The perfect climate inside your enclosure

Basic principles

White Paper

April 2021

Electrical systems are becoming increasingly compact and the density of equipment within enclosures is growing leading to higher heat generation. **The rule of thumb for semiconductors states that increasing the component temperature by 10°C in relation to the maximum permissible component temperature halves the part's service life.** A constant temperature is therefore the best solution for a long service life and the high reliability of all the electronic components. Particularly in the case of a completely populated enclosure, it is important that sufficient cool air flows past the components. There are a number of ways of achieving this as efficiently as possible, but the right choice depends on a number of factors. This White Paper explains the basics of enclosure climate control.

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Introduction

A safe and secure environment for sensitive electronic devices is of great importance in every industry and every process. Still, maintaining an acceptable temperature within an enclosure is often overlooked. Allowing an electronic device to overheat can cause failures, which can in turn lead to large scale issues within the process including expensive line stoppages. In this White Paper, we explain the foundation of a perfect climate for the sensitive electronic devices in the enclosure.

High-quality enclosures are essential in every industry. Just as the enclosure in a food manufacturer's production process must be cleanable, reliability, in other words high availability, is of the utmost importance for the server enclosures in data centres. In every industry, however, the sensitive devices in these enclosures have an ever-increasing power density. This is very welcome, of course, but it also has a drawback: More heat is generated over a smaller area, so increasing the risk of malfunctions due to overheating.
There are also standards that these systems must meet. One of these concerns the detection of heat. The DIN EN IEC 61439 standard "Low-voltage switchgear and controlgear assemblies" has been in effect since 1 November 2014. Depending on the strength of the current, proof by calculation or testing is required. If such proof has not been provided, liability and insurance problems may arise in extreme cases.

Consideration

When designing the enclosure, it is important to think carefully in advance about where it will stand. It seems logical to avoid places where it gets particularly hot, but that is not always possible in practice. You must also take into consideration any required reserves of space for future extensions. Is there enough space to comfortably accommodate the additional control system? Nevertheless, the most important issue remains: Is the temperature level within the permissible operating range of the installed components or does the enclosure need climate control?

A constant temperature is the best precondition for a long service life and the high reliability of every electronic component. It is important that enough sufficiently cool air flows past the components, especially in the case of a fully populated enclosure. There are a number of ways to achieve this as efficiently as possible. Knowledge and understanding of the basics of enclosure climate control are very important in making the right choice. Consequently, these fundamentals are explained step by step below.

Table of contents

- Introduction ……………………………………………………………..2
- Heat transfer 3
- Basic terms - dimensions.. 3
- Calculating the effective enclosure area.. 4
- Installation method.. 4
- Dimensioning 5
- Conclusion 8
- Sources.. 8

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Heat transfer

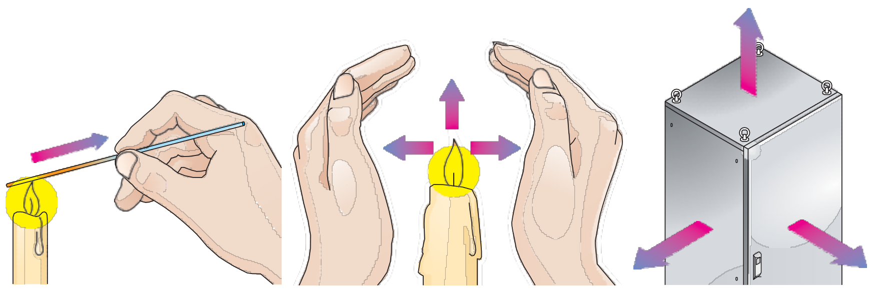
Heat is transferred in three ways: by radiation, conduction and convection.

Radiation: Heat transfer by radiation occurs through electromagnetic waves. Heat is passed from one body to another in the form of radiated energy, without any material acting as medium.
One example of this is solar energy, which reaches the earth and heats it up.

Conduction: Heat can also be transferred between materials by conduction, without them moving together. Thus, for example, a processor can transfer its heat to a heat sink by conduction and thus become cooled.

Convection: Here the energy flows with the matter. The transport medium, for example, a liquid or gas, picks up energy in the form of heat and then dissipates energy as heat at the heat sink. We distinguish between natural and forced convection. In natural convection, the heat of an enclosure is released to the environment as a result of a difference in temperature between the enclosure and the environment.
In the case of forced convection, an air stream ensures an accelerated transfer of heat.

Most cooling solutions are a combination of heat transfer types. For example, a processor is cooled with a heat sink (heat conduction), which is often also equipped with a fan (forced convection). A variety of solutions are available to ensure that the ideal operating temperature within the enclosure is maintained, even at high ambient temperatures. The most common cooling methods for enclosures (in ascending order of cost) are natural cooling (convection), fan-and-filter units, air/air heat exchangers, air/water heat exchangers, and cooling units.



Conduction Radiation Convection

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Basic terms
Dimensions

Pt = total heat loss in the enclosure [W]
Pc = convection: heat dissipated by the enclosure surface [W]
  Pc > 0: Radiation (Ti > Tu)
  Pc < 0: Irradiation (Ti < Tu)
Pn = required cooling output [W]
Pv = required thermal output of an enclosure heater [W]
Pa = heat loss to be dissipated (fan-and-filter unit)
Qw = specific heat capacity of a heat exchanger [W/K]
V = required volumetric flow of a fan-and-filter unit [m^3/h]
Ti = desired temperature in the enclosure [°C]
Tu = ambient temperature of the enclosure [°C]
ΔT = Ti - Tu = Maximum allowable temperature difference [K]
k = heat transfer coefficient [W/m^2K] for steel sheet, k = 5.5 W/m^2K
A = effective, heat loss-dissipating enclosure surface area [m^2]

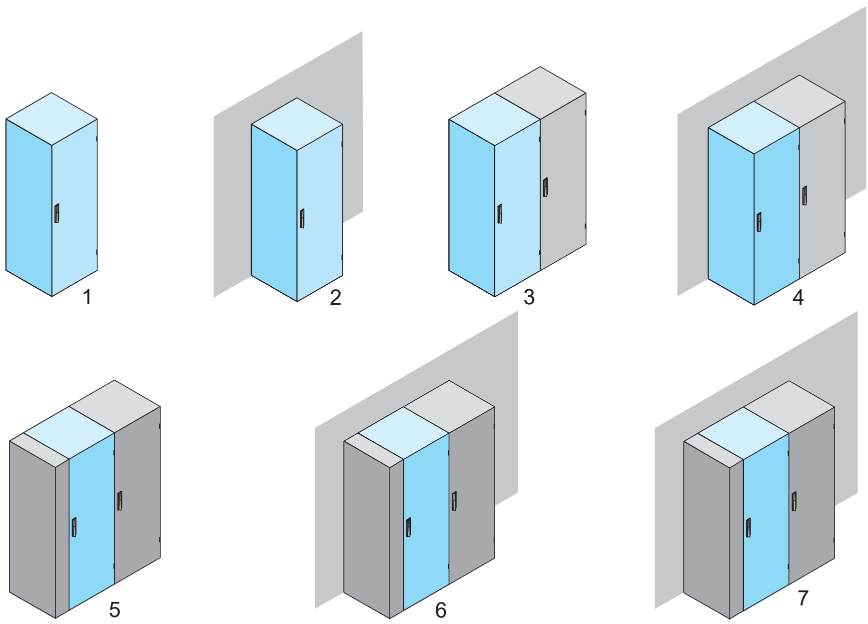
Calculating the effective surface area of an enclosure

Before we start calculating the required cooling or heating, the effective, heat loss-dissipating enclosure surface area A still needs some explanations. The heat output of the enclosure not only depends on the actual area itself but also on the way in which the enclosure is constructed. An enclosure that is free-standing to all sides can radiate or absorb more heat than an enclosure standing next to a wall or in a niche. For this reason, there are calculation formulas that make it possible to calculate the effective enclosure area, depending on the type of installation. The formulae for calculating A are defined in IEC 60 890.

Type of installation
as per IEC 60 890

1 Stand-alone free-standing enclosure
2 Free-standing enclosure – wall installation
3 Initial or final enclosure – free-standing
4 Initial or final enclosure – wall installation
5 Intermediate enclosure – free-standing
6 Intermediate enclosure – wall installation
7 Intermediate enclosure – wall installation | covered surface

Formula for calculating A (m^2)
1 $A = 1.8 \times H \times (W+D) + 1.4 \times W \times D$
2 $A = 1.4 \times H \times (W+D) + 1.8 \times W \times D$
3 $A = 1.4 \times H \times (W+D) + 1.8 \times W \times D$
4 $A = 1.4 \times H \times (W+D) + 1.4 \times W \times D$
5 $A = 1.8 \times W \times H + 1.4 \times W \times D + D \times H$
6 $A = 1.4 \times W \times (H+D) + D \times H$
7 $A = 1.4 \times W \times H + 0.7 \times W \times D + D \times H$
A = Effective enclosure surface area
W = Enclosure width (m)
H = Enclosure height (m)
D = Enclosure depth [m]



Natural convection

Natural convection is the simplest type of cooling. In natural convection, the heat is transported to the outside via the enclosure walls. The prerequisite here is that the ambient temperature is lower than the temperature within the enclosure. If the ambient temperature is higher than the temperature in the enclosure, irradiation will occur, causing additional heat to enter the enclosure.
The natural convection (= radiation) or irradiation can be calculated as follows:

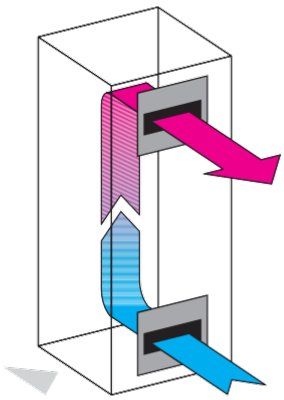
Pc = k x A x ΔT

The power loss to be dissipated is then the total heat loss of the components within the enclosure minus its own convection.

Pa = Pt - Pc

Fan-and-filter units

Fan-and-filter units are most commonly used for enclosure climate control.
The ambient air is blown through a filter mat directly into the enclosure, so cooling the components very effectively. The air is discharged via an outlet filter. However, care must be taken to ensure that the air sucked in does not contain any contaminants that may attack the electronics or the copper rails or bars.



With a dissipated heat loss of Pa, the fan power required can be calculated as follows:

$$V = \frac{f \times Pa}{\Delta T}$$

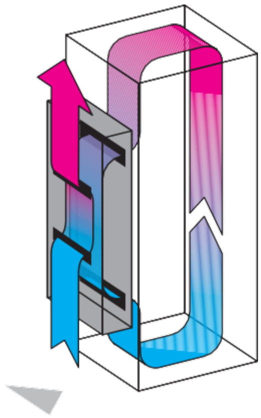
Height (m)	cp (kJ/kg · K)	kg/m³	f (m³/k)/Wh
0	0.9480	1.225	3.1
500	0.9348	1.167	3.3
1000	0.9250	1.112	3.5
1500	0.8954	1.058	3.8
2000	0.8728	1.006	4.1
2500	0.8551	0.9568	4.4
3000	0.8302	0.9091	4.8
3500	0.8065	0.8633	5.2

Practical guidelines

- The ambient temperature should be (approx. 5K) lower than the desired enclosure temperature.
- The volumetric flow depends on the height above NN [m], see table.
- The installation of fan-and-filter units on the enclosure depends on the arrangement in the enclosure.
- The fan-and-filter unit and outlet filter must be positioned so that the air inlet port is at the bottom and the air outlet port is at the top.
- The airflow can be either of a blowing or an extracting nature

Air/air heat exchangers

Air/air heat exchangers are useful if the ambient temperatures are lower than the temperatures desired in the enclosure. The air/air heat exchanger with its separate inner and outer circuit is the ideal solution particularly if the ambient air contains dust, oil and aggressive substances, which must under no circumstances enter the enclosure. The capacity of an air/air heat exchanger depends on the temperature difference between the air in the enclosure and the environment and it is therefore stated in W/K. The required output of an air/air heat exchanger can be calculated as follows:



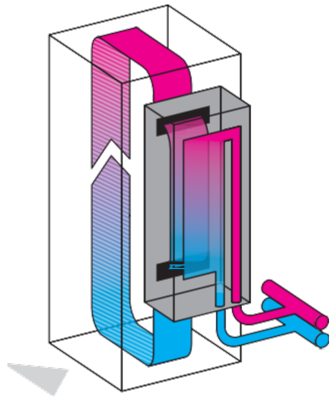
$$Q_w = \frac{P_t - P_c}{\Delta T}$$

Practical guidelines

- The ambient temperature should be (approx. 5K) lower than the desired enclosure temperature.

Air/water heat exchangers

Air/water heat exchangers offer the most thermally effective way to achieve maximum cooling outputs in the smallest space. The air/water heat exchanger is an especially good choice if a cold water supply is available.
The required output of an air/water heat exchanger can be calculated as follows:



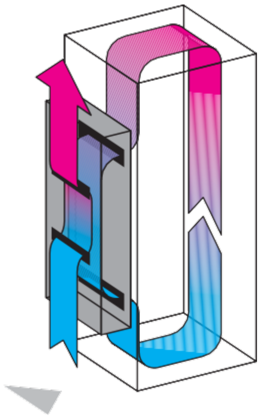
$$P_n = P_t - P_c$$

Practical guidelines

- Operation is also possible at ambient temperatures as high as +70 °C.
- Air/water heat exchangers are particularly suited for polluted environments.
- A cooling water system must be available.
- Maintenance is minimal, as there is no external air circuit, so there is no contamination of the filter mats and no contact with the ambient air.
- it is essential to observe the VGB guidelines on cooling water (VGB-R-455 P) to operate the devices safely.
- Heat exchanger for roof and wall mounting, also with all water-bearing parts in stainless steel (V4a / 1.4571).
- The calculation is the same as that of a cooling unit.

Cooling unit

A cooling unit is the right solution wherever optimum operating temperatures are needed in an enclosure, even at high ambient temperatures. It is even possible to cool the air inside the enclosure to below the ambient temperature. The air intake and air injection openings in the inner and outer circuits, which are arranged in a favourable manner in terms of air technology, ensure an optimum flow of air inside the enclosure. The required output of a cooling unit can be calculated as follows:



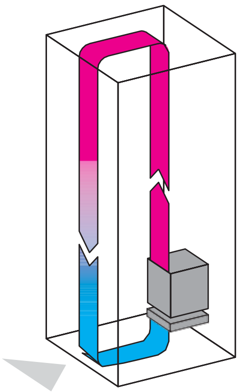
Pn = Pt - Pc

Practical guidelines

- The cooling unit should only be operated when the door is closed.
- The enclosure should be of protection category IP 54 or higher.
- Do not set the enclosure interior temperature lower than is necessary as this may lead to increased condensation and will thus waste energy.

Heating

Sometimes the environment may cool down so much that the enclosure will have to be heated to protect the sensitive electronics.
The necessary heater output can be calculated as follows, where Ti is the desired enclosure temperature and Tu is the minimum ambient temperature:



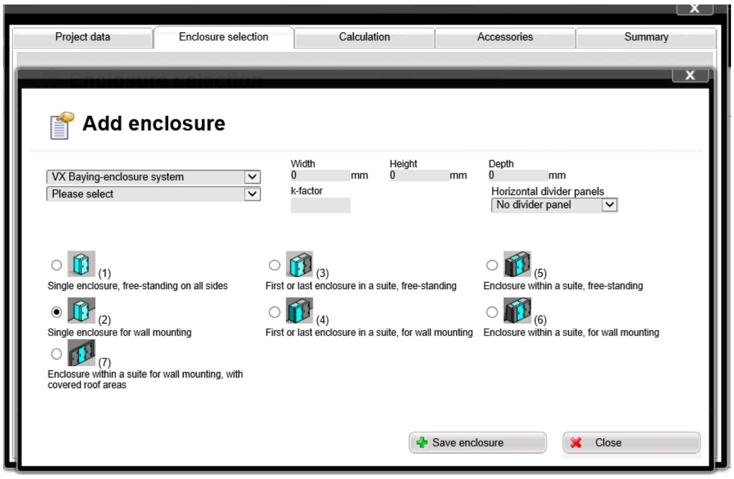
Pv = k x A x ΔT

Practical guidelines

- The heaters must be placed as far as possible below the components that need be protected, as the heated air rises and the components will thus be heated indirectly (required minimum distances must be taken into consideration)
- With larger enclosures, uniform heat distribution is best achieved by the installing several heating elements with lower outputs.
- Use a thermostat (for example an SK 3110.000) or a hygrostat (e.g. SK 3118.000)to ensure exact temperature and humidity control in the enclosure.

Software

Of course, you can indeed calculate everything using the formulas described above. However, software is also available that lets you calculate the required cooling or thermal output easily and quickly. Rittal offers its Therm software application, which you can use to select the right cooling solution in just a few simple steps.



Conclusion

In order to ensure the reliability and longevity of your system, you must consider whether and how the heat generated must be dissipated from the enclosure. This can be done in a number of ways, including natural convection, fan and filter units, air/air heat exchangers, air/water heat exchangers and cooling devices. When making your selection, it is first important to check which temperature parameters are given and whether other factors need to be considered, such as: Is cooling water available / does the air contain pollutants?

Sources

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Rittal GmbH & Co.KG
Auf dem Stützelberg · 35745 Herborn · Germany
Tel.: +49 (0)2772/505 9052 · Fax: +49 (0)2772/505 2319
E-mail: mtv@rittal.de · www.rittal.com