SAFETY FEATURES IN ANAESTHESIA MACHINES

Prof. J. Edward Johnson, M.D., D.C.H
HOD, Department of Anaesthesiology,
KGMCH.
Why safety features?

To safeguard human life from unknown human errors.

To prevent delivery of hypoxic mixture

To prevent excessive pressure which is traumatic to patient
PISS= Pin Index Safety System
Master switch

Power failure indicator

Reserve power

Electrical Outlets

Circuit Breakers

Data Communication Ports
PNEUMATIC SYSTEM

- High pressure system
- Intermediate system
- Low pressure system
- Alternative oxygen control

Diagram showing a pneumatic system with sections for high, intermediate, and low pressure with various components like check valves, cylinder pressure gauges, flowmeters, calibrated vaporizers, and oxygen regulators.
GAS CYLINDER

Color coding

Pin index

Markings

Cylinder labels

Safety relief device
<table>
<thead>
<tr>
<th>Gas</th>
<th>Color Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>Black body, white shoulder</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>Blue</td>
</tr>
<tr>
<td>Air</td>
<td>Black body, white and black quarters shoulder</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Grey</td>
</tr>
<tr>
<td>Helium</td>
<td>Brown</td>
</tr>
<tr>
<td>Entonox</td>
<td>Blue body, blue/white quarter shoulder</td>
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PIN INDEX SAFETY SYSTEM

It aims to ensure that the correct cylinder or central pipeline supply is attached to the appropriate hanger yoke of anesthesia machine or workstation.

- Pins are 4mm in diameter, 6mm long, pin 7 is slightly thicker.
- The positions of 7 holes are on the circumference of a circle of 9/16 inch (14.3mm) radius centered on the port (7mm).
Labelling

Diamond shaped figure denoting the hazard class

A white panel with the name of the contained gas

A signal word is present (Danger, warning or caution)

Statement of Hazard

Should contain the name and address of the cylinder manufacturer or distributor
Every cylinder is fitted with pressure relief device.

**Purpose**: is to vent the cylinders content to atmosphere if the pressure of enclosed gas increases to dangerous level.

The safety relief device is composed of at least one of

1) **Frangible disc**: [bursts under extreme pressure]
2) **Fusible plug**: [wood’s metal which has a low melting Point]

WOOD’S METAL - A fusible alloy that contains 50% bismuth, 25% lead, 12.5% tin, and 12.5% cadmium, and melts at 158°F (70-72°C); used for automatic sprinkler plugs
3) combination
4. Spring loaded pressure relief valve-
   - reclosing device.
   - when the set pressure exceeds, the pressure in the cylinder forces the spring to open the channel for letting out gases till the excess pressure is relieved.
   - They are more susceptible for leakage
Check valves

- Allows gas from cylinder to enter machine but prevents gas from exiting machine when yoke has no cylinder.
- Allows replacement of cylinders without losing gas.
- Prevents transfer of gas from a cylinder with high pressure to one with low pressure if connected to a double yoke and turned on simultaneously (TRANSFILLING)
Convert high variable pressure of gas to low constant working pressure (4bar, 60psi).

To prevent damage to the structures of flow meter, of wall outlet, especially the flow control valve needles.

Maintain a constant inlet pressure at the level of flow control valves.

Pressure regulators have safety relief valves

Safety valve blow off at a set pressure of 525 kpa (70psi)
Bodok seal

Washer [bodok seal] – rubber made of neoprene with peripheral rim of aluminium

Ensures gas tight seal between the cylinder valve and the machine

Broken or more than one washer can nullify PISS or prevents tight seal
Safety features in cylinder pressure indicator

- Gauge is usually colour coded.
- Name and symbol of gas are written over dial.
- If bourdon tube ruptures gas is vented from back side.
- Gauges are angled and placed in such a way that it can be easily read by anaesthetist.
- Instructions like “use no oil” “open the valve slowly” are written on the gauge.
• Wall outlet: Labelled and colour coded
• Schraeders probes, quick connectors or diameter index safety system to prevent interchangeability
• Pipeline hoses – colour coded
Wall outlet

NIST system
Non-Interchangeable Screw Threaded system

Sleeve Index System (SIS)

NIST
Diameter Indexed Safety System (DISS)

Australian Standard

Schrader Indexed Probe

Australian Standard

DIN Wall Connector

UK

American standard

German
Oxygen Pressure Failure Safety Device Fail-safe valve

- It is located downstream from the nitrous oxide and other gases supply source
- This valve shuts off or proportionally decreases the supply of nitrous oxide (and other gases) if the oxygen supply pressure declines
- Do not offer total protection against a hypoxic mixture being delivered
Threshold principle

This valve operates in a threshold manner and is either open or closed.

Oxygen supply pressure opens the valve, and the valve return spring closes the valve.

At 20 psi oxygen, the flow of all other gases are shut off.

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**Datex-Ohmeda machines**

“Pressure Sensor Shut off Valve”

3/6/2020
Dräger's "oxygen failure protection device" (OFPD)

- OPFD is based on a **proportioning principle**
- The pressure of all gases controlled by the OPFD will decrease proportionally with the oxygen pressure.
- Consists of a seat nozzle assembly connected to a spring-loaded piston
Resistors generate back pressure on a control diaphragm, in proportion to oxygen and nitrous oxide flows. S-ORC guarantees a minimum FIO₂ of 21% by limiting nitrous oxide flow.
• The oxygen flow control knob is distinctively fluted, projects beyond the control knobs (2mm) of the other gases, and is larger in diameter
• All knobs are color-coded for the appropriate gas,
• the chemical formula or name of the gas is permanently marked on each.
Flow meter

- Bobbin rotates on flow which prevents it from sticking.
- Antistatic spray in flowmeter
- Master and slave safety mechanism for gas delivery between N2O and O2
- Downstream placement of oxygen flowmeter
- Radio florescent plastic sheet behind flow meter
- Float stop
- Auxiliary oxygen flowmeter
Flow meter arrangement
• An oxygen leak from the flow tube can produce a hypoxic mixture, regardless of the arrangement of the flow tubes.
Hypoxia prevention safety devices

- **Proportionating devices**
  1. Link 25 in datex ohmeda [mechanical, pneumatic and electronic linkage]
  2. S-ORC (sensitive oxygen ratio controller) ORMC (oxygen ratio monitor controller) in drager,
  3. Mandatory minimum oxygen flow: 150 to 250 ml/min
Mandatory minimum oxygen flow

- Mandatory minimum oxygen flow: **50 to 250 ml/min**
- The minimum flow is activated when the *master switch* is turned on
- Some machines activate an alarm if the oxygen flow goes below a certain minimum, even if no other gases are being used
- The minimum oxygen flow does not in itself prevent a hypoxic gas concentration from being delivered.
Whenever the oxygen supply pressure falls below a manufacturer-specified threshold (usually 30 psig (205 kPa))

- At least a medium priority alarm shall be enunciated within 5 seconds
- It shall **not be possible to disable this alarm**.

**Limitations**

- Depend on pressure and not flow
- Do not prevent anesthetic gas from flowing if there is no flow of oxygen
- Crossovers in the pipeline system or a cylinder containing the wrong gas
- Leaks downstream
• Present in older machines – **Ohmeda**
• When the oxygen pressure drops below 260 kpa( **38 psi**), oxygen failure whistle valve opens
• Whistle sounds continuously, until oxygen pressure has fallen to approx 40.5 kpa ( **6 psi**)
• At **30 psi** ( 200 kpa ), it cuts off the supply of anesthetic gases to the patient

A reservoir is filled with O2 when the machine is turned on. When the O2 pressure reduces < 30-35 psig, the gas in the reservoir will pass through a clarinet-like reed sound.
Oxygen flush valve

- Receives oxygen from the pipeline inlet or cylinder pressure regulator and directs a high unmetered flow directly to the common gas outlet
- Labeled “O2+.”
- **Activated regardless of whether the master switch is turned ON or OFF.**
- Flow between **35 and 75 L/minute** delivered
- The button is commonly **recessed or placed in a collar** to prevent accidental activation
- Activation does not increase or decrease the pressure at the vaporizer outlet > 10 kPa or increase the vapor output > 20%
Check valve

- Its purpose is to **prevent backflow into the vaporizer** during positive-pressure ventilation, thereby minimizing the effects of intermittent fluctuations in downstream pressure on the concentration of inhaled anesthetic.
Safety features of newer machines

• More accurate and corrected tidal volume through compliance and fresh gas compensation

• Fresh gas decoupling prevent hyperinflation of the lung
Fresh gas decoupling (FGD)

Fresh gas decoupling (FGD), which is a feature of machines such as newer models of Draeger machines, prevents addition of FGFs to the ventilator delivered tidal volume thus ensuring accuracy of delivered tidal volume and at the same time preventing barotrauma and volutrauma.
Vaporizer safety mechanism

- Agent specific filling system –colour coded
- Low filling port-minimize overfilling
- Interlocks - one agent at a time
• It is the only machine safety device that evaluates the integrity of the low-pressure circuit

• Oxygen concentration–sensing element must be exposed to room air for calibration to 21%.
• There is always the possibility that the electronics will fail.
• Some machine provide an alternative means to administer oxygen
• This is separate from the auxiliary flowmeter
• This can be used to supply oxygen in case of total loss of electrical power supply
Modern anaesthesia machine

Pneumatic component
- High pressure system
  1. Colour coded cylinders
     - Oxygen: Black body, white shoulder in UK and India
     - Green in USA
     - N2O: French blue
   2. Molybdenum steel alloy construction.
      (stronger and lighter than its carbon steel predecessor)
   3. Pin index safety system / PISS (bypassed with a double Bodok seal/washer)
   4. Pressure relief valve/rupture disc/fusible plug
   5. Pressure regulators for reducing pressure from high pressure cylinders

- Intermediate pressure system
  - Schrader probe to prevent misconnection to the wrong gas service
    - Colour coded, kink proof hose pipes
    - Diameter/index safety system (DISS) and quick couplers
  - Non-interchangeable screw thread NIST connection to the anaesthetic machine
    - Colour coded pipeline pressure indicators

- Low pressure system
  - Mandatory minimum oxygen flow (200 ml/min in Drager Primus)
    - Flow control knob for oxygen is largest, most protruding and fluted
    - Link 25: Mechanical linkage of O2 and N2O flow control knobs
    - Tubes have an antistatic coating on both surfaces, preventing the bobbin from sticking.
    - Neoprene washers (O-rings) at both ends of the flow meter
    - Oxygen flow meter is always positioned downstream or last in a sequence of flow meters
      - Vaporizer: push (release) button to be activated before the dial can be turned on
      - Interlock mechanism prevents more than one vaporizer being put to use at the same time
    - Keyed/funnel filling systems with unique sizing of fillers/funnels that are agent specific

- Electronic component
  - Computer-controlled anaesthesia systems have safety self check out feature
    - Main on/off switch for electrical power to integral monitors and alarms
    - Electronic / virtual flowmeters for oxygen and N2O in Drager Primus (no sticky bobbins)
    - Battery backup of at least 45 minutes

- Scavenging system
  1. All connections in the scavenging system are of 30 mm diameter; distinctly different from the airway accessories (15/22 mm) making misconnections improbable
  2. Negative pressure relief valve and a reservoir are needed in active scavenging systems
  3. Positive pressure valve is needed in a passive system
  4. Transfer tubings are of different colour and configuration than those of breathing gases, kink resistant and occlusion proof
Checklist

Mandatory
Electronic Checking

3/6/2020

Press rotary knob to exit
### TO BE COMPLETED DAILY

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<td>Item #5: Verify that pressure is adequate on the spare oxygen cylinder mounted on the anesthesia machine</td>
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<td>Item #6: Verify that the piped gas pressures are ≥ 50 psig</td>
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<td>Item #7: Verify that vaporizers are adequately filled and, if applicable, that the filler ports are tightly closed.</td>
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<td>Item #8: Verify that there are no leaks in the gas supply lines between the flowmeters and the common gas outlet</td>
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<td>Item #9: Test scavenging system function.</td>
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1: Verify Auxiliary Oxygen Cylinder and Self-inflating Manual Ventilation Device are Available & Functioning

**Frequency: Daily**

- A self-inflating manual ventilation device (eg. AMBU bag) should be present at every anesthetizing location for every case and should be checked for proper function.

- A source of oxygen separate from the anesthesia machine and pipeline supply, specifically an oxygen cylinder with regulator and a means to open the cylinder valve, should be immediately available and checked.
2: Verify patient suction is adequate to clear the airway

Frequency: Prior to each use.

FIGURE 33.5  Check of suction. The strength of the vacuum is tested by determining that the weight of the suction tubing can be supported at waist height by the seal between the tubing and the underside of a finger. If the vacuum is unsatisfactory, the tubing will not remain in contact with the finger.
3: Turn on anesthesia delivery system and confirm that AC power is available.

Frequency: Daily

- Anesthesia delivery systems typically function with backup battery power if AC power fails.
- Unless the presence of AC power is confirmed, the first obvious sign of power failure can be a complete system shutdown when the batteries can no longer power the system.
- Indicators
4: Verify availability of required monitors and check alarms.

**Frequency:** Prior to each use

- The first step is to visually verify that the appropriate monitoring supplies (BP cuffs, oximetry probes, etc.) are available.

- *Capnometer* function can be verified by exhaling through the breathing circuit to generate a capnogram or verifying that the patient’s breathing efforts generate a capnogram before the patient is anesthetized.

- *Pulse oximeter function*, including an audible alarm, can be verified by placing the sensor on a finger and observing for a proper recording.
5: Verify that pressure is adequate on the spare oxygen cylinder mounted on the anesthesia machine.

Frequency: Daily

- The FDA check list recommends that the cylinder be at least half full (about 1000 psig)

- If the cylinder is intended to be the primary source of oxygen then a cylinder supply sufficient to last for the entire duration is required.

- A pneumatically-powered ventilator that uses oxygen as its driving gas. Electrically-powered ventilators do not consume oxygen so that the duration of a cylinder supply will depend only on total fresh gas flow.

- A full E cylinder will contain about 625L of oxygen with a pressure of around 2000 psig. One full cylinder will last less than 3.5 hours at a flow of 3L/minute. But in a pneumatically powered ventilator only 30mins of oxygen will be provided.
6: Verify that piped gas pressures are ≥ 50 psig.

Frequency: Daily

• Checked by tug test

Connect O2 pipeline to the oxygen wall outlet using the Schrader quick coupler system.

Correct coupling will not allow detachment of the pipeline from the Schrader coupler when a tug is given to the pipeline.

Similar test can be performed with the N2O pipeline with N2O wall outlet.
7: Verify that vaporizers are adequately filled and the filler ports are tightly closed.

Frequency: Prior to each use.

- Partially open filler ports are a common cause of leaks that may not be detected if the vaporizer control dial is not open when a leak test is performed.

- This leak source can be minimized by tightly closing filler ports.

- Newer vaporizer designs have filling systems that automatically close the filler port when filling is completed.
8: Verify that there are no leaks in the gas supply lines between the flowmeters and the common gas outlet.

Frequency: Daily and whenever a vaporizer is changed

- **UNIVERSAL LEAK TEST**
  
  Verify that the machine master switch and flow control valves are OFF.
  
  Attach a “suction bulb” to the common (fresh) gas outlet.
  
  Squeeze the bulb repeatedly until fully collapsed.
  
  Verify that the bulb stays fully collapsed for at least 10 seconds.
  
  Open one vaporizer at a time and verify the bulb stays collapsed.
  
  Remove the suction bulb and reconnect the fresh gas hose.
Checking Low Pressure System

The Negative-pressure leak test

Positive-pressure leak test

> 10 sec
9: Test scavenging system function.

Frequency: Daily

- Ensure proper connections between the scavenging system and both the APL valve and ventilator relief spill valve. Fully open the APL valve and occlude the Y-piece. With minimum oxygen flow allow the scavenger reservoir bag to collapse completely and verify that the absorber pressure gauge reads about zero.

- With the oxygen flush activated allow the scavenger reservoir bag to distend fully and then verify that the absorber pressure gauge reads <10 cm H2O.
10: Calibrate or verify calibration of the oxygen monitor and check the low oxygen alarm.

Frequency: Daily

- The oxygen sensor should be removed from the breathing system and moved away from sources of gas that might change the ambient oxygen concentration. It should be calibrated to 21%.

- The low oxygen alarm checked by setting it above 21%. The sensor should then be placed securely in its mount in the breathing system and the breathing system flushed with oxygen. This should result in a reading of over 90%.
Verify carbon dioxide absorbent is not exhausted.

Frequency: Prior to each use

- Exhausted absorbent is indicated by color change and should be replaced. It is possible for absorbent material to lose the ability to absorb CO₂ yet the characteristic color change may be absent or difficult to see. Some newer absorbents do change color when desiccated. Hence capnography should be utilized.

- Rebreathing carbon dioxide as indicated by an inspired CO₂ concentration > 0 can also indicate exhausted absorbent.
12: Breathing system pressure and leak testing

Frequency: Prior to each use.

- To initiate the breathing system leak test all gas flows should be at zero. The APL valve should be closed and the patient port occluded. The breathing system should be pressurized to 30 cm H2O by using the oxygen flush. If there is no leak, the pressure will remain near this level for at least 10 seconds. The APL valve is then opened. The pressure should decrease. [Retrograde fill test]

- The leak can be quantified by adjusting the oxygen flowmeter to maintain a pressure of 30 cm H2O in the breathing system. The breathing system standard requires that this does not exceed 300 mL/minute.
13: Verify that gas flows properly through the breathing circuit during both inspiration and exhalation

Frequency: Prior to each use

TWO BAG TEST-

A second reservoir bag should be placed on the patient port and the oxygen flow meter should be set at the minimum flow or 300 ml/minute.

As the reservoir bag on the bag mount in the breathing system is squeezed, the bag on the patient port should inflate. The bag on the patient port should then be squeezed. The reservoir bag on the bag mount should inflate.
Checks for incompetent unidirectional valves. A: The inspiratory limb is detached and occluded. The tester tries to breathe through the Y-piece. It should be possible to exhale freely but not inhale. B: The exhalation tubing is detached and occluded. The tester should be able to inhale from the Y-piece but not exhale.
Checking the unidirectional valves using a valve tester

3/6/2020
14: Document completion of checkout procedures.

Frequency: Prior to each use.

- Each individual responsible for checkout procedures should document completion of these procedures.
15: Confirm ventilator settings and evaluate readiness to deliver anesthesia care. *(ANESTHESIA TIME OUT)*

**Frequency: Immediately prior to initiating the anesthetic procedure**

- This step is intended to avoid errors due to production pressure or other sources of haste. The goal is to confirm that *appropriate checks have been completed* and that essential equipment is indeed available.

  - Monitors functional?
  - Capnogram present?
  - Oxygen saturation by pulse oximetry measured?
  - Flowmeter and ventilator settings proper?
  - Manual/ventilator switch set to manual?
  - Vaporizer(s) adequately filled?
Prior to each procedure

3/6/2020

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THANK YOU

3/6/2020

WhatsApp me
9443392974
WhatsApp Group

Anaesthesia today
consultant

Anaesthesia and Me PGs TN
Anaesthesia and Me PGs KL
Anaesthesia and Me PGs KA
Anaesthesia and Me PGs SI
Anaesthesia and Me PGs NG

Every Sunday 9 PM – Rapid Fire Quiz
Consultants case discussions

257 × 6 = 1542

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Exam case discussions