Anesthesia Machines

“Give me to drink mandragora…
That I might sleep out this great gap of time
my Anthony is away.”
[excerpt from Anthony and Cleopatra]

- Mandrake (*Mandragora officinarum*) is a plant related to the potato family.

Purpose

- Anesthesia units dispense a mixture of gases and vapors and vary the proportions to control a patient's level of consciousness and/or analgesia during surgical procedures.

Functions

- Provide oxygen (O_2) to the patient.
- Blend gas mixtures that can include (besides O_2) an anesthetic vapor, nitrous oxide (N_2O), other medical gases, and air.
- Facilitate spontaneous, controlled, or assisted ventilation with these gas mixtures.
- Reduce, if not eliminate, anesthesia-related risks to the patient and clinical staff.

Anesthesia delivery

- The patient is anesthetized by inspiring a mixture of O2, the vapor of a volatile liquid halogenated hydrocarbon anesthetic, and, if necessary, N2O and other gases.

- Because normal breathing is routinely depressed by anesthetic agents and by muscle relaxants administered in conjunction with them, respiratory assistance — either with an automatic ventilator or by manual compression of the reservoir bag — is usually necessary to deliver the breathing gas to the patient.

Principles of operation

ORBIS
saving sight worldwide

- An anesthesia system comprises four basic subsystems:
  - a gas supply and control circuit;
  - a breathing and ventilation circuit;
  - a scavenging system;
  - a set of system function and breathing circuit monitors (e.g., inspired O2 concentration, breathing circuit integrity).

Safe practice of anesthesia

- Anesthesia machines incorporate a number of alarms that indicate:
  - levels and variations of several physiologic variables and parameters associated with cardiopulmonary function; and/or
  - gas and agent concentrations in breathed-gas mixtures.

Safe practice of anesthesia

- Anesthesia machines must monitor:
  - O2 concentration;
  - airway pressure; and either
  - the volume of expired gas (V_{exp}); or
  - the concentration of expired CO2 (capnography).

- Stand-alone monitors may be used to track other essential variables:
  - electrocardiogram;
  - SpO2;
  - blood pressure (invasive / non-invasive);
  - temperature.

MAJOR COMPONENTS

- Gas Supply
- Pressure Regulators
- Flowmeters
- Vaporizers
- Safety Devices
- Breathing System

Continuous-flow anesthesia system

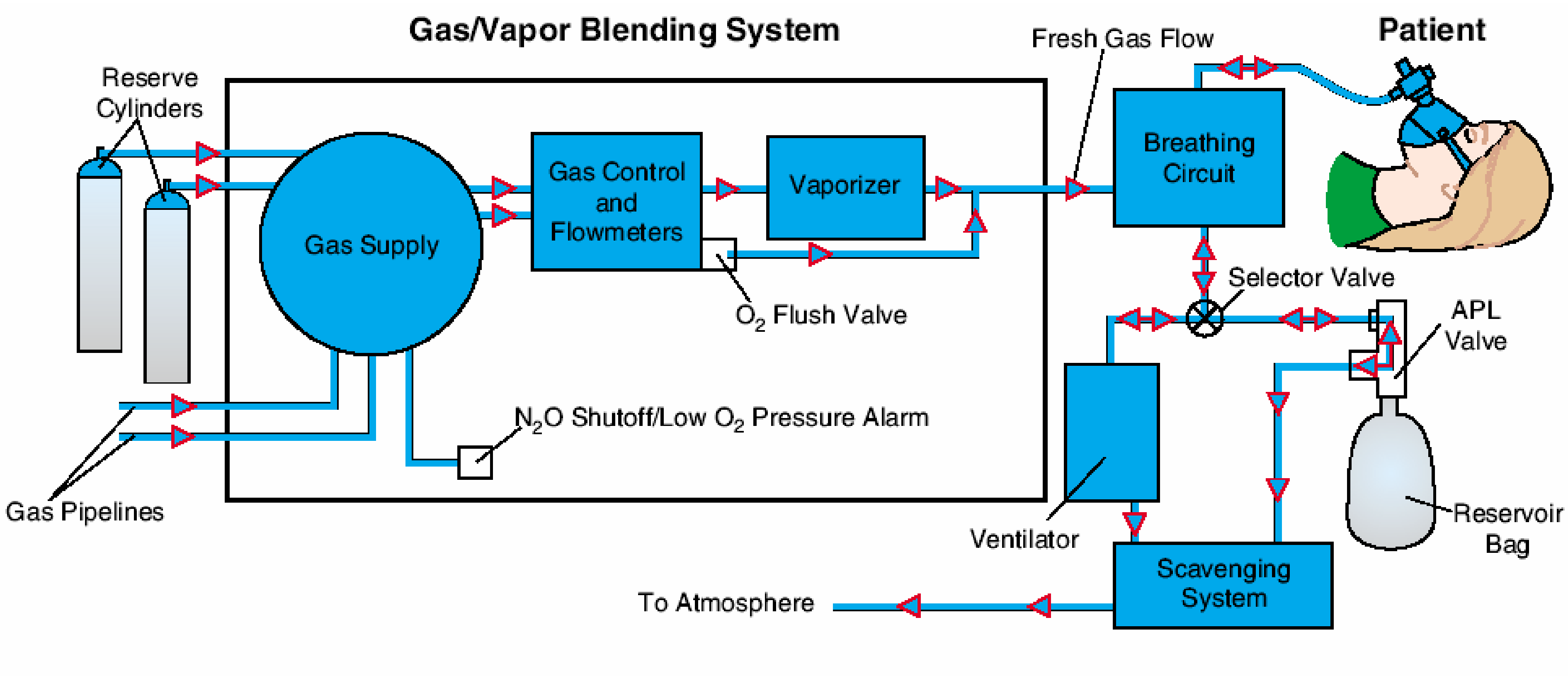


Figure . Continuous-flow anesthesia system

Reproduced from Health Care Product Comparison System, ECRI. 2003 – Anesthesia Units

Breathing circuits used in continuous-flow systems

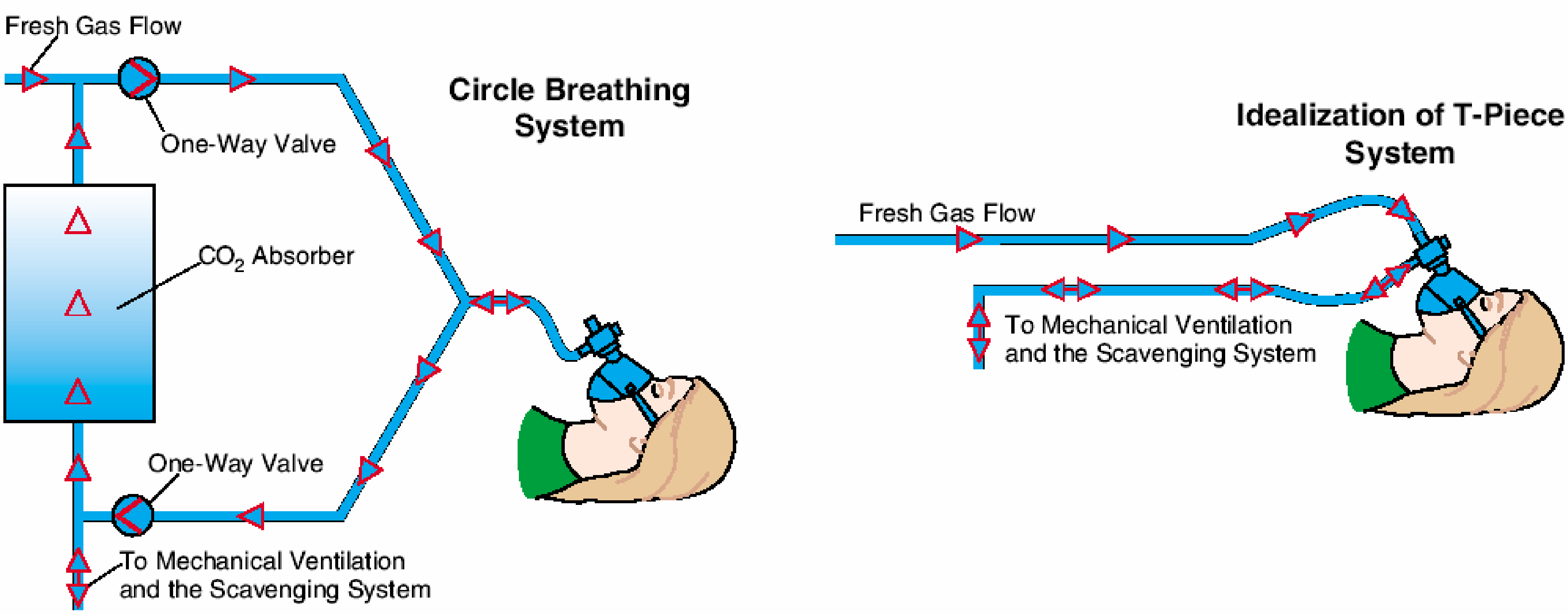


Figure . Examples of breathing circuits

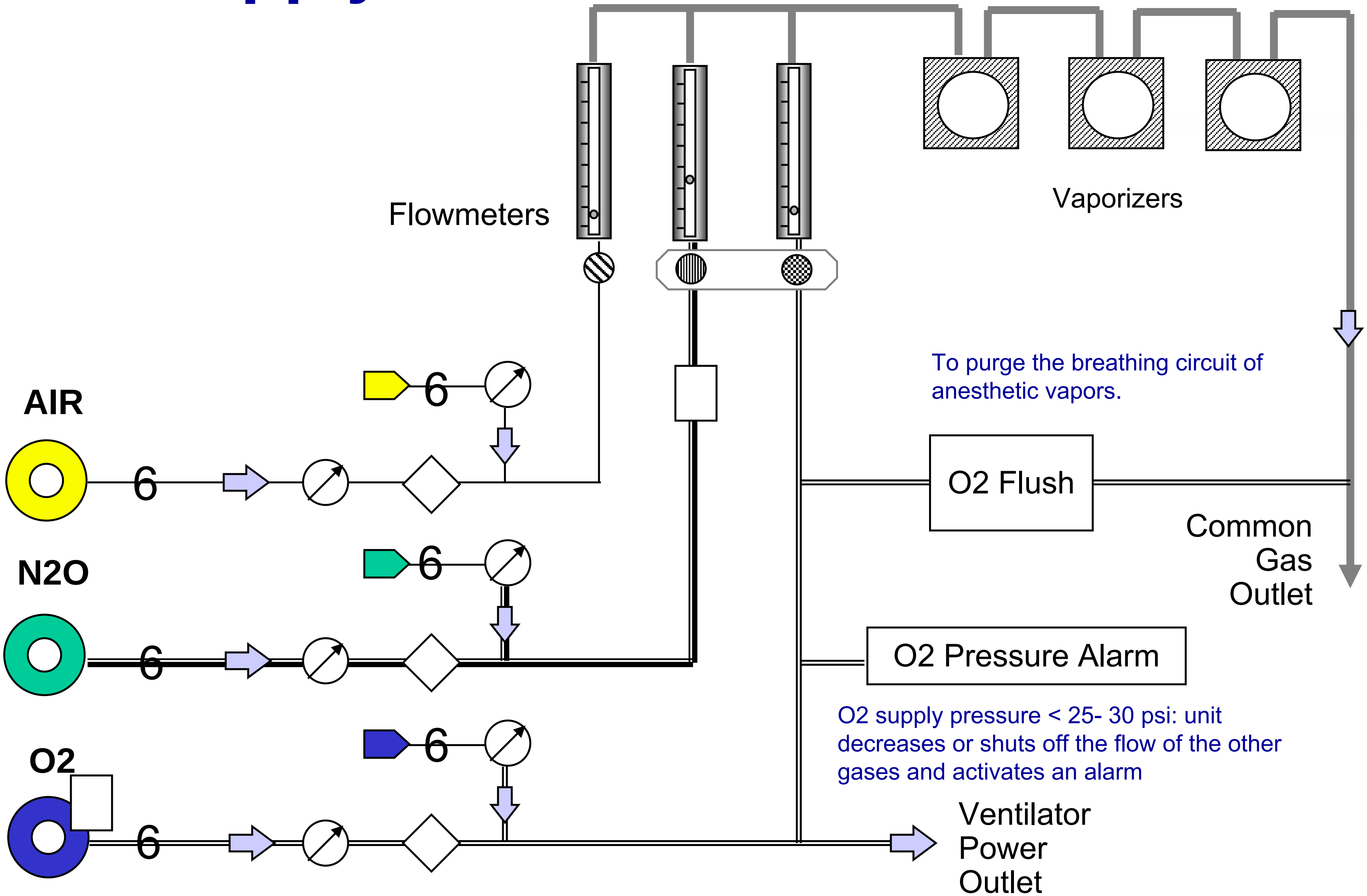
Reproduced from Health Care Product Comparison System, ECRI. 2003 – Anesthesia Units

- Circle systems – advantages:
  - conserve a greater proportion of the anesthetic gases: ↓ cost;
  - conserve body heat and moisture from the patient.

- T-piece systems – advantages:
  - lower circuit compliance;
  - easier circuit sterilization;
  - less complex design requiring fewer valves and no CO2 absorber (although one can be used with it).

Note: T-piece systems are used most often in pediatric anesthesia.

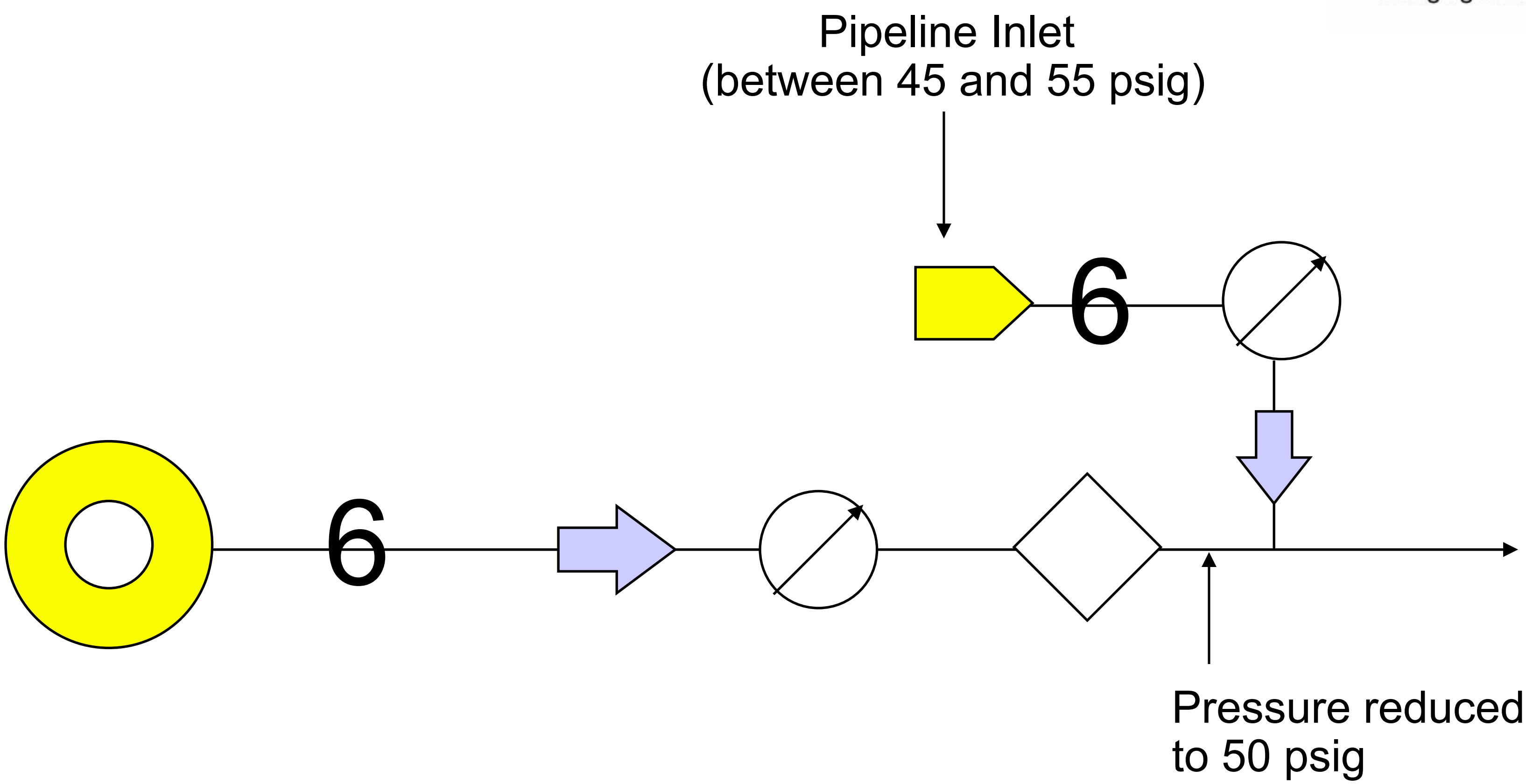
Gas Supply


Flowmeters
Vaporizers
To purge the breathing circuit of anesthetic vapors.
AIR
6
6
N2O
6
6
O2
6
6
O2 Flush
Common Gas Outlet
O2 Pressure Alarm
O2 supply pressure < 25- 30 psi: unit decreases or shuts off the flow of the other gases and activates an alarm
Ventilator Power Outlet

- Lack of O2 delivered to the patient (Hypoxia):
  - can result in brain damage or death.

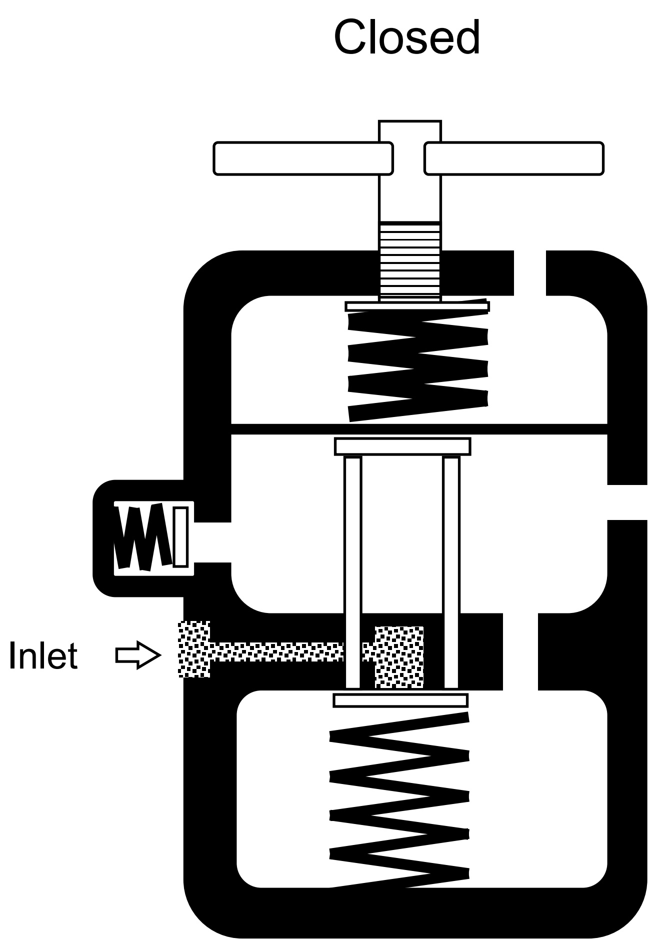
- Administration of O2 in a concentration of 100%, even for a short duration, may be toxic:
  - resorption atelectasis;
  - particularly acute in neonatal anesthesia; can cause retrolental fibroplasia and bronchopulmonary dysplasia.

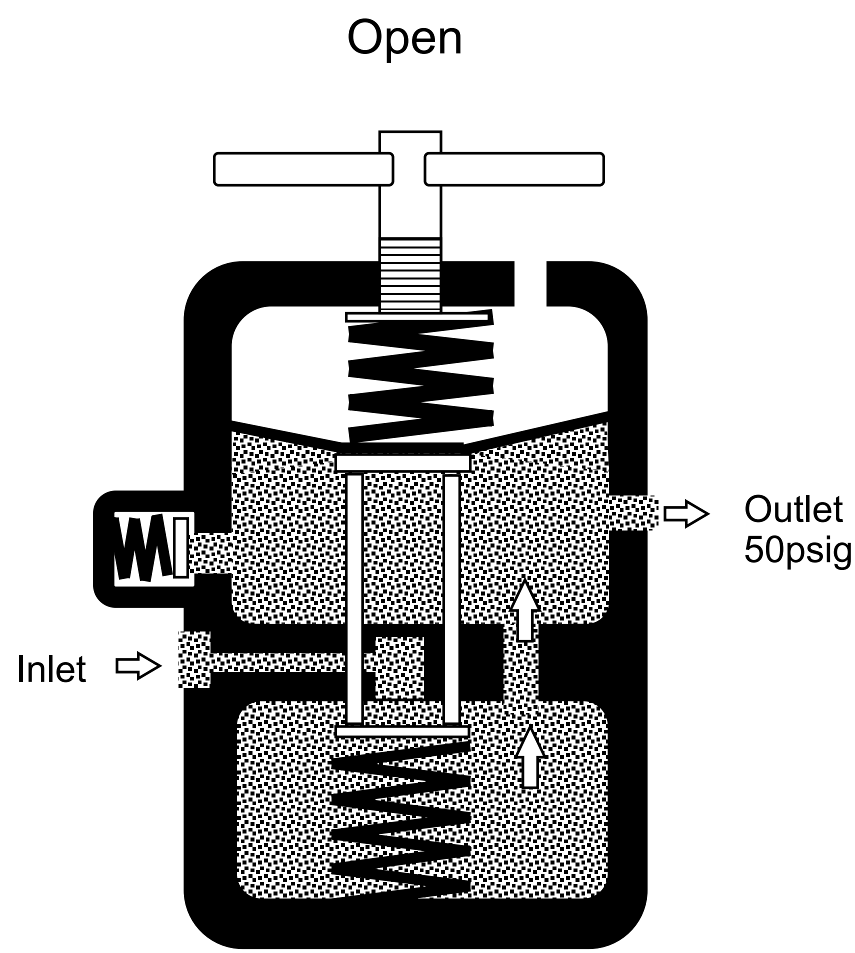
Gas Supply



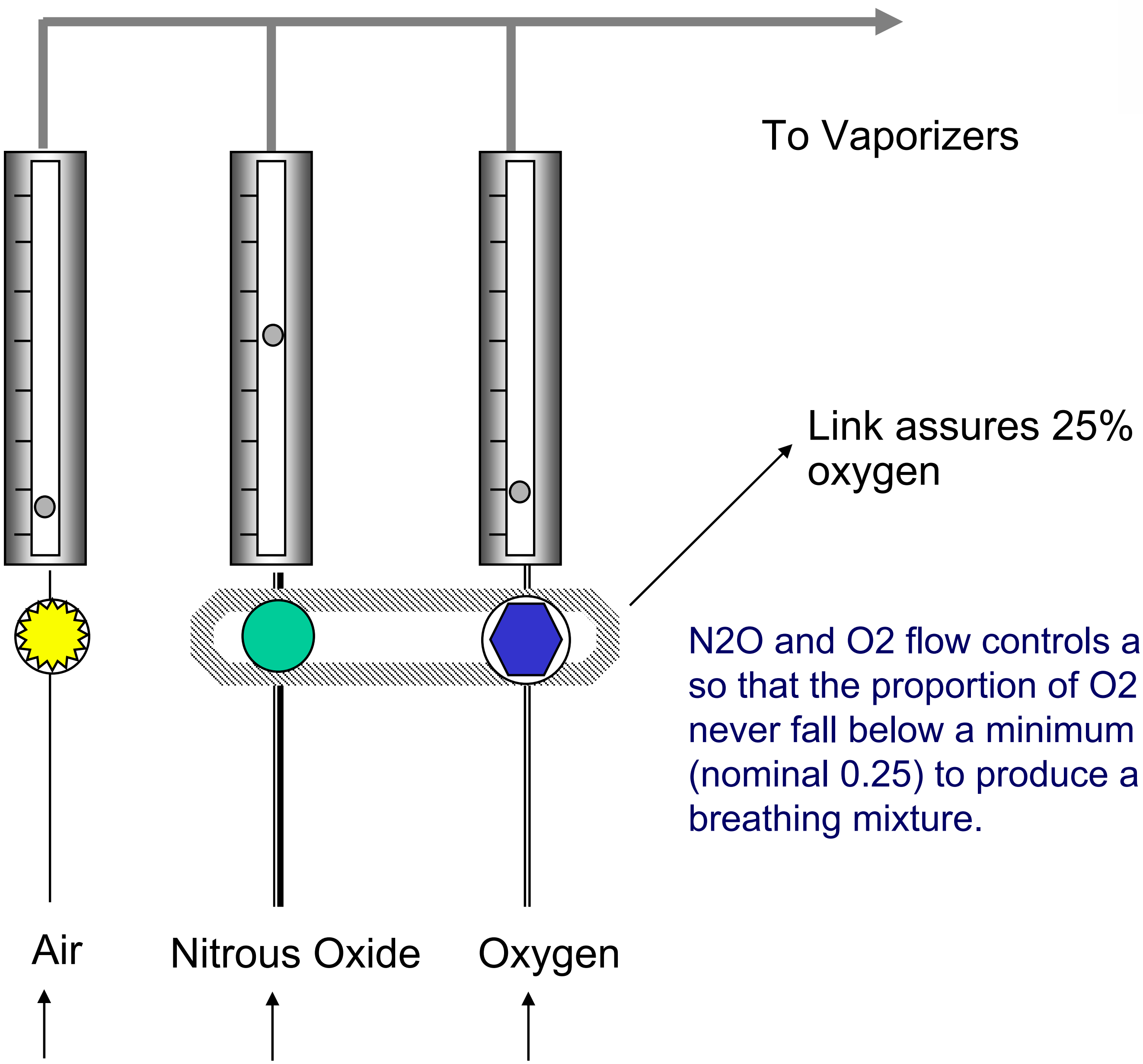
Pipeline Inlet
(between 45 and 55 psig)
6
6
Pressure reduced
to 50 psig

Pressure Regulators





Flowmeters

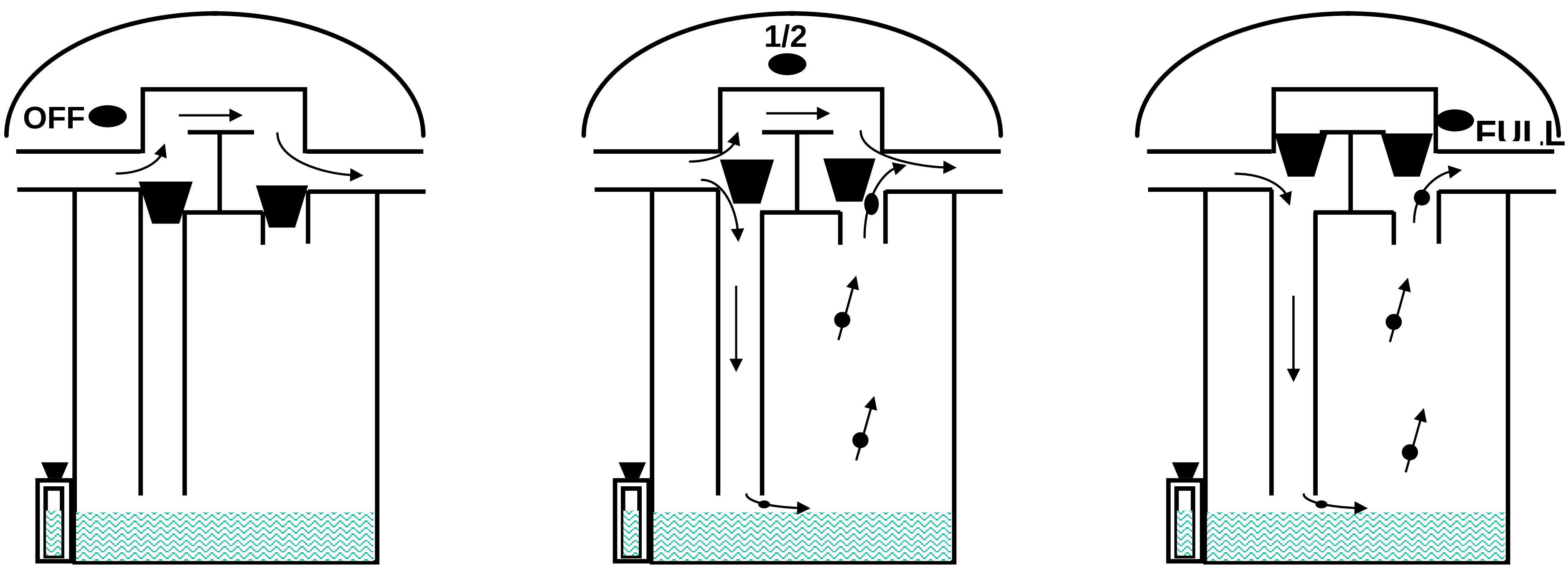


N2O and O2 flow controls are interlocked so that the proportion of O2 to N2O can never fall below a minimum value (nominal 0.25) to produce a hypoxic breathing mixture.

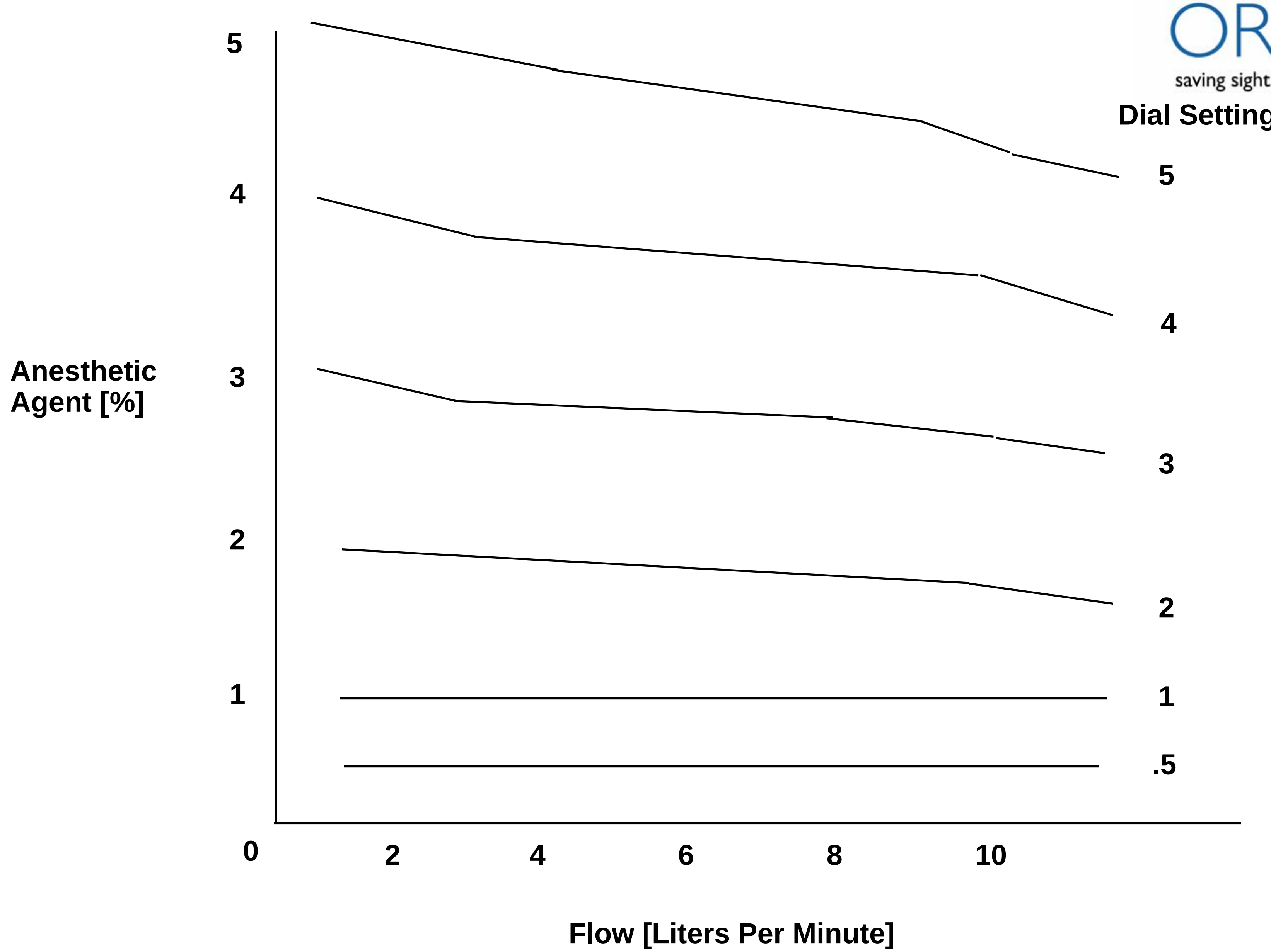
Vaporizers

- Inhaled anesthetic agents, with the exception of N2O, exist as liquids at room temperature and sea-level ambient pressure.
- Vaporizers add a controlled amount of anesthetic vapor to the gas mixture.
- Types of vaporizers:
  - variable bypass (conventional);
  - heated blender;
  - Measured flow;
  - draw-over.

Vaporizers



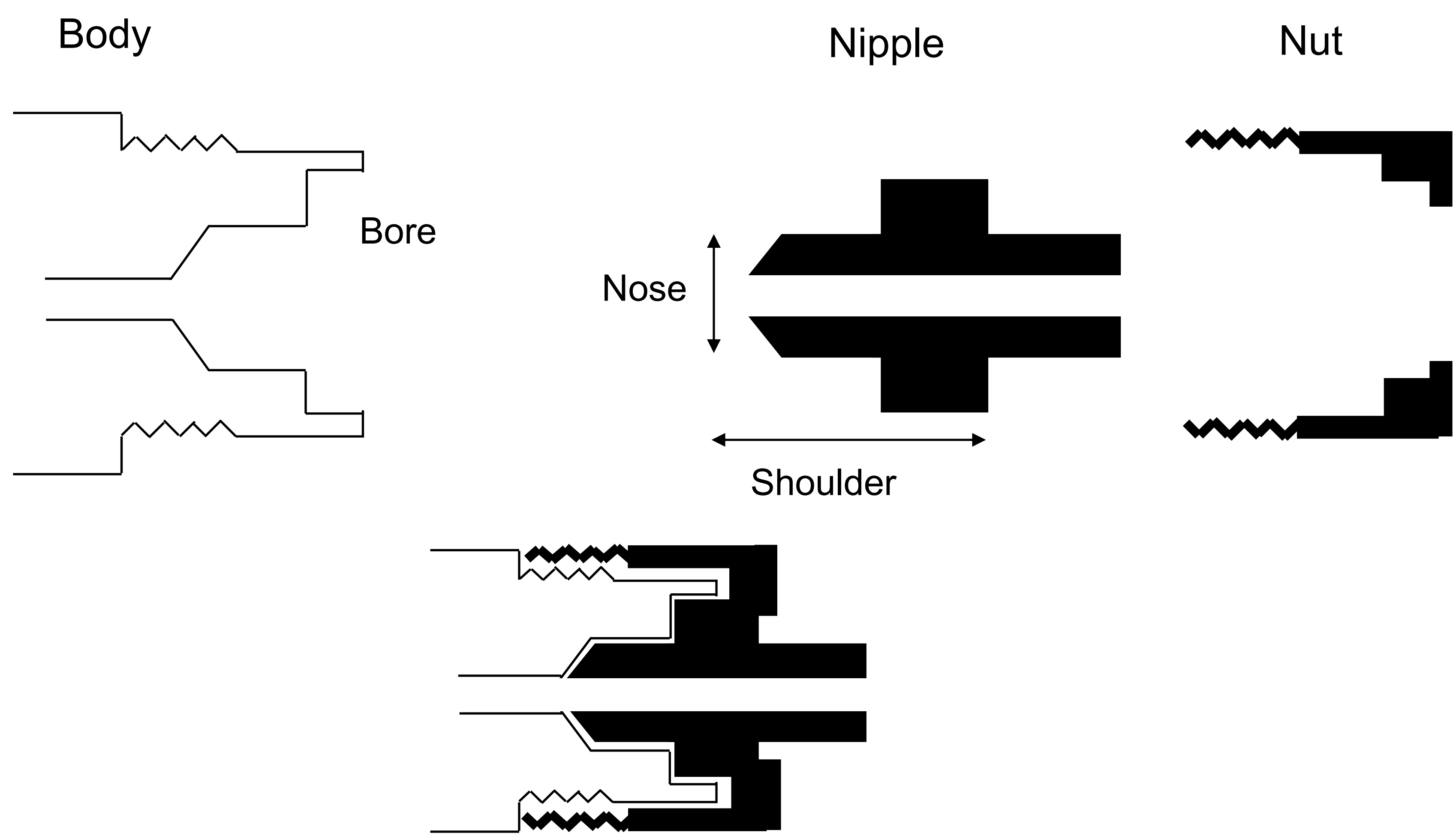
Vaporizers



saving sight worldwide
Dial Settings
5
4
3
2
1
.5
Anesthetic
Agent [%]
0
2
4
6
8
10
Flow [Liters Per Minute]

Safety Devices

Diameter Index Safety System

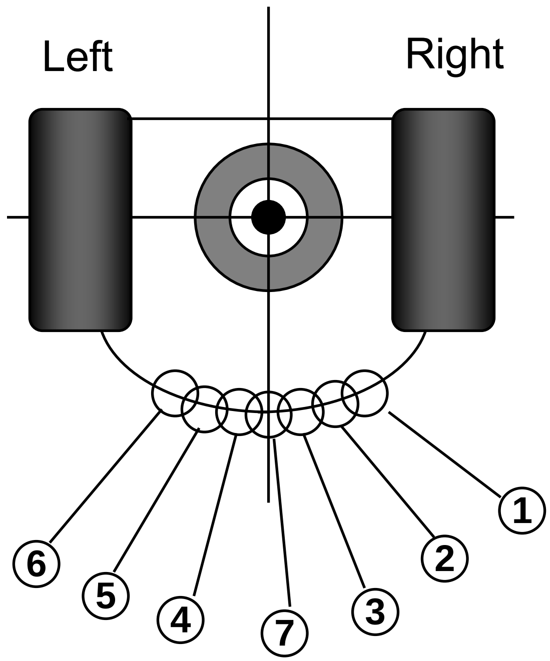


Safety Devices

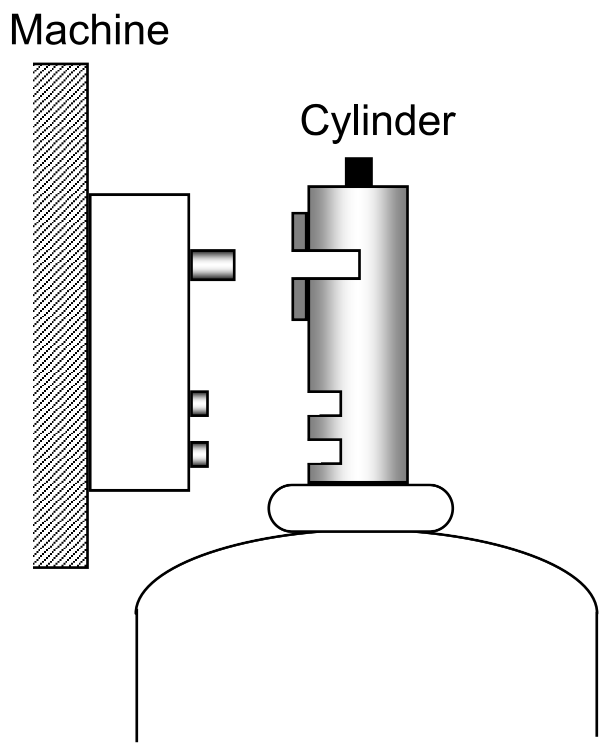
Pin Index Safety System

Gas	Index Pins
Oxygen	2-5
Nitrous Oxide	3-5
Air	3-6
Cyclopropane	3-6

Front View

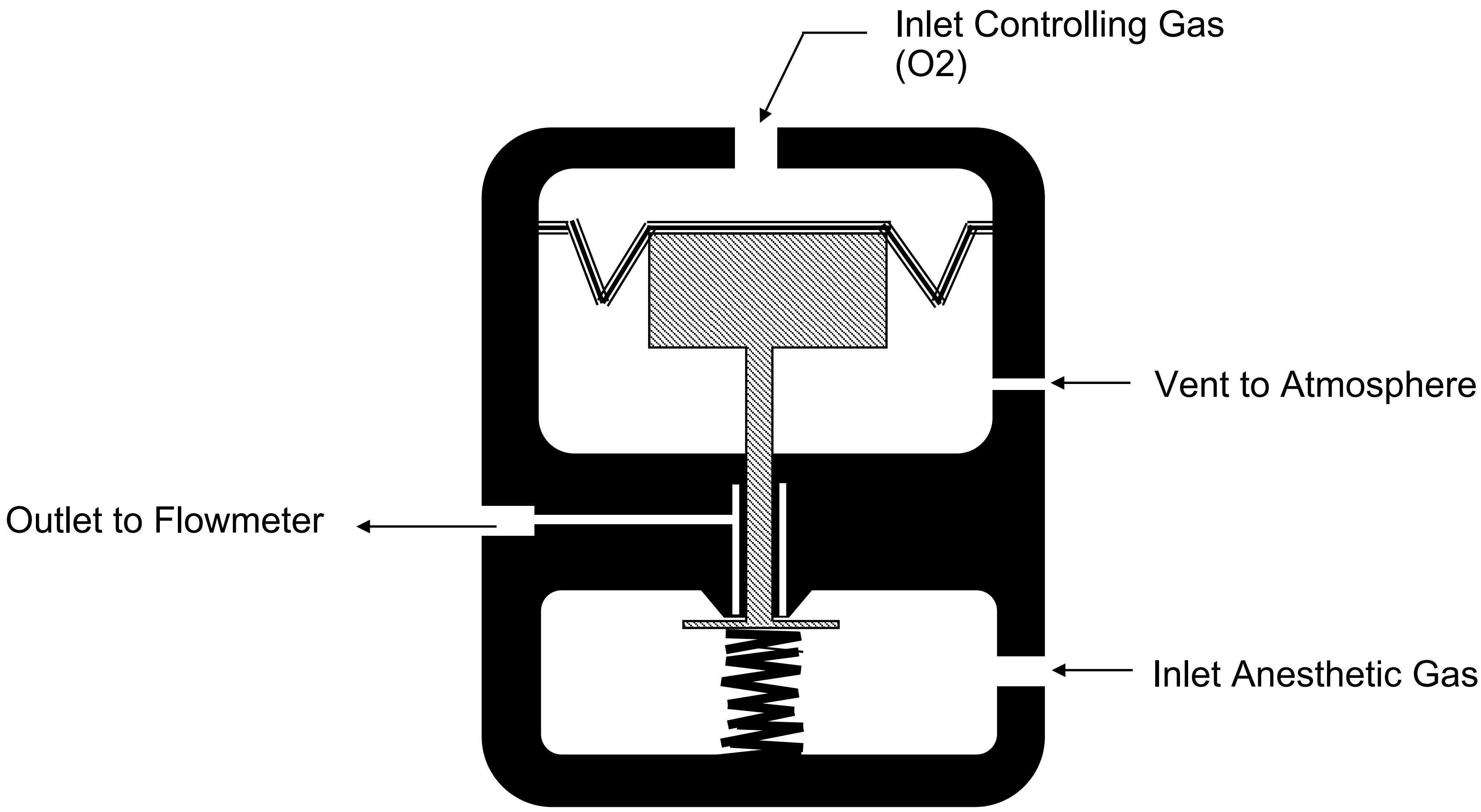


Side View



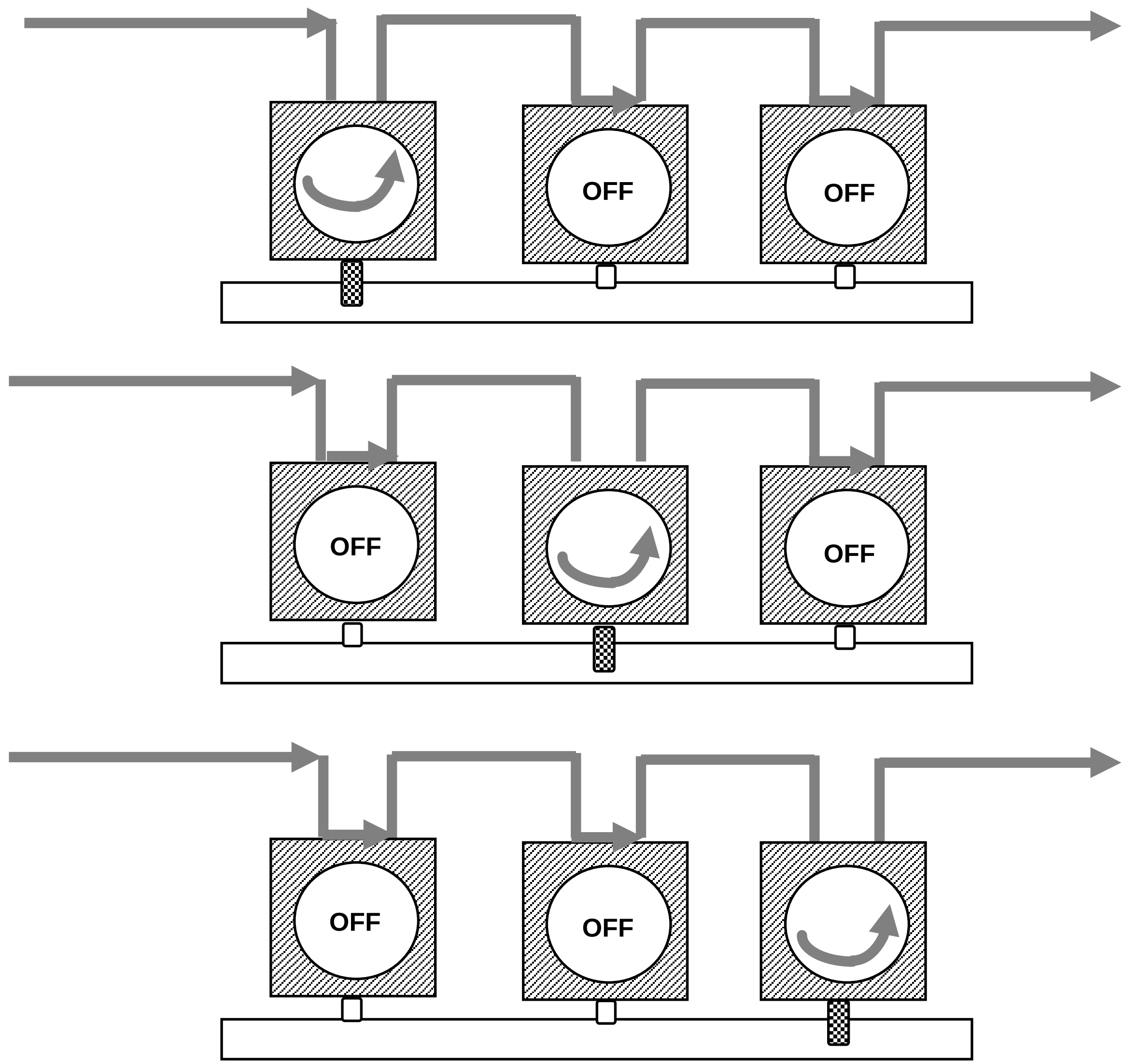
Safety Devices

Oxygen Pressure Failure Devices

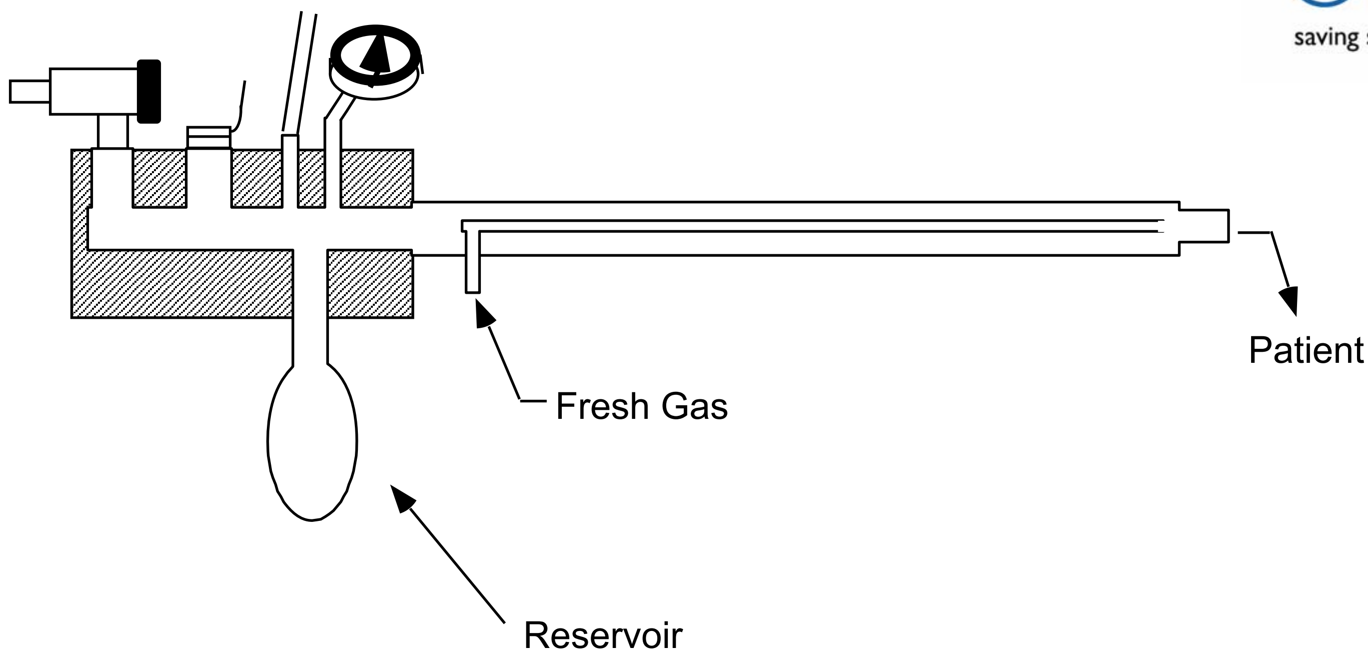


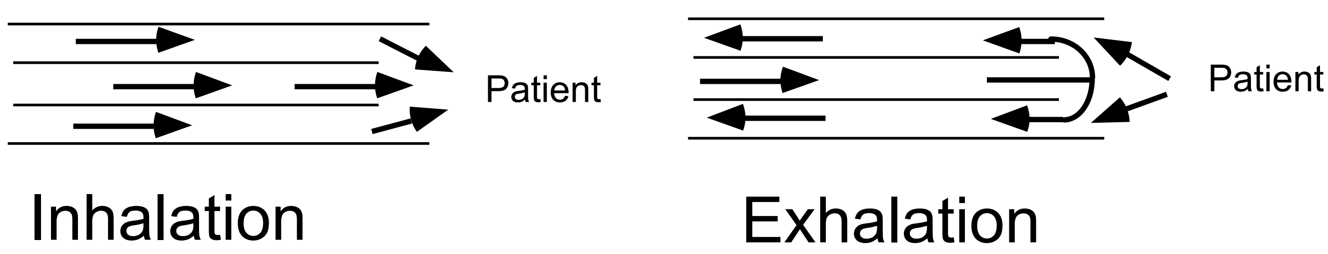
Safety Devices

Vaporizer Interlock

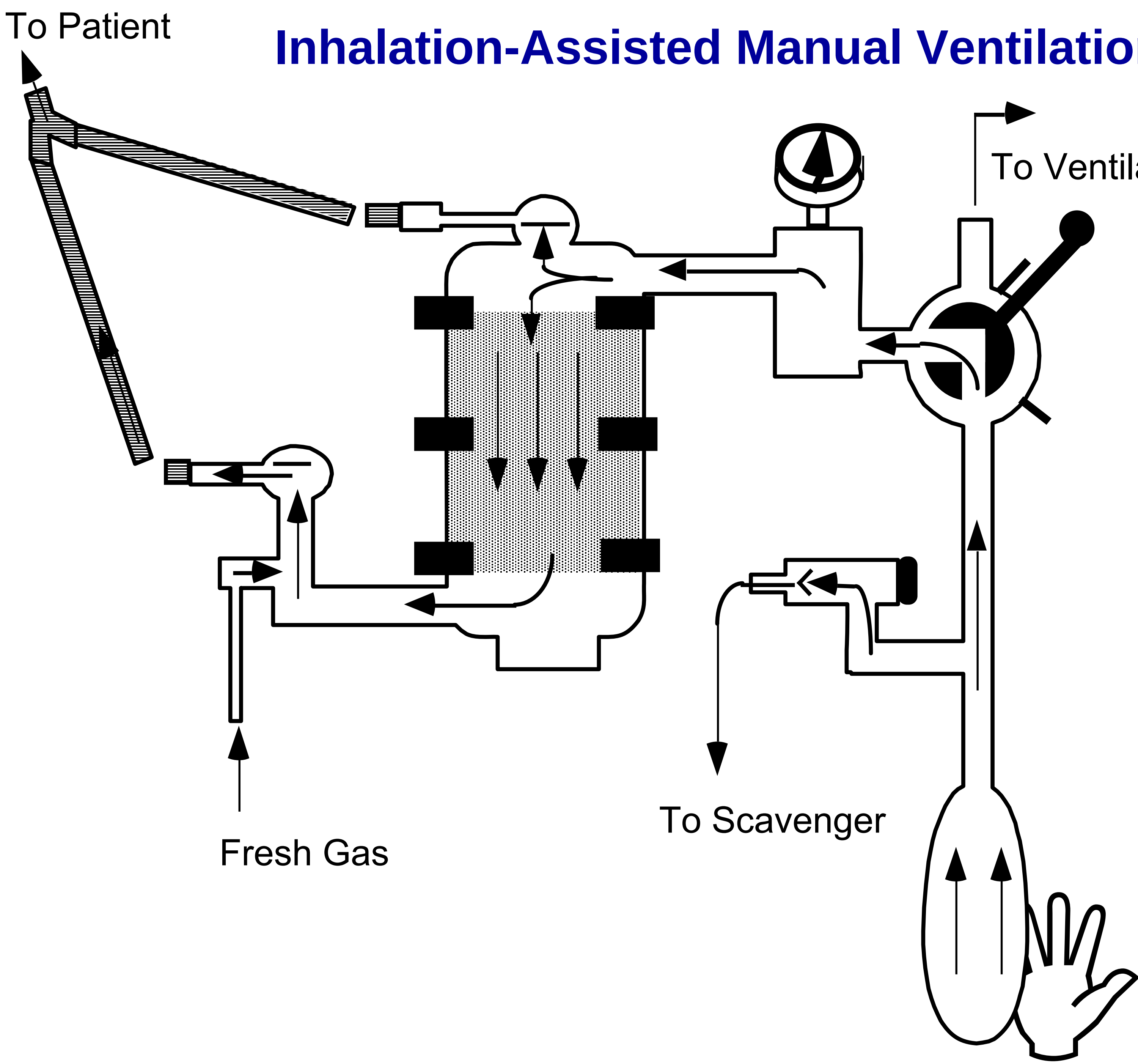


Bain System – a common configuration of the T-piece system



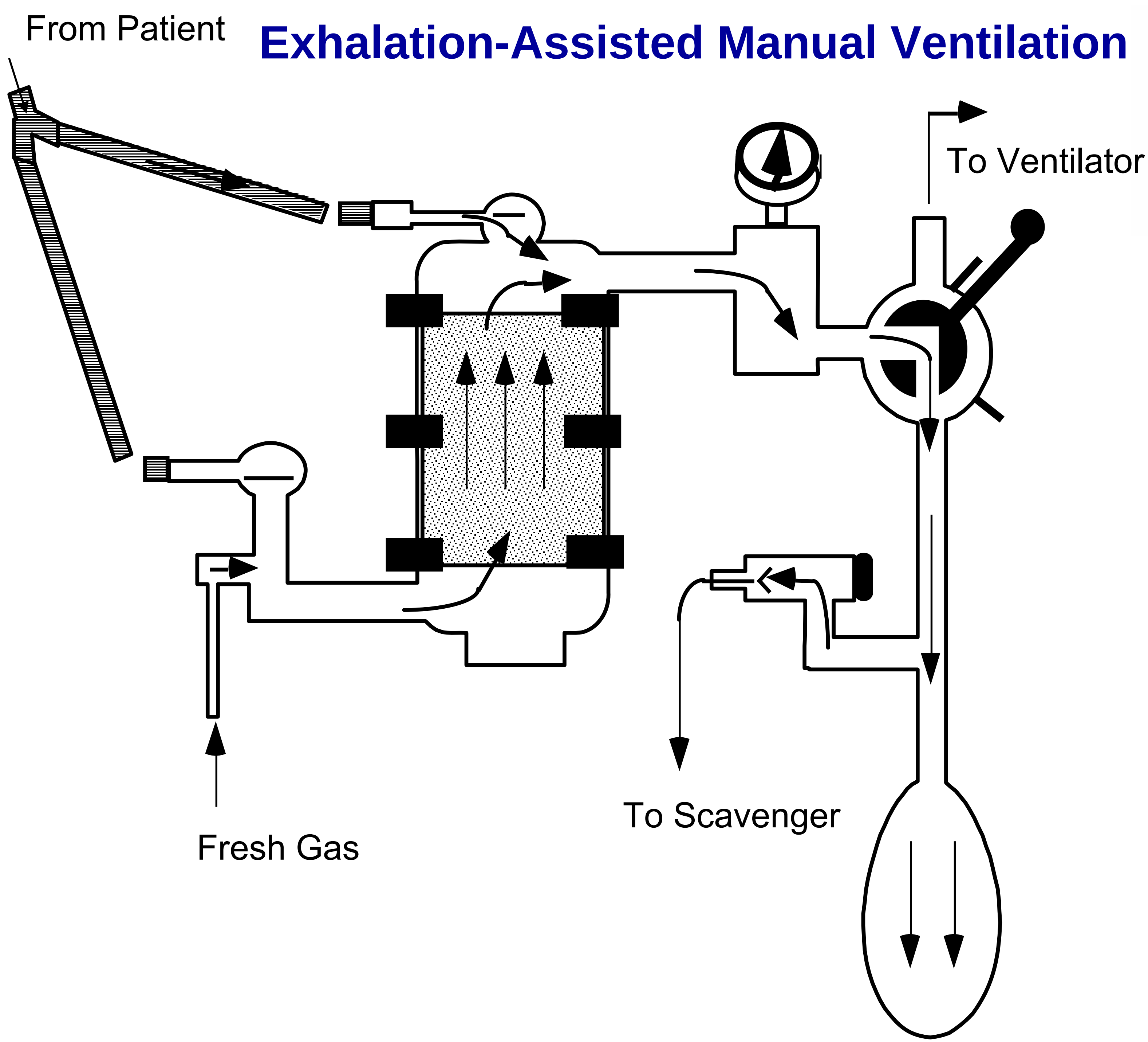


Inhalation-Assisted Manual Ventilation



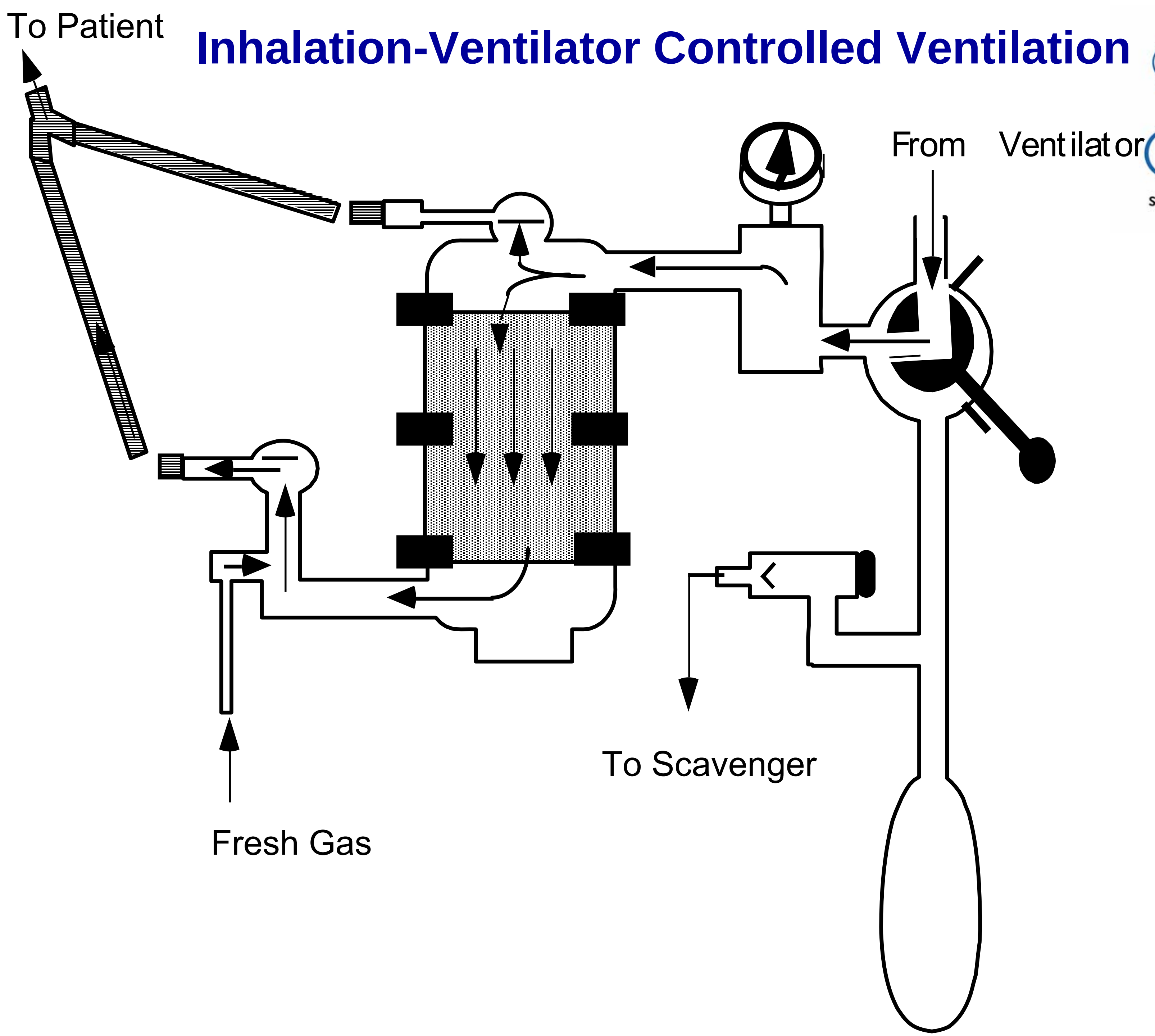
ORBIS
saving sight worldwide

Exhalation-Assisted Manual Ventilation

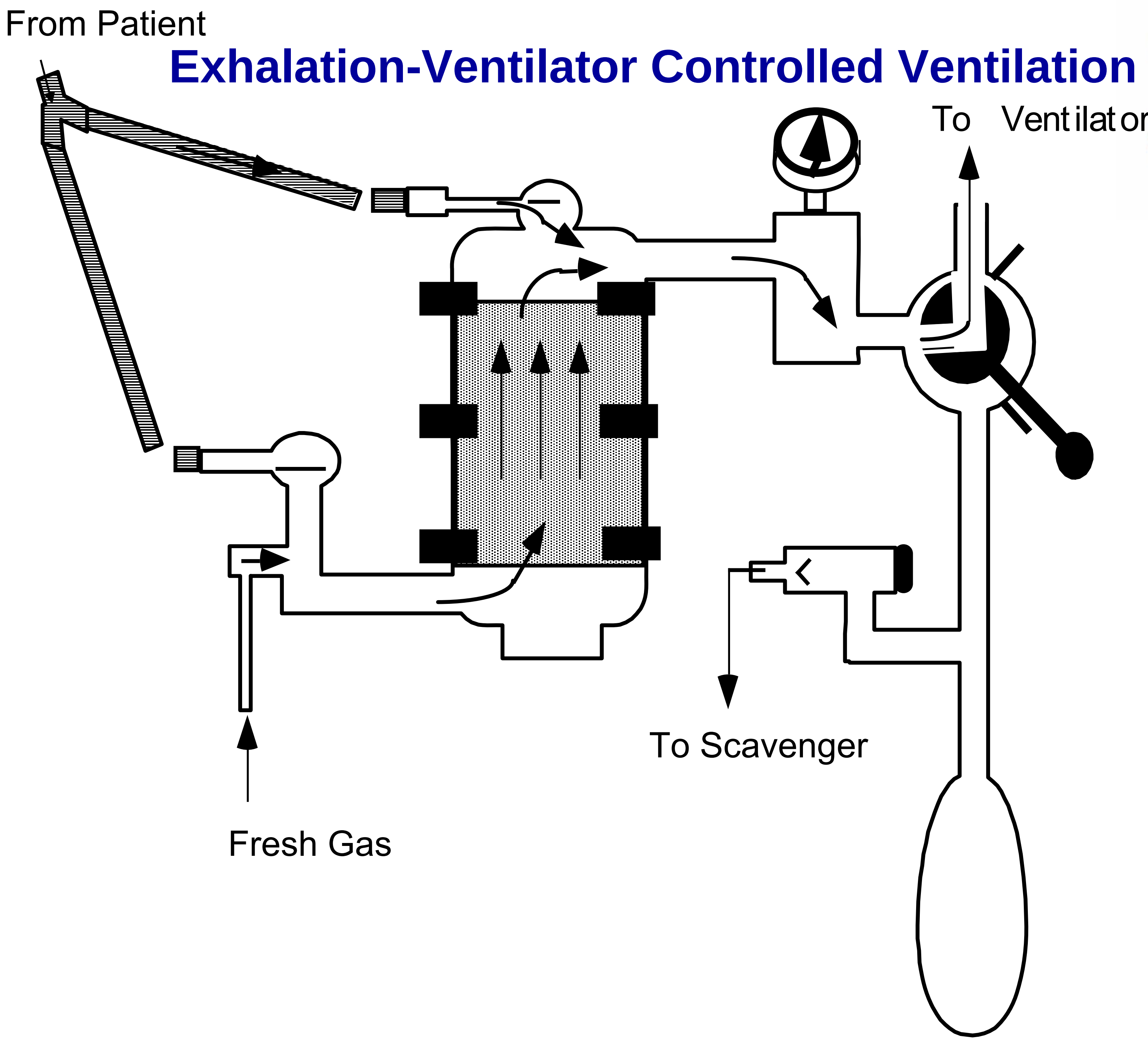


ORBIS
saving sight worldwide

Inhalation-Ventilator Controlled Ventilation



Exhalation-Ventilator Controlled Ventilation



CO_2 Absorbers

- soda lime
- barium hydroxide lime

O2 Monitor

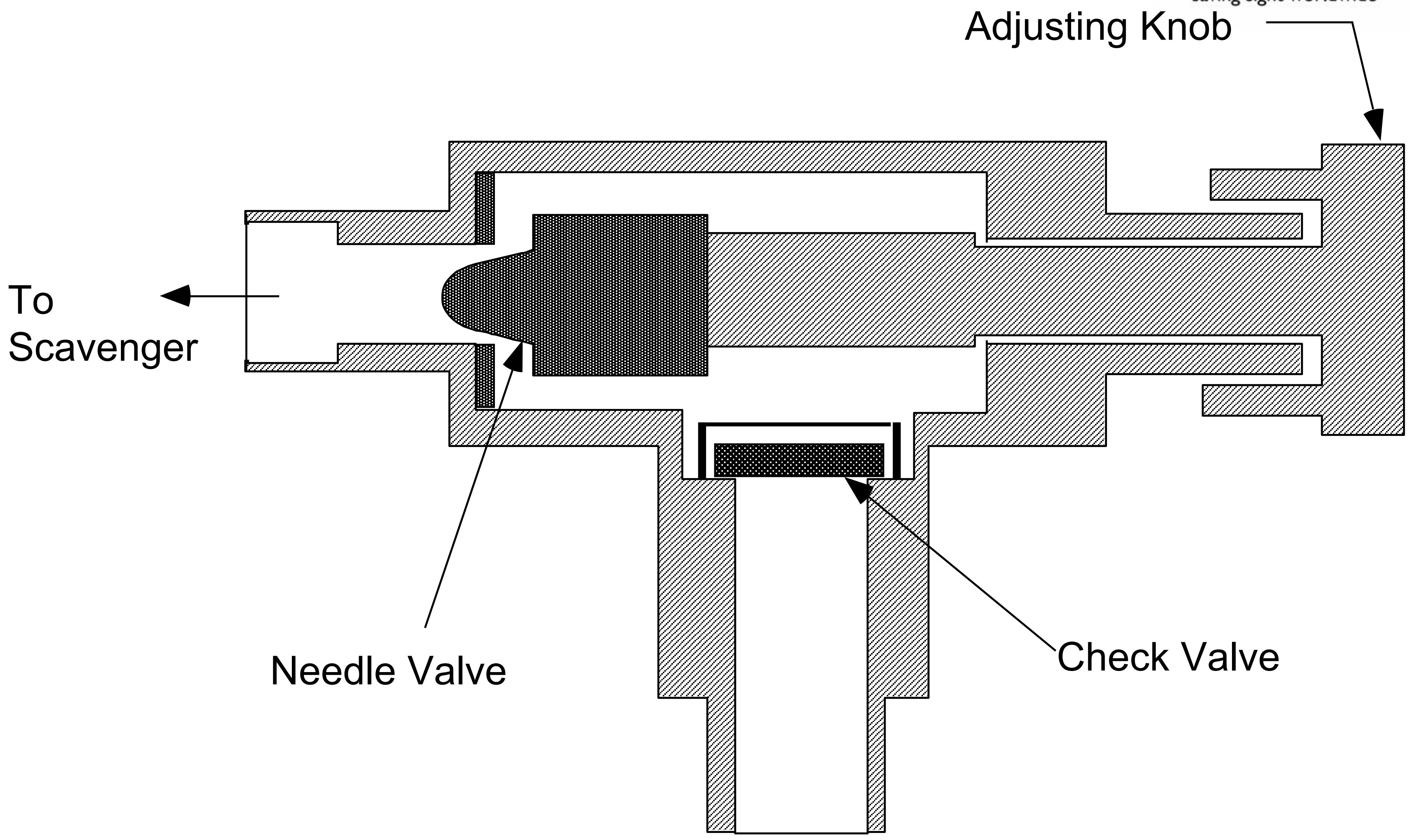
- An O2 monitor located on the inspiratory side of the breathing circuit analyzes gas sampled from the Y-piece of the patient's breathing circuit and displays O2 concentration in volume percent.

- O2 monitors sound an alarm if the O2 concentration falls below the preset limit.

Adjustable Pressure Limiter (APL) Valve

- Pressure imposed on the patient's lungs can cause serious lung damage.
- Either an APL valve or a valve in the ventilator allows excess gas to escape when a preset pressure is exceeded.
- Types:
  - spring-loaded;
  - needle.
- Many APL valves do not have calibrated markings: The anesthetist must adjust them empirically to give a desired peak inspired pressure.
- Circle systems and T-piece systems also include a pressure gauge for monitoring circuit pressure and setting the APL valve.

Adjustable Pressure Limiter (APL) Valve



Scavenging System - Rationale

- Captures and exhausts waste gases to minimize the exposure of the operating room staff to occupational risks.

- Exposure to trace levels of anesthetic gases continually present in the operating room can cause adverse health effects in operating room personnel:
  - increased incidence of spontaneous abortion;
  - congenital anomalies in babies.

- Trace gas levels in the air may have a slight anesthetizing effect on the anesthetist and surgeon.

Scavenging System

- Scavenging systems remove gas by a vacuum, a passive exhaust system, or both.

- Note: Inadequate evacuation of some scavenging systems can cause pressure to build up in the breathing circuit, with the potential for pneumothorax (air in the pleural cavity).

Scavenging System

Vacuum (active):

- Vacuum scavengers use the suction from an operating room vacuum wall outlet or a dedicated vacuum system.
- To prevent positive or negative pressure in the vacuum system from affecting the pressure in the patient circuit, manifold-type vacuum scavengers use one or more positive or negative pressure-relief valves in an interface with the anesthesia system.
- Open-type vacuum scavengers have vacuum ports that are open to the atmosphere through some type of reservoir; such units do not require valves for pressure relief.

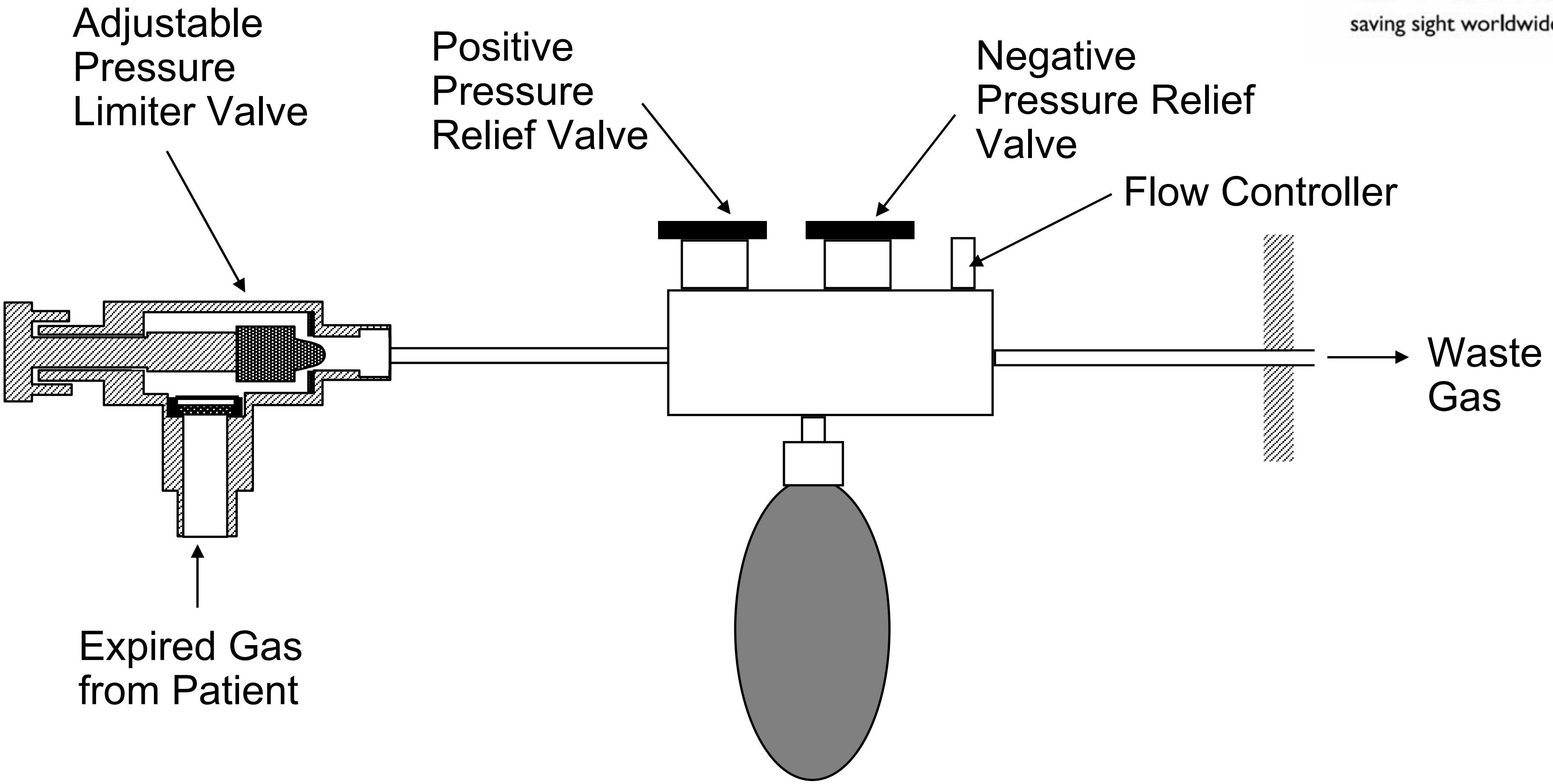
Scavenging System

Passive exhaust system:

- Passive-exhaust scavengers can vent into a hospital ventilation system (if the system is the non-recirculating type) or, preferably, into a dedicated exhaust system.

- The slight pressure of the waste-gas discharge from the anesthesia machine forces gas through large bore tubing and into the disposal system or directly into the atmosphere.

Scavenging System



Preventive Maintenance

- Test apparatus and supplies:
  - Lung simulator with adjustable compliance or ventilator tester
  - Pressure gauge or meter with 2 cm H_2O resolution, from -20 to +120 cm H_2O
  - Various breathing circuit adapters
  - Leakage current meter or electrical safety analyzer
  - Ground resistance ohmmeter
  - Additional items as required for specific manufacturers’ procedures

Preventive Maintenance

- Qualitative tests:
  - Chassis/Housing
  - Mount/Fasteners
  - Casters/Brakes
  - AC Plug
  - Line Cord
  - Strain Reliefs
  - Circuit Breaker/
  - Tubes/Hoses
  - Cables
  - Fittings/Connectors
  - Filters
  - Controls/Switches
  - Fan
  - Battery/Charger
  - Indicators/Displays
  - Alarms/Interlocks
  - Labeling
  - Accessories
  - Bellows

Preventive Maintenance

- Quantitative tests:
  - Grounding resistance [≤0.5 Ω]
  - Leakage current [≤300 μA chassis]
  - Modes and settings [±10% accuracy]
  - Monitors and Alarms [±10% accuracy]
  - Alarms tested:
    - Airway pressure
    - Tidal volume
    - FIO2
    - Others

Preventive Maintenance

- Others:
  - Gas Supply
  - Pneumatic lines (including air filters)
  - Gas cylinders (and gauges and regulators, if so equipped)

  - Patient Circuit
  - Breathing circuit (including filters)
  - Humidifiers
  - Pressure-relief mechanism
  - Absorber

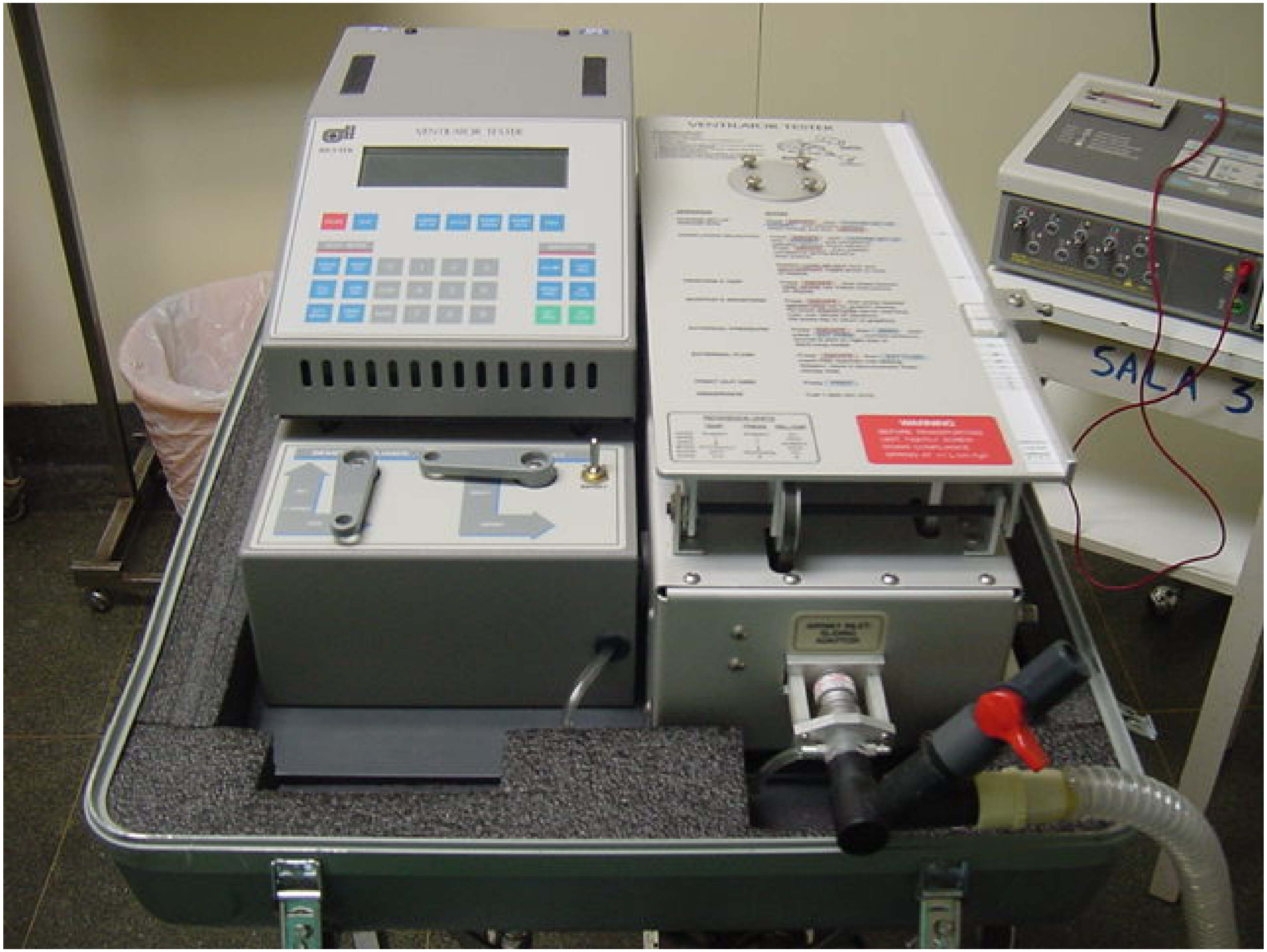
IEC Standards

- International Electrotechnical Commission. Medical electrical equipment — part 1: general requirements for safety [standard]. IEC 60601-1 (1988-12). 1988.
- Medical electrical equipment — part 1: general requirements for safety. Amendment 1 [standard]. IEC 60601-1-am1 (1991-11). 1991.
- Medical electrical equipment — part 1: general requirements for safety. Amendment 2 [standard]. IEC 60601-1-am2 (1995-03). 1995.
- Medical electrical equipment — part 1: general requirements for safety. Section 1. Collateral standard: safety requirements for medical electrical systems. IEC 60601-1-1 (1992-06). 1992.
- Medical electrical equipment — part 1: general requirements for safety. Section 1. Collateral standard: safety requirements for medical electrical systems. Amendment 1. IEC 60601-1-1-am1 (1995-11). 1995.
- Medical electrical equipment — part 1: general requirements for safety. Section 2. Collateral standard: electromagnetic compatibility — requirements and tests. IEC 60601-1-2 (2001-09). 2001.
- Medical electrical equipment — part 2-13: particular requirements for the safety of anesthetic workstations [standard]. IEC 60601-2-13 (1998-05). 1998.

ISO Standards

- International Organization for Standardization. Anaesthesia and respiratory care alarm signals — part 1: visual alarm signals [standard]. 1st ed. ISO 9703: Part 1:1992. 1992.
- Anaesthesia and respiratory care alarm signals — part 2: auditory alarm signals [standard]. 1st ed. ISO 9703-2:1994. 1994.
- Anaesthetic and respiratory equipment — conical connectors — part 1: cones and sockets [standard]. 2nd ed. ISO 5356:1-1996. 1987 (revised 1996).
- Anaesthetic and respiratory equipment — conical connectors — part 2: screw-threaded weight-bearing connectors [standard]. 1st ed. ISO 5356-2:1987. 1987.
- Anaesthetic and respiratory equipment — heat and moisture exchangers (HMEs) for humidifying respired gases in humans [standard]. ISO 9360:2001. 2001.
- Anaesthetic machines for use with humans [standard]. 2nd ed. ISO 5358:1992. 1992.

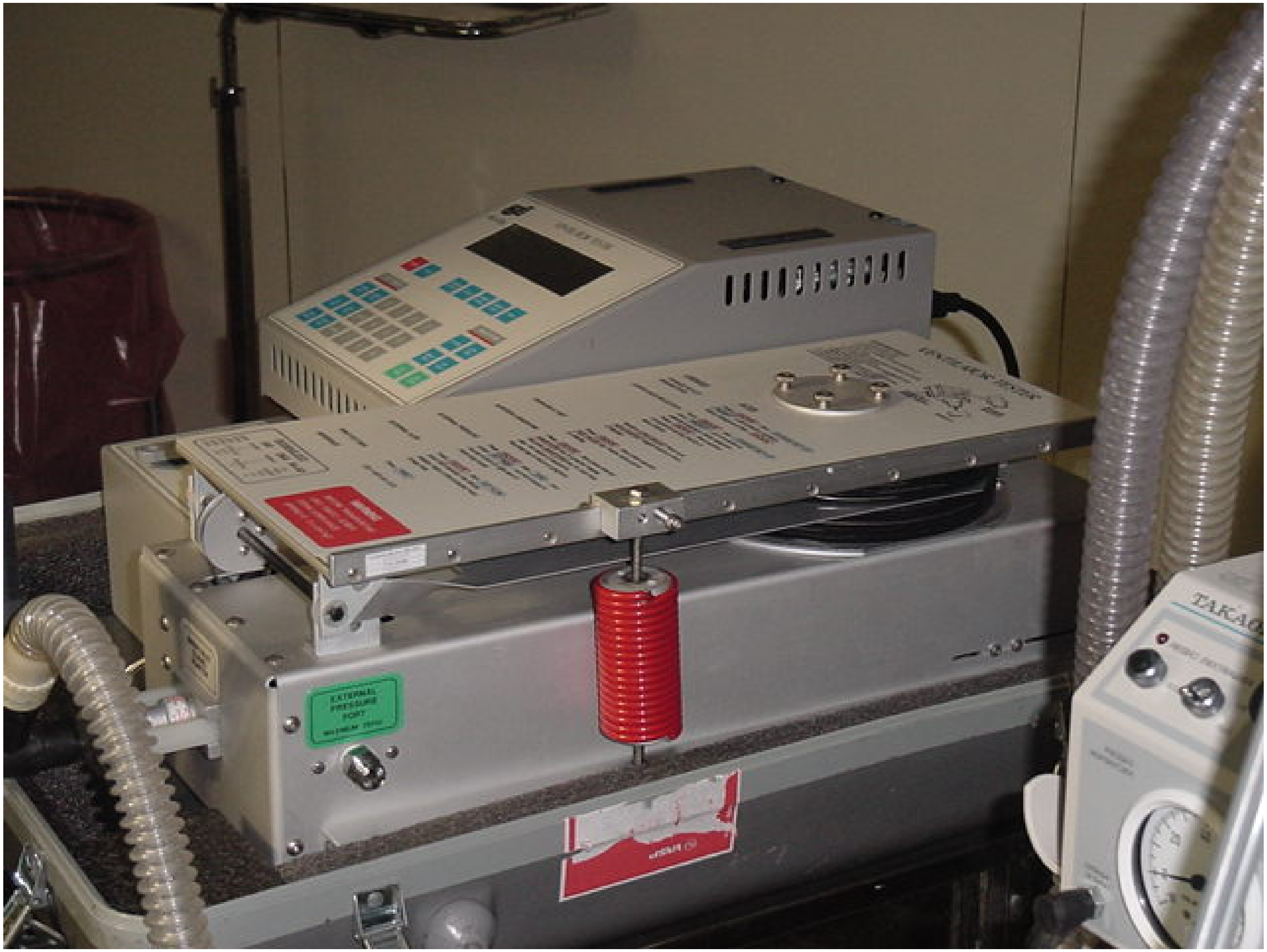
ORBIS
saving sight worldwide



ORBIS

saving sight worldwide

ORBIS
saving sight worldwide



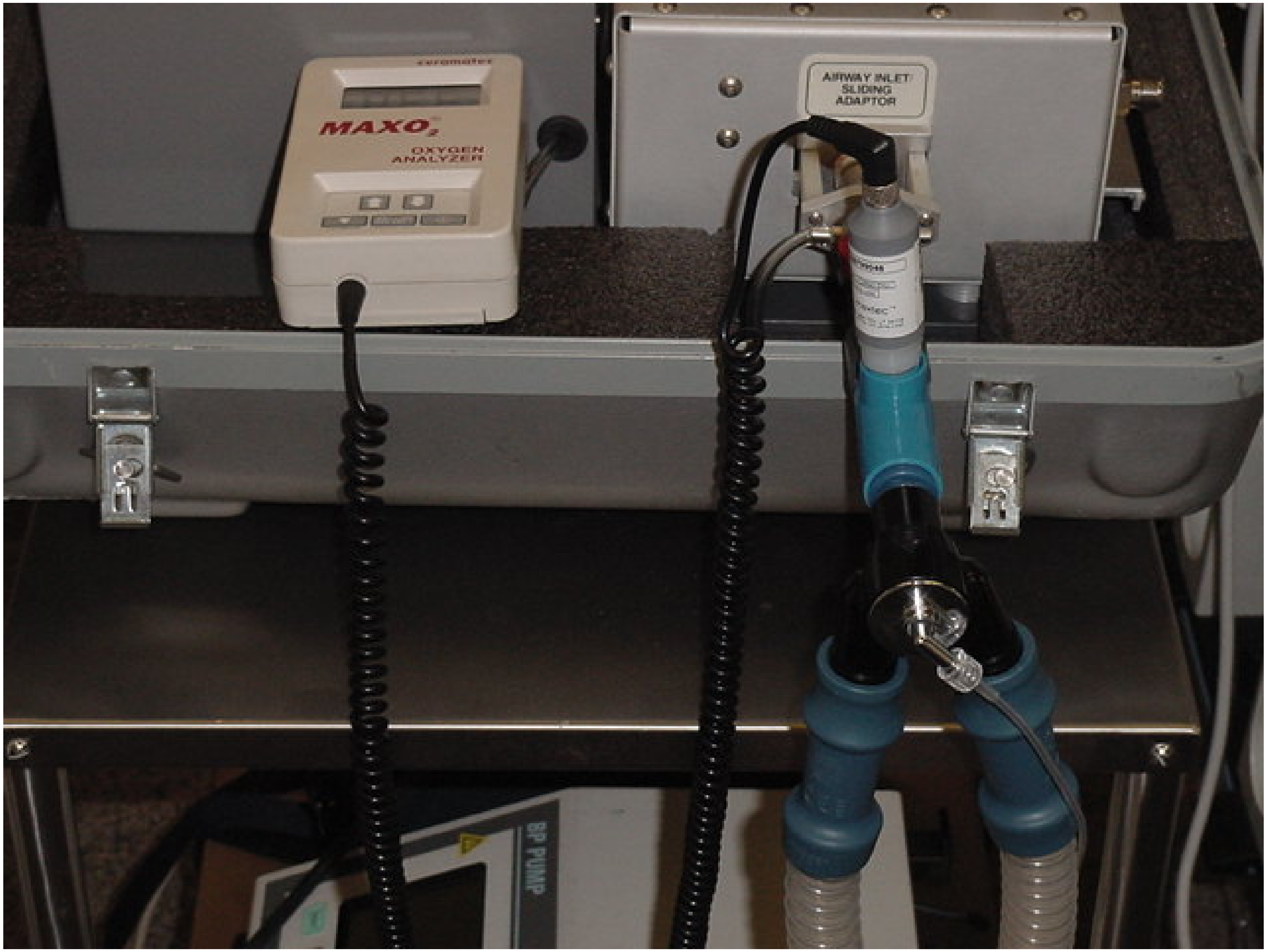
ORBIS
saving sight worldwide

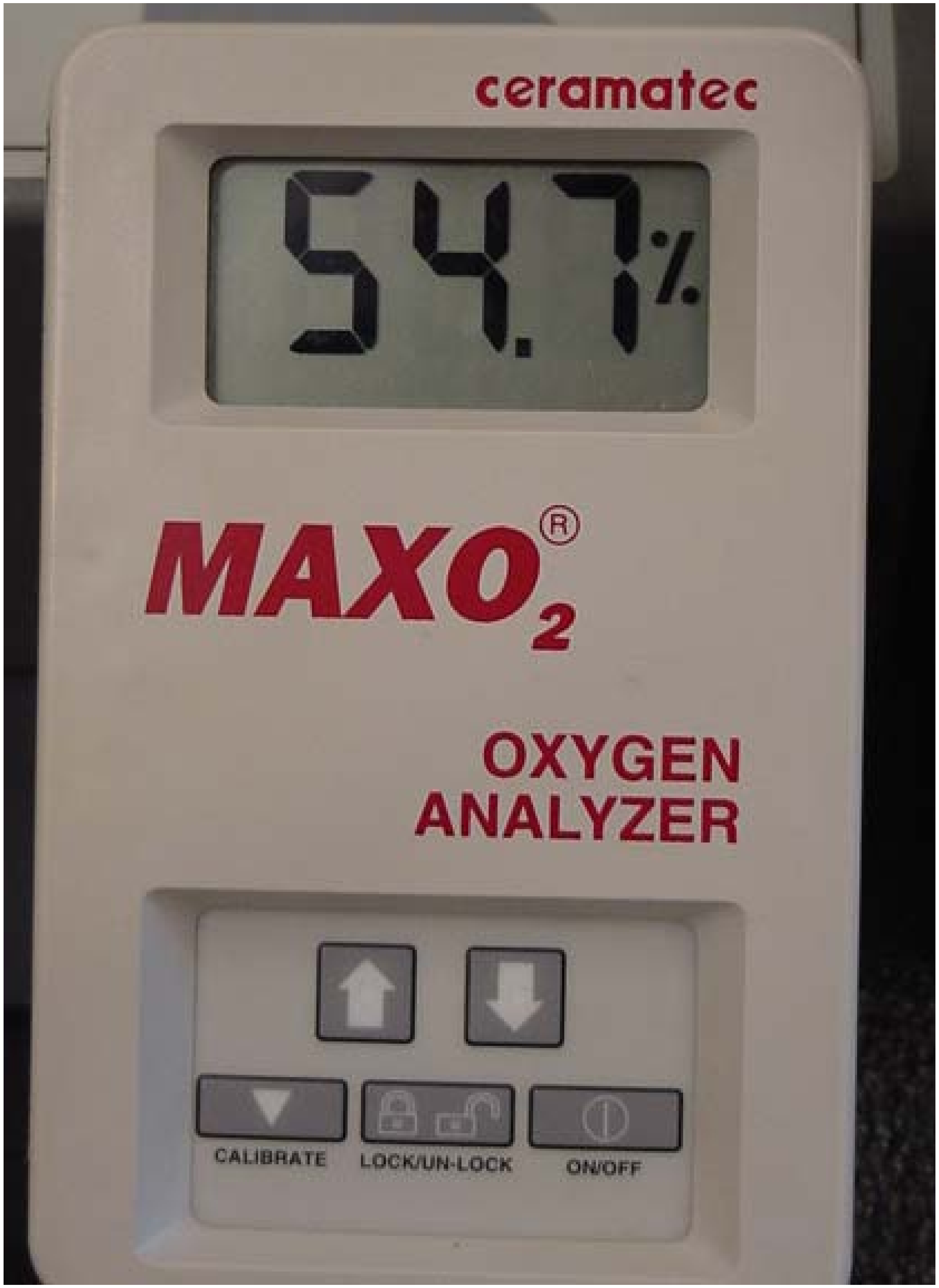
ORBIS

saving sight worldwide

ORBIS

saving sight worldwide





ORBIS
saving sight worldwide

ORBIS

saving sight worldwide