INDUSTRIAL COOLING WHITEPAPER

TAKE CONTROL OF INDUSTRIAL COOLING WITH INTELLIGENCE

DEEP DIVE INTO INDUSTRIAL COOLING CHALLENGES AND LEARN HOW TO MAXIMIZE EFFICIENCY WITH **GRUNDFOS iSOLUTIONS**

UP TO **30%** REDUCED OPEX

UP TO **70%** ENERGY SAVINGS

FULL **CONTROL**

GRUNDFOS iSOLUTIONS | A SMART SOLUTION FOR YOU

Table of Contents

Grundfos Americas
Brookshire, TX 77423

www.grundfos.us
www.grundfos.ca
www.grundfos.mx

GRUNDFOS

Introduction:

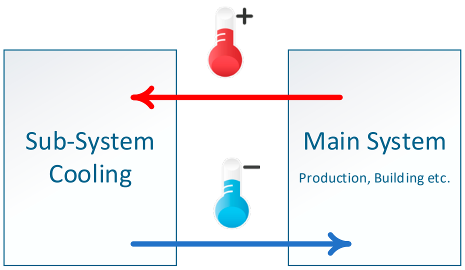
Cooling and/or refrigeration is present in some form in almost every industrial production or process facility. The purpose of industrial cooling is to cool and remove heat from industrial machines, such as welding and injection molding machines, as well as industrial processes, including dairy, chemical and fermentation.

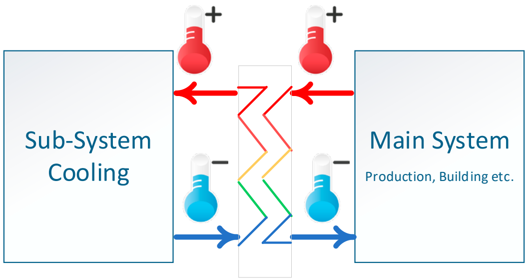
Purpose:

Cooling is part of a wide range of processes and industries, meaning the cooling industry is rather fragmented and a one-size-fits-all approach doesn't always work. As pumps play a large role in industrial cooling systems, this document will offer an overview of the typical areas where pumps impact performance and the benefits of variable speed pumps from Grundfos.

Introduction to Industrial Cooling

The purpose of an industrial cooling system is to remove heat from a machine or process to ensure their protection and optimal operation.





Cooling and/or refrigeration will be present in some form in almost every industrial production or process facility. The purpose of industrial cooling is to cool and remove heat from industrial machines, such as welding and injection molding machines, as well as industrial processes, including dairy, chemical and fermentation.

Cooling is part of a wide range of processes and industries, meaning the cooling industry is rather fragmented and a one-size-fits-all approach doesn't always work. Because pumps play a large role in industrial cooling systems, this document offers an overview of the typical areas where pumps impact performance and the benefits of variable speed pumps from Grundfos.

Industrial Cooling Process

The function of most pumps installed in an industrial cooling system is to circulate water through the different steps of the cooling system. The following diagram illustrates a typical industrial cooling system.

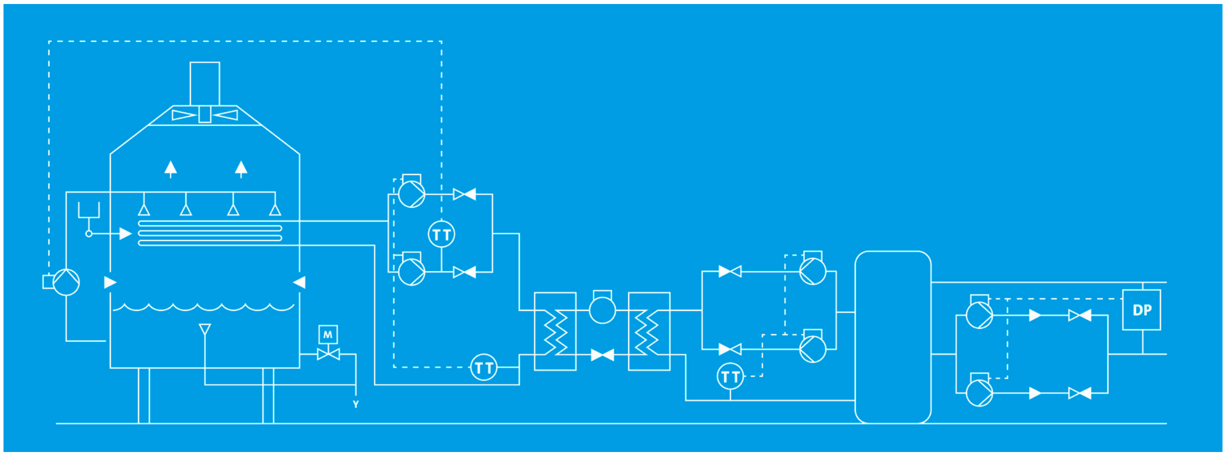
On the right side is the main circulator system which circulates cold water from the cooling system, removing heat from the process or machine, and transporting it back to the cooling plant.

The main circulator pumps are normally large pumps that are running constantly, so it's important to be able to control them. The most efficient way to control them is by differential pressure or proportional differential pressure, so the pump only delivers the water needed in the system.

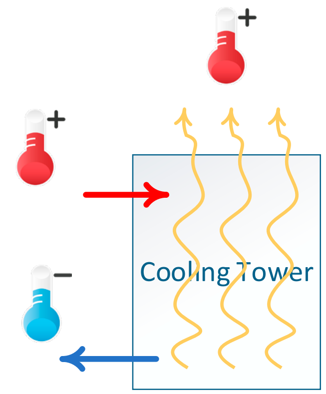
Next, are the chiller pumps. The chiller pumps circulate water between the buffer tank and the cold side of the chiller. Here, you can optimize the use of your buffer tank by having a signal from your chiller to start and stop your pump. This way you don't waste energy circulating water when the chiller isn't running.

Condenser pumps transfer heat from the chiller to the cooling tower. You can run them via a temperature signal, or from your chiller control, and it is possible to have a slow start-up when the condenser water temperature is low.

The last step is the cooling tower. In this case, we have a closed evaporating cooling tower, which removes heat from the system by evaporating the water. You can control the tower's water circulation according to the condenser water temperature and start/stop the tower fan as much as possible.



Cooling Towers

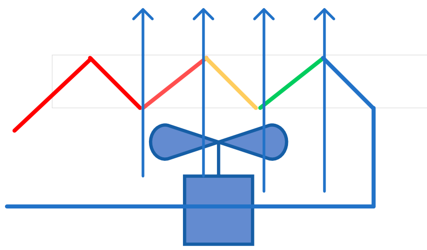


A cooling tower is a heat rejection device that ejects waste heat to the atmosphere by using ambient air to cool water to a lower temperature. Cooling towers either use the evaporation of water (evaporative cooling towers) to remove process heat and cool the working fluid to near wet-bulb air temperature, or by using ambient air (dry cooling towers). This relies solely on air to cool the working fluid to near dry-bulb air temperature.

Common cooling tower applications include cooling the circulating water used in oil refineries, petrochemical and other chemical plants, thermal power stations, process cooling, and HVAC systems for industrial buildings. The classification is based on the type of air induction into the tower and whether industrial water is evaporating in the tower.

Different types of cooling towers:

- Dry coolers
- Evaporative cooling towers
  - Closed loop
  - Open loop
  - Condenser



Dry Coolers

Dry coolers are used either as a free cooler or to cool the condenser in a refrigeration system.

There are typically two designs of dry coolers: flatbed and V-shapes. The function of both are the same. In flatbed designs, there is a cooling coil, constructed of pipes and fins, in the frame of the bed. In V-shape designs, the coil is in the V-shaped sides of the dry cooler. In most cases, the dry cooler will be controlled by a dedicated fan controller and operate the pump in a fixed flow. An MPC can control the fans in the dry cooler, although this isn't a cost-effective way of doing it.

Working with a dry cooler as a cooling condenser, the general understanding is to have constant flow for the condenser and the lowest possible temperature. In cases where the dry cooler operates as a free cooler, the pump can take over temperature control in low-load situations when fan cooling isn't needed.

Some V-shape dry coolers have a separate adiabatic system where a water-evaporating system is added to the sides. The adiabatic system has a relatively small flow of water, either sprayed over the coil or in a panel with a fill material that provides a larger surface for the water to evaporate from. Grundfos LCSEs, VLSEs, MAGNAs and UPs could be used here. The MAGNA 3, for example, can start/stop control when the temperature is low enough not to use the adiabatic system.

Evaporative Cooling Towers

The evaporative cooling tower is one of the most common types of equipment used in industrial cooling. This topic is too broad to cover in total here, but essentially, there are three main types that are constructed in a variety of ways. The pump circulating the water in the cooling tower is called the spray pump or the circulator pump. The best control for this pump is a start/ stop control.

Evaporative Condensers

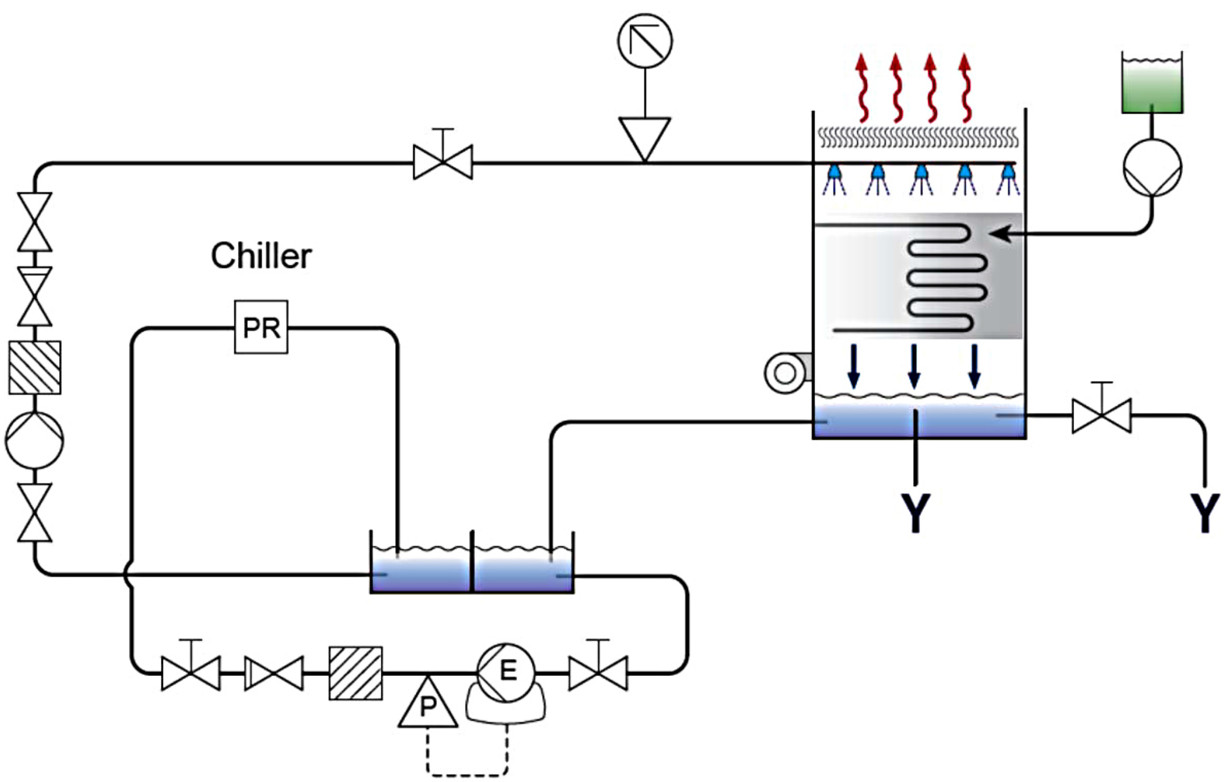
The evaporative condenser is very similar to the closed-loop cooling tower. The condenser coil is positioned in the tower so there is a relatively small pump (TP/LC) circulating water. The pump circulating the water in the cooling tower is called the spray pump or the circulator pump. The pump should only provide the necessary pressure for the spray nozzles to have the correct distribution. The temperature control in the tower is performed by the fan.

Closed-Loop Cooling Towers

As the name implies, closed-loop cooling towers have the process/cooling water as a closed system. The cooling tower normally has a small pump circulating water in the tower (TP/LC) and a larger pump circulating the process/cooling water (LC, LCSE, TP/E). The smaller cooling tower pump should run at a fixed pressure for the correct spray of the nozzles in the tower. For the larger system pump, the control mode depends on the system – most larger systems have several consumers and will therefore benefit from a pressure-controlled system. The best control for the spray pump is a start/ stop control.

Open-Loop Cooling Towers

In an open-loop cooling tower, the process/cooling water is distributed and sprayed in the tower and then returned to the process. The controls of the pump depend on the system the tower is cooling.



Industrial Chiller

Industrial chillers are classified as refrigeration systems that cool process water, large HVAC systems and industrial facilities. A chiller will use either a vapor compression or absorption cycle to cool. Chilled water has a variety of applications, from facility cooling to process cooling. An industrial chiller is defined by the refrigerant used. Its components (compressor, evaporator, condenser, throttle valve) are built on a single frame.

Types of industrial chillers

A chiller is rated in either cooling energy BTU or cooling capacity kW. There are three main types of chillers: air chiller, water chiller and evaporative condensed chiller. There are four types of technologies used in industrial chillers: reciprocating, centrifugal, screw driven and absorption chillers. The first three types are used in mechanical chillers, which are powered by electric motors. An absorption chiller is powered by a heat source such as steam and uses no moving parts.

Components of an industrial chiller

The mechanical compression cycle has four basic components through which the refrigerant passes: evaporator, compressor, condenser and expansion valve. The evaporator in the chiller will operate at a lower pressure and temperature than the condenser.

Evaporators in industrial chillers

Shell-and-tube evaporators: typically configured with the refrigerant flowing through the tube side and the process fluid through the shell side of the unit. This style of evaporator has lower pressure drops than brazed plate technology and is available in larger capacities.

Brazed plate evaporators: the advantages of this technology are higher efficiency and lower costs, and is available from fractional tonnages to lower capacities.

Semi-welded heat exchangers are also highly efficient and can be used for large capacities.

Compressor types in industrial chillers

Reciprocating compressor: this uses pistons driven by a crankshaft and is used for delivering a small amount of refrigerant at a very high pressure. Reciprocating compressors are usually semi-hermetic compressors, which simply means they are serviceable.

Centrifugal compressor: this has fewer moving parts than a reciprocating compressor. They are energy efficient and give a higher refrigerant flow than a similarly sized reciprocating compressor. Centrifugal compressors are more suited to high-volume but low-pressure applications, such as those that use ventilation fans, cooling units and air movers. The centrifugal compressor operates by using the centrifugal force applied to an air mass to achieve compression.

Screw compressor: this has two screws (male and female) that are fitted together in stationary housing. As the rotors rotate, the gas is compressed by direct volume reduction between the two rotors. These compressors are also semi-hermetically sealed compressors. By using a VFD on the screw compressor, the efficiency is similar to other compressor types.

Location of industrial chillers

Large industrial chillers are commonly located in a machine room, circulating cold water into the factory or close to the process in which they are cooling. Some industrial chillers may be located directly beside the process, depending on the size of the chiller and compressor. Others may even be placed completely outdoors.

Cooling Buffer Systems

A buffer tank is a storage tank that can be used on the cold side of a cooling system. The system can be the cold side of a traditional refrigeration/chiller system, or a free cooling system where only a cooling tower is needed.

A buffer tank is typically used when there is a variable cooling load. In such applications, the tank is used as storage to cover peak loads or in situations when a surge in demand exceeds the capacity of the cooling system.

When a cooling system starts up, it increases energy consumption and wear on the cooling compressor in comparison to continuous operation. A buffer tank is well-suited to situations where cooling loads are small because it reduces the number of starts and therefore decreases wear and energy consumption.

In large industry plants, several pumps can be used on many different levels. Buffer tanks are also used to accumulate cooling capacity, and buffer tank sizes vary from small to very large tanks. Pumps can either be single-stage or multistage. Pump sizes vary from large LC/LCSE primary pumps to small UPS pumps in the smallest of cooling loops.

Free Cooling

The cooling business is increasingly focusing on energy reduction, and the term “free cooling” is becoming increasingly popular.

Free cooling is an economical method of using low external water or air temperatures to assist in chilling water, which can then be used for industrial processes. The chilled water can either be used immediately or stored for the short or long term. When external water with low temperatures is available, or outdoor temperatures are lower than the machinery/ process cooling temperature, this system uses the external water/air as a free cooling source. In this way, the system replaces the chiller in traditional refrigeration systems while achieving the same cooling result. Such systems can be used in production facilities or district cooling.

Free cooling with air

When the ambient air temperature drops to a set temperature, a modulating valve, which can be operated by an MLE or MPC, allows all or part of the chilled water to bypass an existing chiller and run through the free cooling system. This consumes less power and uses the lower ambient air temperature to cool the water in the system.

This can be achieved by using an existing dry cooler, or by installing a new dry cooler or cooling tower. The free cooling can be used to support an existing chiller or directly with the dry cooler. During low ambient temperatures, an installation can bypass an existing chiller, giving energy savings of up to 75% without compromising cooling requirements.

Free cooling with water

When an external water source of water (river, lake or sea) is available with a lower temperature than the cooling requirements, it’s possible to add this to the cooling system or bypass the existing cooling system. The external source must be separated from the cooling system with a heat exchanger to avoid the risk of contaminating the source, or introducing solids and biofouling into the cooling system. The advantage of the water-based free cooling system is that it will rarely change in temperature during the seasons. But be aware that there will be some environmental restrictions using external water sources.

Methods

Cooling tower water can be directly linked into the flow through the chilled water circuit. If the cooling tower is open, then a strainer is required to eliminate any debris that could accumulate within the tower. This method offers cost savings due to the limited use of water-chiller energy but there is an increased risk of corrosion.

A heat exchanger can also transfer heat directly from the chilled water loop to the cooling tower loop. The exchanger keeps the cooling tower water separate from the coolant flowing through the cooling coils. The chiller water is therefore pre-cooled. Energy savings come from the reduced chiller loading, which means a reduction in energy consumption.

Seasonal operation for free cooling with air

High ambient temperature
When the process return water temperature is equal to or lower than the ambient air temperature, free cooling isn't suitable. The system's three-way valve will bypass the free cooling heat exchanger and direct fluid flow through the chillers so it can be cooled to the required set-point temperature.

Mid-season operation
For mid-season operation, the water is partially cooled by the compressor and partially by ambient temperatures. The percentage of free cooling achieved mid-season is dependent on seasonal temperatures, although partial free cooling starts when the ambient air temperature is 34°F (1.5-2) below the process return water temperature. The water is partially cooled through the free cooler and then flows through the chillers to achieve the required set-point temperature.

Winter operation
In winter, when outdoor temperatures are low enough, the water is chilled solely by the free cooling coil. This allows chiller compressors to stop operating, saving significant amounts of energy. The only electrical power used in winter operation is for fan operation. This can be achieved once the ambient air temperature is 37 – 41°F below the process supply water temperature.

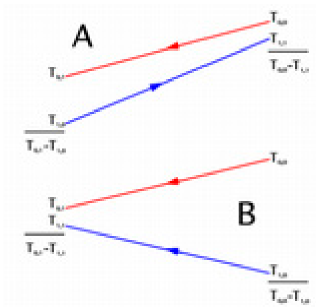
Limitations

Freezing can occur once the ambient air temperature drops below 32°F. Another limitation is the temperature difference across the heat exchanger. A heat exchanger that has a very low temperature difference can become economically unrealistic. The economics of the heat exchanger allow for a minimum free cooling water temperature of about 36.5 °F. When using an on/off valve to switch between free cooling and chiller operation, it's best to avoid this switch too often within a short time. The start/stop of the chiller will use excessive energy and cause high wear. In cases where the chiller stands inactive for months at a time, a turning procedure for the chiller is advised.

Heat Exchangers

A heat exchanger is a component used to transfer heat between two or more fluids. In other words, heat exchangers are used in both cooling and heating processes. The fluids are separated by a plate to prevent mixing of cooling water and process water. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in a refrigeration system. Here, the evaporator is often a heat exchanger between the process liquid and refrigeration, transferring the heat from the process to the refrigeration.

Flow arrangement



Counter-current (A) and parallel (B) flows

The most common heat exchangers in industrial cooling are "plate heat exchangers" and "shell-and-tube heat exchangers"

Shell-and-tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that needs to be cooled. The second fluid runs over the tubes that are being cooled so it can absorb the required heat. Shell-and-tube heat exchangers are typically used for high-pressure applications with pressures greater than 435 psi. This is because shell-and-tube heat exchangers have a robust shape.

Plate heat exchangers are composed of many slightly separated plates that have very large surface areas and small fluid flow passages for heat transfer. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical. Large heat exchangers of this type are called plate-and-frame. When used in open loops, these heat exchangers are normally of the gasket type to allow periodic disassembly, cleaning and inspection. There are many types of permanently-bonded plate heat exchangers, such as dip-brazed, vacuum-brazed, and welded plate varieties, and they are often specified for closed-loop applications such as refrigeration. Plate heat exchangers also differ in the types of plates that are used, and in the configurations of those plates. Some plates may be stamped with "chevron", be dimpled or have other patterns, while others may have machined fins and/or grooves.

When compared to shell-and-tube exchangers, the stacked-plate arrangement typically has lower volume and cost. Another difference between the two is that plate exchangers typically serve low to medium pressure fluids, compared to the medium and high pressures of shell-and-tube. A third and important difference is that plate exchangers employ more counter-current flow rather than cross-current flow, which allows lower approach temperature differences, high temperature changes and increased efficiencies.

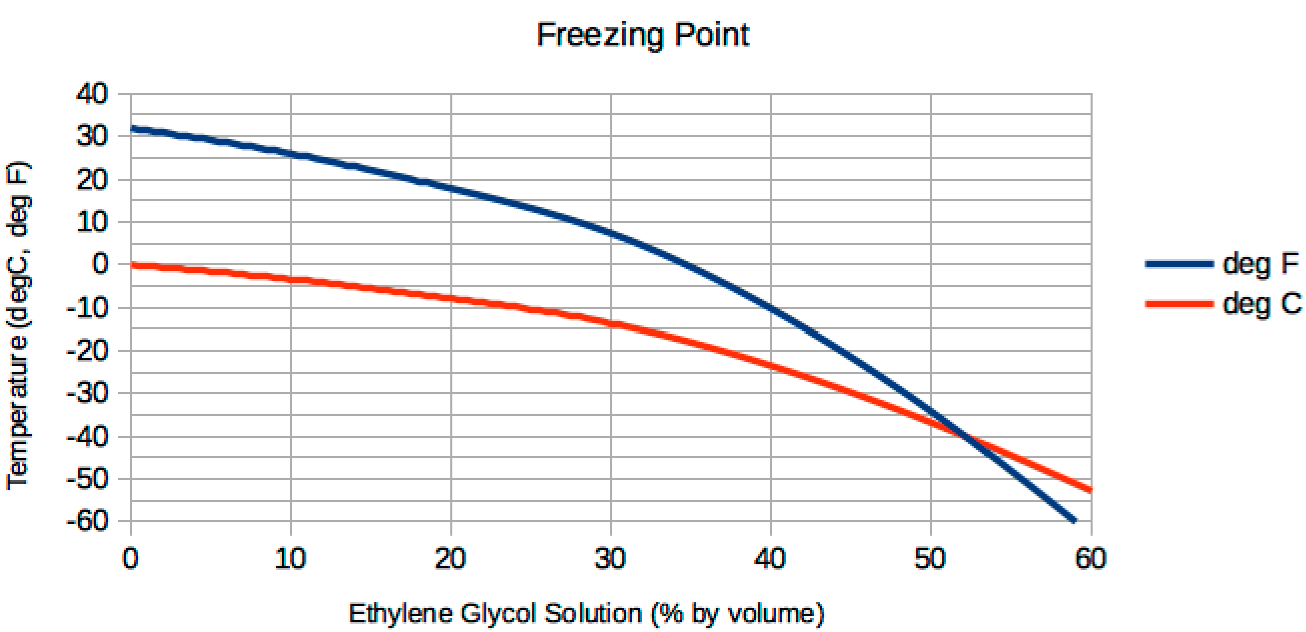
There are three primary classifications of heat exchangers according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel with one another to the other side. In counter-flow heat exchangers, the fluids enter the exchanger from opposite ends. The counter-current design is the most efficient in that it can transfer the most heat from process fluid per unit mass since the average temperature difference along any unit length is larger. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.

Coolant/Glycol

In liquid systems with piping and equipment that's installed outside where freezing temperatures can occur, or where the process requires temperatures at freezing (or below), an anti-freeze coolant known as glycol must be used. However, glycol should never be used in an evaporative cooling tower. The heat from the process/condenser will keep the tower from freezing, so it's advised to use heating elements at standstill.

The density and viscosity vary significantly depending on the type of glycol and the concentration. The most common are ethylene and propylene. Propylene glycol is used in food and beverage. Water mixed with ammonia is increasingly used where the pumping distance is long, e.g. ice rings. The water ammonia mixture is corrosive.

WATER AND ETHYLENE GLYCOL



Water Quality

Water quality is very important for cooling performance. Poor water quality can cause corrosion or fouling by either damaging cooling equipment or lowering performance.

The list below features standard water quality recommendations – supplier recommendations should always be followed if any are given.

WATER QUALITY RECOMMENDATIONS			
Category	**Symbol/ Compound**	**Value**	**Unit**
Appearance		Clear, without sediments	
Color		Colorless	
Odor		Without	
pH Level at 68°F		7.5 – 9.0	
Electrical Conductivity	LF	<220	mS/m
Soil Alkali	Ca^2+, Mg^{2+}	<0.5	Mol/m^3
General Hardness	GH	<20	°d
Carbonate Hardness without Stabilizer	KH	<4	°d
Chloride	Cl	<150	mg/L
Sulphur	SO_4	<325	mg/L
Active Biological Components	KBE	<10,000	/ml

Control Techniques

To operate a cooling process properly, with both cost effectiveness and safety in mind, automation and monitoring equipment must be installed. The complexity of the automatic control depends to a great extent on the size of the system and where it's installed. The most important control tasks are:

Cold side

- Evaporator pressure control
- Capacity control on the compressor
- Flow control

Hot side

- Condenser pressure control
- Dry cooler or cooling tower circulation
- Dry cooler or cooling tower fan speed

Other

- Correct distribution of the refrigerant in the system
- Control of secondary refrigerant to the condenser (water or air)
- Defrosting of the evaporator if the secondary side is air
- Monitoring equipment (pressure etc.)
- Protection of motors

MLE/CUE Functions

With Grundfos iSOLUTIONS, effectiveness, connectivity and functionality are the most important factors.

Here are the most common control modes across the product families.

Control Mode	TPE3(D)	TPE2 (D) LCSE	TPE (D) Series 2000	CRE, CRIE, CRNE, MTRE, CME	LF/LC, VLS/VL, KP/KPV, and CUE	LCSE, VLSE
AUTOADAPT	X					
FLOWADAPT	X					
Proportional Pressure	X		X		X	
Constant Pressure		X		X	X	X
Constant Temperature	X	X		X	X	X
Constant Differential Pressure	X	X	X	X	X	X
Constant Differential Temperature	X	X		X		X
Constant Flow Rate		X		X	X	X
Constant Level		X		X	X	X
Constant Curve	X	X	X	X		X

WE ARE IN THE WATER BUSINESS WITH YOU

As a pioneer and global leader in water pump technology, Grundfos creates intelligent, sustainable solutions to help solve the world's water and climate challenges. Through our heritage, we have the experience and innovative capabilities to help our partners, customers and communities move water in an increasingly energy and water efficient manner. We see this as not only a great business opportunity, but as an obligation to ensure the world heads toward a more sustainable tomorrow. Our complete portfolio of pumps and solutions are designed for commercial, residential, groundwater, municipal and industrial applications with emphasis in trendsetting, energy efficient technologies such as permanent magnet motors and advanced pump controls and monitoring. Because water matters, and so does your business.

To learn more, visit **grundfos.us** or follow us on Facebook and LinkedIn.

Visit grundfos.us/pei to learn more about Department of Energy (DOE) pump energy index (PEI) requirements and PEI ratings on specific Grundfos models.

L-IND-CWP-001 0120

Grundfos Americas
Brookshire, TX 77423

www.grundfos.us
www.grundfos.ca
www.grundfos.mx

GRUNDFOS