



Notes on Anaesthetic breathing systems

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Basic information

What setting do I set the flow meter at?

This will depend on the breathing system in use and whether the patient is on a rebreathing circuit or a non-rebreathing circuit.

Non-rebreathing circuits

Non-rebreathing circuits are simpler to understand, so we can begin with these:

In a non-rebreathing circuit such as a **Magill** or **Lack** the reservoir bag serves to hold fresh anaesthetic gas ready for a patient to take a breath. The fresh gas flow rate set on the flow meter must be set to match the patient's requirements. In this case the minimum flow rate for a non-rebreathing circuit must be at least equal to the minute volume of the patient.

The minute volume of a patient is the amount of air/oxygen that it breathes in and out in a minute: **Minute Volume = Tidal Volume x breathing rate**

Example 1:

10kg Terrier breathing 20 breaths per minute

Tidal Volume = 10mls/kg = 10mls x 10kg = 100mls

Minute Volume = Tidal Volume x Breathing rate = 100 x 20 = 2000mls/minute

So for a Magill or a Lack system you would need to set the Gas Flow rate to at least 2.0L per minute and your reservoir bag must be at least as big as the tidal volume. A 500ml bag would be fine here.

Example 2:

30kg Labrador breathing 15 breaths per minute

Tidal Volume = 10mls/kg = 10mls x 30kg = 300mls

Minute Volume = Tidal Volume x Breathing rate = 300 x 15 = 4500mls/minute

So for a Magill or a Lack system you would need to set the Gas Flow rate to at least 4.5L per minute and your reservoir bag must be at least as big as the tidal volume. A 2.0L bag would be fine here. A 500ml bag would be too small in case the patient took a big breath.



In a non-rebreathing circuit such as a **T-piece** or **Bain** circuit, the reservoir bag is in the waste part of the circuit. Its function is not the same as with a Lack because it usually contains exhaled gas whereas the bag in a Lack system usually contains fresh gas.

When the patient is spontaneously breathing the fresh gas flow must be sufficient to meet the patient's peak inspiratory flow otherwise gas will be pulled back from the expiratory circuit, causing rebreathing. For that reason the fresh gas flow settings when using a T-piece or Bain circuit must be at least 2.5 times the minute volume.

Example 3:

10kg Terrier breathing 20 breaths per minute

Tidal Volume = 10mls/kg = 10mls x 10kg = 100mls

Minute Volume = Tidal Volume x Breathing rate = 100 x 20 = 2000mls/minute
= 2.0L/minute

So for a T-piece or Bain system you would need to set the Gas Flow rate to at least 5.0L per minute.

10kg is at the upper end of patient sizes used with a T-piece or Bain circuit because of the high use of gas. Note that this 10kg dog requires a higher gas flow rate than a 30kg Labrador on a Lack circuit.

Example 4:

4.5 kg cat breathing 20 times a minute

Tidal volume = 10mls/kg = 10mls x 4.5 = 45mls

Minute volume = Tidal Volume x Breathing rate = 45 x 20 = 900mls/minute

So for a T-piece or Bain system you would need to set the Gas Flow rate to at least 2.5L per minute.

Rebreathing or circle systems

In a rebreathing or circle system the patient draws its breath from the reservoir bag, which is on the inspiratory side of the circle and must be sufficient to hold the animal's maximal breath. The exhaled gas from the patient is "cleaned" of CO₂ by passing it through a canister of soda lime. Because the patient consumes oxygen and releases CO₂ (which is removed) the oxygen levels in the circuit will fall unless the fresh gas supply is sufficient to replace the oxygen that has been used. Again we measure this requirement over a minute.



How much oxygen does a patient need?

The metabolic requirement of a patient will vary slightly with temperature, age and fitness but generally the oxygen requirement in small animals is around 10mls/kg /minute.

Example 5:

30kg Labrador breathing 15 times a minute.

Oxygen requirement = 10mls x 30kg per minute = 300 mls per minute.

In this instance, with a perfectly closed circle system (pop-off valve closed) the fresh gas flow can be set at 300mls per minute.

In practice it takes time for a patient to stabilise on a circle system because of the need to supply initial high fresh gas flow rates to get anaesthetic agent in to the patient. A flow rate of 300mls would add a small amount of Isoflurane per minute which may not be sufficient to keep the animal asleep. For that reason circle systems are usually run effectively as non-rebreathing circuits (pop-off valve open and high fresh gas flow rates) in the initial stages until the patient is settled. Then the pop-off valve can be closed and the fresh gas flow reduced.

Anaesthetic Breathing Systems

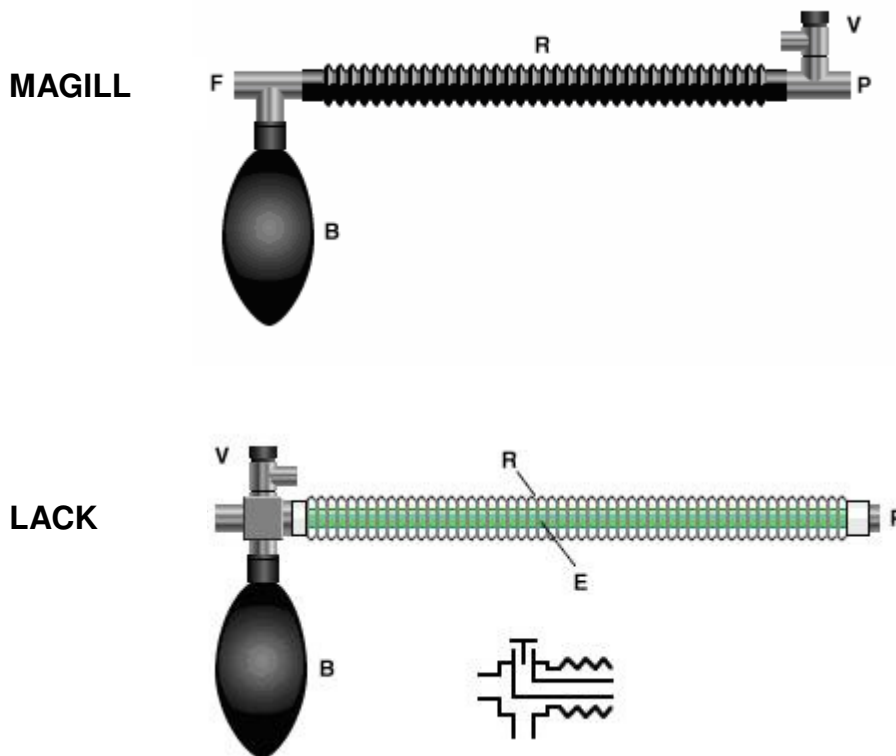
Although there appear to be many variants of breathing systems, they can all be distilled down to two basic types:

- 1) With the reservoir bag/system in the **fresh gas flow** (FGF) circuit
- 2) With the reservoir bag/system in the **exhaust/waste** gas circuit

This means there are two fundamental breathing systems to understand.

The first, with a reservoir bag in the **fresh gas flow** is a Magill circuit.

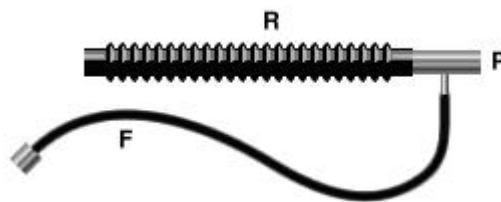
In a standard Magill circuit the exhaust/spill valve is at the patient's head end. If a co-axial tube is added to the circuit so that the waste gases pass up the inner pipe, this spill valve can be relocated at the anaesthetic machine and the waste gas more easily scavenged. In this case it is known as a Lack Circuit, or more properly a modified Lack Circuit. A Magill is classified as a Mapleson A type circuit



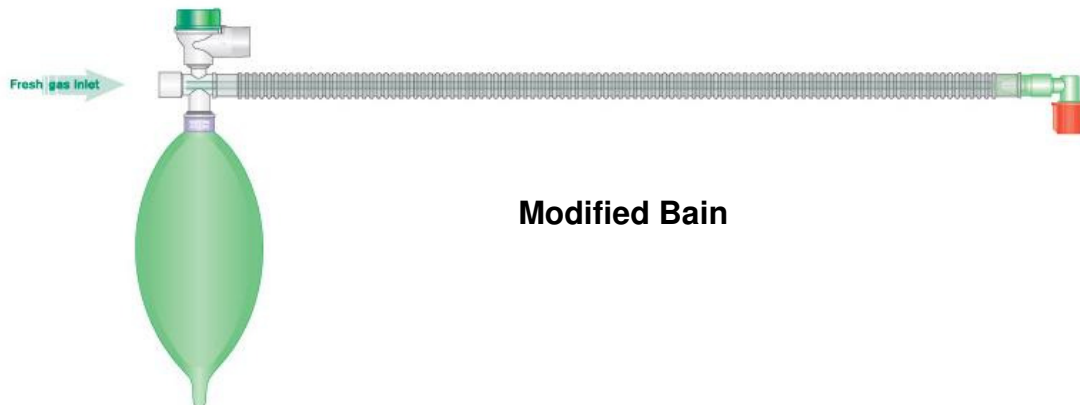
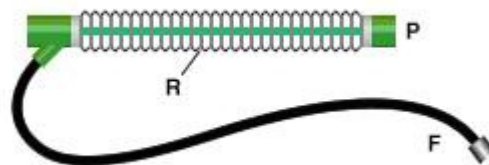
Note how the valve position has changed between the Magill circuit and the modified Lack Circuit. The circuit behaviour is not changed.

The second type of circuit, with a reservoir bag in the **waste** circuit is a T-piece circuit. A T-piece circuit may or may not have a reservoir bag fitted, because the exhaust pipe can act as the reservoir space. If the fresh gas flow is fed down the centre of the waste pipe instead of externally as with a T-piece this circuit is known as a Bain, or if a bag is fitted, as a modified Bain. A T-piece circuit is classified as a Mapleson E type circuit. A T-piece circuit with an open-ended bag is classified as a Mapleson F type circuit (=Jackson-Rees Modification). A Bain is classified as a Mapleson D type circuit

T-Piece



BAIN



Modified Bain

You can now see that a Humphrey ADE encompasses all of the variants described above.



Which circuit to use?

To answer this we need to look at the properties and behaviour of the two different systems. This varies between spontaneous breathing and manual IPPV so for now we will restrict our analysis to spontaneously breathing animals.

With the reservoir bag in the fresh gas flow, exhaled gas will first pass up the FGF pipe and force fresh gas to fill the bag. Once the bag is full the relief or spill valve will open and the remainder of the exhaled gas will be passed out into the waste pipe. Since there is a one-way valve on this pipe this waste gas will not be inhaled during the next inspiration. Because of the preceding action the gas that is preferentially lost from the system is the gas that is last to leave the lungs and this is alveolar gas or gas that has been involved in gaseous exchange. Gas that has merely passed down the trachea and major airways and has not been involved in gaseous exchange is left in the FGF pipe. This gas is exactly the same as when it entered the patient and consists of fresh gas and anaesthetic agent (dead space gas). Therefore the patient can safely re-breathe this, which is what it does at the beginning of the next inspiration. This makes a Magill or Lack system very efficient to use and results in normocapnoea as long as the FGF matches the alveolar minute ventilation. Note that the higher the FGF the less re-breathing of dead space gas can occur.

With the reservoir in the waste circuit the exhaled gas will not pass up the fresh gas pipe because of the pressure from the incoming FGF, so all waste gas from exhalation passes down the waste pipe. The spill valve is now the effective expiratory valve and must be set at "open" to prevent any inadvertent expiratory resistance (or effective PEEP) as this would impede removal of the waste gas. In the expiratory pause period, FGF flushes the exhaled gas further down the waste pipe so that on inspiration exhaled gases are not pulled back from the waste pipe. How far down the pipe the waste gas is flushed depends on the actual FGF rate. Note that in a T-piece system there is no resistance to exhalation at all because there is no expiratory valve. This is why T-piece systems are most suited to the smaller patients who would have difficulty breathing out against the resistance presented by a spill valve. In this system the FGF must be higher than with a Magill/Lack circuit because if the FGF is not high enough then waste gas will not be pushed far enough down the waste pipe and the FGF will be insufficient to support inspiratory flow. The result will be re-breathing. In this circuit FGF flow rates of 2-3 x minute volume are required to maintain normocapnoea.



IPPV performed by squeezing the bag

Magill/Lack systems

Squeezing the bag forces fresh gas from the bag into the patient's lungs. The spill valve has to be partly closed to allow some pressure to develop. On exhalation waste gas fills the FGF pipe and may even reach the reservoir bag. During the expiratory pause period the FGF flushes out the bag and the FGF pipe removing the waste gas through the spill valve. On the next inspiratory phase of IPPV, any waste gas remaining in the FGF pipe or bag will be forced back into the patient. Therefore, unless the FGF is high enough to prevent this, re-breathing and hypercapnoea are common in this type of circuit with IPPV. The Magill/Lack circuit is not well suited to manual IPPV.

T-piece/Bain systems

To allow IPPV, the expiratory valve has to be partly closed so that it opens only after sufficient pressure has developed in the system. Assuming that the fresh gas flow is sufficient for normal T-piece action ($\text{FGF} = 2-3 \times \text{Minute Volume}$) then squeezing the bag will force fresh gas into the lungs of the patient. In this manner the T-piece or Bain system is much more efficient and safe for IPPV compared to a Magill or Lack system. Note that if the IPPV rate is high compared to the spontaneous breathing rate the FGF rate will need to be increased to prevent re-breathing.

Use of capnography during IPPV is the most suitable method of determining the efficiency of IPPV and the degree of rebreathing.