Understanding and optimizing plate and frame heat exchanger design in HVAC systems

Quality of Design

Zero tolerance

AHRI

Alfa Laval takes pride in the integrity of its heat exchanger designs. In 1999, Alfa Laval worked with AHRI to develop a certification process for plate and frame heat exchangers (PHE). AHRI utilizes a manufacturer's configuration software to produce a heat exchanger design. Each year, they physically test a sampling of each manufacture's heat exchanger against the predicted heat load and differential pressure. A performance test is passed if the heat exchanger produces 95% of the expected heat load and 115% of the anticipated differential pressure. Alfa Laval has never failed a performance test on a gasketed heat exchangers.

AHRI CERTIFIED®
www.ahridirectory.org

Globally Recognized. Industry Respected.

Continuous innovation

Alfa Laval is constantly improving upon existing PHE technology. Recent enhancements include a newly designed plate pattern, distribution area and port. The plate corrugations control fluid distribution and turbulence within the channel. A fluid will always take the path of least resistance. Traditional plate designs allow for dead spots on the plate that are prone to fouling and where heat transfer is poor. The newly designed T-series plate pattern and distribution area recaptures the dead space and turns it into effective heat transfer area. The Omega port ensures that our driving force, dP, is used where heat transfer is occurring. These improvements create more turbulence, a higher heat transfer coefficient, less overall surface area, and reduced fouling.

Alfa Laval has also released an asymmetrical plate that has a deeper pressing depth on one side than the other. The plates can be oriented such that the fluid volume is the same for the hot and cold streams. If every other plate is rotated 180 degrees on the X axis, one channel will then be larger than the other. This development allows optimal pressure drop utilization when there are dissimilar flows, such as in domestic hot water applications.

Plate Corrugations

Innovative plate design for enhanced efficiency and performance

Minimum plate thickness

Plate thickness is driven by how a manufacturer presses its plates and the required design pressure. Master spec states that plate material must be 0.0254” before pressing. Many manufactures press their plates in multiple stages, leading to weak spots on the plate. Alfa Laval presses its plates in a single stage. In traditional HVAC applications with a design pressure of 150 psig, 0.4mm plates are suitable. At 300 psig, 0.5mm plates will be required. Thickness greater than 0.5mm are not necessary unless the system pressure is exceeds 300 psig.

Connection velocity

Target connection velocity <= 16 ft/s. If manufacturers are quoting different port sizes, connection velocities should be investigated.

Percent of dP lost in the connections

dP is the driving force that pushes the fluid through the plate pack. If too much dP is taken to get the fluid through the connection and to the first plate, there will not be enough force remaining to push the fluid through the entirety of the plate pack. To ensure proper fluid distribution, limit the %dP lost in connections to 30-35% of total dP across the hxr.

Temperature approach

The relationship between temperature approach (logarithmic mean temperature difference) and required surface area is not linear. The last couple tenths of a degree are exponentially more difficult to transfer. Opening the temperature approach by 0.1-0.2 F can greatly reduce the footprint of a PHE.

Understanding plate patterns

Plate heat exchangers utilize several different corrugation patterns. The most common are high and low theta plates. Theta describes the angle of the “V” on the plates. The more obtuse angle is the called high theta plate (H). It provides more resistance to the fluid and higher turbulence. The more acute angle is called the low theta plate (L) and produces less resistance. Turbulence translates into a higher heat transfer coefficient, less surface area, and greater fouling resistance. The plate pack is configured to optimize both heat transfer and pressure drop utilization.

Best design practices

Proactive performance design

Turbulence

The performance of a plate and frame heat exchanger is dependent upon the turbulence of the fluid as it travels through the heat exchanger. The transition from laminar to turbulent flow occurs at a Reynolds number of 2300 and is directly proportional to the fluid velocity. The fluid velocity through the channel is calculated by dividing the flow rate through the heat exchanger by the cross section of the “pipe” or size of the plate pack. If the cross section is increased (by adding or running two units in parallel) without increasing flow, the channel velocity and turbulence will decrease. As turbulence decreases, so do the heat transfer coefficient and wall shear stress (see Fouling). Many engineers believe excess surface area will provide a safety factor for fouling, but in a PHE, it actually increases the potential for fouling.

Fouling

Fouling factors are based on shell and tube fluid mechanics and should not be applied to PHEs. Fouling factors mathematically reduce the heat transfer coefficient. A traditional fouling factor of 0.0005 reduces an average PHE heat transfer coefficient from 1200 Btu/ft2-hr-F to 750 Btu/ft2-hr-F. Per the energy balance equation, a reduced heat transfer coefficient increases the required surface area. A larger “pipe diameter” will decrease the fluid velocity through the channel and increase fouling. If fouling is a concern, the more important parameter to maintain is wall shear stress.

Wall shear stress

Wall shear stress is the force the fluid exerts on the plate wall to keep particulates suspended in the stream so that they pass through the heat exchanger; it is directly proportional to dP. The target wall shear stress for an open system is 50 Pa with the minimum being 35 Pa. In a typical HVAC application with dT of 10 F and 2 F approach, a wall shear stress of 50 Pa can be achieved with a dP of ~10 psi. As a secondary defence against fouling, we recommend using mechanical filtration (see port filter). The mesh on the filter should be ~75% of the open channel spacing.

Best design practices

Proactive performance design

Impact of seasonal load

PHEs are designed to perform optimally at one set of conditions. Designing a PHE for peak load can cause operational and maintenance issues at partial load. A typical HVAC cooling load is <= 65% for 85% of the year. The relationship between actual flow and calculated dP is inversely squared. At 50% load, the calculated dP will be ¼ of the max allowable. At 25% load, the dP will be $^{1}/_{16}^{th}$ of the max allowable. A heat exchanger designed for a max allowable dP of 10 psi will operate at < 4.2 psi for most of the year. If the system is open, fouling should be considered at partial loads. As a heat exchanger fouls, pumping costs increase and inevitably the heat exchanger will need to be taken out of service to clean. We must look beyond pumping energy at peak load and consider total cost of ownership.

Minimum flow?

Minimum flow is driven by available pumping head. A heat exchanger will transfer heat regardless of the operating conditions. The primary concern at partial load is fouling. We must fully understand the quality of the fluids and range of operating conditions so that all scenarios can be analyzed. We recommend that heat exchangers be optimized for typical operating conditions. To maximize wall shear stress, it may be necessary to accept a higher dP at peak load and ensure proper filtration at low loads.

PHEs are designed to perform optimally at one set of conditions. Designing a hxr for peak load can cause operational as well as maintenance issues. There is no minimum flow for a PHE – it will transfer heat regardless of the operating conditions. The concern is fouling. We must fully understand the range of operating conditions so that all scenarios can be analyzed. We recommended that hxrs be designed for typical operating conditions. If water quality is poor, wall shear stress at lower loads must be considered. In order to maximize wall shear stress, it may be necessary to accept a higher dP at peak load and/or ensure proper filtration is in place.

Best design practices

Proactive performance design

Features and benefits

Many of the other changes that Alfa Laval has made allow the PHE to be serviced more easily/effectively:

- **ClipGrip gaskets** - the gaskets do not tangle as easily and are less cumbersome to install/replace
- **Swing feet** - simpler to pull PHE and less prone to jamming
- **Roller bar on the pressure plate**
- **Five-point alignment system**
- **Bearing boxes on tightening bolts**

Optional features

- **Insulation** to reduce condensation on the exterior of the unit
- **Port filter** for poor water quality. Requires inspection ports on frame plate.
- **Cleaning in Place (CIP)** portable cleaning module

Alfa Laval insight features

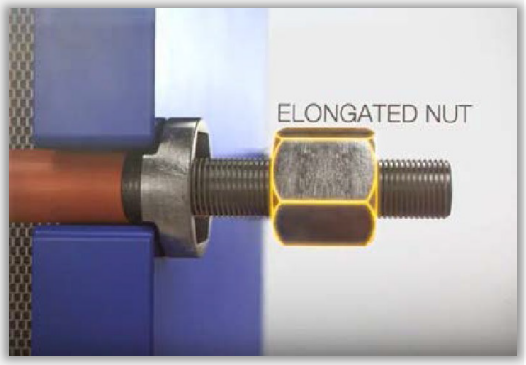
Frame related features – Click each image to view a video

Bearing box

- Ball bearing inside – reduce friction
- Possible to open & close PHE on 4 tightening bolts only (6 on large PHEs)
- Faster maintenance – reduced maintenance cost
- Less risk of paint damage on frame plate – reduce spare cost

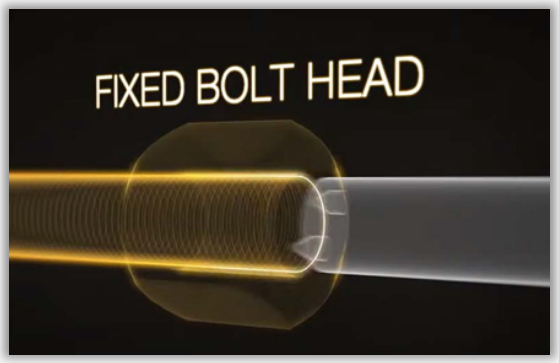
Elongated nut

- Reduced risk of overheating and seizure of nut
- Trouble free service



Fixed bolt head

- Bolt is fixed to tightening bolt under any condition
- Trouble free service
- Safe to do service
- Glued designs are less reliable

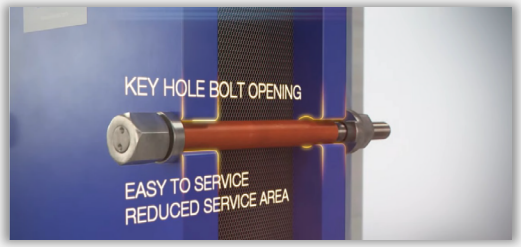


Alfa Laval insight features

Frame related features – Click each image to view a video

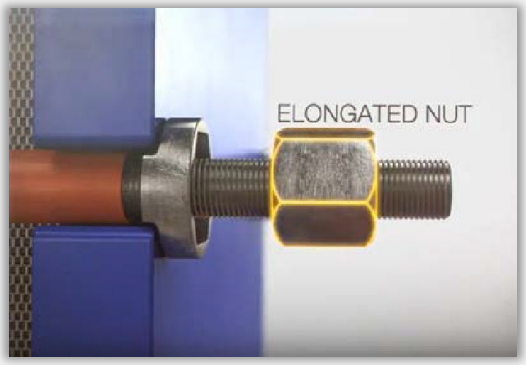
Key holt bolt opening

- Smaller foot print including service area
- Faster service – reduced maintenance cost
- Bolt holes closed from the side are standard on some other manufacturers GPHEs



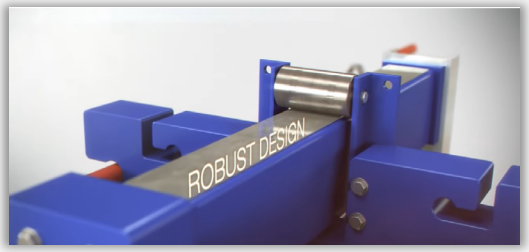
Lock washer

- The tightening bolt can be opened & closed from one side (no rotation)
- Faster maintenance – reduced maintenance costs
- Reduces risk that the tightening bolts fall out – safety
- Many other manufacturers deliver the bolts with standard flat washer



Pressure plate roller

- High quality steel– reduced risk of corrosion
- Steel and not plastic – reduced risk of breakdown
- Faster service – reduced maintenance cost
- Many other manufacturers rollers corrode

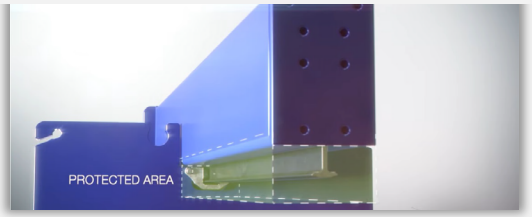


Alfa Laval insight features

Frame related features – Click each image to view a video

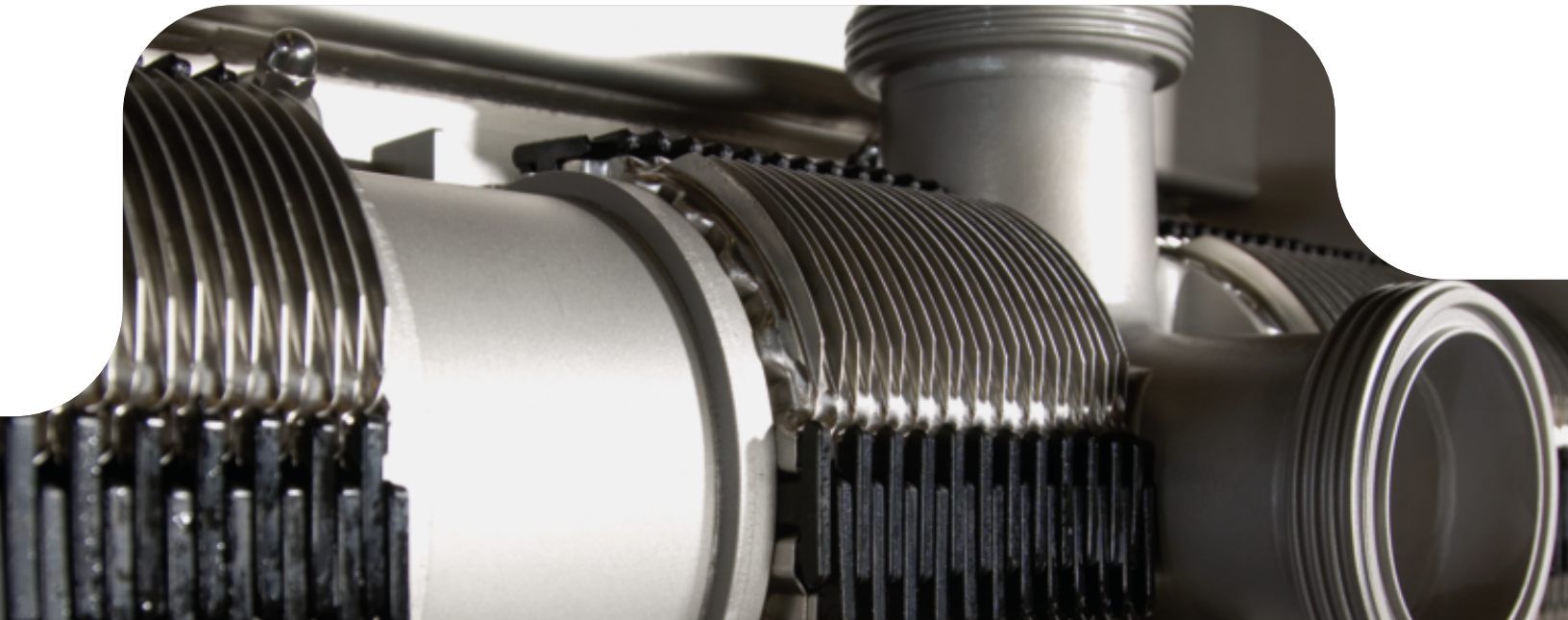
Pressure plate roller on T-bar

- No corrosion on metal roller or T bar
- – reduced maintenance cost
- Roller protected under carrying bar
- Fits in areas with limited space because of lower height



Tightening bolt cover

- Reduced risk of corrosion & stuck tightening bolts
- The nut is locked in the lock washer & the lip prevents it from rotation
- Faster maintenance – reduced maintenance cost
- Longer life time of tightening bolts – reduced spare costs
- Many other manufacturers delivers without bolt protection

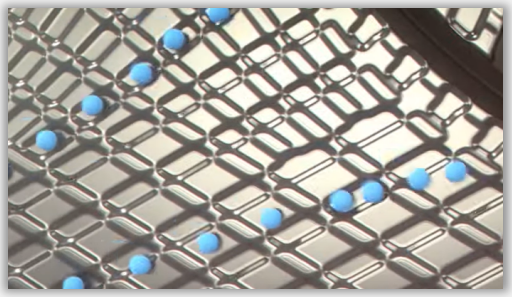


Alfa Laval insight features

Frame related features – Click each image to view a video

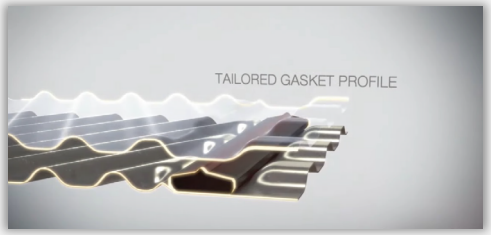
Distribution area chocolate pattern

- Avoid maldistribution and fouling build up
- Lowest possible pressure drop
- Maximization of heat transfer area
- SA



Gasket profile

- Gasket profile tailored to fit the plate type and thickness – longer lifetime of gaskets and plates



Leak chamber

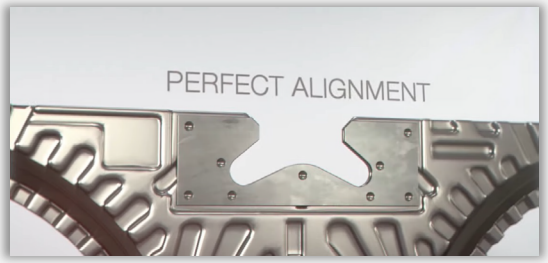
- Early leak indication – minimize intermixing of fluids
- Avoids corrosion on plate – reduce spare parts

Alfa Laval insight features

Frame related features – Click each image to view a video

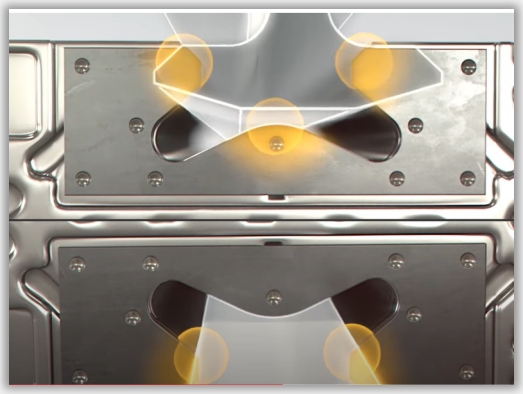
Reinforced hanger

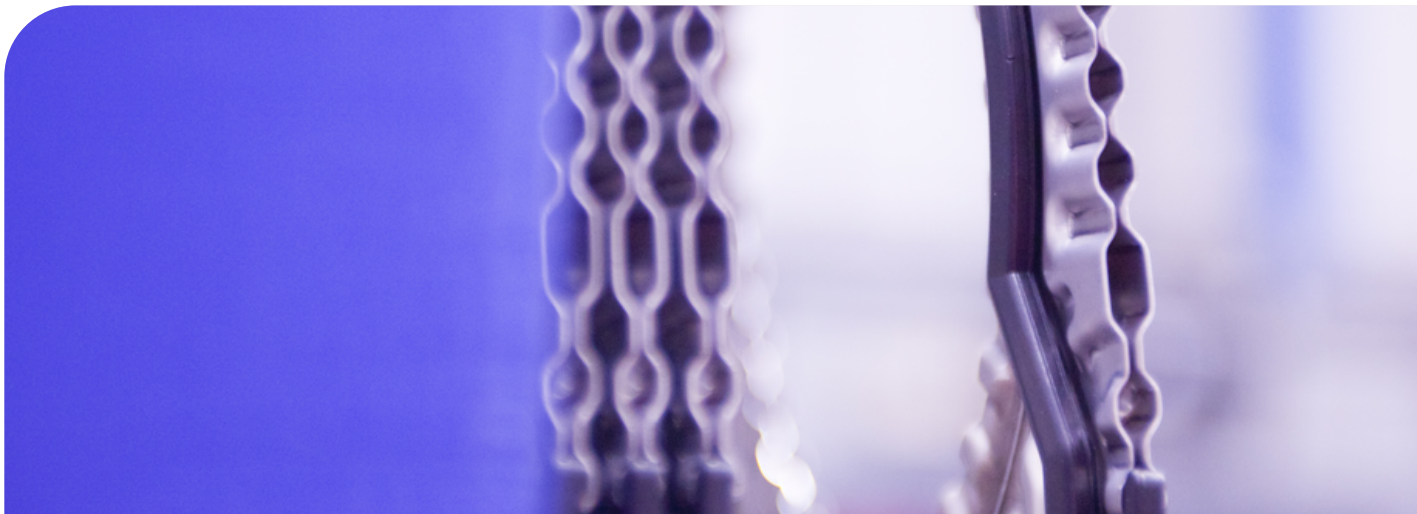
- Perfect alignment
- To avoid plate damage
- Easy to service



Five point alignment

- Five contact points between the plate and the carrying and guiding bar.
- This system ensures a perfect alignment of the plate pack, and facilitates the retightening of the plates after maintenance
- Plates perfectly in place during the critical closing procedure of the plate heat exchanger
- Exact fit – no snaking or leak





Keys to efficient heat transfer

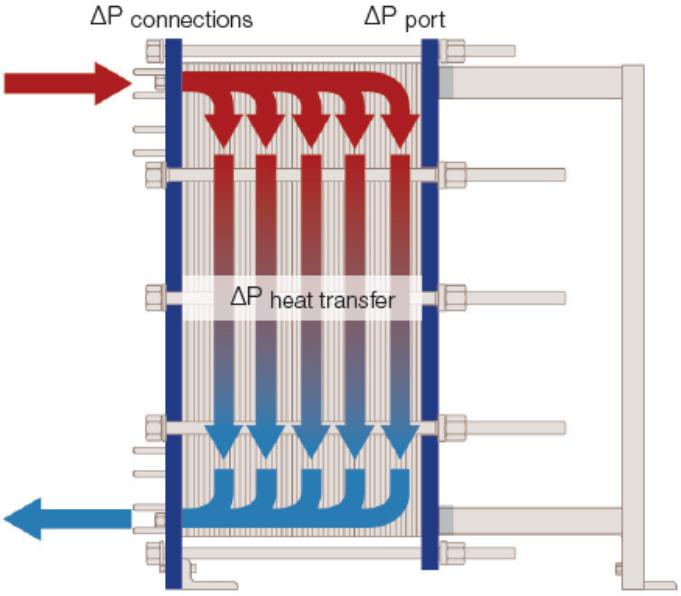
Performance is better than surface area

OmegaPort™

Noncircular port holes

Enhances media flow and thermal efficiency.

- Avoids shortcuts in plate pack.
- Pressure drop better utilized for heat transfer.

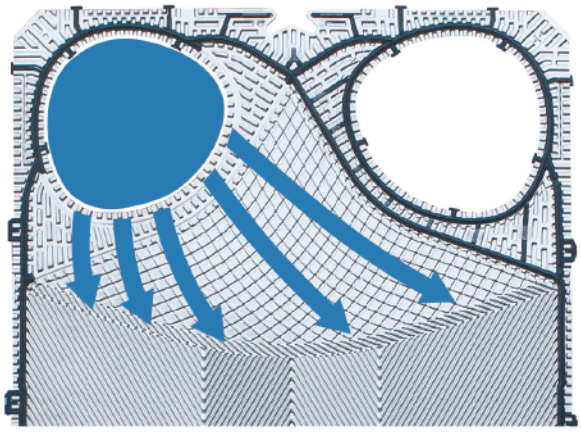


FlexFlow™

Plate design

Improves thermal efficiency and optimizes pressure drop utilization.

- Perfect for applications with unequal flows.
- Both channels stay clean longer.

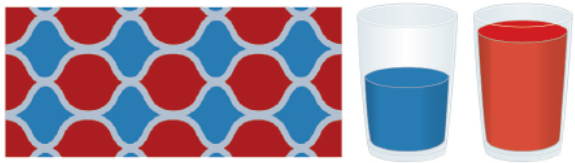


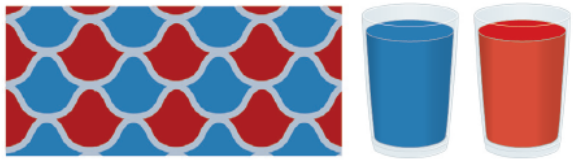
CurveFlow™

Distribution area

Improves media flow and minimizes the risk of fouling.

- Fully utilizes available surface area.
- Provides perfect distribution inside channel, unit stays clean longer.





Discover how Alfa Laval's innovative plate design can enhance heat transfer performance and reduce maintenance costs.

Contact us for a consultation today!