NELSON
HEAT TRACE

NELSON™ CM-2201
HEAT TRACE CONTROLLER
Installation and Operating Instructions

EMERSON™
Industrial Automation

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1.0 Introduction

The Nelson Heat Trace CM-2201 is designed to monitor and control one heating circuit in ordinary and Class I, Division 2, Class I, Zone 2, and Zone 2 hazardous locations. This manual provides information pertaining to the installation, operation, testing, communications and maintenance of this device. See Appendix A for additional details.

1.1 Getting Started

The CM-2201 should be connected to external RTDs; power and communication based on Appendix B and C. If any problems occur, call Nelson technical support or follow the Troubleshooting section.

2.0 General Application Information

The CM-2201 is designed to operate on input voltages between 100 and 277 Vac and 50/60 Hz. Load switching is handled by a 2-Pole solid-state relay and can control resistive loads of 30A continuous @ 40°C ambient.

The CM-2201 is designed to control one heating circuit by monitoring one or two temperature inputs via industry standard 3-wire, 100Ω, Platinum RTDs. Two separate RTDs may be utilized to customize the temperature control inputs. Several different modes are user selectable as well as the sensor failure operational mode.

The CM-2201 assembly is rated UL Type 4X (IP66) and can be operated in temperatures of -40°F to +104°F (-40°C to +40°C).

3.0 Installation

The CM-2201 must be installed only in areas for which it has been approved and in accordance with all applicable electrical codes and ordinances. All conduit entry holes must be appropriately installed and sealed to maintain ingress protection rating.

Do not install this unit prior to functional testing if shipping container or internal packaging shows signs of damage. Notify the appropriate individuals immediately if damage is suspected.

3.1 Selecting Installation Location

The CM-2201 should be installed in an area protected from the elements as much as possible. It is possible to install the unit in unprotected areas, but such often limits maintenance/access. Further, installation in unprotected areas must be carefully considered to ensure it is always in operating conditions consistent with specifications. See Appendix A for additional details.

3.2 Mounting

The CM-2201 should be mounted at a convenient height to suit operator interaction. Conduit entries should be made in the bottom of the enclosure to prevent damage to the internal electronics from moisture intrusion. Conduit entries should be drilled, and the use of suitable bushings is required to maintain the environmental ratings.

3.3 Wiring

Electrical wiring diagrams and schematics are provided in Appendix B and C of this manual. Ensure that all wiring and connections are in accordance with applicable wiring codes. Enclosure grounding must be in accordance with applicable wiring codes for non-metallic devices.

4.0 Initial Set-Up

Upon initial power-up, the CM-2201 display will run self-check, display the software version, then the main program will start.

4.1 Display Modes

This feature determines what messages and functions are displayed during normal operations. If set to “normal user,” only basic information is displayed. If set to “advanced user,” all controller information is displayed. Each parameter shown in this manual will list the Display Mode required to view information and access each function during programming.

4.2 Password Protection

The CM-2201 can have password protection enabled to ensure that sensitive operating parameters are not inadvertently adjusted. If password protection is enabled, the user will be prompted to enter a valid value to access any protected features. The user may also replace the default password value with their own unique value for greater protection of operational parameters. The password can be disabled indefinitely if no protection is desired.

4.3 Security Levels

CM-2201 has two levels of security; the high level (Advanced Display) uses password protection. Disabling the password from the Password Enable / Disable menu will keep the password disabled indefinitely – any parameter can be changed without the use of a password. At this level, all the functions and monitoring parameters are open. The low level (Normal Display) does not give access to parameter settings, but is open for monitoring a few parameters, such as temperature, current, GFI, etc.

If the password is “Enabled”, by going to the parameter to be changed, after the ‘up’ or ‘down’ arrow is pressed, the controller will ask to type the password, and after that, the parameter can be changed and saved. The password will stay disabled for 15 min, then be automatically re-enabled. During the 15 min period when the password is disabled, other parameters can be changed and saved.

5.1 Display

The CM-2201 utilizes a 2 line x 16 character alphanumeric display, viewable from the front keypad. The top line is reserved for the function or operation and the bottom line displays the value range.

5.2 Keypad

The keypad is touch sensitive. The operator must touch the area on the main label and the controller will respond.

5.3 LED Functions

LED indicators will show the status of the respective functions. The power LED will be illuminated when the controller is connected to a source voltage. The heater LED will be illuminated when voltage is applied to the heater. The system LED will illuminate if there is an internal hardware issue with the controller. The comm LED will illuminate when the controller is sending data through external communication. The alarm LED will flash when there is a current active alarm condition; the alarm LED will illuminate solid when an alarm was present, but is not currently active.

5.4 Monitoring

By touching the “Actual” button, followed by an arrow, the controller will display all the active parameters, one at a time.

5.5 Alarm Management

All the alarm(s) will be saved in the alarm log. If the alarm is not active (alarm LED solid red), the Alarm LED can be turned off by touching “Reset”, one alarm at a time. If the alarm is active (alarm LED flashing red), the user cannot reset the alarm.

5.6 Soft-Start Feature

The Soft-Start feature enables self-regulating cables to be energized at low temperatures without causing excessive load on the electrical system, and extends cable life by reducing cable internal heating due to inrush currents. The resistance of self-regulating cables decreases as these cables get colder, which results in higher current draw.

5.6 Soft-Start Feature Continued

This can result in breaker trips if temperatures are very cold and the installed length of cable is high. The Soft-Start feature operates by initially only energizing the cable for a very short period of time – while the current draw may be high during this period, the period is usually short enough to reduce average load on the electrical system. This short energization period is repeated and eventually increased; after a few minutes, the cable is usually warm enough such that the resistance has increased and the current decreased to the point where it can be continuously energized.

5.7 Current-Limiting Feature

The Current-Limiting feature operates similarly to the Soft-Start in that it restricts the amount of time the cable is energized during any given period, thereby reducing the average current draw of the cable during that period. For example, if a cable normally draws 8 Amps, but current limit is set to 6 Amps, then the cable would be energized only 75% of the time.

5.8 Ground Faults

Ground faults typically are the result of damaged or improperly installed cables which allow current-carrying conductors/surfaces/parts to be in contact with grounded objects. For example, if a heating cable has been secured to a pipe with a clamp, and if the clamp has been overtightened, then the ground braid and/or the pipe may come in contact with current carrying parts within the cable. This would result in current leakage to ground through the ground braid of the cable and/or the pipe itself. This type of fault can eventually become serious, resulting in overheating/fire/shock hazards. Current leakage to ground can be monitored by electronic circuitry, and the SPC can be programmed to either alarm or trip when leakage current exceeds the specified maximum allowable amount.

6.0 Control Modes

The CM-2201 allows the user to select different control modes based on their individual process control parameters.

6.1 On-Off Control

This control method simply energizes the cable until the actual monitored temperature rises to the setpoint value plus half the deadband value (upper limit). The cable is then de-energized until the actual monitored temperature drops to the setpoint value minus half the deadband value. Note that this type of control can result in some temperature "overshoot"; this is because the cable is de-energized when the monitored temperature reaches the upper limit. However, the residual heat in the cable continues to transfer to the pipe, and this will cause the pipe temperature to increase slightly above the upper limit. Similarly, there can be some temperature "undershoot".

6.2 Proportional Control

This control method uses the typical proportional control algorithm, wherein the cable is cycled on and off at a rate proportional to the difference between the setpoint value and the actual monitored temperature. As the difference between the setpoint value and the actual monitored temperature increases, the amount of time the cable is energized increases proportionately. This helps reduce the "overshoot" and "undershoot" commonly associated with On/Off control.

6.3 Forced Control Feature

This control method simply allows the user to force the cable on or off as desired.

7.0 Programming

7.1 Program - Setpoints

7.1.1 Setpoint Value

This message displays the name of the sub-menu when entered.

1. Display Mode: All
2. Range: N/A
3. Default: N/A

7.1.2 Maintain Temp

This value sets the control setpoint temperature for all operating modes. For On-Off control, the circuit is energized if the control temperature is less than the maintain temperature minus the deadband. The circuit is de-energized if the control temperature is greater than the maintain temperature plus the deadband. If maintain temp is set to None then the heater circuit will have temperature monitoring with no control temperature. If the maintain temp is set to Off then the heater circuit will have no temperature monitoring or control.

1. Display Mode: All
2. Range: -50°C to 500°C, none or -58°F to +932°F, none, Off
3. Default: 10°F or 50°F

7.1.3 Low Temp Alarm

This value sets the Low Temperature Alarm setpoint. It must be less than the maintain temperature minus the Deadband. To disable this alarm set the value to “Off’. When the measured temperature of either RTD A or RTD B (if activated) is less than or equal to this setpoint, the Low Temperature Alarm is activated and a “LOW TEMP ALARM” message is added to the alarm stack. This alarm deactivates when the temperature rises above the alarm setpoint value.

1. Display Mode: All
2. Range: -50C to Maintain Temperature, Off, -58°F to Maintain Temperature, Off
3. Default: 5°C or 41°F
4. Restrictions: Message does not exist if Maintain Temperature is set to Off.

7.1.4 High Temp Alarm

This value sets the High Temperature Alarm setpoint. It must be greater than the maintain temperature plus deadband. To disable this alarm set the value to “Off”. When the measured temperature of either RTD A or RTD B (if activated) is greater than or equal to this setpoint, the High Temperature Alarm is activated and a “HIGH TEMP ALARM” message is added to the alarm stack. The alarm deactivates when the temperature falls below this alarm setpoint.

1. Display Mode: All
2. Range: Maintain Temperature to +500°C, Off, Maintain Temperature to +932°F, Off
3. Default: Off
4. Restrictions: Message does not exist if Maintain Temperature is set to Off.

7.1.5 Low Current Alarm

This value sets the Low Current Alarm setpoint. It must be less than the high current alarm setpoint. To disable this alarm set the value to “Off’. When the heater current is less than or equal to this setpoint, the Low Current Alarm is activated and a “LOW CURRENT ALARM” message is added to the alarm stack. The alarm deactivates when the Heater Current rises above this alarm setpoint. Note: This setpoint is based on the heater at 100% power. If Proportional Control or Current Limiting is enabled, all current measurements will be scaled to 100% power, based on a constant resistive load, before being compared to the alarm setpoint.

1. Display Mode: All
2. Range: 0.1A to High Current Alarm, Off
3. Default: Off

7.1.6 High Current Alarm

This value sets the High Current Alarm setpoint. It must be greater than the low current alarm setpoint. To disable this alarm set the value to “Off’. When the heater current is greater than or equal to this setpoint, the High Current Alarm is activated and a “HIGH CURRENT ALARM” message is added to the alarm stack. The alarm deactivates when the heater current falls below this alarm setpoint. This setpoint is based on the heater at 100% power.

7.1.6 High Current Alarm Continued

If Proportional Control or Current Limiting is enabled, all current measurements will be scaled to 100% power, based on a constant resistive load, before being compared to the alarm setpoint.

1. Display Mode: All
2. Range: Low Current Alarm to 30.0A, Off
3. Default: Off

7.1.7 Ground Fault Alarm

This value sets the Ground Fault Alarm setpoint. It must be less than the ground fault trip setpoint. To disable this alarm set the value to "Off'. When the Ground Fault Current is greater than or equal to this setpoint, the Ground Fault Alarm is activated and a "GROUND FAULT ALARM" message is added to the alarm stack. The alarm deactivates when the Ground Fault Current falls below this alarm setpoint.

1. Display Mode: All
2. Range: 10 to Ground Fault Trip, Off
3. Default: 30mA

7.1.8 Ground Fault Trip

This value sets the Ground Fault Trip setpoint. It must be greater than the ground fault alarm setpoint. To disable this trip alarm set the value to “Off’. When the Ground Fault Current is greater than or equal to this setpoint, the heater circuit is de-energized, the Ground Fault Trip Alarm is activated and a “GROUND FAULT TRIP” message is added to the alarm stack. This is a latching alarm and trip. When the cause of the alarm has been corrected, the circuit may be energized by the manual reset function.

1. Display Mode: All
2. Range: Ground Fault Alarm to 500mA, Off
3. Default: 50mA

7.1.9 Low Voltage Alarm

This value sets the Low Voltage Alarm setpoint. It must be less than the high voltage alarm setpoint. To disable this alarm set the value to “Off’. When the Line Voltage is less than or equal to this setpoint, the Low Voltage Alarm is activated and a “LOW VOLTAGE ALARM” message is added to the alarm stack. The alarm deactivates when the Line Voltage rises above this alarm setpoint.

7.1.9 Low Voltage Alarm Continued

1. Display Mode: All
2. Range: 85VAC to High Voltage Alarm, Off
3. Default: Off

7.1.10 High Voltage Alarm

This value sets the High Voltage Alarm setpoint. It must be greater than the Low Voltage Alarm setpoint. To disable this alarm set the value to “Off’. When the Heater Voltage is greater than or equal to this setpoint, the High Voltage Alarm is activated and a “HIGH VOLTAGE ALARM” message is added to the alarm stack messages. The alarm deactivates when the Heater Voltage drops below this alarm setpoint.

1. Display Mode: All
2. Range: Low Voltage Alarm to 280VAC, Off
3. Default: Off

7.2 Program - Heater Setup

7.2.1 Heater Setup

This message displays the name of the sub-menu when entered.

1. Display Mode: Advanced
2. Range: N/A
3. Default: N/A

7.2.2 Enable Heater

This selection enables control and monitoring of the heater circuit. Setpoints and measured value messages cannot be accessed unless the heater is enabled. Select “No” if the circuit is not used.

1. Display Mode: All
2. Range: yes, no
3. Default: yes

7.2.3 Heater ID

This selection allows for user defined Heater Identification. It provides a unique, identifiable tag or label for each heater circuit. The Heater Name allows up to 20 alphanumeric characters which are entered one at a time from left to right. The cursor indicates which character is being selected. Press the [SELECT UP/DOWN] arrow keys to change the character. Move to the next character by pressing [NEXT] arrow. Press [ENTER] in the last character position to save the Heater ID.

1. Display Mode: Advanced
2. Range: 20 Characters
3. Default: Blank

7.2.4 Manual Override

This selection sets the response of the heater circuit to the Override inputs. The Override inputs respond to contact closure. If the Override is set to “Off”, the override inputs are ignored and control of the heater circuit operates normally based on the measured temperature and maintain temperature setpoint. If the Override is set to “On”, an open contact on the override inputs forces the heater Off. When the contact on the override input is closed, the heater control resumes in normal manner.

1. Display Mode: Advanced
2. Range: On, Off
3. Default: Off

7.2.5 Deadband

The Deadband is defined as the difference between the setpoint temperature and the actual maximum temperature that is ideally allowed in excess of the setpoint temperature. Decreasing the deadband increases the temperature control accuracy but also increases the heater switching frequency.

1. Display Mode: Advanced
2. Range: 1 °C to 5 °C, 1 °F to 10 °F
3. Default: 2 °C or 5 °F
4. Note: Deadband is disabled for Proportional Control mode.

7.2.6 Control Type

This selection determines the type of control method used by the controller: either On-Off (Deadband), or Proportional Control. The On-Off control mode is available for all heating devices. Proportional Control mode is only available for series type heating devices.

Warning: Proportional Control should never be selected for use with self-regulating heating cable types due to the constantly changing characteristics of self-regulating cables – this will cause the control to be unstable. Further, the continual cycling associated with Proportional Control can result in internal heating of the cable and lead to reduced life expectancy.

1. Display Mode: Advanced
2. Range: On-Off, Proportional
3. Default: On-Off
4. Selection does not exist if Maintain Temperature is set to Off.

7.2.7 Current Limiting

This selection sets the maximum average current limit allowed for the heater circuit. It is useful for reducing the power output of constant wattage heaters. The load will be turned on for a period of time, then turned off for a period of time to maintain the average current draw to the value set.

1. Display Mode: Advanced
2. Range: 0.5 to 30.0 A, Off
3. Default: Off
4. Note: The value range is in 0.5A increments.

7.2.8 Soft Start Mode

This function ramps the heater output from Off to nominal current of the heater over the set softstart cycle time. It is useful for reducing inrush currents of self-regulating heaters. At the end of the soft start cycle time, the load will no longer be controlled by the soft start function.

1. Display: Advanced
2. Range: 10 to 999 seconds, Off
3. Default: Off

7.2.9 Auto Test Cycle

This value sets the frequency at which the Auto Test Cycle is activated. Auto Test is a feature that exercises the system by automatically applying power to the heater at specified time intervals. If an alarm condition is detected during this period, the Auto Test Alarm is activated and an "ALARM DURING AUTO TEST" message is added to the System Status messages. This is a latching alarm. To clear the alarm, locate the alarm message in the Alarm Menu and press [ENTER]. To disable this feature, set the value to "Off". The Auto Test Cycle does not operate if heater is forced off for any reason, including ground fault trip. Auto Test decreases maintenance by providing an early warning of problems that would otherwise go undetected until the heater was needed.

1. Display Mode: Advanced
2. Range: 1 to 720 hours, Off
3. Default: 24 hours

7.2.10 RTD Operation

This selection determines how the control temperature is utilized by the RTD inputs.

In One RTD Mode, the temperature is based on the measured temperature from RTD-A.

In Backup Mode, control temperature is based on RTD-A. If for any reason RTD-A fails, then RTD-B takes over.

In Average Mode, the control temperature is based on the average of RTD-A and RTD-B measured temperatures.

In Lowest Mode, control temperature is based on the lowest of the two temperature measurements.

In Highest Mode, control temperature is based on the highest of the two temperature measurements.

In High Temperature Cutoff Mode, control temperature is based on RTD-A, but if the temperature from RTD-B exceeds the high temperature alarm, the heater is turned Off and a high temperature alarm is activated. The High Temperature cutoff mode will operate in One RTD mode if the high temperature alarm is turned Off.

7.2.10 RTD Operation Continued

Functions requiring two RTDs to operate, such as Average, Lowest, Highest and High Temperature Cutoff, will operate in One RTD mode if one of the two RTDs fail.

1. Display Mode: Advanced
2. Range: One RTD, Backup, Average, Lowest, Highest, High Temperature Cutoff
3. Default: One RTD
4. Restrictions: Message does not exist if Maintain Temperature is set to Off.

7.2.11 RTD Failure Mode

This selection sets the controller's fail-safe mode. The controller detects if RTD-A has failed and will use RTD-B if available. If RTD-B is not installed or has also failed, the heater will be set to its fail-safe state as selected in this mode. For freeze protection where there is no hazard from overheating, you may select "On" to operate the heater continuously and prevent freeze up.

For processes where there is a potential hazard from overheating, you may select "Off", to de-energize the circuit until one of the RTDs becomes available.

1. Display Mode: Advanced
2. Range: On, Off
3. Default: Off
4. Restrictions: Message does not exist if Maintain Temperature is set to Off.

7.3 Program – System Setup

7.3.1 System Setup

This message displays the name of the sub-menu when entered.

1. Display Mode: Advanced
2. Range: N/A
3. Default: N/A

7.3.2 Password

This selection determines if password protection is required for programming changes. The display will show "Disabled" if program access is currently enabled, and show "Enabled" if program access is currently disabled.

1. Display Mode: All
2. Range: Enabled or Disabled
3. Default: Enabled

7.3.3 Change Password

This selection allows the user to change the default password. The user is prompted to enter the old password, press [ENTER]. If verified, the user is then able to enter the new password, press [ENTER]. The user is prompted to re-enter the new password. By not entering a password and pressing [ENTER], the controller assumes no password.

1. Display Mode: Advanced
2. Range: Any combination of 2 to 16 characters 0 – 9, A – Z.
3. Default: 1234

7.3.4 Units

This selection determines the unit of measure for temperature values. All temperatures are displayed in the selected units of either Celsius degrees (°C) or Fahrenheit degrees (°F).

1. Display Mode: Advanced
2. Range: Celsius, Fahrenheit
3. Default: Celsius

7.3.5 Operational Costs

This value sets the cost per kWh of electrical power. This is used to calculate energy costs for operating this control circuit.

1. Display Mode: Advanced
2. Range: $0.01 to 1.00
3. Default: $0.05

7.3.6 Display Mode

This selection determines what messages are displayed by the controller for operations personnel. If set to “advanced user”, all messages are displayed. If set to “normal user,” only the basic messages are displayed. Each message listed throughout this manual shows the Display Mode required to see the message. “Advanced only” indicates that the display mode must be set to “advanced user” to view the message.

1. Display Mode: All
2. Range: Normal, Advanced
3. Default: Advanced

7.3.7 Default Display

This function specifies the information that will be displayed when no key has been pressed for the Display Timeout interval as described below.

VALUE	INFORMATION DISPLAYED
System status	Alarm status of all the heaters
Heater status	Alarm status of the heater
Heater temp	Temperature of the heater

1. Display Mode: Advanced
2. Range: System Status, Heater Status, Heater Temp
3. Default: system status
4. Restrictions: Temperature messages are not displayed if Maintain Temperature is set to Off.

7.3.8 Display Timeout

This function sets the length of time from the last key press to automatically return to the Default Display information. Selecting “Off’ disables this function.

1. Display Mode: Advanced
2. Range: 5 to 600 seconds, Off
3. Default: 120 seconds

7.3.9 Modbus Address

This selection sets a unique address to ensure only one CM-2201 attempts communications with the master unit at any time. See Section 8.0 for complete information on Modbus communications.

1. Display Mode: Advanced
2. Range: 1 to 255 to accommodate multiple devices on same network.
3. Default: 1

7.3.10 Baud Rate

Sets the communication baud rate for the RS485 serial port. All controllers connected to the same data highway must operate on the same baud rate.

1. Display Mode: Advanced
2. Range: 1200, 2400, 4800, 9600, 19200
3. Default: 9600

7.3.11 Reset Module

This selection resets controller memory parameters to factory default values. If the controllers memory becomes corrupt, resetting the module will force the controller to overwrite each register and may correct any problems that exist.

1. Display Mode: Advanced
2. Range: yes, no
3. Default: no

7.4 Program - System Test

7.4.1 System Test

This message displays the name of the sub-menu when entered.

1. Display Mode: Advanced
2. Range: N/A
3. Default: N/A

7.4.2 Alarm Output Test

This function is used for testing and commissioning purposes allowing the alarm output to be forced On, either for a short period of time, or continuously. At the end of the specified time duration, the testing option is automatically disabled. The alarm test function will not operate if the alarm configuration is set to “Disabled”; the message “ALARM DISABLED” will appear.

1. Display Mode: Advanced
2. Range: 1-24 hours, Disabled, Continuously
3. Default: Disabled

7.4.3 Heater Test

This function overrides heater control for maintenance purposes. For normal operation, set to “Disabled”. If a period of time is selected, the heater is forced On or Off for the selected interval. If “continuous” is selected, the heater is forced On or Off until “Disabled” is selected.

1. Display Mode: Advanced
2. Range: 1-24 hours, Disabled, On Continuously
3. Default: Disabled

7.4.4 Ground Fault Test

This function will test the ground fault trip function of the controller to ensure proper operation. When selected, the controller will generate an artificial ground fault current; if the ground fault current is sensed as being greater than 30 mA, the test passes. The GF test function will verify actual ground fault current and heater trip. Status of the test will be displayed as pass or fail. If this test has been invoked by the “Now” option and it passes, the user is prompted to reset the ground fault trip, at which time the load is capable of being re-energized as required. If this test has been invoked by the “Autotest” option, and it passes, the load is allowed to be reenergized as required. If this test has been invoked by the Autotest cycle, and it fails, an Autotest alarm is generated, but the load is allowed to be reenergized as required.

1. Display Mode: Advanced
2. Range: Autotest cycle, Now, Disabled
3. Default: Disabled

8.0 Communications

The Nelson Heat Trace CM-2201 supports a subset of the Modbus® RTU protocol format that provides monitoring, programming, and control functions using Read (03) and Write (05-06) register commands.

8.1 General Information

Serial Port:	Select the serial port that corresponds to your RS-485 adapter. USB to Serial adapter may be used for devices without serial connections.
Baud Rate:	User Defined at 1200, 2400, 4800, 9600 or 19200
Data Bits:	8
Stop Bits:	1
Parity:	None
Device Address:	User Defined between 1 and 255

8.2 Modbus Registers

For all Modbus registers, see Appendix D.

9.0 Troubleshooting

9.1 Operator Checks

Upon receipt of the controller, or to check the controller for an indication of normal operation, follow the operational procedures shown below. These procedures are designed to familiarize the operator with the controller and to provide an understanding of its operation.

In order to determine if a fault is associated with the heat tracing, wiring, or the controller, it will be necessary to troubleshoot the wiring and tracer circuit. If the fault remains, remove power from the controller and exchange it with another controller. This may require some reprogramming of the new CM2201. Refer to the following sections for the appropriate topic.

9.1.1 RTDs

RTD failures after installation can generally be attributed to incorrect wiring or improper installation of the sensor. Troubleshooting of these failures is a very simple procedure if the proper steps are undertaken in the correct order. Some specific RTD problems and the correct methods for troubleshooting are outlined as follows.

1. RTD Failure Alarm(s)

If the CM2201 controller indicates a failure of an RTD:

a) Ensure that the RTD is a 3-wire 100Ω (Platinum Type).
TURN THE POWER TO THE CONTROLLER OFF BEFORE PROCEEDING!
b) Disconnect the RTD wiring from the input terminals.
c) Measure the RTD's resistance between the source (RED) and sense (RED) leads at the controller (it should not exceed 40 Ω). Excessive lead resistance will cause an RTD FAILURE ALARM, and must be corrected. Look for loose terminals, excessive lead length, or insufficient wire gauge, and correct as necessary.
d) Measure the RTD's resistance between the source (RED) or sense (RED) lead and the common (WHT) lead of the RTD at the controller (should be between 60 and 330 Ω depending on the temperature and the lead resistance. Verify that the RTD is wired correctly—the heat tracing controllers will always be terminated in the order: source (RED), common (WHT), sense (RED). When wiring to the CM2201, the terminals are marked as follows:

Terminal No.	Description
GND Bus	Shield
R1	RTD 1 Source (RED)
W1	RTD 1 Common (WHT)
R1	RTD 1 Sense (RED)
GND Bus	Shield
R2	RTD 2 Source (RED)
W2	RTD 2 Common (WHT)
R2	RTD 2 Sense (RED)

The RTD manufacturer will typically color code the leads with the source and sense being the same color, and the common a different color. Ensure that the RTD extension wire shield is terminated at one end only, normally using the terminal block provided at the terminal board.

Note: Some manufacturers use the common Black-White-Red triad color code for the RTD connections. Usually, the RED lead is the common connection (same as the White-White-Red color scheme) and the White and Black connections may be used interchangeably.

2. Temperature Verification

If you feel that the indicated or displayed temperature is not correct, the controller and the RTD can be quickly checked for correct operation. To verify the RTD:
TURN THE POWER TO THE CONTROLLER OFF BEFORE PROCEEDING!

a) Disconnect the RTD wiring from the input terminals.
b) To calculate the temperature indicated by the RTD, measure the resistance from source (red wire) or sense (red wire) to common (white wire) and subtract the resistance measured between source and sense. This will give a compensated resistance value that can be cross-referenced to one of the RTD tables found in Appendix E or Appendix F. Compare the measured resistance and cross-referenced temperature value obtained from the RTD table to the indicated or displayed value. These should agree to within the accuracy standards of the CM2201 and the RTD.

Note: Ensure you refer to the correct RTD table for the type of RTD you are using.

2. Temperature Verification Continued

To verify the Controller:
TURN THE POWER TO THE CONTROLLER OFF BEFORE PROCEEDING!

a) Disconnect the RTD wiring from the input terminals.
b) Connect a 100 Ω resistor across the source or sense terminal and common. Insert a jumper between the source and sense terminals.
c) Apply power to the controller. The indicated or displayed temperature should be about 32°F (0°C), depending on the actual resistance of the test resistor if RTD TYPE is set to 100Ω Platinum. Any resistor may have a +/- 10% tolerance.

3. Unstable Temperature

An erratic indication of temperature can be caused by several factors external to the controller. The controller's accuracy and resolution will result in an indicated temperature change of a couple of degrees if the measured resistance temperature falls between two discrete values (this is sometimes referred to as quantization error).

If the instability is excessive, check:

a) Wire used for extension of the RTD should be three-wire, twisted and shielded with the shield grounded at the controller only. Each of the three lead wires must be of the same gauge.
b) The ideal installation has a separate conduit for the RTD leads (if they have been extended).It is not usually a problem to run low signal levels in the same conduit as the power leads even in high power applications, as long as the RTD wire is a twisted, shielded type with an insulation rating equal to or greater than the highest voltage in the conduit. Follow the proper Electrical Code requirements for your particular installation.
c) Check the specifications for the particular cable being used to ensure that it does not have excessive capacitance when used in long lengths. This can cause a temperature offset between what the controller reads and what the RTD actually measures. This again is normally not a problem since the controller compensates for all but the worst cases of this.

3. Unstable Temperature Continued

d) Check, one by one, if the all RTD leads are connected to the connector.
e) Lastly, it is possible for the RTD itself to fail on an intermittent basis but this failure mode should be considered unusual. This kind of failure is probably the most difficult to find, but fortunately, it is also the least likely as a failure mechanism.

9.2 Ground Fault

Ground fault warning/alarms can be due to incorrect installation as well as leakage resulting from wet system components or faulted cables.

The CM2201 Controller detects ground faults by summing the outgoing and return trace currents through an internal current transformer. Under normal operating conditions (no ground fault condition), this current will be zero. When there is a flow of current from one of the trace supply wires to ground, a ground fault condition occurs.

If a ground fault alarm is present on start-up of a new installation, it is likely due to a wiring error or damaged cable. To verify this condition:

a) Check that the heating circuit neutrals return to the controller and are not connected directly to the distribution panel. This can be a common problem if the installation is a retrofit situation.
b) On paralleled circuits, be certain that ALL neutrals return. The late addition of a circuit may not be obvious.

Note: The controller monitors the integrity of the ground fault (GF) detection. If a fault is detected, the controller will generate a GFI warning/alarm, depending on the settings.

9.3 Common Warnings/Alarms - What to Look for

The CM-2201 has a wide range of warning and alarming features that may be selectively enabled or disabled to allow the monitoring and indication of trouble conditions. Described below are the different warning and alarm conditions available on the CM2201, their meanings, and possible causes. The warning settings must be below alarm settings. If an alarm is activated, the two low power SSRs will be activated.

9.3.1 High RTD 1/ RTD 2 Temperature Reading

This warning/alarm appears when the temperature exceeds the HIGH RTD WARNING/ALARM temperature setting.

Cause of Warning/Alarm:
- Warning/Alarm temperature setting too close to maintain temperature
- Flow of hot product
- Steaming out lines
- Incorrect tracer wiring

9.3.2 Low RTD 1/ RTD 2 Temperature Reading

This warning/alarm appears when the temperature decreases below the LOW RTD WARNING/ALARM temperature setting.

Cause of Warning/Alarm:
- Warning/Alarm temperature setting too close to maintain temperature
- Flow of cold product
- Empty pipe
- Damaged, wet, or missing insulation
- Heating cable not sized properly for the application

9.3.3 RTD 1/ RTD 2 Failure

This alarm indicates a sensor is not operating properly. The temperature sensor may fail due to an “open” or “shorted” condition.

Cause of Alarm:
- Incorrect or damaged field wiring - open leads or excess resistance (either intermittent or continuous) may be due to broken or damaged wires or loose terminals.
- Damaged or inoperative temperature sensors

9.3.4 High Current Warning/Alarm

This warning/alarm activates when current levels are greater than the HIGH CURRENT WARNING/ALARM setting for the application.

9.3.4 High Current Warning/Alarm Continued

Cause of Warning/Alarm:
- Warning/Alarm setting too close to normal operating current
- High in-rush current from “cold start” of self regulating cable
- Damaged or partially shorted heating cable
- “As built” cable length is greater than design value

9.3.5 Low Current Warning/Alarm

This alarms current levels which are less than the LOW CURRENT WARNING/ALARM setting.

Cause of Warnings/Alarm:
- Warning/Alarm setting too close to normal operating current
- Low source voltage
- Damaged or inoperative heating cable
- Open connection—wiring problem
- SSR or contactor failed open

9.3.6 High GFI Warning

This warns that ground fault current levels are greater than the HIGH GFI WARNING setting.

Cause of Warning:
- Warning setting too close to normal leakage current
- Damaged cable insulation and/or moisture present
- Moisture in junction box
- Poor splice or termination
- Moisture provides conductive ground path, which allows ground fault current

9.3.7 GFI Alarm

This value sets the upper limit of allowable ground fault leakage. Exceeding this limit will result in the output switch being latched off, and the alarm activated to indicate a ground fault condition.

9.3.7 GFI Alarm Continued

Cause of Alarm:
- Trip setting too close to normal leakage current
- Damaged cable insulation and/or moisture present
- Moisture in junction box
- Poor splice or termination
- Moisture provides conductive ground path, which allows ground fault current

9.3.8 High Voltage Warning/Alarm

This warning/alarms voltage levels that are greater than the HIGH VOLTAGE WARNING/ALARM setting.

Cause of Warning/Alarm:
- Warning/Alarm setting too close to normal operating voltage
- Incorrect wiring
- Power surge

9.3.9 Low Voltage Warning/Alarm

This warns/alarms of voltage levels that are less than the LOW VOLTAGE WARNING/ALARM setting.

Cause of Warning/Alarm:
- Warning/Alarm setting too close to normal operating voltage
- Damaged power cable
- Incorrect VOLTAGE TURNS RATIO
- “Brown-out” conditions
- Loss of power to the circuit

9.3.10 Overcurrent Trip

If the controller is unable to start the cable due to high current, or after attempting to soft-start it, the controller will trip its output switch off.

Cause of Alarm:
- Excessive in-rush current
- Incorrect CM-2201 settings
- Incorrect wiring
- Damaged cable

9.3.11 Switch Failure

This alarm indicates that the controller senses current flow when the output switch should be off.

Cause of Alarm
- Some other device energized heat trace
- Output switch has failed “closed”

9.3.12 Power Limiting (Current Limiting)

This alarm indicates that the solid state relay is limiting the average amount of power that is applied to the trace circuit as defined by the MAXIMUM POWER setting.

Cause of Alarm:
- Power applied to trace circuit is being limited to the MAXIMUM POWER setting

9.3.13 EEPROM Data Failure

This alarm indicates that the controller has detected a failure in its non-volatile memory (this is where all of the controller’s configuration and calibration settings are stored). This indicates an internal problem, and the CM2201 should be replaced and returned to the factory for repair.

Cause of Alarm:
- The CM-2201 cannot bypass the failed area of its memory and has loaded factory defaults into this failed area.

10.0 Maintenance

The CM-2201 should be regularly maintained as follows:

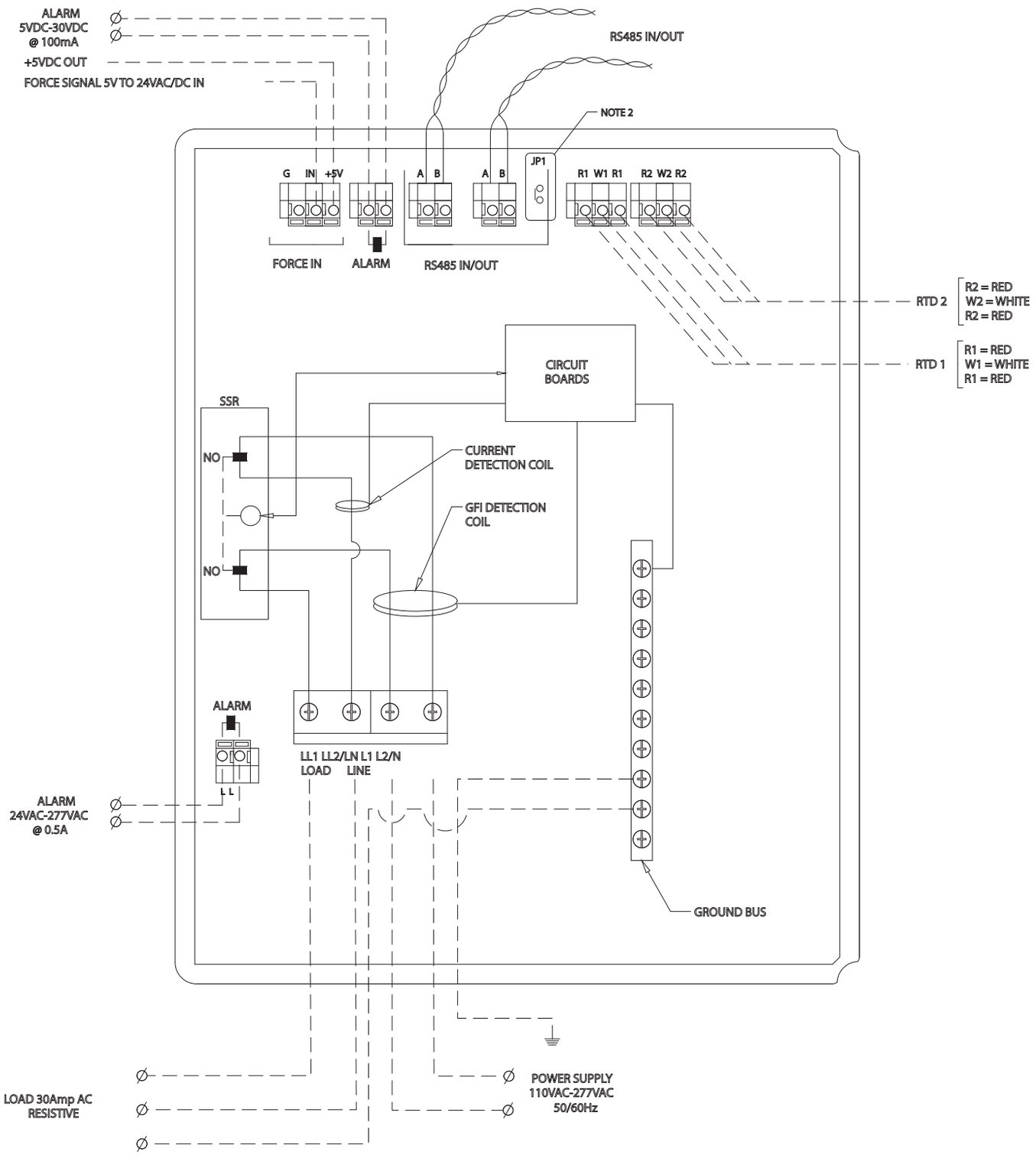
a) Check fit of door gasket and adjust as required. Clean door gasket.
b) Verify that moisture is not entering enclosure; repair as required.
c) Check terminals to ensure connections are secure.
d) Check wiring for any signs of overheating.
e) Clean front panel with mild soap on damp cloth.

Do not use any cloth from synthetic material or similar. During the cleaning process, the front label may charge electrostatically, and touching the front panel may generate sparks.

Appendix A – Specifications

Model:	CM-2201
Rating:	110 – 277 Vac, 30 Amps (Solid State Relays)
Maximum Current:	30 Amps
Frequency:	50 or 60 Hz
Switching:	Solid State Relay (STDP) Normally Open (NO)
Enclosure:	NEMA 4X
Alarm Outputs:	1. 24VAC to 277VAC @ Max. 0.5 Amps 2. 30VDC @ Max. 0.1 Amps
Agency Approval for Hazardous Locations:	cCSAus Class1, DIV.2, Groups A, B, C, D Class 1, Zone 2: IIC
Temperature Code:	T4 (135 °C)

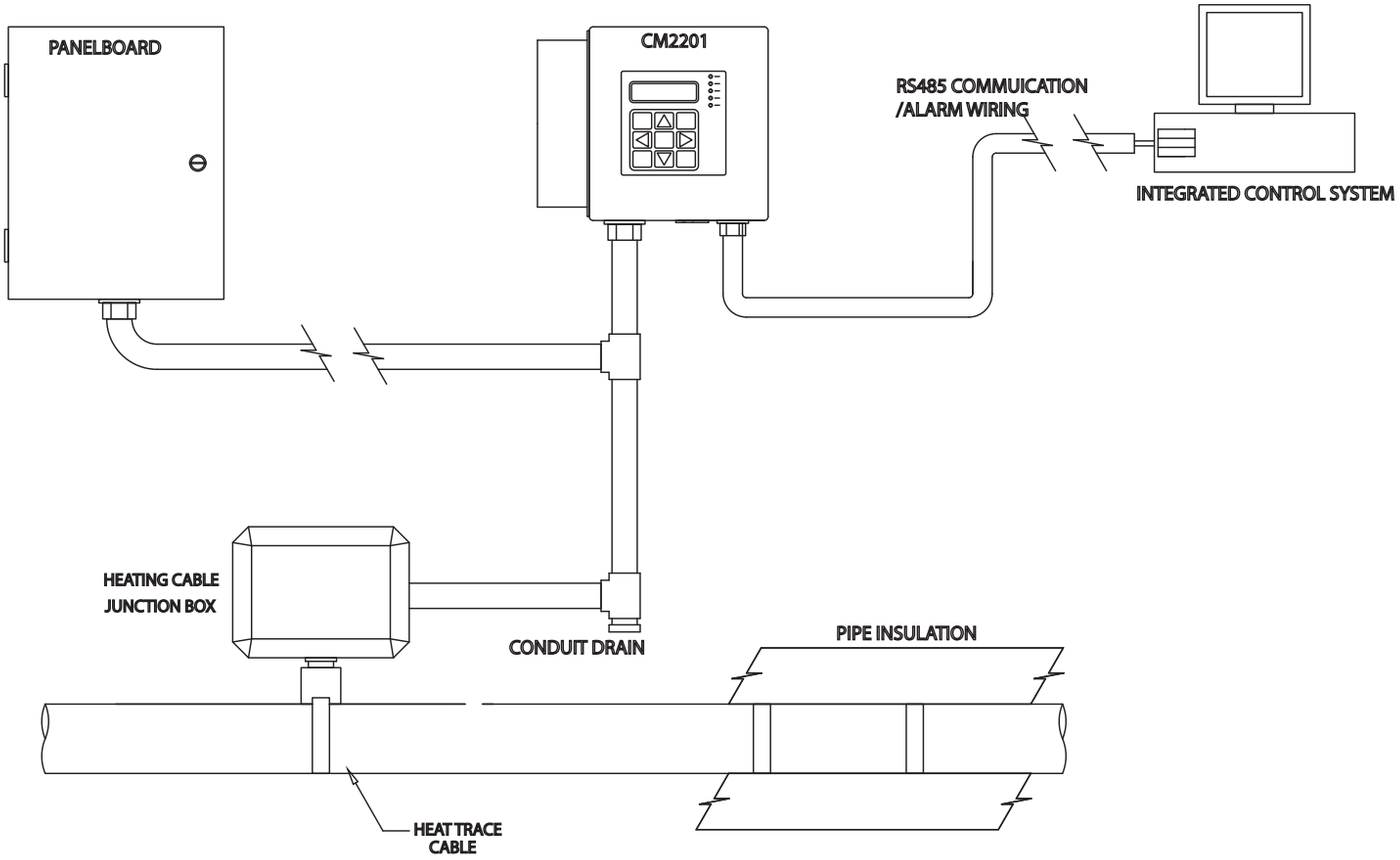
Appendix B - Wiring Diagram



Notes:

1. Solid State Contact
2. Install Jumper at JP1 (120 OHM Resistor) on both terminals if CM-2201 is last device on network. Else install jumper on one terminal only of JP1.
3. If "Force " feature is activated by external "dry contact", use "+5V" and "IN" terminals; Ground connection is not required. If activated by external voltage signal, use "IN" and "G" (Ground) terminals as noted.

Appendix C - Typical Installation Diagram



Appendix D
D.1 Module Setup Group (Read/Write)

Modbus Register	Index Value	Length Bytes	Variable Name	Description/Value Range
40001	0	2	Maintain Temp in °F	= x per 1°F (-58 to +932) = 32766 if Set to None = 32767 if Set to Off
40002	1	2	Maintain Temp in °C	= x per 1°C (-50 to +500) = 32766 if Set to None = 32767 if Set to Off
40003	2	2	Low Temp Alarm in °F	= x per 1°F (-58 to +932) = 32767 if Set to Off
40004	3	2	Low Temp Alarm in °C	= x per 1°C (-50 to +500) = 32767 if Set to Off
40005	4	2	High Temp Alarm in °F	= x per 1°F (-58 to +932) = 32767 if Set to Off
40006	5	2	High Temp Alarm in °C	= x per 1°C (-50 to +500) = 32767 if Set to Off
40007	6	2	Deadband in °F	= x per 1°F (1 to 10)
40008	7	2	Deadband in °C	= x per 1°C (1 to 5)
40009	8	2	Low Current Alarm	= x per 0.1A (1 to 300) = 32767 if Set to Off
40010	9	2	High Current Alarm	= x per 0.1A (1 to 300) = 32767 if Set to Off
40011	10	2	Ground Fault Alarm	= x per 1mA (10 to 500) = 32767 if Set to Off
40012	11	2	Ground Fault Trip	= x per 1mA (10 to 500) = 32767 if Set to Off
40013	12	2	Low Voltage Alarm	= x per 1V (85 to 280) = 32767 if Set to Off
40014	13	2	High Voltage Alarm	= x per 1V (85 to 280) = 32767 if Set to Off
40015	14	2	Power Control	= x per 10% (1 to 10) = 32767 if Set to Off
40016	15	2	SoftStart	= x per 1 Second (10 to 999) = 32767 if Set to Off
40017	16	2	Auto Test Time	= x per 1 Hour (1 to 720) = 32767 if Set to Off
40018	17	2	Display Time	= x per 1 Second (5 to 600) = 32767 if Set to Off
40019	18	2	Cost per kwh	= x per $0.01 (1 to 100)
40020	19	2	Reserved	
40021	20	2	Reserved	
40022	21	2	Reserved	
40023	22	2	Alarm Test	= x per 1 Hour (1 to 24) = 32764 if Set to Disable =32765 if Set to Continuously

D.1 Module Setup Group (Read/Write) Continued

Modbus Register	Index Value	Length Bytes	Variable Name	Description/Value Range
40024	23	2	Heater Test	= x per 1 Hour (1 to 24) = 32764 if Set to Disable =32765 if Set to Continuously
40025	24	2	Reserved	
40026	25	16	Heater Name	
40043	42	4	Heater Settings	b0:Units 0 = Fahrenheit 1 = Celsius b1:Enable Heater 0 = No 1 = Yes b2:Manual Override 0 = Off 1 = On b3:Control Type 0 = On/Off 1 = Proportional b4-b6:RTD Operation 000 = Single RTD Mode 001 = Backup 010 = Average 011 = Lowest 100 = Highest 101 = High Temp Cutout b7:RTD Failure Mode 0 = Off 1 = On b8:Enable Password 0 = Disable 1 = Enable b9:Display Mode 0 = Normal 1 = Advanced b10-b11:Default Display 00 = System Status 01 = Heater Status 10 = Heater Temp b12-b14:Baud Rate 000 = 1200 bps 001 = 2400 bps 010 = 4800 bps 011 = 9600 bps 100 = 19200 bps b15-b16:GF Test 00 = Auto Test Cycle 01 = Now 10 = Disable b17:Heater Type 0 = Fixed Resistance 1 = Self-Regulating

D.2 Module Monitoring Group (Read Only)

Modbus Register	Index Value	Length Bytes	Variable Name	Description/Value Range
40045	44	2	System Temp in °F	= x per °F = 32765 if RTD Open = 32767 if RTD Shorted
40046	45	2	System Temp in °C	= x per °C = 32765 if RTD Open = 32767 if RTD Shorted
40047	46	2	Low Temp Alarm in °F	= x per °F = 32765 if RTD Open = 32767 if RTD Shorted
40048	47	2	Low Temp Alarm in °C	= x per °C = 32765 if RTD Open = 32767 if RTD Shorted
40049	48	2	High Temp Alarm in °F	= x per °F = 32765 if RTD Open = 32767 if RTD Shorted
40050	49	2	High Temp Alarm in °C	= x per °C = 32765 if RTD Open = 32767 if RTD Shorted
40051	50	2	Heater Power	= x per 10%
40052	51	2	Reserved	
40053	52	2	Current	= x per 0.1A = 32766 as Out of Range
40054	53	2	GF Current	
40055	54	2	Voltage	= x per 1V = 32766 as Out of Range
40056	55	2	Reserved	
40057	56	2	Max Temp in °F	= x per °F = 32765 if RTD Open = 32767 if RTD Shorted
40058	57	2	Max Temp in °C	= x per °C = 32765 if RTD Open = 32767 if RTD Shorted
40059	58	2	Min Temp in °F	= x per °F = 32765 if RTD Open = 32767 if RTD Shorted
40060	59	2	Min Temp in °C	= x per °C = 32765 if RTD Open = 32767 if RTD Shorted
40061	60	2	Max Current	= x per 0.1A = 32766 as Out of Range
40062	61	2	Max GF Current	= x per 1mA = 32766 as Out of Range
40063	62	2	Max Volt	= x per 1V = 32766 as Out of Range

D.2 Module Monitoring Group (Read Only) Continued

Modbus Register	Index Value	Length Bytes	Variable Name	Description/Value Range
40064	63	2	Min Volt	= x per 1V = 32766 as Out of Range
40065	64	2	Energy	= x per 1MWh = 32766 as Out of Range
40066	65	2	Cost	= x per $0.01 = 0x7FFFFFFF as Out of Range
40067	66	2	Reserved	
40068	67	2	Heater On Time	= x per 1 Hour = 1500000 as Out of Range
40069	68	2	Reserved	
40070	69	2	Heater on %	= x per 1%
40071	70	2	Alarm Stack 01	0 = No Alarm 1 = Low Temp Alarm 2 = High Temp Alarm 4 = Low Current Alarm 8 = High Current Alarm 16 = GF Alarm 32 = GF Trip 64 = Low Voltage Alarm 128 = High Voltage Alarm 256 = Auto Test Alarm 512 = Continuity Failure Alarm 1024 = SSR Failed Shorted Alarm 2048 = RTD-A Open Alarm 4096 = RTD-A Shorted Alarm 8192 = RTD-B Open Alarm 16384 = RTD-B Shorted Alarm 32768 = Self Check Failure
40072	71	2	Alarm Stack 02	
40073	72	2	Alarm Stack 03	
40074	73	2	Alarm Stack 04	
40075	74	2	Alarm Stack 05	
40076	75	2	Alarm Stack 06	
40077	76	2	Alarm Stack 07	
40078	77	2	Alarm Stack 08	
40079	78	2	Alarm Stack 09	
40080	79	2	Alarm Stack 10	
40081	80	2	Alarm Stack 11	
40082	81	2	Alarm Stack 12	
40083	82	2	Alarm Stack 13	
40084	83	2	Alarm Stack 14	
40085	84	2	Alarm Stack 15	
40086	85	2	Alarm Stack 16	
40087	86	2	Alarm Stack 17	
40088	87	2	Alarm Stack 18	
40089	88	2	Alarm Stack 19	
40090	89	2	Alarm Stack 20	

D.3 Module Reset Group (Write Only)

Modbus Register	Index Value	Length Bytes	Variable Name	Description/Value Range
00092	91	2	Acknowledge All	= Set to 1 to Reset
00093	92	2	Reset Max Temp	= Set to 1 to Reset
00094	93	2	Reset Min Temp	= Set to 1 to Reset
00095	94	2	Reset Max Current	= Set to 1 to Reset
00096	95	2	Reset Max GF	= Set to 1 to Reset
00097	96	2	Reset Max Voltage	= Set to 1 to Reset
00098	97	2	Reset Min Voltage	= Set to 1 to Reset
00099	98	2	Reset Energy	= Set to 1 to Reset
00100	99	2	Reset Cost	= Set to 1 to Reset
00101	100	2	Reset Heater On Time (Hours)	= Set to 1 to Reset
00102	101	2	Reset Heater On Percentage	= Set to 1 to Reset
00103	102	2	Reset Statistics	= Set to 1 to Reset
00104	103	2	Reset Low Temp	= Set to 1 to Reset
00105	104	2	Reset High Temp	= Set to 1 to Reset
00106	105	2	Reset Low Current	= Set to 1 to Reset
00107	106	2	Reset High Current	= Set to 1 to Reset
00108	107	2	Reset GF	= Set to 1 to Reset
00109	108	2	Reset GF Trip	= Set to 1 to Reset
00110	109	2	Reset Low Voltage	= Set to 1 to Reset
00111	110	2	Reset High Voltage	= Set to 1 to Reset
00112	111	2	Reset Auto Test	= Set to 1 to Reset
00113	112	2	Reset Continuity Failure	= Set to 1 to Reset
00114	113	2	Reset SSR Shorted	= Set to 1 to Reset
00115	114	2	Reset RTD-A Open	= Set to 1 to Reset
00116	115	2	Reset RTD-A Shorted	= Set to 1 to Reset
00117	116	2	Reset RTD-B Open	= Set to 1 to Reset
00118	117	2	Reset RTD-B Open	= Set to 1 to Reset
00119	118	2	Reset Self-Check Failure	= Set to 1 to Reset

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-200°C to 239°C)
Temperature Coefficient - 0.00385 Ohms/Ohm/°C

°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms
-200	18.49	-160	35.53	-120	52.11	-80	68.33	-40	84.27	0	100.00
-199	18.93	-159	35.95	-119	52.52	-79	68.73	-39	84.67	1	100.39
-198	19.36	-158	36.37	-118	52.92	-78	69.13	-38	85.06	2	100.78
-197	19.79	-157	36.79	-117	53.33	-77	69.53	-37	85.46	3	101.17
-196	20.22	-156	37.21	-116	53.74	-76	69.93	-36	85.85	4	101.56
-195	20.65	-155	37.63	-115	54.15	-75	70.33	-35	86.25	5	101.95
-194	21.08	-154	38.04	-114	54.56	-74	70.73	-34	86.64	6	102.34
-193	21.51	-153	38.46	-113	54.97	-73	71.13	-33	87.04	7	102.73
-192	21.94	-152	38.88	-112	55.38	-72	71.53	-32	87.43	8	103.12
-191	22.37	-151	39.30	-111	55.78	-71	71.93	-31	87.83	9	103.51
-190	22.80	-150	39.71	-110	56.19	-70	72.33	-30	88.22	10	103.90
-189	23.23	-149	40.13	-109	56.60	-69	72.73	-29	88.62	11	104.29
-188	23.66	-148	40.55	-108	57.00	-68	73.13	-28	89.01	12	104.68
-187	24.09	-147	40.96	-107	57.41	-67	73.53	-27	89.40	13	105.07
-186	24.52	-146	41.38	-106	57.82	-66	73.93	-26	89.80	14	105.46
-185	24.94	-145	41.79	-105	58.22	-65	74.33	-25	90.19	15	105.85
-184	25.37	-144	42.21	-104	58.63	-64	74.73	-24	90.59	16	106.24
-183	25.80	-143	42.63	-103	59.04	-63	75.13	-23	90.98	17	106.63
-182	26.23	-142	43.04	-102	59.44	-62	75.53	-22	91.37	18	107.02
-181	26.65	-141	43.45	-101	59.85	-61	75.93	-21	91.77	19	107.40
-180	27.08	-140	43.87	-100	60.25	-60	76.33	-20	92.16	20	107.79
-179	27.50	-139	44.28	-99	60.66	-59	76.73	-19	92.55	21	108.18
-178	27.93	-138	44.70	-98	61.06	-58	77.13	-18	92.95	22	108.57
-177	28.35	-137	45.11	-97	61.47	-57	77.52	-17	93.34	23	108.96
-176	28.78	-136	45.52	-96	61.87	-56	77.92	-16	93.73	24	109.35
-175	29.20	-135	45.94	-95	62.28	-55	78.32	-15	94.12	25	109.73
-174	29.63	-134	46.35	-94	62.68	-54	78.72	-14	94.52	26	110.12
-173	30.05	-133	46.76	-93	63.09	-53	79.11	-13	94.91	27	110.51
-172	30.47	-132	47.18	-92	63.49	-52	79.51	-12	95.30	28	110.90
-171	30.90	-131	47.59	-91	63.90	-51	79.91	-11	95.69	29	111.28
-170	31.32	-130	48.00	-90	64.30	-50	80.31	-10	96.09	25	109.73
-169	31.74	-129	48.41	-89	64.70	-49	80.70	-9	96.48	26	110.12
-168	32.16	-128	48.82	-88	65.11	-48	81.10	-8	96.87	27	110.51
-167	32.59	-127	49.23	-87	65.51	-47	81.50	-7	97.26	28	110.90
-166	33.01	-126	49.64	-86	65.91	-46	81.89	-6	97.65	29	111.28
-165	33.43	-125	50.06	-85	66.31	-45	82.29	-5	98.04	30	111.67
-164	33.85	-124	50.47	-84	66.72	-44	82.69	-4	98.44	31	112.06
-163	34.27	-123	50.88	-83	67.12	-43	83.08	-3	98.83	32	112.45
-162	34.69	-122	51.29	-82	67.52	-42	83.48	-2	99.22	33	112.83
-161	35.11	-121	51.70	-81	67.92	-41	83.88	-1	99.61	34	113.22

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-200°C to 239°C)
Temperature Coefficient - 0.00385 Ohms/Ohm/°C

°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms
35	113.61	76	129.37	117	144.93	158	160.30	198	175.10	239	190.09
36	113.99	77	129.75	118	145.31	159	160.67	199	175.47		
37	114.38	78	130.13	119	145.68	160	161.04	200	175.84		
38	114.77	79	130.51	120	146.06	160	161.04	201	176.21		
39	115.15	80	130.89	121	146.44	161	161.42	202	176.57		
40	115.54	81	131.27	122	146.81	162	161.79	203	176.94		
41	115.93	82	131.66	123	147.19	163	162.16	204	177.31		
42	116.31	83	132.04	124	147.57	164	162.53	205	178.04		
43	116.70	84	132.42	125	147.94	165	162.90	206	178.41		
44	117.08	85	132.80	126	148.32	166	163.27	207	178.78		
45	117.47	86	133.18	127	148.70	167	163.65	208	179.14		
46	117.85	87	133.56	128	149.07	168	164.02	209	179.51		
47	118.24	88	133.94	129	149.45	169	164.39	210	179.88		
48	118.62	89	134.32	130	149.82	170	164.76	211	180.24		
49	119.01	90	134.70	131	150.20	171	165.13	212	180.97		
50	119.40	91	135.08	132	150.57	172	165.50	213	181.34		
51	119.78	92	135.46	133	150.95	173	165.87	214	181.71		
52	120.16	93	135.84	134	151.33	174	166.24	215	182.07		
53	120.55	94	136.22	135	151.70	175	166.61	216	182.44		
54	120.93	95	136.60	136	152.08	176	166.98	217	182.80		
55	121.32	96	136.98	137	152.45	177	167.35	218	183.17		
56	121.70	97	137.36	138	152.83	178	167.72	219	183.53		
57	122.09	98	137.74	139	153.20	179	168.09	220	183.17		
58	122.47	99	138.12	140	153.58	180	168.46	221	183.53		
59	122.86	100	138.50	141	153.95	181	168.83	222	183.90		
60	123.24	101	138.88	142	154.32	182	169.20	223	184.26		
61	123.62	102	139.26	143	154.70	183	169.57	224	184.63		
62	124.01	103	139.64	144	155.07	184	169.94	225	184.99		
63	124.39	104	140.02	145	155.45	185	170.31	226	185.36		
64	124.77	105	140.39	146	155.82	186	170.68	227	185.72		
65	125.16	106	140.77	147	156.19	187	171.05	228	186.09		
66	125.54	107	141.15	148	156.57	188	171.42	229	186.45		
67	125.92	108	141.53	149	156.94	189	171.79	230	186.82		
68	126.31	109	141.91	150	157.31	190	172.16	231	187.18		
69	126.69	110	142.29	151	157.69	191	172.53	232	187.54		
70	127.07	111	142.66	152	158.06	192	172.90	233	187.91		
71	127.45	112	143.04	153	158.43	193	173.26	234	188.27		
72	127.84	113	143.42	154	158.81	194	173.63	235	188.63		
73	128.22	114	143.80	155	159.18	195	174.00	236	189.00		
74	128.60	115	144.17	156	159.55	196	174.37	237	189.36		
75	128.98	116	144.55	157	159.93	197	174.74	238	189.72		

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (240°C to 629°C)
Temperature Coefficient - 0.00385 Ohms/Ohm/°C

°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms
240	190.45	278	204.16	316	217.70	354	231.07	392	244.28	430	257.32
241	190.81	279	204.52	317	218.05	355	231.42	393	244.62	431	257.66
242	191.18	280	204.88	318	218.41	356	231.77	394	244.97	432	258.00
243	191.54	281	205.23	319	218.76	357	232.12	395	245.31	433	258.34
244	191.90	282	205.59	320	219.12	358	232.47	396	245.66	434	258.68
245	192.26	283	205.95	321	219.47	359	232.82	397	246.00	435	259.02
246	192.63	284	206.31	322	219.82	360	233.17	398	246.35	436	259.36
247	192.99	285	206.67	323	220.18	361	233.52	399	246.69	437	259.70
248	193.35	286	207.02	324	220.53	362	233.87	400	247.04	438	260.04
249	193.71	287	207.38	325	220.88	363	234.22	401	247.38	439	260.38
250	194.07	288	207.74	326	221.24	364	234.56	402	247.72	440	260.72
251	194.44	289	208.10	327	221.59	365	234.91	403	248.07	441	261.06
252	194.80	290	208.45	328	221.94	366	235.26	404	248.41	442	261.40
253	195.16	291	208.81	329	222.29	367	235.61	405	248.76	443	261.74
254	195.52	292	209.17	330	222.65	368	235.96	406	249.10	444	262.08
255	195.88	293	209.52	331	223.00	369	236.31	407	249.45	445	262.42
256	196.24	294	209.88	332	223.35	370	236.65	408	249.79	446	262.76
257	196.60	295	210.24	333	223.70	371	237.00	409	250.13	447	263.10
258	196.96	296	210.59	334	224.06	372	237.35	410	250.48	448	263.43
259	197.33	297	210.95	335	224.41	373	237.70	411	250.82	449	236.77
260	197.69	298	211.31	336	224.76	374	238.04	412	251.16	450	264.11
261	198.05	299	211.66	337	225.11	375	238.39	413	251.50	451	264.45
262	198.41	300	212.02	338	225.46	376	238.74	414	251.85	452	264.79
263	198.77	301	212.37	339	225.81	377	239.09	415	252.19	453	265.13
264	199.13	302	212.73	340	226.17	378	239.43	416	252.53	454	265.46
265	199.49	303	213.09	341	226.52	379	239.78	417	252.87	455	265.80
266	199.85	304	213.44	342	226.87	380	240.13	418	253.22	456	266.14
267	200.21	305	213.80	343	227.22	381	240.47	419	253.56	457	266.48
268	200.57	306	214.15	344	227.57	382	240.82	420	253.90	458	266.82
269	200.93	307	214.51	345	227.92	383	241.17	421	254.24	459	267.15
270	201.29	308	214.86	346	228.27	384	241.51	422	254.59	460	267.49
271	201.65	309	215.22	347	228.62	385	241.86	423	254.93	461	267.83
272	202.01	310	215.57	348	228.97	386	242.20	424	255.27	462	268.17
273	202.36	311	215.93	349	229.32	387	242.55	425	255.61	463	268.50
274	202.72	312	216.28	350	229.67	388	242.90	426	255.95	464	268.84
275	203.08	313	216.64	351	230.02	389	243.24	427	256.29	465	269.18
276	203.44	314	216.99	352	230.37	390	243.59	428	256.63	466	269.51
277	203.80	315	217.35	353	230.72	391	243.93	429	258.98	467	269.85

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (240°C to 629°C)
Temperature Coefficient - 0.00385 Ohms/Ohm/°C

°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms
468	270.19	499	280.56	530	290.83	561	300.98	592	311.02	623	320.95
469	270.52	500	280.90	531	291.16	562	301.31	593	311.34	624	321.27
470	270.86	501	281.23	532	291.49	563	301.63	594	311.66	625	321.59
471	271.20	502	281.56	533	291.81	564	301.96	595	311.99	626	321.91
472	271.53	503	281.89	534	292.14	565	302.28	596	312.31	627	322.22
473	271.87	504	282.23	535	292.47	566	302.61	597	312.63	628	322.54
474	272.20	505	282.56	536	292.80	567	302.93	598	312.95	629	322.86
475	272.54	506	282.89	537	293.13	568	303.26	599	313.27		
476	272.88	507	283.22	538	293.46	569	303.58	600	313.59		
477	273.21	508	283.55	539	293.79	570	303.91	601	313.91		
478	273.55	509	283.89	540	294.11	571	304.23	602	314.24		
479	273.88	510	284.22	541	294.44	572	304.56	603	314.56		
480	274.22	511	284.55	542	294.77	573	304.88	604	314.88		
481	274.55	512	284.88	543	295.10	574	305.20	605	315.20		
482	274.89	513	285.21	544	295.43	575	305.53	606	315.52		
483	275.22	514	285.54	545	295.75	576	305.85	607	316.16		
484	275.56	515	285.87	546	296.08	577	306.18	608	316.48		
485	275.89	516	286.21	547	296.41	578	306.50	609	316.48		
486	276.23	517	286.54	548	296.74	579	306.82	610	316.80		
487	276.56	518	286.87	549	297.06	580	307.15	611	317.12		
488	276.89	519	287.20	550	297.39	581	307.47	612	317.44		
489	277.23	520	287.53	551	297.72	582	307.79	613	317.76		
490	277.56	521	287.86	552	298.04	583	308.12	614	318.08		
491	277.90	522	288.19	553	298.37	584	308.44	615	318.40		
492	278.23	523	288.52	554	298.70	585	308.76	616	318.72		
493	278.56	524	288.85	555	299.02	586	309.09	617	319.04		
494	278.90	525	289.18	556	299.35	587	309.41	618	319.36		
495	279.23	526	289.51	557	299.68	588	309.73	619	319.68		
496	279.56	527	289.84	558	300.00	589	310.05	620	319.99		
497	279.90	528	290.17	559	300.33	590	310.38	621	320.31		
498	280.23	529	290.50	560	300.65	591	310.70	622	320.63		

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-328°F to 1220°F)
Temperature Coefficient - 0.00385 Ohms/Ohm/°F

°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms
-328	18.52	-292	27.10	-256	35.54	-220	41.80	-184	52.11	-148	60.26
-327	18.76	-291	27.33	-255	35.78	-219	44.11	-183	52.34	-147	60.48
-326	19.00	-290	27.57	-254	36.01	-218	44.34	-182	52.56	-146	60.71
-325	19.24	-289	27.81	-253	36.24	-217	44.57	-181	52.79	-145	60.93
-324	19.48	-288	28.04	-252	36.47	-216	44.80	-180	53.02	-144	61.16
-323	19.72	-287	28.28	-251	36.71	-215	45.03	-179	53.25	-143	61.38
-322	19.96	-286	28.51	-250	36.94	-214	45.26	-178	53.47	-142	61.61
-321	20.20	-285	28.75	-249	37.17	-213	45.48	-177	53.7	-141	61.83
-320	20.44	-284	28.98	-248	37.40	-212	45.71	-176	53.93	-140	62.06
-319	20.68	-283	29.22	-247	37.64	-211	45.94	-175	54.15	-139	62.28
-318	20.92	-282	29.46	-246	37.87	-210	46.17	-174	54.38	-138	62.5
-317	21.16	-281	29.69	-245	38.10	-209	46.40	-173	54.61	-137	62.73
-316	21.39	-280	29.93	-244	38.33	-208	46.63	-172	54.83	-136	62.95
-315	21.63	-279	30.16	-243	38.56	-207	46.86	-171	55.06	-135	63.18
-314	21.87	-278	30.40	-242	38.8	-206	47.09	-170	55.29	-134	63.4
-313	22.11	-277	30.63	-241	39.03	-205	47.32	-169	55.51	-133	63.63
-312	22.35	-276	30.87	-240	39.26	-204	47.55	-168	55.74	-132	63.85
-311	22.59	-275	31.10	-239	39.49	-203	47.78	-167	55.97	-131	64.08
-310	22.83	-274	31.34	-238	39.72	-202	48.00	-166	56.19	-130	64.30
-309	23.06	-273	31.57	-237	39.95	-201	48.23	-165	56.42	-129	64.52
-308	23.3	-272	31.80	-236	40.19	-200	48.46	-164	56.65	-128	64.75
-307	23.54	-271	32.04	-235	40.42	-199	48.69	-163	56.87	-127	64.97
-306	23.78	-270	32.27	-234	40.65	-198	48.92	-162	57.1	-126	65.2
-305	24.02	-269	32.51	-233	40.88	-197	49.15	-161	57.32	-125	65.42
-304	24.25	-268	32.74	-232	41.11	-196	49.38	-160	57.55	-124	65.64
-303	24.49	-267	32.98	-231	41.34	-195	49.6	-159	57.78	-123	65.87
-302	24.73	-266	33.21	-230	41.57	-194	49.83	-158	58.00	-122	66.09
-301	24.97	-265	33.44	-229	43.88	-193	50.06	-157	58.23	-121	66.31
-300	25.20	-264	33.68	-228	43.65	-192	50.29	-156	58.45	-120	66.54
-299	25.44	-263	33.91	-227	43.42	-191	50.52	-155	58.68	-119	66.76
-298	25.68	-262	34.14	-226	43.19	-190	50.74	-154	58.9	-118	66.99
-297	25.91	-261	34.38	-225	42.96	-189	50.97	-153	59.13	-117	67.21
-296	26.15	-260	34.61	-224	42.73	-188	51.2	-152	59.35	-116	67.43
-295	26.39	-259	34.84	-223	42.49	-187	51.43	-151	59.58	-115	67.66
-294	26.62	-258	35.08	-222	42.26	-186	51.65	-150	59.81	-114	67.88
-293	26.86	-257	35.31	-221	42.03	-185	51.88	-149	60.03	-113	68.10

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-328°F to 1220°F)
Temperature Coefficient - 0.00385 Ohms/Ohm/°F

°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms
-112	68.33	-76	76.33	-40	84.27	-4	92.16	32	100.00	68	107.79
-111	68.55	-75	76.55	-39	84.49	-3	92.38	33	100.22	69	108.01
-110	68.77	-74	76.77	-38	84.71	-2	92.60	34	100.43	70	108.23
-109	71.00	-73	76.99	-37	84.93	-1	92.82	35	100.65	71	108.44
-108	70.78	-72	77.21	-36	85.15	0	93.03	36	100.87	72	108.66
-107	70.55	-71	77.43	-35	85.37	1	93.25	37	101.09	73	108.87
-106	70.33	-70	77.66	-34	85.59	2	93.47	38	101.30	74	109.09
-105	70.11	-69	77.88	-33	85.81	3	93.69	39	101.52	75	109.3
-104	69.89	-68	78.1	-32	86.03	4	93.91	40	101.74	76	109.52
-103	69.66	-67	78.32	-31	86.25	5	94.12	41	101.95	77	109.73
-102	69.44	-66	78.54	-30	86.47	6	94.34	42	102.17	78	109.95
-101	69.22	-65	78.76	-29	86.69	7	94.56	43	102.39	79	110.17
-100	68.99	-64	78.98	-28	86.91	8	94.78	44	102.60	80	110.38
-99	71.22	-63	79.2	-27	87.13	9	95.00	45	102.82	81	110.6
-98	71.45	-62	79.42	-26	87.34	10	95.21	46	103.04	82	110.81
-97	71.67	-61	79.64	-25	87.56	11	95.43	47	103.25	83	111.03
-96	71.89	-60	79.86	-24	87.78	12	95.65	48	103.47	84	111.24
-95	72.11	-59	80.09	-23	88.00	13	95.87	49	103.69	85	111.46
-94	72.33	-58	80.31	-22	88.22	14	96.09	50	103.90	86	111.67
-93	72.56	-57	80.53	-21	88.44	15	96.3	51	104.12	87	111.89
-92	72.78	-56	80.75	-20	88.66	16	96.52	52	104.34	88	112.10
-91	73.00	-55	80.97	-19	88.88	17	96.74	53	104.55	89	112.32
-90	73.22	-54	81.19	-18	89.10	18	96.96	54	104.77	90	112.53
-89	73.45	-53	81.41	-17	89.32	19	97.17	55	104.98	91	112.75
-88	73.67	-52	81.63	-16	89.54	20	97.39	56	105.20	92	112.96
-87	73.89	-51	81.85	-15	89.75	21	97.61	57	105.42	93	113.18
-86	74.11	-50	82.07	-14	89.97	22	97.83	58	105.63	94	113.39
-85	74.33	-49	82.29	-13	90.19	23	98.04	59	105.85	95	113.61
-84	74.55	-48	82.51	-12	90.41	24	98.26	60	106.07	96	113.82
-83	74.78	-47	82.73	-11	90.63	25	98.48	61	106.28	97	114.04
-82	75.00	-46	82.95	-10	90.85	26	98.7	62	106.50	98	114.25
-81	75.22	-45	83.17	-9	91.07	27	98.91	63	106.71	99	114.47
-80	75.44	-44	83.39	-8	91.29	28	99.13	64	106.93	100	114.68
-79	75.66	-43	83.61	-7	91.50	29	99.35	65	107.15	101	114.90
-78	75.88	-42	83.83	-6	91.72	30	99.57	66	107.36	102	115.11
-77	76.11	-41	84.05	-5	91.94	31	99.78	67	107.58	103	115.33

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-328°F to 1220°F)
Temperature Coefficient - 0.00385 Ohms/Ohm/°F

°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms
104	115.54	140	123.24	176	130.90	212	138.51	248	146.07	284	153.58
105	115.76	141	123.46	177	131.11	213	138.72	249	146.28	285	153.79
106	115.97	142	123.67	178	131.32	214	138.93	250	146.49	286	154.00
107	116.18	143	123.88	179	131.53	215	139.14	251	146.70	287	154.21
108	116.40	144	124.09	180	131.74	216	139.35	252	146.91	288	154.42
109	116.61	145	124.31	181	131.96	217	139.56	253	147.11	289	154.62
110	116.83	146	124.52	182	132.17	218	139.77	254	147.32	290	154.83
111	117.04	147	124.73	183	132.38	219	139.98	255	147.53	291	155.04
112	117.26	148	124.95	184	132.59	220	140.19	256	147.74	292	155.25
113	117.47	149	125.16	185	132.8	221	140.4	257	147.95	293	155.46
114	117.68	150	125.37	186	133.01	222	140.61	258	148.16	294	155.66
115	117.90	151	125.59	187	133.23	223	140.82	259	148.37	295	155.87
116	118.11	152	125.80	188	133.44	224	141.03	260	148.58	296	156.08
117	118.33	153	126.01	189	133.65	225	141.24	261	148.79	297	156.29
118	118.54	154	126.22	190	133.86	226	141.45	262	149.00	298	156.49
119	118.76	155	126.44	191	134.07	227	141.66	263	149.21	299	156.7
120	118.97	156	126.65	192	134.28	228	141.87	264	149.41	300	156.91
121	119.18	157	126.86	193	134.5	229	142.08	265	149.62	301	157.12
122	119.4	158	127.08	194	134.71	230	142.29	266	149.83	302	157.33
123	119.61	159	127.29	195	134.92	231	142.5	267	150.04	303	157.53
124	119.82	160	127.50	196	135.13	232	142.71	268	150.25	304	157.74
125	120.04	161	127.71	197	135.34	233	142.92	269	150.46	305	157.95
126	120.25	162	127.93	198	135.55	234	143.13	270	150.67	306	158.15
127	120.47	163	128.14	199	135.76	235	143.34	271	150.88	307	158.36
128	120.68	164	128.35	200	135.97	236	143.55	272	151.08	308	158.57
129	120.89	165	128.56	201	136.19	237	143.76	273	151.29	309	158.78
130	121.11	166	128.78	202	136.4	238	143.97	274	151.50	310	158.98
131	121.32	167	128.99	203	136.61	239	144.18	275	151.71	311	159.19
132	121.53	168	129.20	204	136.82	240	144.39	276	151.92	312	159.40
133	121.75	169	129.41	205	137.03	241	144.60	277	152.13	313	159.61
134	121.96	170	129.62	206	137.24	242	144.81	278	152.33	314	159.81
135	122.18	171	129.84	207	137.45	243	145.02	279	152.54	315	160.02
136	122.39	172	130.05	208	137.66	244	145.23	280	152.75	316	160.23
137	122.60	173	130.26	209	137.87	245	145.44	281	152.96	317	160.43
138	122.82	174	130.47	210	138.08	246	145.65	282	153.17	318	160.64
139	123.03	175	130.68	211	138.29	247	145.86	283	153.38	319	160.85

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-328°F to 1220°F)
Temperature Coefficient - 0.00385 Ohms/Ohm/°F

°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms
320	163.12	356	168.48	392	175.86	428	183.19	464	190.47	500	197.71
321	161.26	357	168.68	393	176.06	429	183.39	465	190.67	501	197.91
322	161.47	358	168.89	394	176.26	430	183.59	466	190.88	502	198.11
323	161.67	359	169.09	395	176.47	431	183.80	467	191.08	503	198.31
324	161.88	360	169.30	396	176.67	432	184.00	468	191.28	504	198.51
325	162.09	361	169.51	397	176.88	433	184.20	469	191.48	505	198.71
326	162.29	362	169.71	398	177.08	434	184.40	470	191.68	506	198.91
327	162.50	363	169.92	399	177.29	435	184.61	471	191.88	507	199.11
328	162.71	364	170.12	400	177.49	436	184.81	472	192.09	508	199.31
329	162.91	365	170.33	401	177.69	437	185.01	473	192.29	509	199.51
330	163.12	366	170.53	402	177.90	438	185.22	474	192.49	510	199.71
331	163.33	367	170.74	403	178.10	439	185.42	475	192.69	511	199.91
332	163.53	368	170.94	404	178.3	440	185.62	476	192.89	512	200.11
333	163.74	369	171.15	405	178.51	441	185.82	477	193.09	513	200.31
334	163.95	370	171.35	406	178.71	442	186.03	478	193.29	514	200.51
335	164.15	371	171.56	407	178.92	443	186.23	479	193.49	515	200.71
336	164.36	372	171.76	408	179.12	444	186.43	480	193.70	516	200.91
337	164.57	373	171.97	409	179.32	445	186.63	481	193.90	517	201.11
338	164.77	374	172.17	410	179.53	446	186.84	482	194.10	518	201.31
339	164.98	375	172.38	411	179.73	447	187.04	483	194.30	519	201.51
340	165.18	376	172.58	412	179.93	448	187.24	484	194.50	520	201.71
341	165.39	377	172.79	413	180.14	449	187.44	485	194.70	521	201.91
342	165.60	378	172.99	414	180.34	450	187.65	486	194.90	522	202.11
343	165.80	379	173.20	415	180.55	451	187.85	487	195.10	523	202.31
344	166.01	380	173.40	416	180.75	452	188.05	488	195.30	524	202.51
345	166.21	381	173.61	417	180.95	453	188.25	489	195.50	525	202.71
346	166.42	382	173.81	418	181.16	454	188.45	490	195.71	526	202.91
347	166.63	383	174.02	419	181.36	455	188.66	491	195.91	527	203.11
348	166.83	384	174.22	420	181.56	456	188.86	492	196.11	528	203.31
349	167.04	385	174.43	421	181.77	457	189.06	493	196.31	529	203.51
350	167.24	386	174.63	422	181.97	458	189.26	494	196.51	530	203.71
351	167.45	387	174.83	423	182.17	459	189.46	495	196.71	531	203.91
352	167.66	388	175.04	424	182.38	460	189.67	496	196.91	532	204.11
353	167.86	389	175.24	425	182.58	461	189.87	497	197.11	533	204.31
354	168.07	390	175.45	426	182.78	462	190.07	498	197.31	534	204.51
355	168.27	391	175.65	427	182.98	463	190.27	499	197.51	535	204.71

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-328°F to 1220°F)
Temperature Coefficient - 0.00385 Ohms/Ohm/°F

°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms
536	204.90	572	212.05	608	219.15	644	226.21	680	233.21	716	240.18
537	205.10	573	212.25	609	219.35	645	226.40	681	233.41	717	240.37
538	205.30	574	212.45	610	219.55	646	226.60	682	233.60	718	240.56
539	205.50	575	212.64	611	219.74	647	226.79	683	233.80	719	240.75
540	205.70	576	212.84	612	219.94	648	226.99	684	233.99	720	240.95
541	205.90	577	213.04	613	220.13	649	227.18	685	234.18	721	241.14
542	206.10	578	213.24	614	220.33	650	227.38	686	234.38	722	241.33
543	206.30	579	213.44	615	220.53	651	227.57	687	234.57	723	241.52
544	206.50	580	213.63	616	220.72	652	227.77	688	234.77	724	241.72
545	206.70	581	213.83	617	220.92	653	227.96	689	234.96	725	241.91
546	206.89	582	214.03	618	221.12	654	228.16	690	235.15	726	242.10
547	207.09	583	214.23	619	221.31	655	228.35	691	235.35	727	242.29
548	207.29	584	214.42	620	221.51	656	228.55	692	235.54	728	242.49
549	207.49	585	214.62	621	221.70	657	228.74	693	235.73	729	242.68
550	207.69	586	214.82	622	221.90	658	228.94	694	235.93	730	242.87
551	207.89	587	215.02	623	222.10	659	229.13	695	236.12	731	243.06
552	208.09	588	215.21	624	222.29	660	229.33	696	236.31	732	243.26
553	208.29	589	215.41	625	222.49	661	229.52	697	236.51	733	243.45
554	208.48	590	215.61	626	222.68	662	229.72	698	236.7	734	243.64
555	208.68	591	215.80	627	222.88	663	229.91	699	236.89	735	243.83
556	208.88	592	216.00	628	223.08	664	230.11	700	237.09	736	244.02
557	209.08	593	216.20	629	223.27	665	230.30	701	237.28	737	244.22
558	209.28	594	216.40	630	223.47	666	230.49	702	237.47	738	244.41
559	209.48	595	216.59	631	223.66	667	230.69	703	237.67	739	244.60
560	209.67	596	216.79	632	223.86	668	230.88	704	237.86	740	244.79
561	209.87	597	216.99	633	224.06	669	231.08	705	238.05	741	244.98
562	210.07	598	217.18	634	224.25	670	231.27	706	238.25	742	245.18
563	210.27	599	217.38	635	224.45	671	231.47	707	238.44	743	245.37
564	210.47	600	217.58	636	224.64	672	231.66	708	238.63	744	245.56
565	210.67	601	217.77	637	224.84	673	231.86	709	238.83	745	245.75
566	210.86	602	217.97	638	225.03	674	232.05	710	239.02	746	245.94
567	211.06	603	218.17	639	225.23	675	232.24	711	239.21	747	246.13
568	211.26	604	218.37	640	225.42	676	232.44	712	239.41	748	246.33
569	211.46	605	218.56	641	225.62	677	232.63	713	239.6	749	246.52
570	211.66	606	218.76	642	225.82	678	232.83	714	239.79	750	246.71
571	211.85	607	218.96	643	226.01	679	233.02	715	239.98	751	246.90

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-328°F to 1220°F)
Temperature Coefficient - 0.00385 Ohms/Ohm/°F

°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms
752	247.09	788	253.96	824	260.78	860	267.56	896	274.29	932	280.98
753	247.28	789	254.15	825	260.97	861	267.75	897	274.48	933	281.16
754	247.47	790	254.34	826	261.16	862	267.94	898	274.67	934	281.35
755	247.67	791	254.53	827	261.35	863	268.12	899	274.85	935	281.53
756	247.86	792	254.72	828	261.54	864	268.31	900	275.04	936	281.72
757	248.05	793	254.91	829	261.73	865	268.50	901	275.22	937	281.90
758	248.24	794	255.10	830	261.92	866	268.69	902	275.41	938	282.09
759	248.43	795	255.29	831	262.11	867	268.87	903	275.60	939	282.27
760	248.62	796	255.48	832	262.29	868	269.06	904	275.78	940	282.46
761	248.81	797	255.67	833	262.48	869	269.25	905	275.97	941	282.64
762	249.00	798	255.86	834	262.67	870	269.44	906	276.15	942	282.83
763	249.20	799	256.05	835	262.86	871	269.62	907	276.34	943	283.01
764	249.39	800	256.24	836	263.05	872	269.81	908	276.53	944	283.20
765	249.58	801	256.43	837	263.24	873	270.00	909	276.71	945	283.38
766	249.77	802	256.62	838	263.43	874	270.18	910	276.90	946	283.56
767	249.96	803	256.81	839	263.61	875	270.37	911	277.08	947	283.75
768	250.15	804	257.00	840	263.8	876	270.56	912	277.27	948	283.93
769	250.34	805	257.19	841	263.99	877	270.75	913	277.46	949	284.12
770	250.53	806	257.38	842	264.18	878	270.93	914	277.64	950	284.30
771	250.72	807	257.57	843	264.37	879	271.12	915	277.83	951	284.49
772	250.91	808	257.76	844	264.56	880	271.31	916	278.01	952	284.67
773	251.10	809	257.95	845	264.74	881	271.49	917	278.20	953	284.86
774	251.30	810	258.14	846	264.93	882	271.68	918	278.38	954	285.04
775	251.49	811	258.33	847	265.12	883	271.87	919	278.57	955	285.22
776	251.68	812	258.52	848	265.31	884	272.05	920	278.75	956	285.41
777	251.87	813	258.70	849	265.5	885	272.24	921	278.94	957	285.59
778	252.06	814	258.89	850	265.68	886	272.43	922	279.13	958	285.78
779	252.25	815	259.08	851	265.87	887	272.61	923	279.31	959	285.96
780	252.44	816	259.27	852	266.06	888	272.80	924	279.50	960	286.14
781	252.63	817	259.46	853	266.25	889	272.99	925	279.68	961	286.33
782	252.82	818	259.65	854	266.44	890	273.17	926	279.87	962	286.51
783	253.01	819	259.84	855	266.62	891	273.36	927	280.05	963	286.70
784	253.20	820	260.03	856	266.81	892	273.55	928	280.24	964	286.88
785	253.39	821	260.22	857	267.00	893	273.73	929	280.42	965	287.06
786	253.58	822	260.41	858	267.19	894	273.92	930	280.61	966	287.25
787	253.77	823	260.6	859	267.37	895	274.11	931	280.79	967	287.43

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-328°F to 1220°F)
Temperature Coefficient - 0.00385 Ohms/Ohm/°F

°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms
968	287.62	1004	294.21	1040	300.75	1076	307.25	1112	313.71	1148	320.12
969	287.8	1005	294.39	1041	300.94	1077	307.43	1113	313.89	1149	320.29
970	287.98	1006	294.57	1042	301.12	1078	307.61	1114	314.07	1150	320.47
971	288.17	1007	294.76	1043	301.30	1079	307.79	1115	314.24	1151	320.65
972	288.35	1008	294.94	1044	301.48	1080	307.97	1116	314.42	1152	320.82
973	288.53	1009	295.12	1045	301.66	1081	308.15	1117	314.60	1153	321.00
974	288.72	1010	295.30	1046	301.84	1082	308.33	1118	314.78	1154	321.18
975	288.9	1011	295.48	1047	302.02	1083	308.51	1119	314.96	1155	321.36
976	289.08	1012	295.67	1048	302.2	1084	308.69	1120	315.14	1156	321.53
977	289.27	1013	295.85	1049	302.38	1085	308.87	1121	315.31	1157	321.71
978	289.45	1014	296.03	1050	302.56	1086	309.05	1122	315.49	1158	321.89
979	289.64	1015	296.21	1051	302.75	1087	309.23	1123	315.67	1159	322.06
980	289.82	1016	296.40	1052	302.93	1088	309.41	1124	315.85	1160	322.24
981	290	1017	296.58	1053	303.11	1089	309.59	1125	316.03	1161	322.42
982	290.19	1018	296.76	1054	303.29	1090	309.77	1126	316.21	1162	322.59
983	290.37	1019	296.94	1055	303.47	1091	309.95	1127	316.38	1163	322.77
984	290.55	1020	297.12	1056	303.65	1092	310.13	1128	316.56	1164	322.95
985	290.73	1021	297.31	1057	303.83	1093	310.31	1129	316.74	1165	323.13
986	290.92	1022	297.49	1058	304.01	1094	310.49	1130	316.92	1166	323.30
987	291.1	1023	297.67	1059	304.19	1095	310.67	1131	317.10	1167	323.48
988	291.28	1024	297.85	1060	304.37	1096	310.85	1132	317.27	1168	323.66
989	291.47	1025	298.03	1061	304.55	1097	311.02	1133	317.45	1169	323.83
990	291.65	1026	298.21	1062	304.73	1098	311.20	1134	317.63	1170	324.01
991	291.83	1027	298.40	1063	304.91	1099	311.38	1135	317.81	1171	324.18
992	292.02	1028	298.58	1064	305.09	1100	311.56	1136	317.98	1172	324.36
993	292.2	1029	298.76	1065	305.27	1101	311.74	1137	318.16	1173	324.54
994	292.38	1030	298.94	1066	305.45	1102	311.92	1138	318.34	1174	324.71
995	292.56	1031	299.12	1067	305.63	1103	312.10	1139	318.52	1175	324.89
996	292.75	1032	299.30	1068	305.81	1104	312.28	1140	318.7	1176	325.07
997	292.93	1033	299.49	1069	305.99	1105	312.46	1141	318.87	1177	325.24
998	293.11	1034	299.67	1070	306.17	1106	312.64	1142	319.05	1178	325.42
999	293.3	1035	299.85	1071	306.35	1107	312.81	1143	319.23	1179	325.60
1000	293.48	1036	300.03	1072	306.53	1108	312.99	1144	319.41	1180	325.77
1001	293.66	1037	300.21	1073	306.71	1109	313.17	1145	319.58	1181	325.95
1002	293.84	1038	300.39	1074	306.89	1110	313.35	1146	319.76	1182	326.12
1003	294.03	1039	300.57	1075	307.07	1111	313.53	1147	319.94	1183	326.30

Appendix E - RTD Tables

Temperature Conversion
Platinum Resistance (-328°F to 1220°F)
Temperature Coefficient - 0.00385 Ohms/Ohm/°F

°F	Ohms	°F	Ohms	°F	Ohms						
1184	326.48	1200	329.29	1216	332.09						
1185	326.65	1201	329.46	1217	332.27						
1186	326.83	1202	329.64	1218	332.44						
1187	327.00	1203	329.82	1219	332.62						
1188	327.18	1204	329.99	1220	332.79						
1189	327.36	1205	330.17								
1190	327.53	1206	330.34								
1191	327.71	1207	330.52								
1192	327.88	1208	330.69								
1193	328.06	1209	330.87								
1194	328.24	1210	331.04								
1195	328.41	1211	331.22								
1196	328.59	1212	331.39								
1197	328.76	1213	331.57								
1198	328.94	1214	331.74								
1199	329.11	1215	331.92								

Appendix F - Warranty

Nelson Heat Trace Products
LIMITED WARRANTY AND LIABILITY

Appleton Grp LLC - d/b/a Appleton Group warrants that if there are any defects in material or workmanship in any heating cable or accessory during the first year after the date of purchase, we will provide new products to replace any defective items, or we will refund the purchase price paid for the accessory or cable, not including any labor or other installation costs. As an alternate, we may elect to repair the cable or accessory at our factory with all shipping and other removal costs borne by the purchaser.

We further warrant that, for a period of twelve (12) months after the date of performance, any services performed hereunder will be in a good and skillful manner, based on our understanding of pertinent technical data as of the date of performance of such services. Appleton Group's sole responsibility and liability in the event of any defect, error, omission, or failure in the services rendered hereunder shall be to provide corrected services of the type provided for herein, designed to correct such defect, error, omissions, or failure, and in no event shall Appleton Group's liability with respect to such warranty exceed the amount received by it from the Buyer on account of such services.

Our obligation to provide corrected services, new products, refund the purchase price, or perform the repair described above is conditioned upon (a) the installation of the accessory or cable conforming to the directions set forth in our installation instructions and (b) the accessory or cable not having been damaged by mechanical or electrical activities unrelated to the operation of the accessory or cable.

A refund of your purchase price, provision of replacement products, repair of the accessory or cable or provision of corrected services as described above, shall be your sole and exclusive remedy for a breach of this warranty. THESE ARE THE SOLE AND EXCLUSIVE WARRANTIES GIVEN BY APPLETON GROUP WITH RESPECT TO THE GOODS AND SERVICES AND ARE IN LIEU OF AND EXCLUDE ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, ARISING BY OPERATION OF LAW OR OTHERWISE, INCLUDING WITHOUT LIMITATION, MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE WHETHER OR NOT THE PURPOSE OR USE HAS BEEN DISCLOSED TO NELSON IN SPECIFICATIONS, DRAWINGS OR OTHERWISE, AND WHETHER OR NOT APPLETON GROUP'S PRODUCTS ARE SPECIFICALLY DESIGNED AND/OR MANUFACTURED BY NELSON FOR YOUR USE OR PURPOSE.

This warranty does not extend to any losses or damages due to misuse, accident, abuse, neglect, normal wear and tear, negligence, unauthorized modification or alteration, use beyond rated capacity, or improper installation, maintenance or application. To the extent that you or your agents have supplied specifications, information, representation of operating conditions or other data to Appleton Group in the selection or design of the Goods and the preparation of Appleton Group's quotation, and in the event that actual operating conditions or other conditions differ from those represented by you, any warranties or other provisions contained herein which are affected by such conditions shall be null and void.

If within thirty (30) days after your discovery of any warranty defects within the warranty period, you notify Appleton Group thereof in writing. Appleton Group shall, at its option, repair, correct or replace F.O.B. point of manufacture, or refund the purchase price for, that portion of the Goods found by Appleton Group to be defective. Failure by you to give such written notice within the applicable time period shall be deemed an absolute and unconditional waiver of your claim for such defects. Goods repaired or replaced during the warranty period shall be covered by the foregoing warranty for the remainder of the original warranty period or ninety (90) days from the date of shipment of the repaired or replaced goods, whichever is longer.

This limited warranty does not cover any costs relating to the repair or replacement of any accessory or cable at the installation site. Our accessories and cables are not easily accessible. A failed accessory or cable usually cannot be easily repaired. Replacement of a failed accessory or cable will require that the materials under which it is installed be removed to permit replacement of the accessory or cable. We will not reimburse any costs relating to the repair or replacement of any accessory or cable at the installation site.

IN NO EVENT, REGARDLESS OF THE FORM OF THE CLAIM OR CAUSE OF ACTION (WHETHER BASED IN CONTRACT, INFRINGEMENT, NEGLIGENCE, STRICT LIABILITY, OTHER TORT OR OTHERWISE), SHALL APPLETON GROUP'S LIABILITY TO YOU AND/OR YOUR CUSTOMERS EXCEED THE PRICE PAID BY YOU FOR THE SPECIFIC GOODS PROVIDED BY APPLETON GROUP GIVING RISE TO THE CLAIM OR CAUSE OF ACTION. YOU AGREE THAT WE SHALL NOT BE LIABLE TO YOU OR YOUR CUSTOMERS FOR ANY INCIDENTAL, SPECIAL OR CONSEQUENTIAL OR PUNITIVE DAMAGES. No agent, employee or representative of ours has authority to bind us to any affirmation, representation or warranty concerning the goods sold unless such affirmation, representation or warranty is specifically incorporated by written agreement.

To obtain new products, arrange repair of existing product, or a refund under this warranty, please contact Appleton Group (800-621-1506) with a description of the defect and proof of purchase at the address noted herein.

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Rosemont, IL 60018