Equipment Packet: Anesthesia Machine

UMDNS #: 10134

Date of Creation: September 8, 2015

Creator: Complied by Cassandra Stanco for Engineering World Health (EWH)

Equipment Packet Contents:

This packet contains information about the operation, maintenance, and repair of anesthesia machines.

Part I: External From the Packet:

1. **An Introduction to Anesthesia Machines** (PowerPoint)

Part II: Included in this Packet:

1. Operation and Use of Anesthesia Machines

Featured in this Section:

Malkin, R. “Anesthesia Machines,” From the publication: Medical Instruments in the Developing World. Engineering World Health, 2006.

WHO. “Anesthesia Unit,” From the publication: *Core Medical Equipment*. Geneva, Switzerland, 2011.

Wikipedia. “Pulse Oximetry.” *Wikipedia*, pgs. 1-4. Retrieved from: https://en.wikipedia.org/wiki/Pulse_oximetry

Anesthesia Unit **Brief Introduction to Anesthesia Units**

UMDNS	GMDN
10134 Anesthesia Units	47769 Anaesthesia unit, mobile

Other common names:
Anesthesia machines; Anaesthesia apparatus; Gas-machine, anesthesia

Core medical equipment - Information

Health problem addressed

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.

Product description

An anesthesia system comprises of a gas delivery platform, a data analysis and distribution system, and physiologic and multigas monitors (optional in most units), which indicate levels and variations of several physiologic variables and parameters associated with cardiopulmonary function and/or gas and agent concentrations in breathed-gas mixtures. Manufacturers typically offer a minimum combination of monitors, alarms, and other features that customers must purchase to meet standards and ensure patient safety.

Principles of operation

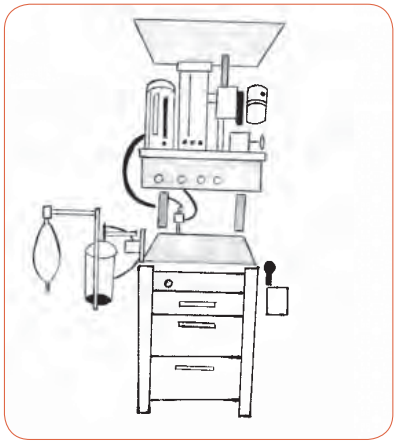
Because O2 and N2O are used in large quantities, they are usually drawn from the hospital's central gas supplies. Vaporizers add a controlled amount of anesthetic vapor to the gas mixture. An automatic ventilator is generally used to mechanically deliver breaths to the patient. The ventilator forces the anesthesia gas mixture into the patient's breathing circuit and lungs and, in a circle breathing system, receives exhaled breath from the patient as well as fresh gas. A scavenging system captures and exhausts waste gases to minimize the exposure of the operating room staff to harmful anesthetic agents. Scavenging systems remove gas by a vacuum, a passive exhaust system, or both.

Operating steps

A mask is placed over the nose and mouth. The anesthesia unit dispenses a mixture of gases and vapors and varies the proportions to control a patient's level of consciousness and/or analgesia during surgical procedures. 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.

Reported problems

One of the greatest dangers of anesthesia is hypoxia, which can result in brain damage or death, though the administration of concentrated O2 (100%) may be toxic. Gas with excessive CO2 concentration, an inadequate amount of anesthetic agent, or dangerously high pressure may cause hypoventilation, compromised cardiac output, pneumothorax, and asphyxiation. Contamination of the anesthesia breathing circuit may lead to nosocomial infections.



Use and maintenance

User(s): Anesthesiologist, nurse anesthetist, medical staff

Maintenance: Biomedical or clinical engineer/ technician, medical staff, manufacturer/ servicer

Training: Initial training by manufacturer, operator's manuals, user's guide, some manufacturers offer offsite training or remote training

Environment of use

Settings of use: Hospital (surgery), ambulatory surgery centers

Requirements: Uninterruptible power source, O2 fail-safe and hypoxic mixture fail-safe systems, gas cylinder yokes for O2 if central supplies fail, internal battery (for units with automatic ventilators) capable of powering the unit for at least 30 minutes

Product specifications

Approx. dimensions (mm): 1,500 x 700 x 700

Approx. weight (kg): 130

Consumables: Anesthetic agents, tubing, masks

Price range (USD): 5,000 - 100,000

Typical product life time (years): 8-10

Shelf life (consumables): Variable

Types and variations

Cart mounted, ceiling mounted, wall mounted, mobile

WHO. "Anesthesia Unit," From the publication: Core Medical Equipment. Geneva, Switzerland, 2011.

World Health Organization http://www.who.int/medical_devices/en/index.html

Principles and Use of Anesthesia Machines

2.17 Anesthesia Machines

2.17.1 Clinical Use and Principles of Operation

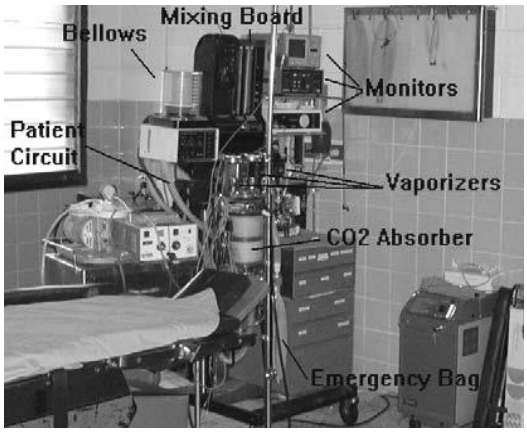
Anesthesia is defined as the loss of feeling or sensation. During most surgical procedures, some form of anesthesia is used. There are at least four different types of anesthesia that are encountered in the developing world.

General anesthesia is a state of unconsciousness, with an absence of pain sensation over the entire body, produced by anesthetic agents, often with muscle relaxants. General anesthesia is administered by inhalation, intravenously, intramuscularly, rectally or via the stomach. Local anesthesia is where a specific area is "numbed" such as in a dentist's office. The patient is awake and may feel some limited pain. Saddle block anesthesia is where the patient is conscious and the area of the body that would touch a saddle is affected. This is accomplished by injecting an anesthetic agent low in the dural sac and is common for childbirth. Spinal anesthesia is where an anesthetic agent is injected beneath the membrane of the spinal cord. There is no sensation below that point until the agent wears off.

General Anesthesia unit, inhalation

The anesthesia machine, sometimes called a Boyle machine, works by mixing selected concentrations of gases and drugs that the patient inhales. Consciousness is regained relatively quickly after the procedure terminates.

This anesthesia machine in Togo shows all the basic components. There is little difference between this unit and the most modern units seen in the US.



Anesthesia machines are generally large, on wheels, and contain one or more vaporizers, flow tubes, attachments for compressed gas cylinders, a ventilator, ports for obtaining compressed gases from wall connections, a carbon dioxide absorber other gas traps (or scrubbers) and various monitoring devices either built in or attached to the unit. These machines can cost over $60,000.00 to purchase and require regular maintenance. Some of the maintenance requires specialized testing equipment that may not be available in a developing world hospital, including devices for the measurement of the concentration of gases, flow rates and pressures. Additional training is typical in western hospitals before attempting any calibration or repair of the gas delivery system. However, in the developing world, repair, calibration and maintenance are often done by whoever is available.

Malkin, R. "Anesthesia Machines," From the publication: Medical Instruments in the Developing World. Engineering World Health, 2006.

The flow of gases can be traced from the source to the patient. Typically, compressed gases such as air, oxygen, and nitrous oxide are supplied from gas cylinders or from wall outlets. By passing through a pressure regulator, gas in a cylinder is reduced from thousands of psi to a typical delivery pressure between 20 and 50 psi (regulators and cylinders are covered elsewhere is this book). From the regulator, gas in the line will often pass through an O2 failure detector. Next the gases enter the mixing board which contains rotameters for measuring gas flow. From there, the gases move through vaporizers where a volatile agent such as halothane will be added to the mixture. Delivery of the final gaseous product to the patient is achieved with a series of tubes, valves and a mask that is referred to as the anesthesia circuit.

Vaporizers

Vaporizers are used to convert a liquid anesthetic agent into a vapor. Because they are designed to function under continuous pressure and flow environment, they are sometimes called plenum vaporizers. As air enters the vaporizer, it is directed into either the vaporizing chambers or a bypass chamber. The anesthesiologist will control the bypass valve to allow more or less of the incoming gases to flow through the vaporizing chamber usually via a large knob on fob of the vaporizer. The liquid anesthetic agent resides in the lower part of the unit. As the gas moves across the top of the liquid, the anesthetic agent vaporizes and is carried by the gas towards the outlet, where it is blended with the gas that had bypassed the chamber.

Two vaporizers (for two different anesthetics) sit to the right of the mixing board and a large manometer.

Since vapor pressure is affected by temperature, a warm environment would normally encourage more of the anesthetic agent to vaporize and a cold environment less. Furthermore, the process of vaporization itself removes heat from the vaporizer and the anesthetic agent. In order to compensate for temperature effects, a bi-metallic valve is added to the by-pass system. The bi-metallic valve physically distorts to adjust for temperature changes. It is possible to compensate for temperature variations by warming the fluid to a fixed temperature, but this approach is less common.

The vaporizer should be maintained level as operation out of level can affect the calibration. Also, when working with a vaporizer, care should be exercised not to tip vaporizer as this can cause a hazardous spill. Should a spill occur, water can be used to clean up the anesthetic agent and doors should be opened to clear the vapors. Vaporizers should generally be calibrated every six months; however, in the developing world this is rarely undertaken. Vaporizers are very reliable, but if the vaporizer does break, it must be sent back to the factory or other qualified repair service. There is little a field engineer can do to repair a broken vaporizer.

Rotameters

A mixing board on the anesthesia machine will allow the anesthetist to mix oxygen, anesthetic gases and the patients expired air to the desired ratios for delivery to the patient. The ratio of the fresh gasses is continuously measured by their flow rates. A typical mixing board will contain several rotameters for measuring gas flow. Rotameters are made from either glass or plastic tubes containing a metal or ceramic ball that serves as a float. The walls of the rotameters are slightly "V" shaped so that as the ball rises, more of the gas is diverted around the ball lowering the force upwards on the ball. When the force of gravity is just balanced by the force upwards of the gas, the ball will stop moving. As the flow rate increases, the ball moves up and as the flow rate decreases, the ball moves down. However, as the ball moves up, the force of the gas on the ball drops because more of the gas is diverted around the ball. Thus, the height of the ball can be used to determine the flow rate of the gas in the rotameter.

A small mixing board with only two rotameters. In some anesthesia machines there can be four or five rotameters.

Rotameters are calibrated in cubic centimeters (cc) or milliliters (ml) of gas per minute. The amount of each gas entering the mixing board is controlled by needle valves at the base of each rotameter.

Gas Handling

Anesthesia gases are supplied from tanks that are mounted on the anesthesia cart or from a central source in the hospital. In the latter case, there will be wall mounts in the room with specialized fittings so that hoses are not misconnected. As a safety feature, gas tanks may have what is called a pin index connection that allows only specific yokes to be connected to the tank. The tank is attached to a yoke that has pins sticking out that match the holes in the neck of the tank. During every inspection of the anesthesia unit, the pins on each yoke should be verified that they are present and in the correct positions for the designated tank. However, in the developing world as donations may come from many sources, the pin indexes may be missing, tampered with or ignored. A backup to the pin index is the color-coding of the paint on the tanks. In the US, oxygen tanks are painted green (blue in some other countries) while nitrous oxide tanks are blue and air tanks are yellow. Similarly, the connection hoses for the centralized gas system should be color coded to match the gas tank. Europe has a different color-coding scheme, and in the developing world, there may be no system to the color of the tanks or hoses.

Faced with unmarked tanks, connectors and hoses, the engineer should first thoroughly discuss the system, and label it, before attempting service.

The modern anesthesia machine will contain a purge button which serves as a bypass button, bypassing the mixing board, vaporizers and rotameters. This button allows for 100% oxygen to flow to the patient connection. It is used before a surgical case begins to clear out any residual gases from the patient connection. Additionally, it is used to provide a quick burst of oxygen to the waking patient (and reduce the level of anesthesia to the patient) as the case terminates.

Since the expired gases of the patient contain anesthetic agents, they must not be allowed to enter the operating room. In addition to potentially placing the operating staff under the anesthetics effects, certain agents are flammable, and chronic exposure can cause high fevers and severe liver damage. To remove this danger, anesthesia machines will contain a scavenger (or scrubber or trap) before venting the expired gas into the room. In the developing world, the activated carbon may not be changed –or even available– forcing the staff to vent the expired gas outside.

In the expired air is to be rebreathed - that is, returned to the patient - then a CO2 absorber is used. A CO2 absorber contains a soda-lime filter that strips the expired gases of CO2.

This scavenging system shows the CO2 absorbing material (white material in glass container behind cage in lower left). Two valves are shown under the glass domes in the middle right.

Self-inflating bags or bellows are purely mechanical devices that allow the anesthetist to measure the patient's ventilation. By its movement in a calibrated chamber, a bellows indicates the volume of air that the patient is breathing. The bellows will rise when the patient exhales and will fall when the patient inhales.

The bellows may be connected to a ventilator that controls the patient's ventilation. The ventilator forces air into the patient's lungs at a prescribed rate and volume. Ventilators are covered elsewhere in this text. When intermittent ventilation is required, the doctor can use a bag (emergency bag), or reservoir bag. The bag allows the doctor to manually push air into the patient's lungs. This bag is also used to give the anesthetist a sense of the patient's lung compliance and resistance, which can be used to indicate that more or less anesthetic agents are needed or that the physiology of the lungs is changing.

The Circuit

The circuit contains tubing and valves required for the operation of the anesthesia machine. Both the bellows and self-inflating bag are filled through a non-return valve that ensures that the proper gases are always delivered to the patient. The circuit will also contain a non-rebreathing expiratory valve at the patient end that diverts inspired and expired gases through two different pathways. Often, these non-rebreathing valves are part of the circuit. The circuit includes the connection to the patient, the mask, endotracheal tube and other components.

Malkin, R. "Anesthesia Machines," From the publication: Medical Instruments in the Developing World. Engineering World Health, 2006.

While considered a disposable item, in the developing world, the circuit may not be replaced after every patient. Even in the developed world, there may be connections to and from the absorber that, while part of the circuit, are not replaced with each use. If the circuit is to be reused, after patient use, it is best to hang the tubing vertically to dry in a storage area.

Monitoring

The anesthesia machine may also have a monitor for the patient's ECG, invasive or non-invasive blood pressure, and pulse oximetry. More details about these monitors are available in their respective chapters.

Drawover Anesthesia

A drawover anesthesia system provides anesthesia without necessitating a supply of compressed gases. Drawover anesthesia systems have the added advantages of being (1) inexpensive to purchase, (2) easy to maintain, and (3) compact and portable. In using a drawover system, atmospheric air serves as the primary carrier gas and is drawn through the vaporizer by the patient's inspiratory effort. Whether a patient is being artificially ventilated or breathing spontaneously, the patient will draw air through the vaporizer. Therefore the vaporizer must have a low resistance to the intermittent gas flow. Once in the vaporizer, the atmospheric air mixes with the anesthetic agent which is typically ether or halothane. The patient now inhales this air via a non-rebreathing valve. Low-flow oxygen, such as from an oxygen concentrator, may be added to the drawover system by using a T-connector

General Anesthesia, Injectables

Injectable anesthesias are cheaper and therefore more common in the developing world than in the US. They are more dangerous as an overdose cannot be as easily reversed. These agents are combined with muscle relaxants and should be used only for short-term procedures. Ketamine is a very common general anesthetic agent, and lidocaine is a popular local anesthetic. No additional equipment is required to use these agents.

2.17.2 Common Problems

As with other pieces of medical equipment, power supply and user error problems account for most of the problems in anesthesia machines. Injectable anesthetics are not generally referred to the technician when there is a problem. Drawover machines have fewer problems than other anesthesia machines, but all machines suffer from with leaks and sticky valves.

Leaks

Tubes tend to deteriorate in hot and humid environments. Also, reusing disposable materials tends to favor deterioration. An expiration-side leak occurring before the scavenger is most critical to check, but also the easiest because anesthetic gases have a distinctive smell which is easily detected. If a leak occurs in the OR, doors to the room should be opened to allow air to flow through the room (consult with the staff before doing so). Moreover, a second danger with gas leaks is that some anesthetic gases are flammable. Halothane and ether are two explosive anesthetic gases.

The tubing most often develops leaks in between the corrugations. You can check for leaks by placing the tubing in a bucket of water, blocking one end, blowing in the other, and looking for bubbles to escape. Repair tubing leaks with epoxy or a silicon sealant. However, this is a temporary repair. It is better to replace the tubing. In some cases, the tubing can be shortened to remove the leaking section. Consult with the anesthetist before shortening a section of the circuit.

Other problems

The monitoring devices are covered in other sections of this book.

The needle valves controlling the flow into the rotameters can be sticky or blocked. Also, the floats in a rotameter can be stuck. Rotameters and needle valves can be dismounted and flushed alcohol. Make sure they are completely dry before using again. When taking apart multiple rotameters, floats and needle valves, be sure to put them back together in a set. The float from one gas may not work in the glass tube from another. One simple solution is to disassemble only one rotameter at a time.

If there are valves which appear to be sticky in the circuit, the circuit needs to be replaced. Other sticky valves may be cleaned with water and dried thoroughly before reuse.

If the problem is in the ventilator, CO2 absorber or vaporizer, and the problem is not a leak, the problem is typically very difficult to repair in the field. It is generally necessary to replace the entire subunit with one from another anesthesia machine.

2.17.3 Suggested Minimal Testing

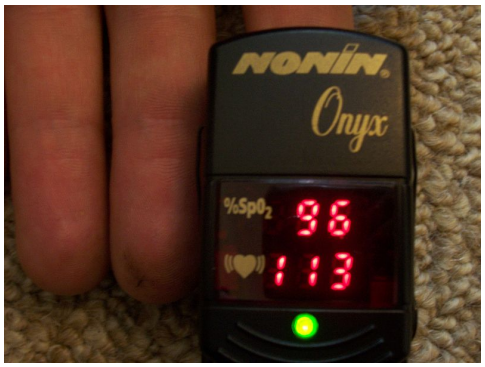
If the device has been removed from the operating room due a problem that you have now fixed, you should test it before returning it to use. However, most often you will not have the equipment required to test the function of a vaporizer, CO2 absorber or ventilator. As the surgical schedules may be severely affected or even halted until the anesthesia machine is working, it may not be in the hospitals patient population's best interests to wait until you have the proper testing equipment to release the anesthesia machine for use. If a repair resulted in a replacement of the vaporizer, absorber or ventilator, you will need to consult with the anesthetist on what testing will be required before use.

If the repair required the fixing of a leak, it is sufficient to retest the tubing to insure that the leak is repaired.

If the repair involved the rotameters, they should be checked before use, even if the problem was just a sticky valve or float. A simple way to check flow rates is to flow the gas into a calibrated balloon for 60 seconds. The volume can be approximated by connecting a balloon to the patient tubing. You must calibrate the balloon to volume before you begin. The easiest way to do this is to fill the balloon with a known volume of water. Make two marks on the balloon a fixed distance apart, indicating the volume next to the mark. Repeat this procedure for several volumes. Now, when the balloon expands to the indicated volume, the marks should be your set distance apart.

Malkin, R. "Anesthesia Machines," From the publication: Medical Instruments in the Developing World. Engineering World Health, 2006.

Pulse oximetry



Pulse Oximeter

Pulse oximetry (or **~ oxymetry** in the UK) is a non-invasive method allowing the monitoring of the oxygenation of a patient's hemoglobin.

A sensor is placed on a thin part of the patient's body, usually a fingertip or earlobe, or in the case of a neonate, across a foot, and a light containing both red and infrared wavelengths is passed from one side to the other. Changing absorbance of each of the two wavelengths is measured, allowing determination of the absorbances due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) fingernail polish.[1] Based upon the ratio of changing absorbance of the red and infrared light caused by the difference in color between oxygen-bound (bright red) and oxygen-unbound (dark red or blue, in severe cases) blood hemoglobin, a measure of oxygenation (the per cent of hemoglobin molecules bound with oxygen molecules) can be made.

Indication

Pulse oximetry data is necessary whenever a patient's oxygenation may be unstable, as in intensive care, critical care, and emergency department areas of a hospital. Data can also be obtained from pilots in unpressurized aircraft,[2] and for assessment of any patient's oxygenation in primary care. A patient's need for oxygen is essential to life; no human life thrives in the absence of oxygen (cellular or gross). Although pulse oximetry is used to monitor oxygenation, it cannot determine the metabolism of oxygen, or the amount of oxygen being used by a patient. For this purpose, it is necessary to also measure carbon dioxide (CO_2) levels. It is possible that pulse oximetry can also be used to detect abnormalities in ventilation. However, detection of hypoventilation is impaired by the use of supplemental oxygen, as it is only when patients breathe room air that abnormalities in respiratory function can be detected reliably. Therefore, the routine administration of supplemental oxygen may be unwarranted if the patient is able to maintain adequate oxygenation in room air, since it can result in hypoventilation going undetected.

History

In 1935 Matthes developed the first 2-wavelength ear O_2 saturation meter with red and green filters, later switched to red and infrared filters. This was the first device to measure O_2 saturation.

In 1949 Wood added a pressure capsule to squeeze blood out of ear to obtain zero setting in an effort to obtain absolute O_2 saturation value when blood was readmitted. The concept is similar to today's conventional pulse oximetry but was hard to implement because of unstable photocells and light sources. This method is not used clinically. In 1964 Shaw assembled the first absolute reading ear oximeter by using eight wavelengths of light. Commercialized by Hewlett Packard, its use was limited to pulmonary functions and sleep laboratories due to cost and size.

Pulse oximetry was developed in 1974, by Takuo Aoyagi and Michio Kishi, bioengineers, at Nihon Kohden using the ratio of red to infrared light absorption of pulsating components at the measuring site. Susumu Nakajima, a surgeon, and his associates first tested the device in patients, reporting it in 1975.[3] It was commercialized by Biox in 1981 and Nellcor in 1983. Biox was founded in 1979, and introduced the first pulse oximeter to commercial distribution in 1981. Biox initially focused on respiratory care, but when the company discovered that their pulse oximeters were being used in operating rooms to monitor oxygen levels, Biox expanded its marketing resources to

focus on operating rooms in late 1982. A competitor, Nellcor (now part of Covidien, Ltd.), began to compete with Biox for the US operating room market in 1983. Prior to its introduction, a patient's oxygenation could only be determined by arterial blood gas, a single-point measurement that takes a few minutes of processing by a laboratory. (In the absence of oxygenation, damage to the brain starts within 5 minutes with brain death ensuing within another 10–15 minutes). In the US alone, approximately $2 billion was spent annually on this measurement. With the introduction of pulse oximetry, a non-invasive, continuous measure of patient's oxygenation was possible, revolutionizing the practice of anesthesia and greatly improving patient safety. Prior to its introduction, studies in anesthesia journals estimated US patient mortality as a consequence of undetected hypoxemia at 2,000 to 10,000 deaths per year, with no known estimate of patient morbidity.

By 1987, the standard of care for the administration of a general anesthetic in the US included pulse oximetry. From the operating room, the use of pulse oximetry rapidly spread throughout the hospital, first to the recovery room, and then into the various intensive care units. Pulse oximetry was of particular value in the neonatal unit where the patients do not thrive with inadequate oxygenation, but also can be blinded with too much oxygen. Furthermore, obtaining an arterial blood gas from a neonatal patient is extremely difficult.

By 2008, the accuracy and capability of pulse oximetry had further improved, and had allowed for the adoption of the term high resolution pulse oximetry (HRPO).[4] [5] [6] One area of particular interest is the use of pulse oximetry in conducting portable and in-home sleep apnea screening and testing.[4] [7]

In 2009, the world's first Bluetooth-enabled fingertip pulse oximeter was introduced by Nonin Medical, enabling clinicians to remotely monitor patients' pulses and oxygen saturation levels. It also allows patients to monitor their own health through online patient health records and home telemedicine system.[8]

Limitations

Pulse oximetry measures solely of oxygenation, not ventilation, and it is not a substitute for blood gases checked in a laboratory because it gives no indication of base deficit, carbon dioxide levels, blood pH, or bicarbonate HCO3- concentration. The metabolism of oxygen can be readily measured by monitoring expired CO_2. Saturation figures also give no information about blood oxygen content. Most of the oxygen in the blood is carried by hemoglobin. In severe anemia, the blood will carry less total oxygen, despite the hemoglobin being 100% saturated.

Falsely low readings may be caused by hypoperfusion of the extremity being used for monitoring (often due to the part being cold or from vasoconstriction secondary to the use of vasopressor agents); incorrect sensor application; highly calloused skin; and movement (such as shivering), especially during hypoperfusion. To ensure accuracy, the sensor should return a steady pulse and/or pulse waveform. Falsely high or falsely low readings will occur when hemoglobin is bound to something other than oxygen. In cases of carbon monoxide poisoning, the falsely high reading may delay the recognition of hypoxemia (low blood oxygen level). Methemoglobinemia characteristically causes pulse oximetry readings in the mid-80s. Cyanide poisoning can also give a high reading because it reduces oxygen extraction from arterial blood (the reading is not false, as arterial blood oxygen is indeed high in early cyanide poisoning).

Pulse oximetry only reads the percentage of bound hemoglobin. Hemoglobin can be bound to other gases such as carbon monoxide and still read high even though the patient is hypoxemic. The only noninvasive methodology that allows for the continuous and noninvasive measurement of the dyshemoglobins is a pulse co-oximeter. Pulse co-oximetry was invented in 2005 by Masimo and currently allows clinicians to measure total hemoglobin levels in addition to carboxyhemoglobin, methemoglobin and PVI, which initial clinical studies have shown may provide clinicians with a new method for noninvasive and automatic assessment of patient fluid volume status.[9] [10] [11] Appropriate fluid levels are vital to reducing postoperative risks and improving patient outcomes as fluid volumes that are too low (under hydration) or too high (over hydration) have been shown to decrease wound healing, increase risk of infection and cardiac complications.[12]

See also

- Oxygen sensor
- Oxygen saturation
- Pulse oximeter
- Capnography, measuring of carbon dioxide (CO_2) in the respiratory gases
- Sleep Apnea
- Integrated Pulmonary Index

External links

- iPleth: Pulse oximetry on a cell phone for the developing world [13]

References

[1] Brand TM, Brand ME, Jay GD. Enamel nail polish does not interfere with pulse oximetry among normoxic volunteers (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=pubmed&list_uids=12212998) *J Clin Monit Comput.* 2002 Feb;17(2):93-6.

[2] WAGNER Jessica L. ; RUSKIN Keith J. Pulse oximetry : Basic principles and applications in aerospace medicine. Aviation, space, and environmental medicine 2007, vol. 78, no10, pp. 973-978

[3] John W. Severinghaus, MD,and Yoshiyuki Honda, MD: *HISTORY OF BLOOD GAS ANALYSIS. VII. PULSE OXIMETRY* "History of Pulse Oximetry" (http://www.masimo.com/Nellcorfiction/PDF_FF/History of Pulse Oximetry.pdf)

[4] http://www.sleepreviewmag.com/issues/articles/2008-04_10.asp

[5] http://www.maxtecinc.com/assets/docs/pulsox/ml187.p300iDataSheet.pdf

[6] http://www.anesthesiology.org/pt/re/anes/fulltext.00000542-200809000-00004.htm

[7] http://www.post-gazette.com/pg/08009/847751-114.stm

[8] "Tekne Awards Announced" (http://www.startribune.com/blogs/65775732.html?elr=KArks7PYDiaK7DUdcOy_nc:DKUiD3aPc:_Yyc:aUU). *Star Tribune*. . Retrieved 2009-10-23.

[9] Keller G, Cassar E, Desebbe O, Lehot JJ, Cannesson M (2008). "Ability of pleth variability index to detect hemodynamic changes induced by passive leg raising in spontaneously breathing volunteers" (http://www.pubmedcentral.nih.gov/articlerender.fcgi?tool=pmcentrez&artid=2447559). *Crit Care* **12** (2): R37. doi:10.1186/cc6822. PMID 18325089. PMC 2447559.

[10] Cannesson M, Delannoy B, Morand A, *et al.* (April 2008). "Does the Pleth variability index indicate the respiratory-induced variation in the plethysmogram and arterial pressure waveforms?". *Anesth. Analg.* **106** (4): 1189–94, table of contents. doi:10.1213/ane.0b013e318167ab1f. PMID 18349191.

[11] Cannesson M, Desebbe O, Rosamel P, *et al.* (August 2008). "Pleth variability index to monitor the respiratory variations in the pulse oximeter plethysmographic waveform amplitude and predict fluid responsiveness in the operating theatre". *Br J Anaesth* **101** (2): 200–6. doi:10.1093/bja/aen133. PMID 18522935.

[12] Ishii M, Ohno K (March 1977). "Comparisons of body fluid volumes, plasma renin activity, hemodynamics and pressor responsiveness between juvenile and aged patients with essential hypertension". *Jpn. Circ. J.* **41** (3): 237–46. PMID 870721.

[13] http://ecem.ece.ubc.ca/research.htm#iPleth

Article Sources and Contributors

Pulse oximetry *Source*: http://en.wikipedia.org/w/index.php?oldid=358741130 *Contributors*: Academic Challenger, Almazi, Apollo the Archer, Ariel., Beelaj., Bemoeial, Chewkoh, Choij, Clannum, CoyneT, Curps, Dana boomer, Darkwolf325, Davidruben, Dforester, Dkazdan, Doctortomwiki, Draeco, DreamsReign, DuLithgow, ESkog, Elkman, Everyking, Folajimi, FrancoGG, GK tramrunner, Hu12, Inoculatedcities, IronLung2533, Jaksmata, Jengod, Jfdwolff, Jgoldman, Joe Brigen, JoeBrigen, Karensams, Kbdank71, Kintetsubuffalo, Lukobe, M.clare.smith, Mccallusa, Medicaltechwriter, Moxy, Mr Bungle, NellcorPro, Nono64, Orangemarlin, Piano non troppo, ProspectHCH, Rdarwin, Rettetast, Rich Farmbrough, Rjwilmsi, Rsabbatini, SarekOfVulcan, Scientificone, Smuseby, TaintedMustard, Ujalm, VEA Tim, VanGore, WhatamIdoing, Wiki Jibiki, WikiScience1, Wormholio, 84 anonymous edits

Image Sources, Licenses and Contributors

File:Pulse oxi.JPG *Source*: http://en.wikipedia.org/w/index.php?title=File:Pulse_oxi.JPG *License*: GNU Free Documentation License *Contributors*: Tom Mallinson

License

2. Diagrams and Schematics of Anesthesia Machines

Featured in this Section:

Chan, A. *Biomedical Device Technology: Principles and Design*. Charles C. Thomas Publisher: USA (2008).

Subrahmanyam, M. and Mohan, S. "Safety Features in Anesthesia Machine." *Indian Journal of Anesthesia*, Vol. 57, No. 5 (2013), p. 472-480.

WHO. "Anaesthesia Ventilator." From the publication: "WHO Technical Specifications for 61 Medical Devices. *WHO*. Retrieved from: http://www.who.int/medical_devices/management_use/mde_tech_spec/en/

Figure 1: Components of a Gas Supply and Control Subsystem

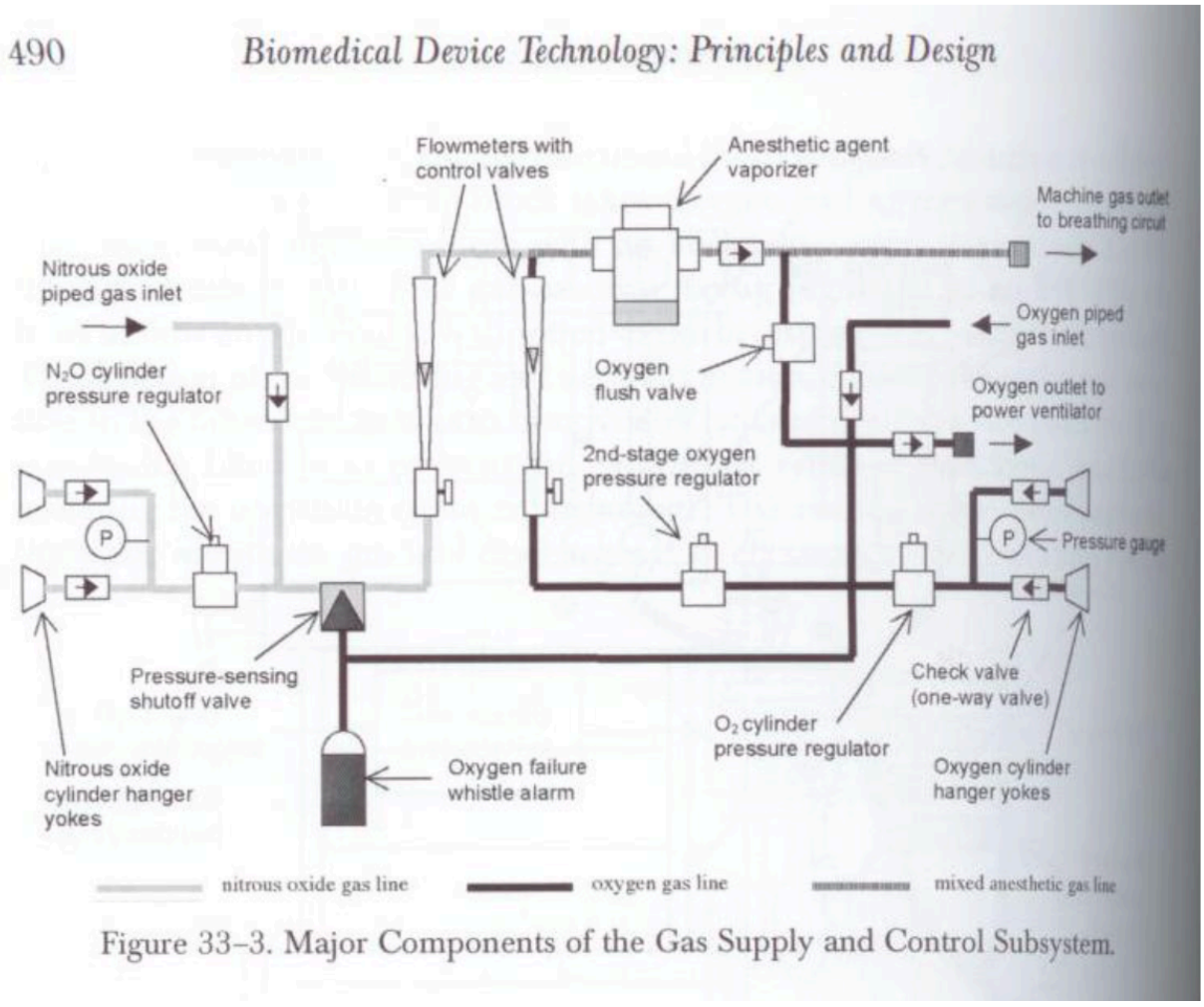
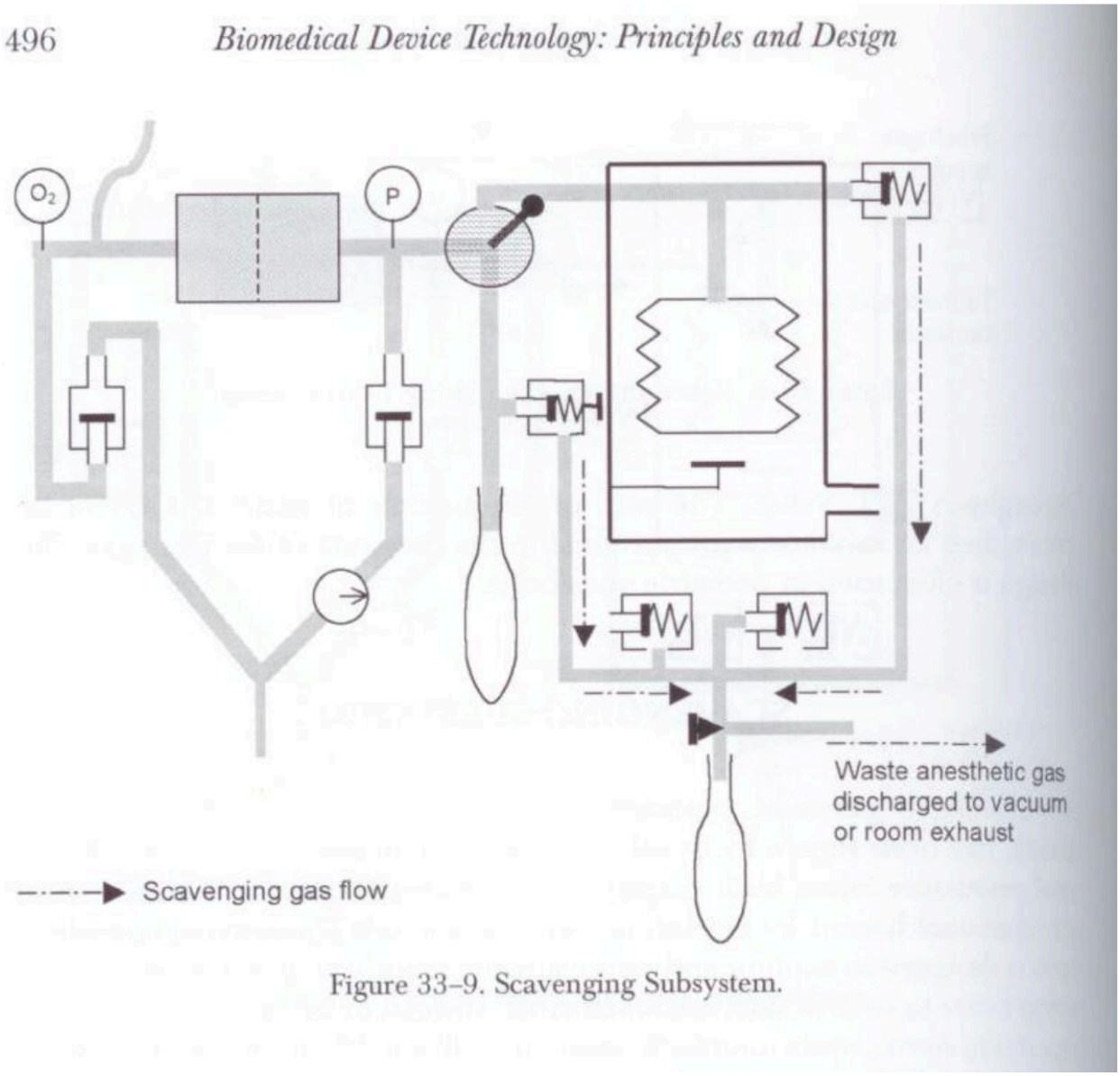


Figure 33–3. Major Components of the Gas Supply and Control Subsystem.

Chan, A. Biomedical Device Technology: Principles and Design. Charles C. Thomas Publisher: USA (2008).

Figure 2: Scavenging Subsystem



Chan, A. Biomedical Device Technology: Principles and Design. Charles C. Thomas Publisher: USA (2008).

Figure 3: Patient Ventilation and Scavenging Systems

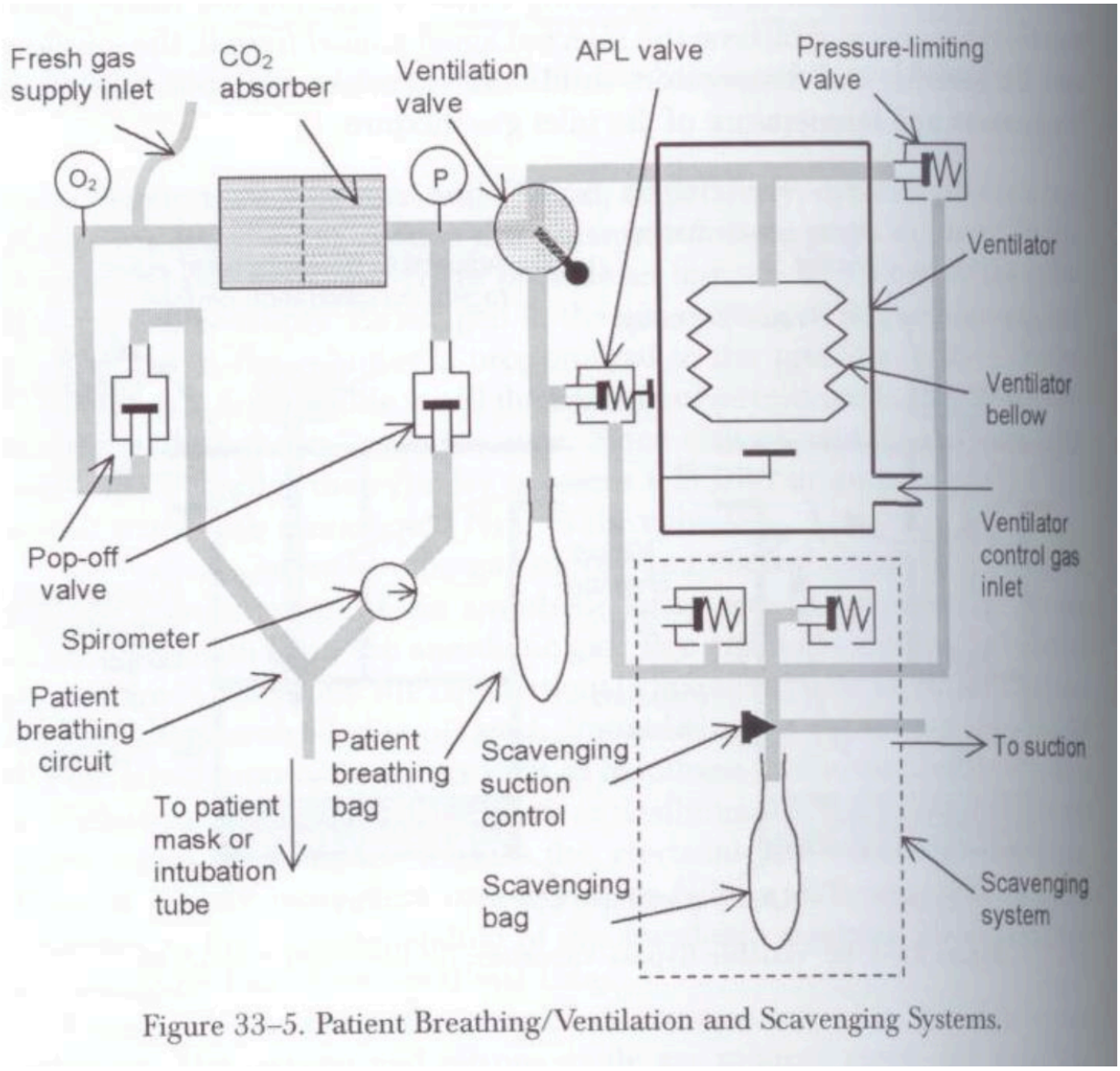


Figure 33–5. Patient Breathing/Ventilation and Scavenging Systems.

Chan, A. Biomedical Device Technology: Principles and Design. Charles C. Thomas Publisher: USA (2008).

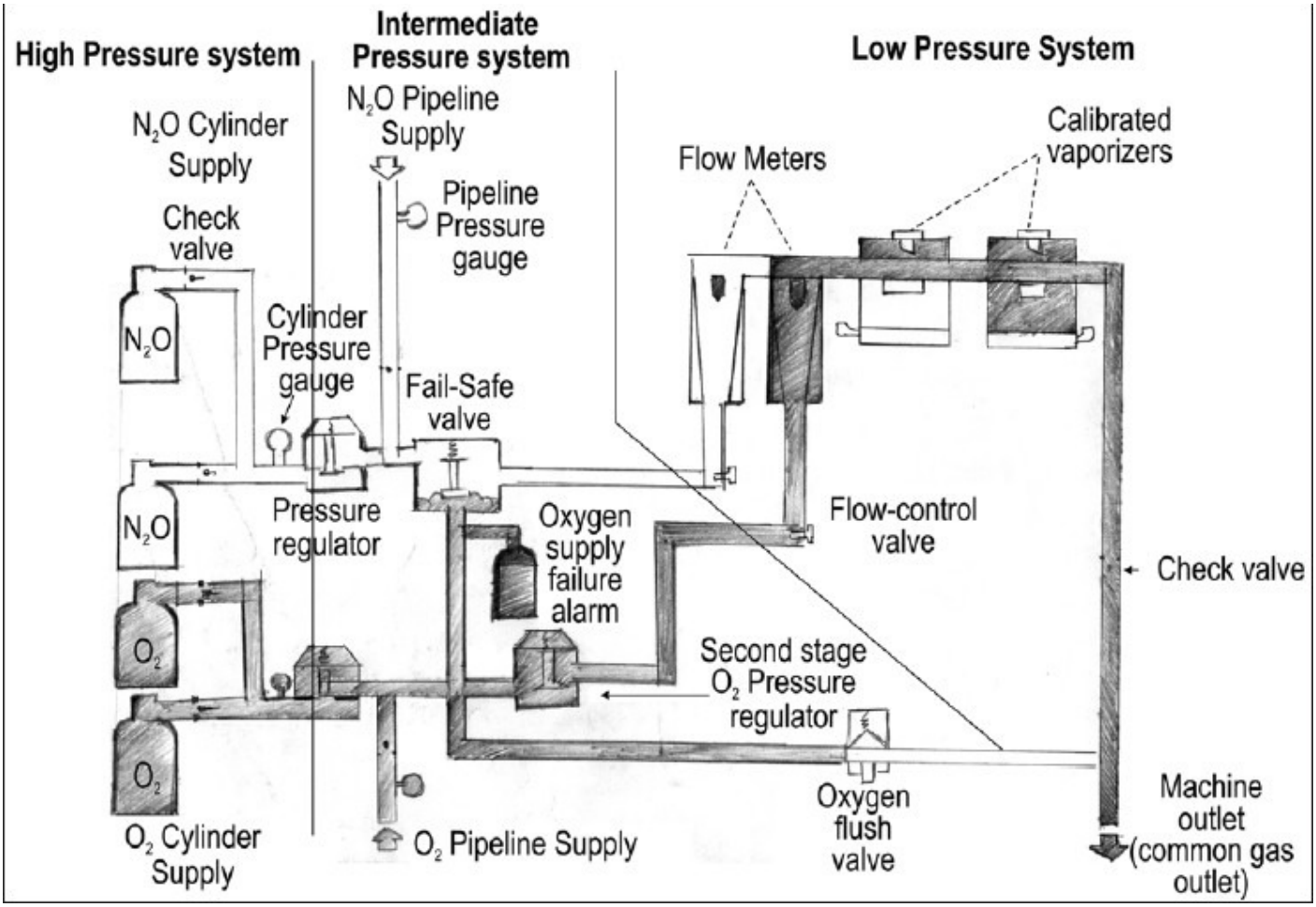
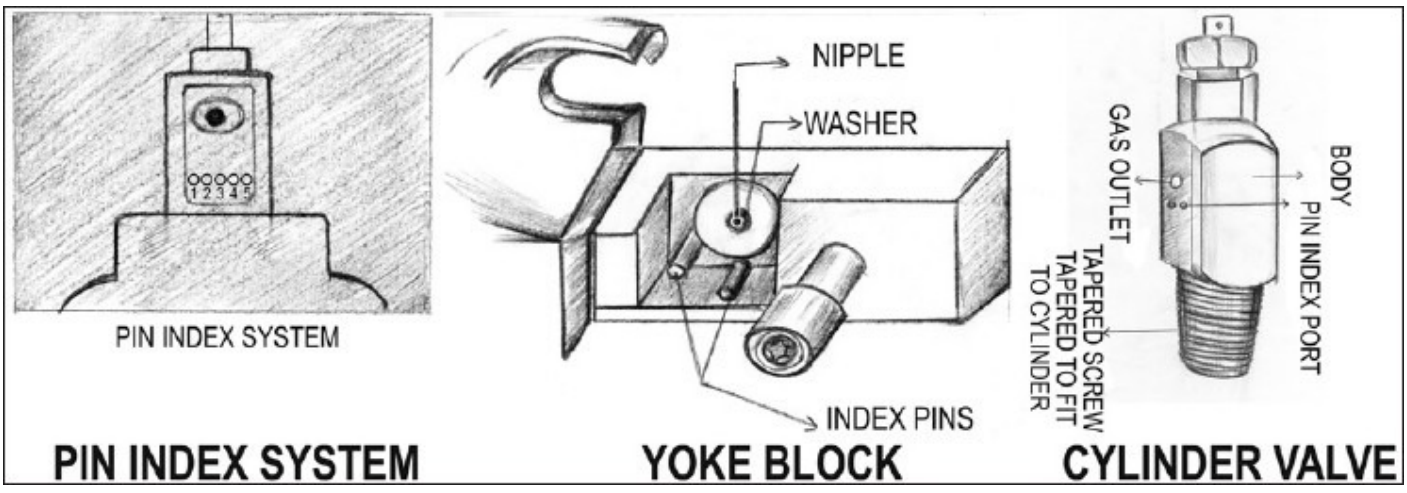


Figure 4: Anesthesia Machine Overview

The high, intermediate and low-pressure systems of the anaesthesia machine

Figure 2



The pin index system and its components

Figure 3

Figure 5: Pin Index System

Subrahmanyam, M. and Mohan, S. "Safety Features in Anesthesia Machine." Indian Journal of Anesthesia, Vol. 57, No. 5 (2013), p. 472-480.

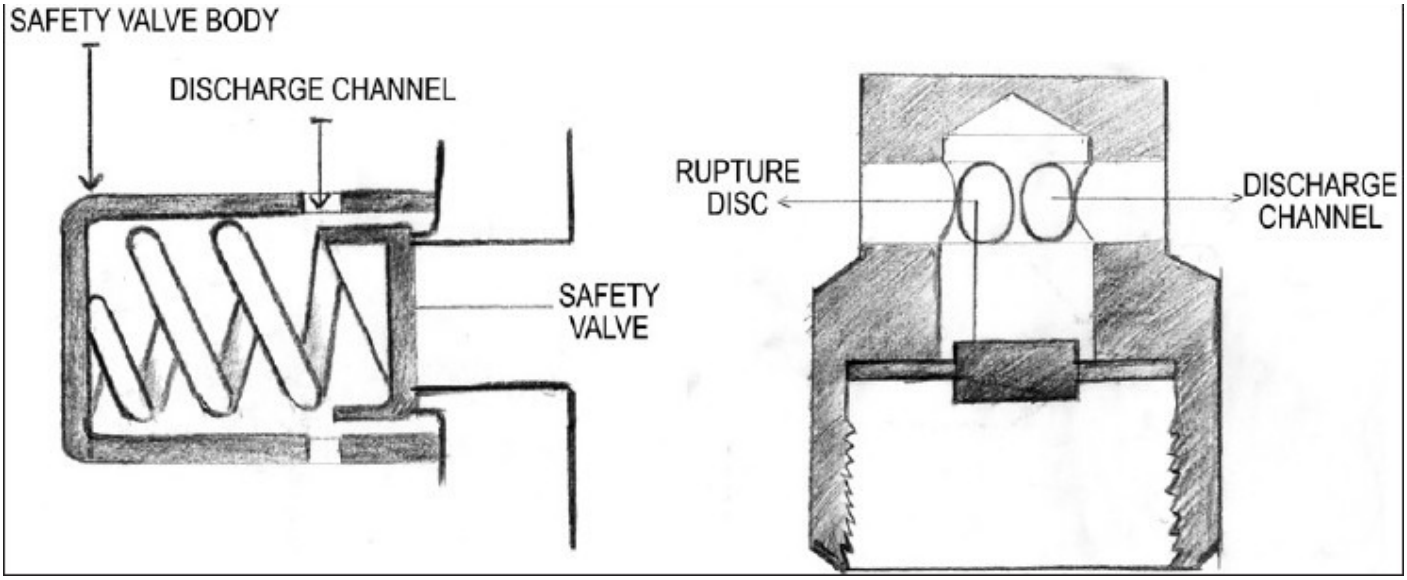
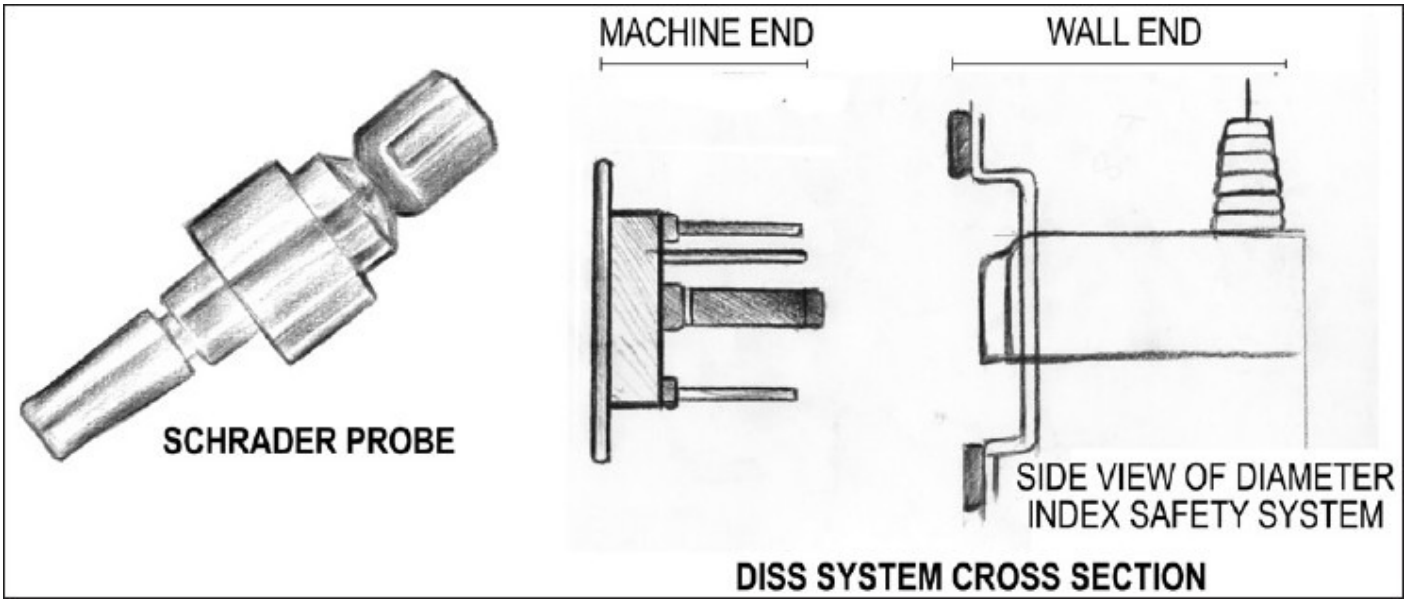


Figure 6: Safety Valves

Safety valves

Figure 4



Different connectors and their safety mechanisms

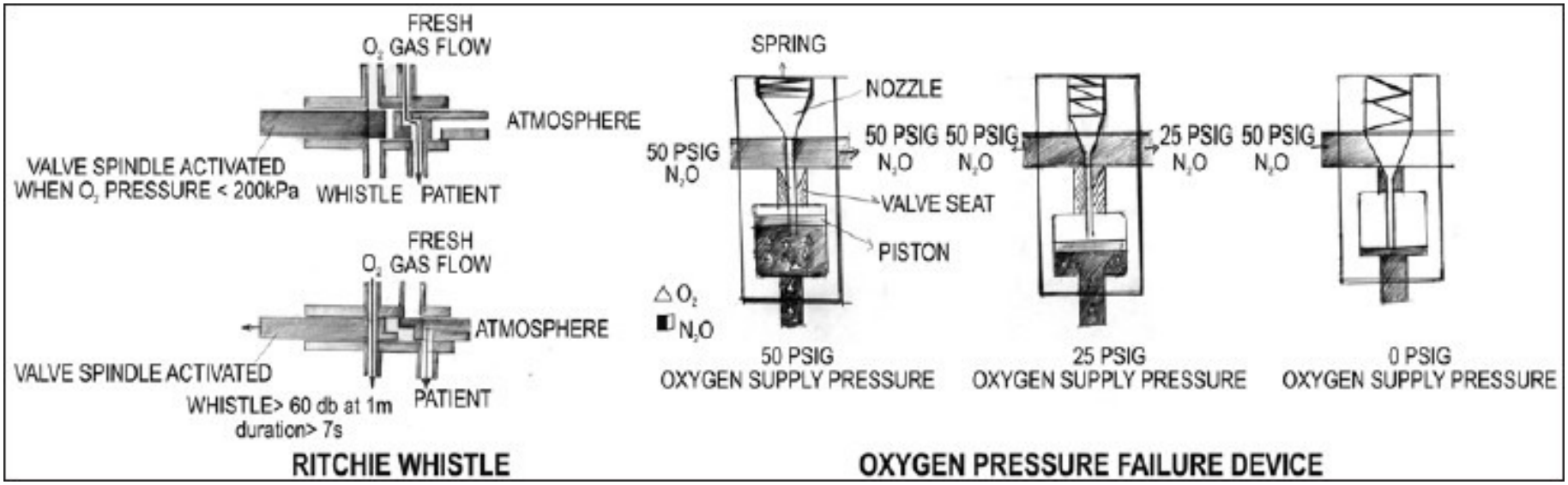
Figure 5

Figure 7: Connectors and Their Safety Mechanisms

Subrahmanyam, M. and Mohan, S. "Safety Features in Anesthesia Machine." Indian Journal of Anesthesia, Vol. 57, No. 5 (2013), p. 472-480.

Figure 6

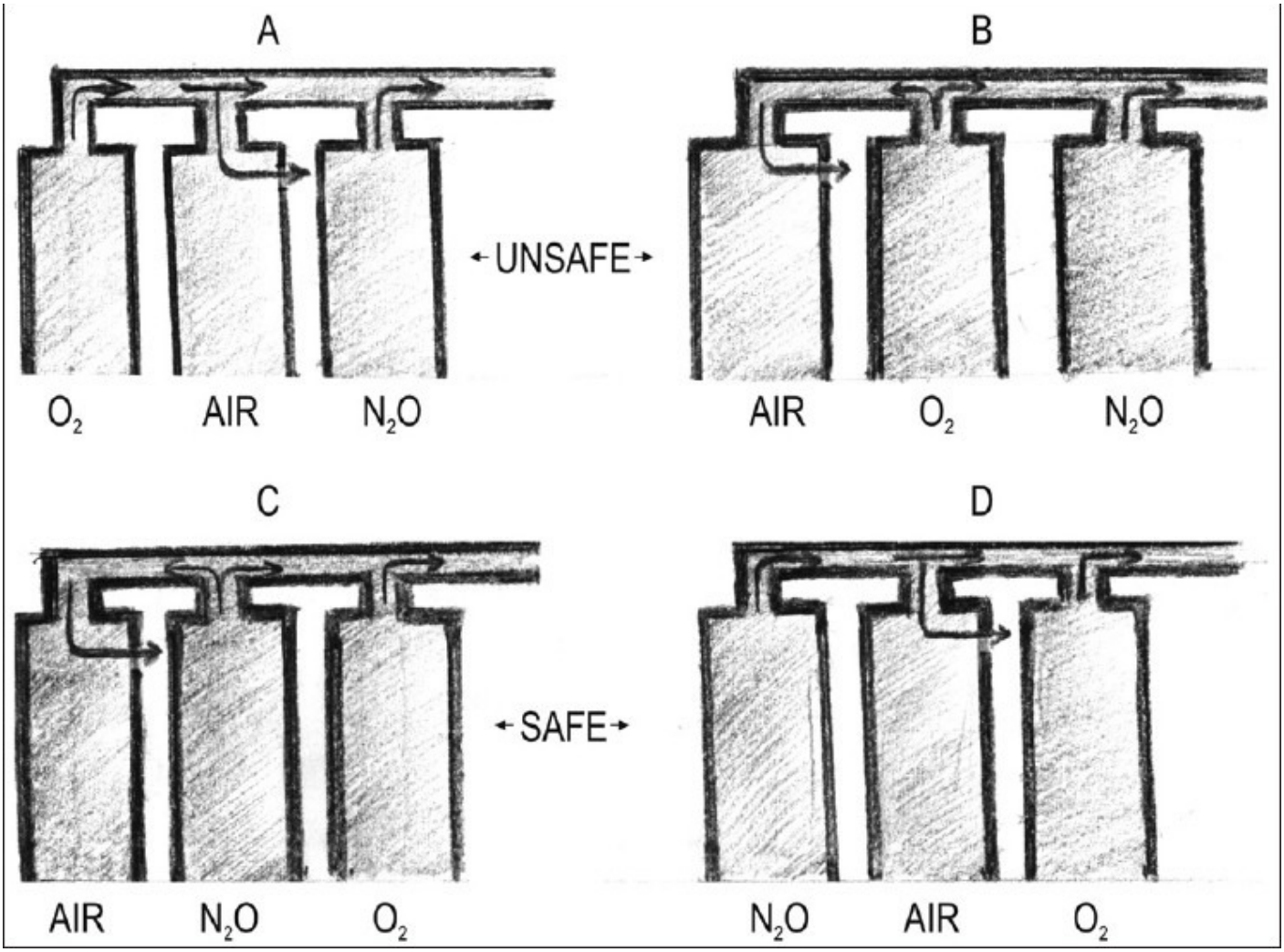
Figure 8: Oxygen Failure Warning Devices



Oxygen failure warning devices

Figure 7

Subrahmanyam, M. and Mohan, S. "Safety Features in Anesthesia Machine." Indian Journal of Anesthesia, Vol. 57, No. 5 (2013), p. 472-480.



Potential unsafe and safe arrangements of flow meter tubes

Figure 8

Figure 9: Safe and Unsafe Flow Meter Tubes

Subrahmanyam, M. and Mohan, S. "Safety Features in Anesthesia Machine." Indian Journal of Anesthesia, Vol. 57, No. 5 (2013), p. 472-480.

Figure 10: WHO Specification for Anesthesia Ventilators

MEDICAL DEVICE SPECIFICATION *(Including information on the following where relevant/appropriate, but not limited to)*		
i	Version No.	1
ii	Date of initial version	6/13/12
iii	Date of last modification	6/18/14
iv	Date of publication	
v	Done by	WHO working group
NAME, CATEGORY AND CODING		
1	*WHO Category / Code*	(under development)
2	Generic name	Anaesthesia ventilator
3	Specific type or variation (optional)	Alone or as a part of anesthesia machine
4	GMDN name	Anaesthesia ventilator
5	GMDN code	34851
6	GMDN category	02 Anaesthetic and respiratory devices
7	UMDNS name	Ventilators, Anesthesia
8	UMDNS code	10145
9	UNSPS code (optional)	
10	Alternative name/s (optional)	Ventilator; Anaesthesia unit ventilator; Anesthesia ventilator
11	Alternative code/s (optional)	MS 42251; S 10145; S 36325
12	Keywords (optional)	Anesthesia machines, Anesthesia Units, Acute Care, Respired/Anesthetic
13	GMDN/UMDNS definition (optional)	A mains electricity (AC-powered) stand-alone, automatic cycling device used to assist and control alveolar ventilation during general anaesthesia, and is compatible with inhaled anaesthetic agents. It has fewer functions and is less complex to operate than an intensive care ventilator, but adequately meets the patient's ventilation needs for oxygen (O2) and carbon dioxide (CO2) exchange to maintain normal blood gas concentrations. The device provides a mechanical means to deliver the breathing gas to the patient in a controlled pattern, and is equipped with alarms to warn of changes in respiration or the onset of unsafe operating conditions.
PURPOSE OF USE		
14	Clinical or other purpose	Provides a mechanical means to deliver the breathing gas to the patient in a controlled pattern, and is equipped with alarms to warn of changes in respiration or the onset of unsafe operating conditions. Ventilators designed to use positive pressure to deliver a prescribed mixture of respiratory and anesthetic gases and vapors to the patient's lungs during surgical procedures that require general anesthesia
15	Level of use (if relevant)	District Hospital, Provincial Hospital, Specialized Hospital, General Hospital
16	Clinical department/ward(if relevant)	Surgery (Operating theatre, Operating room)
17	Overview of functional requirements	Dispenses a controlled mixture of anaesthetic agents (externally supplied), oxygen and air to the patient, gives artificial respiratory support as necessary, fully alarmed with all necessary monitors for continuous operation in operating theatre environment, includes compressor, nebulizer and humidifier, reusable, sterilizable patient masks and connectors, suitable for all ages and body weights of patient, provides port for linkage with ********** anaesthetic delivery system.
TECHNICAL CHARACTERISTICS		

WHO. "Anaesthesia Ventilator." From the publication: "WHO Technical Specifications for 61 Medical Devices. WHO. Retrieved from: http://www.who.int/medical_devices/management_use/mde_tech_spec/en/

18	Detailed requirements	The unit must be able to measure O2 concentration, airway pressure, and the volume of expired gas. Trend display facility for at least the last 8 hours, with minimum 5 minutes resolution Automatic compliance and leakage compensation for circuit and tubes. Closed circuit system with possibility to work in open circuit. Externally supplied anaesthetic gas, oxygen and air mixture ratios fully controllable (mixing system selector for Air-O2 and N2O-O2 gasses mixture management) Expiratory block should be autoclavable and no routine calibration required. Should have the ability to calculate intrinsic PEEP Volume, occlusion pressure and inflection points. Circle breathing circuit to be included, with CO2 absorption chamber Nebuliser to deliver particle size of < 3 micron and to be used in both offline and online modes. Automatic patient detection facility preferable. Minimum oxygen enrichment not lower than 25%. Inlet gas supply (O_2 / N_2O) pressure range at least 35 to 65 psi. Gas supply gauges required, with scales allowing easy reading. Gasses pressure system continuous control with accuracy of at least +/- 10%. At least four analog rotameters (two for oxygen, one for air and one for N2O) with programmed parameters visualization. Digital rotameters are not accepted. Rotameters flow rate range not smaller than 0.0 to 10.0 l/min and resolution at least of 0.2 l/min. Minute volume 2 to 25 L/minute. Tidal volume 20 to 1500ml. Respiratory rate 5 to 70 cycles/minute. Respiratory rate 5 to 70 cycles/minute. I/E ratio 2/1 to 1/4. Inspiration pressure 0 to 80mbar. Peak inspiratory flow 0 to 60 L/minute. Trigger sensitivity 0 to 20mbar. At least the following safety systems: a) oxygen-N2O gasses mixture guaranteed with not less than 25% of Oxygen; b) oxygen leakage or low pressure alarm with simultaneous stop of N2O gas delivery; c) adjustable Pressure Limiting (APL) valve to prevent from too high pressure gas delivering; d) compressed Air leakage or low pressure alarm with automatic passage of the units using air to the oxygen alimentation; e) system safety measure to prevent from the Air and N2O simultaneous delivery. Units should have a power-loss alarm, and the battery backup should have an automatic low-battery alarm. All units should include a backup battery to guard against power loss.
19	Displayed parameters	Facility to measure and display on screen: a) 3 traces against time: pressure, volume and flow b) 3 two-axis displays: Pressure-Volume, Flow-Volume and Pressure-Flow c) Status indicators for ventilator mode, battery life, patient data, alarm settings, clock etc. d) Airway pressure (Peak and Mean). e) Tidal volume (Inspired and Expired). f) Minute volume (Inspired and Expired). g) I:E ratio h) inspiration and expiration times i) Spontaneous Minute Volume j) Respiratory rate (spontaneous and mechanical) k) Total Frequency. l) Oxygen concentration m) End tidal CO2 with capnography n) FiO2 dynamic. o) Intrinsic PEEP and PEEPi Volume. p) Plateau Pressure. q) Resistance and Compliance. r) Blood pressure
20	User adjustable settings	Units should have a power-loss alarm, and the battery backup should have an automatic low-battery alarm Alarms for all measured and monitored parameters, including circuit disconnection and gas failure.
PHYSICAL/CHEMICAL CHARACTERISTICS		
21	Components(if relevant)	External anaesthetic gas supply connection to be secure but easy to fit and release Movable arm holder for supporting patient breathing circuit Whole unit to be mounted on wheeled base, with brakes when in use Screen to be mounted flexibly to enable easy, ergonomic viewing If O2 / N2O supplied by bottle, holders for bottles to include secure locking mechanism If O2 / N2O supplied by bottle, bottles to have ******** type connector
22	Mobility, portability(if relevant)	
23	Raw Materials(if relevant)	
UTILITY REQUIREMENTS		
24	Electrical, water and/or gas supply (if relevant)	Electrical source requirements: Amperage:_____; Voltage:_____. Power input to be ********** fitted with ********** compatible mains plug. Voltage corrector / stabilizer to allow operation at ± 30% of local rated voltage. Resettable overcurrent breaker required on both live and neutral supply lines. Voltage corrector / stabilizer to allow operation at ± 30% of local rated voltage. An internal battery capable of powering the unit for at least 30 minutes. Compliance with ____ electrical standards and regulations.

ACCESSORIES, CONSUMABLES, SPARE PARTS, OTHER COMPONENTS		
25	Accessories (if relevant)	Breathing circuits (two sets) Reusable masks (two sets each of small, medium and large), textured for easy fit. Filters sufficient for 100 patients' use Rechargeable batteries with: a) autonomy of at least 1 hours; b) visual alarm in case of low battery; c) automatic passage from line alimentation to battery operating modes; d) system integrated battery charger.
26	Sterilization process for accessories (if relevant)	
27	Consumables / reagents (if relevant)	
28	Spare parts (if relevant)	Medical units select them according to their needs, ensuring compatibility with the brand and model of the equipment. 1 reusable ECG sensors and connectors set. 1 reusable adult and or pediatric oxygen saturation sensor and connector set. 1 reusable adult and or pediatric invasive pressure transducer and connector set. 1 reusable adult and or pediatric non-invasive pressure transducer and connector set. 1 rectal temperature transducer and connector set. 1 adult and or pediatric cardiac output connector set. 1 CO2 sensor.
29	Other components (if relevant)	Some anesthesia units require stand-alone physiologic monitors (modular approach) and/or anesthetic agent monitors, while others have integrated monitors (preconfigured approach)
PACKAGING		
30	Sterility status on delivery (if relevant)	N/A
31	Shelf life (if relevant)	N/A
32	Transportation and storage (if relevant)	N/A
33	Labelling (if relevant)	N/A
ENVIRONMENTAL REQUIREMENTS		
34	Context-dependent requirements	Capable of being stored continuously in ambient temperature of 0 to 50 deg C and relative humidity of 15 to 90%. Capable of operating continuously in ambient temperature of 10 to 40 deg C and relative humidity of 15 to 90%.
TRAINING, INSTALLATION AND UTILISATION		
35	Pre-installation requirements(if relevant)	
36	Requirements for commissioning (if relevant)	
37	Training of user/s (if relevant)	Training of users in operation and basic maintenance shall be provided Advanced maintenance tasks required shall be documented Supplier to perform installation, safety and operation checks before handover Local clinical staff to affirm completion of installation.
38	User care(if relevant)	Casing to be splash proof and cleanable with alcohol or chlorine wipes
WARRANTY AND MAINTENANCE		
39	Warranty	Two year warranty should be provided by the supplier
40	Maintenance tasks	Advanced maintenance tasks required shall be documented
41	Type of service contract	Service contract is recommended in case no in-house service experience is avialable to ensure that preventive maintenance will be performed at regular intervals. Pricing for service contracts should be negotiated before the system is purchased.
42	Spare parts availability post-warranty	
43	Software / Hardware upgrade availability	Routine software updates should be provided
DOCUMENTATION		
44	Documentation requirements	User, technical and maintenance manuals to be supplied in ********** language Certificate of calibration and inspection to be provided List to be provided of equipment and procedures required for local calibration and routine maintenance List to be provided of important spares and accessories, with their part numbers and cost Contact details of manufacturer, supplier and local service agent to be provided

DECOMMISSIONING		
45	Estimated Life Span	8 to 10 Years
SAFETY AND STANDARDS		
46	Risk Classification	Class C (GHTF Rule 11-1); Class II (USA); Class III (EU, Japan, Canada and Australia)
47	Regulatory Approval / Certification	
48	International standards	ISO 13485:2003 Medical devices -- Quality management systems -- Requirements for regulatory purposes (Australia, Canada and EU) ISO 14971:2007 Medical devices -- Application of risk management to medical devices IEC 60601-1:2012 Medical electrical equipment - Part 1: General requirements for basic safety and essential performance IEC 60601-1-1:2000 Medical electrical equipment - Part 1-1: General requirements for safety - Collateral standard: Safety requirements for medical electrical systems IEC 60601-1-2:2007 Medical electrical equipment - Part 1-2: General requirements for basic safety and essential performance - Collateral standard: Electromagnetic compatibility - Requirements and tests ISO 4135:2001 Anaesthetic and respiratory equipment -- Vocabulary ISO 5356-1:2004 Anaesthetic and respiratory equipment -- Conical connectors -- Part 1: Cones and sockets ISO 5356-2:2012 Anaesthetic and respiratory equipment -- Conical connectors -- Part 2: Screw-threaded weight-bearing connectors ISO 5358:1992 Anaesthetic machines for use with humans ISO 5360:2012 Anaesthetic vaporizers -- Agent-specific filling systems ISO 5361:2012 Anaesthetic and respiratory equipment -- Tracheal tubes and connectors ISO 5362:2006 Anaesthetic reservoir bags ISO 5364:2008 Anaesthetic and respiratory equipment -- Oropharyngeal airways ISO 5366-1:2000 Anaesthetic and respiratory equipment -- Tracheostomy tubes -- Part 1: Tubes and connectors for use in adults SO 5366-3:2001 Anaesthetic and respiratory equipment -- Tracheostomy tubes -- Part 3: Paediatric tracheostomy tubes ISO 5367:2000 Breathing tubes intended for use with anaesthetic apparatus and ventilators ISO 7376:2009 Anaesthetic and respiratory equipment -- Laryngoscopes for tracheal intubation ISO 7396-2:2007 Medical gas pipeline systems -- Part 2: Anaesthetic gas scavenging disposal systems ISO 8835-7:2011 Inhalational anaesthesia systems -- Part 7: Anaesthetic systems for use in areas with limited logistical supplies of electricity and anaesthetic gases ISO 9170-2:2008 Terminal units for medical gas pipeline systems -- Part 2: Terminal units for anaesthetic gas scavenging systems ISO 9360-1:2000 Anaesthetic and respiratory equipment -- Heat and moisture exchangers (HMEs) for humidifying respired gases in humans -- Part 1: HMEs for use with minimum tidal volumes of 250 ml
48	International standards	ISO 9360-2:2001 Anaesthetic and respiratory equipment -- Heat and moisture exchangers (HMEs) for humidifying respired gases in humans -- Part 2: HMEs for use with tracheostomized patients having minimum tidal volumes of 250 ml ISO 11197:2004 Medical supply units ISO 11712:2009 Anaesthetic and respiratory equipment -- Supralaryngeal airways and connectors ISO 15001:2010 Anaesthetic and respiratory equipment -- Compatibility with oxygen ISO 10524-1:2006 Pressure regulators for use with medical gases -- Part 1: Pressure regulators and pressure regulators with flow-metering devices ISO/TS 18835:2004 Inhalational anaesthesia systems -- Draw-over vaporizers and associated equipment ISO 21969:2009 High-pressure flexible connections for use with medical gas systems ISO 23328-1:2003 Breathing system filters for anaesthetic and respiratory use -- Part 1: Salt test method to assess filtration performance ISO 23328-2:2002 Breathing system filters for anaesthetic and respiratory use -- Part 2: Non-filtration aspects ISO 23747:2007 Anaesthetic and respiratory equipment -- Peak expiratory flow meters for the assessment of pulmonary function in spontaneously breathing humans ISO 26782:2009 Anaesthetic and respiratory equipment -- Spirometers intended for the measurement of time forced expired volumes in humans ISO 26825:2008 Anaesthetic and respiratory equipment -- User-applied labels for syringes containing drugs used during anaesthesia -- Colours, design and performance ISO 27427:2010 Anaesthetic and respiratory equipment -- Nebulizing systems and components ISO 80601-2-12:2011 Medical electrical equipment -- Part 2-12: Particular requirements for basic safety and essential performance of critical care ventilators ISO 80601-2-13:2011 Medical electrical equipment -- Part 2-13: Particular requirements for basic safety and essential performance of an anaesthetic workstation ISO 80601-2-55:2011 Medical electrical equipment -- Part 2-55: Particular requirements for the basic safety and essential performance of respiratory gas monitors

49	Reginal / Local Standards	ASTM F1101-90(1996) Standard Specification for Ventilators Intended for Use During Anesthesia ASTM F1208-89(2005) Standard Specification for Minimum Performance and Safety Requirements for Anesthesia Breathing Systems ASTM F1850-00(2005) Standard Specification for Particular Requirements for Anesthesia Workstations and Their Components ASTM F2002-01 Standard Terminology Relating to Anesthesia and Respiratory Equipment JIS T 7201-1:1999 Inhalational anaesthesia systems -- Part 1 Anaesthetic machines for use with humans JIS T 7201-2-1:1999 Inhalational anaesthesia systems -- Anaesthetic and respiratory equipment -- Conical connectors -- Part 2-1 Cones and sockets JIS T 7201-2-2:1999 Inhalational anaesthesia systems -- Anaesthetic and respiratory equipment -- Conical connectors -- Part 2-2: Screw-threaded weight-bearing connectors JIS T 7201-3:2005 Anaesthetic reservoir bags JIS T 7201-4:2005 Breathing tubes intended for use with anaesthetic apparatus and ventilators JIS T 7201-5:1999 Inhalational anaesthesia systems -- Part 5: Anaesthetic circle breathing systems JIS T 7211:2005 Breathing system filters for anaesthetic and respiratory use -- Part 1: Salt test method to assess filtration performance JIS T 7212:2005 Breathing system filters for anaesthetic and respiratory use -- Part 2: Non-filtration aspects
50	Regulations	**US regulations** 21 CFR part 820 21CFR section 868.5160 gas-machine, anesthesia **JP regulations** MHLW Ordinance No.169 34851000 Anaesthesia ventilator (Japan)

3. Preventative Maintenance and Safety of Anesthesia Machines

Featured in this Section:

Pescod, D. *Developing Anesthesia Textbook, Version 1.6.* (2007). Retrieved from: http://www.developinganaesthesia.org/developinganaesthesia-textbook.html

Strengthening Specialised Clinical Services in the Pacific. *User Care of Medical Equipment: A first line maintenance guide for end users*. (2015).

How to Check Anesthetic Equipment Before Use

15. CHECKING THE EQUIPMENT

It is the responsibility of the anaesthetist to check all anaesthetic equipment and drugs before giving an anaesthetic.

There must always be alternative equipment to ventilate the patient's lungs if the anaesthetic machine or oxygen supply fails. A self-inflating resuscitation bag does not need a source of oxygen. It should be available whenever an anaesthetic is given.

Airway Equipment

An alternative method of ventilating the patient must always be available.

Ideally the anaesthetist would have at least two laryngoscopes of different sizes. The light should be checked. Oropharyngeal (and nasopharyngeal) airways should be available in different sizes. A flexible stylet and gum elastic bougies are excellent aids for intubation. The anaesthetist should have several different sized masks and an appropriate sized endotracheal tube (plus one size smaller and one bigger) available. A laryngeal mask may be used as the airway or as an excellent alternative airway if endotracheal intubation is difficult (secondary plan). Emergency airway equipment (e.g. laryngeal masks, intubating laryngeal masks, percutaneous tracheostomy, fibreoptic laryngoscopes) should be kept together in a labelled container in a central area.

Suctioning

Suction equipment should be available. It consists of a pump to generate a vacuum, a reservoir and tubing. The reservoir must be large enough to hold the aspirated fluid but not too large. (The larger the reservoir the longer it will take to achieve a vacuum). The minimal flow rate should be 35 l/min of air and generate at least 600 mmHg (80 kPa) negative pressure.
Suction may be powered by electricity, compressed gas or by hand/foot.

Continuous Flow Anaesthetic Machine (Boyle's machine)

The anaesthetic machine can be considered in thee parts: **high pressure** (pipeline, cylinders, pressure gauges and regulators), **low pressure** (oxygen failure alarm, antihypoxic device, flowmeters, vaporisers, pressure release valve, and common gas outlet) and the **breathing system**.

Cylinders and Pipelines

Cylinder and pipeline gases are too highly pressurised (5,000 kPa to 14,000 kPa) for safe flow regulation. Regulators are used to decrease the pressure to a safe level. Pressurised gases must never be connected directly to the breathing system.
(1 atmosphere = 760 mmHG = 98 kPa = 14 psi. 1 psi =6.9 kPa).

Cylinders should be checked regularly for faults. Full and empty cylinders should be kept separately. Cylinders must be handled carefully. They are heavy and oxygen cylinders are a fire risk.
Different gases are supplied at different pressures. Oxygen is stored at 14,000 kPa. A standard D cylinder contains 400 litres, an E cylinder 680 litre and an F cylinder 1400 litres. The gauge pressure on an oxygen cylinder will decrease at a rate proportional to the amount of oxygen used. When half the contents of a cylinder are used, the gauge pressure will be half of the original pressure.

A second oxygen cylinder must always be available and checked.
Oxygen is available as "industrial" or "medical" grade. The same process is used to produce both grades of oxygen and it is safe to use "industrial" grade oxygen if "medical" grade oxygen is unavailable.

Nitrous oxide cylinders are filled with liquid nitrous oxide. The gauge pressure of a nitrous oxide cylinder will not change as the nitrous oxide is used until all the liquid is depleted. Once the gauge pressure of a nitrous oxide cylinder starts to fall the cylinder is nearly empty. A full C cylinder of nitrous oxide contains 450 litres, a D cylinder 900 litres, an E cylinder 1800 litres and an F cylinder 3600 litres.

In order to ensure that the correct cylinder is attached to the yoke of the anaesthetic machine a series of pins on the machine yoke is made to fit an identical pattern of indentations on the cylinder. This is a **pin-index system**.

Flow Meters

Gases from the cylinders and pipeline pass though **flow meters**. The flow meters are made for a specific gas. They are not interchangeable. Flow meters have a spindle valve in the base to control flow and a bobbin or a ball in a vertical tube. The bobbin should spin. After the gases pass though the flow meters the different gases are joined together. Oxygen is added last to reduce the chance of giving a hypoxic mixture. New anaesthetic machines link the flow of nitrous oxide to the flow of oxygen to prevent less than 25% oxygen being given (**anti-hypoxic device**). Anaesthetic machines without an anti-hypoxic device should have an **oxygen analyser**.

Oxygen Failure Alarm

The anaesthetic machine should have an oxygen failure warning device. An anaesthetist should not use an anaesthetic machine that does not have an oxygen failure warning device or a broken device. If there is no alternative the anaesthetist must check the oxygen gauge pressure every 5 minutes. The cylinder must be changed when the cylinder pressure is less than quarter full.
There are a variety of alarms. Older models depend on batteries to power a red light and nitrous oxide to power a whistle (Bosun oxygen failure alarm). The anaesthetist must check that the batteries are working. Other devices do not rely on batteries and will shut off the nitrous oxide. Some have a reserve supply of oxygen.

Vaporisers

A horizontal pipe (**back bar**) on the anaesthetic machine connects the flow meters to a **common gas outlet**. The breathing systems are connected to the common gas outlet. **Vaporisers** are usually mounted on the back bar. Some older vaporisers may be free-standing and are connected to the common gas outlet. The anaesthetist must check that the vaporisers are connected in the correct direction.
Vaporisers are made for a specific volatile anaesthetic agent. Filling a vaporiser with the incorrect volatile anaesthetic agent will produce the wrong concentration. Some vaporisers have a special filling system to ensure that they are filled with the correct agent. If a vaporiser does become contaminated with the incorrect agent it should be emptied, washed out several times with the correct agent and then blown though with oxygen or air until all smell has been eliminated.

On some anaesthetic machines it is possible to connect more than one vaporiser to the back bar. Newer anaesthetic machines have a mechanism to prevent more than one vaporiser being turned on at the same time. Turning more than one vaporiser on at the same time will produce dangerous concentrations of volatile anaesthetic gases.
The vaporisers made for the back bar are for use with compressed gas. They have a high internal resistance. They must not be used for drawover anaesthesia.

The anaesthetist must check that the vaporiser is filled with the correct agent, correctly fitted to the back bar and that it easily turns on and off. The vaporiser should be left in the off position. (A Boyle's bottle should have both the lever and the plunger pulled up. Check that filling ports are closed). Vaporisers must never be tilted or turned upside down. This will produce dangerous concentrations of the agent when it is turned on.

Oxygen Flush/Pressure Relief Valve

At the end of the back bar there may be an emergency oxygen flow button (**oxygen flush**) and a **pressure relief valve**. Anaesthetic machines should have an emergency high flow rate (20 to 35 litres/min) supply of oxygen that bypasses the flow meters and the vaporisers. The anaesthetist should check the oxygen flush by pressing the spring-loaded button. The pressure relief valve is located downstream from the flow meters and the vaporiser. It protects the anaesthetic machine and vaporisers from high pressures. It does not protect the patient.

Anesthesia Machine Safety Checklist

Checking the Anaesthetic Machine

- ☐ Always have an alternative resuscitation device (e.g. self-inflating bag).
- ☐ Check that cylinders are full and attached to the anaesthetic machine. There must always be a reserve supply of oxygen. Never use a machine if there is no reserve supply of oxygen.
- ☐ Turn off all cylinders.
- ☐ Turn on all flow meters. There should be no flow. Check the flow meters for cracks.
- ☐ Turn on the oxygen cylinder. There should only be flow in the oxygen flow meter. The bobbin should spin. Repeat with each oxygen cylinder. Set the oxygen flow to 4 litres/min.
- ☐ Turn on the nitrous oxide cylinder. Check that there is flow in the nitrous oxide flow meter (the bobbin should spin) and that the oxygen flow meter is still at 4 litres/min.
- ☐ Turn off the oxygen supply and push the oxygen flush button. The oxygen failure alarm should sound.
- ☐ Turn on the oxygen cylinder again. The oxygen failure alarm should go off.
- ☐ Check that all vaporisers are full and correctly fitted. The controls should operate thoughout their full range without sticking. Turn off the vaporisers.
- ☐ If the anaesthetic machine is fitted with a pressure relief valve it should be tested by occluding the common gas outlet whilst gas is flowing. (Never do this test if a pressure relief valve is not fitted).
- ☐ Attach the breathing system. Check that it has been correctly assembled. Close the APL valve, occlude the end and fill with gas. Squeeze the reservoir bag to ensure there are no leaks. Open the valve and ensure the breathing system empties.
- ☐ Check all airway equipment, suction equipment and drugs.

Anesthesia Machine Preventive Manitenance Table

User Care of Medical Equipment – First line maintenance for end users

User Care Checklist – Anaesthesia Machines and Ventilators

Daily	
Cleaning	✓ Remove any dust, dirt, water, waste matter, tape and paper
Audio-Visual checks	✓ If any leak is audible, check with soapy solution ✓ Check all seals, connectors, adapters and parts are tight ✓ Check all moving parts move freely, all holes are unblocked
Function checks	✓ Report any faults to technician immediately ✓ After checks, depressurize system and replace all caps / covers

Weekly	
Cleaning	✓ Clean inside and outside with damp cloth and dry off ✓ Remove dirt from wheels/any moving parts
Audio-Visual checks	✓ Check connections for leakage with soap solution and dry off ✓ Check all fittings and valves for proper assembly ✓ Replace soda lime if it has changed colour ✓ Replace any deteriorated hoses and tubing ✓ If seal, plug, cable or socket are damaged, replace
Function checks	✓ When next used, check pressure gauges rise ✓ When next used, check there are no leaks

Every six months
Biomedical Technician check required

4. Troubleshooting and Repair of Anesthesia Machines

Featured in this Section:

Chan, A. *Biomedical Device Technology: Principles and Design*. Charles C. Thomas Publisher: USA (2008).

Strengthening Specialised Clinical Services in the Pacific. *User Care of Medical Equipment: A first line maintenance guide for end users*. (2015).

Anesthesia Machine Troubleshooting Table

User Care of Medical Equipment – First line maintenance for end users

Troubleshooting – Anaesthesia Machines and Ventilators

	Fault	Possible Cause	Solution
1.	Equipment is not running	No power at mains socket	Check power switch is on. Replace fuse with correct voltage and current rating if blown. Check mains power is present at socket using equipment known to be working. Contact electrician for rewiring if power not present.
		Electrical cable fault	Refer to electrician for repair
2.	No gas output	No O_2 pressure in cylinder / gas supply.	Restore gas supply or replace gas cylinders.
		Check pressure gauges for gas pressure (about 4 bar or 4 kg/cm^2)	Replace O_2 cylinder and/or N_2O cylinder in case of low pressure.
3.	O_2 failure, power failure or breathing alarm not working	Alarm battery is low.	Call biomedical technician to fix the problem.
		Alarm device is not working	
4.	Machine has leaks	Poor seal (commonly occurring around tubing connections, flow valves and O_2 / N_2O yokes)	Clean leaking seal or gasket, replace if broken. If leaks remain, call technician for repair.
		Cylinders not seated in yokes properly	Refit cylinders in yokes and retest. If leaks remain, call technician for repair.
5.	Flowmeter fault	Over tightening of the needle valve or sticking of the float / ball	Refer to biomedical technician
6.	Electrical shocks	Wiring fault	Refer to electrician immediately

Risks Associated with Anesthesia Machines

Table 33–1.
Summary of Hazards and Mitigation Related to Anesthesia Machines

Potential Hazards	*Methods to Minimize Hazards*
Insufficient oxygen supply to the patient	• Oxygen analyzer • Pulse oximeter • Oxygen ratio monitor • Backup oxygen supply • Color-coded gas cylinders and hose • Touch-coded oxygen and nitrous oxide control knobs • DISS and pin-indexed safety system • Different diameters of hoses used • Vital sign monitoring
Insufficient carbon dioxide removal from the patient	• End-tidal carbon dioxide monitor • Pulse oximeter • Carbon dioxide absorber with color indicator
Excessive or wrong anesthetic agent delivered to the patient	• Agent specific keyed filling spouts on the vaporizers with color coding • Interlock to prevent turning on more than one anesthetic agent • Agent concentration monitors • BIS index monitor
Trauma to the lung caused by excessive pressure	• Pressure monitors • APL (adjustable pressure-limiting) valve • Pressure-limiting valve
Foreign matters injuring the airway	• Particle filters and traps • Dust-free carbon dioxide absorber
General	• Regular service by qualified personnel (daily functional check and regular quality assurance inspection and maintenance)

Chan, A. Biomedical Device Technology: Principles and Design. Charles C. Thomas Publisher: USA (2008).

5. External Resources for More Information about Anesthesia Machines

Featured in this Section:

Developing World Healthcare Technology Laboratory. “Routing to Clear Blockage in a Tube.” *Biomedical Technician Assistant (BTA) Skills*. DHT laboratory, Duke University, 2011.

Malkin, Robert. “Bottled Gasses: Operation and Use.” *Medical Instrumentation in the Developing World*. Engineering World Health, 2006.

Resources for More Information:

Internal Resources at library.ewh.org: For more information about anesthesia machines, please see these resources in the BMET Library!

1. Malkin, Robert. “Bottled Gasses: Operation and Use.” *Medical Instrumentation in the Developing World*. Engineering World Health, 2006.

2. Developing World Healthcare Technology Laboratory. “Routing to Clear Blockage in a Tube.” *Biomedical Technician Assistant (BTA) Skills*. DHT laboratory, Duke University, 2011.

Anesthesia Machine Bibliography:

Chan, A. *Biomedical Device Technology: Principles and Design*. Charles C. Thomas Publishers, 2008.

Developing World Healthcare Technology Laboratory. "Routing to Clear Blockage in a Tube." *Biomedical Technician Assistant (BTA) Skills*. DHT laboratory, Duke University, 2011.

Malkin, R. "Anesthesia Machines," From the publication: *Medical Instruments in the Developing World.* Engineering World Health, 2006.

Malkin, R. "Bottled Gasses: Operation and Use." *Medical Instrumentation in the Developing World*. Engineering World Health, 2006.

Ministry of Health and Family Welfare, New Delhi. *Medical Equipment Maintenance Manual: A first life maintenance guide for end users.* Ministry of Health and Family Welfare, 2010.

Pescod, D. *Developing Anesthesia Textbook, Version 1.6.* (2007). Retrieved from: http://www.developinganaesthesia.org/developinganaesthesia-textbook.html.

Strengthening Specialised Clinical Services in the Pacific. *User Care of Medical Equipment: A first line maintenance guide for end users*. (2015).

Subrahmanyam, M. and Mohan, S. "Safety Features in Anesthesia Machine." *Indian Journal of Anesthesia*, Vol. 57, No. 5 (2013), p. 472-480.

WHO. "Anesthesia Unit," From the publication: *Core Medical Equipment*. Geneva, Switzerland, 2011.

WHO. "Anaesthesia Ventilator." From the publication: "WHO Technical Specifications for 61 Medical Devices. *WHO*. Retrieved from: http://www.who.int/medical_devices/management_use/mde_tech_spec/en/.

Wikipedia. "Pulse Oximetry." *Wikipedia*, pgs. 1-4. Retrieved from: https://en.wikipedia.org/wiki/Pulse_oximetry.