ANESTHETIC EQUIPMENT

PURPOSES OF THE ANESTHETIC MACHINE
- Provide oxygen (machine system)
- Deliver precise amounts of anesthetic agent (machine system)
- Remove CO₂ (breathing system)
- Provide assisted or controlled ventilation (breathing system) to the patient

BASIC COMPONENTS OF THE ANESTHETIC MACHINE

- **Gas source- compressed oxygen**
  - Provides for the oxygen requirements of the patient and acts as a carrier gas for the inhalation anesthetic agent.
  - Oxygen is stored as a compressed gas held under pressure in metal cylinders.
  - Cylinder sizes are designated according to letters, with size ‘A’ being the smallest; size ‘E’ (E-tank) is commonly used on anesthesia machine. H-tanks are also used at HSVMA-RAVS clinics, usually with a manifold that allows multiple machines to operate off the same tank.
  - Cylinders are color coded according to the gas contained, green indicates oxygen.
  - Handle pressurized cylinders with respect. Dropping or knocking cylinders can damage them and result in their acting as a “missile”, causing serious personnel or structural damage.
  - Secure cylinders at all times with racks or lay them on their sides to prevent tipping or falling.
  - All pressure tanks have a stem with a valve that allows the flow of oxygen to be turned on or off. You should know where these valves are located. E-tanks take a special key or wrench to operate the valve. H-tanks have a handle permanently attached to the valve stem.

- **Pressure regulator (pressure reducing valves)**
  - As oxygen moves from the high-pressure tank (at up to 2200 psi) into the anesthetic machine, the pressure is lowered by a regulator to provide a safe operating pressure (45-50 psi).
  - Regulator also provides for constant flow as the pressure in the tank decreases.
  - Regulators used at HSVMA-RAVS clinics mount on top of the oxygen tanks. Do not attempt to adjust.

- **Flowmeter:**
  - From the cylinder, pressure gauge and pressure-reducing valve, oxygen travels through a low-pressure hose to the flowmeter.
  - Allows anesthetist to provide measured amount of oxygen to the patient
  - Flow rates are expressed in liters of gas per minute (L/min).
  - Oxygen enters the flowmeter and is delivered to the vaporizer at a constant rate as indicated on the flowmeter dial.

**Note: Oxygen Flow Rates**
- Recommended oxygen flow rates for patients on a non-rebreathing system are at least 200-300 ml/kg/min, with the minimum flow rate being 1 L/min.
- Patients on a semi-closed (circle) system are run at a flow rate of 20-50 ml/kg/min with a maximum of 2 L/min.
- In general, an oxygen flow rate of 1-2 L/min is appropriate for most patients.
- With some vaporizers flow rates less than 1000 ml/minute will not allow accurate delivery of the dialed vaporizer concentration.

- **Vaporizer:**
  - Oxygen exits the top of the flowmeter and continues via a low-pressure hose to the vaporizer.
  - The vaporizer is designed to convert liquid anesthetic to vapor and to add a controlled amount of vapor to the carrier gas flowing through the machine. If the oxygen flow is turned off, no anesthetic is delivered to the patient.
All of the machines we use utilize out-of-circuit precision vaporizers. The precision vaporizer allows delivery of a precise amount of anesthetic vapor to the breathing circuit.

The dial of the vaporizer is graduated in percent concentrations of inhalant in the inspired gas.

A tube running from the “outlet” side of the vaporizer attaches to the breathing circuit and is called the “common gas outlet”.

An indicator window at the base of the vaporizer indicates the amount of liquid anesthetic remaining. This should be checked before the machine is used and refilled if the level is below the half-way mark.

**Patient breathing circuit** *(See ‘ Patient Breathing Circuits’ below)*

- Delivers oxygen and anesthetic and removes carbon dioxide produced by patient
- Provides method for assisting or controlling ventilation
- Two basic types of breathing circuits are used:
  - Rebreathing or circle system-used for patients over 10 lbs body weight.
  - Non-rebreathing system- used for patients under 10 lbs.

**Waste Gas Scavenger systems**

- Eliminate excess anesthetic gases to minimize breathing by personnel.
- In the field we use a passive scavenging system, which consists of an activated charcoal (F-Air®) canister attached to the scavenging or exhalation hose.
- As part of a circle (rebreathing) circuit, the canister is attached to a scavenging hose that is usually part of the ‘pop-off’ valve.
- With a non-rebreathing system, the canister is attached to the exhalation tubing.
- The holes at the bottom of the canister must be left uncovered to allow filtered air to escape. The canister should be either taped to the table leg or laid on its side.
- The F-Air® canister must be changed after 8 hrs of normal use or a weight gain of 50 grams.

**PATIENT BREATHING CIRCUITS - REBREATHERING (CIRCLE SYSTEM)**

In a circle or rebreathing circuit, gases exhaled by the patient travel through the expiratory hose and enter the carbon dioxide canister. They are then directed into the reservoir bag and back toward the patient through the inhalation flutter valve. Fresh oxygen and anesthetic enter the circuit here from the vaporizer and mix with the patient’s exhaled gas.

The flow of gas through the machine is circular: reservoir bag--inhalation valve--inspiration hose--animal--expiration hose--exhalation valve--carbon dioxide canister--back to the inhalation valve.

- Used for patients weighing more than 10 lbs.
- Methods:
  - Closed system - Pressure relief valve is completely closed.
    - Used only with low flow techniques in which oxygen delivery is calculated to meet metabolic needs. We do not use these techniques in the field.
  - Semi-closed system - Pop-off valve is open or partially closed.
    - Used with medium and high-flow techniques in which oxygen delivery exceeds oxygen consumption and excess gases are eliminated through pressure relief valve.
    - Advantages of medium and high flow include safety to the animal and more rapid change in anesthetic concentration.
- Advantages of rebreathing circuit:
  - Economical: expired oxygen and anesthetic vapor are re-circulated and reused, using less oxygen and anesthetic agent compared with a non-rebreathing system.
  - Humidification of inspired gas, preserving heat and moisture of the patient.
- Disadvantages of rebreathing circuit:
  - Resistance to gas flow, primarily caused by the one way valves in the system, soda lime canister, and pressure relief valve can make it difficult for smaller patients to ventilate.
Components of Rebreathing/Circle System

- **Fresh gas inlet**
  - After passing through the vaporizer, the oxygen and isoflurane enters a low pressure hose that delivers the fresh gas to the patient breathing circuit.

- **Rebreathing bag (reservoir bag)**
  - Fresh gas entering the circuit is conveyed to an inflatable rubber reservoir bag.
  - The bag is gradually filled as gases enter the circuit and is deflated with inhalation.
  - The reservoir bag should have a minimum volume of 60 ml/kg of patient weight.
    - <15 lbs: 1 liter bag
    - 15-40 lbs: 2 liter bag
    - 40-120 lbs: 3 liter bag
  - The reservoir bag is easier for the patient to breathe from than a continuous flow of air. It also allows the anesthetist to deliver oxygen (with or without anesthetic) by means of ‘bagging’.
  - The bag should be maintained partly full. It should not be allowed to overfill as this can cause serious lung damage by creating excessive pressure in the breathing circuit.
  - In general, if the reservoir bag is completely full either: 1) the pop-off valve is closed, 2) the patient is not breathing, 3) the oxygen flow is set too high, or 4) the bag is too small.
  - On the other hand, the bag should not be completely deflated as this defeats its purpose as a reservoir. Complete emptying of the bag indicates that: 1) the gas flow is inadequate, 2) the bag is too large, or 3) a leak is present in the system.

- **Inhalation flutter valve, breathing tubes, Y-piece and exhalation flutter valve**
  - Fresh gas entering the circuit passes through a one-way valve (flutter or unidirectional valve), which allows flow in only one direction (toward the patient).
  - When the patient inhales, the inhalation flutter valve opens, allowing oxygen and anesthetic to enter the hoses. These gases travel through the inspiratory hose to the Y-piece and are directed into the endotracheal tube to the patient’s lungs.
  - Exhaled gases travel from the patient through another hose. Where the exhalation hose attaches to the machine, there is an expiratory flutter valve which prevents expired gases from returning to the patient without first passing through the CO\(_2\) absorber.

- **Pressure relief valve (pop-off valve)**
  - Waste gases exit the anesthetic circuit and enter the scavenging system at the pop-off valve.
  - The valve prevents the buildup of excessive pressure or volume of gases within the circuit.
  - Can be turned fully open, partly open, or closed off entirely, allowing varying amounts of gas to exit the system. It is generally kept mostly open during anesthesia, allowing gas to escape.
  - When we need to bag the patient, the valve is closed, increasing the pressure in the circuit. The valve is then re-opened, again allowing the gases to vent.
  - In HSVMA-RAVS clinics, the pop-off valve is left open at all times. A spring loaded pop-off safety allows the anesthetist to close the circuit to ventilate the patient without closing the actual pop-off valve.
  - If valve were to remain closed, the excess pressure in the circuit would eventually reach the animal's lungs, causing alveoli to distend and possibly rupture!

- **Carbon dioxide absorbing canister**:
  - Any gases that do not exit the system through the pop-off valve are directed to the CO\(_2\) absorber canister before being returned to the patient.
  - The canister contains either soda lime or barium hydroxide lime. Calcium hydroxide in the absorbent removes carbon dioxide from the gases that percolate through the canister.
  - Soda lime or barium hydroxide lime granules become exhausted after several hours of use and will no longer absorb CO\(_2\). The use of depleted granules may result in excessive carbon dioxide delivery to the patient and hypercapnia.
  - Exhaustion of the granules can be indicated by several means:
- Color change (from white to blue or purple, depends on dye color). The color indicator reverts to its original color when not in use; therefore, exhausted granules should be changed immediately when noticed.
- Soft and crushable granules are converted to hard and non-crushable granules (calcium hydroxide changes to calcium carbonate - limestone!)
- Generally granules are changed after every 8 hours of normal use.

- **Pressure manometer**
  - Measures the pressure of the gases within the anesthetic system (expressed in centimeters of water), which in turn reflects the pressure of gas in the animal's airway and lungs.
  - Pressures over 15 cm of water indicate a build-up of air within the machine, either because the pop-off valve is closed or the oxygen flow rate is too high
  - When bagging an animal pressure should not exceed 15 to 20 cm H₂O.
  - If a pressure manometer is not present, the anesthetist must rely on observation of the reservoir bag and patient to assess gas pressure. In this case, the reservoir bag should be compressed just enough to cause a slight rise in the patient's chest.

**PATIENT BREATHING CIRCUITS – NON-REBREATHING SYSTEM (NRB)**
The non-rebreathing circuit is a physically simpler system. In this circuit, oxygen flows through a flowmeter and into the vaporizer. At this point, gases exiting the vaporizer go directly to a hose for delivery to the patient with no inhalation flutter valve. Exhaled gases pass through another hose and may enter a reservoir bag, but do not enter a CO₂ absorber. The gas is then released into a scavenger.

- Used for patients weighing less than 10 lbs.
- Several types exist (e.g., Bain, Ayres T, Norman mask elbow, etc)
  - All are modifications of the same basic design
  - Differ in site of fresh gas inflow, position of reservoir bag and location of exhalation port.
- On inspiration, fresh gas is inhaled from both the narrow tubing from the anesthesia machine and the corrugated tubing leading away from the endotracheal tube connector.
- Absence of soda lime means rebreathing must be prevented via high oxygen flow. Inadequate flow rates allow CO₂ to be re-breathed and may create respiratory acidosis.
- Minimum oxygen flows of at least 200-300 ml /kg/min will prevent significant rebreathing in most patients by flushing out expired gases during the pause between breaths.
- Advantages of non-rebreathing circuit:
  - Less resistance to breathing
  - Less mechanical dead space.
  - Rapid manipulation of anesthetic depth: In NRB the fresh gas inlet is adjacent to the endotracheal tube connection; changes in flowmeter or vaporizer setting affect the inspired gas concentration almost immediately. (Volume of rebreathing circuit with 3-L bag is approximately 6 L. Volume acts as "buffer" to changes in anesthetic concentration)
- Disadvantages of non-rebreathing circuit:
  - High flow of dry cool gas is administered to the patient, which can cause significant heat and humidity loss. Can contribute to hypothermia, especially in small patients.
  - Significantly higher waste of both carrier gas and anesthetic results in increased cost.

**Components of Non-Rebreathing System**

- **Inhalation breathing tube**
  - Narrow bore tubing delivers fresh gas (oxygen and anesthetic) to the patient.

- **Exhalation tube**
  - Exhaled gases exit the circuit through larger bore corrugated tubing.

- **Rebreathing bag (reservoir bag)**
  - An open-ended or side-hole bag (0.5-1 liter) is attached to the corrugated tubing.
  - Does not influence the mechanics of the circuit - allows artificial ventilation to be performed.
Pressure relief valve
- Some non-rebreathing circuits have a valve at the end of the reservoir bag.
- The valve can be turned fully open, partly open, or closed off entirely, allowing varying amounts of gas to exit the system. It is kept open during anesthesia, allowing gas to escape.
- When the anesthetist wishes to bag the patient, the valve is closed, increasing the pressure in the circuit. The valve is then re-opened, allowing the gases to vent.
- If the valve were to remain closed, the excess pressure in the circuit would eventually reach the animal's lungs, causing alveoli to distend and possibly rupture!
- If using a system without a relief valve, ventilation can be provided to the patient by occluding the end of the reservoir bag where it attaches to the exhalation tubing by pinching it.

CHAMBER AND MASK INDUCTION
- In certain circumstances, it may be desirable to induce and maintain a patient on only inhalation anesthetic, avoiding the use of injectable agents.
- An anesthetic induction chamber is sometimes used with feral or fractious cats.
- Environmental pollution and personnel exposure to inhalation anesthetics is very high with these techniques. Adequate ventilation is essential to minimize exposure.
- Isoflurane induction can also be extremely stressful for the patient as it will take several minutes to reach an anesthetic plane during which time you are not ensured a patent airway.
- In general, the use of a balanced anesthetic protocol will provide a safer, smoother anesthetic experience than gas induction alone.