Cooling energy recovery

Rotary heat exchangers with a sorption coating bring significant opportunity for energy and carbon emission reductions while also improving the indoor environment.

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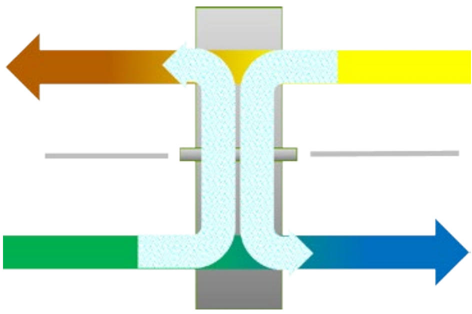
Sorption

The material of the sorption coating has the ability to absorb moisture from the air when the humidity is high and to release it when the humidity is low. This means moisture is recovered; which means we get latent energy recovery as well as sensible energy recovery.

In the summer time when the outdoor air is humid, moisture is removed from the outdoor air and released to the exhaust air. In the winter time the outdoor air has a low moisture content so the sorption coating can recover moisture in the extract air and release it to the supply air. This brings two benefits in cold outdoor conditions. Firstly, the raised humidity in the supply air is beneficial for the indoor environment quality and secondly, because the moisture is removed from the rotor there will be much less risk of frost and the need for defrosting is more or less avoided. This means that the sorption rotor saves some heating power during the winter.



In summer, when the humidity is higher, moisture is removed from the outdoor air and transferred to the exhaust air. In winter, moisture is transferred from extract to supply.

Humidity transfer happens when there is a difference in specific humidity between the extract air and the outdoor air. The amount transferred is given by the latent efficiency performance of the rotor.

$$\text{Latent efficiency} = \frac{x_{22} - x_{21}}{x_{11} - x_{21}} \%$$

Where
x_{11} = specific humidity in the extract air g/kg
x_{21} = specific humidity in the outdoor air g/kg
x_{22} = specific humidity in the supply air g/kg

Cooling Power reduction

Because of the latent energy recovery in the rotor, we significantly reduced the cooling power demand in the cooling system. Even with a plain aluminium heat exchanger we get sensible cooling recovery

Figure 1 illustrates how much more cooling recovery we get with the sorption rotor compared with a normal aluminium rotor. The example is based on 30°C outdoor air and a supply temperature of 12°C. The sensible rotor provides about 20% of the cooling while the sorption rotor is able to provide about half of the cooling power. This will vary depending on the conditions but shows that the cooling power reduction is very significant with the sorption rotor.

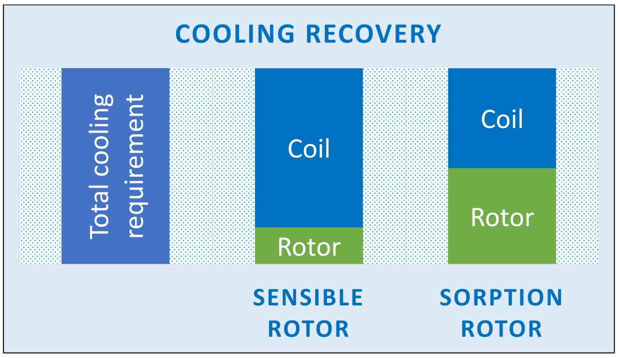


Figure 1. Reducing the capacity of the cooling coil due to the use of sensible and sorption rotors.

This latent cooling recovery means that we can radically reduce the size of the cooling plant. This means the chiller capacity and the cold-water distribution system made much smaller; which means significantly lower installation cost, smaller space requirement and a smaller refrigerant charge.

Cooling Energy reduction

The cooling energy reduction will, of course depend on the duration of warm weather.

The following example has been calculated with the following conditions:

- Airflow rate: 2 m^3/s
- Supply air temperature 16°C
- Extract air temperature 22°C
- The sorption rotor has a temperature efficiency of 82% and a humidity efficiency of 74% in the summer.
- The aluminium rotor has a temperature efficiency of 82% in the summer.
- The pressure drop of the sorption rotor is about 10Pa more than that of the aluminium rotor so the difference in fan energy is small.

Figure 2 shows the cooling recovery using the aluminium rotor and the second diagram shows the recovered cooling recovery using the sorption rotor.

Figure 3 illustrates the reduction in cooling energy consumption is near 50% in the warmer climates of Milan and Frankfurt while in the cooler places it is near 20%

Compared with cooling equipment, sorption rotors are relatively simple machines, so we have the additional benefit that the maintenance cost is much lower per kWh.

Power peak reduction

Occasionally the weather brings higher temperatures and humidity levels that that of the design. This will, of course, lead to an increase in the temperature indoors. The recovered cooling power of the heat exchanger is proportional to the temperature and humidity difference so when the outdoor condition rises and the difference between extract and outdoor condition increases, we get more recovered power.

Humidity recovery

In cold weather outdoor air that is heated will have a low humidity so the indoor air will become dry. In these conditions, the sorption rotor recovers moisture in the extract air and returns it to the supply air; which means the indoor air is kept more moist and more comfortable and hygienic. It may be necessary to add moisture using humidification and then the sorption rotor brings the benefit of a lower humidification load so the installation will be cheaper and the running costs lower.

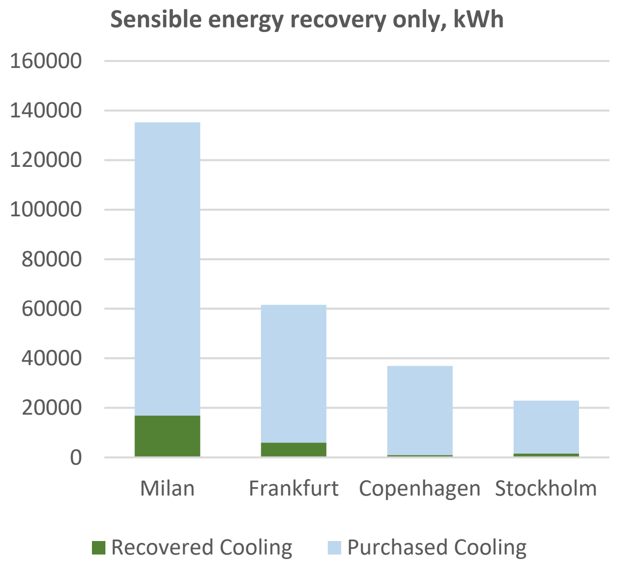


Figure 2. Sensible and latent energy recovery with a aluminium rotor.

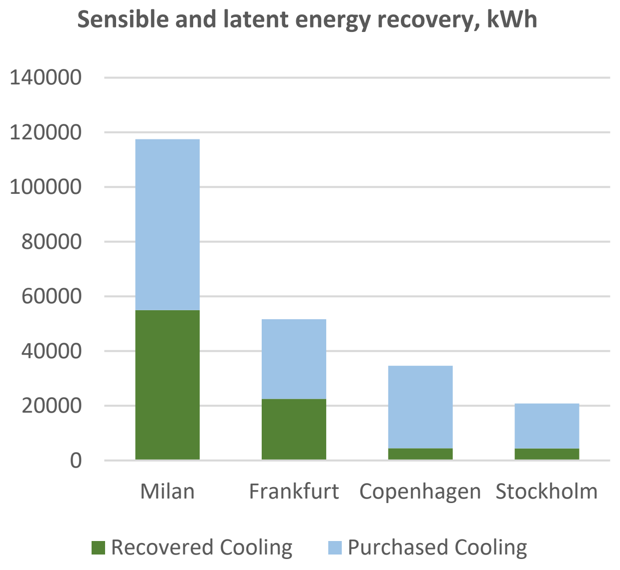


Figure 3. Sensible and latent energy recovery with a sorption rotor.

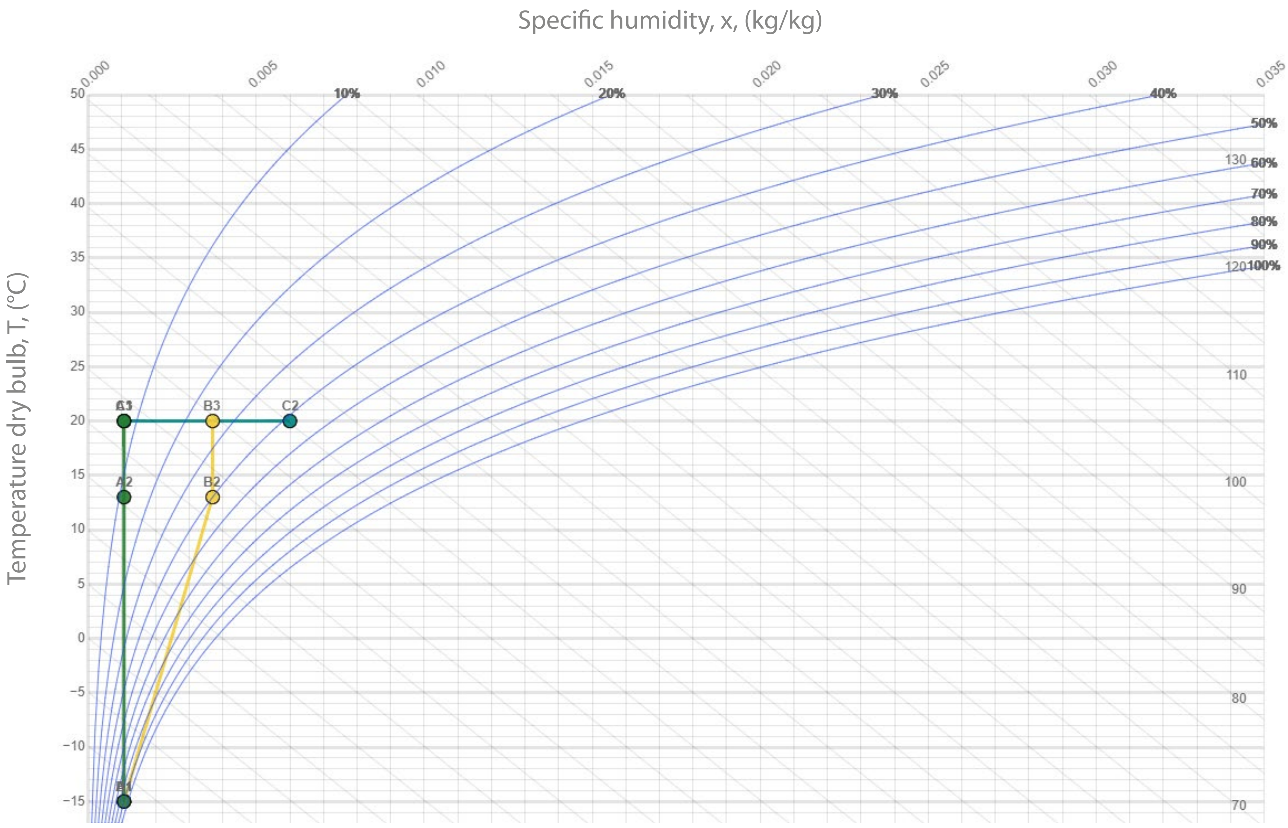


Figure 4. H-x diagram for humid air, x-axis: x (g/kg), y-axis: Celsius temperature.

In this example cold air is heated by the rotor to 13°C and is then reheated to 20°C.

With the aluminium rotor the resulting supply air has a relative humidity of just 10% while with the sorption rotor it is over 25%.

Reduction of humidification power

We can see from the diagram that the cost of humidification is significantly reduced.

The green line represents the heat recovered in a rotor with only sensible recovery. The yellow line is that for a sorption rotor. The rotor heats the air to 13°C and it is then reheated to 20°C.

If we assume the supply air condition needs to be 30% to 40% relative humidity then instead of needing to add about 5-6 g moisture per kg of air, we will only need to add 2-3 g moisture so the cost of humidification will be halved by using the sorption rotor.

If using an adiabatic humidifier, then the sorption rotor can offer the benefit of reduced reheat power and reduced water consumption.

Leakage

The disadvantage with rotary heat exchangers is the problem of leakage. If properly designed and installed, the leakage can be reduced to less than 1%. The rotor needs to be fitted with effective seals, a purging sector and the system needs to be set up with the correct pressure balance.

To get the correct pressure balance, the fans need to be correctly positioned. Both the supply and the extract fans are best placed upstream of the rotor in their respective air streams. It will often be necessary to introduce a pressure reducing device in the extract air.

This has been described in more detail in an earlier article (see REHVA Journal 5/2020 pages 65-68) and is also well documented in Eurovent REC 6/15

The ability of the sorption rotor to recover both sensible and latent cooling has profound impact on both the cooling power demand and the cooling energy consumption. The cooling system is made much smaller saving space and cost. A smaller chiller also means a reduced amount of refrigerant. ■