Operation Instruction Manual

WS-1200CPH

Programmable Precision PID Temperature Controller[*]

Version 1.5
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May, 2013

Introduction

Thank you for purchasing the Auber WS series temperature controller. We sincerely appreciate your decision and trust that our machine will meet your expectations in both the quality of the result and the value of our product. While we are delighted that you may be anxious to operate the controller for your project, a few minutes of your time reading through this manual will only serve to enhance your experience in the months and years ahead. In particular, we would urge you to read through the safety warnings below. Although this plug-and-play controller is very easy to operate, the process involves high temperature and high wattage appliances and your safety is paramount.

⚠ **SAFETY WARNINGS**

- This controller is designed only to be used with devices that have limited power and their own thermal cut off protection, such as a thermostat or thermal fuse in case of controller failure.
- Do not place any objects on the top of controller surface which is used to vent excess heat during its operation.
- When opening the cover of a rice cooker or slow cooker that has been running for extended period of time, the cover will carry a lot of condensation that can drip everywhere. Avoid dripping the water over the controller.
- The maximum electric current this controller can handle is 12 amperes. For 120 volt AC in US and Canada, this limits the heater power to1440 watts. In addition, if the heater power is more than 1400 watts, the volume of the pot is also limited to less than 10 gallons (or 38 liters). Due to its compact size and the splash proof

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[*] Patent pending

design for kitchen applications, the controller has a limited ability to dissipate the heat generated by the internal solid state relay during the initial heat up process. The initial full power heat up process cannot be more than 90 minutes. If you have a pot that is larger than 5 gallons (19 litters), please read Appendix 1 "Managing the heat generated by the controller"

- Always place the sensor in the controlled subject when the controller is on. Before turning on the controller, please make sure the sensor is placed inside the container to be controlled. Leaving the sensor outside of the solution will form an open loop operation. If the sensor is left outside, controller will assume the temperature is low even if the controlled subject is already very hot. The controller will provide full power to the heater which will not only overheat the controller but also damage your appliance, possibly causing a fire.
- The 16 AWG power cord provided with your controller is specially designed for high power applications. Do not replace it with a regular computer power cord when the heating/cooking device is more than 1200 watts.
- This controller is designed to control the devices recommended by Auber Instruments only. Using it to control a not recommended device can be dangerous and cause fires. Auber Instruments is not liable for damages caused by misuse of the controller. If you are not sure the controller can be used, please contact Auber Instruments before use.
- If an abnormal display or noise is observed, turn the controller off, unplug the power cord and contact the manufacturer before using it again.
- Clean the controller only when it is cool and unplugged.
- Do not allow children to operate the controller.

Specifications

Input voltage: 100 to 240 VAC 50 /60 Hz
Output voltage: Same as the input.
Maximum Current: 12A at 120V, 10A at 240V
Fuse Size: 15A Fast blow.
Controller Mode: PID, PI, PD or P.
Output switching device: Built-in optically isolated solid state relay with zero voltage crossing switching.
Sensor tip dimensions: 4 mm diameter x 40 mm long.
Sensor cable length: 5 ft (1.5 m)
Timer Range: 0.1 to 99.9 hours for each step, 6 steps total
Temperature resolution: 1 °C or 1 °F
Temperature display range: -10 to 200 °C or 14 to 392 ° F
Temperature control range: +5 °C (°F) from room temperature to 195 °C (383 °F)
Temperature accuracy: ±1°C (±2°F)
Dimension: 6.5 x 3 x 5.2 inch (170 x 80 x 135 mm) W x H x D.

Weight: 2.2 lb (1 kg) without power cord.
Note, for international orders (except Canada), the input power cord is not included due to its weight and different plug requirement. The controller has standard IEC 320 C13/14 socket. Users can use a power cord that meets the local standard to power it. Please make sure the wire gauge can carry the maximum current required. In addition, an adaptor that can convert the output socket (NEMA 5-15) to the socket of local standard is needed.

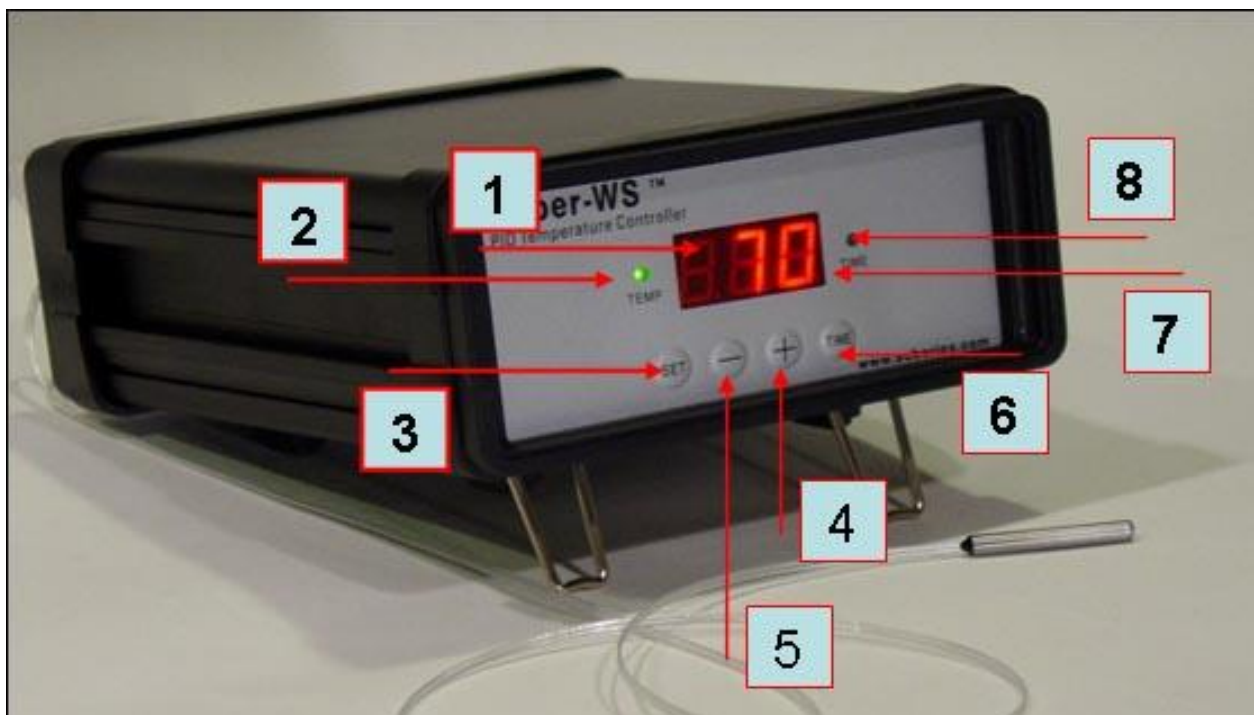## Operating Instructions

1) Description of the controller.

Fig 1. Front Panel

1) **Parameter Window (LED) -** for displaying temperature values and controller's system parameters.
2) **Output status indicator** - In normal mode, this LED indicates the heater status. When it is on (lit), the heater is powered. When it is off, the heater power is off. When it is flashing, it means the heater is on and off intermittently to reduce the power output. It should be synchronized with the power light on the cooking device.
3) **SET Key** - for showing current temperature settings, entering into parameters setting mode and confirming various actions taken.

4) **"+" Key -** To increment displayed value.
5) **"-" Key -** To decrement displayed value.
6) **Time Key** – Change the Parameter Window between current timer and temperature values, when pressed. It also displays which step the program is at before the timer is displayed.
7) **Mode indicator**, the small "dot" – if it is flashing and the Timer Status Indicator ("8)") is lit, the value displayed in the Parameter Window is time passed since power up. If it is flashing but Timer Status Indicator ("8)") is off, the value displayed in the Parameter Window is the parameter that needs to be set. The controller is either in the programming setting mode or parameter setting mode.
8) **Timer status indicator**- In normal mode, When "8)" is on and "7)" is flashing, LED shows the time passed since the controller powered on. When it is off, the LED shows the current temperature detected by the sensor probe
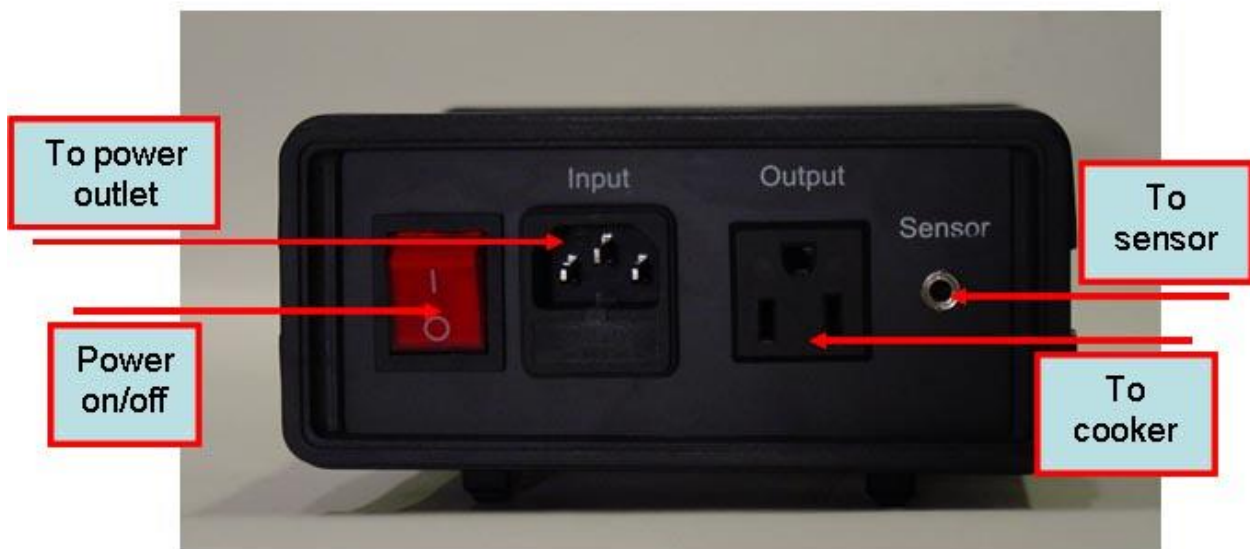

Fig 2, Back Panel

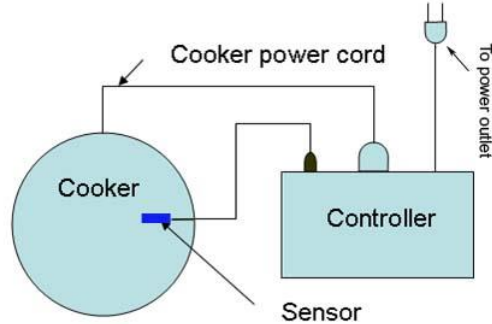**2) Connecting and operating the controller**

Fig 3. Typical connection between the controller and the heating device (in this example, the cooker).

The connection of controller should be done in the following steps.

- Plug the temperature sensor to the back of the controller.
- Plug the power cord to the back of the controller and the other end to the power outlet on the wall.
- Turn on the controller to make sure the controller powers up properly. The temperature display is in the range expected. Then, turn off the controller.
- Plug the heater to the back of the controller. If the heater has a switch, put it in the off position. **Put the sensor inside the container to be controlled**.
- Turn on the controller.
- Turn on the heating device.

3) Programming the smoking temperature profile.

A total of 6 steps can be programmed for this controller. Each step contains the temperature (C0X) and time duration (T0X) setting. They are represented by the symbol C0X and T0X, where "X" is the step number (e. g. Step 4 temperature is represented by C04 and step 4 time is represented by T04). The character, "T", is displayed as the symbol, "Γ". Time is defined as the duration between the last step and the next step. Please make sure the time is long enough for the heater to heat up the smoker. If the time is set too short, the temperature may not be able to reach the current step temperature setting, before it jumps to the next step. The time unit is in hours with 0.1 hour resolution. Each 0.1 hour equals to 6 minutes. If the recipe only needs one step, you can program the time of the rest of the steps to zero.

To program the temperature profile, press SET key once. The display will show C01 for one second and then display the temperature setting for step 1. Use "+" and "-" keys to change the setting. When finished, press the SET again to confirm the change. The

display will show T01 for a second and then change to the cook time setting for step 1. Use "+" and "-" keys to change the setting. When finished, press the SET again to confirm the change. The display will go to the step 2 setting. The following is the flow chart for the setting procedure.
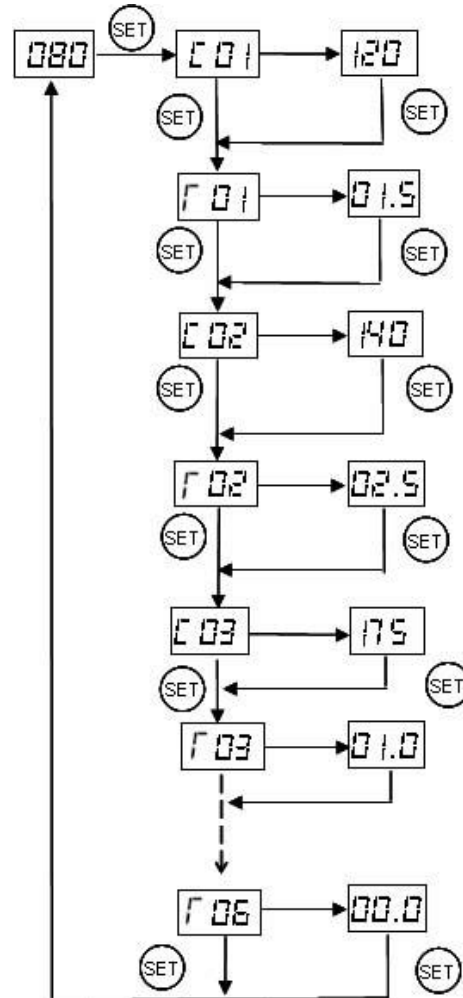

Fig 4, Temperature profile programming flow chart.

The temperature setting will not be changed if SET is not pressed (confirmed). After programming the necessary steps for cooking, you can finish programming by pressing the SET continuously until it passed T06 and displays the current temperature. You can also leave the controller alone. The display will return to the normal display mode if no key is pressed within 15 seconds.

The initial program setting for the controller is for smoking salmon. The temperature profile is programmed to start at 120 °F for 1.5 hour of smoking, rise to 132 °F for 2.5 hours and finish at 175 °F for 1 hour. The recipe is from Kummok: http://forum.bradleysmoker.com/index.php?topic=107.0
If you like more moisture in the fish and serve it within a day, the last step (175 °F) can be

eliminated.

Step #	Temp (F)	Step #	Time (h)
C01	120	T01	01.5
C02	132	T02	02.5
C03	175	T03	01.0
C04	000	T04	00.0
C05	000	T05	00.0
C06	000	T06	00.0

Tabl1 , Initial program for smoking salmon.

The following is an example of setting for one step smoking at 160F for 9 hours.

	Temp (F)		Time (h)
C01	160	T01	09.0
C02	000	T02	00.0
C03	000	T03	00.0
C04	000	T04	00.0
C05	000	T05	00.0
C06	000	T06	00.0

Table 2. Setting for smoking at 160F for 9 hours.

4) Checking the current step and display the time
This is done by pressing the Time Key ("6)") once. The display will show T0X for one second before it displays the time it has been on. e. g., it will display t03 for a second, if the controller is in step 3 of cooking. When "8)" is on (lit) and "7)" is flashing at the same time, LED is in timer mode and shows the actual time passed since the controller was last powered up. Please note that this is the total time, not the time that has passed in the current step. Press Time key again will switch the display to the current temperature. Both "7)" and "8)" will be off.

6) Tuning the controller
This controller is shipped with the system parameters set for the Bradley
Smoker. The user should not need to change these parameters. If you feel the performance is not ideal, you can try to use the recommended PID parameters listed in Table 1. These are the parameters we obtained from tuning the system manually. Fig 5 shows how to change them.

Symbol	P	I	d

Display	P	I	d
Commercial Rice cooker (<12 A)	180	700	40
Home use rice cooker,	54	60	15
Home use rice cooker, wine fermentation. (PD mode) Switch set at Warm position	17	0	40
Slow cooker, 7 quart	180	700	40
Slow cooker, 4 quart	54	60	15
Slow cooker, PD mode (low overshoot)	40	0	40
Bradley Smoker	70	600	150

Table 3. Recommended PID parameters that can be used as reference point. Please note that the P value in table is in Fahrenheit unit. If the controller is using Celsius unit, divide the P value by 1.8.

6.1 Auto-Tune

The controller's most powerful feature is its ability to regulate virtually any cooker with stable temperature control. For stable temperature control the controller requires two things; (1) the controller must be set to the correct power level (see next section) and, (2) that it must be *tuned* to the cooker being used. Tuning is the process that matches the control characteristics of the controller to the heating characteristics of the cooker. The controller is said to be tuned to the cooker when its memory is programmed with values telling it how fast the cooker warms up, cools off, and how efficiently it transfers heat. For example, consider the difference between a heat lamp and a hot plate. When electricity is applied to a heat lamp it begins to heat instantaneously, and when it's turned off it stops heating instantaneously. In contrast, a hot plate may take several minutes to begin heating when electricity is applied and even longer to start cooling when electricity is turned off. But, to do this it must be programmed with the time constants. Describing how fast the heater heats when electricity is turned on and how fast it begins to cool when it's turned off. These time constants are called the *tuning parameters.*

Every type of cooker has its own unique set of tuning parameters. For the controller to heat with stability, it must be programmed with the tuning parameters for the cooker currently being used.

When Should the Controller be Tuned?

If your cooker is not listed in the **Table 1** of our pre-selected cookers, or the PID parameters we provided are not working for your liking, you can use the auto-tuning function to let the controller determine the PID parameters automatically. Auto-tuning function (it's often known as self-tuning) can automatically optimize the PID parameters for your chosen cooking system. The auto-tuning function will heat up your cooker then

let it cool down. It will repeat this heat/cool cycle several times. Based on the response time of the whole cooking system, the controller will calculate and set the PID parameters for your cooker.
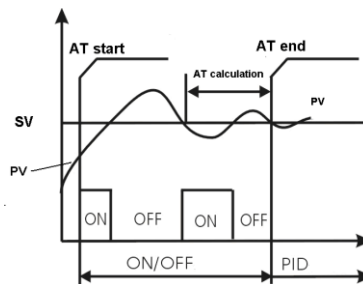

Figure 4

Before using the auto-tune function, you must set the cooking equipment up in the exact configuration it will be used. For example, to tune a rice cooker, place the sensor in the room temperature pot filled with water and plug the cooker into the controller. If the cooker has its own thermostat or power control, turn both as high as they'll go. Set the controller to the appropriate power level (see next Section). Turn the controller and cooker on, and then enter the desired set point temperature close to your normal cooking temperature.

To activate auto-tuning, just enter code 166 to get into the PID setting menu. Set AΓ to 1 then exit the menu (see Fig 5). The display will start to flash alternately between AΓ and the current water bath temperature, which indicates auto-tuning is in progress. When the display stops flashing, the auto-tuning is finished. Now, the newly calculated PID parameters are set and are used for the system. The new parameters will be saved in the memory even when the power is off.

You should always write down your old PID parameters, before letting the controller perform auto-tuning. This way if something goes wrong, you can always go back to your old PID parameters. The water amount in the pot should be the same volume as you would have normally used. Basically, you must setup your cooking system close to your actual cooking environment.

The duration of auto-tuning depends on how fast the system is responding to the heating and cooling cycle. If the temperature of the cooker takes a long time to drop when the heater is off, the auto-tuning could be a very long tuning process. This is especially true with a well insulated cooker. The auto-tuning should be able to tune most of your chosen cookers/smokers with fairly good result.

6.2 Manually Setting the PID parameter.

If you tried auto-tune and the parameters we provide but feel the performance is not ideal, the following sections discusses the definition of these parameters and how to change them.

- LCK. Parameter lock. This function is used to prevent user from changing the critical parameters on accident. Users have to use the code 166 to access the parameter setting menu.
- P. Proportional band. It is in 0.1 degree units. This parameter control the output of the controller based on the difference between the measured and set temperature. Larger the P number means the weaker the action (lower gain). e. g. If P=100, the proportional band is 10 degree (100 x 0.1=10). When the sensor temperature is 10 degrees below the proportional band (10 degrees below the setting), the controller will have 100% output. When the temperature is 5 degree below the set point, the output is 50%. When the temperature is equal to the setting, the controller will have 0% output (assuming integral and derivative functions are turned off). This constant also affects both integral and derivative action. Smaller P values will make the both integral and derivative action stronger. Please note the value of the P is temperature unit sensitive. If you found an optimized P value when operating the controller in Celsius, you need to multiply the P by 1.8 when changing the temperature unit to Fahrenheit.
- I. Integral time. The unit is in seconds. This parameter controls the output of the controller based on the difference between the measured and set temperature integrated with time. Integral action is used to eliminate temperature offset. Larger number means slower action. e. g. assuming the difference between the measured and set temperature is 2 degree and remains unchanged, the output will increase continuously with time until it reaches 100%. When temperature fluctuate regularly (system oscillating), increase the integral time. Decrease it if the controller is taking too long to eliminate the temperature offset. When I=0, the system becomes a PD controller.
- d. Derivative time. The unit is in seconds. Derivative action contributes the output power based on the rate of temperature change. Derivative action can be used to minimize the temperature overshoot by responding to its rate of change. The larger the number is, the faster the action will be. e.g. when the door of an incubator is opened, the temperature will drop at very high rate. The derivative action changes the controller output based on the rate of change rather than the net amount of change. This will allow the controller to act sooner. It will turn the heater to full power before the temperature drops too much
- T, cycle rate. The unit is second. This unit determines how long for the controller to calculate each action. This parameter should remain at 2 second for almost all applications.
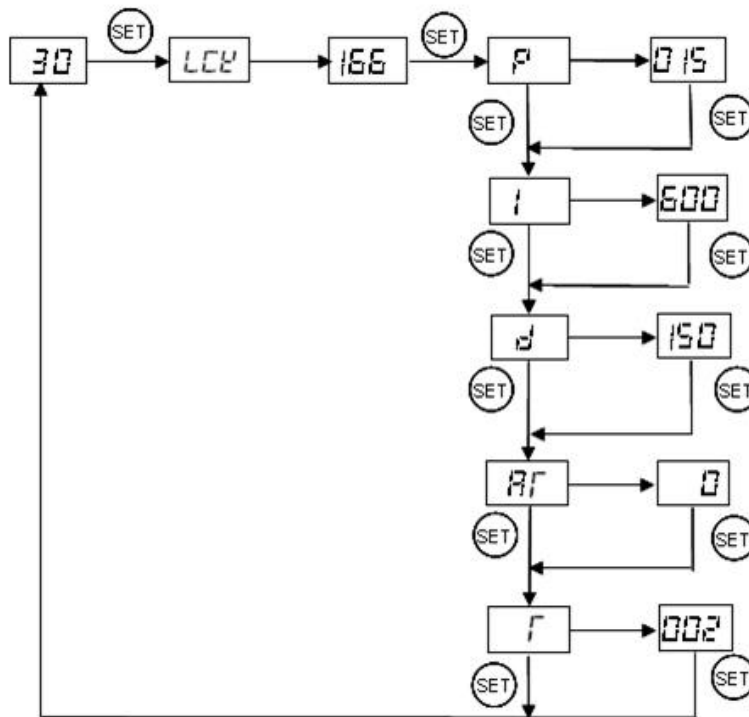
Fig 5. Code 166 Parameter setup flow chart

Press and hold SET key for 4 seconds until LED display "LCK", then release the SET key. The display will show "0". To enter parameters setting mode, you need to key in the pass code. Use "+" and "-"keys to adjust the display to 166 (which is the pass code) and press SET. The LED will show "P" for a second and then its P setting value, Use "+" and "-" keys to change the setting. When finished, press the SET again to confirm the change. The display will show the "I " for a second and its I setting value next, use the same "P" setting procedure to set the I value. When finished, press the SET again to confirm the change. The display will show the "d" for a second and its value next. Use the same "P" setting procedure to set the d value. When finished, press the SET again to confirm the change. The next setting is AΓ, the auto-tune. Use "+" to set the value to 1 and press SET will activate the auto-tune.   The next setting is the "t" setting, use "-" and "+" to set the cycle time value. This value should remain 2 for most application. After changing the PID parameter, the controller needs to be restarted for the best results.

7) Setting other system parameters
These are the parameters that normally do not need to be changed. The lock code to access them is 155.
- SC, calibration offset. The parameter is used to make the input offset to compensate the error produced by a sensor. e.g. if the temperature displays

2.0 °C in ice water mixture (0 °C), set SC=-2.0 will make the display to shown 0.0 degree.

- Out, Output power reduction.   It is expressed as a percentage value. This function will allow you to control the maximum output power delivered by the heater in your cooker, for example, if you set Out=50 and your heater is 1000 watts, the output will use 50% of the 1000 watts as the full output. It treats the 1000W heater as a 500W heater. When the PID algorithm determines 50% output value, the actual power output will be 250 watts. This function can be used in two situations.

  1) When you have a very powerful heater and are using a very small pot of water to cook at very low temperature, for example, a 1400 watts heater with a one litter (1 qt) pot of water at 130 °F. The heater is too powerful for the small water volume. The moment it is on, it releases too much energy and causes the temperature to overshoot. Although it is still possible to stabilize the temperature with proper PID parameters, it is much easier to control if you limit the maximum output to 25%. Ideally, an optimized temperature control system should consume about 25 % of the heater power at the set temperature (steady state). For example, if you found out that only 50 watts of energy is needed to maintain the temperature at 60 °C (141 °F), ideally you should use a 200 watts heater for the job. Too much power will make the system over react too quickly. Too little power will make the system too slow in response. By using the OUt function, you can make the 1400 watts heater to act as a 200 watt heater for stable temperature control.

  2) When the cooker consumes more power than the controller can handle, for example, if you have a 12 A , 120V AC heater and your cooker contains more than 38 liter (10 gallon) of water. It might take more than 90 minutes of full power heating for controller to heat up the pot. Long time of full power operation might cause the controller to over heat. You can set the output to 80%. It will prevent the controller from over heating by staying at full power too long. For details, please see Appendix 1.

- C-F, Display unit setting. You can set the display as either Celsius or Fahrenheit. When changing the display unit, the temperature setting and P constant need to be converted manually.

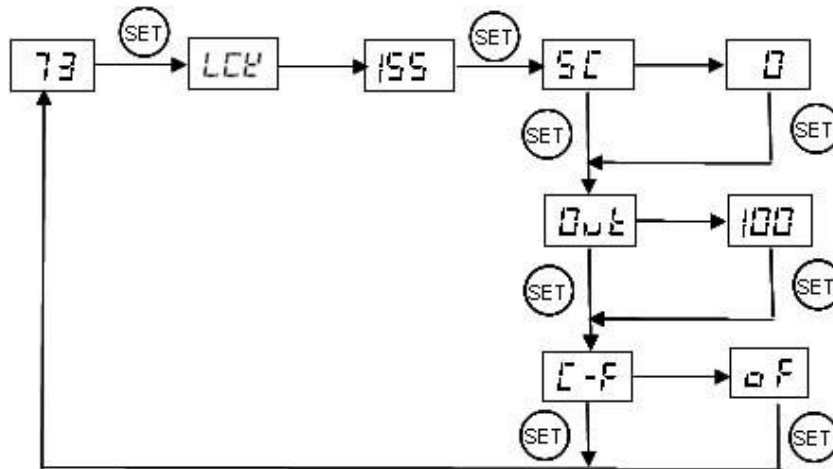- TK, Timer setting. The timer function can be turned off by user.

Fig 6. Code 155 Parameter setup flow chart

Press and hold SET key for 4 second until Parameter Window displays "LCK". Release the SET. The display will show "0". Use "+" and "-" keys to adjust the display to 155 (another pass code) and press SET.

Setting the calibration offset. The parameter window will first show "SC "for a second and then its value, Use "+" and "-" keys to change the setting. When finished, press the SET again to confirm the change. For example, if the temperature is 1 °C too high during calibration then use "-" to set the value to -1 to offset value.

Setting the output reduction. The parameter window will first show "**OUt** "for a second and then its value, Use "+" and "-" keys to change **OUt** value to your desired limit value and press SET.

Setting Celsius (C) or Fahrenheit (F). When SET is pressed, the display will show "C-F" and then its value of either "C" or "F". Press "-" for C or "+" for F. Press SET to return to Normal mode.

Summary: Parameter and its initial setting.

Symbol	Display	Description	Range	Initial
P	p	**Proportional band (in 0.1 degree)**	**0-600**	**70**
I	I	**Integral constant (second)**	**0-900**	**600**
d	d	**Derivative constant (second)**	**0-300**	**150**
AT	A⌐	**Auto-tune**	**0=off 1=on**	**0**
T	⌐	**Cycle rate (second)**	**1-100**	**2**
SC	SC	**Off set (degree)**	**-20~+20**	**0**
Out	OUt	**Output power reduction (%)**	**1-100**	**100**
C-F	C-F	**Temperature unit**	**°C or °F**	**°F**

Table 2. List of control parameters and initial settings

Warranty

Auber Instruments warrants this controller to be free from defects in material and workmanship for a period of one (1) year from the date of the original purchase when utilized for normal household use, subject to the following conditions, exclusions and exceptions. The sensor of the controller is under warranty for 90 days.

If your appliance fails to operate properly while in use under normal household conditions within the warranty period, return the complete appliance and accessories to Auber Instruments
5755 North Point Parkway, Suite 99
Alpharetta, GA 30022
If the appliance is found by Auber Instruments to be defective in material or workmanship, Auber Instruments will repair or replace it free of charge. A dated proof of purchase may be required.

The liability of Auber Instruments is limited solely to the cost of the repair or replacement of the unit at our discretion. This warranty does not cover normal wear of parts and does not apply to any unit that has been tampered with or used for commercial purposes. This limited warranty does not cover damage caused by misuse, abuse, negligent handling or damage due to faulty packaging or mishandling in transit. This warranty does not cover damage or defects caused by or resulting from damages from shipping or repairs, service or alterations to the product or any of its parts which have been performed by a repairperson or facility not authorized by Auber Instruments.

This warranty is available to the original purchaser of the unit and excludes all other legal and/or conventional warranties. The responsibility of Auber Instruments, if any, is limited to the specific obligations expressly assumed by it under the terms of the limited warranty. In no event is Auber Instruments liable for incidental or consequential damages of any nature whatsoever. Some states/provinces do not permit the exclusion or limitation of incidental or consequential damages and therefore the above may not apply to you.

This warranty gives you specific legal rights and you may also have other rights which vary from state to state or province to province.

*Important: Carefully pack item to avoid damage in shipping. Be sure to include proof of purchase date and to attach tag to item before packing with your name, complete address and phone number with a note giving purchase information, model number and

what you believe is the problem with item. We recommend you insure the package (as damage in shipping is not covered by your warranty). Mark the outside of your package "ATTENTION CUSTOMER SERVICE". We are constantly striving to improve our products and therefore the specifications contained herein are subject to change without notice.

Appendix 1

Managing the heat generated by the controller

The heat dissipation of the controller is directly related to the electric current drawing power of the heater. If your cooker consumes less than 10 ampere of current or your pot is less than 5 gal (19 liters), you do not need to worry about the heat generated by the controller.

Sometime, the AC current requirement might not be marked on the cooking appliance. To find out how much current it will draw, divide the power (in wattage) by the line voltage, for example, an 1800 watts 120V heater will draw 15 A. A 2000 watts 240 V heater will draw 8.3 Ampere.

Why the heat becomes an issue?
The solid state relay (SSR) used in the controller is a critical component for the precision temperature control. With the SSR, the power can be switched at high speeds with no noise and no life time limitation. Compared with electromechanical relays, however, SSRs has one drawback. They generate heat when passing the current. SSRs are made of semiconductors that have a limited conductance. When passing current, the heat will be produced from the resistance. Each ampere of current will produce about 1.3 watts of heat. When 12 Amps is passing through the controller, 16 watts of heat is produced in the controller. As more heat is produced, the temperature inside the controller will rise. If it reaches higher than 70 °C, it can shorten the life or even damage some of the components in the controller. The temperature inside of the controller depends on the amplitude of the current, how long the controller needs to run at full power and the ambient temperature.

The heat is only an issue during the start of the heating when the heater is running at full power. Once the temperature is close to the set point, the controller will usually need less than 50% of the power to maintain the temperature. Since the heat is directly related to the current passing the controller, the heat produced at steady state will be insignificant and can be ignored.

When the heat becomes an issue?

This controller can run at 10 A continuously without worry of the temperature of the controller. At 12A, the temperature of the controller will increase with time. The bottom of the controller where the heat sink is located can rise by 63 °F (35 °C) from ambient if running at full power continuously for 90 minutes.   For this reason we don't recommend running the controller at full power for more than 90 minutes. For 120 VAC, 12 A for 90

minutes will provide enough energy to heat 10 gallons (38 liters) of water up by 85 °F (48 °C). If you have a pot that is bigger than 10 gallon, the heater is drawing 12 A, and you need to raise the temperature by 85 °F, it is recommended that you use one of the methods mentioned below to reduce the heat in the controller. Otherwise, you might damage the controller.

Please note that when the ambient temperature is hot, as it is often the case in some commercial kitchens, the temperature of the controller will get hotter. This is because the heat dissipation is mostly determined by the temperature gradient (the temperature difference between the ambient and the controller) instead of absolute temperature of the controller itself. If the controller reaches 50 °C when the ambient is at 20 °C, it will reach 70 °C when the ambient is at 40 °C.

Solutions to reduce the heat stress on the controller.
1) Use hot water. If you fill the pot with hot water that has a temperature close to the set temperature, the heat dissipation of the controller is not an issue. As we have mentioned, once the temperature is close to the set point temperature, the controller starts to pulse (PWM) the power. The effective current is much lower, making heat not an issue.

2) Limit maximum output power. If you set output reduction parameter to 80%, then, a 15 A heater will become a 12 A heater. It will take 25% longer time to heat up the pot, but the controller will not over heat.

In addition to these solutions, the following information will also help you manage the heat.
Place the controller in the right place. The SSR of Auber WS series controller is mounted in the bottom of chassis. The chassis is made of 3 mm thick aluminum for good heat dissipation. Do not cover the controller with any insulation. If you are running at 15 A with a large pot, place the controller in a well ventilated area and tilt the instrument up with its front leg to help remove the heat more efficiently. However, the tilted position might allow the water to be collected at the back frame. Although the controller is splash proof, you should avoid water to be dripped to the controller when you open the lid of the cooker.

Increase the P value. This can only provide limited help for reducing the heat. P is the proportional band. P=200 means the proportional band is 20.0 degrees. When the temperature is raised to less than 20 degree from the set point temperature, the controller will start to reduce the power sooner. But if the integration time is set to very short, the controller might start to run at full power again soon.

Appendix 2

Controlling the Temperature of Bradley Smoker

1) Connecting the controller

There are two ways to power up the controller and smoker.

a) Using two power cords and a power strip. This set up is good for the "Original", Stainless Steel, and Digital Bradley Smoker.
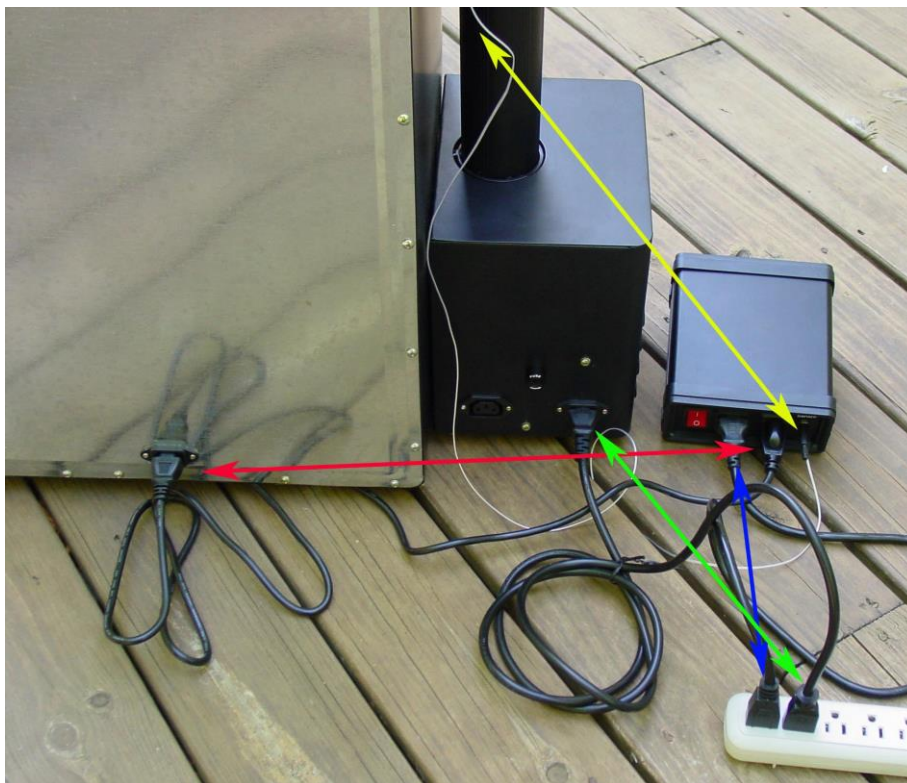

Fig 3. Power connection of the controller and smoker. The input of the controller is connected to the power strip by the 16 AWG power cord supplied (blue arrows).   The generator is connected to the power strip by the power cord from Bradley (green arrows). The controller output is connected to the smoker by an 18 AWG computer power cord (red arrows, not supplied). The sensor is connected to the sensor port on the controller (yellow arrows).

b) Using one power cord. This set up is good for the "Original" and Stainless Steel Bradley Smokers only.
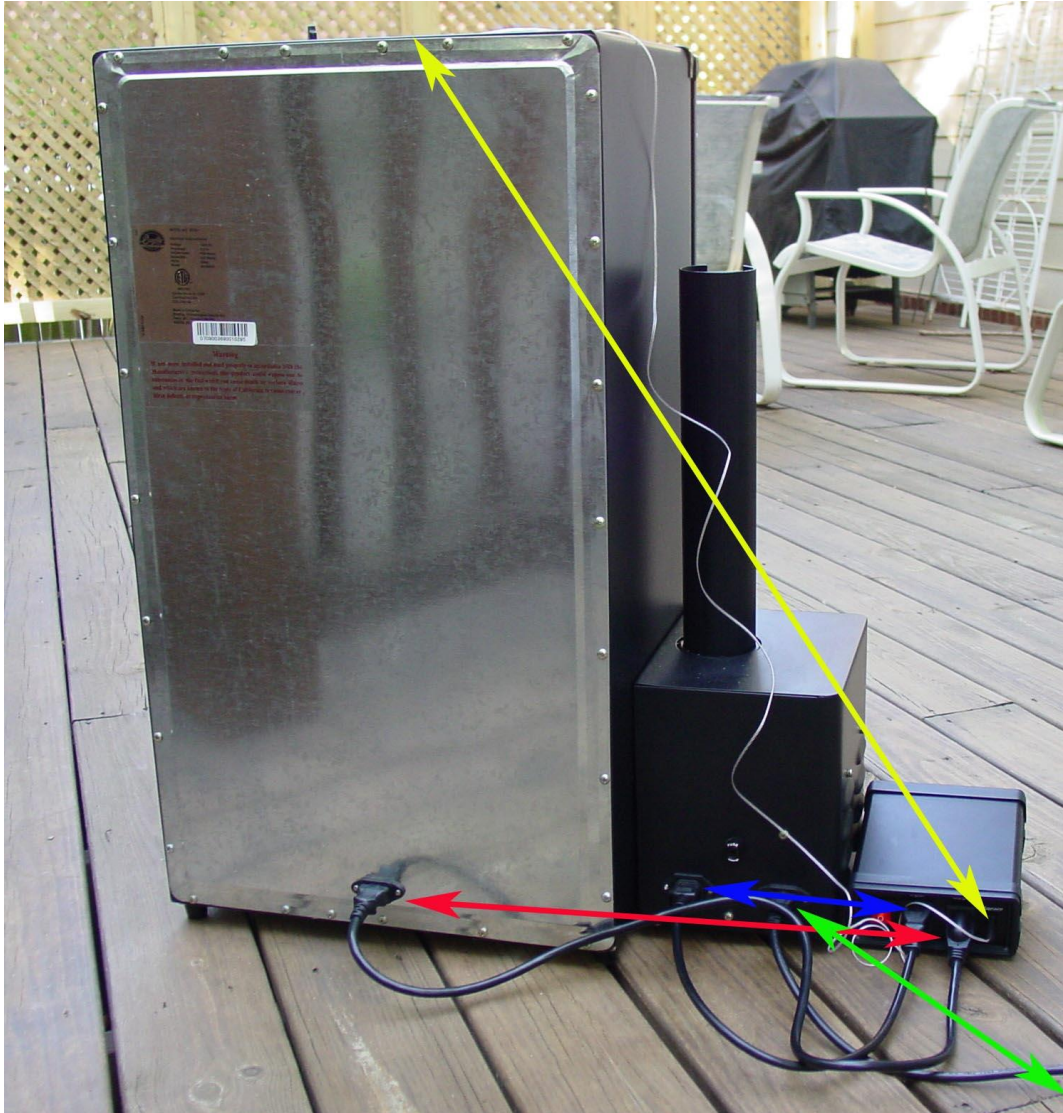
Fig 4. Power connection of the controller and smoker. The generator is connected to the power strip by the power cord from Bradley (green arrows). The input of the controller is connected to the female receptacle on the generator by the power jumper cord provided by the Bradley (blue arrows). It is the cord that used to connect the generator to smoker. The controller output is connected to the smoker by the power cord (red arrows).

Install the sensor. The sensor is plugged into the sensor port on the controller (yellow arrows)(Fig 4). The tip of the sensor is dropped into the damper hole. It is held in place by a piece of tape on the top of the smoker tower. (Fig 5)
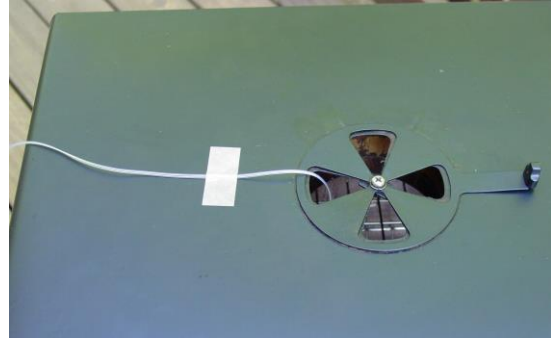
Fig 5. Sensor position. Left, the sensor should be placed close to the food but high enough so that it does not touch the food. Right, hold the sensor in place with a piece of tape.

For the "Original" and Stainless Steel Bradley smoker, the Temperature Heat Control Switch on the smoker tower should be slid to the Hi position (Most right).

For the Bradley Digital Smoker, the original sensor cable from the smoker should be connected between the generator and smoker.
The controller is ready to power up.

2) Important consideration for better control results.
The following is a list of things that could affect the result of temperature control.

a) The smoker and controller location. The smoker should not be placed directly under the sun. Direct sun light can heat the smoker to above 140 °F in the summer time, making controlling the temperature at 140 °F impossible. This is especially the problem for the Bradley Original Smoker because of its black color. The controller should be placed away from direct sun light also. Although the controller uses a high intensity LED display, it will still be difficult to read when sun light is directly shined on its surface. Users should also avoid exposing the controller to water and rain, which could damage the controller.

b) Low temperature control. The control result for temperature below 125 °F will not be as good as higher temperatures when the smoker generator is on. This is because there are two heaters in the smoker tower. One is the smoker heater controlled by PID controller. The other is the heater from generator that is not controlled. Our test shows that the heater in the generator itself can raise the temperature of the smoker tower by 60 °F (2 hours, in the shade with the damper open). That means when the ambient temperature is at 70 °F, the smoker can be heat up to 130 F in 2 hours by the heater of the generator (without using the heater of the smoker).

c) Damper position. Keeping the damper open will result in better temperature stability because more heat loss is created. This is important when the temperature is set below 140 °F. When the damper is closed, the temperature will take a longer time to drop if it is overshot during initial heat up. At higher temperatures, closing the damper will not affect the performance much because the heat loss from the wall of the tower is increased,

d) Temperature uniformity of the smoker tower. Our test showed that when all the shelves were empty, the temperature inside the smoker tower is fairly uniform except in the back half of the lowest shelf that is close to the heater. Users should avoid placing the sensor too close to the heater because it does not represent the temperature of the rest area. When the shelves are filled, temperature variation might depend on how the foods were placed. The bottom shelf can become hotter if more food is placed in it to block the hot air from going up.

e) Operating the controller when ambient temperature is below 32 °F (0 °C). The controller reading is only accurate for temperature ≥ 32 °F (0 °C). In addition, if the ambient temperature is below 14 °F (-10 °C), the controller will not function because it can't read the temperature correctly. In that case, users can warm the sensor by holding it with their hands. Once the sensor is above 14 °F (-10 °C), it will turn on the heater. Once the inside of the smoker is heated to above 32 °F, the controller will run by itself.

3) Initial settings
In case you have changed some of the parameter but want to set the controller back to its original condition, here is a list of the initial settings.

Symbol	Display	Description	Range	Initial
P	p	**Proportional band (in 0.1 degree)**	**0-600**	**70**
I	I	**Integral constant (second)**	**0-900**	**600**
d	d	**Derivative constant (second)**	**0-300**	**150**
AT	A Γ	**Auto-tune**	**0=off 1=on**	**0**
T	Γ	**Cycle rate (second)**	**1-100**	**2**
SC	SC	**Off set (degree)**	**-20~+20**	**0**
Out	OUt	**Output power reduction (%)**	**1-100**	**100**
C-F	C-F	**Temperature unit**	**°C or °F**	**°F**

Table 1. List of system parameters and its initial settings.