



SI-LANGC

*Compact Langendorff*

www.wpiinc.com

## INSTRUCTION MANUAL

Serial No. \_\_\_\_\_

020812

***World Precision Instruments***





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## ABOUT THIS MANUAL

The following symbols are used in this guide:

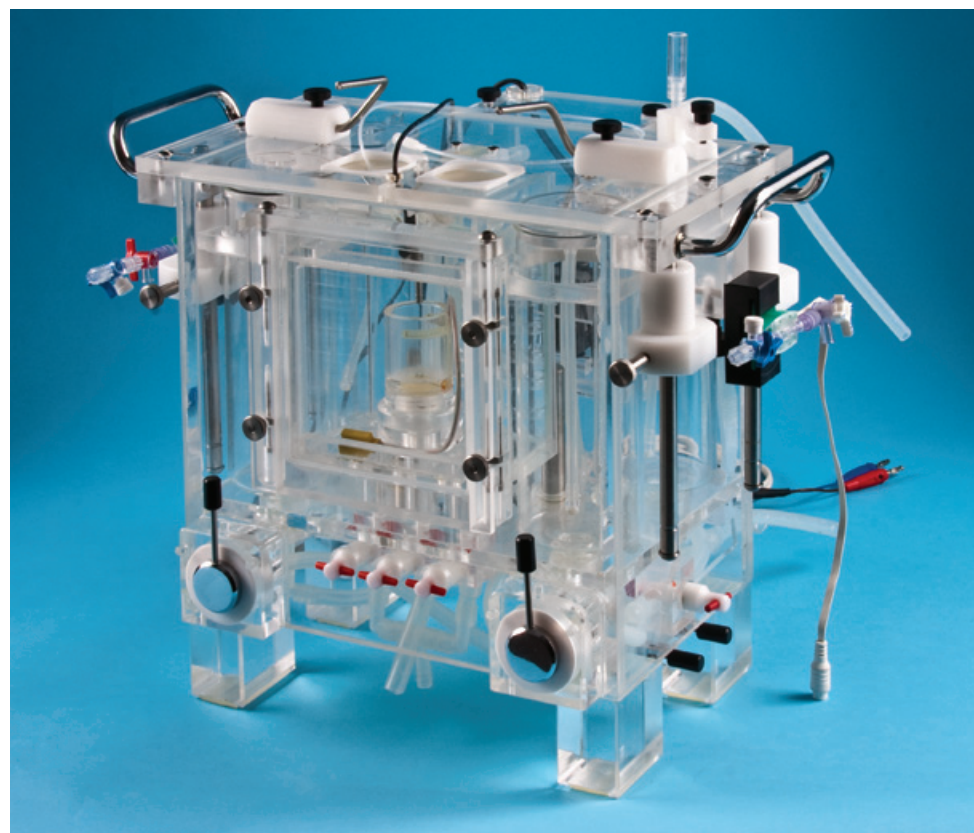


This symbol indicates a **CAUTION**. Cautions warn against actions that can cause damage to equipment. Please read these carefully.



This symbol indicates a **WARNING**. Warnings alert you to actions that can cause personal injury or pose a physical threat. Please read these carefully.

**NOTES** and **TIPS** contain helpful information.



*Fig. 1 The Compact Langendorff requires no columns.*

## INTRODUCTION

The **SI-LANGC** system is designed for perfusion experiments of small animal hearts (mouse, rat, guinea pig, rabbit) in either constant pressure or constant flow mode. While the system fits on a small bench top, it provides all the features necessary for experiments in both Langendorff and in working heart (Janiczky) perfusion modes. The whole system forms one thermostatically controlled unit that includes four reservoirs, a unique lifting heart suspension module and a built-in temperature controller calibrated in 0.1°C degrees increments.

Each perfusion reservoir can store 500mL of preheated and oxygenated saline. When the system is manufactured, it can be configured so that the reservoirs form one large (2L) or two medium (2 x 1L) reservoirs. The four 500mL reservoirs can also be configured for use independently. In the latter case, the effect of a drug at three different doses (plus control) can be investigated consecutively. This configuration also allows the effects of three or four different drugs to be studied either consecutively or simultaneously. The heart suspension module can be lifted up semi-automatically to facilitate the heart attachment to the cannula, and then lowered into position adjacent to an optional sensor, like the 12-lead MAP sensor. The perfusion flow is driven by a peristaltic pump equipped with 8 rollers. Also, the pump can be controlled electronically to maintain a desired pressure (between 0-500mmHg) through the course of the experiment.

In the Langendorff perfusion mode, heart contraction strength, heart rate and LVP can be measured. LVP can be measured with either a fluid-filled balloon catheter or a Millar Mikro-tip pressure catheter. Muscular tone, force and their change in response to electrical, chemical or pharmacological stimuli can be measured with the force/displacement transducer.

## Features

Main advantages of the system include:

- Langendorff perfusion mode
- Janiczky-type working heart mode
- Built-in temperature controller
- Four, independent reservoirs with 2L total volume (2 x 1L or 4 x 500mL)
- Special semi-automatic lifting heart suspension module
- Different sizes of cannulas and optional MAP sensors for mouse, rat, guinea pig and rabbit
- Electronically adjusted flow rate to keep the constant pressure (0–500mmHg)
- Parameters that can be measured include: MAP, LVP, perfusion pressure, coronary flow, buffer temperature, heart rate, muscle surface potential, muscular tone and force (with force/displacement transducer)
- Left ventricular pressure (LVP) measurement
- Optional pacing/stimulation



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## Cautions

**!** **CAUTION:** Do not turn on the Temperature/Pressure Controller unit unless the water jacket of the Compact Langendorff chamber is filled with distilled water. Also, do not drain the water from the water jacket until the heater has been off for at least 15 minutes. Improper use of the heating system can damage the heating coils, as well as the Langendorff bath itself.

**!** **CAUTION:** Do not add any antibacterial agents or other chemicals to the distilled water in the jacket. The plastic components of the chamber or the heating regulating circuitry could be damaged from prolonged exposure to certain chemicals containing alcohols, acids or detergents.

**!** **CAUTION:** Do not plug in the built-in circulating pump until the water jacket is filled to the minimum level. The built-in circulating pump is not equipped with a switch. It will start immediately when plugged in. Running the pump before the water reaches the minimum level could damage the pump.

**!** **CAUTION:** Do not plug the heater control cables into the Temperature/Pressure Controller unit unless the water jacket of the Compact Langendorff chamber is filled with distilled water. Also, do not drain the water from the water jacket until the heater has been turned off for at least 15 minutes. Improper use of the heating system can damage the heating coils, as well as the bath.

**!** **CAUTION:** The Pressure Controller (**PC**) unit is specifically designed for controlling WPI PeriPro pumps. This Pressure Controller cannot be used with other brands of peristaltic pumps. Please contact our technical representative (technicalsupport@wpiinc.com) if you have any questions.

**!** **CAUTION:** The temperature control system was calibrated at the factory. Do not rotate the **High** and **Low** trim potentiometers on the front of the temperature control unit unless the temperature sensor is replaced.

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## Parts List

After unpacking, verify that there is no visible damage to the instrument. Verify that all items are included:

(1) **SI-LANGC** including:

- (1) All-in-One compact system with reservoirs, taps, central heater, heart suspension unit, oxygenation system, heart chamber, pressure sensor holders, tubing set, cables and accessories.
- (1) Temperature/Pressure Controller—The constant pressure controller is used with a 2-channel peristaltic pump to create constant pressure without the use of a hydrostatic column. The temperature controller is used with the internal heater that is built into the compact system.
- (1) 2-Channel Pressure Sensor Amplifier

## SI-LANGC

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- (2) Pressure Sensors: perfusion (aortic) and left ventricular/atrial pressures

(1) **SI-LANGC-KIT** which includes:

- (1) **PERIPRO-4HS** Peristar Pro 4-channel, high output peristaltic pump for filling buffer reservoirs with two different buffers
- (1) **PERIPRO-2HS** Peristar Pro 2-channel, high output peristaltic pump for lung and coronary return circuit
- (1) Package of latex pressure balloons (for the LVP catheter)  
**NOTE:** You must specify the size of balloons.
- (1) Auxiliary bubbling stone

(1) Instruction Manual

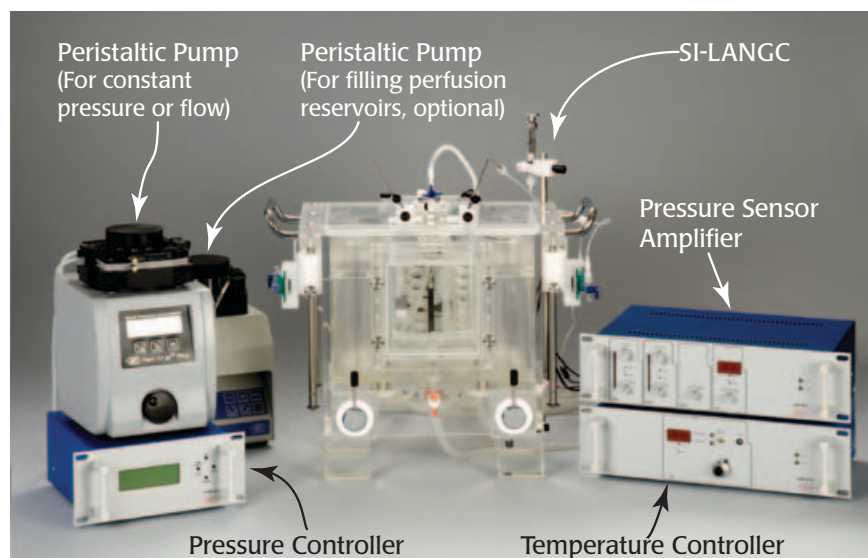
### Unpacking

Upon receipt of this instrument, make a thorough inspection of the contents and check for possible damage. Missing cartons or obvious damage to cartons should be noted on the delivery receipt before signing. Concealed damage should be reported at once to the carrier and an inspection requested. Please read the section entitled "Claims and Returns" on page 42 of this manual. Please contact WPI Customer Service if any parts are missing at 941.371.1003 or [customerservice@wpiinc.com](mailto:customerservice@wpiinc.com).

**Returns:** Do not return any goods to WPI without obtaining prior approval (RMA # required) and instructions from WPI's Returns Department. Goods returned (unauthorized) by collect freight may be refused. If a return shipment is necessary, use the original container, if possible. If the original container is not available, use a suitable substitute that is rigid and of adequate size. Wrap the instrument in paper or plastic surrounded with at least 100mm (four inches) of shock absorbing material. For further details, please read the section entitled "Claims and Returns" on page 42 of this manual.



## INSTRUMENT DESCRIPTION



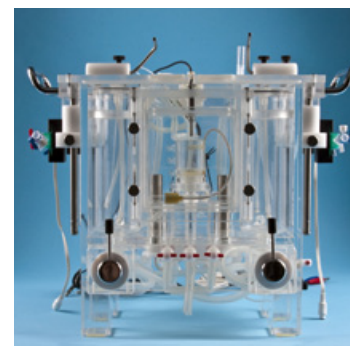
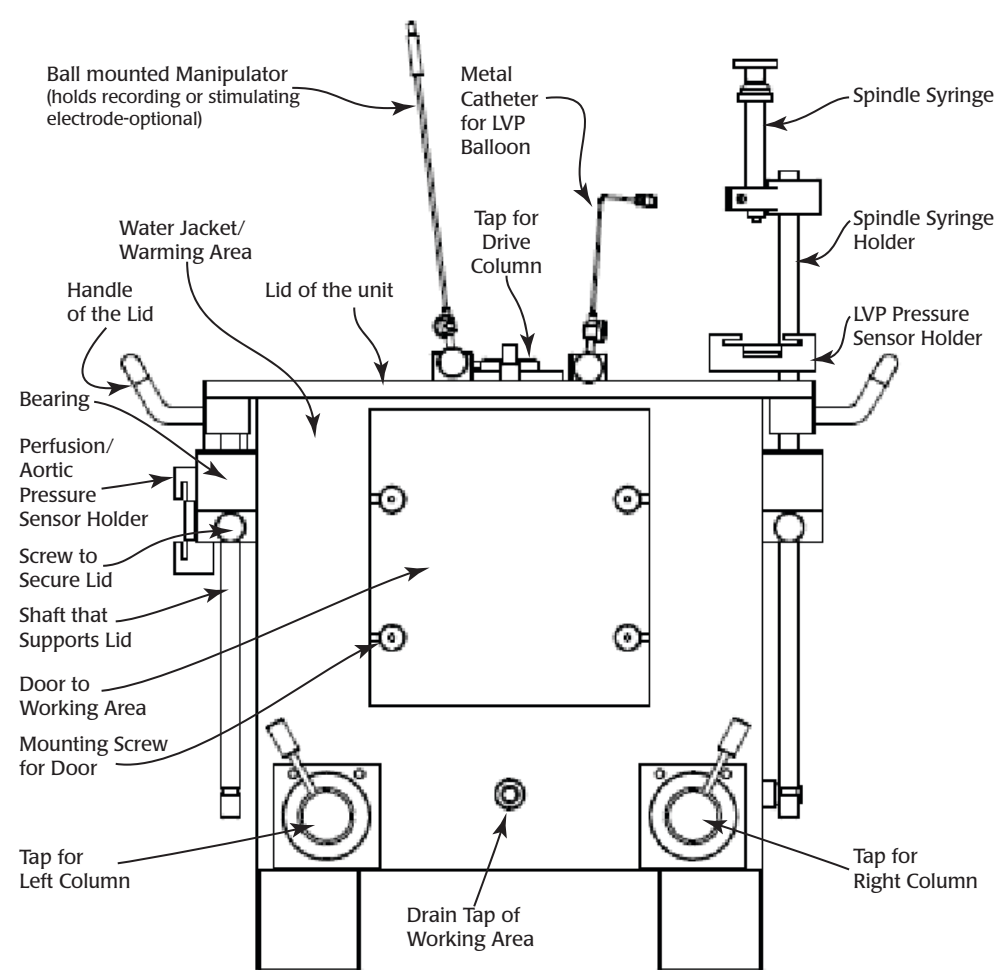
*Fig. 2 A complete Compact Langendorff system includes accessories like the Temperature and Pressure Controllers, peristaltic pumps and a pressure sensor amplifier. In new systems, the Temperature Controller and Pressure Controller are contained in the same unit.*

The Compact Langendorff (**SI-LANGC**) system is composed of four major components:

- Compact Langendorff unit designed to maintain an isolated heart in proper working condition. (See "Compact Langendorff Unit" on page 5.)
- Temperature controller and sensor for precisely maintaining the temperature of the heart. (See "Temperature Controller and Sensor" on page 9.)
- Transducer amplifier and pressure sensors for measuring the perfusion/aortic and left ventricular pressures. (See "Transducer Amplifier and Pressure Sensors" on page 10.)
- Pressure controller and peristaltic pump for maintaining the flow or the pressure of the fluid perfusing the heart. (See "Pressure Controller and Peristaltic Pump" on page 11.)

### Compact Langendorff Unit

The next few pages contain diagrams that detail the parts of the Compact Langendorff unit from various angles. This unit contains reservoirs that hold the perfusion fluid, tubing which delivers that solution to the heart, a chamber in which the heart is suspended and perfused, and a heating system that is designed to maintain the temperature of the tissue as close to the specified temperature (usually 37°C) as possible. The reservoirs can be configured at the factory to provide buffer in 0.5, 1 or 2L aliquots.



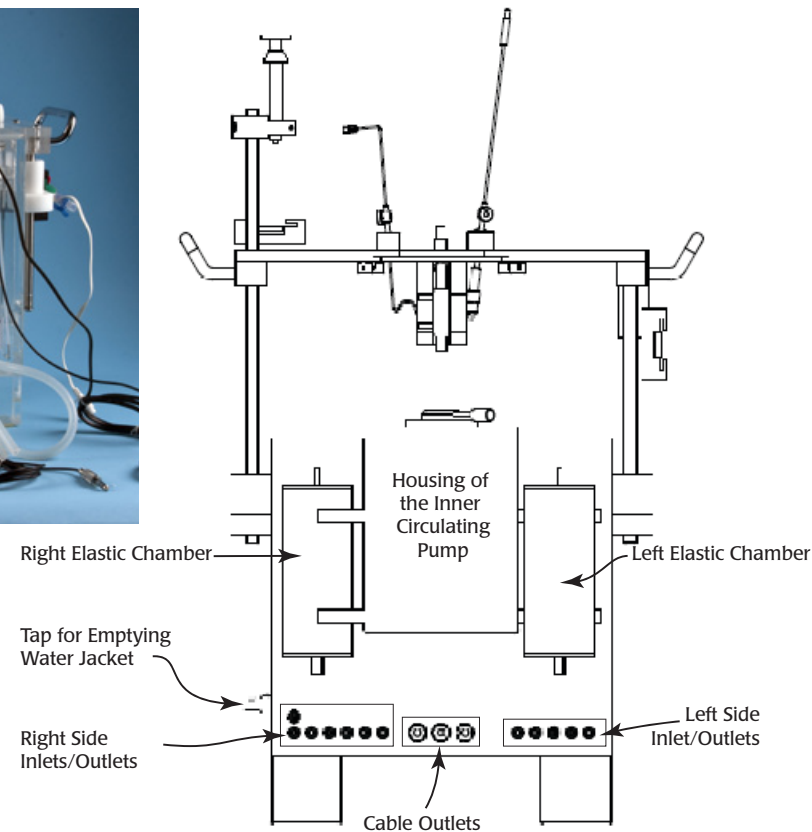
*Fig. 3 The front view of the Compact Langendorff is labeled.*

The heating system employs two heating coils, a temperature sensor, and a circulating pump to warm the key components of the unit. An auxiliary heat exchanger warms the perfusion buffer to the proper temperature before it enters the heart suspension unit and the heart. It is another key part of the heating system.

The reservoirs containing the perfusion fluid and the chamber that contains the heart are surrounded by a water jacket filled with distilled water. This water is warmed by the two heaters strategically located in the jacket and circulated through the jacket by the pump. The temperature sensor is also located in the jacket and works with the Temperature Controller (**Fig. 4**) to maintain the temperature of the water in the jacket. The

perfusion fluid in the reservoirs and the tubing and the heart chamber are warmed by the conduction of heat from warm, distilled water in the water jacket. Warm distilled water is also circulated directly to the heat exchanger that warms the perfusion fluid to the proper temperature before the fluid enters the heart. The use of this heat exchanger prevents dramatic cooling of the perfusion fluid and the heart when the heart suspension unit is lifted up and out of the heart chamber. For proper operation, the Compact Langendorff unit needs to be warmed for about 45 to 60 minutes prior to use.

**! CAUTION:** Do not turn on the Temperature/Pressure Controller unless the water jacket of the Compact Langendorff chamber is filled with distilled water. Also, do not drain the water from the water jacket until the heater has been off for at least 15 minutes. Improper use of the heating system can damage the heating coils, as well as the Langendorff bath itself.



*Fig. 4 The back view of the Compact Langendorff is labeled.*

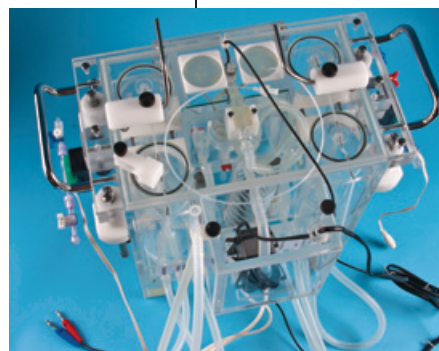
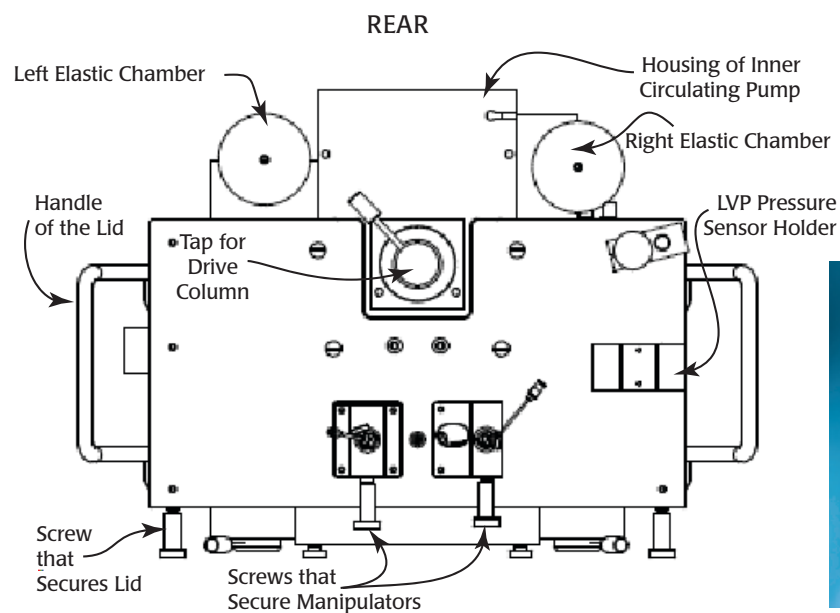


Fig. 5 The top view of the Compact Langendorff is labeled.

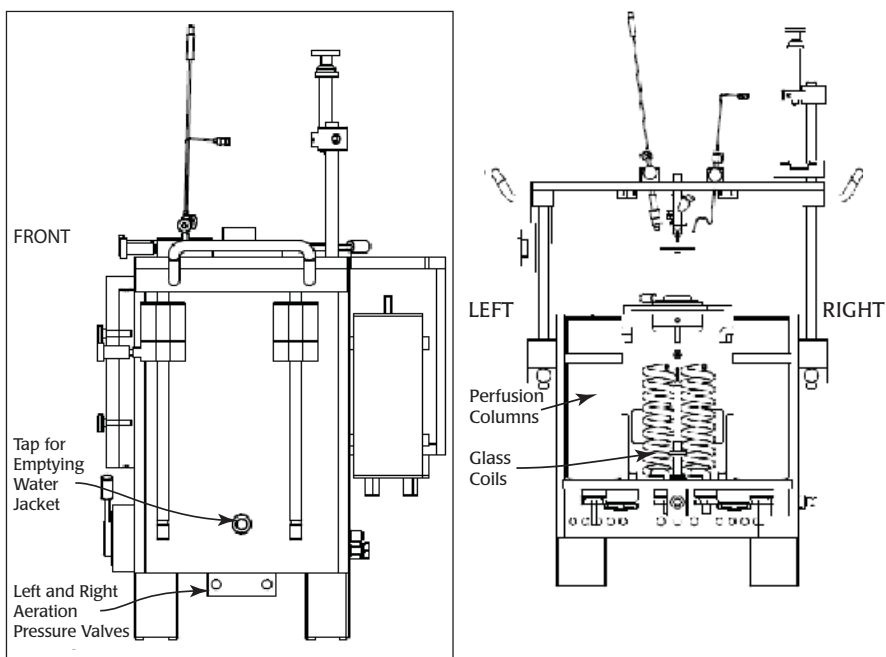
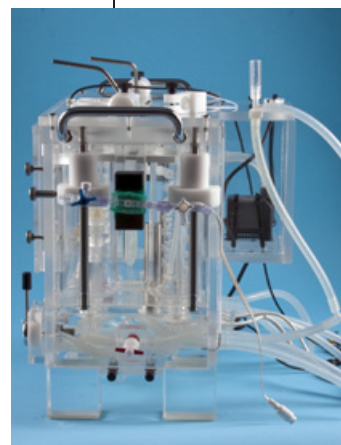
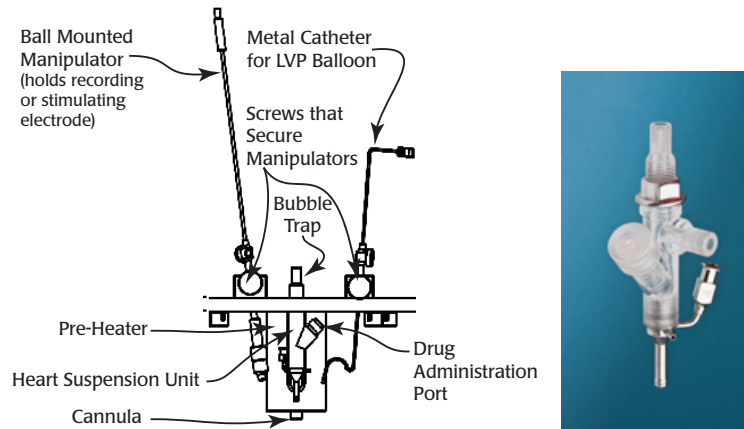


Fig. 6 (Left) The side view of the Compact Langendorff is labeled.

Fig. 7 (Right) The inner view of the Compact Langendorff is labeled.



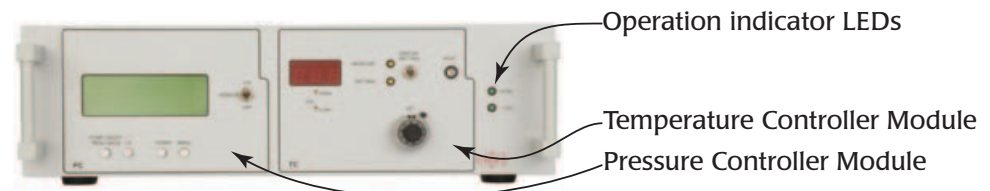


*Fig. 8 The heart suspending unit of the Compact Langendorff is labeled. Note that the cannula image shows a view from the back.*

## Temperature Controller and Sensor

The Temperature Controller (TC) is a module contained in the same unit as the Pressure Controller (PC). It is designed to maintain the temperature of the Compact Langendorff unit within  $\pm 0.1^\circ\text{C}$  of the temperature setpoint.

The controller monitors the temperature of the Compact Langendorff chamber through a sensor that is located in the rear of the chamber's water jacket. If the temperature in the chamber is low, the TC turns on the two heating coils that are also located in the back of the chamber. The coils warm the water that circulates through the water jacket. In turn, the warm water in the jacket heats the perfusate in reservoirs, heat exchange coils and the preheat coil. When the temperature of the system has returned to the temperature setpoint, the controller turns off the heating coils until the cycle is repeated.

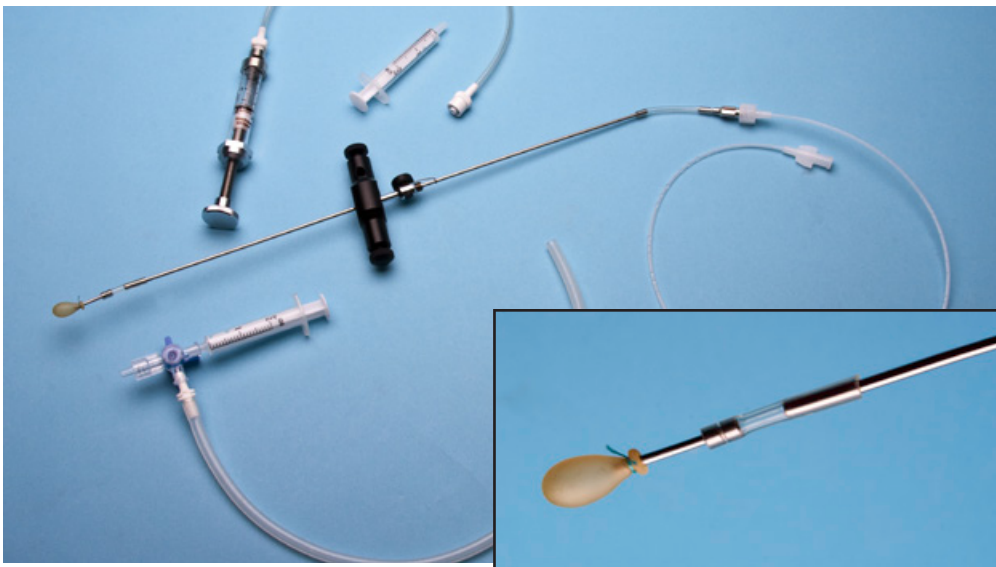


*Fig. 9 The Pressure Controller and the Temperature Controller are housed in the same unit.*

### Transducer Amplifier and Pressure Sensors

The Compact Langendorff unit is equipped with two pressure transducers that are used to measure the left ventricular pressure (LVP) of the heart and the perfusion pressure (in Langendorff mode) or the aortic pressure (in working heart mode).

The LVP is measured using a fluid-filled balloon placed through the left atrium of the heart into its left ventricle. The balloon is attached on the end of a metal catheter mounted on a pivoting manipulator. This pivot allows the catheter to be positioned so that the motion of the heart is restricted as little as possible. The other end of the catheter is connected to a pressure transducer through a spindle syringe. Both the transducer and the spindle syringe are mounted on the right side of the chamber's lid. The spindle syringe is used to increase or decrease the fluid in the balloon to control the stretching (preload) of the left ventricle.



*Fig. 10 A fluid filled balloon is mounted on a spindle syringe.*

The perfusion or aortic pressure is measured using the second pressure transducer, which is mounted on the left side of the Compact Langendorff chamber. Through a line filled with perfusion fluid, the transducer is connected to a port in the cannula housing directly above the heart. With the aorta of the heart mounted over the cannula, the transducer is able to measure the pressure inside the aorta.

- In Langendorff (retrograde) mode, this transducer is used to monitor the pressure used to drive the perfusion fluid through the coronary circulation originating at the proximal end of the aorta.
- In working heart mode, the transducer is used to measure the pressure in the aorta that is created by the contraction of the left ventricle.



## Pressure Controller and Peristaltic Pump

The Pressure Controller (**PC**) is a module in the same unit as the Temperature Controller (**TC**). The **PC** uses a feedback loop to maintain the perfusion pressure at a constant level by adjusting the speed of the peristaltic pump used to generate the pressure.

**CAUTION:** The Pressure Controller (**PC**) is specifically designed for use with WPI PeriStar Pro pumps. It is not advisable to use this controller with any other brand or model of peristaltic pump. If you have any technical question, please contact WPI Customer Support at [technicalsupport@wpiinc.com](mailto:technicalsupport@wpiinc.com).

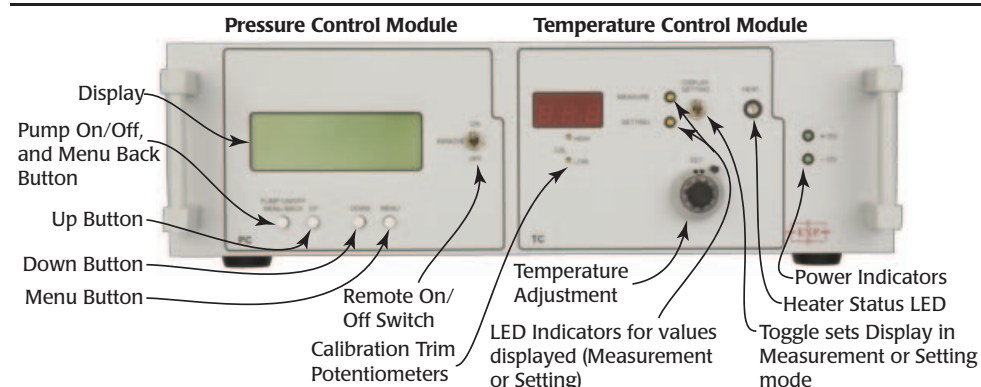


Fig. 11 The **PC/TC** controller buttons and dials are labeled.

When it is connected to the Pressure Controller, the peristaltic pump that is used to deliver perfusion fluid to the heart can be operated in either constant flow or constant pressure mode.

- With the **Remote** switch on the front of the Pressure Controller in the **Off** position, the controller is inactive and the pump works in constant flow mode according to the settings programmed into the pump itself.
- With the **Remote** switch in the **On** position, the controller is active and the pump works in constant pressure mode according to the settings programmed into the Pressure Controller and input from a pressure sensor.

The sensor that is used to provide feedback to the Pressure Controller is the same pressure transducer that is used to monitor the perfusion pressure from the aortic cannula. After being conditioned by a transducer amplifier, the signal from this transducer is conducted through a special cable to the data recording unit and the Pressure Controller (**PC**) simultaneously. If the Pressure Controller receives a signal that indicates the pressure in the aortic cannula is lower than the pressure setpoint, the controller sends a signal to the peristaltic pump which increases the rotation rate of the pump until the pressure in the aortic cannula reaches the pressure setpoint. Likewise, if the pressure in the aortic cannula is higher than the pressure setpoint, the controller sends a signal to the pump that slows its rotation rate and lowers the perfusion pressure.

## Setting Up the System

All SIH Compact Langendorff systems are assembled and tested at the factory before shipping. During the final assembly, all the internal tubing connections of the actual Compact Langendorff unit are permanently installed. The external tubing and cables, which connect the unit and the other components, are also installed, tested and labeled before they are removed and packaged for shipment. The labeling of the tubing, ports and cables allows you to easily assemble your system when the unit arrives.

Determine where the Compact Langendorff unit and its supporting components will be located in the lab. Place the electronic components away from water supplies and near power sources.

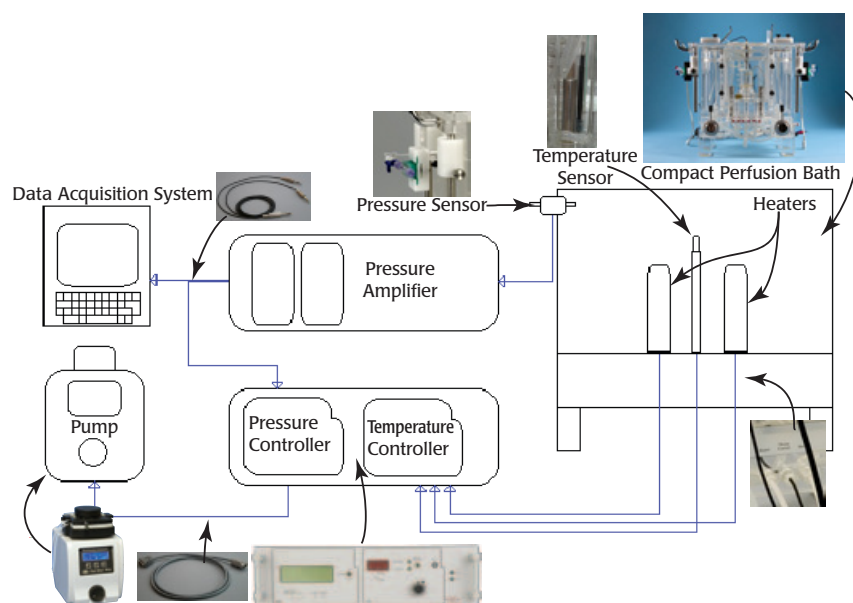


Fig. 12 This connection diagram shows how the system parts interrelate.

## Attaching Tubing to Langendorff Unit

1. Unpack the tubing kit. The tubing is used to connect the Compact Langendorff unit to the pump(s) and buffer containers. Lay out the tubing on a table so that specific pieces can easily be identified by their labels.

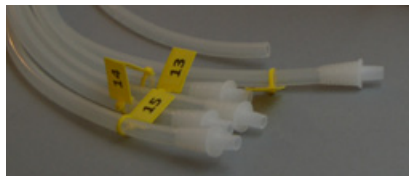


Fig. 13 The tubing is labeled with numbers.



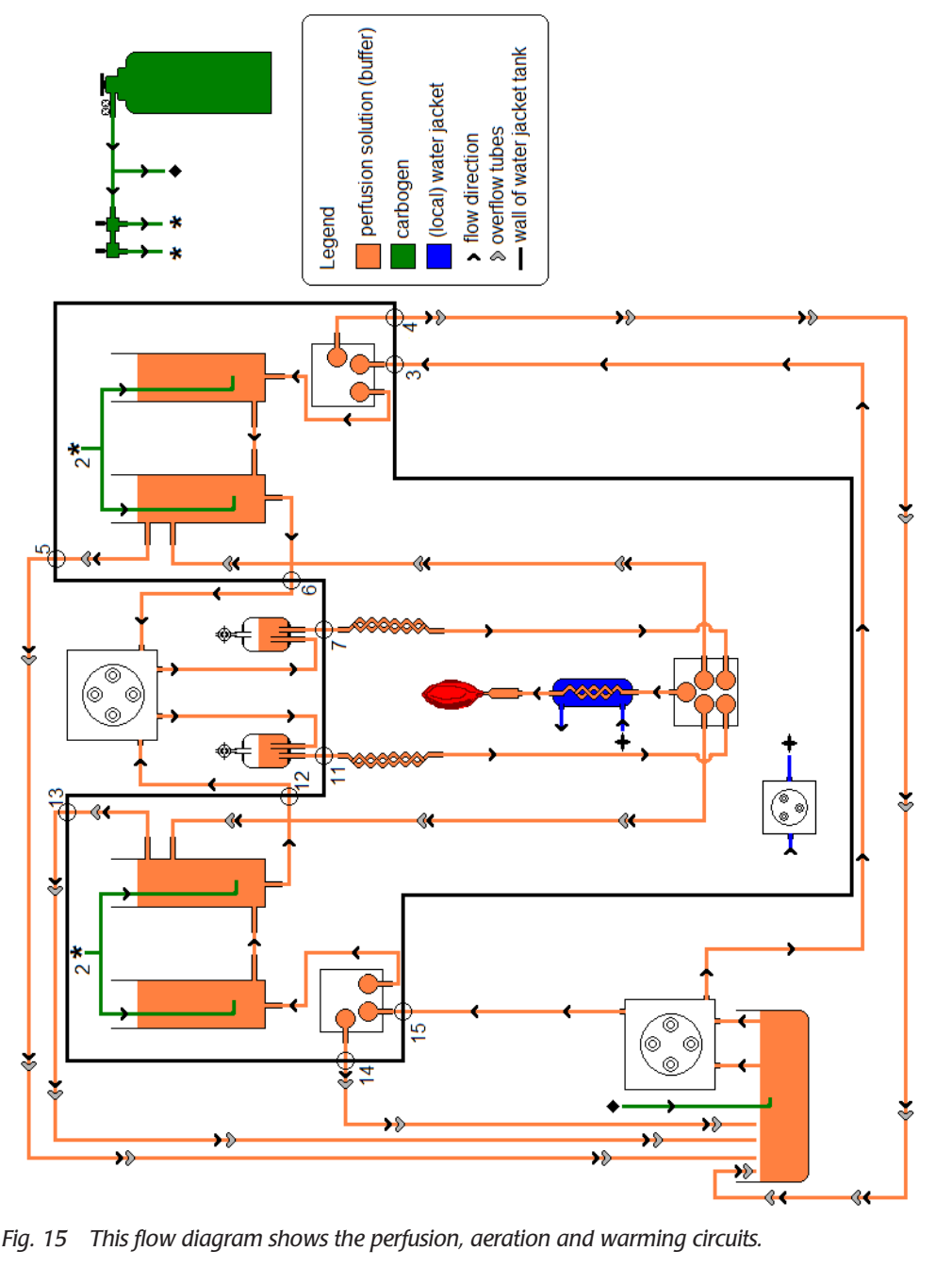
2. Locate the inlets and outlets of the Compact Langendorff unit on the back and side of the unit. The ports are also labeled for the ease of matching the correct tubing to each port.
3. Match each tube to the proper port on the Compact Langendorff unit. Carefully push each piece of tubing onto the fittings of matching ports. Make sure the tubing is firmly attached to each connector to prevent any leaks.



1 Water Jacket Outlet	Right Side								Left Side					
	Filling pump		5	Peristaltic pump			9		Peristaltic pump	13		Filling pump		
2 Carbogen In	3 In	4 Overflow	Over Flow	6 from Column	7 to Heart	8 Heater	Temp. Control	10 Heater	11 to Heart from Column	12 Over Flow	14 Over Flow	15 In		

**Fig. 14** The connections are labeled on the back of the Compact Langendorff.

Right Side	1	Water Jacket Outlet	Distilled water outlet for drain off
	2	Carbogen In	Carbogen inlet
	3	Filling Pump In (Fluid to Reservoirs)	Right perfusion reservoir inlet
	4	Filling Pump Overflow	Overflow of the tap on the right side
	5	Overflow	Overflow of the right perfusion reservoirs
	6	To Peristaltic Pump from Column (Reservoir)	Outlet of the right heart filling circuit, which is from the perfusion reservoir to the pump
	7	From Peristaltic Pump to Heart	Inlet of the right heart filling circuit, which is from the pump through the elastic chamber toward the heart
Left Side	11	From Peristaltic Pump to Heart	Inlet of the left heart filling circuit, which is from the pump through the elastic chamber toward the heart
	12	To Peristaltic Pump from Column (Reservoirs)	Outlet of the left heart filling circuit, which is from the perfusion reservoir to the pump
	13	Overflow	Overflow of the left perfusion reservoirs
	14	Filling Pump Overflow	Overflow of the tap on the left side
	15	Filling Pump In (Fluid to Reservoirs)	Left perfusion reservoir inlet



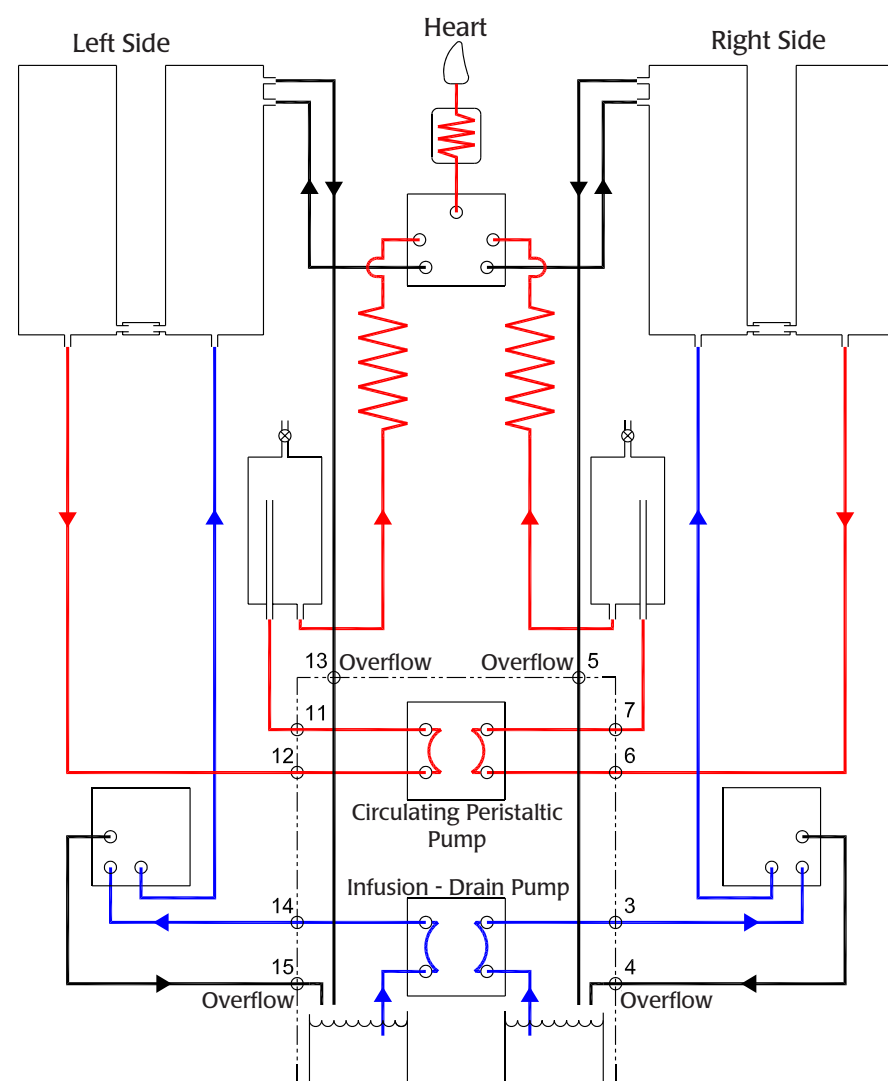


Fig. 16 This flow diagram shows the perfusion fluid in the Compact Langendorff with the positions of the ports connected to the numbered tubing.

### Attaching Tubing to the Pump(s) and Containers

The Compact Langendorff system is equipped with either one or two peristaltic pumps. In the one pump configuration, one pump operates the whole system. It drives the filling of the perfusion reservoirs and filling of the heart at the same time. The advantages are that the cost of the system is lower and the operation of the system is easier. The

disadvantage is that the rate of refilling the perfusion reservoirs is affected by the speed of the pump when used in constant pressure mode. In this mode, the speed of the pump is controlled by the Pressure Controller (PC) that is maintaining the perfusion pressure at a constant level.

In the two pump configuration, one pump drives the filling of the perfusion reservoirs, and the other pump drives the filling of the heart. The advantage is that the filling of the reservoirs is independent of the filling of the heart. However, the cost of the system is higher, and the operation of the system is more difficult.

1. Short, labeled pieces of tubing, which are continuations of the tubing that moves buffer from the supply container or that fill the heart from the reservoirs, may already be installed on the pump(s). Determine if the lengths of the tubing supplied with the system are long enough to reach the pumps and containers needed by the system.
  - Some of the tubing, like the overflow tubes that return buffer to the buffer supply container, may need to be shortened so the ends of the tubing are above the surface of the buffer in the container.
  - Some of the tubing may need to be lengthened, depending on the location of the components. If tubing needs to be longer, try to use complete lengths of tubing, rather than spliced, to prevent the possibility of leaks from connectors.
2. If the system is being used with one pump, connect the tubing to the pump and the buffer supply container in the following manner:

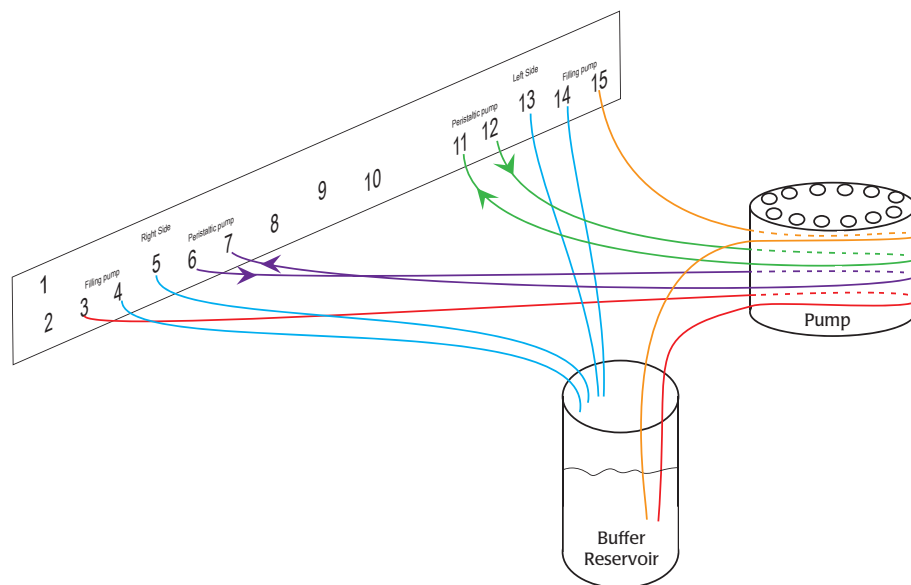
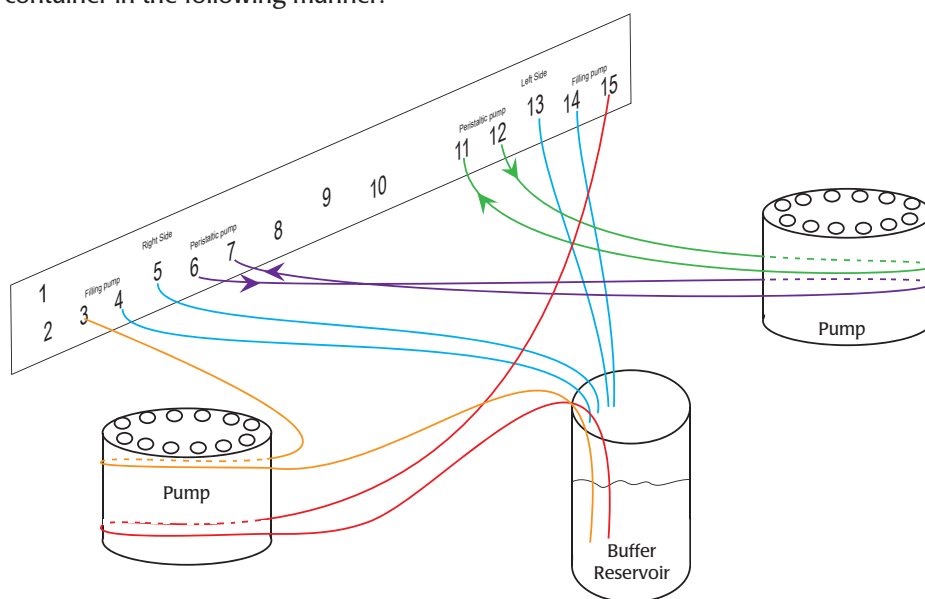


Fig. 17 If one pump is used, connect the tubing as shown.

- The tubing on the inlets (Filling Pump In-3, 15) deliver perfusion fluid to the reservoirs on the right and left side of the Compact Langendorff unit,

respectively. Run these tubes through the pump and place their open ends below the surface of the perfusion fluid stored in the buffer supply container. The supply container should be placed at a level lower than the Compact Langendorff unit.

- The tubing on the outlets (Filling Pump Overflow–4, 14 and Overflow–5, 13) return unused perfusion fluid to the buffer supply container. No pump is required. The open ends of the tubing are placed in the buffer supply container. These tubes may need to be shortened so their open ends hang above the surface of the perfusion fluid. This permits the overflow system to drain properly.
  - The tubing on the heart filling circuit outlets (Peristaltic Pump from Column–6, 12) and inlets (Peristaltic Pump to Heart–7, 11) are used to perfuse the heart. Run these tubes through the same pump used for tubes 3 and 15. From the right outlet (6), the tubing runs through the pump to the right inlet (7). This circuit moves fluid from the heated reservoirs on the right side of the Compact Langendorff unit into the heart. From the left outlet (12), another tube runs through the same pump to the left inlet (11). Likewise, this circuit moves fluid from the heated reservoirs on the left side of the Compact Langendorff unit into the heart.
3. If the system is being used with two pumps, connect the tubing to the pumps and the container in the following manner:



**Fig. 18** If two pumps are used, connect the tubing as shown.

- The tubing on the inlets (Filling Pump In–3, 15) deliver perfusion fluid to the reservoirs on the right and left side of the Compact Langendorff unit, respectively. Run these tubes through one of the pumps and place their open ends below the surface of the perfusion fluid stored in the buffer supply

container. The supply container should be placed at a level lower than the Compact Langendorff unit. Unlike the one pump configuration, these are the only tubes running through this pump.

- The tubing on the outlets (Filling Pump Overflow–4, 14 and Overflow–5, 13) recycle the unused perfusion fluid to the buffer supply container, just like the one pump configuration. Likewise, no pump is required, and the open ends of the tubing must remain above the surface of the perfusion fluid.
- As stated previously, the tubing on the two heart filling circuits are used to perfuse the heart from either the right or left buffer reservoirs. However, the tubing for the four ports in the circuits are connected to a second pump. Just like the one pump configuration, the tubing on outlet (6) and inlet (7) move fluid from the right side reservoirs to the heart, and the tubing on the other two ports move the fluid from the left side reservoirs to the heart. This pump is connected to the Pressure Controller (PC) and generates constant pressure by regulation of its speed.

### Filling the Water Jacket of the Compact Langendorff

1. Make sure the drain of the water jacket (Water Jacket Outlet–1) is closed.
2. Fill the water jacket that surrounds the perfusion reservoirs and the heart chamber with distilled water. It takes approximately 5L to fill the water jacket. Filling can be performed in either of two ways:
  - Lift the lid of the unit and use a funnel to fill the water jacket. If the reservoirs have removable lids, make sure they are in place to prevent distilled water from entering the reservoirs.
  - Temporarily connect a tube to the drain of the water jacket (Water Jacket Outlet–1), and use a pump to fill the jacket with distilled water.
3. Make sure the water level in the jacket is at or above the minimum level marked on the unit, but does not exceed the maximum level.



Fig. 19 Verify the water level in the water jacket.

4. Check the Compact Langendorff unit for leaks.



**CAUTION:** Do not plug in the built-in circulating pump until the water jacket is filled to the minimum level. The built-in circulating pump is not equipped with a switch. It will start immediately when plugged in. Running the pump before the water reaches the minimum level could damage the pump.





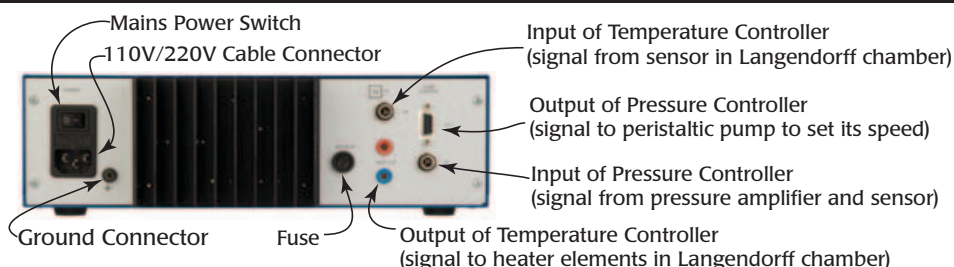
## Connecting the Temperature Controller

The Compact Langendorff unit has a couple of cables that need to be connected to the Temperature Controller (TC). One cable (labeled 9 on the back of the unit) conducts the signal from the temperature sensor in the water jacket to the Temperature Controller. The other cable controls the two heating coils (8, 10) in the water jacket. This cable has two branches, one to each heating coil, that share a common set of connectors.

*Fig. 20 (Left) The heater control cables (8, 9, 10) are located on the back of the Compact Langendorff unit and share a common connector.*



**CAUTION:** Do not plug the heater control cables into the Temperature/Pressure Controller unit unless the water jacket of the Compact Langendorff chamber is filled with distilled water. Also, do not drain the water from the water jacket until the heater has been turned off for at least 15 minutes. Improper use of the heating system can damage the heating coils, as well as the bath.

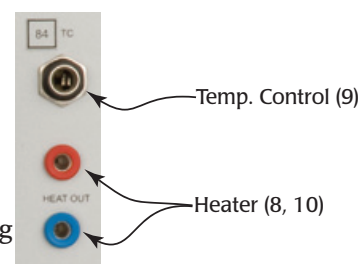


*Fig. 21 Many connections are located on the back of the TC/PC unit.*

1. Connect the plug on the cable of the temperature sensor (labeled 9 on the back of the unit) to the port labeled **TC** on the back of the Temperature/Pressure control unit. This is the **Input of the Temperature Controller**.

*Fig. 22 (Right) The heater of the Compact Langendorff connects to the back of the Temperature Controller.*

2. Connect the banana plugs on the cable of the heating coils (8, 10) to the color-coded banana jacks on the back of the controller unit.



## Connecting the Pressure Amplifier and Controller

The perfusion pressure is monitored using a transducer that is connected to the heart suspension unit in the Compact Langendorff chamber. The cannula on the lower end of the suspension unit is placed in the aorta of the heart. The signal from this pressure transducer is conducted to a transducer amplifier. In turn, the amplified signal is relayed to the recording system and to the Pressure Controller simultaneously. The Pressure Controller responds to changes in the perfusion pressure signal by changing the speed of the motor that drives the filling of the heart.

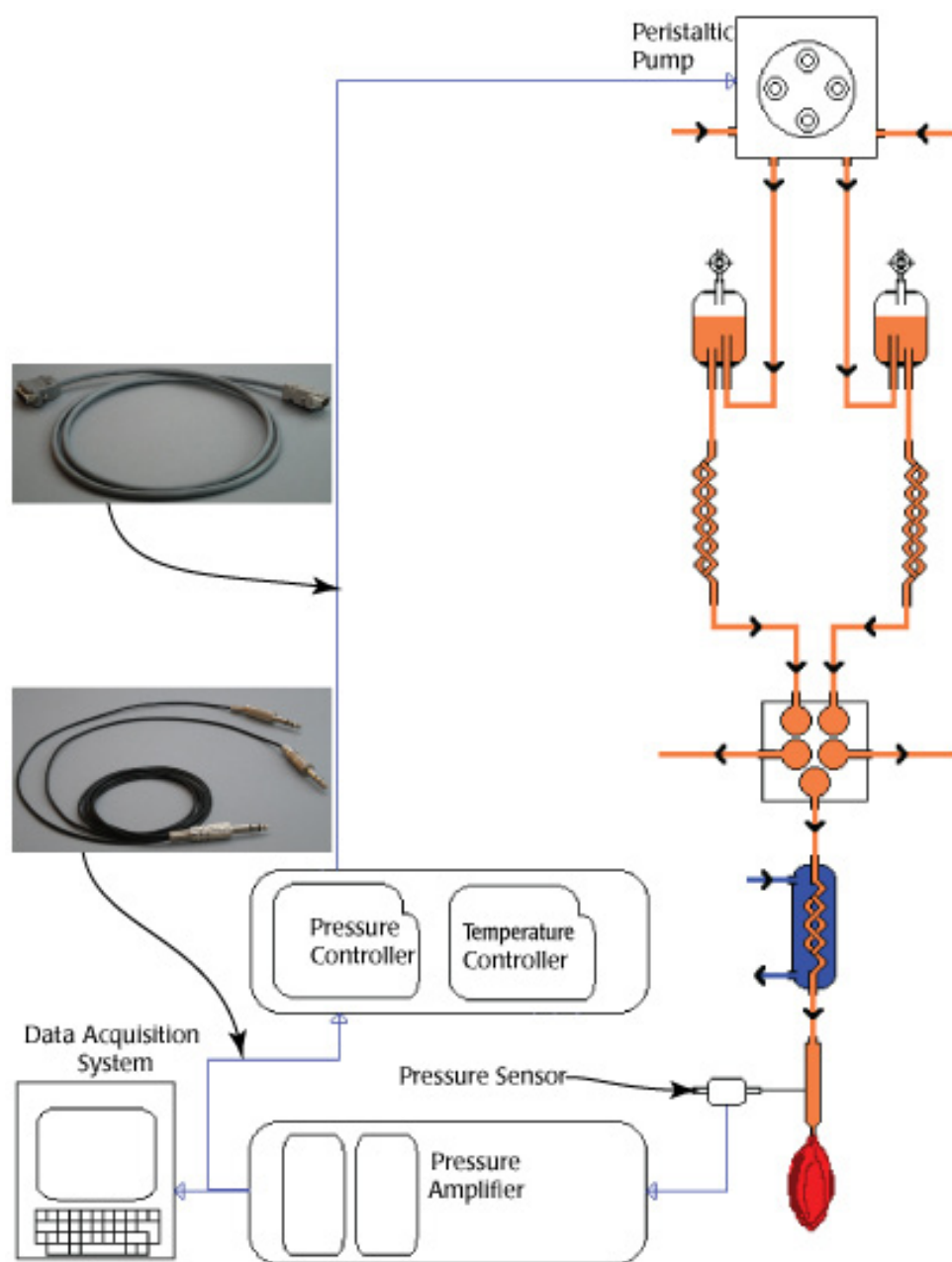


Fig. 23 This schematic diagram shows how the cables are connected.



1. Connect the plug on the cable of the perfusion (aortic) pressure sensor to the input port on the back of the pressure sensor amplifier.
2. Locate the special Y cable used to connect the output of the pressure sensor amplifier to the Pressure Controller and the recording system at the same time.

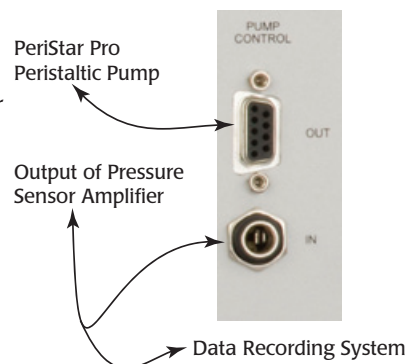


*Fig. 24 The Y cable that connects the output of the pressure sensor amplifier to the Pressure Controller and recording system has two branches.*

3. Connect the plug on the single end of the Y cable to the output jack of the pressure sensor amplifier.

*Fig. 25 (Right) The connections for the Pressure Sensor Amplifier and the pump are located on the back of the Pressure Controller.*

4. Connect one of the plugs on the double end of the Y cable to the input channel of the recording system that is dedicated to monitoring the perfusion pressure.
5. Connect the remaining plug on the double end of this cable to the **Input of the Pressure Controller** jack on the back of the Temperature/Pressure Controller.
6. Locate the D-sub cable that is used to connect the Pressure Controller to the pump.



*Fig. 26 The D-sub cable has a 9-pin connector and a 15-pin connector.*

7. Connect the 9-pin connector on this cable to **Pump Control Out** socket on the back of the Pressure Controller.
8. Connect the 15-pin connector on this cable to the socket on the back of the WPI PeriPro pump.

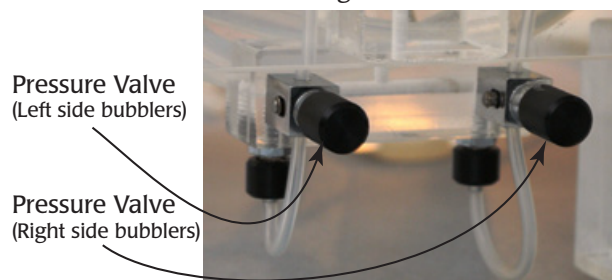


**CAUTION:** The Pressure Controller (PC) unit is specifically designed for controlling WPI PeriPro pumps. This Pressure Controller cannot be used with other brands of peristaltic pumps. Please contact technical support ([technicalsupport@wpiinc.com](mailto:technicalsupport@wpiinc.com)) if you have any questions.

### Connecting the Carbogen Supply

To maintain the health of the heart placed in this system, the perfusion solution must be saturated with a mixture of oxygen (95%) and carbon dioxide (5%) that is often called carbogen. When bubbled through the perfusion fluid, carbogen increases the concentration of oxygen dissolved in the fluid and automatically maintains the pH of the solution at the proper level (7.4). The perfusion fluid must not only be bubbled while it is inside the reservoirs, but also while it is in the supply container in order to maintain concentrations and pH.

1. Procure a cylinder containing a certified mixture of carbogen (95% Oxygen, 5% Carbon Dioxide). Verify that the cylinder is equipped with a two-stage regulator to reduce the pressures used in this oxygenation system to a controllable level. The regulator needs a small needle valve on its outlet to further reduce the pressure of the carbogen entering the Compact Langendorff unit.
2. Connect the carbogen inlets on the right side of the Compact Langendorff unit to the outlet of the compressed carbogen cylinder.
3. Connect the auxiliary bubbling stone and its tubing, which are provided with the system, to the outlet of the carbogen cylinder.
4. Place the bubbling stone in the supply container filled with perfusion fluid. Begin bubbling carbogen through the perfusion fluid stored in this container.
5. Once the reservoirs are filled with perfusion fluid, open the carbogen valves on the side of the Compact Langendorff unit. The valve on the left controls the bubblers in the reservoirs on the left side of the unit, and the valve on the right controls the bubblers in the reservoirs on the right.



*Fig. 27 The pressure valves on the side of the Compact Langendorff control the carbogen bubblers in the reservoirs.*

### Filling the Perfusion Reservoirs

When performing a typical experiment with a Compact Langendorff system, 4–6L of perfusion fluid are required.

1. Make enough perfusion solution as required for the species being studied and the experiments being conducted.
2. Place the perfusion fluid in the supply container and begin bubbling carbogen through it as soon as possible.

3. Check that the tubes on the pump used to move the perfusion fluid to the inlets (Filling Pump In-3, 15) are below the surface of the perfusion fluid stored in the supply container.
4. Check that the tubes on the overflow outlets (Filling Pump Overflow- 4, 14 and Overflow-5, 13) are above the surface of the perfusion fluid in the supply container.
5. Set the **Remote** switch on the front of the Pressure Controller (**PC**) to the **Off** position. The controls on the front of the pump can now be used to control the speed of the pump and the speed of filling the reservoirs with perfusion fluid.
6. Turn the left and right valve taps on the front of the Compact Langendorff unit to the **Filling of Column** position. If one side of the apparatus does not need to be used, turn the valve tap on that side of the unit to the **Overflow** position or simply disconnect the inlet and overflow tubes from that side of the unit.

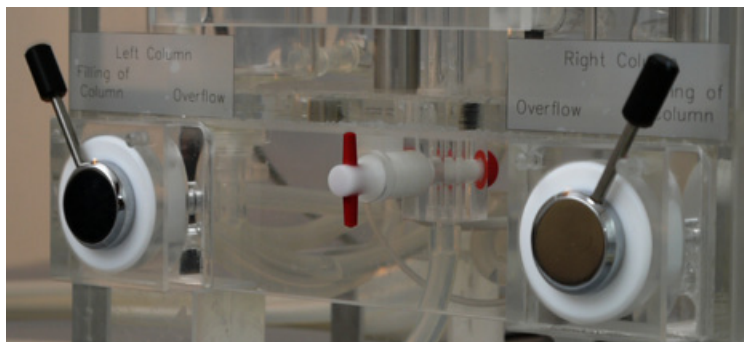


Fig. 28 The taps are set in the Filling of Column positions.

7. Set the valve tap on the top of the unit to the **Closed** position.

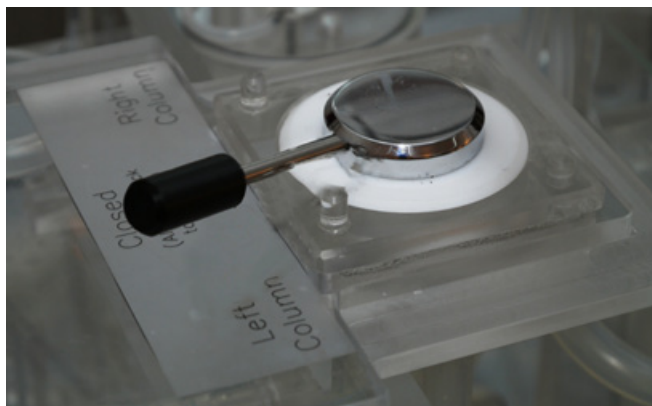


Fig. 29 Set the tap in the center position (Closed).

8. Start the pump.

9. During the filling process, the elastic chambers (Fig. 31) on the back side of the unit are also filled. When the elastic chamber are filled properly, they have a column of air above the fluid in the chamber. The column of air dampens the pulsation of the fluid caused by the pump. The dampening makes it easier to measure pressures and faster to adjust the Pressure Controller.
- To leave a column of air above the fluid in the elastic chamber, open the stopcock on the top of the chamber before filling it with perfusion fluid. Close the stopcock when the solution level reaches the maximum level marked on the chamber.
  - If the maximum level has been exceeded, stop the pump. Connect a large syringe to the stopcock on the top of the elastic chamber. Use the syringe to extract as much fluid as needed to lower the fluid level to the maximum line. Close the stopcock and remove the syringe. Repeat the process, if needed, on the other elastic chamber.



*Fig. 30 The elastic chambers are located on the back of the Compact Langendorff.*

10. When the perfusion fluid reaches the maximum levels in the reservoirs, continue to run the pump. The excess solution is returned to the buffer supply container through the overflow tubes.
11. Make sure that there are no bubbles in any of the tubing that is part of the perfusion system.

## OPERATING INSTRUCTIONS

**CAUTION:** Do not turn on the Temperature/Pressure Controller unless the water jacket of the Compact Langendorff chamber is filled with distilled water. Also, do not drain the water from the water jacket until the heater has been off for at least 15 minutes. Improper use of the heating system can damage the heating coils, as well as the Compact Langendorff bath itself.

### Starting the Temperature Control System

The Temperature Controller (TC) is a module contained in the same unit as the Pressure Controller (PC). It is designed to maintain the temperature of the Compact Langendorff unit within  $\pm 0.1^{\circ}\text{C}$  of the temperature setpoint.

**CAUTION:** The temperature control system was calibrated at the factory. Do not rotate the **High** and **Low** trim potentiometers on the front of the temperature control unit unless the temperature sensor is replaced.

### Setting the Temperature of the Langendorff System

1. Verify that the water jacket of the **SI-LANGC** chamber is filled with water and the perfusion system is properly connected before turning on the Temperature/Pressure Controller. See "Filling the Water Jacket of the Compact Langendorff" on page 18.
2. Turn on the Temperature/Pressure Controller. Looking at the unit from the front, the power switch is on the right side of the back panel. If powered properly, both green LEDs (+15V and -15V) on the right front panel of the controller are illuminated.
3. On the Temperature Control (TC) module, set the **Display Select** switch to the **Setting** position (down). The LED display shows the temperature setpoint.



*Fig. 31 The Temperature Control module has the Display Select switch in the Setting (down) position.*

4. Rotate the ten-turn potentiometer knob on the module to set the proper temperature needed in the Compact Langendorff chamber. Turning the knob clockwise increases the temperature setpoint. The temperature setpoint is shown on the LED display.
5. Set the **Display Select** switch to the **Measure** position (up). The LED display shows the actual temperature in the Compact Langendorff chamber.

6. When the Compact Langendorff chamber heater is on, the red **Heat LED** on the front panel illuminates. For example, the LED is lit until the temperature in the chamber reaches the temperature setpoint.

### Warming the Compact Langendorff System

1. Warm up the system for 45–60 minutes before beginning the isolation of the heart that will be studied.
2. After a suitable warm-up period, set the **Display Select** switch to **Measure** and determine if the system has reached the desired temperature for the experiment.
3. If the system has not reached the desired temperature, allow the system to warm for an additional 5–10 minutes and check the temperature of the system as performed in Step 2.
4. If the system has not reached the desired temperature after additional time, increase the temperature setpoint an amount that will compensate for the difference between the desired temperature and the setpoint.

### Recalibrating the Temperature Controller (Sensor Replacement)

The Temperature Controller only needs to be calibrated when a sensor is replaced.

1. Before installing a new temperature sensor in the Compact Langendorff unit and filling it with water, connect the temperature sensor to the input of the temperature control module.
2. Fill two 400mL beakers with distilled water. Set the water temperature of one to about 25°C and the other 40°C. Suspend a mercury thermometer in each beaker.
3. Place the sensor into the colder solution first. The sensor should not contact the wall of the beaker. Place the sensor near the end of mercury thermometer.
4. Measure the temperature of the water in this beaker. Wait until the value on the display of the Temperature Controller does not change.
5. Set the value displayed on the Temperature Controller equal to the value measured by mercury thermometer by rotating the **Low** trim potentiometer.
6. Repeat Steps 4–6 while the temperature sensor is in the beaker containing the warmer water. Rotate the **High** trim potentiometer to adjust the display to the temperature measured by the mercury thermometer.
7. Once the sensor is calibrated, replace the sensor in its port on the back of the Compact Langendorff unit.

### Starting Up the Pressure Control System

The Pressure Controller (**PC**) is a module in the same unit as the Temperature Controller (**TC**). The **PC** uses a feedback loop to monitor the pressure in the aortic cannula and maintain the perfusion pressure at a constant level by adjusting the speed of the peristaltic pump used to generate the pressure.



Fig. 32 The Pressure Controller module has a four line display.



**CAUTION:** The Pressure Controller (**PC**) is specifically designed for use with WPI PeriStar Pro pumps. It is not advisable to use this controller with any other peristaltic pump. If you have any technical question, contact Technical Support.

## Setting and Maintaining the Perfusion Pressure

When it is connected to the Pressure Controller, the peristaltic pump that is used to deliver perfusion fluid to the heart can be operated in either constant flow or constant pressure mode.

- With the **Remote** switch on the front of the Pressure Controller in the **Off** position, the controller is inactive, and the pump works in constant flow mode according to settings programmed into the pump itself.
  - With the **Remote** switch in the **On** position, the controller is active and the pump works in constant pressure mode according to the settings programmed into the Pressure Controller and input from a pressure sensor.
1. When the Pressure Controller is active, the main display screen shows:
    - Line 1: Name of the controller and the version number of the controller program.
    - Line 2: Perfusion pressure (**Set**) selected by the user. **On/Off** indicates whether the pump is running or not.
    - Line 3: Actual pressure (**Press**) measured by the pressure sensor.
    - Line 4: Strength of the pump controller's signal.

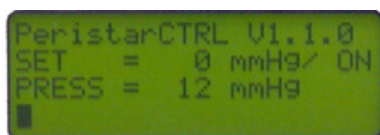


Fig. 33 The Pressure Controller shows pertinent information about the peristaltic pump.

2. Adjust the settings by using the four buttons below the screen display:
  - **Up** or **Down** push buttons adjust the perfusion pressure setpoint.
  - **Pump On/Off** button turns the pump on or off. At the end of Line 2 on the initial screen, **On** or **Off** indicates the pump status.
  - The **Menu** button opens the submenu where various functions of the Pressure Controller are set. Push the **Menu** button to step between the various functions in the submenu where the settings can be modified.
  - The **Menu Back** button steps back to a function in the submenu or returns to main menu from the submenu.



3. Every perfusion system has its own pressure dynamics which requires responsiveness of the Pressure Controller and pump to be tuned for the characteristics of the perfusion system. Push the **Menu** button to open the submenu where the values for various parameters of the Pressure Controller can be set.



Fig. 34 The submenu screen uses abbreviations for the system parameters.

The values for the following parameters are set and displayed on the submenu:

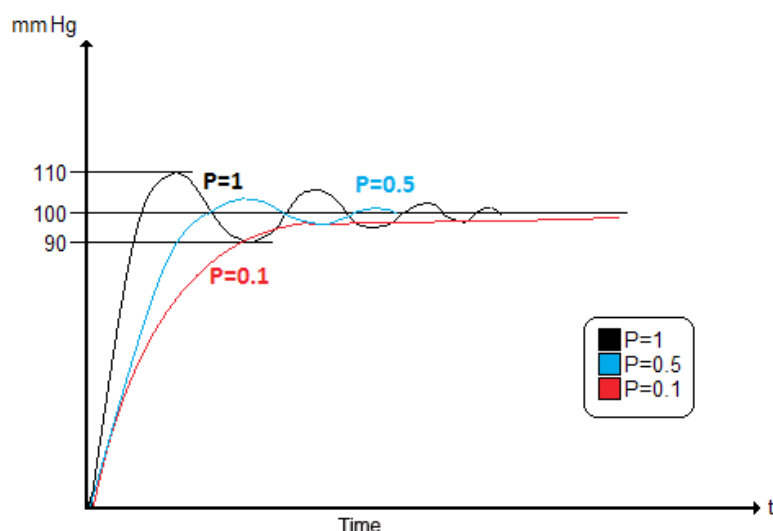
SE	Set value, the perfusion pressure setpoint selected by the user that also appears on the main display
PR	Press value, the perfusion pressure measured by the sensor. This value also appears on the main display.
PU	Actual pressure generated by the peristaltic pump
P	Proportional parameter that controls the responsiveness of the Pressure Controller to differences between the setpoint ( <b>Set</b> ) and actual ( <b>Press</b> ) pressures. Higher <b>P</b> values increase the speed with which the pump responds to changes in pressure detected by the sensor, but the actual pressure oscillates significantly above and below the intended pressure while the pressure is adjusted. Lower <b>P</b> values decrease the speed with which the pump responds to pressure changes, but the pressure oscillations are dampened out (See Fig. 35).
START	Time the start of the pump is delayed
I	Integral parameter that minimizes the deviation in pressure not controlled by the <b>P</b> value. Higher <b>I</b> values increase the degree of control that the pump has over the pressure adjustments. The <b>I</b> parameter works together with the <b>It</b> (I timing) parameter.
It	Rate of change of the <b>I</b> value. Higher <b>It</b> values slow down the fluctuations in the pump speed by increasing the time over which the <b>I</b> value is implemented. With higher <b>It</b> values, sudden jumps in pressure are reduced through reductions in the amplitudes of pressure oscillations and increases in the periods of the oscillations.
delta	Difference between the setpoint and measured pressure values ( <b>Set</b> – <b>Press</b> ).
i	The integrator value provides information used for troubleshooting and servicing of the Pressure Controller.
F or R	Controls the direction of rotation (Forward/Reverse) of the pump
S	Save function for preserving adjustments to the parameters of the Pressure Controller





Even though the pump is operated by a Pressure Controller designed to maintain the perfusion pressure at a constant level, it is not possible to generate a constant perfusion pressure, because of the design of the perfusion system. Parts of the system, like the tubes that have different diameters and lengths, increase flow resistance of the system. The pump itself causes fluctuations in the perfusion pressure, because of its design. The Pressure Controller used to control the pump minimizes the amplitude and frequency of the fluctuations, but the controller cannot eliminate them. Minimal fluctuations still exist, because the pump generates the pressure pulses and the properties of the perfusion solution make it difficult to move through the system smoothly.

For example, if the perfusion pressure is set (**Set**, **SE**) to a value of 100mmHg and the fluctuation (**delta**) is set to  $\pm 10$ mmHg, different **P** values (high, moderate, low) affect the oscillation of the measured pressure. As shown in Fig. 35, the largest **P** value (1) permits the controller and pump to respond to pressure difference very quickly, but with a higher oscillation amplitude. The smallest **P** value (0.1) eliminates oscillations, but requires a good deal of time to reach the **Set** value. The moderate **P** value (0.5) permits the pressure to reach the **Set** value quickly and with smaller oscillations.



*Fig. 35 This graph shows the responsiveness and oscillation of a system with several different proportional control parameters (P).*

The following ranges of values are recommended when the perfusion system is initially set up. The exact values of these parameters that work best on your system depend on the location of the tubing, the lengths of the inlet and outlet tubes and the flow rate of the pump.

**P** set between 0.02 and 0.1

**I** set between 0.02 and 0.1

**It** set between 0.05 and 0.5

When setting the pump controller parameters for the first time:

- The **P** and **I** parameters should be set to small values. If the values are too large, the pump will generate pressure pulses with high amplitudes.
- The **It** parameter should be set to a moderate value. This value could eventually be set to several seconds so that the pump modifies the pressure changes slowly, preventing sudden pressure increases.
- When the perfusion system is started initially, large pressure pulses occur until the Pressure Controller reaches operational efficiency. To prevent large pressure pulses, it is important to begin with lower pressure setpoints, and then increase the pressure setpoint step by step until the desired pressure value is reached. Begin with a pressure setpoint that is 20-30% lower than the desired setpoint. After the Pressure Controller is operating efficiently (approximately 2–3 minutes after startup), slowly increase the pressure setpoint until the desired value is reached.

To set the parameters of the Pressure Controller:

1. Press the **Menu** button to move from function to function on the submenu. To step back to a previous function, press the **Menu Back** button.
2. When the first character in the name of the parameter begins blinking, the value of the parameter can be changed. Use the **Up** or **Down** buttons to change the value of the parameter.
3. The **Pump On/Off** function cannot be used from the submenu. Return to the main menu to use this function. To return to the main menu, push the **Menu** or the **Menu Back** button until the blinking cursor reaches either the upper left or lower right corner of the submenu. The next push of the same button returns to the main menu.

## Operating the Valve Taps

The two valve taps on the front of the Compact Langendorff unit and the one on the top of the unit control the flow of perfusion fluid to and from the perfusion reservoirs. Because of the way the valve taps, the reservoirs and the peristaltic pump used to fill the reservoirs are connected to each other, the operation of the perfusion system is highly automated. Even when the perfusion circuit is closed and the pump is still running, the perfusion fluid is automatically diverted into an overflow system that returns the fluid to the supply container. This prevents the perfusion system from being pressurized to a level that might cause its fluid filled tubing to separate from any fittings.

**NOTE:** The valve taps are not designed to control the flow rate of the perfusion fluid. The flow rate is controlled by the speed of the peristaltic pump, which is adjusted from the control panel of either the pump or the Pressure Controller.

The valve taps on the front of the unit, which are labeled Left Column and Right Column, are not connected to each other. This configuration permits the pair of reservoirs on the left side of the Langendorff unit to be operated independently of the pair of reservoirs on the right side of the unit. Both of these taps have two functions:

- When the tap is set to the **Filling of Column** position, the perfusion reservoirs are filled continuously by the action of the peristaltic pump. Any excess perfusion fluid returns to the buffer supply container through the overflow tubes (5, 13).

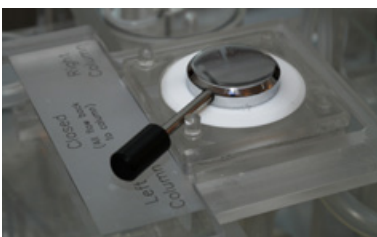
- When the tap is set to the **Overflow** position, the perfusion reservoirs are no longer being filled. Likewise, any excess perfusion solution returns to the buffer supply container through the overflow tubes.



*Fig. 36 The valve taps on the front of the unit control the filling of the perfusion reservoirs.*

The valve tap on the top of the Compact Langendorff unit controls the flow of perfusion solution to the heart and the reservoirs from which the perfusion buffer is taken.

- When the tap is set to the **Left Column** position, the perfusion buffer from the reservoirs on the left side of the Compact Langendorff unit is sent to the heart.
- When the tap is set to the **Right Column** position, the perfusion buffer from the reservoirs on the right side of the Compact Langendorff unit is sent to the heart.
- When the tap is set to the **Closed** position the perfusion solution returns to the perfusion reservoirs through the overflow tubing controlled by this valve tap.



*Fig. 37 The tap on the top of the unit controls the flow of perfusate through the heart.*

### Typical Perfusion Solution

The composition of the perfusion fluid is one of the most critical factors in maintaining the health of an isolated heart. The perfusion fluid needs to have the proper ionic concentrations, pH, energy source, oxygen level and temperature. Because a typical perfusion buffer does not contain proteins like blood, the concentrations of ions in the perfusion solution are usually adjusted to create a buffer that matches the osmolarity of blood. A typical perfusion buffer for mammalian hearts contains:

- |                                   |            |                             |
|-----------------------------------|------------|-----------------------------|
| • NaCl                            | 118.5mM    |                             |
| • KCl                             | 4.7mM      |                             |
| • MgSO <sub>4</sub>               | 1.2mM      |                             |
| • KH <sub>2</sub> PO <sub>4</sub> | 1.2mM      |                             |
| • CaCl <sub>2</sub>               | 2.5mM      |                             |
| • NaHCO <sub>3</sub>              | 25.0mM     | Bicarbonate buffering agent |
| • Glucose                         | 5.5–11.0mM | Energy source               |

Once the buffer solution is brought to its final volume, the pH of the perfusion buffer can be brought to 7.4 by bubbling a mixture of 95% O<sub>2</sub> (722mmHg P<sub>O<sub>2</sub></sub>) and 5% CO<sub>2</sub> (38mmHg P<sub>CO<sub>2</sub></sub>) gases through the solution while it is stored in the supply container.

Additional substances that improve the normal metabolism of the heart can be added to the perfusion buffer when it is being formulated:

- Insulin improves the uptake of glucose, fatty acids or pyruvate by the heart.
- Dextran and protein fractions improve the buffer's osmotic properties.
- Washed red blood cells, or increased P<sub>O<sub>2</sub></sub> levels during bubbling, increase the oxygen carrying capacity of the solution.

### Check List

Before preparing the tissue to be used in the Compact Langendorff unit and taking measurements, check the items on the following list to make sure the system is ready:

1. Verify that the water jacket is filled. See "Filling the Water Jacket of the Compact Langendorff" on page 18.
2. Turn on the heaters and circulating pump. Set the temperature of the water jacket to 37°C. It takes about 30 minutes for the system to reach that temperature. See "Starting the Temperature Control System" on page 25.
3. Run distilled water through the perfusion system. See "Filling the Perfusion Reservoirs" on page 22.
4. Prepare the perfusion solution. Bubble it with carbogen to set the pH.
5. Fill the apparatus with perfusion solution. Set the proper bubbling. Purge bubbles from the tubing and cannula.
6. Prepare ice cold (4°C) perfusion solution for isolating the heart.
7. Prepare the proper surgical tools for:
  - Chest opening (curved forceps and surgical scissors)
  - Fixing the heart to the cannula (two small, curved forceps)
  - Residual tissue removal and shaping of the aorta (fine scissors)
8. Prepare ligature on the perfusion cannula for fixing the heart to the unit.
9. Evacuate all fluid and air from left ventricular balloon so that it can be easily placed into the ventricle.
10. Calibrate the pressure transducers (and flow sensors). Refer to the documentation that came with the your flow sensors for instructions.
11. During the attachment of the heart, set the flow rate of perfusion fluid from the aortic cannula to a low level. See "Setting and Maintaining the Perfusion Pressure" on page 27.



## **MAINTENANCE**

### **Cleaning**

The system should be carefully cleaned after an experiment is finished.



**CAUTION:** Do not add any antibacterial agents or other chemicals to the distilled water in the jacket. The plastic components of the chamber or the heating regulating circuitry could be damaged from prolonged exposure to certain chemicals containing alcohols, acids or detergents.

1. Remove the LVP balloon cannula from the left side of the heart. Remove the heart from the aortic cannula. Dispose of the heart and any other tissue in an approved manner.
2. Make sure the tubing on the drain of the heart chamber is placed in a liquid waste container that is positioned below the level of the drain. Open the drain valve to collect any perfusion buffer that comes out of the aortic cannula.
3. Remove unused perfusion buffer from the reservoirs.
  - Close the valve taps on the front of the Langendorff by moving them to the **Overflow** positions. Close the valve tap on the top of the unit by positioning it in the **Closed** (center) position.
  - Raise the ends of the buffer inlet tubing (3, 15) above the surface of the liquid in the buffer supply reservoir. Make sure the ends of the overflow tubes (4, 5, 13, 14) are also above the surface of the liquid in the same container.
  - Remove the buffer inlet (3, 15) and heart filling (6, 7, 11, 12) tubes from the pump.
  - Open the valve taps on the front of the unit by moving them to the **Filling of Column** positions. Unused perfusion buffer will start to drain from the system. Set the valve tap on the top of the unit to the **Left Column** position. The flow of unused buffer from the left column should increase.
  - When the flow from the left side of the unit stops, switch the valve tap on the top to the **Right Column** position to drain additional buffer from the right column.
4. Use the pump to remove any perfusion buffer that remains in the system.
  - Place the buffer inlet (3, 15) tubes back in the pump. Make sure the ends of these tubes are out of the buffer supply container.
  - Make sure the front valve taps are in the **Filling of Column** positions, and the top valve tap is on the **Left Column** position.
  - Turn on the pump to move air through the left and right columns and the overflow tubes, the preheater and the aortic cannula.
  - Once the left side of the unit is purged of fluid, switch the top valve tap to the **Right Column** position to purge any remaining buffer from the right side of the unit.
5. Rinse the perfusion system with 2–3 complete changes of distilled or deionized water. Each change of water requires about 4L.
  - Make sure the buffer inlet (3, 15) tubes are in the pump. Place the ends of these

- tubes in a container filled with about 4L of fresh distilled or deionized water.
  - Place the ends of the overflow and drain tubes in a waste liquid container.
  - Turn on the pump to move deionized or distilled water through the perfusion system.
  - Make sure the top valve tap is open to either the **Right** or **Left Column** position during this rinsing.
6. Use the pump to remove any distilled water that remains in the system.
    - Make sure the ends of the buffer inlet tubes (3, 15) are out of the fresh distilled water container.
    - Make sure the front valve taps are in the **Filling of Column** positions, and the top valve tap is on the **Left Column** position.
    - Turn on the pump to move air through the left and right columns and the overflow tubes, the preheater and the aortic cannula.
    - Once the left side of the unit is purged of distilled water, switch the top valve tap to the **Right Column** position to purge any remaining water from the right side of the unit.
  7. Flush or rinse all other components that have been in contact with physiological buffers at least 2–3 times. These items include:
    - Pressure transducers and their stopcocks
    - Heart chamber drain and its stopcock
    - Aortic cannula and its side ports
    - LVP balloon cannula, both inside and out
    - Surgical instruments
    - Stimulating and recording electrodes
  8. Change the distilled water in the jacket that surrounds the reservoirs and the other components of perfusion system at least weekly or when contaminated with any biological material (blood, tissue).



## ACCESSORIES

Part Number	Description	Comment
<b>SI-SEN12AM4E-U</b>	Manipulator with removable head (Unipolar electrode)	Select unipolar for stimulating/pacing, or bipolar for recording signals or surface potentials
<b>SI-SEN12AM4E-B</b>	Manipulator with removable head (Bipolar electrodes)	
<b>SI-SEN07RTH2</b>	Temperature probe for measuring the temperature of the buffer entering or exiting the heart. Requires amplifier	Attach to a port on the heart suspension unit. Requires an amplifier
<b>SI-SEN13MAP</b>	12-electrode sensor for recording MAP (ECG) from different positions around the heart	Requires multi-channel amplifier for recording signals from the 12 leads in the sensor
<b>LABTRAX4-24T</b>	Lab Trax Data Recording	Possible signals to record: <ul style="list-style-type: none"> <li>• Perfusion (Aortic) pressure</li> <li>• Left ventricular/atrial pressure</li> <li>• Temperature</li> <li>• Flow</li> <li>• ECG</li> <li>• Muscle force</li> </ul>
<b>WPI-118</b>	Digital Data Recorder	
CALL the WPI sales team for information	Transonic Transit Time Modular Flow Meter, inline flow sensor and meter	Connect the output of the flow meter directly to the data recording system
<b>BRIDGE8</b>	Transducer Amplifier Module	Needed for recording from the pressure transducers and temperature sensor if <b>WPI-118</b> is used
<b>74030</b>	<b>ISDB</b> Chassis and Power Supply	Required for <b>BRIDGE8</b> modules
<b>TBM4M</b>	Transbridge Transducer Amplifier	Needed for recording from the pressure transducers and temperature sensor
<b>SI-KG20</b>	KG Force Transducer	<b>SI-KG20</b> transducers only work with the <b>SI-BAM21E</b> transducer amplifier
<b>SI-BAM21E</b>	Bridge Amplifier	Only controls <b>SI-KG20</b> transducers
<b>DAM 50</b>	Single channel bio-potential amplifier	Record surface potential (composite ECG) from the heart with ball-mounted bipolar electrodes
<b>A385</b>	High Current Isolator	For stimulating or pacing the heart

## TROUBLESHOOTING

Issue	Possible Cause	Solution
Pressure/ Temperature Controller has no power	The power switch is off.	Verify that the power switch on the back of the unit is in the <b>On</b> position
	The power cord is loose or not connected properly to the AC wall outlet.	Unplug the power cord from the wall and the chassis and re-install it.
Pressure Sensor amplifier has no power	The power switch is off.	Verify that the power switch on the back of the unit is in the <b>On</b> position
	The power cord is loose or not connected properly to the AC wall outlet.	Unplug the power cord from the wall and the chassis and re-install it.
Peristaltic pump(s) have no power	The power switch is off.	Verify that the power switch on the back of the unit is in the <b>On</b> position
	The power cord is loose or not connected properly to the AC wall outlet.	Unplug the power cord from the wall and the chassis and re-install it.
Peristaltic pump fails to maintain pressure in setpoint range in constant pressure mode	Remote switch on the front of the controller is in the <b>Off</b> position.	Verify that the <b>Remote</b> switch is in the <b>On</b> position
	The pressure sensor is not connected to Pressure Amplifier correctly.	Check the cabling between the perfusion pressure sensor and the transducer amplifier.
	The Pressure Amplifier is not connected to the Pressure Controller properly.	Check the cabling between the transducer amplifier and the Pressure Controller.
Heating system fails to maintain temperature setpoint in the heart chamber	The power switch is off.	Verify that the power switch on the back of the unit is in the <b>On</b> position.
	The power cord is loose or not connected properly to the AC wall outlet.	Unplug the power cord from the wall and the chassis and re-install it.
	The cables for the heating coils are not connected to the Temperature Controller properly.	Check the cabling between the heater coils of the unit and the Temperature Controller. The two power LEDs on the front of the controller should illuminate when the desired temperature is higher than the current temperature of the water.
	The cable for the temperature sensor is not connected to the Temperature Controller properly.	Check the cabling between the temperature sensor and the Temperature Controller.





Heart rate of the isolated heart is lower than the normal heart rate and decreasing with time	The heart rate never reaches a steady rate after 20-25 minutes of equilibration. The heart has undergone ischemia caused by a lack of oxygen in the heart tissue (hypoxia).	The end of the perfusion cannula is positioned below the inlets of the coronary arteries. The cannula is inserted too far into the aorta. Lower the position of the heart on the cannula. If the heart activity does not increase, replace the heart.
		The aortic valve was damaged during the isolation and mounting of the heart. Perfusion fluid is going to the left ventricle and not the coronary arteries. Replace the heart.
		The $P_{O_2}$ of the perfusion buffer is too low. The perfusion buffer is not carrying enough oxygen. Increase the aeration of the perfusion buffer.
		The pH of the perfusion buffer is incorrect. Check the recipe used to make the buffer. If the solution is correct, increase the aeration of the buffer to improve the dissolved oxygen concentration of the solution.
		Make sure the buffer supply reservoir is well aerated with carbogen to prevent the precipitation of calcium carbonate. If the pH is correct and calcium carbonate still precipitates, cut the calcium ion concentration of the buffer in half (2.5–>1.25 mM).
<p><b>NOTE:</b> If you have a problem/issue with that falls outside the definitions of this troubleshooting section, contact the WPI Technical Support team at 941.371.1003 or <a href="mailto:technicalsupport@wpiinc.com">technicalsupport@wpiinc.com</a>.</p>		

SPECIFICATIONS

This instrument conforms to the following specifications:

Width.....	600mm
Length.....	800mm
Height.....	2550mm
Weight .....	80kg

GLOSSARY

**12-lead MAP sensor**–12-electrode sensor (shown at the right) for recording monophasic action potential (ECG) from different positions around the heart. This is an optional accessory of the **SI-LANGC** system.



**balloon catheter**–A small fluid-filled latex balloon (shown at the right) placed on the end of a metal catheter that is equipped with a pressure transducer. The balloon is normally inserted into the left ventricle and inflated using a syringe to set the diastolic pressure of the ventricle. As the ventricle contracts, its walls press on the balloon creating pressure in the catheter that is measured by the sensor. The pressure created by the contraction of the ventricle is the systolic pressure.



**bipolar electrode**–Sensor placed on the surface of the heart for recording surface potentials from the cardiac musculature.

**cannula**–A small tube inserted into a body, organ, vein, etc. to deliver fluid. In some cases a cannula can also be used to withdraw fluid. When using the **SI-LANGC** system, the cannula that is located on the bottom of the heart suspension unit is inserted into the aorta of the heart under study.

**carbogen**–A mixture of oxygen (95%) and carbon dioxide (5%). When bubbled through the perfusion fluid, carbogen increases the concentration of oxygen dissolved in the fluid and automatically maintains the pH of the solution at the proper level (7.4).

**Langendorff mode (retrograde flow)**– In Langendorff mode, an excised heart is perfused through the aorta so that the fluids run directly into the coronary circulation keeping the heart muscle alive. This pressure keeps the aortic valve sealed. The pressure transducer, which is mounted on the end of a cannula inserted into the heart suspension unit, measures the pressure used to drive the perfusion fluid through the coronary circulation originating at the proximal end of the aorta.

**Dextran**–A complex polysaccharide that can be added to perfusion fluid to increase its osmotic potential and viscosity.

**ECG (Electrocardiogram)**–Recording of the changes in the electrical potentials in heart musculature, sometimes taken from 3, 6 or 12 different points of view.



**elastic chamber**—Twin chambers on the back of the **SI-LANGC**. When filled properly, the chambers have a column of air above the fluid in the chamber. The column of air dampens the pulsation of the fluid caused by the pump.

**isulin**—A hormone produced in the pancreas which regulates carbohydrate and fat metabolism. When added to perfusion buffer, insulin improves the uptake of glucose, fatty acids or pyruvate by the heart.

**LVP**—Left ventricular pressure.

**MAP**—Monophasic action potential.

**osmolarity**—The concentration of solutes dissolved in solutions, like perfusion buffer, that contribute to the osmotic potential of the solution. Osmotic potential is the ability of a solution to drive the movement of water across membranes. To maintain isolated tissues and organs properly, the perfusion buffer should have the same osmotic potential (osmolarity) as blood.

**peristaltic pump**—A rotary pump with a series of rollers around the perimeter of its head. Fluid-filled flexible tubing, which is threaded through the rollers, is squeezed along the section of its length that is in contact with the rollers. As the rollers rotate, the fluid in the tubing is driven from one end of the tube to the other. The rate of head rotation and the size of the tubing determine the volume of fluid that can be pumped. The volume that can be pumped is limited only by the volume of the input source.

**perfusion fluid**—Buffered solution used to bathe tissues and organs to keep them alive. Perfusates need to have the proper ionic concentrations, pH, energy source, oxygen level and temperature. See "Typical Perfusion Solution" on page 31.

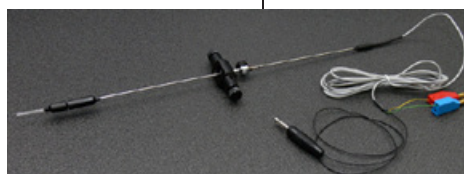
**PID control**—A PID control algorithm is used by the Temperature/Pressure Controller to maintain the desired value (setpoint) of a property (temperature or pressure). It is typically comprised of three primary control factors: Proportional, Integral and Derivative. A PID controller monitors the difference (delta or error value) between the actual sensor reading and the setpoint.

Measured in seconds/repeat, the integral control factor is set based on the recent changes in the error value. It is proportional to the size and duration of the error. Together the P and I control factors bring the system closer to the setpoint more quickly. If the integral time (ti) parameter is set too high, the process value will overshoot the setpoint.

- **Setpoint** - User selected value of the property (for example, temperature or pressure) the system attempts to maintain.
- **Delta**—The difference between the setpoint and actual measured value of the property; the error factor.
- **P**—Proportional parameter that controls the responsiveness of the controller to differences between the selected setpoint and actual pressures. Higher **P** values increase the speed with which the controller responds to changes detected by the sensor, but the actual value oscillates significantly above and below the intended setpoint while the value is adjusted. Lower **P** values decrease the speed with which the controller responds to changes, but the value oscillations are dampened out.

- **I**—Integral parameter that minimizes the deviation in value not controlled by the **P** value. Higher **I** values increase the degree of control that the pump has over the pressure adjustments. The **I** parameter works together with the **It** (I timing) parameter.
- **D**—Derivative control factor that minimizes the setpoint overshoot of proportional/integral control. It is the rate control mechanism. The derivative adjusts the property based on the rate of the actual temperature change. If the derivative value is set too high, the system becomes less responsive. The derivative parameter has two main functions. It provides fast action when the system has a large disturbance, and it reduces oscillation in the system. The larger the derivative time, the stronger its effect. Zero derivative time has no effect.

**unipolar electrode**—Electrode placed on tissue or muscle for stimulation. In this case, electrical pulses are passed down this electrode to the surface of the heart. The indifferent electrode towards which the stimulus pulse flows is the cannula placed in the aorta of the heart.



**Janiczky working heart mode**— Simple working heart mode in which the pressure measured by the transducer connected to the aortic cannula is the pressure generated by the left ventricle. In this mode, the pressure measured is the aortic pressure. During diastole, the aortic pressure is created by the segment of the system that mimics the systemic circulation. During systole, the rise in the aortic pressure is created by the contraction of the left ventricle.



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## WARRANTY

WPI (World Precision Instruments, Inc.) warrants to the original purchaser that this equipment, including its components and parts, shall be free from defects in material and workmanship for a period of one year\* from the date of receipt. WPI's obligation under this warranty shall be limited to repair or replacement, at WPI's option, of the equipment or defective components or parts upon receipt thereof f.o.b. WPI, Sarasota, Florida U.S.A. Return of a repaired instrument shall be f.o.b. Sarasota.

The above warranty is contingent upon normal usage and does not cover products which have been modified without WPI's approval or which have been subjected to unusual physical or electrical stress or on which the original identification marks have been removed or altered. The above warranty will not apply if adjustment, repair or parts replacement is required because of accident, neglect, misuse, failure of electric power, air conditioning, humidity control, or causes other than normal and ordinary usage.

To the extent that any of its equipment is furnished by a manufacturer other than WPI, the foregoing warranty shall be applicable only to the extent of the warranty furnished by such other manufacturer. This warranty will not apply to appearance terms, such as knobs, handles, dials or the like.

WPI makes no warranty of any kind, express or implied or statutory, including without limitation any warranties of merchantability and/or fitness for a particular purpose. WPI shall not be liable for any damages, whether direct, indirect, special or consequential arising from a failure of this product to operate in the manner desired by the user. WPI shall not be liable for any damage to data or property that may be caused directly or indirectly by use of this product.

## Claims and Returns

- Inspect all shipments upon receipt. Missing cartons or obvious damage to cartons should be noted on the delivery receipt before signing. Concealed loss or damage should be reported at once to the carrier and an inspection requested. All claims for shortage or damage must be made within 10 days after receipt of shipment. Claims for lost shipments must be made within 30 days of invoice or other notification of shipment. Please save damaged or pilfered cartons until claim settles. In some instances, photographic documentation may be required. Some items are time sensitive; WPI assumes no extended warranty or any liability for use beyond the date specified on the container.
- WPI cannot be held responsible for items damaged in shipment en route to us. Please enclose merchandise in its original shipping container to avoid damage from handling. We recommend that you insure merchandise when shipping. The customer is responsible for paying shipping expenses including adequate insurance on all items returned.
- Do not return any goods to WPI without obtaining prior approval and instructions (RMA#) from our returns department. Goods returned unauthorized or by collect freight may be refused. The RMA# must be clearly displayed on the outside of the box, or the package will not be accepted. Please contact the RMA department for a request form.
- Goods returned for repair must be reasonably clean and free of hazardous materials.
- A handling fee is charged for goods returned for exchange or credit. This fee may add up to 25% of the sale price depending on the condition of the item. Goods ordered in error are also subject to the handling fee.
- Equipment which was built as a special order cannot be returned.
- Always refer to the RMA# when contacting WPI to obtain a status of your returned item.
- For any other issues regarding a claim or return, please contact the RMA department

**Warning: This equipment is not designed or intended for use on humans.**

\* Electrodes, batteries and other consumable parts are warranted for 30 days only from the date on which the customer receives these items.

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