Spiral Plate Heat Exchanger

SPHE is fabricated by rolling a pair of relatively long strips of plate to form a pair of spiral passages.

Channel spacing is maintained uniformly along the length of the spiral passages by means of spacer studs welded to the plate strips prior to rolling.

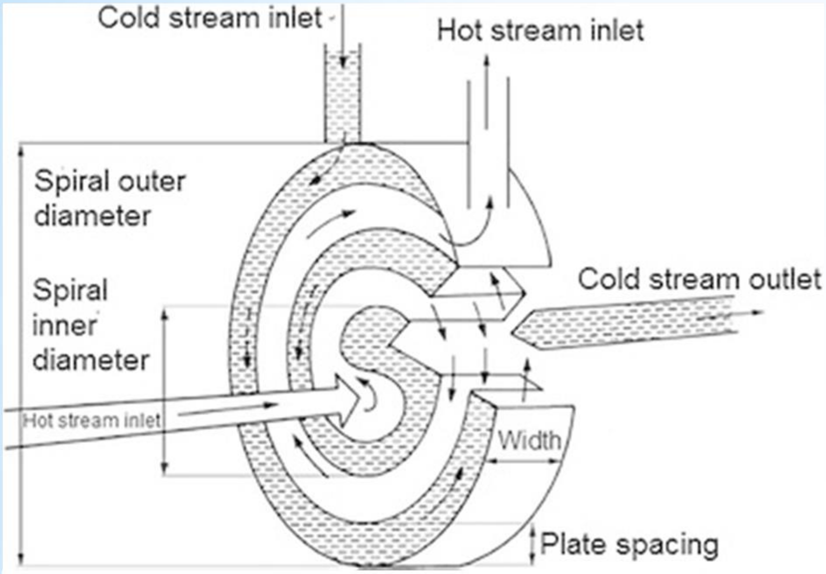
Advantages:

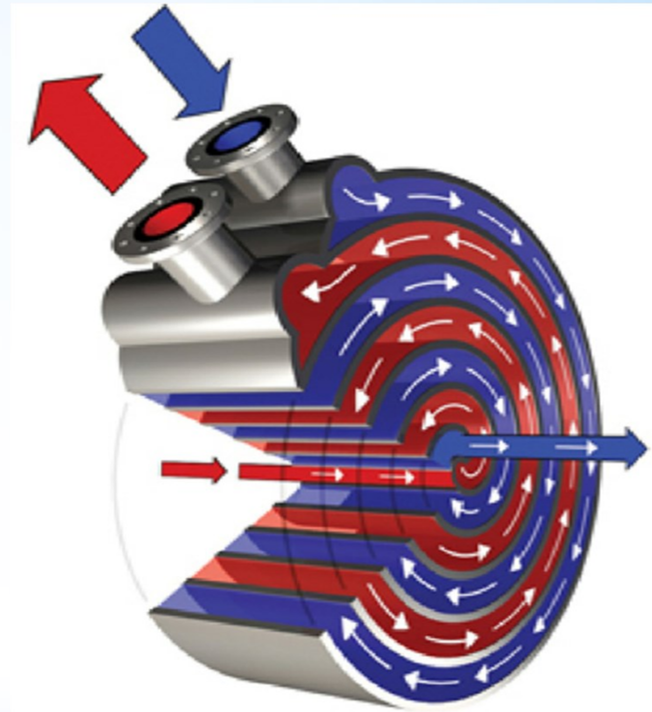
To handle slurries and liquids with suspended fibers, and mineral ore treatment where the solid content is up to 50%. The SPHE is the first choice for extremely high viscosities, say up to 500,000 cp, especially in cooling duties.

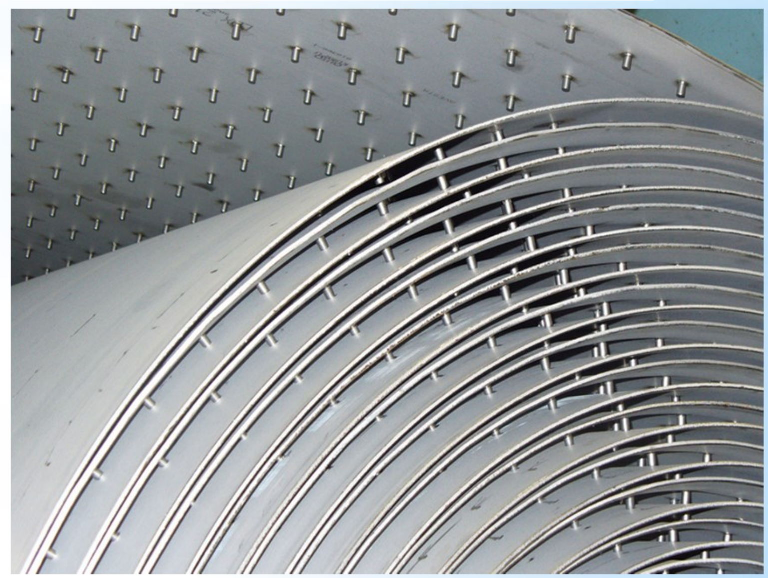
Applications:

SPHEs are finding applications in reboiling, condensing, heating or cooling of viscous fluids, slurries, and sludge.

Abhishek Kumar Chandra







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Lamella Plate Heat Exchanger

A lamella heat exchanger normally consists of a cylindrical shell surrounding a number of heat transferring lamellas.

The design can be compared to a tube heat exchanger but with the circular tubes replaced by thin and wide channels, lamellas.

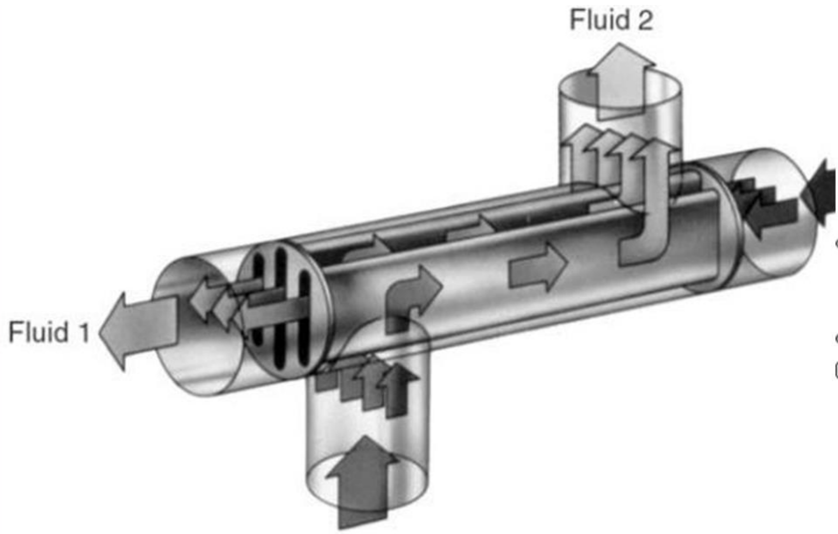
The lamella heat exchanger works with the media in full counter current flow. The absence of baffle plates minimizes the pressure drop and makes handling of most media possible.

Merits:

Since the lamella bundle can be easily dismantled from the shell, inspection and cleaning is easy.

Applications

Cooking fluid heating in pulp mills, Liquor preheaters, Coolers and condensers of flue gas, Oil coolers.



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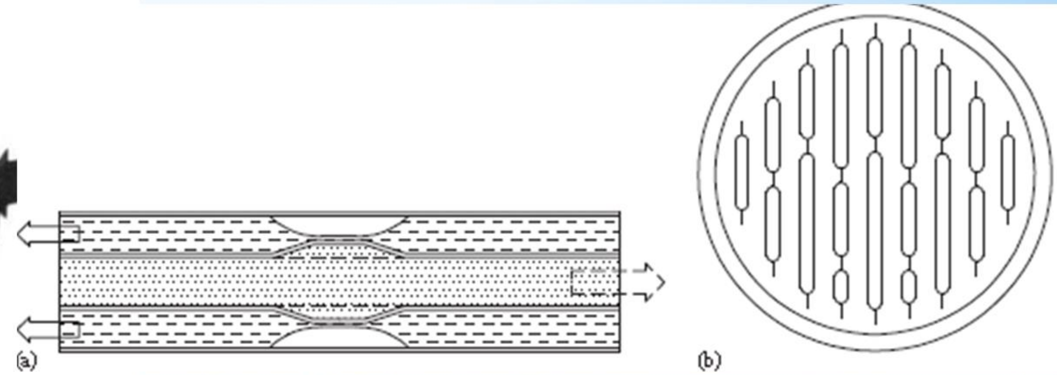

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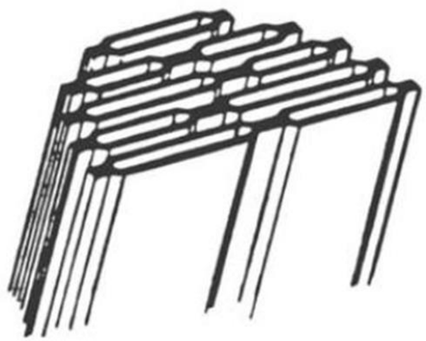

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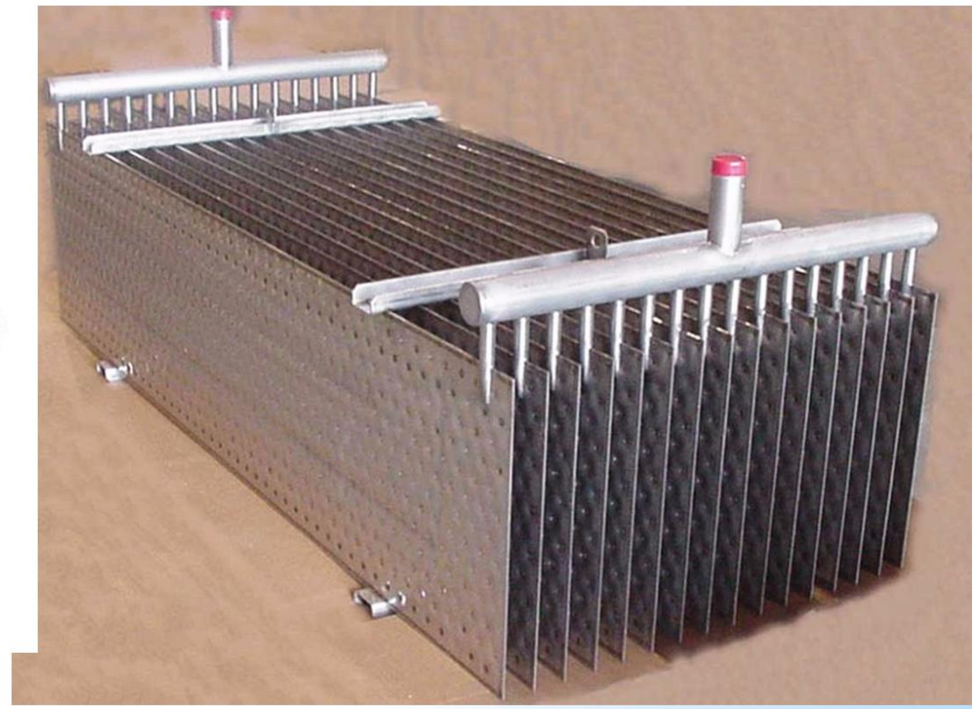


Plate fin heat exchangers

Plate fin heat exchangers (PFHEs) are a form of compact heat exchanger consisting of a stack of alternate flat plates called "parting sheets" and fin corrugations, brazed together as a block.

Different fins (such as the plain triangular, louver, perforated, or wavy fin) can be used between plates for different applications.

Plate-fin surfaces are commonly used in gas-to-gas exchanger applications. They offer high area densities (up to about 6000 m^2/m^3 or 1800 ft^2/ft^3).

Designed for low-pressure applications, with operating pressures limited to about 1000 kPag (150 psig)

Operating temperature from cryogenic to 150°C (all-aluminum PFHE) and about 700°C–800°C (1300°F–1500°F) (made of heat-resistant alloys).

1. PFHE offers superior in thermal performance compared to extended surface heat exchangers.

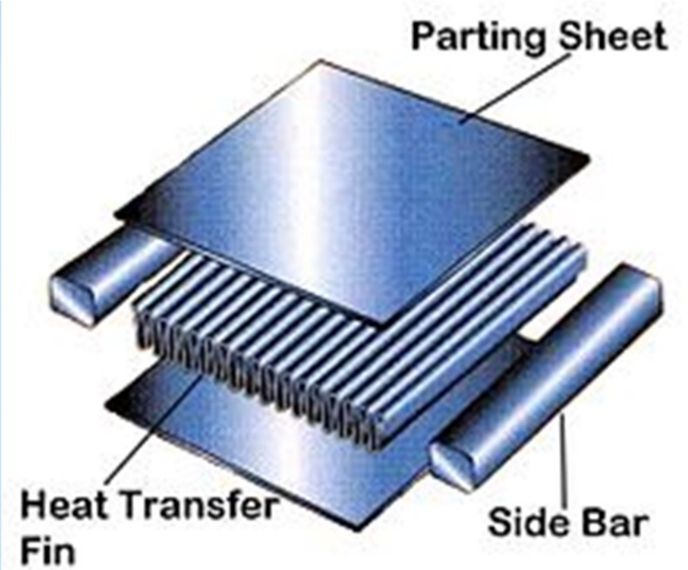
2. PFHE can achieve temperature approaches as low as 1°C between single-phase streams and 3°C between multiphase streams.

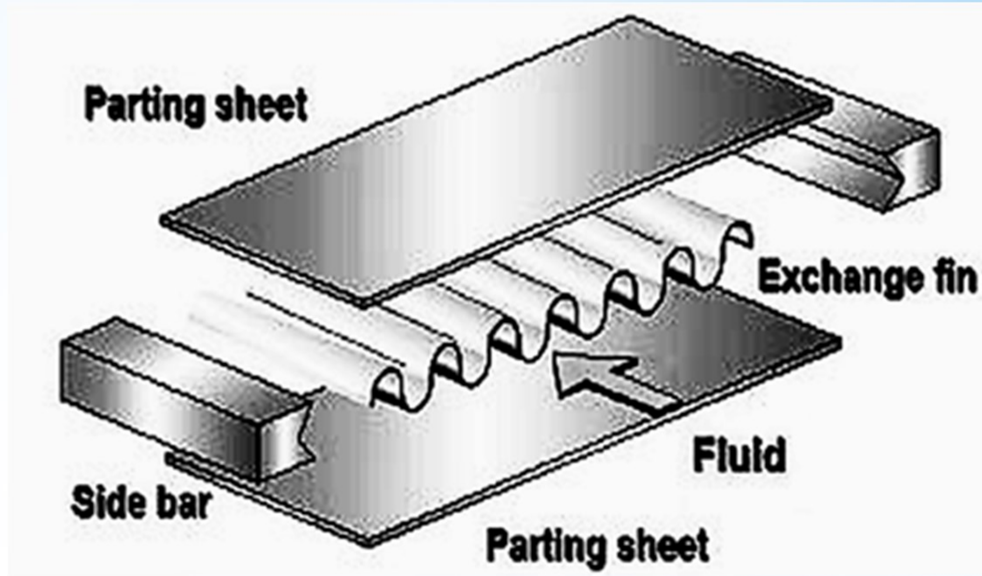
3. With their high surface compactness, ability to handle multiple streams, and with aluminum's highly desirable low-temperature properties, brazed aluminum plate fins are an obvious choice for cryogenic applications.

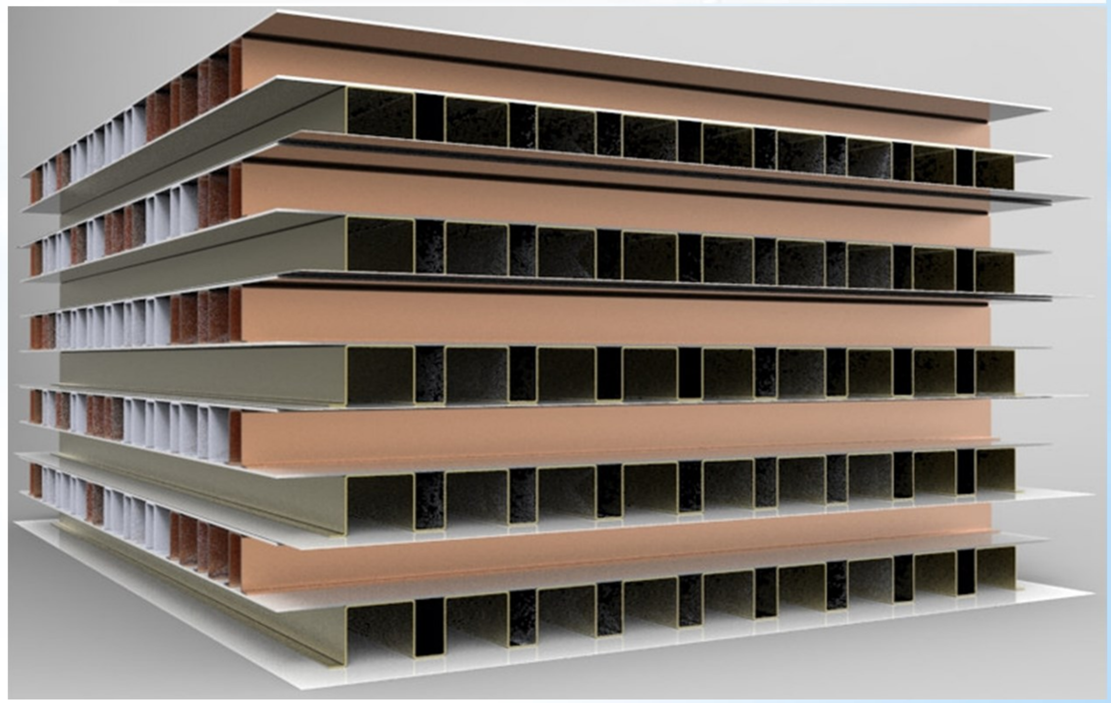
4. Very high thermal effectiveness can be achieved; for cryogenic applications, effectiveness of the order of 95% and above is common.

Limitations:

1. Narrow passages in plate-fin exchangers make them susceptible for fouling and they cannot be cleaned by mechanical means. This limits their use to clean applications like handling air, light hydrocarbons, and refrigerants.







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Finned-tube heat exchanger

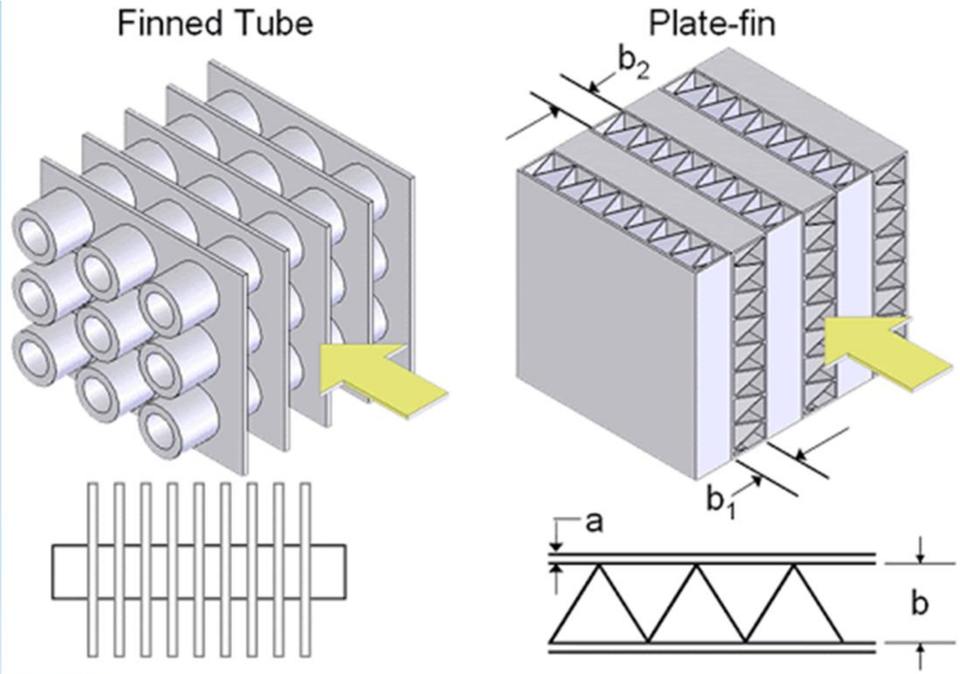
- Normal fins on individual tubes referred to as individually finned tubes.
- Longitudinal fins on individual tubes, which are generally used in condensing applications and for viscous fluids in double-pipe heat exchangers.
- Flat or continuous (plain, wavy, or interrupted) external fins on an array of tubes (either circular or flat tube).
- The tube layout pattern is mostly staggered.

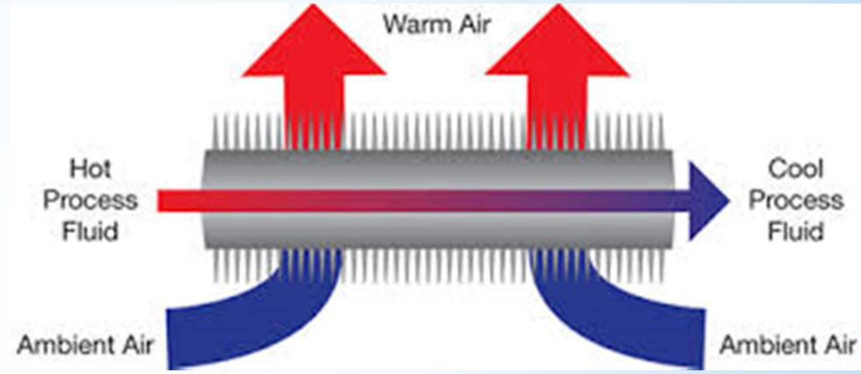
Merits:

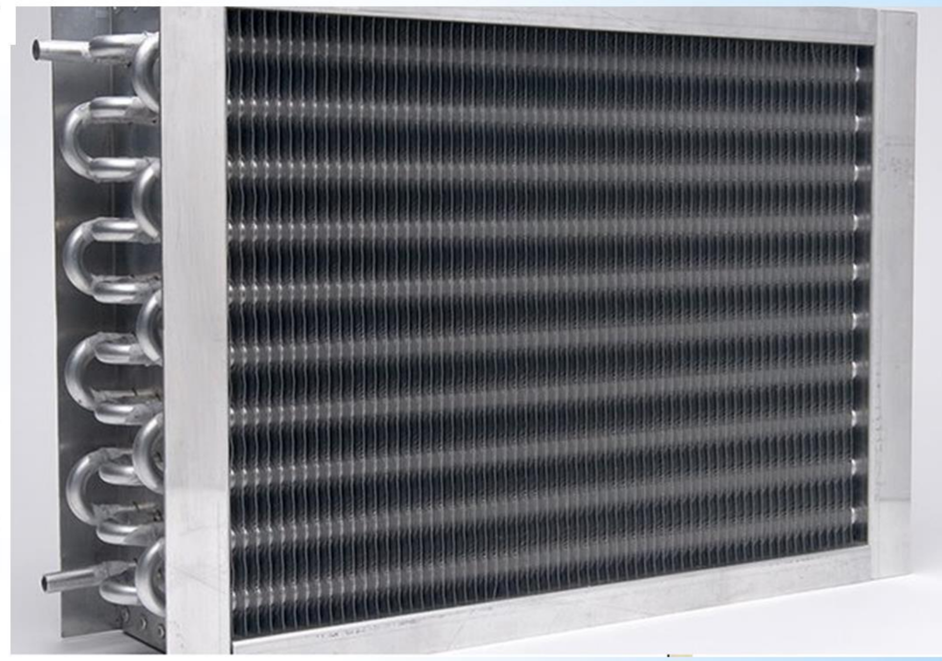
Small inventory, low weight, easier transport, less foundation, better temperature control

Applications

Condensers and evaporators of air conditioners, radiators for internal combustion engines, charge air coolers and intercoolers for cooling supercharged engine intake air of diesel engines, etc.







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Regenerative Type Heat Exchanger

The heat exchanger used to preheat combustion air is called either a recuperator or a regenerator.

A recuperator is a convective heat transfer type heat exchanger like tubular, plate-fin and extended surface heat exchangers.

The regenerator is classified as

(1) fixed matrix or fixed bed

(2) rotary regenerators.

The matrix is alternatively heated by hot fluid and cooled by the cold fluid. Features:

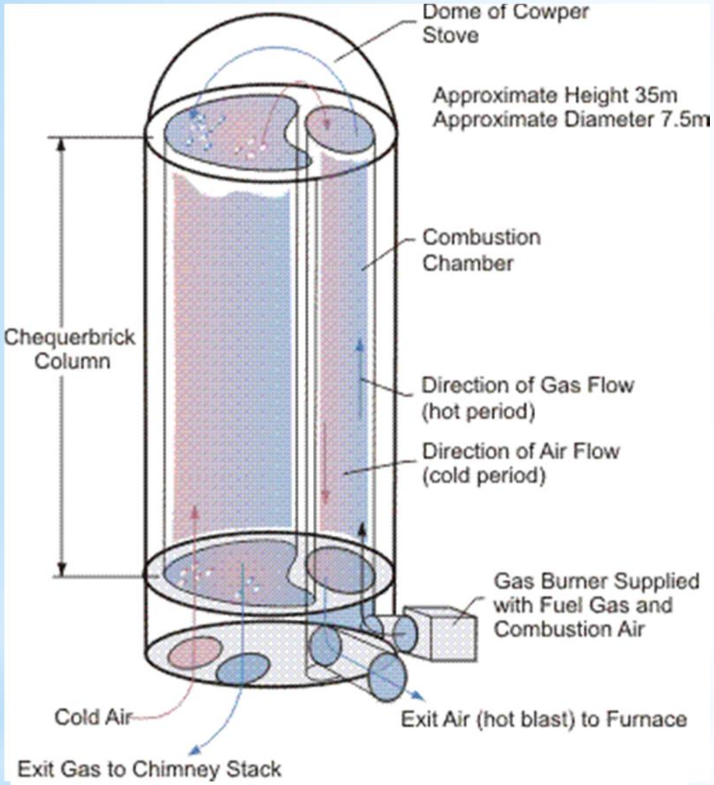
- A more compact size (β = 8800 m^2/m^3 for rotating type and 1600 m^2/m^3 for fixed matrix type).
- Application to both high temperatures (800°C–1100°C) for metal matrix, and 2000°C for ceramic regenerators for services like gas turbine applications, melting furnaces or

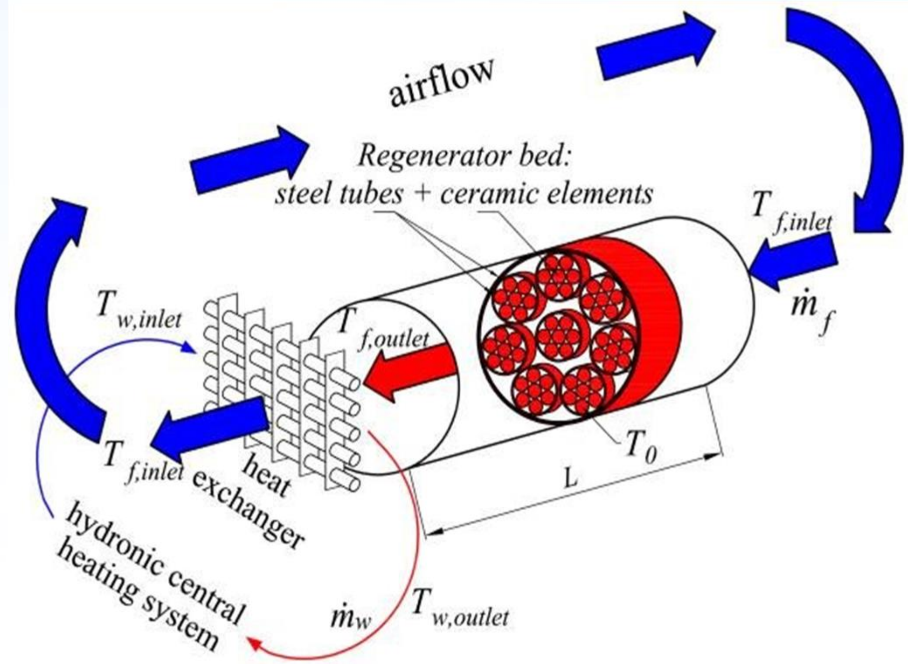
steam power plant heat recovery, and low-temperature applications like space heating (HVAC).

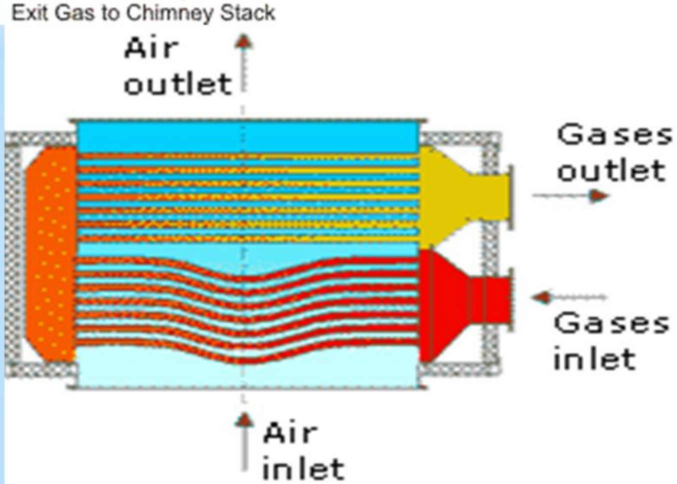
- Operating pressure of 5–7 bar for gas turbine applications and low pressure of 1–1.5 bar for air dehumidifier and waste heat recovery applications.
- The absence of a separate flow path like tubes or plate walls but the presence of seals to separate the gas stream in order to avoid mixing due to pressure differential.

Usage

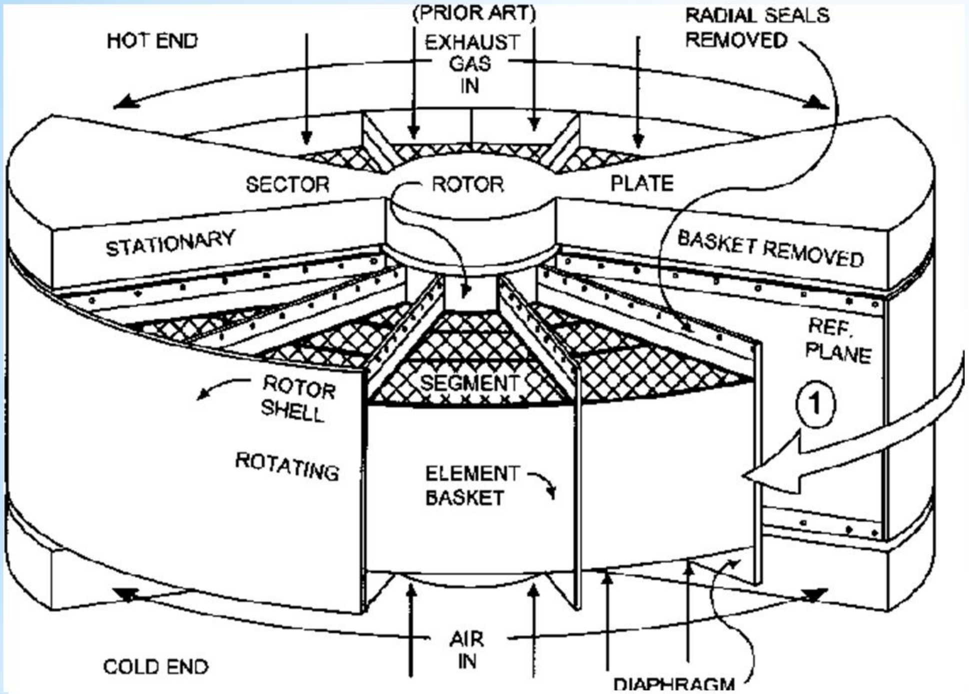
1. Reheating process feedstock.
2. Waste heat boiler and feed water heating for generating steam (low-temperature recovery system).
3. Air preheater—preheating the combustion air (high temperature heat recovery system).
4. Space heating—rotary heat exchanger (wheel) is mainly used in building ventilation or in the air supply/discharge system of air conditioning equipment.

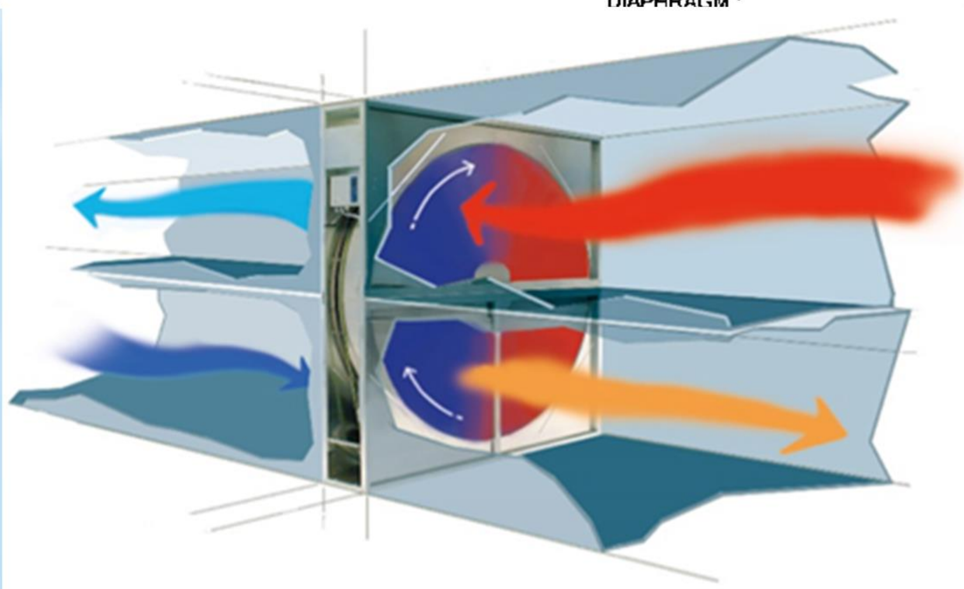

Dome of Cowper Stove
Approximate Height 35m
Approximate Diameter 7.5m
Combustion Chamber
Chequerbrick Column
Direction of Gas Flow (hot period)
Direction of Air Flow (cold period)
Gas Burner Supplied with Fuel Gas and Combustion Air
Cold Air
Exit Air (hot blast) to Furnace
Exit Gas to Chimney Stack

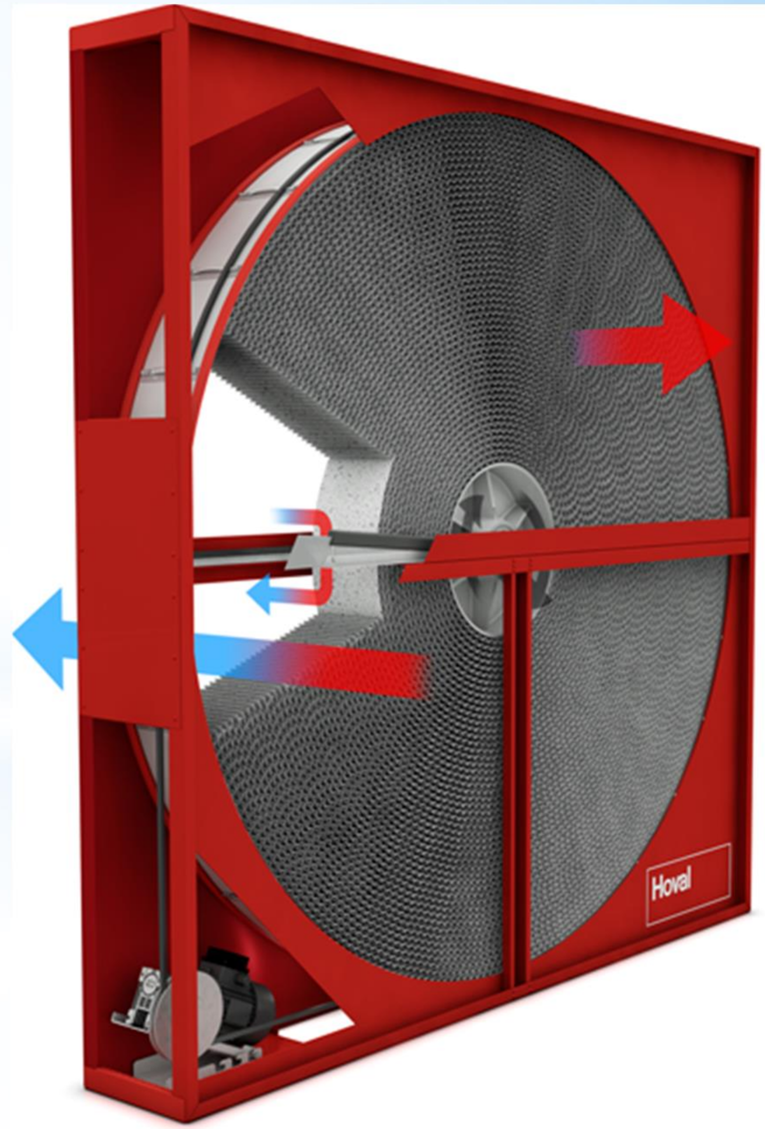

airflow
Regenerator bed:
steel tubes + ceramic elements
$T_{f,inlet}$
$\dot{m}_f$
$T_{w,inlet}$
$T_{f,outlet}$
T_0
L
$T_{f,inlet}$
heat exchanger
hydronic central heating system
$\dot{m}_w$
$T_{w,outlet}$


Air outlet
Gases outlet
Gases inlet
Air inlet


SEC







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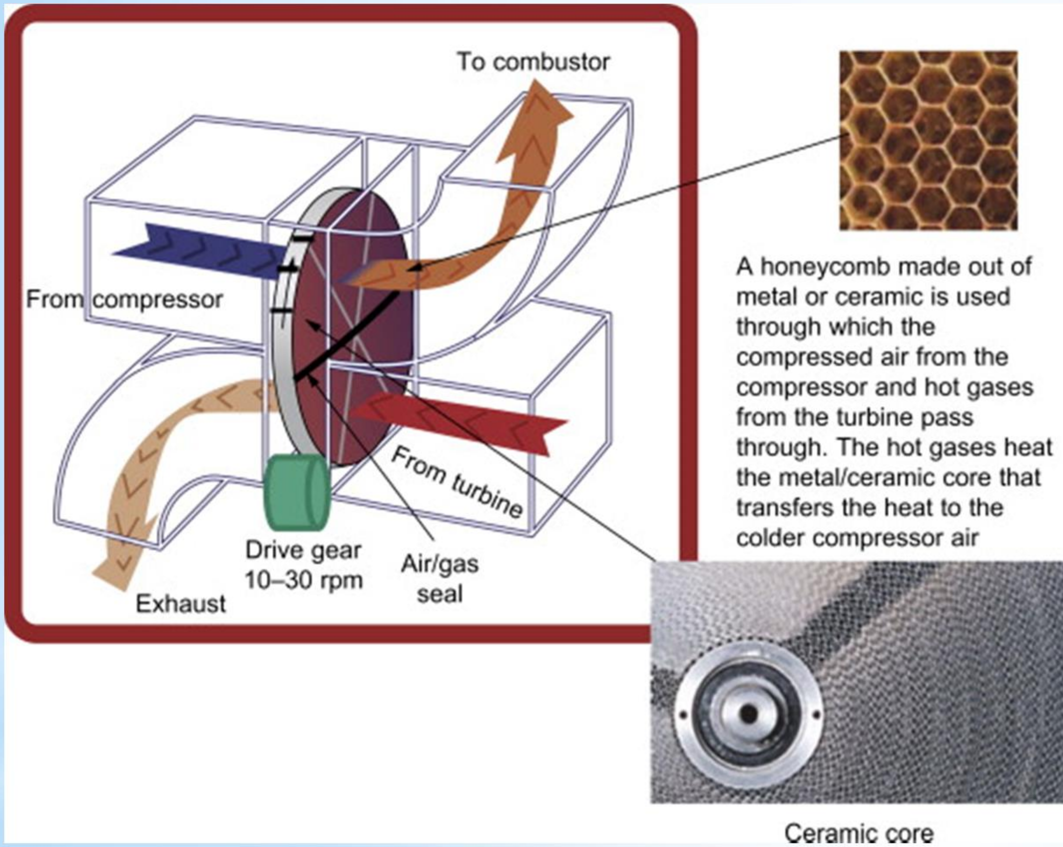
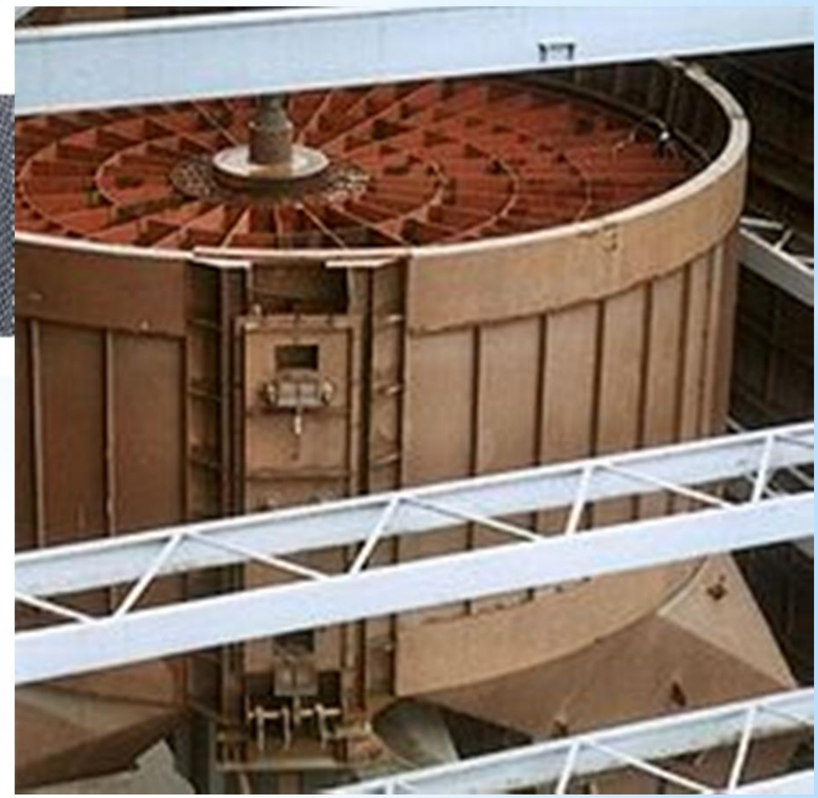

To combustor
From compressor
From turbine
Drive gear
10–30 rpm
Air/gas
seal
Exhaust
A honeycomb made out of metal or ceramic is used through which the compressed air from the compressor and hot gases from the turbine pass through. The hot gases heat the metal/ceramic core that transfers the heat to the colder compressor air
Ceramic core



SELECTION OF HEAT EXCHANGERS

The designer selects a particular type (one among the best) of heat exchanger for a given application (set of conditions) from a variety of heat exchangers.

Selection criteria are many, but primary criteria are type of fluids to be handled, operating pressures and temperatures, heat duty, and cost.

The fluids involved in heat transfer can be characterized by temperature, pressure, phase, physical properties, toxicity, corrosivity, and fouling tendency.

Operating conditions for heat exchangers vary over a very wide range, and a broad spectrum of demands is imposed for their design and performance.

The following points must be considered:

- Materials of construction
- Operating pressure and temperature, temperature program, and temperature driving force
- Flow rates
- Flow arrangements
- Performance parameters—thermal effectiveness and pressure drops
- Fouling tendencies
- Types and phases of fluids
- Maintenance, inspection, cleaning, extension, and repair possibilities
- Overall economy
- Fabrication techniques
- Mounting arrangements: horizontal or vertical
- Intended applications

Materials of Construction

For reliable and continuous use, the construction materials for heat exchangers should have a well-defined corrosion rate in the service environments.

Furthermore, the material should exhibit strength to withstand the operating temperature and pressure.

STHEs can be manufactured in virtually any material that may be required for corrosion resistance.

For example:

STHEs from nonmetals like glass, Teflon, and graphite to exotic metals like titanium, zirconium, tantalum, etc.

Compact heat exchangers with extended surfaces are mostly manufactured from any metal that has drawability, formability, and malleability.

Heat exchanger types like PHEs normally require a material that can be pressed or welded.

Operating Pressure and Temperature

- **Pressure**

The design pressure is important to determine the thickness of the pressure-retaining components.

The higher the pressure, the greater will be the required thickness and the more advantage there is to placing the high-pressure fluid on the tubeside.

The pressure level of the fluids has a significant effect on the type of unit selected.

At low pressures, the vapor-phase volumetric flow rate is high and the low-allowable pressure drops may require a design that maximizes the area available for flow, such as crossflow or split flow with multiple nozzles.

At high pressures, the vapor-phase volumetric flow rates are lower and allowable pressure drops are greater. These lead to more compact units.

In general, higher heat transfer rates are obtained by placing the low-pressure gas on the outside of tubular surfaces.

Operating pressures of the Gasketed PHEs and SPHEs are limited because of the difficulty in pressing the required plate thickness, and by the gasket materials in the case of PHEs.

The floating nature of floating-head shell and tube heat exchangers and lamella heat exchangers limits the operating pressure.

- **Temperature**

Design temperature:

The material at the design temperature can withstand the operating pressure and various loads imposed on the component.

For low-temperature and cryogenic applications, toughness is a prime requirement, and for high temperature applications the material has to exhibit creep resistance.

Temperature driving force:

The effective temperature driving force is a measure of the actual potential for heat transfer that exists at the design conditions.

With a counterflow arrangement, the effective temperature difference is defined by the log mean temperature difference (LMTD).

For flow arrangements other than counterflow arrangement, LMTD must be corrected by a correction factor, F. The F factor can be determined analytically for each flow arrangement but is usually presented graphically in terms of the thermal effectiveness S and the heat capacity ratio R for each flow arrangement.

Flow Rate

Flow rate determines the flow area:

The higher the flow rate, the higher will be the crossflow area. Higher flow area is required to limit the flow velocity through the conduits and flow passages.

The higher velocity is limited by pressure drop, impingement, erosion.

In the case of shell and tube exchanger, by shell side flow-induced vibration.

Sometimes, a minimum flow velocity is necessary to improve heat transfer to eliminate stagnant areas and to minimize fouling.

Flow Arrangement

The choice of a particular flow arrangement is dependent upon Required exchanger effectiveness,

Exchanger construction type,

Upstream and downstream ducting,

Packaging envelope, and other design criteria.

Performance Parameters: Thermal Effectiveness and Pressure Drops

Thermal effectiveness:

For high-performance service requiring high thermal effectiveness, use brazed plate-fin exchangers (e.g., cryogenic service) and regenerators (e.g., gas turbine applications),

Use tube-fin exchangers for slightly less thermal effectiveness in applications,

Use shell and tube units for low-thermal effectiveness service.

Pressure drop:

Pressure drop is an important parameter in heat exchanger design.

Limitations may be imposed either by pumping cost or by process limitations or both.

The heat exchanger should be designed in such a way that unproductive pressure drop is avoided to the maximum extent in areas like inlet and outlet bends, nozzles, and manifolds.

Fouling Tendencies

Fouling is defined as the formation on heat exchanger surfaces of undesirable deposits that impede the heat transfer and increase the resistance to fluid flow, resulting in higher pressure drop.

The growth of these deposits causes the thermohydraulic performance of heat exchanger to decline with time.

Fouling affects the energy consumption of industrial processes.

Compact heat exchangers are generally preferred for non-fouling applications.

In a shell and tube unit, the fluid with more fouling tendencies should be put on the tube side for ease of cleaning.

PHEs and spiral plate exchangers are better chosen for fouling services. The flow pattern in PHE induces turbulence even at comparable low velocities; in the spiral units, the scrubbing action of the fluids on the curved surfaces minimizes fouling.

Philips ROD baffle heat exchanger,

TWISTED TUBE® heat exchanger,

Helixchanger® heat exchanger or

EMbaffle® heat exchanger

Improve flow velocity on shell side, enhance heat transfer performance and reduce fouling tendencies on shell side.

Types and Phases of Fluids

The phase of the fluids within a unit is an important consideration in the selection of the heat exchanger type.

Various combinations of fluid phases dealt in heat exchangers are liquid–liquid, liquid–gas, and gas–gas.

Liquid-phase fluids are generally the simplest to deal with. The high density and the favorable values of many transport properties allow high heat transfer coefficients to be obtained at relatively low-pressure drops.

Maintenance, Inspection, Cleaning, Repair, and Extension Aspects

For example, the pharmaceutical, dairy, and food industries require quick access to internal components for frequent cleaning.

Some of the heat exchanger types offer great variations in design, this must be kept in mind when designing for a certain application.

Spiral plate exchangers can be made with both sides open at one edge, or with one side open and one closed. They can be made with channels between 5 and 25 mm wide, with or without studs.

STHE can be made with fixed tube sheets or with a removable tube bundle, with small- or large-diameter tubes, or small or wide pitch.

A lamella heat exchanger bundle is removable and thus fairly easy to clean on the shell side. Inside, the lamella, however, cannot be drilled to remove the hard fouling deposits.

Gasketed PHEs are easy to open, especially when all nozzles are located on the stationary end-plate side. The plate arrangement can be changed for other duties within the frame and nozzle capacity.

Repair of some of the shell and tube exchanger components is possible, but the repair of expansion joint is very difficult. Tubes can be renewed or plugged.

Repair of compact heat exchangers of tube fin type is very difficult except by plugging of the tube. Similar problem occur in the plate-fin exchanger here, repairing is generally very difficult. And extension of these units for higher thermal duties is generally not possible.

All these drawbacks are easily overcome in a PHE. It can be easily repaired, and plates and other parts can be easily replaced. Due to modular construction, PHEs possess the flexibility of enhancing or reducing the heat transfer surface area, modifying the pass arrangement, and addition of more than one duty according to the heat transfer requirements at a future date.

Overall Economy

There are two major costs to consider in designing a heat exchanger:

the manufacturing cost and the operating costs, including maintenance costs.

In general, the less the heat transfer surface area and less the complexity of the design, the lower is the manufacturing cost.

The operating cost is the pumping cost due to pumping devices such as fans, blowers, and pumps.

The maintenance costs include costs of spares that require frequent renewal due to corrosion, and costs due to corrosion/fouling prevention and control.

Fabrication Techniques

Fabrication techniques are likely to be the determining factor in the selection of a heat transfer surface matrix or core.

They are the major factors in the initial cost and to a large extent influence the integrity, service life, and ease of maintenance of the finished heat exchanger.

For example:

Shell and tube units are mostly fabricated by welding, plate-fin heat exchangers and automobile aluminum radiators by brazing, copper–brass radiators by soldering, most of the circular tube-fin exchangers by mechanical ass

Choice of Unit Type for Intended Applications

According to the intended applications, the selection of heat exchangers will follow the guidelines given in Table 1.2.

Table 1

Choice of Heat Exchanger Type for Intended Applications

Application	Remarks
Low-viscosity fluids	For high temperature/pressures, use STHE or double-pipe heat exchanger. Use PHE or LHE for low temperature/pressure applications.
Low-viscosity liquid to steam	Use STHE in carbon steel.
Medium-viscosity fluids	Use PHE or with high solids content, use SPHE.
High-viscosity fluids	PHE offers the advantages of good flow distribution. For extreme viscosities, the SPHE is preferred.
Slurries, suspensions, and pulps	SPHE offers the best characteristics. Also consider free flow PHE or wide gap PHE, or scraped surface heat exchanger.
Heat-sensitive liquids	PHE fulfills the requirements best. Also consider SPHE.

Application	Remarks
Cooling with air	Extended surface types like tube-fin heat exchanger or PFHE.
Gas or air under pressure	Use STHE with extended surface on the gas side or brazed plate-fin exchanger made of stainless steel or nickel alloys.
Cryogenic applications	Brazed aluminum plate-fin exchanger, coiled tube heat exchangers, or PCHE.
Vapor condensation	Surface condensers of STHE in carbon steel are preferred. Also consider SPHE or brazed plate heat exchanger.
Vapor/gas partial condensation	Choose SPHE.
Refrigeration and air conditioning applications	Finned tube heat exchangers, special types of PHEs, brazed PHE up to 200°C.
Air–air or gas–gas applications	Regenerators and plate-fin heat exchangers. Also consider STHE.
Viscous products, aseptic products, jam, food and meat processing, heat sensitive products and particulate laden products	Scraped surface heat exchanger.