Anesthesia Machine — Safety Features

See online here

There have been remarkable improvements in the drugs, techniques and anesthesia machines being used. As a result anesthesia is a safer procedure today. The safety features were gradually incorporated into the anesthesia machine over the years following problems and mishaps. Although several safety measures have been introduced in the anesthesia machine, the anesthesia provider bears the responsibility for checking the machine prior to use and for its safe deployment.
Safety Features

There are several international standards specifying the desired and absolutely essential safety features for anesthesia machines. The American Society for Testing and Materials (ASTM) Standard covers all anesthesia machines.

Failure of anesthetic machines is a rare event but the providers have to be vigilant at all times to ensure that there are no faults in the machine or in the entire anesthesia delivery apparatus.

The pneumatic systems in the anesthesia machines can be classified as high, intermediate and low pressure systems. Every single component has a safety feature. A comprehensive description of all the safety features is beyond the scope of this
article.

**High pressure systems** are composed of cylinders with their yoke assemblies, cylinder pressure indicators and pressure regulators.

The **intermediate pressure systems** are composed of an inlet pipeline, a master switch, pressure indicators, pressure regulators, ventilator auxiliary gas outlets, oxygen failure and oxygen pressure failure devices, oxygen flush and flow control valves.

The **low pressure systems** consist of flow meters, hypoxia prevention devices, vaporizers, unidirectional valves and pressure relief devices.

### High Pressure System

#### Gas cylinders

To prevent the wrong gas from being used, the gas cylinders are color-coded according to International Safety Standards and a PIN index system:

- Oxygen cylinder: black body with white shoulders
- Nitrous oxide: blue
- Air: black and white
- Carbon dioxide: gray
- Helium: brown
- Entonox: black with blue-white shoulders

The same color codes are also used on all the hoses, caps, knobs, connectors and pressure gauges of the respective gases.

The **PIN index system** prevents the incorrect gas cylinder from being attached to the hanger yokes of the anesthesia machine.

![Image: A simple schematic of an anesthesia machine showing three main subsystems: gas delivery, patient breathing circuit (showing both the absorber and ventilator), and waste gas scavenger. Not shown are safety and monitoring devices.](https://www.publicdomainpictures.net/pic情境/31/04/2016/108702.jpg) by TwoOneTwo - Own work. License: [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

<table>
<thead>
<tr>
<th>Gas</th>
<th>Index PINs</th>
</tr>
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<tbody>
<tr>
<td>Oxygen</td>
<td>2,5</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>3,5</td>
</tr>
<tr>
<td>Cyclopropane</td>
<td>3,6</td>
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</table>
Pressure relief devices are fitted on all cylinders to vent cylinder contents in case there is built up pressure within the cylinder (with over-filling or mis-filling of gas).

Pressure regulators are specific for each gas to provide a constant low pressure to match the anesthesia machine.

Intermediate Pressure System

Schrader probe: to prevent pipelines of different gases crossing over or being connected wrongly, a Schrader socket assembly is fitted only for the same gas.

Hose pipes: kink proof, color-coded and flexible hose pipes are used.

Gas Pipelines at the machine end: a unidirectional valve at the machine end ensures that a color-coded hose pipe delivers gas specific to the gas service.

Pipeline pressure indicators with color coded dials are fitted for each gas.

Oxygen failure system: A loud audible (minimum 60dB), non-mutable alarm is sounded for at least 7 seconds whenever the oxygen pressure falls below a certain pre-determined safe threshold. Older machines had the “Ritchie whistle” to alert when the oxygen pressure decreased to 260 kpa or less. The alarm is linked to a gas shut off valve to cut off the patient from anesthetic gases.

Oxygen flush is a switch located in a shallow recess. It is activated by a finger to activate emergency oxygen direct from the cylinder or pipeline. The switch is turned off as soon as the finger is removed.

Low Pressure System

Flow meters: for ease of identification, the knobs (on/off) on the oxygen flow meters are fluted and larger than the ones on the nitrous oxide or air flow meters. In addition, the oxygen flow meters are always located downstream from the nitrous and air flow meters. This prevents a leak in the low pressure system from diluting the oxygen and leading to a mixture of hypoxic gases.

The nitrous oxide flow meter is set up so that it is automatically disabled whenever the oxygen flow meter is set to less than 21% or if the oxygen supply fails.

Vaporizers have a stiff button which has to be pushed prior to turning on the vapor. To prevent all vaporizers from working simultaneously, there is an interlocking system to ensure that only one vaporizer works at a time.

Pressure relief device is located between the common gas outlet and the vaporizer. It protects the anesthesia machine by venting gas to the atmosphere if high pressures develop within the system.
Common gas outlet (CGO): newer anesthesia machines often have more than one CGO. Therefore, machine standards ensure that in such machines, only one CGO is functioning at any given time.

Hypoxia prevention device ensures that there is a pre-decided level of oxygen flow e.g. the mandatory minimum oxygen flow is 150 - 250ml/min.

Scavenging System

There are strict international regulations for scavenging system standards. All scavenging system connections have 30mm diameter to prevent any misconnections as airway accessories have 15/22 mm diameter.

Negative and positive pressure relief valves are incorporated within the scavenging systems to prevent transmission of high pressures in the breathing system, in case the system malfunctions.

Every anesthetic machine is installed with a standard oxygen analyzer, a low pressure analyzer, a high pressure analyzer and a spirometer.

Monitoring System

It is mandatory for every anaesthesia machine to have the following monitors:

- **ECG**: preferably five lead
- **Blood pressure cuff**: automated and regularly calibrated
- **Pulse oxygen saturation monitor**
- **Carbon dioxide end-tidal monitor** which measures the expired carbon dioxide
- **Tidal volume and airway pressure monitor**

Other monitors which can be installed depending on the anesthesia provider are:

- **Temperature monitor**, which is required in the United States
- **Peripheral nerve stimulator** for monitoring the status of the muscle relaxation
- **End-tidal vapor monitor**
- **Ultrasound** to detect pneumothorax or abdominal problems

Monitors required for high-risk patients include:

- **Invasive blood monitors** for blood pressure, central venous pressure and pulmonary arterial pressure
- **Intracranial pressure monitor**
- **Trans-esophageal echocardiography** (TEEC)
- **Sensory and motor potentials**
- **EEG**
- **Fetal heart monitor**
- **Uterine contraction monitor**
- **Cerebral monitors** (BIS, cerebral oximetry)