Temperature Control for Research and Industry

Model 210 & 210/Timer Manual

J-KEM Scientific, Inc.

Instruments for Science from Scientists

Warranty

J-KEM Scientific, Inc. warrants this unit to be free of defects in materials and workmanship and to give satisfactory service for a period of 12 months from date of purchase. If the unit should malfunction, it must be returned to the factory for evaluation. If the unit is found to be defective upon examination by J-KEM, it will be repaired or replaced at no charge. However, this WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive current, heat, moisture, vibration, corrosive materials, or misuse. This WARRANTY is VOID if devices other than those specified in Section 3.2 are powered by the controller. Components which wear or are damaged by misuse are not warranted. This includes contact points, fuses and solid state relays.

THERE ARE NO WARRANTIES EXCEPT AS STATED HEREIN. THERE ARE NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND OF FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL J-KEM SCIENTIFIC, INC. BE LIABLE FOR CONSEQUENTIAL, INCIDENTAL OR SPECIAL DAMAGES. THE BUYER'S SOLE REMEDY FOR ANY BREACH OF THIS AGREEMENT BY J-KEM SCIENTIFIC, INC. OR ANY BREACH OF ANY WARRANTY BY J-KEM SCIENTIFIC, INC. SHALL NOT EXCEED THE PURCHASE PRICE PAID BY THE PURCHASER TO J-KEM SCIENTIFIC, INC. FOR THE UNIT OR UNITS OF EQUIPMENT DIRECTLY AFFECTED BY SUCH BREACH.

Service

J-KEM Scientific maintains its own service facility and technical staff to service all parts of the controller, usually in 24 hours. For service, contact:

J-KEM Scientific, Inc.
6970 Olive Boulevard
St. Louis, MO 63130 USA
(314) 863-5536
FAX (314) 863-6070
Web site: http://www.jkem.com
E-Mail: jkem911@jkem.com

This manual contains parameters specific to temperature controller Serial #_________________.
When calling with a technical question, please have the controller’s serial number available.

You’ve purchased the most versatile controller available to the research community. We’re confident it can regulate ANY heating/cooling situation you’ll ever encounter. If the information in this manual isn’t adequate to make your application work, call our Engineering Department for assistance.

– With J-KEM’s patented Microtune circuitry –

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WARNING: Adhere to the restrictions of **SECTION 3.2**. Failure to do so may create a significant safety hazard and will void the warranty.

Section 1: Quick Operating Instructions

The four steps below are the basics of using your temperature controller. The User's Manual is a reference that explains the controller more fully as well as some of its more sophisticated features. It's recommended that new users unfamiliar with process controllers read the entire manual carefully. **The controller is preprogrammed for use with heating mantles fitted to round bottomed flasks running "typical" organic reactions (i.e., non-polymeric reactions in solvents such as THF, toluene, DMF, etc.).** If the controller is used with this type of reaction, the 4 steps below will help you get started.

To use heaters other than heating mantles: See Section 2.
Do not use the controller to heat oil baths: See Section 3.2 & Appendix I.
For polymer synthesis, atypical, expensive, or safety critical reactions: See Appendix II.

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1 **Place the thermocouple in the solution being heated.** Place at least the first 1/4" of the thermocouple directly in the solution being heated. Thermocouples can be bent without harming them. If you're heating a corrosive liquid, use Teflon coated thermocouples. If you are heating a sealed reaction, see Section 4.2.

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2 **Set the power level switch to the volume of solution being heated** (not the size of the flask being used). The power level switch can be thought of as a solid state variac. Volume ranges are printed above this switch as a guide to select the correct power level since it's easier to guess the volume being heated than the appropriate "percent power" to apply to a heater. 'Heat Off' turns off the heater so the controller displays temperature only. All new users should read Section 3.6.

A power setting of.....	is equivalent to a variac setting of:
1-10 ml	3%
10-100 ml	10%
50-500 ml	25%
300 ml - 2 L	50%
> 2 L	100%

TIP: Because the power switch acts like a variac, if the reaction is heating too slowly or you need more power (e.g., heating to high temperatures), give the heater more power by turning the power level up one setting. If the reaction needs less power than normal (e.g., heating to low temperatures (<60º C) or the temperature overshoots the set point excessively, turn the power down one setting. **DO NOT** set the power switch on a setting too high initially to heat the reaction quickly and then lower it to the correct setting, this degrades heating performance.

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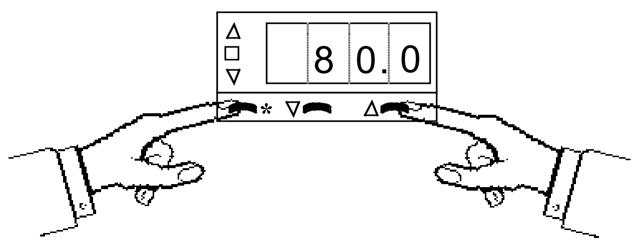
3 **Enter the setpoint** (i.e., the desired temperature). Hold in the * button and simultaneously press the ↑ key to increase or the ↓ key to decrease the setpoint. The setpoint can be seen at anytime by holding in the * button, the setpoint appears as a blinking number in the display.



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4 **For Model 210/Timers Only**

Set the timer. When power is applied to the controller, by default, the timer turns power OFF to the heater as a safety precaution.

To turn power On to the heater, briefly push in on the round timer knob and the display changes to ON to show that power to the heater is ON. For complete instructions on the user of the timer see the section titled *Timer Controls.*
If the display does not change when the timer knob is pressed. make sure that the Power Level Switch is not set to the "Heat Off" position.

KEM-Net Data Logging and Control Software

In 2008, J-KEM completed a redesign of it's research grade controllers. The redesign involved both the hardware running your controller and software for remote control and data logging.

Hardware – The controller may look the same, but inside is our 3rd generation microcontroller. This controller is FLASH programmable and capable of downloading *program modules*(software) from our web site at no charge. Several program modules are in development, but the most exciting is a module that automatically reports exothermic reactions – even during the heating phase of a reaction when an exotherm would normally be undetectable.

Software - Your controller is equipped with a USB port to allow remote control and data logging. J-KEM's KEM-Net is allows up to 16 controllers to be operated from a single PC with data logging, multi-step temperature ramps, software high and low temperature safety alarms and many other features.

<table>
<tr>
<td>KEM-Log implements:

* Data logging directly to Excel or a text file.

* A 16-step temperature ramp that's constructed in an Excel-like table.

* Easy entry of the setpoint

* High and Low Safety temperature alarms</td>
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</table>

KEM-Net is free of charge and can be downloaded from J-KEM's web site.

1. Go to J-KEM's web site at http:\\www.jkem.com, then click on the Download Software link at the bottom of the home page. From the list of software downloads, click on KEM-Net. A popup window appears presenting the options of RUN, SAVE and CANCEL. Selecting the SAVE option brings up a Save File Dialog window. Save the file kemnetzip.exe to your C drive, then exit your web browser.
2. Kem-NetZip.exe is a self-extracting zip file. Double click on its icon to expand it. Once expanded, kemnetzip.exe creates a new folder on your C drive titled "JKEM" which contains the KEM-Net Installation Project and copies of user's manuals and USB drivers.
3. Print the document titled PrintMe_Now.pdf for instruction on how to install the USB drivers and the KEM-Net software.

The USB port on this controller has a feature that allows communications by means of a *virtual comm port* sending and receiving ASCII string characters. This feature can be used by programs like LabView and other third party software packages to communicate with the controller. Instructions for use, and the ASCII command set can be downloaded from J-KEM's web site by clicking on Download Manuals, then selecting the document ASCII Communications With J-KEM Controllers.

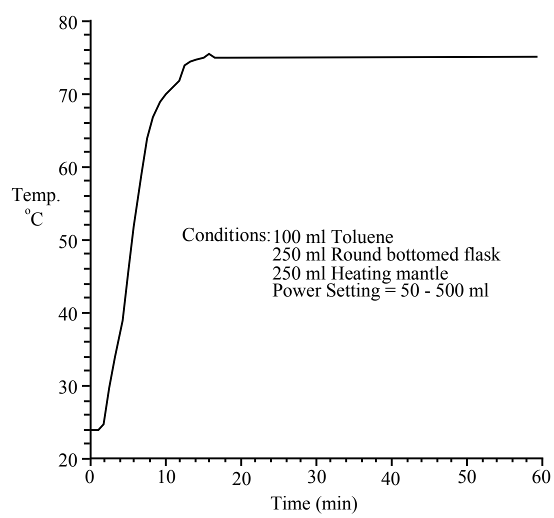
Section 2: Adjusting The Controller For Stable Control With Different Heaters

2.1 What is Tuning. The controller's most powerful feature is its ability to regulate virtually any heater with stable temperature control. For stable control the controller requires two things; (1) the controller must be set to the correct power level (see Section 3.6) and, (2) that it must be *tuned* to the heater being used. Tuning is the process that matches the control characteristics of the controller to the heating characteristics of the heater. The controller is said to be tuned to the heater when its memory is programmed with values representing how fast the heater 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 stop heating when electricity is turned off. Your controller can regulate both a heat lamp and a hot plate to 0.1^{o} C. But, to do this it must be programmed with the time constants appropriate for the heater in use. These time constants are called the *tuning parameters*.

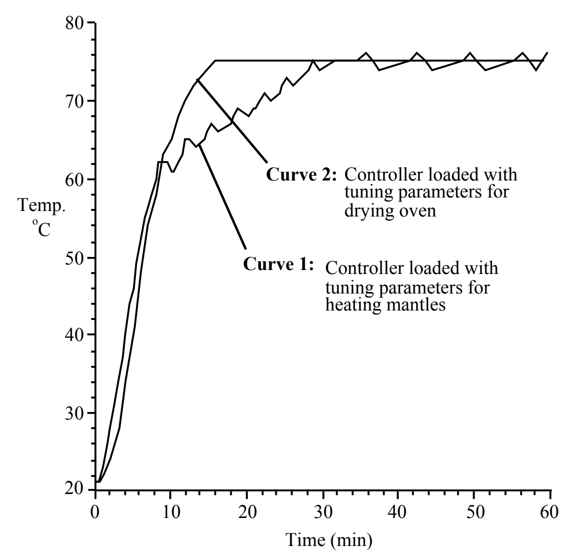
Every type of heater has its own unique set of tuning parameters. For the controller to heat with stability, it must be programmed with the tuning parameters for the heater currently being used. Prior to shipping, tuning parameters were programmed into the controller that maximize heating performance for laboratory heating mantles since these are the most common heaters used in research. Tuning is regulated by 5 of the temperature meter's user programmable functions. The correct value for these 5 functions can be calculated and loaded by the user manually, or the controller can do it automatically with its autotune feature.

When Should the Controller be Tuned? If the controller is tuned to one type of heater, heating mantles for example, any size heating mantle can be used without the need to retune. When changing from heating mantles to a different type of heater, an oven for example, the controller should be tuned with values describing the oven's heating characteristics. The effect of tuning is seen below. When the controller is tuned for heating mantles, using it with any size heating mantle yields stable temperature control (Plot 1), but poor control results when the same tuning parameters are used with an oven (Plot 2, Curve 1). However, after tuning the controller to the oven, stable temperature control results (Plot 2, Curve 2).

Plot 1



Plot 2



It's important to understand that this controller isn't a simple ON/OFF type controller (i.e. ON when below the set point, OFF when above [though it can be made to work this way, see Section 3.8]). Rather it's a ***predictive*** controller. Based on the shape (slope) of the heating curve, the controller predicts (calculates) the percent of power to apply to the heater now to control the shape of the heating curve minutes in advance. The importance of the tuning parameters is that they are constants in the equation the temperature meter uses to perform its predictive calculations. If the temperature meter is programmed with tuning parameters that incorrectly describe the heater being used, poor temperature control will result. But, when the correct values are loaded, temperature regulation of $\pm 0.1^{o}$ is typically achieved.

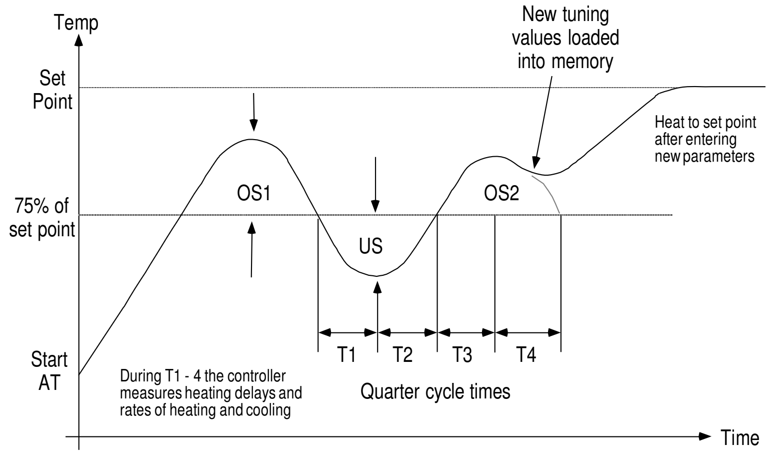
Manual Tuning. Manual tuning is when the values of the 5 tuning parameters are determined manually then entered into the temperature meter via the push buttons on the front of the controller. Experienced users might prefer to manually tune the controller since this allows customization of the heating process.

Autotune. Autotune is a feature built into the temperature meter that automatically calculates the tuning parameters (i.e. delay times, heating efficiency, etc.) for any type of heater. After the autotune procedure is complete the controller automatically stores the tuning parameters in non-volatile memory. Heating mantles are a special case and are covered in a separate paragraph (Section 2.3).

2.2 Autotuning Procedure.

This procedure is not recommended for heating mantles (see Section 2.3).

1. Set the equipment up in the exact configuration it will be used. For example, to tune to a vacuum oven, place the thermocouple in the room temperature oven and plug the oven into the controller. If the oven (or heater) has its own thermostat or power control, turn it to its highest setting.
2. Set the controller to the appropriate power level (see Section 3.6). Make sure the timer circuit is set to ON (i.e., the timer window displays On; see Section 3.5). Turn the controller and heater on, and enter the desired set point temperature. If the set point isn't at least 30^{o} C above ambient, skip this procedure and go to the next procedure, "Autotuning the Controller for Very Fine Control"
3. Press and hold in both the ↑ and ↓ buttons (for 3 seconds) on the front of the temperature meter until the word "tunE" appears in the display then release both buttons.
4. Press the ↑ button (5 times) until "CyC.t" appears in the display (if you go past this setting, press the ↓ button until you get back to it).
5. First, hold in the '∗' button, while holding in the '∗' button press the ↓ button. Continue to hold both buttons in until the display reads "A --", or "A ##" where "##" is some number.
6. Release the '*' button and press the ↓ button until "tunE" once again appears in the display.
7. Press and hold the '∗' button and "tunE" changes to "off" to indicate that autotune is off.
8. While holding in the '*' button, press the ↑ button to change the display to "on", then release both buttons.
9. Press and hold both the ↑ and ↓ buttons (for 3 seconds) until the temperature appears in the display. The controller is now in its autotune mode. While in autotune the display alternates between "tunE" and the process temperature. When the autotune sequence is done (this may take in excess of an hour) the controller stops displaying "tunE" and only displays the process temperature. [To abort autotune manually, repeat steps 3, 8 and 9 except in step 8 press the ↓ button until "off" is displayed]. If during the process of autotuning the message "Tune Fail" appears, see the paragraph at the end of section 2.2.



The autotune sequence. During autotune the controller heats to 75% of the set point temperature where it oscillates for several cycles before loading the new tuning parameters. After the tuning parameters are loaded it heats to the set point temperature. Tuning below the set point prevents any damage that might occur from overheating.

Autotuning the Controller for Very Fine Control.

This procedure is not recommended for heating mantles (see Section 2.3).

In the majority of cases, the normal autotune procedure results in stable temperature control with any heater. A second version of the autotune routine is available and can be used when the heater is 1) at the set point, 2) is being tuned close to room temperature, or 3) for very fine control in demanding situations. If stable temperature control doesn't result after performing the first autotune routine, the procedure below should be performed. Before performing the 'fine tune' autotune procedure, if possible, perform the autotune procedure on the preceding page.

1. Set the equipment up in the exact configuration it will be used. If the heater has its own thermostat or power controls, turn it to its highest setting. With this procedure it's not necessary for the equipment to start at room temperature. This procedure can be performed at any time and any temperature.
2. Set the controller to the appropriate power level (see Section 3.6). Make sure the timer circuit is set to ON (i.e., the timer window displays On; see Section 3.5). Turn the controller and heater on, then enter the desired set point temperature.
3. Press and hold in both the ↑ and ↓ buttons (for 3 seconds) on the front of the temperature meter until the word "tunE" appears in the display then release both buttons.
4. Press the ↑ button (5 times) until "CyC.t" appears in the display (if you go past this setting, press the ↓ button until you get back to it).
5. First hold in the '*' button, while holding in the '*' button press the ↓ button. Continue to hold both buttons in until the display reads "A --", or "A ##" where "##" is some number.
6. Release the '*' button and press the ↓ button until "tunE" once again appears in the display.
7. Press and hold the '*' button and "tunE" changes to "off" to indicate that autotune is off.
8. While holding in the '*' button, press the ↑ button to change the display to "At.SP", then release both buttons.
9. Press and hold both the ↑ and ↓ buttons (≈ 3 seconds) until the temperature appears in the display. The controller is now in its autotune mode. While in autotune the display alternates between "tunE" (for autotune) and the process temperature. When the autotune sequence is done (this may take in excess of an hour) the controller stops displaying "tunE" and only displays the process temperature. [To abort autotune manually, repeat steps 3, 8 and 9 except in step 8 press the ↓ button until "off" is displayed].

Autotune Errors. The autotune routine can fail for several reasons. If it fails, the controller displays the error message "tunE" "FAiL". To remove this message turn the controller off for 10 seconds. Try the procedure titled "Autotuning the Controller for Very Fine Control" above. If autotune fails again, call and discuss your application with one of our engineers. A common problem when tuning at high temperatures or with large volumes is for the heater to be underpowered. A more powerful heater may be needed (contact J-KEM for assistance).

2.3 **Tuning for Heating Mantles: A Special Case.** This section gives special consideration to heating mantles, since they're the most common heaters used in research. Every heating mantle size has its own optimum set of tuning parameters and if you wanted, the controller could be tuned (or autotuned) every time a different size was used. However, this is cumbersome and is also unnecessary. Factory tests show that there's a set of tuning parameters that delivers good performance for all heating mantle sizes. These tuning parameters were loaded into the controller at the factory prior to your receiving it. If you're using a heating mantle and none of the parameters have been changed or the controller hasn't been autotuned since you've received it, you're ready to go. If the tuning parameters have been changed or the controller has been autotuned and you want to go back to using heating mantles, perform the procedure below to manually load the tuning parameters for heating mantles.

Procedure 1. Perform when using **heating mantles** with round bottomed flasks.
[This procedure takes about 2 minutes to perform]

1	Press and hold in both the 🡣 and 🡡 keys on the front of the temperature meter until the word "tunE" appears in the display, then release both keys.
2	Press the 🡡 key once and the word "bAnd" will appear in the display. First hold in the '*' key, then while holding in the '*' key press the 🡣 or 🡡 key until the value "10" appears, then let go of all the keys.
3	Press the 🡡 key once and the word "int.t" will appear in the display. First hold in the '*' key, then while holding in the '*' key press the 🡣 or 🡡 key until the value "10" appears, then let go of all the keys.
4	Press the 🡡 key once and the word "dEr.t" will appear in the display. First hold in the '*' key, then while holding in the '*' key press the 🡣 or 🡡 key until the value "50", then let go of all the keys.
5	Press the 🡡 key once and the word "dAC" will appear in the display. First hold in the '*' key, then while holding in the '*' key press the 🡣 or 🡡 key until the value "3.0", then let go of all the keys.
6	Press the 🡡 key once and the word "CyC.t" will appear in the display. First hold in the '*' key, then while holding in the '*' key press the 🡣 or 🡡 key until the value "30", then let go of all the keys.
7	Press and hold in both the 🡣 and 🡡 keys until the temperature appears in the display, then release both keys.

2.4 **Sensor Placement.** Placement of the sensor is basically common sense. The sensor should be positioned to sense the average temperature of the medium being heated. That means the thermocouple should be shielded from direct exposure to the heater but not so distant that a rise in temperature isn't sensed by the controller within a reasonable period of time. Several examples follow that show the type of consideration that should be given to sensor placement.

Use With:	
Solutions	Place the sensor in the solution. Stir vigorously so that heat is homogeneously mixed throughout the solution.
HPLC column heated with a heating tape	Tape a thin wire thermocouple directly to the HPLC column. Place several layers of paper over the thermocouple to insulate it from the heating tape (the thermocouple should sense the column temperature, not the heater temperature). Wrap the HPLC column completely with heating tape.
Oven	The thermocouple needs to be shielded from transient hot and cold air currents. Don't place the thermocouple near the heating coil or an air vent. A small thermocouple (1/16" or 1/8" thermocouple) that responds rapidly to changes in air temperature is better than a larger one.

Section 3: <u>Operations Guide</u>

3.1 Front Panel Description.

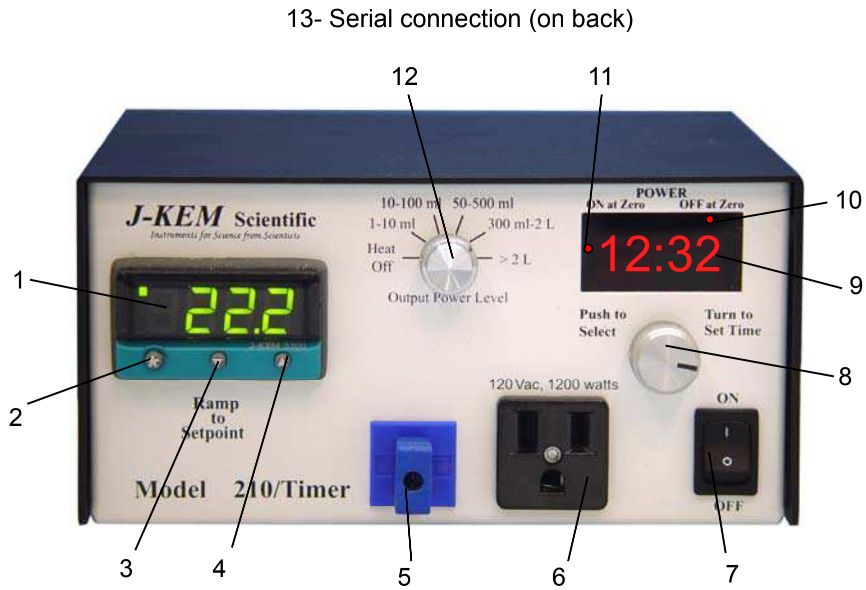


Figure 1

1. Temperature Display. Shows temperature of the process as the default display. Shows set point temperature (i.e. desired temperature) when '*' button is pressed.
2. Control Key. When pressed, the display shows the set point temperature. To decrease or increase the set point, press the ↓ key (3) or ↑ key (4), while simultaneously pressing the control key. The set point appears as a blinking number in the display.
3. Lowers the set point when '*' button (2) is simultaneously pressed.
4. Raises the set point when '*' button (2) is simultaneously pressed.
5. Temperature Sensor Input. Use the same type of sensor probe as the sensor plug installed on the controller (see Section 3.4). The correct sensor type will have the same color plug as the receptacle (5) on the front of the controller.
6. Power Outlet. Plug only 120 VAC devices into this outlet (see Section 3.2).
7. Controller On/Off switch.
8. Timer Function Knob. Multi-function knob that selects timer function (push knob in) and enters the amount of time in the timer (rotate). See Section 3.5.
9. Timer Display. The timer display always shows the status of the timer circuit (see Section 3.5). The display can show "On" meaning that the circuit will allow power to be applied to the heater, "Off", meaning that the circuit will not allow power to be applied to the heater, or it will show a time when power will be applied or removed from the heater depending on the settings in the timer.
10. Timer Status LED's Timer status LED's indicate whether power will be applied or removed from the heater when the time in the timer goes to 0. See Section 3.5.
11. Heater Status LED. This (small) LED is On when power is being applied to the heater and Off when power is not applied to the heater.
12. Power Reduction Circuit. This switch is the interface to J-KEM's patented power control computer that limits the maximum power delivered to the heater. See Sections 3.6 and 4.1.
13. USB serial communication port.

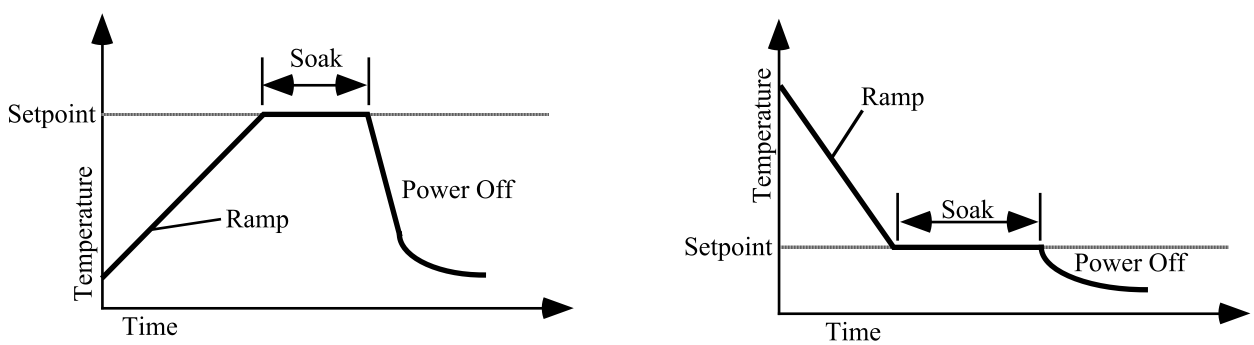
3.2 Heater Restrictions. The controller delivers 10 amps of current at 120 VAC into resistive loads (heating mantles, hot plates, ovens, etc.). **Use only resistive loads that are safely operated at 120 VAC and require less than 10 amps or damage to the controller and a safety hazard may result.**

- **Only 120vac oil baths should be used with this controller.** Other voltage oil baths should be operated using J-KEM's Model 410 controller (See Appendix for an application note describing how to use any voltage oil bath with this controller).
- Devices other than resistive loads can be used with your controller but certain restrictions apply.

Device Type	Restrictions	Comments
Incandescent lamps Infrared heaters	≤ 700 watts	Set the power reduction circuit to the > 2 L setting.
Inductive loads: * solenoids * transformers * motors	≤ 4 amps; 480 watts	The controller must be programmed for this use. Request application note AN5.

3.3 Ramp-to-Setpoint & Soak Feature. A new feature of J-KEM's controllers called 'Ramp-To-Setpoint' allows you to enter a specific heating rate (e.g., heat to 120^{o} C at a rate of 5^{o} C/Hour), a second feature called 'Soak' then lets you specify how long to stay at that temperature before turning off.

Examples of Program Ramps



The controller is shipped with the Ramp-to-Setpoint feature OFF, the user must specifically turn Ramp-to-Setpoint ON. When Ramp-to-Setpoint is OFF, the controller heats to the entered setpoint at the fastest rate possible. When Ramp-to-Setpoint is ON, the controller heats at the user entered ramp rate.
The Ramp-to-Setpoint feature and its associated parameters are turned on and set in the controller's programming mode. The parameters of importance are:

SPrr **SetPoint Ramp Rate. Allowable Values: 0 to 9990 deg/Hr.**

This specifies the desired rate of heating (cooling). Note, this parameter specifies the *desired* rate of heating (cooling), but in cases of extremely high ramp rates the reaction will not actually heat faster than the power of the heater will allow.

SPrn **SetPoint Ramp Run. Allowable Values: ON, OFF, Hold**

This parameter turns the Ramp-to-Setpoint feature ON or OFF. During an active run, if this parameter is set to 'Hold', the setpoint ramp stops and *holds* at its' current value. This continues until the parameter is set to ON or OFF. When set to OFF, the values in SetPoint Ramp Rate and Soak Time are ignored.

SoAK **Soak Time. Allowable Values: "- -", 0 to 1440 min.**

This specifies the amount of time to *soak* at the setpoint after the setpoint temperature ramp is complete. A setting of **"- -"** causes the controller to remain at the final setpoint indefinitely. A numeric value causes the controller to stay at the setpoint for the entered time and then turn power to the heater off after the time expires.

Important Points to Know

1. While the Ramp-to-Setpoint feature in activated, the display alternates between the current reaction temperature and the word "**SPr**" to indicate that a "SetPoint Ramp" is active.

2. If this controller is equipped with a digital 100-hour timer, the digital timer and the Ramp-to-Setpoint feature are completely independent of each other. For example, if the digital timer is set to turn heating OFF after 5 hours, heating **is** turned off even if a ramp step is in progress. Likewise, if a Soak time turns heating off after 3 hours and the digital timer is set to turn heating off after 10 hours, the digital timer has no effect since the expired Soak time already has turned heating off. To avoid confusion and conflicts between the meters "Hold" feature and the front panel digital timer, it's recommended that the Soak Time feature be set to "– –" in the meters setup menu and not changed.

3. Setting a ramp rate will not guarantee that the reaction temperature is at the specified ramp temperature since heating is dependent on the power of the heater. For example, if a ramp rate of 1200 deg/Hr (i.e., 20 deg/min) is set, unless the heater is powerful enough to impart heat at such a high rate, the reaction temperature will not track the ramp temperature. Likewise, a reaction can't cool faster than natural cooling by ambient air.

4. Once the Ramp-to-Setpoint feature is activated in programming mode, it remains on until it's deactivated in programming mode. The Ramp-to-Setpoint feature remains activated even if power is turned off to the controller.

Activating & Programming the Ramp-to-Setpoint Feature

1.	Press and hold in both the ▲ and ▼ keys on the front of the temperature meter until the word "**tunE**" appears in the display, then release both keys.
2.	Press the ▲ key (8 times) until the word "**SPrr**" appears in the display. This is where you set the ramp rate in units of degrees/hour. First hold in the '*' key, then while holding in the *' key press the ▼ or ▲ key until the desired ramp rate appears in the display, then let go of all the keys. Units are in degrees/hour.
3.	Press the ▲ key once and the word "**SPrn**" will appear in the display. This function turns the ramping feature ON, OFF, or to Hold. First hold in the '*' key, then while holding in the *' key press the ▼ or ▲ key until the desired setting appears in the display, then let go of all the keys.
4.	Press the ▲ key once and the word "**SoaK**" will appear in the display. This is where the soak time is set in units of Minutes. A soak time of ' -- ' means to 'soak forever' (this setting is one below '0'). First hold in the '*' key, then while holding in the *' key press the ▼ or ▲ key until the desired time appears in the display, then let go of all the keys. If a soak time is set, the controller display will alternate between showing the current reaction temperature and the word "**StoP**" when the soak time has expired to indicate that power has been turned off.
5.	To exit programming mode, press and hold in both the ▼ and ▲ keys until the temperature appears in the display, then release both keys.

Deactivating the Ramp-to-Setpoint Feature

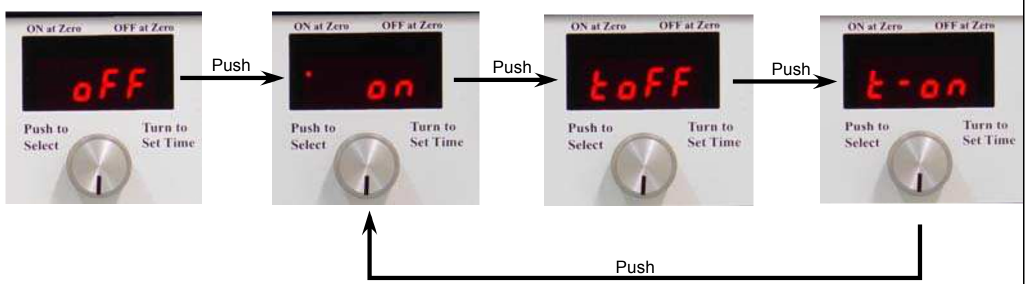
1.	Press and hold in both the ▲ and ▼ keys on the front of the temperature meter until the word "**tunE**" appears in the display, then release both keys.
2.	Press the ▲ key (9 times) until the word "**SPrn**" appears in the display. This function turns the ramping feature ON and OFF. First hold in the '*' key, then while holding in the *' key press the ▼ or ▲ key until OFF appears in the display, then let go of all the keys.
3.	To exit programming mode, press and hold in both the ▲ and ▼ keys until the temperature appears in the display, then release both keys.

3.4 Temperature Sensor Input. Every controller is fitted with a specific *type* of thermocouple input and can only be used with a thermocouple of the same type. For the correct temperature to be displayed, the thermocouple type must match the receptacle type on the front of the controller (Figure 1; # 5). All thermocouples are color coded to show their type (Blue = type T; Yellow = type K; Black = type J). The color of the thermocouple plug must match the color of the receptacle on the front of the controller. If the thermocouple is broken or becomes unplugged, the error message "inPt" "FAiL" blinks in the temperature meter display and the controller stops heating.

3.5 Timer Controls. This section applies to the Model 210/Timer only. The timer circuit works in conjunction with the digital meter to determine when power is applied to the heater. The digital meter is the actual temperature controller, the timer circuit only acts as a *gatekeeper* to determine if the digital meter (temperature controller) is allowed to apply power to the heater or not. By inserting the timer between the digital meter and the heater, the timer can turn heater power On or Off based on a user entered time.

When power to the controller is turned on, the timer defaults to the *Power Off* state as is indicated by the word Off in the display. In this state no power is applied to the heater. This is a safety feature that insures that power is not applied to a heater following recovery from a power failure.

The timer has 4 states. The timer cycles between the 4 states by pushing in on the silver timer knob momentarily. For example, push the timer knob once and the timer changes from the Off state to the On state, push it again and it changes to the toFF state. Repeatedly pushing the knob cause the time to cycle between its three normal states of On, toFF, and t-on. If the Power Reduction Circuit (Section 3.6) is set to the Heat Off position, the timer window always displays oFF.



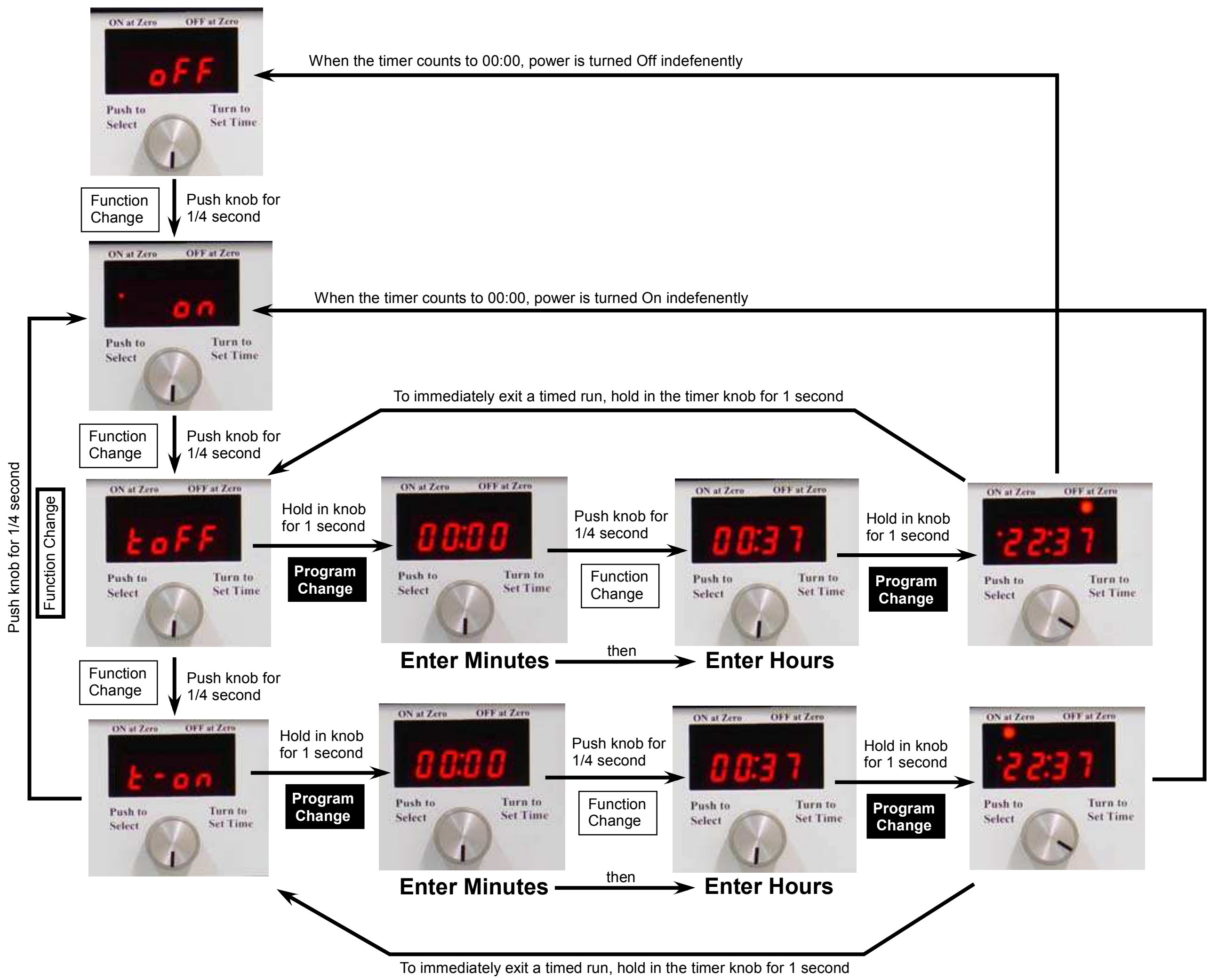
NOTE: Pushing in on the timer knob quickly for about 1/4 second causes it to advance to the next state. Holding in the knob for 1 second changes to the mode where time is entered into the timer.

The four states of the timer circuit are explained below.

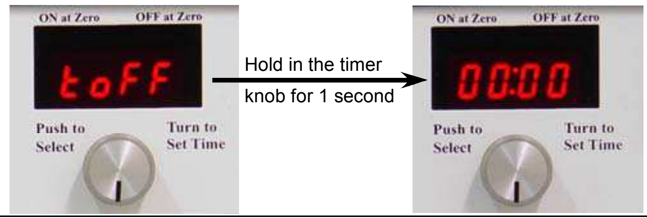
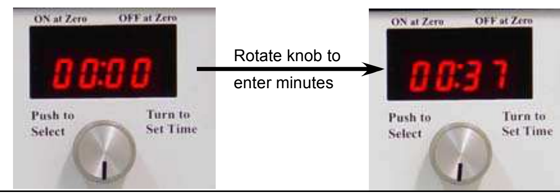
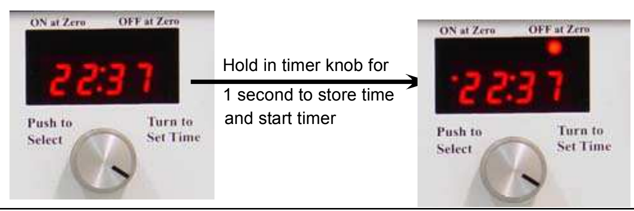
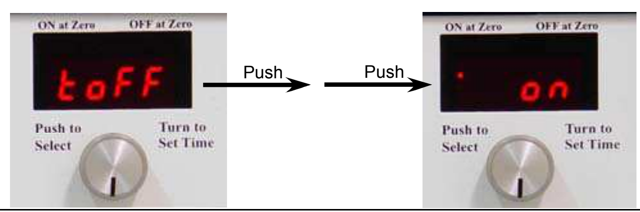
	In the off state, no power is applied to the heater, even if the temperature meter calls for power to be applied. The controller always enters the off state when power is turned on or following recovery from a power failure. The controller also enters the off state when the power reduction circuit is set to the Heat Off position (see Section 3.6).
	In the on state, the timer circuit applies power to the heater when the temperature meter calls for power to be applied. Whenever power is applied to the heater, the small LED *dot* on the left of the timer window is lit. Depending on the power needs of the heater, this dot may blink rapidly.
	The "toFF" state (standing for Time Off) allows the user to enter the amount of time the controller should heat until heating is automatically turned off. While time is present in the timer, power is applied to the heater, when the time counts down to 0, heating is turned off. See the section below titled Heating for a Set Period of Time.
	The "t-on" state (standing for Time On) allows the user to enter an amount of time to delay before applying power to the heater. While time is present in the timer, no power is applied to the heater even if the temperature meter calls for power to be applied, but when time counts down to 0, heat is turned on indefinitely. See the section below titled Delay Heating for a Set Period of Time.

Over View of the Timer Functions

The timer knob is a multi-function knob. When it's pushed in for 1/4 second it causes the timer to advance to the next function. When it's pushed in for 1 second it enters programming mode. In programming mode, the user enters time into the timer or locks the entered time into the timer which starts the program running (a running program can be aborted by holding in the timer knob for 1 second).
When in programming mode, rotating the knob in a clockwise direction increases the amount of time entered into the timer. Rotating the knob in a counter clockwise direction decrease the amount of time (when rotating in a counter clockwise direction, the timer rolls over from "00" to "59" minutes, when entering minutes, or from "00" to "99" hours, when entering hours).



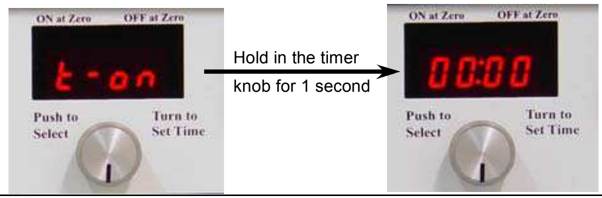
Heating for a Set Period of Time

In this mode, the user enters the amount of time to heat before turning heating off permanently. This is useful to heat a reaction or other lab instrument for a set period of time and then have the reaction stop heating automatically. While at this setting and while entering a time into the timer, no power is applied to the heater.	
Step 1. When the timer displays "toFF", holding in the timer knob causes the display to change to a clock showing 00 : 00. The left 2 digits are hours and the right 2 digits are minutes. The minutes digits are blinking which indicates that their value can be changed.	
Step 2. To increase the number of minutes, rotate the timer knob to the right. To decrease the number of minutes, rotate the timer knob to the left.	
Step 3. To change the number of hours in the display, momentarily press the timer knob (1/4 second) and the hours digits begin to blink. To increase the number of hours, rotate the timer knob to the right. To decrease the number of hours, rotate the timer knob to the left.	
Step 4. When the desired time is displayed, hold in the timer knob for 1 second to enter the time and start the timer. When the timer starts, the LED under the label "OFF at Zero" lights. This indicates that power to the heater will turn OFF when the timer counts down to zero.	
At any time, the timer program can be aborted by holding in the timer knob for 1 second. When this is done, the display changes to toFF. To turn on heating, push the timer knob twice until the display reads On.	

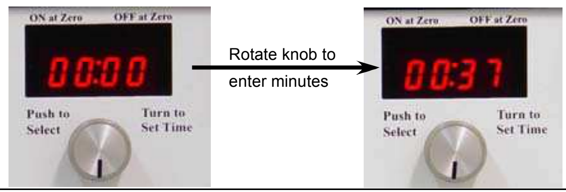
Delay Heating for a Set Period of Time

In this mode, the user enters an amount of time to delay before turning on power to the heater. This is useful to start heating a reaction or piece of equipment automatically at a specific time. While at this setting and while entering a time into the timer, no power is applied to the heater.

Step 1. When the timer displays "t-on", holding the timer knob in for 1 second causes the display to change to a clock that shows 00 : 00. The left 2 digits are hours and the right 2 digits are minutes. The minutes digits are blinking which indicates that their value can be changed.

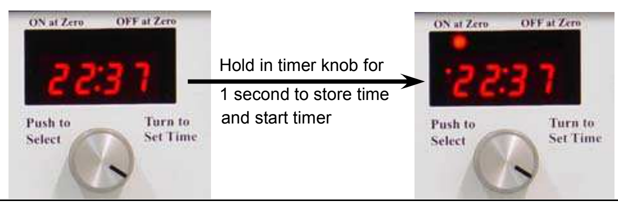


Step 2. To increase the number of minutes, rotate the timer knob to the right. To decrease the number of minutes, rotate the timer knob to the left.

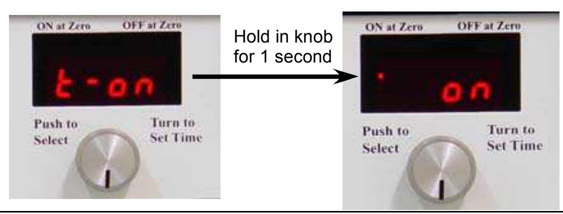


Step 3. To change the number of hours in the display, momentarily press the timer knob (1/4 second) and the hours digits begin to blink. To increase the number of hours, rotate the timer knob to the right. To decrease the number of hours, rotate the timer knob to the left.

Step 4. When the desired time is displayed, hold in the timer knob for 1 second to enter the time and start the timer. When the timer starts, the LED under the label "ON at Zero" lights. This indicates that power to the heater will turn ON when the timer counts down to zero.



At any time, the timer program can be aborted by holding in the timer knob for 1 second. When this is done, the display changes to t-on. To turn on heating, push the timer knob until the display reads On.



3.6 Power Reduction Circuit. This circuit (12) is the interface to J-KEM's patented power control computer which limits the maximum output power delivered by the controller. It determines whether the controller heats at a very low (1-10 mL), low (10 - 100 mL), intermediate (50 - 500 mL), medium (300 mL - 2 L), or high (>2 L) power level. The power reduction circuit acts as a solid state variac. This circuit has an additional setting: "Heat Off" which, when selected, turns heating off and allows the controller to act as a digital thermometer. The table to the right shows the maximum output power from the controller to the heater depending on the position of the power switch. The correct setting for this switch is the setting that supplies adequate power for the heater to heat to the set point in a reasonable period of time while at the same time not overpowering it.

Front Panel Volume Range	Approx. % of Full Power
1 - 10 mL	3
10 - 100 mL	10
50 - 500 mL	25
300 ml - 2 L	50
≥ 2 L	100

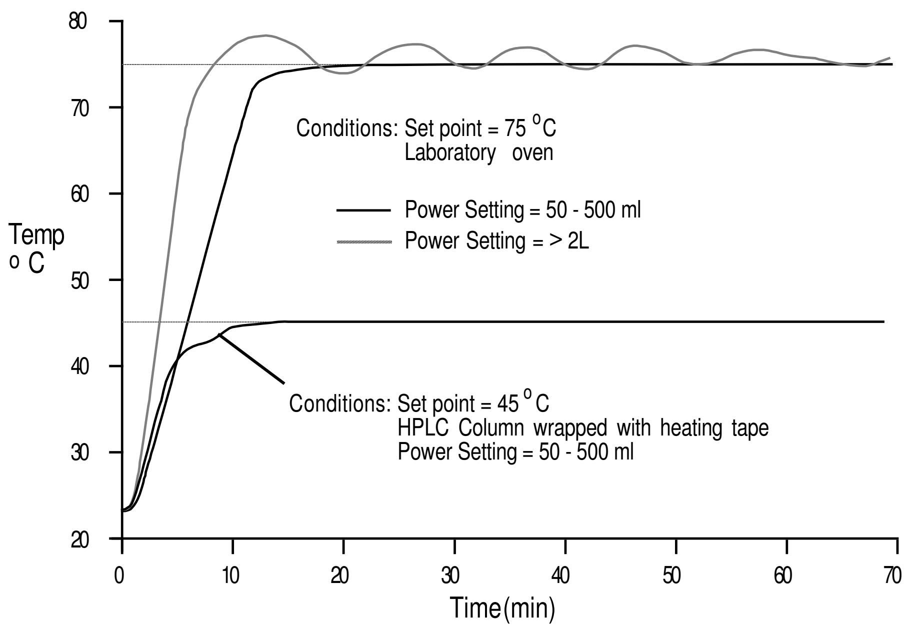
Heating Liquids. Each power level is associated with a volume range which acts as a guide when heating solutions with heating mantles. When solutions are heated with heating mantles set the power switch to the range that includes the volume of solution being heated [Note: this switch is set to the volume of solution, not the size of the flask]. For example to heat 250 ml of toluene to 80^{o} C in a 1 L round bottomed flask choose the third power setting (50 - 500 ml) since the solution volume falls within this range. There are situations when a power level other than that indicated on the front panel should be used:

Example	Power Setting	Explanation
80 ml toluene 100 ml flask 100 ml heating mantle SP = 80^{o} C	50 - 500 ml (25% power)	Organic solvents heated to 50 - 110^{o} C are set to the volume range on the front panel. When choosing between 2 power settings (i.e. 80 ml also falls within both the 10 - 100 ml range and the 50 - 500 ml range) choose the higher setting.
80 ml collidine 100 ml flask 100 ml heating mantle SP = 170^{o} C	300 ml - 2 L (50% power)	Even though the solvent volume is less than the range of this power setting, it should be used because high temperatures require additional power.
80 ml water 100 ml flask 100 ml heating mantle SP = 80^{o} C	300 ml - 2 L (50% power)	While the setting 50 - 500 ml would work, since the heat capacity of water is twice that of a typical organic solvent (1 cal/g/^{o} K), a higher power setting can be used to compensate for the higher heat capacity.
125 ml toluene 1 L flask 1 L heating mantle SP = 80^{o} C	10 - 100 ml (10% power)	When the heating mantle size is substantially larger (5X) than the volume being heated (i.e. the heating mantle has excess heating capacity for the volume being heated), a lower power setting gives better control.
150 ml toluene 250 ml flask 250 ml heating mantle SP = 35^{o} C	10 - 100 ml (10% power)	Even though the solvent volume isn't included in this power setting, it should be used because low temperatures are better regulated with less power.

Avoid switching between power levels while the controller is heating. Specifically, do not initially set the controller on a high power level to rapidly heat the solution, then decrease the power level to the correct setting as the solution approaches the set point. Changing power levels doesn't damage the controller, but it will reduce its heating performance.

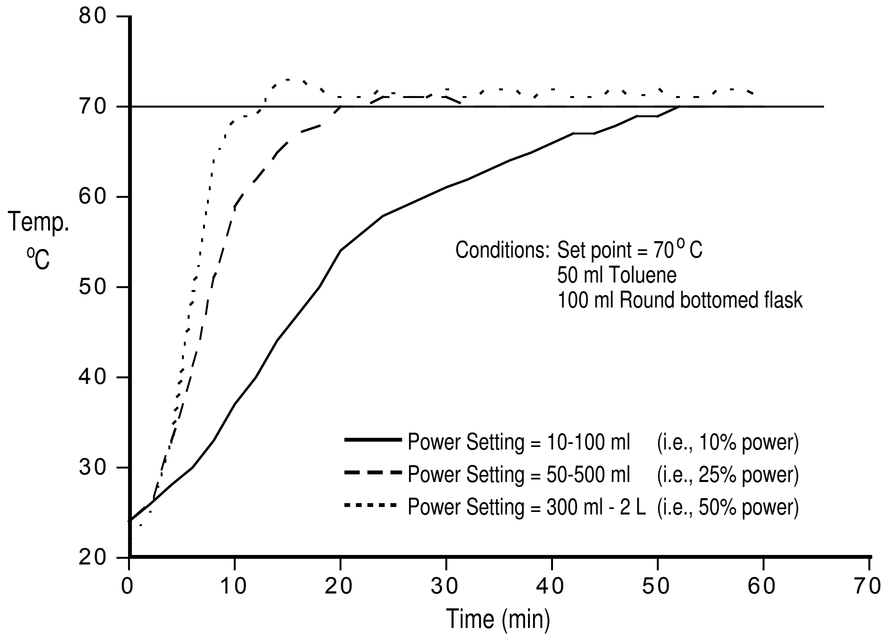
Heating Equipment. Two factors need to be considered when heating equipment (ovens, hot plates, furnaces, HPLC columns, etc.); (1) placement of the temperature sensor (Section 2.4) and, (2) the appropriate power setting. The best guide to the correct power setting for various pieces of equipment is the researcher's experience. If your best guess is that the equipment needs 1/3 full power to heat to the set point, set the power switch on the 300 ml - 2 L setting (i.e., 50% power, it's usually better to have too much power rather than too little). If the heater heats too slow, increase the power (to the >2 L setting), if it heats too fast or has excessive overshoot, decrease the power (to the 50 - 500 ml setting). If the amount of power seems to be adequate, but the heater doesn't heat with stability, the controller probably needs to be tuned (see Section 2). Section 3.7 shows the type of performance you should expect from the controller with different pieces of equipment.

3.7 Effect of Power Setting on Heating Profile. The following graphs show the effect of selected power levels on heating performance in a variety of situations. Each example contains 1 optimal and 1 or 2 less optimal settings demonstrating some characteristic of the power reduction circuit.



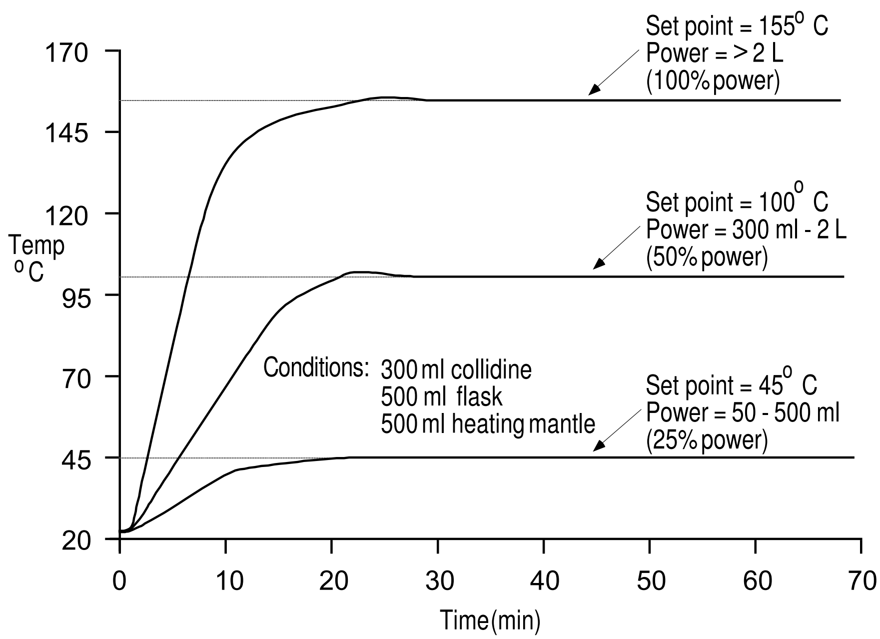
Graph 1

This graph shows typical heating profiles for a laboratory oven and an HPLC column. In the example of the oven the heating curves for 2 different power levels are shown. The 50 - 500 ml setting is the appropriate amount of power to heat to 75° C and thus results in a smooth heating curve. The > 2L power setting is too much power and results in oscillation around the set point.



Graph 2

This graph shows the affect of different power settings when heating liquids with heating mantles. The 10 - 100 ml setting (10% power) is underpowered and results in slow heating. The 300 ml - 2 L setting (50% power) is too much power and results in sporadic control. The controller adapts to a wide range of power settings. In this example the power is varied by a factor of 5X, nevertheless, reasonable control is maintained in each case.



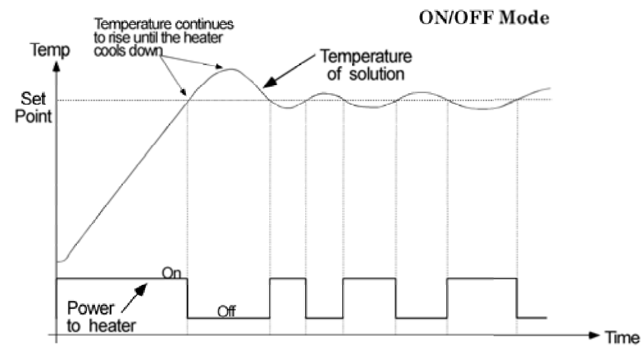
Graph 3

Another factor affecting the choice of power setting is the set point temperature. For set points near room temperature a low power level is adequate. For *average* temperatures (50 - 100°) the volumes printed on the front of the controller are a good guide. For high temperatures, the next higher power setting might be needed to supply the heater with additional power.

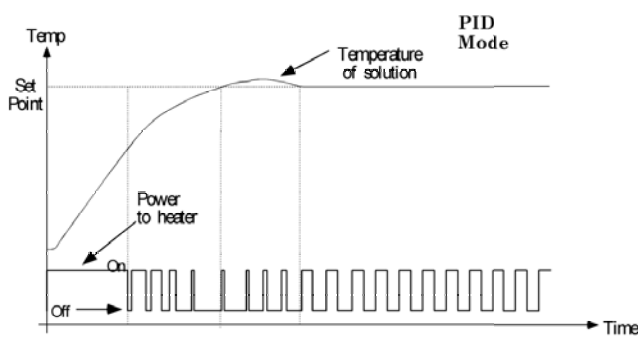
The power reduction circuit limits the total amount of power delivered to the heater. In this sense it works like a variac and can be used like one. If the heater isn't getting enough power, turn the power level up one notch, if it's getting too much power, turn it down.

3.8 Changing Between PID and ON/OFF Operating Modes. The controller can heat in either of 2 operating modes, PID (Proportional, Integral, Derivative) or ON/OFF mode. The difference between them is the way power is supplied to the heater.

In ON/OFF mode (the simplest heating mode), the controller is ON when it's below the set point and OFF when above. The disadvantage of this mode is a large over shoot of the set point (5 - 30°) on initial warm up and oscillation of temperature around the set point thereafter. The reason for the overshoot is because the heater turns off only after crossing the set point and until the heater cools down the temperature continues to rise. This method works well for heaters that transfer heat rapidly (such as heat lamps), it's acceptable for heaters such as heating mantles (≈ 5° overshoot), but it's terrible for heaters that transfer heat slowly (vacuum ovens, heating blocks, etc.).



In PID mode the controller monitors the shape of the heating curve during initial warm up and decreases power to the heater before the set point is reached so that the solution reaches the set point with minimal over shoot. [Notice that the heater turns off for varying periods of time before the set point temperature is reached]. The second feature of PID mode is that it adjusts the percent of time the heater is on so that the set point is maintained precisely. The advantage of PID mode is that it delivers stable temperature control with any heater from heat lamps to vacuum ovens. The disadvantage is that the controller must be properly tuned to the heater being used, whereas ON/OFF mode requires no tuning. Since both heating modes have their advantages (simplicity vs. accuracy), instructions to change the controller to ON/OFF mode are given below (though PID mode will probably give better results 95% of the time). The controller can be set back to PID mode by following Procedure 1 in Section 2.3.



Procedure to change controller to ON/OFF mode

1.	Press and hold in both the ↑ and ↓ keys on the front of the temperature meter until the word "tunE" appears in the display, then let go of the buttons.
2.	Press ↑ until the word "CyC.t" appears in the display.
3.	While holding in the '*' key, press the ↓ key until the word "on.of" appears in the display. NOTE: if the display shows the letter "A" when the '*' keys is held in, press the ↑ key until "on.of" is in the display, then let go of all the keys.
4.	Press the ↓ key until the word "bAnd" appears in the display. While holding in the '*' key, press the ↓ key until the value "0.1" appears in the display, then let go of all the keys.
5.	Press and hold in both the ↑ and ↓ keys on the front of the controller until the temperature is displayed, then release both keys.

The controller can be set back to PID control by following Procedure 1 in Section 2.3. To completely reset the controller to original factory settings, follow the procedure in the Appendix, Section II.

3.9 Troubleshooting.

Problem	Cause	Corrective Action
Large over shoot of the set point (> 3°) during initial warm-up or unstable temperature control.	Output power level is set too high.	Set the output power level to a lower setting (see Section 3.6).
	Controller is not tuned for process being heated.	Tune the controller as outlined in Section 2.
The process heats too slowly.	Output power level is set too low.	Increase the output power to the next higher setting (Section 3.6).
	The heater doesn't have enough power.	Replace with a more powerful heater. For assistance contact J-KEM.
The controller doesn't come on.	Internal 2 amp fuse has blown.	Not user serviceable. Have qualified electrician replace.
	Circuit breaker on back has tripped.	Allow to cool, then reset circuit breaker.
The controller comes on, but does not heat	The timer controls are set incorrectly.	Change the position of switch 8 or enter a time into the timer. See Section 3.5.
	The heater is broken.	To verify that the controller is functioning properly, place the power level switch on the >2L setting and enter a set point of 100° C. Plug a light into the outlet of the controller, then wait 1 minute. If the light comes on the controller is working properly.
Controller blinks: "inPt" "FAiL"	The temperature sensor is unplugged, excessively corroded or broken.	Clean or replace broken sensor, thermocouple extension cord or thermocouple receptacle on the controller's face.
"-SPr-"	This indicates that a setpoint ramp rate program in effect.	See Section 3.3
"tunE" "FAiL"	Autotune routine failed.	Turn off controller for 10 seconds. See Section 2.2.
Displayed temperature is incorrect. [Note: Types 'K' & 'J'	The controller has not warmed-up.	The display temperature reads low when the controller is first turned on, but will self-correct as it warms up. The controller can be used immediately since it will warm up during the initial stages of heating.
	Corroded thermocouple connections.	Clean plug on thermocouple and receptacle on controller with sandpaper or steel wool.
	Corroded thermocouple.	If the temperature-measuring end of the thermocouple is corroded, replace thermocouple.
	Temperature display offset needed.	To enter a controller display offset: 1. Turn on controller. Allow to warm up for 30 minutes. 2. Record displayed temperature. 3. Press both the ↑ and ↓ keys on the front of the temperature meter until "tunE" appears. 4. Press the ↓ key until "LEVL" appears. 5. First hold in the * key, then while holding in the * key press the ↑ key until "3" appears in the display. 6. Press the ↑ key until "ZEro" is showing. Note the current display offset (the number in the display). 7. Calculate the new offset temperature by adding the current offset to the amount that the display is presently in error 8. Enter a new offset by holding in the * key, while holding in the * key press the ↑ or ↓ keys until the new offset temperature is showing, let go of all the keys. Press the ↑ and ↓ keys until the temperature is displayed.

3.10 Changing the Temperature Display Resolution The controller is programmed to display temperature with 0.1° C resolution. The controller can also display 1° C resolution by following the procedure below (the display can also be changed to read in ° F, call for information). There are two reasons to change the display resolution:

1) To enter a setpoint faster (the display scrolls 10X faster in 1° mode than in 0.1° mode).
2) To display temperatures above 999.9°.

1.	Press and hold in both the ↓ and ↑ keys on the front of the temperature meter until the word "tunE" appears in the display, then release both keys.
2.	Press the ↓ key once and "LEVL" appears in the display. First hold in the '*' key, then while holding in the '*' key press the ↑ key until "2" appears in the display then let go of all the keys.
3.	Press the ↑ key repeatedly until the word "diSP" appears in the display. First hold in the '*' key, then while holding in the '*' key press the ↓ or ↑ key until the value "1" [not "**0.1**"] appears in the display, then let go of all the keys.
4.	Press and hold in both the ↓ and ↑ keys until the temperature appears in the display, then release both keys.

3.11 Over-Temperature Protection Circuit The temperature controller is equipped with an over-temperature protection circuit that turns off heating any time the temperature of the reaction goes 5° C above the entered setpoint. When the temperature of the reaction cools below 5° C above the setpoint the circuit is reset and the controller begins to operate normally. The over temperature feature acts to prevent accidents from reactions where something has seriously gone wrong since no application with J-KEM's controllers should over shoot the setpoint by more than 2° C. For applications requiring more versatile and accurate over-temperature protection circuits, the user is refereed to J-KEM's Model 260 and Model 270 controllers.

There may be situations where it's desirable to disable the over temperature protection circuit (for example, if the controller is often used as a digital thermometer). The procedure below gives directions on disabling and re-enabling the over temperature circuit. In reality, the over-temperature alarm can't be turned off because it's hard-wired in the controller, but what can be done is program an over-temperature limit so high (i.e., 999° C) that it has the effect of disabling the alarm.

Procedure to DEACTIVATE Over Temp Alarm		Procedure to RE-ACTIVATE Over Temp Alarm	
1	Press and hold in both the ↓ and ↑ keys on the front of the temperature meter until the word "**tunE**" appears in the display, then release both keys. This places the controller in programming mode.	1	Press and hold in both the ↓ and ↑ keys on the front of the temperature meter until the word "**tunE**" appears in the display, then release both keys. This places the controller in programming mode.
2	Press the ↑ key until "**SEt.2**" appears in the display, then release all keys.	2	Press the ↑ key until "**SEt.2**" appears in the display, and release all keys.
3	Press and hold in the * key. When the * key is held in, the display shows the number of degrees that the set point must be exceeded by to cause the over-temperature alarm to activate. To effectively disable the over-temperature alarm, press the ↑ key (while holding in the * key) until a very high value is entered (such as 999 degrees). When you're done, let go of all the keys. Whatever number you entered at this point is the number of degrees that the reaction temperature must exceed the set point before the alarm comes on.	3	Press and hold in the * key. While holding in the * key, press the ↓ key until the display shows 5.0, then release both keys.
4	To return to normal temperature display, press and hold in both the ↓ and ↑ keys (about 3 seconds) until the temperature appears in the display.	4	To return to normal temperature display, press and hold in both the ↓ and ↑ keys (about 3 seconds) until the temperature appears in the display.

3.12 Do's and Don'ts When Using Your Controller. The controller, heater and thermocouple form a closed loop feedback system (see Fig. 2 in Section 4.1). When the controller is connected to a heater, the feedback loop should not be broken at any point.

Don't	remove either the thermocouple or heater from the solution without setting the power level to the "Heat Off" position. As the thermocouple cools the controller turns the heater on. Since this heat is never fed back to the thermocouple it heats continuously.
Don't	use the controller to regulate an exothermic process. The controller has no capacity for cooling. If an exotherm is expected, it must be controlled in another way.
Do	use an appropriate size flask and heater for the volume being heated. Use the smallest flask and heating mantle that accommodates the reaction. This ensures that the heating power of the heating mantle closely matches the volume being heated. This also allows the solution to radiate excess heat to minimize temperature overshoots.
Do	place the thermocouple directly in the solution. Place at least the first 1/4" of the thermocouple directly into the solution. If a corrosive mixture is heated, use a coated-coated thermocouple (or use the external thermocouple method; Section 4.2).
Do	avoid exposure of the controller to corrosive gases and liquids. The atmosphere of a research hood is corrosive to all electronics. Place the controller outside the hood away from corrosive gases.

Section 4: Application Notes

Supplemental application notes on the following topics are available by contacting J-KEM.

Application Note	Subject
AN1	How to heat oil baths with your controller. (Included in Appendix)
AN2	Changing the controller's thermocouple type.
AN3	Changing the heating outlet into a cooling outlet.
AN4	Using the controller for unattended fractional distillations.
AN5	Using the controller with inductive (motors, valves) loads.

4.1 Theory of How the Controller Works – Simply. For the purpose of explaining how the controller works, the example of a solution heated with a heating mantle is used. The principles are the same for all heater types.

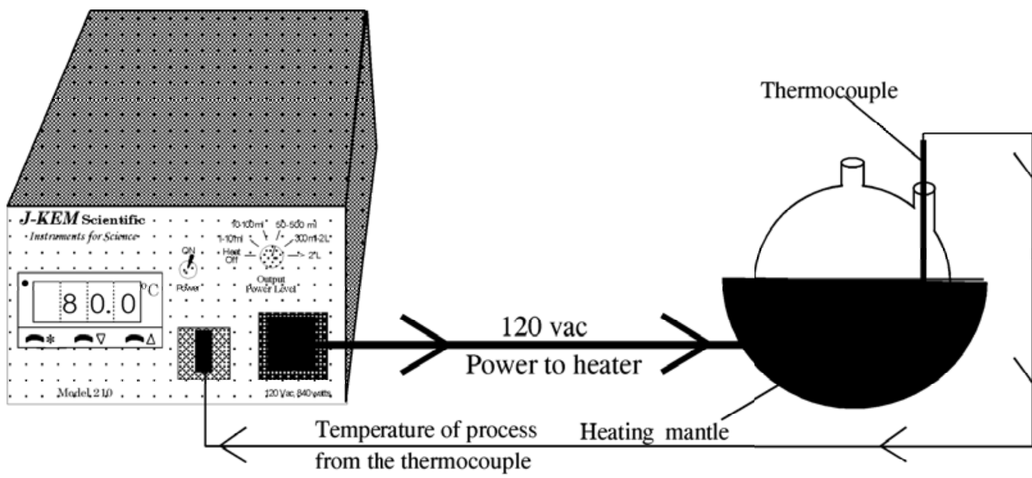


Figure 2

The controller, the heating mantle and the thermocouple form a closed loop feedback system. When the process temperature is below the set point, the controller turns the heating mantle on and then monitors the temperature rise of the solution. If a small rise results (indicating a large volume is being heated) the controller sets internal parameters appropriate for heating large volumes. If a large rise in temperature results, the controller responds by loading a set of parameters appropriate for heating small volumes. For the controller to work ideally, information needs to travel instantaneously around the feedback loop. That means that any power the controller applies to the heating mantle must reflect itself in an instantaneous temperature rise of the solution and the thermocouple. Unfortunately, this type of instantaneous heat transfer from the heating mantle to the solution to the thermocouple just doesn't occur. The delay time between when power is applied to the heating mantle and when the solution rises in temperature; and also the converse, when power is removed from the heating mantle and the solution temperature stops rising is the source of most controller errors. The reason for this can be seen in a simple example.

Imagine heating a gallon of water to 80° C in a 5 quart pan on an electric range. Placing the pan on the range and turning the heat to 'high' you'd observe a delay in heating while the range coil warmed-up. This delay might be a little annoying, but it's really no problem. The real problem comes as the water temperature approaches 80° C. If you turned the range off just as the water reached 80° C the temperature would continue to rise – <u>even though all power had been disconnected</u> – until the range coil cooled down. This problem of overshooting the set point during initial warm-up is the major difficulty with process controllers. Overshooting the set point is minimized in two ways by your J-KEM controller – but first let's finish the range analogy. If you had turned the range off just as the water temperature reached 80º C, the final temperature probably would not exceed 82º C by the time the range coil cooled down, because the volume of water is so large. In most situations a 2º C overshoot is acceptable. But what if you were heating 3 tablespoons (45 mL) of water and turned the stove off just as the temperature reached 80º C. In this case, the final temperature would probably approach 100º C before the range cooled down. A 20º C overshoot is no longer acceptable. Unfortunately, this is the situation in most research heating applications. That is, small volumes (< 2 L) heated by very efficient heating mantles that contain large amounts of heat even after the power is turned off. Your controller handles the problem of 'latent heat' in the heating mantle in two ways:

1) The controller measures the <u>rate</u> of temperature rise during the initial stages of heating. It then uses this information to determine the temperature at which heating should be stopped to avoid exceeding the set point. Using the range analogy, this might mean turning the power off when the water temperature reached 60º C and allowing the latent heat of the burner to raise the water temperature from 60 to 80º C. This calculation is done by the controller and is independent of the operator. The next feature of the controller is directly under operator control and has a major impact on the amount of overshoot on initial warm-up.
2) Again referring to the range analogy, you'd obtain better control when heating small volumes if the range had more than two power settings; <u>Off</u> and <u>High</u>. J-KEM's patented power reduction circuit (12) serves just this function. It allows the researcher to reduce the power of the controller depending on the amount of heat needed. This circuit can be thought of as determining whether the heating power is **Very low** (*1-10 mL*), **Low** *(10-100 mL)*, **Intermediate** *(50-500 mL)*, **Medium** *(300 mL-2 L)*, or **High** *(> 2 L)*. The proper power setting becomes instinctive after you've used your controller for awhile. For additional information see Section 3.6.

4.2 Controlling the Heating Mantle Temperature Directly.

In a *normal* heating setup, the thermocouple is placed in the solution being heated. The controller then regulates the temperature of the solution directly. The thermocouple could alternately be placed between the heating mantle and the flask so that the controller regulates the temperature of the heating mantle directly, which indirectly regulates the temperature of the solution.
Advantages to this method include:

1. The temperature of <u>any</u> volume (microliters to liters) can be controlled.
2. Temperature control is independent of the properties of the material being heated (e.g., viscosity, solid, liquid, etc.).
3. Air and water sensitive reactions can be more effectively sealed from the atmosphere.

The temperature controller must be programmed for use with an external thermocouple before this procedure is used (see following procedure). The following step-by-step procedure programs the controller to regulate heating mantle temperature. If you switch back and use the controller with the thermocouple in solution, Procedure 1 in Section 2.3 will program the controller for heating mantles. For all other heaters, see tuning instructions in Section 2.

After the controller is reprogrammed, place a fine gage wire thermocouple (1/3 the size of kite string; available from J-KEM) in the bottom third of the heating mantle and fit the flask snugly on top so that the thermocouple is in intimate contact with the heating mantle. Set the power reduction circuit to the power level shown in the table at the right. Turn the controller on and enter the set point.

Heating Mantle Size	Power Level
5 & 10 ml	1-10 ml
25 ml	10-100 ml
50 ml - 22 L	50 - 500 ml

For temperatures over 120 °C, the next higher power level may be necessary

Procedure to Load Tuning Parameters for External Thermocouples.

1.	Press and hold in both the ↓ and ↑ keys on the front of the temperature meter until the word "tunE" appears in the display, then release both keys.
2.	Press the ↑ key once and the word "bAnd" will appear in the display. While holding in the '*' key press the ↓ or ↑ key until the value "5" appears in the display, then release all keys.
3.	Press the ↑ key once and the word "int.t" will appear in the display. While holding in the '*' key press the ↓ or ↑ key until the value "2" appears in the display, then release all keys.
4.	Press the ↑ key once and the word "dEr.t" will appear in the display. While holding in the '*' key press the ↓ or ↑ key until the value "5" appears in the display, then release all keys.
5.	Press the ↑ key once and the word "dAC" will appear in the display. While holding in the '*' key press the ↓ or ↑ key until the value "5.0" appears in the display, then release all keys.
6.	Press the ↑ key once and the word "CyC.t" will appear in the display. While holding in the '*' key press the ↓ or ↑ key until the value "5.0" appears in the display, then release all keys.
7.	Press and hold in both the ↓ and ↑ keys until the temperature appears in the display, then release both keys.

To return to using thermocouples in solution, perform Procedure 1 in Section 2.3.

4.3 Automatic Storage of Min/Max Temperatures The controller automatically records the minimum and maximum temperatures of a process by following the procedure below. These temperatures are updated continuously after the routine is started and cleared by turning the controller off. This procedure must be started every time you want to record temperatures.

	Procedure to Start Temperature Logging
1.	Press and hold in both the ↓ and ↑ keys on the front of the temperature meter until the word "tunE" appears in the display, then release both keys.
2.	Press the ↓ key once and the word "LEUL" appears in the display. While holding in the '*' key press the ↑ key until the value "3" appears in the display, then release all keys.
3.	Press the ↑ key until the word "ChEy" appears in the display. While holding in the '*' key press the ↑ key until "on" appears in the display, then release all keys.
4.	Hold in both the ↓ and ↑ keys until the temperature appears in the display, then release both keys. Automatic temperature logging is now on and will remain on until the controller is turned off or logging is turned off manually ↑by repeating this procedure except in Step 3 pressing the ↑ key until the word "off" appears.
	Procedure to Read Minimum and Maximum Temperatures
1.	Press and hold in both the ↓ and ↑ keys on the front of the temperature meter until the word "tunE" appears in the display, then release both keys.
2.	Press the ↓ key once and the word "LEUL" appears in the display. While holding in the '*' key press the ↑ key until the value "3" appears in the display, then release all keys.
3.	Press the ↑ key until the word "rEAd" appears in the display. The "rEAd" screen displays 3 parameters. 1. Variance (the difference between the highest and lowest logged temperatures) Hold in the '*' key and the display will alternate between "UAr°" and number of degrees of variance. 2. High Temperature (the highest temperature since the logging option was turned on). While holding in the '*' key press the ↑ key once and the display will alternate between "hi °" and the highest recorded temperature. 3. Low Temperature. While holding in the '*' key press the ↑ key once and the display will alternate between "Lo °" and the lowest recorded temperature. The High and Lo temperatures can be examined as often as you like since updating and monitoring continues until the monitor is stopped by turning the controller off.
4.	Press and hold in both the ↓ and ↑ keys until the temperature appears in the display, then release both keys.

Table 1 Tuning Parameters for Various Heaters

Fill in values determined for your equipment for quick reference.

Instrument	**Proportional Band** “bAnd”	**Integral Time (Reset)** “int.t”	**Derivative Time (Rate)** “dEr.t”	**Derivative Approach Cont.** “dAC”	**Cycle Time** “CyC.t”
Heating Mantles (Factory Default)	10	10	50	3	30
Heat Lamp					
Oven					
Vacuum Oven					
Oven					
Hot Plate					

Appendix

I. Using the Controller With an Oil Bath

Application Note #1

Using your 200-Series controller with oil baths rated for less than 120 volt operation is not recommended. J-KEM manufactures a 400-Series controller designed for use with oil baths rated for any voltage and is recommended for this application. The 200-Series controller can be used with an oil bath rated for 120 volt operation without any special setup. Simply place the flask and the thermocouple directly in the oil, set the appropriate power setting and enter the reaction setpoint temperature..

If you need to use an oil bath with you J-KEM controller, J-KEM recommends the Instatherm oil baths. The two largest baths, Catalog #'s INS-150 and INS-160 are both rated for use with 120vac controllers and provide good temperature regulation.

If you frequently heat reactions using oil baths, we recommend J-KEM's 400-Series oil bath controller.

If the reason for using an oil bath is that a small volume is being heated, and you want to use your 200-Series controller for the job, you have a second option. J-KEM sells heating mantles for small volumes (5, 10, 25, 50 ml) which can be plugged directly into the temperature controller. Your controller regulates volumes as small as 1 ml in a 5 ml flask using a 5 ml heating mantle. If you need to heat even smaller volumes, your User's Manual describes a technique for heating microliters ("Controlling the Heating Mantle Temperature Directly"; in Section 4). The advantage of this option is that it eliminates the mess and safety hazards associated with oil baths. Accessories for regulating the temperature of small volumes are available from J-KEM including small volume heating mantles and micro thermocouples.

Call if you have any concerns or would like to discuss your application with a technical representative.

Accessories for Heating Small Volumes Available From J-KEM

Heating Mantles	All sizes from 5 ml to 50 L.
Teflon Coated Microscale Thermocouples	See Catalog.
Thermocouples hermetically sealed in various size hypodermic needles	See Catalog

II. Safety Considerations and Accurate Temperature Control

For safety critical and non-typical organic reactions (especially polymeric reactions) or for use with heaters other than heating mantles the user must either 1) monitor the reaction closely to verify the tuning parameters are appropriate for the current application, or 2) autotune the controller for the application. For any safety critical or high value reaction, call J-KEM to discuss your application with an engineer prior to beginning.

Your J-KEM controller is capable of regulating virtually any application to $\pm$ 0.1^{o} C <u>if</u> the controller is tuned to the application being heated. Since it's possible that the tuning parameters are not set correctly for your application, the user must monitor a new reaction to verify the controller's operation. A short primmer on tuning is presented below, a more detailed explanation is presented in Sections 2.1 and 4.1.

Tuning is the process that matches the control characteristics of the controller to the heating characteristics of the process being controlled. The controller uses a PID (<u>P</u>roportional, <u>I</u>ntegral, <u>D</u>erivative) algorithm to regulate heating. Each of the terms in the PID equation have a constant that *scales* the equation to the process being heating. These constants (plus two other related terms) are collectively known as the 'tuning constants' and for the most part they are expressed in units of time, since they represent delay times, rate of heat transfer times, and rate of error accumulation. The relative value of each constant depends on the physical characteristics of the process being heated. For example, for the same amount of input power, the rate of heat transfer is twice as high for hexane as compared to water, since the coefficient of heat for hexane is 0.54 calories/g/^{o} C and water is 1.0 calorie/gram/^{o} C. That means that 1000 watt-seconds of input power will raise the temperature of 10 g of hexane 44^{o} C while the same amount of power causes a 24^{o} C rise in water. In theory, the tuning constants needed to heat hexane are different from those to heat water. Fortunately, your J-KEM controller is self-adaptive and is able to adjust it's heating characteristics for different solvents such as hexane and water. Even with the controller's self-adaptive algorithms, the tuning constants have to be reasonably close to a proper set or the controller will not produce stable temperature control (see Section 2.1).

When a controller is shipped, the default set of tuning constants loaded into the controller are those appropriate for heating *typical* organic reactions (i.e., small molecule chemistry in low boiling (< 160^{o} C) organic solvents) using heating mantles, since this is the most common application for J-KEM controllers. **Since it's impossible for J-KEM to predict the application the controller will be used for, the researcher must be aware of the possibility that the tuning constants loaded into the controller may not be a set that results in stable temperature control. It's the researcher's responsibility to monitor the temperature regulation of a reaction.** If you encounter a process that your J-KEM controller does not heat with stability, you have two resources.

Autotune Feature. Your controller has an autotune feature that when turned on (see Sections 2.1 & 2.2) automatically determines the proper tuning constants for your application and then loads them into memory for future use.
J-KEM Technical Assistance. If you have an application you wish to discuss, call us, we're always anxious to help our users.

For an additional description of the PID algorithm and the concept of tuning, see Sections 2 and 4.1.

III. Resetting the Controller to Original Factory Settings

J-KEM manufactures the most technically advanced temperature controller available which should give you consistently flawless control. If you have difficulty with your controller, a good place to start to correct the problem is by loading the original factory settings. If you still have difficulty with your controller, our Engineering department will help you resolve the problem. The factory settings of a J-KEM controller are: 0.1° C resolution, PID control with tuning parameters for a heating mantle, thermocouple type to match the thermocouple originally installed on the controller, high temperature alarm turned on, and a thermocouple offset entered at the time of original calibration.

1.	Press and hold in both the ↓ and ↑ keys on the front of the temperature meter until the word "tunE" appears in the display, then release both keys.
2.	Press the ↓ key until "LEVL" appears in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until "3" appears in the display. Let go of all the keys.
3.	Press the ↑ key until "rSEt" appears in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the word "All" appears in the display. Let go of all the keys.
4.	Press and hold in both the ↓ and ↑ keys until the word "inPt" appears in the display, then release both keys. The value that needs to be entered depends of the type of thermocouple receptacle your controller was shipped with. Determine the thermocouple type below. **Color of thermocouple receptacle (Fig 1; # 5)** — **Value to enter:** Blue (type T) — "tc t" Yellow (type K) — "tc k" Black (type J) — "tc J" White (RTD) — "rtd" First hold in the '*' key, then while holding in the '*' key press the ↑ key until the value from the table above appears in the display. Let go of all the keys. **NOTE:** Many of the patterns for this parameter look similar, be careful to select the exact pattern shown above.
5.	Press the ↑ key once and "unit" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the value "° C" appears in the display,. Let go of all the keys.
6.	Press the ↑ key once and the word "SP1.d" appears in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the value "SSd" appears in the display. Let go of all the keys.
7.	Press in both the ↓ and ↑ keys until the temperature appears in the display ("PArk" also appears), then release both keys.
8.	Press and hold in both the ↓ and ↑ keys on the meter until the word "tunE" appears in the display, then release both keys.
9.	Press the ↑ key once and the word "bAnd" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the value "10" appears in the display. Let go of all the keys.
10.	Press the ↑ key once and the word "int.t" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the value "10" appears in the display. Let go of all the keys.
11.	Press the ↑ key once and the word "dEr.t" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the value "50" appears in the display. Let go of all the keys.
12.	Press the ↑ key once and the word "dAC" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the value "3.0" appears in the display. Let go of all the keys.
13.	Press the ↑ key once and the word "CyC.t" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the value "30" appears in the display. Let go of all the keys.
14.	Press the ↑ key until the word "SPrn" appears in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↓ or ↑ key until the word "OFF" is displayed. Let go of all the keys.
15.	Press the ↓ key until the word "LEVL" appears in the display.
16.	Hold in the '*' key, then while holding in the '*' key press the ↑ key until "2" appears in the display. Let go of all the keys.
17.	Press the ↑ key until "SP2.A" appears in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↑ key until the word "Dvhi" appears in the display. Let go of all the keys.
18.	Press the ↑ key until "diSP" appears in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↓ or ↑ key until the value "0.1°" appears in the display. Let go of all the keys.
19.	Press the ↑ key until "Lo.SC" appears. Next, hold in the '*' key, then while holding in the '*' key press the ↓ key until the number in the display stops changing (this will be 0, -50, or –199.9 depending on thermocouple type). Let go of all the keys.
20.	Press the ↓ key until the word "LEVL" appears in the display.
21.	Hold in the '*' key, then while holding in the '*' key press the ↑ key until "3" appears in the display. Let go of all the keys.
22.	Press the ↑ key until "ZEro" appears in the display. Next, hold in the '*' key, then while holding in the '*' key press the ↓ or ↑ key until the value ________________ appears in the display. Let go of all the keys.
23.	Press the ↓ key until the word "LEVL" appears in the display.
24.	Hold in the '*' key, then while holding in the '*' key press the ↓ key until "1" appears in the display. Let go of all the keys.
25.	Press the ▲ key until "SEt.2" appears in the display. Next, hold in the '*' key, then while holding in the '*' key press the ▲ or ▼ keys until the value 5.0 is entered. Let of go of all keys. If your controller does not have a USB port on the back, skip to step 31.
26.	Press the ▼ key until the word "LEVL" appears in the display.
27.	First hold in the '*' key, then while holding in the '*' key press the ▼ key until "C" appears in the display. Let go of all the keys.
28.	Press the ▲ key and "Addr" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ▼ or ▲ key until the value "1" appears in the display. Let go of all the keys.
29.	Press the ▲ key and "bAud" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ▼ or ▲ key until the value "9600" appears in the display. Let go of all the keys.
30.	Press the ▲ key and "dAtA" will appear in the display. Next, hold in the '*' key, then while holding in the '*' key press the ▼ or ▲ key until the value "18n1" appears in the display. Let go of all the keys.
31.	Press and hold in both the ▲ or ▼ keys until the temperature appears in the display, then release both keys. The word "PArk" in the display will go away when a set point is entered.