

# Rittal – The System.

Faster – better – everywhere.

## ► Enclosure and process cooling



# Rittal – The System.

Faster – better – everywhere.

## ► Enclosure and process cooling



FRIEDHELM LOH GROUP



Until his retirement, engineer Heinrich Styppa was a divisional director at Rittal in Herborn with international responsibility for enclosure climate control and process cooling. He inspired and initiated many product innovations in this field, leading for example to the market launch of ProOzon CFC-free cooling units and microprocessor technology, air/water heat exchangers, nano-technology and energy-efficient enclosure cooling units. In many professional publications and books and numerous presentations to associations and customers, Heinrich Styppa has described innovative ways of dissipating

heat from enclosures and production machinery.

Mr. Styppa received extensive support from Ralf Schneider, Director International Business Development Climatisation, Rittal GmbH & Co. KG.



## The Rittal technology library, volume 2

Published by Rittal GmbH & Co. KG  
Herborn, September 2013

All rights reserved.  
No duplication or distribution without our explicit consent.

The publisher and authors have taken the utmost care in the preparation of all text and visual content. However, we cannot be held liable for the correctness, completeness and up-to-dateness of the content. Under no circumstances will the publisher and authors accept any liability whatsoever for any direct or indirect damages resulting from the application of this information.

Copyright: © 2013 Rittal GmbH & Co. KG  
Printed in Germany

Produced by:  
Rittal GmbH & Co. KG  
Martin Kandziora, Dagmar Liebegut  
Printed by: Wilhelm Becker  
Grafischer Betrieb e.K., Haiger

ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

# Preface

In view of escalating global environmental problems and rising energy prices, energy efficiency is a key issue for industrial production processes looking ahead to the future.

The advanced technology of German machine tool manufacturers has an added advantage – namely energy efficiency.

The product benefits and features that distinguish them from international competitors include not only their precision, productivity, quality and safety, but also their low energy consumption. The European Union has already responded by including machine tools in the list of energy-using products under the EUP directive.

Due to the increasingly powerful technology used in production processes, heat loss in enclosures has also increased rapidly.

With its highly efficient climate control solutions, in which energy-efficiency is treated as a priority, Rittal has taken this trend on board and developed climate control components and cooling systems with a continuous increase in efficiency of more than 40% compared with the old systems.

Today – and not without good reason – Rittal is an international market leader and above all a technology leader in the field of climate control systems for enclosures, machines, server racks and data centres.

This book describes the possibilities of a future-oriented, energy-efficient cooling system for enclosures and machinery.

Heinrich Styppa

# Rittal – The System.

Faster – better – everywhere.



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

# The whole is more than the sum of its parts

The same is true of “Rittal – The System.” With this in mind, we have bundled our innovative enclosure, power distribution, climate control and IT infrastructure products together into a single system platform. Complemented by our extensive range of software tools and global service, we create unique added value for all industrial applications: Production plant, test equipment, facility management and data centres. In accordance with our simple principle, “Faster – better – everywhere”, we are able to combine innovative products and efficient service to optimum effect.

**Faster** – with our “Rittal – The System.” range of modular solutions, which guarantees fast planning, assembly, conversion and commissioning with its system compatibility.

**Better** – by being quick to translate market trends into products. In this way, our innovative strength helps you to secure competitive advantages.

**Everywhere** – thanks to global networking across 150 locations. Rittal has over 60 subsidiaries, more than 250 service partners and over 1,000 service engineers worldwide. For more than 50 years, we have been on hand to offer advice, assistance and product solutions.

IT INFRASTRUCTURE

SOFTWARE & SERVICES



# Rittal – The System.

Faster – better – everywhere.

# » nextlevel

for industry

With our Therm software and the innovative Therm App, calculating the climate control requirements of individual enclosure assemblies becomes child's play. Meanwhile, the Rittal range of climate control products has the right solution to suit every application.

## Rittal – The System.

- Rittal – Therm
- Rittal – Type-tested climate control systems



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL



IT INFRASTRUCTURE

SOFTWARE & SERVICES





# Rittal – The System.

Faster – better – everywhere.

## Climate control from the smallest to the largest

- Cooling with ambient air
- Cooling units
- Cooling with water
- Heaters



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

- Output – TÜV-tested for TopTherm cooling units
- Environment-friendly – CFC-free refrigerants for over 20 years



IT INFRASTRUCTURE

SOFTWARE & SERVICES



# Rittal – The System.

Faster – better – everywhere.

## Your benefits

As a system supplier, Rittal is the world's leading provider of exceptionally effective yet energy-efficient and environmentally-friendly climate control solutions, precisely tailored to the customer's individual requirements.

**Faster** – Simple project planning with the Therm App

**Better** – Efficient, energy-saving climate control technology, TÜV-tested

**Everywhere** – Global spare parts service



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL



IT INFRASTRUCTURE

SOFTWARE & SERVICES



# Rittal – The System.

Faster – better – everywhere.

## Order info

### Catalogue

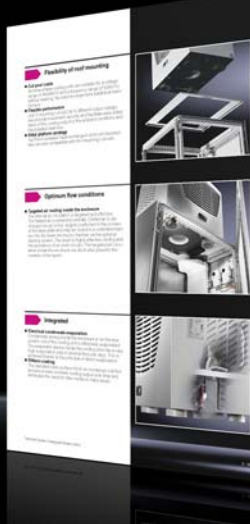
- Product information
- Order information



## Benefits

### Technical System Catalogue

- Benefits
- Arguments
- Advantages
- System info



Print	■	—
CD	■	—
www.rittal.com	■	■

ENCLOSURES

POWER DISTRIBUTION

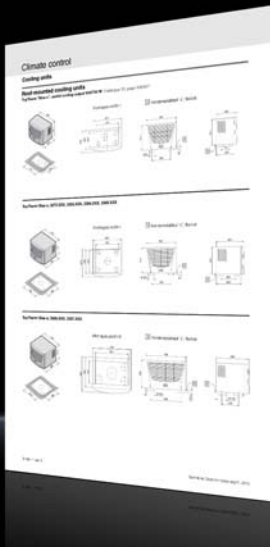
CLIMATE CONTROL

# Info structure

## Technology

### Technical details

- Technical drawings
- Performance diagrams



## Background

### The technology library

- Background information



IT INFRASTRUCTURE

SOFTWARE & SERVICES



# Rittal – The System.

Faster – better – everywhere.



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

# Content

## Fundamental principles

Why do we need enclosures? .....	18
Why must heat be dissipated from an enclosure? .....	20
Types of heat dissipation.....	21
Physical calculation principles of heat dissipation.....	23
Why do enclosures need heaters? .....	28

## Active heat dissipation

Heat dissipation through forced air circulation .....	32
Heat dissipation through fan-and-filter units.....	33
Heat dissipation with air/air heat exchangers .....	37
Heat dissipation with thermoelectric cooling .....	40
Heat dissipation with air/water heat exchangers .....	42
Direct water cooling .....	50
Active climate control with enclosure cooling units .....	53
General overview .....	61
Design and calculation of climate control solutions using Therm software ...	62

## Tips for project planning and operation

Useful and important tips for project planning and operation.....	66
Maintenance .....	71

## What is machine and process cooling?

The necessity of machine and process cooling .....	76
--	----

<b>Index</b> .....	90
<b>Glossary</b> .....	91
<b>Bibliography</b> .....	92

### Note:

IT Cooling (Climate Control) publication date March 2014



# Rittal – The System.

Faster – better – everywhere.



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

# Fundamental principles

<b>Why do we need enclosures? .....</b>	<b>18</b>
<b>Why must heat be dissipated from an enclosure? .....</b>	<b>20</b>
<b>Types of heat dissipation .....</b>	<b>21</b>
■ Enclosure surface cooling .....	21
■ Air flow cooling .....	22
<b>Physical calculation principles of heat dissipation .....</b>	<b>23</b>
<b>Why do enclosures need heaters?.....</b>	<b>28</b>

## ■ Why do we need enclosures?

The main function of an enclosure is to protect electronic components and devices from aggressive media such as humidity, water, oil-contaminated ambient air, corrosive vapours and also dust in the ambient air.

If these are not prevented, electronic components will inevitably fail, eventually leading to the shut-down of entire production systems. The failure of a production system generates costs that can add up to huge sums.

It is therefore the job of a housing or enclosure to provide lasting protection of sensitive and expensive electronic and microelectronic components.

There are different protection categories relating to the ambient conditions, which depend on the installation location of the enclosure.

The protection categories are defined on the basis of **IP codes** or **NEMA type ratings**.

The abbreviation IP stands for **Ingress Protection**. The protection category is defined by means of codes consisting of two letters, which always remain the same, and two numerals.

The relevant standard for enclosure construction or control system design is IEC 60 529 (VDE 0470-1).

### IP classification, degrees of protection against foreign objects and accidental contact

1st numeral	Meaning	
IEC 60 529	Protected against foreign objects	Protected against accidental contact
0	Non-protected	Non-protected
1	Protected against solid foreign objects with a diameter of 50 mm and greater	Protected against access with back of hand
2	Protected against solid foreign objects with a diameter of 12.5 mm and greater	Protected against access with finger
3	Protected against solid foreign objects with a diameter of 2.5 mm and greater	Protected against access with a tool
4	Protected against solid foreign objects with a diameter of 1 mm and greater	Protected against access with a wire
5	Protected against dust in harmful quantities	Fully protected against accidental contact
6	Dust-tight	Fully protected against accidental contact

**IP classification, degrees of protection against water**

2nd numeral	Meaning
IEC 60 529	Protection from water
0	Non-protected
1	Protected against vertically falling water drops
2	Protected against vertically falling water drops when the enclosure is tilted up to 15°
3	Protected against water sprayed at an angle of up to 60° to the vertical
4	Protected against water splashed from any direction
5	Protected against water jets sprayed from any direction
6	Protected against powerful water jets
7	Protected against the effects of temporary immersion
8	Protected against the effects of continuous immersion

**NEMA classification**

Type ratings	
1	Enclosures constructed for indoor use protected against falling dirt
4	Enclosures constructed for indoor or outdoor use protected against windblown dust and rain, splashing water and sprayed water; also protected against external formation of ice on the enclosure
4X	Enclosures constructed for indoor or outdoor use protected against windblown dust and rain, splashing water, sprayed water and corrosion; also protected against external formation of ice on the enclosure
12	Enclosures constructed for indoor use protected against falling dirt, circulating dust and dripping, non-corrosive liquids

NEMA stands for the **National Electrical Manufacturers Association**.

High levels of protection are required nowadays for modern enclosures, therefore the enclosures must be relatively impermeable. This means that influences from the environment

cannot penetrate the enclosure, but also that the heat loss caused by the electronic components cannot be dissipated to the outside.

## ■ Why does heat have to be dissipated from an enclosure?

In addition to negative external influences such as oil-contaminated and humid ambient air and dust, heat is the number one enemy of today's high-performance electronic and microelectronic components in enclosures.

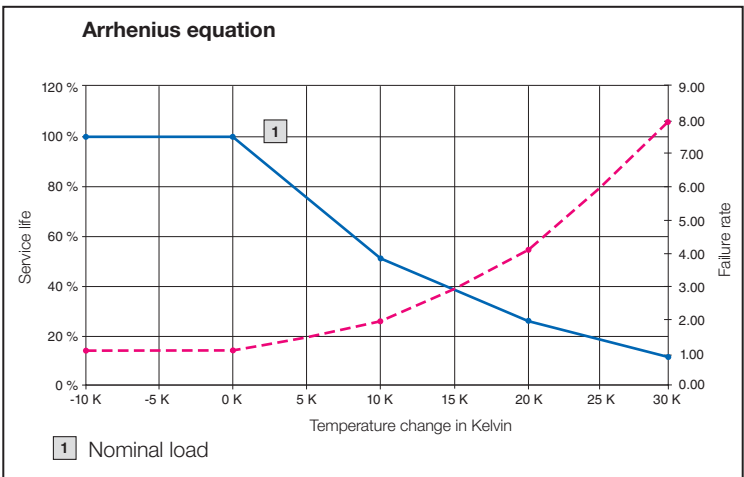
Relative to each individual component, the heat loss of electronic components has diminished significantly in recent years. At the same time, however, the packing density inside enclosures has increased dramatically, resulting in a 50 – 60% increase in heat loss in the enclosures.

With the advent of microelectronics and new electronic components, the requirements for professional enclosure construction have changed and thus also the requirements for heat dissipation from enclosures and electronic housings.

Modern enclosure climate control systems must take these new circumstances into account, offering the best

technical solution whilst guaranteeing optimum energy efficiency.

As already mentioned, heat is the main reason for failure of electronic components inside the enclosure. The service life of these components is halved and the failure rate is doubled in the event of a temperature increase of 10 K relative to the maximum permitted operating temperature (see Arrhenius equation).



## ■ Types of heat dissipation

Trouble-free operation and functioning of production lines is very heavily dependent on how the heat generated by electrical and electronic components is dissipated from the enclosure to the outside.

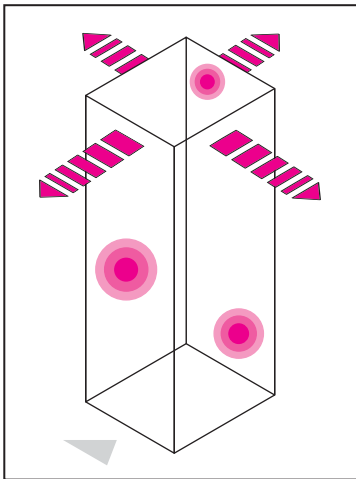
We distinguish three different types/methods of heat transfer:

- Thermal conduction
- Convection
- Thermal radiation

In the case of enclosures and electronic housings, we are mainly concerned with thermal conduction and convection. With thermal radiation, heat is passed from one body to another in the form of radiation energy, without a medium material, and plays a minor role here.

Whether we are dealing with heat conduction or convection depends on whether the enclosure is open (air-permeable) or closed (air-tight). With an open enclosure, the heat (heat loss) can be dissipated from the enclosure by means of air circulation, i.e. convection, from inside to outside. If the enclosure has to remain closed, the heat can only be dissipated via the enclosure walls, i.e. through thermal conduction.

### Cooling via enclosure walls, i.e. thermal conduction, from inside to outside with a positive temperature difference $T_i > T_u$



#### Method:

- Cooling via enclosure surface

#### Protection category:

- Up to IP 68

#### Max. cooling output:

- 350 watts

#### Advantages:

- No additional costs
- High protection category

#### Disadvantages:

- Hotspots may occur in the enclosure

## Cooling by means of air circulation, i.e. convection, from inside to outside with a positive temperature difference $T_i > T_u$

**Method:**

- Cooling by convection

**Protection category:**

- Up to IP 21

**Max. cooling output:**

- 500 watts

**Advantages:**

- No additional costs

**Disadvantages:**

- No high protection category
- Hotspots may occur in the enclosure

What type of heat transfer is possible depends not only on whether an enclosure is open or closed, but above all on the maximum ambient temperature at the enclosure location and the maximum temperature inside the enclosure.

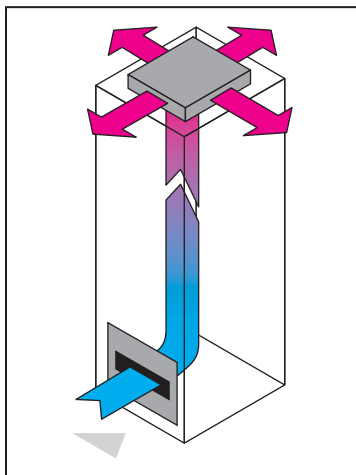
Whether natural convection is sufficient to dissipate the heat loss ( $\dot{Q}_v$ ) from the closed enclosure via the walls to the outside depends on the ambient temperature ( $T_u$ ) and the maximum permitted internal temperature ( $T_i$ ) inside the enclosure. The maximum temperature increase relative to the environment inside the enclosure can be determined from the following equation:

$$(T_i - T_u) = \frac{\dot{Q}_v}{k \cdot A}$$

where  $k$  is the heat transfer coefficient (for sheet steel  $k = 5.5 \text{ W/m}^2 \text{ K}$ ) and  $A$  ( $\text{m}^2$ ) is the enclosure surface area, determined according to DIN 57 660 part 500.

Example calculation:

Calculated heat loss in the enclosure  
 $\dot{Q}_v = 400 \text{ watts}$



Enclosure surface area  
 (W x H x D 600 x 2000 x 600 mm)  
 $A = 5.16 \text{ m}^2$ ;  $T_u = 22^\circ\text{C}$

$$(T_i - T_u) = \frac{400}{5.5 \cdot 5.16} > 22 - 14 = 8^\circ\text{K}$$

**Result:**

The enclosure internal temperature ( $T_i$ ) with heat loss of 400 W and surface area of  $5.16 \text{ m}^2$  at an ambient temperature of  $+22^\circ\text{C}$  will rise to approx.  $+30^\circ\text{C}$ .

**Conclusion:**

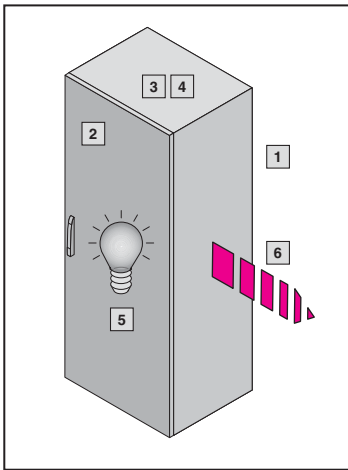
Based on the above parameters, this heat loss can be dissipated to the outside via the surface of the enclosure.

This involves passive heat dissipation from the enclosure, since no fans or other climate control components are used.

## ■ Physical calculation principles of heat dissipation

To determine the necessary climate control solution for an enclosure, it is necessary to calculate the heat loss  $\dot{Q}_v$  in the enclosure. The following parameters must also be calculated:

Parameter	
$\dot{Q}_v$	Heat loss installed in the enclosure [W]
$\dot{Q}_s$	Thermal radiation via enclosure surface [W] $\dot{Q}_s = k \cdot A \cdot \Delta T$
$\dot{Q}_k$	Required useful cooling output [W]
$\Delta T$	Temperature difference between inside and outside temperature [K] $\Delta T = (T_i - T_u)$
$\dot{Q}_e$	Required cooling output [W] $\dot{Q}_e = \dot{Q}_v - \dot{Q}_s$
$V$	Required volumetric flow of a fan-and-filter unit [m <sup>3</sup> /h] Approximate calculation: $V = \frac{3.1 \cdot \dot{Q}_v}{\Delta T}$



1	$T_u$	Maximum ambient temperature
2	$T_i$	Maximum enclosure internal temperature
3	A	Effective enclosure surface area (VDE)
4	k	Heat transfer coefficient
5	$\dot{Q}_v$	Heat loss
6	$\dot{Q}_s$	Thermal radiation via enclosure surface
	IP XX	Protection category
	Installation method, see page 24	










The maximum enclosure internal temperature ( $T_i$ ) must be determined depending on the electrical and electronic components used in the enclosure.

According to IEC 60 204-1 “Safety of Machinery”, the electrical equipment of machines must be able to function correctly at the envisaged ambient air temperature. The minimum requirement is correct operation at ambient temperatures of between +5°C and +40°C. As far as the recommended

enclosure internal temperature is concerned, an average value of +35°C has become the norm. This internal temperature also forms the basis for all calculations for necessary climate control solutions in enclosures.

In addition to the physical values described above, the enclosure surface area must also be determined according to the installation type.

The corresponding requirements for each installation type are laid down in DIN VDE 0660 part 500/IEC 890.

Enclosure installation type according to IEC 60 890	
	Single enclosure, free-standing on all sides $A = 1.8 \cdot H \cdot (W + D) + 1.4 \cdot W \cdot D$
	Single enclosure for wall mounting $A = 1.4 \cdot W \cdot (H + D) + 1.8 \cdot H \cdot D$
	First or last enclosure in a suite, free-standing $A = 1.4 \cdot D \cdot (W + H) + 1.8 \cdot W \cdot H$
	First or last enclosure in a suite, for wall mounting $A = 1.4 \cdot H \cdot (W + D) + 1.4 \cdot W \cdot D$
	Enclosure within a suite, free-standing $A = 1.8 \cdot W \cdot H + 1.4 \cdot W \cdot D + H \cdot D$
	Enclosure within a suite, for wall mounting $A = 1.4 \cdot W \cdot (H + D) + H \cdot D$
	Enclosure within a suite, for wall mounting, covered roof surfaces $A = 1.4 \cdot W \cdot H + 0.7 \cdot W \cdot D + H \cdot D$

A = Effective enclosure surface area [m<sup>2</sup>]

W = Enclosure width [m]

H = Enclosure height [m]

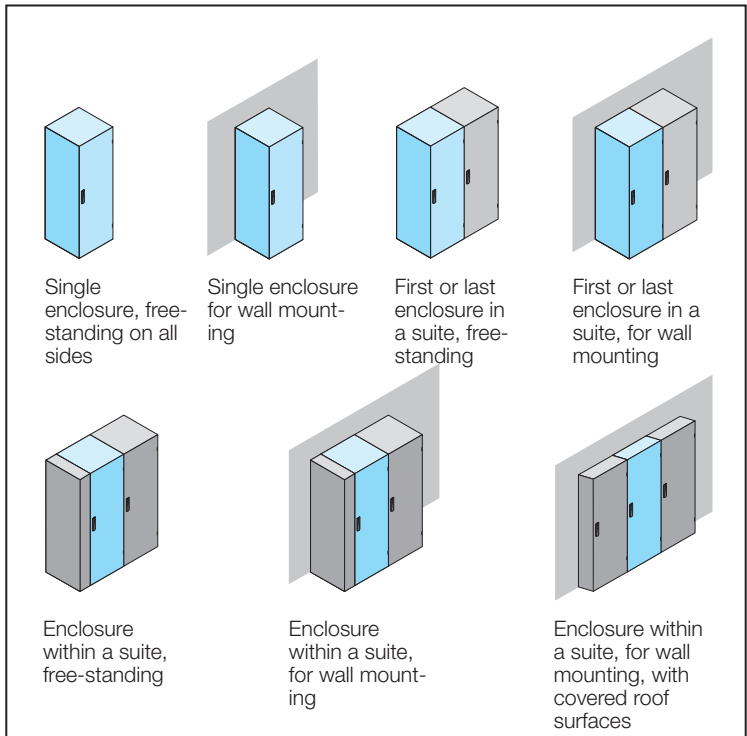
D = Enclosure depth [m]

The radiating power from the enclosure to the environment or the irradiating power from the environment into the enclosure depends on the enclosure installation method.

An enclosure that is free-standing on all sides can dissipate a greater heat loss to the environment via its surface (with a positive temperature difference,  $T_i > T_u$  between internal and external temperature) than an enclosure sited in a niche or integrated into a machine.

## Effective enclosure surface area [m<sup>2</sup>] (VDE 0660 part 507)

The method of installation of the enclosure changes the effective surface area.



## Exclusion criteria

Based on the ratio of the ambient temperature ( $T_u$ ) to the required enclosure internal temperature ( $T_i$ ), it is possible to establish in advance which climate control method should be used.

Passive climate control	
Natural convection	$T_i > T_u$
Active climate control	
Air circulation	$T_i > T_u$
Fan-and-filter units and outlet filters	$T_i > T_u$
Air/air heat exchangers	$T_i > T_u$
Air/water heat exchangers	$T_i < T_u$
Recooling / cold-water systems	$T_i < T_u$
Enclosure cooling units	$T_i < T_u$

The following table should help provide an overview of which type of climate control solution can be used and when, taking into account the protection category and cooling output.

For a detailed explanation of active climate control methods, see from page 31.

### Overview of cooling methods according to protection category and cooling output

Method	Protection category	Cooling output	Page
Cooling via fans	IP 20	8000 W	33
Cooling by convection	IP 21	500 W	32
Thermoelectric cooler	IP 54	1000 W	40
Air/air heat exchangers	IP 54	1000 W	37
Compressor-based climate control units	IP 54	10000 W	53
Fan-and-filter units	Up to IP 54/IP 55	2000 W	33
Air/water heat exchangers	IP 55	10000 W	42
Cooling via enclosure surface	Up to IP 68	250 W	21
Cooling by forced air circulation	Up to IP 68	350 W	32
Water-cooled mounting plate	Up to IP 68	3000 W	50



IT INFRASTRUCTURE

SOFTWARE & SERVICES



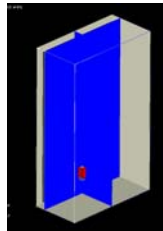
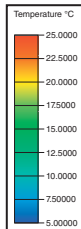
## ■ Why do enclosures need heaters?

The reliability of electrical and electronic components in an enclosure can be put at risk not only by excessively high temperatures, but also by excessively low ones. The enclosure interior must be heated, particularly to prevent moisture and protect against frost. It is also necessary to prevent a condensate film forming on the components.

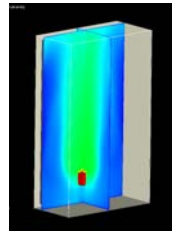
The latest generation of enclosure heaters has been developed with the help of extensive CFD (Computational Fluid Dynamics) analyses. The positioning of the heater is of fundamental importance for even temperature

distribution inside the enclosure. Placement of the heater in the floor area of the enclosure is recommended in order to achieve an optimum distribution of temperature and hence efficiency.

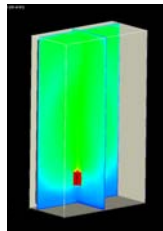
Due to PTC technology, power consumption is reduced at the maximum heater surface temperature. Together with a thermostat, this results in demand-oriented, energy-saving heating. The necessary thermal output depends on the ambient temperature and the actual enclosure surface area according to VDE 0660 part 507.



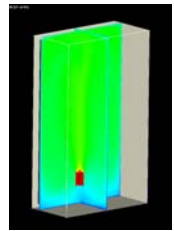
Start



After 5 minutes



After 15 minutes



After 30 minutes

**Example:**

Free-standing enclosure

 $W \times H \times D = 600 \cdot 2000 \cdot 500 \text{ mm}$ 

Lowest ambient temperature

 $T_u = -5^\circ\text{C}$ 

Lowest enclosure internal temperature

 $T_i = +10^\circ\text{C}$ 

The necessary thermal output  $Q_s$  is calculated using the known equation for irradiation

$$\dot{Q} = A \cdot k \cdot (T_i - T_u)$$

$k$  = heat transfer coefficient

5.5 W/m<sup>2</sup>K

$A = 4.38 \text{ m}^2$

$$\dot{Q}_h = 4.38 \text{ m}^2 \cdot 5.5 \text{ W/m}^2 \text{ K} (+10 + 5) > 361 \text{ watts}$$

**Result:**

A heater with a thermal output of at least 361 watts must be chosen.

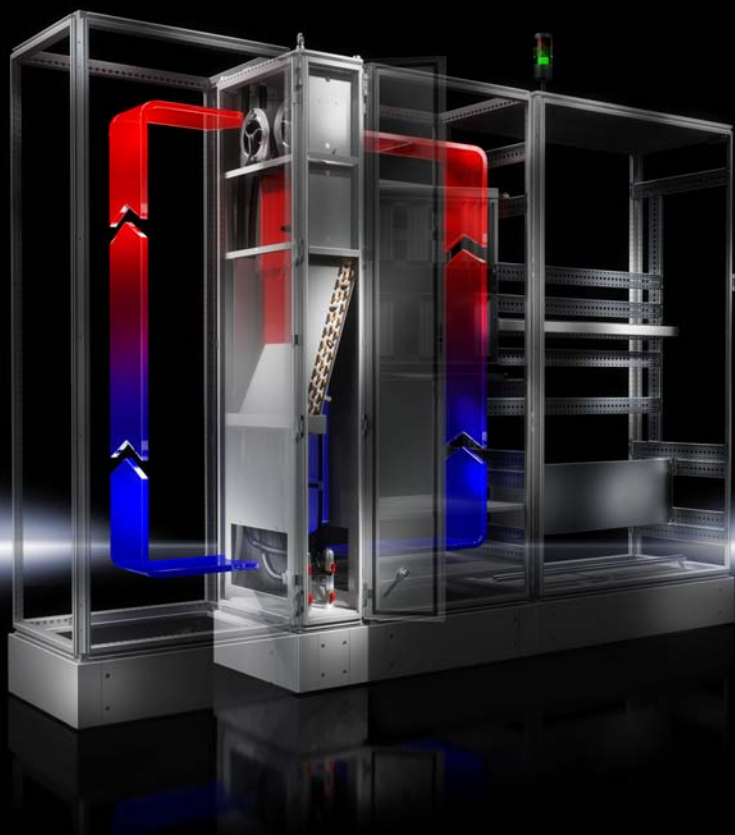
Observe the following points when installing enclosure heaters:

- Install in the floor area as close as possible to the centre
- Distance from floor panel > 100 mm
- Place heaters below the components to be protected
- Distance from side panels > 50 mm
- Distance from thermoplastic materials > 35 mm
- In case of excessive air humidity, a hygostat should be used to achieve accurate temperature control



# Rittal – The System.

Faster – better – everywhere.



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

# Active heat dissipation

<b>Heat dissipation through forced air circulation</b> .....	<b>32</b>
<b>Heat dissipation through fan-and-filter units</b> .....	<b>33</b>
■ Calculation of volumetric flow of a fan relative to the installation height .....	35
<b>Heat dissipation with air/air heat exchangers</b> .....	<b>37</b>
<b>Heat dissipation with thermoelectric cooling</b> .....	<b>40</b>
<b>Heat dissipation with air/water heat exchangers</b> .....	<b>42</b>
■ Benefits of water cooling.....	44
■ Efficiency comparison, cooling units – chillers with heat exchangers .....	46
■ Dissipation of high heat losses (cooling outputs > 10 kW) .....	48
<b>Direct water cooling</b> .....	<b>50</b>
<b>Active climate control with enclosure cooling units</b> .....	<b>53</b>
■ Cooling unit technology .....	54
■ Why use electrical condensate evaporation?.....	59
<b>General overview</b> .....	<b>61</b>
<b>Design and calculation of climate control solutions using Therm software</b> .....	<b>62</b>



## ■ Heat dissipation through forced air circulation

$$T_i > T_u$$

(positive temperature difference between internal and external temperature)

To improve convection, i.e. heat dissipation, by the enclosure walls from the inside to the outside, circulation fans are used. These fans circulate the air inside the enclosure and should result in better heat distribution inside the enclosure and by the enclosure walls.

### Method:

- Cooling by forced air circulation

### Protection category:

- Up to IP 68

### Max. cooling output:

- 350 watts

### Advantages:

- No hotspots thanks to air circulation

### Disadvantages:

- Only limited cooling power

The volumetric air flow that such a fan must generate is determined using the following equation:

$$V = \frac{f \cdot \dot{Q}_v}{T_i - T_u}$$

$V$  = air flow rate

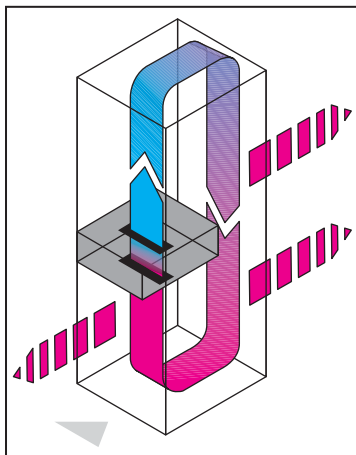
$f$  = air constant, see table  
on page 35

$\dot{Q}_v$  = installed heat loss (thermal output  
of the assembly)

$T_i$  = permitted temperature at the  
assembly

$T_u$  = aspirated air

However, the result of such a solution is very limited.



### Note:

Consider the installation type, see page 24/25.

## ■ Heat dissipation through fan-and-filter units

$$T_i > T_u$$

There is usually some uncertainty when determining the heat loss in the enclosure. Nowadays, almost all manufacturers of electronic and electrical components provide this information for planners in equipment lists and documentation.

In most cases, the necessary constant enclosure internal temperature of 35°C mentioned above cannot be achieved through convection alone.

**The simplest solution is to use fan-and-filter units.**

### Method:

- Fan-and-filter units

### Protection category:

- Up to IP 54/IP 55

### Max. cooling output:

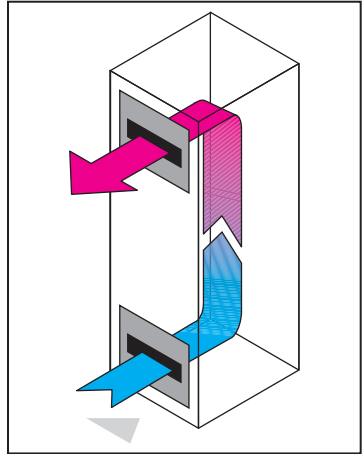
- 2000 watts

### Advantages:

- Low-cost and simple cooling method

### Disadvantages:

- Maintenance required in case of dirty air – filters have to be changed



Innovative fan-and-filter units (with diagonal fan technology) with their novel design provide uniformly constant air throughput with optimised air routing and very low mounting depth, leaving more space in the enclosure compared with conventional axial fan-and-filter units.



### $T_i > T_u$

- Fan-and-filter unit/outlet filter combination
- Volumetric air flow 20 – 900 m<sup>3</sup>/h
- Operating voltages: 230 V, 115 V, 50/60 Hz, 24 V (DC), 48 V (DC)
- Protection category IP 54 (optionally IP 56)
- All variants also available as EMC versions

Depending on the requirements, these fan-and-filter units can be arranged “blowing” into the enclosure or “sucking” out of the enclosure. However, it is recommended to install fan-and-filter units so that they blow, to avoid creating a vacuum in the enclosure. If there is a vacuum, the supply air flows uncontrollably into the enclosure, i.e. it is not only aspirated through the

filter, but is also sucked through all cable passages and other places that are not airtight. Inflowing, unfiltered ambient air containing dust can lead to problems.

With a blowing arrangement, air is selectively routed into the enclosure and an uncontrolled inflow of ambient air is prevented.

### Use of diagonal fans with fan-and-filter units

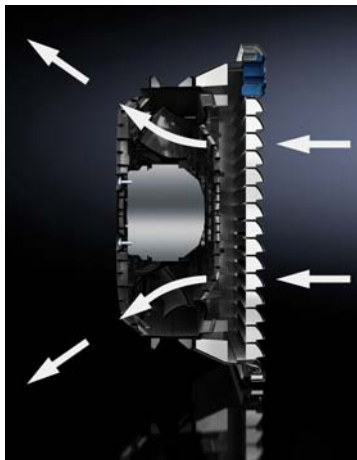
- Air throughput range: 20 – 900 m<sup>3</sup>/h
- Operating voltage: 230 V, 115 V, 400 V, 3~, 50/60 Hz, 24 V (DC)

#### 1st advantage:

Much greater pressure stability resulting in a more constant air flow in the installed state, even with a contaminated filter mat

#### 2nd advantage:

Air flow is expelled diagonally from the fan, promoting a more even air distribution in the enclosure



Diagonal air flow = more even temperature distribution in the enclosure



Proven mounting system on the enclosure



- 1 Screwless spring terminal for tool-free electrical connection
- 2 Bayonet catch for tool-free reversal of airflow direction
- 3 Bayonet catch for tool-free changing of the electrical connection direction (4 x 90°)

## Calculation of volumetric flow of a fan relative to the installation height

The necessary air flow of a fan-and-filter unit is determined from the heat loss  $\dot{Q}_v$  and the difference between the maximum permitted internal and external temperature ( $T_i - T_u$ ).

$$V = \frac{f \cdot \dot{Q}_v}{T_i - T_u}$$

Factor  $f = c_p \cdot \rho$  (specific thermal capacity x air density at sea level)

Height (m)	$c_p$ (kJ/kg · K)	kg/m <sup>3</sup>	$f$ (m <sup>3</sup> /k)/Wh
0	0.9480	1.225	3.1
500	0.9348	1.167	3.3
1000	0.9250	1.112	3.5
1500	0.8954	1.058	3.8
2000	0.8728	1.006	4.1
2500	0.8551	0.9568	4.4
3000	0.8302	0.9091	4.8
3500	0.8065	0.8633	5.2

The specific thermal capacity of air and the air density depend on several factors, such as temperature, air humidity and air pressure. The mean values of these factors vary depending on the altitude above sea level.

The mean values at different altitudes can be determined from the above table.

## Active heat dissipation

Using a selection diagram, you can select a fan-and-filter unit quickly and easily, provided the heat loss  $\dot{Q}_v$  and the temperature difference ( $T_i - T_u$ ) are defined.

### Example:

Heat loss  $\dot{Q}_v = 600$  watts

Temperature difference:

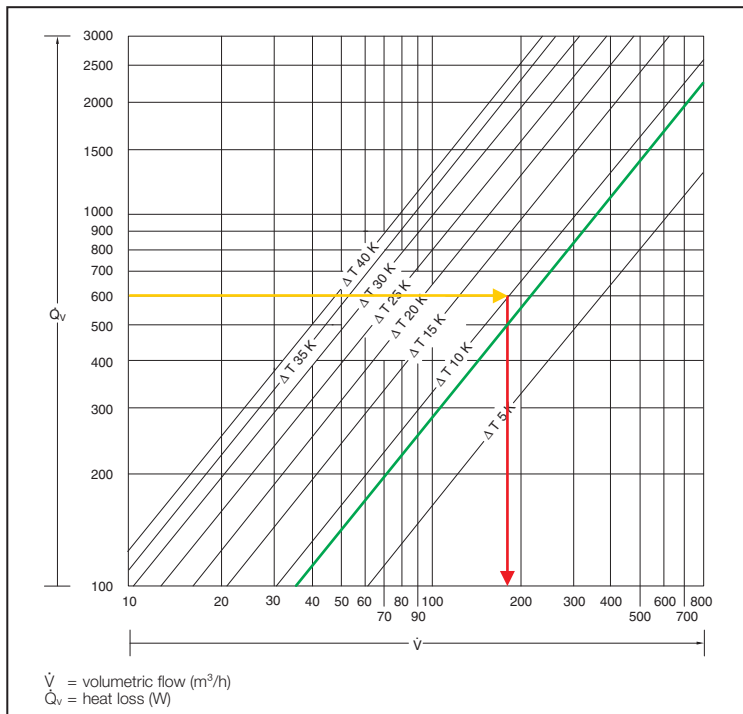
$$T_i - T_u = 35 - 25 = 10 \text{ K}$$

Result:

Necessary air flow rate based on the selection diagram approx. **180 m<sup>3</sup>/h**.

It is recommended to choose a fan-and-filter unit with an air flow approx. 20% greater than the result of the calculation, i.e. in this example approx. 220 m<sup>3</sup>/h. This allows for fouling of the filter mat, depending on the level of contamination of the ambient air.

## Selection diagram



## ■ Heat dissipation with air/air heat exchangers

$$T_i > T_u$$

If a protection category of IP 54 must be observed for an enclosure and there is a positive temperature difference between the ambient air and the enclosure internal temperature ( $T_i > T_u$ ), air/air heat exchangers can be used. The greater the temperature difference between the internal and external temperature, the more heat loss can be dissipated outwards from the enclosure.

### Method:

- Air/air heat exchangers

### Protection category:

- Up to IP 54

### Max. cooling output:

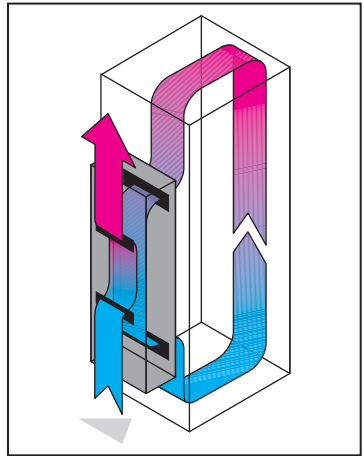
- 1000 watts

### Advantages:

- Relatively low-maintenance compared with fan-and-filter units

### Disadvantages:

- Efficiency is lower than with fan-and-filter units

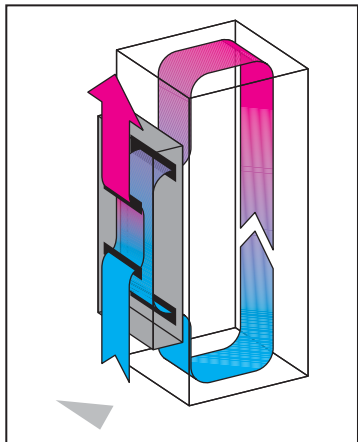


The operating principle is simple but very effective. The warm enclosure internal air is aspirated by a fan in the upper area and led through a cross-flow heat exchanger. The cooler ambient air is likewise aspirated by a fan and also led through this cross-flow heat exchanger, without the two air flows being mixed.

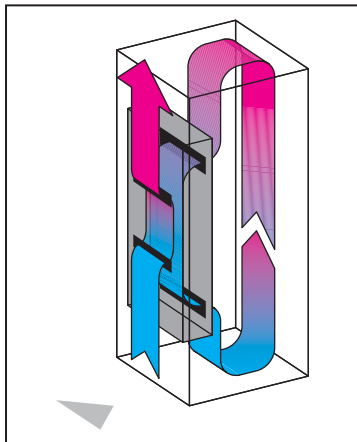
The cooler air flow from the ambient air flow cools the heat exchanger and dissipates the heat loss absorbed by the heat exchanger to the environment. Inside the enclosure, the internal air is cooled in the heat exchanger and led into the lower enclosure.

## Air/air heat exchangers

### Functional characteristics



External mounting



Internal mounting

The rule is: The greater the temperature difference between the external temperature (e.g.  $+22^{\circ}\text{C}$ ) and the required enclosure internal temperature (e.g.  $+35^{\circ}\text{C}$ ), the more heat loss can be dissipated via the air/air heat exchanger.

Depending on the available space and requirements, air/air heat exchangers can be mounted on the enclosure or installed inside the enclosure.

### Product characteristics

- Separate internal and external circuit
- Output 17.5 to approx. 100 W/K
- High protection category guaranteed (e.g. against dust, oil and moisture)
- Internal circuit protection cat. IP 54
- External circuit protection cat. IP 34
- Less maintenance due to separate control of internal and external fan
- Easy to clean thanks to removable cassette
- Control with digital temperature display
- Floating fault signal contact in case of overtemperature



**Example:**

- Free-standing enclosure  
Width = 600 mm, height = 2000 mm, depth = 500 mm
- Heat loss  $\dot{Q}_v = 900$  watts
- Ambient temperature  $T_u = 25^\circ\text{C}$
- Enclosure internal temperature  $T_i = 35^\circ\text{C}$

**Step 1**

Calculate radiation power from the enclosure to the outside via the enclosure surface.

$$\dot{Q}_s = k \cdot A \cdot (T_i - T_u)$$

**Note:**

When using the selection diagram, heat radiation is not taken into account; this allows the heat exchanger capacity reserve to be determined.

**Step 2**

Calculate enclosure surface area  $A$  ( $\text{m}^2$ ) according to VDE 0660 part 500 based on the formula

$$A = 1.8 \cdot H \cdot (W + D) + 1.4 \cdot W \cdot D$$

$$A = 1.8 \cdot 2.0 \cdot (0.6 + 0.5) + 1.4 \cdot 0.6 \cdot 0.5$$

$$A = 4.38 \text{ m}^2$$

$$\dot{Q}_s = 5.5 \cdot 4.38 \cdot 10 = 242 \text{ watts}$$

= radiation power

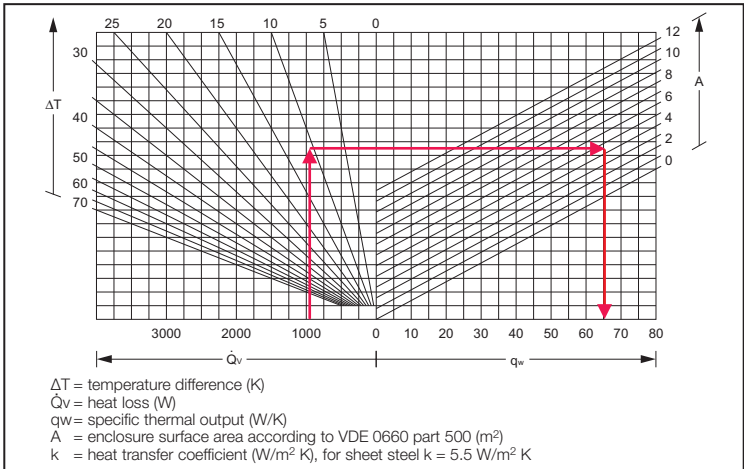
$$\dot{Q}_e = \dot{Q}_v - \dot{Q}_s = 900 \text{ W} - 242 \text{ W}$$

$$= 658 \text{ watts}$$

= heat loss that must still be dissipated via the air/air heat exchanger

A heat exchanger is therefore needed with a specific thermal output of **65.8 W/K**.

The capacity of the air/air heat exchanger can be determined more easily using the selection diagram.

**Air/air heat exchanger selection diagram**



## Heat dissipation with thermoelectric cooling

$$T_i < T_u$$

Thermoelectric coolers are also known as Peltier coolers. The French physicist Jean Charles Peltier discovered this “thermal effect” in 1834.

### Thermoelectric cooling with Peltier cooling units

#### Principle

If a direct electric current flows through a conductor circuit made of two different metals, one contact point cools down, while the other contact point heats up.

Peltier cooling has become more important in recent years, above all because of the innovative thermoelectric cooler developed by Rittal.

For use in small enclosures and operating housings, where IP 54 protection is required for the internal circuit, Peltier cooling is very often the correct and ideal technical solution.

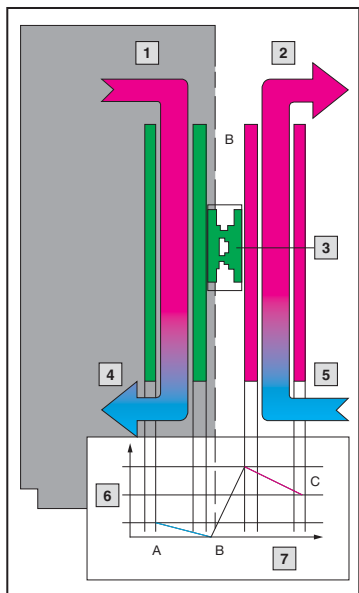
With a very low weight of only 3.0 kg and dimensions of 125 x 155 x 400 mm (W x H x D), heat losses of 100 watts are dissipated with minimal vibration and noise (no compressor).

#### Design of the Peltier element

- Two different plates are connected to one another so as to create a series circuit.
- The introduced DC current flows through all plates one after the other.
- Depending on the current strength and flow direction, the upper connection points cool down, while the lower ones heat up.

#### Operating principle of the thermoelectric cooler

- 1 Air, warm, internal
- 2 Air, warm, external
- 3 Peltier element
- 4 Air, cold, internal
- 5 Air, cold, external
- 6 Temperature T
- 7 Temperature profile through the components



**Method:**

- Thermoelectric cooling

**Protection category:**

- Up to IP 54

**Max. cooling output:**

- 1000 watts

**Advantages:**

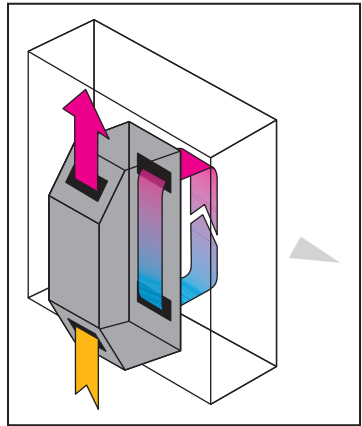
- Small dimensions
- DC-capable
- Additional heating function possible

**Disadvantages:**

- Low efficiency
- High energy consumption

The technical advantages of the Rittal thermoelectric cooler include its modular design and low weight. Up to five devices may be arranged alongside each other and connected in parallel, allowing synchronised control of the units in both cooling and heating operation.

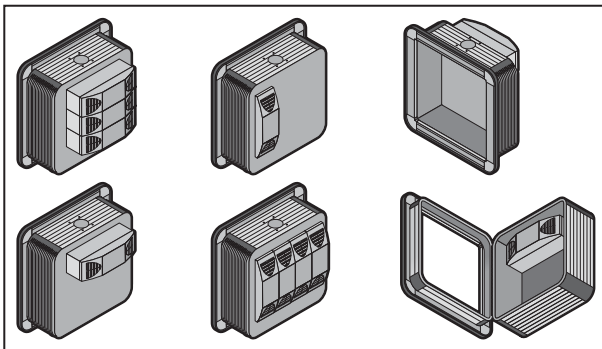
The innovative design and air routing result in the optimum air flow over the Peltier elements and hence a coefficient of performance (COP) of 1.0, i.e. the unit consumes 100 W of electrical energy to supply 100 W of cooling.



There are two variants of this unit, which accept either a 24 V DC power supply or an AC power supply in the range 94 – 264 V.

**Product characteristics**

- Modular capacity expansion
- Simple scalability
- Flexible mounting position:
  - horizontal
  - vertical
  - built-in
  - built-on
- Complete unit ready for connection



## ■ Heat dissipation with air/water heat exchangers $T_i < T_u$

As well as enclosure cooling units, the use of air/water heat exchangers for the dissipation of heat from enclosures and electronic housings has undergone the greatest development. This is partly due to the fact that the greatest cooling power can be achieved in the smallest space with air/water heat exchangers.

### Method:

- Air/water heat exchanger

### Protection category:

- Up to IP 55

### Max. cooling output:

- 10,000 watts

### Advantages:

- High protection category
- Reduced maintenance

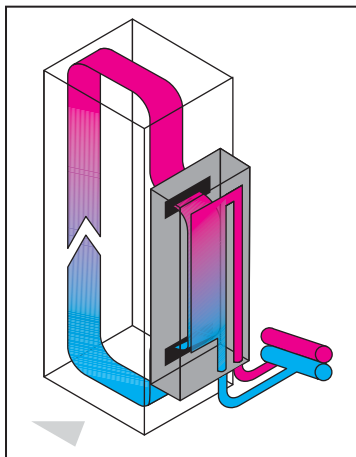
### Disadvantages:

- High infrastructure requirements

The useful cooling output ( $Q$ ) of an air/water heat exchanger is determined by the enclosure internal temperature, water inlet temperature and volumetric water flow ( $l/h$ ) in the heat exchanger.

With this solution a protection category of IP 55 is achieved, since the enclosure is completely closed. The enclosure internal temperature can even be cooled to below the ambient temperature with air/water heat exchangers.

The enclosure internal air is cooled by the circulation of air at the air/water heat exchanger, whereby the heat loss from the enclosure is dissipated from the enclosure via the heat exchanger to the water and led to the outside.



This requires a water connection (supply and return) and a central or decentralised cooling unit (recooler) for water cooling on the air/water heat exchanger. These heat exchangers are available for mounting on walls, installation in walls or roof mounting, depending on the application.

**Product characteristics**

- Wide output range from 500 to 10,000 W
- Voltage:
  - 230 V
  - 115 V
  - 400 V
- Integrated control as standard (Basic or Comfort)
- Slimline design
- Available with all water-carrying parts made from CuAl or V4A (1.4571)



When calculating the air/water heat exchanger it is important to remember that, depending on the ambient temperature relative to the heat loss ( $\dot{Q}_v$ ) in the enclosure, as well as the temperature difference between the ambient temperature ( $T_u$ ) and the required internal enclosure temperature ( $T_i$ ), it may also be necessary to add the thermal irradiation ( $\dot{Q}_s$ ) via the enclosure surface.

$$\dot{Q}_e = \dot{Q}_v + \dot{Q}_s$$

$\dot{Q}_e$  = required cooling output

**Example:**

- Calculated heat loss in the enclosure  $\dot{Q}_v = 1500$  watts
- Calculated enclosure surface area  $A = 4.38 \text{ m}^2$
- Required enclosure internal temperature  $T_i = 35^\circ\text{C}$
- Ambient temperature  $T_u = 45^\circ\text{C}$

$$\begin{aligned} \dot{Q}_s &= k \cdot A \cdot (T_i - T_u) \\ &= 5.5 \cdot 4.38 \cdot (45 - 35) = \mathbf{241 \text{ watts}} \end{aligned}$$

**Result:**

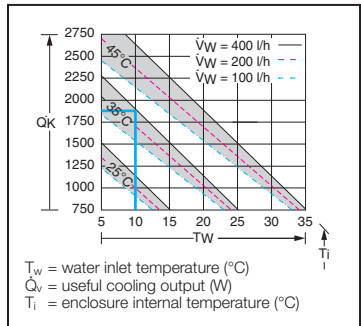
Required cooling output

$$\dot{Q}_e = 1500 + 241 = \mathbf{1741 \text{ watts}}$$

A suitable air/water heat exchanger can be selected from the performance diagram, based on the water inlet temperature, the volumetric water flow, the enclosure internal temperature and the required cooling output.

**Product characteristics**

- High protection category (e.g. against dust), IP 55 (IP 65 possible)
- Maximum ambient temperature ( $T_u$ )  $+70^\circ\text{C}$
- Cooling medium: Water

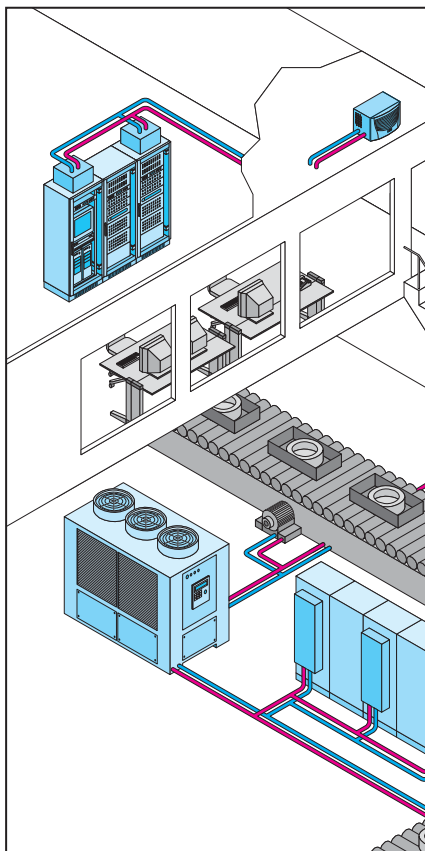


## Benefits of water cooling

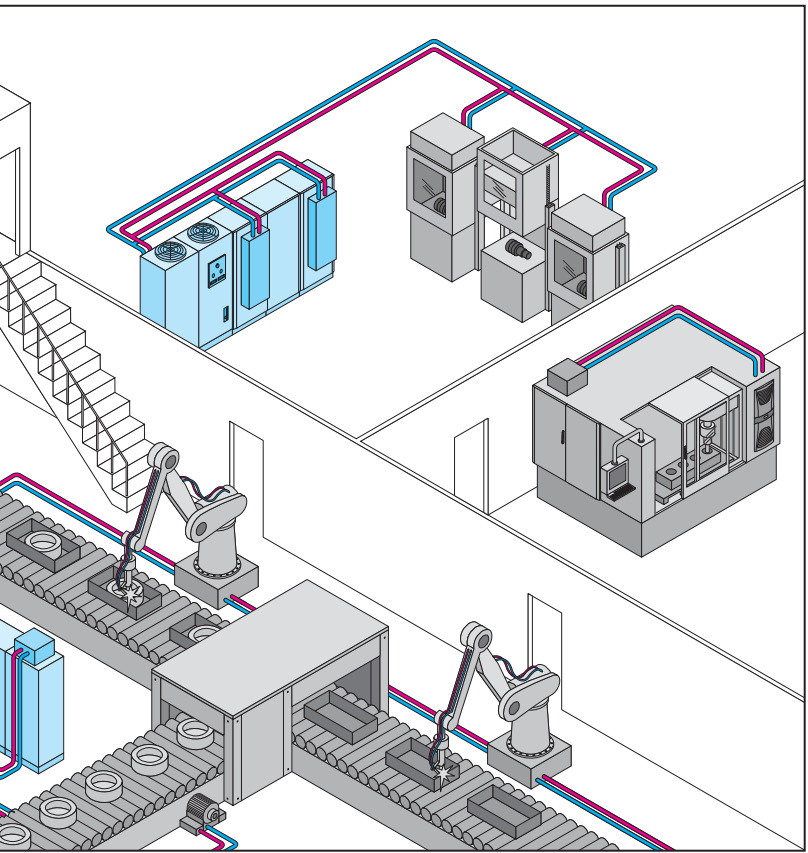
### Focus area: Enclosure cooling

In many large industrial enterprises, in the automotive industry for example, a central supply of cooling water is usually already available. Since this cooling water is provided by a central ring main, the air/water heat exchangers can also be supplied.

With a decentralised solution a chiller is used, in which case it is necessary to ensure that as many air/water heat exchangers as possible are connected to a cold water unit in the interests of economy.



- Higher energy density than e.g. air; in the case of drive units a higher continuous power is possible for the same build volume
- Energy is easily transported e.g. out of the building



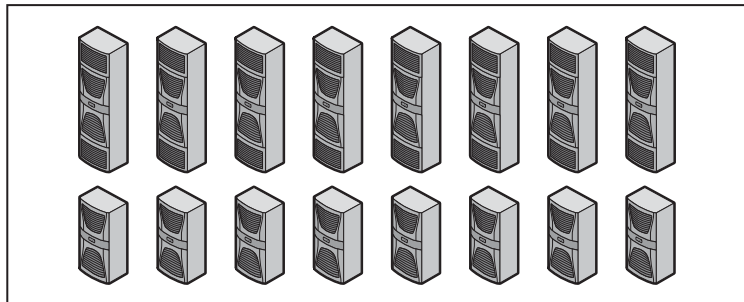
- Compact design combined with dissipation of high thermal loads
- Good energy store, e.g. buffer store for load peaks
- Cooling output is freely scalable: modular, open, building-block systems possible

A comparative calculation (see next page) shows that the use of several air/water heat exchangers can be an economical but also energy-efficient alternative compared with enclosure cooling units.

## Efficiency comparison, cooling units – chillers with heat exchangers

### Comparative calculation

Based on the example of a suite of enclosures with a heat loss of **25 kW**



How much energy is consumed?

TopTherm cooling units				
	Number	Power consumption		Heat loss
		Per unit	Total	
Cooling unit for wall mounting	8	1.02 kW	8.16 kW	
Cooling unit for wall mounting	8	0.58 kW	4.64 kW	
<b>Total</b>			<b>12.74 kW</b>	<b>25 kW</b>

Costs			
	Investment costs	Energy consumption	Total cost
16 cooling circuits, 16 compressors	~18,000 €	~4,500 € <sup>1)</sup>	~22,500 €

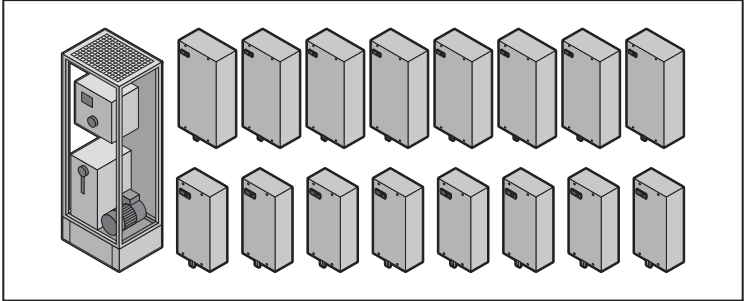
<sup>1)</sup> Example calculation at 0.12 €/kW

**Result 1:**

By using a chiller and 16 air/water heat exchangers, approx. 40% less energy is consumed.

This example demonstrates that a solution with air/water heat exchangers and a central recoler (chiller) can alone reduce energy costs by around 40%.

During the planning phase you are advised to investigate both alternatives very carefully from the point of view of economy and energy efficiency and obtain expert support where necessary.



**How much energy is consumed?**

#### TopTherm chiller with heat exchanger

	Number	Power consumption		Heat loss
		Per unit	Total	
Air/water heat exchanger	8	0.06 kW	0.48 kW	
Air/water heat exchanger	8	0.16 kW	1.28 kW	
Chiller	1	5.91 kW	5.91 kW	
<b>Total</b>			<b>7.68 kW</b>	<b>25 kW</b>

#### Costs

	Investment costs	Energy consumption	Total cost
1 chiller, 16 A/W HE, complete pipework	~19,000 €	~2,800 € <sup>1)</sup>	~21,600 €

#### Result 2:

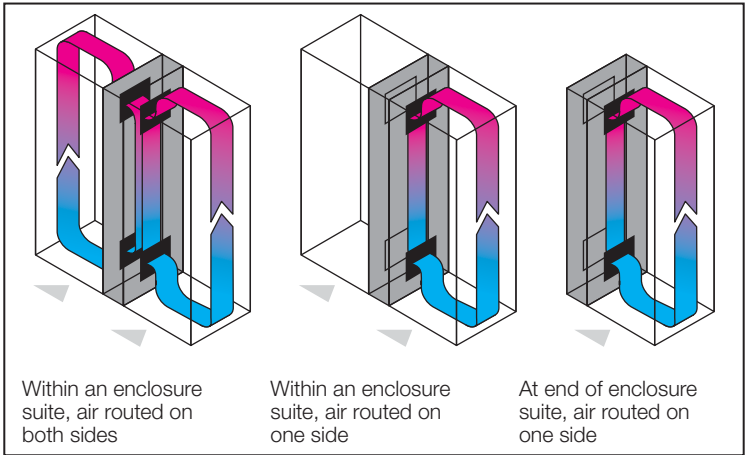
Although the capital costs are greater when using chillers and air/water heat exchangers, these pay for themselves in less than one year through energy savings.



## Dissipation of high heat losses (cooling outputs > 10 kW)

Air/water heat exchangers that can achieve a cooling output spectrum of over 10 kW are increasingly required in industrial applications. Based on very positive experience with IT cooling, Rittal has developed the high-performance Industry LCP (Liquid Cooling Package) especially for use in industrial environments.

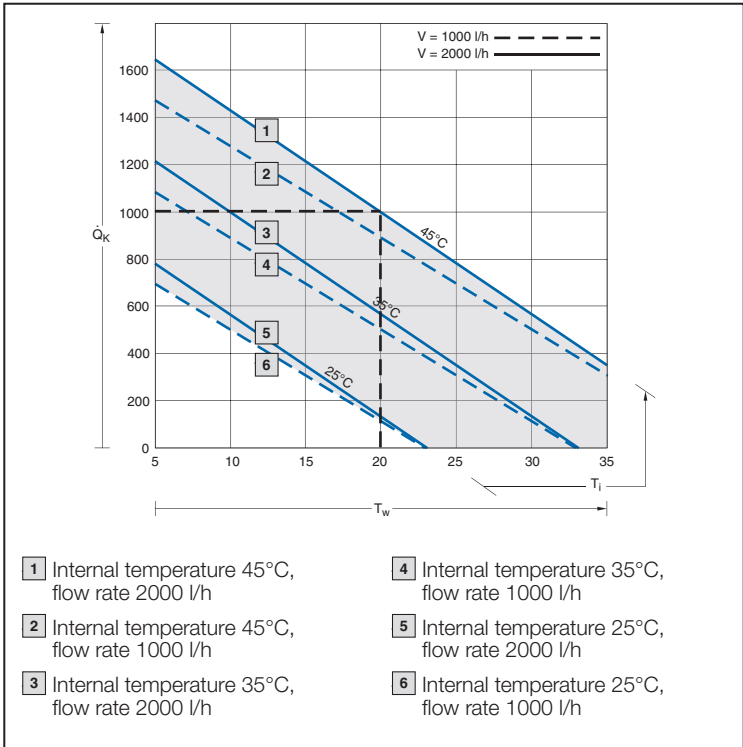
### Air routing



The advantage of these heat exchangers lies not only in the fact that a high cooling output can be achieved, but also that they can be fully and easily integrated into the Rittal TS 8 enclosure system.

The heat exchanger can be flexibly integrated into the enclosure system. Depending on the required cooling output, air can be routed on one side to the left, to the right or, if placed centrally, on both sides.

## Curve



Here too, approx. 2000 l/h of cooling water is required. In particular it is worth noting the high energy efficiency of such a central solution for cooling whole suites of enclosures.

**Advantage:**

- One central air/water heat exchanger, one fan, one control unit and maintenance/service on only one device

**Disadvantage:**

- Failure of the heat exchanger brings the whole system to a standstill

## ■ Direct water cooling

Another method of liquid cooling in a confined space involves direct cooling of the mounting plate with water. A prerequisite for the use of a water-cooled mounting plate, besides a suitable climate-control and mechanical set-up, is the presence of cooling water.

### Method:

- Water-cooled mounting plate

### Protection category:

- Up to IP 68

### Max. cooling output:

- 3000 watts

### Advantages:

- High protection category
- No maintenance

### Disadvantages:

- Only 70% of the heat loss can be dissipated, the remainder via other climate-control methods
- High infrastructure requirements

Water-cooled mounting plates are used in all areas of industry, from mechanical engineering, to clean rooms, to medical technology.

Water-cooled mounting plates are used particularly where the heat loss of e.g. frequency converters, servo controllers, motor chokes or power contactors can be dissipated directly with water. Water-cooled mounting plates also fulfil the requirement for a high protection category (IP 68) and are suitable for use in hazardous areas.



By ensuring a constant component temperature, the water-cooled mounting plate helps extend the life of these elements, while the even dissipation of heat directly at the source reduces energy costs.

## Total flexibility of water-cooled mounting plate thanks to T-slot attachment system



The components are mounted directly on the water-cooled mounting plate. The routing of the water pipe in the mounting plate is visually marked,

so the electrical components can be positioned without difficulty.



### Complete flexibility in the enclosure

- Installation is carried out in the same way as for partial mounting plates
- It can be fitted on the rear panel or side panel
- Variable installation depth through use of punched sections with mounting flanges
- Standardised plate sizes

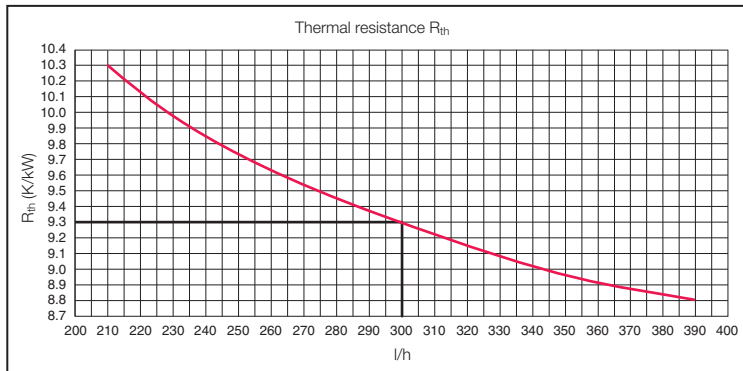
The capacity of a water-cooled mounting plate is defined on the basis of the thermal resistance  $R_{th}$ . The thermal resistance is calculated from the temperature difference between the surface of the water-cooled mounting plate and the coolant inlet temperature, divided by the maximum heat loss of the components mounted on this mounting plate.

**Calculation formula – water-cooled mounting plate**

$$R_{th} = \frac{T_p - T_m}{P_v}$$

- $R_{th}$  = thermal resistance (K/kW)
- $T_p$  = surface temperature of water-cooled mounting plate (°C)
- $T_m$  = temperature of medium (°C)
- $P_v$  = applied heat loss (kW)

**Thermal resistance of water-cooled mounting plate**



Characteristic of a water-cooled mounting plate (499 x 399 mm) with copper pipeline

**Result:**

$$T_p = \frac{25^\circ\text{C} + 1.5 \text{ kW} \cdot 9.3 \text{ K}}{\text{kW}} = 38.95^\circ\text{C}$$

After rounding up, a temperature of approx. 39°C is expected on the surface of the mounting plate.

At the same time, the material used has an influence on the thermal resistance due to its thermal conductivity and thickness.

**Example:**

- Heat loss  $\dot{Q}_v = 1500 \text{ W}$
- Coolant temperature  $T_w = 25^\circ\text{C}$
- Flow rate  $m = 300 \text{ l/h}$

$$R_{th} = \frac{T_p - T_w}{\dot{Q}_v} > T_p = T_w + \dot{Q}_v \cdot R_{th}$$

The thermal resistance is first determined using the performance diagram. At 300 l/h it is

**$R_{th} = 9.3 \text{ K/kW}$**

The special operating principle of water-cooled mounting plates requires a technically complex infrastructure (recooler and pipelines). Their use is therefore confined to special projects.

## ■ Active climate control with enclosure cooling units $T_i > T_u$

The world's most widely used and most flexible solution for the dissipation of heat from enclosures and electronic cases is the enclosure cooling unit. The enclosure internal temperature can be cooled to well below the ambient temperature, e.g.  $T_u = +45^\circ\text{C}$ ,  $T_i = +35^\circ\text{C}$ .

### TopTherm cooling units



Wall-mounted cooling units



Roof-mounted cooling units



Climate control enclosure (doors)

These work on the same principle as a refrigerator. As in refrigerators, a refrigerant is used as the cooling medium (type R134a for enclosure cooling units). The gaseous refrigerant is compressed by a compressor, causing it to heat up. The refrigerant is led through refrigerant pipes to an outdoor air heat exchanger (condenser). The heat of the refrigerant is dissipated to the ambient air (cooled). Due to this cooling, the refrigerant

liquefies and flows via the filter dryer to the expansion valve. Pressure reduction takes place here. The refrigerant is depressurised and flows through the second indoor air heat exchanger located in the internal circuit. The heat loss from the enclosure is absorbed in this heat exchanger. Due to heating, the refrigerant is gaseous once more and is compressed by the cooling compressor. The refrigeration cycle now begins again.

## Cooling unit technology

### Cooling circuit

All enclosure cooling units have two completely separate air circuits and comply with protection category IP 54 in the internal circuit.

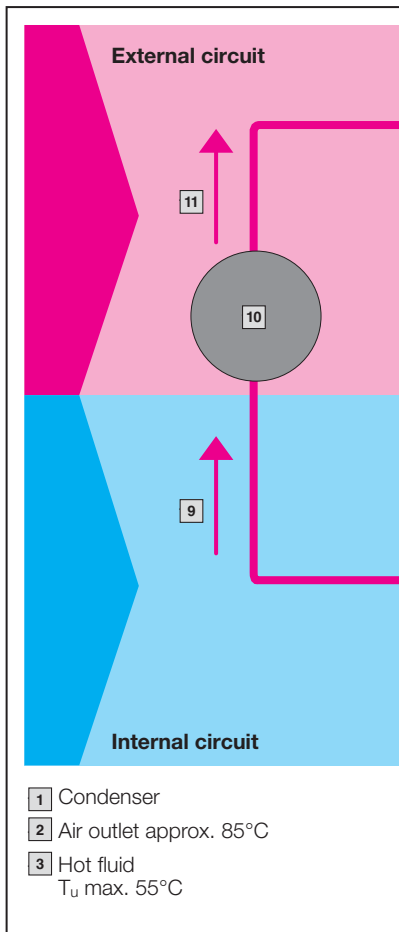
Extensive technical requirements are defined for enclosure cooling units intended for industrial use.

The operating limit for DIN EN 14 511. In the case of enclosure cooling units this is usually an ambient temperature of +55°C.

The design of an enclosure cooling unit, including the necessary components, is clearly and comprehensibly illustrated in the diagram opposite.

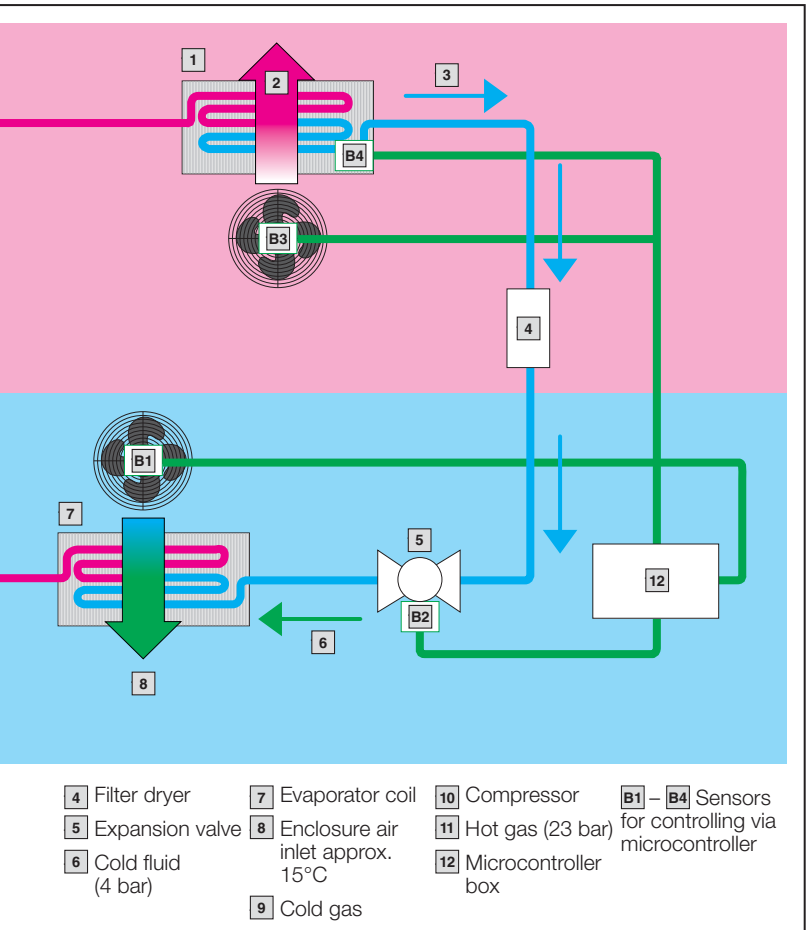
The use of enclosure cooling units always requires extensive integration and adaptation to local circumstances. As the machines and installations are now used all over the world, the flexibility requirements of these cooling systems have increased significantly in recent years.

- B1** Internal temperature sensor
- B2** Icing sensor
- B3** External temperature sensor
- B4** Condensation temperature sensor



The following questions and issues must be answered and dealt with at the planning stage:

- How high is the ambient temperature  $T_u$  and humidity at the installation location?



- What is the installation type according to IEC 890?
- What is the maximum permitted enclosure internal temperature  $T_i$ ?
- What is the heat dissipation in the enclosure?
- What national and international standards (DIN, UL, CSA etc.) must these enclosure cooling units satisfy?
- What protection category is required?



**The calculation of an enclosure cooling unit is described on the basis of an example.**

Heat loss in the enclosure

$$\dot{Q}_v = 2000 \text{ watts}$$

Enclosure dimensions

(W x H x D) = 600 x 2000 x 500 mm, free-standing

Ambient temperature

$$T_u = 45^\circ\text{C}$$

Required internal temperature

$$T_i = 35^\circ\text{C}$$

**Step 1**

Calculate enclosure surface area according to VDE 0660 part 500:

$$A = 1.8 \cdot H \cdot (W + D) + 1.4 \cdot W \cdot D$$

$$A =$$

$$1.8 \cdot 2.0 \cdot (0.6 + 0.5) + 1.4 \cdot 0.6 \cdot 0.5$$

$$A = 4.38 \text{ m}^2$$

**Step 2**

Calculate irradiation from the environment +45°C to the interior +35°C

$$(T_i < T_u)$$

$$\dot{Q}_s = k \cdot A \cdot (T_i - T_u)$$

$$\dot{Q}_s = 5.5 \cdot 4.38 \cdot (45 - 35)$$

$$\dot{Q}_s = 242 \text{ watts}$$

$$\dot{Q}_e = \dot{Q}_v + \dot{Q}_s = 2000 + 242$$

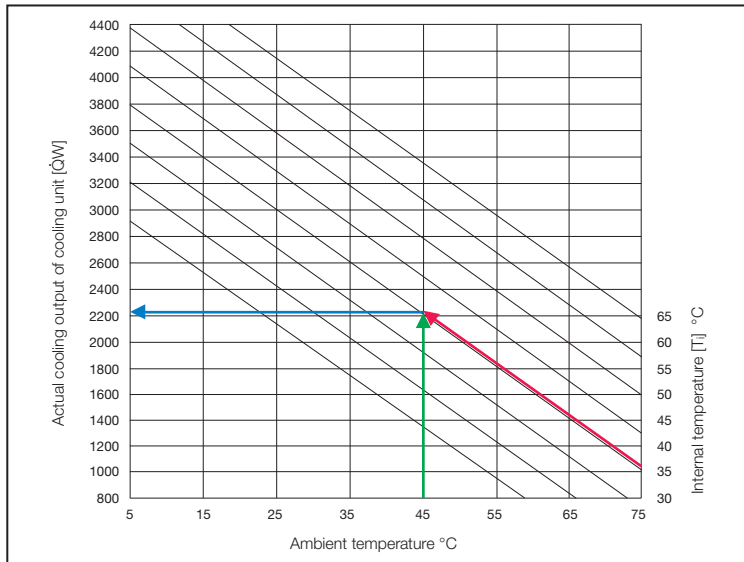
$$\dot{Q}_e = 2242 \text{ watts}$$

This heat loss must be dissipated to the outside via the enclosure cooling unit.

**Step 3/Result**

For an ambient temperature of +45°C and an enclosure internal temperature of +35°C, a cooling unit with a cooling output of 2242 watts must be found.

**Selection diagram**



From the two reference variables of ambient temperature 45°C and enclosure internal temperature 35°C, one can determine the appropriate cooling unit (wall or roof-mounted) from a cooling performance diagram. Rittal has developed the “**Therm**” calculation program to simplify the design and calculation of enclosure cooling units and other climate control components.

### Enclosure dehumidification

A very welcome side-effect of using enclosure cooling units is that they also dehumidify the interior of the enclosure. As the air inside the enclosure cools down, part of the moisture in the air condenses in the enclosure on the internal heat exchanger (evaporator). This water/condensate is safely led from the enclosure to the outside via the condensate drain.

How much condensate actually occurs depends on the relative air humidity, the air temperature and the volume of the enclosure or electronic housing. The condensate quantity is always directly related to the volume of the enclosure and can be calculated from the cooling in the Mollier H-X diagram.

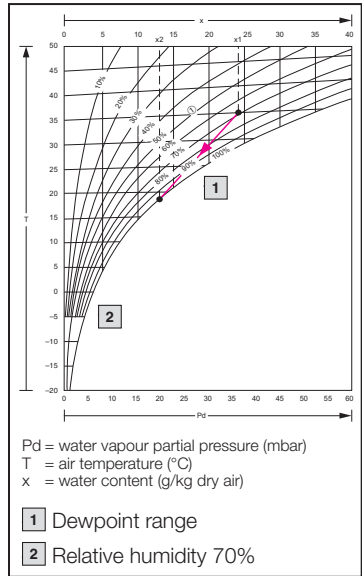
### Example:

Ambient temperature/humidity  
35°C/70%

Temperature at the evaporator  
 $T_v = +18^\circ\text{C}$

Enclosure volume  
 $> V = W \times H \times D$   
 $= 2 \cdot 0.6 \cdot 0.6 = 0.72 \text{ m}^3$

### Mollier H-X diagram



### Calculation of condensate quantity:

$$W = V \cdot \rho \cdot (X_1 - X_2) = 0.72 \text{ m}^3 \cdot 1.2 \text{ kg/m}^3 \cdot (24 - 13 \text{ g/kg})$$

In this example, a condensate quantity  $W = 9.5 \text{ g} - 9.5 \text{ ml}$  occurs.

This example shows that, depending on the enclosure volume, only very small amounts of condensate are obtained upon dehumidification of the enclosure. In practice, however, significantly larger condensate quantities may occur due to leaks in the enclosure (cable passages, open floor panels or operation of the cooling unit with the enclosure door open).

**Observe the following rules:**

- Enclosure cooling units should only be operated with the door closed
- Always use door limit switches when using cooling units
- Seal the enclosure in accordance with the required protection category IP 54
- If possible, to avoid excessive cooling in the enclosure, do not select an enclosure internal temperature below +35°C
- Condensate must be led safely to the outside in accordance with the installation instructions
- Rittal “Blue e” cooling units have active electrical condensate evaporation

**Energy efficiency of enclosure cooling units**

Modern enclosure cooling units offer users the maximum flexibility in use worldwide and integration into the infrastructure of a machine, independent of the installation location.

**“Blue e” cooling units from Rittal**

The following measures have been taken, tailored to the individual device types, to make “Blue e” cooling units more efficient:

- Larger heat exchanger surfaces
- Use of EC fans
- Use of energy-efficient compressors
- Performance-optimised condensate evaporation
- Eco-mode control

“Blue e” cooling units were developed in light of the increased requirements relating to energy efficiency.

**These innovative “Blue e” cooling units consume up to 70% less energy than cooling units that are approximately 5 years old.**

This has been achieved through the use of the latest compressor and fan technology (EC fan motors). The switching cycles have also been significantly reduced. The use of nanotechnology for the heat exchanger in the external circuit, including an optimised operating point, not only saves energy, it also significantly increases the service life of the components.

**Note:**

In practice, queries often arise concerning the estimation of heat loss in the enclosure, e.g. where no heat loss data is provided by the component manufacturers. As a rough estimate, the installed nominal power can be used, e.g. for a nominal power of 40 kW, the heat loss is approx. 5%, i.e. approx. 2000 watts.



## Why use electrical condensate evaporation?

From the automotive industry comes a requirement to avoid the risk of accidents due to puddle formation, but without having to install costly condensate drainage pipes. Therefore, cooling units with integrated electrical condensate evaporation have been developed.



These use an efficient PTC heating cartridge with automatic adjustment of thermal output depending on the amount of condensation. Approx. 120 ml of condensate can be evaporated per hour. This ensures complete removal of condensate.

### Note:

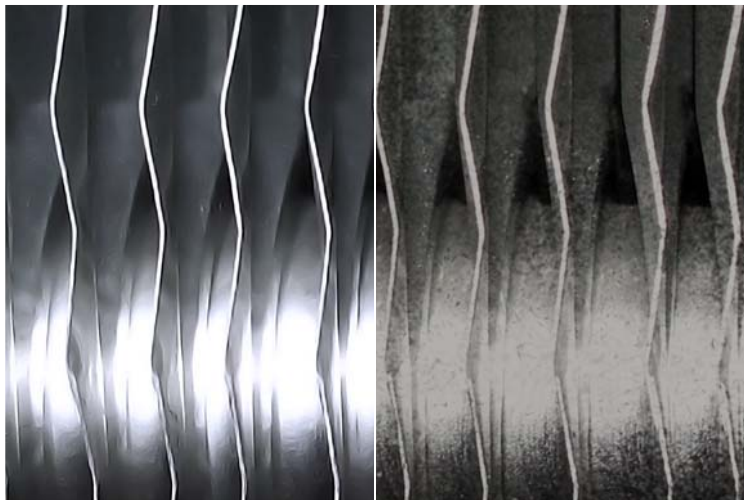
With larger amounts of condensation, the condensate is drained out of the enclosure via a safety overflow.

### Better energy efficiency thanks to Rittal nano-coating

In the total cost of ownership analysis for an enclosure cooling unit over an observation period of 5 years, the energy and maintenance costs alone account for approximately 60% of the total costs. Based on this finding, Rittal has looked for ways of reducing these costs as far as possible. The nano surface coating of the condenser in the external circuit of the cooling unit has proved the best way of further reducing maintenance and energy costs.

### Advantages of Rittal nano-coating

- Reduced deposits of industrial dirt on the heat exchanger membranes
- Increased operational reliability
- Significantly reduced service intervals
- Reduced adhesion of dirt, hence easier cleaning of heat exchangers
- **Uniformly high thermal conductivity**



## ■ General overview

**Fast selection of all enclosure cooling options according to environmental conditions and required cooling output**

	Heat loss to be dissipated $\Delta T = 10 \text{ K}$		$T_{\text{environment}}$ in °C			Air quality			
	< 1500 W	> 1500 W	20...55	20...70	>70	dust-free	dusty	oil-contaminated	corrosive
<b>Fan-and-filter units</b>	■	■	■			■	■		
Fine filter mat (chopped fibre mat)	■	■	■				■		
Filter mat (chopped fibre mat)	■	■	■				■		
<b>Air/air HE</b>	■		■			■	■		
<b>Air/water heat exchanger</b>									
Standard	■	■	■	■	■	■	■	■	■
Stainless steel variant	■	■	■	■	■	■	■	■	■
<b>Cooling unit</b>									
Standard	■	■	■			■			
Chemical version	■	■	■						■
Filter mat (open-celled PU foamed plastic)	■	■	■				■		
Metal filter	■	■	■				■	■	■
RiNano coating	■	■	■				■	■	■

## ■ Design and calculation of climate control solutions using Therm software

Rittal first made its Therm software for calculating and selecting climate control components available to customers as long ago as 1992. Today, software version 6.1 takes care of the entire laborious calculation process. A simple user interface guides the user to the appropriate, correctly dimensioned climate control components. All calculations are based on the requirements of IEC/TR 60 890 AMD 1/02.95 and DIN EN 14 511-2:2011.

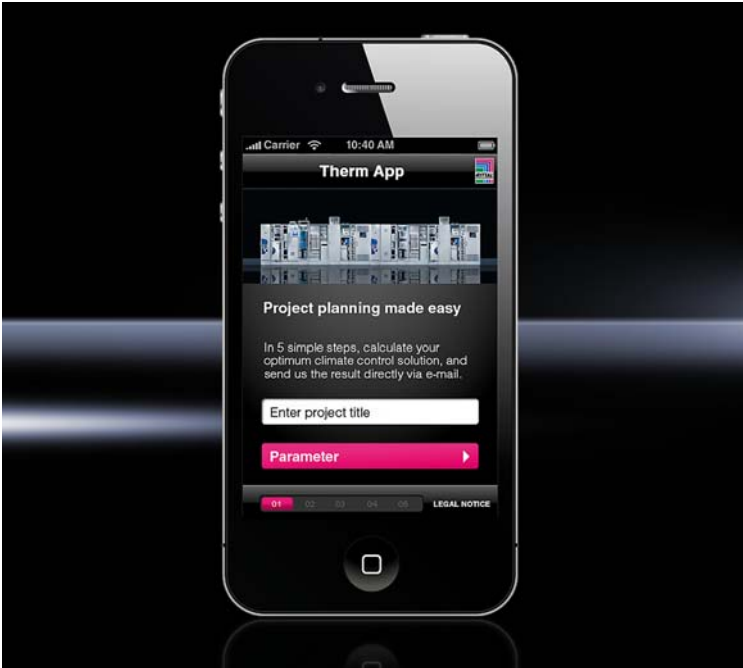
Configuration of all climate control components can be carried out with this software, which includes a configurator for recooling systems.

Another advantage of this software is the direct link to the EPLAN Cabinet planning software. By placing the necessary electrical components on the mounting plate, the heat losses are calculated and transmitted to the Therm software, which eventually calculates and specifies the correct climate control components.

An important point is that these calculations can be made available to the end customer as and when needed in the form of detailed documentation.

This software saves the planner a great deal of time and effort in designing the climate control solution.





## Therm climate control calculation using a Smartphone

For the project planning of your optimum climate control solution in 5 easy steps:

- Project title (reference line for e-mail)
- Parameters
- Enclosure
- Selection
- Recommendation

The Therm app for Android and iOS (iPhone) handles the time-consuming process of calculating climate control requirements for individual enclosure assemblies.

With its fast selection feature, the app provides a compact variant of the full software version "Therm 6.2". The result can be sent quickly and easily as an e-mail. A user-friendly interface guides the operator to the most suitable, correctly dimensioned climate control component using the typical smartphone controls.

All evaluations are closely based on the requirements of IEC/TR 60 890 AMD1/02.95 and DIN 3168 for enclosure cooling units.



# Rittal – The System.

Faster – better – everywhere.



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

# Tips for project planning and operation

**Useful and important tips for project planning and operation**..... 66

- Correct enclosure construction and heat dissipation ..... 66
- The external circuit – clear spaces ..... 68
- Innovative air routing in the internal circuit..... 69
- Air duct system..... 69

**Maintenance** ..... 71

- Use of filter mats ..... 72
- Outside air filter ..... 73



## ■ Useful and important tips for project planning and operation

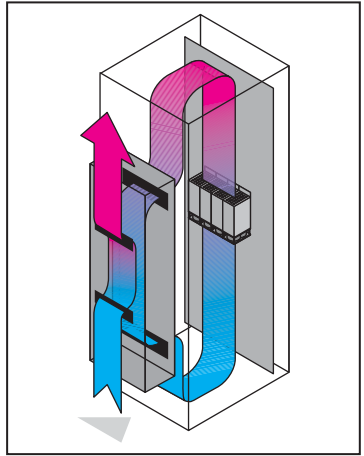
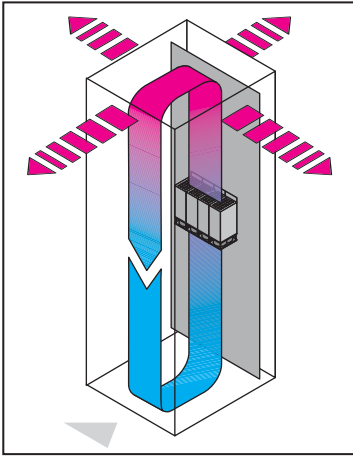
In addition to the calculation and selection of solutions for the dissipation of heat from enclosures and electronic housings, the correct planning and arrangement of the equipment and resources is important. Devices and electrical components should be installed in the enclosure in accordance with the instructions of the respective manufacturers and the information in the device manual.

### The following points should be observed regarding arrangement inside the enclosure:

- The cooling air passing through the components must flow from bottom to top
- There must be sufficient space for air to flow between the parts and electrical components

- Air intake openings of the climate control components must not be obstructed by electrical devices, equipment or cable ducts

## Correct enclosure construction and heat dissipation



Electrical wires and cables are increasingly routed over the components. This inhibits the free dissipation of heat from these components to the ambient air in the enclosure.

The wires have an insulating effect. Despite climate control, it becomes more difficult or even impossible to prevent components from overheating.

### Common practical errors

Ventilation opening covered



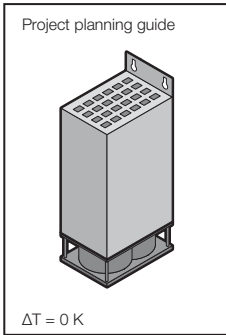
Incorrect



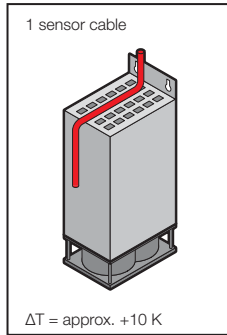
Correct

### Ventilation clearances

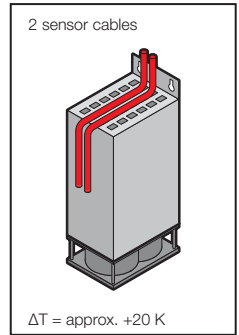
Especially in the case of narrow components, the heat dissipation of the devices is significantly hindered if cables are laid on the ventilation grilles.



50 mm modules have 4 rows with openings in the ventilation grille



→ +10 K →  
50% service life and twice the failure rate



→ +20 K →  
25% service life and four times the failure rate

### Common practical errors

#### Air intake opening misaligned

- Storage space for the necessary documents and circuit diagrams should be taken into account as early as the planning phase.

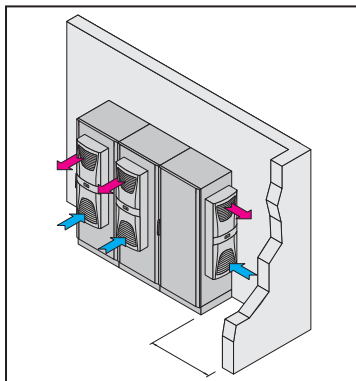
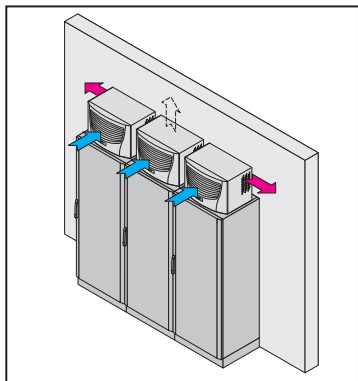


## The external circuit – clear spaces

- With all climate control solutions, care must be taken to ensure that the air intake and air discharge of the climate control components through walls, machines or other structures is not hindered.

#### Note:

In the case of roof-mounted cooling units – regardless of the installation type – one air outlet opening must always be kept free, because with these devices air enters from the front. The warm air is led away through the side panels, the back wall and, optionally, via the roof.



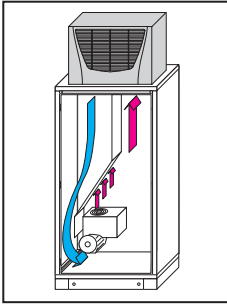
## Air circulation inside the enclosure

- The air routing in the enclosure, taking into account the air flow direction of electronic components with their own blower or fan, must be considered as early as the planning stage. When planning the climate control solution, it is important to avoid

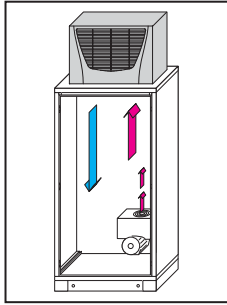
routing the air against the air flow of the electronic components. Such problems are especially common with roof-mounted solutions. In this case, cooling units and air/water heat exchangers with air routing ducts offer the optimum technical solution.

## Layout of electronic components in the enclosure

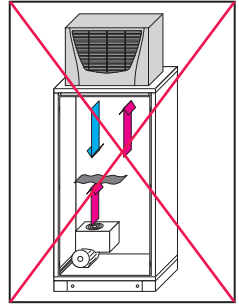
Especially where roof-mounted units are used, particular attention should be paid to the air flow from blowers built into electronic components.



Correct

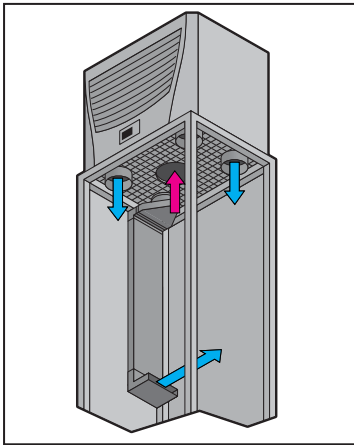


Correct



Incorrect

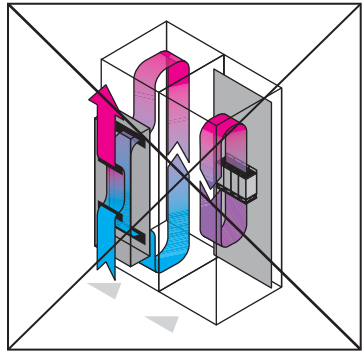
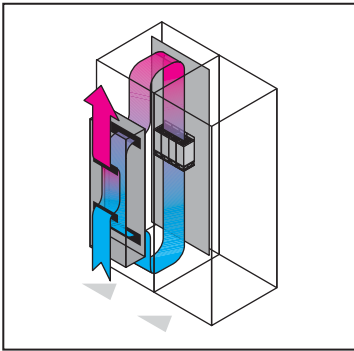
## Innovative air routing in the internal circuit



- Thanks to the air routing system, the supply air from the cooling unit or air/water heat exchanger can be selectively guided to the components without counteracting the air routing of the installed equipment.

### Air duct system

- Air short circuits must be avoided through the use of air duct systems
- Targeted supply of self-ventilated components with cold air
- The use of air duct systems is advisable particularly in the case of roof-mounted cooling units



■ With all climate control solutions, the cold air should always be routed close to drive units (see illustration above). This is where the greatest heat losses occur. This arrangement ensures that the cold supply air from the climate control solution optimally cools the drive units without losses.

■ With the arrangement shown in the above illustration, the enclosure is not optimally cooled. The drive units or electronic devices in the right-hand enclosure do not receive the necessary cooling. Therefore, despite thermal calculation, the heat losses of the electrical components cannot be dissipated.



■ The internal temperature of the enclosure should always be set to +35°C. There is no technical justification for setting the temperature any lower. If the temperature inside the enclosure is lower than that, e.g. +15°C, condensation will be significantly increased.

The parts and components will also become sub-cooled and form condensate after the cooling is switched off or the enclosure door is opened.

- With a chosen internal temperature of e.g. +15°C, the cooling unit has only about 50% of the original output specified according to DIN EN 14 511 (internal temperature = +35°C).
- If the installation requirements of the parts and electronic components are not observed, this will lead to a reduction in the service life and ultimately the premature failure of the components.
- All over the world, climate control components are used mainly in industrial environments, i.e. in surroundings affected by dirt, dust and oil. Nowadays, climate control components are low-maintenance, but not maintenance-free. Only air/ water heat exchangers do not come into direct contact with the ambient air. To ensure long-lasting operation of these components and systems, they must be maintained according to a fixed, systematic cycle.

## ■ Maintenance



- With fan-and-filter units, air/air heat exchangers and enclosure cooling units, maintenance largely concerns the external filters of the climate control components.
- Do not allow filters to become so clogged with dust and oil-contaminated dirt that correct operation of the devices is no longer guaranteed.
- Use only filter mats recommended by the manufacturer. Chopped fibre mat filters are not recommended for cooling units.



## Useful tips for project planning

- If the ambient air is contaminated with oil, metal filters should be used. These can be cleaned and reused if necessary.
- Due to the nano-coating, Rittal cooling units do not need a separate filter for a dust-laden environment.

## Use of filter mats



In heavily dust-laden atmospheres, PU filters should be used and replaced on a regular basis. Cooling units with Ri-Nano coating do not need a dust filter.



If the air is oil-contaminated, use metal filters. These separate the oil condensate from the air and can be cleaned with appropriate detergents.



In the textile industry, the use of lint filters is recommended.



**Note:**  
Chopped fibre mat filters are not suitable for cooling units.

- If lint is present in the ambient air, as in the textile industry for example, a lint filter should be used in the external circuit.

## Outside air filter

Operation in a lint-laden environment (textile industry)



All these tips and instructions are based on decades of practical experience in the use of enclosure climate control solutions in industrial environments. By observing this information, the cooling of electrical components can be optimised and the dissipation of heat from enclosures and electronic housings can be made more energy-efficient.

# Rittal – The System.

Faster – better – everywhere.

ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

# Machine and process cooling

<b>What is machine and process cooling? .....</b>	<b>76</b>
■ Applications of recooling systems chillers .....	78
■ The modular re cooler/chiller .....	80

## IT cooling

<b>Recooling systems for IT climate control .....</b>	<b>81</b>
<b>Summary .....</b>	<b>88</b>

## ■ What is machine and process cooling?

The operation of a high-performance machine tool with very high demands in terms of processing accuracy and speed is no longer imaginable without precision cooling.

High-performance cooling requires the temperature at the workpiece and in the machine to be kept as constant as possible. These cooling processes can only be realised with recooling systems (chillers). According

to numerous studies, e.g. by Aachen University and Darmstadt University, the cooling of a machine tool alone accounts for around 15% of the total energy requirement of a modern machine tool.

### Water cooling of machine tool and enclosure

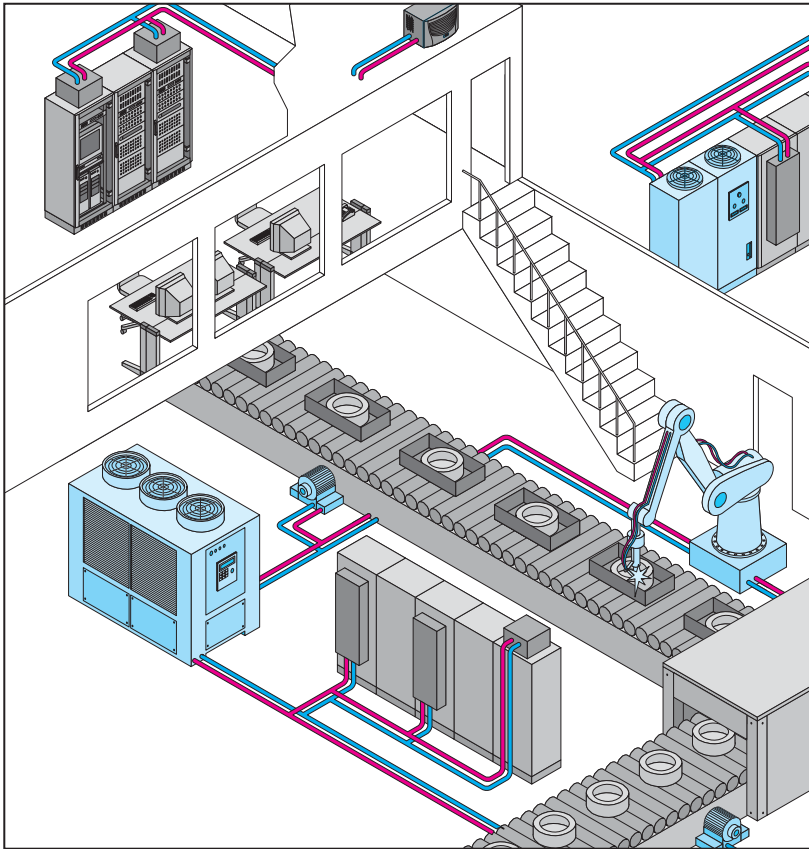




IT INFRASTRUCTURE

SOFTWARE & SERVICES





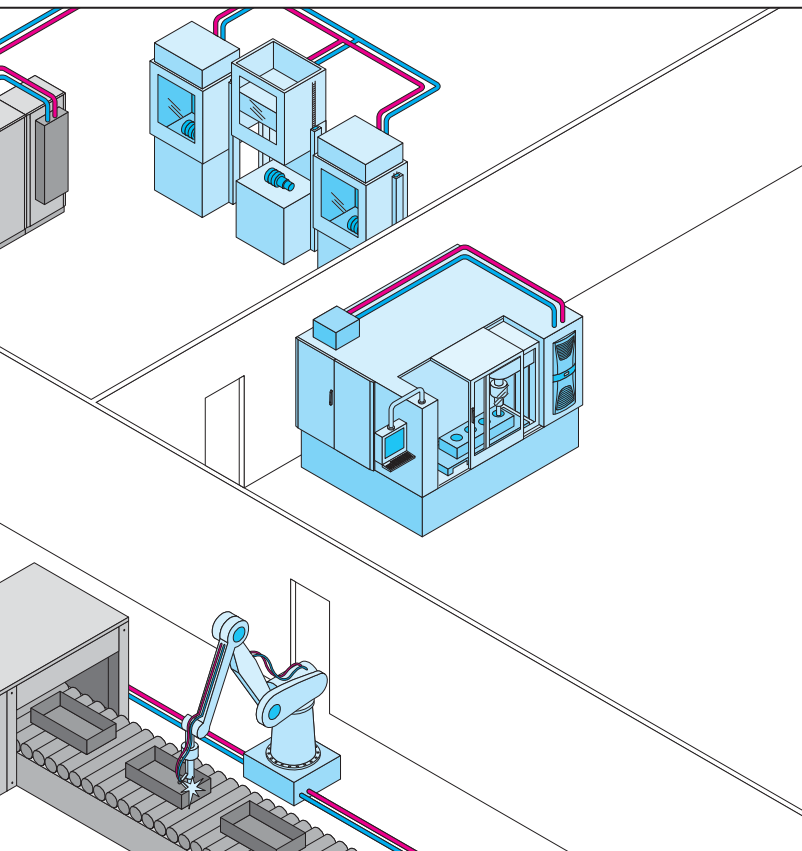
## Recooler applications

### Energy-efficient water cooling in the production area

#### Focus area: Machine and process cooling

Great flexibility, but above all the ability to dissipate high heat loads from machines and enclosures via water have

led to a sharp increase in the use of recooling systems in recent years. Due to the use of recooling systems on machines, a significant trend towards enclosure cooling with air/water heat exchangers is also apparent.



If a recooling system is intended to serve several pieces of equipment having different requirements in terms of the inlet temperature and flow rate of the cooling medium, e.g. combined machine and enclosure cooling, multi-circuit systems are used. With this solution, the different circuits

can be adapted to the equipment in question, e.g. water inlet temperature of machine  $+15^{\circ}\text{C}$ , enclosure  $+20^{\circ}\text{C}$ .



## The modular recoler

Due to cost pressures and the availability of components on world markets, customers increasingly demand standardisation of recooling systems. Rittal has recognised this trend and developed the TopTherm chiller, which is modular in design.

### The Rittal building block principle



Hydraulic module +



chiller module +



electrical module =



Complete recoler

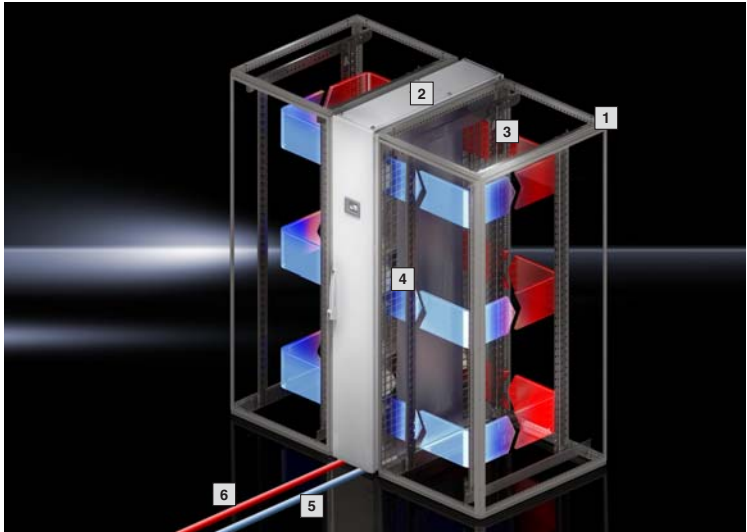
This development can be fully integrated into the Rittal system, as the set-up is based on a TS 8 enclosure. The modular design means that the individual modules are standardised, thereby guaranteeing great flexibility in terms of the set-up and air routing principle.

Apart from recooling systems for oil and emulsion, all recooling systems are only suitable for the cooling of water or a water/glycol mixture. The mixing ratio should be approx. 1:2 for an outdoor installation or approx. 1:4 for an indoor installation. Almost without exception, water post-treatment with additives is necessary. As well as protecting against frost, this also serves to inhibit bacterial growth and ensure optimum corrosion protection.

## ■ Recooling systems for IT climate control

Today, it is no longer possible to operate a data centre without a dedicated cooling system. The requirements are: efficiency, reliability and availability for 99.99% of the year. At the same time, however, heat is the number one enemy of all servers in a modern data centre.

### Liquid cooling systems



1 Server rack

3 Air inlet temperature

5 Water inlet temperature

2 Heat exchanger

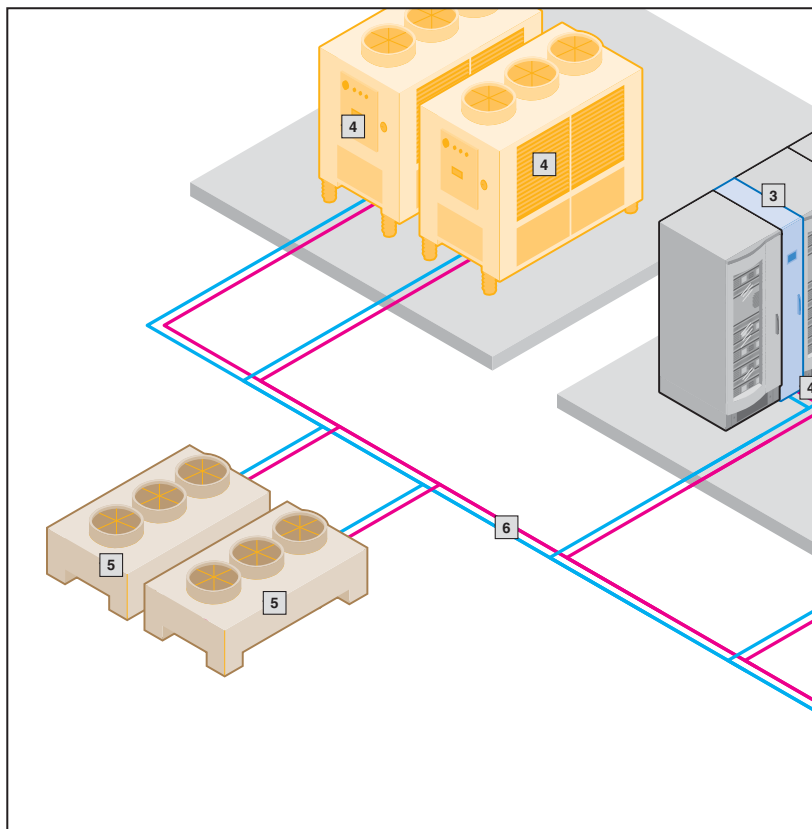
4 Air outlet temperature

6 Water outlet temperature

The goal therefore is to dissipate the very high heat losses of the computer in a server enclosure to the outside as efficiently as possible. As a competent specialist, Rittal is well placed to meet all the requirements expected of a modern infrastructure in relation to energy efficiency and environmental protection in data centres.

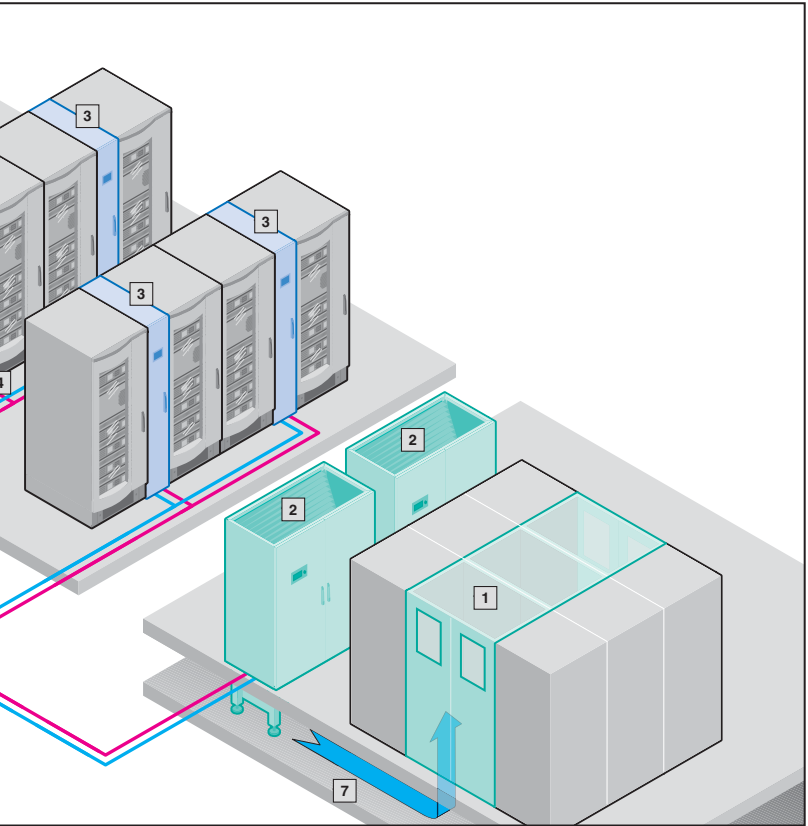
Use of a Rittal chiller for liquid cooling ensures that the cooling water needed to cool the server enclosures is available at all times.

**CRAC system with integrated air/water heat exchanger and recirculation fans. Performance class 23 – 118 kW**



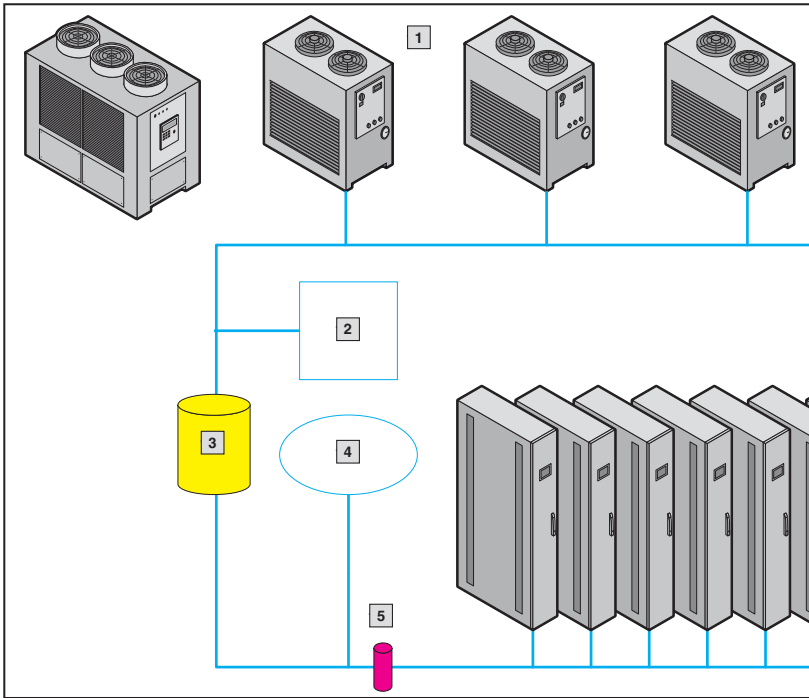
The cooling or air conditioning of a data centre is usually carried out using a raised floor, i.e. the air entering the data centre is cooled in an air-circulating climate control system (CRAC) and led to the room via the raised floor. The warm air from the

server enclosures and the room is extracted from above by the CRAC system and cooled in the air/water heat exchanger. The cooling water is generated in a Rittal recoler and made available to the CRAC system.

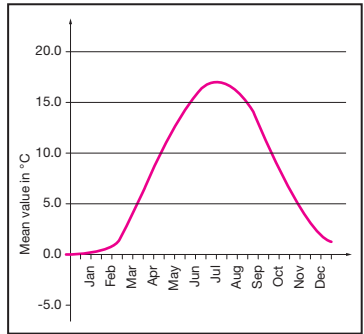
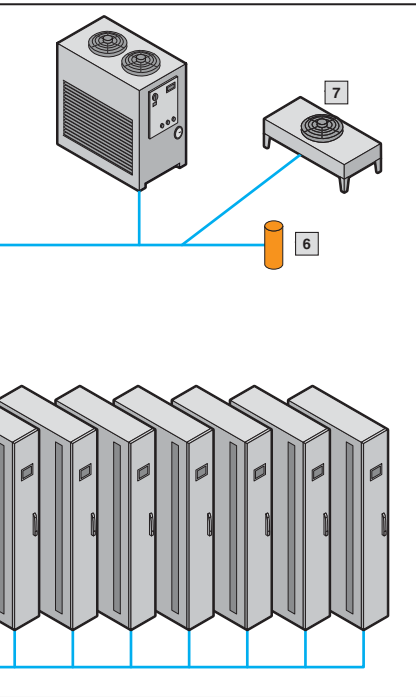


- |                                       |   |
|---------------------------------------|---|
| <b>1</b> Aisle containment            | <b>5</b> Free cooling                     |
| <b>2</b> CRAC systems                 | <b>6</b> Pipework                         |
| <b>3</b> LCP (Liquid Cooling Package) | <b>7</b> Raised floor for cold air supply |
| <b>4</b> IT chillers                  |   |

## Average monthly, yearly and seasonal temperatures



In addition, the use of “free cooling” ensures that the recooling systems, which are usually redundantly designed in the case of IT systems, are only used if the outdoor temperature exceeds the annual average of approx. 8.4°C, i.e. for about half the year. Through this technical solution, the system design actively helps reduce the energy costs of the data centre by a significant amount.



Average temperature profile based on the example of Germany

- 1 Chiller
- 2 Building air conditioning
- 3 Buffer tank
- 4 Water tank
- 5 Pump station
- 6 Heating return pump
- 7 Free cooling

## IT cooling

Rittal systems and infrastructures for the cooling of computer and data centres satisfy all requirements of national and international standards such as DIN, TÜV, GS and UL. The "Data Centre Infrastructure Efficiency"

metric is used to assess the energy efficiency of a data centre. This metric has been defined by the EU Code of Conduct for Data Centres since 2008 as follows:

$$\text{DCIE} = \frac{\text{Energy consumption of IT system}}{\text{Total energy consumption}} \cdot 100 \%$$

### Realised data centre with server enclosures and water cooling



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

**Under optimum conditions, the DCIE can be 100%.**

Above all, it is vital to ensure, as early as the planning phase, that the infrastructure and systems of a data centre, and also the operation, are optimally tailored to one another.



IT INFRASTRUCTURE

SOFTWARE & SERVICES





## Summary

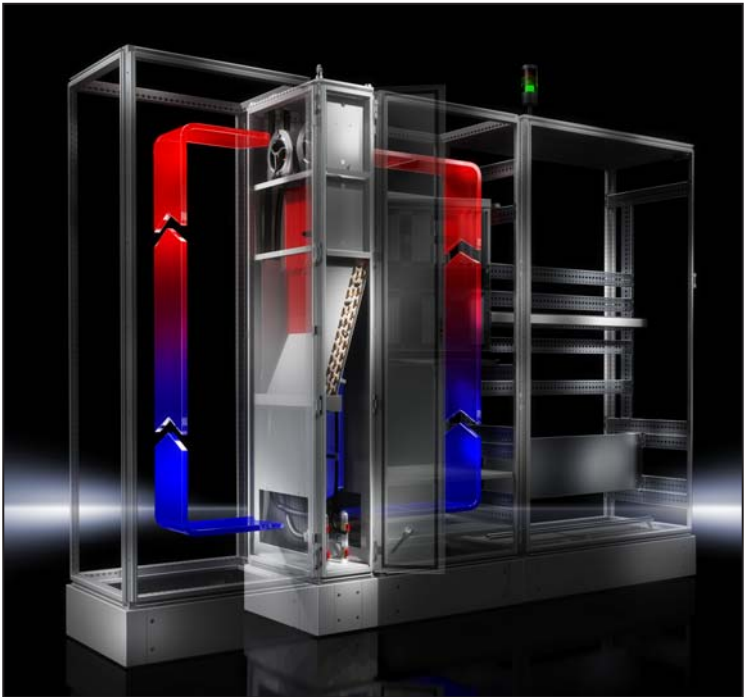
Due to the increasing heat losses to be dissipated, water is becoming more and more important as a cooling medium for the cooling of machines, systems and enclosures.

### **No other solution is more effective or efficient!**

A flexible system that meets all requirements for dissipating heat from machines and enclosures used in industry, in medical technology (CT and MRI scanning), for the cooling of

machines in plastics processing and systems in the chemical industry, as well as servers in IT environments, is no longer imaginable without recooling systems.

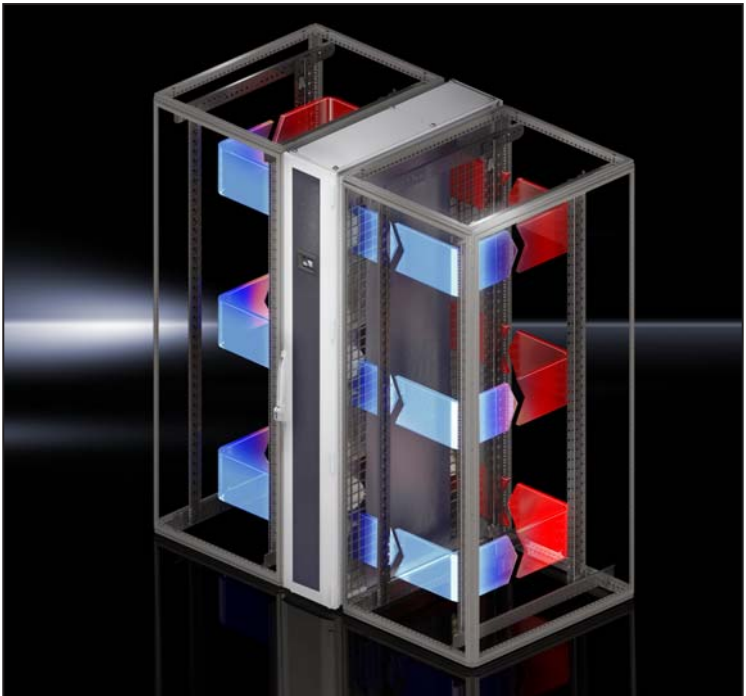
### **Liquid cooling systems**



LCP industry

At the same time, these systems must be technologically optimised so that they make a significant contribution to the energy efficiency of the systems and machines.

**Today, Rittal offers the most energy-efficient heat dissipation solutions for virtually all applications, both in the industrial sector and in the field of climate control for IT systems. All solutions in this environment are compatible with "Rittal – The System."**



Rack cooling

IT INFRASTRUCTURE

SOFTWARE & SERVICES



## Index

### A

- Air flow cooling 22
- Arrhenius equation 20

### B

- “Blue e” cooling units 58

### C

- Climate control, active 26, 53
- Climate control, passive 26
- Convection 21
- Condensate evaporation, electrical 59
- Cooling circuit 54

### D

- Direct water cooling 50
- Dissipation of high heat losses 48

### E

- Efficiency comparison, cooling units – chillers with heat exchangers 46
- Enclosure heaters 28
- Enclosure installation type 24
- Enclosure surface area 25
- Energy efficiency of enclosure cooling units 58
- EPLAN planning software 62

### F

- Fast selection of enclosure cooling 61

### H

- Heat conduction 21
- Heat dissipation with air/air heat exchangers 37
- Heat dissipation with air/water heat exchangers 42

- Heat dissipation with fan-and-filter units 33
- Heat dissipation through forced air circulation 32
- Heat loss  $\dot{Q}_v$  23

### I

- IEC 60 529 18
- IP classification 18

### N

- Nano-coating 60
- Natural convection 22
- NEMA classification 19

### O

- Overview of cooling methods 26

### P

- Peltier cooling unit 40
- ProOzon cooling unit 9
- PTC technology 59

### R

- Radiation power 24
- Recooling system 81

### T

- Thermal radiation 21
- Thermoelectric cooling 40
- Types of heat dissipation 21

### V

- Volumetric flow of a fan 35

### W

- Water-cooled mounting plate 26, 50
- Water-cooling, advantages 44

## ■ Glossary

### **Arrhenius**

- Svante Arrhenius, Swedish physicist, 1859 – 1927

### **CFD analysis**

- Computational Fluid Dynamics (thermal simulation of flow and heat conditions with a PC program)

### **cp**

- Specific thermal capacity, e.g. of air at 20°C

### **DCIE**

- Data Centre Infrastructure Efficiency (metric used to calculate the energy efficiency of a data centre)

### **DIN**

- German Institute for Standardisation

### **GS**

- Quality certification mark, product safety tested by TÜV

### **IEC**

- International Electrotechnical Commission

### **IP protection category**

- International protection codes (protection of electrical equipment against moisture, foreign bodies and accidental contact)

### **k value**

- Heat transfer coefficient, dependent on material (steel)

### **Convection**

- Transmission of heat or cold through walls in case of a temperature difference

### **Mollier**

- Richard Mollier, German professor of applied physics and mechanics

### **Nano**

- A billionth of a unit, e.g. nanometre = 0.000000001 m

### **NEMA**

- National Electrical Manufacturers Association (US standard)

### **Peltier**

- Jean Charles Peltier, French physicist, 1785 – 1845

### **PTC technology**

- Positive Temperature Coefficient (the ability of an electrical conductor to conduct electricity “well” at low temperatures)

### **Recooler or chiller**

- System for producing cooling water using a cooling machine

### **UL**

- Underwriters Laboratories (body that determines whether products, materials and systems meet US safety standards)

### **VDE**

- The German Association for Electrical, Electronic and Information Technologies

### **VDMA**

- The German Engineering Federation

### **Heat loss**

- Thermal output of all installed electrical devices, e.g. in the enclosure

### **Thermal radiation**

- Heat transfer through a surface

### **ZVEI**

- German Central Association of the German Electrical and Electronics Industry

---

## ■ Bibliography

- Bliesner, Jürgen: Wichtige Installationshinweise beim Schaltschrankaufbau [Important installation instructions for enclosure design], Siemens AG, 2007.
- Rittal GmbH & Co. KG: Praxis-Tipps zur Schaltschrank-Klimatisierung und Maschinenkühlung [Practical tips for enclosure climate control and machine cooling], Rittal GmbH & Co. KG, 2004.
- Rittal GmbH & Co. KG: Rittal SK – System-Klimatisierung [Rittal SK – System climate control], Rittal GmbH & Co. KG, 2006.
- Siemens AG: Schaltschrankintegration, SINAMICS S120 Booksize/SIMODRIVE – Systemhandbuch 09/2007 [Enclosure integration, SINAMICS S120 Book-size/SIMODRIVE – System manual 09/2007], Siemens AG, 2007.
- Styppa, Heinrich: Klimatisierung für Gehäuse, Maschinen und Anlagen – Grundlagen, Komponenten, Anwendungen [Air-conditioning for enclosures, machines and plants – Fundamentals, Components, Applications]. Die Bibliothek der Technik, vol. 284, sv corporate media, 2005.
- Schneider, Ralf, et al.: Projektierungshandbuch Schaltschrank-Entwärmung [Project Planning Manual: Enclosure Heat Dissipation], 2nd edition, December 2011, Süddeutscher Verlag onpact GmbH, 81677 Munich.

# Rittal – The System.

Faster – better – everywhere.



IT INFRASTRUCTURE

SOFTWARE & SERVICES



# Rittal – The System.

Faster – better – everywhere.



ENCLOSURES

POWER DISTRIBUTION

CLIMATE CONTROL

# TÜV-tested output to DIN EN 14 511:2012-01

An important aspect when stating the cooling output of an enclosure cooling unit is the measurement of output according to the relevant European standard (EN).

This European standard sets out the conditions for testing the cooling output of air conditioning units, liquid cooling packages (recooling systems) and heat pumps that use air, water or brine as a thermal transfer medium, with electrical compressors for space heating and/or cooling. These output measurements independently carried out by TÜV give customers the assurance that their enclosure cooling unit achieves the required cooling output and complies with the current energy efficiency ratio (EER), i.e. delivers optimum energy efficiency.

Rittal "Blue e" cooling units have been tested according to this standard in the output range from 300 to 4000 watts and bear the TÜV test mark.

Except cooling units with Atex authorisation for Zone 22 and NEMA 4X.



# Previously published:

**1**

2013

## Standard-compliant switchgear and controlgear production

Application of IEC 61439

**2**

2013

## Enclosure and process cooling

**3**

2013

## Technical aspects of enclosures



# Rittal – The System.

---

**Faster – better – everywhere.**

- Enclosures
- Power Distribution
- Climate Control
- IT Infrastructure
- Software & Services

Normal fee 12,50 €

You can find the contact details of all Rittal companies throughout the world here.



[www.rittal.com/contact](http://www.rittal.com/contact)

