# Humidification devices

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## Abstract

Humidification is concerned with the addition of water vapour to a gas and can be measured as either absolute or relative. Adequate humidification is a vital consideration in anaesthesia given that the anatomical source of natural gas humidification (the nasopharynx) is generally bypassed, which can lead to complications including hypothermia, thickening of respiratory secretions, mucus plugging and airway keratinization. Humidification may be passive or active. Equipment involved in passive humidification includes HME filters, soda lime and cold water baths, with these devices able to achieve varying efficiencies without extrinsic energy input. Active humidification devices (including hot water baths) are capable of delivering a higher relative humidity but are associated with higher cost and potential hazards. While not strictly classed as true humidification devices, nebulizers are considered in this article as they add water droplets into a gas flow using a Venturi system, spinning discs or ultrasound vibration technology.

**Keywords** Cold water bath humidifier; heat and moisture exchange devices; hot water bath humidifier; humidification; nebulizers; soda lime

**Royal College of Anaesthetists CPD Matrix:** 1A01, 1A03, 1C02, 2C02, 2D02

## Learning objectives

After reading this article, you should be able to:
- identify the main physiological advantages of warming and humidifying gases
- define absolute and relative humidity
- evaluate humidification devices based on their advantages and disadvantages

Humidity describes the amount of water vapour in a gas and humidification is the addition of water vapour to a volume of gas. Application of cold and dry inspired medical gases and volatile agents to a patient's airway can result in a number of complications, which can be reduced with efficient humidification. Humidification is particularly important in prolonged anaesthesia, patients at extremes of age, those with respiratory morbidity and during inhalational anaesthesia to reduce coughing and breath holding. The process of addition of water vapour to anaesthetic gases can be achieved via a number of methods. These systems utilize key physiological and physical principles in their method of action to deliver an appropriate relative humidity to the patient's airway, which results in improved gas exchange and avoidance of complications.

## Physics of humidification

The humidity of a gas is a measurement defining the amount of water vapour present in that sample and can be expressed as *absolute* or *relative*.

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The mass of water vapour in a volume of gas is termed the *absolute humidity* ($gm^{-3}$ or $mg\ l^{-1}$), and the maximum achievable absolute humidity is related in a direct fashion to the saturated vapour pressure (SVP) of that liquid at a given temperature. As temperature increases, SVP increases and the ability of that gas sample to hold water in the vapour form is increased. The importance of this relationship can be demonstrated when comparing cool and heated inspired gases; at room temperature (20°C) the absolute humidity of fully saturated inspired air is 34 $gm^{-3}$, compared with 44 $gm^{-3}$ when fully saturated at body temperature (37°C).

The *relative humidity* of a sample is a measure of the mass of water vapour in a volume compared with the maximum achievable mass, and thus can be expressed as a ratio or percentage. Relative humidity is dependent on ambient temperature; in both examples above, relative humidity is 100%. However, there is a difference in the mass of vapour delivered, therefore both the mass of vapour and temperature of the inspired gas are important considerations.

## Physiology of airway humidification

In normal breathing, inspired air is heated and humidified within the nasopharynx, delivering gas with a temperature of 36°C and a relative humidity of greater than 80% to the carina. Key to this process is the large surface areas and turbulence of flow generated by the nasal turbinates. Around 10% of total body heat loss occurs from the respiratory tract, with 6% the result of natural humidification as the latent heat of vaporization causes energy transfer from the patient and thus heat loss. Delivery of highly saturated and warmed air to the alveoli results in more efficient gas exchange, optimal conditions for mucociliary clearance and avoidance of mucosal injury from drying of secretions. The opposite process occurs during expiration, with water condensing onto the airway surface and rewarming the airway fluid lining. This bidirectional process is a counter current exchange system which efficiently allows heat and water conservation.

Fresh gases from cylinders, manifolds and pipeline supplies are provided at room temperature and with a relative humidity of 0%, therefore energy losses from the body in the humidification and warming of these gases are higher. Furthermore, use of a supraglottic or endotracheal airway device further exacerbates the above problems as the nasopharynx (the normal site of maximum humidification) is entirely bypassed. Thus, the potential for secretion thickening, ciliary paralysis, airway keratinization/ulceration and hypothermia is increased without the use of a humidification device.[1] Importantly, this damage through delivery of dry gases can occur quickly, with mucociliary




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clearance stopping after 10 minutes, and epithelial damage apparent within an hour.[2]

## Humidification devices

The devices and systems used to humidify inspired gases in anaesthetic practice can be classified as either passive or active with the latter requiring an energy input in the form of a driving gas, heat or electromechanical power. Nebulizers are also considered in this article.

### Passive humidification

**Heat and moisture exchange devices (HME)**: these cheap, single-use devices contain a particle and bacterial filter along with a hygroscopic material in the inner core (Figure 1). The device acts as a counter current exchanger. Thus, during expiration water condenses on the inner material and the filter is warmed by the latent heat of condensation to a temperature above 20°C. On inspiration the inspired gas flow passing through the HME is humidified and warmed by the previous energy expenditure which has created a temperature differential between the dry, room temperature gas and the moist filter.

Due to their mechanism of action, utilizing vapour and energy from the patient's own expired gases, these filters require a short period of use to reach their peak efficiency of 50–70%. Efficient function depends on the ambient temperature; a high ambient temperature will reduce efficiency due to a reduction in the temperature differential and therefore poorer condensation. Their use is associated with an increase in respiratory dead space (an especially important consideration in paediatric anaesthesia), a higher resistance to gas flow and obstruction of the filter due to secretions. The devices are also inefficient at high minute volumes, and there is a risk of bacterial colonization.[3] To address this, HMEs are usually combined with a microbiological filter that is designed to filter microbes. A design with a pore size <0.2 μm will trap 99.9% of bacteria; however, manufacturers do recommend that they are replaced regularly.

**Soda lime**: circle system breathing circuits utilize soda lime as the process for removing carbon dioxide. The soda lime (Figure 2) is commonly composed of sodium hydroxide and calcium hydroxide. Via a sequence of exothermic reactions, the carbon dioxide is removed with water being a by-product in the reactions (Box 1). Thus, the key factors for efficient humidification are present. Unlike HME devices, soda lime takes a much longer period of time to provide a suitable level of humidification (approximately 1 hour to provide 20 $gm^{-3}$). The soda lime reaction is most efficient at lower gas flow rates, and so the system works best with low flow anaesthesia.[4]

**Cold water bath humidifier**: with this system, the fresh gas flow is bubbled through cold water, allowing for a relatively inefficient humidification process producing up to 10 $gm^{-3}$. Furthermore, loss of energy as latent heat of vaporization results in a reduction in system entropy, further decreasing the efficiency of an already inefficient process. Water sources should be kept below the patient for safety reasons.

### Active humidification

**Hot water bath humidifier**: incorporated into the breathing system, water is heated to 60°C (to prevent bacterial growth) with the fresh gas flow passed over within an enclosed unit (Figure 3). This system allows for approximately 80% humidification and efficiency can be improved with increasing surface area, for example with the use of wicks. It is noteworthy that

**Figure 1** Heat and moisture exchange filter (HME) (Humid-Vent Filter Compact, Gibeck™).

**Figure 2** Soda lime canister (CLIC Absorber 800+, Dräger™).




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