Boehringer Model 3930
Vacuum Assisted Venous Drainage
Frequently Asked Questions

This training information is meant to be a supplement and not be a replacement for the complete product instructions for use (Dwg#3930.003 P/N 34031). Please refer to the website www.boehringerlabs.com for the most current product instructions for use. The information contained within this document is ©2013 by Boehringer Laboratories, LLC and may not be used in whole or in part without the expressed written consent of Boehringer Laboratories, LLC.
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VAVD Basics

History / Overview
Traditional Cardiopulmonary Bypass was done with an open circuit. Blood was removed from the patient using a gravity siphon and withdrawn into the Venous Reservoir. To increase the rate of venous return more 'head height' would be employed, typically by raising the level of the patient in relation to the venous reservoir. Vacuum assist was first proposed to be able to augment venous return independent of this head height. To utilize Vacuum assist, the venous drainage reservoir needed to be sealed to consistently apply low levels of vacuum. Vacuum Assisted Venous Drainage and the sealed canisters required add unique risks to the circuit not found in open circuits.

Open circuits have inherent safeties built in. When there is an imbalance of fluid entering and leaving the reservoir, this does not result in a change in pressure in the circuit. Any excess air/liquid entering the circuit can be vented. If there is a net deficit in materials entering the circuit, room air can replace the volume. In a closed circuit a net increase in air/liquid would result in increased pressure, likewise any deficit would result in decreased pressure.

Vacuum assist likewise has unique benefits over gravity drainage. Circuit prime volumes can be lower since there is no need to fill the venous return line with any priming solution. Likewise gross air that is returned from the patient in the venous drainage line can be vented automatically. Vacuum circuits may be much easier to re-prime in an emergent situation than gravity assist.

What adds material to hardshell canister?
- Blood from the Venous return line
- Sucker Pumps - - adding both air and blood
- Additional IV fluid components.

What removes material from the hardshell canister?
- Arterial Pump
- Vacuum Assist Suction Regulator - - removing air from the system

What are the risks of Positive Pressure in the Venous Drainage Canister?
- Venous Drainage will be slowed
- Air and blood can reverse flow up the venous drainage line to the patient
- The venous drainage canister may empty since drainage has been stopped yet the arterial pump continues to run.
- Gross amounts of air may be moved down the arterial line if the canister empties thus depriming the circuit.
- Catastrophic failure of the venous drainage reservoir may occur due to accumulated pressure.

What are the risks of excessive negative pressure in the Venous Drainage Canister?
- Increase risk of Micro Gas Emboli MGE as suction increases above 60mmHg as dissolved gases are removed from solution in the blood, but are not given adequate time to resorb.
- Decrease in efficiency of centrifugal arterial pumps as they work against suction applied to their inputs. Their efficiency is typically computed with assuming atmospheric pressure at the pump inlet.
- Catastrophic failure of the venous drainage canister if it implodes under excess suction.
- Depriming of the circuit as air is drawn across the Membrane Oxygenator due to excessive suction pressures applied to the blood circuit.
- Accumulation of large gas emboli under full line suction conditions where most of the dissolved blood gases come out of solution.
Cardiotomy Reservoir vs. Venous Drainage Reservoir.?
In modern “hardshell” systems these two circuits are intertwined. Sucker blood from the field is directed into a separate portion of the hardshell reservoir which is correctly called the Cardiotomy Reservoir. This blood is filtered before it enters the venous reservoir side of the canister. Venous drainage blood directly enters the venous reservoir without filtering. Laypeople may refer to the entire hardshell reservoir as a cardiotomy reservoir, but vacuum is correctly attached to the Venous Drainage Reservoir.

Setup / Installation

How can you use a Y-connector with this device?
With the Boehringer VAVD Controller, the use of the Y-Connector is redundant and adds additional risks as opposed to increasing the safety of the circuit. The Control valve of the Boehringer VAVD Controller will BOTH discontinue the supply of suction at the same time it opens a large passive circuit vent. Both of the actions happen simply by turning the single piece machined control valve.

What are the inherent risks of a Y-Connector?
The diagram on the last page shows some of the most common connection options for Vacuum to the Venous Drainage Canister. A suction line is run from the Regulator (1) to a Y-Connector (4). A vent line (3) is attached to the y-connector. A separate line connects the Y-connector to the balance of the circuit. In common practice a hemostat is moved between positions (A) and (B).

Position A
Suction supply is turned off and the circuit is allowed to vent through open port (3).

Position B
Vent port (3) is closed and suction is applied to the system.

Position C (human error fault)
Suction is shut off to the circuit, and the vent port (3) no longer communicates with the circuit. The venous reservoir is now completely closed and cannot vent excess positive or negative pressure. All of the safety features typically found in the suction control (1) have also effectively been isolated from the system.
Neither A nor B nor C
Some practices remove the hemostat from the circuit with the assumption that all of the suction delivered from the regulator is effectively vented through vent port (3). Unless the suction control is intentionally flow limited the vent port (3) may not effectively release all of the vacuum.

The control valve design of the Boehringer 3930 makes the use of a Y-Connector redundant. In a single turn vacuum is applied to the circuit, and once it is turned to the ‘OFF” position the suction supply is interrupted as well as the system is allowed to passively vent.

How would you clean these units should they become fluid intruded?
Please arrange for return of the units to the factory for service by calling 800-642-4945. Typical turnaround time is five days. Given the intricate nature of the safety mechanisms on these devices, we would like to ensure the unit is fully cleaned and PM’d before it is returned.

Why do you recommend dedicated connection tubing?
Suction supply pressures need to be a minimum 508mmHg per NFPA99 code. All too often we have encountered perfusion carts that have been plumbed with disposable tubing to bring high vacuum from the wall. Under continued exposure to these high levels of vacuum, disposable tubing will slowly collapse. Once this tubing has collapsed the flow through the circuit is greatly decreased. Boehringer offers a VAVD connection kit http://www.boehringerlabs.com/img/zoom_9342.jpg that includes 12’ of reinforced suction tubing, as well as an appropriate quick connect fitting to ensure consistent supply. Please order -
P/N 3941 for Diamond Ohio quick connect
P/N 3942 for Chemetron quick connect
P/N 3943 for DISS quick connect

Where should the Vapor Trap be located, what is its purpose?
The Vapor trap should be located proximal to the Venous Drainage Canister in the circuit. Referring to Figure 1 the Vapor Trap is item (5). The blood in the circuit is typically at physiological temperatures while the operatory is typically less than 70°F. This causes condensation in the line. The vapor trap is meant to prevent condensation ‘rain out ‘ from going into the venous drainage reservoir. The vapor trap is not meant to provide vapor protection for the suction controller, since it will always be drawing humidified air through it. The vapor trap does not provide for overflow protection, so in the unlikely event the venous drainage reservoir overflows, the vapor trap will quickly fill before allowing this same fluid to travel to the suction controller.

What are some of the risks of a vapor trap?
On some Vapor traps, sometimes a silicone line is used to attach them to the venous reservoir. Referring to Figure 1, this connection tubing has been labeled (D). If proper support is not provided, it is possible to bend and kink this line. A kink in this line would essentially close the circuit without the application of vacuum or a vent line. The results could be an increase in positive or negative pressure in the venous drainage canister.

Can you mount the VAVD Controller on a horizontal rail?
Right now the VAVD Controller is designed to mount on a vertical downbar and may be placed immediately underneath any of your hung IV Solutions. If you are unsure of a suitable mounting location, please contact the factory.
Clinical Use

What suction levels are typically used for VAVD - -

Normally 20mmHg to 40mmHg. Levels above 60mmHg decrease the efficiency of the arterial pump and put the patient at greater risk of air embolism. Some facilities use pediatric suction equipment thinking it is range limited. An evaluation of a popular pediatric suction regulator (advertised as a 0-160mmHg range) revealed the average maximum suction delivered was 220mmHg. Only the 3930 has a clinical range which is appropriate for this application and the needed safety mechanisms.

Can VAVD and the 3930 be used with a closed Bag System?
The 3930 could provide vacuum for a closed system utilizing a bag. A system such as the V-Bag by Circulation Technologies (www.cirtec.com) allows for the use of a closed system with the application of vacuum assist. These ‘Bag in a Box’ circuits have unique features not found in traditional bag or hardshell systems.

How does the excess negative pressure relief work in the VAVD?
The redundant safety relief (affectionately called the hockey puck by its engineers) has the same fiber reinforced diaphragm and precision ground stainless steel spring found in the main regulator, except it has been factory set to automatically vent the circuit starting at 85mmHg and to not allow the circuit to exceed 100mmHg, even with a 10lpm high suction flow on the circuit. An audible sound will also be heard coming from this relief port. Any time there is an audible noise from the port it is an indication the system is operating in a safety mode to keep the circuit pressures within safe limits, this is not normal operation.

How does the safety relief compared to others I have seen?
100mmHg is only 2psi. The 1.5" diameter diaphragm multiplies this force so that the Boehringer Model 3930 can always accurately and reliably vent the circuit to prevent a pressure overrun. Some competitive devices rely on a small ball and spring to vent the circuit. Given the small effective area of the ball and the metal to metal seat contacts, these designs may be prone to fouling with corrosion or foreign materials. Also the small effective areas means that they may have only 2% of the opening force of the large diaphragm of the 3930.

Suction Flowmeter and Waste Anesthetic Gas Removal

What should the suction flowmeter be set at?
We recommend the suction flowmeter be set to 8-10lpm. This gives a visual indication that waste gas is being removed. Any additional flow beyond the sweep from the oxygenator will be made up by room air drawn in through the installed vent in the distal end of the tubing. Some facilities have enacted protocols whereby the WAGD flowmeter is set at 1-2lpm above the sweep, this can be done at the discretion of the facility, however, for proper WAGD removal the flowmeter must be set higher than the effective sweep. The suction flowmeter is factory limited to 12lpm so as to allow sufficient supply for VAVD uses. The suction flowmeter can be used independent of the VAVD control, and vice versa.

Can the Suction Flowmeter Affect the Airflow / Saturation of the Circuit?
By design the suction flowmeter is not meant to impart more than 0.5cmH2O pressure on the oxygenator. The inclusion of a passive vent immediately proximal to the oxygenator helps ensure negative pressure is not applied to the oxygenator. The suction flowmeter will not impart a pressure differential on the oxygenator, so it cannot affect flow or saturation levels in the circuit.
Why can't I feel suction in the suction flowmeter line?
The inclusion of a passive vent immediately proximal to the end of the line ensures that in a static
condition the unit cannot deliver more than 0.5cmH20 to the vent port of the oxygenator. This low
level of suction is meant to remove waste gas in a laminar flow and not the typical high flow fashion
you would normally attribute to a suction circuit.

Can the suction flowmeter degrade performance of the VAVD circuit?
The manifold bracket of the 3930 ensures that even if the suction flowmeter were turned to its
maximum setting, only 15lpm could be delivered to the oxygenator and removed from the available
supply for the VAVD circuit. Per the NFPA99 standard, the supply line to the 3930 should be capable of
89lpm of flow, so the suction flowmeter at most could remove 11% of the available flow, leaving more
than adequate static pressure and flow to power the VAVD circuit.

Can I remove the blue end piece from the suction flowmeter line?
Do not cut/modify the piece that attaches to the oxygenator. This has a special fitting modified to
function as a passive vent. In the event someone shuts off the suction flowmeter, the system will vent
passively. By having this passive vent immediately proximal to the oxygenator we lessen the possibility
the tubing could be bent or kink.

Can I shorten the suction flowmeter hose?
Yes. Do not modify the end which is proximal to the oxygenator, shorten the length that is immediately
attached to the suction flowmeter. Use a knife to score the tubing and peel it off of the barb fitting. Do
not put undue pressure on the flowmeter by trying to pry the tubing off.

Can Waste gas be run into the central suction system?
NFPA99 requires that waste anesthetic gas be diluted below flammable levels before introduction into
the central suction system. The Boehringer VAVD Controller has been designed in a single manifold
with both VAVD and Waste Anesthetic Gas removal functions. In addition an auxiliary vent port on the
distal end of the suction flowmeter brings room air into the suction flowmeter. The combination of
these features allows the anesthetic gas to be diluted appropriately before introduction into the
hospital suction system. If there are any questions please have your facilities engineer contact the
Boehringer factory engineers.

Why is WAGD tubing permanently attached to the Suction Flowmeter?
The suction flowmeter is meant to facilitate scavenging of the waste anesthetic gas using a flow
limited circuit. Without the downstream passive vent, in a completely occluded condition, this circuit
could apply full line vacuum (>500mmHg). The VAVD output from the 3930 is pressure limited, but not
flow constrained. In a completely occluded condition the output line from the VAVD regulator would
only apply the regulated output from the regulator. By permanently attaching the WAGD tubing with
a color coded line in compliance with the NFPA requirements, we hope to alleviate the possibility of
cross connecting the WAGD circuit to the VAVD circuit.
Does the Suction Flowmeter and WAGD affect the sat levels of the blood?
By design and when used in conjunction with the factory installed WAGD line and coupler the Suction Flowmeter of the VAVD controller is not meant to impart more than 0.5cm H2O (0.36mmHg) onto the vent side of the oxygenator. This very low pressure ensures there is no undue pressure differential across the membrane of the oxygenator.

Safety

Why have a 0-60mmHg Operation Range?
Clinical inputs supported a normal operating range of 20-40, and clinical literature identifies the increased risk of air embolism over 60mmHg. These units are factory calibrated to deliver 0-60mmHg, with a high vacuum production specification of 65-75mmHg. The control knob on the front of the Boehringer Model 3930 has a calibrated set screw to define the maximum range. Boehringer is the only manufacturer of suction equipment that factory limits the high end range of our suction controls without having to rely on auxiliary safety device to set the high end.


Why is an Independent Negative Pressure Relief needed on the regulator?
The addition of a redundant safety relief device is intended to ensure that in the unlikely event the main regulator fails, a separate safety relief can vent atmospheric pressure to ensure circuit pressures are maintained less than 100mmHg. Another scenario can arise where the regulator is set to an operational set-point, but imbalance in the mass flow to the venous drainage canister (arterial pump removing fluid from the canister quicker than it is being replaced) can result in the generation of suction in this vessel. The production test specification for the 3930 requires the main control be set to its maximum operational range, and then an additional high vacuum line at 10lpm is applied to the circuit. These controls begin to vent at 90+/− 5mmHg and the circuit must be less than 95mmHg. The 10lpm would far exceed the volume which could be removed from the circuit from the arterial pump.

On / Off / Vent Control Mechanism
All Boehringer suction regulators utilize a single piece machined control valve, without the need for rubber gaskets or O-Rings to make a seal. This means that when you need vacuum you can be assured that operating the control valve will deliver vacuum, likewise when you turn the circuit off, you have the same assurance that suction will be turned off and the circuit will be vented. The Boehringer design has a large 5mm vent port that opens the circuit to atmosphere when suction is shut OFF.

How much Positive Pressure is Vented?
The same device which provides for negative pressure relief also vents excess positive pressure. Given the design of the 3930 there is only one identified condition where you could apply positive pressure to the circuit. While the unit is turned to REG and you are applying suction to the circuit, any positive pressure would be suctioned away. When the unit is in the OFF position the large 5mm vent will exhaust any excess positive pressure. The one identified mode where the unit would need to vent positive pressure is where you must have the unit in the REG (regulator) mode, and then turn the control knob down until the resultant output is Zero. In this case the 3930 would not be applying
suction and the 5mm vent is not open. The unit begins to vent positive pressure at 1.5cmH2O (~1mmHg) and even with 10lpm of air entering the reservoir (an instance where two or more sucker pumps are turned all of the way up) the circuit will be maintained to less than 25cmH2O (18mmHg). The in-line positive pressure relief valves found in most disposable circuits have low cracking pressures, but they could maintain very high circuit pressures if challenged with high flow through the circuit. Many disposable valves exceed 20mmHg even with only 5lpm of flow applied to the circuit.


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**Design Considerations**

**Is the Boehringer VAVD Controller tolerant to fluid intrusion?**

The patented Self-Clearing™ control mechanism found in Boehringer 3800 & 3900 series controls ensures the device will continue to function after it has been intruded with fluid. Once the case is complete the device should be disassembled, cleaned, disinfected and retested.

**Can the Boehringer VAVD Controller handle humidity and aerosol?**

The internal control mechanisms are stainless steel, and tolerant to humidity and aerosols.

**What is the use of the supply gauge?**

The VAVD Controller was designed to work with a suction supply compliant to the National Fire Protection Association code (NFPA99). It is recommended you purchase and install the VAVD connection kit that will include the proper fittings and reinforced supply tubing. The supply gauge serves a two-fold purpose. Per NFPA99, your suction supply pressure should be a minimum of 20inHg.
(508mmHg). Should anything compromise your supply such as a hose disconnection, line kink, or equipment running over the supply hose, you will readily see a decrease in supply. If there is any excess circuit demand on vacuum, possibly due to a dislodged cap on the venous reservoir, you will likewise see a decrease in the supply gauge. The suction flowmeter will impart a slight draw on the supply of the system. When fully open, on a compliant outlet, the suction flowmeter will reduce supply pressure less than 100mmHg.

**How does the control valve work?**

The ON/OFF control valve of the VAVD controller serves a twofold purpose. In one action (from ON to OFF) it not only turns off suction to the circuit, but it also opens a large 5mm vent to the circuit. Some other suction equipment sold into this market will only shut off the supply and not actively vent the circuit. These types of controls necessitate the use of a Y-Connector and vent in the circuit. The inclusion of a Y-connector leaves open the possibility to completely occlude the circuit, or not to fully vent the circuit (see the FAQ's on the Y-Connector).

**Why is high flow important?**

Sucker pumps may be able to generate upwards of 5lpm of free air flow. Multiple high suckers setup at high flow could create a scenario where 10lpm or more is being pumped into the venous reservoir. If the suction control you utilize is not able to remove a minimum of 10lpm in the operating pressure range (20-40mmHg) you can encounter a scenario where even with vacuum applied to the circuit, positive pressure can still develop. The high flow nature of the Boehringer VAVD controller, ensures that if suction is turned on, you can safely remove the free airflow from the sucker pumps and maintain vacuum on the circuit.

**Self-Clearing Control Surfaces**

Every suction control currently marketed uses a spring opposed diaphragm for its internal control. The control chamber of these units effectively creates a pumping mechanism in an attempt to regulate and maintain pressure. When aerosols or liquids enter these designs they can be entrapped in the control chamber. Once the working surfaces of a suction unit become fouled it requires more force to enable them to operate properly. Once fouled their output could be unreliable/unpredictable or in a worst case of if the internal piston is seized the device is no longer a regulator and it essentially becomes a valve, capable of adjusting flow, but unable to achieve a output pressure regulation. The Boehringer 3800 & 3900 series controls use a patented design that provides for a dedicated air-curtain of fresh air to flush over the control surfaces in normal operation. This prevents liquids and aerosols from fouling the controls mechanism even under the most grueling conditions.

**Patented Linear Gauge**

Boehringer utilizes a patented linear gauge that is elegant in design, extremely accurate, and tolerant to many common forms of abuse. This design also has a large 5mm orifice in its base so that any entrained material can quickly clear the gauge. Traditional dial gauges have 35-40 internal parts including a gear multiplier and rack/pinion mechanism. This makes them delicate and prone to breakage should they be dropped or jarred. Dial gauges also rely on a micro-orifice to dampen the motion of the needle. These orifices can be as small as 0.1mm to 0.3mm. Any internal debris or liquid is prone to clog these and make the gauge unresponsive or inaccurate. Some manufacturers offer digital gauges on their devices, even though these gauges are accurate, they are attached to the same inaccurate underlying control mechanism found in older generation suction controls. Digital controls also occasionally need to be correct for Zero and Span readings, as well as their readings may drift as their internal batteries are drained.
100% American Made Craftsmanship

Boehringer Laboratories was founded in 1972 by John Boehringer in his home in Wynnewood, Pennsylvania. All Boehringer Controls are proudly designed and produced here in the United States at our facility just outside of Philadelphia.
Basic Setup Options

This figure shows some of the most common circuit configurations. Not every circuit will need all of these components. Please read the FAQ’s concerning the Y-connector before choosing to employ a Y-Connector with the circuit for your 3930 Controller. In many cases the Y-Connector may create added human risk factors that are avoided simply by using the control valve on the Boehringer Model 3930.

1- Suction Controller
2- In-line pressure relief found in some disposable circuits
3- Vent Port (when utilizing a y-connector)
4- Y-Connector
5- Vapor Trap
6- Venous Drainage Reservoir

A. Hemostat Clamp Location to Discontinue Vacuum and Vent the Circuit
B. Hemostat Clamp Location to Apply Vacuum to the Circuit.
C. Improper Clamp Location which will disable most pressure safeties of the circuit.
D. Potential kink location of the vapor trap.