PILANI ATMANIRBHAR RESOURCE CENTER PARC

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TECHNO INDIA NJR INSTITUTE OF TECHNOLOGY

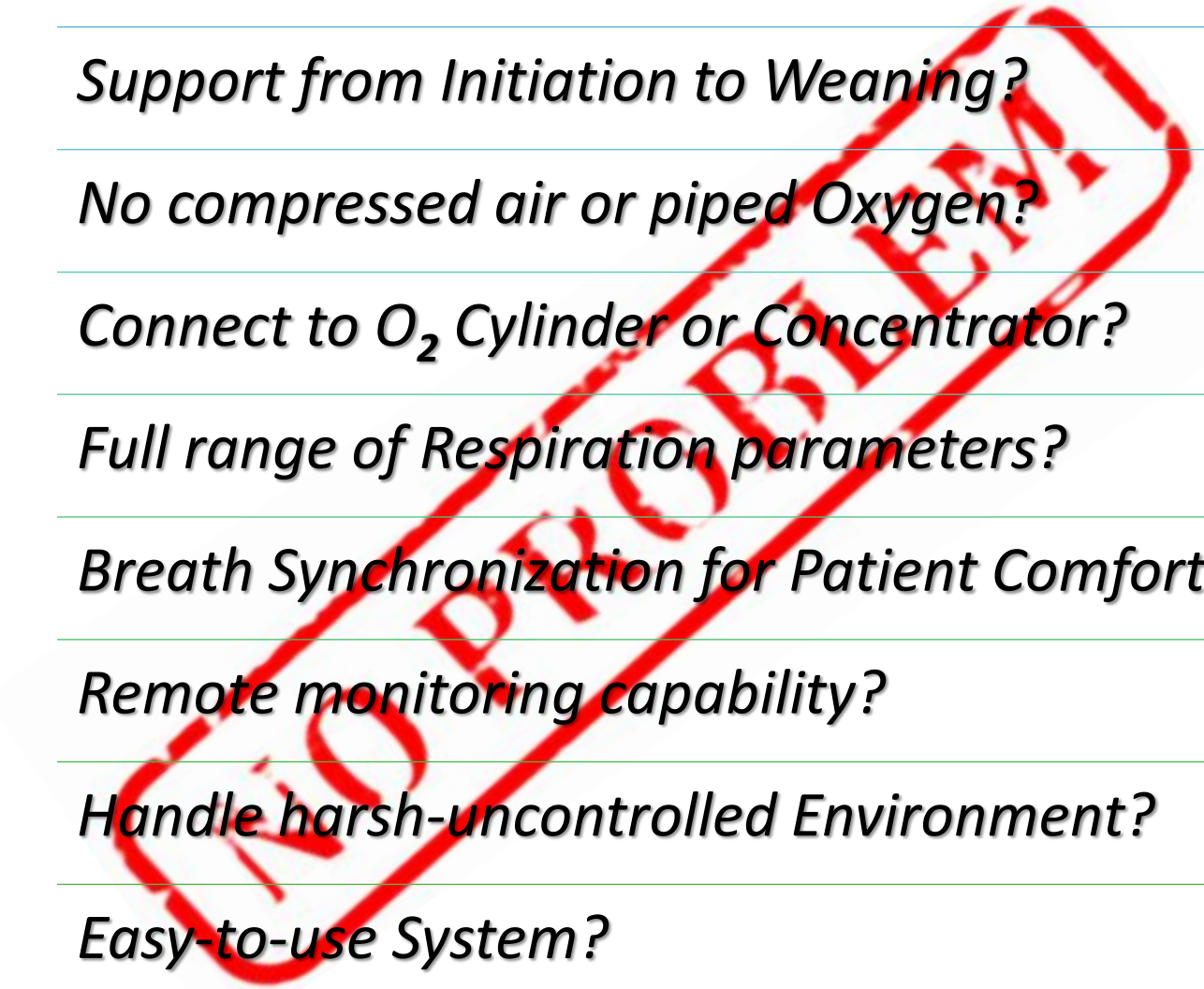
Respimatic 100

Sunil Nanda (PARC)

RESPIMATIC 100
(Patent Pending)

Is it right for you?

- *Only non-invasive 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?*

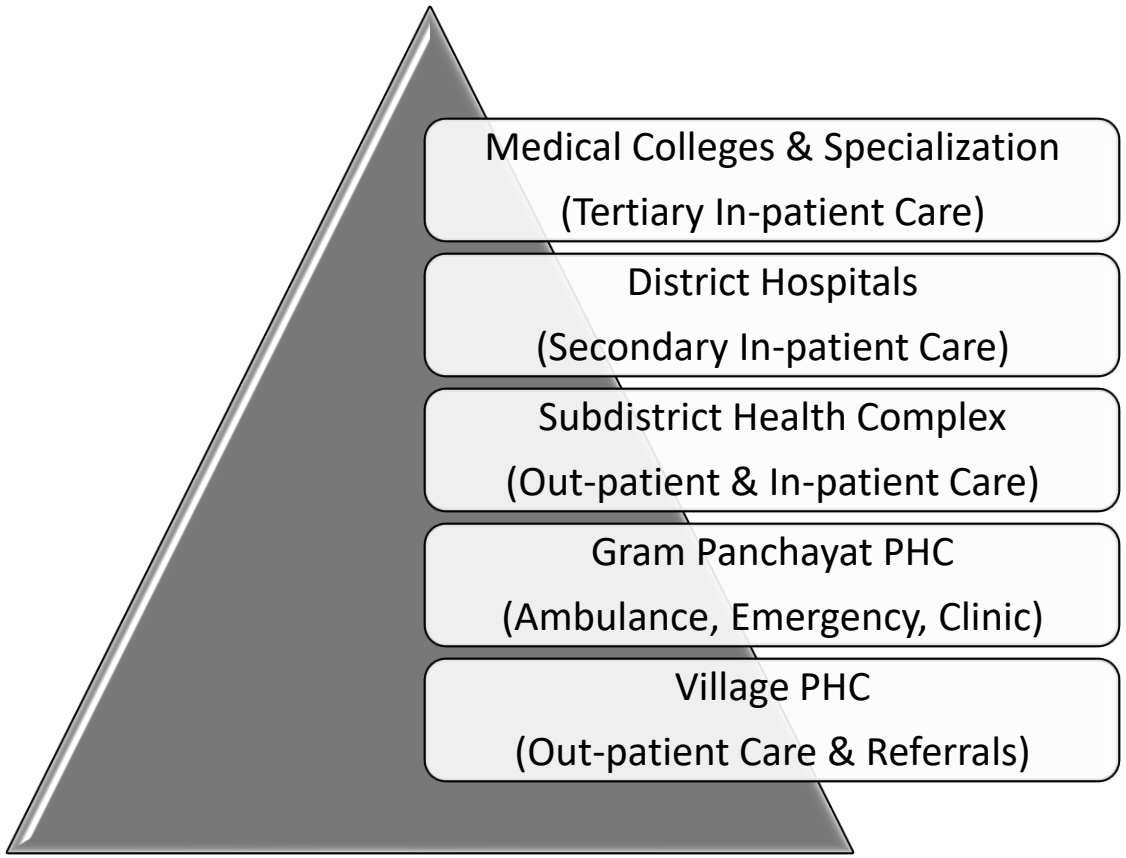


Setting the Context

The Motivation

The Problem Statement

The Motivation
Serve the Bottom of the Pyramid



Provide a robust, portable respiration assist system to 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 oxygen

A system that requires minimum training

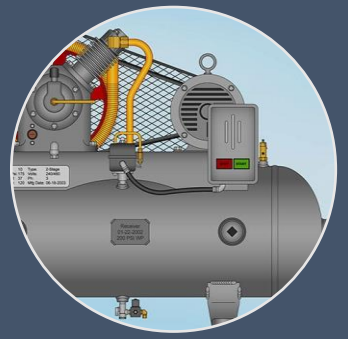
Within the budget of the bottom of the pyramid

The Problem

2 BIG Challenges

- Lack of Affordability leading to Scarcity
- Lack of Skilled Practitioners

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 – Respiratory Technology Revisited

Remote Diagnosis and Monitoring (Telemedicine)	**Rural, remote geographies** do not have skilled specialists **BUT Communication** Technologies have come of age
Leverage Time-proven Technologies	**Simplify** design and feature list **Simplify** HMI **Use Off-the-shelf** proven components
Maintenance Breaths in case of unexpected errors	System cannot stop delivering breaths. Implement appropriate **Backup** mechanism for each 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, Support Pressure Controls
- Volume Controlled and Pressure Supported Breaths
- Mandatory & Spontaneous Breaths with Full Breath Synchronization

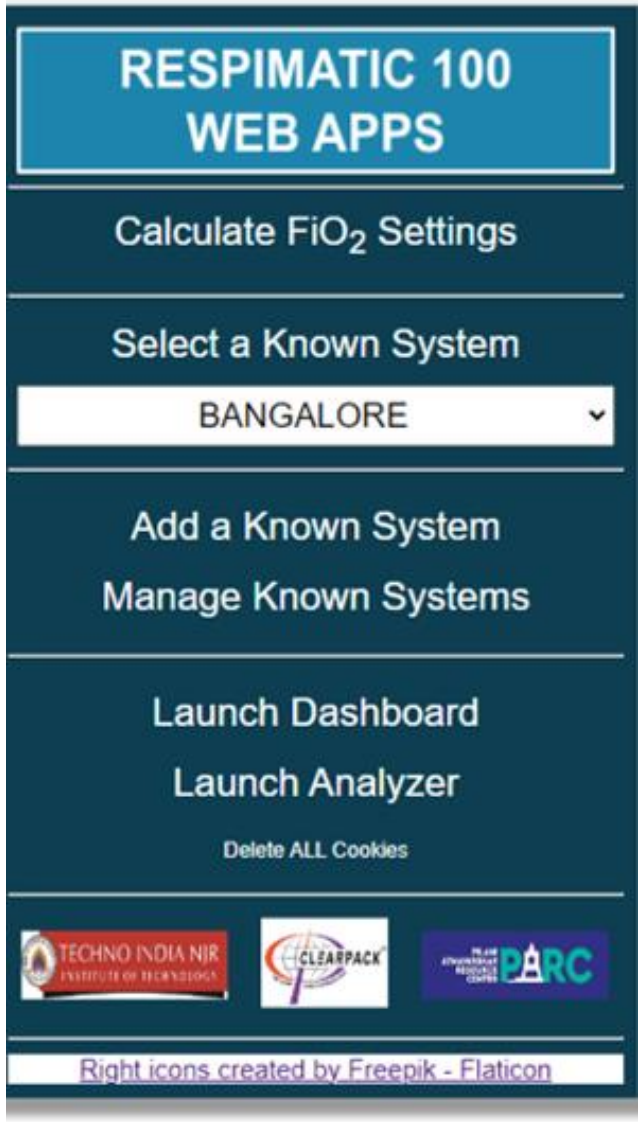
Complete set of WEB Apps

- **Remote Dashboard**
- **Remote Recorder**
- **Remote Analyzer**
- **FiO_2 Calculator**

Low-speed Wi-Fi sufficient

- **Phone Hot-spot also sufficient**

Uses secure HTTPS protocol



https://www.respimatic.com

Remote WEB Dashboard Snapshot View

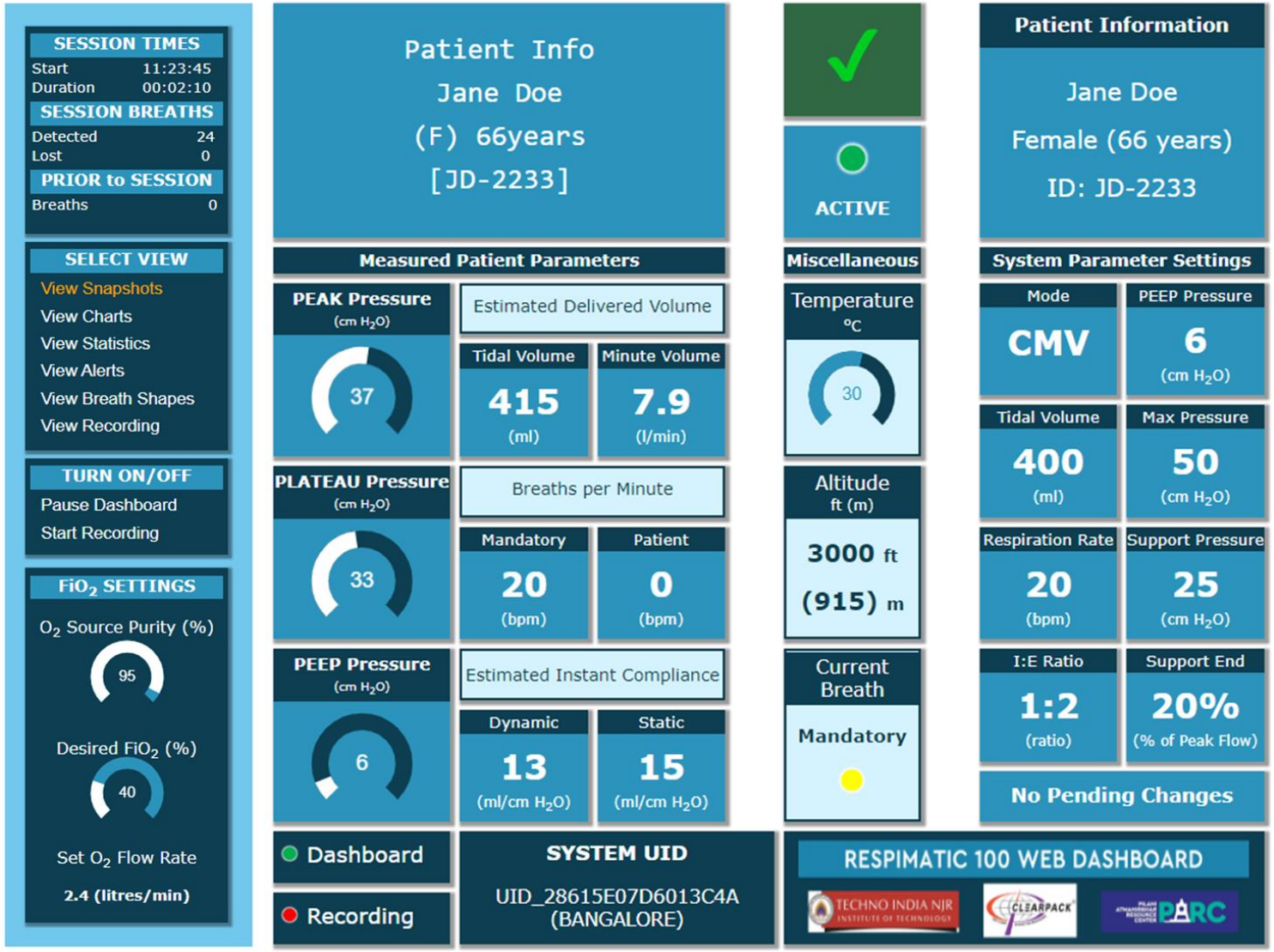
Anyone, anywhere in the world can monitor any patient via the WEB

Multiple specialists can monitor the same patient

One specialist can monitor multiple patients

5 Dashboard views

- Snapshots
- Charts
- Statistics
- Breath Shapes
- Alerts



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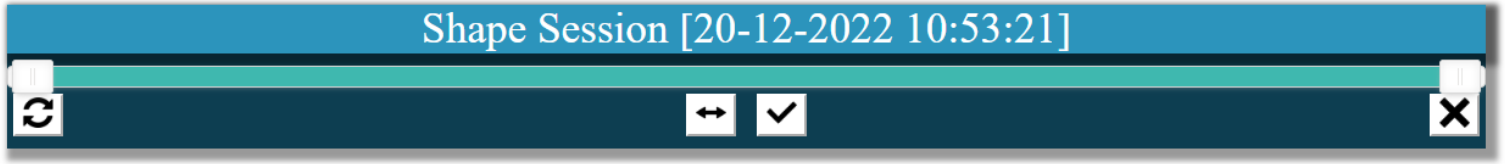
Remote WEB Dashboard – Charts View

Remote WEB Dashboard – Statistics View



Parameters Measured

Parameter	Units	Min	Max	Avg
Peak Pressure	cmH20	1	35	28.1
Plateau Pressure	cmH20	17	33	27.1
PEEP Pressure	cmH20	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/cmH20	14	30	18.4
Instantaneous Dynamic Compliance	ml/cmH20	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)

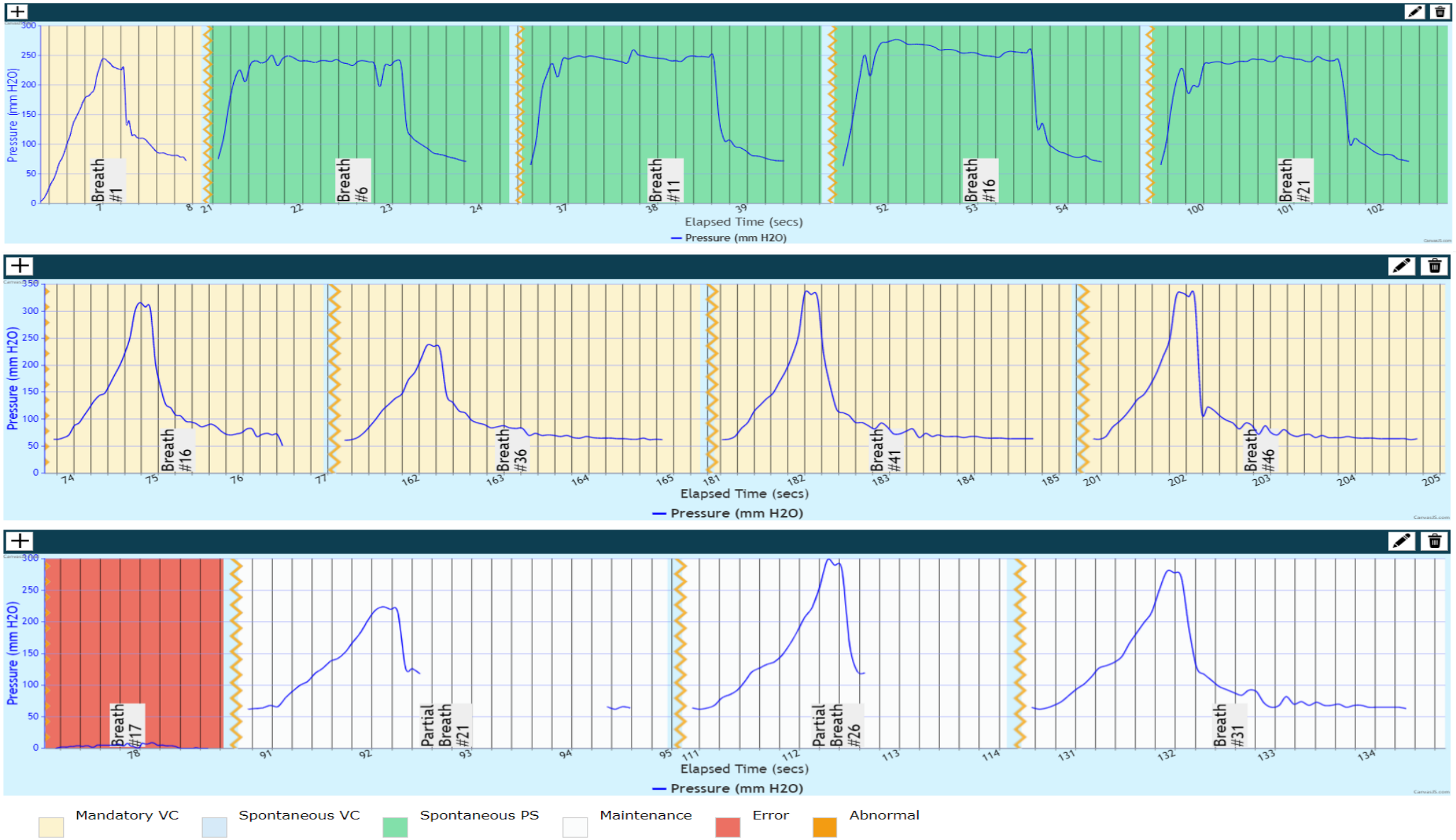
Parameter Settings Used

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	cmH20	6
Maximum Pressure	cmH20	50
Support Pressure	cmH20	25
Support Pressure Termination	%flow,secs	F20%
FIO2	%	50

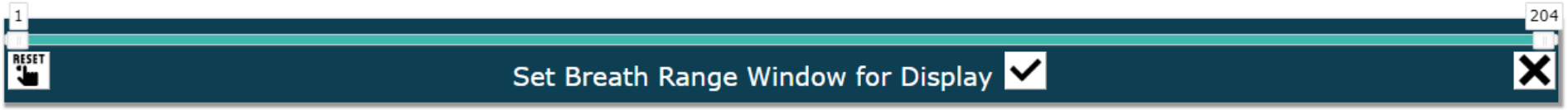
Sequence of Parameter Combinations

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

Remote WEB Dashboard – Breath Shapes View



Remote WEB 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

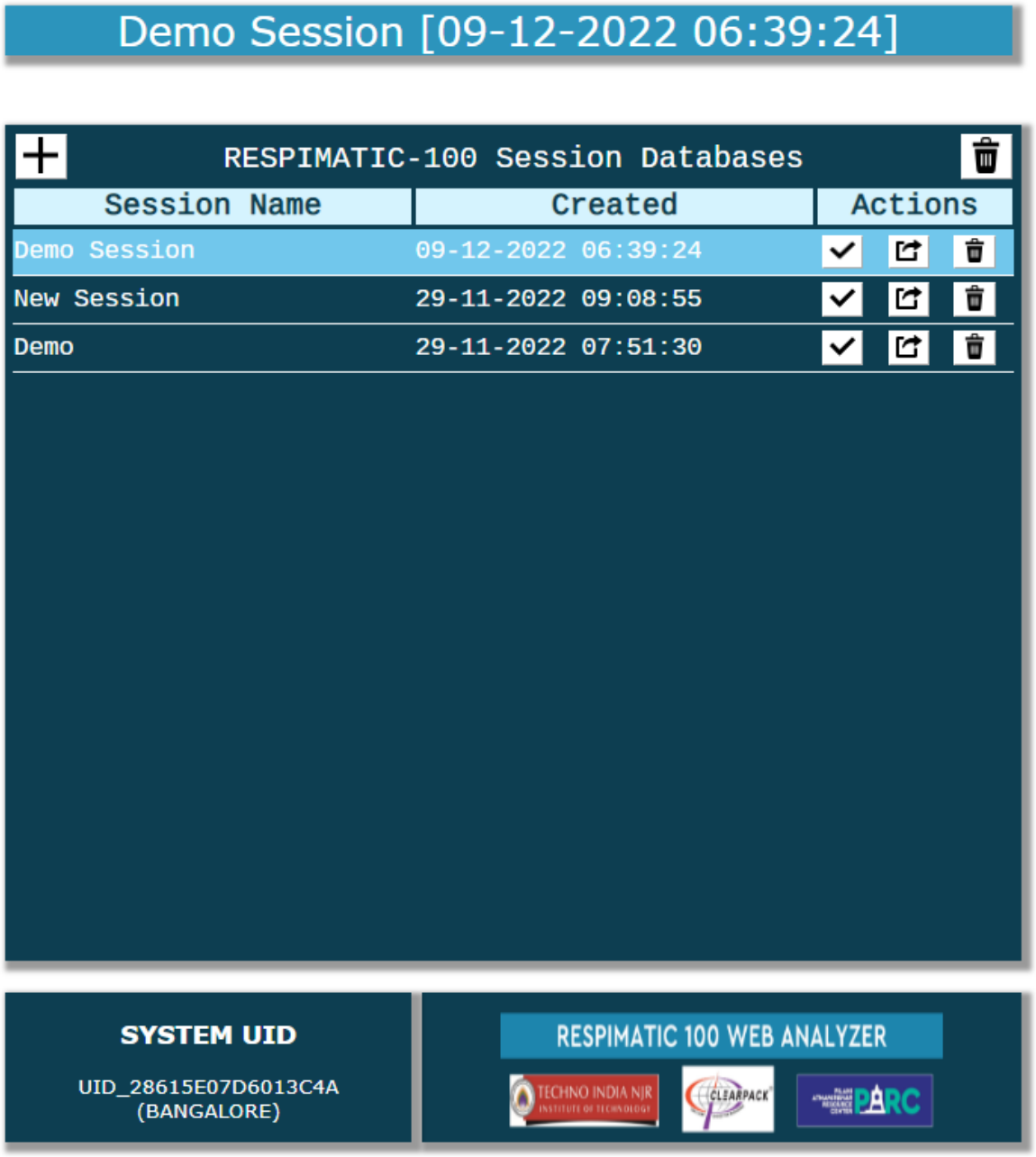
INFO #3 DateTime: [09-12-2022]06:47:17
1 Breath(s) missed
Info not received by
Dashboard due to
Internet packet loss

INFO #4 DateTime: [09-12-2022]06:47:28
1 Breath(s) missed

Remote WEB Analyzer

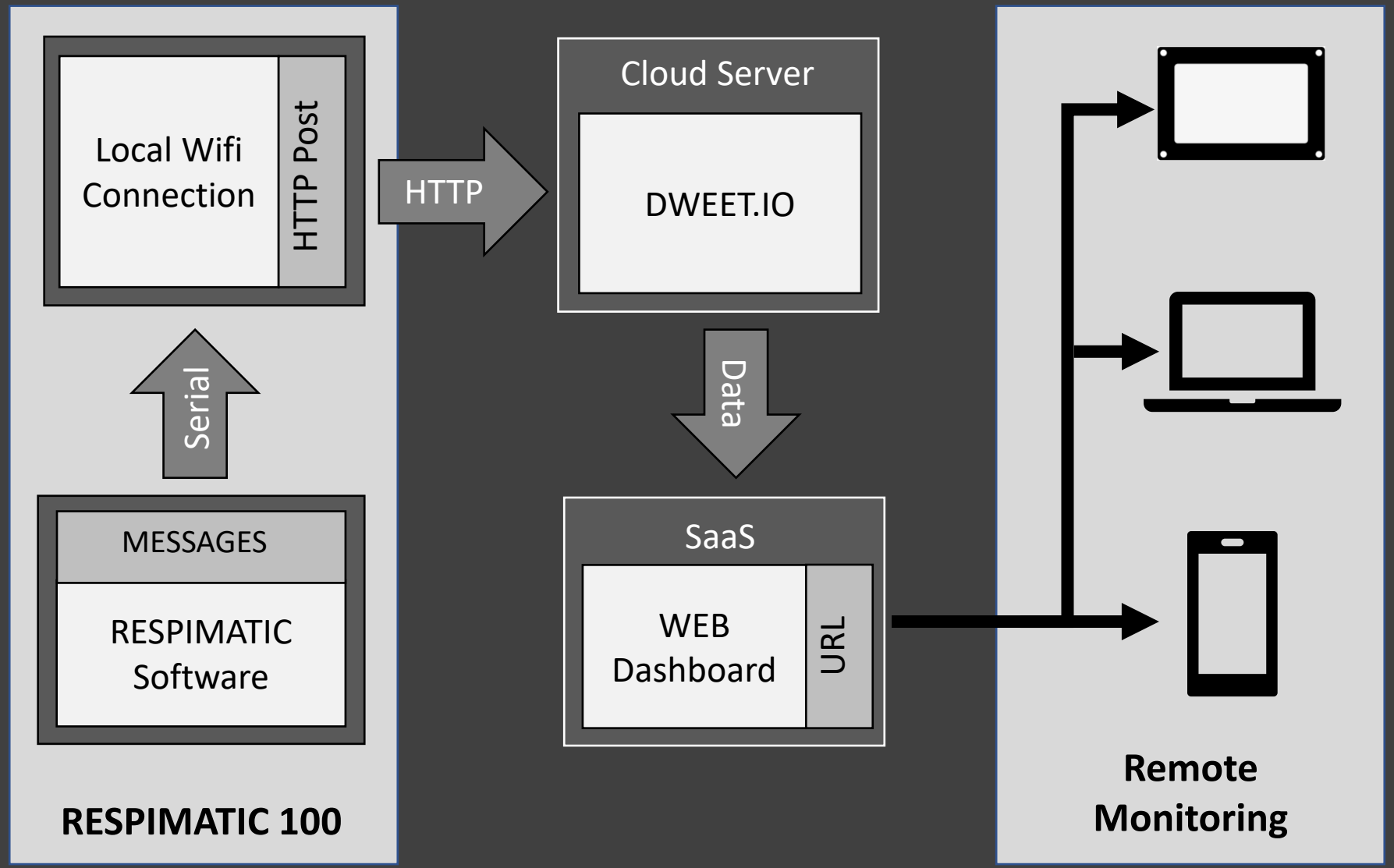
Any patient Session can be recorded locally or remotely.

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



https://www.respimatic.com

WEB Apps Architecture



The Human-Machine Interface – Front Panel

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

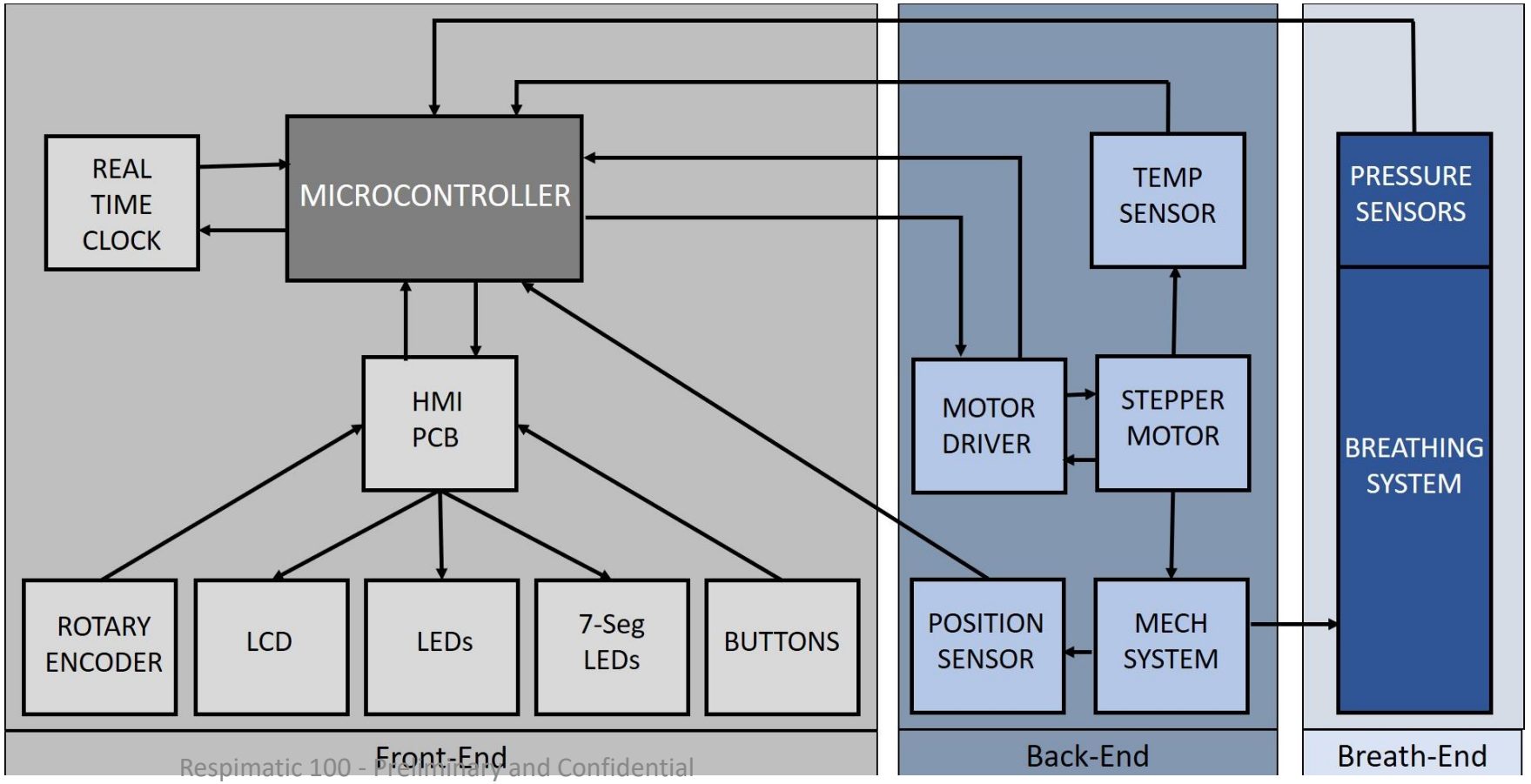
Also shows Delivered Volumes, Lung Compliance, Breath types etc.

System Architecture

Clearly separated Frontend, Backend and Breathing system

IP is in the Frontend design and Algorithms

Backend and Breathing System can have multiple avatars



Respimatic 100 Under the hood

Production Cost Rs. 50,000

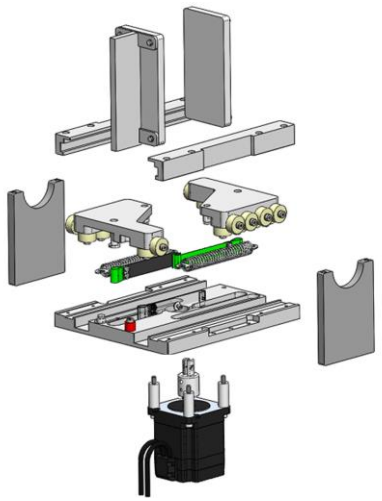
Potentially lower with bulk negotiations

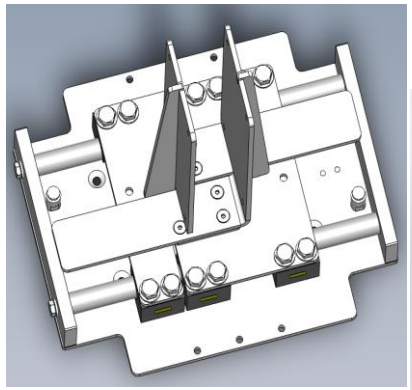
Compact, Lightweight, and Robust

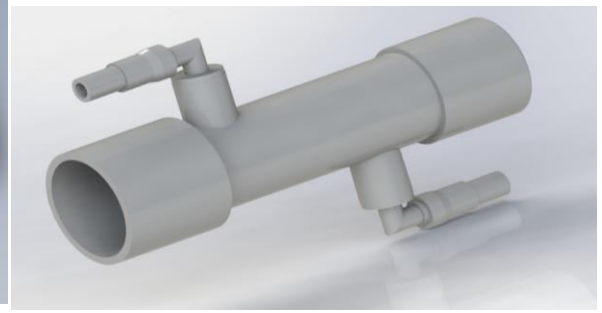
Usable in harsh environments

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.

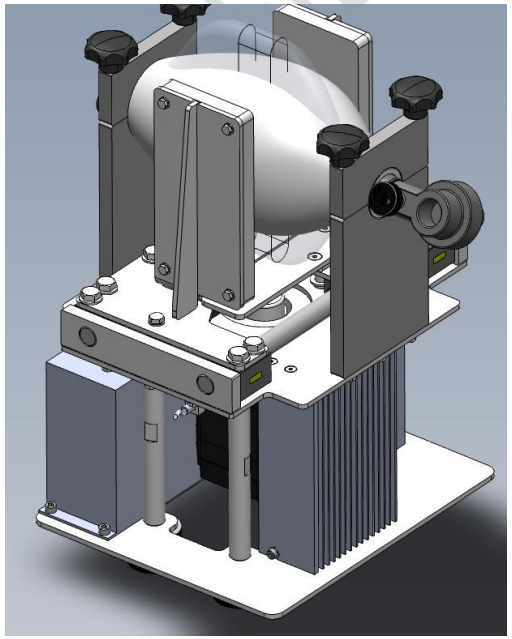
$$Q = K * \sqrt{E * (P_{G1} - P_{G2})}$$

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

or $K = \frac{f(Re)}{\sqrt{Patmoshpere} * \sqrt{E}}$ where Re 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 with time proven COTS components

Rugged mechanical system – various alternatives possible

Essential Parameter monitoring and carefully vetted alarm conditions

Robust and easy to clean enclosure surfaces

Suitable for mass production

Breathing Circuit

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

Off-the-shelf single-limb Breathing Circuit with NRBV

BVM or Ambu Bag with Reservoir

Pressure sensors, PEEP valve

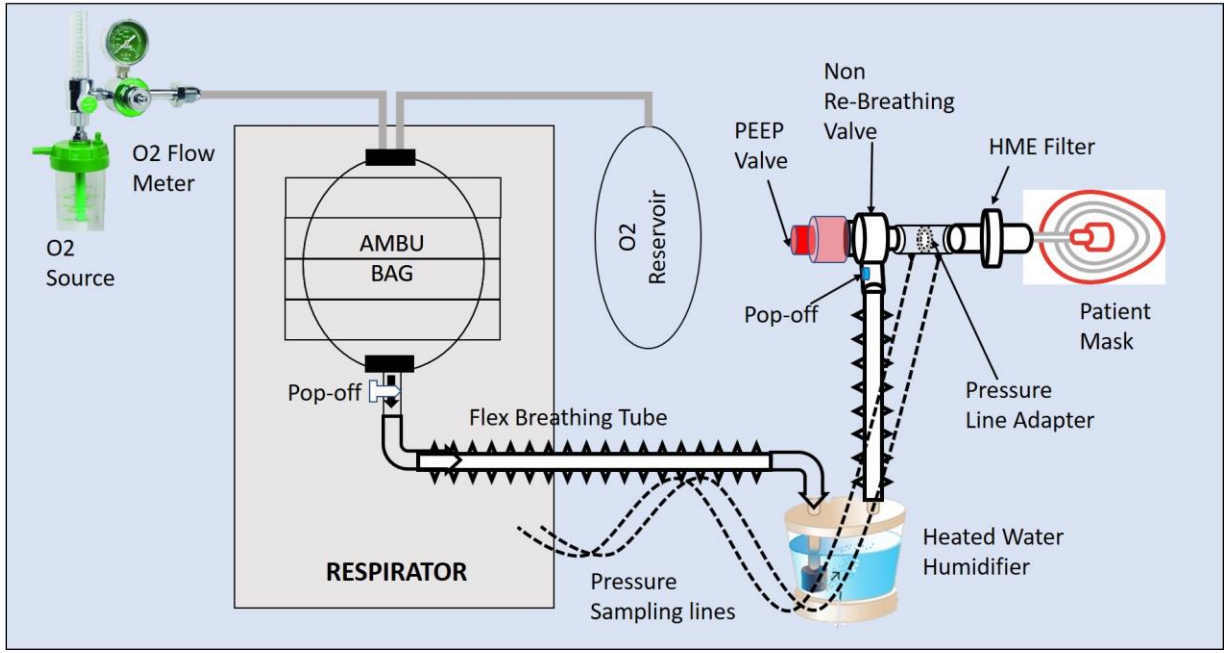
HME Filter

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)	***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	Careful Monitoring of Minute Volume
	Breath Synchronization	Breath Synchronization	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 60 cmH2O
increments of 5 cmH2O

FiO_2 Support

Externally Table Driven
21% to 100%

Pressure Supported Breaths

(SIMV & PSV modes)

Support Pressure (PS)

10 cm H2O to 40 cm H2O in increments of 5 cm H2O

Support Pressure Termination (TPS)

Flow-dependent

Terminate when flow falls below 10%, 20% or 30% of peak flow

Time dependent

Terminate after 1.0 secs to 3.0 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

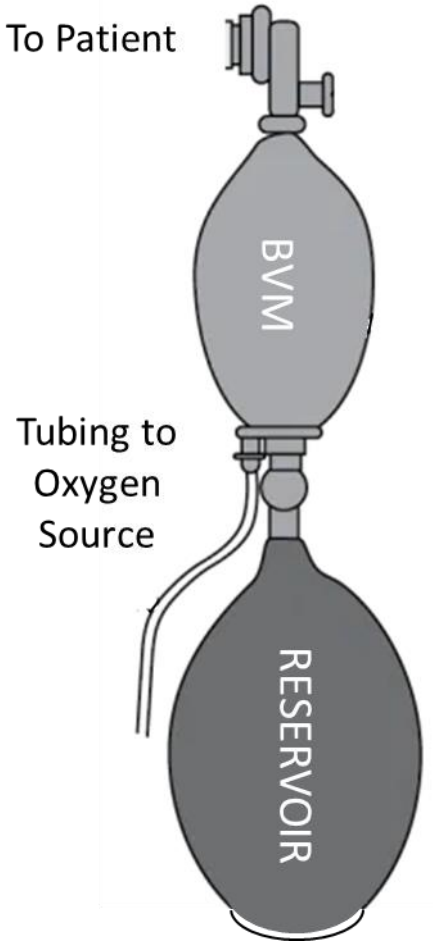
Without the Reservoir bag, FiO_2 delivered is 21% which is normal Atmospheric O_2 content

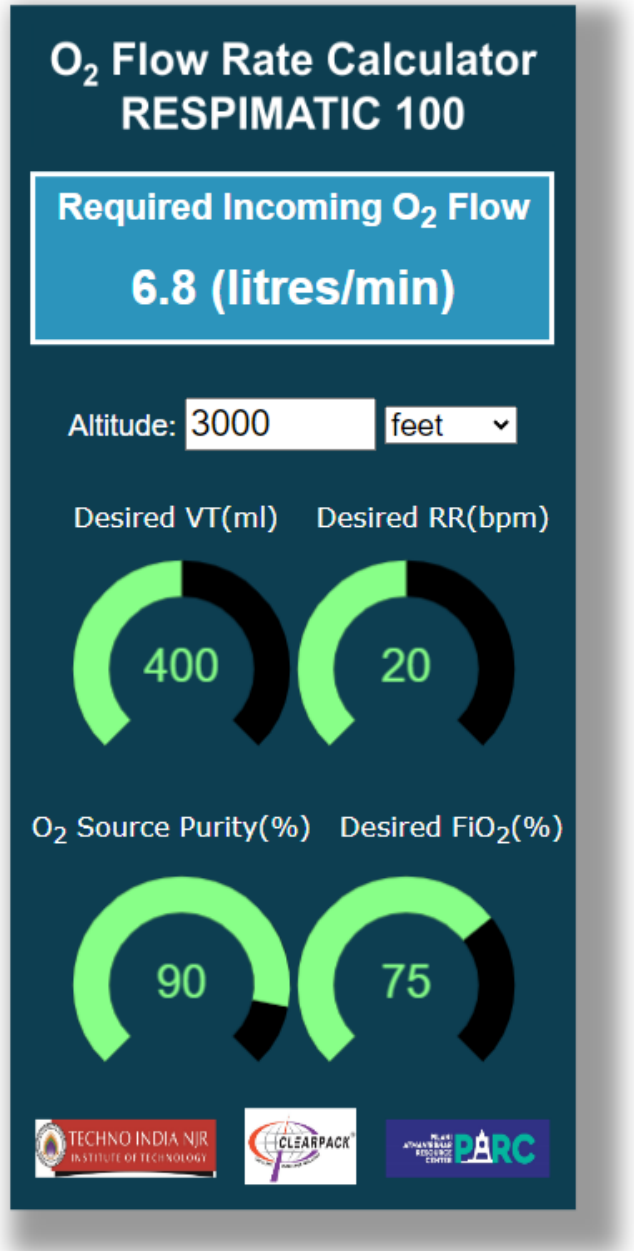
FiO_2 delivery with the Reservoir bag is mathematically modelled, calibrated and verified in the Lab to provide +/- 5% accuracy

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%)

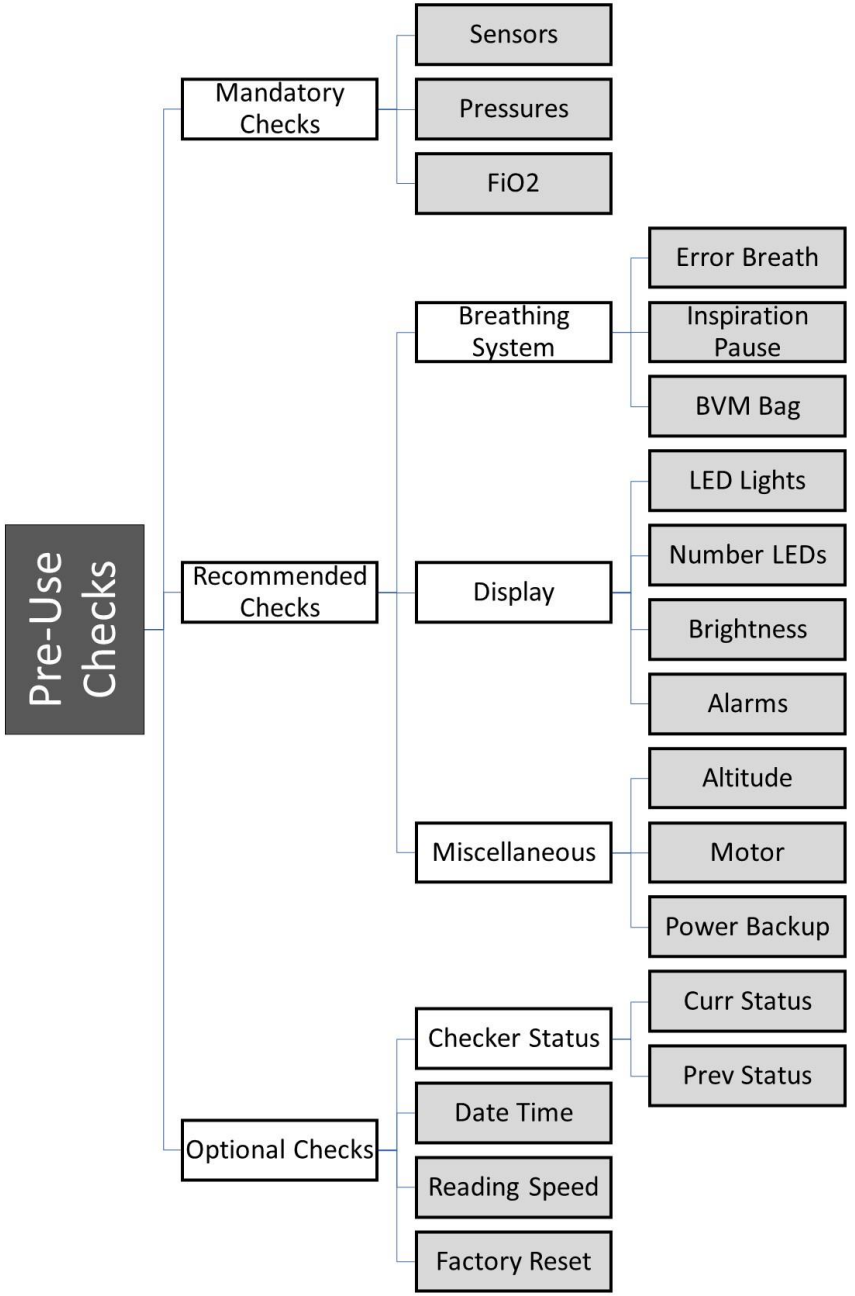
Online Web-accessible FiO_2 calculator is also provided for exploration purposes





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
  - Mechanical jam 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

Future Roadmap

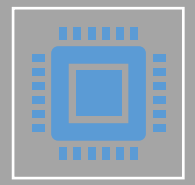
A version using a mini turbine

A version using compressed air

Neo-natal & Invasive Version

Add Vitals (SPO2, Pulse etc.) to the Dashboard

Dual Limb Breathing circuit



More powerful Microcontroller

About Us

Evangelizing Community Service through Technology

An extension of the community service initiative that delivered PARC

(Pilani AtmaNirbhar Resource Center*)
www.atmanirbhar.org

Establish pathways that students from various institutes can follow to serve our rural community

Establish a stepping-stone for more sophisticated systems targeting the bottom of the pyramid in future

* *The term AtmaNirbhar has been in use by PARC since 2008, and our URL!*

Thank you

Backup Details

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

sion. 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 की सांसें उखड़ रहीं, यहां स्टोर में 'शो-पीस' बने वेंटीलेटर

कहीं पर्याप्त प्रशिक्षित स्टाफ ही नहीं

पत्रिका न्यूज नेटवर्क

चूरू/चित्तौड़गढ़. 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 जहां चूरू में आधे वेंटीलेटर अभी तक स्टोर में ही हैं। वहीं, चित्तौड़गढ़ के जिला अस्पताल में पर्याप्त प्रशिक्षित स्टाफ नहीं होने से परेशानी आ रही है तथा यहां भी 25 वेंटीलेटर इंस्टाल ही नहीं किए गए।

चूरू स्थित डेडराज भरतिया 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 यहां 27 वेंटीलेटर उपयोग लिए जा रहे हैं। शेष 15 इंस्टॉल तक नहीं कराए गए।

चूरू स्थित भरतिया अस्पताल के स्टोर में रखे वेंटीलेटर।

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

डॉ. हनुमान जयपाल, एसोसिएट प्रोफेसर, मेडिकल कॉलेज, चूरू

दरअसल, वेंटीलेटर का संचालन प्रशिक्षित स्टाफ ही कर सकता है। वह भी उस स्थिति में जब निश्चेतना विशेषज्ञ मॉनिटरिंग कर रहा हो। कोविड-19 के चलते सरकार ने जिला अस्पतालों को वेंटीलेटर उपलब्ध करा दिए, लेकिन चलाने के लिए यहां 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 कार्मिक हैं।

25 वेंटीलेटर इंस्टाल ही नहीं किए गए

चित्तौड़गढ़ के जिला अस्पताल में कोरोना से पूर्व पांच वेंटीलेटर थे, जो बढ़कर 42 हो गए हैं। इनमें से कुछ फोल्डिंग वेंटीलेटर हैं। वेंटीलेटर पर मरीज को रखने के लिए आईसीयू का प्रशिक्षित स्टाफ चाहिए और निश्चेतन के चिकित्सक की निगरानी की व्यवस्था होनी चाहिए। यहां आईसीयू का प्रशिक्षित स्टाफ करीब आधा दर्जन का ही है जो आईसीयू में हैं। यहां कुल 42 वेंटीलेटर में से अभी भी पांच पुराने एवं सात नए वेंटीलेटर ही काम में आ रहे हैं। 25 तो इंस्टाल नहीं किए गए।

स्टोर की बढ़ा रहे शोभा

कुचेरा (नागौर). स्थानीय सांसद हनुमान बेनीवाल की अनुशंसा पर शहर के राजकीय सामुदायिक स्वास्थ्य केन्द्र को मिले पोर्टेबल वेंटीलेटर को सीएचसी के स्टोर में रख दिया गया है। चिकित्साकर्मियों ने बताया कि पोर्टेबल वेंटीलेटर वर्किंग मोड में है तथा जैसे ही जरूरत पड़ेगी। वार्ड में लेकर काम में ले लिया जाएगा।

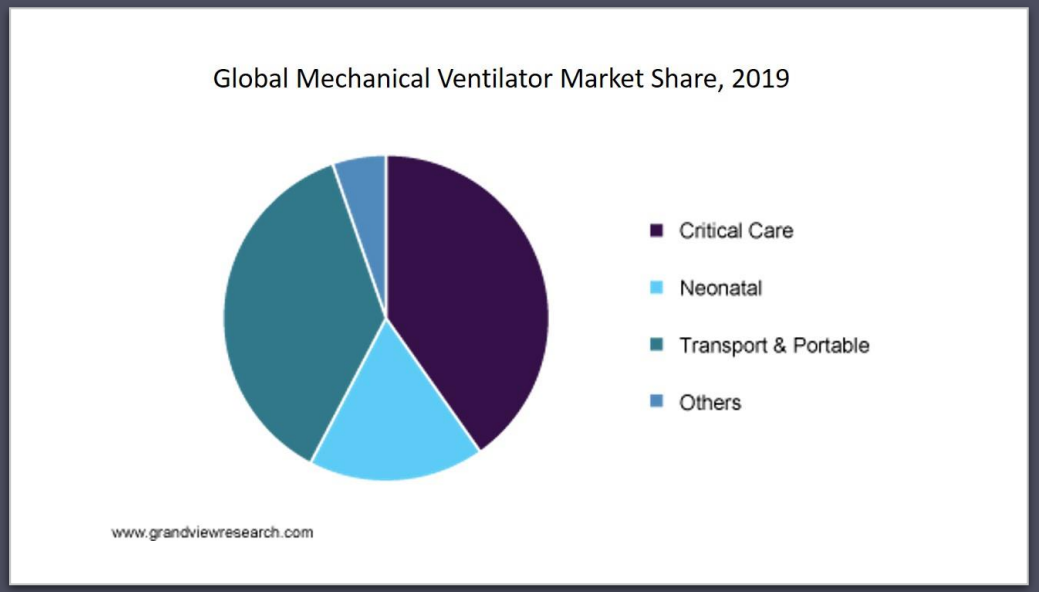
Market Need

25 to 50 ventilators per lakh people in developed countries

1.8 ventilators per lakh people* (India)

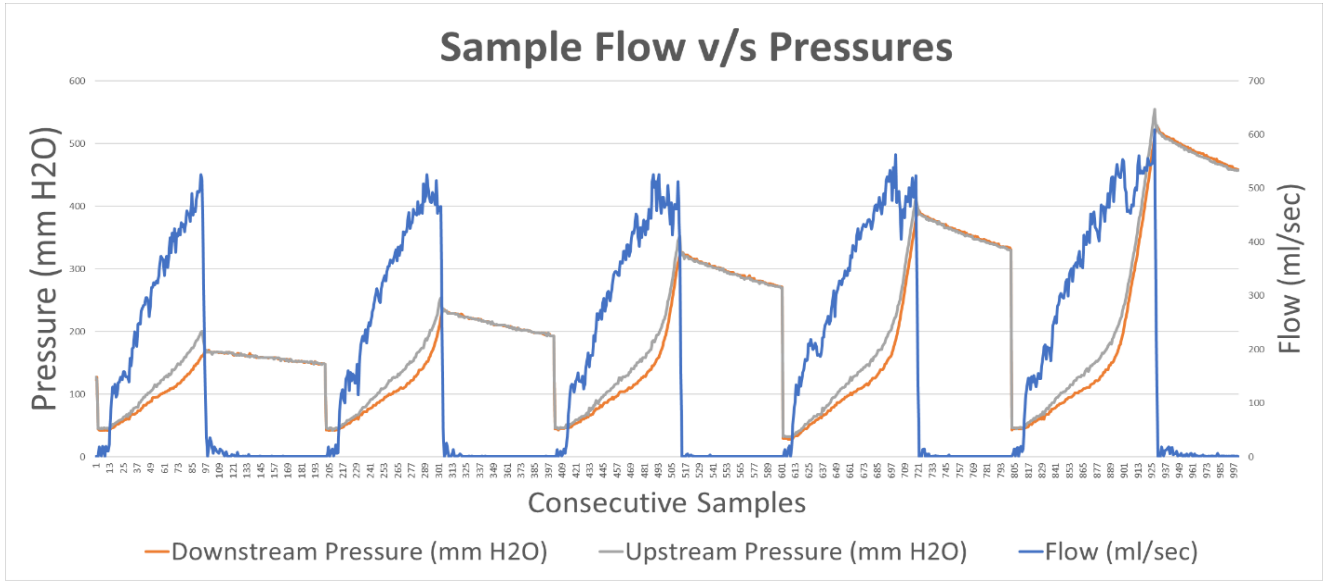
Even less for lower income developing and underdeveloped countries*

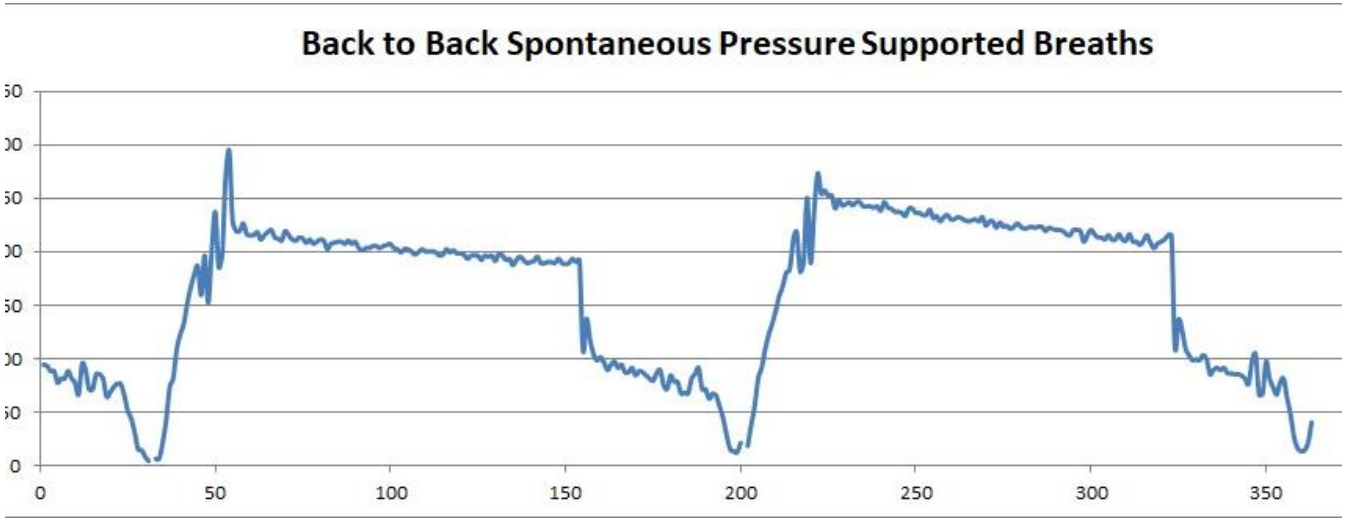
** As per April 2020 Study by Center for Disease Dynamics, Economics & Policy at Princeton University, USA*



Respimatic Sample Waveforms

Pressure , Flow and Spontaneous Breaths





Breath Synchronization in ACV Mode

Tidal volume is delivered at regular intervals T_i.

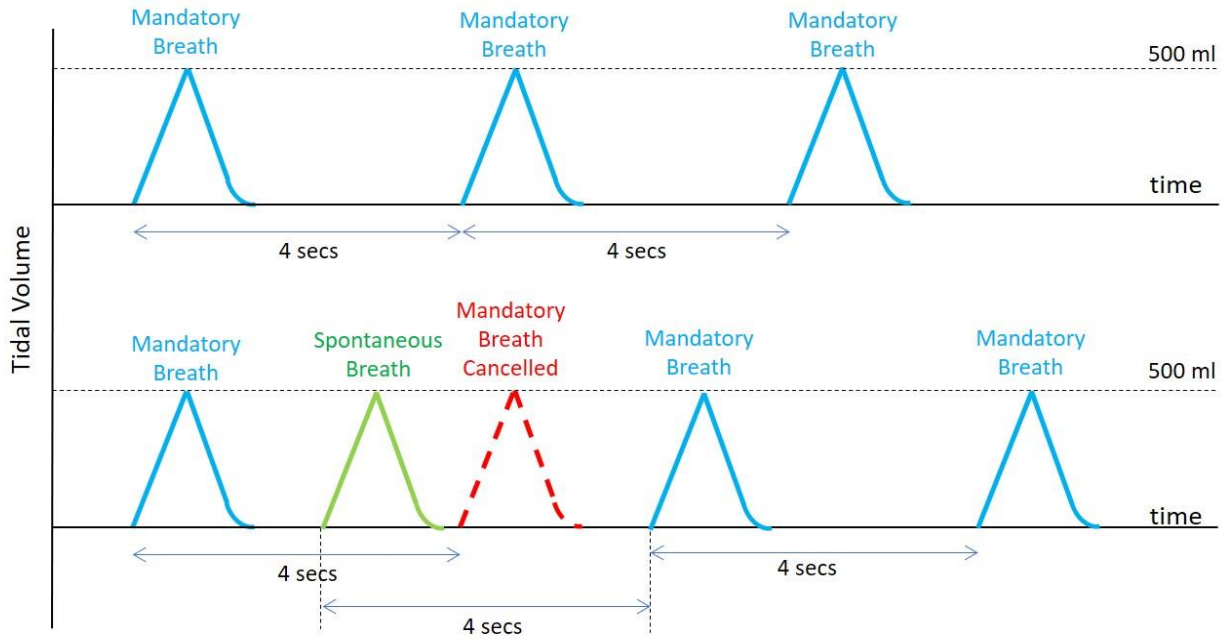
If spontaneous breath occurs during this interval at time T_s, the set tidal volume is delivered in response, and the next mandatory breath is set for (T_s+ T_i).

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

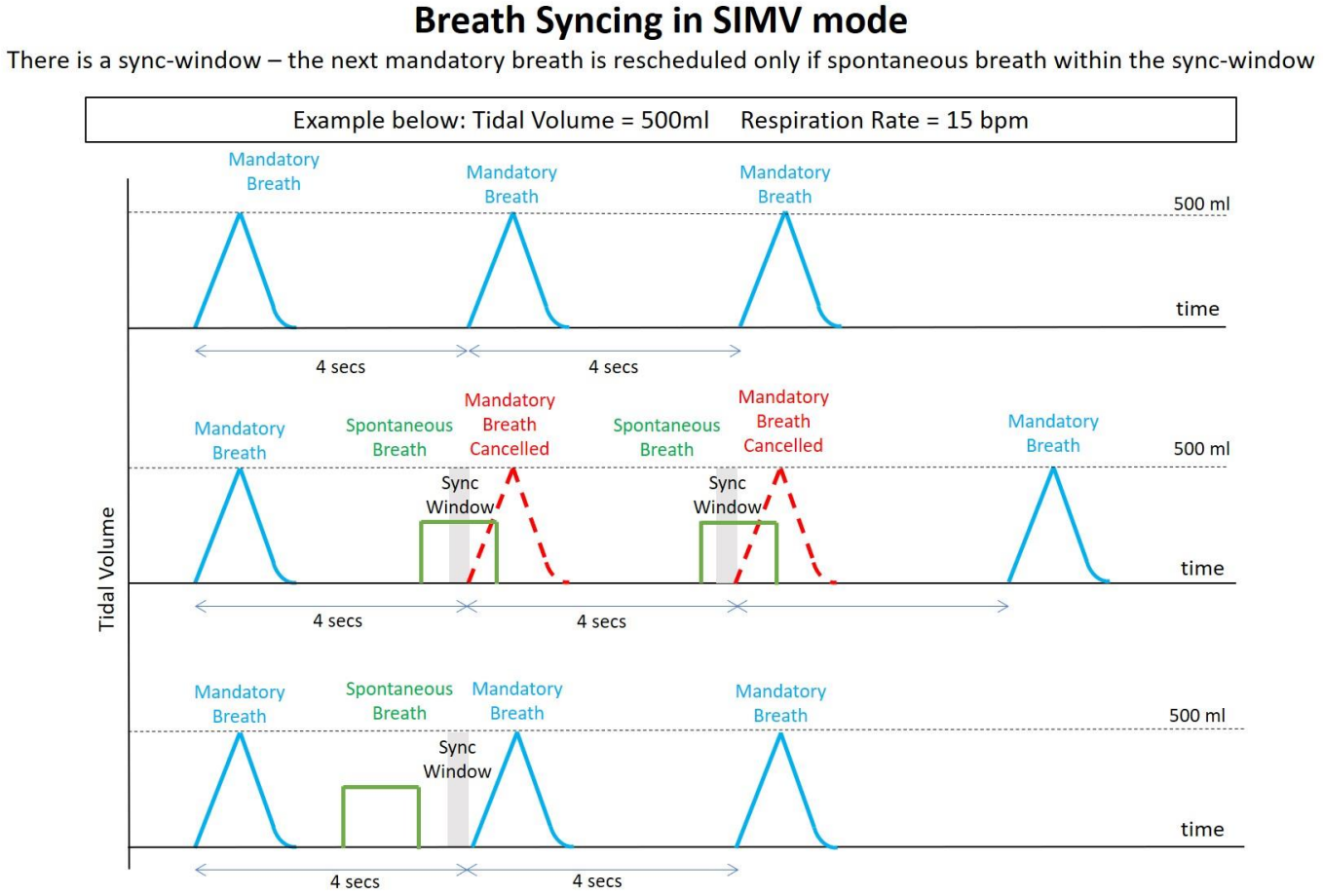


Breath Synchronization in SIMV Mode

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.



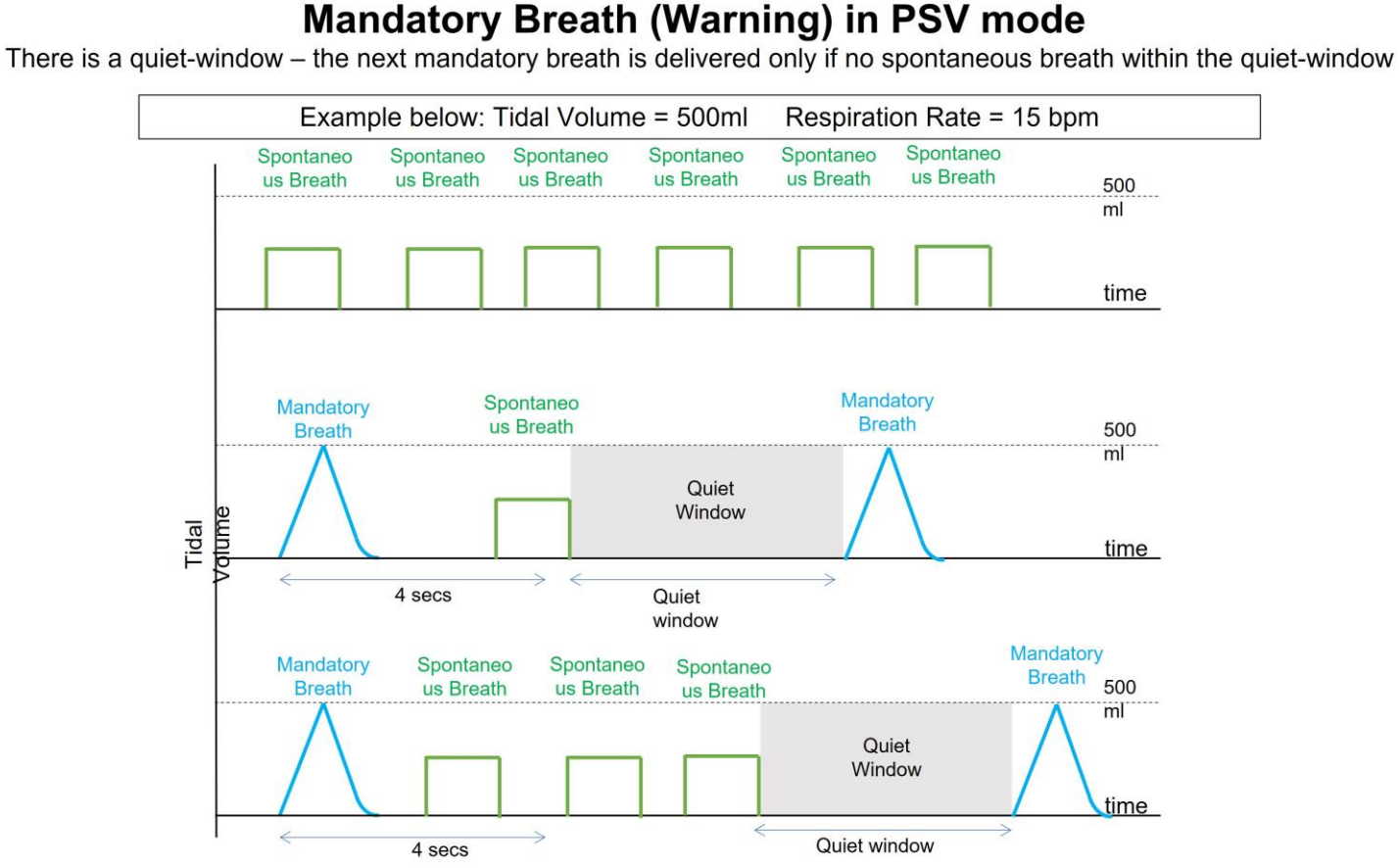
Exceptional Mandatory Breath in PSV Mode

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.



Expectations from the session

Gather feedback on overall product concept.

Do we have the right price/feature tradeoff ?

Is the feature set missing something critical ?

Need access to a sophisticated test lung for final calibration and tuning.

How can you help?