Recooling system cooling circuit, introduction, assessment, evaluation of economic efficiency

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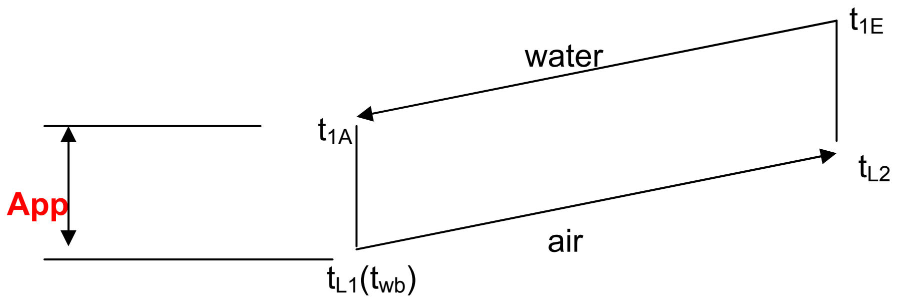
1. Introduction

Today, the market provides a wide range of recooling systems for cooling cycles. Thus, the planner and the operator have to consider the advantages and disadvantages of the different systems in order to make the right choice.
The following paper will introduce the different recooling systems and explain their limitations of their economic use.
Especially the unique hybrid dry coolers by Jäggi/Güntner AG that work on a patented principle and are characterized by an extraordinary economic operation will be introduced and explained.
Furthermore, a possibility to calculate the annual operating expenses of a hybrid cooling system as compared to a cooling tower system will be introduced. Especially the influence of the reduced cooling water temperature in order to improve the refrigerator's efficiency (COP ***C****oefficient* ***o****f* ***P****erformance*) and its influence on the recooling system's operating costs will be discussed.

2. Definitions

2.1 Approach

In air-cooled recooling systems, the return temperatures are physically limited. The ambient air temperatures are relevant in dry systems, and the wet-bulb temperatures in evaporative systems the wet-bulb temperatures.



For dry systems, an approach (App) of about 6 to 8 K is still considered economic, i.e. at an ambient air temperature of 34°C, a return temperature of about 40°C can be economically realized. For evaporative systems, an economic App of 4-7 K is presumed, i.e. return temperatures of 26°C - 29°C can be realized if the wet bulb temperature is 22°C.

2.2 Wet temperature

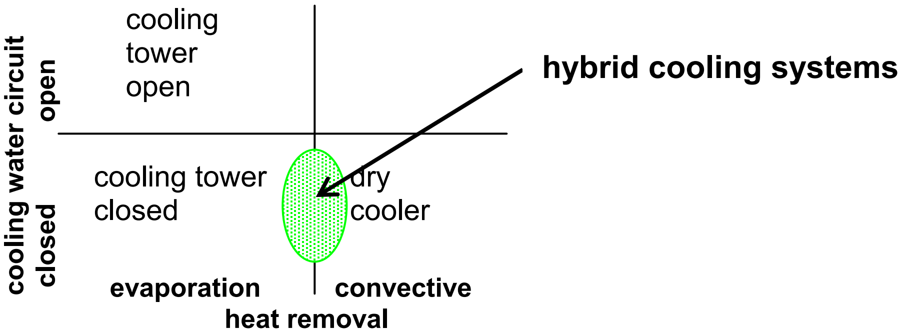
The wet-bulb temperature tW is the temperature measured with/shown by a thermometer covered in wet cloth (aspiration psychrometer) during psychromatic measuring. Due to the evaporation heat loss, this temperature is below the air temperature – in dependence on the relative air humidity – shown by the dry reference thermometer. The drier the ambient air, the higher is the temperature difference

2.3 Dry temperature

The dry temperature tD ist he temperature shown by a thermometer with a dry temperature sensor.

3. Introduction of cooling systems

Classification of different recooling systems

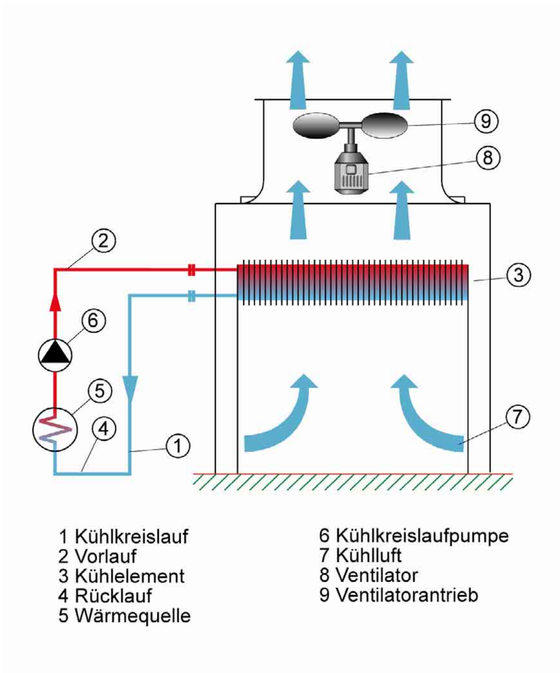


3.1 Dry recooler

Relevant cooling temperature	t_L , usually 32°C–34°C
Economic approach	6 –8 K
Economic return temperature	38 - 42°C
Power density rel. to floor space	(30 kW/m^2)

Advantages:
- little maintenance required
- many appliance types available
- low investment costs
- low weight
- free cooling possible

Disadvantages:
- much space required
- high condensation temperature
- relatively high power consumption



Kühlkreislauf	cooling circuit
Vorlauf	flow
Kühlelement	cooling elements
Rücklauf	return
Wärmequelle	heat source
Kühlkreislaufpumpe	cooling circuit pump
Kühlluft	cooling air
Ventilator	fan
Ventilatorantrieb	fan motor

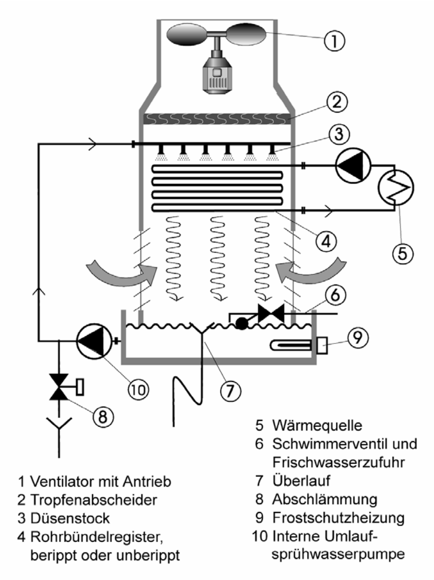
Functioning

The cooling agent flows through the pipes of a heat exchanger. Usually, a water-glycol mixture is used as a cooling agent due to the risk of freezing when the system is idle. In the reverse current, ambient air is led over the finned heat exchanger pipes. Thus, the heat is transmitted from the cooling agent (inside of pipe) to the ambient air (outside of pipe/fin). The limiting temperature of the dry cooler is the temperature of the ambient air. The heat removal is purely convective.

Güntner dry cooler

3.2 Open evaporation cooling tower

Relevant cooling temperature	$t_{w,}$ usually 21°C–22°C
Economic approach	6-11 K
Economic return temperature	27-34°C
Power density rel. to floor space	(60-80 kW/m^2)



Advantages:
- many appliance types available
- little space required
- low condensation temperature

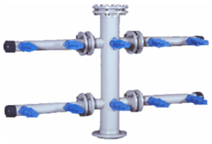
Disadvantages:
- vapor
- high water consumption
- high weight
- no or little performance during free cooling
- risk of ice formation in case of lower cooling water temperatures
- water processing required
- cooling air has direct contact to cooling water
- qualitative and quantitative change of cooling water

Ventilator mit Antrieb	fan with motor
Tropfenabscheider	spray eliminator
Düsenstock	jet head
Rohrbündelregister, berippt oder unberippt	tube bundle register, finned or unfinned
Wärmequelle	heat source
Schwimmerventil und Frischwasserzufuhr	float valve and fresh water feeding
Überlauf	overflow
Abschlämmung	water drain
Frostschutzheizung	frost protection heating
Interne Umlaufsprühwasserpumpe	internal pump for circulating spray water

Functioning

In the wet cooling tower, the cooling water is sprayed over fillings dispersed via a channel system. In the reverse current, the air is led through the filler and thus has direct contact with the cooling water. The heat is removed by means of a combined material and heat transmission process. About $^2/_3$ of the heat flow is discharged to the ambient air by evaporation (material transmission) and only about $^1/_3$ by convection (heat transfer). Quality and quantity of the cooling water are changed. The cooling tower's theoretical limit of cooling is the wet-bulb temperature.

spray eliminator



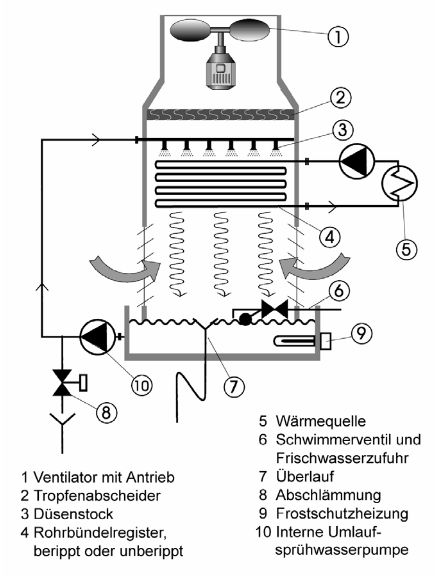
spray system

filler

Components and examples of cooling towers

3.3 Closed evaporation coolig tower

Relevant cooling temperature	$t_{w,}$ usually t 21°C-22°C
Economic approach	7-11 °C
Economic return temperature	28-32°C
Power density rel. to floor space	(60-80 kW/m[2])



Advantages:
- many appliance types available
- little space required
- low condensation temperature
- closed cooling water system
- no contamination in the consumer circuit

Disadvantages:
- vapor
- high water consumption
- high weight
- no or little performance during free cooling
- water processing required
- qualitative and quantitative change of cooling water

Ventilator mit Antrieb	fan with motor
Tropfenabscheider	spray eliminator
Düsenstock	jet head
Rohrbündelregister, berippt oder unberippt	tube bundle register, finned or unfinned
Wärmequelle	heat source
Schwimmerventil und Frischwasserzufuhr	float valve and fresh water feeding
Überlauf	overflow
Abschlämmung	water drain
Frostschutzheizung	frost protection heating
Interne Umlaufsprühwasserpumpe	internal pump for circulating spray water

Functioning

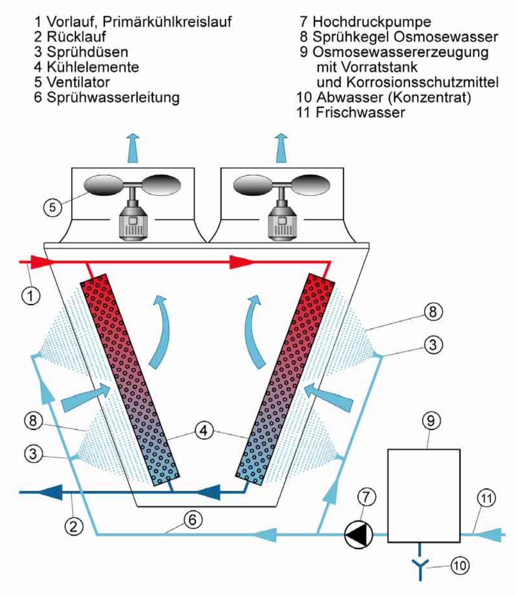
Similar to the dry cooler (para. 3.1), the medium requiring cooling flows through a heat exchanger and thus has no contact with the ambient air (indirect cooling). Additionally, the heat exchanger (straight-tube heat exchanger) is sprayed or wetted with water via a secondary circuit in order to exploit the evaporation energy.

Usually, straight-tube heat exchangers are used because of the risk of pollution. The cooling water is cooled below the air temperature by means of exploiting the evaporation energy. Due to the small heat exchanger surfaces, switching to dry running is only possible when the air temperature and the cooling load are very low.

The theoretical limit of cooling of the evaporation cooling tower (closed circuit) is the wet-bulb temperature.

4. Hybrid cooling systems
4.1 Dry recooler with spraying

Relevant cooling temperature	t_L and t_w
Economic approach	8-10 °C
Economic return temperature	29-31°C
Power density rel. to floor space	30 kW/m^2



Advantages:
- free cooling possible
- low weight

Disadvantages:
- risk of corrosion
- osmosis water required
- high water costs
- exact performance calculation not possible
- much space required
- relatively high power requirement
- spray ejection

Vorlauf, Primärkühlkreislauf	flow, primary cooling circuit
Rücklauf	return
Sprühdüsen	spray nozzles
Kühlelemente	cooling elements
Ventilator	fan
Sprühwasserleitung	spray water pipe
Hochdruckpumpe	high pressure pump
Sprühkegel Osmosewasser	spraying cone for osmosis water
Osmosewassererzeugung mit Vorratstank und Korrosionsschutzmittel	osmosis water generation with reservoir and anti-corrosion agent
Abwasser (Konzentrat)	sewage water (concentrated)
Frischwasser	fresh water

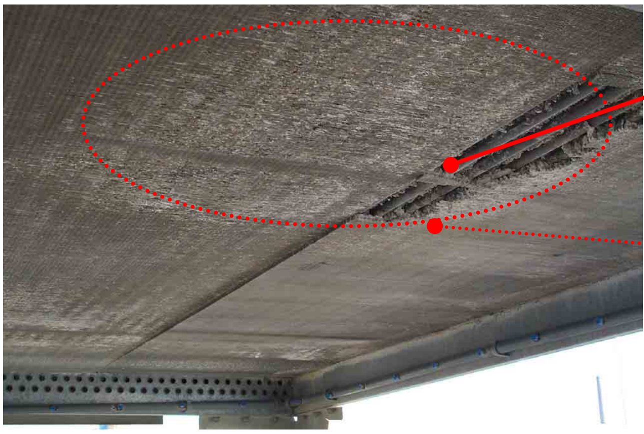
Functioning

Water is sprayed into the intake air in front of the cooler in order to cool down said intake air. The fine drops of water in the intake air evaporate, which causes the air temperature to drop (not due to cooling but due to the conversion of palpable heat to latent heat). This process could be called adiabate, although this is not really the case since the temperature of the sprayed water is always above 0 °, so that the heat content (enthalpy) of the air increases slightly.

This slightly improves the efficiency of the dry cooler. Our own measurements showed that the usual constructions can reduce the air temperature by 3 – 4°C at most; cooling the air down to the wet-bulb temperature is not possible. The drops' time of exposure between the injector and the finned heat exchanger is much too short. Consequently, the fins are wetted, which has the same effect as the spraying. Most drops, though, are blown out by the fans.

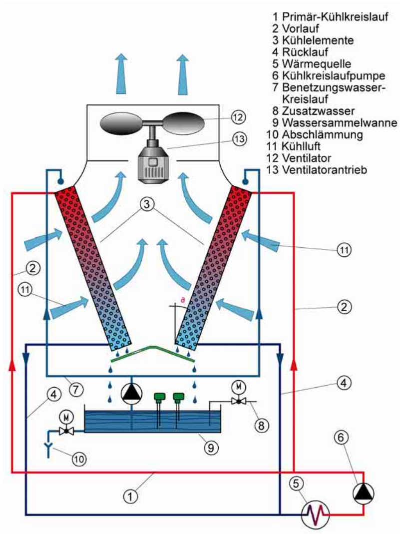
In sprayed coolers as well as in so-called adiabatic coolers, a defined wetting of the finned surface is not possible. This is due to wind, the degree of pollution of the finned surface, fluctuations of the oncoming air flow etc. The consequence is that the cooler's efficiency cannot be exactly calculated in case of spraying or atomization.

Since these systems do not exclusively work on the principle of evaporation, no clear statement can be made on the theoretical limit of cooling. According to our experiences, though, this is about 4 K below the ambient air temperature.


corrosion of aluminium
fins on a sprayed cooler
fan intake

4.2 Hybrid dry cooler

Relevant cooling temperature	t_L and t_w
Economic approach	4-8 °C
Economic return temperature	25-29°C
Power density rel. to floor space	60-80 kW/m^2



Advantages:

- no vapor
- little water and power consumption
- compact, little space required
- easily accessible, service-friendly
- extremely quiet

Disadvantages:

- disadvantageous for installation of sound absorbers
- high investment costs
- water processing required

Primär-Kühlkreislauf	primary cooling circuit
Vorlauf	flow
Kühlelemente	cooling elements
Rücklauf	return
Wärmequelle	heat source
Kühlkreislaufpumpe	cooling circuit pump
Benetzungswasser-Kreislauf	wetting water circuit
Zusatzwasser	makeup water
Wassersammelwanne	water reservoir
Abschlämmung	water drain
Kühlluft	cooling air
Ventilator	fan
Ventilatorantrieb	fan motot

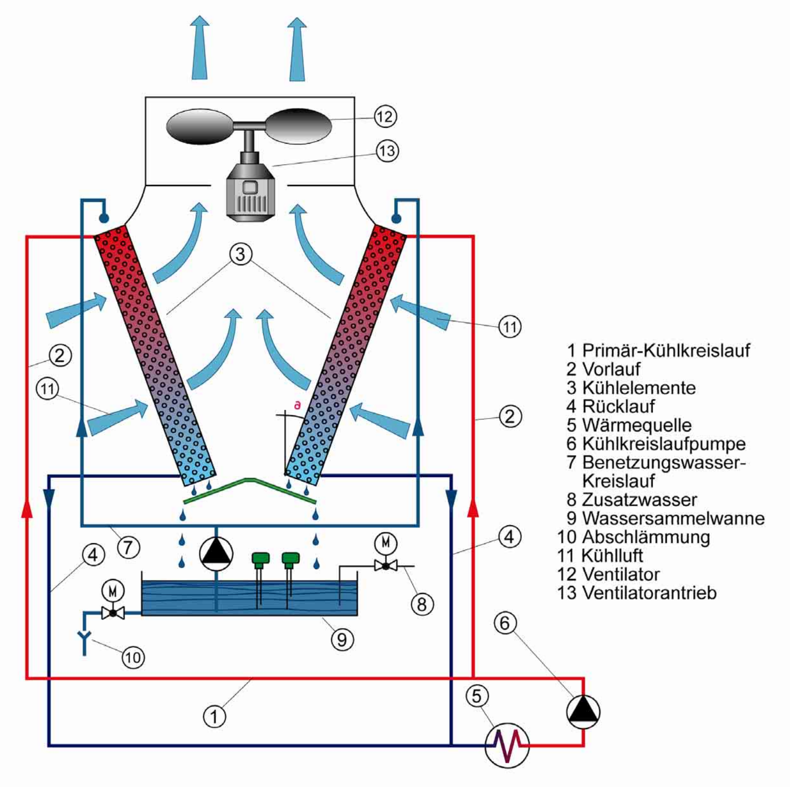
Functional principle

„Hybrid“ means „mixed or combined“. Indeed, the hybrid dry cooler is a combination of an air-cooled recooler and an evaporation cooling tower without the disadvantages of these systems.
The hybrid dry cooler is intended to recool fluid media or liquefy refrigerants. The cooling is done via the ambient air and the evaporation of water. During dry operation, i e. if the ambient air temperature is low, the heat removal is purely convective. In case of high ambient air temperatures, the fins of the heat exchanger are wetted with water applying a patented method. Due to the evaporation effect, the heat is latently removed, which results in a 3- to 4-fold increase, resp. in the fact that the cooling water can be cooled down below the air temperature.
The theoretical limit of cooling for the Jäggi /Güntner hybrid dry cooler is the wet-bulb temperature.

Design

In principle, the system is designed just as a dry recooler. The installation of additional special components makes it a hybrid dry cooler. In the HDK type, two finned heat exchanger elements are positioned in the shape of a V in a load-bearing steel structure. Over the V and between the heat exchanger elements, 1 to 4 axial suction fans (depending on size and type) are placed. A covered water vat is placed under the cooler. In the water vat there is a pump for the wetting of the outside of the heat exchanger elements.
The water overflow channels are over the heat exchanger elements.
The overflow channels are fed with the pump via a plastic tube system. The materials as well as the corrosion protection are geared toward a long life.

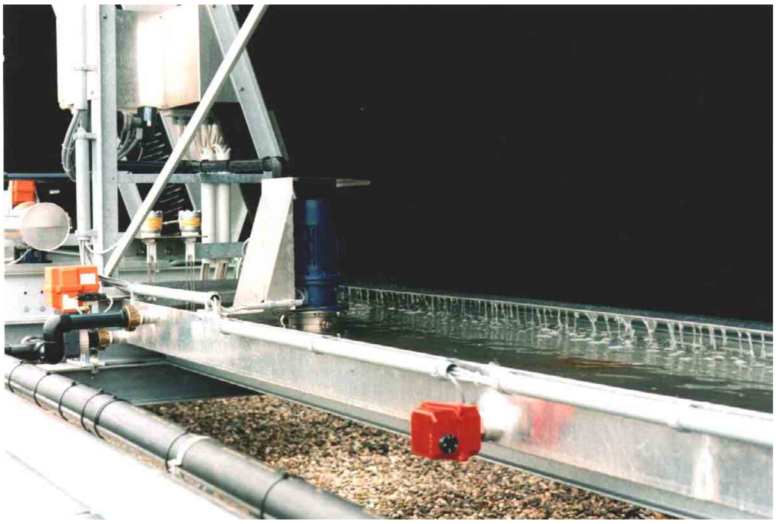
Functional description
The medium requiring cooling (1), usually water or a water-glycol mixture, flows throughthe tubes of the two fanned heat exchangers positioned in the shape of a V (3). The ambient air (11) flows around the finned outsides of the heat exchanger elements, and these absorb the heat of the medium. The ambient air is drawn by the axial suction fans (12). The actuation (13) is either direct (wheel directly on the motor shaft) or via belt transmission, which is characterized by its long life and low noise level.



Primär-Kühlkreislauf	primary cooling circuit
Vorlauf	flow
Kühlelemente	cooling elements
Rücklauf	return
Wärmequelle	heat source
Kühlkreislaufpumpe	cooling circuit pump
Benetzungswasser-Kreislauf	wetting water circuit
Zusatzwasser	makeup water
Wassersammelwanne	water reservoir
Abschlämmung	water drain
Kühlluft	cooling air
Ventilator	fan
Ventilatorantrieb	fan motot

If the prescribed cooling water setpoint or condensation pressure at maximum fan speed during dry operation (usually at an ambient air temperature between 12°C and 17°C) is not reached anymore, the control unit of the hybrid cooler prompts the wetting of the outside surface of the heat exchangers.
For this purpose, open channels, from which the wetting water is fed as a water line, are positioned above the longitudinal sides of the heat exchanger. As a result of the airflow and the special design of the fins, a turbulent water film over the entire fin depth is generated.
Depending on the length of the coolers, one or two wetting pumps are installed. However, the gradual activation of individual wettings enables an additional fine-tuning of the control.

The water reservoir (9) is under the cooling elements. Here, the wetting water, which is applied excessively, is collected noiselessly. The excess wetting water prevents to a large extent the depositing of dirt from the ambient air on the fins by rinsing it off. On the water vat, the water drain valve and the fresh water valve are installed, as well as the wetting pump and the required safety equipment, such as electronic dry running protection and level measuring. The increase of salinity of the water is monitored by means of conductivity measuring in the wetting water pipe.



Cooler in operation with wetting. Heat tracing, wetting pump, level measuring sensors, water drain motor valve and overflow are also visible.

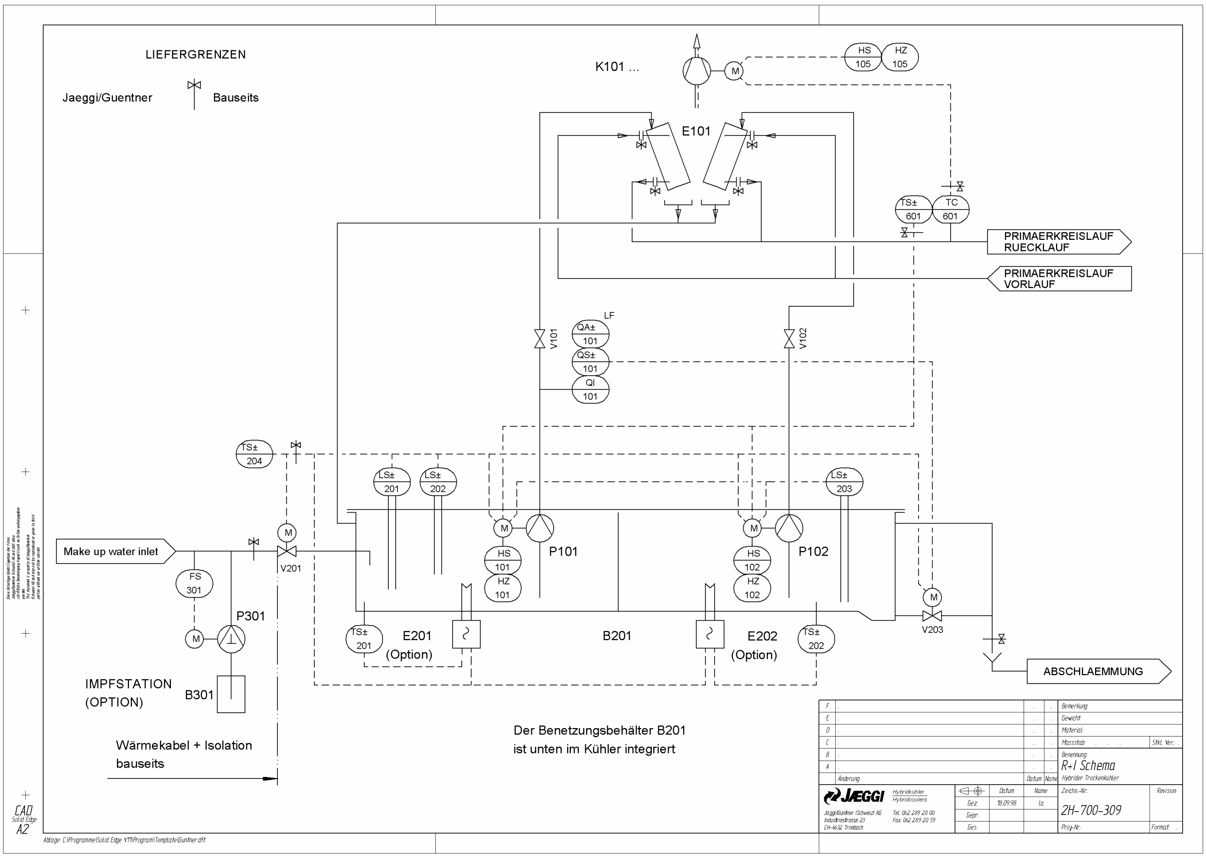
Furthermore, the covered water vat can be equipped with frost protection heating, however, in most cases the vat is emptied in winter when wetting is not required any more.
The holding capacity of the water reservoir is small on purpose, so that as little water as possible is wasted when it is drained.

For the wetting, softened drinking water with a pH value of 6.5 to 8.5, blended, is sufficient. The concentration of the wetting water is monitored by the control unit; when the allowable limits are reached, it is blown down, and fresh water is added.
Demineralized water or osmosis water are not required!

The fans are gradually regulated by means of a frequency converter. This often leads to a considerable reduction of power consumption, especially if the cooler is operating below the design point or in the part-load range.
The fans are not separated on the air side in order to improve their accessibility. Thus, the fans are paralleled so that all of them always run with the same speed.

Control / regulation „HybriMatic“
As has become apparent in the past few years, the controlling of the hybrid cooler has become more and more important for an optimal operation mode of the cooling water circuit. The newly developed HybriMatic control enables an adaptation to all operating conditions with full and part load.
The control unit monitors the wetting water circuit of the cooler as well as the power regulation. Speed controlled fans are used for the power regulation; frequency converters are applied for this purpose. Furthemore, the wetting pumps are activated or deactivated depending on the load.
The monitoring and control of the wetting water includes the conductivity measuring with selection of water drain valve and fresh water valve as well as a possible selection of a biocide dosing pump.

The level monitoring and the dry running protection are monitored additionally. The control is geared towards reliability and economy as regards the water and power consumption of the entire cooling circuit.
Communication with the building control is possible via all established bus systems.



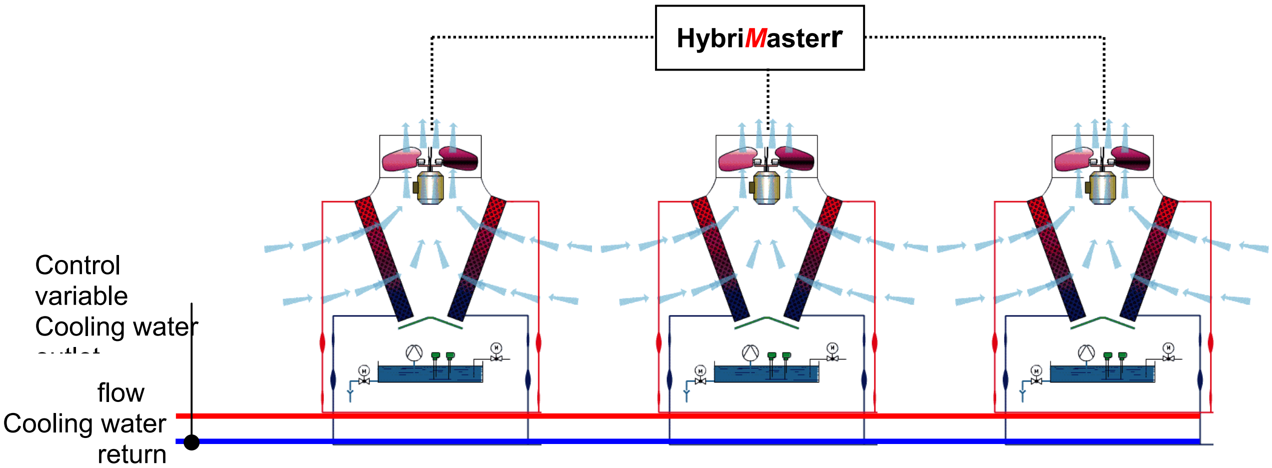
Example: pipes & instruments control diagram

LIEFERGRENZEN	DELIVERY LIMITS
Bauseits	on site
PRIMAERKREISLAUF RUECKLAUF	PRIMARY CIRCUIT RETURN
PRIMAERKREISLAUF VORLAUF	PRIMARY CIRCUIT FLOW
ABSCHLAEMMUNG	WATER DRAIN
Option	option
Der Benetzungsbehälter B201 ist unten im Kühler integriert	The wetting container B201 is integrated in the bottom of the cooler
Wärmekabel + Isolation bauseits	heat cable + insulation on site
IMPFSTATION (OPTION)	INOCULATION STATION (OPTION)
Make up water inlet	make up water inlet
Änderung	modification
Datum	date
Name	name
Gez.	signed
Gepr.	checked
Ges.	stored
Bemerkung	note
Gewicht	weight
Material	material
Massstab	scale
Stkl. Ver.:	parts list index:
Benennung: R+I/ Schema Hybrider Trockenkühler	designation: pipes and instruments diagram of hybrid dry cooler
Zeichn.-Nr.:	drawing no.:

Revision	revision
Proj.-Nr.:	Project no:
Format	format

Regulation for composite systems

If several hybrid coolers are operated in parallel in large systems, the individual heat exchangers are wetted sequentially in order to only expose those heat exchanger surfaces to water that are required for the heat removal. This makes for an economic operation of the entire system, including reduced water consumption.



Characteristics and advantages of hybrid dry coolers

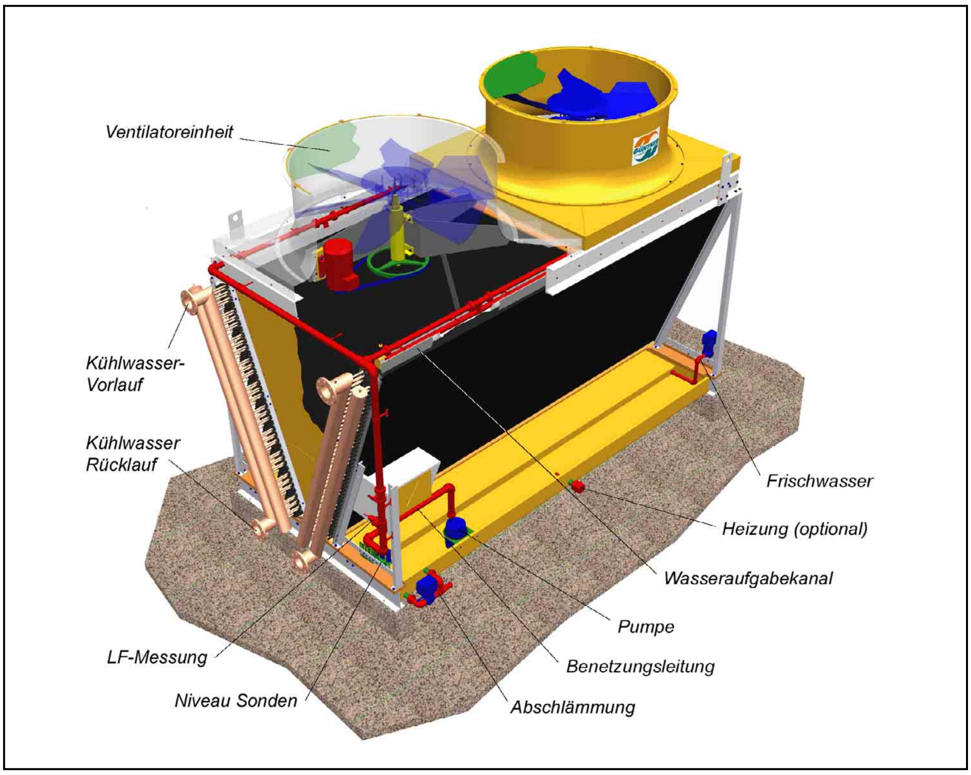
Characteristics:	**Advantages:**
The hybrid dry cooler has a closed cooling water circuit	The cooling water is not contaminated by polluted air and oxygen
The hybrid dry cooler works vapor-free under all climate conditions	No acceptance problems No industrial snow No problems in the neighborhood No problems with authorities
The hybrid dry cooler works with the lowest Possible water consumption since it is in dry operation for the best part of the year	Low operating expenses Lower investment costs for pipework and water processing
Small approaches can be realized even more economically with hybrid dry coolers	Low condensation temperature, smaller refrigerator, lower power consumption Small construction volume, low weight
Free cooling possible	Energy conservation
The hybrid dry cooler has a low noise level	Problem-free compliance with obligations, without expensive sound absorbers
The hybrid dry cooler has very low power consumption	Low operating costs
The heat exchangers are wetted without pressure, the secondary water is not sprayed.	No aerosol formation, infection with legionella bacteria thus almost impossible

Range of capacity and physical sizes

For the design of the hybrid cooler, the heat exchanger surface and quantity of air required fort he heat removal during wetted operation are determined first. Then the fans are designed for the operating points in dependence on the physical size.

All in all, there are 3 different heat exchanger block heights and about 20 different heat exchanger lengths. In combination with up to 4 fans and the corresponding hydraulic connection, this amounts to more than 500 different appliance sizes.

The capacity range is between about 150 kW and 1800 kW at a cooling water temperature of 34°C / 28°C and an air temperature of 34°C with 36% relative humidity.



Ventilatoreinheit	fan unit
Kühlwasser Vorlauf	coolong water flow
Kühlwasser Rücklauf	cooling water return
LF-Messung	AH measuring
Niveau Sonden	level probes
Abschlämmung	water drain
Benetzungsleitung	wetting pipe
Pumpe	pump
Wasseraufgabekanal	feed water channel
Heizung (optional)	heating (optionnel)
Frischwasser	fresh water

5. Calculation of operating costs

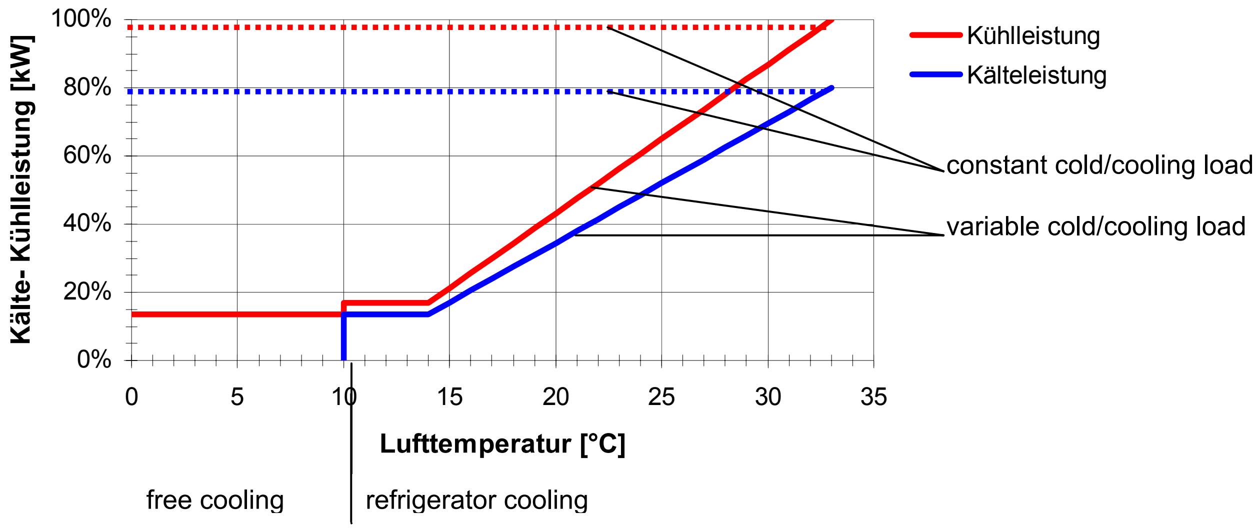
5.1. Calculation method

In order to calculate the operating costs of a hybrid cooling system as compared to those of a cooling tower system with open or closed cooling water circuit, a special software was developed. This software enables the calculation of the operating costs of systems with hydraulically paralleled hybrid coolers.

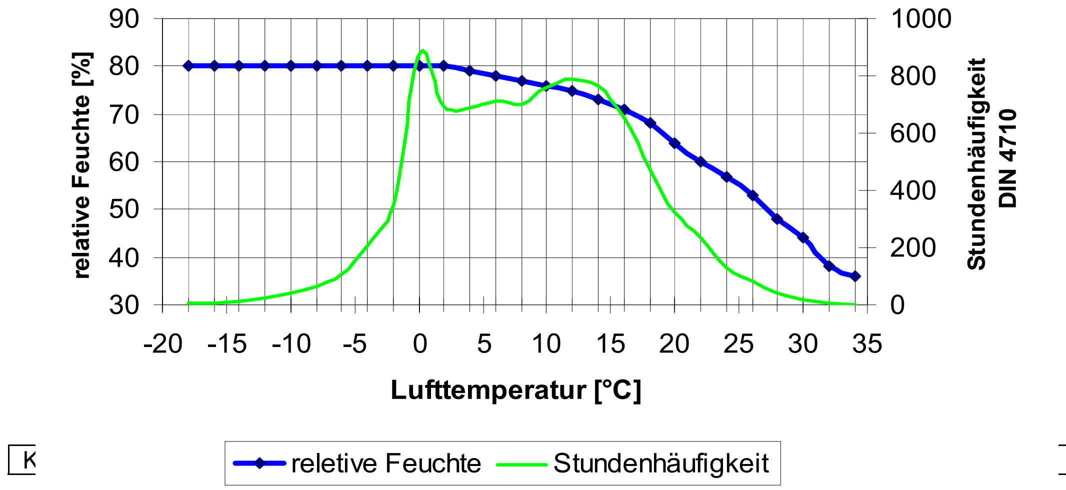
5.2. Load profiles

The load profile of the system is required for the calculation of the operating costs. Load profiles can be calculated in dependence on the air temperature. For example, a load profile with a constant cold or cooling load in the air temperature range between –20°C and +34°C can be calculated. Since a constant cold load only occur in case of process cooling, it is also possible to define the load profile in dependence on the air temperature, the free cooling can be taken into account additionally.

Load profile in dependence on the air temperature



On the basis of the load profile, the specific consumption data (water and power consumption) for every point are calculated, starting at the lowest air temperature and continuing in steps of 1 K. Via the temperature profile of the respective installation site, the absolute consumption values are calculated from this and added. The results are the annual consumption values of water and power in dependence on the load and temperature profiles.



annual temperature profile and allocation of relative humidity using the example of Stuttgart

Lufttemperatur [C°]	air temperature [C°]
Kühlleistung	thermal capacity
Kälteleistung	cooling capacity
Zuordnung Lufttemperatur	allocation air temperature
relative Feuchte	Relative humidity
Stundenhäufigkeit DIN 4710 für Stuttgart	hourly frequence according to DIN 4710 for Stuttgart
Relative Feuchte [%]	relative humidity [%]
Lufttemperatur [C°]	air temperature [C°]
Stundenhäufigkeit DIN 4710	hourly frequence according to DIN 4710
relative Feuchte	relative humidity
Stundenhäufigkeit	hourly frequence

5.3 Refrigerator cooling

If recooling systems are used for the removal of condenser heat (cooling water circuit or direct condensation), the condensation pressure is often continuously adjustable in order to improve the refrigerator’s efficiency.

In water-cooled refrigerators, the cooling water temperature is continuously adjustable up to the allowable temperature, e.g. 20°C flow.

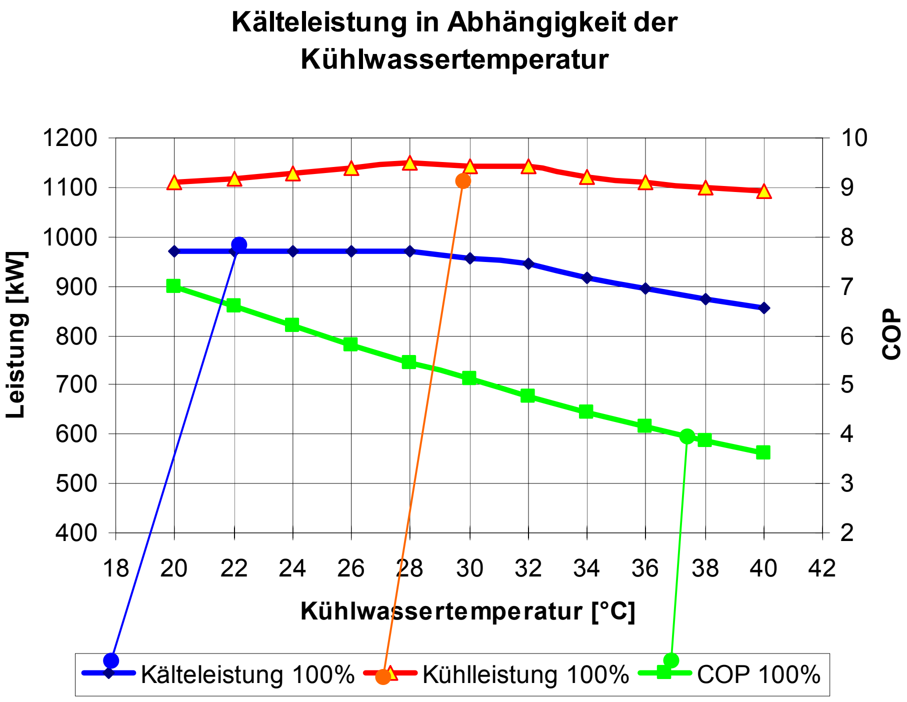
The following graphic clearly shows the influence of the cooling water temperature on the refrigerator’s efficiency, using the example of a screw compressor water chiller with a flooded evaporator.

Example 1
Design data:

Cooling capacity	970 kW
Cold water temperature	12°C / 6°C
Thermal capacity	1,140 kW
Cooling water temperature	34°C / 28°C
Air temperature	34°C / 36% relative humidity

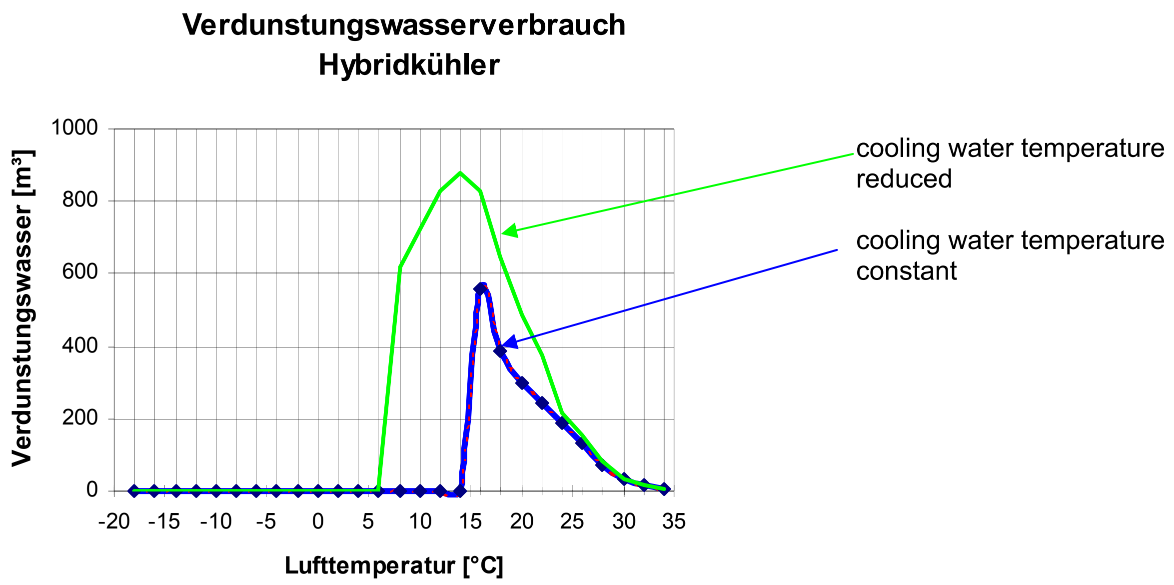
If the cooling water temperature is higher than the design temperature, the refrigerator`s cooling capacity and efficiency drop accordingly. If the cooling water temperature is lower than the design temperature, the efficiency increases; if the cooling capacity is constant, this causes the recooling capacity to drop.

This operating method, however, leads to an increased water consumption in hybrid cooling systems, which negates the advantage of energy conservation in the refrigerator.



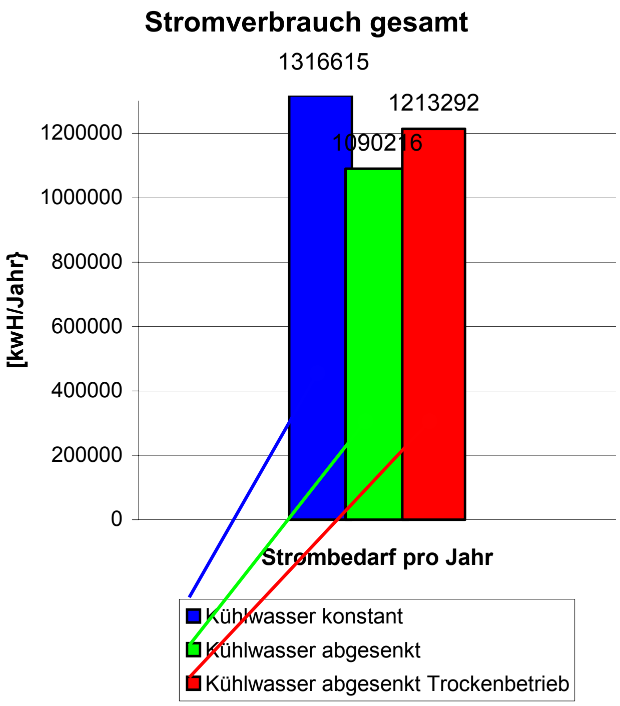
Kälteleistung in Abhängigkeit der Kühlwassertemperatur	Cooling capacity in dependence on cooling water temperature
Leistung [kW]	capacity [kW]
Kühlwassertemperatur [C°]	cooling water temperature [C°]
COP	COP
Kälteleistung 100%	cooling capacity 100%
Kühlleistung 100%	thermal capacityt 100%
COP 100%	COP 100%

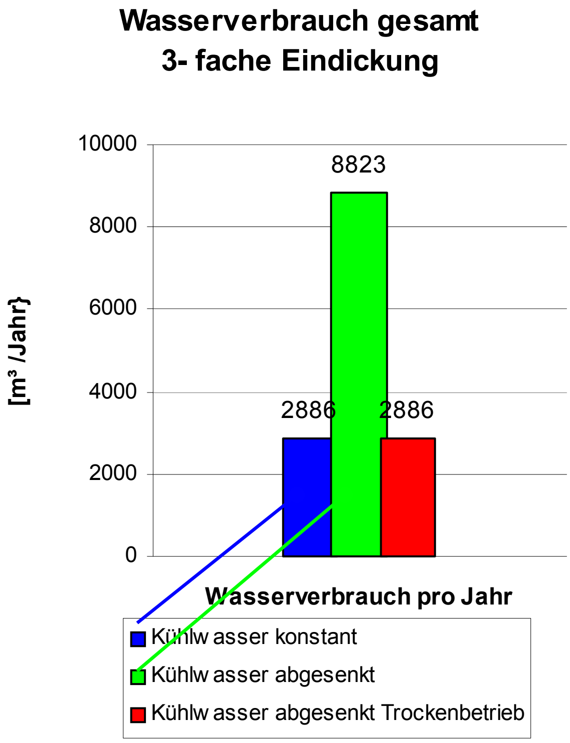
The following graphic shows the influence of the operating mode with reduced cooling water temperature on the water consumption of the hybrid cooling system.



The following bar diagrams clearly show the increased water consumption due to the reduced operating method.

Therefore, we recommend reducing the cooling water temperature in order to save energy in the refrigerator only during dry operation.

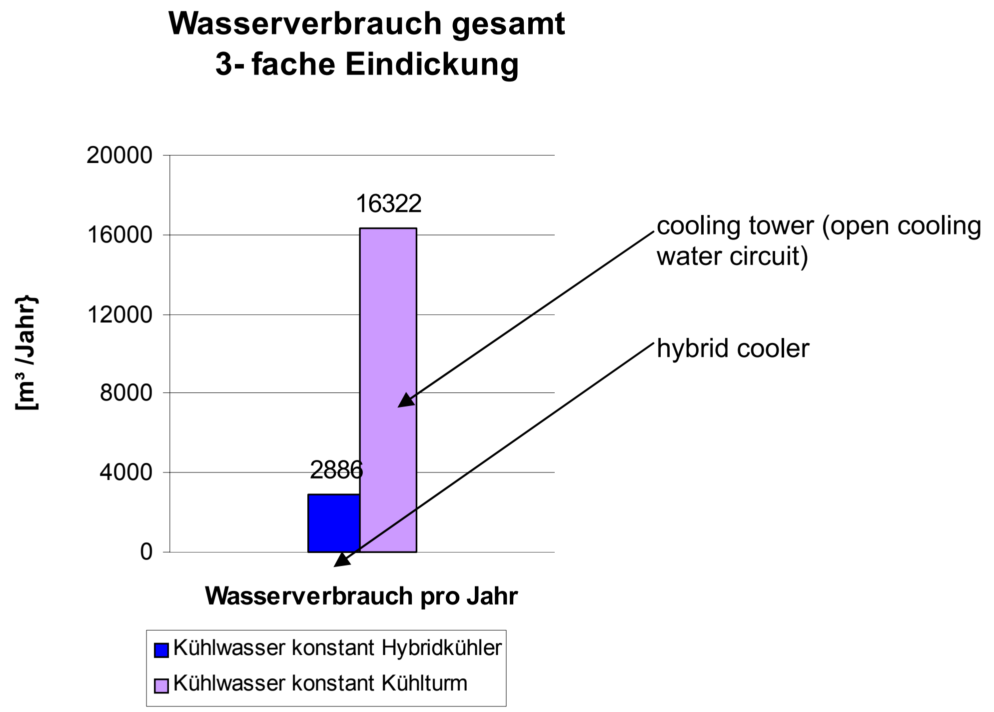




Stromverbrauch gesamt	total power consumption
[kwH/Jahr}	[kwH/year}
Strombedarf pro Jahr	power requirement per year
Kühlwasser konstant	cooling water constant
Kühlwasser abgesenkt	cooling water reduced
Kühlwasser abgesenkt Trockenbetrieb	cooling water reduced during dry operation
Wasserverbrauch gesamt 3-fache Eindickung	total water consumption 3-fold condensation
[m³/Jahr}	[m³/year}
Wasserverbrauch pro Jahr	water consumption per year

Comparison with cooling tower system

In comparison with a cooling tower system with open cooling water circuit, the water conservation in this example is 83%. The additional costs for the hybrid cooling system will be amortized after about 2 – 3 years.



Wasserverbrauch gesamt 3-fache Eindickung	total water consumption 3-fold condensation
[m³/Jahr}	[m³/year}
Wasserverbrauch pro Jahr	water consumption per year
Kühlwasser konstant Hybridkühler	cooling water constant hybrid cooler
Kühlwasser konstant Kühlturm	cooling water constant cooling tower

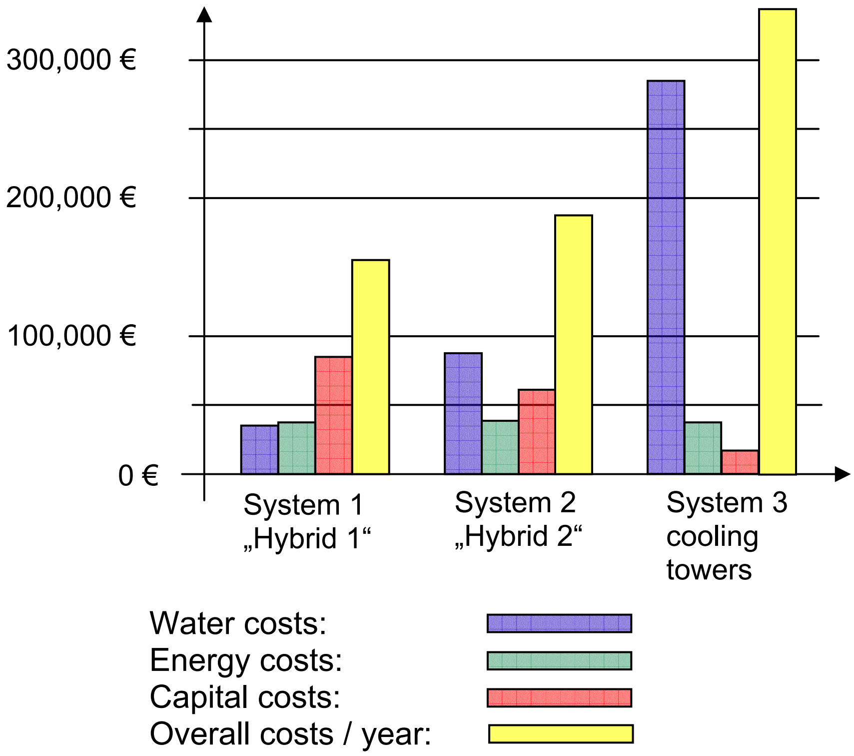
Example 2
Computer center, Frankfurt area

In this example, the efficiency of 2 hybrid cooling systems (variant 1 with capacity reserve, variant 2 designed for the nominal capacity) is tested. Additionally, the operating costs of a cooling tower system were determined and compared.

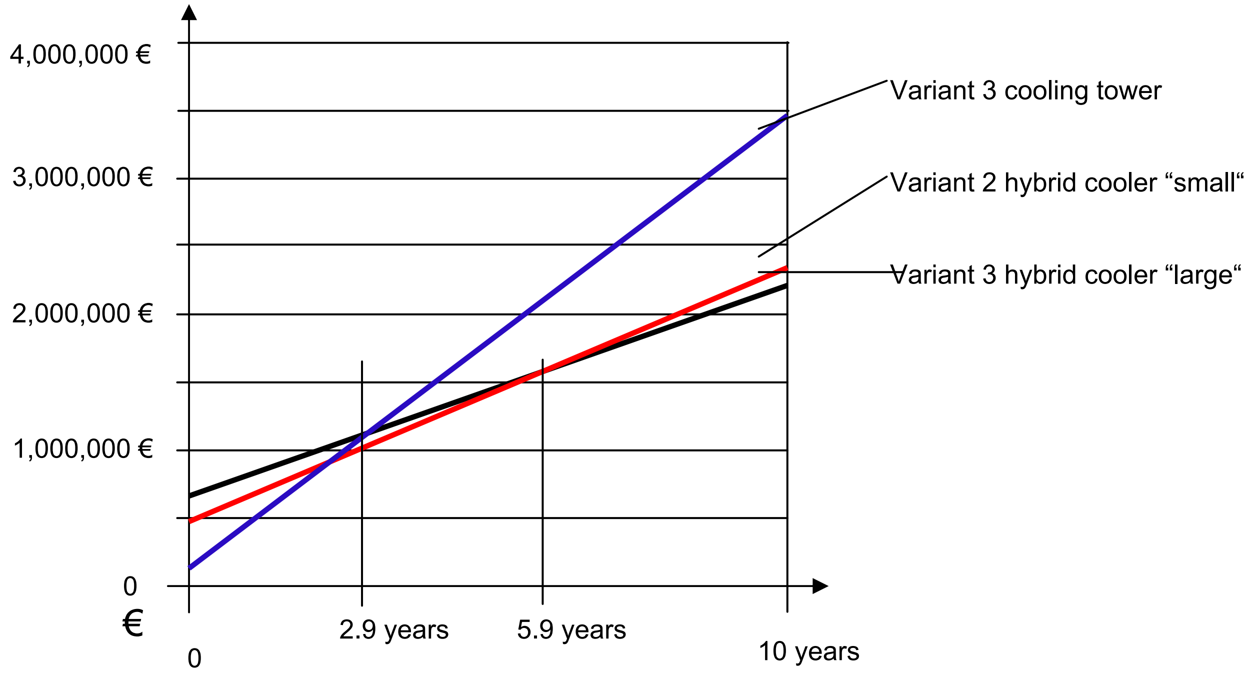
Design data:

Cooling capacity	5,000 kW
Cold water temperaturer	12°C / 6°C
Thermal capacits	6,120 kW
Cooling water temperature	36°C / 30°C
Air temperature	34°C / 38% relative humidity
Free cooling	<= -2°C
Variant 1	4 hybrid coolers HDK 2.4 / 9.0 – 2S-P2-Cu SLNF Investment costs 654,800.00 €
Variant 2	4 hybrid coolers HDK 2.4 / 6.6 – 2S-P2-Cu SLNF Investment costs 470,000.00 €
Variant 3	4 cooling towers (open cooling water circuit) Investment costs 130,00.00 €

Comparison of operating costs of the tested variants



Development of operating costs of the system



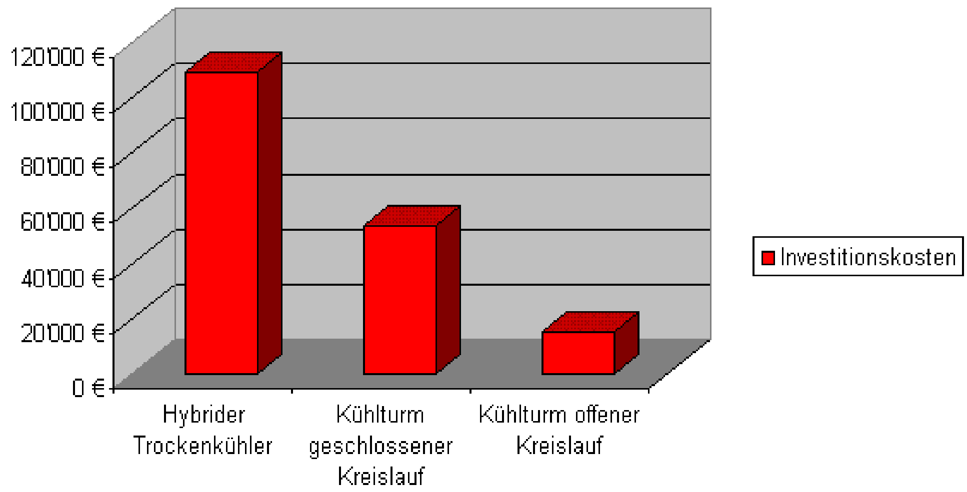
Example 3

Industrial application

Industrial application, 8760 operating hours

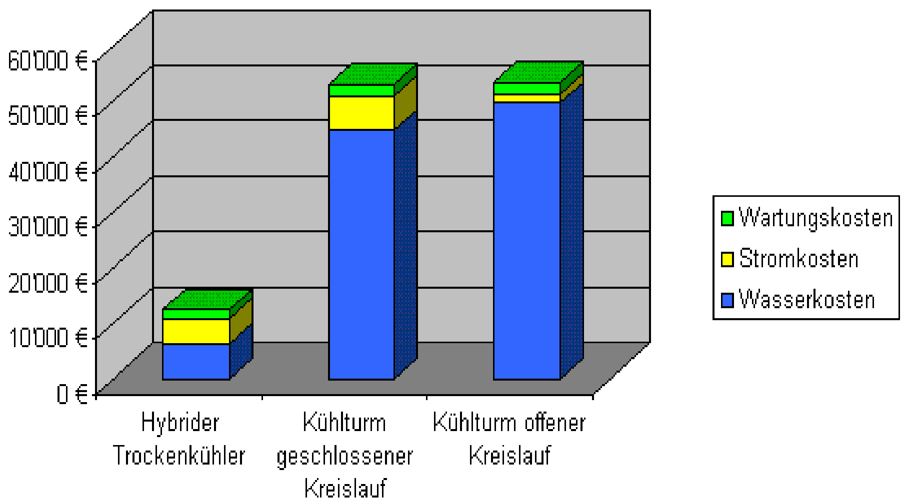
Thermal performance:	900 kW	
Cooling water:	34°C / 26°C	(without frost protection)
Wet-bulb temperature:	21°C	(32°C tc and 38% rh
Sound power level LWA:	85 dB(A)	
Hybrid dry cooler:	HDK 2.4/6.6-2S	

Investitionskostenvergleich



Investitionskostenvergleich	comparison of investment costs
Hybrider Trockenkühler	hybrid dry cooler
Kühlturm geschlossener Kreislauf	cooling tower (closed circuit)
Kühlturm offener Kreislauf	cooling tower (closed circuit)
Investitionskosten	investment costs
Betriebskosten pro Jahr	operating costs per year
Wartungskosten	maintenance costs
Stromkosten	electricity costs
Wasserkosten	water costs

Betriebskosten pro Jahr

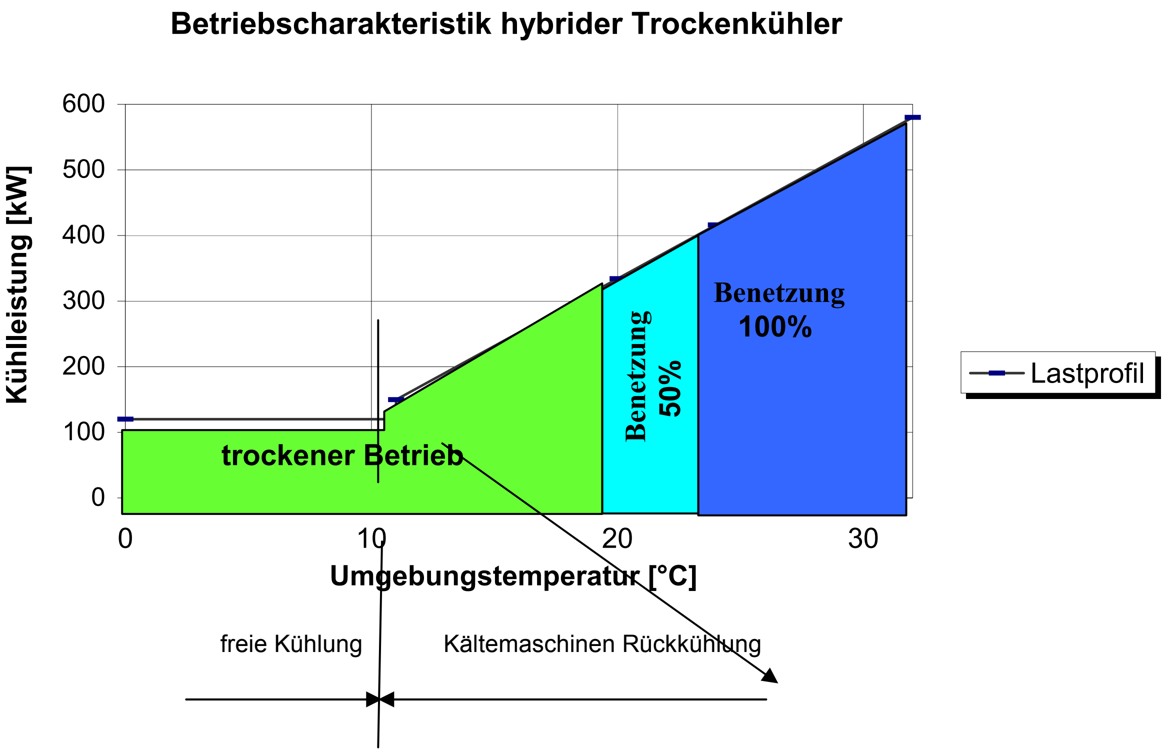


Trockenkühler geschlossener Kreislauf Kreislauf

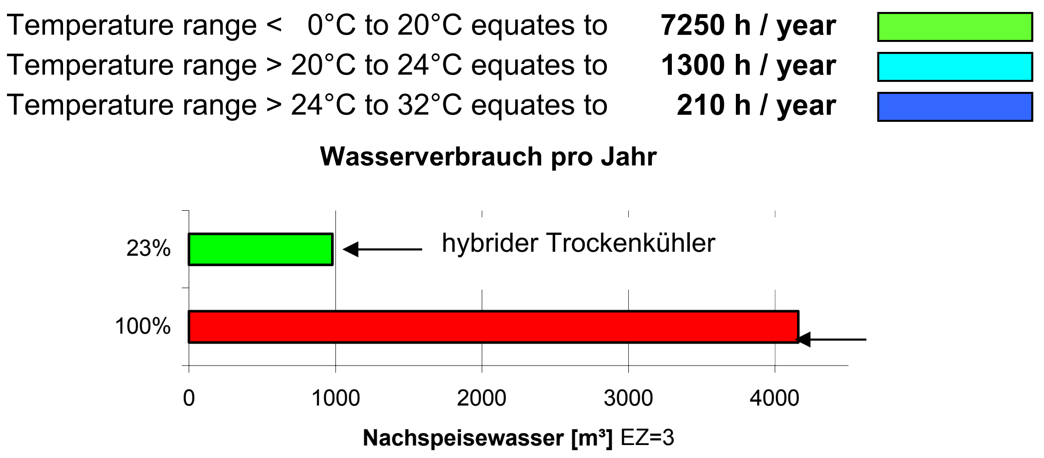
Example 4

Ambient cooling with free cooling

Thermal capacity:	580 kW	
Cooling water:	32°C / 27°C	(with 30% ethylene glycol)
Wet-bulb temperature:	21°C	(32°C tc and 38% rh)
Free cooling:	120 kW	
Cooling water:	16°C / 14°C	(with 30% ethylene glycol)
Ambient temperature:	12°C	
Sound power level LWA:	80 dB(A)	
Hybrid dry cooler:	HDK 1.8/5.45-2S	



Betriebscharakter hybrider Trockenkühler	operating characteristic of hybrid dry cooler
Kühlleistung [kW]	thermal capacity [kW]
Trockener Betrieb	dry operation
Benetzung 50%	wetting 50%
Benetzung 100%	wetting 100%
Umgebungstemperatur [C°]	ambient temperature [C°]
Freie Kühlung	free cooling
Kältemaschinen Rückkühlung	refrigerator recooling
Lastprofil	load profile



Wasserverbrauch pro Jahr	water consumption per year
Nachspeisewasser [m³] EZ = 3	makeup water [m³] RD = 3