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A whistle-stop tour of the anaesthetic machine

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ABSTRACT: The anaesthetic machine is vital for providing safe anaesthesia for veterinary patients; however, its importance is often overlooked. When purchasing a new anaesthetic machine, the buyer is faced with a wide range of options. Often the price range is dictated not only by additional features, but also additional safety mechanisms. This article aims to familiarise the reader with the key components of an anaesthetic machine and the additional components that various machines may boast. Care and maintenance will be covered, as will a description of safety checks. A discussion of medical gas provision and anaesthetic gas scavenging systems will also be provided.

Gas supply

Anaesthetic machines provide medical gases to patients from two main sources – cylinders or pipeline gases (oxygen can also be provided from an oxygen concentrator). The most common gases used in modern practice are oxygen, nitrous oxide and medical air.

Cylinders are generally made from molybdenum steel, but lighter weight aluminium versions are also available for portability or MRI. Cylinders are seamless, as they contain gases at very high pressures; they are examined by the manufacturer at regular intervals and a plastic disc at the cylinder neck shows when this is next due.

The cylinder valve is designed to be gas specific and has the relevant gas chemical formula engraved into it. Cylinders are colour-coded nationwide and also show a clear label of contents and safety information at the neck.

Piped medical gases are often combined with an active scavenging system and so are known as 'piped medical gas & vacuum' (PMGV) by suppliers. One central gas source provides several locations via a network of copper alloy pipes. The central source is often large-sized cylinders, but can involve liquid oxygen contained in a vacuum-insulated evaporator (VIE) for larger practices (Figures 1 & 2).

Cylinder manifolds are normally divided into primary and secondary banks, with a reserve cylinder. As a safety mechanism, pipeline wall outlets and gas pipes are colour coded for each gas and only accept the correct gas hose (Figures 3, 4 & 5).

Standard components

Cylinders are attached into cylinder yokes on the anaesthetic machine using the pin-index system – preventing the wrong gas being attached. Likewise, for attachment of pipeline supplies, each gas inlet is threaded to allow only the correct gas hose (Figures 6 & 7).

Pressure gauges show the incoming pressure from either the cylinder or pipeline for each gas (Figure 8). For most gases the cylinder pressure will drop in a linear fashion as the gas is exhausted, but as nitrous oxide is stored as a liquid with a vapour phase, the pressure will continuously show 440kPa until all the liquid has vaporised, towards the very end of use.

Pipeline pressures should be 400kPa for medical use or 700kPa in the case of medical air used for driving power tools.

Figure 1: Nitrous oxide manifold system

Figure 2: Liquid oxygen VIE

Figures 3, 4, 5: Oxygen and nitrous oxide hoses and wall outlets – note the differing collar sizes between gases

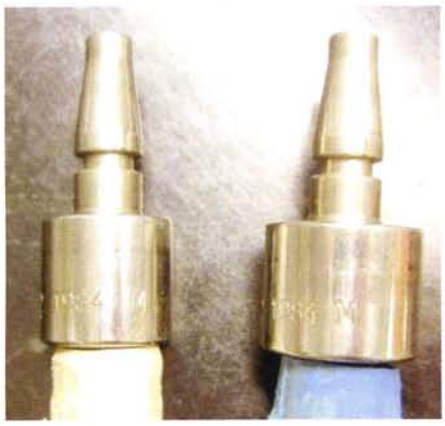
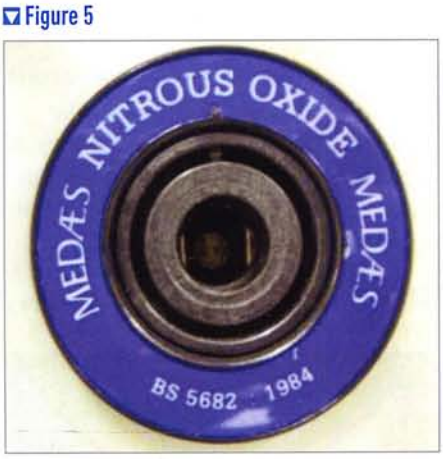


Figure 4

Figure 5

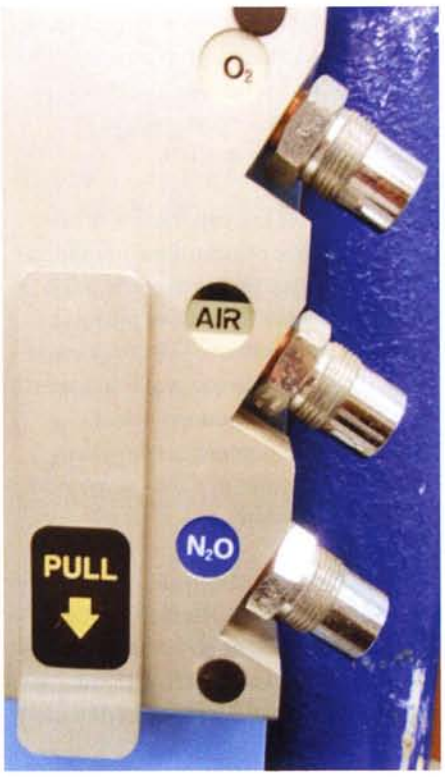


Downstream from each cylinder yoke is a pressure-reducing valve (Figure 9). The purpose of this valve is to reduce the high pressure of the cylinder gas to a workable pressure, similar to pipeline pressure. The valve also regulates a constant pressure of gas to the anaesthetic machine as the cylinder empties or environmental conditions change.

A one-way valve is situated in the cylinder supply line to prevent gas escaping out of an empty cylinder yoke or moving from one cylinder into another.

To adjust the flow of each gas, every anaesthetic machine has a flow control valve and a flowmeter (Figure 10). The flow control valve is a needle valve located at the bottom of the flowmeter. As a safety device, the oxygen valve usually protrudes further than any other valves and has a more obvious texture – all valves are labelled and colour coded.

Figures 6, 7: Piped gas inlets on an anaesthetic machine – note different-sized connections



The flowmeter (or rotameter) is a tapered tube made of transparent plastic or glass. It contains a bobbin which rises in the flowmeter as the flow of gas increases; this is used to measure the gas flow against calibrated markings on the flowmeter.

Bobbins can be various shapes, but readings are usually taken from the top – apart from spherical bobbins where it is taken from the centre. To prevent an accidental hypoxic mixture being provided if a flowmeter cracks, oxygen is the last gas to be added to the 'back-bar' (although the flowmeter is situated on the furthest left in UK machines).

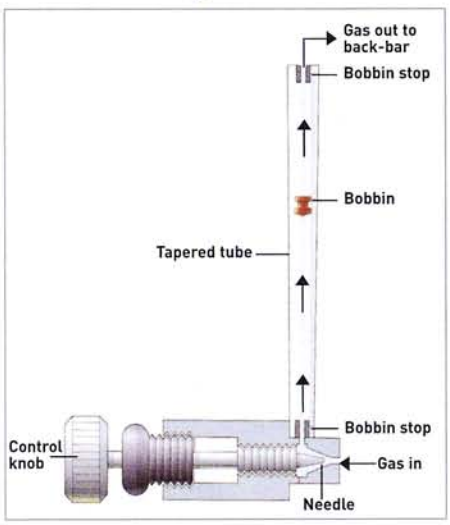
Gas leaves the top of the flowmeter and enters the back-bar, which supports the flowmeter and vaporisers. With older machines vaporisers are permanently secured on to the back-bar, but more modern machines allow vaporisers to be removed more easily, allowing different agents to be used.

Figure 8: Oxygen pressure gauges

The most commonly used vaporisers in veterinary anaesthesia are plenum temperature-compensated (TEC Mk 3 & 4) out-of-circuit vaporisers for isoflurane or sevoflurane.

Figure 9: Pressure-reducing valves

Figure 10: Diagram of flow control valve and flowmeter (image courtesy of Al-Shaikh & Stacey)



The role of the vaporiser is to add a controlled amount of anaesthetic vapour to the fresh gas mixture in the back-bar. As gas enters the vaporiser it is split, depending on the dial setting and temperature. One stream flows through the bypass chamber, and the second smaller stream flows into the vaporisation chamber where it becomes saturated with agent. The saturated gas then reunites with the bypass gas and re-enters the back-bar. If the vaporiser is turned off, no gas enters it at all.

Figure 11: Non-return pressure relief valve

Vaporisers are always gas specific and most have safety mechanisms to prevent accidental filling with the wrong agent. Vaporisers should never be tipped up or severely tilted as spillage of anaesthetic agent into the bypass channel results in dangerously high concentrations of agent leaving the vaporiser.

Downstream of the vaporiser – either on the back-bar or near the common gas outlet – is a non-return pressure relief valve (Figure 11). This valve opens at pressures greater than 35kPa to prevent damage to the vaporiser and flowmeter. Also near the common gas outlet (although sometimes located on the front of the machine) is the emergency oxygen flush button.

If this is depressed, oxygen flows directly from the pipeline or cylinder supply, bypassing the flowmeter and vaporiser. Therefore, it is not suitable for filling a breathing system with anaesthetic vapour.

Indeed, its use at all when a patient is connected to the machine is contraindicated because oxygen will be delivered at flows of 30-40l/min and at a pressure of 400kPa thereby putting the patient's airways at severe risk of barotrauma. Its use should be restricted to the flushing of breathing systems when not connected to a patient.

The common gas outlet may either be fixed or swivel. The latter reduces the risk of disconnection or kinked tubing when either the patient or anaesthetic machine is moved. The common gas outlet is a standard size (22mm male/15mm female) allowing for connection of breathing apparatus.

Additional components and modifications

All anaesthetic machines should be fitted with a working oxygen supply failure alarm. It is not uncommon, however, for this to be found to be faulty on older un-serviced machines, or missing altogether on smaller, cheaper machines.

The oxygen alarm should be fitted downstream of pressure-reducing valves and should provide a recognisable audible alarm when oxygen pressure falls. Ideally, it should automatically cease the provision of other gases. It should be gas-driven and not rely on any other power source.

Anaesthetic machines are designed just to provide only selected gases and this can be adjusted by a qualified engineer. Some machines may only provide oxygen, whilst others may provide a wide range – sometimes including 'historically used' gases.

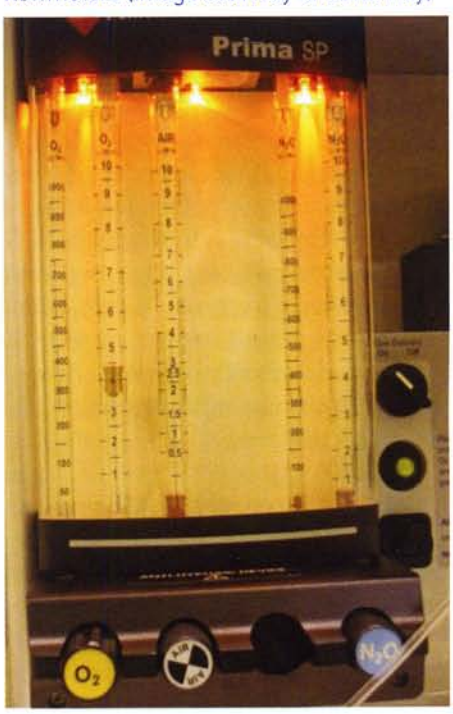
Anaesthetic machines may be designed to allow just cylinders, just pipeline gases or both. It is recommended that where pipeline gases are used, the anaesthetic machine still has a reserve oxygen cylinder yoke to allow oxygen to be provided if there were ever to be a problem with the central pipeline system.

To minimise risk of hypoxic gas mixtures being delivered to the patient, some machines will mechanically link flow-control valves to ensure that a minimal ratio of oxygen to other gases is provided.

Machines designed for low flow anaesthesia may have dual flowmeters situated in series. This allows gas to be delivered in precise increments up to 1000ml from the first flowmeter, and then larger flow rates from the subsequent flowmeter – one flow-control valve controls both flowmeters (Figure 12).

Some anaesthetic machines can be fitted to allow two or more vaporisers to be situated on the back-bar. A rod system in modern vaporisers (TEC 4+) prevents more than one vaporiser being turned on at a time.

Figure 12: Dual oxygen and nitrous oxide flowmeters (image courtesy of Carol Hoy)



Auxiliary gas sockets may be fitted – often to the side or underside of the machine body – to allow attachment of gas-driven ventilators, or to provide an additional medical suction feature to the anaesthetic machine.

Scavenging systems

There are three main types of system to scavenge waste anaesthetic gases.

Passive systems rely on the movement of gases from the breathing system, driven by either the patient's respiratory movement or the gas flow rate from the anaesthetic machine. Often this system simply consists of a length of tubing attached to an outside wall.

Active scavenging systems involve a fan or pump to create a vacuum that actively draws waste gases away and delivers them into the outside atmosphere (Figure 13).

The third system, the Aldasorber, is a derivative of the passive system, but contains a canister of activated charcoal to store waste gases. It does not absorb nitrous oxide, however, and requires frequent replacement.

Care and maintenance

A safety check should be carried out on each anaesthetic machine prior to its use (Table 1).

Anaesthetic machines should be wiped over with standard veterinary disinfectants after each use. Lubricants and alcohol (surgical spirit) should never be used on the machine because of the risk of fire – this includes alcohol-based hand sanitizers (hands should be fully dry).

Qualified engineers should make all repairs and service the machine annually or biannually, depending on its use.

Figure 13: Active scavenging system: anaesthetic gas receiving system

TABLE 1 Routine safety check on an anaesthetic machine

1. Ensure all flow control valves and vaporisers are turned off.
2. Check each cylinder is securely fastened to the machine. Open each cylinder in turn and check the pressure, label each cylinder 'full' or 'in use'. Replace any that are empty. Connect pipeline gases and check the pressure is reading 400kPa.
3. Slowly turn the oxygen flow control valve on and then back off. The function should be smooth, with the bobbin returning to zero. Repeat with other gases.
4. Turn the oxygen flowmeter on and disconnect oxygen supply. Check the oxygen failure alarm sounds. Turn off the flowmeter and reconnect the gas supply.
5. Check the vaporiser is securely fastened to the machine and contains enough agent. Turn the dial all the way on and then off again. The function should be smooth.
6. Check the emergency oxygen supply functions.

Useful reading

ALIBHAI, H. (2007) The Anaesthetic Machine and Vaporizers. In: Seymour, C. & Duke-Novakovski, T. eds. BSAVA Manual of Canine and Feline Anaesthesia and Analgesia. 2nd ed. Gloucester, England: British Small Animal Veterinary Association, 2007.

AL-SHAIKH, B. and STACEY, S. (2007) Essentials of Anaesthetic Equipment. 3rd ed. Edinburgh: Churchill Livingstone, 2007.

These multiple choice questions are based on the above text.
Answers appear on page 36.

1. **Which of the following cannot provide oxygen to an anaesthetic machine:**
   a. **ventilator**
   b. **cylinder**
   c. **pipeline system**
   d. **oxygen concentrator**

2. **What is the 'Pin index' system used for:**
   a. **safely attaching cylinders to anaesthetic machines**
   b. **turning a cylinder on and off**
   c. **categorising cylinder types**
   d. **removing a cylinder from an anaesthetic machine**

3. **What pressure should pipeline gas be at for medical use:**
   a. **400kPa**
   b. **4000kPa**
   c. **700kPa**
   d. **7000kPa**

4. **What is not a function of a pressure reduction valve or the one-way valve:**
   a. **preventing a fire hazard**
   b. **providing a workable pressure to the anaesthetic machine**
   c. **preventing gases moving from one cylinder to another**
   d. **preventing gases leaking out an empty cylinder yoke**

5. **What should the emergency oxygen flush be used for:**
   a. **flushing a breathing system that is not connected to a patient**
   b. **delivering emergency oxygen to a patient**
   c. **increasing anaesthetic gases in a breathing system**
   d. **flushing a breathing system while attached to a patient**

6. **What is not a type of scavenging system:**
   a. **electronic**
   b. **passive**
   c. **active**
   d. **Aldasorber**

BVNA Regional Meetings

All practice staff are welcome to attend and CPD certificates are provided. Fees are non-refundable in the event of non-attendance.

Are your patients still breathing down straws? | Booking Ref: R11-15/01/13

Tuesday 15th January 2012 • Registration & Buffet @ 7.00pm for a 7.30pm start

Kent Region • The New Animal Management Unit, Hadlow College, Hadlow, Tonbridge

Speaker: Dawn Sheppard VN

£12.00 BVNA members - £14.00 to non members.

For further information or to book, please contact:
Donna Lewis RVN MBVNA • Email: donnaleighlewis@hotmail.com • Tel: +44 (0)7976 963342

Client care and communication in practice | Booking Ref: R24-21/01/13

Monday 21st January 2012 • Registration & refreshments @ 7.00pm for a 7.30pm start

Nottingham Region • Rolleston Village Hall, The Greenaway, Staythorpe Road, Rolleston, Nottingham, NG23 5SG

Speaker: Joy Howell DipAVN(Surg) RVN MBVNA

£12.00 BVNA members - £17.00 to non members.

For further information or to book, please contact:
Zoe Davies RVN MBVNA • Email: zoedavies81@yahoo.co.uk • Tel: +44 (0)7877 499389

Answers to questions on page 11
A whistle-stop tour of the anaesthetic machine
1. a; 2. a; 4. a; 5. a; 6. a.

Nutritional management off feline diseases | Booking Ref: R4-24/01/13

Thursday 24 thJanuary 2013 • Registration & refreshments @ 7.00pm for a 7.30pm start

Norfolk/Cambs Region • Great Dunham Village Hall, Litcham Road, Great Dunham, Kings Lynn. PE32 2LJ

Speaker: Fiona Marjoram VN

£12.00 BVNA members - £17.00 to non members.

For further information or to book, please contact:
Faye Davis VN MBVNA • Email: faye@anchoragebarnequineclinic.co.uk • Tel: +44 (0)7721 361265

Canine Parvovirus | Booking Ref: R5-24/01/13

Thursday 24th January 2013 • Registration & refreshments @ 7.00pm for a 7.30pm start

Midlands Region • The Holiday Inn, Coventry South. CV8 3DY

Speaker: Alex Allen BVM&S MRCVS

£12.00 BVNA members - £15.00 to non members.

For further information or to book, please contact:
Becky Winter RVN MBVNA • Email: sherah70@hotmail.com • Tel: +44 (0)7885 477471

Neurology: from one nurse to another | Booking Ref: R6-29/01/13

Tuesday 29th January 2013 • 7pm Registration & buffet for a 7.30pm start

South East Wales Region • Abbeydale Vetlink Veterinary Training, Wyastone Business Park, Wyastone Leys, Monmouth. NP25 3SX

Speaker: Samantha Bell BSc(Hons) DipCVN RVN

£13.00 BVNA members - £18.00 to non members.

For further information or to book, please contact:
Kirsty Gwynne RVN MBVNA • Email: kirsty.gwynne@abbeydale-vetlink.org • Tel: +44 (0)1600 892682

The role of the VN in dermatology | Booking Ref: R26-29/01/13

Tuesday 29th January 2013 • 7.15pm registration & refreshments for a 7.30pm start

Bedfordshire/Hertfordshire Region • The Meridian School, Garden Walk, Royston, Herts. SG8 7JH

Speaker: Chris Taylor BVSc MRCVS

£12.00 BVNA members - £18.00 to non members.

For further information or to book, please contact:
Helen Tomsett RVN MBVNA • Email: helengriz@supanet.com • Tel: +44 (0)7880 513839

Anaesthesia refresher day | Booking Ref: R8-02/02/13

Saturday 2nd February 2013 • 9.30am registration & refreshments for a 10.00am start

Wiltshire/Dorset Region • Great Western Exotic Vets, Unit 10 Berkshire House, County Park Business Park, Shrivenham Road, Swindon. SN1 2NR

Speaker: Paul Crawford BVetMed CertVA MRCVS

£50.00 BVNA members - £60.00 to non members.

For further information or to book, please contact:
Sarah Wyatt RVN MBVNA • Email: splvn@hotmail.co.uk • Tel: +44 (0)7793 813898

A current list of meetings can be found on: www.bvna.org.uk.