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(54) **COMBINATION CPAP AND RESUSCITATION SYSTEMS AND METHODS**

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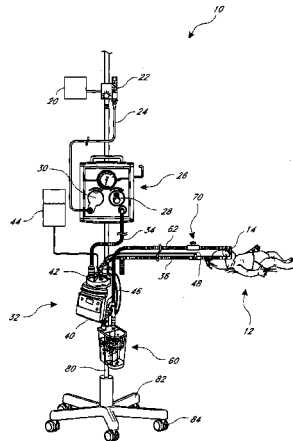
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(57) **ABSTRACT**

A combination positive airway pressure (PAP) or continuous positive airway pressure (CPAP) and resuscitation system and related methods. The systems can be well-suited for use in providing CPAP therapy for a neonate or infant patient, with the ability to also provide resuscitation therapy at a peak inspiratory pressure (PIP) as needed or desired without switching to another system or switching the patient interface. The system can include an expiratory pressure device capable of regulating a positive end expiration pressure (PEEP) of the system, which preferably can also induce pressure oscillations relative to a mean PEEP.

24 Claims, 5 Drawing Sheets



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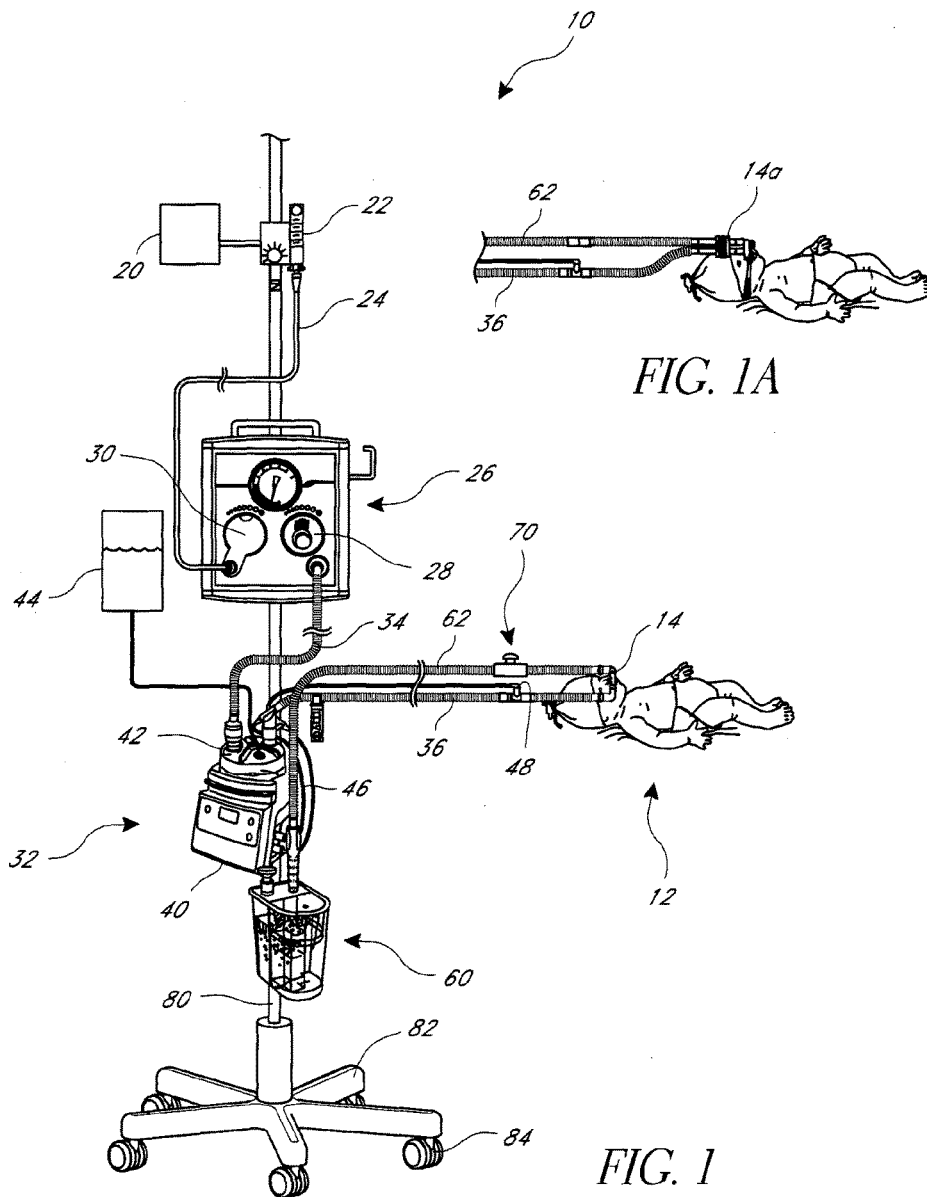


FIG. 1A

FIG. 1

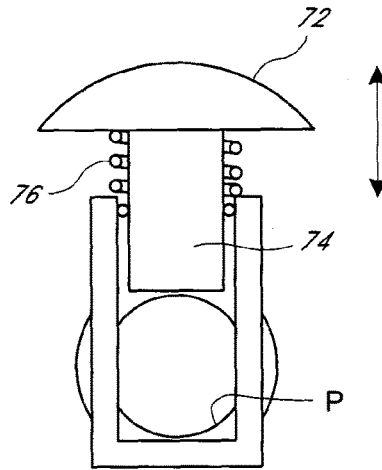


FIG. 2

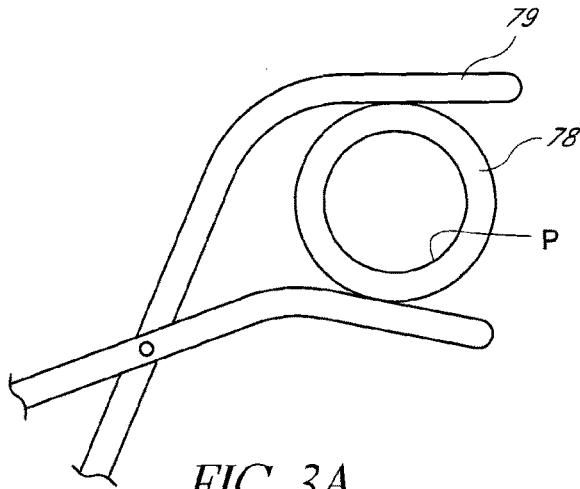


FIG. 3A

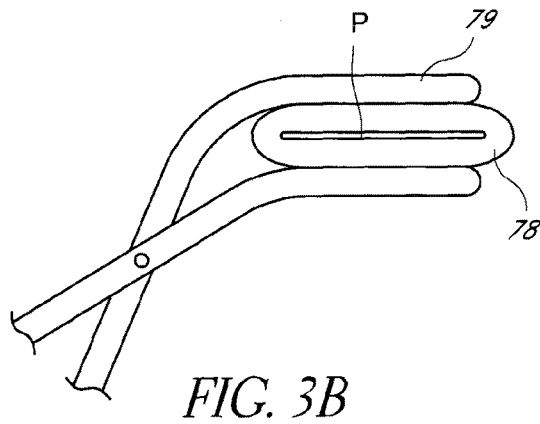


FIG. 3B

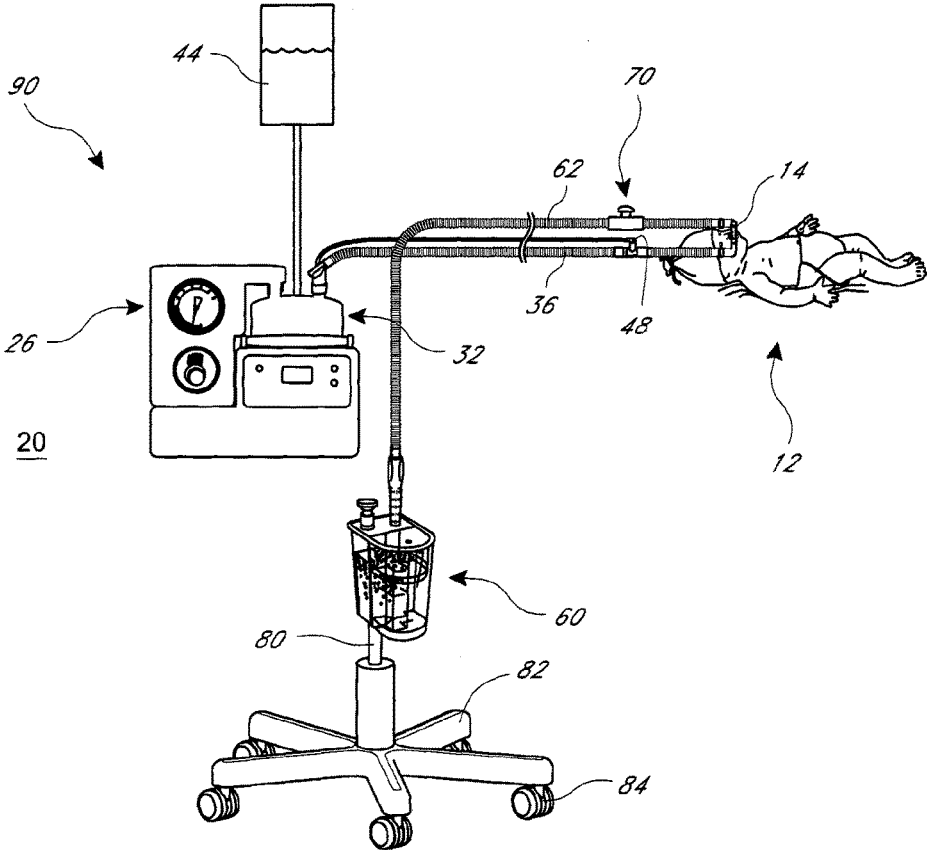


FIG. 4

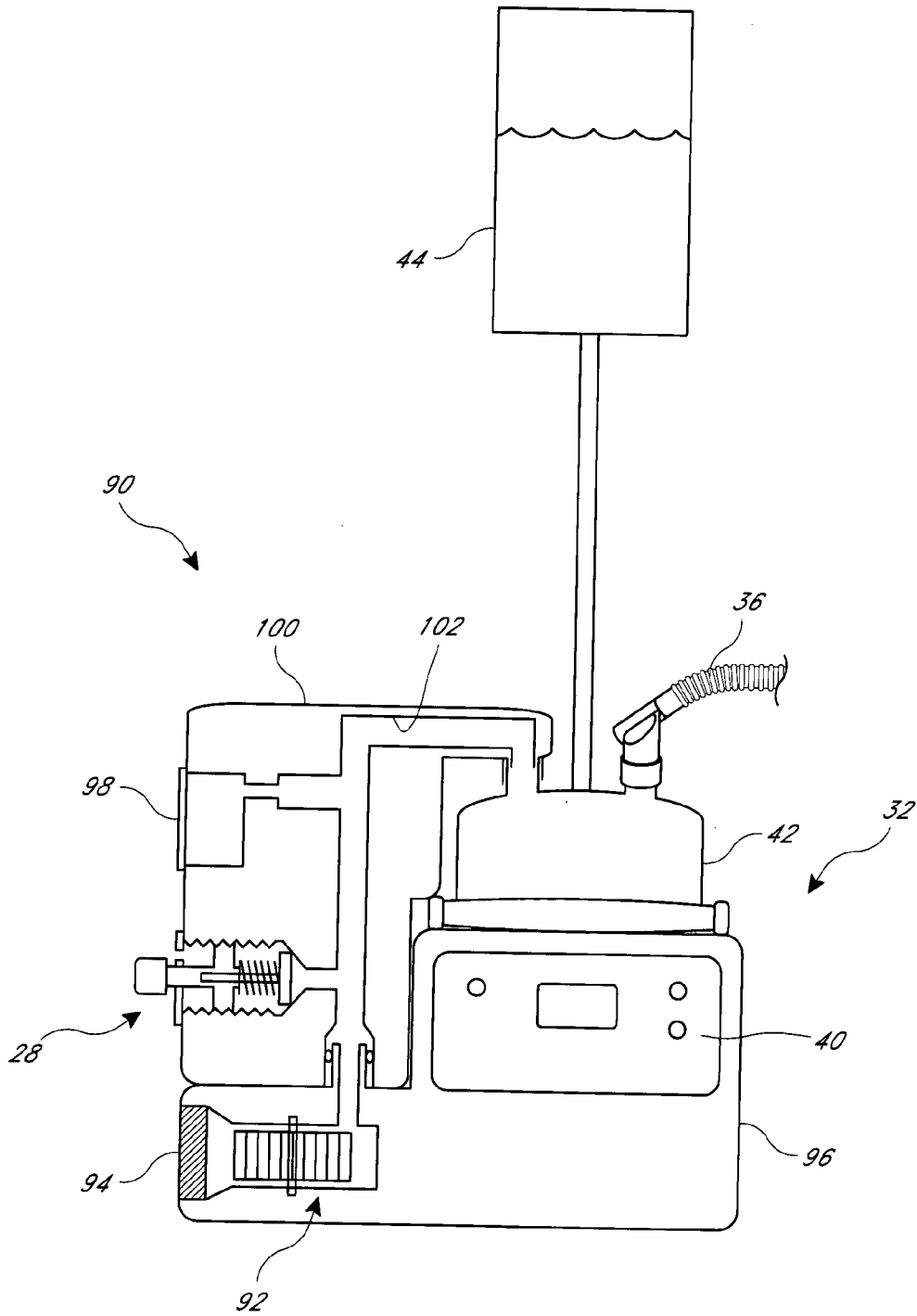


FIG. 5

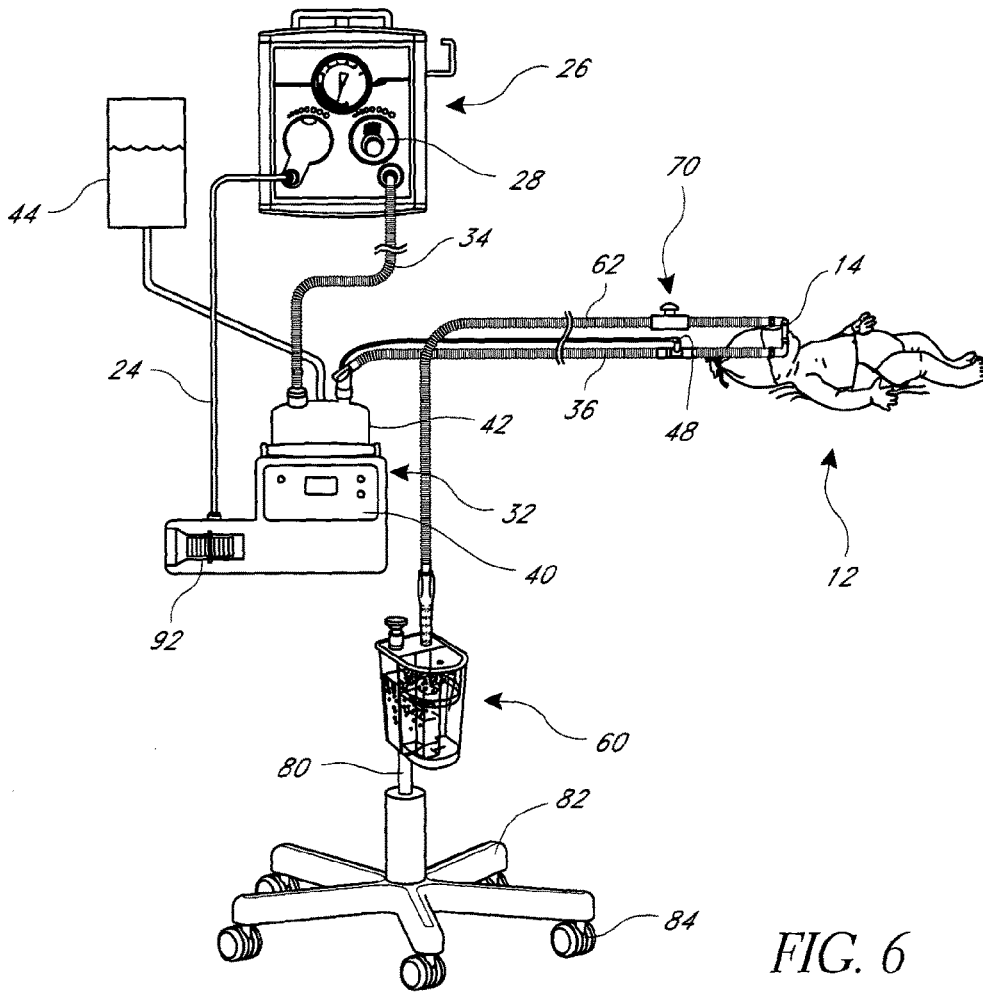


FIG. 6

COMBINATION CPAP AND RESUSCITATION SYSTEMS AND METHODS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to breathing assistance systems and methods. In particular, the present invention relates to systems and methods for providing positive airway pressure therapy or resuscitation therapy to an infant.

Description of the Related Art

Under certain circumstances it is necessary or desirable to provide breathing assistance to a patient under respiratory distress. For example, breathing assistance is often a necessary therapy to treat respiratory distress syndrome (RDS) in infants, which can also be referred to as neonatal respiratory distress syndrome or respiratory distress syndrome of newborn. The breathing assistance provided is often in the form of providing breathing gases at a positive pressure, or a pressure somewhat greater than atmospheric pressure. Such treatments may be referred to in general as positive airway pressure (PAP) therapy. Often, the positive pressure is provided by a continuous flow of breathing gases, which is referred to as continuous positive airway pressure (CPAP) therapy. Infants on CPAP therapy to treat respiratory distress syndrome may also be likely to stop breathing and require resuscitation therapy.

SUMMARY OF THE INVENTION

A preferred embodiment is a combination positive airway pressure and resuscitation system and, preferably, a continuous positive airway pressure and resuscitation system, as well as methods relating to the set-up and use of such a system. Conventionally, in response to RDS, an infant is treated with a PAP system for an extended period of time. If necessary, a separate resuscitation system is utilized to provide resuscitation. Subsequently, the use of the PAP system is resumed. This method results in inefficiencies caused by the switchover from one system to the other. In particular, the patient interface is usually switched when going from one system to the other, which can be time consuming and disruptive to the infant. The preferred systems and methods allow PAP or CPAP therapy for extended periods, along with intermittent resuscitation, in a quick and efficient manner and without requiring the patient interface to be changed.

A preferred embodiment involves a combination infant positive airway pressure and resuscitation system, including an integrated inspiratory pressure device comprising a resuscitator and a humidifier. The resuscitator is capable of regulating a flow of breathing gas to a desired peak inspiration pressure. The humidifier humidifies the flow of breathing gas. An expiratory pressure device is configured to receive expiratory gases from an expiratory circuit and regulate the expiratory gases to a positive end expiration pressure. An occlusion device is within the expiratory circuit upstream from the expiratory pressure device and is configured to permit occlusion of the expiratory circuit at desired times such that the pressure within the inspiratory circuit rises to the peak inspiration pressure of the resuscitator.

In some embodiments of the above-described system, the resuscitator is separable from the humidifier. The resuscitator can be integrated with a first housing and the humidifier can be integrated with a second housing. Some of the above-described system can include a flow generator that

generates the flow of breathing gas. The flow generator can be integrated with the second housing.

A preferred embodiment involves a combination infant positive airway pressure and resuscitation system. The system includes an inspiratory pressure device that outputs a flow of breathing gas at a desired peak inspiration pressure to an inspiratory circuit. A patient interface receives the flow of breathing gas from the inspiratory circuit, wherein the patient interface is configured to deliver the flow of breathing gas to an infant patient and receive expiratory gases from the patient. An expiratory circuit receives the expiratory gases from the patient interface. An expiratory pressure device receives expiratory gases from the expiratory circuit and regulates the expiratory gases to a positive end expiration pressure. An occlusion device is positioned within the expiratory circuit upstream from the expiratory pressure device. The occlusion device is configured to permit occlusion of the expiratory circuit at desired times such that the pressure within the inspiratory circuit rises to the peak inspiration pressure.

Another preferred embodiment involves a combination infant positive airway pressure and resuscitation system. The system includes a supply of breathing gas and an inspiratory pressure device that receives a flow of breathing gas from the supply of breathing gas. The inspiratory pressure device is capable of outputting the flow of breathing gas at a desired peak inspiration pressure to an inspiratory circuit. A patient interface receives the flow of breathing gas from the inspiratory circuit, wherein the patient interface is configured to deliver the flow of breathing gas to an infant patient and receive expiratory gases from the patient. An expiratory circuit receives the expiratory gases from the patient interface. An oscillatory expiratory pressure device receives expiratory gases from the expiratory circuit and regulates the expiratory gases to a mean positive end expiration pressure with pressure oscillations relative to the mean pressure. An occlusion device is positioned within the expiratory circuit and is configured to permit occlusion of the expiratory circuit at desired times such that the pressure within the inspiratory circuit rises to the peak inspiration pressure.

In some arrangements of the above-described systems, the expiratory pressure device is or includes a water resistance valve, which can be adjustable to permit adjustment of the positive end expiration pressure. The occlusion device can be a manual push button valve or a clamp valve, among other possible valve types. In some arrangements, the system can include a humidifier positioned within the inspiratory circuit between the inspiratory pressure device and the patient interface. Preferably, the occlusion device is located less than 500 millimeters from the patient end of the expiratory circuit. In some arrangements, the expiratory circuit can include an expiratory hose coupled to the patient interface and the occlusion device can be located within the expiratory hose.

In some arrangements, a source of breathing gas is provided separately from the inspiratory pressure device, such as via a bottle or wall source. In other arrangements, the source of breathing gas is ambient air and a flow of air is generated by a flow generator or blower. The blower can be provided in an integrated unit with the inspiratory pressure device (e.g., resuscitator) and the humidifier. In some arrangements, the blower and humidifier are contained or associated with a first housing and the inspiratory pressure device (e.g., resuscitator) can be integrated with a second housing, which can be removed from the first housing. In some arrangements, the humidifier is contained or associ-

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ated with a first housing and the inspiratory pressure device (e.g., resuscitator) can be integrated with a second housing, which can be removed from the first housing. In some arrangements, the blower can be integrated with the humidifier and the inspiratory pressure device (e.g., resuscitator) can be a separate component.

Another preferred embodiment involves a combination infant positive airway pressure and resuscitation system. The system includes a patient interface that receives expiratory gases from the patient and an expiratory circuit that receives the expiratory gases from the patient interface. An expiratory pressure device receives expiratory gases from the expiratory circuit and regulates the expiratory gases to a positive end expiration pressure. An occlusion device is positioned within the expiratory circuit upstream from the expiratory pressure device and is configured to permit occlusion of the expiratory circuit at desired times such that the pressure within the system rises above the positive end expiration pressure.

A preferred embodiment involves a breathing circuit for a combination infant positive airway pressure and resuscitation system. The circuit includes an expiratory circuit that is configured for connection to a patient interface to receive expiratory gases from the patient interface and an inspiratory circuit that is configured for connection to the patient interface to deliver a flow of breathing gas to the patient interface. An occlusion device is configured to permit occlusion of the expiratory circuit at desired times such that the pressure within the system rises above the positive end expiration pressure.

In some arrangements of the above-described circuits, the expiratory circuit is further configured for connection to an expiratory pressure device that receives expiratory gases from the expiratory circuit and regulates the expiratory gases to a positive end expiration pressure. The occlusion device can comprise a manual push button valve. The occlusion device can comprise a clamp. The occlusion device can be located less than 500 millimeters from the patient interface along the expiratory circuit. The occlusion device can be located in the expiratory circuit. In some embodiments, the occlusion device can be located in the patient interface.

Another preferred embodiment involves a method of providing continuous positive airway pressure and resuscitation to an infant, including using an inspiratory pressure device to provide a flow of breathing gas, the inspiratory pressure device capable of generating a peak inspiratory pressure in the flow of breathing gas. The flow of breathing gas is supplied to an infant patient through a patient interface and expiratory gases are received from the infant patient through the patient interface. A water resistance valve or other type of oscillatory resistance valve is utilized to vent the flow of breathing gas and expiratory gases and maintain a mean positive end expiration pressure within the patient interface that is less than the peak inspiratory pressure. A resuscitation breath is provided to the infant patient by blocking the flow of breathing gas and expiratory gases between the patient interface and the water resistance valve such that the pressure within the patient interface increases to the peak inspiratory pressure.

In some applications, the method can include providing repeated resuscitation breaths to the infant patient by repeatedly alternating between blocking and allowing the flow of breathing gas and expiratory gases between the patient interface and the water resistance valve. In some applications, the blocking of the flow of breathing gas and expiratory gases between the patient interface and the water resistance valve can be accomplished by actuating a push

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button occlusion valve or by clamping a portion of an expiratory tube. In some applications, the flow of breathing gas can be passed through a humidifier after the inspiratory pressure device and before the patient interface. The positive end expiration pressure can be adjusted by adjusting a depth of an outlet of the flow of breathing gas and expiratory gases within a water reservoir of the water resistance valve.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments, having certain features, aspects and advantages of the present invention, are described with reference to the accompanying drawings. The drawings contain six (6) figures.

FIG. 1 is an illustration of an infant patient receiving CPAP therapy and/or resuscitation therapy from a system including an inspiratory pressure device, a humidifier, a patient interface and an expiratory pressure device.

FIG. 1A is an illustration of an infant patient and an alternative patient interface.

FIG. 2 is a partial cross-sectional view of a linear motion, push button occlusion valve.

FIGS. 3A and 3B are partial cross-sectional views of a clamp-type occlusion valve in which a tube can be collapsed or occluded by a clamp. FIG. 3A shows the tube in an open configuration and FIG. 3B shows the tube in a collapsed or occluded configuration.

FIG. 4 is an illustration of a modification of the system of FIG. 1, in which the inspiratory pressure device is integrated with the humidifier.

FIG. 5 is a partial sectional view of the integrated inspiratory pressure device and humidifier of FIG. 4.

FIG. 6 is an illustration of another modification of the system of FIG. 1, in which a flow generator is integrated with the humidifier.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates a combination infant positive airway pressure (PAP) or continuous positive airway pressure (CPAP) and resuscitation system, generally referred to by the reference numeral 10. The system 10 is capable of providing PAP or CPAP therapy to a neonate or an infant patient 12 for an extended period of time, while also permitting resuscitation breaths to be delivered to the infant patient 12 if or when necessary. Preferably, both the PAP or CPAP therapy and the resuscitation breaths are delivered through a single patient interface 14 without requiring removal of the interface 14 from the infant patient 12. The present system 10 is disclosed herein in the context of continuous positive airway pressure (CPAP) therapy; however, the system 10 could also provide other types or modes of positive airway pressure (PAP) therapy. Accordingly, references to CPAP therapy herein are understood to also include other types of PAP therapies, unless specifically noted otherwise.

The illustrated system 10 includes a source of breathing gas 20, which can be a gas cylinder (not shown), a wall supply 20, or any other suitable source of breathing gas. The breathing gas can be air, oxygen, a blend of air and oxygen, or any other suitable gas for use in respiratory therapy. The source of breathing gas 20 provides a flow of breathing gas at an initial feed pressure or within an initial feed pressure range. The flow rate of the flow of breathing gas can be adjusted by a suitable flow meter or gas blender 22 to a suitable level for the desired therapy.

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A suitable conduit, such as a gas supply line **24** supplies the flow of breathing gas to an inspiratory pressure device **26**, which can be a resuscitator. More preferably, the inspiratory pressure device **26** is an infant resuscitator, such as an infant resuscitator sold by Fisher and Paykel Healthcare, the Assignee of the present application, under the NEOPUFF trademark. Although referred to herein as a “resuscitator” for convenience, it is understood that the term can encompass other suitable types of inspiratory pressure devices capable of providing a breathing gas at a controlled output pressure.

Preferably, the resuscitator **26** is capable of receiving a flow of breathing gas from the source of breathing gas **20** and outputting the flow of breathing gas at a controlled pressure greater than atmospheric pressure. In particular, the resuscitator **26** can output the flow of breathing gas at a peak inspiratory pressure (PIP), which preferably can be up to about 75 cmH₂O or greater. Preferably, the resuscitator **26** includes an adjustment mechanism, such as an adjustment valve **28**, which allows the PIP to be adjusted to a desired pressure level. Preferably, the resuscitator **26** also incorporates a pressure relief valve **30** that regulates a maximum pressure within the system **10**. The pressure relief valve **30** can be adjustable such that the maximum system pressure can be adjusted. For example, an adjustment range can be between about 5-70 cmH₂O. The pressure relief level can be factory set to a particular value, such as about 40 cmH₂O, for example. However, in alternative arrangements, a separate pressure regulator could be provided within the system **10** to regulate the maximum system pressure. Such a pressure regulator is described in U.S. Pat. No. 6,644,313, which is incorporated by reference herein in its entirety. In embodiments having a blower unit, a pressure relief valve may not be necessary because the maximum achievable pressure of the system can be regulated by the blower unit. The blower unit can be designed so that the maximum pressure it can produce is lower than a desired pressure relief level. In other embodiments, the maximum achievable pressure of the blower unit can be limited by software in the system.

The flow of breathing gas outputted from the resuscitator **26** preferably is delivered to an optional humidifier system **32** by a suitable conduit, such as an inspiratory tube or supply tube **34**. In some embodiments, the resuscitator and the humidifier system can be integrated into a single unit, as discussed below. The humidifier system **32** provides humidity or vaporized liquid, such as water, to the flow of breathing gas received from the resuscitator **26** to output a flow of humidified breathing gas to the patient interface **14** through a suitable conduit, such as a supply tube **36**. The humidifier system **32** can include a humidifier unit or humidifier **40** and a humidity chamber **42**. The humidity chamber **42** holds a volume of liquid, such as water, which is heated by the humidifier **40** to create a vapor within the humidity chamber **42** that is transferred to the flow of breathing gas. The humidity chamber **42** can be an auto-fill variety, in which a source of liquid **44** is connected to the humidity chamber **42** to refill the volume of liquid, as appropriate. A suitable humidifier **40** is the MR850 Humidifier sold by the Assignee of the present application. A suitable humidity chamber **42** is the MR225 or MR290 humidity chamber sold by the Assignee of the present application. The humidifier system **32** can output a flow of humidified breathing gas at a desired temperature and absolute humidity, such as an optimal temperature of about 37 degrees Celsius and absolute humidity of about 44 mg/L, or within a desirable or acceptable range of the optimal temperature and absolute humidity.

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The supply tube **36** can be a heated supply tube such that a temperature of the flow of breathing gas is maintained at an elevated level within the supply tube **36** and to avoid or limit condensation within the supply tube **36** or patient interface **14**. A heating element cable **46** can connect a heating element of the supply tube **36** to the humidifier **40** (or other power/heat source) to power the heating element. A sensor or probe **48** can be coupled to the humidifier **40** and supply tube **36** to detect the temperature and/or flow rate of the flow of breathing gas through the supply tube **36**. Preferably, the sensor **48** is spaced from the inlet end of the supply tube **36** and can be located at the outlet end of the supply tube **36**. The sensor **48** can include a wire that couples the sensor **48** to the humidifier **40**. The humidifier **40** can utilize information from the sensor **48** to control the operating parameters of the humidifier **40**, for example, to maintain the temperature and/or humidity of the flow of breathing gas within the supply tube **36** at a desirable level or range.

From the humidifier system **32**, the flow of breathing gas is supplied to the patient interface **14**, which can be any suitable type of interface capable of supplying a breathing gas to the respiratory system of the patient. The illustrated interface **14** is a lateral nasal interface, which includes nasal cannula or nasal prongs that are inserted into the nostrils of the infant patient **12**. In a lateral interface, the inlet and outlet are laterally spaced on opposing sides of the nasal cannula or prongs and a midline of the infant patient **12**. FIG. 1A illustrates an alternative nasal interface **14A**, which can be referred to as a midline nasal interface. The midline nasal interface **14A** positions the inlet and the outlet of the interface **14A** are located in line with the nasal cannula or nasal prongs and substantially along the midline of the infant patient **12**. The inlet and outlet of the interface **14A** can be positioned side-by-side; however, in a preferred arrangement, the inlet and outlet are stacked one on top of the other. One suitable interface **14A** is an infant nasal tube or mask in combination with nasal prongs sold by the Assignee of the present application under the trademark FLEXITRUNK. However, other suitable patient interfaces **14** can also be used, such as a face mask that covers both the nose and mouth of the infant patient **12** (e.g., RD Series Infant Resuscitation Masks sold by the Assignee of the present application) or an appropriate interface device in combination with an endotracheal tube. An infant resuscitation mask is described in U.S. Pat. No. 7,341,059, which is hereby incorporated by reference in its entirety.

Preferred interfaces **14** provide a sealed system that delivers the flow of breathing gas to the infant patient **12** and receives expiratory gases from the patient **12**. Preferably, the system **10** is a biased flow system in which breathing gas is constantly flowing within the system **10** generally in a direction from the inlet of the patient interface **14** to the outlet of the patient interface **14**. Thus, the infant patient **12** can inhale a portion of the flow of breathing gas and the remainder is passed through the patient interface **14**. Exhaled or expiratory gases can mix with the flow of breathing gas and exit the patient interface **14** along with the unused portion of the flow of breathing gas. For convenience, the gases exiting the patient interface **14** are referred to as expiratory gases or the flow of breathing gas, although it is understood that either or both of patient exhaled gases and unused breathing gases can be present at any particular point in time.

Expiratory gases flow from the patient interface **14** to an expiratory pressure device **60**, which is configured to regulate the minimum pressure within the system **10**, preferably

to a level above ambient or atmospheric pressure. Preferably, the expiratory pressure device **60** is connected to the patient interface **14** by a suitable conduit, such as an expiratory hose **62**. However, in an alternative arrangement, the expiratory pressure device **60** can be connected directly to or integrated with the patient interface **14**.

Preferably, the expiratory pressure device **60** is configured to provide a minimum pressure or minimum backpressure within the system **10** and, in particular, at the patient interface **14**, which can be referred to as the positive end expiration pressure (PEEP). In the illustrated system **10**, the PEEP is equivalent to, or generally equivalent to, the continuous positive airway pressure (CPAP). Accordingly, such a device can be referred to as a CPAP generator. However, preferably, the expiratory pressure device **60** is an oscillatory valve capable of providing pressure oscillations relative to a mean PEEP pressure. It is believed that such pressure oscillations are beneficial to the infant patient **12** and may result in improved gas exchange and reduce the infant patient's **12** work of breathing. Thus, an oscillatory pressure expiratory pressure device **60** is particularly preferred. One type of oscillating pressure expiratory pressure device **60** is a fluid resistance valve, in particular a liquid or water resistance valve, which is often referred to as a bubbler. In general, a water resistance valve delivers the expiratory gases to an outlet that is submerged in a water reservoir resulting in a resistance to the exit of the expiratory gases that is greater than that caused by ambient or atmospheric pressure and related to the depth of the outlet relative to a surface of the water within the water reservoir. In some arrangements, the depth of the outlet is adjustable to allow the PEEP to be adjusted to a desired level. One suitable bubbler is the Bubble CPAP generator sold by the Assignee of the present application. Additional details of a suitable bubbler device are described in U.S. Pat. No. 6,805,120, which is incorporated by reference herein in its entirety. Preferably, the bubbler (or other oscillatory pressure device) is capable of producing vibrations in the infant patient's chest at a frequency of between about 5-30 Hz.

The illustrated system **10** also includes an occlusion device or occlusion valve **70** that is configured to selectively block the flow of gases within the system **10** and preferably block the flow of expiratory gases, such as within the patient interface **14**, expiratory tube **62** or expiratory pressure device **60**. Preferably, the occlusion valve **70** is located upstream of the expiratory pressure device **60** and downstream of the patient interface **14**, such as within the expiratory tube **62**. Preferably, the occlusion valve **70** is located at or near the patient interface **14**, such as within about 500 millimeters or less of the patient interface **14**. However, in other arrangements, the occlusion valve **70** can be integrated with the patient interface **14** or expiratory pressure device **60**. The occlusion valve **70** is configured to block the exit of gases from the system **10** to a sufficient extent such that the gas pressure within the system **10** rises above the PEEP. With the exit of gases from the system **10** blocked, the inspiratory pressure device **26** can increase the pressure in the system **10** preferably to or near the set PIP level. The occlusion valve **70** can completely or substantially completely block the flow of gas within the system **10**, or can block or interrupt the flow to a sufficient extent to allow the inspiratory pressure device **26** or integrated unit **90** to raise the pressure toward the PIP. Preferably, the occlusion valve **70** can block the flow of gas within the system **10** to a sufficient extent that the inspiratory pressure device **26** or integrated unit **90** can raise the pressure within the system **10** to or substantially to the PIP pressure. However, to quickly

and accurately achieve the PIP pressure, it is desirable that the occlusion valve **70** completely or substantially completely block the flow of gas within the system **10**. Although described as a sealed system, it is understood that some leakage of gas may occur from the system **10**, such as between the patient interface **14** and the patient **12**, for example. In addition, pressure losses may occur throughout the system **10** such that the pressure is not the same throughout the entire system **10**. Accordingly, it is understood that the PEEP or PIP may vary between the point of measurement and some other point within the system **10**. Therefore, it is understood that discussion of specific pressures or pressure ranges herein, such as PIP or PEEP, incorporates a range of acceptable variation, which can result from pressure leakage, pressure loss or measurement error.

In operation, the occlusion valve **70** can be utilized to perform a resuscitation procedure or resuscitation therapy by raising the pressure within the system **10** to at or near the PIP pressure to deliver a resuscitation breath to the infant patient **12** in a manner similar to a conventional resuscitation procedure. However, advantageously, with the present system **10**, resuscitation breaths can be provided to an infant patient **12** that is undergoing CPAP therapy immediately and without requiring additional equipment or set-up. Furthermore, the CPAP therapy can be immediately resumed after the resuscitation procedure. Preferably, the resuscitation breaths can be provided through the same patient interface **14** as the CPAP therapy without removal or exchange of the interface and with breathing gases flowing in the same direction within the system **10** as the CPAP therapy. The occlusion valve **70** can be used to provide repeated resuscitation breaths to the infant patient **12** at or near PIP pressure with intervening periods of PEEP. The resuscitation breaths delivered by use of the occlusion valve **70** can be at any suitable rate, such as about 40-60 breaths per minute. The relative duration of the resuscitation breath time at PIP pressure to the exhalation time at PEEP can be any suitable ratio, such as 40:60, 50:50, 60:40, or any value in between. The resuscitation procedure typically lasts for less than 30 minutes or less than 15 minutes. Often, the resuscitation procedure lasts between about 3-5 minutes. Thus, the present system **10** is particularly advantageous in reducing the switchover time between CPAP therapy and resuscitation therapy, which avoids delay in providing resuscitation therapy once it is recognized as necessary or desirable.

The occlusion valve **70** can be of any suitable arrangement or structure to selectively accomplish a partial or complete occlusion of gas flow within the system **10**. Preferably, the occlusion valve **70** allows the cycling between an occluded or closed position and an open position at a suitable rate, such as the rates described herein. In some arrangements, the occlusion valve **70** is a manual valve that is operated by manually by a caregiver. Accordingly, preferably the occlusion valve **70** facilitates repeated cycling between the open and closed position multiple times per minute.

For example, FIG. **2** illustrates a push button valve arrangement **70** having a manually operated push button **72** that actuates a valve body **74** movable between an open position and a closed position. The valve body **74** can simply move into or out of a flow passage **P** of the system **10** (linear movement or translation) to selectively allow and occlude gas flow within the system **10**. In some embodiments, the valve arrangement can include a safety feature to help prevent accidental actuation. For example, the push button may be lockable in the open position by rotating the push

button a quarter turn. In order to use the valve arrangement, the user can rotate the push button to unlock before actuating. Preferably, the valve body 74 is biased to the open position by a biasing member, such as a spring 76, so that gas flow is normally unobstructed. The valve body 74 can be movable to the closed position (e.g., using the manual push button 72) when it is desired to deliver a resuscitation breath at PIP. In other arrangements, the valve 70 could be a rotatable valve, such as a stopcock. FIG. 3 illustrates another possible occlusion valve arrangement 70, in which a compliant section of tubing 78 that has sufficient resilience to remain open in the absence of an external force (FIG. 3A), but can be collapsed to a closed position in response to an external squeezing force (FIG. 3B), such as a force applied by a clamping mechanism 79. In still other arrangements, the valve 70 could be automatically movable (e.g., electronically actuated).

As described, the occlusion valve 70 can be positioned in any suitable location within the system 10. The system 10 can be considered to have an inspiratory circuit and an expiratory circuit. In the illustrated arrangement, the inspiratory circuit can include all or portions of the source of breathing gas 20, the gas supply line 24, the inspiratory pressure device 26, the supply tube 34, the humidifier system 32, and the supply tube 36. The expiratory circuit can include all or portions of the expiratory tube 62 and the expiratory pressure device 60. A portion of the patient interface 14 can be predominantly occupied by a flow of inspiratory breathing gas prior to inspiration by the infant patient 12 or prior to availability to the infant patient 12, while another portion of the patient interface 14 can be predominantly occupied by a flow of expiratory gas exhaled by the infant patient 12 or that has bypassed the infant patient 12. Accordingly, the patient interface 14 can be considered to form a part of each of the inspiratory circuit and the expiratory circuit. A portion of the patient interface 14 can also include a mixture of inspiratory gas and expiratory gas, at least for certain time durations, and may not be considered part of either of the inspiratory circuit or the expiratory circuit or may be considered as a part of each.

The various components of the system 10, including those described above, can be arranged and/or mounted in any suitable manner. Some or all of the components can be stationary (e.g., wall mounted) or movable. In the illustrated arrangement, some of the components are mounted to a support pole 80, which includes a base portion 82 having a plurality of rollers or casters 84 to provide mobility. A suitable pole 80 is the 900MR292 or 900MR293 pole sold by the Assignee of the present application. In the illustrated arrangement, the inspiratory pressure device 26, the humidifier system 32 and the expiratory pressure device 60 are mounted to the support pole 80. Although not specifically illustrated, the source of water 44 preferably is also supported by the support pole 80. In other arrangements, some of the components could be mounted on another support pole 80. The source of breathing gas 20 and the flow meter or gas blender 22 can be mobile or can be stationary (e.g., wall mounted). In one arrangement, for example, the resuscitator 26 can be integrated with an infant warmer, such as the 900 Series infant warmers sold by the Assignee of the present invention.

To set up the system 10 for use, the components can be gathered and mounted to the support pole 80 or other support structure, if necessary or desired. The components can be connected to a power source, if necessary, and turned on. The inspiratory pressure device 26 can be coupled to the source of breathing gas 20 through the flow meter or gas

blender 22 by the gas supply line 24. The humidifier system 32 can be coupled to the inspiratory pressure device 26 by the supply tube 34. The source of water 44 can be coupled to the humidity chamber 42. The patient interface 14 can be coupled to the humidifier system 32 by the supply tube 36. The expiratory pressure device 60 can be coupled to the patient interface 14 by the expiratory tube 62. The occlusion valve 70 can be integrated into the expiratory tube 62; however, the occlusion valve 70 can also be assembled to the expiratory tube 62 (such as intermediate two tube portions of the expiratory tube 62) or otherwise assembled in a suitable location within the system 10, as described above.

If necessary, the expiratory pressure device 60 can be filled with a liquid, such as about 500 milliliters of water. If adjustable, the expiratory pressure device 60 can be initially adjusted to a maximum pressure level (maximum PEEP). The humidifier system 32 can be adjusted to a desired temperature and absolute humidity, such as about 37 degrees Celsius and 44 mg/L. The flow meter or gas blender 22 can be adjusted to a desired flow rate, preferably less than 15 liters per minute (LPM). In embodiments having a blower unit, the flow meter or gas blender can be integrated with the blower unit. More preferably, the flow rate is adjusted to between about 6-8 LPM.

If necessary or desirable, the pressure relief valve 30 of the inspiratory pressure device 26 can be adjusted to a suitable pressure relief level. The pressure relief valve 30 can be factory set to a pressure relief level, such as about 40 cmH₂O. The pressure relief valve 30 can be set to a lower level, such as between about 5-70 cmH₂O and, more preferably, 30-40 cmH₂O. To set the level of the pressure relief valve 30, the PIP adjustment of the inspiratory pressure device 26 is adjusted to a maximum level. The patient interface 14 can be blocked or connected to a test lung apparatus, such as the RD020-01 test lung apparatus sold by the Assignee of the present application. The occlusion valve 70 can be actuated to allow the pressure within the system 10 to rise to the pressure relief level, which can be adjusted to a desired level. With the occlusion valve 70 still actuated, the PIP can be adjusted to a desirable level, preferably less than about 75 cmH₂O. More preferably, the PIP is between about 10-40 cmH₂O or 20-30 cmH₂O. In one application, the PIP pressure is adjusted to about 20 cmH₂O, using the PIP valve 28. The occlusion valve 70 can be moved to an open position such that the system pressure is reduced to the PEEP value as determined by the expiratory pressure device 60. The PEEP level can be adjusted to a desirable pressure, such as less than about 25 cmH₂O, by adjusting a depth of the gas outlet within the water reservoir. Preferably, the PEEP level is adjusted to less than about 15 cmH₂O, less than about 9 cmH₂O or less than about 5 cmH₂O. In one application, the PEEP level is set to about 5 cmH₂O. If necessary, the test lung apparatus can be removed and the system 10 is ready for use.

To use the system 10, the patient interface 14 can be applied to an infant patient 12 following an appropriate methodology. For example, a face mask can be positioned over the nose and mouth of the infant patient 12 and, if desired, held in place by hand, a strap or other retention device. If an endotracheal tube is used, the interface 14 or portion of the interface 14 can be coupled to the endotracheal tube. In the illustrated arrangement, the nasal prongs can be coupled to the nasal mask or tube and the nasal prongs can be inserted into the nostrils of the infant patient 12. The nasal mask 14 can be held in place by any suitable retention mechanism, such as a chin strap or head strap.

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Once the patient interface **14** is in place on the infant patient **12**, the CPAP therapy can be commenced. A flow of breathing gas is supplied to the infant patient **12** by the patient interface **14** at the CPAP or PEEP level, as regulated by the expiratory pressure device **60**. As discussed, preferably the expiratory pressure device **60** is configured to produce pressure oscillations within the system **10**, which is believed to have an improved therapeutic effect on the infant patient **12**. The CPAP therapy can continue for a desired period of time.

If necessary or desirable, resuscitation therapy can be administered. As described above, the occlusion valve **70** can be actuated to block the exit of expiratory gases from the system **10** and cause the pressure within the system **10** to rise toward or to the PIP pressure to deliver a resuscitation breath to the infant patient **12**. The occlusion valve **70** can be moved to an open position, or allowed to return to an open position, to return the system to the PEEP. In some arrangements, the actuation of the occlusion valve **70** is accomplished manually. The actuation and release of the occlusion valve **70** can be repeated at a desired frequency, such as between about 40-60 breaths per minute, for a suitable duration, such as about 3-5 minutes. However, if necessary or desirable, the duration of the resuscitation therapy can be up to 15-30 minutes, or longer. At the conclusion of the resuscitation therapy, the system **10** can automatically return to the CPAP mode at the PEEP. Accordingly, with the illustrated system **10**, resuscitation therapy can be immediately commenced on an infant patient **12** that is undergoing CPAP therapy without requiring the set-up of additional equipment and without requiring the replacement of the patient interface **14**.

FIGS. **4** and **5** illustrate a modification of the system **10** of FIG. **1**. Because the system of FIGS. **4** and **5** is similar to the system **10** of FIG. **1** in many respects, the same reference numbers are used to indicate the same or corresponding components. In the system of FIGS. **4** and **5**, the resuscitator **26** (or other inspiratory pressure device) is integrated with the humidifier **32** in a resuscitator/humidifier unit **90** (hereinafter "integrated unit **90**"). In addition, preferably, the source of breathing gas **20** is or includes ambient air from an environment adjacent the integrated unit **90**. Therefore, the integrated unit **90** preferably comprises a flow generator or flow source, such as a fan, gas pump or blower **92** (FIG. **5**), which generates a flow of air. In some embodiments, however, the integrated unit **90** can be connected to a source of breathing gas, such as a gas cylinder or a wall supply, instead of or in addition to the flow generator. In some arrangements, the system can utilize supplemental breathing gases (oxygen or other suitable respiratory gases) that are blended in combination with air. However, in many arrangements, only air is used and the source of breathing gas (reference number **20** in FIG. **1**) can be omitted.

In the illustrated arrangement, the integrated unit **90** generates a flow of breathing gas (e.g., air) and outputs the flow of breathing gas at a controlled pressure greater than atmospheric pressure to the humidifier, which humidifies the flow of breathing gas. The flow of humidified breathing gas is delivered to the patient **12** via the supply tube **36** and patient interface **14**. Exhaled and unused gases are delivered to the expiratory pressure device **60** via the expiratory hose **62**. The expiratory pressure device **60** can provide a minimum pressure or minimum backpressure within the system and, in particular, at the patient interface **14** preferably to or near the PEEP pressure. The occlusion valve **70** can be used to block the flow of breathing gas such that the inspiratory pressure device **26** can increase the pressure in the system

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preferably to or near the set PIP level. The system of FIGS. **4** and **5** preferably operates in substantially the same manner as described above with respect to the system **10** of FIG. **1**.

With reference to FIG. **5**, in addition to the blower **92**, the integrated unit **90** preferably includes a filter **94** upstream from the blower **92**. The filter **94** is of a suitable arrangement to separate impurities or other undesirable elements from the ambient air that is used to generate the flow of air within the system. The filter **94** and the blower **92** preferably can be coupled to or contained within a housing **96** that contains portions of the humidifier **40** and supports the humidifier chamber **42**. The pressure adjustment valve **28** and a manometer **98**, or other pressure gauge or measurement device, can be coupled to or contained within a housing **100** that is separate from the housing **96**. Preferably, the housing **100** can be removable from the housing **96**. When the housing **100** is removed, the integrated unit **90** can be used as a blower **92** and humidification system **32** without the resuscitation feature. In the illustrated arrangement, the housing **100** defines or contains a conduit **102** for delivering the flow of breathing gas from the blower **92** to the humidification chamber **42** of the humidifier system **32**. When the housing is removed, an auxiliary conduit (not shown) can be utilized in place of the conduit **102**. Alternatively, an auxiliary conduit can be integrated with or otherwise incorporated with the housing **96** that is utilized when the housing **100** is removed. A valve arrangement could be configured to automatically switch between the conduit **102** and the auxiliary conduit depending on the presence or absence of the housing **100**.

With reference to FIG. **6**, in another modification of the systems of FIG. **1** and FIGS. **4** and **5**, the flow generator (hereinafter "blower **92**") is integrated with the humidifier **40** of the humidification system **32**. However, unlike the system of FIGS. **4** and **5**, the resuscitator **26** is a separate system component from the humidifier **40**, humidification chamber **42** or the entire humidifier system **32**. Thus, in the system of FIG. **6**, the blower **92** is connected to the resuscitator **26** via the supply line **24** to deliver the flow of air (or other breathing gas) from the blower **92** to the resuscitator **26**. The flow of air then flows from the resuscitator **26** to the humidification chamber **42** of the humidifier system **32** and to the patient **12** as described above. If the resuscitator **26** is not necessary or desired, the blower **92** can be connected to the humidification chamber **42** of the humidifier system **32**, without passing through the resuscitator **26**, via a suitable internal or external auxiliary conduit, as described above.

Although described in the context of an infant patient system, the illustrated system can be used in, or modified for use in, other applications or contexts, as well. Thus, although this invention has been disclosed in the context of certain preferred embodiments and examples, it will be understood by those skilled in the art that the present invention extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the invention and obvious modifications and equivalents thereof. In particular, the skilled artisan will appreciate, in view of the present disclosure, that certain advantages, features and aspects of the system may be realized in a variety of other applications, many of which have been noted above. Additionally, it is contemplated that various aspects and features of the invention described can be practiced separately, combined together, or substituted for one another, and that a variety of combination and subcombinations of the features and aspects can be made and still fall within the scope of the invention. Thus, it is intended that the scope of the present invention herein disclosed should not be limited by the

particular disclosed embodiments described above, but should be determined only by a fair reading of the claims.

What is claimed is:

1. A combination infant positive airway pressure and resuscitation system, comprising:

an integrated inspiratory pressure device comprising a resuscitator and a humidifier, wherein the resuscitator is capable of regulating a flow of breathing gas to a desired peak inspiration pressure, and wherein the humidifier humidifies the flow of breathing gas;

an expiratory pressure device configured to receive expiratory gases from an expiratory circuit and regulate the expiratory gases to a positive end expiration pressure; an occlusion device within the expiratory circuit, the occlusion device being separate from and upstream of the expiratory pressure device, wherein the occlusion device is manually-operated and configured to permit selective occlusion of the expiratory circuit at desired times to substantially completely block the flow of the expiratory gases through the expiratory circuit downstream of the occlusion device such that the pressure within the inspiratory circuit rises to the peak inspiration pressure of the resuscitator.

2. The combination infant positive airway pressure and resuscitation system of claim 1, wherein the resuscitator is separable from the humidifier.

3. The combination infant positive airway pressure and resuscitation system of claim 2, wherein the resuscitator is integrated with a first housing and the humidifier is integrated with a second housing.

4. The combination infant positive airway pressure and resuscitation system of claim 3, further comprising a flow generator that generates the flow of breathing gas.

5. The combination infant positive airway pressure and resuscitation system of claim 3, wherein the flow generator is integrated with the second housing.

6. The combination infant positive airway pressure and resuscitation system of claim 1, wherein the expiratory pressure device comprises a water resistance valve.

7. The combination infant positive airway pressure and resuscitation system of claim 6, wherein the water resistance valve is adjustable to permit adjustment of the positive end expiration pressure.

8. The combination infant positive airway pressure and resuscitation system of claim 1, wherein the occlusion device comprises a manual push button valve.

9. The combination infant positive airway pressure and resuscitation system of claim 1, wherein the occlusion device comprises a clamp.

10. The combination infant positive airway pressure and resuscitation system of claim 1, wherein the occlusion device is located less than 500 millimeters from a patient end of the expiratory circuit.

11. A combination infant positive airway pressure and resuscitation system, comprising:

an inspiratory pressure device that outputs a flow of breathing gas at a desired peak inspiration pressure;

an inspiratory circuit that receives the flow of breathing gas from the inspiratory pressure device;

a patient interface that receives the flow of breathing gas from the inspiratory circuit, wherein the patient interface is configured to deliver the flow of breathing gas to an infant patient and receive expiratory gases from the patient;

an expiratory circuit that receives the expiratory gases from the patient interface;

an expiratory pressure device that receives expiratory gases from the expiratory circuit and regulates the expiratory gases to a positive end expiration pressure; an occlusion device within the expiratory circuit, the occlusion device being separate from and upstream of the expiratory pressure device, wherein the occlusion device is manually-operated and configured to permit selective occlusion of the expiratory circuit at desired times to block the flow of the expiratory gases through the expiratory circuit to a sufficient extent downstream of the occlusion device such that the pressure within the inspiratory circuit rises to the peak inspiration pressure.

12. The combination infant positive airway pressure and resuscitation system of claim 11, wherein the expiratory pressure device comprises a water resistance valve.

13. The combination infant positive airway pressure and resuscitation system of claim 12, wherein the water resistance valve is adjustable to permit adjustment of the positive end expiration pressure.

14. The combination infant positive airway pressure and resuscitation system of claim 11, wherein the occlusion device comprises a manual push button valve.

15. The combination infant positive airway pressure and resuscitation system of claim 11, wherein the occlusion device comprises a clamp.

16. The combination infant positive airway pressure and resuscitation system of claim 11, further comprising a humidifier positioned within the inspiratory circuit between the inspiratory pressure device and the patient interface.

17. The combination infant positive airway pressure and resuscitation system of claim 11, wherein the occlusion device is located less than 500 millimeters from the patient interface along the expiratory circuit.

18. The combination infant positive airway pressure and resuscitation system of claim 11, wherein the expiratory circuit comprises an expiratory hose coupled to the patient interface and the occlusion device is located within the expiratory hose.

19. A breathing circuit for a combination infant positive airway pressure and resuscitation system, comprising:

an expiratory circuit that is configured for connection to a patient interface to receive expiratory gases from the patient interface;

an inspiratory circuit that is configured for connection to the patient interface to deliver a flow of breathing gas to the patient interface;

an occlusion device within the expiratory circuit, the occlusion device being separate from and upstream of an expiratory pressure device, wherein the occlusion device is manually-operated and configured to permit selective occlusion of the expiratory circuit at desired times to block the flow of the expiratory gases through the expiratory circuit to a sufficient extent downstream of the occlusion device such that the pressure within the system rises above a positive end expiration pressure.

20. The breathing circuit for a combination infant positive airway pressure and resuscitation system of claim 19, wherein the expiratory pressure device receives expiratory gases from the expiratory circuit and regulates the expiratory gases to a positive end expiration pressure.

21. The breathing circuit for a combination infant positive airway pressure and resuscitation system of claim 19, wherein the occlusion device comprises a manual push button valve.

22. The breathing circuit for a combination infant positive airway pressure and resuscitation system of claim 19, wherein the occlusion device comprises a clamp.

23. The breathing circuit for a combination infant positive airway pressure and resuscitation system of claim 19, wherein the occlusion device is located less than 500 millimeters from the patient interface along the expiratory circuit.

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24. The breathing circuit for a combination infant positive airway pressure and resuscitation system of claim 19, wherein the occlusion device is located in the expiratory circuit.

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