CAPITAL

Comprehension
Climate
Cooling

IV PRODUKT

Air handling with the focus on LCC

Table of Contents

Capital C **1**

Reading instructions **1**

General **2**

Selection procedure 2

Formulae 3

Mollier chart 4

Definitions 5

Alternative 1. Optimised calculation **6**

Air flow 6

Total cooling output 14

Summary **21**

Calculation form 21

Cost analysis **22**

Pay-off 22

Operating cost 22

Free cooling, active cooling and cooling recovery **25**

Alternative 2. Historical rough estimate **27**

Appendix 1. Mollier chart **29**

Appendix 2. Calculation form **30**

Production:
Idea and manuscript: IV Produkt AB, Birger Karlsson
Graphic design: Sörman Information & Media AB
Item number: LK 12.10.31.02 GB

ISBN 978-91-637-1688-1

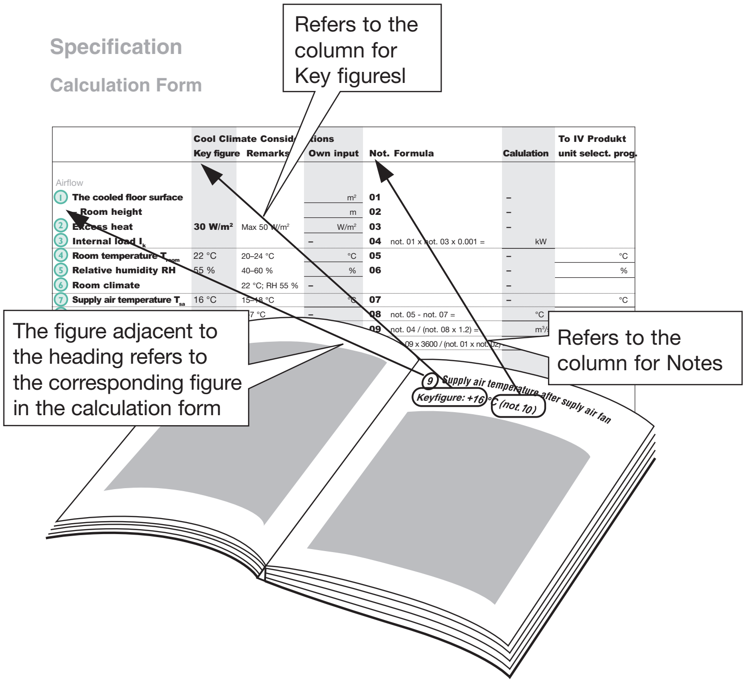
Capital C

“The need for chilled air increases, and this places higher demands on the environment, output and energy-efficient solutions. However, the requirements initially set for the indoor climate of a building, are that room temperatures must be at a comfortable level regardless of the outdoor weather conditions.

Air conditioning units designed as direct-acting cooling systems in an air handling unit, permit such a solution at the same time as both the thermal climate and air quality are maintained.

”The total power requirement for cooling and electrical power is greatly reduced through the combination of free cooling and cooling recovery with a cooling unit.”

Reading instructions



General

Selection procedure

In the ventilation industry, we try to produce the right climate in rooms where people and machines reside.

Several requirements must be met for people to feel good. The air in the room must meet certain requirements. Here we deal with problems with air such as temperature and humidity.

The purpose of “Capital C” is to show, in a practical and clear manner, the calculations we use to find the optimal choice of cooling unit that corresponds to the indoor climate we need.

Two alternative calculations are presented here in order to arrive at the installations’ total cooling requirement and air flow.

Alternative 1, gives us an optimised selection, where we can analyse and compare alternative assumptions, and assess results such as capacity, efficiency, operating cost, pay-off, etc.

In this alternative we can create our own sustainable key figures for future calculations.

Throughout we have used air as the heating and cooling medium, and have known both the type of operations (office, shop, school, computer room, nursing room, etc.) and the served premises’ cooled floor area.

Alternative 2, is a selection method based on a historical rough estimate, using values from experience as key figures.

Formulae

In order to calculate the installation's total cooling output, we use the formula:

$$P_t = q \times \Delta i \times \rho \times C_p$$

Total cooling output is the sum of sensible and latent cooling. Requisite cooling units are selected for the total cooling output.

Sensible here is defined as noticeable or the cooling that results in a change of temperature, which can be measured with a thermometer.

Latent here is defined as hidden cooling, which is involved in changes of state such as when water condenses from air without the temperature changing.

In order to calculate an installation's total air flow, we use the formula:

$$q = I_k / (\Delta T \times \rho)$$

$$P_t = q \times \Delta i \times \rho \times C_p$$

P_t = Total cooling output in kW
q = Airflow in m^3/s
Δi = $i_{DUT} - i_{KB}$ i kJ/kg dry air.

where:

i_{DUT} = Outside air's enthalpy
i_{KB} = Supply air's enthalpy after the cooling coil
ρ = Air density in kg/m^3 (= 1.2)
C_p = Air's specific heat capacity, kJ/kg (≈ 1.0)

$$q = I_k / (\Delta T \times \rho)$$

q = Airflow in m^3/s
I_k = Internal cooling requirement for excess heat in kW
ΔT = $T_{room} - T_{supply\ air}$ i °C

where:

T_{room} = Room temperature
$T_{supply\ air}$ = Supply air temperature
ρ = Air's density in kg/m^3 (= 1.2)

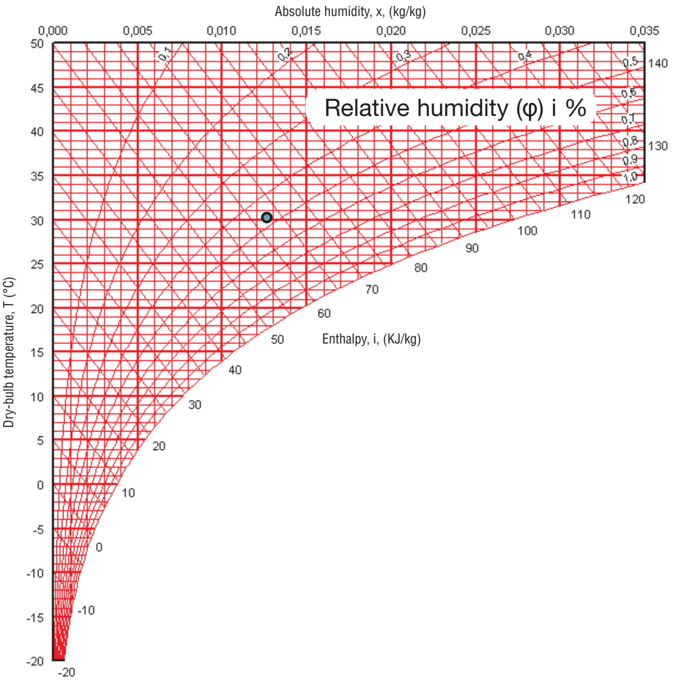
Mollier chart

We use a Mollier chart to clearly describe and understand the changes of state, that occur with the air when we cool and heat it in the following processes.

The Mollier chart has different scales and curves that illustrate the state of the air.

For the room conditions we generally deal with in the range 0 °C to 30 °C the density of the air lies between 1.1 - 1.3 kg/m³.
The normal value at 20 °C lies at 1.2 kg/m³, which in practice can always be used.

The Mollier chart for moist air, barometric pressure 101.3 kPa



Appendix 1 shows a Mollier chart with a larger scale.

This simplified Mollier chart shows:

- Dry air temperature (T) in °C
- Absolute humidity (x) in kg/kg dry air
- Relative humidity (φ) in %
- Enthalpy (i) in kJ/kg air

Definitions

Dry air temperature in °C (T) – is the temperature we read on a standard thermometer, which is not affected by evaporation or radiation.

Absolute humidity in kg/kg (x) – is the weight of water vapour per mass dry air.

Example: T = 27 °C
φ = 42 %
x = 0.0093 kg/kg

Relative humidity in % (φ) – to describe how "moist" or how "dry" the air is at a given temperature, we use the term relative humidity. Relative humidity is a measure of how much water vapour the air contains in relation to how much it can contain at the same dry temperature.

Example: Dry temp. (T) of 27 °C with a water content (x) of 0.0093 kg/kg has a saturation content (x) of 0.0224 kg/kg.

$$\varphi = \frac{0.0093}{0.0224} = 0.415 \text{ or } 42\ \%$$

Enthalpy in kJ/kg (i) – moist air's heat content

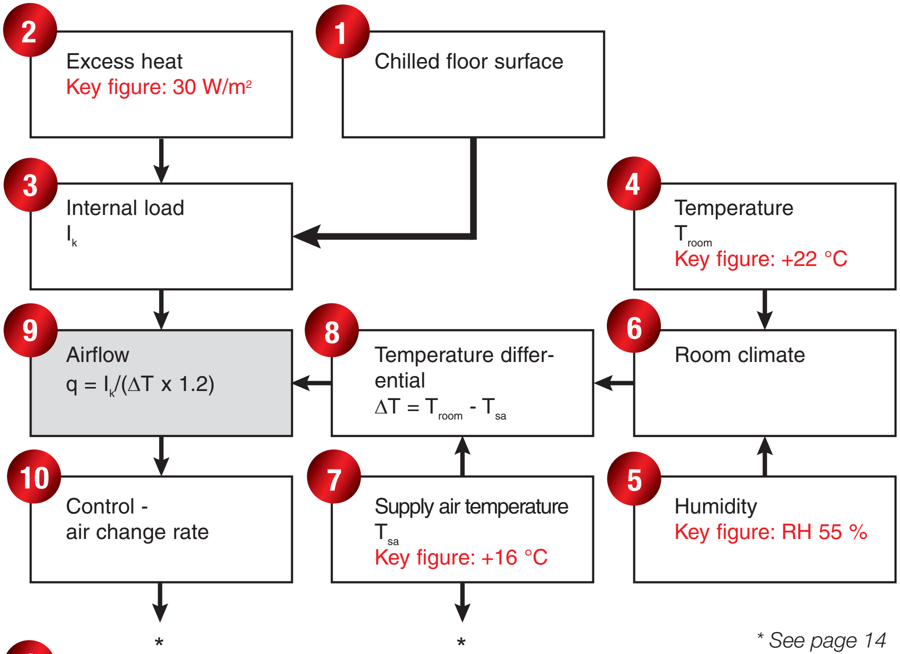
Example: T = 27 °C and
φ = 42 % has
Enthalpy (i) = 50.9 kJ/kg

Dew point temperature in °C – is the surface temperature at which moisture starts to condense on the surface. A higher moisture content results in a higher dew point temperature and vice versa.

Example: T = 27 °C and
φ = 42 % has
Dew point temperature = 13 °C

Alternative 1. Optimised calculation

Air flow



* See page 14

1 Cooled floor area

Cooled floor area means the total floor area served by the supplied air. If we only know the building's total floor area, we can then assume, for schools, offices, day care centres and similar buildings, that 70% of the total floor area is equal to the cooled floor area.

2 Excess heat

Key figure: 30 W/m² (note 03)

There is very sophisticated software available that takes into account wandering shadows, lag due to the accumulation in the building structure, etc., in order to determine the room heat load. To make a quick and practical calculation, if you are only looking at a part of the building or a simple building, the values set out in table 1 can be used.

Example: A typical office with an exterior wall towards NE and a cooled floor area of 12 m²

Heat load (see table 1)

1.6 m²	Triple glazed windows with blinds
1	Person
120 W	Lighting fluorescent tube
100 W	Computer

	Object	Area-quantity-output	Intensity coefficient			Heat load W
			Double glazing	Triple glazing	Blinds	
Windows	NW.N.NE	1.6 m²	330	300	x 0.35	168
Windows	E, S	m²	500	450	x 0.35	
Windows	SW	m²	520	470	x 0.35	
Windows	W	m²	450	400	x 0.35	
External wall		m²	12			
Roof	Suspended ceiling	m²	18			
Roof	No suspended ceiling	m²	6			
Number of persons		1	115			115
Fluorescent tube		120 W	1.2			144
Electricity consumers, computers		100 W	1.0			100
Total heat load in W						527

Table 1 Rough cooling requirement calculation

A rule of thumb can be that for simultaneity of the heat load, assume that there are blinds in the windows and there is no sun load at the same time as lighting.

Total excess heat will then be: 527-168 = 359/12 = **30 W/m²**

3 Internal load (I_k)

The internal load is the heat to be dissipated from the premises, caused by, e.g., lighting, people, machines, sun, etc. I_k = excess heat (W/m^2) x cooled floor area (m^2)

4 Temperature (T_{room})

Key figure: +22 °C (note 05)

A measure of perceived thermal comfort is PPD, the index that yields the expected number of those dissatisfied among a larger group of people.

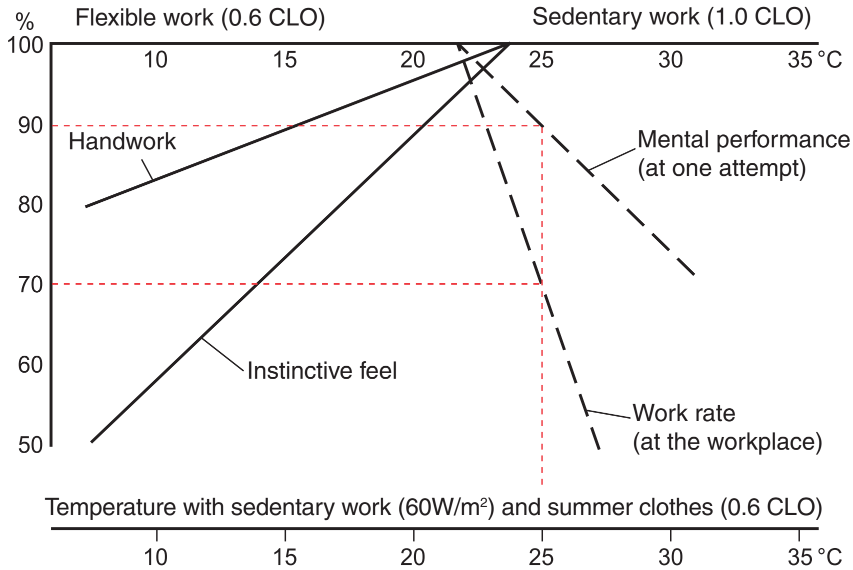
Indoor climate factor	Factor value in quality class		
	TQ1*	TQ2	TQ3
Operative temperature (to)			
Winter instance			
- Highest value °C	23	24	26
- Optimal value °C	22	22	22
- Lowest value °C	21	20	18
Summer instance			
- Highest value °C	25.5	26	27
- Optimal value °C	24.5	24.5	24.5
- Lowest value °C	23.5	23	22
Air speed in the occupied zone			
- Winter instance m/s	0.15	0.15	0.15 (0.25)
- Summer instance m/s	0.20	0.25	0.40

Table 2. Examples of requirement levels for thermal parameters

** TQ1 is judged to be only possible to meet with individual regulation of temperature and air flow.*

Climate class TQ1 is believed to yield less than 10% of dissatisfied persons, while climate class TQ2 is equivalent to 10% of dissatisfied persons and climate class TQ3 20%.

Trials have shown that the room temperature has a significant impact on human performance. It is evident how quickly mental performance and work rate decrease with increasing room temperature.



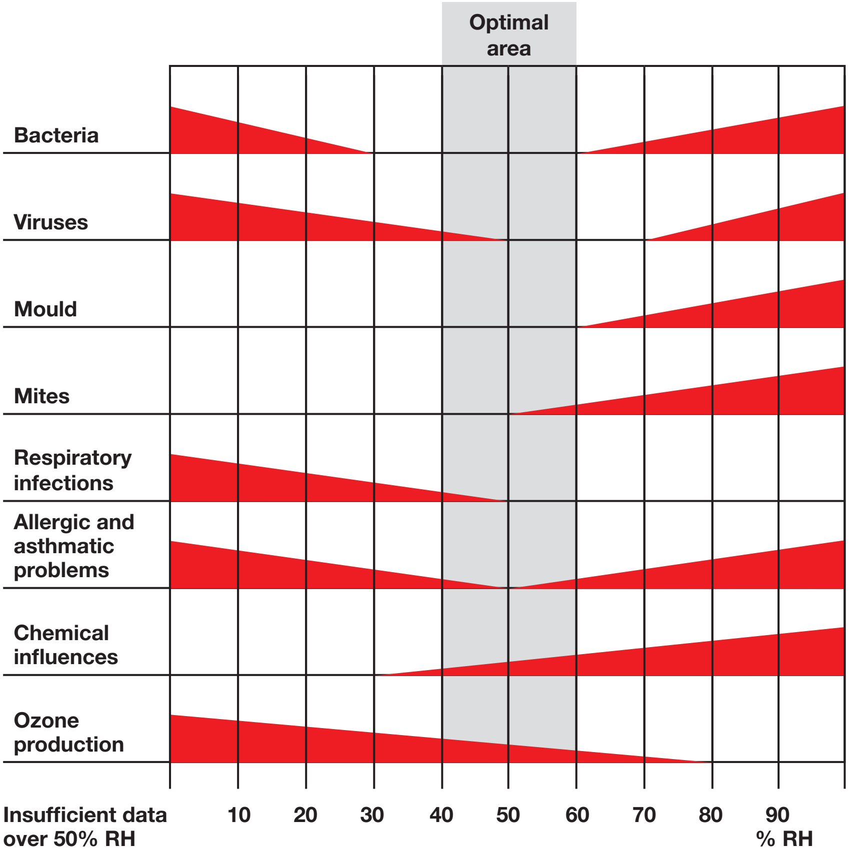
Indoor climate - productivity

For a person performing normal office work at a room temperature of +25 °C in relation to the comfort temperature +22 °C the work rate drops to 70% and mental performance to 90%. This means that employers get 70% of their employees' capacity at the higher temperature.

5 Moisture

Key figure: 55 % (note 06)

A number of research reports that deal with the impact of relative humidity on people, from countries including Sweden, Finland and Germany, show that the negative health risks for humans are at their lowest when the relative humidity indoors can be kept between 40 - 60% RH.



As we do not intend to introduce moisture into this construction, it is of great importance that when cooling the outdoor air more moisture than necessary is not removed.

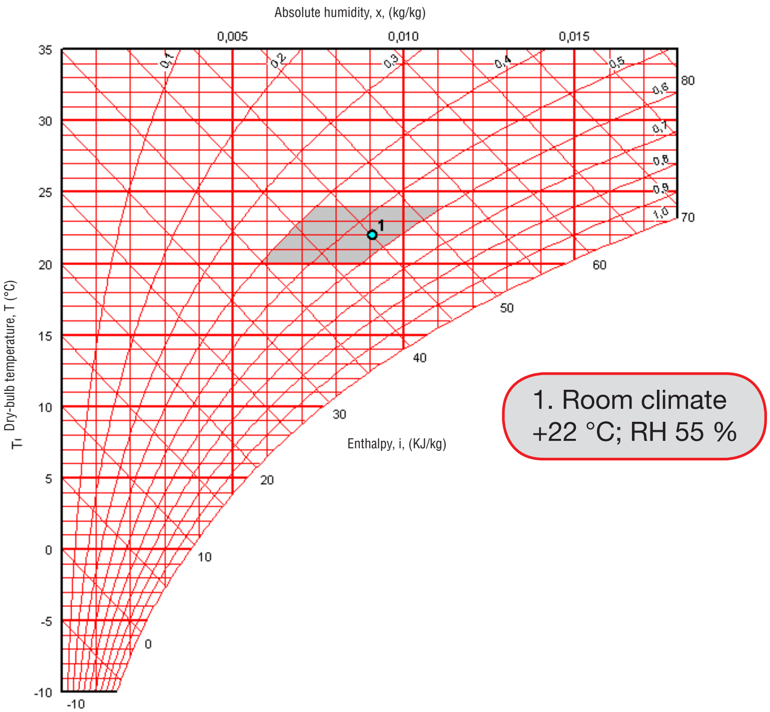
6 Room climate

(+22 °C; RH 55 %)

Independently of which combination of air temperature, humidity, etc., you choose, the individual differences between how people perceive the climate are immense. The threshold for what is a nuisance in terms of temperature in a room environment lies below +18 °C and above +28 °C. However, you need to distinguish between good comfort that is much narrower, usually in the range +20 °C to +24 °C, which we regard as the ideal climate range for temperature.

Studies have shown that the maximum combination could only satisfy 60% of the subjects of experiments. 20% thought it was too hot, and 20% thought it was too cold. We chose +22 °C at 55% relative humidity, which we entered on the Mollier chart.

The Mollier chart for moist air, barometric pressure 101.3 kPa



7 Supply air temperature after the supply air fan ($T_{supply\ air}$)

Key figure: +16 °C (note 07)

In order to be able to remove excess heat in the room, we need to supply air at a lower temperature than room temperature.
The selection of supply air temperature is controlled by several parameters, blow-in system, selection and placement of terminals, etc. The usual supply air temperature is 15 - 18 °C.

Low supply air temperatures give more dehumidification and less use of outdoor air for free cooling. High supply air temperatures give great air flow and high air speeds.

A design value for the supply air temperature can be said to be +16 °C. To supply air to the room of a lower air temperature can be associated with a draught problem.
Make sure not to cool the air more than 7 °C!

8 Temperature difference (or sub-temperature)

(max 7 °C)

The temperature difference or sub-temperature refers to the difference in degrees Celsius that occurs between room temperature and the supplied air temperature.

9 Air flow

The design internal load and the difference between the room and the supplied air temperature determine the requisite air flow. Accordingly, it is the thermal requirements and not the air quality requirements that are the design criteria.

10 Checking the air change rate

(2.5-8 times/h)

As we have determined the air flow, we check whether the air change rate in the room lies within acceptable values.

The air flow in m^3/h divided by the room volume in m^3 should lie between 2.5 and 8 times/h.

NOTE!

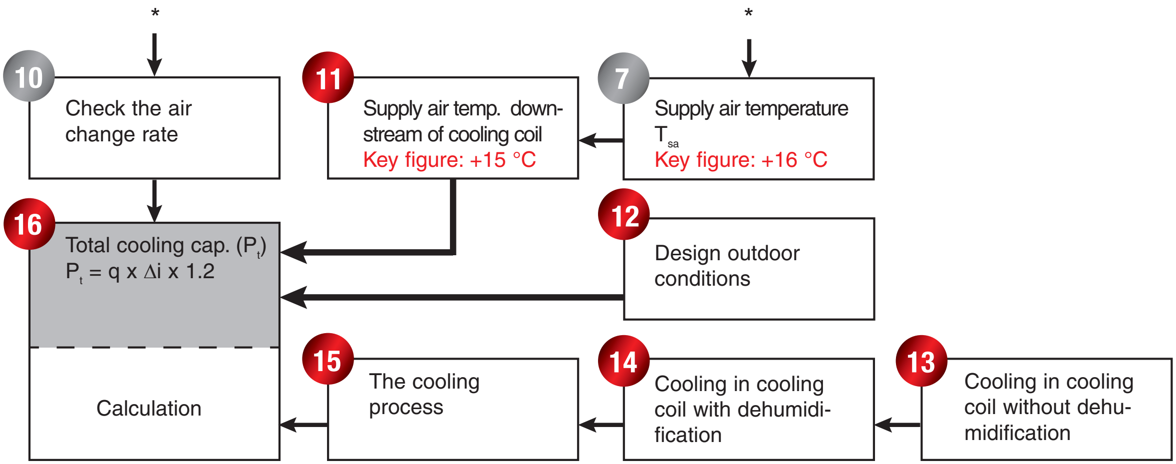
If the air circulation in the room is greater than 8 times, while the supply air temperature is lower than 15 °C, the cooling needed in the room will be greater than what is appropriate to be cooled with air as the cooling medium.

Accept a higher room temperature or choose a different cooling system.

At an air change rate per hour of less than 2.5 we will have difficulty in controlling the room temperature. If the temperature difference then decreases by raising the supply air temperature, you get a higher air flow and with that more air change.

If we exceed 8 air changes per hour, it will be difficult to supply air to the room without causing draught and noise. Reduce the air flow by accepting a lower supply air temperature.

Total cooling output

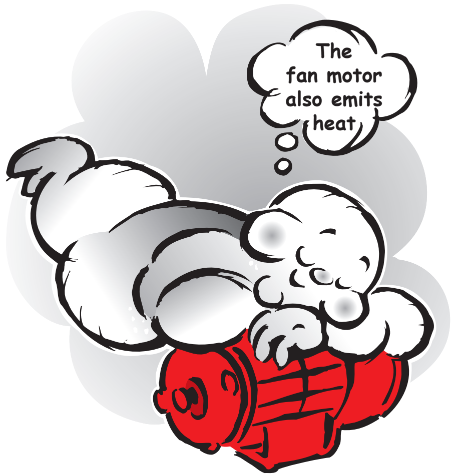


** See page 6*

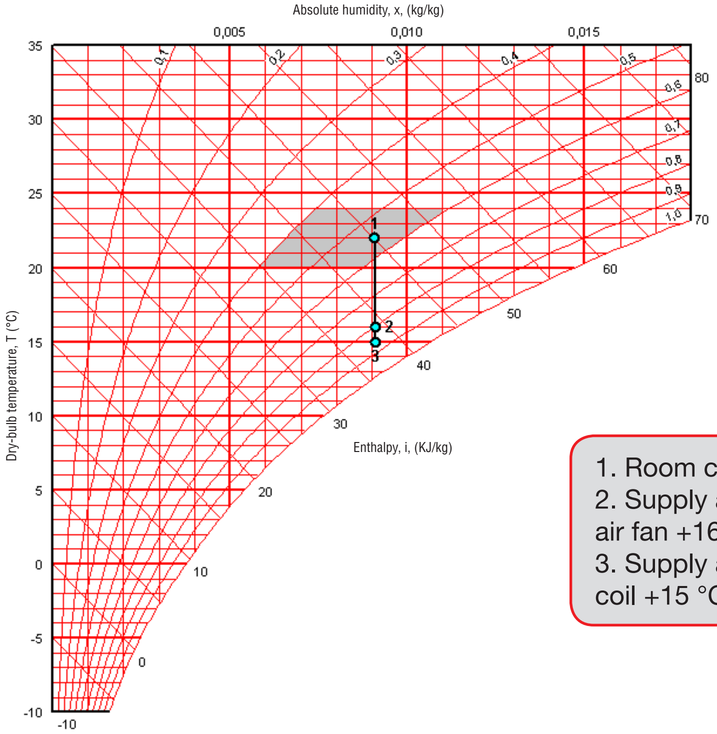
11 Supply air temperature after the cooling coil

Key figure: +15 °C (note 11)

In most installations the supply air fan motor is placed in the air stream and emits heat to the supply air. The temperature increase can be calculated when we know the motor output, normally we get a temperature increase over the fan motor of about 1 °C.
The air temperature after the cooling coil will then be 16 -1 °C = 15 °C.
We now use the Mollier chart where we draw the process. We start with a room climate of +22 °C at 55% relative humidity.
When our cooler air is heated in the room and all heating occurs at a constant water content, the air temperature after the supply fan and cooling coil will be on the same line, i.e., about 0.009 kg.



The Mollier chart for moist air, barometric pressure 101.3 kPa



1. Room climate +22 °C; RH 55 %
2. Supply air temperature after the supply air fan +16 °C
3. Supply air temperature after the cooling coil +15 °C

The curve in the chart gives us the temperature of the supply air that the outdoor air must be cooled to: +15 °C.
Exactly where this point will come in the actual process is determined by:

- the design outdoor state
- selected evaporation temperature in the cooling process
- with or without cooling recovery

12 Design outdoor air state

Towns' DUT summer

The design temperature and relative humidity that we shall cool the air from during the summer can be obtained through statistics from the Swedish Meteorological and Hydrological Institute, SMHI. The following extract from these data show the towns' highest values. Statistics are based on values exceeding the maximum of 50 hours/year.

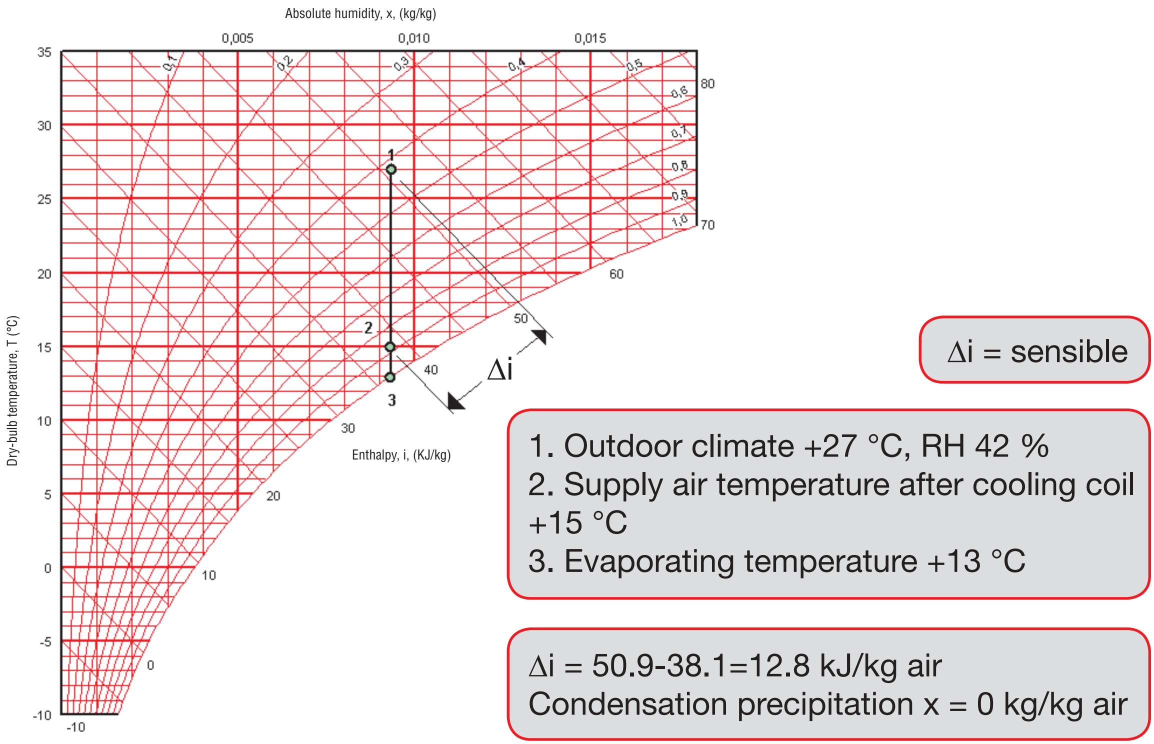
Town	DUT 50	Relative humidity
	°C	%
Borlänge	28	36
Linköping	27	42
Växjö	27	42
Örebro	27	42
Malmö	26	48
Halmstad	26	47
Stockholm	26	45
Sundsvall	26	41
Gävle	26	39
Jönköping	25	51
Kalmar	25	48
Östersund	25	46
Luleå	25	46
Umeå	24	48

Example:
Design values for Växjö are:
Temperature = 27 °C
Relative humidity = 42 %

13 Cooling in cooling coils without dehumidification

When cooling, the process is dependent on the surface temperature of the coil. If the incoming cooling medium's evaporation temperature is higher than the incoming air's dew point, no condensation precipitation occurs and you get so-called "dry cooling". Cooling in this case occurs according to a vertical line in the Mollier chart with constant water content (x).

The Mollier chart for moist air, barometric pressure 101.3 kPa



This is the optimum cooling process, which we wish to emulate. That is to say, cooling without condensation precipitation indicates pure sensible cooling.

14 Cooling in the cooling coil with dehumidification, evaporation 12 °C

If the evaporation temperature is lower than the dew point of the air the process becomes more complicated.

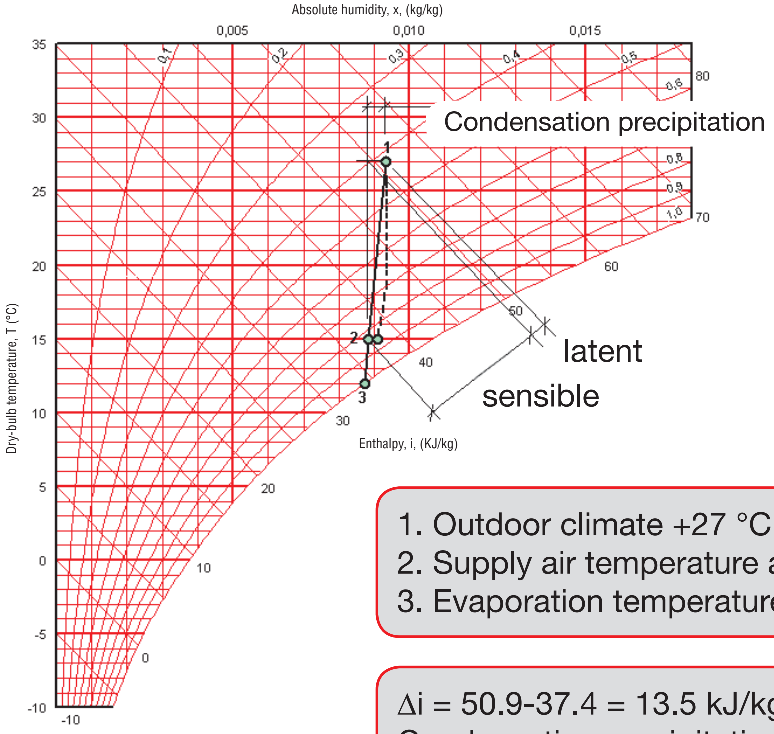
In a direct-acting cooling system, the temperature of the cooling medium is fairly constant through the entire coil. The condensation precipitation in such a system, will then be greater the lower the evaporation temperature and we say here that besides sensible cooling we also get latent cooling.

The actual process in the Mollier chart is not able to describe the entire phase change, as it follows a curved line from the air's initial state to the desired blow-in air temperature. The reason is that the temperature of the cooled surface is not constant through the whole cooling coil, but usually is higher on the first pipe ends than further in. Therefore a larger heat flow results, even if the temperature of the cooling medium is constant, in that part of the cooling coil where the air is warmest in higher surface temperature, than further inside where the air is colder.

We therefore perform our calculations according to the theoretical process, where we follow the straight line from the outdoor air state, towards the evaporation temperature on the saturation line.

However, the calculation method gives us a slightly higher cooling capacity than the requirement.

The Mollier chart for moist air, barometric pressure 101.3 kPa



Δi = sensible + latent

1. Outdoor climate +27 °C, RH 42 %
2. Supply air temperature after cooling coil +15 °C
3. Evaporation temperature +12 °C

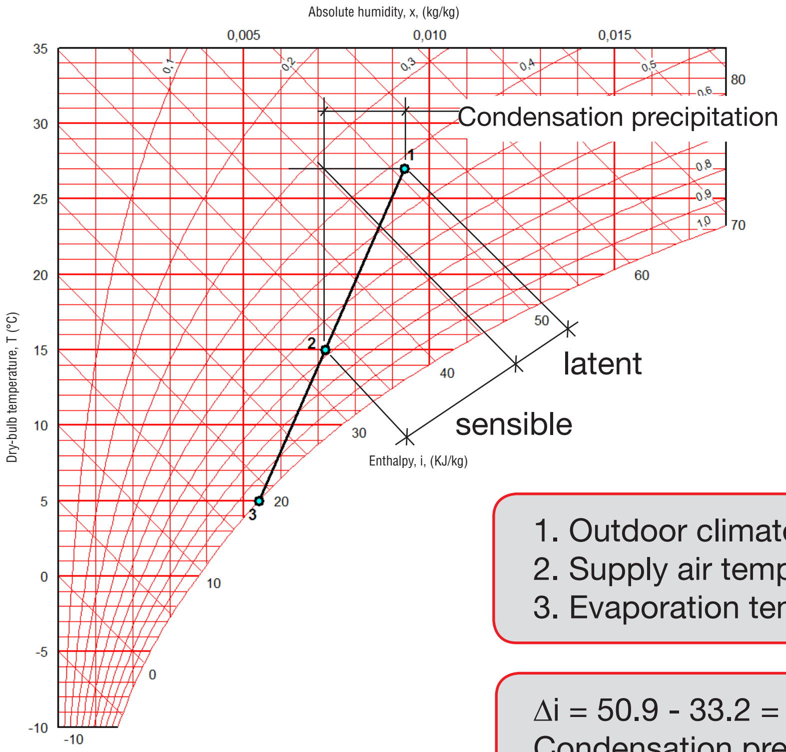
Δi = 50.9-37.4 = 13.5 kJ/kg air
Condensation precipitation x = 0.0005 kg/kg air

Here we can read that by lowering the evaporation temperature from 13 to 12 °C the total cooling requirement increases by (13.5-12.8) / 12.8 = 5.5%.

Cooling in the cooling coil with dehumidification, evaporation 5 °C

Cooling systems with an evaporation temperature of +5 °C are traditionally common. Therefore let us also study this process in the Mollier chart.

The Mollier chart for moist air, barometric pressure 101.3 kPa



Δi = sensible + latent

1. Outdoor climate +27 °C, RH 42 %
2. Supply air temperature after cooling coil +15 °C
3. Evaporation temperature +5 °C

Δi = 50.9 - 33.2 = 17.7 kJ/kg air
Condensation precipitation x = 0.0021 kg/kg air

For the same planned temperature decrease as with cooling in cooling coils without dehumidification, we get a cooling machine with about 40% greater cooling capacity.

An unnecessarily large cooling machine starts and stops frequently, which causes difficulties in regulating the supply air temperature, and jeopardises operating reliability through short operating times.

An economic and technical design has its evaporisation temperature 3 – 5 °C lower than the air temperature after the cooling coil.

15 Cooling process

The following requirements must be made on the cooling equipment to get the right mix of cooling and moisture, so:

- It can reduce the air temperature without condensing the water.

This is obtained by designing for high evaporation.

The selection of the evaporation temperature is crucial for how large the total cooling output will be. High evaporation temperature yields the following result:

- low total cooling output
- low connection power for electricity
- low power consumption

16 Total cooling output (P_t)

The total cooling capacity can be calculated when the total cooling requirement and air flow are known.

- The total cooling requirement is obtained as a difference between the outdoor enthalpy and the cooled air enthalpy after the cooling coil.

Summary

Calculation form

	Large K Key figure	Remarks	Own input data	Note	Formula	Calculation	To IV Produkt's product selection program
Air flow							
1 **Premises' cooled floor area**			**560 m²**	**01**		**–**	
– Room height			**2.4 m**	**02**		**–**	
2 **Excess heat**	**30 W/m²**	Max 50 W/m²	**30 W/m²**	**03**		**–**	
3 **Internal load I_k**			**–**	**04**	note 01 x note 03 x 0.001 =	**16.8 kW**	
4 **Room temperature T_{room}**	**22 °C**	20-24 °C	**22 °C**	**05**		**–**	**22.0 °C**
5 **Relative humidity RH**	**55 %**	40-60 %	**55 %**	**06**		**–**	**55.0 %**
6 **Room climate**		22 °C; RH 55 %	**–**			**–**	
7 **Supply air temperature $T_{supply\ air}$**	**16 °C**	15-18 °C	**16 °C**	**07**		**–**	**16 °C**
8 **Temperature difference ∆T**		5-7 °C	**–**	**08**	note 05 - note 07 =	**6 °C**	
9 **Air flow q**			**–**	**09**	note 04 / (note 08 x 1.2) =	**2.33 m³/s**	**2.33 m³/s**
10 **Checking the air change rate**		2.5-8 times/h	**–**	**10**	note 09 x 3600 / (note 01 x note 02) =	**6.25 times/h**	
Cooling output							
11 **Supply air after the cooling coil**			**–**			**–**	
– Temperature	**15 °C**		**15 °C**	**11**		**–**	
– Enthalpy		Acc. to Mollier chart	**37.4 kJ/kg**	**12**		**–**	
12 **Design outdoor air state**			**–**			**–**	
– Town		Acc. to SMHI	**Vaxjö**	**13**		**–**	
– Temperature		Acc. to SMHI	**27 °C**	**14**		**–**	**27 °C**
– Relative humidity		Acc. to SMHI	**42 %**	**15**		**–**	**42.0 %**
– Enthalpy ∆i		Acc. to Mollier chart	**50.9 kJ/kg**	**16**		**–**	
16 **Total cooling output P_t**			**–**	**17**	note 09 x (note 16 - note 12) x 1.2 x 1.0 =	**37.8 kW**	

Cost analysis

The installation and operation of a cooling system has been considered throughout the years as too costly and with that seen as an unnecessary luxury!

By using some examples we shall try to clarify whether this is the case and if so, why.

Pay-off

Can an installation with cooled air pay for itself? Let's see!

With today's increasing internal heat loads from computers, printers, copiers, etc., it is not inconceivable that indoor temperatures are or exceed 25 °C for more than 200 hours/year.

With reference to the previous analysis of the room temperature, it can be ascertained that the work rate drops to 70% at a room temperature of 25 °C.

Assuming an hourly cost per employee of 30 EURO including contributions, the loss will be 0.3 x 200 x 30 = 1800 EURO per employee per year!

If each employee uses an area of 20 m^2, this means that an investment of SEK 900/m^2 for cooled air would pay for itself after only one year.

In our presentation example on the calculation form we have a room with a cooled floor area of 560 m^2. According to the key figures above we can appropriate 560 x 90 EURO = 50 400 EURO for installation of cooling!

Operating cost

Let us now study what costs our cooling equipment can involve with regard to its operation.

We presuppose that the ventilation system's air flow is the same for cooling as for heating and so we will concentrate on the additional cost for cooling operations.

At the same time we will compare the two alternatives described with different evaporation temperatures.

Our alternative at +12 °C evaporation

Conditions		
		Supply air
Air flow		2.33 m^3/s
Temperatures	Cooling instance	16 °C
Mean annual temperature		6.4 °C
Type of operation		Day time 9 am to 9 pm
Operating time		4380 hrs
Energy price		SEK 1.2/kWh
Evaporation temperature		12 °C

According to our calculation, in this case a total cooling output of 37.8 kW is required, and we assume efficiency over the compressor (COP) of 3.8 and a supply fan with output power equal to 3.0 kW.

Result		
Duration		**Cooling**
Annual cooling		7356 kJh/kg air
Energy distribution		
Total requirement		20568 kWh
Latent cooling energy (dehumidification of air)		1413 kWh
Energy for operation		
Compressors	Total	5413 kWh
Operating cost		
Cooling	Total	SEK 6496 /year
Requisites outputs		
Electricity for cooling		9.9 kW

Alternative with +5 °C evaporation

Conditions		
		Supply air
Air flow		2.33 m^3/s
Temperatures	Cooling instance	16 °C
Mean annual temperature		6.4 °C
Type of operation		Day time 9 am to 9 pm
Operating time		4380 hrs
Energy price		SEK 1.2/kWh
Evaporation temperature		5 °C

According to the examples presented in the Mollier chart, a total cooling output of 2.33 x 17.7 x 1.2 = 49.5 kW is required here.
At the same time we get impaired efficiency, COP = 3.1, due to the lower evaporation temperature, while we maintain the supply air fan's motor output of 3.0 kW.

Result		
Duration		**Cooling**
Annual cooling		8078 kJh/kg air
Energy distribution		
Total requirement		22587 kWh
Latent cooling energy (dehumidification of air)		3432 kWh
Energy for operation		
Compressors	Total	7286 kWh
Operating cost		
Cooling	Total	SEK 8744 /year
Requisites outputs		
Electricity for cooling		16.0 kW

Summary
Here we can see that the annual cost for the operation of the cooling system is exceedingly small and that, together with the installation cost, it should not form the basis for the installation of cooled air.

In the comparison between the examples we can also see that there is economy in designing the installation to cool air with a high evaporation temperature.

Free cooling, active cooling and cooling recovery

Free cooling

As long as the outside temperature is lower than or equal to the desired room temperature, it is an obvious alternative to cool with outdoor air - “free cooling”

Active cooling

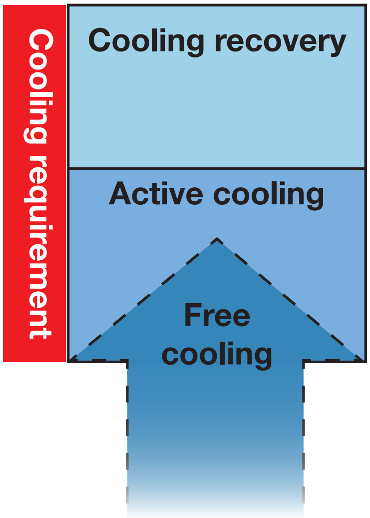
When the outdoor air is not sufficient to maintain the desired indoor temperature, we need to supplement with supplied cooling output – “active cooling” (preferably in the form of a direct-acting integrated cooling compressor set).

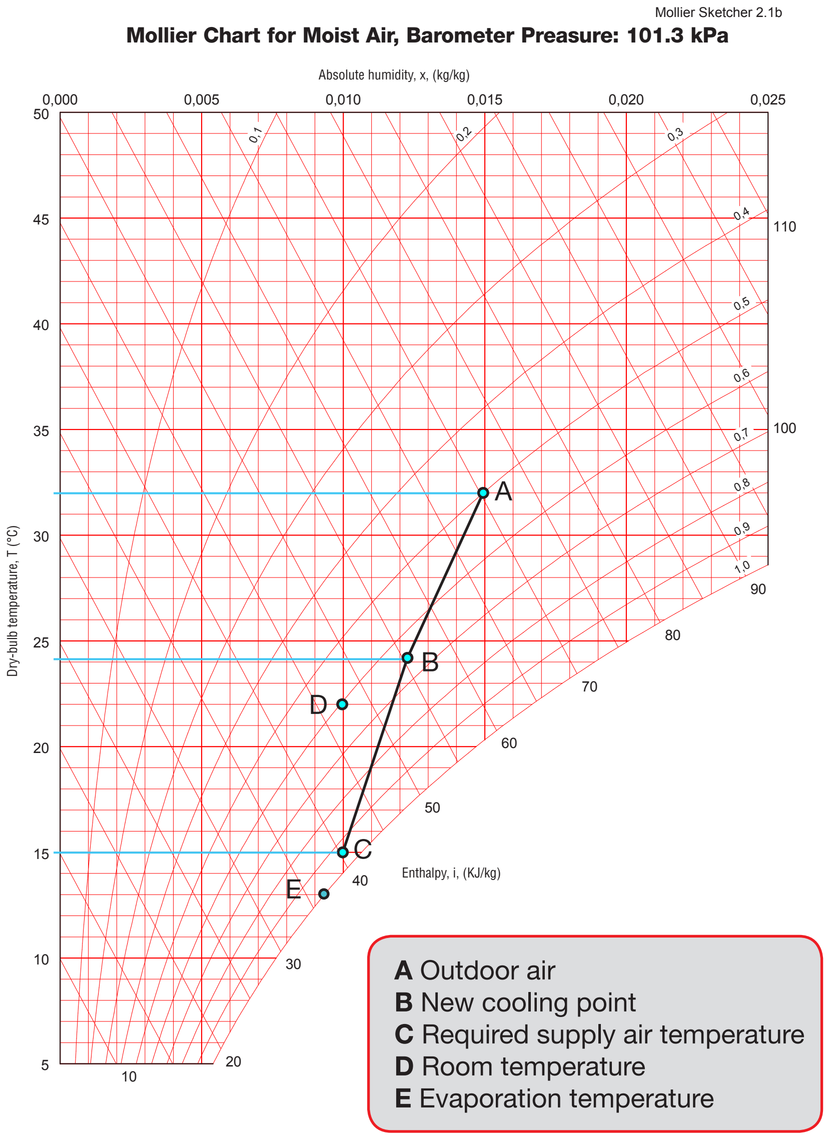
Cooling recovery

Most air handling units are supplied today with some form of heat recovery. By placing the cooling unit’s evaporator on the supply air side and the condenser on the exhaust air side (i.e., on either side of the heat recovery unit), we have the opportunity to also recover cooling in combination with active cooling.

Temperature and moisture recovery cuts the power requirement of the cooling unit and ensures that we have efficient cooling when it’s needed the most.

Principle showing the cooling process with free cooling, active cooling and cooling recovery in a supply and exhaust air unit with hygroscopic rotary heat exchanger.





Subject to change without prior notice.

Alternative 2. Historical rough estimate

We have dimensioned the need for air flow and cooling output for a long time. Frequently we have settled for simple rough estimates using values from experience (key figures), to determine a premises' need for air flow and cooling output.

Key figures gave us the possibility to determine the air flow and size of the ventilation unit with a cooling coil. In this way we also produced the data needed to select a cooling machine.

However, we could not read out what our assumption gave us as a result, regarding the supply air temperature, capacity for internal load, COP, connected power, etc.

Commonly used key figures were to multiply the premises' cooled floor area with:

The unit's air flow requirement	12 –15 $m^3/m^2/h$
The cooling machine's total cooling output	80 – 85 W/m^2 floor area

According to our "optimised calculation examples" with a cooled floor area of 560 m^2, we receive an air flow of 2.33 m^3/s and a total cooling output of 37.8 kW.

We shall now see whether the "historical rough estimate" can also apply today.
Let us calculate the air flow at 15 $m^3/m^2/h$ and the cooling output 85 W/m^2.

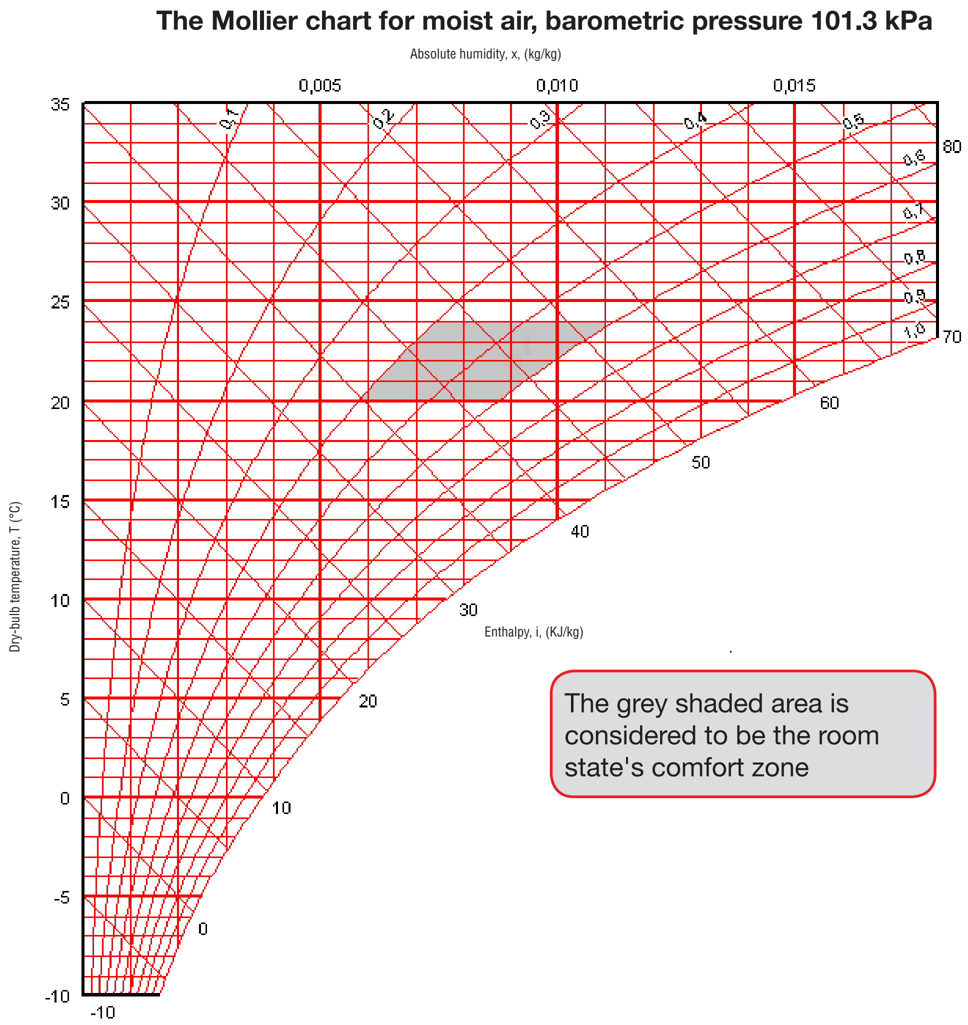
The air flow will then be: 560 x 15 = 8400 m^3/h or 2.33 m^3/s and the cooling machine's total cooling output: 560 x 85 = 47600 W or 47.6 kW.

As we can see, we would have arrived at the right figure for air flow if we had chosen 15 m^3/m^2/h as a key figure.

For cooling, we would have selected a too large cooling machine, which can be explained by the key figure at that time, being based on the cooling unit having an evaporation temperature of +5 °C instead of our optimised calculation of +10 to 12 °C.

From this we can see that the key figure can be used for quick rough estimates, but it is not accurate enough for the final design.

Appendix 1. Mollier chart



Appendix 2. Calculation form

	Large K Key figure	Remarks	Own input data	Note	Formula	Calculation	To IV Produkt's product selection program
Air flow							
1 Premises' cooled floor area			m²	01		–	
– Room height			m	02		–	
2 Excess heat	30 W/m²	Max 50 W/m²	W/m²	03		–	
3 Internal load I_k			–	04	note 01 x note 03 x 0.001 =	kW	
4 Room temperature T_{room}	22 °C	20-24 °C	°C	05		–	°C
5 Relative humidity RH	55 %	40-60 %	%	06		–	%
6 Room climate		22 °C; RH 55 %	–			–	
7 Supply air temperature $T_{supply\ air}$	16 °C	15-18 °C	°C	07		–	°C
8 Temperature difference ΔT		5-7 °C	–	08	note 05 - note 07 =	°C	
9 Air flow q			–	09	note 04 / (note 08 x 1.2) =	m³/s	m³/s
10 Checking the air change rate		2.5-8 times/h	–	10	note 09 x 3600 / (note 01 x note 02) =	times/h	
Cooling output							
11 Supply air after the cooling coil			–			–	
– Temperature	15 °C		°C	11		–	
– Enthalpy		Acc. to Mollier chart	kJ/kg	12		–	
12 Design outdoor air state			–			–	
– Town		Acc. to SMHI		13		–	
– Temperature		Acc. to SMHI	°C	14		–	°C
– Relative humidity		Acc. to SMHI	%	15		–	%
– Enthalpy Δi		Acc. to Mollier chart	kJ/kg	16		–	
16 Total cooling output P_t			–	17	note 09 x (note 16 - note 12) x 1.2 x 1.0 =	kW	

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"The need for chilled air increases, and this places higher demands on the environment, output and energy-efficient solutions. However, the requirements initially set for the indoor climate of a building are that room temperatures must be at a comfortable level regardless of the outdoor weather conditions. Air conditioning units designed as direct-acting cooling systems in an air handling unit permit such a solution at the same time as both the thermal climate and air quality are maintained. The - otherwise requisite - total power requirement for cooling and electrical power is greatly reduced through the combination of free cooling and cooling recovery with a cooling unit."

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ISBN 978-91-637-1688-1

LK 12.10.31.02.GB