TSE
Technical & Scientific
Equipment GmbH

TSE Animal Respirator

“Advanced“ model

Contents

TSE Animal Respirator
"Advanced" model

1. Introduction

The new **TSE Animal Respirator, "Advanced" model,** is a modern and versatile electronically controlled system for the respiration of laboratory animals.

The respirator is supplied complete with a special tracheal cannula adapter and tubing connections that can be connected to any commercially available tracheal cannula.

The instrument has already been calibrated by the manufacturer. All the sensors used are practically maintenance-free.

1.1. Operating principle

The instrument works according to the intermittent positive pressure ventilation principle. A continuous air/gas stream, adjustable by means of metering valves, is led via solenoid valves to the animal (inspiration phase) or to the overflow outlet (plateau or expiration phase).

In contrast to the Starling respiration principle, in this type of respiration system the ratio between the inspiration phase and the expiration phase is not fixed but is **freely selectable**.

Air/O_2 and/or anesthetic gas flows are set on the flow controllers and, after any further enrichment with added anesthetics (via an evaporator), are led to the animal via the inspiration valve.

The air which the animal exhales is not removed by suction but only led away to the atmosphere (passive exhalation) and is available for further measurements.

1.2. Animal-specific configuration

Because of its flexibility the system can be configured according to the customer's requirements for the respiration of all commonly used types of laboratory animals (from mouse to dog). Adaptation is carried out by equipping the instrument with suitable flow controllers which differ from each other in the volume flow rate per time unit.

The system is supplied with 2 mechanical flow controllers selected by the user. Retrofitting with other flow controllers is possible.

Animal	Flow controller	Range
Mouse	max. 1 l/min	0.1 - 1 l/min
Rat / guinea pig	max. 4 l/min	0.4 - 4 l/min
Rabbit / cat	max. 10 l/min	1-10 l/min
Dog	max. 20 l/min	2-20 l/min

Flow adaptation is carried out by control knobs with built-in needle valves. The particular air flow is read off above this knob from the float in the metering tube (in **liters/minute)**.

Each flow controller has its own input on the rear panel of the instrument. After passing through the controllers both channels are united by a Y-connector so that a mixture is possible; in such cases the individual flows add together to give a total flow.

1.3. Adjustable respiration parameters

With the help of the operating elements on the instrument front panel all the necessary respiration parameters can be set by the operator:

Adjustable respiration parameters	
Time parameters:	
Inspiration length	in % of a breathing cycle
Plateau length	in % of a breathing cycle
Breathing frequency	breaths/minute
Breathing pressure:	
End inspiration (EIP)	adjustable (mm H_2O)
Leak alarm	adjustable (mm H_2O)

The instrument can also be controlled from a PC and will then work in a fully automatic mode. *Please contact us to receive detailed information*.

1.4. Types of respiration

In principle the respirator allows 2 different respiration modes:

Constant flow respiration

The respiration gas is administered during the *whole* inspiration phase at the constant and generally low flow rate selected on the **flow controller**. An upper respiration pressure limit set by the operator is monitored; this is the so-called **EIP limit** (max. 300 mm H_2O).

If this limit is set so (high) that this pressure is *not* reached during the inspiration phase then the *respiration volume*, which is obtained from the set flow rate and the laid down time parameters, is actually achieved.

On the other hand, if the EIP limit is **exceeded** (e.g. because the bronchial resistance changes) then the inspiration valve will be closed immediately *independent of the elapsed time*. In this way the animal is effectively protected against the pressure in the lungs increasing too much. By actively controlling the pressure if the pressure is falling during the remaining inspiration phase time the achieved pressure remains constant.

Constant pressure respiration

In this respiration mode the respiration pressure rises *rapidly* at the start of the inspiration phase as a result of the very high flow rate to a value selected by the operator (EIP limit) and is maintained at this level by active control during the whole of the total length of the inspiration phase (not, however, during the plateau phase). Constant pressure respiration avoids pressure peaks which could damage the lungs.

1.5. Respiration gas

Normally ***atmospheric air*** is used as the air source and is supplied by the built-in pump. Alternatively the air can be supplied externally from a compressed air line or compressed air cylinder.

The addition of ***oxygen*** or ***anesthetic gas*** and the connection of an evaporator are possible. This means that the respirator is suitable for the following different operating modes:

- only air
- air with added oxygen (e.g. 70:30)
- anesthetic gas mixtures, e.g. nitrous oxide/oxygen
- air with added inhalation anesthetics.

1.6. Built-in pressure sensor

During respiration the pressure (tracheal pressure) in the expiration lead (i.e. in the animal's trachea) is measured continuously via a **pressure sensor** in a by-pass circuit. End-inspiration (EIP) and end-expiration pressure (EEP) are shown on a display. In addition a chart recorder can be connected to show the pressure curve.

1.7. Alarm monitoring

The whole system is monitored continuously for tightness with a minimum pressure selected by the operator (**leak alarm**). In this way pressure loss caused by faulty tubing connections, etc., can easily be recognized.

1.8. O_2/CO_2 measurement

An external **O_2/CO_2 combination sensor unit** is available allowing the determination of the O_2/CO_2 concentration in the expiration air. The measuring ranges are:

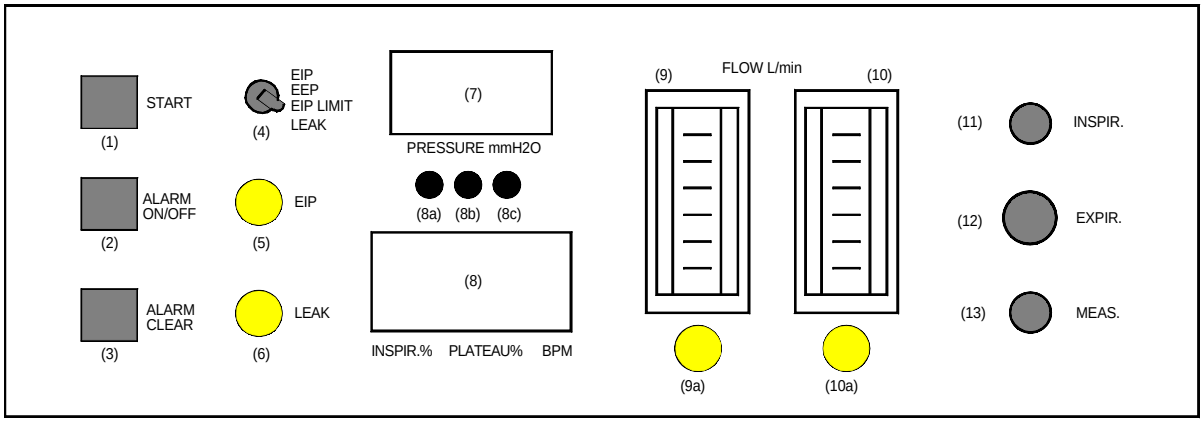
O_2 0-25%,
CO_2 0-10%.

The unit has two digital displays on the front panel which show the measured concentrations at any time. The display is calibrated in the factory. Two BNC outputs on the rear panel additionally allow the signals to be exported to an external instrument, e.g. a chart recorder.

2. Operating elements

The connections, display and operating elements of the respirator are described below.

2.1. Front panel



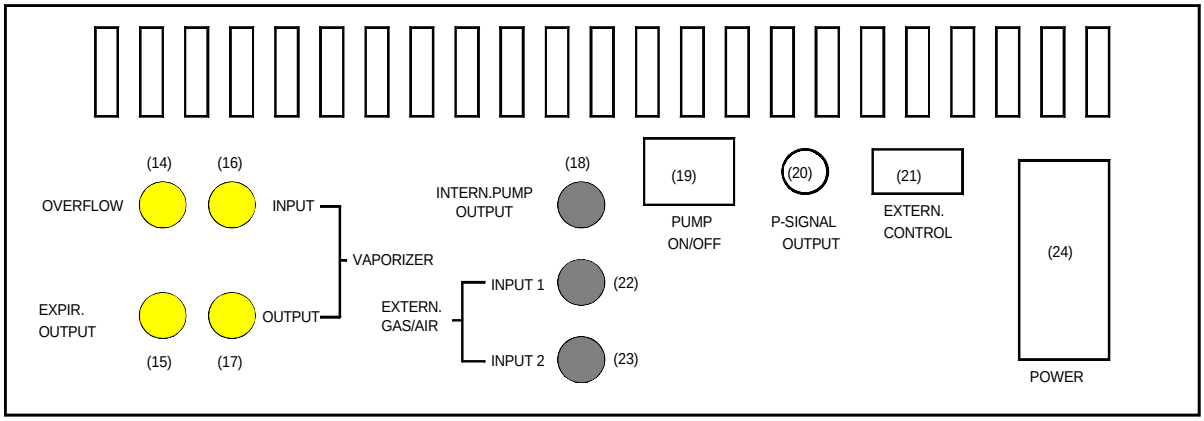
Front panel

1	**START** (green)	switch for respiration start/stop
2	**ALARM ON/OFF** (yellow)	switch to activate/deactivate the acoustic alarm signal (undercutting the leak alarm)
3	**ALARM CLEAR** (red)	optical alarm display for undercutting the leak alarm. *(depending on instrument configuration this key may also be used to switch off the alarm)*
4	**EIP** **EEP** **EIP LIMIT** **LEAK**	4-position switch for • display of EIP or EEP during respiration • display of EIP limit and the leak alarm during setting with controllers (5) + (6)
5	**EIP**	controller for selecting the EIP limit
6	**LEAK**	controller for selecting the leak alarm
7	**PRESSURE mm H2O**	3-place display for EIP/EEP/EIP limit or leak alarm, depending on setting of switch (4)
8	**INSPIR.%, PLATEAU%, BPM**	digital pressure switch for setting the inspiration length, plateau length and respiration frequency
8a	LED (red)	indicates inspiration phase
8b	LED (yellow)	indicates plateau phase
8c	LED (green)	indicates expiration phase
9	-	flow controller 1 - display (FLOW L/min)*
9a	-	setting control for flow controller 1
10	-	flow controller 2 - display (FLOW L/min)*
10a	-	setting control for flow controller 2
11	**INSPIR.**	connection for inspiration tubing to animal

12	**EXPIR.**	connection for expiration tubing from animal
13	**MEAS.**	connection for pressure measuring tubing

*** The flow controllers with which your instrument is fitted are mentioned in the delivery documentation.**

2.2. Rear panel



Rear panel

14	**OVERFLOW**	tubing connection: overflow from inspiration valve
15	**EXPIR.OUTPUT**	tubing connection: outlet expiration air from expiration valve
16	**INPUT**	tubing connection: inlet to inspiration valve; possible connection *from* evaporator
17	**OUTPUT**	tubing connection: outlet from flow controllers; possible connection *to* evaporator
18	**INTERN.PUMP OUTPUT**	tubing connection: outlet of built-in pump
19	**PUMP ON/OFF**	mains switch for switching pump on/off
20	**P-SIGNAL OUTPUT**	BNC socket; pressure signal (tracheal pressure)
21	**EXTERN.CONTROL**	connection for automatic control by PC)
22	**INPUT 1**	tubing connection: inlet flow controller 1
23	**INPUT 2**	tubing connection: inlet flow controller 2
24	**POWER**	input socket for mains cable; mains switch to switch respirator on/off; fuse holder

All tubing connections on the rear panel are intended for use with tubing 6 mm i.d.

3. Connections

Only tubing with the inner diameter given should be used for making the connections.

3.1. Respiration gas

a. Respiration with atmospheric air via the built-in pump

- connection of pump outlet **(18)** (6mm i.d.) to rear-panel connection **(22)** or **(23)** (6 mm i.d.)

b. Air provided from external air/O_2 source

- connection of external source to rear-panel connection **(22)** or **(23)** (6 mm i.d.)

The pressure reducing valve of the gas cylinder or compressed air station must be set to approx. 0.5bar.

The two flow controllers are usually set out for different volume flow rates. The flow controller with the lower volume flow rate is normally at the left-hand side (flow controller 1). The range can be read off from the scale.

Which flow controller is suitable for connection of the air supply depends on the respiration mode chosen:

Constant flow respiration
When the required flow has been calculated the most suitable connection is selected.

Constant pressure respiration
In this mode the larger flow meter is normally used.

Flow controller equipment - configuration for rats:		
Setting range	flow controller 1	0.1-1 l/min
	flow controller 2	0.4-4 l/min

3.2. Tubing bridges

If **no** anesthetic evaporator is used then the connections **(16)** and **(17)** on the rear panel of the respirator are to be connected kink-free with a short length of tubing (6 mm dia.). The respiration air is then led directly to the inspiration valve.

If an evaporator is included then the information given in **section 6** must be observed!

3.3. Expired air

The expired air as well as the superfluous respiration air, i.e. the excess air when is not led to the animal during the total expiration phase/plateau phase can be allowed to flow off into the atmosphere (e.g. with non-toxic gases, without anesthetics from the evaporator).

If an anesthetic evaporator or anesthetic gases are used then proper disposal in normally required. In this case tubing connections **(14)** and **(15)** can be used to exhaust the expired air into an internal laboratory exhaust system. Filters may be included if necessary (they must not hinder the escape of the expired air!).

- connection **(14)** overflow from inspiration valve (6 mm i.d.)
- connection **(15)** expired air (6 mm i.d.)

3.4. External measurements

External measuring instruments for further measurements on the expired air can be connected via connection **(15)**.

3.5. Connecting up the animal

The following tubing connections must be made:

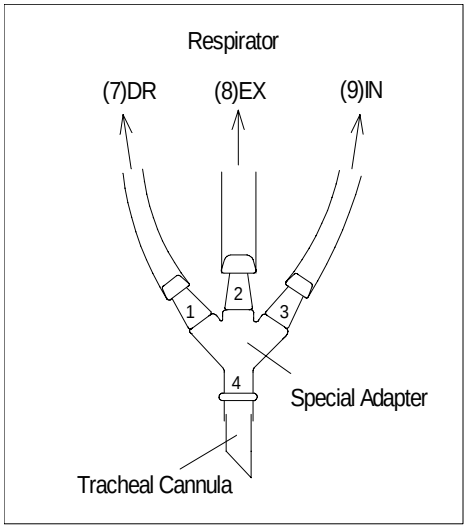
- connection **(11)** inspiration lead to animal (4 mm i.d.)
- connection **(12)** expiration lead from animal (6 mm i.d.)
- connection **(13)** pressure measurement tubing (4 mm i.d.)

The animal, which must be fitted with a tracheal needle, is connected to the respirator with the **TSE cannula set**. This set consists of:

- the **special adapter** and
- the **tubing connections**.

Different versions are available which depend on the type of animal used.

Special adapter



The adapter has 3 connections for

- pressure measuring tubing (1)
- expiration tubing (2)
- inspiration tubing (3).

The two thinner connections of the adapter (1+3) are identical and can be interchanged. The expiration tubing must only be connected to the middle connection (largest cross section). Care must be taken that the tubing is free from kinks as these impede the air flow.

The standard adapter for rats has an i.d. of 6 mm at the tracheal needle connection (4).

Tubing connections

Thin-walled elastic silicone tubing is recommended. Tubing connections should be kept as short as possible (max. 75-100 cm).

Small animals:	inspiration tubing	**4 mm (o.d.)**
	expiration tubing	**6 mm (o.d.)**
	pressure measuring tubing	**4 mm (o.d.)**

3.6. Connecting a chart recorder (tracheal pressure curve)

In order to show the tracheal pressure waveform during respiration a recorder must be connected to rear panel socket **(20)**.

20	**P-SIGNAL OUTPUT**	**BNC socket; pressure signal**

The output voltage is **0 ... 10 V**.

4. Preparations for respiration

4.1. Switching on the respirator

When the respirator is switched on with mains switch **(24)** on the rear panel the display on the front panel **(7)** becomes active.

The built-in pump has its own mains switch **(19)**. If the pump is to be used than the switch can ***always*** be kept in the ON position so that the pump starts up immediately when the respirator is switched on.

If the built-in pump is not required, i.e. no atmospheric air but an air/O_2 mixture is fed in externally then the pump switch should be in the OFF position.

4.2. Instrument settings

Before respiration is started all the control parameters must be set on the front panel.

In order to provide the animal with optimal respiration either values gained from experience or from appropriate tables should be used so that correct respiration parameters are guaranteed. In many cases internal laboratory graphs exist which show the volume of breath in relationship to the weight of the laboratory animal, etc.

4.2.1. Time parameters

A breathing cycle consists of inspiration phase, plateau time and expiration phase. The length of the expiration phase is obtained as follows:

Expir% = 100% - Inspir% - Plateau%

In order to allow the animal to exhale as completely as possible a value of 50-60% is recommended for the expiration phase.

With the help of the digital pressure switches **(8)** the length of the inspiration and plateau phases are set to two places. For each of the 2 positions there are 2 setting keys available: **key +** switches one digit upwards, **key –** one digit downwards.

Inspir. %

Length of the **inspiration phase** in % of a breathing cycle. **Range: 1 ... 99%** (Note! can be set from **0** to 99).

Guide value: 30 - 40%

Plateau %

Length of the **plateau time** in % of a breathing cycle. **Range: 0 ... 99%** (can be set from 0 to 99).

Guide value: 0 - 10%

Note: Pressure is not controlled during the plateau phase.

The respiration frequency is also laid down (3-place):

BPM

Breathing frequency (breaths/minute); **Range: 1 ... 200** (NOTE: can be set from 0 ... 999!). The frequency depends on the type of animal used.

Breathing parameters of some laboratory animals

Animal	Weight gram	Breathing volume ml	Breathing frequency per minute
Mouse	30	0.1-0.2	150-200
Rat	300-600	1-5	60-180
Guinea pig	300	1.5-3.0	45-70
Rabbit	2500	10-20	40-50
Cat	5000	25-50	10-25

4.2.2. Flow setting / respiratory mode

The flow (i.e. inhaled amount of gas per time unit) is adjusted with control knob **(9a)** and **(10)** of the two mechanical flow controllers. The setting is made in **liters/minute**.

Depending on the respiration gas only one or both flow controllers may be required.

If there is **no** mixing to be carried out then the unused flow controller is closed to avoid pressure losses (set control knob to zero); the input on the rear panel is not closed.

If an anesthetic gas is to be added and therefore both flow controllers must be used the volume flow rates of both controllers must be added together. During the plateau and expiration phases the continuous flow of air is diverted to the overflow.

The instrument settings depend on the mode to be used:

1. Constant flow respiration

In **constant flow** respiration the gas flow to be set must first be *calculated* (see *example*). In this mode the set flow rate is usually considerably smaller than for constant pressure respiration.

When the inspiration valve is opened the low flow rate means that pressure is built up very slowly.

The pressure is also continuously monitored for exceeding the EIP limit pressure. Because of the low flow rate high pressures are not normally achieved. Nevertheless setting a maximum pressure by setting an EIP limit is recommended for the protection of the animal.

The flow rates shown on the flow controllers correspond to 100% inspiration phase, i.e. if the inspiration phase is set to 40% then only 40% of the displayed volume flow actually reaches the animal.

1st calculation example:

A rat with a breathing volume of 2 ml and a frequency of 80 breaths per minute (Bpm) is to undergo respiration with air with no added anesthetic gas. The inhalation phase is to be 40% of the total time; the plateau time is 0%. The volume flow rate to be set on the flow controller is to be calculated (l/min).

Calculation:

1.	breathing minute volume (BMV)	2ml x 80 Bpm = 160 ml
2.	flow rate (l/min)	160 ml x 100%/40% = 400 ml/min = 0.4 l/min

This means that a gas amount of **0.4 l/min** most be set on the flow controller. The unused second flow controller is closed by setting the control knob to zero.

2nd calculation example:

As above, but a gas mixture of 30% air and 70% nitrous oxide (N2O) is to be used. This requires the use of both flow controllers. The calculation is as follows:

Total flow (100%) = 0.4 l/min

1.	air	30%	0.4 l/min x 30% / 100% =	0.12 l/min
2.	nitrous oxide	70%	0.4 l/min x 70% / 100% =	0.28 l/min
	total	100%		0.40 l/min

Taking the above-mentioned mixing relationship into consideration then a value of 0.12 l/min must be set on the smaller flow controller 1 (air) and a value of 0.28 l/min set on the larger flow controller 2.

2. Constant pressure respiration

In **constant pressure** respiration the flow controller(s) is/are always set to ***higher flow rates*** (take mixing ratio into account!). An **EIP limit must** be defined to set a maximum for the tracheal pressure which is to be maintained during the whole inspiration phase by continuous readjustment.

When the inspiration valve is opened the high flow rate causes a very rapid build up of pressure.

4.2.3. Setting the EIP limit

The tracheal pressure is checked continuously to see whether a pressure limit is exceeded. This pressure limit, the so-called EIP limit (End Inspiration Limit (in mm H_2O)), is set with the aid of controller **(5)**:

5	**EIP**	**setting controller**

Switch **(4)** must be in the **EIP-Limit** position. The selected value can be read off from the display **(7)**. The maximum pressure which can be set is **300 mm H_2O** (right-hand full scale of the potentiometer).

The way in which the EIP limit is set depends on the respiration mode.

1. In **constant pressure** respiration this value determines the pressure which is maintained by active control.

2. In **constant flow** respiration the EIP limit is the upper permitted limit for the tracheal pressure. If the pressure limit is reached the inspiration valve is closed immediately.

4.2.4. Setting the limit for the leak alarm

The system can be checked for tightness during operation by defining a **leak alarm** limiting pressure (e.g. for the occurrence of leaks). Work should **always** be carried out with the leak alarm activated.

The alarm limit (in mm H_2O) is set with controller **(6)**:

6	**LEAK**	**controller leak alarm**

Switch **(4)** must be set to the **LEAK** position. The set limit can be read off from the display **(7)**.

Guide value: 30-40 mm H_2O

Display of the alarm condition, i.e. the undercutting of the defined limit is carried out during the respiration in 2 different ways:

Optical alarm

3	**ALARM CLEAR**	**display key**

When the leak limit is undercut the key is illuminated **red**. The lamp goes out automatically when the alarm condition has ended.

Acoustic alarm

2	**ALARM ON/OFF**	**switch (yellow)**

The undercutting of the leak limit can also be indicated by an **acoustic signal**.

The acoustic signal is activated with switch **(2)** ALARM ON/OFF (lights up **yellow** when activated).

5. Operation

5.1. Starting the artificial respiration

When all parameters have been set and checked the switch **START (1)** can be used to start respiration. It clicks into place and lights up green.

5.2. Artificial respiration

5.2.1. Display of the current respiration phase

- The LEDs below the pressure display show the current phase of the respiration cycle:

  (8a) inspiration phase red
  (8b) plateau phase yellow
  (8c) expiration phase green

5.2.2. Course of the respiration cycle

Constant flow mode – low flow rates

- if the **EIP limit** has been set so high that this pressure limit is not reached during the inspiration phase then respiration is carried out according to the set time parameters.
- if the **EIP limit** has been set low then the inspiration valve will be closed when this pressure is reached during the inspiration phase.

Constant pressure mode – high flow rates

- in this case the tracheal pressure builds up rapidly until the selected **EIP limit** is reached and then maintained at this level until the end of the set inspiration phase (with active control).

5.2.3. Reading off the measurements

- The actual final values for the end-inspiration pressure (EIP) and the end-expiration pressure (EEP) for each breathing cycle can be read off from the display **(7)** if switch **(4)** is moved to position EIP or EEP respectively.

End-inspiration pressure **EIP**	pressure value immediately before the start of the plateau or expiration phase
End-expiration pressure **EEP**	pressure value immediately before the start of the inspiration phase (i.e. before the inlet valve is opened)

- If a recorder has been connected to rear panel socket **(20)** then the tracheal pressure curve can be printed.

5.2.4. Alarm condition

- If a **leak alarm** occurs an optical signal is shown at key **(3)**. The key lights up red. When the alarm has ended the lamp goes out automatically.
- An acoustic signal is also heard if this has been activated. This can be switched off even during the alarm condition by pressing switch **(2)**.
- The set value for the leak alarm can be read off from display **(7)** if switch **(4)** is moved to the LEAK position.

5.2.5. Altering the operating parameters

The operating parameters can be altered at any time during the respiration process!

5.3. End of the artificial respiration

When the switch **START (1)** is pressed again the respiration is ended.

6. Use of an anesthetic evaporator

An anesthetic evaporator is used to prepare an anesthetic present in liquid form, e.g. Halothane, to be fed into the respirator air flow.

The fresh gas led into the evaporator via connection **(17)** passes through the anesthetic gas atmosphere and a certain adjustable proportion of the anesthetic vapor is mixed with it.

In order to compensate for the inhibited oxygen uptake of the animal when an anesthetic evaporator is used air enriched with oxygen should always be used (e.g. air 70%, O_2 30%). If pure air is used the oxygen supply to the animal is inadequate.

A suitable evaporator must be used for each anesthetic. The permitted volume flow range of the evaporator must be observed. Please study thoroughly the operating instructions and safety information provided by the evaporator manufacturer.

If an evaporator is to be included in the system then the following tubing connections must be made:

- outlet **(17) (6 mm)** to evaporator inlet
- evaporator outlet to inlet **(16) (6 mm)**

The respiration air (or air mixture) then passes from outlet **(17)** into the evaporator and after loading with anesthetic is led to the inspiration valve via inlet **(16)**.

If an evaporator is included in the system then the exhaled air and the overflow air should be disposed of properly!

7. Technical data

Respiration parameters*:

Inspiration phase: 1 ... 99%
Plateau phase: 0 ... 99%
Respiration frequency: **1 ... 200 per minute**

***** *Note: the setting switches allow all entries between 0 ... 99 or 0 ... 999.*

Tubing connections:

Inputs:
- Pressure measurement
- Expiration air
- Input inspiration valve; possibly outlet evaporator connection
- Flow meter 1
- Flow meter 2

Outputs:
- Inspiration air
- Overflow inspiration air
- Expiration air
- Outlet flow controller; possibly outlet evaporator connection
- Pump

Pressure:

Measuring range: **0 ... 300 mm H_2O**
Max. overpressure: 3571 mm H_2O
(this pressure will not be shown on the display)

Ambient conditions:

Operating temperature 15 ... 35 °C
Storage temperature -10 ... 50 °C
Relative humidity 20 ... 80 °C

Power supply:

230V, 50Hz
210V, 60Hz