

SELECTION GUIDE

FOR MOBILE DEHUMIDIFIERS

NEW

ECO-Friendly
Refrigerant

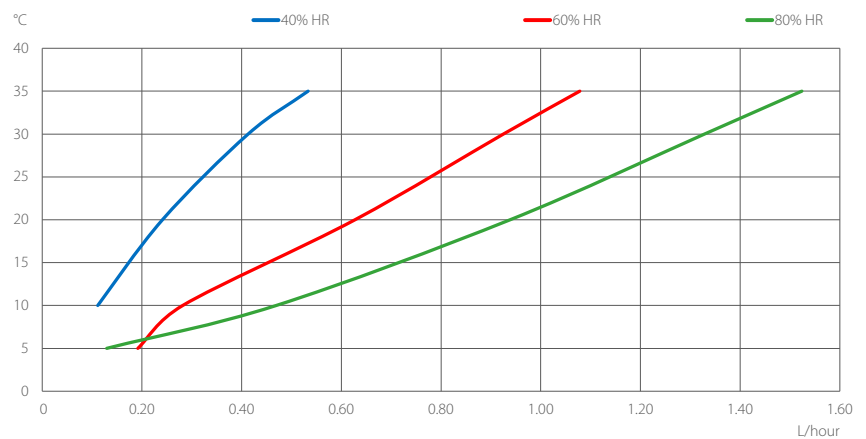


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PREFACE

In order to choose the right mobile dehumidifier from the Dantherm CDT range, you need to know three parameters: the temperature of the air in °C, the required relative humidity of the air in % RH, and how many litres of water per hour you need to remove from the air.



If you know these parameters, it is simply a matter of checking out the capacity curves of the CDTs (like the one shown above for CDT 30) to find one that is suitable for the job. You will find the capacity curves for all of the mobile dehumidifiers in the Dantherm CDT range in chapter 5.

While temperature and relative humidity are fairly easy to establish, the actual amount of water to be removed from the air in a given situation is quite another matter.

This selection guide aims to help you understand the functional principles of dehumidification and the theoretical basics required to calculate the necessary dehumidification load in any given situation.

Quick and efficient dehumidification is crucial in buildings that have fallen victim to damage caused by floods or fires. The same applies to construction work where an effective means of drying out brick or concrete walls can successfully speed up the building process. Moreover, the CDT range is also ideal for occasional dehumidification or drying of manufacturing and storage facilities.

Although mobile dehumidifiers might very well provide all the capacity you require, we advise that you to check out the Dantherm CDF and CDP ranges too, if your need for dehumidification is permanent.

Enjoy the read!



This selection guide for mobile dehumidifiers includes information about Dantherm's CDT 30, 30S, 40, 40S, 60 and 90 MK III.

1

WHY DO WE NEED DEHUMIDIFICATION?



The need for efficient dehumidification is not just relevant in connection with water damage, construction work, production processes, swimming pools, waterworks and other obviously damp areas. Buildings, valuables and people in all sorts of climates will often benefit from dehumidification in less obvious everyday situations.

The outdoor air is never completely dry anywhere in the world, and indoors multiple sources add to the relative humidity of the indoor air: transpiration from people; steam from cooking and bathing; humidity emanating from production processes or the storage of damp goods; even building materials and furniture slowly drying out add to the overall humidity of a room.

Due to ever-rising energy prices, buildings of today are much better insulated than before. While keeping out the cold, the insulation also reduces the air change and traps humidity. A sure sign is dew on windows. That can easily turn into moisture causing damage to the woodwork.

The main reasons and signs showing that dehumidification is needed:

- Mould and fungus attacks
- Conditions favourable to microorganisms
- Metal surfaces becoming unpaintable
- Electronic equipment malfunctioning
- Corrosion attacks
- Moisture damages on goods, building parts, furniture, etc.
- Discomfort due to humid indoor climate.

In all these instances, lowering the relative air humidity is required. This can be done in a number of different ways.

Example 1

On a hot dry summer's day in Denmark with a room temperature of 20°C and 60% RH (relative humidity), the content of water in the air is approximately 8.5 g water/kg air. In an 80 m³ room, this amounts to close to 1 litre water.

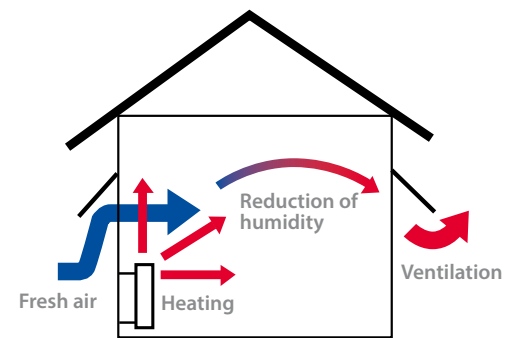
If the temperature at night drops to 0°C, more than 50% of the water content in the air will condense as dew. That equals 5 g water/kg air or close to half a litre of condensed water in an 80 m³ room. This could cause all sorts of serious problems.

1.1 Heating and ventilation

The longest known method for reducing humidity is based on the physical fact that warm air is capable of holding more moisture than cold air. In practice, fresh air is drawn into the room and heated up so it can absorb more water. Followingly, the then humid air is ventilated out of the room. This process continues until reaching the desired conditions in the room.

This drying method based on heating and ventilation is used less and less because it is a very energy-consuming and uneconomic solution. Heat is – literally – thrown out the window. Furthermore, the air drawn into the room also contains a certain level of relative humidity. That prolongs the drying process depending on the time of year, the outside temperature and weather conditions.

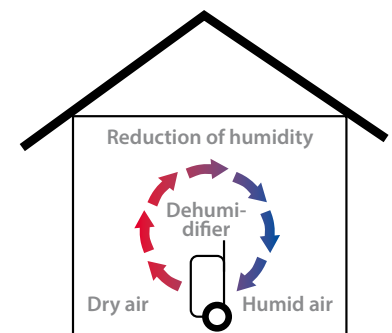
Combined with the high energy prices of modern day, this has made dehumidification the preferred drying method across the planet.



1.2 Dehumidification

The basic principle of dehumidification assumes that the room is closed. Windows and doors are closed and no, or at least very little, outside air enters the room. The air is continuously circulated through the dehumidifier, and gradually the humidity is condensed into a water container with no resulting heat loss to the outside. Quite the opposite of the traditional method of heating and ventilation.

In addition to the obvious advantages of a reduced energy consumption, the dehumidification process is much easier to control as long as the room stays closed.

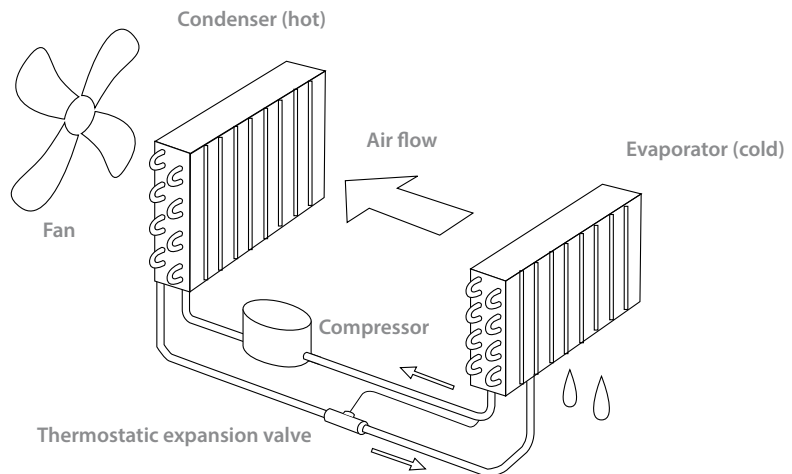


1.3 Advantages of condense drying

- Reduced energy consumption
(approximately 80% reduction compared to traditional heating and ventilation)
- Less risk of surface drying cavitations and critical point drying because the temperature is lower
- No energy loss. The electrical energy led to the compressor and fan motor is converted into heat
- Controllable process as the room is closed

2

HOW DOES A MOBILE DEHUMIDIFIER WORK?

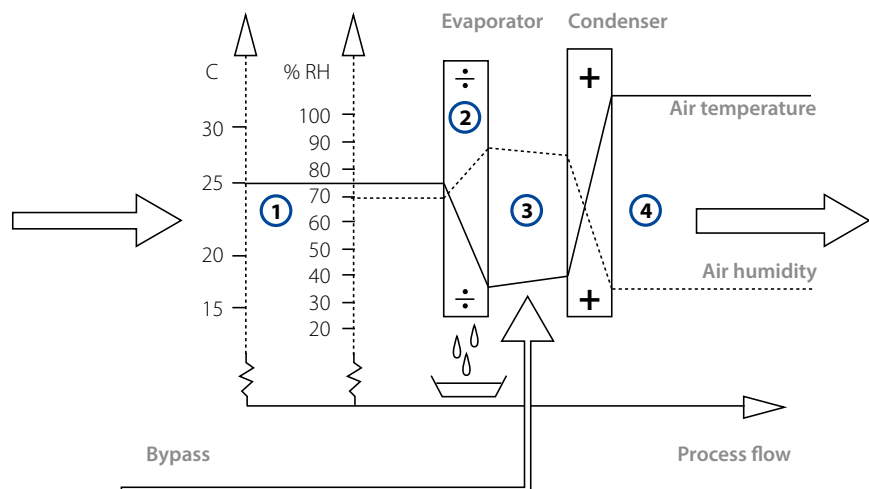


The basic functional principle of a condense drying dehumidifier is really quite simple. A fan draws humid air through a refrigerated evaporator. The air is cooled well below its dew point. The water condenses on the cold surface of the evaporator and drips into a water container or is led directly to a drain. Then, the cold dry air continues through a hot condenser which heats it up and returns it to the room to pick up new humidity. This procedure is continued until the desired condition is achieved.

Example 2

2.1 Temperature and airflow

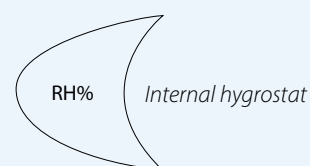
TEMPERATURE AND RH VALUE		
1.	25°C	70% RH
2.	17°C	88% RH
3.	18°C	85% RH mixed air flow
4.	33°C	35% RH



In the illustrated example on the previous page, 25°C hot air with 70% RH (relative humidity) (1) enters the evaporator. Inside the refrigerated evaporator (2), the air temperature drops to 17°C and the RH increases to 88%. The water condenses and drips into a water container.

To remove all of the water even with relatively dry air conditions, it is important that the evaporator does not cool down the entire air stream as that increases the risk of not fully reaching the dew point. Therefore, only part of the air is led through the evaporator to ensure maximum condensation while the rest is by-passed as shown in example 2.1. This results in a mixed 18°C and 85% RH air flow between the evaporator and the condenser (3). When passing the hot condenser, the mixed air flow will ensure that the condenser is sufficiently cooled.

The final result is an outlet air temperature from the dehumidifier of 33°C and 35% RH (4). The temperature is increased because energy is added by the compressor and by the latent heat from the condensation process.



2.1.1 Humidity control

The internal hygrometer on the display allows control of exactly how much you want to lower the relative humidity. Set the degree of relative humidity required, and the hygrometer will automatically stop the dehumidification process when reaching the value. This way, you do not risk possible damage from drying out materials too much, and the dehumidification process becomes much more energy efficient.

2.1.2 Temperature control

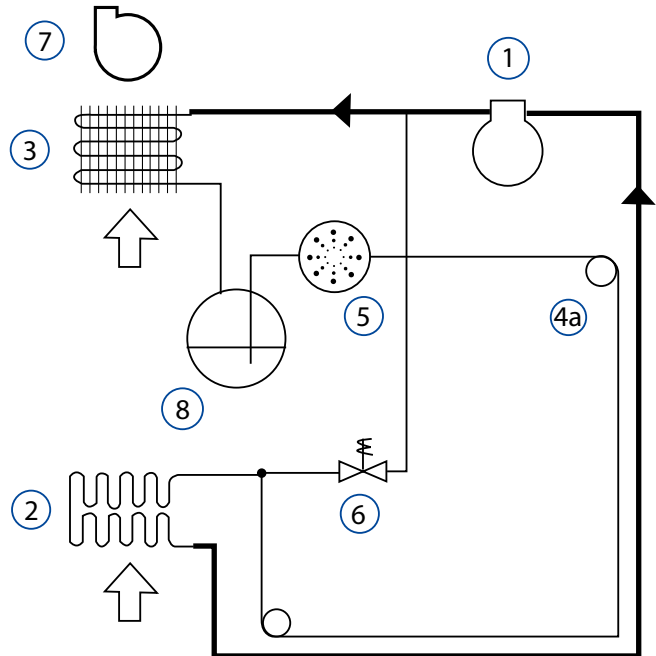
If the room temperature is outside the operating range (3-35°C) the dehumidifier stops. It will restart automatically when the room temperature is within the operating range.

This means that the dehumidifier will keep running as long as the room temperature remains within the operating range, continuously reducing the RH value.

CDT 30 AND 30S

With capillary tube

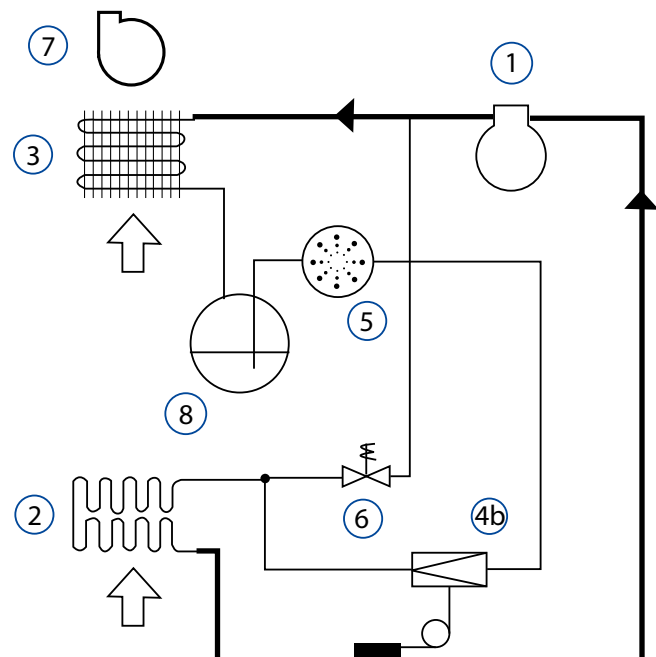
- 1: Compressor
- 2: Evaporator
- 3: Condenser
- 4a: Capillary tube
- 5: Liquid line drier
- 6: Solenoid valve
- 7: Fan
- 8: Receiver



CDT 40, 40S, 60 AND 90

With thermostatic expansion valve

- 1: Compressor
- 2: Evaporator
- 3: Condenser
- 4b: Thermostatic expansion valve
- 5: Liquid line drier
- 6: Solenoid valve
- 7: Fan
- 8: Receiver



2.2 Principal functionality of the various components

The compressor (1) takes hot gas from the low pressure side and presses it into the condenser (3). The fan (7) draws the cold air from the evaporator (2) through the condenser (3) where it is heated up by the hot gas. In this process, the gas is cooled down and ends up as liquid in the receiver (8).

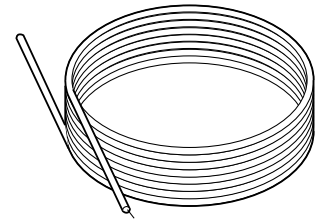
The now high pressure liquid refrigerant is passed through a liquid line drier (5) that removes any unwanted moisture from the refrigerant. The refrigerant is then passed through a capillary tube or a thermostatic expansion valve (4a/4b) to reduce the pressure before it enters the evaporator (2), where it reaches its boiling point and turns back into a low pressure hot gas.

Basically, a capillary tube and a thermostatic valve serve the same purpose. Namely to reduce the pressure from high to low level and to control the flow of refrigerant through the evaporator. At low pressure levels, the heat from the air drawn through the outside of the evaporator will turn all the refrigerant inside the evaporator into gas.

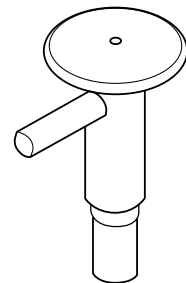
The capillary tube is a static resistance. All the refrigerant has to pass through a long thin tube, reducing the pressure.

The thermostatic expansion valve is a dynamic resistance. The sensor provides feedback to the valve, causing the valve to open a little or vice versa. If the evaporator does not get sufficient refrigerant, the sensor temperature will increase, causing the valve to open a bit and vice versa.

In contrast to a capillary tube, a thermostatic expansion valve can compensate for differences in the RH value and the temperature of the air drawn into the dehumidifier. This clearly makes the expansion valve the better solution when it comes to large dehumidifiers, but it is a more expensive solution and no significant difference in performance is achieved when using it in small units.



Capillary tube



Thermostatic expansion valve

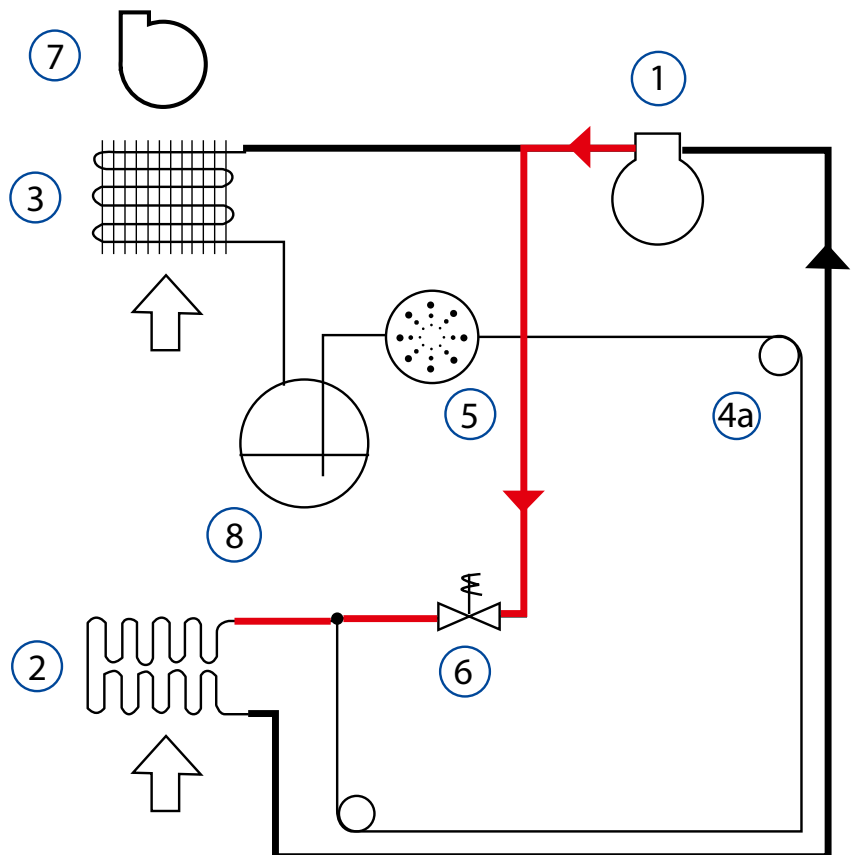
2.3 Defrosting

Depending on the room temperature and the RH value of the air, the evaporator will run very cold. In general, low air temperature means low evaporator temperature. If the air temperature is below approximately 15-20°C (depending on the relative humidity), ice will start forming on the surface of the evaporator.

If the ice is allowed to accumulate on the evaporator, it will reduce the dehumidification capacity of the unit. To prevent this, defrosting is carried out by means of hot gas from the compressor.

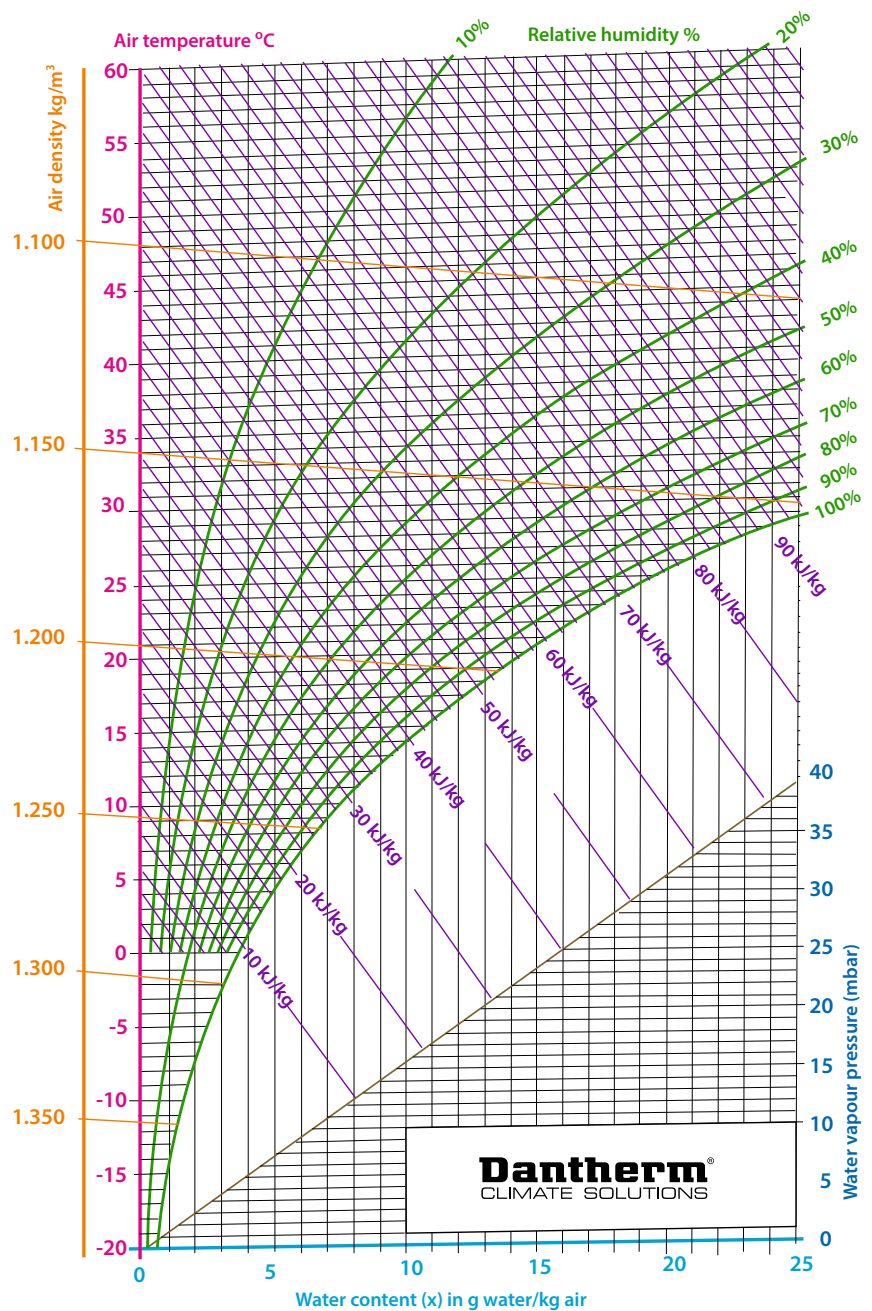
When the surface of the evaporator reaches the set temperature of 5°C, a timer is activated and after 20 uninterrupted minutes of being <5°C, the solenoid valve (6) opens, and hot gas is circulated through the evaporator, efficiently melting the ice on the surface. When the set evaporator temperature of 12°C is reached, the solenoid valve closes and the system returns to normal active mode.

- 1: Compressor
- 2: Evaporator
- 3: Condenser
- 4a: Capillary tube
- 5: Liquid line drier
- 6: Solenoid valve
- 7: Fan
- 8: Receiver



3 THEORETICAL PRINCIPLES

The basic functional principles of dehumidification and dehumidifiers are fairly straightforward. The psychrometric calculations involved in the dehumidification process, however, are quite complex. Several interrelating parameters need to be taken into consideration.



The Mollier hx-diagram is a graphical representation of the interrelation of the temperature and the relative humidity of the air. This diagram is key to determining the various parameters required to calculate the dehumidification load required for any situation.

This is an introduction aiming to help you understand how this basic tool works. Chapter 4 contains a number of examples on how to calculate specific dehumidification loads referring to the Mollier hx-diagram and using the terms and quantities found in the diagram.

Table 1

THE MOLLIER HX-DIAGRAM QUANTITIES	
Air density (ρ)	The vertical orange axis to the extreme left. Read the air density by following the slanting orange lines in the diagram. Air density is the specific gravity measured in kg/m^3 .
Air temperature (t)	The vertical pink axis to the left with corresponding slightly slanting horizontal gridlines. Temperature is measured in $^{\circ}\text{C}$.
Enthalpy (h)	The purple diagonal lines. The enthalpy is the heat energy content of the air measured in kJ/kg air. Starting at $0^{\circ}\text{C}/0\% \text{ RH} = 0 \text{ kJ/kg}$.
Relative humidity (RH)	The green curved lines. The relative humidity is the proportion of actual water vapour pressure in the air expressed as a percentage (%) of the water vapour pressure at saturation.
Water content (x)	The horizontal light blue axis at the bottom. The actual water content of the air measured in g water/kg air .
Water vapour pressure (p)	The vertical blue axis to the right. The water vapour pressure measured in mbar is read to determine the partial water vapour pressure (rarely used when calculating the dehumidification load). - The brown diagonal line in the bottom half of the diagram is a help line used when determining the partial water vapour pressure.

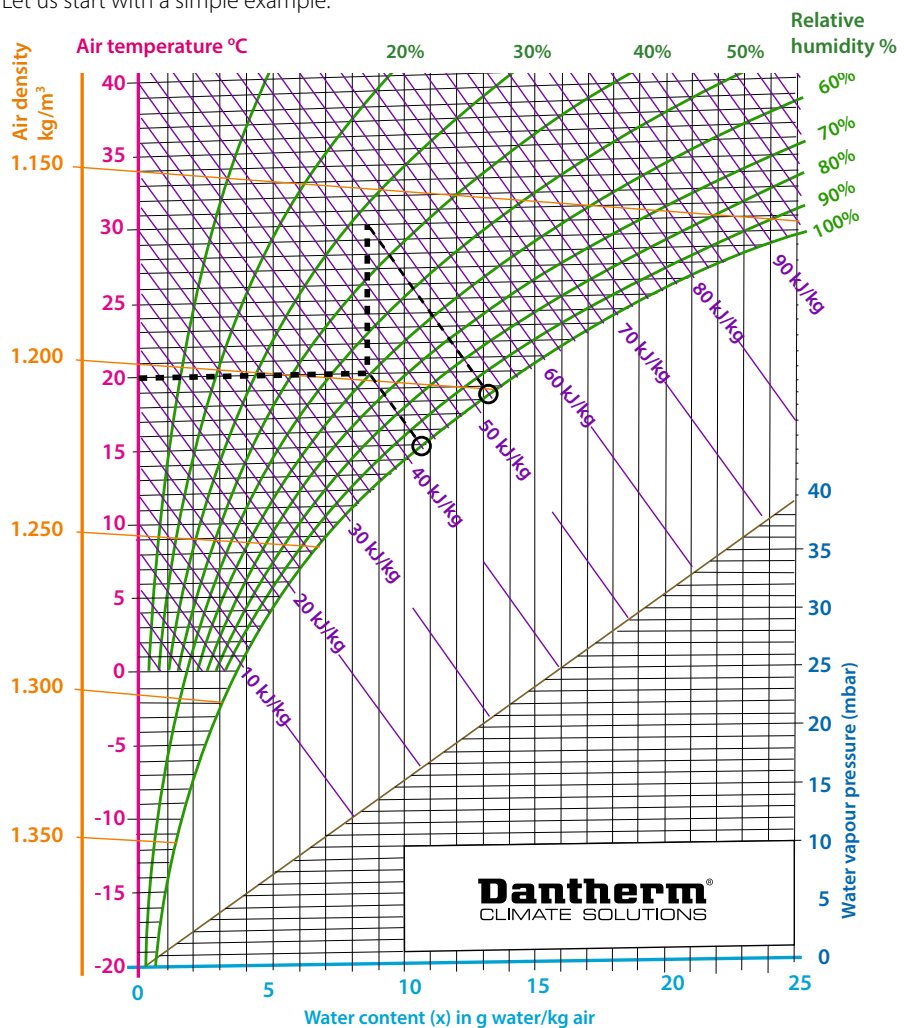
Note that the hx-diagram used throughout this booklet applies to an atmospheric pressure of 1.013 mbar.

3.1 Using the Mollier diagram

At first glance, the Mollier diagram may seem rather confusing with all of its curved, diagonal and slanting lines, but it is actually a quite easy and useful tool once you get the hang of it. Identify the easily measured temperature and the relative humidity of the air inside the room, and you are all set.

Example 3

Let us start with a simple example:



We want to calculate the enthalpy or heat energy needed to raise the temperature in a given room with a relative humidity of 60% RH from 20°C to 30°C.

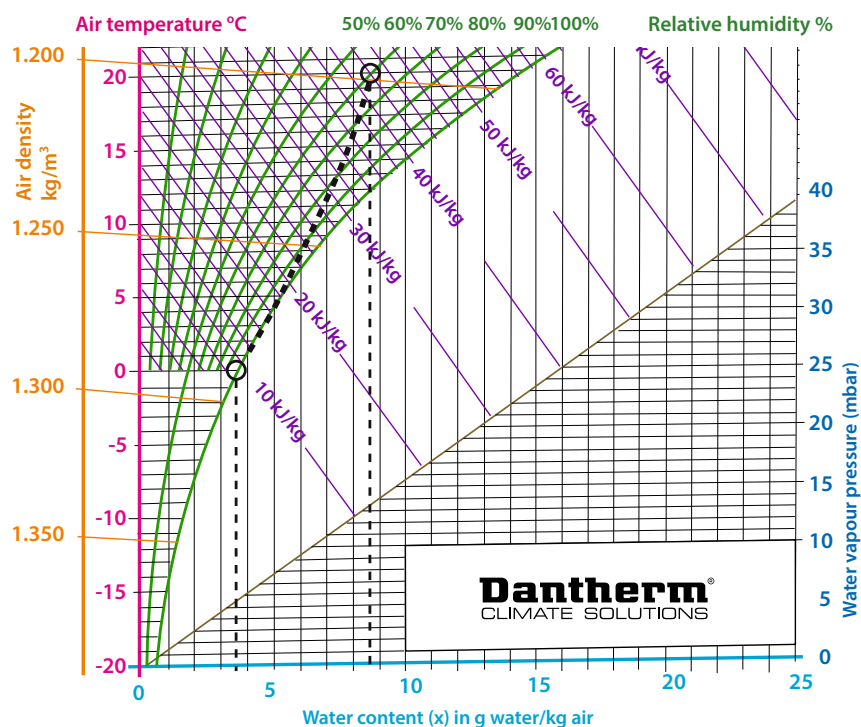
Start off by finding the 20°C point on the pink axis to the left. Now follow the slightly upward slanting horizontal gridline to the point where it crosses the 60% RH green curved line. If you follow the purple diagonal line to the point where it crosses the green 100% RH line, you will see that $h=42$ kJ/kg.

Now go back to the point indicating 20°C/60% RH. Raise the temperature vertically until you cross the 30°C gridline. You will notice that the relative humidity drops to about 35% in the process. But as we are interested in the enthalpy needed to raise the temperature to this point, you should again follow the purple diagonal line to the point where it crosses the green 100% RH line. Now you should get $h=52$ kJ/kg.

The rest is easy: $h = (52-42) = 10$ kJ/kg air heat energy must be added to the air in the room in order to raise the temperature from 20°C to 30°C.

Now let us have a look at the data found in example 1 on page 6. In this example, we established that on a hot dry summer's day in Denmark a drop from 20°C daytime temperature to 0°C nighttime temperature inside a 80 m³ room would result in almost a half a litre of water being condensed out of the air, and this water would form on cold surfaces.

Example 4



The condensation starts as soon as the temperature reaches the dew point. To establish the dew point at 20°C and 60% RH, find the 20°C point on the pink axis. Follow the gridline to the 60% RH point. Now go down the vertical gridline until it meets the green 100% RH line. From this point, follow the horizontal gridline to the left to read a dew point temperature of 12°C on the pink axis. Between this temperature and 0°C, the water content in the air will condense into water inside the room.

Now follow the vertical line from the 20°C and 60% RH point all the way down to the horizontal light blue axis at the bottom to read $x=8.5$ g water/kg air water content in the air. Do the same reading down from the 0°C and 100% RH which should read $x=3.5$ g water/kg air.

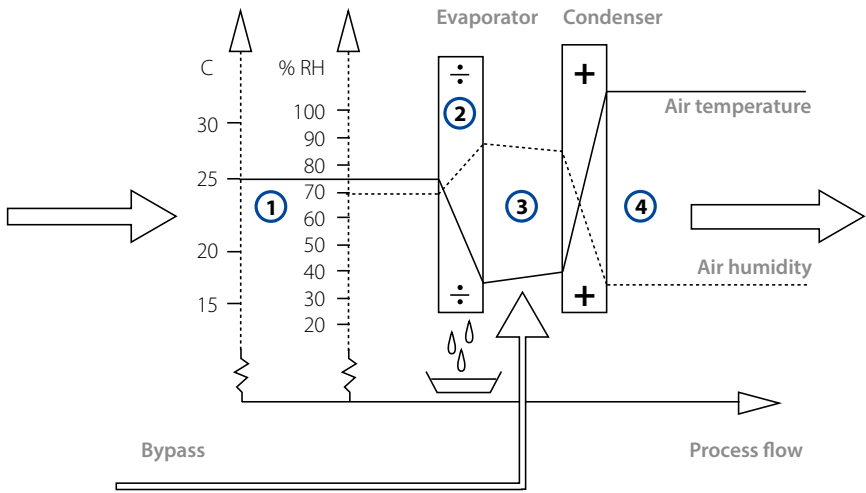
From these readings, you can easily calculate that 5 g water/kg air (8.5-3.5) has condensed and formed into condensation inside the room. In an 80 m³ room, this equals 0.48 litre.

Please note that if you want to show how the conditions of air changes during the drop from 20°C to 0°C, the curve will be deflected because condensation will start at the coldest areas in the room when the average RH value is about 85% RH.

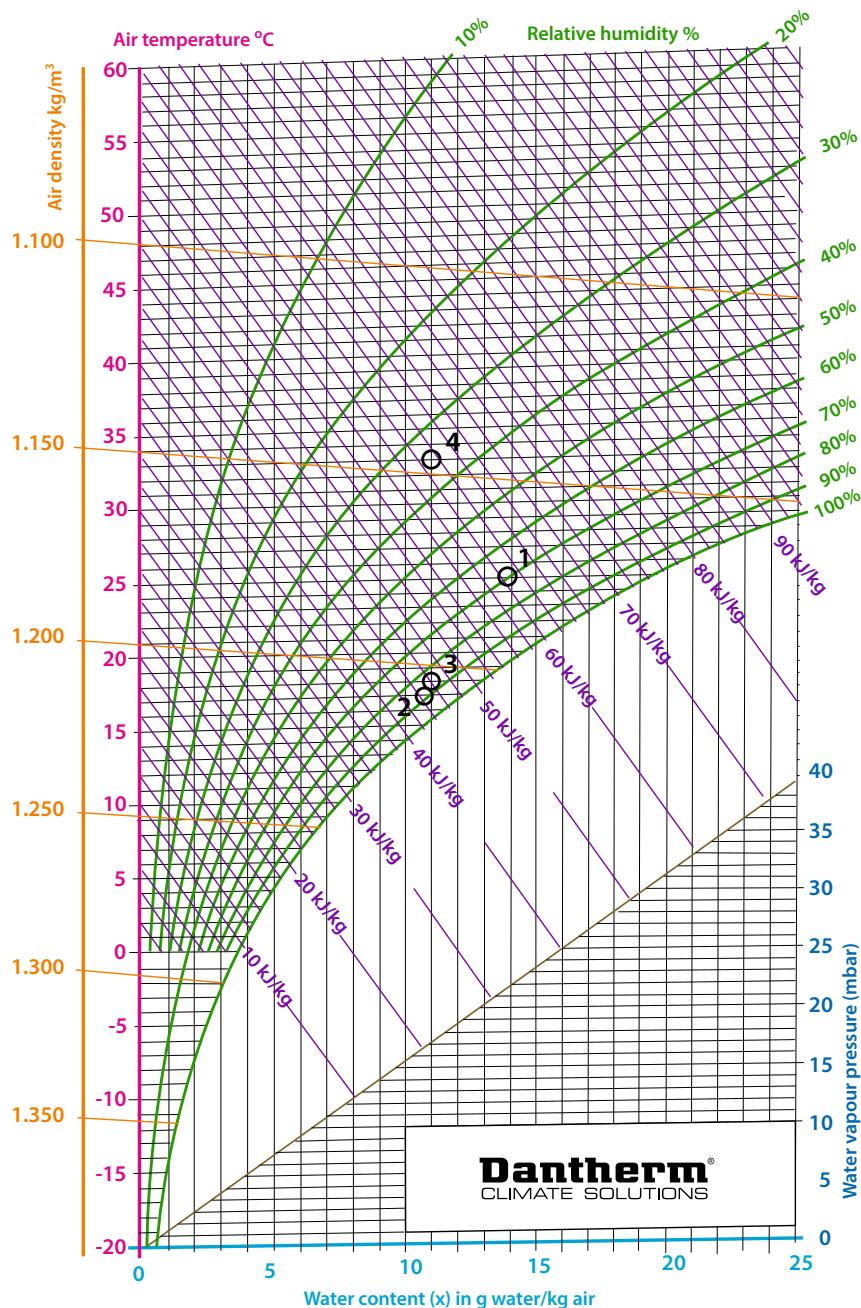
Example 5

In example 2 (page 8), temperature and airflow through a dehumidifier were described with this example.

TEMPERATURE AND RH VALUE		
1.	25°C	70% RH
2.	17°C	88% RH
3.	18°C	85% RH mixed air flow
4.	33°C	35% RH



If you put this data into a Mollier diagram, the 4 points read like this:



Notice the way the dew point shifts during the process.

These examples should give you the basic idea of how the hx-diagram works.

In chapter 4, we will put it to use in a number of examples on how to calculate the dehumidification load under various circumstances.

4

CALCULATING THE DEHUMIDIFICATION LOAD

After each example in this chapter, we will recommend a mobile dehumidifier from the Dantherm CDT range. These recommendations are based on the capacity curves found in chapter 5.

Humidity problems fall into two main categories. One category relates to problems mainly concerning excess water content in the air. In such cases, mobile dehumidifiers can help establish a comfortable indoor climate and/or preserve rare documents, books, artifacts and other precious materials at museums and archives, or they can protect electronics and machinery in offices and factories, or even the buildings themselves.

The second category concerns drying out the water content in different materials. Typically, this is a question of drying out building materials in connection with construction work or water damage. Mobile dehumidifiers can also be used as an alternative to costly stationary dehumidifiers in connection with production drying processes (drying wood, herbs, fur, hides, etc.).

It is important to distinguish between these two categories when determining which of the mobile dehumidifiers to use. Table 2 offers an overview of typical problems and where they tend to occur.

Table 2

PROBLEM	REQUIREMENT	TYPICAL LOCATION
Excess water content in the air	Establish good indoor climate	Office buildings, domestic properties, conference rooms
	Preserve and protect goods and materials	Museums and exhibitions, storage rooms for sensitive goods, water works, etc.
Excess water content in the materials	Dry out buildings	Construction site
	Repair water damage	Sites affected by floods, fires or burst pipes

4.1 Excess water content in the air

The humidity of the air affects both people, electronic equipment, machinery and various materials in the room. Table 3 is a list of limit RH values indicating when various negative effects of excess water content in the air set in. Please note that the values listed are merely indicative as there are situations in which even lower RH values might cause problems. For instance, you should keep the RH value below 40% when dealing with large cold surfaces.

ACTIVITY	RH VALUE
Dust mites start to propagate drastically	RH 45
Corrosion occurs, especially in aggressive atmospheres	RH 45
Hygroscopic materials absorb water and start to deteriorate (wood, paper, textiles, foodstuffs, etc.)	RH 45-50
Paper starts to thicken	RH 55
Corrosion becomes more progressive	RH 60
People start to feel uncomfortable at warm temperatures	RH 65
It becomes increasingly difficult for people to control their sweating at hot temperatures	RH 70
Dry rot and mould fungus start growing	RH 70

Table 3

In all cases concerning continuously high levels of relative humidity, we recommend identifying the root cause of the problem instead of just fixing the symptoms. Often, you will find ways to reduce or even eliminate the problem before applying mechanical dehumidification.

As demonstrated in the previous chapter, the Mollier-hx chart is an important tool in determining the desired temperature and RH value for a room or a building. However, you need to consider several parameters before calculating the required dehumidification load and choosing the right dehumidifier for the job.

Meteorological data

First, you have to get hold of some general meteorological information for your geographic area. Temperature and RH values change from region to region and they also vary quite a lot during the year. Statistics are available for most geographical areas and can be obtained locally (table 4 demonstrates how much outside conditions fluctuate during a year in Denmark). To ensure sufficient capacity, always use the worst case scenario figures for water content (July level for Denmark). Notice that even with a high RH value in a cold winter month, the water content of the air is relatively low, whereas the hot summer months normally constitute worst case scenarios with a relatively low RH value and high water content due to the fact that hot air holds more water.

Table 4

	Average temperature (°C)	Average humidity (% RH)	Water content (g water/kg air)
January	0	91	2.1
February	0	90	2.0
March	+2	89	3.0
April	+6	85	4.5
May	+11	79	6.5
June	+15	80	8.7
July	+17	83	10.0
August	+16	87	9.5
September	+13	90	8.3
October	+8	91	5.5
November	+4	91	3.7
December	+2	92	3.0

Room size

The size of the room or the building is an indirect influence factor as the amount of water in the air determines the required dehumidification capacity. To do that, you need to calculate the volume of the room in cubic metres to determine how much air it holds.

Air change

The air change, n , is very important as outside air contributes to both the temperature and RH values inside the room. Research has shown that most problems related to excess water content in the air are caused by air change problems.

You must determine or estimate how many times per hour the air of the room is changed. This ventilation might occur naturally because the room is not completely tight or it might be forced due to mechanical ventilation and by doors or windows being opened regularly.

The additional water content added to the room by the air change is measured in kg water/hour and calculated using this formula:

$$W(\text{ventilation}) = \rho * V * n * (x_1 - x_2)$$

W = g water/hour

ρ = air density (kg/m³) = the value commonly used is approximately

1.2 kg/m³ at 15-25°C

V = room volume (m³)

n = air change in the room (hour⁻¹)

x_1 = water content in the outside air (worst case) (g water/kg air)

x_2 = water content in the inside air at the required RH value (g water/kg air)

Other sources

Finally, you have to determine the humidity coming from people, processes, products and other sources.

Not all sources are applicable to every case, but the general formula is:

$$W(\text{total}) = W(\text{people}) + W(\text{process}) + W(\text{goods}) + W(\text{ventilation})$$

- W(people):

Water content contributed by people perspiring. (See Table 5)
- W(process):

Water content contributed by activities and processes inside the room i.e. production, cooking, washing, etc. and by open water surfaces inside water works, production facilities, etc. This contribution can vary quite a lot and must be determined in each case.
- W(goods):

Water content contributed by goods and products drying inside the room. Often, you can obtain information about this contribution from the supplier
- W(ventilation):

Water content contributed by the air changing allowing outside air to enter the room.

A word of caution

Normally, a temperature rise triggers an increase in relative humidity, enabling the dehumidifier to dry out the room faster. However, be cautious not to increase temperature too much too fast. Too high temperatures may dry out wooden ceilings, walls or floors too much and cause them to crack. And, a quickly increased temperature may trap humidity inside your building construction.

4.1.1 Establishing a good indoor climate

The key concern when establishing a comfortable indoor climate is to ensure a sufficient air change. In general, an air change of 0.5 per hour is recommended to provide a sufficient supply of fresh air, but in rooms with a large number of people, increasing the rate of air change may be required.

An equally important factor is the relative humidity in the room. Many people are allergic to dust mites, fungus and mould. These microorganisms thrive in humid air, but they cannot survive in relatively dry air. This is why you should maintain an RH value below 45% to ensure a healthy indoor climate.

Table 5

LEVEL OF ACTIVITY	Perspiration rate (g water/h for one person) at a room temperature of 20°C
Low	45
Medium	125
High	200



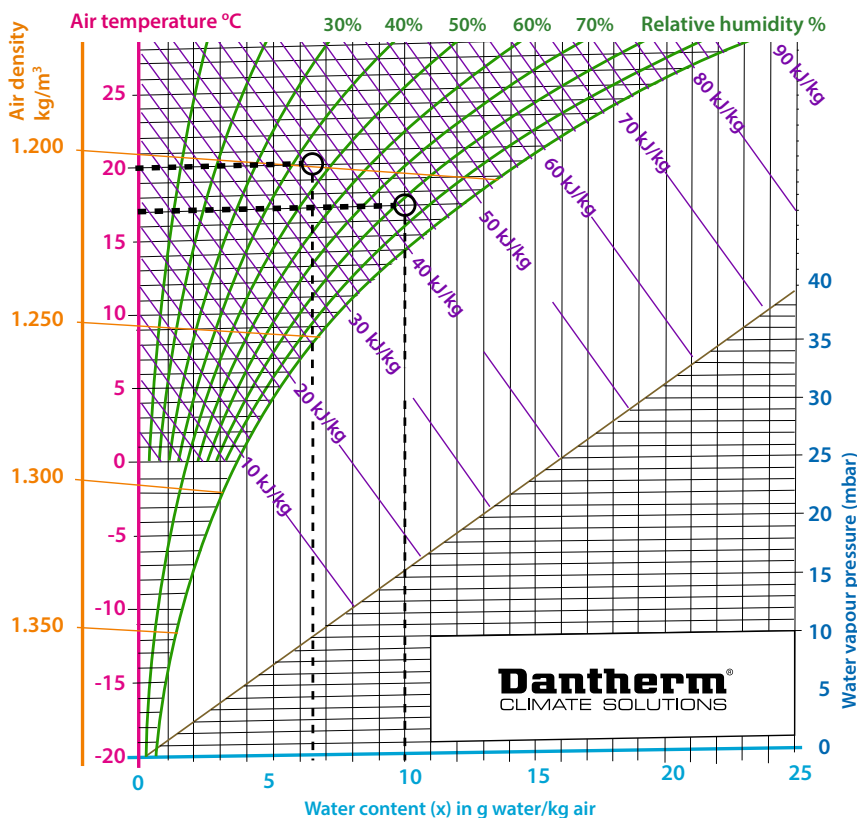
In general an air change of 0.5 per hour will ensure a low RH value, but as we have already seen, it really depends on a number of factors.

In the following example, 5 people are living in an ordinary residential room situated in Denmark. We want to calculate the required dehumidification capacity needed to establish an indoor climate with 20°C and 45% RH.

Example 6

The data:

Country:	Denmark
Room:	Ordinary residential room, average
Volume of the room:	300 m ³
Air change:	n = 0.5 pr. hour (See Table 6)
Air density	$\rho = 1.2 \text{ kg/m}^3$ (See hx-diagram)
Number of people:	5
Activity level:	Medium = 125 g water/hour/person (See Table 5)
Worst case situation:	$x_1 = 10 \text{ g water/kg air}$ (See Table 4)
Desired condition:	$t = 20^\circ\text{C}$ and 45% RH $\Rightarrow x_2 = 6.5 \text{ g water/kg air}$ (x_2 is found by using the hx-diagram)





The calculation:

$$W(\text{ventilation}) = 1.2 * 300 * 0.5 * (10-6.5) = 630 \text{ g water/hour}$$

$$W(\text{people}) = 5 * 125 \text{ g} = 625 \text{ g water/hour}$$

$$W(\text{total}) = 630 + 625 = 1,255 \text{ g water/hour}$$

In other words we need to remove 1.255 litre of water per hour from the air inside the room to establish and maintain the desired humidity and temperature.

Recommendation: Two CDT 60 units. Capacity: 0.7 litre/hour each unit at 20°C/45% RH (see capacity curve page 42).

4.1.2 Preserve and protect goods and materials

Humidity problems concerning the preservation and protection of goods and materials are typically a question of making sure the RH value never exceeds a predetermined level. Usually the room is a storage facility or a warehouse.

The quality of such storage rooms varies considerably. Often, they are either very well sealed off from the outside air or poorly insulated. In both cases, the air change is an important quantity. Table 6 illustrates the difference in air change in various rooms depending on the quality of the insulation.

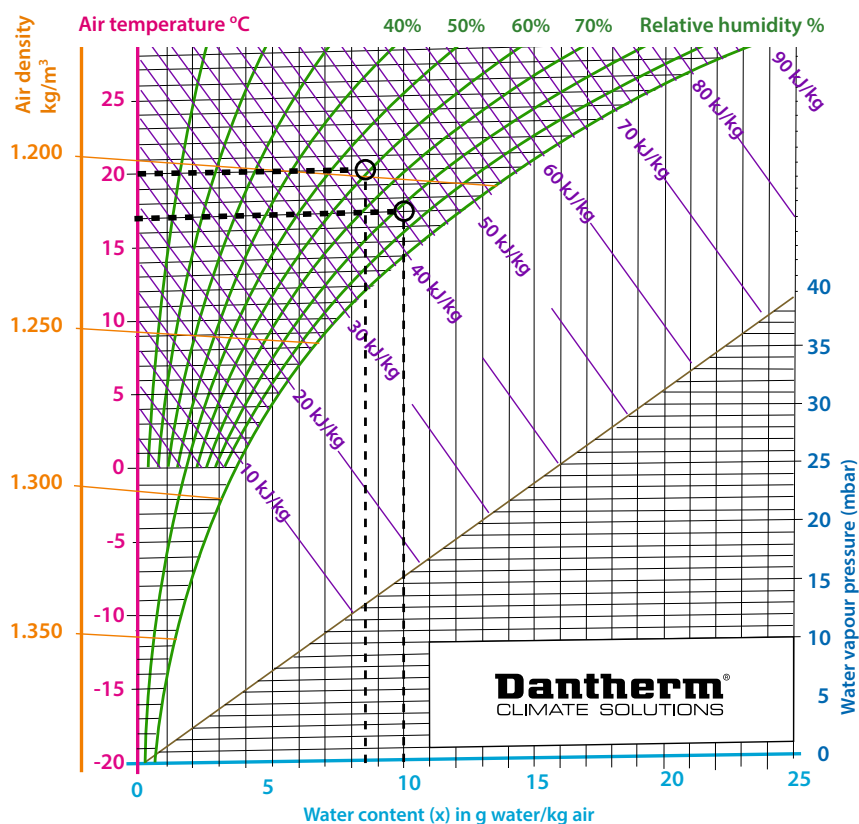
However, the air change is not the only parameter to take into account. Again, you must consider the humidity contribution from people, outside air, goods and possible processes inside the storage room.

Table 6

ROOM	Air change: n (hour -1)		
	Good	Average	Poor
Insulation quality			
Storage room	0.2	0.4	0.6
Normal residential property	0.3	0.5	0.8
Large storage room	0.1	0.3	0.7

Example 7

In this example, we have 100 m³ of completely dry goods stored in a 500 m³ large storage room that is poorly insulated. We want to ensure a temperature of 20°C and that the RH value stays below 60% RH.



The data:

Country:	Denmark
Room:	Storage room , poorly insulated
Volume of the room:	500 m ³
Volume of the stock:	100 m ³
Air change:	n = 0.6 pr. hour (See Table 6)
Air density	$\rho = 1.2 \text{ kg/m}^3$
Worst case situation:	$x_1 = 10 \text{ g water/kg air}$ (See table 4. July: $t = 17^\circ\text{C}$; $\text{RH} = 83\%$)
Desired conditions:	$t = 20^\circ\text{C}$ and $60\% \text{ RH} > x_2 = 8.5 \text{ g water/kg air}$ (See hx-diagram)

The calculation:

$$W(\text{ventilation}) = 1.2 \cdot (500 - 100) \cdot 0.6 \cdot (10 - 8.5) = 432 \text{ g water/hour}$$

$$W(\text{total}) = 0.432 \text{ litre water/hour}$$

Recommendation: CDT 30. Capacity: 0.54 litre/hour at $20^\circ\text{C}/60\% \text{ RH}$.

(See capacity curve page 40).



4.1.3 Waterworks

Humidity conditions at a waterworks can be quite extreme. Here, dehumidification is a question of protection and preservation of the water pipes, pumps and other equipment as well as the building itself.

If the relative humidity is too high, a large amount of condensation will form on all metal surfaces. Paint will peel off the water pipes and serious attacks of corrosion will set in. This increases maintenance costs and reduces the lifetime of the installations and the building.

The humid environment also accelerates the growth of fungus and mold. Mosquitos thrive in the humid atmosphere and deposit their eggs in the open water reservoirs, making it difficult to meet the hygienic requirements.

In most cases, the water temperature is 6-9°C. This means that the surface temperature of the pipes is roughly the same. To avoid condensation, the dew point temperature has to be lower than the surface temperature of the pipes.

Normally, you should maintain a temperature inside the waterworks that is at least 2°C higher than the water temperature. At the same time, you must keep the RH value at a relatively low level, and that requires dehumidification. Usually, ventilation is applied at waterworks. An air change between 0.1 - 0.3 times per hour is recommended.

In general, the temperature inside a waterworks will rarely exceed 16-18°C due to the cold water pipes and because part of the building is normally underground. This means that an RH value below 45% will suffice to avoid condensation all year round. Table 7 shows the max. RH value if the water temperature is 7°C at different room temperatures to avoid condensation.

Table 7

ROOM TEMPERATURE	°C	10	12	14	16	18	20
Max. RH value , water = 7°C	% RH	80	70	61	54	48	42

The total dehumidification requirement is determined by:

$$W(\text{total}) = W(\text{water reservoir}) + W(\text{ventilation})$$

$$W(\text{water reservoir}) = c * A * (x_{sa} - x_1)$$

W = g water/hour

c = constant empiric value 6.25 when the air temperature is min. 2°C higher than the water temperature

A = water surface area (m²)

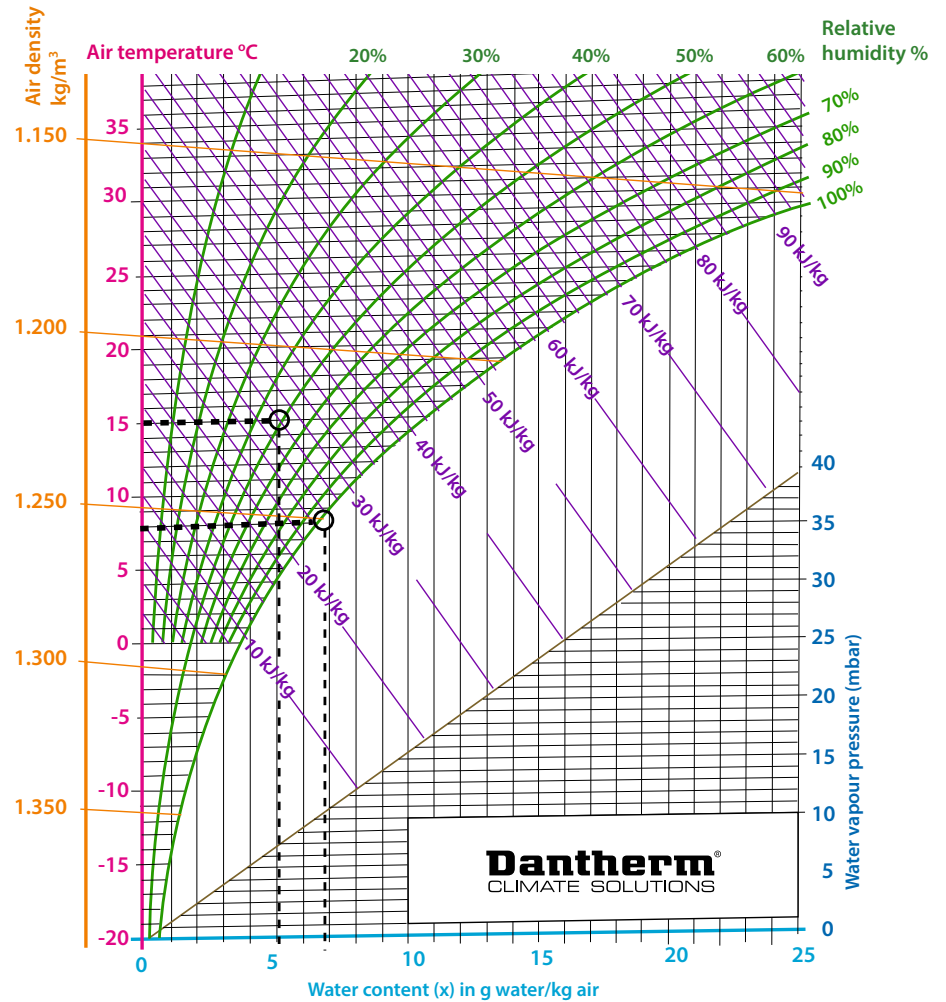
x_{sa} = water content in the saturated air at water temperature
(g water/kg air) at 100% RH.

x_1 = water content in the air at the desired RH value and temperature
(g water/kg air)

$$W(\text{ventilation}) = \rho * V * n * (x_1 - x_2) \text{ (see page 23 for further explanation).}$$

In this example we want to determine the dehumidification requirement of a waterworks with an air temperature of 15°C and a desired RH value 50% RH. The size of the waterworks is 300 m³, the water surface is 40 m² and the water temperature is 8°C.

Example 8



The data:

Volume of water works:	300 m ³
Air change rate:	0.3 pr. hour
Water surface :	40 m ²
Water temperature :	t = 6.8°C (and 100% RH)
Water content in the air at water temperature:	x _{sa} = 7 g water/kg air (see hx-diagram)
Desired condition:	t = 15°C and 50% RH > x _i = 5 g water/kg air (see hx-diagram)

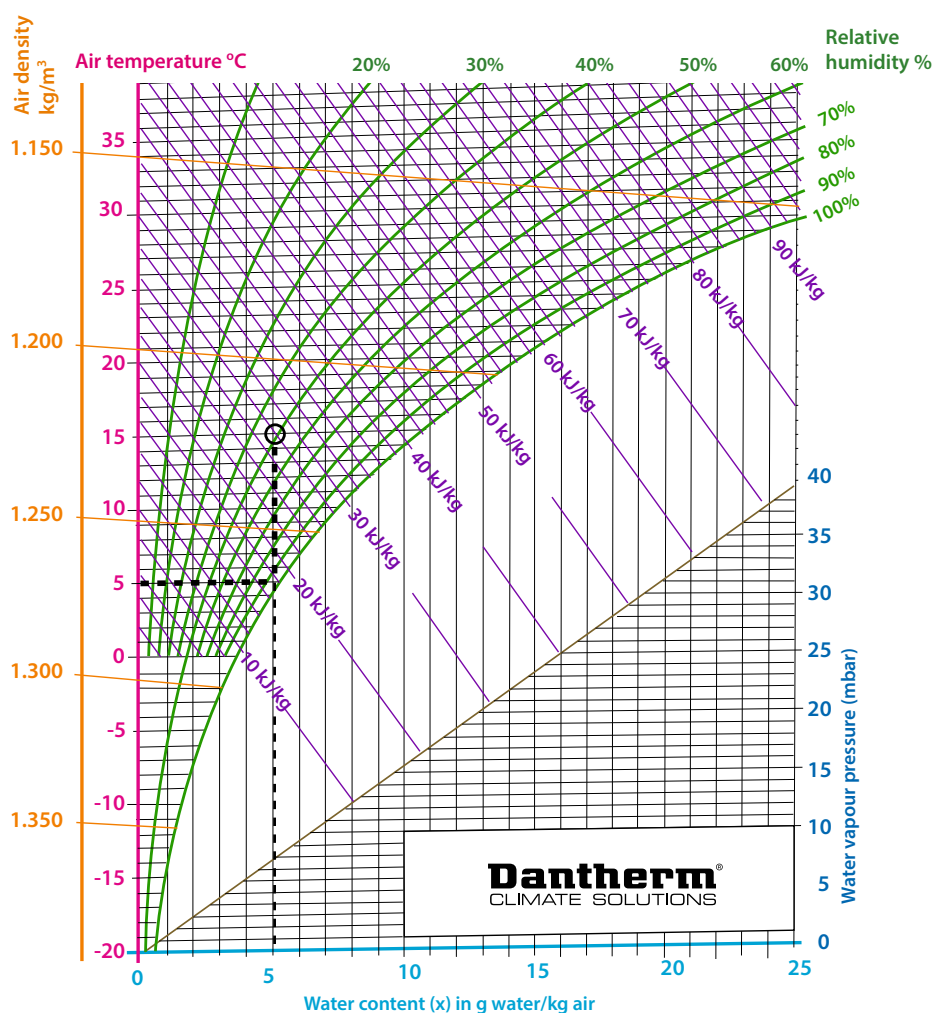
The calculation:

$$W \text{ (water reservoir)} = 6.25 * 40 * (7-5) = 500 \text{ g water/hour}$$

$$W \text{ (ventilation)} = \rho * V * n * (x_1 - x_2) = 1.2 * 300 * 0.3 * (10-5) = 540 \text{ g water/hour}$$

$$W \text{ (total)} = 500 + 540 = 1.04 \text{ ltr/hour}$$

The dew point temperature at 15°C and 50% RH is approximately 5°C according to the hx-diagram. This means that the surface temperature of the water pipes must drop below 5°C before condensation occurs on the pipes. If the temperature is 8°C, there will be NO condensation of water on the pipes as the actual water temperature is higher than the dew point temperature.



Recommendation: Two CDT 60 units. Capacity: 0.6 litre/hour per unit at 15°C/50% RH. As we have seen it is extremely important to have full control of the relation between temperature and RH value in this type of situation. To do so, we recommend that you equip each CDT 60 unit with a hygrostat set to 50% RH (see table 7) that automatically keeps temperature and humidity conditions at a level preventing condensation.

4.2 Excess water content in materials

In accordance with table 2 (page 20), dehumidification is mainly applied to dry out excess water content in materials in connection with construction work or water damage.

In case of water damage, the general rule is to apply dehumidification as soon as possible, but as the nature and extent of water damages varies considerably, it is necessary to assess the right approach from situation to situation.

An equally important parameter in case of water damage is how much time the water has had to penetrate the building structure, furnishings, etc. It is also essential to keep the air change as low as possible to avoid humid air from entering the room. The rules of thumb in the appendix will give you some directional empiric data to follow as it is often nearly impossible to calculate the 100% correct dehumidification requirement in a water damage situation.

In case of drying out a newly constructed building, you should also keep air change low, but the most important parameter to consider is the water content in the various materials used. Often, you have to meet a deadline, i.e. you only have a limited amount of time to get the job done.

4.2.1 Drying out buildings

Historically, construction work on an average building went on for 6-9 months and the building materials were usually dried out by natural ventilation by the time the building was finished. Today, however, construction work is very efficient and much faster. This means that dehumidification is required to remove the excess water in the various building materials before the building can be occupied.

When selecting a dehumidifier for drying out a building, you need to determine how much water to remove and the amount of time you have to do it.

This can be a difficult task. Sometimes, you can estimate the amount of water in the building materials using tables. Please note that in relation to drying out a newly constructed building, it all comes down to the specific building materials used for walls, floors and roofs. The water content of various building materials differ so much that a simple rule of thumb is unworkable. Please refer to table 8 and example 9, page 33.



Table 8

WATER CONTENT OF DIFFERENT BUILDING MATERIALS (KG/M ³)				
Material	At start of project	Water chemically bound	Desired condition by 50% RH	Water to be dehumidified
Wood	80	-	40	40
Tile, roof	10	-	10	0
Brick, wall	80	-	10	70
Lightweight concrete	100 - 200	-	20	80 - 100
Concrete K 15 II	180	42	38	100
Concrete K 25 II	180	57	46	77
Concrete K 40 II	180	71	51	58

Source: Fukthandbok, AB Svensk Byggtjänst, Stockholm

Example 9

In this example, we want to calculate the dehumidification capacity required to dry out excess water from a newly constructed building in 30 days. The building is 2.4 m high, 7 m wide and 16 m long. The walls and ceiling are made from pre-dried wood. The floor, however, needs to be dried out as it is made from 10 cm thick concrete, K 40 II.

The data:

Period:	30 days
Drying condition:	t = 20°C and 50% RH (average between starting humidity at 60% RH and ending at approx. 40% RH)
Volume of building:	$2.4 * 7 * 16 = 268.8 \text{ m}^3$
Materials:	Concrete K 40 II, 10 cm (see table 8)

The calculation:

Concrete volume to be dehumidified:

$$V = 16 * 7 * 0.1 = 11.20 \text{ m}^3$$

Water content in concrete floor:

$$Q = 11.20 * 58 \text{ kg water/m}^3 = 649.6 \text{ kg water}$$

We need to remove 649.6 L water in 30 days:

$$W = 649.6/30 = 21.65 \text{ L/24 hours}$$

We need a dehumidification capacity of 21.65 L/24 hours.

Recommendation: CDT 40. Capacity: 0.70 litre/hour at 20°C/50% RH. One CDT 40 will remove 16.8 L/24 hours. This means that two CDT 40 units should do the job.

Note that the drying process is quickest in the beginning as the water content is very high when you start the process. As the RH value decreases, the overall dehumidification capacity will also decrease.

4.2.2 Guidelines for the drying process

When dehumidification is used to dry out buildings and materials, the dehumidifier runs continuously. The relative humidity is gradually lowered, allowing further evaporation from the damp materials in the room. The amount of evaporation depends on the temperature of the room, the materials and the humidity of the air.

One of the advantages of condense drying is that the drying process is stable and gentle. If time is not a crucial factor, the optimum dehumidification process is achieved by maintaining 20°C and approximately 40% RH in the room. This way, you maintain a perfect balance between the dry air in the building and humid building materials, avoiding surface drying and cavitation as well as damage to pre-dried materials such as parquet floors.

Add heat if necessary, but keep in mind that forcing the drying process might be harmful. It creates a risk of surface drying and cavitation that only dries surfaces, leaving a lot of humidity inside the wall behind the dry surface. This prolongs the drying period as the humidity will not easily penetrate the dry surface. Surface drying also involves the risk of cracks appearing in the surfaces of walls, ceilings and floors.

It is important that the room/building is as sealed as possible. Also, make sure that the building is well protected against rain and snow. You need to ventilate while painting inside the building, but remember to seal the room or building properly when it is empty. Moreover, remember to avoid pre-dried materials absorbing water because of open windows.

If the air change inside the room is not controlled, fluctuating ambient temperature and humidity conditions make it hard to control the drying process. In the winter, the cold outside air normally contains a minimum of water and the humidity is not likely to increase much even if the air change is considerable. Energy consumption, however, will increase dramatically as you need to heat up the cold incoming air. In the summer, the water content could be quite high and you will have to remove even more water from the building or room if it is not sealed off adequately.

In most cases, the humidity is concentrated in cellars and in areas where water is being used in the construction work such as painting or concrete mixing. Set up your dehumidifiers where they do most good.

4.3 Drying out water damage

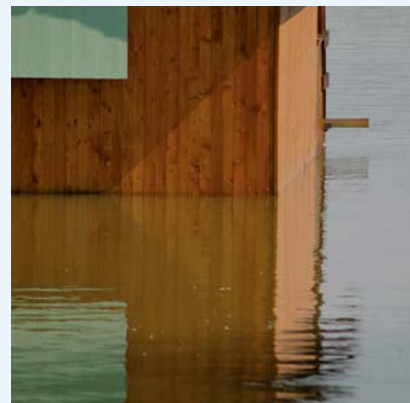
As mentioned earlier, it is difficult to give exact guidelines on how to approach a water damage situation, as both the nature and extent of water damage can vary considerably. However, there are some general points that you should always take into consideration.

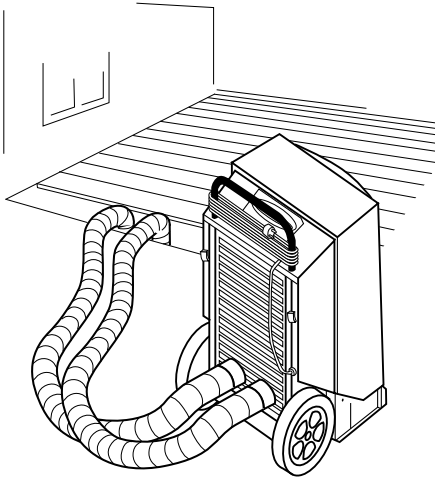
It is essential to contain the damage by sealing off the afflicted area as quickly as possible to avoid outside air or other sources adding humidity to the room. This way, you only have to deal with the water already in the room.

It is equally important to remove the moisture as quickly as possible. In most cases it is beneficial to add heat to the room to increase the evaporation. This is especially true if the water damage occurred recently and the water has not had time to penetrate deeply into furniture, walls, floors and other parts of the building structure.

If the water has had time to penetrate deeply into the building structure you need extended dehumidification capacity for quick results.

Empirical values are essential to ascertain the required dehumidification load. Please see the rules of thumb in the appendix.





Drying out water damage under the floor

4.3.1 Water damage under floors

Underfloor water damages often require you to tear up the flooring to replace the wet insulation. This is a time-consuming, troublesome and costly process because the damaged area becomes virtually useless for the duration of the repair work.

Oftentimes, a dehumidifier equipped to add heat to the process such as the CDT 30S and CDT 40S will spare you the time-consuming and costly inconvenience of having to break up all the flooring.

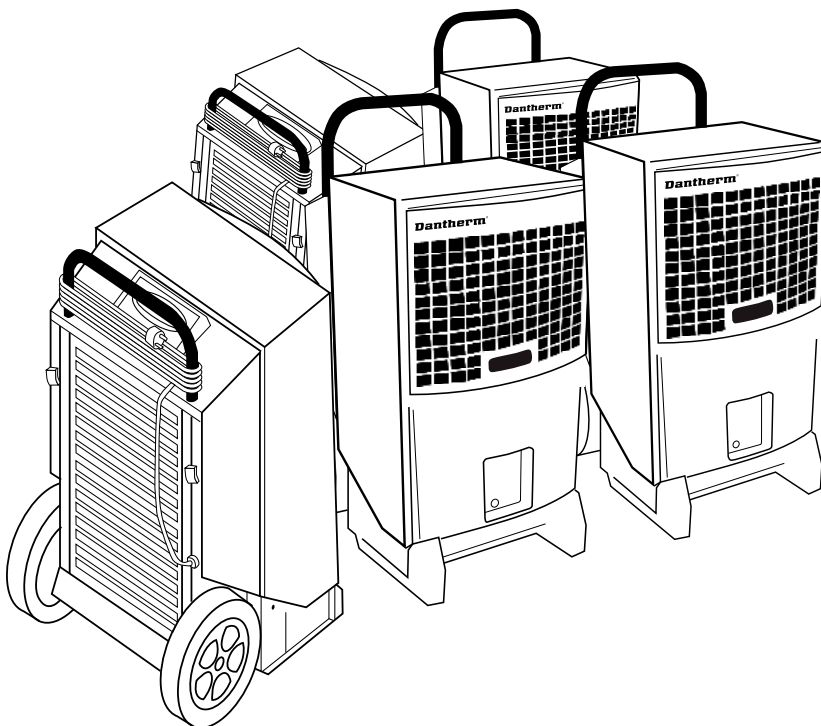
Hot dry air is fed underneath the floor at one end by means of ducts from the 1 kW heater of the dehumidifier. To ensure sufficient air supply, the length of the ducts should not exceed 5 metres. The hot air continuously feeds through a hole at the other end, evaporating water from the insulation and taking up moisture as it passes under the floor. This allows you to use the room above the afflicted floor while the insulation is being dried out.

The theoretical calculation involved is extremely difficult. You are advised to use empirical values and the rules of thumb found in the appendix.





CDT display



In the previous chapters, we have covered the principles of dehumidification. We have also established the theoretical background needed to calculate the required dehumidification capacity for any given situation.

In this chapter, we would like to present the features and advantages of the Dantherm CDT range as well as the specifications and diagrams needed to select the right dehumidifier for the job.

5.1 Sophisticated control

Our range of mobile high-performance CDT dehumidifiers is designed for user-friendly control, handling and transport.

The digital touch control display is conveniently placed on top of the dehumidifier. Offering easily accessible settings and clearly visible data readouts during and after operation (please note that older versions of Dantherm CDTs do not feature digital display and control. Instead, they are equipped with an hour meter and indicator lamps for operation, full water container and failure alerts).

The display shows the exact room temperature, relative humidity, total running hours and total energy consumption. The integrated battery backup allows you to see total hours and kWh when the dehumidifier is switched off.

The control panel also offers easy access to setting parameters of the built-in hygrostat.

Finally, the control panel lets you set a service interval for the CDT unit. When it is time, the display will read "SERVICE" to alert you to keep your CDTs in perfect working order. The digital control also offers self-diagnosis and faultfinding features to identify the most common sources of malfunction.

5.2 User-friendly design

Special care has been put into the design features facilitating handling and transportation. A mobile dehumidifier should be sturdy enough to withstand rough use and frequent transportation being hauled in and out of vehicles. The heavy-duty protective cover and robust construction of the CDT product range ensures a long lifetime even under harsh working conditions.

Positioning of the CDT is important. You should always allow a space of at least 60 cm between the intake and the wall and no less than 300 cm for the outlet. Never place the unit near a heat source.

To ensure optimal positioning in all situations, all CDTs are equipped with large rubber wheels and (except CDT 90) adjustable handles. This makes the units surprisingly easy to move, even up and down stairs and across seemingly impassable areas.

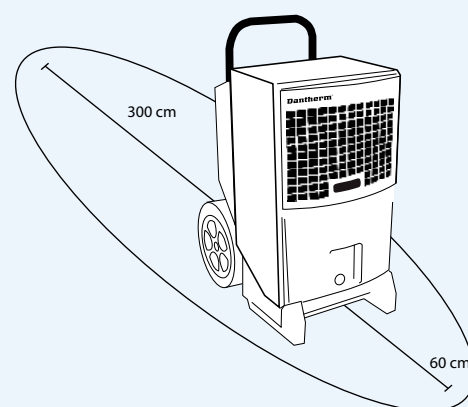
Low weight and optimum weight distribution make handling and transport even easier. Furthermore, the CDTs are designed for stacking, so they take up as little space as possible during transportation and storage. During operation, you will appreciate both the low noise level and the easy-to-empty water container.

5.3 Energy efficiency

The capacity of a mobile dehumidifier is obviously your main concern, but energy consumption is almost equally important. Special care has been taken to make every CDT unit as energy efficient as possible to minimise overall dehumidification costs.

Table 9 offers a quick overview of the specific energy consumption for the CDT range at different temperature and RH values. SEC = actual power consumption/capacity in litres/hour measured as kWh/l. The digital display of the unit shows a calculated readout of the kWh used for your dehumidification tasks (not MID-approved for billing).

$$SEC = \frac{kW}{l/h} = \frac{kWh}{l}$$



Positioning of the CDT

	Dehumidification capacity at 20°C/60% RH	Dehumidification capacity at 30°C/80% RH	Air volume	Operating range humidity	Operating range temperature	Specific energy consumption SEC, 20 °C & 60% RH	Specific energy consumption SEC, 30 °C & 80% RH	Power consumption, 20 °C & 60% RH	Noise level – 1 m from the unit	Water container	Weight
	l/24h	l/24h	m ³ /h	%RH	°C	kWh/L	kWh/L	W	dB(A)	l	kg
CDT 30 MK III	15.1	31.9	250	40-100	3-35	0.85	0.47	461	56	7	31
CDT 30S MK III	14.4	34.4	350/300*	40-100	3-35	0.86	0.43	456	60	7	33
CDT 40 MK III	18.4	43.5	350	40-100	3-35	0.66	0.50	614	59	14	40
CDT 40S MK III	18.6	43.5	560/460*	40-100	3-35	0.83	0.47	664	62	14	43
CDT 60 MK III	28.4	65.0	725	40-100	3-35	0.67	0.43	800	62	14	46
CDT 90 MK III	37.0	86.5	1,000	40-100	3-35	0.71	0.42	1,214	62	-	62

Table 9

* first figure is free exhaust, second figure is with 5 m hose.

5.4 Latent heat

When considering the total energy consumption involved in using a dehumidifier, you should also take into account the considerable amount of heat emitted from the condenser during operation. In isolation, this saves energy because that does not have to be supplied from other energy sources.

Let us use a CDT 30 running at 20°C and 60% RH as an example. According to table 9, it takes 461W to dehumidify 0.54 litre/hour (see capacity curve, page 40). The 461W of energy is transformed into heat and helps warm the surroundings.

The heat energy resulting from condensing 1 litre of water from the air at 20°C, equals approx. 680Wh, thus the heat of evaporation (latent heat) from a CDT 30 amounts to $680 \times 0.54 = 367\text{W}$. In total, this means that the dehumidifier supplies $461 + 367 = 828\text{W}$ heat to the room. This heat causes the temperature of the dehumidifier outlet air to be a few degrees higher than the intake air.

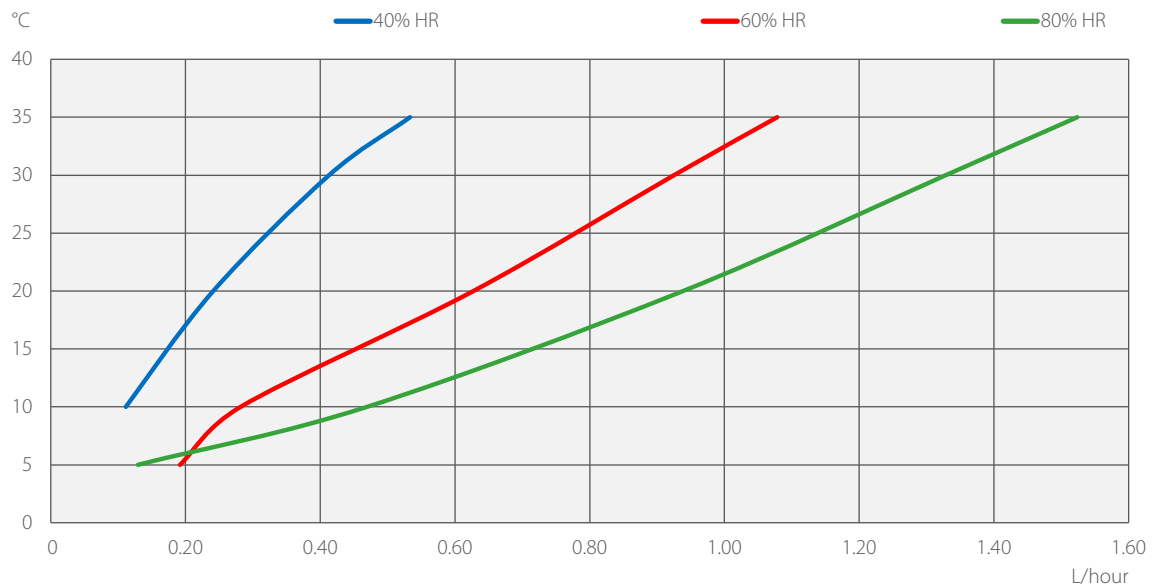
Example 2 on page 8 shows an increase of 8°C in the air temperature as a result of the dehumidification process. For in-depth technical specifications and optional accessories, please consult the data sheets for the individual units in the CDT range, available from Dantherm A/S.

5.5 Selecting the right dehumidifier

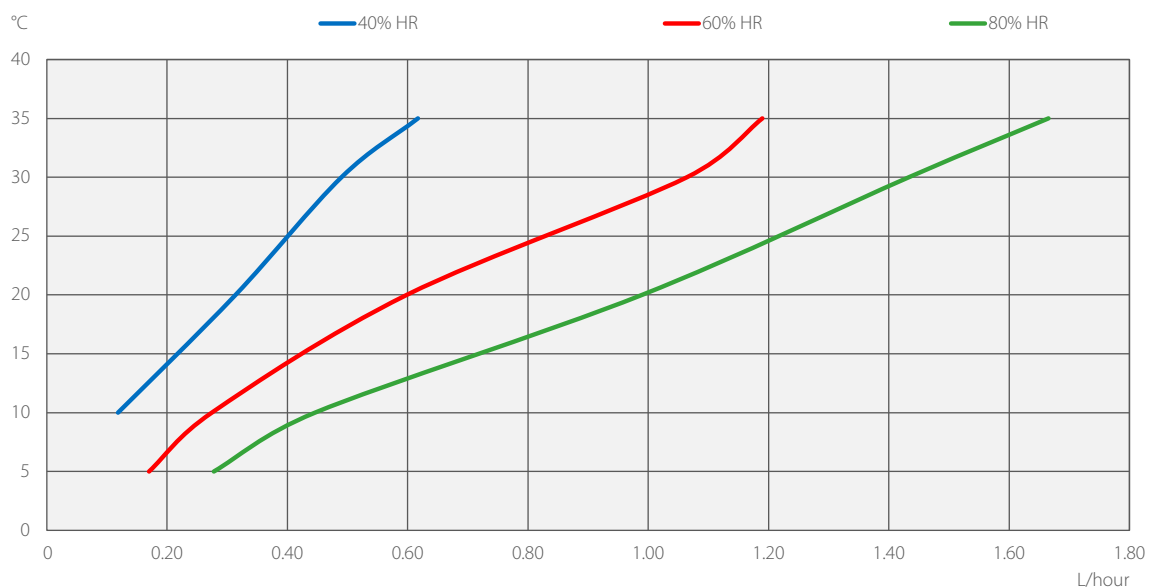
The capacity diagrams in this chapter are the key to selecting the right dehumidifier for a specific task. Always choose a dehumidifier with a capacity equal to or slightly higher than the calculated necessary dehumidification capacity.

There is a diagram for each unit in the CDT range. The three curves in the diagram show the capacity at 40, 60 and 80% RH respectively. Values for 50 and 70% RH, etc. are found using linear interpolation between the curves.

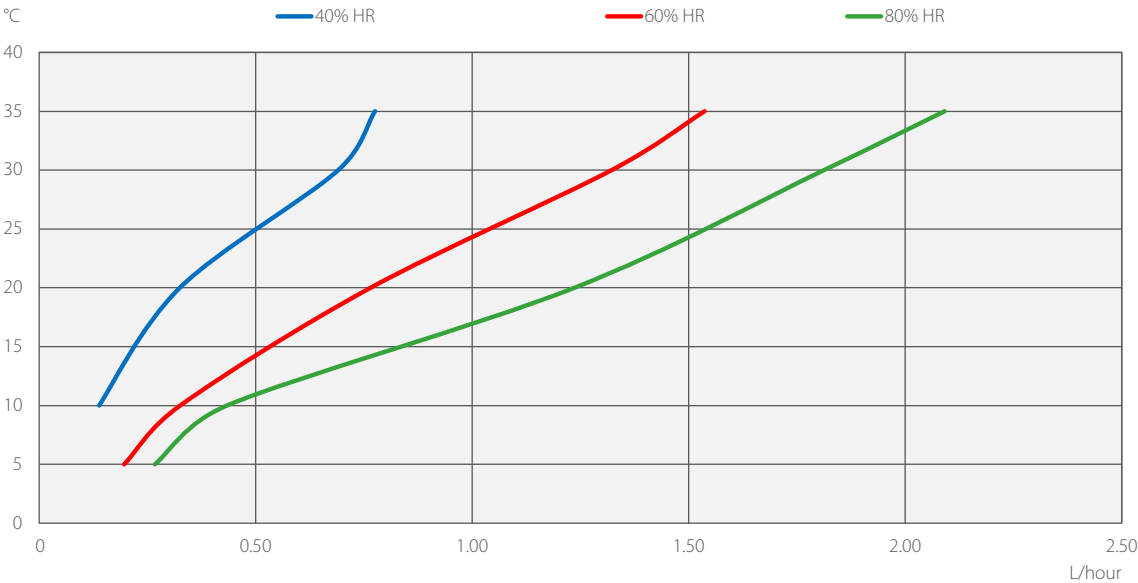
CDT 30



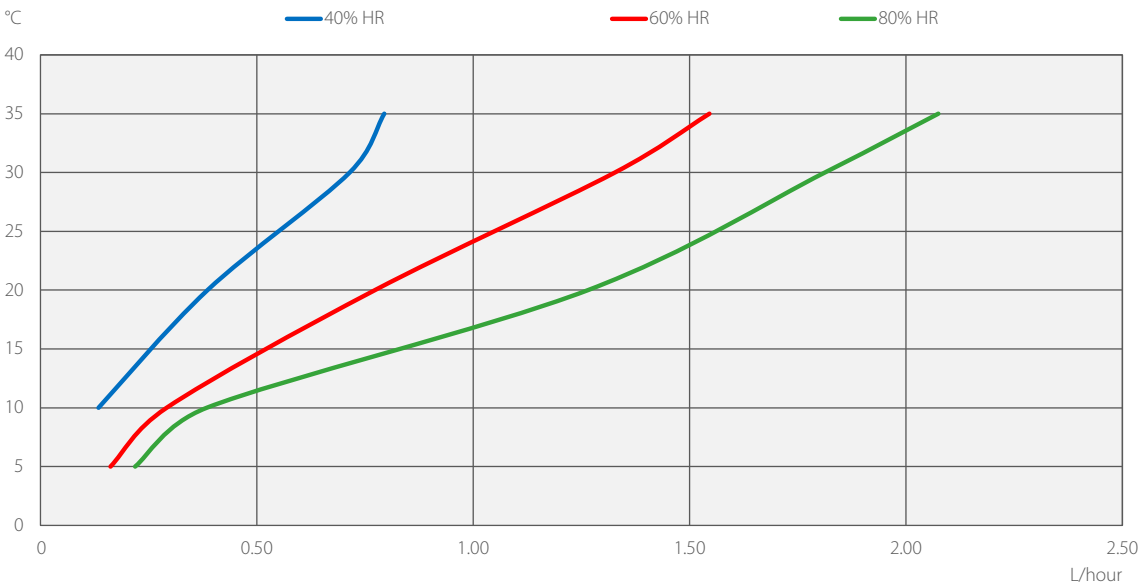
CDT 30 S



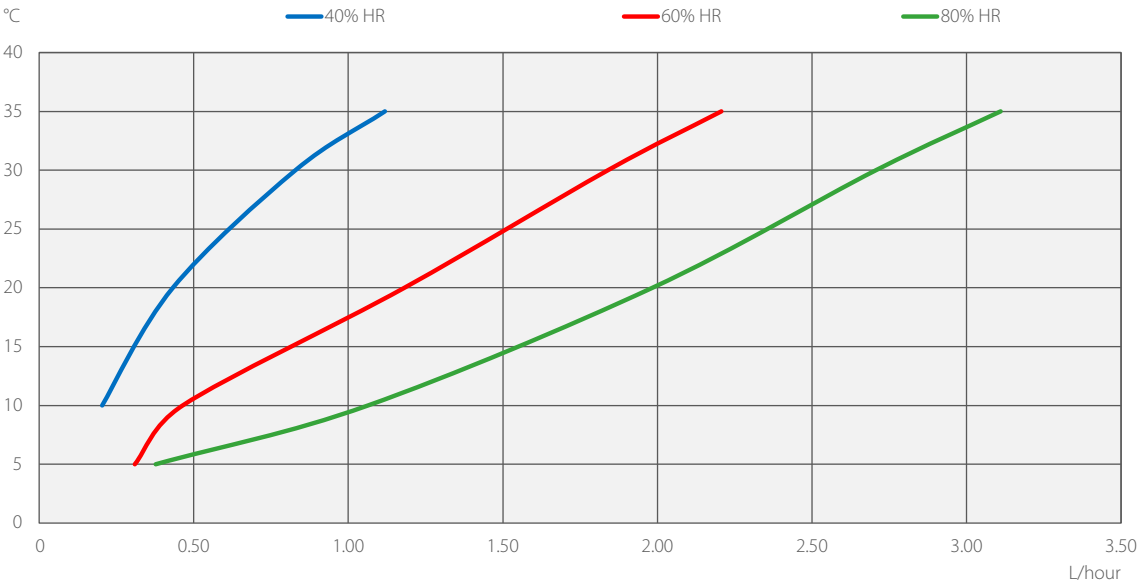
CDT 40



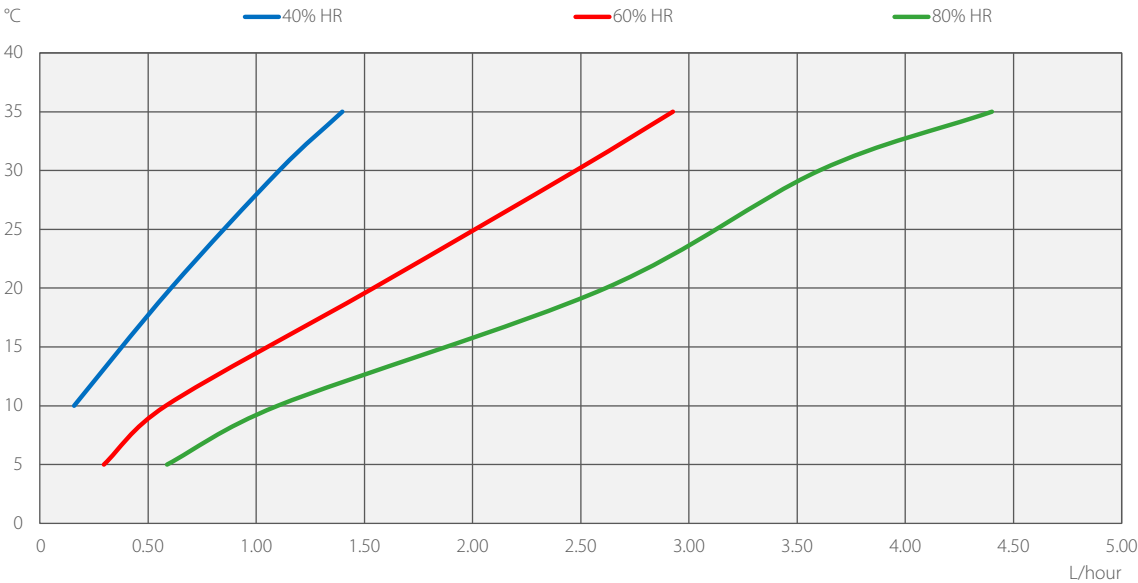
CDT 40 S



CDT 60



CDT 90



APPENDIX

Quick Reference Guide – rules of thumb

Often, it is not strictly necessary to perform all the extensive calculations described in this guide. Experience allows you to use some shortcuts when selecting a mobile dehumidifier. This empirical data is presented in the table below with easy rule-of-thumb formulas referring to the problems solved in the examples given in the guide.

W refers to the amount of water drawn from the air in g/hour.

V refers to the volume of the room in m³.

PROBLEM	REQUIREMENT	TYPICAL LOCATION	ASSUMED AIR CHANGE RATE	RULES OF THUMB
Excess water content in the air	Establish good indoor climate	Office buildings, domestic houses, conference rooms, etc.	0.5 pr. hour	$W = V * 2.0$ (g/hour)
	Preserve and protect goods and materials	Museums and exhibitions, storage rooms for sensitive goods, water works, etc.	0.3 pr. hour	$W = V * 1.2$ (g/hour)
Excess water content in the materials	Repair water damage*	Floods, fires, burst water pipes, etc.	As low as possible	$W = V * 4.0$ (g/hour)

* Based on a drying period of 8-12 days

Please note that concerning drying out a newly constructed building it all comes down to the specific building materials used for walls, floors and roofs. The water content of various building materials differ so much that a simple rule of thumb would not make sense. Please refer to Table 8 and Example 9, page 33.

1. Establishing a comfortable indoor climate

If the desired RH value is to be approx. 50% RH use this formula:

$$W = V * 2.0 \quad (\text{g/hour})$$

Example: $V = 500\text{m}^3 > W = 2.0 * 500 = 1,000 \text{ g/hour}$.

Recommendation: Two CDT 40 units. Capacity: 0.65 litre/hour at 20°C/50% RH.

2. Preserve and protect goods and materials

If the desired RH value is to be approx. 50% RH use this formula:

$$W = V * 1.2 \quad (\text{g/hour})$$

Example: $V = 450 \text{ m}^3 > W = 1.2 * 450 = 540 \text{ g/hour}$

Recommendation: CDT 40. Capacity: 0.65 litre/hour at 20°C/50% RH

3. Repair water damage

Assuming a drying process of 8-12 days and an average condition of $t = 20^\circ\text{C}/50\% \text{ RH}$ (starting at 60% RH ending at 40% RH), use this formula:

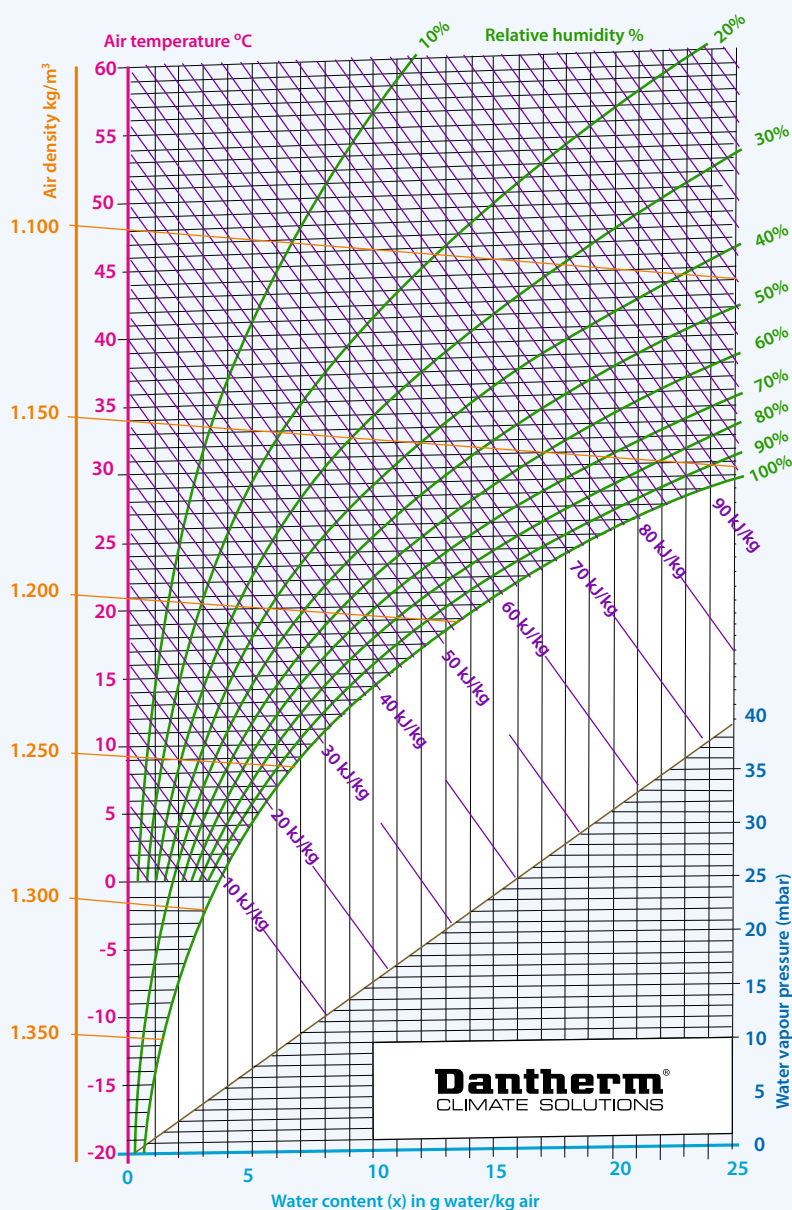
$$W = V * 4.0 \quad (\text{g/hour})$$

Example: $V = 280 \text{ m}^3 > W = 4 * 280 = 1,120 \text{ g/hour}$

Recommendation: Two CDT 40 S units. Capacity pr. unit: 0.60 litre/hour at 20°C/50% RH. We recommend that you use S-models with extra air volume and built-in 1kW heaters to force the evaporation and speed up the dehumidification process when dealing with water damage.

ROOM VOLUME (V)	CDT 30 (S)	CDT 40 (S)	CDT 60	CDT 90
< 200 m ³	2 units	1 unit	1 unit	1 unit
200 - 300 m ³	3 units	2 units	2 units	1 unit
300 - 500 m ³	5 units	3 units	3 units	2 units
500 - 750 m ³	7 units	4 units	3 units	2 units

Mollier hx-diagram



The Mollier hx-diagram quantities

Air density (p)	The vertical orange axis to the extreme left. Air density is the specific gravity measured in kg/m ³ .
Air temperature (t)	The vertical pink axis to the left. Temperature is measured in °C.
Enthalpy (h)	The purple diagonal lines. Enthalpy is the heat content of the air measured in kJ/kg air. Starting at 0°C/0% RH = 0 kJ/kg.
Relative humidity (RH)	The green curved lines. The relative humidity is the proportion of actual water vapour pressure in the air expressed as a percentage (%) of water vapour pressure at saturation.
Water content (x)	The horizontal light blue axis at the bottom. The actual water content of the air measured in g water/kg air.
Water vapour pressure (p)	The vertical blue axis to the right. The water vapour pressure measured in mbar is read to determine the partial water vapour pressure (rarely used when calculating the dehumidification load). The brown diagonal line in the bottom half of the diagram is a help line used when determining the partial water vapour pressure.

Definitions

Air change n (hour⁻¹)

The air change is measured as the number of times the air inside a room is exchanged by outside air per hour.

Air density p (kg/m³)

The specific gravity of the air. The air density decreases as temperature increases. Empirical value commonly used is 1.2 kg/m³ at 15-25°C.

Air temperature (°C)

The air temperature corresponds to the average temperature of the room. In certain cases, it is advisable to measure the air temperature close to cold surfaces as this is where condensation starts.

Condensation

The process of water vapour turning into liquid water. This happens at the dew point temperature. (See below).

Defrosting

The evaporator inside the dehumidifier runs cold enough for ice to form and accumulate on the surface (it is after all the same principle that applies to a refrigerator). Defrosting is the automatic process that removes the ice from the evaporator.

Dew point temperature

The specific temperature at which moisture starts condensing on cold surfaces.

Enthalpy h (kJ/kg air)

The heat content of the air. Enthalpy is defined as 0 kJ/kg air at 0°C.

Evaporator

The cooling surface inside the dehumidifier. It cools the air well below its dew point temperature and drains the water into a container. The name relates to the process going on inside the evaporator, where the liquid refrigerant is evaporated into hot gas by the heat taken out of the air.

Hygrostat

Optional accessory that enables the dehumidifier to work only within a set RH range.

Mollier, Richard (1863 – 1935)

Professor at Dresden University who pioneered the hx-diagram – a graphical chart of the relationship of temperature, pressure, enthalpy, entropy and volume of steam and moist air, which has since aided the teaching of thermodynamics to many generations of engineers.

Relative Humidity (RH %)

Term used to describe the quantity of water vapour in a gaseous mixture of air and water. Relative humidity is defined as the ratio of the partial pressure of water vapour in a gaseous mixture of air and water to the saturated vapour pressure of water at a given temperature.

Specific Energy Consumption (SEC)

SEC = actual power consumption/capacity in litres per hour measured as kWh/L. See page 38.

Water content in the air W (g water/kg air)

The actual amount of water in the air coming from W(people), W(process), W(goods), W(Ventilation).

1 kg water = 1L water

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