

# WeatherStation



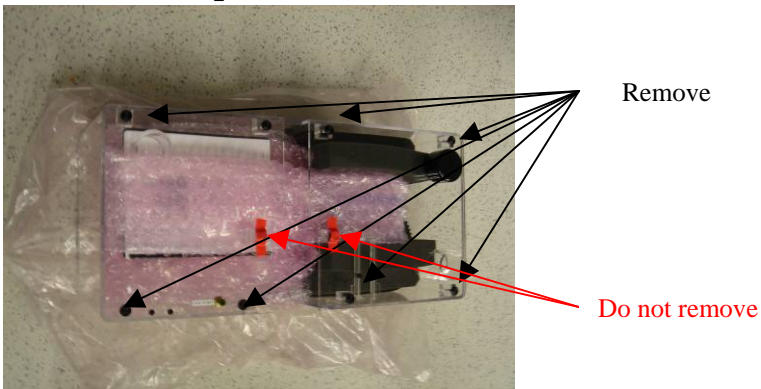
# User's Manual

## ENVIROMENTAL CHAMBER INSTALLATION INSTRUCTION

1. Unpack system.



2. Remove system from the box, and remove eight thumbscrews. **Note:** don not remove thumbscrews covered with red tape.



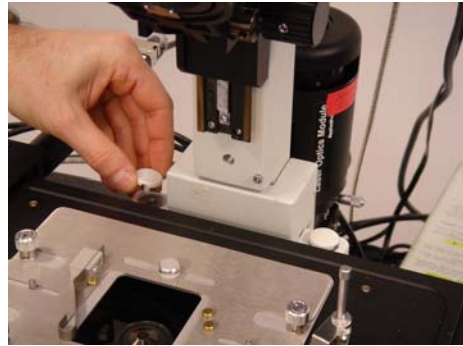
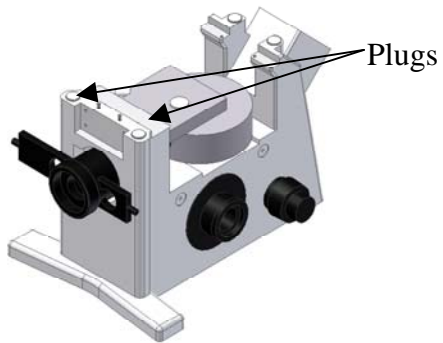
3. Using 3mm wrench remove microscope nosepiece as shown on picture below.



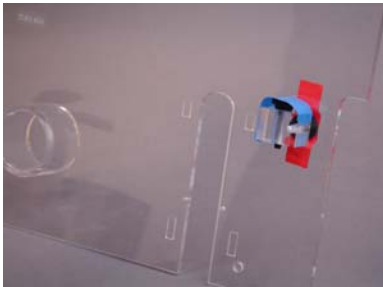
4. Remove camera cover.



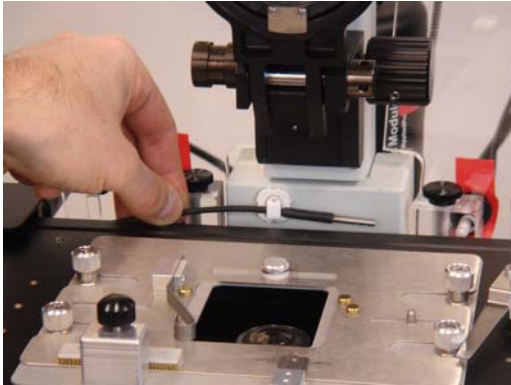
5. Remove two plugs from microscope stand (ref. picture bellow).



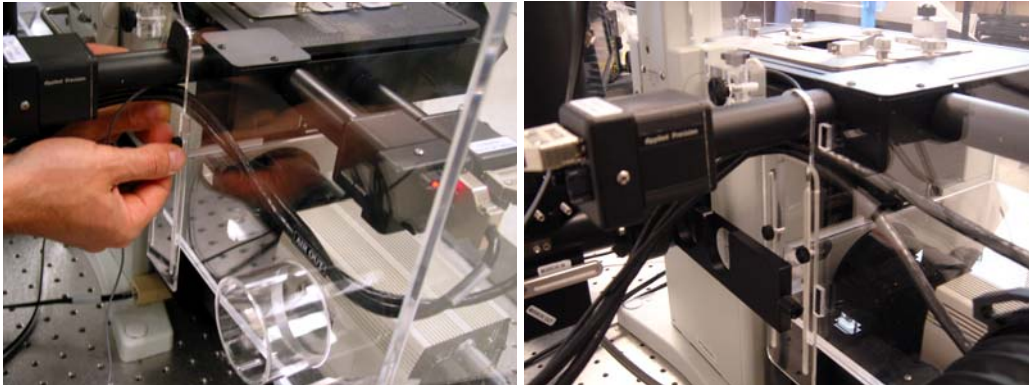
6. Remove back panels from chamber, and install them on the microscope base.



7. Remove Temperature controller from the chamber, install it next to the microscope base. Remove temperature control sensor from plastic bag secured on the top of temperature controller, and install it on the microscope pillar.



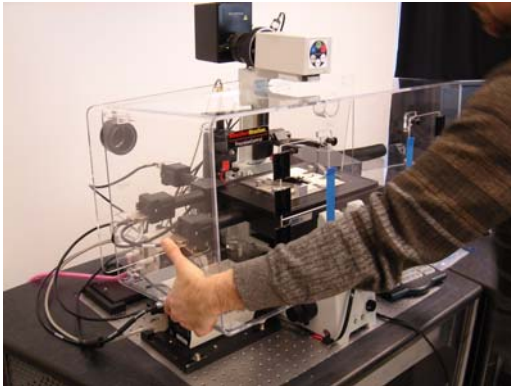
8. Route X & Z motor cables as well as temperature control sensor cable underneath Y motor. Install and secure Y motor cover plate with two M3x10 thumbscrews.



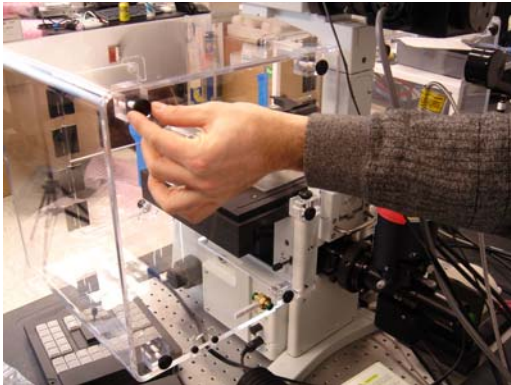
9. Lower all the way down DIC support unit. Secure microscope tower.



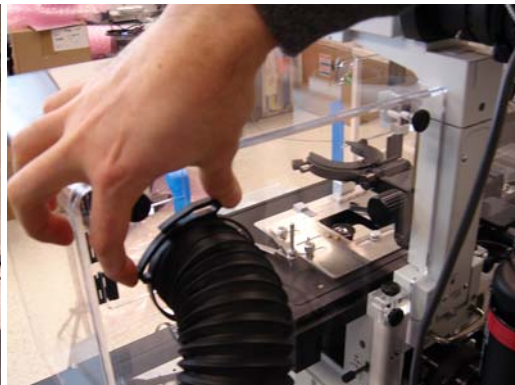
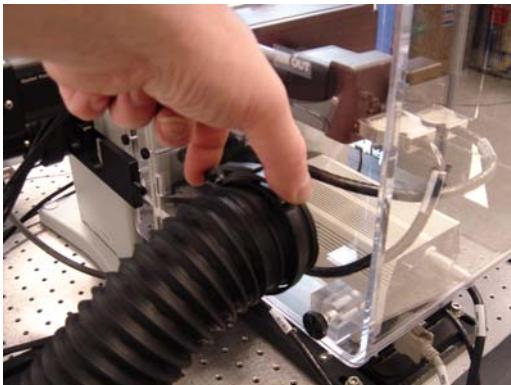
10. Carefully install main component. **Note:** Enclosure should be slightly tilted when installed.



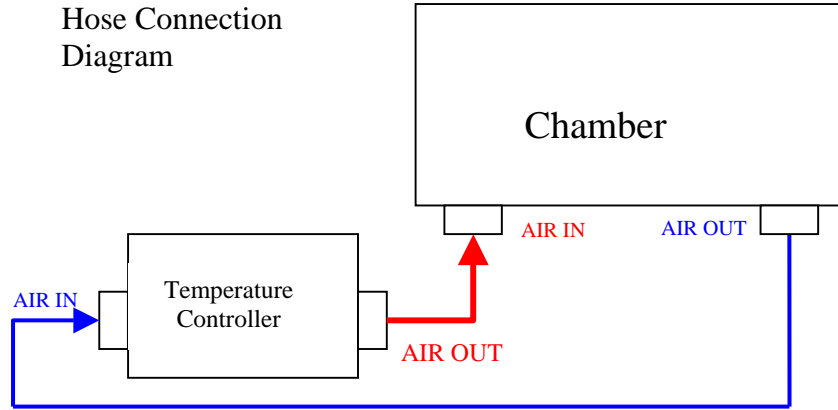
11. Using eight M6x20 thumbscrews secure back panels. **Note:** Tighten thumbscrews only after all of them have been installed.



12. Connect and secure two hoses to the hose connectors on the chamber. **Note:** reference diagram below for proper orientation.



Hose Connection  
Diagram



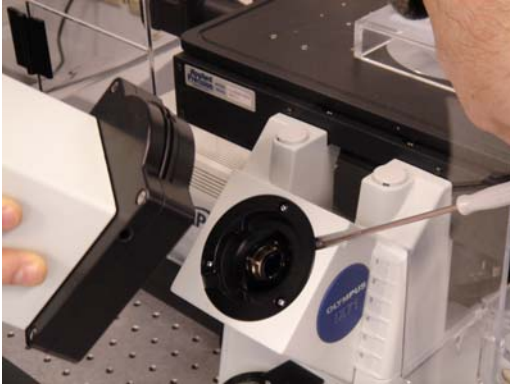
13. Connect temperature control sensor and power cable to temperature controller.



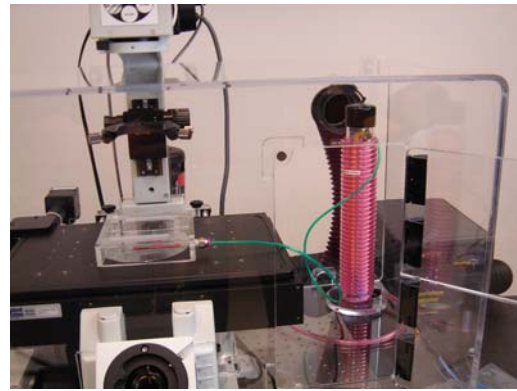
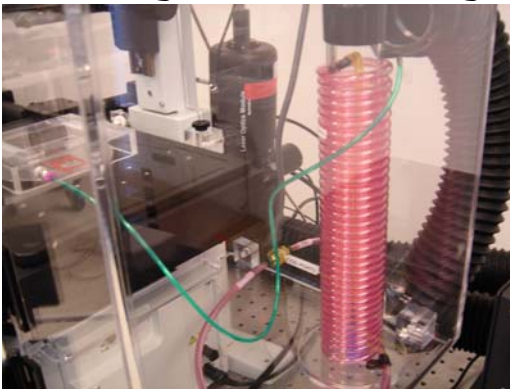
14. If applicable, connect CO2 tube to push to release connector marked "CO2 Port 1" on the back of the chamber.



15. Replace and secure microscope nosepiece.



16. If applicable, place CO2 humidifier bottle and CO2 chamber inside main enclosure, and connect CO2 tubing according to the labeling.



17. Follow the User's Manual instructions to set desire temperature settings.



## For *WeatherStation* Temperature Controller

is a precise temperature controlled air heater for bioscience laboratories. Sending temperature-controlled air directly to the site provides an attractive alternative to a heated water bath or electric heater. The "smart" controller responds quickly and precisely to thermal changes while maintaining temperature control. *WS* can be adapted quickly to different environments by selecting one of three operating modes -- Auto-tuning, manual-tuning, or standard Proportional-Integral-Derivative (PID) tuning. One of the main applications of the *WS* is for controlling the temperature of a chamber (not included) that covers live cell-imaging systems in which a stable and uniform temperature of the sample and optics is essential. With *WS*, the temperature of the sample and optics can be controlled within 0.2 C. During the operation, the air is drawn out of the chamber through the flexible hose, heated at *WS* heater, and then re-circulated back to chamber by the return hose. The temperature sensor can be placed at the air outlet of the hose or near the sample where the temperature control is most critical. This configuration allows the entire optics of the imaging system to stay at a uniform and stable temperature without any drift. No vibration noise is introduced because the *WS* can be placed away from the optical isolation table. The sensor is also electrically "quiet". The temperature sensor is shielded for very high impedance recording.

The newly improved *WS* provides more than three times more airflow than the original model. The airflow rate is also adjustable. It allows the user to use the high-speed flow to speed up the initial heating up and then use the lower airflow setting for a quieter operation. The higher airflow also improves the uniformity of the temperature in the chamber and capability of controlling larger chambers. A BNC connector provides an analog temperature measurement output for a chart recorder, RS232 communication provides software driven full control of *WS*

### ***Operation***

The "POWER" switch controls the main power for fan, heater, and microprocessor controller. The "HEATER" switch controls only the heater; when this switch is off and "POWER" is on, the controller and fan will still be powered. *WeatherStationBT* may then be used as precision digital thermometer with better than 0.2 °C accuracy and 0.1 °C resolution.

### ***Fan Speed Control***

The fan speed control nub on the front panel will control the airflow rate from 20 to 50 cubic feet per minute (CFM). Lower flow rate will offer a quiet operation and is suitable for most of application. However, the higher flow rate can generate more turbulence so that the temperature in the chamber will be more uniform. It will speed up the heating and allowing controlling larger size chamber. For safety reason, the fan can't be turned off unless the instrument is off.

***Caution: void blocking the airflow.***

Although a built-in thermal cutoff switch is designed to reduce the hazard, *fan failure or obstruction in the airflow has the potential for overheating the system and damaging the instrument or even causing a fire.*



## **Temperature Sensor**



The sensor is shielded and grounded with a stainless steel sleeve. The sensor can be directly inserted near sites that involve electric recording without introducing any interference from the heating unit. It can be safely placed in water, but it will ground the system unless a moisture-resistant coating is applied. We recommend using silicone or epoxy to coat the stainless steel portion of the sensor. The coating should not be applied unless it is absolutely necessary since it will slow the response time.

## **Applications**

### **Using WS with chambers that covers the live cell imaging microscope System**

The circulation of the heated air will make the temperature easier to control; keeping the humidity and preventing potentially dangerous sample from pollute the laboratory environment. In order to achieve temperature uniformity, we recommend the heated air to be introduced to the top of the chamber and cold air to be sucked out from the lower part of the chamber. Because the hotter air is lighter and tends to stay on the top, this arrangement will cause more turbulence and make the temperature more uniform. If a uniform temperature for a large area is needed, both in flow and out flow air should be baffled. A simple baffle can be made by drill some 10 mm holes evenly distributed on a piece of acrylic sheet. The number of holes and size of the plate will depend on the size of the chamber. Place the sheet at the front of the air entrance. Varying the distance between the port and the plate to make the temperature more uniform.


Connect the temperature sensor to the WeatherStation. Feed the temperature sensor into the chamber and place it at the desired position. Most common position is at the back stage of the microscope.

Turn on **WS POWER** switch. Use  and  to adjust the temperature set point on the lower display to the desired value. The upper display shows the temperature reading from the sensor. Turn on **WS HEATER** switch and the system will start to work. It might take 30-40 minutes for the air inside a chamber to stabilize from room temperature to 37 °C.

**Automatic control:** This uses PID (Proportional, Integral, and Derivative) control to automatically find the heater power output necessary to reach and maintain the temperature set point. Three parameters can be adjusted to optimize it for different systems. These can be entered manually, or determined automatically by the controller.

**Auto tune:** The controller will evaluate the process and select the PID values to maintain good control. Once the user starts a learning process, the controller lets the temperature go up and down three to four times until good PID parameters are established. After auto tuning, it immediately begins regulating the temperature using these values.

### **Manually setting PID values:**

In this mode, user can manually adjust the PID parameters, which appear in the Operations menu (press ). The Total heat power is the sum of the three PID terms:

$$\text{Power Heat (Po.ht)} = 100(\text{ProP} + \text{it} + \text{dE})\%$$

The proportional and derivative terms range from -1 to 1 and the integral term goes from 0 to 1. The PID controller determines the magnitude of each term from temperature measurements and the values of three PID parameters **ProP**, **it**, and **dE**. In

the following table  $\Delta T = T - SV$  where T is the current temperature and SV is the temperature set value.

<b>Term</b>	<b>Parameter</b>	<b>Parameter Units</b>	<b>Equation</b>
<b>Proportional (ProP)</b>	<b>Proportional Band Heat(Pb.ht)</b>	<b>Degrees C</b>	<b>ProP = -</b> $(1/Pb.ht) \Delta T$
<b>Integral (it)</b>	<b>Integral Heat (It.ht)</b>	<b>Minutes</b>	<b>it = -</b> $(1/It.ht)(1/Pb.ht) \int \Delta T dt$
<b>Derivative (dE)</b>	<b>Derivative Heat (dE.ht)</b>	<b>1/Minutes</b>	<b>dE =</b> $(dE.ht)(1/Pb.ht) d(\Delta T)/dt$

The proportional term looks at the current value of  $\Delta T$ , the integral term evaluates how long it has been there, and the derivative term depends on how fast it is changing. The heat power is always 100% if  $\Delta T < -2 * Pb.ht$  and 0% if  $\Delta T > 2 * Pb.ht$ . When  $|\Delta T|$  is less than twice the proportional band, the derivative term slows down the approach rate to help keep the temperature from overshooting the set point. When  $|\Delta T| < Pb.ht$ , the other two terms are activated. The proportional term can bring the temperature within a few degrees of the set point by itself, but not all the way since  $dE = 0$  when  $\Delta T = 0$ . The integral term adds the necessary offset by continuously increasing at a rate proportional to  $\Delta T$ . If the system starts losing heat (ex: someone opens the chamber door), the derivative term will detect the rapid drop in temperature and increase the power output accordingly.

The heat output is usually zero above the set point since the proportional term is negative in this region and the integral term is usually zero. However, the integral term will still be positive if the temperature has just passed the set point and the derivative term will be positive if the temperature is approaching the set point from above. In some cases the sum of these other terms will be greater than the proportional term so the WeatherStationBT will still be heating the chamber even though it is already hotter than the set point! This situation makes more sense if we remember that heat has to be constantly added in order to cancel out the heat lost to the air surrounding the chamber. If 40% heat is required to maintain the temperature at the set point, then 39% will cool it down

Here is an example of a possible PID setting:

Temperature Set Point (**SP**): 37 °C

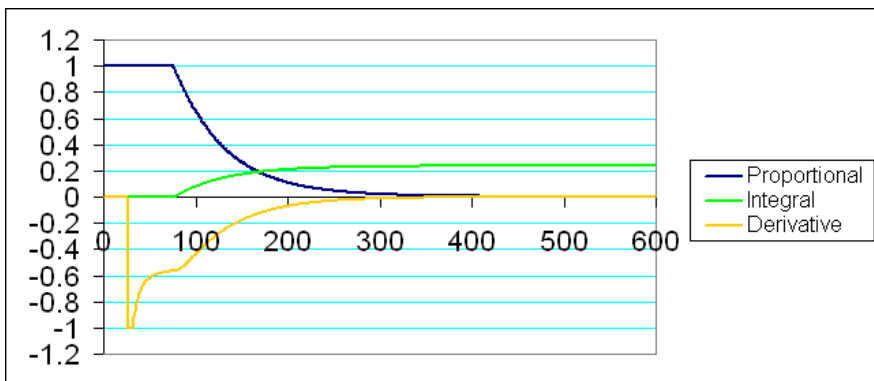
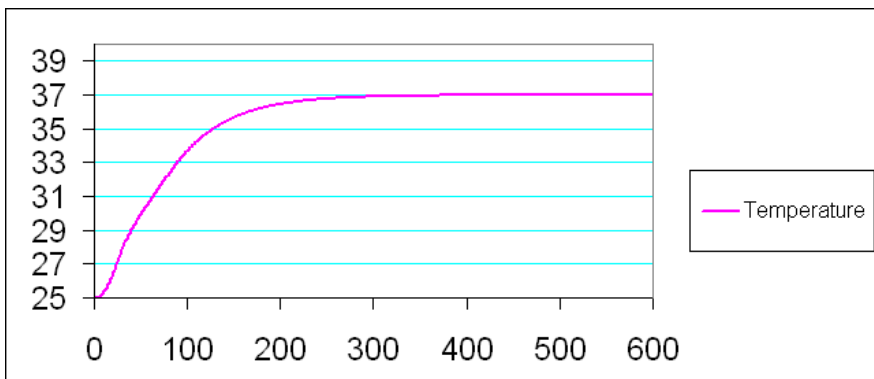
Proportional Band (**Pb.ht**): 5 °C

Integral Heat Time (**It.ht**): 4 minutes

Derivative Time (**dE.ht**): 0.5 minutes

Suppose that the current temperature is 32°C and is rising at 2 °C/minute. At this point, the proportional term is  $-(1/Pb.ht) \Delta T = -(1/5) (32-37) = 1.0$  and the derivative term is  $(dE.ht)(1/Pb.ht) d(\Delta T)/dt = (.5)(1/10)(2) = -0.1$ . The integral term is zero since it resets every time the temperature passes outside the proportional band. Therefore, the total heat output is  $1.0+0.0-0.1 = 90\%$ . After one minute the proportional term has changed to  $-(1/5) (34-37) = 0.6$  and the integral term has increased to  $-(1/It.ht)(1/Pb.ht) \int \Delta T dt = -(1/4)(1/5) (-4) = 0.2$ . The new heat output is  $0.6+0.2-0.1 = 70\%$ .

Of course, this is assuming a constant  $d(\Delta T)/dt$ . A real system is more complicated since the decrease in heat output as the set point is approached will slow down the increase in temperature. The diagrams below show the temperature and PID parameters as the set point is approached in a well-tuned system. The temperature is in degrees Celsius and time is in seconds (600 seconds = 10 minutes).



An easy way to use this mode is to use the Auto tune first to get a preliminary value, then to manually fine-tune the system.

If the integral action is too small (large **It.ht**) or the proportional band (**Pb.ht**) is too big, the temperature will take a long time to reach the set point. However, making the values of **It.ht** or **Pb.ht** too small will make the system unstable, causing oscillations about the set point.

Oscillations about other points besides the set point are usually caused by derivative action. If reducing **dE.ht** does not make the system more stable, try increase the input filter value (make sure **Ftr.E** is set to **Cont** and adjust **FL.tr** to desired number of seconds. See the “Temperature Input Options” section of the **Setup** page in the appendix).

If it is particularly difficult to stabilize your system, try decreasing the heat output range. The heat output range should be adjusted so that it takes about 25% to 75% of the heater power (as shown by the **Po.ht** parameter) to maintain the temperature set point. The heat output range can be adjusted with parameters in the “Power Output” options section of the **Setup** page in the appendix.

Here are some examples of PID parameters for systems with varying response times:

**Slow response process : Pb.ht=7, It.ht=20.0, dE.ht=1.67**

**Normal response process:** Pb.ht =4, It.ht =7.0, dE.ht =0.58

**Fast response process :** Pb.ht =3, It.ht =3.0, dE.ht =0.25

**Manual control:** The operator manually controls the percentage of the total power of heater that is used. Go into this mode by setting **Pb.ht** to **MAAn**. The lower display in the HOME position shows the output in percent.

### **Using WS as a constant temperature blower:**

This is an easy method to provide a constant temperature for a small subject. To do this, leave both the air inlet and outlet hoses on the instrument. Set the controller parameters to **Pb.ht** =3, **It.ht** =4.2, **dE.ht** =0.06. (These parameters are determined by the auto-tune process for a typical condition. If the stability is poor, the user can use the auto-tune to adapt to the special condition.) Put the temperature sensor very close to the subject, and let the outlet hose blow the air directly onto the subject. Note that the heat output scale can be controlled with this system by simply adjusting the fan speed.

### **Analog temperature read-out**





The BNC connector on the rear of the WeatherStationBT case is for temperature read-out. It is set at slope 50 mV/C° and a range from 0 °C = 0 V to 200 °C = 10 V. For example, at 50 °C the read-out should be 2.5 V. Slope and range can be changed in the secondary menu. Accuracy will be ±1% of range. If greater accuracy is desired, adjust sensitivity and offset of recording device to match the reading on the WeatherStationBT panel.





Please note that the input of the recording device should be off ground. The outside of the BNC connector, therefore, should not be grounded. Grounding the outer shell of the BNC may seriously interfere with proper recording.

## Watlow Controller Functions

### **Front Panel:**



-  Up Key: Increments a value or changes a menu item.
-  Down Key: Decrements a value or changes a menu item.
-  Advance Key: Moves to next menu item.
-  Infinity Key: Returns to Home page.

The controller starts out on the Home page. Press  to scroll through the Operations page. Hold down  and  for 3 seconds to go into the Setup page. Press  at any time to return to the Home page.

### ***Home Page:***

**Temperature:** Current temperature of probe. Always present on the upper display.

**Set Value:** Temperature set point. Appears on the lower display when in Automatic mode.

**Percent Heat Output:** Appears on the lower display when in Manual mode. Can be set anywhere from 0% to 100%. If A-M is set to Auto, Po.ht can't be manually changed but it will still appear in the Operations page for diagnostic purposes

### ***Operations Page:***

**Po.ht Power Heat:** When A-M set to auto, shows instantaneous percent heat output.

**A-M Auto-Manual Mode:** Set to Auto or MAn. In Auto mode, heat is controlled according to the ht.M setting. In manual mode, the user inputs the percent heat output.

**Aut Autotune:** On/Off (appears if A-M set to Automatic). When turned on, the upper display on the Home page flashes "tune" until the unit is done auto-tuning.

**ht.M Heat Control Method:** OFF, Pid, or on.of

**Pb.ht Proportional Band Heat:** determines temperature band in which PID control is used. Proportional and integral controls are active within +-**Pb.ht** of the set point, and derivative control is active within +-2 **Pb.ht**. All PID parameters, including **Pb.ht**, only appear when **ht.M** set to Pid control

**It.ht Integral Heat:** minutes per repeat. Used in SI system. The Unit parameter in the setup page changes the temperature controller from the SI to the US system.

**rE.ht Reset Heat:** repeats per minute. Used in US system. It is equal to 1/**It.ht**.

**dE.ht Derivative Heat:** derivative time in minutes. Used in SI system

**rA.ht Rate Heat:** rate time in minutes. Used in US system. It is exactly the same as **dE.ht**

**h.hyS Heat Hysteresis:** How far the temperature goes below the set point before the heat turns on. Used only when heat control method is set to on/off.




**ProP Proportional Term:** View the active proportional term for PID diagnostics.

**it Integral Term:** View the active integral term for PID diagnostics

**dE Derivative Term:** View the active derivative term for PID diagnostics

Notes: The PID parameters are only visible if the heat control method (ht.M) is set to Pid. Others are only used when the controller is in US or SI mode (see the Unit parameter in the Setup page).

### **Setup Page:**

Hold down  and  for 3 seconds to get to setup menu.  moves from one parameter to the next.

The setup page contains settings that are not needed as often as those in the Operation page. This section of the manual will list the parameters that are relevant to the operation of the WeatherStation. Any which do not appear in the list should not be changed. Parameters are grouped into categories in this list in order to make them easier to find.

## **Temperature Input Options**

**C-F Celsius-Fahrenheit:** Sets the temperature units used by the WeatherStation. When this is changed, all temperature settings are automatically converted.

**S.dEC: Set Decimal Places:** Decimal places of precision to display (temperature can be measured up to .1 degree resolution).

**Ftr.E Input Filter:** OFF: no filtering, diSP: filter only the display value, Cont: filter the control input values, both: display and input values are filtered. If a system has a lot of random temperature fluxuations (Ex: sensor is in a box with turbulent air flow), the derivative term in PID control will not give appropriate feedback unless the input is filtered.

**FLtr Filter Value:** 0 to 60 seconds

## **Power Output Options**

**PL 1 Power Limit:** maximum heat (0 to 100%) (if set to 80%, a PID calculated output of 80% or 100% will both give 80%. Value of 50% will also give 50%)

**PSL 1 Output Power Scale Low:** actual power output when the controller is set to 0%

**PSH 1 Output Power Scale High:** actual power output when the controller is set to 100%. If the low scale is set to 20 and high is 40, then a PID calculated output of 50% will give an actual output of 30%. If the power output that is required to maintain the temperature set point is not between 25% and 75%, either adjust the scale parameters, or change the fan speed appropriately.

**Unit Units of Measurement:** Determines PID units (US or SI)

## **Ramping Control**

**RP Ramping mode:** OFF: no ramping, Str: ramp at startup, On: ramp at startup and

when the set point changes.

**RP.Sc Ramp Scale:** hours or minutes

**RpP.rt Ramp Rate:** degrees per unit (hour or minute as chosen in **RP.Sc**).

### **Temperature Re-Transmit**

**A01.U Analog Output Units:** volts or milli-amps (voLt or MA).

**03.Lo Analog Output Scale Low**

**03.hi Analog Output Scale High**

**r1.So Retransmit Source:** current temperature or temperature set point (Proc or SP)





**r3.Lo Retransmit Scale Low**

**r3.Hi Retransmit Scale High**

**r3.CO Retransmit Offset**

Example: Set **r1.So** = Proc and **A01.U** = volt to make it retransmit the measured temperature in volts. Set **03.Lo** = 0, **03.hi** = 10, **r3.Lo** = 0, and **r3.Hi** = 100 to make 0 to 100 degrees translate to 0 to 10 volts.

### ***Changing the temperature sensor***

The controller starts out on the Home page. *WS* temperature sensor, a Pt 100 DIN RTD, has been matched with the controller. If the sensor must be replaced, the system should be recalibrated. To recalibrate, fill a beaker with distilled water and ice made of distilled water. There should be more ice than the water in the beaker. Put in a magnetic stirrer bar and stir the ice water beaker on a magnetic stirrer. Connect the sensor to the instrument, place the sensor in the beaker of water, and wait for 15 minutes or until the temperature reading on the instrument stabilizes. The reading should be zero. If it is not zero, get into the Programming page by holding down  then pressing  and holding both for about 6 seconds. Press  to scroll to P4 and change it from “none” to “Cal”. Press  to return to the Home page and scroll through the Operations page till you get to the newly inserted calibration offset parameter. Adjust the calibration offset until the temperature reads zero. Afterwards, it is a **good idea to go back into the Programming page and remove CAL from the Operations page so that it is not accidentally changed.**

For more information visit [www. watlow.com](http://www.watlow.com)

### **Contact Information**

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