

Your L&L Special Furnace Co., Inc., furnace is a high temperature electric box furnace. It is heated by means of coiled electric resistance type alloy elements which are supported in hard ceramic element holders. The standard insulation used in the XL, XT, and TF Series furnaces consists of a primary layer of lightweight refractory insulating firebrick. This is backed up with 2" of high temperature mineral fiber board insulation. Roof insulation of models larger than 18" nominal width consists of high temperature ceramic fiber modules, with a secondary layer of high temperature mineral fiber board insulation, all arranged in sheet metal modules which are approximately 12" square for easy handling.

The standard control system includes two separate zones of heating elements, which are controlled independently with manual rheostat/bimetal percentage type input controls. In addition to these input controls, the overall furnace temperature is set by means of an automatic temperature control. The standard temperature control in most models is a West Model 2070 microprocessor-based, digital, P.I.D. three-mode controller with +0.25% of scale accuracy. Your particular furnace may come equipped with an optional control such as the West 2050 program control or the Honeywell 511 program control. Also optionally available are several types of temperature recorders, normally supplied with a separate thermocouple. Most furnaces are additionally equipped with an overtemperature protection control with safety back up contactors. All controls and control components are normally mounted in one removable control panel which is specially made for the exact configuration of options that you have ordered.

Most models are controlled in the following manner. The thermocouple senses the furnace chamber temperature, which is measured by the temperature controller and compared to the "set point" temperature which is set by the operator. The controller circuit then demands a percentage of output in response to the deviation of the measured temperature from the set point temperature. This percentage of output is "tuned" by means of the Proportional Band (Gain), Rate, and Reset, adjustments in the controller circuit. In most models, the controller has an internal relay which is turned on and off within a set cycle time to provide the output called for. The control relay turns the input controls on and off, and these in turn operate the power contactors which switch power to the heating elements. Ideally, the temperature controller will allow the furnace to come up to temperature as quickly as possible with little or no overshoot, and will hold furnace temperature right at set point indefinitely. Certain options include solid state SCR power controllers, which are controlled by means of varying a milliampere signal to the SCR firing circuit. Read the component and control manufacturers' instructions manuals included for more information; also, more information may be found in following sections of this instruction manual.

UNIFORMITY AND ACCURACY

The uniformity of the temperature inside the furnace chamber is a function of many aspects of electric furnace design. Element spacing and location, insulation value of refractory lining, seals, element circuit zone control, and circulation all can affect the temperature uniformity of the furnace chamber. L&L Special Furnace Co., Inc., is very careful to employ proven engineering concepts in the design of all its furnace models to achieve close temperature gradients. The door seals are refractory to refractory type, with a heat seal plug to minimize heat losses at the door. Heating elements are normally located on all walls except the top. (Top elements are known to cause maintenance problems without significantly improving temperature uniformity.) The insulation in L&L Special Furnace Co., Inc., furnaces is selected to give the optimum combination of lightweight, low heat storage, and minimal heat loss, all of which are important factors for successful batch heating.

Most important in considering temperature uniformity in box furnaces are element circuit zone control and circulation. L&L Special Furnace Co., Inc., provides two input controls in all XL, XT and TF models. With two zone controls the operator can balance the natural tendency of any furnace chamber to be hotter at the top than the bottom. Two thermocouple sensors are provided, one measuring each zone temperature. A selector switch is provided to switch the controller from one thermocouple to the other, allowing the operator to monitor any difference in temperature. With the input zones an adjustment can be made to decrease the effective power delivered to the elements of either zone.

To decrease the effects of radiation hot spots on the load, the load should be spaced to fill only the inner 2/3 of the chamber volume. Using the above zone control system, and loading within this space, temperature uniformity of at least $+20^{\circ}\text{F}$. is achieved. $+10^{\circ}\text{F}$. has been reported in certain cases.

Another factor that affects uniformity is the loading conditions in the chamber. Loose loads allow the natural convection currents and radiant energy to flow unhindered, but dense loading can block this flow and tend to widen the temperature gradients.

As the furnace temperature increases, the radiant energy becomes more important as the molecules of air become more and more excited. At very high temperatures (above 1600°F .) the radiant energy actually starts to narrow the temperature gradients in the chamber, because the molecules bounce from wall to wall at a very rapid rate and tend to produce an isothermal (equal temperature) environment. As the temperature increases, the chamber gradients tend to narrow and can become as close as $+5^{\circ}\text{F}$. at 2350°F .

Your furnace may also come with a fan or a fan and recirculation muffle to further enhance gradient uniformity. If so see the specific information in the OPTIONS OPERATION Section.

OPERATION OF THE CONTROL PANEL: XL, XT, AND TF MODELS

OPERATION OF THE ON/OFF SWITCH: To activate furnace, turn on main power at your own customer installed fused disconnect switch and then push the On/Off switch. This is an oiltight, maintained contact push button type switch which has an internal pilot light to indicate "ON." When the switch is turned on, the pilot light lights, and the control circuit is activated. Pushing the switch again turns off the control circuit and the pilot light.

OPERATION OF THE TWO-ZONE INPUT CONTROL SYSTEM: This furnace is equipped with an exclusive feature of L&L Special Furnace Co., Inc., furnaces, which is the two-zone input control system. Using one temperature controller, the control panel is equipped to accurately control temperature in two heating zones, with the input to each zone controlled by independent rheostat/bimetal type percentage input switches.

To use the system properly, a thermocouple selector switch is used to monitor the temperature in both zones. Flip the switch to "TOP" to monitor the top zone, and then to "BOTTOM" for the bottom zone. The temperature is displayed on the main temperature controller. Any temperature differential, or gradient, is then adjusted by trimming the input to the higher-temperature zone with the respective input controller. For most applications, both controls may be set for 100%. However, certain critical applications may require some trimming to achieve optimum results. You will want to make the adjustments on the input switches for your most average load at the most commonly used temperature. Alternately, you can keep records of the various adjustments that you make for different temperatures and loads and reset the input switches each time you use the furnace.

Power to the input control switches is controlled by the main temperature controller, so that the actual temperature in the chamber is always controlled by the temperature controller. The control output, instead of directly controlling a power contactor, is used to turn the input control switches on and off. These switches break the control output signal into 15 second cycles of time on and time off. The switches then turn the respective contactors for each zone on and off per the setting established by the operator. Actual power to the elements for each zone is controlled by the combination of temperature controller output and input control switch setting.

MERCURY CONTACTORS: All furnaces in the XL, XT, and TF Series are equipped with mercury contactors. There are several sizes of mercury contactors used in L&L Special Furnace Co., Inc.. furnaces; see the wiring diagram or the parts list for the actual type used. Cycle times for mercury contactors can be set much higher than for conventional electro-mechanical power contactors; this feature allows potentially better accuracy than with mechanical contactors. Contactor operation is quiet because there are no solid contacts to click or buzz, and there should be a far longer time period between contactor servicing because of the long life of mercury contacts.

OPERATION OF THE CONTROL PANEL: XL, XT, AND TF MODELS

OPERATION OF THE DOOR AND BACK CUT OFF SWITCHES: All furnaces in the XL, XT, and TF Series are equipped with a door cut off switch that cuts power to the elements when the door is opened. This is required by OSHA. The cutoff switch for the floor standing models is an oiltight NEMA 13 switch located at the front of the furnace. The switch on the bench models is a lever actuated limit switch that is protected in the base of the furnace. Adjustments for the oil tight switch on the floor models are made with a threaded bolt attached to the actuating lever on the bottom door pivot. On floor models equipped with a counterbalanced vertical door, adjustments may be made by moving the switch itself, attached to a bracket with slots. On bench models, adjustment is made by bending the lever of the switch.

All furnaces are also equipped with a switch to cut off all line voltage to the fuse blocks and terminal boards in the back connection panel if the back cover panel is removed. This switch is an open type limit switch with a long actuator arm, which is bendable for adjustments.

CAUTION: THESE CUT OFF SWITCHES ARE INSTALLED FOR YOUR PROTECTION. DO NOT DEFEAT THE PURPOSE OF THESE IMPORTANT SAFETY DEVICES BY DISCONNECTING THEM!

IMPORTANT: This L&L Special Furnace Co., Inc., furnace is equipped with the Honeywell 3000 Temperature Control described below. Many are also equipped with an Overtemperature Control system. It is the user's responsibility to read and understand the control manufacturer's instructions. Be sure to fill out any control warranty cards and send back to the control manufacturer.

NOTE: The user must monitor the furnace and controls for failure. L&L Special Furnace Co., Inc., assumes no responsibility for any losses or damages caused by the malfunction of temperature controls. We strongly recommend the use of a separate safety control with high temperature equipment. As we understand the regulations, this is also an OSHA requirement. All L&L Special Furnace Co., Inc., Furnaces manufactured after March, 1983, can be easily retrofitted with an Overtemperature protection system. Contact factory for further information.

NOTE CONCERNING CONTROL WITH 4 TO 20 MILLIAMP OUTPUT TO SCR:

Some Honeywell 3000 controllers are optionally connected to an SCR power control unit rather than to power contactors. In this case, controller output is 4 to 20 milliamps, and is connected to the milliamp input control signal terminals of the SCR device. Note: If Honeywell 3000 is supplied with milliamp output to an SCR disregard "CYC-SEC" during tuning. Control output in this case does not involve a control relay cycle.

All other control functions are the same. See the instruction section on the SCR for tuning the SCR unit to the control signal.

OPERATION OF THE HONEYWELL 3000 CONTROL

A Configuration Sheet has been included with the testing documents in the Wiring Diagram section of the instruction manual. This shows how the Honeywell 3000 has been configured at L&L. The PID (Tuning) constants are approximate only and will have to be changed by the user to suit load and furnace conditions.

Reading the Honeywell Operating Manual provides the most detailed operating instructions of the instrument; the purpose of this write-up is to point out some of the most important features of the instrument as they relate to the operation of the furnace.

Normally the instrument displays the temperature measured on the thermocouple selected with the thermocouple selector switch on the top display, and the lower display shows the current setpoint. A deviation scale is located on the right side of the display, with setpoint indicated by a blue line and deviation indicators in red lit above the blue line when furnace is over setpoint, and under the blue line when furnace is under setpoint. At the top of the display, a letter (F or C) indicates temperature units, and M or A is lit to indicate either automatic or manual operation. An R or H

indicates whether the instrument is in running a program, or holding.

The function of the instrument is to control furnace temperature at the setpoint entered into the instrument. To adjust any offset of the measured temperature from the setpoint, tuning parameters are adjusted.

When power is first turned on, the instrument performs a power-up sequence. The display cycles through RAM, Configuration, and Calibration tests, then all indicators are lit for a short time. At the end of the power-up sequence, the control goes into either the Manual, Automatic-Local Setpoint, or Automatic-Remote Setpoint - depending on configuration choices. At L&L, this choice has been made as A-LSP, Automatic-Local Setpoint.

LOWER DISPLAY: The Lower Display Key can be used to select different parameters to be shown in the lower display. These are:

- "OUT" Percent Output
- "RSP" Remote Setpoint - N/A for normal L&L-supplied units
- "DEV" Deviation from setpoint is degrees
- "SAM" Samples remaining for Autotune (See Honeywell Manual)
- "#RA" Minutes remaining in Setpoint Ramp segment
- "#SK" Minutes remaining in Soak Segment
- "SP" Setpoint
- "2IN" Input 2 - N/A for normal L&L-supplied units
- "1IN" Input 1
- "2SP" Second Local Setpoint (If configured with this)
- "CSP" Computer Setpoint (Remote)
- "PIDSETX" Tuning Parameter
- "RECYC" Recycles left in Ramp/Soak program run

MANUAL/AUTOMATIC KEY: Alternately selects manual or automatic operation.

UP/DOWN KEYS: Increases or decreases setpoint, output, or configuration values. To change values quickly, while holding either the UP or DOWN key, press the other. The display will shift to the next highest digit.

AUTOTUNE KEY: Starts Autotune procedure. "KEY ERROR" is displayed if this feature is either not available, or disabled during configuration. This feature is not available unless by special order.

RUN/HOLD KEY:

Restore Value: Used to restore the originally displayed value when using the FUNC and UP/DOWN keys to change a parameter.

Note: If KEY ERR is displayed after a key is pressed, either:

- the parameter is not available
- the control is not in SETUP mode
- or the key is malfunctioning.

See the Honeywell Manual, Operation section, and perform a keyboard test.

MODES:

In CONTROL mode, the Honeywell 3000 is in normal control operation. All current tuning parameters are actuated. Local setpoint can be changed, and the controller simply controls at the displayed setpoint.

In CONFIGURATION mode, the 3000 is configured to suit the furnace and load processes. TUNING, SP RAMP, AUTOTUNE, ALGORITHM, INPUT 1, INPUT 2, CONTROL, OPTIONS, ComRS422, ALARM, CALIB, and STATUS parameters can be accessed and changed by using the SETUP, FUNC, and UP/DOWN keys.

Use the SETUP key to enter CONFIGURATION. Press SETUP repeatedly, or hold in, until the desired prompt appears in the lower display. Then press the FUNC key, or hold in, until the desired parameter prompt appears. Use the UP/DOWN keys to change the parameter value.

To exit CONFIGURATION at any time, press the LOWR DISP key. This returns the display to the same state as before entry into the setup mode.

TUNING configuration allows the PID tuning parameters to be changed.

SP RAMP configuration allows three major choices. The simplest is to disable both the SP RAMP and SP PROG features. This leaves the 3000 as a simple single setpoint controller in CONTROL mode. The second choice is to enable the SP RAMP feature, which allows an initial setpoint (the current setpoint), an ending setpoint, and a ramp time. The third choice, only available with optional Ramp/Soak Program Controllers, is to enable the SP PROG feature, which allows 12 ramp/soak segments. SP RAMP and SP PROG cannot be both enabled at the same time.

AUTOTUNE allows the user to choose the Autotune feature to automatically select the PID tuning parameters on demand. A full explanation of this feature is included in the Honeywell manual.

ALGORITHM configuration allows the type of control action of the instrument to be configured.

INPUT 1 configuration allows the type of main input to be configured.

INPUT 2, if the instrument has been ordered with this feature, allows this to be configured.

CONTROL configuration allows changes to how the 3000 will control the furnace. Such parameters as the number of PID sets, setpoint source, setpoint tracking, power-up mode, setpoint high and low limits, control action, output high and low limits, failsafe output level, PID units, and others not normally used for L&L furnaces, are all selected and changed in the CONTROL configuration setup.

OPTIONS configuration is only used if the 3000 has been ordered with options.

ComRS422 configuration is only used if the 3000 has been ordered with options.

ALARMS configuration is only used if the 3000 has been ordered with alarm relays. These can be configured as Process Variable, Deviation, Input, Output, and Event alarms. There are up to two alarms available, each with two setpoint values. See further information in following sections on Alarms and Events.

CALIBRATION configuration should ONLY be attempted by qualified personnel.

STATUS is used only for determining the cause of an instrument failure. Refer to the Troubleshooting section in the Honeywell Manual for further information.

IMPORTANT: The LOCKOUT parameter in TUNING configuration allows the user to lockout selected groups from inadvertent changes. No lockout allows all groups to be accessed and changed. The CALIB selection locks out CALIB but leaves access to all other groups. The +CONF selection allows access to Tuning, SP Ramp, and Autotune (if available) for changes, plus allows all other groups and parameters to be Read. The +VIEW selection allows only Tuning and SP Ramp to be changed or viewed. The MAX lockout prevents any changes from being made, and allows only Tuning and SP Ramp parameters to be read.

TUNE MODE PARAMETERS AND TUNING METHODS

To access the TUNING mode, press the SETUP key until "TUNING" is displayed. Press the FUNC key, and the first tuning parameter, "PROP BD," is displayed. Use the FUNC key to move through the various tuning parameters and their values. When a parameter value is displayed, it can be changed by pressing the UP or DOWN keys.

With the Honeywell 3000 configured by L&L, "PROP BD" is in display when "TUNING" mode is first accessed. This is the output proportional band width, which is the band around setpoint within which tuning takes place. This is a percentage of controller range. Set this initially to 2.0 percent.

"RATE MIN" is displayed next; this is the rate adjustment, which is made in minutes. Set this to 0.00 (off) initially, and change if necessary.

"RESET" is the automatic reset, or integral, adjustment and is made in Repeats (of PROB BD action) per Minute. This corrects for offset. Initially set this to 0.02 (off.)

"CYC-SEC" is the cycle time for a time proportioning output. Set this to 4 for furnaces with mercury contactors, and to 16 for furnaces with mechanical contactors.

Other tuning parameters are displayed if the hardware configuration includes other relays, and if the software configuration assigns these relays to Second Outputs, Events or Alarms. See following sections on these possibilities if they are included with your furnace.

TUNING: To tune the control to the furnace, read Appendix B in the Honeywell 3000 instruction manual. Most Honeywell 3000 controls used in L&L furnaces are equipped with time proportioning outputs; some are current proportioning; and rarely are the Honeywell 3000 units equipped with On-off outputs. All single output proportioning type Honeywell 3000 controllers can be tuned to the processes they control in basically the same way as described below, or in the Honeywell instruction manual.

Some concepts associated with tuning are:

SETTLING TIME: This is the time it takes for a furnace to reach a normal steady state condition.

OVERSHOOT: This is the extent to which the furnace exceeds the setpoint on its first cycle.

OFFSET: (Also called load error.) The settling of furnace temperature at a point other than setpoint, due to load variations.

OSCILLATION: Continuing temperature fluctuations around setpoint.

There are four adjustments that can be made in tuning time proportioning controllers: Proportional Band, Auto Reset (or Integral,) Rate (Derivative,) and Cycle Time. Current proportioning controllers have all the above tuning adjustments except for Cycle Time. See the above paragraph on "CYC-SEC" for set up instructions for cycle time.

In order to tune the Honeywell 3000 to a furnace, the first parameter to be adjusted is "PROP BD" width. Optimum "Pb1" adjustment is with quick settling time, no overshoot, and no oscillations. Offset is not adjusted with "PROP BD." For L&L furnaces, start with 2.0%. Make further adjustments as follows:

LONG SETTling TIME:	DECREASE PROP BD
HIGH OVERSHOOT	INCREASE PROP BD
OSCILLATIONS	INCREASE PROP BD

"RESET-RPM" corrects offset for all load variations. Optimum adjustment is made AFTER "PROP BD" is satisfactorily adjusted - set "RESET-RPM" to 0.02 during the "PROP BD" adjustment process. If offset is noticed either over or under the setpoint, increase the "RESET-RPM" and then change setpoint. Observe the furnace reaction and adjust "RESET-RPM" as follows:

LONG SETTling TIME	INCREASE RESET-RPM
OSCILLATIONS	DECREASE RESET-RPM

"RATE" is used only if necessary to eliminate overshoot or oscillations. Set "RATE" to 0.00 for initial "PROP BD" tuning. If overshoot cannot be totally adjusted out with "PROP BD," increase "RATE" slightly and then change setpoint. Observe the furnace reaction and adjust "RATE" as follows:

HIGH OVERSHOOT	INCREASE RATE
OSCILLATIONS	DECREASE RATE
LONG SETTling TIME	DECREASE RATE

The above notes should allow the user to arrive at good tuning parameter values. Optimum adjustment allows a short settling time with little or no overshoot, no offset, and no oscillations.

ALARMS

Alarms are optionally available on Honeywell 3000 controllers used on L&L furnaces. These can be used for turning accessories (venturi motors, solenoid valves, etc.) on or off depending on furnace temperature. These can be independent of control setpoint, or can be based on a deviation from control setpoint. Two Alarm outputs are available with the Honeywell 3000; if included.

A Process Alarm is independent of control setpoint, and turns the assigned relay on or off according to a temperature value entered while configuring the Alarm setpoints. Depending on the process requirements, this can be a N.O. or N.C. relay actuation depending on the alarm jumper selection. A N.O. alarm is on when the furnace temperature is above the alarm setpoint, off when below. A N.C. alarm is on when the furnace is below alarm setpoint, off when above. For instance, to use a venturi to cool the furnace below 800°F., use a N.C. alarm and set it to 800°F. The alarm will be on below 800°F., and the venturi will be activated. Above setpoint, the venturi is turned off.

A Deviation Alarm is based on a certain amount of deviation from control setpoint. This can be a positive or a negative deviation; that is, either over or under setpoint - this is set during the Alarm configuration as either a HI or LO state. For instance, to use a venturi to cool the furnace if temperature rises 25°F. over setpoint, use a Deviation HI alarm and set it to 25°F. If the furnace should rise 25°F. over setpoint, then the alarm is activated and the venturi is turned on. When the temperature is below the deviation, the venturi is turned off.

A third type of alarm is Deviation Band. This is a deviation around setpoint (both over and under.) This can be set in the Alarm configuration by setting both ALS1 and ALS2 Type to Deviation, then setting ALS1 State to LO, and ALS2 state to HI; then setting the same (or different) setpoints for the alarm values. When furnace temperature is beyond the band within the limits set, the alarm is turned on. For instance, in a critical process it may be necessary to alert the operator if temperature is 25°F. above or below setpoint. An audible alarm would be triggered to alert the operator. When the temperature goes out of the deviation band, the alarm goes on and the operator is alerted.

HOW TO TUNE YOUR DIGITAL CONTROL TO ACHIEVE OPTIMUM RESULTS

Your furnace comes equipped with a digital temperature control with programmable P.I.D. Setting. For purposes of discussion, this instruction sheet will use the Honeywell UDC 3000 temperature control for an example. However, most other digital controls operate in a similar manner. Be careful to make sure that the control is set up with the tuning constants reading the way they are discussed in this instruction sheet because they can be set up as inverses which will cause much confusion and wasted time.

P.I.D. CONSTANTS

P.I.D. stands for "proportional-integral-derivative." P.I.D. tuning is common to many control situations where there is a feedback loop telling the output device (or heaters in the instance of a furnace) how much to output to reach and maintain a given value or set point. There is always a characteristic delay or lag built into the system caused by such factors as thermal mass, etc. Keep in mind the following simple information: PB or proportional band has the most effect on the overshoot or undershoot of the furnace. The larger the number, the longer the heat up. At a value of 0, the control becomes in effect an on/off control. It would not "proportion" at all around set point but would rather wait until the furnace reached set point and then completely turn off until the furnace was below set point. The proportioning band is essentially a figure representing a percentage of set point around which the control "proportions" the amount of power going to the furnace. (NOTE: The UDC 3000 can be configured to have this setting as "gain" which is the inverse of PB. We suggest keeping it set as PB.) The Integral or Reset has the most effect on cycling or stability of the system. It shifts the power output level as a result of the error between the measured value and set point. Basically it is "resetting" the power level. The faster the Reset the less information it is using to make its correction but the more "responsive" it is to changes. The slower it is the more "correct" its power setting is because it is using more information to make its decision. In the UDC 3000 control this is expressed as either Reset in "Minutes per Repeat" or Reset in "Repeats per Minute." Set the control up for Reset in "Minutes per Repeat". (This is set up under CONTROL/MIN OR RPM). The smaller this number in Minutes per Repeat, the faster the power will shift in response to a change. A setting of 0.02 (the smallest setting in the UDC 3000) will definitely cause oscillation because the control is working faster than the system can accept it. Derivative action or Rate provides a sudden shift in output as a result of a quick change in measured value (for instance when a set point is changed). In the UDC 3000 this is expressed as a Rate in Minutes. It is also related to time but has a much lesser effect on the system response.

PURPOSE OF TUNING THE CONTROL

The P.I.D. settings allow the control to be "tuned" for optimum results. In most batch furnace applications this "optimum result" is the best balance between fast heat up and little or no overshoot past the set point. The idea is to anticipate set point temperature before getting there and gradually slow down heater output so that the furnace doesn't overshoot the set point because of system inertia. Some processes are more critical in terms of allowing for some overshoot. In fact, the "optimum result" is something that must be determined by the user.

HOW TO TUNE YOUR DIGITAL CONTROL TO ACHIEVE OPTIMUM RESULTS

THE FURNACE AND LOAD

Each heating condition is different. It depends on the load, the temperature, the characteristics of the furnace, elements, air circulation, etc. That is why no standard P.I.D. tuning constants can be given which will work in all or most situations. It is possible to tune a furnace with no load or from deep inside a load or retort. Each situation will have its own characteristic lag time or responsiveness built into it.

SIMPLIFIED METHOD OF TUNING

- 1) Hook up a recorder, if you have one, to continuously record furnace temperature. If you can scale the recorder, scale it with a small scale of about 100° to 200° around set point. If you don't have a recorder, use graph paper to record time vs temperature. Wait until the furnace is cycling before making up a graph (that way you will know what kinds of temperature extremes and time periods to make on the graph).
- 2) Set the PB to 2.0. (Try 3.0 or 1.0 if this doesn't work as described at first.) Set the Reset (in Minutes per Reset) to 0.02 (or 0.00 if you have a control that allows that). Set the Derivative to 0.0. Set the set point to any temperature setting that is at least 50°F to 100°F above whatever temperature the furnace is at, with a minimum of about 500°F.
- 3) Let the furnace cycle. "Cycling" means that the temperature is rising and falling in a predictable sine wave pattern. IT WILL PROBABLY NOT CYCLE AROUND THE SET POINT. An offset from set point is not relevant at this time. We are merely looking for the characteristics of the cycle time. Record the cycle. Note that the cycle may be anywhere from a few seconds to many minutes. It will repeat itself fairly consistently. Two or three cycles are enough to get good data. This time cycle will be a "snapshot" or insight into the time delay built into the system.
- 4) Once you have a characteristic time cycle measure this in terms of minutes.
 - a) If you want the furnace to be responsive and you don't care about slight overshoot then enter the time you have measured (say, for instance, 11.5 minutes) as your Reset value. Multiply the time value times 1/6 or .167 and enter this value as your Rate.
 - b) If you want to have a very responsive system and some overshoot and some cycling is O.K. before the furnace settles down to set point then the Reset value should be .5 (1/2) times the measured time value (.5 x 11.5 = 5.75 in the above example) and the Rate should be 1/8 or .125 times the measured value (.125 x 11.5 = 1.43 Minutes in the above example).

HOW TO TUNE YOUR DIGITAL CONTROL TO ACHIEVE OPTIMUM RESULTS

- c) If you want to prevent overshoot totally multiply the measured value times 1.5 (in the above example $11.5 \times 1.5 = 18/25$ Minutes per Repeat) and enter this value as your Reset value. The Rate value stays the same (.125 x the measured time cycle) for such a critically damped tuning.
- 5) Raise the set point by 50 to 75°F and record the rise. With the Reset and Rate values entered properly you should notice that oscillation has been removed or minimized (depending on your preference) from the system. You have adjusted the time based tuning constants to match the characteristic lag of the system. If the furnace does not reach set point the PB is too great and must be lowered. If it overshoots and stabilizes above set point the PB is too small and must be raised. Raise or lower the PB in 1 or .5 increments (raising the furnace set point 50 to 75°F each time) until the curve is exactly the way you want it and the system maintains set point.
- 6) Note that on time proportioning systems (contactors vs fully proportioning power controls like SCRs) there is a further adjustment of Cycle Time. This is the amount of time the contactor stays on or off when the control tells it to proportion. The faster the cycle time the more "tunable" the system will be. The downside to fast cycle time is short contactor life. With mercury contactors we recommend a Cycle Time of 2 or 4 seconds. With time proportioning systems there may always be some cycling. With completely proportional systems it is possible to eliminate all cycling.

CHANGING P.I.D. CONSTANTS

The Honeywell UDC 3000 control can have two sets of P.I.D. constants which can be switched easily. This allows you to tune the instruments for two critical temperatures or load sizes (i.e. two different sets of conditions). The P.I.D. settings can be toggled manually or changed automatically based on a process variable or a set point. Therefore you could easily have two different sets of P.I.D. settings come into play at different temperatures. This can be used, for instance, to have a fast approach to a particular temperature and then have critically damped P.I.D. constants as the furnace approached a critical temperature.