Nebulizers

These produce a mist of micro droplets 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. Droplets of 2–5 μm deposit in the tracheobronchial tree, whereas 0.5–1 μm droplets deposit in the alveoli.

In addition to delivering water, nebulizers are used to deliver medications to peripheral airways and radioactive isotopes in diagnostic lung ventilation imaging.

There are three types of nebulizer: gas-driven, ultrasonic, and spinning disc all types can generate large numbers of water droplets, equivalent to a moisture output of several hundred grams per cubic metre, compared to 44 gm-3 for humidity at saturation at 37°c.

Nebulizers are used to humidify respirable gasses by generating aerosols containing droplets of water from a reservoir of water. The water may additionally contain medication.

Some of these droplets evaporate as the gas flows to the patient so that the gas is likely to be fully saturated with water vapour when it reaches the patient's airways.

However, as heat is required for evaporation, the temperature of the gas will fall. The temperature can be increased by warming the water in the reservoir.

1. Gas-driven (jet) nebulizers

These devices use the Bernoulli principle to force driving gas under pressure to entrain water into the system from a reservoir. The water is sucked into the gas stream and is broken up into droplets by the high flow of gas. An anvil,

placed in the path of the flow of gas, breaks up the larger droplets into smaller ones, suitable for delivery to the patient.

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 Venturi, 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 of 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 4 μm or less to float out with the fresh gas flow.
4. The device is compact, making it easy to place close to the patient.

2. 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 with diameters less than 0.3 μm due to Brownian motion. However, droplets of this size carry only a very small mass of medication. Deposition in the alveoli, particularly when breathing nasally, is a small fraction of the overall deposition. Deposition in the alveoli will be greater during oral breathing and particularly when the upper airways are bypassed.

3. Spinning disc nebulizer

This is a motor-driven spinning disc throwing out micro droplets of water by centrifugal force. The water impinges onto the disc after being drawn from a reservoir via a tube over which the disc is mounted.

Problems with nebulizers

With nebulizers, it is relatively easy to add a large amount of moisture to the delivered gas, leading to excessive loading of the lungs with water and subsequent hypoxia due to blockage of the alveoli. In addition droplets of the sizes produced are very effective carriers of microbes, so care must be taken to ensure that the liquid water in the nebulizer is sterile. Some nebulized drugs can block some types of filter. Also if the nebulizer is operating continuously then a proportion of the medication will also be lost into the expiratory limb of the breathing system during exhalation. This proportion depends on the inspiratory: expiratory ratio of the breathing pattern.

Producing droplets less than 1-2 μm in size. Droplets of 1 μm or less are deposited in alveoli and lower airways. This is a highly efficient method of humidifying and also delivering drugs to the airway. There is a risk of overhydration especially in children.

In this device, a plate containing a piezo-electric crystal vibrates at an ultrasonic frequency, typically around 2 MHz. Water is either dropped onto the plate, or the plate is placed in the water. The frequency of oscillations of the plate causes the water to break up into droplets. Gas flowing into the nebulizing chamber picks up the droplets to deliver them to the patient.

Deposition in the airways

Deposition of droplets in the airways depends on similar mechanisms as Deposition of particles in filters Deposition, therefore, depends on the size of the Droplets. Droplets with a diameter greater than 5 um are deposited in the upper Airways (gravitational settling), droplets with a diameter in the range of 2-6 um Are deposited in the tracheobronchial airways (interception) and droplets with a Diameter in the range of 0.5-3 um are deposited in the alveoli (inertial impaction And diffusion). As with particles and filters, deposition and retention of droplets Within the airways is a minimum for droplets with an aerodynamic diameter of About 0.3 μm. The mass of the droplets is also important. The mass of the droplet Is proportional to 13, where r is the radius. A droplet with 10 times the radius will Carry 1000 times the mass, or 1000 times the medication. Deposition increases for Droplets .

Fig. Mechanism of action of a gas-driven nebulizer humidifier.

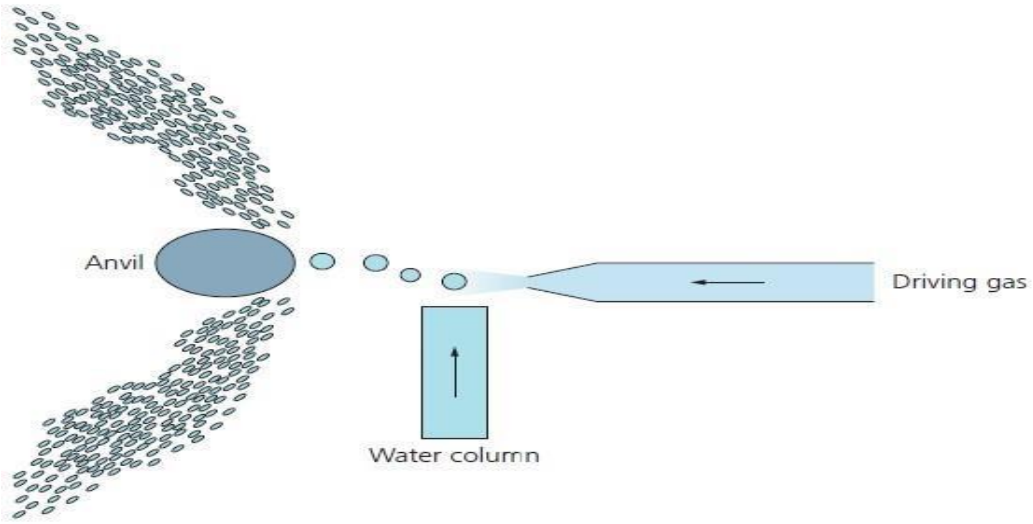


Fig. Operating principle of the nebulizer. **A.** Gas-powered; **B.** ultrasonic. In **A.** rapid expansion of the gas at the end of the tube causes a reduction in pressure, drawing liquid up the tube, which is then broken up into droplets as it emerges. The droplets are broken into smaller droplets when they strike an anvil. In **B.** a plate vibrates at an ultrasonic frequency (around 2 MHz) which breaks up liquid water into small droplets

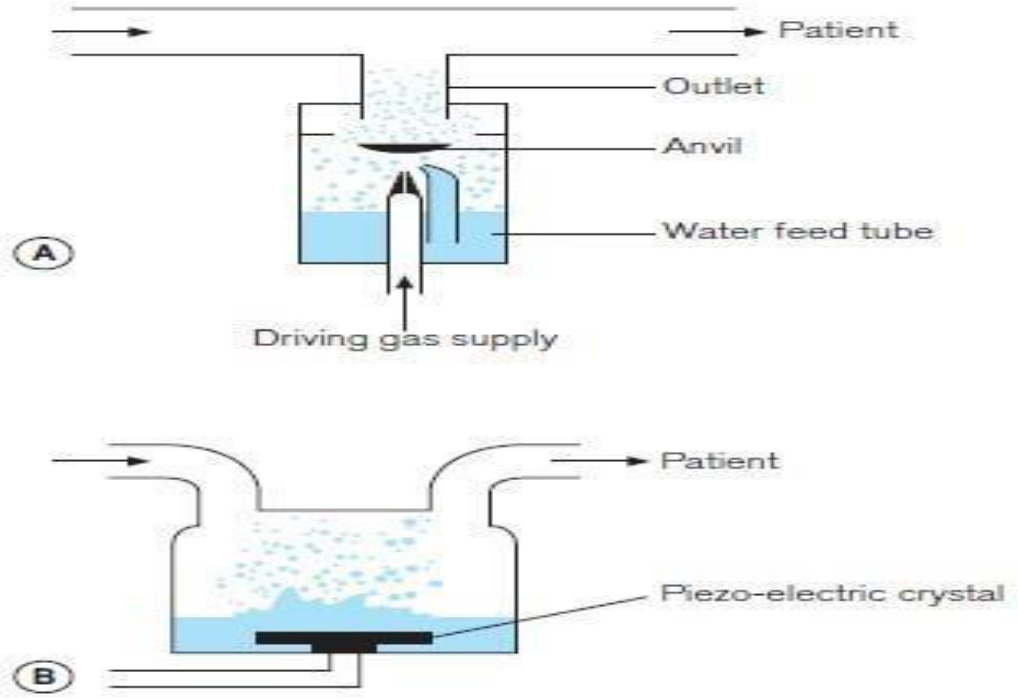
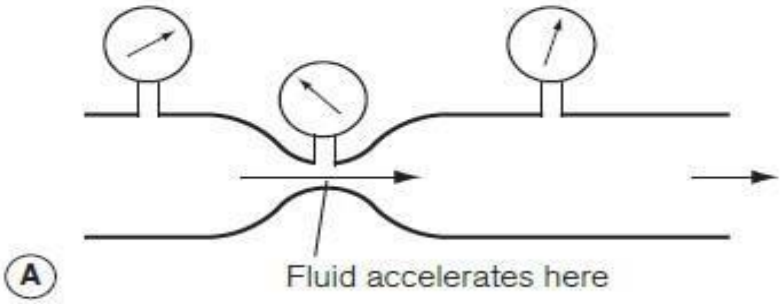


Fig. Aerosol generated by a nebulizer.

Fig. A. Bernoulli effect. **B.** A Venturi.



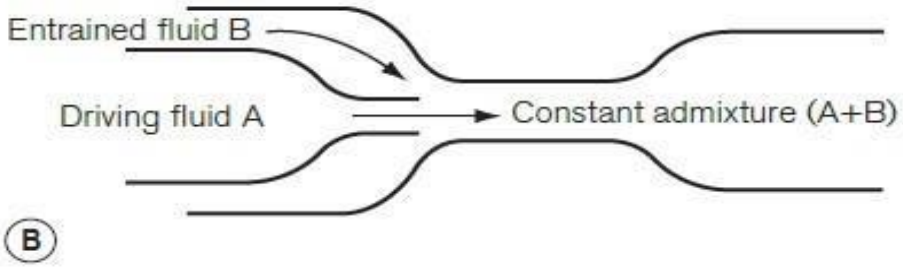
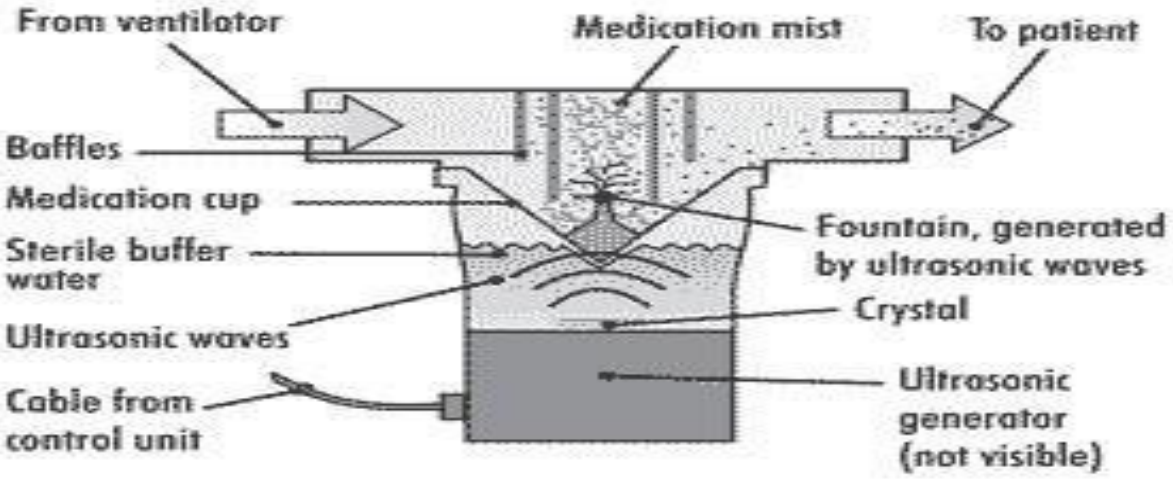


Figure 3: The Ultrasonic Nebulizer



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