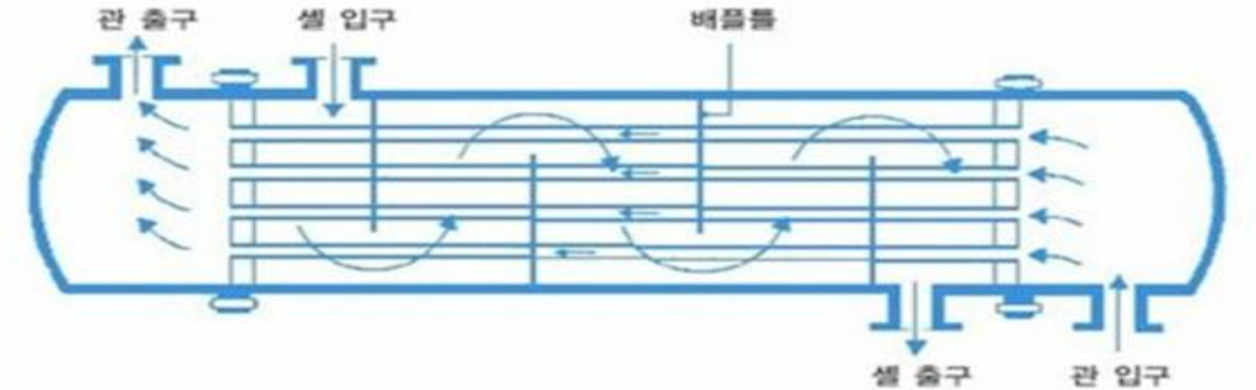
$$Index_{initial} = \frac{Heat\ Transfer\ Rate}{Material\ Cost}$$

Running cost analysis

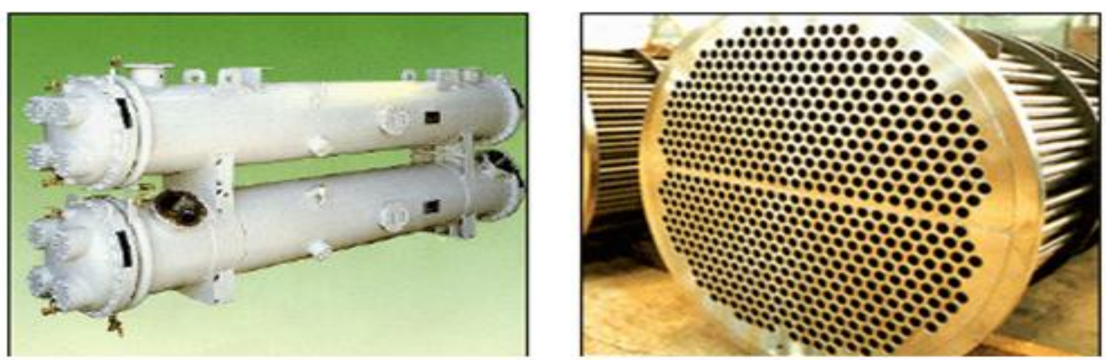
$$Index_{Running} = \frac{Heat\ Transfer\ Rate}{Power_{Fan}}$$

Shell-and-tube HEX(다관식 열교환기)

- 일반적으로 열교환기로 불러지는 것은 대부분이 원통다관식 열교환기이며 가장 흔히 사용되는 형식
- 원통 다관식 열교환기는 동체 내부에 많은 전열관을 갖추고(2개의 관판을 다수의 전열관으로 연결) 이들의 관벽을 거쳐서 동체측 유체와 관내 유체간에 열교환을 행하는 것

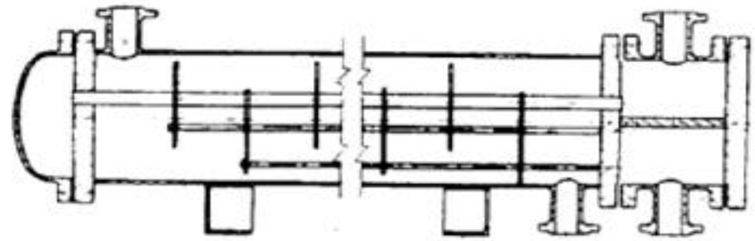


< Shell & Tube 열교환기의 유동형태 >

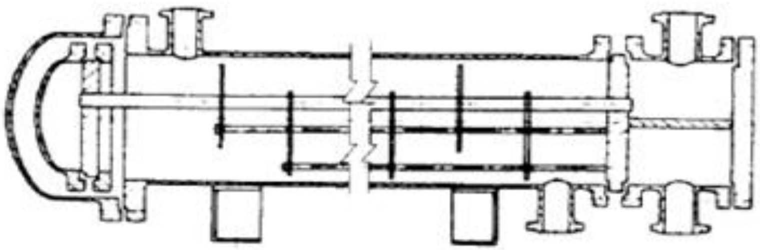


< Shell & Tube 열교환기의 제품형태 >

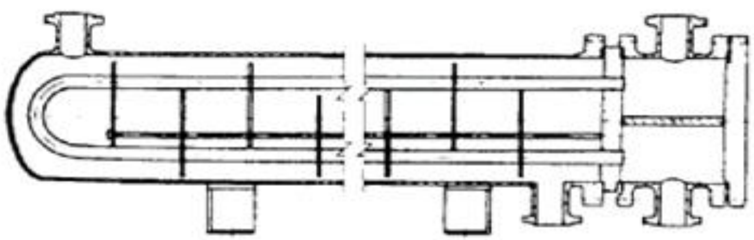
Shell-and-tube HEX(다관식 열교환기)



(a) 고정관판식



(b) 유동두식



(c) U튜브식

주요용도

➢ 가열기,냉각기,증발기,응축기 등 다양한 용도로 사용.

장점

➢ 고온,고압,저온,저압 등 사용이 광범위하고 제작조건도 간단.

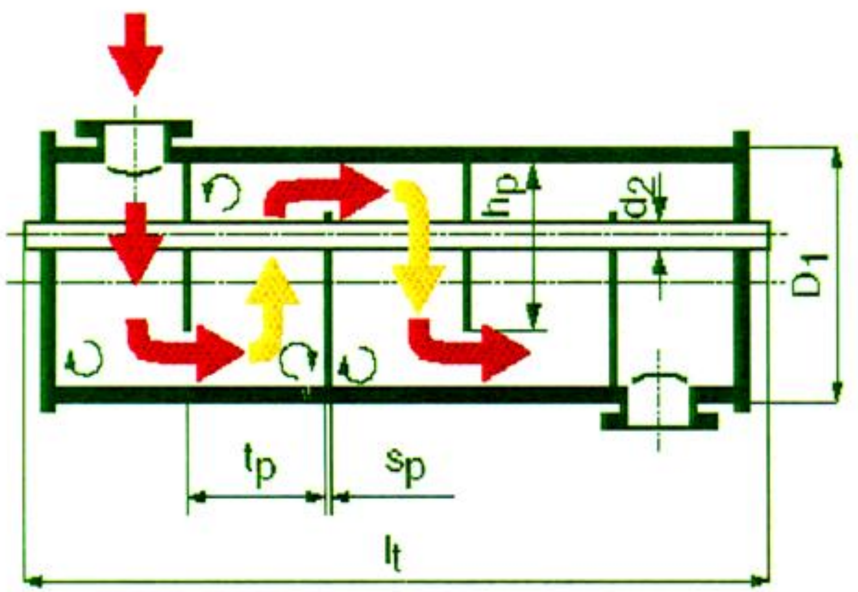
단점

➢ 총괄열전달계수가 작은 편.

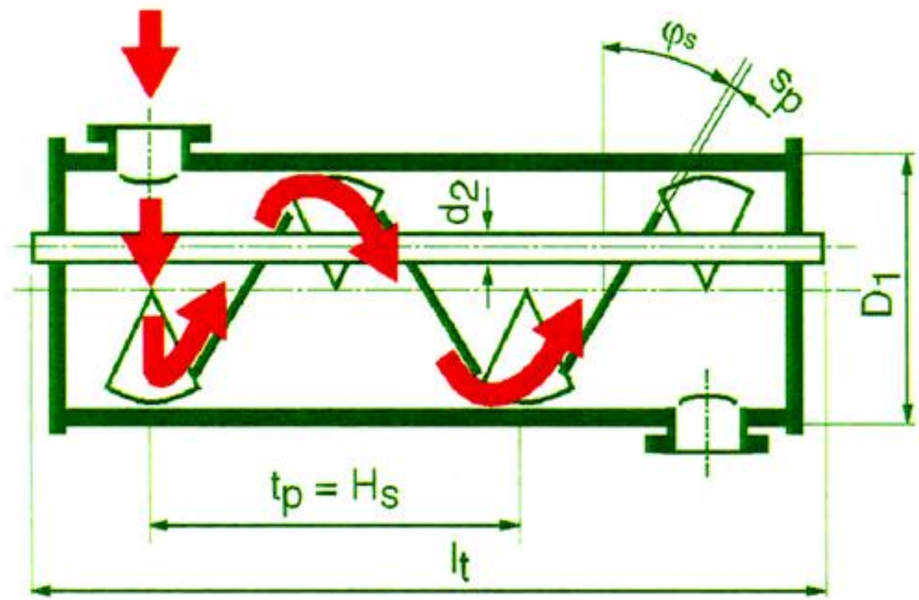
Shell-and-tube HEX(다관식 열교환기)

나선형 Baffle 열교환기

기존 수직형 Baffle을 가진
Shell & Tube Type 열교환기



나선형 Baffle을 가진
Shell & Tube Type 열교환기

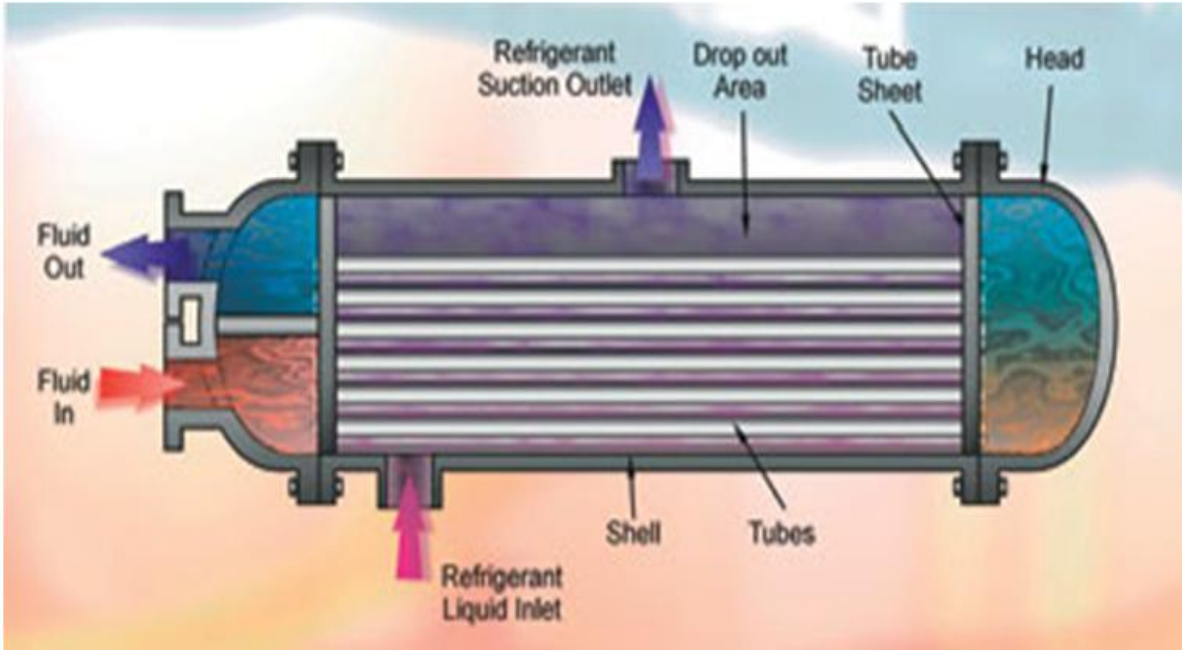


- 열전달율 : **30%** 이상 향상
- 압력강하 : **25%** 이상 감소
- 내부오염 : 나선유동으로 오염감소

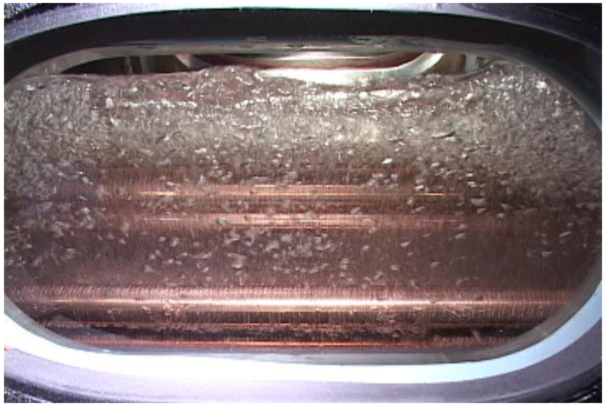
Shell-and-tube HEX(다관식 열교환기)

만액식 증발기(Flooded evaporator)

만액식 증발기는 원통측의 냉매가 관측으로 흐르는 액체에서 열을 전달받아 증발하는 형식임



Oil-free

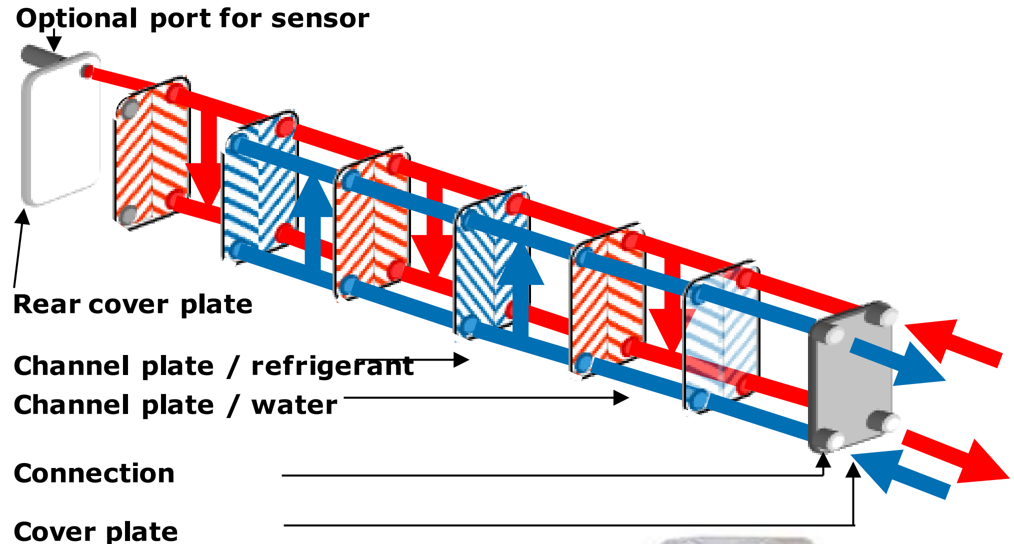


Oil 2%

Plate heat exchanger (PHE, 판형열교환기)

판형열교환기는 고정된 사각 **Head plate**와 이동이 가능한 **Head plate** 사이에 얇고 주름진**(corrugated)** 여러 장의 전열판**(plate)**이 서로 다른 방향으로 존재하여 이들 전열판 사이에서 가열유체와 수열유체가 교대로 흐르면서 열전달을 수행하는 장치

- 아주 낮은 **Reynolds** 수에도 난류를 유도할 수 있는 전열판의 주름**(corrugation)**을 가짐
  → 난류와 와류현상**(**스케일 생성 방지 효과**)** → 전열성능 우수
- 전열의 효과를 높이기 위하여 유체의 유동방향을 수열유체는 상향**,** 가열유체는 하향



- Gasketed PHE / Brazed PHE

Gasketed PHE

Brazed PHE

Historical background of PHE

- The earliest development and usage of PHEs were in response to increasingly stringent statutory requirements from foodstuffs, particularly dairy products, in the late nineteenth century. The very first patent for a PHE was granted to a German by the name of Albrecht Dracke in 1878.
- Around 1930, Bergedorfer Eisenwerk of Alfa Lavel in Sweden developed a similar commercial PHE, the company's first such products.

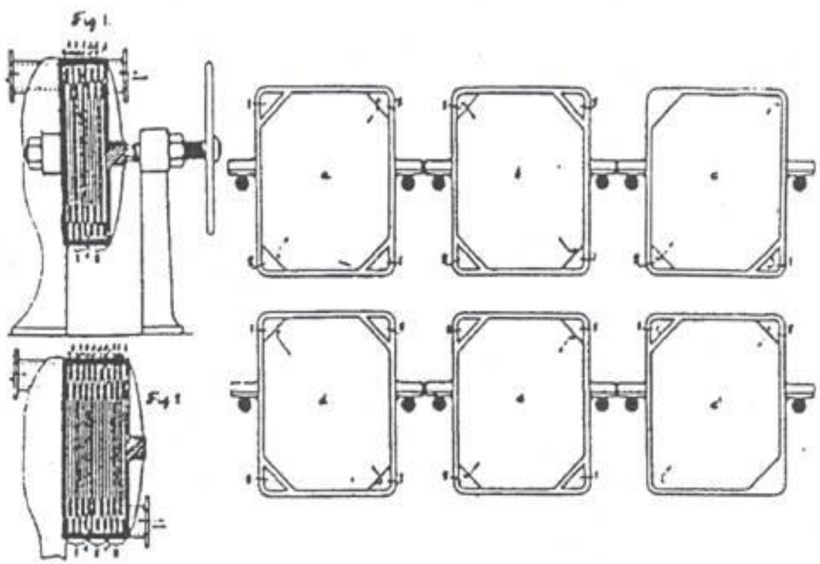


Figure 1.1: Patent No. 58504 for an early PHE issued on 5 April 1890 [13].

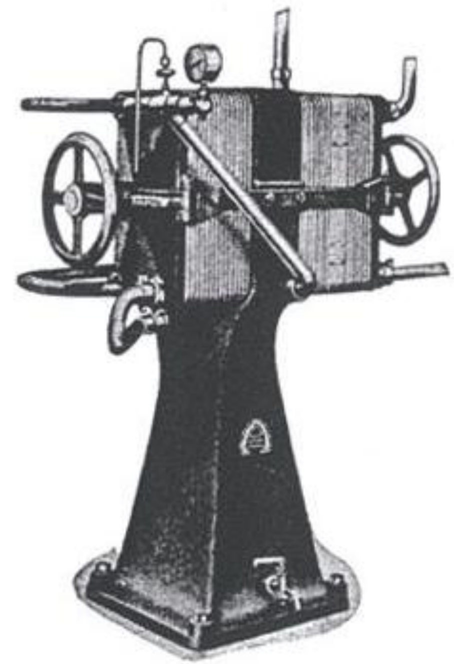
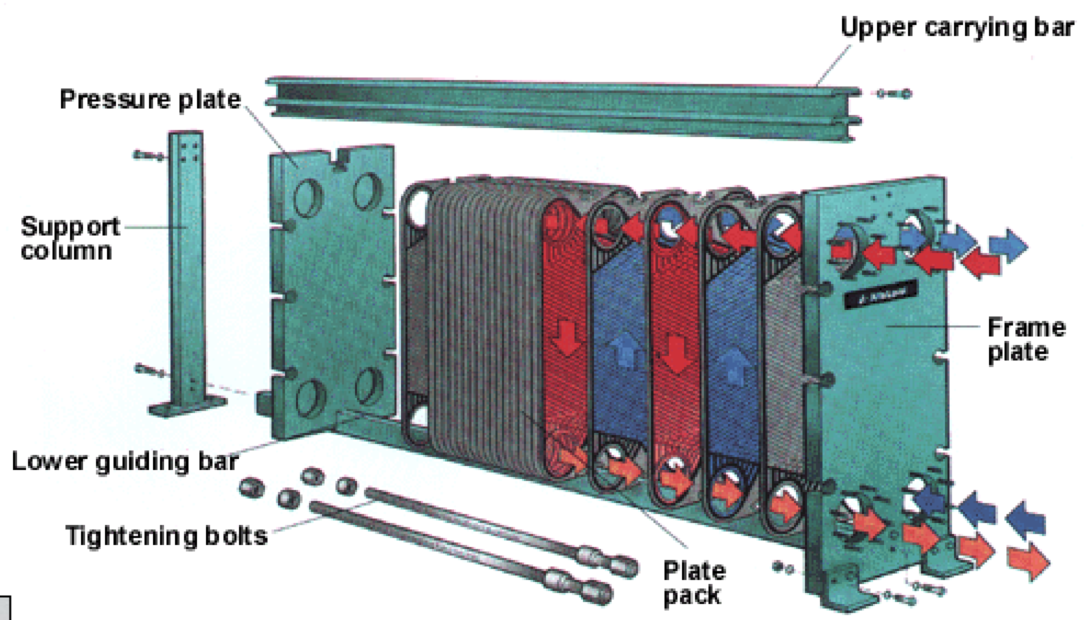


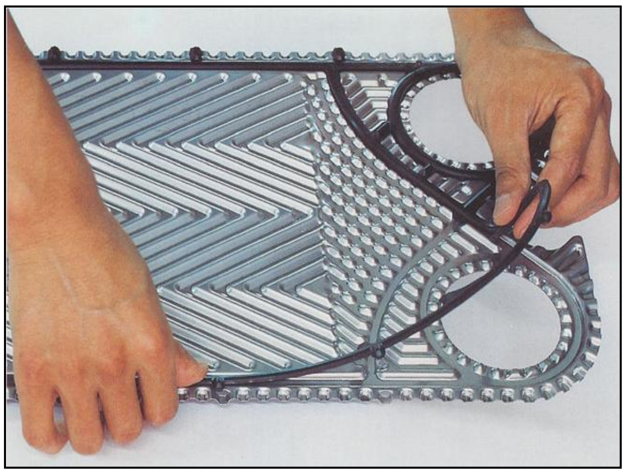
Figure 1.3: The PHE developed by Bergedorf (courtesy of Alfa Laval).

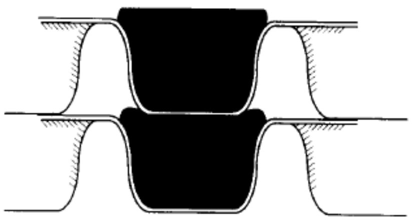
Historical background of PHE

- **Gasketed plate heat exchanger were introduced in the 1930s mainly for the food industries because of their ease of cleaning, and their design reached maturity in the 1960s with the development of more effective plate geometries, assemblies, and improved gasket materials.**
- **The brazed plate heat exchanger (BPHE) is simply the most compact, rugged, efficient and cost effective type of heat exchanger available. 1970s BPHE technology emerged in Europe to serve the needs of the growing district heating market.**
- **1980s the BPHE was first put into use for two-phase applications (evaporators & condensers).**
- **Today's BPHE's have more than 30 years of development behind them with many innovations and improvements in both performance and efficiency.**

Gasketed PHE



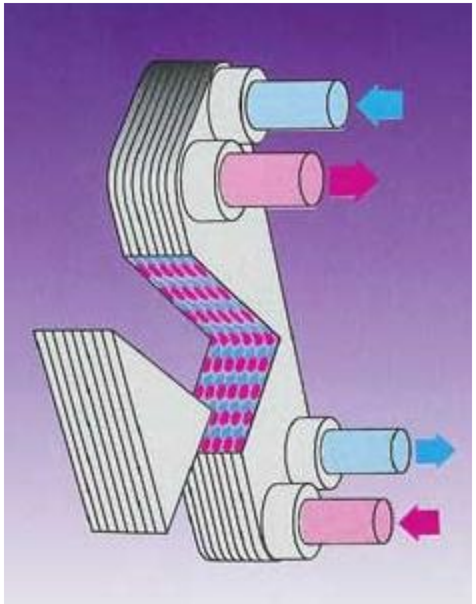


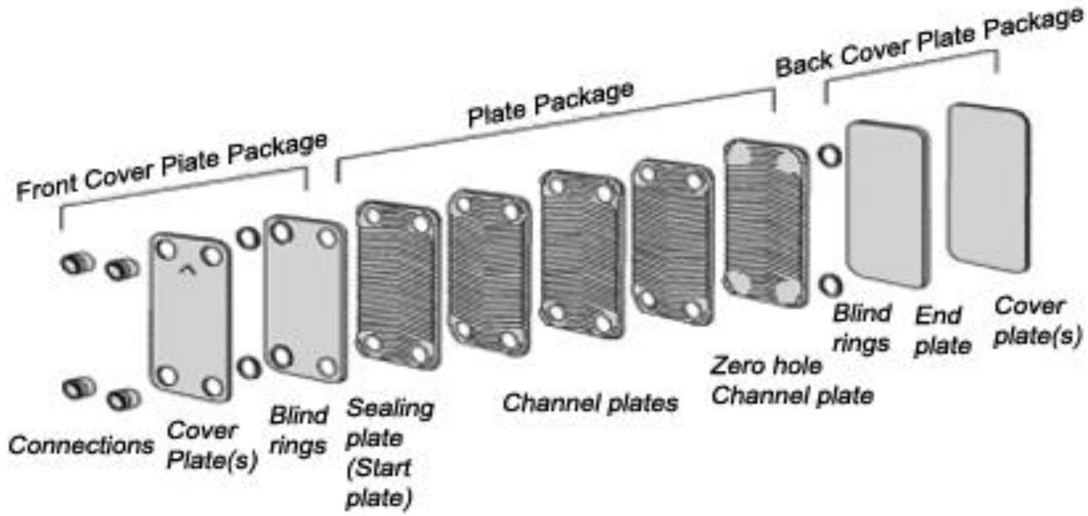


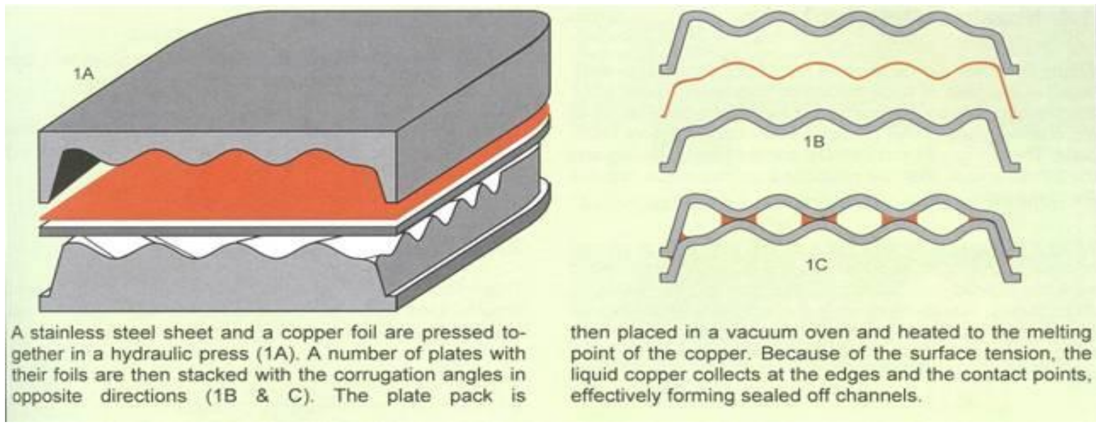
< Gasket* 형상 >

* Gasket : 유로형성 및 열판(plate) 안쪽의 유체를 밀봉시키기 위한 것

Brazed PHEX







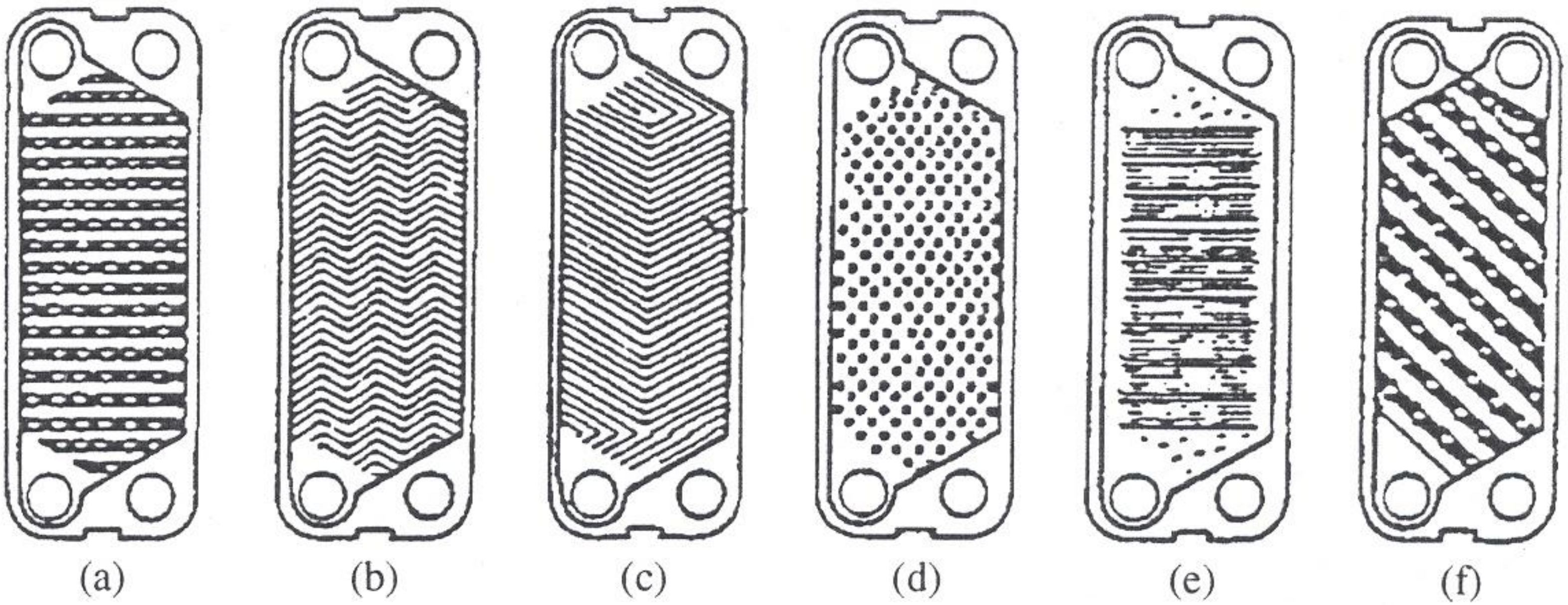
※ 브레이징(Brazing) : 450℃ 이상에서 접합하고자 하는 모재의 용융점(Melting point)이하에서
모재는 상하지 않고 용가재와 열을 가하여 두 모재를 접합하는 기술

Gasketed & Brazed PHE

Table 2.1: Typical operating range of gasketed and brazed PHEs.

	Gasketed PHEs	Brazed PHEs
Maximum operating pressure	25 bar (30 bar with special construction)	30 bar
Maximum operating temperature	160°C (200°C with special gaskets)	225°C (minimum ~195°C)
Maximum flow rate	3600 m^3/h	140 m^3/h
Heat transfer coefficient	Up to 7500 $W/m^2 \cdot K$	Up to 7500 $W/m^2 \cdot K$
Heat transfer area	0.1–2200 m^2	0.02–60 m^2
Maximum connection size	450 mm	100 mm
Approach temperature difference	As low as 1°C	
Heat recovery	As high as 93%	
NTU	0.3–6.0	
Pressure drop	Up to 100 kPa per m channel length	
Number of plates	Up to 700	
Port size	Up to 435 mm	
Plate thickness	0.4–1.2 mm	
Plate size	0.3–3.5 m length	
Plate spacing	1.5–5.4 m	
Corrugation depth	1.5–5.4 mm	

Plate patterns of PHE



(a) washboard, (b) herringbone or zig-zag, (c) chevron, (d) protrusions and depressions, (e) washboard with secondary corrugations, and (f) oblique washboard.

PHE의 Geometric effects

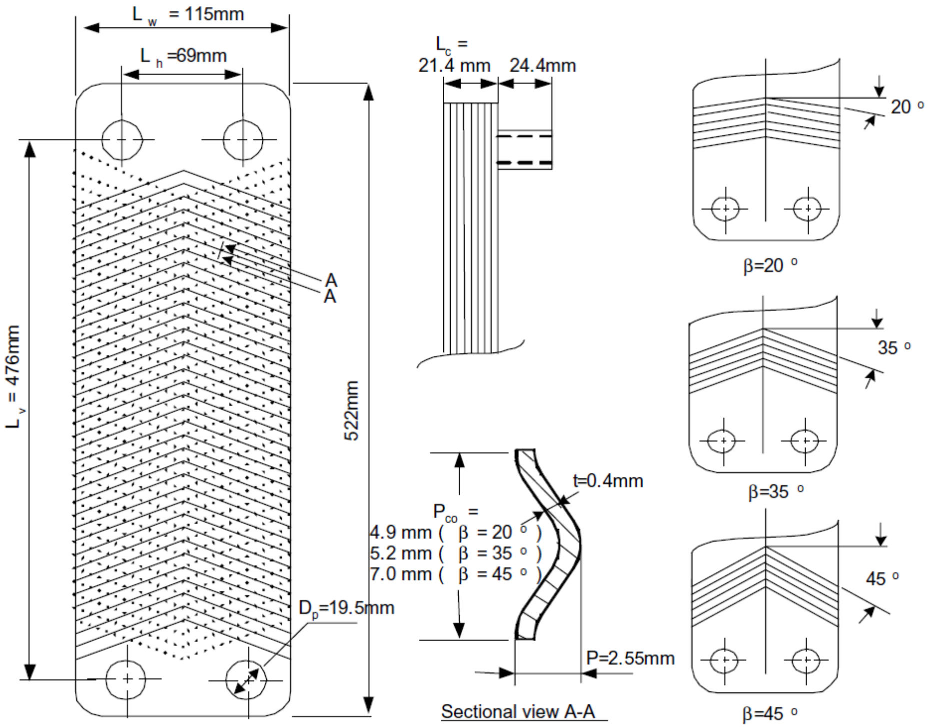
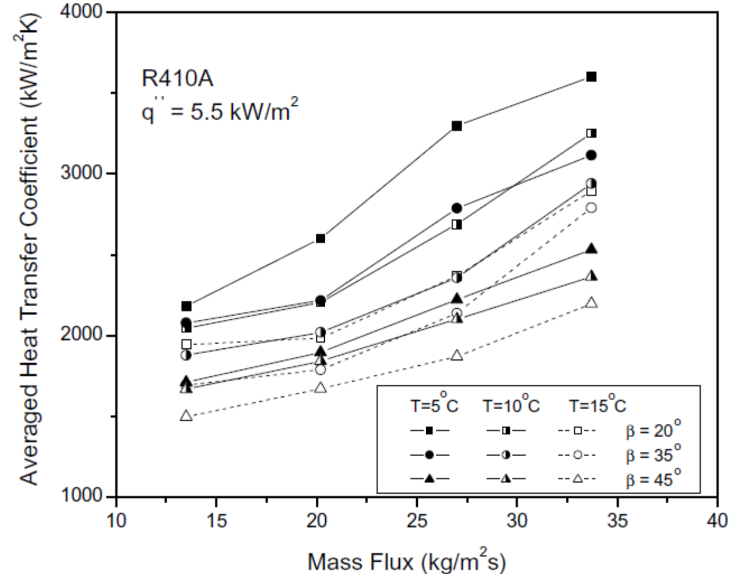
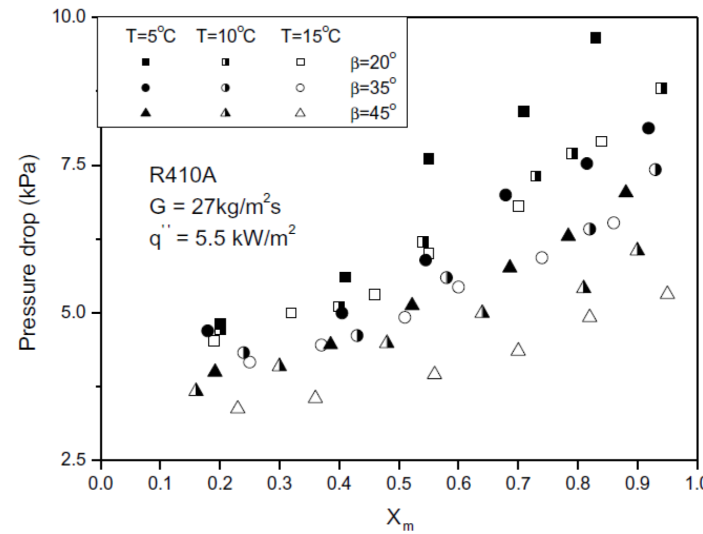


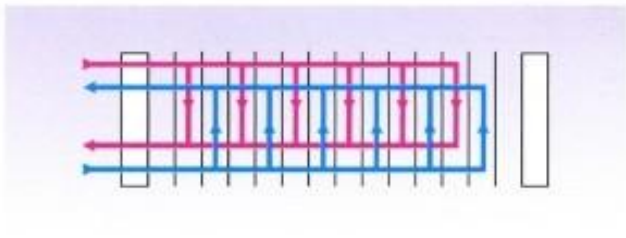
Fig. 2. Schematic diagram of BPHE.





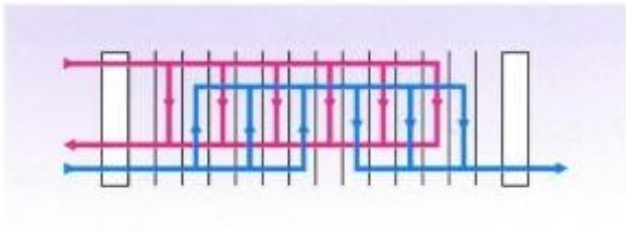
<Ref.> Han et al., 2004, "Experiments on the characteristics of evaporation of R410A in brazed plate heat exchangers with different geometric configurations", Applied Thermal Engineering

PHE flexible design



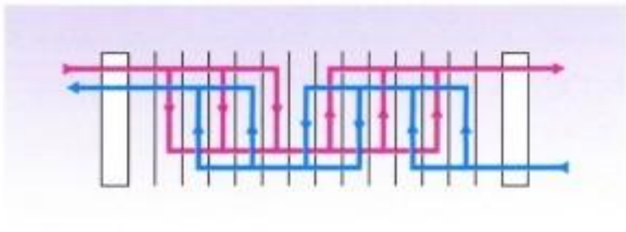
Single Pass

Counter flow 형성, Nozzle이 고정 프레임에 취부
유지 보수시 이동 프레임만 이동
용량 증감 및 유지보수 용이



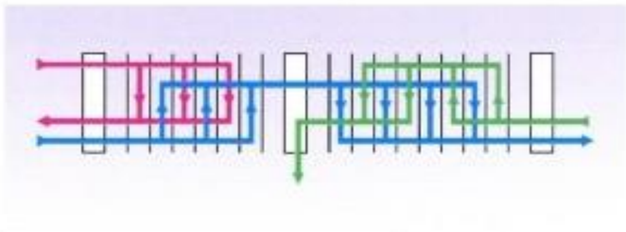
Single Pass & Multi Pass

Inlet와 Outlet의 온도차이가 크고 Hot side와 Cold side의 허용 압력손실의 차이가 클 경우 한쪽은 1 Pass로 하고 다른 쪽은 Multi pass로 하여 총괄 전열계수를 높여 성능을 향상



Multi Pass

장점 : 전열량에 비해 Flowrate가 현저히 작고 오염도가 적은 경우 Hot side와 Cold side를 Multi pass로 디자인하여 전열효과를 현저히 높일 수 있음
단점 : 용량증가시에 이동 프레임의 Nozzle 부분의 Piping을 수정해야 함

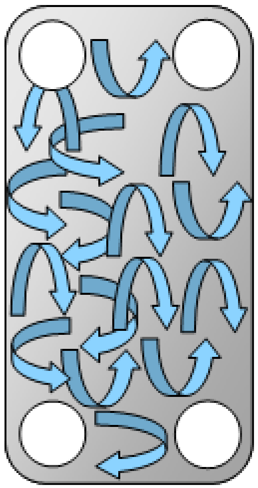


Single & Multi-Multi Pass

격리 프레임(Seperator frame)을 사용
열교환기 1대로 3가지 이상 유체의 열교환 가능
식품 공업의 살균기 등에 사용

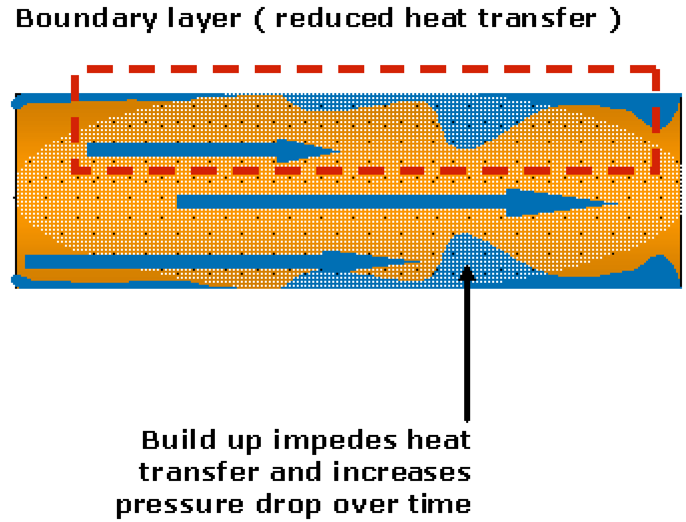
PHE & Shell-and-tube HEX

PHE
(Turbulent flow)



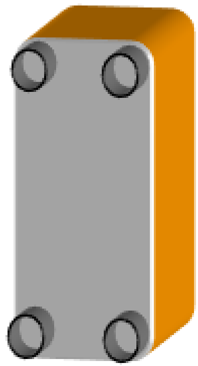
- Maximum heat transfer
- Minimizes fouling
- Keeps particulates in suspension
- Self-cleaning turbulent flow
- Requires less velocity
- Typically 1/6 the size of laminar device

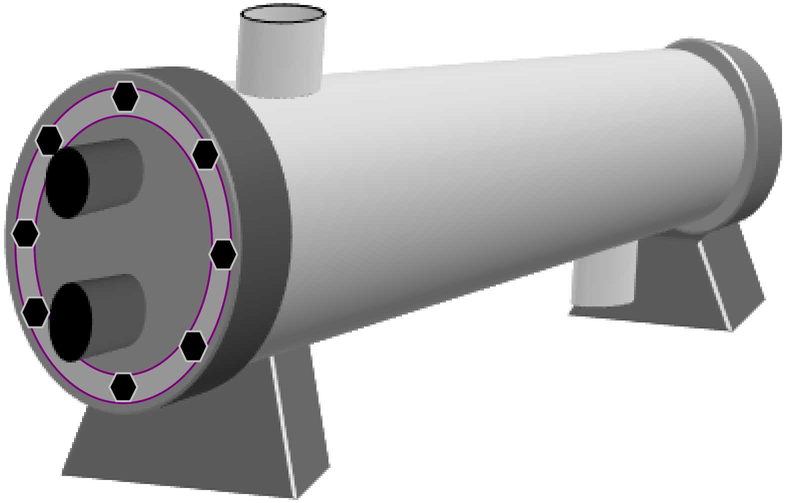
Shell-and-tube HEX
(Laminar flow)



- Less efficient heat transfer
- Contributes to fouling
- Creates boundary layer
- Over time pressure drop rises
- Over time heat transfer drops
- Used in shell & tube, coax, etc.

PHE & Shell-and-tube HEX





Brazed Plate Heat Exchanger

Heat transfer utilizes almost all the material in the heat exchanger.

A 50 Ton [176 kW] heat exchanger weighs less than 220 lbs [100 kg] and is less than 2 feet [.609 m] tall and 1 foot [.304 m] wide.

Shell & Tube Heat Exchanger

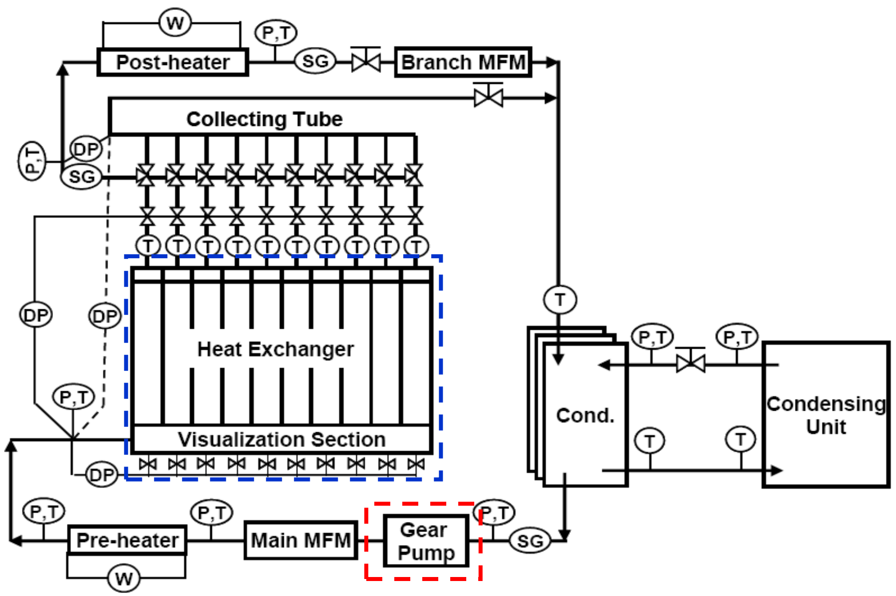
Heat Transfer only takes place at the tube bundle.

A 50 Ton [176 kW] S&T weighs over 2000 lbs [907 kg] and is as much as 12 feet [3.65 m] long.

열교환기 성능평가 장치

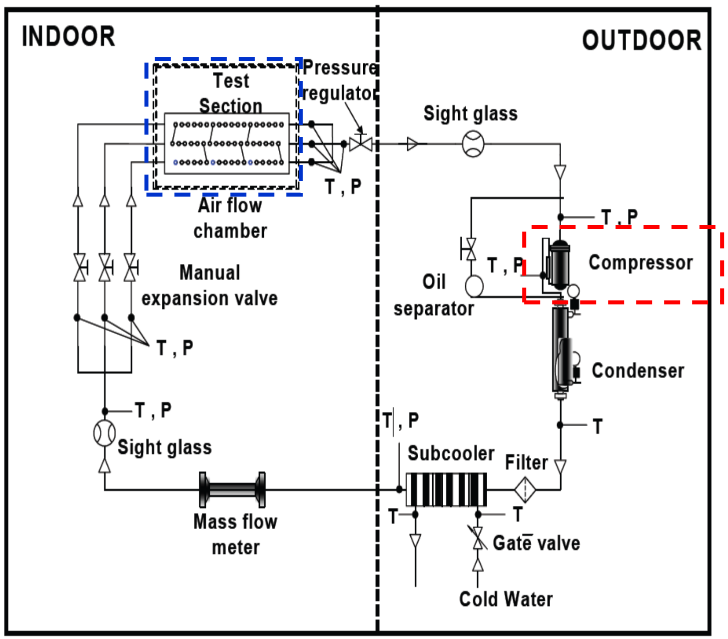
열교환기 성능평가장치는 냉매공급 방식에 따라 **Pump type**과 **Compressor type**이 있음.

Pump type*



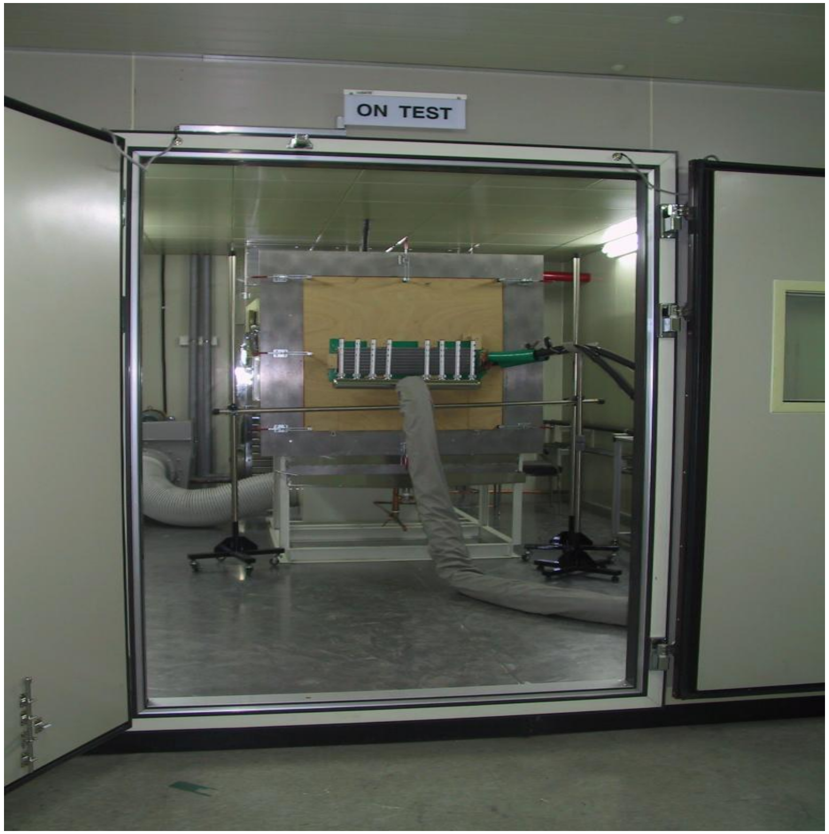
DP: Differential pressure transducer, P: Pressure transducer, MFM: Mass flow meter
SG: Sight glass, T: Thermocouple, W: Power meter,

Compressor type**



* CEEE, Department of Mechanical Engineering, University of Maryland
** 최종민(국립 한밭대학교 기계공학과), 2004, “핀의 전도 열전달 및 과열도 변화에 따른 증발기 성능 특성에 관한 연구”

Finned-tube HEX 성능평가 시스템



Finned-tube HEX 성능평가 시스템

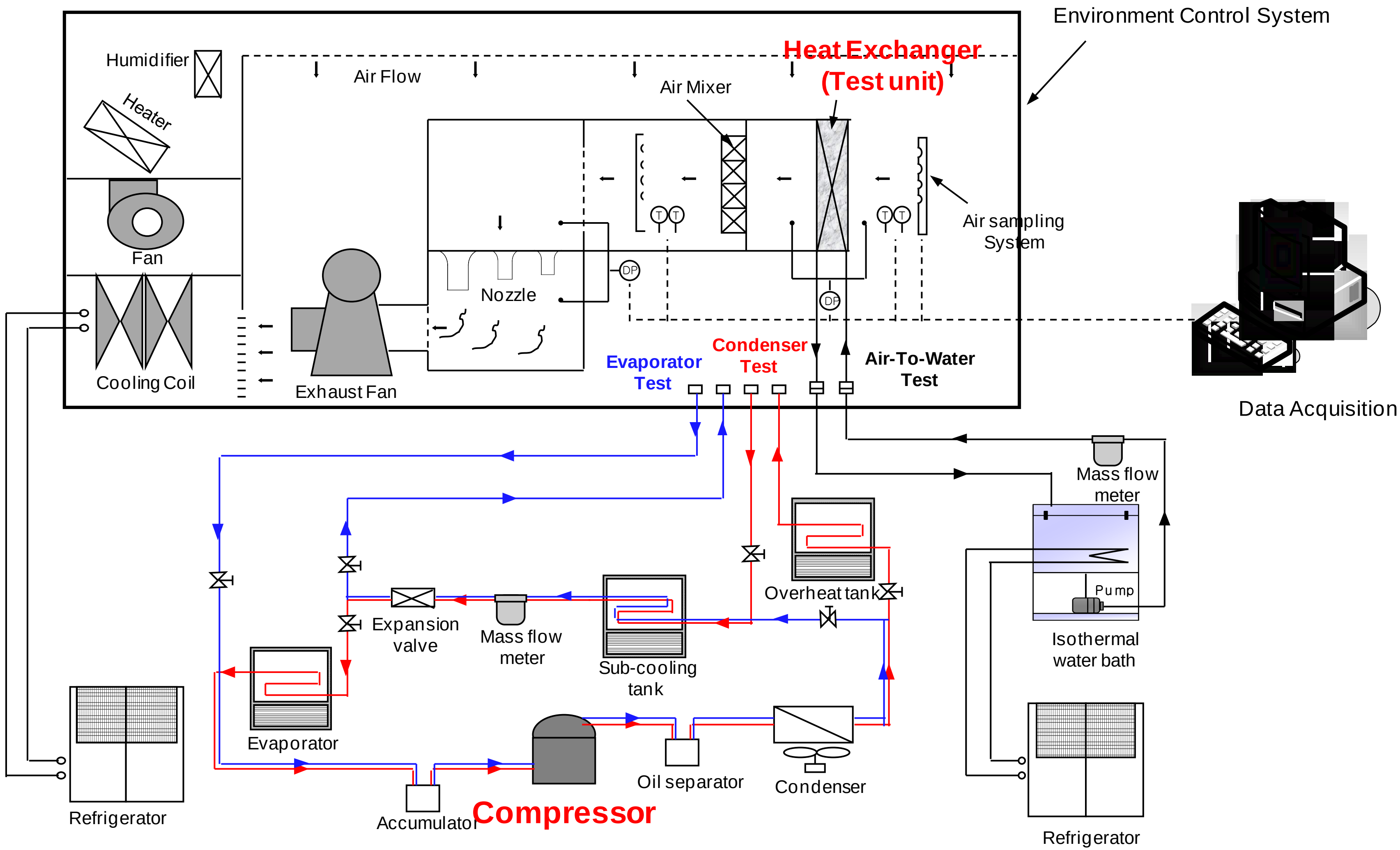


Plate HEX 성능평가 시스템

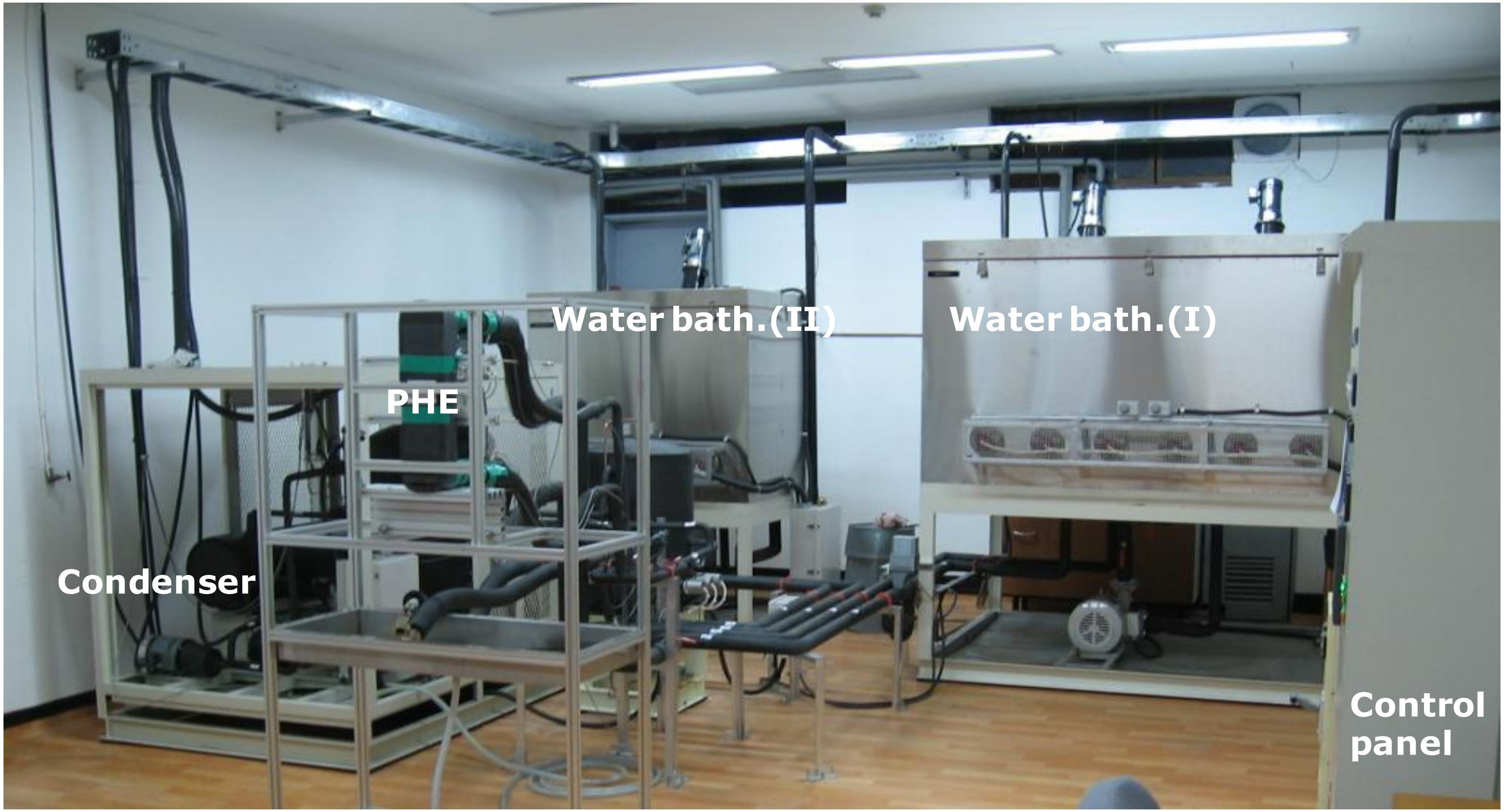
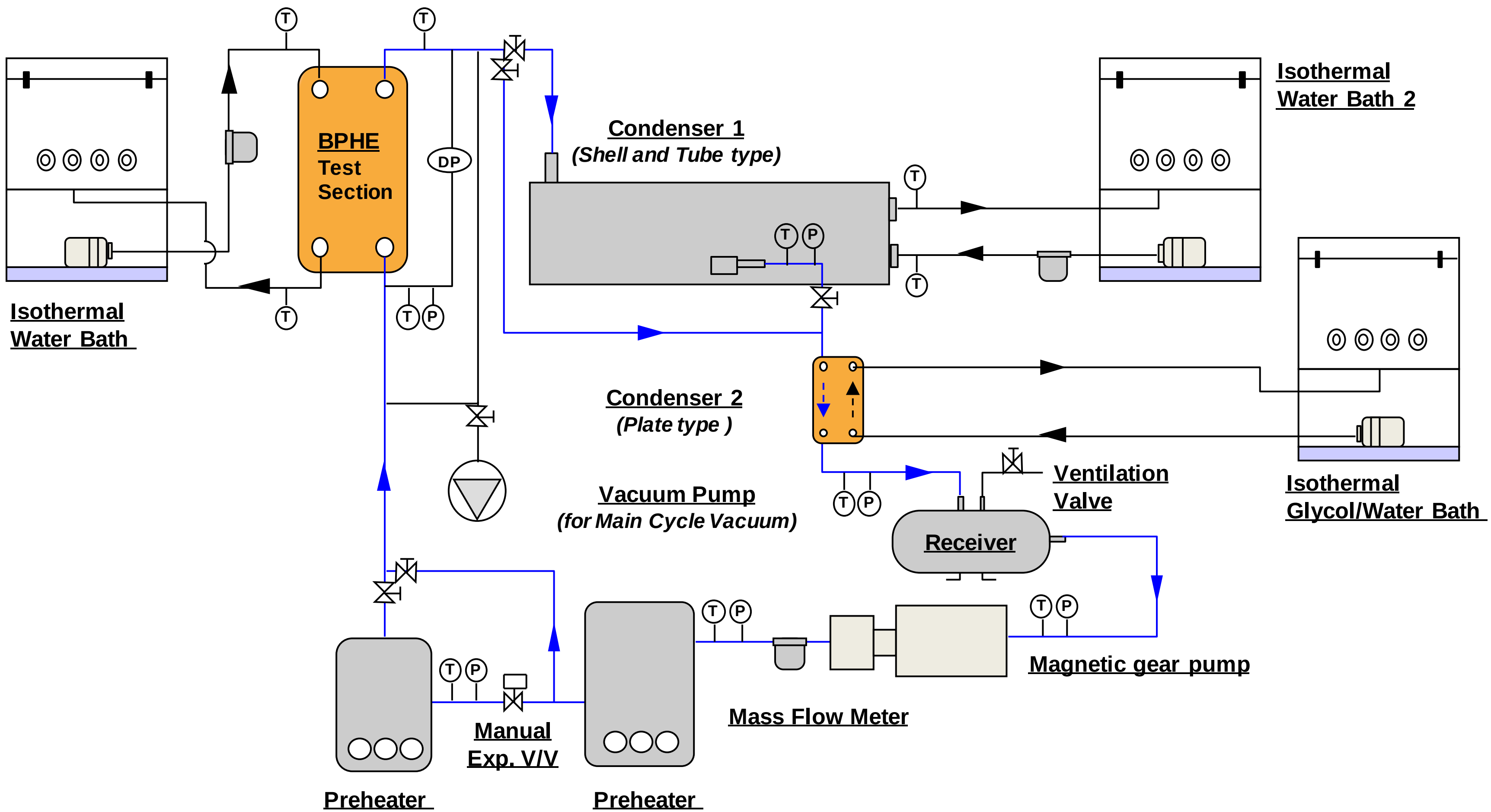


Plate HEX 성능평가 시스템



Valve T Temperature P Pressure DP Differential Pressure

Water
Refrigerant

Plate HEX 성능평가 조건 (ARI 기준)

■ 응축 성능평가(ARI Standard 450-1999)

Rating Group	Saturated Condensing Temperature of the Entering Refrigerant		Minimum Actual Temperature of the Entering Refrigerant Vapor		Temperature of Entering Water		Temperature of Leaving Water	
	°F	℃	°F	℃	°F	℃	°F	℃
1	105	40.6	125	51.7	75	23.9	95	35
2	105	40.6	125	51.7	85	29.4	95	35
3	85	29.4	105	40.6	50	10	70	21.1
4	100	37.8	120	48.9	70	21.1	85	29.4

■ 증발 성능평가(ARI Standard 480-2001)

Rating Condition	Liquid Being Cooled	Entering Liquid Temperature		Leaving Liquid Temperature		Saturated Refrigerant Temperature Leaving the Evaporator		Liquid Refrigerant Entering Expansion Device	
		°F	℃	°F	℃	°F	℃	°F	℃
1	Water	54	12	44	6.7	35	1.7	100	37.7
2	30% ethylene glycol	20	-6.7	15	-9.4	5	-15	100	37.7
3	Water	68	20	60	16	43	6.1	110	43.3