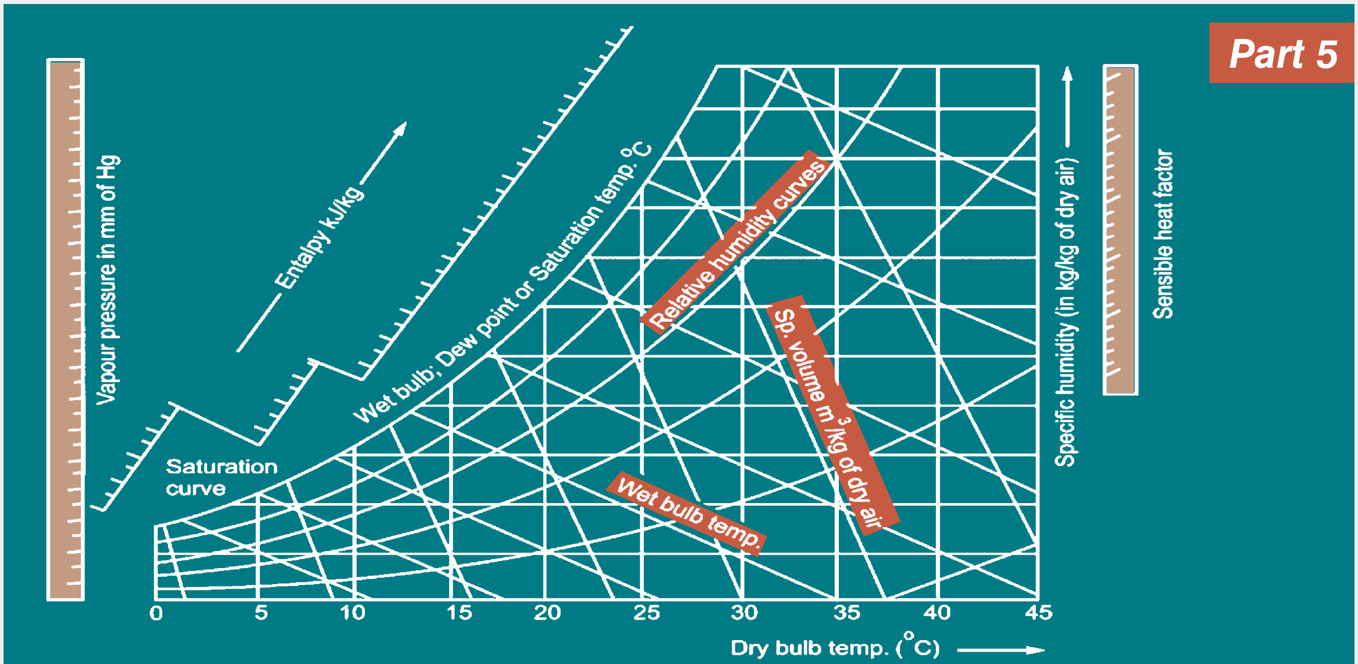

Understanding Psychrometrics

By Ramesh Paranjpey, *Distinguished 50-Year Member, ASHRAE*
Supported by Mukund Ranade, *AC Consultant and* **Gayatri Adhikari**, *Aqua Chill Solutions*

Introduction

Psychrometric process occurs when air at initial stage undergoes a transformation and ends up at final stage. Psychrometric processes are changes in the thremodynamic properties of moist air such as temperature and moisture content or humidity.

The processes can be plotted and analyzed using a psychrometric chart. For ease of understanding, pychrometric chart has been divided arbitrarily in four quadrants:

1. The processes lying above 'X'axis-quadrant A,B relate to humidification or increase in moisture content.
2. Processes below 'X' axis quadrant C,D relate to dehumidification or reduction in moisture content.
3. Processes on the right side of 'Y' axis line quadrant B,C relate to heting or increase in dry bulb temperature.

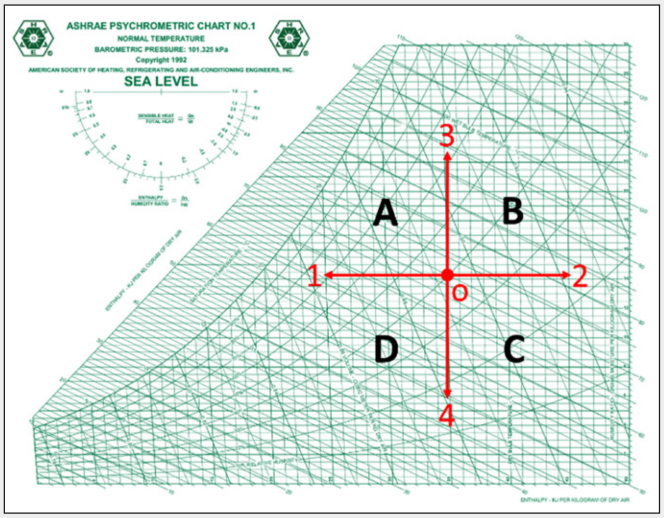

Figure 1: Four basic processes involving either transfer of heat or transfer of mass (water vapor) only

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About the Authors

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4. processes lying on the left side of 'Y' axis quadrant D,A relate to cooilng or decrease of dry bulb temperature.

It is possible that these processes can ovelap for qudrant to quadrant, however, we are going to consider only processes lying in the four qudrants. There are four basic processes involving either transfer of heat or transfer of mass (water vapor) only. These are shown in *Figure 1*.

These are:

1. Sensible cooling 0-1
2. Sensible heating 0-2
3. Latent heating (humidification) 0-3
4. Latent cooling (dehumidification) 0-4

Sensible cooling and heating process lines are plotted along or parallel to 'X' axis. Humidification and dehumidification process line are plotted along or parallel to 'Y' axis. Out of the above four processes, in commercial and actual practice only sensible cooling and sensible heating processs are predominently used.

Let us now discuss each process independantly.

Sensible Cooling

Sensible cooling involves cooling of air at constant water vapor content (g/$_{da}$). On the psychrometric chart the sensible cooling line is a horizontal line extending from right to left at constant humidity ratio towards the saturation line. It, however, should normally stop earlier than the saturation curve.

The lower dry bulb temperature limit is upto 85% relative humidity. Additional sensible cooling usually results in moisture condensation on the surface of the cooling coil.

Observable Features of a Sensible Cooling Process

1. The dry bulb temperature decreases.
2. The relative humidity increases.
3. The enthalpy decreases.
4. The wet bulb temperature decreases.
5. The specific volume decreases.
6. The humidity ratio, vapor pressure and dew point temperature remain constant.

Applications of Sensible Cooling

1. Cooling of air with chilled water in the chilled water cooling coil.
2. Sensible only rotary wheel.
3. Indirect evaporative cooler.
4. A blacksmith cooling the red-hot iron metal blade by dipping it into water.

Sensible Heating

It involves heating of air using a steam coil or hot water coil, a heat pipe or air to air heat exchanger. On the psychrometric chart, the sensible heating process line proceeds horizontally to the right along the constant humidity ratio (g/kg$_{da}$).

Observable Features of a Sensible Heating Process

- The dry bulb temperature increases.
- The relative humidity decreases.
- The enthalpy increases.
- The wet bulb temperature increases.
- The specific volume increases.
- The humidity ratio, vapor pressure and dew point temperature remain constant.

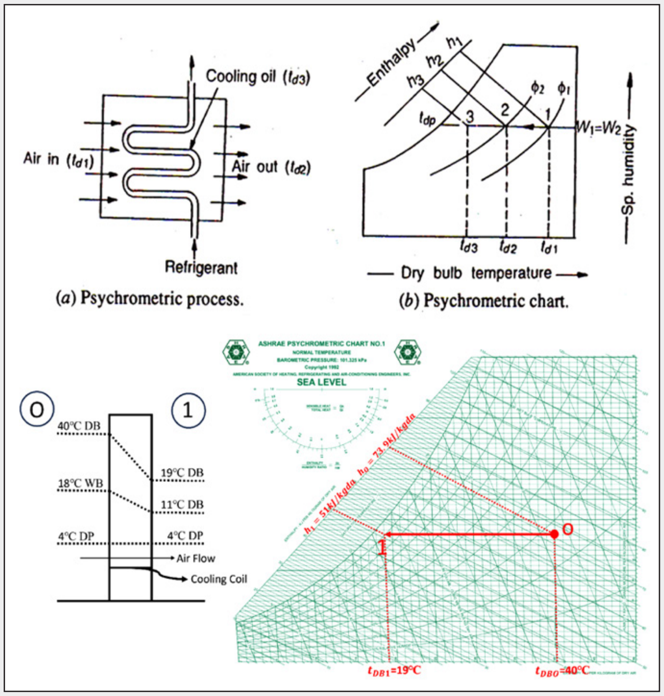

Figure 2: Sensible cooling line is a horizontal line extending from right to left at constant humidity ratio towards the saturation line

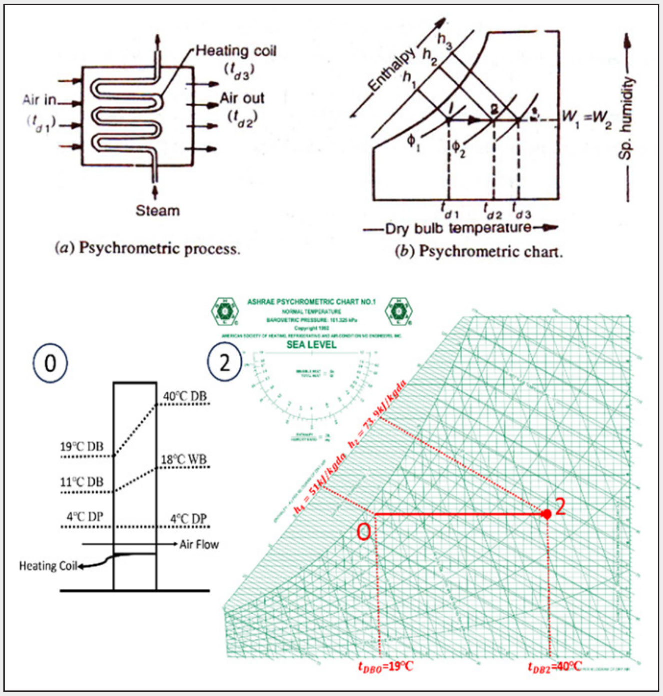

Figure 3: Sensible heating process line proceeds horizontally to the right along the constant humidity ratio

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Applications of Sensible Heating Only

Furnaces

An electric furnace heats air, increasing its temperature to warm a building. This process only changes the air's temperature, not its moisture level.

Ventilation

Sensible heat calculations are used to design ventilation systems to control the temperature of incoming air during winters.

Cooking

Heating water in a pot on a stove is an example of sensible heating, where the water's temperature rises from room temperature to boiling point.

Medical Treatments

Medical devices that use heat to raise a patient's body temperature utilize sensible heating.

Power Generation

Sensible heat is used in power plants to heat water to produce steam for turbines.

Phase Change Materials (PCMs)

Sensible heating is involved in raising the temperature of a PCM to its phase-change point, after which latent heat is absorbed during the phase transition.

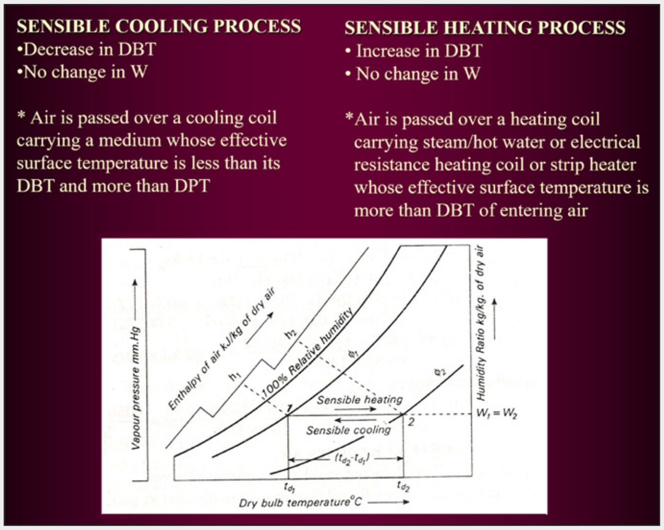

Figure 4: Sensible cooling and sensible heating process

Humidification and Dehumidification

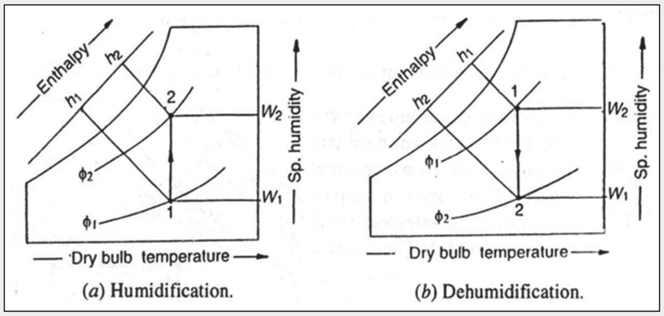

Figure 5: Humidification and dehunidification process

Humidification Only

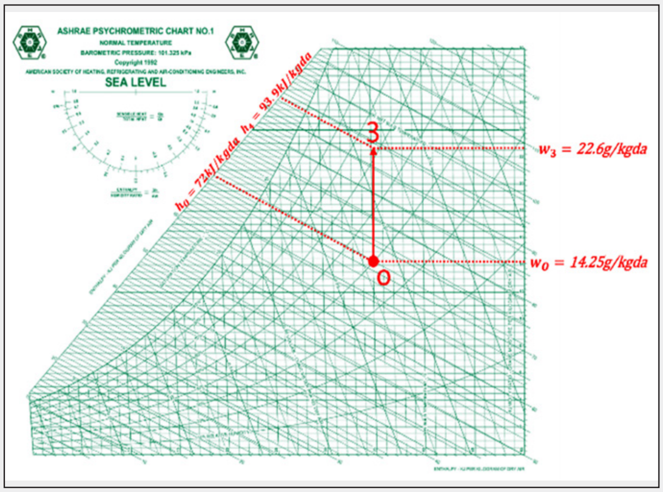

Figure 6: Humidification only

On the psychrometric chart, it is shown as a vertical line moving from lower end to upper level 0 to 3, at the constat dry-bulb temperature. So, the moisture content in the air increases.

In humidification process, we add water vapor to the air. This Is done without increasing the dry bulb temperature. This is achieved by evaporating water vapor in the air. The process is known as adiabatic humidification. It is called adiabatic since it occurs from no heat added or removed from the surrounding air. The energy required for water to evaporate is entirely drawn from surrounding air and hence, the temperature of surrounding air drops and then to bring it to original dry-bulb temperature level, the air needs to be reheated. This process is not practical and therefore, rarely used in actual practice.

In almost all real situations, humidification without change in dry-bulb temperature is not possible and is therefore, considered as a theoretical process. In actual practice, the process used is normally cooling and humidification.

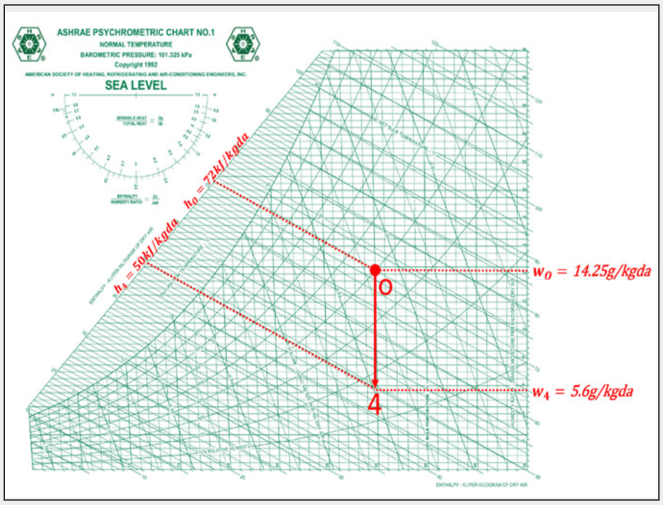

Figure 7: A vertical line moving from lower end to upper level 0 to 3, at constat dry-bulb temperature

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Dehumidification Only

The process is displayed by a vertical line running from higher moisture content to lower moisture content 0-4, the dry bulb temperature remaining constant. The process consists of first cooling the air in the cooling coil till it reaches saturation. Further, cooling will remove the moisture content along the saturation line till the desired moisture content level is reached. Because air is cooled, its dry-bulb temperature drops. Then reheating the air to its original dry-bulb temperature is the only alternative. The other method is to use desiccant dehumidifier. Humid ambient air (process air) is drawn in by a fan and pushed through an adsorption rotor. The adsorption rotor is coated with highly hygroscopic silica gel or any other hygroscopic material. A continual, slow turning of the adsorption rotor is carried out by the motor. The air stream to be dried is continuously pushed through the drying sector of the rotor. In the process, the water vapor it contains is almost fully adsorbed. The air is reheated again due to rotational movement of the wheel. Because the desiccant process is not a simple condensation like in a cooling coil, the dry-bulb temperature is lower and needs reheating. There is often a need for a separate regeneration cycle to dry the desiccant and a subsequent reheating or sensible cooling step to bring the supply air to the desired temperature.

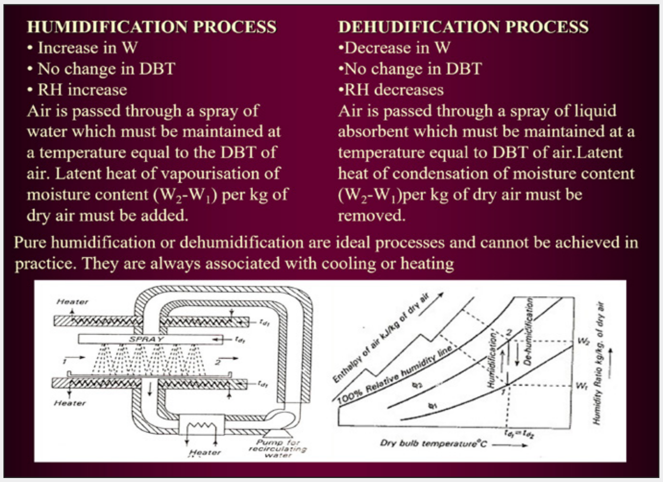

Figure 8: Humidification and dehumidification process

So, direct dehumidification without changes in dry-bulb temperature (DBT) is normally not possible and practical and is considered only as a theoretical process.

We shall now discuss the processes 08-07-06-05. They are lying in the four quadrants A,B,C,D as shown in the *Figure 8*.

These processes are mixed processes. We shall discuss all these four mixed processes in detail.

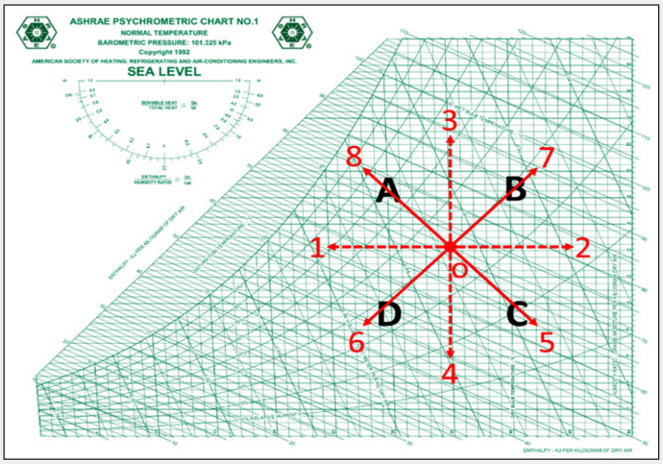

Figure 9: The processes 08-07-06-05 that are lying in the four quadrants - A,B,C,D

Cooling and Humidification: Quadrant A Process 0-8

Cooling and humidification process is one of the most commonly used air conditioning application for cooling purposes, also known as spray water cooling or air washer cooling. It is especially popular and used in high temperature and dry air condition cities in tropical countries. For example, cities like Nagpur, Kanpur, and Lucknow.

In this process, moisture is added to the air by passing it over the stream or spray of water, which is at a temperature lower than the dry-bulb temperature of the air. When the ordinary air passes over the stream of water, the particles of water present within the stream tend to get evaporated by giving up the heat to the stream. The evaporated water is absorbed by the air so its moisture content, thus the humidity, increases.

At the same time, since the temperature of the absorbed moisture is less than the dry-bulb temperature of the air, there is reduction in the overall temperature of the air giving comfort to occupants. Since the heat is released in the stream or spray of water, water temperature increases.

One of the most popular applications of cooling and humidification is the evaporative cooler, also called the desert cooler or fresh air-cooling unit.

The evaporative cooler is a sort of box inside which is a small water tank, small water pump and the fan. The water from the tank is circulated by the pump and is also sprayed inside the box. The fan blows strong currents of air over the water sprays, thus cooling the air and humidifying it simultaneously.

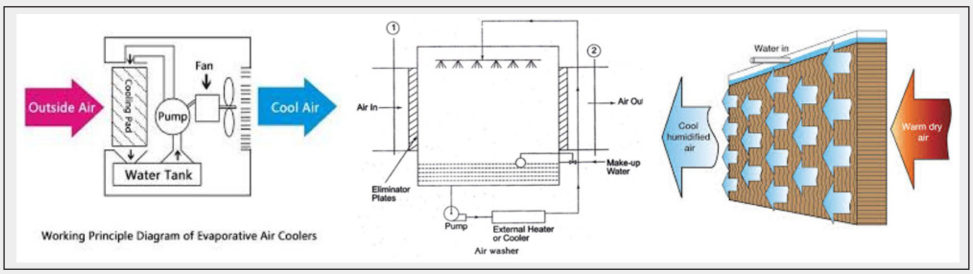

Figure 10: The most popular application of cooling and humidification is the evaporative cooler

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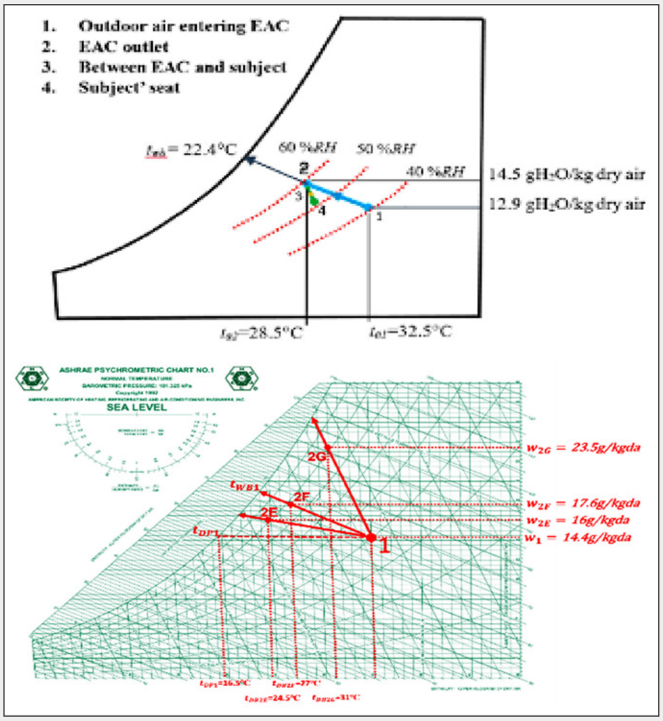

Figure 11: Three types of cooling and humidification processes in quadrant 1

The evaporative cooler is a highly effective cooling device having very low initial and running cost compared to the unitary air conditioners. For cooling purposes, the cooling and humidification process can be used only in dry and hot climates like desert areas, countries like India, China, and Africa. Evaporative cooler is ineffective in high humidity climates like coastal cities Chennai and Mumbai. During the cooling and humidification process the dry-bulb temperature of the air reduces, its wet bulb and the dew point temperature increases, while its moisture content and thus the relative humidity also increases.

There are three types of cooling and humidification processes in quadrant 1 as given below:

- Tdp1 is dew poit temperature
- Tw is spray water temperature
- Twb1 is wet bulb temperature

Process 2E: (tdp1 < tw < twb1)

The surface temperature of water is less than the wet-bulb temperature of air but more than the dew point temperature. Water is required to be externally cooled.

Process 2F: Adiabatic saturation, constant wet bulb temperature process (tw=twb1)

This is the case of pumped recirculation of water without any external heating or cooling. There is no heat gain or loss from the spray of water and the same water is circulated again and again. The recirculated water reaches the equilibrium temperature, which is equal to the wet bulb temperature of entering air. The cooling and dehumidification of air occurs at almost constant enthalpy.

Process 2G: (twb1 < tw < td1)

The mean temperature of water is less than the dry bulb temperature of air but greater that the wet bulb temperature of entering air. Though the air is cooled, its enthalpy increases as a result of humidification. *The water is, therefore, required to be externally heated.*

Advantages of Air Washer

Energy-Efficient Cooling

Air washers provide effective cooling without the need for costly refrigeration equipment. They are especially useful in arid regions where regular air conditioning may be ineffective.

Improved Indoor Comfort

Air washers may improve indoor air quality by adding moisture and filtering out impurities, making it more pleasant and healthier for inhabitants.

Cost Savings

When compared to traditional air conditioning systems, air washers are less expensive and often use less energy, which lowers operating expenses.

Sustainability

Evaporative cooling is an environmentally friendly process that uses water as the primary cooling agent, reducing the carbon footprint associated with cooling.

Conclusion

The psychrometric process within air washers is pivotal for achieving desired temperature and humidity levels, making them essential devices across various applications, including HVAC systems, industrial processes, and agriculture.

Heating and Humidification: Second Quadrant B-Process 0-7

This is a common cold climate application, in which cold and dry outside air or a mixture of return air and cold-dry outside air is heated first and then humidified. This may be also accomplished in a single process of heating and humidification using an air washer with externally heated water. Heating rises the temperature of a space for comfort, while humidification increases water vapor in the air.

Heating and humidifying is the process of simultaneously increasing both the dry-bulb temperature and humidity ratio of the air. The total heat gained (Q) in going from the initial to the final condition can be broken into sensible and latent heat portions. To separate the total enthalpy into sensible and latent heat, consider a horizontal movement on the chart as sensible heat and a vertical movement as latent heat.

On psychrometric chart, this process is shown sloping upward and to the right. The heating and humidification of the air is best considered by looking at the two processes sequentially. The first, from state 1 to state 0, is the sensible heating that occurs when the air passes through the heat exchanger. The second, from state 0 to state 2, is the humidification process. In actual practice, both the processes occur simultaneously.

Applications of Humidification

- In medical practice, it is done to prevent dryness of respiratory tract.

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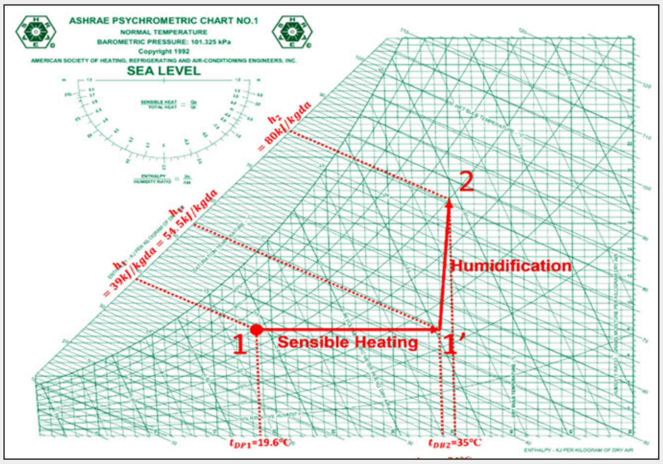

Figure 12: The process is shown sloping upward and to the right

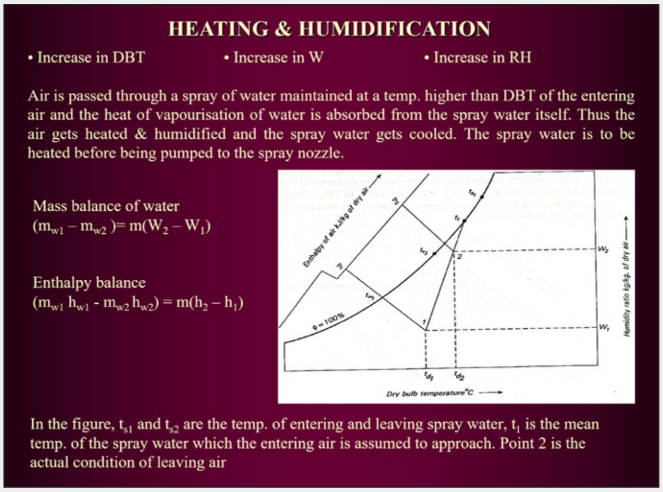

Figure 13: Heating and humidification

- In textile manufacturing, it prevents yarn tear.
- In food preservation, it prevents water loss, maintains freshness.
- In fermentation process of cheese, yeast it aids the process.

Heating and Dehumidification: Third Quadrant-C-Process 0-5

Adiabatic or Chemical Dehumidification

This process is mainly used in industrial air conditioning and can also be used for some comfort air conditioning installations requiring either a low-relative humidity or low dew point temperature in the room. In this process, the air is passed over chemicals, which have an affinity for moisture. As the air comes in contact with these chemicals, the moisture gets condensed out of the air and gives up its latent heat.

Adsorption Dehumidification

Adsorption dehumidifier uses a desiccant material like silica gel or other chemicals, in a rotating wheel to physically trap water vapor from humid air and in the process drying the air.

A separate stream of heated air regenerates the rotor by removing the absorbed moisture and releasing it to outside, creating a continuous and efficient process. It is mainly used for critical applications where liquid desiccant dehumidifier is not adequate in removing the moisture to the required level. The applications are clean room, food storages, ice rings, water damage restoration, warehouses, etc. The process is as under

- Fans pull air into the dehumidifier and move it over drying mechanism.
- The drying mechanism removes moisture as the air moves over it.
- The dehumidifier moves the air to the output duct and releases it back into the room.

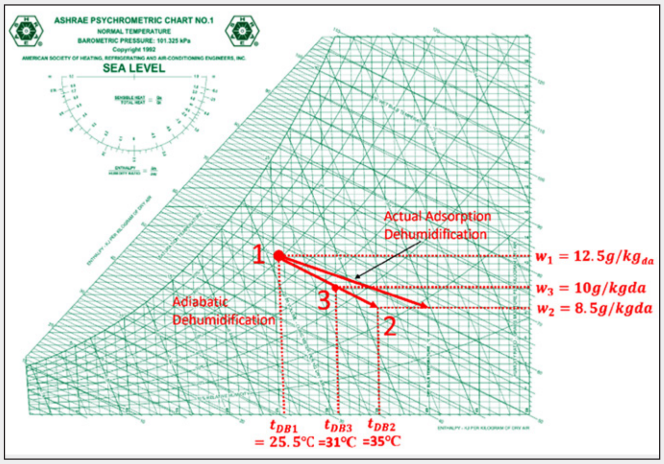

Figure 14: Actual adsorption dehumidification and adiabatic dehumidification

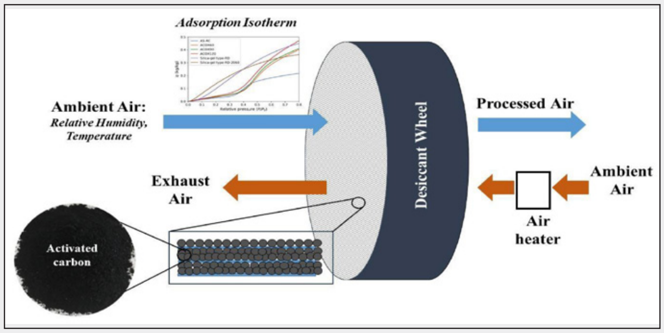

Figure 15: Adsorption dehumidifier

Applications of Dehumidification

1. Controlling humidity in computer rooms,
2. Preserving food items, which have been dried,
3. Improving comfort areas where humidity is generally high like closed indoor swimming pools,
4. Clean rooms,
5. Printing presses areas.

Conclusion

In this part, we have covered all the processes except the most important one i.e. cooling and dehumidification or what we normally call as air conditioning process, Quadrant-D-Process-0-6. We will deal with it in detail in the next part VI.