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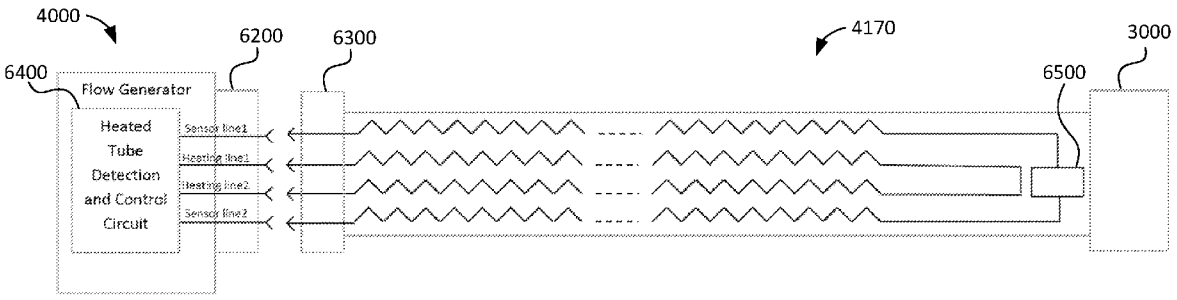

FIG. 5D

(57) Abstract: An apparatus may include: processing circuitry; a humidifier configured to humidify breathable gas; an air delivery tube configured to pass the humidified breathable gas to a patient interface, the air delivery tube including a heating element, a sensor configured to measure a property of the breathable gas, and a connector having a plurality of electrical tube contacts at least a portion of which are coupled to the heating element and the sensor; and a contact assembly including a plurality of electrical apparatus contacts configured to electrically couple the plurality of electrical tube contacts to the processing circuitry. The processing circuitry may be configured to determine a type of air delivery tube coupled to the humidifier based on (1) which electrical apparatus contacts are coupled to the heating element and/or the sensor, and/or (2) electrical characteristic measured via one or more electrical apparatus contacts.

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TUBE DETECTION SYSTEMS AND METHODS

1 CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of US Provisional Application No. 62/868,674, filed June 28, 2019, which is hereby incorporated herein by reference in its entirety. This application is related to US Provisional Application 62/835,094, filed on April 17, 2019, the contents of which is incorporated herein by reference in its entirety.

2 BACKGROUND OF THE TECHNOLOGY

2.1 FIELD OF THE TECHNOLOGY

[0002] The present technology relates to one or more of the screening, diagnosis, monitoring, treatment, prevention and amelioration of respiratory-related disorders. The present technology also relates to medical devices or apparatus, and their use, and more particularly to methods and systems for identifying a type of device (e.g., type of air delivery tube) coupled to an apparatus configured to provide a flow of breathable gas.

2.2 DESCRIPTION OF THE RELATED ART

2.2.1 Human Respiratory System and its Disorders

[0003] The respiratory system of the body facilitates gas exchange. The nose and mouth form the entrance to the airways of a patient.

[0004] The airways include a series of branching tubes, which become narrower, shorter and more numerous as they penetrate deeper into the lung. The prime function of the lung is gas exchange, allowing oxygen to move from the inhaled air into the venous blood and carbon dioxide to move in the opposite direction. The trachea divides into right and left main bronchi, which further divide eventually into terminal bronchioles. The bronchi make up the conducting airways, and do not take part in gas exchange. Further divisions of the airways lead to the respiratory bronchioles, and eventually to the alveoli. The alveolated region of the lung is where the gas exchange takes place, and is referred to as the respiratory zone. See "*Respiratory Physiology*", by John B. West, Lippincott Williams & Wilkins, 9th edition published 2012.

[0005] A range of respiratory disorders exist. Certain disorders may be characterised by particular events, e.g. apneas, hypopneas, and hyperpneas.

[0006] Examples of respiratory disorders include Obstructive Sleep Apnea (OSA), Cheyne-Stokes Respiration (CSR), respiratory insufficiency, Obesity Hyperventilation Syndrome (OHS), Chronic Obstructive Pulmonary Disease (COPD), Neuromuscular Disease (NMD) and Chest wall disorders.

[0007] Obstructive Sleep Apnea (OSA), a form of Sleep Disordered Breathing (SDB), is characterised by events including occlusion or obstruction of the upper air passage during sleep. It results from a combination of an abnormally small upper airway and the normal loss of muscle tone in the region of the tongue, soft palate and posterior oropharyngeal wall during sleep. The condition causes the affected patient to stop breathing for periods typically of 30 to 120 seconds in duration, sometimes 200 to 300 times per night. It often causes excessive daytime somnolence, and it may cause cardiovascular disease and brain damage. The syndrome is a common disorder, particularly in middle aged overweight males, although a person affected may have no awareness of the problem. See US Patent No. 4,944,310 (Sullivan).

[0008] Cheyne-Stokes Respiration (CSR) is another form of sleep disordered breathing. CSR is a disorder of a patient's respiratory controller in which there are rhythmic alternating periods of waxing and waning ventilation known as CSR cycles. CSR is characterised by repetitive de-oxygenation and re-oxygenation of the arterial blood. It is possible that CSR is harmful because of the repetitive hypoxia. In some patients CSR is associated with repetitive arousal from sleep, which causes severe sleep disruption, increased sympathetic activity, and increased afterload. See US Patent No. 6,532,959 (Berthon-Jones).

[0009] Respiratory failure is an umbrella term for respiratory disorders in which the lungs are unable to inspire sufficient oxygen or exhale sufficient CO_2 to meet the patient's needs. Respiratory failure may encompass some or all of the following disorders.

[0010] A patient with respiratory insufficiency (a form of respiratory failure) may experience abnormal shortness of breath on exercise.

[0011] Obesity Hyperventilation Syndrome (OHS) is defined as the combination of severe obesity and awake chronic hypercapnia, in the absence of other known causes for hypoventilation. Symptoms include dyspnea, morning headache and excessive daytime sleepiness.

[0012] Chronic Obstructive Pulmonary Disease (COPD) encompasses any of a group of lower airway diseases that have certain characteristics in common. These include increased resistance to air movement, extended expiratory phase of respiration, and loss of the normal elasticity of the lung. Examples of COPD are emphysema and chronic bronchitis. COPD is caused by chronic tobacco smoking (primary risk factor), occupational exposures, air pollution and genetic factors. Symptoms include: dyspnea on exertion, chronic cough and sputum production.

[0013] Neuromuscular Disease (NMD) is a broad term that encompasses many diseases and ailments that impair the functioning of the muscles either directly via intrinsic muscle pathology, or indirectly via nerve pathology. Some NMD patients are characterised by progressive muscular impairment leading to loss of ambulation, being wheelchair-bound, swallowing difficulties, respiratory muscle weakness and, eventually, death from respiratory failure. Neuromuscular disorders can be divided into rapidly progressive and slowly progressive: (i) Rapidly progressive disorders: Characterised by muscle impairment that worsens over months and results in death within a few years (e.g. Amyotrophic lateral sclerosis (ALS) and Duchenne muscular dystrophy (DMD) in teenagers); (ii) Variable or slowly progressive disorders: Characterised by muscle impairment that worsens over years and only mildly reduces life expectancy (e.g. Limb girdle, Facioscapulohumeral and Myotonic muscular dystrophy). Symptoms of respiratory failure in NMD include: increasing generalised weakness, dysphagia, dyspnea on exertion and at rest, fatigue, sleepiness, morning headache, and difficulties with concentration and mood changes.

[0014] Chest wall disorders are a group of thoracic deformities that result in inefficient coupling between the respiratory muscles and the thoracic cage. The disorders are usually characterised by a restrictive defect and share the potential of long term hypercapnic respiratory failure. Scoliosis and/or kyphoscoliosis may cause severe respiratory failure. Symptoms of respiratory failure include: dyspnea on

exertion, peripheral oedema, orthopnea, repeated chest infections, morning headaches, fatigue, poor sleep quality and loss of appetite.

[0015] A range of therapies have been used to treat or ameliorate such conditions. Furthermore, otherwise healthy individuals may take advantage of such therapies to prevent respiratory disorders from arising. However, these have a number of shortcomings.

2.2.2 Therapies

[0016] Various respiratory therapies, such as Continuous Positive Airway Pressure (CPAP) therapy, Non-invasive ventilation (NIV), Invasive ventilation (IV), and High Flow Therapy (HFT) have been used to treat one or more of the above respiratory disorders.

2.2.2.1 Respiratory pressure therapies

[0017] Respiratory pressure therapy is the application of a supply of air to an entrance to the airways at a controlled target pressure that is nominally positive with respect to atmosphere throughout the patient's breathing cycle (in contrast to negative pressure therapies such as the tank ventilator or cuirass).

[0018] Continuous Positive Airway Pressure (CPAP) therapy has been used to treat Obstructive Sleep Apnea (OSA). The mechanism of action is that continuous positive airway pressure acts as a pneumatic splint and may prevent upper airway occlusion, such as by pushing the soft palate and tongue forward and away from the posterior oropharyngeal wall. Treatment of OSA by CPAP therapy may be voluntary, and hence patients may elect not to comply with therapy if they find devices used to provide such therapy one or more of: uncomfortable, difficult to use, expensive and aesthetically unappealing.

[0019] Non-invasive ventilation (NIV) provides ventilatory support to a patient through the upper airways to assist the patient breathing and/or maintain adequate oxygen levels in the body by doing some or all of the work of breathing. The ventilatory support is provided via a non-invasive patient interface. NIV has been used to treat CSR and respiratory failure, in forms such as OHS, COPD, NMD and

Chest Wall disorders. In some forms, the comfort and effectiveness of these therapies may be improved.

[0020] Invasive ventilation (IV) provides ventilatory support to patients that are no longer able to effectively breathe themselves and may be provided using a tracheostomy tube. In some forms, the comfort and effectiveness of these therapies may be improved.

2.2.2.2 Flow therapies

[0021] Not all respiratory therapies aim to deliver a prescribed therapeutic pressure. Some respiratory therapies aim to deliver a prescribed respiratory volume, by delivering an inspiratory flow rate profile over a targeted duration, possibly superimposed on a positive baseline pressure. In other cases, the interface to the patient's airways is 'open' (unsealed) and the respiratory therapy may only supplement the patient's own spontaneous breathing with a flow of conditioned or enriched gas. In one example, High Flow therapy (HFT) is the provision of a continuous, heated, humidified flow of air to an entrance to the airway through an unsealed or open patient interface at a "treatment flow rate" that is held approximately constant throughout the respiratory cycle. The treatment flow rate is nominally set to exceed the patient's peak inspiratory flow rate. HFT has been used to treat OSA, CSR, respiratory failure, COPD, and other respiratory disorders. One mechanism of action is that the high flow rate of air at the airway entrance improves ventilation efficiency by flushing, or washing out, expired CO_2 from the patient's anatomical deadspace. Hence, HFT is thus sometimes referred to as a deadspace therapy (DST). Other benefits may include the elevated warmth and humidification (possibly of benefit in secretion management) and the potential for modest elevation of airway pressures. As an alternative to constant flow rate, the treatment flow rate may follow a profile that varies over the respiratory cycle.

[0022] Another form of flow therapy is long-term oxygen therapy (LTOT) or supplemental oxygen therapy. Doctors may prescribe a continuous flow of oxygen enriched gas at a specified oxygen concentration (from 21%, the oxygen fraction in ambient air, to 100%) at a specified flow rate (e.g., 1 litre per minute (LPM), 2 LPM, 3 LPM, etc.) to be delivered to the patient's airway.

2.2.2.3 Supplementary oxygen

[0023] For certain patients, oxygen therapy may be combined with a respiratory pressure therapy or HFT by adding supplementary oxygen to the pressurised flow of air. When oxygen is added to respiratory pressure therapy, this is referred to as RPT with supplementary oxygen. When oxygen is added to HFT, the resulting therapy is referred to as HFT with supplementary oxygen.

2.2.3 Respiratory therapy Systems

[0024] These respiratory therapies may be provided by a respiratory therapy system or device. Such systems and devices may also be used to screen, diagnose, or monitor a condition without treating it.

[0025] A respiratory therapy system may comprise a Respiratory Pressure Therapy Device (RPT device), an air circuit, a humidifier, a patient interface, an oxygen source, and data management.

[0026] Another form of therapy system is a mandibular repositioning device.

2.2.3.1 Patient Interface

[0027] A patient interface may be used to interface respiratory equipment to its wearer, for example by providing a flow of air to an entrance to the airways. The flow of air may be provided via a mask to the nose and/or mouth, a tube to the mouth or a tracheostomy tube to the trachea of a patient. Depending upon the therapy to be applied, the patient interface may form a seal, e.g., with a region of the patient's face, to facilitate the delivery of gas at a pressure at sufficient variance with ambient pressure to effect therapy, e.g., at a positive pressure of about 10 cmH_2O relative to ambient pressure. For other forms of therapy, such as the delivery of oxygen, the patient interface may not include a seal sufficient to facilitate delivery to the airways of a supply of gas at a positive pressure of about 10 cmH_2O. For flow therapies such as nasal HFT, the patient interface is configured to insufflate the nares but specifically to avoid a complete seal. One example of such a patient interface is a nasal cannula.

[0028] Certain other mask systems may be functionally unsuitable for the present field. For example, purely ornamental masks may be unable to maintain a suitable pressure. Mask systems used for underwater swimming or diving may be configured

to guard against ingress of water from an external higher pressure, but not to maintain air internally at a higher pressure than ambient.

[0029] Certain masks may be clinically unfavourable for the present technology e.g. if they block airflow via the nose and only allow it via the mouth.

[0030] Certain masks may be uncomfortable or impractical for the present technology if they require a patient to insert a portion of a mask structure in their mouth to create and maintain a seal via their lips.

[0031] Certain masks may be impractical for use while sleeping, e.g. for sleeping while lying on one's side in bed with a head on a pillow.

[0032] The design of a patient interface presents a number of challenges. The face has a complex three-dimensional shape. The size and shape of noses and heads varies considerably between individuals. Since the head includes bone, cartilage and soft tissue, different regions of the face respond differently to mechanical forces. The jaw or mandible may move relative to other bones of the skull. The whole head may move during the course of a period of respiratory therapy.

[0033] As a consequence of these challenges, some masks suffer from being one or more of obtrusive, aesthetically undesirable, costly, poorly fitting, difficult to use, and uncomfortable especially when worn for long periods of time or when a patient is unfamiliar with a system. Wrongly sized masks can give rise to reduced compliance, reduced comfort and poorer patient outcomes. Masks designed solely for aviators, masks designed as part of personal protection equipment (e.g. filter masks), SCUBA masks, or for the administration of anaesthetics may be tolerable for their original application, but nevertheless such masks may be undesirably uncomfortable to be worn for extended periods of time, e.g., several hours. This discomfort may lead to a reduction in patient compliance with therapy. This is even more so if the mask is to be worn during sleep.

[0034] CPAP therapy is highly effective to treat certain respiratory disorders, provided patients comply with therapy. If a mask is uncomfortable, or difficult to use a patient may not comply with therapy. Since it is often recommended that a patient regularly wash their mask, if a mask is difficult to clean (e.g., difficult to assemble or

disassemble), patients may not clean their mask and this may impact on patient compliance.

[0035] While a mask for other applications (e.g. aviators) may not be suitable for use in treating sleep disordered breathing, a mask designed for use in treating sleep disordered breathing may be suitable for other applications.

[0036] For these reasons, patient interfaces for delivery of CPAP during sleep form a distinct field.

[0037] Respiratory Pressure Therapy (RPT) Device

[0038] A respiratory pressure therapy (RPT) device may be used individually or as part of a system to deliver one or more of a number of therapies described above, such as by operating the device to generate a flow of air for delivery to an interface to the airways. The flow of air may be pressure-controlled (for respiratory pressure therapies) or flow-controlled (for flow therapies such as HFT). Thus RPT devices may also act as flow therapy devices. Examples of RPT devices include a CPAP device and a ventilator.

[0039] Air pressure generators are known in a range of applications, e.g. industrial-scale ventilation systems. However, air pressure generators for medical applications have particular requirements not fulfilled by more generalised air pressure generators, such as the reliability, size and weight requirements of medical devices. In addition, even devices designed for medical treatment may suffer from shortcomings, pertaining to one or more of: comfort, noise, ease of use, efficacy, size, weight, manufacturability, cost, and reliability.

[0040] An example of the special requirements of certain RPT devices is acoustic noise.

[0041] Table of noise output levels of prior RPT devices (one specimen only, measured using test method specified in ISO 3744 in CPAP mode at 10 cmH_2O).

RPT Device name	A-weighted sound pressure level dB(A)	Year (approx.)
C-Series Tango™	31.9	2007

C-Series Tango™ with Humidifier	33.1	2007
S8 Escape™ II	30.5	2005
S8 Escape™ II with H4i™ Humidifier	31.1	2005
S9 AutoSet™	26.5	2010
S9 AutoSet™ with H5i Humidifier	28.6	2010

[0042] One known RPT device used for treating sleep disordered breathing is the S9 Sleep Therapy System, manufactured by ResMed Limited. Another example of an RPT device is a ventilator. Ventilators such as the ResMed Stellar™ Series of Adult and Paediatric Ventilators may provide support for invasive and non-invasive non-dependent ventilation for a range of patients for treating a number of conditions such as but not limited to NMD, OHS and COPD.

[0043] The ResMed Elisée™ 150 ventilator and ResMed VS III™ ventilator may provide support for invasive and non-invasive dependent ventilation suitable for adult or paediatric patients for treating a number of conditions. These ventilators provide volumetric and barometric ventilation modes with a single or double limb circuit. RPT devices typically comprise a pressure generator, such as a motor-driven blower or a compressed gas reservoir, and are configured to supply a flow of air to the airway of a patient. In some cases, the flow of air may be supplied to the airway of the patient at positive pressure. The outlet of the RPT device is connected via an air circuit to a patient interface such as those described above.

[0044] The designer of a device may be presented with an infinite number of choices to make. Design criteria often conflict, meaning that certain design choices are far from routine or inevitable. Furthermore, the comfort and efficacy of certain aspects may be highly sensitive to small, subtle changes in one or more parameters.

2.2.3.2 Air circuit

[0045] An air circuit is a conduit or a tube constructed and arranged to allow, in use, a flow of air to travel between two components of a respiratory therapy system such as the RPT device and the patient interface. In some cases, there may be separate limbs of the air circuit for inhalation and exhalation. In other cases, a single limb air circuit is used for both inhalation and exhalation.

2.2.3.3 Humidifier

[0046] Delivery of a flow of air without humidification may cause drying of airways. The use of a humidifier with an RPT device and the patient interface produces humidified gas that minimizes drying of the nasal mucosa and increases patient airway comfort. In addition in cooler climates, warm air applied generally to the face area in and about the patient interface is more comfortable than cold air. Humidifiers therefore often have the capacity to heat the flow of air was well as humidifying it.

[0047] A range of artificial humidification devices and systems are known, however they may not fulfil the specialised requirements of a medical humidifier.

[0048] Medical humidifiers are used to increase humidity and/or temperature of the flow of air in relation to ambient air when required, typically where the patient may be asleep or resting (e.g. at a hospital). A medical humidifier for bedside placement may be small. A medical humidifier may be configured to only humidify and/or heat the flow of air delivered to the patient without humidifying and/or heating the patient's surroundings. Room-based systems (e.g. a sauna, an air conditioner, or an evaporative cooler), for example, may also humidify air that is breathed in by the patient, however those systems would also humidify and/or heat the entire room, which may cause discomfort to the occupants. Furthermore medical humidifiers may have more stringent safety constraints than industrial humidifiers

[0049] While a number of medical humidifiers are known, they can suffer from one or more shortcomings. Some medical humidifiers may provide inadequate humidification, some are difficult or inconvenient to use by patients.

2.2.3.4 Oxygen source

[0050] Experts in this field have recognized that exercise for respiratory failure patients provides long term benefits that slow the progression of the disease, improve quality of life and extend patient longevity. Most stationary forms of exercise like tread mills and stationary bicycles, however, are too strenuous for these patients. As a result, the need for mobility has long been recognized. Until recently, this mobility has been facilitated by the use of small compressed oxygen tanks or cylinders mounted on a cart with dolly wheels. The disadvantage of these tanks is that they

contain a finite amount of oxygen and are heavy, weighing about 50 pounds when mounted.

[0051] Oxygen concentrators have been in use for about 50 years to supply oxygen for respiratory therapy. Traditional oxygen concentrators have been bulky and heavy making ordinary ambulatory activities with them difficult and impractical. Recently, companies that manufacture large stationary oxygen concentrators began developing portable oxygen concentrators (POCs). The advantage of POCs is that they can produce a theoretically endless supply of oxygen. In order to make these devices small for mobility, the various systems necessary for the production of oxygen enriched gas are condensed. POCs seek to utilize their produced oxygen as efficiently as possible, in order to minimise weight, size, and power consumption. This may be achieved by delivering the oxygen as series of pulses or "boli", each bolus timed to coincide with the start of inspiration. This therapy mode is known as pulsed or demand (oxygen) delivery (POD), in contrast with traditional continuous flow delivery more suited to stationary oxygen concentrators.

2.2.3.5 Data Management

[0052] There may be clinical reasons to obtain data to determine whether the patient prescribed with respiratory therapy has been "compliant", e.g. that the patient has used their RPT device according to one or more "compliance rules". One example of a compliance rule for CPAP therapy is that a patient, in order to be deemed compliant, is required to use the RPT device for at least four hours a night for at least 21 of 30 consecutive days. In order to determine a patient's compliance, a provider of the RPT device, such as a health care provider, may manually obtain data describing the patient's therapy using the RPT device, calculate the usage over a predetermined time period, and compare with the compliance rule. Once the health care provider has determined that the patient has used their RPT device according to the compliance rule, the health care provider may notify a third party that the patient is compliant.

[0053] There may be other aspects of a patient's therapy that would benefit from communication of therapy data to a third party or external system.

[0054] Existing processes to communicate and manage such data can be one or more of costly, time-consuming, and error-prone.

2.2.3.6 Mandibular repositioning

[0055] A mandibular repositioning device (MRD) or mandibular advancement device (MAD) is one of the treatment options for sleep apnea and snoring. It is an adjustable oral appliance available from a dentist or other supplier that holds the lower jaw (mandible) in a forward position during sleep. The MRD is a removable device that a patient inserts into their mouth prior to going to sleep and removes following sleep. Thus, the MRD is not designed to be worn all of the time. The MRD may be custom made or produced in a standard form and includes a bite impression portion designed to allow fitting to a patient's teeth. This mechanical protrusion of the lower jaw expands the space behind the tongue, puts tension on the pharyngeal walls to reduce collapse of the airway and diminishes palate vibration.

[0056] In certain examples a mandibular advancement device may comprise an upper splint that is intended to engage with or fit over teeth on the upper jaw or maxilla and a lower splint that is intended to engage with or fit over teeth on the upper jaw or mandible. The upper and lower splints are connected together laterally via a pair of connecting rods. The pair of connecting rods are fixed symmetrically on the upper splint and on the lower splint.

[0057] In such a design the length of the connecting rods is selected such that when the MRD is placed in a patient's mouth the mandible is held in an advanced position. The length of the connecting rods may be adjusted to change the level of protrusion of the mandible. A dentist may determine a level of protrusion for the mandible that will determine the length of the connecting rods.

[0058] Some MRDs are structured to push the mandible forward relative to the maxilla while other MADs, such as the ResMed Narval CC™ MRD are designed to retain the mandible in a forward position. This device also reduces or minimises dental and temporo-mandibular joint (TMJ) side effects. Thus, it is configured to minimises or prevent any movement of one or more of the teeth.

2.2.4 Screening, Diagnosis, and Monitoring Systems

[0059] Polysomnography (PSG) is a conventional system for diagnosis and monitoring of cardio-pulmonary disorders, and typically involves expert clinical staff to apply the system. PSG typically involves the placement of 15 to 20 contact sensors

on a patient in order to record various bodily signals such as electroencephalography (EEG), electrocardiography (ECG), electrooculograpy (EOG), electromyography (EMG), etc. PSG for sleep disordered breathing has involved two nights of observation of a patient in a clinic, one night of pure diagnosis and a second night of titration of treatment parameters by a clinician. PSG is therefore expensive and inconvenient. In particular it is unsuitable for home screening / diagnosis / monitoring of sleep disordered breathing.

[0060] Screening and diagnosis generally describe the identification of a condition from its signs and symptoms. Screening typically gives a true / false result indicating whether or not a patient's SDB is severe enough to warrant further investigation, while diagnosis may result in clinically actionable information. Screening and diagnosis tend to be one-off processes, whereas monitoring the progress of a condition can continue indefinitely. Some screening / diagnosis systems are suitable only for screening / diagnosis, whereas some may also be used for monitoring.

[0061] Clinical experts may be able to screen, diagnose, or monitor patients adequately based on visual observation of PSG signals. However, there are circumstances where a clinical expert may not be available, or a clinical expert may not be affordable. Different clinical experts may disagree on a patient's condition. In addition, a given clinical expert may apply a different standard at different times.

3 BRIEF SUMMARY OF THE TECHNOLOGY

[0062] The present technology is directed towards providing medical devices used in the screening, diagnosis, monitoring, amelioration, treatment, or prevention of respiratory disorders having one or more of improved comfort, cost, efficacy, ease of use and manufacturability.

[0063] A first aspect of the present technology relates to apparatus used in the screening, diagnosis, monitoring, amelioration, treatment or prevention of a respiratory disorder.

[0064] Another aspect of the present technology relates to methods used in the screening, diagnosis, monitoring, amelioration, treatment or prevention of a respiratory disorder.

[0065] An aspect of certain forms of the present technology is to provide methods and/or apparatus that improve the compliance of patients with respiratory therapy.

[0066] One form of the present technology comprises identifying a type of air delivery tube coupled to an apparatus so that operation of apparatus can be optimized for the identified air delivery tube.

[0067] Another aspect of the present technology relates to processing circuitry configured to identify a type of air delivery tube coupled to an apparatus for humidifying a flow of breathable gas based which electrical contacts of the apparatus are used by contacts of the air delivery tube.

[0068] Another aspect of the present technology relates to processing circuitry configured to identify a type of air delivery tube coupled to an apparatus for humidifying a flow of breathable gas based on measured characteristics of a passive or active circuit component in the air delivery tube.

[0069] Another aspect of the present technology relates to processing circuitry configured to identify a type of air delivery tube coupled to an apparatus for humidifying a flow of breathable gas based on measuring characteristics of circuitry in the air delivery tube that is not part of the sensing circuit used for measuring temperature in the air delivery tube. The characteristics of the circuitry may include presence or absence of a resistance value on one or more electrical connections of the air delivery tube.

[0070] Another aspect of the present technology relates to a respiratory treatment apparatus including processing circuitry configured to identify a type of air delivery tube coupled to a humidifier and/or a flow generator of the apparatus based on measured circuitry characteristics of the air delivery tube that is not part of the sensing circuit used for measuring temperature in the air delivery tube. The characteristics of the circuitry may include presence or absence of a connection and/or a resistance value on one or more electrical connections of the air delivery tube.

[0071] Another aspect of the present technology relates to an apparatus including processing circuitry; a humidifier configured to humidify breathable gas; an air delivery tube configured to pass the humidified breathable gas to a patient interface, the air delivery tube including a heating element, a sensor configured to measure a property of the breathable gas, and a connector having a plurality of electrical tube contacts, at least a portion of the electrical tube contacts coupled to the heating element and the sensor; and a contact assembly including a plurality of electrical apparatus contacts configured to electrically couple the plurality of electrical tube contacts to the processing circuitry. The processing circuitry may be configured to determine a type of air delivery tube coupled to the humidifier based on (1) which electrical apparatus contacts are coupled to the heating element and/or the sensor, and/or (2) electrical characteristic measured via one or more electrical apparatus contacts.

[0072] Another aspect of the present technology is directed to an apparatus for humidifying a flow of breathable gas, comprising: processing circuitry; a humidifier configured to humidify breathable gas; an air delivery tube configured to pass the humidified breathable gas to a patient interface, the air delivery tube including one or more heating elements extending along at least a portion of the length of the air delivery tube, a sensor configured to measure a property of the humidified breathable gas in the air delivery tube, and a connector having a plurality of electrical tube contacts; and a contact assembly including a plurality of electrical apparatus contacts configured to electrically couple the plurality of electrical tube contacts to the processing circuitry, wherein the one or more heating elements and the sensor are coupled to the electrical tube contacts, and the electrical tube contacts are adapted to electrically engage only a portion of electrical apparatus contacts in an operative configuration of the apparatus.

[0073] In examples of the preceding aspects: (a) the processing circuitry may be configured to control, based on a signal received from the sensor, operation of the one or more heating elements and the humidifier, and determine, based on which electrical apparatus contacts of the contact assembly are coupled to the electrical tube contacts in the operative configuration of the apparatus, a type of the air delivery tube coupled to the apparatus; (b) the processing circuitry may be configured to determine, based

on which electrical apparatus contacts of the contact assembly are coupled to the electrical tube contacts in the operative configuration of the apparatus, a type of the air delivery tube coupled to the apparatus; (c) the processing circuitry may be configured to control, based on the determined type of air delivery tube, operation of the one or more heating elements and/or the humidifier; (d) the processing circuitry may be configured to determine the type of the air delivery tube coupled to the apparatus based on absence of a connection by one or more electrical apparatus contacts to the heating element and/or the sensor; (e) the contact assembly may include only four electrical apparatus contacts, a first pair of the electrical apparatus contacts configured to electrically couple to the one or more heating elements, and only one contact of a second pair of electrical apparatus contacts configured to electrically couple to the sensor; (f) the processing circuitry may determine the type of the air delivery tube coupled to the apparatus based which one of the second pair of electrical apparatus contacts is coupled to the sensor; (g) the contact assembly may include only four electrical apparatus contacts, a first pair of the electrical apparatus contacts are configured to electrically couple to the one or more heating elements, and the processing circuit may be configured to determine that a first type of air delivery tube is coupled to the apparatus when a first contact of a second pair of the electrical apparatus contacts is not coupled to the sensor, and determine that a second type of air delivery tube is coupled to the apparatus when a second contact of a second pair of the electrical apparatus contacts is not coupled to the sensor; (h) the contact assembly may include only four electrical apparatus contacts and the air delivery tube may include only three electrical tube contacts configured to couple to the electrical apparatus contacts; and/or (i) the processing circuitry may be configured to determine, based on which electrical apparatus contact of the contact assembly is not coupled to the electrical tube contacts, a type of the air delivery tube coupled to the apparatus.

[0074] Another aspect of the present technology is directed to an apparatus for humidifying a flow of breathable gas, comprising: processing circuitry; a humidifier configured to humidify breathable gas; an air delivery tube configured to pass the humidified breathable gas to a patient interface, the air delivery tube including one or more heating elements extending along at least a portion of the length of the air delivery tube, a sensor configured to measure a property of the breathable gas in the air delivery tube, and a connector having a plurality of electrical tube contacts; and a

contact assembly including a plurality of electrical apparatus contacts configured to electrically couple to the plurality of electrical tube contacts to the processing circuitry in an operative configuration of the apparatus, wherein the one or more heating elements and the sensor are coupled to a set of the electrical tube contacts configured to electrically couple to the corresponding electrical apparatus contacts in the operative configuration of the apparatus, and the processing circuit is configured to determine a type of air delivery tube coupled to the apparatus based on an electrical characteristic measured by the processing circuit via another electrical apparatus contact of the contact assembly.

[0075] In examples of the preceding aspects: (a) the processing circuitry may be configured to control, based on a signal received from the sensor, operation of the one or more heating elements and the humidifier; (b) the measured characteristic may include a voltage set based on a resistive element disposed in the air deliver tube and coupled to the other electrical apparatus contact and an electrical tube contact configured to electrically couple to heating element; (c) the processing circuitry may be configured to determine that a first type of air delivery tube is coupled to the apparatus when the measured characteristic indicates zero volts and that a second type of air delivery tube is coupled to the apparatus when the measured characteristic indicates a voltage greater than zero; (d) the air delivery tube may include a resistor or a shunt coupled between a contact of the set of the electrical tube contacts and an electrical tube contact configured to electrically couple to the other electrical apparatus contact; (e) the processing circuitry may be configured to control, based on the determined type of air delivery tube, operation of the one or more heating elements and the humidifier; and/or (f) the contact assembly may include only four electrical apparatus contacts and the air delivery tube includes only three electrical tube contacts configured to couple to the electrical apparatus contacts.

[0076] Another aspect of the present technology is directed to a respiratory treatment apparatus comprising: a power supply; a processing system; a pressure generator configured to generate a flow of breathable gas; a humidifier configured to store a supply of water to humidify the breathable gas and comprising a first heating element configured to heat the supply of water; an air delivery tube configured to pass the flow of breathable gas that has been humidified to a patient, the air delivery tube

including second heating element configured to heat the humidified breathable gas in the air delivery tube and a thermistor configured go generate a temperate signal representing a temperature of the humidified breathable gas in the air delivery tube; a transducer configured to generate a flow signal representing a property of the flow of breathable gas; and a contact assembly configured to mechanically couple the air delivery tube to the humidifier and electrically couple a plurality of main contacts coupled to the processing system to a plurality of tube contacts coupled to the second heating element and the thermistor, wherein only a portion of the main contacts are coupled to corresponding tube contacts in an operative configuration of the respiratory treatment apparatus. The processing system may be configured to: determine, based on signal values received from one or more main contacts, which of the main contacts are coupled to the second heating element and the thermistor via the tube contacts; determine, based on which of the main contacts are determined to be coupled to the second heating element and the thermistor, a type of air delivery tube coupled to the humidifier; and based on the determined tube type, the flow signal and the temperate signal, determine (1) a first control signal for controlling the first heating element (2) a second control signal for controlling the second heating element, and (3) a third control signal for controlling the pressure generator.

[0077] In examples of the preceding aspects: the contact assembly includes two main contacts configured to electrically coupled to two tube contacts coupled to the second heating element, and two additional main contacts configured to couple to two additional tube contact of which only one is coupled to the thermistor, and the processing system is configured to determine the type of air delivery tube coupled to the humidifier based on which one of the two additional main contacts is coupled to the thermistor via the tube contact.

[0078] Another aspect of one form of the present technology is a patient interface that is moulded or otherwise constructed with a perimeter shape which is complementary to that of an intended wearer.

[0079] An aspect of one form of the present technology is a method of manufacturing apparatus.

[0080] An aspect of certain forms of the present technology is a medical device that is easy to use, e.g. by a person who does not have medical training, by a person who has limited dexterity, vision or by a person with limited experience in using this type of medical device.

[0081] An aspect of one form of the present technology is a portable RPT device that may be carried by a person, e.g., around the home of the person.

[0082] An aspect of one form of the present technology is a patient interface that may be washed in a home of a patient, e.g., in soapy water, without requiring specialised cleaning equipment. An aspect of one form of the present technology is a humidifier tank that may be washed in a home of a patient, e.g., in soapy water, without requiring specialised cleaning equipment.

[0083] The methods, systems, devices and apparatus described may be implemented so as to improve the functionality of a processor, such as a processor of a specific purpose computer, respiratory monitor and/or a respiratory therapy apparatus. Moreover, the described methods, systems, devices and apparatus can provide improvements in the technological field of automated management, monitoring and/or treatment of respiratory conditions, including, for example, sleep disordered breathing.

[0084] Of course, portions of the aspects may form sub-aspects of the present technology. Also, various ones of the sub-aspects and/or aspects may be combined in various manners and also constitute additional aspects or sub-aspects of the present technology.

[0085] Other features of the technology will be apparent from consideration of the information contained in the following detailed description, abstract, drawings and claims.

4 BRIEF DESCRIPTION OF THE DRAWINGS

[0086] The present technology is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings, in which like reference numerals refer to similar elements including:

4.1 RESPIRATORY THERAPY SYSTEMS

[0087] Fig. 1 shows a system including a patient 1000 wearing a patient interface 3000, in the form of nasal pillows, receiving a supply of air at positive pressure from an RPT device 4000. Air from the RPT device 4000 is conditioned in a humidifier 5000, and passes along an air circuit 4170 to the patient 1000. A bed partner 1100 is also shown. The patient is sleeping in a supine sleeping position.

[0088] Fig. 2 shows a system including a patient 1000 wearing a patient interface 3000, in the form of a nasal mask, receiving a supply of air at positive pressure from an RPT device 4000. Air from the RPT device is humidified in a humidifier 5000, and passes along an air circuit 4170 to the patient 1000.

[0089] Fig. 3 shows a system including a patient 1000 wearing a patient interface 3000, in the form of a full-face mask, receiving a supply of air at positive pressure from an RPT device 4000. Air from the RPT device is humidified in a humidifier 5000, and passes along an air circuit 4170 to the patient 1000. The patient is sleeping in a side sleeping position.

4.2 RPT DEVICE

[0090] Fig. 4A shows an RPT device in accordance with one form of the present technology.

[0091] Fig. 4B is a schematic diagram of the pneumatic path of an RPT device in accordance with one form of the present technology. The directions of upstream and downstream are indicated with reference to the blower and the patient interface. The blower is defined to be upstream of the patient interface and the patient interface is defined to be downstream of the blower, regardless of the actual flow direction at any particular moment. Items which are located within the pneumatic path between the blower and the patient interface are downstream of the blower and upstream of the patient interface.

[0092] Fig. 4C is a schematic diagram of the electrical components of an RPT device in accordance with one form of the present technology.

[0093] Fig. 4D is a schematic diagram of the algorithms implemented in an RPT device in accordance with one form of the present technology.

[0094] Fig. 4E is a flow chart illustrating a method carried out by the therapy engine module of Fig. 4D in accordance with one form of the present technology.

4.3 HUMIDIFIER

[0095] Fig. 5A shows an isometric view of a humidifier in accordance with one form of the present technology.

[0096] Fig. 5B shows an isometric view of a humidifier in accordance with one form of the present technology, showing a humidifier reservoir 5110 removed from the humidifier reservoir dock 5130.

[0097] Fig. 5C shows a schematic of a humidifier in accordance with one form of the present technology.

4.4 TUBE TYPE IDENTIFICATION

[0098] Fig. 5D shows a schematic view of an air delivery tube including four wires connected to an RPT device in accordance with one form of the present technology.

[0099] Fig. 5E shows a schematic view of an air delivery tube including three wires connected to an RPT device in accordance with one form of the present technology.

[0100] Fig. 5F shows a schematic view of an air delivery tube including three wires connected to an RPT device in accordance with another form of the present technology.

[0101] Fig. 5G shows a schematic view of an air delivery tube connected to an RPT device including a detection line for identifying a tube type, in accordance with one form of the present technology.

[0102] Fig. 5H shows a schematic view of an air delivery tube connected to an RPT device including a detection line for identifying a tube type, in accordance with one form of the present technology.

[0103] Fig. 5I illustrates an example heated tube detection circuit in accordance with one form of the present technology.

[0104] Fig. 5J illustrates another example heated tube detection circuit in accordance with one form of the present technology.

4.5 BREATHING WAVEFORMS

[0105] Fig. 6A shows a model typical breath waveform of a person while sleeping.

[0106] Fig. 6B shows selected polysomnography channels (pulse oximetry, flow rate, thoracic movement, and abdominal movement) of a patient during non-REM sleep breathing normally over a period of about ninety seconds.

[0107] Fig. 6C shows polysomnography of a patient before treatment.

[0108] Fig. 6D shows patient flow rate data where the patient is experiencing a series of total obstructive apneas.

[0109] Fig. 6E shows a scaled inspiratory portion of a breath where the patient is experiencing low frequency inspiratory snore.

[0110] Fig. 6F shows a scaled inspiratory portion of a breath where the patient is experiencing an example of flattened inspiratory flow limitation.

[0111] Fig. 6G shows a scaled inspiratory portion of a breath where the patient is experiencing an example of “mesa” flattened inspiratory flow limitation.

[0112] Fig. 6H shows a scaled inspiratory portion of a breath where the patient is experiencing an example of “panda ears” inspiratory flow limitation.

[0113] Fig. 6I shows a scaled inspiratory portion of a breath where the patient is experiencing an example of "chair" inspiratory flow limitation.

[0114] Fig. 6J shows a scaled inspiratory portion of a breath where the patient is experiencing an example of "reverse chair" inspiratory flow limitation.

[0115] Fig. 6K shows a scaled inspiratory portion of a breath where the patient is experiencing an example of “M-shaped” inspiratory flow limitation.

[0116] Fig. 6L shows a scaled inspiratory portion of a breath where the patient is experiencing an example of severely "M-shaped" inspiratory flow limitation.

[0117] Fig. 6M shows patient data from a patient with Cheyne-Stokes respiration.

[0118] Fig. 6N shows patient data from a patient with another example of Cheyne-Stokes respiration, using the same three channels as in Fig. 6M.

5 DETAILED DESCRIPTION OF EXAMPLES OF THE TECHNOLOGY

[0119] Before the present technology is described in further detail, it is to be understood that the technology is not limited to the particular examples described herein, which may vary. It is also to be understood that the terminology used in this disclosure is for the purpose of describing only the particular examples discussed herein, and is not intended to be limiting.

[0120] The following description is provided in relation to various examples which may share one or more common characteristics and/or features. It is to be understood that one or more features of any one example may be combinable with one or more features of another example or other examples. In addition, any single feature or combination of features in any of the examples may constitute a further example.

5.1 THERAPY

[0121] In one form, the present technology comprises a method for treating a respiratory disorder comprising applying positive pressure to the entrance of the airways of a patient 1000.

[0122] In certain examples of the present technology, a supply of air at positive pressure is provided to the nasal passages of the patient via one or both nares.

[0123] In certain examples of the present technology, mouth breathing is limited, restricted or prevented.

5.2 RESPIRATORY THERAPY SYSTEMS

[0124] In one form, the present technology comprises a respiratory therapy system for treating a respiratory disorder. The a respiratory therapy system may comprise an RPT device 4000 for supplying a flow of air to the patient 1000 via an air circuit 4170 and a patient interface 3000 or 3800.

5.3 PATIENT INTERFACE

[0125] A non-invasive patient interface 3000 in accordance with one aspect of the present technology comprises the following functional aspects: a seal-forming structure 3100, a plenum chamber 3200, a positioning and stabilising structure 3300, a vent 3400, one form of connection port 3600 for connection to air circuit 4170, and a forehead support 3700. In some forms a functional aspect may be provided by one or more physical components. In some forms, one physical component may provide one or more functional aspects. In use the seal-forming structure 3100 is arranged to surround an entrance to the airways of the patient so as to maintain positive pressure at the entrance(s) to the airways of the patient 1000. The sealed patient interface 3000 is therefore suitable for delivery of positive pressure therapy.

[0126] An unsealed patient interface 3800, in the form of a nasal cannula, includes nasal prongs 3810a, 3810b which can deliver air to respective nares of the patient 1000 via respective orifices in their tips. Such nasal prongs do not generally form a seal with the inner or outer skin surface of the nares. The air to the nasal prongs may be delivered by one or more air supply lumens 3820a, 3820b that are coupled with the nasal cannula 3800. The lumens 3820a, 3820b lead from the nasal cannula 3800 to a respiratory therapy device via an air circuit. The unsealed patient interface 3800 is particularly suitable for delivery of flow therapies, in which the RPT device generates the flow of air at controlled flow rates rather than controlled pressures. The "vent" at the unsealed patient interface 3800, through which excess airflow escapes to ambient, is the passage between the end of the prongs 3810a and 3810b of the cannula 3800 via the patient's nares to atmosphere.

[0127] If a patient interface is unable to comfortably deliver a minimum level of positive pressure to the airways, the patient interface may be unsuitable for respiratory pressure therapy.

[0128] The patient interface 3000 in accordance with one form of the present technology is constructed and arranged to be able to provide a supply of air at a positive pressure of at least 6 cmH_2O with respect to ambient.

[0129] The patient interface 3000 in accordance with one form of the present technology is constructed and arranged to be able to provide a supply of air at a positive pressure of at least 10 cmH_2O with respect to ambient.

[0130] The patient interface 3000 in accordance with one form of the present technology is constructed and arranged to be able to provide a supply of air at a positive pressure of at least 20 cmH_2O with respect to ambient.

5.4 RPT DEVICE

[0131] An RPT device 4000 in accordance with one aspect of the present technology comprises mechanical, pneumatic, and/or electrical components and is configured to execute one or more algorithms 4300, such as any of the methods, in whole or in part, described herein. The RPT device 4000 may be configured to generate a flow of air for delivery to a patient's airways, such as to treat one or more of the respiratory conditions described elsewhere in the present document.

[0132] In one form, the RPT device 4000 is constructed and arranged to be capable of delivering a flow of air in a range of -20 L/min to +150 L/min while maintaining a positive pressure of at least 6 cmH_2O, or at least 10cmH_2O, or at least 20 cmH_2O.

[0133] The RPT device may have an external housing 4010, formed in two parts, an upper portion 4012 and a lower portion 4014. Furthermore, the external housing 4010 may include one or more panel(s) 4015. The RPT device 4000 comprises a chassis 4016 that supports one or more internal components of the RPT device 4000. The RPT device 4000 may include a handle 4018.

[0134] The pneumatic path of the RPT device 4000 may comprise one or more air path items, e.g., an inlet air filter 4112, an inlet muffler 4122, a pressure generator 4140 capable of supplying air at positive pressure (e.g., a blower 4142), an outlet muffler 4124 and one or more transducers 4270, such as pressure sensors 4272 and flow rate sensors 4274.

[0135] One or more of the air path items may be located within a removable unitary structure which will be referred to as a pneumatic block 4020. The pneumatic block 4020 may be located within the external housing 4010. In one form a pneumatic block 4020 is supported by, or formed as part of the chassis 4016.

[0136] The RPT device 4000 may have an electrical power supply 4210, one or more input devices 4220, a central controller 4230, a therapy device controller 4240, a pressure generator 4140, one or more protection circuits 4250, memory 4260, transducers 4270, data communication interface 4280 and one or more output devices 4290. Electrical components 4200 may be mounted on a single Printed Circuit Board Assembly (PCBA) 4202. In an alternative form, the RPT device 4000 may include more than one PCBA 4202.

5.4.1 RPT device mechanical & pneumatic components

[0137] An RPT device may comprise one or more of the following components in an integral unit. In an alternative form, one or more of the following components may be located as respective separate units.

5.4.1.1 Air filter(s)

[0138] An RPT device in accordance with one form of the present technology may include an air filter 4110, or a plurality of air filters 4110.

[0139] In one form, an inlet air filter 4112 is located at the beginning of the pneumatic path upstream of a pressure generator 4140.

[0140] In one form, an outlet air filter 4114, for example an antibacterial filter, is located between an outlet of the pneumatic block 4020 and a patient interface 3000 or 3800.

5.4.1.2 Muffler(s)

[0141] An RPT device in accordance with one form of the present technology may include a muffler 4120, or a plurality of mufflers 4120.

[0142] In one form of the present technology, an inlet muffler 4122 is located in the pneumatic path upstream of a pressure generator 4140.

[0143] In one form of the present technology, an outlet muffler 4124 is located in the pneumatic path between the pressure generator 4140 and a patient interface 3000 or 3800.

5.4.1.3 Pressure generator

[0144] In one form of the present technology, a pressure generator 4140 for producing a flow, or a supply, of air at positive pressure is a controllable blower 4142. For example the blower 4142 may include a brushless DC motor 4144 with one or more impellers. The impellers may be located in a volute. The blower may be capable of delivering a supply of air, for example at a rate of up to about 120 litres/minute, at a positive pressure in a range from about 4 cmH_2O to about 20 cmH_2O, or in other forms up to about 30 cmH_2O when delivering respiratory pressure therapy. The blower may be as described in any one of the following patents or patent applications the contents of which are incorporated herein by reference in their entirety: U.S. Patent No. 7,866,944; U.S. Patent No. 8,638,014; U.S. Patent No. 8,636,479; and PCT Patent Application Publication No. WO 2013/020167.

[0145] The pressure generator 4140 is under the control of the therapy device controller 4240.

[0146] In other forms, a pressure generator 4140 may be a piston-driven pump, a pressure regulator connected to a high pressure source (e.g. compressed air reservoir), or a bellows.

5.4.1.4 Transducer(s)

[0147] Transducers may be internal of the RPT device, or external of the RPT device. External transducers may be located for example on or form part of the air circuit, e.g., the patient interface. External transducers may be in the form of non-contact sensors such as a Doppler radar movement sensor that transmit or transfer data to the RPT device.

[0148] In one form of the present technology, one or more transducers 4270 are located upstream and/or downstream of the pressure generator 4140. The one or more transducers 4270 may be constructed and arranged to generate signals representing

properties of the flow of air such as a flow rate, a pressure or a temperature at that point in the pneumatic path.

[0149] In one form of the present technology, one or more transducers 4270 may be located proximate to the patient interface 3000 or 3800.

[0150] In one form, a signal from a transducer 4270 may be filtered, such as by low-pass, high-pass or band-pass filtering.

5.4.1.4.1 Flow rate sensor

[0151] A flow rate sensor 4274 in accordance with the present technology may be based on a differential pressure transducer, for example, an SDP600 Series differential pressure transducer from SENSIRION.

[0152] In one form, a signal generated by the flow rate sensor 4274 and representing a flow rate is received by the central controller 4230.

5.4.1.4.2 Pressure sensor

[0153] A pressure sensor 4272 in accordance with the present technology is located in fluid communication with the pneumatic path. An example of a suitable pressure sensor is a transducer from the HONEYWELL ASDX series. An alternative suitable pressure sensor is a transducer from the NPA Series from GENERAL ELECTRIC.

[0154] In one form, a signal generated by the pressure sensor 4272 is received by the central controller 4230.

5.4.1.4.3 Motor speed transducer

[0155] In one form of the present technology a motor speed transducer 4276 is used to determine a rotational velocity of the motor 4144 and/or the blower 4142. A motor speed signal from the motor speed transducer 4276 may be provided to the therapy device controller 4240. The motor speed transducer 4276 may, for example, be a speed sensor, such as a Hall effect sensor.

5.4.1.5 Anti-spill back valve

[0156] In one form of the present technology, an anti-spill back valve 4160 is located between the humidifier 5000 and the pneumatic block 4020. The anti-spill back valve is constructed and arranged to reduce the risk that water will flow upstream from the humidifier 5000, for example to the motor 4144.

5.4.2 RPT device electrical components

5.4.2.1 Power supply

[0157] A power supply 4210 may be located internal or external of the external housing 4010 of the RPT device 4000.

[0158] In one form of the present technology, power supply 4210 provides electrical power to the RPT device 4000 only. In another form of the present technology, power supply 4210 provides electrical power to both RPT device 4000 and humidifier 5000.

5.4.2.2 Input devices

[0159] In one form of the present technology, an RPT device 4000 includes one or more input devices 4220 in the form of buttons, switches or dials to allow a person to interact with the device. The buttons, switches or dials may be physical devices, or software devices accessible via a touch screen. The buttons, switches or dials may, in one form, be physically connected to the external housing 4010, or may, in another form, be in wireless communication with a receiver that is in electrical connection to the central controller 4230.

[0160] In one form, the input device 4220 may be constructed and arranged to allow a person to select a value and/or a menu option.

5.4.2.3 Central controller

[0161] In one form of the present technology, the central controller 4230 is one or a plurality of processors suitable to control an RPT device 4000.

[0162] Suitable processors may include an x86 INTEL processor, a processor based on ARM® Cortex®-M processor from ARM Holdings such as an STM32 series microcontroller from ST MICROELECTRONIC. In certain alternative forms of

the present technology, a 32-bit RISC CPU, such as an STR9 series microcontroller from ST MICROELECTRONICS or a 16-bit RISC CPU such as a processor from the MSP430 family of microcontrollers, manufactured by TEXAS INSTRUMENTS may also be suitable.

[0163] In one form of the present technology, the central controller 4230 is a dedicated electronic circuit.

[0164] In one form, the central controller 4230 is an application-specific integrated circuit. In another form, the central controller 4230 comprises discrete electronic components.

[0165] The central controller 4230 may be configured to receive input signal(s) from one or more transducers 4270, one or more input devices 4220, and the humidifier 5000.

[0166] The central controller 4230 may be configured to provide output signal(s) to one or more of an output device 4290, a therapy device controller 4240, a data communication interface 4280, and the humidifier 5000.

[0167] In some forms of the present technology, the central controller 4230 is configured to implement the one or more methodologies described herein, such as the one or more algorithms 4300 expressed as computer programs stored in a non-transitory computer readable storage medium, such as memory 4260. In some forms of the present technology, the central controller 4230 may be integrated with an RPT device 4000. However, in some forms of the present technology, some methodologies may be performed by a remotely located device. For example, the remotely located device may determine control settings for a ventilator or detect respiratory related events by analysis of stored data such as from any of the sensors described herein.

5.4.2.4 Clock

[0168] The RPT device 4000 may include a clock 4232 that is connected to the central controller 4230.

5.4.2.5 Therapy device controller

[0169] In one form of the present technology, therapy device controller 4240 is a therapy control module 4330 that forms part of the algorithms 4300 executed by the central controller 4230.

[0170] In one form of the present technology, therapy device controller 4240 is a dedicated motor control integrated circuit. For example, in one form a MC33035 brushless DC motor controller, manufactured by ONSEMI is used.

5.4.2.6 Protection circuits

[0171] The one or more protection circuits 4250 in accordance with the present technology may comprise an electrical protection circuit, a temperature and/or pressure safety circuit.

5.4.2.7 Memory

[0172] In accordance with one form of the present technology the RPT device 4000 includes memory 4260, e.g., non-volatile memory. In some forms, memory 4260 may include battery powered static RAM. In some forms, memory 4260 may include volatile RAM.

[0173] Memory 4260 may be located on the PCBA 4202. Memory 4260 may be in the form of EEPROM, or NAND flash.

[0174] Additionally or alternatively, RPT device 4000 includes a removable form of memory 4260, for example a memory card made in accordance with the Secure Digital (SD) standard.

[0175] In one form of the present technology, the memory 4260 acts as a non-transitory computer readable storage medium on which is stored computer program instructions expressing the one or more methodologies described herein, such as the one or more algorithms 4300.

5.4.2.8 Data communication systems

[0176] In one form of the present technology, a data communication interface 4280 is provided, and is connected to the central controller 4230. Data communication interface 4280 may be connectable to a remote external communication network 4282

and/or a local external communication network 4284. The remote external communication network 4282 may be connectable to a remote external device 4286. The local external communication network 4284 may be connectable to a local external device 4288.

[0177] In one form, data communication interface 4280 is part of the central controller 4230. In another form, data communication interface 4280 is separate from the central controller 4230, and may comprise an integrated circuit or a processor.

[0178] In one form, remote external communication network 4282 is the Internet. The data communication interface 4280 may use wired communication (e.g. via Ethernet, or optical fibre) or a wireless protocol (e.g. CDMA, GSM, LTE) to connect to the Internet.

[0179] In one form, local external communication network 4284 utilises one or more communication standards, such as Bluetooth, or a consumer infrared protocol.

[0180] In one form, remote external device 4286 is one or more computers, for example a cluster of networked computers. In one form, remote external device 4286 may be virtual computers, rather than physical computers. In either case, such a remote external device 4286 may be accessible to an appropriately authorised person such as a clinician.

[0181] The local external device 4288 may be a personal computer, mobile phone, tablet or remote control.

5.4.2.9 Output devices including optional display, alarms

[0182] An output device 4290 in accordance with the present technology may take the form of one or more of a visual, audio and haptic unit. A visual display may be a Liquid Crystal Display (LCD) or Light Emitting Diode (LED) display.

5.4.2.9.1 Display driver

[0183] A display driver 4292 receives as an input the characters, symbols, or images intended for display on the display 4294, and converts them to commands that cause the display 4294 to display those characters, symbols, or images.

5.4.2.9.2 Display

[0184] A display 4294 is configured to visually display characters, symbols, or images in response to commands received from the display driver 4292. For example, the display 4294 may be an eight-segment display, in which case the display driver 4292 converts each character or symbol, such as the figure "0", to eight logical signals indicating whether the eight respective segments are to be activated to display a particular character or symbol.

5.4.3 RPT device algorithms

[0185] As mentioned above, in some forms of the present technology, the central controller 4230 may be configured to implement one or more algorithms 4300 expressed as computer programs stored in a non-transitory computer readable storage medium, such as memory 4260. The algorithms 4300 are generally grouped into groups referred to as modules.

[0186] In other forms of the present technology, some portion or all of the algorithms 4300 may be implemented by a controller of an external device such as the local external device 4288 or the remote external device 4286. In such forms, data representing the input signals and / or intermediate algorithm outputs necessary for the portion of the algorithms 4300 to be executed at the external device may be communicated to the external device via the local external communication network 4284 or the remote external communication network 4282. In such forms, the portion of the algorithms 4300 to be executed at the external device may be expressed as computer programs stored in a non-transitory computer readable storage medium accessible to the controller of the external device. Such programs configure the controller of the external device to execute the portion of the algorithms 4300.

[0187] In such forms, the therapy parameters generated by the external device via the therapy engine module 4320 (if such forms part of the portion of the algorithms 4300 executed by the external device) may be communicated to the central controller 4230 to be passed to the therapy control module 4330.

5.4.3.1 Pre-processing module

[0188] A pre-processing module 4310 in accordance with one form of the present technology receives as an input a signal from a transducer 4270, for example a flow

rate sensor 4274 or pressure sensor 4272, and performs one or more process steps to calculate one or more output values that will be used as an input to another module, for example a therapy engine module 4320.

[0189] In one form of the present technology, the output values include the interface pressure *Pm*, the respiratory flow rate *Qr*, and the leak flow rate *Ql*.

[0190] In various forms of the present technology, the pre-processing module 4310 comprises one or more of the following algorithms: interface pressure estimation 4312, vent flow rate estimation 4314, leak flow rate estimation 4316, and respiratory flow rate estimation 4318.

5.4.3.1.1 Interface pressure estimation

[0191] In one form of the present technology, an interface pressure estimation algorithm 4312 receives as inputs a signal from the pressure sensor 4272 indicative of the pressure in the pneumatic path proximal to an outlet of the pneumatic block (the device pressure *Pd*) and a signal from the flow rate sensor 4274 representative of the flow rate of the airflow leaving the RPT device 4000 (the device flow rate *Qd*). The device flow rate *Qd*, absent any supplementary gas 4180, may be used as the total flow rate *Qt*. The interface pressure algorithm 4312 estimates the pressure drop ΔP through the air circuit 4170. The dependence of the pressure drop ΔP on the total flow rate *Qt* may be modelled for the particular air circuit 4170 by a pressure drop characteristic $\Delta P(Q)$. The interface pressure estimation algorithm, 4312 then provides as an output an estimated pressure, *Pm*, in the patient interface 3000 or 3800. The pressure, *Pm*, in the patient interface 3000 or 3800 may be estimated as the device pressure *Pd* minus the air circuit pressure drop ΔP.

5.4.3.1.2 Vent flow rate estimation

[0192] In one form of the present technology, a vent flow rate estimation algorithm 4314 receives as an input an estimated pressure, *Pm*, in the patient interface 3000 or 3800 from the interface pressure estimation algorithm 4312 and estimates a vent flow rate of air, *Qv*, from a vent 3400 in a patient interface 3000 or 3800. The dependence of the vent flow rate *Qv* on the interface pressure *Pm* for the particular vent 3400 in use may be modelled by a vent characteristic $Qv(Pm)$.

5.4.3.1.3 Leak flow rate estimation

[0193] In one form of the present technology, a leak flow rate estimation algorithm 4316 receives as an input a total flow rate, *Qt*, and a vent flow rate *Qv*, and provides as an output an estimate of the leak flow rate *Ql*. In one form, the leak flow rate estimation algorithm estimates the leak flow rate *Ql* by calculating an average of the difference between total flow rate *Qt* and vent flow rate *Qv* over a period sufficiently long to include several breathing cycles, e.g. about 10 seconds.

[0194] In one form, the leak flow rate estimation algorithm 4316 receives as an input a total flow rate *Qt*, a vent flow rate *Qv*, and an estimated pressure, *Pm*, in the patient interface 3000 or 3800, and provides as an output a leak flow rate *Ql*, by calculating a leak conductance, and determining a leak flow rate *Ql* to be a function of leak conductance and pressure, *Pm*. Leak conductance is calculated as the quotient of low pass filtered non-vent flow rate equal to the difference between total flow rate *Qt* and vent flow rate *Qv*, and low pass filtered square root of pressure *Pm*, where the low pass filter time constant has a value sufficiently long to include several breathing cycles, e.g. about 10 seconds. The leak flow rate *Ql* may be estimated as the product of leak conductance and a function of pressure, *Pm*.

5.4.3.1.4 Respiratory flow rate estimation

[0195] In one form of the present technology, a respiratory flow rate estimation algorithm 4318 receives as an input a total flow rate, *Qt*, a vent flow rate, *Qv*, and a leak flow rate, *Ql*, and estimates a respiratory flow rate of *air*, *Qr*, to the patient, by subtracting the vent flow rate *Qv* and the leak flow rate *Ql* from the total flow rate *Qt*.

5.4.3.2 Therapy Engine Module

[0196] In one form of the present technology, a therapy engine module 4320 receives as inputs one or more of a pressure, *Pm*, in a patient interface 3000 or 3800, and a respiratory flow rate of air to a patient, *Qr*, and provides as an output one or more therapy parameters.

[0197] In one form of the present technology, a therapy parameter is a treatment pressure *Pt*.

[0198] In one form of the present technology, therapy parameters are one or more of an amplitude of a pressure variation, a base pressure, and a target ventilation.

[0199] In various forms, the therapy engine module 4320 comprises one or more of the following algorithms: phase determination 4321, waveform determination 4322, ventilation determination 4323, inspiratory flow limitation determination 4324, apnea / hypopnea determination 4325, snore determination 4326, airway patency determination 4327, target ventilation determination 4328, and therapy parameter determination 4329.

5.4.3.2.1 Phase determination

[0200] In one form of the present technology, the RPT device 4000 does not determine phase.

[0201] In one form of the present technology, a phase determination algorithm 4321 receives as an input a signal indicative of respiratory flow rate, *Qr*, and provides as an output a phase Φ of a current breathing cycle of a patient 1000.

[0202] In some forms, known as discrete phase determination, the phase output Φ is a discrete variable. One implementation of discrete phase determination provides a bi-valued phase output Φ with values of either inhalation or exhalation, for example represented as values of 0 and 0.5 revolutions respectively, upon detecting the start of spontaneous inhalation and exhalation respectively. RPT devices 4000 that "trigger" and "cycle" effectively perform discrete phase determination, since the trigger and cycle points are the instants at which the phase changes from exhalation to inhalation and from inhalation to exhalation, respectively. In one implementation of bi-valued phase determination, the phase output Φ is determined to have a discrete value of 0 (thereby "triggering" the RPT device 4000) when the respiratory flow rate *Qr* has a value that exceeds a positive threshold, and a discrete value of 0.5 revolutions (thereby "cycling" the RPT device 4000) when a respiratory flow rate *Qr* has a value that is more negative than a negative threshold. The inhalation time *Ti* and the exhalation time *Te* may be estimated as typical values over many respiratory cycles of the time spent with phase Φ equal to 0 (indicating inspiration) and 0.5 (indicating expiration) respectively.

[0203] Another implementation of discrete phase determination provides a tri-valued phase output Φ with a value of one of inhalation, mid-inspiratory pause, and exhalation.

[0204] In other forms, known as continuous phase determination, the phase output Φ is a continuous variable, for example varying from 0 to 1 revolutions, or 0 to 2π radians. RPT devices 4000 that perform continuous phase determination may trigger and cycle when the continuous phase reaches 0 and 0.5 revolutions, respectively. In one implementation of continuous phase determination, a continuous value of phase Φ is determined using a fuzzy logic analysis of the respiratory flow rate *Qr*. A continuous value of phase determined in this implementation is often referred to as "fuzzy phase". In one implementation of a fuzzy phase determination algorithm 4321, the following rules are applied to the respiratory flow rate *Qr*:

1. If the respiratory flow rate is zero and increasing fast then the phase is 0 revolutions.

2. If the respiratory flow rate is large positive and steady then the phase is 0.25 revolutions.

3. If the respiratory flow rate is zero and falling fast, then the phase is 0.5 revolutions.

4. If the respiratory flow rate is large negative and steady then the phase is 0.75 revolutions.

5. If the respiratory flow rate is zero and steady and the 5-second low-pass filtered absolute value of the respiratory flow rate is large then the phase is 0.9 revolutions.

6. If the respiratory flow rate is positive and the phase is expiratory, then the phase is 0 revolutions.

7. If the respiratory flow rate is negative and the phase is inspiratory, then the phase is 0.5 revolutions.

8. If the 5-second low-pass filtered absolute value of the respiratory flow rate is large, the phase is increasing at a steady rate equal to the patient's breathing rate, low-pass filtered with a time constant of 20 seconds.

[0205] The output of each rule may be represented as a vector whose phase is the result of the rule and whose magnitude is the fuzzy extent to which the rule is true. The fuzzy extent to which the respiratory flow rate is "large", "steady", etc. is determined with suitable membership functions. The results of the rules, represented as vectors, are then combined by some function such as taking the centroid. In such a combination, the rules may be equally weighted, or differently weighted.

[0206] In another implementation of continuous phase determination, the phase Φ is first discretely estimated from the respiratory flow rate *Qr* as described above, as are the inhalation time *Ti* and the exhalation time *Te*. The continuous phase Φ at any instant may be determined as the half the proportion of the inhalation time *Ti* that has elapsed since the previous trigger instant, or 0.5 revolutions plus half the proportion of the exhalation time *Te* that has elapsed since the previous cycle instant (whichever instant was more recent).

5.4.3.2.2 Waveform determination

[0207] In one form of the present technology, the therapy parameter determination algorithm 4329 provides an approximately constant treatment pressure throughout a respiratory cycle of a patient.

[0208] In other forms of the present technology, the therapy control module 4330 controls the pressure generator 4140 to provide a treatment pressure *Pt* that varies as a function of phase Φ of a respiratory cycle of a patient according to a waveform template $\Pi(\Phi)$.

[0209] In one form of the present technology, a waveform determination algorithm 4322 provides a waveform template $\Pi(\Phi)$ with values in the range [0, 1] on the domain of phase values Φ provided by the phase determination algorithm 4321 to be used by the therapy parameter determination algorithm 4329.

[0210] In one form, suitable for either discrete or continuously-valued phase, the waveform template $\Pi(\Phi)$ is a square-wave template, having a value of 1 for values of phase up to and including 0.5 revolutions, and a value of 0 for values of phase above 0.5 revolutions. In one form, suitable for continuously-valued phase, the waveform template $\Pi(\Phi)$ comprises two smoothly curved portions, namely a smoothly curved (e.g. raised cosine) rise from 0 to 1 for values of phase up to 0.5 revolutions, and a smoothly curved (e.g. exponential) decay from 1 to 0 for values of phase above 0.5 revolutions. In one form, suitable for continuously-valued phase, the waveform template $\Pi(\Phi)$ is based on a square wave, but with a smooth rise from 0 to 1 for values of phase up to a "rise time" that is less than 0.5 revolutions, and a smooth fall from 1 to 0 for values of phase within a "fall time" after 0.5 revolutions, with a "fall time" that is less than 0.5 revolutions.

[0211] In some forms of the present technology, the waveform determination algorithm 4322 selects a waveform template $\Pi(\Phi)$ from a library of waveform templates, dependent on a setting of the RPT device. Each waveform template $\Pi(\Phi)$ in the library may be provided as a lookup table of values Π against phase values Φ. In other forms, the waveform determination algorithm 4322 computes a waveform template $\Pi(\Phi)$ "on the fly" using a predetermined functional form, possibly parametrised by one or more parameters (e.g. time constant of an exponentially curved portion). The parameters of the functional form may be predetermined or dependent on a current state of the patient 1000.

[0212] In some forms of the present technology, suitable for discrete bi-valued phase of either inhalation ($\Phi = 0$ revolutions) or exhalation ($\Phi = 0.5$ revolutions), the waveform determination algorithm 4322 computes a waveform template Π "on the fly" as a function of both discrete phase Φ and time t measured since the most recent trigger instant. In one such form, the waveform determination algorithm 4322 computes the waveform template $\Pi(\Phi, t)$ in two portions (inspiratory and expiratory) as follows:

$$\Pi(\Phi,t)=\begin{cases}\Pi_i(t), & \Phi=0\\ \Pi_e(t-T_i), & \Phi=0.5\end{cases}$$

[0213] where $\Pi_i(t)$ and $\Pi_e(t)$ are inspiratory and expiratory portions of the waveform template $\Pi(\Phi, t)$. In one such form, the inspiratory portion $\Pi_i(t)$ of the waveform template is a smooth rise from 0 to 1 parametrised by a rise time, and the expiratory portion $\Pi_e(t)$ of the waveform template is a smooth fall from 1 to 0 parametrised by a fall time.

5.4.3.2.3 Ventilation determination

[0214] In one form of the present technology, a ventilation determination algorithm 4323 receives an input a respiratory flow rate *Qr*, and determines a measure indicative of current patient ventilation, *Vent.*

[0215] In some implementations, the ventilation determination algorithm 4323 determines a measure of ventilation *Vent* that is an estimate of actual patient ventilation. One such implementation is to take half the absolute value of respiratory flow rate, *Qr*, optionally filtered by low-pass filter such as a second order Bessel low-pass filter with a corner frequency of 0.11 Hz.

[0216] In other implementations, the ventilation determination algorithm 4323 determines a measure of ventilation *Vent* that is broadly proportional to actual patient ventilation. One such implementation estimates peak respiratory flow rate *Qpeak* over the inspiratory portion of the cycle. This and many other procedures involving sampling the respiratory flow rate *Qr* produce measures which are broadly proportional to ventilation, provided the flow rate waveform shape does not vary very much (here, the shape of two breaths is taken to be similar when the flow rate waveforms of the breaths normalised in time and amplitude are similar). Some simple examples include the median positive respiratory flow rate, the median of the absolute value of respiratory flow rate, and the standard deviation of flow rate. Arbitrary linear combinations of arbitrary order statistics of the absolute value of respiratory flow rate using positive coefficients, and even some using both positive and negative coefficients, are approximately proportional to ventilation. Another example is the mean of the respiratory flow rate in the middle *K* proportion (by time) of the inspiratory portion, where $0 < K < 1$. There is an arbitrarily large number of measures that are exactly proportional to ventilation if the flow rate shape is constant.

5.4.3.2.4 Determination of Inspiratory Flow limitation

[0217] In one form of the present technology, the central controller 4230 executes an inspiratory flow limitation determination algorithm 4324 for the determination of the extent of inspiratory flow limitation.

[0218] In one form, the inspiratory flow limitation determination algorithm 4324 receives as an input a respiratory flow rate signal *Qr* and provides as an output a metric of the extent to which the inspiratory portion of the breath exhibits inspiratory flow limitation.

[0219] In one form of the present technology, the inspiratory portion of each breath is identified by a zero-crossing detector. A number of evenly spaced points (for example, sixty-five), representing points in time, are interpolated by an interpolator along the inspiratory flow rate-time curve for each breath. The curve described by the points is then scaled by a scalar to have unity length (duration/period) and unity area to remove the effects of changing breathing rate and depth. The scaled breaths are then compared in a comparator with a pre-stored template representing a normal unobstructed breath, similar to the inspiratory portion of the breath shown in Fig. 6A. Breaths deviating by more than a specified threshold (typically 1 scaled unit) at any time during the inspiration from this template, such as those due to coughs, sighs, swallows and hiccups, as determined by a test element, are rejected. For non-rejected data, a moving average of the first such scaled point is calculated by the central controller 4230 for the preceding several inspiratory events. This is repeated over the same inspiratory events for the second such point, and so on. Thus, for example, sixty five scaled data points are generated by the central controller 4230, and represent a moving average of the preceding several inspiratory events, e.g., three events. The moving average of continuously updated values of the (e.g., sixty five) points are hereinafter called the "scaled flow rate ", designated as *Qs(t)*. Alternatively, a single inspiratory event can be utilised rather than a moving average.

[0220] From the scaled flow rate, two shape factors relating to the determination of partial obstruction may be calculated.

[0221] Shape factor 1 is the ratio of the mean of the middle (e.g. thirty-two) scaled flow rate points to the mean overall (e.g. sixty-five) scaled flow rate points.

Where this ratio is in excess of unity, the breath will be taken to be normal. Where the ratio is unity or less, the breath will be taken to be obstructed. A ratio of about 1.17 is taken as a threshold between partially obstructed and unobstructed breathing, and equates to a degree of obstruction that would permit maintenance of adequate oxygenation in a typical patient.

[0222] Shape factor 2 is calculated as the RMS deviation from unit scaled flow rate, taken over the middle (e.g. thirty two) points. An RMS deviation of about 0.2 units is taken to be normal. An RMS deviation of zero is taken to be a totally flow–limited breath. The closer the RMS deviation to zero, the breath will be taken to be more flow limited.

[0223] Shape factors 1 and 2 may be used as alternatives, or in combination. In other forms of the present technology, the number of sampled points, breaths and middle points may differ from those described above. Furthermore, the threshold values can be other than those described.

5.4.3.2.5 Determination of apneas and hypopneas

[0224] In one form of the present technology, the central controller 4230 executes an apnea / hypopnea determination algorithm 4325 for the determination of the presence of apneas and/or hypopneas.

[0225] In one form, the apnea / hypopnea determination algorithm 4325 receives as an input a respiratory flow rate signal *Qr* and provides as an output a flag that indicates that an apnea or a hypopnea has been detected.

[0226] In one form, an apnea will be said to have been detected when a function of respiratory flow rate *Qr* falls below a flow rate threshold for a predetermined period of time. The function may determine a peak flow rate, a relatively short-term mean flow rate, or a flow rate intermediate of relatively short-term mean and peak flow rate, for example an RMS flow rate. The flow rate threshold may be a relatively long-term measure of flow rate.

[0227] In one form, a hypopnea will be said to have been detected when a function of respiratory flow rate *Qr* falls below a second flow rate threshold for a predetermined period of time. The function may determine a peak flow, a relatively

short-term mean flow rate, or a flow rate intermediate of relatively short-term mean and peak flow rate, for example an RMS flow rate. The second flow rate threshold may be a relatively long-term measure of flow rate. The second flow rate threshold is greater than the flow rate threshold used to detect apneas.

5.4.3.2.6 Determination of snore

[0228] In one form of the present technology, the central controller 4230 executes one or more snore determination algorithms 4326 for the determination of the extent of snore.

[0229] In one form, the snore determination algorithm 4326 receives as an input a respiratory flow rate signal *Qr* and provides as an output a metric of the extent to which snoring is present.

[0230] The snore determination algorithm 4326 may comprise the step of determining the intensity of the flow rate signal in the range of 30-300 Hz. Further, the snore determination algorithm 4326 may comprise a step of filtering the respiratory flow rate signal *Qr* to reduce background noise, e.g., the sound of airflow in the system from the blower.

5.4.3.2.7 Determination of airway patency

[0231] In one form of the present technology, the central controller 4230 executes one or more airway patency determination algorithms 4327 for the determination of the extent of airway patency.

[0232] In one form, the airway patency determination algorithm 4327 receives as an input a respiratory flow rate signal *Qr*, and determines the power of the signal in the frequency range of about 0.75 Hz and about 3 Hz. The presence of a peak in this frequency range is taken to indicate an open airway. The absence of a peak is taken to be an indication of a closed airway.

[0233] In one form, the frequency range within which the peak is sought is the frequency of a small forced oscillation in the treatment pressure *Pt*. In one implementation, the forced oscillation is of frequency 2 Hz with amplitude about 1 cmH_2O.

[0234] In one form, airway patency determination algorithm 4327 receives as an input a respiratory flow rate signal *Qr*, and determines the presence or absence of a cardiogenic signal. The absence of a cardiogenic signal is taken to be an indication of a closed airway.

5.4.3.2.8 Determination of target ventilation

[0235] In one form of the present technology, the central controller 4230 takes as input the measure of current ventilation, *Vent*, and executes one or more target ventilation determination algorithms 4328 for the determination of a target value *Vtgt* for the measure of ventilation.

[0236] In some forms of the present technology, there is no target ventilation determination algorithm 4328, and the target value *Vtgt* is predetermined, for example by hard-coding during configuration of the RPT device 4000 or by manual entry through the input device 4220.

[0237] In other forms of the present technology, such as adaptive servo-ventilation (ASV), the target ventilation determination algorithm 4328 computes a target value *Vtgt* from a value *Vtyp* indicative of the typical recent ventilation of the patient.

[0238] In some forms of adaptive servo-ventilation, the target ventilation *Vtgt* is computed as a high proportion of, but less than, the typical recent ventilation *Vtyp*. The high proportion in such forms may be in the range (80%, 100%), or (85%, 95%), or (87%, 92%).

[0239] In other forms of adaptive servo-ventilation, the target ventilation *Vtgt* is computed as a slightly greater than unity multiple of the typical recent ventilation *Vtyp*.

[0240] The typical recent ventilation *Vtyp* is the value around which the distribution of the measure of current ventilation *Vent* over multiple time instants over some predetermined timescale tends to cluster, that is, a measure of the central tendency of the measure of current ventilation over recent history. In one implementation of the target ventilation determination algorithm 4328, the recent history is of the order of several minutes, but in any case should be longer than the

timescale of Cheyne-Stokes waxing and waning cycles. The target ventilation determination algorithm 4328 may use any of the variety of well-known measures of central tendency to determine the typical recent ventilation *Vtyp* from the measure of current ventilation, *Vent*. One such measure is the output of a low-pass filter on the measure of current ventilation *Vent*, with time constant equal to one hundred seconds.

5.4.3.2.9 Determination of therapy parameters

[0241] In some forms of the present technology, the central controller 4230 executes one or more therapy parameter determination algorithms 4329 for the determination of one or more therapy parameters using the values returned by one or more of the other algorithms in the therapy engine module 4320.

[0242] In one form of the present technology, the therapy parameter is an instantaneous treatment pressure *Pt*. In one implementation of this form, the therapy parameter determination algorithm 4329 determines the treatment pressure *Pt* using the equation

$$Pt = A\Pi(\Phi, t) + P_0 \tag{1}$$

[0243] where:

- A is the amplitude,
- $\Pi(\Phi, t)$ is the waveform template value (in the range 0 to 1) at the current value Φ of phase and t of time, and
- P_0 is a base pressure.

[0244] If the waveform determination algorithm 4322 provides the waveform template $\Pi(\Phi, t)$ as a lookup table of values Π indexed by phase Φ, the therapy parameter determination algorithm 4329 applies equation (1) by locating the nearest lookup table entry to the current value Φ of phase returned by the phase determination algorithm 4321, or by interpolation between the two entries straddling the current value Φ of phase.

[0245] The values of the amplitude A and the base pressure P_0 may be set by the therapy parameter determination algorithm 4329 depending on the chosen respiratory pressure therapy mode in the manner described below.

5.4.3.3 Therapy Control module

[0246] The therapy control module 4330 in accordance with one aspect of the present technology receives as inputs the therapy parameters from the therapy parameter determination algorithm 4329 of the therapy engine module 4320, and controls the pressure generator 4140 to deliver a flow of air in accordance with the therapy parameters.

[0247] In one form of the present technology, the therapy parameter is a treatment pressure *Pt*, and the therapy control module 4330 controls the pressure generator 4140 to deliver a flow of air whose interface pressure *Pm* at the patient interface 3000 or 3800 is equal to the treatment pressure *Pt*.

5.4.3.4 Detection of fault conditions

[0248] In one form of the present technology, the central controller 4230 executes one or more methods 4340 for the detection of fault conditions. The fault conditions detected by the one or more methods 4340 may include at least one of the following:

- Power failure (no power, or insufficient power)
- Transducer fault detection
- Failure to detect the presence of a component
- Operating parameters outside recommended ranges (e.g. pressure, flow rate, temperature, PaO_2)
- Failure of a test alarm to generate a detectable alarm signal.

[0249] Upon detection of the fault condition, the corresponding algorithm 4340 signals the presence of the fault by one or more of the following:

- Initiation of an audible, visual &/or kinetic (e.g. vibrating) alarm
- Sending a message to an external device
- Logging of the incident

5.5 AIR CIRCUIT

[0250] An air circuit 4170 in accordance with an aspect of the present technology is a conduit or a tube constructed and arranged to allow, in use, a flow of air to travel

between two components such as RPT device 4000 and the patient interface 3000 or 3800.

[0251] In particular, the air circuit 4170 may be in fluid connection with the outlet of the pneumatic block 4020 and the patient interface. The air circuit may be referred to as an air delivery tube. In some cases there may be separate limbs of the circuit for inhalation and exhalation. In other cases a single limb is used.

[0252] In some forms, the air circuit 4170 may comprise one or more heating elements configured to heat air in the air circuit, for example to maintain or raise the temperature of the air. The heating element may be in a form of a heated wire circuit, and may comprise one or more transducers, such as temperature sensors. In one form, the heated wire circuit may be helically wound around the axis of the air circuit 4170. The heating element may be in communication with a controller such as a central controller 4230. One example of an air circuit 4170 comprising a heated wire circuit is described in United States Patent 8,733,349, which is incorporated herewithin in its entirety by reference.

5.5.1 Supplementary gas delivery

[0253] In one form of the present technology, supplementary gas, e.g. oxygen, 4180 is delivered to one or more points in the pneumatic path, such as upstream of the pneumatic block 4020, to the air circuit 4170, and/or to the patient interface 3000 or 3800.

5.6 HUMIDIFIER

5.6.1 Humidifier overview

[0254] In one form of the present technology there is provided a humidifier 5000 (e.g. as shown in Fig. 5A) to change the absolute humidity of air or gas for delivery to a patient relative to ambient air. Typically, the humidifier 5000 is used to increase the absolute humidity and increase the temperature of the flow of air (relative to ambient air) before delivery to the patient's airways.

[0255] The humidifier 5000 may comprise a humidifier reservoir 5110, a humidifier inlet 5002 to receive a flow of air, and a humidifier outlet 5004 to deliver a humidified flow of *air*. In some forms, as shown in Fig. 5A and Fig. 5B, an inlet and

an outlet of the humidifier reservoir 5110 may be the humidifier inlet 5002 and the humidifier outlet 5004 respectively. The humidifier 5000 may further comprise a humidifier base 5006, which may be adapted to receive the humidifier reservoir 5110 and comprise a heating element 5240.

5.6.2 Humidifier components

5.6.2.1 Water reservoir

[0256] According to one arrangement, the humidifier 5000 may comprise a water reservoir 5110 configured to hold, or retain, a volume of liquid (e.g. water) to be evaporated for humidification of the flow of air. The water reservoir 5110 may be configured to hold a predetermined maximum volume of water in order to provide adequate humidification for at least the duration of a respiratory therapy session, such as one evening of sleep. Typically, the reservoir 5110 is configured to hold several hundred millilitres of water, e.g. 300 millilitres (ml), 325 ml, 350 ml or 400 ml. In other forms, the humidifier 5000 may be configured to receive a supply of water from an external water source such as a building's water supply system.

[0257] According to one aspect, the water reservoir 5110 is configured to add humidity to a flow of air from the RPT device 4000 as the flow of air travels therethrough. In one form, the water reservoir 5110 may be configured to encourage the flow of air to travel in a tortuous path through the reservoir 5110 while in contact with the volume of water therein.

[0258] According to one form, the reservoir 5110 may be removable from the humidifier 5000, for example in a lateral direction as shown in Fig. 5A and Fig. 5B.

[0259] The reservoir 5110 may also be configured to discourage egress of liquid therefrom, such as when the reservoir 5110 is displaced and/or rotated from its normal, working orientation, such as through any apertures and/or in between its sub-components. As the flow of air to be humidified by the humidifier 5000 is typically pressurised, the reservoir 5110 may also be configured to prevent losses in pneumatic pressure through leak and/or flow impedance.

5.6.2.2 Conductive portion

[0260] According to one arrangement, the reservoir 5110 comprises a conductive portion 5120 configured to allow efficient transfer of heat from the heating element 5240 to the volume of liquid in the reservoir 5110. In one form, the conductive portion 5120 may be arranged as a plate, although other shapes may also be suitable. All or a part of the conductive portion 5120 may be made of a thermally conductive material such as aluminium (e.g. approximately 2 mm thick, such as 1 mm, 1.5 mm, 2.5 mm or 3 mm), another heat conducting metal or some plastics. In some cases, suitable heat conductivity may be achieved with less conductive materials of suitable geometry.

5.6.2.3 Humidifier reservoir dock

[0261] In one form, the humidifier 5000 may comprise a humidifier reservoir dock 5130 (as shown in Fig. 5B) configured to receive the humidifier reservoir 5110. In some arrangements, the humidifier reservoir dock 5130 may comprise a locking feature such as a locking lever 5135 configured to retain the reservoir 5110 in the humidifier reservoir dock 5130.

5.6.2.4 Water level indicator

[0262] The humidifier reservoir 5110 may comprise a water level indicator 5150 as shown in Fig. 5A-5B. In some forms, the water level indicator 5150 may provide one or more indications to a user such as the patient 1000 or a care giver regarding a quantity of the volume of water in the humidifier reservoir 5110. The one or more indications provided by the water level indicator 5150 may include an indication of a maximum, predetermined volume of water, any portions thereof, such as 25%, 50% or 75% or volumes such as 200 ml, 300 ml or 400ml.

5.6.2.5 Humidifier transducer(s)

[0263] The humidifier 5000 may comprise one or more humidifier transducers (sensors) 5210 instead of, or in addition to, transducers 4270 described above. Humidifier transducers 5210 may include one or more of an air pressure sensor 5212, an *air* flow rate transducer 5214, a temperature sensor 5216, or a humidity sensor 5218 as shown in Fig. 5C. A humidifier transducer 5210 may produce one or more output signals which may be communicated to a controller such as the central

controller 4230 and/or the humidifier controller 5250. In some forms, a humidifier transducer may be located externally to the humidifier 5000 (such as in the *air* circuit 4170) while communicating the output signal to the controller.

5.6.2.5.1 Pressure transducer

[0264] One or more pressure transducers 5212 may be provided to the humidifier 5000 in addition to, or instead of, a pressure sensor 4272 provided in the RPT device 4000.

5.6.2.5.2 Flow rate transducer

[0265] One or more flow rate transducers 5214 may be provided to the humidifier 5000 in addition to, or instead of, a flow rate sensor 4274 provided in the RPT device 4000.

5.6.2.5.3 Temperature transducer

[0266] The humidifier 5000 may comprise one or more temperature transducers 5216. The one or more temperature transducers 5216 may be configured to measure one or more temperatures such as of the heating element 5240 and/or of the flow of *air* downstream of the humidifier outlet 5004. In some forms, the humidifier 5000 may further comprise a temperature sensor 5216 to detect the temperature of the ambient air.

5.6.2.5.4 Humidity transducer

[0267] In one form, the humidifier 5000 may comprise one or more humidity sensors 5218 to detect a humidity of a gas, such as the ambient air. The humidity sensor 5218 may be placed towards the humidifier outlet 5004 in some forms to measure a humidity of the gas delivered from the humidifier 5000. The humidity sensor may be an absolute humidity sensor or a relative humidity sensor.

5.6.2.6 Heating element

[0268] A heating element 5240 may be provided to the humidifier 5000 in some cases to provide a heat input to one or more of the volume of water in the humidifier reservoir 5110 and/or to the flow of air. The heating element 5240 may comprise a heat generating component such as an electrically resistive heating track. One suitable example of a heating element 5240 is a layered heating element such as one described

in the PCT Patent Application Publication No. WO 2012/171072, which is incorporated herewith by reference in its entirety.

[0269] In some forms, the heating element 5240 may be provided in the humidifier base 5006 where heat may be provided to the humidifier reservoir 5110 primarily by conduction as shown in Fig. 5B.

5.6.2.7 Humidifier controller

[0270] According to one arrangement of the present technology, a humidifier 5000 may comprise a humidifier controller 5250 as shown in Fig. 5C. In one form, the humidifier controller 5250 may be a part of the central controller 4230. In another form, the humidifier controller 5250 may be a separate controller, which may be in communication with the central controller 4230.

[0271] In one form, the humidifier controller 5250 may receive as inputs measures of properties (such as temperature, humidity, pressure and/or flow rate), for example of the flow of air, the water in the reservoir 5110 and/or the humidifier 5000. The humidifier controller 5250 may also be configured to execute or implement humidifier algorithms and/or deliver one or more output signals.

[0272] As shown in Fig. 5C, the humidifier controller 5250 may comprise one or more controllers, such as a central humidifier controller 5251, a heated air circuit controller 5254 configured to control the temperature of a heated air circuit 4171 and/or a heating element controller 5252 configured to control the temperature of a heating element 5240.

5.7 TUBE TYPE IDENTIFICATION

[0273] In one form of the present technology there is provided a system and/or method to identify type of peripheral component (e.g., type of air delivery tube 4170 and/or patient interface) connected to the RPT device 4000. In some examples, an air delivery tube type may be determined based one or more unique electrical characteristic of the air delivery tube 4170 and/or one or more unique connectors of the air delivery tube 4170. In an example, contact assembly of the air delivery tube 4170 coupling the air deliver tube 4170 to the RPT device 4000 may be used as an identifier of various parameters of the air delivery tube 4170 and/or the patient

interface. For example, the contact assembly may be configured to provide identification of the type of air delivery tube 4170 (e.g., non-heated tube, heated tube, tube with heat and moisture exchanger (HME), tube unknown), size of air delivery tube (e.g., 15mm, 19 mm), presence and type of HME, type of patient interface connected to tube, etc. The data from identification may be communicated and used by a controller, to optimize operation of the RPT device 4000 and/or humidifier 5000. For example, the controller may be configured to recognize a unique identifying feature so that the controller can recognize the specific characteristics of the air delivery tube 4170 coupled to the RPT device 4000, and therefore the controller can automatically configure the RPT device 4000 and/or humidifier 5000 to optimize operation.

[0274] Figs. 5D-5H show schematic views of an air delivery tube 4170 connected to an RPT device 4000 in accordance with various forms of the present technology. Each of the schematics shows an air delivery tube 4170 may provide different characterises which can be used to identify the type of tube connected to the RPT device 4000.

[0275] The RPT device 4000 may include a contact assembly 6200 for mechanically and electrically coupling to a tube connector 6300 to provide power, signals, and/or air to the air delivery tube 4170. The contact assembly 6200 may be provided as a separate component coupled to or integrated into the housing of the RPT device 4000 or the humidifier 5000. The connections in the tube may be solid pins, but are not so limited. In some examples, the connections may be provided by, for example, leadframe terminals. In one example, when the tube 4170 is connected, solid pins in one of the devices connect to corresponding pogo pins in the other device.

[0276] In one form of the present disclosure, the contact assembly 6200 includes four connections coupled to processing circuitry 6400. The processing circuitry 6400 may be provided as part of the central controller 4230, central humidifier controller 5251, air circuit controller 5254, or a separate circuit that is coupled to the central controller 4230, central humidifier controller 5251, and/or the air circuit controller 5254. The processing circuitry 6400 may include one or more analog and/or digital hardware elements for performing the operations discussed in this application.

[0277] In one form of the present disclosure, at least two of the connections (Heating line 1 and Heating line 2) are coupled to a heating control circuit and two of the connections (Sensor line 1 and Sensor line 2) are coupled to a heated tube detection circuit. One of the heating lines may be coupled to ground of the heating control circuit. In some examples, one or both of the sensor line connections may be coupled to a sensor 6500 that has electrical characteristics (e.g., resistance) dependent on temperature. The sensor 6500 may include a thermistor formed of a Negative Temperature Coefficient (NTC) material. The parameters of the thermistor (e.g., resistance) may change with a change of tube temperature.

[0278] The heater control circuit may supply power to heating elements in the tube 4170 via a switch (e.g., a transistor). The heating elements may include heating wires distributed along at least a portion of the length of the tube 4170 to the mask end of the tube 4170. The heater control circuit may control the duration, voltage, and/or frequency and/or period of Pulse Width Modulation (PWM) signal supplied to the heating elements 5240 in the tube 4170.

[0279] The heated tube detection circuit may be configured to receive signal(s) from the sensor 6500 disposed in the tube 4170, indicative of the operation of the heating elements in the tube 4170. The sensor 6500 may be disposed at the mask proximal end of the tube 4170. For example, the heated tube detection circuit may measure voltage and/or current of the sensor 6500 to determine the operating characteristics (e.g., temperature) of the heating elements. The heater control circuit may control the heating elements based on the signals received by the heated tube detection circuit and the settings sets for the heating tube 4170. Other sensors disposed anywhere in the tube, i.e., humidity sensors, may also be connected in a similar way.

[0280] The heated tube detection circuit may automatically identify the type of tube 4170 connected to the RPT device 4000 based on unique characteristic(s) provided by active and/or passive components in the tube 4170 or lack of any connected components via one or more of the four electrical connectors between the tube 4170 and the RPT device 4000. Based on the indicated type of tube 4170 connected, a controller may change the operating parameter of the system. For example, different heating control settings may be provided for different tubes (e.g.,

non-heated tube, heated tube, tube with heat and moisture exchanger (HME), tube unknown). In some example, the settings may be modified based on the size of the identified air delivery tube (e.g., 15mm, 19 mm), presence and type of HME, type of patient interface connected to tube, etc..

5.7.1 Four pin four wire identification

[0281] In Fig. 5D, heating elements are coupled to two pins in tube 4170 and the sensor 6500 is coupled to two other pins in the tube 4170. The characteristics of the sensor 6500 and/or heating elements may be used identify the type of tube connected to the RPT device 4000. For example, the thermistor may be selected based on the type air delivery tube 4170. A 10k thermistor may be provided in a first type of tube (e.g., 15mm heated air tube), a 100k thermistor may be provided in a second type of tube (e.g., a 19mm heated air tube), and an open circuit may be provided in a third type of tube (e.g., a passive air tube without heating elements). The different resistance values provided by the sensor 6500 may allow for the processing circuitry 6400 to determine the type of tube that is connected and which control parameters to use for the operation of the RPT device 4000. Using tube detection as described in US Provisional Application 62/835,094, filed on April 17, 2019, contents of which is incorporated herein by reference in its entirety, may be applied to the present technology disclosure.

5.7.2 Four pin three wire identification

[0282] Because using certain thermistors may provide more accurate measurements of the temperature in the air delivery tube 4170, certain example embodiments provide for identifying air delivery tube type without using sensors with different characteristics (e.g., resistances). In one example, a 10K thermistors can be used in different air delivery tubes 4170, to provide more accurate measurements of the temperature in the tube as compared to a 100k thermistor.

[0283] Figs. 5E and 5F show schematic views of an air delivery tube 4170 connected to an RPT device 4000 in which one of the sensor lines is not coupled to the sensor 6500. The sensor 6500 shown in Figs. 5E and 5F may have parameters that are similar to the parameters of the sensor 6500 shown in Fig. 5D. In one example, the sensor 6500 in Figs. 5D, 5E and 5F may be a 10k thermistor.

[0284] In Figs. 5E and 5F, the sensor 6500 is coupled to only one of the sensor lines and the heating lines. The sensor 6500 may be coupled to one or more heating lines via the heating elements or directly to the heating lines via the connections in the tube connector 6300 and bypassing the heating elements in one or more heating lines. In one example, the sensor 6500 may be coupled to one of the sensor lines and a pin in the tube connector 6300 coupled to ground of the heated tube control circuit.

[0285] The different air delivery tube type may be designated by coupling the sensor 6500 to a different sensor line from a plurality of sensor lines (two sensor lines are shown but more may be included). For example, a first tube type (e.g., 15 mm heated air tube) may be designated by coupling the sensor 6500 to sensor line 2 and the heating line(s), and a second tube type (e.g., 19 mm heated air tube) may be designated by coupling the sensor 6500 to sensor line 1 and the heating line(s).

[0286] In the examples shown in Figs. 5E and 5F, the contact assembly 6200 of the RPT device 4000 may include a 4 pin connection while the tube connector 6300 may include a 3 pin connection. The different manner in which the lower number of pins in the air delivery tube 4170 connect to the higher number of pins in the RPT device 4000 may be used to distinguish between different air delivery tubes 4170. In these examples, the air delivery tube 4170 may include 3 wires (i.e., two for the heating elements and one for the sensor 6500) extending in the tube to the tube end coupled to the patient interface 3000. In some examples, an additional pin may be provided in the tube connector 6300 that is not electrically coupled to any component in the air delivery tube. In other example, the tube connector 6300 may not include an additional electrical pin (e.g., 4^{th} pin).

[0287] The heated tube detection circuit may determine the type of air delivery tube 4170 coupled to the RPT device 4000 by measuring the presence and/or absence of a signal on the pins of the contact assembly 6200. If a signal is absent on the sensor line 1, then a first type of air delivery tube may be identified by the heated tube detection circuit. If a signal is absent on the sensor line 2, then a second type of air delivery tube may be identified by the heated tube detection circuit.

[0288] In another example, a signal is present on the sensor line 2, then a first type of air delivery tube may be identified by the heated tube detection circuit. If a

signal is present on the sensor line 1, then a second type of air delivery tube may be identified by the heated tube detection circuit.

[0289] In some examples, an absence of a signal on both sensor lines may designate that an air delivery tube is not connected to the RPT device 4000 or that a third type of air delivery tube (e.g., a non-heated tube) is coupled to the RPT device 4000.

[0290] Figs. 5G and 5H show schematic views of an air delivery tube 4170 connected to an RPT device 4000 in which signals measured via a detection line are used to identify a type of air delivery tube 4170 coupled to the RPT device 4000. In Figs. 5G and 5H, heating elements in the air delivery tube 4170 are coupled to a heating line in the RPT device 4000 via a connection in the tube connector 6300, and a sensor 6500 is coupled to a sensor line in the RPT device 4000 via a connection in the tube connector 6300. The heating control circuit in the RPT device 4000 may provide power to the heating elements in the air delivery tube 4170 via the heating line and ground. The control circuit may determine the temperature in the air delivery tube 4170 by measuring a signal from the sensor 6500 across the sensor line and ground.

[0291] The heated tube detection circuit may determine an air delivery tube type based on the signals received via the detection line in the contact assembly 6200. As shown in Fig. 5G, a first tube type (e.g., 15 mm heated air tube) may be designated by absence of an electrical connection (or a pin) in the tube connector 6300 to the detection line in the contact assembly 6200. As shown in Fig. 6H, a second tube type (e.g., 19 mm heated air tube) may be designated by a pin in the tube connector 6300 being electrically connected (e.g., in the tube cuff) by means of a detectable electrical connection 6350. The electrical connection 6350 may include, for example, a flat short, a resistive connection, a shunt, non-symmetrical (e.g., diode type), or active signalling. As shown in Fig. 5H, the electrical connection 6350 may be provided between the detection line and ground terminal of the contact assembly 6200 and tube connector 6300.

[0292] The heated tube detection circuit may determine the type of air delivery tube 4170 coupled to the RPT device 4000 by measuring the presence and/or absence

of a circuit component on the detection line of the contact assembly 6200. For example, a voltage may be applied to the detection line to determine if there is current flow via a component coupled to between the detection line and ground line. If a signal is absent on the detection line (as shown in Fig. 5G), then a first type of air delivery tube may be identified by the heated tube detection circuit. If a signal is present on the detection line (as shown in Fig. 5H), then a second type of air delivery tube may be identified by the heated tube detection circuit.

[0293] In some examples, different types of electrical connection 6350 (e.g., different values of resistive elements) may be used to further distinguish between different type of air delivery tubes, and the heated tube detection circuit may determine the type of tube based on signals received via the detection line

[0294] In another example, when a signal is present on the sensor line 2, then a first type of air delivery tube may be identified by the heated tube detection circuit. When a signal is present on the sensor line 1, then a second type of air delivery tube may be identified by the heated tube detection circuit.

[0295] The heated tube detection circuit may determine the type of air delivery tube 4170 coupled to the RPT device 4000 by determining whether there is an open circuit or a closed circuit on a circuit including the detection line and one of the other connections (e.g., one of the heating lines). A first type of air delivery tube may be identified when the circuit is open, and a second type of air delivery tube may be identified when the circuit is closed (e.g., due to a resistor or shunt coupling the detection line to one of the other connections in the air delivery tube 4170).

[0296] The air delivery tube identification may be performed based on signals received from the sensor line(s) and/or detection line in hardware and/or software. In some examples, the hardware and/or software may be configured to perform the tube identification when the RPT device 4000 is started, when an air delivery tube is connected to the RPT device 4000, periodicly during operation of the RPT device 4000, and/or at the start of an operation by the RPT device 4000.

[0297] Fig. 5I illustrates an example heated tube detection circuit in accordance with one form of the present technology. The heated tube detection circuit shown in

Fig. 5I may be used to identify air delivery tube type using the identification circuitry provided in Figs. 5E and 5F.

[0298] A comparator 5290 may be coupled to the sensor lines and provide an output signal to a controller 5250 configured to control heating element 5240, heating air circuit 4171, and/or other components of the RPT device 4000 based on the determined tube type and data received from sensors 5210. Sensor line 1 and sensor line 2 may be coupled to a comparator configured to compare the signals received via the sensor lines. The comparator may output a first value (e.g., a zero) if the signal on sensor line 1 is lower than signal on sensor line 2 (configuration shown in Fig. 5E), and output a second value (e.g., a one) if the signal on the sensor line 2 is lower than the signal on line 1 (configuration shown in Fig. 5F). In this example, the digital output of one or zero may distinguish between two tube types and indicate the type of air delivery tube 4170 coupled to the RPT device 4000. In some examples, the comparator 5290 may further be configured to determine when the signals on the sensor lines are equal to indicate a third type of air delivery tube 4170 or absence of an air delivery tube 4170. The third type of air delivery tube may correspond to an air delivery tube without a heating element and/or sensor.

[0299] Fig. 5J illustrates an example heated tube detection circuit in accordance with another form of the present technology. The heated tube detection circuit shown in Fig. 5J may be used to identify air delivery tube type using the identification circuitry provided in Figs. 5G and 5H.

[0300] A comparator 5292 may be coupled to the detection line and provide an output signal to a controller 5250 configured to control heating element 5240, heating air circuit 4171, and/or other components of the RPT device 4000 based on the determined tube type and data received from sensors 5210. Detection line may be coupled to a comparator configured to compare the signal received via the detection line to a reference value (e.g., ground or a reference voltage). The comparator 5292 may output a first value (e.g., a one) if the signal on the detection line is higher than the reference value (configuration shown in Fig. 5H), and output a second value (e.g., a zero) if the signal on the detection line is equal to or lower than the reference value (configuration shown in Fig. 5G). In this example, the digital output of one or zero may indicate the type of air delivery tube 4170 coupled to the RPT device 4000.

[0301] While the above examples of the present technology have been described with reference to a three or four wire system and connectors having three or pins in the connectors, the examples are not so limited. The examples of the present technology may be applied to systems with other number of wires, e.g., two wires, three wires, or five or more wires, and/or other number of pins. For example, additional sensor line may be included in the RPT device 4000 to distinguish between a larger number of air delivery tube types.

5.8 BREATHING WAVEFORMS

[0302] Fig. 6A shows a model typical breath waveform of a person while sleeping. The horizontal axis is time, and the vertical axis is respiratory flow rate. While the parameter values may vary, a typical breath may have the following approximate values: tidal volume *Vt* 0.5L, inhalation time *Ti* 1.6s, peak inspiratory flow rate *Qpeak* 0.4 L/s, exhalation time *Te* 2.4s, peak expiratory flow rate *Qpeak* -0.5 L/s. The total duration of the breath, *Ttot*, is about 4s. The person typically breathes at a rate of about 15 breaths per minute (BPM), with Ventilation *Vent* about 7.5 L/min. A typical duty cycle, the ratio of *Ti* to *Ttot*, is about 40%.

[0303] Fig. 6B shows selected polysomnography channels (pulse oximetry, flow rate, thoracic movement, and abdominal movement) of a patient during non-REM sleep breathing normally over a period of about ninety seconds, with about 34 breaths, being treated with automatic PAP therapy, and the interface pressure being about 11 cmH_2O. The top channel shows pulse oximetry (oxygen saturation or SpO_2), the scale having a range of saturation from 90 to 99% in the vertical direction. The patient maintained a saturation of about 95% throughout the period shown. The second channel shows quantitative respiratory airflow, and the scale ranges from -1 to +1 LPS in a vertical direction, and with inspiration positive. Thoracic and abdominal movement are shown in the third and fourth channels.

[0304] Fig. 6C shows polysomnography of a patient before treatment. There are eleven signal channels from top to bottom with a 6 minute horizontal span. The top two channels are both EEG (electoencephalogram) from different scalp locations. Periodic spikes in the second EEG represent cortical arousal and related activity. The third channel down is submental EMG (electromyogram). Increasing activity around the time of arousals represents genioglossus recruitment. The fourth & fifth channels

are EOG (electro-oculogram). The sixth channel is an electocardiogram. The seventh channel shows pulse oximetry (SpO_2) with repetitive desaturations to below 70% from about 90%. The eighth channel is respiratory airflow using a nasal cannula connected to a differential pressure transducer. Repetitive apneas of 25 to 35 seconds alternate with 10 to 15 second bursts of recovery breathing coinciding with EEG arousal and increased EMG activity. The ninth channel shows movement of chest and the tenth shows movement of abdomen. The abdomen shows a crescendo of movement over the length of the apnea leading to the arousal. Both become untidy during the arousal due to gross body movement during recovery hyperpnea. The apneas are therefore obstructive, and the condition is severe. The lowest channel is posture, and in this example it does not show change.

[0305] Fig. 6D shows patient flow rate data where the patient is experiencing a series of total obstructive apneas. The duration of the recording is approximately 160 seconds. Flow rates range from about +1 L/s to about -1.5 L/s. Each apnea lasts approximately 10-15s.

[0306] Fig. 6E shows a scaled inspiratory portion of a breath where the patient is experiencing low frequency inspiratory snore.

[0307] Fig. 6F shows a scaled inspiratory portion of a breath where the patient is experiencing an example of flattened inspiratory flow limitation.

[0308] Fig. 6G shows a scaled inspiratory portion of a breath where the patient is experiencing an example of “mesa” flattened inspiratory flow limitation.

[0309] Fig. 6H shows a scaled inspiratory portion of a breath where the patient is experiencing an example of “panda ears” inspiratory flow limitation.

[0310] Fig. 6I shows a scaled inspiratory portion of a breath where the patient is experiencing an example of "chair" inspiratory flow limitation.

[0311] Fig. 6J shows a scaled inspiratory portion of a breath where the patient is experiencing an example of "reverse chair" inspiratory flow limitation.

[0312] Fig. 6K shows a scaled inspiratory portion of a breath where the patient is experiencing an example of “M-shaped” inspiratory flow limitation.

[0313] Fig. 6L shows a scaled inspiratory portion of a breath where the patient is experiencing an example of severely "M-shaped" inspiratory flow limitation.

[0314] Fig. 6M shows patient data from a patient with Cheyne-Stokes respiration. There are three channels: pulse oximetry (SpO_2); a signal indicative of flow rate; and thoracic movement. The data span six minutes. The signal representative of flow rate was measured using a pressure sensor connected to a nasal cannula. The patient exhibits apneas of about 22 seconds and hyperpneas of about 38 seconds. The higher frequency low amplitude oscillation during apnea is cardiogenic.

[0315] Fig. 6N shows patient data from a patient with another example of Cheyne-Stokes respiration, using the same three channels as in Fig. 6M. The data span ten minutes. The patient exhibits hyperpneas of about 30 seconds and hypopneas of about 30 seconds.

5.9 RESPIRATORY THERAPY MODES

[0316] Various respiratory therapy modes may be implemented by the disclosed respiratory therapy system.

5.9.1 CPAP therapy

[0317] In some implementations of respiratory pressure therapy, the central controller 4230 sets the treatment pressure Pt according to the treatment pressure equation (1) as part of the therapy parameter determination algorithm 4329. In one such implementation, the amplitude A is identically zero, so the treatment pressure Pt (which represents a target value to be achieved by the interface pressure Pm at the current instant of time) is identically equal to the base pressure P_0 throughout the respiratory cycle. Such implementations are generally grouped under the heading of CPAP therapy. In such implementations, there is no need for the therapy engine module 4320 to determine phase Φ or the waveform template $\Pi(\Phi)$.

[0318] In CPAP therapy, the base pressure P_0 may be a constant value that is hard-coded or manually entered to the RPT device 4000. Alternatively, the central controller 4230 may repeatedly compute the base pressure P_0 as a function of indices or measures of sleep disordered breathing returned by the respective algorithms in the therapy engine module 4320, such as one or more of flow limitation, apnea,

hypopnea, patency, and snore. This alternative is sometimes referred to as APAP therapy.

[0319] Fig. 4E is a flow chart illustrating a method 4500 carried out by the central controller 4230 to continuously compute the base pressure P_0 as part of an APAP therapy implementation of the therapy parameter determination algorithm 4329, when the pressure support A is identically zero.

[0320] The method 4500 starts at step 4520, at which the central controller 4230 compares the measure of the presence of apnea / hypopnea with a first threshold, and determines whether the measure of the presence of apnea / hypopnea has exceeded the first threshold for a predetermined period of time, indicating an apnea / hypopnea is occurring. If so, the method 4500 proceeds to step 4540; otherwise, the method 4500 proceeds to step 4530. At step 4540, the central controller 4230 compares the measure of airway patency with a second threshold. If the measure of airway patency exceeds the second threshold, indicating the airway is patent, the detected apnea / hypopnea is deemed central, and the method 4500 proceeds to step 4560; otherwise, the apnea / hypopnea is deemed obstructive, and the method 4500 proceeds to step 4550.

[0321] At step 4530, the central controller 4230 compares the measure of flow limitation with a third threshold. If the measure of flow limitation exceeds the third threshold, indicating inspiratory flow is limited, the method 4500 proceeds to step 4550; otherwise, the method 4500 proceeds to step 4560.

[0322] At step 4550, the central controller 4230 increases the base pressure P_0 by a predetermined pressure increment ΔP, provided the resulting treatment pressure Pt would not exceed a maximum treatment pressure $Pmax$. In one implementation, the predetermined pressure increment ΔP and maximum treatment pressure $Pmax$ are 1 cmH_2O and 25 cmH_2O respectively. In other implementations, the pressure increment ΔP can be as low as 0.1 cmH_2O and as high as 3 cmH_2O, or as low as 0.5 cmH_2O and as high as 2 cmH_2O. In other implementations, the maximum treatment pressure $Pmax$ can be as low as 15 cmH_2O and as high as 35 cmH_2O, or as low as 20 cmH_2O and as high as 30 cmH_2O. The method 4500 then returns to step 4520.

[0323] At step 4560, the central controller 4230 decreases the base pressure P_0 by a decrement, provided the decreased base pressure P_0 would not fall below a minimum treatment pressure *Pmin*. The method 4500 then returns to step 4520. In one implementation, the decrement is proportional to the value of P_0-*Pmin*, so that the decrease in P_0 to the minimum treatment pressure *Pmin* in the absence of any detected events is exponential. In one implementation, the constant of proportionality is set such that the time constant τ of the exponential decrease of P_0 is 60 minutes, and the minimum treatment pressure *Pmin* is 4 cmH_2O. In other implementations, the time constant τ could be as low as 1 minute and as high as 300 minutes, or as low as 5 minutes and as high as 180 minutes. In other implementations, the minimum treatment pressure *Pmin* can be as low as 0 cmH_2O and as high as 8 cmH_2O, or as low as 2 cmH_2O and as high as 6 cmH_2O. Alternatively, the decrement in P_0 could be predetermined, so the decrease in P_0 to the minimum treatment pressure *Pmin* in the absence of any detected events is linear.

5.9.2 Bi-level therapy

[0324] In other implementations of this form of the present technology, the value of amplitude *A* in equation (1) may be positive. Such implementations are known as bi-level therapy, because in determining the treatment pressure *Pt* using equation (1) with positive amplitude *A*, the therapy parameter determination algorithm 4329 oscillates the treatment pressure *Pt* between two values or levels in synchrony with the spontaneous respiratory effort of the patient 1000. That is, based on the typical waveform templates $\Pi(\Phi, t)$ described above, the therapy parameter determination algorithm 4329 increases the treatment pressure *Pt* to $P_0 + A$ (known as the IPAP) at the start of, or during, or inspiration and decreases the treatment pressure *Pt* to the base pressure P_0 (known as the EPAP) at the start of, or during, expiration.

[0325] In some forms of bi-level therapy, the IPAP is a treatment pressure that has the same purpose as the treatment pressure in CPAP therapy modes, and the EPAP is the IPAP minus the amplitude *A*, which has a "small" value (a few cmH_2O) sometimes referred to as the Expiratory Pressure Relief (EPR). Such forms are sometimes referred to as CPAP therapy with EPR, which is generally thought to be more comfortable than straight CPAP therapy. In CPAP therapy with EPR, either or both of the IPAP and the EPAP may be constant values that are hard-coded or

manually entered to the RPT device 4000. Alternatively, the therapy parameter determination algorithm 4329 may repeatedly compute the IPAP and / or the EPAP during CPAP with EPR. In this alternative, the therapy parameter determination algorithm 4329 repeatedly computes the EPAP and / or the IPAP as a function of indices or measures of sleep disordered breathing returned by the respective algorithms in the therapy engine module 4320 in analogous fashion to the computation of the base pressure P_0 in APAP therapy described above.

[0326] In other forms of bi-level therapy, the amplitude A is large enough that the RPT device 4000 does some or all of the work of breathing of the patient 1000. In such forms, known as pressure support ventilation therapy, the amplitude A is referred to as the pressure support, or swing. In pressure support ventilation therapy, the IPAP is the base pressure P_0 plus the pressure support A, and the EPAP is the base pressure P_0.

[0327] In some forms of pressure support ventilation therapy, known as fixed pressure support ventilation therapy, the pressure support A is fixed at a predetermined value, e.g. 10 cmH_2O. The predetermined pressure support value is a setting of the RPT device 4000, and may be set for example by hard-coding during configuration of the RPT device 4000 or by manual entry through the input device 4220.

[0328] In other forms of pressure support ventilation therapy, broadly known as servo-ventilation, the therapy parameter determination algorithm 4329 takes as input some currently measured or estimated parameter of the respiratory cycle (e.g. the current measure *Vent* of ventilation) and a target value of that respiratory parameter (e.g. a target value *Vtgt* of ventilation) and repeatedly adjusts the parameters of equation (1) to bring the current measure of the respiratory parameter towards the target value. In a form of servo-ventilation known as adaptive servo-ventilation (ASV), which has been used to treat CSR, the respiratory parameter is ventilation, and the target ventilation value *Vtgt* is computed by the target ventilation determination algorithm 4328 from the typical recent ventilation *Vtyp*, as described above.

[0329] In some forms of servo-ventilation, the therapy parameter determination algorithm 4329 applies a control methodology to repeatedly compute the pressure

support A so as to bring the current measure of the respiratory parameter towards the target value. One such control methodology is Proportional-Integral (PI) control. In one implementation of PI control, suitable for ASV modes in which a target ventilation $Vtgt$ is set to slightly less than the typical recent ventilation $Vtyp$, the pressure support A is repeatedly computed as:

$$A = G\int (Vent - Vtgt)dt \tag{2}$$

[0330] where G is the gain of the PI control. Larger values of gain G can result in positive feedback in the therapy engine module 4320. Smaller values of gain G may permit some residual untreated CSR or central sleep apnea. In some implementations, the gain G is fixed at a predetermined value, such as -0.4 $cmH_2O/(L/min)/sec$. Alternatively, the gain G may be varied between therapy sessions, starting small and increasing from session to session until a value that substantially eliminates CSR is reached. Conventional means for retrospectively analysing the parameters of a therapy session to assess the severity of CSR during the therapy session may be employed in such implementations In yet other implementations, the gain G may vary depending on the difference between the current measure $Vent$ of ventilation and the target ventilation $Vtgt$.

[0331] Other servo-ventilation control methodologies that may be applied by the therapy parameter determination algorithm 4329 include proportional (P), proportional-differential (PD), and proportional-integral-differential (PID).

[0332] The value of the pressure support A computed via equation **(Error! Reference source not found.)** may be clipped to a range defined as $[Amin, Amax]$. In this implementation, the pressure support A sits by default at the minimum pressure support $Amin$ until the measure of current ventilation $Vent$ falls below the target ventilation $Vtgt$, at which point A starts increasing, only falling back to $Amin$ when $Vent$ exceeds $Vtgt$ once again.

[0333] The pressure support limits $Amin$ and $Amax$ are settings of the RPT device 4000, set for example by hard-coding during configuration of the RPT device 4000 or by manual entry through the input device 4220.

[0334] In pressure support ventilation therapy modes, the EPAP is the base pressure P_0. As with the base pressure P_0 in CPAP therapy, the EPAP may be a constant value that is prescribed or determined during titration. Such a constant EPAP may be set for example by hard-coding during configuration of the RPT device 4000 or by manual entry through the input device 4220. This alternative is sometimes referred to as fixed-EPAP pressure support ventilation therapy. Titration of the EPAP for a given patient may be performed by a clinician during a titration session with the aid of PSG, with the aim of preventing obstructive apneas, thereby maintaining an open airway for the pressure support ventilation therapy, in similar fashion to titration of the base pressure P_0 in constant CPAP therapy.

[0335] Alternatively, the therapy parameter determination algorithm 4329 may repeatedly compute the base pressure P_0 during pressure support ventilation therapy. In such implementations, the therapy parameter determination algorithm 4329 repeatedly computes the EPAP as a function of indices or measures of sleep disordered breathing returned by the respective algorithms in the therapy engine module 4320, such as one or more of flow limitation, apnea, hypopnea, patency, and snore. Because the continuous computation of the EPAP resembles the manual adjustment of the EPAP by a clinician during titration of the EPAP, this process is also sometimes referred to as auto-titration of the EPAP, and the therapy mode is known as auto-titrating EPAP pressure support ventilation therapy, or auto-EPAP pressure support ventilation therapy.

5.9.3 High flow therapy

[0336] In other forms of respiratory therapy, the pressure of the flow of air is not controlled as it is for respiratory pressure therapy. Rather, the central controller 4230 controls the pressure generator 4140 to deliver a flow of air whose device flow rate Qd is controlled to a treatment or target flow rate $Qtgt$ that is typically positive throughout the patient's breathing cycle. Such forms are generally grouped under the heading of flow therapy. In flow therapy, the treatment flow rate $Qtgt$ may be a constant value that is hard-coded or manually entered to the RPT device 4000. If the treatment flow rate $Qtgt$ is sufficient to exceed the patient's peak inspiratory flow rate, the therapy is generally referred to as high flow therapy (HFT). Alternatively, the treatment flow rate may be a profile $Qtgt(t)$ that varies over the respiratory cycle.

5.10 GLOSSARY

[0337] For the purposes of the present technology disclosure, in certain forms of the present technology, one or more of the following definitions may apply. In other forms of the present technology, alternative definitions may apply.

5.10.1 General

[0338] *Air*: In certain forms of the present technology, air may be taken to mean atmospheric air, and in other forms of the present technology air may be taken to mean some other combination of breathable gases, e.g. atmospheric air enriched with oxygen.

[0339] *Ambient*: In certain forms of the present technology, the term ambient will be taken to mean (i) external of the treatment system or patient, and (ii) immediately surrounding the treatment system or patient.

[0340] For example, ambient humidity with respect to a humidifier may be the humidity of air immediately surrounding the humidifier, e.g. the humidity in the room where a patient is sleeping. Such ambient humidity may be different to the humidity outside the room where a patient is sleeping.

[0341] In another example, ambient pressure may be the pressure immediately surrounding or external to the body.

[0342] In certain forms, ambient (e.g., acoustic) noise may be considered to be the background noise level in the room where a patient is located, other than for example, noise generated by an RPT device or emanating from a mask or patient interface. Ambient noise may be generated by sources outside the room.

[0343] *Automatic Positive Airway Pressure (APAP) therapy*: CPAP therapy in which the treatment pressure is automatically adjustable, e.g. from breath to breath, between minimum and maximum limits, depending on the presence or absence of indications of SDB events.

[0344] *Continuous Positive Airway Pressure (CPAP) therapy*: Respiratory pressure therapy in which the treatment pressure is approximately constant through a respiratory cycle of a patient. In some forms, the pressure at the entrance to the

airways will be slightly higher during exhalation, and slightly lower during inhalation. In some forms, the pressure will vary between different respiratory cycles of the patient, for example, being increased in response to detection of indications of partial upper airway obstruction, and decreased in the absence of indications of partial upper airway obstruction.

[0345] *Flow rate*: The volume (or mass) of air delivered per unit time. Flow rate may refer to an instantaneous quantity. In some cases, a reference to flow rate will be a reference to a scalar quantity, namely a quantity having magnitude only. In other cases, a reference to flow rate will be a reference to a vector quantity, namely a quantity having both magnitude and direction. Flow rate may be given the symbol *Q*. 'Flow rate' is sometimes shortened to simply 'flow' or 'airflow'.

[0346] In the example of patient respiration, a flow rate may be nominally positive for the inspiratory portion of a breathing cycle of a patient, and hence negative for the expiratory portion of the breathing cycle of a patient. Device flow rate, *Qd*, is the flow rate of air leaving the RPT device. Total flow rate, *Qt*, is the flow rate of air and any supplementary gas reaching the patient interface via the air circuit. Vent flow rate, *Qv*, is the flow rate of air leaving a vent to allow washout of exhaled gases. Leak flow rate, *Ql*, is the flow rate of leak from a patient interface system or elsewhere. Respiratory flow rate, *Qr*, is the flow rate of air that is received into the patient's respiratory system.

[0347] *Flow therapy*: Respiratory therapy comprising the delivery of a flow of air to an entrance to the airways at a controlled flow rate referred to as the treatment flow rate that is typically positive throughout the patient's breathing cycle.

[0348] *Humidifier*: The word humidifier will be taken to mean a humidifying apparatus constructed and arranged, or configured with a physical structure to be capable of providing a therapeutically beneficial amount of water (H_2O) vapour to a flow of air to ameliorate a medical respiratory condition of a patient.

[0349] *Leak*: The word leak will be taken to be an unintended flow of air. In one example, leak may occur as the result of an incomplete seal between a mask and a patient's face. In another example leak may occur in a swivel elbow to the ambient.

[0350] *Noise, conducted (acoustic)*: Conducted noise in the present document refers to noise which is carried to the patient by the pneumatic path, such as the air circuit and the patient interface as well as the air therein. In one form, conducted noise may be quantified by measuring sound pressure levels at the end of an air circuit.

[0351] *Noise, radiated (acoustic)*: Radiated noise in the present document refers to noise which is carried to the patient by the ambient air. In one form, radiated noise may be quantified by measuring sound power/pressure levels of the object in question according to ISO 3744.

[0352] *Noise, vent (acoustic)*: Vent noise in the present document refers to noise which is generated by the flow of air through any vents such as vent holes of the patient interface.

[0353] *Patient*: A person, whether or not they are suffering from a respiratory condition.

[0354] *Pressure:* Force per unit area. Pressure may be expressed in a range of units, including cmH_2O, g-f/cm^2 and hectopascal. 1 cmH_2O is equal to 1 g-f/cm^2 and is approximately 0.98 hectopascal (1 hectopascal = 100 Pa = 100 N/m^2 = 1 millibar ~ 0.001 atm). In this specification, unless otherwise stated, pressure is given in units of cmH_2O.

[0355] The pressure in the patient interface is given the symbol *Pm*, while the treatment pressure, which represents a target value to be achieved by the interface pressure *Pm* at the current instant of time, is given the symbol *Pt*.

[0356] *Respiratory Pressure Therapy (RPT)*: The application of a supply of air to an entrance to the airways at a treatment pressure that is typically positive with respect to atmosphere.

[0357] *Ventilator*: A mechanical device that provides pressure support to a patient to perform some or all of the work of breathing.

5.10.1.1 Materials

[0358] *Silicone or Silicone Elastomer*: A synthetic rubber. In this specification, a reference to silicone is a reference to liquid silicone rubber (LSR) or a compression

moulded silicone rubber (CMSR). One form of commercially available LSR is SILASTIC (included in the range of products sold under this trademark), manufactured by Dow Corning. Another manufacturer of LSR is Wacker. Unless otherwise specified to the contrary, an exemplary form of LSR has a Shore A (or Type A) indentation hardness in the range of about 35 to about 45 as measured using ASTM D2240.

[0359] *Polycarbonate*: a thermoplastic polymer of Bisphenol-A Carbonate.

5.10.1.2 Mechanical properties

[0360] *Resilience*: Ability of a material to absorb energy when deformed elastically and to release the energy upon unloading.

[0361] *Resilient*: Will release substantially all of the energy when unloaded. Includes e.g. certain silicones, and thermoplastic elastomers.

[0362] *Hardness*: The ability of a material *per se* to resist deformation (e.g. described by a Young's Modulus, or an indentation *hardness* scale measured on a standardised sample size).

- 'Soft' materials may include silicone or thermo-plastic elastomer (TPE), and may, e.g. readily deform under finger pressure.
- 'Hard' materials may include polycarbonate, polypropylene, steel or aluminium, and may not e.g. readily deform under finger pressure.

[0363] *Stiffness (or rigidity) of a structure or component*: The ability of the structure or component to resist deformation in response to an applied load. The load may be a force or a moment, e.g. compression, tension, bending or torsion. The structure or component may offer different resistances in different directions. The inverse of stiffness is *flexibility*.

[0364] *Floppy structure or component:* A structure or component that will change shape, e.g. bend, when caused to support its own weight, within a relatively short period of time such as 1 second.

[0365] *Rigid structure or component*: A structure or component that will not substantially change shape when subject to the loads typically encountered in use. An

example of such a use may be setting up and maintaining a patient interface in sealing relationship with an entrance to a patient's airways, e.g. at a load of approximately 20 to 30 cmH_2O pressure.

[0366] As an example, an I-beam may comprise a different bending stiffness (resistance to a bending load) in a first direction in comparison to a second, orthogonal direction. In another example, a structure or component may be floppy in a first direction and rigid in a second direction.

5.10.2 Respiratory cycle

[0367] *Apnea*: According to some definitions, an apnea is said to have occurred when flow falls below a predetermined threshold for a duration, e.g. 10 seconds. An obstructive apnea will be said to have occurred when, despite patient effort, some obstruction of the airway does not allow air to flow. A central apnea will be said to have occurred when an apnea is detected that is due to a reduction in breathing effort, or the absence of breathing effort, despite the airway being patent. A mixed apnea occurs when a reduction or absence of breathing effort coincides with an obstructed airway.

[0368] *Breathing rate*: The rate of spontaneous respiration of a patient, usually measured in breaths per minute.

[0369] *Duty cycle*: The ratio of inhalation time, *Ti* to total breath time, *Ttot*.

[0370] *Effort (breathing)*: The work done by a spontaneously breathing person attempting to breathe.

[0371] *Expiratory portion of a breathing cycle:* The period from the start of expiratory flow to the start of inspiratory flow.

[0372] *Flow limitation*: Flow limitation will be taken to be the state of affairs in a patient's respiration where an increase in effort by the patient does not give rise to a corresponding increase in flow. Where flow limitation occurs during an inspiratory portion of the breathing cycle it may be described as inspiratory flow limitation. Where flow limitation occurs during an expiratory portion of the breathing cycle it may be described as expiratory flow limitation.

[0373] Types of flow limited inspiratory waveforms:

(i) *Flattened*: Having a rise followed by a relatively flat portion, followed by a fall.

(ii) *M-shaped*: Having two local peaks, one at the leading edge, and one at the trailing edge, and a relatively flat portion between the two peaks.

(iii) *Chair-shaped*: Having a single local peak, the peak being at the leading edge, followed by a relatively flat portion.

(iv) *Reverse-chair shaped*: Having a relatively flat portion followed by single local peak, the peak being at the trailing edge.

[0374] *Hypopnea*: According to some definitions, a hypopnea is taken to be a reduction in flow, but not a cessation of flow. In one form, a hypopnea may be said to have occurred when there is a reduction in flow below a threshold rate for a duration. A central hypopnea will be said to have occurred when a hypopnea is detected that is due to a reduction in breathing effort. In one form in adults, either of the following may be regarded as being hypopneas:

(i) a 30% reduction in patient breathing for at least 10 seconds plus an associated 4% desaturation; or

(ii) a reduction in patient breathing (but less than 50%) for at least 10 seconds, with an associated desaturation of at least 3% or an arousal.

[0375] *Hyperpnea*: An increase in flow to a level higher than normal.

[0376] *Inspiratory portion of a breathing cycle*: The period from the start of inspiratory flow to the start of expiratory flow will be taken to be the inspiratory portion of a breathing cycle.

[0377] *Patency (airway)*: The degree of the airway being open, or the extent to which the airway is open. A *patent* airway is open. Airway patency may be quantified, for example with a value of one (1) being patent, and a value of zero (0), being closed (obstructed).

[0378] *Positive End-Expiratory Pressure (PEEP)*: The pressure above atmosphere in the lungs that exists at the end of expiration.

[0379] *Peak flow rate (Qpeak)*: The maximum value of flow rate during the inspiratory portion of the respiratory flow waveform.

[0380] *Respiratory flow rate,* patient *airflow rate, respiratory airflow rate (Qr)*: These terms may be understood to refer to the RPT device's estimate of respiratory flow rate, as opposed to "true respiratory flow rate" or "true respiratory flow rate", which is the actual respiratory flow rate experienced by the patient, usually expressed in litres per minute.

[0381] *Tidal volume (Vt)*: The volume of air inhaled or exhaled during normal breathing, when extra effort is not applied. In principle the inspiratory volume *Vi* (the volume of air inhaled) is equal to the expiratory volume *Ve* (the volume of air exhaled), and therefore a single tidal volume *Vt* may be defined as equal to either quantity. In practice the tidal volume *Vt* is estimated as some combination, e.g. the mean, of the inspiratory volume *Vi* and the expiratory volume *Ve*.

[0382] *(inhalation) Time (Ti)*: The duration of the inspiratory portion of the respiratory flow rate waveform.

[0383] *(exhalation) Time (Te)*: The duration of the expiratory portion of the respiratory flow rate waveform.

[0384] *(total) Time (Ttot)*: The total duration between the start of one inspiratory portion of a respiratory flow rate waveform and the start of the following inspiratory portion of the respiratory flow rate waveform.

[0385] *Typical recent ventilation*: The value of ventilation around which recent values of ventilation *Vent* over some predetermined timescale tend to cluster, that is, a measure of the central tendency of the recent values of ventilation.

[0386] *Upper airway obstruction (UAO)*: includes both partial and total upper airway obstruction. This may be associated with a state of flow limitation, in which the flow rate increases only slightly or may even decrease as the pressure difference across the upper airway increases (Starling resistor behaviour).

[0387] *Ventilation* (*Vent*): A measure of a rate of gas being exchanged by the patient's respiratory system. Measures of ventilation may include one or both of inspiratory and expiratory flow, per unit time. When expressed as a volume per minute, this quantity is often referred to as "minute ventilation". Minute ventilation is sometimes given simply as a volume, understood to be the volume per minute.

5.10.3 Ventilation

[0388] *Adaptive Servo-Ventilator (ASV)*: A servo-ventilator that has a changeable, rather than fixed target ventilation. The changeable target ventilation may be learned from some characteristic of the patient, for example, a respiratory characteristic of the patient.

[0389] *Backup rate*: A parameter of a ventilator that establishes the minimum breathing rate (typically in number of breaths per minute) that the ventilator will deliver to the patient, if not triggered by spontaneous respiratory effort.

[0390] *Cycled*: The termination of a ventilator's inspiratory phase. When a ventilator delivers a breath to a spontaneously breathing patient, at the end of the inspiratory portion of the breathing cycle, the ventilator is said to be cycled to stop delivering the breath.

[0391] *Expiratory positive airway pressure (EPAP)*: a base pressure, to which a pressure varying within the breath is added to produce the desired interface pressure which the ventilator will attempt to achieve at a given time.

[0392] *End expiratory pressure (EEP)*: Desired interface pressure which the ventilator will attempt to achieve at the end of the expiratory portion of the breath. If the pressure waveform template $\Pi(\Phi)$ is zero-valued at the end of expiration, i.e. $\Pi(\Phi) = 0$ when $\Phi = 1$, the EEP is equal to the EPAP.

[0393] *Inspiratory positive airway pressure (IPAP)*: Maximum desired interface pressure which the ventilator will attempt to achieve during the inspiratory portion of the breath.

[0394] *Pressure support*: A number that is indicative of the increase in pressure during ventilator inspiration over that during ventilator expiration, and generally

means the difference in pressure between the maximum value during inspiration and the base pressure (e.g., *PS = IPAP – EPAP*). In some contexts pressure support means the difference which the ventilator aims to achieve, rather than what it actually achieves.

[0395] *Servo-ventilator*: A ventilator that measures patient ventilation, has a target ventilation, and which adjusts the level of pressure support to bring the patient ventilation towards the target ventilation.

[0396] *Spontaneous/Timed (S/T)*: A mode of a ventilator or other device that attempts to detect the initiation of a breath of a spontaneously breathing patient. If however, the device is unable to detect a breath within a predetermined period of time, the device will automatically initiate delivery of the breath.

[0397] *Swing*: Equivalent term to pressure support.

[0398] *Triggered*: When a ventilator delivers a breath of *air* to a spontaneously breathing patient, it is said to be triggered to do so at the initiation of the respiratory portion of the breathing cycle by the patient's efforts.

5.10.4 Patient interface

[0399] *Anti-asphyxia valve (AAV):* The component or sub-assembly of a mask system that, by opening to atmosphere in a failsafe manner, reduces the risk of excessive CO_2 rebreathing by a patient.

[0400] *Elbow:* An elbow is an example of a structure that directs an axis of flow of air travelling therethrough to change direction through an angle. In one form, the angle may be approximately 90 degrees. In another form, the angle may be more, or less than 90 degrees. The elbow may have an approximately circular cross-section. In another form the elbow may have an oval or a rectangular cross-section. In certain forms an elbow may be rotatable with respect to a mating component, e.g. about 360 degrees. In certain forms an elbow may be removable from a mating component, e.g. via a snap connection. In certain forms, an elbow may be assembled to a mating component via a one-time snap during manufacture, but not removable by a patient.

[0401] *Frame*: Frame will be taken to mean a mask structure that bears the load of tension between two or more points of connection with a headgear. A mask frame may be a non-airtight load bearing structure in the mask. However, some forms of mask frame may also be air-tight.

[0402] *Headgear:* Headgear will be taken to mean a form of positioning and stabilizing structure designed for use on a head. For example the headgear may comprise a collection of one or more struts, ties and stiffeners configured to locate and retain a patient interface in position on a patient's face for delivery of respiratory therapy. Some ties are formed of a soft, flexible, elastic material such as a laminated composite of foam and fabric.

[0403] *Membrane*: Membrane will be taken to mean a typically thin element that has, preferably, substantially no resistance to bending, but has resistance to being stretched.

[0404] *Plenum chamber*: a mask plenum chamber will be taken to mean a portion of a patient interface having walls at least partially enclosing a volume of space, the volume having air therein pressurised above atmospheric pressure in use. A shell may form part of the walls of a mask plenum chamber.

[0405] *Seal*: May be a noun form ("a seal") which refers to a structure, or a verb form ("to seal") which refers to the effect. Two elements may be constructed and/or arranged to 'seal' or to effect 'sealing' therebetween without requiring a separate 'seal' element *per se*.

[0406] *Shell*: A shell will be taken to mean a curved, relatively thin structure having bending, tensile and compressive stiffness. For example, a curved structural wall of a mask may be a shell. In some forms, a shell may be faceted. In some forms a shell may be airtight. In some forms a shell may not be airtight.

[0407] *Stiffener*: A stiffener will be taken to mean a structural component designed to increase the bending resistance of another component in at least one direction.

[0408] *Strut:* A strut will be taken to be a structural component designed to increase the compression resistance of another component in at least one direction.

[0409] *Swivel* (noun): A subassembly of components configured to rotate about a common axis, preferably independently, preferably under low torque. In one form, the swivel may be constructed to rotate through an angle of at least 360 degrees. In another form, the swivel may be constructed to rotate through an angle less than 360 degrees. When used in the context of an air delivery conduit, the sub-assembly of components preferably comprises a matched pair of cylindrical conduits. There may be little or no leak flow of air from the swivel in use.

[0410] *Tie* (noun): A structure designed to resist tension.

[0411] *Vent*: (noun): A structure that allows a flow of *air* from an interior of the mask, or conduit, to ambient air for clinically effective washout of exhaled gases. For example, a clinically effective washout may involve a flow rate of about 10 litres per minute to about 100 litres per minute, depending on the mask design and treatment pressure.

5.11 OTHER REMARKS

[0412] A portion of the disclosure of this patent document contains material which is subject to copyright protection. The copyright owner has no objection to the facsimile reproduction by anyone of the patent document or the patent disclosure, as it appears in Patent Office patent files or records, but otherwise reserves all copyright rights whatsoever.

[0413] Unless the context clearly dictates otherwise and where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit, between the upper and lower limit of that range, and any other stated or intervening value in that stated range is encompassed within the technology. The upper and lower limits of these intervening ranges, which may be independently included in the intervening ranges, are also encompassed within the technology, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the technology.

[0414] Furthermore, where a value or values are stated herein as being implemented as part of the technology, it is understood that such values may be approximated, unless otherwise stated, and such values may be utilized to any suitable significant digit to the extent that a practical technical implementation may permit or require it.

[0415] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this technology belongs. Although any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the present technology, a limited number of the exemplary methods and materials are described herein.

[0416] When a particular material is identified as being used to construct a component, obvious alternative materials with similar properties may be used as a substitute. Furthermore, unless specified to the contrary, any and all components herein described are understood to be capable of being manufactured and, as such, may be manufactured together or separately.

[0417] It must be noted that as used herein and in the appended claims, the singular forms "a", "an", and "the" include their plural equivalents, unless the context clearly dictates otherwise.

[0418] All publications mentioned herein are incorporated herein by reference in their entirety to disclose and describe the methods and/or materials which are the subject of those publications. The publications discussed herein are provided solely for their disclosure prior to the filing date of the present application. Nothing herein is to be construed as an admission that the present technology is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided may be different from the actual publication dates, which may need to be independently confirmed.

[0419] The terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced.

[0420] The subject headings used in the detailed description are included only for the ease of reference of the reader and should not be used to limit the subject matter found throughout the disclosure or the claims. The subject headings should not be used in construing the scope of the claims or the claim limitations.

[0421] Although the technology herein has been described with reference to particular examples, it is to be understood that these examples are merely illustrative of the principles and applications of the technology. In some instances, the terminology and symbols may imply specific details that are not required to practice the technology. For example, although the terms "first" and "second" may be used, unless otherwise specified, they are not intended to indicate any order but may be utilised to distinguish between distinct elements. Furthermore, although process steps in the methodologies may be described or illustrated in an order, such an ordering is not required. Those skilled in the art will recognize that such ordering may be modified and/or aspects thereof may be conducted concurrently or even synchronously.

[0422] It is therefore to be understood that numerous modifications may be made to the illustrative examples and that other arrangements may be devised without departing from the spirit and scope of the technology.

5.12 REFERENCE SIGNS LIST

patient	1000
bed partner	1100
patient interface	3000
seal - forming structure	3100
plenum chamber	3200
structure	3300
vent	3400
connection port	3600
forehead support	3700
ISO	3744
patient interface	3800
cannula	3800
RPT device	4000
external housing	4010
upper portion	4012
portion	4014
panels	4015

chassis	4016
handle	4018
pneumatic block	4020
air filter	4110
inlet air filter	4112
outlet air filter	4114
muffler	4120
inlet muffler	4122
outlet muffler	4124
pressure generator	4140
blower	4142
motor	4144
brushless DC motor	4144
anti - spill back valve	4160
air delivery tube	4170
air circuit	4170
heating air circuit	4171
supplementary gas	4180
electrical components	4200
PCBA	4202
power supply	4210
input device	4220
central controller	4230
clock	4232
therapy device controller	4240
protection circuits	4250
memory	4260
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flow rate sensor	4274
motor speed transducer	4276
data communication interface	4280
remote external communication network	4282
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humidifier inlet	5002
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humidifier base	5006
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conductive portion	5120
humidifier reservoir dock	5130
locking lever	5135
water level indicator	5150
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air pressure sensor	5212
flow rate transducers	5214
temperature sensor	5216
humidity sensor	5218
heating element	5240
humidifier controller	5250
central humidifier controller	5251
heating element controller	5252
air circuit controller	5254
comparator	5290
comparator	5292
contact assembly	6200
tube connector	6300
electrical connection	6350
processing circuitry	6400
sensor	6500
nasal prongs	3810a

nasal prongs	3810b
air supply lumens	3820a
air supply lumens	3820b

CLAIMS

1. An apparatus for humidifying a flow of breathable gas, comprising:

processing circuitry;

a humidifier configured to humidify breathable gas;

an air delivery tube configured to pass the humidified breathable gas to a patient interface, the air delivery tube including one or more heating elements extending along at least a portion of the length of the air delivery tube, a sensor configured to measure a property of the humidified breathable gas in the air delivery tube, and a connector having a plurality of electrical tube contacts; and

a contact assembly including a plurality of electrical apparatus contacts configured to electrically couple the plurality of electrical tube contacts to the processing circuitry,

wherein the one or more heating elements and the sensor are coupled to the electrical tube contacts, and the electrical tube contacts are adapted to electrically engage only a portion of electrical apparatus contacts in an operative configuration of the apparatus.

2. The apparatus of claim 1, wherein the processing circuitry is configured to control, based on a signal received from the sensor, operation of the one or more heating elements and the humidifier, and determine, based on which electrical apparatus contacts of the contact assembly are coupled to the electrical tube contacts in the operative configuration of the apparatus, a type of the air delivery tube coupled to the apparatus.

3. The apparatus of claim 1, wherein the processing circuitry is configured to determine, based on which electrical apparatus contacts of the contact assembly are coupled to the electrical tube contacts in the operative configuration of the apparatus, a type of the air delivery tube coupled to the apparatus.

4. The apparatus of any one of claims 1 to 3, wherein the processing circuitry is configured to control, based on the determined type of air delivery tube, operation of the one or more heating elements and/or the humidifier.

5. The apparatus of any one of claims 1 to 4, wherein the processing circuitry is configured to determine the type of the air delivery tube coupled to the apparatus based on absence of a connection by one or more electrical apparatus contacts to the heating element and/or the sensor.

6. The apparatus of any one of claims 1 to 5, wherein the contact assembly includes only four electrical apparatus contacts, a first pair of the electrical apparatus contacts are configured to electrically couple to the one or more heating elements, and only one contact of a second pair of electrical apparatus contacts is configured to electrically couple to the sensor.

7. The apparatus of any one of claims 1 to 6, wherein the processing circuitry determines the type of the air delivery tube coupled to the apparatus based which one of the second pair of electrical apparatus contacts is coupled to the sensor.

8. The apparatus of any one of claims 1 to 7, wherein the contact assembly includes only four electrical apparatus contacts, a first pair of the electrical apparatus contacts are configured to electrically couple to the one or more heating elements, and the processing circuit is configured to determine that a first type of air delivery tube is coupled to the apparatus when a first contact of a second pair of the electrical apparatus contacts is not coupled to the sensor, and determine that a second type of air delivery tube is coupled to the apparatus when a second contact of a second pair of the electrical apparatus contacts is not coupled to the sensor.

9. The apparatus of any one of claims 1 to 8, wherein the contact assembly includes only four electrical apparatus contacts and the air delivery tube includes only three electrical tube contacts configured to couple to the electrical apparatus contacts.

10. The apparatus of any one of claims 1 to 9, wherein the processing circuitry is configured to determine, based on which electrical apparatus contact of the contact assembly is not coupled to the electrical tube contacts, a type of the air delivery tube coupled to the apparatus.

11. An apparatus for humidifying a flow of breathable gas, comprising:

processing circuitry;

a humidifier configured to humidify breathable gas;

an air delivery tube configured to pass the humidified breathable gas to a patient interface, the air delivery tube including one or more heating elements extending along at least a portion of the length of the air delivery tube, a sensor configured to measure a property of the breathable gas in the air delivery tube, and a connector having a plurality of electrical tube contacts; and

a contact assembly including a plurality of electrical apparatus contacts configured to electrically couple to the plurality of electrical tube contacts to the processing circuitry in an operative configuration of the apparatus,

wherein the one or more heating elements and the sensor are coupled to a set of the electrical tube contacts configured to electrically couple to the corresponding electrical apparatus contacts in the operative configuration of the apparatus, and the processing circuit is configured to determine a type of air delivery tube coupled to the apparatus based on an electrical characteristic measured by the processing circuit via another electrical apparatus contact of the contact assembly.

12. The apparatus of claim 10, wherein the processing circuitry is configured to control, based on a signal received from the sensor, operation of the one or more heating elements and the humidifier.

13. The apparatus of any one of claims 11 or 12, wherein the measured characteristic includes a voltage set based on a resistive element disposed in the air deliver tube and coupled to the other electrical apparatus contact and an electrical tube contact configured to electrically couple to heating element and.

14. The apparatus of any one of claims 11 to 13, wherein the processing circuitry is configured to determine that a first type of air delivery tube is coupled to the apparatus when the measured characteristic indicates zero volts and that a second type of air delivery tube is coupled to the apparatus when the measured characteristic indicates a voltage greater than zero.

15. The apparatus of any one of claims 11 to 14, wherein the air delivery tube includes a resistor or a shunt coupled between a contact of the set of the electrical tube contacts and an electrical tube contact configured to electrically couple to the other electrical apparatus contact.

16. The apparatus of any one of claims 11 to 15, wherein the processing circuitry is configured to control, based on the determined type of air delivery tube, operation of the one or more heating elements and the humidifier.

17. The apparatus of any one of claims 11 to 16, wherein the contact assembly includes only four electrical apparatus contacts and the air delivery tube includes only three electrical tube contacts configured to couple to the electrical apparatus contacts.

18. A respiratory treatment apparatus comprising:

a power supply;

a processing system;

a pressure generator configured to generate a flow of breathable gas;

a humidifier configured to store a supply of water to humidify the breathable gas and comprising a first heating element configured to heat the supply of water;

an air delivery tube configured to pass the flow of breathable gas that has been humidified to a patient, the air delivery tube including second heating element configured to heat the humidified breathable gas in the air delivery tube and a thermistor configured go generate a temperate signal representing a temperature of the humidified breathable gas in the air delivery tube;

a transducer configured to generate a flow signal representing a property of the flow of breathable gas; and

a contact assembly configured to mechanically couple the air delivery tube to the humidifier and electrically couple a plurality of main contacts coupled to the processing system to a plurality of tube contacts coupled to the second heating element and the thermistor, wherein only a portion of the main contacts are coupled to corresponding tube contacts in an operative configuration of the respiratory treatment apparatus;

the processing system configured to:

determine, based on signal values received from one or more main contacts, which of the main contacts are coupled to the second heating element and the thermistor via the tube contacts;

determine, based on which of the main contacts are determined to be coupled to the second heating element and the thermistor, a type of air delivery tube coupled to the humidifier; and

based on the determined tube type, the flow signal and the temperate signal, determine (1) a first control signal for controlling the first heating element (2) a second control signal for controlling the second heating element, and (3) a third control signal for controlling the pressure generator.

19. The respiratory treatment apparatus of claim 18, wherein the contact assembly includes two main contacts configured to electrically coupled to two tube contacts coupled to the second heating element, and two additional main contacts configured to couple to two additional tube contact of which only one is coupled to the thermistor, and the processing system is configured to determine the type of air delivery tube coupled to the humidifier based on which one of the two additional main contacts is coupled to the thermistor via the tube contact.

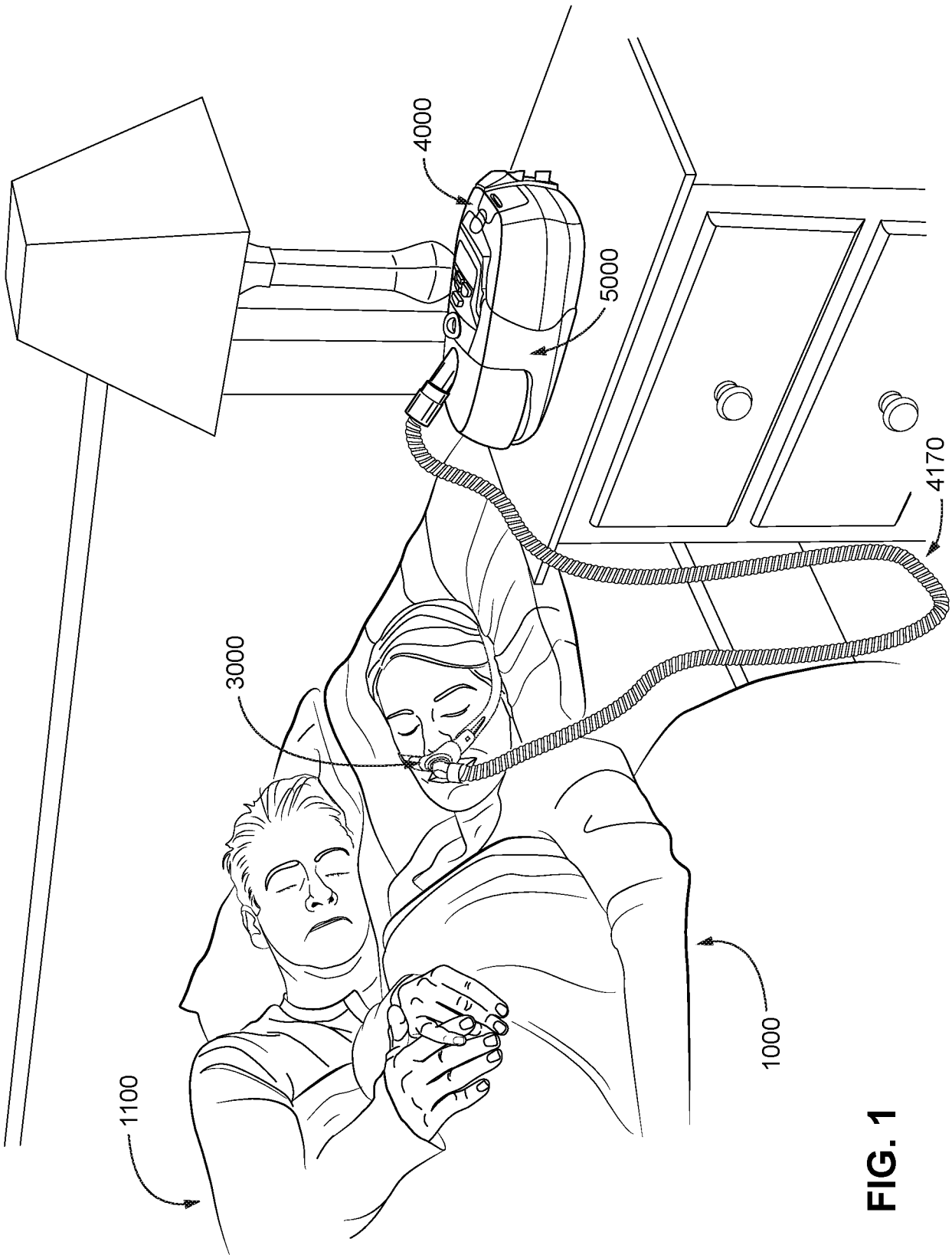

FIG. 1

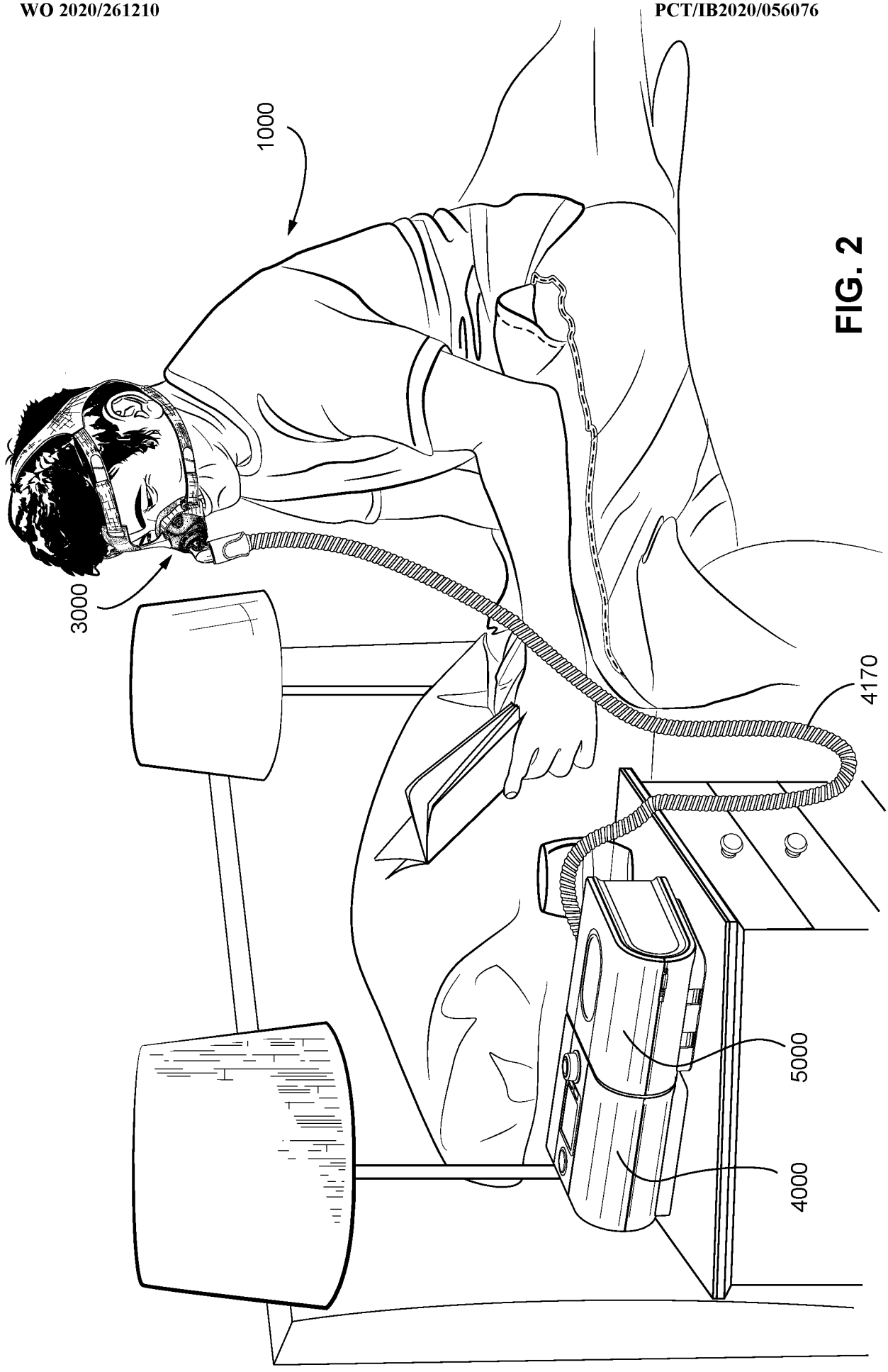

FIG. 2

FIG. 3

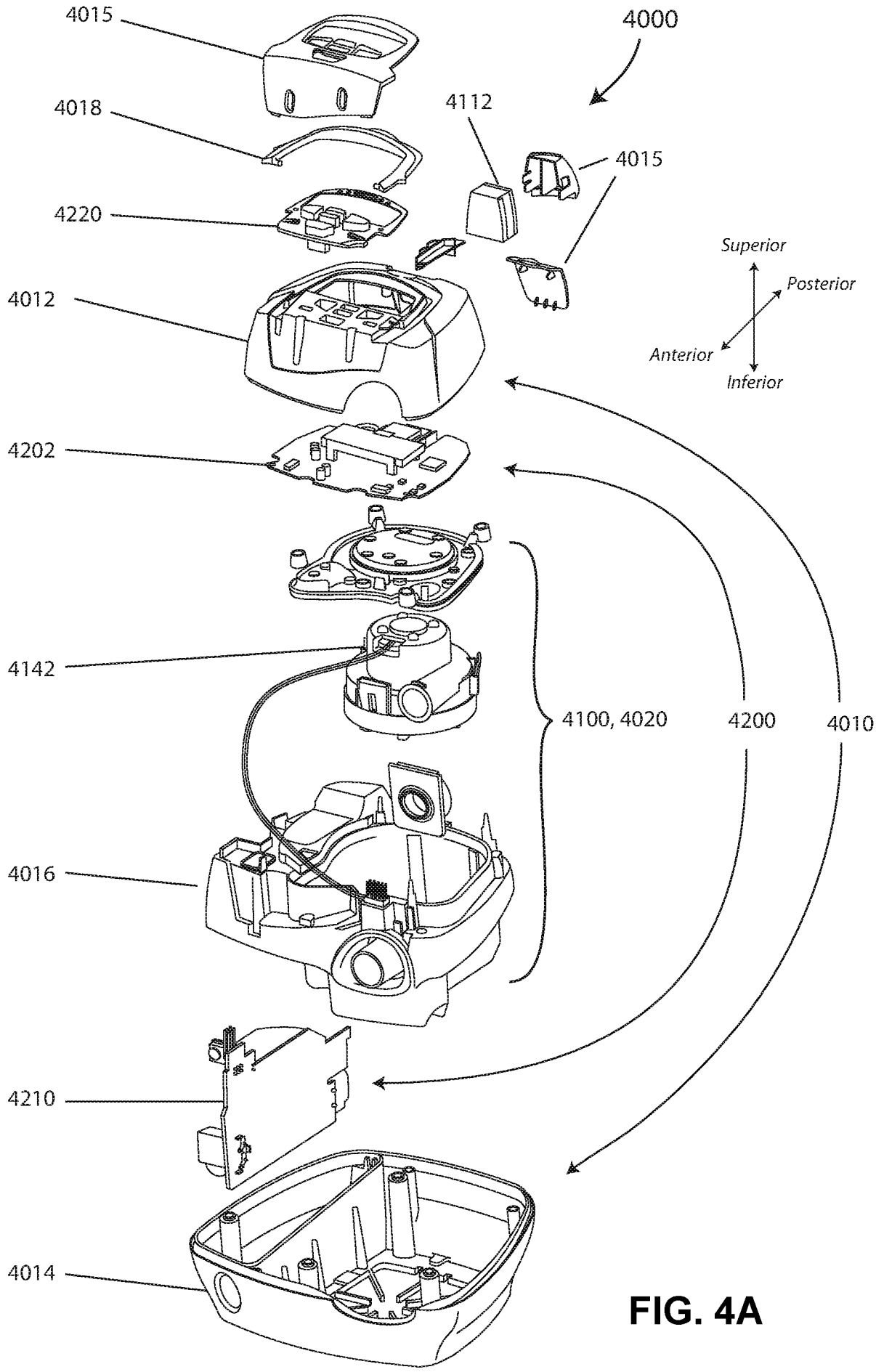
4015
4000
4018
4112
4015
4220
Superior
Posterior
Anterior
Inferior
4012
4202
4142
4100, 4020
4200
4010
4016
4210
4014

FIG. 4A

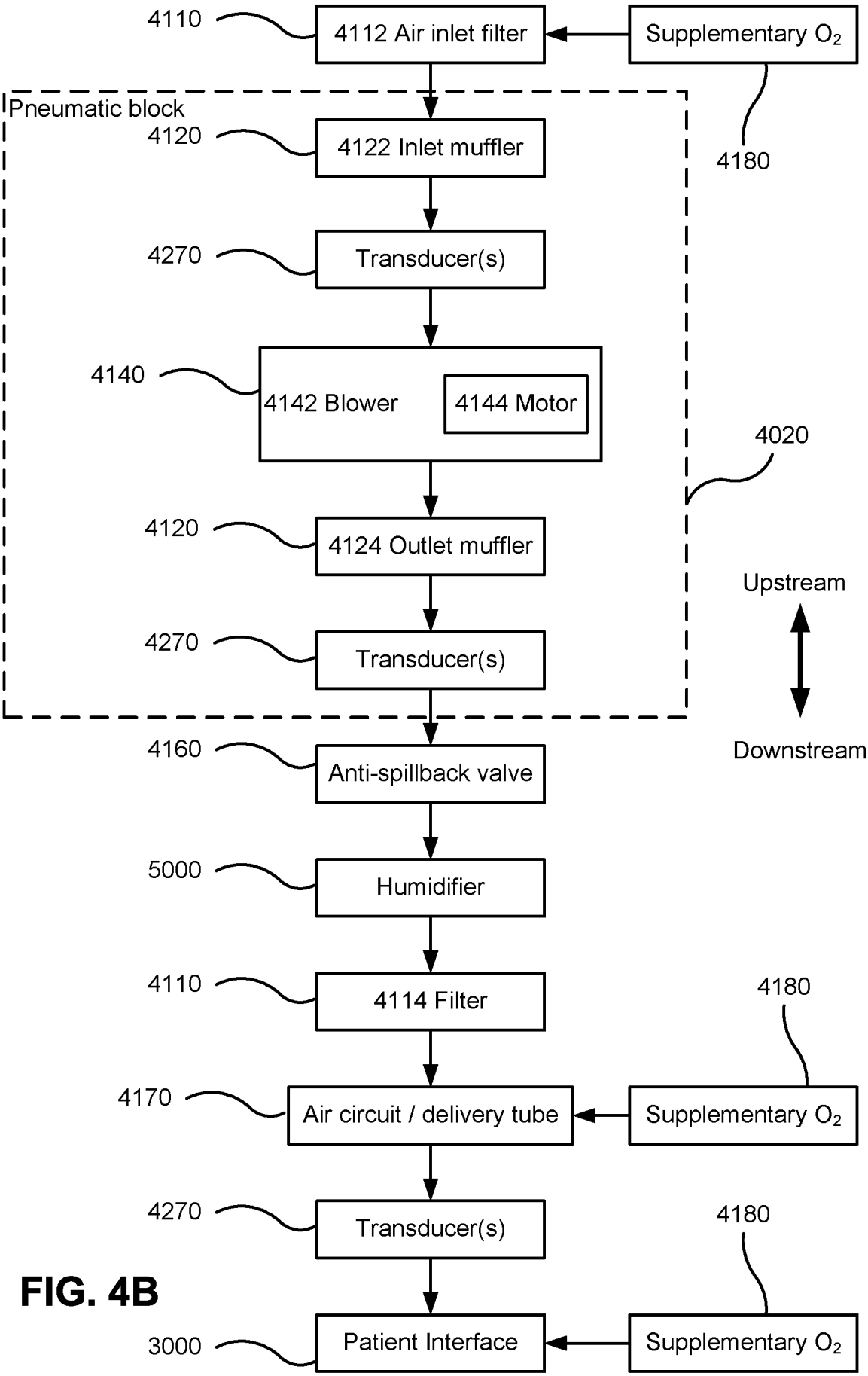
4110
4112 Air inlet filter
Supplementary O_2
4180
Pneumatic block
4120
4122 Inlet muffler
4270
Transducer(s)
4140
4142 Blower
4144 Motor
4020
4120
4124 Outlet muffler
Upstream
4270
Transducer(s)
Downstream
4160
Anti-spillback valve
5000
Humidifier
4110
4114 Filter
4180
4170
Air circuit / delivery tube
Supplementary O_2
4270
Transducer(s)
4180
3000
Patient Interface
Supplementary O_2

FIG. 4B

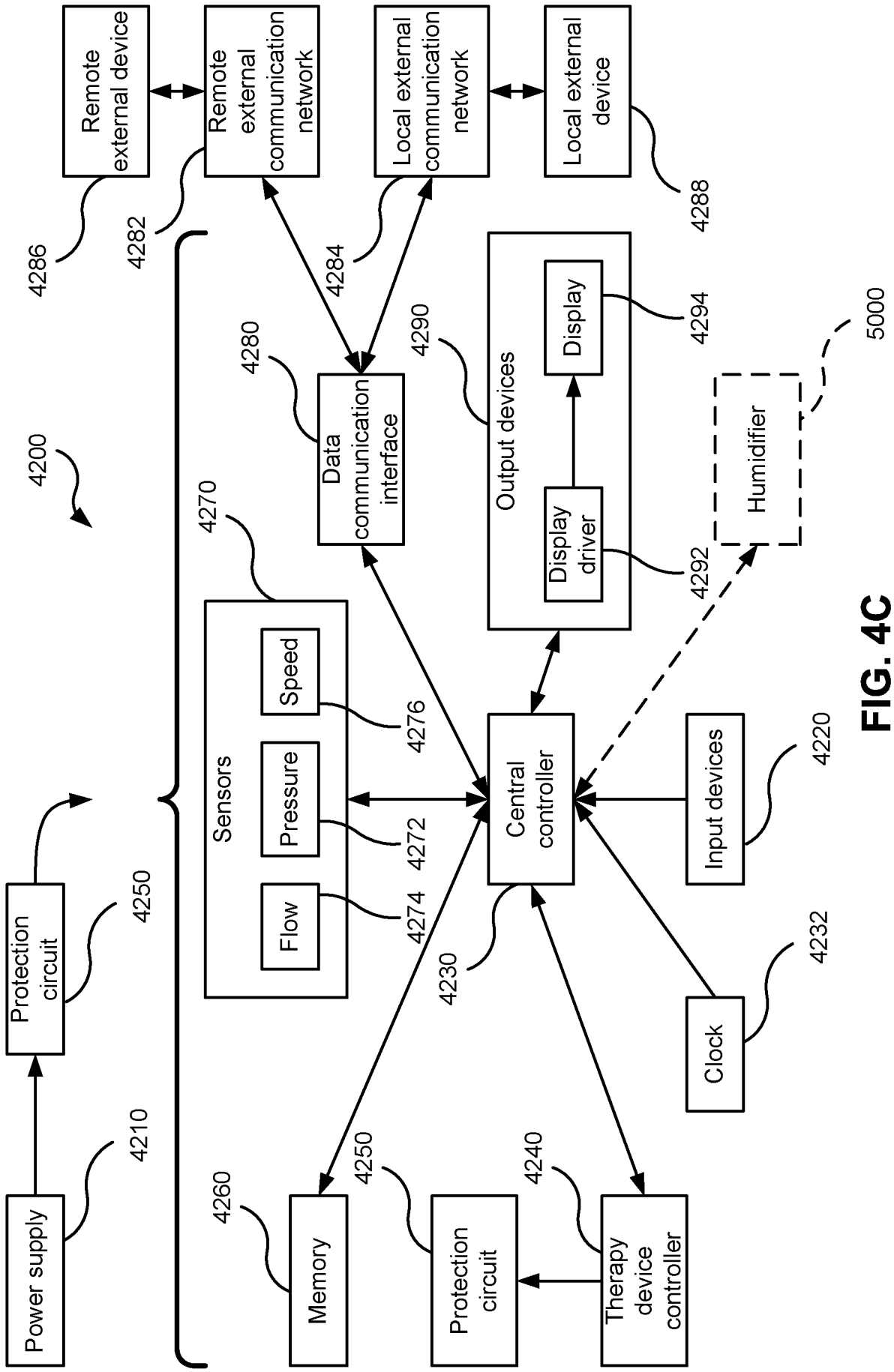
Remote external device
Remote external communication network
Local external communication network
Local external device
4286
4282
4284
4288
4200
4280
Data communication interface
4290
Output devices
Display
4294
Display driver
4292
Humidifier
5000
4270
Sensors
Speed
4276
Pressure
4272
Flow
4274
Central controller
Input devices
4220
4230
Clock
4232
Protection circuit
4250
Power supply
4210
Memory
4260
Protection circuit
4250
Therapy device controller
4240

FIG. 4C

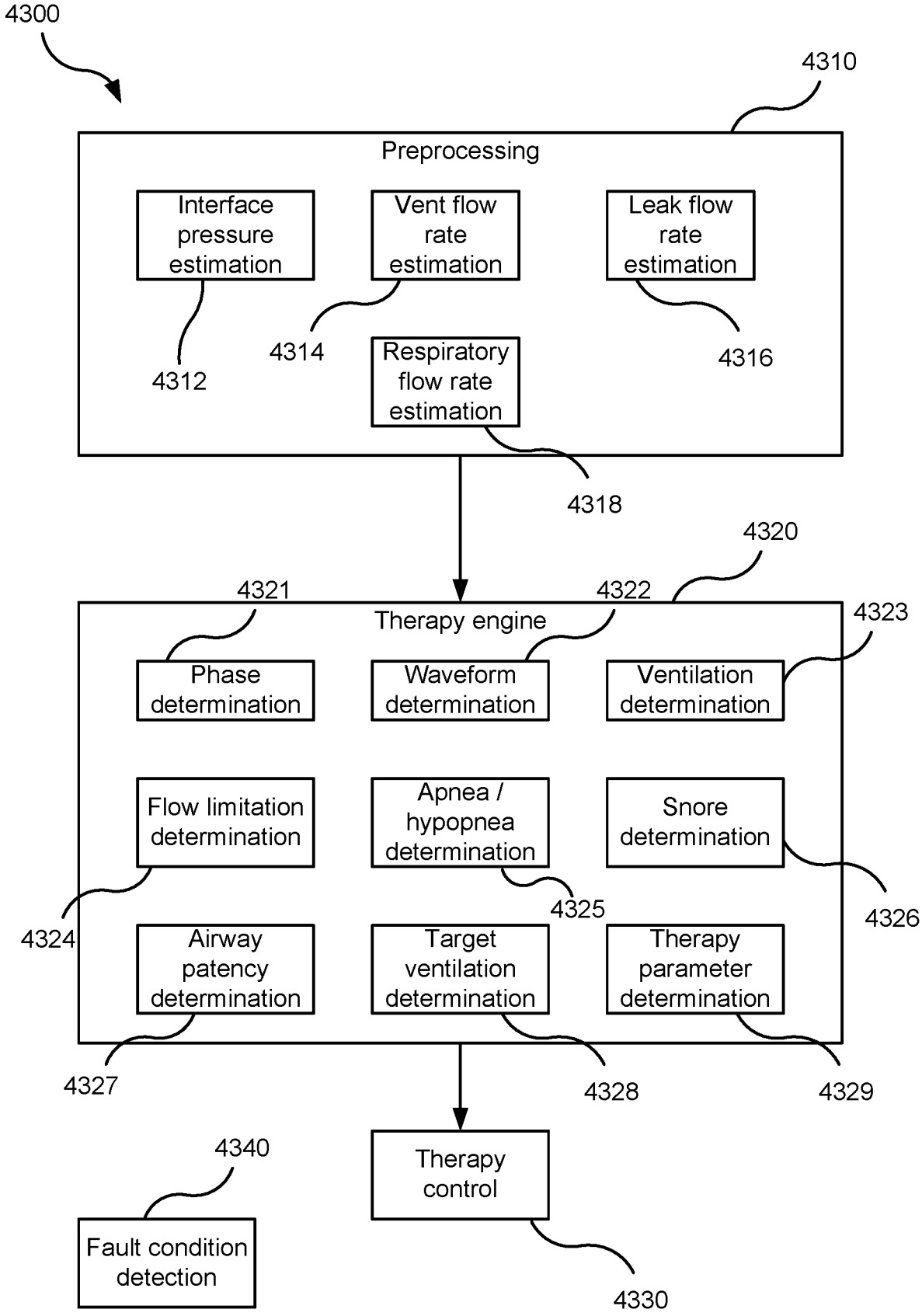
4300
4310
Preprocessing
Interface pressure estimation
Vent flow rate estimation
Leak flow rate estimation
4312
4314
Respiratory flow rate estimation
4316
4318
4320
4321
4322
Therapy engine
4323
Phase determination
Waveform determination
Ventilation determination
Flow limitation determination
Apnea / hypopnea determination
Snore determination
4324
4325
4326
Airway patency determination
Target ventilation determination
Therapy parameter determination
4327
4328
4329
4340
Therapy control
Fault condition detection
4330

FIG. 4D

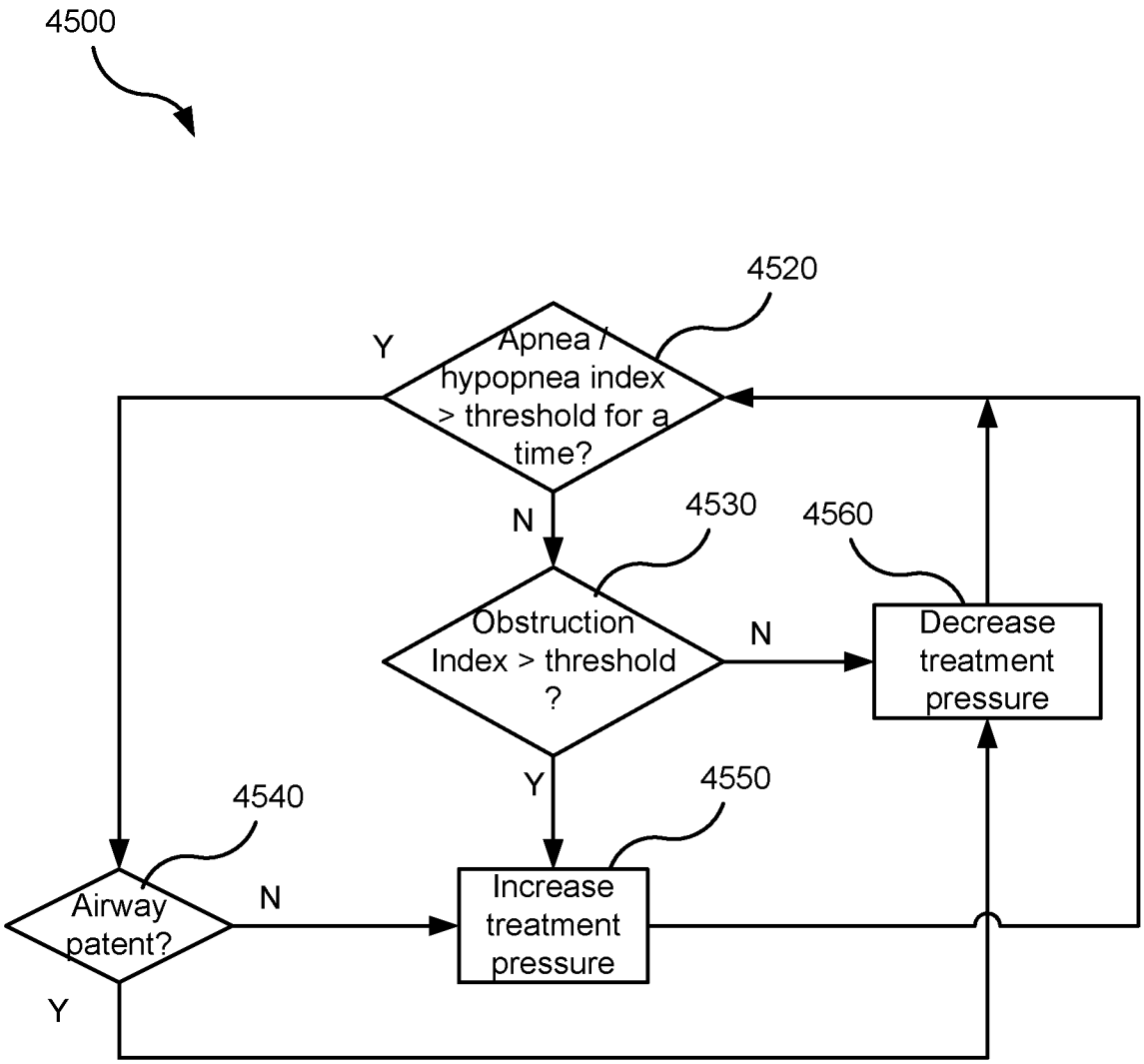
4500
4520
Apnea / hypopnea index > threshold for a time?
Y
N
4530
Obstruction Index > threshold ?
4560
Decrease treatment pressure
N
Y
4550
Increase treatment pressure
4540
Airway patent?
N
Y

FIG. 4E

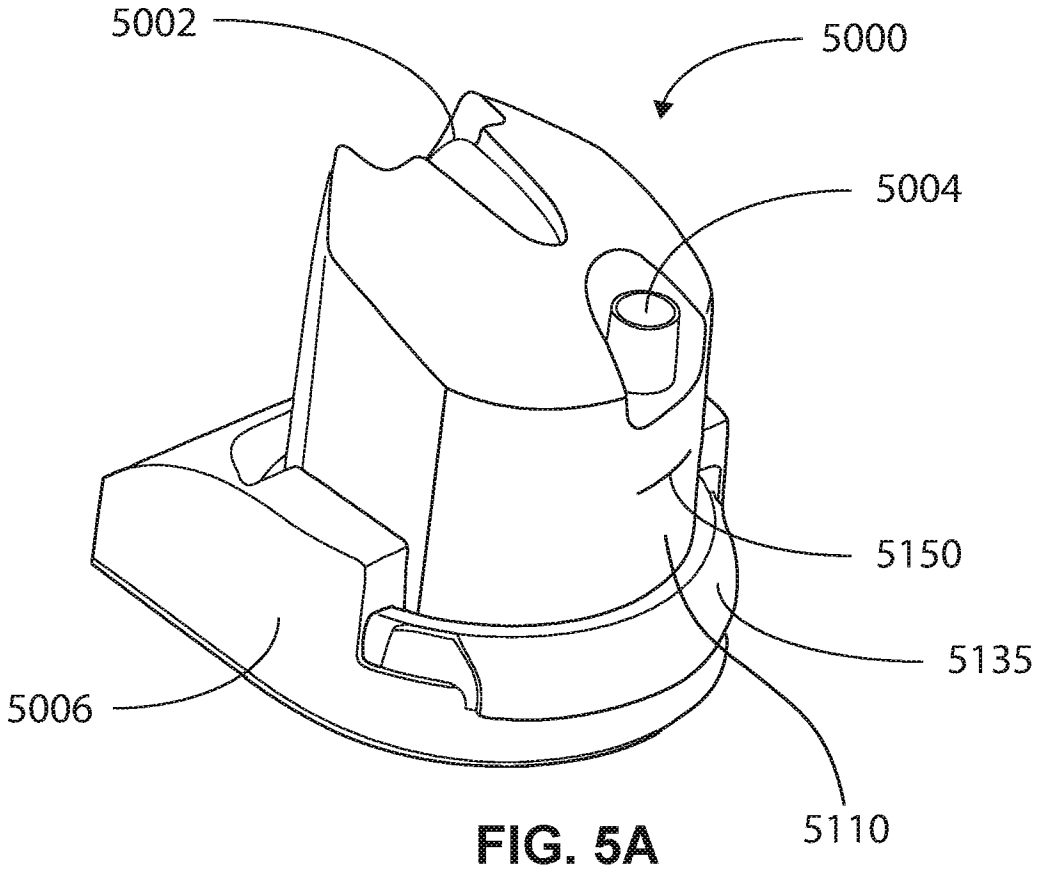
5002
5000
5004
5150
5135
5006
5110

FIG. 5A

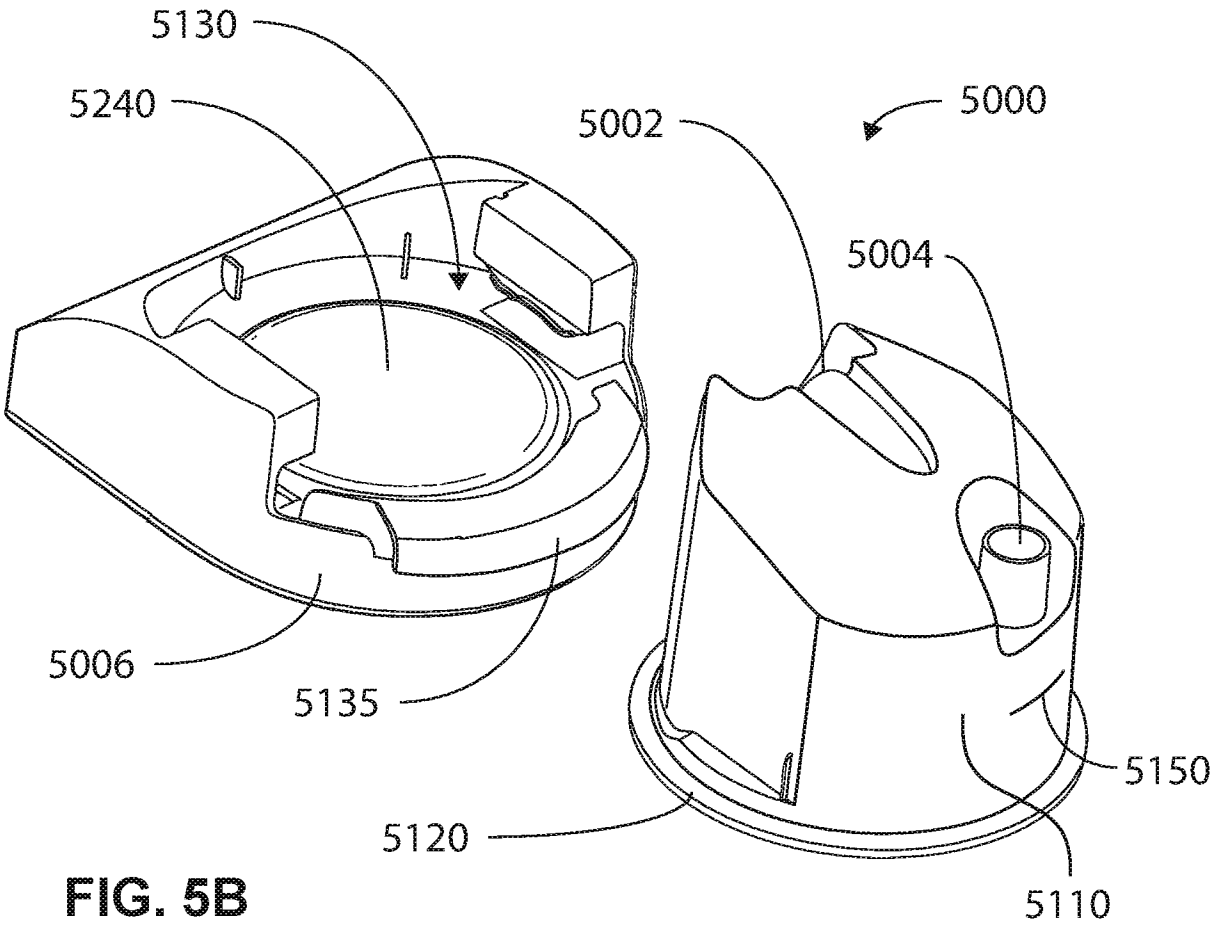
5130
5240
5002
5000
5004
5006
5135
5150
5120
5110

FIG. 5B

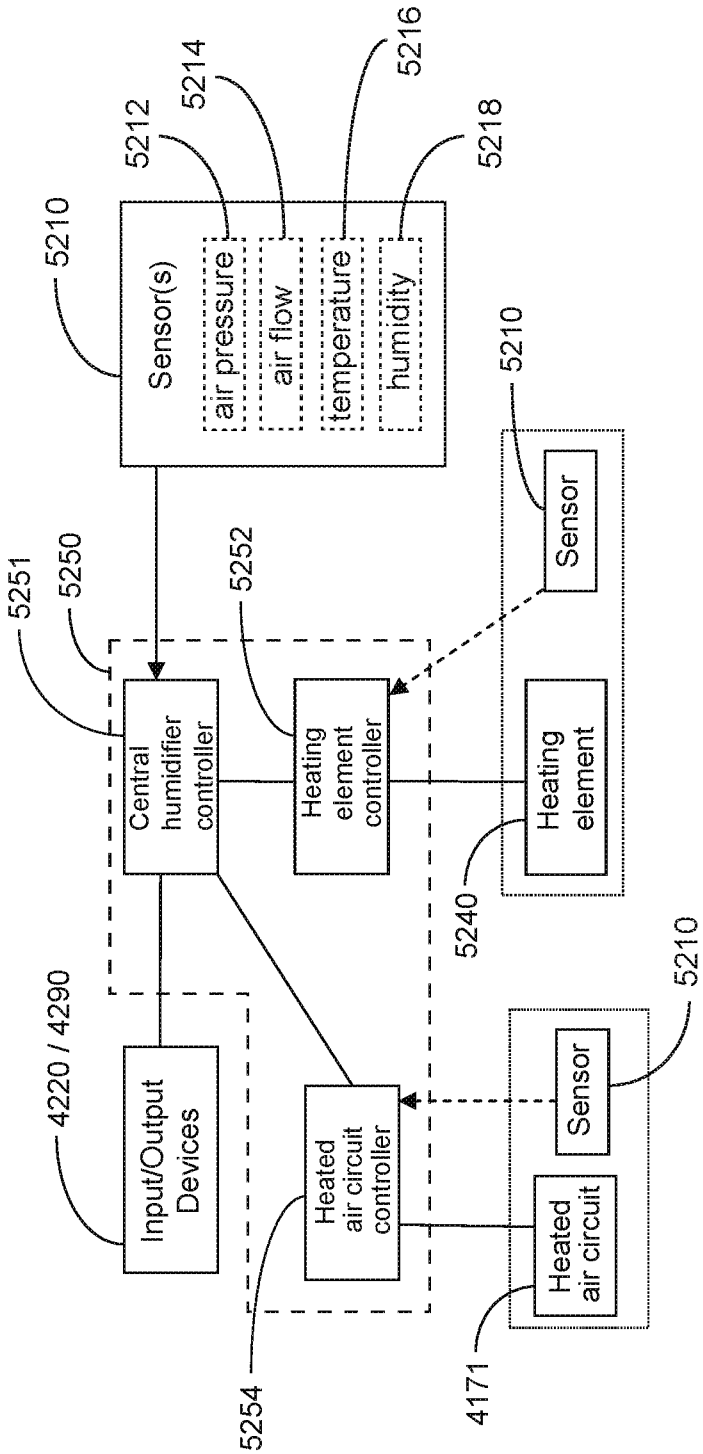
5210
Sensor(s)
5212
air pressure
5214
air flow
5216
temperature
5218
humidity
5210
Sensor
5251
5250
5252
Central humidifier controller
Heating element controller
Heating element
5240
4220 / 4290
Input/Output Devices
Heated air circuit controller
5210
Sensor
Heated air circuit
5254
4171

FIG. 5C

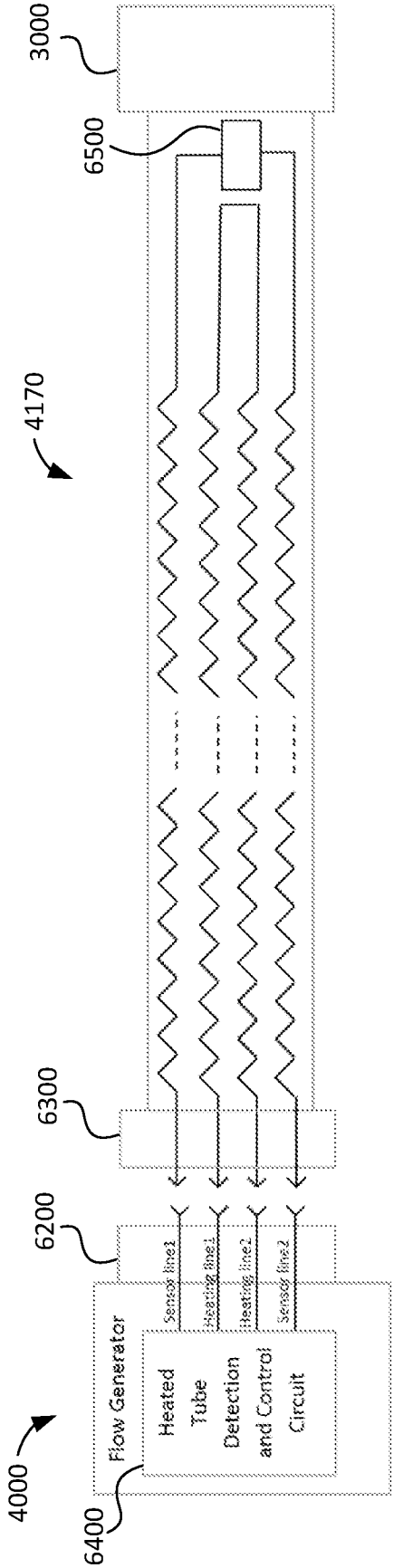
3000
6500
4170
6300
6200
Sensor line1
Heating line1
Heating line2
Sensor line2
Flow Generator
Heated Tube Detection and Control Circuit
4000
6400

FIG. 5D

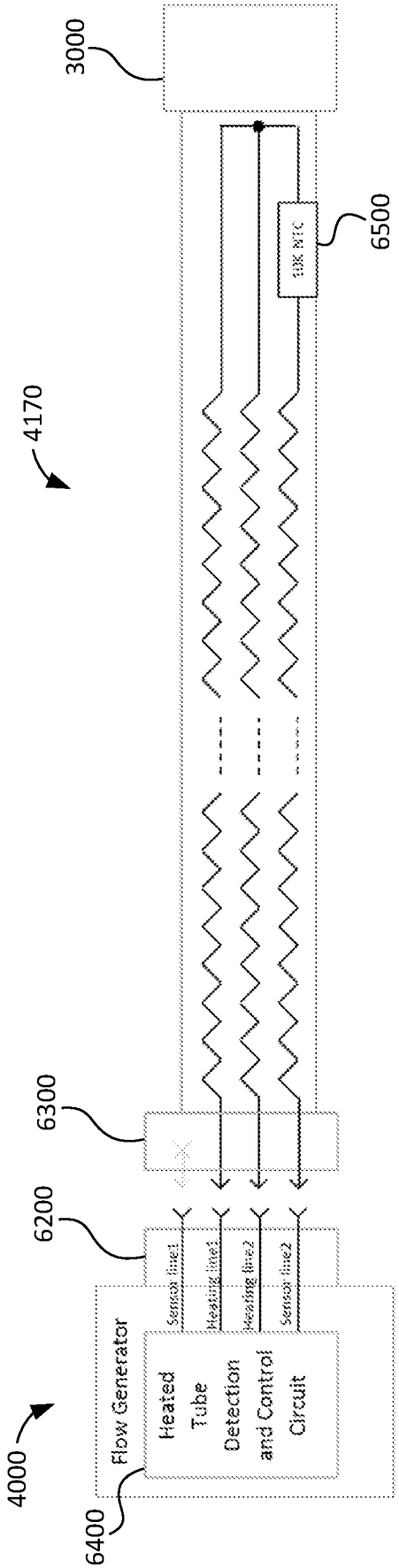
3000
6500
10K NTC
4170
6300
6200
Sensor line1
Heating line1
Heating line2
Sensor line2
Flow Generator
Heated Tube Detection and Control Circuit
4000
6400

FIG. 5E

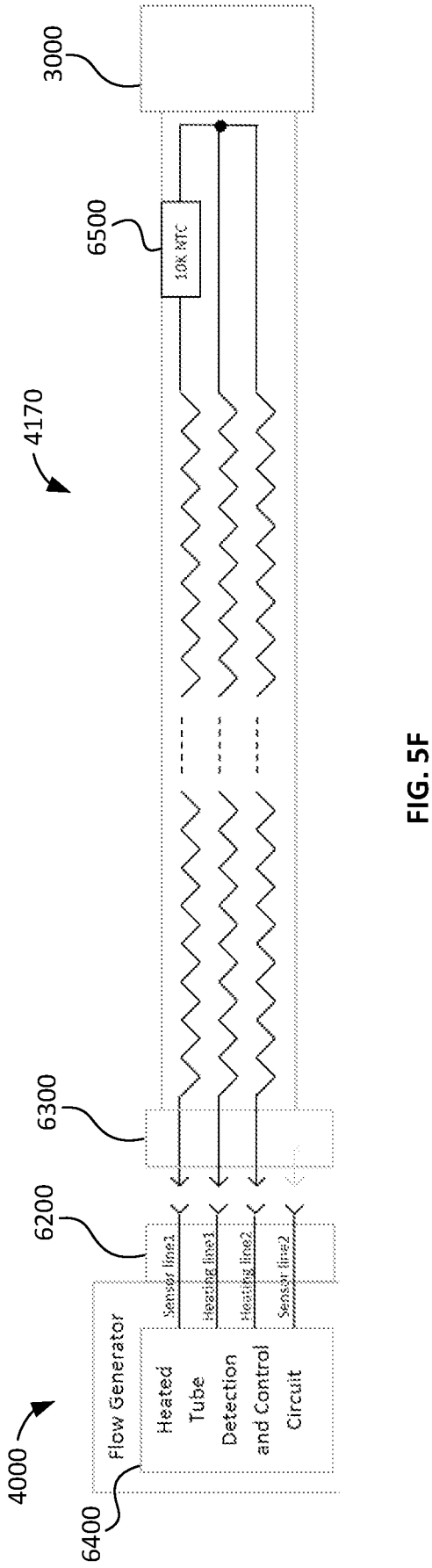
3000
6500
10K NTC
4170
6300
6200
Sensor line1
Heating line1
Heating line2
Sensor line2
Flow Generator
Heated Tube Detection and Control Circuit
4000
6400

FIG. 5F

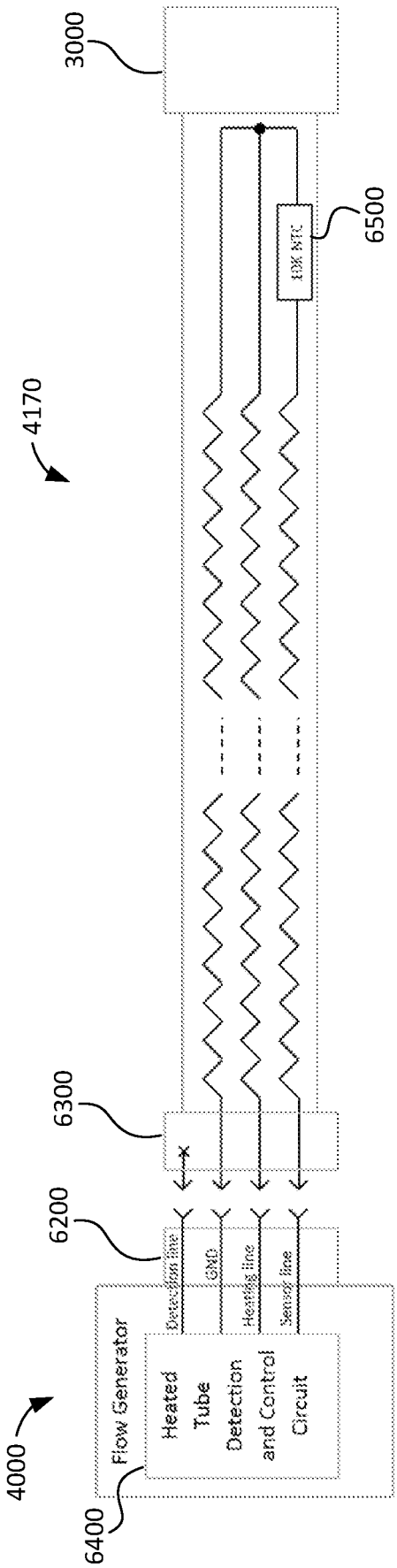
3000
6500
10K NTC
4170
6300
6200
Detection line
GND
Heating line
Sensor line
Flow Generator
Heated Tube Detection and Control Circuit
4000
6400

FIG. 5G

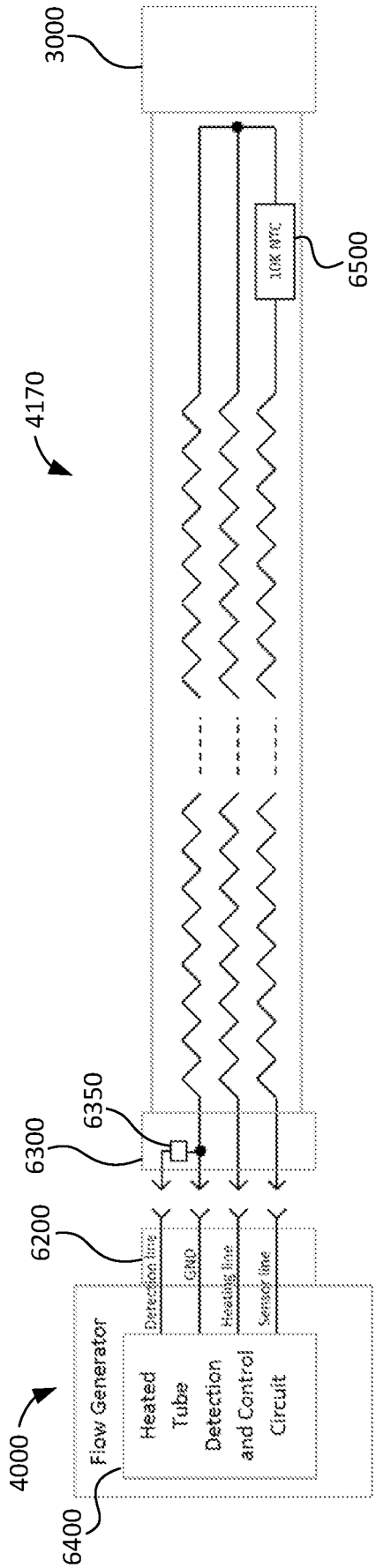
3000
6500
10K NTC
4170
6350
6300
6200
Detection line
GND
Heating line
Sensor line
Flow Generator
Heated Tube Detection and Control Circuit
4000
6400

FIG. 5H

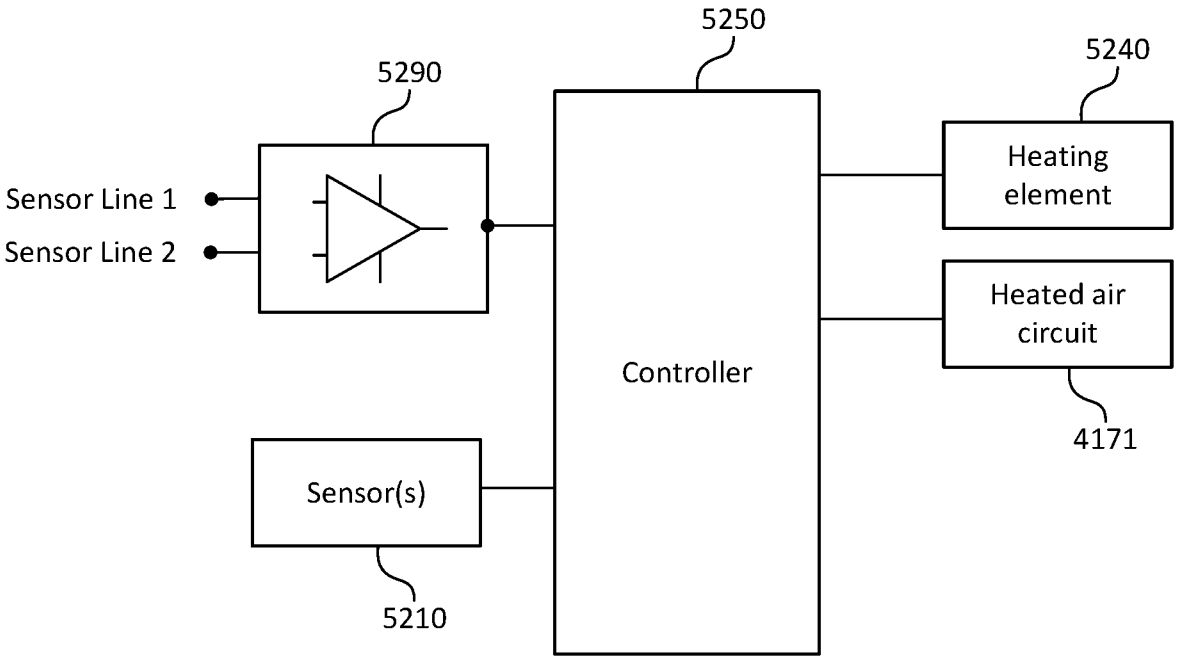
5250
5290
5240
Sensor Line 1
Sensor Line 2
Heating element
Heated air circuit
Controller
4171
Sensor(s)
5210

FIG. 5I

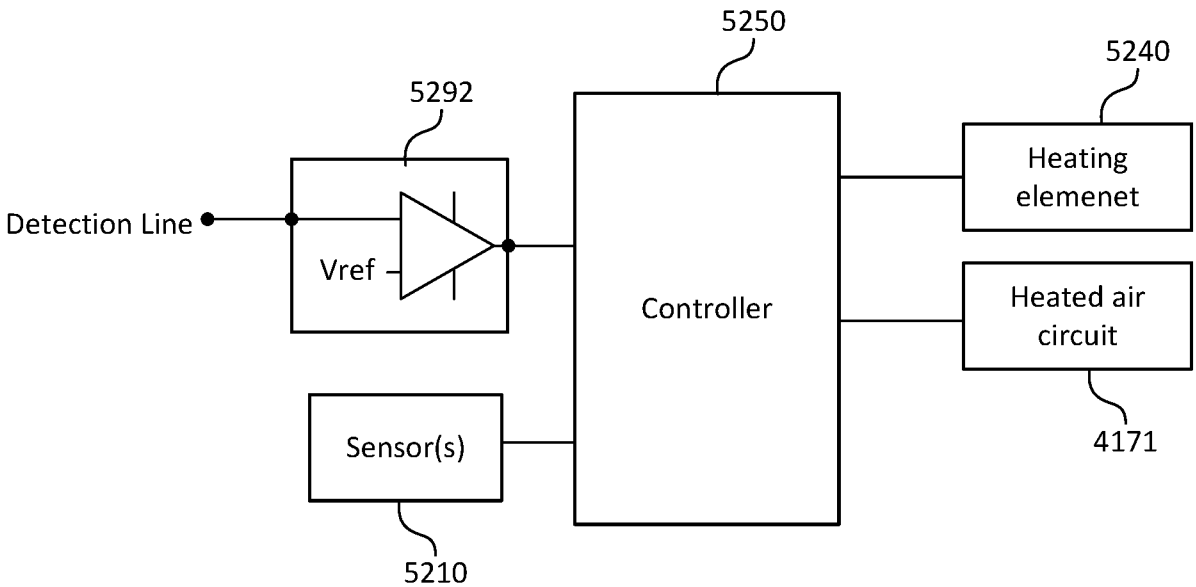
5250
5292
5240
Detection Line
Vref
Heating elemenet
Heated air circuit
Controller
4171
Sensor(s)
5210

FIG. 5J

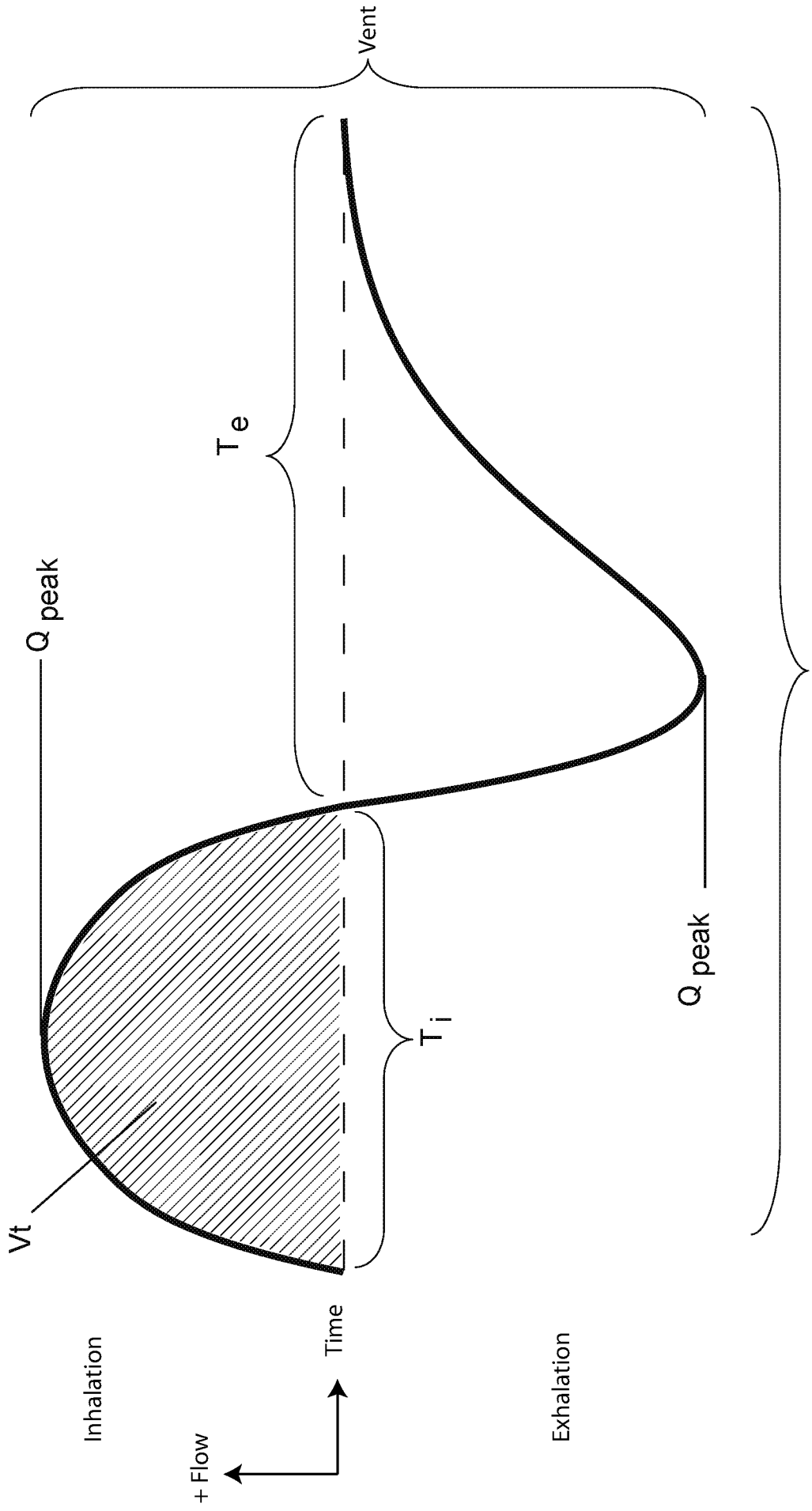
Vent
Te
Q peak
Ti
Vt
Q peak
Ttot
Inhalation
Time
+ Flow
Exhalation

FIG. 6A

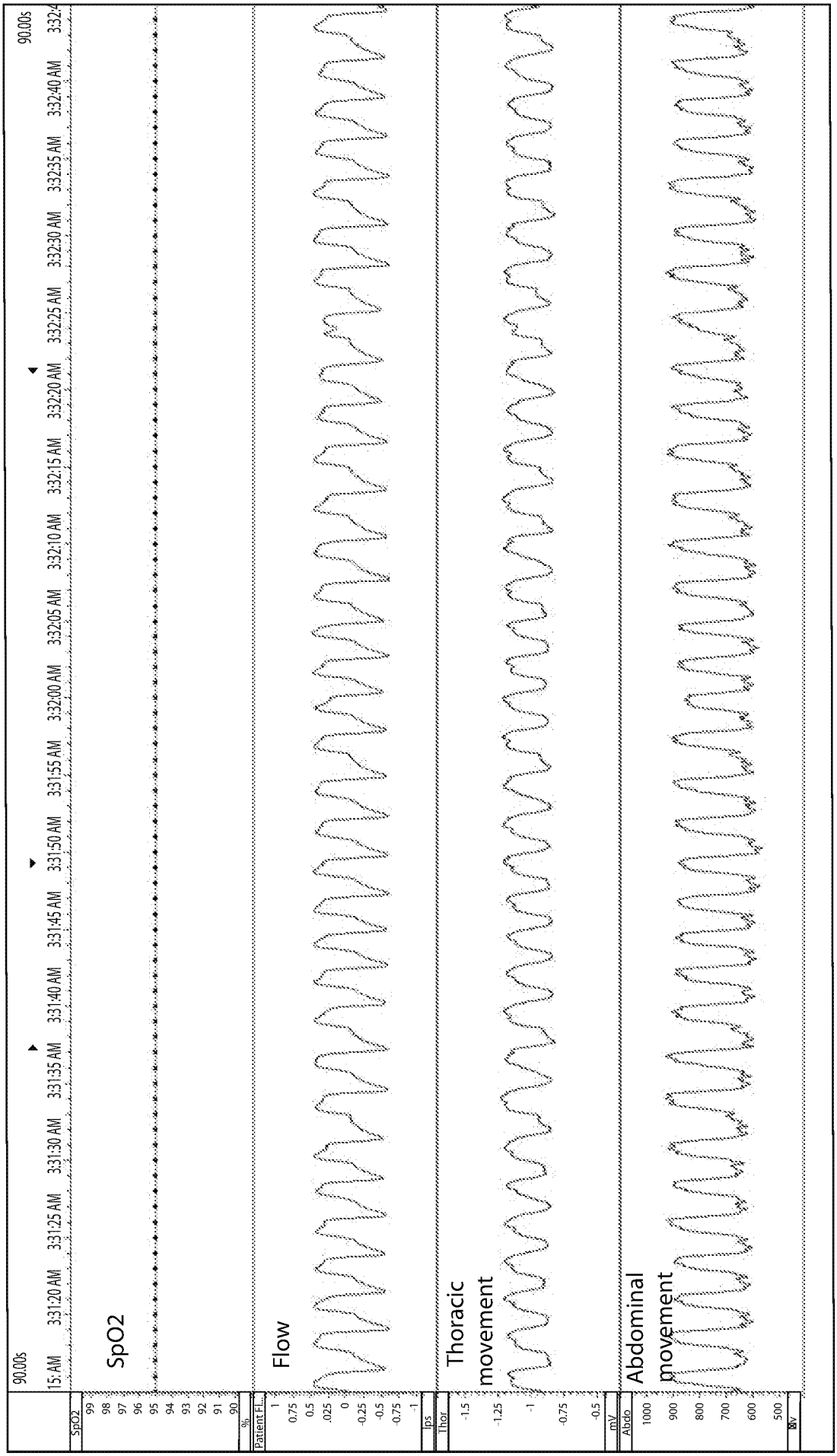
90.00s
15: AM
3:31:20 AM
3:31:25 AM
3:31:30 AM
3:31:35 AM
3:31:40 AM
3:31:45 AM
3:31:50 AM
3:31:55 AM
3:32:00 AM
3:32:05 AM
3:32:10 AM
3:32:15 AM
3:32:20 AM
3:32:25 AM
3:32:30 AM
3:32:35 AM
3:32:40 AM
SpO2
Flow
Thoracic movement
Abdominal movement
SpO2
%
Patient Fl...
lps
Thor
mV
Abdo
mV

FIG. 6B

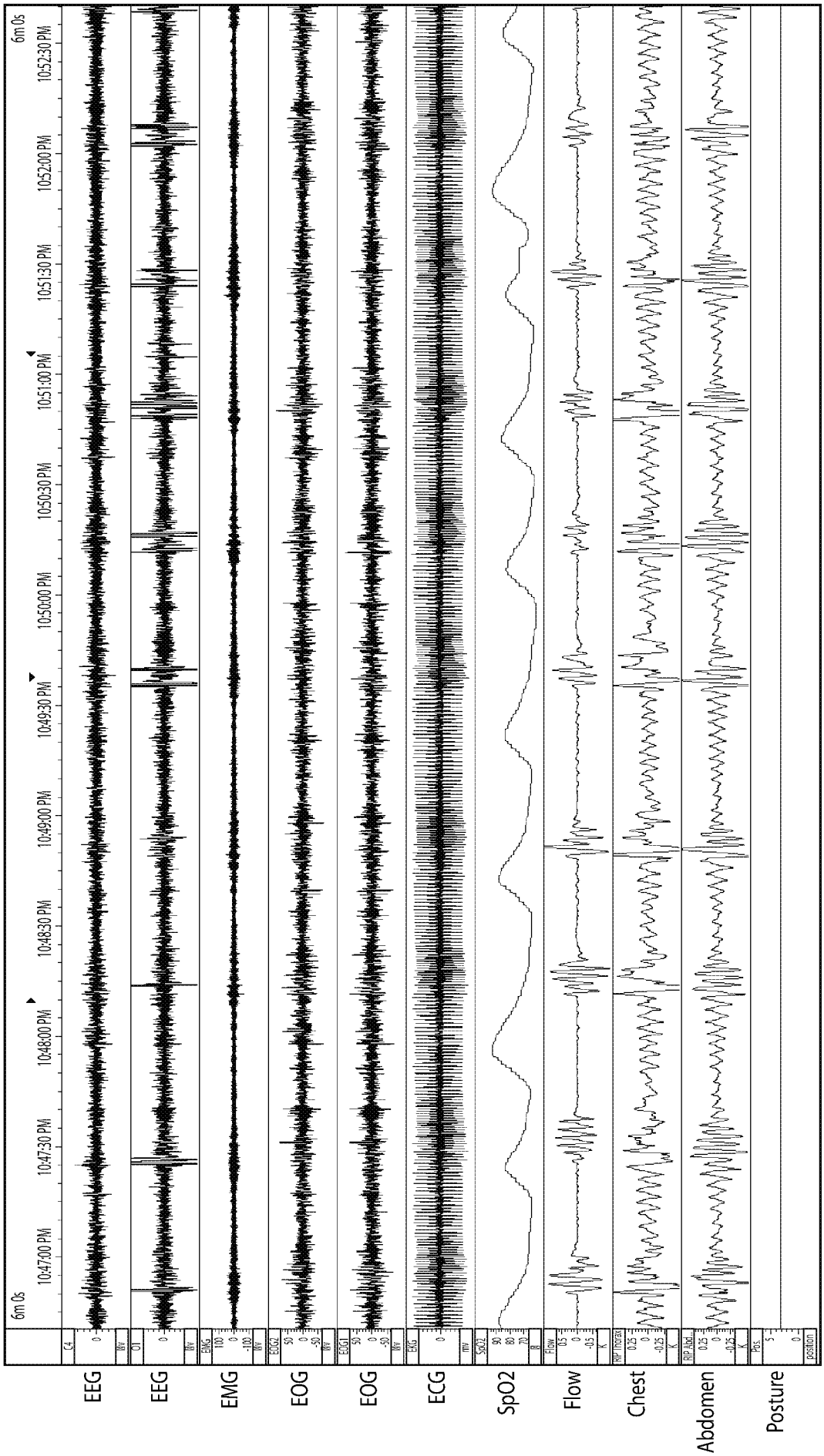
6m 0s
10:47:00 PM
10:47:30 PM
10:48:00 PM
10:48:30 PM
10:49:00 PM
10:49:30 PM
10:50:00 PM
10:50:30 PM
10:51:00 PM
10:51:30 PM
10:52:00 PM
10:52:30 PM
C4
O1
EMG
EOG2
EOG1
ECG
SpO2
Flow
RIP Thorax
RIP Abd.
Pos.
EEG
EEG
EMG
EOG
EOG
ECG
SpO2
Flow
Chest
Abdomen
Posture

FIG. 6C

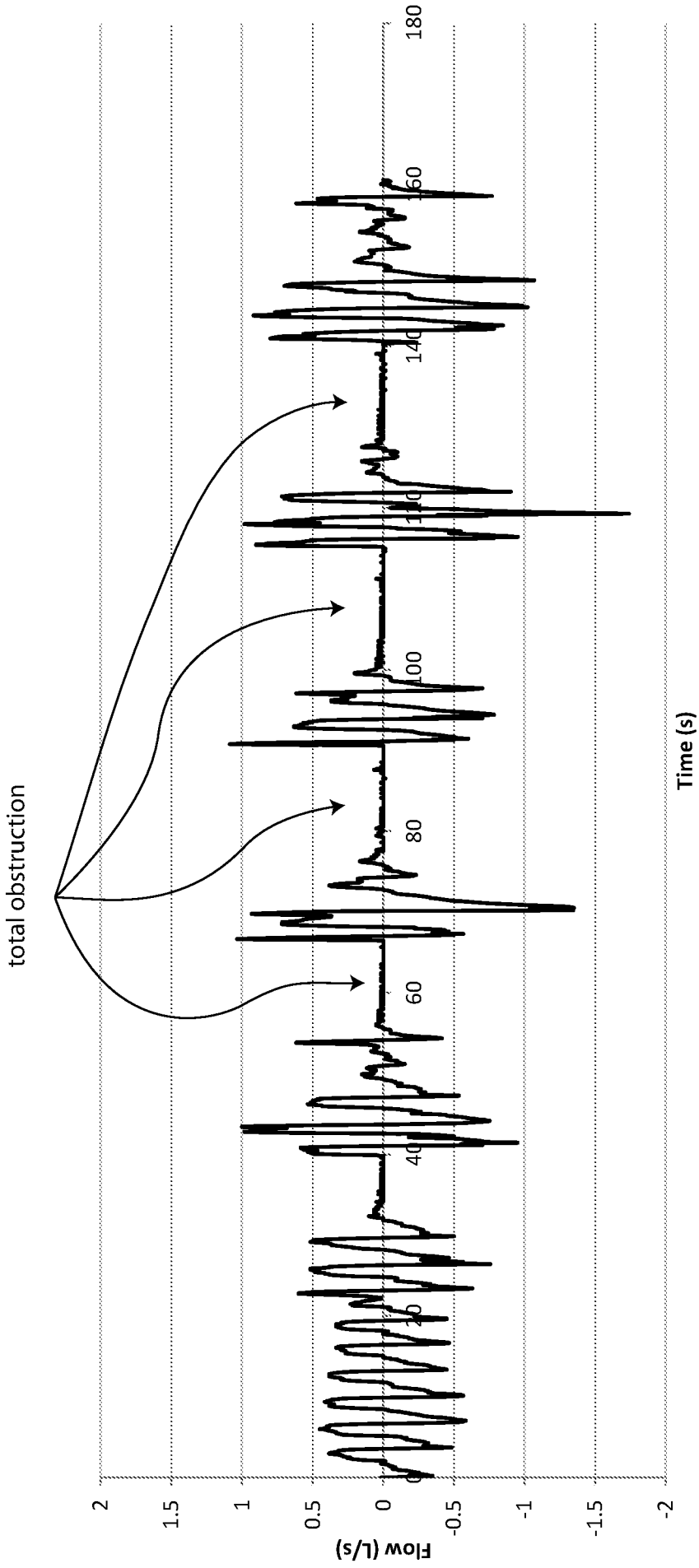
total obstruction
Flow (L/s)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
20
40
60
80
100
120
140
160
180
Time (s)

FIG. 6D

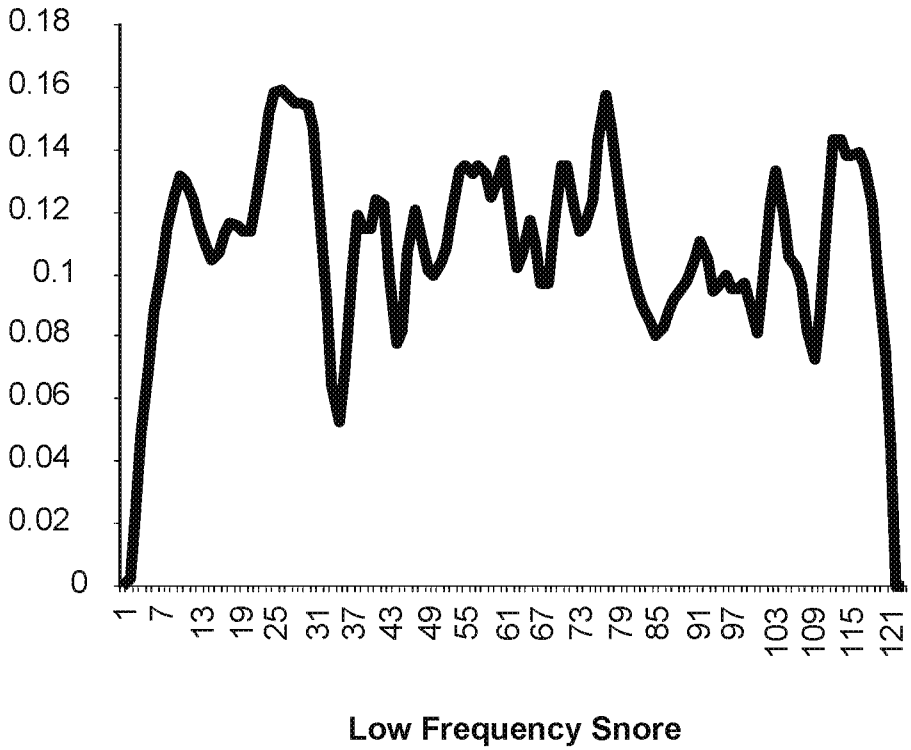
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
109
115
121
Low Frequency Snore

FIG. 6E

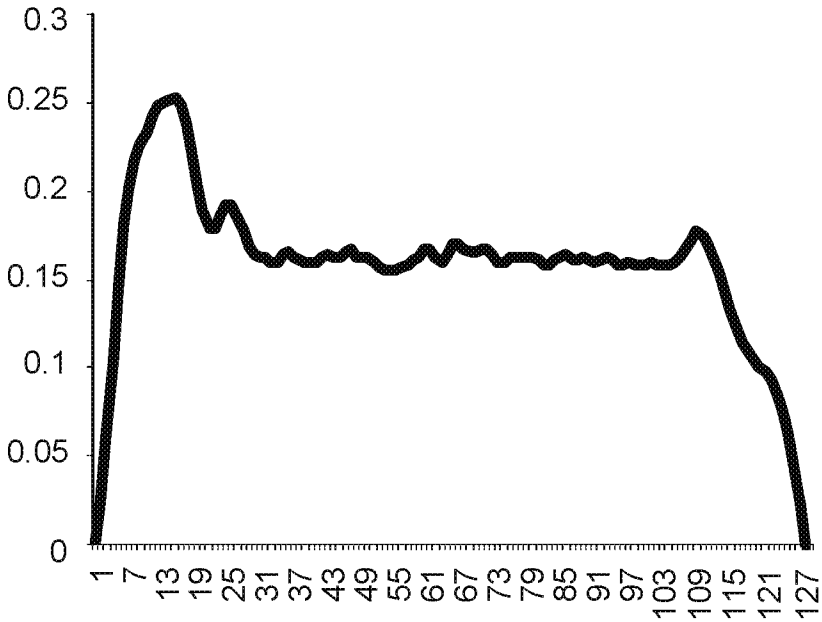
0.3
0.25
0.2
0.15
0.1
0.05
0
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
109
115
121
127

FIG. 6F

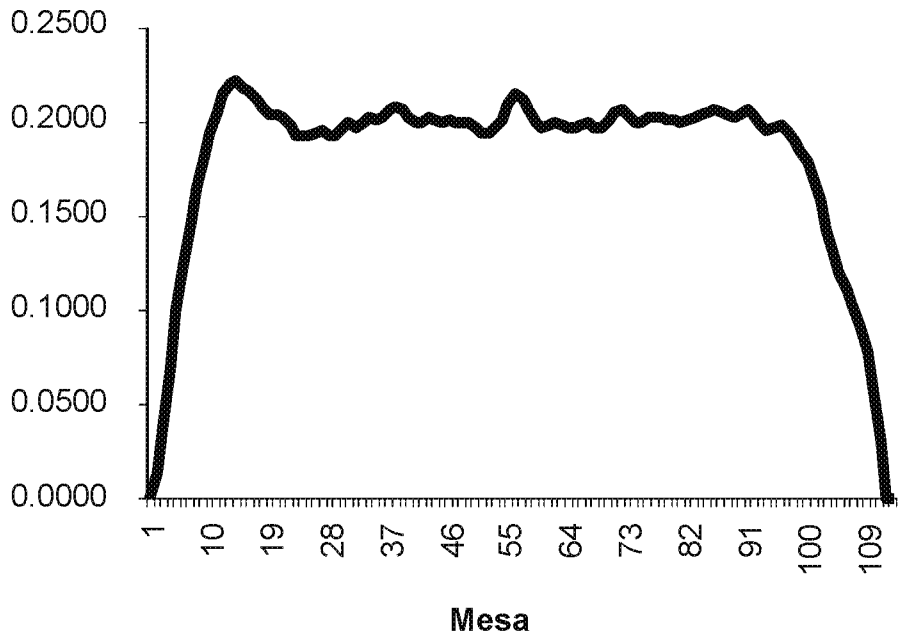
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
1
10
19
28
37
46
55
64
73
82
91
100
109
Mesa

FIG. 6G

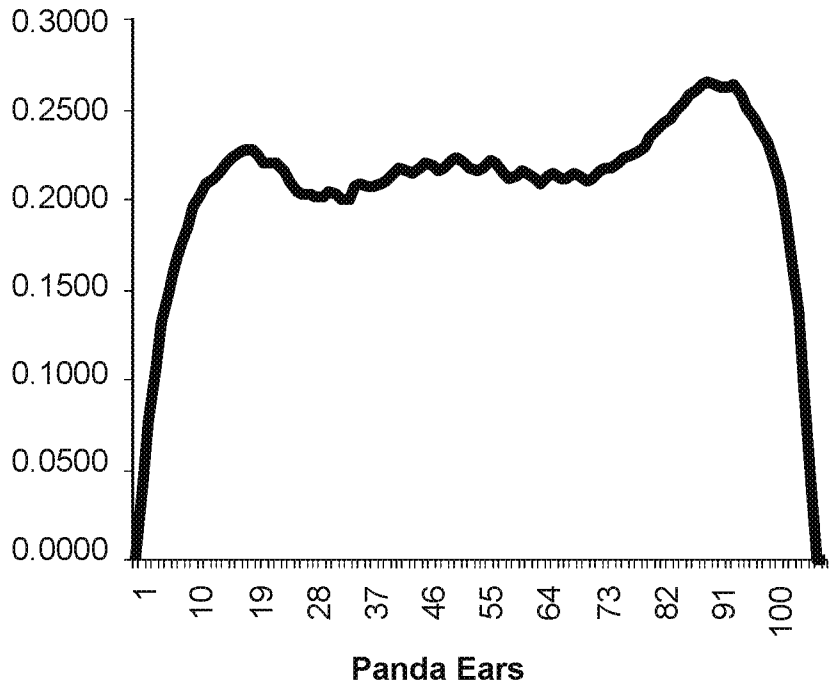
0.3000
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
1
10
19
28
37
46
55
64
73
82
91
100
Panda Ears

FIG. 6H

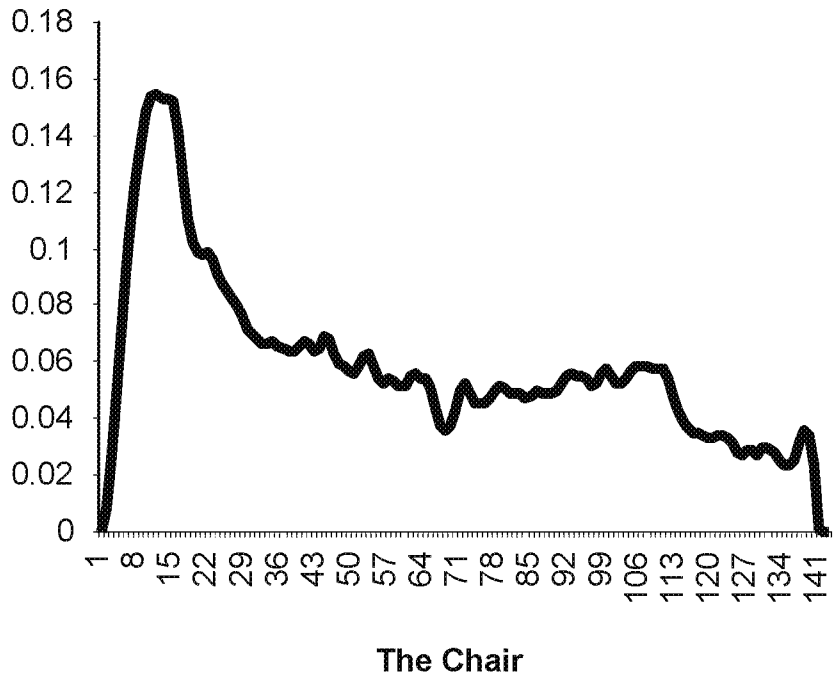
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1
8
15
22
29
36
43
50
57
64
71
78
85
92
99
106
113
120
127
134
141
The Chair

FIG. 6I

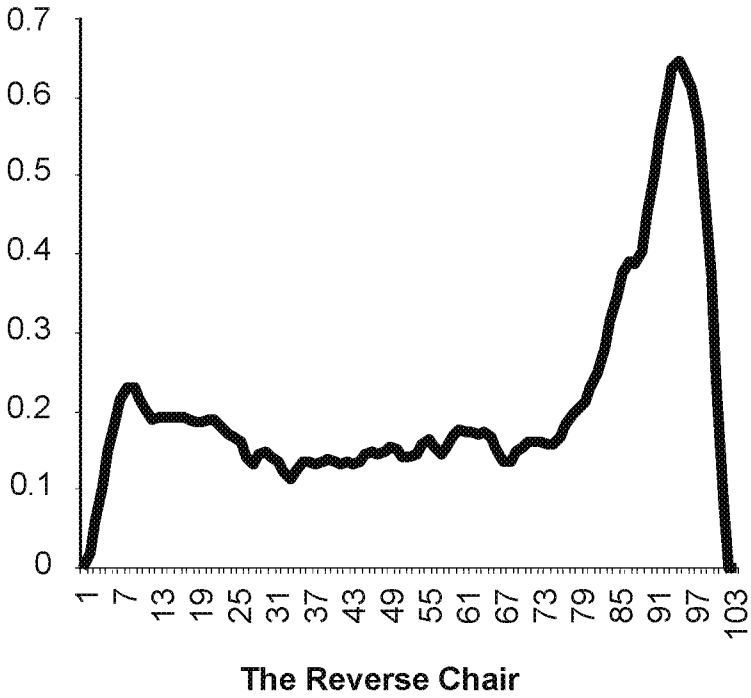
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
The Reverse Chair

FIG. 6J

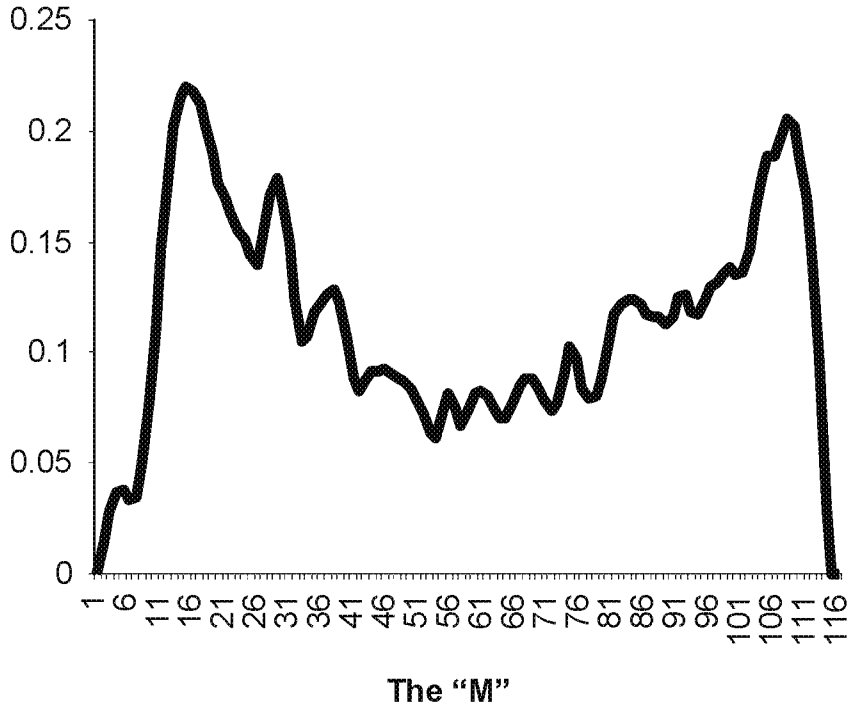
0.25
0.2
0.15
0.1
0.05
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
The “M”

FIG. 6K

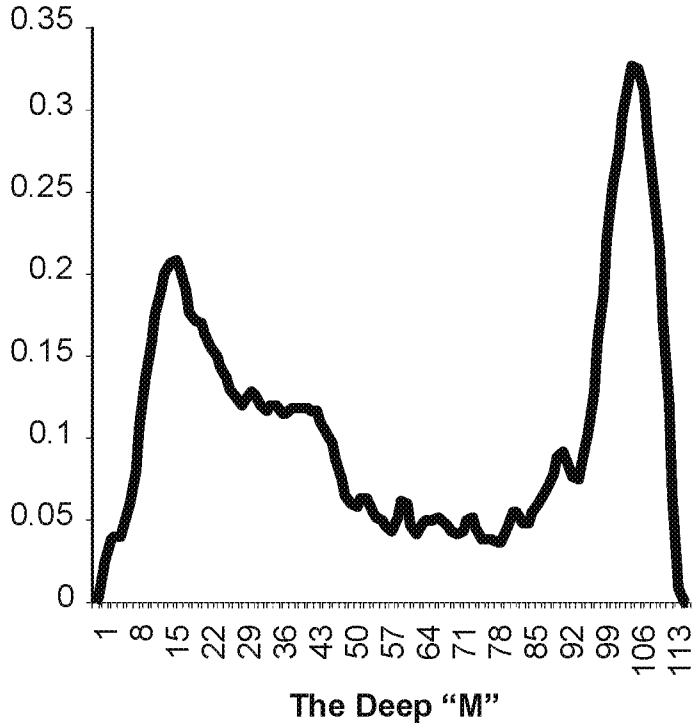
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
8
15
22
29
36
43
50
57
64
71
78
85
92
99
106
113
The Deep “M”

FIG. 6L

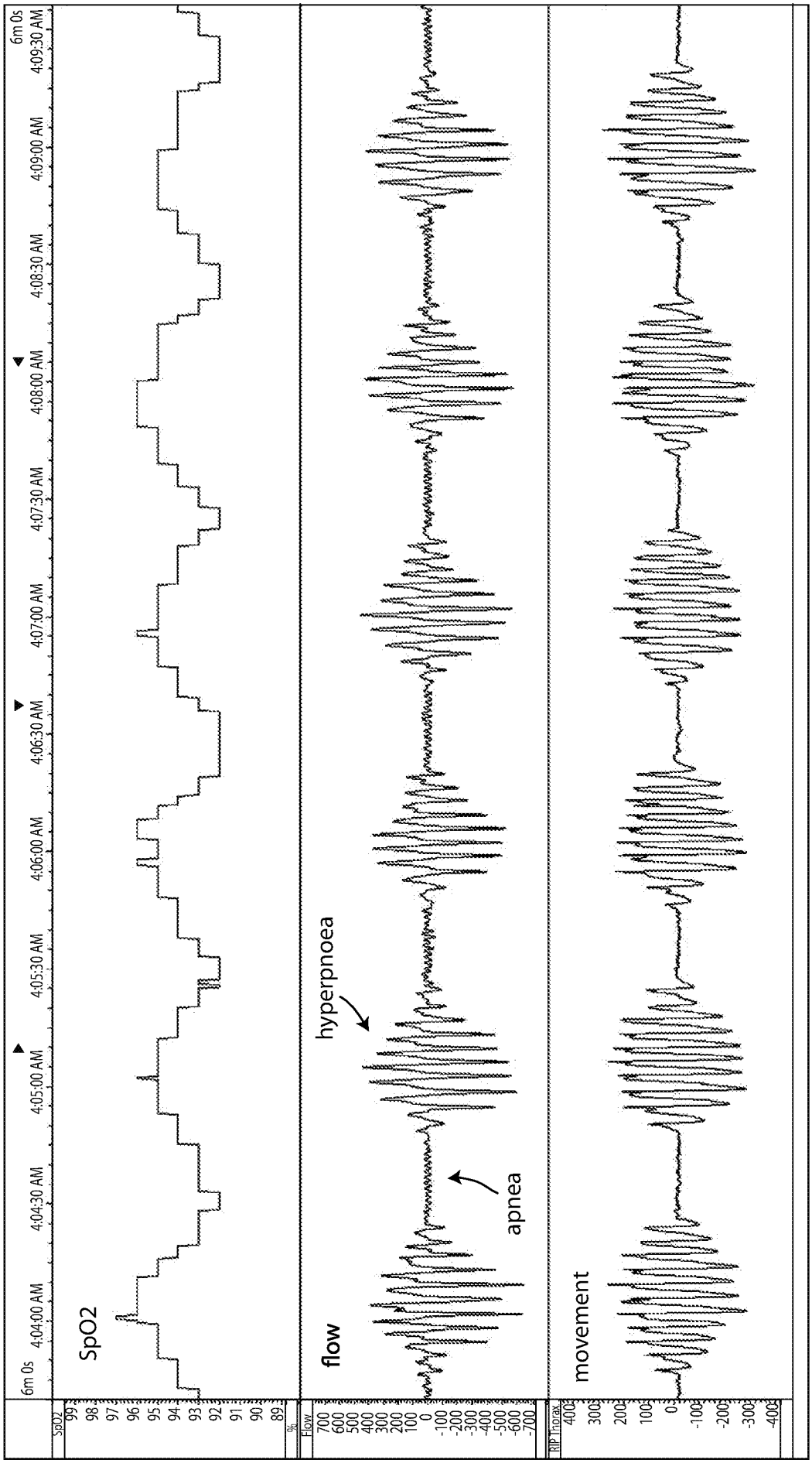
6m 0s
4:04:00 AM
4:04:30 AM
4:05:00 AM
4:05:30 AM
4:06:00 AM
4:06:30 AM
4:07:00 AM
4:07:30 AM
4:08:00 AM
4:08:30 AM
4:09:00 AM
4:09:30 AM
SpO2
SpO2
99
98
97
96
95
94
93
92
91
90
89
%
flow
hyperpnoea
apnea
Flow
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
movement
RIP Thorax
400
300
200
100
0
-100
-200
-300
-400

FIG. 6M

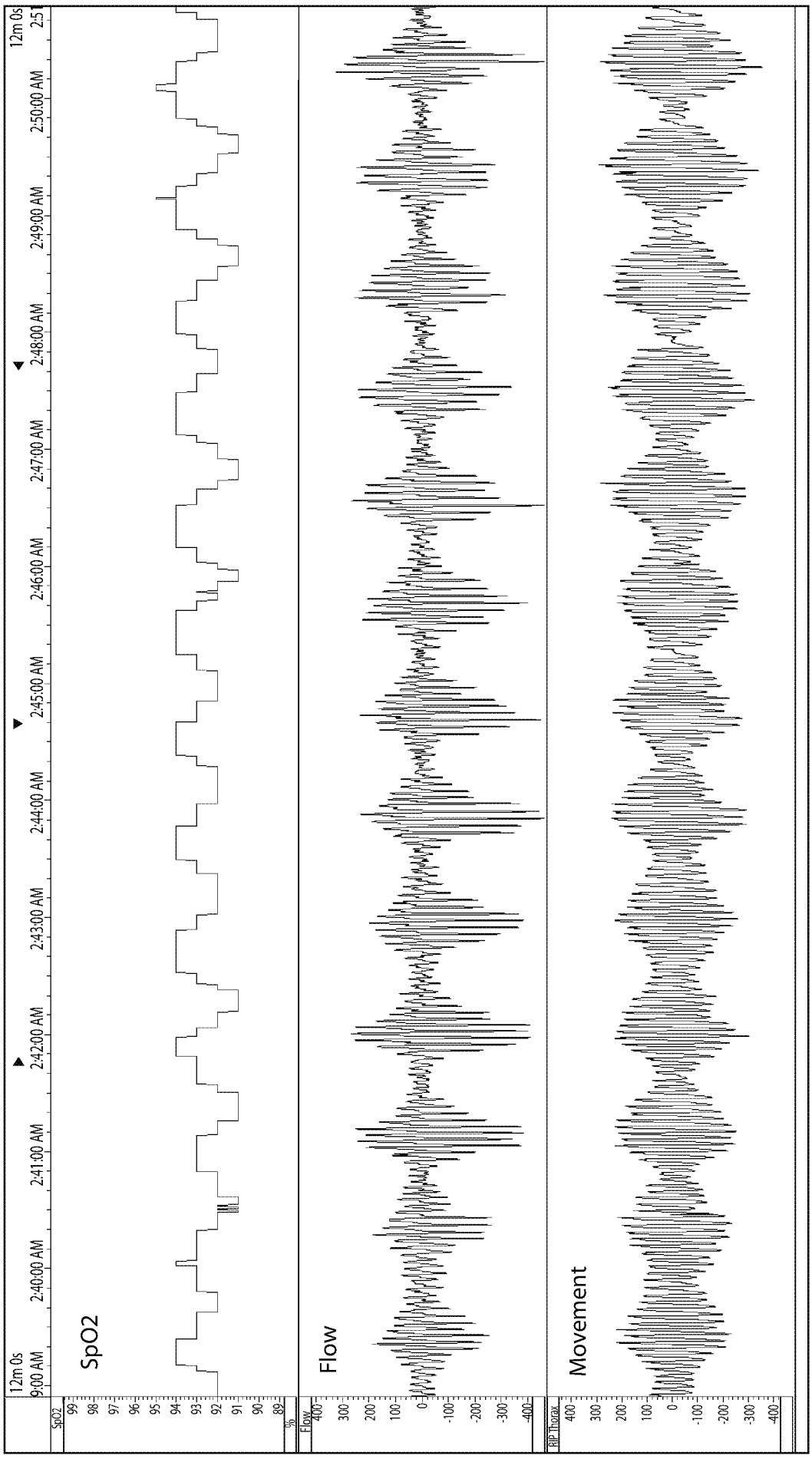
12m 0s
9:00 AM
2:40:00 AM
2:41:00 AM
2:42:00 AM
2:43:00 AM
2:44:00 AM
2:45:00 AM
2:46:00 AM
2:47:00 AM
2:48:00 AM
2:49:00 AM
2:50:00 AM
2:51
SpO2
99
98
97
96
95
94
93
92
91
90
89
%
Flow
400
300
200
100
0
-100
-200
-300
-400
RIP Thorax
Movement

FIG. 6N

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2020/056076

A. CLASSIFICATION OF SUBJECT MATTER

A61M 16/08 (2006.01) A61M 16/16 (2006.01) A61M 16/10 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC: CPC & IPC A61M 16/-; CPC A61M 2205/6018, A61M 16/0875, A61M 16/0875, A61M 2205/3653 and ***keywords*** (((humidif+ 3d (tube, tubing, pipe, conduct+)), (heat+, sens+) 3d (electric+, contact+, connect+, coupl+, engag+, operat+), portion?, part+, (automatic 3d identif+), identif+) and similar words; ***Inventors:*** DOUDKINE DMITRI ANATOLIEVICH; MAURER DIMITRI MARCO; ***Applicant:*** *RESMED PTY LTD*;

Applicant and inventor names searched in **EPODOC, Espacenet** and **internal databases** provided by IP Australia.

Google Scholar and Espacenet: Search words: (humidif+) and (tube, tubing, pipe, conduct+) and (heat+, sens+) and (electric+, contact+, connect+, coupl+, engag+, operat+) and (portion?, part+) and (automatic 3d identif+) and (identif+) and similar words

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2020	08 September 2020

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INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/IB2020/056076**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/0278221 A1 (SCHERMEIER et al.) 14 December 2006 Abstract; Figures and related text; claims	1 to 19
X	US 8733349 B2 (BATH et al.) 27 May 2014 Abstract; Figures and related text; claims	1 to 19
X	US 2017/0113009 A1 (RESMED LIMITED) 27 April 2017 Abstract; Figures and related text; claims	1 to 19
X	EP 2055337 A1 (SMITHS MEDICAL ASD, INC.) 06 May 2009 Abstract; Figures and related text; claims	1 to 19
A	US 2008/0105257 A1 (KLASEK et al.) 08 May 2008 Figures and related text	1 to 19
A	WO 2013/165263 A1 (FISHER & PAYKEL HEALTHCARE LIMITED) 07 November 2014 Figures and related text	1 to 19

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/IB2020/056076**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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		US 8496001 B2	30 Jul 2013
		CA 2549700 A1	08 Dec 2006
		CN 1876196 A	13 Dec 2006
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		AU 2009212880 A1	01 Apr 2010
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		CN 105963842 A	28 Sep 2016
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		CN 107715271 A	23 Feb 2018
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/IB2020/056076**

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		JP 5718232 B2	13 May 2015
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		NZ 590924 A	30 Aug 2013
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		NZ 597179 A	27 Sep 2013
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INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/IB2020/056076**

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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/IB2020/056076**

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INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/IB2020/056076**

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Patent Document/s Cited in Search Report		**Patent Family Member/s**	
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		US 2018256846 A1	13 Sep 2018

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.