Respiratory Mechanics option

Introduction

The Respiratory Mechanics (RM) option for the 840™ ventilator provides respiratory maneuvers, including Negative Inspiratory Force (NIF), Occlusion Pressure (P_{0.1}) and Vital Capacity (VC), as well as automatic calculations of lung function and performance, such as Dynamic Compliance and Resistance, Peak Expiratory Flow, End Expiratory Flow, and Peak Spontaneous Flow.

Intended Use

Respiratory Mechanics information allows clinicians to assess lung health and performance, and helps to determine if the patient is ready to be weaned from the ventilator.

Overview — Respiratory Mechanics Maneuvers

RM maneuvers can be performed in all breathing modes except BiLevel™, and are not available during the following conditions:

- Apnea ventilation
- Safety PCV
- Occlusion Status Cycling (OSC)
- Non-invasive ventilation (NIV)
- When the circuit type is Neonatal
- When any other RM maneuver has already taken place during the same breath

The GUI also displays any RM request, distinguishing between requests that are accepted or rejected, and any RM maneuver that has begun, ended, or has been canceled.

When an RM maneuver is selected, a GUI information panel is opened, displaying the maneuver name, user prompts and controls, and recent calculated results.
Any RM maneuver is canceled automatically upon declaration of any of the following alarms:

- $\uparrow P_{\text{PEAK}}$ alarm
- $\uparrow P_{\text{VENT}}$ alarm
- $\uparrow V_{\text{TI}}$, $\uparrow \dot{V}_{\text{TI}}$ SPONT, $\uparrow \dot{V}_{\text{TI}}$ MAND, $\uparrow V_{\text{TI}}$

**Negative Inspiratory Force (NIF) maneuver**

The Negative Inspiratory Force (NIF) maneuver is a coached maneuver where the patient is prompted to draw a maximum inspiration against an occluded airway (the inspiratory and expiratory valves are fully closed).

A NIF maneuver is canceled if:

- Disconnect is detected
- Occlusion is detected
- SVO is detected
- Apnea is detected
- Communications with the GUI is lost
- The maneuver has been active for 30 seconds
- Inspiration Too Long alarm is declared

When a NIF maneuver is activated, a single Pressure-Time waveform is automatically displayed. This screen displays as long as the screen remains frozen.

During a NIF maneuver, the circuit pressure is displayed on the waveforms screen and regularly updated, producing a real-time display.

When an active NIF maneuver ends successfully, the calculated NIF result is displayed on the waveforms screen and on the maneuver panel. The NIF value displayed represents the maximum negative pressure from PEEP.

When a NIF maneuver ends, a PEEP restoration breath is delivered to the patient, then normal breath delivery resumes.
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**P\textsubscript{0.1} Maneuver (Occlusion Pressure)**

P\textsubscript{0.1} is the negative airway pressure (delta pressure change) generated during the first 100 ms of an occluded inspiration. It is an estimate of the neuromuscular drive to breathe.

When a P\textsubscript{0.1} maneuver ends successfully, the calculated airway pressure is displayed on the waveforms screen and on the maneuver panel. A P\textsubscript{0.1} maneuver is canceled if the maneuver has been requested for 7 seconds.

When the P\textsubscript{0.1} maneuver ends normally or abnormally, control is relinquished to the previously active breath scheduler.

**Vital Capacity (VC) Maneuver**

The Vital Capacity (VC) maneuver is a coached maneuver where the patient is prompted to draw a maximum inspiration (regardless of the current settings) and then to slowly and fully exhale.

When the Vital Capacity maneuver becomes active, the 840 ventilator delivers a spontaneous inspiration in response to patient effort (with P\textsubscript{SUPP} = 0, Rise time % = 50, and E\textsubscript{SENS} = 25), and then allows for a full exhalation effort.

When a Vital Capacity maneuver is requested, a single Volume-Time waveform is automatically displayed. This screen displays as long as the screen remains frozen. A Vital Capacity maneuver is canceled if:

- Disconnect is detected
- Occlusion is detected
- SVO is detected
- Apnea is detected
- Communications with the GUI is lost
- The maneuver has been requested for 5 seconds
- The maneuver as been active for 15 seconds
- The operator terminates it
When an active VC maneuver ends successfully, the calculated expiratory volume is displayed on the waveforms screen and on the maneuver panel.

Table 1 describes the RM maneuvers and the range, resolution, and accuracy for each.

**Table 1: RM monitored data**

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>Function</th>
<th>Range, resolution, accuracy</th>
</tr>
</thead>
</table>
| NIF      | Measures maximum inspiratory force against an occluded airway. | Range: -50 to 0 cmH\textsubscript{2}O  
Resolution:  
0.1 cmH\textsubscript{2}O NIF > -10 cmH\textsubscript{2}O  
1 cmH\textsubscript{2}O for NIF ≤ -10 cmH\textsubscript{2}O  
Accuracy: ± (2 + 4% of reading) cmH\textsubscript{2}O for flows < 60 L/min |
| P\textsubscript{0.1} | Measures pressure generated during the first 100 ms of inspiration against an occluded airway. | Range: -20 to 0 cmH\textsubscript{2}O  
Resolution:  
0.1 cmH\textsubscript{2}O for P\textsubscript{0.1} > -10 cmH\textsubscript{2}O  
1 cmH\textsubscript{2}O for P\textsubscript{0.1} ≤ -10 cmH\textsubscript{2}O  
Accuracy: ± (2 + 4% of reading) cmH\textsubscript{2}O |
| VC       | Measures maximum lung volume. | Range: 0 to 6000 mL  
Resolution:  
0.1 mL for 0 to 9.9 mL  
1 mL for 10 to 6000 mL  
Accuracy:  
For T\textsubscript{I} < 600 ms:  
± [10 + (10% x 600/T\textsubscript{E} ms of setting)] mL  
For T\textsubscript{I} > 600 ms:  
± [10 + (10% of setting)] mL  
where T\textsubscript{E} = time to exhale 90% of volume. |
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Access and Use

When a NIF, P_{0.1}, or VC maneuver is requested, a single Pressure-Time or Volume-Time waveform is displayed in the Waveforms area of the Patient Data screen. Scaling is appropriate to the requested maneuver. Following a completed maneuver, the waveform is frozen and the measured value for the maneuver is displayed above the displayed waveform.

To access and use the RM options:

1. On the lower GUI screen, touch the OTHER SCREENS button to access the RM options, Figure 1.

![Figure 1. Accessing RM options](image)

2. Touch the corresponding button to select the desired RM maneuver (NIF, P_{0.1}, or VC).
To perform a NIF maneuver:

1. Touch the NIF Maneuver button, \textbf{NIF Maneuver}.
2. Touch and hold the START button, as directed on the screen, Figure 2.

3. To complete the maneuver, release the START button.
4. Observe the screen display following the successful NIF maneuver, Figure 3.

\textbf{Figure 2. Beginning a NIF maneuver}
5. If you want to store the data for recall later, touch the ACCEPT button on the right side of the screen, as shown in Figure 4 (or initiate another maneuver). If not, touch REJECT. If you do not touch either button, the data are stored automatically. The data storage area displays the three most recently accepted maneuver results.
**P₀.₁ Maneuver**

To perform a P₀.₁ maneuver:

1. Touch the P₀.₁ Maneuver button, \[ \text{P₀.₁ Maneuver} \].
2. To activate the maneuver, touch the START button, as directed on the screen, Figure 5.

3. Once the maneuver is activated, the ventilator will wait for up to seven seconds for the patient to take a breath and complete the maneuver.
4. Observe the screen display following the successful P₀.₁ maneuver, Figure 6.

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**Figure 5. Beginning a P₀.₁ maneuver**

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5. If you want to store the data for recall later, touch the ACCEPT button on the right side of the screen, as shown in Figure 7 (or initiate another maneuver). If not, touch REJECT. If you do not touch either button, the data are stored automatically. The data storage area displays the three most recently accepted maneuver results.
VC Maneuver

To perform a VC maneuver:

1. Touch the VC Maneuver button.
2. To begin the maneuver, touch the START button, as directed on the screen, Figure 8.
3. A maximum inspiratory effort followed by a maximum expiratory effort will complete the maneuver.
4. Observe the screen display following the successful VC maneuver, Figure 9.

Figure 8. Beginning a VC maneuver
5. If you want to store the data for recall later, touch the ACCEPT button on the right side of the screen, as shown in Figure 10 (or initiate another maneuver). If not, touch REJECT. The data storage area displays the three most recently accepted maneuver results.

![Figure 9. VC Maneuver Results Display](image)

![Figure 10. Accept or Reject VC data](image)
Respiratory Mechanics Calculations

RM calculations of lung function and performance are automatically displayed on the Respiratory Mechanics subscreen of the More Patient Data display:

- Dynamic Compliance ($C_{DYN}$) and Dynamic Resistance ($R_{DYN}$)
- Peak Spontaneous Flow
- Peak Expiratory Flow
- End Expiratory Flow

1. To access calculated values, press the MORE PATIENT DATA button.

2. Observe the standard data subscreen, as shown in Figure 11.

3. Touch the Respiratory Mechanics button in the lower right corner of the subscreen, as shown in Figure 11.
4. Observe the calculated RM values, Figure 12.

Figure 12. RM More Patient Data screen
Technical Discussion

Respiratory Mechanics Calculations

The Respiratory Mechanics option calculates and displays clinical indicators that may be useful in assessing the patient’s current pulmonary condition lung and chest wall impedance, airway integrity, flow demand, and potential for Auto-PEEP. The RM calculations displayed in the RM subscreen of the More Patient Data screen are:

- Dynamic Compliance and Resistance
- Peak Expiratory Flow rate
- End Expiratory Flow rate

These calculations are performed on every qualified breath (e.g., they are not calculated during Apnea Ventilation, Severe Occlusion, nor during PEEP restoration breaths).

- Peak Spontaneous Flow rate — This value is calculated for spontaneous inspirations only.

In addition to the above calculations, currently available calculations are also displayed on the RM subscreen as the data become available. These include:

- Static Compliance ($C_{\text{STAT}}$)
- Static Resistance ($R_{\text{STAT}}$)
- Intrinsic PEEP ($\text{PEEP}_I$)
- Rapid Shallow Breathing Index ($f/V_T$)

Refer to the 840 Ventilator Operator’s and Technical Reference Manual for more information on these calculated parameters.

General characteristics applicable to the display of RM calculations

When no spontaneous breaths have occurred for a period greater than 2 minutes, the spontaneous RM patient data indicators in the RM Subscreen are not shown. The indicators reappear when their value is updated (when the next spontaneous breath is measured).
When no mandatory breaths have occurred for a period greater than 2 minutes, the mandatory RM patient data indicators in the RM Subscreen are not shown. The indicators reappear when their value is updated (when the next mandatory breath is measured).

Respiratory Mechanics calculations are not performed under the following conditions:

- When vent type is NIV
- When mode is BILEVEL
- During Apnea ventilation, OSC, disconnect, or Safety PCV
- If there is a loss of patient data monitoring functions

**Dynamic Compliance (CDYN) and Dynamic Resistance (RDYN)**

**NOTE:**

The presence of auto-PEEP may affect the accuracy of RDYN and CDYN calculations.

RM estimates the compliance and resistance of the patient’s lungs and chest wall. The measurement of CDYN and RDYN indicate the impedance characteristics of the lungs, chest wall and conducting airways. Changes in either of these values may reveal changes in the elastic properties of the lung and/or chest wall or in the ability of the conducting airways to accommodate a particular flow of gas.

Dynamic Compliance and Dynamic Resistance are calculated only for mandatory breaths.

**Peak Expiratory Flow (PEF) rate**

Peak Expiratory Flow is the maximum flow rate observed during exhalation, excluding the first 100 ms of data. PEF can be used as an indicator of obstructed airways.

**End Expiratory Flow (EEF) rate**

End Expiratory Flow is the rate of expiratory flow that occurs at the end of exhalation and can be used to determine whether expiratory time is adequate to prevent gas trapping and intrinsic PEEP.
The End Expiratory Flow rate is calculated as the expiratory flow that occurs when either flow integration terminates during exhalation or when a new breath is initiated.

**Peak Spontaneous Flow (PSF) rate**

Peak Spontaneous Flow is the maximum inspiratory flow rate sampled during a spontaneous inspiration. It is a good predictor of impending air hunger and helps the clinician set peak flow or choose an optimum level of pressure support.

Table 2 describes the RM calculated parameters and the range, resolution, and accuracy for each.

**Table 2: RM calculated data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Function</th>
<th>Range, resolution, accuracy</th>
</tr>
</thead>
</table>
| Dynamic compliance (CDYN)  | Estimates the elastic properties of the lung, chest wall, and airways. Based on least squares estimation algorithm. | Range: 0 to 200 mL/cmH\textsubscript{2}O  
Resolution:  
0.1 mL/cmH\textsubscript{2}O for CDYN < 10 mL/cmH\textsubscript{2}O  
1 mL/cmH\textsubscript{2}O for CDYN ≥ 10 mL/cmH\textsubscript{2}O  
Accuracy: ± (1 + 20% measured value) mL/cmH\textsubscript{2}O |
| Dynamic resistance (RDYN)  | Estimates the resistive characteristics of the lung, chest wall, and airways. Based on least squares estimation algorithm. | Range: 0 to 100 cmH\textsubscript{2}O/L/s  
Resolution:  
0.1 cmH\textsubscript{2}O/L/s for RDYN < 10 cmH\textsubscript{2}O/L/s  
1 cmH\textsubscript{2}O/L/s for RDYN ≥ 10 cmH\textsubscript{2}O/L/s  
Accuracy: ± (3 + 20% measured value) cmH\textsubscript{2}O/L/s |
| Peak expiratory flow (PEF) | Estimates maximum exhaled flow rate.               | Range: 0 to 150 L/min  
Resolution:  
0.1 L/min for PEF < 20 L/min  
1 L/min for PEF ≥ 20 L/min  
Accuracy: ± (0.5 + 10% of actual value) |
### Table 2: RM calculated data (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Function</th>
<th>Range, resolution, accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>End expiratory flow (EEF)</td>
<td>Estimates expiratory flow rate at the end of exhalation.</td>
<td>Range: 0 to 150 L/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resolution:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1 L/min for EEF &lt; 20 L/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 L/min for EEF ≥ 20 L/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accuracy:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>± (0.5 + 10% of actual value)</td>
</tr>
<tr>
<td>Static compliance (CSTAT)</td>
<td>Estimates the elasticity of the patient’s lungs. Based on the occlusion maneuver.</td>
<td>Range: 0 to 500 mL/cmH₂O</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resolution:</td>
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<tr>
<td></td>
<td></td>
<td>0.1 mL/cmH₂O for 0 to 9.9 mL/cmH₂O</td>
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<tr>
<td></td>
<td></td>
<td>1 mL/cmH₂O for 10 to 500 mL/cmH₂O</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accuracy:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>± (1 + 20% of actual value) mL/cmH₂O for 1 to 100 mL/cmH₂O</td>
</tr>
<tr>
<td>Static resistance (RSTAT)</td>
<td>Estimates the restrictiveness of the patient’s airway. Based on the occlusion maneuver.</td>
<td>Range: 0 to 500 cmH₂O/L/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resolution:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.1 cmH₂O/L/s for 0 to 9.9 cmH₂O/L/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 cmH₂O/L/s for 10 to 500 cmH₂O/L/s</td>
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<tr>
<td></td>
<td></td>
<td>Accuracy:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>± (3 + 20% of actual value) cmH₂O/L/s (Does not apply if CSTAT &lt; 5 mL/cmH₂O or VMAX &lt; 20 L/min)</td>
</tr>
<tr>
<td>Intrinsic PEEP (PEEPi)</td>
<td>Estimates the pressure above PEEP at the end of exhalation.</td>
<td>Range: -20.0 to 130 cmH₂O</td>
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<tr>
<td></td>
<td></td>
<td>Resolution:</td>
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<tr>
<td></td>
<td></td>
<td>0.1 cmH₂O for -20.0 to 9.9 cmH₂O</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 cmH₂O for 10 to 130 cmH₂O</td>
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<tr>
<td></td>
<td></td>
<td>Accuracy:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
### Table 2: RM calculated data (continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Function</th>
<th>Range, resolution, accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak spontaneous flow (PSF)</td>
<td>Estimates the maximum inspiratory flow rate during a spontaneous breath.</td>
<td>Range: 0 to 200 L/min&lt;br&gt;Resolution: 0.1 L/min for PSF &lt; 20 L/min&lt;br&gt;1 for PSF ≥ 20 L/min&lt;br&gt;Accuracy: ± (0.5 + 10% of actual value)</td>
</tr>
<tr>
<td>Rapid shallow breathing index (f/V̇T)</td>
<td>Estimates the ratio of respiratory rate to inspired volume measurements.</td>
<td>Range: 0.0 to 600 1/min-L&lt;br&gt;Resolution: 0.1 for f/V̇T &lt; 10 1/min-L&lt;br&gt;1 for f/V̇T ≥ 10 1/min-L&lt;br&gt;Accuracy: Not applicable</td>
</tr>
</tbody>
</table>