ALFA LAVAL PCHE & HYBLOC

Installation, Operation and Maintenance Manual

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1. Introduction

1.1 General Description

A PCHE (Printed Circuit Heat Exchanger) is a compact plate type heat exchanger. It typically consists of a heat exchanger core to which distribution assemblies are welded.

The heat exchanger core is comprised of metal sheet plates which have fluid flow channels chemically etched into them. After etching, the metal sheet plates are stacked on top of each other and then diffusion-welded together to form a solid block of metal. Depending on the required heat transfer area, several blocks can be manufactured and then welded together to form a complete heat exchanger core.
For Hybloc type of PCHE, the header boxes are inside the of the core block and one will only see the connections or threaded holes. Hybloc does not use multiblock construction.

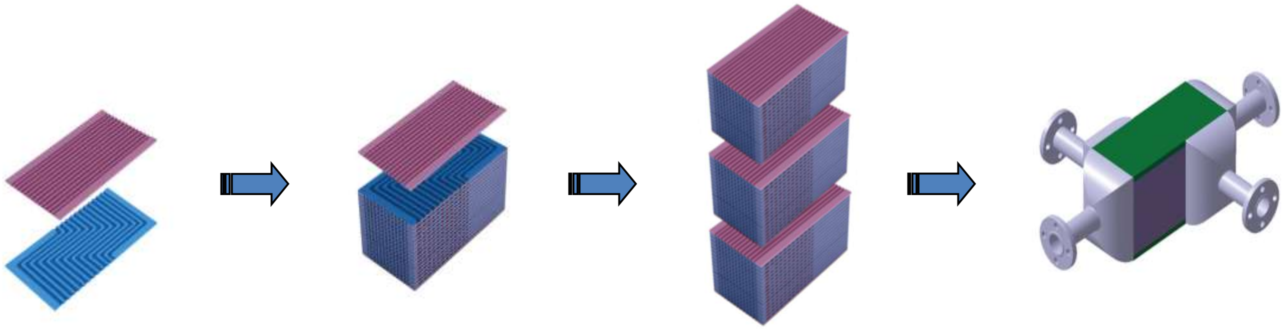
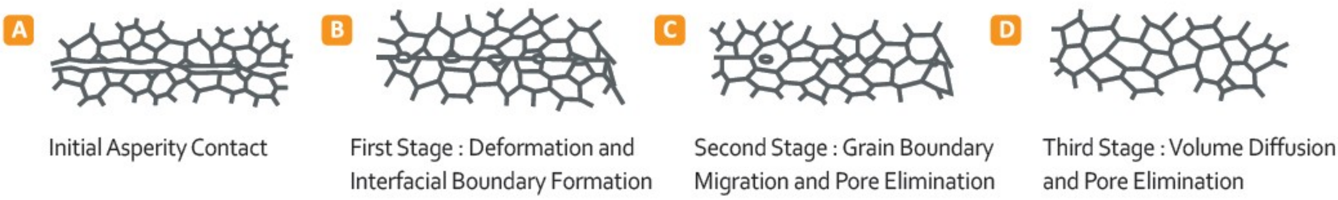


Figure1: PCHE manufacturing process

A few words about diffusion Welding…

Diffusion welding is a solid-state welding process wherein the principal mechanism of joining is movement of grain boundaries across the interface of the plates. No welding or brazing consumables are used.

Unlike traditionally welded and brazed products, diffusion-welded components have the same physical and mechanical properties as the base material.



After the core is manufactured, distribution assemblies are welded to it via traditional welding methods. The assemblies typically consist of a nozzle welded to a distribution header. The nozzles can be provided as stub ends or with flanges to enable connection of the pipework.

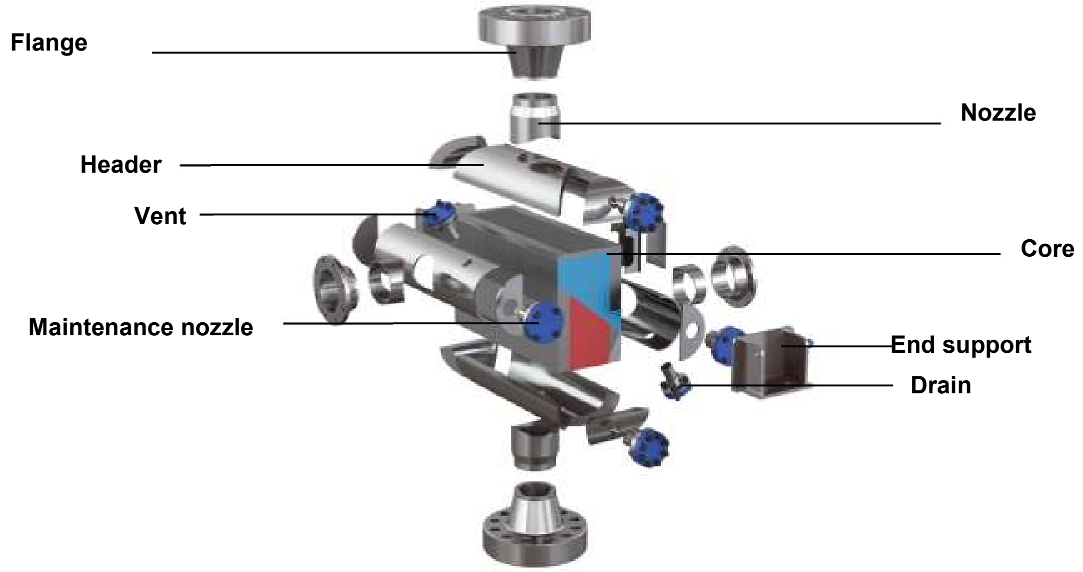


Figure 1. Exploded view of typical PCHE.

Figure 2.1. View of a typical Hybloc

PCHEs are custom designed for each application and heat transfer duty. The design form or shape may be different to the depiction in the figure above. Please refer to the General Arrangement (GA) drawing for the project specific PCHE design.

In the case of figure 2.1 a typical Hybloc Is depicted. Please also refer to the drawing for more details.
Hybloc is a special design PCHE that is specifically designed for use inside a hydrogen refuelling station and that is mounted inside a hydrogen dispenser. Hyblocs are the typically

bloc shaped, and the connections are mounted directly onto the bloc. The headers are part of the plate pack and therefore not mounted on the outside of the unit.

Specific process or design conditions may result in the substitution of external headers with internal distribution ports in the core. Where internal ports are used, nozzles are welded directly onto the heat exchanger core.

PCHEs are also supplied with lifting lugs, a nameplate (see *Appendix 1*), earthing bosses and supports. Supports are normally end-type but may be designed as saddle-type or others depending on project requirement.

Vents, drains and maintenance nozzles can be provided. Vents and drains facilitate adequate venting and draining of the exchanger. Maintenance nozzles are attached to header ends for effective cleaning, to remove fouling or clogging.

1.2 Design Codes & local regulations

PCHEs are designed and manufactured in accordance with a Pressure Vessel Code (typically ASME Sec. VIII Div. 1) and for defined working conditions. The minimum and maximum design conditions are noted on the pressure vessel nameplate (see *Appendix 1*).

The design and manufacture of the PCHEs are in accordance with Alfa Laval's Quality Management System, which is certified to ISO 9001.

PED & Risk analysis

All units delivered in the EEC (European Economic Community) follow the PED (Pressure Equipment Directive) with a level of risk depending on parameters such as nature of the fluid (gas, liquid, steam, fluid vapour pressure), and the danger level of the fluid, Design Pressure, Volume of each circuit or Design temperature.
These parameters will determine a PED Category to which is linked to a risk analysis as per the PED. Make sure that the category of your unit matches your operating conditions.

1.3 Function and Duty

A PCHE is a compact plate type heat exchanger with a high heat transfer area per unit volume. Compared to other heat exchanger technologies such as shell-and-tube heat exchangers, PCHEs are significantly smaller. Typical applications for PCHEs include cooling, heating, evaporating and/or condensing of relatively clean fluids, high temperature and pressure applications, high pressure gas processing, compact reactors, compact recuperators for gas turbines, re-liquefaction units…

Each application, or duty, requires a specific installation which must be in conformity with the PCHE Data Sheet and General Arrangement (GA) drawing of the unit.

- **Pressure and temperature limits**
  Never operate the PCHE outside of the limits (design pressure and design temperature) indicated on the nameplate (*see Appendix 1*).

- **Duty**
  To ensure optimal efficiency, it is strongly recommended to operate your PCHE as close as possible to the conditions and the fluids used initially for designing the heat exchanger.

- **Corrosion risk**
  The contact materials of the PCHE are stainless steel (either AISI 304 or AISI 316 grades). The media passing through the unit and the operating temperatures should be in line with what the used stainless grade can handle, the customer is responsible for preventing corrosion by safeguarding operations.

  Special attention shall be given to the chloride content of the streams, as this is a frequent cause of corrosion of stainless-steel materials.

If not otherwise agreed with Alfa Laval, responsibility regarding the duty or cleaning medium, and checking its compatibility with the materials used in the heat exchanger is with the customer or contractor. The quality of medium can considerably affect the operation and lifetime of the heat exchanger.

- **Applicability of specific conditions (on request only)**
  Specific allowable external loads (nozzle loads, wind, seismic…) can be calculated on request. It is customer's responsibility to inform Alfa Laval about these specific conditions to make sure that the design of the PCHE is suitable with these specific conditions. Check on the General Arrangement drawing and/or on the calculation note which specific conditions can be applied on your Alfa Laval PCHE.

- **Cyclical duty**
  PCHE heat exchangers are very strong by design and can handle severe conditions. In a cyclic service it can be requested that the unit must be capable to withstand a certain number of cycles (thermal and/or mechanical cycles). It is recommended that the user provides the manufacturer with data relating to the cyclic conditions up front of an order award. Cyclic duty data prognosis will allow the manufacturer to evaluate the suitability of the design of the PCHE with such conditions. As an option the manufacturer can also supply a thorough Fatigue analysis report.
  The theorical number of cycles can be found on the General Arrangement drawing or a dedicated notice describing the cycling conditions.

- **Utilities (recommendations in case of water-based coolant)**
  If the application uses a water-based coolant on the cold side, there are specific requirements that need consideration early in the project during design of the coolant system, and later during operation of the coolant system.

  Typical descriptions given to water-based utilities used within PCHEs are inhibited fresh water, closed-loop cooling medium or glycol water of varying concentration.

  Although the name may vary, recommendations for the utility fluid chemistry are as follows:
    - Use of corrosion inhibitors appropriate to the expected operating temperature range in service
    - Low chloride level (up to 500 ppm where oxygen scavenger is present)
    - Low salinity and hardness
    - Alkaline pH (pH 9-10)
    - Low oxygen level (<0.2 ppm using additives)
    - Non-scaling throughout its expected operating temperature range

  Permanent, operating strainers are recommended for use in these applications; please refer to Section 2.10 and 4.2.1 for information about strainers.

2. Installation

2.1 General requirements and precautions

Personnel protection should be considered, and appropriate warning signage put in place to make sure that no one can touch the PCHE once in operation (risk of personnel injury). If also required, to avoid heat loss, suitable insulation or a cold box is recommended. Significant heat loss affects the performance of the PCHE and may influence the temperature of the fluids. Alfa Laval can provide clips for installation of insulation or personnel protection.

Similarly, for cryogenic or very cold services, thermal breaks should be installed between the PCHE support and its installation frame/foundation. Insulation is also recommended to prevent condensation or ice formation.

Safety device shall be installed by the user to protect the PCHE against over-pressure.

Alfa Laval does not supply safety devices with PCHE: they must be incorporated with the pressure relief device of the system by the customer. Ensure that the pressure relief device is installed in the mating pipework and that there is no dangerous discharge of pressure relief blow off.

2.2 Site Preparation

The unit is supplied with supports that can be bolted on to a frame, a foundation or others; these are project-specific, and the relevant project-specific drawings should be referred to for method of installation. The installation method must be able to withstand the entire weight of the unit once filled with liquid. The weight and dimensions are shown in the GA drawing.

The PCHE's maximum allowable nozzle loads have been calculated as specified on the GA drawing. Do not exceed these loads as it may cause damage and deformation to the heat exchanger. Heavy on-site piping systems may need additional support to ensure the loads are not exceeded.

2.3 Receiving

Upon initial delivery, check the packing list to ensure all items have been delivered as expected and inspect the nameplate (see *Appendix* 1) to ensure the information (material, design conditions, etc.) complies with the order.

Upon delivery, remove the protective coverings.

Before throwing away the packaging accordingly to the applicable local regulations regarding the protection of the environment, verify that it does not contain any parts, such as spare bolts or gaskets, delivered with the equipment.

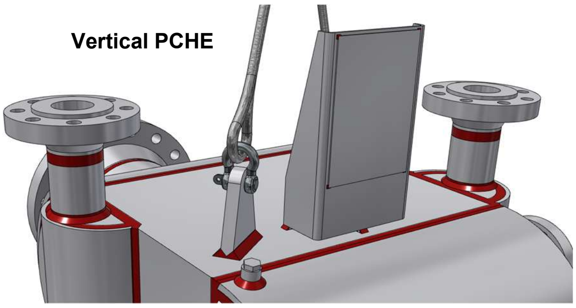
If the PCHE is shipped with nitrogen preservation (filled with nitrogen gas), before installation unlock the valve to release the nitrogen and then disassemble the blank flanges. To avoid moisture ingress, the PCHE should be installed and connected to its pipework promptly.

2.4 Handling and Lifting

The handling of the PCHE should be done by qualified and competent personnel using certified lifting equipment and by appropriate lifting means. A lifting plan should be prepared so that hazards can be identified and managed. Ensure that the capacity of the lifting means correspond to the lift weight.
When handling the PCHE, avoid physical shocks to the core, nozzles, and headers as they can cause deformation and damage its structural integrity.

Lift the PCHE using the provided lifting lugs. Never lift the heat exchanger by its nozzles.

Lifting lugs position and design are depending on how the PCHE will be installed in your process (vertically or horizontally). Use Dee-type shackles to connect to the lifting lugs and lift using slings. Where provided, reference drawings or documentation will contain information such as unit weight, lift points and centre of gravity.



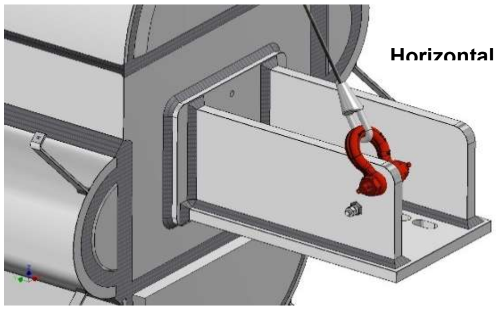
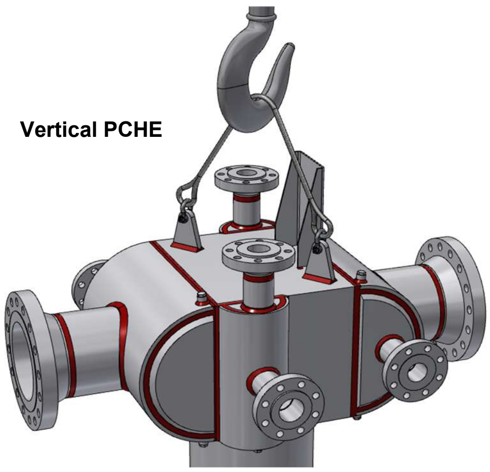


Figure 3. Dee-type shackles connected to lifting lugs for vertical unit (left) or horizontal unit (right).

The lifting load should be distributed evenly during lifting. Ensure the heat exchanger has safety landed on the intended location before removing the lifting devices.



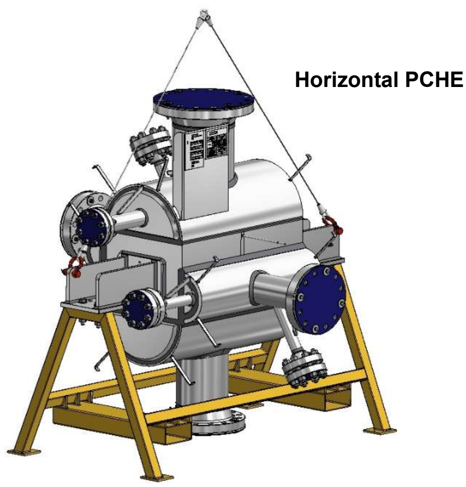


Figure 4. PCHEs with single-point lifting - vertical unit (left) or horizontal unit (right).

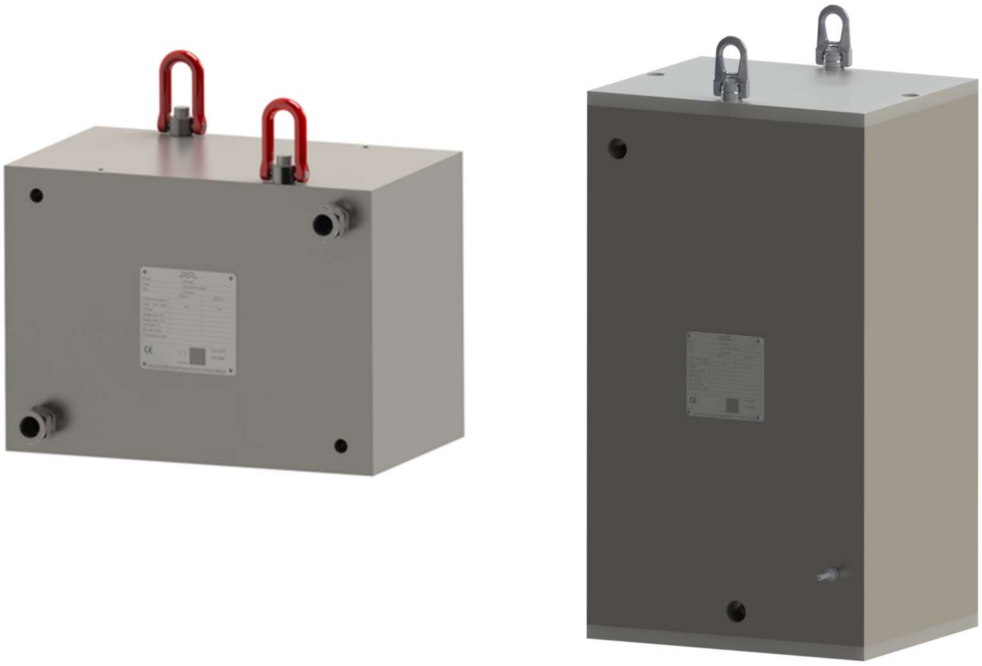


Figure 5. Hyblocs with lifting shackles attached. Single point lifting as shown in figure 4 can be applied

When lifting Hybloc or PCHE please use stainless steel shackles or lifting devices to avoid carbon steel contamination onto the stainless-steel.

For safety reasons, never stand or work under suspended loads. Maintain a safe distance from the PCHE during lifting. Relevant personal protective equipment and safety equipment should be used.

2.5 Test and Inspection

If carrying out a pressure test, the test pressures shall not exceed those stated on the nameplate (see *Appendix 1*). For routine testing, use the design pressure (unless local regulation says otherwise).

If performing a hydrotest, ensure that the test medium is drained immediately after the test. Water quality for inspection or testing should be clean, with a low chloride content (recommended content <50ppm). Never use sea water.

2.6 Installation and connection

Installation must conform with the General Arrangement (GA) drawing of the unit. The PCHE should be installed in the right direction as designed (vertical or horizontal) for optimal operation. Flow direction (inlet and outlet) and nozzles of the hot and cold side are not interchangeable. They must be connected as per the GA drawing.

Ensure there are no packing materials or other loose parts around the PCHE before installation. Where possible, prepare adequate space around the PCHE to allow easy access for maintenance and inspection.

Clean and flush all mating pipework and ensure they are drained and dry prior to hook-up. Commissioning or other debris and any scale in the piping system should be removed; see Section 2.10 for guidance on commissioning strainers.

During hook-up, ensure there is no leakage around connection points such as sensor ports, drain or vent ports, nozzles, and flanges. Piping flanges should be correctly aligned, and all connections should be correctly tightened.

All connections/nozzles are marked and should be piped accordingly. In case of doubt, check with the general arrangement drawing. Standard nozzle load limits are indicated on the General Arrangement drawing. For piping connections, Alfa Laval strongly recommends using bolting with material and gasket with properties (gasket factor / seating load). appropriate for performance required for this joint. Alfa Laval may set minimum requirements for bolting and/or gaskets for high performing joints. Where this occurs, notification will be made within the strength calculation notes provided with the product. The minimum requirements should be met under alle conditions to prevent unsafe situations from occurring.

For installation of Fuel gas preheaters and other high temperature applications we recommend torquing bolts used for the supports of the unit to a torque value of 50 N.m. This will allow the unit to adapt to the thermal changes of the system during start-up or shut down

2.7 Insulation

Depending on the service of the PCHE it is recommended to insulate the heat exchanger, if not for energy saving purposes it is also useful for personnel protection or condensation effects (cryogenic applications).

For the higher temperatures it is recommended to use mineral wool insulation or comparable insulation types, for cryogenic applications it is recommended to use foam insulation that is directly adhered to the unit to prevent condensation build-up. Consult your insulation specialists for the best insulation set-up for your application

2.8 Grounding Connection

The connection of the PCHE to Earth is mandatory prior to operation start-up. Please use the earthing bosses provided for this purpose.

2.9 Storage

The PCHE needs to be stored indoors, and the internals should not be directly exposed to air or moisture.

Prior to storage, the PCHE should be cleaned, rinsed, fully drained, and dried to avoid corrosion and to maintain its thermal performance. Connections must be closed with blind flanges, wooden covers, or plastic tape to prevent contamination.

For long-term storage, nitrogen preservation can be used to maintain dry internals and prevent rust formation. Regular visual inspection is recommended to monitor the nitrogen level and to detect any formation of rust.

If the PCHE is delivered with spare parts, these spare parts must be stored without time limitation in their original packing an in a dry indoor area. Gaskets must be stored in horizontal position.

2.10 Strainers or Filters

It is recommended to ensure that any particles or contaminants are removed from the fluid channels, and that they are prevented from entering the channels by installing the right strainers or filters to prevent clogging, fouling or erosion.

Ensure that the proper mesh size is installed. The maximum aperture opening is noted on the PCHE Data Sheet. Alfa Laval recommends installing a strainer with a mesh of channel size/2. Please note that the generated pressure drop of strainers and filters are not considered when calculating the overall performance of the heat exchanger.

Even if fluids are expected to be clean while the exchanger is in operation, in our experience, we have found that even in clean applications, debris or other foulants can be introduced during commissioning.

Therefore, it is recommended to install temporary strainers in a removable spool leg upstream of all inlets to the exchanger during commissioning. The temporary strainer can be removed after commissioning and replaced with a spool pipe, or a permanent strainer if desired.

Where there is a liquid utility fluid entering the heat exchanger, such as water, an automatic self-cleaning strainer is recommended for continuous operation. Non-automatic self-cleaning strainers, such as tee-type or bucket-type strainers, may be used instead, with potentially more frequent operational maintenance stops should the strainers need to be cleaned.

To avoid fouling due to corrosion of pipes, it is recommended that stainless steel piping is used. If carbon steel, aluminised piping or other material is used, it is highly recommended that permanent or in-service strainers be utilised, and all pipework in between the inlet strainer and the heat exchanger should be made from stainless steel.

When sizing your installation, please consider the pressure drop related to the strainer or the filter (not included in the heat exchanger pressure drop indicated on the PCHE Data Sheet).

For more information on strainer monitoring during operation, please refer to Section 4.2.1.

3. Operation

3.1 Start-Up

3.1.1 Before Start-Up

Check that the actual operating conditions do not exceed the limits noted on the nameplate (see *Appendix 1*).

The heat exchanger in operation can operate with high or very cold temperatures and with aggressive media. It is necessary to provide personnel protection measures in accordance with the applicable safety regulations and work safety codes at the customer site.

Ensure the unit has appropriate personnel protection or insulation for operator safety.

Ensure that all the blind flanges are sealed. During shipment or prolongated periods of shutdown, gaskets and/or bolting may loosen. Torque all bolts. The maintenance/service point bolts (and any vents/drains) should be tightened in a diagonally opposite sequence.

Connect the PCHE to Earth.

3.1.2 Venting

Venting can be carried out via the process nozzles or dedicated vent nozzle.

Ensure venting during the start-up process. Remaining air pockets can cause air locks, reducing the heat transfer capacity and increasing the risk of corrosion.

3.1.3 PCHE Start-up

To extend the lifetime of the unit, start-up must be gradual and smooth. Flow rate increase must be slow to avoid the risk of water hammer or fatigue effects. Rapid temperature changes can also reduce the lifetime of the PCHE.

Unless specifically recommended, the fluid that is the closest to room temperature shall be introduced first. Our recommendation is to have a temperature ramp-up lower than 180°C per hour.

It is recommended that once the flowrate reaches 100% in the side that is started up first, then the fluid in the other side can be gradually introduced. Our recommendation is to have a temperature ramp-up lower than 180°C per hour for general applications.

Temperature control valves shall be open progressively.
Commissioning is a critical period where you have the highest likelihood of process instability. Subsequently, it is recommended that the temperature control valve is set to manual to avoid/limit unstable flow (rapid temperature change) during commissioning.
In case of multi-stream design, it is recommended to start the section that is the closest to room temperature. The next section can be started up once the outlet temperatures on both sides are fully stabilized.

If the start-up temperature of the multi-stream sections are the same, the sections can be started up simultaneously.

Temperature control valves shall be open progressively.

Commissioning is a critical period where you have the highest likelihood of process instability. Subsequently, it is recommended that the temperature control valve is set to manual to avoid/limit unstable flow (rapid temperature change) during commissioning.

3.1.4 Hybloc start-up

Hybloc is a special design PCHE that was developed specifically for hydrogen refueling stations, the start-up procedures is different form that of the general PCHE applications
To extend the lifetime of the Hybloc, gradual and smooth starts and stops are generally recommended. Hybloc is designed for back-to-back refuelling of vehicles and a such the start- and stop sequence will go faster than with normal PCHE's.
The design of the unit is done in such a way that it can better handle the stresses involved.

Flow rate increase must be slow to avoid the risk of water hammer or fatigue effects. Rapid temperature changes can also reduce the lifetime of the PCHE.

Coolant flow should be stopped during idle moments so the Hybloc can return to ambient temperature. When a vehicle arrives and the hydrogen fuelling cycle starts the hydrogen flow starts first and then the coolant flow should follow. The inertia in the Hybloc will dampen the thermal shock in the Hybloc and since it is already at ambient temperature, the temperature difference will be relatively small. With this way of operating the Hybloc will have the longest life. Hybloc does not have a very big metal mass, the introduction of the coolant can be done relatively short after the hydrogen flow has started. This is necessary to deliver the right temperature hydrogen to the vehicle.

3.2 In Service

3.2.1 During Operation

The operating pressures and temperatures must not exceed the maximum or minimum design values stated on the nameplate (*see Appendix 1*).

Maintain flow rates at or near to the designed values as much as possible. Flow rates much lower than design values may result in accelerated fouling, reduced thermal efficiency or other unexpected effects. In installations with multiple units or trains in parallel, variations in capacity are best handled by varying the number of units in operation rather than by major variations in flow per unit.

The PCHE is designed to be operated with the specified fluids on the PCHE Data Sheet. Process stream compositions should be maintained for compliance with the specified process data. Should the compositions change, ensure they are stable (i.e., will not decompose over time or at the operating temperature and pressure) and suitable for use (non-reactive) with the heat exchanger material of construction.

Operate at nominal steady state; keep fluctuations within or better than +/- 5% for both temperatures and flows.

Never touch the heat exchanger directly while it is operating. Ensure personnel protective insulation is provided and do not enter within proximity of the PCHE without any protection or safety clothes.

The exchanger must not be exposed to open flame.

3.2.2 Process Control

Control equipment is not provided with the PCHE. This is generally installed later by the package builder or the plant contractor.

The control system must not introduce substantial instabilities when applying performance control to the exchanger.

A PCHE's internal metal temperature reacts very quickly to changes in conditions, such as changes in flow. This is due to its low thermal mass, a feature in common with other compact exchangers.

Temperature sensing devices and transmitters, in comparison, have a slower thermal response time. Hence, there is a time delay between the fluid's actual temperature in the conveying piping, and the measured temperature.

The control system must consider this and make allowances to be adjusted. Its response should be dampened to avoid overshooting and to prevent resulting cycling. If the control system is poorly tuned or responding too quickly, the resulting harmful instability will create thermal stresses inside the core and will shorten the expected lifespan of the heat exchanger.

3.2.3 Gas heating/cooling Applications

How to avoid thermal fatigue in gas heaters/coolers:

- **Consider the preliminary control valve controller settings carefully.**

  Review the settings early, during test and commissioning, to confirm they are suitable for long term operation. Tune the control valve. Monitor the control system for stability.

- **Avoid sudden changes in fluid flow rates or flow instabilities.**

  The control system should be tuned to avoid large amplitude, high frequency flow variation. The exchanger should be operated at nominal steady state; that is, keep fluctuations within or better than ±5% for temperature and flow, which should be readily achievable in the field.

  The paragraph above applies to nominal steady operation. Outside of that, the PCHE can withstand instantaneous flow rate changes during the brief periods of changing operating mode such as during normal start-up and shutdown, and process upsets. The recommendation for a long lifespan of the heat exchanger is to minimize these situations from occurring.

- **Install a physical minimum stop on the control valve.**

  For utility streams that have a control valve fitted, it is recommended that a minimum stop is included on the flow control valve. This stop prevents undesired full closure of the valve and flow. This can occur if the valve is not tuned.

  Minimum stops of 20-30% are recommended.

  Ideally, once operating, this stop should be raised to as high a level as possible which still allows control during operation. The flow stop is recommended to be a physical stop rather than a digital (software) limit.

  Ensure the minimum stop provides adequate coolant flow during start-up. There may be a minimum flow to ensure gas cooling to a specific temperature requirement, or minimum flow to avoid particulate settlement and wall shear.

- **Ensure coolant pressure is high enough to avoid boiling.**

  Boiling can be highly unstable, damaging the exchanger with fluctuation wall temperatures during this process. Boiling and flashing can shorten the expected lifespan of the heat exchanger considerably.

3.2.4 System Monitoring

Instrumentation is not provided with the unit. This is generally installed later by the package builder or the plant contractor.

Regular inspections should be carried out on instrumentation such as pressure transmitters, flow meters and temperature gauges to secure that they work correctly.

To ensure trouble free operation, it is recommended that the following parameters are monitored and recorded for both sides:

- Stream flow rate
- Stream inlet and outlet temperatures
- Stream pressure drop
- Control valve(s) output

Recorded measurements should be taken over a period of two hours, at intervals of 15 seconds. Raw measurements should be recorded. Do not average measurements as these can reduce peaks and troughs.

If possible, also take measurements during different operating modes. A different operating mode can be any large operational change or significant change in process conditions, including but not limited to:

- Turndown conditions
- Changes in flow
- Significant changes in gas compositions (gas application)
- Start-up / shut-down

The critical recording period is during the first 3 months of operation.

System stability should be reassessed once a year or whenever there are changes to the process. System stability should also be checked after each turnaround cycle of the plant

3.3 Shut Down

3.3.1 During Shut Down

Unless specifically recommended, flow rates on both sides should be reduced simultaneously in a slow and gradual way.

To avoid injury to operators, do not touch the unit until its external temperature is the same as the ambient temperature and make sure that the unit is depressurized before performing any maintenance.

For Hybloc the cooling fluid can be switched of when the refuelling activity is stopped (when the hydrogen flow is stopped). The Hybloc can gradually return to ambient temperatures

3.3.2 Draining

Draining can be carried out via the process nozzles or dedicated drain nozzle (when they exist).

If the planned stoppage period is of a short duration and if the unit will not be opened, the unit need not be drained to facilitate restart.

For longer stoppage periods or if the PCHE is shut down for several days, it should be drained. Draining must also be done if the process is shut down and the ambient temperature is below the freezing temperature of the fluid to prevent damage due to freezing effects.

If the fluids are hot, allow the unit to cool down to ambient temperature before draining, to prevent possible injury to operators.

Make sure that pressure has been removed on both sides before opening or draining.

Make sure toxic, hazardous, lethal vapours or liquids are not released to the atmosphere or to the ground. These could cause injury to people and/or damage to the environment. Any toxic or hazardous fluids should be treated as per local environmental, health and safety regulations.

Depending on the process fluids used, it is also recommended to clean, rinse, drain, dry the unit and put it under inert atmosphere if the shutdown is a long duration.

4. Maintenance

Before any examination requiring to be in contact with the inside of a heat exchanger, both circuits shall be drained and rinsed to avoid any risk of injury due to toxic or corrosive fluids or gasses.

4.1 Inspection

It is recommended that the heat exchanger is visually inspected at regular intervals such as during regular plant shutdowns and maintenance periods.

External inspection should check for intactness of the surface finishing (paint or other coatings) and any signs of corrosion or leakages.

Internal inspection can be used to check for signs of fouling (with borescope at the inlet of the channels via service connections).

Mandatory inspections must be achieved according to local regulations with the periodicity required by local authorities.

4.2 Fouling and Clogging

Due to the size of the fluid flow channels, the PCHE should be used with clean fluids.

If topping up utilities such as water or water-glycol mixtures, ensure that the make-up fluid is clean, and the concentration of any inhibitors are maintained as per the original specification.

Any carry-over of oil, lubricant or other foulants from upstream equipment should be minimised as far as practicable, as they will result in fouling of the heat exchanger. Fouling can cause performance loss, clogging and corrosion.

4.2.1 Strainer or Filter

Where filters and strainers are installed, they should be checked and cleaned at regular intervals to prevent clogging and to ensure optimal performance. Check-up periods will be dependent on the amount of contaminant, cleanliness of fluid, flow rate, etc.

It is recommended to visually inspect the strainers. This is mostly likely to occur during any convenient shutdown period of the process.

The pressure drop across the strainer must be monitored. It is an indicator for scheduling strainer maintenance and cleaning.

Do not allow excessive build-up of particulates in the strainer and ensure that the pressure drop does not exceed its burst pressure. If a strainer becomes so clogged that it bursts, foulant and strainer mesh parts will enter and clog the heat transfer channels, resulting in unwanted stops and expensive maintenance needs.

4.2.2 Heat Exchanger

During operation, temperatures, flow rates, and pressure drops should be checked regularly. Differential pressure drop monitoring across both sides of the heat exchanger is recommended. Increased pressure drops or falling temperatures and flow rates indicate that there is restriction and fouling inside the unit.

If the pressure drop is higher than that specified on the PCHE Data Sheet, first check that the pressure transmitter is working properly and that the flow rate is within limits. Make sure that no other equipment in your line also causes unexpected pressure drop.

Check if the control valves in the filed to see if the valve position corresponds with the real valve position.

If fouling is suspected, please contact Alfa Laval for further investigation to assess whether the heat exchanger is fouled or whether the pressure drop level is expected for the process conditions at the time operation.

If a heat exchanger becomes fouled, as part of preventative maintenance it is important to clean sooner rather than later as a heavily fouled exchanger will be more difficult to clean.

4.3 Cleaning

The more often cleaning is carried out, the better the heat transfer performance is maintained at original levels. Delaying cleaning makes the recovery of initial heat transfer performances more difficult.

While cleaning, the correct safety procedures should always be followed. Personnel shall wear protection gear and clothes before entering the cleaning area.

Install PCHE within a spill containment tray to avoid any pollution in case of run-offs during cleaning. All applicable health, safety, and local environmental code shall be followed by the operator while cleaning is carried out.

4.3.1 Gas puffing or back flushing

If fouling is not severe, gas puffing or flushing can remove light fouling or small particles which are stuck in the channels.

Gas puffing is a mechanical cleaning method that uses sudden high pressure gas depressurisation against the direction of normal flow (i.e., from outlet to inlet).

A calibrated bursting disc is located on the inlet of the exchanger. The heat exchanger is then slowly pressurised from the outlet, with nitrogen or service air, up to but not higher than either 15 barg or the design pressure of the side being cleaned, whichever is lower.

The bursting disc is calibrated to burst at no higher than 15 barg or 80% of the design pressure. When the bursting disc ruptures, particulates in the heat exchanger are expelled along with the nitrogen or service air. The procedure can be repeated several times to achieve the best results.

Cleaning by flushing involves flushing the heat exchanger with a large volume of water, either in the same direction as during operation or in the opposite direction. Flushing works best with >80% of the design flow of heat exchanger. Consult with Alfa Laval about how to determine for the gas side how to translate this in a proper flushing flow.

Water quality should be clean and non-scaling, with a low chloride concentration. Never use dirty water or sea water for flushing as they may cause corrosion inside the unit.

4.3.2 Ultra-High Pressure (UHP) Water Jetting

UHP water jetting uses high pressure water to break up and expel foulant from the internals of the heat exchanger. Fouling can be removed efficiently using this method.

UHP water jetting can be performed if the heat exchanger is fitted with maintenance nozzles, or if the process nozzle is large enough. It can be performed in-place, or the exchanger can be taken offline for cleaning. If cleaning in-place, ensure there is at least 1.5m clearance at the maintenance nozzles to provide UHP working access to direct flow into the PCHE.

UHP water jetting is a dangerous activity must therefore only be performed by authorized and qualified personnel.
Personnel shall wear protection gear and clothes before entering the cleaning area.

Before cleaning a PCHE, make sure it is empty and at atmospheric pressure.
Collect the fluid to avoid any pollution of the environment.

4.3.3 Chemical Cleaning

Fouling can usually efficiently dissolve in chemical solvents or acids. The correct chemicals shall be chosen: the selected cleaning fluid shall be compatible with, and not affect, the integrity of the heat exchanger. PCHEs are generally made from stainless steel. The material(s) of parts in contact with the fluids are indicated on the GA Drawing.

Chemical cleaning can be performed in-place (CIP) or the exchanger can be taken offline for cleaning. When cleaning, ensure that there is sufficient space for cleaning equipment.

Use an adapted container to collect the cleaning effluents.

Never use hydrochloric acid or other cleaning substances containing chlorides as their presence will inevitably lead to corrosion of stainless-steel alloy components

The chemical cleaning must be carried out by an authorized and qualified operator.

Chlorine, commonly used as a growth inhibitor in cooling water systems, reduces the corrosion resistance of stainless steels).

Chlorine weakens the protection layer of these steels making them more susceptible to corrosion attacks then they otherwise would be. It is a matter of time of exposure and concentration.

Water of more than 330 ppm chloride ions may not be used in the preparation of cleaning solutions.

Alfa Laval can provide the below cleaning agents.

LIQUID	DESCRIPTION
ALFACAUS	A strong alkaline liquid, for removing organic material like fat, oil and biological deposits.
ALFAPHOS	An acid cleaning liquid for removing inorganic material like metallic oxides, rust, lime and other inorganic scale. Contains corrosion inhibitor.
ALFANEUTRA	A strong alkaline liquid for neutralization of AlfaPhos before drainage.
ALFA P-SCALE	An acidic powder cleaner for the removal of primary carbonate scale but also other inorganic scale.
ALFA P-NEUTRA	For neutralization of Alfa P-Scale.
ALPACON DESCALENT III	A non-hazardous acidic cleaning agent for the removal of inorganic scale. Contains corrosion inhibitor.
ALPACON DEGREASER III	A non-hazardous cleaning agent for the removal of oil, grease or wax deposits. Intended for manual cleaning. Can be used with Alpacon Descalant III to avoid foaming.
ALPACON MULTI CIP II	A non-hazardous cleaning agent for the removal of oil grease or wax deposits. Intended for CIP.
ALFA ADD	A neutral cleaning strengthener designed to be used with AlfaPhos, AlfaCaus and Alfa P-Scale. 0.5–1 vol% is added to the total diluted cleaning solution to provide better cleaning results on oily and fatty surfaces and where biological growth occurs. AlfaAdd also reduces foaming.

4.4 Cleaning in Place

CIP equipment
Many processes have built-in CIP equipment and cleaning procedures tailor made for their processes. Alfa Laval provides portable CIP equipment of different sizes and can recommend CIP cleaning cycles. For instructions of the CIP equipment, see separate manual. Contact an Alfa Laval sales representative for sizing of CIP equipment.

Examples of cleaning cycles
Depending on application and frequency of cleaning, the cleaning agents and the cycle times may vary. Note that the heat exchanger shouldn't be left filled with cleaning agents for a prolonged time. The cycle times are normally not longer than indicated in the examples, and they are always followed by rinsing. Below are a few typical examples of cleaning by means of CIP. These are meant as examples only, and the cleaning procedures must be validated for each installation.

The chemical cleaning must be carried out by an authorized and qualified operator.

The residuals after a cleaning procedure shall be handled according to local environmental regulations. After neutralization, and provided that the fouling deposits do not contain heavy metals or other toxic or environmentally dangerous compounds, most cleaning solutions may be drained into the waste water system.

Prior to disposal, it is recommended to analyze the neutralized chemicals for any hazardous compounds that were removed from the system.

The cleaning cycles described are intended to remove any foreign material from the heat exchanger in logical steps whereby mechanical cleaning activities are followed by chemically cleaning that will dissolving fouling inside the heat exchanger.

The first step in defining a cleaning procedure is to determine what kind of fouling needs to be removed from the heat exchanger. The cleaning procedure should then be tailored to that specific type of fouling. For example: carbonate fouling, use an acid cleaning agent, grease/oil fouling, use a degreaser cleaning agent etc.

Examples of materials or fouling that can be removed by chemical cleaning:

1. Grease and oil components
2. Corrosion deposits (can be generated elsewhere in the system)
3. Scaling (carbonates or other)
4. Biofouling (not likely in PCHE)

Some cleaning procedures benefit from heating of the cleaning media. If this is needed depends on the CIP chemicals and cleaning method.

Cleaning performance improves when the cleaning agents can be circulated with sufficient turbulence. The circulation pump should be sufficiently sized to meet this requirement (check with Alfa Laval how much flow is needed to obtain the right cleaning conditions for the involved unit).

The PCHE technology uses microchannels for heat transfer. When performing a chemical cleaning one should be careful not to dislodge fouling to fast, so that chips or lumps start traveling through the unit. This may result in clogged channels which will be very difficult to clean.

Heat exchanger that are severely fouled may not be cleanable with CIP. CIP requires the possibility to circulate chemicals. When channels are completely blocked, the CIP chemicals are not able to remove the fouling. It is therefore recommended to act when the thermal performance of the unit begins to drop, or increases are observed in the pressure drop.

Example 1: Fouling from cooling water in industrial application
Cooling water can cause fouling of various types. Organic substances are dissolved by alkaline cleaning agents and scaling from salts are dissolved by acidic cleaning agents.

A cleaning cycle can typically be:

1. Rinsing with water 30 minutes
2. Circulating AlfaCaus 10% at 70 °C for up to 4 hours
3. Rinsing with water 30 minutes
4. Circulating AlfaPhos 10% at 70 °C for up to 4 hours
5. Rinsing with water 30 minutes

Depending on the type of fouling and frequency of cleaning, the cycle times can be shorter or longer.

Example 2: General fouling removal procedure combining oil/grease fouling removal and scaling removal (acid or caustic cleaning)

1. Uninstall the unit and transport to a suitable cleaning workshop that has the right facilities to safely perform chemical cleaning and that can handle any spend chemicals in a proper and sustainable way.

2. Inspect the headers and remove any large debris from the headers if this is covering the inlet to the plate pack. Ensure the header boxes are completely empty. The header boxes can be cleaned using high pressure hydro jetting. Care should be taken that the dirty is not pushed in to the channels.

3. Connect the cleaning system to the unit and perform an air leak test to verify if the unit is leak free connected.

4. Flush the unit with clean water (< 50 ppm chloride), preferably demineralised water

5. Drain the unit and dispose of the water in an environmentally friendly way. Dry the unit if needed.

6. Circulating decreasing agent (this can involve several hours; ~1-2 hrs)

7. Circulating cleaning agent (acid/caustic other) including inhibitor to protect exposed metal surfaces when scaling is dissolved.

8. During cleaning check the pH value and acid/caustic strength. Stable acid strength indicates that the unit is clean.
   (This cleaning step can involve several hours of circulation; ~3-4 hrs)

9. Rinsing/neutralisation of cleaning agent
   Drain the unit and dispose of the neutralized cleaning fluid in an environmentally friendly way.

10. Circulation of a passivation agent (involves several hours of circulating; ~1-2 hrs)

11. Perform Ferroxyl tests to verify that the passivation is completed

12. Drain the unit and dispose of the passivation agent in an environmentally friendly way.

13. Rinse unit with demineralized water

14. Drain unit

15. Drying (air blowing or dew point drying) and nitrogen conditioning of the unit if stored after cleaning.

16. Installation and commissioning of the unit

4.5 Leak Detection

Periodic pressure retaining test

Alfa Laval recommends conducting periodic leak tests, typically once every two years. These will disclose the presence of any inter-stream leakage and allow the operator to act before it becomes problematic.

Real-time leak detection

In the case of high-pressure hydrocarbon streams paired with lower pressure utilities such as water, monitoring for leakage during operation is possible and recommended. If the lower pressure utility has an expansion tank, any leakage will bubble or dissolve from the hydrocarbon stream into the lower pressure utility flowing out of the exchanger. The hydrocarbon will collect in the expansion tank high point. It is recommended that the expansion tank is blanketed using an inert gas such as nitrogen so that a hydrocarbon sensing device can be installed to detect leakage.

4.6 Recommended Spare Parts

It is recommended to keep a supply of spare bolts and gaskets for the flanges (standard PCHE). Refer to the chapter 2.8 for the storage of the spare parts.

5. Waste management and scrapping

Throughout the lifecycle of the PCHE, the owner is responsible for managing the waste related to any equipment or material delivered by Alfa Laval (e.g., packing material of the delivered PCHE, packaging of spare parts, used spare parts like gaskets, etc.) according to the applicable local regulations regarding the protection of the environment.

The PCHE can be subject to scrapping if, according to results of a technical inspection, the end of life of the PCHE is confirmed. The owner is responsible for carrying out the disposal of the scrap-metal in accordance with the applicable local legislation and regulations regarding protection of the environment.

Appendix 1: Nameplate

A nameplate is fixed to the frame of the heat exchanger with the following data (*see drawing below*):

- 1: manufacturer
- 2: type of heat exchanger
- 3: serial number
- 4: year of built
- 5: fluid group : 1 for dangerous fluid and 2 for non-dangerous fluid
  This field is related to PED regulation filled only for units submitted to PED
- 6: identification of nozzle (please refer to General arrangement drawing)
- 7: volume per side including nozzles
- 8: design pressure for both media (maximum pressure for which the equipment is designed (FV = Full Vacuum))
- 9: design temperatures for both media (maximum and minimum temperatures for which the equipment is designed)
- 10: differential / simultaneous test pressure per side
- 11: maximum operating temperature per side
- 12: date of pressure test
- 13: weight of the unit (empty/full)
- 14: Tag Number or other customer identification information (if specified and required by customer)
- 15: maximum differential pressure between both sides
  Please notice that this information is only indicated when this restriction is applicable Differential pressure across sides A and B shall never exceed this value when this value is specified!
- 16: “CE” tag - when required by PED.
  A paper copy of filled nameplate is attached to documentation accompanying physically the unit when PED applicable. Customer’s values are engraved on the nameplate of each.
- 17: core material (when indicated)
- 18: other information (like QR code for example…)
- 19: warning reminder: always read Instruction Manual before any activity regarding installation, operation and maintenance of the heat exchanger!
- 20: construction code (and local regulation if applicable) used for designing the unit
- 21: Type of service, for instance “interstage cooler”

Example of nameplate: