Energy Hunter for savings in HVAC and Manufacturing industries

Alfa Laval provide customers with clean technology to meet their sustainability needs in every day HVAC and Light Industry applications

Energy Hunter for savings in HVAC and Manufacturing industries

Sustainability helps a company's profitable growth, through energy efficiency, heat recovery, reduced fuel bills, reduced CO_2 emissions, savings in maintenance costs, and has a positive impact on the environment.

The series of Energy Hunter from Alfa Laval offers real-life application examples on how gasketed plate heat exchangers can help companies with sustainability targets, on the way to a better planet. Each case listed in the series is a true story, with global references each operating with continued savings since their installation.

With rapidly, increasing energy costs, plant managers have more and more pressure for their contribution to sustainability. Major equipment installed in food, beverage, manufacturing, and HVAC industries consume high amounts of energy by burning natural resources such as carbon fuels or electricity, which are generated with the same.

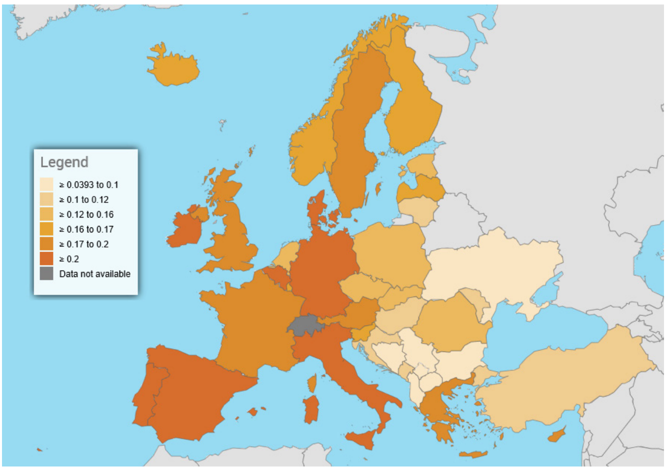
Sustainability savings can be in operation, maintenance and energy consumption of equipment such as open cooling tower, how water boiler, steam boiler, chiller, air compressor, cogeneration equipment, and shell-and-tube heat exchangers. Similarly, fluids to be considered for savings are cooling tower water, hot water, flash steam, oils, chilled water, warm wastewater, and compressed air.

What can heat be used for

- Preheating hot water boiler feed
- Preheating steam boiler feed
- Hot water for cleaning
- Hot water for bathing & showers
- Heating of office or production facilities
- Use in production processes
- Supply to district heating network

Purchasing the correct gasketed plate heat exchanger is also delivering sustainability, as fierce market conditions are forcing manufacturers to size gasketed plate heat exchangers with tolerances of up to 0.5°C and higher pressure drop limitation of up to 30 kPa or more. Due to seasonal and variable loads, accurate measurement of these tolerances is impossible with standard instrumentation and under performance has a severe effect on the running costs of associated equipment such as pumps, chillers, and boilers. Hence gasketed plate heat exchangers designed and supplied with AHRI Performance Certification, is sustainability in itself.

The map show European electricity prices for industries in Europe. The higher the rate, the shorter the return on investment period for a given kWh.



Electricity cost for industry (2019) Euro/kWh

1. **Chiller condenser protection and savings with AHRI performance certification**
   The condenser of a chiller using open cooling tower water is prone to develop a layer of $CaCO_3$. Rule of thumb in the industry is that a 1 mm coating of $CaCO_3$ inside the tubes, can mean 3°C higher condensation temperature of the refrigerant gas at the condenser. This equates to approximately 10% higher condensation pressure and higher electricity consumption of the compressor.

2. **AHRI performance certified gasketed plate heat exchangers for sustainable high-rise buildings**
   Can you accurately measure 0.5°C? What happens to the operation of the chiller if the installed pressure breaker gasketed plate heat exchanger under performs by 0.5°C? Lower evaporation temperatures lead to higher lift with the chiller compressor and increasing electricity consumption of up to 3%. Installing AHRI performance certified gasketed plate heat exchangers provides a payback period of under three years.

3. **Free cooling with chiller bypass**
   A chiller is one of the highest running cost equipment in many plants. Those with a water-cooled condenser can win in two ways with an Alfa Laval gasketed plate heat exchanger. One to protect the chiller from $CaCO_3$ coating on the tubes, saving electricity with lower condensing temperature and pressure and the other is by turning the chiller off up to 30 days per year, depending on the geographic location and the wet-bulb temperature. AHRI performance certification is vital as approach temperatures of 1°C are needed and who can measure 0.5°C!

4. **Heat recovery from air compressors**
   72% is the conversion of electricity to waste heat with air compressors. Compressed air and lubricating oil are often cooled with in built heat exchangers, releasing the heat to the atmosphere. Cooling the air also helps the dryer run effectively, reducing moisture content for critical air equipment.

5. **Heat recovery from warm wastewater**
   With Alfa Laval wide gap plate technology, heat recovery is efficient at the same time blockage free for wastewater containing < 5 mm particles or fibres. Wastewater temperatures as low as 35°C and as low 10 m^3 per hour can save 175 kW (150,000 kCal/hr) with a payback period of less than six months, preheating the boiler feed water to 30°C.

6. **Heat recovery from waste flash steam**
   All industries using steam as a heat source have problems with steam management. With a simple cyclone separator at the condensate collection point, flash steam can be condensed, heating water up to 80°C. Recovering 500 kg per hour of flash steam can save up to 5,000 euro per month. The return on investment is less than 3-6 months.

7. **Boiler protection with gasketed plate heat exchangers**
   Especially for retrofit applications, the building circuit can contain debris, mud, $CaCO_3$ and oxygenated water. The $CaCO_3$ can bake at 300°C plus fuel temperatures and with thermal expansion/contraction crack the boiler's heater. Two identical buildings located side by side, one with gasketed plate heat exchanger protection and the other without, has fuel costs 30% less, as with protection, the boiler heater does not have a coating of $CaCO_3$.

8. **Heat recovery from open cooling tower**
   This is exceptionally beneficial where heating and cooling takes place at the same plant. Typically for preheating boiler feed water close as 2°C to cooling tower return. Savings are in increased cooling tower capacity, less fuel costs for boiler operation (almost half) and less evaporation of water at the tower, hence saving water.

9. **Cooling tower interchanger**
   Plant cooling equipment protection from open cooling tower mineral deposits $CaCO_3$ and Chloride ions, minimum fouling from debris. Savings are in maintenance-free operation of plant equipment, lower pumping costs avoiding pipe diameter reduction and replacement of corroded equipment.

10. **Shell-and-tube replacement with only dimensional data**
    Based on the right channel type of gasketed plate heat exchanger and proportional heat surface area. Savings are with less footprint - including removal space for tube bundle, less hold up volume hence faster response times, easier and quicker maintenance and heat losses to the atmosphere from the shell-and-tube surface.

How to calculate savings

Savings in water consumption depends on the overall cost for a plant to source, treat, and produce the quality of water used in their process. On average, the treated water cost in Europe is 0.1 euro/m^3.

Quantifiable savings and return on investment depend on the type of fuel used and its cost per kilowatt-hour consumed during a given period. For example, saving 100 kilowatts of natural gas consumption at a cost of 0.10 euro/kilowatt-hour, for 24 hours can be calculated as below:

100 kW x 24 hrs x 0.10 euro/kW hour = 240 euro per day

Savings in maintenance costs, avoidance of unplanned shutdowns, failure of associated equipment will depend on plant to plant with varying labour costs in different countries. Please contact your nearest Alfa Laval sales offices or Alfa Laval Certified Distributors globally who are ready to support customers with their sustainability targets.

Use the QR-code to visit the **Energy Hunter – HVAC and Utilities** pages in the Partner Portal, including the **ROI Calculator** (Return On Investment).

Chiller condenser protection and savings with AHRI performance certification

Industrial chillers are widely used in many industries such as HVAC, general manufacturing, food processing, pharmaceutical and industrial applications such as packaging material manufacturing and plastics.

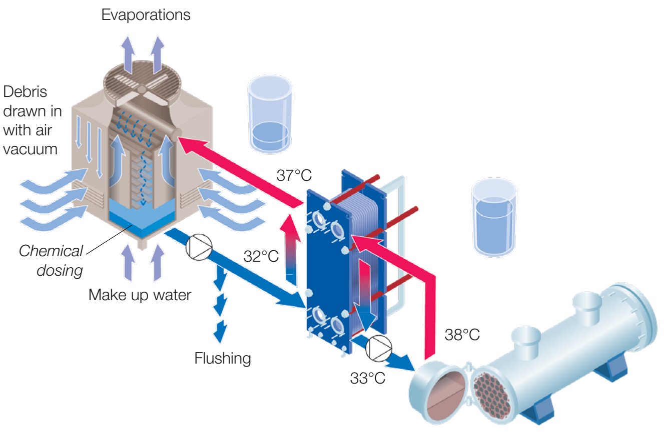
The condenser of a chiller can be either water cooled or air cooled. In the case of water cooled, often the cooling source is an open cooling tower. A sustainability concern is the increasing electricity consumption of the refrigerant compressor, due to higher condensing pressures caused by fouling and inefficiencies of the condenser.

Three problems are associated with an open cooling tower water (CTW) and chiller condenser:

1. Calcium carbonate ($CaCO_3$) coating of the inside of the condenser tubes, leading to reduced heat transfer efficiency, higher condensing temperature and pressure.
2. Debris blocking the tubes, reducing CTW flow to the condenser and loss in efficiency.
3. Chloride ion corrosion of the tubes, forced to be manually blanked which will reduce heat transfer area and efficiency.

Each of the above three effects lead to higher electricity costs. This is due to the higher lift in the compressor caused from higher condensing temperatures and higher condensing pressures. These detrimental effects accumulate over the years and cannot be reversed with manual or chemical cleaning.

As little as a 1 mm coating of $CaCO_3$ inside the tubes, can lead to an average 5-7°C higher condensing temperature, which means 7-10% higher chiller running costs in electricity bills, all year round and every year (1.5% for every °C).



An Alfa Laval gasketed plate heat exchanger (GPHE), installed between the condenser and the cooling tower, will protect the condenser from the detrimental effects associated with open cooling towers. The chiller condenser's tubes will be life long free of debris, $CaCO_3$ coating, corrosion and will life long run as new.

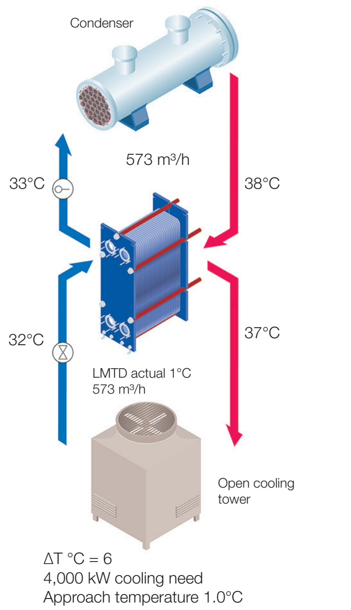
Selection of chiller condenser protection gasketed plate heat exchanger

Selection and specification of the GPHE is critical with some manufacturers using software with tolerances of 0.5°C, resulting in lower capital cost (CAPEX) but higher operating costs (OPEX) from under surfaced GPHE. Growing trends in the competitive GPHE market can see offers of as low as half the required and specified performance, with half the price of a performance certified GPHE.

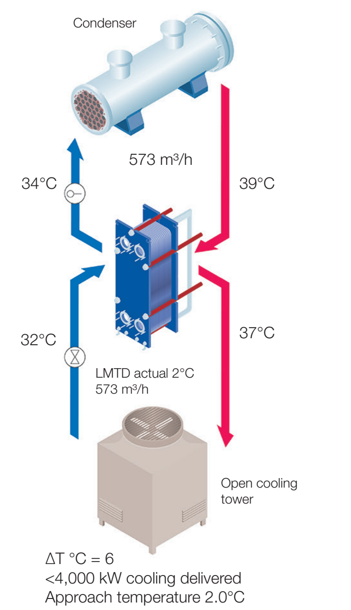
Hence AHRI performance certification is becoming a necessity in today's GPHE market.

The available cooling tower water temperature delivered to the condenser from an under surfaced GPHE, can be 1°C higher than design, all year long. This will cause saturation temperature (Tsat), to be 1°C higher and hence the saturation pressure (Psat) will be higher, according to the enthalpy graph of the refrigerant gas.

AHRI performance certified GPHE operation *exactly* to design



30% under surfaced GPHE operation gives higher condensing temperature



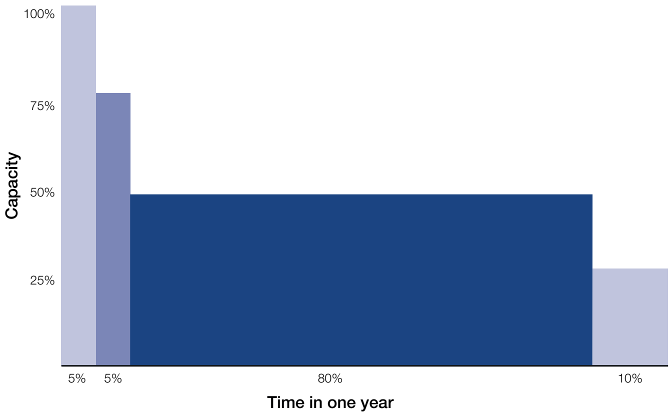
Performance of an under-surfaced GPHE will cause higher plant OPEX due to higher condensing temperatures at the chiller condenser.

T_{con} ↑ P_{sat} ↑

Payback period for sustainability

Chillers are one of the highest consumers of electricity in utilities part of a plant with huge compressors, running constantly to compress the refrigerant gasses as a part of the refrigeration cycle. To save our natural resources and help sustainability, there are new legislations in many countries to monitor the condenser efficiency. Regulations require condensers to be opened, inspected and cleaned annually to ensure efficient operation and reduce national electricity costs.

A peak cooling capacity of 4 MW obtained from a chiller, equates to a compressor power consumption of 800 kW based on a COP of 5 as an example.



Assuming an annual average of 25% of peak load due to seasonal conditions, 200 kW of electricity in one year means 200 kW x 8,760 hrs/year x 0.10 euro/kW hr is 175,200 euro per year in chiller electricity bills.

Due to an under surfaced GPHE a 1°C higher condensing temperature from 32.8°C to 33.9°C results in 7.34 bar to 7.60 bar higher condensing pressure (3.6%) for R134a refrigerant.

Pressure bar(g)	Dew °C
6.83	30.6
6.95	31.1
7.08	31.7
7.21	32.2
7.34	**32.8**
7.47	33.3
7.60	**33.9**
7.73	34.4

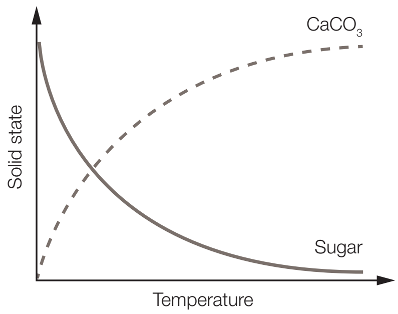
An average of 3.6% savings* with an AHRI performance certified GPHE installed, is equal to 175,200 euro x 3.6 = 6,318 euro per year in electricity costs. Each year every year!

Performance certified GPHEs pay back the initial investment difference, in under one year.

* Power consumption is assumed to be proportional to the pressure increase.

Less formation of scale with GPHE installed

The condenser is often the hottest point of the cooling tower loop. With condensing temperatures of 40-80°C, it is here most of the scale forms and adheres to hot condenser surfaces. With a GPHE installed to protect the condenser, the formation of scale is very much less as the wall temperatures will be 30-40°C. Scale $CaCO_3$ behaves opposite to that of sugar. The higher the surface temperature the more the formation of scale on hot surfaces.



▼ PRACTICAL TIPS

1. Specify what you want and get what you specify with AHRI performance certified gasketed plate heat exchangers using the description below when purchasing gasketed plate heat exchangers for condenser protection.

"The plate heat exchangers shall be AHRI certified in accordance with the AHRI Liquid to Liquid Heat Exchangers Certification Program".

The gasketed plate heat exchanger specs as selected, shall be verified and registered by AHRI before purchase"

AHRI CERTIFIED® www.ahridirectory.org Liquid to Liquid Heat Exchangers AHRI Standard 400

2. A commonly used **thermistor** temperature measurement device will read as accurate to 1% of the compete scale. If scale is 50°C the accuracy is 1% hence, plus or minus 0.5°C. Inaccuracy in measuring performance in the plant, using delta T between inlet and outlet 0.5°C + 0.5°C = 1°C.

Can you ever be sure of actual performance with seasonal load and cooling capacities?

Can we afford to waste our natural resources with under-surfaced non-performance certified gasketed plate heat exchangers as chiller condenser protection units?

Rule of thumb:

1 ton of refrigeration = 3.5 kW of cooling. I.e. 1,000 tons = 3,516 kW

AHRI performance certified gasketed plate heat exchangers for sustainable high-rise buildings

High-rise buildings carry high levels of static pressure due to their height. A building with 300 meters height means static pressure at the ground level of at least 30 bar. This demands unnecessary high investment costs to HVAC critical equipment such as chillers, boilers, and their associated automation equipment if located at the basement, as they need to withstand this high pressure.

Gasketed plate heat exchangers (GPHE) are standard industry practice for breaking this static pressure, located in plant rooms at regular intervals along with the height of the structure. Taller height means a greater number of zones as pressure breakers and security for associated equipment such as chillers.

Many designers specify an approach between the inlets and outlets at 2.0°C or 1.5°C or even 1.0°C depending on the water temperatures required at the fan coils and the total system design. With equal flow rates and equal delta T for each side, this approach temperature equates to the LMTD for the selection of the GPHE.

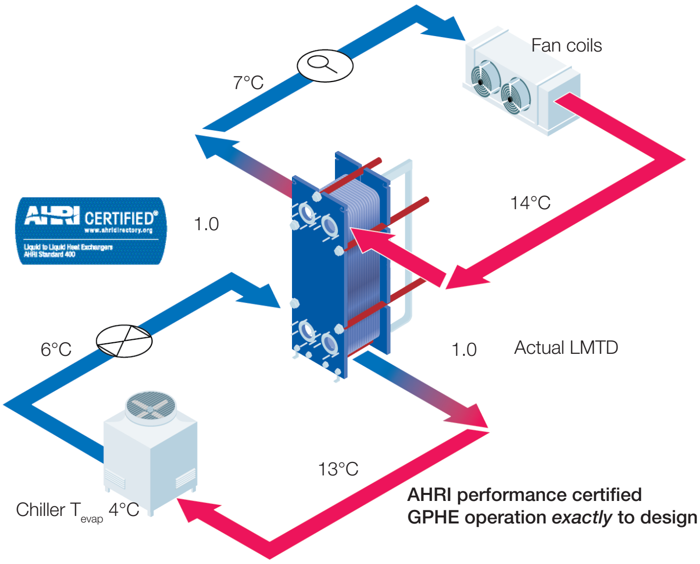
Buildings are getting taller and taller with the tallest (2019) being Burj Khalifa in Dubai at almost 1 km into the sky installed with Alfa Laval GPHEs. With energy savings in mind and total cost of ownership, for taller buildings, the trend is down to as low as 0.6°C approach temperature.

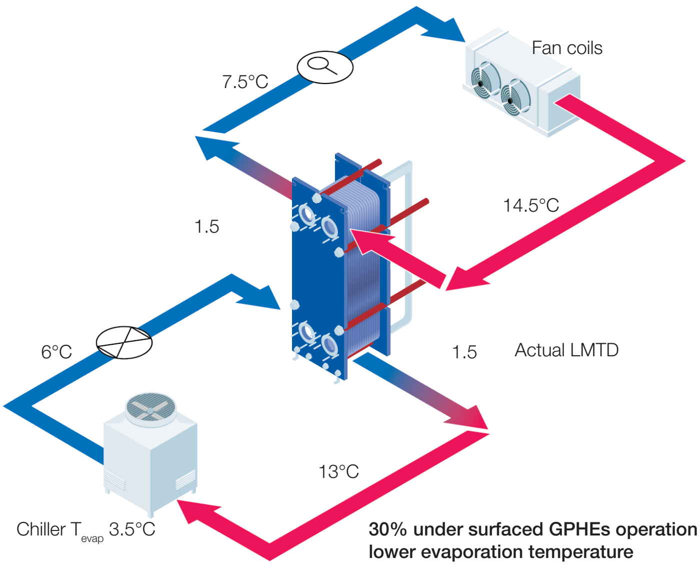
Why AHRI performance certified gasketed plate heat exchangers should be specified

Fan coils located at cooling points require chilled water for cooling and hot water for heating. In case of a GPHE for cooling working as a pressure breaker, the temperature program can be 14°C → 7°C on the fan coil side cooled by chilled water at 6°C →13°C. This means an approach temperature of 1°C.

A non-AHRI performance certified GPHE operating as a pressure breaker if selected with tolerances can deliver only an approach temperature of 1.5°C, providing 7.5°C water to the fan coils, returning at 14.5°C.

To meet the set 7°C, the chiller will have to operate at a lower temperature regime and hence a lower evaporation temperature resulting in a higher compressor lift.





0.5°C lower chiller evaporation temperature means lower saturation temperature of the gas, lower evaporation pressure and hence a higher compressor lift.

A 1°C lower evaporation temperature results in 3.5% higher chiller energy consumption.

T_{con} ↓ P_{sat} ↓

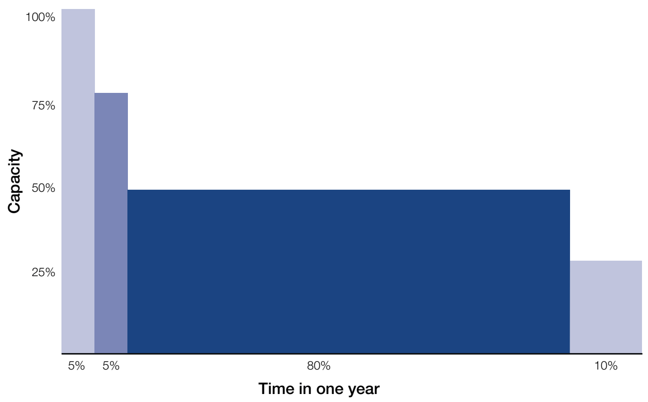
Calculation of savings with AHRI performance certified gasketed plate heat exchanger in a 4,000 kW cooling capacity

Typical operation of HVAC systems are constant temperature and variable flow rate to minimize on overall pumping costs.

With an underperforming GPHE, the set 7°C going to the fan coils is not met, actuating the flow control valve to allow more chilled water flow. In turn, the return to the chiller is not 13°C as system design and reduces to 12°C. Hence the plate heat exchanger operates with 1.5°C LMTD instead of the designed 1°C, and the chiller evaporation temperature T_{evap} reduces from design 4.0°C to 3.5°C.

Generally accepted chiller compressor energy consumption is 3.5% more power is used for every 1°C lower T_{evap}.

For a cooling capacity of 4,000 kW, the chiller power consumption will be 1,259 kW with a COP of 3.2 and with a lower evaporation temperature 0.5°C, the extra compressor power consumed will be 63 kW.



Cost of energy kWh 0.10 euro

Capacity	Flow rate	Duration in one year		Chiller compressor extra energy		Additional annual cost
4,000 kW	491 m³/hr	10%	876 hrs	63 kW	55,188 kW	5,519 EUR
3,000 kW	369 m³/hr	20%	1,752 hrs	47 kW	82,782 kW	8,278 EUR
2,000 kW	246 m³/hr	60%	5,256 hrs	32 kW	165,564 kW	16,556 EUR
1,000 kW	123 m³/hr	10%	876 hrs	16 kW	13,797 kW	1,380 EUR
		100%	**8,760 hrs**	**36 kW**	**317,331 kW**	**31,733 EUR**

Annual average

HVAC cooling applications, the operation of the system is not always at peak design capacity, and flow conditions, hence the extra energy consumption of pump and chiller will vary throughout the year. The table above shows the annual seasonal effect on capacity demand, resulting in extra yearly power consumption of 31,733 euro/year for a 4,000 kW cooling capacity, with an underperformance GPHE installed.

Ultimately it is our **social responsibility to specify AHRI performance certification** to ensure the correct operation of chillers at design parameters to save on chiller compressor electricity consumption!

Market trends and why vastly differing solutions are offered

Many engineers believe that it is the kW capacity that determines the size of a GPHE, but it is the approach temperature and the allowed maximum pressure drop that plays the highest role in the selection of a unit. Yes, a 500 kW unit can be double the size of a 1,000 kW unit, depending on the value of LMTD.

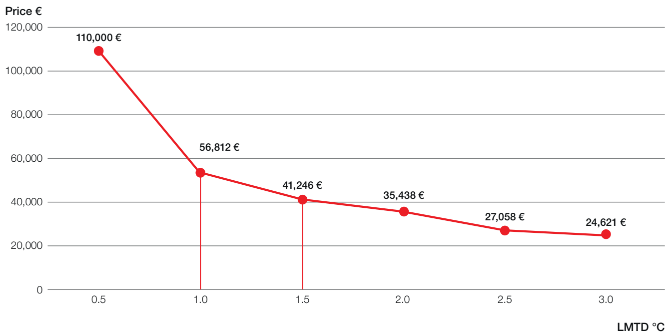
When it comes to measuring the actual temperature and pressure drop of either side, the accuracy at best is 0.5°C and 10 kPa with thermocouples, digital equipment and at full flow. With higher demands from GPHEs and expected 1°C LMTD (approach temperature), the effect of 0.3°C tolerance equates to 30% underperforming GPHEs.

Heat transfer equation

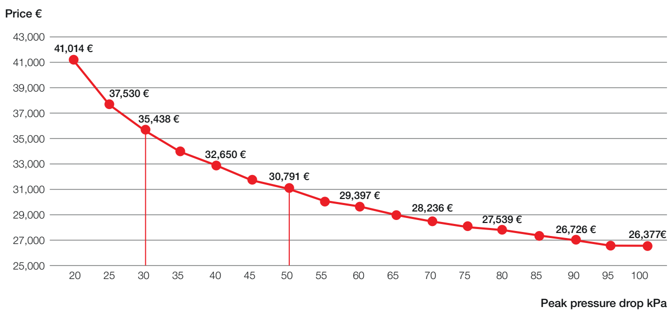
$$Q = k \cdot A \cdot LMTD$$

LMTD Tolerance:	0.3°C	0.3°C	0.3°C
Specified LMTD:	2.0°C	1.0°C	0.6°C
Less area and underperformance	15%	30%	50%

What if the selection was made with 1.5°C LMTD instead of the specified 1.0°C?



What if the selection was made with 50 kPa pressure drop instead of the specified 30 kPa?



Free cooling with chiller bypass

Industrial chillers are widely used in many industries such as HVAC, data centres, general manufacturing, food processing, pharmaceutical and industrial applications such as packaging material manufacturing and plastics. They deliver cool chilled water to the process with the evaporator, typically with a temperature regime of 7°C to 12°C and collect the heat from the process and release it to atmosphere via the condenser.

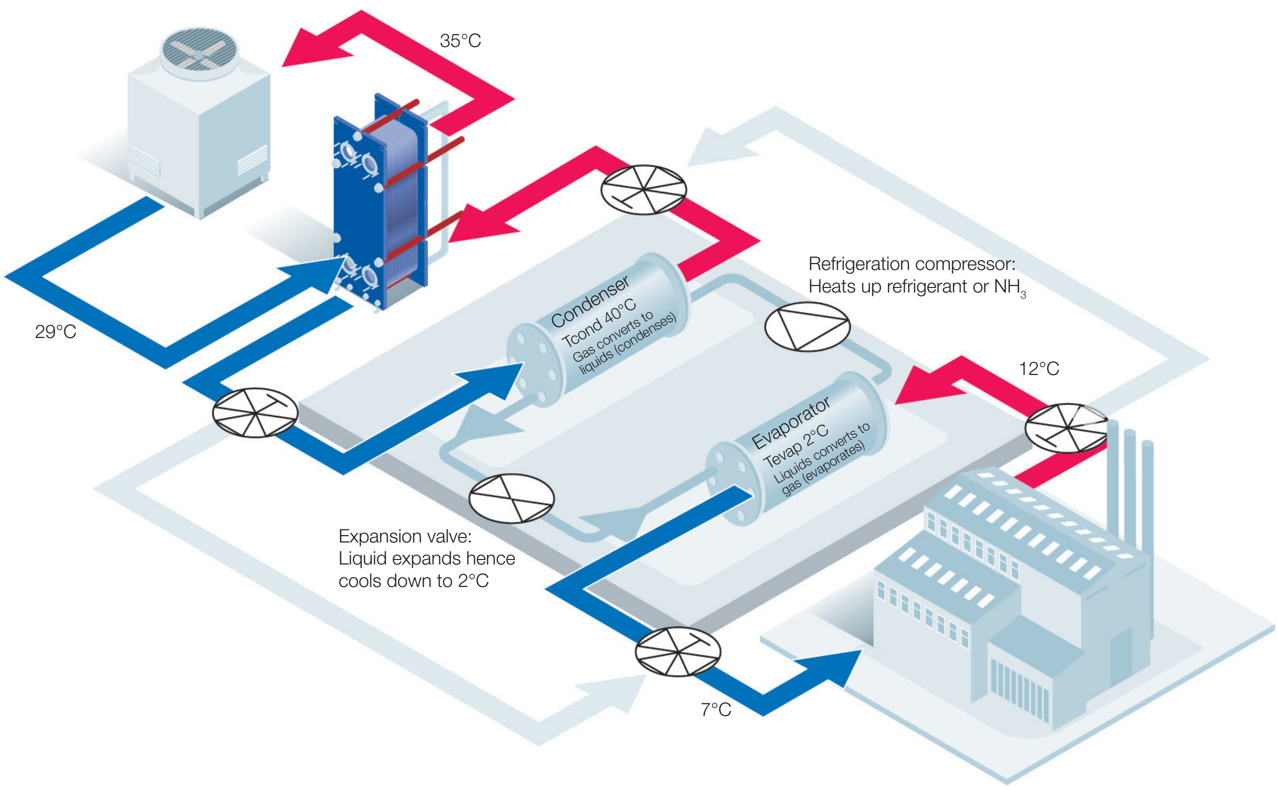
Chillers are one of the highest consumers of electricity in utilities part of a plant with large compressors constantly running to compress the refrigerant gases as a part of the refrigeration cycle — a significant sustainability concern not only with high operating costs but with environmental concerns.

Chiller energy consumption can be estimated by the amount of cooling it needs to deliver. For example, a chiller cooling capacity of 4,000 kW and compressor working with a COP of 5 will have an electricity consumption 800 kW during peak capacity. The chiller compressor is one of the highest running costs in any plant and has a critical influence on plant profitability and sustainability.

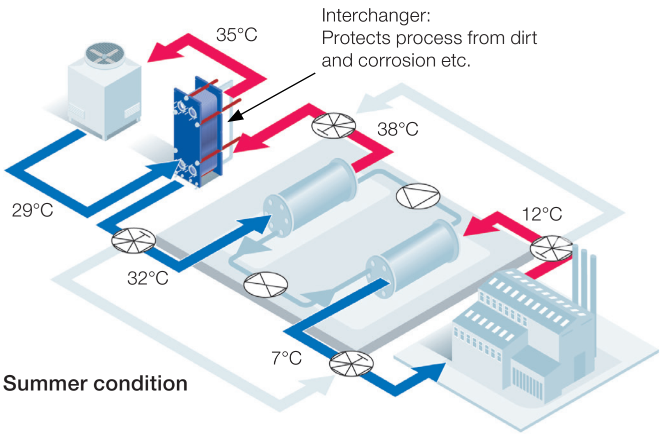
The cost to run and the electrical power consumed in 800 kW can be calculated based on the duration of the cooling need. If the chiller is running 24 hrs per day and 30 days per month, assuming the electricity cost is 0.10 euro/kWh:

800 kW x 24 hrs x 30 days/month x 0.10 euro/kWh = 57,600 euro per month.

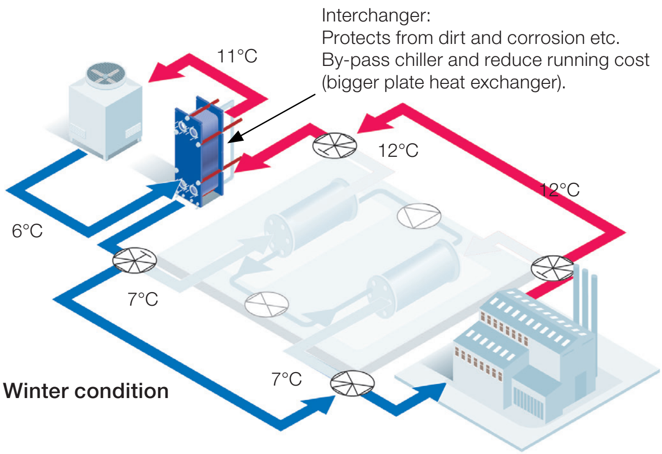
Water cooled condenser



When a plant needs 7°C cold water supplied by the operation of the chiller and the chiller's condenser is working with an open cooling tower, there is an opportunity to save thousands of euro by turning off the chiller. The possibility for free cooling for certain hours or days in winter, when the open cooling tower water is cold enough for the required cooling needs and is relatively free, with the chiller completely turned off.

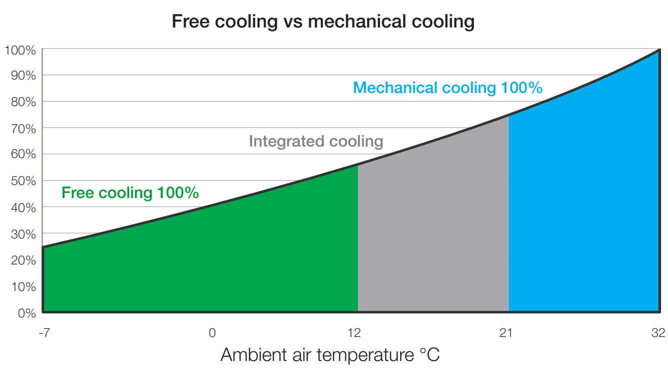


Summer condition



Winter condition

The automation should be designed according to ambient conditions as when the ambient temperature drops to a set level, the modulating valve supplying the condenser should change so that the cold closed-circuit water is directed to the cooling need. In this way, the chiller can be completely turned off, and the savings are impressive without compromising cooling requirements of the plant.



The design and selection of the gasketed plate heat exchanger should be as close approach temperature as possible to maximize the days or hours which the chiller can be turned off. During winter/summer operation, typically the gasketed plate heat exchanger can work as an interchange protecting the condenser from unwanted debris and calcium carbonate formation.
Recommended design conditions for summer operation:

Condenser circuit water	38°C → 32°C
Cooling tower water	35°C ← 29°C

The selected gasketed plate heat exchanger **should also** be able to perform winter conditions with a 1°C approach. Because of economies of scale and investment costs, a 2°C approach designed gasketed plate heat exchanger can also be considered:

Condenser circuit water	12°C → 7°C
Cooling tower water	11°C ← 6°C

The bigger gasketed plate heat exchanger of the winter and summer condition selections should be installed. Most often as the winter conditions is a more thermally difficult duty, the likely gasketed plate heat exchanger to be installed will be the winter design conditions selection.

The design pressure drop limitation is recommended as 100 kPa to ensure high turbulence with the open cooling tower water and minimum fouling, especially with lower than design flow and seasonal operational conditions.

▼ PRACTICAL TIPS

AHRI performance certification – With small approach temperatures, contractors, installers and end-users will be protected from good enough plate heat exchanger performance. Please specify AHRI performance certified plate heat exchangers using the following text:

The plate heat exchangers shall be AHRI-certified in accordance with the AHRI Liquid to Liquid Heat Exchangers Certification Program. The plate heat exchanger specifications as selected shall be verified and registered by AHRI before purchase."

AHRI CERTIFIED® www.ahridirectory.org Liquid to Liquid Heat Exchangers AHRI Standard 400

Heat recovery from air compressors

Air compressors are widely used in industrial applications to compress air from ambient conditions; that can be humid and at 1 bar absolute, to most popularly 6 bar and dried from entrapped moisture. Compression is either by piston type or screw-type compressors, whereby the air molecules are squeezed, consequently increasing the compressed air temperature up to 60°C. The friction also increases the lubrication oil temperature as high as 80°C, which must be cooled down for efficiency.

A well-known fact is that a massive **72% to 90% of the electrical energy used by air compressors is released as waste heat**. This heat, if not recovered, is thrown out to the atmosphere and wasted, where at the same time, there can be a boiler burning fossil fuels to heat water or generate the steam needed for different processes in the plant. Sadly, the waste heat from the compressor is released to the atmosphere by an open/closed cooling tower or where not available can be an air cooler.

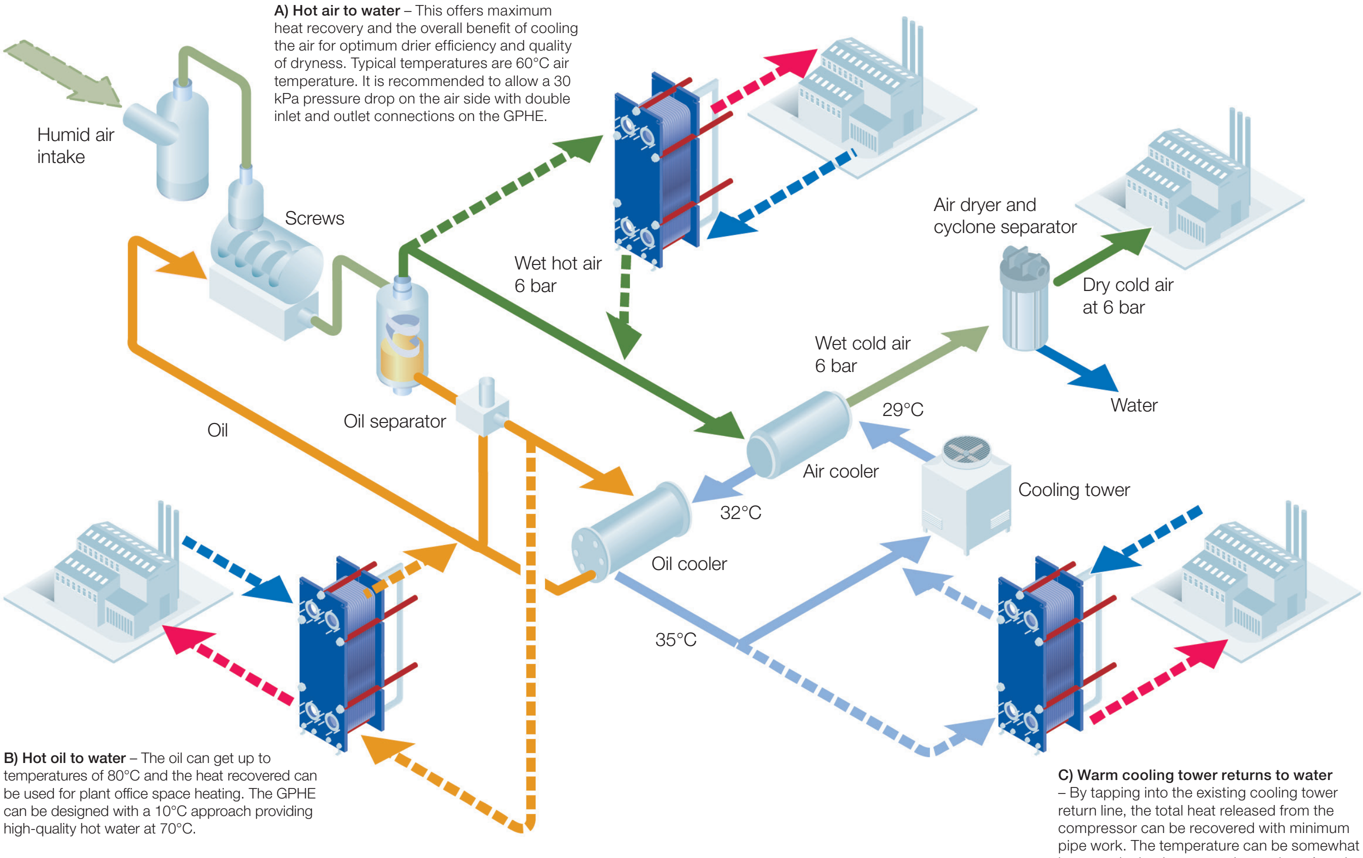
Typically, there are two in built heat exchangers to exchange the heat which can either be shell and tubes, brazed plate heat exchangers for their compactness or gasketed plate heat exchangers (GPHE) for their ease of cleaning and compactness. The choice will depend on the manufacturer of the compressor.

Benefits of heat recovery

Recovering waste heat from air compressors not only has environmental benefits in sustainability, reducing carbon emissions and monetary savings, helping plant profitability but also improves the dryness quality of the air that has just been compressed. For the dryer located after the air cooler, needs to further cool the air down to 3°C to remove the moisture that is inherent in the humid air intake. Heat recovery savings are also in the extended life of power tools and other air-operated equipment, as *moist compressed air* is a significant problem at points of usage

The diagram below shows a typical compressor working. For previously installed and operating air compressors heat recovery is still possible not having to remove or replace the existing coolers. If the compressor is cooled with an open cooling tower, all the above alternatives in heat recovery will provide extra savings as below:

- Free up cooling tower capacity
- Savings in water with less water evaporation
- Reduction in tower water treatment costs
- Reduced electricity costs with tower fan operation
- Less make up water usage, hence less $CaCO_3$ in the system avoiding build-up.



A) Hot air to water – This offers maximum heat recovery and the overall benefit of cooling the air for optimum drier efficiency and quality of dryness. Typical temperatures are 60°C air temperature. It is recommended to allow a 30 kPa pressure drop on the air side with double inlet and outlet connections on the GPHE.

B) Hot oil to water – The oil can get up to temperatures of 80°C and the heat recovered can be used for plant office space heating. The GPHE can be designed with a 10°C approach providing high-quality hot water at 70°C.

C) Warm cooling tower returns to water – By tapping into the existing cooling tower return line, the total heat released from the compressor can be recovered with minimum pipe work. The temperature can be somewhat lower and mixed compared to options A and B; however, this is the simplest and cheapest way to recover.

How to identify potential savings
Model numbers typically refer to the installed motor power. A model XXX 72 YY would mean a 72 kW power consumption. This compressor can provide between 4-13 bar compressed air depending on the need, with a varying proportional compressed air volume of 8.8 to 6.4 normal m³/min. The equipment weight is approximately 1.5 tonnes.

Example:
The running cost of a compressor consuming 72 kW of electricity for 24 hours a day is 1,173 euro per month (72 kW x 24 hr x 0.1 euro/kWh = 1,173 euro). The produced heat is 80% of this power consumed and is released to the atmosphere as waste heat which can be recovered.

Heat recovered from the compressed air or lubricating oil can produce hot water that can be used for a multitude of applications in a plant:

- Heating of office or production facilities
- Preheating hot water boiler feed
- Preheating steam boiler feed
- Hot water for cleaning
- Hot water for bathing & showers
- Use in production processes
- Supply to district heating network

Of the 72 kW of electrical motor power driving the screws, we can assume 80% is heat rejection which will be 72 x 80% = 57.6 kW

Most of the heat is absorbed into the lubricating oil and not the compressed air. The proportion is close to 90/10. Heat in the oil in the above example is approximately 52 kW and the compressed air is only 6 kW (compressed air is not a worthwhile investment for heat recovery).

Heat recovery

Oil to heating circuit

Lubricating oil:	95/90/85°C → 65/60/55°C
Heating water:	80/75/70°C ← 50/45/40°C

Oil to tap water

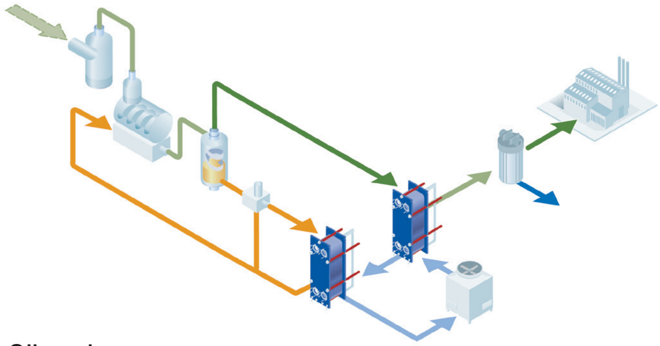
Lubricating oil:	95/90/85°C → 65/60/55°C
Heating water:	80/75/70°C ← 30/25/20°C ***

*** Keep the exit temperature on the oil above 50°C in order to maintain desired physical properties of viscosity and lubrication, with good automation.

- With the compressor located inside the plant room, the GPHE can be partially installed inside the cabinet or protruding slightly from the cabinet.
- With replacement, existing heat exchangers can be removed.
- With heat recovery, it is advisable to keep the installed heat exchangers, which need to be used when heat recovered is not used and cooling done with existing systems.

A protective shroud can be installed over the plate pack for the compressed air cooler to prevent leakage to surroundings.

Replacing a shell-and-tube heat exchanger



Oil cooler
Assume worst case temperatures for oil and cooling tower water.

Lubricating oil:	85°C → 55°C
Cooling tower water:	35°C ← 29°C (or local conditions)

Air cooler
Compressed air is typically expressed in volumetric flow as Nm³ /min. We must assume the air is with some moisture which we can disregard.

Compressed air:	60°C → 40°C
Cooling tower water:	31°C ← 29°C (or local conditions)

Manufacturers literature will show the amount of compressed air flow per model of compressor, as minimum and maximum flow.

The more the compressed air is cooled the better, as this will help drying the air at the dryer, which reduces the air temperature to 3°C with refrigerant, drains the water via a cyclone separator and is reheated with incoming air, ultimately available to the user at 25-35°C and dry from moisture.

▼ PRACTICAL TIPS

When selecting GPHEs for compressor oil cooling to recover heat, Oil ISO VG 46 properties can be used as a general guide. Its properties are such that at 15°C the density is 0.86 kg/dm³, and at 40°C the viscosity of the oil is 40 centipoise.

Heat recovery from warm wastewater

Warm wastewater either discharged or treated in effluent plants, is a by-product of many processes including beverage, food processing, dairies, abattoirs, chemical processing, and pulp and paper industries. Hot wastewater is found in abundance at textile dye houses, laundries and tanneries as a part of their processes. Most of the time, wastewater is sent out to the effluent treatment plant, without recovering the heat due to perhaps low temperatures or particles and fibres it may contain.

Finding the right heat transfer equipment that can handle fibres at the same time provide close approach temperatures for heat recovery is not easy. Fibres require minimum contact points to avoid blockage, and at the same time, heat recovery needs efficient heat transfer. Here the Alfa Laval WideGap plate heat exchangers play a perfect role.

The heat stored in wastewater generated by burning fossil fuels such as natural gas, LPG, fuel oil, or coal. Sometimes, steam may have been used to indirectly heat the water, used in various processes and then discharged from the plant. Throwing away this heat is a loss in plant profitability, time and can have severe environmental effects.

A single ***degree Celsius in cubic metre (m³)*** *of warm waste water holds 1,000 kCal of heat. Dividing by 860 results in 1.2 kW of energy that should be recovered,* ***saving 2.9 euro per day*** *(1.2 kW x 24 hr x 0.10 euro/h).*

Fact: Specific heat of water is 1 kCal/kgK or 4.172 kJ/kgK

Example:
A plant with average wastewater of 20 m°/hr at 50°C can save 51,100 euro per month, by cooling it down to 20°C, preheating incoming cold water at 15°C up to 45°C. This preheated water can be groundwater or ambient mains water, usable for steam or hot water boiler make up. If unused immediately, the preheated water can be saved in a tank for various needs at 45°C.

- Preheating hot water boiler feed
- Preheating steam boiler feed
- Hot water for cleaning
- Hot water for bathing and showers
- Heating of office or production facilities
- Use in production processes
- Supply to district heating network

Warm waste water	20 m³/hr	50°C → 20°C
Clean incoming water	20 m³/hr	45°C ← 15°C*

* Incoming groundwater or mains water for Europe assumed at 15°C.

Savings in this application is 600,000 kCal/hr or 700 kW:

700 kW x 8,760 hrs per year x 0.10 euro/kWh = 613,200 euro per year.

Even if saving is a total of one month in the year, this equates to 51,100 euro per month!

Daily saving is 1,710 euro per day, 71 euro per hour, every hour.

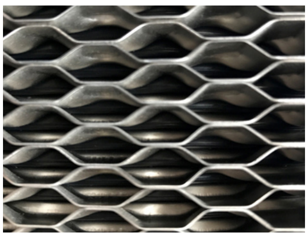
Heat recovery equipment

Shell-and-tube heat exchangers for wastewater applications are less prone to blockage but not so ideal for heat recovery, as their approach temperature is limited at best to 10°C due their non counter-current flow behaviour. Standard plate heat exchangers provide excellent efficiency with up to 1°C approach temperature but can block with fibres. Alfa Laval WideGap gasketed plate heat exchangers fall right in between with ideal efficiency and blockage free operation.

With a channel gap of 11 mm Alfa Laval WideGap plate technology provides a rectangular channel flow path without contact points, for wastewater containing particles, debris, fibres and do not require fine pre-filtration below 5 mm. In other words, anything under 5 mm will pass through the channels without causing blockages.

While the fibrous wastewater flows in the wide channels, Alfa Laval offers technology such that the clean water can flow through narrow channels for maximum turbulence.

The Alfa Laval WideGap gasketed plate heat exchanger can be operated a long time without the need for manual maintenance with periodic back flushing when needed.



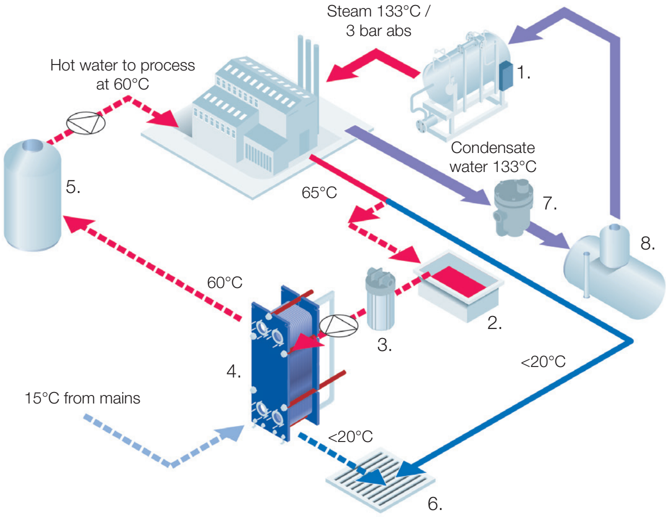
Conventional plate heat exchanger

Wide channel both sides

Wastewater wide, clean water narrow channels

Productivity savings

Many processes use steam to generate hot water for process requirements. The time it takes to heat the water to the required temperature is a loss in operational time for plant capacity. By having hot water ready at the desired temperature means faster batch processes and an increase in plant capacity.



1. Steam boiler
2. Collection tank
3. Pre-filter <5 mm
4. WideGap plate heat exchanger
5. Hot water storage tank
6. Drain/effluent treatment
7. Steam trap
8. Condensate tank 104°C

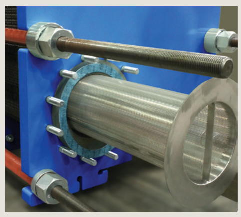
Effluent from the plant under 20°C can be separately sent directly to drain without mixing with the valuable hotter water using a two-way solenoid valve giving direction when the effluent temperature is too low for the recovery. The savings are not only in unnecessary cooling the temperature of the effluent but reduce pumping costs of effluent through the plate heat exchanger.

Simple sedimentation filter with 5 mm perforation mesh can be recommended to keep out particles larger than 5 mm to enter the gasketed plate heat exchanger channels.

▼ PRACTICAL TIPS

Back flushing is a handy way of cleaning a gasketed plate heat exchanger without opening the unit. With suitable diameter connections installed on the inlet and outlet of the wastewater to the gasketed plate heat exchanger, manual or automatic back flushing can be done. When to back flush can be followed by monitoring the pressure drop across the gasketed plate heat exchanger.

Port filter is an Alfa Laval original equipment supply shipped with the unit installed at the inlet of the wastewater. The perforations diameter of 5 mm is suitable as anything under 5 mm will enter and leave the widegap gasketed plate heat exchanger.



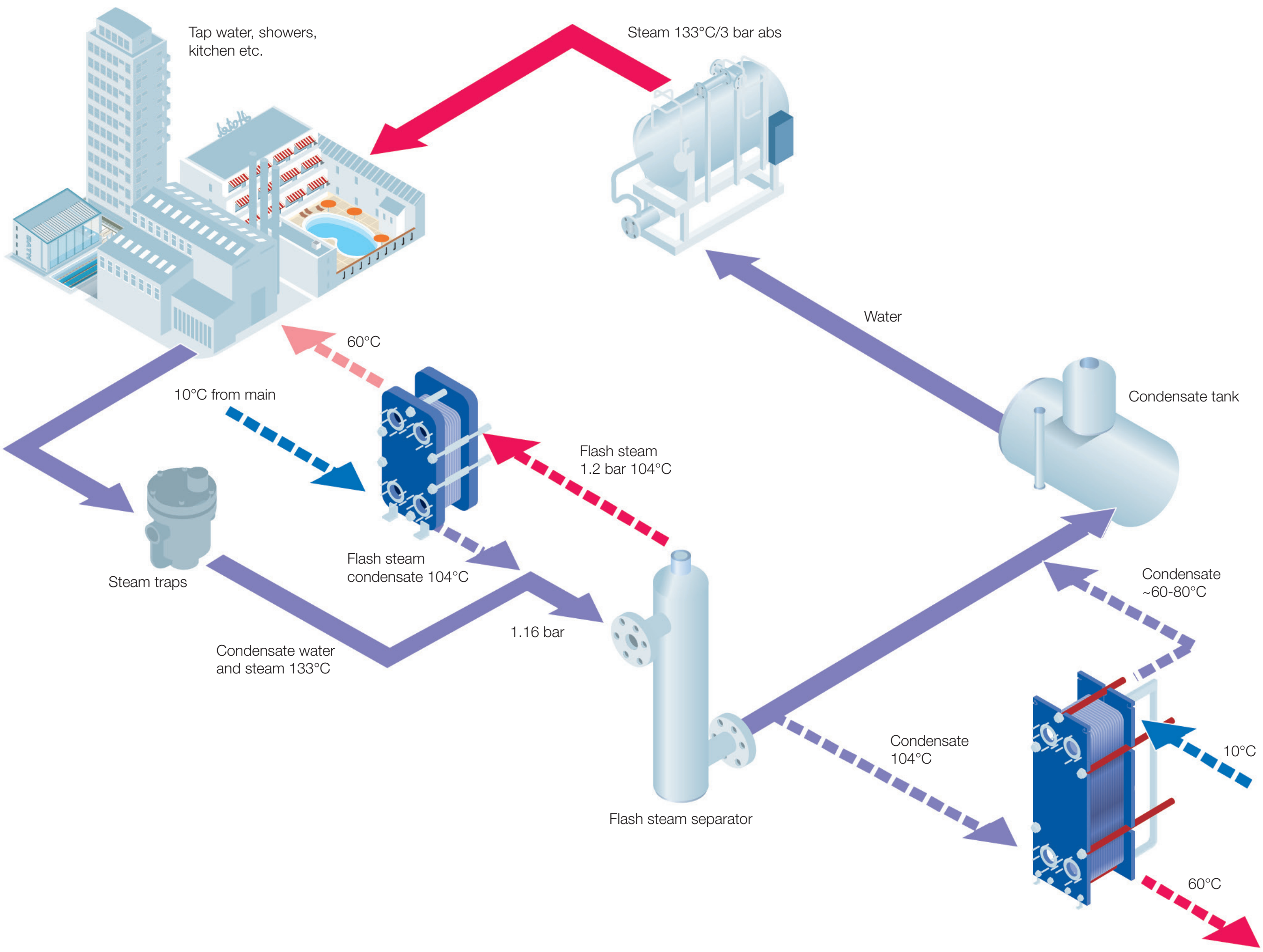
Heat recovery from waste flash steam

Steam is found in abundance as a primary heating media in many manufacturing industries, hotels, hospitals, food processing, and pharmaceutical industries. The popularity of steam can be attributed to its high calorific value per ton, economic benefits and not requiring pumping around long distances in large plants. Some of the challenges in steam lie in its regulation, control, and condensate management.

Flash steam is undesired in a perfect steam system. Ideally, 100% of the produced steam vapour should condense at the usage points, and good steam traps should not permit flash steam to enter the condensate tank. Steam systems are designed to minimize heat losses with insulation on piping and control valves and release of flash steam to the atmosphere, which is a massive waste of valuable energy if not recovered.

The below diagram shows a simple steam cycle where the steam generated at the boiler, used for various processes at 3 bar or 133°C releasing its heat by condensation and the condensate returning to the condensate tank. Uncondensed steam travelling with the condensate usually released to the atmosphere as flash steam. This is undesired as steam not returned as condensate needs to be refilled with costly treated makeup water. For heat recovery, a gasketed plate heat exchanger (GPHE) installed with a simple separation vessel containing a conic rise inhibitor.

Heat recovered from flash steam can produce hot water for plant cleaning, bathing facilities, heating offices, and production facilities, returned to the production process, preheat makeup water or sold to surrounding district heating networks.

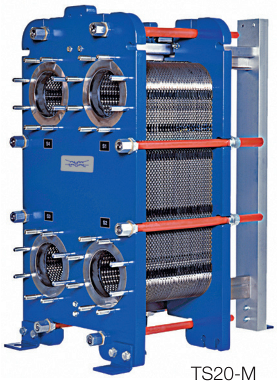


Heat recovery equipment

Steam is a highly efficient heating media; hence the over efficiency that is offered by most widespread liquid to liquid application plate heat exchangers, is not right. Liquid to liquid units are designed with efficient plate design, a tall height, narrow channel gap, and a narrow width – forcing a small connection diameter. This will result in oversized units with high-pressure drops that can lead to stalling and mechanical plate fatigue. Hence, steam requires precisely the opposite geometry of the plate, being short and fat; allowing a larger diameter connection and with wide channel gaps.

The Alfa Laval TS6-M and TS20-M are designed for steam and are perfect for heat recovery from flash steam with minimum steam pressure drop, as flash steam is generally at atmospheric pressures.

TS6-M



TS20-M

The technology to efficiently recover heat from flash steam are best suited with gasketed plate type heat exchangers, especially designed for steam. The proportion of condensate return depends on the industry and process. The table below shows the proportion of condensate return for different applications:

Steam application	% condensate return
Autoclave heating	0%
Jacket heating	90-100%
CIP	90-100%

In flash steam heat recovery, the vapour collected at the separator before the condensate tank (can be a concrete in ground pit) is connected to the top inlet of the GPHE and can condense with a minimum pressure drop. On the other side, cold water entering at the bottom connection will be heated by the condensing flash team.

Calculation of savings per ton of condensed flash steam

- Flash steam at 103°C / 1.1 bar atmosphere.
- Savings 8 hours/day 20 days/month.
- Cost of heating with natural gas 0.10 euro/kWh.
- Investment other than GPHE is 10,000 euro.
- Return on Investment (ROI) based on GPHE exchanger product pricelist.
- (TS6M FG Alloy 316 0.6 mm EPDM Clip-On DN65 flanged connections.)

Radiator water or process water heating with recovered flash steam

Amount of flash steam recovered (kg/hr)	Amount of water (kg/hr) heated*	Energy savings (kW)	Alfa Laval model	No. of plates	Savings in euro per month	Approximate Return on Investment (ROI months)
100	2,730	63.6	TS6-M FG	8	1,018	13.2
200	5,464	126.8	TS6-M FG	12	2,029	6.8
300	8,216	190.7	TS6-M FG	16	3,051	4.6
500	13,693	317.9	TS6-M FG	22	5,086	2.9
750	20,609	478.4	TS6-M FG	32	7,654	2.1
1,000	27,485	638.0	TS6-M FG	42	10,208	1.7

* 60°C → 80°C, ΔT 20°C

Tap water heating with recovered flash steam

Amount of flash steam recovered (kg/hr)	Amount of water (kg/hr) heated*	Energy savings (kW)	Alfa Laval model	No. of plates	Savings in euro per month	Approximate Return on Investment (ROI months)
100	1,100	63.9	TS6-M FG	8	1,022	13.1
200	2,192	127.3	TS6-M FG	10	2,037	6.7
300	3,307	192.1	TS6-M FG	14	3,074	4.5
500	5,521	320.7	TS6-M FG	20	5,131	2.8
750	8,285	481.2	TS6-M FG	28	7,699	2.0
1,000	11,056	642.2	TS6-M FG	34	10,275	1.6

* 10°C → 60°C, ΔT 50°C

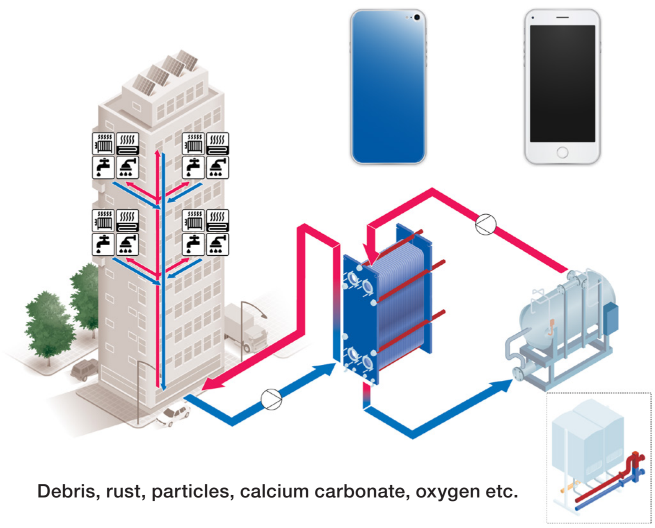
▼ PRACTICAL TIPS

Stalling can be reduced by minimizing oversurfacing with a flow by-pass method, condensate level control or installation of a vacuum breaker.

Boiler protection with gasketed plate heat exchangers

Be it new or retrofit, boilers are a major investment in communal living and need protection. Gasketed plate heat exchangers (GPHE) installed between the boiler and the point of use, do exactly that. Protection of the new boiler from harm caused by fouling, debris, calcium carbonate and oxygenated water from the dwelling side.

Without protection, the layer of calcium carbonate scale on the boiler heat transfer surfaces increases fuel costs, exhaust gases released and an overall negative impact to the environment. A boiler with a gasketed plate heat exchanger, is like a smart phone with cover for protection.



Debris, rust, particles, calcium carbonate, oxygen etc.

Sustainability with Alfa Laval gasketed plate heat exchanger protecting the boiler

1. Save with protection from debris

Debris, rust particles, solid matter and calcium carbonate break off's enter the boiler tubes or boiler heat exchanger and block the flow passage increasing electricity costs in pumping. This is especially a concern with small flow passages in cascade boiler heat exchangers, which are difficult to access and maintain.

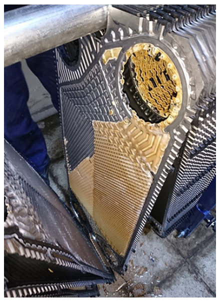
Alfa Laval GPHE's are fast and easy to open, clean or flush from debris.

2. Save with protection from $CaCO_3$

With Monobloc type, a coating of scale will build up inside the tubes leading to higher fuel costs from resistance in heat transfer. A 1 mm coating is approximately 12% higher fuel bills. With a Cascade type, a coating will build up between the narrow boiler heat exchanger channels. This will result in high fuel costs.

However, another major concern is the growth of deposit over the years, baking rock hard with the high flame temperatures of >1,000°C and eventually crack the SS heat exchanger due to thermal expansion and contraction. Replacement is costly at 80% of the boiler price which does not help sustainability.

In hard water regions, 40% of the installations require costly replacement of the boilers SS heat exchanger within a few years.


Calcium carbonate will attach itself to the hottest surfaces, the hotter the more. Alfa Laval GPHEs restrict the calcium carbonate formation from going to the difficulty of cleaning the boiler. With high turbulence and high velocities, lower temperatures than the boiler flame (1,000°C) and perfect flow distribution across the plate with Alfa Laval CurveFlow™ technology, there will be even less buildup of CaCO3 with Alfa Laval compared to others.

3. Protection from static pressure

Tall building heights cause increased static pressure which the boiler is subject to.

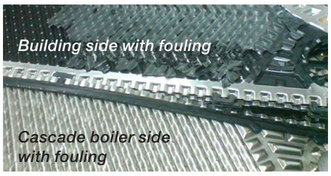
An Alfa Laval GPHE can work as an interceptor with up to 25 bar on the building side and lowest design pressure on the boiler side. Savings in Capital Expenditures (CAPEX) of boiler construction materials and automation helps sustainability.

4. Protection from non-oxygen barrier floor tubing

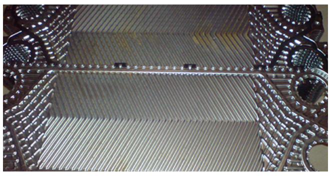
Oxygen permeation is a cause for corrosion in plant equipment due to oxygenated water. Oxygen enters the system at the usage point from radiator flushing or air venting. This will oxidize the water leading to corrosion of the boiler tubes with ferrous oxide. Care must be taken to assure that each component in the system is nonferrous (meaning that it contains no iron).

The Alfa Laval GPHE plates of stainless steel alloy 316 material can easily withstand the harm from corrosive oxygenated water allowing the use of 25% less expensive non-oxygen barrier PEX (Polyethylene Crosslink) pipes for floor heating.

With fast and easy maintenance and access to all surfaces, buildup of calcium carbonate can be mechanically removed within a few hours.



Before cleaning


After cleaning

Boiler protection with an Alfa Laval GPHE is like taking an insurance policy for the boiler. Protects from harm and operation will be lifelong as new for a little as 10% of the investment of the boiler price.

5. Fuel savings

Building A and Building B are equivalent in construction, in the same compound estate, having independent but identical boilers. Tap water heating is via electric heaters per apartment. There is no solar heating available.

Building A has installed an Alfa Laval T5-M GPHE as protection for the gas fired boiler. The debris, oxygen and scale are contained in the building closed loop and does not enter the boiler. The boiler loop has less water and remains clean lifelong. The GPHE is easily maintained annually removing all fouling and scale formation. There is less scale formation as the hard water in the building loop is only subject to 80-90°C and not the flame 300-600°C. Boiler efficiency is maintained at 85%.

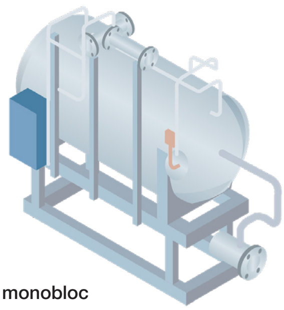

Building A's natural gas heating bill is on average 2,470 euro per year.

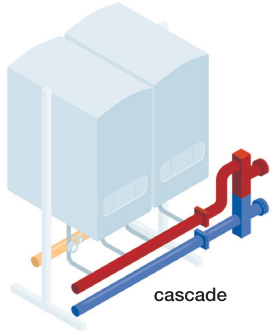
Building B has the heating water of the building circuit, going directly to the boiler. The scale (CaCO3) normally dissolved in cold water is subject to hot flame temperatures of 300-600°C precipitating a lot more from the water. This scale attaches to boiler hot heat transfer surfaces and bakes to a rock hard formation. Boiler efficiency reduced to 75%


Building B's natural gas heating bill is on average 3,211 euro per year, 30% more!

Boiler comparisons

How water boiler configuration can be a traditional monobloc single large boiler or smaller cascade boilers either wall hung or free-standing, working in parallel.


monobloc


cascade

	monobloc*	cascade*
Installation	Floor	Floor or wall
Fuel	Coal, LPG, NG	NG
Heat transfer material	Carbon steel shells Carbon steel tubes	Corrugated 316 or 316Ti plate, diagonal or radial
Applications	Large buildings, hospitals, universities, factories	Corrugated 316 or 316Ti plate, diagonal or radial
Types	Water tube or fire tube	Cascade parallel
Operating pressure	3-5 bar	>6 bar
Advantages	Robust, lower Capital Expenditures (CAPEX), plug leaking tubes	SS heater, lower hold-up volume, faster response, flue gas condenses further reheats water 109% efficiency
Disdvantages	Size, footprint, low efficiency, heat losses with radiation and flue gas	Smaller orifices or gap between plates, blockage risks, can only replacement of heat exchanger
Calcium Carbonate effects ($CaCO_3$)	Coating on inner surfaces of tubes, increasing fuel costs	Baking inside SS heat exchanger gap, cracking heat exchanger with thermal expansion
Efficiency	60-70%	109% condensing boiler

* Selection of either in an installation depends on fuel type, capacity need, space available, partial loads etc.

▼ PRACTICAL TIPS

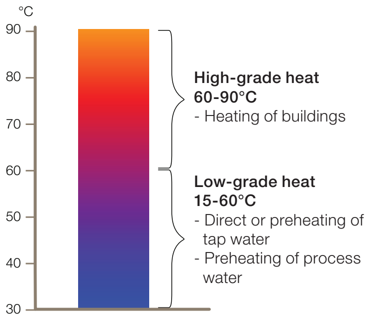
1. Installing an Alfa Laval gasketed plate heat exchanger will provide lower water temperature needed for floor heating applications. The limitation in temperature is due to plastic, PEX floor heating pipes and health and safety issues.
2. The design pressure limitations of cast iron boiler is a maximum of 4 bar.
3. A gasketed plate heat exchanger to a boiler is protection, like a cover for a smart phone.
4. Installation of a balance tank can be avoided, reducing investment costs with an Alfa Laval gasketed plate heat exchanger installed to protect the boiler.

Heat recovery from open cooling tower

Global warming, climate change, carbon foot print is on everyone's agenda, how to be more efficient, more environmentally friendly and saving natural resources is the highest priority. Waste heat is waste energy, because heat is generated by energy obtained by burning natural resources such as fossil fuels, LPG, fuel oil and natural gas. By recovering waste heat, we not only protect the environment, but also save money and contribute to profitability of one's total operations.

Energy from waste heat can be recovered from different grades of temperature and transferred to other fluids which are required to be heated.

For example high grade heat can be hot water at 90°C, which can be used for heating buildings and low grade can be that from return cooling tower water, at 35°C at its peak, that can be used to preheat boiler feed water or process water.



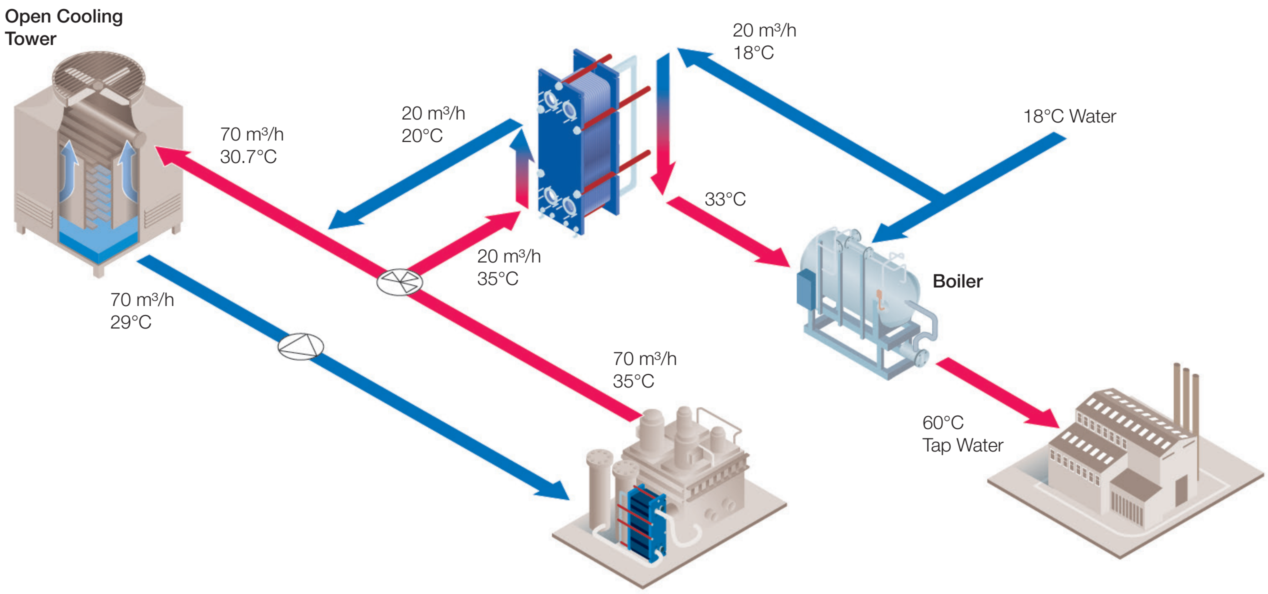
Heat recovery from low- and/or high-grade heat

Manufacturing industries use heat for reactions, treatment and various processes after which, the unwanted waste heat is released to the atmosphere with an open cooling tower. Similarly, in **HVAC applications**, many people spaces need heat to be removed with the help of a chiller, which in turn releases the unwanted waste heat to an open cooling tower via the chiller's condenser.


Typical open cooling towers

Typically, open cooling towers are designed for peak hottest summer conditions and a ΔT of 6°C. This can be 35°C to 29°C at a dew point of 27°C. Whether or not 35°C return cooling tower water is valuable for recovering, can only be evaluated when compared to a plant using boiler feed water at ambient temperatures of 10°C or 20°C.

Gasketed plate heat exchangers with counter-current flow are commonly used for heat recovery applications because of their excellent flow regime, making it possible to achieve a temperature approach of as low as 1°C. Hence for a cooling tower water return temperature of 35°C, boiler feed water can be preheated to as high as 34°C. However, for best economies of scale and optimum payback period, Alfa Laval recommends a 2°C approach, i.e. preheating to 33°C.



Savings with heat recovery

There are several savings in this heat recovery application.

- Savings with almost halving the boiler fuel bills, as the boiler will heat water from 33°C to 60°C instead of 10°C to 60°C
- Savings with increased cooling tower capacity, as lower return temperature will require lower cooling demands from the cooling tower.

Saving water with less evaporation release to atmosphere

Enthalpy of water at 30°C is 125 kJoules/kg or 522 kCal/kg (multiplied by Cp of 4.18).

Water lost before and after heat recovery:

$$\frac{420{,}000 \text{ kCal/hr}}{522 \text{ kCal/kg}} = 804 \text{ kg/hr} \qquad \frac{120{,}000 \text{ kCal/hr}}{522 \text{ kCal/kg}} = 230 \text{ kg/hr}$$

Saving 804 - 230 = 574 kg/hr x 8 hrs a day and 365 days per year = 110 m³ per year waste of natural sources.

In monetary terms at 1 euro/m³ perhaps this is little, but as chemically treated water with RO is a huge impact to the environment wasting natural resources.

Calculation of savings

Example: Heat recovery from cooling tower 420,000 kCal/hr operating 35° to 29°C and 70 m³/hr. Assume heat recovery form only a partition of the total flow: 20 m³/hr.

Cooling tower water returning to the tower at 35°C cooling to 20°C, preheating ambient temperature boiler feed water at 18°C to 33°C.

Alfa Laval gasketed plate heat exchanger selection:

Cooling tower return water	20 m³/hr	35°C → 20°C
Boiler feed water	20 m³/hr	33°C ← 18°C

What will be the:

a) Amount of waste heat recovered in kW?
b) Duration savings for in kWh?
c) Savings in monetary terms, assuming cost of 0.10 euro/ kWh?
d) Payback period in months?
e) New return temperature to tower?

a) Amount of waste heat recovered in kW?

Heat absorbed by boiler feed water = Heat released from cooling tower

$$\mathbf{Q = m \times c \times \Delta T_{(cold)} = m \times c \times \Delta T_{(hot)}}$$

Q: Waste heat recovered kCal/hr
m: Flowrate m³/hr
c : Specific heat of water (assume as 1 for water)
ΔT: Temperature change, $T_{out} - T_{in}$ °C

Q = 20 x 1 x (35-20)
= 300,000 kCal/hr
= 349 kW (divided by 860)

b) Duration savings for in kWh?

Assuming operation is 8 hours per day and 20 days per month.

Savings = 349 x 8 x 20
= **55,840 kWh per month**

c) Savings in monetary terms, assuming cost of 0.10 euro / kWh?

Savings = 55,840 x 10
= **5,584 euro per month**

d) Payback period in months?

Assuming a total investment cost of 15,000 euro (Alfa Laval gasketed plate heat exchanger 7,000 euro and associated costs such as piping, installation and commissioning 8,000 euro).

The **payback period will be 3 months** to recover the capital investment.

e) New return temperature to tower?

With a total of 70 m³/hr split as 50 m³/hr at 35°C and 20 m³/hr at 20°C. Hence the overall return cooling tower temperature will be:

$$= \frac{50 \times 35}{70} + \frac{20 \times 20}{70}$$

= **30.7°C for 70 m³/hr** total flow instead of 35°C

▼ PRACTICAL TIPS

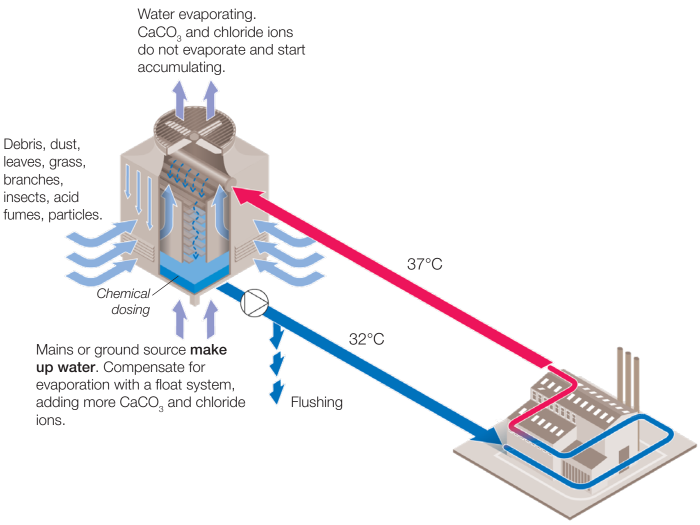
If preheated water cannot instantly be used at the boiler, this water can be stored in a buffer tank to be used at a later stage when needed. The payback period will be reduced if the cooling tower and boiler are placed close to each other, as the piping investment cost will be reduced.

Cooling tower interchanger

Open cooling towers are a major source of fouling for industrial plants, causing the need for frequent maintenance of other equipment in the plant. The plant cooling loop is normally completely closed and chemically treated, other than the open cooling tower - which forms the only interface with the atmosphere.

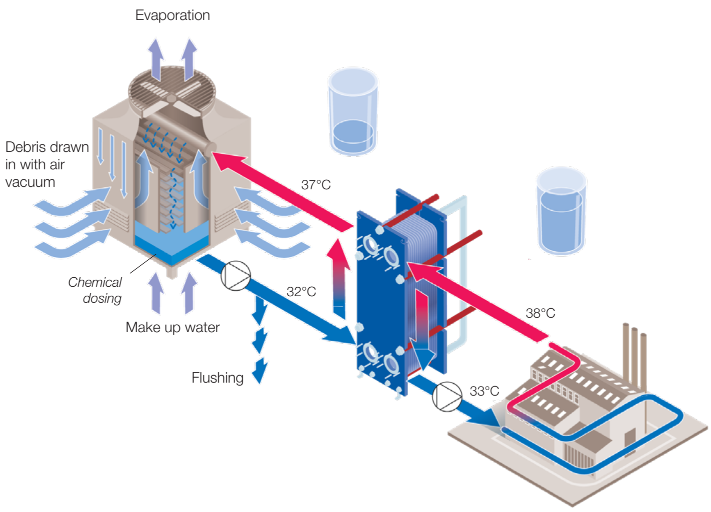
As the cooling water, circulating through the plant, falls freely across the cooling tower packing, the fan(s) pull in fresh air, creating a vacuum around the tower, which attracts air borne particles in close vicinity. These many and varied debris will find their way inside the plant's cooling equipment such as shell-and-tube heat exchangers. The debris settle in low flow areas or dead spots and cause high costs in maintenance, unplanned shut down, condensers' losses in heat transfer efficiencies and additional pumping costs.

Open cooling tower systems are also a source for increasing levels of calcium carbonate and corrosive chloride ions in the circulating cooling water. These unwanted minerals enter via make-up water and accumulate over time to unacceptable levels. The water in the open cooling tower water loop evaporates, but the minerals stay and increase in concentration in the cooling system. **Over a six-month period, calcium carbonate and chloride ions can double in concentration!** The only way to rid the system of these unwanted minerals is to periodically flush the loop. This means increased operational costs and is normally not done, as water costs are high (typically in western Europe at 1 euro per m³).



Alfa Laval gasketed plate heat exchangers as an interchanger

Plate type heat exchangers with countercurrent flow are commonly used as a 'cooling water loop circuit breaker' because of their excellent flow regime making it possible to achieve a **temperature approach of as low as 1°C**. With the help of an Alfa Laval gasketed plate heat exchanger installed as an interchanger, instead of sending 32°C dirty cooling tower water to the plant, it is possible to supply 33°C closed clean water.



Benefits of a gasketed plate heat exchanger as an interchanger

- Closed loop cooling with clean cooling water that is free of debris and steady acceptable levels of calcium carbonate and chloride ions.
- Savings in pumping costs with clean pipes, which diameter has not reduced due to adhesion of calcium deposits on inner hot pipe surfaces.
- Savings in reduced maintenance costs of downstream cooling equipment like shell-and-tube heat exchangers.
- Savings in heat transfer area, not having to plug tubes of a shell-and-tube due to crevice corrosion caused by high levels of chloride ions.
- Less money spent on chemical dosing and treatment of a smaller volume of open cooling tower loop. Typically, 10% of overall cooling loop in volume.
- Savings in unplanned shut downs interrupting processes due to mechanical corrosion and needs of maintenance.
- Plant's low grade steel equipment will be protected from corrosion as a gasketed plate heat exchanger interchanger with Alloy 316 stainless steel plate material, will handle up to 300 ppm of chlorides at 40°C.
- Fast simple and easy cleaning of gasketed plate heat exchanger by a single person in a few hours.

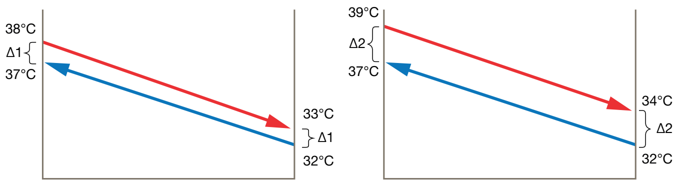
Typical temperature profile for a 27°C dew point are:

With a 1°C approach

Clean closed loop water to plant	38°C → 33°C
Dirty open cooling tower	37°C ← 32°C

With a 2°C approach

Clean closed loop water to plant	39°C → 34°C
Dirty open cooling tower	37°C ← 32°C



Other than protecting the plant from fouling due to air borne particles, biological growth, and other debris, a gasketed plate heat exchanger will ensure a lower life cycle cost for numerous other cooling equipment throughout the plant.

Problems form calcium carbonate accumulation

Increasing concentration of calcium carbonate minerals in the cooling water loop will cause major losses in energy efficiency, higher pumping costs with reduced diameter of cooling water pipes, maintenance, replacement of cooling equipment, unexpected shutdowns, losses in heat transfer efficiency, requiring more cooling water hence further investments in cooling tower capacity.

Due to its nature, calcium carbonate is soluble in cold water but will precipitate in hot water or hot surfaces. The bone like material will deposit itself on surfaces of equipment like cooling water pipes, shell side of a shell-and-tube heat exchanger and other cooling equipment. Every millimetre of calcium coating on a shell-and-tube, means resistance for heat transfer and the need for more cooling water, leading to higher pumping costs.

Cooling tower water piping circulating throughout the plant, will reduce in flow diameter over time, with calcium carbonate deposits on the inner surfaces. This will result in reduced flow to needed cooling equipment and higher pumping costs due to increased friction and smaller diameter.

Problems from chloride ion accumulation

Many cooling equipment in the plant like shell-and-tube heat exchangers are constructed of mild steel or carbon steel and will corrode due to increasing high levels of chloride ions with accumulation from make-up water. Dead spots or crevices are specially at risk with higher concentration of chloride ions in sedimentation, which is difficult to clean.

▼ PRACTICAL TIPS

1. It is advised to keep the cooling equipment full of water during shutdowns to avoid crevice corrosion with evaporating water on the surfaces due to ambient conditions. In a system drained and open to atmosphere, a droplet of water on a heat transfer surface will half in volume over time, hence doubling the concentration of chloride ions at that point. With continued evaporation, concentration will increase, hence corrosion will be inevitable.

2. Install a Y strainer (or two in parallel) of 2 mm mesh at the cooling tower inlet to the gasketed plate heat exchanger, to ensure longer periods of operation before cleaning. Any debris under 2 mm diameter will travel through the gasketed plate heat exchanger and exit at peak running conditions.

Shell-and-tube replacement with only dimensional data

Shell-and-tube (S&T) heat exchangers have been around for ages and are widely used in many industries. Their popularity comes from its simple construction, manufacturability by anyone, made from any simple material, made to any size and to withstand any temperature or pressure.

Disadvantages can be listed as below:

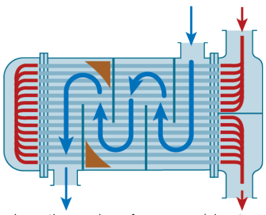
- Very low flow velocities causing fouling, likely dead zones for start of fouling.
- Not 100% counter current flow hence low efficiency.
- High hold up volume hence lagging temperature control.
- Costly to transport, heavy machinery is needed for installation.
- Large footprint, room to pull out the tube bundle.
- Difficult to maintain especially the shell side.
- Heat losses from the shell hold up volume.

The shell side usually contains the clean fluid, as the tube side is comparatively easier to clean by manual rodding. Due to these difficulties, S&T heat exchangers are seldom fully maintained, and fouling grows to such levels that it is faster and easier to replace them depending on the material of construction. Replacement with a gasketed plate heat exchanger (GPHE) can be as low as $1/3^{rd}$ of the cost.

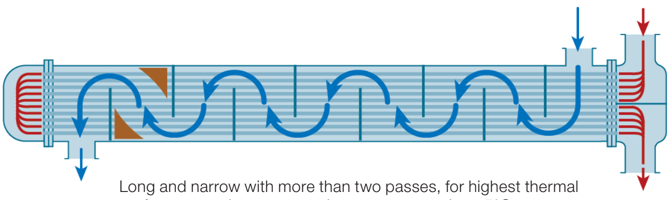
Typical construction of shell-and-tube heat exchangers

A short and fat S&T is typical for lowest thermal efficiency and performance. Approach temperatures for the two fluids cannot be better than 10°C and typical for oil cooling or steam applications with large diameter tubes and single pass.

Standard construction and flow regime



Low thermal performance (short and fat) approach temperature 10°C



Long and narrow with more than two passes, for highest thermal performance, closer approach temperature at best 5°C

Shell

Construction material is usually carbon steel with a tube sheet on either end and a header for the tube side inlet/outlet connections.

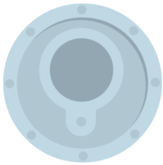
Tubes

Standard material can be copper, carbon steel, stainless steel. Tube diameter used in the construction of S&T is generally what is readily available in the market from tube manufacturers.

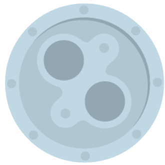
Copper or carbon steel tube diameters in inches: ¼ ½ ¾ $^{3}/_{8}$

Tube geometry is generally triangular pitch which is more efficient in layout of number of tubes. A square pitch is seldom used which aids cleaning on the shell side.

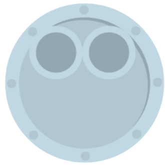
Tube side number of passes:



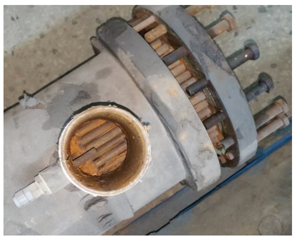
1-pass



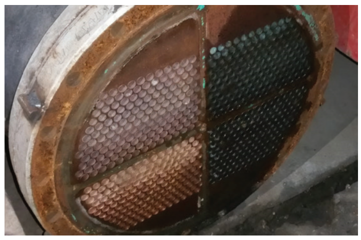
2-pass



4-pass



Disconnect to see tube diameter and pitch



Disconnect to see number of passes

Visual look for replacement

Gasketed plate heat exchanger types for replacement

Poor thermal performance from S&T heat exchangers is mainly due to the flow regime of cocurrent flow and low turbulence. Best approach temperatures reachable with most S&T heat exchangers is 5°C. Hence, low thermal efficiency and low pressure drop type plates are best suited for replacement. These GPHEs are short, wide and have large channel gaps, e.g. M3, T6-P and T10-M.

Construction showing S&T cocurrent flow, gasketed plate heat exchanger 100% countercurrent flow

Replacement with only dimensional information

Step 1 – Disconnecting the shell side fluid inlet which will show the material, diameter and pitch of tubes in the tube bundle.

Step 2 – Disconnecting the header will show the number of passes.

Shell diameter and tube diameter in a triangular pitch will give the number of tubes. Using the tube length, the approximate heat transfer area of the tubes can be calculated. Using the table to the right for matching the heat transfer area for an Alfa Laval GPHE, an approximate number of plates will perform the duty 90% of the time, based on seasonal load and peak design conditions.

Example case:

- Application: water / water
- Shell: External diameter of 0.3 m and tube length of 3 m
- Tubes are copper material and 12.5 mm external diameter, pitch of 6 mm
- Construction: two passes

Using the surface area calculation table shows approximate heat transfer area is 15.4 m² including 20% safety factor which can be used as the approximation accuracy.

Selecting an equivalent GPHE is as easy as approximating the heat transfer area required from a GPHE. Considering a higher turbulence, better efficiency as higher heat transfer coefficients achieved with GPHE, the area will be much less than the S&T.

For typical applications, comparative heat transfer area can be chosen from the table below.

Water / Water	GPHE area m² = S&T area m² / 4
Oil / Water	GPHE area m² = S&T area m² / 2
Steam / Water	GPHE area m² = S&T area m²

Alfa Laval model	Connection diameter (mm)	Area per plate	Number of plates					
			20	40	60	80	100	120
M3	36	0.032	0.64	1.28	–	–	–	–
TL3	36	0.065	1.30	2.60	–	–	–	–
T5-M	50	0.084	1.68	3.36	–	–	–	–
T6-P	50	0.14	2.70	5.60	8.50	11.50	14.40	17.40
T8-M	80	0.17	3.40	6.80	10.20	13.60	17.00	20.40
T10-M	100	0.24	4.50	9.50	14.50	19.50	24.50	29.50
TL10-P	100	0.48	9.60	19.20	28.80	38.40	48.00	57.60
M15-M	150	0.62	12.4	24.8	37.60	49.60	62.00	74.4

As this case is a water/water application with a S&T of approximately 15.4 m².
An Alfa Laval GPHE with 15.4 / 4 = 3.9 m² will be enough.
A T5-M with 40 plates is 3.36 m² but no room for expansion.
An T6-P with 30 plates is just right with 4.2 m² heat transfer area (30 x 0.14 = 4.2 m²). This unit will have capacity for expansion should you need after installation.

Savings from heat losses to atmosphere

In comparison to a S&T a GPHE provides savings and contributes to sustainability in many ways. A major saving is reduced maintenance costs but there are also measurable savings from heat losses to atmosphere, from the large hold up volume which can pay back replacement with a GPHE in a few years.

In the below example, the shell side hold up volume is 1 m³ (1,000 kg) of water held at 60°C loosing 1°C in one hour, every hour.

Specific heat of water at 60°C is 1 kCal/kgK or 4.172 kJ/kgK

Hourly heat lost = 1,000 kCal/hr
= 4,172 kJ/hr
= 1.2 kW (3,600 seconds in 1 hour)

Duration savings for in kWh?
Assuming equipment temperature is maintained 24 hours per day and 30 days per month.

Savings = 1.2 x 24 x 30 = 834 kWh per month
Savings in monetary terms, assuming cost of 0.10 euro / kWh?
Savings = 834 x 0.10 = 83 euro per month

With a 4 m³ hold up volume at 60°C, annual savings from heat losses will be 4,000 euro.

▼ PRACTICAL TIPS

When sizing a S&T, usually a safety factor of at least 20% is applied to account for possible errors and expected fouling. GPHE plates can be added or taken away at any time after initial installation, to cater for mistakes or additional load that may be required at a later stage.

This is Alfa Laval

Alfa Laval is active in the areas of Energy, Marine, and Food & Water, offering its expertise, products, and service to a wide range of industries in some 100 countries. The company is committed to optimizing processes, creating responsible growth, and driving progress – always going the extra mile to support customers in achieving their business goals and sustainability targets.

Alfa Laval's innovative technologies are dedicated to purifying, refining, and reusing materials, promoting more responsible use of natural resources. They contribute to improved energy efficiency and heat recovery, better water treatment, and reduced emissions. Thereby, Alfa Laval is not only accelerating success for its customers, but also for people and the planet. Making the world better, every day. It's all about *Advancing better*™.

How to contact Alfa Laval

Contact details for all countries are continually updated on our web site. Please visit www.alfalaval.com to access the information.

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