MAQUET

SERVO Education
TUTORIAL

CRITICAL CARE

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1 INTRODUCTION

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The objective of this Tutorial is to help the user understand the different modes of ventilation.

This Tutorial includes the following information:

- information about pressure, flow and volume curves
- description of the different modes of ventilation
- exercises
- workshops (i.e. practical training)

1.1 INTRODUCTION

Mechanical ventilation is required when a patient cannot ventilate adequately, resulting in gas exchange.

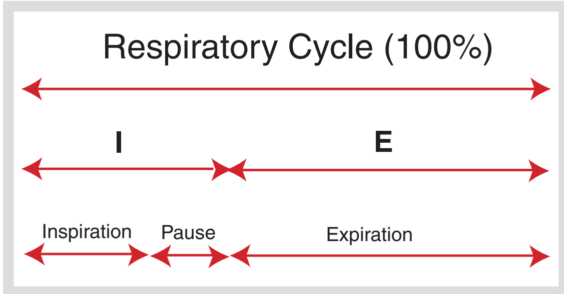
As all functions of the ventilator are represented by electrical signals in the Patient Unit, a continuous and real-time recording of the inspiratory and expiratory pressure, flow and volume is displayed on the User Interface.

- V_T = Tidal Volume (Volume of a breath)
- Resp Rate = Respiratory Rate every minute
- I:E ratio = Inspiration/Expiration ratio, or Inspiratory time in seconds
- Minute Volume = Volume delivered during 1 minute

1.2 GENERAL

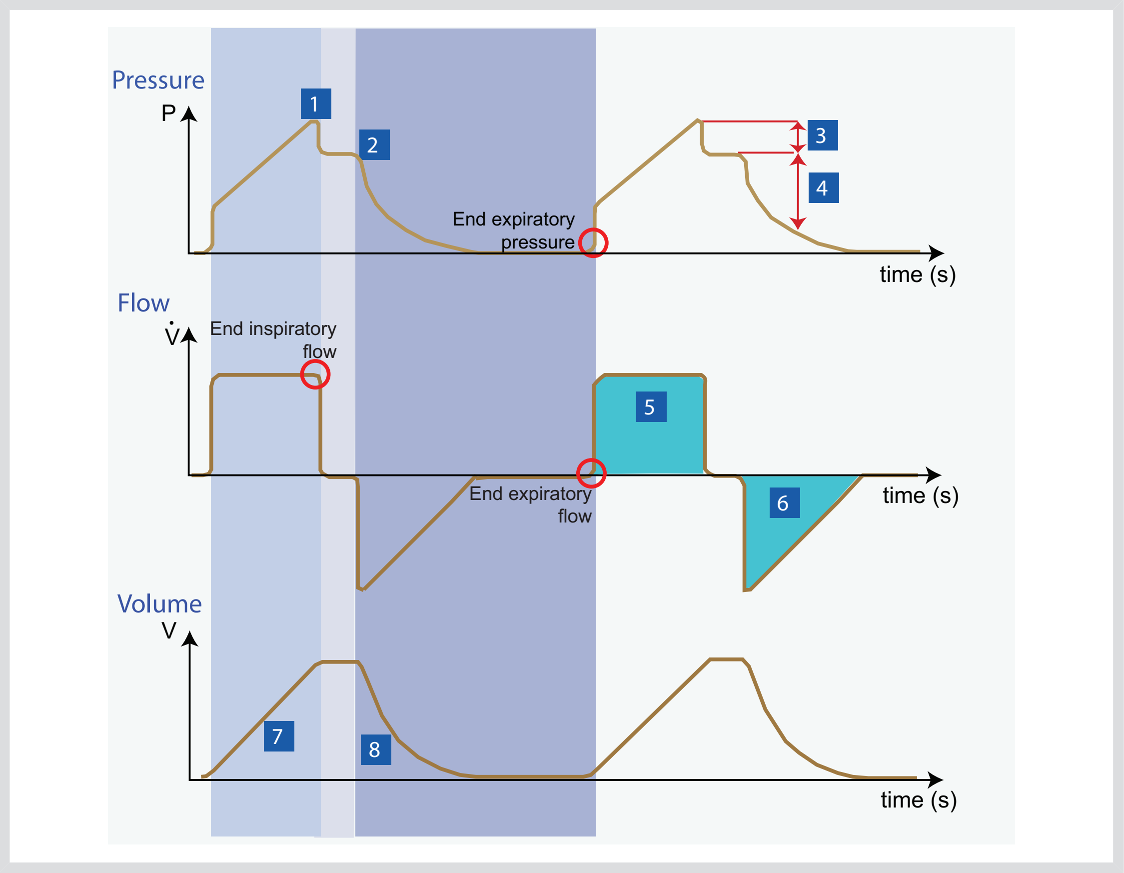
The respiratory cycle comprises:

- Inspiration
- Inspiratory pause
- Expiration



1.3 TERMINOLOGY

1.4 PRESSURE (P), FLOW ($\dot{V}$) AND VOLUME (V) CURVES IN VOLUME CONTROLLED VENTILATION



See next page for explanation of terminology.

1. Peak Pressure (P_{peak})	The maximum pressure attained during inspiration (end inspiratory pressure).
2. Pause Pressure/Plateau Pressure (P_{plat})	The pressure at the end of pause time (end pause pressure).
3. P_{res} (res = resistance)	The difference between peak pressure and pause pressure. This is the drop in pressure caused by the resistance to the gas flow in the airways of the patient.
4. P_{comp} (comp = compliance)	The difference between pause pressure and end expiratory pressure. It is a measure of the elasticity of the patient´s lungs.
5. Inspiratory volume (VTi) 6. Expiratory volume (VTe)	The volumes for inspiration and expiration are equal if no leakage occurs. They are represented by the sectioned areas between the flow curves and the zero line.
7. Inspiratory volume (VTi)	
8. Expiratory volume (VTe)	

$$\frac{\text{Preset Inspiratory Minute Volume l/min}}{\text{Inspiratory time \%}}$$

Example: Preset Insp. Min. Vol. = 8 l/min
Insp. time = 25%
gives inspiratory flow $\frac{8 \times 100}{25} = 32$ l/min

In the example of the pressure, flow and volume curves the patient does not breath spontaneously.

The ventilator is set for Volume Control ventilation with constant flow. During Volume Control ventilation (constant flow), the inspiratory flow is calculated by using the formula opposite:

2 VOLUME CONTROL VENTILATION

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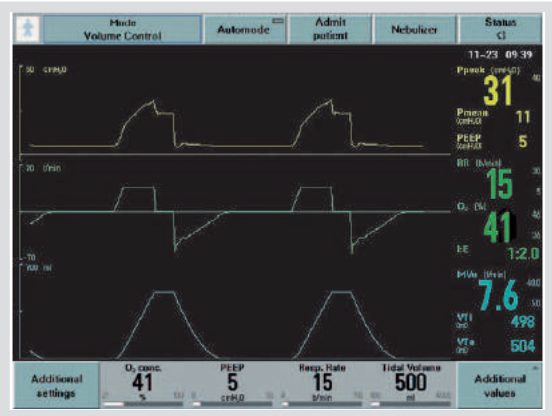
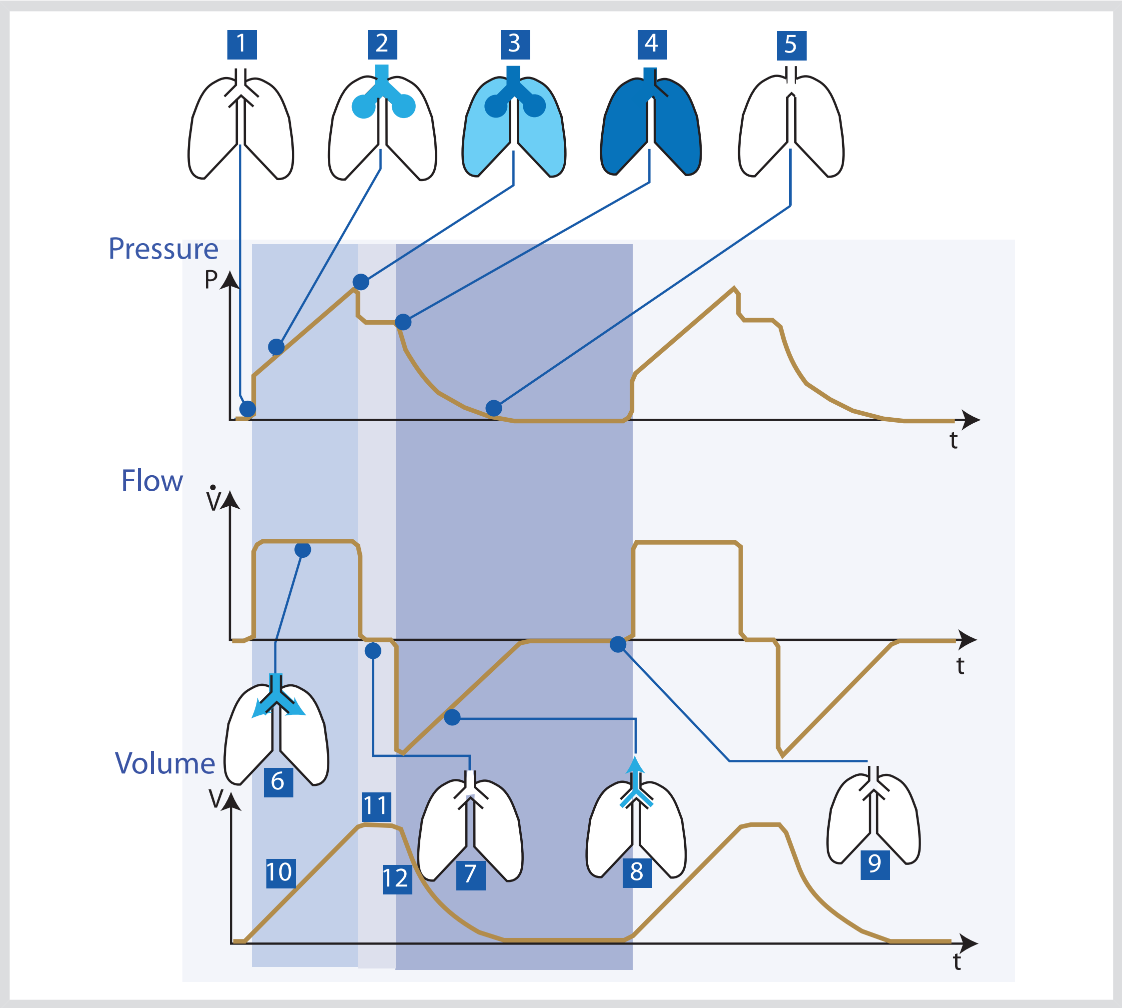
2.1 GENERAL

Volume Control provides controlled ventilation, and by setting the correct parameters the patient is assured of adequate ventilation.



The illustrations on the following pages show typical airway pressure, gas flow and volume curves. The illustrations of the lungs are shaded blue as inspiration progresses. Gas flow is indicated with arrows.

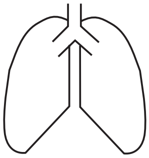
2.1.1 OVERVIEW OF CURVE INFORMATION IN VOLUME CONTROLLED VENTILATION



see next page for explanation

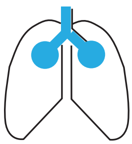
2.1.2 PRESSURE CURVE

1



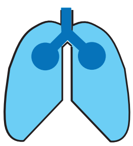
At the start of **inspiration**, the counter pressure in the lungs is 0 cm H_2O, or the set PEEP level.

2



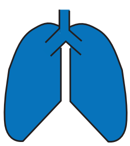
The more the lungs are filled, the higher the pressure must be to maintain a constant gas flow.

3



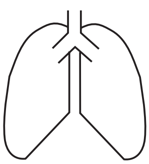
On the curve you can see that airway pressure is highest immediately before the pause.

4



The inspiratory valve and the expiratory valve are shut during **pause**. The gas is retained in the lungs and distributed amongst parts with low resistance (e.g. main bronchus), and those with high resistance (e.g. alveoli).

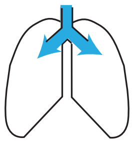
5



The expiratory valve opens during **expiration**. The lungs are emptied. Airway pressure falls to zero or to the set PEEP level.

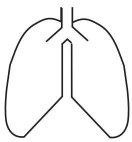
2.1.3 FLOW CURVE

6



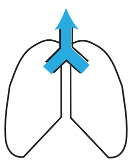
The curve shows that the flow is constant during **inspiration**.

7



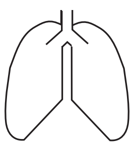
The inspiratory valve and the expiratory valve are shut during **pause**. No gas is supplied, and the flow is 0.

8



The expiratory valve opens during **expiration**. Initially, the flow is large, since the lungs have been filled by means of positive pressure.

9



The lower the positive pressure (i.e. lungs are emptied), then the smaller the flow. At the end of expiration the lungs are emptied of the gas supplied by the ventilator. Flow is 0.

2.1.4 VOLUME CURVE

10 The ascending curve represents insufflation.

11 The flat face represents an unchanged volume.

12 The descending slope represents expiration.

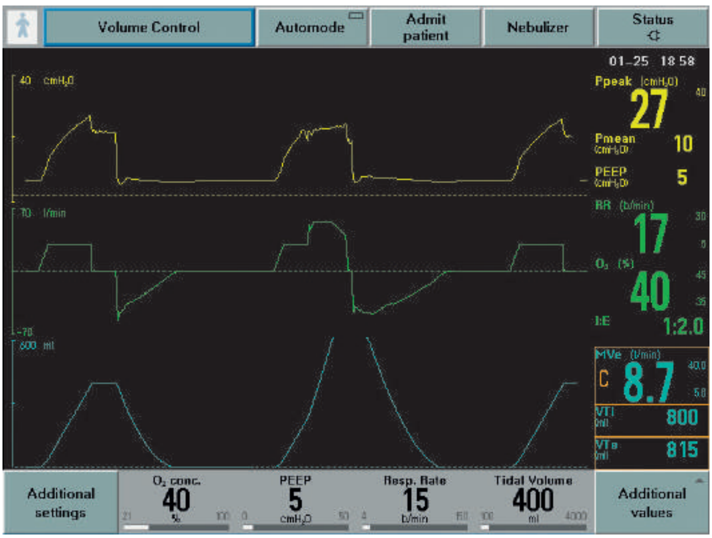
2.2 SUMMARY

2.2.1 INSPIRATION

Gas flows into the lungs at a constant rate. The more the lungs are filled, the greater the airway pressure becomes, and is at its greatest at the end of inspiration.

In some cases the patient may demand a higher Tidal Volume/flow than is set on the ventilator, e.g. if the patient is in pain, has an increased temperature or there is a change in the respiratory drive. The flow-adapted Volume Controller™ will always work with the patient and deliver the extra volume requested. If the patient decreases airway pressure by 3 cmH_20 during the inspiratory phase, the ventilator switches to Pressure Support and delivers a flow profile adapted to the patient´s immediate needs.

By triggering, the patient can increase the respiratory rate and then the minute volume.



summary continued on next page..............

2.2.2 PAUSE

Inspiratory and expiratory valves are shut and the pressure is equalised in the lungs/lung compartments.

2.2.3 EXPIRATION

The expiratory valve opens. The flow of expired gas is greatest at the start since it is then that the pressure is greatest. However, the flow decreases successively and is 0 at the end. The positive pressure in the lungs falls rapidly to 0 or the set PEEP, and the ventilator starts a new inspiration.

To reduce the resistance at the beginning of expiration, the expiratory valve has a controlling algorithm which continually calculates the elastic and resistive forces on the respiratory system. The initial opening of the expiratory valve is adapted to keep resistance as low as possible while strictly maintaining the set PEEP in the airway.

IMPORTANT: It is very important to set a sensitive triggering level (without risking auto-cycling), so that the patient can breath by himself as soon as possible. If the patient is making an inspiratory effort during the expiratory phase, then he will receive an assisted breath with the same tidal volume as set on the ventilator. Immediate sensing of inspiratory effort from the patient is mandatory in achieving synchronicity.

2.3 EXAMPLES OF VOLUME CONTROL VENTILATION

Note: Ventilators can be configured either for I:E or Ti. Please refer to the examples that are relevant for your ventilator.

2.3.1 EXAMPLE 1

V_T = 500 ml

Resp Rate = 12 breaths/min

I:E ratio = 1:2

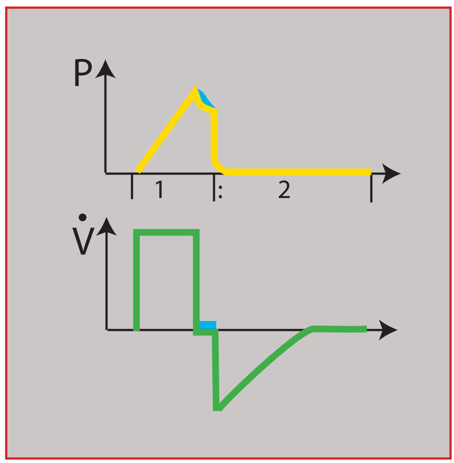
MV = 500 ml x 12 = 6 liters

Time for each breath is 60/1 = 5 s

Time for inspiration = 1.67 s
Time for expiration = 3.33 s
5 s

During this 1.67 s the ventilator should deliver 500 ml

In Volume Controlled ventilation it is possible to set a Pause time from 0 to 30% of the respiratory cycle. Both the inspiratory and the expiratory valves are closed during the pause time. There is no flow to the patient and no flow from the patient.



2.3.2 EXAMPLE 2

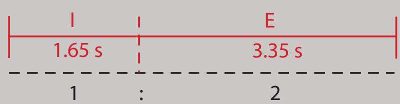
V_T	=	500 ml
Resp Rate	=	12 breaths/min
I:E ratio	=	1:2
Pause time (P)	=	10%

Pause time 10% of 5 s	=	0.50 s
Inspiration time 1.67 s - 0.50 s	=	1.17 s
Expiration time	=	3.33 s

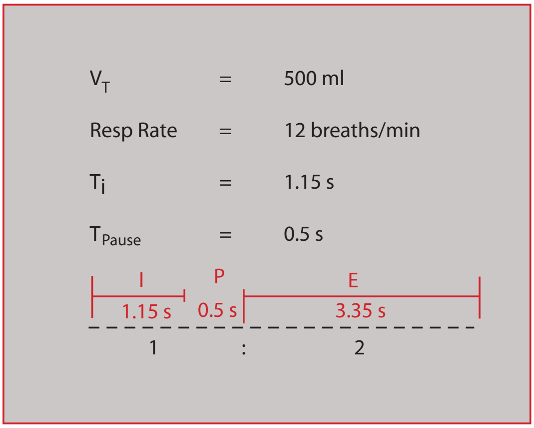
2.3.3 EXAMPLE 3

Examples are shown below if the SERVO-i is configured for Inspiratory time in seconds (Ti).

V_T	=	500 ml		
Resp Rate	=	12 breaths/min		
Time for each breath	=	60/12	=	5 s
T_i	=	1.65 s		
T_{Pause}	=	0 s		

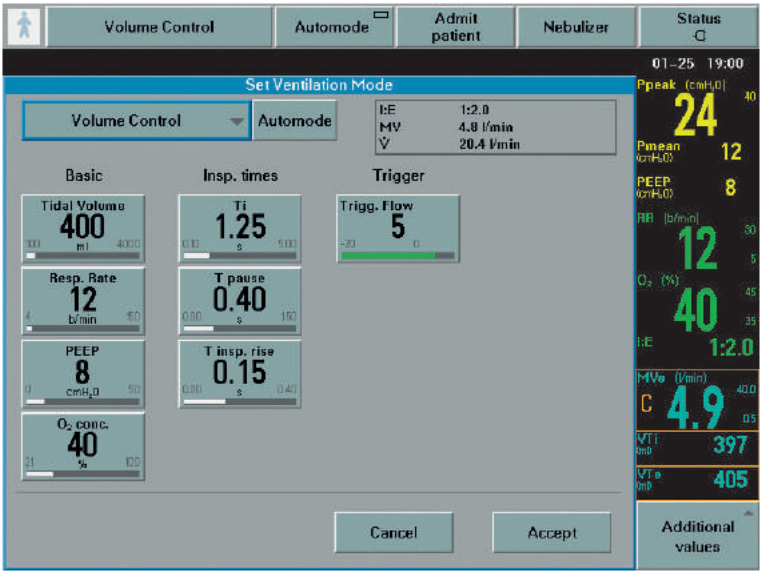


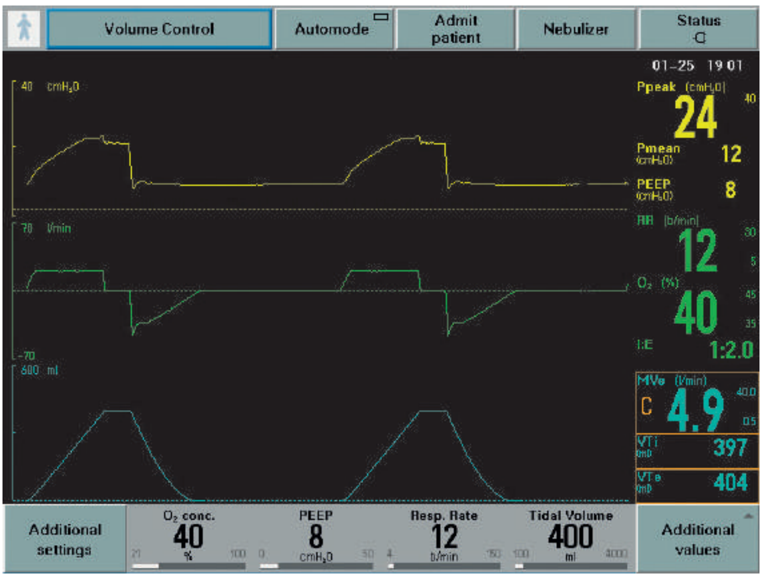
2.3.4 EXAMPLE 4



A result of a shorter inspiratory time is that the peak pressure will increase as the same volume will be delivered during a shorter time.

3 PRACTICAL EXERCISES - VOLUME CONTROL VENTILATION





See questions 1 to 4 on next page.

3.1 EXERCISES

Look at the settings on the previous page and answer the following questions:

1. How much is the Exp. Minute Volume?

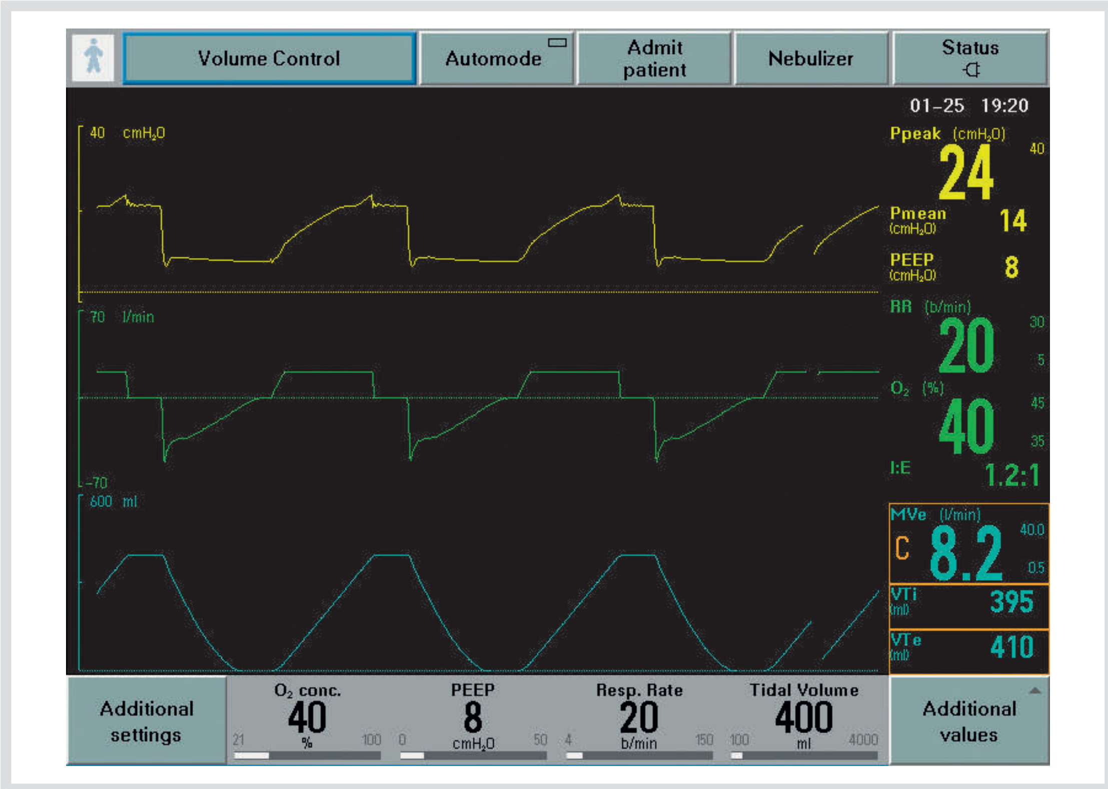
2. What is the measured I:E ratio?

The duration of the respiratory cycle is calculated as follows:

$$\frac{60}{\text{Resp. rate/min}}$$

3. How many seconds is the duration of the respiratory cycle?

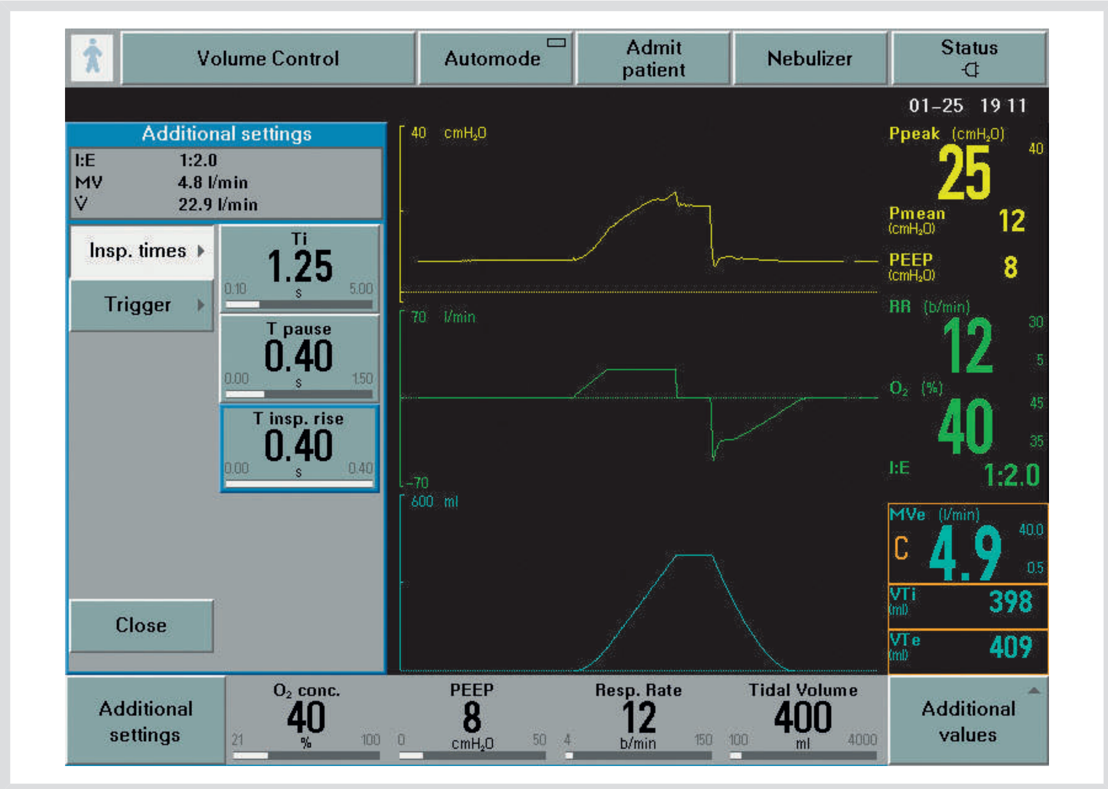
4. What is the calculated flow rate?



5. The SERVO-i is configured for Tidal volume settings and Inspiratory time in seconds. The respiratory rate is increased from 12 to 20 breaths/min.

a. What happens with the Insp. Minute Volume?

b. What happens with the measured I:E ratio?



6. Return to a Respiratory Rate of 12 breaths/min. Increase T Insp. rise to 0.40 s.

a. What happens with the shape of the pressure and flow curves?

b. What happens with the Peak pressure?

4 WORKSHOP - VOLUME CONTROL VENTILATION

4.1 WORKSHOPS - GENERAL FOR ALL MODES OF VENTILATION

To complete the Workshops the course participants must be familiar with the SERVO-i User Interface and have a thorough understanding of the basic hardware and functionality of the ventilator.

Pre-requisites for carrying out the workshop tasks are:

- a SERVO-i ventilator
- the appropriate patient breathing circuit (Adult)
- a test lung (Adult)
- a Pre-use check must have been performed

After completing the tasks outlined in the Workshop participants will be able to:

- Explain the pressure, flow and volume curves in the different modes of ventilation.
- Explain the difference between Volume and Pressure Control ventilation when there is a leakage in the system.
- Fully understand the parameters in the different modes of ventilation.

4.2 WORKSHOP - VOLUME CONTROL VENTILATION

1. Select Volume Control ventilation, and set the parameters shown opposite:

	V_T	=	400 ml
	Respiratory Rate	=	12 breaths/min
	PEEP	=	8 cmH_2O
	I:E	=	1:2
or	T_i = 1,25 s and T_{Pause}	=	0,4 s
	Trigger sensitivity	=	Flow 5

2. Set alarm limits

3. Start ventilation

4. Look at the curves (pressure, flow and volume).

5. Note the measured values for:

P_{Peak}	
RR	
MVe	
VTi	
VTe	

6. Make a small leakage in the patient breathing circuit.

7. Note the measured values for:

P_{Peak}	
RR	
MVe	
VTi	
VTe	

5 PRESSURE CONTROL VENTILATION

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5.5.1 EXAMPLE 1 | 37

5.1 GENERAL

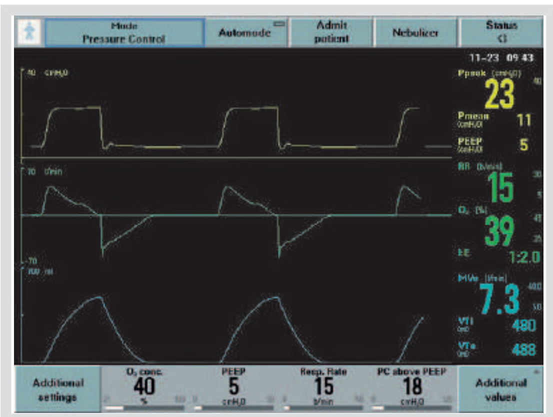
Pressure Control provides controlled ventilation, and by setting the correct parameters the patient is assured of adequate ventilation.

In Pressure Controlled ventilation the ventilator delivers a flow to maintain the preset pressure during the preset Inspiratory time and at the preset Respiratory rate.

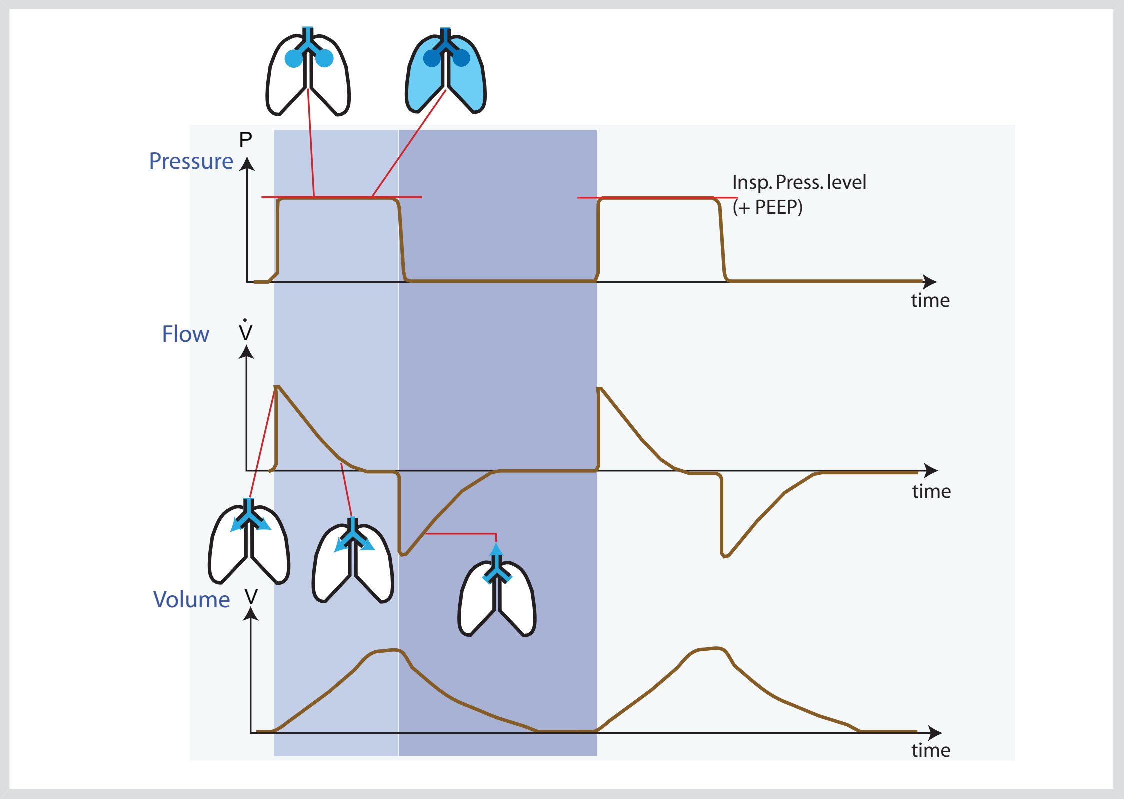
Pressure Controlled ventilation is used, for example, when there is a leakage at the endotracheal tube.

The Pressure Control level above PEEP is set on the ventilator, and the higher this level, then the more gas flows into the patient. However, the patient´s airway pressure also influences the gas flow - if the resistance increases during the treatment, then the less gas flows to the patient for a given Pressure Control level.

Check the Tidal Volume on the digital display (Exp. Tidal Volume is preferred if there is a leakage).



5.2 PRESSURE CONTROLLED VENTILATION - PRESSURE, FLOW AND VOLUME CURVES



Refer to sections 2.1.2 and 2.1.3 for more information.

5.3 SUMMARY

The flow curve during Pressure Controlled ventilation can vary a great deal depending, for example, on the patient´s resistance.

5.3.1 INSPIRATION

The flow is greatest at the start of inspiration. Since the pressure is constant, then the more the lungs are filled the more the flow decreases (i.e. decelerating flow).

summary continued on next page.....

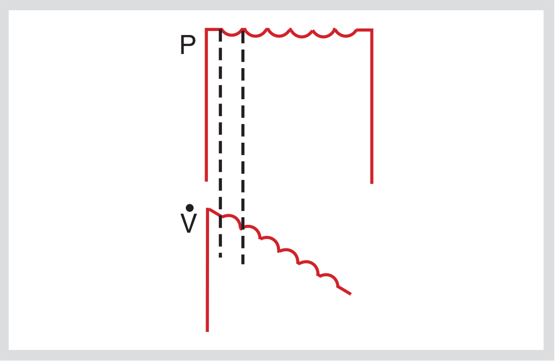
5.3.2 EXPIRATION

When the expiratory valve opens, the flow of expired gas is greatest at the start since the pressure is then greatest (1). To reduce the resistance at the beginning of expiration, the expiratory valve has a controlling algorithm which continually calculates the elastic and resistive forces on the respiratory system. The initial opening of the expiratory valve is adapted to keep resistance as low as possible while strictly maintaining the set PEEP in the airway.

5.4 USER CONSIDERATIONS

The SERVO-i keeps the pressure constant during the inspiratory time.

A decrease in pressure will give a precise increase in flow to keep the pressure constant during the inspiratory time.



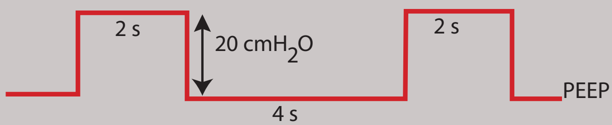
5.5 EXAMPLES OF PRESSURE CONTROL VENTILATION

5.5.1 EXAMPLE 1

In Pressure Control no pause time is available and the I:E ratio or Inspiratory time in seconds (T_i) can be set.

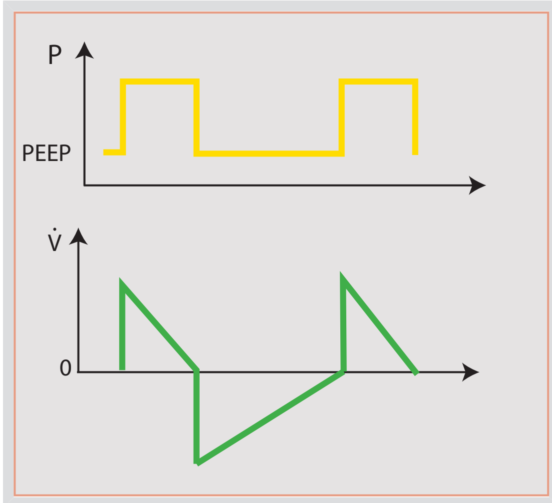
Insp. pressure level	=	20 cmH_2O
Resp Rate	=	10 breaths/min
I:E ratio	=	1:2
T_i	=	2 s
Each breath is 60/10	=	6 s
Inspiration time	=	2 s
Expiration time	=	4 s

During these 2 s a constant pressure is delivered. In this example a pressure of 20 cmH_2O above PEEP is delivered during 2 s.



The flow is decelerating and is high at the beginning of each breath in order to reach the set pressure.

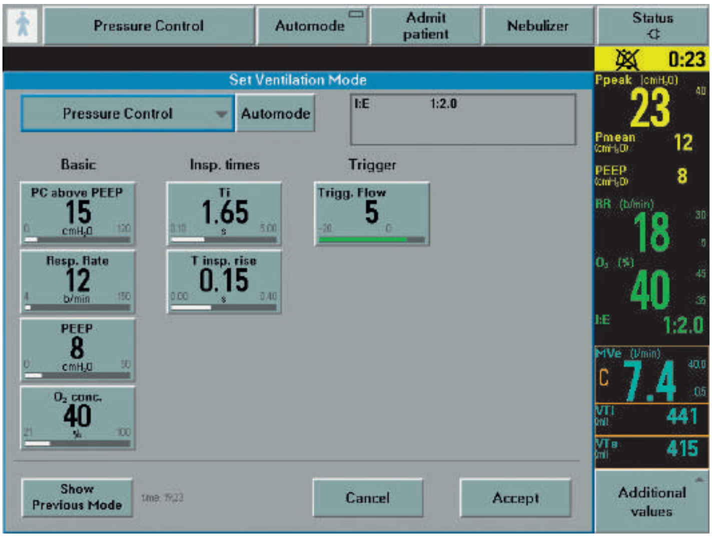
The higher the inspiratory pressure level, the more gas flows to the patient. The patient´s resistance and compliance influences the gas flow. If the resistance increases during the treatment, then less gas flows to the patient at a given inspiratory pressure level.



The flow curve during Pressure Controlled ventilation can vary greatly depending on the leakage, resistance and compliance.

IMPORTANT: As the delivered Tidal Volume can vary, it is very important to set the alarm limits for expired Minute Volume to adequate levels.

6 PRACTICAL EXERCISES - PRESSURE CONTROL VENTILATION



See questions 1 to 3 on next page.

6.1 EXERCISES

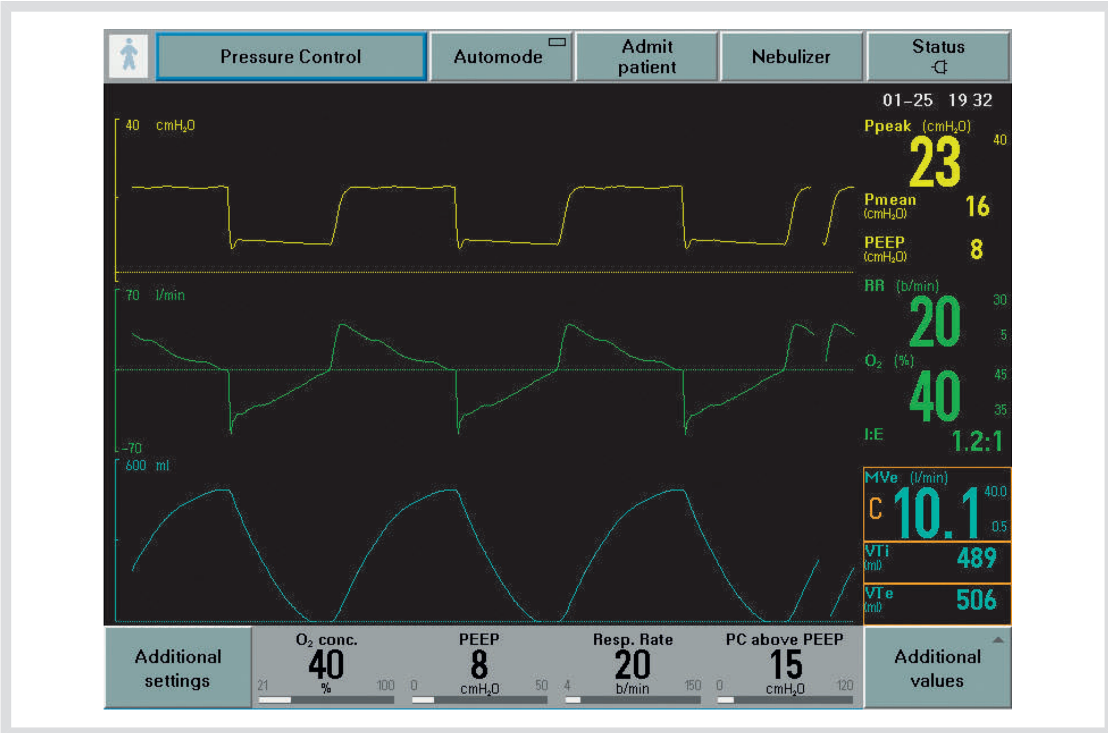
1. Select Pressure Control and set the following parameters.

PC above PEEP	=	15 cmH_2O
Respiratory Rate	=	12 breaths/min
PEEP	=	8 cmH_2O
O_2 concentration	=	40%
I:E T_1	= =	1:2 1.65 s
T. insp. rise	=	5%/0.15 s
Trigg.	=	Flow 5

Look at the settings on the previous page and answer the following questions:

2. How much is the Insp. Tidal Volume in these settings? (use a SERVO-i test lung).

3. What is the I:E ratio?

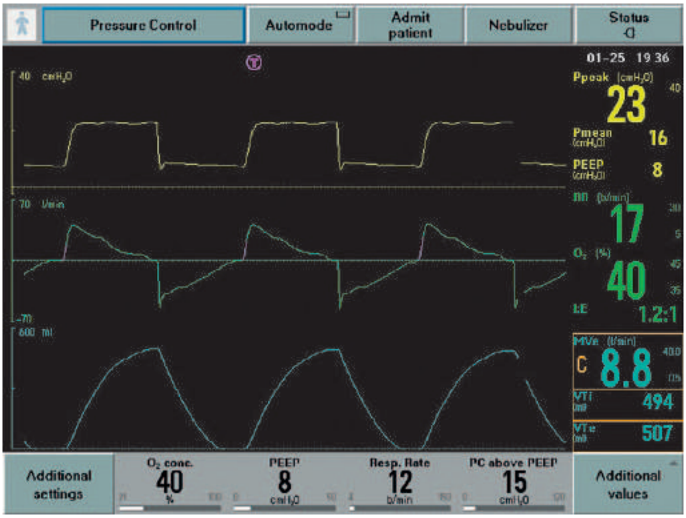


4. Increase the resp. rate from 12 to 20.

4a. What happens with the Exp. Minute Volume?

4b. What happens with the I:E ratio?

4c. What happens with the Peak Pressure?



5. What happens to the following if the patient triggers during Pressure Control ventilation?

5a. Tidal Volume

5b. Peak Pressure

5c. Respiratory Rate

7 WORKSHOP - PRESSURE CONTROL VENTILATION

1. Select Pressure Control ventilation, and set the parameters shown opposite.

	Inspiratory pressure above PEEP	=	15 cm H_2O
	Respiratory rate	=	12 breaths/min
	PEEP	=	8 cmH_2O
	I:E	=	1:2
or	T_i	=	1.65 s
	Trigger sensitivity	=	Flow 5

2. Set alarm limits

3. Review the curves (pressure, flow and volume).

4. Note the measured values for:

P_{Peak}	
RR	
MVe	
VTi	
VTe	

5. Make a small leakage in the patient breathing circuit.

6. What happens with the pressure and flow in this case?

7. Note the measured values for:

P_{Peak}	
RR	
MVe	
VTi	
VTe	
$\dot{V}ee$	
Total PEEP	

8. Explain the difference between Volume and Pressure Control ventilation.

8 PRESSURE REGULATED VOLUME CONTROL VENTILATION

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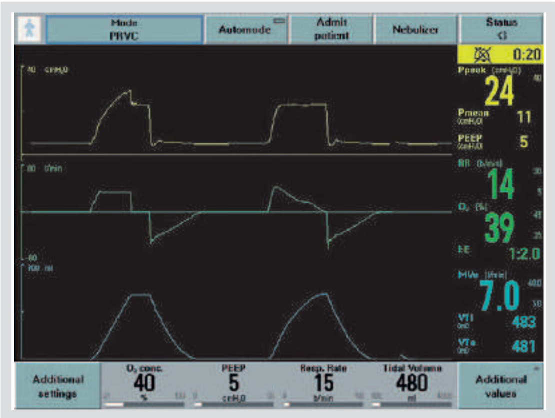
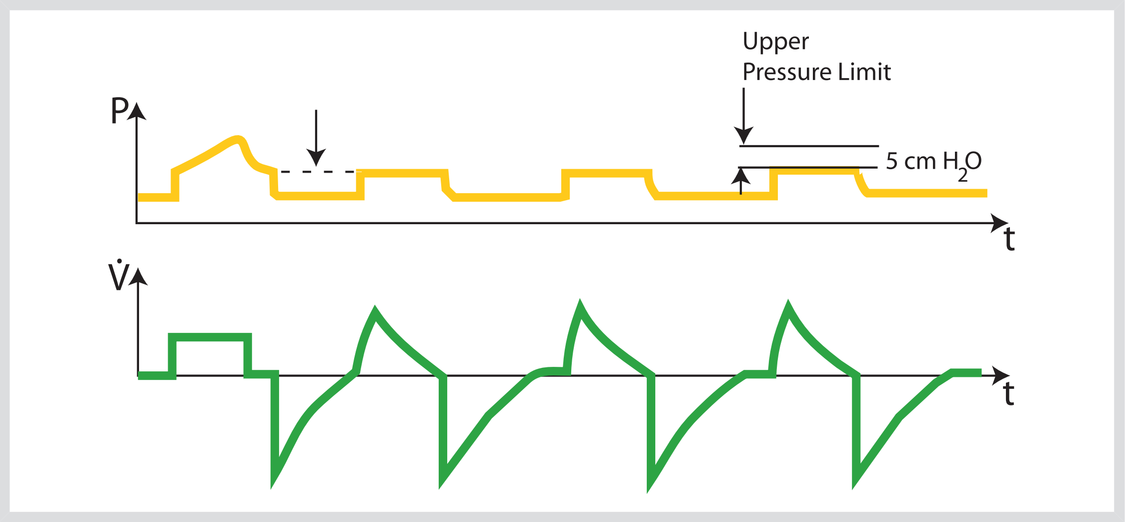
8.1 GENERAL

PRVC can be used when the patient needs controlled ventilation. In this mode the patient can trigger extra breaths, and delivers the set Tidal Volume with the lowest possible pressure.

Note: PRVC is not recommended when there is a leakage in the patient´s breathing circuit.



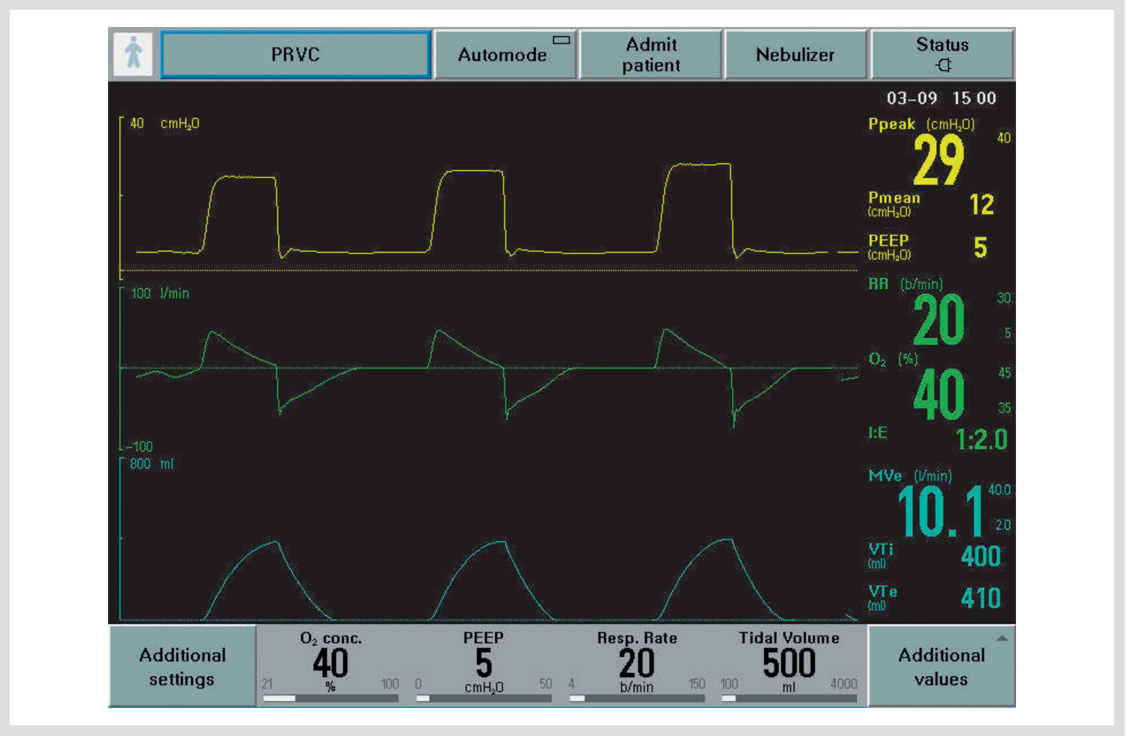


The first breath in the start up sequence is a Volume Controlled breath. The second breath is a Pressure Controlled breath with the pressure taken from the measured pause pressure of the Volume Controlled breath. The set Tidal Volume is delivered by automatic, breath-by-breath regulation. The start up sequence is four breaths.

The SERVO-i uses the information from the previous breath. If the Tidal Volume is below target then the SERVO-i increases the pressure to increase the Tidal Volume. Conversely, if the Tidal Volume is above the target, then the SERVO-i decreases the pressure to decrease the Tidal Volume.

However, if there is a leakage, for example around the patient´s endotracheal tube, then pressure regulation is difficult as the leakage is never constant.

The start up sequence is completed and the patient is stabilized with a pressure of 24 cmH_2O to deliver the set Tidal Volume.



Suddenly, the patient receives a large amount of secretion and the Tidal Volume decreases. During the following breaths, the pressure increases in steps of a maximum of 3 cmH_2O.

The goal is to return to the target volume. The closer the delivered volume comes to the target volume, the smaller the adjustment of the pressure level. The pressure needed to deliver the target volume will probably be lower after suctioning.

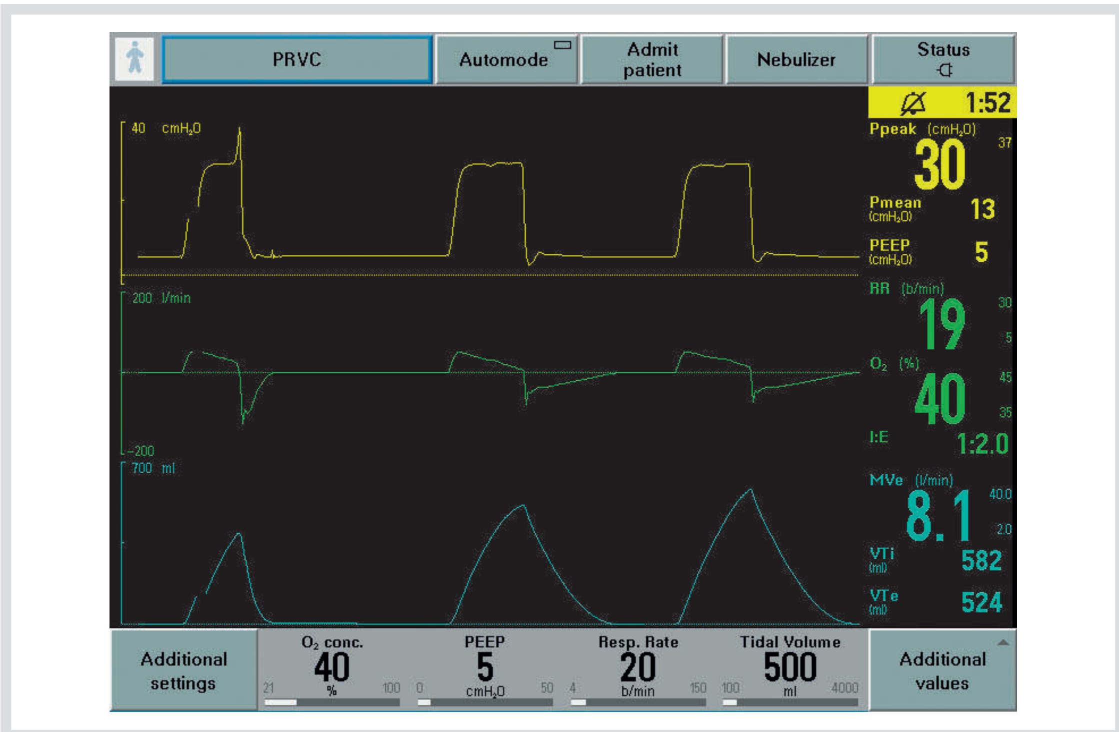
The SERVO-i will restart with the start-up sequence should one of the following criteria occur:

- if the delivered Vt is 50% less than the set Vt, or
- when the Upper pressure limit is exceeded during 3 consecutive breaths.

8.2 SPECIAL CRITERIA

If the measured Insp. Tidal Volume is more than 1.5 times higher than the set Tidal Volume, the breath is interrupted and the next breath is delivered with 25% reduced pressure compared with the previous breath. However, the maximum pressure decrease is 20 cmH_2O.

If the patient suddenly coughs during an inspiration, and if the pressure reaches the set Upper pressure limit, then the ongoing inspiration will be cut off and the next breath is delivered with the same pressure as the previous breath.

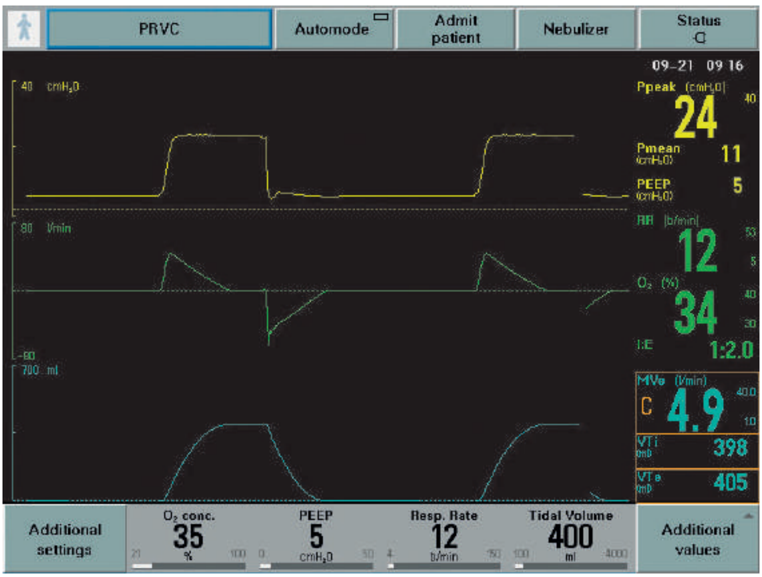


8.3 EXAMPLE

The compliance decreases, the lung becomes stiffer and the Tidal Volume decreases. The pressure immediately increases in steps of a maximum of 3 cmH_2O in order to retain the Tidal Volume.

Note: The available pressure is limited to 5 cmH_2O below the set Upper pressure limit. If this level is reached, then the SERVO-i delivers as much volume as possible with this pressure. At the same time, the information *"Regulation Pressure Limited"* is displayed in the alarm message area.

9 PRACTICAL EXERCISES - PRVC VENTILATION



See questions 1 to 5 on the following pages.

1. Select PRVC and set the following parameters:

VT	=	400 ml
Respiratory Rate	=	12 breaths/min
PEEP	=	5 cmH_2O
O_2 concentration	=	35%
I:E	=	1:2
T_i	=	1.65 s
T. insp. rise	=	0.15 s
Trigg.	=	Flow 5

2. What do the pressure and flow curves look like in PRVC?

Pressure curve

Flow curve

3. What is the maximum pressure increase between 2 consecutive breaths after the startup sequence?

4. What is the maximum available pressure level in PRVC?

5. If the patient triggers during PRVC, what happens to:

the Insp. Tidal Volume

the Peak pressure

10 WORKSHOP - PRVC VENTILATION

1. Select Pressure Regulated Volume Control ventilation, and set the parameters shown opposite:

	V_T	=	400 ml
	Respiratory rate	=	12 breaths/min
	PEEP	=	8 cmH_2O
	I:E	=	1:2
or	T_i	=	1.65 s
	Trigger sensitivity	=	Flow 5

2. Set the Upper Pressure Limit to 35 cmH_2O.

3. Note the measured values for:

P_{Peak}	
VTi	
VTe	

4. Look at the curves for Pressure, Flow and Volume.

5. Place 3 rubber bands around the test lung and observe what happens with the ventilation. Check the following:

- Curves
- Peak inspiratory pressure
- Inspiratory tidal volume

6. Note the measured values for:

P_{Peak}	
VTi	
VTe	

7. Remove one rubber band, wait for a few breaths and then:

Note the measured values for:

P_{Peak}	
VTi	
VTe	

8. Remove another rubber band, wait for a few breaths and then:

Note the measured values for:

P_{Peak}	
VTi	
VTe	

9. Remove the last rubber band, wait for a few breaths and then:

Note the measured values for:

P_{Peak}	
VTi	
VTe	

11 PRESSURE SUPPORT VENTILATION

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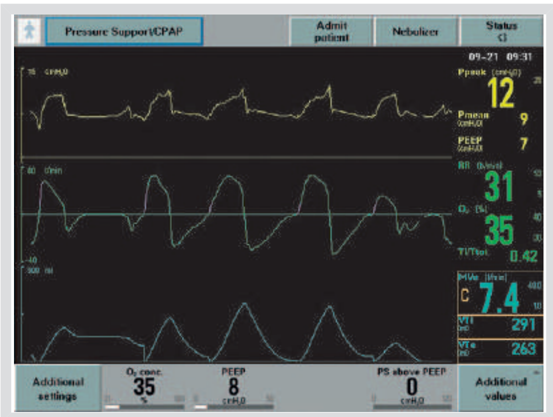
11.1 GENERAL

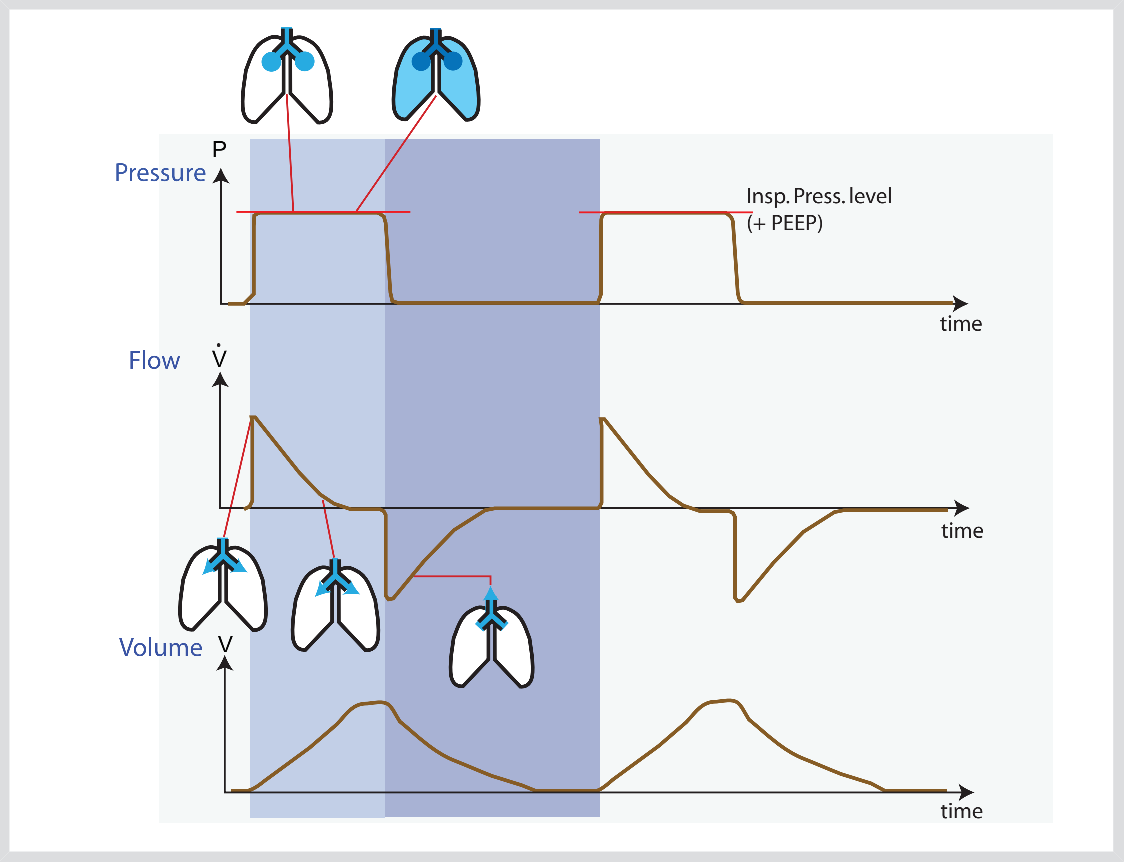
Pressure Support (PS) is a spontaneous mode of ventilation where no mandatory breaths are given.

The patient initiates Pressure Support by triggering each breath and the ventilator delivers support with the preset pressure level.

The patient regulates the Respiratory Rate and the Tidal Volume with support from the ventilator.



11.2 PRESSURE SUPPORTED VENTILATION - PRESSURE, FLOW AND VOLUME CURVES



During Pressure Support ventilation the flow curve can vary a great deal, depending on, for example, the patient´s breathing activity and resistance.

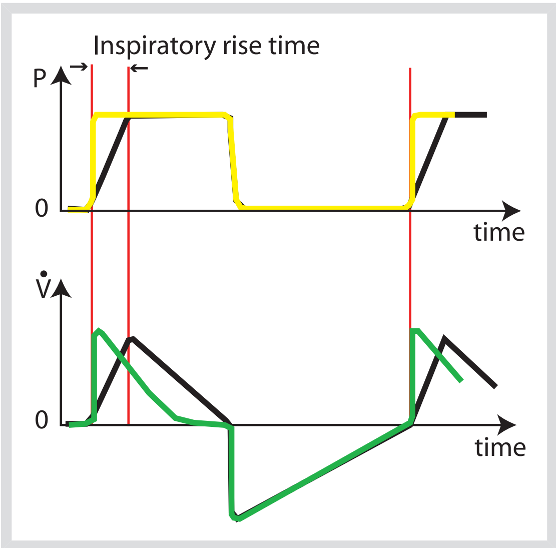
Moreover, the respiratory rate, inspiration time and expiration time can also vary a great deal as the patient regulates these by him/herself.

11.3 SUMMARY

INSPIRATION

When the patient triggers a breath which corresponds to the pre-set value on the User Interface, then pressure support is given and gas flows into the lungs at a constant pressure.

Inspiratory rise time is the time(s) taken to reach peak inspiratory flow or pressure at the start of each breath.



The Inspiratory rise time setting should be optimised to suit the patient´s condition. A short Inspiratory rise time will result in a fast flow delivery.

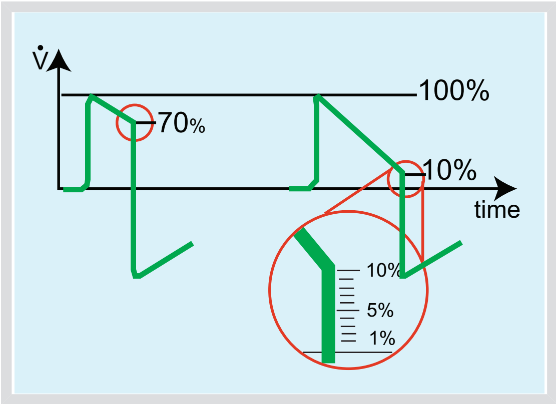
If the Inspiratory rise time is increased, then the initial flow diminishes, the delivery is more controlled and the patient can interact during inspiration.

Since the pressure is constant, the more the lungs are filled and the more the flow decreases.

If the patient has either a high resistance in the airways or has a narrow endotracheal tube, then it is useful to increase the Inspiratory rise time to avoid overshoot of the initial pressure.

EXPIRATION

Expiration starts when the instantaneous flow rate drops to a user set value of the peak inspiratory flow. Settings are within the range 1 - 70% of the inspiratory peak flow.



The pressure during expiration drops to the preset PEEP level. The next Pressure Supported inspiration starts when the patient triggers again.

It is important to adapt both inspiration and expiration to the patient.

11.4 BACKUP

If the patient is not breathing and the set apnea alarm limit is reached, then the SERVO-i will automatically switch to Backup Pressure Support - Pressure Controlled ventilation.

Default settings are used for:

- I:E ratio = 1:2
- Respiratory rate **adults** = 15 breaths/min
- Respiratory rate **infant** = 30 breaths/min
- PC level above PEEP **adult** = 20 cmH_2O
- PC level above PEEP **infant** = 10 cmH_2O

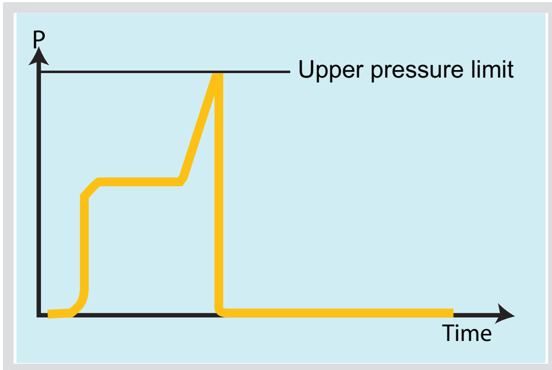
The apnea alarm can be set for:

- Adult apnea alarm can be set from 15 - 45 s.
- Infant apnea alarm can be set from 5 - 45 s.

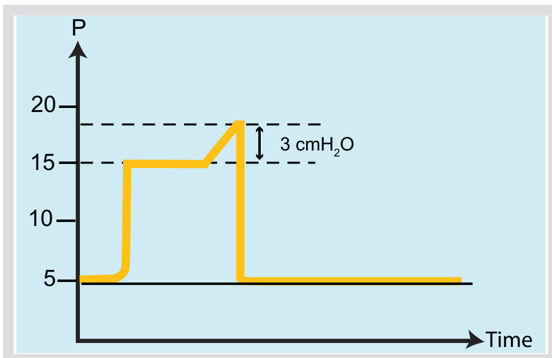
11.5 SAFETY FUNCTIONS

There are several built-in safety functions which can be activated with Pressure Support when inspiration changes to expiration:

- if the Upper pressure limit is exceeded

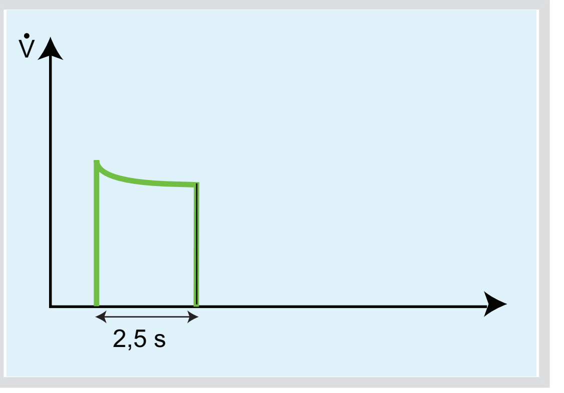


- if the pressure exceeds 3 cmH_2O above the preset inspiratory pressure level and PEEP.



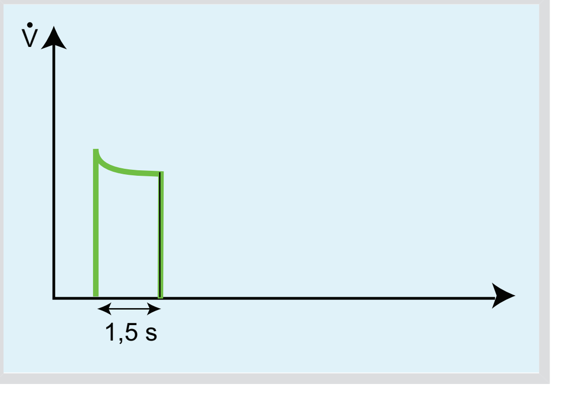
- Pressure support level above PEEP 10 cmH_2O
- PEEP 5 cmH_2O

- if the maximum inspiration time is 2.5 s **(for adults)** or,

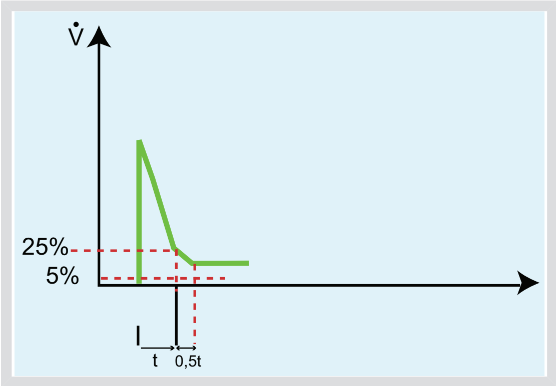


- 1.5 s **(for infants)**.

Note: This situation can arise when there is an excessive leakage.

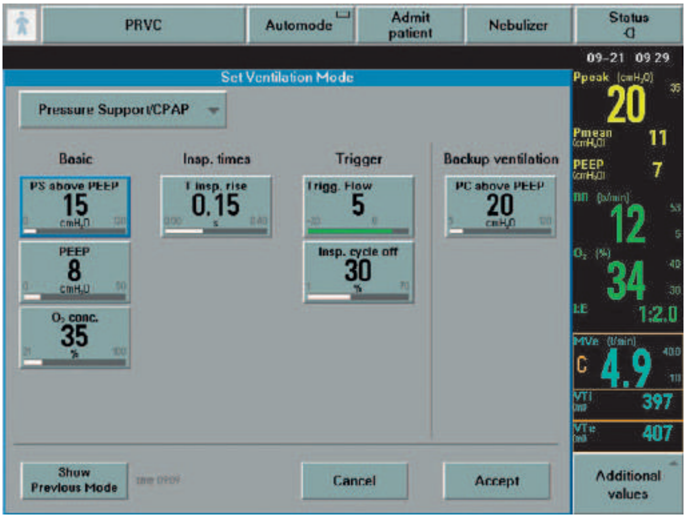


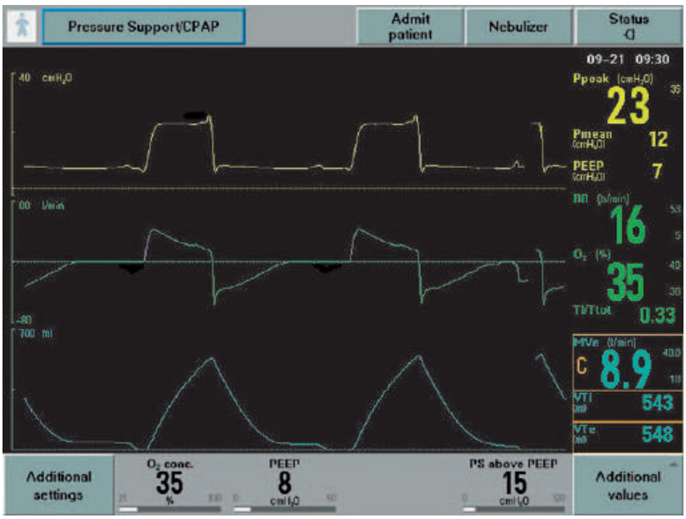
- if the flow drops to a flow range between 25% of the peak flow and the lower limit for the Inspiratory cycle off fraction level, and the time spent within this range exceeds 50% of the time spent in between the start of the inspiration and entering this range.



In this example the Inspiratory cycle off is set to 5%.

12 PRACTICAL EXERCISES - PRESSURE SUPPORT VENTILATION





With reference to the settings in Pressure Support on the previous page:

1. How much is the Insp. Tidal Volume?

2. How much is the Peak pressure?

3. When will the inspiration change to expiration?

4. What happens with the Tidal Volume if the Inspiratory cycle off changes from 20% to 60%?

5. What will happen with the ventilation if the apnea alarm is activated?

6. How do you change the settings to avoid a situation when there is almost no Inspiratory flow and no obvious inflections in the flow curve?

13 WORKSHOP - PRESSURE SUPPORT VENTILATION

1. Select Pressure Support ventilation, and set the parameters shown opposite:

PS level above PEEP	=	12 cmH_2O
PEEP	=	8 cmH_2O
Inspiratory rise time	=	0.05 s
Trigger sensitivity	=	Flow 5
Inspiratory cycle off	=	10%

2. Ventilate by pressing the test lung approximately 15 times/minute.

3. Check the curves, observe the beginning of the breath and the shape of the curves.

4. Change the Inspiratory rise time to 0.4 s.

5. Check the curves, observe the beginning of the breath and the shape of the curves.

6. Change the Inspiratory rise time to 0.5 s.

7. Check the curves and observe when the breaths change from inspiration to expiration.

8. Change the Inspiratory cycle off to 40%.

9. Check the curves and observe when the breaths change from inspiration to expiration.

10. Check the Inspiratory tidal volume and Expiratory tidal volume.

11. Change the Inspiratory cycle off to 10%.

12. Discuss within the group why it is so important to adjust the Inspiratory rise time and the Inspiratory cycle off for each patient.

In order to fully understand the different functionality, connect your own personal, clean bacteria filter to the Y-piece and breathe spontaneously.

13. Select Pressure Support ventilation, and set the parameters shown opposite:

PS level above PEEP	=	3 cmH_2O
PEEP	=	3 cmH_2O
Inspiratory rise time	=	0.05 s
Trigger Sensitivity	=	Flow 5
Inspiratory cycle off	=	5%

14. Try to breathe as normally as possible - not too fast.

15. Change the Inspiratory rise time from 0.05 s to 0.4 s.

16. Take a few breaths and change the Inspiratory cycle off from 5% to 40%. Adjust the Inspiratory rise time to suit you.

17. Take a few breaths and select the Inspiratory cycle-off that suits you best - please observe the Insp. Tidal Volume.

18. Change the Trigger Sensitivity from Flow 5 to Pressure -8.

19. Take a few breaths.

20. Set the Trigger Sensitivity back to Flow 5.

14 VOLUME SUPPORT VENTILATION

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14.1 GENERAL

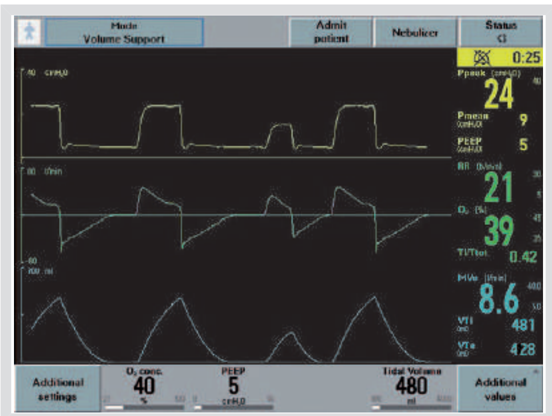
In Volume Support mode of ventilation, the patient must initiate the breath by spontaneously triggering the ventilator.

The ventilator delivers the level of support in proportion to the inspiratory effort from the patient and the set Tidal Volume.

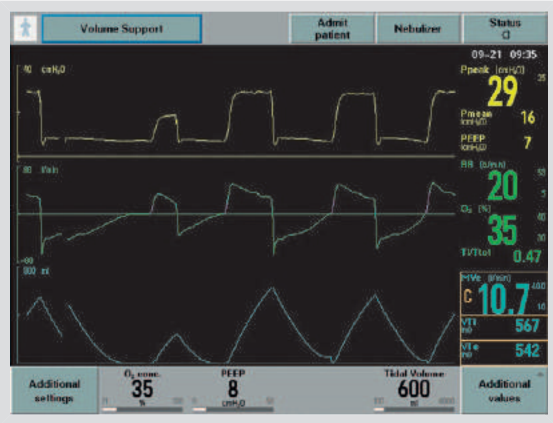
If the patient´s spontaneous breathing strength increases, then the Pressure Support from the SERVO-i decreases. Conversely, when the patient´s spontaneous breathing strength decreases, then the Pressure Support automatically increases to continuously keep to the target Tidal Volume.

When using Volume Support, it is important to minimize leakage to ensure that the pre-set Tidal Volume is delivered.

The pressure curve during Volume Support ventilation can vary greatly depending on, for example, the patient´s spontaneous breathing strength and resistance/compliance.

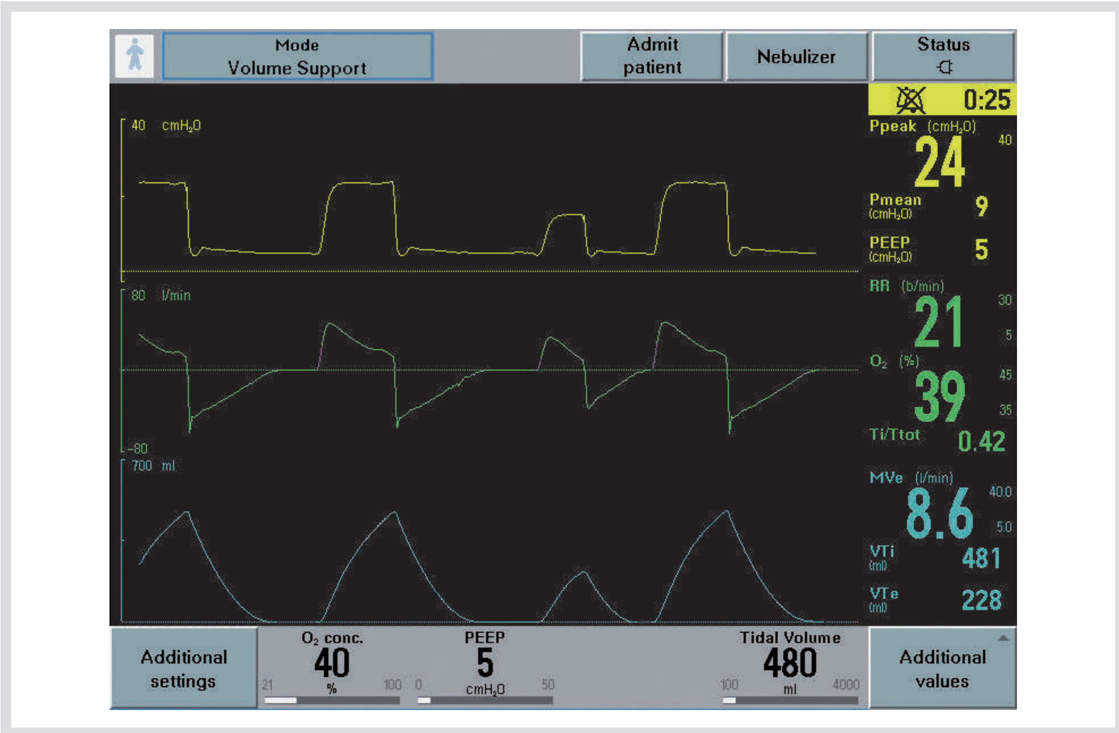


14.2 THE START-UP SEQUENCE



The start-up sequence comprises four breaths. During these four breaths the ventilator regulates the pressure level to support the patient so that he/she receives the pre-set Tidal Volume.

The first breath is given with a support of 10 cmH_2O. During the remaining three breaths, the maximum pressure increases in increments of three up to a maximum of 20 cmH_20 for each breath.



14.3 SUMMARY

INSPIRATION

Inspiration after the start-up sequence:

The patient triggers a breath which corresponds to the pre-set Trigger Sensitivity on the User Interface. Pressure Support is given and gas flows into the lungs at a constant pressure. The more the lungs are filled, the more the flow decreases.

If the Tidal Volume is less than the preset Tidal Volume, then the ventilator will increase the Pressure Support for the next triggered breath. The pressure increase can be from 1 to 3 cmH_2O.

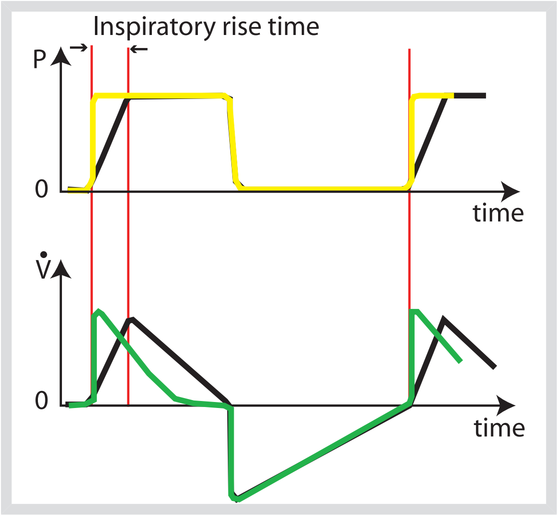
If the Tidal Volume is more than the pre-set Tidal Volume, then the Pressure Support for the next triggered breath will decrease in steps from 1 to 3 cmH_2O.

The inspiratory Pressure Support level will automatically adapt to changes in the mechanical properties of the lung/thorax and patient effort.

The Tidal Volume can vary from breath to breath, depending on patient activity, but the SERVO-i delivers support in proportion to the inspiratory effort and the target volume. The SERVO-i changes the Pressure Support level in order to retain the set Tidal Volume.

The Inspiratory rise time is adjustable from a rapid response, and in this case the patient only performs the triggering work to receive the flow delivery.

If the Inspiratory rise time is increased, then the initial flow diminishes, the delivery is more controlled and the patient can interact during inspiration.

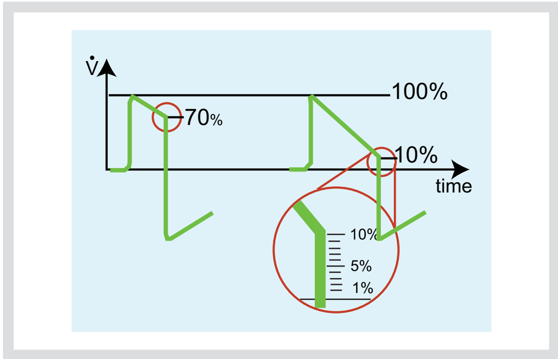


If the patient has either a high resistance in the airways or has a narrow endotracheal tube, then it is useful to increase the Inspiratory rise time to avoid overshoot of the initial pressure.

EXPIRATION

Expiration starts:

- when the inspiratory flow decreases to the pre-set Inspiratory cycle off level (this can be set from 1% to 70% of the inspiratory peak flow).



The pressure drops to the preset PEEP level. The next breath starts when the patient triggers again.

It is important to adapt both inspiration and expiration to the patient.

If the patient is not breathing and the set apnea alarm limit is reached, then the SERVO-i will automatically switch to Backup Volume Support - Volume Control mode. The same Tidal Volume as the preset Tidal Volume is delivered to the patient.

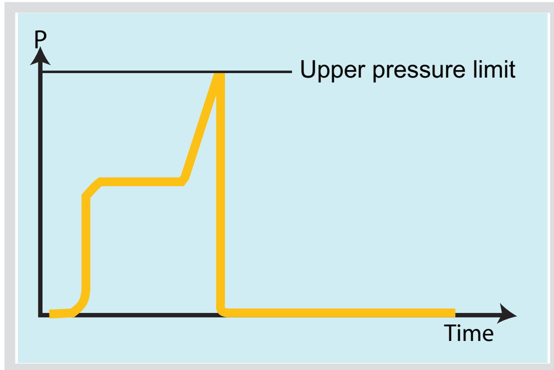
Default settings are used for:

- I:E ratio 1:2
- Respiratory rate **adult** = 15 breaths/min
- Respiratory rate **infant** = 30 breaths/min

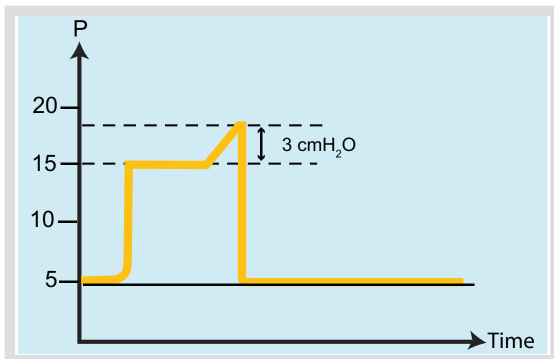
14.4 SAFETY FUNCTIONS

There are several built-in safety functions when the ventilator switches from inspiration to expiration.

- if the Upper pressure limit is exceeded

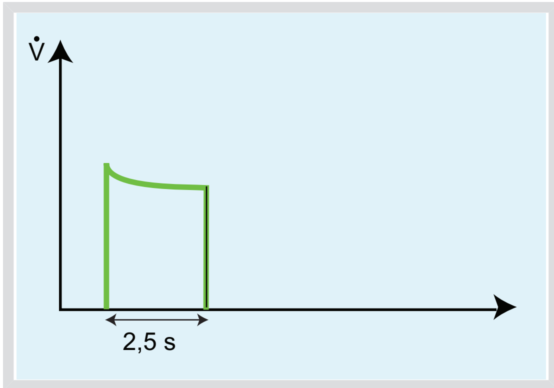


- if the pressure exceeds 3 cmH_2O above the preset inspiratory pressure level and PEEP.

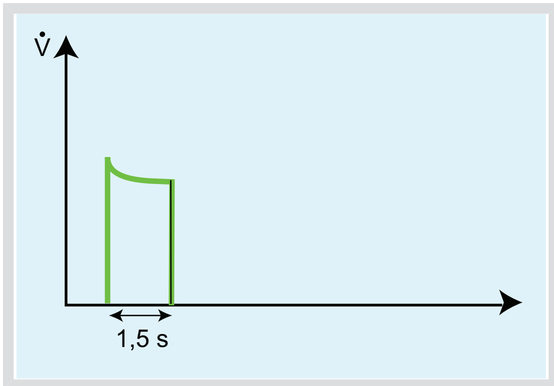


- Pressure support level above PEEP 10 cmH_2O
- PEEP 5 cmH_2O

- if the maximum inspiration time is 2.5 s **(for adults)** or,

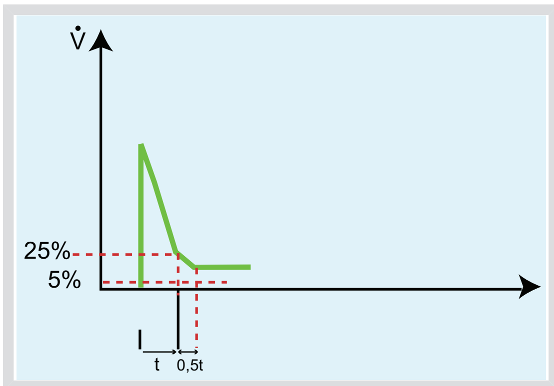


- if the maximum inspiration time is 1.5 s (**for infants**)



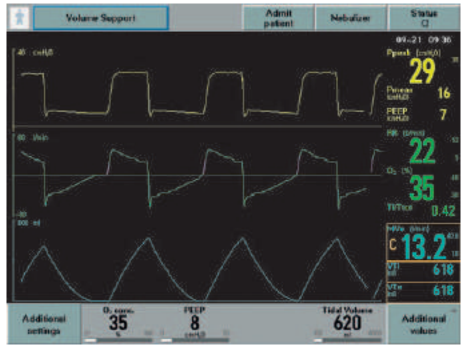
- if the flow drops to a flow range between 25% of the peak flow and the lower limit for the Inspiratory cycle off fraction level, and the time spent within this range exceeds 50% of the time spent in between the start of the inspiration and entering this range.

In this example the Inspiratory cycle off is set to 5%.



APPLICATION NOTE

If the cycle off fraction is too short, then the patient will not receive adequate support for the whole breath.



Avoid phases where there is almost no flow. If the patient tries to exhale, increase the value of Inspiratory cycle off. If the inspiration is too long (a low value of Inspiratory cycle off), the patient recruits the expiratory muscles and cycles the ventilator to expiration by generating a counter-pressure. This process utilises patient energy and may shorten the time for expiration. Consequently, this may induce auto PEEP, increase the work of breathing and cause trigger efforts due to increasing internal threshold to triggering. In this case, increase the Inspiratory cycle off value.

To minimize the patient´s work of breathing, it is important that compensation for compressible volume has been performed, a sensitive Trigger Sensitivity is set, and an adaptation of the Inspiratory rise time and Inspiratory cycle off is made.

When the set Tidal Volume is delivered and, at the same time, the peak pressure is decreasing, then this is an indication that the patient´s activity is increasing.

15 PRACTICAL EXERCISES - VOLUME SUPPORT VENTILATION

With reference to the above settings:

1. How much is the pressure support?

2. Is the Inspiratory cycle off set to a value adapted to the patient?

3. How much is the patient´s Respiratory Rate?

4. What is the T_i/T_{tot} ratio?

5. What is the highest pressure support that the SERVO-i will use if necessary with reference to these settings?

16 WORKSHOP - VOLUME SUPPORT VENTILATION

1. Select Volume Support ventilation and set the parameters shown opposite.

Tidal volume	=	350 ml
PEEP	=	5 cmH_2O
Inspiratory rise time	=	0.05 s
Trigger Sensitivity	=	Flow 5
Inspiratory cycle off	=	30%

2. Ventilate by squeezing the test lung approximately 14 times/minute.

3. Check the startup sequence (4 breaths).

4. How much pressure support is needed to give 350 ml? (squeeze the test lung harder, and observe what happens to the Peak pressure).

5. Check the pressure and flow curves. Observe the beginning of each breath and the shape of the curves.

6. Change the inspiratory rise time to 0.4 s.

7. Check the changes in the curves at the beginning of the breaths, and the shape of the curves.

8. Check the curves and observe when the breaths change from inspiration to expiration.

9. Check the Tidal Volume.

10. Change the Inspiratory cycle off to 70%.

11. Check the curves and observe when the breaths change from inspiration to expiration.

12. Check the Inspiratory tidal volume and the Expiratory tidal volume.

17 AUTOMODE

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17.1 GENERAL

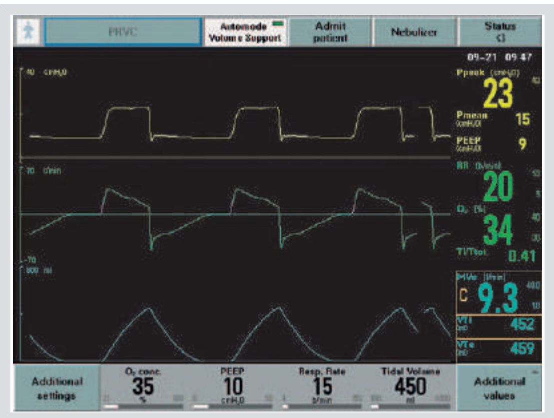
Automode is an interactive mode of ventilation. One controlled mode is coupled with one supported mode of ventilation. There are three combinations available:

- Volume Control <-> Volume Support
- Pressure Control <-> Pressure Support
- PRVC <-> Volume Support

Automode can be used for all patients who have an adequate respiratory drive. The patient is free to breathe whenever he wants. However, in case the patient stops breathing, the ventilator takes over.

Early detection and adaptation to patient effort promotes spontaneous breathing and early weaning. At the first sensing of spontaneous effort, Automode delivers supported breaths which are adapted to patient effort, instead of delivering a controlled, mechanically pre-programmed pattern.

The "*Trend*" window gives information about spontaneous breathing (e.g. Respiratory Rate, Tidal Volumes, Minute Volume, CO_2 conc.)



17.2 TRIGGER TIMEOUT

Trigger Timeout is the maximum allowed apnea time in Automode before controlled ventilation is activated.

The settings are within the ranges:

- 7 - 12 s (default 7 s) for Adults.
- 3 - 15 s (default 3 s) for Infants

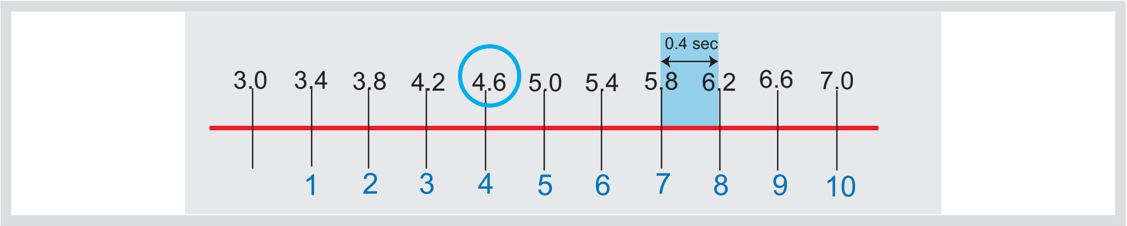
Initially, the ventilator adapts with a dynamic Trigger Timeout limit. This means that for the spontaneously triggering patient, the timeout increases successively during the first 10 breaths.

17.2.1 EXAMPLE

TRIGGER TIMEOUT - ADULT

- Respiratory Rate = 20 breaths/min
- Time for each breath = 60/20 = 3 s.
- Trigger timeout = 7 s.
- 7 - 3 = 4 s.
- 4 s divided into 10 steps = 0.4 s

If the patient stops breathing after 4 breaths, the ventilator delivers a controlled breath after 4.6 s. After 10 triggered breaths the ventilator waits 7 s before providing a controlled breath.

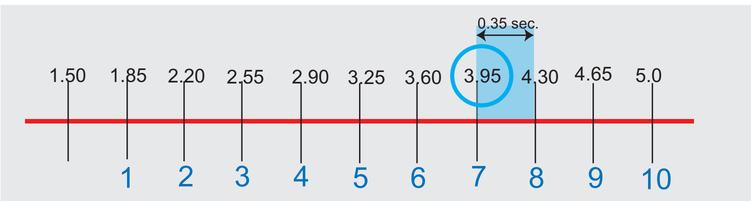


17.3 EXAMPLE

TRIGGER TIMEOUT - INFANT

- Respiratory Rate = 40 breaths/min
- Time for each breath = 60/40 = 1.5 s.
- Trigger timeout = 5 s.
- 5 - 1.5 = 3.5 s.
- 3.5 s. divided into 10 steps = 0.35 s.

If the patient stops breathing after 7 breaths, the ventilator delivers a controlled breath after 3.95 s. After 10 triggered breaths the ventilator waits 5 s. before providing a controlled breath. Early apnea in the sequence leads to a shorter time before a controlled breath starts.



18 PRACTICAL EXERCISES - AUTOMODE

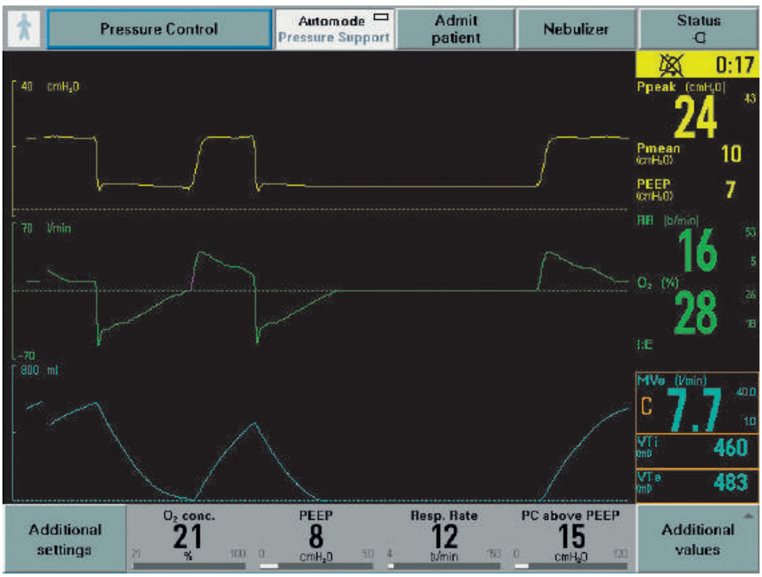
1. When does the SERVO-i switch from a controlled mode into a supported mode?

2. When does the SERVO-i switch from a supported mode to a controlled mode?

3. How is the activation of Automode indicated?

4. What does "Trigger timeout" mean?

19 WORKSHOP - AUTOMODE VENTILATION



1. Set the following parameters:

PC above PEEP	=	15 cmH_2O
Respiratory Rate	=	12 breaths/min
PEEP	=	8 cmH_2O
O_2	=	21%
I:E	=	1:2
or T_i	=	1.65 s
T insp. rise	=	0.15 s
Trigg	=	Flow 5

2. Activate Automode and set the following parameters:

Insp. cycle off	=	40%
Trigger timeout	=	10 s
PS above PEEP	=	15 cmH_2O

3. Squeeze the test lung approximately 3 times, then stop and observe the curves. Check the time between the supported (triggered) breaths, and the start of the controlled breaths.

4. Squeeze the test lung approximately 12 times, then stop and observe the curves. Check the time between the supported (triggered) breaths, and the start of the controlled breaths.

5. Open the "*Trend*" window and set the resolution to 1 hour. Check the spontaneous Respiratory Rate, Tidal Volume, Minute Volume and Compliance.

20 SYNCHRONIZED INTERMITTENT MANDATORY VENTILATION

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20.1 GENERAL

With the SERVO-i it is possible to implement three different SIMV modes:

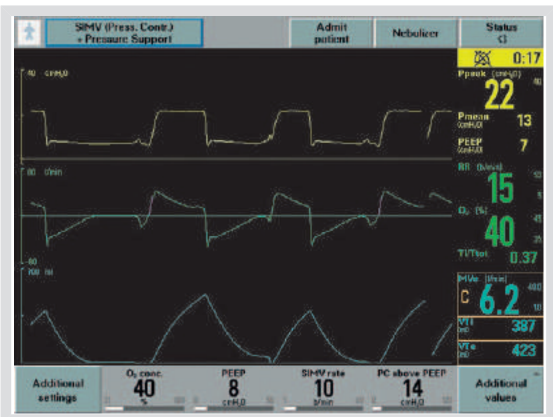
- SIMV - Volume Control and Pressure Support ventilation
- SIMV - Pressure Control and Pressure Support ventilation
- SIMV - PRVC and Pressure Support Ventilation

Mandatory (controlled) breaths are synchronized with the breathing efforts of the patient. These breaths are either Volume Controlled, Pressure Controlled or Pressure Regulated Volume Controlled, depending on the chosen mode of ventilation.

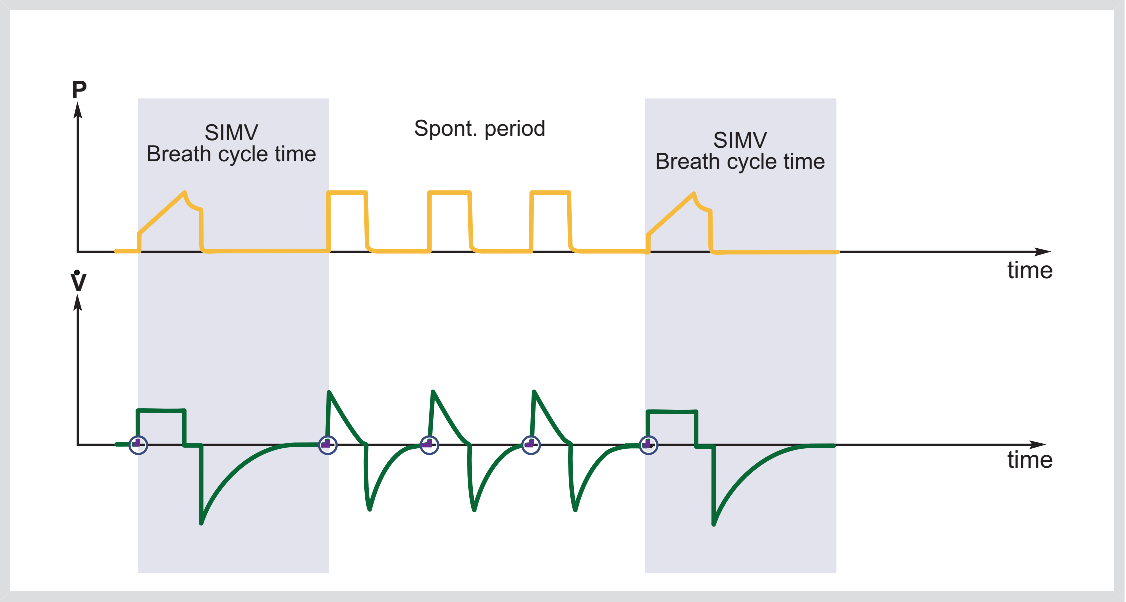
SIMV is used, for example, for weaning the patient from the ventilator. As the rate of the mandatory SIMV breaths/min gradually decreases, then the patient gets more and more time for spontaneous breathing.

The spontaneous breaths are supported with a set Pressure Support level, and when the patient´s activity increases, then the Pressure Support level can gradually be decreased.

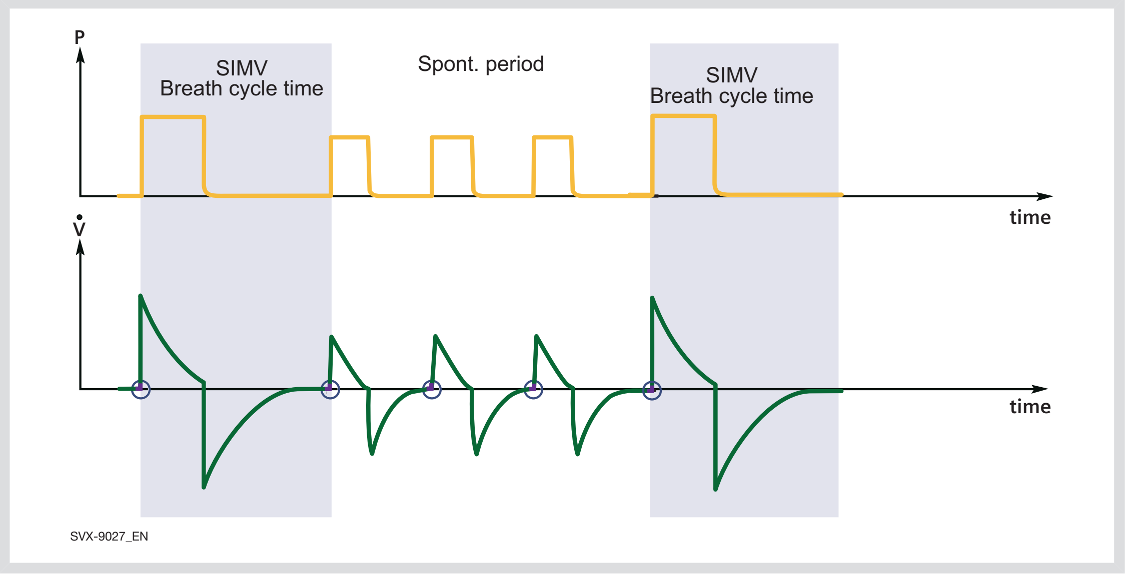
The spontaneous breaths are Pressure Supported in all the SIMV modes.



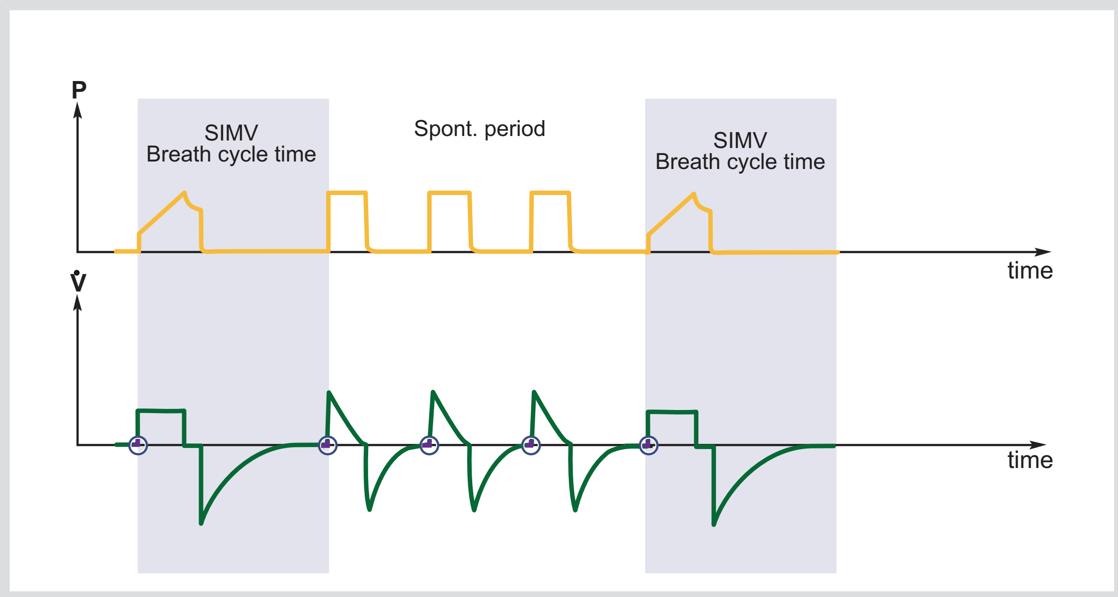
20.2 SIMV VC + PS



20.3 SIMV PC + PS



20.4 SIMV PRVC + PS

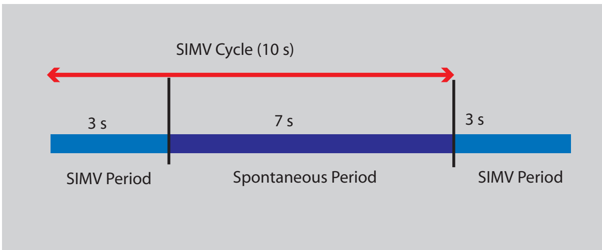


IF THE SERVO-I IS CONFIGURED FOR SETTING THE INSPIRATORY TIME BY SETTING I:E RATIO:

20.5 BREATH CYCLE TIME (BREATH CYCLE T)

This is the length of the total respiratory cycle of the mandatory breath. The total time for inspiration and expiration.

The SIMV cycle is calculated as follows: 60 seconds divided by the SIMV rate. The SIMV cycle is divided into an SIMV period and a spontaneous period.



EXAMPLE

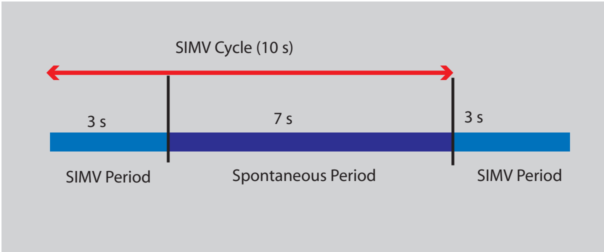
The following settings are made:

- SIMV rate = 6 breaths/min
- Breath cycle time = 3 s
- I:E Ratio 1:2

- The time for the mandatory breath is 3 s = SIMV period.
- I:E ratio 1:2 = 1 s for inspiration : 2 s for expiration.
- The time for one SIMV cycle is 60 s divided by the set SIMV rate. In this example 60 divided by 6 = 10 s.
- The time for the spontaneous period is 10 - 3 = 7 s.

IF THE SERVO-I IS CONFIGURED FOR SETTING THE INSPIRATORY TIME IN SECONDS.

The soft key "*Breath cycle time*" is not shown when SIMV is selected. The breath cycle time is calculated from I:E 1:2. If the inspiratory time is set to 1 s, then the breath cycle time is shown as 3 s.



EXAMPLE

The following settings are made:

- SIMV rate = 6 breaths/min
- Insp. time 1 s (the breath cycle is 3 s)

- The time for one SIMV cycle is 60 s divided by the set SIMV rate. In this example 60 divided by 6 = 10 s.
- The time for the spontaneous period is 10 - 3 = 7 s.

20.6 CONTROLLED BREATHS

INSPIRATION

A controlled breath is delivered during a preset Inspiratory time with either the preset Tidal Volume or the Pressure Control level.

Alternatively, if the patient triggers, then an assisted, ventilator-controlled breath is given with the pre-set Tidal Volume or Pressure Control level during a pre-set Inspiratory time.

Pause is only valid in SIMV Volume Control + Pressure Supported Ventilation mode. Inspiration and expiration valves are closed - thus no flow is delivered to the patient.

EXPIRATION

The expiratory valve opens. The flow of expired gas is greatest at the start since the pressure is greatest then. To reduce the resistance at the beginning of expiration, the expiratory valve has a controlling algorithm which continually calculates the elastic and resistive forces of the respiratory system. The initial opening of the expiratory valve is adapted to keep resistance as low as possible while strictly maintaining the set PEEP in the airways.

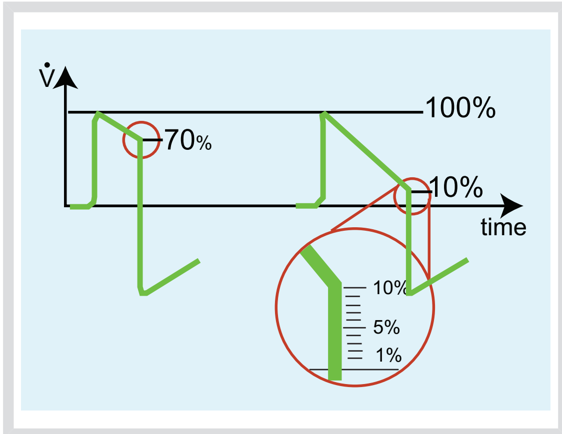
20.7 SPONTANEOUS/SUPPORTED BREATHS

INSPIRATION

When the patient triggers to the preset value, a Pressure Support is given and gas flows into the lungs at a constant pressure.

EXPIRATION

Expiration starts when the instantaneous flow rate drops to a user set value of the peak inspiratory flow. Settings are within the range 1 - 70% of the inspiratory peak flow.



The pressure during expiration drops to the preset PEEP level. The next Pressure Supported inspiration starts when the patient triggers again.

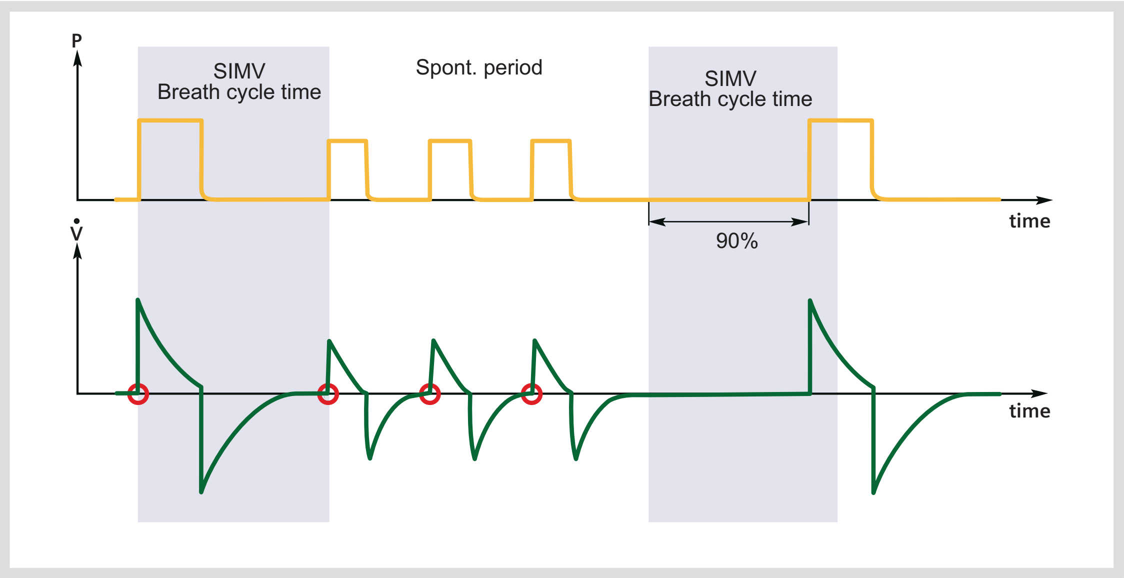
Note: The flow curve during pressure supported ventilation can vary depending, for example, on the patient´s breathing activities and resistance. The Respiratory Rate, Inspiration time and Expiration time can also be variable as the patient regulates these by him/herself.

In the first SIMV period/Breath cycle time, the patient triggers a mandatory breath. In the Spontaneous period the patient can take one or more breaths, depending on the length of the Spontaneous period.

In the next SIMV period the ventilator will wait for the patient to trigger, but if this does not happen within the first 90% of the SIMV period, then a mandatory breath will be delivered.

If the patient is not breathing (i.e. triggering) at all, then only the mandatory breaths will be delivered.

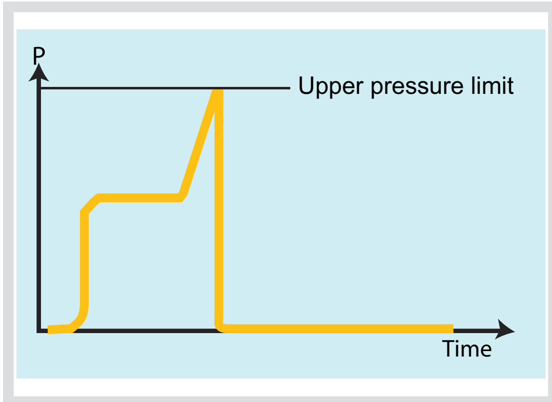
EXAMPLE



20.8 SAFETY FUNCTIONS

There are several built-in safety functions which can be activated with Pressure Support when inspiration changes to expiration:

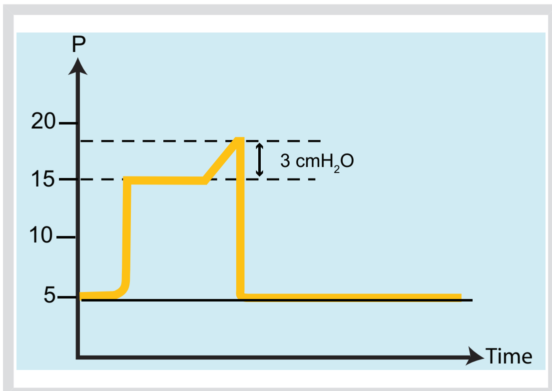
- if the Upper pressure limit is exceeded



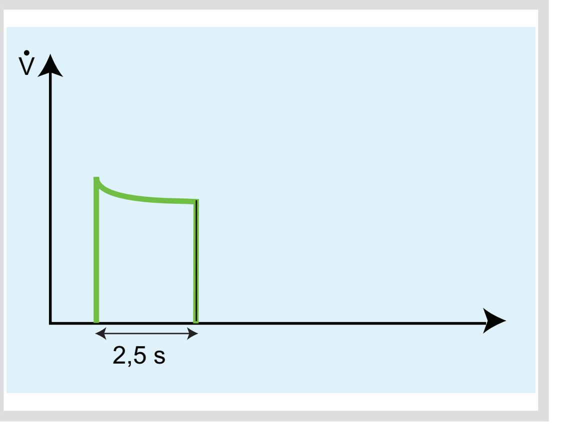
- if the pressure exceeds 3 cmH_2O above the preset inspiratory pressure level and PEEP.

In this example:

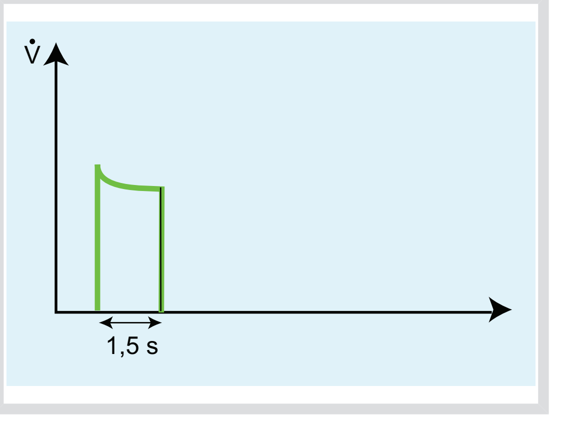
- Insp. pressure level above PEEP - 10 cmH_2O
- PEEP - 5 cmH_2O



- if the maximum inspiration time is 2.5 s **(for adults)** or,



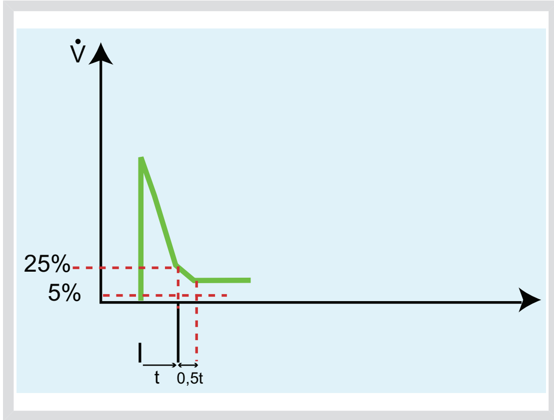
- 1.5 s **(for infants)**.



Note: This situation can arise when there is an excessive leakage.

- if the flow drops to a flow range between 25% of the peak flow and the lower limit for the Inspiratory cycle off fraction level, and the time spent within this range exceeds 50% of the time spent in between the start of the inspiration and entering this range.

In this example the Inspiratory cycle off is set to 5%.



APPLICATION NOTE

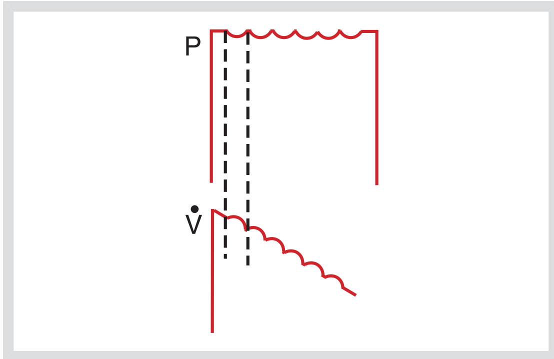
IMPORTANT:

1. The Insp. rise time, Inspiratory cycle off, Trigger Sensitivity and Pressure Support level settings are very important. These settings should be adapted to the patient´s condition.
2. If the SIMV rate is too high in relation to the patient´s effort, then the time for spontaneous breathing will be too short.

20.9 USER CONSIDERATIONS

The SERVO-i keeps the pressure constant during the inspiratory time.

A decrease in pressure will give a precise increase in flow to keep the pressure constant during the inspiratory time.



21 PRACTICAL EXERCISES - SIMV

1. Select SIMV and set the parameters shown below:

2. How much time (s) in the above settings, does the patient have for each spontaneous period?

3. How much time (s) in the previous settings, does the ventilator have to deliver one mandatory breath?

4. What happens if the patient triggers in the SIMV period?

5. Decrease the SIMV rate to 6.

6. How many seconds in the above settings, does the patient have now for each spontaneous period?

7. How much time does the patient now have for each SIMV period?

22 WORKSHOP - SIMV

1. Change to SIMV PVRC + PS and set the parameters as shown below.

2. How much is the Minute Volume if the patient is not breathing spontaneously at all?

3. Squeeze the test lung for a few minutes, 12-14 breaths/min.

4. Check the pressure, flow and volume curves.

5. Enter the "*Trend*" window and check the Expiratory Minute Volume and the Expiratory Tidal Volume.

6. How much is the Expiratory Minute volume which the patient breathes spontaneously?

23 BI-VENT

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23.1 GENERAL

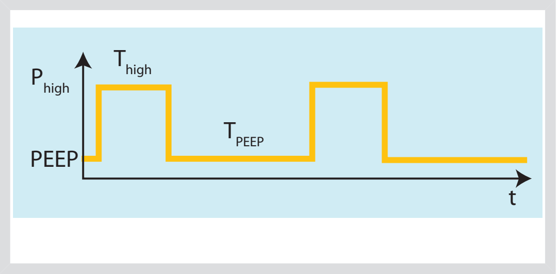
Bi-Vent can be used when the patient needs controlled ventilation. However, this mode also gives the patient the opportunity for unrestricted spontaneous breathing.

In Bi-Vent the SERVO-i switches between two, time-cycled pressure levels. The patient can breath spontaneously on both these pressure levels, and the spontaneous breaths can be either with or without support.

23.2 EXAMPLES OF BI-VENT

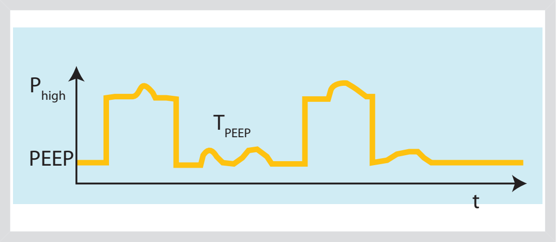
EXAMPLE 1

Bi-Vent without spontaneous breathing. The ventilator switches between PEEP and P_{high} after the set Time for PEEP and P_{high}.



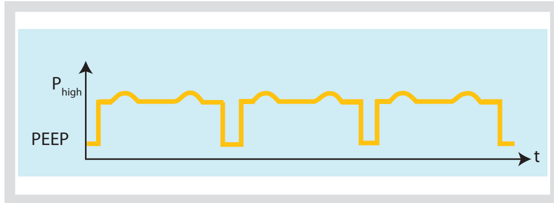
EXAMPLE 2

Bi-Vent with spontaneous breathing on both PEEP and P_{high}.



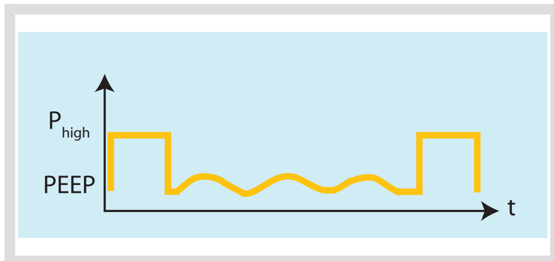
EXAMPLE 3

Bi-Vent with a long time for P_{high} and a short time for PEEP. Spontaneous breathing only on the P_{high}. Bi-Vent as Airway Pressure Release Ventilation (APRV).



EXAMPLE 4

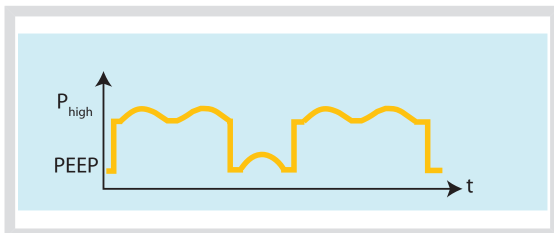
Bi-Vent with Pressure Support on the PEEP level.



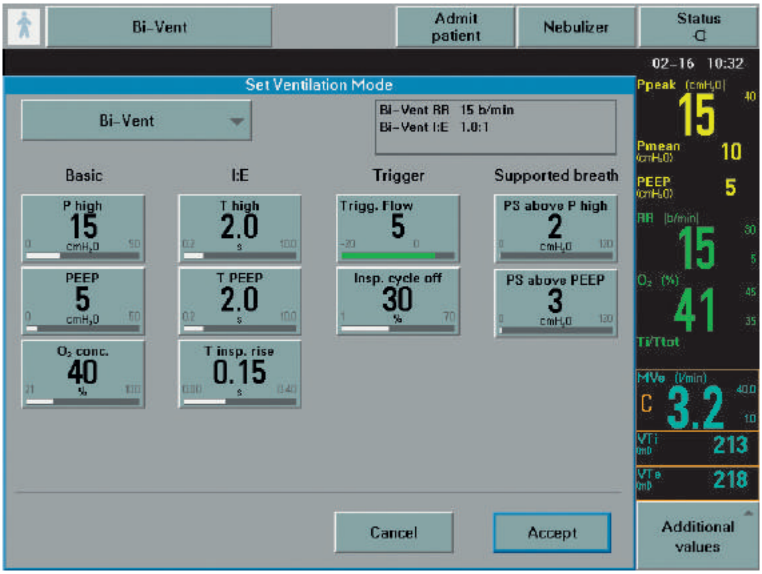
EXAMPLE 5

Bi-Vent with Pressure Support on the PEEP level and P_{high}.

Caution: Caution must be used when adding Pressure Support above the set P_{high}.



24 PRACTICAL EXERCISES - BI-VENT



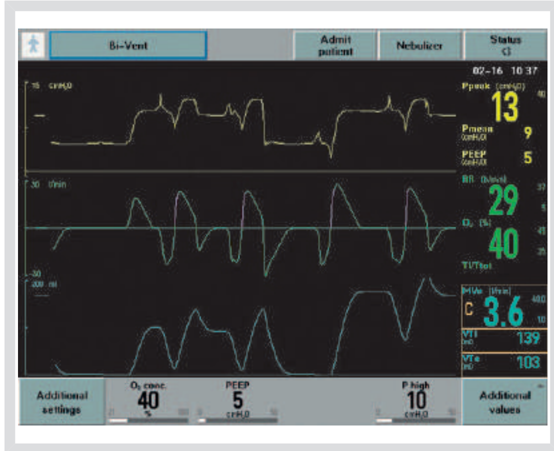
With reference to the above settings:

1. How many Bi-vent breaths are set?

2. What is the I:E ratio of the Bi-vent breath?

3. How many seconds is every T_{high}?

4. How much Pressure Support is given if the patient breathes spontaneously on P_{high}?



With reference to the above settings:

5. What is the I:E ratio of the Bi-vent breath?

6. How do you change inspiration to expiration in the Pressure Supported breath?

25 WORKSHOP - BI-VENT

1. Select Bi-vent and set the parameters as shown opposite.

P_{high}	=	15 cmH_2O
PEEP	=	5 cmH_2O
T_{high}	=	2 s
T_{PEEP}	=	6 s
Trigger flow	=	5
Insp. cycle off	=	50%
PS above P_{high}	=	0 cmH_2O
PS above PEEP	=	5 cmH_2O

2. Set the alarm limits.

3. Review the curves (pressure, flow and volume).

4. Ventilate by squeezing and releasing the test lung during the PEEP time.

5. Check the Tidal Volume for the Pressure Supported breath.

6. What is the value of T_i/T_{tot}?

7. Change the settings as shown opposite:

PEEP	=	0 cmH_2O
T_{high}	=	5.5 s
T_{PEEP}	=	0.8 s
PS above P_{high}	=	5 cmH_2O
PS above PEEP	=	0 cmH_2O

8. Ventilate by applying pressure to the test lung during the time for P_{high}.

9. Check whether there is an auto PEEP

10. Change the settings as shown opposite:

PEEP	=	8 cmH_2O
T_{high}	=	4 s
T_{PEEP}	=	4 s
PS above P_{high}	=	5 cmH_2O
PS above PEEP	=	5 cmH_2O

11. Ventilate by squeezing and releasing the test lung both during P_{high} and PEEP.

12. After a few moments check the MV_e.

13. Stop activating the test lung and write down how many Bi-vent breaths are delivered to the patient.

14. Open the "Trend" window and observe the Minute volumes, Tidal volumes and Respiratory rates during the Bi-vent mode.

26 NON INVASIVE VENTILATION

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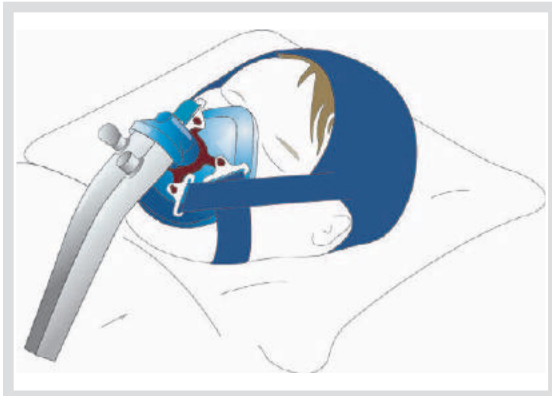
26.1 GENERAL

Non Invasive ventilation (NIV) can be used with one of the following:

- facemask
- nasal mask
- helmet (not available in the US), only for adult and pediatric use
- nasopharyngeal tube
- nasal prongs



The primary reason for the increased use of NIV is the avoidance of complications caused by invasive ventilation.

Nasal CPAP for patients weighing from 500g to 10kg will be discussed separately.

26.2 INTERFACES FOR APPLICATION OF NIV

As patients have different facial contours, it is very important to have a variety of masks to ensure a proper fit.

When using NIV with the SERVO-i, never use a mask which has a built-in valve.

To hold the mask in place, use straps and caps which are available in several designs and materials.

APPLICATION NOTES

- The success of NIV depends on staff competence.
  - The staff must act calmly and ensure that they spend time with the patient.
  - The patient must feel comfortable and reassured when they are being prepared for treatment.
  - Try out the interface to ensure a proper fit. Never use a mask with a built-in valve.
  - Keep the head of the bed at a 30^{o} angle to obtain a respiratory physiological position for the patient.
  - To avoid anxiety, it could be beneficial to let the patient practice breathing into the mask without connecting the tubing system and ventilator.
  - A nasal mask can be an alternative if the patient feels claustrophobic with a full facemask. Ensure the patient is breathing with a closed mouth.
  - If a good mask fit is hard to achieve, then a helmet is another alternative. Leakage is not a primary concern when using a helmet, but rather the large volume of gas that will have an impact on triggering. In many cases, the invasive function of the SERVO-i will be superior to the NIV function for the helmet application. The helmet is only to be used for pediatric and/or adult patients.
- **Note:** The user must monitor the patient with extra care to ensure that the chosen helmet is safe for the individual patient.

27 NIV PRESSURE SUPPORTED VENTILATION

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27.1 GENERAL

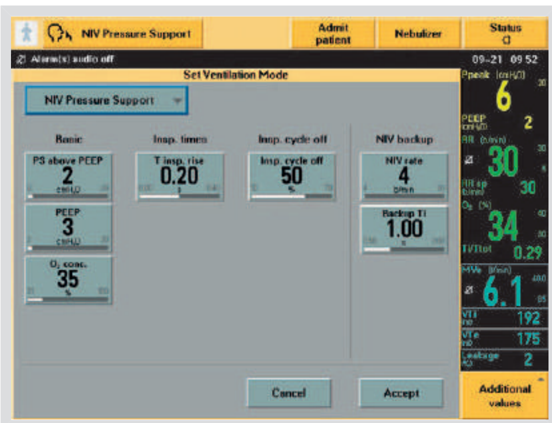
NIV Pressure Support is a spontaneous mode of ventilation with back-up apnea ventilation.

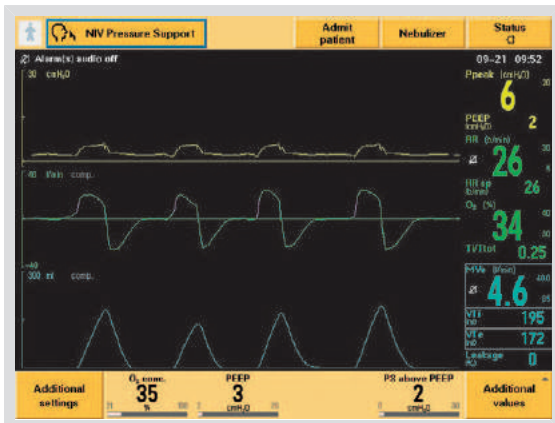
The patient initiates Pressure Support by triggering each breath and the ventilator delivers support with the preset pressure level.

IMPORTANT: Start the treatment with a low Pressure Support level, approx. 2-3 cmH_2O. The Pressure Support level above PEEP is then slowly titrated to the level that will give a comfortable breathing pattern.

The patient regulates the Respiratory Rate and the Tidal Volume with support from the ventilator.

NIV Pressure Support ventilation can be used as a weaning mode, when the patient does not have the muscle strength to breath adequately by her/himself.



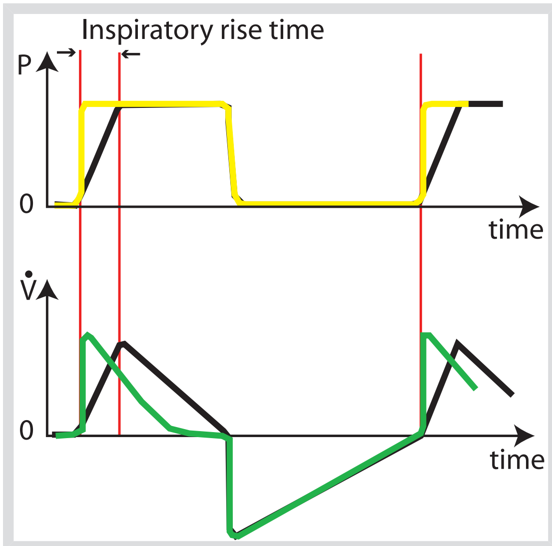


INSPIRATION

The SERVO-i delivers a breath when the patient triggers by:

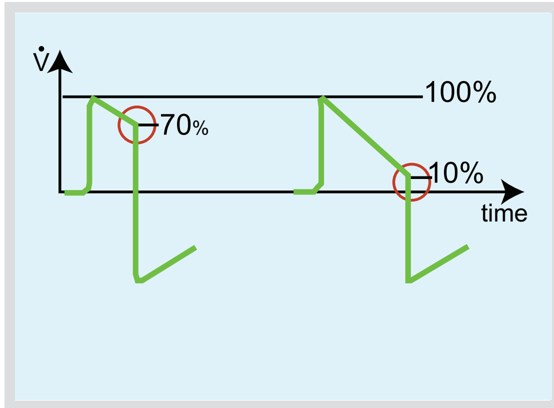
- lowering the pressure 1 cmH_2O below PEEP, or
- causing an expiratory volume decrease of 6 ml during 100 ms.

The speed of the flow delivered at the beginning of the breath depends on the set Inspiratory rise time.



EXPIRATION

Expiration starts when the flow rate drops to the user set value of the peak inspiratory flow. Settings are within the range 10-70% of the inspiratory peak flow.



The pressure during expiration drops to the preset PEEP level. The next Pressure Supported inspiration starts when the patient triggers again.

27.2 NIV BACKUP

27.2.1 EXAMPLES:

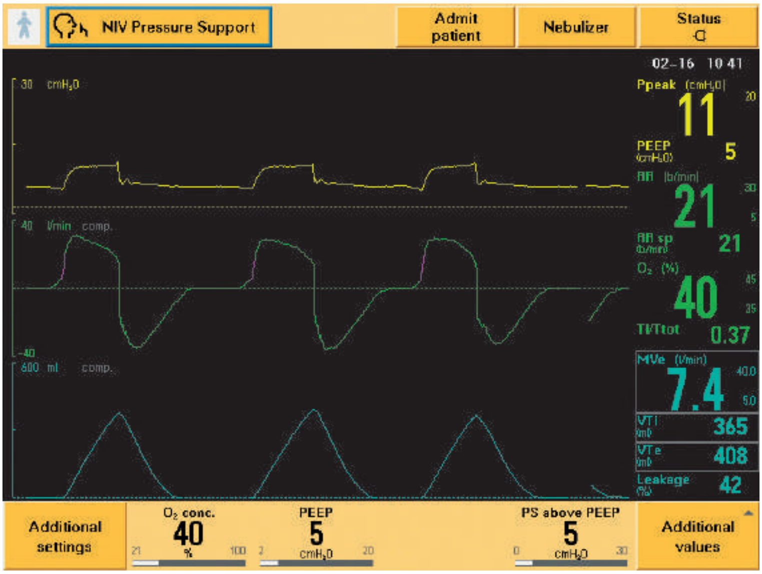
EXAMPLE 1

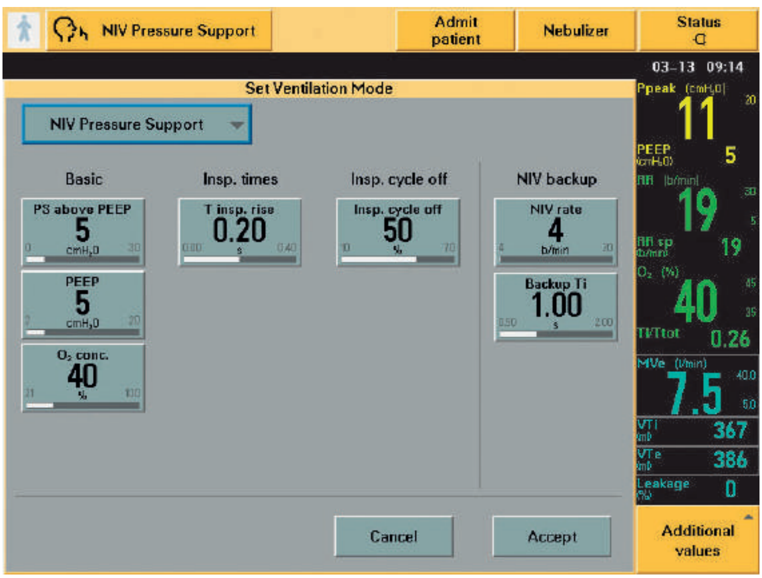
- The set NIV backup rate is **4**, the backup T_i is **0.65 s** and the patient does not breath within **15 s**.
- **60/4 = 15 s**
- A backup breath is delivered with the same pressure as the Pressure Support above PEEP. The inspiration time is **0.65 s**.

EXAMPLE 2

- If the set NIV backup rate is **10**, the backup T_i is **0.65 s** and the patient does not breath within **6 s:**
- **60/10 = 6 s**
- A backup breath is delivered with the same pressure as the Pressure Support above PEEP. The inspiration time is **0.65 s**.

28 PRACTICAL EXERCISES - NIV PS VENTILATION





With reference to the screen copies on the previous page:

1. When the NIV PS mode of ventilation is started, what is the first position?

2. Why is this the case?

3. How much is the leakage % in the screen copy?

4. Is the Exp. Minute Volume value compensated for leakage?

5. How much flow is used in the above settings?

6. How long will it take before a backup breath is delivered if the patient stops breathing?

7. How long is the Insp. time of the backup breath?

8. How much will the Peak pressure be?

29 WORKSHOP - NIV PS VENTILATION

1. Select a new, clean face mask.

2. Select NIV.

3. Select Pressure Support ventilation and set the parameters as shown opposite:

PS above PEEP	=	3 cmH_2O
PEEP	=	2 cmH_2O
Inspiratory rise time	=	0.20 s
Inspiratory cycle off	=	50%

4. Position the mask over your mouth and breath normally.

5. Change the Insp. rise time to 0.4 s.

6. Whilst breathing, try to set the most comfortable value for the Insp. rise time.

7. Change the Insp. cycle off to 70%.

8. Whilst breathing, set the most comfortable value for the Insp. cycle off.

9. Cause a leakage around the mask and check the leakage value on the User Interface.

30 NIV PRESSURE CONTROLLED VENTILATION

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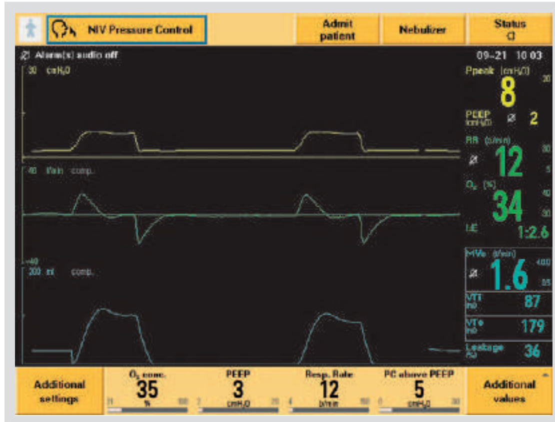
30.1 GENERAL



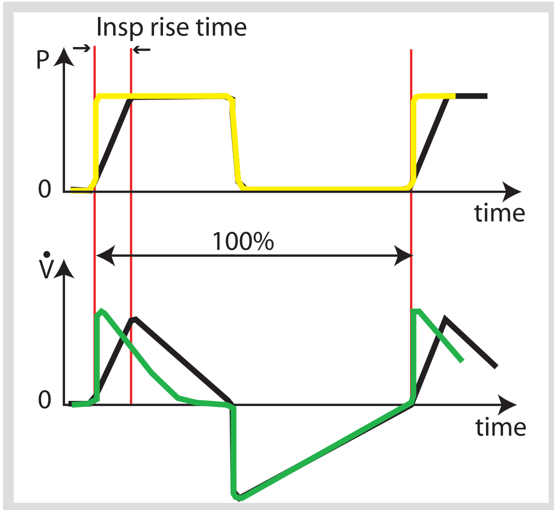
30.2 INSPIRATION

The ventilator delivers a flow to maintain the preset pressure. The pressure is constant during the set inspiratory time and the resulting flow is decelerating.

The volume may vary from breath to breath depending on the patient´s compliance and resistance.

The speed of the flow delivered at the beginning of the breath depends on the set Inspiratory rise time.

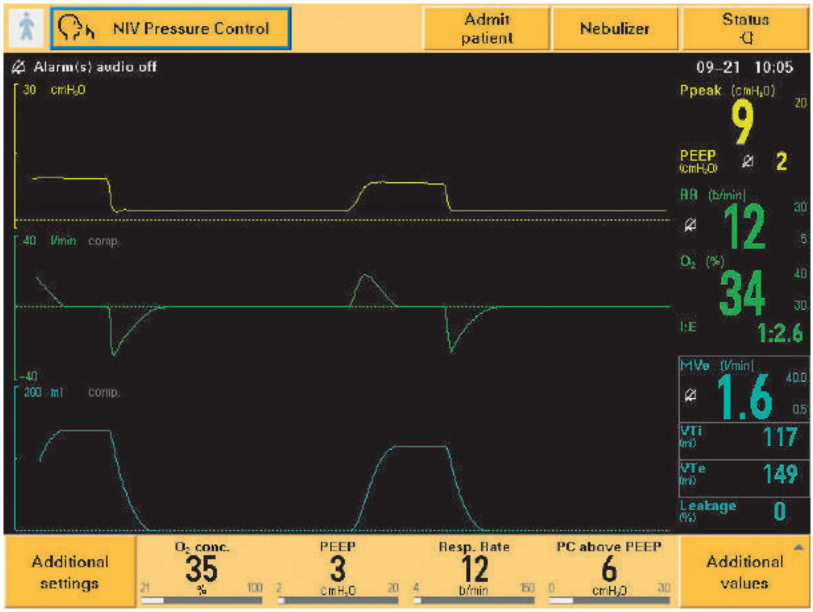
In the non invasive Pressure Controlled mode of ventilation, the inspiratory rise time is set in seconds if the SERVO-i is configured to set the inspiratory time in seconds. Inspiratory rise time in % is applicable in the Pressure Controlled mode of ventilation if the SERVO-i is configured with the I:E ratio setting.

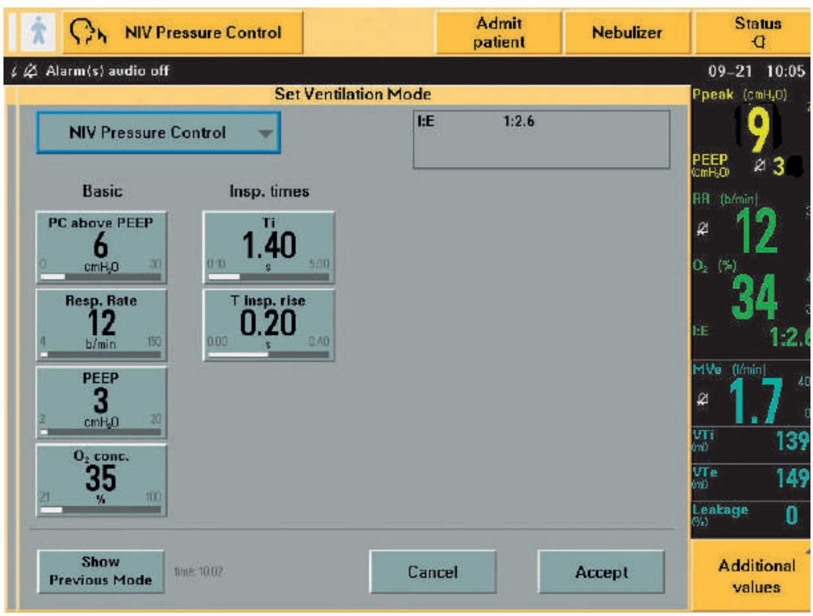


30.3 EXPIRATION

The expiration valve opens. The flow of expired gas is greatest at the start since the pressure is then greatest. To reduce the resistance at the beginning of expiration, the expiratory valve has a controlling algorithm which continually calculates the elastic and resistive forces on the respiratory system. The initial opening of the expiratory valve is adapted to keep resistance as low as possible while strictly maintaining the set PEEP in the airway.

31 PRACTICAL EXERCISES - NIV PC VENTILATION





With reference to the screen copies on the previous page:

1. How high is the Peak pressure?

2. For how many seconds is the pressure delivered during one breath?

3. Is the Exp. Minute Volume value compensated for leakage?

32 WORKSHOP - NIV PC VENTILATION

1. Select NIV.

2. Select NIV Pressure Control and set the following parameters:

	PC above PEEP	=	10 cmH_2O
	Resp. rate	=	14 breaths/min
	PEEP	=	5 cmH_2O
	O_2 conc.	=	21%
	I:E	=	1:2
or	Ti	=	0.65 s
	T insp. rise	=	5%/0.20 s

3. Connect a test lung.

4. Start ventilation. After one minute, check the Exp. Tidal Volume and the Exp. Minute Volume.

5. Change the Respiratory Rate from 14 to 10 breaths per minute. Check the Exp. Minute Volume and explain why it has changed.

6. Change the T Insp. rise from 5% to 20%. Observe what happens to the shape of the pressure and flow curves at the beginning of the breath.

7. Enter the "*Trend*" menu and set the "*Hours*" to 1. Check whether the leakage has changed during this time.

33 NASAL CPAP (CONTINUOUS POSITIVE AIRWAY PRESSURE)

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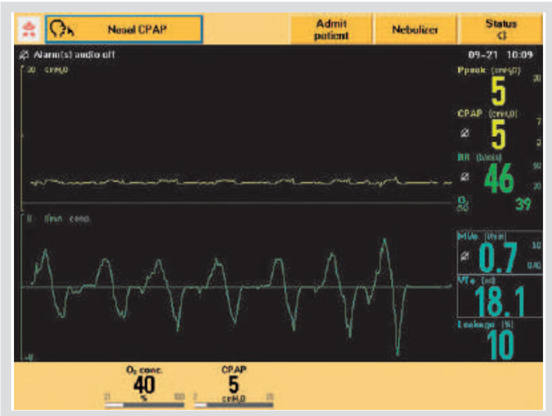
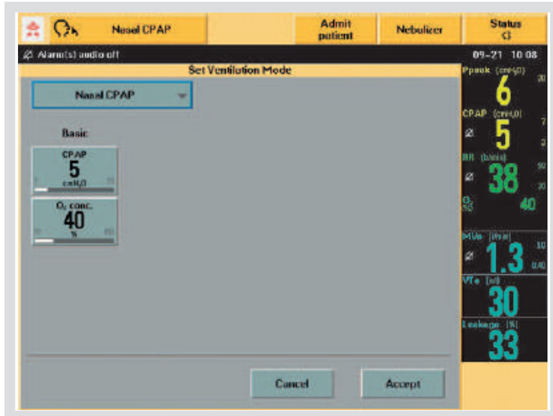
33.1 GENERAL





33.1.1 NASAL CPAP (FOR INFANTS FROM 500 g TO 10 kg)

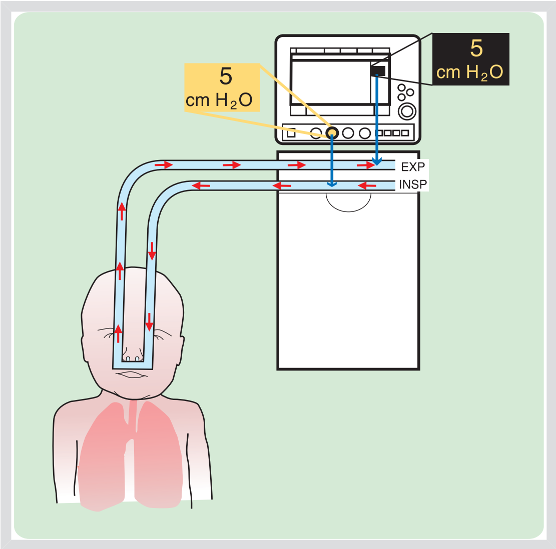
CPAP helps to:

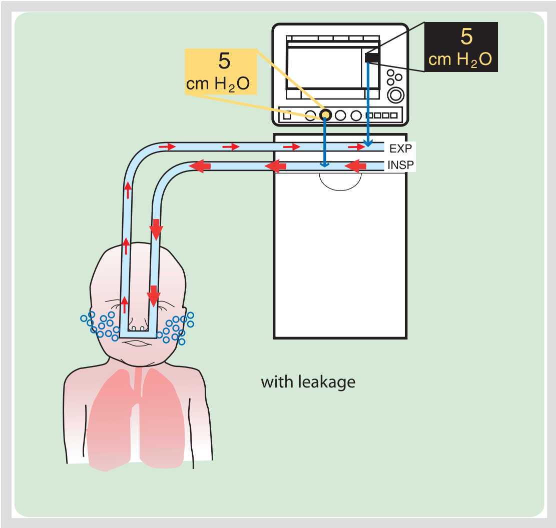
- recruit collapsed alveoli.
- improve oxygenation.
- stabilize the chest wall.
- inhibit paradoxical movements during inspiration and collapse during expiration.

Newborns are obligate nose breathers and the Nasal CPAP application can be implemented via nasal prongs or a nasal mask.

It is extremely important that the positioning and fitting of the nasal mask or nasal prongs is correctly carried out to ensure Nasal CPAP is implemented without any complications.

33.2 SERVO-i NASAL CPAP

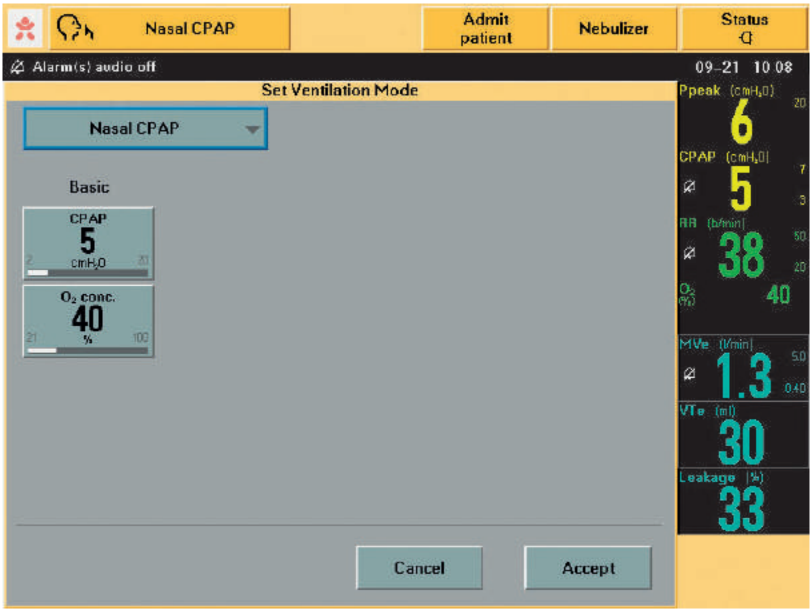




The flow delivered by the SERVO-i maintains the pressure set by the user. The SERVO-i regulates the pressure from the set CPAP level in order to minimize the pressure fluctuation, whereas the flow varies.

Infants breath spontaneously from the delivered flow and there are no triggering criteria. Inspiration and expiration are regulated by the infants, and the ventilator regulates the flow in order to maintain the set CPAP level.

34 PRACTICAL EXERCISES - NASAL CPAP



With reference to the screen copies on the previous page:

1. What is the CPAP pressure?

2. What is the maximum available flow in the Nasal CPAP mode?

3. What happens if the leakage increases, for example, from 10% to 23%?

4. How does the infant trigger in Nasal CPAP?

5. How much is the maximum leakage before the ventilator activates an alarm?

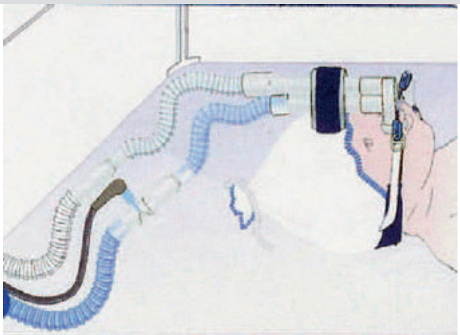
35 WORKSHOP - NASAL CPAP

To practice the application of Nasal CPAP it is a good idea to train on a small doll, as it is very important that the prongs or mask are fitted correctly to avoid complications such as leakage or injury to the patient (i.e. skin injury or skin blanching).

EXAMPLE OF INFANT MASK

EXAMPLE OF NASAL PRONGS

The key to a successful setup is keeping the nasal tubing in place. Ensure the weight of the circuit is supported to reduce tension on the nasal tubing.



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