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Artificial Ventilation,
Standardised-Terminology Handbook
(See Appendix A for Accompanying Illustrations)

1. Introduction

With the advances in ventilators and the modes of ventilation that have evolved over recent years, many new ventilatory terms have been introduced and many of the earlier terms no longer have a consistently understood meaning. A review of published literature, manufacturers' manuals and discussions and contributions available on the internet highlights that, in the absence of action by any universally recognised coordinating body, the use of ventilator terminology has become increasingly confused. It would be remarkable if such confusion is not leading, at the least, to a failure to achieve the full potential benefit offered by modern ventilators and, in some cases, to inappropriate use.

ECRI Health Devices, in July 2002, stated, "Health Devices has repeatedly stressed the need for users to understand the operation and features of ventilators, regardless of whether they will be used to ventilate neonatal/paediatric or adult patients. The fact that ventilators are such an established technology by no means guarantees that these issues are clearly understood…we continue to receive reports of hospital staff misusing ventilators because they're unaware of the devices' particular operational considerations."

Although this statement does not suggest reasons for this deficiency it seems probable that confused terminology is a significant factor, compounded by the fact that the terminology has not developed in a way that facilitates communication as to how the ventilator interacts with the patient, which is essential for modern critical care ventilators.

The situation has by no means improved over the past 10 years and during that time an additional need for a coherent and well defined vocabulary has become apparent. There is an increasing interest in data exchange between medical devices for the purposes of device inter-operability and the creation and interchange of medical record databases. These systems require standardisation to provide not only lists of valid terms but definitions and explanations to ensure that encoded information always has the same meaning.

Current terminology goes back to the early days of artificial positive-pressure ventilation: the time when bag-ventilation and subsequently automatic bellows/piston type ventilators were introduced. With these devices a set volume of gas was periodically mechanically displaced from the device and forcibly delivered to the patient's airway. As most of the gas displaced entered the lungs, apart from any, normally small, leakage and compliance losses, it was convenient to refer to this displaced volume as the breath. The patient was invariably apnoeic, naturally or artificially induced, and the devices delivered the set volume according to a set time base, thereby acquiring the name continuous mandatory ventilation (CMV). Later on, in order to permit the patient to have some freedom to contribute to the ventilation between imposed deliveries, the concept of intermittent mandatory ventilation (IMV) was introduced. These, and other patterns of ventilation, were offered as 'modes' of ventilation with their names or acronyms used to promote specific treatments.

Other developments in automatic ventilation have seen the introduction of the facility for synchronisation with the patient's breathing efforts, volume-targeted, pressure-control inflations of the lungs and the facility for the patient to breathe spontaneously at any time, including during phases of elevated airway pressure. All these developments have changed the way that the ventilator interacts with the patient but until the working groups responsible for the creation of the proposed ISO Standard 81000 (hereafter referred to as 'the Standard') were formed there had been no formally-organised systematic review to ensure that the definitions of widely used terms were adapted to encompass these changes. The Standard is the outcome of such a review, involving international participants.

In the preparation of the Standard the objective was not to introduce new terms but, wherever possible, to refine the definitions of existing terms, normally bringing them back to their original meaning. In the absence of widely accepted standards there has been an inevitable tendency for clinicians and manufacturers to take well-established terms and stretch their meanings, sometimes for marketing advantage, sometimes to make it sound familiar and sometimes, apparently, to make it sound more technical. The consequence of such lack of control is that terms lose their usefulness because of a loss of precision and hence ability to discriminate between concepts. They sometimes also lose their relationship with their common use outside the field of ventilation – thereby adding to the confusion. The current usage of terms such as 'trigger' and 'cycle' are examples of this progressive misuse.

In other cases multiple terms have been created for the same concept and this leaves the user confused as to whether there is a subtle difference being invoked or not.

The logical, fundamental, approach that was adopted in this review was aimed at ensuring retention of the ability of terms to describe earlier, basic ventilation while, at the same time, making them more focussed, with benefits not only for current use but also for future developments.

The process of refining the definitions of existing terms inevitably exposed important concepts that have become almost universally adopted but for which there is no common term. For these cases new terms have been formulated and introduced into this Standard. Two key examples are the terms 'enhanced pressure control (*e*PC)', used to identify an important distinction from pressure control as has been conventionally provided on adult ventilators, and 'baseline airway pressure (BAP)', used to identify a set pressure level used in the automatic management of the expiratory airway pressure in a way that optimises the rate of exhalation while achieving the underlying clinical objectives of alveolar PEEP.

One of the most significant recent developments with respect to ventilation terminology is the introduction of a facility for the patient to interact with the ventilator in what have become known as bi-level ventilation modes. These allow a patient to spontaneously *exhale* as well as inspire, with a minimum of impediment, both at baseline pressure and at the elevated pressure pertaining during an extended inflation phase. No consensus has appeared in the use of terms to describe the operation of this interaction, nor of how to adapt legacy terminology for this purpose. This has been a major additional source of confusion for users. The review has, therefore, considered these issues from first principles and the standardised terminology fully accommodates this requirement.

Other concepts that have influenced the way terminology is defined in the Standard include that of making distinctions between terms that are related to ventilator settings against those that are used to describe outcomes and clarifying which terms are describing patient related functions and which are specific to the ventilator.

It is recognised that the definitions in the Standard may appear to be complicated and at times pedantic but artificial-ventilation terminology has already become inherently complicated and its rationalisation can only be effective if performed rigorously. The complexity of the task has been greatly increased by the underlying objective of retaining as much of current understanding and language as possible. This was seen as essential so that a typical operator will be able to adapt to the revised definitions and new terms with no more difficulty than experienced at present in moving from ventilator to ventilator - particularly those from different manufacturers.

The purpose of this Handbook is to provide an introduction to the Standard and an explanation of the underlying conceptual frameworks that have been developed as a means of achieving consistency in the meaning of, and relationship between, the defined terms.

These texts must be seen not simply as a list of terms but also as providing the grammar for the language of artificial-ventilation so that the terminology can be correctly adapted to accommodate future developments. They are intended for authors, manufacturers, editors and those involved in the creation of databases and other IT functions; those who are dependent upon a coherent vocabulary and its grammar for their work to be effective and those who will be responsible for explaining the terminology to everyday users.

1.1 Proposed application

The purpose of the Standard is to formalise the use of nomenclature and terminology relevant to current practice relating to automatic ventilation and to clearly explain what these terms mean. In doing so it seeks both to reflect a consensus view and lead to a coherent language for describing ventilator function. Now that ventilation practice has matured it has been possible to review the boundaries between the various established mode patterns and inflation types and to formulate descriptions that clarify the common elements and the distinctions.

Terms that were relevant to earlier technology and practice but are not adaptable to current practice have been discarded and the application of many other terms has been constrained to earlier, more specific, usage.

The objective is to encourage a more disciplined use of ventilator terminology so that operators trained in the standardised language will be able to move easily from one ventilator to another and operate each one, with confidence, after a minimum of training. Although change will not be immediate it is expected that this discipline will feed through into articles, textbooks and training so that over time a standard basic ventilation language will become internationally established.

The terms, names and acronyms listed in this standard have been described in a manner that formalises their interpretation to the extent that it minimises ambiguity and provides a rigid usage discipline for formal data handling and informatics, whilst retaining phraseology that is suitable for user instructions and clinical dialog.

The resultant descriptions may still be too formal for some applications and the intention is that manufacturers may still retain their proprietary names and acronyms and substitute their own phraseology in preparing instructions for use, subject to the following:

a) the standardised term should be used in preference to any other where it is applicable

b) the standardised terms may be used in a variety of combinations and with alternative grammatical forms provided that the meaning conveyed is in accordance with the definitions of the terms and concepts in the Standard

c) where proprietary and trade names and acronyms for modes and control algorithms are used they must be explained in standardised terms in an appropriate section of, or supplement to, the instructions for use and, as a minimum requirement after major upgrades or on new models, on a help screen on the ventilator

d) the meaning conveyed by any proprietary terms must be the same as that described in the Standard

e) text prepared by the manufacturer and others to explain and describe artificial ventilation may use their own phraseology in expressing the concepts involved but the underlying principles defined in the Standard must be of adhered to and the text must avoid causing confusion to those trained to understand the terminology described in this standard

f) in order to conform to the Standard manufacturer user interfaces and mode-of-ventilation descriptions are required to be in accordance with the Standard. However, the intent is not to inhibit innovation and the terminology in the Standard has been structured so that it is sufficiently adaptable to facilitate the description of novel deviations.

2. Overview of Ventilation Modes

The Introduction summarises the factors that led to a comprehensive review of the vocabulary of **artificial ventilation** and the preparation of the Standard. A key term in the review was that of **ventilation mode** because the concepts behind it are fundamental to the structure of the terminology presented in the Standard. An explanation of how the definitions associated with it were derived is, therefore, an essential background to understanding that structure.

Early devices for delivering **automatic ventilation** by means of **intermittent positive pressure**, operated to a fixed cyclic pattern with a range of settings for just the basic parameters. As new devices were developed additional patterns became available and these were proposed and offered as selectable modes of operation. In order that specific modes could be easily identified for selection in order to provide particular treatments these modes were given names or acronyms.

However, with the increasing flexibility offered by electronic control systems, more and more permutations and combinations of the basic elements of gas delivery were devised – to the point where it was no longer practical to provide every set pattern with a unique name. Today, nearly 100 different names and approaching 30 'unique' modes make it impossible to teach, comprehensively, which mode to use in which situation. Consequently, most users have only been taught just a limited range of these modes and it has become very difficult for them to relate different manufacturers' modes to each other – a problem compounded by a lack of consistency in the terminology used to describe them.

A simple analysis of the structure of these modes reveals that they all require the selection of both the type of control used to **inflate** the lungs and the pattern that determines when **inflations** occur; functions that can be conveniently referred to as the **inflation type** and the **mode pattern**. It also becomes clear that, conceptually and from a clinical perspective, in most cases the **inflation type** is unrelated to the **mode pattern**.

In the terminology of the Standard this concept has been formalised with the mode becoming a composite of two independent, operator-selectable elements, classified as a **mode pattern** and an **inflation type**, with the **inflation type** determining how the **airway pressure** and **flow** will be **regulated** during an **inflation**, once initiated, and the mode pattern determining how the **ventilator** will respond to **patient trigger events** and what and when it will cause to be delivered irrespective of any patient actions.

This is a logical step because most of the clinically distinctive characteristics of the classical modes that still form the foundation of modern ventilation modes are those that relate to the time-pattern of interactive events between the ventilator and the patient, and which are largely independent of the **delivery-regulation** means.

In practice, many manufacturers have already, at least partially, informally introduced such a separation in the manner in which they have labelled their ventilator control panels and structured their instructions for use.

From this perspective, it is pertinent to note that part of the confusion with respect to **ventilation modes** resulted from manufacturers labelling their modes with names that feature just one of these

attributes; some modes may be labelled **SIMV** - a **mode pattern**, and others **VCV** - a **type of inflation**. In accordance with the Standard both of these **mode** labels would be incomplete; the correct designation would be, for example, **SIMV-PC/PS** and **CMV-VC**.

The above approach reduces the number of names required significantly. As any of a number of **types of inflation** can be independently selected for use with each **mode pattern**, instead of N*M different mode names to learn there are just M **mode patterns** *plus* N **types of inflation**. Ventilation operation can therefore be described as if made up from elements of a construction set. As an example, it enabled a list of 58 mode names, taken from manufacturers' literature, to be reduced to just 8 mode patterns and 8 types of inflation – each of which can be placed into one of an even smaller number of easily remembered groups.

This format focuses on the pattern of the mode and of the type of inflation, irrespective of which mode-pattern and inflation-type combination can be used with which setting, and for which clinical intention. Not only is the number reduced but the structured format of these names makes them much easier to recognise, learn and remember.

With this perception of what constitutes a **mode** in current practice, in order to understand how modes relate to each other, it is necessary to create a classification system that groups them in terms of what they have in common and in what way they differ. Until fairly recently, there was a feeling that certain patterns of ventilation were appropriate for particular clinical purposes, i.e., that CMV type patterns were largely applicable to patients with very little breathing function, IMV type patterns were for weaning patients and support modes were applicable to spontaneously breathing patients that need help with their work of breathing. As it has become possible to provide increasing flexibility and 'intelligence' in the way the ventilator interacts with the patient and as users have explored the full possibilities of the facilities offered, these correlations have become more blurred: in particular, the actual settings used can change the clinical applicability significantly.

It is considered that present trends are likely to increase this disconnection between a functional classification of mode -patterns and clinical intention and that the only viable option is to base mode classifications on function alone. When this is done, only three groupings are required. Teaching can then be in terms of the common characteristics of the mode-patterns in each group coupled with the differences between the mode-patterns within each group and the appropriate settings for each of these mode patterns for different clinical intentions. Additionally, with only 3 or 4 basic families of inflation types the instructions can be centred on the clinical considerations of the alternative methods of inflation and of its termination. Most of this will be independent of the mode pattern with which it will be used but some instruction will be necessary where the selected inflation type may affect the clinical intention of certain mode patterns. Although, conceptually, around 20 standardised types of inflation could be made available for operator selection with each mode pattern, in practice manufacturers will only offer the much more limited range of combinations likely to be most used in clinical practice.

When viewed in this way it can be seen that, in the past, many 'new' modes that have been introduced, with their own proprietary names, have in fact been nothing more than an easily described sub-set of a standard **inflation type**.

Although it leads to an unambiguous classification, this system, by itself, does not help the day-to-day operation of ventilators because users are mainly interested in the composite function, consisting of mode-pattern and inflation-type related rules. It is easier to say "use APRV" instead of "use a Group (ii) Mode without patient trigger, with an inverse timing ratio in conjunction with enhanced pressure-control inflation". However, it is these short-hand notations have frequently led to misunderstandings.

To ensure that the requirement for a shorthand format is addressed this Standard specifies **generic mode-pattern names** and **generic inflation-type names**. This will enable users to be able to operate current ventilators the same as at present. The difference will be that the named mode patterns and inflation types will be classified into the main groups so those users interested in the differences between modes will find that these are always explained from the same reference points. These classifications also form the basis of the framework for the standardised nomenclature and terminology listed in the Standard.

A further area that required attention is where the **patient-triggering function** fits into these classifications. In some previous classification proposals, in which **initiation** has been considered to be a property of the **inflation**, the **triggering-function** was also included in these properties. ***In this classification system the initiation of an inflation is a property of the mode pattern.*** However, a **mode pattern** is just a set of rules defining how the ventilator responds to various inputs. Logically, therefore, the mode pattern is simply responding to a signal from a ventilator detection function indicating that the measurement of a patient parameter has passed a set threshold value. With this concept, the trigger function becomes just another ventilation monitoring function that provides a signal to the ventilator control system. In practice, most major manufacturers treat patient-triggering in this way - as an independently-selectable, settable monitoring function to provide an input signal when the monitored parameter reaches a set level, as may be required by the selected mode-pattern algorithm.

With this overview, the following sections explain in more detail these and other key concepts used in the standard.

3. Artificial positive-pressure ventilation

3.1 Natural Breathing

When a patient's spontaneous breathing ceases or becomes inadequate then blood oxygenation can be maintained if the ventilation of the lungs is **totally controlled** or **assisted** by artificial means. Historically, this has been achieved by manual manipulation of the torso, applying negative pressure to the torso intermittently or generating **intermittently-elevated positive pressure** in the **patient's airway**. The scope of this standardised terminology has been limited to the last of these means because this has become the almost universal current practice.

Concepts of **artificial ventilation** are inevitably derived from those of **natural breathing** as illustrated in Figure 1. In this case all the **work of inspiratory breathing** comes from the patient's muscular activity in lowering the pressure within the pleural cavity. This expands the lungs and causes the **alveolar pressure** to drop below the **ambient pressure** at the mouth, thereby creating a pressure difference across the **airway** that causes ambient air to enter the lung. A normal, passive, exhalation results from relaxation of the inspiratory muscles such that the sub-ambient pleural pressure is no longer maintained. The **elastic recoil** of the lungs, diaphragm and the chest wall then cause the pressure in the lungs to rise above ambient, resulting in a decreasing gas-discharge waveform; this being determined by the remaining alveolar pressure matching the instantaneous pressure drop across the airway.

This **respiratory cycle** results in a **breath**, which is defined in the Standard as: an increase in the volume of gas in the lungs resulting from an inwards gas flow though the airway (inspiration) paired with a decrease in volume resulting from an outward flow (exhalation). The resultant **ventilation of the lungs** replaces the air in the alveoli that has been depleted of oxygen and enriched with CO2, with ambient air. The volume of gas that enters and leaves the lungs during each **respiratory cycle** has become universally known by the descriptive term **tidal volume**.

The waveforms clearly illustrate how the pressure at the mouth remains at ambient pressure throughout the cycle and that the movement of gas into and out of the lungs is solely due to the changing pressure in the lungs: below ambient to induce **inspiratory flow** and above ambient to achieve **exhalation**.

3.2 Artificial Breaths

3.2.1 General

In the early days of **artificial ventilation** there does not appear to have been any particular attempt to use language to distinguish between the concepts of a breath as defined above and that of what the ventilator is set to deliver. This is understandable because, as has been explained, at that time **artificial positive-pressure ventilation** was often achieved by displacing volumes from a mechanical device and so it was reasonable that the mental model was of the volume of gas being displaced as the **breath**.

However, as has been recently highlighted, "ventilators do not breathe" [Ref1], and as artificial ventilation has become more interactive this looseness has contributed to the lack of clarity in the description of more complex modes. In the Standard, therefore, the term **breath** is used exclusively from the perspective of the volume of gas within the patient's **respiratory system**; a ventilator inflates the lung by means of **an inflation**.

Considering artificial ventilation from first principles and considering **the lung** as a compliant chamber connected to the ventilator through a resistive airway then, in the absence of **patient respiratory activity** the compliant element of the lung can only be inflated by raising the pressure at the **connection to the ventilator**. Similarly, **the lung** will only deflate if that pressure is reduced or if the patient uses muscular activity to raise the pressure in the lung. The natural datum for these pressure changes is local ambient pressure but if there is a clinical requirement that the pressure in the compliant chamber does not fall below a set level then this can be adopted as a new datum.

How this relates to natural breathing is illustrated in Fig 2. This diagram shows representative waveforms for four respiratory parameters as they might appear during four different scenarios while a patient is connected to a ventilator.

The scenario, represented in the first column, shows the conditions necessary for the patient to be able to **breathe naturally**, as if not connected to a ventilator and as was shown in Fig 1. Although this is not what a **ventilator** is intended to do it is the state that the patient will at the least be approaching by the time they no longer require ventilatory assistance and so is the 'corner case' of what is meant by **unassisted spontaneous breathing**. For this scenario, the patient is doing all the **work of breathing**, as shown by the waveform for the pressure in the lung being the same as in Fig 1, but for this to be so the pressure at the mouth is required to be maintained at **ambient pressure**, irrespective of the changes of flow shown in the airway-flow waveform. In practice, a small change of pressure with flow is inevitable but any drop in pressure during **inspiration**, will add to the **patient's work of breathing**.

Note: An increase in pressure during exhalation will generally only add to the expiratory time and may create some discomfort but will only add to the work of breathing if the patient has to use muscular effort to maintain the spontaneous breathing rate.

It is common practice, therefore, for manufacturers to compensate for these artefacts of the control system, and at the same time for inevitable pressure drops across any **artificial airway**, by superimposing a slight elevation of pressure at the commencement of each inspiration.

In the Standard, the term **natural breathing** has been used in reference to where the patient is expected to be able **breathe spontaneously** without **assistance**; with the definition that it is '**breathing** with a workload within the range that a typical patient would have felt to be normal before requiring **artificial ventilation'**. This definition recognises that connection to a ventilator will always have some effect on the **work-of-breathing** pattern but that this pattern continuously changes during normal life too. It would be for performance standards to specify what level of imposed work of breathing might be acceptable to justify the use of this term but in their current absence it is for manufacturers to justify their claim based on clinical data and feedback.

The scenario represented in the second column again shows the conditions for natural breathing but this time with a **datum pressure** set above that of ambient. It can be seen that if the **airway pressure** is maintained at a constant level then the pattern of the pressure in the lung is the same as in the previous case but that it occurs relative to the same raised datum as applied to the airway connection. It follows that the patient's work of breathing has not changed. This may be contrary to subjective experience but, as mentioned above, this is because all ventilator systems either impose at least some extra load due to inherent limitations of the **pressure-regulation functions** used or more than compensate for such limitations by small levels of added assistance.

The scenario represented in the third column illustrates the situation where a breath of the same **tidal volume** as in the previous scenarios is generated entirely by the action of the **ventilator**. In this case, there is no reduction of pressure in the lung and the entire equivalent force required to inflate the lung is now provided by the **temporary elevation of the pressure at the mouth**, above its datum level.

With a **constant flow** the shape of the **airway pressure waveform** will approximate to that shown. There will be an initial rise in pressure as soon as the flow commences, resulting from the back pressure generated as the flow passes through the airway, but as the compliant element of the lung is inflated at a constant rate the pressure in the entire lung will rise at the same rate until flow is terminated. However, as the flow is being maintained at a constant level by the **flow- regulator function** it is unaffected by changes in the patient parameters or by respiratory efforts because the pressure is automatically adjusted to counteract these changes and perturbations. It follows that the shape of the **airway-pressure waveform**, but not the **flow waveform**, may vary within a **breath**, **breath to breath** and as a longer-term variation.

The scenario represented in the final column illustrates **pressure-control inflation**. In this case it is the **airway-pressure waveform** that is **regulated** to a constant level and it is the **flow waveform** that varies with changes in **patient parameters** and respiratory efforts.

With all these representative waveforms it can be seen that it is only by the intermittent elevation of the mouth pressure above a set datum that the lung is inflated by the ventilator. The ventilator delivers the flow to maintain the pressure pattern in all four scenarios but if there is no elevation of pressure, the ventilator only delivers the flow that the patient is demanding as a consequence of lowering the lung pressure below the datum pressure at the mouth with spontaneous efforts.

It is with the above considerations that in the Standard:

- a **breath** is a volume of gas that has entered and been expelled from **the lung**
- an **inflation** is a **periodic elevation of the pressure at the patient's mouth** above a **datum level** in order to increase the volume of gas in **the lung** as the first phase of an **artificial breath**
- the flow into **the lung** associated with an **inflation** is the **inflation flow**

- the flow from a **ventilator** during an **unassisted spontaneous breath** is the **demand flow**

3.2.2 Classification of types of inflation

It has been shown above how **(artificial) inflations** are only achieved by the generation of **cyclical positive-pressure waveforms** at the connection between the ventilator and the patient's airway – just as **spontaneous breaths** are only achieved if the patient generates corresponding **cyclical negative-pressure waveforms** in the lung. There are an infinite number of possible pressure waveforms that could be used in both cases but, in the early days of artificial ventilation, established mechanical/pneumatic means of generating pseudo-sinusoidal-flow, constant-flow and constant-pressure were readily available. A constant flow for a set time provided a known delivered volume and so the parameters being controlled not only had the merit of being easily understood but were also the basic parameters relevant to the clinical assessment of breathing, i.e., airway flow, inflation volume and differential-pressure across the patient's airway.

Although a sinusoidal-flow waveform was seen as closest to that of natural breathing, the mechanical mechanisms that were used for producing it were inflexible and involved cumbersome moving parts, so **constant-flow** and **constant-pressure generators** became established as the primary means of delivering **positive-pressure inflation**. Although these means are still employed in more basic ventilators they have been largely replaced in modern ventilators by electrically-powered proportional-valves under microprocessor-based closed-loop control. Such systems are capable of generating any inflation waveform but, in the absence of any evidence to the contrary, it is still normal practice to regulate the pressure at the patient connection at either a constant pressure level or so as to achieve a constant inflation flow.

This practice has been reflected in the Standard with **pressure regulation** and **flow regulation** remaining as the two **primary classifications** of **types of inflation**. However, the classification system also accommodates **derivative subclasses** in order to be able to formally classify, amongst other things, alternative inflation waveforms.

The **secondary feature** of an **inflation type** that is essential for its classification is the means used for its **termination**. This may be time, a threshold value of a respiratory parameter such as flow, pressure, volume or diaphragm EMG, or the output of a control algorithm. These and other features used for encoding the description of a range of types of inflation are tabulated and explained in the Table in Fig 3 and in Sections 3.2.2.3 & 3.2.2.4.

3.2.2.1 Pressure-regulation

A **pressure-regulator function** is used to implement required inflation pressure waveforms but dynamic and compressibility considerations, for both the patient and the ventilator circuit, mean that it cannot be tuned to attempt to provide a step change in the pressure in the airway following the initiation of an inflation; neither would it be desirable for the patient. The response of the regulator has to be attenuated sufficiently, therefore, that the set pressure is attained with a minimum of overshoot and oscillatory response. Because this response is patient dependent it is usually operator-adjustable by

means of a setting, which may typically be associated with the **slope** of a **ramp** or the **time-constant** of the rise. In the Standard this setting is named as the **rise time**.

An **inflation type** in which the **pressure-regulator function** maintains a **constant set pressure** following the **rise time**, and which is **time terminated**, is named a **pressure-control inflation**, which is commonly abbreviated to a **PC inflation -** or where appropriate, simply **pressure-control,** represented by the abbreviation **PC**.

It is a required characteristic of **PC inflations** that whenever the regulator senses that the airway pressure is below the set level then the flow is proportionally increased to restore it back to that level. This not only serves to inflate the lung by means of a constant airway pressure but has the additional benefit that any **concurrent spontaneous inspirations** by the patient will always result in the additional flow required to supply that additional demand. However, with the trend to make ventilators more interactive and to encourage the patient to contribute as much as possible to their ventilation there is now a growing expectation for the patient to be able to exhale as well as inspire at any time, including during an **inflation phase**. To meet this requirement many adult ventilators are now equipped with the type of **pressure-regulation function** that has been commonly used in **paediatric ventilators** and which maintains a set pressure that is **independent of the direction of flow through the patient connection**. In the absence of any agreed nomenclature to identify this additional functionality the Standard has introduced the term **bi-active pressure-regulator function** to identify the function and **enhanced pressure-control** the **type of inflation** - represented by the symbol ***e*PC -** if **time terminated**.

Another variation of a PC inflation that is used to enable increased patient-ventilator interaction is one where the inflation is flow terminated instead of time terminated. This inflation type is named pressure-support inflation, commonly abbreviated to 'PS inflation', or where appropriate, simply 'pressure-support' **-** represented by the abbreviation 'PS'. This designation of this type of inflation is restricted to use with mode patterns where it can only be initiated by a 'patient trigger event'. It should be noted that in all cases such as this, where the termination means is other than time, it is to be assumed that a time limit is in place to protect against the foreseeable failure of the primary termination means, e.g., as a result of excessive circuit leakage.

An extension of the concept of pressure-support inflation has introduced a case where the pressure-regulator function is used to follow a pressure trajectory set by an algorithm and not simply maintain a constant value. The intention is that the inflation pressure is proportional to either the resistive or the elastic load, or both, so that the support is proportional to the instantaneous effort required by a spontaneously breathing patient during their inspiratory phase. This variant of pressure-control inflation is identified as 'proportional pressure-support', represented by the symbol '*p*PS'.

3.2.2.2 Flow-regulation

As explained above, the use of a pressure-regulator function for delivery is one of the two primary classifications of types of inflation. With this concept, unless otherwise specified, the airway pressure is set to rise from its datum value to a set inflation pressure, with a set rise time, following the initiation of inflation, and is then held at that level until termination when it makes a step change back to its datum value.

The alternative primary classification of types of inflation is 'flow-regulation'. With this concept, unless otherwise specified, the inflation flow is set to rise to a set flow as a step change following the initiation of inflation and is then held at that level until its termination, when it makes a step change back to zero flow. A 'flow-regulator function' is used to implement these settings, which it does either by the use of a back-pressure compensating, choked, pneumatic restrictor or by monitoring the instantaneous flow

and continuously adjusting the airway pressure as necessary to maintain this flow at the set value(s) throughout the inflation phase.

As the concept of flow is a measure of the volume passing a reference point per unit of time it follows that the volume of gas delivered to a lung is inter-related with the flow and the time of its delivery. Examples of this are:

- When the flow is held to a constant value then the volume delivered during the inflation is simply that flow multiplied by the time of delivery.
- If the flow-regulation is imperfect, or if the flow is regulated to a non-constant waveform, then the delivered volume can still be computed by the ventilator as the time-integral of the flow delivered.
- If the volume delivered is as the result of a measured displacement of a piston or bellows, then the volume is predetermined but it is necessary to regulate the flow delivery to achieve the desired inflation time.

Any method such as the above, where two of the three variables, volume, flow and time are set – directly or indirectly – constitute an inflation type named 'volume-control inflation', which is commonly abbreviated to 'VC inflation' - or where appropriate, simply 'volume-control', represented by the abbreviation 'VC'.

Although it is seen that volume-control inflation can be achieved by several different means, for any particular ventilator the settings required will inform the operator which of the three variables are regulated and which is independent.

3.2.2.3 Structure of alphabetic-codes used to designate inflation types

As has been explained, the primary classification of possible inflation types has been based, by convention, on the two basic parameters that can be conveniently regulated - pressure and flow – and a hierarchy of letters used to codify how an inflation will be managed - after initiation.

The core element is a pair of capital letters that have been universally adopted in current ventilation terminology and have already been introduced in the previous section, i.e., VC, PC, and PS. In this terminology, these pairs, in isolation, represent an inflation type that, once initiated by the selected mode pattern, regulate the delivered flow or pressure to the set value until terminated by time, or in the case of PS, flow.

More specifically:

- VC represents Volume-Control, in which a set flow is maintained for a set duration. These settings may be made directly, or indirectly with such combinations as volume and time, phase time ratio and volume, or volume and flow.
- PC represents Pressure-Control, in which, after a set rise time, a set pressure is maintained for a set duration. The pressure is set as the inflation pressure and the duration either directly as the inflation time or indirectly by, e.g., the phase time ratio and the frequency.
- PS represents pressure support, in which, after a set rise time, a set pressure is maintained until the inflation flow declines to a specified level after reaching an initial peak, at which point the set pressure returns to its datum level. This specified flow level is often expressed as a percentage of the measured peak inflation flow.

Variations from these specific conditions are designated by the attachment, to the base pair, of leading lower case letters and contained trailing letters - the containment being by means of round brackets for termination parameters, square brackets for conditional termination means and curly brackets for additional regulation parameters.

Leading lower case letters are used to indicate features that provide additional functionality to the basic control. These can be either specific to the particular control to which it is attached, in which case it is in italics, or of more general application. Examples of the former are *e*PC, to represent enhanced pressure control, and *p*PS to represent proportional pressure support. The letters vt (volume-targeted) are applicable to PC and *e*PC inflation types and indicate that the set inflation pressure is automatically adjusted inflation-to-inflation in order to get closer to achieving the set tidal volume with the next inflation.

Allowance has also been made to accommodate the possibility of switching between regulated variables during an inflation phase. All these are codes are presented in a structured, tabular format in Fig.3 and are explained individually in section 3.2.2.4.

3.2.2.4 Descriptions on other inflation-type codes

The following descriptive notes relate to the tabulated codes in Fig 3. The table is intended to demonstrate the structure of the coding, both as aid to memory and to provide a template for future developments.

Where the primary means of termination is shown to be other than by time it is to be assumed that there is always some sort of ultimate time limit on an inflation for reasons of safety. This may be a factory set default or an operator-settable value - with a limit on the maximum setting - but such secondary time limits are not shown in the coding so as not to make them overcomplicated.

It is envisaged that these codes will be used as symbols, as PC, VC & PS are at the present, with the spoken form being either the spoken abbreviation or the full name that has been abbreviated, as written in bold type in the following listing:

Note # 1: v**olume control**; an inflation type that is flow-regulated to a constant value and time terminated, which, by convention, has been identified under its more generally applicable name of volume-control, with the abbreviation, VC.

Note # 2: **pressure control**; an inflation type that, after an initial rise time, is pressure-regulated to a constant value and time terminated. By convention, it has been identified with the name pressure-control, with the abbreviation, PC.

Note # 3: **pressure support** or **flow-terminated pressure control**; a PC inflation type that has the facility to be alternatively terminated if the flow reduces to a set flow level before the set time termination, and which is only used with mode patterns in which it can only be initiated by a patient-trigger event, has been identified with the name pressure-support, with the abbreviation, PS.
If used in a mode pattern in which it may be time initiated its code reverts to that of a variant of PC, i.e., PC(q).

Note # 4: v**olume-targeted -** ; inflation types, which unlike VC, do not control the delivered volume directly but which target a set delivered or exhaled volume by adjusting inflation settings inflation-to-inflation, depending on measurements of previous deliveries, are identified by the prefix volume-targeted, with the prefix code of vt, e.g., vtPS.

Note # 5: A PC inflation type that is terminated by time if time initiated, but which is terminated by flow if initiated by a patient trigger event occurring before the set time, is identified as a conditional variant of PC, i.e., PC[q/t]. There is no currently no name for this inflation type, although it is used in a mode type often identified as ST. A possible spoken name would be '**q t pressure control'**.

Note # 6: **-- synchronised termination**; an inflation type, during which the patient may spontaneously exhale without terminating the delivery, may modulate the set termination point with a view to synchronising it with the patient's breathing. Such a facility is indicated by the conditional-termination variation trailing code [S], spoken as 'enhanced pressure control with synchronised termination'.

Note # 7: **proportional pressure support**; a variant of a PS inflation type that is pressure regulated to a non-constant waveform that is dependent upon the instantaneous compliance or resistive component of the patient's breathing efforts - or the sum of the two – with the intention of providing support to the breathing that is always proportion to the effort.

Note # 8: **pressure-limited volume control**; a variant of VC in which, when the inflation pressure attains a set level during normal operation, excess regulated flow is spilt to atmosphere if necessary to avoid the inspiratory pressure exceeding the set level, resulting in a possibly un-quantified loss of the set delivered volume. This variant is indicated by the addition of the trailing code {p̂}. If the pressure is limited by pressure regulation then the code becomes VC↔PC (see Note 11). As this loss is part of the normal operation of this inflation type it is not accompanied by an alarm but if there is any loss of delivered tidal volume patient safety considerations dictate that it should be indicated.

Note # 9: There are several variants of *p*PS, depending upon the components of the breathing effort selected to be supported. The variant selected is indicated by trailing codes in curly brackets, e.g., {q}, {V}, indicating flow and volume respectively - the variables related to the resistive and compliance loading. {EMG} is used to indicate that the breathing effort is assessed using the detected level of the electromyographic activity of the diaphragm and intercostal muscles. There is currently no agreed name to designate these additional regulation parameters, other than the use of a verbal description.

Note # 10 & 11: **dual-control**; these codes represent hybrid inflations that start with the first inflation type but under specified conditions may be changed to an alternative type during the course of the delivery. These changes may be bi-directional or unidirectional as indicated by the coupling arrows.

Note # 12: **flow regulated, pressure terminated**; this code represents a flow-regulated inflation that is pressure terminated and with which, as a consequence, there is no direct correlation between the setting and the volume delivered. It is not, therefore, a variant of VC and is classified as a flow regulated, pressure terminated inflation type. This inflation type is not currently used in mainstream ventilators but is still sometimes used in low-cost, gas-powered resuscitators.

Note # 13: **volume control**; this code represents an alternative means of achieving control of the delivered volume, with time being a dependent variable instead of the directly determined parameter. The outcomes are sufficiently similar that the definition of volume-control in this standard includes both arrangements and, therefore, both are identified as VC.

Note # 14: **volume-terminated pressure control**; this code represents a variant of a PC inflation type in which the inflation is terminated after a set volume has been delivered, if this occurs before a set time limit. As a variant it is coded as PC(v).

4. Ventilator Modes

4.1 General

A ventilator mode is defined in the Standard as the specified manner in which a ventilator performs its function when connected to a patient, which includes how the two interact with each other. As implied by its name, positive-pressure artificial ventilation can be implemented only by the continuous control of the temporal pattern of the 'airway pressure' waveform (two typical examples are shown in the illustrations in Fig 4). This pattern will include characteristics that are imposed on the patient and may include others that are in response to patient parameters and respiratory activities. Conceptually, there are an infinite number of possibilities of such characteristics and their combinations but in practice specific implementations have become established and selection has been facilitated by classifying them according to names or acronyms.

As explained in Section 2, the classification, understanding and setting of modes is greatly improved and simplified if a mode is treated as the combination of two constituent concepts: those of types of inflation and of their pattern of initiation. With this approach, artificial ventilation can be conveniently regarded as the intermittent delivery of one or more selected types of inflations and, where appropriate, demand flows, in accordance with a selected mode pattern; each inflation type with its own characteristics and settings and each mode pattern provisioned for the specified interaction with the patient's respiratory activity. In principal, the selected inflation(s) can be of any type and it is for clinical practice to determine and teach which inflation types may or may not be appropriate with each mode pattern so, conversely, the description of the mode pattern must, as far as possible, be independent of the type of inflation(s) that can be used with it. The description of the mode pattern must also be independent of the values to which the control parameters (e.g. frequency, patient-trigger sensitivity, phase time ratio, etc.) can be set and must therefore also be independent of the clinical intention.

Although all modes involve the selection of a type(s) of inflation and a mode pattern, some named modes use higher-order or interventional control algorithms in order to achieve additional objectives, e.g., a ventilation strategy or procedure, and these have often been identified solely by a name relating only to that objective. Names have also been given to modes with a specific combination of attributes that provide the conditions for a particular approach to ventilation. Although this practice can be useful as a shorthand reference it has to be recognised that such mode names do not provide a complete description and so the specification of any such ventilation mode, and its settings, must always make the operator aware of the underlying standardised selected mode pattern and selected inflation type(s).

4.2 Mode Groups

As mentioned in Section 2, pattern-based modes can be usefully classified, according to their characteristics, into just three groups that relate to the degrees of control the ventilator might be set to exercise over the patient's breathing. The defining characteristics of each of these groups are listed in the following Sub-section. There is no requirement in the Standard for manufacturers to include reference to these groups in product labelling but such grouping is intended to assist with the understanding and teaching of how the large numbers of modes currently in use are related to each other.

As also mentioned previously, some modes have been presented, or have become know by, a characteristic or feature independent of the underlying mode pattern or type of inflation, often because they provide an overarching input of a supervisory or interventional nature. In the Standard, the higher-order modes that fall into this group and which have been widely recognised are categorised together and placed into a conceptually separate, Group (iv). However, the designation of a mode in this group is incomplete without reference to the mode pattern and type of inflation with which it provides its function.

4.2.1 Mode Pattern Groups

The three groups of mode patterns are identified simply as (i), (ii) and (iii) in order to avoid using language that might be confused with legacy terms. The scope of each of these groups is in the following paragraphs - with the implicit understanding that the definition of a mode pattern is independent of the breath -type selected and of the set values for parameters such as the ventilator set rate:

> Group (i): only one type of inflation is selectable and this is assured to be delivered, mandatorily, at the set rate minimum rate. Mode-patterns in this group may include the facility for patient triggering, in which case every patient-trigger event occurring between set deliveries initiates the next delivery, thereby increasing the total respiratory rate above the ventilator set rate.
>
> Group (ii): one type of inflation is selectable as the primary inflation type, the delivery of which is assured to be instigated, mandatorily, at the ventilator set rate. Between these assured deliveries the patient is able to breathe spontaneously. Such spontaneous inspirations may be either assisted, by the selection (which includes the setting) of a second type of inflation, or unassisted (no inflation type available for selection or the second inflation type is set to 'zero').
>
> Where *e*PC is selected as the primary inflation type, concurrent inspirations may be assisted by either the second inflation type or by a third selection.
>
> Group (iii): the patient is able to breathe spontaneously at a set, positive, airway pressure. Spontaneous inspirations may be assisted by a selected type of inflation but there are no assured deliveries of that inflation**.**

Group (i) modes include the currently used terms, CMV and A/C (now A/MV). They also cover supporting modes, in which the ventilator set rate serves only as a safety-net (implicit backup ventilation).

Group (ii) modes include IMV and SIMV. The scope of any mode in this group is independent of whether spontaneous breaths are set to be assisted, or not, between the mandatorily instigated inflations or whether these inflations are set to be mandatorily instigated only of the order of once per minute in order to recruit the patient's lungs - they are independent of the set assistance and frequency.

5. Baseline airway pressure & PEEP

Inherent in the concept of a mode pattern that determines how and when inflations are delivered is the determination of what happens between inflations. The steady-state clinical requirement during these phases is to allow the volume of gas that has been delivered in each respiratory cycle to be fully discharged and while doing so maintaining a required minimum pressure within the alveoli; also to facilitate unassisted natural breathing where this is part of the mode specification.

These considerations will therefore be addressed in detail in this Section before going on to explain how the standardised terminology is used to describe the function of a range of widely recognised named modes.

As explained in Section 3.2, inflations elevate the airway pressure above a datum pressure. This datum could be ambient pressure but is generally set to a positive pressure to satisfy a clinical requirement that the alveolar pressure does not fall below a set level - a level usually referred to as PEEP, the well established acronym for **positive *end*-expiratory pressure**.

In early ventilators the pressure at the patient connection was not controlled while the patient exhaled and so the rate of decline of the patient's alveolar pressure was determined solely by the patient's airway resistance and the resistance of the components in the expiratory limb of the ventilator breathing system with the expiratory valve in its 'open' state.

The term PEEP was first used in about 1970 as a name for the clinical concept of maintaining a minimum pressure in the alveoli at the end of expiration as had been made possible by either creating a backpressure using a bubble water jar with a dip tube or a feature on an early Engström ventilator that enabled the minimum expiratory pressure at the patient connection to be set to a required value. With these arrangements the fall of the expiratory airway-pressure was limited to the set value.

Although it was always clear that the clinical requirement was that it was the alveolar pressure that should be prevented from falling below the **PEEP** level, in practice, as it was only possible to measure and control the pressure at the patient connection port (by convention identified as the 'airway pressure') this became the PEEP reference point and the name became associated with the 'setting' for the relief valve. This was reasonable at the time because, providing the expiratory time was set sufficiently high, the alveolar pressure would fall to the level set before the next inflation. However, the use of a simple spring loaded relief valve also increases the exhalation resistance, thereby increasing the time required for full exhalation – particularly when associated with a lung with high airway resistance. It is also susceptible to leakage in that, once the airway pressure has reached the set level, there is no means to replace any lost gas and so the pressure may continue to fall.

With the introduction of microprocessor control systems it became practical to use feedback signals and proportional expiratory valves to manage the expiratory pressure throughout its decline towards the set end-expiratory pressure level. If the valve is operated as part of a **pressure-regulator function**, the **expiratory-pressure control algorithm** can be used to generate waveform trajectories that minimise the expiratory time required to achieve the required alveolar PEEP by fully opening the valve in the initial stages of exhalation and then progressively closing it as the end of exhalation is approached. If the exhalation pressure is reduced to a level below the set end-expiration level while there is still more than an equivalent resistive pressure drop across the patient's airway then the expiratory flow can be safely augmented before it is necessary to bring the pressure back up to the set level as the pressure drop across the airway diminishes.

Such expiratory algorithms are designed to ensure that the release of alveolar pressure is relatively unimpeded by the necessary valves in the expiratory limb of the ventilator breathing-circuit, while never letting it fall below the set positive level during an exhalation phase.

With the advances such as these, which have greatly improved ventilators' abilities to treat patients with severely impaired respiratory systems, there is now a need for a more nuanced use of language to convey exactly how the ventilator is interacting with the patient, not just at specific points, but throughout the respiratory cycle. In particular, failure to address the ambiguity and lack of precision in the use of the term PEEP has resulted in it now being used with several different meanings - while not even properly describing one of the most important clinical requirements, i.e., that the alveolar pressure must not fall below the set level throughout the expiratory phase, not just at its end.

PEEP is now used not only to quantify the clinical requirement and the setting of the ventilator but also to name the measured pressure at the patient connection port at the end of an exhalation phase - and sometimes even to name an entire phase. The terms auto-PEEP and intrinsic-PEEP have also entered the terminology used but a review of published material shows that there is disagreement as to what these terms mean and whether or not they mean the same thing. In such a situation a solution can only be found by returning to first principles.

There are on-going discussions concerning the precise physiological mechanisms of alveolar PEEP and its distribution, both spatially and temporally, but it is not possible for currently available ventilators to continuously measure and control other than the pressure and airway flow at the patient's mouth throughout an exhalation phase. The operator therefore has to discern what is happening at the alveolar level from indications provided by these ventilator parameters- and this will be best achieved by using an unambiguous terminology that distinguishes between settings and displayed parameters and between ventilator parameters and alveolar parameters.

Two existing terms intended for this purpose, but which, in the absence of any previous concerted recognition of the problem being addressed, have not been widely adopted, are **baseline airway pressure** and **end expiratory (airway) pressure** - with the respective acronyms of **BAP** and **EEP**.

The first of these terms, baseline airway pressure, has been formalised and adopted in the Standard as a significant concept; one that underlies the terminology used for the description of the sometimes complex relationship between ventilator settings and the clinical requirements for alveolar PEEP in modern ventilators. This term has been used informally for a long while but the concept had never been formally defined. Its adoption provides a sound basis not only for the description of the expiratory-pressure waveform but also for a new name for the entire phase between primary inflations, i.e., the BAP phase, a phase for which there was no previous consensus as to a suitable term.

The application of these concepts and terms is illustrated in Figs 5 - 8. They show the expiratory phase waveforms of a range of scenarios that illustrate the distinctions that have to be made to communicate the effects of settings, patient parameters and control algorithms on outcomes. For the purposes of these explanations the illustrations are all based on an uncomplicated CMV-PC mode setting.

At the end of the expiratory phase, the alveolar and airway pressures are labelled, respectively, as total PEEP, represented by the symbol tPEEP, and EEP. With a healthy lung and optimum ventilator settings, tPEEP should be equal to the measured EEP, which in turn should be at the set BAP level, all as shown in Fig 5. If there is any difference between these three values, such as shown in the other figures, it will be due to dynamic factors. These result in tPEEP not reaching the set BAP value, due to insufficient time before the next inflation is initiated. The cumulative effect of these dynamic factors causing the difference is labelled as dynamic PEEP, represented by the symbol dPEEP.

It can be seen, therefore, that the parameter that determines the minimum alveolar pressure setting for the algorithm throughout the phase is the set baseline airway pressure, BAP, which consequently also becomes the setting for the required end-expiratory alveolar pressure, i.e., the total PEEP.

Considering the illustrations in more detail, Fig 5 shows representative expiratory waveforms with a healthy lung, on a typical ventilator. The broken orange line represents the level to which the 'baseline airway pressure', BAP, has been set.

The continuous black line represents the pressure at the patient connection port of the ventilator. Following termination of an inflation phase the ventilator allows this pressure to fall, following a waveform pattern determined by the design of the ventilator, with the intention that the measured pressure at the end of the exhalation phase is equal to the set baseline level (BAP), as shown in this figure. As previously explained this may be achieved by the use of a simple relief valve function or by employing specifically conceived expiratory-pressure control algorithms.

The broken green line represents the alveolar pressure. Expiratory flow causes an inevitable pressure drop across the patient's airways causing a 'dynamic' lag between the rate of fall of the alveolar pressure and that of the airway pressure. As the airway pressure approaches the BAP level its rate of fall diminishes and the dynamic lag will decrease so that, given sufficient time as shown, both the airway pressure and the alveolar pressure will reduce to the set BAP level.

The measured end-expiration (airway) pressure is labelled with the acronym **EEP** and the end-expiratory alveolar pressure is labelled with the symbol **tPEEP**, representing the concept of **total PEEP** that will be illustrated in the following figures.

Note: It is more correct to use EEP, without an initial 'P', because this is a measurement not a requirement. It is superfluous and misleading to add an initial 'P', without further qualification, because it is the measurement itself that will have a positive or negative value and it is convention that measurements of ambient parameters such as pressure and temperature are taken to be above ambient unless indicated to the contrary. With this approach, the acronym PEEP is only used as, or as part of, a term directly referencing actual alveolar pressures, the site where the 'positive' applies as a requirement.

Fig 6 shows representative expiratory waveforms with an impaired lung, on a typical ventilator. The BAP level and the measured expiratory airway-pressure waveform are the same as in the previous figure but the impaired lung is causing a larger dynamic lag, particularly towards the end of the exhalation, such that the alveolar pressure has not attained the BAP level by the time that the exhalation phase is terminated. The component of the average end-expiratory alveolar pressure above the BAP level resulting from this higher dynamic lag is named the **dynamic PEEP** and the total average PEEP in the alveoli at that point is, therefore, the sum of the set BAP and the dynamic PEEP - commonly referred to as the **total PEEP**.

The dynamic PEEP could be simply the result of insufficient time for the expiratory airway pressure to reach the set baseline pressure but in most cases it will be due to the sum of a large number of varying individual elements within a non-homogenous lung, all of which have delayed the final discharge of the lung beyond the point where the next inflation is initiated. Typical factors include gas trapping from flow limitation and airway closure.

Although ventilators are able to manage and measure both the pressure and the flow at the patient connection port, currently, it is only possible to measure one alveolar parameter non-invasively; although even this is only possible by occasionally interspersing an expiratory-hold manoeuvre within the set ventilation pattern. With such a manoeuvre all the gas in the lung is trapped for a period long enough to allow any higher pressures to dissipate and spread equally throughout the lung. The difference of pressure at the patient connection port at the end of the manoeuvre, above the set

baseline pressure, is currently considered to be the best estimate of the dynamic component of the total PEEP in the lung.

This dynamic component is sometimes called auto PEEP and sometimes intrinsic PEEP but both terms are also used to name the total PEEP - in both cases sometimes with the same meaning and sometimes to identify the opposite. Because this confusion leads to the terms having to be explained every time they are used and because neither term is inherently self descriptive, in the Standard they are deprecated for the labelling of ventilators and replaced by the plain-English, descriptive terms already used in these notes, i.e., **dynamic PEEP** and **total PEEP**.

Fig 7 shows typical expiratory waveforms when ventilating an impaired lung using more advanced algorithmic management of the expiratory airway pressure.

In this illustration the black waveform representing the expiratory airway pressure can be seen to fall below the baseline level before returning back to it towards the end of the phase. As referred to earlier, proportional exhalation valves provide the opportunity to manage the expiratory-pressure waveform in the manner shown in order to achieve an optimum rate of exhalation whilst still maintaining the alveolar pressure at not less than the set BAP value. If a **bi-active pressure-regulator function** is used then the pressure can be allowed to fall below the BAP level while the alveolar pressure is still above it and then brought back up to the BAP level, by adding more gas if necessary, as the alveolar pressure approaches the set BAP level. The set waveform for the regulation function to follow is determined by an **expiratory-pressure control algorithm**.

Whichever method of control is used to control the expiratory airway pressure waveform, factors such as a build-up of contamination on a filter or insufficient expiratory time can mean that the phase is terminated before the airway pressure has reached the BAP level. Fig 8 illustrates how that if the measured end-expiration airway pressure, labelled EEP, is greater than set BAP then the end-expiratory alveolar pressure will be even more so, demonstrating why it is necessary to clearly distinguish this measurement from the setting.

5.1 Extensions of the concept of BAP

The concept of BAP has so far been explained in terms of its function during a single expiratory phase but its potential scope is much broader. For example, during the phase between primary inflations in an SIMV mode provision is made for the patient to breathe spontaneously as shown in Fig 9. The set BAP level will be applicable not just to the first exhalation following the primary inflation but to all of the breaths within the phase, which means that the setting is active throughout the whole phase.

This usage of the concept suggests a standardised name, **BAP phase**, for any phase between primary inflations where there is provision for unassisted or assisted breathing; a phase for which there was no previous consensus as to a suitable term. It is a name based on the most important common characteristic of such phases and obviates the use of the unsatisfactorily, ambiguous, ad hoc names, such as **PEEP/CPAP** or **Spontaneous**, currently used.

Within a BAP phase, if the selected mode pattern requires that the patient is able to breathe spontaneously once the airway pressure has declined to the set BAP level, as previously described, then the use of a **bi-active pressure-regulator function** will maintain the set pressure irrespective of whether the patient is exhaling or inhaling, as can be seen in Fig. 9. This configuration has the additional benefit that it compensates for leakage from the ventilator breathing-circuit or at the patient interface.

If the mode is set to assist such spontaneous breathing then the regulated pressure is raised above the BAP level by the selected inflation-type control algorithm and the exhalation is controlled in the same manner as following a primary inflation, i.e., with the intention that at no point throughout the BAP phase will the alveolar pressure fall below the set BAP level.

The scope of the BAP concept also extends to *e*PC inflations as illustrated in Fig 10. During an *e*PC inflation phase, as between primary inflations, provision is made for unassisted or assisted breathing, so this can also be named as a BAP phase, although this needs to be identified as BAP high, with the symbol BAP_H, to distinguish it from BAP. This means that a mode using an *e*PC inflation can be described and labelled as either a pattern based mode with an *e*PC inflation type, e.g., SIMV-*e*PC[S], or as a bi-level BAP mode (with the description disclosing that it is based on an SIMV mode pattern with a synchronised termination to the inflation).

The concept extends, ultimately, to an infinitely long phase, of which a typical section is shown in Fig. 11, where a patient breathes spontaneously, with or without assistance, continuously; leading to the possible name, CBAP, for that function. This acronym was proposed during the committee's deliberations but it was considered that the term already used for this mode, i.e., CSV (continuous spontaneous ventilation), is not only equally graphic in conveying its function but is also consistent with the other mode pattern acronyms and so should be retained.

An overview of the function of **expiratory-pressure control algorithms** in managing the airway pressure during BAP phases for a range of scenarios is illustrated in Fig 12.

6 Generic Named Modes

6.1 Generically Named Mode Patterns

The most commonly used acronyms of the descriptions of mode patterns are tabulated according to their grouping in the table in Fig 13. The forms of each of these patterns, both from the setting perspective and as a typical outcome, are illustrated in Figs 14 – 18. The list below provides the standardised name and description along with background information. Each name has been chosen as the most appropriate from the point of view of compatibility with the underlying concepts on which the Standard is based and consistency of use.

The term **mandatory** appears in several of these legacy names. It was first used in modes that used VC inflations and provided no trigger facilities, i.e., where the ventilation could be said to be **mandatory** in every aspect. The term was retained as IMV-VC developed into SIMV-VC, which, in turn, went on to include SIMV-PC; to the point that the retention of the word only made sense with its alternative but equally valid meaning of **assured to occur**. With modern ventilation there is some element of imposition in the delivery of all inflations but the essential aspect from the operators perspective is the assurance of what will happen if the patient fails to make respiratory efforts and this is the sense in which **mandatory** is currently used by manufacturers. It is therefore retained in the generic acronyms with this sense of the meaning but, because of the term's inherent ambiguity and consequent inconsistent use, is replaced for all other purposes in this standard by the term **assured**.

- **CMV – Continuous Mandatory Ventilation**

  This is a pattern used for Group (i) modes in which a set inflation is delivered at a period determined by the ventilator set rate.

Although it has been widely misused, this term is useful to retain with its original meaning because some basic emergency and anaesthetic ventilators still operate in that way. In the Standard it is used only for the name of a mode pattern that cannot be influenced by any patient breathing efforts, i.e., its function is the same as A/MV (aka A/C) with the trigger function switched off.

Note: With the use of a bi-active pressure-regulator function in a BAP phase it would be possible to set this mode to replicate IMV with no assistance for spontaneous breaths. The manufacturer then has the choice of labelling either way, according to the stated intended use although IMV should be the default choice.

- **A/MV - Assist/Mandatory Ventilation**

This is a pattern used for Group (i) modes in which a set inflation is assured to be delivered after the period determined by the ventilator set rate but which will be initiated earlier by a patient-trigger event occurring before the expiration of that period. Patient-trigger events will result in an increase in the total respiratory rate above the ventilator set rate.
This mode pattern is currently known as Assist/Control, or A/C, implying that the mode either assists or controls the patient's ventilation, but the term control in this context is too ambiguous to be useful. The sense in which it is used is that the ventilator will assure the delivery of the selected inflation type at the set rate but that, if the patient makes breathing efforts at a faster rate, then triggered inflations of the same type will assist those efforts. To be consistent with other established acronyms an inflation delivery that is assured is a 'mandatory' delivery.
The 'ventilation' is added to provide a consistent representation for all the generic mode patterns, e.g., CMV, IMV.

- **IMV – Intermittent Mandatory Ventilation**

This is a pattern used for Group (ii) modes in which a set inflation is assured to be initiated at the period determined by the ventilator set rate. Between these assured deliveries, spontaneous inspirations may, or may not, be supported by a second set inflation.
Where *e*PC is selected as the primary inflation type, concurrent inspirations may be assisted by either the second inflation type or by a third selection.
It is possible to set modes conforming to this pattern to replicate modes with a CMV pattern where they use a bi-active pressure-regulation function in the BAP phase. There is then the choice of labelling either way, according to the stated intended use.

- **SIMV – Synchronised Intermittent Mandatory Ventilation**

This is a pattern used for Group (ii) modes in which the mandatory instigation of the primary set inflation leads to the opening of a synchronisation window that either allows time for the exhalation of a previous spontaneous inhalation or provides an opportunity for a patient-trigger event to initiate the inflation. If no trigger event occurs while the window is open the ventilator initiates the inflation when it closes. Successive windows are opened at constant intervals equal to the ventilator set rate (60/f) and so inflation-to-inflation variations in initiation due to synchronisation have no affect on the average delivery rate, which is maintained at the set rate.
Between primary inflations, spontaneous inspirations may be either unassisted, or assisted by the selection of a second inflation type.

Where *e*PC is selected as the primary inflation type, concurrent inspirations may be assisted by either the second inflation type or by a third selection.

- **CSV - Continuous Spontaneous Ventilation**

This is a Group (iii) mode pattern in which the patient is able to breathe spontaneously at any time at a set baseline airway pressure (BAP) level. Breaths are unassisted unless an appropriate type of inflation is selected.
As explained in an earlier section, during unassisted spontaneous breathing it is common practice for manufacturers to compensate for inherent minor imperfection in the pressure regulation, and for inevitable pressure drops across any artificial airway, by superimposing a slight elevation of pressure at the commencement of each inspiration even when assistance is set to 'zero' or 'off'.

- **CPAP – Continuous positive airway pressure**

This is a pattern used for Group (iii) modes in which the patient is able to breathe spontaneously at any time at a set baseline airway pressure (BAP) level in order to provide breathing therapy but which, unlike CSV, has no provision for ventilatory assistance. As with CSV it is common practice for manufacturers to compensate for inherent minor imperfection in the pressure regulation, and for inevitable pressure drops across any artificial airway, by superimposing a slight elevation of pressure at the commencement of each inspiration.

6.2 Generically Named Other Modes:

The following named modes are classified as Group (iv) modes:

- **Bi-level BAP**

This name identifies an alternative class of ventilation modes that are characterised by the use of an *e*PC inflation type and a BAP phase between inflations. The name is used to project the concept of the patient being able to breathe at two alternating baseline airway pressure levels, while receiving an assured inflation each time the airway pressure is raised to the higher BAP level. The concept includes the facility to be able to set such modes to simulate the pattern of other classical modes utilising PC inflation types, with the advantage that any patient breathing efforts will never be obstructed.

This is an area of ventilation practice that badly needs a standardised terminology. When the concepts were first introduced ventilation terminology had already become unstructured to such an extent that there was no clear pre-existing format with which to explain them. This resulted in the various promoters of the different versions of the concept introducing their own terminology – often with a view of emphasising the differences of their proposals rather than the similarities. There was clearly an implication that this was some sort of CPAP at alternating levels, i.e. 'bi-level CPAP', but, with reason, there seemed to have been a reluctance to state this explicitly. Terms such as 'bi-level PAP' and 'Bi-Phasic' were also used but did not become established for this purpose, while the proprietary name 'BiPAP', which is still in use, means something different. This has resulted, at the present time, in all manufacturers seeming to use their own particular scheme and name for describing their 'bi-level', often without actually saying what 'is' at two levels.

After considerable discussion in the preparation of the Standard it became clear that a term was required that reflected the function's commonality with the concept of CPAP but allowed for the additional conditional functions that need to be included in the scope.

Parallel considerations of the terminology of PEEP led to the formalisation of the use of the concept of 'baseline airway pressure'; leading on to its extension as the name of a phase - and on to two phases (see Section 5). This provided a suitable term for this class of modes which is consistent with the terminology in the Standard, i.e., 'bi-level BAP'.

Using this term removes the inherent contradictions implied by some other terms that have been used such as PEEP, PAP and CPAP, and introduces the concept of an algorithm controlling the pressure in its attainment of a set baseline for the respective phase but with the defined flexibility within its scope for the algorithm to permit additional algorithmic functions that may be specified.

BAP utilises the bi-active pressure-regulator function as its basic feedback controller which means that every time the BAP level is raised and then lowered an *e*PC inflation type is generated. It follows that every bi-level mode variant can be described in terms of a classical mode pattern with an *e*PC inflation type. Similarly, every mode presented as 'bi-level' can be qualified by the classical mode pattern that is being used to determine the selected inflation deliveries. It is apparent from this that 'bi-level BAP' is not a separate class of mode patterns but is in fact an important, functionally separate, alternative means of classification of classical mode types characterised by the use of the *e*PC inflation type, the concept of which justifies it being separately identified with its own name in cases where the declared intended use is directed towards the potential advantages of concurrent breathing.

The terminology in the Standard leaves the manufacturer free to describe such a mode either by its classical name or by its alternative bi-level class name, according to the requirements and training of the intended operators. However, as the scope of the classical modes never did include **pressure support** *concurrent* with primary inflation deliveries, as such a facility was not available, modes that permit the selection of such concurrent inflation types should always be described as 'bi-level'.

Irrespective of the manufacturer's labelled description, a mode's standardised classification will always include its systematic mode name as detailed in the 'Mode Table' spreadsheet (Fig 8), e.g., SIMV-*e*PC/PS, A/MV-*e*PC, etc.

In practice, for modes promoted for the specific intention of the patient breathing at two levels of BAP, as against just providing free breathing to prevent conflict, the manufacturer will generally provide an *e*PC[S] inflation type in an SIMV pattern so that both initiation and termination can be synchronised with the patient's breathing pattern.

It is, therefore, this configuration, i.e., an SIMV-*e*PC[S]/PS or SIMV-*e*PC[S]/PS/PS mode, which is generally provided as a manufacturer's **Bi-level BAP** mode.

- **APRV** - **airway pressure release ventilation**

This is a special case of a bi-level ventilator mode, characterised by provisions for the patient to take natural breaths during an extended inflation (BAP_H) phase and for the BAP phase to be set so that it terminates as soon as the alveolar pressure has had time to descend to the set BAP level.

These provisions were seen as particularly suitable for patients requiring high levels of CPAP but also assured periodic inflations. Because of the high CPAP levels, there was concern that superimposed inflations would not only increase the mean airway pressure but also increase the risk of ventilator-induced lung injury. Obtaining assured lung ventilation by periodically reducing the pressure from the already high CPAP level for just short intervals was seen as an innovative approach to this problem.

This mode can be realised by making specific settings on any of a range of bi-level BAP modes. The essential features are that the ventilator operates with a high inverse phase-time ratio such that the BAP phase time ($\boldsymbol{t}_L$) is only sufficient to allow the alveolar pressure to descend to a required PEEP level. At this point the airway pressure is returned to BAP_H. The patient then breathes at this elevated airway pressure level without assistance for the set BAP_H phase time, $\boldsymbol{t}_H$.

The BAP phase time, $\boldsymbol{t}_L$, may be set as a fixed time or by an algorithm, e.g., as the time for the expiratory flow to reduce by a set amount or to a set level.

APRV is classified as IMV-*e*PC or IMV-*e*PC[S]. The rationale underlying the APRV mode excludes the provision for pressure support at either BAP level; at the BAP_H setting because the high inverse time ratios used already give rise to mean airway pressures above customary values and at the low level because when used as intended no time is provided for additional spontaneous breaths at this level.

Synchronised inflation termination is sometimes provided but, by convention, the rationale excludes synchronised initiation (e.g., SIMV) because of concern that the alveolar PEEP could continue to fall if the expiratory time is extended by the insertion of a synchronisation window. However, with the better control of alveolar PEEP provided by modern ventilators, as described in Section 6, this concern may no longer be valid.

This classification clearly distinguishes APRV from IRV (Inverse Ratio Ventilation) using CMV. The described function invokes an IMV mode pattern but set, as implied by its name, for the assured inflation of the lungs to be maintained for extended periods, with short, intermittent, pressure releases down to the set BAP level. Spontaneous breathing is concurrent with the inflation rather than at the BAP level as with classic IMV settings.

In order to fulfil these intentions modes labelled as APRV should use expiratory-pressure control algorithms that ensure that, during the release phase, the airway pressure falls at an optimum rate whilst keeping the alveolar pressure from falling below the set BAP level.

Ventilator modes labelled as APRV must also have their associated parameter settings labelled appropriately as outlined above.

The intention of the mode, as originally expounded, is to allow patients with acute oxygenation failure to breathe with better coordination, improved gas exchange and less barotraumas. The periodic release and near-immediate subsequent build-up of airway pressure is intended to assist the patient's own breathing efforts while not allowing the lung to collapse.

Although this intention specifies the essential concept of APRV it is recognised that, with this mode selected, many manufacturers permit the operator to set BAP phase times ($\boldsymbol{t}_L$) far in excess of any expected expiratory flow times. The justification for this is that the ongoing treatment of a patient requiring APRV during the initial acute period may well involve the

progressive adjustment of the two BAP levels and also the two phase times, both as individual values and their differentials, in order to provide a step-less continuity of treatment - working towards a single, reducing, level of BAP, without the discontinuity involved in changing over to a different mode.

- **MMV - Minimum minute ventilation**
  This is the generic name for a sub-group of higher-order modes that provide assurance to the operator that the patient will receive at least a set minimum minute volume in accordance with the selected mode algorithm. The patient is able to demand minute volumes in excess of the set value.

  One implementation of this mode uses an SIMV pattern where the set rate is adjusted by the MMV algorithm to maintain the set minute volume until the lower limit of the setting is reached.

  Another implementation uses an A/MV pattern with vtPC[q/t] type inflations where the set frequency and the set inspiratory pressure are both continually adjusted in relation to each other in accordance with an established minimum WOB equation, with the objective of maintaining the set minute volume using an optimal breathing pattern.

  Minimum minute ventilation is not to be confused with 'mandatory minute ventilation', which was the first implementation of a mode that was described by this initialism. That implementation was an adaption of a ventilator intended for use during anaesthesia in the operating room and did not provide for spontaneous ventilation in excess of the set minute volume and was not suitable, in that form, for longer-term ventilation. Subsequent developments of the concept have eliminated that, and other, limitations and led to its replacement by various forms of 'minimum minute ventilation'

- **SmartCare**
  This is the proprietary name for a knowledge-based, supervisory mode that manages the settings of a classical CSV-PS mode throughout a weaning procedure, using physiological parameter feedback.

- **PAV**
  A higher-level mode name placing the emphasis on the use of a proportional pressure support (*p*PS) inflation type in a CSV mode pattern.

- **NAVA**
  A higher-level mode name placing the emphasis on the use of neural diaphragm input signals to initiate and terminate PS inflation types in a CSV mode pattern.

- **Dual-modes**
  A group of higher-level modes that automatically switch between, generally two, selected mode patterns in accordance with the patient's breathing ability as determined by a ventilator algorithm.

7. Overview of revised terms in the Standard

In the preparation of the Standard, although many of the descriptions of the basic concepts of positive pressure ventilation have been rewritten, which has led to a redefinition of several of the terms in current use, care has been taken to preserve as much of the current terminology as possible. The intention was that, to a typical operator, any changes will appear to be no different from those that they presently experience when moving between ventilators. Similarly, the inevitable new terms have been carefully chosen to be intuitively understood adaptations of existing terminology. The following sub-sections provide a brief overview of these changes, which is supported by Figs 20 & 21a - j that illustrate the application of the terminology in the Standard.

A fundamental objective underlying the Standard is that the terms should clearly distinguish patient parameters and activities from those of the ventilator. As has already been quoted, "ventilators do not breathe" and so to speak of 'ventilator breaths' creates ambiguity because what is really meant is that the breath passing through the patient's lung has to some extent been influenced by the ventilator. To establish that distinction, the ventilator's contribution to the patient's breath is identified as an 'artificial inflation', which can be referred to with a minimum of ambiguity within the context of 'artificial ventilation', by its abbreviation, 'inflation'.

In fact, this term has been used with respect to the lung since before the advent of automatic ventilators, and more recently in the context as adopted in the Standard, without ambiguity but it has not previously been recognised for the important distinction its use can convey.

This single new term automatically gives rise to a number of derivative terms such as: inflation flow, inflation pressure, inflation time, inflation phase, inflation cycle, and inflation pause.

7.1 Triggering and cycling

The initiation and termination of an inflation has increasingly become referred to as 'triggered' and 'cycled'. These are casual corruptions of 'patient-triggered' and 'cycled-off'.

The word trigger in normal usage can be used to make the valuable, fine distinction between an ordinary sense of starting something, as against something happening only when an external input rises to a critical tripping point. In ventilation, it was originally introduced specifically to describe the initiation of a ventilator delivery when a patient's inspiratory effort reached an adjustable, set threshold level that could be finely balanced between false initiations and adequate sensitivity. If the same word is used for the timed initiation of an inflation then the distinction provided by the word is annulled. In the Standard 'trigger' is only used in the sense of a trigger mechanism that can be operated when the magnitude of a certain patient parameter attains a set threshold level. Also in the Standard an inflation is 'initiated' - it may be 'ventilator initiated', 'operator initiated' or 'initiated' by a 'patient trigger event'.

A 'cycle' is a complete sequence of events that is regularly repeated. In the early days of automation it was common to use rotary selector switches to switch functions on and off within a fixed cycle. These functions were said to be cycled-on and cycled-off. Electro-mechanical sequencers were used to drive early automatic ventilators in what was a simple 'cycle-on', cycle-off' timed sequence. With the advent of micro-processor control these terms have been largely discarded in common usage and the continued use of its corruption is not helpful to a clear terminology. Its use for this purpose has therefore been deprecated and replaced with the unambiguous term 'terminate', along with its grammatical derivations.

7.2 Breath descriptions

The previous explanations in this Handbook have focussed on the terminology required when setting a ventilator to interact with a patient in a required manner. When describing the outcome of that interaction, as shown on a user interface display, the same terminology is applicable but the changed perspective will require a change of emphasis and different grammatical forms as illustrated by the following examples.

One of the key considerations for an operator attending a ventilated patient is whether, and which, breaths are being initiated by the ventilator and which by a patient trigger event. It is not within the remit of a terminology standard to require that this is displayed but, in practice, it is almost universal practice for electronically controlled ventilators to provide an indication for each breath that has been initiated by a patient trigger event. Typically, such breath will be referred to as having been 'patient triggered', although it has to be always remembered that a patient trigger event can also be caused by an artefact.

Beyond that, each breath can be characterised by the inflation type, if any, involved with its delivery.

7.2.1 Spontaneous breath

In the Standard the term 'spontaneous breath' is always used in reference to the component of a breath generated by the patient's own work of breathing. If unqualified it refers to a 'demand breath', i.e., a spontaneous breath drawn from the ventilator without assistance, but if the spontaneous component is only a proportion of the total WOB then it is an 'assisted spontaneous breath', a 'supported spontaneous breath' or, in the case of a ventilator instigated inflation, an 'assisted-spontaneous, assured breath. However, as the terms 'assist' and 'support' are only used as qualifiers in the Standard to qualify a 'spontaneous breath' the 'spontaneous' becomes redundant and so the qualified terms can become 'assisted breath' and 'supported breath', respectively.

7.2.2 Assured breath

As explained in Section 4, an 'assured breath' is one that is coupled with an inflation that has been assured to occur either at a set interval after the initiation of the previous breath or assured to be instigated at a set rate, with actual delivery occurring within a following 'synchronisation window'. The term 'mandatory' has been retained in the generic mode pattern names because they are the basis of several of the generic legacy acronyms. However, the term is only used for that purpose, and is only used there in the sense of 'assured to occur'.

7.2.3 Bi-level Modes

The understanding of bi-level modes of ventilation has become very confused because, as with so many other terms, with no standardised terminology from its first use the term has been used with very different meanings.

One of the problems was that this common term emerged from two alternative base technologies that were originally adopted for different clinical purposes but which have converged as they have been developed and extended.

One of these technologies involved a breathing-therapy treatment for spontaneously breathing patients that became known as CPAP. Its intention was to generate a constant positive pressure in the patient's upper airways either to hold these airways open in the case of sleep apnoea or to provide a constant alveolar PEEP in the case of various lung-disease conditions. Simple, blower-based CPAP machines, intended mainly for home care use, are now produced in large quantities to treat these conditions. The

main therapeutic requirements are to hold a certain positive pressure in the airway during inspiration, and that the expiratory pressure is not in excess of the inspiratory pressure. In practice, with the typical constant-pressure regulator functions that are used there is an inevitable drop of pressure as the flow towards the patient increases during inspiration and a rise as the flow decreases during exhalation, resulting in an increase in the patient's WOB. By good design this non linearity will be minimised but it was realised that if the pressure level is intentionally reduced as the patient exhales it not only compensates for the artefact but can improve patient comfort by assisting breathing.

Because the CPAP device was now being used to generate two PAP levels instead of one this therapy mode was introduced under the proprietary name BiPAP - although it subsequently acquired the generic name of bi-level PAP, and more recently BPAP. From the perspective of breathing-therapy for spontaneous breathing patients these are valid descriptions but as seen from the perspective of conventional ventilation modes, bi-level PAP is nothing more than continuous spontaneous ventilation with pressure support, i.e., CSV-PS.

In parallel with these developments, further exploration of the possibilities opened up by the concept of CPAP led to a growing appreciation that outcomes of conventional ventilation could be significantly improved if the patient was able to contribute as much as possible to their own work of breathing, not just between timed inflations as had been made possible with IMV but also concurrently with PC inflation phases, particularly if these were extended beyond normal temporal settings. This led to the development of what is named in the Standard as a **bi-active pressure-regulator function,** which can be utilised to facilitate natural breathing by the patient throughout the respiratory cycle. This development opened the possibility of being able to set a ventilator with longer phases at both pressure levels; a development that was described just before that of BiPAP under the name BIPAP.

Independently, but at about the same time, the concept of APRV was described. This addressed the needs of patients requiring relatively high levels of PEEP during the spontaneous breathing phase of SIMV modes, where further intermittent increases of pressure in order to achieve assured ventilation could lead to lung injury. It was realised that if the patient is able to breathe spontaneously at the required higher PEEP levels then any assured component of the patient's ventilation could then be achieved by the use of short pressure releases, just sufficient to allow the alveolar pressure to reduce to a set lower PEEP level, followed by immediate restoration to the inflation pressure level.

Although it can be seen how the name 'bi-level' became associated with both breathing-therapy and artificial ventilation - because they both involve two pressure levels - it is clear that in reality they are quite different in their intention and implementation.

As explained above, using a CPAP device with two pressure settings, which change with each inspiratory or expiratory effort by the patient, although 'bi-level' with respect to the concept of CPAP, is simply intermittent elevated pressure ventilation on a conventional ventilator, e.g., the device is delivering a PS inflations to a CSV mode pattern. On the other hand, providing the facility for a patient to breathe naturally at two levels of baseline airway pressure is a conceptually different approach to artificial ventilation as previously practiced.

In summary, from a CPAP breathing-therapy perspective, offering two pressure levels can reasonably be described as bi-level. However, from a conventional artificial ventilation perspective all ventilation using a pressure-regulated type of inflation is, in fact, providing PAP at two levels in the same way - so the use of a 'bi-level PAP' term to describe it would be misleading.

It has to be recognised that both of these perspectives are valid for their own field of use so the two applications need to be differentiated by name. In the Standard the term CPAP is restricted to breathing

therapy and so where two levels are used it is logical to use the name bi-level PAP - or alternatively the increasingly recognised, generic, name BPAP. On the other hand, where the patient is expected to breathe at two levels of BAP during conventional ventilation the logical name is bi-level BAP, which could be abbreviated to bi-BAP.

7.2.3.1 Related terminology

NIV:

Although the application of intermittent elevated pressure ventilation to a patient by means of a face mask has a long history it was largely replaced once practical artificial airway devices were developed. However, the mask was the ideal patient interface for breathing-therapy procedures and its further development was a key element in the introduction of such procedures in the treatments for sleep apnoea. As these procedures were extended to the treatment of other respiratory problems and to include artificial ventilation they became known as non-invasive ventilation, or more commonly by its abbreviation, NIV.

This association with CPAP generating devices has led to some sources adopting NIV as a generic term for the whole class of CPAP devices. This is incorrect because the term relates solely to the form of the patient interface and it is equally possible to use the same interface with a conventional ventilator. In the Standard, therefore, the term NIV is restricted to the designation of ventilation or breathing-therapy set ups that utilise a non-invasive patient interface; all blower based CPAP breathing-therapy devices may be classified as NIV devices but not all NIV set ups are restricted to providing CPAP therapy. This is an important point because it is a useful classification; for example, a ventilator may use special settings for NIV configurations used with its classical ventilation modes in order to provision for the possibility of increased gas leakage.

Breathing therapy modes:

As with bi-level ventilation modes, bi-level breathing-therapy modes must be set to operate to a mode pattern. As already explained, what is understood to be simple bi-level PAP operates to a CSV mode pattern and employs a PS inflation type, making it a CSV-PS mode.

However, many CPAP therapy devices have now been adapted to additionally provide not only bi-level modes but also assured inflations, typically labelled as ST and T modes. An ST mode is classified as A/MV-PC[q/t] in the systematic classification of the Standard and a T mode is classified as CMV-*e*PC. Although passed off as bi-level breathing-therapy modes in many cases, these modes must inevitably be considered as ventilation modes within a terminology conforming to the Standard.

It should be noted that correct classification should now become less contentious as a consequence of the recent publication of a separate standard for ventilators intended for use with non-ventilator-dependent patients.

In addition to the mode pattern the systematic mode name for devices delivering pressure at two levels must include the selected type of inflation. From this respect, although blower-based CPAP devices have the capability to allow exhalation concurrent with an inflation, when used in their therapy modes the inflation phase is always flow terminated and so it is not possible for the patient to exhale during the inflation phase because any such effort immediately terminates the inflation. Such inflations are therefore classified in the same way as a conventional PS inflation type.

7.3 General ventilation terms *Work in progress*

8. Alarm & Limitation-means Terminology *Work in progress – to be completed after approval of NP*

9. Additional functions *Work in progress – to be completed after approval of NP*

10. Special procedures *Work in progress – to be completed after approval of NP*

11. Overview of FSM and reference to a separate set of illustrated instances *Work in progress*

12. Bibliography

[1] Morley, Colin & Keszler, Martin. Ventilators do not breathe. fn.bmj.com BMJ Publishing group Aug 2012

Appendix A

of

Artificial Ventilation,

Standardised-Terminology Handbook

Illustrations

13/05/2013

Fig. 1

A Breath

Typical breath waveforms of natural spontaneous breathing

***Breath**: An increase in the volume of gas in the lungs resulting from an inwards gas flow though the airway (inspiration) paired with a decrease in volume resulting from an outward flow (exhalation), thereby ventilating the lungs in order to deliver oxygen and remove CO_2. This volume of gas that has entered and left the lungs has been named the **tidal volume**.*

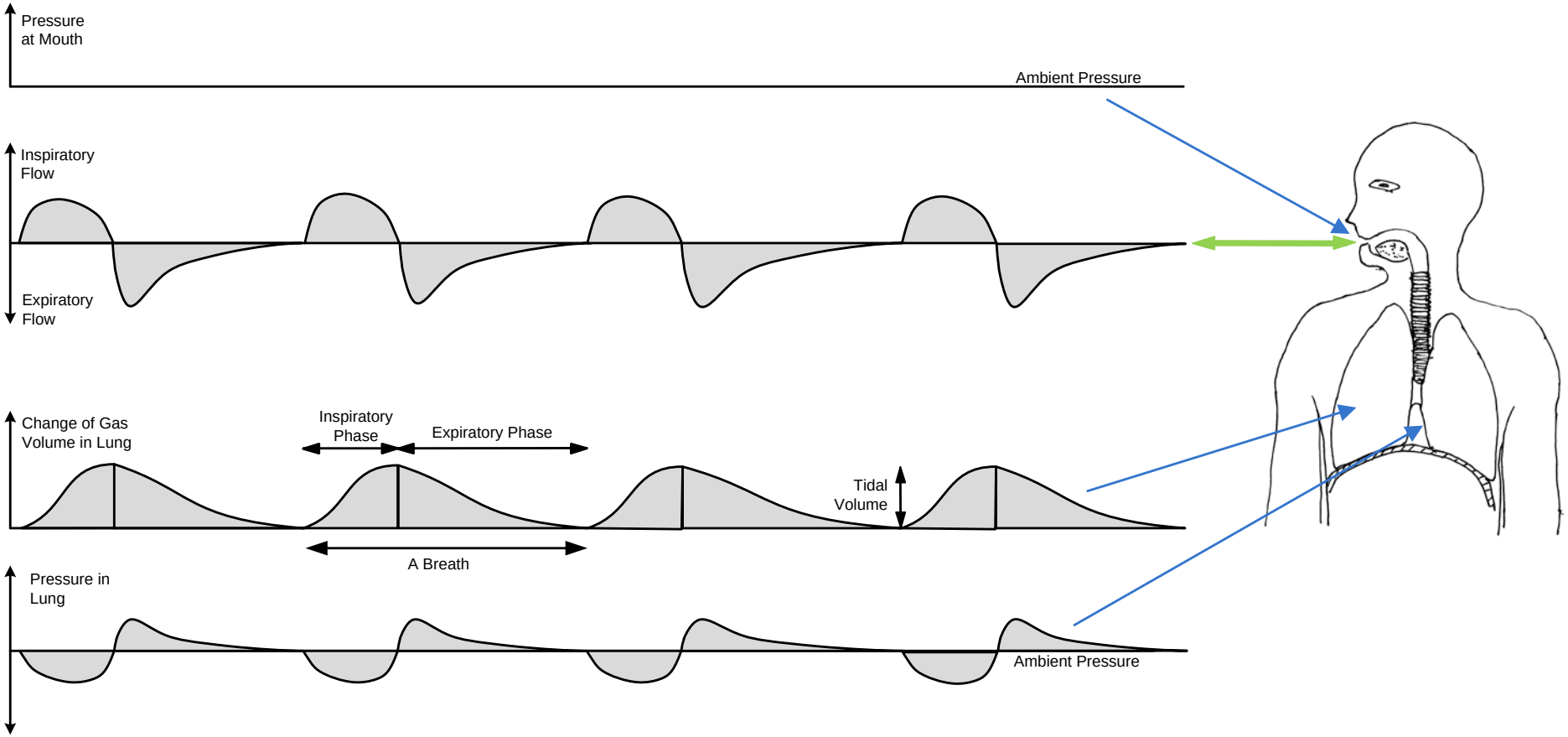
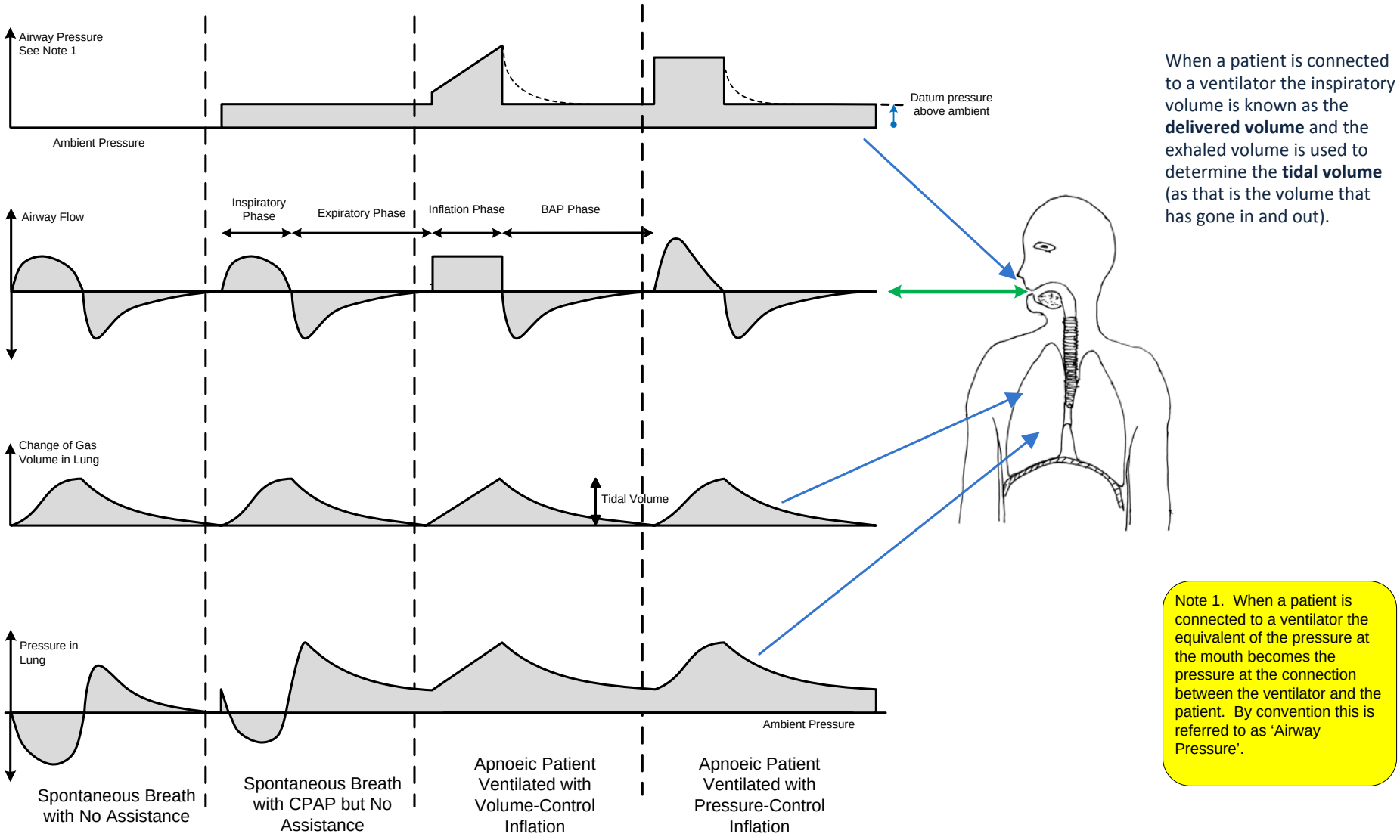


Fig. 2

Typical breath waveforms when connected to a ventilator



When a patient is connected to a ventilator the inspiratory volume is known as the **delivered volume** and the exhaled volume is used to determine the **tidal volume** (as that is the volume that has gone in and out).

Note 1. When a patient is connected to a ventilator the equivalent of the pressure at the mouth becomes the pressure at the connection between the ventilator and the patient. By convention this is referred to as 'Airway Pressure'.

Inflation-type Alphabetic Coding Table

		Flow-regulator Group	See Note:	Pressure-regulator Group	See Note:
Means of Termination	Time	FR(t) becomes VC	#1	PR(t) becomes PC	#2
	Flow	Not applicable		PR(q) becomes PS or PC(q)	#3
	Pressure	FR(p)	#12	N.A	
	Volume	FR(v) becomes VC	#13	PR(v) becomes PC(v)	#14
	Conditional	Not applicable		PR[q/t] becomes PC[q/t]	#5
Variation on Termination	Synchronised	Not applicable		[S]; e.g., *e* PC[S]	#6
Variation on Regulation	Enhanced	Not applicable		*e* PC	#3
	Proportional	Not applicable		*p* PS	#7
	Dual control	VC↔PS, VC→PC	#11	PC↔VC	#10
	Additional factors	VC{p̂}	#8	{q&v}, {q}, {v}, {EMG}; e.g., *p* PS{EMG}	#9
Variation on Algorithm	Volume-targeted	Not applicable		vt; e.g., vtPC	#4

General Notes:

All Inflations are required by device standards to be pressure limited, or pressure terminated, at an independent, operator-set, safe-pressure limit for the patient.

Inflations that are not time terminated are taken to be also time limited, whether operator settable or not.

Inflation type code: variation designators

↔	Inflation type that conditionally interchanges with characteristics of second inflation type
Trailing codes	
(*)	Parameter used for termination
[*]	Conditional variation on termination means
{*}	Additional regulation parameters
Key for trailing codes:	
t	Time
p	Pressure
v	Volume that has been added to lung
q	Flow
q/t	Flow or pressure, depending on means of initiation
EMG	Electromyographic activity of the diaphragm and intercostal muscles
p̂	Pressure limit
Prefix codes	
Lower-case	Variation on general inflation algorithms, e.g., vt
Lower-case italic	Variation on inflation-regulation algorithms, e.g., *e* PC
Key for prefix codes:	
vt	Volume targeted
e	Enhanced
p	Proportional

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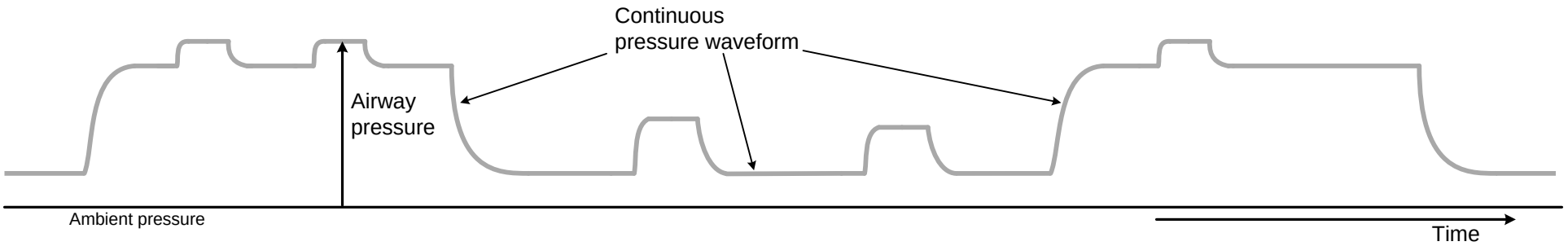
Fig. 3

Fig. 4

Typical continuous waveforms showing how the pressure at patient's mouth is typically varied with time to achieve automatic, artificial-ventilation of the lung in harmony with the patient's spontaneous breathing.



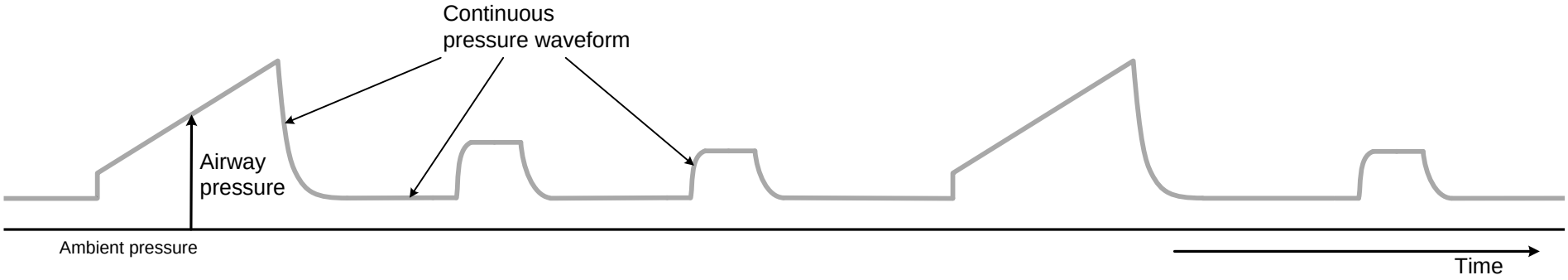


Fig. 5: Typical ideal expiratory-airway-pressure waveforms

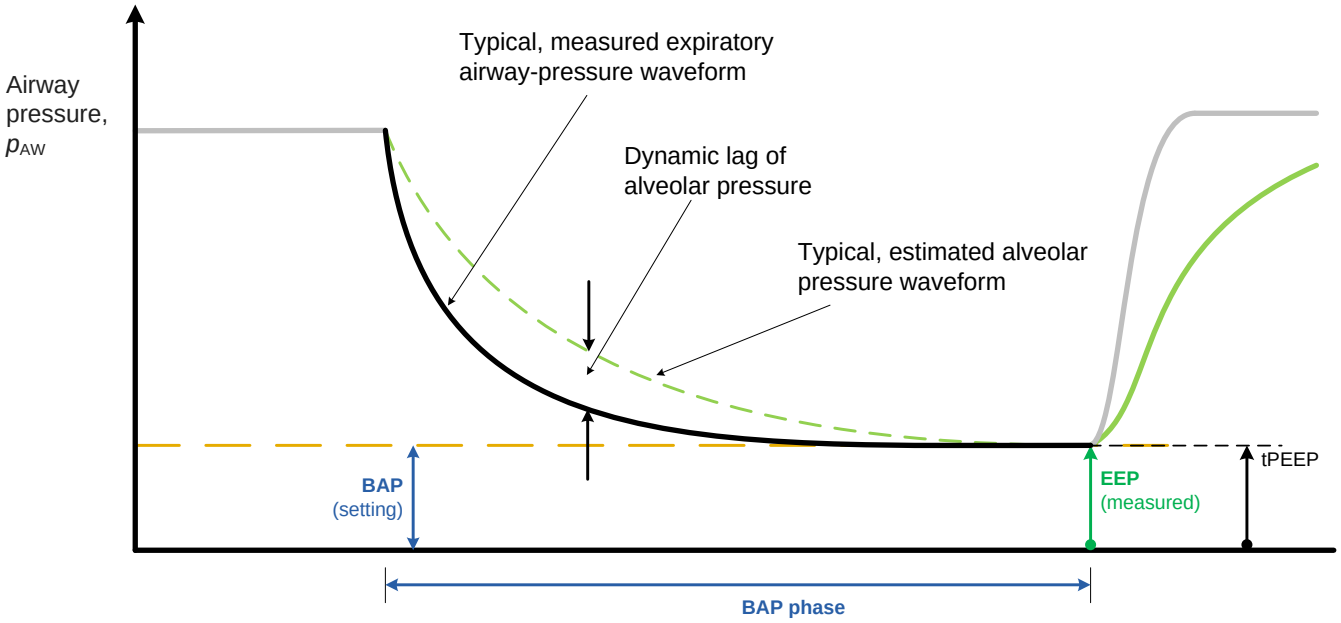


Fig.6: Typical expiratory-airway-pressure waveforms with an impaired lung

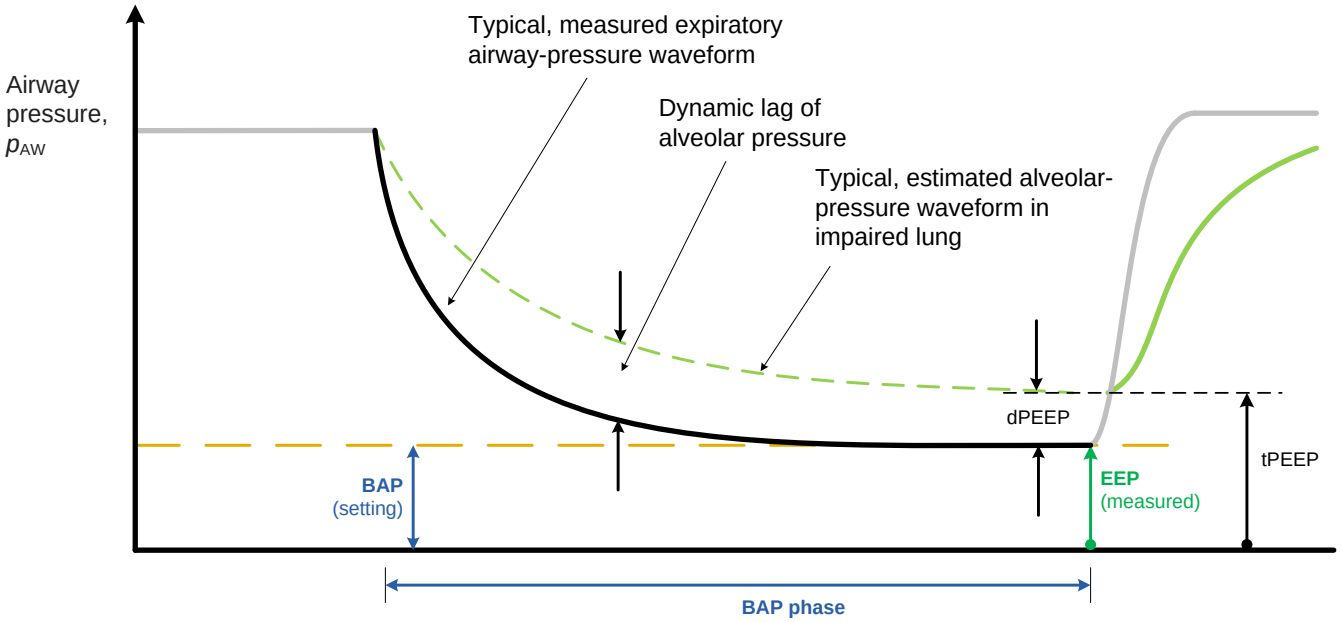


Fig.7: Typical expiratory-airway-pressure waveforms with an impaired lung

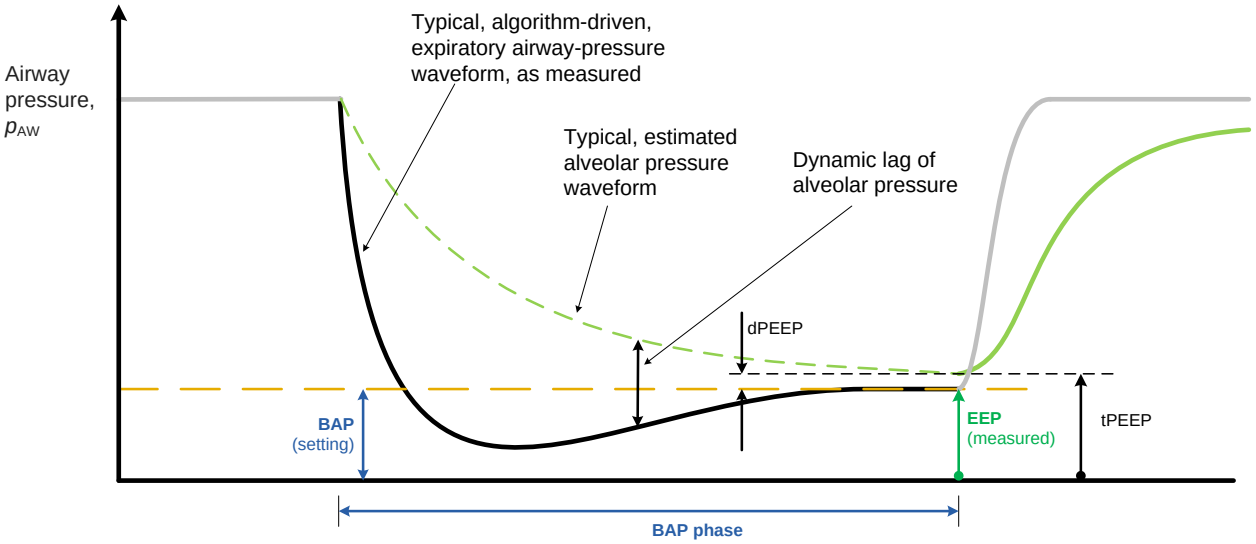


Fig.8: Typical expiratory-airway-pressure waveforms on a basic ventilator with inadequate set expiratory time or excessive expiratory-limb resistance (e.g., due to kinked tube or increased resistance filter).

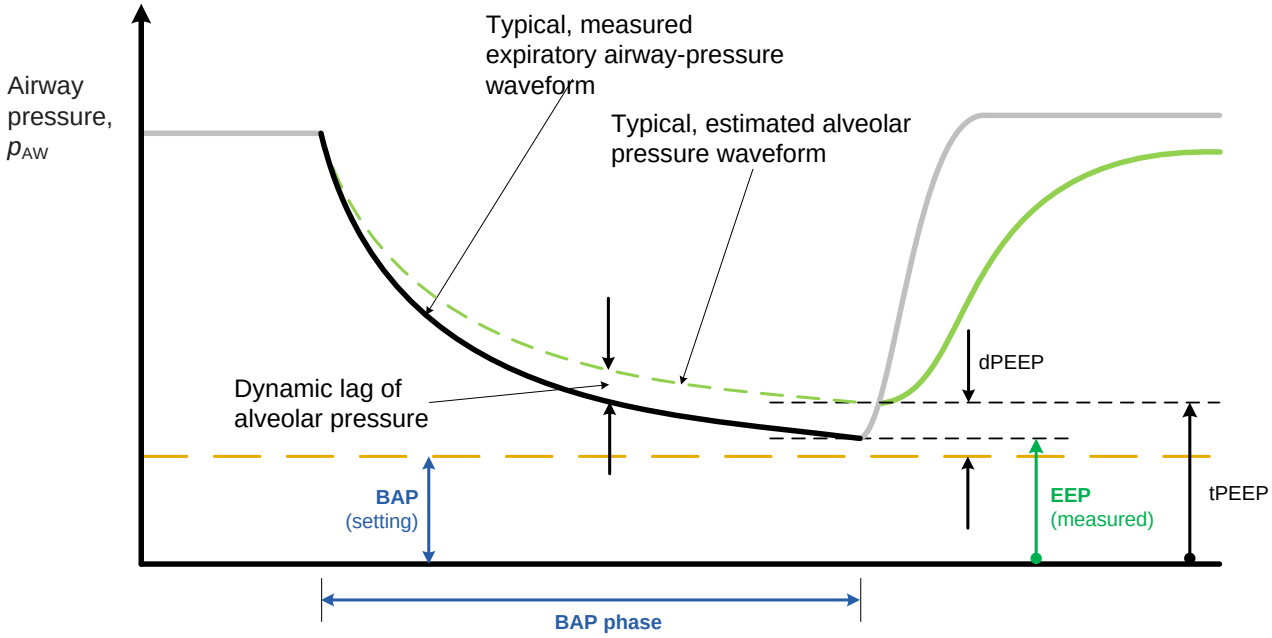


Fig 9: The BAP phase

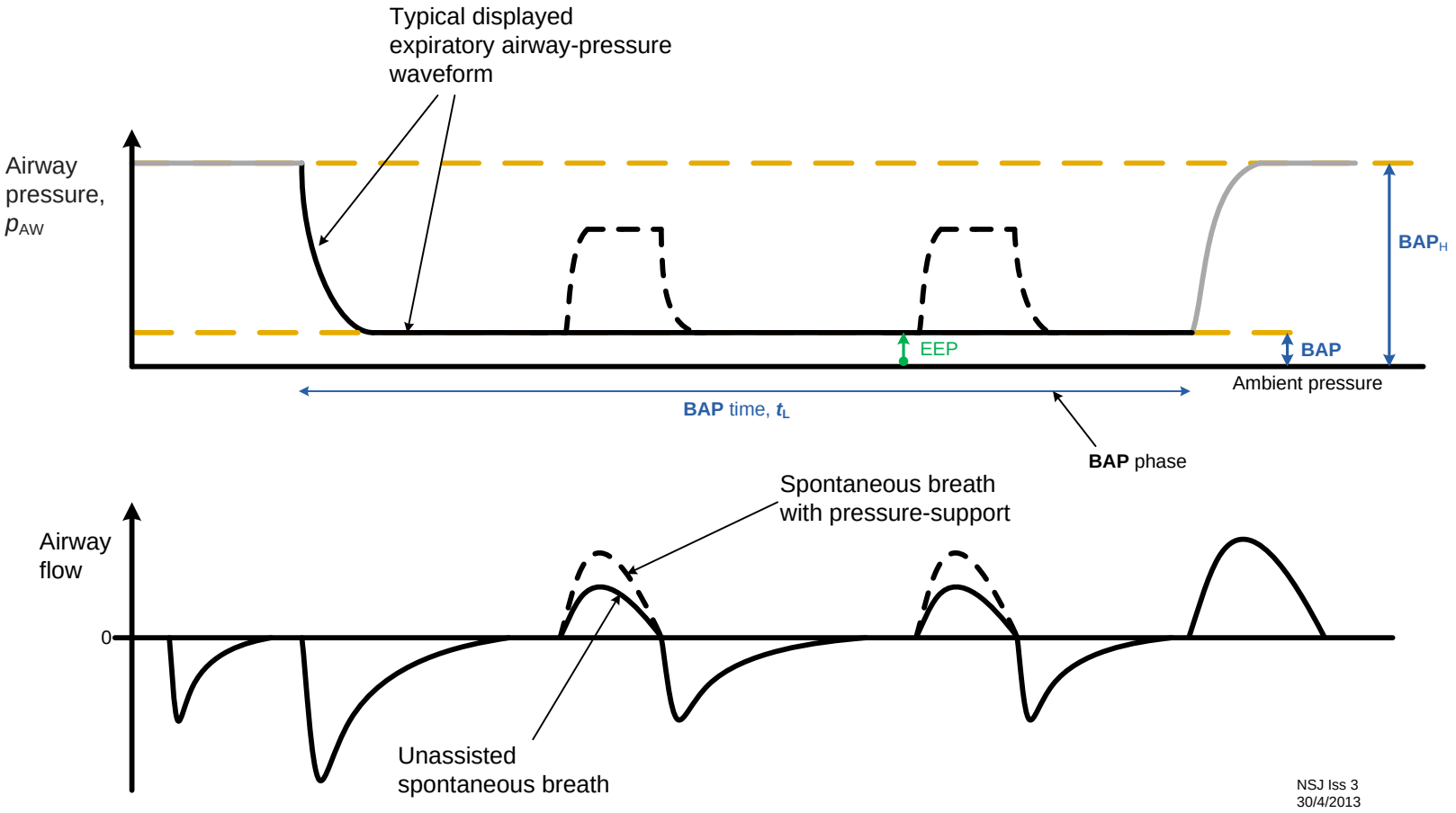


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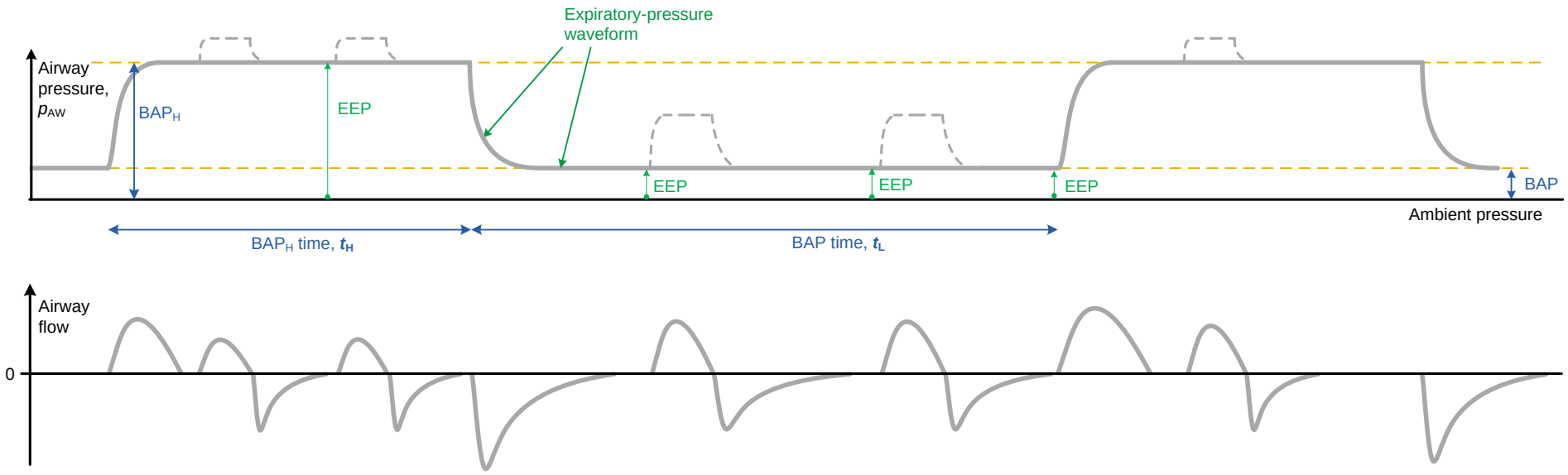
Fig 10: Bi-level BAP



Typical bi-level BAP mode based on SIMV mode pattern

Bi-level BAP (SIMV-ePC/PS/PS)

Fig 11: CSV with PS

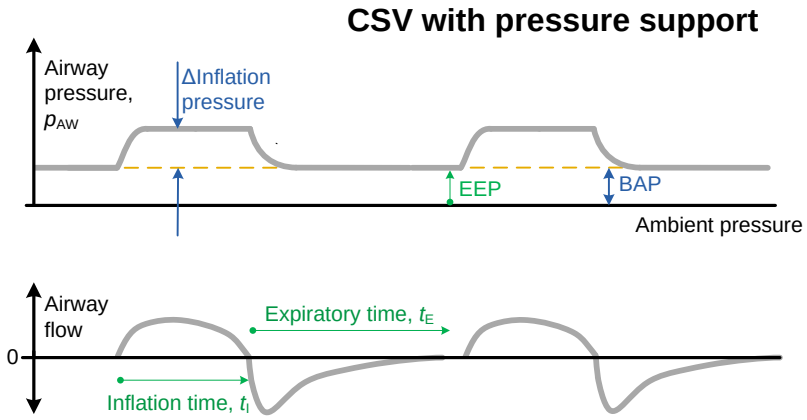
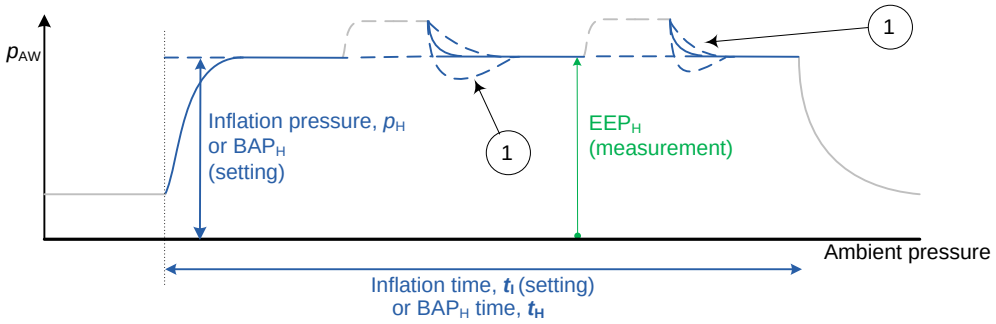
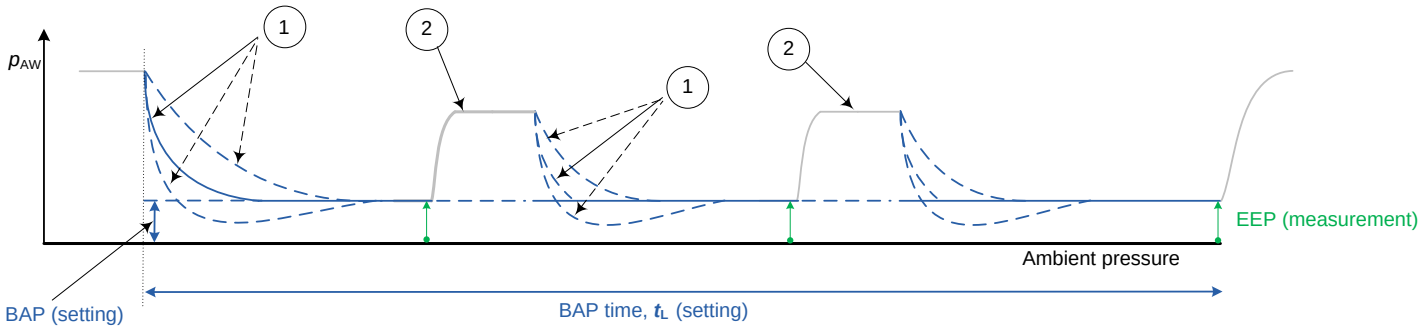


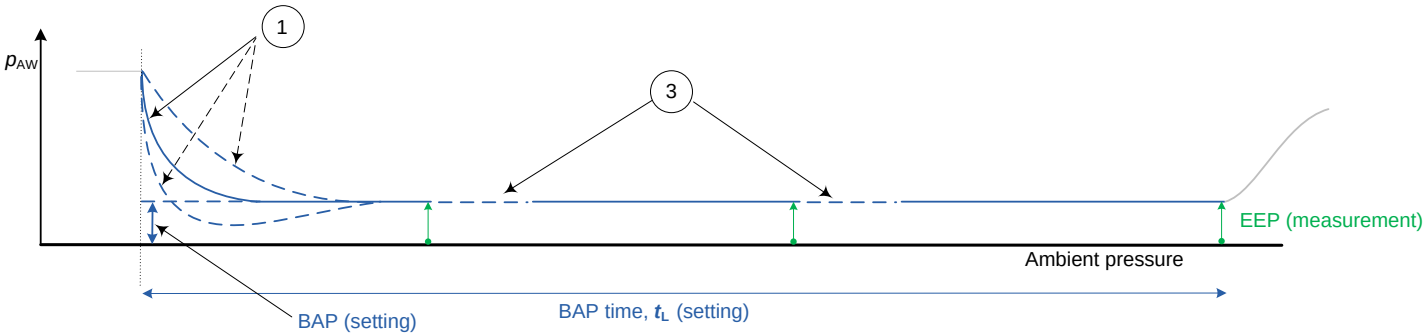
Fig. 12



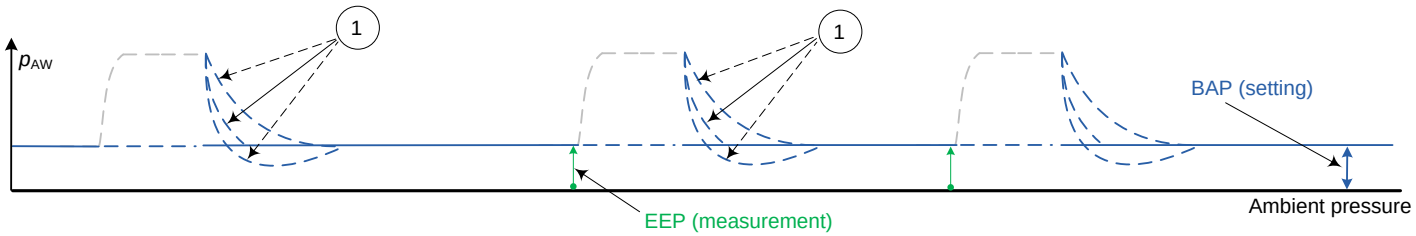
Function of the expiratory-control algorithm during a primary inflation phase



Function of the expiratory-control algorithm during a BAP phase with supported breaths



Function of the expiratory-control algorithm during a BAP phase with un-supported breaths



Function of the expiratory-control algorithm in CSV modes

(1) Typical expiratory pressure temporal waveforms, following an inflation, as determined by the 'expiratory-control algorithm'

(2) PS type inflation to support spontaneous inspirations

(3) Bi-active pressure-regulator function is intended to maintain the airway pressure at the set BAP to facilitate unsupported natural breathing

Ident No.	Mode Pattern Group	Mode Pattern Generic Name	Illustrative Primary Inflation Type Selection	Means of initiation	Means of termination	Control Algorithm in use between Primary Inflation Type deliveries	Illustrative Support Inflation Type Selection	Abbreviation of Systematic Mode Name	Optional 'bi-level' sub-class name	Name of **set** level for Mandatory Inflation	Name for **set** baseline level	Name for Primary Inflation Phase	Name & symbol for **set** primary inflation time		Name & Symbol for **set** lower press level phase	
1	(i)	CMV	VC	t	t	Expiratory-control	None	CMV-VC	N/A	Vdel	BAP	Inflation phase	Inspiratory time	t_I	BAP phase	t_E
2			PC	t	t	Expiratory-control	None	CMV-PC	N/A	Inflation Press	BAP	Inflation phase	Inspiratory time	t_I	BAP phase	t_E
3			vtPC	t	t	Expiratory-control	None	CMV-vtPC	N/A	Vdel	BAP	Inflation phase	Inspiratory time	t_I	BAP phase	t_E
4			*e*PC	t	t	Expiratory-control	None	CMV-*e*PC	CMV bi-level	Inflation Press	BAP	Inflation phase	Inspiratory time	t_I	BAP phase	t_E
5			vte PC	t	t	Expiratory-control	None	CMV-vte PC	CMV bi-level	Vdel	BAP	Inflation phase	Inspiratory time	t_I	BAP phase	t_E
6		A/MV aka A/C	VC	t/trig	t	Expiratory-control	None	A/M-VC	N/A	Vdel	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
7		aka A/C	PC	t/trig	t	Expiratory-control	None	A/M-PC	N/A	Inflation Press	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
8		aka A/C	vtPC	t/trig	t	Expiratory-control	None	A/M-vtPC	N/A	Vdel	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
9		aka A/C	*e*PC	t/trig	t	Expiratory-control	None	A/M-*e*PC	A/M bi-level	Inflation Press	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
10		aka S/T	*e*PC[q/t]	t/trig	[q/t]	Expiratory-control	None	A/M-*e*PC[q/t]	None	Inflation Press	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
11		aka A/C	vte PC	t/trig	t	Expiratory-control	None	A/M-vte PC	A/M bi-level	Vdel	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
12		aka A/C	*e*PC[S]	t/trig	[S]	Expiratory-control	None	A/M-*e*PC[S]	A/M bi-level	BAP_H	BAP	BAP_H phase	BAP_H (phase)time	t_H	BAP phase	t_L
13	(ii)	IMV	VC	t	t	Expiratory-control	PS	IMV-VC/PS	N/A	Vdel	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
14			PC	t	t	Expiratory-control	PS	IMV-PC/PS	N/A	Inflation Press	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
15			vtPC	t	t	Expiratory-control	PS	IMV-vtPC/PS	N/A	Vdel	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
16			*e*PC	t	t	Expiratory-control	PS	IMV-*e*PC/PS	IMV bi-level	Inflation Press	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
17			*e*PC	t	t	Expiratory-control	None	IMV- *e*PC	APRV	BAP_H	BAP	BAP_H phase	BAP_H (phase)time	t_H	BAP phase	t_L
18			vte PC	t	t	Expiratory-control	PS	IMV-vte PC/PS	IMV bi-level	Inflation Press	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
19			*e*PC[S]	t	[S]	Expiratory-control	PS	IMV-*e*PC[S]/PS	IMV bi-level	BAP_H	BAP	BAP_H phase	BAP_H (phase)time	t_H	BAP phase	t_L
20			*e*PC[S]	t	[S]	Expiratory-control	PS	IMV-e PC[S]/PS	APRV	BAP_H	BAP	BAP_H phase	BAP_H (phase)time	t_H	BAP phase	t_L
21		SIMV	VC	S	t	Expiratory-control	PS	SIMV-VC/PS	N/A	Vdel	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
22			PC	S	t	Expiratory-control	PS	SIMV-PC/PS	N/A	Inflation Press	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
23			vtPC	S	t	Expiratory-control	PS	SIMV-vtPC/PS	N/A	Vdel	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
24			*e*PC	S	t	Expiratory-control	PS	SIMV-*e*PC/PS	SIMV bi-level	Inflation Press	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
25			vte PC	S	t	Expiratory-control	PS	SIMV-vte PC/PS	SIMV bi-level	Vdel	BAP	Inflation phase	Inflation time	t_I	BAP phase	t_L
26			*e*PC[S]	S	[S]	Expiratory-control	PS	SIMV-*e*PC[S]/PS	SIMV bi-level aka Bi-level	BAP_H	BAP	BAP_H phase	BAP_H (phase)time	t_I	BAP phase	t_L
27	(iii)	CSV aka SPONT	None	N/A	N/A	Expiratory-control	PS	CSV-PS	N/A	N/A	BAP	N/A	N/A		N/A	
28		aka PAV	None	N/A	N/A	None	*p*PS	CSV-*p*PS	N/A	N/A	BAP	N/A	N/A		N/A	
29		aka SPONT	None	N/A	N/A	Expiratory-control	vtPS	CSV-vtPS	N/A	N/A	BAP	N/A	N/A		N/A	
30		CPAP	None	N/A	N/A	None	None	CPAP	N/A	N/A	BAP	N/A	N/A		N/A	

Modes on rows of this color all come under the alternative class of 'bi-level' but the name ('Bi-level') is normally only used as the primary classification for modes shown under Ident Nos 19 & 26

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Fig. 13

Key to figures: 14 - 18

This coloured rectangle represents the inflation type that has been selected for assured deliveries. The same inflation type may also be initiated by a patient trigger event in accordance with the mode pattern.

This red arrow in this symbol represents an assured occurrence and the clock signifies that this is set to occur at a timed interval from the previous assured occurrence. This timed interval (60/f) is determined by the ventilator set rate (f).

This symbol represents the delay period that has been named as the 'synchronisation window'.

This symbol represents the ventilator initiation of the assured inflation in the absence of any patient trigger event during the preceding synchronisation window.

This composite symbol represents the function of the synchronisation window. After an assured instigation at a the timed interval determined by the ventilator set rate it provides time for the exhalation of any previously inhaled breath but responds immediately to a patient trigger event by initiating the already assured inflation.

This coloured rectangle represents the inflation type that has been selected for initiation solely in response to a spontaneous occurrence.

This arrow is used to represents an envisaged pattern of patient trigger events. It is shown with a broken outline in the following figures because they represent the setting perspective of what 'could' happen.

Figure 14: CMV Mode Pattern: (Group (i)

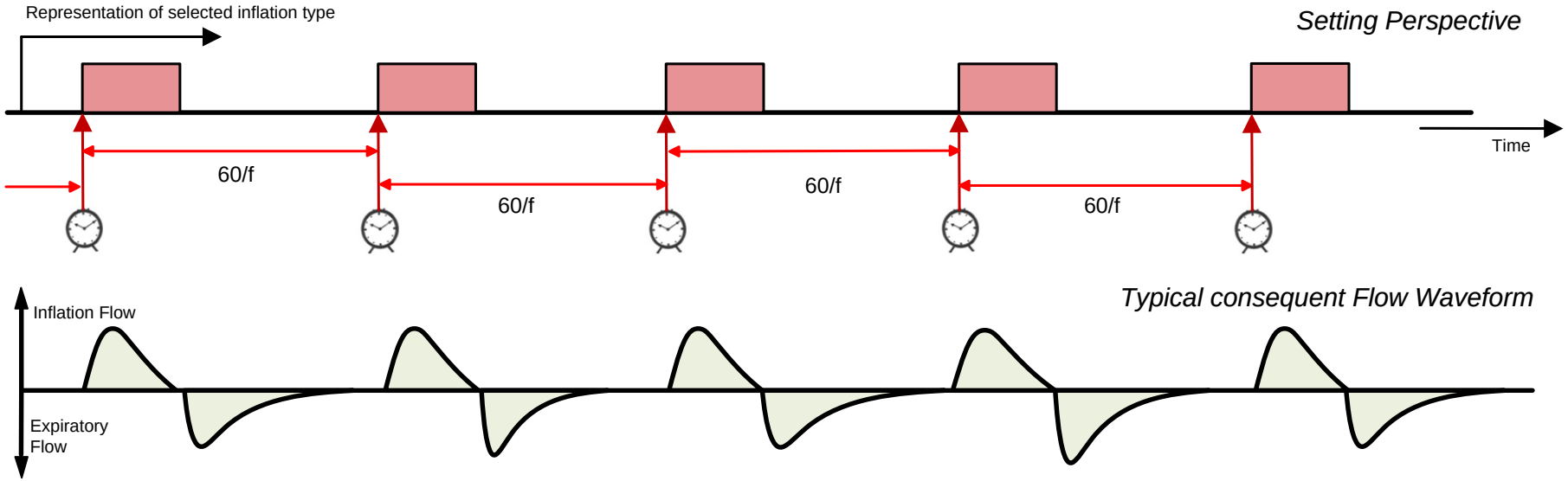


Figure 15: A/MV Mode Pattern: Group (i)

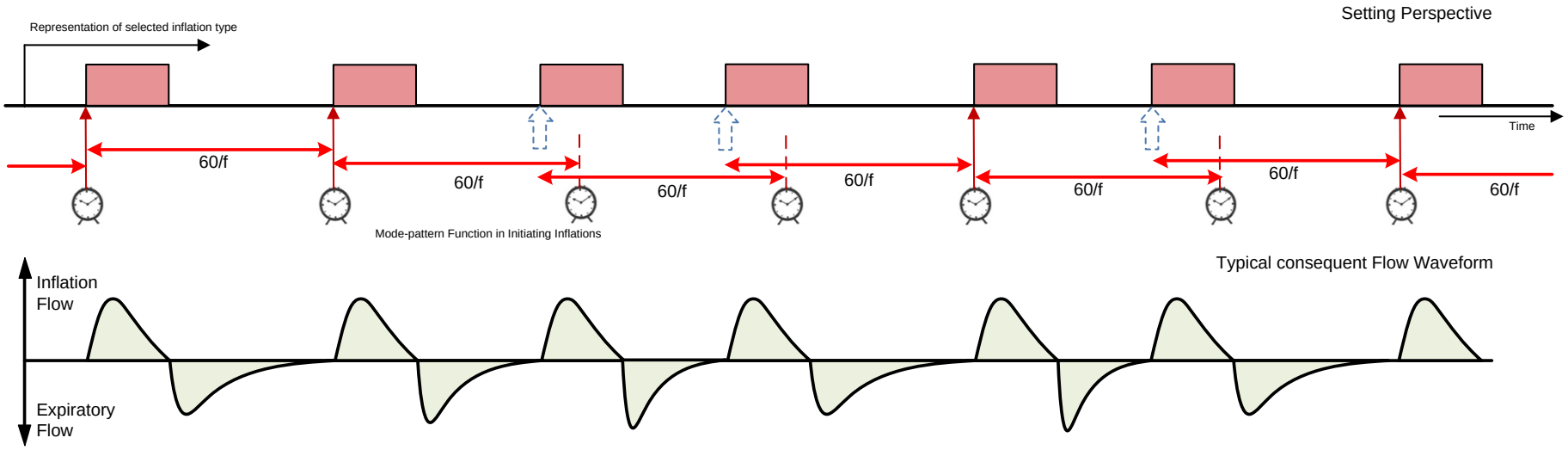


Figure 16: IMV Mode Pattern : Group (ii)

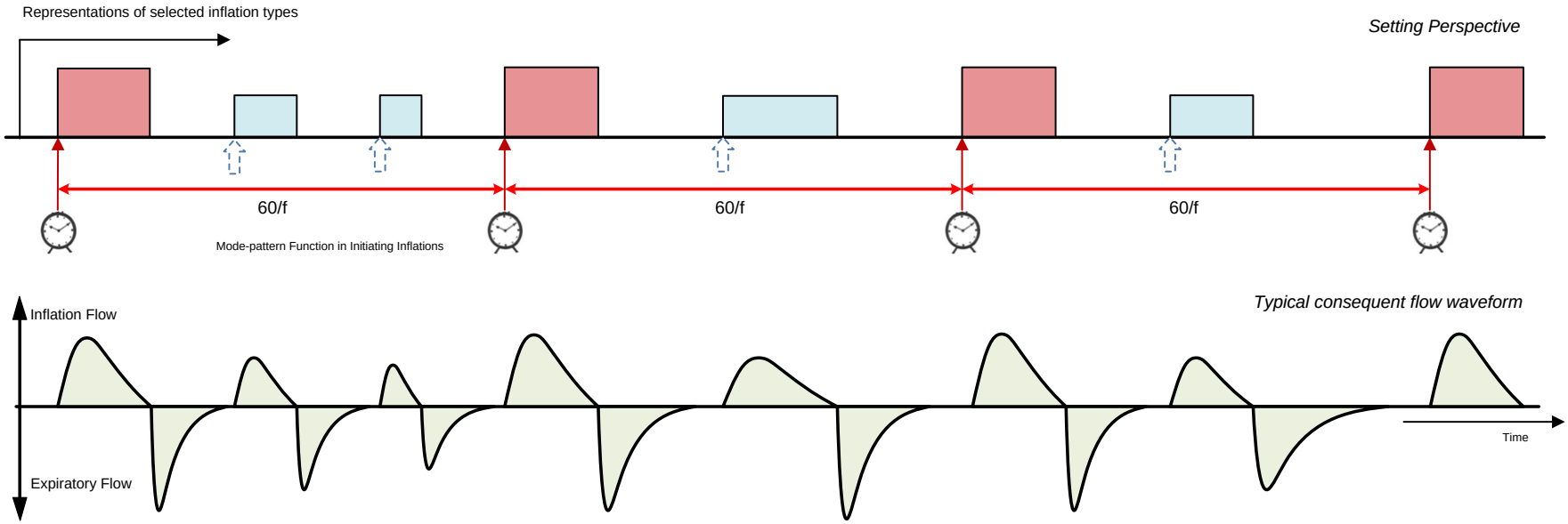


Figure 17: SIMV Mode Pattern : Group (ii)

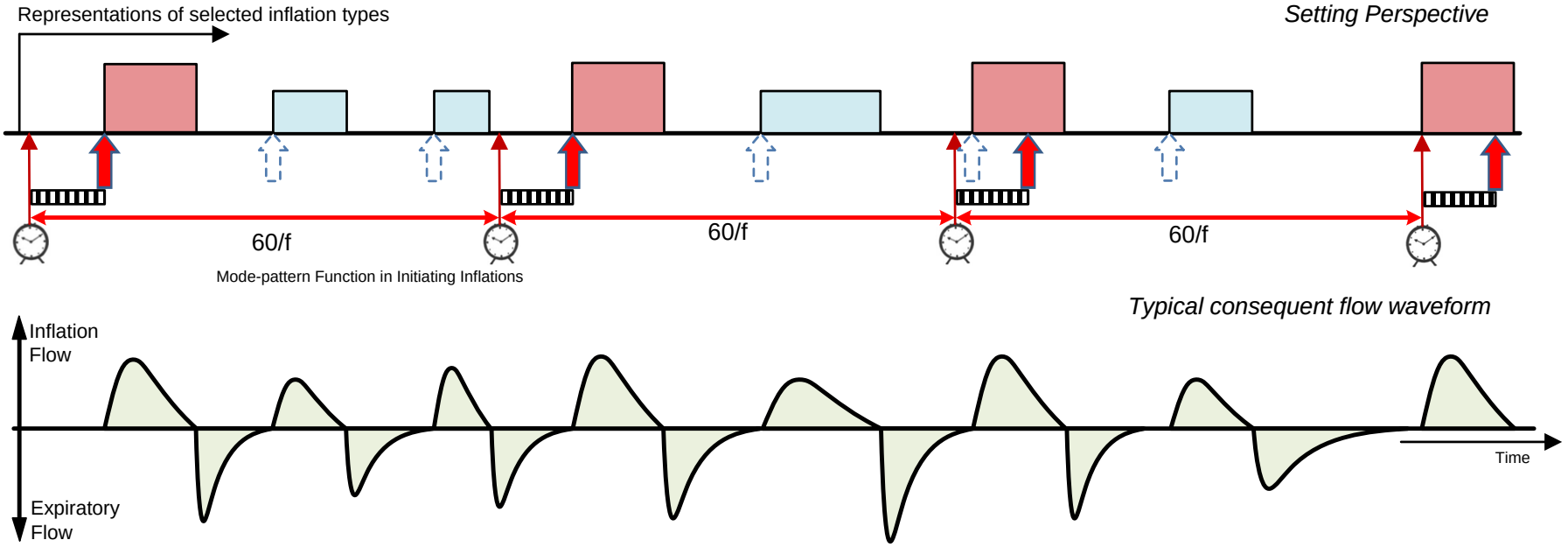


Figure 18: ASV Mode Pattern: Group (iii)

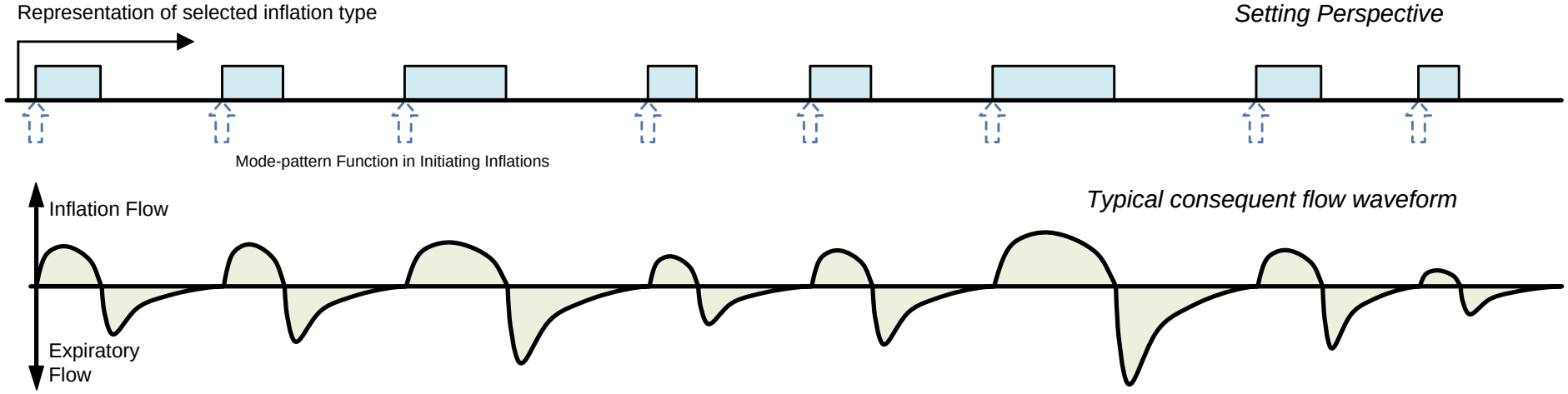


Figure 19: Format used for representations of mode patterns & inflations

An important aspect identified in the development of the terminology for the Standard is that part of the present confusion in the use of ventilation terminology is the lack of distinction between the setting perspective and the outcome perspective.

Most representations of ventilator-mode patterns and inflations are based on typical waveforms as seen on user interface displays, which is inevitably an outcome perspective. This is a helpful approach when describing the interpretation of the function of a specific ventilator but inevitably this introduces indeterminate artefacts and these can detract from the clarity of a formal diagrammatical representation of the changes of state that are actually set to occur. In particular, although set flow changes can be made to occur almost instantaneously this is not possible with pressure changes because of the impedance characteristics of a respiratory system. With such changes at the initiation and termination of an inflation where, conceptually, the set value makes a step change, in practice, the responses of pressure-regulator based functions have to be suitably restrained to set rise times in order to avoid excessive overshoots and subsequent oscillations

With this perspective, and as appropriate, diagrammatic representations of settings are shown without artefacts whereas those of typical outcomes include them. The examples below illustrate typical differences, highlighted by the use of the colour coding employed in other diagrams in this document and the Standard, with blue representing set parameters and green representing outcomes.

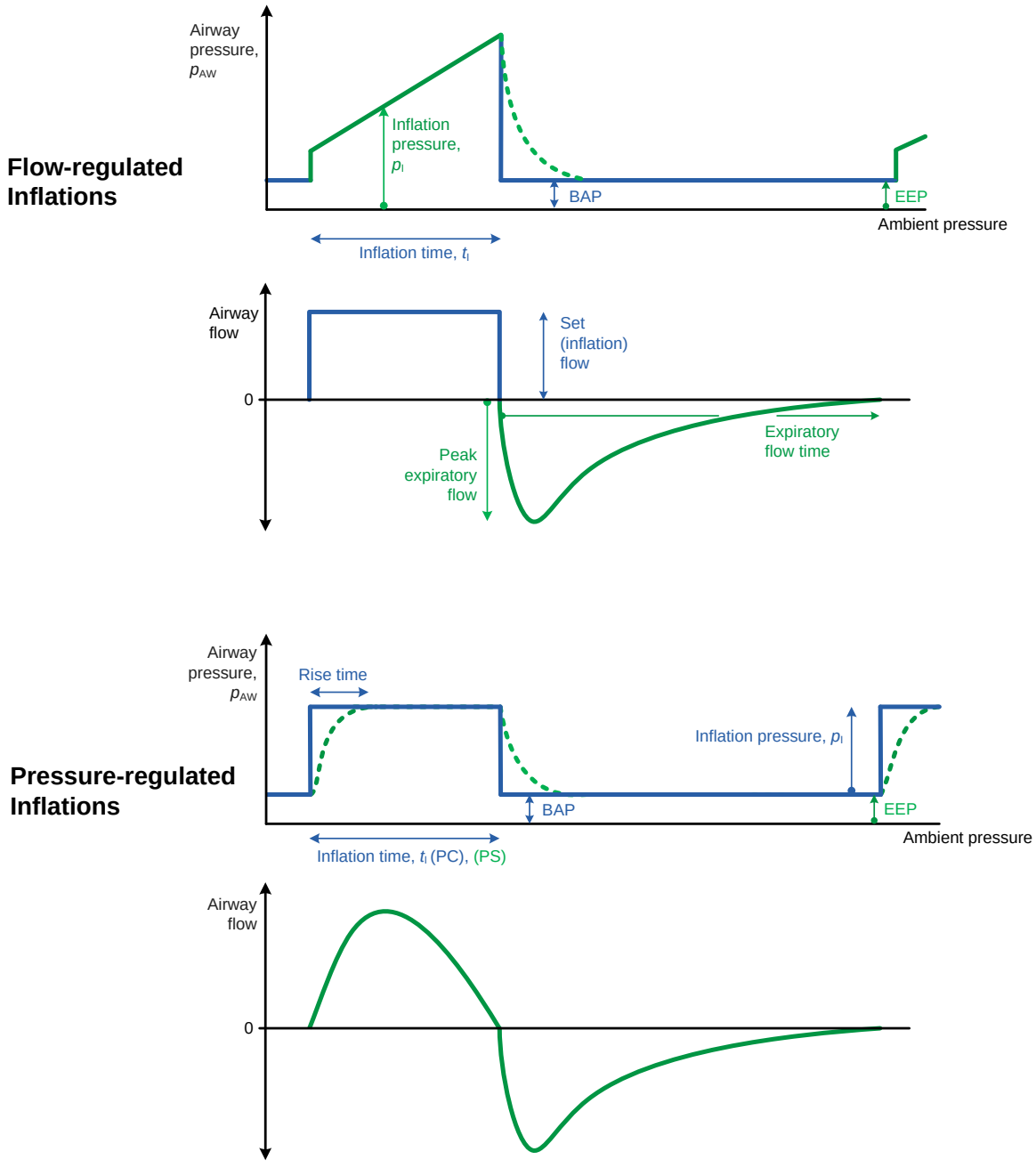
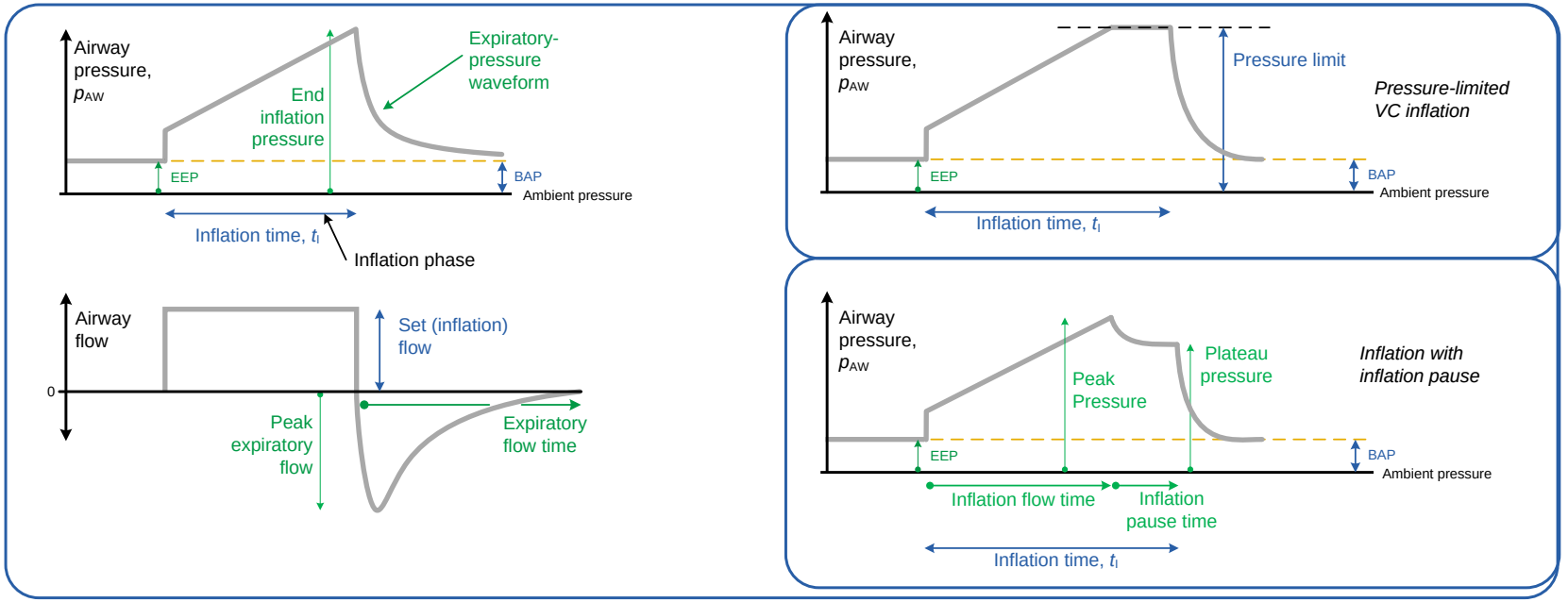


Figure 20: Illustrative representation of ventilation terms related to volume-control (VC), pressure-control (PC), & pressure-support (PS) inflations

Volume-control inflation types



Pressure-control & pressure-support inflation types

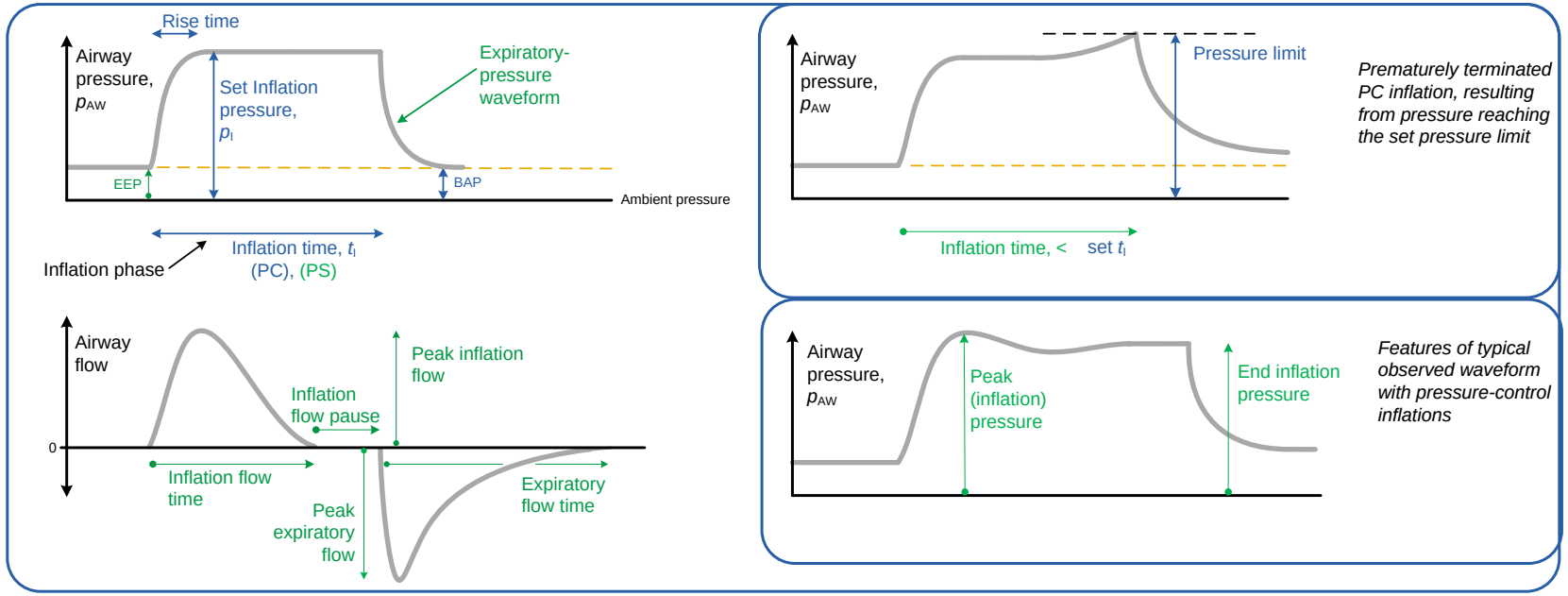


Fig 21: Illustrations of the application of the ventilation terminology in the Standard

Refer to Figure 19 for information on the format used in these illustrations & in those of Figure 20.

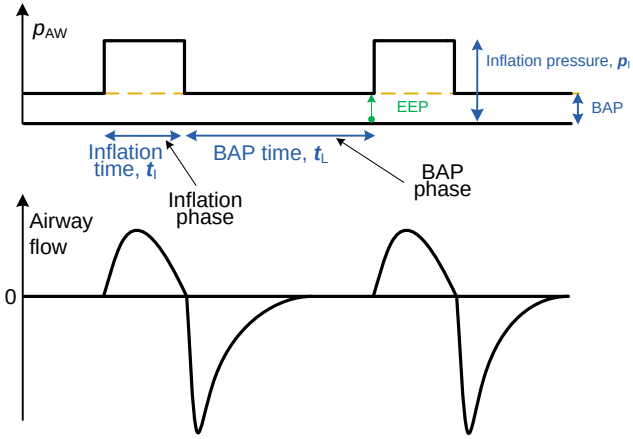


Fig 21a CMV-PC

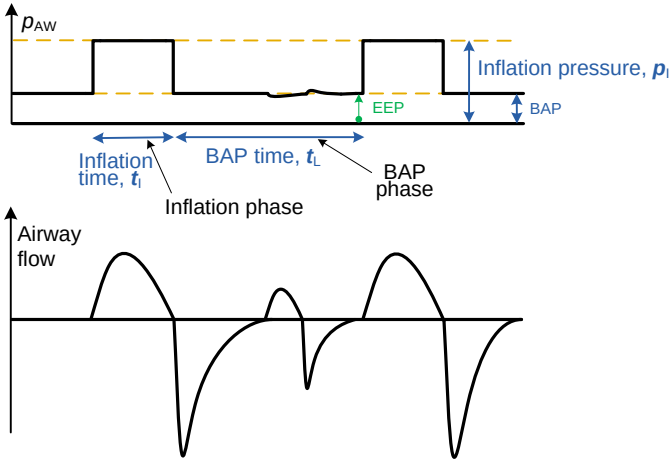


Fig 21b CMV-*e*PC

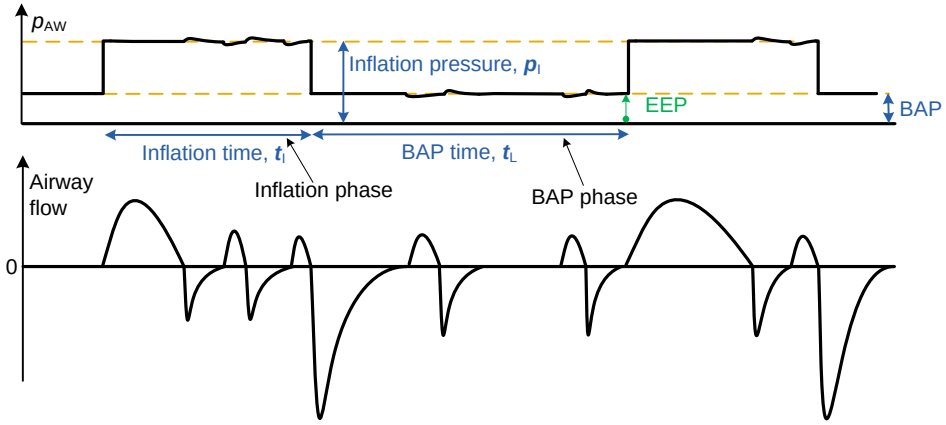


Fig 21c **CMV-*e*PC set with extended phase times**

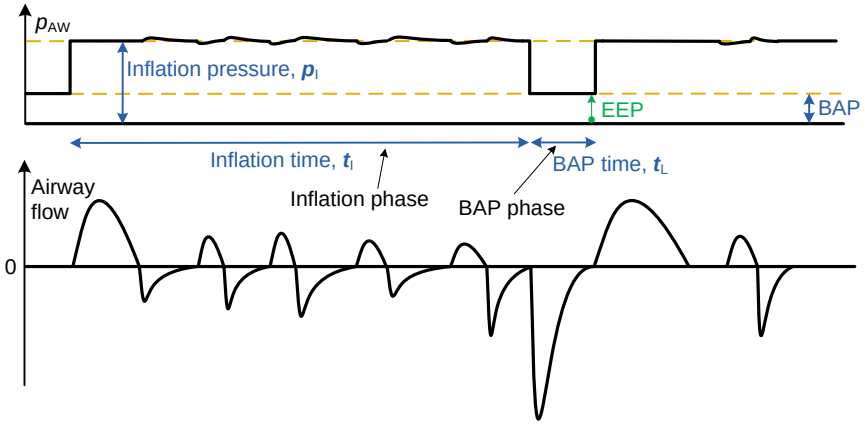
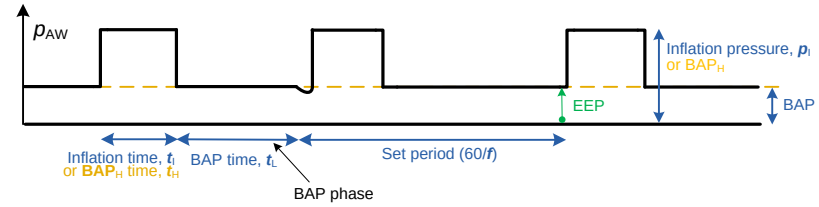


Fig 21d **CMV-*e*PC set with extreme inverse I:E ratio**



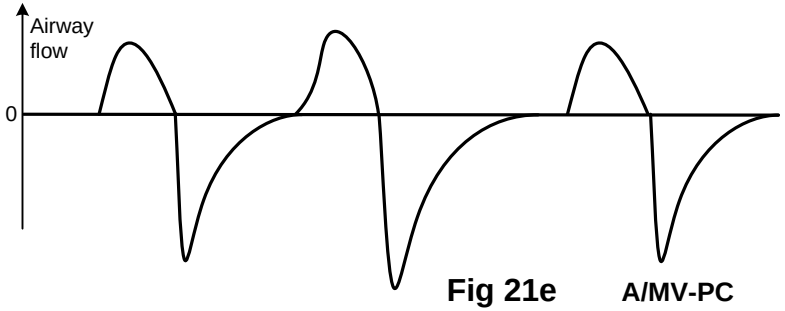
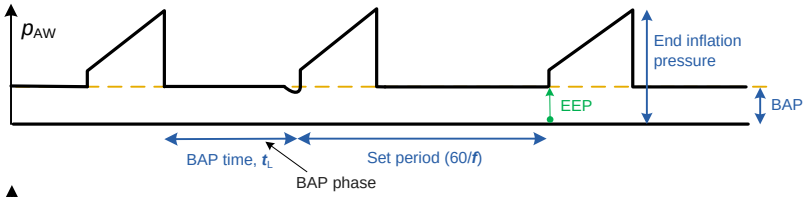


Fig 21e **A/MV-PC**



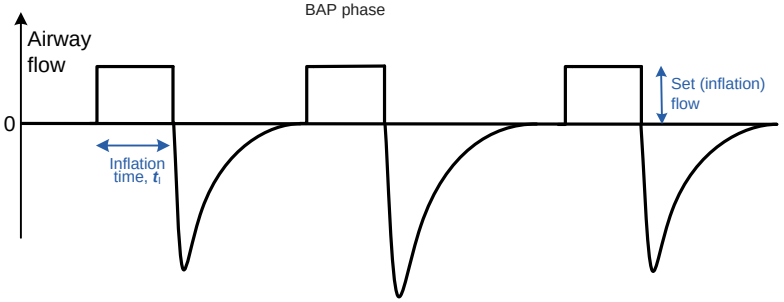


Fig 21f **A/MV-VC**

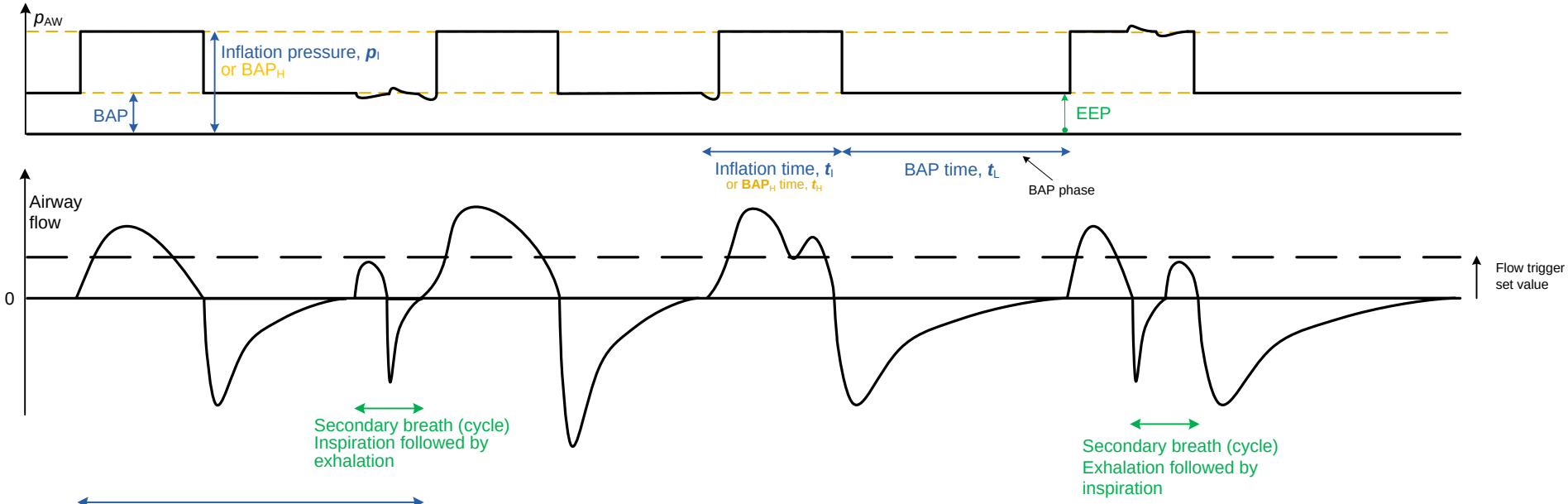


Fig 21g

Classification: A/MV-ePC (No PS permitted)
Optional bi-level sub-class name: A/MV bi-level
Typically labelled as 'CMV-PC, or A/C, allowing free breathing'

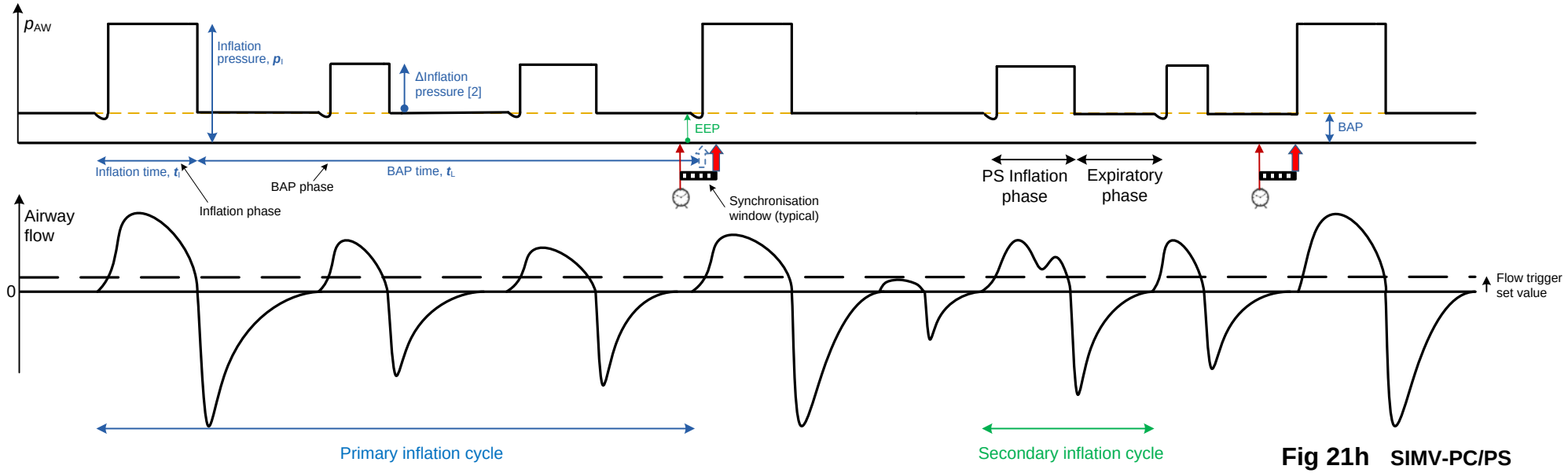


Fig 21h **SIMV-PC/PS**

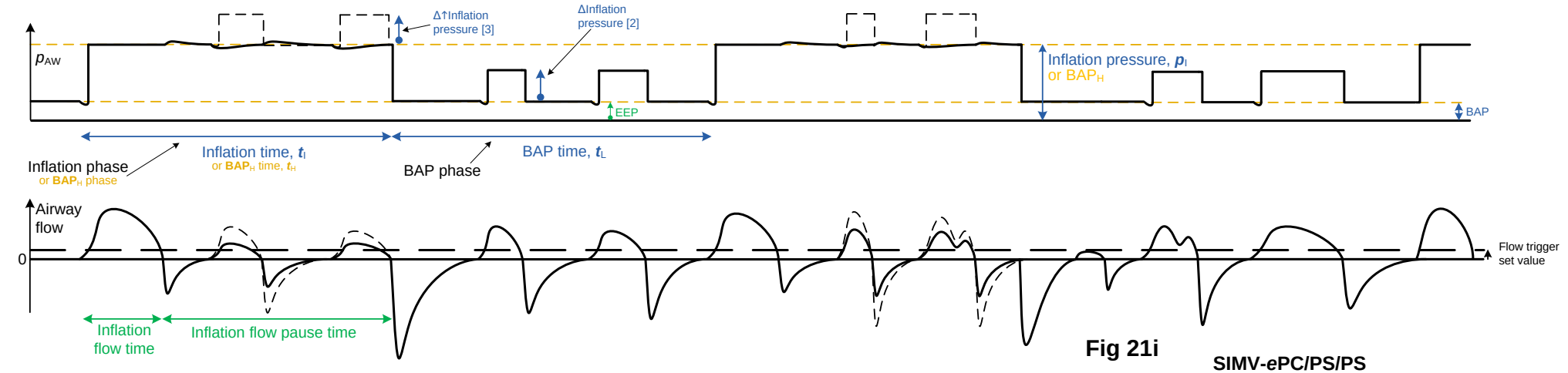


Fig 21i

SIMV-ePC/PS/PS
with alternative terms used for bi-level labelling

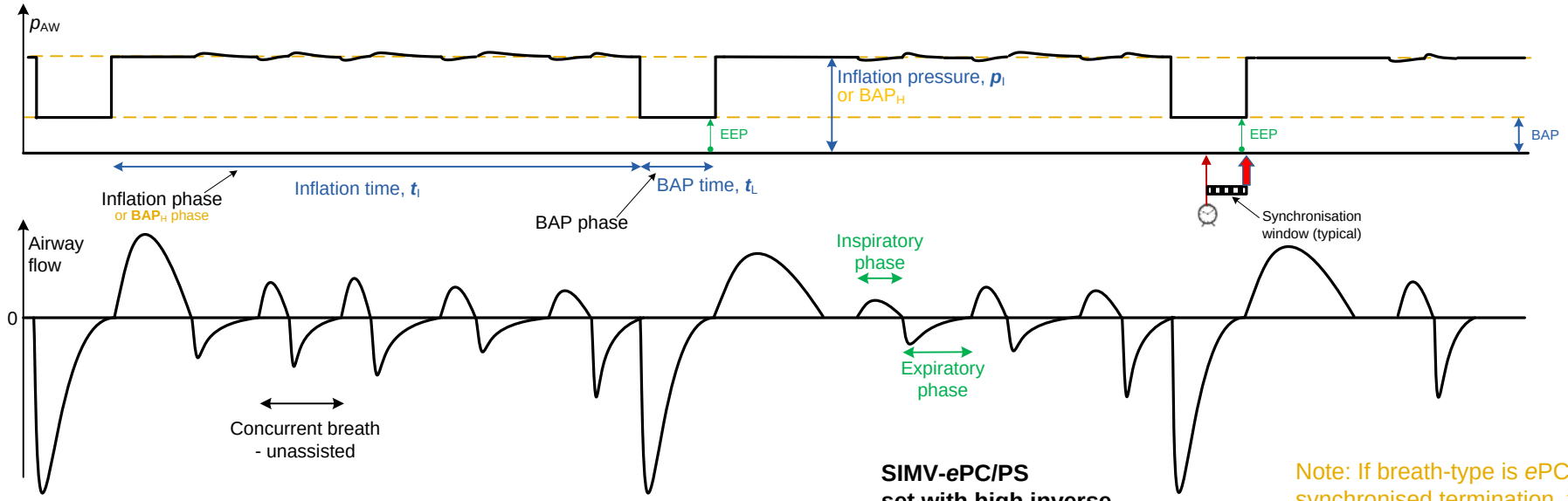


Fig 21j **SIMV-*e*PC/PS set with high inverse time ratio**

Note: If breath-type is *e*PC[S], i.e, with synchronised termination, then orange option only applies