Merlin Training for Vets and Nurses

Objectives

- To familiarise users with the controls of Merlin
- To familiarise users with the pneumatic connections of Merlin
- To ensure that users understand the behaviour of Merlin in terms of gas flow, both during normal use and with the machine OFF/Power failure
- To train users to set up Merlin for Volume Cycling in a range of patients and to understand the implications and effects of changing different controls
- To train users to respond to patients 'fighting the ventilator' and to establish breathing control using IPPV
- To train users to set up Merlin for Pressure Cycling and to understand the benefits of Pressure Cycling over Volume Cycling
- To train users how to run a Leak test as part of their daily routine

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Merlin Controls

Despite its appearance Merlin only has 5 control knobs and three switches to control all forms of ventilation. The control functions will be covered first. Their role in the full control of assisted ventilation will be covered more fully later.

The control knobs will be discussed first, left to right.

Flow Rate / Volume
The first knob has dual functionality depending on which cycling mode is selected.
All volumes are in whole mls and all Flow values are in decimal values e.g. 2.5, so it is easy to tell which mode is selected.
If the number is a whole number then the knob is in Volume Mode
If the number is a decimal number then the knob is in Flow Mode

Volumes go from 1ml to 800 mls
Flows go from 0.1L/min to 25.0L/min

Inspiratory Time
This knob also has dual functionality. For most of its use the control will allow setting of the inspiratory time. This is the time taken to deliver the breath to the patient and is the time that the piston will be seen to be moving forward for. Inspiratory times are always in decimal format e.g. 1.0
Values range from 0.2 to 9.0 seconds

When turned fully clock-wise the legend above the Inspiratory Time knob will change from a decimal number to the letters **PL** indicating that the machine is now in **P**ressure cyc**L**ing mode.
When set for Pressure Cycling mode the Flow Rate/Volume control will be fixed in Flow mode.
In Pressure Cycling mode a constant flow of gas is delivered to the patient until the airway pressure reaches a pre-determined pressure. Therefore in this mode the inspiratory time of the patient is not known and cannot be set. Only the Flow value and the Target pressure can be set. It is for this reason that the Inspiratory Time control is used to set the machine in Pressure Cycling mode.

Expiratory Time
This knob has one function only. It allows the setting of the expiratory time. The expiratory time is the total time from the end of inspiration to the start of the next inspiration. In Merlin this period will always include the time taken for the cylinder to return to its starting point. It may include a resting period as well if the Expiratory time is long enough.
Expiratory times are always in decimal format e.g. 2.0
Values range from 0.2 to 9.0 seconds

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Maximum Airway Pressure
This control knob has dual functionality. It always represents a maximum permissible airway pressure but depending on the operating mode of the ventilator this will be interpreted in one of two different ways.

In volume cycling mode the Maximum Airway Pressure is the 'Safety Valve' pressure that the airway is allowed to reach before inspiration is halted. As such in normal use it rarely has any effect on the operation of the machine. The Maximum Airway Pressure should be set to approximately 10 cm above the normal Peak Inspiratory Pressure (PIP). For example the normal Peak Inspiratory Pressure for a 30kg Labrador would be 12-15 cm H_2O. The Maximum Airway Pressure in this instance should be set to 25. Only if the airway pressure got to 25 would inspiration be halted.

In pressure cycling mode the value of the Maximum Airway Pressure control is the pressure that the ventilator will reach when delivering the fixed flow of gas. For example, when ventilating a 30kg Labrador the Maximum Airway Pressure should be set at 15. Gas will be delivered until the airway pressure equals 15 at which point inspiration will end and expiration begin.

Assist Threshold
This knob controls the trigger point at which Merlin will deliver an assisted breath. The control has no function unless the Assist switch above the control is set to **ON**.
The value indicated by this control is the negative pressure that needs to be reached by a patient making an inspiratory effort in order to trigger the ventilator.
For example, with a setting of 4 the patient would need to create -4cm of negative pressure in order to trigger the ventilator.

Switches
There are 4 switches on Merlin but because one is a reset switch, only three are used to control the ventilator.

Stop/Run
This switch stops and starts the running of the ventilator. If the ventilator is running and the switch is set to ***OFF*** the ventilator movement will stop immediately. When the switch is set to ***RUN***, the ventilator will usually begin to move. If the piston is not at its resting position then the piston will be fully withdrawn before the inspiratory phase begins. If the piston is already fully withdrawn then inspiration will normally begin immediately. However, if the Assist mode switch is ON then the ventilator will wait for an effort from the patient before delivering a breath and so there may be no initial movement.

Flow Rate / Volume Switch
This switch changes the control function from a Volume Control (in mls) to a Flow Control (in L/min). This does NOT set the ventilator into a pressure cycling mode but simply provides another way of determining how to deliver a volume breath. When the switch is ***down*** the value shown by the control is in mls and the Tidal Volume is exactly the same as shown on the top line of the main display. When the switch is ***up*** the value shown is a flow value and that combined with the inspiratory time will determine the delivered volume. Again the actual volume, calculated by the machine, will be shown on the top line of the main display.
This switch is designed for use by anaesthetists that wish to deliver a fixed flow and use the inspiratory time to control the delivered volume.

Assist Mode Switch
This switch is used to put the ventilator into Assist Mode. Assist mode is active whenever the switch is UP irrespective of cycling mode. Therefore Assist Mode can be used in Pressure Cycling or Volume Cycling modes.

Features of the main Display
The main display shows the following:
Tidal Volume, Minute Volume, Airway Pressure (PIP and PEEP), I:E Ratio, Compliance and Respiratory Rate.

Tidal Volume:
In volume cycling mode this will mirror the setting of the Tidal Volume control. The value is continuously updated and reflects any changes made to the TV control.
In pressure cycling mode this value will be the measured value during the preceding inspiratory phase. The value is updated at the end of every inspiratory phase.

Minute Volume:
This value shows the set or measured minute volume.
In volume cycling mode this is the set minute volume as determined by the tidal volume and the respiratory rate.
In pressure cycling mode this value is the measured value and is based on the measured tidal volume and the measured respiratory rate. The value is updated at the end of each inspiratory phase.

Airway Pressure:
Two values are shown, Peak Inspiratory Pressure (PIP) and PEEP. The values are shown separated by a forward slash e.g. 15/0 for an inspiratory peak pressure of 15 and no PEEP. The PIP value is continuously updated during inspiration and the PEEP value is updated during expiration.

I:E Ratio:
This shows the ratio between the inspiratory time and expiratory time. It is usual when using prolonged mechanical ventilation to maintain this ratio at greater than 1:2, so that expiration is always at least twice as long as inspiration. This reduces the effect of mechanical IPPV on the cardiovascular system.
In volume cycling mode this value is continuously updated as changes are made to the controls.
In pressure cycling mode this value is updated at the end of each inspiratory phase.

Compliance:
This value measures the dynamic compliance of the patient and the patient circuit. Usually the patient compliance dominates the total compliance because the compliance of the patient circuit is low. The value is calculated from the delivered tidal volume divided by the PIP value and is in the form of mls/cm H_2O. Compliance varies with patient, species, position and may also vary with length of surgery. Compliance is a measure of the elasticity of the lungs and is not a predictable value. Because compliance is calculated from tidal volume divided by PIP and because PIP varies relatively little with patient size, it follows that compliance will increase with patient size. Expect a higher compliance in a 30kg Labrador than in a 3 month old kitten. Expect a reduced compliance in an old cat compared with a young cat and expect compliance to reduce with prolonged surgery and to increase just after muscle relaxants are given.

Respiratory Rate
This value shows the actual Respiratory Rate delivered by the ventilator.

In volume cycling mode this will reflect the setting of the inspiratory and expiratory controls. The value is continuously updated and reflects any changes made to those controls.

In pressure cycling mode this value will be calculated from the set expiratory time and the measured inspiratory time during the preceding inspiratory phase. The value is updated at the end of every inspiratory phase.

Pneumatic connections

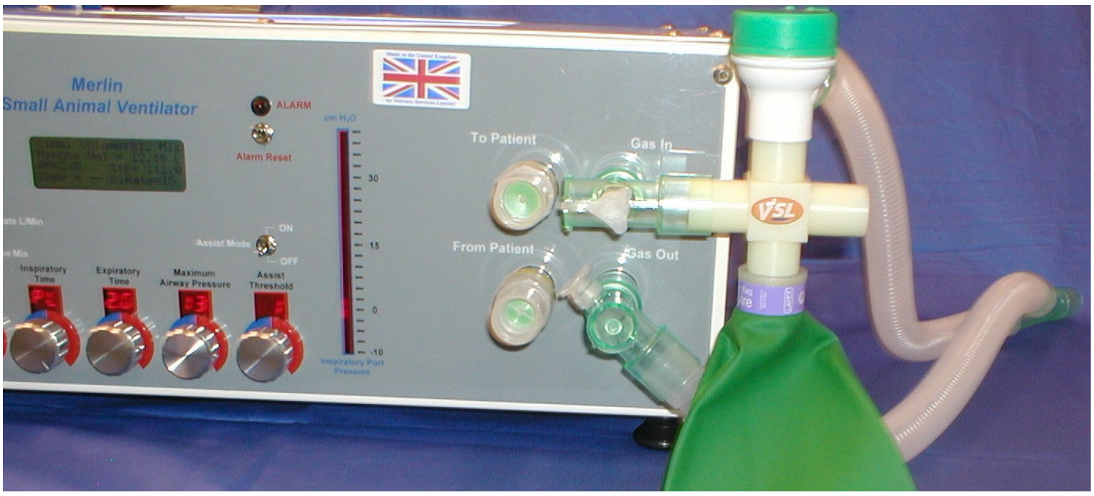
Merlin does not need a pressurised gas supply to drive the piston or cylinder so the only gas connections are those to and from the anaesthetic machine and to and from the patient.

The connections to and from the patient are simple. A port labelled **To Patient** delivers gas down to the patient and a port labelled **From Patient** receives exhaled gas from the patient. Use a normal Y-piece with connecting tubes to connect Merlin to the patient.

All incoming gas to the machine enters via the **Gas In** port and all gas leaving the machine exits via the **Gas Out** port.
Because of this 4-port arrangement Merlin differs from other ventilators and cannot be used to 'replace the bag' .

Rebreathing or Non-rebreathing

Merlin can be configured for both systems. In a non-rebreathing system the gas expired by the patient leaves the machine via the Gas Out port and then passes to the scavenging circuit. Fresh gas is fed in to the Gas In port.
In a rebreathing system the gas leaving the Gas Out port passes to a CO2 absorber and then returns from the CO2 absorber to the Gas In port. Fresh gas is fed in to the CO2 absorber chamber. Because Merlin has a passive expiratory phase, all normal circuit resistances are seen by the patient. For this reason a rebreathing system should only be used on patients large enough to cope with the absorber resistance.
In both systems the connections to the patient do not change.



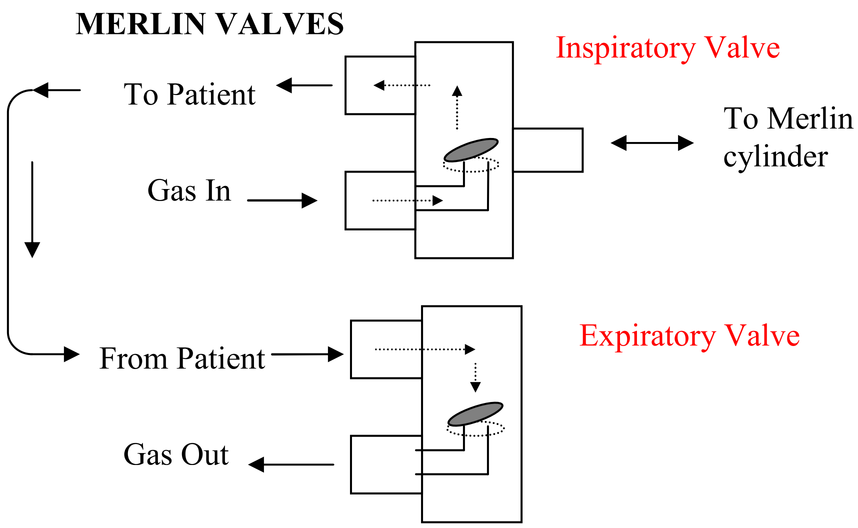
For a non-rebreathing circuit, Fresh Gas Flow (FGF) is delivered from the common gas outlet of the anaesthetic machine. Because the inlet valves inside Merlin cut off this gas flow during certain phases of the breathing cycle it is important that a reservoir bag be placed in the path of the incoming gas so that the fresh gas can continue to flow and fill this bag when the inlet valves are closed. Because this reservoir bag may become full it is necessary to fit an APL valve to this reservoir bag.
In summary, to set the machine up for non-rebreathing, a reservoir bag and spill valve need to be placed in the FGF path between the anaesthetic machine and Merlin Gas In. Any gas leaving the spill valve should be connected to the scavenge circuit in the normal way.

For a rebreathing circuit the situation is usually a lot easier. 22mm regular tubing or 15mm smooth-bore tubing can be used to connect the Gas-Out port of Merlin to the Expiratory port of the absorber. Similar tubing connects the Inspiratory port of the absorber to the Gas-In port of Merlin.
In a lot of cases the rebreathing bag fitted to the absorber can be used as the reservoir bag for Merlin incoming FGF as long as it sits in the Inspiratory side. Different circle manufacturers place them in different locations. For example the Burtons circle unit has the rebreathing bag on the expiratory limb and so a reservoir bag will still need to be fitted in the FGF path to Merlin along with a spill valve and scavenge tubing.

To test which side the rebreathing bag is connected to on a circle system, do the following:

Place the circle on a desk, disconnected from any anaesthetic machine. It is also a good idea to flush fresh oxygen through the absorber before this, to remove any anaesthetic residue.
Block the inspiratory port with your hand and blow down the Fresh Gas tube connected to the circle. If the bag is on the inspiratory port, it will fill up as you blow. If it is on the expiratory port then you will feel total resistance as you blow.

Gas Flow through the Merlin ventilator
As described above there is a continual flow of gas through Merlin and the patient. The only difference in a rebreathing circuit is that the waste gas is recycled.



FGF enters Merlin by the Gas-In port and fills up the cylinder. When inspiration starts, the inspiratory valve cuts off the FGF inlet and the expiratory valve cuts off the Gas-out port so gas is driven into the patient. At the end of inspiration both of these valves open and the patient exhales passively. Because of the passive one-way valves in the patient connections, gas from the patient leaves via the From-Patient port and because the expiratory valve is now open, gas passes directly to the Gas-Out port.
When Merlin is in Stop mode or not powered, both of the control valves are left open. This means that in the event of a power failure the ventilator 'fails safe' and the patient can breath spontaneously, can be manually ventilated by the bag in the system and has no restriction to breathing. It also means that a patient can be allowed to breathe spontaneously until such time as IPPV is required at which time it is a simple matter to set the Mode switch to RUN without having to change any gas connections.

Setting up for Volume Cycling

Volume cycling is the simplest form of ventilation to use. It is conceptually easier because a dog of a certain size can be reasonably equated to a tidal volume. The set up for a typical 30kg Labrador will be described.

Tidal Volume
First, it is important to know the weight of your patient in kg. Secondly, using the Merlin Volume Chart or using the value of 10mls tidal volume per kg bodyweight the tidal volume is calculated.

TV = 30 kg x 10mls/kg = 300mls
Set the Tidal Volume control to 300.
Note: If the control only shows values between 0.1 and 25.0 then make sure the Inspiratory control is not on PL and that the switch above the TV knob is set to 'Volume mls'

Inspiratory Time
The inspiratory time should be set at 1.0 second. This is a good value to use. It can be easily adjusted later but for most patients a starting value of 1.0 second is appropriate.

Expiratory Time
The expiratory time should be set so that a respiratory rate slightly higher than the normal resting rate is seen on the screen. With the inspiratory time fixed at 1 second, adjust the expiratory time and look at the main LCD display to see the resultant respiratory rate : "RR= " Our Labrador will have a normal resting rate of around 15 breaths per minute. So set the expiratory control to 3 seconds (3 + 1 seconds = 4 seconds = 15 breaths per minute)

Maximum Airway Pressure
This is volume cycling so set the MAP to be 10cm above the normal expected. We would expect our Labrador to be adequately ventilated at 12-15 cm H_2O pressure, so set the MAP to 25.

Assist Mode
The setting of the Assist mode knob is not required here and the Assist switch must be set to OFF.

With your patient connected, all that is required is to set the mode switch to RUN. Merlin will begin delivering 30omls in 1 second and with a respiratory rate of 15 breaths per minute.

Control of Respiration

Now that you understand how to set up the Merlin ventilator in its basic configuration you will want all of your patients to be nicely controlled and asleep during your anaesthetics. Achieving this requires some understanding of the physiology surrounding the control of respiration.

Basic Physiology

Respiration is an autonomic function that can be overridden by conscious control. During mechanical IPPV we want to remove the conscious control and heavily reduce the autonomic control. For the most part we can dismiss the concern over conscious control since that function is lost very quickly during anaesthesia and even heavy sedation. It is the innate autonomic control mainly mediated through the vagus nerve that we need to moderate. During sleep and anaesthesia the respiratory centre in the brain maintains a cyclical rhythm of control via the inspiratory and expiratory centres of the medulla.
The feedback control of ventilation comprises of two parts:

- Chemical receptors in the Medulla Oblongata and the Aortic and Carotid bodies.
- Mechanical receptors in the lungs and skeletal muscles of the thorax

Chemo-receptors

The drive to breathe is enforced by low oxygen and high CO2 levels that are sensed centrally (medulla) and peripherally (Carotid and Aortic bodies) using chemo-receptors .
Low oxygen levels of less than 100mmHg will start to stimulate the respiratory centre leading to increased inspiratory drive. Higher levels will remove this stimulation but do not have a direct inhibitory effect. This is a poor stimulus - it takes levels of less than 60 mmHg to actually initiate breathing.

CO2 levels and hence pH have a strong effect in controlling the respiratory centre. Increasing CO2 levels lead to a fall in pH that is effectively 'amplified' in the CSF since there is very little buffering. CSF bathing the medulla will allow the chemoreceptors in the ventro-lateral aspect of the medulla to detect these changes. The changes involved can be a little overwhelming but the main effects are listed here to indicate how they can be used in controlling our patients.

A rising CO2 has the following effects:

- A direct positive effect on the inspiratory centre stimulating respiration
- An increase in the phrenic nerve activity increasing the depth of inspiration
- A depression on the stretch receptor response that inhibits respiration

Thus it can be seen that by allowing the patient's CO2 levels to rise we will be priming the system for resumption of spontaneous breathing.

A falling CO2 has the following effects:

- A removal of drive to the inspiratory centre thus reducing spontaneous respiration
- A reduction in phrenic nerve activity
- A lifting of the inhibition of the stretch receptor response, thus suppressing respiration.

Thus it can be seen that by reducing a patient's CO2 levels the innate spontaneous drive is removed.

Mechanoreceptors

There are 2 main mechanisms involving mechanoreceptors:

- Pulmonary stretch receptors located in the airways and parenchyma of the lung.
- Muscle stretch receptors located in the respiratory muscles

The pulmonary stretch receptors are involved in the Hering-Breuer (HB) reflex which is a natural reflex intended to end the inspiratory phase. When the pulmonary stretch receptors sense expansion of the lung they send impulses via the vagus nerve to the medulla and pneumotaxic centre of the pons. This inhibits the Inspiratory Area and also prevents excitation of the Inspiratory Area by the Apneustic centre. So this is a fundamental control mechanism that means the medulla won't allow inspiration and won't allow anything else to control it either. The HB reflex normally acts to stop the inspiratory period of normally breathing individuals. If the HB reflex is stimulated in the period immediately after the innate inspiratory drive, in the so-called period of neural expiration, then there is an even greater inhibition of the next neural inspiratory phase.

The muscle stretch receptors play a relatively minor role in the control of ventilation but there is a reflex arc involving the spinal cord that reduces the tone of the respiratory muscles when the stretch receptors are activated.

So, stretching the lung by delivering full breaths will invoke the HB and muscle stretch receptor responses. This will reduce spontaneous drive. Similarly by reducing lung expansion there will be a lifting of the inhibition and spontaneous drive will return.

All of the above section can be condensed into some simple rules:

To overcome a patient's spontaneous respiratory drive

- Deliver large tidal volumes to stretch the lung and invoke the Hering Breuer reflex and local muscle-stretch reflex.
- Increase the minute volume delivered to the patient to reduce the end-tidal (and hence the arterial) CO2 levels of the patient. Achieve this by increasing the respiratory rate as well as the tidal volume.

To allow resumption of a patient's spontaneous respiratory drive:

- Deliver smaller tidal volumes to reduce the stimulation of stretch receptors
- Reduce the minute volume delivered to the patient by reducing the respiratory rate and/or reducing the tidal volume. This will reduce the removal of CO2 and therefore arterial and end-tidal values will increase.

Setting the ventilator up for Pressure Cycling mode

With Pressure Cycling the end of inspiration is controlled by the airway pressure reaching a pre-determined value. The behaviour of Merlin is essentially the same. It will continue to deliver breaths at the rate set but the volume may vary from breath to breath depending on external influences.
With Volume Cycling the delivered volume is always the same. This is usually OK but consider the situation where the surgeon leans on the patient's chest thus restricting expansion. With volume cycling the ventilator will continue to deliver the full volume into a restricted space. The usual result is that the pressure rises markedly and reaches the Maximum Airway Pressure value which abruptly stops inspiration. Because the MAP value is often quite a bit higher than the normal value the end of inspiration is often a noisy if not violent event.
With Pressure Cycling a set flow of gas is delivered until the target pressure is reached. Now if the surgeon leans on the chest the pressure will never exceed the target value. The result is a safer control over the pressures but with variation in the delivered tidal volume. With our 30kg labrador the benefits of pressure cycling over volume cycling is not obvious and either can be used quite safely and normally. The real benefit of pressure cycling comes when ventilating quite small animals. Imagine a rat of 300g needs ventilating. Using a volume calculator you might come up with a tidal volume of 3.6 mls. But if the rat was a little fat its true tidal volume may be nearer 3mls. A difference of 0.6mls may not seem much but it could be the difference between normal inflation and over-inflation. If pressure cycling is used the calculation of tidal volume is irrelevant because the rat will be ventilated to a safe pressure of 8-9cm H2O irrespective of the true lung volume.

Merlin controls for pressure cycling

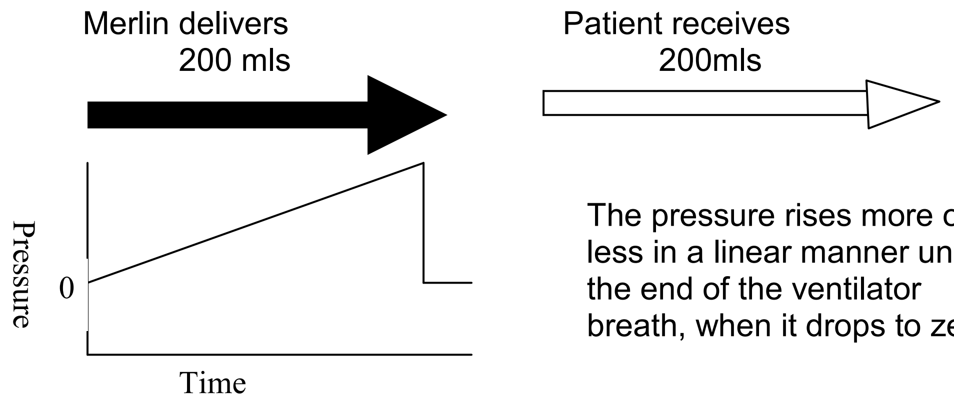
- Turn the inspiratory knob fully clockwise until it shows the letters PL.
- Now set the first knob to a flow rate.
  Typically you still want to deliver the inspiratory phase in about one second, maybe less for the really small animals. A good rule of thumb is to use the animals weight in kg divided by 2 as the flow rate. So a 10kg animal would have the flow rate set to 10/2 = 5L/min as a starting point. The flow rate will affect the inspiratory time only, so changing the flow rate to change the inspiratory time can be done at any time, without affecting any other parameter.
- Set the Expiratory time based on your inspiratory time to give you the required respiratory rate. If Merlin has not yet delivered a pressure cycled breath to your patient then the value given by RR will not be based on a measured inspiratory time but rather on the last known inspiratory time. If in doubt assume an inspiratory time of 1 second and set the expiratory time accordingly. e.g. for a respiratory rate of 15 breaths per minute select an expiratory time of 3 seconds: BPM = 60/(3+1) = 60/4 = 15.
- Set the Maximum Airway Pressure to the target ventilation pressure. This again will vary with patients but will nearly always lie in the range 6 to 15, with smaller more delicate animals having a lower value. e.g. a young kitten would have a setting of 7-8 and a larger obese cat a setting of 11-12. These values can be fine tuned once capnograph readings are available.
- Make sure the Assist mode switch is set to OFF unless explicitly required. Assist mode can be used in exactly the same manner as in volume cycling mode. See the later section on Assist mode for more information.
- Now with everything set up set the mode switch to RUN. Merlin will deliver gas at the selected flow rate until the target pressure is reached. There will then be a pause as set by the Expiratory Time control before the cycle repeats.

What alarms can be seen when pressure cycling?
Because the system delivers gas until the pressure is reached, if there is a leak in the patient circuit then the pressure may never be reached. In this instance the piston would reach the end of the cylinder and have to return to refill with gas. At this point either a 'TARGET PRESSURE NOT REACHED' alarm would occur, or if the pressure failed to rise above 4cm then a LOW INSP PRESSURE alarm would occur.

'Fighting the Ventilator'
This term is often used to describe what happens when the ventilator and the patient are not synchronised. In other words the ventilator is attempting to run independently of the patient and impose its own rhythm on the patient. This can result in two undesirable scenarios:

1. The patient breathes in while the ventilator delivers a breath
2. The patient breathes out while the ventilator delivers a breath

Before we look at what can happen in these situations, here is a depiction of the pressure graph generated during a breath delivered by the ventilator to a patient with no spontaneous respiratory drive:

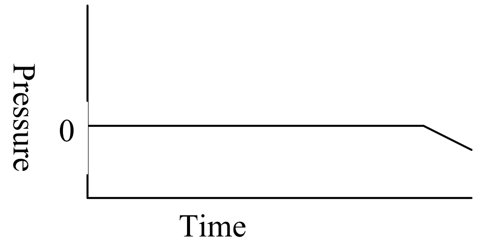


The pressure rises more or less in a linear manner until the end of the ventilator breath, when it drops to zero

Fighting the ventilator Scenario 1

If the patient breathes in while the ventilator is delivering a breath then the result will depend on the relative size of the patient's natural breath and the size of the delivered ventilator breath.

Large breath
If the patient breath is larger than the ventilator delivered breath then the ventilator will see no external resistance and so the airway pressure will not rise. In this case Merlin would give a LOW INSP PRESSURE alarm e.g.

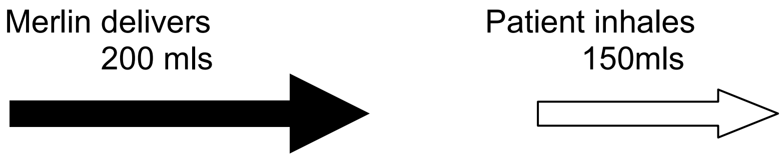


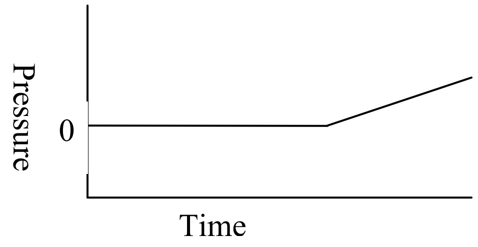
May see a slight dip in pressure towards the end as the patient draws air from the circuit. All valves are open at this point so will only be a minor dip of -1 or-2 cm

LOW INSP PRESSURE !

Small breath

If the patient breath is smaller than the ventilator delivered breath then the ventilator will see some resistance at the end and therefore some pressure. If the final pressure is over 4cm then no alarm will sound





You will see a rise in airway pressure towards the end of the ventilator breath as the ventilator continues to fill the lung and the patient stops inhaling

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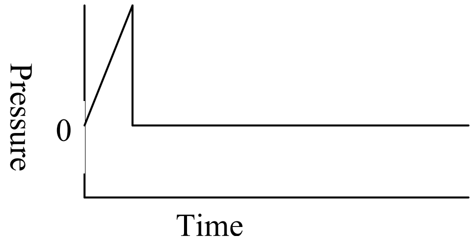
Fighting the ventilator Scenario 2

Merlin delivers 200 mls

Patient inhales 200mls



There is a rapid rise in pressure as the two gas streams meet. This will trip the MAP alarm and the inspiratory phase of Merlin will stop immediately allowing the patient to breathe out

MAX PRESSURE EXCEEDED!

If the patient breathes in or out while Merlin is not in the active inspiratory phase then this is the same as the patient breathing normally with Merlin turned off. Breathing in this case is not impeded.

Because the rates of Merlin and the patient are not linked, the same patient may produce multiple alarms alternating between MAX PRESSURE EXCEEDED and LOW INSP PRESSURE. When this is seen there are a number of options available to you:

1. Turn off the ventilator support. The patient has clear respiratory drive. If this is at the end of a procedure then ventilator support is not required. If the procedure does not require complete ventilator support then allow the patient to breathe spontaneously until such time as ventilator support is needed.

2. Turn off the ventilator support and manually bag the patient timing the ventilations to be in between the patient's own breaths. This extra minute volume ventilation will 'blow off' some CO_2, deliver anaesthetic to the patient and should result in the patient ceasing spontaneous efforts within a minute or so.

3. Increase the frequency and volume of the delivered ventilator breaths. By increasing the frequency you are likely to deliver ventilator breaths between the patient's breaths and thereby 'blow off' CO_2 and deliver anaesthetic to the patient, thereby gaining control. By increasing the volume you will slightly stretch the lungs thus inhibiting spontaneous drive (see later)

4. Use the Merlin Assist mode. The assist mode imposes a form of SIMV or Synchronised Intermittent Mandatory Ventilation, on the patient. In essence the ventilator becomes synchronised to the patient's breathing rate by detecting when the patient starts inspiration. In Assist mode if the patient does not take a breath in the time taken for 3 normal breathing cycles a mandatory breath will be given.
   Enter Assist mode by putting the Assist switch to ON. Because the patient has clear respiratory drive you will need to set the trigger value fairly high compared to the settings used for weaning off the ventilator. Use a value of around 5 or 6. When the patient starts to inhale the pressure in the circuit will drop and Merlin will sense this and begin to deliver a breath. It is important that the delivered breath is slightly larger than normal. Increase the TV setting to add an extra 10-20 % of calculated Tidal Volume. In our example of the 30kg Labrador the calculated TV was 300mls. In Assist mode to overcome spontaneous drive, set the TV control to 330 or 360mls. Be guided by the end-inspiratory pressure which should be reaching at least 15cm. If it is not then the TV is not large enough. Remember, the available lung capacity consists of normal Tidal Volume + the Functional Residual Capacity (FRC) and if a patient is fighting the ventilator it will be drawing on its reserves of FRC so may have quite a large inspired tidal volume. It would be quite in order to increase the TV setting to 400mls if required. Once the animal loses its spontaneous drive you will see that the 400mls is resulting in a higher than normal pressure and the TV setting can then be reduced.
   The above section assumes Volume Cycling mode. If the ventilator is in Pressure Cycling mode, then the situation is actually easier since Merlin will deliver gas until the required pressure is reached. In that instance set the MAX AIRWAY PRESSURE setting to slightly above normal, say 15cm in a patient that is normally ventilated at 12 cm.

   Also note that in Assist mode you will still get LOW INSP PRESSURE warnings if the Tidal Volume setting is too low and you may still get MAX PRESSURE EXCEEDED alarms until the patient loses its spontaneous drive. For more information, see the section on Overcoming Spontaneous Respiratory Drive.

The primary aims when using a mechanical ventilator

1. Override the patient's own spontaneous respiratory drive so that fine tuning of ventilation can be achieved through variation in controls of the ventilator
2. Deliver an adequate minute volume to deliver oxygen and anaesthetic agent and remove carbon dioxide. Aim for an end-tidal CO_2 value of between 35 and 40 mmHg (4.5 - 5.0%)
3. Allow end-tidal CO_2 to rise at the end of mechanical ventilation to allow return of the patient's spontaneous respiratory drive

Performing a leak test

The leak test on Merlin can be performed quickly and easily without any special equipment, just a short length of 22mm tubing. The leak test will test all the internal connections of Merlin and the effectiveness of the inspiratory and expiratory valve. If you perform a whole system leak test when Merlin is connected to an anaesthetic machine and patient circuit and discover a leak, run this test on Merlin to eliminate it as a cause of leaks.
The leak test as described is a very severe test and will detect leaks as low as 2mls per second.

Procedure: Remove any connections to the Gas In and Gas Out pipes.

Set Insp control to PL (fully clock-wise)
Set Flow/TV control to 0.1
Set Exp control to 9.0
Set Max Airway Pressure to 57
Turn Assist mode OFF

Connect a single short piece of 22mm hose between the To-Patient and the From-Patient ports

Set the machine to **RUN**.

Merlin will deliver gas at 0.1L (100ml/min), which is just over 1ml/second. This is very slow and if there is even a tiny leak it will not get to 57cm pressure. Note, that this tests for any leaks in the Inspiratory valve, Expiratory valve, Merlin chamber and internal connecting pipes.
When the pressure reaches 57cm, Merlin will stop the Inspiratory phase and return to its resting position. The screen will show the delivered volume in mls. Repeat the test 3 or 4 times and make sure the results are consistent. To test for valves that begin leaking with prolonged use, run this test for at least 3 hours. If at any point a leak develops and the pressure cannot be reached an Alarm screen will appear - "TARGET PRESSURE NOT REACHED" . If the pressure measured does not even reach 4cm then the alarm message LOW INSP PRESSURE will be displayed instead. The machine does not need to be attended during the test as the Error screen will not clear unless the Reset switch is pressed. If Merlin fails this leak test consult your Merlin supplier for advice.

Merlin cleaning and disinfection

Periodically and specifically after use with animals known or suspected of having contagious respiratory disease it will be required to thoroughly clean Merlin and its associated tubing.
All tubing external to Merlin should be removed and cleaned with a suitable disinfectant. We recommend the use of a product called F10 for cleaning of Merlin as well as the external tubing. F10 is a very safe product and residue will cause no harm if it is inhaled, should any residue remain. In fact F10 is intended for use as a nebulising agent across a range of species. This procedure has been validated using an independent laboratory and details of the validation procedure can be obtained on request.

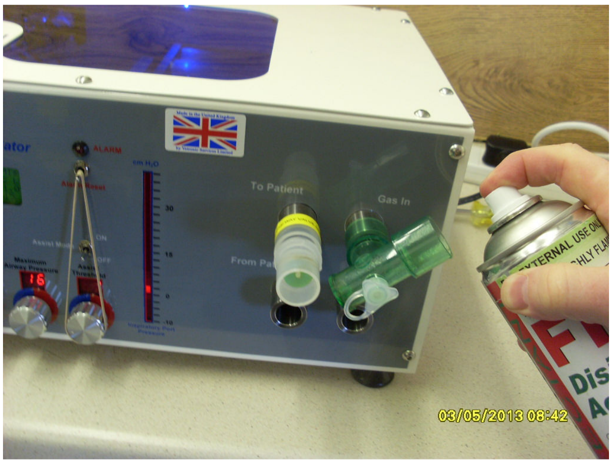
To clean the internal structure of Merlin, follow the set of instructions below:

The Merlin ventilator is put in continuous fast run mode by the following settings:

Flow: 25.0L/min
Inspiratory time: PL (pressure cycling mode)
Expiratory time : 2.0 seconds
MWPL: Greater than 10
Assist: not used - make sure the Assist mode is OFF

Use a weak rubber band to permanently hold the Alarm in Reset as shown.

Fit a right-angled 22mm connector to the Gas-In port of Merlin and angle it at about 45 degrees. Fit a one-way valve on the To-Patient port of Merlin. No other connections are necessary or required.



Set Merlin to Run so that the ventilator cycles continuously. Spray a 2-second burst of F10 into the open green connector on the return stroke of the piston. This is when the piston is filling with gas and sucking air from the Gas-In port. Do this at least 6 times. This will allow F10 aerosol to be pulled directly into Merlin and leave a small pool of F10 in the green connector.

Now, leave Merlin running in this continuous mode for 15 minutes at which time repeat the above procedure by spraying in a further 6, 2-second bursts of F10. Allow the ventilator to run continuously for a further 30 minutes or until the pool of F10 in the green connector has gone, ***whichever is the longer***.

Disinfection is then complete.

F10 is a safe compound suitable for inhalation and nebulising of animals. Therefore any residue or remains of F10 will have no deleterious effect on any animals subsequently ventilated with Merlin.

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