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# THERMAL CONTROL SYSTEM

## *OPERATION AND MAINTENANCE MANUAL*

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# INTRODUCTION

## *Scope*

This manual provides information and instructions for installing and operating the Thermal Control System (TCS).

## *System Description*

Figure 1 provides a top-level view of the TCS.

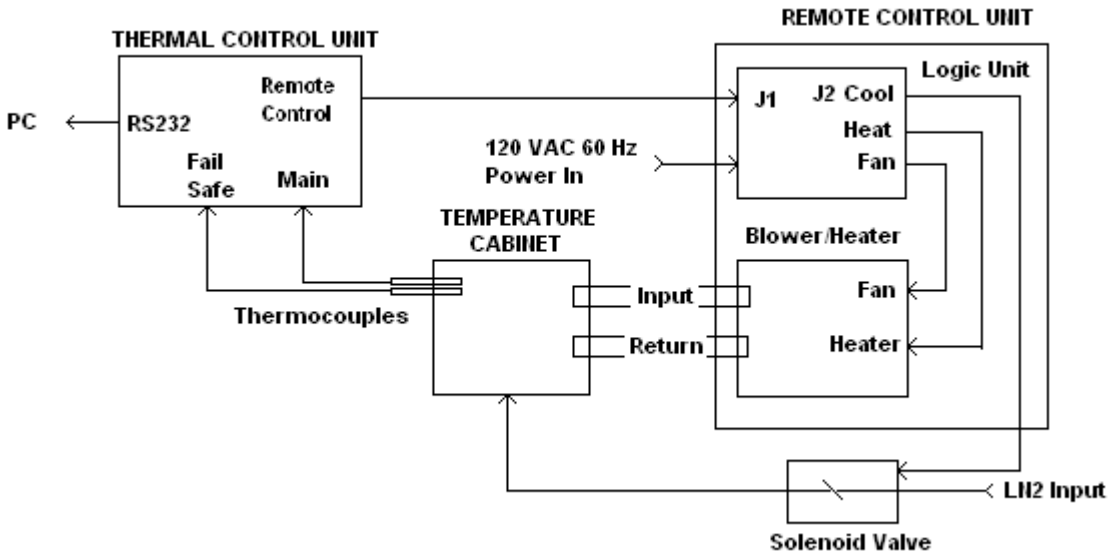


*Figure 1 Thermal Control System configuration.*

The TCS consists of three separate units: The Thermal Control Unit, the Remote Control Unit and a Temperature Cabinet.

The Thermal Control Unit is housed in a rack mountable chassis. It contains a PID controller, a temperature limit switch and switches for turning heating and cooling on and off. It also interfaces to a PC through a serial RS232 port that can be used to remotely control the system.

The Remote Control Unit mounts to a wall and contains a Logic Unit that houses solid-state relays that are used to control the application of power to the Blower/Heater and to the solenoid activated LN2 control valve.

The Temperature Cabinet is a standalone insulated box constructed with non-magnetic material. When used in conjunction with the MEDA HCS01CL Helmholtz Coil System it is mounted on a pedestal in the center of the coil system. Ducts are connected between the Remote Control Unit and the Temperature Chamber that provide input and return paths for hot air that is circulated by the blower/heater to heat the interior of the Temperature Cabinet. An orifice attached to the Temperature Cabinet is connected by tubing to the solenoid-controlled valve that controls the application of LN2 used to cool the interior of the Temperature Cabinet.

Figure 2 is a more detailed functional block diagram of the TCS.

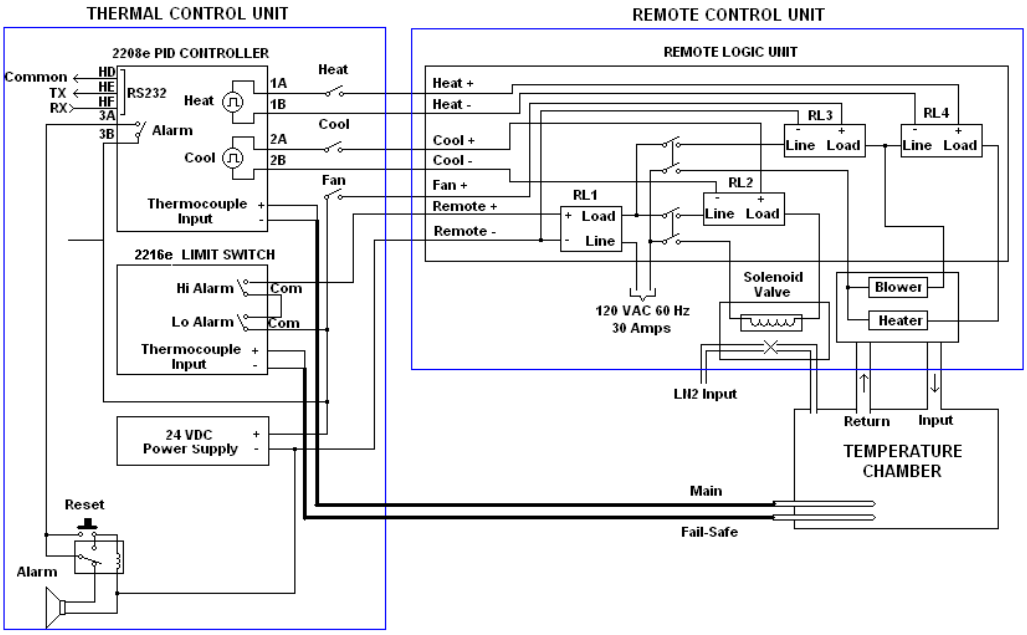


*Figure 2 Thermal Control System functional block diagram*

The TCS has two separate temperature control systems. A Eurotherm 2208e PID controller controls the temperature of the Temperature Cabinet. A thermocouple inserted inside the Temperature Cabinet and connected to the PID controller provides the feedback necessary for controlling the temperature ramping rate and regulation at a specified set point. The 2208e manual that is provided with the system explains the operation of the PID controller.

A second controller, a Eurotherm 2216e temperature limit switch, provides fail-safe system protection by removing power from the main temperature system if the temperature in the Temperature Cabinet goes above or below specified temperature limits. It has it's own dedicated thermocouple. The system will also be shut down if there is a power failure. Refer to the 2216e manual for a description of how it operates.

During normal operation the Hi and Lo alarm relays of the 2216e temperature limit switch, which are connected in series, are closed. This connects the 24 Volt activation signal to the input of solid-state relay RL1 in the Remote Control Unit, which provides overall power to the line inputs of the other solid-state relays through two 30-Ampere circuit breakers. The 2208e PID controller controls the application of heat or cool to the Temperature Cabinet. The 2208e Heat and Cool outputs are logic signals that range from 0 Volts to 18 Volts with 0 Volts representing OFF and 18 Volts representing ON. These signals are applied to the control inputs of the solid state relays RL2 and RL3 in the Remote Control Unit whose load outputs are connected to the solenoid controlled LN2 valve and blower/heater respectively. Front panel switches in the Thermal Control Unit determine if the heating or cooling outputs of the PID are active. A switch that turns the fan in the blower/heater ON or OFF further controls the heating output. Power will not be provided to the heater unless the fan is ON.

If there is a power failure or one of the 2216e temperature limits is exceeded the Hi and/or Lo alarm relays will open cutting power off to the Remote Control Unit and thus to the blower/heater and the solenoid controlled LN2 valve.

The Thermal Control Unit includes an audible alarm that can be programmed to turn on for various different alarm conditions. See the 2208e manual for an explanation of how to activate the alarm output for

different alarm conditions. A push button on the front panel can be used to turn the audible alarm OFF after it has been activated. It does not affect the condition that set off the alarm.

## *Specifications*

Table 1 lists the Thermal Control System specifications.

*Table 1 Thermal Control System specifications*

| | |
|---|---|
| **INPUT POWER** | |
| Voltage: | 115 VAC @ 60 Hz |
| Current: | 30 Amperes maximum |
| **TEMPERATURE CONTROL** | |
| Range: | -55° C to +85° C |
| Accuracy: | ±1º C |
| Ramp Rate: | 0.01 to 99.99º C/min programmable (6º C/min Standard) |
| Controller Type: | PID (Proportional Integral Derivative) |
| Thermocouple Type: | "T" Copper Constantan non-magnetic |
| **COMMUNICATIONS** | |
| Type: | EIA 232 |
| Baud rate: | 19,200 standard |
| **PHYSICAL CHARACTERISTICS** | |
| Thermal Control Unit size: | 17"W x 5.25"H x 15"D |
| Thermal Control Unit weight: | TBD |
| Remote Control Unit size: | 30"W x 18"H x 6"D |
| Remote Control Unit weight: | TBD |
| Temperature Box size: | 24"W x 20"H x 24"D |
| Temperature Box weight: | TBD |

# INSTALLATION

This section provides step-by-step instructions for installing the Thermal Control System.

## *Thermal Control Unit*

The Thermal Control Unit mounts into a 19" rack. Figure 3 is a picture of the front panel and Fig. 5 is a picture of the rear panel. Figure 4 shows the interior of the Thermal Control Unit.


*Figure 3 Thermal Control Unit Front Panel*

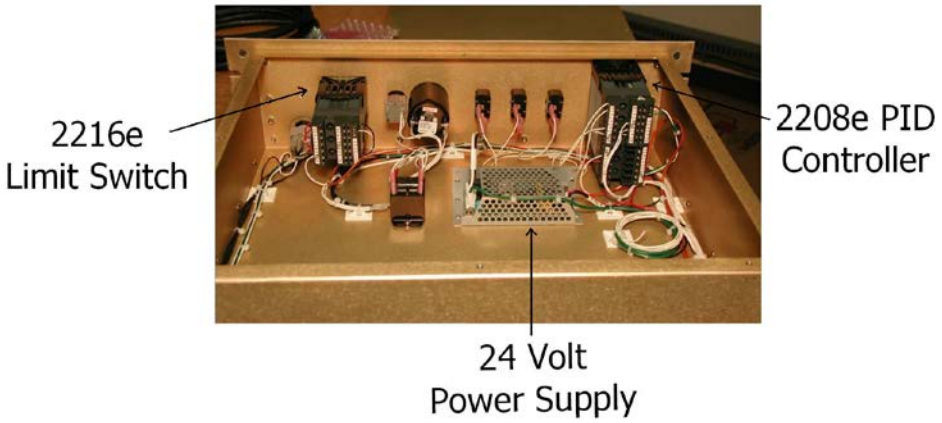


*Figure 4 Rear View of Controller Interior*


*Figure 5 Thermal Control Unit Rear Panel*

Slides that are attached to the Thermal Control Unit chassis mate with slides that are attached to the rack. After unpacking the Thermal Control Unit, place the chassis into the rack and secure the unit to the rack using the four supplied screws. Plug the power cord into a 120 VAC 60 Hz outlet.

## *Remote Control Unit*

The Remote Control Unit mounts to a vertical or horizontal surface using four screws. Figure 6 is a picture of the Remote Control Unit.

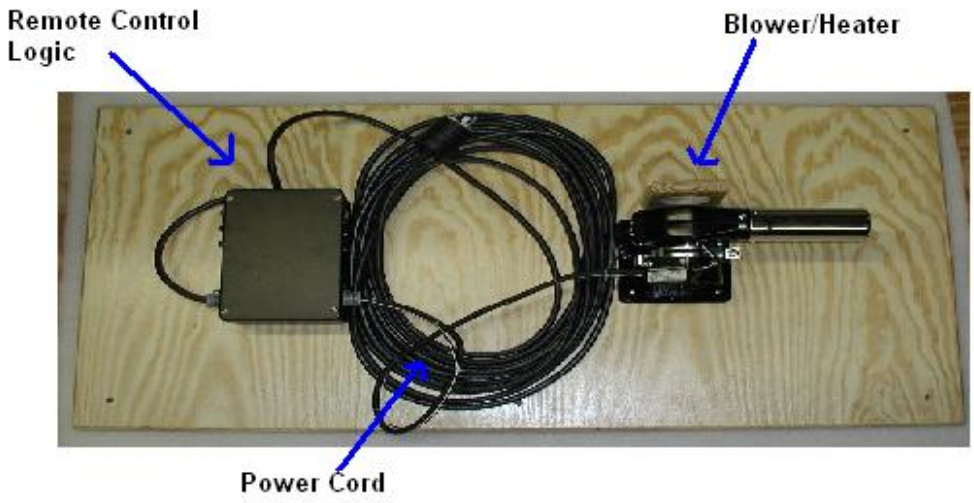


*Figure 6 Remote Control Unit*

1. Mount the remote control unit to a vertical or horizontal surface at least 4 feet from the edge of the HCS01 CL Helmholtz Coil Assembly and at the same height as the temperature chamber in the center of the coil system.

2. Plug the Remote Control Unit power cord into a 120 VAC 60 Hz 30 Amperes outlet.

## *Temperature Chamber*

The Temperature Chamber mounts to a horizontal surface using four screws. Refer to Fig. 7 below.

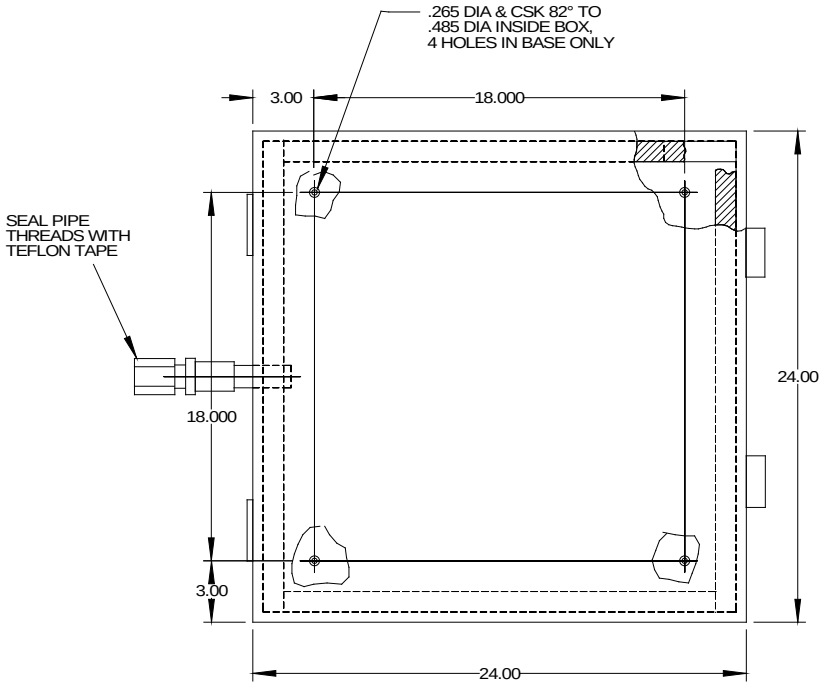


*Figure 7 Temperature Chamber*

## *Heater/Blower Ducts*

Supplied with the Thermal Control System are materials for connecting the Remote Control Unit blower/heater to the Temperature Chamber. Figure 8 illustrates how the heater/blower could be mounted and connected through the supplied duct tubes to the thermal control box.

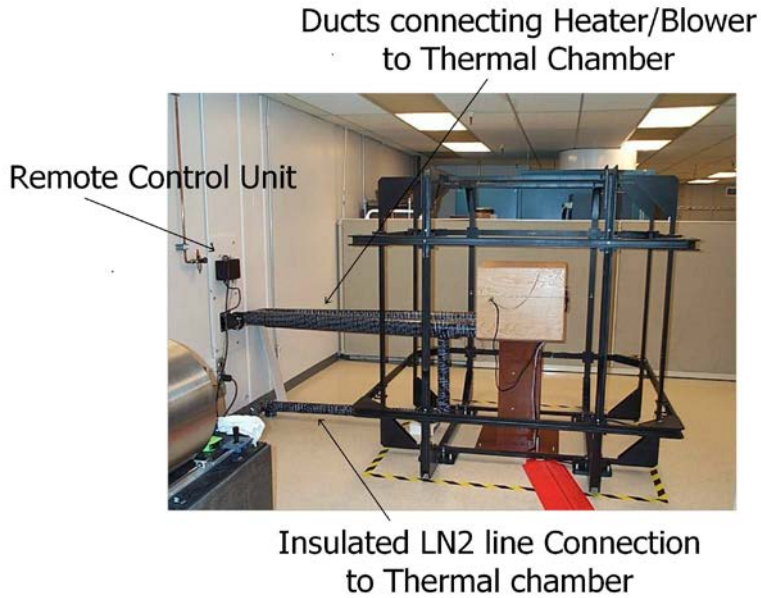


*Figure 8 Typical Installation*

MEDA recommends that a platform be constructed that covers the bottom structure of the HCS01 CL Helmholtz Coil Assembly. This will make it easier to work inside the coil assembly without interference.

### *System Cabling*

Refer to Fig. 9 below.

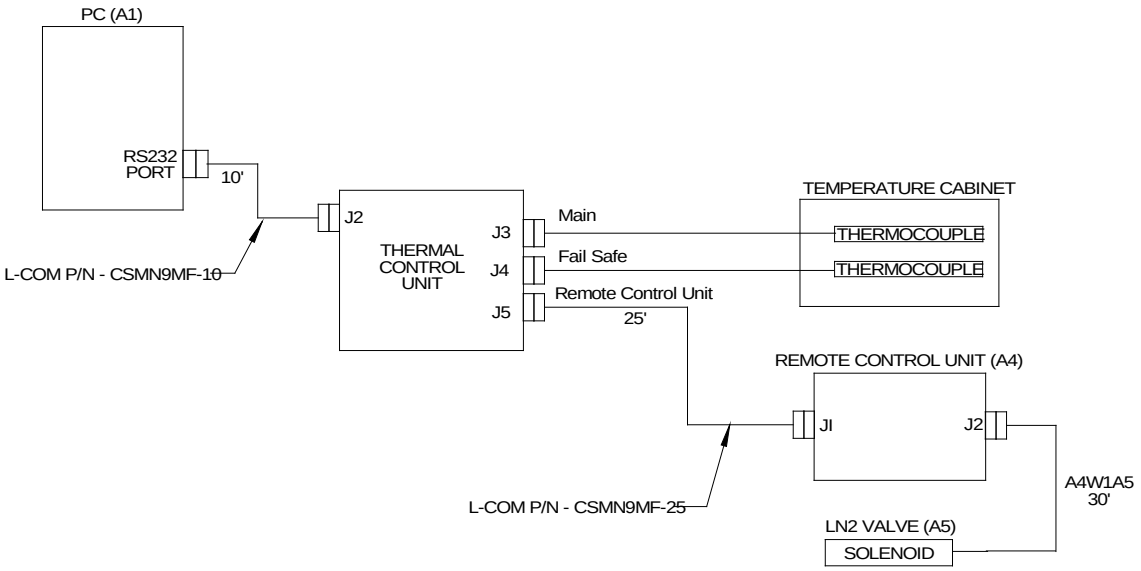


*Figure 9 Thermal Control System Cabling*

1. Insert the two thermocouples into the Temperature Chamber through the holes on the same side of the chamber in which the ducts are inserted. Make sure the ends of the thermocouples are inserted far enough for the tips to be located approximately in the center of the chamber. Make sure the tips are not in contact with anything.

2. Mark one thermocouple *MAIN* and the other *FAIL-SAFE*.

3. Rout the thermocouple cables over to the Thermal Control Unit mounted in the rack.

4. Connect the thermocouple marked *MAIN* into J3 and the thermocouple marked *FAIL-SAFE* into J4 on the back of the Thermal Control Unit.

5. Connect the female end of the 25’ cable with the 9-pin D connectors to J5 on the back of the Thermal Control Unit and the male end to J1 on the back of the Remote Logic Unit of the Remote Control Unit.

6. Connect the solenoid control valve cable to J2 on the back of the Remote Logic Unit of the Remote Control Unit.

7. Optionally connect the 10’ cable with the 9-pin D connectors between the RS232 port of a PC and J2 on the back of the Thermal Control Unit.

**CAUTION: DO NOT CONNECT J5 OF THE THERMAL CONTROL UNIT TO AN RS232 PORT OF A PC. THIS COULD CAUSE SERIOUS DAMAGE TO THE PC.**

# OPERATION

This section describes how to set-up and operate the Thermal Control System.

## *Thermal Control Unit*

The operation of the Thermal Control System is controlled by switches on the Thermal Control Unit front panel along with the controls on the front panels of the 2208e PID controller and the 2216e temperature limit switch. Please refer to the Eurotherm manuals for a description of how to operate the 2208e and 2216e.

### Front Panel Controls

Figure 3 above shows the location of the Thermal Control Unit front panel controls. Table 2 below provides a functional description of the front panel controls.

*Table 2 Description of front panel controls*

| CONTROL | FUNCTION |
|---|---|
| HEAT | Enables/disables heater control. The fan must be ON for the heater to operate. |
| FAN | Turns the fan ON or OFF. |
| COOL | Enables/disables cooling control. The cooling control operates the solenoid control valve. |
| ALARM | Emits a tone whenever an operator-set limit is exceeded. See the 2208e manual for a description of how to set the alarm conditions. |
| RESET | Turns the audible ALARM tone OFF. It does not reset the system. |
| POWER | Turns the Thermal Control Unit ON or OFF |

### Temperature Controller

The Temperature Controller is a Eurotherm 2208e Proportional Integral Derivative (PID) controller that should be properly configured for the process being controlled before it is placed in service. When received from MEDA the PID is configured to display temperature in ºC to a resolution of 1ºC. The ramp rate has been set to 6ºC/minute. Alarm 1 is set for Full Scale High (+85ºC) condition. Alarm 2 is set for Full Scale Low (-55ºC) condition. Alarm 3 is set for Deviation High condition. Alarm 4 is set for Deviation Low condition. Deviation limit is set to 3ºC. Power output range is set for –100 to +100 (required for both heating and cooling to operate). All other settings are the 2208e default settings. See the manual for a description of how to configure and tune the controller.

The PID uses a “T” type thermocouple. It is highly recommended that the PID be calibrated with a dedicated thermocouple prior to the system being placed in service. The 2208e instruction manual provides a procedure for performing this calibration. A reference thermometer with appropriate accuracy that is traceable to NIST will be needed to perform the calibration.

The PID can be controlled locally using its front panel controls or by a PC through an RS232 connection. Supplied with the Thermal Control System is the Eurotherm iTools software package. This software package provides a convenient way to control the PID using a PC. It also contains two ActiveX controls that can be imbedded in a computer program and used to control the PID. Refer to the iTools documentation for a description of how to use the iTools program and ActiveX controls.

## 2216e Temperature Limit Switch

The 2216e Temperature Limit Switch is operated from the front panel controls only. It is an independent temperature measurement system that is used by the Thermal Control System to provide fail-safe operation. The operator manually sets the upper and lower temperature limits within which the system may operate. If the temperature exceeds the upper limit or goes below the lower limit the unit sets an alarm and shuts down power to the PID controlled process. When received from MEDA the upper temperature limit is set to +90ºC and the lower limit is set to -60ºC. See the 2216e instructions to learn how to change these settings.

When the 2216e is turned ON using the Thermal Control Unit POWER switch or when power is restored after a power failure the unit is in the default alarm condition. The alarm must be cleared before the system will operate. Pressing the Page button on the bottom left side of the controller will perform this task. See the 2216e instructions to learn more about setting the alarms.

When one of the alarm conditions occurs an indicator on the front panel of the 2216e flashes and the control signal to the Remote Control Unit is turned OFF causing the power to the blower/heater and the solenoid control valve to be disconnected. The operator must remove the conditions causing the alarm and clear the 2216e alarm before power will be restored to the blower/heater and solenoid control valve.

The 2216e uses a “T” type thermocouple. It is highly recommended that the 2216e be calibrated with a dedicated thermocouple prior to the system being placed in service. The 2216e instruction manual provides a procedure for performing this calibration. A reference thermometer with appropriate accuracy that is traceable to NIST will be needed to perform the calibration.

## *Remote Control Unit*

The Remote Control Unit supplies hot air from the blower/heater and cooling from the LN2 through the solenoid to the Temperature Chamber. The Remote Control Unit is electrically connected to the Thermal Control Unit that is mounted in a rack. There are two 20-Ampere circuit breakers on the side of the Thermal Control Unit that are used to apply 120 VAC 60 Hz power to solid-state relays. The Thermal Control Unit controls the states (ON or OFF) of the solid-state relays.

*Table 3 Remote Control Unit Controls*

| CONTROL/INDICATOR | FUNCTION |
|---|---|
| COOL CIRCUIT BREAKER | Enables/disables the application of 120 VAC 60 Hz power to the solid-state relay that controls the solenoid activated LN2 valve. The circuit breaker is lit when power is being applied. |
| HEAT CIRCUIT BREAKER | Enables/disables the application of 120 VAC 60 Hz power to the solid-state relays that control the blower and heater. The circuit breaker is lit when power is being applied. |
| YELLOW LAMP | When lit indicates that the blower is ON. |
| RED LAMP | When lit indicates that the heater is ON. During normal operation this lamp will flash ON at a rate determined by the PID. |
| GREEN LAMP | When lit indicates that the solenoid activated LN2 valve is open. During normal operation this lamp will flash ON at a rate determined by the PID. |

Under normal operations the two circuit breakers should be left in the ON state. If the blower, heater or solenoid fails causing excess current to flow (greater than 20 Amperes) the associated circuit breaker will turn OFF disconnecting the 120 VAC power from the solid-state relays and their loads.

If the Remote Control Unit is connected to the 120 VAC power and the circuit breakers are in the ON state but their lamps are not lit then the Thermal Control Unit is not enabling power to the Remote Control Unit. This condition will occur if the 2216e Limit Switch is in the OFF (fail-safe) state or the Thermal Control Unit is OFF.

## *Operational Considerations*

The temperature of the Thermal Chamber is sampled at only one location. During initial transition to a set point temperature there will be a temperature gradient within the Thermal Chamber, therefore only the temperature at the main thermocouple will correspond to the specified set point temperature. During this initial transient condition other parts of the Thermal Chamber will be at different temperatures. It will take some finite time for the Thermal Chamber to reach an equilibrium condition in which the temperature is uniform throughout the chamber. The length of time required to reach equilibrium will depend on the thermal load within the chamber. Some experimentation will be required to determine the transient time for a specific load. The user may want to sample the temperature at different locations during initial setup and under different thermal load conditions to determine the transient time. This is also true for the fail-safe system.

The recommended location for sampling the temperature in the chamber is at the end furthest away from the hot air source. This means that the temperature at the end of the thermal chamber where the hot air is entering will be hotter at first than the end with the thermocouples. If this is unacceptable, reverse the location of the thermocouples.

The 2208e PID controller does not have an analog output that can be used for recording the temperature profile of the process being controlled. The user can monitor and record a temperature profile using some independent measurement system or through an RS232 connection to the 2208e. The RS232 connection can also be used to control the process instead of the 2208e front panel controls.

The fail-safe system as designed cannot be monitored remotely. If the fail-safe system has shut down the main thermal control system for any reason the 2208e will continue to try to control the temperature of the thermal chamber. This will result in a 2208e alarm being activated. This condition can be monitored remotely and used to alert the user that something is wrong.

# Appendix A Parts Lists and Drawings