Humidification

Dry anaesthetic gases can cause damage to the cells lining the respiratory tract, impairing ciliary function. This increases the patient's susceptibility to respiratory tract infection. A decrease in body temperature (due to the loss of the latent heat of vaporization) occurs as the respiratory tract humidifies the dry gases.

Air fully saturated with water vapour has an absolute humidity of about 44 mg/litre at 37^{o}C. The humidifying property of soda lime can achieve an absolute humidity of 29 mg/litre when used with the circle breathing system.

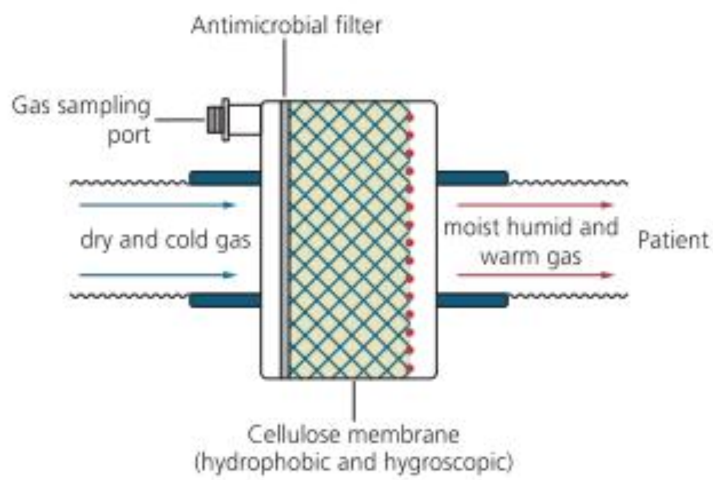
Heat and moisture exchanger (HME) humidifiers:

These are compact, inexpensive and effective humidifiers for most clinical situations.

The efficiency of an HME is gauged by the proportion of heat and moisture it returns to the patient. A relative humidity of 60-70% is achieved. Inspired gases are warmed to temperatures of between 29° and 34°C.

Components:

1. Two ports, designed to accept 15 and 22 mm size tubings and connections. Some designs have provision for connection of a sampling tube for gas and vapour concentration monitoring.
2. The head which contains a medium with hydrophobic properties. It can be made of ceramic fibre, corrugated aluminum or paper, cellulose, metalized polyurethane foam or stainless steel fibres.



Mechanism of action:

1. Warm humidified exhaled gases pass through the humidifier, causing water vapour to condense on the medium. The condense water is evaporated and returned to the patient with the next inspiration of dry gases, humidifying them. There is no addition of water over and above that previously exhaled.

2. The HME humidifier requires a few breaths before it reaches its optimal ability to humidify dry gases.
3. Some designs with a pore size of about 0.2 μm can filter out bacteria, viruses and particles from the gas flow in either direction. The filter has hydrophobic properties preventing the passage of liquids into the patient's respiratory tract. The filter is not affected by the anaesthetic agents. The filtration action achieves a 99.99% efficiency via:
    a. Direct interception: large particles (≥1 μm) are physically prevented from entering the pores of the filter due to their large size;
    b. Inertial impaction: smaller particles (0.5-1μm) collide with the filter medium due to their inertia;
    c. Diffusional interception: very small particles (<0.5 μm) are captured because they undergo considerable Brownian motion.
4. Their volumes range from 7.8 ml (paediatric practice) to 59 ml. this increases the apparatus dead space.

Problems in practice and safety features:

1. The estimated increase in resistance to flow due to these humidifiers ranges from 0.1 to 2.0 cm H_2O depending on the flow rate.
2. It is recommended that they are used for a maximum of 24 hours and for single patient use only. There is a risk of increased airway resistance due to dry hard secretions if used for long periods without change.
3. The humidifying efficiency decreases when large tidal volumes are used.

4. They can leak gas under high pressure.

Hot water bath humidifier

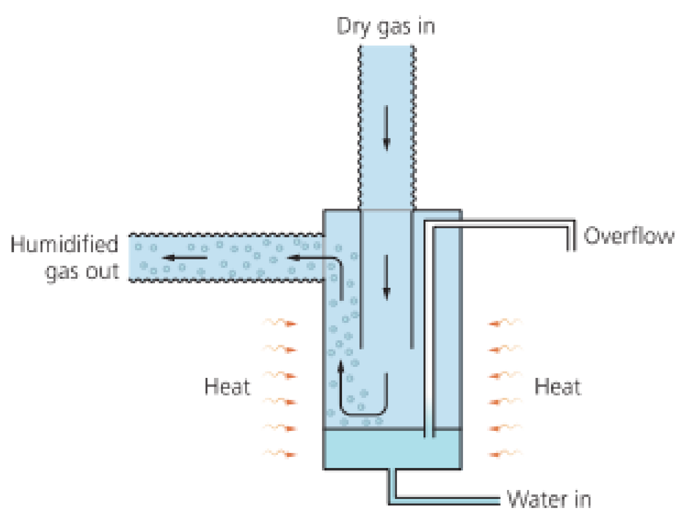
This humidifier is used to deliver relative humidities higher than the heat and moisture exchange humidifier. It is usually use in intensive care units.

Components:

1. A container with an inlet and outlet for inspired gases. Heated sterile water partly fills the container.
2. A thermostatically controlled heating element.
3. Tubing is used to deliver the humidified and warm gases to the patient. It should be as short as possible. A water trap is positioned between the patient and the humidifier along the tubing. The trap is positioned lower than the level of the patient.

Mechanism of action:

1. The water is continuously heated to the desired temperature.
2. Dry cold gas enters the container where some passes close to the water surface, gaining maximum saturation. Some gas passes far from the water surface, gaining minimal saturation and heat.



3. The container has a large surface area for vaporization. This is to ensure that the gas is fully saturated at the temperature of the water bath. The amount of gas effectively bypassing the water surface should be minimal.
4. The tubing has poor thermal insulation properties causing a decrease in the temperature of inspired gases. This is partly compensated for by the release of the heat of condensation.
5. By raising the temperature in the humidifier above body temperature, it is possible to deliver gases at 37^{o}C and fully saturated. The temperature of gases at the patient's end is measured by a thermistor. Via a feedback mechanism, the

thermistor controls the temperature of water in the container.

6. Temperature of gases at the patient's end depends on the surface area available for vaporization, flow rate and the amount of coling and condensation taking place in the inspiratory tubing.

Problems in practice and safety features:

1. The humidifier, which is electrically powered, should be safe to use with no risk of scalding and overhydration. A second back-up thermostat cuts in should there be malfunction of the first thermostat.
2. The humidifier and water trap(s) should be positioned below the level of the tracheal tube to prevent flooding of the airway by condensed water.
3. Colonization of the water by bacteria can be prevented by increasing the temperature to 60^{o}C.

Nebulizers

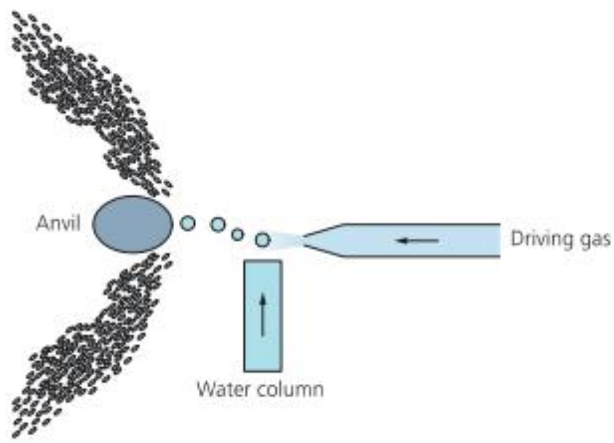
These produce a mist of microdroplets of water suspended in a gaseous medium. The quantity of water droplets delivered is not limited by gas temperature (as is the case with vapour). The smaller the droplets, the more stable they are. In addition to water, nebulizers are used to deliver medications to peripheral airways.

There are three types: gas driven, spinning disc and ultrasonic.

Gas driven nebulizer

Components:

1. A capillary tube with the bottom end immersed in a water container.
2. The top end of the capillary tube is close to a Venturi constriction.



Mechanism of action:

1. A high pressure gas flows through the venture, creating a negative pressure.
2. Water is drawn up through the capillary tube and broken into a fine spray. Even smaller droplets can be achieved as the spray hits an anvil or a baffle.
3. The majority of the droplets are in the range 2-4 µm. these droplets tend to deposit on the pharynx and upper airway with a small amount reaching the bronchial level. This nebulizer is also capable of producing larger droplets of up to 20 µm in size. Droplets with diameters of 5 µm or more fall back into the container leaving droplets of 4µm or less to float out with the fresh gas flow.

4. The device is compact, making it easy to place close to the patient.

Spinning disc nebulizer

A motordriven spinning disc throwing out microdroplets of waer by centrifugal force. The water impinges onto the disc after being drawn from a reservoir via a tube over which the disc is mounted.

Ultrasonic nebulizer

A transducer head vibrates at an ultrasonic frequency (e.g. 3 MHz). The transducer can be immersed into water or water can be dropped on to it, producing droplets less than 1-2 µm in size. Droplets of 1 µm or less are deposited in alveoli and lower airways. There is a risk of overhydration, especially in children.