

# Respimatic 100





# *Setting the Context*

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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<sub>2</sub> Cylinder or Concentrator?*

*Full range of Respiration parameters?*

*Breath Synchronization for Patient Comfort?*

*Remote monitoring capability?*

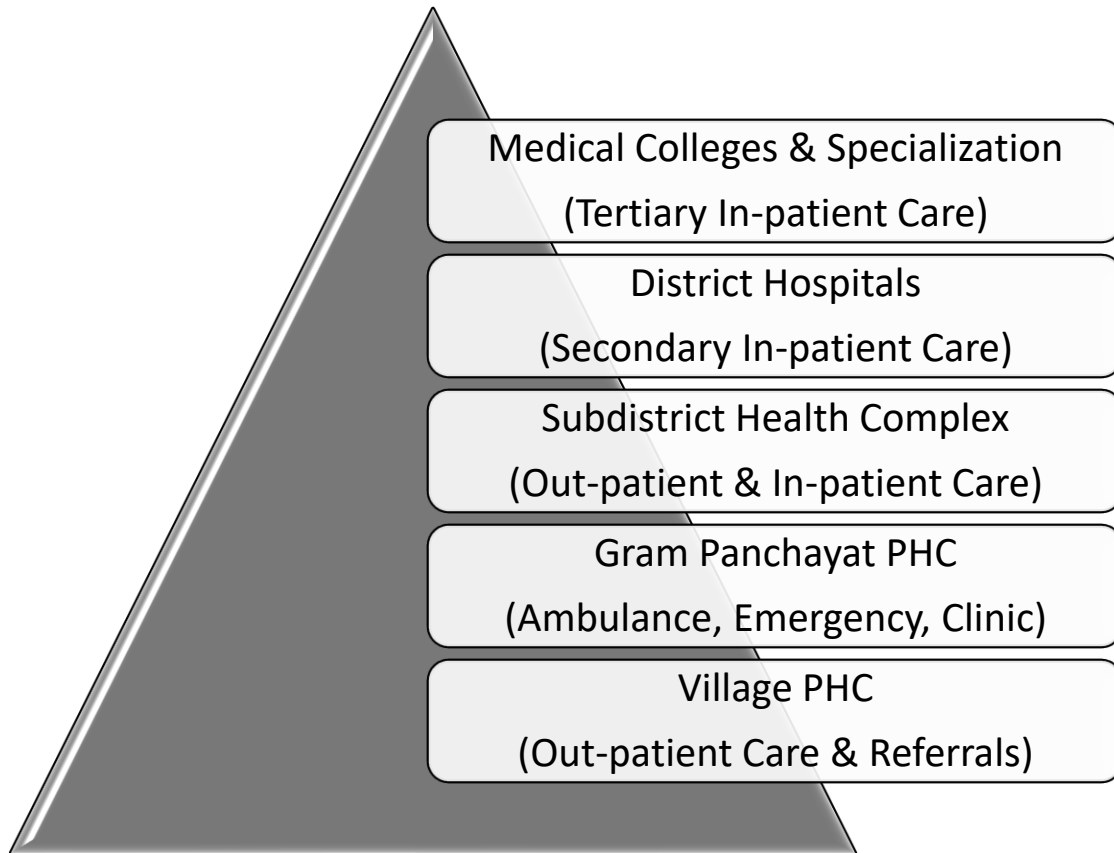
*Handle harsh-uncontrolled Environment?*

*Easy-to-use System?*

*Budget Friendly?*

# *The Motivation*

## *Serve the Bottom of the Pyramid*



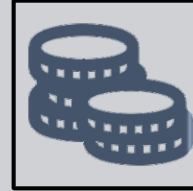
A robust, portable respiration support system for remote Primary Health Centers in India and other developing countries.

A system that works in a harsh uncontrolled environment and as a travel ventilator without piped compressed air or piped oxygen.

A system that requires minimum training.  
Fits budget of the bottom of the pyramid.



# 2 BIG Challenges

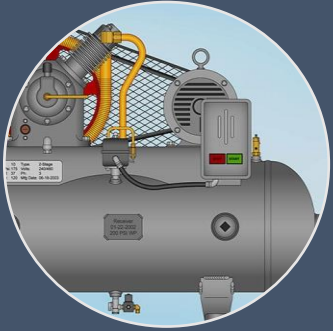


Lack of Affordability  
leading to Scarcity



Lack of Skilled  
Practitioners

# Observations on Ventilator Evolution



Iron Lung  
Age



Pneumatic  
Age



$\mu$ Controller  
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 – Respiratory Technology Revisited

## Remote Diagnosis and Monitoring (Telemedicine)

Rural, remote areas do not have skilled specialists  
BUT Communication Technologies have come of age

## Leverage Time-proven Technologies

Simplify design and feature list  
Simplify Human-Machine Interface  
Use Off-the-shelf proven components

## Maintenance Breaths in case of unexpected errors

System must never stop delivering breaths.  
Implement Fallback mechanism for each error scenario.





# *Respimatic 100 Details*

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System Components

Technical Details

# Our Solution *RESPIMATIC 100*

4 Commonly Used  
Ventilation Modes  
CMV, ACV, SIMV, PSV

Respiration Rate, Tidal  
Volume, PEEP, Pressure  
Support & FiO<sub>2</sub> Controls

Volume Controlled and  
Pressure Supported  
Breaths

Mandatory &  
Spontaneous Breaths  
with Full Breath  
Synchronization

Complete set of WEB Apps

Remote Dashboard

Remote Recorder

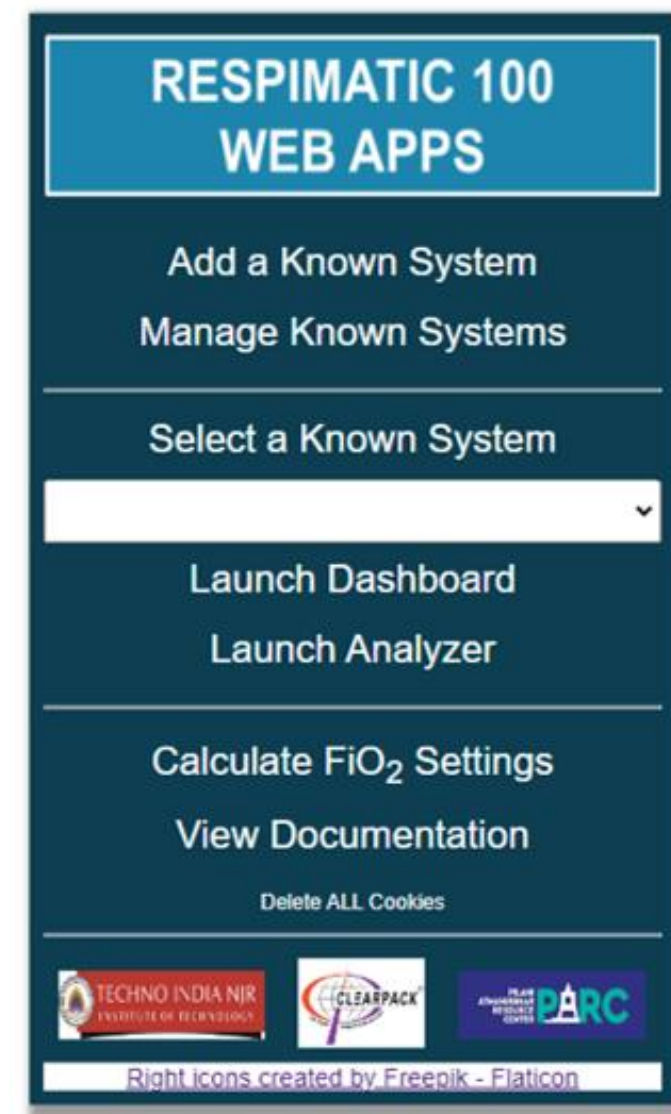
Remote Analyzer

FiO<sub>2</sub> Calculator

Low-speed Wi-Fi sufficient

Phone Hot-spot sufficient

Uses secure HTTPS protocol



<https://www.respimatic.com>

# Dashboard Snapshot View

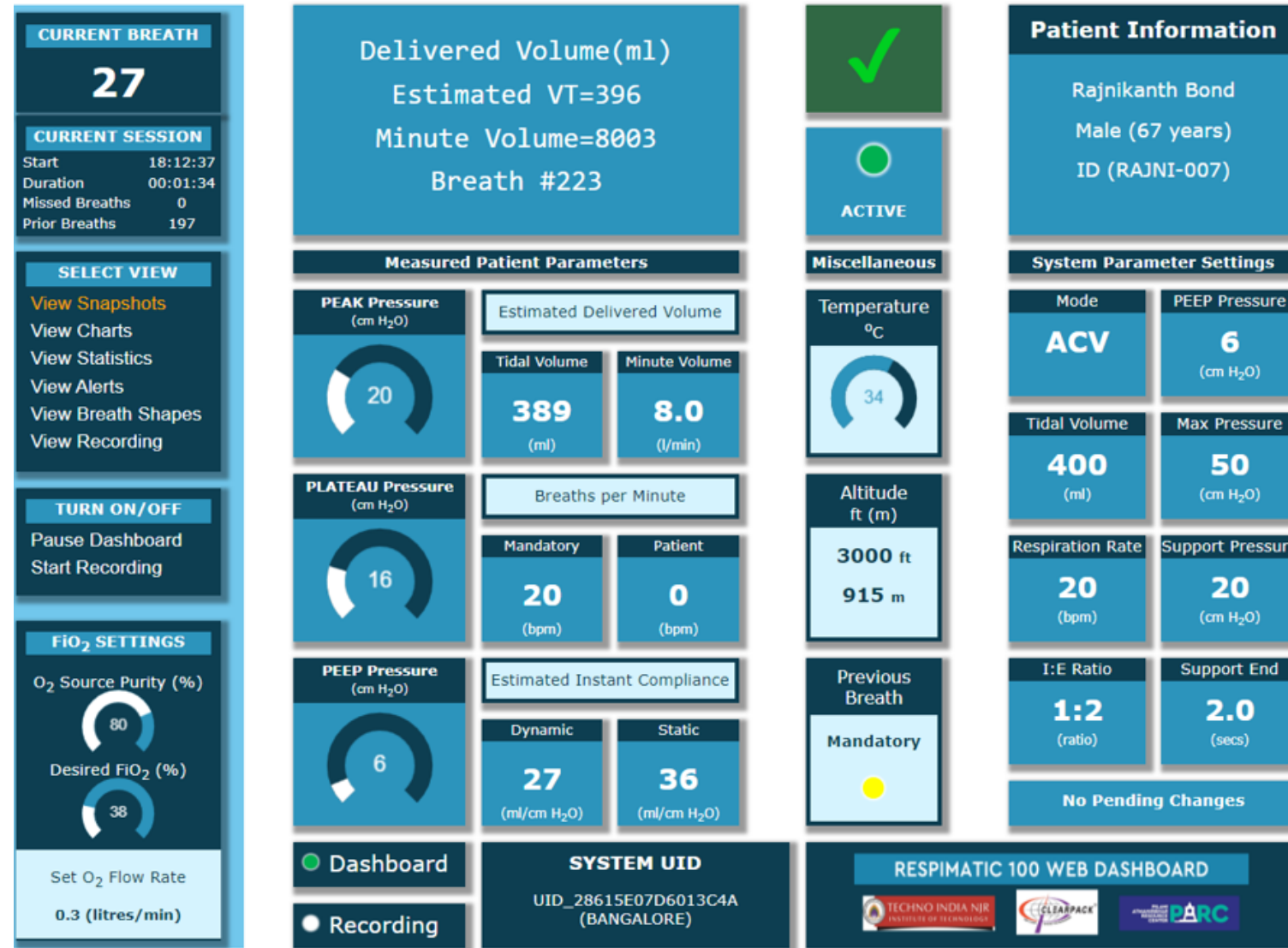
Anyone, anywhere in the world can monitor any patient via the WEB

Multiple specialists can monitor same patient

One specialist can monitor multiple patients

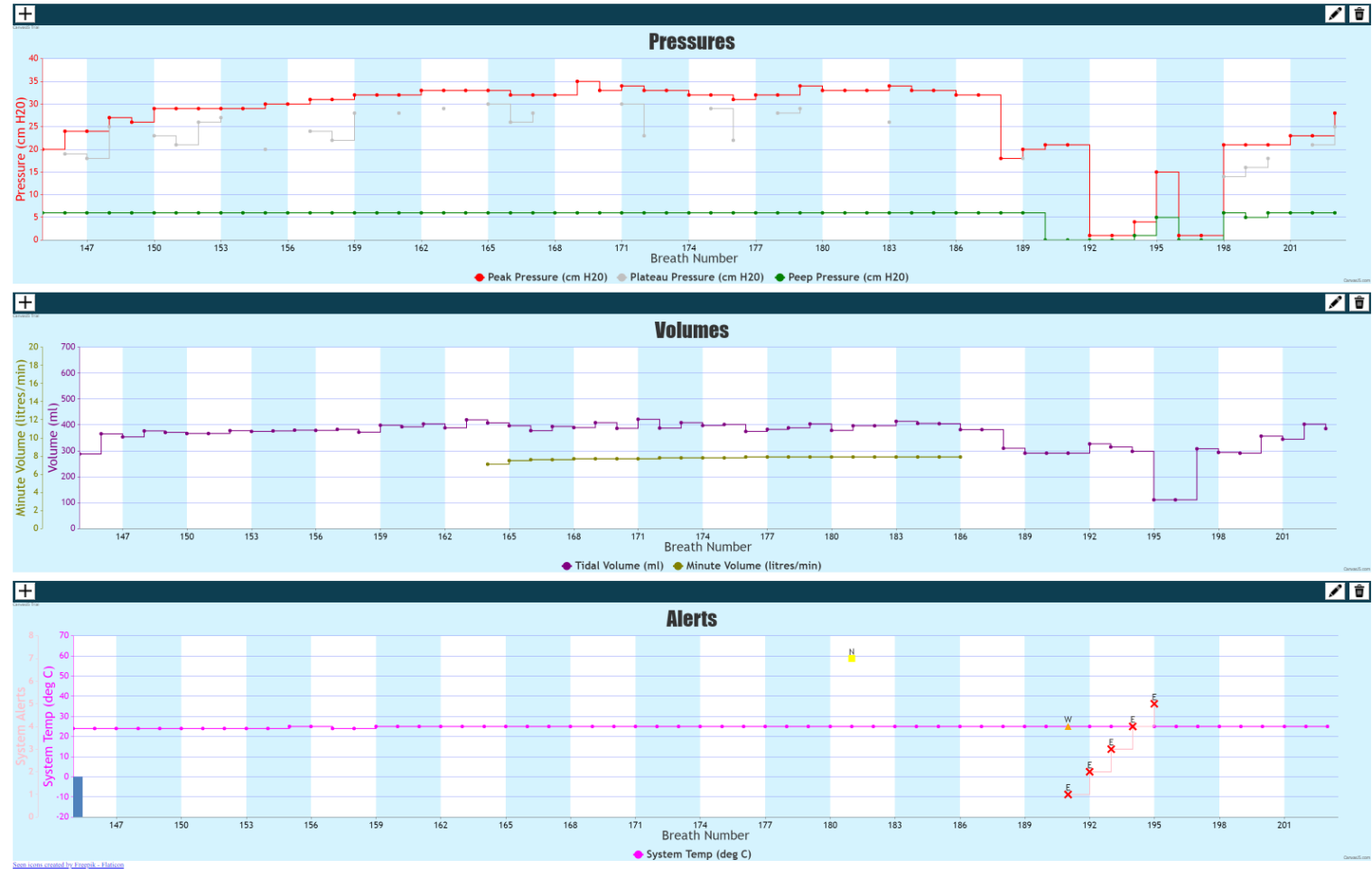
5 Dashboard views

- Snapshots
- Charts
- Statistics
- Breath Shapes
- Alerts



<https://www.respimatic.com>

# Dashboard Charts View



# Dashboard Statistics View

## Parameters Measured

Parameter	Units	Min	Max	Avg
Peak Pressure	cmH2O	1	35	28.1
Plateau Pressure	cmH2O	17	33	27.1
PEEP Pressure	cmH2O	5	7	6.0
Tidal Volume Delivered	ml	150	412	359.4
Minute Volume Delivered	litres/min	5.6	5.9	5.7
Mandatory BPM	bpm	15	16	15.2
Spontaneous BPM	bpm	0	1	0.7
FIO2	%	50	50	50.0
Instantaneous Static Compliance	ml/cmH2O	14	30	18.4
Instantaneous Dynamic Compliance	ml/cmH2O	14	22	16.5
System Temperature	degC	29	30	29.2

## Miscellaneous Information

Information	Value
Number of Breaths	73
Number of Mandatory Breaths	56
Number of Spontaneous Breaths	17
Number of Maintenance Breaths	0
Number of Missing Breaths (Comms Failure)	0
Number of Notifications	0
Number of Warnings	2
Number of Errors	17

## Static Information

Patient Name: --

Patient Info: --

System Deployment Altitude: 3000 (915) ft(m)

## Parameter Settings Used

Parameter	Units	Values
Ventilation Mode	mode	ACV,CMV
Tidal Volume	ml	400,300
Respiration Rate	bpm	15,20
I:E Ratio	ratio	1:3,1:2
PEEP Pressure	cmH2O	6
Maximum Pressure	cmH2O	50
Support Pressure	cmH2O	25
Support Pressure Termination	%flow,secs	F20%
FIO2	%	50

## Sequence of Parameter Combinations

MODE	VT	RR	I:E	PEEP	PMAX	PS	TPS	FIO2	# of BREATHS	Before BREATH#
ACV	400	15	1:3	6	50	25	F20%	50	17	0
CMV	300	15	1:2	6	50	25	F20%	50	16	17
ACV	400	15	1:3	6	50	25	F20%	50	21	33
ACV	400	20	1:3	6	50	25	F20%	50	19	54

# Dashboard

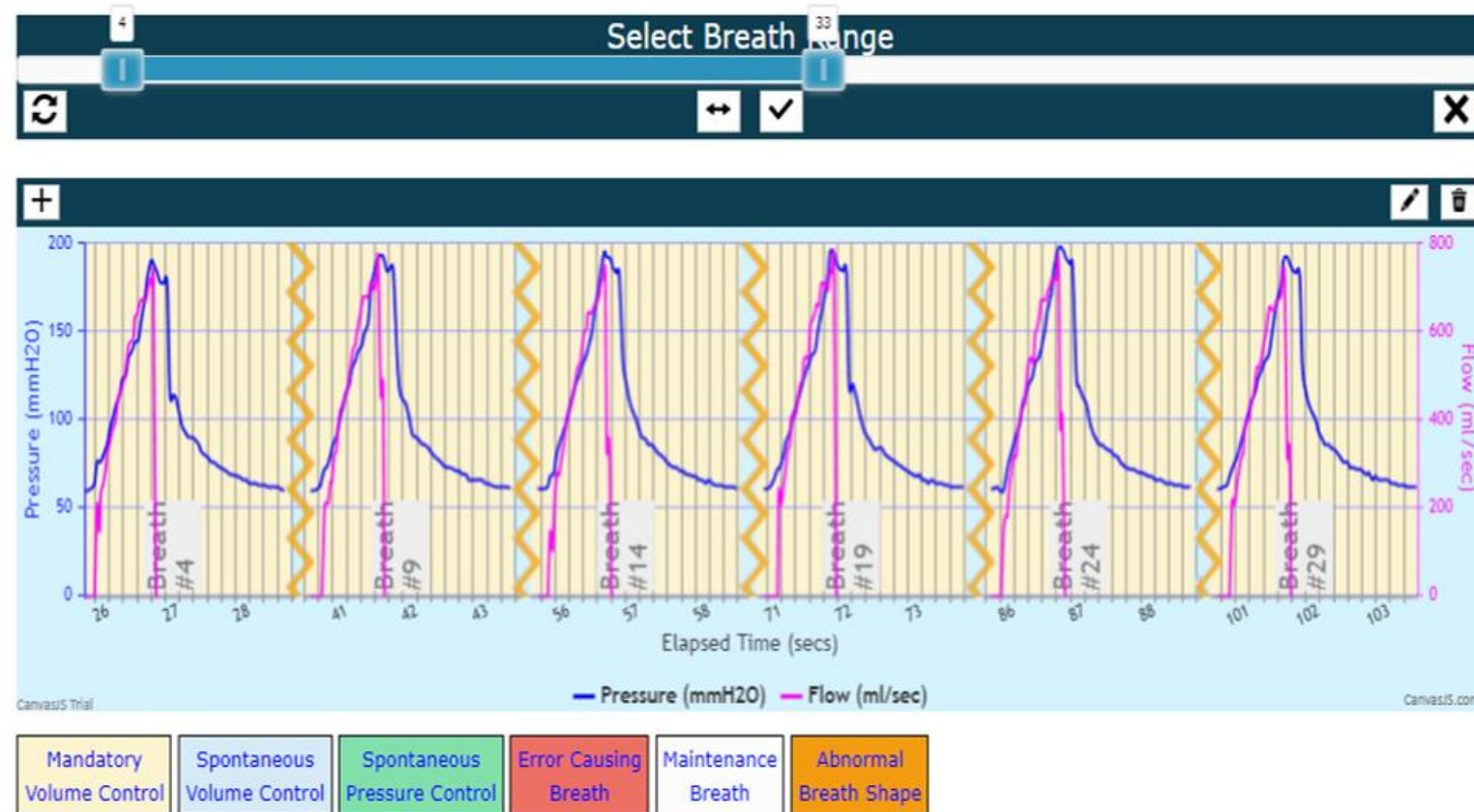
## Breath Shapes View

Pressure and  
Flow Graphs

For Selected  
Breaths

Periodic  
Display

Display on  
demand



# Dashboard Alerts View

## Session Errors

ERROR #1 DateTime: [09-12-2022]06:55:16

Leakage in  
Breathing Circuit  
Switching to  
Maintenance Breaths

ERROR #2 DateTime: [09-12-2022]06:55:21

[ERROR] state  
Press PAUSE to show  
the System state  
leading to ERROR

ERROR #3 DateTime: [09-12-2022]06:55:25

Leakage in  
Breathing Circuit  
Maintenance mode  
Deliver safe breaths

ERROR #4 DateTime: [09-12-2022]06:55:29

[ERROR] state

## Session Warnings

WARNING #1 DateTime: [09-12-2022]06:43:16

PEEP delta measured  
up to -0.8 cm H2O  
Adjust valve/setting  
YES -> Commit

WARNING #2 DateTime: [09-12-2022]06:43:19

PEEP delta measured  
up to -1.0 cm H2O  
Adjust valve/setting  
YES -> Commit

WARNING #3 DateTime: [09-12-2022]06:43:21

PEEP delta measured  
up to -0.9 cm H2O  
Adjust valve/setting  
YES -> Commit

WARNING #4 DateTime: [09-12-2022]06:55:14

PEEP delta measured

## Session Information

INFO #1 DateTime: [09-12-2022]06:45:23

1 Breath(s) missed  
Info not received by  
Dashboard due to  
Internet packet loss

INFO #2 DateTime: [09-12-2022]06:46:26

1 Breath(s) missed  
Info not received by  
Dashboard due to  
Internet packet loss

INFO #3 DateTime: [09-12-2022]06:47:17




1 Breath(s) missed  
Info not received by  
Dashboard due to  
Internet packet loss

INFO #4 DateTime: [09-12-2022]06:47:28

1 Breath(s) missed



Any patient Session can be recorded locally or remotely.

RESPIMATIC-100 Session Databases			
Session Name	Created	Actions	
Demo Session	09-12-2022 06:39:24	<input checked="" type="checkbox"/>	
New Session	29-11-2022 09:08:55	<input checked="" type="checkbox"/>	
Demo	29-11-2022 07:51:30	<input checked="" type="checkbox"/>	

# Front Panel

## The Human-Machine Interface

Simple Tactile buttons  
No delicate touch screen etc.

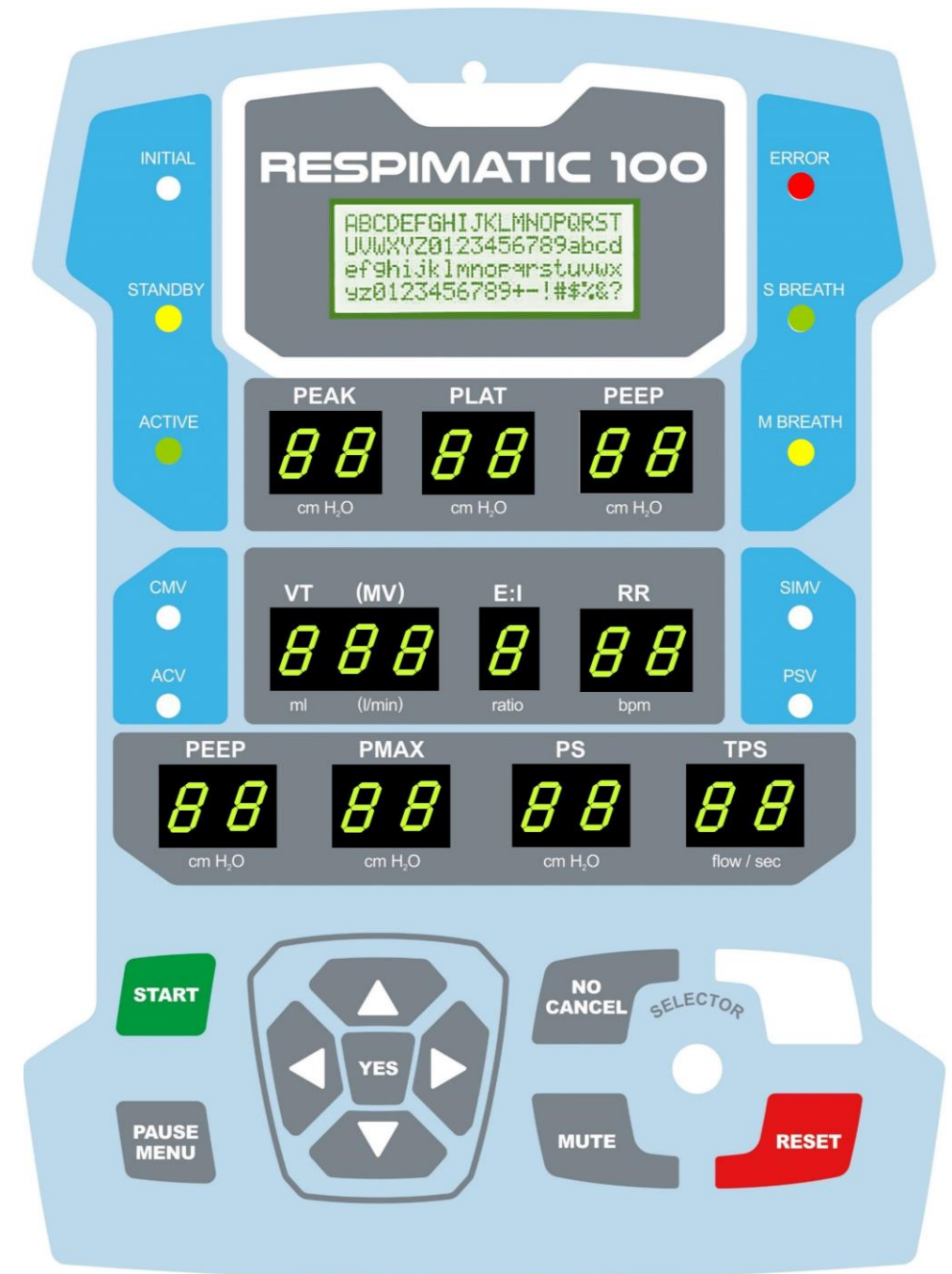
Easy to read 7-seg LED Parameters Display

Parameter selection using simple arrow buttons

4-line LCD Display for displaying Messages and Menus

Peak, Plateau, PEEP pressures displayed after each breath

Also shows Delivered Volumes, Lung Compliance, Breath types etc.

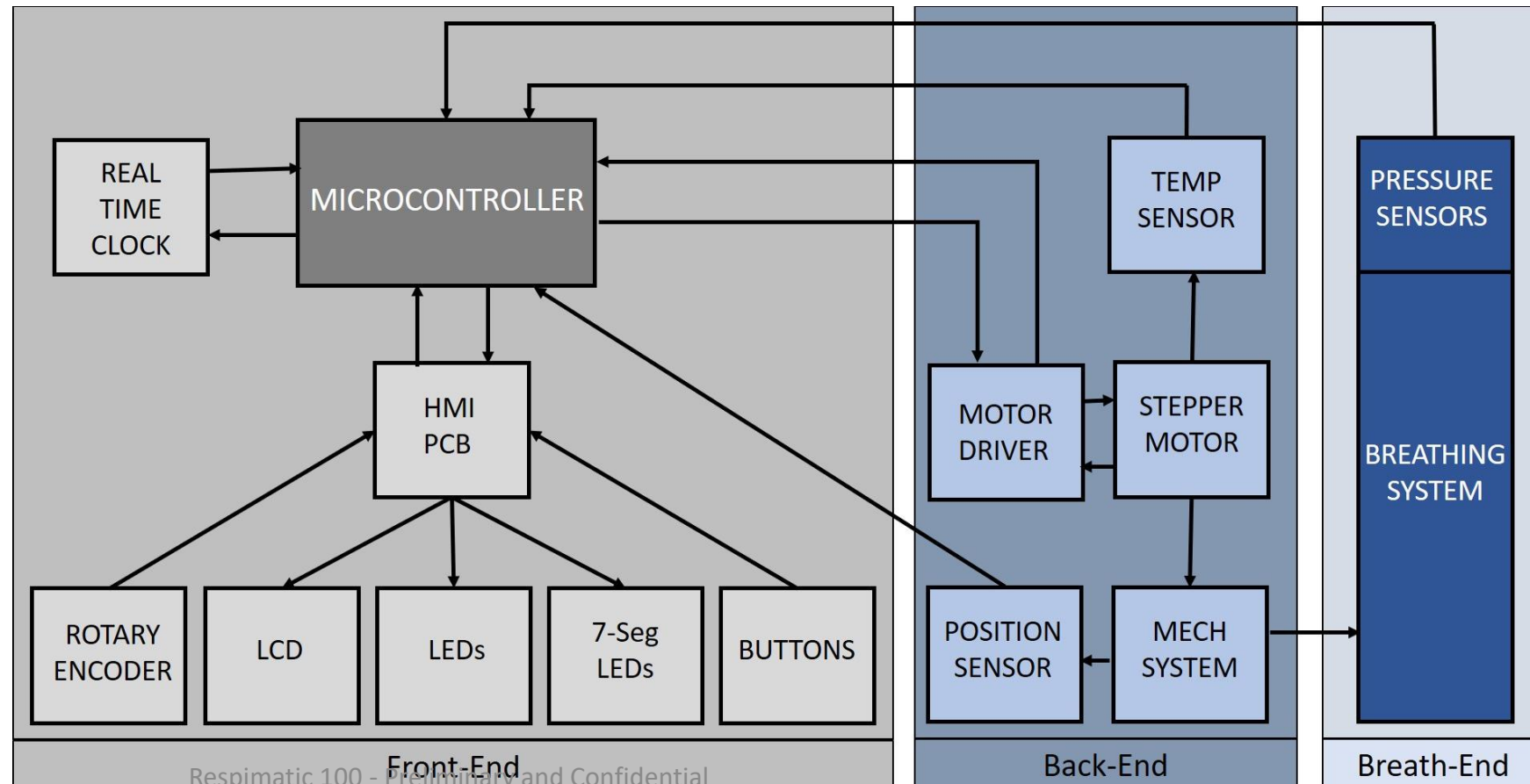


# System Architecture

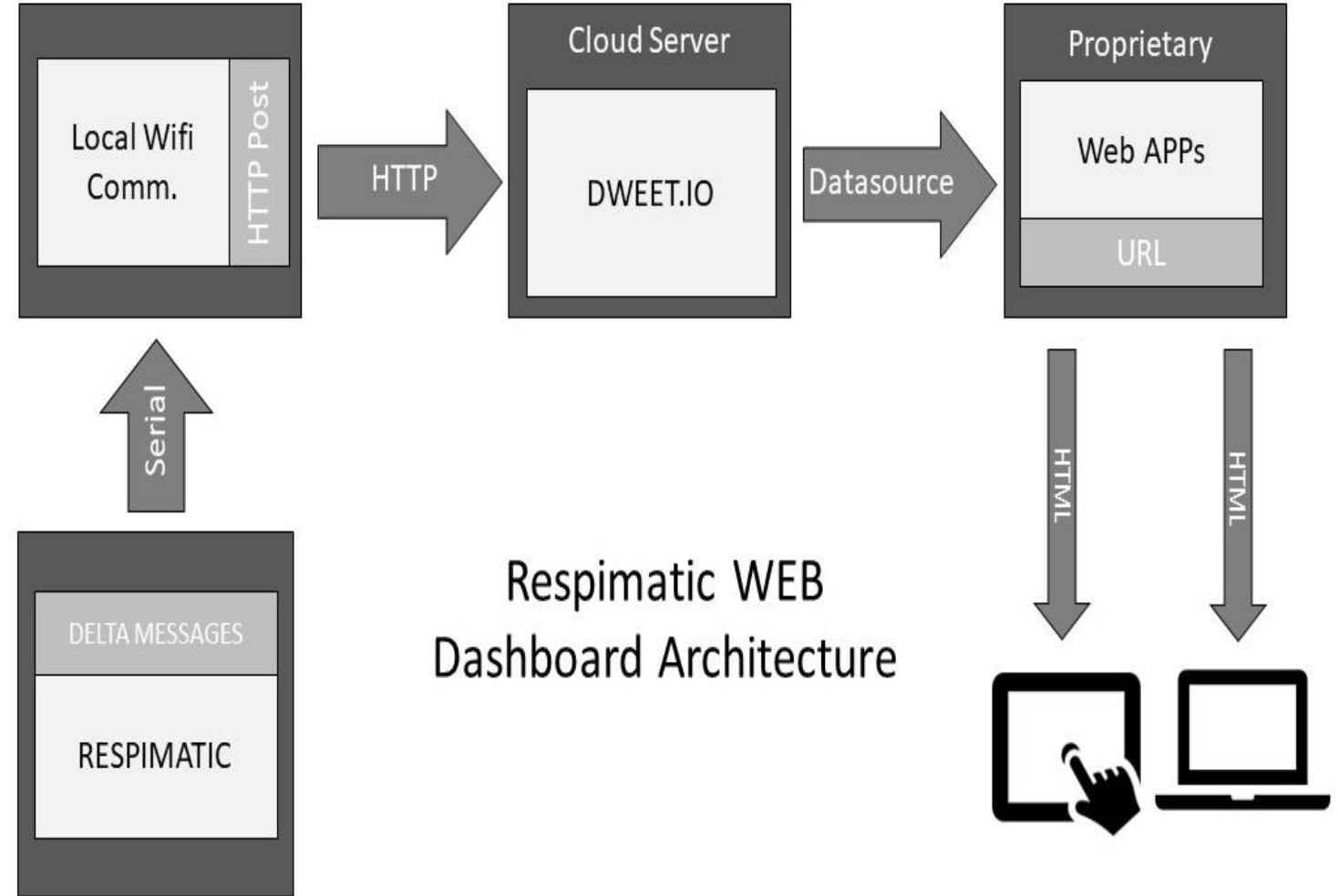
Clearly separated  
Frontend, Backend and  
Breathing system

IP is the Frontend  
design and Algorithms

Backend and Breathing  
System can have  
multiple avatars



# Remote WEB Architecture

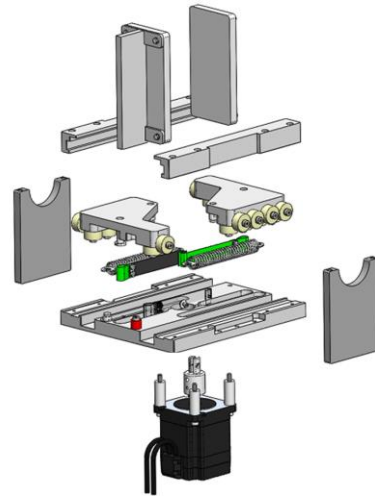


Respimatic WEB  
Dashboard Architecture

# Respimatic 100

## Under the hood

Low Production Cost  
Compact and Robust  
Intuitive HMI  
Simple to operate



So,  $(P_{G1} - P_{G2})$  can be replaced by  $E * (P_{G1} - P_{G2})$  for an appropriate transforms to the one below.

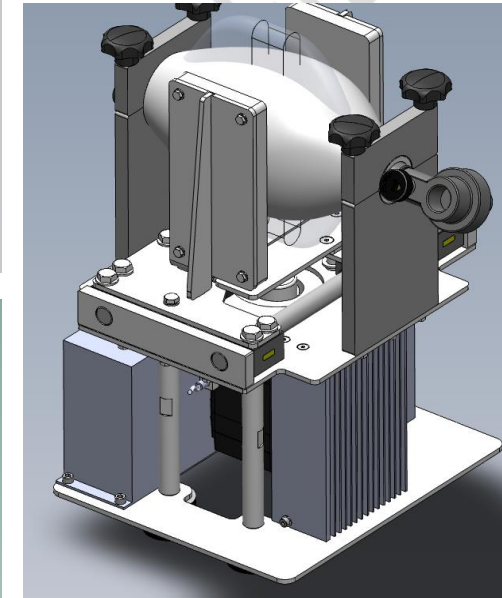
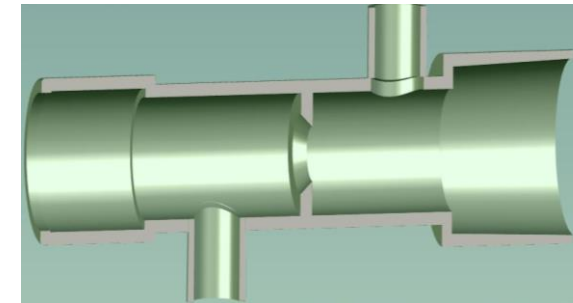
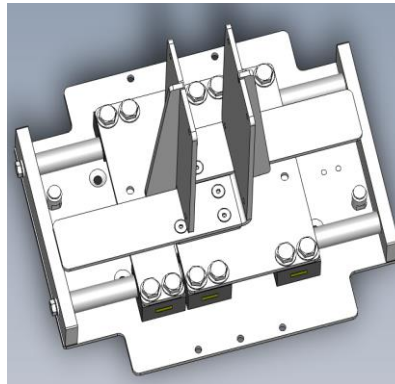
$$Q = K * \sqrt{E * (P_{G1} - P_{G2})}$$

$$\text{where } K = \frac{C}{\sqrt{\text{Patmosphere} * \sqrt{E}}}$$

$$\text{or } K = \frac{f(Re)}{\sqrt{\text{Patmosphere} * \sqrt{E}}} \text{ where } Re \text{ is the Reynold}$$

Rewriting for every sample interval time  $t$ , the equation is as below.

$$Q(t) = K * \sqrt{E * (P_{G1}(t) - P_{G2}(t))}$$



Simple  
Electronics  
COTS  
components

Rugged  
mechanical  
system

Essential  
Parameter  
monitoring

Full set of alarm  
conditions

Robust, Suitable  
for mass  
production



# 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 sensors, PEEP valve

## HME Filter

## Humidifier

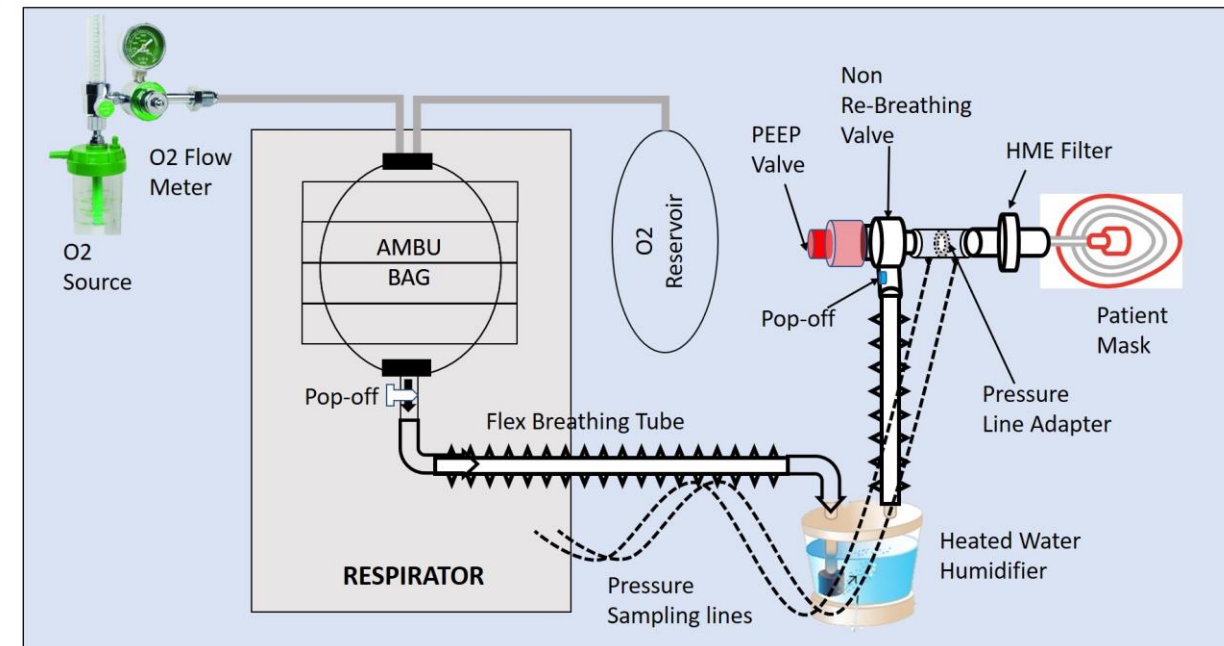
## Oxygen Source



## Off-the-Shelf Single limbed Circuit with NRBM



Proprietary Dual  
Pressure line Connector



# Ventilation Modes

*The 4 most frequently used*

## ***Continuous Mandatory Ventilation (CMV)***

Volume Controlled  
Mandatory Breaths

Ignore spontaneous  
breaths

## ***Synchronized Assist Control Ventilation (Sync ACV)***

Volume Controlled  
Mandatory Breaths

Volume controlled  
breaths in response  
to spontaneous  
breaths

Breath  
Synchronization

## ***Synchronized Intermittent Mandatory Ventilation (SIMV)***

Volume Controlled  
Mandatory Breaths

Pressure supported  
breaths in response  
to spontaneous  
breaths

Breath  
Synchronization

## ***Pressure Support Ventilation (PSV)***

Pressure supported  
breaths in response  
to spontaneous  
breaths

Monitoring of Minute  
Volume

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<sub>2</sub>O)***

4 to 15 cmH<sub>2</sub>O  
increments of 1 cmH<sub>2</sub>O

### ***Max Pressure (cmH<sub>2</sub>O)***

20 to 50 cmH<sub>2</sub>O  
increments of 5 cmH<sub>2</sub>O

### ***FiO<sub>2</sub> Support***

System Managed  
Externally Controlled  
21% to 100%

# *Pressure Supported Breaths*

*(SIMV & PSV modes)*

## *Support Pressure (PS)*

5 cmH<sub>2</sub>O to 30 cmH<sub>2</sub>O in increments of 5 cmH<sub>2</sub>O

## *Support Pressure Termination (TPS)*

Flow-dependent

Terminate when flow falls to 10%, 20%, 30% 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

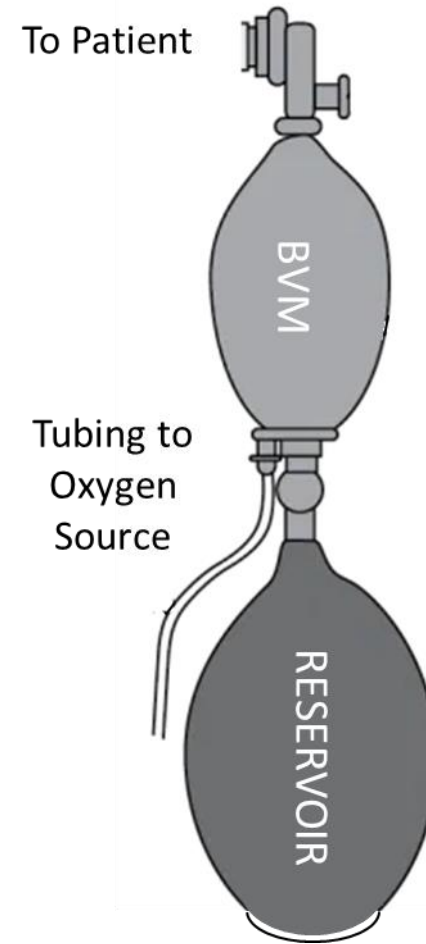
Without the Reservoir bag,  $FiO_2$  delivered is the Atmospheric  $O_2$  content at site

$FiO_2$  delivery with the Reservoir bag is mathematically modelled, calibrated and verified in the Lab to provide  $\pm 5\%$  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



## $O_2$ Flow Rate Calculator RESPIMATIC 100

Required Incoming  $O_2$  Flow  
**6.8 (litres/min)**

Altitude:  feet

Desired VT(ml)    Desired RR(bpm)

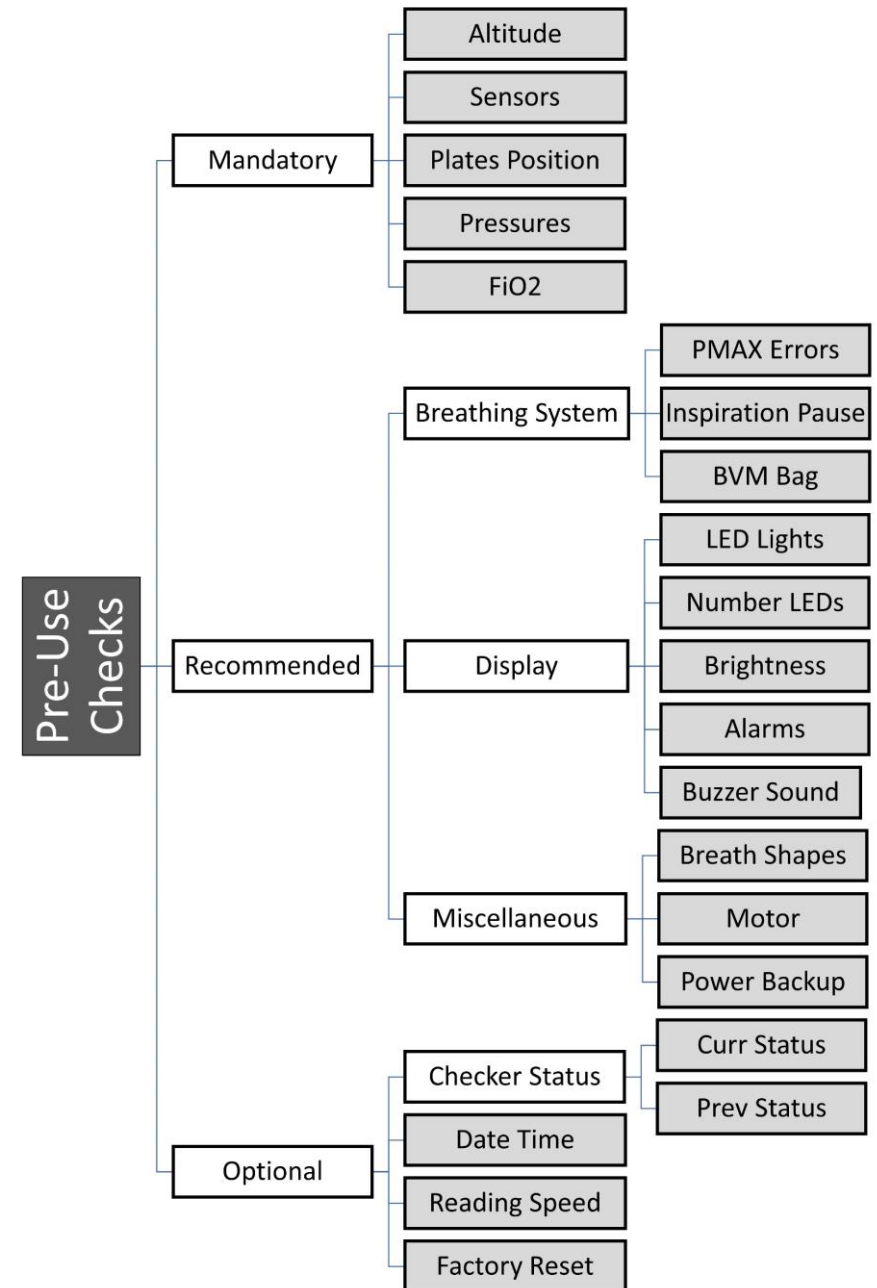


$O_2$  Source Purity(%)    Desired  $FiO_2$ (%)



# Alarms and Safety Features

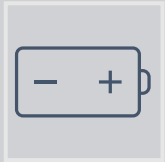
- Enforcement of Pre-use checks
- Alarms, Warnings and Notifications
- Maintenance Breaths till Alarm situation rectified
  - Max Pressure Alarm
  - Pressure Loss Alarm
  - System Temperature Alarm
  - Sensor failure Alarm
  - Breathing Circuit Failure Alarm
  - Detect coughing/hiccuping fits
  - Inconsistent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



# Power Consumption



An online, sine-wave, external battery UPS recommended to continue operation during power outages



50 AH Car battery is sufficient to run the system for 5+ hours



100 AH Tubular battery is sufficient to run the system for 10+ hours



Input Voltage	180-250 V
Power Consumption	< 100 Watts

# *Respimatic Testing Process*

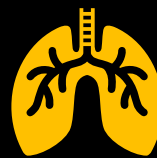
Timing, Flow and  
Pressure Checks  
for all  
combinations of  
various settings



Automated Testing for all combinations of VT, RR, IE, PEEP, PS with randomized spontaneous breath triggers



Automated testing of full day runs checked for timing within 1% of theoretical expectations



All testing so far with a simple test lung  
Next step needs a more sophisticated test lung



CPAP	BiPAP	Respimatic-100	ICU Ventilator
Continuous Positive Airway Pressure	Continuous Bi-Level Airway Positive Pressure	Mechanical Ventilation with 4 frequently used ventilation modes and controls	Mechanical Ventilation with sophisticated ventilation modes and controls
Non-invasive	Non-invasive	Non-invasive	Non-invasive / Invasive
High Flow + PEEP	Inspiratory Pressure + PEEP	VT + PS + PEEP	VT + PS + PEEP
Useful for Type 1 respiratory Failure (Hypoxemic)	Useful for Type 2 respiratory Failure (Hypercapnic)	Useful for Type 1 and Type 2 respiratory Failure	Useful for Type 1 and Type 2 respiratory Failure
Continuous flow at a constant pressure. Increases mean airway pressure to recruit collapsed alveoli.	Continuous flow at a constant pressure during inspiration and a different constant pressure during expiration	Independent control over the volume, the respiration rate and the pressure as required.	Independent control over the volume, the respiration rate and the pressure as required.
Useful only when patient can breathe on their own	Useful only when patient can breathe on their own	Useful when patient can or cannot breathe on their own	Useful when patient can or cannot breathe on their own
Only Spontaneous breaths that are patient triggered.	Only Spontaneous breaths that are patient triggered.	Spontaneous breaths PLUS Mandatory breaths controlled by RR and I:E	Spontaneous breaths PLUS Mandatory breaths controlled by RR and I:E
External FiO2 control	External FiO2 control	External FiO2 control	Direct Internal FiO2 control
Breath Syncing N/A	Breath Syncing N/A	Full Breath Syncing	Full Breath Syncing
No VT control	Indirect VT control (IPAP-EPAP)	Direct VT control	Direct VT control
No RR control	No RR control	Direct RR control	Direct RR control
No I:E control	No I:E control	Direct I:E control	Direct I:E control
External Humidity control	External Humidity control	External Humidity control	Direct Humidity control
No monitoring of Peak, Plateau or PEEP pressures	No monitoring of Peak, Plateau or PEEP pressures	Direct monitoring of Peak, Plateau and PEEP pressures	Direct monitoring of Peak, Plateau and PEEP pressures
Minimal alarm signals	Minimal alarm signals	Full set of Alarm signals	Full set of Alarm signals

# *Compare & Contrast Various Systems*

*Thank you*

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# Backup

Market Analysis

Sample Waveforms



# *The Problem*

## *Scarcity & Affordability*

- India has amongst the lowest per capita ICU beds in the World\*
- 1.46 beds / 1000 people\*
- 3.65 ICU beds / Lakh people\*
- Only half of ICU beds are equipped with Ventilators
- A meagre 1.8 Ventilators for one lakh people\*
  
- ICU ventilators are expensive equipment
- Unaffordable in remote clinics
  
- Ventilator Ambulances are
- Either non-existent except in few major urban centres,
- Or beyond the reach of majority of population

*\* As per April 2020 Study by Center for Disease Dynamics, Economics & Policy at Princeton University, USA*

# The Problem Skilled Practitioners

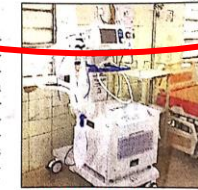
ICU Ventilators require highly skilled manpower to operate and monitor

## Ventilators lie unutilised due to shortage of doctors

TIMES NEWS NETWORK

**Jaisalmer:** The state government has given 17 ventilators, including 12 to Jaisalmer and five to Pokhran government hospitals. However, they were lying unutilised due to lack of doctors. The serious patients are being referred to Jodhpur and a large number of corona patients have died while undergoing treatment in Jodhpur.

On Tuesday, there were 42 fresh cases of Covid-19 in Jaisalmer district. On Sunday, 54 cases were reported. The condition of some patients is serious as they are being referred to Jodhpur which is a five hours journey from Jaisalmer.



MUCH TO IMPROVE

The main reason behind referring serious patients to Jodhpur is non-availability of ventilator facility and posts of main doctors are lying vacant.

There are only two physicians in the Jaisalmer hospital of which duty of one of the doctors is to take

tional doctor to run the ventilator whereas there is need of minimum two to three physicians, cardiologists etc.

Jaisalmer collector Ashish Modi said that all the 17 ventilators in the district are in operational condition and oxygen and other resources are available. He said that posts of cardiologist, physician are lying vacant due to which ventilators cannot be used for corona patients. Serious patients are referred to Jodhpur on time and Jodhpur divisional commissioner Dr Samit Sharma is monitoring the situation, he said. Jaisalmer government hospital PMO Dr VK Verma said that ventilator

**व्यवस्थाओं को कोरोना:** सरकार ने दिए वेंटीलेटर, आधे से अधिक इंस्टाल नहीं किए

## प्रदेश में मरीजों को सासें उखड़ रहीं, यहाँ स्टोर में 'शो-पीस' बने वेंटीलेटर

कहीं पर्याप्त प्रशिक्षित स्टाफ ही नहीं

पत्रिका न्यूज नेटवर्क

चुरू/जिंदगढ़, प्रदेश में लगातार बढ़ रहे कोरोना वायरस के संक्रमण के बीच वेंटीलेटर की कमी होने पर सरकार ने वेंटीलेटर उपलब्ध करा दिए, लेकिन अस्पताल प्रशासन की लापरवाही के चलते जहाँ चुरू में आगे वेंटीलेटर आने तक स्टोर में ही हैं। वहीं, जिंदगढ़ के जिला अस्पताल में पर्याप्त प्रशिक्षित स्टाफ नहीं होने से परेशानी आ रही है तथा यहाँ भी 25 वेंटीलेटर इंस्टॉल ही नहीं किए गए।

चुरू स्थित डेडराज मेडिकल अस्पताल में कोरोनाकाल से पहले 12 वेंटीलेटर थे। बाद में प्रधानमंत्री राहत कोष के तहत तीन चरणों में 30 नए वेंटीलेटर भेजे गए थे। वर्तमान में यहाँ 27 वेंटीलेटर उपयोग लिए जा रहे हैं। शेष 15 इंस्टॉल तक नहीं कराए गए।



चुरू स्थित भरतिया अस्पताल के स्टोर में रखे वेंटीलेटर।

सात वेंटीलेटर मेल वाई में लगा दिए हैं। तीन को भी एक-दो दिन में इंस्टॉल करवा दिया जाएगा। भरतिया अस्पताल के पास जो वेंटीलेटर हैं, उन्हें जरूरत से इंस्टॉल कर दिया जाएगा। मेडिकल टीम को डेमी देकर प्रशिक्षित किया जाता है।

**डॉ. हनुमान जयपाल,** एरोसिस्ट प्रोफेसर, मेडिकल कॉलेज, चुरू

सरकार ने जिला अस्पतालों को वेंटीलेटर उपलब्ध करा दिए, लेकिन चलाने के लिए यहाँ पर पर्याप्त प्रशिक्षित स्टाफ नहीं होने से परेशानी आ रही है।

23 वेंटीलेटर को इंस्टाल होने का इंतजार

कोटा, कोटा मेडिकल कॉलेज के कोविड अस्पताल में 52 वेंटीलेटर हैं और सभी चालू हैं। वहीं, कोरोना के

बढ़ने के बाद 23 नए वेंटीलेटर और आए हैं। इंस्टॉल होना बाकी है। संचालन के लिए पर्याप्त कर्मिक हैं।

25 वेंटीलेटर इंस्टाल ही नहीं किए गए

जिंदगढ़ के जिला अस्पताल में कोरोना से पूर्व पाँच वेंटीलेटर थे, जो बढ़कर 42 हो गए हैं। इनमें से कुछ फोर्डिंग वेंटीलेटर हैं। वेंटीलेटर पर मरीज को रखने के लिए आईसीयू का प्रशिक्षित स्टाफ चाहिए और निश्चित के चिकित्सक की निगरानी की व्यवस्था होनी चाहिए। यहाँ आईसीयू का प्रशिक्षित स्टाफ करीब आधा दर्जन का ही है जो आईसीयू में हैं। यहाँ कुल 42 वेंटीलेटर में से अभी भी पाँच चालू हैं। शेष 37 वेंटीलेटर की काम में आ रहे हैं। 25 तो इंस्टॉल नहीं किए गए।



**कुवेरा (नागौर),** स्थानीय सांसद हनुमान बेनीवाल की अनुरोधों पर शहर के राजकीय सामुदायिक स्वास्थ्य केन्द्र को मिले फोर्टबल वेंटीलेटर को सौंपने की स्टोर में रख दिया गया है। चिकित्सक कर्मियों ने बताया कि फोर्टबल वेंटीलेटर वर्किंग मोड में है तथा जैसे ही जरूरत पड़ेगी। वाई में लेकर काम में ले लिया जाएगा।



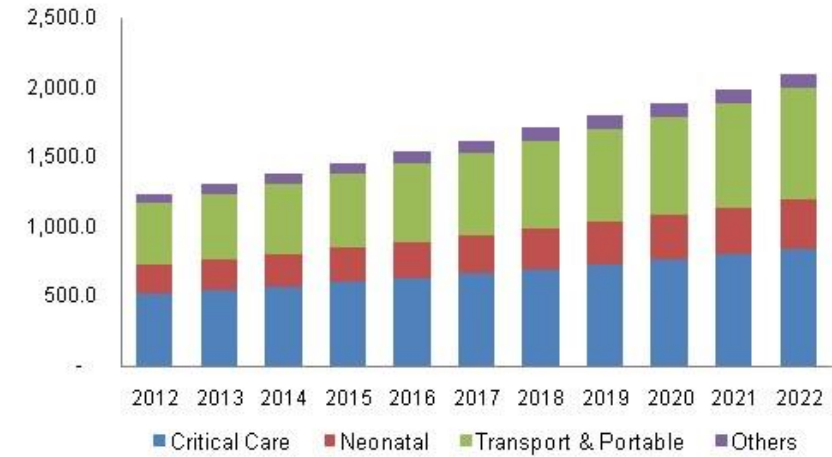
# Market Need

25 to 50 ventilators per lakh people in developed countries

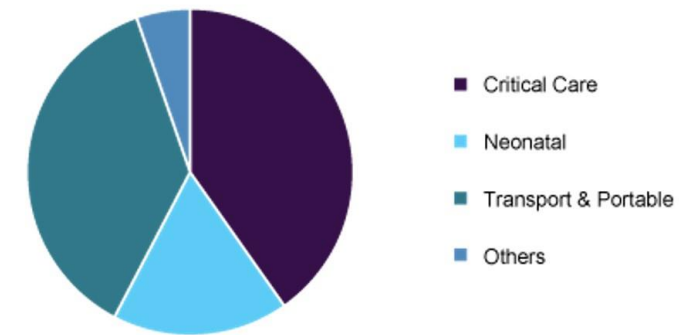
1.8 ventilators per lakh people\* (India)

Even less for lower income developing and underdeveloped countries\*

*\* As per April 2020 Study by Center for Disease Dynamics, Economics & Policy at Princeton University, USA*



Global Mechanical Ventilator Market Share, 2019



[www.grandviewresearch.com](http://www.grandviewresearch.com)

# Breath Synchronization in ACV Mode

Tidal volume is delivered at regular intervals  
 $T_i$ .

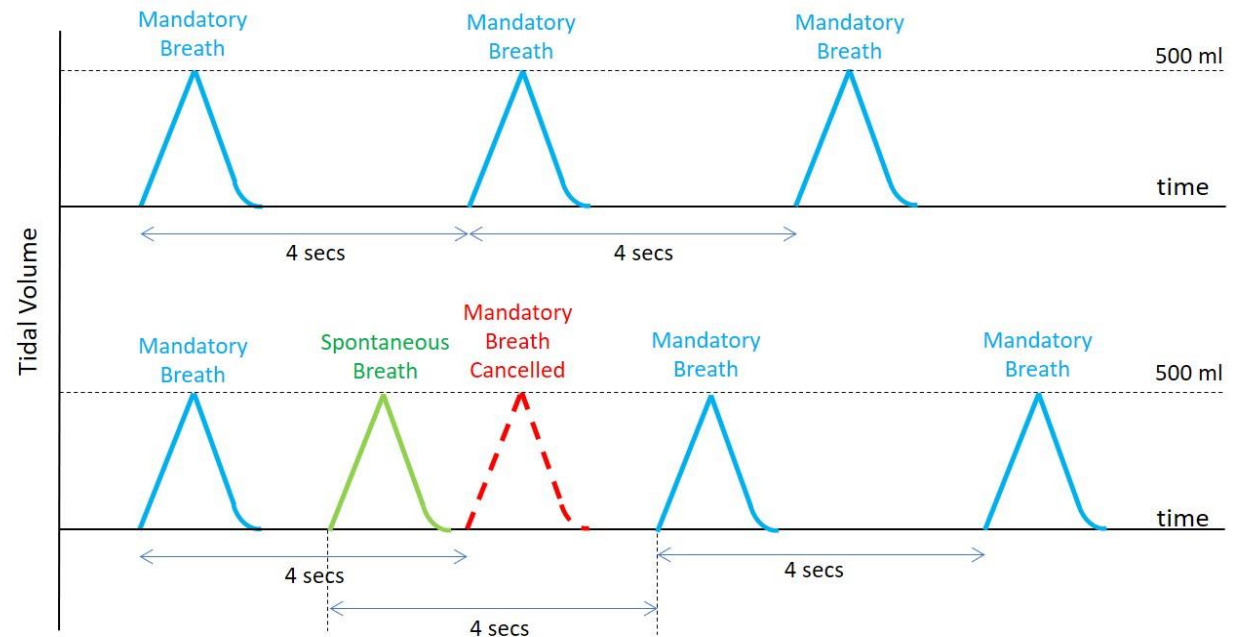
If spontaneous breath occurs during this interval at time  $T_s$ , the set tidal volume is delivered in response, and the next mandatory breath is set for  $(T_s + T_i)$ .

Again, if another spontaneous breath is detected before  $T_s + T_i$ , a mandatory breath scheduled  $T_i$  time in future.

## Breath Syncing in Synchronized AC Mode

There is no sync-window – the next mandatory breath is always rescheduled after a spontaneous breath

Example below: Tidal Volume = 500ml    Respiration Rate = 15 bpm





# Breath Synchronization in SIMV Mode

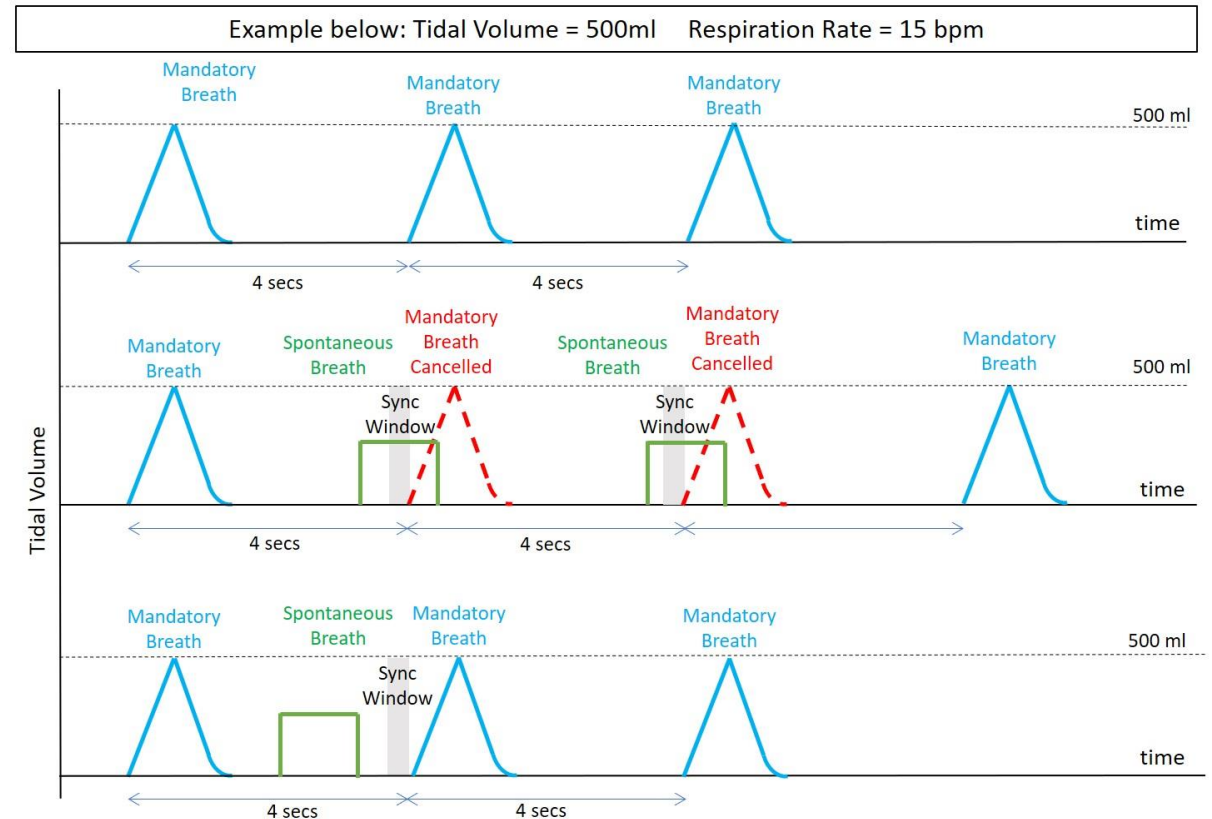
Tidal volume is delivered at regular intervals  
 $T_i$ .

If spontaneous breath occurs during this interval at time  $T_s$ , a pressure supported breath is delivered in response, and the next mandatory breath is set for  $(T_s + 0.9 T_i)$ .

This is to allow more spontaneous breaths but to trigger a mandatory VC breath if spontaneous breath is not detected within 90% of the mandatory breath interval.

## Breath Syncing in SIMV mode

There is a sync-window – the next mandatory breath is rescheduled only if spontaneous breath within the sync-window



# Exceptional Mandatory Breath in PSV Mode

Tidal volume is delivered at regular intervals

$T_i$ .

If spontaneous breath occurs during this interval at time  $T_s$ , a pressure supported breath is delivered in response.

The next mandatory VC breath is not delayed at all unless it is too close to the spontaneous breath (within 20% of  $T_i$ ).

This avoids breath stacking issues.

## Mandatory Breath (Warning) in PSV mode

There is a quiet-window – the next mandatory breath is delivered only if no spontaneous breath within the quiet-window

