

Respimatic 100



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 O₂ Cylinder or Concentrator?

Full range of Respiration parameters?

Breath Synchronization for Patient Comfort?

Remote monitoring capability?

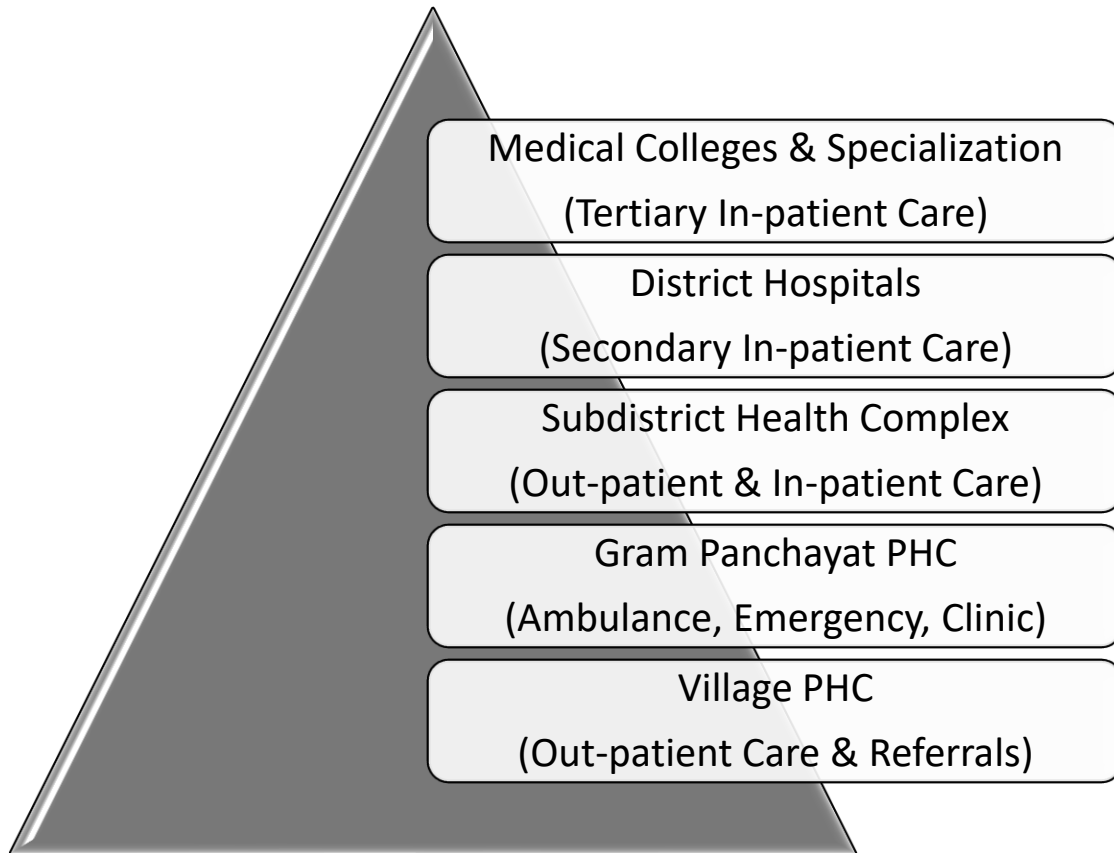
Handle harsh-uncontrolled Environment?

Easy-to-use System?

Budget Friendly?

The Motivation

Serve the Bottom of the Pyramid



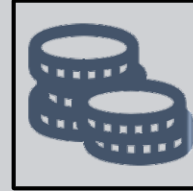
A robust, portable respiration support system for remote Primary Health Centers in India and other developing countries.

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.
Within the budget of the bottom of the pyramid.



2 BIG Challenges

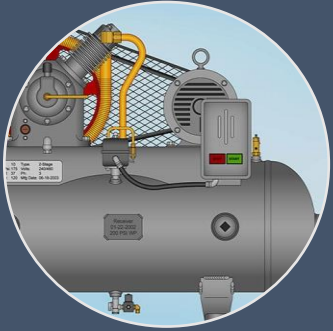


Lack of Affordability
leading to Scarcity



Lack of Skilled
Practitioners

Observations on Ventilator Evolution



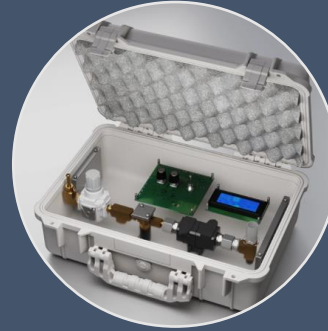
Iron Lung
Age



Pneumatic
Age



μ 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 not stop delivering breaths.
Implement Fallback mechanism for each error scenario.



Respimatic 100 System Details

System Components

Technical Details

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

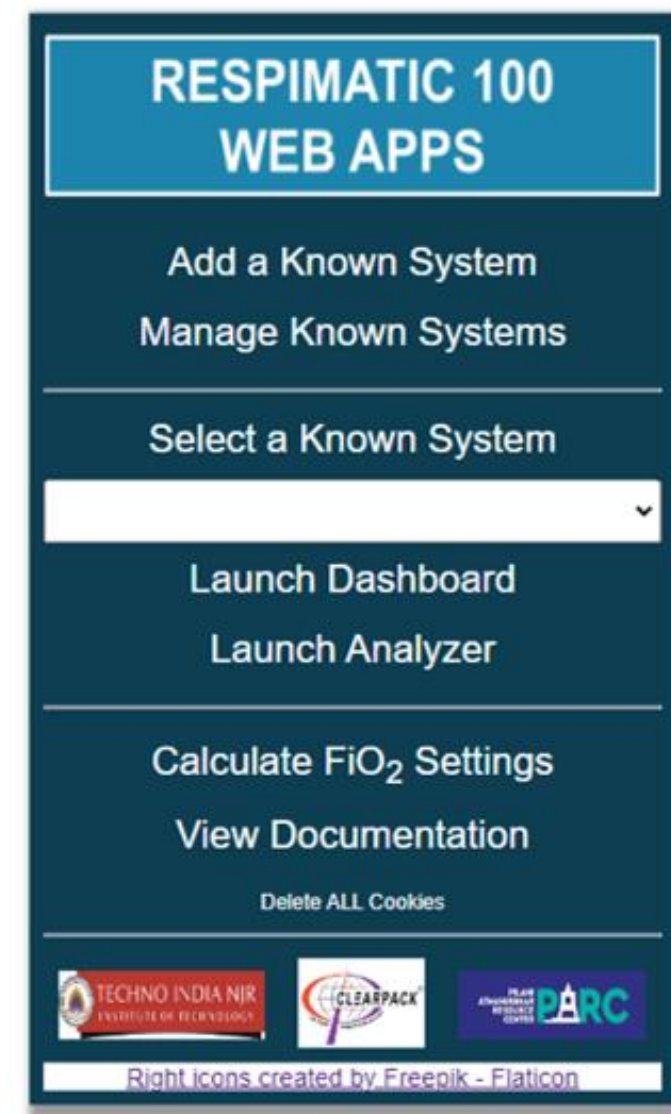
Remote Analyzer

FiO₂ Calculator

Low-speed Wi-Fi sufficient

Phone Hot-spot sufficient

Uses secure HTTPS protocol



<https://www.respimatic.com>

Remote WEB Dashboard Snapshot View

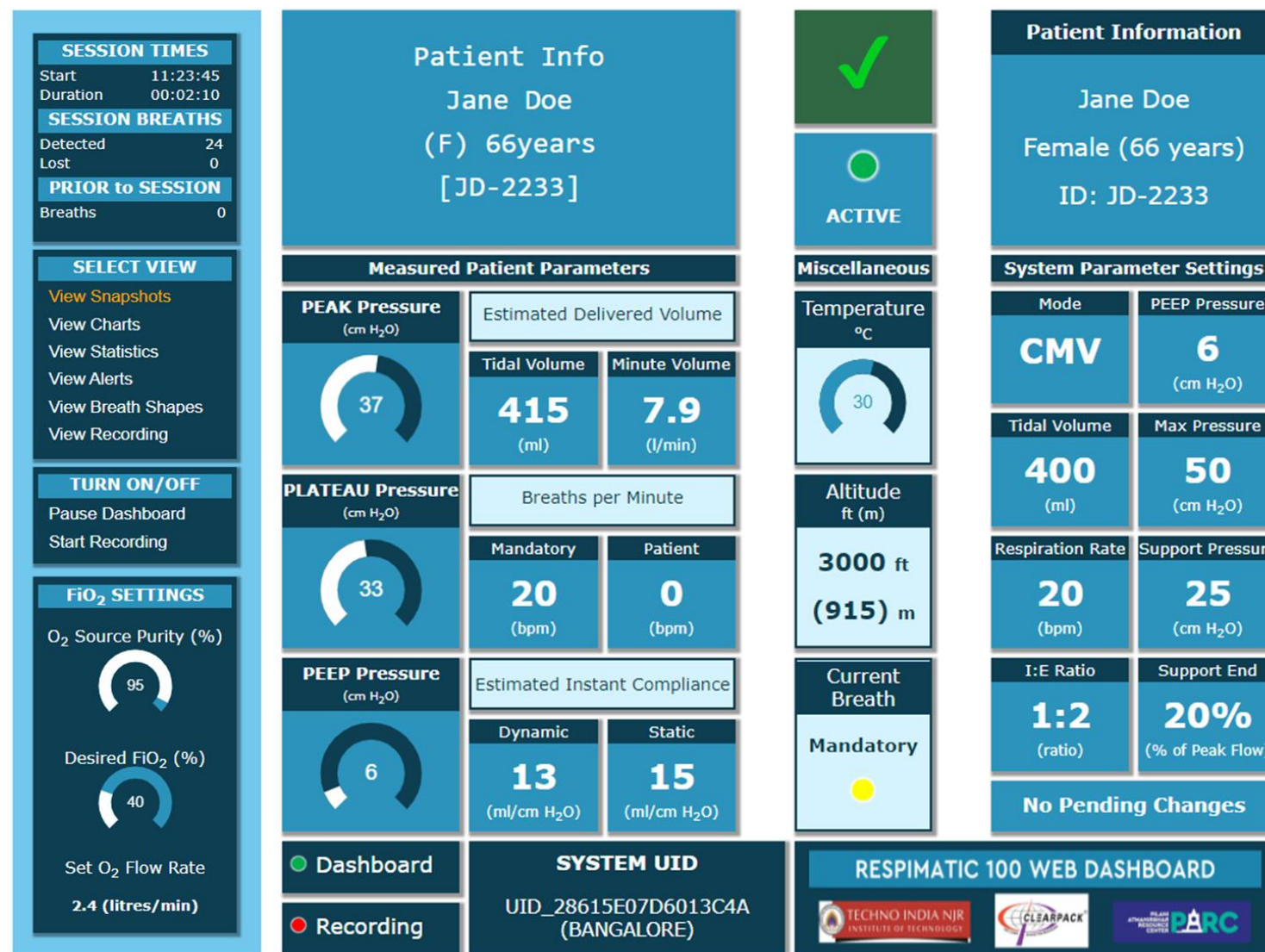
Anyone, anywhere in the world can monitor any patient via the WEB

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>

Remote WEB Dashboard Charts View



Remote WEB Dashboard Statistics View

Shape Session [20-12-2022 10:53:21]

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	PPMAX	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

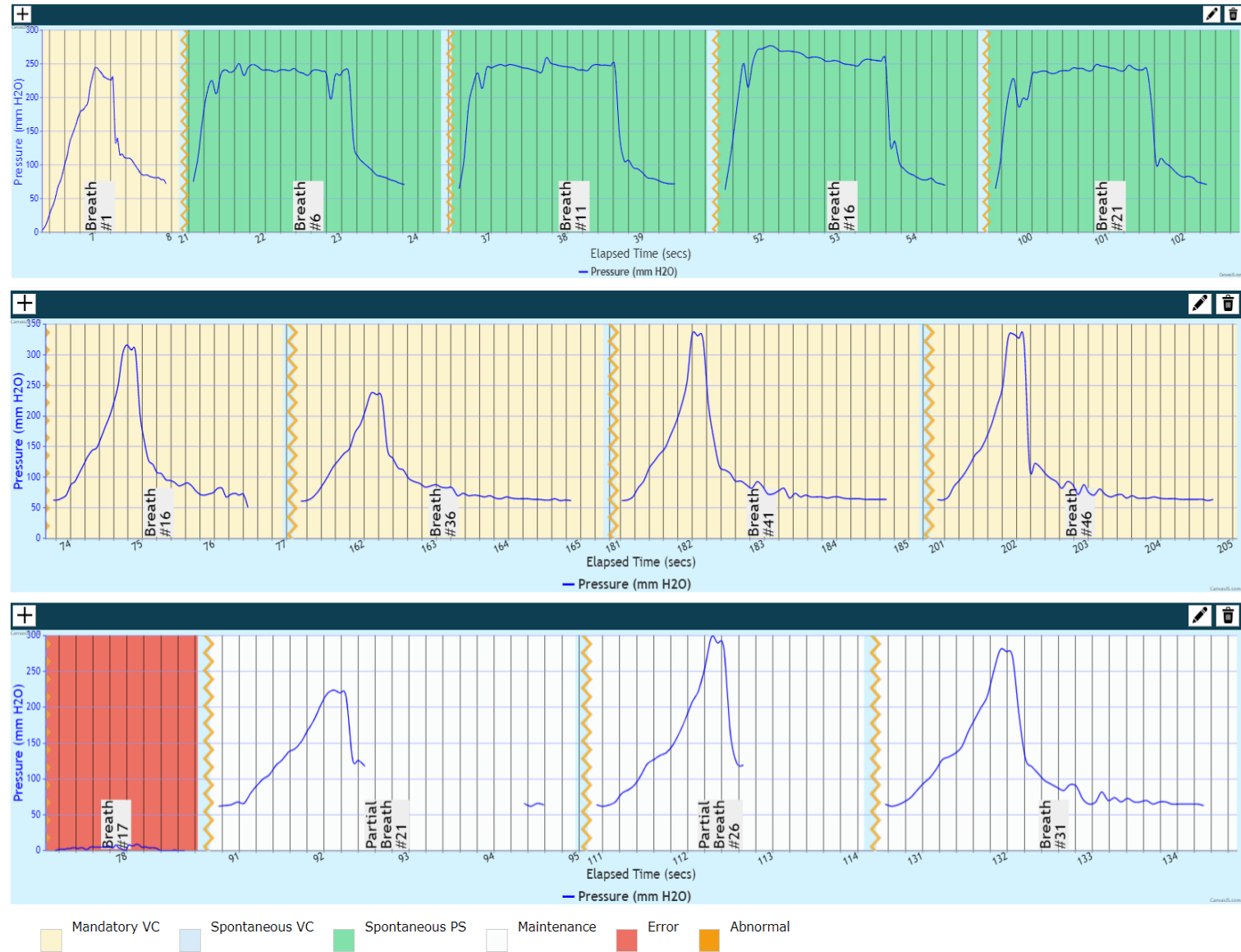
Remote WEB Dashboard Breath Shapes View

Detailed
Pressure
Graphs

For Selected
Breaths

Periodic
Display

Display on
demand



Remote WEB Dashboard Alerts View

1

204

RESET

Set Breath Range Window for Display ☒

X

Session Errors	Session Warnings	Session Information
<div>ERROR #1 DateTime: [09-12-2022]06:55:16</div> <div>Leakage in Breathing Circuit Switching to Maintenance Breaths</div>	<div>WARNING #1 DateTime: [09-12-2022]06:43:16</div> <div>PEEP delta measured up to -0.8 cm H2O Adjust valve/setting YES -> Commit</div>	<div>INFO #1 DateTime: [09-12-2022]06:45:23</div> <div>1 Breath(s) missed Info not received by Dashboard due to Internet packet loss</div>
<div>ERROR #2 DateTime: [09-12-2022]06:55:21</div> <div>[ERROR] state Press PAUSE to show the System state leading to ERROR</div>	<div>WARNING #2 DateTime: [09-12-2022]06:43:19</div> <div>PEEP delta measured up to -1.0 cm H2O Adjust valve/setting YES -> Commit</div>	<div>INFO #2 DateTime: [09-12-2022]06:46:26</div> <div>1 Breath(s) missed Info not received by Dashboard due to Internet packet loss</div>
<div>ERROR #3 DateTime: [09-12-2022]06:55:25</div> <div>Leakage in Breathing Circuit Maintenance mode Deliver safe breaths</div>	<div>WARNING #3 DateTime: [09-12-2022]06:43:21</div> <div>PEEP delta measured up to -0.9 cm H2O Adjust valve/setting YES -> Commit</div>	<div>INFO #3 DateTime: [09-12-2022]06:47:17</div> <div>1 Breath(s) missed Info not received by Dashboard due to Internet packet loss</div>
<div>ERROR #4 DateTime: [09-12-2022]06:55:29</div> <div>[ERROR] state</div>	<div>WARNING #4 DateTime: [09-12-2022]06:55:14</div> <div>PEEP delta measured</div>	<div>INFO #4 DateTime: [09-12-2022]06:47:28</div> <div>1 Breath(s) missed</div>

Remote WEB Analyzer

Any patient Session can be recorded locally or remotely.

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

Demo Session [09-12-2022 06:39:24]

SYSTEM UID

UID_28615E07D6013C4A
(BANGALORE)

RESPIMATIC 100 WEB ANALYZER



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.

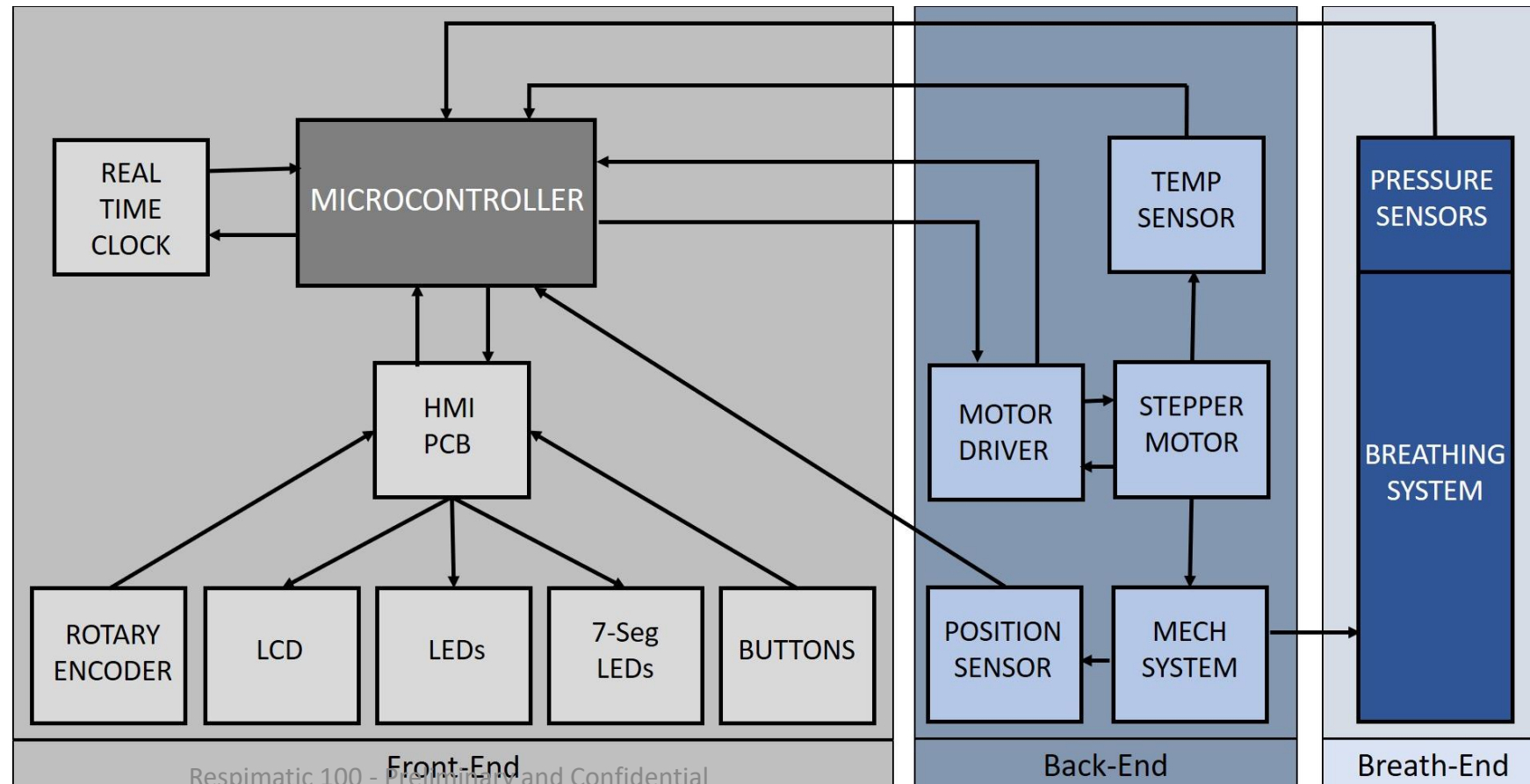


System Architecture

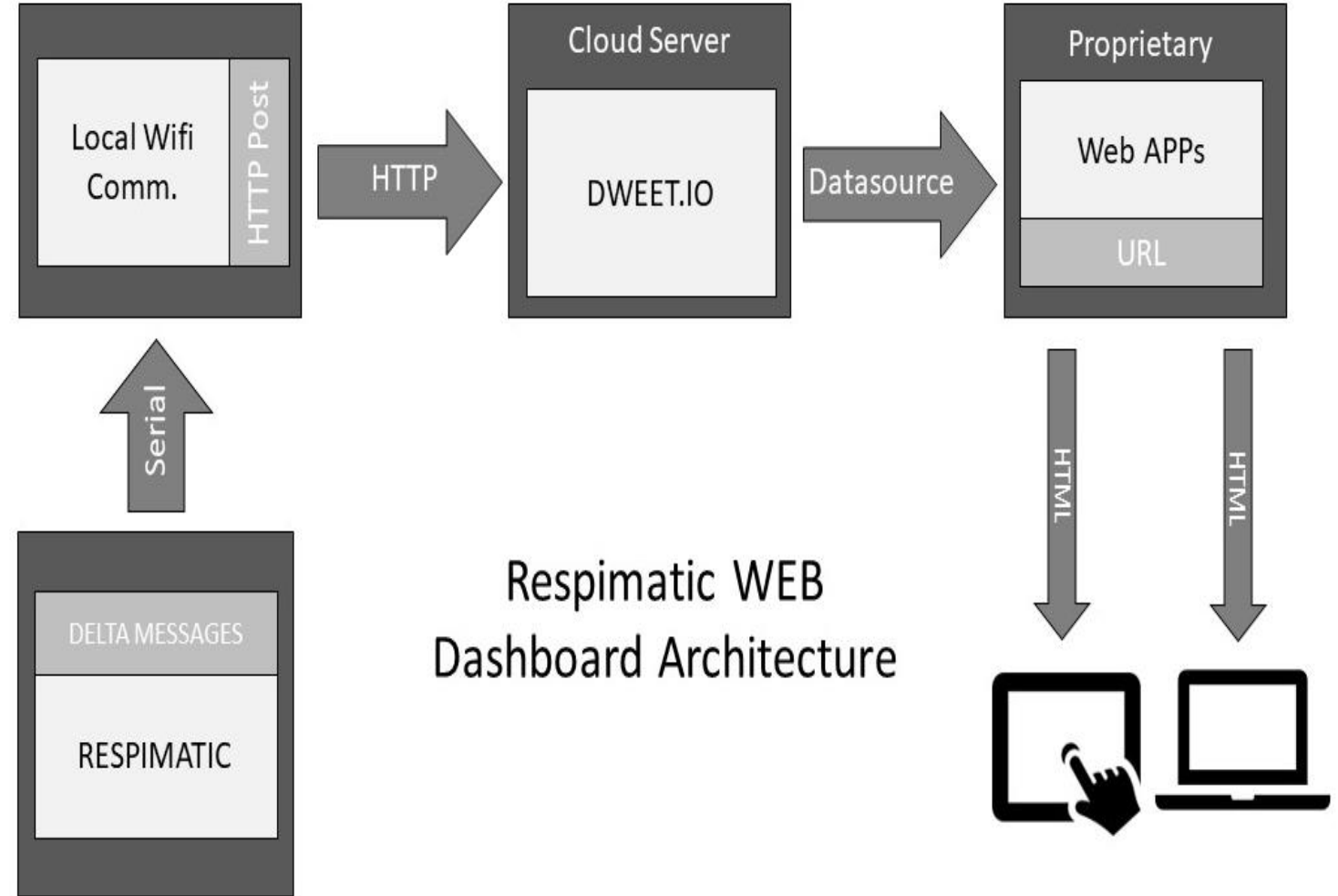
Clearly separated
Frontend, Backend and
Breathing system

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

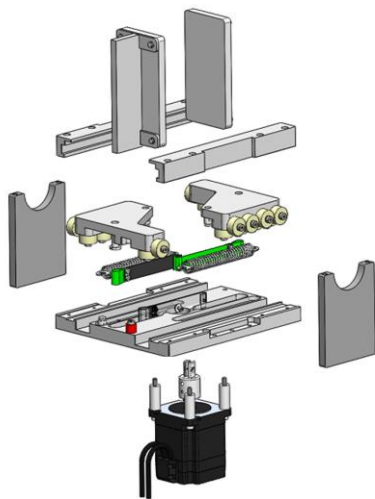
Potentially lower with bulk negotiations

Compact, Lightweight, and Robust

Usable in harsh environments

Intuitive HMI - Simple to operate

Front Control Panel & Remote Monitoring



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

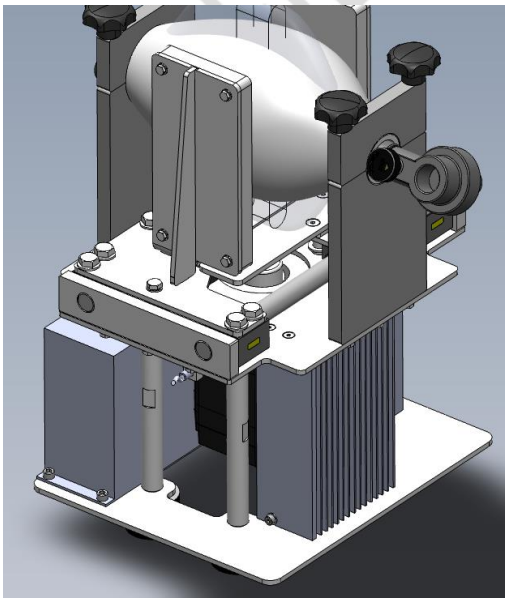
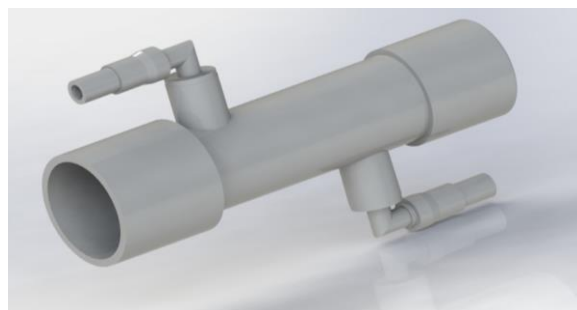
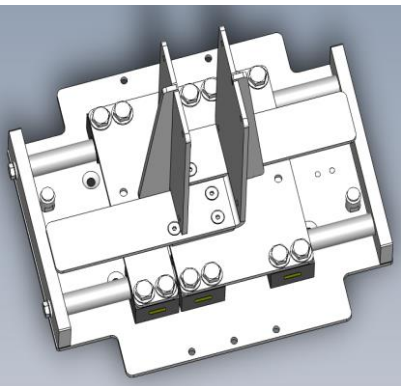
$$Q = K * \sqrt{E * (P_{G1} - P_{G2})}$$

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

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

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, and
Suitable for
mass production

Breathing Circuit

One proprietary, **patent-pending** Dual Pressure line connector with Orifice plate

COTS single-limb Breathing Circuit with NRBM

BVM or Ambu Bag with Reservoir

Pressure sensors, PEEP valve

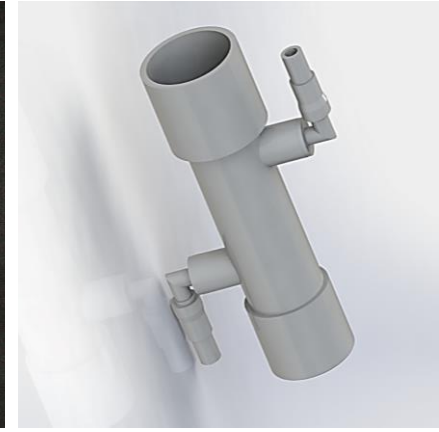
HME Filter

Humidifier

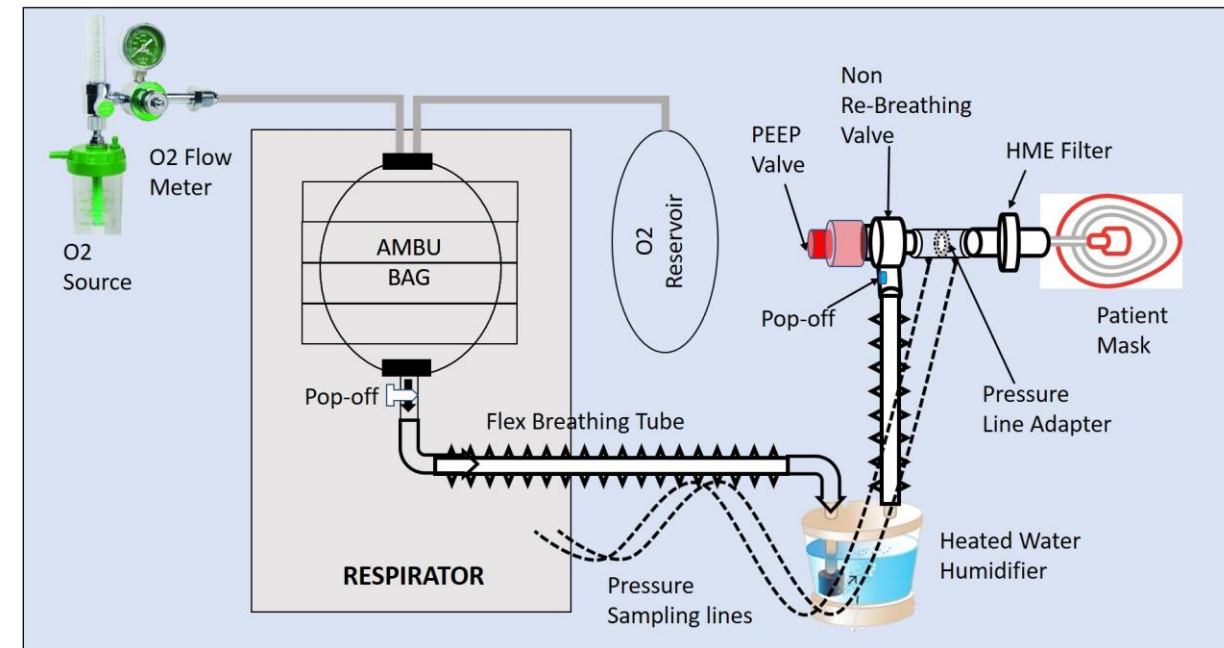
Oxygen Source



Off-the-Shelf Single limbed Circuit with NRBM



Patent-pending 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

Careful Monitoring of
Minute Volume

No Mandatory
breaths except when
in dire need

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

Inspiration/Expiration Ratio (I:E)

1:1, 1:2, 1:3

PEEP (cmH2O)

4 to 15 cmH2O
increments of 1 cmH2O

Max Pressure (cmH2O)

20 to 50 cmH2O
increments of 5 cmH2O

FiO₂ Support

System Managed
Externally Controlled
21% to 100%

Pressure Supported Breaths

(SIMV & PSV modes)

Support Pressure (PS)

5 cmH₂O to 30 cmH₂O in increments of 5 cmH₂O

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

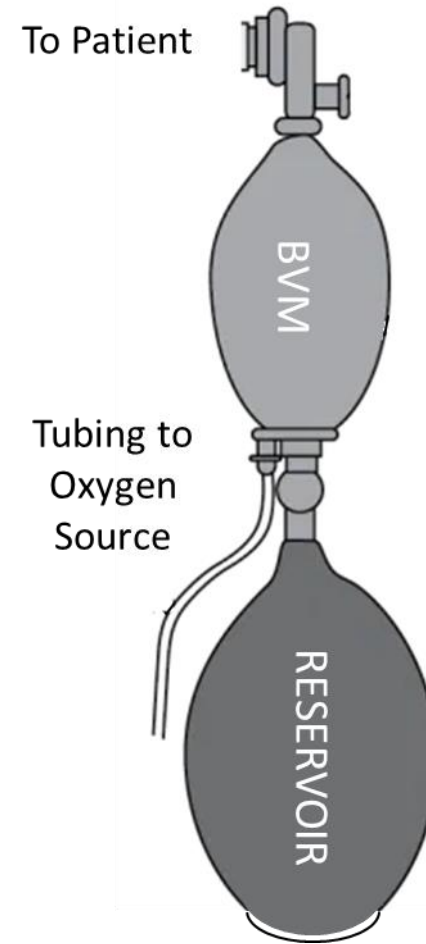
Without the Reservoir bag, FiO_2 delivered is 21% which is normal Atmospheric O_2 content

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

Front-panel HMI guides the user in setting the appropriate input O_2 flow rate on the connected 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: 3000 feet

Desired VT(ml) Desired RR(bpm)

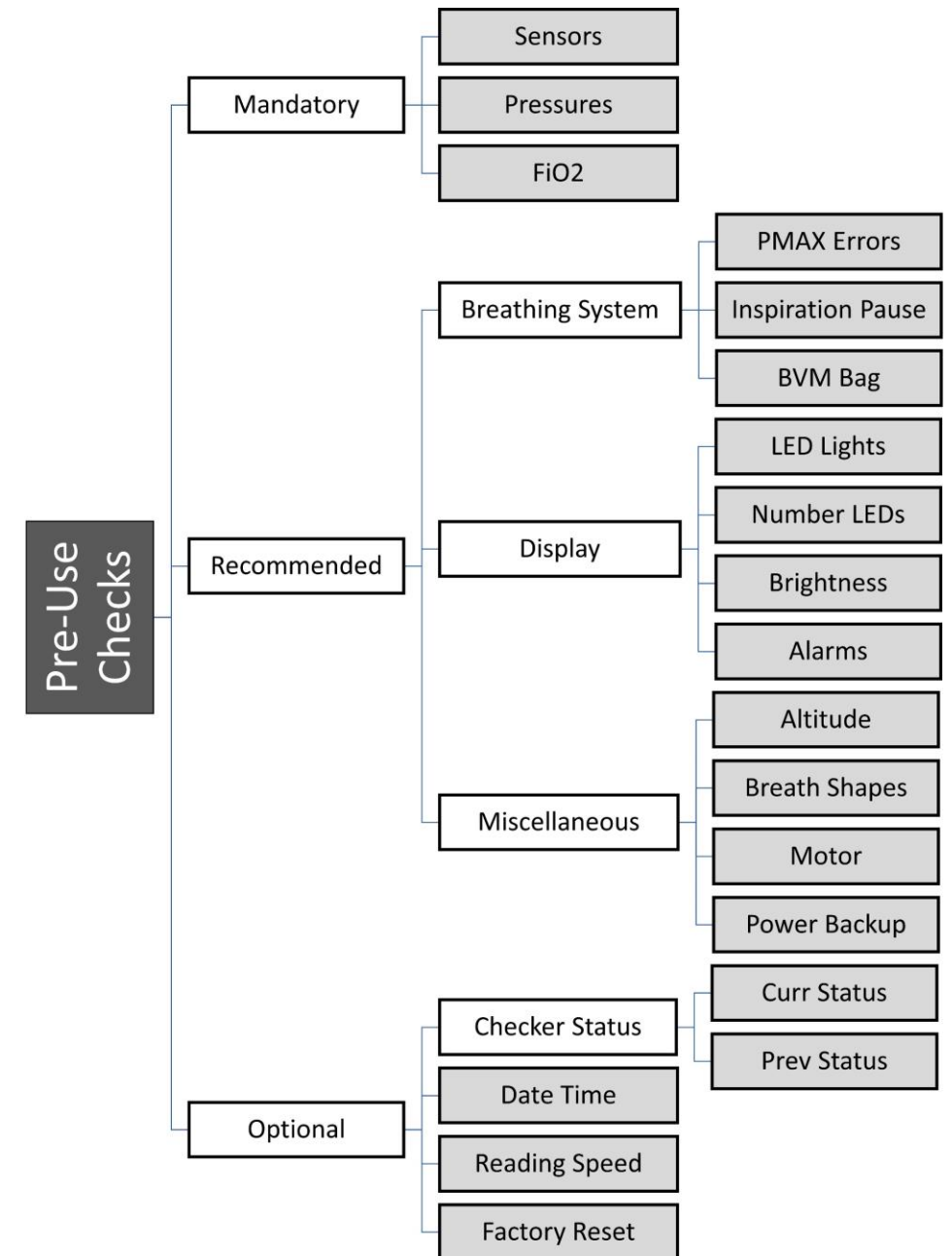


O_2 Source Purity(%) Desired FiO_2 (%)



Alarms and Safety Features

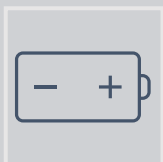
- Enforcement of Pre-use checks
- Distinction between Alarms, Warnings and Notifications
- Maintenance Breaths till Alarm situation rectified
 - Max Pressure Alarm
 - Pressure Loss Alarm
 - System Temperature Alarm
 - Sensor failure Alarm
 - Breathing Circuit Failure Alarm
 - Detect coughing fits
 - 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

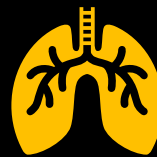
Timing, Flow and
Pressure Checks
for all
combinations of
various settings



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

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/जिंदगिदह, 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 अनेक स्टोर में ही हैं। वहीं, चित्तौड़गढ़ 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 चेतिया अस्पताल में कोरोनाकाल से पहले 12 वेंटीलेटर ही 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

चित्तौड़गढ़ 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 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 सीपवरी के 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।

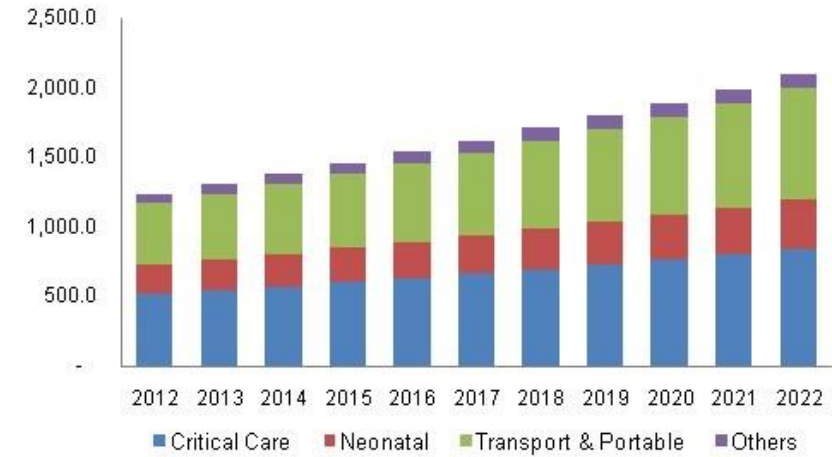
Market Need

25 to 50 ventilators per lakh people
in developed countries

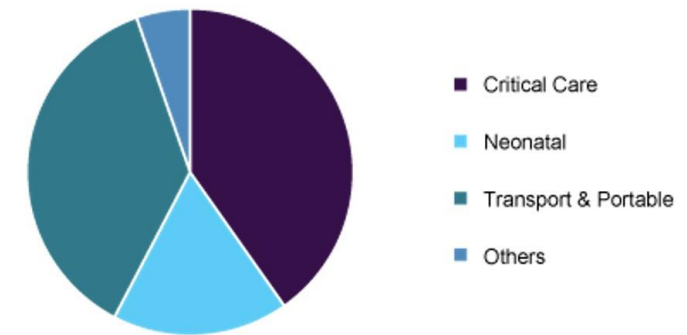
1.8 ventilators per lakh people*
(India)

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

Breath Synchronization in ACV Mode

Tidal volume is delivered at regular intervals
 T_i .

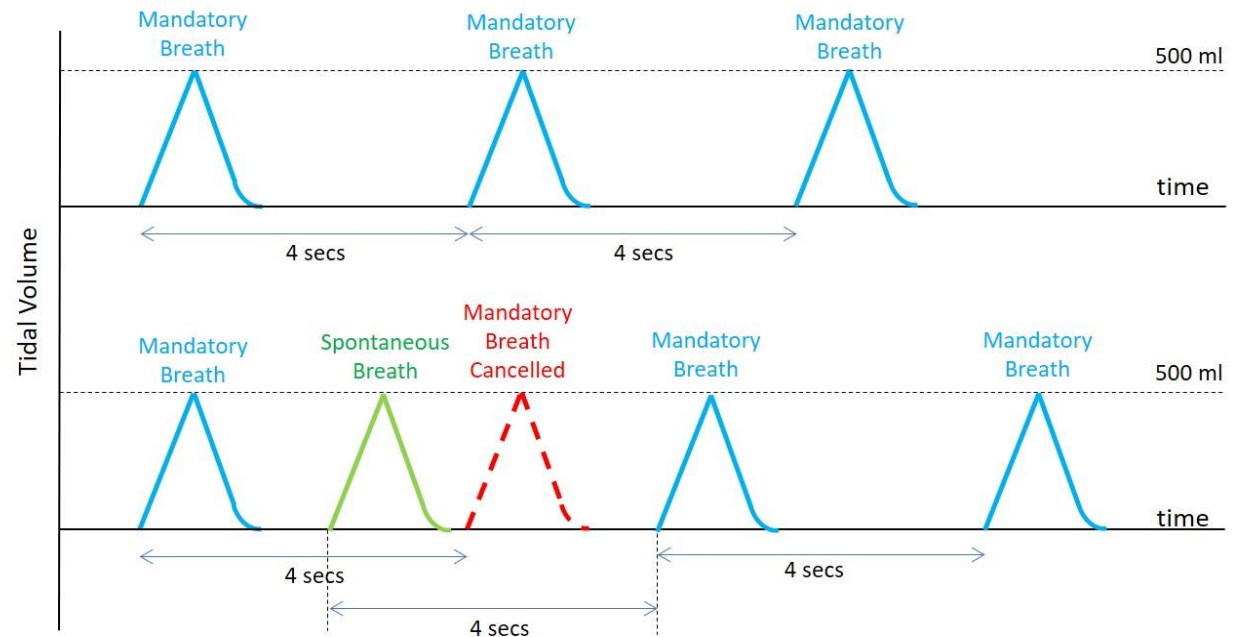
If spontaneous breath occurs during this interval at time T_s , the set tidal volume is delivered in response, and the next mandatory breath is set for $(T_s + T_i)$.

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

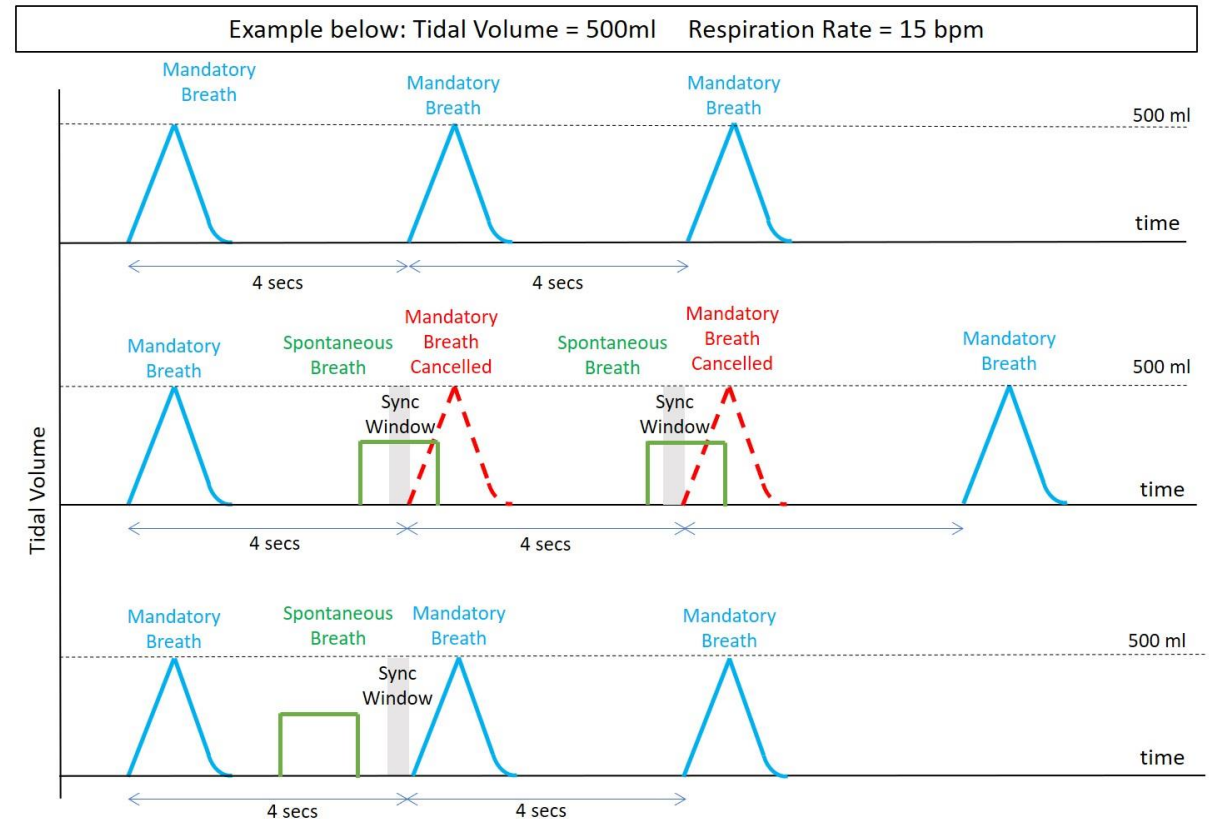
Tidal volume is delivered at regular intervals
 T_i .

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

