KONTRON MEDICAL

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CAPNOGRAPHY

$EtCO_2$ Monitor

User's Manual

Société Anonyme par Actions Simplifiée au capital de 5.000.000 Francs
RCS Versailles B 423 305 168 - SIRET 423 305 168 00027 - Code APE : 331 A
N° identification Communautaire : FR 52 423 305 168

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CAT NO; / 386080004407 EN ISSUED / MARCH 2001

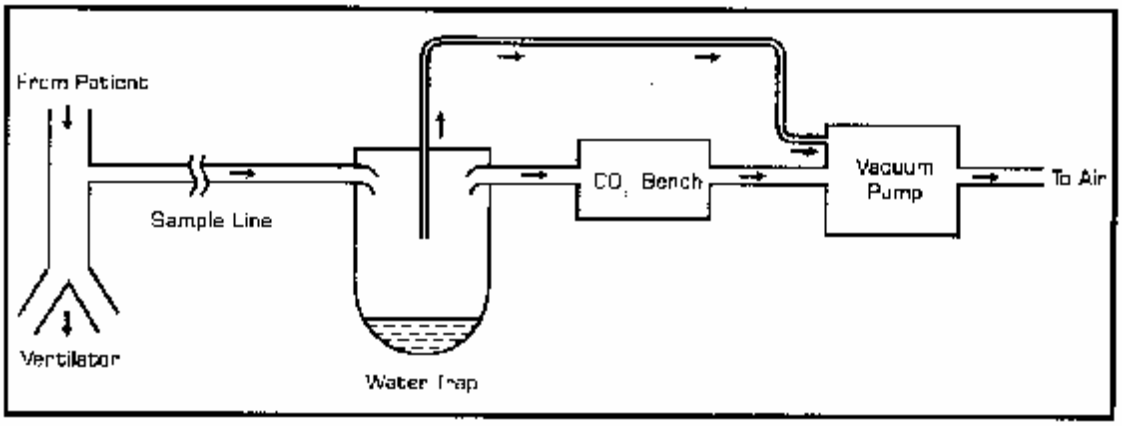
CONTENTS

1 *INTRODUCTION*

M 7138 & M 7139 are bed-side and transportable multi-parameter monitors. Capnograph is an upgradable parameter for both. Capnograph module is integrated in a separate enclosure, which sits beside the monitor. An interface cable runs between monitor and Capnography module. M 7138/39 with Capnography are ideally suited for use in hospital, operating rooms, intensive care units & emergency rooms where it continuously and non-invasively measures the carbon dioxide concentration of expired & inspired breath and respiration rate. This module shares a power supply and other necessary functions from the main monitor.

General

In order to get the full benefit from M 7138/39 Capnograph read the manual thoroughly and comply with the instructions that follow. Ensure that the Capnograph should be only used by personnel trained in its applications and familiar with its operations. Be sure that the qualified individual provides constant attention to the patient in case immediate corrective action is required. Pay particular attention to all warnings and cautions, which appear throughout this manual.



THEORY OF OPERATION

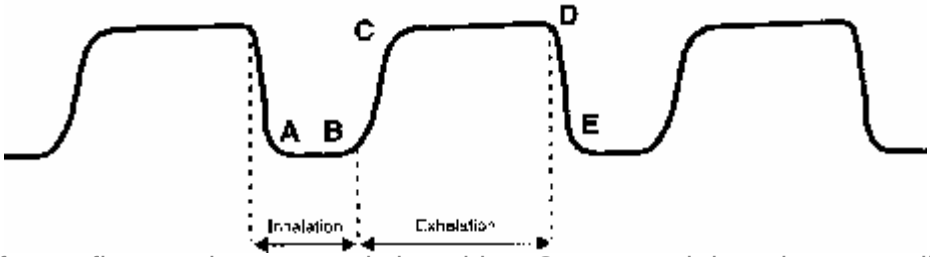
The principle of Capnograph is based on the absorption of infrared radiation by CO_2. The technique is known as non-dispersive infrared absorption technique. The spectral region is particularly appropriate for measuring carbon dioxide because it has a strong absorption band in the near Infrared wavelength (4.26µm). CO_2 selectively absorbs specific wavelengths of Infrared light. The main part of the system is CO_2 bench, which consist of one IR source and detector. A sample of patient's expired gas that consists of CO_2, Water vapours, Nitrogen, Anaesthetic Agents, etc is drawn from a lightweight T-piece through a sampling line and water trap into the CO_2 bench Condensed water and secretions from the patient gets collected at water trap. Dry expired air further aspirated into measuring chamber (CO_2 bench) by a small pump. The amount of light passing through a sample cell varies according to the concentration of CO_2 in the cell. When concentration of CO_2 in sample cell is high, more light is absorbed by the sample and therefore a small amount of light reaches the detector as compared to low concentration of CO_2. The amount of light absorbed is proportional to the concentration of CO_2. The CO_2 concentration measured by the monitor is usually expressed as end tidal concentration of CO_2 ($EtCO_2$), expressed in terms of mm Hg or percentage (%) or Kilopascal (KPa)

Measuring Respiration Rate

KONTRON MEDICAL Capnograph uses continuous CO_2 waveform to detect each breath cycle. It uses an adaptive algorithm to recognize each breath in the waveform, even in the presence of an elevated baseline (rebreathing) and higher frequencies in the CO_2 waveform (cardiogenic oscillations).
The device computes respiration rate from the total number of seconds for the last four breaths according to this formula:

$$\text{BPM (breath/min)} = \frac{\text{60 seconds x 4 breaths}}{\text{Number of seconds for 4 breaths}}$$

Capnogram - Nature of waveform



CO_2 waveform reflects various stages in breathing. Capnogpaph is an important diagnostic tool because its shape is virtually identical in all basically healthy people.

End tidal CO_2 is the concentration of CO2 measured at the end of tidal volume expired (Point D in above diagram).

A - B : The baseline, that is the level of minimum CO_2 concentration, observed immediately after inspiration.

B – C : The expiration phase of respiration cycle.

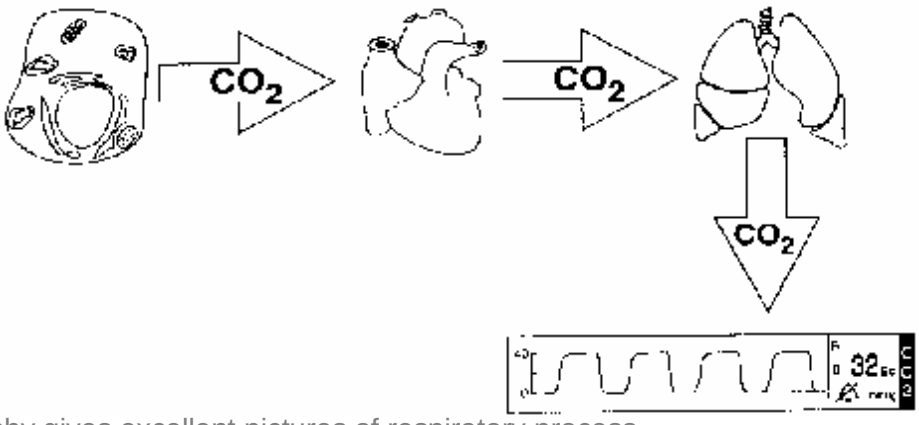
C – D : The expiratory plateau that is the period during which the level of CO_2 in the lungs ceases to increase significantly.

D : The end-tidal concentration point that is the point at the end of the expiration phase, at which $EtCO_2$ is measured.

D – E : The onset of the inspiration phase of the respiration cycle.

The production, transportation and elimination of CO_2

CO_2 is produced by all the cells in all the tissues in body as a by-product of metabolism. From the cell, CO_2 diffuses into capillary blood, from where CO_2 is transported into venous circulation. During contraction of heart, venous blood is pumped through pulmonary circulation to the lungs for gas exchange. Lungs are made up of millions of alveoli, which permits easy gas diffusion from pulmonary blood to alveolar gas space. CO_2 diffuses into this space because continuous breathing keeps CO_2 concentration in alveoli lower than that in pulmonary circulation. During exhalation, gas leaving lungs mixes thoroughly, so Capnograph measures average concentration of CO2 from all the alveoli.



Capnography gives excellent pictures of respiratory process.

Arterial to alveolar difference of CO_2.

Although end tidal CO_2 closely follows blood CO_2 level, they are not exactly same. Normally, the arterial blood CO_2 level ($PaCO_2$) is higher by 3-4 mm Hg than the alveolar CO_2 ($PACO_2$), The $aADCO_2$ is due to a mismatch of ventilation and perfusion of the alveoli in the lungs. [Even in healthy patient, there are some parts of lungs which are not perfused as well as they are ventilated). In such case when patient exhales, CO_2 gas from the unperfused part of the lungs will dilute the CO_2 rich alveolar gas coming from rest of the lungs, lowering the $EtCO_2$, hence $aADCO_2$ increases. This is known as alveolar dead space ventilation.

Arterial Blood CO_2 : $PaCO_2$ Alveolar CO_2 : $PACO_2$ Arterial to alveolar difference $aADCO_2$ which is normally 3-4 mm Hg.

3 METHODS OF CAPNOGRAPHY

Capnography measurement is broadly classified into 2 types

1. Side Stream Capnography
2. Main Stream Capnography

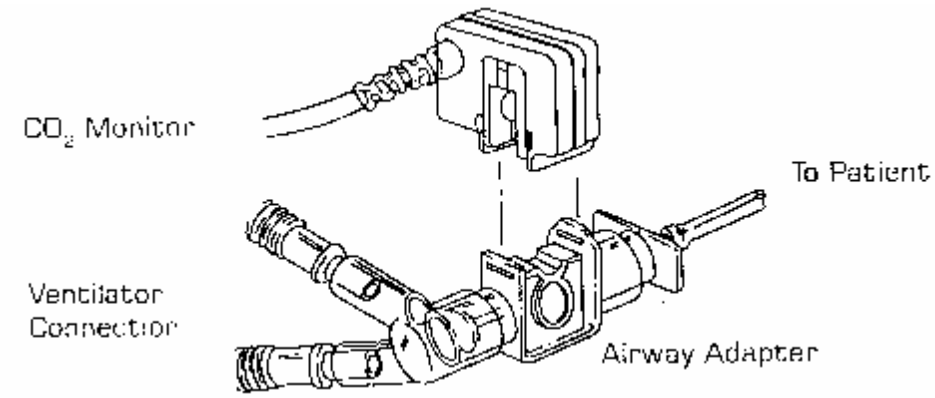
Kontron Medical offers Side Stream Capnography with its M 7138 & M 7139 monitors.

1. Side Stream Capnography

In side stream method the optical sensor is incorporated in the module. Gas sample is aspirated from the patient at a flow rate of 140 ml/min (+20/-10) with the help of sample line (connected to endotrachial tube with the help of 'T' connector or directly from nose with the help Nasal prongs) and is given to module via Water Trap. Water Trap helps in trapping moisture (water vapours) in the gas exhaled by the patient and prevents it from entering into CO_2 bench. The CO_2 measurement takes place at the CO_2 bench. After the measurement, the waste gas exhausted from the rear panel of the module.

2. Main Stream Capnography

The principle of main stream is similar to the principle of side stream. The difference is only in positioning of optical sensor.
In main stream the optical sensor is located outside the module near to the patient as shown in the diagram. The CO_2 measurement takes place at the patient airway circuit.



3 METHODS OF CAPNOGRAPHY

DEFINITIONS

Breath	:	A rise and fall in the carbon-dioxide concentration of at least one- percent carbon-dioxide is no less than 0.4 seconds. One inhalation + One exhalation = One Breath.
Respiration Rate (RR)	:	Number of Breaths per Min.
End Tidal Carbon-dioxide (EtCO2)	:	The level of CO_2 in the airway at the end of expiration. In Kontron Medical's Capnography one breath is the sampling interval, therefore monitor will report the CO_2 level at the end-respiration point of each breath.
Final Inspired Carbon-dioxide (FiCO2)	:	The amount of CO_2 inspired during inspiration i.e. rebreathing of CO_2.

RED ALARMS: (patient related)

1. $EtCO_2$ - high and low alarms.
2. $FiCO_2$ - high alarm.
3. APNEA - 30 Sec [Fixed duration).

YELLOW ALARMS: (Equipment related)

1. OCCLUSION... PURGING...
   Monitor flashes this message if he sample line is blocked or kinked.

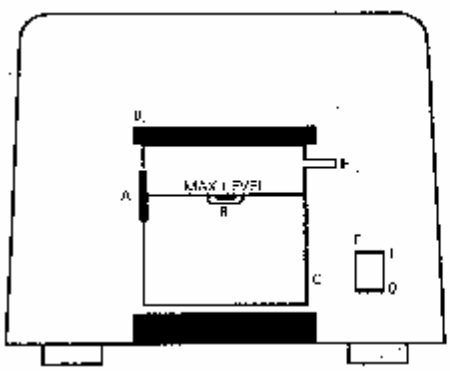
2. CHANGE SAMPLE LINE
   If "OCCLUSION.. PURGING...." message occurs continuously for more than 2 minutes and user doesn't change sample line.

3. WATER TRAP FULL
   If water trap is getting filled up completely and requires replacement.

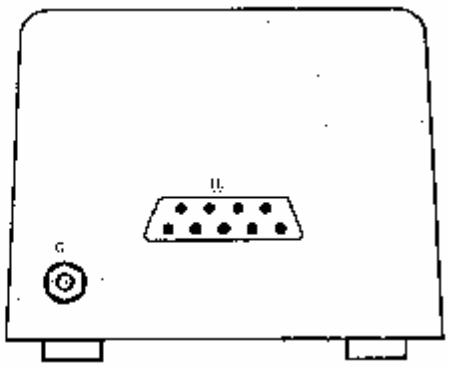
4. CHANGE WATER TRAP
   If "WATER TRAP FULL" message occurs continuously for more than 5 minutes, user is prompted to change water trap.

5 DESCRIPTION OF MODULE AND ACCESSORIES

FRONT PANEL



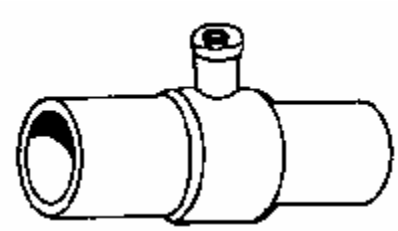
REAR PANEL



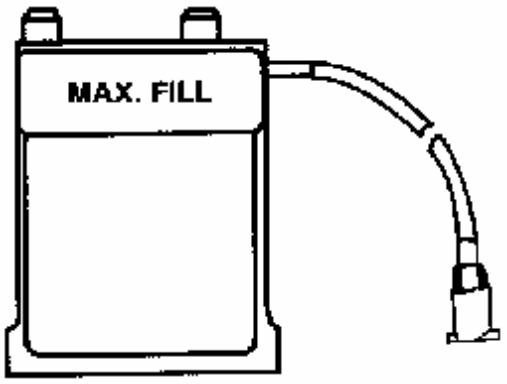
A = Detector [Light source) for water level detector
B = Transmitter for water level detector for water trap.
C = Water trap.
D = Water trap holder.
E = Sample inlet.
F = Power ON/OFF
G = Sample outlet
H = Connector for interfacing cable between Module and Monitor

5 DESCRIPTION OF MODULE AND ACCESSORIES

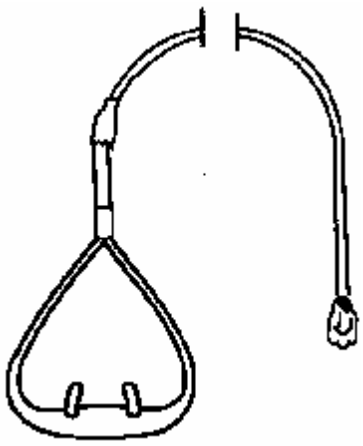
ACCESSORIES



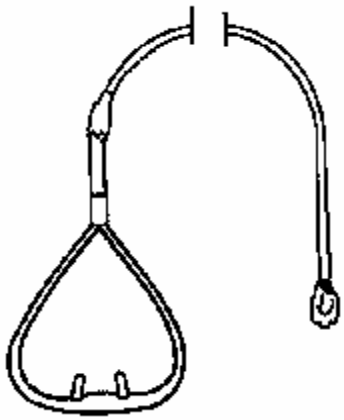
Airway Adapter, Straight 15 ID x 15 OD (mm);
Circuit sample Adapter to be inserted into an anaesthesia or ventilator circuit with a sidestream outlet. Standard adult circuits.
PN 1100 (set of 10).



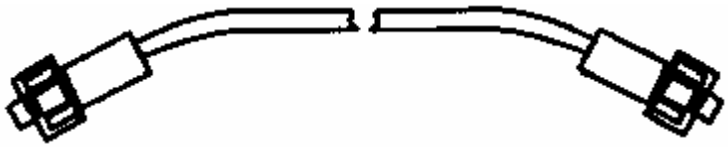
Water Trap;
Patented moisture removal system used in CO_2 monitors.
Disposable and removable.
PN 89147.



Sample line, Nasal CO_2,
Standard adult tubing for nasal sample of CO_2
Adult PN 1123 (Set of 10)



Sample line, Nasal CO2, Paediatric
Standard Paediatric tubing for nasal sample of CO_2
Adult PN 1124 (Set of 10)



Sample line, 8-ft.
Extension tubing which connects via a male/male adapter to sample tubing.
PE, PVC, M-M
PN 8044 (Set of 10).

Airway adapter (Filterless) paediatric; PN 1151 (set of 10)

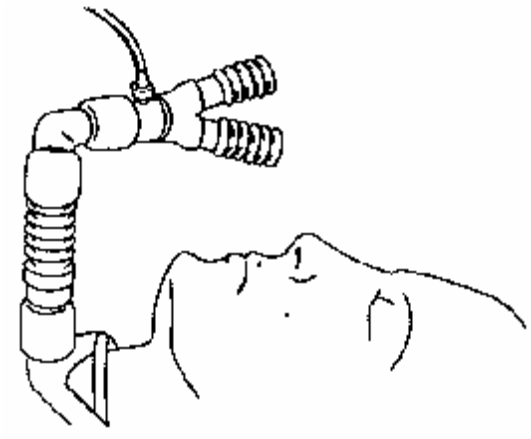
6 MACHINE AND PATIENT PREPARATION

MACHINE PREPARATION

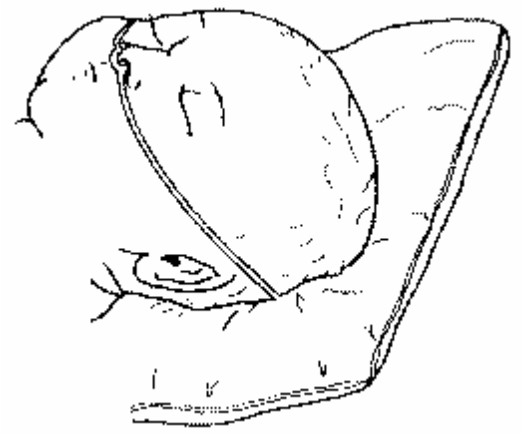
1. Connect the module to the monitor with the help of interfacing cable.
2. Make sure that Water trap is connected to the module.
3. Switch ON the module
4. Make sure the patient connection to the module with the help of sample line and T Connector.
5. Switch ON the monitor.
6. Machine takes approx. 90 seconds for its initialisation. During this time sensor gets warm up and "SENSOR WARMUP" message will appear on the screen.
7. Out of these 90 seconds 25 seconds is initial warm up when no info will be displayed on the screen For remaining 65 seconds respiration rate and CO_2 waveform will appear on the screen but $EtCO_2$ and $FiCO_2$ value will appear only after completion of initialisation process (i.e. after 90 seconds).
8. Then monitor will perform Zero Calibration and "ZERO CALIBRATION" message will appear on the screen.
9. Monitor is ready for Capnography monitoring

PATIENT PREPARATION

1. Prepare the patient for CO_2 measurement. Use recommended accessories.
2. Fix a water trap in the trap housing on the module. Check the water level in the trap. It should be empty (dry).
3. To the tube on the water trap, screw up one end of the "T" Connector through sample tubing or one end of the nasal pronge. Use proper types for adults and neonatal accessories.
4. For connecting nasal pronge fix up the loop of the sample line around the patient's head, over the ears, with the two nasal openings in close proximity with the nostrils and tighten up the loop, to keep it in place.



Patient with "T" connector connected to Endotrachial tube



Patient with Nasal Pronge (Adult & Paediatric nasal prongs are available).

6 MACHINE AND PATIENT PREPARATION

Caution

1. Do not strain the sample line during the measurement. Connection should be done in such way that the sample lines will not surround any part of the body.

2. Ensure that the sample line does not have blockage or occlude with moisture before use.

7 CALIBRATION

There are three types of calibrations.

1. Zero Calibration
2. Low Calibration
3. High Calibration

1. Zero Calibration:
   This procedure is done automatically by the unit at regular intervals & no separate menus are provided. (Zero Calibration reads 0% CO_2 by aspirating air through a CO_2 scrubber). It removes baseline drift as well as base line shift (due to a dirty sample cell).

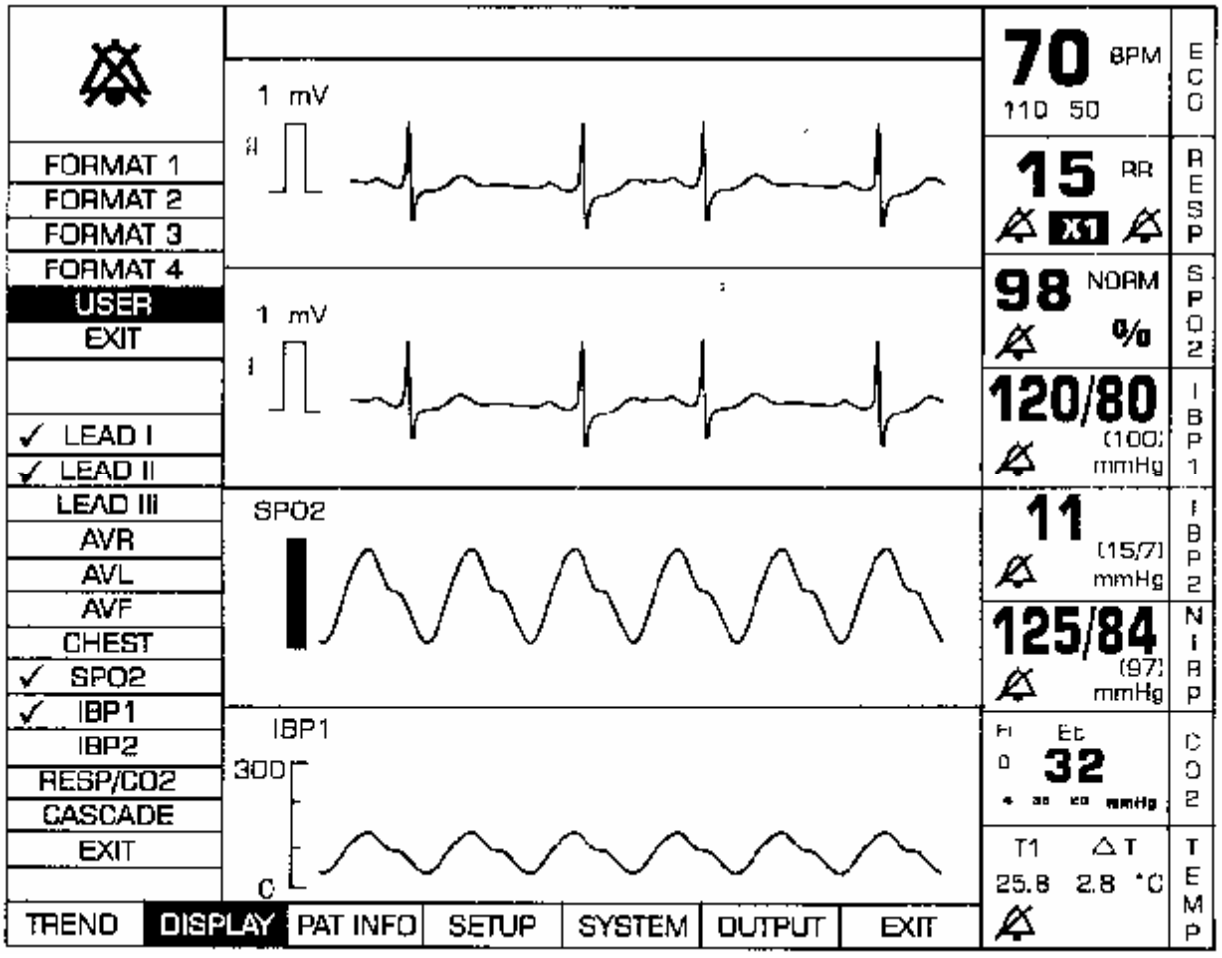
2. Low Calibration:
   This can be done by entering CO_2 menu and press "LOW CAL"
   This is same as Zero Calibration, in addition reading ambient (room) pressure. Ambient pressure is used to calculate the CO_2 at ambient pressures.
1. Convert from % CO_2 at bench pressure to ambient pressure. It sets offset errors).
   In a month by the user.

3. High Calibration:
   This should be done by authorised service personnel only.

NOTE: Low Calibration should always be done before high Calibration

SELECTION FOR THE DISPLAY OF CO2 WAVEFORM
(CAPNOGRAM)

Select - MENU → DISPLAY → USER → RESP/CO2 → EXIT

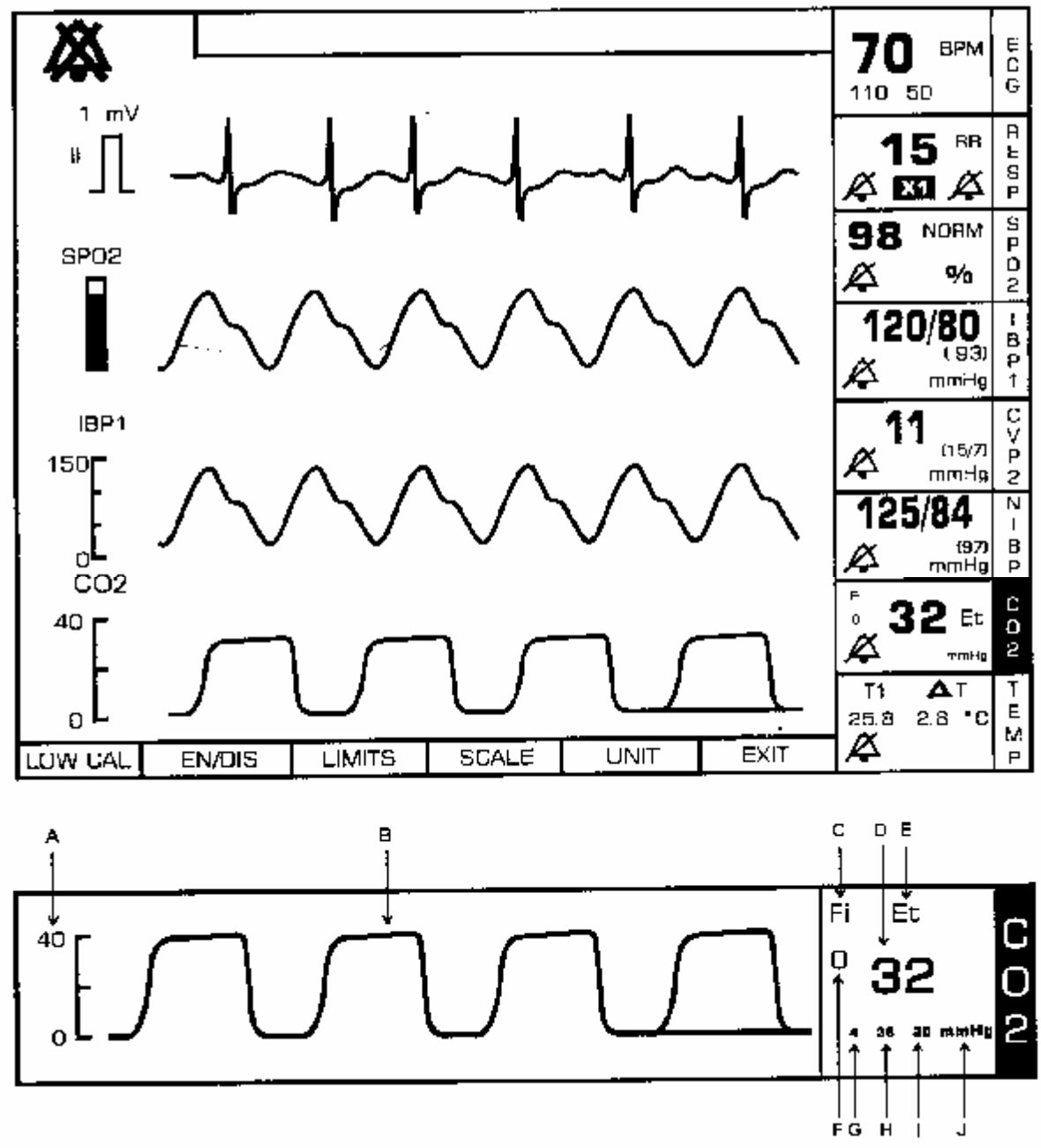


MAIN SCREEN

MENU	Allows the user to go to MONITOR SETTINGS / TREND RECALL/ SYSTEM FUNCTIONS.
AUTOSET	Sets alarm limits automatically HR/PR high limit = (Present HR/PR) x 8/10 + 54 HR/PR low limit = (Present HR/PR) x 8/10 + 4 SpO_2 high limit = 100 SpO_2 low limit = (Present Sp02 Value - 8) or 80 whichever is greater Systolic high limit = Present Systolic value + 10 Systolic low limit = Present Systolic value – 10 Diastolic high limit = Present Diastolic value + 10 Diastolic low limit = Present Diastolic value 10 $EtCO_2$ high limit = Present $EtCO_2$ + 6 $EtCO_2$ low limit = Present $EtCO_2$ – 6 $FiCO_2$ high limit = Present $FiCO_2$ + 4 $FiCO_2$ low limit = 0 (Zero) Respiration high limit = Present Respiration rate + 5 low limit = Present Respiration rate - 5 Temperature T1 high limit = Present T1 value + 2 T1 low limit = Present T1 value - 2
RECALL	Allows the user to recal1 last 16 patient related alarm conditions in tabular format.
ALA VOL	Allows the user to change the alarm volume to an appropriate level by clockwise or anti-clockwise rotation of Optical Encoder.
BEEP VOL	Allows the user to change the beep volume to an appropriate level by clockwise or anti-clockwise rotation of Optical Encoder
CO PROC	Allows the user to enter cardiac output menu.

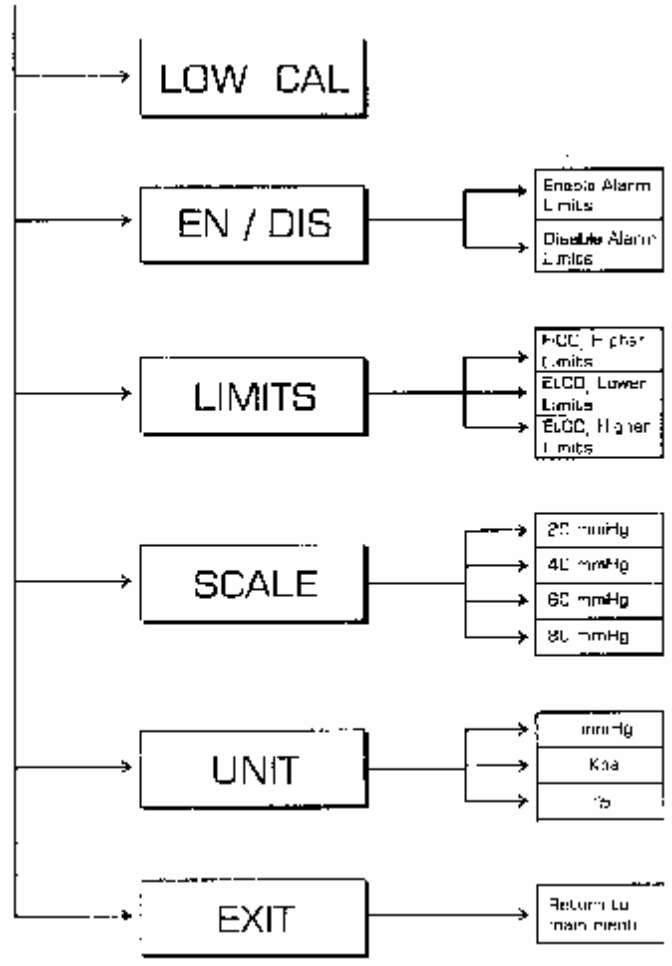
TEMP	Allows the user to enter. into TEMPERATURE menu.
CO2	Allows the user to enter CO_2 menu
NIBP	Allows the user to enter into NIBP menu.
IBP2	Allows the user to enter into IBP2 menu.
IBP1	Allows the user to enter into IBP1 menu
SpO2	Allows the user to enter into SpO_2 menu
RESP	Allows the user to enter into RESPIRATION menu.
ECG	Allows the user to enter into ECG menu

CO_2 Main screen



A. : Scale of Capnograph which can be selected either 20, 40, 60, 80.
B. : Capnograph.
C. : Fi = $FiCO_2$.
D. : $EtCO_2$ reading.
E. : Et = $EtCO_2$.
F. : $FiCO_2$ reading.
G. : Higher limit of $FiCO_2$
H. : Higher limit of $EtCO_2$.
I. : Lower limit of $EtCO_2$.
J. : Unit which can be selected either mm Hg, or KPa or %

CO_2



Parameter Settings: CO_2

LOW CALL	EN/DIS	LIMITS	SCALE	UNIT	EXIT

LOW CAL : Allows the user to do low calibration of the CO_2 module.

EN / DIS : Allows the user to either enable (switch ON) or disable (switch OFF) the alarm limits.

LIMITS : Allows the user to set individual high and low limit.

SCALE : Allows the user to select CO_2 waveform scales out of 20, 40, 60, 80. whereas 80 will have least amplitude.

UNIT : Allows the user to select units for $EtCO_2$ and $FiCO_2$, out of mm Hg, KPa (Kilo Pascal) and % (Percentage).

EXIT : Allows the user to return to the main menu.

MESSAGES	MEANING
ZERO CALIBRATION	Whenever CO2 module does zero calibration.
NO RESPIRATION DETECTED	After Power ON if No Respiration is detected for about 8 seconds
OCCLUSION… PURGING...	When sample tube is blocked.
CHANGE SAMPLE LINE	If "OCCLUSION .. PURGING..." message continuous for more than 2 minutes.
WATER TRAP FULL	If water trap is getting filled up completely & requires replacement
CHANGE WATER TRAP	If "WATER TRAP FULL" message continuous for more than 5 minutes.
LOW CALIBRATING	If the user does calibration.
CAL ERROR	During high calibration if the User does not turn on the cal gas or it is CO_2 bench problem. (Light sources have failed or bench is contaminated).

10 *MAINTENANCE SCHEDULE AND TROUBLE SHOOTING*

MAINTENANCE SCHEDULE

A. Sample lines, airway adapters and water traps are disposable and single use only.

B. In case of any water condensation in sample line please replace the sample line with a new one.

C. Check the accessories before use.

D. Do not attempt to sterilise the accessories

E. Use specified accessories only.

F. Low cal should be done at least once in month.

G. High cal should be done once in six month by authorised Service Engineer

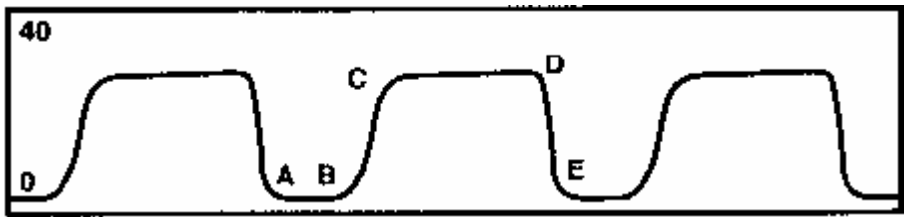
H. CO_2 scrubber inside the module should be checked periodically by authorised Service Engineer

TROUBLE SHOOTING GUIDE

PROBLEM	CAUSE	CORRECTION
No CO_2 waveform.	Sample line not connected	Ensure proper patient connections.
"NO RESPIRATION DETECTED" Message	Air leak in the circuit	Ensure water trap fixed properly no leaks in the sample Line, CO_2 cable connected tightly
Continuously Occlusion	Sample line is blocked	Search for any twists and Rectify or change Sample Line
Module performs ZERO Cal Very Often	Changes in room temperature or rapid variation in RR of Patient.	Check temperature or RR
Incorrect CO_2 Values	Different catheter is used	Ensure proper Catheter is used as per Operating manual.

Normal Waveform:

The "normal" capnogram provides a waveform of changing levels of expired CO_2.



The letters A - E indicate the phase of the respiration cycle:

A - B : The baseline, that is the level of minimum CO_2 concentration, observed immediately after inspiration.

B - C : The expiration phase of respiration cycle.

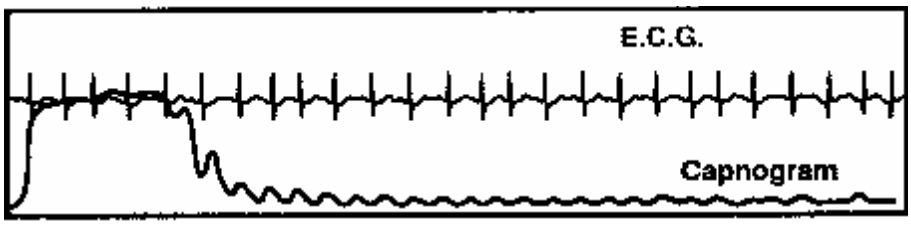
C - D : The expiratory plateau, that is the period during which the level of CO_2 in the lungs ceases to increase significantly

D : The end-tidal concentration point that is the point at the end of the expiration phase, at which EtCO2 is measured.

D - E : The onset of the inspiration phase of the respiration cycle.

Cardiogenic Oscillations:

Cardiogenic oscillations appear during the final phase of the alveolar plateau and during the descending limb. They are caused by the heart beating against the lungs.



Characteristics:

a. Rhythmic and equal to heart rate

b. May be observed in paediatric patient, mechanically ventilated at low respiratory rates with prolonged expiratory times.

Hyperventilation :

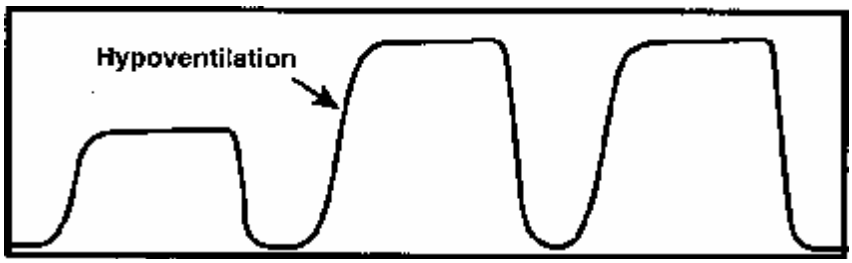
An decrease in the level of the End Tidal CO_2 from previous levels.

Possible Causes:
a. Increase in respiratory rate
b. Increase in Tidal Volume
c. Decrease metabolic rate
d. Fall in body temperature

NOTE:
Exponentially decrease in the level in CO_2 can also be because of cardiac arrest or severe hypotension (massive bleeding)

Hypoventilation:

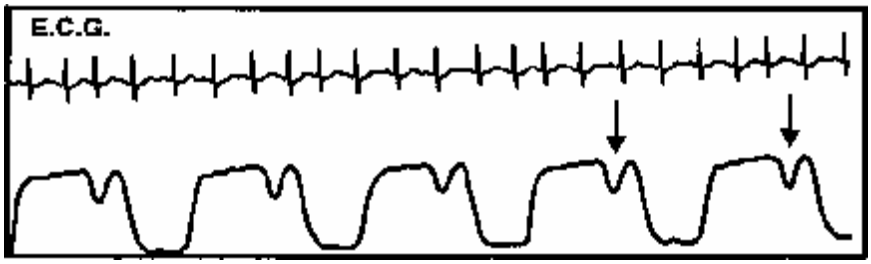
An increase in the level of the End Tidal CO_2 from previous levels.



Possible Causes:
a. Decrease in respiratory rate
b. Decrease in tidal volume
c. Increase in metabolic rate
d. Rapid rise in body temperature (malignant hypertermia)

Muscle Relaxants

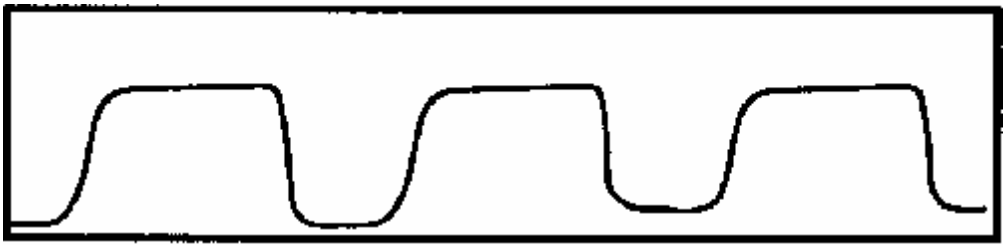
Clefts are seen in the final third portion of the alveolar plateau. They appear when the action of the muscle relaxant is affected by spontaneous ventilation.



Characteristics:
a. Depth of the cleft is inversely proportional to the degree of drug activity
b. Position fairly constant on the same patient but may not be present in every capnogram.

Rebreathing:

Rebreathing is characterised by an elevation in the baseline with a corresponding increase in End Tidal CO_2, It indicates the rebreathing of the previously exhaled CO_2.

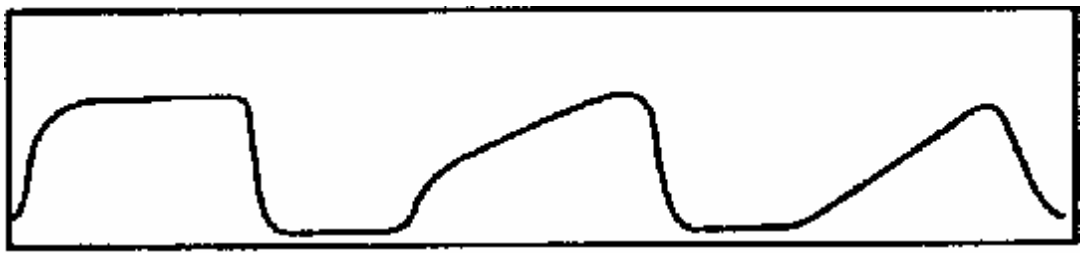


Possible Causes:

a. Insufficient expiratory time
b. Faulty expiratory valve
c. Inadequate inspiratory flow
d. Malfunction of CO_2 absorber system
e. Partial rebreathing circuits.

Obstruction in Breathing Circuit Airway

An obstruction to ,the expiratory gas flow noted as a change in the slope of the ascending limb of the capnogram. The expiratory portion may be diminish without plateau.



Possible Causes/

a. Partial obstruction in the expiratory limb of the breathing circuit
b. Presence of a foreign body in upper airway
c. Partially kinked or occluded artificial airway
d. Herniated endotracheal/tracheotomy tube cuff
e. Bronchosplasm

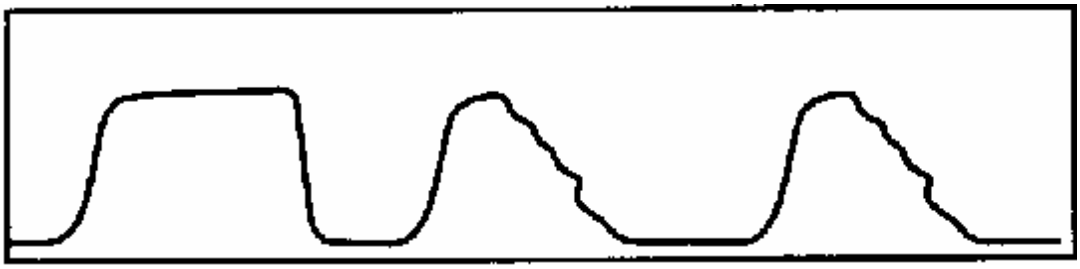
Endotracheal Tube Kinked

Waveform Evaluation

a. Any obstruction will cause an abrupt change in the ascending limb resulting in either a diminished plateau or no plateau. $EtCO_2$ and slope will depend on the degree of obstruction.

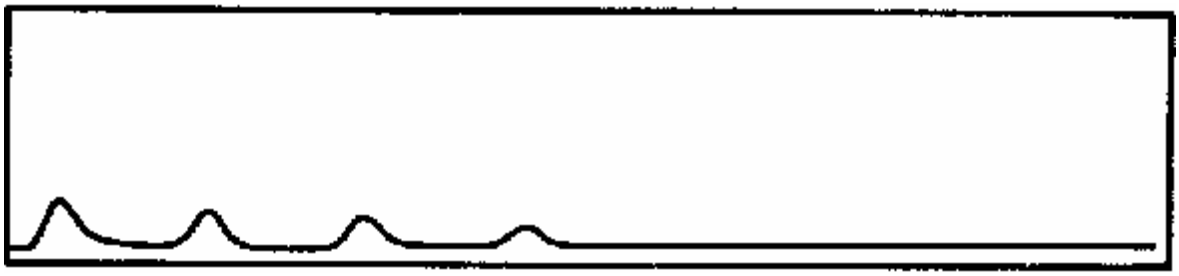
Inadequate Seal around Endotracheal Tube

A capnogram in which the downward slope of the plateau blends in with the descending limb.



Possible Causes:
a. A leaky or deflated endotracheal or tracheotomy cuff
b. An artificial airway that is too small for the patient

Endotracheal Tube in Oesophagus

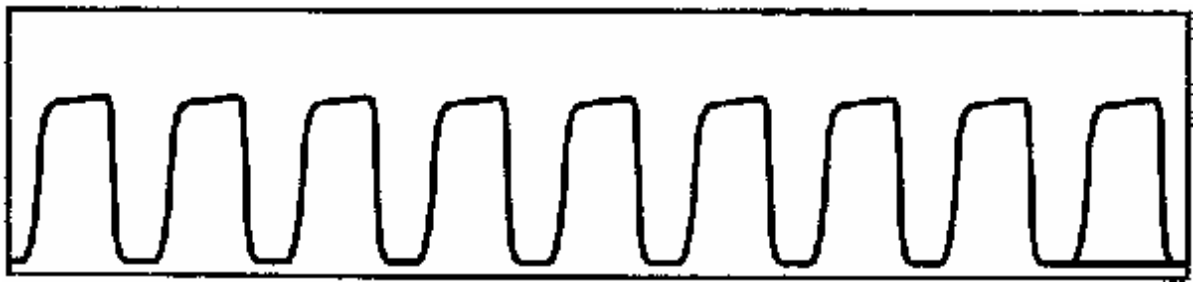


Waveform Evaluation :
a. A normal capnogram is the best available evidence that the Et tube is correctly positioned and that the ventilation is occurring. When the Et tube is placed in, the oesophagus either no CO_2 is sensed or any small transient capnograms are present.

Faulty Ventilator Circuit Valve

Waveform Evaluation:
a. Baseline elevated
b. Sloping descending limb of capnogram
c. Allows patient to rebreathe exhaled gas.

Paediatric Capnogram



Typical Capnogram for a Paediatric Patient.

Measurement ranges

EtCO2	High: 5-80 mm Hg or 0.6-10.6 KPa or 0.6-10.6 Vol % Low: 0-60 mm Hg or 0-8.0 KPa or 0-8.0 Vol %
FiCO2	High: 2-20 mm Hg or 0.2-2.6 KPa or 0.2-2.6 Vol %
RR	0-150 bpm

Measurement

Resolution	± 1 mm Hg or 0.1 KPa or 0.1 Vol %
Units	mm Hg or KPa or Vol %
Scale	20 , 40 , 60 . 80 mm Hg 2.1 , 5.1 , 8.0 , 11.0 KPa 2.1 , 5.1 , 8.0 , 11.0 Vol %
Flow Rate	140 ml / min (+20 / -10)

Calibration

Zero Calibration	Automatically performed by the module. Indicated to the user through a message on the screen
Low Calibration	Initiated by the user through on screen menu
High Calibration	Initiated through service menu

Alarms

	Low and High limits adjustable over the complete measurement range for $EtCO_2$ and $FiCO_2$ Fixed limit of 30 seconds for Apnoea
Default alarm setting	$EtCO_2$ Adult - High Limit : 45 Low limit : 15 Neonatal - High Limit: 35 Low Limit: 15 $FiCO_2$ High Limit: 5 Low Limit : 0

Auto Set:

$EtCO_2$ High Limit	Present Value + 6
$EtCO_2$ Low Limit	Present Value - 6
$FiCO_2$ High Limit	Present Value + 4
$FiCO_2$ Low Limit	0 (Zero)

Display

$EtCO_2$ reading's display	3 digits (24 x 40 and 16 x 24 Pixels)
$FiCO_2$ reading's display	2 digits (8 x 10 Pixels) , Each updation every alternate second
Trace Speed	6.25 , 12.5 , 25 mm /sec.
Waveform sampling rate	240 samples / second (Fixed)
Connection for $EtCO_2$	On rear panel , 9 pin REDEL / LEMO connector

Trends 24 hours Graphical and Tabular trend for display and printing

Accessories Adult or Neonatal airway adapters , sample lines and water traps.

Support

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