

“Body Temperature & Pressure, Saturated” & Ambient Pressure Correction in air medical transport

Mechanical ventilation can be especially challenging during air medical transport, particularly due to the impact of varying atmospheric pressure with changing altitudes. The Oxylog® 3000 plus and Oxylog® 2000 plus help to effectively deal with these challenges.



Artificial ventilation uses compressed gas to deliver the required volume to the patient. This breathing gas has normally an ambient temperature level and is very dry. Inside the human lungs the gas expands due to a higher temperature and humidity level. These physical conditions are described as “Body Temperature & Pressure, Saturated” (BTPS), which presumes the combined environmental circumstances of

- a body temperature of 37 °C / 99 °F
- ambient barometrical pressure conditions and
- breathing gas saturated with water vapour (= 100 % relative humidity).

Aside from the challenge of changing temperatures and humidity inside the patient lungs, the ambient pressure is also important to consider. Flight altitudes in air medical transports can reach up to 14,800 ft/4,500 m. Although helicopter rescue missions rarely go to altitudes that require the body to adapt, alterations associated with the changing ambient pressure can have a significant impact on

the ventilation volumes delivered by the ventilator. Mechanical ventilation in fixed wing aircraft without a pressurized cabin is subject to the same dynamics. In case of a pressurized cabin it is still relevant to correct the inspiratory volumes, as the cabin is usually maintained at a pressure of approximately 800 mbar (600 mmHg), comparable to an altitude of 8,200 ft/2,500 m.

- Without BTPS correction, the delivered inspiratory volume can deviate up to 14 % (at 14,800 ft/4,500 m altitude) from the targeted set volume (i.e. 570 ml instead of 500 ml).
- Without ambient pressure correction, the inspiratory volume can deviate up to 44 % (at 14,800 ft/4,500 m altitude) from the targeted set volume (i.e. 720 ml instead of 500 ml).

The Oxylog 3000 plus and Oxylog 2000 plus automatically correct the delivered volume for BTPS and ambient pressure, while also taking atmospheric pressure differences into account.



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Figure 1: Oxylog® 3000 plus
The Oxylog® 3000 plus automatically compensates volume delivery and measurement



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Figure 2: Oxylog® 2000 plus



Figure 3: Example of a medical interior system

With BTPS and ambient pressure correction the operator is able to spend more time on patient care.

BTPS CORRECTION IN OXYLOG

The Oxylog 3000 plus and Oxylog 2000 plus correct the delivered and measured volume of the breathing gas in order to achieve optimal BTPS conditions within the patient's lungs, where temperature, humidity and pressure differ from those of the outside environment. The correction is based on the assumption that the temperature of the breathing gas delivered by the Oxylog (the inspiratory gas) is 21.1°C/70°F as well as dry and that the temperature of the breathing gas inside the human lungs will be 37°C/99°F fully saturated.

AMBIENT PRESSURE CORRECTION IN OXYLOG

In addition to the BTPS correction, the Oxylog 3000 plus and Oxylog 2000 plus automatically compensate ambient pressure changes. Oxylogs automatically correct the volumetric flow rate for changes in ambient pressure due to changing

altitudes in volume controlled ventilation modes. As a result, the volume delivered to the patient is kept at a constant level, regardless of the altitude.

The Oxylog 3000 plus and Oxylog 2000 plus measure the ambient air pressure via two internal pressure sensors and measure the flow rate via an internal flow sensor, which is assumed to be delivered at 1023 mbar (767 mm Hg) which is the pressure at sea level + 10 mbar (10 cm H₂O) Airway Pressure (PAW). Based on the measured ambient pressure, this measured flow rate is then converted into the correct flow at actual ambient pressure conditions, which is required for delivering the set volume in BTPS. The flow rate correction is dynamic and is adjusted breath by breath to compensate for aircraft changing altitudes and can vary between 1% and 44% (44% at 14,800 ft/4,500 m).



Figure 4: The Oxylog® 3000 plus in action

EXAMPLE BTPS AND AMBIENT PRESSURE CORRECTION

If you set a Vt of 500 ml at sea level, the Oxylog 3000 plus and Oxylog 2000 plus will deliver 447 ml as this volume will expand to 500 ml in the patients lungs.

Formula: $V_t \text{ of } 500 \text{ ml} \times (294 \text{ Kelvin} / 310 \text{ Kelvin})^1 \times (1023 \text{ mbar (767 mmHg)} / 1086 \text{ mbar (815 mmHg)})^2 = 447 \text{ ml}$.
(Assumption of PAW mean = 10 mbar (10 cmH₂O))

If you set a Vt of 500 ml at an altitude of 14,800 ft/4,500 m, the ventilator will deliver 428 ml.

Formula: $V_t \text{ of } 500 \text{ ml} \times (294 \text{ Kelvin} / 310 \text{ Kelvin})^1 \times (580 \text{ mbar (435 mmHg)} / 643 \text{ mbar (482 mmHg)})^3 = 428 \text{ ml}$.
(Assumption of PAW mean = 10 mbar (10 cmH₂O))

Formula's explained:

Note 1:

294 Kelvin \approx 21 °C and 310 Kelvin \approx 37 °C/99 °F.

Note 2:

1023 mbar (767 mmHg) = 1013 mbar (760 mmHg) ambient pressure at sea level + 10 mbar (10 cmH₂O) PAW.
1086 (815 mmHg) mbar = 1023 mbar (767 mmHg) (see above) + 63 mbar (47 mmHg) of the PH₂O at 37 °C/99 °F.

Note 3:

580 mbar (435 mmHg) = 570 mbar (428 mmHg) ambient pressure at 14,880 ft/4,500 m + 10 mbar (10 cm H₂O) PAW.
643 mbar (482 mmHg) = 580 mbar (435 mmHg) (see above) + 63 mbar (47 mmHg) of the P H₂O at 37 °C/99 °F.

Oxylog 3000 plus and Oxylog 2000 plus compensate volume delivery and measurement for typical environmental influences during air medical transport by applying BTPS and ambient air pressure correction. The corrections are automatic, dynamic and are adjusted breath by breath to compensate for aircraft changing altitudes and therefore can help preventing barotrauma. As a result the operator is able to spend more time on patient care.



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Figure 5: Oxylog® 3000 plus
BTPS and ambient pressure correction is automatically done

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