Operating Instructions

for the

PLUGSYS® Module

VCM Ventilation Control Module Type 681

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Contents **Page**

Please note: SWITCH OFF THE PUMP between experiments !

The internal pump and the valves are subject to a certain amount of wear. In order to avoid shortening their life unnecessarily you should therefore switch off the pump between experiments by means of the switch "PUMP ON / OFF".

1. Introduction, manufacturer's details

These Operating Instructions describe the operation and use of the **VCM** Module Type 681. It is part of the equipment and should be kept close to it.

All the information in these Instructions has been drawn up after careful examination but does not represent a warranty of product properties. Alterations in line with technical progress are reserved.

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2. Safety note

Important: This equipment is not suitable for operation in hazardous areas and/or in a flammable atmosphere.

This equipment is designed exclusively for animal experiments.
Not for humans use!

3. General description, applications

The Ventilation Control Module (VCM) is a module of the PLUG-SYS system. It has been developed essentially for producing negative pressures at a respiratory rhythm as required for operating an isolated perfused lung (rat, guinea-pig).

The module operates with a positive pressure. The negative pressure required for ventilation is generated by means of a venturi nozzle which is fitted externally. When used with a restrictor nozzle the module can also be employed for positive-pressure ventilation.

The VCM module works independently; it requires neither a vacuum nor a compressed air supply. It operates from the standard supply voltages of the PLUGSYS Series 600 housing. The only modification required is to wire an existing voltage to the module slot (see Section 4).

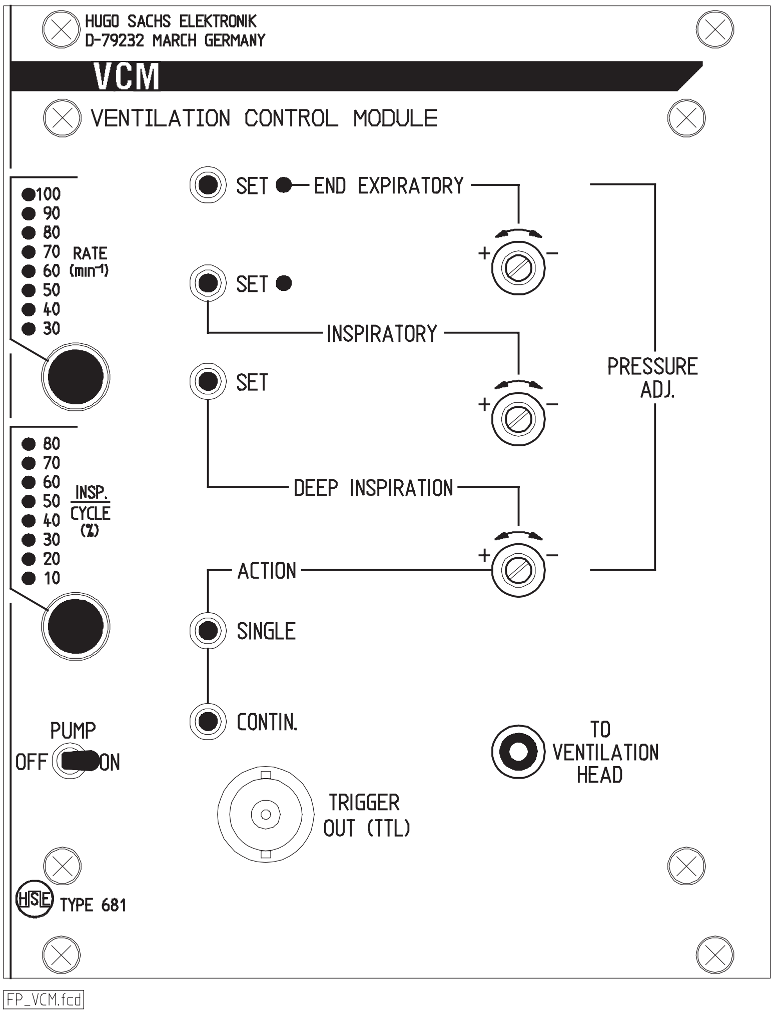

Fig. 2: Front panel

3.1 Operating principle

The module consists of an electronic and a pneumatic section. A low-noise pump stores compressed air in a small reservoir where it is stabilised electronically to approx. 100 mmHg.

The air stream which appears at the outlet connection (TO VENTILATION HEAD) passes through adjustable valves. The air is controlled electronically according to the selected respiration rate (RATE) and the selected inspiration cycle (INSP.CYCLE %). In addition one (or several) deep breaths (DEEP INSPIRATION) can be triggered by pressing a button.

The output therefore consists of a rhythmically modulated air stream at a positive pressure. By connecting it to a suitable nozzle a rhythmically modulated negative or positive pressure of the desired magnitude can be produced.

Negative pressures are generated with a venturi nozzle. This operates in the same way as the well-known water jet vacuum pump, except that it uses air (or gas). The magnitude of the vacuum generated can be accurately adjusted with the controls on the VCM module.

A positive pressure can be produced by means of restrictor nozzle. In principle this is also a venturi nozzle but with the connections interchanged. The restrictor nozzle should be used during the preparation phase to provide positive pressure ventilation of the donor animal. The nozzle carries an additional adjustment so that the ventilation can be varied to suit the requirements of the animal without having to alter the basic settings on the module.

Through the use of a changeover valve (3-way stopcock) it is possible to switch over between positive and negative pressure ventilation. This is particularly important when using the module in connection with the "isolated lung". Ventilation is performed at all times at a controlled pressure. The lung cannot collapse through the pressure dropping to zero.

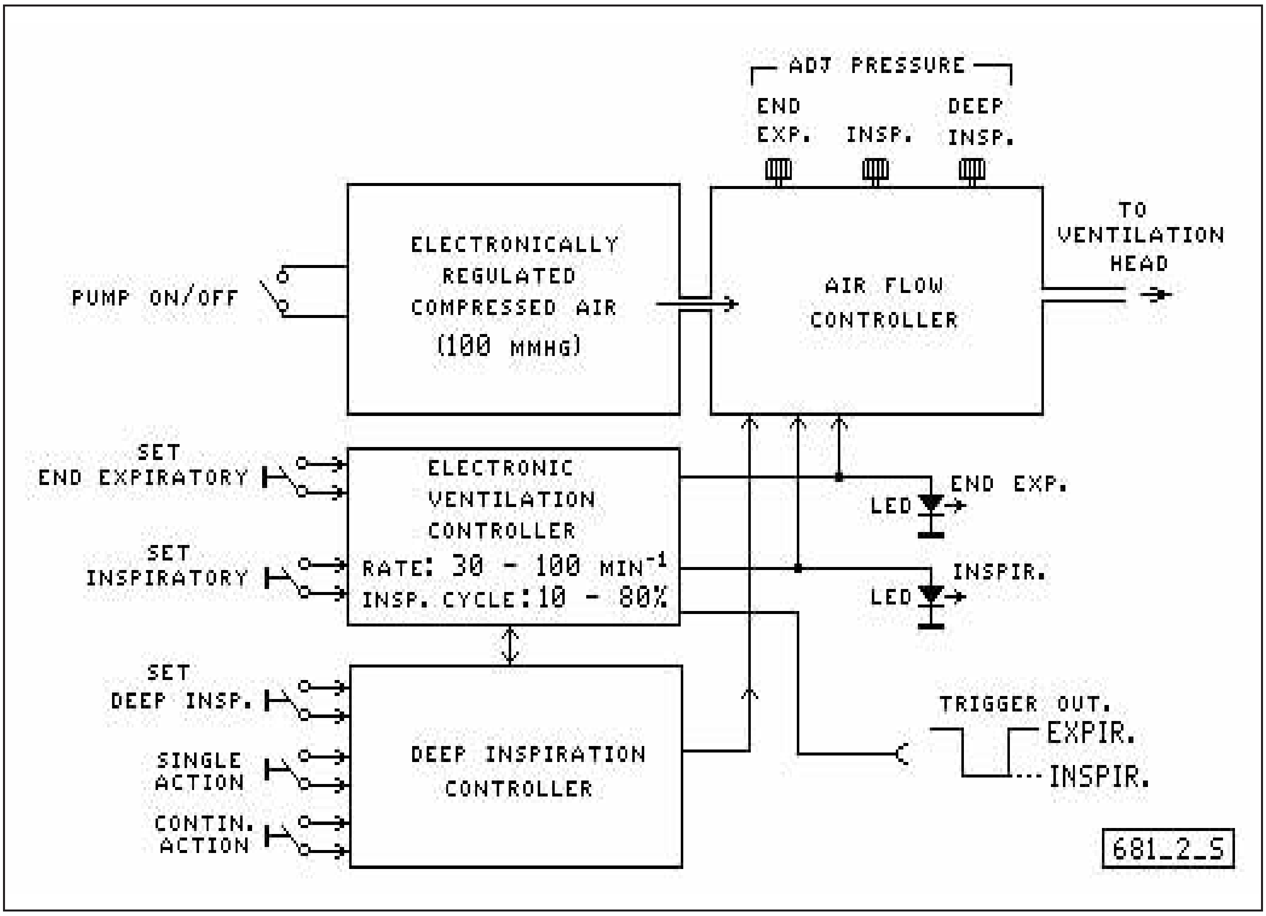

Fig. 3: Functional diagram of the VCM

The functional diagram of the VCM (Fig. 3) shows 4 functional blocks. At the top left is the air compressor. To the right of it is the pneumatic controller; it operates from the two electronic blocks shown at the bottom of the diagram.

The pneumatic controller incorporates three adjustable valves whose adjustment spindles are brought out through the front panel and marked according to their function (Fig. 2). The air flow appears on the front panel at the connection "TO VENTILATION HEAD".

From the positive-pressure air flow of the VCM a corresponding negative pressure ($-P_{out}$) can be generated by connecting a venturi nozzle at this point (Fig. 4); alternatively positive pressure ventilation ($+P_{out}$) can be carried out by connecting a restrictor nozzle (Fig. 5). The rhythm is controlled by the electronic circuit and the pressure in the individual phases is set by the corresponding controls.

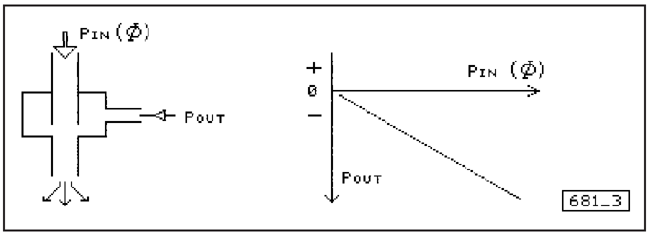

Fig. 4: Characteristic of the venturi nozzle

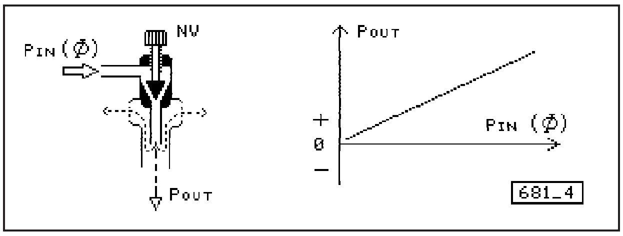

Fig. 5: Characteristic of the restrictor nozzle

When the VCM module is operating in conjunction with the experimental setup "Isolated perfused lung" Type 829, both nozzles are being used. The venturi nozzle produces the necessary rhythmical negative pressure in the artificial thorax and the restrictor nozzle is employed for ventilating the donor animal during the preparation phase. The lung can then be carefully dissected out of the animal without collapsing and without being overstretched. After preparation has been completed the system can be changed over quickly with a changeover cock from negative to positive pressure ventilation without producing uncontrolled pressure conditions on the lung.

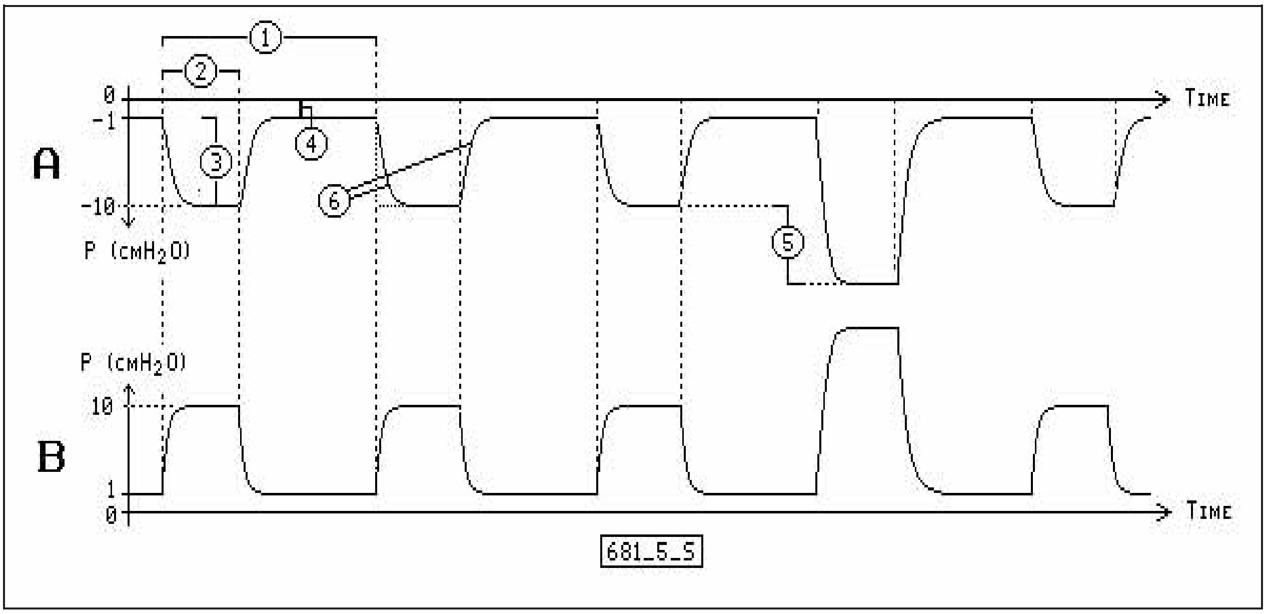

Fig. 6: Ventilation curves.

A: pressure curve (negative pressure!), generated with the venturi nozzle;
B: ventilation curve (positive pressure!), generated with
the restrictor nozzle. For further details see text.

The individual curves of the pressure signals are shown in Fig. 6. Curve (A) represents the negative pressure generated with the venturi nozzle. The maximum inspiration pressure is set at 10 cm H_2O and the PEEP at 1 cm H_2O. The segments marked (1) to (5) have the following significance:

(1) Duration of a respiration cycle. The duration is the reciprocal of the RATE setting. The unit of RATE is 1/minute or respiration cycles per minute.

(2) Inspiration duration as a proportion of the total ventilation cycle duration in % (INSP./CYCLE in %).

(3) Negative pressure during the inspiration phase.

(4) Negative pressure during the expiration phase. This also sets the PEEP (Positive End Expiratory Pressure).

(5) Magnitude of the additional negative pressure which is added to the normal inspiratory pressure during a so-called "deep inspiration". Deep inspirations can be produced by pressing a button.

(6) Distortion of the pressure curve due to the dead volume of the artificial thorax. Pressure changes in the artificial thorax are produced by air being sucked out or pushed in. This process involves a certain latency period.

Fig. 6 also shows at (B) the pressure curve with positive-pressure ventilation using the restrictor nozzle. Inspiration pressure and PEEP were set at 1 and 10 cm H_2O resp. as at (A).

4. Installing the module in the housing

The module can only be operated if it is installed in a PLUGSYS housing Series 600 (Oct. 89: 600 - 603). A number of adjustments are required before this can be done; they include setting of jumpers on the circuit board (see below) and the provision of the appropriate voltage supply.

The module requires a special 24 Volt supply. This supply is provided by the power supply in the housing but is not available at every slot. The supply has to be wired internally on the bus board to the desired slot position. Null (PGND) must be connected to POWER-2 (pins 30 a/b/c) and +24 Volt to POWER-0 (pins 28 a/b/c).

If you want to change the slot position of the module in the housing you have to alter the 24 Volt supply wiring and move it to the new slot as described above. If this is not done the module will not operate when the equipment is switched on.

If the module is supplied completely installed in its housing, these wiring connections have already been made at the factory. In addition a coding screw is fitted on the front panel which engages with a corresponding hole in the front panel of the module. This ensures that no other module can be installed in this slot position.

4.1 Internal adjustments, jumpers

Before the module is installed in the housing three trigger lines must be linked to a suitable bus line (TRIGGER 1-4 or B_INT).

Note: the trigger signals are intended for operating the module in conjunction with a computer. This provides e.g. for producing deep inspirations under computer control, or conversely to record manually triggered deep inspirations on the computer. If the module is being operated without computer the trigger signals are unnecessary and do not have to be linked to the system bus.

If the module is supplied as part of a fully installed PLUGSYS measuring system the trigger lines are normally connected up at the factory and the bus lines carrying the signal are marked on the bus diagram (see Operating Instructions for the housing); they can be identified on the diagram when required.

The jumper pins are located on the circuit board at the back top near the heat sink. If the trigger signals are not linked to the system bus the jumpers must be placed on the parking pins provided (NC).

Signal designation	Function
DEEP INSP.IN	a deep inspiration can be triggered via the bus line
DEEP INSP. OUT	a signal is output to the bus for each manually triggered deep inspiration
EXP/INSP. OUT	the alternating expirations and inspirations appear as a corresponding voltage signal at this output. The same signal appears at the BNC socket on the front panel.

Note: check on the bus diagram (Operating Instructions PLUGSYS Housing) whether the selected bus line (Trigger 1-4 or BINT) is free or whether it is already in use for another module.

Do not forget: enter the selected jumpers in the bus diagram "trigger bus" of the Operating Instructions for the PLUGSYS housing !

If the trigger signals are not connected to the system bus the jumpers must be placed on the parking pins provided (NC).

Note: an incorrectly linked trigger line may cause the computer to fail. Special care must be taken when linking to the bus line BINT (BUS-INTERRUPT); this line operates directly on the computer interface (ICI or ACI).

The trigger signals are at TTL level (5 V) and are active LOW. They are TTL outputs with open collector with a working resistance of 2.2 kOhm.

5. Installation and starting up

After the module has been installed in a PLUGSYS housing (Section 2) it is ready for immediate use. In accordance with the function description either a venturi nozzle or a restrictor nozzle is required depending on the application; it is connected by tubing to the outlet marked "TO VENTILATION HEAD" on the VCM module. In order to keep the flow resistance low it is desirable that the internal diameter of this tubing should be between 3 and 5 mm. Length not exceeding 1.5 m.

The details below are based on the module being used in conjunction with the HSE setup "Isolated Perfused Lung" or in short "Isolated Lung" Type 829.

Both nozzles are in use when operating with the isolated lung. Fig. 6 is a diagram showing the arrangement. The output of the VCM Module (1) is connected to the changeover cock (2); this permits rapid changeover between the two nozzles. While the lung is being dissected from the donor animal (4) the latter is ventilated at a positive pressure through the cannulated trachea connected to the restrictor nozzle. For this operation the inner cover (removable) of the artificial thorax is mounted at the top of the operating table (3). After preparation is completed and the lung is placed into the apparatus, the cock (2)

is switched over to the venturi nozzle (5) and the lung is now ventilated at a negative pressure via the artificial thorax (6). The restrictor nozzle can then be removed from the cover; it is no longer required for the experiment.

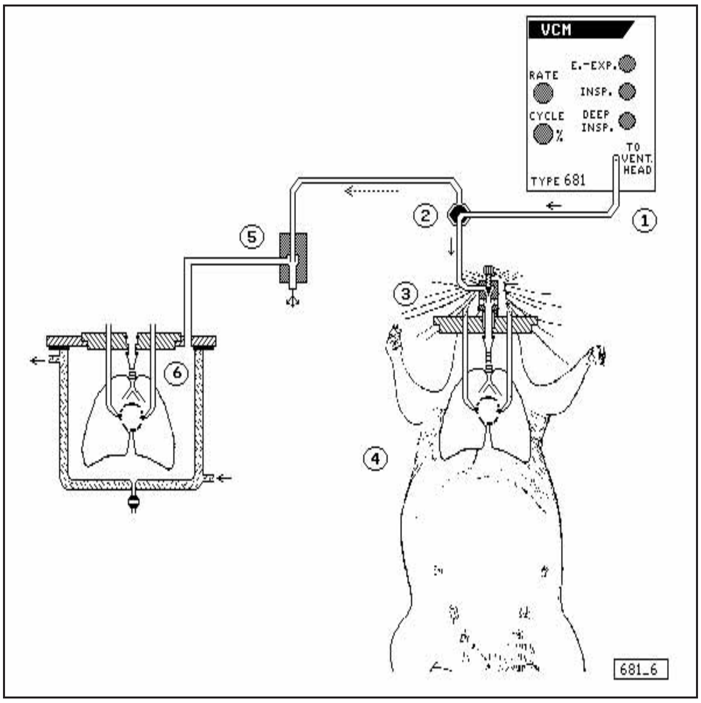

Fig. 7: Positive and negative pressure ventilation with the VCM

5.1 Adjusting the ventilation parameters, functional test

Before using the unit you should adjust the generated pressure. If suitable calibrated pressure measuring devices are available they can be used for the adjustment. Typical values are given below which can be used for initial trials with the equipment. If you start the experiment with these setting there is no danger that the lung is damaged immediately through overextension, or that it collapses at any time. In order to see certain effects you can of course change the values at any time within the adjustment range. It is important, however, to ensure that the inspiratory pressure is always greater than the end-expiratory pressure; otherwise the times for inspiration and expiration are interchanged. In addition the deep breaths would be triggered during an incorrect respiration phase.

Respirations phase		Normal value	Adjustment range
Inspiratory pressure:	(INSPIRATION)	10 cmH_2O	(5...15)
Endexpiratory pressure:	(END EXPIRATION)	1 cmH_2O	(0... 5)
Deep breath:	(DEEP INSPIRATION)	+10 cmH_2O	(+0...30)

In the absence of suitable measuring devices you can adopt a simpler procedures. Connect the venturi nozzle to a piece of tubing approx. 50 cm long instead of the artificial thorax and immerse the free end a few cm deep in water; 30 cm of the tubing should be outside the water and should be vertical.

Now switch on the pump of the VCM and press the key "SET INSPIRATION". If the module operates correctly the water level in the tubing should now move upwards. Next adjust the corresponding adjusting screw while maintaining the pressure on the button so that the water level in the tubing rises 10 cm.

Repeat the procedure with "SET END EXPIRATION". Adjust the appropriate adjusting screw so that the rise of the water level inside the tubing is nown 1 cm.

Carry out the same operation for the deep breath "DEEP INSPIRATION" and set the water level rise in the tubing to about 20 cm. When turning this adjusting screw, note that you can reduce the pressure only down to the inspiratory pressure which has been set before (10 cm H_2O). The reason is that the pressure for the deep breath is added to the normal inspiratory pressure.

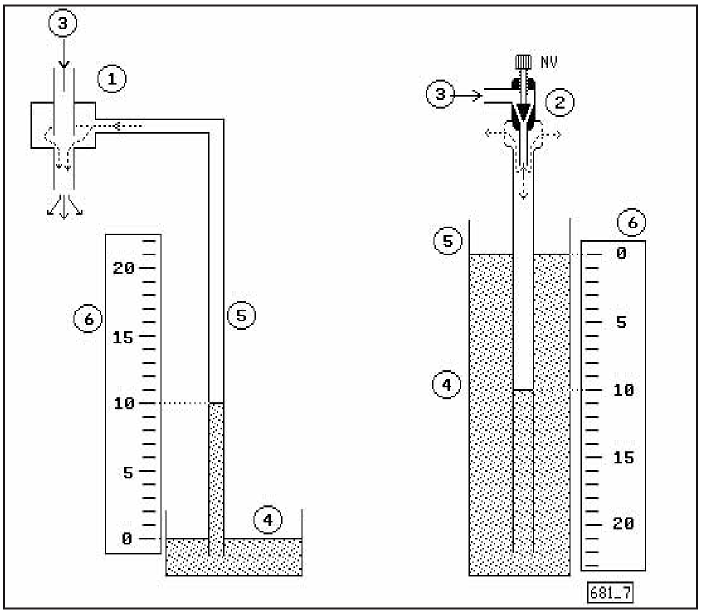

Fig. 8: Preliminary adjustement of the ventilation pressure using a simple water manometer.

When you have completed the adjustment procedures described above you should check the rhythmical changes in ventilation.

Select a RATE = 30 (min-1) and INSP./CYCLE = 80 (%). Inside the tubing you can now see the water level rise and fall in line with the ventilation rhythm. It rises to a level of 10 cm for 80% of the cycle time and falls only for a brief instant. Because of the overshoot of the water column it is not possible to establish the exact endexpiratory pressure. Then set the control "INSP./CYCLE" to 10%. The water level in the tubing will then be at 1 cm for 90% of the cycle time (1.8 seconds).

The function of the deep breath (DEEP INSPIRATION) is best checked by setting the inspiration cycle back to 80%. If you now press the button "SINGLE ACTION" you can produce a deep breath. The water column in the tubing should rise to 20 cm in the inspiration phase. If you press the key "CONTIN.ACTION" the deep breaths are produced until you release the key again.

You can use the same procedure for the basic setting of positive-pressure ventilation using the restrictor nozzle. The pressure adjustment should in this case be made directly on the adjusting knob of the nozzle so that the settings for negative pressure ventilation are not altered (see above).
For adjusting the restrictor nozzle you need a glass vessel at least 30 cm high; the tubing is immersed in this vessel so that it is as nearly vertical as possible. If you now connect the tubing to the distal end of the restrictor nozzle in place of the trachea you can test the positive ventilation pressure just as before you tested the negative pressures on the venturi nozzle. In this case the water level is not raised but is lowered below the level in the vessel in accordance with the positive pressure.

Note that the endexpiratory pressure (PEEP) depends only on the setting of the VCM. It cannot be altered by adjusting the control on the restrictor nozzle.

5.2 Important notes on the operation of the module

- Be certain to provide adequate cooling !
- Do not allow any liquid to enter the module !
- Changes in pressure settings between experiments:
  the cause is always: LEAKAGE !
- Limitation of pressure: leakage
  intake filter clogged
  pump faulty

5.2.1 Warming up during operation / cooling

Ensure that the ventilation slots in the bottom and top covers of the housing are open.

- Do not place any papers on the housing!
- Do not place the housing on a thick foam rubber mat!

The air cooling would no longer be effective and the unit would heat up excessively. The consequences would be faulty operation through increased temperature drift of the pressure settings and increased wear of the pump.

5.2.2 Protection against entry of liquid

Make sure that no liquid passes into the connections of the VCM, especially when cleaning the experimental setup!
Any liquid entering the module, especially perfusion solution or cleaning solution, could damage the control valves or at least interfere with their correct operation.

5.2.3 Stability of the pressure settings

The negative pressures generated with the venturi nozzle are very stable. The pressure setting is maintained even during a small leakage in the experimental setup.

If you find that the pressure settings have fallen off since the last experiments you should check where there is a major leakage in the system (open connection, a hole in the lung tissue, faulty seal etc.)

5.2.4 Pressure limitation, life of pump, clogged filters

(a) The built-in pump is subject to a certain amount of wear. It is however operating far below its rated capacity so that you can expect a long life.

The end of its life is reached when the internal, electronically controlled operating pressure of 100 mm Hg can no longer be maintained in the various operating modes of the VCM. You can recognise this condition by the pump running at higher speed and the triggering of a deep breath produces no speed increase or only a small one.

The above condition applies only when the venturi nozzle is in position and when the inspiratory pressure is adjusted to -10 cm H_2O and the endexpiratory pressure to -1 cm H_2O.

An exact diagnosis of the pump condition (or of the suction filter, see below) can be made by measuring the electrical voltage at the terminals of the pump motor.

Normal operation (see above): 14 - 17 Volt

Limit: 20 Volt

When the limit is exceeded, check first the suction filter (see below) and only then return the module for repair.

(b) The pump draws in air through internal built-in filters. Whenit is operating under dusty conditions these may become clogged. This condition becomes apparent as described under (a): the internal operating pressure is no longer stable and the pump is running at increased speed.

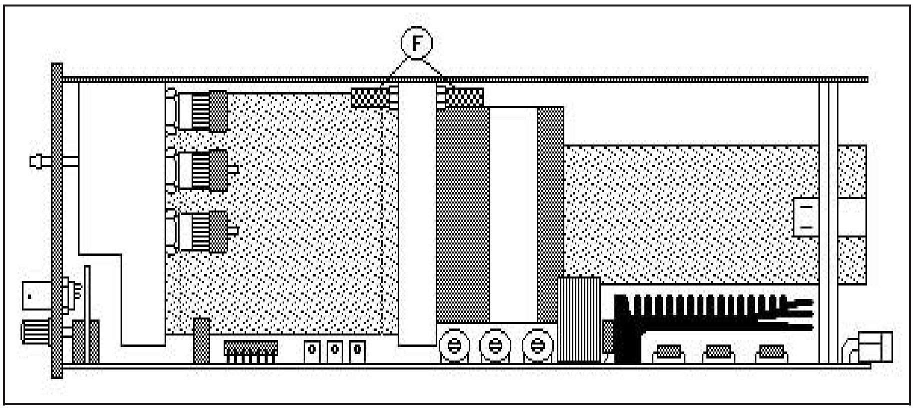

Fig. 9: View of module from below.
F: suction filters. Screw out for cleaning.

The two sintered brass filters can readily be cleaned. It is necessary to pull out the module from the housing. You find the filters at the bottom in the region of the pump head (see Fig. 8). They have an M5 thread. Screw the two filters out of the Plexiglass block with a 7 mm spanner and blow them clean with compressed air <u>from inside outwards</u>. Do not forget the seal when fitting them back into position!

Note the maximum tightening torque: 50 Ncm.

If the filters have a solid deposit or incrustations on the outside you can wash them in any cleaning solution.

Note: do not use acid or alkali!

Before fitting the filters back into position ensure that they are completely dry.

5.2.5 Unstable pressure, checking the internal operating pressure

In case of faults which are not covered by the points described above you should check the internal operating pressure.

You require a manometer with a range of 0 - 110 mm Hg. Connect the manometer to the VCM at the connection "TO VENTILATION HEAD" and switch on the unit. Press alternatively the setting buttons for INSPIRATION and for END EXPIRATION and note the manometer reading.

The reading should always be steady; the exact value is not very important, it may be between 95 and 105 mm Hg. If you do not obtain a stable pressure or if the pressure is outside the indicated tolerances the unit is faulty. You have to return the module for repair.

6. Maintenance

The VCM module does not require any special maintenance. As explained in Section (3.2) it is important to ensure adequate air cooling during operation, i.e. the ventilation slots in the housing must not be blocked.

When operating under dusty conditions the suction filters have to be cleaned when the operation becomes unsatisfactory (see Section 5.2.4).

Any dirt on the front panel can be wiped off with a moist cloth. Any dirt which adheres firmly can be removed with ordinary domestic or laboratory cleaning liquid. It important, however, to prevent any liquid entering the unit. In particular the switches and buttons must be protected against moisture.

NOTE: do not use organic solutions for cleaning plastic parts (control knobs, Plexiglass parts, restrictor nozzle!). When using such solutions many plastics have their surface dissolved and become brittle.

7. CE Declaration of Conformity

This product and accessories conform to the requirements of the Low-voltage Directive 73/23 EEC as well as the EMC Directive 89/336 EEC and are accordingly marked with the CE mark. For conformity to the standards during operation it is essential that the details in the instructions provided are observed.

8. Technical data

Adjustment ranges for:	
■ ventilation rate "RATE":	30,40,50,60,70,80,90,100 (min^{-1})
■ inspiration time "INSP.CYCLE":	10,20,30,40,50,60,70 80 (%)
Air flow at outlet:	0 - 4 l/min, no back pressure
Internal operating pressure:	100 ± 5 mm Hg, electronically controlled
Trigger output, BNC socket on the front panel:	inspiration:0V; expiration: 5V (TTL level, open collector, load resistance 1 kOhm)
Trigger signals, through internal jumpers to the system bus (TTL level, open collector, load resistance 2.2 kOhm):	DEEP INSP.OUT, output
	EXP./INSP.OUT, output
	DEEP INSP.IN, input
Ambient conditions:	
Operating temperature:	15 to 40°C
Relative humidity:	20 - 80%, no condensation
Storage temperature:	-20 to 60°C
Supply:	5 V 0.4 A, 24 V 0.4 A
Dimensions:	module for PLUGSYS housing
	width 20 E (191.2 mm)
	height 3 U (127.5 mm)
	depth long Euroboard (220 mm)
Connector:	DIN 41 612, 96-pin VG connector
Weight:	1.8 kg