High
Efficiency
Solutions.

CAREL

compendium

Air humidification in hospitals and healthcare structures with the objective of saving energy

carel.com

This document is based on the standards described. For all information provided herein, we recommend you read and apply the standards in force in the country where the humidification system is installed.

Introduction

Control and management of air humidification in healthcare structures is needed to reduce the risk of contagion and ensure the comfort of healthcare workers, patients and visitors. In addition, when relative humidity is too low, electrostatic discharges may occur, representing a risk to patients and damage expensive medical equipment.

Health comes first

Low air humidity affects both personal health and comfort. In winter, when relative humidity falls in heated indoor spaces, dry air increases respiratory problems, as well as affecting the eyes, skin, nose and mouth. This is why air-conditioning systems are used in hospital wards to control both air temperature and humidity.
Accurate humidity control also helps protect electronic equipment against electrostatic discharges, ensuring a safer place for personnel and visitors and, at the same time, safeguarding patient health.

Standards

For operating rooms, European Directive 2002/91/EC and the EN ISO 13790:2008, EN 13779:2008, VDI 6022, DIN 1946-4, UNI 11425 and ASHRAE 170 standards, just to list a few, specify that ventilation and air-conditioning systems must ensure ideal working temperature-humidity conditions for medical personnel, while at the same time meeting the needs of patients. Humidification systems therefore need to be designed so as to prevent the production and spread of contaminants, be easily accessible, cleanable and inspectable. Special emphasis is placed on continuity of service, especially in operating rooms: humidifiers must guarantee continuous operation and "must not stop" for maintenance.

Hygiene

Automatic washing and drain cycles, certification and careful choice of construction materials are just some of the features that CAREL products stand out for as regards hygiene.

Optimum humidity

Relative humidity in the range between 40 and 60% minimises the impact of bacteria and respiratory infections. Higher relative humidity leads to proliferation of bacteria and other biological contaminants (viruses, fungi, mould, mites).

Energy Saving

CAREL's objective is to eliminate waste, minimise water consumption, minimise energy consumption and avoid environmental pollution. These principles guide all our products, from design through to development and production.

Water saving

Experience acquired in the field of humidification has led to the development of accurate software procedures to reduce humidifier water wastage. Precise control of water properties, humidification demand and filling and dilution cycles all help minimise water consumption.

Personal comfort

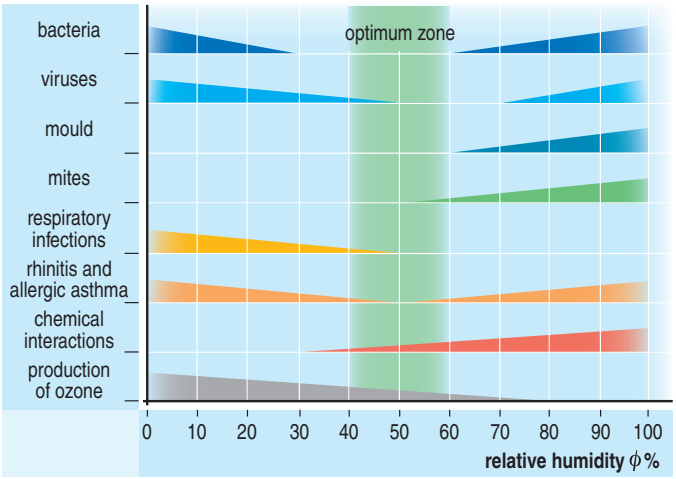
Personal comfort requires relative humidity between 40 and 60%. Higher humidity levels cause a feeling of discomfort, while lower humidity causes dryness and inflammation of mucous and chapped skin.

Health and comfort

Humidity control is essential for achieving a level comfort that guarantees working efficiency and quality of life in hospitals. Analysis of building and office structures also takes into account occupant comfort: this aspect is even more important in hospitals, where there are patients, visitors and healthcare workers at risk of infection due to germs, bacteria and viruses. The right humidity reduces airborne proliferation and propagation of pathogens, making the environment safer.

Sick Building Syndrome (SBS)

Indoor relative humidity can also cause eye, respiratory and skin irritations, as well as coughing, nausea, drowsiness and headaches; these symptoms are due to contaminants in the buildings themselves, a phenomenon known as Sick Building Syndrome (SBS).
Studies carried out on the effects of humidity on the development of contaminants in buildings show how there is less incidence of respiratory illnesses in places where humidity is controlled. The graph below shows the trend in the proliferation of certain biological species and illnesses according to relative humidity. For example, there is an increase (indirect) in bacteria and viruses both at low and high relative humidity values, as well as a weakening of the airways due to mucous drying out at low relative humidity values, with an increased probability of respiratory infections, allergic rhinitis and asthma



Sterling chart taken from "Criteria for human exposure to humidity in occupied buildings"

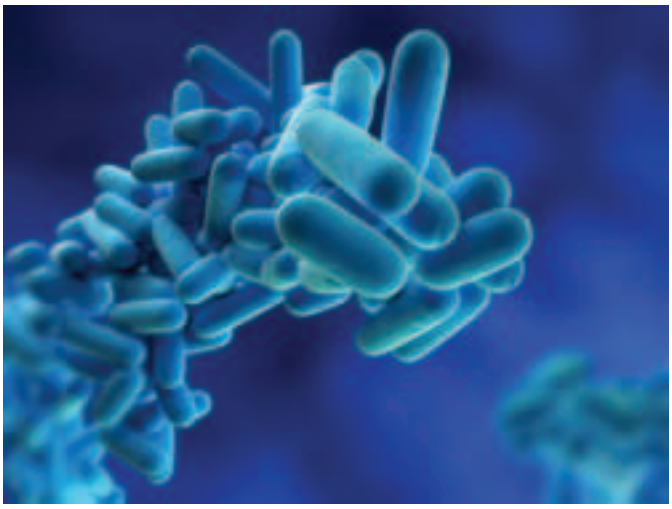
Legislation and standards on humidity control

It can be seen how optimum relative humidity (green area) is between 40 and 60%.
Hospital HVAC (Heating, Ventilation and Air Conditioning) systems therefore need to keep air relative humidity within these values.
Humidity in hospitals is very important, its quality and quantity (relative humidity) needs to be constantly controlled, in compliance with strict regulations and standards depending on the country in question.
Accurate humidity control is therefore not just an additional attribute, but rather a statutory requirement.

Bacteria and hygiene in humidification systems

Hygiene and safety

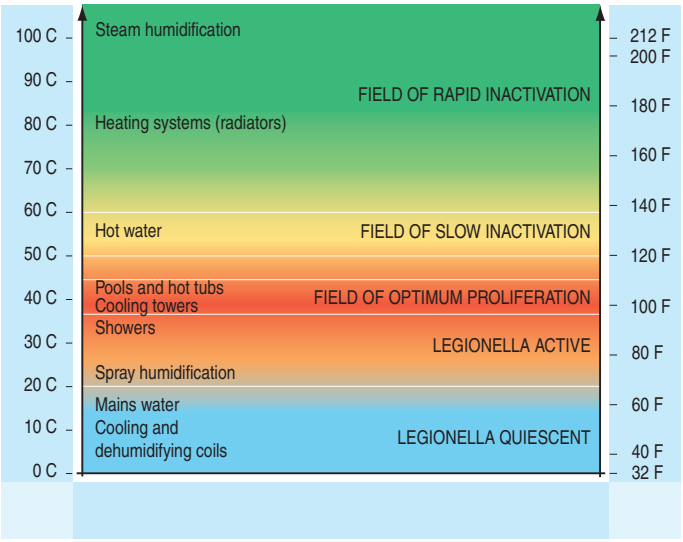
The growth of bacteria depends on temperature and the presence of nutrients to provide the basis for proliferation.
The Legionella bacterium (Legionella pneumophila) lives at temperatures between 25 and 42 °C (77 and 108 °F), temperatures found commonly in plumbing and air-conditioning systems. Legionella can be found in natural environments such as lakes and rivers, as these contain organic material. Organic sediments, rust, materials that accumulate on rough surfaces and water distribution all aid the spread of Legionella. This is why Legionnaire's disease represents such a serious public health problem, above all in situations where people gather together in the same place.
Due to their size, colonies of Legionella bacteria can be easily carried over large distances by airborne water. Consequently, equipment used for atomising water (such as showers, whirlpool baths and spray systems in general), may also spread the bacteria if this is contained in the atomised water.
The most significant source of Legionella contamination is however outside of air-conditioning systems, as the bacteria are very often carried in the fresh outside air taken into the system.



Legionella bacterium

Preventing Legionella

The primary measure to be adopted regarding Legionella, or bacterial contamination in general, involves humidification systems only using drinkable water from the mains supply, and therefore bacteriologically pure.
It must also be stressed that at temperatures above 70 °C (158 °F), Legionella begins to be destroyed: as steam humidifiers eliminate the spread of bacteria, these humidifiers (also called isothermal humidifiers) are universally recognised as being safe in terms of bacterial proliferation.



Activity of Legionella: effects of temperature and typical operating ranges

In addition, using materials with surface finishes that prevent the release of fibres and limit accumulation of dirt, such as AISI304 (or higher grade) stainless steel also guarantees reduced proliferation of bacterial colonies.
The use of UV (ultraviolet) lights to disinfect humidifier supply water further weakens the reproduction of bacteria.
In general, other important measures that can be adopted to minimise the risk of spreading bacteria are:

- using droplet separators or mist eliminators to remove any droplets in the air that are not evaporated (these may also be required for evaporative humidifiers and not just for spray appliances);
- draining the water when the appliance stops. At the end of each humidification cycle, the system should empty the humidifier;
- periodically washing the internal parts with once-through water. It is clear that water residues can remain trapped in small spaces even after the system has been emptied, and therefore in favourable conditions, these residues may become stagnant: periodical washing or flushing eliminates such residues;
- avoiding the use of recirculated water.

Preventing electrostatic discharges

Electrostatic discharges are generated due to contact between materials and their subsequent separation, for example when rubbing two insulating materials together, electrical charge may be transferred from one object to another. If the electric field generated by separation exceeds the dielectric strength of the medium that separates them (e.g. air), electrostatic discharges will occur.
The electric field that is generated depends on the type of materials and the relative humidity in the environment. Electric field strength increases as relative humidity decreases, at RH <20% electrostatic discharges may reach levels in the tens of kilovolts. The sensitivity threshold of electronic components (CMOS, MOSFET, EPROM, JFE…) used in medical instruments and equipment ranges from several hundred to several thousand volts.
This means that electrostatic discharges can cause equipment malfunctions and considerable damage, such as:

- damage or destruction of components and medical electrical equipment;
- shutdown of medical electrical equipment;
- incorrect readings by measuring instruments or devices used in operating rooms;
- deletion of instrument memory;
- accumulation of static electricity on X-ray films.

To avoid such risks, with consequent costs or problems for patients, measures are adopted aimed at protecting medical electrical equipment against electrostatic discharges.

Air humidity control in hospital environments reduces the risk of electrostatic charge accumulation. Relative humidity must be kept above 35%, the minimum value required to avoid electrostatic discharges.

Personal comfort

For healthcare "centres of excellence", patient comfort is the focus of hospital operations right from the building design stage. In new structures in particular, all hospital activities revolve around a patient-centred approach.

Definition of comfort in hospital environments

Comfort is defined in different ways, all of which based on an individual's sense of physical and mental wellbeing within a certain environment. The definition of comfort within a given environment can be summarised in three points:

- thermal comfort:
  - temperature;
  - humidity;
  - air velocity;
- indoor air quality:
  - percentage of air charge (volumes/hour, l/s per person);
  - CO_2, VOC (Volatile Organic Compound) concentration;
  - microorganisms;
- noise levels

Thermal comfort is a person's sense of wellbeing in relation to their perception of hot or cold. An environment with a good level of thermal comfort is one in which at least 90% of the occupants are in comfortable conditions. In practice, the PPD (Predicted Percentage of Dissatisfied) for hospital environments must be less than 10% (EN 15251 category II). The right relative humidity level inside a room contributes to thermal comfort, as it affects perspiration from the body and internal energy balance.

Air humidity control allows patients and healthcare workers to breathe easily, avoiding dryness of the respiratory tracts, as well as reducing the amount of airborne dust in closed spaces. The recommended relative humidity range for hospitals is between 40 and 60% (also see local standards in force). Ventilation and air-conditioning systems therefore need to ensure ideal temperature-humidity conditions for the duration of the patients' stay inside the structure, to improve working conditions for doctors and healthcare workers, and guarantee correct operation of medical electrical equipment.

Thermal comfort must also be accompanied by indoor air quality: normally this is affected by human activity within the environment, and consequently fresh air needs to be introduced in order to reduce levels of CO_2 or organic compounds. Air quality is not easy to measure, so normally the number of air changes per each hour or litres of fresh air per person are controlled.
All this must be done while minimising noise levels, so as to create an acoustically comfortable environment.


ChillBooster
heaterSteam
ultimateSAM
humiFog
humiSteam

Energy saving and sustainability

Starting from water savings in the humidification process, right up to high performance energy saving solutions, CAREL guarantees the best solution for every system, exploiting its significant experience acquired in the field.

Savings for isothermal humidifiers

CAREL's experience in the field of steam humidification has led to the development of accurate software procedures to minimise water waste in humidifiers. Precise control of water properties, steam demand and filling and dilution cycles all help minimise wasted water in immersed electrode (humiSteam), heater (heaterSteam) and gas-fired humidifiers (gaSteam).
If gas supply is available (natural gas, propane, butane), further cost savings can be achieved using the gaSteam humidifier. The difference in cost between gas and electricity makes gaSteam the ideal choice for more heavy-duty applications, where steam is required for many hours a day, allowing savings in the thousands of euros a year. Continuous modulation of steam flow-rate also makes this solution suitable for precision applications.
Gas-fired (gaSteam) and electric heater humidifiers (heaterSteam) running on demineralised water significantly reduce maintenance requirements and cleaning of the water circuit where the salts contained in the supply water may accumulate. Consequently, unit running costs and downtime for maintenance are considerably lower.
The ultimateSAM series steam distributors with short non-wetting distance reduce condensate formation, thanks to air cushion insulation and AISI 304 stainless steel structure that insulates the steam pipe against direct contact with the air in the AHU/duct, bringing a 30% reduction in condensate formation and consequently energy consumption for steam generation. In addition, a regulating valve is used to deliver only the steam that's needed into the air handling unit (or duct), saving steam in the main pressurised line.

Energy saving in the humidification of wards, common areas, clinics, pharmacies and administration offices

From the viewpoint of system optimisation and energy saving, CAREL proposes humiFog, a solution with low energy consumption. In places where the use of steam humidifiers is not required by law, energy saving can be attained using adiabatic technology. Atomisation of very fine droplets into the air in fact consumes less energy than steam technology, as each l/h of atomised water requires just 4 W of electricity, against the around 750 W required to produce 1 kg/h of "steam". Humidification is also accompanied by evaporative cooling, which can be exploited in summer for efficient air cooling. The reduction in humidifier power consumption also means less installed power and lower peaks in air-conditioning system power consumption. Continuous capacity modulation minimises water usage by only atomising the amount that is effectively required at any given moment.
humiFog uses a volumetric pump to pressurise the water, which is atomised by special stainless steel nozzles. The sophisticated control system combines the action of an inverter, which controls the speed and consequently the flow-rate of the pump, with a series of solenoid valves that activate only the nozzles that are necessary, allowing the system to always operate at the ideal pressure to atomise the water (up to 70 bars), across a wide range of flow-rates.

In addition, different rooms can be connected to a single pumping unit, meaning one central master unit serves several different independent slaves, further rationalising investments.

humiFog uses demineralised water without the addition of chemical biocides (such as silver ions) and is suitable for all applications requiring a high level of hygiene, ensured by: emptying the lines when the unit stops, automatic periodical washing of the lines, certification issued by outside laboratory compliant with VDI6022, VDI3803 and DIN1946-4 hygiene regulations.

Energy saving for chillers and drycoolers

Atomiser technology can also be used to save energy on chillers and drycoolers. chillBooster cools the air before this reaches the cooling coils or condensers by evaporation of atomised water (adiabatic): the lower air temperature increases heat exchange and consequently chiller or drycooler capacity. Some of the droplets form on the coils, where they evaporate: evaporation takes place by absorbing a considerable amount of heat from the coil. Chillers and drycoolers can therefore operate in more favourable conditions, allowing them to reach rated capacity (drycooler and chiller performance can be boosted by up to 40%).

Evaporative cooling

Evaporative cooling can be used to achieve considerable energy savings. Indeed, the evaporation of water is exploited to cool the air

Evaporative cooling is the name given to the process by which water evaporates and thus cools the surrounding air. For this process to occur spontaneously, i.e. without requiring an external energy source, the water needs to be atomised into the air in the form of very fine droplets with a lower surface tension than the surrounding air, and consequently able to "dissolve" into the air.
Evaporation of water requires a certain amount of energy. This energy is taken from the air that, in order to absorb the water, has to give up sensible heat and consequently its temperature decreases. Each kilogram of water evaporated absorbs 0.69 kWh of heat from the air. This is why the evaporative cooling process achieves the dual effect of humidification and cooling, which in many air handling applications are both desirable.
The main benefit of evaporative cooling is its energy cost, which is practically zero. Comparing the energy cost of evaporative cooling against other typical processes (for example, air humidification by introducing hot steam or cooling the air using chillers and cooling coils), the energy savings are significant. The only energy required is to pressurise the water delivered to the spray nozzles, using a pump. Power consumption ranges between 4 and 10 W/l of atomised water, in other words less than the 2% of the energy needed to evaporate the same quantity of water through electric heating.

Cooling without increasing humidity

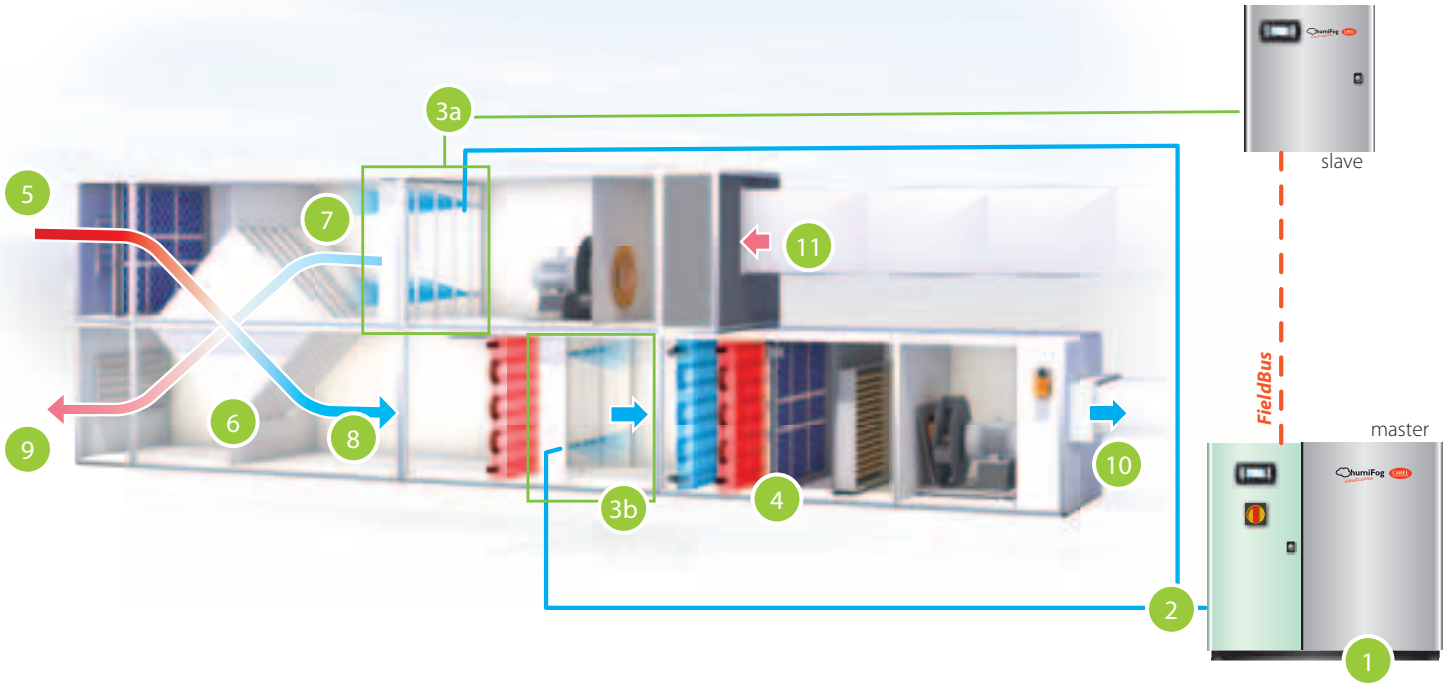
A pumping unit can be used in winter to humidify the supply air, and in summer to cool the air intake without increasing humidity. Exhaust air can be cooled by several degrees without humidity limits, as it is discharged from the AHU. Via a heat exchanger, this cooling capacity, can be used to cool the fresh intake air, with efficiency that depends on the heat recovery unit used, yet easily exceeds 80%! All this means lower energy consumption, smaller dimensions and capacity of the cooling coil and chiller.

CAREL provides a complete range of products that exploit the principle of evaporative cooling and all the related benefits. Standard unit configuration (i.e. humiFog and optiMist) includes:

- cabinet, containing: the pump to pressurise the water, water and electrical connections, filters to purify the supply water, control unit to manage system operation;
- atomising nozzles, available in different configurations in terms of pressure requirements and flow-rate delivered; these atomise water into very fine particles (even down to a few hundredths of a millimetre), extending the heat exchange surface (one litre of water mist can cover up to 170 m^2);
- distribution system, made up of steel manifolds in different shapes and configurations, depending on whether they are used for humidification in ducts or directly in rooms.

Humidifier compliance

All Carel products comply with the European hygiene standards defined by VDI6022. In particular, as regards products that exploit evaporative cooling, hygiene is achieved using a sophisticated electronic system that manages the drain solenoid valve on the distribution line, so as to prevent stagnant water from forming in the piping, the main danger for the proliferation of germs and bacteria. As well as the drain cycles, Carel products also automatically wash the distribution lines at predefined time intervals when the unit is not operating.
All this in addition to the use of materials such as stainless steel, demineralised water and UV disinfection lamps to maximise humidification hygiene.



1. *pumping unit*
2. *pressurised water line*
3. *a: rack for cooling in summer*
   b: rack for humidification in winter
4. *droplet separator*
5. *outside air*
6. *heat exchanger*
7. *exhaust air*
8. *cooled outside air*
9. *outlet air*
10. *supply air*
11. *return air*

Success story

Reduction in hospital power consumption is now possible!
Replacement of steam humidifiers with adiabatic systems Hospital "Bambino Gesù" of Rome (Italy) .

Rome – Italy

The Children's Hospital "Bambino Gesù" of Rome, born in 1869, has always embraced a philosophy of constant improvement, so as to face new challenges and expand its horizons.
The hospital operates within the European context. Around 30% of the patients are from different regions of Italy.
The objective of the retrofit was to reduce energy consumption, so as to extend the range of medical electrical equipment and consequently improve customer service.
Analysis conducted by the hospital highlighted how the running costs of steam humidifiers cold be reduced.
Carel suggested replacing the humiSteam units, using immersed electrode technology, with humiFog adiabatic humidifiers.
Prior to the retrofit, the system used Carel humiSteam series humidifiers, in different sizes (UE045, UE065, UE090 and UE130), with power consumption exceeding 600 kW.
To reduce energy consumption, CAREL proposed replacing the steam humidification units with adiabatic systems. Seven humiFog units were thus installed, with corresponding stainless steel droplet separators, as well as two gas-fired units (gaSteam) for the operating theatres.

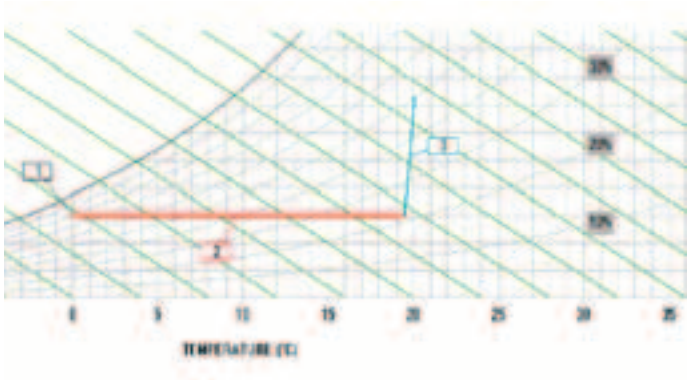
Adiabatic systems installed:

Department	Unit installed after the retrofit
Giovanni Paolo II lab. 1	UA100HD300 humiFog 100 kg/h RACKSM3161 semi-assembled atomising rack stainless steel droplet separator
Giovanni Paolo II lab. 2	UA100HD300 humiFog 100 kg/h RACKSM3166 semi-assembled atomising rack stainless steel droplet separator
Giovanni Paolo V day hospital	UA100HD300 humiFog 100 kg/h RACKSM3146 semi-assembled atomising rack stainless steel droplet separator
Giovanni Paolo II degenze	UA320HD310 humiFog 320 kg/h RACKSM3145 semi-assembled atomising rack stainless steel droplet separator
Spellman degenze	UA100HD300 humiFog 100 kg/h RACKSM3165 semi-assembled atomising rack stainless steel droplet separator
Gerini ambulatori	UA320HD310 humiFog 320 kg/h RACKSM3147 semi-assembled atomising rack stainless steel droplet separator
Ford	UA100HD300 humiFog 100 kg/h RACKSM3144 semi-assembled atomising rack stainless steel droplet separator
Surgery operating room	UG090HD001 gaSteam gas-fired humidifier 90 kg/h
Operating room	UG045HD001 gaSteam gas-fired humidifier 45 kg/h

Estimated energy saving for "Ford"

Set Point	Outside conditions in winter (Rome - IT)
relative humidity: 50% RH;	relative humidity: 80% RH;
temperature: 20 °C	temperature: 0 °C

Immersed electrode humidifiers

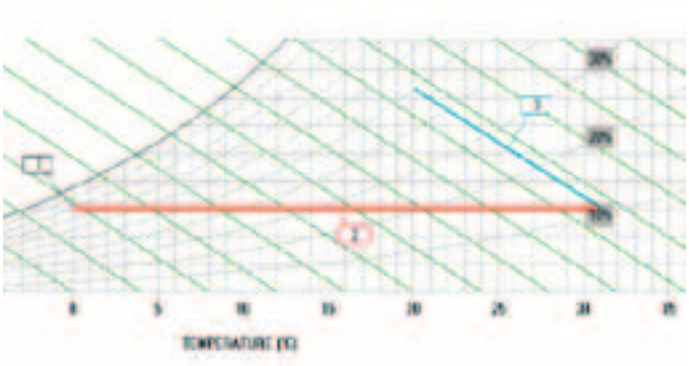


Energy needed for gas preheating (transformation 2)= 100 kW
Preheating cost = 8.5 €/h

Electricity consumed by steam humidifier (transformation 3)= 54 kW
Electricity cost = 8.1 €/h

Total energy cost = 16.6 €/h

Adiabatic humidifiers



Energy needed for gas preheating (transformation 2)= 150 kW
Preheating cost = 12 €/h

Electricity consumed by adiabatic humidifier (transformation 3)= 1 kW
Electricity cost = 0.15 €/h

Total energy cost = 12.15 €/h

Values considered in the calculations:
Electricity cost: 0.15 €/kWh
Cost for 1m^3 of gas: 0.8 €/m^3
Gross heating value of gas: 34 MJ/m^3

The savings come to € 4.45 for each hour of operation (this only looks at "Ford"). Assuming four hours of operation at rated capacity per day, over a year the savings would exceed € 6000 for "Ford" alone.
It is clear then that adiabatic humidifiers are much more cost effective than electric-powered isothermal units.
The savings in running costs are due to the significant difference in power required for humidification (in the example of "Ford": 54 kW isothermal against 1 kW adiabatic). Adiabatic humidification requires more preheating to reach the same final set point, due to the air cooling effect that this process involves. Nonetheless, as such heat is provided by gas, it brings a slight increase in the costs that is negligible when compared against the considerable savings achieved in the actual humidification process itself.
For installation of the humiFog units, droplet separators and adaptation of the humidifier compartment on each AHU, CAREL provided technical support through its authorised service centre in Rome.

Location:	Rome (Italy)
CAREL agent:	STUDIO D'ANGELO
CAREL service centre:	Acquapoint s.r.l.
CAREL contact person:	Emanuele Pittarello

Legislation in force on hospital environments

Standards have been established to define the values that must be met in different departments of healthcare structures . The main requirements for correct air humidification concern the temperature and humidity values, and the number of air changes.
General information and some national standards are shown

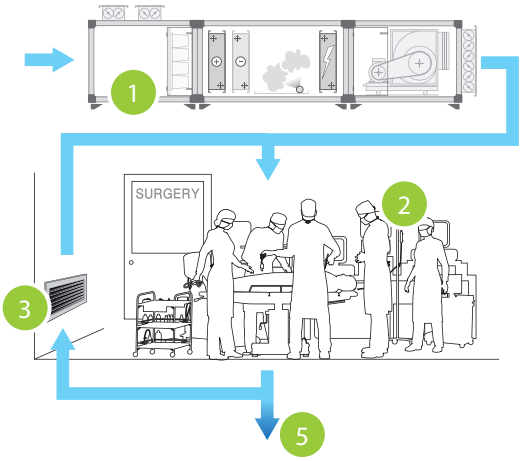
The procedures performed in operating rooms represent an intrinsic risk for both patients and healthcare workers. This is why international standards on air quality and safety in operating rooms are very clear and precise.
In accordance with such standards, CAREL only recommends the use of clean, saturated or superheated steam for humidification of operating rooms,.
To avoid the risk of condensate forming in the air handling unit and consequently entrainment or proliferation of microorganisms, CAREL humidifiers are designed not only to connect a humidity control probe, but also a limit probe for modulating control. The limit probe is proportional, in other words, limits effective humidifier output based on the humidity measured, where necessary stopping operation when humidity exceeds a maximum limit (settable, however VDI 6022 recommends 90% RH). The use of a proportional limit probe rather than a limit switch avoids swings in humidity due to on/off operation, and consequently the risk of condensate forming in the ducts when the humidifier resumes operation. In other words, the proportional limit probe ensures optimum humidity control while at the same time preventing the risk of condensation inside the ventilation ducts.
In addition, safety functions are activated in the event of ventilation system malfunctions, such as "remote on/off" to stop steam delivery (humiSteam, heaterSteam, gaSteam) or closing the steam flow regulating valve on the ultimateSAM series distributors.

The relevant standards define the values of parameters required in operating rooms, the main requirements concern cleanliness, pressure, temperature and humidity set points and the number of air changes per hour.
Air quality is divided into cleanliness classes by ISO 14644; this classification is based on the maximum number of particles measuring greater than or equal to the established values (0.1 to 5 µm). For operating rooms, classes from ISO 5 to ISO 8 are usually applied, depending closely on the type of surgery being performed in the room. There is an increasing trend towards the use of air supply ceilings (ceilings with laminar airflow). This is due to need to ensure ISO 5 air quality inside the room for maximum patient protection.
Overpressure in operating rooms must be 15 Pa on average (values range from 2.5 Pa (0.4x10-3 PSI) to 30 Pa (4.3x10-3 PSI), refer to local standards in force) compared to adjacent rooms with different cleanliness classes.

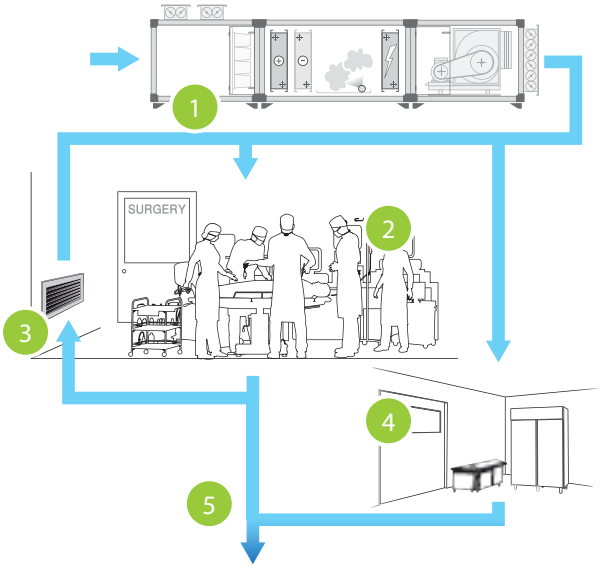
Average set points for operating rooms (refer to local standards in force):

temperature: 17 to 27 °C (62° to 80 °F)
relative humidity: 40 to 60%

To limit indoor contamination and continuously dilute the amount of pollution, the number of air changes per hour must be between 5 and 20 v/h, depending on the country (refer to local standards in force), in some cases standards refer to the number of cubic metres of fresh air per person working in the operating room.
In order to reduce energy consumption, air recirculation is allowed, as long as this derives from the same operating room, so as to avoid possible contamination between different rooms while still maintaining the need to handle and filter the air in the same way as fresh outside air (refer to local standards in force).



example of air recirculation for operating room



example of air recirculation for operating room and support room

1 *air handling unit*
2 *operating room*
3 *Recirculation*
4 *support room*
5 *exhaust*

gaSteam ultimateSAM heaterSteam humiSteam

Italian standards: humidification in hospital wards and operating rooms (Italian Presidential Decree 14/01/1997 and UNI 11425)

These standards define the values of parameters required in operating rooms (UNI 11425 of September 2011 – "Ventilation and air-conditioning system for contamination control (VCCC) - Design, construction, commissioning, qualification, management and maintenance"), the main requirements concern cleanliness class, pressure, temperature and humidity set points and the number of air changes per hour.
For humidification in operating rooms, UNI 11425 exclusively specifies the use of clean, saturated or superheated steam. In addition, it recommends avoiding formation of condensate in the ventilation system and interlocking steam delivery with correct operation of the ventilation system (interlock for no flow, interlock for maximum humidity output, control with feedback at outlet, closing in event of mains power failure, etc.).

Overpressure in operating rooms must be 15 Pa compared to adjacent rooms with different cleanliness classes (for infected patients, operating rooms are at lower pressure than surrounding rooms).

Set points for operating rooms:

temperature: 20 to 24°C
relative humidity: 40 to 60%

features	operating rooms		
	very high air quality	high air quality	standard air quality
temperature (°C):	winter: ≥20 summer: ≤24		
relative humidity (%)	winter: ≥40 summer: ≤60		
overpressure from outside (Pa)	15		
air change (vol/h)	15		
recirculated air	yes	yes	-
ISO14644-1 cleanliness classes	ISO5	ISO7	ISO8
final filtering grade	H14		
sound pressure level (dBA)	45		

Operating room requirements (taken from UNI 11425)

To limit indoor contamination and continuously dilute the amount of pollution, the number of air changes per hour must be 15 v/h.
In order to reduce energy consumption, air recirculation is allowed,

as long as this derives from the same operating room, so as to avoid possible contamination between different rooms while still maintaining the need to handle and filter the air in the same way as fresh outside air.

Below is a list of room air-conditioning requirements specified by Italian Presidential Decree 14/01/1997 "Approval of guidelines and coordination document between the regions and autonomous provinces of Trento and of Bolzano in relation to minimum structural, technological and organisational requirements for operation of public and private healthcare structures".

Operating rooms

Minimum system requirements
Operating rooms must feature air-conditioning systems that ensure the following temperature-humidity conditions:
- winter and summer indoor temperature: 20 to 24 °C
- winter and summer relative humidity: 40 to 60%
- air changes/hour (outside air without recirculation): 15 v/h
- air filtering: 99.97%

Maternity units - birthing centres

Birthing centres must feature air-conditioning systems that ensure the following temperature-humidity conditions:
- winter and summer indoor temperature: 20 to 24 °C
- winter and summer relative humidity: 30 to 60%
- air changes/hour (outside air without recirculation): 6 v/h

Intensive care units

Intensive care must feature air-conditioning systems that ensure the following temperature-humidity conditions:
- winter and summer indoor temperature: 20 to 24 °C
- winter and summer relative humidity: 40 to 60%
- air changes/hour (outside air without recirculation): 6 v/h

Pharmacy and medical supplies

Temperature-humidity conditions:
- winter and summer indoor temperature: 20 to 26 °C;
- relative humidity: ±5 to 50%;
- air changes/hour (outside air): 2 v/h;
- filtering class • medium efficiency filters.

Sterilisation service

The sterilisation service must feature air-conditioning systems that ensure the following temperature-humidity conditions:
- winter and summer indoor temperature: 20 to 27 °C;
- winter and summer relative humidity: 40 to 60%;
- air changes/hour (outside air): 15 v/h.

Disinfection service

The disinfection service must feature air-conditioning systems that ensure the following temperature-humidity conditions:
- winter and summer indoor temperature: 20 to 27 °C;
- winter and summer relative humidity: 40 to 60%;
- air changes/hour (outside air): 15 v/h.

Morgue

Minimum system requirements
The morgue must feature air-conditioning systems that ensure the following temperature-humidity conditions:
- winter and summer indoor temperature: not exceeding 18 °C for rooms containing corpses;
- relative humidity: ±5 to 60%;
- air changes/hour (outside air): 15 v/h.

English standards: Health Technical Memorandum HTM 03-01: Specialised ventilation for healthcare premises

Health Technical Memorandum (HTM) was published in November 2007 and gives comprehensive advice and guidance on the legal requirements, design implications, maintenance and operation of specialised ventilation in all types of healthcare premises.

Operating rooms:

- Recommended temperature: 18 – 25°C
- Air filtration: F7
- Pressure within the room: 25Pa
- Recommended air change rate: 25
- Humidity levels: 35 – 60%

Birthing rooms:

- Recommended temperature: 18 – 25°C
- Air filtration: G4
- Recommended air change rate: 15
- Humidity levels: 35 – 60%

Intensive Care:

- Standards for intensive care units 2007
- Recommended temperature: 16 – 27°C
- Air filtration: 99% efficiency down to 5 microns
- Recommended air change rate: 55
- Humidity levels: 25 – 95%

UCV (Ultra clean Ventilation) Operating rooms:

- Recommended temperature: 18 – 25°C
- Air filtration: H10
- Pressure within the room: 25Pa
- Recommended air change rate: 25
- Humidity levels: 35 – 60%

Pharmacy aseptic rooms:

- Recommended temperature: 18 – 22°C
- Air filtration: H14
- Recommended air change rate: 20
- Humidity levels: 35 – 60%

Chinese standards: for air humidification in operating departments (People's Republic of China standard GB50333-2002)

People's Republic of China national legislation defines the main values to be used as references in the design and development of hospital operating departments.
The requirements concern the temperature and relative humidity set point, the number of air changes per hour, as well as limits on the time for decontaminating operating theatres and the maximum noise level allowed.

Set point for operating theatres:

- temperature: 22 to 25 °C
- relative humidity: 35 to 60°C (depending on the type of operating room)

below are the values of parameters applying to operating departments:

	Department							
	Special operating room	Standards operating room	Normal operating room	Nurse station	Preparation room (disinfect room)	Pre-anesthetic room	Clean corridor	Changing room
Temperature (°C)	22 to 25			21 to 27		22 to 25	21 to 27	
Relative humidity (%)	40 to 60		35 to 60	≤60		30 to 60	≤65	30 to 60
Air change times (vol/h)	-	30 to 36	18 to 22	10 to 13				8 to 10
Minimum fresh air (m^3/h x person)	60				30	60	-	
Self clean time (min)	≤15	≤25	≤30	-				
Noise dB(A)	≤52	≤50		≤60		≤55	≤52	

Environmental parameters in the operating departments (extracted from Chinese standard GB 50333-2002

Relevant international standards and references

The main international standards on air quality in hospital environments are listed below. The main guidelines provided in this document are taken from these standards. Nonetheless, always refer to the standards in the country where the system is installed.

DIN 1946-4	Ventilation and air conditioning – Part 4: Vantilation hospitals (VDI Ventilation roules)
NFS 90351	Salles propres et environnments maîtrisés apparéntes – Exigences relatives pour la maîtrise de la contamination aéroportée
SWKI 993-F	Installation de chauffage, ventilation et climatisation des hôpitaux.
ÖNORM H 6020-1	Ventilation and air conditioning plants in hospital. Design, construction and inspectioning.
GOST R 52539	Air cleanliness in hospitals. General requirements
VDI 6022	Hygiene requirements for ventilation and air-conditioning systems and -units
EN 13779	Ventilation for non–residential buildings – Performance requirements for ventilation and room conditioning systems
ASHRAE	HVAC Manual for design Hospital and Clinics
ASHRAE	Advanced Energy Design Guide for Large Hospitals (Achieving 50% Energy Savings Toward a Net Zero Energy Building)
ASHRAE	Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities (Achieving 30% Energy Savings Toward a Net Zero Energy Building)
UNI 11425	Impianto di ventilazione e condizionamento a contaminazione controllata (VCCC) per il blocco operatorio. Progettazione, installazione, messa in marcia, qualifica, gestione e manutenzione.
HTM03-01	Health Technical Memorandum: ventilazione specializzata per ambienti sanitari
GB50333-2002	technical specifications of operating department based on the standard of Ministry Of Construction of the PRC (2002) NO.85

Table comparing the most common standards on air handling in hospital environments (operating department)

		UNI 11425:2011	ASHRAE, Std 170, 9/05	DIN 1946-4	
Temperature-humidity conditions	Supply air temperature, relative humidity	Winter ≥20 °C, ≥40% RH; summer ≤24 °C, ≤60% RH	17 to 27 °C adjustable, 45 to 55% RH	19 to 26 °C adjustable, RH as per DIN 13779	
	Δt max between supply temp. and room temp.	-0.5<ΔT<-2 °C	Not specified	Not specified	
Cleanliness class	ISO class required	3 cleanliness classes: ISO 5, ISO 7, ISO 8	Not specified	Classification according to RKI: classes Ia, Ib, II	
	Measurement of contamination	Six-monthly monitoring of cleanliness class (ISO 14644-3)	Not specified	Bacteriological and particulate counts	
Air change and recirculation	Recirculation allowed?	Yes, with air from the same operating room	Yes	Yes but from same group of rooms	
	Air changes with outside air	15 vol/h	"Min 5 vol/h with recirc., min 15 vol/h without recirculation"	1200 m3/h outside air	
Filters	Filter requirements	3 filtering levels: standard (H12), high (H13), very high (H13/H14)	Transplants and orthopaedics (7, 8, 17); operating rooms (8 and 14) (STD classes to ASHRAE 52.2-1999)	1st stage F5 (F7 recommended), 2nd F9, 3rd H13 within 0.5 m of the room	
	Filter positions	Absolute filters located inside the operating room	Upstream of AHU and second stage downstream of AHU, absolute filters in operating rooms	1st stage upstream of AHU, 2nd on supply, 3rd on supply	
Specifications on decontamination time		ISO 14644-3	Not specified	Not specified	
Types of air flow	Recommended flow	Turbulent or mixed unidirectional airflow	Downward unidirectional airflow, intake grills at bottom	Unidirectional airflow for type A rooms, unidirectional or mixed flow for type B rooms	
	Dedicated units required	Not specified	Not specified	Not specified	
Air velocity	Max turbulence allowed in operating room	Not specified	Not specified	Not specified	
	Limit air velocity in operating room	Not specified	Not specified	Not specified	
	Air velocity at outlets/ diffusers	So as to not disturb unidirectional airflow	Recommended 0.15 m/s after filter	Minimum 0.23 m/s after filter	
Subdivision of zones	Sub-division of operating rooms	Physical sub-division of rooms according to function	Not specified	Reference to table 2 of the standard	
	Identification of zones with different cleanliness classes	Zones with different contamination according to asepsis	Not specified	Class I zone, high bacteria control requirements (operating rooms)	
	Method for controlling contamination	Press. diff. ≥10 Pa in operating room block and 15 to 20 Pa in operating room	Overpressure of 2.5 Pa with doors closed	Air flow between rooms cross pattern to establish direction of flow	
Position of air openings	Supply	Not specified	On ceiling, unidirectional	Not specified	
	Return	Not specified	At least 2 openings near ground (75 mm from floor)	At top (recirculation) and bottom (exhaust)	
Anaesthetic gases	Operating room concentration limits	N_2O: <100 ppm built before '89, <50 ppm renovated before '89, <25 ppm built after '89, <2 ppm new rooms	Not specified	N_2O= 25 ppm; halogenated = 2 ppm ceiling (NIOSH values)	
Minimum flow-rate in standby		15 vol/h	Not specified	In standby min 2 m/s in ducts before HEPA filters	
Maximum noise level allowed		<45 dB in operating room (if ISO 5 <48 dB)	Not specified	48 dB(A)	

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	NF S 90 351	SWKI 99-3F	ONORM H 6020-1	GOST R 52539/2006
	19 to 26 °C, 45 to 65% RH	18 to 24 °C adjustable, 30 to 50% RH	22 to 26 °C ±1 °C adjustable, 40 to 60% RH	18 to 24 °C ±1 °C, min value 30% RH with 22 °C
	Not specified	ΔT max 1 °C, max air supply temp. deviation ±1 °C	Not specified	Not specified
	ISO 5 B10 (zone 4), ISO7 B10 (zone 3), ISO 8 B100 (zone 2)	Classification not required	4 purity classes: A and B= ISO 5, C= ISO 7, D= ISO 8	Risk divided into 5 levels, highest risk rooms ISO 5
	ISO classes, kinetic decontamination classes, bacteriological classes (CFU/m^3)	Particulate counts with sample source (CFU/m^3 classification is not useful)	CFU/m^3 limits for indoor air and rooms of various classes: I, II, III, IV, class I	Particulate counts with measurement 30 cm from operating table
	Yes but from same group of rooms	Yes	Yes with air filtered using absolute filters	Yes, with air from the same operating room
	≥6 vol/h	Outside air 100 m^3/(h*pers);	Outside air flow-rate 20 m^3/h per m2 of surface areas	100 m3/h p.p.; >12 vol/h operating rooms
	1st stage F6 (outside air), 2nd stage F7, 3rd stage H13, min F5 for grills	1st stage F5 (outside air), 2nd stage F9, 3rd stage H13	"For classes I and II; F7, F8, H13; extraction F6"	3 filtering levels: F7, F9, H14 (this one directly into the room)
	1st stage upstream of AHU, 2nd upstream of humidif, 3rd entrance to controlled area	1st stage upstream of AHU, 2nd on supply, 3rd on supply	1st stage upstream of AHU, 2nd on supply, 3rd on supply	1st stage upstream of AHU, 2nd on supply, 3rd on supply
	Time to reduce concentration by 90% for the various zones	Not specified	Not specified	Not specified
	Unidirectional airflow in zone 4, mixed in zone 3, turbulent for others	Unidirectional airflow above the occupied area	Class I: supply airflow with low turbulence	Unidirectional airflow for most critical applications, not unidirectional for others
	Not specified	Not specified	Yes, in class I and II rooms	Not specified
	Not specified	Max 10% at 1.5 m in height	Not specified	Not specified
	Not specified	Not specified	0.45 m/s for classes I and II	Not specified
	Air vel. near cool coil <3m/s	Supply 0.24 m/s, average 0.2 m/s	Not specified	Between 0.24 and 0.30 m/s
	Not specified	Not specified	Not specified	Not specified
	4 zones, not necessarily physically separated into operating rooms and service rooms	Zones with different contamination, not necessarily physically separated	Physical separation of the various rooms	Physical separation of the various rooms
	Air vel. >0.2 m/s or alternatively pressure >15 to 20 Pa	Dynamic protection of zones with downward vertical airflow	DP>30 Pa with extraction system off, dampers to close ducts	DP>10 Pa between adjacent rooms, continuous control of overpressure
	Not specified	Filtering ceiling, area >9 m^2	Not specified	Unidir. ceiling diffusers >9 m^2
	Not specified	Uniform division of openings on ceiling/wall	Top and bottom, extracted air 75% bottom, 25% top	>50% from return at top (ceiling and walls)
	Not specified	Not specified	Not specified	Not specified
	Minimum 6 vol/h air change	Not specified	System off when not used, restart 30 min before	Not specified
	Not specified	48 dB(A) at 1.75m from floor	45 dB(A) in operating room, 35 dB(A) in sterile stores and others rooms	Not specified

CAREL references

List of some the main Carel references in the hospital sector

Country	City	Project name	Type of humidifier
England	Birmingham	"Queen Elizabeth" hospital	humiSteam
Scotland	Inverness	"Raigmore" hospital oncology department	humiSteam
England	Newcastle	"Royal Victoria" infirmary	ultimateSteam
England	Pembury	"Pembury" hospital	humiSteam
England	Portsmouth	"Portsmouth" hospital	ultimateSteam
Saudi Arabia	Taif	"AL HADA" hospital	mc multizone
Norway	Oslo	"Radiumhospitalet" hospital	heaterSteam
Estonia	Tallinn	"North Estonia Medical Centre"	heaterSteam
Iraq	Sulymania	"SULYMANIA" hospital	heaterSteam
Kuwait	-	"AL SALAAM" hospital	ultimateSteam
Poland	Warsaw	"Medicover" hospital	heaterSteam
Rep. Czech	České Budejovice	"České Budejovice" hospital	humiSteam
Sweden	Göteborg	"Sahlgrenska sjukhuset"	heaterSteam
China	Beijing	"China Army 301" hospital	heaterSteam and ultimateSteam
Germany	Hildeseim	Hildeseim "Krakenhouse" hospital	humiFog
Kazakhstan	Astana	"Multi-hospital"	heaterSteam
China	Beijing	Beijing "University Hospital Ophthalmology Center"	humiSteam
China	Shanghai	Shanghai "Xinhua" hospital	humiSteam
China	Beijing	Beijing "Xiehe" hospital	heaterSteam
China	HangZhou	Zhejiang "ShaoYiFu" university hosiptal	humiSteam
Italy	Schio/Tiene	Schio hospital	humiFog
Italy	Barletta	Barletta hospital	humiFog
Italy	Turin	Turin hospital	humiFog
Italy	Florence	"Careggi" hospital	humiFog
Italy	Rome	"Bambino Gesù" children's hospital	humiFog
USA	Langhorne PA	"St Mary" hospital	ultimateSteam
USA	Hershey PA.	"Hershey Medical Center"	ultimateSteam
USA	New York	"Cornell" hospital	compactSteam
USA	Lebanon PA	Good Samaritan" hospital	humiSteam and ultimateSteam
USA	Lebanon PA	"VA" hospital	humiSteam and ultimateSteam
France	Paris	"Necker-Enfants malades" children's hospital	ultimateSAM
France	Laval	"Chu Laval"	heaterSteam
France	Limoges	"Chenieux" clinic	heaterSteam
France	Périgueux	"Ch Perigueux"	heaterSteam
France	Besançon	"Chu Besancon"	humiSteam

This document is based on the standards described. For all information provided herein, we recommend you read and apply the standards in force in the country where the humidification system is installed.

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