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# Respimatic 100






*Sunil Nanda (PARC)*

00 - Preliminary and Confidential

# *Setting the Context*

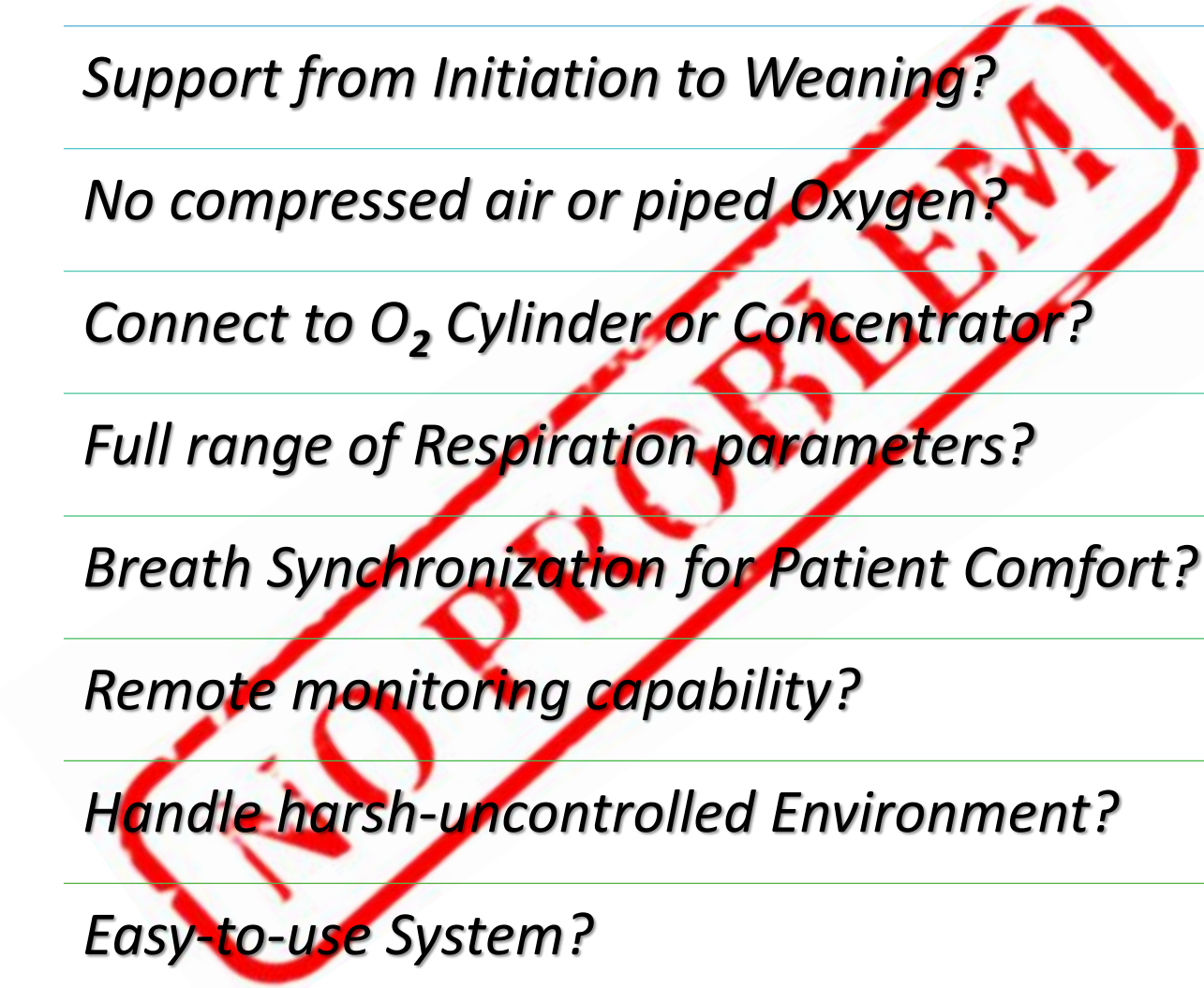
The Motivation

The Problem Statement

# RESPIMATIC 100
*(Patent Pending)*

*Is it right for you?*

- *Need adult, non-invasive respiratory support?*
- *Support from Initiation to Weaning?*
- *No compressed air or piped Oxygen?*
- *Connect to $O_2$ Cylinder or Concentrator?*
- *Full range of Respiration parameters?*
- *Breath Synchronization for Patient Comfort?*
- *Remote monitoring capability?*
- *Handle harsh-uncontrolled Environment?*
- *Easy-to-use System?*
- *Budget Friendly?*



# *Respiration Assist Devices*

*Categories – Usage and Pricing*

Features

Less than Rs 50,000


CPAP

Less than Rs 1 Lakh


BiPAP

AFFORDABLE feature set for PHC, Small Clinic, and Ambulance Use?

Big Hole

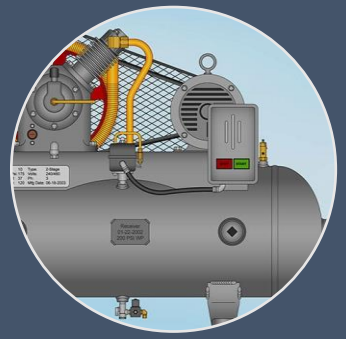
Rs 12 Lakhs ++


ICU Ventilator

# CPAP *v/s* BiPAP *v/s* RESPIMATIC 100 *v/s* ICU-VENTILATOR

| CPAP | BiPAP | Respimatic 100 | ICU Ventilator |
|---|---|---|---|
| Continuous Positive Airway Pressure | Continuous Bi-Level Airway Positive Pressure | Mechanical Ventilation with 4 most-used ventilation modes and controls | Mechanical Ventilation with very sophisticated modes and controls |
| Non-invasive | Non-invasive | Non-invasive | Non-invasive + Invasive |
| High Flow + PEEP | Inspiratory Pressure + PEEP | Tidal Volume + Support Pressure + PEEP | Tidal Volume + Support Pressure + PEEP |
| Useful for Type 1 respiratory Failure (Hypoxemic) | Useful for Type 2 respiratory Failure (Hypercopnic) | Useful for Hypoxemic and Hypercopnic respiratory failure | Useful for Hypoxemic and Hypercopnic respiratory failure |
| Continuous flow of air at a constant pressure. Increases mean airway pressure to recruit collapsed alveoli | Continuous flow of air at different constant pressures during inspiration and expiration breathing phase | Independent control over the volume, the respiration rate and pressure | Independent control over the volume, the respiration rate and pressure |
| Useful only when patient can breathe on his own | Useful only when patient can breathe on his own | Useful when patient can or CANNOT breathe on his own | Useful when patient can or CANNOT breathe on his own |
| Only Spontaneous breaths that are patient triggered. | Only Spontaneous breaths that are patient triggered. | Spontaneous breaths + Mandatory breaths controlled by RR and I:E | Spontaneous breaths + Mandatory breaths controlled by RR and I:E |
| External FiO2 control | External FiO2 control | System assisted FiO2 control | Direct FiO2 control |
| Breath Synchronization N/A | Breath Synchronization N/A | Full Breath Synchronization | Full Breath Synchronization |
| No Tidal Volume control | Indirect Tidal Volume control (IPAP-EPAP) | Direct Tidal Volume control | Direct Tidal Volume control |
| No Respiration Rate control | No Respiration Rate control | Direct Respiration Rate control | Direct Respiration Rate control |
| No Inspiration:Expiration ratio control | No Inspiration:Expiration ratio control | Direct Inspiration:Expiration control | Direct Inspiration:Expiration control |
| External Humidity control | External Humidity control | External Humidity control | Direct Humidity control |
| No display of Peak, Plateau or PEEP | No display of Peak, Plateau or PEEP | Full display of Peak, Plateau and PEEP | Full display of Peak, Plateau and PEEP |
| Minimal alarm signals | Minimal alarm signals | Full set of Alarm signals | Full set of Alarm signals |
| No remote monitoring | No remote monitoring | Sophisticated Remote WEB Dashboard | Minimal Remote monitoring (if any) |

# *Observations on Ventilator Evolution*



Iron Lung Age

Pneumatic Age

µController Age

Smart "E"-Age

## Most-used Ventilation Modes have not changed

- Volume and Pressure Control
- Control BPM, I/E, VT and PS
- Monitor pressures and flow
- Safety Alarm systems

## Diminishing Returns from what has evolved …

- Exotic Ventilation modes
- Multitude of Sensors
- Fancy Touch-screen LCD Displays

# *Respimatic 100 Details*

System Components

Technical Details

# US and INDIA IP Protection

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**Nanda et al.**

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(54) **VENTILATOR**

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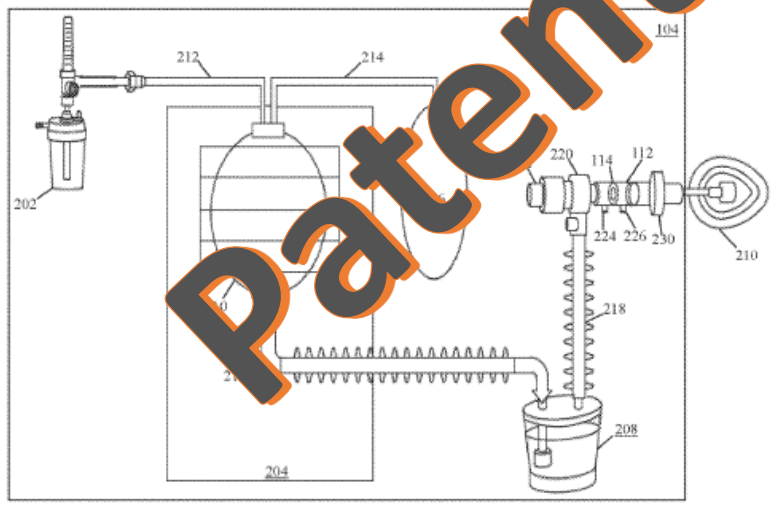
(57) **ABSTRACT**

Provided is a ventilator that includes a breathing system, a mechanical system coupled to breathing system, and a control system coupled to breathing system and mechanical system. The control system includes pressure sensors, processing circuitry, and memory configured to store a look-up table. The processing circuitry receives a set of values for plurality of parameters, identifies a compression value from a plurality of compression values in the look-up table based on the received set of values. The processing circuitry causes the mechanical system to compress a bag valve of the breathing system in accordance with the identifi... sion value. The compression of the bag ... gaseous inhalant to flow through the breathi... em wit... a time-interval. The processing circuitry ... actual volume of the gaseous inhalant and itera... fies the compression value of the bag valve to ... desired volume of the gaseous inhalant.




$$Q \propto \sqrt{\frac{(P_{G1}-P_{G2})}{(P_{G1}+P_{G2})+2*Patmosphere}}$$

An important and necess... simplifi... is t... and $P_{G2}$ encountered in our system are of the order of tens of $cmH_2O$ wh... ...mosp... is of ... order of a thousand $cmH_2O$ of pressure. At sea level, *Patmosphere* is a... ...1000 ...O. Even at an altitude of 15,000 feet, *Patmosphere* is appro... ...ely 60... . On the other hand, the $P_{G1}$ and $P_{G2}$ in the system range from 1... ...60...

...($P_{G1}$ ...) term is negligible compared to (2* *Patmosphere*) , even more so since it ... ...ed by a square root. The flow equation can be simplified to the one below.

$$Q \propto \sqrt{\frac{(P_{G1}-P_{G2})}{Patmosphere}}$$

Recalling *Equation 2* from the theory section above, this equation can be recast as below given that the orifice characteristics and pressure tap locations are the same for every system.

$$Q = C * \frac{\sqrt{(P_{G1}-P_{G2})}}{\sqrt{(Patmosphere)}} \quad \text{where } C = f(Re) \text{ Reynold's number}$$

At a given geographical location, *Patmosphere* is also a constant. So, the above equation further reduces to the one below.

$$Q = \left(\frac{C}{\sqrt{Patmoshpere}}\right) * \sqrt{(P_{G1}-P_{G2})}$$

The equation needs further simplification to ease the computation burden of the square root computation for and inexpensive micro-controller. The constraints are as below.

# *Our Solution RESPIMATIC 100*

- 4 Commonly Used Ventilation Modes
  CMV, ACV, SIMV, PSV
- Respiration Rate, Tidal Volume, PEEP, Pressure Support & FiO2 Controls
- Volume Controlled and Pressure Supported Breaths
- Mandatory & Spontaneous Breaths with Full Breath Synchronization

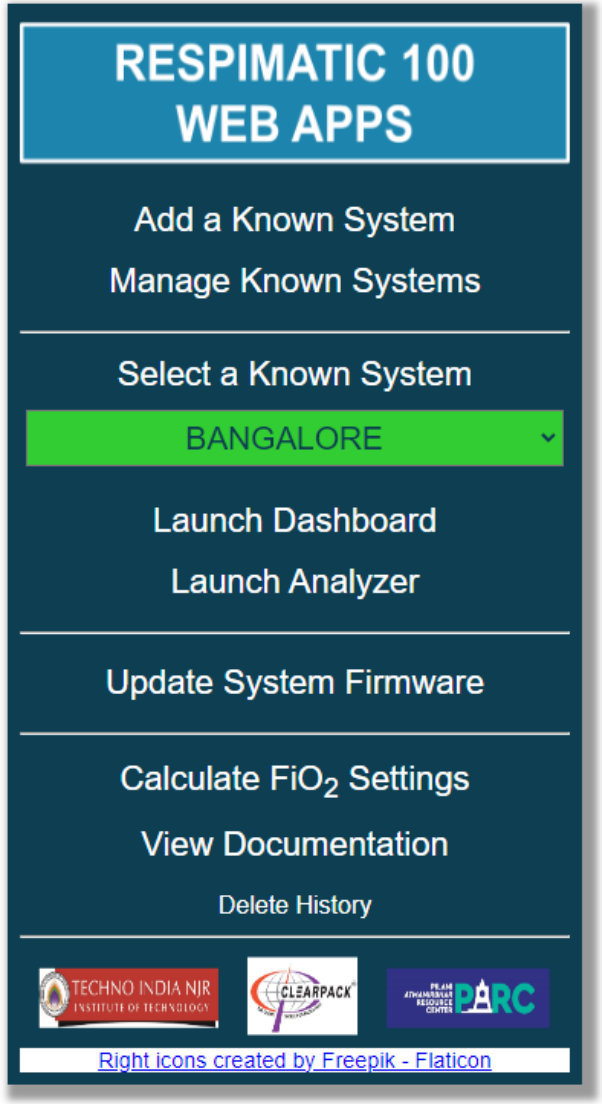
Complete set of WEB Apps
- Remote Dashboard
- Remote Recorder
- Remote Analyzer

Low-speed Wi-Fi sufficient

Phone Hot-spot sufficient

Uses secure HTTPS protocol

Field upgradable with new Firmware releases



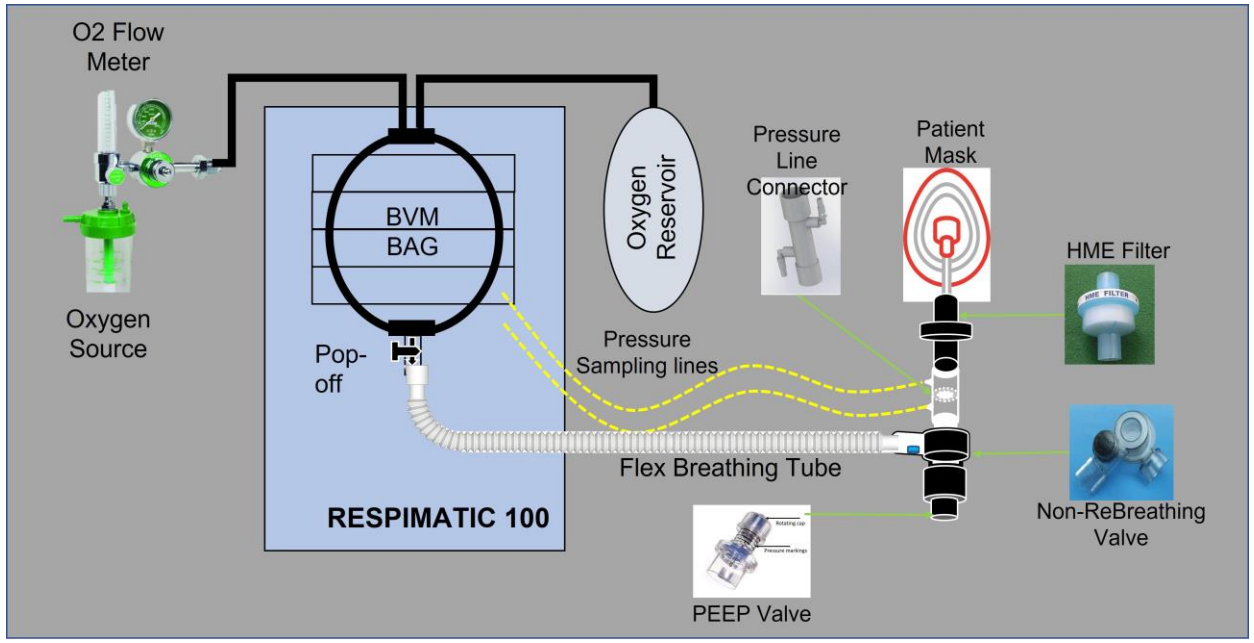

https://www.respimatic.com

# *Breathing Circuit*

- Proprietary, *patent-pending* Pressure line connector with Orifice plate
- COTS single-limb Breathing Circuit with NRBM
- BVM or Ambu Bag with Reservoir
- Pressure sensing lines
- PEEP valve
- HME Filter
- Oxygen Source

Off-the-Shelf Single limbed Circuit with NRBM

Proprietary Dual Pressure line Connector



# *Front Panel*
# *The Human-Machine Interface*

Simple Tactile buttons
No delicate touch screen etc.

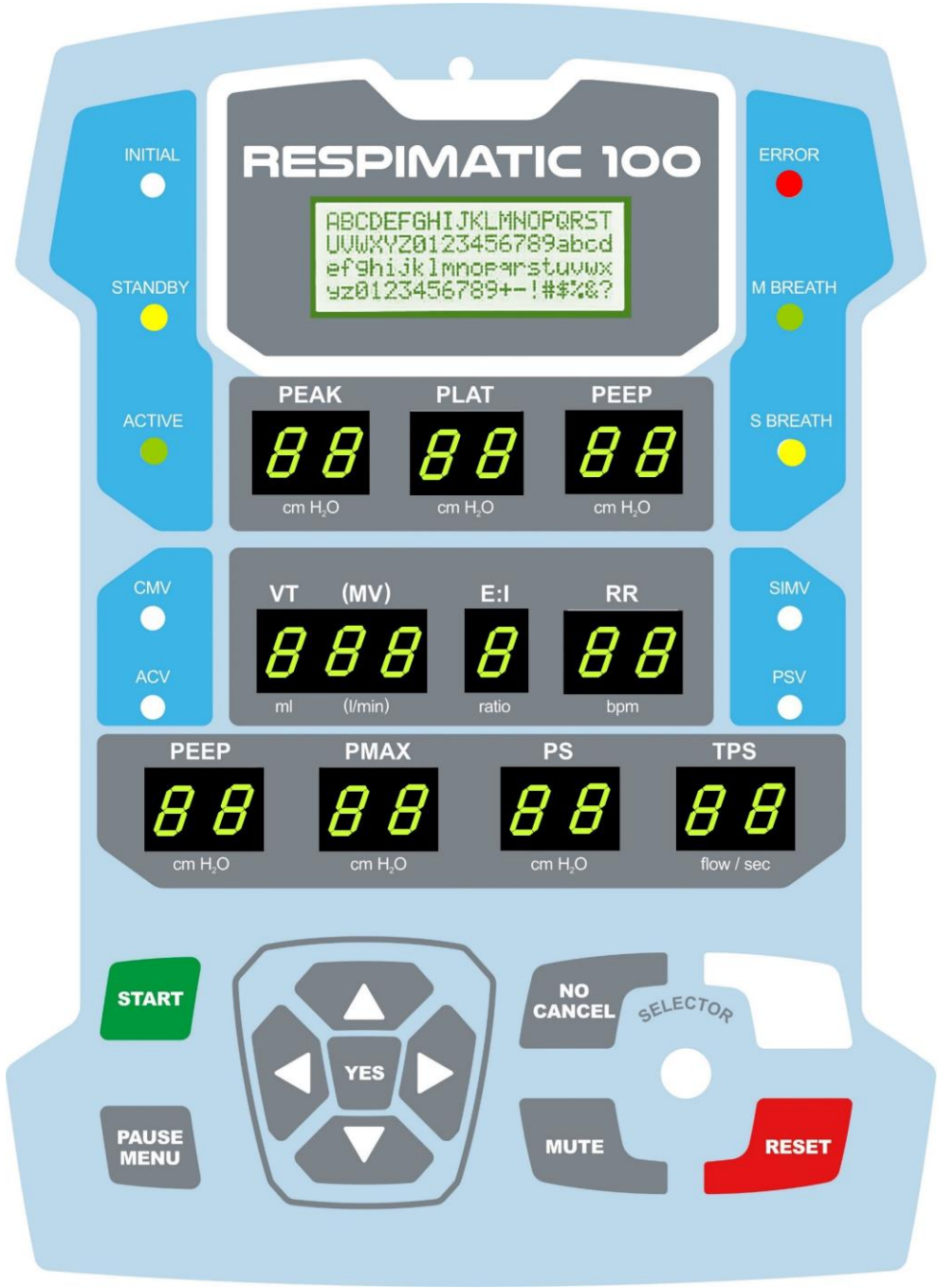
Easy to read 7-seg LED Parameters Display

Parameter selection using navigation arrow buttons

4-line LCD Display for displaying Messages and Menus

Peak, Plateau, PEEP pressures displayed after each breath

Shows Delivered Volumes, Lung Compliances, Breath types etc.



# *Dashboard Snapshot View*

Anyone can monitor any patient via the WEB

- Must know the UID of the system

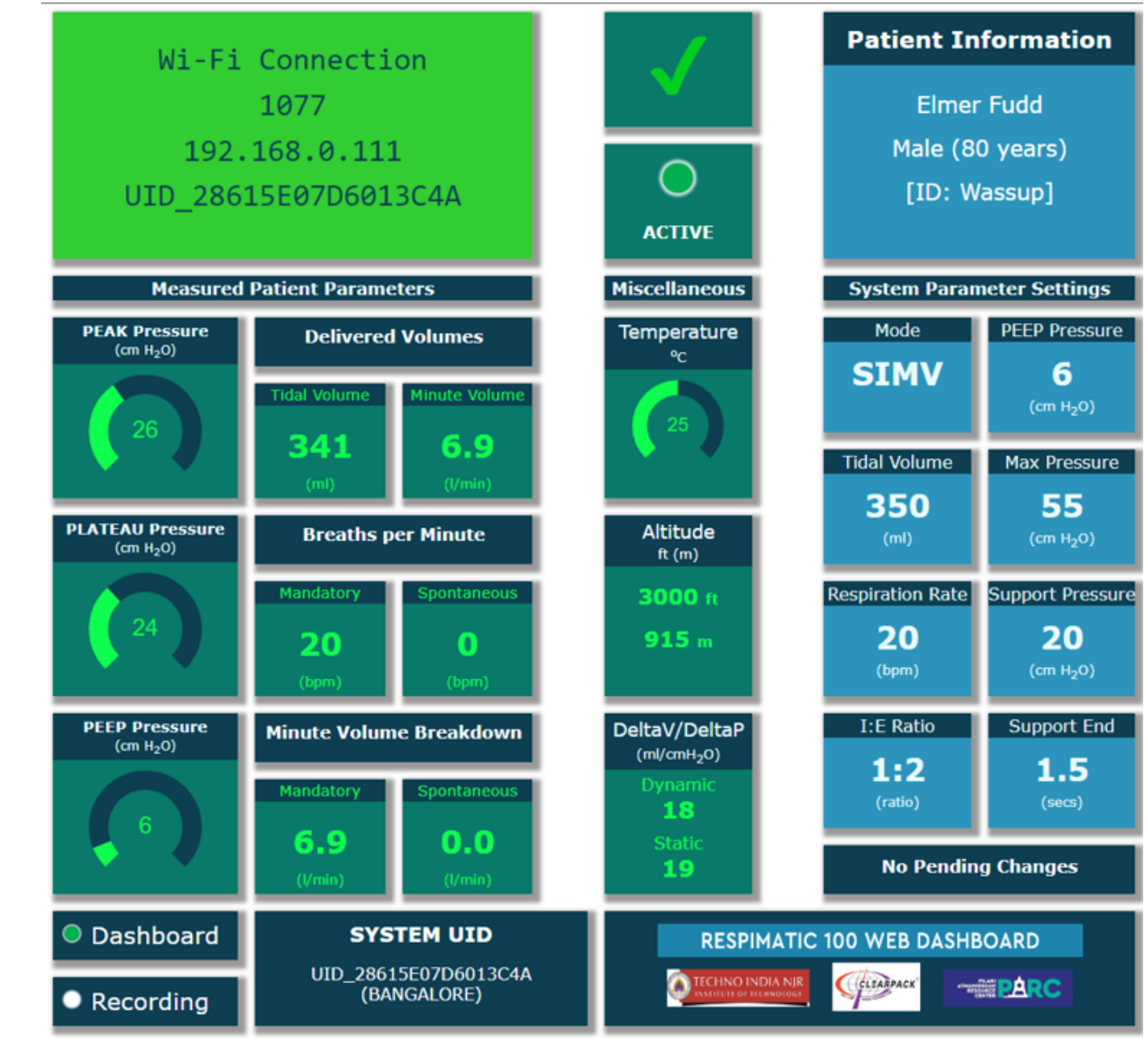
One-to-many and many-to-one monitoring

5 Dashboard views

- Snapshots
- Breath Waveforms
- Charts
- Statistics
- Alerts

Breath Range Selector on every view to display data for different breath ranges

- For instance, use to compare the statistics for the first hour of ventilation against the second hour.




https://www.respimatic.com

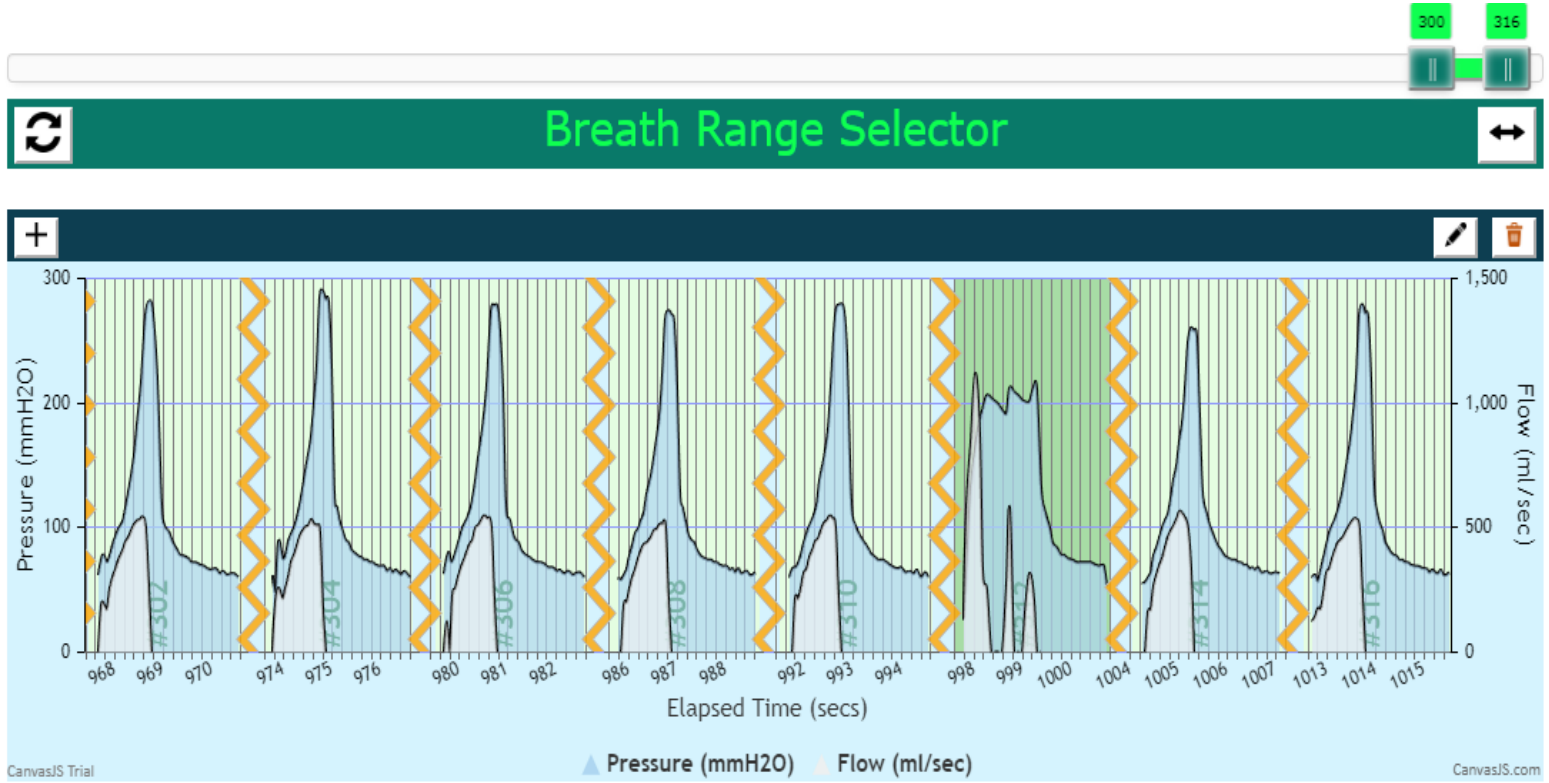
# *Dashboard*
## *Waveforms View*

Pressure and Flow Graphs

For Selected Breaths

Periodic Display

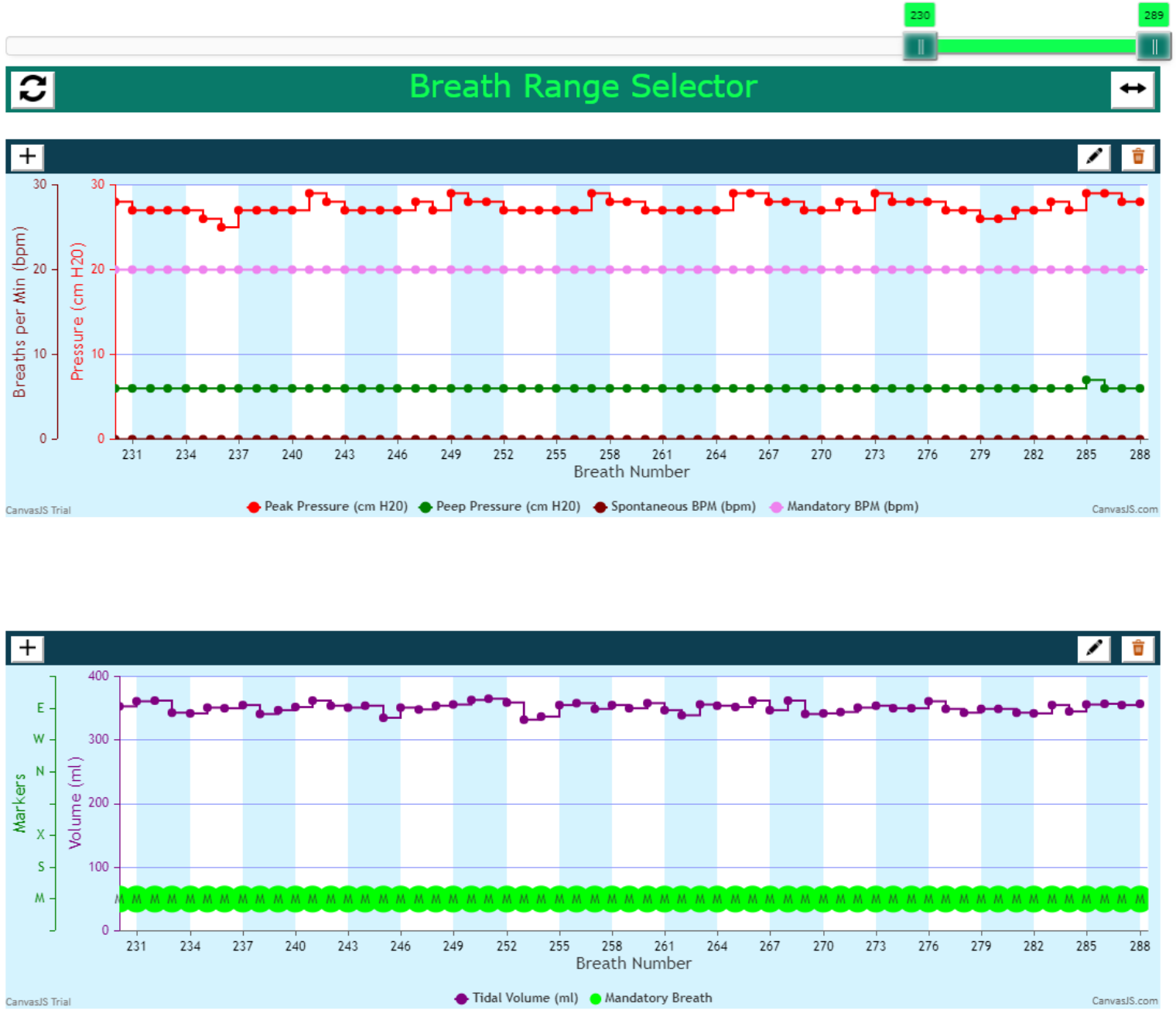
Display on demand



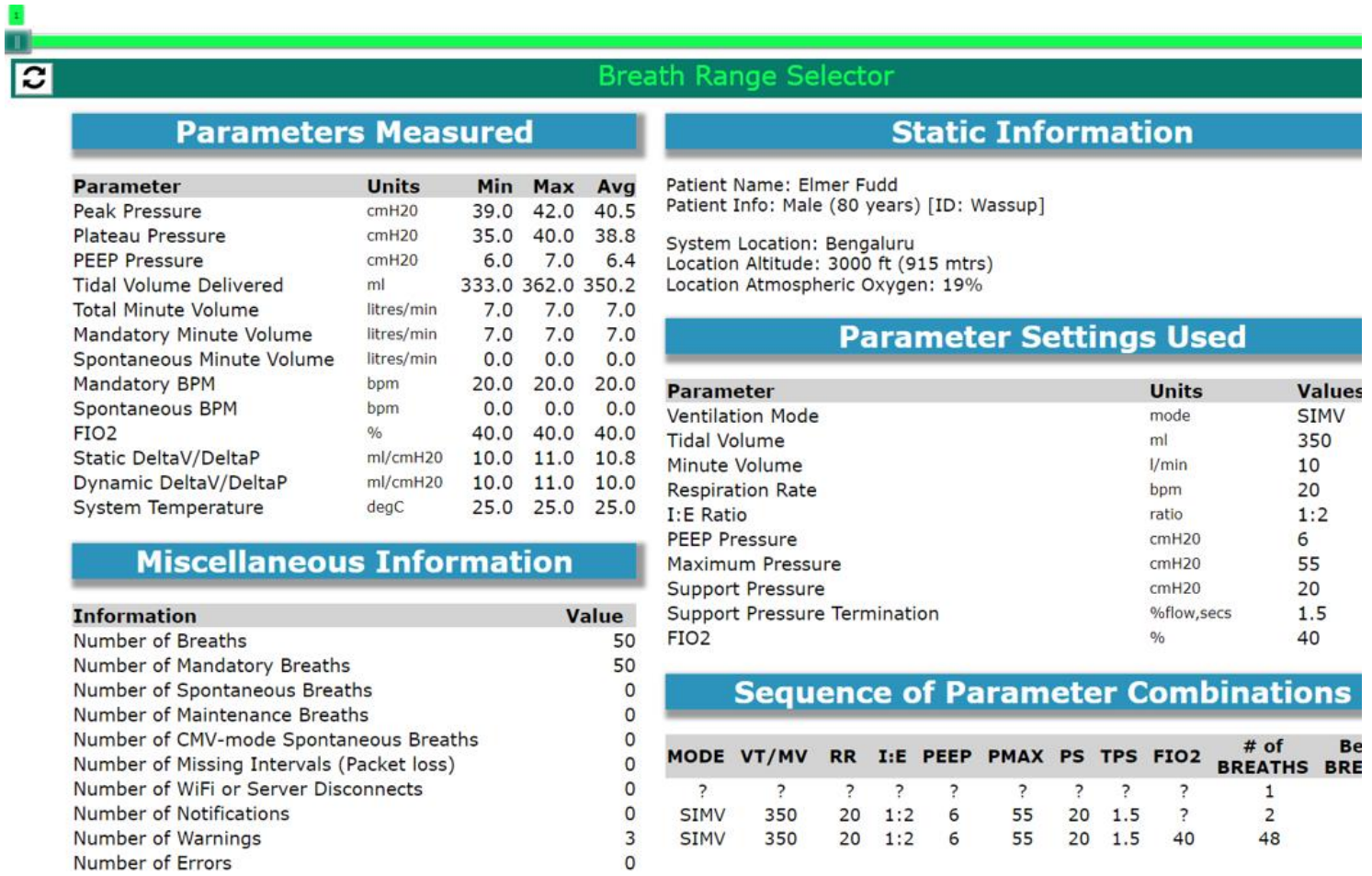

| Normal Breaths | | | Maintenance Breaths | | | Exception Breaths | |
|---|---|---|---|---|---|---|---|
| Mandatory Volume Control | Spontaneous Volume Control | Spontaneous Pressure Control | Mandatory Volume Control | Spontaneous Volume Control | Spontaneous Pressure Control | Abnormal Seeming Breath | Error Causing Breath |

Broken lines indicate few missing datapoints
Red label indicates too many missing datapoints

# *Dashboard*
## *Charts View*



# *Dashboard Statistics View*



Breath Range Selector

## Parameters Measured

| Parameter | Units | Min | Max | Avg |
|---|---|---|---|---|
| Peak Pressure | cmH20 | 39.0 | 42.0 | 40.5 |
| Plateau Pressure | cmH20 | 35.0 | 40.0 | 38.8 |
| PEEP Pressure | cmH20 | 6.0 | 7.0 | 6.4 |
| Tidal Volume Delivered | ml | 333.0 | 362.0 | 350.2 |
| Total Minute Volume | litres/min | 7.0 | 7.0 | 7.0 |
| Mandatory Minute Volume | litres/min | 7.0 | 7.0 | 7.0 |
| Spontaneous Minute Volume | litres/min | 0.0 | 0.0 | 0.0 |
| Mandatory BPM | bpm | 20.0 | 20.0 | 20.0 |
| Spontaneous BPM | bpm | 0.0 | 0.0 | 0.0 |
| FIO2 | % | 40.0 | 40.0 | 40.0 |
| Static DeltaV/DeltaP | ml/cmH20 | 10.0 | 11.0 | 10.8 |
| Dynamic DeltaV/DeltaP | ml/cmH20 | 10.0 | 11.0 | 10.0 |
| System Temperature | degC | 25.0 | 25.0 | 25.0 |

## Miscellaneous Information

| Information | Value |
|---|---|
| Number of Breaths | 50 |
| Number of Mandatory Breaths | 50 |
| Number of Spontaneous Breaths | 0 |
| Number of Maintenance Breaths | 0 |
| Number of CMV-mode Spontaneous Breaths | 0 |
| Number of Missing Intervals (Packet loss) | 0 |
| Number of WiFi or Server Disconnects | 0 |
| Number of Notifications | 0 |
| Number of Warnings | 3 |
| Number of Errors | 0 |

## Static Information

Patient Name: Elmer Fudd
Patient Info: Male (80 years) [ID: Wassup]

System Location: Bengaluru
Location Altitude: 3000 ft (915 mtrs)
Location Atmospheric Oxygen: 19%

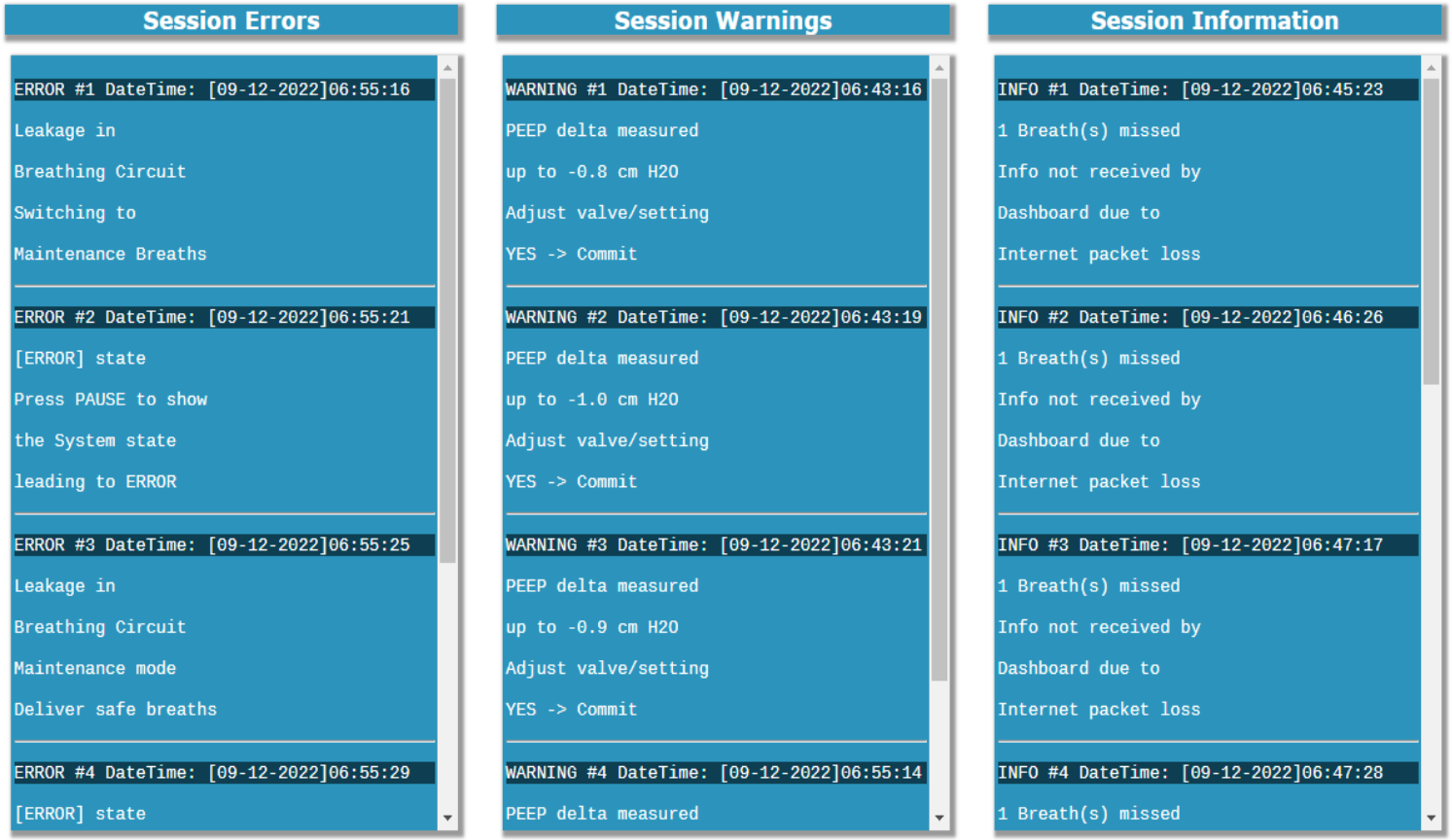
## Parameter Settings Used

| Parameter | Units | Values |
|---|---|---|
| Ventilation Mode | mode | SIMV |
| Tidal Volume | ml | 350 |
| Minute Volume | l/min | 10 |
| Respiration Rate | bpm | 20 |
| I:E Ratio | ratio | 1:2 |
| PEEP Pressure | cmH20 | 6 |
| Maximum Pressure | cmH20 | 55 |
| Support Pressure | cmH20 | 20 |
| Support Pressure Termination | %flow,secs | 1.5 |
| FIO2 | % | 40 |

## Sequence of Parameter Combinations

| MODE | VT/MV | RR | I:E | PEEP | PMAX | PS | TPS | FIO2 | # of BREATHS | Be BRE |
|---|---|---|---|---|---|---|---|---|---|---|
| ? | ? | ? | ? | ? | ? | ? | ? | ? | 1 | |
| SIMV | 350 | 20 | 1:2 | 6 | 55 | 20 | 1.5 | ? | 2 | |
| SIMV | 350 | 20 | 1:2 | 6 | 55 | 20 | 1.5 | 40 | 48 | |

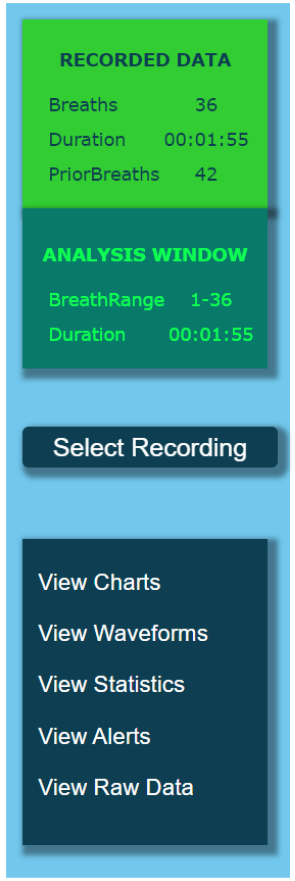
# *Dashboard*
## *Alerts View*



# *Analyzer*

Any patient Session can be recorded locally or remotely.

The recorded Session can then be analyzed off-line using the Analyzer.




# *Updating Firmware*

Firmware releases available on the WEB.

Step-by-step menu driven update procedure

# *Ventilation Modes*

## *The 4 most frequently used*

| ***Continuous Mandatory Ventilation (CMV)*** | ***Synchronized Assist Control Ventilation (Sync ACV)*** | ***Synchronized Intermittent Mandatory Ventilation (SIMV)*** | ***Pressure Support Ventilation (PSV)*** |
|---|---|---|---|
| Volume Controlled Mandatory Breaths | Volume Controlled Mandatory Breaths | Volume Controlled Mandatory Breaths | Pressure supported breaths in response to spontaneous breaths |
| Ignore spontaneous breaths | Volume controlled breaths in response to spontaneous breaths | Pressure supported breaths in response to spontaneous breaths | Monitoring of Minute Volume |
| | Breath Synchronization | Breath Synchronization | Fallback to SIMV if insufficient Minute volume |

# *Volume Controlled Breaths*
## *(All modes)*

### *Tidal Volume (ml)*

200 to 600 ml
increments of 50 ml

### *Respiratory Rate (bpm)*

10 to 30 bpm
increments of 1 bpm

### *Inspiration/Expiration Ratio (I:E)*

1:1 1:2 1:3

### *PEEP ($cmH_2O$)*

4 to 15 $cmH_2O$
increments of 1 $cmH_2O$

### *Max Pressure ($cmH_2O$)*

15 to 50 $cmH_2O$
increments of 5 $cmH_2O$

### *$FiO_2$ Support*

System Managed
Externally Controlled
21% to 100%

# *Pressure Supported Breaths*

*(SIMV & PSV modes)*

## *Support Pressure (PS)*

5 $cmH_2O$ to 35 $cmH_2O$ in increments of 5 $cmH_2O$

## *Support Pressure Termination (TPS)*

Flow-dependent

Terminate when flow falls to 10%, 20%, 30%, 40%, 50% or 60% of peak flow

Time dependent

Terminate after 1.0 to 2.5 secs in increments of 0.5 secs

## *Both ACV and SIMV modes*

- A must for patient comfort
- Synchronize Mandatory breaths with Spontaneous breaths
- Prevent breath stacking

# *Breath Synchronization*

# $FiO_2$ Settings

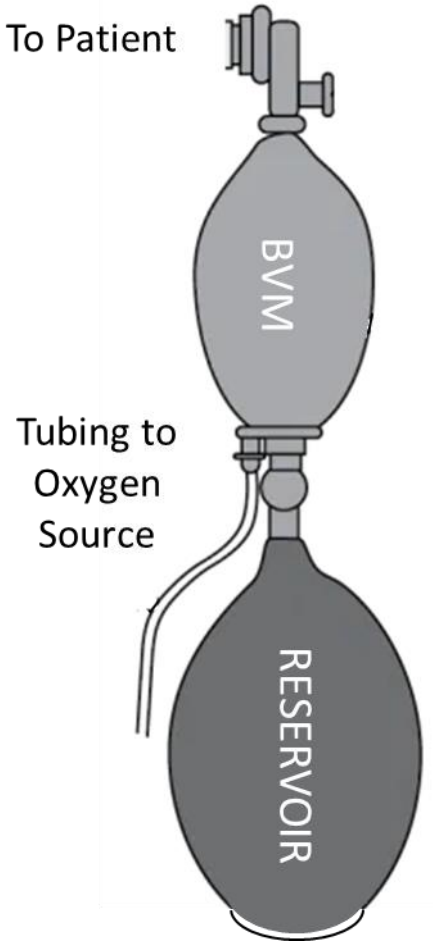
Without the Reservoir bag, $FiO_2$ delivered is the Atmospheric $O_2$ content at site

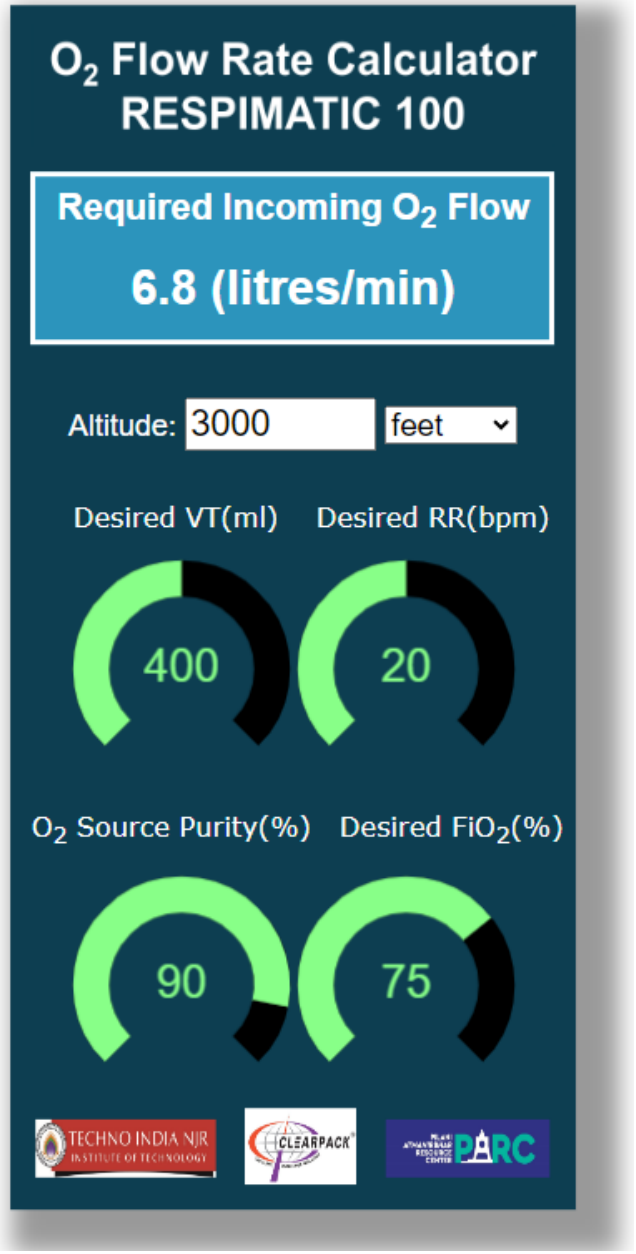
$FiO_2$ delivery with the Reservoir bag is mathematically modelled, calibrated and verified in the Lab to provide +/- 5% accuracy

Front-panel guides the user in setting the appropriate input $O_2$ flow rate from the $O_2$ source for a given $FiO_2$

The mathematical model provides for a possible $O_2$ concentrator as an $O_2$ source (purity < 100%)

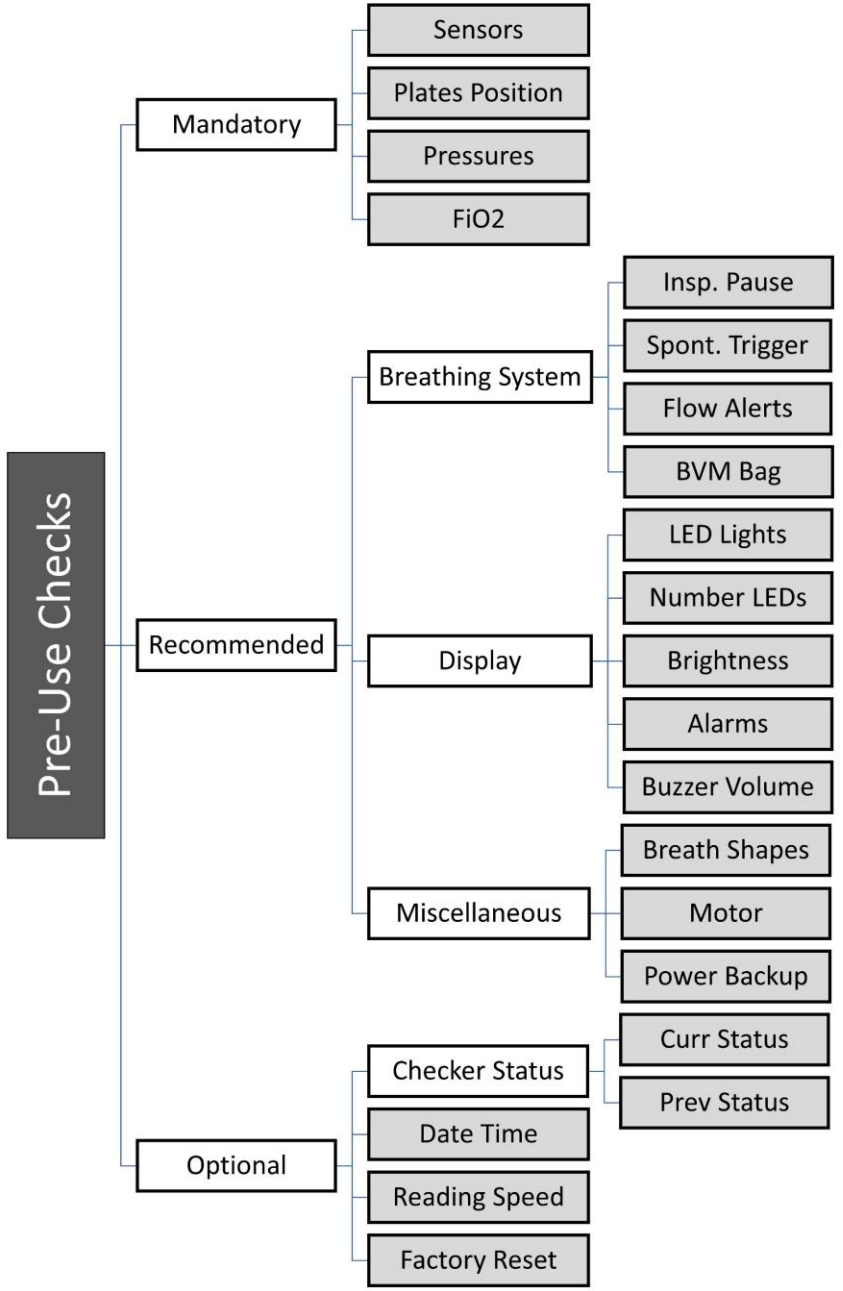
Online Web-accessible $FiO_2$ calculator is also provided for exploration purposes



# *Alarms and Safety Features*

- **Enforcement of Pre-use checks**
- **Alarms, Warnings and Notifications**
- **Maintenance Breaths till Alarm situation rectified**
  - Max Pressure Alarm
  - Pressure Leak Alarm
  - Mask OFF Alarm
  - System Temperature Alarm
  - Sensor failure Alarm
  - Breathing Circuit Failure Alarm
  - Detect coughing/hiccuping fits
  - Inconsistent input parameters
  - And many more …



*Thank you*