Circle-System with inhalation anesthesia for totally controlled ventilation for mouse and rat.

A. Flowmeter with gas supplies of $O_2$, $N_2O$ (and air) with 1 tube per gas for extra low flow adjustment.

B. Vaporizer for halothane, isoflurane or enflurane with very accurate performance also at low flows, and fully temperature compensated.

C. Concept of the UNO Micro-Ventilator for Mouse/Rat ventilation. Adjustable for volume, frequency and gas pressure with a sinus-form ventilation pattern.

UNO offers a complete range of anesthetic equipment, i.e.:
- Flowmeters
- Vaporizers for Isoflurane or Enflurane
- Ventilators for mice and rats with bodyweight > 15 grams.
Anaesthetic pump for small animals
Down-scaling does not mean miniaturising! * May Bost: CPV Maastricht University -Oct - ‘99

Small animals such as rats and mice naturally have a high basal metabolism, with a corresponding rapid heart rate and breathing rate. This should be taken into account when these animals are given an anaesthetic using inhalation gasses, particularly if active ventilation is given using an anaesthetic pump. The animals should generally be ventilated at a high frequency and with a low pressure. The small diameter of the intubation tubes used means that the resistance for the gasses is high and the gas-flow-rates will also be high due to this small diameter. As a result the pump has to be able to generate relatively high pressures in order to pump enough gas in and out of the lungs. The pressure change in the intubation tube is strongly dependent on the pressure pattern supplied by the pump.

Traditionally a block- or trapezium-shaped pressure pattern is delivered by the ventilation (or anaesthetic) pumps. This pattern includes a so-called plateau pressure. In heavier animals, such as rabbits, the pressure in the lungs will follow the delivered pressure pattern, partly due to the large diameter and low pressure loss in the tube. The pumps which are used for these animals are often over-sized. They usually contain actively-controlled magnetic valves which cause peak pressures in the system when small gas volumes are delivered during opening and closing. The delivered pressure patterns are markedly influenced by this. A small change in the pump’s settings can make these patterns as good as unpredictable, with negative consequences for the quality of the anaesthetic. Thus the stroke volume delivered by the pump will increasingly deviate from the tidal volume (the actual gas pumped in and out of the lungs), as the resistance in the tube increases.

It can therefore happen that the pump’s settings for a 20 g mouse and a 300 g rat are the same! Even if the pump’s settings are the same, the peak pressures which occur during ventilation of a mouse are significantly higher. Furthermore, a completely different respiration pressure pattern will develop. This is an important matter to take into consideration. To overcome these peak pressures, a pressure pattern has been searched for where no peaks occur so that the nature of the ventilation does not change when the pump’s settings are changed. No kinks or other abrupt pressure differences should occur in this pattern.

Observation of the breathing pattern of awake mice and rats found that the frequency was so high that there was no rest phase at any point. Consequently there will be no plateau pressure during spontaneous breathing. On the basis of this information, an anaesthetic pump which generates a sinus pressure pattern was chosen. Ventilation pressure measurements in the trachea, just before the bifurcation, in anaesthetised and ventilated rats and mice found that the pressure pattern here followed that delivered by the pump. Regardless of the sinus pump settings, there were no peak loads in the breath-pressure pattern. This is in contrast to the pumps with magnetic valves.

The development of this pump with a sinus-pressure-wave pattern together with further development of the low-flow anaesthetic vaporisers, has made it possible to reliably apply inhalation anaesthesia with active ventilation to small animals.
Figure 2.

**Ventilation pattern** of the ventilator.

**Pressure pattern** in the lungs of the animal.

**Block Wave**
produced by magnet-valve operated ventilator.

Risk of peak pressure in the lungs of the animal at opening of the valve in the ventilator.

**Trapezium**
produced by big bellows operated ventilator.

Not really suitable for small animals such as mouse and rat.

**Flattened Sinus**
produced by the UMV.

No risk of peak-pressure and very similar to the spontaneous breathing pattern of mouse and rat.
Pressure Measuring at the trachea/bifurcation in a rat during inhalation anesthesia with controlled ventilation.

At this point, the UMV settings for volume and pressure were greatly reduced. It can be seen that after ± 6 - 7 “breathings”, the ventilation pattern forms again the UMV characteristic SINUS-form.
LUNG VOLUMES AND CAPACITIES

I. Lung Volumes
A. Tidal volume ($V_T$) = volume of air entering or leaving the lungs during a single breath.
B. Inspiratory reserve volume (IRV) = volume of air which can be inspired over and above the resting tidal volume.
C. Expiratory reserve volume (ERV) = volume of air which can be expired after a normal expiration.
D. Residual volume (RV) = volume of air remaining in the lungs after a maximal expiration.
   Can be estimated as 25% of the vital capacity.

II. Lung Capacities.
A. Inspiratory capacity (IC) = maximum volume which can be inspired after a normal expiration
   = $V_T$ + IRV.
B. Vital capacity (VC) = maximum volume that can be expired after a maximal inspiration
   = $V_T$ + IRV + ERV.
C. Functional residual capacity (FRC) = volume of air left in the lungs after a normal expiration
   = ERV + RV.
D. Total lung capacity (TLC) = volume of the lungs when fully inflated = VC + RV (or 1.25 x VC).

III. Other.
A. Respiratory rate ($f$) = number of breaths per min.
B. Minute ventilation ($V_{\text{E}}$) = total volume of air expired per minute = $V_T \times f$.
C. Dead space ($V_d$) = volume of inspired air which is not available for gas exchange.
D. Alveolar ventilation ($V_a$) = volume of air which reaches the alveoli per min = ($V_T - V_d$) x $f$. 

- Lung Volumes
- Lung Capacities