SAFETY FEATURES IN ANAESTHESIA MACHINES

Prof. J.Edward Johnson.M.D.,D.C.H
HOD, Department of Anaesthesiology, KGMCH.

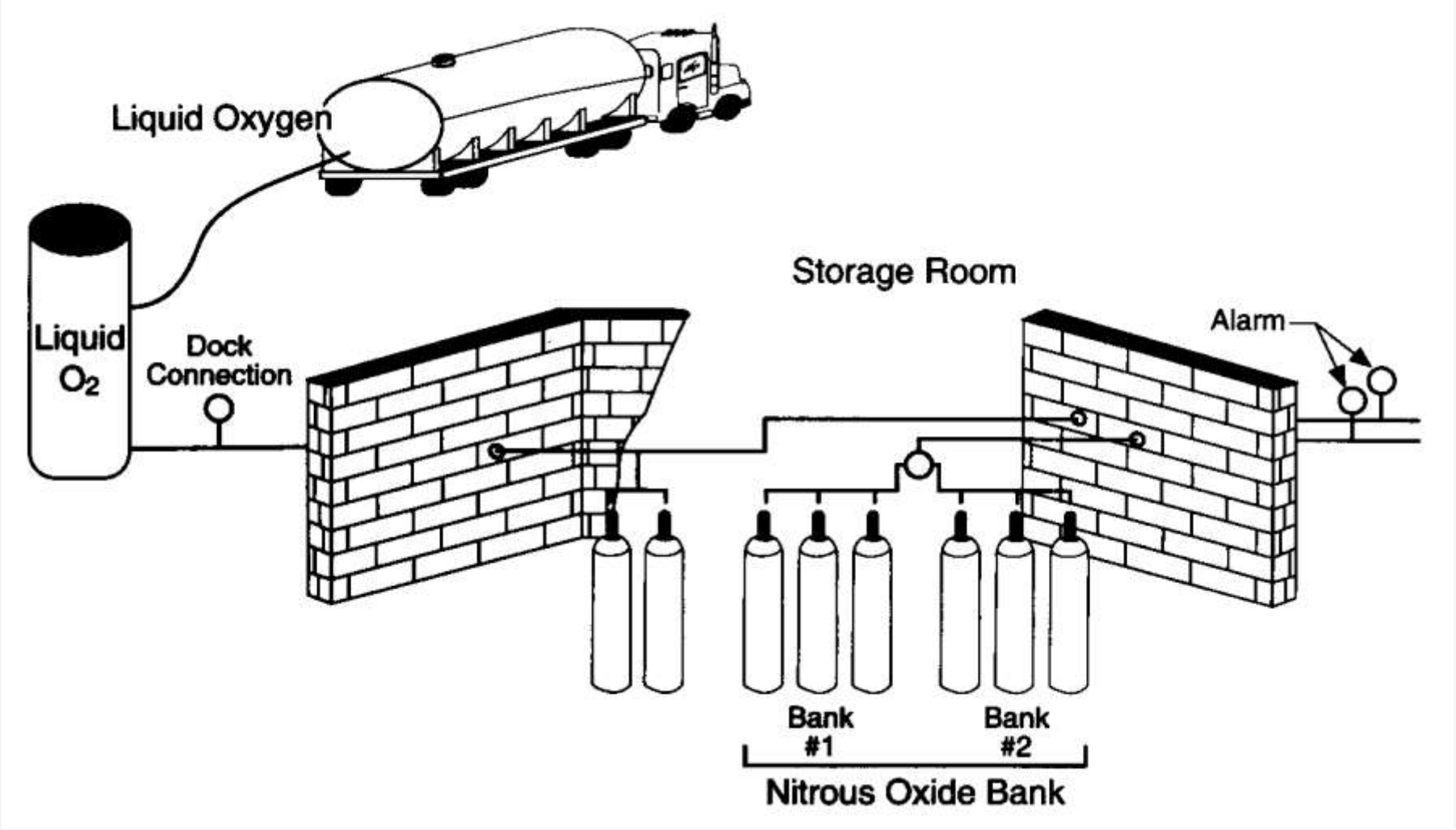
Why safety features?

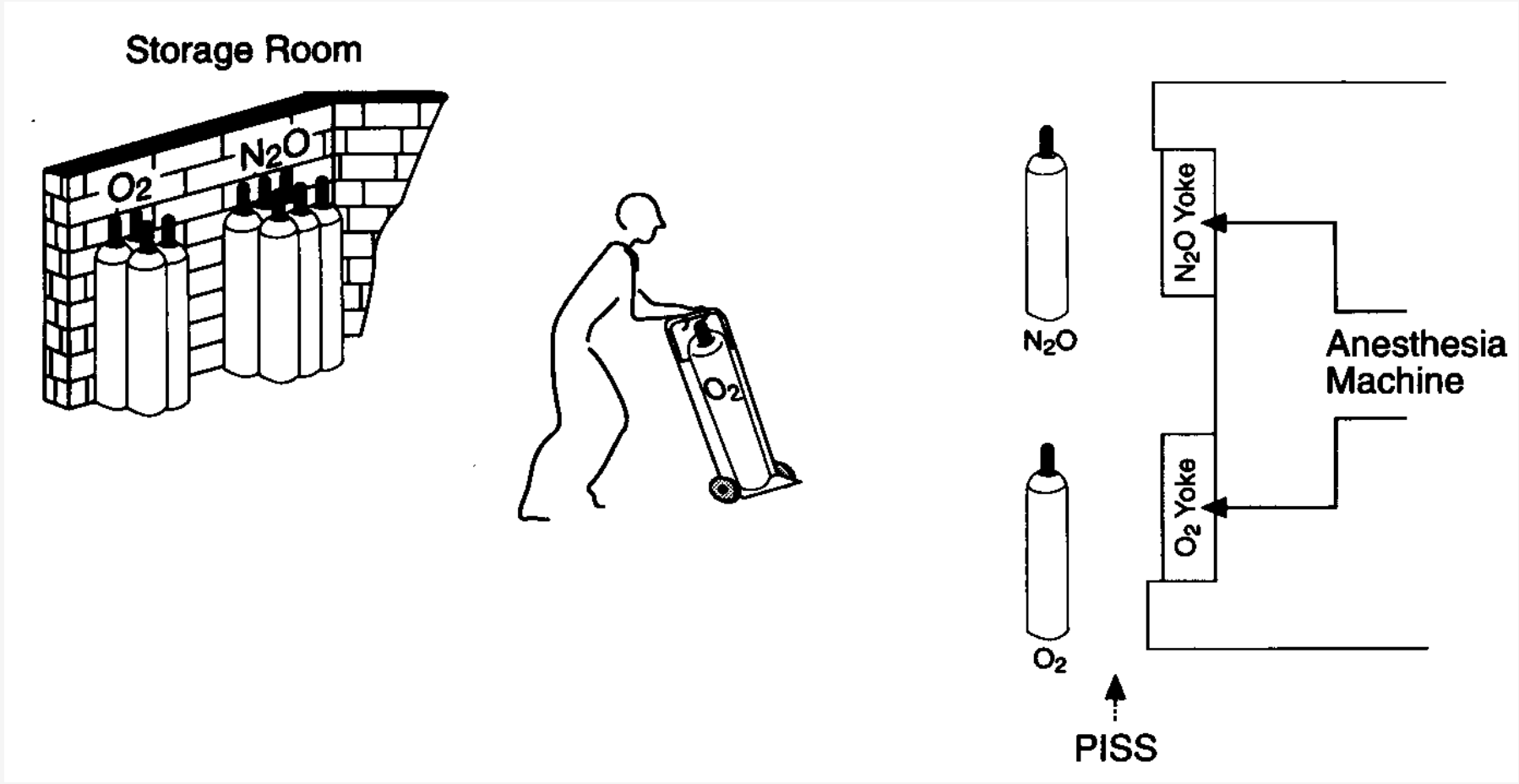
3/6/2020

To safeguard human life from unknown human errors.

To prevent delivery of hypoxic mixture

To prevent excessive pressure which is traumatic to patient


Liquid Oxygen
Liquid
O_2
Dock
Connection
Storage Room
Alarm
Bank
#1
Bank
#2
Nitrous Oxide Bank



PISS= Pin Index Safety System

ELECTRICAL COMPONENTS

3/6/2020

Master switch

Power failure indicator

Reserve power

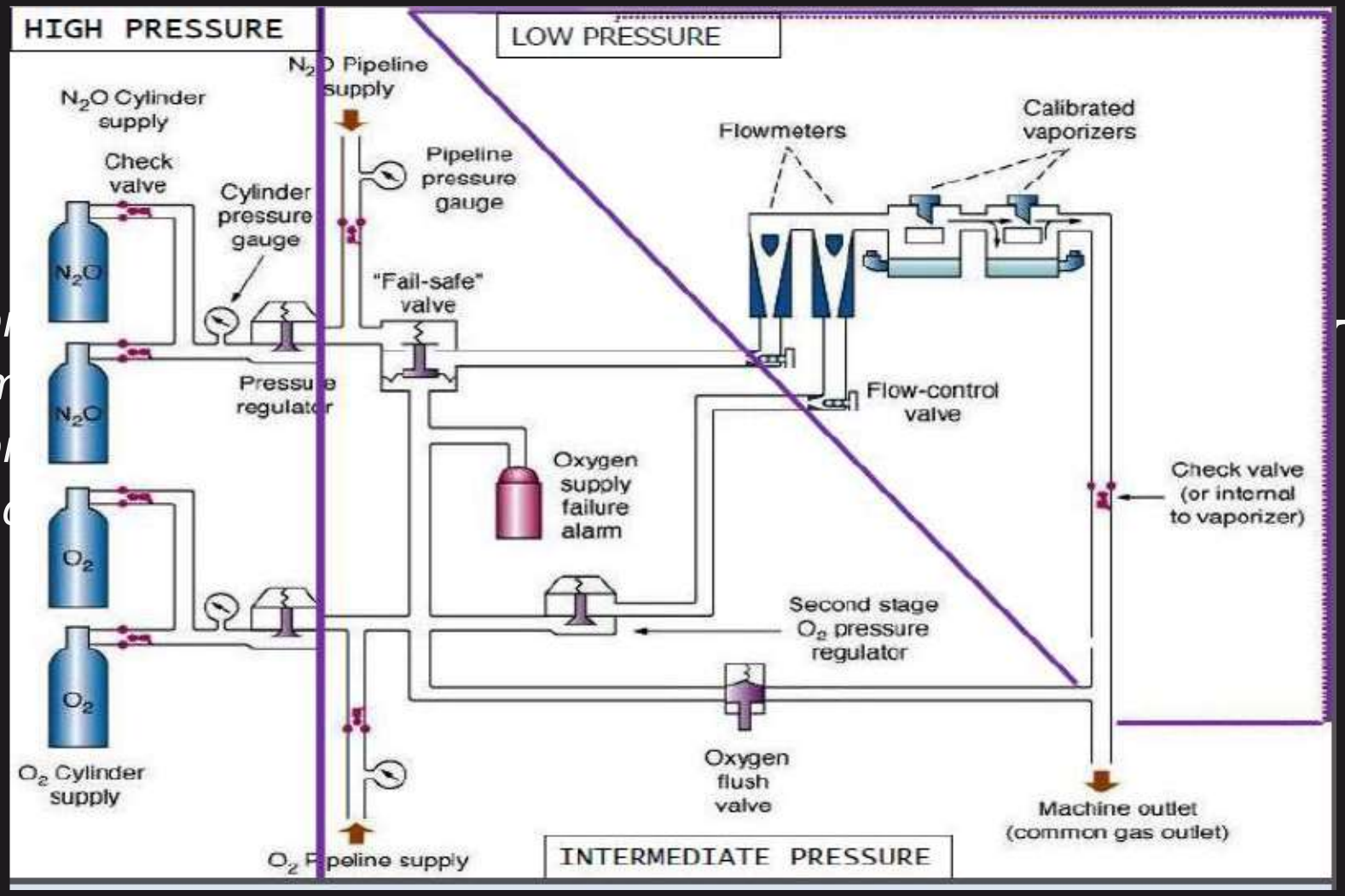
Electrical Outlets

Circuit Breakers

Data Communication Ports

High pr
Interm
Low pr
Alternative

TIC



High pressure system

3/6/2020

GAS CYLINDER

Color coding

Pin index

Markings

Cylinder labels

Safety relief device

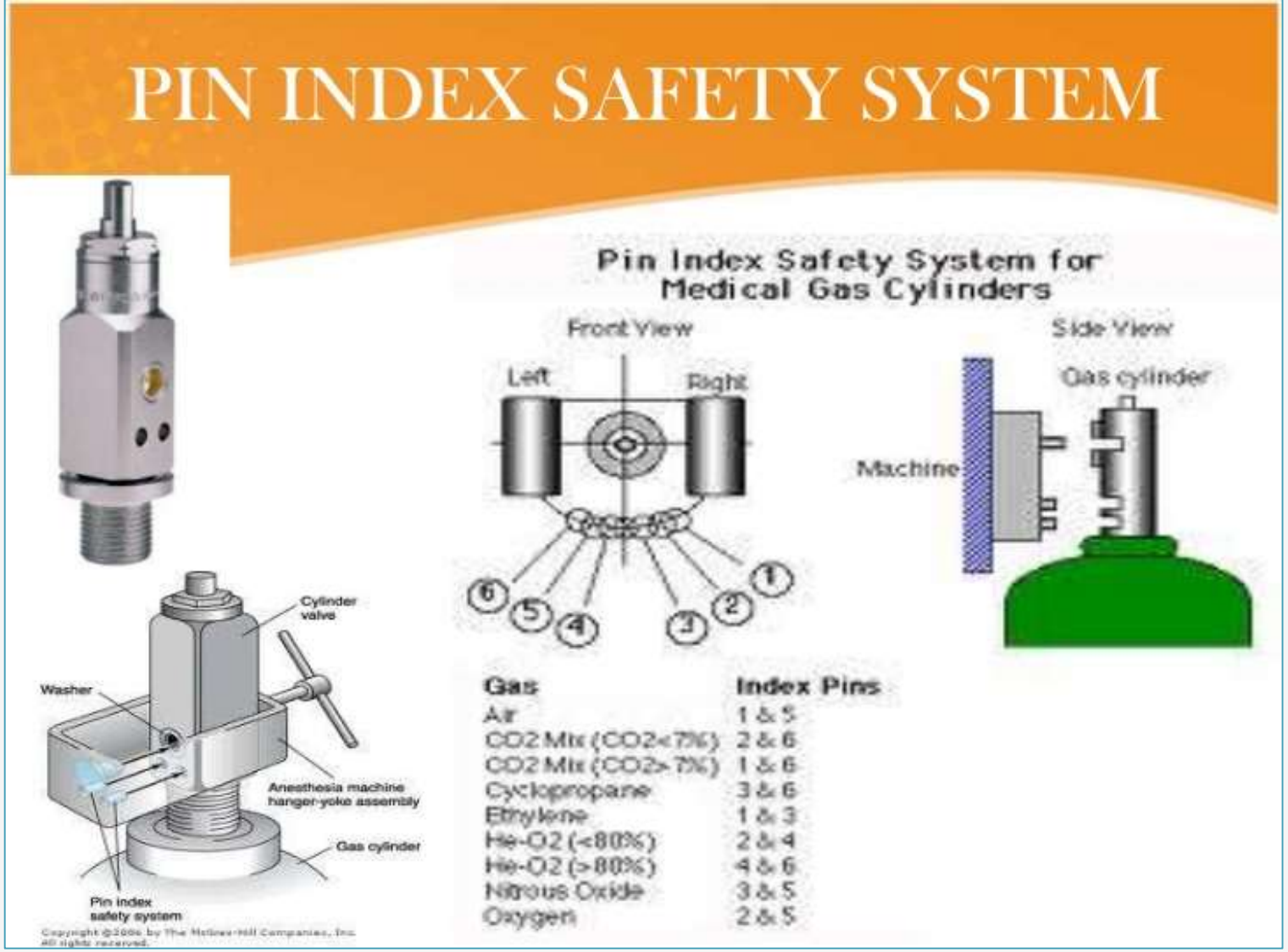
COLOR CODING

3/6/2020

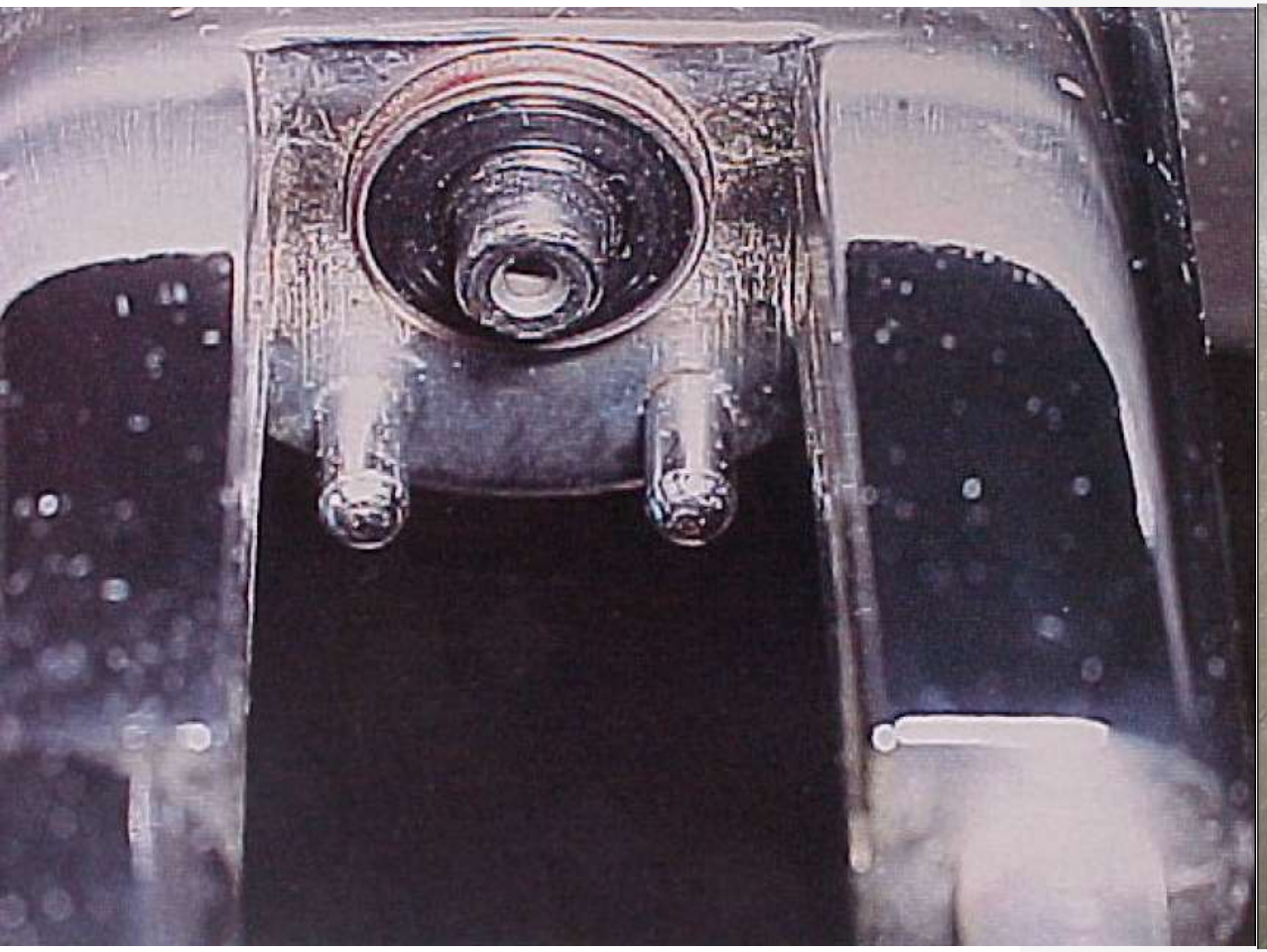
Oxygen	Black body, white shoulder
Nitrous oxide	Blue
Air	Black body,white and black quarters shoulder
Carbon dioxide	Grey
Helium	Brown
Entonox	Blue body, blue/white quarter shoulder

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

Safety relief device

3/6/2020

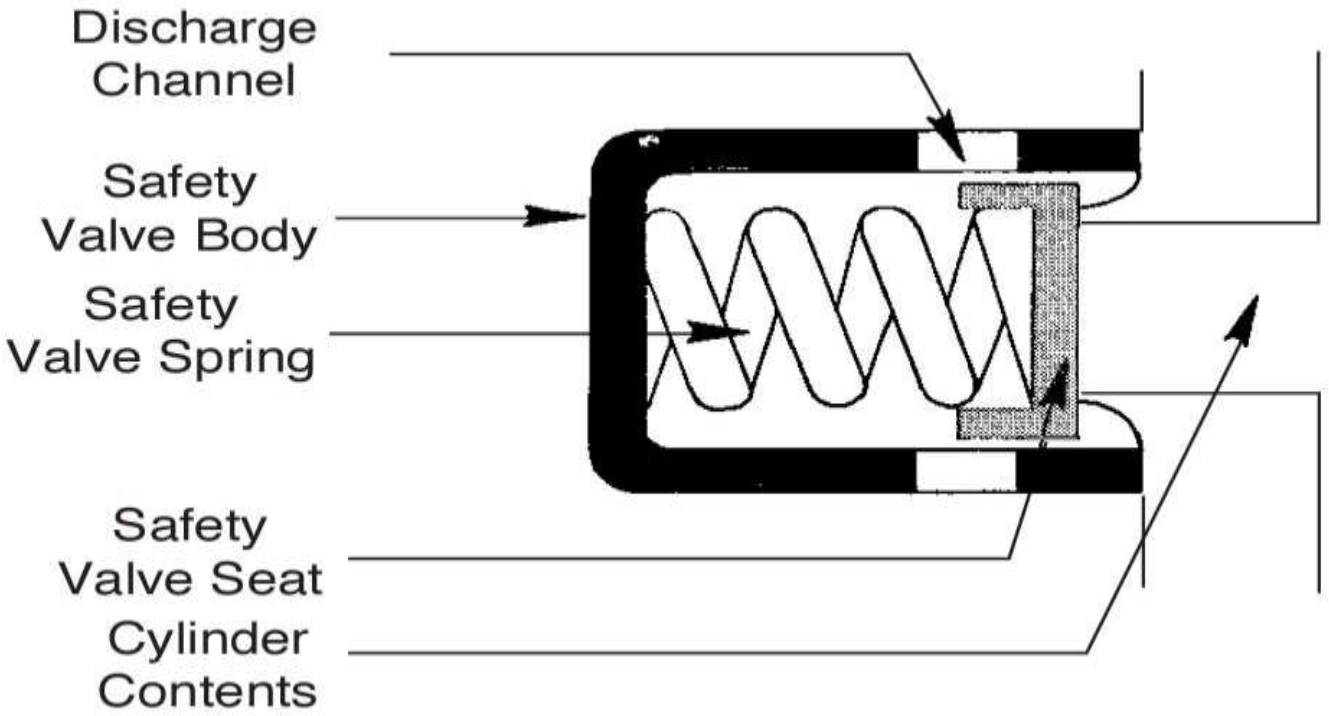
- **Every cylinder is fitted with pressure relief device.**
- **Purpose**: is to vent the cylinders content to atmosphere if the pressure of enclosed gas increases to dangerous level.
- The safety relief device is composed of at least one of

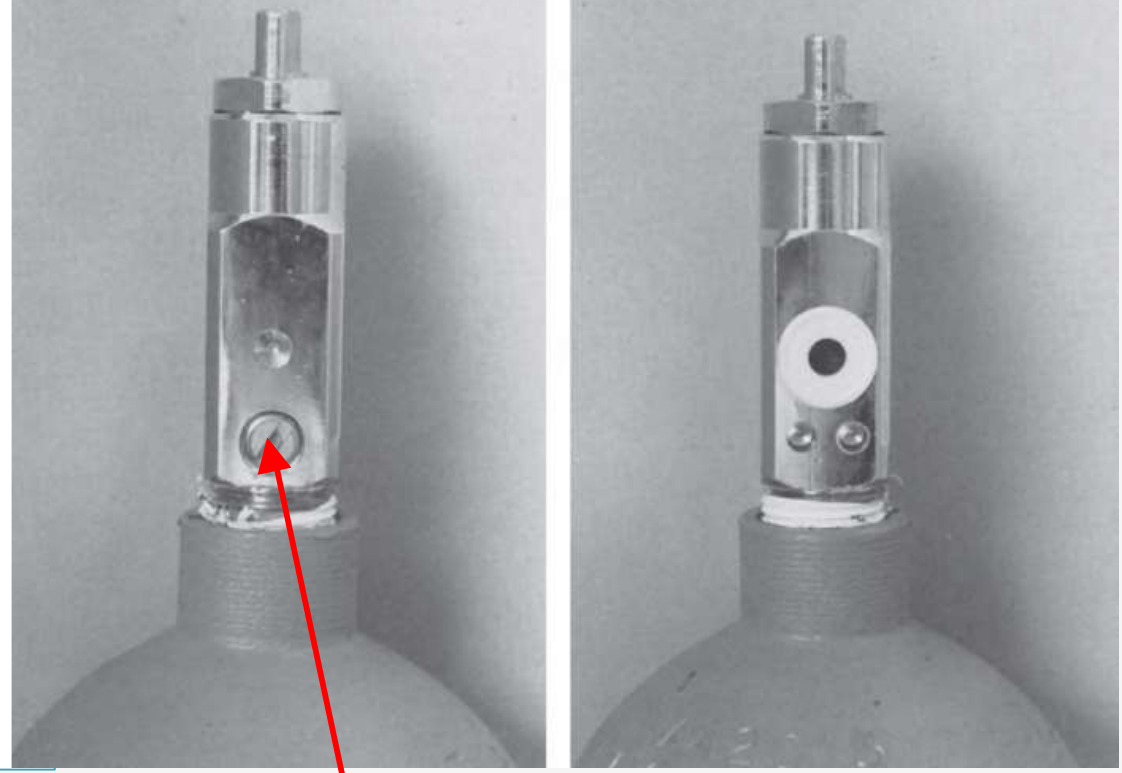
1) Frangible disc: [bursts under extreme pressure]

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

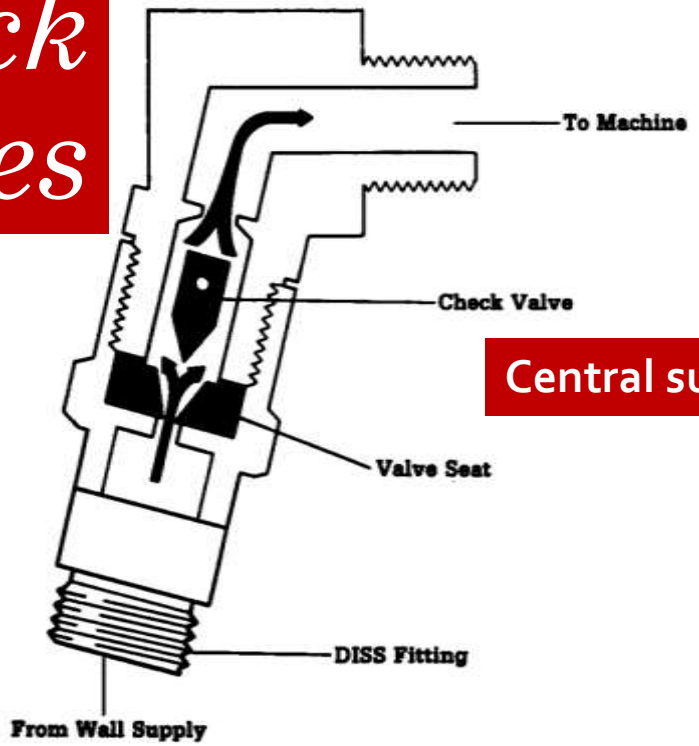
3)combination



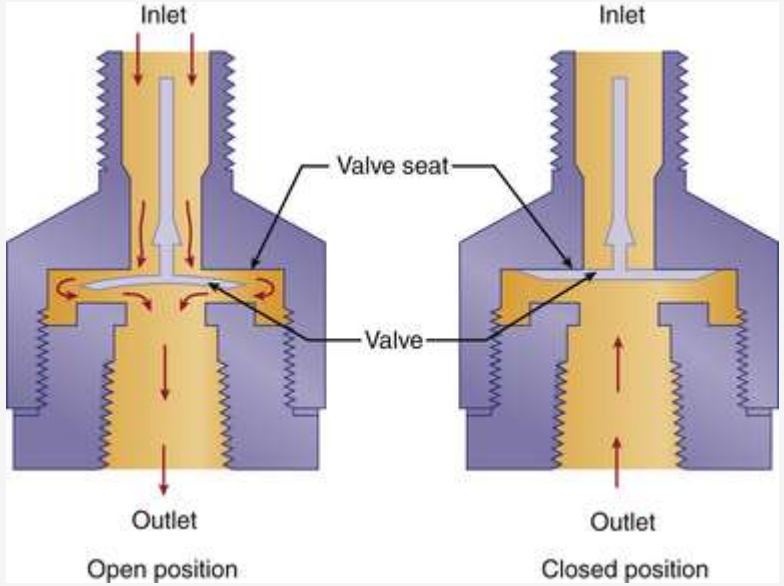


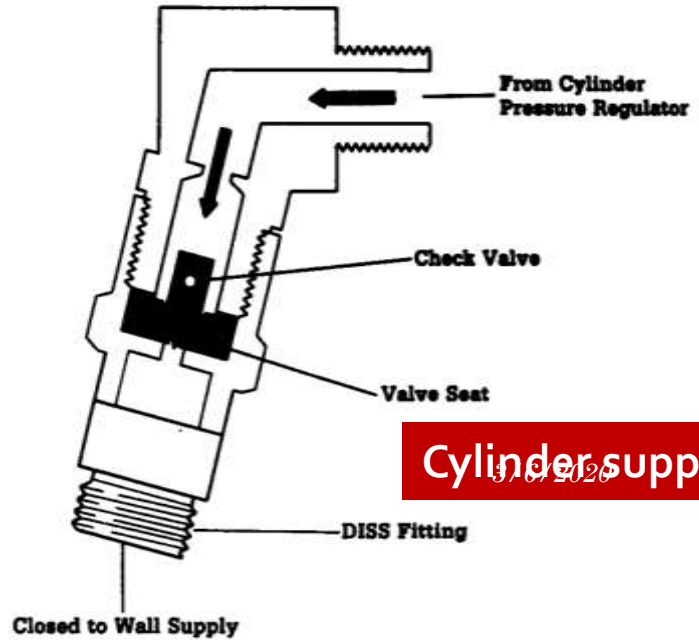
- **4. Spring loaded pressure relief valve-**
  - reclosing device.
  - when the set pressure exceeds, the pressure in the cylinder forces the spring to open the channel for letting out gases till the excess pressure is relieved.
  - They are more susceptible for leakage

Check valves



Central supply





Cylinder supply

- 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)

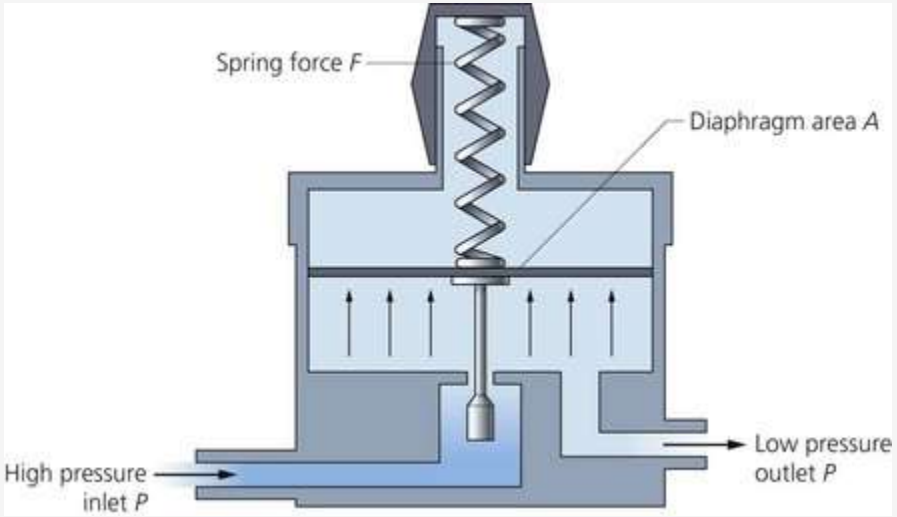
Pressure regulator & Safety features

3/6/2020

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 k pa(70psi)

Bodok seal

3/6/2020

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

Ensures gas tight seal between the cylinder valve and the machine

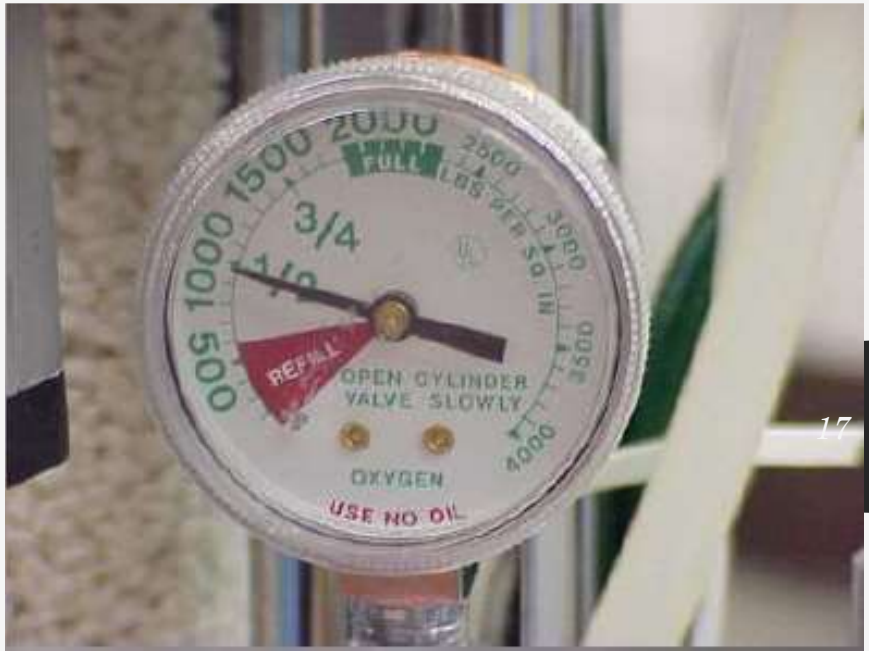
Broken or more than one washer can nullify PISS or prevents tight seal

Safety features in cylinder pressure indicator

3/6/2020

- 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



Pipeline

3/6/2020

- 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

NIST

Sleeve Index System (SIS)

Australian Standard

NIST

Australian Standard

Diameter Indexed Safety System (DISS)

American standard

Schrader Indexed Probe

UK

DIN Wall Connector

German

Oxygen Pressure Failure Safety Device Fail-safe valve

3/6/2020

- *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*

Datex-Ohmeda machines-

"Pressure Sensor Shut off Valve"

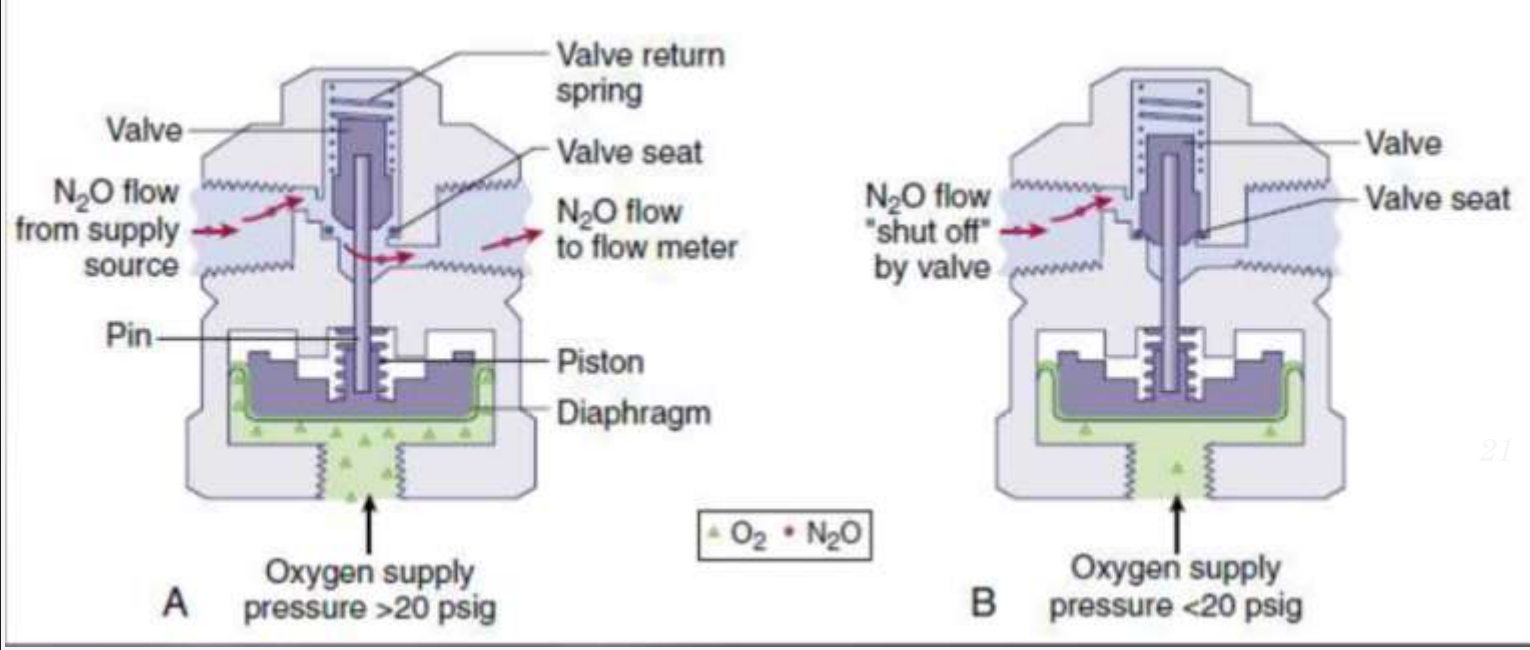
3/6/2020

Threshold principle

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

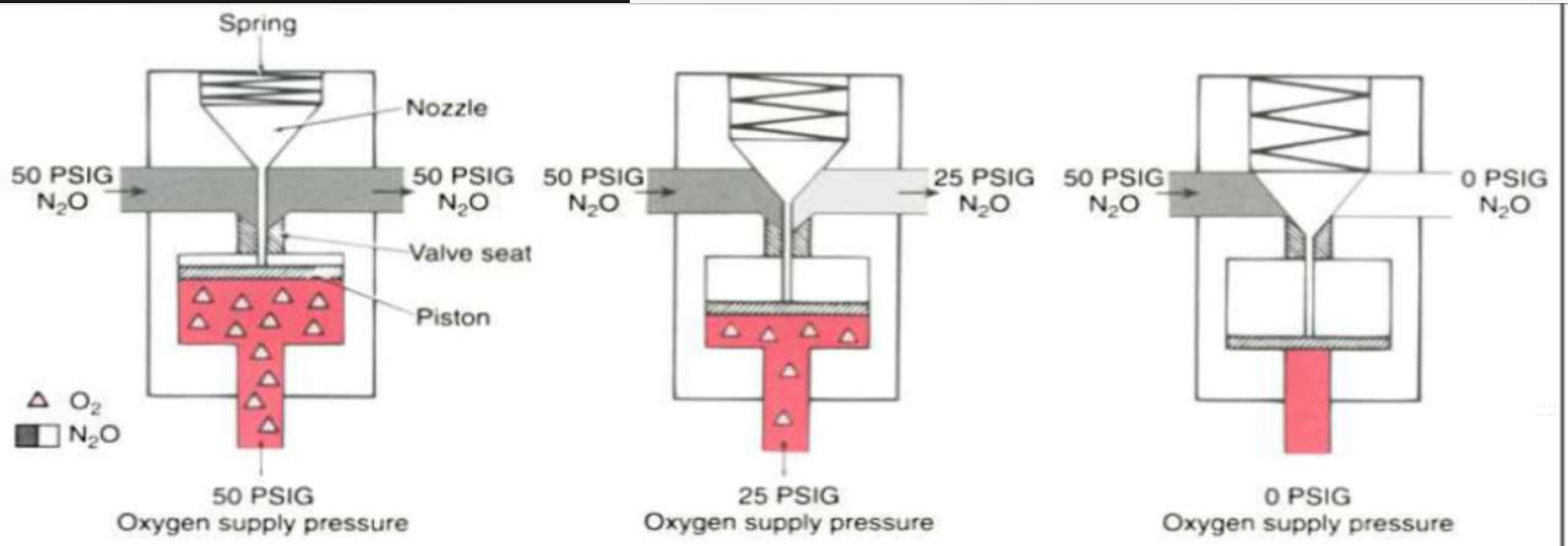
Oxygen supply pressure opens the valve, and the valve return spring closes the valve

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



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

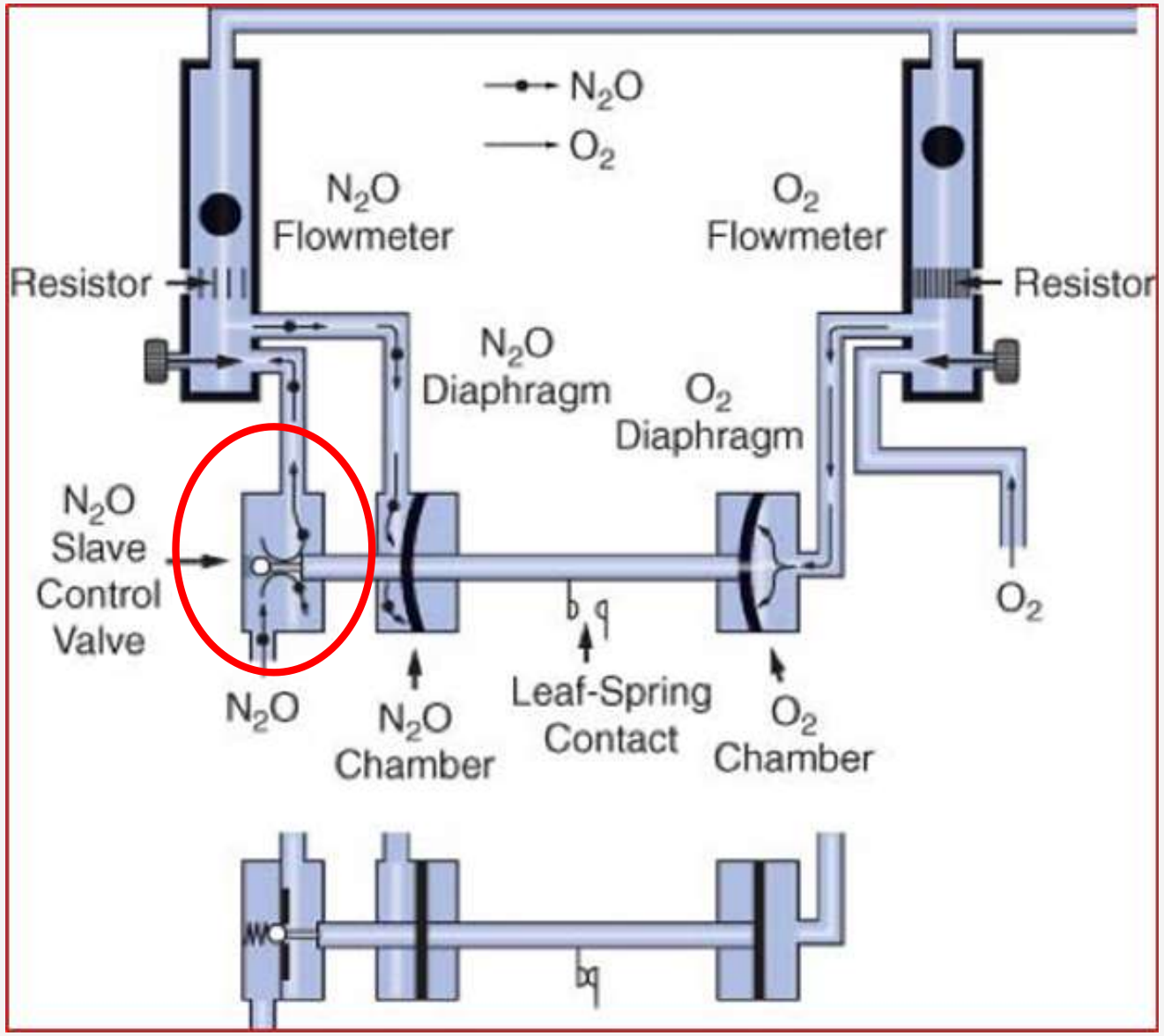


Dräger S-ORC - Fabius GS

Sensitive Oxygen Ratio Controller

3/6/2020

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.



Flowmeters

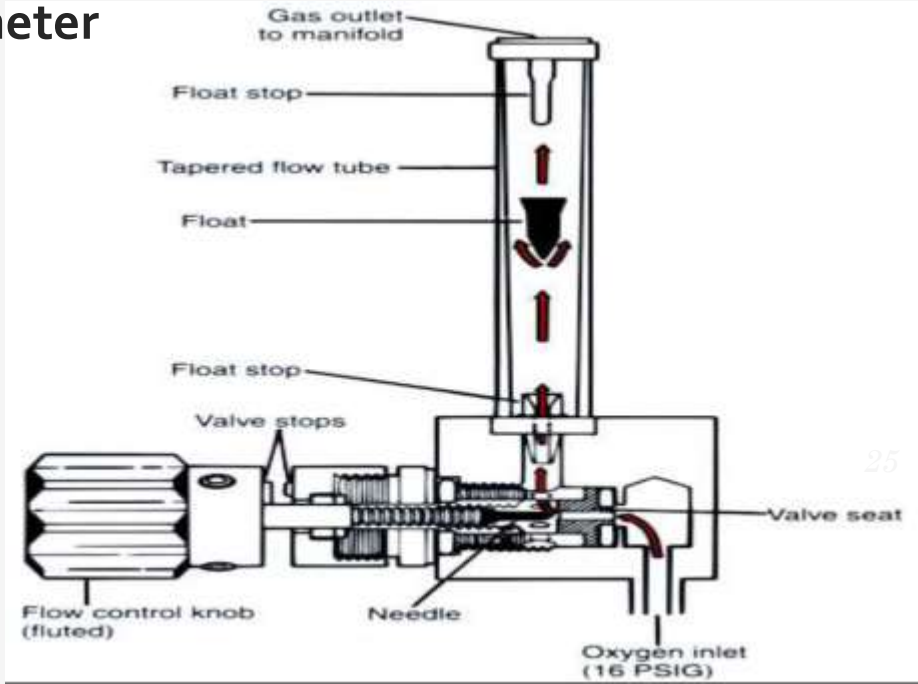
3/6/2020

- 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

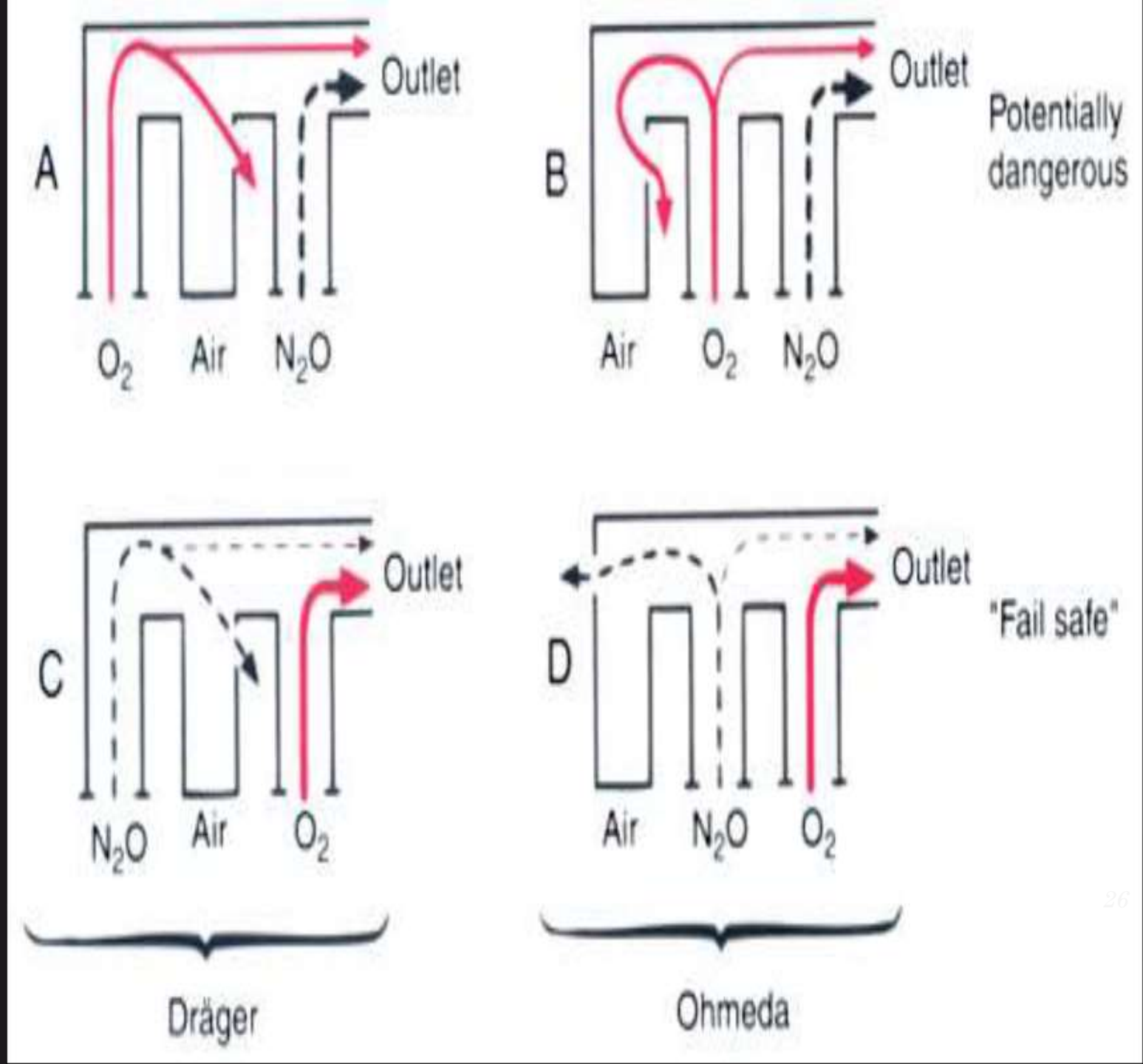
3/6/2020

- Bobbin rotates on flow which prevents it from sticking.
- Antistatic spray in flowmeter
- Master and slave safety mechanism for gas delivery between N_2O and O_2
- Downstream placement of oxygen flowmeter
- Radio florescent plastic sheet behind flow meter
- Float stop
- Auxiliary oxygen flowmeter



Flow meter arrangement

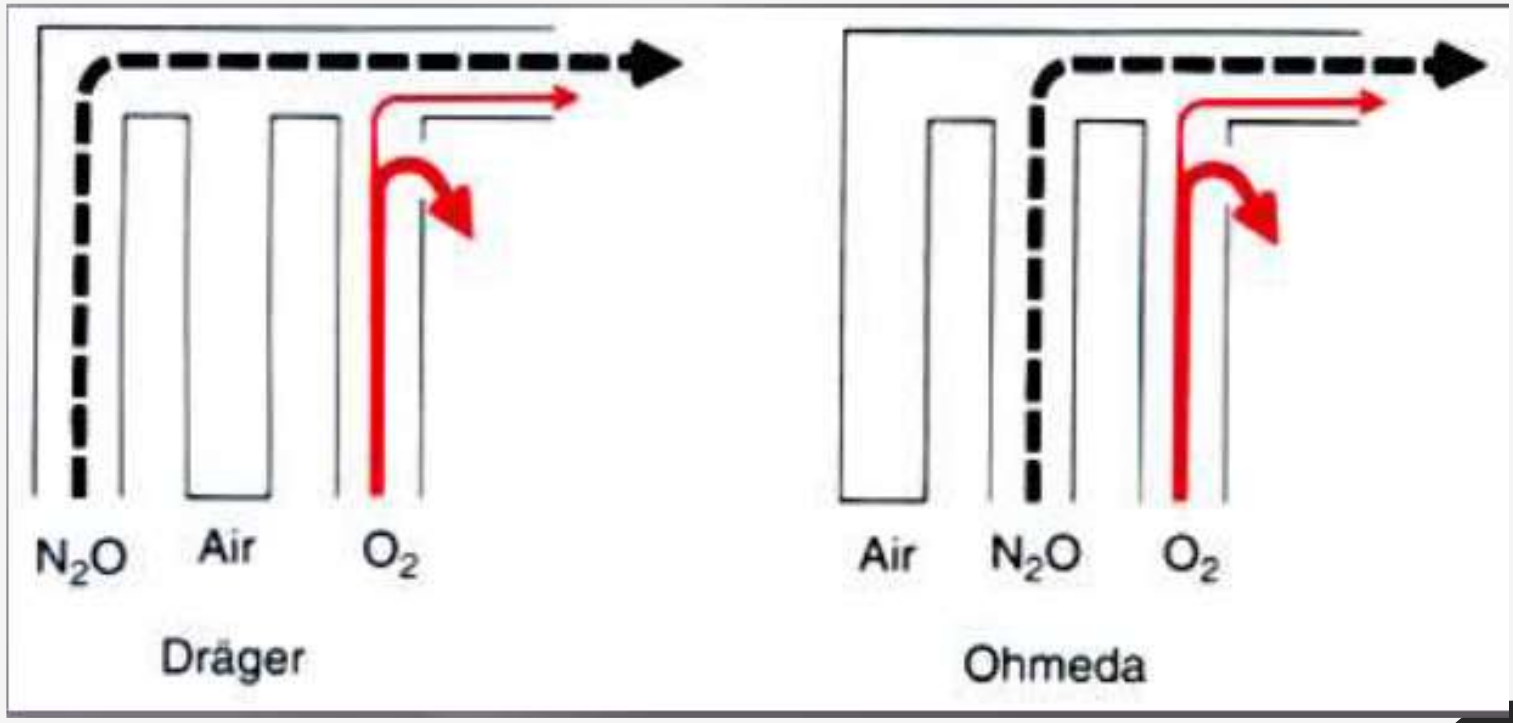
3/6/2020



Not fool proof

3/6/2020

- An oxygen leak from the flow tube can produce a hypoxic mixture, regardless of the arrangement of the flow tubes



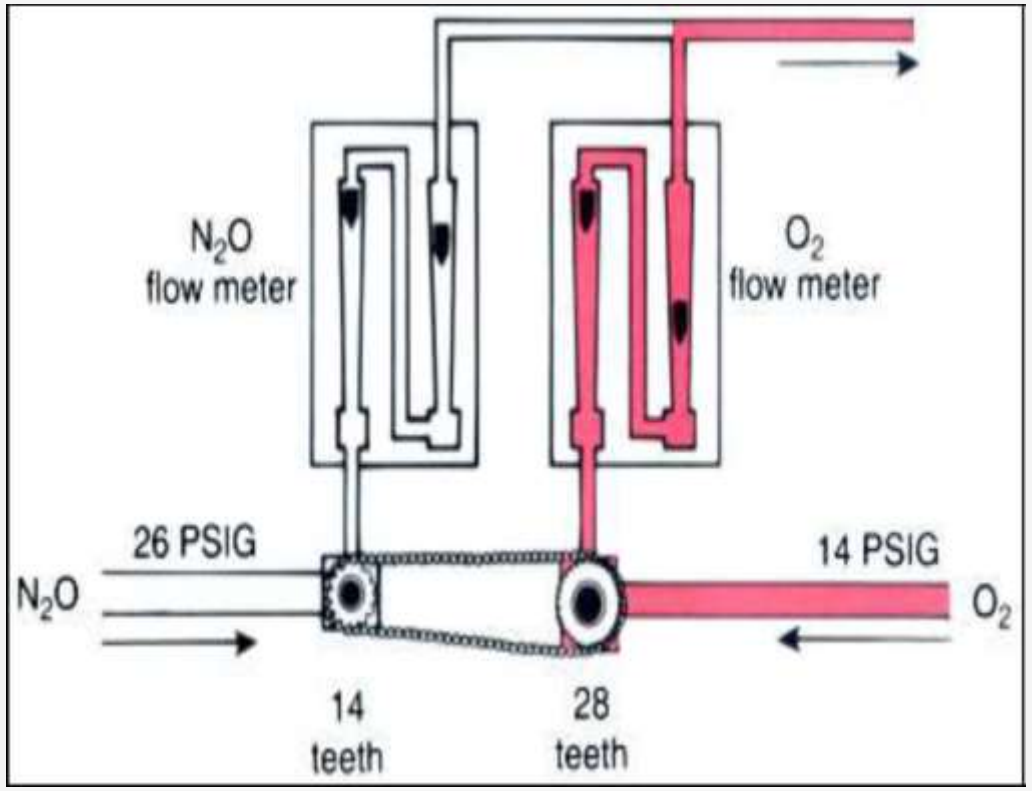
Hypoxia prevention safety devices

3/6/2020

- **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

N2O– oxygen flow ratio of 3 : 1

Datex ohmeda link 25



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.

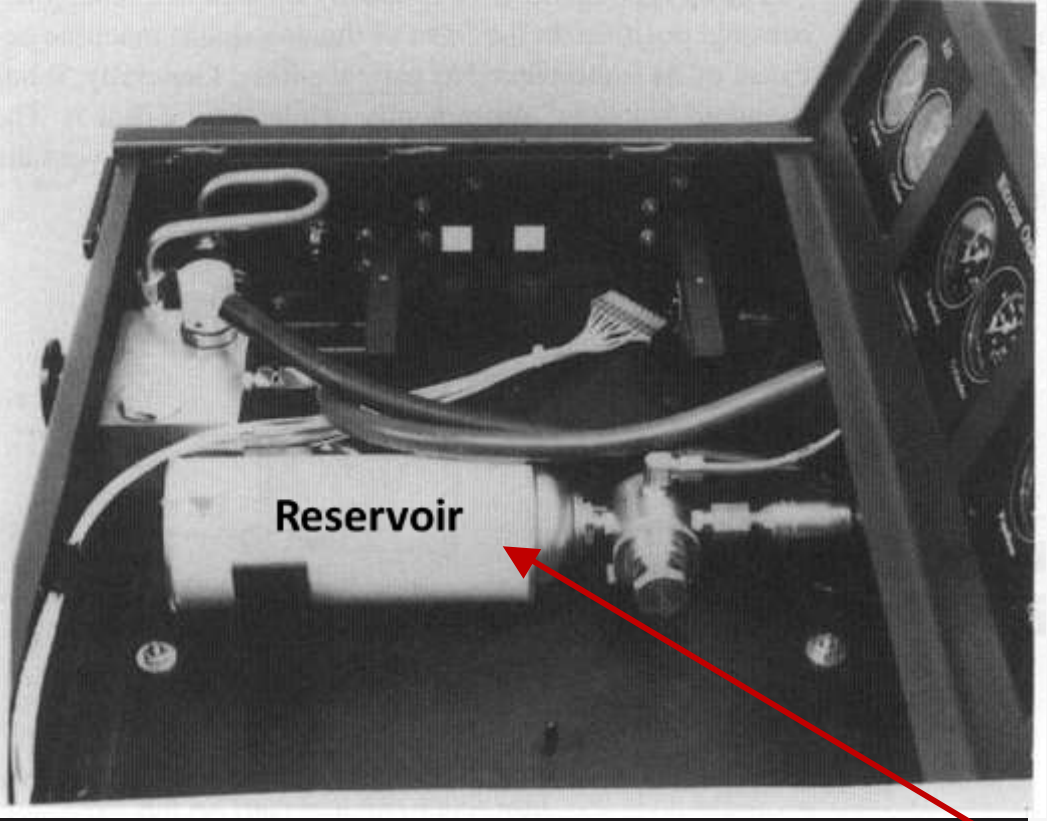
Oxygen supply failure alarm

3/6/2020

- 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

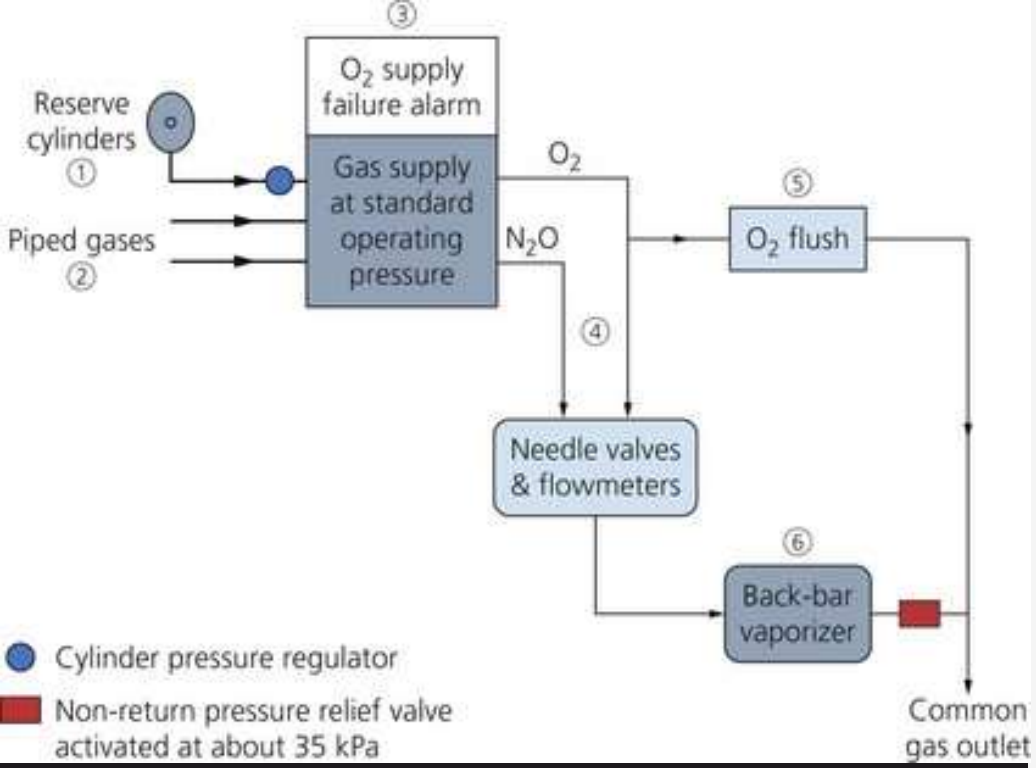


Ritchie whistle

3/6/2020

- 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

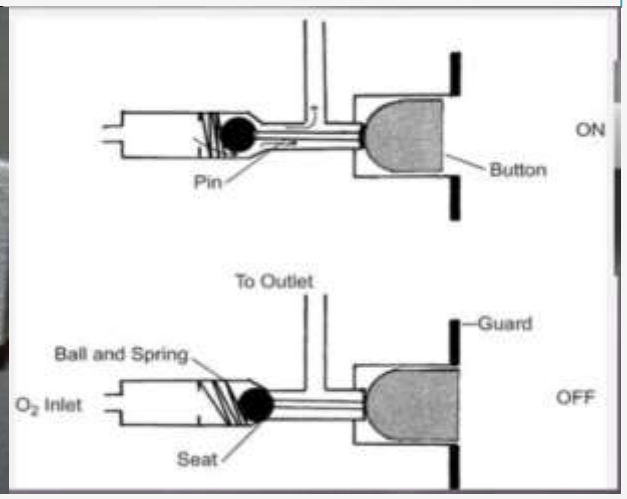
A reservoir is filled with O2 when the machine is turned on. When the O2 pressure reduces < 30-35 psig, the gas in the reservoir will pass through a clarinet-like reed sound.



Oxygen flush valve

3/6/2020

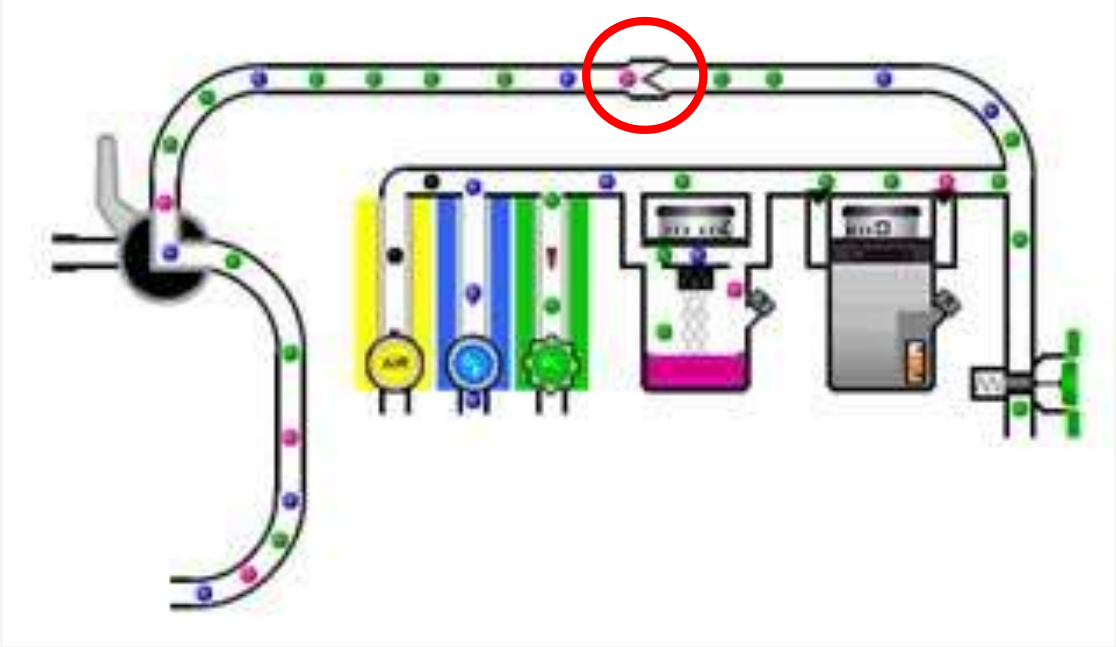
- Receives oxygen from the pipeline inlet or cylinder pressure regulator and directs a high unmetered flow directly to the common gas outlet
- Labeled "O2+."
- ***Activated regardless of whether the master switch is turned ON or OFF.***
- Flow between ***35 and 75 L/minute*** delivered
- The button is 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

3/6/2020

- 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



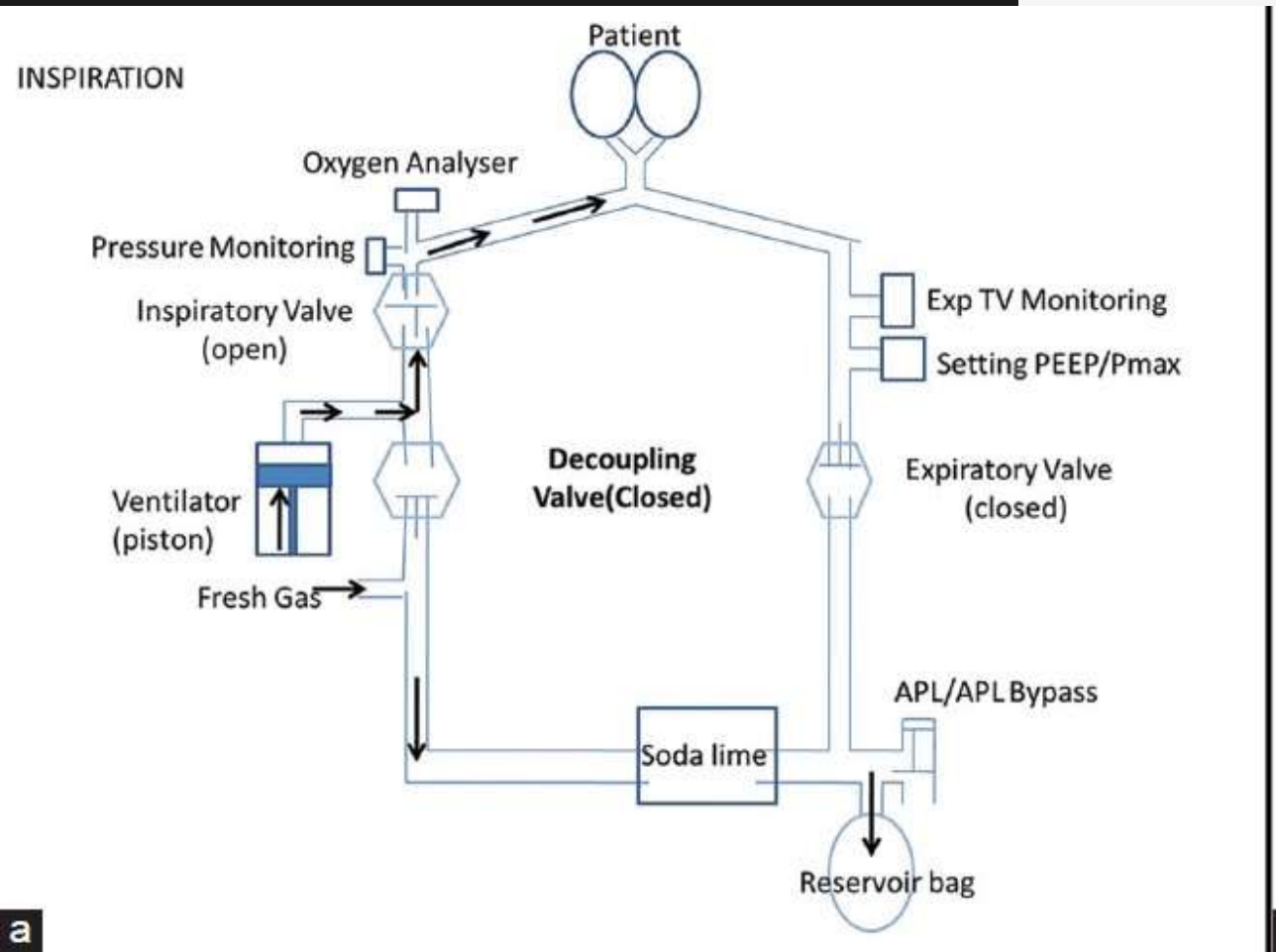
Safety features of newer machines

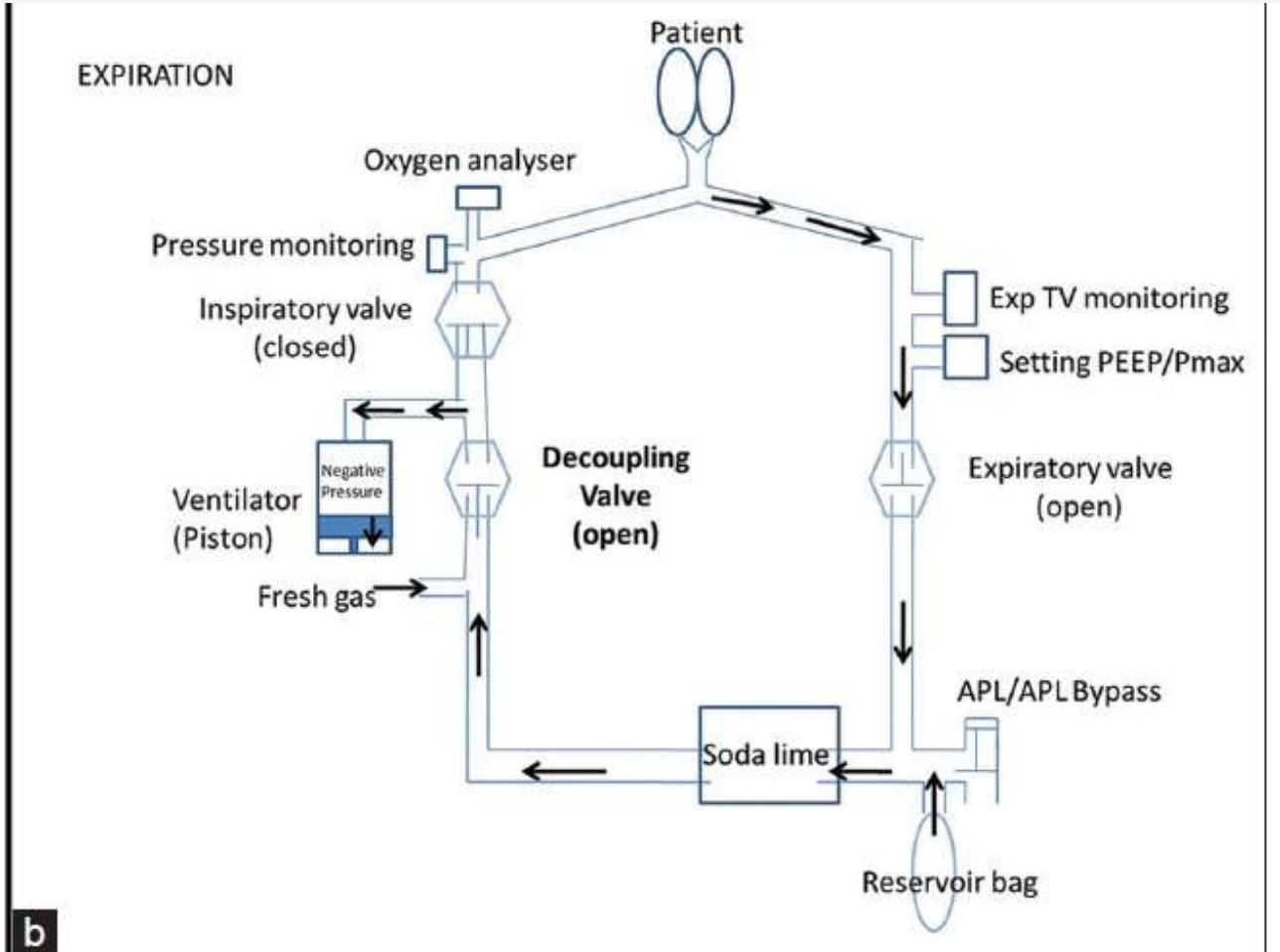
3/6/2020

- **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

Oxygen analyser

3/6/2020

- **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%.

Alternative oxygen control

3/6/2020

- There is always the possibility that the electronics will fail.
- Some machine provide an alternative means to administer oxygen
- This is separate from the auxillary 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

White is the international colour

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

Diameterindex safety system (DISS)and quick couplers

Non-interchangeable screw threadNIST connection to the anaesthetic machine

Colour coded Pipeline pressure indicators

Oxygen flush (35 - 75 litre min^{-1})control protected from accidental activation

Low pressure system

Mandatory minimum oxygen flow(200ml/min in Drager Primus)

Flow control knob for oxygen is largest, most protruding and fluted

Link 25: Mechanical linkage of O2 and N2O flowcontrol 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 the fillers/funnels that are agent specific

Colour coding of the anaesthetic agent is applied to the concentration dial and filling port

Pressure relief device(30–40 kPa) between vaporizer and CGO which vents to the atmosphere if dangerous pressures develop downstream due to occlusions

Electronic component

Computer-controlled anaesthesia systems have safety self checkout 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

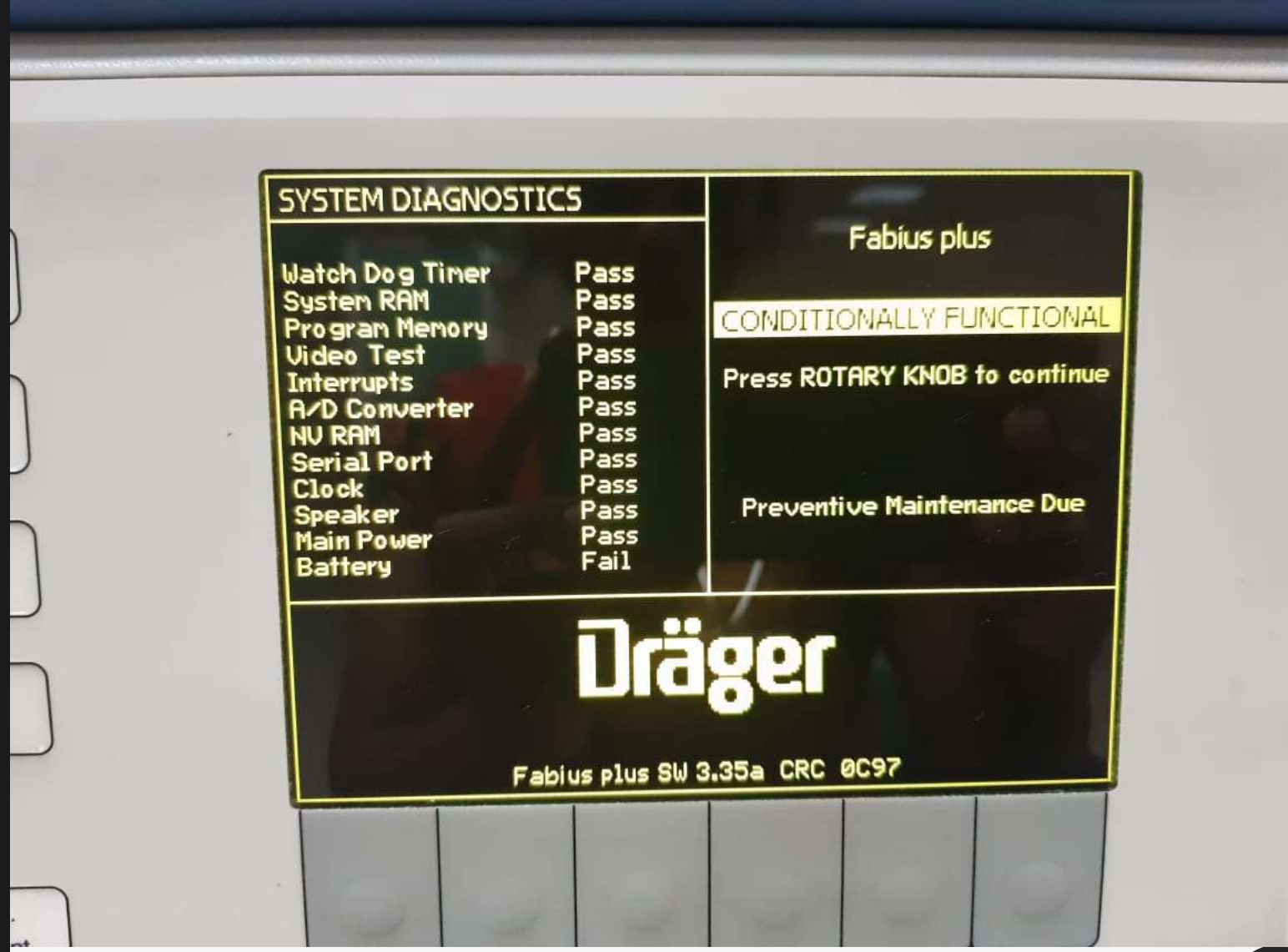
4.Transfer tubings are of different colour and configuration than those of breathing gases, kink resistant and occlusion proof.

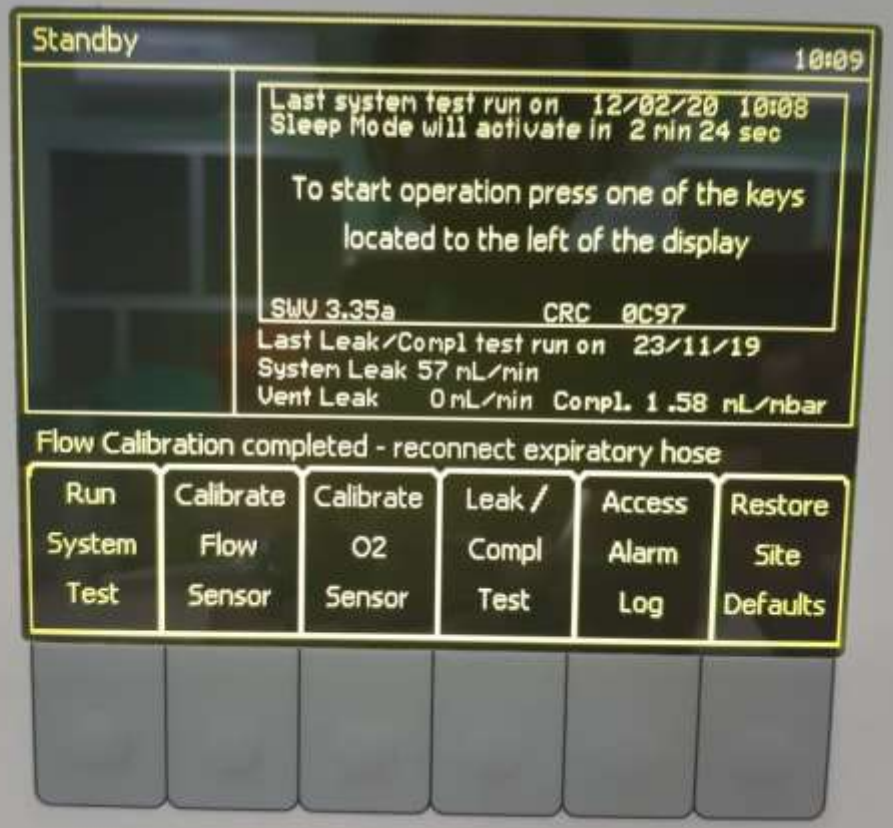
Checklist

Mandatory

Electronic Checking

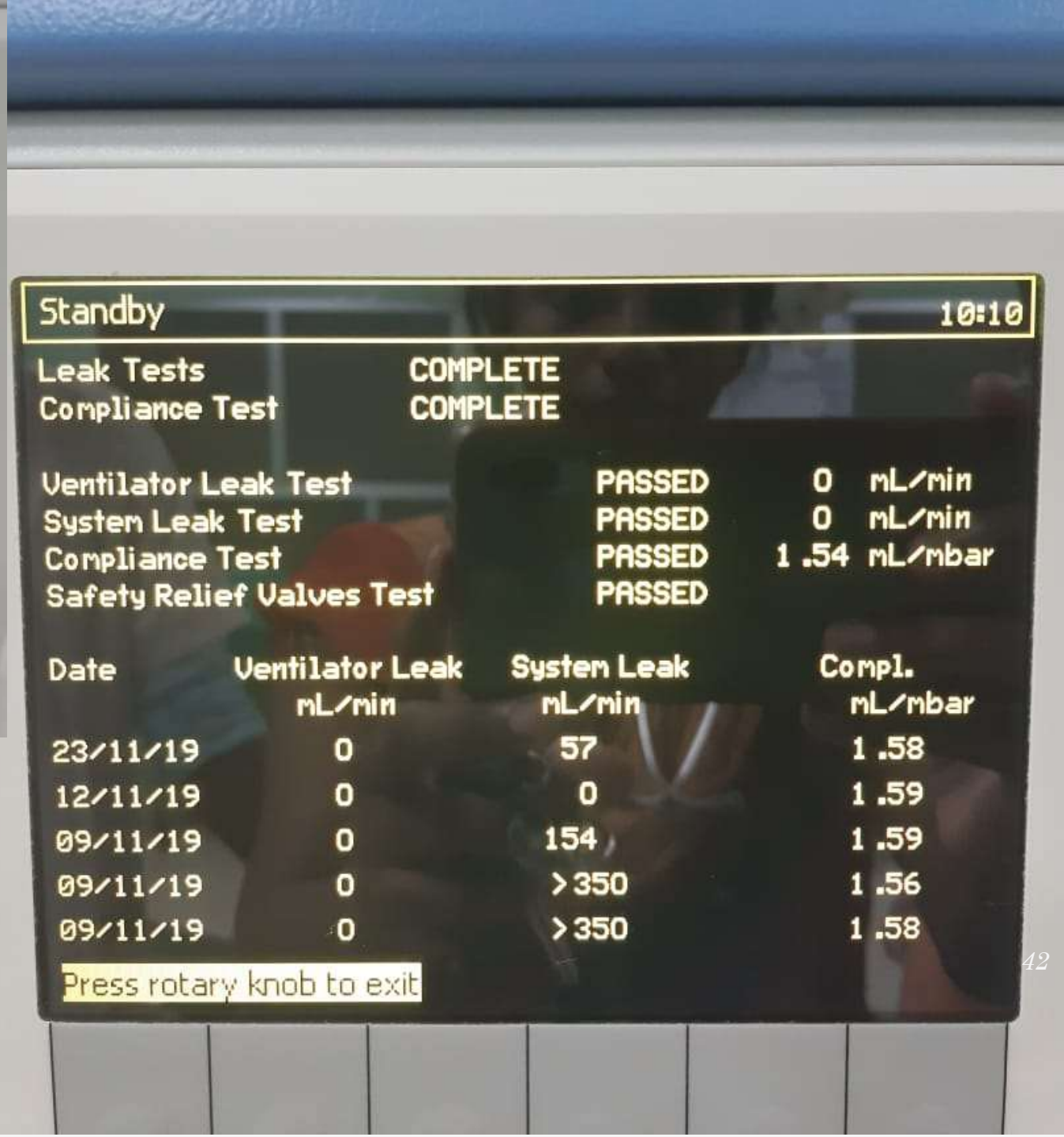
3/6/2020





Electronic Checking

3/6/2020



Anaesthesia apparatus checkout Recommendation, 2008

ASA Guidelines for Pre-anesthesia Checkout

3/6/2020

TO BE COMPLETED DAILY

ITEM TO BE COMPLETED
Item #1: **Verify Auxiliary Oxygen Cylinder and Self-inflating Manual Ventilation Device are Available & Functioning**
Item #2: **Verify patient suction is adequate to clear the airway**
Item #3: **Turn on anesthesia delivery system and confirm that ac power is available.**
Item #4: **Verify availability of required monitors, including alarms**
Item #5: **Verify that pressure is adequate on the spare oxygen cylinder mounted on the anesthesia machine**
Item #6: **Verify that the piped gas pressures are ≥ 50 psig**
Item #7: **Verify that vaporizers are adequately filled and, if applicable, that the filler ports are tightly closed.**
Item #8: **Verify that there are no leaks in the gas supply lines between the flowmeters and the common gas outlet**
Item #9: **Test scavenging system function.**
Item #10: **Calibrate, or verify calibration of, the oxygen monitor and check the low oxygen alarm.**
Item #11: **Verify carbon dioxide absorbent is not exhausted**
Item #12: **Breathing system pressure and leak testing.**
Item #13: **Verify that gas flows properly through the breathing circuit during both inspiration and exhalation.**
Item #14: **Document completion of checkout procedures.**
Item #15: **Confirm ventilator settings and evaluate readiness to deliver anesthesia care. (ANESTHESIA TIME OUT)**

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.

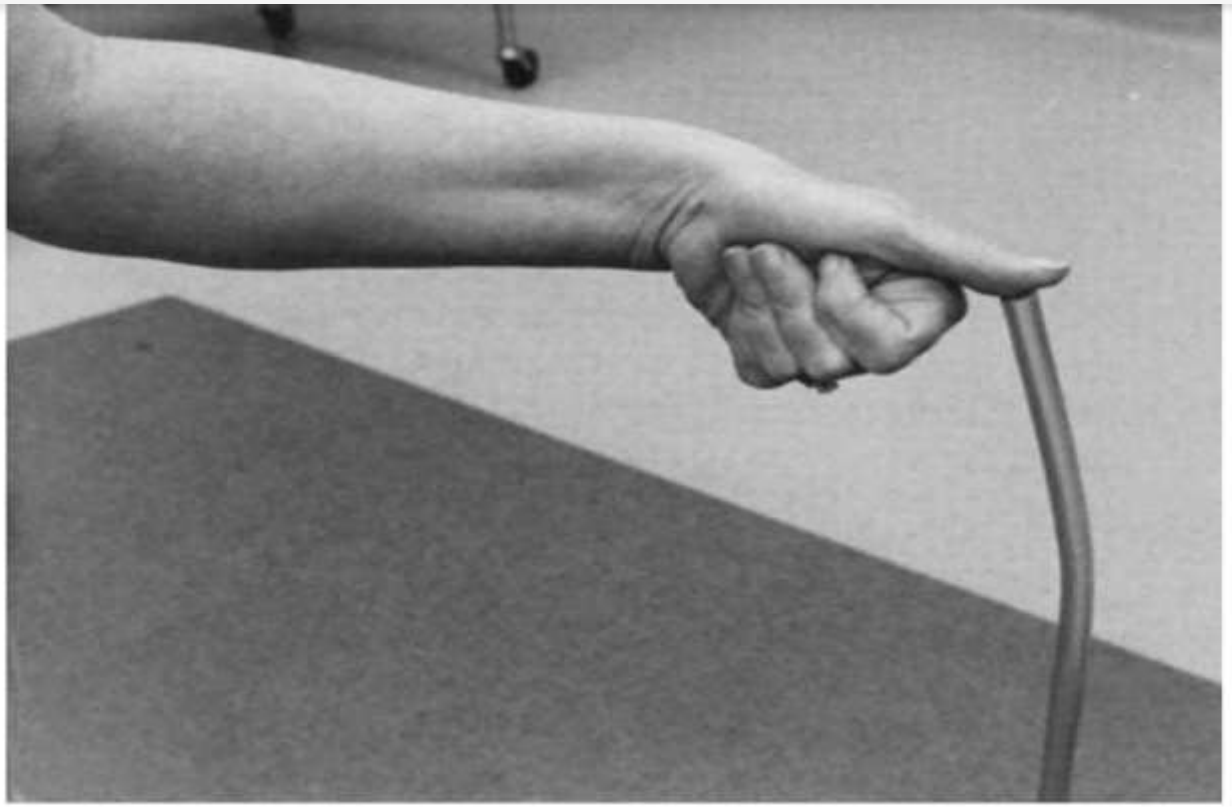


FIGURE 33.5 Check of suction. The strength of the vacuum is tested by determining that the weight of the suction tubing can be supported at waist height by the seal between the tubing and the underside of a finger. If the vacuum is unsatisfactory, the tubing will not remain in contact with the finger.

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.

3/6/2020

Frequency: Daily

- The FDA check list recommends that the cylinder be atleast 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.

3/6/2020

Frequency: Daily and whenever a vaporizer is changed

- ***UNIVERSAL LEAK TEST***

Verify that the machine master switch and flow control valves are OFF.

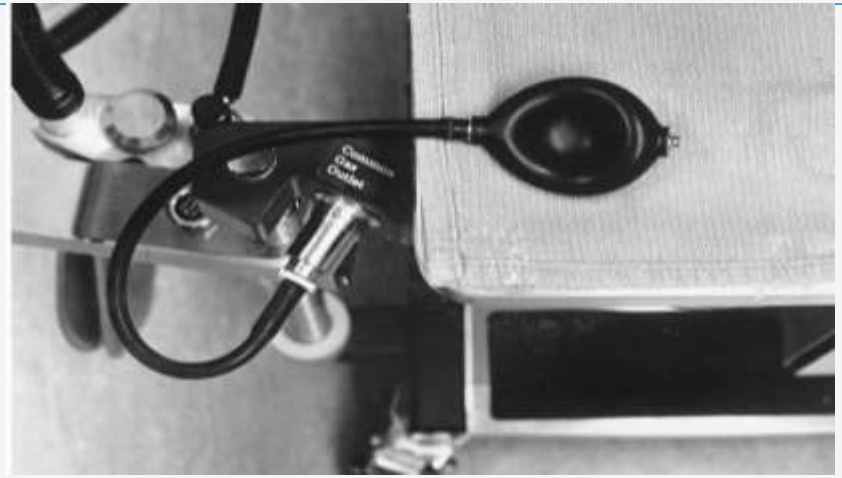
Attach a "suction bulb" to the common (fresh) gas outlet.

Squeeze the bulb repeatedly until fully collapsed.

Verify that the bulb stays fully collapsed for atleast 10 seconds.

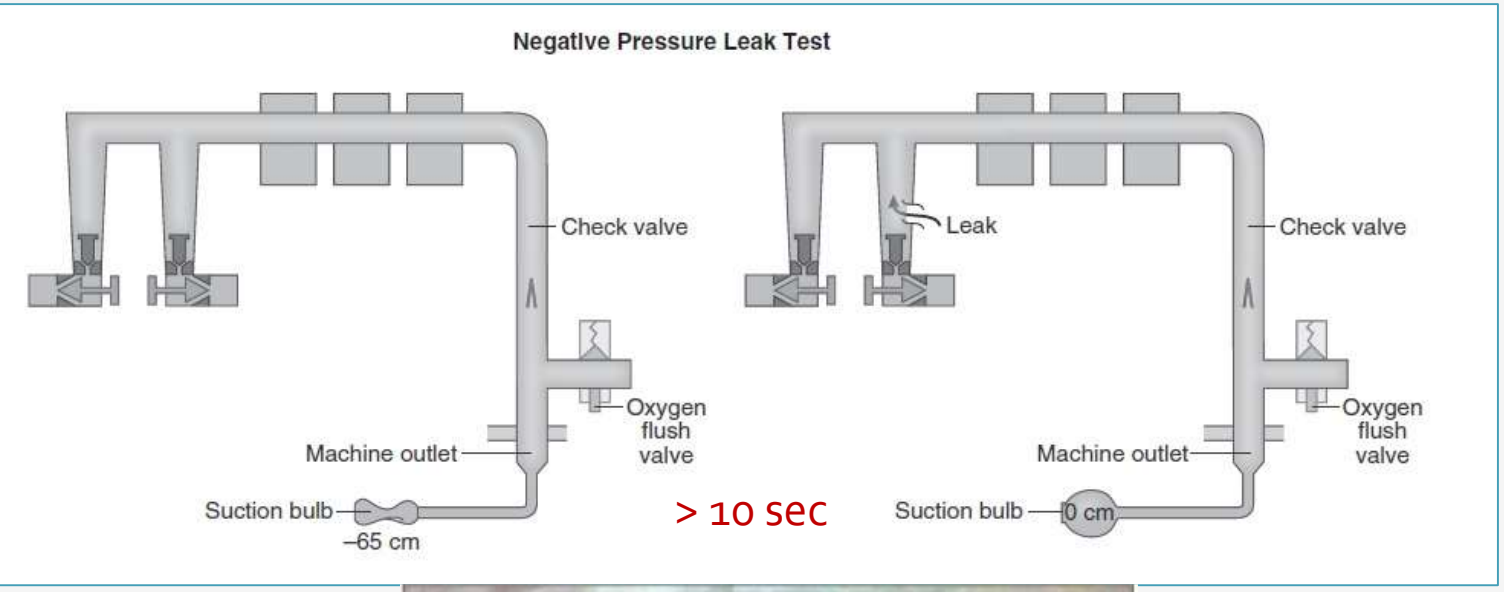
Open one vaporizer at a time and verify the bulb stays collapsed.

Remove the suction bulb and reconnect the fresh gas hose.

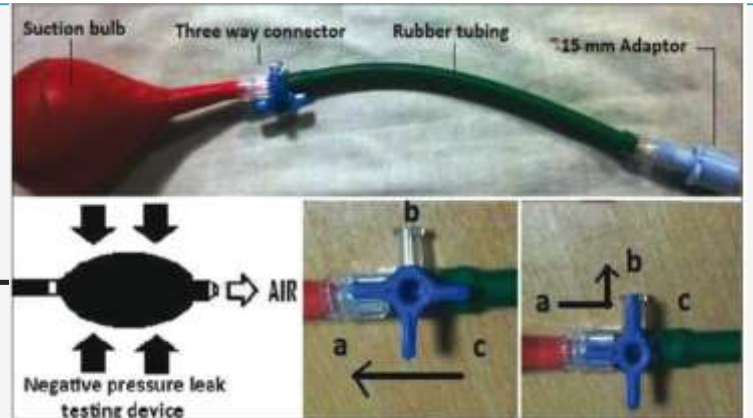


Checking Low Pressure System

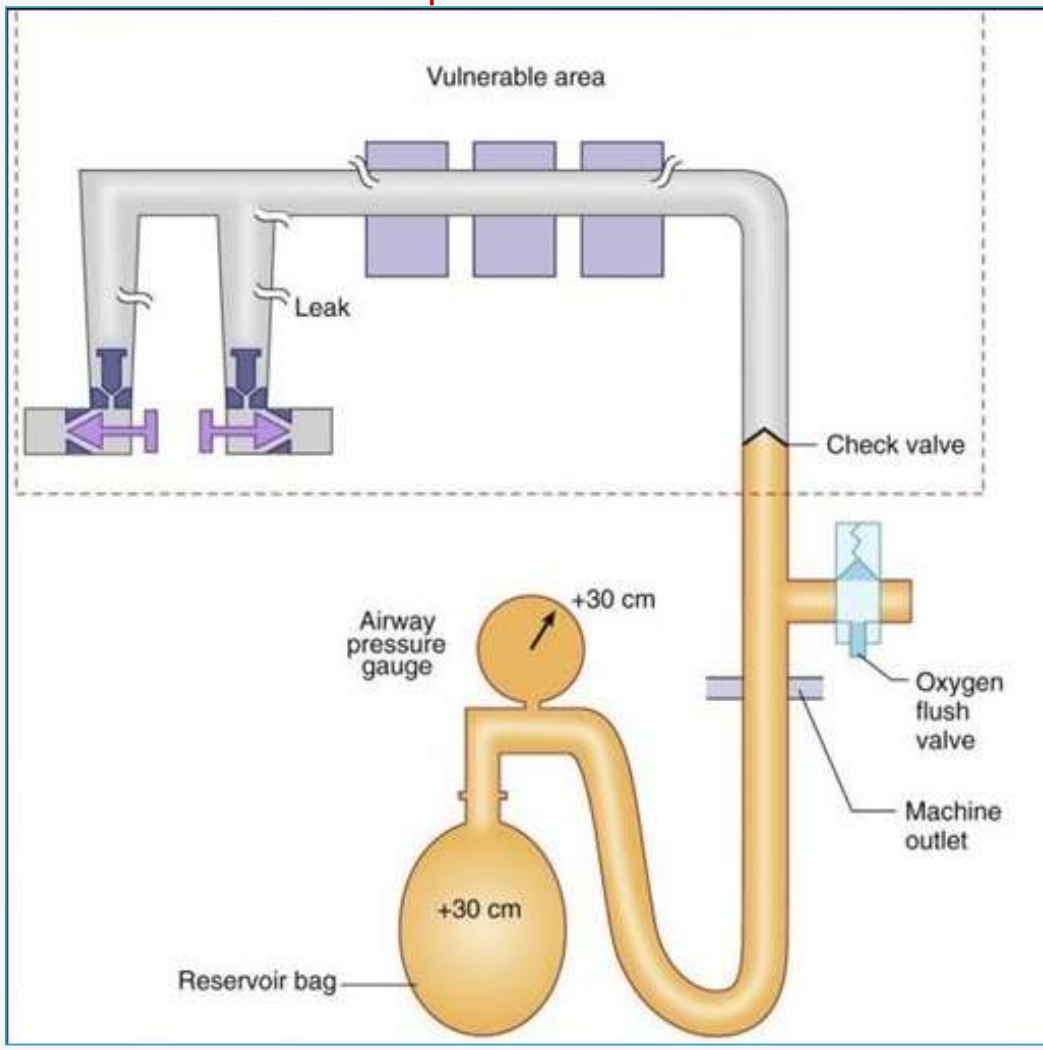
The Negative-pressure leak test



> 10 sec



Positive-pressure leak test



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 **<10cm H2O**.

10: Calibrate or verify calibration of the oxygen monitor and check the low oxygen alarm.

3/6/2020

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%.**

11: 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 CO_2 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 CO_2 concentration > 0 can also indicate exhausted absorbent.

12: Breathing system pressure and leak testing

3/6/2020

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

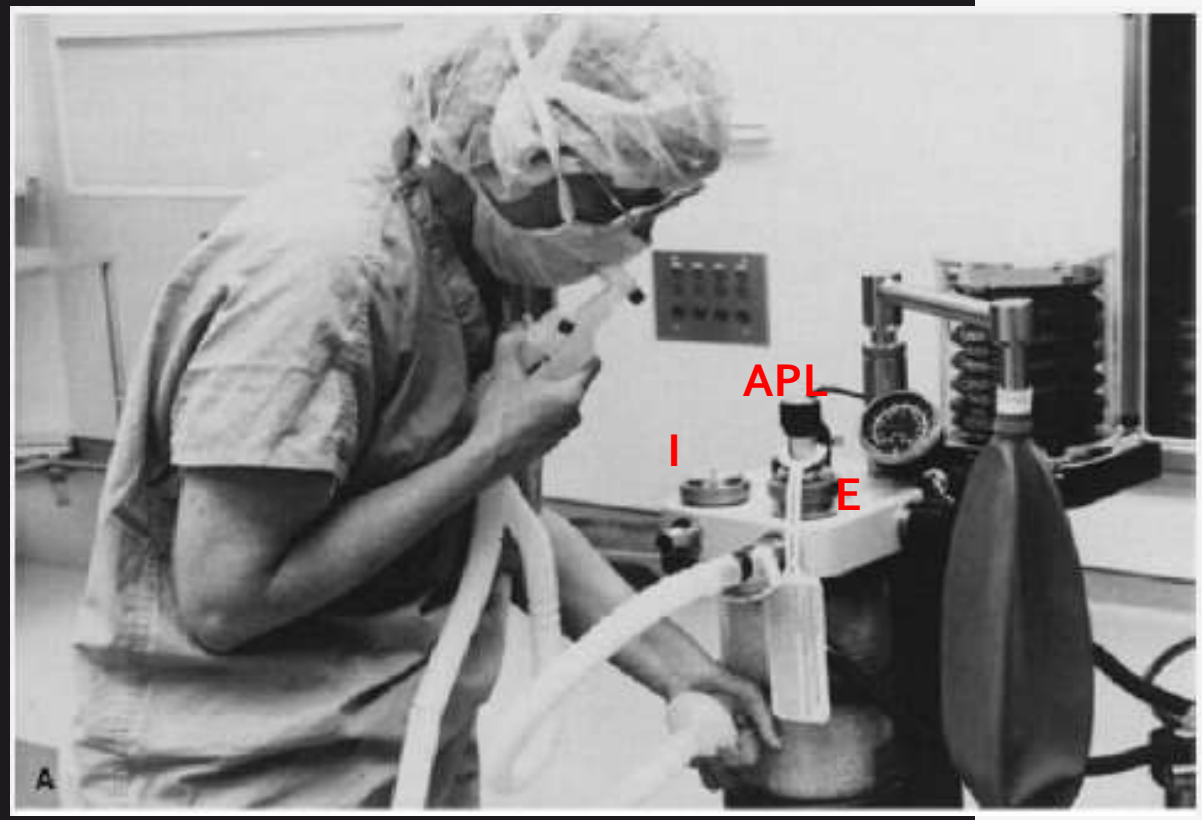
3/6/2020

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

Inspiratory unidirectional valve

Expiratory unidirectional valve

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)

3/6/2020

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

TO BE COMPLETED PRIOR TO EACH PROCEDURE

ITEM TO BE COMPLETED
Item #2: **Verify patient suction is adequate to clear the airway**
Item #4: **Verify availability of required monitors, including alarms.**
Item #7: **Verify that vaporizers are adequately filled and if applicable that the filler ports are tightly closed.**
Item #11: **Verify carbon dioxide absorbent is not exhausted**
Item #12: **Breathing system pressure and leak testing.**
Item #13: **Verify that gas flows properly through the breathing circuit during both inspiration and exhalation.**
Item #14: **Document completion of checkout procedures.**
Item #15: **Confirm ventilator settings and evaluate readiness to deliver anesthesia care. (ANESTHESIA TIME OUT)**

THANK YOU

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

Every Sunday 9 PM – Rapid Fire Quiz
Exam case discussions

257 × 6 = 1542