

THERMODYNAMIC CHARACTERISTICS OF A PROTOTYPE RESPIRATORY HEAT AND MOISTURE EXCHANGER.

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INTRODUCTION

The benefits of inspiring humidified gas has long been recognized, and consequently applied, in clinical environments. Inspired gas from compressed gas cylinders is dry and may cause irritation and enhanced heat loss. Similarly, intubated patients and patients with tracheostomies, cannot benefit from the heat and moisture exchange that is normally present in the upper airways. Thus, a plethora of humidifiers and heat and moisture exchangers (HME) have been developed and tested.

The possibility of humidifying and heating inspired *air* in subzero ambient conditions has also received some attention, as it may benefit personnel working in such environments (1, 2). Whereas the HME's for clinical *use* have been subject to much scrutiny and evaluation, similar evaluation of HME's for subzero ambients is scant.

The present study evaluated the efficiency of a prototype HME over a range of simulated ambient temperature conditions.

METHODS

Prototype HME

The prototype heat and moisture exchanger comprises a thermally insulated oro-nasal mask with a cylindrical heat and moisture exchanging unit protruding from the centre of the mask. The heat exchanging unit contains a "honeycomb" aluminum structure (Goodfellow Corp., Malver, PA.), providing a total surface area of **478.5**cm² for the exchange of heat and moisture between the inspired and expired air.

Principle of operation

As with most passive HME devices, the expired gas cools as it passes through the aluminum honeycomb structure, thus transferring heat to the aluminum walls. As the *gas* cools, water condenses and is retained *in* the honeycomb-shaped cells. On inspiration, the heat *and* moisture retained by these cells is transferred to the colder and drier *gas*. Thus, the HME minimizes the total loss of respiratory heat and moisture.

Experimental arrangement

A breathing simulator provided two levels of ventilation: **11.25** and **28.00** Lmin⁻¹, simulating rest and light exercise conditions. The breathing simulator was a hydraulically driven piston, whose frequency and distance of travel could be controlled. The former simulating respiratory frequency and the latter tidal volume. For the purpose of this investigation, the tidal volume was kept constant at 1.5L and only the frequency varied to achieve the two levels of simulated respiration.

The breathing simulator was connected to a valve arrangement, such that the expired gas was drawn through a water bath and subsequently through the HME. On inspiration, the gas was returned via respiratory tubing to the breathing simulator. The temperature of the water bath was maintained at a level ensuring that the expired gas was approximately 37°C and saturated with water vapour (≈43°C).

The HME was strapped to the head of a manikin, whose mouth was connected to the respiratory simulator. The entire arrangement was placed in a climatic chamber maintained at the desired temperature. The temperature of the ambient air was monitored in close proximity of the HME.

Instrumentation

The temperature within the oro-nasal mask of the HME was measured with a T-type thermocouple and recordings made at 0.9 sec. intervals with a Hewlett Packard Data Acquisition System (Model HP 3497A, Hewlett Packard, Andover, MA). At any given temperature condition, the measurements were made over a one minute period for the two levels of ventilation. This time was found to be adequate to attain a steady state level of inspired/expired temperatures.

The HME was evaluated at ambient temperatures of -24.0 ± 0.3, -13.8 ± 0.5, -3.8 ± 0.3, 8.2 ± 0.1 and 21.7 ± 20.03 °C and at two levels of ventilation.

Analysis

The efficiency of the HME was evaluated by determining the performance coefficient (PC) under each condition, as suggested by Johnson *et al.* (3), whereby:

$$PC (\%) = (T_{in} - T_a) / (T_{ex} - T_a) \times 100 \quad \dots(1)$$

where,

- T_{in} = inspired air temperature
- T_{ex} = expired air temperature
- T_a = ambient air temperature

RESULTS

Results of the trial conducted at -24.0°C are presented in Fig. 1. The first half of the two minute period shown represents the portion of the trial during which ventilation was maintained at 11.25 L.min⁻¹, whereas the latter half of the graph represents the period during which ventilation was elevated to 28.00 L.min⁻¹. For this trial, with V_E=11.25 L.min⁻¹, expired air temperature was maintained at 34.9 ± 0.4 °C, inspired air temperature at 22.2 ± 0.2 °C. When ventilation was increased to 28.00 L.min⁻¹, expired temperature was 36.3 ± 0.7°C and inspired temperature 24.9 ± 0.6°C. For this simulated ambient condition, the HME was able to elevate the inspired air temperature by 47.4 ± 0.6°C. The humidity in the oro-nasal mask was maintained near saturation throughout the trial. The efficiency of the HME for the conditions tested is summarized in Fig. 2.

The performance coefficients (PC) calculated according to equation 1 for all conditions tested are presented in Table 1. It can be seen that the PC for the HME at -24.0°C was 78.4 ± 0.8 and 80.6 ± 0.6 % at ventilation rates of 11.25 and

28.00 L.min⁻¹, respectively; at temperatures above 0°C, the PC decreased progressively.

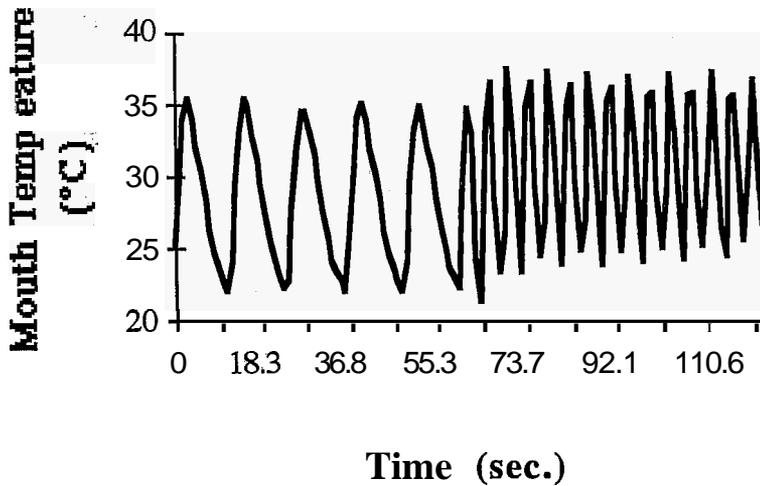


Fig. 1: Temperature in the oro-nasal mask of the prototype HME during evaluation at -24°C at ventilation rates of 11.25 L.min⁻¹ (initial 60sec. of the trace) and 28.00 L.min⁻¹ (last 60 sec. of the trace).

Ambient Temperature (°C)	Performance Coefficients(%)	
		$V_E = 11.25$ L.min ⁻¹

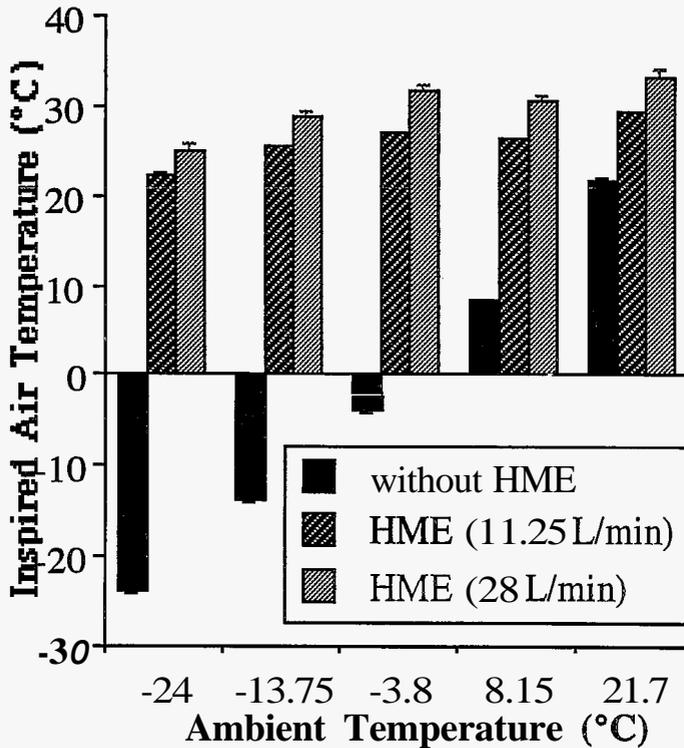


Fig. 2: Temperature within the oro-nasal mask of the prototype HME for a range of ambient temperatures at ventilation rates of 11.25 and 28.00 L.min⁻¹ (hatched bars). The solid bars indicate the temperature of the inspired air, with no HME employed.

REFERENCES

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