Humidification Equipment
• A humidifier is a device that adds molecular liquid (e.g. water vapor) to gas, most often by simple evaporation - these devices are used primarily to humidify inspired gases
• A nebulizer is a device that adds particulate liquid (e.g. saline aerosol) to gas through a process known as nebulization - these devices are used when therapeutic amounts of liquid are needed

Aerosol Therapy
• Delivery requires
  – gas source
  – aerosol generator (____________________)
  – aerosol delivery device
    • aerosol mask
    • face tent
    • Briggs’ adapter (t-tube)
    • tracheostomy mask
  – appropriate tubing
Aerosol Generators

- Large volume jet nebulizers
  - _______________ device used to deliver bland aerosol
  - pneumatically powered
  - use the _______________ theory (similar to Venturi)
  - create aerosol by passing gas at high velocity through a small jet - this causes a pressure drop which draws fluid up through a siphon tube where the high velocity gas shears it and shatters it into liquid particles – producing a heterodisperse spray

Heterodisperse refers to an aerosol consisting of particles of varying diameters and sizes. Particle size, in part, determines where aerosol particles will be deposited in the lungs.

<table>
<thead>
<tr>
<th>Area of Deposition</th>
<th>Particle Diameter</th>
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</thead>
<tbody>
<tr>
<td>Upper airway: nose, larynx, trachea</td>
<td>5-20 microns</td>
</tr>
<tr>
<td>Lower airways</td>
<td>2-5 microns</td>
</tr>
<tr>
<td>Parenchyma: alveolar region</td>
<td>1-3 microns</td>
</tr>
</tbody>
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Aerosol Generators

- Large volume jet nebulizers
  - large particles hit against surfaces or fall back into the reservoir (_____________)
  - some nebulizers incorporate a built-in structural baffle near the jet
  - smaller, more stable particles are carried through the outlet by the gas stream
  - a venturi with variable entrainment ports allows _______________ mixing and various
Aerosol Generators

• Large volume jet nebulizers
  – can deliver cool or heated aerosol
  – total output from a typical unheated large volume nebulizer is approximately mg H$_2$O/L
  – total output from a typical heated large volume nebulizer is approximately ___________ mg H$_2$O/L
  – heating is accomplished with some type of heater, e.g. hot-plate, immersion, collar or wrap-around - when using heated aerosol, a ________________ should be used in-line

Aerosol Generators

• Large volume jet nebulizers
  – nebulizers that attach to ____________________ at the bedside are suitable for most general aerosol delivery needs
  – larger versions with reservoirs of 2-3 liters are used for aerosol delivery in ____________
    • these devices can generate flows of _______ L/min with water outputs up to _________ ml/hr
    • except where room temperatures are set very low, these systems should be run on "__________"

Large Volume Nebulizer
Aerosol Generators

- Ultrasonic nebulizers
  - use a radio frequency device and a ___________ transducer to generate aerosol
  - the radio frequency device transmits radio waves through a shielded cable to the piezoelectric transducer
  - crystal converts radio waves into high-frequency mechanical waves (sound)

- these waves are transmitted either indirectly through a ___________ chamber or directly to a liquid surface where the intense mechanical energy produces a "geyser" of liquid and aerosol particles
  - a ___________ generates flow through the aerosol chamber which carries aerosol particles through the outlet to the patient – flow is adjustable only with a simple damper or butterfly valve

- the radio waves determine aerosol output and particle size
  - aerosol output is determined by ___________ (height)
  - aerosol particle size is determined by ___________ (cycles per second)
Aerosol Generators

- Ultrasonic nebulizers
  - aerosol output is directly proportional to wave amplitude, whereas aerosol particle size is inversely proportional to wave frequency, so by increasing both, output is _________________ and particle size is _________________ for optimal aerosol delivery
  - usually the frequency is preset during by the manufacturer – most operate at frequencies of 1.25-2.25 MHz (megahertz = 1 million cycles per second)

- set properly, some units can deliver _____ ml/min or close to ______ mg/L
  - since the incorporated blowers only move room air, to increase FIO₂ above 0.21, O₂ must be added
  - USNs are quite _________________ compared to pneumatic large volume nebulizers – as much as 10 times the cost

- USNs are most suitable for special uses, such as _________________
  - also now available for home use in the form of room humidifiers
Aerosol Generators

• Babington nebulizers
  – ___________________ powered
  – use the principle of a jet stream of gas being directed through a thin film of continually flowing liquid spread across a rounded surface
  – the gas penetrates the liquid surface causing aerosol particles to be formed which are then baffled and sent to the patient
  – a venturi with variable entrainment ports allows air/O₂ mixing and various FIO₂s

Aerosol Generators

• Babington nebulizers
  – while not as expensive as ultrasonic nebulizers, these devices are still considerably more expensive than standard large volume jet nebulizers
  – do have advantages over standard large volume jet nebulizers in terms of output and particle size, but probably not enough to justify the added cost
  – also available in large reservoir sizes that can be used in tents and other enclosures
Aerosol Generators

• Small volume jet nebulizers
  – used for the administration of ____________________
  – work on the same principles as the large volume jet nebulizers (Bernoulli theory)
  – gas passing through the jet passes by the opening of a capillary tube immersed in solution, which is drawn up into the gas stream – the solution is sheared into droplets with diameters in the ______ micron range
  – the droplets are then directed against one or more baffles

Aerosol Generators

• Small volume jet nebulizers
  – hand-held SVNs
    • the patient's inhalation draws the aerosol through the outlet
    • a t-piece is placed over the outlet – a mouthpiece is attached to one side, a 6-inch reservoir is attached to the other side
Aerosol Generators

• Small volume jet nebulizers
  • one problem with hand-held SVNs is that they run __________, so if a patient is breathing at a 1:2 I:E ratio, only 33% of the aerosol will be inhaled
  • to help conserve medication, some SVNs utilize a patient-controlled thumbport – the patient closes the thumbport during inhalation, directing the gas through the jet; on exhalation, the thumbport is open, directing the gas out through the port – this effectively stops nebulization

Aerosol Generators

• Small volume jet nebulizers
  • the gas flow powering the nebulizer should be set at the manufacturer’s recommended liter flow – usually about ______ L/min
  • in the hospital setting, O2 is used to power the nebulizer more out of convenience than necessity
  • hand-held SVNs will run as well using air
  • _______________ can also be used, but aerosol production will be significantly decreased
Aerosol Generators

- Small volume jet nebulizers
  - manifold units
  - incorporated into breathing circuits for IPPB and other devices
  - operating principle is the same
  - do not rely on patient's inhalation, flow is controlled by the positive pressure device
  - most of these devices can be set to power the nebulizer continuously or during inhalation only
Aerosol Delivery Devices

• Aerosol mask
  – similar in design to O₂ masks, except that the exhalation port openings are larger
  – device of choice for short-term therapy to patients with intact ___________
  – has the same disadvantages and problems with patient compliance as O₂ masks

• Face tent
  – better choice for long-term therapy and for patients who will not wear the ___________ mask
  – has a large reservoir extending out from the face
  – more comfortable and patient compliance is better
  – tolerated well by most patients

• Briggs’ adapter (TP; t-piece; t-tube)
  – most commonly used device for patients with an ___________ in place
  – only choice for endotracheal tubes
  – since it does attach directly to the airway, it puts traction on the tube, causing discomfort and possibly accidental ___________
  – for best results, attach a 6-inch reservoir to the distal side of the airway
Aerosol Delivery Devices

• Tracheostomy mask
  – better choice for the patient with a tracheostomy tube in place
  – more _______________ with no traction on the tube
  – if not kept clean, it can pose a risk of infection
  – position should be monitored

Aerosol Delivery Devices

• the choice of the device used should be based on the patient’s condition, comfort and compliance with therapy