Datex-Ohmeda Compact Airway modules

S/5™ Compact Airway Module, M-CAiOVX (rev. 01)
S/5™ Compact Airway Module, M-CAiOV (rev. 03)
S/5™ Compact Airway Module, M-CAiO (rev. 02)
S/5™ Compact Airway Module, M-COVX (rev. 02)
S/5™ Compact Airway Module, M-COV (rev. 03)
S/5™ Compact Airway Module, M-CO (rev. 02)
S/5™ Compact Airway Module, M-C (rev. 02)

Technical Reference Manual Slot

All specifications are subject to change without notice.

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S/5 Compact Airway Modules

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INTRODUCTION

This section provides information for maintenance and service of the S/5 Compact Airway modules. The Compact Airway modules are double width plug-in modules. M-C, M-CO, M-COV, M-COVX, M-CAiO, M-CAiOV, M-CAiOVX and M-CAiOVX/SERVICE are designed for use with the S/5 monitors. The modules provide airway and respiratory measurements.

Letters in the module name stand for:
M = plug-in module, C = CO_2 and N_2O, O = patient O_2, V = patient spirometry, X = gas exchange, A = anesthetic agents, and i = agent identification

About M-CAiOVX/SERVICE module

The M-CAiOVX/SERVICE module is meant for service purposes only. It can be used as a loan module if the module in the hospital should be sent to the factory for repair. The specifications that apply to the M-CAiOVX apply also to the M-CAiOVX/SERVICE module. Module differences: the colour of the front mask is green, the front panel has a “SERVICE” text and there are no front panel keys equipped.

Table 1 Options for Compact Airway modules

Modules	Parameters/measurements						
	CO_2	N_2O	O_2	Anesthetic agents	Agent ID	Spirometry	Gas exchange
M-CAiOVX	•	•	•	•	•	•	•
M-CAiOV	•	•	•	•	•	•	
M-CAiO	•	•	•	•	•		
M-COV	•	•	•			•	
M-COVX	•	•	•			•	•
M-CO	•	•	•				
M-C	•	•					
M-CAiOVX/SERVICE	•	•	•	•	•	•	•

NOTE: Do not use identical modules in the same monitor simultaneously. The M-C, M-CO, M-COV, M-COVX, M-CAiO, M-CAiOV, M-CAiOVX and M-CAiOVX/SERVICE are considered identical modules.

NOTE: The Compact Airway Module and Airway Module, G-XXXX, cannot be used simultaneously in the same monitor.

NOTE: The Compact Airway modules cannot be used in the Extension Frame, F-EXT4.

NOTE: Anesthetic agents and N_2O values are not displayed with Critical Care main software, but when present in the module they are calculated for compensation of CO_2 and O_2.

1 SPECIFICATIONS

1.1 General specifications

Module size, W × D × H	75 × 228 × 112 mm, 2.9 × 9.0 × 4.4 in
Module weight	1.6 kg/3.7 lbs
Operating temperature	+10…+40 °C
Storage temperature	-25…+70 °C
Atmospheric pressure	666…1060 hPa / (67…106 kPa) (500…800 mmHg) (666…1060 mbar)
Humidity	10…95 % non-condensing (in airway 0…100 %, condensing)
Power consumption	12.6 W Prms, 14.6 W momentary

Protection against electrical shock
Type BF

1.2 Typical performance

1.2.1 CO_2

Measurement range	0…15 vol% (0…15 kPa, 0…113 mmHg)
Measurement rise time	< 400 ms typical
Accuracy	±(0.2 vol% +2 % of reading)
Gas cross effects	< 0.2 vol% (O_2, N_2O, anesthetic agents)

If CO_2 concentration is below 0.1%, 0.0% is displayed.

1.2.2 O_2

Measurement range	0 to 100 vol%
Measurement rise time	< 400 ms typically
Accuracy	±(1 vol% +2% of reading)
Gas cross effects	< 1 vol%; anesthetic agents < 2 vol%; N_2O
O_2 Fi-Et difference	resolution 0.1 vol%

1.2.3 N_2O

Measurement range	0 to 100 %; N_2O
Measurement rise time	< 450 ms typically
Accuracy	±(2 vol% +2% of reading)
Gas cross effects	< 2 vol%; anesthetic agents

1.2.4 Respiration Rate (RR)

Measurement range	4...60 breaths/min
Detection criteria	1 % variation in CO_2

1.2.5 Anesthetic Agents (AA)

Measuring range	
Hal, Enf, Iso	0 to 6 vol%
Sev	0 to 8 vol%
Des	0 to 20 vol%
Measurement rise time	< 400 ms typically
Accuracy	±(0.15 vol% +5% of reading)
Gas cross effects	< 0.15 vol% N_2O

Resolution is two digits when the AA concentration is below 1.0 vol%.
If AA concentration is below 0.1 vol%, 0.0% is displayed.

Identification threshold	0.15 vol% typically
Identification time	< 20 s (for pure agents)

Mixture identification threshold for 2. agent:
0.2 vol% +10% of total conc.

1.2.6 MAC

Range 0...9.9 MAC

Equation:

$$MAC(AA) = \frac{\%(ETAA)}{x(AA)} + \frac{\%ETN_2O}{100}$$ **Formula 1**

where x(AA): Hal=0.75 %, Enf=1.7 %, Iso=1.15 %, Sev=2.05 %, Des=6.0 %.

1.3 Gas specifications

Airway humidity	0...100 %, condensing
Sampling rate	200 ±20 ml/min. (sampling line 2-3 m, normal conditions)
Sampling delay	2.5 seconds typical with a 3 m sampling line
Total system response time	2.9 seconds typical with a 3 m sampling line, including sampling delay and rise time
Display update rate	breath-by-breath

Automatic compensation for pressure, CO_2-N_2O and CO_2-O_2 collision broadening effect.

Warm up time	2 min. for operation with CO_2, O_2, and N_2O 5 min. for operation of anesthetic agents 30 min. for full specifications
Autozeroing interval	Immediately after 'calibrating gas sensor' and 2, 5, 10, 15, 30, 45, 60 minutes after start-up, then every 60 minutes

1.3.1 Normal conditions

Accuracy specifications apply in normal conditions (after 30 minutes warm-up period):

Ambient temperature	18...28 °C, within ±5 °C of calibration
Ambient pressure	500...800 mmHg, ±50 mmHg of cal.
Ambient humidity	20...80 % RH, ±20 % RH of cal.

Non-disturbing gases

- Ethanol C_2H_5OH(< 0.3%)
- Acetone (< 0.1%)
- Methane CH_4 (< 0.2%)
- Nitrogen N_2
- Carbon monoxide CO
- Nitric Oxide NO (< 200 ppm)
- water vapor

Maximum effect on readings

- CO_2 < 0.2 vol%
- O_2, N_2O < 2 vol%
- anesthetic agents < 0.15 vol%

Effect of Helium decreases CO_2 readings < 0.6 vol% typically

1.3.2 Conditions exceeding normal

Accuracy specifications under the following conditions; ❶❷❸:

❶ Ambient temperature	10...40 °C, within ±5 °C of calibration
Ambient pressure	500...800 mmHg, ±50 mmHg of calibration
Ambient humidity	10...98 % RH, ±20 % RH of calibration

❷ During warm-up 2 to 10 minutes (anesthetic agents 5-10 minutes), under normal conditions

❸ During warm-up 10 to 30 minutes, under normal conditions

	Accuracy under different conditions (see above)	
	Condition ❶ and ❸	Condition ❷
CO_2	±(0.3 vol% + 4 % of reading) (at 5 vol% error ±0.5 vol%)	±(0.4 vol% + 7 % of reading) (at 5 vol% error ±0.75 vol%)
O_2	±(2 vol% + 2% of reading)	±(3 vol% + 3% of reading)
N_2O	±(3 vol% + 3% of reading)	±(3 vol% + 5% of reading)
Agents: Hal, Enf, Iso, Sev, Des	±(0.2 vol% + 10% of reading)	±(0.3 vol% + 10% of reading)

1.4 Patient spirometry specifications

1.4.1 Normal conditions

Accuracy specifications apply in normal conditions (after 10 minutes warm-up period):

Ambient temperature	10...40 °C
Ambient pressure	500...800 mmHg
Ambient humidity	10...98 %RH
Airway humidity	10...100 %RH
Respiration rate	4...35 breaths/min (adults) 4...50 breaths/min (pediatric)
I:E ratio	1:4.5...2:1
Intubation tube	5.5...10 mm (adults), 3...6 mm (pediatric)

Airway pressures (P_{aw}, P_{peak}, P_{plat}, $PEEP_e$, $PEEP_{iStat}$, $PEEP_{iDyn}$, P_{mean})

Measurement range	-20...+100 cmH_2O
Resolution	0.5 cmH_2O
Accuracy	±1 cmH_2O

Airway flow

Measurement range (for both directions)	1.5...100 l/min (adults) 0.25...25 l/min (pediatric)

Tidal volume

Measurement range	150...2000 ml (adults), 15...300 ml (pediatric)
Resolution	1 ml
Accuracy	±6 % or 30 ml (adult), ±6 % or 4 ml (pediatric)

Minute volume

Measurement range	2...20 l/min (adults), 0.5...5 l/min (pediatric)
Resolution	0.1 l/min

Compliance

Measurement range	4...100 ml/cmH_2O (adult), 1...100 ml/cmH_2O (pediatric)
Resolution	1 ml/cmH_2O (adult), 0.1 ml/cmH_2O (pediatric)

Airway resistance

Measurement range	0...40 cmH_2O/ l/s
Resolution	1 cmH_2O/ l/s

Other parameters

Specifications apply in conditions listed in patient spirometry specifications.

Dead space of the sensor

9.5 ml (adult), 2.5 ml (pediatric)

Resistance of the sensor

0.5 cmH_2O @ 30 l/min (adult), 1.0 cmH_2O @ 10 l/min (pediatric)

1.4.2 Conditions exceeding normal

Accuracy specifications under the following condition (during warm-up 2 to 10 minutes):

Airway Pressure(P_{aw})

Accuracy	$\pm$2 cmH_2O

Tidal volume

Accuracy	$\pm$10 % or 100 ml (adult), $\pm$10 % or 10 ml (pediatric)

1.5 Gas exchange specifications

Mathemathical integration of airway flow and gas concentration for intubated, mechanically ventilated and/or partly spontaneously breathing patients.

NOTE: These specifications apply only when a 2 meter gas sampling line is used, and a Y-piece with a physical dead space less than 8 ml.

NOTE: These specifications only apply if the FiO_2 level delivered to the patient is varing by less than 0.2 % during the inspiratory cycle at the measurement point.

1.5.1 VO_2 and VCO_2

Measurement range	50...1000 ml/min
Resolution	10 ml/min
Accuracy	±10 % or 10 ml; when $FiO_2 < 65$ %
	±15 % or 15 ml; when 65 % < $FiO_2 < 85$ %

1.5.2 RQ

Measurement range	0.6...1.2
Resolution	0.05

2 FUNCTIONAL DESCRIPTION

2.1 Measurement principle

2.1.1 CO_2, N_2O, and agent measurement

TPX is a side stream gas analyzer, measuring real time concentrations of CO_2, N_2O and anesthetic agents (Halothane, Enflurane, Isoflurane, Desflurane, and Sevoflurane).

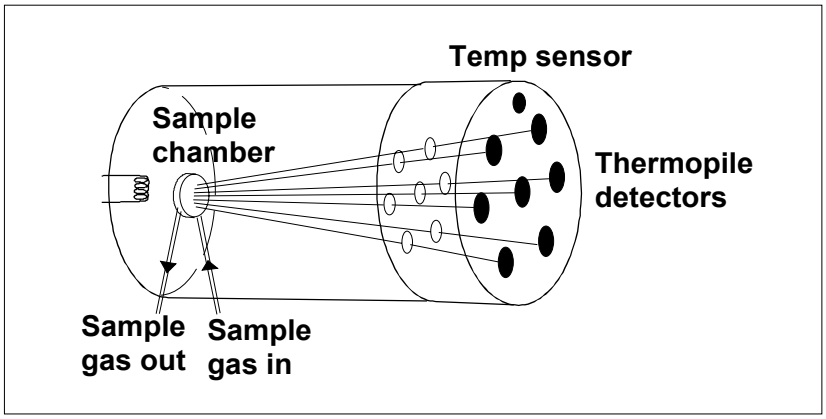


Figure 1 TPX sensor principle

Anesthetic agents or mixtures of two anesthetic agents are automatically identified and concentrations of the identified agents are measured. TPX also detects mixtures of more than two agents and issues an alarm.

TPX is a nondispersive infrared analyzer, measuring absorption of the gas sample at seven infrared wavelengths, which are selected using optical narrow band filters.

The infrared radiation detectors are thermopiles.

Concentrations of CO_2 and N_2O are calculated from absorption measured at 3-5 μm.

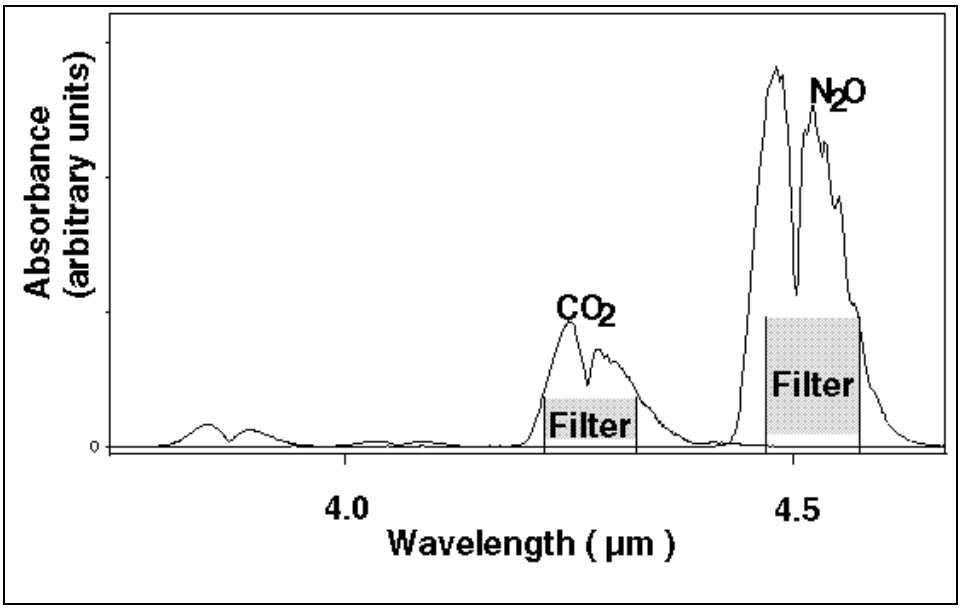


Figure 2 Absorbance of N_2O and CO_2

Identification of anesthetic agents and calculation of their concentrations is performed by measuring absorptions at five wavelengths in the 8-9 µm band and solving the concentrations from a set of five equations.

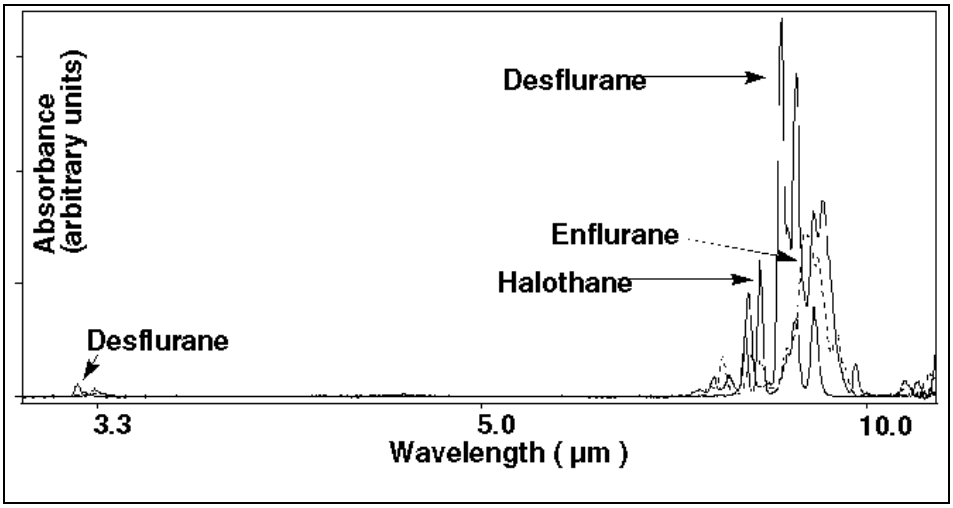


Figure 3 Infrared absorbance of AAs

The measuring accuracy is achieved utilizing numerous software compensations. The compensation parameters are determined individually for each TPX during the factory calibration.

2.1.2 O_2 measurement

The differential oxygen measuring unit uses the paramagnetic principle in a pneumatic bridge configuration. The signal picked up with a differential pressure transducer is generated in a measuring cell with a strong magnetic field that is switched on and off at a frequency of 165 Hz. The output signal is a DC voltage proportional to the O_2 concentration difference between the two gases to be measured.

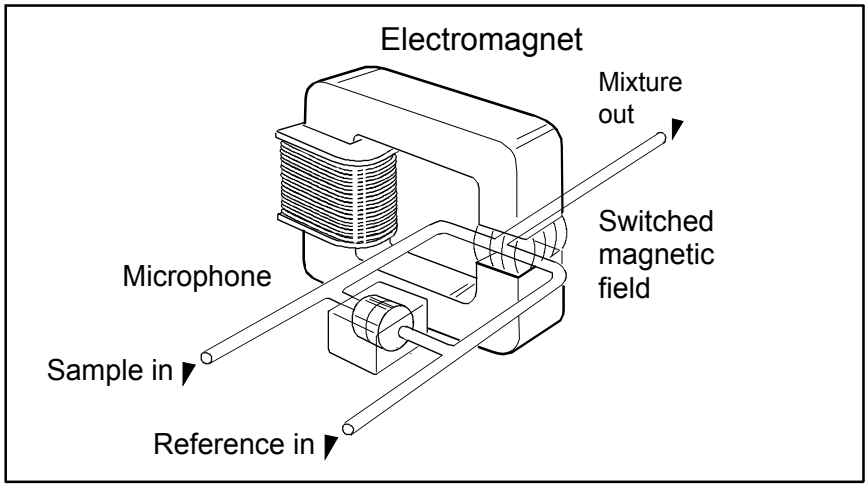


Figure 4 O_2 measurement principle

2.1.3 Patient spirometry

In mechanical ventilation breaths are delivered to the patient by a ventilator with a proper tidal volume (TV), respiration rate (RR), and inspiration / expiration ratio in time (I:E) determined by the settings of the ventilator.
The Patient Spirometry monitors patient ventilation. The following parameters are displayed:

- Expiratory and inspiratory tidal volume (TV) in ml
- Expiratory and inspiratory minute volume (MV) in l/min
- Expiratory spontaneous minute volume in l/min
- Inspiration/expiration ratio (I:E)

Airway pressure

- Peak pressure (P_{peak})
- Mean airway pressure (P_{mean}); available only in S/5 Critical Care and Compact Critical Care monitors
- End inspiratory pressure (P_{plat})
- PEEPi, PEEPe; available only in S/5 Critical Care and Compact Critical Care monitors
- Total positive end expiratory pressure ($PEEP_{tot}$); available only in S/5 Anesthesia and Compact Anesthesia monitors
- Real time airway pressure waveform (P_{aw})
- Static Positive end expiratory pressures (Static $PEEP_i$ and Static $PEEP_e$); available only in S/5 Critical Care and Compact Critical Care monitors

- Static Plateau pressure (Static Pplat); available only in S/5 Critical Care and Compact Critical Care monitors
- Static Compliance (Static Compl); available only in S/5 Critical Care and Compact Critical Care monitors

PEEP, P_{peak}, P_{mean}, and P_{plat} are measured by pressure transducer on the PVX board. Atmospheric pressure is used as a reference in measurement. The pressure measurement is made from the airway part that is closest to the patient between patient circuit and intubation tube.

$PEEP_i$=intrinsic PEEP, $PEEP_{tot}$-$PEEP_e$

Static pressure measurement maneuvres are automatically identified based on a increased zero flow period at the end of the inspiration or expiration.

Static Compliance is calculated if Static PEEP and Static P_{plat} measurements were done within a 2 minutes period.

Airway flow

- Real time flow waveform (V')
- Compliance (Compl)
- Airway resistance (Raw)
- Pressure volume loop
- Flow volume loop

The measurement is based on measuring the kinetic gas pressure and is performed using the Pitot effect. A pressure transducer is used to measure the Pitot pressure. The obtained pressure signal is linearized and corrected according to the density of the gas. Speed of the flow is calculated from these pressure values and TV value is then integrated. MV value is further calculated and averaged using TV and RR (respiratory rate) values.

Compliance and airway resistance
Compliance is calculated for each breath from the equation

$$Compl = \frac{TV_{exp}}{P_{plat} - PEEP_i - PEEP_e}$$ **Formula 2**

Compliance tells how big a pressure difference is needed to deliver a certain amount of gas into the patient.

The airway resistance, Raw, is calculated using an equation, that describes the kinetics of the gas flow between the lungs and the D-lite. The equation states that the pressure at the D-lite can at any moment of the breath be approximated using the equation

$$p(t) = \frac{Raw \times V'(t) + V(t)}{Compl + PEEP_e + PEEP_i}$$ **Formula 3**

where p(t), V'(t) and V(t) are the pressure, flow and volume measured at the D-lite at a time t, Raw is the airway resistance, Compl is the compliance and $PEEP_e$+$PEEP_i$ is the total positive end expiratory pressure ($PEEP_{tot}$).

D-lite™

Patient Spirometry uses a specific sensor called D-lite™ flow sensor. Different types of the D-lite sensors are available: adult sensor for measuring adults and pediatric sensor for children. Both are available as reusable versions and D-lite sensor also for single use.
D-lite adapter is designed to measure kinetic pressure by two-sided Pitot tube. Velocity is calculated from pressure difference according to Bernoulli's equation. Flow is then determined using the calculated velocity.

$$v = \sqrt{\frac{2 \times dP}{\rho}}$$ (from Bernoulli's equation) **Formula 4**

$$F = v \times A ,$$

where:

F = flow (l/min), v = velocity (m/s), A = cross area (m^2), dP = pressure difference (cmH_2O), ρ = density (kg/m^3)

Finally the volume information is obtained by integrating the flow signal.

2.1.4 Gas exchange measurement

The gas exchange measurement uses the D-lite™ flow sensor and the gas sampler.

The basic data which is needed to obtain O_2 consumption and CO_2 production are **volumes** and **concentrations**.

Concentrations have been corrected for delay and deformation during the transport of the gas sample in a sidestream gas measurement sensor.

To obtain the amount of O_2 consumed in ml/min, the amount which is exhaled is subtracted from the amount that is inhaled.

To obtain the amount of CO_2 producted in ml/min, the amount which is inhaled is subtracted from the amount that is exhaled.

These amounts can be obtained by multiplying each measured volume piece (dv) by the corresponding gas concentration:

$$VO_2 = \int_{insp} f_{O_2} dv - \int_{exp} f_{O_2} dv$$ **Formula 5**

and

$$VCO_2 = \int_{exp} f_{CO_2} dv - \int_{insp} f_{CO_2} dv$$ **Formula 6**

Using inspiratory and expiratory minute volumes MV_i and MV_e and volume-weighted inspiratory concentrations fi and fe these equations can be rewritten as:

$$VO_2 = fi_{O_2} \times MV_i - fe_{O_2} \times MV_e \quad [ml/min]$$ **Formula 7**

$VCO_2 = fe_{CO_2} \times MV_e - fi_{CO_2} \times MV_i$ [ml/min] **Formula 8**

To obtain results which are less sensitive to errors in volume measurements, so-called *Haldane transformation* is used. This means taking advantage of the fact that the patient is not consuming nor producing nitrogen: the amount of nitrogen inhaled is equal to the amount exhaled $fi_{N2} \times MV_i = fe_{N2} \times MV_e$.
VO_2 and VCO_2 can then be written as:

$VO_2 = (fi_{O_2} - f_{Hald} \times fe_{O_2})MV_i$ [ml/min] **Formula 9**

$VCO_2 = (f_{Hald} \times fe_{CO_2} - fi_{CO_2})MV_i$ [ml/min] **Formula 10**

with

$f_{Hald} = (1-fi_{CO2} - fi_{O2} - fi_{N2O} - fi_{Ane1} - fi_{Ane2}) / (1-fe_{CO2} - fe_{O2} - fe_{N2O} - fe_{Ane1} - fe_{Ane2})$

$EE=(5.5 \times VCO_2) + (1.76 \times VO_2) + (1.99 \times Un)$ [kcal/day] **Formula 11**

with Un=Urea Nitrogen Excretion = 13 g/day (for adults only).

2.2 Main components

The compact airway modules consist of:

- Gas sampling system
- TPX measuring unit
- OM measuring unit
- PVX measuring unit
- CPU board
- OM board
- PVX board

2.2.1 Gas sampling system

The sampling system takes care of drawing a gas sample to the analyzers at a fixed rate.

The gas sampling system samples the measured air to the module, and removes water and impurities from it. A sampling line is connected to the water trap. The pump draws gas through the sampling line to gas measuring units. After the measurements, the gas is exhausted from sample gas out connector.

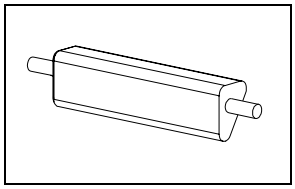
The M-COVX and M-CAiOVX modules have a different gas sampling system compared to the other modules. A number of flow restrictors have been changed to create a bigger pressure difference with ambient pressure in the gas sensors. The sample flow is however about the same (200 ml/min).

A bigger pressure difference makes the deformations of the gas concentration curves less sensitive to high variations of the airway pressures thus meeting also the accuracy requirements of gas exchange for these applications.

D-fend™

The sample is drawn through a sampling line. Then gas enters the monitor through the water trap, where it is divided into two flows, a main flow and a side flow. The main flow goes into the analyzers. This flow is separated from the patient side by a hydrophobic filter. The side flow creates a slight subatmospheric pressure within the D-fend water trap which causes fluid removed by the hydrophobic filter to collect in the bottle.

Zero valve and absorber



The main flow passes through a magnetic valve before proceeding to the analyzers. This valve is activated to establish the zero points for the TPX and OM units. When the valve is activated, room air is drawn through the absorber into the internal system and the gas sensors. Paralyme is used as an absorbent.

Figure 5 Absorber

Nafion™ tubes [1)]

A nafion tube is used between the water trap and the zero valve to balance the sample gas humidity with that of ambient air. The tube will prevent errors caused by the effect of water vapor on gas partial pressure when humid gases are measured after calibration with dry gases. Another nafion tube is used between the absorper and the pneumatic unit to prevent humidity caused by absorb of CO_2.

Gas analyzers

After the zero valve and nafion tube the gas passes through TPX and OM units. The oxygen sensor has two inputs. One input accepts the main flow and the other draws in room air for reference. Both gas flows exit from a single port.

Sample flow differential pressure transducer

The sample flow differential pressure transducer measures pressure drop across OM inlet restrictor and calculates sample flow from the pressure difference.

Working pressure transducer

The working pressure transducer measures absolute working pressure between the TPX unit and OM unit. It is used for messages: ‘sample line blocked’, ‘check D-fend’, ‘replace D-fend’ and ‘check sample gas outlet’.

[1)] Nafion is a trademark of Perma Pure Inc.

Pneumatic unit

The pneumatic unit contains zeroing valve, occlusion valve and tubing connections. There is a series of restrictors and chambers forming a pneumatic filter to prevent pressure oscillations from the pump to reach the measuring units. The occlusion valve connection to room air includes a dust filter and the zero valve connection to room air includes an absorber.

Connection block

The connection block contains sample gas outlet connector and OM unit reference gas inlet. The inlet is equipped with a dust filter.

Occlusion valve

The valve is activated when the sampling line gets occluded. The main flow is then diverted to the side flow of the D-fend water trap to faster remove the occlusion.

Sampling pump and damping chamber

The gas sampling pump is a membrane pump that is run by a brushless DC-motor. Sample flow is measured with a differential pressure transducer across a known restriction. The motor is automatically controlled to maintain a constant flow, even when the D-fend water trap ages and starts to get occluded. It also enables use of sample tubes with varying lengths and diameters.

The damping chamber is used to even out the pulsating flow and silence the exhaust flow.

NOTE: In no occasion is the flow reversed towards patient.

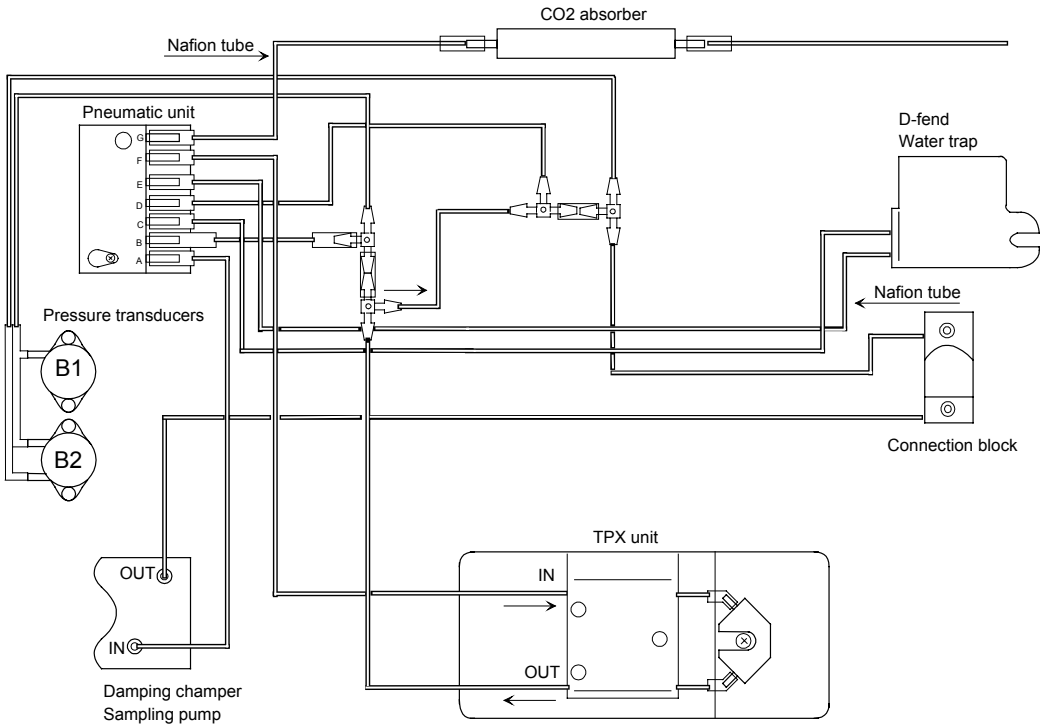


Figure 6 Gas sampling system layout, M-C

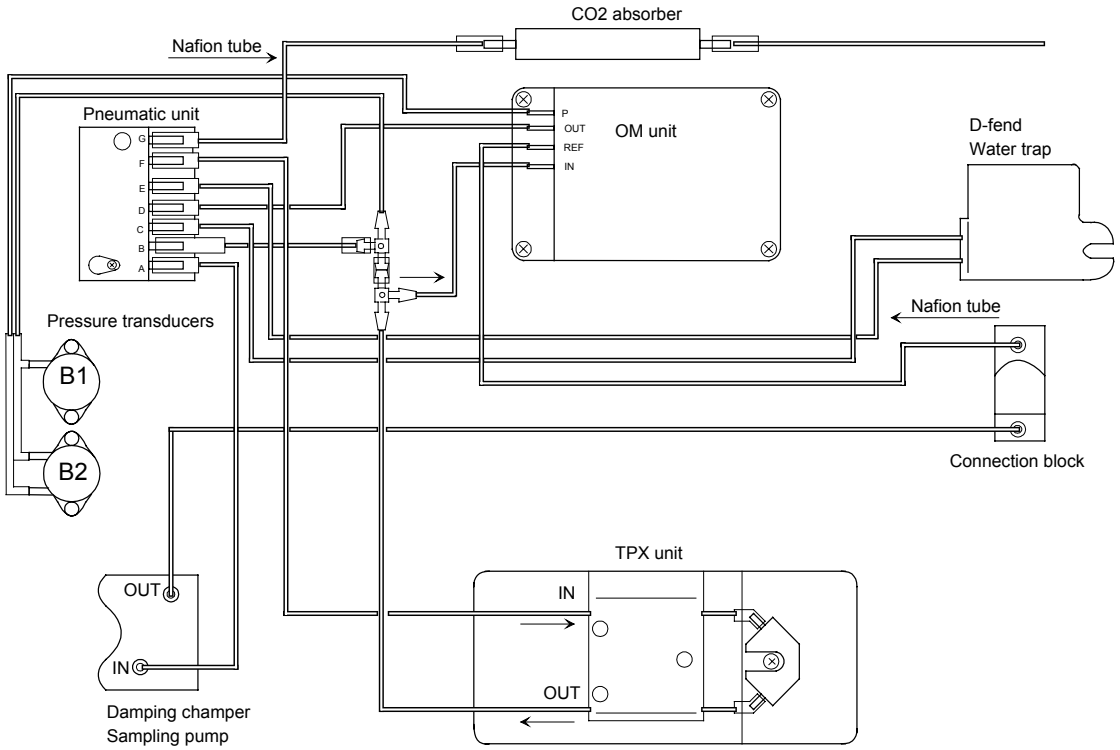
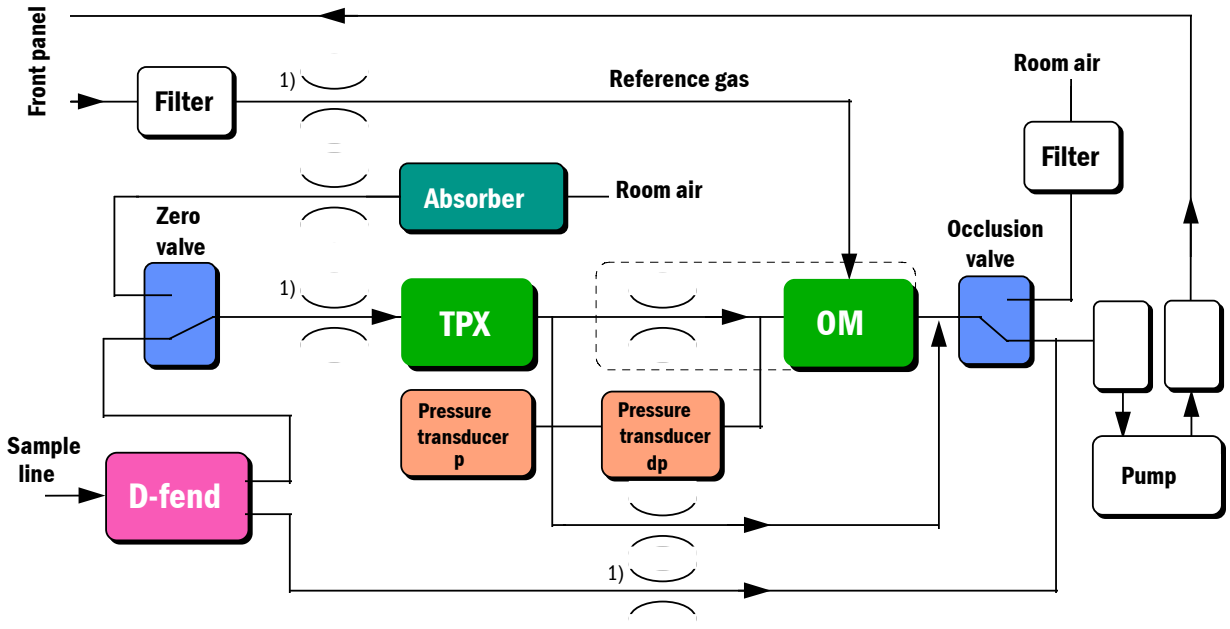


Figure 7 **Gas sampling system layout, M-CAiOV, M-CAiOVX, M-CAiO, M-COVX, M-COV, M-CO**



Tubing marked with 1) is thinner in M-CAiOVX and M-COVX module.

Figure 8 **Gas tubing layout**

2.2.2 TPX measuring unit

The TPX unit is a non dispersive infrared analyzer, measuring absorption of the gas sample at seven infrared wavelengths, which are selected using optical narrow band filters. The IR lamp is a 4 W filament, surrounded by thermal isolation. There is a hole in the isolation, passing the radiation to a conical measuring chamber with 4 mm length.

From the sample chamber, radiation goes into seven tubular light guides with reflective inner surface. At the other end of each light guide, there is a thermopile detector with an optical filter in front of it.

The Temp sensor measures TPX units' temperature and it is used for temparature compensation.

The TPX unit includes TPX board located at the end of the unit. Its function is to connect the 7 thermopile signals and the temperature sensor signal to the CPU board.

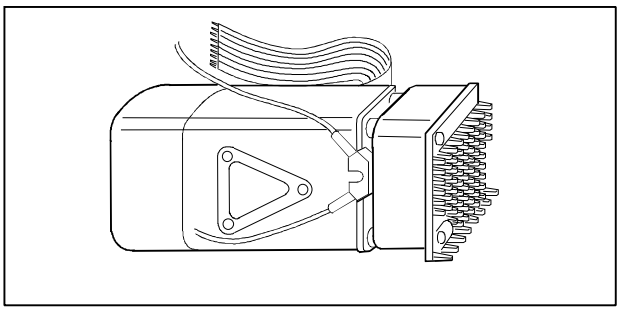


Figure 9 TPX measuring unit

2.2.3 OM measuring unit

The oxygen measurement is based on paramagnetic susceptibility. The gas and the reference gas, which usually is room air, are conducted into a gap in an electromagnet with a strong magnetic field switched on and off at a frequency of approximately 165 Hz.

An alternating differential pressure is generated between the sample and reference inputs due to forces acting to the oxygen molecules in a magnetic field gradient.

The pressure is measured with a sensitive differential transducer, rectified with a synchronous detector and amplified to produce a DC voltage proportional to the oxygen partial pressure difference of the two gases.

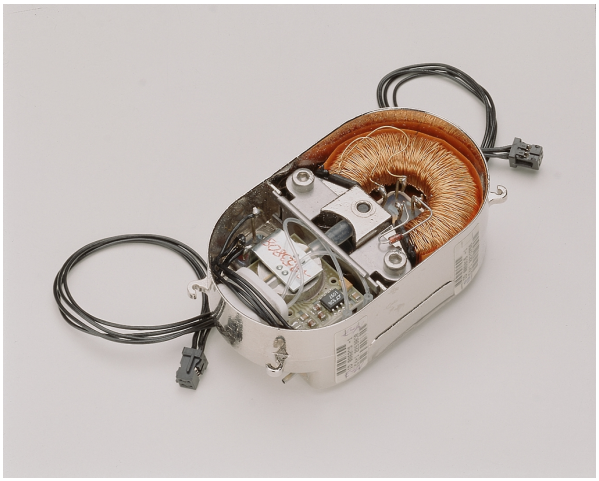


Figure 10 OM measuring unit

2.2.4 PVX measuring unit

NOTE: Never apply overpressure or negative pressure of more than 300 cmH_2O to the flow and volume tubing. Differential pressure max 25 cmH2O on one port at a time e.g. when connecting tubes.

When Patient Spirometry is used, a special sensor, D-lite, replaces the normal airway adapter in the patient circuit. A double lumen tubing is attached to the two connectors on the adapter and on the module front panel.

The Patient Spirometry provides patient respiration monitoring capabilities using the D-lite and Pedi-lite flow sensors.

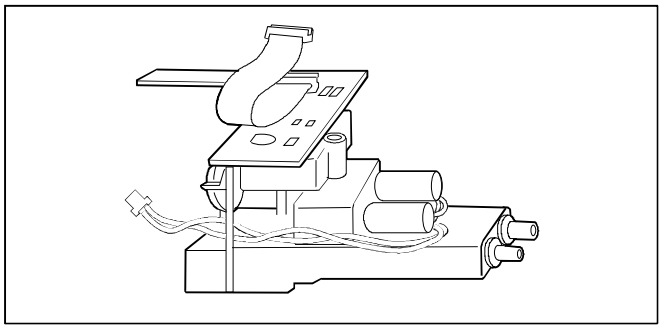


Figure 11 PVX measuring unit

The measurement is based on measuring the kinetic gas pressure and is performed using the Pitot effect. A pressure transducer is used to measure the Pitot pressure. The signal is then linearized and corrected according to the density of the gas. Speed of the flow is calculated from the pressure and TV is integrated from it.
The Patient Spirometry consists of airway connections, two pressure transducers, valves and preamplifiers. The preamplifiers are connected to the A/D-converter on module main CPU.
The breathing flow of a patient passing through the D-lite adapter creates a pressure difference. This pressure difference is measured by pressure transducer, B1. Overpressure and negative pressure in airways are measured by another pressure transducer B2.

2.2.5 Gas exchange

The gas exchange measurement uses the concentrations measured by the TPX measurement unit and the O_2 measurement unit, in combination with the flow from the PVX measurement unit. The gas exchange calculation is done by software.

CAUTION The gas exchange measurement in the M-CAiOVX and M-COVX modules works accurately only with 2 meter gas sampling lines.

2.2.6 CPU board

The CPU board contains the processor and memories and A/D-converters that are common to the whole module. The CPU board also contains preamplifiers of TPX-sensor and drivers for valves, fan, pump and lamp. The module is connected to the module bus through a RS-485 serial channel.

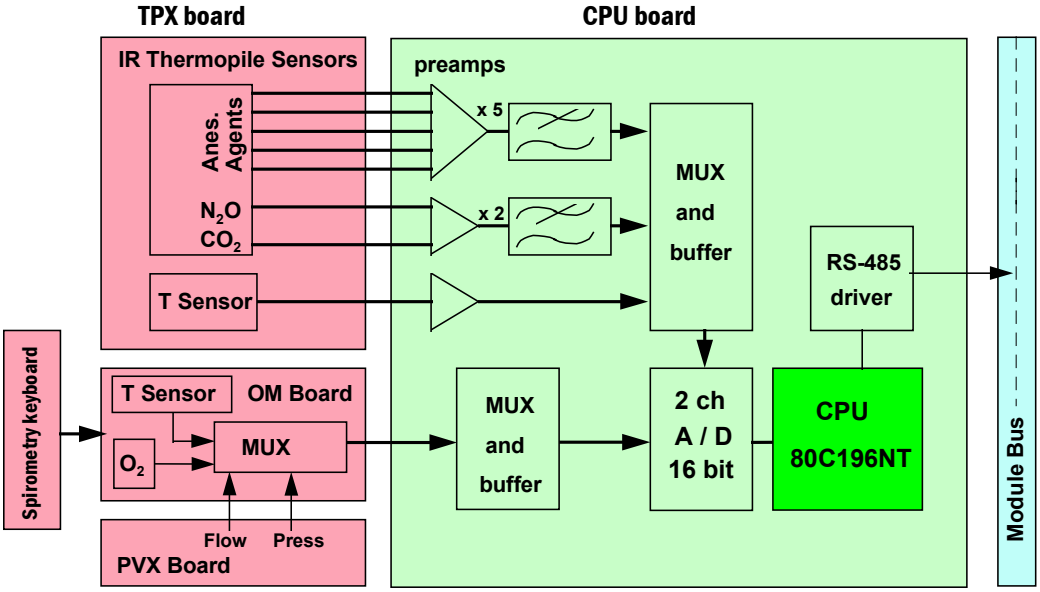


Figure 12 Signal processing

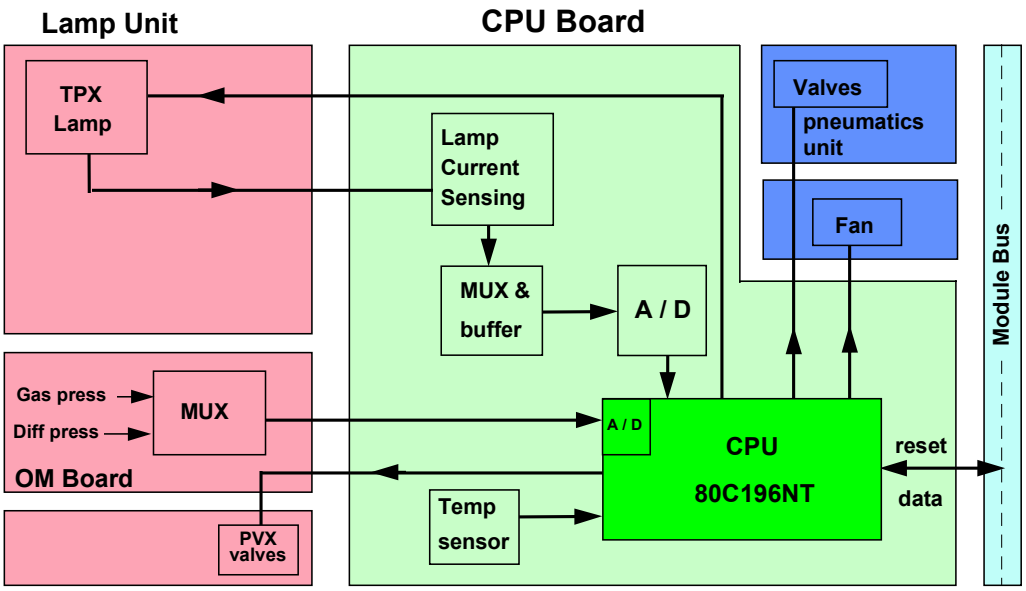


Figure 13 Control logic

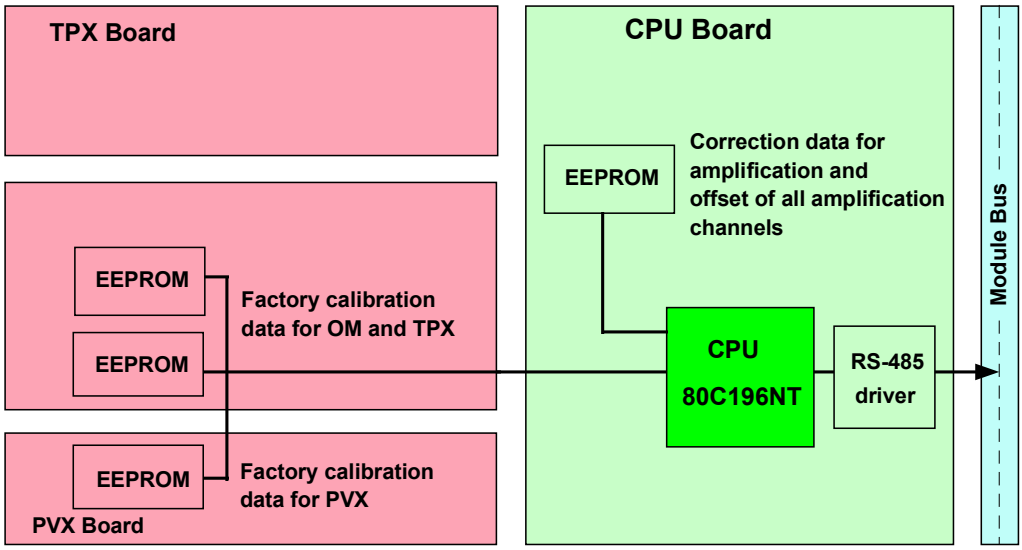


Figure 14 Calibration data stored in EEPROM

2.2.7 OM board

The Oxygen board contains the specific electronics for the oxygen sensor. Sample flow measurement and sampling system pressure sensors are on this board. It also contains EEPROM's that store calibration data of both TPX and OM-sensors. The spirometry keyboard connection is on this board.

2.2.8 PVX board

The Spirometry board is connected to the oxygen board. It contains pressure sensors for airway pressure and flow measurement differential pressure and preamplifiers for those. Calibration data of spirometry is stored on it's own EEPROM.

2.3 Connectors and signals

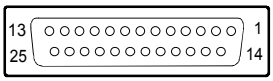


Figure 15 Module bus connector pin layout

Table 2 Module bus connector pin description

Pin No	I/O	Signal
1	I	RESET RS485
2	I	-15 VDC
3	I	+15 VDIRTY
4	I	+15VDC
5	I/O	-DATA RS485
6	I/O	DATA RS485
7		Ground and Shield
8	I	-RESET RS485
9		n/c
10		n/c
11		n/c
12		n/c
13		Ground and Shield
14	I	+24/+32 VDIRTY depends on power supply (not used)
15	I	Ground DIRTY
16		n/c
17		n/c
18		n/c
19		n/c
20	I	GASFR (not used)
21	I	CTSD (not used)
22	I	TXDD (not used)
23	O	RXDD (not used)
24	I	+5 VDC
25	I	+5 VDC DIRTY, for infrared lamps

3 SERVICE PROCEDURES

3.1 General service information

Field service of the compact airway modules is limited to replacing faulty circuit boards or mechanical parts. The circuit boards should be returned to Datex-Ohmeda for repair.

Datex-Ohmeda is always available for service advice. Please provide the unit serial number, full type designation and a detailed fault description.

CAUTION Only trained personnel with appropriate equipment should perform the tests and repairs outlined in this section. Unauthorized service may void warranty of the unit.

CAUTION The module electronics can only be repaired and calibrated at the factory.

3.1.1 OM measuring unit

CAUTION Due to the complicated and sensitive mechanical construction any service inside the O_2 measuring unit should not be attempted.

3.1.2 TPX measuring unit

CAUTION The TPX photometer and its components are repaired/calibrated at the factory. Attempts to repair/calibrate the unit elsewhere will adversely affect operation of the unit. The information provided is for reference only.

3.1.3 OM, TPX, and PVX measuring unit

CAUTION The OM, TPX, and PVX measuring units can be repaired only at the factory.

3.1.4 Serviceable or exchangeable parts

- Absorber
- D-fend
- Nafion tubes
- Fan filter
- Fan
- CPU board
- CPU software
- PVX Unit including PVX board
- Pump

NOTE: After any component replacement see chapter *Adjustments and calibrations*.

3.2 Service check

These instructions include complete procedures for a service check. The service check is recommended to be performed after any service repair. However, the service check procedures can also be used for determining possible failures.

The procedures should be performed in ascending order.

The instructions include a check form, *Appendix A,* which should be filled in when performing the procedures.

The mark  in the instructions means that the check form should be signed after performing the procedure.

The procedures are designed for monitors with software of level 00.

3.2.1 Recommended tools

Tool	Order No.	Notes
Screwdriver		
Ambient pressure manometer		
Flowmeter		
Flow cassette 50/1.1	873812	
Extra silicon tubing		
Calibration gas and the regulator	755583 (gas) 755533	for M-CAiOVX/M-CAiOV/M-CAiO
Calibration gas and the regulator	755587 (gas) 755530	for M-COVX
Calibration gas and the regulator	755581 (gas) 755533	for M-COV/M-CO/M-C
Gas Interface Cable 2.5 m / 8 ft	884299	

3.2.2 Recommended parts

Part	Order No.	Notes
Absorber	895933	
D-fend	876446	
D-fend+	881319	for M-COVX
Sampling line 3 m/10 ft	73319	anesthesia gas sampling line
Sampling line 2 m/7 ft	73318	for M-CAiOVX/M-COVX
D-lite / Pedi-lite	733950/73393	
D-lite+		for condensing active humidification circuits

Part	Order No.	Notes
Spirometry tube 2 m	890031	
Spirometry tube 3 m	884101	
D-fend O-ring (2 pcs)	65312	
Filter (3 pcs)	886136	1 pcs @ latest revisions
Filter assembly	896025	@ latest revisions
Nafion tubes (2 pcs)	733382	
Fan filter	886236	

All modules

Detach the module box by removing the two screws from the back of the module. Be careful with loose latch and spring pin for locking.

1. Check internal parts:
   - all screws are tightened properly
   - all cables are connected properly
   - tubes are not pinched and there are no sharp bends on them
   - all tubes are connected properly
   - the front cover grounding pins are not bent against the CPU board
   - there are no loose objects inside the module

   NOTE: The tubes that are connected to the Oxygen board pressure transducers should not be pressed too deep.
   NOTE: Make sure that tubes are not in contact with the sampling pump or the O_2 sensor, or its springs.

2. Check external parts:
   - the front cover and the front panel stickers are intact
   - all connectors are intact and are attached properly
   - the D-fend latch is moving properly
   - the module box, the latch and the spring pin are intact

3. Clean or replace the fan filter.

4. Detach the D-fend. Check the condition of the rubber O-rings on the metal D-fend connectors, located in the Compact Airway Module front cover.
   If necessary, detach the connectors by first disconnecting the tubes, then removing the locking rings from the back of the front cover.
   NOTE: The O-rings are recommended to be replaced annually.

5. Check that flow of air through the filters in the reference gas connection block (1 pc) and in the pneumatic unit (2 pcs) is not obstructed.

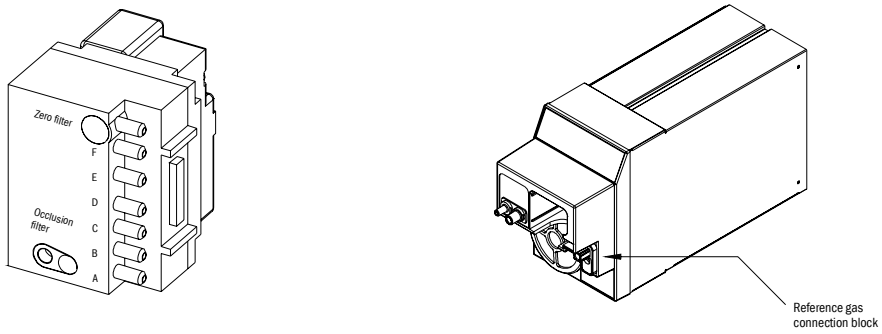


Figure 16 Pneumatic unit and reference gas connection block

NOTE: The filters are recommended to be replaced annually.

- Replace the D-fend and sampling line by new.

  NOTE: Use only Datex-Ohmeda sampling lines in order to ensure proper functioning. 2 m/7 ft sampling line should be used with M-COVX and M-CAiOVX.

- Connect the Compact Airway Module to the Central Unit's Module motherboard using the Gas interface cable (the grounding plates of the cable should be removed).
- Turn the monitor on.
- Configure the monitor screen so that all the needed parameters are shown, for example as follows:

  Monitor Setup - ***Screen 1 Setup*** - ***Waveform fields*** - ***Field 1 - Paw***
  Field 2 - Flow
  Field 3 - Off
  Field 4 - O2
  Field 5 - AA
  Field 6 - CO2
  Digit Fields
  Lower Field 1 - Gases

  - Preset the following gas measurement settings (if available):

    Airway Gas - Select Agent - Hal
    Spirometry Setup - Scaling Vol
    Paw Scale - 20
    Flow Scale - 15

6. Check that the fan is running.

7. Wait until the message 'Calibrating gas sensor' disappears from the screen, then enter the Service menu.

   Monitor Setup - *Install/Service* (password 16-4-34) **- *Service*** (password 26-23-8)

   Take down the information regarding Compact Airway Module software.

8. Enter the Compact Airway Module service menu.

   Parameters - Gas Unit - General

   Check that the shown module configuration corresponds with the used Compact Airway Module type.

9. Check that the 'Timeouts', 'Bad checksums' and 'Bad c-s by mod' -values are not increasing faster than by 50 per second.
   If one of the values is increasing faster it indicates a failure in module bus communication.

10. Enter the service menu ***Gases***:

    Gas Unit - Gases

    Check that the flow measurement offset, i.e. the shown sample 'Zero' -value is within ±10 ml/min.

11. Check that the shown 'Ambient' -value corresponds with the current ambient pressure (±20 mmHg).

12. Check the zero valve.
    Feed calibration gas and check that the gas readings in the service menu correspond with the values on the gas bottle sticker. Keep feeding gas, then activate the zero valve from the menu. The CO_2 (N_2O, AA) reading should drop back near 0 %, the O_2 reading near 21 %.

13. Perform the steam test for the Nafion tubes, or replace those by new. Replace the CO_2 absorber, if necessary.

    NOTE: The Nafion tubes are recommended to be replaced annually. In case of exchanging the absorber it is recommended to replaced also this nafion tube.
    NOTE: The CO_2 absorber is recommended to be replaced once in four years.

14. Perform sampling system leak test.

    Prevent the module from performing the normal occlusion functions, i.e. controlling the valves, by turning the pump first off, then on again from the menu.

    Block the reference gas connector at the front panel.
    Connect a flow cassette with high flow resistance value (50/1.1) to the end of the sampling line and start following the 'Amb-Work' -value in the service menu. When the value exceeds 170 mmHg connect the other port of the flow cassette to the sample gas out connector and switch the pump off.
    Wait until pressure inside the sampling system is stabilized then notice the shown 'Amb-Work' -value. The value, i.e. the pressure inside the sampling system should not drop more than 6 mmHg in one minute.

    If the pressure drops more, first ensure the made connections and repeat the test.

15. Check the flow rates.

    Wait until the 'Sample Flow' -value is back near 200 ml /min.
    Connect a flowmeter to the 3 meter sampling line (use a 2 meter sampling line for M-CAiOVX and M-COVX) and check that the flow (the flowmeter reading) is within the following range:

Sampling flow (ml/min)	180...220

    If necessary, readjust the sampling flow:
    Select 'Sample gain adj' from the menu. To increase the sampling flow, turn the ComWheel counterclockwise, to decrease the flow, turn the ComWheel clockwise.
    A change of 0.050 in the 'Gain' -value changes the flow approximately 10 ml/min.
    After you have changed the gain, wait until the 'Sample Flow' -value on the screen gets back near the original then check the flowmeter reading again.

    Connect the flowmeter to the reference gas connector, check that the flow is within the following range:

Reference flow (ml/min)	M-CAiOVX/ M-COVX	M-C	Others
	27...40	25...45	31...45

    Activate the zero valve on from the service menu. The 'Sample Flow' -value should not change more than 20 ml/min. If the absorber is connected the value is 30 ml/min.

16. Check that the 'Amb-Work' -value in the service menu is within the following range:

Amb-Work (mmHg)	M-CAiOVX/M-COVX	Others
	70...115	40...75

17. Perform the gas calibration.

Airway Gas - ***Gas Calibration***

NOTE: The calibration is not recommended to be performed before 30 minutes warm-up time. Use calibration gas 755587 (5 % CO_2, 95 % O_2) for calibrating Airway Module, M-COVX, and calibration gas 755583 (2 % Desflurane, 5 % CO_2, 33 % N_2O, 55 % O_2, balance N_2) for M-CAiOVX/M-CAiOV/M-CAiO,
and calibration gas 755581 (5 % CO_2, 40 % N_2O, 55 % O_2) for calibrating M-COV/M-CO/M-C.

NOTE: You can calibrate the modules M-CO and M-COV also with the same calibration gas as the M-COVX module, but M-C must always be calibrated with the gas 755581.

NOTE: For correct measurement values, modules need different amounts of oxygen in the calibration. If you do not use the recommended calibration gases, the calibration does not succeed.

18. Perform the fall time measurement in the GASES service menu.

Monitor Setup - ***Install/Service*** (password 16-4-34) - ***Service*** (password 26-23-8) - ***Parameters - Gas Unit - Gases***
Activate the measurement by selecting Fall Time Meas from the service menu. Feed calibration gas until the message 'Feed' near the fall time values changes to 'READY'. If necessary, repeat the same procedure to get all the values on the screen.

Check that the measured values are within the following ranges:
CO_2 fall time < 400 ms
O_2 fall time < 400 ms
CO_2-O_2 delay < 800 ms

Anesthesia Agent measurement

19. Agent ID reliability.
    Feed calibration gas (order code 755583) continuously at least for 30 seconds and check that the 'ID' in the service menu shows 'DES' and that the value for 'ID unrel.' is lower than 50.

    If the value is higher, repeat the gas calibration and check the value again.

Patient Spirometry measurement

20. Enter the service menu ***Spirometry***:

    Gas Unit - Spirometry

    Connect a clean Spirometry tube to the module and a clean D-lite to the other end of the tube. Block the D-lite's sampling line port, for example with a Luer stopper.

    NOTE: Make sure that the date marking on the D-lite is 10/94 or newer.

    Take the D-lite into your hand and occlude both ends tightly with your fingers (or with both hands). Pressing creates a pressure inside the D-lite. Check that pressure near 5 cmH_2O is generated (the 'Aw Pressure' -value in the service menu).

    If the system leaks heavily, no pressure will be generated.

    If there is a small leak in the connections, the monitor will measure a pressure difference which is then interpreted as flow and seen on the monitor screen. The pressure waveform (and the 'Aw Pressure' -value) decreases slowly and the flow waveform (the 'Flow' -value) either goes above, or below the zero line, depending on which of the connectors is leaking.

    In case of leakage, first check all the connections and try again.

21. Remove the blockage from the sampling line port and connect the sampling line. Breath through the wider side of the D-lite. Check that the flow waveform moves downwards when you breath in, and upwards when you breath out.

22. If possible, check the Side Stream Spirometry measurement also with the Spirometry Tester (order code 884202). Follow the instructions that are supplied with the tester.

All modules

Turn the monitor off, disconnect the Gas interface cable and reassemble the module. Remember to attach the plastic cover against the CPU board before installing the module box.

NOTE: When reassembling the module make sure that the tubes are not pinched between the module box and internal parts.

23. Perform electrical safety check and leakage current test.

Install the Compact Airway Module into the Central Unit, turn the monitor on and wait until the message 'Calibrating gas sensor' disappears from the screen.

24. Block the tip of the sampling line by your finger and check that the message 'Sample line blocked' appears onto the monitor screen within 60 seconds.

25. Detach the D-fend and check that the messages 'Check D-fend' appears onto the monitor screen within 30 seconds.

Reattach the D-fend. Simulate at least 5 breaths by feeding calibration gas into the sampling line. Check that the shown gas information is correct.

26. Check that the monitor shows the message 'Apnea' within 30 seconds after you have stopped feeding the gas.

27. Turn the monitor off, disconnect and clean the module.

- Fill in all necessary documents.
- It is recommended to fill in the PM sticker, since the service check includes all the Planned Maintenance actions. Attach it to a suitable place on the module box.

3.3 Disassembly and reassembly

Disassemble the compact airway module in the following way. See also the exploded view of the module.

1. Remove two screws from the back of the module.
2. Pull the module box slowly backwards and detach it from the main body.

Reassembling is essentially reversing what was described above.

CAUTION When reassembling the module, make sure that the tubes and cables are not pinched between the boards and the cover.

3.3.1 PVX unit

1. Remove the module box.
2. Detach the CPU board and OM board from the module chassis (4 screws).
3. Disconnect the pump cable, pneumatics unit cable, fan cable, and the other cable of the TPX unit from CPU board.
4. Disconnect OM unit's cables, spirometry keyboard cable and PVX unit's cables from the OM board.
5. Detach the front panel from the module chassis (1 screw).
6. Detach the PVX unit from the front panel (1 screw).
7. Reassembling is essentially reversing what was described above.

3.3.2 Pump unit

1. Remove the module box.
2. Cut off the pump's clamp (panduit).
3. Unplug the hoses of the pump.
4. Disconnect the pump's cable from CPU board. Pass the cable under the pneumatic unit by lifting it.
5. Reassembling is essentially reversing what was described above.

3.3.3 CPU board

1. Remove the module box.
2. Detach the CPU board and OM board from the module chassis (4 screws).
3. Disconnect the pump cable, pneumatics unit cable, fan cable, and both cables of the TPX unit from CPU board.
4. Detach the CPU board from the OM board.
5. Reassembling is essentially reversing what was described above.

3.3.4 Software of CPU board

1. Remove the module box.
2. Detach the CPU board and OM board from the module chassis (4 screws).
3. Disconnect the pump cable, pneumatics unit cable, fan cable, and the other cable of the TPX unit from CPU board.
4. Detach the CPU board from the OM board.
5. Detach the software from the CPU board.
6. Reassembling is essentially reversing what was described above.

3.3.5 Instructions after replacing software or CPU board

After replacing the software or CPU board:

- perform the sampling system leak test.
- perform the occlusion test
- perform the gas calibration.
- perform Fall time Measurement

3.4 Adjustments and calibrations

See *User's Reference Manual* for normal gas calibration instructions.

3.4.1 Gas sampling system adjustment

NOTE: Let the monitor run for 15 minutes before measuring flow rates.

For the flow rate measurements a flowmeter with a low flow resistance and capability to measure low flow rates is required. A normal length of sampling line has to be connected to the monitor as it has a considerable effect on the flow.

3.4.2 Flow rate measurement

If any flow rates are not correct, first replace the D-fend water trap. Then recheck the incorrect flows.

Sampling flow rate is measured by rotameter at the sampling line. The rate should be between 180 and 220 ml/min. The flow rate is adjusted in the Gas Service Menu with 'Sample Gain Adj.'.

Reference flow of the oxygen measuring unit are checked as follows:
Connect rotameter to the Gas Ref. inlet on the front panel. The flow rate should be between 31 and 45 ml/min (M-CAiOVX/M-COVX: 27-40 ml/min, M-C: 24-45 ml/min). The flow rate is not adjustable.

3.4.3 Flow rate adjustment

NOTE: Before adjusting the sampling flow make sure there is no leakage in the sampling system.

Refer to chapter *3.2 Service check,* step 15; *Check the flow rates.*

Wait until the 'Sample Flow' -value is back near 200 ml /min.
Connect a flowmeter to the 3 meter sampling line (use a 2 meter sampling line for M-CAiOVX and M-COVX) and check that the flow (the flowmeter reading) is within the following range:

3.4.4 Gas calibration

The gas calibration is performed in the ***Airway Gas*** menu. Please refer *User's Reference Manual.*

3.4.5 Flow calibration

PVX measuring unit is calibrated at the factory and due to the unit's design calibration is not regularly needed. The calibration data is saved into the board's EEPROM. In case calibration is needed, it is recommended to perform the calibration both with adult values using the D-lite, and with pediatric values using Pedi-lite.

1. Connect a spirometry tube with a D-lite sensor to the compact airway module. To improve the accuracy, the endotracheal tube and all accessories which normally are in use should be attached also during the calibration.
2. Enter the Gas Unit service menu: **Monitor Setup** - ***Install Service*** - ***Service*** - ***Parameters***. Enter the Spirometry menu.
3. After the flow is zeroed ('Zero OK' message displayed) attach a preferably spirometry tester to the flow sensor (D-lite or Pedi-lite). Select the sensor type.
4. Perform the calibration according to the tester instructions. Observe the values of inspired and expired tidal volumes.
5. Adjust the reading to match the calibration volume (about 1000 ml for the D-lite and 300 ml for the Pedi-lite). Adjust Exp Flow Gain and Insp Flow Gain values in proportion to the difference between measured values and the spirometry tester reading.

4 TROUBLESHOOTING

4.1 Troubleshooting charts

Trouble	Possible cause/treatment
No response to breathing	Sampling line or water trap blocked or loose, or improperly attached. Water trap container full. See the gas sampling system troubleshooting.
SENSOR INOP. -message	The temperature is too high, check fan and filter at the front panel Communication error, check timeout and bad checksum values at the service menu
xx ZEROING ERROR -message	Gas zeroing failed. Condensation or residual gases are affecting zero measurement. Allow module to run drawing room air for half an hour and calibrate again.
CHECK D-FEND -message (Air leak-message)[1)]	Probably water trap or the sampling line is not attached properly. Gas zero valve failure. Pump failure or gas outlet blockage.
REPLACE D-FEND -message (Replace water trap -message)[1)]	Indicates residue build-up on the water trap membrane. This decreases air flow. Replace the D-fend.
REBREATHING-message ($FiCO_2$ high -message)[1)]	CO_2 concentration in inspiratory air is too high. Possibly CO_2 absorber in ventilation is saturated. Change the ventilation absorber.
SAMPLE LINE BLOCKED-message (Air leak -message)[1)]	Sampling line or water trap is occluded. Water trap container is full. If occlusion persists check internal tubing for blockages.
(SELECT AGENT -message)[1)]	No anesthetic agent is selected though delivery is started. Vaporizer valve is broken, or traces of cleaning or disinfecting agent in the water trap container affecting the readouts. Let the container dry properly after disinfection before use.
No response to any gas	Sampling line, water trap, or internal tubing blocked or loose, or improperly attached. Occlusion or zero valve malfunction. Pump failure. Supply voltage missing. Serial communication error.

Trouble	Possible cause/treatment
Sudden increase in gas display	Water trap malfunction. Check all internal tubing and the interior of the water trap for occlusions or leaks. Replace water trap. Check flow rates.
Abnormally high response to all gases (or abnormally low) or sudden occlusion warning	Pressure transducer failure.

[1)] @ earlier revisions

Trouble	Possible cause/treatment
Strong drift in all gases	Leak in sampling line or internal tubing (especially in conjunction with too low readings).
MVexp << MVinsp message	Leak in patient circuit between patient and D-lite, or in the patient lungs, or leak in tubes from D-lite to module. Check D-lite connection and D-lite tubing.
(Disconnection)[1)] (MVexp < 0.5 l/min message)[1)] Low volumes	Too small tidal volumes for accurate measurement (not shown during Apnea). Gas sampling is working correctly. Check D-lite connections and D-lite tubing.

4.1.1 CO_2 measurement

Problem	Possible clinical cause	Possible technical cause	Action
too low $ETCO_2$ value	• sudden decrease in circulation • pulmonary embolism • hyperventilation • very large dead-space • large shunting	• leak in sampling system • calibration error • high by-pass flow from ventilator	• check all connections • check calibration
too high $ETCO_2$	• hypoventilation • increased metabolism	• D-fend contaminated • calibration error	• change D-fend • check calibration
waveform clipped	•	• incorrect scaling	• change scale
no response to breathing	• apnea • (disconnection)[1)]	• sampling line or water trap loose or blocked (air leak)[1)] • sample gas outlet blocked	• check all connections • check that outlet is open
$ETCO_2$ overscale >15 % (>20 %)[1)] Shown untill 32 %, specified range 0...15 %	• abnormally high $ETCO_2$ (permissive hypercapnia)	• CO_2 sensor contaminated • D-fend malfunction	• call service technician • change D-fend
$ETCO_2$>$PaCO_2$	• unit is mmHg or kPa and $ETCO_2$ is close to arterial PCO_2	• “dry gas” as default	• change to “wet gas” by using install/service menu

[1)] @ earlier revisions

4.1.2 Patient spirometry

Problem	Possible clinical cause	Possible technical cause	Action
insp TV>exp TV	• leak in lungs • ET tube cuff leak	• spirometry tube leak • water inside D-lite or tubings • another side stream gas sampling between D-lite and patient • D-fend leaks	• check leakages -- perform leak test • change tubings and D-lite • don't use active humidification • connect gas sampling only and always to D-lite • check D-fend
exp TV> insp TV		• spirometry tube leak • water inside D-lite or tubings	• check leakages -- perform leak test • change tubings and D-lite • don't use active humidification
loop overscale		• wrong scale selected	• change scaling
monitored volumes < set volumes		• leak between ventilator and D-lite	• check ventilator connections
strongly vibrating loop	• mucus in ET tube	- • water or secretions in hoses or D-lite	• suction the patient • change dry D-lite and/or empty the water from hoses
too large or too small volumes		• wrong mode vs sensor selection • incompatible between selected sensor and sensor used	• check mode and sensor – D-lite for adult – Pedi-lite for pediatric

Problem	Possible clinical cause	Possible technical cause	Action
fluctuating Raw	• mucus in airways or tubings • breathing effort against the ventilator • patient triggered breaths	• ventilator exp. valve causes fluctuations during exp. flow	
too high Raw	• kink in tubing • mucus • asthmatic patient • bronchospasm		
Raw value invalid	• spontaneous breaths • breathing efforts against the ventilator • patient triggered breaths		
too high Ppeak	• bronchospasm • patient is coughing • patient breaths against the ventilator • obstruction in airways • HME obstructed		
static PEEPi not measured		• CO_2 measurement is not connected • stat PEEPi measurement not selected[1)] • exp. pause did not last at least 4 sec.	• connect CO_2 meas. to D-lite • go to spirometry setup[1)]
Compl value invalid	• spontaneous breaths		

[1)] only @ earlier revisions

4.1.3 Gas exchange

Problem	Possible clinical cause	Possible technical cause	Action
"Strange" values	• ventilation mode: BiPaP, CPAP with high continuous by-pass flow • presence of N_2O or anesthetic agents in ICU applications		• gas exchange not measurable • do not use N_2O or AA in ICU, or use a M-CAiOVX module
Unphysiological VO_2 readings	• unstable O_2 delivery – gas mixer		• select oxygram and verify the stableness of the curve
	• RR over 35/min	• reference gas inlet port blocked	• check reference port
		• gas sampling line longer than 2 m	• change 2 m sampling line
		• dead space of Y-piece > 8 ml	• check the dead space of Y-piece
		• gas sampling line connected to HME	• gas sampling line should ALWAYS be connected to D-lite
		• D-lite incorrectly placed	• do not connect anything between D-lite and Y-piece • ALWAYS connect D-lite between the HME and Y-piece
VO_2 value invalid, no VO_2, FiO_2 > 85 %, (FiO_2+FiN_2O) > 85 %	• over range • no VO_2 value • 999 ml/min < VO_2 < 0		

4.2 Gas sampling system troubleshooting

The faults which can occur in the sampling system are: leaks or blockages in the tubing, failure of the sampling pump or the magnetic valves, or diminishing of the flow rates because of dirt accumulating in the internal tubing.

The following checks should help in localizing the fault. Whenever suspecting the sampling system and always after having done any work on the sampling system check and if necessary adjust the flow rate.

CAUTION The special internal sample tube is mechanically fragile. Sharp bends will cause leaks.

NOTE: D-fend water trap should be replaced when the REPLACE D-FEND message appears during the monitor startup.

NOTE: If any liquid has entered the TPX measuring unit due to water trap filter failure, contact Datex-Ohmeda Technical Services.

4.2.1 Sampling system leak test

1. Prevent the module from performing the normal occlusion functions, i.e. controlling the valves, by turning the pump first off, then on again from the menu.
2. Block the reference gas connector at the front panel.
3. Connect a flow cassette with high flow resistance value (50/1.1) to the end of the sampling line and start following the 'Amb-Work' -value in the service menu. When the value exceeds 170 mmHg connect the other port of the flow cassette to the sample gas out connector and switch the pump off.
4. Wait until pressure inside the sampling system is stabilized then notice the shown 'Amb-Work' -value. The value, i.e. the pressure inside the sampling system should not drop more than 6 mmHg in one minute.
5. If the pressure drops more, first ensure the connections you have made and repeat the test.

4.2.2 Steam test for the Nafion™ tubes

Choose Halothane as anesthetic agent and let the monitor sample room air. Then quickly feed air of 100 % relative humidity (for instance from a kettle in which you are boiling water) to the monitor. If the digital reading jumps as much as 0.1 % replace the Nafion tubes.

4.3 OM measuring unit troubleshooting

CAUTION Because of the complex and very sensitive construction of the oxygen measuring unit no repairs should be attempted inside the unit. Instead, if the fault has been found in the measuring unit itself, the whole module should be replaced and the faulty module be sent to Datex-Ohmeda for repair.

In cases of no response to O_2 or strong drift, check the tubing for loose connections, blockages and leaks.

CAUTION Never apply overpressure to the O_2 measuring unit as the pressure transducer may be permanently damaged.

If the O_2 signal is noisy, check the measurement unit suspension.

4.4 TPX measuring unit troubleshooting

CAUTION The TPX measuring unit can only be repaired and calibrated at the factory. In case of failure the whole module should be replaced and the faulty module be sent to Datex-Ohmeda for repair.

4.5 PVX measuring unit troubleshooting

In case of failure the PVX unit can be replaced.

NOTE: Never apply overpressure or negative pressure of more than 300 cmH_2O to the flow and volume tubing. Also never apply differential pressure of more than 25 mmHg on one PVX-connection at a time.

4.6 CPU board troubleshooting

Due to the complexity of the large scale integrated circuitry there are few faults in the CPU digital electronics that can be located without special equipment.

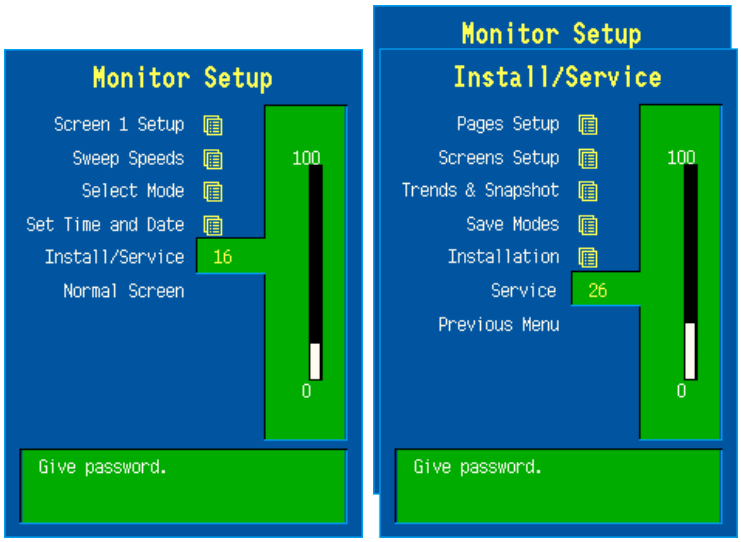
Check only that RAM, EPROM, CPU, and other socketed ICs are properly installed.

4.7 Error messages

Message	**Explanation**
Occlusion or Sample Line Blocked	The sample tube inside or outside the monitor is blocked or water trap is occluded. If occlusion persists, measured gas values disappear.
Continuous occlusion. Check sampling line and D-fend.	Occlusion over 40 seconds.
Check D-Fend (Air leak)[1)]	-the water trap is not connected -there is a leak in the sampling line inside the module. If air leak persists measured gas values disappear. Check sample gas out
Air leak detected. Check water trap and sample gas out-flow. Press normal screen to continue.	Air leak over 40 seconds.
Replace D-fend (replace water trap)[1)]	Indicates residue build-up on the water trap membrane. This decreases air flow.
Gas calibration is not available during first 5 minutes/during occlusion/during air leak	Entering calibration is not allowed during 5 minutes after power up and during occlusion or air leak.
Select agent[1)]	No agent selected
Select agent[1)]	Mixture of agent is detected, but no agent is selected.
Check agent[1)]	Agent is selected manually, but it differs from the identified one.
Failure in Agent ID (unknown agent)	The agent ID has failed (due to a third agent).
Overrange	FiO_2 >100 % measured
Recalibration	Time out, fluctivating gases, gain adjusted “over”
CO_2, O_2, AA, N_2O	
Zero error	Unsuccessful zeroing.
Unstable, Calibr error	Unsuccessful calibration.
Menu messages during calibration:	
Zero error	Unsuccessful zeroing
Adjust	Calibration gas accepted and monitor is ready for adjusting the gas values to match the calibration gas concentration
Unstable	Unsuccessful calibration

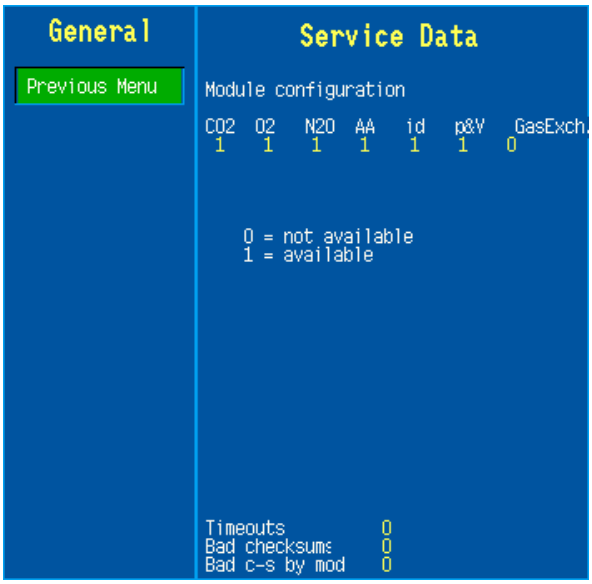
[1)] only @ earlier revisions

5 SERVICE MENU



Press the **Monitor Setup** key - select ***Install/Service*** (password: 16-4-34) - select ***Service*** (password: 26-23-8) - select ***Parameters*** - select ***Gas Unit***.

5.1 General menu



Service Data field

Module configuration shows which measurement options are available, i.e. are detected by the module.

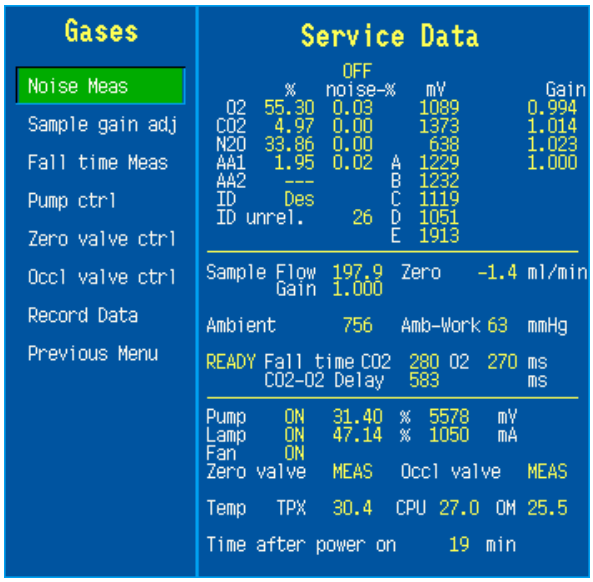
Timeouts is a cumulative number that indicates how many times the module has not responded to the monitor's inquiry.

Bad checksums is a cumulative number that indicates how many times communication from the module to monitor broke down.

Bad c-s by mod is a cumulative number that indicates how many communication errors the module has detected.

The monitor starts counting these items at power up and resets to zero at power off. The nonzero values do not indicate a failure, but the continuous counting (more than 50 per second) indicates either serial communication failure or module not in place. Also other modules can cause these numbers to rise.

5.2 Gases service menu



Noise Meas A selection for activating the noise measurement.

Sample gain adj A selection for adjusting the sampling pump gain, i.e. for for adjusting the sample flow measurement.

Fall time Meas A selection for activating the fall time measurement.

Pump ctrl A manual control for the sampling pump

Zero valve ctrl A manual control for the zero valve.

Occl valve ctrl A manual control for the occlusion valve.

Record Data Record Data prints out the shown service data and board information (id. serial number and software id.) onto the recorder module XXX TAI MUUALLE, MIHIN? XXX, M-REC.

Service Data field

O_2, CO_2, N_2O, AA **%** -field shows realtime concentrations, **noise-%** is standard deviation of concentration.

O_2, CO_2, N_2O, AA channels A-E

mV -field: signal is scaled to mV, **Gain**: User gain. It is scaled as (User gain)/(Factory gain).

ID Shows the identified agent.

ID unrel. The shown value tells how **unreliable** the identification is. With pure agent the value is normally < 50.

Sample Flow **Sample Flow** is calculated from differential pressure and is adjusted by the module. **Zero** value as measured during initialization when the pump is off. **Gain**: sample flow measurement can be calibrated by adjusting the gain.

Ambient **Ambient**: ambient pressure is measured every 30 min. **Amb-Work**: ambient pressure - sampling system internal pressure.

Fall time CO_2 and O_2 in ms. For N_2O and AA same as CO_2.

CO_2-O_2 Delay In ms. No delay between CO_2, N_2O, and agents.

Pump Can be toggled ON/OFF.
PWM output 0-100% is shown. Pump voltage is also shown.

Lamp The state, PWM control, and current of the lamp are shown.

Fan The state of the fan is shown.

Zero and Occl valve

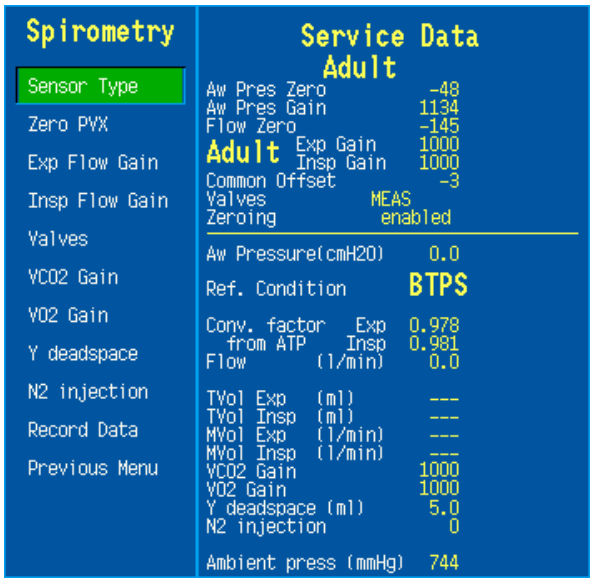
Can be toggled between measurement state (MEAS) and zeroing/occlusion states (ZERO/OCCL).

Temp Temperatures measured by the module from TPX, CPU, and OM.

Time after power on

In minutes after power on.

5.3 Spirometry service menu



Insp and exp flow gains can be adjusted if calibration is needed. Calibration pump or spirometry tester is used and readings are observed from display. If a deviation exists, gains are adjusted accordingly. Gain scaling is 1.000 when factory settings are in effect.

When Adjust key is pressed, a separate box for adjusting the value appears. During adjustment calibration values are sent to module. When comwheel is pressed, the values are permanently stored in EEPROM of module and the box disappears.

Zero PVX Start zeroing of the pressure sensors. Effects Aw Pres Zero and Flow Zero value.

Exp Flow Gain / Insp Flow Gain
Adjust the Flow sensor gains.

Valves Switch between MEASUREMENT and ZEROING

VCO2 / VO2 Gain Adjust the VCO_2 and VO_2 gain.

Y deadspace Adjust the Y-deadspace.

N2 injection Select between on (1) and off (0).

Record Data Record Data prints out the shown service data and board information (id. serial number and software id.) onto the recorder module, M-REC.

Service Data field

- Sensor ADULT/PEDIATRIC according to selected measurement mode (sensor). Insp/Exp Flow Gains shown apply to the selected sensor.
- Aw Press Zero and Flow Zero are a result of zeroing in user service menu. In factory calibration menu they can be adjusted, but not permanently stored.
- Aw Press Gain is directly the value used in sw. It can be adjusted, but not permanently stored.
- Exp Flow and Insp Flow Gains are scaled as (user gain)/(factory gain). Exp and Insp Flow Gains can be adjusted also in user service menu.

- Common Offset is the compensation factor for pressure difference reading of the difference sensor when applying a equal pressure on both sides of the sensor.
- Valves can be changed between MEASUREMENT and ZEROING.
- Zeroing automatic zeroing either ENABLED or DISABLED (only factory service menu).
- Aw Pressure shows the real time value of airway pressure
- Condition shows in which reference conditions results are. With calibration pump or spirometry tester the results are always in ATP. If breathing is detected ($EtCO_2 > 1.0$ %), results are according to Flow & Vol Setup selection.
- Flow shows flow measurement value.
- TVol Exp, TVol Insp, MVol Exp and MVol Insp are shown to ease calibration. The numbers are the same as on main display. The former pump calibration procedure has been dropped out. We claim that calibration is not needed in routine clinical use, so a separate Flow calibration menu is not needed. Calibration can be done with the pump or spirometry tester. The results must be taken from the screen and gains adjusted accordingly.
- VCO_2 and VO_2 Gain shows a value near 1000, the correct gains have been measured in the factory.
- Y deadspace is the geometric volume in ml between the Y-piece and the D-lite. Default is 5 ml for a standard Y-piece (as delivered with Siemens 900C ventilators). Used for VCO_2 and VO_2 delay time corrections.
- Set N_2 injection to 1 during laboratory tests with a Spirometry tester and injection of N_2 gas (for scientific validations use only). At power on of the module, the value is always zero.
- Ambient pressure

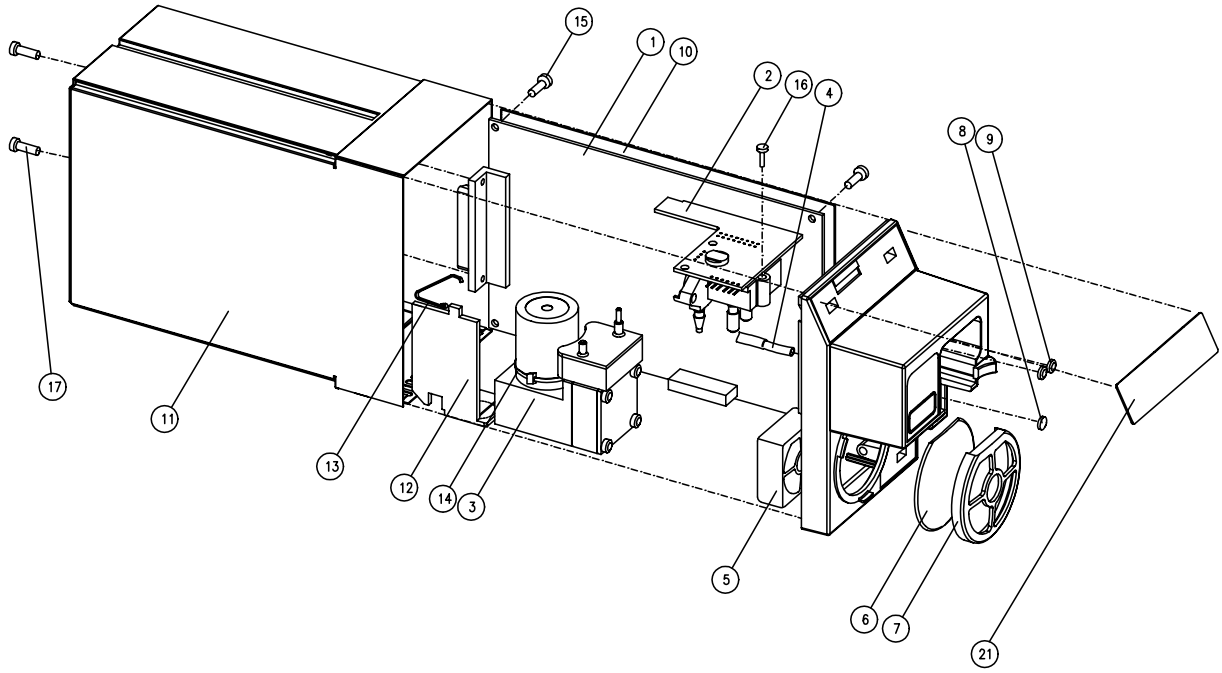
6 SPARE PARTS

6.1 Spare parts list

NOTE: Only changed part numbers are listed under later revisions. To find the desired part: check first the list of the revision that corresponds your device. If the part is not listed there, check the previous revision, etc. until you find the right number.

NOTE: Accessories are listed in the *Patient Monitor Supplies and Accessories* catalogue.

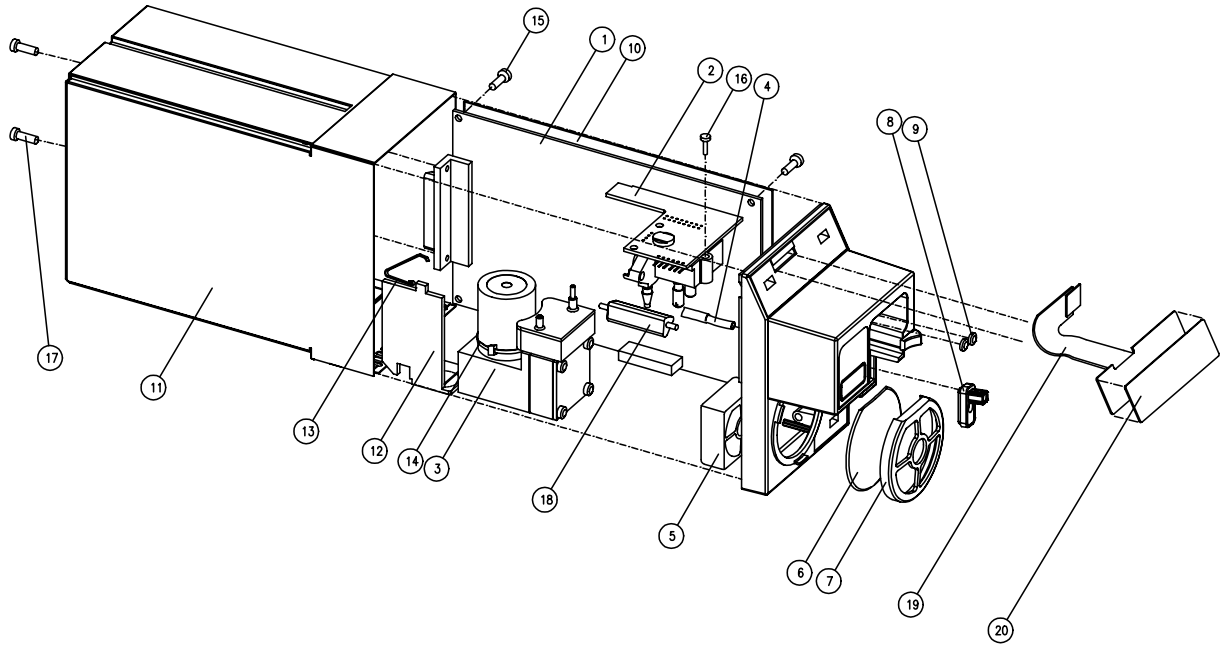
6.1.1 M-C rev. 00, M-CO rev. 00, M-CAiO rev. 00, M-COV rev. 01, M-CAiOV rev. 01, M-COVX rev. 00



Item	Description	Order No.	Item	Description	Order No.
1	CPU board, Compact Airway Module	*884313	11	Module box (double width)	893225
2	PVX unit, Compact Airway Module	*895946	12	Latch	879181
3	Sampling pump, Compact Airway Module	*57313	13	Spring pin	879182
4	Special tube, 300mm	*733382	14	Cable tie	640013
5	Fan, Compact Airway Module	886213	15	Cross recess screw UNC4-40	61841
6	Fan filter	*886236	16	Cross cylinder-head screw M3x6	61721
7	Fan filter cover	886659	17	Cross cylinder-head screw M3x6	61721
8	Filter	*886136	21	Front panel sticker, plain	880471
9	O-ring	*65312	-	Ref. gas sticker	893110
10	Insulation plate	890873			

* this part is recommended for stock

6.1.2 M-CAiOVX rev. 00, M-CAiOV rev. 02, M-CAiO rev. 01, M-COVX rev. 01, M-COV rev. 02, M-CO rev. 01, M-C rev. 01



Item	Description	Order No.	Item	Description	Order No.
2	PVX unit	*895946	18	Zero absorber	*895933
8	Output and reference gas connector	886245	19	Membrane keypad for spirometry modules	895785
8	Filter assembly	*896025	20	Spirometry/blanco sticker (see below)	-
14	Cable tie	640013			

6.1.3 S/5 M-CAiOVX rev. 01, S/5 M-CAiOV rev. 03, S/5 M-CAiO rev. 02, S/5 M-COVX rev. 02, S/5 M-COV rev. 03, S/5 M-CO rev. 02, S/5 M-C rev. 02

No new spare parts. See S/5 stickers below.

6.1.4 Front panel stickers

Front panel stickers that are related to the Compact Module type and adaptation:

Adaptation codes: DA=Danish, DE=German, EN=English, ES=Spanish, FI=Finnish, FR=French, IT=Italian, JA=Japanese, NL=Dutch, NO=Norwegian, PT=Portuguese, SV=Swedish

Adaptation	M-C (rev. 00-01)	M-CO (rev. 00-01)	M-CAiO (rev. 00-01)	+plain sticker for all Item 20/21
DA	892222	892223	892226	880471
DE	890695	890692	890686	880471
EN	890694	890691	890685	880471
ES	892240	892241	892244	880471
FI	892246	892247	892250	880471
FR	890696	890693	890687	880471
IT	892234	892235	892238	880471

Adaptation	M-C (rev. 00-01)	M-CO (rev. 00-01)	M-CAiO (rev. 00-01)	+plain sticker for all Item 20/21
JA	894986	894987	894991	880471
NL	892228	892229	892232	880471
NO	893544	893547	893543	880471
PT	895245	895246	895244	880471
SV	891101	891104	891100	880471

Adaptation	M-COV (rev. 01-02)	M-COVX (rev. 00-01)	M-CAiOV (rev. 01-02)	M-CAiOVX (rev. 00)	+ keyboard sticker for all Item 20
DA	892224	892225	892227	897790	897801
DE	890689	890698	890683	897781	897792
EN	890688	890697	887312	896594	896331
ES	892242	892243	892245	897784	897795
FI	892248	892249	892251	897787	897798
FR	890690	890699	890684	897782	897793
IT	892236	892237	892239	897785	897796
JA	894988	894989	894990	897791	897802
NL	892230	892231	892233	897783	897794
NO	893546	893545	893542	897789	897800
PT	895247	895248	895243	897786	897797
SV	891103	891102	891099	897788	897799

6.1.5 S/5 stickers

Adaptation	S/5 M-C (rev. 02)	S/5 M-CO (rev. 02)	S/5 M-CAiO (rev. 02)	+blanco sticker for all item 20/21
DA	898516	898621	898528	898624
DE	898507	898612	898519	898624
EN	898506	898611	898518	898624
ES	898510	898615	898522	898624
FI	898513	898618	898525	898624
FR	898508	898613	898520	898624
IT	898511	898616	898523	898624
JA	898517	898622	898529	898624
NL	898509	898614	898521	898624
NO	898515	898620	898527	898624
PT	898512	898617	898524	898624
SV	898514	898619	898526	898624

Adaptation	**S/5 M-COV (rev. 03)**	**S/5 M-COVX (rev. 02)**	**S/5 M-CAiOV (rev. 03)**	**S/5 M-CAiOVX (rev. 01)**	**+spirometry sticker for all item 20**
DA	898659	898671	898540	898552	898637
DE	898650	898662	898531	898543	898628
EN	898649	898661	898530	898542	898627
ES	898653	898665	898534	898546	898631
FI	898656	898668	898537	898549	898634
FR	898651	898663	898532	898544	898629
IT	898654	898666	898535	898547	898632
JA	898660	898672	898541	898553	898638
NL	898652	898664	898533	898545	898630
NO	898658	898670	898539	898551	898636
PT	898655	898667	898536	898548	898633
SV	898657	898669	898538	898550	898635
-	-	-	-	Service sticker 898542	898623

6.1.6 Planned Maintenance (PM) Kits:

Compact Airway Module, M-xxxxxx	Anesthesia, w/o CO2 absorber	8001758
Compact Airway Module, M-xxxx	Critical care, w/o CO2 absorber	8001759
Compact Airway Module, M-xxxxxx	Anesthesia, w/ CO2 absorber	8001760
Compact Airway Module, M-xxxx	Critical care, w/ CO2 absorber	8001761

7 EARLIER REVISIONS

Revision	Manual slot/main manual	Note
Compact Airway Module, M-CAiOVX (rev. 00) Compact Airway Module, M-CAiOV (rev. 02) Compact Airway Module, M-CAiO (rev. 01) Compact Airway Module, M-COVX (rev. 01) Compact Airway Module, M-COV (rev. 02) Compact Airway Module, M-CO (rev. 01) Compact Airway Module, M-C (rev. 01)	896 619/896 624	

APPENDIX A

SERVICE CHECK FORM

Compact Airway modules

Customer					
Service		Module type		S/N	
Service engineer				Date	

☐ OK = Test OK ☐ N.A. = Test not applicable ☐ Fail = Test Failed

All modules

	OK	N.A.	Fail		OK	N.A.	Fail
1. Internal parts	☐	☐	☐	2. External parts	☐	☐	☐
3. Fan filter	☐	☐	☐	4. D-fend O-rings	☐	☐	☐
5. Other filters	☐	☐	☐				

Notes _____

	OK	N.A.	Fail		OK	N.A.	Fail
6. Fan	☐	☐	☐				
7. Module software	GAS						
8. Module configuration	☐	☐	☐	9. Module bus communication	☐	☐	☐
10. Flow measurement offset					±10 ml/min		
11. Ambient pressure	☐	☐	☐	12. Zero valve	☐	☐	☐
13. Special tubes	☐	☐	☐	CO_2 absorber	☐	☐	☐
14. Leak test					≤ 6 mmHg/min		
15. Flow rates							
Sampling flow					180...220 ml/min		
Reference flow (M-CAiOVX/M-COVX)					27...40 ml/min		
Reference flow (M-CAiOVX/M-COVX)					27...40 ml/min		
Reference flow (M-C)					25...40 ml/min		
Reference flow (M-C)					24...45 ml/min		

Reference flow (others)		31...45 ml/min
Zeroing flow		±20 ml/min

16. Working pressure

Amb-Work		40...75 mmHg
Amb-Work (M-CAiOVX/M-COVX)		70...115 mmHg

	OK	N.A.	Fail
17. Gas calibration	☐	☐	☐

18. Fall time measurement

CO_2 fall time		< 400 ms
O_2 fall timeb		< 400 ms
CO_2-N_2O delay		< 800 ms

AA option S/N

19. ID unrel.		< 50

Patient spirometry option S/N

	OK	N.A.	Fail		OK	N.A.	Fail
20. Spirometry system leak test	☐	☐	☐	21. Flow waveform	☐	☐	☐
22. Spirometry tester	☐	☐	☐				

All modules

23. Electrical safety check	☐	☐	☐	24. Occlusion detection	☐	☐	☐
25. Air leak detection	☐	☐	☐	26. Apnea detection	☐	☐	☐
27. Final cleaning	☐	☐	☐				

Notes _____

_____

Used Spare Parts _____ _____ _____

_____ _____ _____

Signature _____