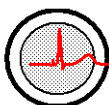


**Model 1035
MR-compatible
Monitoring and Gating System
for Veterinary use**

Operation Manual



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Introduction

This Operation Manual accompanies the release of revision 10.02 of PC-VET software for the Model 1035 MR-compatible Monitoring and Gating System for Veterinary use. For more than a decade SA Instruments has provided MR-compatible physiological monitoring systems to medical schools and research facilities for use in medical research with rodents. Every major medical school in the world has at least one of SA Instruments small animal monitoring and gating systems and many have several.

The Model 1035 brings SAII MR-compatible physiological monitoring and gating capabilities to the veterinary community. Specialty veterinary centers with MR have for the most part been using old clinical monitors. But, animals have lots of hair and tails which are not present on humans. The Model 1035 MR-compatible Monitoring and Gating System for Veterinary use offers an economic alternative to clinical monitors and it has been specifically designed for use with animals.

The Model 1035 monitoring and gating system measures and records physiological parameters of animals. It currently measures ECG, heart rate (two ways) respiration (two ways), temperature, pressure including invasive and non-invasive blood pressure, oxygen saturation, end-tidal CO₂ and minimally inspired CO₂.

The system generates an output trigger or gate based on a user defined algorithm. It also provides flexible control for a fluid based heater system to regulate animal temperature.

Chapters 2. Through 9 of the Operation Manual cover basic system operation. This information may be all that is needed for some users. Viewing and reformatting trend data for export to a spread sheet program is covered in Chapter 11. The SnapView program to view SnapShot data files is covered in Chapter 12. A troubleshooting guide with useful tips is presented in Appendix C.

Visit our web site www.i4sa.com for latest information on software and hardware upgrades and extended system capabilities.

Please do not hesitate to contact us at service@i4sa.com or (631) 689-9408, if you have questions, comments or need additional information.

Ron Morris
President
SA Instruments, Inc.
Stony Brook, New York, USA
September 2018

Introduction

Chapter 1

System Overview

Chapter 1

System Overview

Monitoring

The Model 1035 monitoring and gating system was designed specifically to meet the physiological monitoring and gating needs for anesthetized veterinary animals in the MR environment. Both anesthesia and the local environment can adversely alter animal physiology. For that reason, it is necessary to monitor some or all of the following physiologic parameters: electrocardiogram, heart rate, respiration rate, temperature, blood pressure, CO₂ and oxygen saturation. It can also be necessary to control the temperature of the animal.

Caution – The Model 1035 is not for human use. Use the Model 1035 for animal use only.

System Components

The Model 1035 monitoring and gating system consists of data acquisition modules located near the animal and a Control/Gating Module connected to a PC either in the magnet room or outside the magnet room. The PC displays multiple waveforms, measured values, trends and gating pulses, which can be used to trigger MR data collection. The data acquisition modules are controlled by menu driven software from the PC. A SAIL heater system can be used with the monitoring system to regulate the temperature of animals in the magnet bore.

This photo shows the configuration with the PC and Control/Gating Module in the magnet room. The PC and Control/Gating Module are inside an RF enclosure mounted



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System Overview

to the top shelf of the roll stand. A wireless keyboard and mouse are used to enter data in the PC.

The other configuration with the PC and Control/Gating Module located outside the magnet room is show below.



The **ER Module** located on the patient bed measures ECG using three leads connected to ECG electrodes and respiration from a small pneumatic pillow sensor. Power is supplied by an external, rechargeable battery. ECG and respiration measurements are transmitted on an optical fiber to the Control/Gating Module.

The **Multi-parameter Module** on an instrument roll stand is positioned near the magnet gantry. It monitors non-invasive blood pressure, temperature and pulse oximetry. Fiber optic and pneumatic sensors extend to the animal in the magnet bore. The module has a small amount of ferromagnetic material so it is fix mounted to the instrument stand. The NIBP pump and valves operate in a fringe magnetic field of 100 gauss or less. Most magnetically shielded MR magnets have a fringe field of 100 gauss 1 to 3 feet from the magnet bore. The module has a built in magnetic field detector that flashes a red LED when in a magnetic field greater than 100 gauss.

The **Capnograph Module**, also fix mounted on the instrument stand, monitors end-tidal CO₂, minimally inspired CO₂ and respiration. It has a pump and valves that operate in a fringe magnetic field of 100 gauss or less. The module also has a built in magnetic field detector that flashes a red LED when in a magnetic field greater than 100 gauss.

The **Control/Gating Module** receives data from the ER Module, the Multi-parameter Module, the Capnograph Module and any of several optional acquisition modules. The Control/Gating Module sends data to the PC for display and receives user instructions from the PC to control measurement and gating functions. Gates from ECG and respiration are generated by the Control/Gating Module's microprocessor and sent to the MR system. The delay from the R-wave peak to the MR system gate is user selectable as is the expiration gate delay and width.

System Overview

A **Remote Display** can be either of the following;

- For configurations with the PC outside the magnet room -a flat panel TV located outside the magnet viewing window so it can be viewed from the magnet.
- For configurations with the PC inside the magnet room – a second PC is located near the operator console to provide a second monitor display'

The **Single Pump Fluid Heater System** is a popular option for the Model 1035. It supplies warm fluid to a heating blanket in the magnet bore. The system consists of a Fluid Heater Module, a Circulation Module and a Reservoir located on the roll stand base. The PC using the measured value of rectal temperature and a user defined set point controls the water temperature in the blanket to regulate the animal's temperature.

The following **options** are also available for use with the Model 1035: One or two channels of invasive blood pressure (IBP) measuring systolic, diastolic, mean arterial pressure and heart rate, one additional channel of fiber optic temperature (FOT) to measure rectal or skin temperature and a Respiration Module in configurations that do not include ECG. The Respiration Module uses mains power eliminating the need for an ER Module battery pack.

Gating

Motion artifacts in MR images can be eliminated or greatly reduced by employing gating techniques during the acquisition of the MR image data. By synchronizing MR data collection with the electrocardiogram, images can be obtained at specific times during the animal's cardiac cycle. These images, which are free of cardiac motion, can be viewed individually or in a cine time sequence to visualize heart movement.

Motion artifacts due to breathing can also be eliminated or reduced by synchronizing MR data collection with the respiratory cycle. Typically the largest movement of the diaphragm and abdomen is during inspiration. Thus, selective acquisition of MR data during expiration can be effective in reducing breathing artifacts.

In some cases it is advantageous to employ gating combinations to trigger MR data acquisition. For example, both cardiac and respiratory gating can be employed to selectively acquire cardiac data only during expiration. These acquisition techniques can produce anatomic images free of breathing, heart and/or blood flow artifacts.

System Overview

Chapter 2

System Setup

System Setup

Setting up the hardware

The Model 1035 has several options and can be configured with the PC and Control/Gating Module in the magnet room or outside the magnet room. This section assumes the PC and Control/Gating Module (CGM) are located outside the magnet room and the ER, Multi-parameter (MPM) and Capnograph (CO₂) Modules are all located inside the magnet room on the MR-compatible Roll Stand. Ignore items of the manual for options not present with your system. Refer to Appendix B for a list of major system components and accessories. Refer to Chapter 10 for instructions on setting up and testing IBP and Chapter 8 for setting up additional channels of Fiber Optic Temperature. Refer to Chapter 14 for instructions for the Single Pump Fluid Heater System.

1. Locate the simplex and duplex fiber optic cables (25SFOC-23 and 25DFOC-23). If your system includes the Single Pump Fluid Heater System there will be two duplex fiber optic cables. If the MR scanner has a RF room, it will be necessary to install the fiber optic cables passing through a wave guide. Follow the color code on the fiber optic cables connecting gray plugs to gray receptacles and blue plugs to blue receptacles. Note: the simplex fiber for the ER Module will have a gray plug near the magnet and a blue plug near the operator console.
2. Assemble the MR-compatible instrument Roll Stand according to instructions in Appendix E.
3. Connect the Control/Gating Module (720200) (CGM) to the PC using the Prolific USB to serial adapter cable (USB-21). Note: use the PC's USB port labeled "USB CGM".
4. Power the Control/Gating Module with the external 12 VDC power supply (PS-2-12-CG).
5. Connect the Control/Gating Module to the ER Module (110100) using the simplex fiber optic cable. Connect to the port on the Control/Gating Module labeled "ECG" and to the ER Module's "Gray Fiber" port
6. Connect the ER Module Battery Pack (ERBP3-108-PCC) to the ER Module using the ER Module Battery Pack Cable (BPC-310-4B). A red light should be visible in the fiber optic port labeled "gray fiber". The battery pack should be connected to the ER battery charger when not in use. The ER battery pack charger is internal to the Control/Gating Module. An optional ER Battery Pack Wall Charger (BPCG-210) is also available. It is not necessary to deep discharge the battery or to disconnect it from the charger after it is fully charged.

System Setup

7. Fix mount the Multi-parameter Module (635600) and the Capnograph Module (635300) to the shelf of the instrument stand using 4 each 4-40 flat head screws (provided).
8. Connect the Multi-parameter and Capnograph Modules to each other using a simplex 1' long fiber optic cable (1FTSFOC-23). Connect the duplex fiber optic cable to the Multi-parameter and Capnograph Module. Power the modules using the MPM 12 VDC power supply (PS-4VET-12) and daisy chain cable (DCPC-2).
9. Use the Plastic Cable Mold (XXX) to attach the duplex fiber and the 12 VDC power cord to the pole of the instrument stand. Cable tie the MPM 12 VDC power supply to the base of the instrument stand.
10. Attach the Remote Display (LED-TV-24) to the PC using the HDMI cable (HDMI-144). Position the remote outside the magnet room window so it can be viewed from the magnet room.
11. To provide a trigger to the MR system, connect a BNC cable (not supplied) from the MR scanner's gate input to the GATE connection on the Control/Gating Module. Note the Control/Gating Module is shipped from the factory with the gate output pulse configuration set to "active high" or "TTL". If your MR system has a different requirement contact SAll Customer Service.
12. If the PC was delivered with the Model 1035 system you are all set to go. If it was not or if you need to use a new PC follow the SAll procedure PRD/0051 – PC-SETUP FOR THE MODEL 1035.

Testing the monitoring system

Turn on the PC and wait for the Windows operating system to boot. Click to launch the program PC-VET.exe from the desktop. If you wish to add or delete monitoring parameters open the full setup window otherwise select the option to open the main monitor display. You should have a sweeping display from left to right. If not, contact SAll Customer Service.

Open the SYSTEM INFO window and observe the 50/60 Hertz notch filter setting for the ER Module. Make certain the filter is set properly for your location (50 Hz in Europe, 60 Hz in US, etc.) The ER Module has a provision for the filter to be changed by the user (refer to Chapter 4).

Connect sensors to the Multi-parameter Module and do the following:

- Place the small adult NIBP cuff on your wrist and start a large animal blood pressure. The cuff should inflate and then begin to deflate. Pressure values should be indicated on the monitor display in 20 – 60 seconds.
- Room temperature should display and holding the tip of the temperature probe between thumb and index finger should make the reading rise rapidly.

System Setup

- Place the large SpO2 clip on your finger. A plet waveform should display.

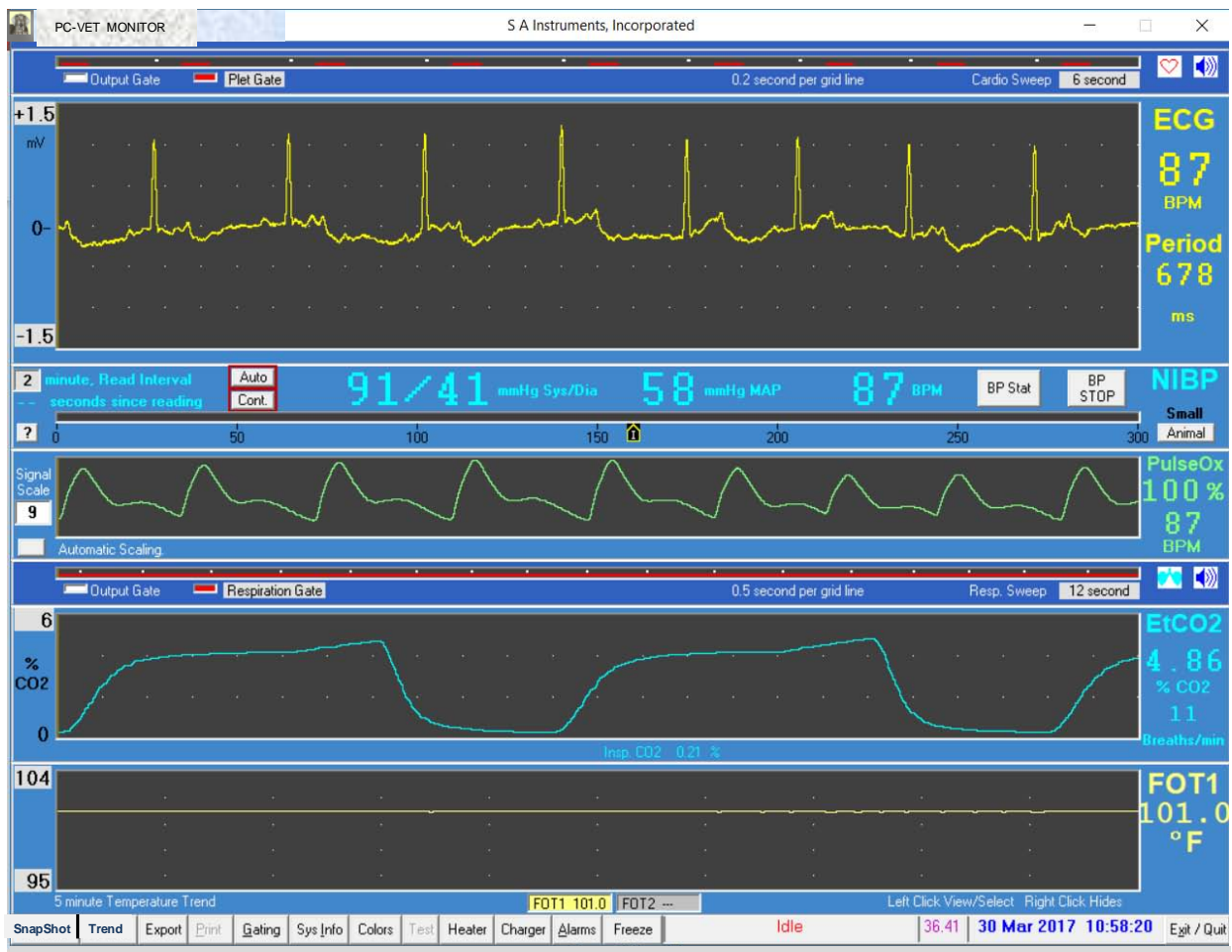
Connect a filter and sample line to the Capnograph Module.

- Breathing into the sample line should result in a CO2 waveform.

Step by step Instructions for monitoring and gating

Click the PC-VET icon on the desktop. Select “Start Monitor with Selected Setup” to view the main monitor display screen. The “selected setup” should be “factory defaults” which includes ECG, NIBP, SpO2, CO2 and temperature. Refer to Chapter 3 to alter the monitor configuration.

Attach ECG electrodes to the animal following instructions in Chapter 4. Connect a CO2 sample line to the animal according to instructions in Chapter 6.



ECG and CO2 waveforms should appear similar to those shown below. If your ECG waveform has negative rather than positive R-wave, switch the red and white connectors on the ER Module.

System Setup

Position a SpO₂ sensor on the animal according to instructions in Chapter 9. The plethysmogram waveform will appear along with measured values for heart rate and oxygen saturation.

Note the presence of small white dots in the Cardio Sweep display above the peaks of the ECG waveform. These dots appear when a R-wave is detected. A red bar also appears in the Cardio Sweep display above peaks in the plet waveform. Longer red bars appear in the Resp Sweep display above the CO₂ waveform coinciding with the animal's expiration. White dots appear at the same time in both the Cardio and Resp Sweep displays whenever a gate is sent from the Control/Gating Module to the MR scanner.

The heart and respiration rates are displayed to the right of the waveforms measured in beats or breaths per minute. The period displayed below ECG rate is the time interval in milliseconds for the cardiac cycle. Refer to Chapter 3 for additional information regarding the main monitor display.

Attach an NIBP cuff to the animal according to instructions in Chapter 7. Select large or small animal algorithm as appropriate and press "BP Stat". The cuff should inflate and then slowly reduce the pressure. Real time indication of the cuff pressure will display. After 20 – 60 seconds blood pressure and heart rate values will appear. Repeat the measurement manually or automatically as appropriate.

Position the rectal temperature probe in a pre-lubricated probe cover. Insert the temperature probe and cover in the animal's rectum. The animal's core temperature will appear.

Recommendations for daily operation

Connect the ER Module Battery Pack to the charger at the end of the day. The battery pack can be left on the charger when not in use. It can not be over charged.

The Control/Gating Module can be powered on all the time.

We recommend that 12 VDC power be switched off on the Multi-parameter and Capnograph Modules at the end of the day. Turning off power turns off the light sources for temperature and oximetry which greatly extends light source lifetime.

Fluid Heater System – turn off the power to the Heater Module and Circulation Module when not in use.

Chapter 3
PC and Control/Gating Module

Chapter 3

PC and Control/Gating Module

Overview

The Control/Gating Module is connected to a PC to provide operator control as well as display and storage of waveforms, computed gates, measured values and trends.

The optical signal received at the Control/Gating Module from the ER Module is demodulated and separated into ECG and respiration components before being processed to detect the R-wave (primary) peak of the ECG waveform. Operator control of the QRS (R-wave) detection algorithm is affected from the PC by selecting threshold values for the QR (leading) and RS (trailing of opposite polarity) slew rates as well as ECG gate blanking time. Slew rate control allows reliable determination of the ECG R-wave peak with minimal delay. Gate blanking time is set to eliminate unwanted gates from secondary peaks and/or interference.

The respiration waveform is automatically processed to detect inspiration. When the animal takes air into the lungs, the pillow sensor is compressed and the respiration waveform dips. The dip in the waveform is detected and an inspiration gate is generated. The inspiration gate is usually inverted to make an expiration gate. Both the beginning delay and maximum width of the gate are user controlled.

Monitor display

The monitor display is user configurable from the MONITOR SETUP window. Double clicking the PC-VET icon on the PC desktop generates an option to enter the MONITOR SETUP window before starting the monitor.

A typical monitor display configuration is shown on the next page. In this example, the parameters monitored are ECG, NIBP, pulse oximetry, CO₂ and temperature.

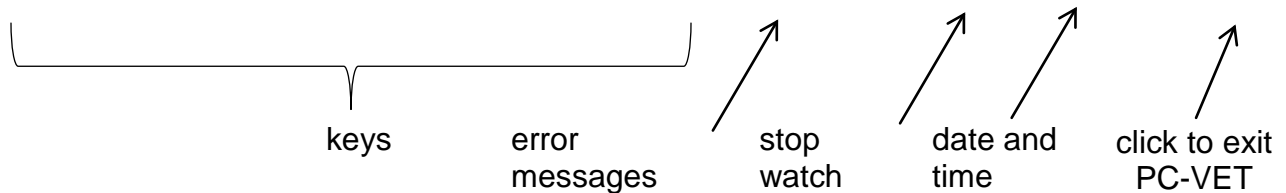
Detection of the R-wave (QRS complex) is indicated by the presence of a white dot on the cardio sweep display above the R-wave peak.

The CO₂ waveform dips during animal inspiration and exhibits only small changes in amplitude during expiration. Expiration is indicated by the presence of a red bar above the appropriate portion of the waveform.

White dots in the cardio sweep display are also shown in the respiration sweep display. They indicate times when gates have been sent to the scanner to initiate image data acquisition. In this case, the gating algorithm included only ECG but it can also be configured to include ECG and respiration. In that case, red dots (R-waves) only generate white dots (gates) when they occur during animal expiration.

Gates and waveforms sweep from left to right. The number of white dots (R-waves) determines the measured heart rate and the R to R period. Likewise the number of red bars (expirations) generates the measured respiration rate and period.

PC and Control/Gating Module

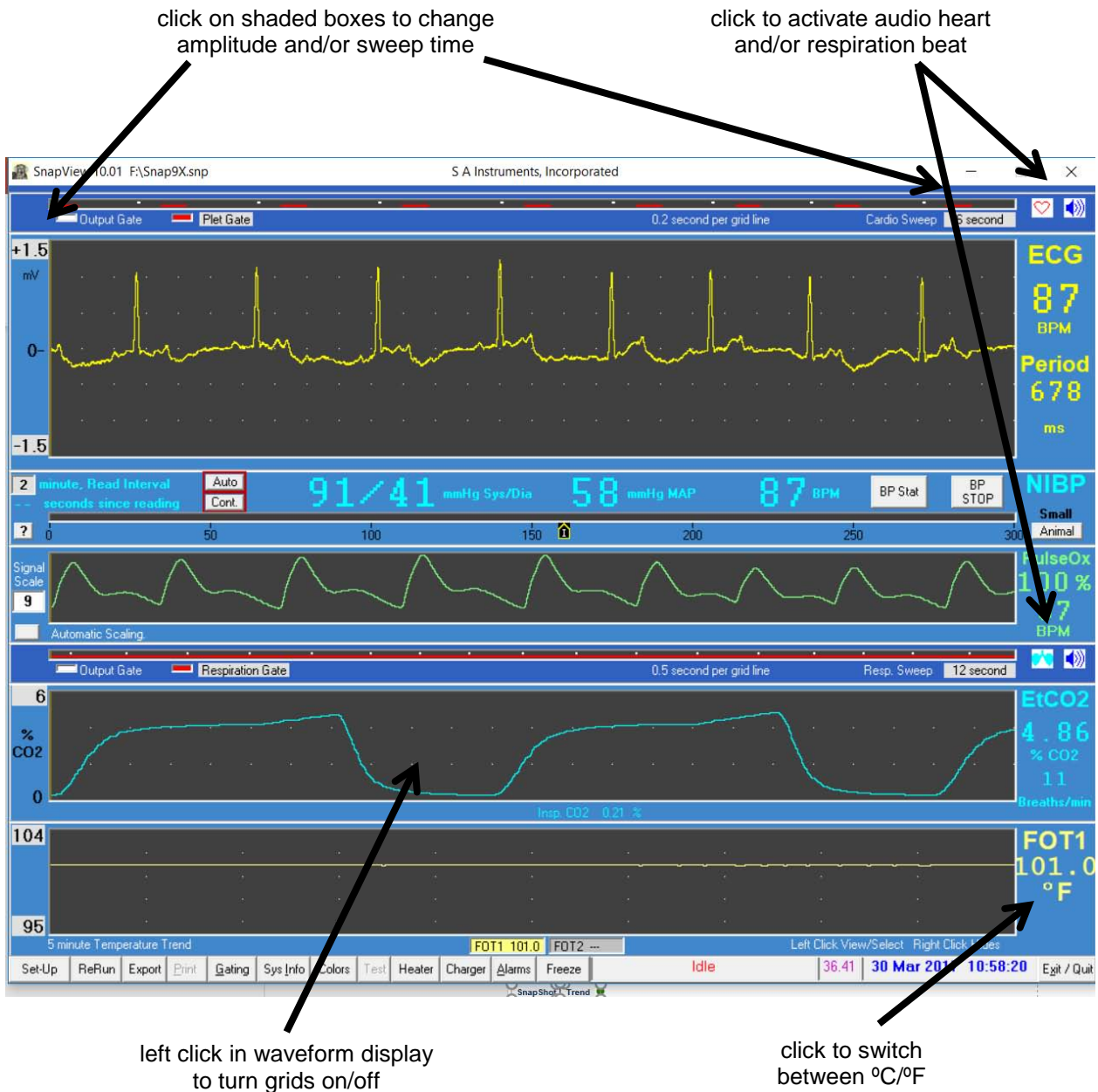


Temperature measurements are displayed in a 5 minute trend with the most recent measurement on the right of the display. Each new temperature measurement is displayed in digits as it is entered in the trend portion of the display.

Located along the bottom of the monitor display are several keys which perform special functions, display data or allow user entry of operating parameters. Each of the keys will be discussed in a later section of this chapter. In addition to the keys, there are regions for display of error messages, a stop watch and the date and time.

The stop watch displays in hours and minutes. A bar flashes to indicate the stop watch is running. Click on the stop watch display, to reset to zero.

PC and Control/Gating Module



Right click on the shaded waveform amplitude values to increase or left click to decrease the maximum and minimum values. Right click on the shaded sweep time boxes to increase or left click to decrease the sweep time. Note the cardiac and respiratory sweep times are independent and can be set to different values.

Switch between °C and °F by clicking on the digits in the temperature display

Clicking on the speaker icon associated with the cardiac sweep activates an audible beep for each ECG R-wave. Likewise clicking on the speaker icon associated with the respiration sweep activates an audible beep for respiration. It is not intended for both the ECG and respiration audio indicators to be on at the same time.

PC and Control/Gating Module

Grids can be turned off and on by left clicking inside a waveform display. Note the time separation of the grid lines is displayed above the waveform.

Right or left clicking on the gray box next to the red indicator of the cardio or respiration sweep gate displays will sequentially change the gate displayed. For the cardiac sweep the most useful gates are ECG and R-detect + Blanking Time.

Control/Gating Module input/output connections

Electrical connections:

Gate	output gate to trigger scanner
PC	Serial connection to PC
RESP GATE	output respiration gate to trigger scanner
Power	12 VDC input power connection
AUX	Aux gate input, a user TTL input gate channel

Fiber optic connections:

ECG	Input from the ER Module
AUX GATE IN	fiber optic aux in, a user digital gate input channel
AUX GATE OUT	Gate or trigger pulse out
OPTION IN	Input from the Multi-parameter Module
OPTION OUT	Output to the Multi-parameter Module
HEATER CONTROL	control signal for Air Heater Module

Gate output pulse signal configuration

The Control/Gating Module is shipped from the factory with the gate output pulse configured appropriate for the user's anticipated scanner either TTL (H) or active low (L). The gate output pulse can be changed by removing the cover of the Control/Gating Module. The switch is located inside a small access hole in the RF shield.

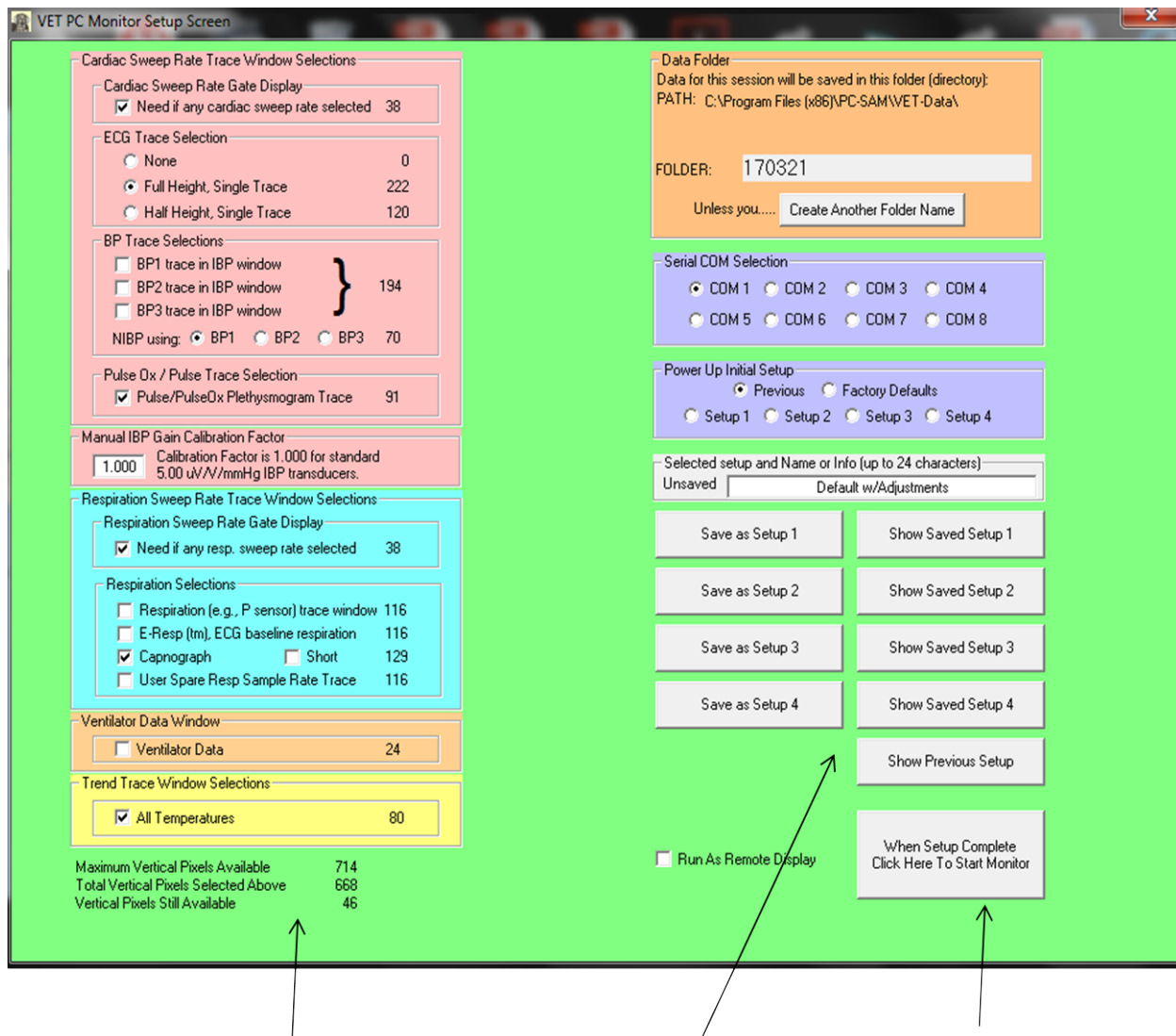
Altering monitor configuration

An option exists to open the MONITOR SETUP window after executing PC-sam. The SETUP window is shown on the next page.

The MONITOR SETUP window allows the user to do the following:

1. Define which waveforms, gates and trends to display
2. Change the name for the data folder for the current session
3. Change the serial communication port
4. Select a default stored setup file at startup
5. Select an alternate stored setup for the current session.

PC and Control/Gating Module



The portion of the setup window for waveform, gate and trend selection includes sections for cardiac, respiration and temperature. The numbers to the right of the trace selections are the number of vertical pixels necessary for that portion of the display. The total number of pixels used can not exceed the number available for the PC's display. A calculation to determine the number of pixels still available is performed in the lower left corner of the display.

The data folder for storage of trend data defaults to a date encoded name of the form yymmdd(letter). The letter changes for each successive session during the day. The user can change the file name and storage location from the setup window.

Up to four user defined setup files allow different monitor configurations to be saved for easy retrieval. For example, setup files could be stored for different types of animals or

PC and Control/Gating Module

different users or for different types of studies. In addition Factory Defaults can be selected or the previously configured setup. In the later case, any changes made during the last monitoring session will be remembered and restored for the next monitoring session.

SnapShot key

The SnapShot key in the lower left portion of PC-sam's main monitor display causes storage of the last 36 seconds of monitor data. All data transmitted to the PC during the last 36 seconds is stored not just displayed data. Parameter values set by the PC (e.g. slew rates for R-wave detection, blanking time, gating selections, etc.) are stored once, at the time the SnapShot key was clicked.

Data files can be viewed by selecting the SnapView option after launching PC-sam. Options exist to allow the entire file to be played back or to view the last few seconds of data. Most features available in PC-sam are also available in SnapView. For example sweep rates and amplitudes can be adjusted while viewing the files and the keys are active to display windows with associated parameter values. (Refer to Chapter XXX).

Trend key

The Trend key in the lower left portion of the monitor allows the current Trend file to be restarted or saved. When the saved selection is made a new Trend file is automatically started.

GATING SETUP window

Click the Gating key to open the GATING SETUP window. This window provides a means to include one or more signals in the gating algorithm. Selections would be for ECG or Plet with or without respiration.

Gate width and delay can be controlled for each signal source. Delay and width entries are in msec. A zero setting for Max Width is used to automatically determine the width from the gate detection software.

A check in the "Pulse Invert" column inverts the gate logic. For example, the Resp gate detection algorithm detects the dip in the waveform which occurs at inspiration. A check is placed in the Pulse Invert column to switch the gate to the expiration portion of the waveform. If desired, the expiration gate can be delayed in time or shortened in width.

PC and Control/Gating Module

R-DETECT SETUP window

Click the ECG button in the GATING SETUP window or right click in the ECG waveform display to view the R-DETECT SETUP window.

The **high pass filter** removes low frequency components of the ECG waveform. It can be useful with large animals and low heart rates. The order number can be selected between 16 and 6. Order number 6 produces the strongest filter function. Use the high pass filter with low order numbers for large animals to reduce low frequency “T-wave” flow artifacts.

The **R-detect blanking period** or blanking time is a very useful feature. Once an R-wave has been detected, the software inhibits R-wave gate generation for the blanking time. This feature can be used to eliminate false triggers from gradient vibrations. In that case, the blanking time should be set to exceed the MR scanner acquisition time by about 10 msec.

The screenshot displays the PC-VET MONITOR interface. The main window shows an ECG waveform with a heart rate of 84 BPM and a period of 637 ms. A yellow vertical line marks the detected R-wave. The R-DETECT SETUP window is open, showing the following settings:

- High Pass Filter: On, Order: Off
- R-Detect Blanking Period: Auto, 3/8ths R-R Period, Manual: 100 milliseconds
- Wave Feature Detection: Pos Peak, Positive Slope: 16 Samples = 8.9 ms, 15 uV minimum; Negative Slope: 15 Samples = 8.3 ms, 15 uV minimum
- Detection Threshold: Auto, 1001 uV Maximum

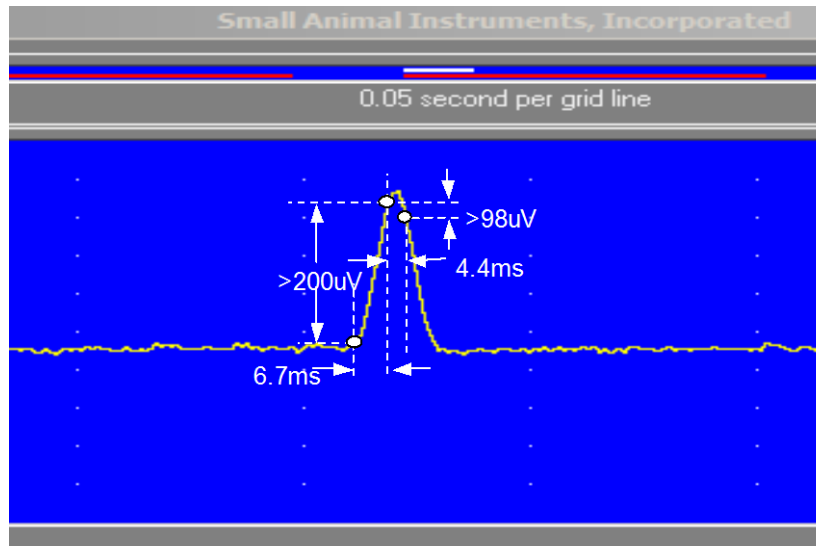
Three arrows point to specific settings in the R-DETECT SETUP window:

- 1) Right click on the ECG waveform to open the R-detect window
- 2) select values for R-detection
- 3) set blanking time

The interface also shows other vital signs: BP 91/41 mmHg Sys/Dia, 58 mmHg MAP, 87 BPM, NIBP 85 BPM, and EtCO2 4.75 % CO2. The bottom status bar indicates the system is running and the wave/data is frozen.

PC and Control/Gating Module

The **R-detect algorithm** is based on 2 or 3 points and their positive and/or negative slew rates or slopes (amplitude/time). The waveform shown exhibits R-wave gate generation for factory defaults: positive peak with positive slope of $200\mu\text{V}/6.7\text{ms}$ and a negative slope of $98\mu\text{V}/4.4\text{ms}$. The gate is generated at the end of the negative slope. In this example the R-wave is about $800\mu\text{V}$ in amplitude. The positive slope requirement is easily exceeded and the gate is generated as soon as the negative slope requirement is satisfied. Note that the mid point that satisfies the gate requirement is earlier in time than the R-wave peak. Thus the delay of the scanner gate is less than the negative slope time (i.e. less than 4.4 msec)



Proper selection of parameters for R-wave detection are important in obtaining reliable results. This is especially true when the ECG waveform contains large contributions from blood flow, vibration or respiration.

Perform the following steps to determine optimum settings for ECG detection (note we assume a positive R-wave for this discussion, but the software works in a similar manner for a negative R-wave):

Select a wave feature to detect: Usually this is a positive going R-wave. Selecting positive peak will give more reliable detection than selecting a rising edge. The only reason to select a rising edge would be to obtain a gate occurring before the R-wave peak in time.

Pick the times for the slopes: There are a maximum of 31 sample points or about 17 ms. Different animals have different rise times for the R-wave. Select the largest time appropriate for the animal's rise time. For mice the rise time is about 7.5 ms. Because the gate is generated at the end of the fall time, the fall time is usually set to be less than the rise time.

Select the amplitude(s): Determine the peak amplitude of the R-wave: usually $500\mu\text{V}$ to $1000\mu\text{V}$. In the case of mice with a rise and fall time selected of 6.7 and 4.4 ms respectively, we select rise & fall amplitudes of less than $6.7/7.5 = 90\%$ and $4.4/7.5 = 60\%$ of the peak amplitude. The system can be used to determine the amplitudes: set the amplitudes smaller than you expect, but large

PC and Control/Gating Module

enough not to get false gates, then slowly increase one of the amplitudes until gates begin to be missed. Final setting of 30 - 50% of max works well with auto detection threshold and 60 – 80% for manual detection threshold.

The **auto detection threshold** is a proprietary additional detection criterion. To turn it off, select manual and set the threshold to the positive slope amplitude.

CHARGER window

The CHARGER window reports the current status of the IBP Module power, the IBP internal battery and the external charging battery (i.e. the ER Battery Pack) if one is connected to the Control/Gating Module's battery charger.

PC and Control/Gating Module

Chapter 4

ER Module

ER Module

Overview

The animal's electrocardiograph (ECG) is obtained from three leads connected to MR-compatible ECG electrodes. The leads are constructed to minimize RF induced currents from the MR scanner. ECG electrodes include sub-dermal platinum needle electrodes and optional stick on surface electrodes that are MR-compatible. Measurement of the animal's respiration is made using a small pneumatic respiration pillow sensor.

ER Module signals are passed sequentially through an RF filter, amplifier and pulsed gradient filter before being combined and digitized. The digitized signal is transmitted to the Control/Gating Module using a fiber optic cable.

Positioning the ER Module

The ER Module powered by an external battery pack is positioned on the patient bed. Either needle electrodes or grabber leads for surface electrodes are connected directly to the ER Module. Keep the ER Module and electrodes away from the imaging coil,

Caution: Do not allow large loops to form in electrically conductive leads. Note the skin of the patient is electrically conductive.

Connecting the Battery Pack Cable

The Battery Pack Cable attaches to the ER Module and Battery Pack using small Lemo connectors. To make the connection, align the red dots and push the connector straight into the receptacle. To disconnect the cable, grasp the connector with the thumb and index finger near the red dot and pull straight back. Do not turn or twist the connector housing.

Attaching ECG electrodes

The red and white ECG electrodes are active in that they generate the ECG signal. The third electrode connected to the black ECG lead is the driven lead. The main purpose of the driven lead is to stabilize the ECG waveform baseline.

Optimal electrode placement on animals in the MR should be within 3 to 4 inches of each other on the chest near the heart. Larger electrode spacing can lead to RF heating of leads and/or electrodes. The red electrodes should be positioned on the chest above the heart and to the patient's right. The white electrode should be below the heart and to the patient's left. The black electrode can be positioned at any nearby location. However, electrodes can also successfully be positioned on the animal's left side or on the back.

ER Module

Electrodes should not be attached to the paws or legs of the patient as this would create a large conductive loop from one electrode to the other through the patient's skin.

Attachment of sub-dermal ECG needle electrodes

It is not necessary to shave the animal when using the needle electrodes. Make certain the needle does not enter the muscle, but rather is positioned between the muscle and skin. The platinum needles are thin and easily bent. If the skin is tough an entry hole can be made with a non-magnetic needle before inserting the platinum needle. It may be beneficial to secure the electrode or lead wire with tape.

If the needle electrodes are inserted in the muscle, a large offset voltage can occur which can lead to the ECG being flat lined. The offset voltage should be 2.5 +/- 1 V. It is displayed in the SYSTEM INFO window (refer to chapter 13).

Attachment of stick on surface electrodes

It is necessary to shave the animal when using surface electrodes. Special MR-compatible grabber leads connect between the ECG extension cable and MR-compatible surface stick on electrodes. The electrodes have a black graphite stud.

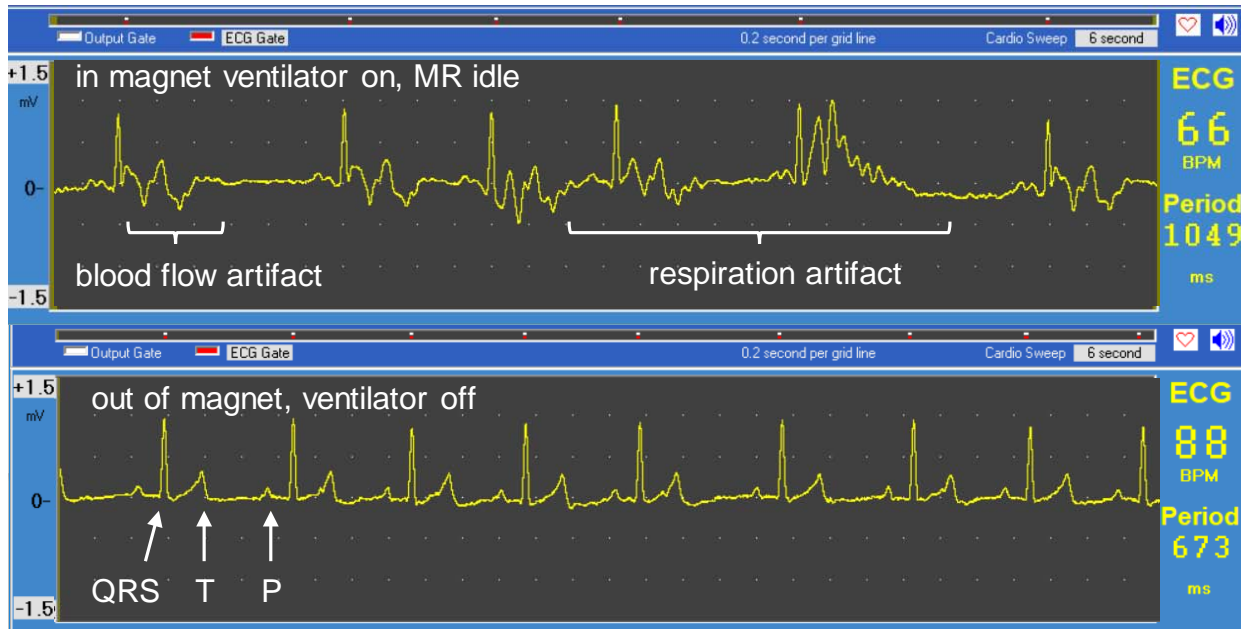
ECG waveform in the presence of a strong magnetic field

It is well known that the ECG waveform is distorted in MR imaging due to the presence of a strong static magnetic field. The distortion is due to the superposition of the normal biopotential with the potential created from ionic blood flowing in the presence of the static magnetic field. This phenomena is known as the magnetohydrodynamic (MHD) effect.

The R-wave provides the neuro stimulus for the heart. 10 to 40 msec after the R-wave the heart starts to contract. In doing so, a large volume of ionic blood starts to flow. The largest effect on the ECG waveform comes from blood flowing around the aortic arch and down the descending aorta. This distortion occurs in the ST region of the ECG waveform greatly reducing diagnostic capability of the measurement.

There can also be a respiration component to the distorted ECG waveform in a strong static magnetic field. When ECG lead wires move during respiration a distortion in the waveform can result. In this case the distortion is due to the electrical conductor moving in the static magnetic field. The motion is largest during inspiration. If red and white leads (the active leads) move the same the distortion is minimized.

The waveforms below show the effects of both blood flow and respiration on the electrocardiogram. The waveforms were obtained only a few minutes apart from a large dog being imaged in a 1.5 T magnet. Note that the artifacts are much broader than the R-wave. The R-detect algorithm makes use of this fact and generally correctly detects the presence of the R-wave.



Attachment of the respiration pneumatic pillow sensor

Position the pneumatic pillow sensor near the animal's abdomen and secure it with tape. Attach the sensor's tube to the ER Module at the Leur connection. It may be necessary to use one of the Respiration Extension Tubes to make the connection.

The respiration circuit incorporates an automatic gain stage that adjusts the amplitude of the respiration waveform within preset limits. After attaching the pillow, small respiratory signals may take a few seconds to gain up and produce respiration gates and a respiration rate.

The respiration waveform exhibits a negative peak during inspiration. The gating algorithm detects the negative peak and produces a respiration gate during the peak. To gate on expiration, check the "invert" box for respiration in the GATING SETUP window (refer to Chapter 3).

Charging the ER Battery Pack

The ERT Battery Pack should be connected to the ER battery charger when the system is not in use. The battery pack voltage is between 5.8 V and 6.5 V. A fully charged

ER Module

pack will operate for more than 15 hours when the battery is new. The battery pack voltage is displayed in the “System Info” window (refer to Chapter 3).

The ER battery pack charger is internal to the Control/Gating Module. An optional wall charger is also available. The battery pack will obtain a full charge in less than 2 hours. It is not necessary to deep discharge the battery or disconnect it from the charger after it is fully charged.

To obtain maximum battery life and performance:

- Recharge after each use
- Store in a charged state
- Store at room temperature or lower
- Recharge stored batteries every 9 months

Setting the 50/60 Hz notch filter

The notch filter is selected for 50 or 60 Hz using a screw near the Battery Pack Cable connection. For 60 Hz remove the screw, for 50 Hz leave the screw in place. The filter setting is reported in PC-sam’s SYSYEM INFO window (refer to chapter 13).

Chapter 5

Multi-parameter Module

Multi-parameter Module

Chapter 5

Multi-parameter Module

Overview

The **Multi-parameter Module** on an instrument roll stand is positioned near the magnet gantry. It monitors non-invasive blood pressure (NIBP), temperature and pulse oximetry. Fiber optic and pneumatic sensors extend to the animal in the magnet bore.

The module has a small amount of ferromagnetic material so it is fix mounted to the instrument stand. The NIBP pump and valves operate in a fringe magnetic field of 100 gauss or less. Most magnetically shielded MR magnets have a fringe field of 100 gauss 1 to 3 feet from the magnet bore. The module has a built in magnetic field detector that turns on a red LED when in a magnetic field greater than 100 gauss.

Sensor connections

The Multi-parameter Module sensor panel is shown below. Pneumatic tubing connects to the non-invasive blood pressure input. Fiber optic sensors connect to the temperature and pulse oximeter inputs. The sensors extend to the animal in the magnet bore. Sensor length is different depending on the magnet, but the length allows the instrument stand to be 4' or more from the magnet bore.



Multi-parameter Module

The sensor panel includes the following:

- Yellow LED that flashes when a cardiac pulse is detected in the plet waveform.
- Yellow LED that illuminates when a NIBP measurement is in progress.
- Switches to start and abort NIBP measurements.
- Red LED that flashes when the module is in a high magnetic field.

Power panel

The Multi-parameter Module power panel is shown below. It includes the following:

- 12 VDC power connection with power switch and indicator LED.
- Fiber optic communication ports to connect to the Control/Gating Module.



Multi-parameter Module

Operation

Caution - Not for Human use.

Caution do not use the Multi-parameter Module in the presence of flammable anesthetics; this could cause an explosion

Later chapters in this manual cover operation of non-invasive blood pressure, fiber optic temperature and pulse oximetry measurements of the Multi-parameter Module.

The 12 VDC power should be switched off to the Multi-parameter Module at the end of the day. Turning off power turns off the light sources for temperature and oximetry greatly extending light source lifetime.

Multi-parameter Module

Chapter 6
Capnograph Module

Capnograph Module

Chapter 6

Capnograph Module

Overview

The **Capnograph Module** provides continuous monitoring of respiratory carbon dioxide in animals with respiration rates less than or equal to 150 breaths per minute. It includes a CO₂ sensor, barometric pressure transducer, sampling flow control and a miniature vacuum pump. A microprocessor collects data from the sensor and calculates the following real-time parameters: CO₂ concentration, respiration rate, end-tidal CO₂, minimally inspired CO₂, inspiration and expiration times. The CO₂ waveform, end-tidal CO₂ and minimally inspired CO₂ can be displayed in mmHg, kPa or percent.

The module has a small amount of ferromagnetic material so it is fix mounted to the instrument stand. The vacuum pump and valves operate in a fringe magnetic field of 100 gauss or less. Most magnetically shielded MR magnets have a fringe field of 100 gauss 1 to 3 feet from the magnet bore. The module has a built in magnetic field detector that flashes a red LED when in a magnetic field greater than 100 gauss.

Sensor connections

The Capnograph Module sensor panel is shown below. It includes the following:

- Gas sample input connection.
- Yellow LED that illuminates when respiration is detected.
- Red LED that flashes when the module is in a high magnetic field.



Capnograph Module

A gas sample line with a 24" length of Nafion™ tubing connected to a moisture trap at the gas sample input connection delivers respiratory gas to the module. Total tubing length can be 9' or greater which allows the instrument stand to be 3' or more from the magnet bore.

Caution: Do not connect the sample line directly to the gas sample input port. Connect the moisture trap to the gas input port then connect the sample line to the moisture trap.

Power panel

The Capnograph Module power panel is shown below. It includes the following:

- 12 VDC power connection with power switch and indicator LED.
- Fiber optic communication ports to connect to the Multi-parameter and Control/Gating Modules.
- Leur exhaust port which can be connected to a scavenger system
- Push button switches for calibration.



Capnograph Module

Sample gas flow

The water trap and Nafion tubing™ prevent water vapor from entering the IR bench but allow gas to pass. Sample gas flow rate is user selectable from 50 to 200 mL/min. A flow regulation system controls the flow rate and attempts to clear the sample line if it gets occluded.

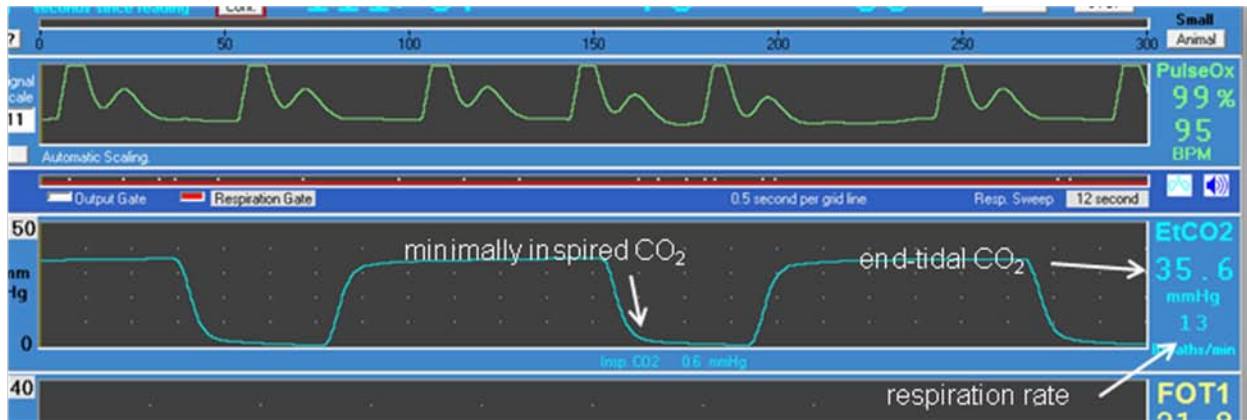
Caution: Not for Human use.

Caution: Do not use the Capnograph Module in the presence of flammable anesthetics; this could cause an explosion

The 12 VDC power should be switched off to the Capnograph Module at the end of the day.

PC-VET main display

The capnograph display is shown below. The instantaneous carbon dioxide waveform is displayed along with end-tidal CO₂, respiration rate and minimally inspired CO₂. Click on the label to the left of the waveform to change between %, mmHg and kPa.



Capnograph Module

Moisture trap replacement

The moisture trap and Nafion™ tubing remove moisture from the gas sample. The moisture trap shown below has a green threaded connection that attaches to the gas sample input port and a Leur connection that attaches to the Nafion™ tubing. Note the direction of sample gas flow is from the patient into the monitor.



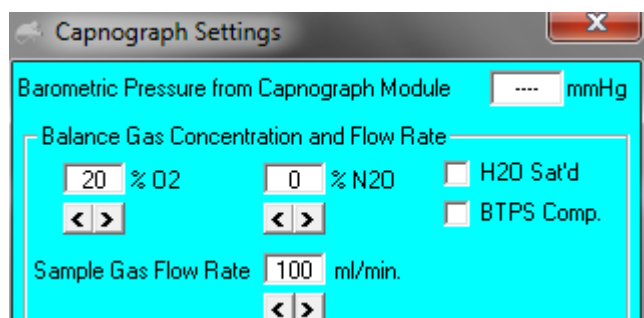
The Nafion™ tubing allows water vapor to pass through the tubing wall while blocking the passage of the gas sample. While the Nafion™ tubing does not retain moisture the moisture trap does. The moisture trap should be replaced when air flow is restricted. To test if the moisture trap is restricting air flow compare the sound of the pump to the sound with a new moisture trap. If the trap is restricting air flow the sound from the pump will increase as it works to maintain flow.

O₂ and N₂O compensation

The interfering effect of O₂ and N₂O results in inaccurate CO₂ readings. However the device has the ability to compensate for this error.

Right click on the CO₂ waveform to open the Capnograph Settings window. The % O₂ and N₂O can be entered to compensate for interfering gas being delivered to the patient. The atmospheric pressure reported by the module is displayed in this window.

The sample gas flow can be set using the arrows at the bottom of the window. The setting can be between 50 and 200 mL/min in 10 mL/min steps.



Capnograph Module

Calibration

The module automatically performs 0% CO₂ calibrations in order to correct for changes in temperature, pressure and electronic component drift. When performing an automatic calibration a solenoid valve switches for a few seconds from the patient sample line to ambient air from the gas port above the calibration buttons. Automatic calibrations are performed at 1, 2, 5, 10 and 15 minutes after power up and every 30 minutes thereafter.

It is recommended to periodically perform a 5% CO₂ calibration. Perform the calibration monthly or whenever the measurement seems to be in doubt.

To perform the calibration power up the Module and wait for 20 minutes. Connect the calibration gas bottle with the regulator and tubing kit to the moisture trap in the gas sample input. The tubing kit has a tee that is open to room air. The tee open to air protects the Capnograph Module from being over pressured. First press the 0% button to perform a room air cal. Then open slightly the regulator on the cal gas bottle. You should observe the CO₂ reading rise to near 5%. Press the 5% cal button wait 3 seconds and turn the gas regulator off.

Capnograph Module

Chapter 7

Non-Invasive Blood Pressure

Chapter 7

Non-Invasive Blood Pressure

Overview

The oscillometric method of blood pressure measurement is a non-invasive method that monitors the amplitude of cuff pressure changes during cuff deflation to determine arterial blood pressure. The cuff pressure is first elevated above the patient's systolic blood pressure level and the cuff begins to deflate at a certain rate. The initial rise in amplitude of these pressure fluctuations during cuff deflation corresponds closely to the systolic blood pressure. As the cuff is further deflated, these pressure fluctuations increase in amplitude until a peak is reached which is referred to as the mean arterial pressure (MAP). As cuff deflation continues, the diastolic pressure can be determined based upon the rapidly diminishing amplitude of the pressure fluctuations.

Each NIBP measurement cycle results in systolic, diastolic and mean arterial pressure readings as well as values for heart rate.

The Model 1035 Multi-parameter Module incorporates the SunTech Medical ADVANTAGE OEM BP™ veterinary NIBP module. This module has been specifically designed for use with dogs and cats.

NIBP components and connections

The NIBP hose is black polypropylene with durometer of 85 Shore A (firm). The tubing is 9/32 OD, 5/32 ID and with length that varies depending on the magnet.. It has a nylon CPC quick connect connector on one end and a nylon Leur connector on the other end.

The CPC quick connect connector mates with the NIBP connection on the Multi-parameter Module. To make the connection align the connectors and twist clockwise to lock the connection.

NIBP cuffs come with a short length of tubing and a male Leur connector. To connect a cuff to the NIBP hose push the male Leur of the cuff into the female Leur of the hose.

The following cuff sizes are provided:

Cuff size	Circumference range, cm
#1	3 - 6
#2	4 - 8
#3	6 - 11
#4	7 - 13
#5	8 - 15
#6	12 - 19
#7	17 - 25

Non-Invasive Blood Pressure

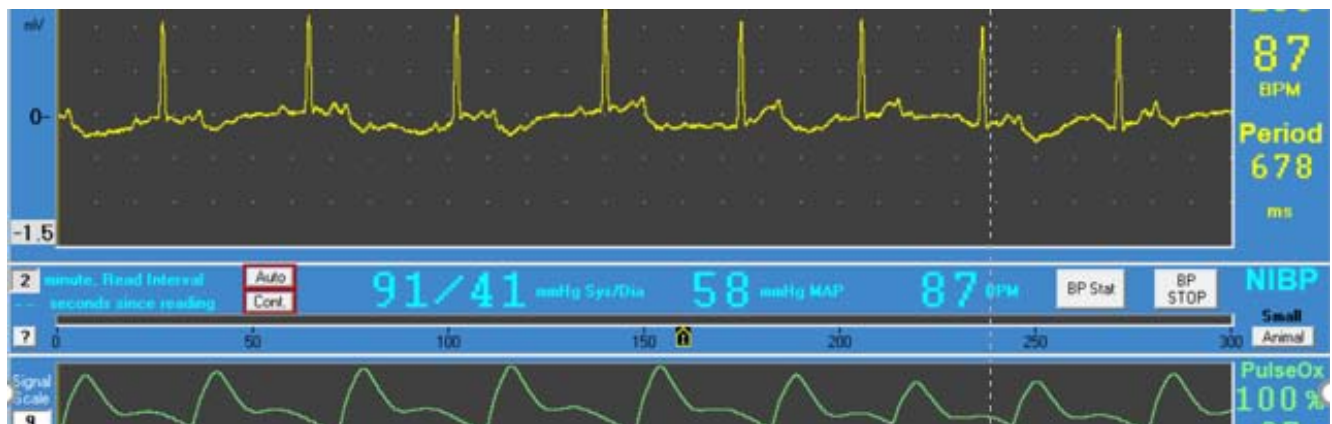
Animal modes

There are two animal modes that are needed to handle the large variety of animal sizes within the dog and cat populations. These are Small and Large Animal modes.

The *Small Animal Mode* has been developed to perform on smaller animals including cats and small dogs. Cats typically have very low oscillometric signal strength and are difficult patients for non-invasive blood pressure. The Small Animal Mode in the SunTech veterinary BP algorithm was specifically designed for this patient population and cuff placement plays a key role in obtaining BP measurements. This mode should be chosen when taking BP measurements on all cats up to a # 3 cuff. Also, dogs equal to or less than 8kg (~17.5 lb) should also have their blood pressures measured in this mode. Dogs or cats that require a #4 cuff or larger should use the Large Animal Mode. Animals that require a # 3 cuff usually can have their blood pressures measured with the Small Animal mode. If problems arise, then try the Large Animal mode.

The *Large Animal Mode* has been designed for animals requiring a #4 cuff or larger. This typically is dogs weighing more than 8kg (~17.5 lb). If a patient is using a #3 cuff in this mode and problems arise, then try the Small Animal mode or a larger cuff. For cats and dogs, the preferred position for all NIBP measurements is either left or right lateral recumbency. This will position the limbs fairly close to heart level.

PC-VET main display



The NIBP system uses one of the data channels of the IBP system. The data channel is assigned in the Setup Screen available at the launch of PC-VET. Once set, the channel is not changed during the study.

The NIBP portion of PC-VET's main display includes systolic, diastolic, mean arterial pressure and heart rate readings as well as the elapsed time since the measurement

Non-Invasive Blood Pressure

currently being displayed. The cuff pressure is displayed in real time in a manometer bargraph at the bottom of the NIBP display

Control of NIBP measurements is facilitated using the following buttons:

- BP Stat – to immediately initiate a measurement
- BP Stop – to stop the NIBP measurement
- Auto – starts auto cycling measurements (button turns from red to green)
- Cont – starts continuous measurements for 6 minutes or until BP Stop.

To the left on the NIBP display is a box where the time interval between successive NIBP measurements can be entered. The time interval can be 1 to 99 minutes. After entering a new value hit the enter key. The color of the box will change to indicate the new value was accepted. Regardless of the interval setting, the minimum interval between successive measurements will be the inflation time plus the deflation time plus 10 seconds. The NIBP measurement typically takes between 20 and 60 seconds. After three successive unsuccessful measurement cycles PC-VET software turns auto off. This routinely occurs at the end of a study when the NIBP cuff is removed from the patient.

The legend above the “Animal” button shows the active mode. Clicking the button toggles the mode between Small and Large Animal.

Before initiation of a measurement, a small icon is present on the manometer bargraph indicating initial inflation pressure. The default pressure is 160 mmHg for both animal modes. The initial inflation pressure can be changed by clicking and dragging the icon to a new pressure value. After completion of the initial NIBP cycle the icon disappears and the inflation pressure for the next cycle is set to the measured systolic pressure plus 30 mmHg.

Click on the “?” to the left of the manometer to open a window with a description of the NIBP measurement and also the “Signal Quality” which gives a relative measurement of the quality of the last measurement. Numbers typically are between 10 and 100 with larger numbers indicating a stronger signal.

Cuff selection and placement

It is important to select the cuff size that is appropriate to the diameter of the patient's limb or tail. Use the *Range Lines* on the inside of the cuff to determine the correct size cuff or use the width of the cuff. The cuff width should be approximately 40% of the limb circumference.

It is better to use a cuff that is slightly too big than one that is slightly too small. The cuff should never extend over a joint. Wrap the cuff around the limb making sure that the *Artery Marker* is reasonably close to the artery. It may become necessary to shave the

Non-Invasive Blood Pressure

animal fur if there is trouble obtaining BP measurements. The cuff should fit snug to the patient's limb for maximum oscillometric signal quality.

Ensure that the air hose from the monitor to the cuff is not compressed, crimped or damaged.

The cuff should be at heart level for proper measurement accuracy. When the cuff is below heart level, measurement results may be higher and when the cuff is above heart level, measurement results may be lower than comparative results obtained at heart level.

Please remember that using a cuff that is the wrong size may give false and misleading results.

Chapter 8

Fiber Optic Temperature

Chapter 8

Fiber Optic Temperature

Overview

Fiber optic temperature probes provide an alternative method to thermister temperature probes for measuring temperature in the MR environment. Fiber optic probes are not affected by the strong RF and magnetic fields of the MR scanner. They can not contribute to RF heating and they do not produce an artifact in MR images.

Components and connections

The Multi-parameter Module contains one channel of fiber optic temperature. The PC-VET software has provision for up to two channels of fiber optic temperature. The second channel of fiber optic temperature is an option for the Model 1035.

The fiber optic temperature sensors is 2, 6 or 9 feet long and has a 3 mm OD tip. A 10' long fiber optic sensor extension cable is available to allow the temperature probe to extend into the magnet bore.

One or more fiber optic temperature probes extend into the bore and attach to the animal. The temperature probe connects to the MPM by pushing the connector into the receptacle and turning clockwise to lock in place. To remove the probe press in and twist the connector counter clockwise.

When the option for a second channel of fiber optic temperature is in place, a Model 1035 Fiber Optic Temperature Module is also present on the instrument stand. Power is supplied using a two or three way daisy chain power cable connected to the Multi-parameter Module's 12 VDC power supply. Fiber optic communication cables connect in a data loop between the modules on the instrument stand and the Control/Gating Module.

The data loop connects one fiber from the duplex fiber optic cable to two modules on the instrument stand. It does not matter which cable connects to which module, but the color of the fiber optic connector should match the color of the fiber optic driver/receiver. The modules are then connected to each other using one or more short fiber optic cables.

Display configuration

To add fiber optic temperature to the monitor configuration, execute PC-VET and select the option to "open the MONITOR SETUP window". Select the "all temperatures" box at the lower left portion of the display.

Attaching, handling and cleaning fiber optic temperature probes

Use a lubricated probe cover on the tip of the temperature probe before inserting it into the rectum. Secure the probe lead by taping it to the animal's tail. Clean the temperature probe with isopropyl alcohol.

Fiber Optic Temperature

Temperature probes should be handled with care. The tip of the probe can be broken or cracked if the tip is bent. We recommend the fiber optic probe be suspended from a hook on the instrument stand when not in use to minimize the possibility of damage.

PC-VET's main display



When the “all temperatures” selection is made in the MONITOR SETUP window, two buttons appear below the temperature trend in PC-VET's main display. These buttons allow the user to select which temperatures are displayed in the trend and which current temperature is displayed in the digital display to the right of the trend.

In the example above, both FOT1 and FOT2 have been selected and are present in the trend display. FOT2 was selected last, so that probe's current measurement is also displayed to the right of the trend. The current measurement can be switched to FOT1 by left clicking on the FOT1 button. To remove a measurement set from the trend display right click on the corresponding button.

Chapter 9

Pulse Oximetry

Chapter 9

Pulse Oximetry

Overview

Pulse Oximetry allows noninvasive monitoring of arterial blood oxygen saturation. Fiber optic oximetry sensors are used to transmit pulses of red and infrared light through the animal's peripheral vascular region. Oxygen saturation is determined by measuring the differential absorption of the red and infrared light. In addition to oxygen saturation, the module measures the cardiac plethysmogram waveform, generates a plethysmogram gate, measures pulse distension and the animal's heart rate.

Oximeter components and connections

The Pulse Oximeter electronics is located in the Model 1035 Multi-parameter Module located on an instrument stand close to the magnet bore. A fiber optic pulse oximeter sensor 9' or 12' long extends into the magnet bore to connect to the animal.

The fiber optic oximeter sensor attaches to the module using a Lemo connector. To make the connection, align the red dots and push the connector straight into the receptacle. To disconnect grasp the connector with the thumb and index finger near the red dot and pull straight back. The pulling action retracts internal teeth allowing the connector to be released. Do not turn or twist the connector housing.

Display configuration

To add pulse oximetry to the monitor configuration, execute PC-VET and select the option to "open the MONITOR SETUP window". Select the Pulse Ox Plethysmogram Trace option on the left side of the window.

Changing sensor clips and forms

Fiber optic pulse oximetry sensors are constructed so the fibers can be detached from the clip or form that attaches to the animal. Small and large clips and a reflectance form are available.

Each fiber has a collar. The collars have a groove on each side that lock into tracks on the clips and form. Small and large clips are shown.



Pulse Oximetry

To attach a fiber to the clip, use the index finger to open the clip and position the fiber as shown. Grasp the collar with the thumb and index finger and insert the collar grooves into the tracks of the clip. Use the index finger to push the collar to the end of the clip opening.



Push the fiber into the large groove along the length of the clip making sure the collar is close to the end of the clip



To remove the fiber, grasp the fiber with the thumb and index finger as shown. Push the fiber to move the collar away from the clip. Then grasp the collar with the thumb and index finger and remove the collar from the clip.



To attach the fibers to the reflectance form, hold the collars together side by side with the ends of the fibers pointed down.

Slide the two collars onto the tracks of the reflectance form making sure the groves in the collars engage the tracks on the form. Press the two fibers into the groove along the top of the form. .



Attachment of fiber optic oximetry sensors

In general animals have lots of hair and often also have dark skin pigmentation. The best site for the attachment of oximetry sensors is on well perfused tissue (pink) with little or no hair.

The small and large clips have O-rings that can be used to relieve pressure on the attachment site. When the clip exerts large pressure circulation and the resulting signal are decreased. The pulse ox relative signal strength (Signal Scale) is displayed to the left of the plet waveform. Refer to the picture on the next page. For a clip on the tongue of a dog the signal scale should be between 9 and 13. Move the O-ring along the clip to decrease the clip pressure and increase the signal strength.

Tape the sensor to the patient bed to keep it from moving at the sensor site as the patient is positioned in the magnet. When using a clip on the tongue make certain the clip does not interfere with airway tubing. If the tongue is thin it can be folded.

For most animals, the reflectance sensor works well under the tail. Wet and part the fur on the ventral tail base. Wrap, not tape, the sensor in place. It may be necessary to shave a small spot on the ventral tail base for animals with thick undercoat. If the reflectance sensor is inserted rectally, use a lubricant and a transparent probe cover and shine the light on the sphincter muscle.

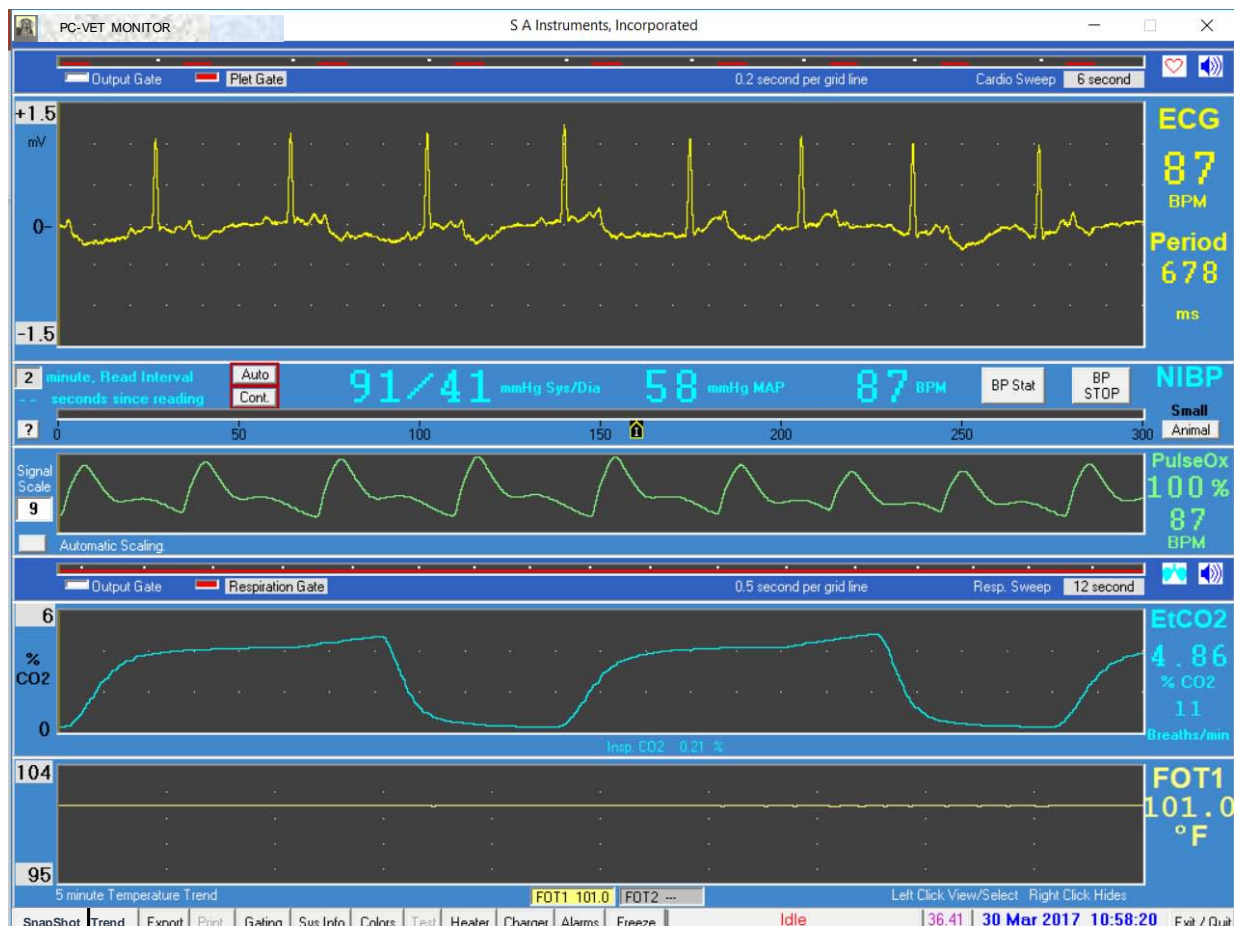
Pulse Oximetry

Recommended application sites

- Tongue -clips
- Prepuce or vulva of large animals - clips
- Achilles tendon of cats and small to medium size dogs - clips
- Ear - clips
- Thigh and armpit for birds – reflectance and clips
- Toe webbing - clips
- Under tail – reflectance

PC-VET main display

The PC-VET main display is shown below with ECG, NIBP, pulse oximetry, capnography and temperature measurements. ECG was selected in the Gating display so that a white dot in the Cardio Sweep display would indicate the detection of the R-wave. Plet Gate was selected to display as a red dot, by clicking on the label next to the red Cardio Sweep icon.



Pulse Oximetry

Note the following:

- There is a delay between the ECG and plet gates, because blood flows to a peripheral site after the heart beats.
- The plethysmogram waveform has no interference from the MR scanner.
- There is a small modulation of the plethysmogram waveform from respiration.

Plethysmogram gate threshold

A threshold parameter is used to detect the plethysmogram gates for oximetry. In the current version of the software, the threshold's default value can be changed in real time by the user.

The display below shows how to change the pulse ox threshold. The best selection depends on the signal strength which is reported on the left side of the pleth waveform display. The higher the signal strength, the larger will be the optimum setting for the



- 1) Click Gating button to display the Gating Setup Form
- 2) Click Pulse/Pulse Ox button to display the Gating Setup Form
- 3) Change value and click send to set a new threshold value

Pulse Oximetry

threshold. The objective is to set the threshold so only one gate is present above each peak in the pleth waveform with no extra gates.

For small animals like cats the signal can be 6 or more and the threshold setting would be 20 to 40. For larger animals like dogs, the signal can be 10 to 15 with a threshold setting of 75 or more.

Chapter 10

Invasive Blood Pressure

Chapter 10

Invasive Blood Pressure

Overview

The IBP Module measures invasive blood pressure using a blood pressure transducer connected with tubing to an invasive line in the animal. System design accommodates up to three IBP channels. The Model 1035 uses one of the IBP channels for non-invasive blood pressure (NIBP) measurements. The other two channels are available as options for the Model 1035.

Fiber optic communication cable connections

When the option for IBP is in place, an IBP Model is also present on the instrument stand. Power is supplied using a daisy chain power cable connected to the Multi-parameter Module's 12 VDC power supply. Fiber optic communication cables connect in a data loop between the modules on the instrument stand and the Control/Gating Module.

The data loop connects one fiber from the duplex fiber optic cable to each module on the instrument stand. It does not matter which cable connects to each module. But the color of the fiber optic connector should match the color of the fiber optic driver/receiver. The modules are then connected to each other using one or more short fiber optic cables.

IBP transducers

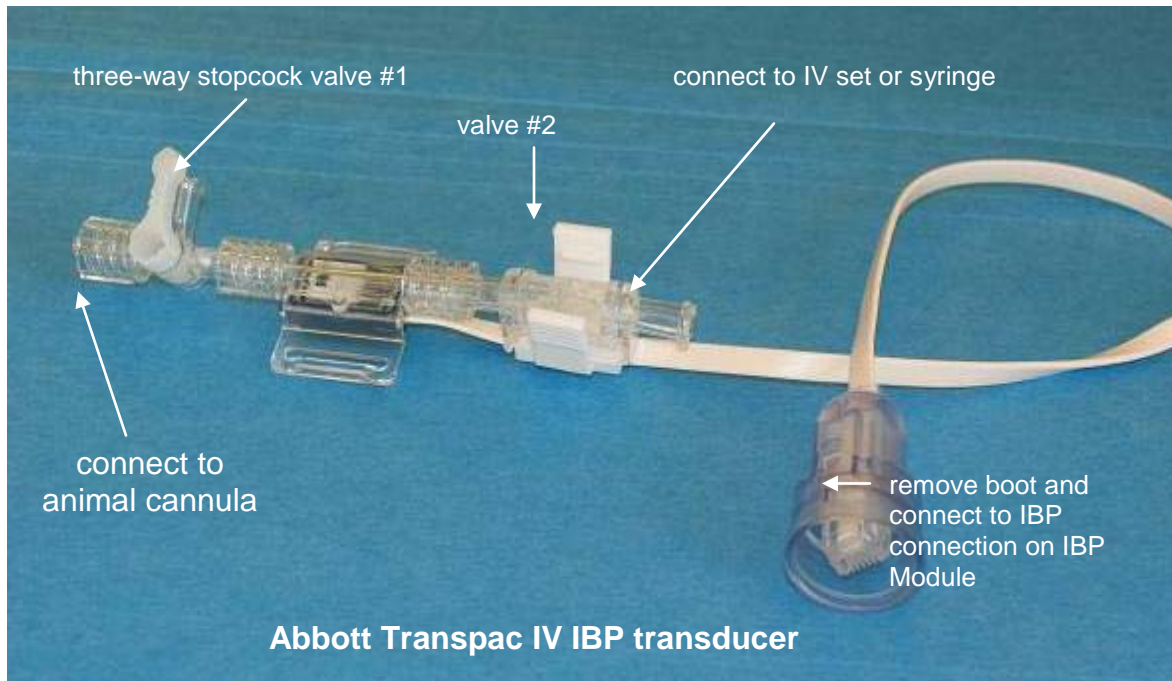
The IBP Module is configured to operate using disposable invasive blood pressure transducers which meet the specification of $5\mu\text{V/V/mmHg}$. The following IBP transducers meet this specification and can be used with the Model 1035.

Invasive Blood Pressure

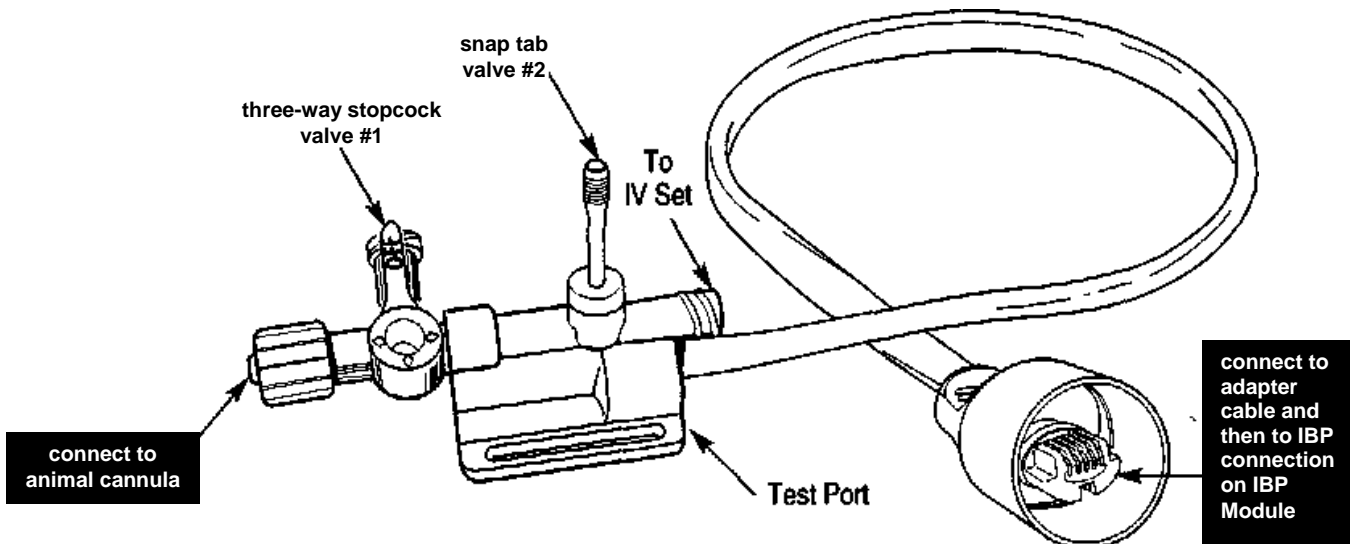
Transducer name	Manufacturer contact information
Abbott Critical Care Systems Transpac IV	Hospira, Inc. Lake Forest, IL 60045 (877) 946-7747, www.hospira.com
Baxter Edwards TruWave	Baxter/Edwards Lifesciences, LLC One Edwards Way Irvine, CA 92614 (949) 250-2500, www.edwards.com
Utah Medical Deltran IV	Utah Medical Products, Inc. 7043 South 300 West Midvale, UT 84047 (801) 566-1200, www.utahmed.com
Becton Dickinson Gabarith PMSET 1DT-XX	Becton Dickinson 1 Becton Drive Franklin Lakes, NJ 07417 (201) 847-6800
Braun Exadyn-Combitrans	B. Braun Carl-Braun-Strasse 1 D-34212 Melsungen Germany +49 5661710

Many other IBP transducers also meet the specification and can be used with the Model 1035. In many cases a transducer adapter cable is necessary to connect the transducer to the monitor. Contact SA Instruments Customer Service for additional information.

Invasive Blood Pressure



The Abbott Transpac IV transducer can be connected directly to the IBP Module at the IBP connection. If the transducer connector has a protective boot around it, remove the boot. The connection snaps into the receptacle and locks with the locking clip.



Invasive blood pressure transducers from other manufacturers can also be used with the system. However, an adapter cable will be required. Adapter cables can be obtained by contacting SAIL Customer Service.

Invasive Blood Pressure

IBP transducers have an electrical connection (for the IBP Module), three fluid connections (for the animal, syringe and/or IV set) and two valves. A very small piezoelectric pressure sensor is located in the fluid pathway between the two valves. Pressure changes caused by the animal's blood in the tubing are converted to electrical signals by the transducer for display on the monitor.

Each manufacturer of IBP transducers provides detailed instructions for use. Please refer to those instructions for information in addition to that given below.

Transducer valves

IBP transducers have two valves: a three position stopcock (valve #1) and a normally closed valve (valve #2).

The three position stopcock valve makes a connection between two of the three ports while blocking the third. The stopcock lever can be rotated to select which port is blocked.

The second valve is a normally closed flow through valve. Action by the operator is required to open the valve. In the case of the Abbott Transpac IV, pressing the plastic tabs between the thumb and fore finger will open the valve. In the case of the Baxter Edwards TruWave transducer, pulling the snap tab opens the valve. Note the IBP transducer manufacturer's instructions should be followed in the event the port attached to valve #2 is to be connected to an IV set for fluid delivery to the animal.

Animal cannula

A cannula inserted in the animal's vessel will allow blood to enter the blood pressure



tubing. Cannulas can be constructed in a number of ways using needles, tubing and Luer connectors.

A simple cannula can be made using PE50 tubing and a Luer stub (Harvard Apparatus part number NP 72-4439 www.harvardapparatus.com). The Luer stub has a female Luer connection on one end and a short 22 gage metal stub on the other end. The

Invasive Blood Pressure

metal stub can be inserted into one end of a length of PE50 tubing to fabricate the cannula.

When using the IBP function in the MR environment, make certain the tubing is no longer than necessary to extend from the animal in the bore to the IBP transducer location at the entrance of the bore, typically 1 to 1.5 m.

Flushing the IBP transducer and cannula

Before insertion of the cannula in the animal, the IBP transducer and cannula must be flushed and filled with heparinized saline. The tube and cannula must be completely filled with fluid (i.e. no air bubbles). Failure to eliminate entrapped air can result in inaccurate blood pressure readings due to the compressibility of air.

Flush the transducer and cannula by connecting a syringe or elevated IV bag to the port at valve #2. Opening valve #2 allows fluid to pass through and out the end of the cannula. Air bubbles can be eliminated by raising or lowering and tapping on the tubing. Note the three-way stopcock should be positioned to block the port with no connection (open to air).

Making blood pressure measurements

The following steps to make IBP measurements should be integrated with animal handling and aseptic protocols established for your facility:

Connect the transducer with cannula to the IBP port on the IBP Module. If necessary use an adapter cable to make the connection. Select the IBP3 option in the monitor's SETUP MENU. A flat waveform should be present on the IBP portion of the monitor's display. The IBP waveform amplitude should change in response to pressure variations on the transducer.

Flush the transducer and cannula with heparinized saline solution. Remove all air bubbles.

When using the transducer in the MR environment, it should be constrained from moving in the magnet's fringe magnetic field. After positioning the IBP Module near the entrance to the magnet bore, tape the transducer to the canopy or bed near the entrance to the bore. Position the transducer at the level of the animal to maximize accuracy of Blood pressure measurements. Transducer offset changes with the magnetic field, so after securing the transducer it should be zeroed. Check to make certain air bubbles were not introduced.

Establish an invasive line in the animal by inserting the cannula according to the surgical protocol for your facility. Add additional heparinized saline if necessary to position the blood saline interface between the animal and the transducer. Repeat as necessary to keep blood from entering the transducer. A blood pressure waveform should be present on the monitor display.

Invasive Blood Pressure

Most IBP transducers provide a specified level of electrical isolation for the animal. However, if additional isolation is desired, the IBP Module can be operated on internal battery rather than mains power.

Zeroing the invasive pressure transducer

The transducer must be zeroed to ensure that accurate absolute pressure values are displayed. When the transducer is connected to the IBP Module, a yellow LED flashes to indicate zeroing is required. After securing the transducer in the magnet fringe field, follow these steps to zero the transducer:

1. Position the three-way stopcock valve to block the port connected to the animal cannula. This exposes the fluid in the transducer to atmospheric pressure.
2. Press the zero button on the IBP Module. The LED will turn off when the transducer is zeroed.
3. Position the three-way stopcock valve to block the port with no connection. This exposes the fluid in the transducer to the animal's blood pressure.

Calibrating the invasive pressure transducer

The IBP transducer can be calibrated using a manometer or other source of known pressure. The pressure source can be connected to the air port on the three-way stopcock valve. Some transducers (e.g. Baxter Edwards TruWave) provide a separate test port to allow verification of pressure readings without compromising sterility of the system. An IBP gain calibration factor is available in the PC-VET SETUP WINDOW to allow for adjustment of the readings.

Charging the IBP Internal battery

The IBP Module has a built in battery charger for the internal battery. The internal battery is charged when the module is connected to 12 VDC power. If line power is available near the magnet, the 12 VDC power supply can always be connected to the module. If line power is not available near the magnet, the module should be removed from the magnet and connected to the 12 VDC power supply for charging whenever the system is not in use. The battery will reach full charge in 2.5 hours.

The IBP Module's internal battery operates between 7.0 and 8.2 V. A fully charged battery will operate the Module for 6 hours. A low battery warning is displayed on the PC when the battery is low. The module will operate for approximately 1.5 hours following the first indication of low battery. The battery voltage is displayed in CHARGER window (refer to Chapter 3) and the SYSTEM INFO window (refer to Chapter 13).

Chapter 11

Trends

Overview

During operation, the Windows based PC-VET software continuously logs data to a trend file located in a project folder. The data sample rate is once per second and more than 70 items are included in the recorded data point. The items include measured values of physiological functions (e.g. heart rate, temperature, etc) as well as status indicators of the hardware (e.g. battery voltage, offset voltage, etc.) The data file name and location is defined in the setup menu (refer to Chapter 3). The user has the option to save or discard the data when exiting the program.

To view data previously collected, execute the TrendMap program from the desktop. TrendMap was developed for use with Trend files collected by SA Instruments software for small animals PC-sam. Some of the items displayed by TrendMap for files collected by PC-VET will be zero because PC-Vet has fewer trend entries than PC-sam.

The TrendMap program allows all or a subset of the data to be organized and output in a user defined format for import into a spread sheet program.

Provision exists to allow the user to configure the way the data is organized and viewed. Each new configuration can be saved as a setup file with the data set for recall at a later date.

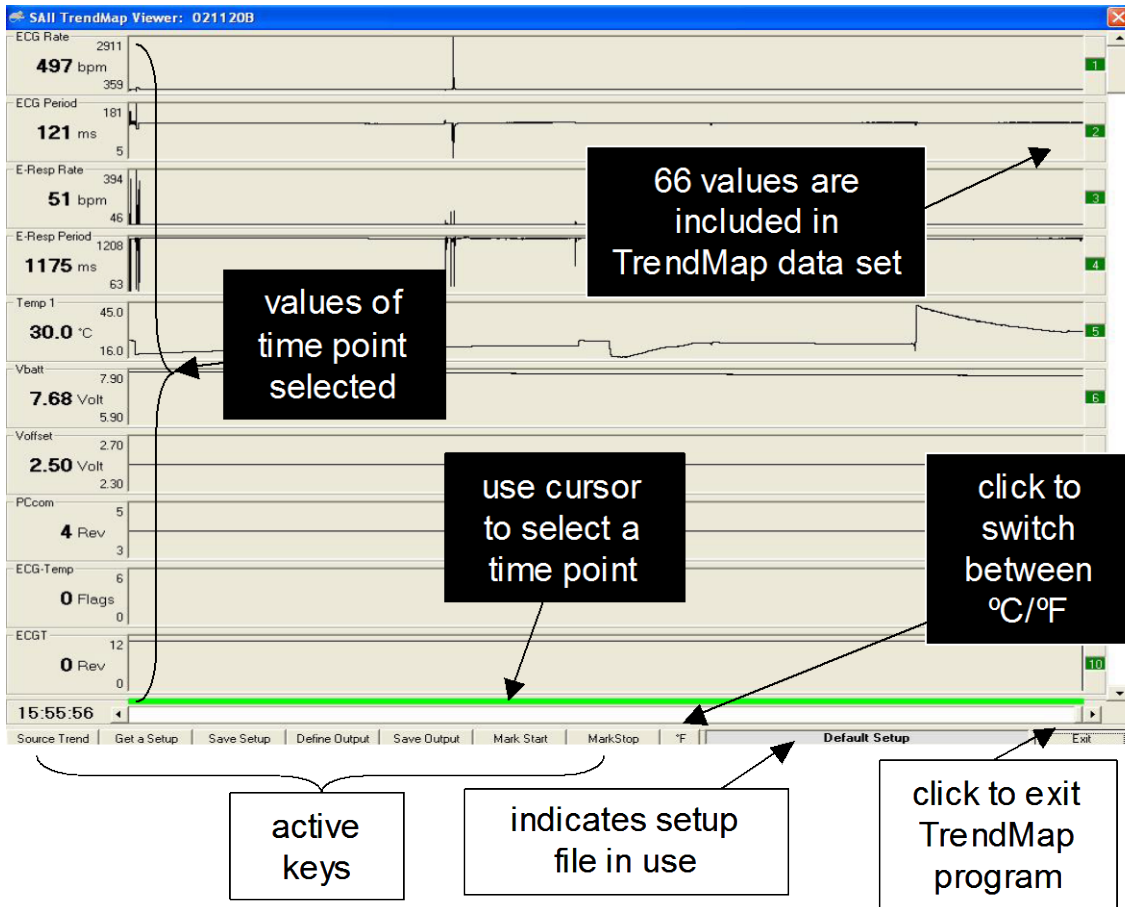
Events logged in PC-VET are recorded in the trend file as item 42 and can be viewed with TrendMap.

TrendMap Viewer display

The TrendMap Viewer display is shown on the next page. More than 70 values are included in each TrendMap data set. A time cursor is displayed near the bottom and an item cursor is displayed on the right side of the display. Individual values are displayed on the left for the time point selected.

A subset of the trend data set is selected by the user for export. The exported data set is bound by a start and stop time and includes all trends up to one selected as the last to output. Commands exist to allow trend reordering before data is exported.

Trends



Several keys are located on the bottom of the display along with a message area. The following keys allow the data set to be retrieved, reconfigured and exported:

- Source Trend – opens a trend data file
- Get a Setup – opens a setup file for display of data
- Save a Setup – saves a setup file
- Define Output – specifies format for the exported data file
- Save Output – saves the exported data file
- Mark Start – selects the start time for data to be exported
- Mark Stop – selects the stop time for data to be exported
- °C/°F – toggle units for temperature measurements

In addition to the keys, a TRENDR ORDER ADJUSTMENT window is available to allow adjusting the order of trends in the data set. Click on any trend number on the right side of the TrendMap Viewer display to obtain the TRENDR ORDER ADJUSTMENT window.

A window for adjusting the displayed max/min of each trend data set is opened by clicking anywhere in the trend display

Source Trend key

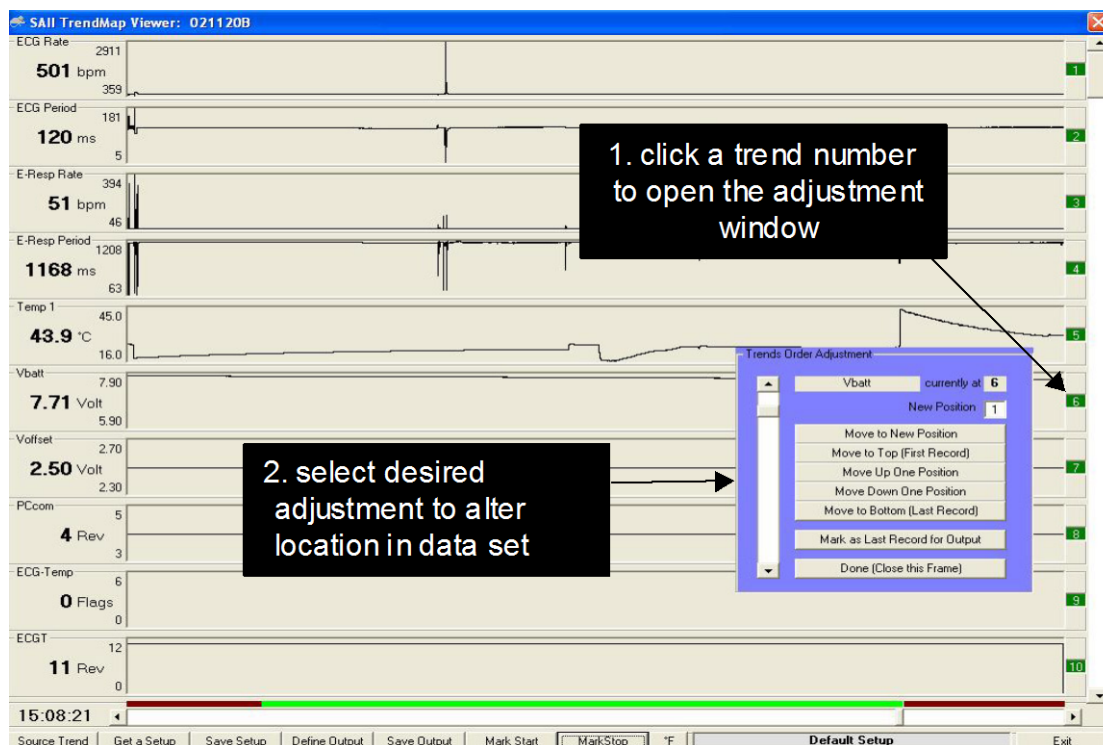
Clicking this key opens a window that allows selection of a trend data set. The window opens when TrendMap is executed or when the Source Trend key is clicked.

Get and Save Setup keys

These keys allow files which define the setup to be retrieved and saved. It can be useful after defining the order of trends in the data set (i.e. heart rate, temperature, respiration rate, time stamp events, etc.) and the output format to save the setup for future use.

TREND ORDER ADJUSTMENT window

Clicking any trend number opens the TREND ORDER ADJUSTMENT window. The scroll bar on the left of the window can select any trend location.



The trend selected is identified by name and current location number. Change the location of the selected trend by entering a new position number and clicking the Move to New Position key. Additional keys provide quick ways to move the trend up and down in the data set.

Trends

Clicking the “Mark as Last Record for Output” key defines the trends which will be included in the exported data set. The trends to be exported (number 1 through the last record) are indicated in green while all others are indicated in red.

Mark Start and Mark Stop keys

Mark Start and Mark Stop keys define the time portion of the exported data set. Select the beginning and end time points with the cursor as shown and click the keys.

Define Output key

1. click to open output setup window

2. make selections to define format of output file.

3. note data set selected for output is indicated as green.

4. click to save output.

The OUTPUT FILE SETUP window allows the following items to be defined for the exported data file:

- Header information
- Time column format
- Seconds per output line
- Trends per output line
- Column and line delimiters
- Number for bad data

The time exported can be as seconds from the start or actual time. Usually one second is output per line, but very large data sets may necessitate multiple seconds per output line. The number of trends per output line defaults automatically to the number selected for output. The most common choices for column and line delimiters are accommodated. Bad data which is set to “-1” in the trend file can be set to any other value.

Selecting events recorded in trend data

Events are recorded in the trend data file as item 64. An event selection key can be used to step through the events. A comment window displays comments entered for each event.

Trends

Trend data item list

The following table lists the items recorded in trend data. Note that all items are not present in files collected by PC-VET.

Item #	Label	Unit	explanation
1	ECG rate	bpm	heart rate from ECG leads
2	Resp Rate	resp/m	respiration rate from the pneumatic pillow input
3	Temp 1	°C or F	temperature from channel 1
4	SpO2	% Sat	oxygen saturation in % of hemoglobin
5	FOT1	°C or F	temperature of fiber optic channel 1
6	BP3 Sys	mmHg	IBP channel 3 systolic pressure measurement
7	BP3 Dia	mmHg	IBP channel 3 diastolic pressure measurement
8	BP3 Mean	mmHg	IBP channel 3 mean pressure
9	EtCO2	mmHg	end tidal CO2 measurement
10	Insp CO2	mmHg	inspired CO2 measurement
11	FiO2	%	final inspired O2 measurement
12	E-resp rate	bpm	respiration rate from E-resp
13	ECG period	ms	R to R time interval from ECG leads
14	Resp Period	ms	respiration period from the pillow input
15	Ox Rate	bpm	heart rate from SpO2 waveform
16	Ox Period	ms	heart period from SpO2 waveform
17	BP3 rate	bpm	heart rate from IBP 3 measurement
18	BP3 period	ms	heart period from IBP3 measurement
19	CO2 rate	Resp/m	respiration rate from CO2 measurement
20	CO2 period	ms	respiration period from CO2 measurement
21	Vent period	ms	respiration period from the ventilator
22	Vent Insp time	ms	time of inspiration from the ventilator
23	Vent tidal vol	ml	tidal volume from the ventilator
24	E-resp period	ms	R to R time interval from E-resp
25	BP1 Sys	mmHg	IBP channel 1 systolic pressure measurement
26	BP1 Dia	mmHg	IBP channel 1 diastolic pressure measurement
27	BP1 Mean	mmHg	IBP channel 1 mean pressure
28	BP1 rate	bpm	heart rate from IBP 1 measurement
29	BP1 period	ms	heart period from IBP 1 measurement
30	BP2 Sys	mmHg	IBP channel 2 systolic pressure measurement
31	BP! Dia	mmHg	IBP channel 2 diastolic pressure measurement
32	BP2 Mean	mmHg	IBP channel 2 mean pressure
33	BP2 rate	bpm	heart rate from IBP 2 measurement
34	BP2 period	ms	heart period from IBP 2 measurement
35	FOT2	°C or F	temperature of fiber optic channel 2
36	FOT3	°C or F	temperature of fiber optic channel 3
37	FOT4	°C or F	temperature of fiber optic channel 4

Item #	Label	Unit	explanation
38	USER Rate	cpm	rate from USER Resp channel
39	USER Period	ms	period from USER Resp channel
40	Pambient	mmHg	ambient barometric pressure
41	Temp; 2	°C or F	temperature from channel 2
42	Event	text	users text message input
43	Vbatt	volts	battery voltage of ERT Battery Pack
44	Voffset	volts	offset voltage of ECG leads measurement
45	Chg Vplus	volts	Respiration Module's operating voltage
46	Chg Vbint	Volts	voltage for the Resp Module's internal battery
47	Chg Vbext	Volts	voltage for an external battery being charged
48	Chg Ipwm	mA	charging current for an external battery
49	Resp Gain	number	auto gain setting for the respiration channel
50	USER Gain	number	gain setting from USER Resp channel
51	Ox Monitor	level	auto gain level for oximeter measurement
52	ECGT	Rev #	ECGT software revision number
53	ETGate	Rev #	ETGate software revision number
54	PCcom	Rev #	PC com software revision number
55	RFcom	Rev #	RFcom software revision number
56	Resp	Rev #	respiration software revision number
57	Oximeter	Rev #	oximeter software revision number
58	FOT Rev	Rev #	Fiber Optic Temperature Module software rev
59	IBP	Rev #	IBP software revision number
60	Chg Rev	Rev #	battery charger software revision number
61	capnograph	Rev #	capnograph software revision number
62	Vent Rev	Rev #	ventilator software revision number
63	CVcom	Rev #	Capno/ventilator software revision number
64	POX Rev	Rev #	oximeter software revision number
65	FOT Rev	Rev #	fiber optic temp software revision number
66	ECG-Temp	flags	proprietary data for service
67	Resp	flags	proprietary data for service
68	Oximeter	flags	proprietary data for service
69	FOT Flags	flags	proprietary data for service
70	IBP	flags	proprietary data for service
71	Chg Flags	flags	proprietary data for service
72	Capno/vent	flags	proprietary data for service
73	Aux/FO in	flags	proprietary data for service
74	PCcom	flags	proprietary data for service
75	Number FOTs	number	number of fiber optic temperature channels
76	Plet signal	number	signal strength from the Oximeter Module

Trends

Chapter 12

SnapView

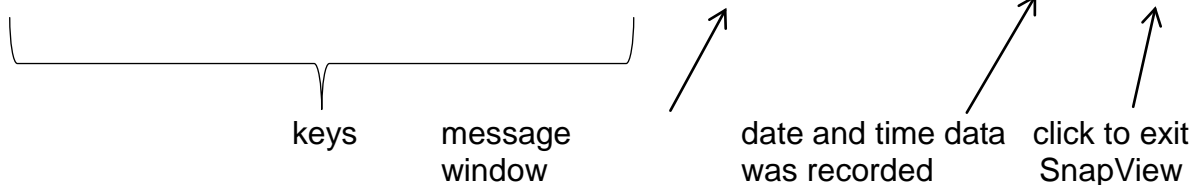
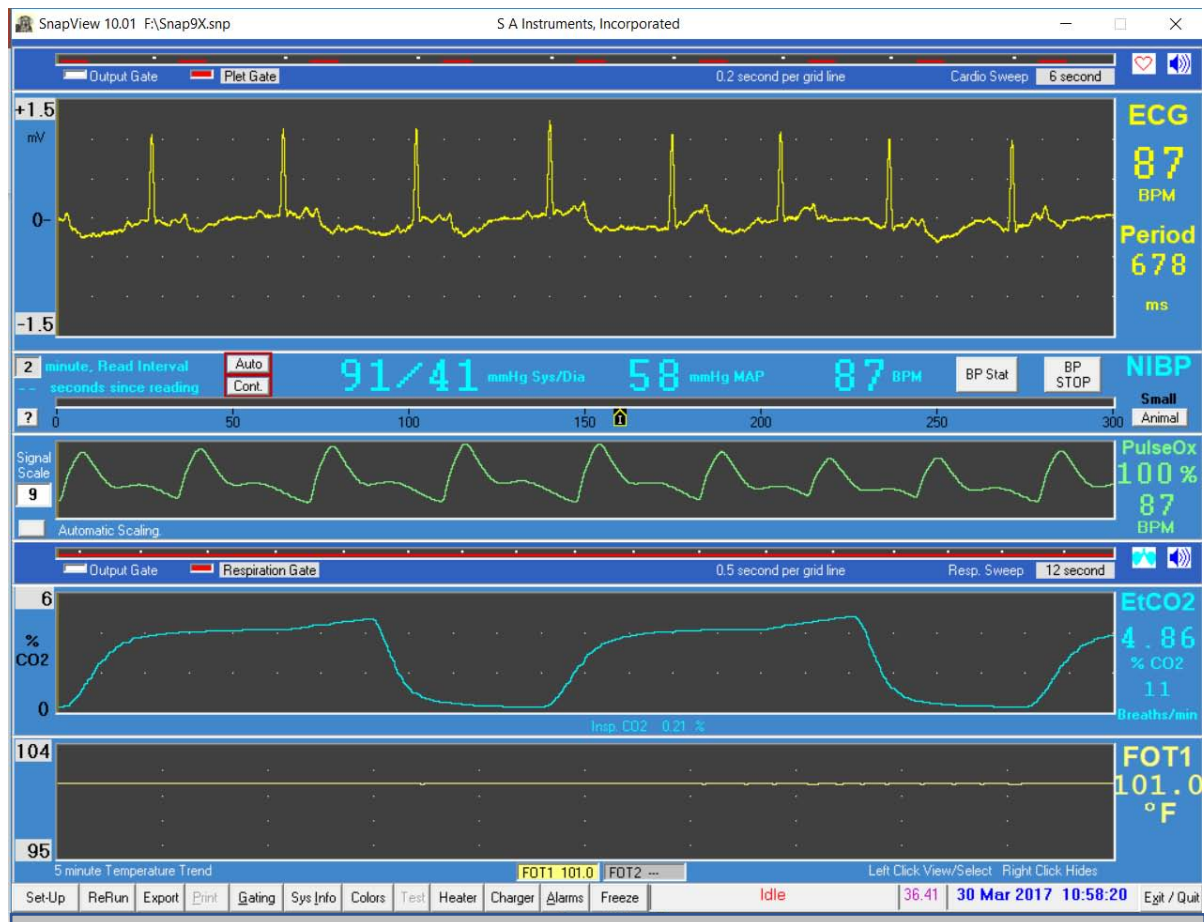
Chapter 12 SnapView

Overview

SnapShot data files record all measured data for a short time interval. The SnapShot key is located in the lower left portion of PC-VET's main display. Clicking the key causes storage of the last 36 seconds of all measured data.

SnapShot data files are viewed with SnapView. SnapView is embedded in PC-VET. When PC-VET is launched there is an option to execute SnapView. Most features available in PC-VET are also available in SnapView. For example sweep rates and amplitudes can be adjusted while viewing the files and the keys are active to display windows with associated parameter values.

SnapView display

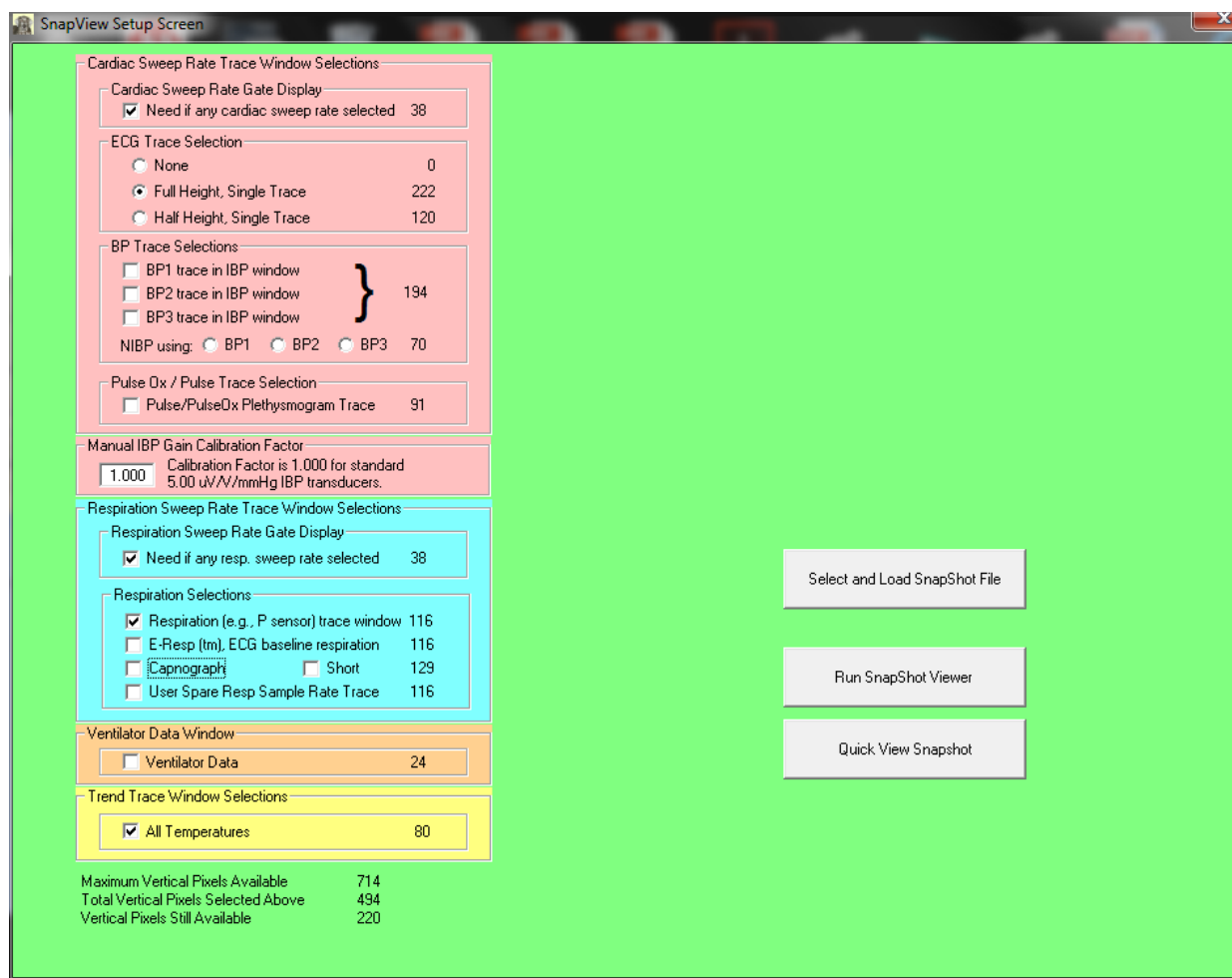


SnapView

The SnapView main display is very similar to the monitor display of PC-VET. Most keys perform the same function as in PC-VET. The only differences are the Setup, ReRun and Export keys.

SETUP window

The SETUP window is displayed when SnapView is executed or when the Set-Up key is clicked. First select and open a SnapView data file, then make any desired changes to the display configuration before displaying SnapView data.



Two keys for data display are available: Run SnapShot Viewer and Quick View SnapShot. The Run key plays back the entire 36 second data set before freezing the display waveforms with the most recent data. The Quick View key plays back 1 second of data before freezing the display waveforms with the most recent data.

ReRun key

Click the ReRun key on the SnapView display to play back the 36 second data set.

Export key

The Export key allow SnapView's raw data to be exported. This feature can be useful in the event wave shapes or features need to be analyzed offline.

Keying the EXPORT key opens an export setup window with preset parameters. The user can modify the parameters and make measurement selections before exporting the data to a .txt file. Up to 32766 lines of 19 items comma delimited can be exported to a .txt file. Each text line starts with a time sample number (0-32766) followed by a raw data count for the measurements selected.

If SnapView is at the end of displaying the data set and EXPORT is keyed, then the export routine is setup to dump the entire data set. The resulting file when opened and saved by Excel will be about 4.6 Mbytes.

If SnapView is running (or FROZEN) and EXPORT is keyed the export parameters are setup to output data from the beginning of the data set up to the current (or frozen) time point. Note the time counter SS:HH (seconds: hundredths of seconds) displays the time of the data set from 0 to 36.4 seconds.

SnapView

Chapter 13

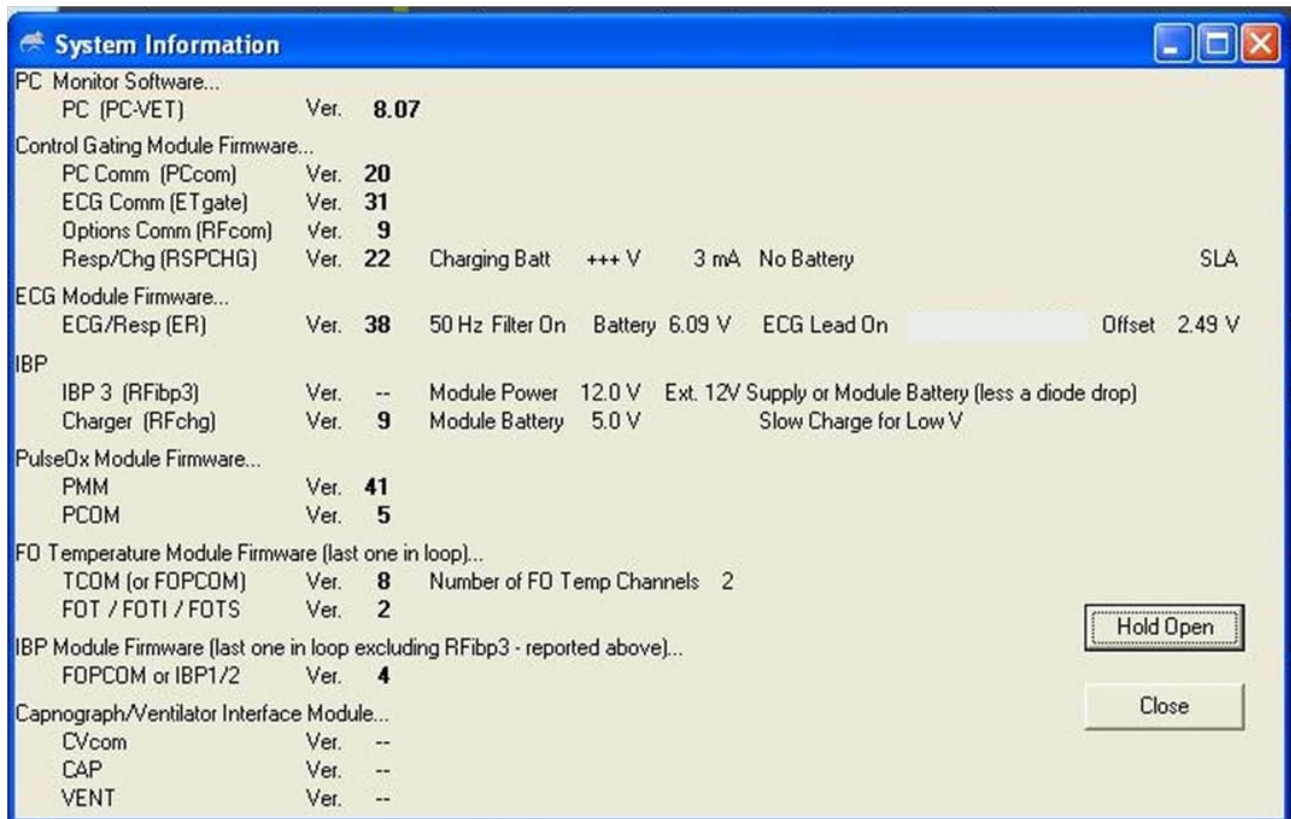
Additional Features

Chapter 13

Additional Features

SYSTEM INFORMATION window

The SYSTEM INFORMATION window lists software revisions, current status for the ER Module and other useful information. The window will automatically close after several seconds. Click the “Hold Open” button to keep the window visible.



ER Module status includes the 50Hz/60Hz notch filter setting, battery voltage, ECG lead status and offset voltage.

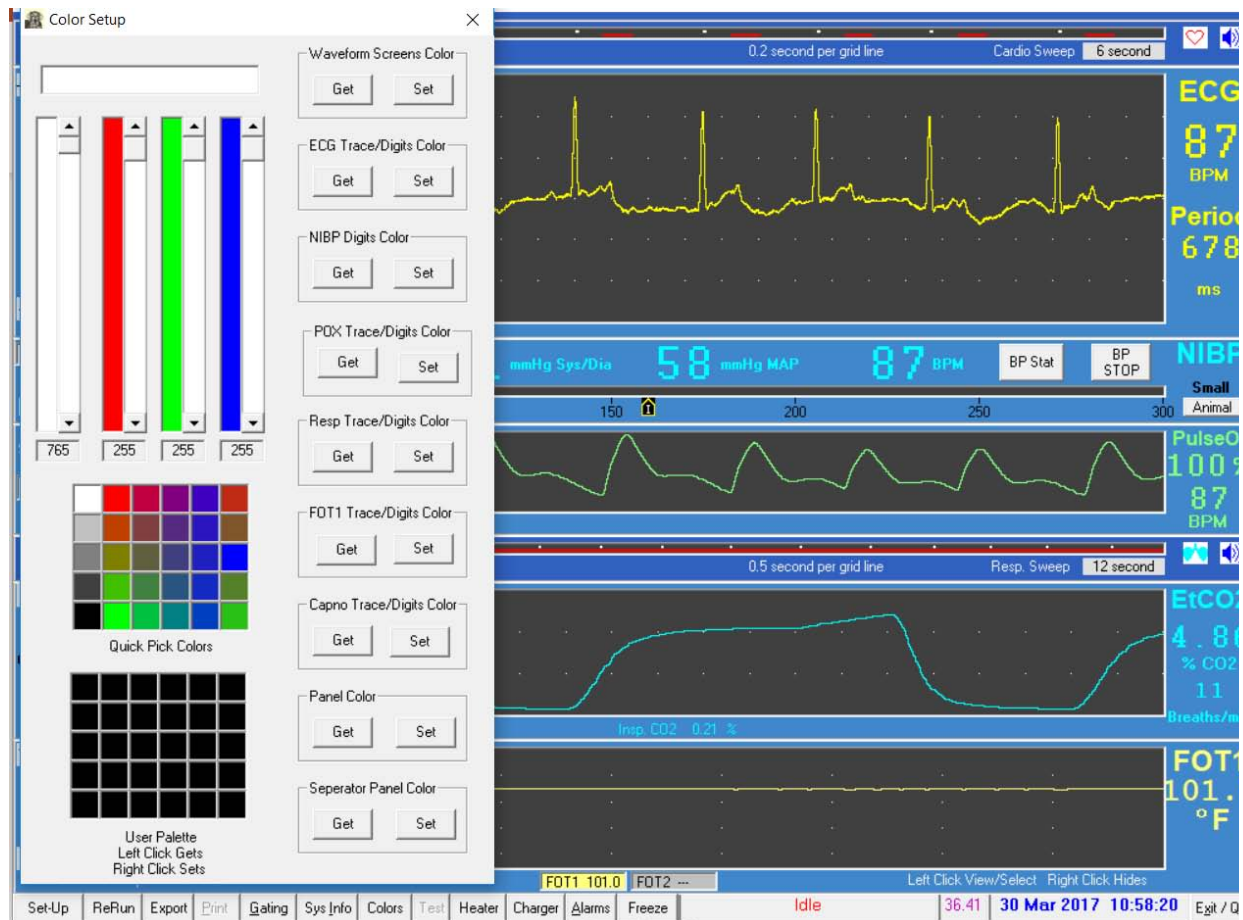
The ET Module operates on 5 VDC. But to display both positive and negative signals the zero point is offset to 2.5V. Any additional offset appears in this measurement and can affect the ECG. If the offset gets too close to zero or 5V, the software flat lines the ECG waveform and issues a lead off warning. The offset can deviate from 2.5V if needle electrodes are inserted in animal's muscle.

The IBP Module status includes the modules power source (12V or internal battery) and status of the internal battery charger.

Additional Features

SET COLORS window

The SET COLORS window allows selection of colors for regions of the display and for waveforms and digits.



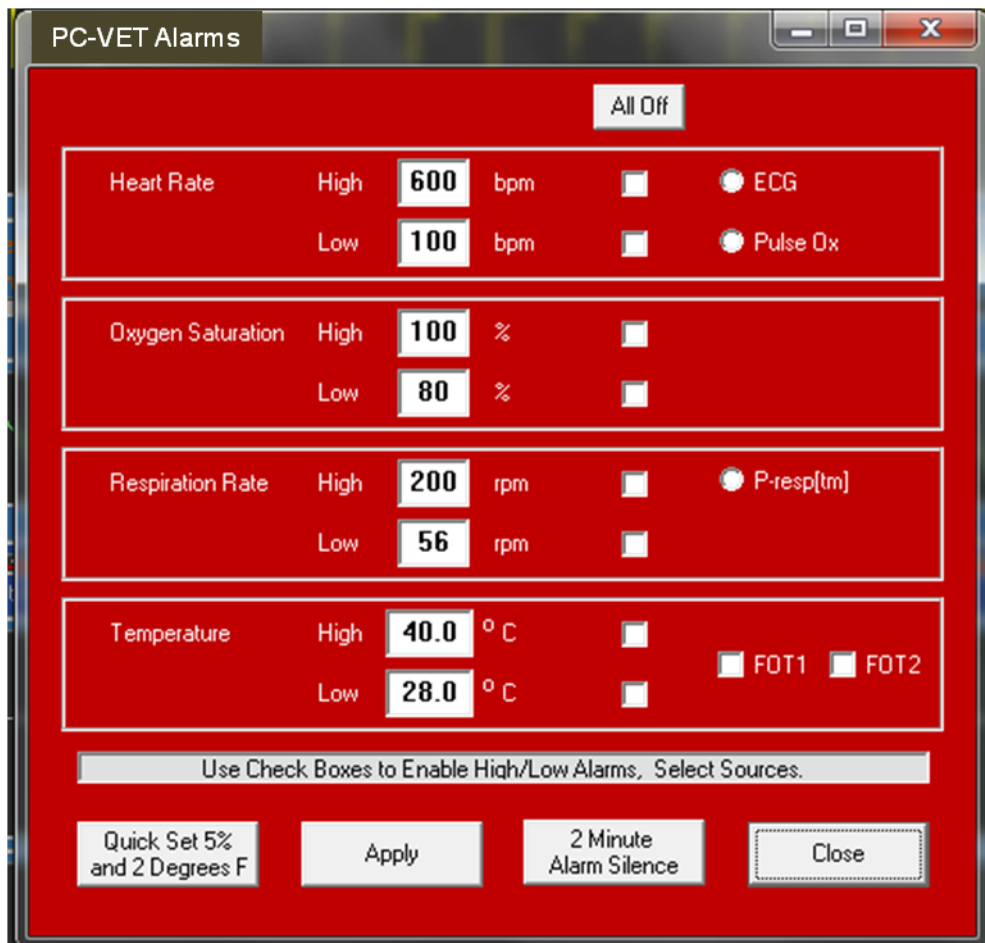
The set button sets the current color for the region or waveform selected. Colors can be selected from Quick Pick or made from combinations of red, green and blue in the upper left of the window. Once colors have been constructed, they can be stored in the User Palette. Right click sets and left click gets.

Additional Features

ALARMS window

The ALARMS window allows high and low alarm limits to be set for heart rate, oxygen saturation, respiration rate and/or temperature. A check mark next to an alarm limit followed by clicking the Apply key will activate the alarm. When the measured value meets or exceeds the limit, an audible alarm sounds.

The window has an area for messages and keys for Quick Set Alarms and Alarm Silence. The Quick Set key provides a convenient way to quickly set all alarm limits. Clicking the Quick Set key sets the high and low alarm limits 5% above and below the current measurement for heart rate, oxygen saturation and respiration rate and 2 °F above and below the current temperature measurement.

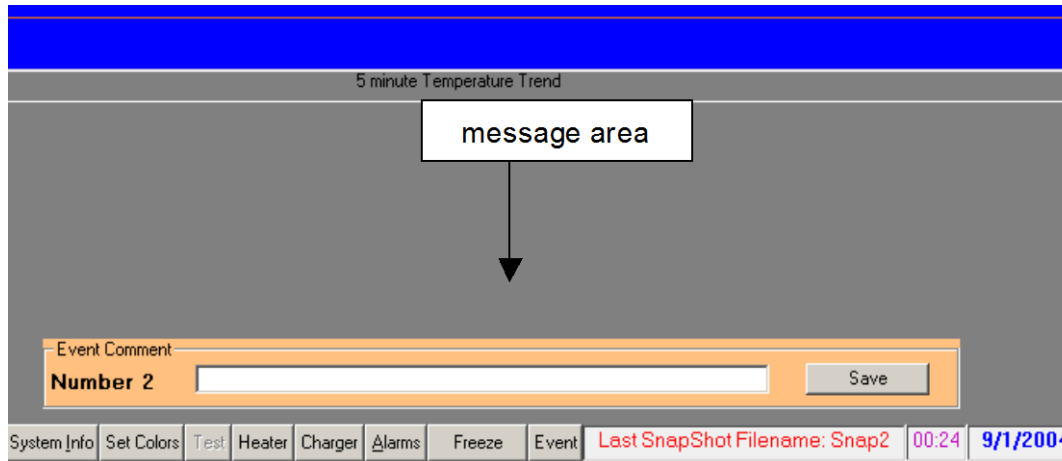


Additional Features

FREEZE THAW key

The key freezes the waveform display. Pressing the key a second time restarts the waveform display.

EVENT key



Pressing (left clicking) the event key causes an event to be logged in the trend file at the time the event key is pressed.

Each event is given a number in sequence beginning with one for each monitoring session. Upon pressing the Event key, a window opens and a comment can be entered and saved. The event number, time and comment are logged in the trend data and can be viewed with TrendMap.

Chapter 14
Single Pump Fluid Heater System

Chapter 14

Single Pump Fluid Heater System

Overview

The MR-compatible Single Pump Fluid Heater System is used to control the temperature of companion animals undergoing imaging procedures. It is an option for the Model 1035 Monitoring and Gating System. The System has been designed to control the temperature of the fluid flowing to the heating pad or the heating pad temperature or the body temperature of animals.

The Single Pump Fluid Heater System, shown below, consists of a Circulation Module, a Heater Module and a Reservoir located in the magnet room on the base of the instrument roll stand. The Heater and Circulation Modules are RF shielded. The heater



Module is non-magnetic. The Circulation Module contains a small amount of ferromagnetic material and is fix mounted to the roll stand. The system is powered from 100, 115 or 230 VAC, 50 – 60 Hz.

Water is circulated through the closed loop system at constant flow (1.5 GPH) and low pressure (5 psi). The Heater Module's internal microprocessor controls the temperature of the water being circulated through a heating blanket covering the animal in the magnet bore. Control is based on a user defined set point for the water output temperature, the blanket temperature or the animal temperature.

Single Pump Fluid Heater System

Operation

PC-VET software provides user control of the heating system. The PC connects to the Heater Module through a FORT Module and also to the Model 1035 Control/Gating Module using two separate USB ports.

Clicking on the Heater button at the bottom of PC-VET's main display opens the WBH USER INTERFACE window.

WBH USER INTERFACE window



The message area at the bottom of the window gives system status and error messages. On the left of the window the user can select the method of control, the temperature probe in use for measuring the animal or heating pad and the temperature set point. Click in the box to change between available probes. Note the control selection is grayed out or made inactive if the probe selected does not have a valid temperature reading. Measured values for fluid output and temperature probes are displayed.

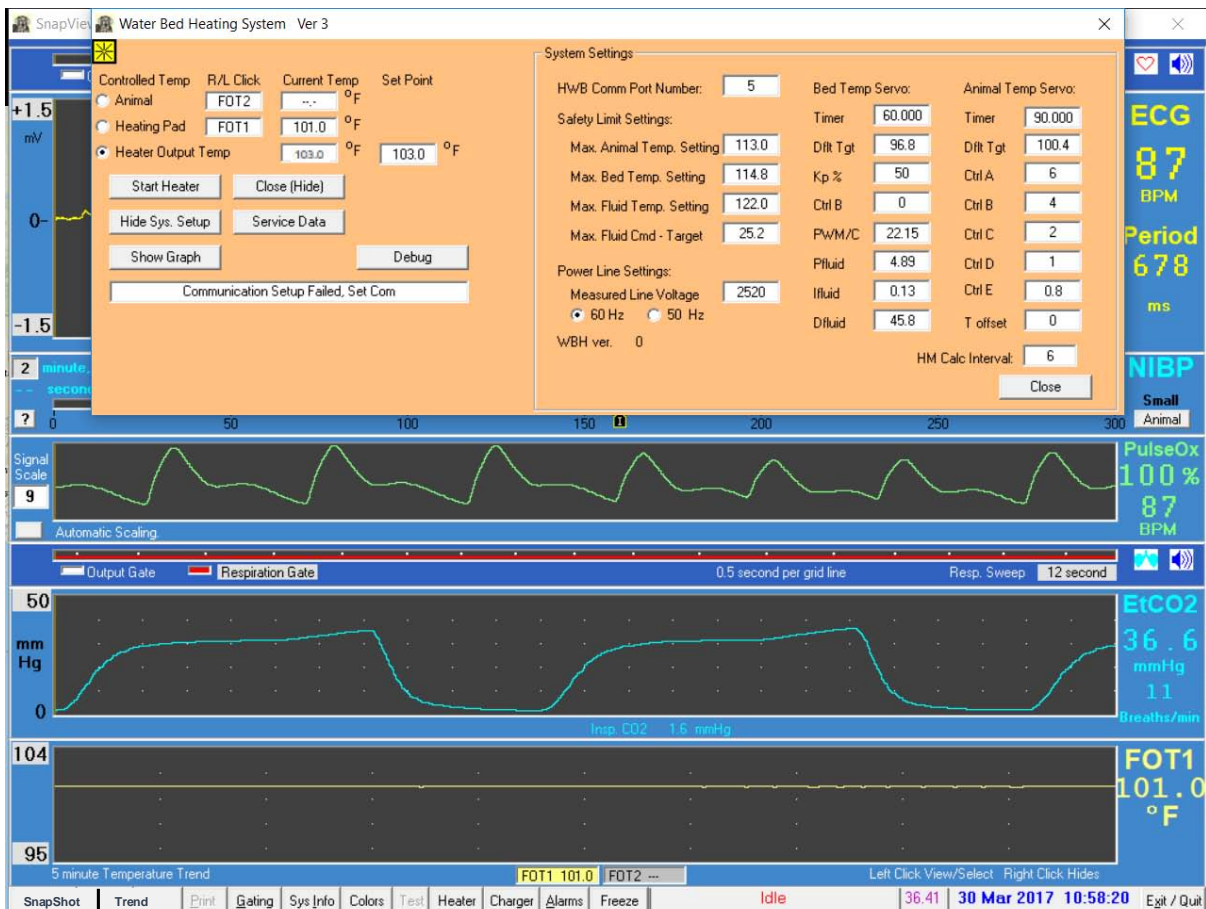
Single Pump Fluid Heater System

The window contains the following buttons:

- Start or stop the heater
- Display or hide Systems Settings window
- Show or hide graph which displays temperature trends
- Service data window

SYSTEM SETTINGS window

This window contains the communication port assignment, safety limit settings, power frequency setting, timer in seconds and controls for the heater output temperature and bed and animal control systems. These controls are discussed in a later section of this chapter.



SERVICE DATA window

The Service Data window allows many parameters to be viewed and entered which are not useful to the user. However, the window does allow the user to see the parameter that the control software is setting "PWM count" which determines the current delivered to the heating element.

Single Pump Fluid Heater System

PWM count is between 0 and 1024. PWM of 0 turns the heater off. PWM of 1024 delivers maximum current to the heating element.

GRAPH window

The graph window accumulates over time up to 8 WBH parameters including PWM, several temperatures and set points. The display is a useful tool to diagnose problems with the system.

Circulation Module input output connections

Electrical connections:

Power	12 VDC power connection
-------	-------------------------

Fluid connections:

FROM RESERVOIR	cool fluid to Circulation Module
TO HEATER	cool fluid to Heater Module
FROM HEATER	warm fluid from Heater Module
TO RESERVOIR	cool fluid from Circulation Module

Heater Module input output connections

Cold fluid end:

FROM CIRCULATOR	cool fluid input
TO CIRCULATOR	warm output from the heating blanket
FROM FORT	optical input from FORT Module
TO FORT	optical output to FORT Module

Warm fluid end:

AC power	input power for 100 – 120 VAC or 230 VAC
WARM	output for fluid to the heating blanket
RETURN	input for fluid from the heating blanket

Heating blanket

The heating blanket is a 12" x 24" thin flexible polycarbonate sheet with tubing attached. Two tubes 10' long extend from the blanket and connect to the Heater Module without the need for fittings or connectors. This construction minimizes the risk of getting water in the bore of the magnet. A sheet is normally positioned between the animal and the heating blanket.

System setup

Position the shelf (321966) on the base of the roll stand and secure it with cable ties. Position the Single Pump Circulation Module (880200), the Heater Module (76x200) and

Single Pump Fluid Heater System

the Reservoir (321322) on the shelf as shown in the photo on page 14-1. Fittings for the tubes are at the back of the stand while the power switches are at the front of the stand. Fix mount the Circulation Module to the shelf by attaching the shelf ring lug to a screw on the bottom and front of the Circulation Module.

Connect the 3/8 OD tubing (SPFHSTS-10) as shown in the photo on page 14-1. Connect the heating blanket (FHS-BLANKET) to the Heater Module at fittings labeled WARM and RETURN. Connect the Circulation Module to the 12 VDC power supply (SPCMPS-12)

Prime the Circulator pump following instructions on page D-2 of Appendix D.

Connect the duplex fiber optic cable to the Heater Module. Connect the other end of the duplex cable to the FORT Module (420900) located near the PC and Control/Gating Module. Connect a USB to serial adapter cable (USB-21) to a USB port on the PC and to the FORT.

If the PC was delivered with the Model 1035 system you are all set to go. If it was not or if you need to use a new PC follow the SAI procedure PRD/0051 – PC-SETUP FOR THE MODEL 1035.

Control on Heater Module output fluid temperature

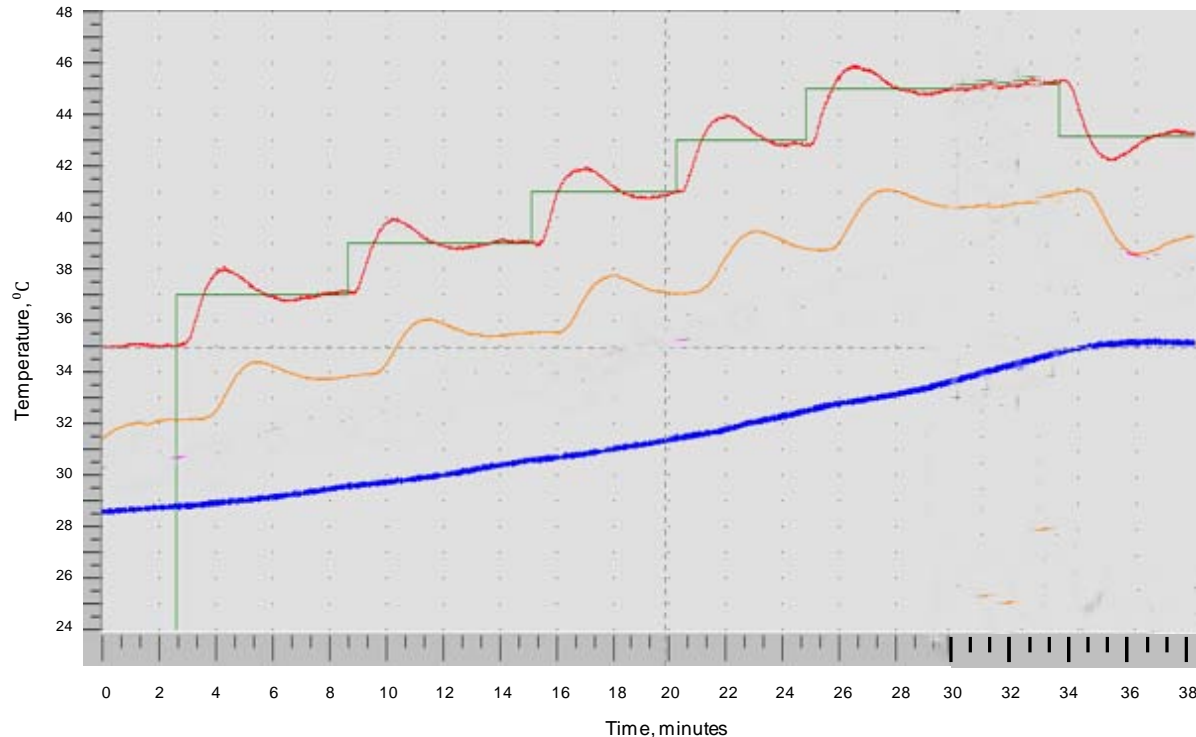
The simplest and a very effective way to regulate animal temperature is to control on the output fluid temperature. Power on the Heater and Circulation Modules. If the com port for the heater system has not been previously set, open the SYSTEM SETTINGS window and set the com. Select the option to control on output fluid temperature in the HWB USER INTERFACE window and enter a value for the set point. Click START HEATER. You should see the output temperature rapidly rise to the set point as in the graph on the next page.

In the graph on the next page, the output temperature is red, the blanket temperature is yellow and the reservoir temperature is blue. The set point was changed in 2 °C increments from 35 °C to 45 °C and then decreased to 43 °C. For each new setting the output temperature reaches the set point in just under a minute. Then there is an overshoot of about 1 °C for almost 2 minutes. Finally there is a very small decaying oscillation about the set point temperature.

Note that the blanket temperature is lower than the Heater Module output temperature by about 3 °C. But the difference will depend on the heat loss of each setup. The blanket temperature lags the Heater Module output temperature by about 40 seconds due to the flow rate and the length of tubing. The fiber optic temperature probe was positioned on the blanket at the middle of the tubing. That is the measurement was made at a position half of the total tubing length.

The PID control algorithm uses 4 parameters from the SYSTEM SETTINGS window PWM/c, Pfluid, Ifluid and Dfluid. Changing the flow or altering tubing length could make it necessary to calculate new parameters.

Single Pump Fluid Heater System



Controlling on heating pad temperature

This feature is under development. It uses the timer and three parameters in the SYSTEM SETTINGS window under Bed Timer Servo. We recommend controlling on the output temperature until development of this feature is completed.

Controlling on animal temperature

This feature is under development. It uses the timer and all parameters in the SYSTEM SETTINGS window under Animal Timer Servo. We recommend controlling on the output temperature until development of this feature is completed.

Turning off the Fluid Heater System

Let the Circulation Module run for a few minutes after turning off power to the Heater Module, to allow hot water in the system to cool.

Chapter 15
Fiber Optic Universal Gating Module

Chapter 15

Fiber Optic Universal Gating Module

Overview

The Fiber Optic Universal Gating Module can be used to supply a gate pulse to imaging systems. It is always used to supply the gate pulse for clinical imaging systems. The module gets an input from the fiber optic AUX GATE OUTPUT of the Model 1035 Control/Gating Module. The fiber optic pulse is converted to both low level (2 mV) and high level (TTL) output pulses. The imager's ECG cable can be connected to ECG studs on the gating module to feed the low level gate to the imaging system. Alternatively, the high level gate can be obtained from the Module's BNC connection.

The module is non-magnetic and RF shielded, so when it is being used with a MR system it can be located in the magnet room. Power is supplied from an internal 9 V battery. The module has both power on and low battery indicator lights.

Controls and connections



Fiber Optic Universal Gating Module

Input	fiber optic gate light pulse
Output	2 mV pulse on RA, LA, RL, LL studs TTL pulse on BNC connector
Power switch	activates the 9 V internal battery, the power on and low battery LEDs

Setup and use

When used with a clinical MR system, the Fiber Optic Universal Gating Module is positioned near the patient gantry. A simplex fiber optic cable is connected between the Model 1035 Control/Gating Module's fiber optic AUX GATE output and the Universal Gating Module's fiber optic gate input. The Model 1035 Control/Gating Module is located outside and the Universal Gating Module is located inside the RF shielded room. So the simplex cable should pass through a wave guide installed in the room.

The optical gate signal is converted to an electrical signal by the Universal Gating Module. The electrical signal can be input to the clinical MR either by supplying the TTL signal to a gate input port (if available) or by supplying the 2 mV pulse to the scanner's clinical ECG cable. In either case, it may be advantageous to change the gate width or invert the gate pulse using controls in PC-VET's GATING window.

Clinical scanners typically use both analog and digital filters to remove gradient interference from their ECG input. These filters necessarily add delay to the time the gate is received by the scanner. This delay can be quite large, a few 10s of msec. So, if a TTL gate input is available, it is preferred over input from the clinical ECG cable.

Caution: the 9 V battery should only be replaced with a battery obtained from SAll. Many 9 V batteries are magnetic and may be attracted by the MR magnet.

Appendix A Specifications

Model 1035 Multi-parameter Module

NIBP	Analysis method	oscillometric
	Blood pressure range	systolic 40 – 265 mmHg MAP 27 – 222 mmHg Diastolic 20 – 200 mmHg
Heart rate	Cuff number & size	7 for 3 to 33 cm circumference
	Pulse rate range	25 – 300 bpm
	Modes of operation	large and small animal
	Inflation pressure	120 – 280 mmHg large animal
	Inflation pressure	60 – 280 mmHg small animal
	Algorithm accuracy	ANSI/AAMI SP10:1992 & 2002
Temp	Probe type``	fiber optic rectal
	Tip OD, mm	3.0
	Range	20 – 60 °C
	Accuracy	±0.2 °C
SpO₂	Probe type	fiber optic clips, reflectance & Universal Y wrap
	Probe length	9'
	O ₂ saturation range	0 – 100%
	Resolution	1 count
Heart rate	Range	40 – 450 bpm
	Accuracy	±1%
Module	Power -	12 VDC, 1 A
	Size: hxwxcm	10.3x15.6x16.1

Module 1035 Control/Gating:

Gating	R-wave to gate delay	selectable - 0 to 600 ms
	Expiration gate width and delay	selectable - 1 ms step size
Module	Auxiliary inputs	2 TTL
	Power	12 VDC, 70 mA
	Size: hxwxcm	3.8x13.3x12.5

Specifications

Model 1035 Capnograph Module

CO₂	Analysis method	single beam IR
	Measurement range end-tidal	0 – 13%
	Measurement range mmHg	0 – 99.
Resp	Accuracy mmHg	±2 mmHg, 0 – 38 mmHg 5% of reading, 39 – 76 mmHg 8% of reading, 77 – 99 mmHg
	Sample flow	100 ml/min
	Rate	2 – 150 bpm
	Pneumatic tube length	9' or longer
	Module	Power -
	Size: hxwxcm	8.4x15.6x16.1

Model 1035 ER Module:

ECG	Range:	40 - 450 BPM
	Accuracy:	±1%
	Input range:	-2.50 mV to 2.5mV
	Input Impedance:	>10 MΩ @ 10 Hz
Resp	CMRR:	100 dB @ 60 Hz
	Range	15 - 150 bpm
	Accuracy	1 count
Module	Sensor	pneumatic pillow
	Power – rechargeable battery	6 VDC, 15 mA
	Battery life:	>15 hours
	Time to full charge	<2 hours
	ER module size: hxwxcm	2.1x5.1x15.0
	Battery Pack size: hxwxcm	1.8x5.6x7.4

Single Pump Fluid Heater System:

System	Heater control	fluid, heating pad and animal temperature
	Control temp	92 – 115 °F ±0.5 °F
Heater	Heating pads	blanket
	power	100/115/ 230 VAC
	Size: hxwxcm	16.4x8.9x26.0
Circulation	power	12 VDC, 2.0 A
	Size: hxwxcm	10.8x22.9x20.3

Specifications

		IBP:	
IBP	Display range		0 – 300 mmHg
	Channels		1 or 2
Heart rate	Range		40 – 450 bpm
	Accuracy		±1%
Module	Auxiliary inputs		2 analog 0 - 5 V
	Power		12 VDC, 50 mA & battery
	Battery life:		>6 hours
	Time to full charge		<3 hours
	Size: hxwxcm		4.2x15.8x15.0

Fiber Optic Temperature Module:

Temp	Probe type		fiber optic, rectal
	Tip OD, mm		3.0
	Range		20 – 60 °C
	Accuracy		+/-0.2 °C
Module	Power		12 VDC, 280 mA
	Number of channels		1
	Size: hxwxcm		3.8x13.3x12.5

PC requirements:

Software:	Windows		any version 95 to 10
Hardware:			>1 GHz processor
			USB port
			Display resolution 1024 x 768 pixels or greater

Specifications

Appendix B

System Components and Accessories

Part No.	Description
211004	Op Manual, 1035 Monitoring & Gating System for Veterinary use
M1035PCS-rev	PC-VET Software CD
M1035SFD-rev	PC-VET Software USB flash drive
635600	Model 1035 Multi-parameter Module (NIBP, SpO2, FOT)
CUFF-3-6	Blood Pressure Cuff 3 – 6 cm circumference
CUFF-4-8	Blood Pressure Cuff 4 – 8 cm circumference
CUFF-6-11	Blood Pressure Cuff 6– 11 cm circumference
CUFF-7-13	Blood Pressure Cuff 7 – 13 cm circumference
CUFF-8-15	Blood Pressure Cuff 8 – 15 cm circumference
CUFF-12-19	Blood Pressure Cuff 12 – 19 cm circumference
CUFF-17-25	Blood Pressure Cuff 17 – 25 cm circumference
NIBP-BLKH-108	NIBP Hose with male quick connect to female slip Luer 9' (2.7 m)
530110	Fiber Optic Pulse Ox Sensor, 9' long.
PO-LCLIP	Pulse Ox large clip
PO-SCLIP	Pulse Ox small clip
PO-REF	Pulse Ox reflectance probe
PO-UNIVY	Pulse Ox universal Y form
PO-MFTAPE	Pulse Ox pre-punched microfoam tape
FOTS-2-3	Fiber Optic Temperature Sensor, 2' long, 3 mm tip OD
FOTE-10	Fiber Optic Temperature Extension Cable, 10' long
TPC-200	Temperature probe covers
PS-4VET-12	Multi-parameter Module Power Supply
PSLC-2-E	Line Cord 230 VAC Europe
PSLC-2	Line Cord 115 VAC
25DFOC-23	Duplex Fiber Optic Cable, 25 m
635300	Model 1035 Capnograph Module
CMW-TRAP	Water Trap
NSLT-CO2-84	Nasal CO2 Sample Line Tube with Male Luer Connector 7ft
SLET-48	Sample Line Extension Tubing 4ft (1.2 meter)
SLET-96	Sample Line Extension Tubing 8ft (2.4 meter)
SA-ADAPTER	Straight Airway Adapter
CAL-CO2-5%	Calibration Gas - Carbon Dioxide 5%
C-VALVE	Control Valve
CV-TUB-20	Control Valve Tubing Assembly
DCPC-2	Daisy Chain Power Cable for two modules
1FTSFOC-23	Simplex Fiber Optic Cable, 1' long
635700	Model 1035 ER Module
RMEC-703-810	3 Lead Needle Electrode Set for veterinary use

System Components and Accessories

Part No.	Description
EGW-707-8	3 Lead Grabber ECG Lead Set for veterinary use
ECGSE-30	MR-compatible ECG Stick on Electrodes (box of 30 electrodes)
RS-301	Respiration Pillow Sensor 24"
RSET-303-9	Respiration Extension Tubing, 9" long
RSET-3	Respiration Extension Tubing, 36" long
ERBP3-103-PCC	ER Module Battery Pack
BPC-310-9	ER Battery Pack Cable
25SFOC-23	Simplex Fiber Optic Cable, 25 m
635100	Model 1035 Control/Gating Module
CGIC-201	Control/Gating Module Serial Interface Cable
USB-20	Prolific USB to Serial Adapter Cable
PS-2-12	Power Supply, 12V
UGM-100	Universal Gating Module
15SFOC-23	Simplex Fiber Optic Cable, 15 m
731100-1	IBP Module 1 channel
731100-2	IBP Module 2 channel
IBPX-A	IBP Transducer Abbott Transpac IV
810100	Fiber Optic Temperature Module 1 channel
M9003	Single Pump Fluid Heater System (SPFHS)
763200	SPFHS Fluid Heater Module 115 VAC
762200	SPFHS Fluid Heater Module 230 VAC
880200	Single Pump Circulation Module (SPCM)
420900	FORT Module for use with SPFHS
SPFHSTS-10	SPFHS tube set with fittings and clamps
FHS-BLANKET	flexible heating blanket 12"x24" with 10' long heater tubing
SPCMPS-12	SPCM power supply, 12 VDC

Appendix C Troubleshooting

Problem	Possible Cause	Corrective Action	See
No waveform on display. Trace frozen & communication error.	Wrong com port selected.	Select the correct com port in PC-VET setup menu.	2-2 3-5
No waveform on display. Trace frozen & no communication error.	No power to the Model 1035 Control/Gating Module or communication problem.	Check the power and serial connections	2-1 2-2
Sweeping waveform but no ECG signal.	No communication to the ER Module.	Check power to the ER Module & fiber optic cable connections. Look for red light in the ER Module fiber optic driver.	2-1
Sweeping waveform but no ECG signal.	Lead off.	Check lead attachment.	4-1
Sweeping waveform but no ECG signal.	Offset voltage too large.	Check offset voltage in system info window. check for needles in muscle.	13-1 4-2
ECG waveform but no heart rate display.	R-detect parameters incorrect.	Set correct values.	3-7
Excessive artifacts on ECG without scanning'	Movement of leads in magnet bore.	Check for vibration or air flow. Tape leads and/or ER module.	4-1
Excessive artifacts on ECG while scanning'	Movement of leads or module in magnet bore.	Check for vibration. Tape leads & ER module to restrain motion.	4-1

Troubleshooting

Problem	Possible Cause	Corrective Action	See
No gate detected by MR scanner.	Improper gating setup selection.	Check for the presence of trigger output to the scanner (white dots in Cardio Sweep display). If trigger is not present check selections in Gating Setup menu.	3-2 3-8
No gate detected by MR scanner.	Improper switch setting on Model 1035 Control/Gating Module.	Check for the presence of trigger output to the scanner (white dots in Cardio Sweep display). If trigger indication is present check gate output pulse signal characteristic switch setting is appropriate for the MR scanner.	3-4 3-6
SPFHS Heater System has no flow	Power is not on.	Check power to the Heater and Circulation Modules. Green LEDs indicates power is on.	14-4
SPFHS Heater System has no flow	Reservoir is low on water	Add water to the Reservoir	14-4
SPFHS Heater water temperature (Tout) is not being updated.	Fiber optic connection problem.	Check fiber optic cables for a red light in the blue fo cable at the FORT Module or gray fo driver at the Heater Module.	14-4
SPFHS Heater blanket is not hot.	Control signal not present	Power indication OK, but Heat LED not flashing on the WBH Heater Module. Check the set point for water temperature.	14-2

ER communication error

This error means the Model 1035 Control/Gating Module is not receiving valid data from the ER Module. It can occur for one of the following reasons:

1. battery is discharged
2. faulty connection of the Battery Pack Cable at the Battery Pack or at the Module
3. fiber optic signal is not getting to the Model 1035 Control/Gating Module

The **Battery Pack voltage** can be checked with a digital volt meter. A fully charged battery will be > 6.5V it will stop operating the module when it is less than 5.8 V. We issue the low voltage error message when the battery's voltage reached 6.0 V.

If the battery is OK, **test the ER Module's Battery Pack and cable** by holding the ER Module and Battery Pack with one hand so that the Battery Pack connections are visible. Connect the Battery Pack Cable with the other hand and observe a red light in the module's fiber optic port. Gently move the cable at each connection. Any interruption of light from the fiber optic port would indicate a potential short in the cable or connections.

Check the fiber optic signal by observing the red light at the fiber optic driver on the ER Module. Connect the fiber optic cable to the module and observe red light on the other end of the fiber. Connect the fiber to the Model 1035 Control/Gating Module at the port labeled ECG. If the communication error persists, check for lint or blockage inside the ECG port on the Model 1035 Control/Gating Module and or try another fiber optic cable.

Check communication between the PC and Model 1035 Control/Gating Module

With the system running and with red bars for "R-detect + blanking time" open the R-detect setup window (right click on the ECG waveform display) and change the wave feature detection from "positive peak" to "negative peak". Within 2 seconds the red bars should disappear. Switch back to "positive peak" and in 2 seconds or less the red bars should again be displayed.

Determine if other features of the system are working? When pressing on the pillow, do you get red bars indicating inspiration (when the signal dips)? If you click the invert pulse box for respiration in the GATING SETUP window does the red bar switch to the expiration portion of the waveform (flat portion between the dips)? Since the ECG and respiration detection is performed by the Model 1035 Control/Gating Module, a response 1 to 2 seconds to changes in parameters from the PC is a test that communication is working.

Troubleshooting

Gating Setup when large artifacts are present in the ECG waveform

The most common artifact in the ECG waveform is generated by vibrations of the ECG leads due to activation of the pulsed gradients during MR system data acquisition. When the MR scanner acquires imaging data, pulsed gradients are activated which generates acoustic noise, movement of the gradient insert and corresponding movement of the ECG leads. Vibration or movement of the ECG leads in the presence of the strong static magnetic field creates artifacts on the ECG waveform.

Many factors contribute to the size and extent of vibration artifacts on the ECG waveform. High field strength, long lead length, leads that are not taped and close coupling of the animal to the gradient insert all make vibration artifacts more extensive. However, in many cases it is not necessary to minimize the effects of vibration. It is usually possible to create accurate and reliable triggers even with the presence of large artifacts on the ECG waveform.

Follow these steps to generate accurate gating when large artifacts are present:

1. When the scanner is not acquiring data, check that each R-wave is detected and that no false gates are generated. i.e make certain a red dot (ECG gate) is present for each R-wave and that there are no extra red dots in the Cardio Sweep display. If this is not the case, adjust the R-detect parameters according to Chapter 3 of the Operation Manual.
2. Set the blanking time to 90% of the R-R interval. Note the R-R interval is displayed below the heart rate. Right clicking the ECG display will open the R-DETECT SETUP window.
3. Run a gated scan with the total slice acquisition time at least 20 msec less than the animal's R-R interval. It maybe useful to initially run a single slice scan to observe the effect of gradient vibrations on the ECG waveform. As you increase the number of slices, you will observe an increase in the width of the artifact following the trigger generated by the R-wave. Note that 5 to 10 msec are required for the vibrations to damp after the pulsed gradients are turned off. If the total slice acquisition time is too long, a false trigger will be generated at the end of the blanking time.

As an example, consider the case of a cine field echo sequence run on an animal with a heart rate of 600 beats per minute (R-R interval of 100msec). Setting the blanking time to 90 msec will accommodate an arrhythmia rate of up to 10%. If the single slice acquisition time is 10 msec, then 8 slices can be acquired each at a different phase in the cardiac cycle. Note that if 9 slices are attempted, false gates will occur, as the vibrations ring down after the end of the blanking time, and the images will not be accurately gated.

PC-VET data files as diagnostic tools

Both SnapShot and Trend data files are extremely useful in troubleshooting. SnapShot files give a 36 second recording of all measured data while Trend data files continuously record system measurements once per second.

Trend data files are collected automatically in the background while PC-VET is running. Each Trend file has an associated Events file. SnapShot data files are collected every time the SnapShot key is pressed. The SnapShot key is in the lower left of PC-VET's main display. When the SnapShot key is pressed, the previous 36 seconds of all measured data are stored on the disk drive.

The factory default location for these files is

- For older Windows versions: - c:/ProgramFiles/PC-VET/SAM-data/yymmdd
- For newer Windows versions – c:/users/saii/AppData/Local/VirtualStore/
ProgramFiles(x86)/PC-VET/VET Data/yymmdd

where the folder saii may be a different name based on who installed the PC-VET software and yymmdd is date encoded. If PC-VET is opened more than once in a day a letter is appended to the folder name. Trend files have a “.trd” extension. Event files have a “.evt” extension. SnapShot files have a “.snp” extension.

These data files are not large. They can easily be attached to e-mail. It can be very useful to send these data files with a description of a problem to service@i4sa.com.

Troubleshooting

Appendix D

Routine Maintenance

Clean the monitor's surfaces or probes with a soft cotton cloth moistened in a mild soap solution. If disinfection is required, wipe the surface with alcohol, sodium hypochloride or glutaraldehyde (Cidex, Metrucude, etc.). Follow the instructions provided by the manufacturer.

Charge the ER Battery Pack when the system is not in use. The battery pack can be left attached to the charger after it is fully charged. There is no requirement to deep discharge the battery before charging.

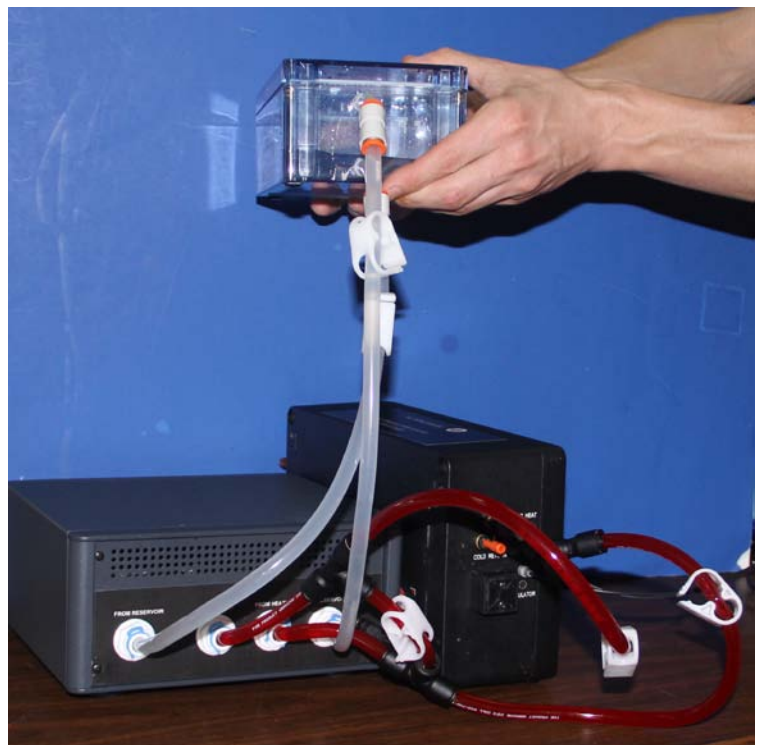
Charge the battery in the IBP Module when the system is not in use. The charger is internal to the module. The internal charger automatically charges the internal battery when the IBP Module is connected to 12 VDC power.

The water in the Single Pump Fluid Heater System should be changed every six months or if the water becomes contaminated. Add a teaspoon of chlorine to new water. Follow the procedure on the next page to prime the pump.

Routine Maintenance

Prime the Single Pump Circulator Module when the pump loses it's prime. This usually happens when the water is changed. In addition to filtered water and chlorine it is a good idea to have plenty of paper towels.

1. Fill the Reservoir and add a teaspoon of chlorine. Secure the Reservoir lid.
2. Open the clamps on the two clear tubes. Close the clamps on the red tubes connected to the Heater Module. Open the clamp on the red jumper tube.
3. Turn on the power to the Circulator Module.
4. Lift the Reservoir above the Circulator Module. The pump should prime in a minute or less and water should spray into the Reservoir.
5. Place the Reservoir on top of the Circulator Module.
6. Open the two clamps on the red tubes connected to the Heater Module. Make certain the clamps are open on the heating blanket tubing. Close the clamp on the red jumper tube. Water should slowly flow into the Reservoir.



Appendix E

Roll Stand Assembly

The roll stand provides a platform to fix mount the Multi-parameter and Capnograph Modules which have small amounts of ferromagnetic material.. It also provides a basket for storage of accessories.

Assemble the roll stand base, with 5 wheels, to the pole using the ¼-20 bolt with lock washer.

Next attach the basket with clamps on the pole. Loosely tighten the bolt in the basket clamp. Note that the pole has small holes drilled and tapped. The basket should be aligned so the holes are behind the basket.

Next attach the handle to the pole. Note the alignment of the handle with regard to the basket according to the photo on the next page.

Next attach the tray to the pole using the 3 flat head screws.

Finally fix mount the Mult-parameter Module and Capnograph Module to the tray using 4 each 4-40 flat head ¼” screws.

The 12 VDC power supply for the Modules can be cable tied to the roll stand base. The fiber optic cables and the 12 VDC power cable can be contained in the cable wrap and cable tied to the pole using the retaining mounting brackets and screws.

Roll Stand Assembly

