Dantherm®
Air Handling

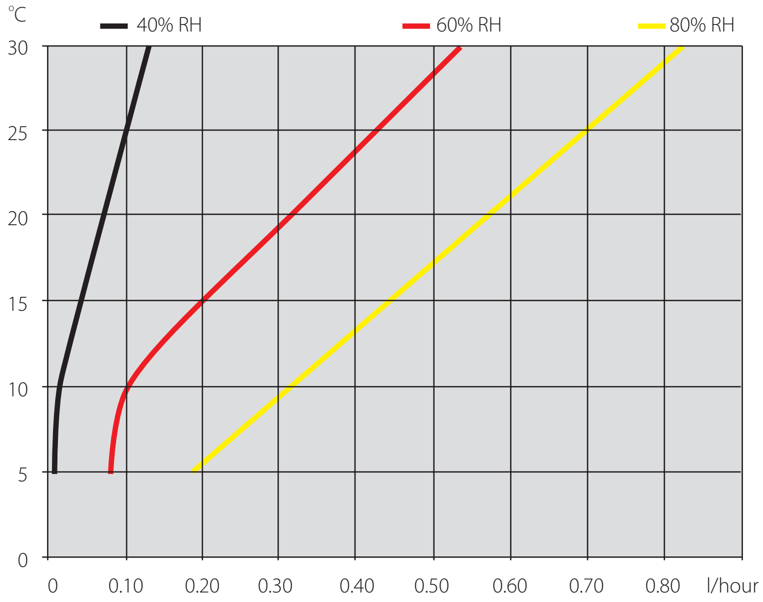
# Selection Guide

for mobile dehumidifiers


Dantherm®
CDT 20

# Contents

# 0. Preface



In order to choose the right mobile dehumidifier from the Dantherm Air Handling 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 20) to find one that is suitable for the job. You will find the capacity curves for all of the mobile dehumidifiers in the Dantherm Air Handling CDT range in Chapter 5.

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

This dehumidifier guidebook, however, aims to give you a working knowledge of the functional principles of dehumidification and the theoretical background you need to calculate the required dehumidification load in any given situation.

Quick and easy dehumidification is essential in buildings that have fallen victim to damage caused by floods, fires, etc. The same applies to construction work where an effective means of drying out brick or concrete walls can successfully speed up the building process. Occasional need for dehumidification or drying out in production and storage facilities is also easily taken care of with the CDT range.

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

Dantherm Air Handling. September 2007.

# 1. Why do we need dehumidification?

The need for efficient dehumidification is not just restricted to neither water damage, construction work, production processes, swimming pools and 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 are much better insulated than before. The insulation might keep out the cold, but it also reduces the air change and traps humidity. A sure sign is dew on on windows, which 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.

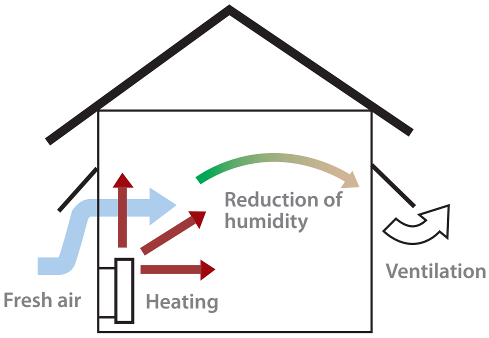
In all these instances you need to lower the relative humidity of the air. This can be achieved by different methods.

**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 a 80 $m^3$ 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 is 5 g water/kg air or close to half a litre of condensed water in an 80 $m^3$ room. This could cause all sorts of serious problems.

### 1.1 Heating and ventilation

Warm air holds more moisture than cold air, and for centuries the traditional method for reducing humidity was based on this fact.



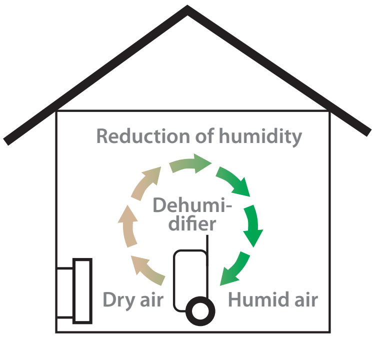
In the traditional method fresh air is taken into the room and heated up to ensure that it holds more water. Then the air is ventilated out of the room to reduce the humidity. This process is continued until the desired conditions are achieved.

During the last few decades this method of heating and ventilating has become more and more obsolete. It is an obviously very energy consuming and uneconomic solution as the heat is – often literally – thrown out of the windows. Furthermore the air taken into the room contains its own relative humidity prolonging the process depending on the time of year, the outside temperature and weather conditions.

This is why high energy prices have made dehumidification the preferred economic solution all over the world.

### 1.2 Dehumidification

The basic principle of dehumidification assumes that the room is closed. No or at least very little outside air should be allowed to enter 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 to the traditional method of heating and ventilation.

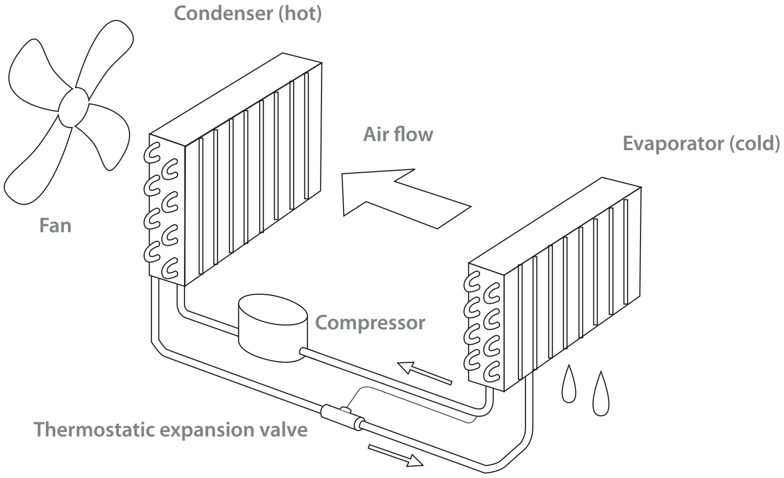


Besides the obvious advantages of lower energy consumption, the dehumidification process is much easier to control as long as the room stays closed.

### 1.3 Advantages of condense drying

- reduced energy consumption
  (approx. 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?

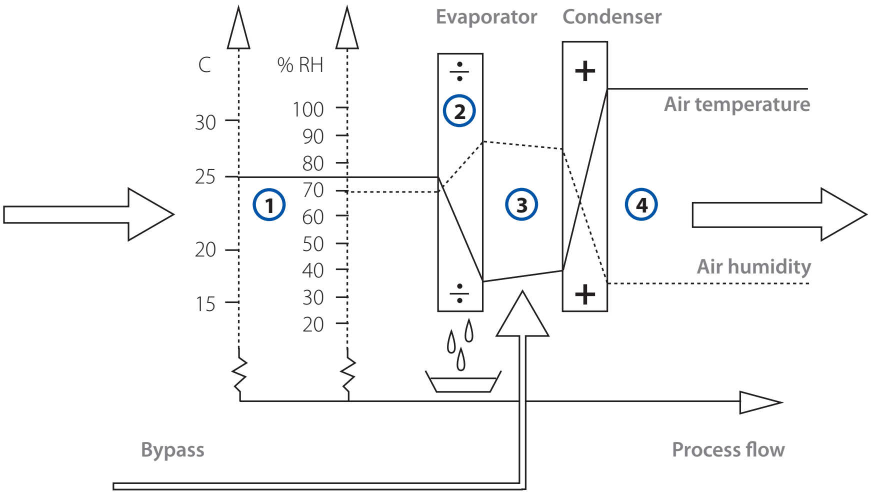


The basic functional principle of a condense drying dehumidifier is really quite simple. A fan draws in humid air and carries it through a refrigerated evaporator. The air is cooled well below its dew point. The water condenses on the cold surface of the evaporator and drips into a water container or 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

| 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 |

### 2.1 Temperature and airflow



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%, resulting in condensation and the water is dripping off into a container.

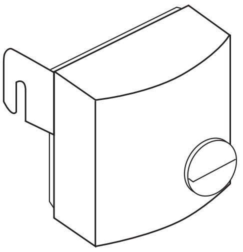
To remove all of the water water even with relatively dry air conditions, it is important that not all the air is cooled down by the evaporator as there is a risk that the dew point cannot be fully achieved. Instead only part of the air is led through the evaporator to ensure maximum condensation while the rest is by-passed as shown above. 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

If for some reason the dehumidifier only needs to be working within a given range of RH-values a hygrostat can easily be connected to the dehumidifier.

Set the degree of relative humidity required. The hygrostat stops the dehumidifier when the required RH-value is reached, and automatically starts it up again if the relative humidity of the air increases above the desired RH-value.

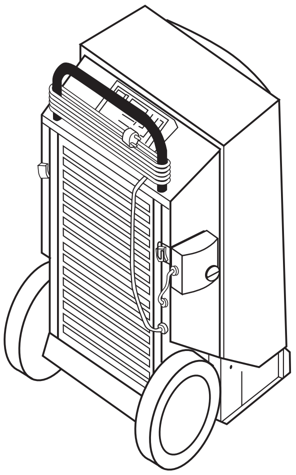


*Hygrostat*

### 2.1.2 Temperature control

If the room temperature is outside the operating range (3-30°C) the dehumidifier stops. It starts up again automatically when the room temperature is once again 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.



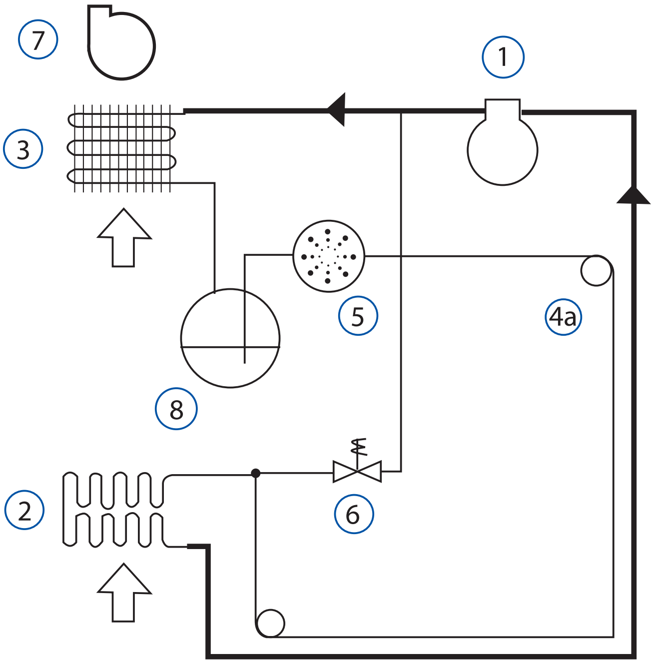
*CDT with hygrostat*

## 2.2 Principal functionality of the various components

**CDT 30, 30 S, 40, 40 S**

### With capillary tube

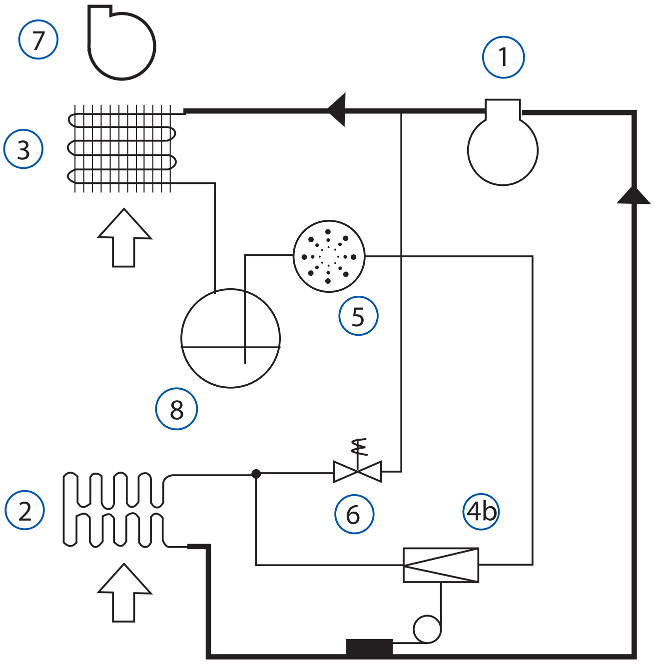
| | |
|---|---|
| 1: | Compressor |
| 2: | Evaporator |
| 3: | Condenser |
| 4a: | Capillary tube |
| 5: | Liquid line drier |
| 6: | Solenoid valve |
| 7: | Fan |
| 8: | Receiver |



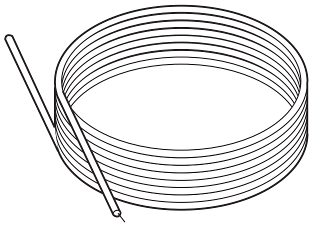
**CDT 20, CDT 60 and CDT 90**

### 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 |

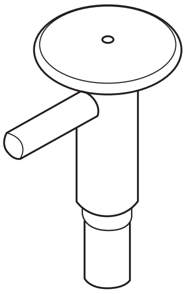


The compressor (1) takes hot gas from the low pressure side and presses it into the condenser (3). The fan (7) draws the cold air from the evaporator (2) through the condenser (3) where it is heated up by the hot gas. In this process the gas is cooled down and ends up as liquid in the receiver (8).
The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



*Capillary tube*

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.



*Thermostatic expansion valve*

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

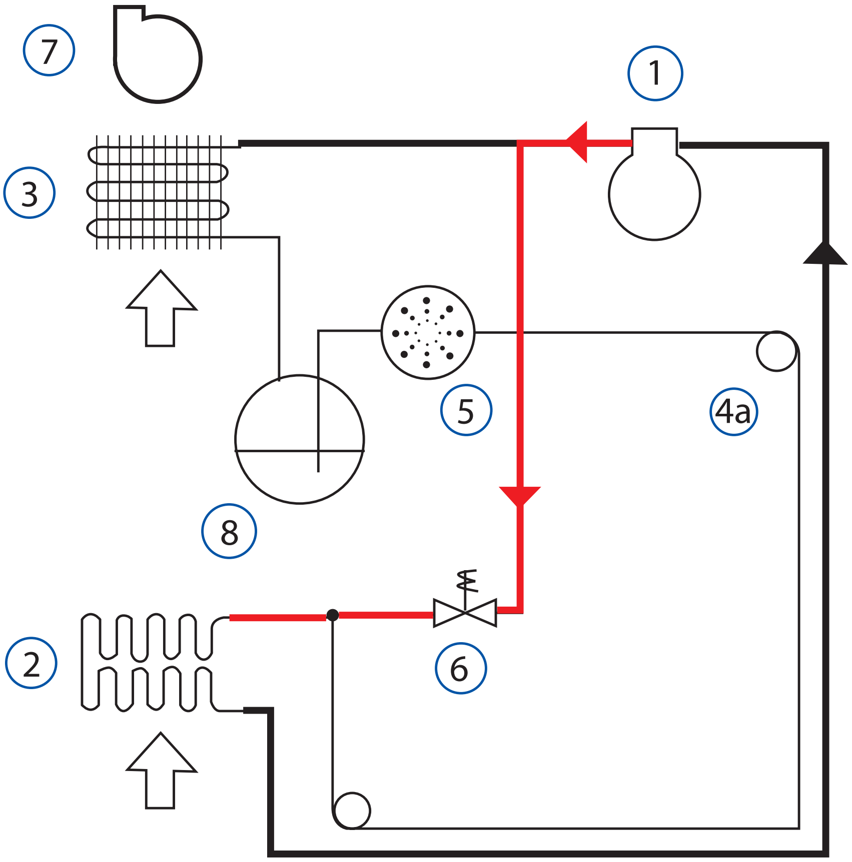
The thermostatic expansion valve is a dynamic resistance. The sensor provides feedback to the valve, causing the valve to open a little or vice versa. If the evaporator does not get sufficient refrigerant the sensor temperature will increase, causing the valve to open a bit and vice versa.

Compared 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 it the better solution when it comes to larger dehumidifiers, but it is a more expensive solution and no significant difference in performance is achieved when using it in smaller units.

## 2.3 Defrosting

Depending on the room temperature and the RH-value of the air, the evaporator will run very cold. In general lower air temperature means lower 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.

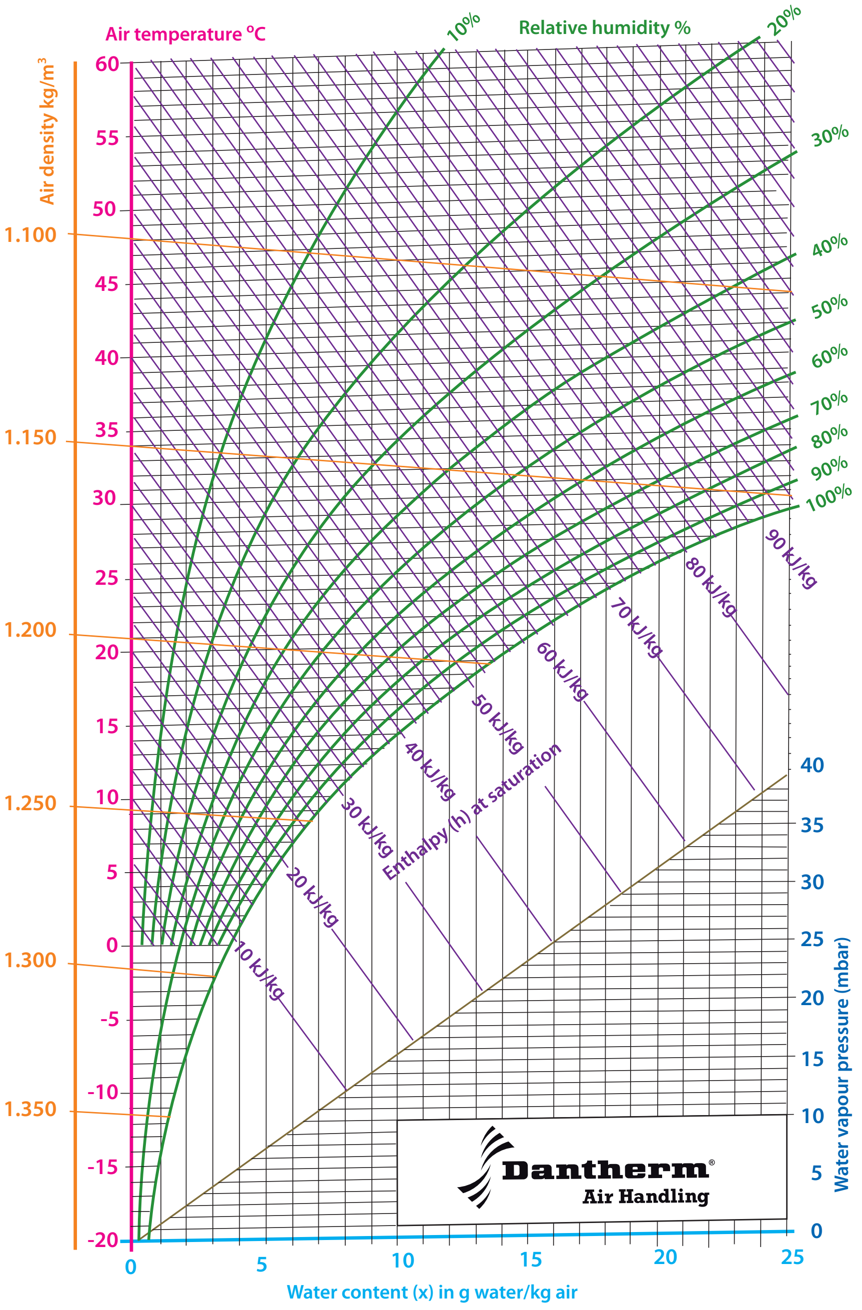


**1: Compressor**
**2: Evaporator**
**3: Condenser**
**4a: Capillary tube**
**5: Liquid line drier**
**6: Solenoid valve**
**7: Fan**
**8: Receiver**

When the set temperature of 5°C is reached on the surface of the evaporator a timer is activated and after 30 minutes the solenoid valve (6) opens, and hot gas starts to flush to the evaporator, efficiently melting the ice on the surface. When the set temperature is reached the solenoid valve closes and the system returns to normal active mode again.

# 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 the key to determing the various parameters required to calculate the dehumidification load required under any given circumstance.

This is an introduction to help you understand how this basic tool works. In Chapter 4 you will find a number of examples of how to calculate specific dehumidification loads refering 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.<br>Temperature is measured in °C. |
| **Enthalpy (h)** | The **purple** diagonal lines. The enthalpy is the heat energy content of the air measured in kJ/kg air.<br>Starting at 0°C = 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 the water vapour pressure at saturation. |
| **Water content (x)** | The horizontal **light blue** axis at the bottom.<br>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 humidification load). - The **brown** diagonal line in the bottom half of the diagram is a help line used when determining the partial water vapour pressure. |

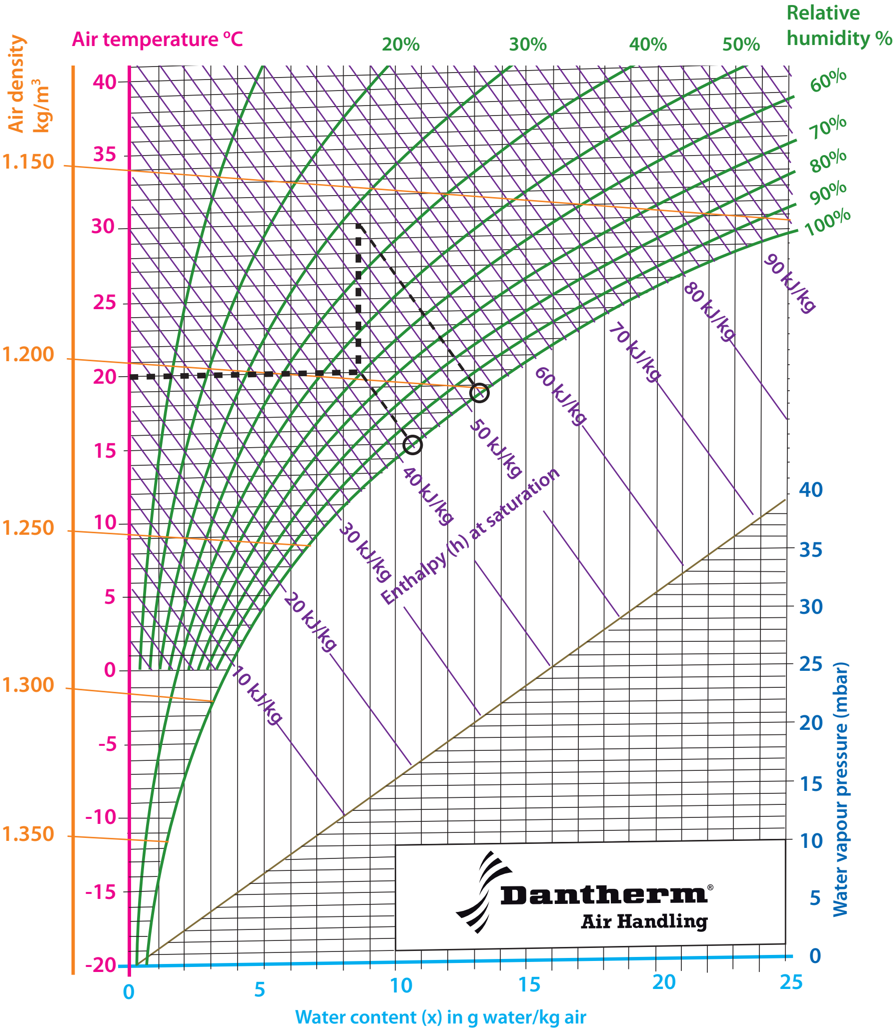
Note that the hx-diagram used throughout this booklet applies to an atmospheric pressure of 1.013 mbar.

### 3.1 Using the Mollier diagram

When you first look at the Mollier diagram it might appear rather confusing with all its curved, diagonal and slanting lines, but it is actually a quite easy and useful tool once you get the hang of it. Actually all the data you need is, the easily measured temperature and the relative humidity of the air inside the room.

**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.

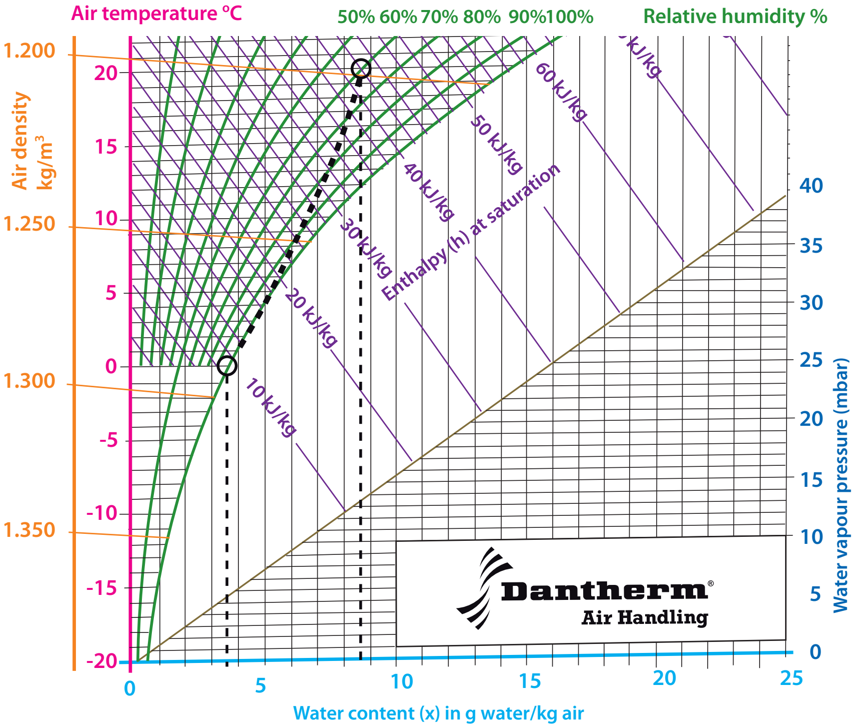
Start off by finding the 20°C point on the pink axis to the left. Now follow the slightly upward slanting horizontal gridline to the point where it crosses the 60% RH green curved line. If you follow the purple diagonal line to the point where it crosses the green 100% RH line you will see that h=42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

**Example 4**

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 nightime temperature inside a 80 m$^3$ 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.



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.

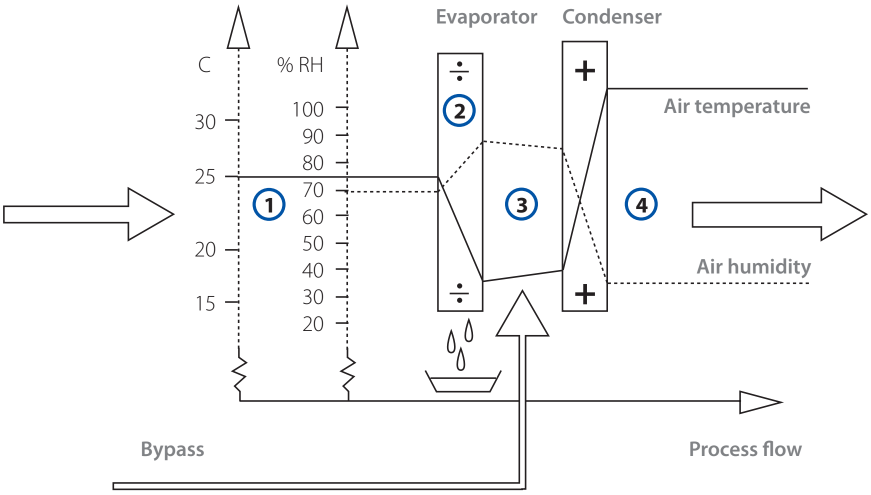
From these readings you can easily calculate that 5 g water/kg air (8.5-3.5) has condensed and formed into condensation inside the room. In an 80 $m^3$ room this equals 0.48 litre.

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

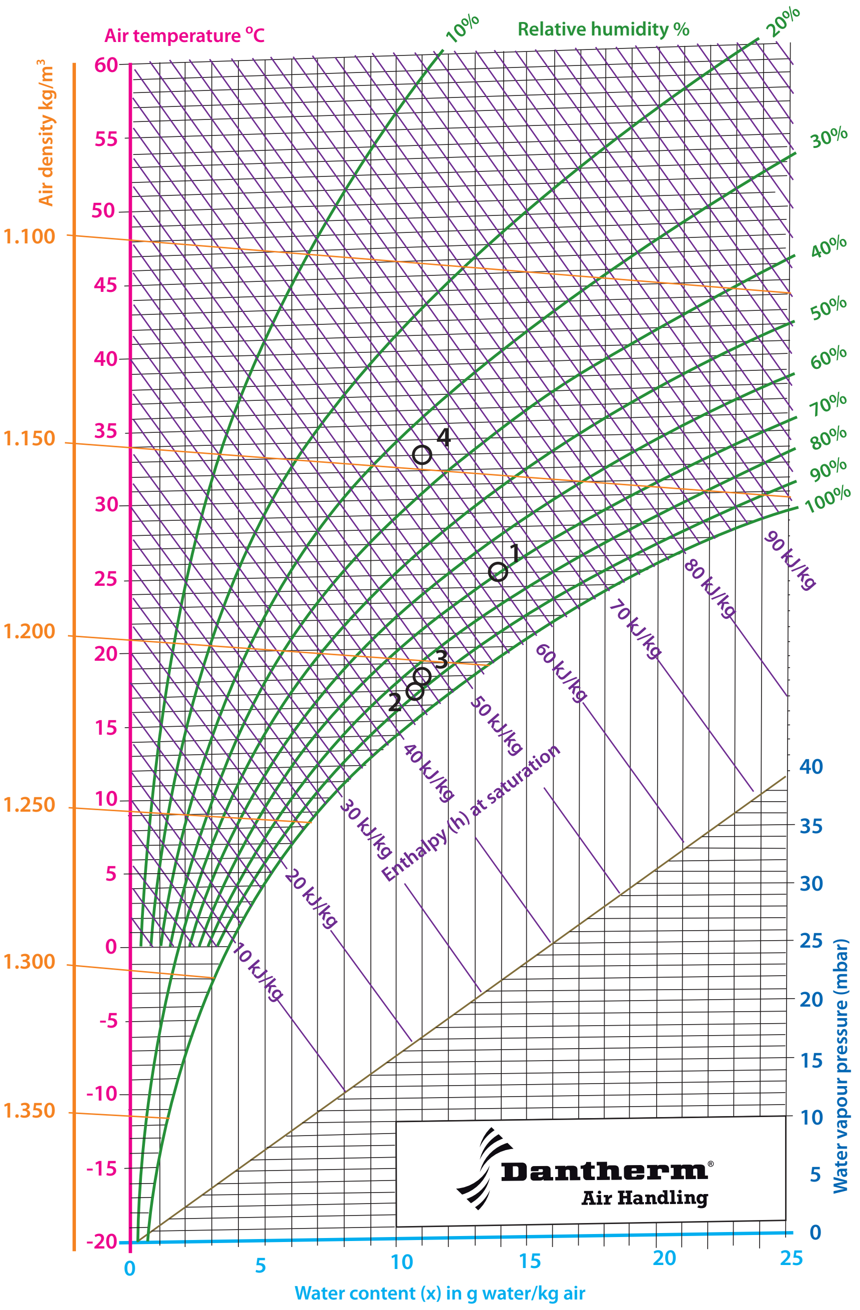
## Example 5

In Example 2 (page 8) the temperature and airflow through a dehumidifier was 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 |



Now 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 Air Handling 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 this case the application of a mobile dehumidifier is often a question of establishing a comfortable indoor climate and/or the preservation of rare documents, books, artifacts and other precious materials at museums and archives, or the protection of electronics and machinery in offices and factories, or even the buildings themselves.

The second category concerns drying out the water content in different kinds of 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 the model type of mobile dehumidifier that needs to be used. Table 2 gives a summary 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, waterworks, etc. |
| Excess water content in the materials | Dry out buildings | Construction site |
| | Repair water damage | Sites where there have been floods, fires or where pipes have burst. |

### 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 that indicates 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.

**Table 3**

| 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 |

In all cases concerning continously high levels of relative humidity it is advisable to look into the actual reasons for the problem – not just cure the effects. 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 geograhical areas and can be obtained locally. (See Table 4 for an example of how much outside conditions fluctuate during a year in Denmark). To make sure that you always have sufficient load you should normally enter the temperature and RH-values as worst case scenarios into the hx-diagram. 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 constitutes 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 |

**Size of the room**

The size of the room or the building has an indirect influence as it is the amount of water in the air that determines the actual dehumidification load required, however, you should calculate the volume of the room in cubic metres to see how much air it will hold.

**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 in most cases problems concerning excess water content in the air are caused by air change problems.

You must determine how many times pr. 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 from time to time.

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

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

W = g water/hour
$\rho$ = air density ($kg/m^3$) = the value commonly used is approximately
1.2 $kg/m^3$ at 15-25°C
V = room volume ($m^3$)
n = air change in the room ($hour^{-1}$)
$x_1$= worst case situation (g water/kg air)
$x_2$= water content in the air required RH value (g water/kg air)

**Other sources**

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

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

**W(total) = W(people) + W(process) + W(goods) + W(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 waterworks, 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

It is normally NOT advisable to increase the room temperature while using a dehumidifier. Even a slight rise in temperature will reduce performance as the dehumidifier has to cool the air down to the dew point before condensation can begin.

### 4.1.1 Establishing a good indoor climate

The key concern when establishing a comfortable indoor climate is to ensure 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 it might be necessary to increase the rate of air change.

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 a RH-value below 45% in order 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 |

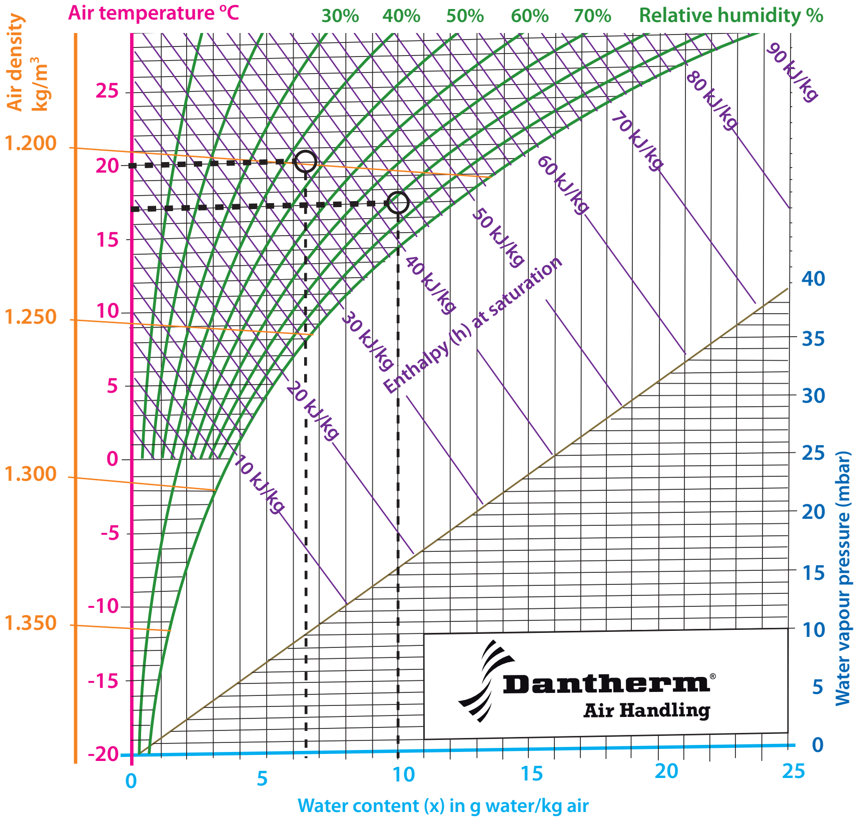
In general an air change of 0.5 per hour will ensure a low RH-value, but as we have already seen, it really depends on a number of factors.

**Example 6**

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

**The data:**

| | |
|---|---|
| Country: | Denmark |
| Locale: | Basement room |
| Volume of the room: | 300 $m^3$ |
| Air change: | $n = 0.5$/hour |
| Air density | $\rho = 1.2$ kg/$m^3$ (See hx-diagram) |
| Number of people: | 5 |
| Activity level: | Medium = 125 g water/hour/person (See Table 5) |
| Worst case situation: | $x_1 = 10$ g water/kg air (See Table 4) |
| Desired condition: | t = 20°C and 45% RH > $x_2 = 6.5$ g water/kg air |
| | ($x_2$ is found by using the hx-diagram) |



**The calculation:**

W(ventilation) = 1.2 $*$ 300 $*$ 0.5 $*$ (10-6.5) = 630 g water/hour
W(people) = 5 $*$ 125 g = 625 g water/hour
W(total) = 630 + 625 = 1,255 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 is typically a question of ensuring that the RH-value never exceeds a predetermined level. Usually the locale is a storage room or a warehouse.

The quality of storage facilities 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. In Table 6 you will see the difference in air change in various locales depending on the quality of the insulation.

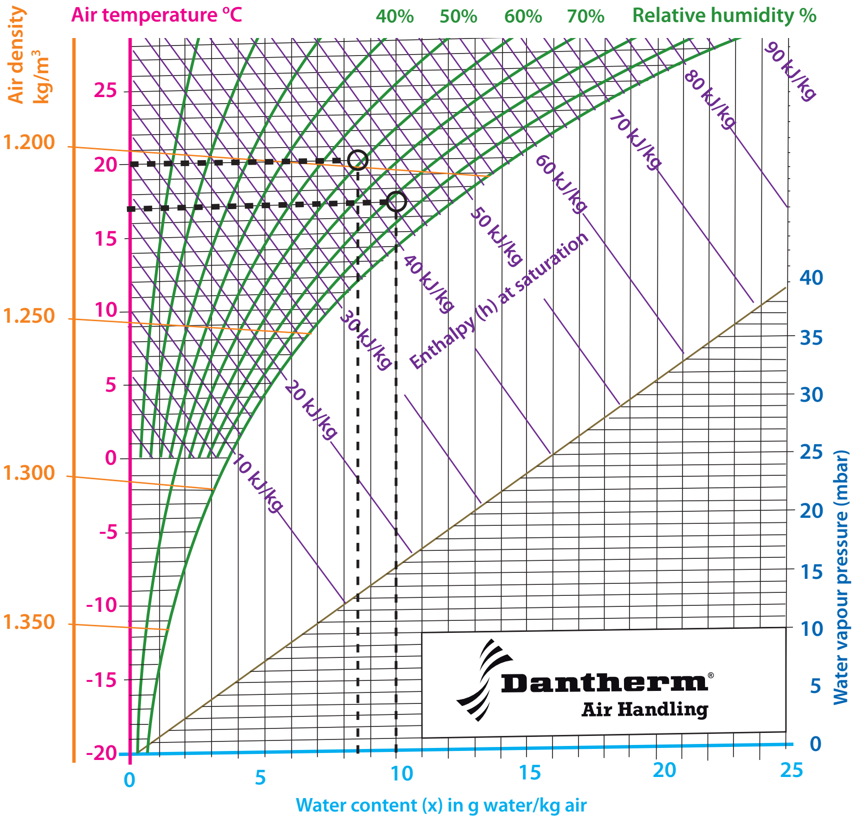
However, the air change is not the only parameter to take into account. Again you must consider the humidity contribution from people, outside air, goods and possible processes inside the storage room.

**Table 6**

| Room | Air change: n (hour $^{-1}$) | | |
|---|---|---|---|
| Insulation quality | Good | Average | Poor |
| Well sealed room | 0.4 | 0.6 | 0.8 |
| Normal residential property | 0.5 | 0.8 | 1.0 |
| Workshop | 0.6 | 0.9 | 1.2 |
| Large storage room without windows | 0.3 | 0.5 | 0.7 |

**Example 7**

In this example we have 150 m$^3$ of completely dry goods stored in a 300 m$^3$ 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 |
| Locale: | Large storage room |
| Volume of the room: | 300 $m^3$ |
| Volume of the stock: | 150 $m^3$ |
| Air change: | n = 0.7/hour (See Table 6) |
| Air density | $\rho = 1.2$ kg/$m^3$ (See Table 1) |
| Worst case situation: | $x_1 = 10$ g water/kg air |
| | (See Table 4. July: t = 17°C; RH = 83%) |
| Desired condition: | t = 20°C and 60% RH > $x_2 = 8.5$ g water/kg air |
| | (See hx-diagram) |

**The calculation:**

W(ventilation) = 1.2 * (300-150) * 0.7 * (10-8.5) = 189 g water/hour

W(total) = 0.189 litre water/hour

Recommendation: CDT 20. Capacity: 0.3 litre/hour at 20°C/60% 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 you will get a large amount of condensation 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 reservoir making it altogether very difficult to meet the hygienic requriements.

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 to do so you need dehumidification. Usually ventilation is applied at waterworks. An air change between 0.3 - 0.7 times per hour is recommended.

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

**Table 7**

| **Room temperature** | **° C** | 10 | 12 | 14 | 16 | 18 | 20 |
|---|---|---|---|---|---|---|---|
| **Max. RH-value** | **% RH** | 80 | 70 | 61 | 54 | 48 | 42 |

The total dehumidification load is determined by:

W(total) = W(water reservoir) + W(ventilation)

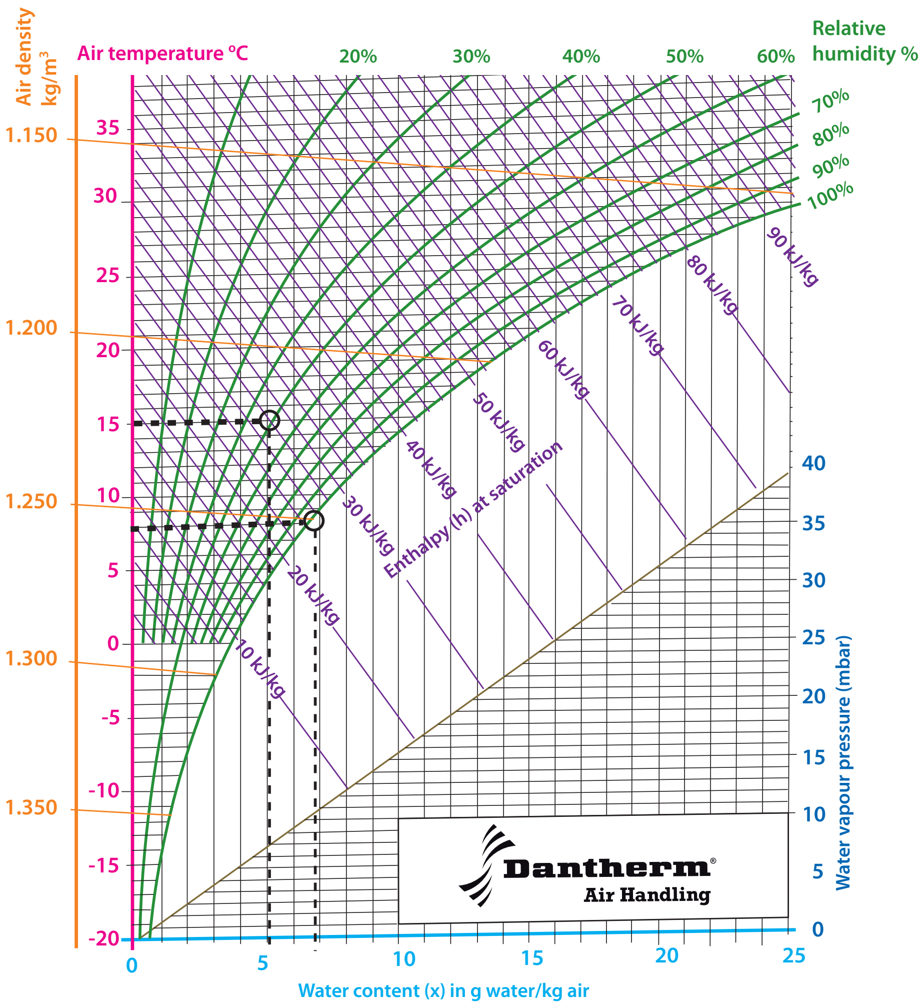
$$\boxed{\mathbf{W(water\ reservoir) = c * A * (x_{sa} - x_1)}}$$

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 ($m^2$)
$x_{sa}$ = 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 humidity and temperature (g water/kg air)

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

In this example we want to determine the dehumidification load needed in a waterworks with an air temperature of 15°C and a desired RH value 50% RH. The size of the waterworks is 300 $m^3$, the water surface is 40 $m^2$ and the water temperature is 8°C.

**Example 8**



**The data:**

| | |
|---|---|
| Volume of waterworks: | 300 m$^3$ |
| Air change rate: | 0.3 pr. hour |
| Water surface : | 40 m$^2$ |
| Water temperature : | t= 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 > $x_1$ = 5 g water/kg air (see hx-diagram) |

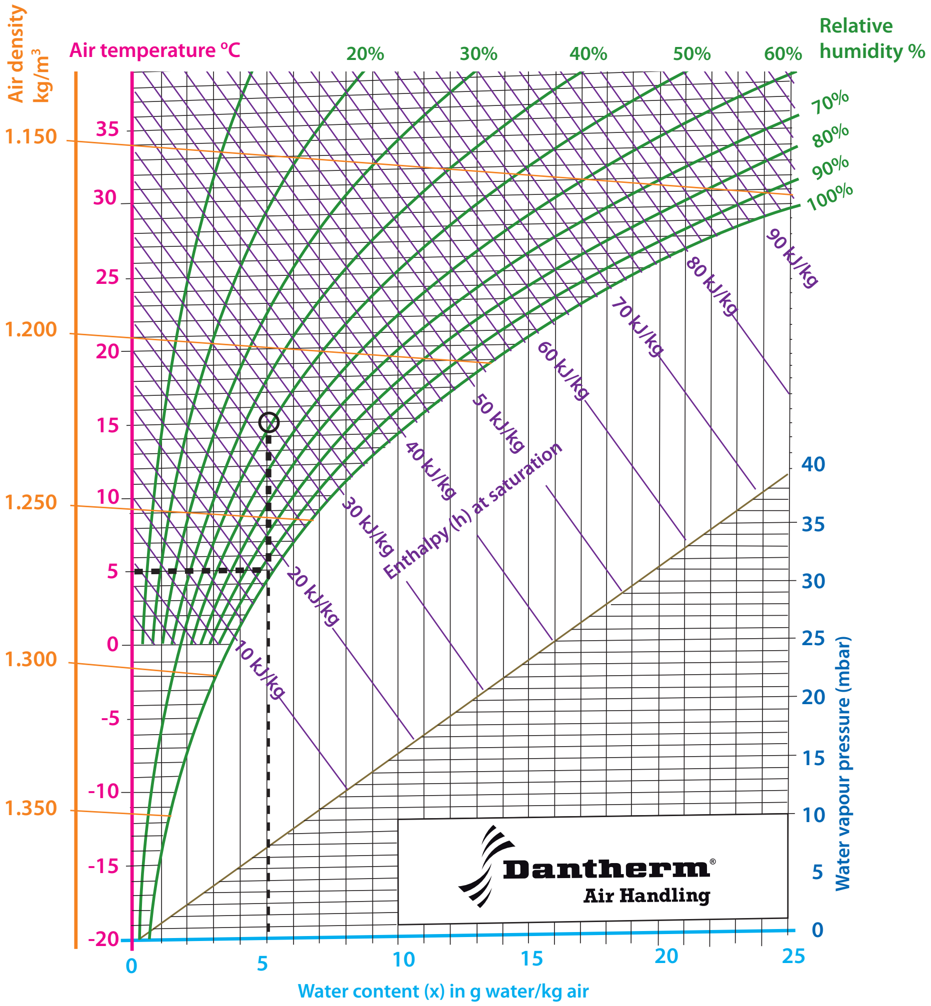
**The calculation:**

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

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

W (total) = 500 + 540 = 1.04 ltr/hour

The dew point temperature at 15°C and 50% RH is approximately 5°C according to the hx-diagram. If the water temperature is 8°C and the relative humidity around the pipes is close to 90% there will be NO condensation of water on the pipes as the actual water temperature is higher than the dew point temperature. This is in line with the values in Table 7.



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 55% RH (see Table 7). This will automatically control that temperature and humidity conditions are always kept at a level ensuring that condensation is avoided.

### 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 damage varies considerably it is necessary to assess the right approach from situation to situation.

An all 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 empiric data to go by as it is often almost impossible to calculate the absolute accurate dehumidification load needed 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 have to consider a finite amount amount of time to do the job.

#### 4.2.1 Drying out buildings

Formerly 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 consider how much water should be removed and how much time you have to do it.

This is actually quite a difficult task. In some cases it is possible to estimate the amount of water in the building materials from tables. Please note that in regards 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/m³)**

| 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 | 80-180 |
| 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 load 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 constructed 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: | $2.4 * 7 * 16 = 268.8$ m³ |
| Materials: | Concrete K 40 II, 10 cm (see Table 8) |

**The calculation:**

Concrete volume to be dehumidified:

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

Water content in concrete floor:

$Q = 11.20 * 58$ kg water/$m^3$ = 649.6 kg water

We need to remove 649.6 L water in 30 days:

W = 649.6/30 = 21.65 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 proces is stable and gentle. If time is not of the essence the optimum dehumidification process is achieved by maintaining a stable condition of 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. There is a risk of surface drying and cavitation, with only surfaces being dried, whereas a lot of humidity remains within cavities inside the wall. 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 locale or building properly when it is empty. Also remember to avoid pre-dried materials absorbing water because of open windows.

If the air change inside the room is not controlled, then changing ambient temperatures and humidities make the process much more difficult to control. In the winter the cold outside air will normally contain 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 locale 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 going on i.e. painting, concrete mixing, etc. Set up your dehumidifiers at these positions where they can do most good.

### 4.3 Drying out water damage

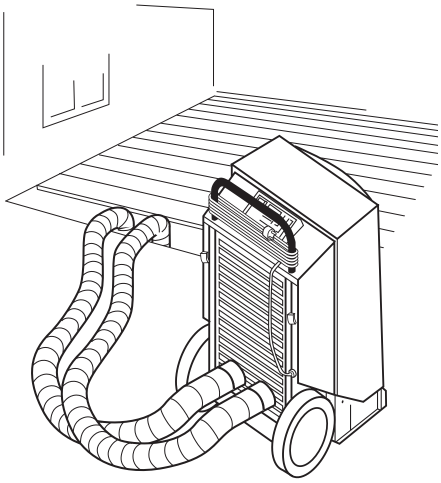
As mentioned earlier it is difficult to give exact guidelines for how to approach a water damage situation, as both the nature and extent of water damage varies considerably. However, there are some general points that you should always take into consideration.

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 locale. This way you only have to deal with the water that is already in the locale.

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 deep into furniture and moveables, or walls, floors and other parts of the building structure.

If the water has had time to penetrate deep into the building structure you need to use a larger dehumidification capacity to get 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

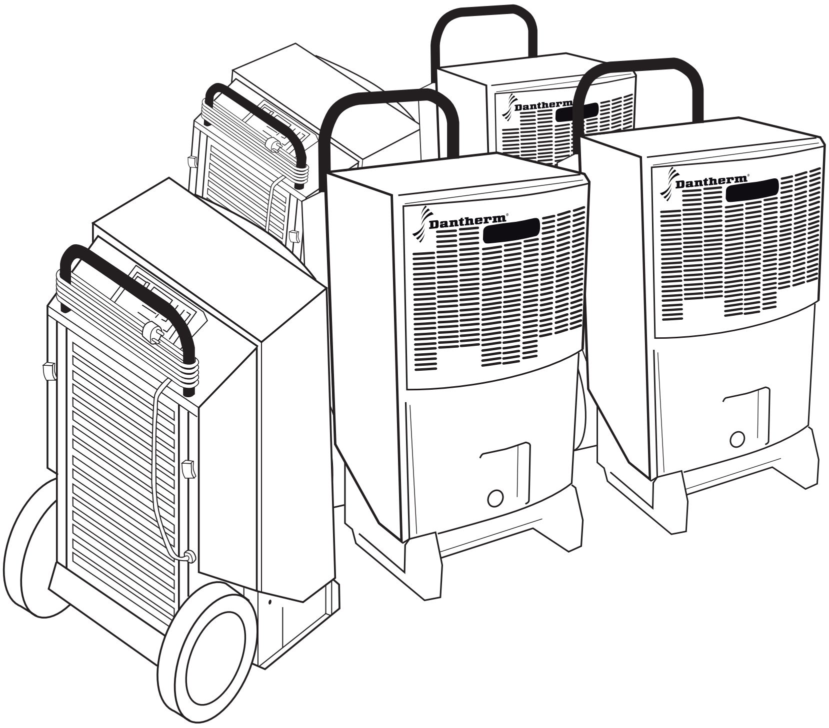
In the case of underfloor water damage, it is often necessary to tear up the flooring to replace the wet insulation. This is time consuming work and often it is both very inconvenient and costly as it renders the room virtually useless for as long as the repair work goes on.

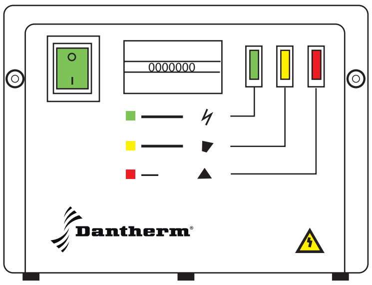
In quite a lot of instances, however, a dehumidifier equipped to add heat to the process such as the CDT 30 S and CDT 40 S will spare you the inconvenience of breaking up all the flooring and save a lot of money.

Hot dry air is fed underneath the floor at one end by means of ducts from the dehumidifiers 1 kW heater. 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. We advise you to use empirical values and rules of thumb found in the appendix.

# 5. Selecting the right dehumidifier

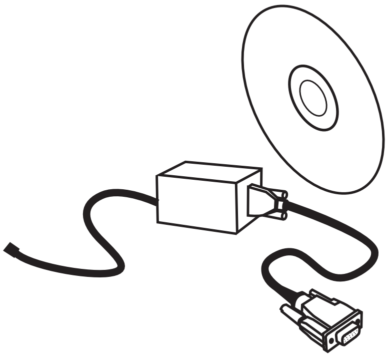




In the previous chapters we have covered the principles of dehumidification and the theoretical background needed to calculate the required dehumidification load for any given situation. By now you should be fully equipped to select the right mobile dehumidifier from the Dantherm Air Handling CDT range.

First let us have a look at the general characteristics of the CDT range. Our range of mobile CDTs are high-performance dehumidifiers, designed for user-friendly handling and transport.

The control board is conveniently placed on top of the dehumidifier. You have a full and easy view of the hours run meter and the lamps indication normal operation, full water container, and failure alert.



*CDT test kit*

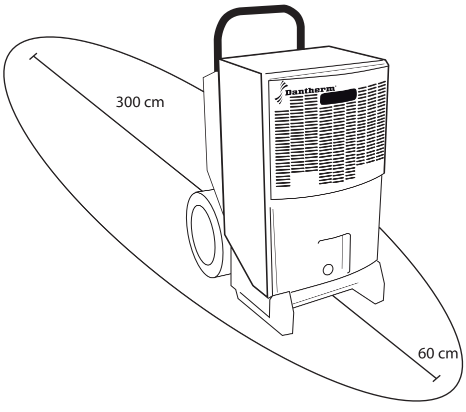
Special care has been put into the design features facilitating handling and transportation. A mobile dehumidifier should be sturdy enough to withstand a reasonably rough time on the road, as it is hauled in and out of vehicles time and again.

The heavy-duty protective cover and robust construction of the CDT product range design ensures a long operating lifetime. However, you will be surprised at the low weight of a CDT and easy safe handling due to optimum weight distribution. Futhermore transportation of several CDTs requires little space as they are designed to be stacked.

All CDT units are equipped with large rubber wheels and an adjustable handle to make it easy to move the dehumidifier from one room to the next, up and down stairs and across seemingly impassable areas.

During operation you will appreciate both the low noise level and thethe water reservoir's ease of use.

When using the CDT you should always place it in the middle of the room. You must allow a space of at least 60 cm between the intake and the wall and no less than 300 cm for the outlet. Do not place the unit near a heat source.



*Positioning of the CDT*

### 5.1 Specific Energy Consumption – SEC

The capacity of a mobile dehumidifier is obviously your main concern, but with the costs of energy constantly increasing, it is also important to consider the energy consumption of a unit in relation to its capacity. SEC = actual power consumption/capacity in litre/hour measured as kWh/L.

Table 9 lists the SEC values for the CDT range at different temperature and RH-values.

| | Working range, temperature | Working range, humidity | Air volume | Condense capacity, 20 °C & 60% RH | Condense capacity, 30 °C & 80% RH | Specific energy consumption SEC, 20 °C & 60% RH | Specific energy consumption SEC, 30 °C & 80% RH | Power supply | Power consumption, 20 °C & 60% RH | Noise level – 1 m from the unit | Water tank capacity | Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | °C | % RH | $m^3/h$ | L water/24 h | L water/24 h | kWh/L | kWh/L | V/ 50 Hz | W | dB(A) | L | Kg |
| CDT 20 | 3-30 | 40-100 | 250 | 7 | 20 | 0.93 | 0.39 | 230 | 280 | 55 | 7 | 28 |
| CDT 30 | 3-30 | 40-100 | 250 | 13 | 30 | 0.85 | 0.47 | 230 | 461 | 56 | 7 | 32 |
| CDT 30 S | 3-30 | 40-100 | 350/ 300* | 13 | 30 | 0.86 | 0.43 | 230 | 456 | 60 | 7 | 34 |
| CDT 40 | 3-30 | 40-100 | 350 | 22 | 39 | 0.66 | 0.50 | 230 | 614 | 59 | 14 | 43 |
| CDT 40 S | 3-30 | 40-100 | 560/ 460* | 19 | 42 | 0.83 | 0.47 | 230 | 664 | 62 | 14 | 46 |
| CDT 60 | 3-30 | 40-100 | 725 | 29 | 62 | 0.67 | 0.43 | 230 | 800 | 62 | 14 | 47 |
| CDT 90 | 3-30 | 40-100 | 1000 | 41 | 94 | 0.71 | 0.42 | 230 | 1214 | 62 | - | 62 |

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

**Table 9**

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 the process. This in itself saves you energy, as you don't have to supply that heat from other energy sources.

Let us take for instance a CDT 30 running at 20°C and 60% RH. According to Table 9 a power consumption of 461W goes into dehumidifying 0.54 litre/hour (see capacity curve, page 40). That 461W of energy is transformed into heat and warms the surroundings.

The heat energy resulting from condensing 1 litre of water from the air at 20°C is approx. 680Wh, thus the heat of evaporation from a CDT 30 amounts to 680 * 0.54 = 367W.

In total this means that the dehumidifier supplies 461 + 367 = 828W heat to the room. This heat contribution is the reason for the rise in air temperature after the air has passed through the dehumidifier.

Example 2 on page 8 shows an increase of 8°C in the air temperature as a result of the dehumidification process.

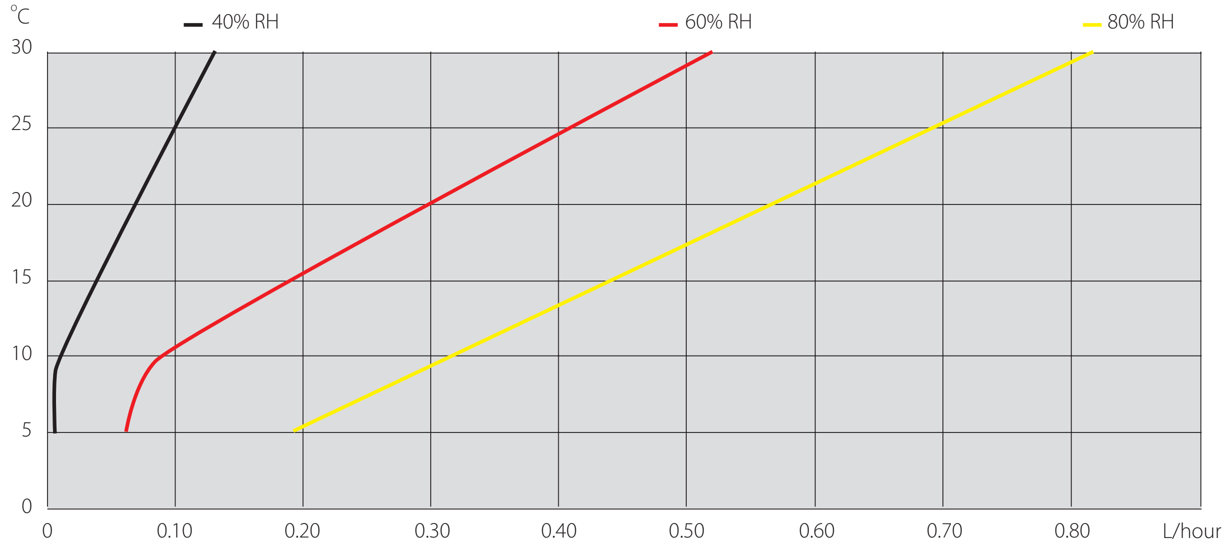
For in depth technical specifications and optional accessories please consult the data sheets for the individual units in the CDT range, available from Dantherm Air Handling.

## 5.2 Capacity diagrams

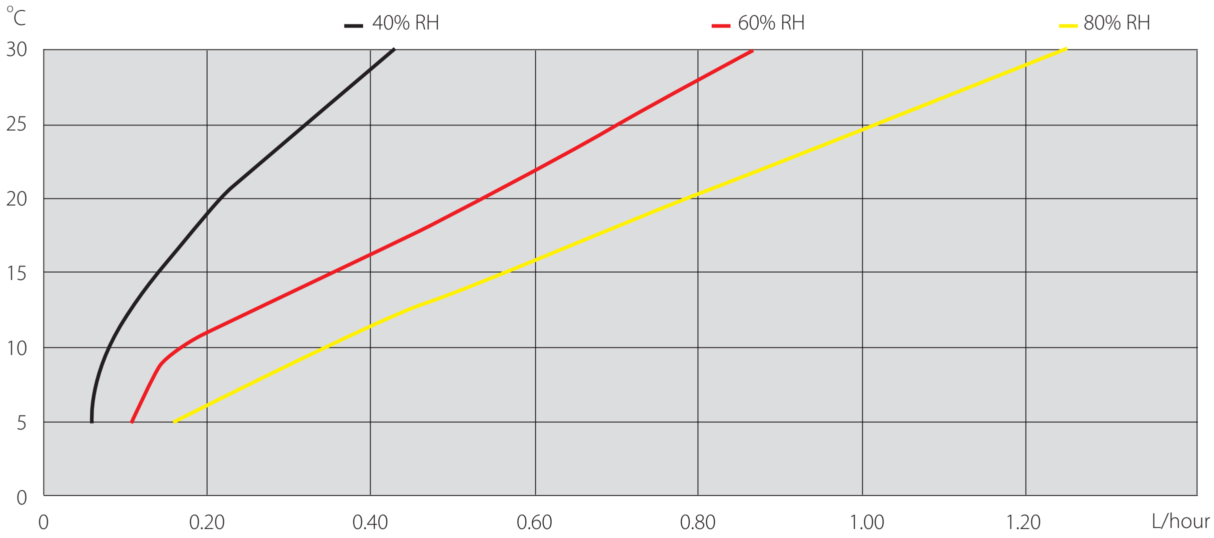
The capacity diagrams in this chapter are the key to selecting the right dehumidifier for a specific task. You should always choose a dehumidifier with a capacity equal to or slightly higher than the calculated dehumidification load.

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 by interpolating between the curves.

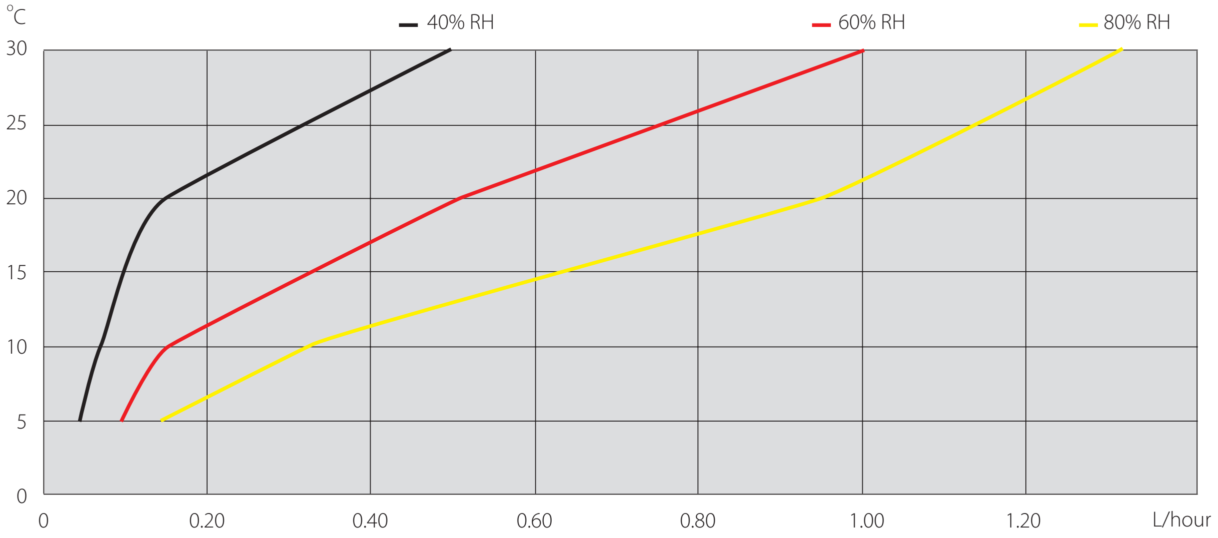
**CDT 20**



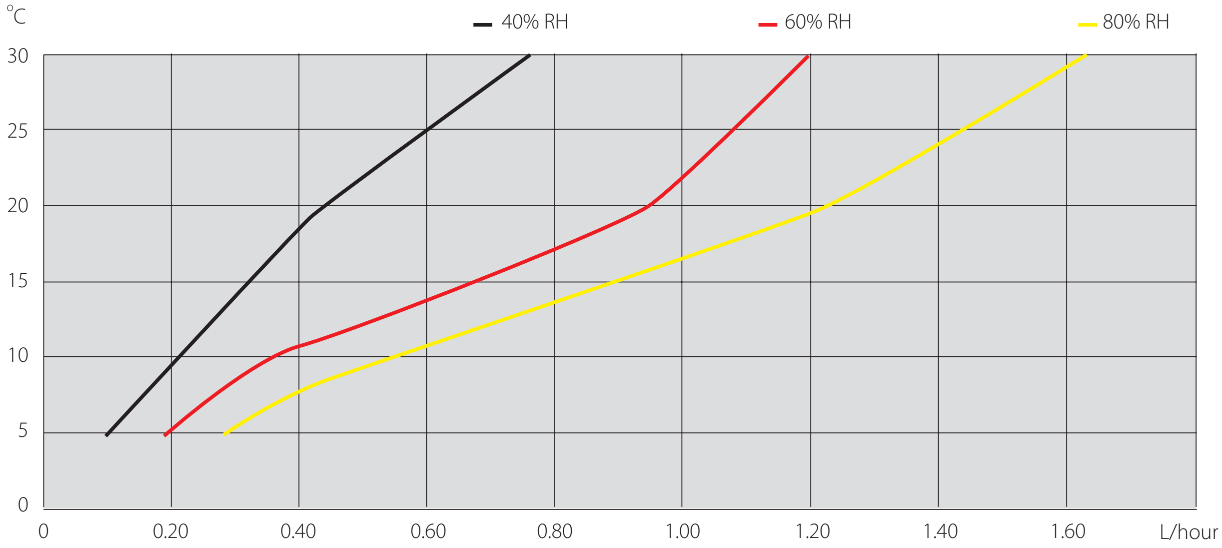
**CDT 30**



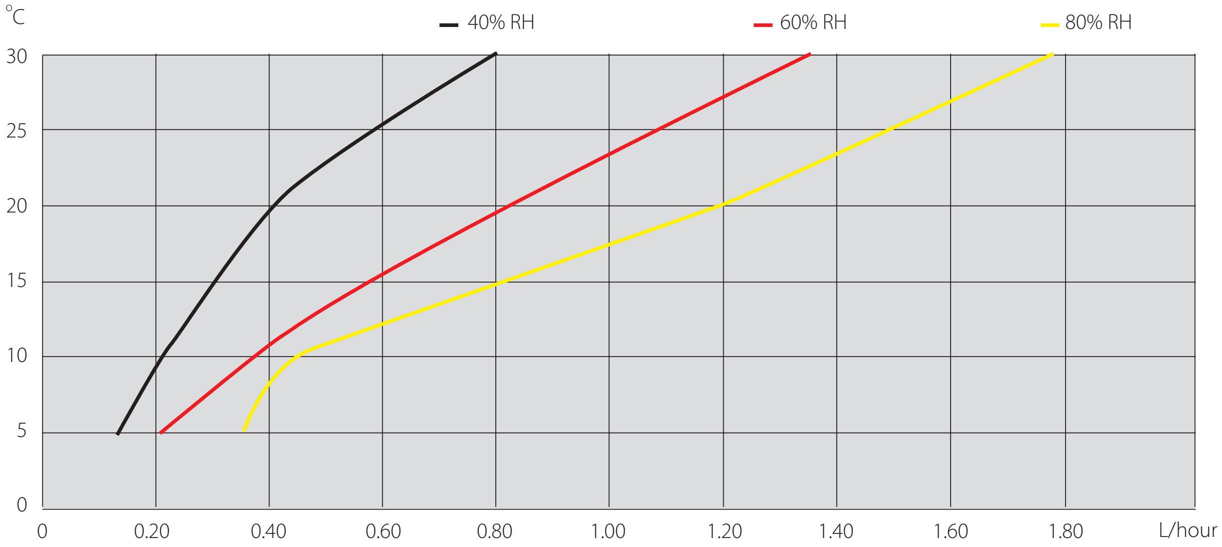
**CDT 30 S**



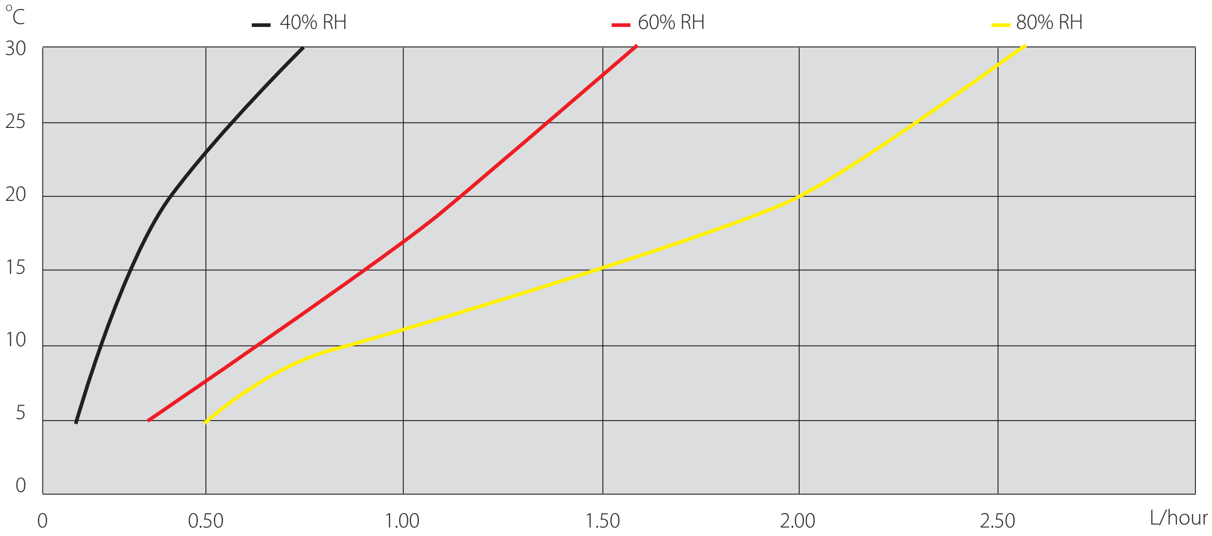
**CDT 40**



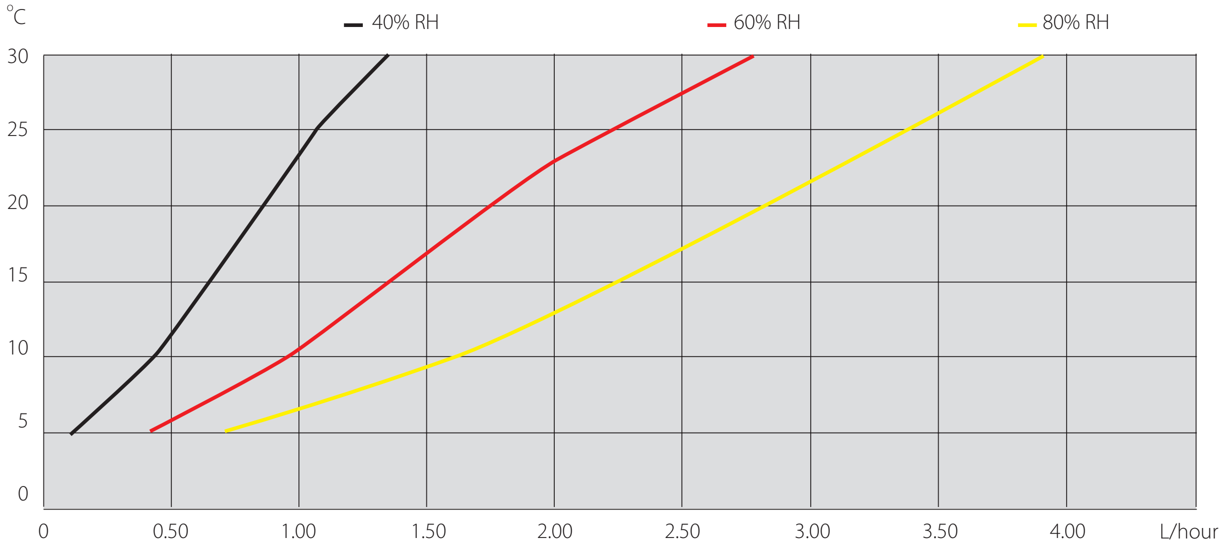
**CDT 40 S**



**CDT 60**



**CDT 90**



°C
40% RH
60% RH
80% RH
30
25
20
15
10
5
0
0
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
L/hour

# Appendix

## Quick Reference Guide – Easy rules of thumb formulas

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

W refers to the amount of water drawn from the air in g/hour.
V refers to the volume of the room in $m^3$.

| 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, waterworks, 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:

**$W = V * 2.0$ (g/hour)**

**Example**: $V = 500m^3 > W = 2.0 * 500 = 1{,}000$ 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:

**$W = V * 1.2$ (g/hour)**

**Example**: $V = 450\ m^3 > W = 1.2 * 450 = 540$ 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°C/50% RH (starting at 60% RH ending at 40% RH) use this formula:

**$W = V * 4.0$ (g/hour)**

**Example**: $V = 280\ m^3 > W = 4 * 280 = 1{,}120$ 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 |

## Notes

# 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 ρ (kg/m$^3$)**
The specific gravity of the air. The air density decreases as temperature increases. Empirical value commonly used is 1.2 kg/m$^3$ 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 has since aided the teaching of thermodynamics to many generations of engineers.

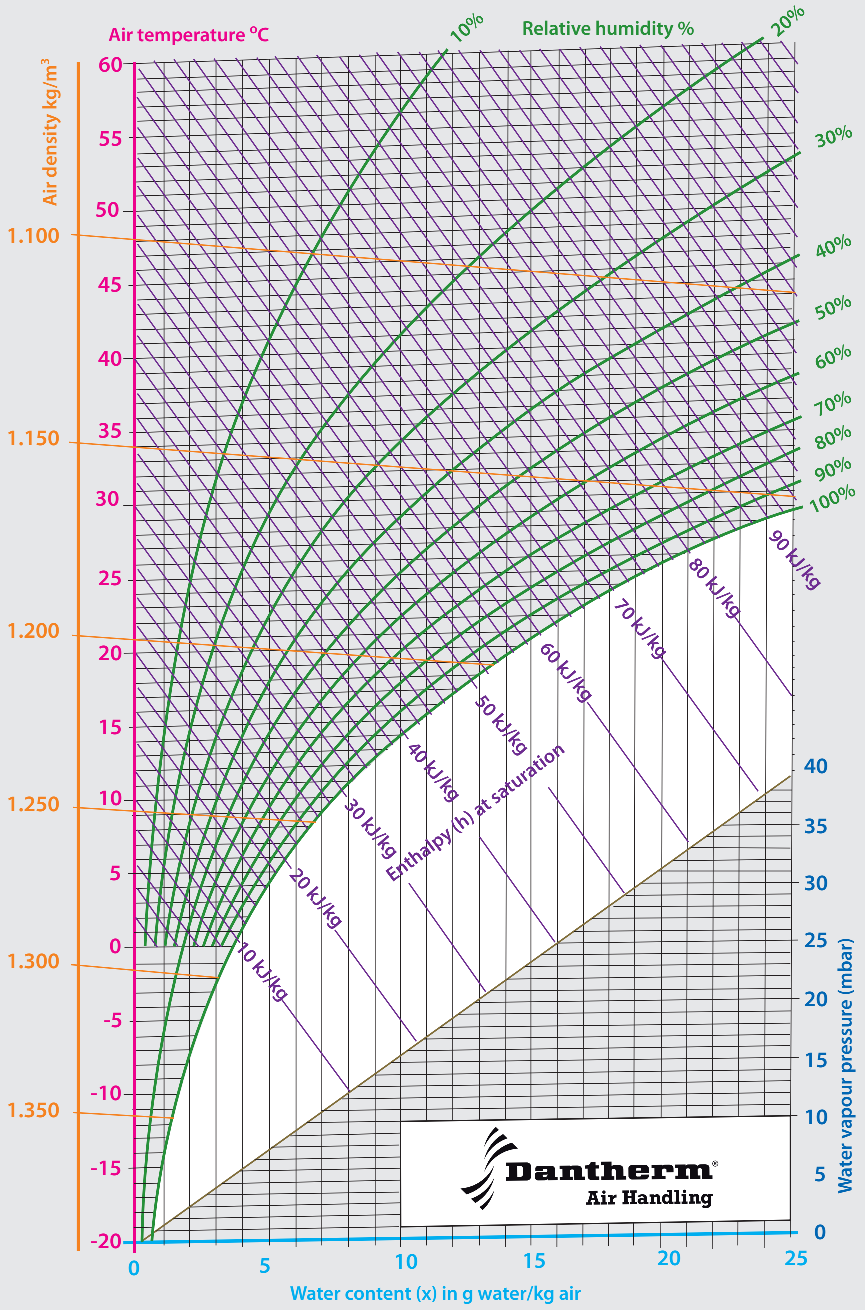
**Relative Humiditiy  (RH %)**
Term used to describe the quantity of water vapour in a gaseous mixture of air and water. Relative humidity is defined as the ratio of the partial pressure of water vapour in a gaseous mixture of air and water to the saturated vapour pressure of water at a given temperature.

**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**

# Mollier hx-diagram



### The Mollier hx-diagram quantities

| | |
|---|---|
| **Air density (ρ)** | The vertical **orange** axis to the extreme left.<br>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 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.<br>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 humidification load). The **brown** diagonal line in the bottom half of the diagram is a help line used when determining the partial water vapour pressure. |

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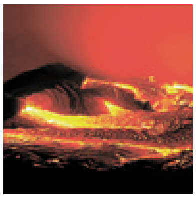

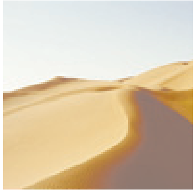

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