An Introductory guide to the AISYS CS^2 ventilator for non-Intensivists who may be expected to use this ventilator in the context of the current COVID 19 pandemic

Disclaimer: These ventilators are designed for the provision of anaesthesia and not for long term ventilation of the critically ill patient and are therefore being used out-with their licensed indications. This is acknowledged on the NHS Lothian clinical risk register.

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Adapted for use at the WGH site by Dr Alastair Morgan

For those of you who are familiar with the AISYS CS^2 ventilator as an anaesthetic machine see below. For those who are not familiar with the machines, move to page 3 and read this document in full. This document should be read in combination with the Standard Operating Procedure for use of AISYS CS^2 ventilators to ventilate Critical Care patients.

Initial ventilator settings

FiO_2 100%

Total Flow rate – 3L/min if using **low flow** (with soda lime) or 6L/min if using **high flow** (without canister soda lime)

Mode – **SIMV PCV-VG**

Vt– initially 400mls and then adjusted to lung protective ventilation (6mls/kg predicted body weight) using ulnar ruler

Respiratory Rate 20-24 breaths per minute

Pressure support - 5 cmH_2O

PEEP – 12cm H_2O – note COVID positive patients are likely to require high PEEP levels (12-20 H_2O)

I:E ratio 1:1.5 (**RR and I:E ratio are not linked – I:E ratio must be changed using the "More Settings Tab")**

Ventilatory goals

$PaO_2 \geq 8kpa$

$PaCO_2$ – no limit but aim to maintain $H+ \leq 60$ ($pH \geq 7.2$)

Peak inspiratory pressure $\leq 30cmH_2O$ (when using SIMV PCV-VG, peak pressure $\approx$ plateau pressure)

Do not increase Vt in order to achieve increased minute ventilation without discussion with ICU consultant.

Troubleshooting hypoxaemia in COVID 19 patients

Diuretics aiming neutral to negative balance

Increase PEEP (caution if haemodynamic instability)

Consider neuromuscular blocking agents

Prone ventilation

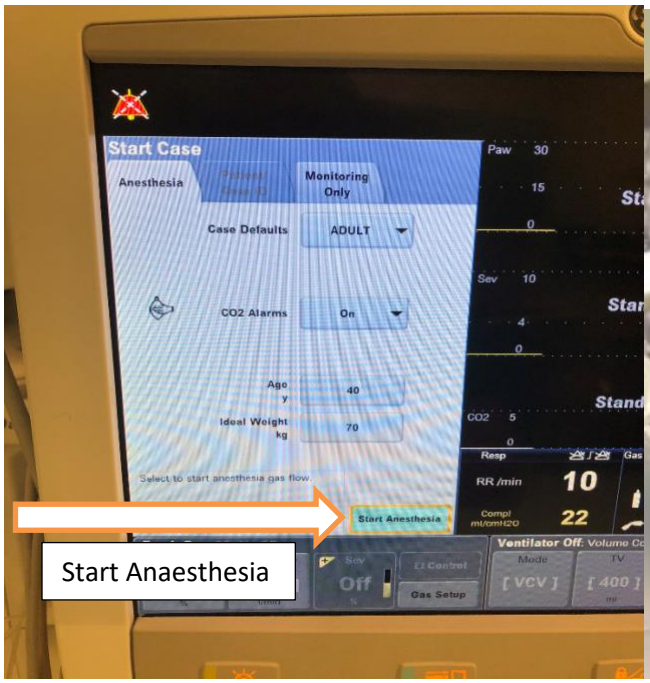
Commencing ventilation

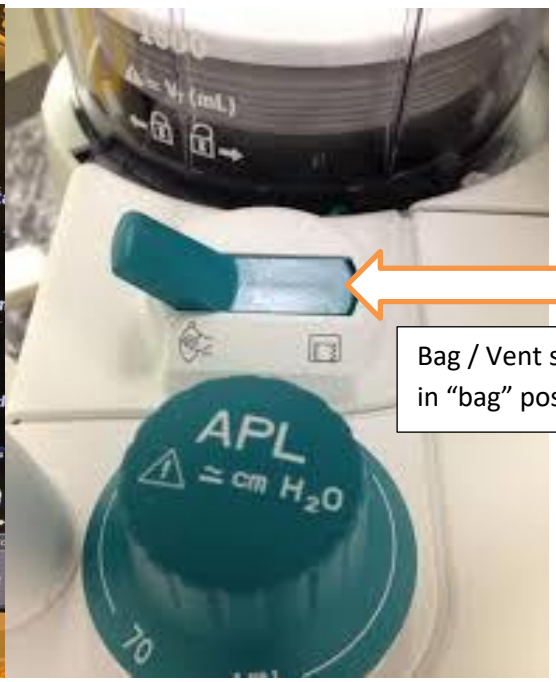
To turn on the system turn the system switch (highlighted by the red arrow below) to On and confirm that the main indicator light is green (green arrow).

Use the touchscreen and comwheel shown below to navigate windows. All changes to settings need to be confirmed by pressing the com wheel.

If the machine has been checked and then put into standby, you will see the screen on the left initially. If the full-test has just been completed, the “checkout” screen will be shown. Select and confirm the start case tab.

After you select the start case menu you will be shown the window below with the option to customise the default settings. Ensure bag / vent switch is toggled to bag (see picture below). Do not make any changes on this window but select “Start Anaesthesia” which will start gas flow.





Following this you will be confronted with the screen below. You are NOT yet ventilating the patient. These are the machines default settings.

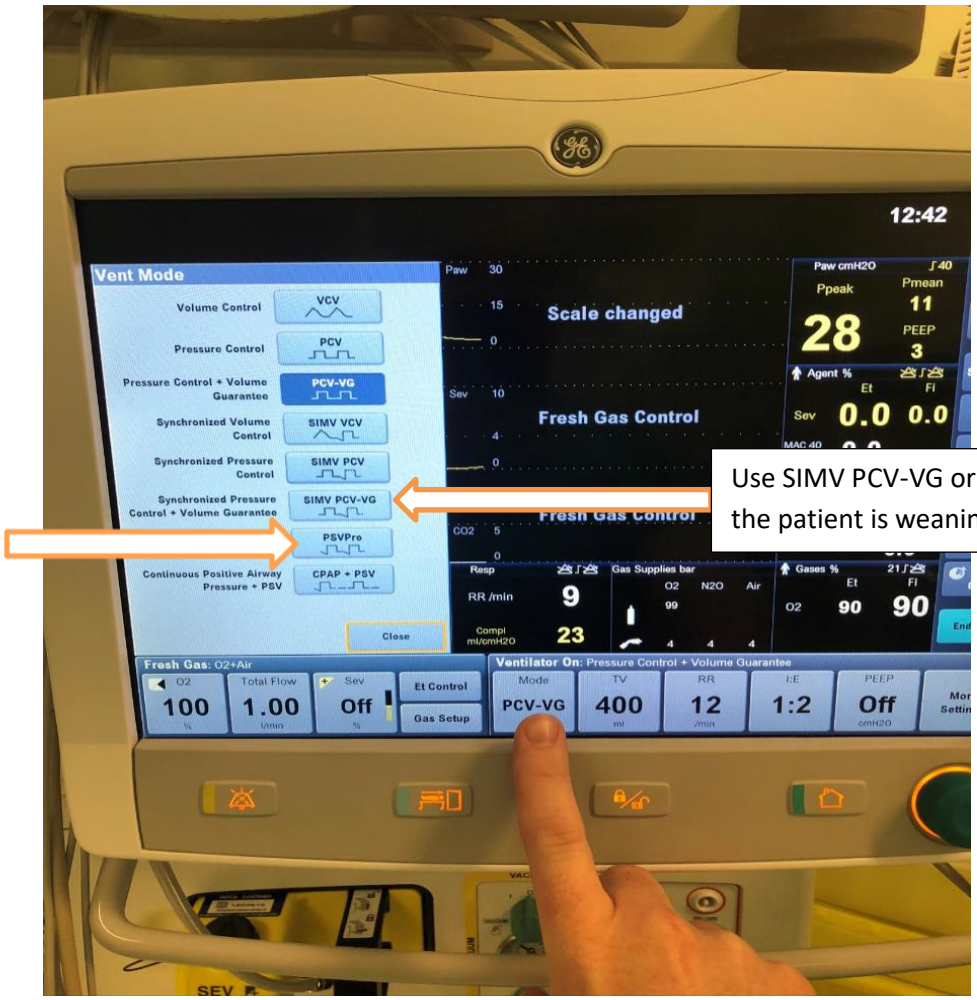
The default gas flow will be O_2 + Air, 100% O_2 at 6l/min flows. Adjust the flows to 3l/min if using low-flows (with soda-lime), or keep initially at 6l/min (high flow). The volatile should be OFF. You should now move the bag vent switch to vent and you will begin to ventilate the patient using the default settings: Volume Controlled Ventilation (VCV) with FiO_2 100%, a tidal volume of 400ml, a RR of 12 and NO PEEP.

The mode of ventilation menu is accessed by selecting on the touch screen as shown below. The Modes of ventilation will be familiar to you although some of the names will be slightly different. They are listed below.

Modes of Ventilation

SIMV - VCV	Synchronised intermittent mandatory ventilation – volume controlled ventilation
SIMV - PCV	Synchronised intermittent mandatory ventilation – pressure controlled ventilation
SIMV – PCV -VG	**Synchronised intermittent mandatory ventilation – pressure controlled ventilation – volume guaranteed**
PSV pro	**Pressure support ventilation**
PCV VG	Pressure controlled ventilation – volume guaranteed
PCV	Pressure controlled ventilation
CPAP and PSV	Continuous positive airway pressure and pressure support ventilation
VCV	Volume controlled ventilation

The ventilator mode options are as shown in the picture below.



Use SIMV PCV-VG or PSV Pro if the patient is weaning

The ventilator parameters including FiO_2 can be adjusted as defined by the medical team. When the respiratory rate is adjusted, this will change the I:E ratio. Select “More Settings” and adjust the Tinsp (as shown above) to maintain the I:E ratio of between 1:1.5 and 1:2.

We will plan to use SIMV PCV-VG as our default initial setting as this is the mode that best corresponds to our usual ICU ventilator settings (it uses autoflow to minimise airway pressures). We will select a tidal volume using the ulnar ruler posters and will in most instances need to increase respiratory rate with an initial setting of 20-24 breaths per minute being our preferred starting position. All patients should be ventilated with PEEP and an initial setting of 12cm H_2O will be selected (note COVID 19 patients are likely to require additional PEEP to this). All settings will need to be adjusted to best optimise individual patient ventilation.

Our desired spontaneously breathing mode of ventilation will be PSVPro as unlike CPAP and PSV, it incorporates an apnoea ventilation setting and it is the safer of the 2 options. See below for representation of adjustable parameters in this mode of ventilation and we would anticipate that all settings remain standard and that only pressure support and PEEP be adjusted according to clinical need.

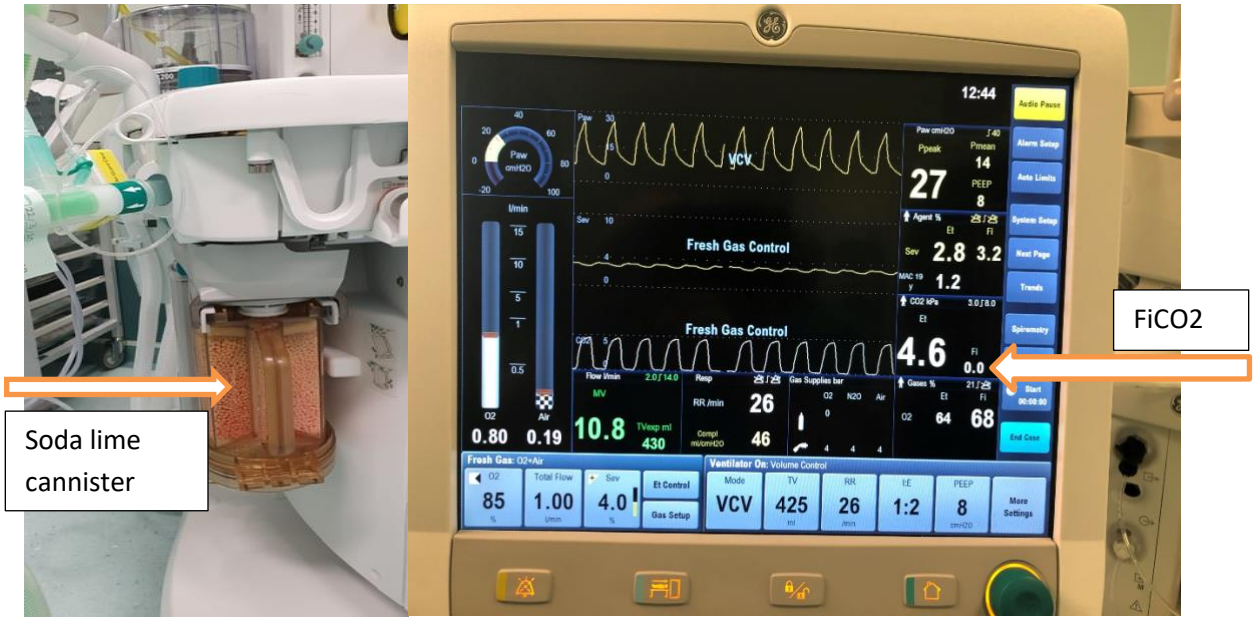
Fresh Gas Flows (FGF)

One significant difference between the AISYS CS^2 and standard ICU ventilators is the requirement to set the ventilator fresh gas flow rate.

The AISYS CS^2 can either be run at higher flows (>6-8l/min) or low flows (1-3l/min) with a soda lime canister in the circuit. With the latter, flow rates can be set extremely low as expired CO_2 is absorbed by the soda lime and not re-inspired. Please note that soda lime becomes exhausted and needs changing on a regular basis. There are 2 indicators that this is occurring and these are:

1- soda lime changes colour to demonstrate to what extent it has been used.

2- The $FiCO_2$ will begin to rise (see picture below for where this information can be found).

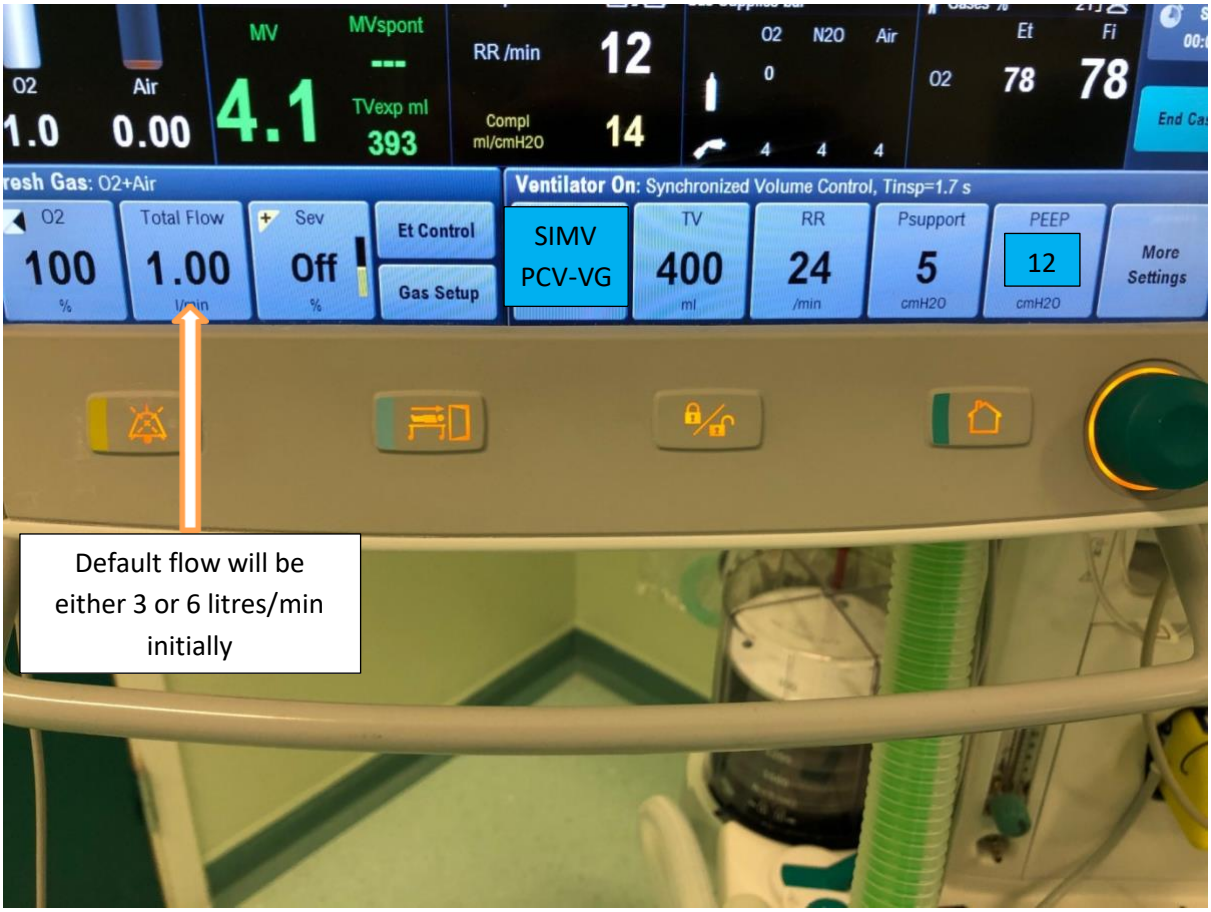


How do I select the fresh gas flow rate?

We plan to have two phases. Initially for the satellite ICU in recovery, we are planning to use higher flows at 6-8 litres/min which will reduce soda lime use. We will also run some patients without soda lime but expect that flows >10l/minute may be required. Should COVID surge ICU open in theatres, we are anticipating that oxygen demand throughout the hospital will prevent us from using higher flows. At this point, we expect to change to a low-flow system. Initial flow rates will be 3 litres/minute which will be a balance between oxygen demand and soda lime use (soda lime will need changing more frequently with lower flows). This may need to be reduced to 1 litre/min.

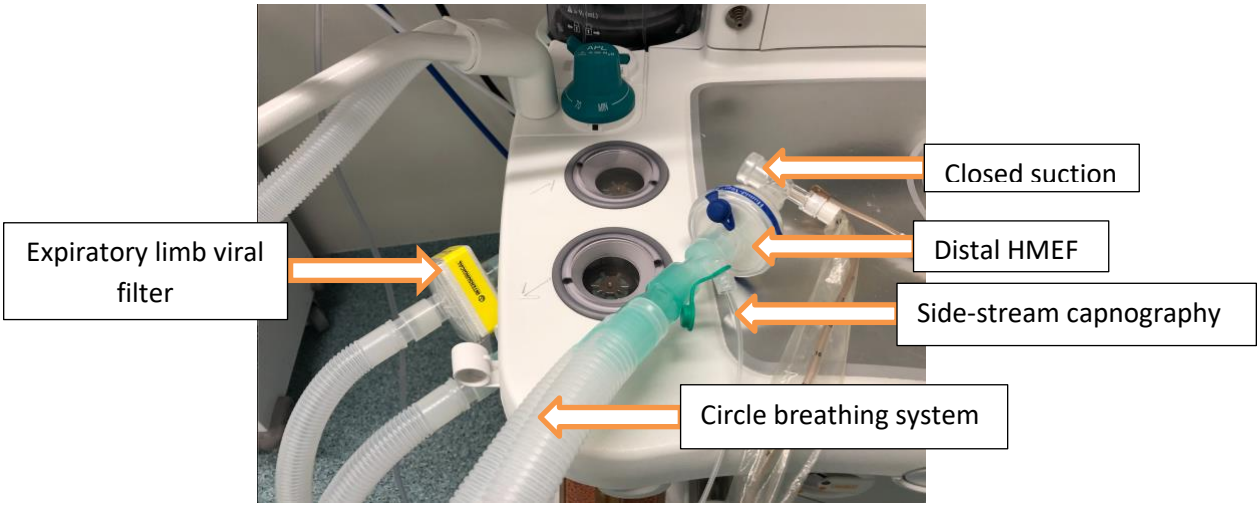
Flow rate is adjusted by selecting the flow rate menu shown below and adjusted by rotating the com wheel or selecting from the available default settings.

It is important to note that if soda lime supplies are limited, the ventilators will be run without it. Flow rates should be increased back to at least 6-8 litres per minute to wash expired CO_2 out via the spill valve.



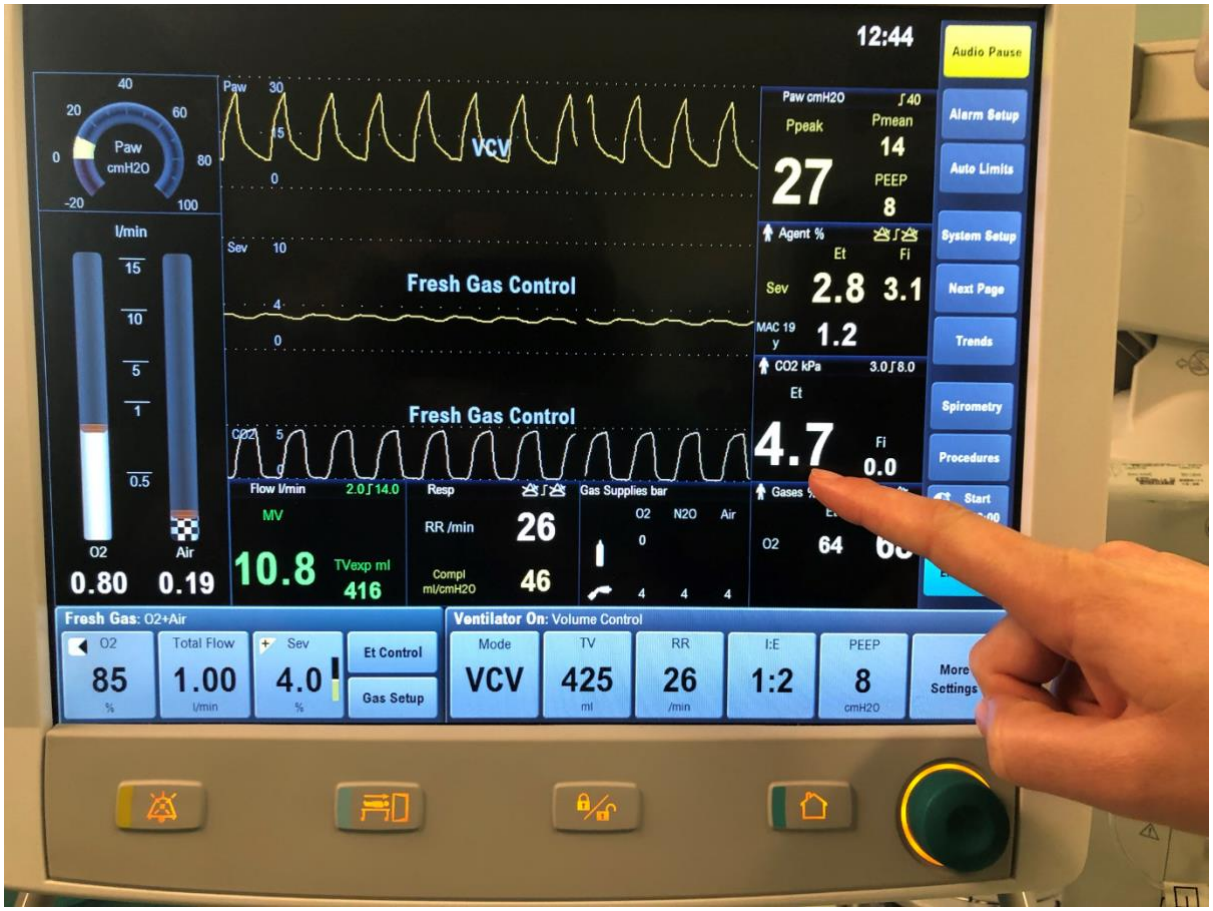
Breathing Circuits

The AISYS CS^2 works with a closed breathing system called a circle breathing system shown in the picture below. At WGH our circle consists of an inspiratory and expiratory tube.



In order to reduce the potential for contamination we will run with 2 filters located in the positions highlighted above. We do not plan to routinely change circuits or filters unless necessary (see SOP).

In line capnographs are not required as the Aisys uses a sidestream capnograph (see above) and displays $EtCO_2$ on the ventilator monitor and not on the mindray monitor, as shown below.



Solutions to known challenges

Checkout

By default, the Aisys CS^2 will ask for a "checkout" after 12hrs and display a warning message.This message is intended to remind users to conduct a pre-use check-out procedure after 12-hours under normal clinical use. The message has no impact on the performance or reliability of the machine or its operating system. There is no requirement to reboot or conduct a checkout. We cannot change or alter the 12-hour message. Simply acknowledge and cancel the message.

The maximum time an Aisys CS^2 machine can stay on is 49 days. Users would be expected to carry out a pre-use check and reboot after this 49-day time period.

Soda lime

As mentioned earlier we will be using the ventilators both with soda lime (low flow) and without (high flow). When using high flows, the soda lime canister should be emptied and returned to the circle. There will be a small continuous leak if the canister is removed completely. When the ventilators are used with low flows (1-3L/min), the soda lime will require changing 1-3 times in 24-hours depending on the patient's minute ventilation and metabolic rate. This will be less frequent when soda lime is run with higher flows (>6l/min). You should enlist the expertise of an ODP or anaesthetic nurse to assist. Although the cicuit is self-sealing when the canister is removed, there will be a temporary drop in pressure within the circuit. Fresh gas flow should be increased to 10l/min during the procedure to mitigate this. If the patient is very PEEP dependent, the COETT should be temporarily clamped so that PEEP is not lost.

Circuit disconnection

Should the circuit become disconnected then the machine will alarm and the patient should be reconnected. However, the AISYS uses a bellows style ventilator and these bellows will empty at the point of disconnection. Upon reconnecting the patient, flow rates should be increased for a short period (10L/min) until the bellows have completely reinflated before then being reduced back to baseline settings. Please do not use the O2 flush system as this has the potential to induce barotrauma.

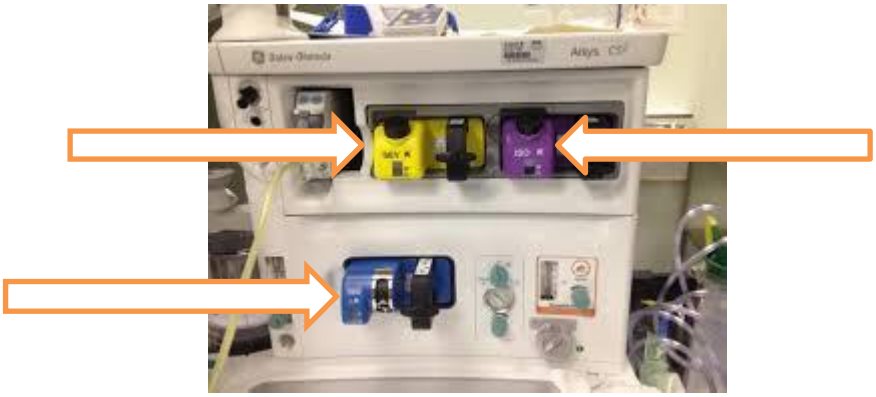
Suctioning

The use of closed suction will cause the ventilator bellows to collapse when flow rates are low. Prior to suctioning, the flow rates should be increased to 10 L/min and then returned to baseline settings following the completion of the suctioning procedure. The ventilator is likely to alarm during suctioning and can be cancelled. Suctioning should only be undertaken when clinically indicated.

Safety warning

The Aisys CS^2 can be operated either with the vapouriser cassetes in or out of the circle. To ensure that anaesthetic vapour is not used inadvertently (without scavenging), the cassette should be removed before ventilating a patient in the satellite recovery ICU. Should we have a shortage of propofol, we may need to maintain sedation using either sevoflurane or isoflurane. In this situation, anaesthetic gas scavenging must be functional and the patient in theatres (refer to SOP).

If the ventilator is used in satellite recovery ICU, it must have a full-test run without the volatile cassette in the circuit. It is not possible to remove it during the machine full-test unless the test is restarted.



Unable to drive bellows

"Unable to drive bellows" is an alarm that may occur frequently with lower fresh gas flow rates. In order to overcome this please increase fresh gas flow rate to 10l/min until the bellows are completely filled again. Assess the circuit for any potential leaks using a push and twist approach. Check the COETT pressure using a manometer. If no leaks are identified, return to baseline gas flows but increase by 0.5l/min. If this problem continues, the ventilator may need to undergo a check and an ODP and medical staff should be contacted.

Falling FiO_2

When low fresh gas flows are used, it is possible that the oxygen demands of the patient are not being met by the replacement gas flow. If the FiO_2 measured in the circuit is lower than the target that has been set by the bedside team, fresh gas flow should be increased by 0.5l/min and the FiO_2 re-checked in 5 minutes. If the difference persists, this should be discussed with the medical team.

Increasing $FiCO_2$

Neuro ICU patients requiring tight $PaCO_2$ control must be run on a circuit with soda lime with FGF initially at 6l/min

When the circle is used with soda lime, an increase in $FiCO_2$ is due to either soda lime exhaustion or malignant hyperpyrexia. When soda lime is not used, CO_2 clearance is dependent upon FGF and the patients minute volume. This should initially be set at 6 litres/minute. Higher FGF is likely to be required if the patient has an elevated minute volume. The $FiCO_2$ alarm should be set at 0.5. If $FiCO_2$ is >0.5, initially increase FGF by 1l/minute then recheck after 15 minutes. If FGF >10l/min is required to prevent CO_2 rebreathing, soda lime should be added to the circuit and FGF reduced to 6l/min.

Breaking the circuit in COVID positive patients

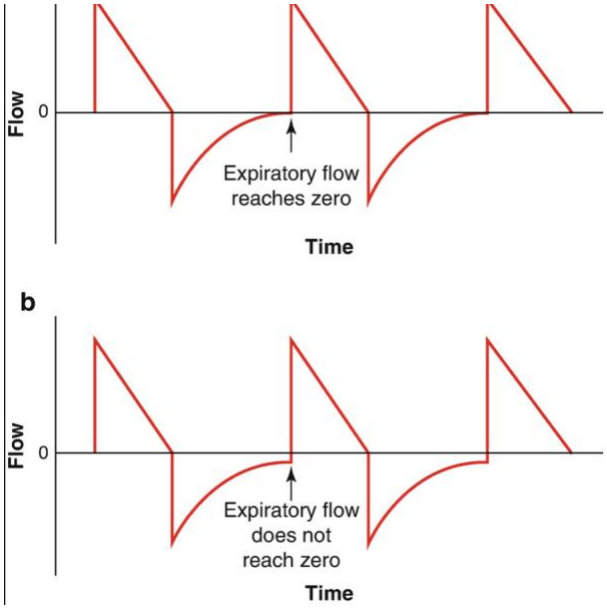
The presence of the bacterial/viral filter at the patient end of the circuit will reduce risk to staff should the circuit need to be broken proximal to it. This risk can be reduced further by clamping the COETT. The COETT should be clamped during inspiration, and fresh gas flow paused. Once the circuit has been reconnected, the ventilator can be restarted and the COETT unclamped.

Circuit Disposables

When ventilating a non-COVID patient using an ICU ventilator, the disposables (HMEF, circuit, closed-suction) are routinely changed. With COVID-positive patients, routine disposable changes are high-risk procedures and should only be performed if they are soiled (filters) or their integrity is questioned.

Elevated airway pressures, reduced peak expiratory flow, prolonged expiratory flow (see below) and increasing $EtCO_2$ may suggest reduced efficiency of the HMEF. Using circle circuits and low-flows will increase moisture production. Increasing fresh-gas flow every 4 hours to 10 litres/min for 5 minutes will assist in drying the internal circle components (including the flow valves).

The expiratory limb filter (yellow Intersurgical) could become very wet and should be changed every 24 hours. With increasing experience, this may prove to be unnecessary.



Difference in measured inspiratory/expiratory volumes

Differences between the inspired and expiratory volumes are usually due to a leak in the circle. The ventilator bellows may also collapse. Visually inspect, push and twist all connections, check COETT pressure using a manometer and ensure that the COETT has not been displaced. If this persists, a medical review is required and consideration of whether there is a machine problem (flow sensor).