Humidification Applications Part 1: Isothermal Humidification

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Introduction

The air conditioning industry in India is focused mainly on cooling and dehumidification with some heating with the objective of catering to very cold climate and maintaining relative humidity (RH) in industrial applications. Barring a few exceptions like the textile industry (requiring RH above 60 per cent), humidification has been on the back seat. As an example, many pharmaceutical facilities were set up without any consideration to humidify the air during dry weather – whether cold or hot.

Need for Humidification

ASHRAE has published a chart showing optimum relative humidity to be between 30 per cent and 60 per cent (2016 ASHRAE HVAC Systems and Equipment, Chapter 22). However, when inspected carefully, one can see that actually 40 per cent is the minimum RH at which viruses are far less effective than at 30 per cent.

ASHRAE has recently published 'ASHRAE Position Document on Infectious Aerosols' that refers to studies correlating mid-range humidity levels with improved mammalian immunity against respiratory infections. It further mentions that scientific literature generally reflects that the most unfavourable survival for microorganisms is when the RH is between 40 per cent and 60 per cent. A modified humidity range chart would indicate as in *Figure 1*.

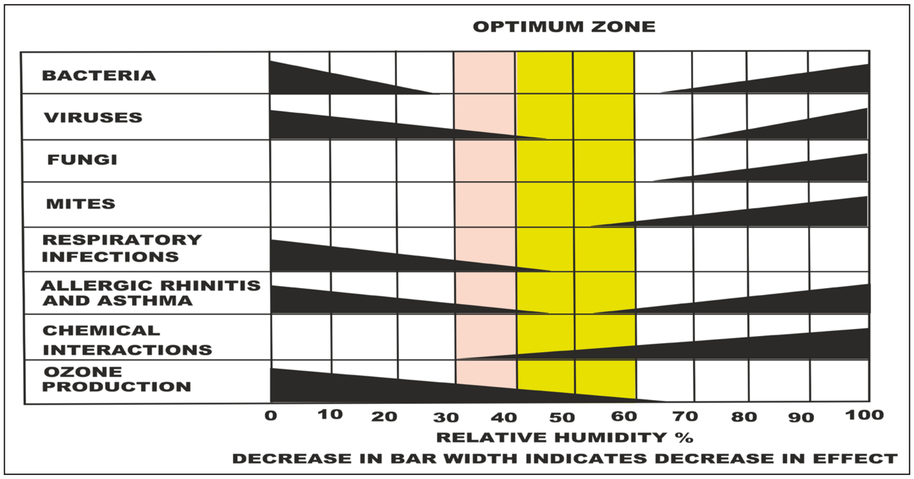

Figure 1: A modified humidity range chart

About the Author

Shridhar Gokhale is a humidification engineer trained in Europe and has been working in the field of humidification for more than a decade. Prior to this, he ran a design-build contracting firm in the HVACR field for three decades. His company Humidity Technologies represents the Condair Group of Switzerland.

In fact, 50 per cent can be considered as an ideal RH for a healthy environment. In many industries, the importance of maintaining the correct RH to reduce wastage is now being understood by manufacturers and the demand for humidification is now increasing.

Indian Climate

Tropical climate and mild winters were perhaps the cause for humidification to be neglected so far. However, continuous development of new products and innovative manufacturing techniques are now being the drivers to bring humidification to the forefront in some industries. Many industrial hubs are in non-coastal areas and the climate tends to be dry during winter as well as peak summer.

Companies that are planning new facilities or even re-development of an existing facility may probably go to a regular HVAC consultant for designing the environmental control systems. Humidification is a specialized subject. It is an art as much as a science and not many regular consultants or system designers have the necessary know-how to integrate humidification in HVAC system design. There are different types of humidifiers available. The application along with regulations is the deciding factor in choosing the right type.

It is necessary to consider the ambient dry bulb temperature and the lowest ambient absolute humidity as well as the desired space conditions and draw the humidification process on a psychrometric chart. In-depth knowledge of psychrometrics is a required tool for designing humidification. The humidification duty is solely dependent on the fresh air introduced in the AHU. Room dimensions, supply air flow or equipment load have no bearing on the required humidification capacity.

Humidification Options

Humidification can generally be divided into three physical methods: vaporization, atomization and evaporation. Vaporization is an isothermal process while atomization and evaporation are adiabatic processes. *In Part 1 of the article, we shall focus on isothermal humidification*.

Isothermal Humidification

In the isothermal humidification process, the dry bulb temperature remains almost constant. The absolute moisture content of the air increases to raise the level of relative humidity. Energy is required for this purpose. Steam is the source of adding moisture in the isothermal process. However, boiler steam is not recommended for humidification as it is generated from water to which corrosion inhibitors are added; in addition, boiler steam is circulated through mild steel pipes and rust can flow with steam, causing undesired effects. Electrical steam humidifiers generate clean steam for humidification and typically 0.75 kW energy is needed per kilogram of steam generated.

Steam can be generated by two methods using electricity. One is using electric heaters to boil the water in a vessel. This type of humidifier is known as resistive steam humidifier (more

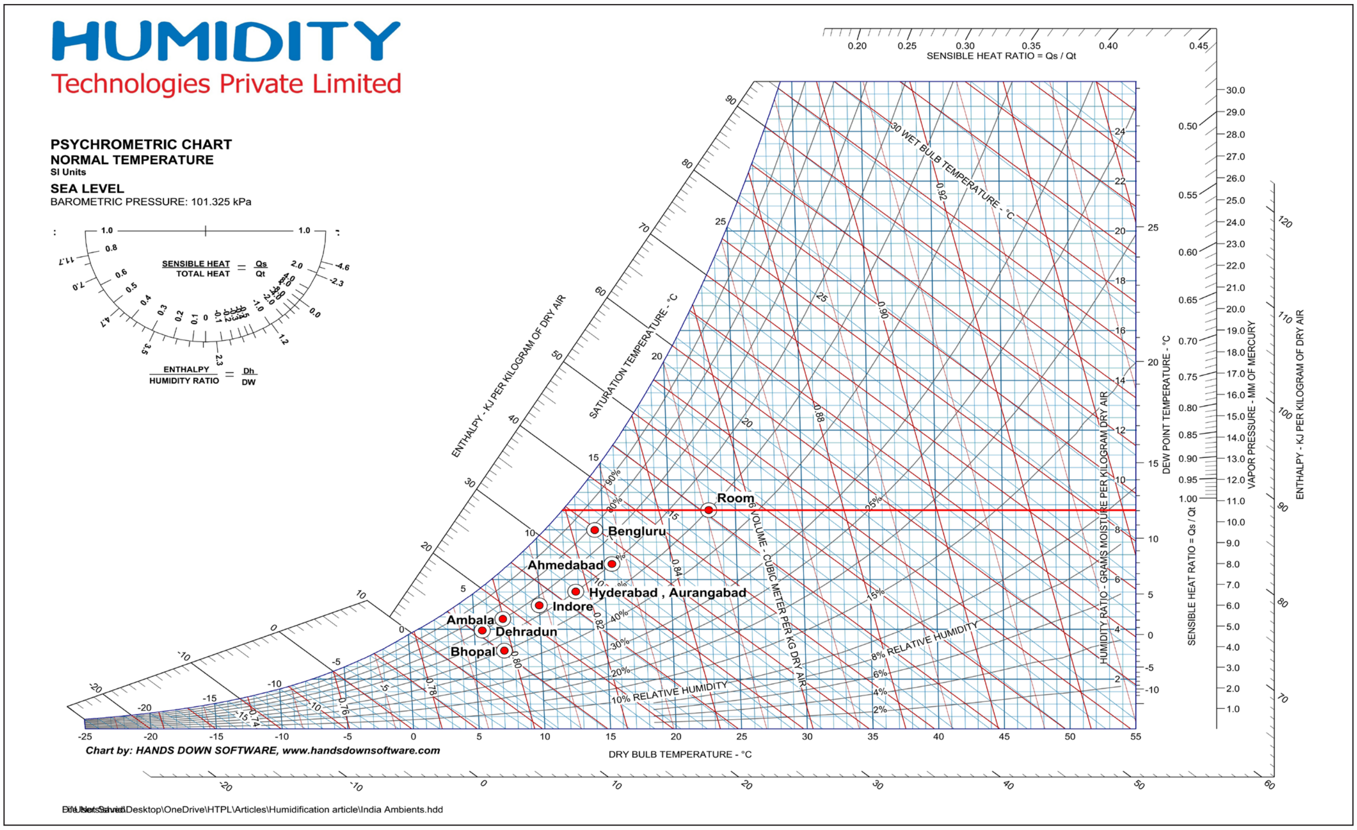

Figure 2: Winter ambient conditions in some Indian cities

commonly known in India as pan humidifier, which incidentally has been phased out in developed countries decades ago.) The other is electrode type in which current is passed through water to generate steam. This type of humidifier is suitable for non-critical applications – the reason being water has to be conductive so current can pass through. Conductive water leads to scaling of electrodes resulting in loss of accuracy, and over a period the steam cylinder needs replacement. Although some large capacity humidifiers are cleanable – the increased maintenance cost needs to be considered in the total cost of ownership.

Figure 3: Typical resistive steam humidifier

Figure 4: Typical electrode steam humidifier

The steam from the above generators is used for humidification. But installing the right sized humidifier does not guarantee correct humidification. The air gets humidified only if the steam is completely absorbed in the air and does not impact any object downstream. It is necessary to provide an empty section in an AHU or supply air duct (wherever steam is to be injected). The steam absorption distance is calculated by a humidification engineer based on the incoming air condition to the humidifier and the final space conditions required. The geometry of the AHU or supply air duct is also an important factor in the calculation as the absorption distance varies with air velocity. Steam is injected in the AHU or supply duct through correctly sized and positioned steam distribution pipe(s).

Applications of Isothermal Humidification

Isothermal humidifiers are the most suitable for humidifying in pharmaceutical as well as healthcare industries.

Humidification in Pharmaceutical Manufacturing

Poor environmental control, particularly in respect of humidity, can directly affect the pharmaceutical production line in a number of ways. Levels of humidity below 45 per cent RH will allow static charges to build up. This can have major implications where solvents are used in the process, and it can also cause the product to dry out, affecting its performance. Other results of static build-up include products sticking to each other, leading to packing problems. Equally, high humidity can cause products to absorb moisture during production and final packaging. Some antibiotic tablets are degraded, and their effectiveness reduced if moisture is absorbed. The product that is long-term moisture-sensitive will degrade over time if packed under the wrong conditions. Therefore, the control of the production environment is becoming more critical as product development moves forward.

The requirement for environmental control is not just from production areas, it can also be within a production machine. Tablet coatings with aqueous solutions require extremely tight control of air humidity to ensure that the coating does not dry too fast or too slowly. This is of particular importance in the coating of extended release tablets. There are pharmaceutical printing processes that require control of humidity to prevent water based inks from drying during processing.

In the high technology medical device manufacturing industry, cleanrooms are commonly used. The design of cleanrooms is well documented. However, the technology that is used to give the environmental control is again often achieved using standard heating, ventilation and air conditioning equipment. It is felt that the environment needs to be controlled for personal comfort, and it is assumed that the product will also be stable in this wide-ranging environment. It is not until low productivity levels are found, and the production problems are traced back to temperature and humidity control, that the importance of the right equipment can be truly seen.

Budget Decisions

The problem for many companies is that the finance directors fix the budget for the project. This capital expenditure budget will many a time only allow the purchase of low-cost equipment, particularly, in terms of the environmental control plant. It is rare that the operating costs or possible production losses are taken into account. If they were, it is likely that it would be a very different picture. Whilst it may apparently cost more to initially purchase specific equipment that will give the optimum control required, the overall running and maintenance costs of correctly selected equipment will often show that an apparently more expensive capital item will actually give a payback inside 12 months. In some cases, the production losses due to wastage can reduce the payback time considerably as the cost of a product batch many a time runs into millions of rupees.

Why Humidify?

Typically, five to 10 per cent fresh air is introduced in AHUs to maintain the pressure differential across room and the corridor. Climatic changes are seen all over the world and at times the ambient moisture content is lower in summer than in winter. During dry seasons, the ambient absolute humidity pulls down the room humidity to unreasonable levels unless humidification is provided in the AHU or supply air duct.

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Cleanrooms

Many cleanroom manufacturing processes require control over humidity. In tablet processing areas, if the humidity post coating is not optimal, the coating may dry too rapidly, detrimentally affecting its properties. Capsule manufacturing as well as filling requires optimum humidity levels closer to 50 per cent. Lower humidity causes brittleness, which could lead to deformation and capsules get sticky in high humidity. High speed capsule filling machines operate more efficiently with less stoppages and wastage if the RH is closely controlled.

Figure 5: Five to 10 per cent fresh air is introduced in AHUs to maintain pressure differential

Stability Testing

Regulations on accelerated or long-term stability testing mostly require humidity to be controlled within a tolerance of (±) 5% RH. If the condition of the atmosphere falls outside this window, it can result in a test having to be restarted. This is expensive and can even delay the launch of a new product.

Static Prevention

Levels of humidity below 40% RH can lead to static build-up. The results of this include materials adhering to each other on the production line and not locating correctly inside the packaging. A humidity level of between 45-55% RH will significantly reduce the probability of electrostatic discharge, which is vital for sensitive electronic equipment or where flammable gases or substances are being used.

Humidification Solution

World Health Organization (WHO) has prohibited the use of adiabatic humidification (whether evaporative or spray type) in pharmaceutical applications as cold water humidification may become a source of microbial contamination. Steam humidification is the only acceptable solution in the pharmaceutical industry. The humidification system should be well drained and no condensate should accumulate in the air handling systems. Filters should not be installed immediately downstream the humidifiers as moisture on the filters can be a source of microbial growth.

Electrode or Resistive?

Electrode and resistive are the two main types of electric steam humidifiers that HVAC contractors can buy and install. Both are versatile and come in a variety of capacities. From a contractor's perspective, the main considerations while selecting a unit are often purchase cost and ease of installation. For a customer or end-user, the initial cost is also important but so are on-going operating costs and maintenance requirements. The main differences between electrode and resistive technologies are how they heat the water to create steam and how they control steam output.

The electrode boils water by passing electrical current through it. The more current passes through the water, the greater the steam production. So, output increases with a higher water level or when higher mineral levels make the water more conductive. To maintain an accurate output, the concentration of minerals in the water is regulated through drainage and replacement with fresh water. This typically allows for humidity control of around (±) 5% RH to (±) 7% RH.

Resistive humidifiers create steam through the transfer of heat from the resistance heater elements to the water. Steam output is controlled by applying more or less heat to the water rather than controlling water level or conductivity. As the mineral content of the water has no impact on steam output, resistive humidifiers can also operate on Reverse Osmosis (RO) water. As the mineral content of the water is very low, this virtually eliminates scale build-up, significantly reducing maintenance requirements. It also improves humidity control by removing the need for fresh (cold) water to be regularly introduced to reduce mineral levels. A consistent water temperature results in a consistent steam output and enables a resistive humidifier operating on RO water to control humidity to (±) 2% RH. With potable water RH can be controlled within (±) 5% RH.

Electrode humidifiers tend to have the lower capital cost of the two technologies. Installation costs for both electrode and resistive are comparable, and both are simple to install as they only require connection to power, water mains supply and drain. With an electrode boiler, as steam is produced, any minerals in the water build up within the plastic cylinder as limescale. When these cylinders are full of limescale, they are replaced, which is straightforward and offers the benefit of very rapid maintenance and minimal downtime for the humidification system. The disadvantage is that cylinders can be expensive and represent an ongoing spares cost. As resistive steam humidifiers do not pass current through water, they can operate with stainless steel boiling chambers that can be cleaned rather than replaced. This avoids the expense of disposable cylinders, reducing spares costs. So much so that the initial cost of the more expensive resistive unit can be recouped within a couple of years.

Humidification in Healthcare Environment

Humidification in healthcare environment is essential to combat many detrimental effects dry air has on the human body and immune system. It is also needed to reduce airborne infection rates and provide the optimum condition for the successful operation of some medical equipment. In isolation rooms or in some operation theatres, where air is not recirculated, humidification is imperative as during dry seasons – especially winters – the treated fresh air supplied can reduce the room RH as low as 25-30 per cent. Even when limited fresh air is introduced in the air handling system, the RH will drop to the same level in due course as the entire room air is replaced by outside air.

Studies have shown that a healthy level is between 40 and 60% RH as bacteria and viruses do not survive long in this range. Maintaining the correct RH can thus reduce the incidence of hospital acquired infections.

Sensitive babies, expensive electrical equipment, electrostatic shocks and stress are just some of the reasons why it is essential to maintain the correct humidity in hospital environments. Low relative humidity in the atmosphere of an operating theatre will cause the air to draw moisture from all possible sources in the room – including any body tissue exposed during operations. This can cause premature drying and promote the formation of a scab from coagulated blood during operations. By maintaining an optimum humidity of between 50-60% RH, drying of body tissue is prevented.

Perhaps more important in an Operation Theatre is the effect of electrostatic shocks that build up below 40% RH. The uncomfortable, surprising jolts caused by a sudden static discharge can have potentially damaging and dangerous effects on surgery, and consideration must also be given to the prevention of electrostatic sparks in relation to flammable anaesthetic gases.

Electrostatic build-up poses a real threat to electrical equipment. Radiology departments contain very sensitive and expensive equipment that can be easily damaged by static sparks. By maintaining humidity levels of above 45% RH, static build-up can be eliminated.

Young babies are also extremely susceptible to dry air. Membranes in the throat and nose can very easily dry out when the humidity drops below 40% RH. For this reason, humidity levels in maternity and obstetric departments should be maintained at 45-65% RH. For many adults with respiratory problems, low RH can aggravate their condition as mucosae lose moisture to the environment. In fact, there are very few areas in a hospital that do not benefit from humidification. The problem can often be a compromise between those areas that need it and the running costs of humidifiers in a sector where budgets are always tight.

Figure 6: Humidity levels in maternity and obstetric departments should be maintained at 45-65% RH

Ironically, directives govern RH levels for laboratory animals but not for a hospital.

Considerations for Different Departments

Operation Theatres

The optimum humidity level in an operation theatre will depend on the type of surgery and sometimes the preference of the surgeons involved. For procedures such as open heart or cranial surgery, dry air can promote electrostatic micro-shocks, which can pass from surgeon to patient and are potentially fatal. Typically, it is desirable to maintain levels of 50% ± 5% RH during these operations. Other reasons for humidity control in operating theatres include preventing delicate membranes drying during stomach procedures, inhibiting the spread of airborne spores during operations, involving highly infectious diseases, and preventing evaporation from swabs prior to weighing for more accurate blood loss assessment.

Burns Units and Dressing Rooms

These areas are maintained at a very high temperature of above 27°C to help the healing process during and after a dressing change. With such high temperatures, humidification is necessary to prevent uncomfortable and unhealthy low relative humidity.

Airborne Infection Control

Many scientific studies have concluded that humidity between 40-60% RH is the optimum range to reduce the risk to health from airborne viruses, bacteria and other pollutants. Maintaining this optimum level in wards and waiting rooms significantly reduces the infectivity and survival rates of airborne viruses, which in turn reduces airborne infection rates. Low RH below 40% has been shown to detrimentally affect our immune system. Dry air will draw moisture from mucous membranes in our nose and throat, which is one of our body's main defences against airborne contaminants. So, as well as increasing the survival rates of airborne viruses, dry air also impairs our natural ability to fight them off.

Humidification Options

Moisture can be introduced into the atmosphere of an air handling system by injecting steam in the supply air duct. Hospital environments require sterility. So, it is important to ensure any system has fail safe hygiene features. Steam is a very popular solution in hospitals as it ensures the moisture being introduced is 100 per cent safe. Resistive steam humidifiers being far more reliable as compared to electrode humidifiers are the obvious choice for this application.

Conclusion

Designing a humidification system for a hospital environment is a very detailed process, and each unit should be tailored to the specific installation. Consideration must be given to the design of the air handling system that will carry the moisture, the rate of air flow through the system, the size of the ducts and many other factors. This is to ensure 100 per cent absorption of the moisture into the atmosphere of the air handling duct. Even with steam, if complete absorption is not achieved, moisture will condense and lead to problems of microbiological contamination in the air supplied.