SHIFT-CONTROLS.COM

Temperature Control Panel
Operations Manual for ISPA and IFPA Models

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Shift Controls temperature control panels are to be installed only by a qualified electrician. Only qualified personnel should work on electrical equipment, including control panels and electric heaters. Verify power has been disconnected before performing any work on electrical equipment, following proper lockout, tagout procedures.

All wiring must be done by qualified individuals in accordance with applicable codes such as the NEC (National Electric Code) ANSI / NFPA specifications or the Canadian Electrical Code Part 1. It is the responsibility of the installer to verify all local and national electrical codes are met and to verify that the equipment, installation and operation is in compliance with the latest revision of these codes.

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Warranty

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SECTION 1:

INTRODUCTION

Section 1: Introduction

Please read and understand this manual before using Shift Controls products. Consult Shift Controls if you have any questions or comments.

1.1 Panel Description

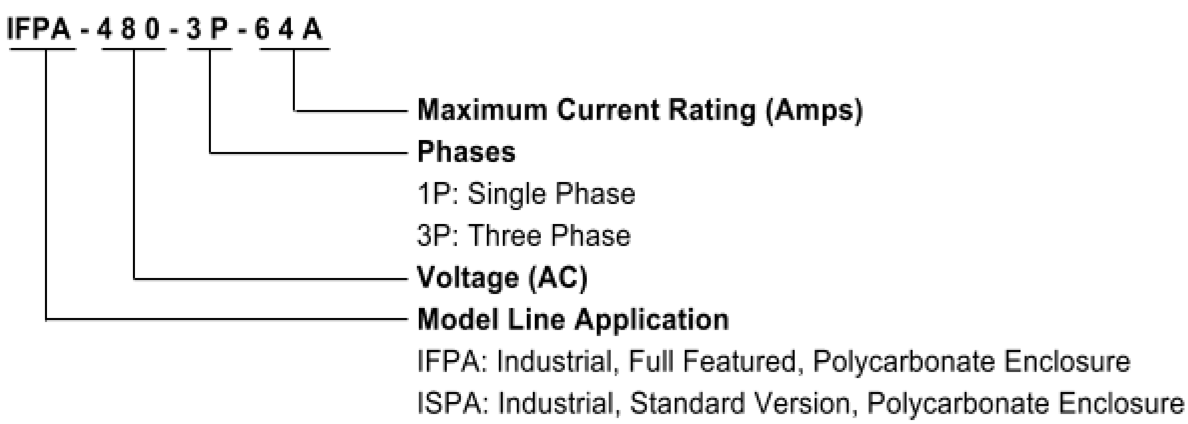
Shift Controls temperature control panels are designed for temperature control of industrial and laboratory electric heaters, heat trace, furnaces and other resistive heater loads. The controller measures the process temperature using a thermocouple input. The operator inputs a setpoint with the keypad and the heater output is controlled by a proportional (0-100% output) power controller. Power output is calculated using a PID process control algorithm. The power controller and PID controller allow processes to be controlled within a tighter temperature band than if using a traditional contactor or switched output controller, while also extending the contactor and heater life.

This manual will walk through the steps required to get the control panel to an operational state as quickly as possible.

Required steps to install and commission the temperature control panel:

1. Installation and mounting (Section 2.1)
2. Power and control circuit fusing, fuses included (Section 2.4)
3. Conduit entries and bonding (Section 2.6)
4. Line and and load side wiring connections (Section 3.1 - 3.2)
5. Control input and output wiring (Section 3.3)
6. Controller functions and terminology (Section 4.1 - 4.2)
7. Commission the control panel (Section 4.3)
8. Commission the process heater (Section 4.4)

1.2 Model Number Explanation



1.3 Enclosure Specifications

Table 1.3.1 Model Lineup Power, Disconnect, and Enclosure Specifications

Model Number	Model Line Application	Phases	Rated Voltage at 60 Hz	Maximum Full Load Current	Maximum Heating Load	Power Controller	Disconnect Method	Enclosure Environmental Rating
ISPA-120-1P-15A	Standard Features, Industrial	Single	120 VAC	15 Amps	1.80 kW	SSR, Zero Crossing	Disconnect Fuse Holder	NEMA 4X
IFPA-120-1P-35A	Full Featured, Industrial	Single	120 VAC	35 Amps	4.20 kW	SCR Zero Crossing	External Front Door Mount Handle, Fused Disconnect	NEMA 4X
IFPA-208-1P-35A			208 VAC		7.28 kW			
IFPA-240-1P-35A			240 VAC		8.40 kW			
IFPA-480-1P-35A			480 VAC		16.8 kW			
IFPA-208-3P-24A	Full Featured, Industrial	Three	208 VAC	24 Amps	8.65 kW	SCR, Zero Crossing	External Front Door Mount Handle, Fused Disconnect	NEMA 4X
IFPA-208-3P-64A				64 Amps	23.1 kW			NEMA 4X Enclosure, NEMA 12 Fan & Vent
IFPA-480-3P-24A			480 VAC	24 Amps	20.0 kW			NEMA 4X
IFPA-480-3P-64A				64 Amps	53.2 kW			NEMA 4X Enclosure, NEMA 12 Fan & Vent

Table 1.3.2 Shared Specifications for All Models

Electrical	
Short Circuit Current Rating (SCCR)	100kA
Heater Types	Rated for Resistive Heater Loads
Environmental	
Enclosure Construction	Rugged Construction Suitable for Industrial and Laboratory Locations
Environmental Rating	Indoor Use Only, NEMA 4X Models Rated for Washdown
Ambient Temperature Rating	32°F to 95°F (0°C to 35°C)
Storage Temperature Range	-4°F to 149°F (-20°C to 65°C)
Relative Humidity	10-85% Non-Condensing
Altitude	2000m or less
Process Controller	
Form Factor	1/8 DIN, 96x48 mm (Height x Width)
Process Input Sensor	Factory Standard Configurations Thermocouple: K (Standard), J (Optional - No Charge) Factory Custom Configurations (Consult Factory) Analog Input: 0 to 5 V, 0 to 10 V, 0 to 20 mA, 4 to 20 mA, 0 to 50 mV Thermocouple: T, E, N, R, S, B, L, U, TXK / RTD: Pt100, JPt100, Cu50, Ni120
Control Mode	PID, PID Program (Ramp/Soak) , Fuzzy, Manual, Slope Limited Control
Tuning Method	Auto-Tuning, Self-Tuning

1.3 Enclosure Specifications (continued)

Table 1.3.2 Shared Specifications for All Models (Continued)

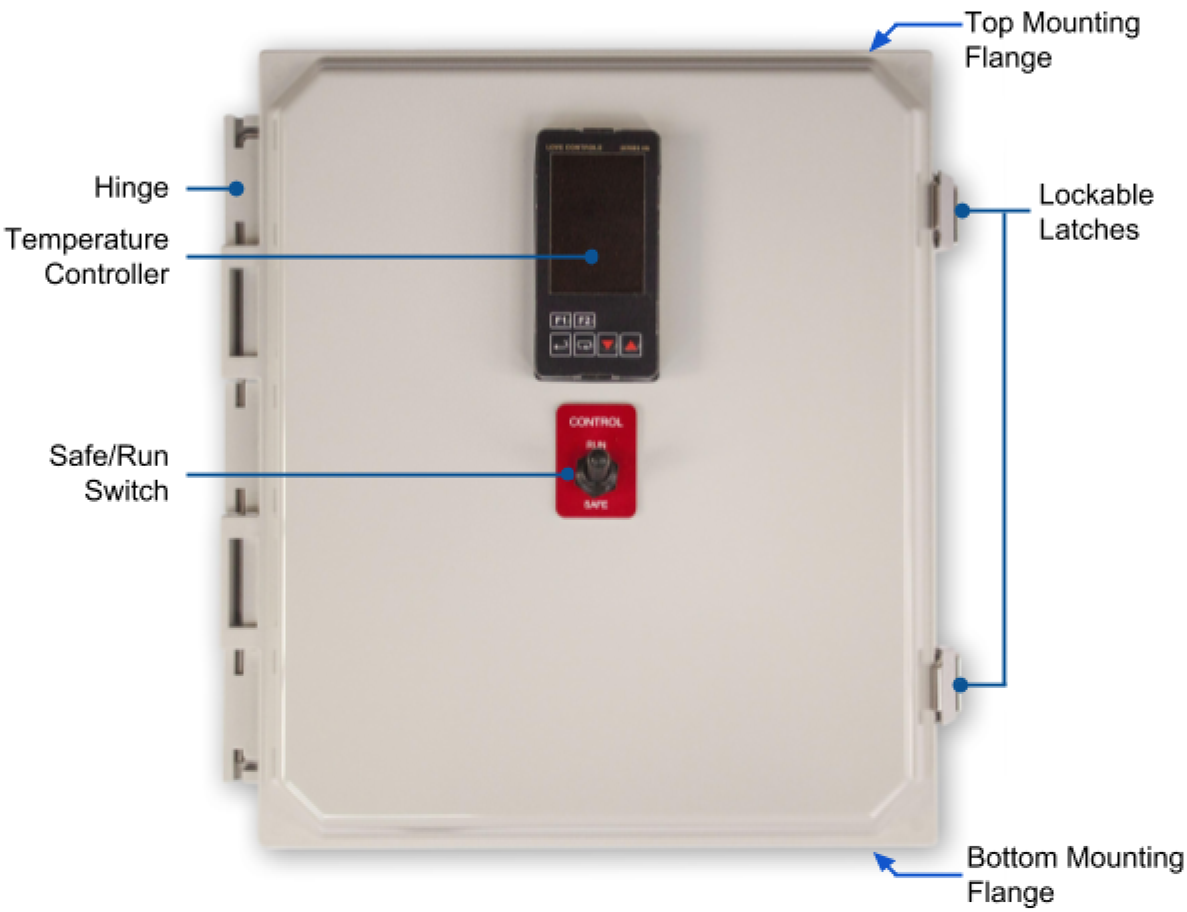
Process Controller (Continued)	
Display	LED, 4 Digit PV and SV, 10 Bar Segment Output PV Backlight and Digits Change from Yellow to Red on Alarm Unit, Output1, Output2, Alarm1, Alarm2, Alarm3, Autotune, Lock, Mode Indication
Display Resolution	0 or 1 Digit to the Right of the Decimal Point
Sampling Rate	0.1 seconds
Input Process Filtering	User Adjustable Time-Base and Range
Interfacing Features - Field Wiring Connections Through Terminal Blocks	
Thermocouple Process Input	Standard Size Female Panel Jack or Bi-Metal Terminal Block
External Enable/Interlock Control (Optional)	120 VAC or 24 VDC Interface Relay (Customer Specified) High Signal Allows Controller RUN and Contactor to be Energized Low Signal Places the Controller in STOP and De-Energizes Contactor
User Programmable Alarm/Status Dry Contacts	Normally Open, Electromechanical Dry Contacts, 250VAC 5A, for Resistive Loads 20 Configurable Alarm/Status Modes
Temperature Analog Retransmit	4-20mA Analog Output, Sourcing, 10 bit
Digital Monitoring and Control	RS-485 2-Wire, Addressable Modbus RTU or ASCII
Safety Features	
Electrical Construction	All Terminals and Components are Finger-Safe (IP-20) Electrical Design, Construction, and Wiring are NEC 70 and UL-508A Compliant DIN-Rail Mounting
Main Branch Power Fusing	Current Limiting Class CC or J, Finger Safe Fuse Holder, Disconnecting Type
Control Power Fusing	1 Amp, Fast Acting, Finger Safe Fuse Holder, Disconnecting Type
Safety Power Contactor	Power is Positively Disconnected from the Load Under the Following Conditions: Front Panel Switch is in the SAFE Position Latching High Temperature Alarm Thermocouple Fault External Interlock (Optional)
Front Panel SAFE/RUN Switch	Manual 2-Position Switch RUN Places Controller in RUN Mode and Energizes Contactor SAFE Places Controller in STOP Mode and De-Energizes Contactor
Latching High Temperature Alarm	User Configurable Temperature and On Delay Timing High Temperature Alarm Places Controller in STOP Mode and De-Energizes Safety Contactor Thermocouple Fault Places Controller in STOP Mode and De-Energizes Safety Contactor
Factory Acceptance Testing	All Components and the Full Assembly are Inspected and Tested Under Load
Agency Approvals	Electrical Design and Construction are NEC 70 and UL-508A Compliant All Components are UL Listed or Recognized Installation Must Comply with Local Electrical Codes
Documentation	
Included Hardcopies	Complete Wiring Diagram, Operations Manual
Construction	User Connections are Clearly Labeled and Documented User Interfaces are Labeled Terminal Blocks

1.4 Unpacking

Remove the temperature control panel from the shipping box. Refer to the equipment overview diagrams below, to become familiar with the major components of the panel.

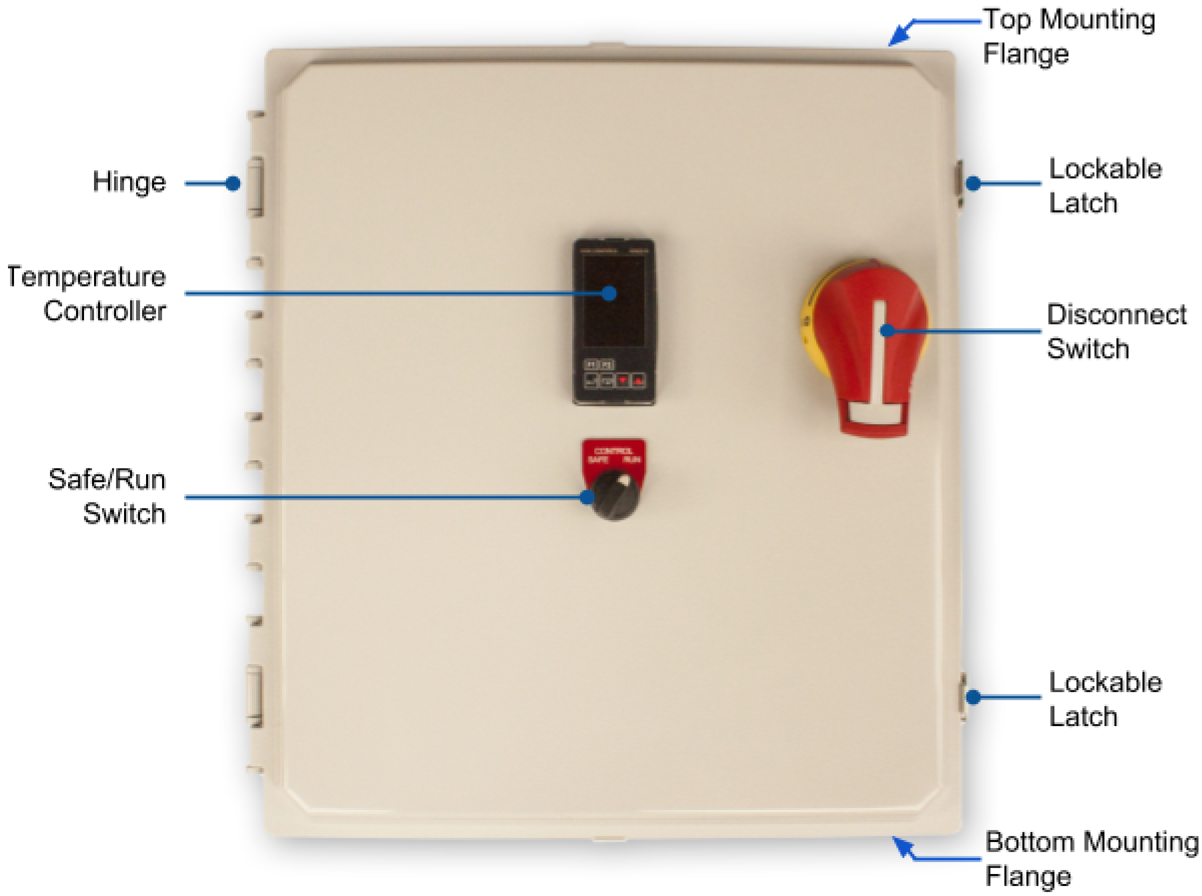
Required Documentation
In addition to this manual, the wiring schematics must be read and understood by all persons installing or maintaining this equipment in addition to NEC, NFPA, and any other documents inforced by the Authority Having Jurisdiction (AHJ).

Figure 1.4.1 Equipment Overview (ISPA Model)



1.4 Unpacking (continued)

Figure 1.4.2 Equipment Overview (IFPA Model)



SECTION 2:

MOUNTING & INSTALLATION

Section 2: Mounting and Installation

It is the responsibility of the installer to ensure that the temperature control panel is installed to comply with local and national electrical codes and the authority having jurisdiction (AHJ).

2.1 Enclosure Mounting

Mounting Location Requirements
The IFPA and ISPA panels are designed for indoor use only. Do not store or use panels in the following locations:

- Locations subject to heat radiated from heating equipment, transformers, etc.
- Locations subject to intense temperature change, icing or condensation
- Locations subject to vibration and large shocks.
- Locations where explosive atmospheres could be present.

Several considerations should be made for the installation location:

Physical
The enclosure should be mounted to a flat, sturdy wall that can handle the weight of the enclosure and is suitable for conduit mounting. Metal, concrete, wood framed walls and plywood will make suitable mounting structures.

Ensure the proper mounting hardware is used to secure the enclosure. Install the enclosure using the included mounting flanges with flat washers to prevent damage to the flanges.

Access
Once a location is selected, verify there is adequate space to fully open the door, operate the front disconnect switch, and that there is room to remove and replace the vent and fan covers (models IFPA-208-3P-64A and IFPA-480-3P-64A) for filter element replacement.

Enclosure Dimensions & Cooling

Refer to Table 2.1.1 Enclosure Dimensions and Required Clearance, below and ensure adequate clearances are maintained to allow for proper cooling of the enclosure. Ensure the enclosure is not mounted adjacent to large heat sources or in continuous, direct sunlight.

Table 2.1.1 Enclosure Dimensions and Required Clearance

<table>
<tr><th rowspan="2">Model Part Number</th><th colspan="3">Enclosure Dimensions</th><th colspan="3">Required Free Air Clearance</th></tr>
<tr><th>Height (inches)</th><th>Width (inches)</th><th>Depth (inches)</th><th>Top (Inches)</th><th>Bottom (Inches)</th><th>Sides (Inches)</th></tr>
<tr><td>ISPA-120-1P-15A</td><td>11.93</td><td>10.15</td><td>5.94</td><td>12</td><td>12</td><td>6</td></tr>
<tr><td>IFPA-120-1P-35A
IFPA-208-1P-35A
IFPA-240-1P-35A
IFPA-480-1P-35A</td><td>15.98</td><td>13.98</td><td>7.81</td><td>12</td><td>18</td><td>6</td></tr>
<tr><td>IFPA-208-3P-24A
IFPA-480-3P-24A</td><td rowspan="2">18.04</td><td rowspan="2">16.04</td><td rowspan="2">9.81</td><td>12</td><td>18</td><td>6</td></tr>
<tr><td>IFPA-208-3P-64A
IFPA-480-3P-64A</td><td>12</td><td>18</td><td>12</td></tr>
</table>

2.2 Environmental Requirements

Enclosure Type

Enclosures, disconnects, panel controller, and operator switches are rated NEMA 4X or equivalent and are suitable for washdown applications. Models with external cooling fans and vents (IFPA-208-3P-64A, IFPA-480-3P-64A) are rated NEMA 12 and not rated for washdown.

Temperature

The ambient temperature is not to exceed 35 degrees Celsius (95 degrees Fahrenheit) to ensure adequate cooling of the internal electronics. Do not mount the enclosure where it could be exposed to direct sunlight or in close proximity to large heat sources.

Relative Humidity

The enclosure should be used in environments of 0 - 85% relative humidity, where moisture is non-condensing.

Indoor locations

Although the enclosures are rated for outdoor use, the temperature control panels are designed for indoor use only. Enclosures in direct sunlight have an increased heating load which require additional cooling systems for the internal electronics. Consult with the factory if an outdoor application is required.

Material compatibility

The enclosure is manufactured from polycarbonate. The material is selected for its electrical insulative properties, chemical resistance, reduced weight, and ease of cutting conduit entries for installation. Polycarbonate has excellent resistance to mild acids, is satisfactory for alkalis, and can handle limited solvent use. Below is an abridged chemical compatibility table.

Table 2.2.1 Enclosure Chemical Compatibility Guidelines

Chemical Category	Chemical	
	Excellent Compatibility	Good Compatibility
Mild Acids	Aluminum Chloride Beer Boric Acid Calcium Chloride Carbonic Acid Nitric Acid (<20%) Potassium Nitrate Sea Water Sodium Carbonate Sulfuric Acid (<10%) Zinc Chloride	Acetic Acid Nitric Acid (50%) Sulfuric Acid (10-75%)
Alkalis	Ammonium Chloride Ammonium Nitrate Magnesium Hydroxide Sodium Carbonate Sodium Hydroxide (20%)	
Oils / Solvents	Diesel Fuel Gasoline Heptane Hydrogen Peroxide Motor Oil Soap Solutions	Alcohols Fuel Oils Lacquer Thinners

Note: This chart is only intended to be used as a general guideline for material compatibility. Before permanent installation, test the enclosure with the chemicals and under the specific conditions of your application to ensure compatibility.

2.3 Wiring Schematics

Wiring schematics are included as a supplement to this manual. The wiring schematics contain detailed information, specific to the model purchased. The schematics document terminal block numbers, wire routing and numbers, component designations, and information for the installation and wiring of the electrical supply, heater load, and control connections.

Refer to the wiring diagrams before making any field wiring connections. Refer to and follow all NEC, NFPA, and Local Electrical Codes to determine conductor sizing and installation requirements.

2.4 Fusing

Main Branch Fusing

Verify that the power and control fuses are installed properly and have not become loose during shipping. Verify the main branch fuses are of the proper current rating, based on the connected heater full load power, by referencing the fuse current rating table in the electrical schematics. Refer to the included wiring schematics for fuse type, speed, size, voltage rating and quantity required, and location depending on control panel model and heater load.

Branch circuit fuse protection of heater loads should be sized to at least 125% (UL508A, 31.6.1, a) and not more than 160% (power controller manufacturer recommendation) of the heater full load current. The wiring schematics and appendix G contain a reference table with heater full load power, current, and the appropriate fuse size.

All IFPA models use Class J current limiting branch fuses. Note that Class J fuses are not all the same dimension. Fuses of 1-30 Amps, 35-60 Amps, and 70-100 Amps classes are three different sizes. Due to the different sizes, fuse reducers are available to fit smaller class fuses into larger class fused disconnect holders. The Table 2.4.1 details the maximum fuse sizing and fuse reducer requirements.

Table 2.4.1 Maximum Heater Full Load Current and Fuse Sizing

Model Number	Maximum Rated Current	Maximum Fuse Size	Fuse Holder Type	Fuse Reducers
ISPA-120-1P-15A	15 Amps	20 Amps	30 Amp Class CC	N/A
IFPA-120-1P-35A IFPA-208-1P-35A IFPA-240-1P-35A IFPA-480-1P-35A	35 Amps	45 Amps	60 Amp Class J	Littlefuse ® LRUJ63 Reducers Required for 1-30A Fuses
IFPA-208-3P-24A IFPA-480-3P-24A	24 Amps	30 Amps	30 Amp Class J	N/A
IFPA-208-3P-64A IFPA-480-3P-64A	64 Amps	80 Amps	100 Amp Class J	Littlefuse ® LRUJ16 Reducers Required for 35-60A Fuses

Control Fusing

The control circuit fuses are supplementary and installed to protect the control circuit. Replace supplied control fuses with the same type, speed, and current rating only. Refer to the electrical schematics for fuse type, speed, current rating, number and voltage rating required, depending on the model.

Short Circuit Current Rating (SCCR)
The included main branch fuses are current-limiting fuses which are required to maintain the SCCR (short-circuit current rating) of the control panel. Replace main branch fuses with only high-speed, current-limiting fuses that are rated for semiconductor applications. This type of fuse is required to protect the power controller and maintain the enclosure SCCR rating. The control panel maximum SCCR is labeled inside the door, as required by UL508A.

Maximum Heater Load
Each control panel model has been designed for a maximum current limit. Never connect a load that exceeds the maximum rated current of the control panel.

2.5 Disconnecting Means

All electrical service inside the the temperature control panel, including changing fuses should be performed by qualified personnel only. The disconnecting means allow power to be disconnected from the heater and the fuse holder so that the heater or fuses may be changed or serviced. The disconnecting means will **NOT** de-energize the line side supply terminals or the supply terminals to the disconnect. These terminals may still have line voltage present when the disconnect is in the OFF position and there is power supplying the temperature control panel. It is recommended the power supplying the temperature control panel is de-energized before performing any maintenance. Extreme care should be taken to not touch the line terminals with tools or fingers, if servicing the panel with power supplied.

IFPA Models
A door mounted power disconnect handle and fused disconnect block are included on IFPA model enclosures, as a disconnecting means. The disconnect handle must be in the *OFF* position (handle in the horizontal position) to open the front door. The disconnect handle can be locked in the OFF position by lifting the white tab on the top of the handle and inserting a lock when the door is closed and handle in the OFF position. The fused disconnect block can also be locked out inside the enclosure, by pulling out the metal tab below the disconnect shaft and inserting a padlock.

ISPA Models
ISPA Models have a disconnect fuse holder as the the disconnecting means. The ISPA Models have an option to be pre-wired with a cord and plug for the line side wiring and a cord and receptacle for the load. The line and load plugs should be disconnected and lock-out-tag-out (LOTO) procedure performed before any maintenance is performed. Install and ensure there are external disconnecting means if required by local electrical codes.

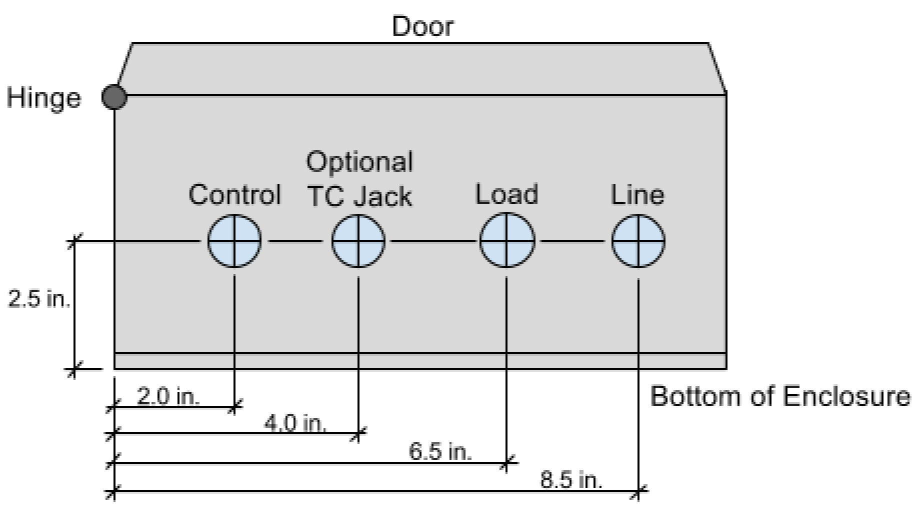
2.6 Conduit Installation

Location
It is recommended to install the line, load, and control conduit entries on the bottom of the enclosure, using NEMA 4X hubs. Installing the conduit entries on the bottom of the enclosure reduces the risk of water entering the enclosure, compared to installing entries on the sides or top. The recommended power line and load conduit entry locations are directly under the line and load terminal blocks on the bottom of the enclosure. The control circuit conduit entry should also be located on the bottom of the enclosure, positioned below the control terminal blocks. Figures 2.6.1-2.6.4 shows the recommended conduit entry locations for the different models.

The polycarbonate enclosure cuts cleanly with conventional hole-saws and step-bits. Ensure when drilling the conduit entry holes, to leave adequate clearance between the back panel, sides, and door flange for the conduit hub and that the drill does not come into contact with any of the components. Ensure the conduit entries are positioned so that the minimum bending radius of the wires can be maintained when terminating the wires to the terminal blocks.

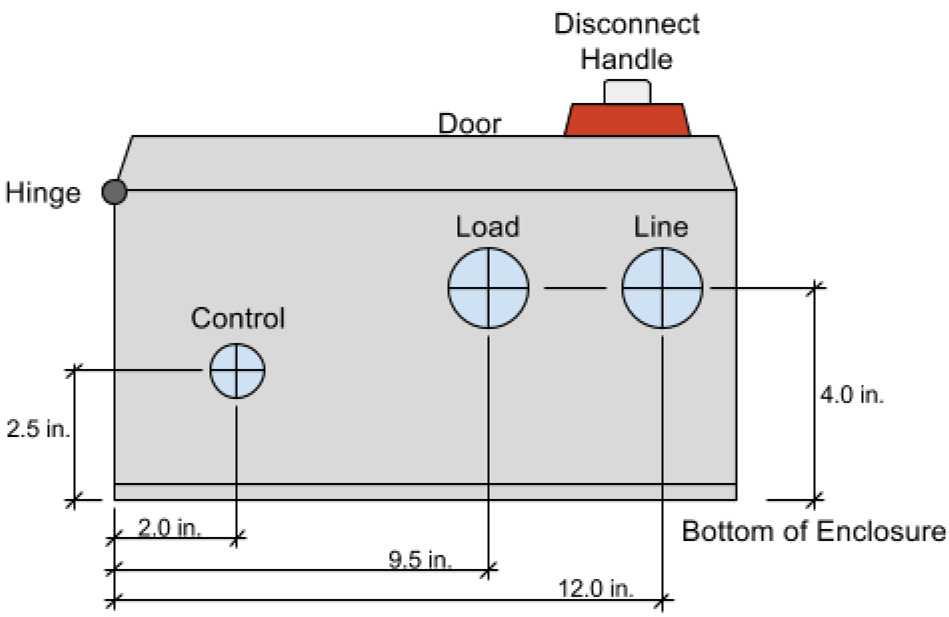
Conduit Bonding
The enclosure is made of an electrically insulating material. In order to maintain the continuity of the conduit grounding, install conduit bonding means between the line and load side conduits.

Figure 2.6.1 Recommended Conduit Entry Locations for the following Model Numbers: ISPA-120-1P-15A



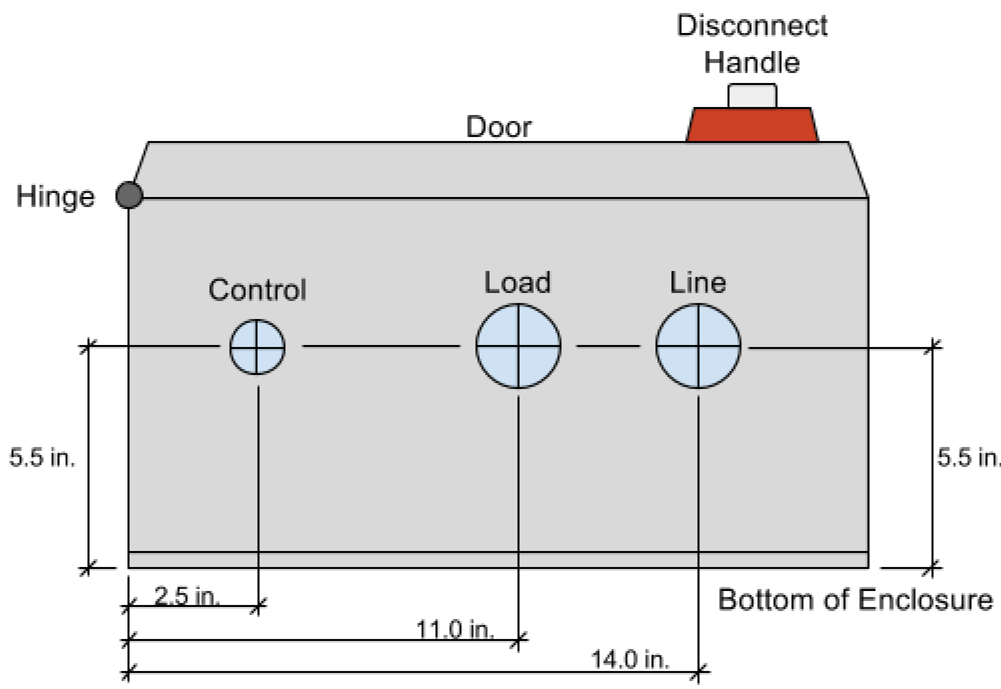
2.6 Conduit Installation (continued)

Figure 2.6.2 Recommended Conduit Entry Locations for the following Model Numbers:
IFPA-120-1P-35A,
IFPA-208-1P-35A,
IFPA-240-1P-35A
IFPA-480-1P-35A



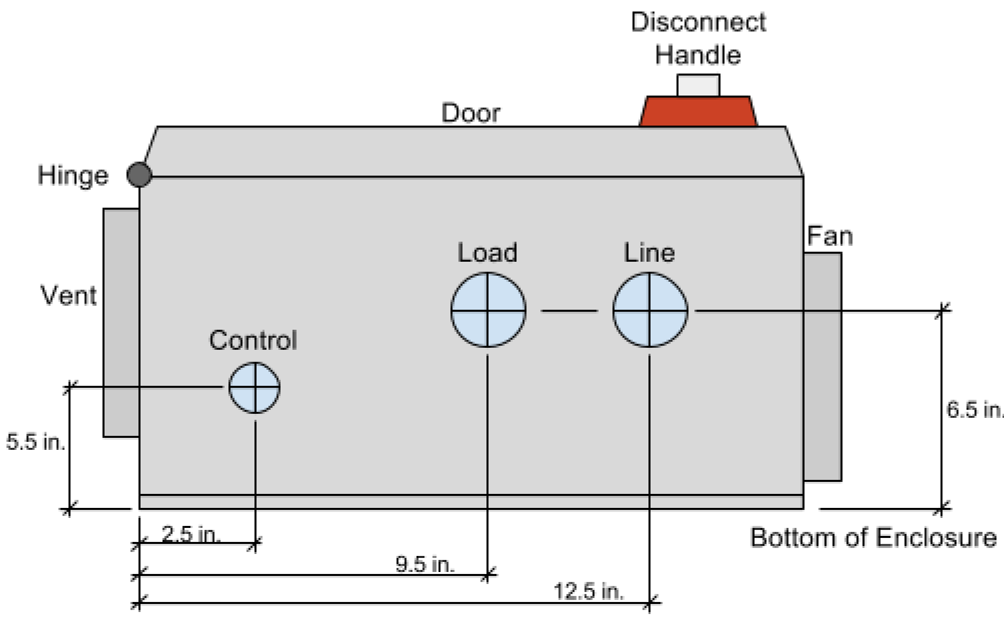
2.6 Conduit Installation (continued)

Figure 2.6.3 Recommended Conduit Entry Locations for the following Model Numbers:
IFPA-208-3P-24A,
IFPA-480-3P-24A



2.6 Conduit Installation (continued)

Figure 2.6.4 Recommended Conduit Entry Locations for the following Model Numbers:
IFPA-208-3P-64A,
IFPA-480-3P-64A



SECTION 3:
WIRING INSTRUCTIONS

Section 3: Wiring Instructions

All wiring must be done by qualified individuals in accordance with applicable local and national electrical codes such as the NEC (National Electric Code) ANSI / NFPA specifications or the Canadian Electrical Code Part 1. This includes wire conductor sizing, wire insulation material and color, number of conductors carried in conduit, minimum wire bending radius and clearance, and any other installation requirements.

Ensure to read the safety precautions section at the beginning of the manual. Before proceeding, refer to and become familiar with the included wiring schematics.

Place the Disconnecting Means in the Disconnected (OFF) Position
Before terminating the line side wiring to the line terminal blocks, verify that the user supplied power is de-energized and the panel disconnecting means are in the OFF or disconnected position. Follow any lock-out-tag-out (LOTO) requirements in your area and for your facility.

3.1 Line Side (Supply) Wiring

Supply the panel with only the voltage and number of phases for which the panel is rated.

Line Terminations
Terminate the electrical supply wiring to the labeled line terminal blocks in the temperature control panel, according to the included wiring schematic. The minimum wire temperature rating of the customer line wiring and terminal tightening torque for the line terminal blocks can be found in the electrical schematics. For ISPA models with included power cord and plug, this step is not necessary.

3.2 Load Side (Heater) Wiring

Never connect a heater that is not rated for the voltage or number of phases of the control panel. Ensure the heater full load current of the heater does not exceed the rated current of the panel, listed on the door label or the included wiring schematics.

ISPA Models (with optional cord and receptacle)
If the temperature control panel included the optional power cord and receptacle, plug the heater into the power cord receptacle.

IFPA Models and ISPA Models (without optional cord and receptacle)
Terminate the the heater wiring to the labeled load terminals, according to the included wiring schematic diagram. The minimum wire temperature rating of the customer line wiring and terminal tightening torque for the line terminal blocks can be found in the electrical schematics.

Types of Heaters
The following technical discussion outlines the different types of heater loads and the optimum type power controller for each type of heater.

Shift Controls products use zero-cross SSR or SCR power controllers for standard resistive heater applications. Zero-crossing power controllers are ideal for the most common type of process heaters, resistive heating loads.

Resistive Heaters - Ideal for zero-cross SSRs and SCRs
Resistive heater element resistance is very stable across the heater's temperature range. The heater element resistance has small changes relative to the temperature change. This is known as a low hot to cold ratio. Because the resistance is stable with temperature, the current draw of the heater is quite constant over large changes in temperature.

Examples of resistive heater element materials are:

- Iron Chromium
- Aluminum Alloy
- 80% - 20% Nickel Chromium

Most common process heaters, heat trace, and many furnaces are resistive heaters. For these applications, zero cross controllers are typically the best solution.

Inductive Heaters - May require custom solutions
A minority of applications will fall into the category of high inrush or high hot to cold ratio applications, which may require a custom power controller solution. When cold, these heaters have a low element resistance which cause a high current during initial heat up. The current decreases as the heater element temperature increases and the resistance increases. This type of heater may require the power controller to limit the current to the elements until the heater is up to operating temperature.

Elements with high hot to cold ratios can exhibit this behavior, some examples are:

- Molybdenum
- Tungsten
- Graphite
- Quartz (Tungsten)
- Infrared (Tungsten)
- Silicon Carbide (higher resistance when cold)

Heater loads coupled to transformers offer a similar problem. The high inductance of the transformer causes high inrush currents. This inrush current is higher than the expected current draw from the heater element alone. An over-sized or phase-angle SCR with current limiting protection may be required.

3.3 Control Wiring

The thermocouple input and optional interlock relay are the only required control wiring necessary to operate the temperature control panel. All other control wiring connections are optional and are included to remotely interface the temperature control panel with an external control system. These options can be used to monitor the process temperature, the user specified alarm state, and to externally control the panel interlock. In addition, the process controller can be monitored and controlled through a RS-485 communication interface.

Refer to the wiring schematics, in the notes, for details on Class 1 or Class 2 wiring. Class 2 wiring is for power limited, low voltage control circuits.

Terminate the control wiring to the numbered terminals according to the included wiring schematic diagram. The minimum wire temperature rating and terminal tightening torque for the control terminal blocks can be found in the notes of the electrical schematics.

Thermocouple Input

A control thermocouple is not included with the temperature control panel because of the almost unlimited options of sizes and styles available. The user should select the thermocouple based on position in the process, durability, response time, ease of replacement, and other engineering factors.

Be aware that the physical dimensions of the thermocouple and installation position in the process will affect process control.

Thermocouples are available in different calibrations or 'Types'. The standard for ISPA and IFPA temperature control panels is a Type-K input, due to its wide temperature range and high accuracy. In addition, type-J thermocouple input is available as an option. Consult the factory for other thermocouple types, RTD, or analog input options.

Thermocouple Wiring

The user supplied thermocouple, thermocouple wire, and any thermocouple connectors should be of the same 'type' as the temperature control panel. Failure to use compatible thermocouple 'type' equipment will cause measurement errors and could damage heaters and equipment.

Thermocouples, thermocouple wire, and thermocouple connectors have polarity, meaning they have a '+' and '-' wire/terminals that must be connected to terminals of the same polarity. In addition, differing metal types, including solder and non-thermocouple connectors should not be used in thermocouple wire junctions, as it will affect the temperature measurement.

Thermocouple Terminal Block

IFPA and ISPA Models

A thermocouple terminal block is mounted inside the enclosure with the control wiring. Terminate the thermocouples wires directly to the terminal block (terminals 97 and 98). Type-K thermocouples use yellow for '+' and red for '-'. Type-J thermocouples use white for '+' and red for '-'.

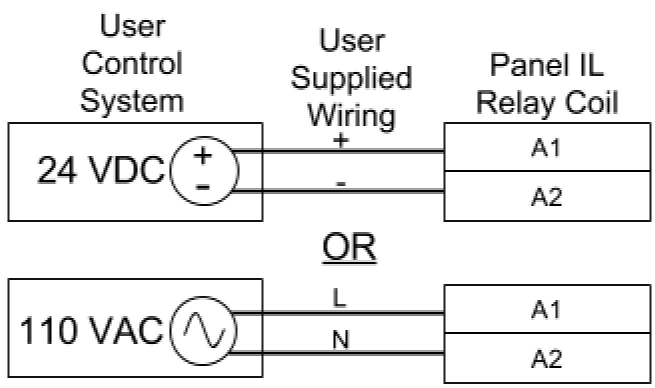
Thermocouple Jack Panel
ISPA Model (Optional)
Plug the thermocouple connector plug into the jack panel receptacle.

If other sensor options were ordered, refer to the included wiring diagram for details.

Interlock Relay (Factory Option)
The interlock relay option allows the heater load to be placed in an un-powered, safe state by an external switch, PLC, or DCS system. The interlock relay coil must be in a powered state to enable the controller. When the interlock is disabled, the controller behaves as if the front door SAFE/RUN switch is in the SAFE position. The heater load will be disconnected through the contactor disconnect, and the controller run state will be put in the STOP mode.

Refer to the supplied wiring schematics for wiring connections to the optional interlock relay. The coil side of the relay is to be field wired by the customer with either a 24 VDC or 120 VAC signal, depending on the option ordered. Confirm the correct control voltage before supplying power to the relay coil.

Figure 3.3.1 Temperature Control Panel External Interlock Schematic



Process Value (PV) Retransmit
The 4-20mA PV retransmit output can be read by a PLC or DCS system and scaled to a temperature value for data recording, alarming, or other external control functionality.

This feature scales the 4-20mA sourcing, 10 bit, analog output linearly, in proportion to the temperature PV. Note that the output may require calibration, either through parameters ‘RtMI’ and ‘RtMA’ in the Regulation Mode menus (Section 5.2) or through software scaling on the field wired 4-20mA input.

For scaling, 4mA is equal to parameter ‘tP-L’, the low temperature limit in the Initial Setting menu. 20mA is equal to parameter ‘tP-H’, the high temperature limit in the initial setting mode. See the sensor input types table, Table 5.4.1, for default input type high and low ranges. The default scaling for a type K thermocouple is 4ma = -200 degrees C and 20mA = 1300 degrees C.

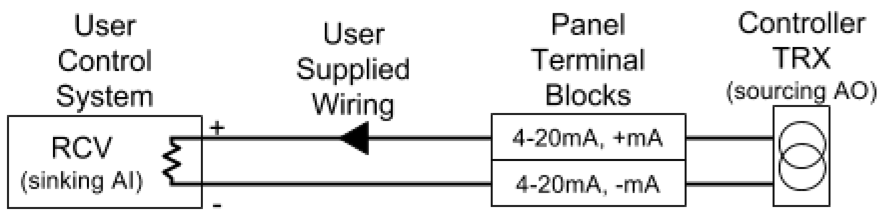
3.3 Control Wiring (continued)

If more signal resolution is required, decrease parameter ‘tP-H’ and increase ‘tP-L’ closer to the operating temperature range. The smaller range covered will result in tighter resolution of the scaled PV value.

When a thermocouple is open or unplugged, the output will read 20mA, indicating an error condition.

Refer to the supplied wiring schematics for wiring connections to the PV retransmit terminals. Terminal block 93 is +mA and 94 is -mA.

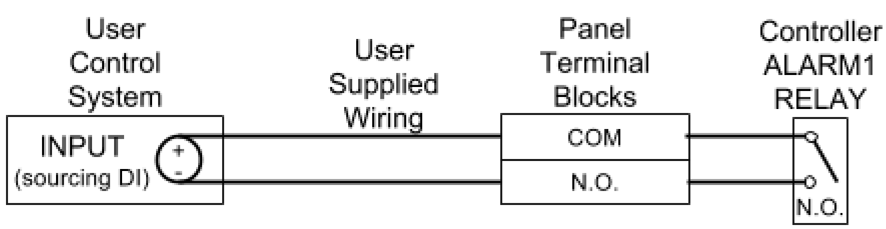
Figure 3.3.2 Temperature Control Panel Temperature Re-Transmit Schematic



Programmable Alarm Contacts (Alarm 1)
Refer to the Initial Setting Mode menu (Section 5.3) to edit the alarm 1 limits and the alarm mode parameter, ‘ALA1’. The user programmable alarm can run in one of several modes, as found in Table 5.4.6. It is not recommended to change the mode of Alarm 2, ‘ALA2’ as it functions as the over-temperature alarm and controls the power contactor.

Refer to the supplied wiring schematics for wiring connections to the programmable alarm contacts.

Figure 3.3.3 Temperature Control Panel Programmable Alarm Contacts Schematic



RS-485 / Modbus Communications
RS-485 communication is a daisy-chain or point-to-point wiring configuration, multi-node addressable communication protocol. The controller runs in a 2-wire configuration without echo, in either ASCII or RTU modes.

RS-485 nodes are to be arranged in a point-to-point topology. A 120 ohm termination resistor is required on the beginning of the chain - at the RS-485 card or converter and at the last node in the RS-485 chain.

Refer to the Initial Setting Menu (Section 5.3) for programming the communication parameters.

To perform write commands, first verify that the ‘CoSH’ parameter is set to ON. This allows configuration and writes over the modbus communication port. If this is OFF, the controller will not accept any writes over the RS-485 communication port.

Note that not all parameters allow writes, regardless of the state of ‘CoSH’, for example the PV can not be written to.

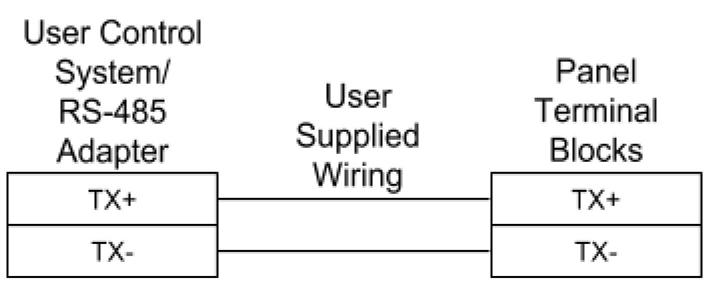
A maximum of 8 registers can be read or written at a time, some modbus servers may try to read or write more, resulting in not all registers being read or written. If this is the case, limit the maximum registers to 8 at a time.

Each register holds an unsigned integer value, 16 bits of data. For example, if the PV is 261.4, it would be returned as 2614; because it is returned as an integer, the decimal must be inserted to create the real value.

See Appendix F for information on RS-485 communication protocols and registers.

Refer to the supplied wiring schematics for wiring connections to the RS-485 communication port.

Figure 3.3.4 Temperature Control Panel RS-485 Modbus Interface Schematic



3.3 Control Wiring (continued)

End of Section 3.

SECTION 4:

SYSTEM OVERVIEW & COMMISSIONING

Section 4: System Overview and Commissioning

Before powering and commissioning the system, ensure the enclosure is properly mounted and wired. Refer to the sections above for instructions.

It is important to understand the components, controls and functions before powering up the control panel and supplying the heater with power.

4.1 Control Panel Overview and System Description

This section defines important terms and highlights key components of the control panel. The temperature control panel consists of several components that users interface with. Refer to *Figure 1.4.1* for an overview diagram of the control panel and component locations.

Disconnect Switch (IFPA Models)
The disconnecting means allows power to be physically disconnected from the heater and the fuse holders so that the heater or fuses may be changed or serviced. The disconnect switch must be in the ‘OFF’ position before the door can be opened. Additionally, the disconnect contains the branch circuit fuses.

Control Switch (SAFE/RUN Switch)
The control switch has two positions, RUN and SAFE. The control switch function is to set the controller mode and to energize or de-energize the power disconnect contactor.

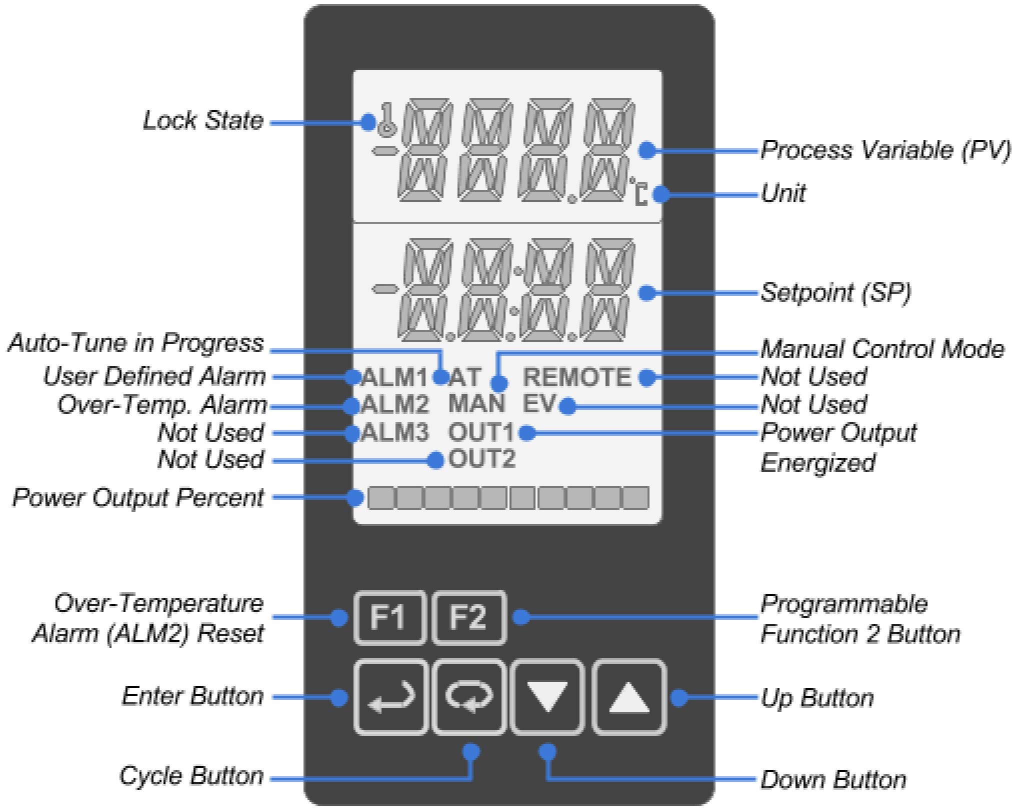
> *Run*
> When the switch is in the run position, the controller software is placed in a run mode, where its output is allowed to control the power controller. Run also closes the main power contactor, providing an electrical connection with the heater.
>
> *Safe*
> When the switch is in the safe position, the controller software is placed in a stop mode, where its output is forced to 0% output (off), regardless of the setpoint. Safe also opens the main power contactor, so that power can not be applied to the heater.

Power Contactor
The power contactor is located inside the control panel and acts as a heater power shutoff switch. If the high temperature alarm is exceeded or the SAFE/RUN Switch is in the SAFE mode, the contactor will be in an open position. This feature prevents the heater from being powered, regardless of the controller output or state.

Temperature Controller
The temperature controller is the user interface to the temperature control panel. When programmed and running, its main function is to control the power controller’s output to control the process temperature.

4.1 Control Panel Overview and System Description (continued)

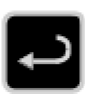
Figure 4.1.1 is the PID temperature controller, mounted in the front door of the enclosure.



F1 F1 - programmable button, the default action is to reset a latched over-temperature alarm

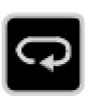
F2 F2 - programmable button, the default action is to return to main operation screen

Refer to the function key table, Table 5.4.2, for information on programming the function buttons.



Enter - multiple functions:

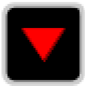
1. Press to confirm a changed value
2. Press for less than 3 seconds to enter the Regulation Mode menu (Level 2)
3. Press for more than 3 seconds to enter the Initial Setting Mode menu (Level 3)
4. Press to return to the Operation Level and the Main Display

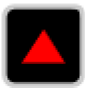


Cycle - multiple functions:

1. Press to enter the Operation Mode menu (Level 1)
2. Press to cycle between parameters within a menu
3. When editing a numeric value, press to change which digit to edit

4.1 Control Panel Overview and System Description (continued)

 Down - used to change numeric values or to cycle down between settings

 Up - used to change numeric values or to cycle up between settings

When changing settings with the arrow buttons, the value will flash, indicating a change. Press the Enter button to confirm the change and save the new setting.

Press the Enter button to exit a menu structure and return to the main operating display.

4.2 Controller Terminology and Functions

Process Value (PV)
The process value is the temperature measured at the thermocouple junction. The PV is displayed on the top row of the temperature controller's display. The temperature units are either degrees Celsius (°C) or Fahrenheit (°F), as indicated to the right of the process value.

Setpoint Value (SP)
The setpoint is the operator set, desired process temperature. The setpoint is indicated on the bottom row of the controller's display. To change the setpoint, press the Up or Down arrow until the desired setpoint temperature is displayed and then press the Enter button to confirm the setpoint. The Cycle button is used to change which digit is being edited.

Control Mode
The controller mode is set to PID from the factory. See the Initial Setting Mode tables in Section 5.3 for more information on available control modes. The PID control mode (commonly referred to as automatic mode) will calculate and control the output, from 0-100%, as required to reach the process setpoint. Manual mode is also available, where a constant percent output can be set by the operator.

Controller Output (0-100% Power)
The controller output is indicated by the 10 segment bar graph on the very bottom of the display. 0% (no bars) indicates the heater is off and 100% (10 bars) indicates full power. The output is calculated by the controller when in PID mode or constant when in manual mode.

Programmable Alarm (Alarm 1)

The user programmable alarm is programmed from the factory as a high temperature alarm and set at the high range temperature of the thermocouple input. See Section 5.3, parameter 'ALA1' in the Initial Settings Mode menu, for details on changing the Programmable Alarm mode. The alarm limit values can be changed from the Operation Mode menu, see Section 5.1 for details.

Refer to Table 5.4.3 for information on the programmable alarm contact options. Parameter 'AL1o' allows the contacts to be switched to N.C. from N.O, among other options.

See the wiring schematics for details on wiring the alarm contacts. The programmable alarm allows the control panel to alarm or control external devices through a dry contact. Alarm 1 does not affect the operation of the control panel. Below are a few examples of the uses for the Alarm 1 Programmable contact:

- Contacts close on high temperature which sounds an external alarm for the operator.
- Contacts open on high temperature which is read by a PLC or DCS system that there has been an over-temperature condition.
- Contacts close when within desired temperature range which lights a beacon for the operator to inform them that the heater is at the correct temperature.
- Contacts close when within desired temperature range as an input to a PLC or DCS which advances a sequence in a production plant.

Note: The alarm relay is designed for use with resistive devices. Install a snubber device for any inductive loads.

Over-Temperature Disconnect Alarm (Alarm 2)

The over-temperature alarm value is set from the factory as the high range temperature of the thermocouple input. The high limit value can be changed from parameter 'AL2H' (1-08) in the Operation Mode menu. See Section 5.1 for details on accessing and changing the 'AL2H' parameter.

The over-temperature alarm behaves the same functionally as the SAFE/RUN Switch. When the over-temperature alarm value is exceeded, the controller is set to the STOP mode setting the controller's output off and the main power contactor is opened, electrically disconnecting the heater load.

The factory default mode for the over-temperature alarm is latching, meaning the operator must press the 'F1' key on the front of the controller to acknowledge and reset the alarm and re-enable the controller to RUN mode . Until the alarm is reset, the controller will remain in the STOP mode and the power contactor will remain open.

The over-temperature alarm should not be used to regulate the process temperature. It is a fail-safe to prevent damage to the process heater and installed equipment. The over temperature alarm value should be set to a temperature above the setpoint and would not be experienced during normal operations. Continually cycling above the over-temperature alarm value will cause premature wear to the over-temperature contactor.

4.2 Controller Terminology and Functions (continued)

External Interlock Relay (Optional)
The external interlock relay option allows the heater load to be placed in an un-powered safe state with an external switch, PLC, or DCS system. The interlock relay coil must be in a powered state to enable the temperature control panel. When the interlock relay is disabled (de-energized), the temperature control panel behaves as if the SAFE/RUN Switch is in the SAFE position. The heater load will be disconnected through the contactor disconnect and the controller will be in a STOP mode.

Refer to the supplied wiring schematics for wiring connections to the optional interlock relay. The coil side of the relay is to be field wired with either a 24VDC or 120VAC customer supplied signal. Confirm the correct control voltage is connected before supplying power to the relay coil.

4.3 Commissioning - Powering the Temperature Control Panel

The following section outlines applying power to the control panel. Read and understand all the steps below before starting the commissioning process and energizing the temperature control panel. Refer to the included wiring schematics to determine the correct terminal blocks for customer supplied line, load and control wiring.

Powering the Temperature Control Panel

1. Ensure the electrical circuit supplying power to the panel is de-energized. If the control panel has an optional cord and plug, verify the plug is unplugged.
    a. Follow all Lock-Out/Tag-Out (LOTO) policies and practices
2. Verify the front disconnect switch (IFPA Models) is in the OFF (horizontal) position.
3. Verify the SAFE/RUN Switch is in the SAFE position.
4. Verify all fuses are installed and fuse holders are closed.
5. Terminate supplying power wires (Line Feed) directly to the Line terminal blocks (Section 3.1). If the control panel has an optional cord and plug, skip this step.
6. Terminate the heater power wires (Load Side) to the terminal blocks (Section 3.2).
7. Terminate the thermocouple input wires to the thermocouple terminal blocks (Section 3.3).
    a. Ensure to terminate the thermocouple wires to the terminal block with the correct polarity. Reversing the polarity will cause false temperature readings and possible damage to the process heater.
    b. If the panel has an optional thermocouple jack, plug the thermocouple into the jack.
8. Terminate user controlled 24VDC or 120VAC to the optional External Interlock Relay.
    a. If the External Interlock option is installed, the user must wire and energize the External Interlock Relay for the panel to operate.
9. Terminate the Programmable Alarm1 contact terminals to the user controls (optional)
10. Terminate the temperature Re-Transmit contact terminals to the user controls (optional)
11. Close the enclosure door and secure the latches.
12. Energize the electrical circuit supplying power to the panel. If the panel has a cord and plug, plug it into an outlet.
13. Switch the front disconnect switch (IFPA Models) to the ON (vertical) position.
14. Verify the temperature process value (PV) is reading an expected value for the location of the thermocouple and the current process temperature.
    a. The controller will display “No CoNt” if a thermocouple in not wired, if there is a break in the wiring or connector, or the wires are not properly terminated at the terminal blocks. When corrected, press the “F1” key to reset the latched over temperature alarm (ALM2).

The controller should be powered and displaying the process temperature. Refer to Appendix E, for troubleshooting information if necessary.

4.4 Commissioning - Powering the Process Heater

The following section outlines commissioning the process heater. Read and understand all of the steps below, before continuing the commissioning process and applying power to a process heater. It is strongly recommended to read the remainder of the manual to become familiar with the control panel before continuing.

The temperature control panel should be powered and displaying the process temperature after following the previous commissioning steps, from Section 4.3.

Powering the Process Heater

1. Verify the front panel SAFE/RUN Switch is in the SAFE position.
2. If the control panel was ordered with the External Interlock Relay option, verify the Interlock Relay coil is energized with the correct voltage. A yellow LED light on the relay will be lit to indicate the coil is energized.
3. Verify the controller is displaying the expected process temperature
4. Verify the process temperature (PV) is less than the Alarm 2 (over-temperature alarm) value. The over-temperature alarm value is set from the factory as the high range temperature of the thermocouple input. The high limit value can be changed from parameter ‘AL2H’ in the Operation Mode menu. The PV value will change from an orange font to red and display an ‘ALM2’ status light, if the process temperature is above the ‘AL2H’ limit value.
5. If the over-temperature alarm (Alarm 2) is tripped, the F1 key must be pressed to reset the alarm and re-enable the controller.
6. Verify that the setpoint (SP) is set to a value less than the current process temperature (PV).
7. Turn the SAFE/RUN Switch to the RUN position. An audible “thunk” will be heard when the contactor disconnect is closed.
8. When the SAFE/RUN Switch is switched the RUN position, the controller will change from the STOP mode to the RUN mode, which will allow the controller output to power the process heater.
9. Change the Setpoint Value (SP) to a value above the current temperature Process Value (PV). Choose a value that will not cause process upsets or safety consequences if there is an overshoot or instability of the process temperature. Use the Up and Down arrow buttons to change the temperature and the Enter button to confirm the change.
10. The controller output will increase and send power to the process heater. The controller output will be indicated by the Output bar graph and a flashing ‘OUT1’ on the bottom of the display. The temperature of the process heater and the temperature process value (PV) should increase in response to the controller output.
    a. If the process temperature does not increase, verify all connections and settings and then refer to Appendix E, the Troubleshooting section.

Continue to Section 5 for controller configuration menus and more advanced features and topics. Section 5 includes setting the over-temperature alarm and tuning the controller.

SECTION 5:
CONTROLLER CONFIGURATION & PROGRAMMING

Section 5: Controller Configuration and Programming

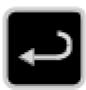
Controller configuration parameters are organized into three levels of programming menus:

1. *Operation Mode (Level 1)* - common operating and alarm parameters
2. *Regulation Mode (Level 2)* - PID tuning, input filters and analog output compensation
3. *Initial Setting Mode (Level 3)* - sensor input type, units, range, control modes, ramp/soak programming, alarm modes, RS-485 settings

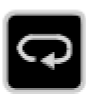
Menu navigation is explained below, followed by tables of each programming level, each outlining the parameters and their function.

Press the Enter button to exit a menu structure and return to the main operating display.

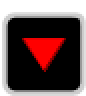
Menu Navigation

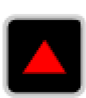

Enter - multiple functions:

1. Press to confirm a changed value
2. Press for less than 3 seconds to enter the Regulation Mode menu (Level 2), from the Main Display
3. Press for more than 3 seconds to enter the Initial Setting Mode menu (Level 3), from the Main Display
4. Press to return to the Operation Level and the Main Display


Cycle - multiple functions:

1. Press to enter the Operation mode menu (Level 1), from the Main Display
2. Press to cycle between parameters within a menu
3. When editing a numeric value, press to change which digit to edit, when changing a numeric value


Down - used to change numeric values or to cycle down between settings


Up - used to change numeric values or to cycle up between settings

5.1 Operation Mode Menu (Level 1)

Scroll through Operation Mode parameters by pressing the cycle button.
Press the Enter button to exit a menu structure and return to the main operating display.

Table 5.1.1 Basic Operation Mode Parameters

<table>
<tr><td colspan="5">Operation Mode Parameters - Cycle button to scroll between parameters
Note: Not all parameters are always accessible. For example, if alarm 3 mode is not configured, its high and low alarm values will not be available to edit.</td></tr>
<tr><th>Parameter Name (Parameter Number)</th><th>Display Symbol</th><th>Description</th><th>Factory Default Value</th><th>Customer Value</th></tr>
<tr><td>Operation Mode, Main Display</td><td>1234</td><td>Process Value (PV) - Measured process temperature (upper line)
Setpoint (SP) - Target process temperature (lower line)</td><td>N/A</td><td></td></tr>
<tr><td>R-S (1-01)</td><td>R-S</td><td>Controller RUN or STOP mode. When ‘CtRS’ is in program mode, allows control of the program function - Run, Stop, Hold, End</td><td>Mode set by SAFE/RUN Switch</td><td></td></tr>
<tr><td>PtRN (1-02)
Accessible when ‘CtRS’ is in the ‘PRoG’ mode</td><td>PtRN</td><td>Start pattern number, see Appendix D for details on ramp/soak programming.</td><td></td><td></td></tr>
<tr><td>StEP (1-03)
Accessible when ‘CtRS’ is in the ‘PRoG’ mode</td><td>StEP</td><td>Start step, within the selected pattern.</td><td></td><td></td></tr>
<tr><td>SP (1-04)</td><td>SP</td><td>Number of decimal places. Change to 0 to display temperatures over 999.9</td><td>1</td><td></td></tr>
<tr><td rowspan="3">LoC (1-05)</td><td>LoC</td><td><u>Lock the Keypad</u>:
LoC1= lock out keypad
LoC2 = lock out menu access, can still change setpoint.</td><td>Off (Unlocked);

Default unlock passcode: 0000</td><td></td></tr>
<tr><td colspan="4">To unlock the keypad:
1. Press the Enter and Down buttons at the same time
2. When ‘KEYP’ is displayed, press the up or down buttons to enter the passcode (default: 0000)</td></tr>
<tr><td colspan="4">To change the passcode:
1. Put the controller in the lock mode
2. Press the Enter and Down buttons at the same time
3. When ‘KEYP’ is displayed, press the Cycle button to display ‘ch6p’
4. Enter the current passcode
5. Enter a new passcode twice to confirm the code.</td></tr>
</table>

Table 5.1.2 Alarm Operation Mode Parameters (Continued)

Alarm Configuration:
Alarm 1 - User Programmable Alarm
Alarm 2 - Over Temperature Limit, Latching - reset with ‘F1’ key
Alarm 3 - Not configured
Note: Alarm modes, ‘ALAn’ are configured in the Initial Setting mode (Level 3)

Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
AL1H (1-06) Accessible when ‘ALA1’ is in alarm mode 1,2,4,5,7,8	AL 1H	Alarm 1 (user programmable alarm) high temperature value	High range of thermocouple input: 1300 deg C, type K 1200 deg C, type J 2372 deg F, type K 2192 deg F, type J	
AL1L (1-07) Accessible when ‘ALA1’ is in alarm mode 1,3,4,6,7,8	AL 1L	Alarm 1 (user programmable alarm) low temperature value	Not accessible - alarm 1 in mode 5, high temperature alarm	
AL2H (1-08) Accessible when ‘ALA2’ in alarm mode 1,2,4,5,7,8	AL2H	Alarm 2 (over temperature alarm) high temperature value	High range of thermocouple input: 1300 deg C, type K 1200 deg C, type J 2372 deg F, type K 2192 deg F, type J	
AL2L (1-09) Accessible when ‘ALA2’ is in alarm mode 1,3,4,6,7,8	AL2L	Alarm 2 (over temperature alarm) low temperature value	Not accessible - alarm 2 in mode 5, high temperature alarm	
AL3H (1-10) Accessible when ‘ALA3’ is in alarm mode 1,2,4,5,7,8	AL3H	Alarm 3 (not used) high temperature value	Not accessible	
AL3L (1-11) Accessible when ‘ALA3’ is in alarm mode 1,3,4,6,7,8	AL3L	Alarm 3 (not used) low temperature value	Not accessible	

The alarm peak detection function must be enabled for the following alarm peak value parameters to be accessible. Refer to the Alarm options programming table, Table 5.4.3 for details.

Table 5.1.2 Alarm Operation Mode Parameters (Continued)

Output 1 Configuration				
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
oUt1 (1-12)		Output 1 value, 0-100%. Read only in PID mode, read/write in MAN mode	N/A	
o1MA (1-13)		Upper output 1 limit, 0-100% output. Use to restrict maximum output power	100%	
o1MI (1-14)		Lower output 1 limit, 0-100% output	0%	

5.2 Regulation Mode Menu (Level 2)

Press the Enter button for less than 3 seconds, to enter the regulation mode menu.
Scroll through Regulation Mode parameters by pressing the Cycle button.
Press the Enter button to exit a menu structure and return to the main operating display.

Table 5.2.1 Regulation Mode Parameters (Tuning)

<table>
<tr><td colspan="5">Regulation Mode Parameters - cycle button to scroll between parameters
Note: Not all parameters are always accessible.</td></tr>
<tr><td colspan="5">PID Tuning
See Appendix B for more information on PID algorithms and their tuning parameters
See Appendix C for more information on auto-tuning</td></tr>
<tr><td>Parameter Name
(Parameter Number)</td><td>Display Symbol</td><td>Description</td><td>Factory Default Value</td><td>Customer Value</td></tr>
<tr><td colspan="5">The following tuning parameters are only accessible when the ‘CtRL’ parameter (3-05) is set to ‘PID’ (default value) or ‘FUZZ’</td></tr>
<tr><td>At (2-01)
Accessible when:
1. ‘tUNE’ parameter set to At (default)
2.‘R-S’ in RUN mode (front control switch in Run)</td><td>At</td><td>Auto-tune mode on or off. On enables the auto-tune sequence, to calculate tuning parameters. Initiates cycles of 100% and 0% output.</td><td>Off</td><td></td></tr>
<tr><td>St (2-02)
Accessible when:
1. ‘tUNE’ parameter set to St (Initial Setting menu)
2.‘R-S’ in RUN mode (front control switch in Run)</td><td>St</td><td>Self-tuning mode on or off. On enables self-tune mode, where controller recalculates tuning parameters when setpoint change causes the output to go to 100% output.</td><td>Off</td><td></td></tr>
<tr><td>PID (2-03)</td><td>PId</td><td>Selected PID tuning group; 0-5 or Auto. In Auto, the controller selects the group (0-5) with the closest setpoint, and uses its tuning parameters.</td><td>0
Note: the parameters for group n can be edited and tuned, regardless of setpoint used, when PID is not set to ‘Auto’.</td><td></td></tr>
</table>

Table 5.2.1 Regulation Mode Parameters (Tuning - Continued)

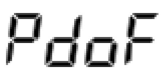
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
SVn (2-05) Where n (0-5) is the number of the selected PID tuning group, from the ‘PID’ parameter		The corresponding setpoint temperature of the selected PID tuning group, 0-5. Used when ‘PID’ is set to ‘Auto’	SV0 = 100.0 SV1 = 200.0 SV2 = 300.0 SV3 = 400.0 SV4 = 500.0 SV5 = 600.0	
Pn (2-06) Where n (0-5) is the number of the selected PID tuning group, from the ‘PID’ parameter		The corresponding proportional value of the selected PID tuning group, 0-5.	P0 = 47.6 P1 = 19.9 P2 = 42.9 P3 = 47.6 P4 = 47.6 P5 = 47.6	
In (2-07) Where n (0-5) is the number of the selected PID tuning group, from the ‘PID’ parameter		The corresponding integral value of the selected PID tuning group, 0-5.	I0 = 260 seconds I1 = 186 I2 = 58 I3 = 260 I4 = 260 I5 = 260	
dn (2-08) Where n (0-5) is the number of the selected PID tuning group, from the ‘PID’ parameter		The corresponding derivative value of the selected PID tuning group, 0-5.	D0 = 41 seconds D1 = 46 D2 = 14 D3 = 41 D4 = 41 D5 = 41	
Iofn (2-09) Where n (0-5) is the number of the selected PID tuning group, from the ‘PID’ parameter		Integral offset of the PID algorithm. Creates an integral offset in PID mode that creates an offset of the controller’s output at startup.	IoF0 = 0.0 IoF1 = 0.0 IoF2 = 0.0 IoF3 = 0.0 IoF4 = 0.0 IoF5 = 0.0	
PdoF (2-10) Accessible when the integral parameter, In, is set to 0.		P or PD control offset, defines the control output offset when the integral parameter is set to 0.	0	

Table 5.2.1 Regulation Mode Parameters (Tuning - Continued)

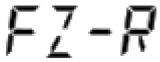
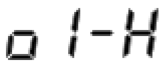
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
The following tuning parameters are only accessible when the 'CtRL' parameter (3-05) is set to 'FUZZ'				
FZ-R (2-11) Accessible when 'CtRL' is in 'Fuzz' mode		Fuzzy logic gain. Increase for more aggressive fuzzy control.	4	
FZdb (2-12) Accessible when 'CtRL' is in 'Fuzz' mode		Fuzzy logic control deadband. Fuzzy logic is used if PV = SP +/- FZdb. Fuzzy logic is used near the setpoint, PID control is used outside this deadband range.	0.0	
The following is only applicable to ISPA models, with a solid-state relay power controller.				
o1-H (2-13) Accessible for Voltage Pulse Output Models Only (solid-state relays)		Control cycle time for output 1. The time to complete a complete cycle of an on and off duration of the output	1.0 seconds	

Table 5.2.2 Regulation Mode Parameters (Continued - Filtering and Linear Compensation)

Digital Filter and Linear Compensation Settings				
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
PV-F (2-14)	PV -F	PV filter factor. PV = (last PV*n+PV) / (n+1), where n = 0-50. Input signal smoothing increases with larger n values.	1	
PV-R (2-15)	PV -R	PV filter range, range of 0.1 - 10.0 degrees. Range of filtering, from last temperature. Use a larger value for noisier signals.	1.00	
PVoF (2-16)	PVoF	Linear PV offset, range of -99.9 - 99.9. PV = PV + PVof. Acts as a zero calibration factor.	0.0	
PVGA (2-17)	PVGA	Linear PV compensation gain, range of 0-0.999. PV = PV*(1+PVGa/1). Acts as a span calibration factor.	1	
SVSL (2-18) Accessible when Initial Setting Menu parameter ‘CtRS’(3-06)=’SLoP’	SVSL	Rising setpoint slope, when in slope control. Defines the ramp rate to reach the setpoint.	1.0 deg C / min	

Table 5.2.3 Regulation Mode Parameters (Continued - Analog Input and Output)

Analog Input and Output Configuration				
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
A1MA (2-19) Accessible for milliamp output models only (IFPA)	A 1MA	Adjusts the upper limit compensation (span) for analog output 1, 1 unit = 2 microamps.		
A1MI (2-20) Accessible for milliamp output models only (IFPA)	A 1MI	Adjusts the lower limit compensation (zero) for analog output 1, 1 unit = 2 microamps.		
RtMA (2-21)	RtMA	Adjusts the upper limit compensation (span) for the PV retransmission analog output, 1 unit = 2 microamps.	0	
RtMI (2-22)	RtMI	Adjusts the lower limit compensation (zero) for the PV retransmission analog output, 1 unit = 2 microamps.		
EVt1 (2-23)	EVt 1	Sets the event 1 input function: 'R-S' - Run/Stop mode 'SV2' - swap setpoints 'MANU' - manual control mode 'P-Hd' - program hold mode 'oFF' - no function	'R-S' The event input is wired to the SAFE/RUN Switch to place the controller in RUN and STOP modes.	

5.3 Initial Setting Mode Menu (Level 3)

Press the Enter button for more than 3 seconds, to enter the initial setting mode menu.
Scroll through initial setting mode parameters by pressing the Cycle button.
Press the Enter button to exit a menu structure and return to the main operating display.

Table 5.3.1 Initial Setting Mode Parameters (Sensor Input and Control Modes)

Initial Setting Mode Parameters - Cycle button to scroll between parameters Note: Not all parameters are always accessible.				
Sensor Input Configuration				
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
INPt (3-01)	INPt	Sensor input type. K type thermocouple, -200 C - 1300 C, J type thermocouple -100 C - 1200 C. See the sensor input types table, Table 5.4.1, below for full list of options.	K (J thermocouple wiring optional)	
tPUN (3-02)	tPUN	Temperature units for the PV measurement, C or F.	C	
tP-H (3-03)	tP-H	Input sensor upper limit and the upper limit of the PV retransmit analog output.	1300 deg C, type K 1200 deg C, type J 2372 deg F, type K 2192 deg F, type J	
tP-L (3-04)	tP-L	Input sensor lower limit and the lower limit of the PV retransmit analog output.	-200 deg C, type K -100 deg C, type J -328 deg F, type K -148 deg F, type J	
Control Modes				
CtRL (3-05)	CtRL	Controller mode: 'PID' - PID algorithm 'oNoF' - on/off control (N/A) 'MANU' - manual output control 'FUZZ' - Fuzzy logic '2PID' - 2 output PID control (N/A)	PID	
CtRS (3-06)	CtRS	Setpoint Control mode: 'CoNS' - Constant setpoint 'PRoG' - Ramp/Soak programming - see Appendix D 'SLoP' - Setpoint slope control ('SVSL' parameter (2-18) in Regulation Mode menu defines rising slope rate)	CoNS	

Table 5.3.2 Initial Setting Mode Parameters (Continued - Ramp/Soak and Slope)

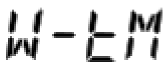
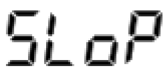
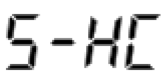
Note: The following parameters are only available when ‘CtRS’ (3-06) is set to ‘PRoG’, the programming mode. Refer to Appendix D for details on programming temperature profiles				
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
WtSV (3-07) Accessible when ‘CtRS’ is in programming mode ‘PRoG’.		Waiting temperature setpoint value deadband. Allows step to continue if PV = SP +/- ‘WtSV’	0.0	
W-tM (3-08) Accessible when ‘CtRS’ is in programming mode ‘PRoG’.		Step waiting time. Allow step time + ‘W-tM' for PV to reach SP +/- ‘WtSV’	0	
SLoP (3-09) Accessible when ‘CtRS’ is in programming mode ‘PRoG’.		Set starting slope, in programming mode, ‘PRoG’	1.0 degC / minute	
PAtN (3-10) Accessible when ‘CtRS’ is in programming mode ‘PRoG’.		Select the pattern to be edited: off, save (select when changes have been made), 0-9 and A-F. See Appendix D for programming instructions.	oFF	
Note: when the ‘PAtN’ parameter above, is changed from ‘off’ to a pattern number, additional programming parameters become accessible. Refer to appendix D for instructions on profile programming.				
tUNE (3-11)		Select either ‘At’ for Autotune mode or ‘St’ for self-tuning mode. Initiate tune from regulation mode parameters.	At	
S-HC (3-12)		Select output control mode, heating or cooling.	H1A2 Output 1 is the heater control, output 2 is an alarm	

Table 5.3.3 Initial Setting Mode Parameters (Continued - Alarming)

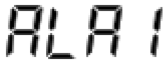
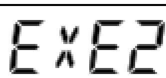
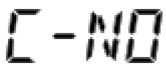
Alarm Programming				
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
ALA1 (3-13)		Set alarm 1 limit mode (programmable alarm), refer to the alarm modes table, Table 5.4.6, for details.	5 Enable alarm when temperature exceeds AL1H.	
AL1o (3-14)		Set alarm 1 options, see the alarm options programming table, Table 5.4.3, for details.	0000 No alarm functions enabled	
AL1d (3-15)		Set alarm 1 delay, in seconds.	0 seconds 0 Represents immediate alarm change when alarm is tripped	
ALA2 (3-16)		Set alarm 2 limit mode (over-temperature alarm). It is not recommended to change this value.	5 Enable alarm when temperature exceeds AL2H.	
AL2o (3-17)		Set alarm 2 options, see the alarm options programming table, Table 5.4.3, for details.	0100 Alarm 2 (over-temperature) is latching. Press F1 button to reset, once latched	
AL2d (3-18)		Set alarm 2 delay, in seconds.	0	
ALA3 (3-19)		Set alarm 3 (disabled) mode.	0	
PVC (3-20)		PV color change on alarm, select which alarm changes display color of the PV indicator	ALL	
EXEC (3-21)		Misc. Programming options. See Table 5.4.4 for details.	0000	
EXE2 (3-22)		Misc. Programming options. See Table 5.4.5 for details.	0000	

Table 5.3.4 Initial Setting Mode Parameters (Continued - RS-485)

RS-485 Communication				
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
CoSH (3-23)		Enable / disable RS-485 to write to registers and change parameter values. Must be turned on for remote writes.	oFF	
C-SL (3-24)		Select either ASCII or Modbus RTU for RS-485 communication.	RtU	
C-No (3-25)		RS-485 Communication address/node (1-247).	1	
bPS (3-26)		Baud rate selection.	96 (9600 bps)	
LEN (3-27)		Data length.	8	
StoP (3-28)		Stop bits	1	
PRtY (3-29)		Parity bit	EVEN	

5.4 Initial Setting Mode - Parameter Tables

The Initial Setting Mode menu, presented in Section 5.3, outlines the parameters within the menu structure. The following tables cover advanced features and settings available within individual parameters from Section 5.3.

Each table presents a detailed explanation of the settings available within specific Initial Setting Mode parameters.

Table 5.4.1 Sensor Input Types Table

Sensor Input Types, set by 'INPt' (3-01) parameter in Initial Setting Mode Menu			
Parameter Value	Display Symbol	Sensor Type	Temperature Range
Thermocouple			
K	K	K type Thermocouple	-200 - 1300 deg C
J	J	J type Thermocouple	-100 - 1200 deg C
t	t	T type Thermocouple	-200 - 400 deg C
E	E	E type Thermocouple	0 - 600 deg C
N	N	N type Thermocouple	-200 - 1300 deg C
R	R	R type Thermocouple	0 - 1700 deg C
S	S	S type Thermocouple	0 - 1700 deg C
b	b	B type Thermocouple	100 - 1800 deg C
L	L	L type Thermocouple	-200 - 850 deg C
U	U	U type Thermocouple	-200 - 850 deg C
tXK	tXK	TXK type Thermocouple	-200 - 800 deg C

Table 5.4.1 Sensor Input Types Table (Continued)

Sensor Input Types, set by 'INPt' (3-01) parameter in Initial Setting Mode Menu			
RTD			
Parameter Value	Display Symbol	Sensor Type	Temperature Range
JPt		Platinum RTD (JPt100)	-20 - 400 deg C
Pt		Platinum RTD (Pt100)	-200 - 850 deg C
NI		Resistance RTD (Ni120)	-80 - 300 deg C
CU		Resistance RTD (Cu50)	-50 - 150 deg C
Voltage and Current			
V5		Analog Voltage Input (0-5V)	
V10		Analog Voltage Input (0-10V)	
MA0		Analog Current Input (0-20mA)	PV scaled by 'tP-L' - 'tP-H' parameters, in Initial Setting Menu
MA4		Analog Current Input (4-20mA)	
MV		Analog Voltage Input (0-50mV)	

Table 5.4.2 Function Key Table - User Settings of F1 and F2 Function Keys

Function Key Programming, hold F1 or F2 function key for more than 3 seconds to select programming menu.		
Parameter Value	Display Symbol	Function when F1 or F2 Button is Pressed
MENU	MENU	Exits menu and returns to main SP/PV operation mode display (default for F2 key)
AT	At	Start / Stop Auto-tune
R-S	R-S	Switch between Run/Stop mode
PRoG	PRoG	Switch between Run/Hold mode
AtMt	AtMt	Switch between PID/Manual control mode
ALRS	ALRS	Resets a latched alarm (default setting for F1 key)
SV2	SV2	Switch between SP1 and SP2

Table 5.4.3 Alarm Options Table

Alarm options, set by parameters ‘AL1o’ and ‘AL2o’ in the Initial Setting Mode menu. The alarm option is a 4 bit number, where each bit can be either 0 or 1 (off or on). Each bit represents a different alarm function. Functions can be combined to enable multiple functions simultaneously. For example, a parameter setting of 1111 would enable all functions.		
Parameter Value	Alarm Function	Description
0000	None	No alarm functions active
0001	Standby Alarm	Disables the alarm function on a power restart
0010	Invert Alarm Mode	Inverts alarm contact from normally open (N.O.) to normally closed (N.C.)
0100	Latch Alarm State	Latches the alarm until the user manually resets the alarm, by pressing the ‘F1’ key on the keypad
1000	Alarm Peak Detection	Records the maximum and minimum alarm values to memory. Values retrieved through the Operation Mode menu parameters ‘AnHP’ and ‘AnLP’.
1111	Example: All 4 alarm modes enabled	Bits can be enabled in combination to turn on multiple alarm functions

Table 5.4.4 Miscellaneous Parameter 1 Table

Miscellaneous options set by parameter 'EXEC' in Initial Setting Mode menu The parameter is a 4 bit number, where each bit can be either 0 or 1 (off or on). Each bit represents a different function. Functions can be combined to enable multiple functions simultaneously. For example, a parameter setting of 1111 would enable all functions.		
Parameter Value	Function	Description
0000	None	No functions active
0001	Invert PV retransmission	Inverts the output scaling from 4-20mA to 20-4mA.
0010	Setpoint ramping units of parameter 'SVSL'	Changes setpoint slope units from degC/minute to degC/second
0100	N/A	N/A
1000	Internal thermocouple cold junction compensation	Disables the cold junction compensation
1111	Example: All 4 options enabled	Bits can be enabled in combination to turn on multiple alarm functions

Table 5.4.5 Miscellaneous Parameter 2 Table

Miscellaneous options set by parameter 'EXE2' The parameter is a 4 bit number, where each bit can be either 0 or 1 (off or on). Each bit represents a different function. Functions can be combined to enable multiple functions simultaneously. For example, a parameter setting of 1111 would enable all functions.		
Parameter Value	Function	Description
0000	None	No functions active
0001	Program control on power restart	On controller power loss and restart, resume program progress. Default of 0 will reset program.
0010	N/A	
0100	N/A	
1000	Dynamic setpoint when in program control	When running a program, will show dynamic/ramping setpoint in operation mode
1111	Example: All 4 options enabled	Bits can be enabled in combination to turn on multiple alarm functions

Table 5.4.6 Alarm Modes Table

Alarm Modes for parameter ‘ALA1’
SP = controller setpoint, when in automatic mode
PV = process value
'AL1L' = alarm low value
'AL1H' = alarm high value

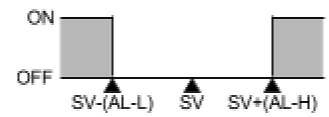
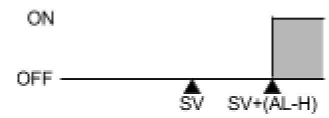
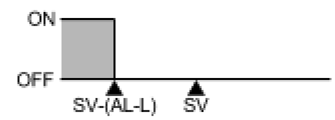
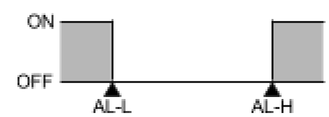
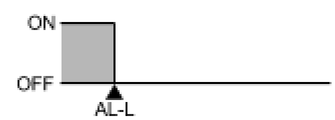
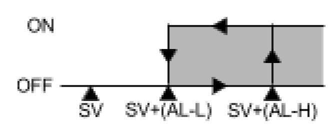
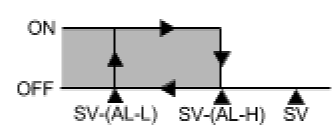
Parameter Value	Description	Alarm high 'AL1H’ output action	Alarm low ‘AL1L’ output action	Alarm Output Operation
0	No Alarm	No Action		N/A
1	PV low OR high deviation	Alarm output ON when PV > SP + AL-H	Alarm output ON when PV < SP - 'AL1L'	
2	PV high deviation	Alarm output ON when PV > SP + 'AL1H'		
3	PV low deviation		Alarm output ON when PV < SP - 'AL1L'	
4	PV high OR low	Alarm output ON when PV > 'AL1H'	Alarm output ON when PV < 'AL1L'	
5	PV high	Alarm output ON when PV > 'AL1H'		
6	PV low		Alarm output ON when PV < 'AL1L'	
7	PV high deviation with hysteresis	Alarm output ON when PV > SP + 'AL1H' Alarm output OFF(reset) when PV < SP + 'AL1L'		
8	PV low deviation with hysteresis		Alarm output ON when PV < SP - 'AL1H' Alarm output OFF (reset) when PV > SP - 'AL1L'	

Table 5.4.6 Alarm Modes Table (Continued)

Parameter Value	Description	Alarm high 'AL1H' output action	Alarm low 'AL1L' output action	Alarm Output Operation
9	No sensor input	Alarm output on when a thermocouple or input sensor is not connected		
10	N/A			
11	N/A			
12	N/A			
	Alarms specific to profile and ramp programs (Appendix D)			
13	Program in SOAK	Alarm output on when the program is in SOAK mode		
14	Program in RAMP UP	Alarm output on when the program is in RAMP UP mode		
15	Program in RAMP DOWN	Alarm output on when the program is in RAMP DOWN mode		
16	Program in RUN	Alarm output on when the program is in RUN mode		
17	Program in HOLD	Alarm output on when the program is in HOLD mode		
18	Program in STOP	Alarm output on when the program is in STOP mode		
19	Program in END	Alarm output on when the program is in END mode		

APPENDICES

Appendix A: Control Panel Maintenance and Inspection

Control Panel Cleaning
Use a damp cloth and mild soap to wipe down the outside surfaces of the enclosure.

Fuse Replacement
Refer to the wiring schematics for information on replacement fuse instructions. Only replace fuses with like fuses.

Annual inspection
The control panel should be inspected annually. Verify power is disconnected to the control panel, before continuing. The following items are to be checked:

Clear Debris from Power Controller Heat Sink Fins
Use low pressure compressed air to blow out any dust or debris accumulated in the cooling fins of the heat sink. If an electric cooling fan is attached to the heat sink, hold the fan blades in position to prevent damaging the bearings, by over-spinning the fan.

Inspect and Change Air Filters
Some models have cooling fans and vents mounted to the control panel enclosure. Both the inlet fan and outlet vents have filters installed that should be replaced annually, at a minimum and more often in dirty environments.

The vent covers are clipped in place from the outside of the enclosure and can be removed by sliding a small flat-blade screwdriver under the side of the cover and prying with light pressure to unclip the cover. The filter element can now be removed and replaced.

Filter elements (2 required per enclosure):
Manufacturer: Stego
Model Number: 08604.0-00
Description: Fine filter element for 4.92” x 4.92” exhaust fan and grill, Nema12 rating

Verify Terminal Block Torque
It is possible for terminal screws to loosen over time due to heating and cooling cycles inside the enclosure. Refer to the wiring schematics for terminal torque specifications. Verify that all terminal block and wiring connections are tight and within specification.

Appendix B: PID Control and Tuning

A PID controller is a control algorithm that calculates an output from the user desired setpoint (SP) and the measured process value (PV). It is a closed loop control algorithm where the measured PV input acts as feedback into the algorithm to calculate output.

PID controller tuning refers to the process of setting the Proportional, Integral, and Derivative parameters of a PID control algorithm. These parameters define the behaviour of a PID process controller - i.e. how aggressively or how slowly a controller responds to the measured temperature (PV), desired setpoint (SP), and the error (difference between SP and PV).

There are a few typical signs of a poorly tuned PID controller:

1. Large process overshoot upon a setpoint change (underdamped) - output response is too aggressive, causing high temperatures.
2. Process undershoot upon a setpoint change (overdamped) - doesn't reach setpoint or is slow to respond to process upsets.
3. Unstable response (during steady state operation) - process oscillations are unchecked and may become larger in amplitude over time.

The controller ships with a set of tuning parameters that will work for many, but not all processes. Some processes may require tuning to be functional, while for others, tuning may only offer a slightly better response or even make control worse than the default values. The tune depends on the physical configuration and location of the temperature sensor, heater type and size, heat load, and process configuration.

A common confusion when using a PID controller is that the controller output can still be on (greater than 0%) when the temperature is already above the setpoint. This is typically the correct response for a heater. The PID algorithm is not an on/off controller. The algorithm is calculating an intermediate output that will keep the process at temperature. Simply turning the output off will generally cause the temperature to fall, where the goal is to maintain a stable temperature. The PID parameters, namely the integral, will determine how much output is used to maintain temperature.

Another misconception is that the PID controller is "learning" your process. The controller uses an algorithm to calculate an output based on the process temperature and current setpoint and the history of these values. However, the control algorithm and the tuning will not adapt or change over time, it is always the same calculation.

The controller is only as good as its tune and the process configuration. If a heater is improperly sized or the sensor location is installed incorrectly, no amount of tuning or controller programming can remedy the installation problem.

PID Parameter Explanation

PID “tuning” is the process of determining optimal settings for the PID algorithm for the specific process to be controlled. Every control loop and process is unique and requires a unique set of PID parameters for optimal control. However, many processes will work well with the default parameters that are shipped with the controller.

The three tuning parameters are Proportional (P), Integral (I), and Derivative (D). Most temperature control loops will work well as a “PI” controller - meaning the derivative term is set to 0, and not used by the controller. The use of the derivative term can be helpful, but can potentially destabilize control loops. If you are interested in learning more about derivative control, there are many online resources and books available to learn about its interaction in PID algorithms. This guide will focus on “PI” control.

Proportional Term

The proportional term, also referred to as gain, calculates the controller output as the proportion of the difference between the setpoint and process value. A large difference between the setpoint and process value produces a proportionally error and therefore a larger output. As the process value approaches the setpoint, the proportional term’s effect is reduced. The default value for P is 47.6. Numerically decreasing this value (P has an inverse relationship) will cause it to have a larger effect, causing the controller to act more aggressively (having larger changes in output). Too aggressive of a value can cause the temperature to become unstable from large output changes in response to small temperature upsets. Numerically increasing the P value will cause the proportional term to have less of an effect. A numerically large P value may cause the output to be too slow to respond, creating slow heat up of processes or the inability for the output to keep up with process upsets.

A proportional only controller typically results in an offset between the setpoint and process value. Proportional controllers don’t have a way to correct for this offset as there must be a difference between the setpoint and the measured temperature to create an output to the heater. Temperature control typically requires and integral term to correct for this offset.

Integral Term

The integral term accumulates error, or the difference between the setpoint and process value over time. The integral term integrates error over time (sums the instantaneous error). The accumulated error provides an offset output which is then added to the P term to provide a steady state offset output to the heater. A large error over a longer time will cause the integral term to have a larger effect. As the proportional term has a small effect near the setpoint, the integral continues to control. The integral term of the controller is the product of the accumulated error and the integral value. The default value is 260. Numerically decreasing the integral value will cause it to have a larger effect, causing the controller to act more aggressively.

In general terms, for manual tuning:

Proportional (P)
1. If the output reacts too aggressively on a setpoint change, increase the proportional value.
2. If the process has a long time constant - the time to reach steady state, use a smaller P value.

Integral (I)
1. If there is a longer delay from when the output changes, until the PV responds (dead time) - use a larger value for I. Use a smaller I value for processes that respond quickly.
2. If the process won’t reach steady state and has large or continuous output oscillations, the integral value may need to be increased.

Appendix C: PID Auto-Tuning

The controller can be tuned manually, or with the integrated auto-tune features. The controller has two auto-tuning modes: auto-tune (AT) and self-tune (ST). Select the preferred tuning method through the ‘tUNE’ parameter in the Initial Setting Mode menu.

Typically, the auto-tune (AT) mode would be selected and tuning would be performed during commissioning, to determine PID parameters for a process. AT is ideal for processes that typically run at the same setpoint.

Self-tune (ST) is ideal for processes where the temperature setpoint is changed frequently and a constant set of tuning parameters results in unstable control.

Auto-tune

The auto-tune algorithm cycles the output between 100% and 0% on, through several cycles. The output will stay at 100%, until the setpoint value is reached, and then allow the PV to fall below the SP, before repeating. The controller monitors the slope of the increasing temperature and the time between cycles. This tuning algorithm is based on the Astrom-Hagglund tuning method. Note that this tuning method may not be appropriate for all cases that can’t handle a large swing in temperature and output.

Steps to begin the auto-tune sequence:

1. Select the AT mode, through the ‘tUNE’ parameter, AT is the default setting.
2. Choose a setpoint above the current process value, ideally near the typical operating setpoint.
3. When ready to start the tune, place the control panel ‘Control’ switch in the ‘Run’ position.
4. Select the ‘At’ parameter, through the Regulation Mode menu and change the value to ‘oN’
5. The controller will immediately begin the auto-tune sequence and flash a small “AT” on the display. This process could take only several minutes or an hour or more, depending on the response time of the system.
6. Once the auto-tune sequence is complete, it will stop flashing “AT” and return to normal PID control.
7. The tuning values are automatically updated and saved - they can be reviewed through the Regulation Mode menu tuning parameters.

Self-tune

The self-tune algorithm is less invasive than the auto-tune method. The self-tune method monitors the system response during PID control and adjusts the tuning parameters to improve the control. When a significant setpoint change is made, that causes the output to reach 100% output, the self-tune will temporarily go into an open loop mode. Once the setpoint is reached, tuning parameters are calculated and the controller returns to PID control.

The self-tune algorithm calculates the process gain, process time constant, and process dead time while the controller is in open loop control and at 100% output. These constants are then used to calculate new tuning parameters.

Steps to begin the self-tune sequence:

1. Select the ST mode is through the ‘tUNE’ parameter
2. Choose a setpoint above the current process value, ideally near the typical operating setpoint. The change in setpoint must be large enough to force the controller to 100% output.
3. When ready to start the tune, place the control panel ‘Control’ switch in the ‘Run’ position.
4. Select the ‘St’ parameter, through the Regulation Mode menu and change the value to ‘oN’
5. When in the ST mode, a setpoint change must be selected that causes the controller to go to 100% output to activate the auto-tune sequence. Once started, the controller will flash a small “AT” on the display.
6. Once the self-tune sequence is complete, it will stop flashing “AT” and return to normal PID control.
7. The tuning values are automatically updated and saved - they can be reviewed through the Regulation Mode menu tuning parameters.

Note: Controlling to a setpoint temperature

When controlling a process from a cold start, it can be beneficial to incrementally increase the setpoint over time. This allows the process to get to temperature and reach equilibrium before increasing (or decreasing) the setpoint again. This process also allows more “aggressive” controller tuning to be implemented without large overshoots in temperature. Generally, slower, more conservative tuning parameters are required to take a process from a cold state to fully operational, in a stable manner.

The setpoint slope control mode is another way to control a process from a cold start. Placing the control mode parameter ‘CtRS’ (3-06) to value ‘SloP’ mode will limit the output to control the setpoint to a fixed slope, defined by the parameter ‘SVSL’ (2-18).

Appendix D: Ramp / Soak Programming and Operation

The programming mode of the controller allows ramp and soak patterns to be created. A program consists of patterns and steps. A step is a temperature setpoint with a time defined to ramp to that setpoint. A pattern is a series of steps (up to 16), run in order, to create a temperature profile. Multiple patterns can be run within the program, repeated and linked to one another to create more complex programming sequences.

Once these patterns are created (up to 16), the program can be run, allowing temperature profiles to be followed. For example, a simple pattern could ramp a furnace to 800 degrees C over 2 hours (step0), hold at that temperature for 30 minutes (step1), then ramp down to 50 degrees C over 3 hours (step2).

There are several processes to create a program that must be followed:

Enable the Programming Mode

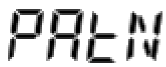
1. Set the Control switch on the front of the control panel to the ‘Safe’ position
2. Enter the Initial Setting Mode, by holding the Enter button for more than 3 seconds
3. Scroll to parameter ‘CtRS’ and change the value to ‘PRoG’, to enter the programming mode. This will enable additional parameters in the Initial Setting Mode menu.
4. Scroll to the ‘PAtN’ parameter and select the pattern number to edit.

Programming a Pattern

1. Within the Initial Setting Mode menu, cycle to the ‘PAtN’ parameter and select the pattern to be edited.
2. Once the pattern number to edit is selected, cycle through the parameters in Table D.1.1 below, to edit the programming parameters.

Table D.1 Ramp/Soak Programming Parameters

Initial Setting Mode, Programming Specific Parameters - use the cycle button to scroll between parameters Parameters are specific to programming ramp and soak profiles.				
Note: The following parameters are only accessible when ‘CtRS’ is in ‘PRoG’ mode.				
Parameter Name (Parameter Number)	Display Symbol	Description	Factory Default Value	Customer Value
WtSV (3-07) Accessible when ‘CtRS’ is in programming mode ‘PRoG’.	WtSV	Waiting temperature setpoint to control at, for waiting time ‘W-tM’ - before starting ramp program.	0.0	
W-tM (3-08) Accessible when ‘CtRS’ is in programming mode ‘PRoG’.	W-tM	Waiting time to control at waiting temperature setpoint ‘WtSV’ before starting ramp program.	0	
SLoP Accessible when ‘CtRS’ is in programming mode ‘PRoG’.	SLoP	Set starting slope.	1.0 degrees C / minute	
PAtN Accessible when ‘CtRS’ is in programming mode ‘PRoG’.	PAtN	Select the pattern to be edited: off, save (select when changes have been made), 0-9 and A-F.	oFF	
Note: The following parameters are only accessible when a ‘PAtN’ (above) is selected, and not set to ‘oFF’				
SP0n Where n (0-9,A-F) is the number of the selected profile step.	SP0n	Temperature setpoint for step n, within the selected profile. Repeat a previous steps setpoint to soak at a constant temperature.	SP0..9 = 0.0 ... SPa..F = 0.0	
tM0n Where n (0-9,A-F) is the number of the selected profile step	tM0n	Time for step n, units of hh:mm, within the selected program. This time can be the time to ramp between setpoints or the time to soak at a held temperature.	tM00..9 = 00:00... tM0a..F = 00:00	
PSY0	PSY0	Scroll through all steps (0-9,A-F), to get to the PSY0 parameter. Select the number of the last step to execute when the program is running.	15	
CYC0	CYC0	The number of additional cycles for the program to run (0-99).	0	

LIN0		Link pattern to run at the end of pattern's execution: *<u>End</u>* After the program is complete, stays at the last step of the pattern and holds temperature, displays "E-SS". *<u>Stop</u>* After the program is complete, returns to the first step of the pattern and holds. *<u>0-9,A-F</u>* After the program is complete, run the linked pattern.	ENd	
Note: When a pattern is edited, the controller returns to the 'PAtN' parameter after editing the parameters above.				
PAtN After cycling through all 15 steps, the menu returns to PAtN.		See the saving a pattern section below, for more instructions.		
Note: the 'PAtN' parameter is used for editing purposes only, see below for instructions on selecting a pattern to run.				

Saving a Pattern

There are two ways to save a program:

1. Once the pattern has been configured, cycling through the parameters will return to the 'PAtN' parameter. Press the down arrow to cycle to the 'SAVE' setting, press return to confirm. The controller will display 'doNE' to confirm the save.
2. If the pattern was not saved after making changes, enter the Initial Setting Mode, by holding the cycle button for more than 3 seconds. Cycle through the parameters to get to 'PAtN'. Press the up key, if unsaved changes exist, 'SAVE' will be displayed. Press return to confirm. The controller will display 'doNE' to confirm the save.

If the 'SAVE' option is not available under 'PAtN', then the pattern has been saved.

Running a program

Now that the program has been created, it can be run.

1. Verify the controller mode, from the Initial Setting Mode, 'CtRL' (3-05) is in 'PID' mode.
2. Verify the SP control mode, from the Initial Setting Mode, CtRS' (3-06) is in 'PRoG' mode.
3. Return to the Operation Mode, by pressing the Enter button
4. Within the Operation Mode, the starting pattern 'PtRN' and 'StEP' parameters can be selected.
5. Switch the 'Control' switch on the front of the control panel to the 'Run' position to start the pattern.
6. Once the program is complete, it goes to 'End' or 'Stop', depending on the selection of parameter 'LINO'. End will hold at the setpoint temperature of the last step of the pattern. Stop will return to the first pattern and step's setpoint.

Controls available while running a program
The Operation Mode display, normally reserved for displaying the setpoint and process value, displays the PV, current pattern and step.

Figure D.1 Controller Display While Running Ramp/Soak Program

The up and down arrows (confirm with enter button to switch displays) switch between the following displays:

1. ‘P-St’; The pattern and step that is currently being run
2. ‘SP’; The temperature setpoint of the active step
3. ‘R-tI’; The remaining time left in the active step

Within the Operation Mode, cycle to the ‘R-S’ parameter. When the ‘Control’ switched is toggled to ‘Run’ the ‘R-S’ parameter is changed to ‘Run’.

Modes available, from the ‘R-S’ parameter, in program mode:

1. ‘Run’ - starts the selected pattern and step program
2. ‘Stop’ - stops the current program running, returns to the first step of the pattern
3. ‘PENd’ - end the program, stay at the last step of the pattern and hold temperature
4. ‘PHoL’ - program hold

Appendix E: Troubleshooting

Table E.1.1 Troubleshooting

Problem	Possible Causes and Solutions
The 'Alarm2' indicator is lit on the temperature controller, even though the temperature is below the Alarm 2 (over-temperature limit) limit.	Alarm 2 is latching, by default. Reset the over-temperature alarm, by pressing the F1 key or changing the setpoint.
Controller PV display = "No CoNt"	Verify the thermocouple is wired, connected, and has a good and connected junction. Thermocouples with poorly welded junctions can expand when hot, creating an open connection and create intermittent temperature readings.
Controller PV display= "----"	The temperature has exceeded the displayable range. Refer to Section 5.1, to change decimal place parameter 'SP' to 0. This will allow temperatures greater than 999.9 to be displayed.
Controller PV display= "SEN ERR"	Sensor Error state - the sensor is outside of the input range. Refer to Table 5.4.1, Sensor Input Types for sensor ranges.
Controller PV temperature value is flashing	Indicates that the measured PV is outside of the configured input sensor range. Sensor range set by parameters 'tP-H' and 'tP-L' in Section 5.3.
The controller display is off	Verify the following (qualified personnel only): 1. The door mounted disconnect switch is in the ON position (IFPA models) 2. All fuses are installed and good 3. The control panel supply power is on - breakers, fuses, etc. upstream of control panel
The controller output doesn't turn on (verify by checking output bar graph indicator on control display).	For PID mode control, verify: 1. Setpoint is greater than the process value 2. Control panel, door mount 'Control' switch is in 'Run' position 3. The thermocouple is wired and installed 4. Control mode 'CtRL' is in 'PID' mode 5. Setpoint control mode 'CtRS' is in 'CONS' mode 6. Verify the PV is below the 'AL2H', alarm 2 limit - the over-temperature alarm shutoff limit. Press F1 to reset a latched alarm. 7. If an optional external interlock relay is installed, verify the coil is energized 8. The main power contactor is pulled down - qualified personnel only.

Table E.1.1 Troubleshooting (Continued)

Problem	Possible Causes and Solutions
The controller output is on, but the temperature does not increase	Verify the following:: 1. Check the controller's output setting - the current output may not provide enough power to increase the temperature anymore, may require tuning 2. Thermocouple placement is correct 3. Fuses are good 4. Heater wiring is correct 5. Heater resistance, check heater is in working order
The temperature will not reach the setpoint temperature	Check: 1. If the output is at or near 100%, the heater may not have enough power to reach the desired temperature. A larger heater may be required 2. If the over-temperature alarm limit 'AL2H' is set to a value below the setpoint, the controller will turn off power before reaching the setpoint. Decrease the setpoint or increase the alarm limit - when safe 3. Verify parameter 'o1MA', the upper output limit is not limiting the output 4. PID tuning parameters could be limiting the output - refer to the tuning Appendix B
The temperature and output swing up and down, and never stabilizes	The first step is to determine if this is a process or tuning issue: 1. Place the controller parameter 'CtRL' in manual mode, at a constant output 2. Monitor the temperature, if the temperature stabilizes, it is most likely a tuning issue. Refer to the tuning appendix to tune the controller. 3. If the temperature does not stabilize, even at a constant output, their is most likely a process issue causing the temperature swings.
The temperature increases, regardless of setpoint	Verify the following: 1. The correct thermocouple is plugged into the controller and not crossed with another control zone or process thermocouple 2. PID tuning parameters could be too aggressive - refer to the tuning Appendix B

Table E.1.1 Troubleshooting (Continued)

Problem	Possible Causes and Solutions
The temperature increases, even when the controller output is off	Determine if the following conditions are true (qualified personnel only): 1. Check voltage at the heater, to test if it is powered, when the output indicates no output. Is full line voltage measured at the heater? 2. Does the temperature decrease when the control switch is placed in the 'Safe' position? 3. Does the temperature increase when the control switch is in 'Run' mode, but the controller output is off? If the above are both true, the power controller may be damaged.
The temperature decreases, when the heater is on.	Verify all thermocouple wiring polarity is correct. Type K: yellow wire is '+' and the red wire is '-' Type J: white wire is '+' and the red wire is '-' Verify all connectors and wire of the same type.
The temperature does not read as expected	Verify the following: 1. The sensor input type parameter 'INPt' is set to the correct type. If the wrong input type is selected, the wrong calibration will be used, causing an incorrect temperature reading. 2. The connectors, cable, and thermocouple are all of the same type 3. The PV offset 'PVoF' and gain 'PVGA' can be adjusted to correct temperature readings
The temperature reading fluctuates quickly or is "noisy"	Grounding issues or other electrical issues may create electrical "noise". 1. If a grounded thermocouple is used, try changing to an ungrounded thermocouple 2. Additional structure grounding may help 3. Ground one end of a shielded thermocouple cable

Appendix F: RS-485 Communication and Modbus Protocol

The temperature controller is capable of remote communication with a control system or user PC by RS-485 2-Wire hardware specification through ASCII or RTU Modbus protocols. The temperature controller values such as mode, temperature, setpoint, output percentage, and alarm state can be monitored and/or controlled. This allows a control system or PC to remotely monitor and log the temperature and change the setpoint. The controller configuration parameters can also be queried and modified.

RS-485 Supported Serial Communication Parameters

Refer to Section 5.3 for details on setting the RS-485 parameters. Below are the supported serial communication parameters:

Factory Default Configuration: RTU, 9600 bps, 8 bits, Even-Parity, 1 Stop Bit

Supported Communication Speeds: 2400, 4800, 9600,19200,38400 bps

Recommended Formats: *RTU:* *8* bits, Even-Parity, 1 Stop Bit
ASCII: 7 bits, Odd-Parity, 1 Stop Bit

Non-Supported Formats: 7 bits, No-Parity, 1 Stop Bit
8 bits, Odd-Parity, 2 Stop Bits
8 bits, Even-Parity, 2 Stop Bits

Communication Protocol: ASCII or RTU

Modbus Supported Function Codes:

Function Code (Hexadecimal)	Description	Maximum to Read/Write
02	Read Data Bits	16 Bits
05	Write Single Data Bit	1 Bit
03	Read Multiple 16-bit Holding Registers	8 Registers
06	Write Single 16-bit Holding Register	1 Register

Modbus Communication Protocol
The temperature controller can be setup to communicate on standard Modbus networks using either of two transmission modes: ASCII or RTU. Select the desired mode, along with the serial communication parameters (baud rate, parity, bits per byte, and number of stop bits), during configuration of each controller. The mode (ASCII or RTU) and serial parameters must be the same for all devices on a Modbus network . The mode defines the bit contents of message field, how they are framed, and how they should be decoded.

ASCII Mode
When the controller is setup to communicate on a Modbus network using ASCII (American Standard Code for Information Interchange) mode, each 8–bit byte in a message is sent as two ASCII characters. The main advantage of this mode is that it allows the user to construct and receive messages from the controller that are human readable.

The format for each byte in ASCII mode is as follows:

Coding System:	Hexadecimal, ASCII characters 0–9, A–F One hexadecimal character contained in each ASCII character of the message
Bits per Byte:	1 start bit 7 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stop bit if parity is used; 2 bits if no parity
Error Check Field:	Longitudinal Redundancy Check (LRC)

RTU Mode
When the controller is setup to communicate on a Modbus network using RTU (Remote Terminal Unit) mode, each 8–bit byte in a message contains two 4–bit hexadecimal characters. The main advantage of this mode is that its greater character density allows better data throughput than ASCII for the same baud rate. A Modbus RTU message must be transmitted continuously without inter-character hesitations. Modbus messages are framed (separated) by idle (silent) periods.

The format for each byte in RTU mode is as follows:

Coding System:	8–bit binary, hexadecimal 0–9, A–F Two hexadecimal characters contained in each 8–bit field of the message
Bits per Byte:	1 start bit 8 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stop bit if parity is used; 2 bits if no parity
Error Check Field:	Cyclical Redundancy Check (CRC)

ASCII and RTU Examples

Example 1: Request the Measured Temperature (PV) from Temperature Controller Address 1
Slave Address: 1 (Decimal), 01 (Hex)
Function: 03 (Hex) Read 16-Bit Holding Register(s)
Measured Temperature (PV) Address: 1000 (Hex) From Parameter Table F.1
Number of Consecutive Addresses to Read: 1 (Decimal), 01 (Hex)
Calculated LRC: EB (Hex), Calculated CRC: 80 CA (Hex)

ASCII Query Message from Master (Control System or PC)

Start	Slave Address		Function		Starting Register Address				Address Count				LRC Check		End	
1 Char	2 Char		2 Char		4 Chars				4 Chars				2 Chars		2 Chars	
:	0	1	0	3	1	0	0	0	0	0	0	1	E	B	CR	LF

ASCII Response Message from Slave Address 1 (Temperature Controller)

Start	Slave Address		Function		Data Byte Count		Data Hi Byte		Data Lo Byte		LRC Check		End	
1 Char	2 Char		2 Char		2 Chars		2 Chars		2 Chars		2 Chars		2 Chars	
:	0	1	0	3	0	2	0	3	D	A	1	D	CR	LF

RTU Query Message from Master (Control System or PC)

Start	Slave Address	Function	Register Address		Address Count		CRC Check		End
>3.5 Char Time	1 Byte	1 Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	>3.5 Char Time
	01	03	10	00	00	01	80	CA	

RTU Response Message from Slave Address 1 (Temperature Controller)

Start	Slave Address	Function	Data Byte Count	Address Data		CRC Check		End
>3.5 Char Time	1 Byte	1 Byte	1 Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	>3.5 Char Time
	01	03	02	03	DA	39	2F	

Decoded Response:
Slave Address: 1 (Decimal), 01 (Hex)
Function: 03 (Hex) Read 16-Bit Holding Register(s)
Data Message Length: 02 (Hex), 2 (Decimal)
Data Received: 03 DA (Hex), 986 (Decimal)
Units: 0.1, °C or °F (From Parameter Table, temperature unit is the current controller setting)
Measured Temperature (PV): 98.6 °C or °F
ASCII Response LRC: 1D (Hex), RTU Response CRC: 39 2F (Hex)

Example 2: Request the Measured Temperature (PV) and Setpoint (SP) from Temperature Controller Address 14 (Decimal)

Slave Address: 14 (Decimal), 0E (Hex)
Function: 03 (Hex) Read 16-Bit Holding Register(s)
Measured Temperature (PV) Address: 1000 (Hex) From Parameter Table F.1
Setpoint (SP) Address: 1001 (Hex) From Parameter Table F.1
Number of Consecutive Addresses to Read: 2 (Decimal), 02 (Hex)
Calculated LRC: DD (Hex), Calculated CRC: C0 34 (Hex)

ASCII Query Message from Master (Control System or PC)

Start	Slave Address		Function		Starting Register Address				Address Count				LRC Check		End	
1 Char	2 Char		2 Char		4 Chars				4 Chars				2 Chars		2 Chars	
:	0	E	0	3	1	0	0	0	0	0	0	2	D	D	CR	LF

ASCII Response Message from Slave Address 14 (Temperature Controller)

Start	Slave Address		Function		Data Byte Count		Data Hi		Data Lo		Data Hi		Data Lo		LRC Check		End	
1 Char	2 Char		2 Char		2 Chars		2 Chars		2 Chars		2 Chars		2 Chars		2 Chars		2 Chars	
:	0	E	0	3	0	4	0	3	D	A	0	3	E	8	2	3	CR	LF

RTU Query Message from Master (Control System or PC)

Start	Slave Address	Function	Register Address		Address Count		CRC Check		End
>3.5 Char Time	1 Byte	1 Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	>3.5 Char Time
	0E	03	10	00	00	02	C0	34	

RTU Response Message from Slave Address 14 (Temperature Controller)

Start	Slave Address	Function	Data Byte Count	Address Data		Address Data		CRC Check		End
>3.5 Char Time	1 Byte	1 Byte	1 Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	>3.5 Char Time
	0E	03	04	03	DA	03	E8	24	32	

Decoded Response:
Slave Address: 14 (Decimal), 0E (Hex)
Function: 03 (Hex) Read 16-Bit Holding Register(s)
Data Message Length: 04 (Hex), 4 (Decimal)
Data Received: 03 DA, 03E8 (Hex), 986, 1000 (Decimal)
Units: 0.1, °C or °F (From Parameter Table, temperature unit is the current controller setting)
Measured Temperature (PV): 98.6 °C or °F
Setpoint (SP): 100.0 °C or °F
ASCII Response LRC: 23 (Hex), RTU Response CRC: 24 32 (Hex)

Example 3: Write the Setpoint (SP) of 105.4 to Temperature Controller Address 08 (Decimal)

Slave Address: 08 (Decimal), 08 (Hex)
Function: 06 (Hex) Write 16-Bit Holding Register
Setpoint (SP) Address: 1001 (Hex) From Parameter Table F.1
Units: 0.1, °C or °F (From Parameter Table F.1, temperature unit is the current controller setting)
Data to Write: 04 1E (Hex), 1054 (Decimal)
Calculated LRC: BF (Hex), Calculated CRC: 5E 9B (Hex)

ASCII Write Message from Master (Control System or PC)

Start	Slave Address		Function		Write to Register Address				Data Hi		Data Lo		LRC Check		End	
1 Char	2 Char		2 Char		4 Chars				2 Chars		2 Chars		2 Chars		2 Chars	
:	0	8	0	6	1	0	0	1	0	4	1	E	B	F	CR	LF

ASCII Response Message from Slave Address 08 (Temperature Controller)
Echo of the Write Message

Start	Slave Address		Function		Register Address				Data Hi		Data Lo		LRC Check		End	
1 Char	2 Char		2 Char		4 Chars				2 Chars		2 Chars		2 Chars		2 Chars	
:	0	8	0	6	1	0	0	1	0	4	1	E	B	F	CR	LF

RTU Write Message from Master (Control System or PC)

Start	Slave Address	Function	Register Address		Address Data		CRC Check		End
>3.5 Char Time	1 Byte	1 Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	>3.5 Char Time
	08	06	10	01	04	1E	5E	9B	

RTU Response Message from Slave Address 08 (Temperature Controller)
Echo of the Write Message

Start	Slave Address	Function	Register Address		Address Data		CRC Check		End
>3.5 Char Time	1 Byte	1 Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	Hi Byte	Lo Byte	>3.5 Char Time
	08	03	10	01	04	1E	5E	9B	

Decoded Response:
Slave Address: 08 (Decimal), 08 (Hex)
Function: 06 (Hex) Write 16-Bit Holding Register
Setpoint (SP) Address: 1001 (Hex) From Parameter Table
Units: 0.1, °C or °F (From Parameter Table F.1, temperature unit is the current controller setting)
Data Written: 04 1E (Hex), 1054 (Decimal)
ASCII Response LRC: BF (Hex), RTU Response CRC: 5E 9B (Hex)

Table F.1 Modbus Holding Register Table

Parameter Name (Parameter Number)	R/W	Hex Address	Decimal Address	Address Values/Notes
Process Value (PV) (Main Operation Display)	R	1000	44097	Measured Value Unit: 0.1, °C or °F Updated every 0.1s The Following are Error Values: 8002H: Temperature not yet Acquired 8003H: No Sensor Connected 8004H: Temp Sensor Input Error 8006H: ADC Input Error 8007H: Memory R/W Error
Setpoint Value (SP) (Main Operation Display)	R/W	1001	44098	Setpoint Value Unit: 0.1, °C or °F
'tP-H' (3-03) Upper Limit of Temperature Range	R/W	1002	44099	Unit: 0.1, °C or °F Cannot exceed the default value - see sensor input types table, Table 5.4.1 for default values
'tP-L' (3-04) Lower Limit of Temperature Range	R/W	1003	44100	Unit: 0.1, °C or °F Cannot fall below the default value - see sensor input types table, Table 5.4.1 for default values
'INPt' (3-01) Input Temperature Sensor Type	R/W	1004	44101	Values: See Table 5.4.1 for Details 0: K type Thermocouple 1: J type Thermocouple 2: T type Thermocouple 3: E type Thermocouple 4: N type Thermocouple 5: R type Thermocouple 6: S type Thermocouple 7: B type Thermocouple 8: L type Thermocouple 9: U type Thermocouple 10: TXK type Thermocouple 11: Platinum RTD (JPt100) 12: Platinum RTD (Pt100) 13: Resistance RTD (Ni120) 14: Resistance (Cu50) 15: Analog Voltage Input (0-5 VDC) 16: Analog Voltage Input (0-10 VDC) 17: Analog Current Input (0-20 mA) 18: Analog Current Input (4-20 mA) 19: Analog Voltage Input (0-50 mVDC)

Table F.1 Modbus Holding Register Table (Continued)

Parameter Name (Parameter Number)	R/W	Hex Address	Decimal Address	Address Values/Notes
'CtRL' (3-05) Control Mode	R/W	1005	44102	0: PID 1: On/off 2: Manual 3: Fuzzy 4: 2PID
'S-HC' (3-12) Heating/Cooling Output Control	R/W	1006	44103	Output 1 / Output 2 Controlling Modes (Output 2 Not Used) 0: Heating / Heating 1: Cooling / Heating 2: Heating / Cooling 3: Cooling / Cooling 4: Heating / Alarm 5: Cooling / Alarm
'o1-H' (2-13) Output 1 Heating Cycle Time	R/W	1007	44104	Range: 1-990 Unit: 0.1 seconds Control Cycle Time for Output 1 Duration to Complete an On/off Cycle of the Output (ISPA Models Only)
'o2-H' (N/A) Output 2 Heating Cycle Time	R/W	1008	44105	Range: 1-990 Unit: 0.1 seconds Control Cycle Time for Output 2 Duration to Complete an On/off Cycle of the Output
'Pn' (2-06) Proportional Value (P) of current PID group	R/W	1009	44106	Range: 0.1 - 999.9 Unit: 0.1
'In' (2-07) Integral Value (I) of Current PID Group	R/W	100A	44107	Range: 0 - 9,999
'Dn' (2-08) Derivative Value (D) of Current PID Group	R/W	100B	44108	Range: 0 - 9,999
'Iofn' (2-09) Integral Offset	R/W	100C	44109	Range: 0 - 100% Unit: 0.1%
'PdoF' (2-10) Proportional Control Offset Error Value, when I=0	R/W	100D	44110	Range: 0 - 100% Unit: 0.1%

Table F.1 Modbus Holding Register Table (Continued)

Parameter Name (Parameter Number)	R/W	Hex Address	Decimal Address	Address Values/Notes
'COEF' (N/A) Coefficient when Dual Loop Output is Used	R/W	100E	44111	Range: 0.01 - 99.99 Unit: 0.01
'dEAd' (N/A) Deadband Setting when Dual Loop Output is Used	R/W	100F	44112	Range: -999-9,999 Unit: 0.1
'o1-S' (N/A) Hysteresis Setting of 1st Output Group	R/W	1010	44113	Range: 0 - 9,000 Unit: 0.1
'02-S' (N/A) Hysteresis Setting of 2nd Output Group	R/W	1011	44114	Range: 0 - 9,000 Unit: 0.1
'oUt1' (1-12) Output 1 Value	R/W	1012	44115	Range: 0 - 100.0% Unit: 0.1% Write Operation is Valid Under Manual Control Mode Only.
'oUt2' (N/A) Output 2 Value	R/W	1013	44116	Range: 0 - 100.0% Unit: 0.1% Write Operation is Valid Under Manual Control Mode Only.
'PVoF' (2-16) Linear PV Offset	R/W	1016	44119	-99.9 - 99.9 Unit: 0.1
'SP' (1-04) Display Decimal Setting	R/W	1017	44120	Values: 0, 1, 2, 3 Not all decimal places are available based on sensor input type
'PID' (2-03) PID Group Selection	R/W	101C	44125	Values: 0-6, Auto = 6 Unit: 1
'SVn' (2-05) SP Value Corresponded to PI Group	R/W	101D	44126	Range: Only valid within input high 'tP-H' and input low 'tP-L' values Unit: 0.1 scale

Table F.1 Modbus Holding Register Table (Continued)

Parameter Name	R/W	Hex Address	Decimal Address	Address Values/Notes
'ALA1' (3-13) Alarm 1 Type	R/W	1020	44129	Range: 0 - 19 Refer to Alarms Table 5.4.6 for Type Codes
'ALA2' (3-16) Alarm 2 Type	R/W	1021	44130	Range: 0 - 19 Refer to Alarms Table 5.4.6 for Type Codes
'ALA3' (3-19) Alarm 3 Type	R/W	1022	44131	Range: 0 - 19 Refer to Alarms Table 5.4.3 for Type Codes
'AL1H' (1-06) Alarm 1 Upper Limit	R/W	1024	44133	Valid only if Alarm 1 Type = High Unit: 0.1, °C or °F
'AL1L' (1-07) Alarm 1 Lower Limit	R/W	1025	44134	Valid only if Alarm 1 Type = Low Unit: 0.1, °C or °F
'AL2H' (1-08) Alarm 2 Upper Limit	R/W	1026	44135	Valid only if Alarm 2 Type = High Unit: 0.1, °C or °F
'AL2L' (1-09) Alarm 2 Lower Limit	R/W	1027	44136	Valid only if Alarm 2 Type = Low Unit: 0.1, °C or °F
'AL3H' (1-10) Alarm 3 Upper Limit	R/W	1028	44137	Valid only if Alarm 3 Type = High Unit: 0.1, °C or °F
'AL3L' (1-11) Alarm 3 Lower Limit	R/W	1029	44138	Valid only if Alarm 3 Type = Low Unit: 0.1, °C or °F
Controller LED Status (N/A)	R	102A	44139	The LED Status Sent as One Byte, Each Bit Represents the Status of an LED Indicator Off = 0, On = 1 bit 0: ALM3 bit 1: ALM2 bit 2: °C bit 3: °F bit 4: ALM1 bit 5: OUT2 bit 6: OUT1 bit 7: AT (auto-tune)
Keypad Button Status (N/A)	R	102B	44140	The Keypad Status is Sent as one Byte, Each Bit Represents the Status of a Keypad Button Pressed = 0, Not Pressed = 1 b0: Always 1 b1: F2 b2: Up b3: Cycle b4: Always 1 b5: F1 b6: Down b7: Enter

Table F.1 Modbus Holding Register Table (Continued)

Parameter Name	R/W	Hex Address	Decimal Address	Address Values/Notes
'LoC' (1-05) Controller Lock Mode	R/W	102C	44141	0: Unlocked 1: Lock1- Keypad Locked 2: Lock2- Setpoint can be Changed, Menus Locked
Software Version (N/A)	R	102F	44144	Unit: .01 0x100 Indicates Software Version V1.00
'PtRN' (1-02) Start Pattern Number	R/W	1030	44145	Range: 0 - 15
'CoSH' (3-23) Communication Write Enabled	R	1039	44154	Read Only. Enable Locally at Controller. 0: Disabled 1: Enabled
'tPUN' (3-02) Temperature Unit Displayed	R/W	103A	44155	The temperature unit value cannot be written to 2 (None) if the input type is a thermocouple or RTD. The unit cannot be written to 0 or 1 (°F or °C) if the input type is analog. 0: °F 1: °C 2: None
'At' (2-01) Auto-Tune Status	R/W	103B	44156	0: Off 1: On
'R-S' (1-01) Controller Run Status	R/W	103C	44157	0: Stop 1: Run 2: End program 3: Hold program
'StEP' (1-02) Start Step Number	R/W	101F	44128	Range: 0 - 15
Pattern Temperature SP Parameters 'SP0n' Pattern Execution Time Parameters 'tM0n'	R/W	1200 - 13FF	44609 - 45120	See Pattern Temperature SP Address Table F.2 for Complete Listing of Pattern/Step Addresses Temp SP Range: -999 - 9999, Units: 0.1 °C or °F See Pattern Execution Time Address Table F.3 for Complete Listing of Pattern/Step Addresses Time Range: 0 - 900, Units: 1 Minutes
Last Step of the Pattern Parameters 'PSyn'	R/W	1400 - 140F	45121 - 45136	See Pattern Control Parameter Table F.4 Range: 0 - 15 Pattern is Executed from Step 0 to Step N
Additional Cycles of the Pattern Parameters 'CyCn'	R/W	1410 - 141F	45137 - 45152	See Pattern Control Parameter Table F.4 Range: 0 - 199 (Additional Cycles)
Next Pattern Number of the Pattern (Link) Parameters 'LiNn'	R/W	1420 - 142F	45153 - 45168	See Pattern Control Parameter Table F.4 Range: 0 - 15 (Next Pattern) 16: End 17: Stop

Table F.1 Modbus Holding Register Table (Continued)

Parameter Name	R/W	Hex Address	Decimal Address	Address Values/Notes
'PVGA' (2-17) Adjust Temperature Gain	R/W	1100	44353	Range: -999 to 999 Unit: 0.001
'PV-R' (2-15) Temperature Filter Range	R/W	1101	44354	Range: 10 - 1000 Unit: 0.01°C, Default: 100 (1.0°C)
'PV-F' (2-14) Temperature Filter Factor	R/W	1102	44355	Range: 0-50 Higher = More Filtering
Reverse Output (N/A)	R/W	1103	44356	Values: Reverse = 1 bit0: Output 1 bit1: Output 2
'SVSL' (2-18) Slope of Temperature Increase	R/W	1104	44357	Unit: 0.1 °C or °F per Minute or Second Rate unit depends on parameter 'EXEC', see Table 5.4.5
Remote Input Type Selection (N/A)	R/W	1105	44358	Values: 0 - 4 0: 0-20mA 1: 4-20mA 2: 0-5V 3: 1-5V 4: 0-10V
'tUNE' (3-11) Auto-Tune Type	R/W	1106	44359	Values: 0 - 1 0: AT (Auto-Tune) 1: ST (Self-Tune)
Remote Input Reverse Setting (N/A)	R/W	1107	44360	Values: 0 - 1 0: Forward 1: Reverse
'AL1o' (3-14) Alarm 1 Function Selection	R/W	1108	44361	Each Bit Represents the State of the Alarm Function Parameter 1 = Enabled, 0 = Disabled Digit0: Standby Enable Digit1: Output Reverse Digit2: Hold Enable Digit3: Peak Record
'AL2o' (3-17) Alarm 2 Function Selection	R/W	1109	44362	
'AL3o' (N/A) Alarm 3 Function Selection	R/W	110A	44363	

Table F.1 Modbus Holding Register Table (Continued)

Parameter Name	R/W	Hex Address	Decimal Address	Address Values/Notes
‘AL1d’ (3-15) Alarm 1 Output Delay Time	R/W	110B	44364	Range: 0 - 100 Unit: 1 seconds
‘AL2d’ (3-18) Alarm 2 Output Delay Time	R/W	110C	44365	Range: 0 - 100 Unit: 1 seconds
‘AL3d’ (N/A) Alarm 3 Output Delay Time	R/W	110D	44366	Range: 0 - 100 Unit: 1 seconds
‘o1MA’ (1-13) Upper Limit of Output 1	R/W	110E	44367	Range: Lower Limit - 1000 Unit: 0.1%
‘o1MI’ (1-14) Lower Limit of Output 1	R/W	110F	44368	Range: 0 - Upper Limit Unit: 0.1%
‘o2MA’ (N/A) Upper Limit of Output 2	R/W	1110	44369	Range: Lower Limit - 1000 Unit: 0.1%
‘o2MI’ (N/A) Lower Limit of Output 2	R/W	1111	44370	Range: 0 - Upper Limit Unit: 0.1%
‘WtSV’ (3-07) Program Waiting Temperature Deviation	R/W	1112	44371	Range: 0 - 1000 Unit: 0.1°C
‘W-tM’ (3-08) Program Waiting Time	R/W	1113	44372	Range: 0 - 900 Unit: 1 Minute
‘SLoP’ (3-09) Program Slope Increase	R/W	1114	44373	Unit: 0.1 °C or °F per Minute or Second Rate unit depends on ‘EXEC’ parameter, see Table 5.4.4
Testing Mode (N/A)	R/W	1115	44374	
‘A1MA’ (2-19) Output 1 Analog Upper Limit Adjust	R/W	1116	44375	Range: X - XXX Unit of Current Output Adjustment: 1 =1μA
‘A1MI’ (2-20) Output 1 Analog Lower Limit Adjust	R/W	1117	44376	Range: X - XXX Unit of Current Output Adjustment: 1 =1μA
Output 2 Analog Upper Limit Adjust (N/A)	R/W	1118	44377	Range: X - XXX Unit of Current Output Adjustment: 1 =1μA
Output 2 Analog Lower Limit Adjust (N/A)	R/W	1119	44378	Range: X - XXX Unit of Current Output Adjustment: 1 =1μA
‘RtMA’ (2-21) Retransmission Upper Limit Adjust	R/W	111A	44379	Range: -9999 to 1016 Unit of Current Output Adjustment: 1 =1μA
‘RtMI’ (2-22) Retransmission Lower Limit Adjust	R/W	111B	44380	Range: -3948 to 9999 Unit of Current Output Adjustment: 1 =1μA

Table F.1 Modbus Holding Register Table (Continued)

Parameter Name	R/W	Hex Address	Decimal Address	Address Values/Notes
'EVt1' (2-23) Event 1 Selection	R/W	111C	44381	Values: 0 - 4 0: OFF 1: Run/Stop 2: Change SP Value 3: PID/Manual control 4: Switch to Programmable Hold Mode
'EVt2' (N/A) Event 2 Selection	R/W	111D	44382	Values: 0 - 4 0: OFF 1: Run/Stop 2: Change SP Value 3: PID/Manual control 4: Switch to Programmable Hold Mode
'EVt3' (N/A) Event 3 Selection	R/W	111E	44383	Values: 0 - 4 0: OFF 1: Run/Stop 2: Change SP Value 3: PID/Manual control 4: Switch to Programmable Hold Mode
PV Control Mode Selection (N/A)	R/W	111F	44384	Values: 0 - 3 0: PID 1: ON/OFF 2: Manual Control 3: Fuzzy
'CtRS' (3-06) SP Control Mode Selection	R/W	1120	44385	Values: 0 - 3 0: Constant SP 1: Slope Increase 2: Programmable Input 3: Remote Input (N/A)
Remote Compensation Adjust (N/A)	R/W	1121	44386	Range: -999 - 999
Remote Gain Adjust (N/A)	R/W	1122	44387	Range: -999 - 999
Positive/Reverse Remote Selection (N/A)	R/W	1123	44388	Values: 0 - 1 0: Forward 1: Reverse
Slope Time Unit	R/W	1124	44389	Values: 0 - 1 0: Minutes 1: Seconds
Cold Junction Compensation	R/W	1125	44390	Values: 0 - 1 0: Enabled 1: Disabled
Resume the Program Status when Power OFF	R/W	1126	44391	Values: 0 - 1 0: None 1: Running status is saved and will continue from previous status when powered ON

Table F.1 Modbus Holding Register Table (Continued)

Parameter Name	R/W	Hex Address	Decimal Address	Address Values/Notes
'FZ-R' Fuzzy Gain	R/W	1127	44392	Range: 0 - 10
'FZdb' Fuzzy Deadband	R/W	1128	44393	Range: 0.0 - PB
Save Programmable Settings into Memory	R/W	1129	44394	Values: 0 - 1 0: None 1: Saves the program settings into memory
CT1 Read Value (N/A)	R	1182	44483	Unit: 0.1A
CT2 Read Value (N/A)	R	1183	44484	Unit: 0.1A

Table F.2 Hexadecimal Modbus Holding Registers Table for Pattern/Step Temperature Setpoints

Step Number	Pattern 0	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5	Pattern 6	Pattern 7
0	1200	1220	1240	1260	1280	12A0	12C0	12E0
1	1202	1222	1242	1262	1282	12A2	12C2	12E2
2	1204	1224	1244	1264	1284	12A4	12C4	12E4
3	1206	1226	1246	1266	1286	12A6	12C6	12E6
4	1208	1228	1248	1268	1288	12A8	12C8	12E8
5	120A	122A	124A	126A	128A	12AA	12CA	12EA
6	120C	122C	124C	126C	128C	12AC	12CC	12EC
7	120E	122E	124E	126E	128E	12AE	12CE	12EE
8	1210	1230	1250	1270	1290	12B0	12D0	12F0
9	1212	1232	1252	1272	1292	12B2	12D2	12F2
10	1214	1234	1254	1274	1294	12B4	12D4	12F4
11	1216	1236	1256	1276	1296	12B6	12D6	12F6
12	1218	1238	1258	1278	1298	12B8	12D8	12F8
13	121A	123A	125A	127A	129A	12BA	12DA	12FA
14	121C	123C	125C	127C	129C	12BC	12DC	12FC
15	121E	123E	125E	127E	129E	12BE	12DE	12FE
Step Number	Pattern 8	Pattern 9	Pattern 10 (xA)	Pattern 11 (xB)	Pattern 12 (xC)	Pattern 13 (xD)	Pattern 14 (xE)	Pattern 15 (xF)
0	1300	1320	1340	1360	1380	13A0	13C0	13E0
1	1302	1322	1342	1362	1382	13A2	13C2	13E2
2	1304	1324	1344	1364	1384	13A4	13C4	13E4
3	1306	1326	1346	1366	1386	13A6	13C6	13E6
4	1308	1328	1348	1368	1388	13A8	13C8	13E8
5	130A	132A	134A	136A	138A	13AA	13CA	13EA
6	130C	132C	134C	136C	138C	13AC	13CC	13EC
7	130E	132E	134E	136E	138E	13AE	13CE	13EE
8	1310	1330	1350	1370	1390	13B0	13D0	13F0
9	1312	1332	1352	1372	1392	13B2	13D2	13F2
10	1314	1334	1354	1374	1394	13B4	13D4	13F4
11	1316	1336	1356	1376	1396	13B6	13D6	13F6
12	1318	1338	1358	1378	1398	13B8	13D8	13F8
13	131A	133A	135A	137A	139A	13BA	13DA	13FA
14	131C	133C	135C	137C	139C	13BC	13DC	13FC
15	131E	133E	135E	137E	139E	13BE	13DE	13FE

Table F.2 Decimal Modbus Holding Registers Table for Pattern/Step Temperature Setpoints

Step Number	*Pattern 0*	*Pattern 1*	*Pattern 2*	*Pattern 3*	*Pattern 4*	*Pattern 5*	*Pattern 6*	*Pattern 7*
0	*44609*	*44641*	*44673*	*44705*	*44737*	*44769*	*44801*	*44833*
1	*44611*	*44643*	*44675*	*44707*	*44739*	*44771*	*44803*	*44835*
2	*44613*	*44645*	*44677*	*44709*	*44741*	*44773*	*44805*	*44837*
3	*44615*	*44647*	*44679*	*44711*	*44743*	*44775*	*44807*	*44839*
4	*44617*	*44649*	*44681*	*44713*	*44745*	*44777*	*44809*	*44841*
5	*44619*	*44651*	*44683*	*44715*	*44747*	*44779*	*44811*	*44843*
6	*44621*	*44653*	*44685*	*44717*	*44749*	*44781*	*44813*	*44845*
7	*44623*	*44655*	*44687*	*44719*	*44751*	*44783*	*44815*	*44847*
8	*44625*	*44657*	*44689*	*44721*	*44753*	*44785*	*44817*	*44849*
9	*44627*	*44659*	*44691*	*44723*	*44755*	*44787*	*44819*	*44851*
10	*44629*	*44661*	*44693*	*44725*	*44757*	*44789*	*44821*	*44853*
11	*44631*	*44663*	*44695*	*44727*	*44759*	*44791*	*44823*	*44855*
12	*44633*	*44665*	*44697*	*44729*	*44761*	*44793*	*44825*	*44857*
13	*44635*	*44667*	*44699*	*44731*	*44763*	*44795*	*44827*	*44859*
14	*44637*	*44669*	*44701*	*44733*	*44765*	*44797*	*44829*	*44861*
15	*44639*	*44671*	*44703*	*44735*	*44767*	*44799*	*44831*	*44863*
Step Number	*Pattern 8*	*Pattern 9*	*Pattern 10 (xA)*	*Pattern 11 (xB)*	*Pattern 12 (xC)*	*Pattern 13 (xD)*	*Pattern 14 (xE)*	*Pattern 15 (xF)*
0	*44865*	*44897*	*44929*	*44961*	*44993*	*45025*	*45057*	*45089*
1	*44867*	*44899*	*44931*	*44963*	*44995*	*45027*	*45059*	*45091*
2	*44869*	*44901*	*44933*	*44965*	*44997*	*45029*	*45061*	*45093*
3	*44871*	*44903*	*44935*	*44967*	*44999*	*45031*	*45063*	*45095*
4	*44873*	*44905*	*44937*	*44969*	*45001*	*45033*	*45065*	*45097*
5	*44875*	*44907*	*44939*	*44971*	*45003*	*45035*	*45067*	*45099*
6	*44877*	*44909*	*44941*	*44973*	*45005*	*45037*	*45069*	*45101*
7	*44879*	*44911*	*44943*	*44975*	*45007*	*45039*	*45071*	*45103*
8	*44881*	*44913*	*44945*	*44977*	*45009*	*45041*	*45073*	*45105*
9	*44883*	*44915*	*44947*	*44979*	*45011*	*45043*	*45075*	*45107*
10	*44885*	*44917*	*44949*	*44981*	*45013*	*45045*	*45077*	*45109*
11	*44887*	*44919*	*44951*	*44983*	*45015*	*45047*	*45079*	*45111*
12	*44889*	*44921*	*44953*	*44985*	*45017*	*45049*	*45081*	*45113*
13	*44891*	*44923*	*44955*	*44987*	*45019*	*45051*	*45083*	*45115*
14	*44893*	*44925*	*44957*	*44989*	*45021*	*45053*	*45085*	*45117*
15	*44895*	*44927*	*44959*	*44991*	*45023*	*45055*	*45087*	*45119*

Table F.3 Hexadecimal Modbus Holding Registers Table for Pattern/Step Execution Times

Step Number	Pattern 0	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5	Pattern 6	Pattern 7
0	1201	1221	1241	1261	1281	12A1	12C1	12E1
1	1203	1223	1243	1263	1283	12A3	12C3	12E3
2	1205	1225	1245	1265	1285	12A5	12C5	12E5
3	1207	1227	1247	1267	1287	12A7	12C7	12E7
4	1209	1229	1249	1269	1289	12A9	12C9	12E9
5	120B	122B	124B	126B	128B	12AB	12CB	12EB
6	120D	122D	124D	126D	128D	12AD	12CD	12ED
7	120F	122F	124F	126F	128F	12AF	12CF	12EF
8	1211	1231	1251	1271	1291	12B1	12D1	12F1
9	1213	1233	1253	1273	1293	12B3	12D3	12F3
10	1215	1235	1255	1275	1295	12B5	12D5	12F5
11	1217	1237	1257	1277	1297	12B7	12D7	12F7
12	1219	1239	1259	1279	1299	12B9	12D9	12F9
13	121B	123B	125B	127B	129B	12BB	12DB	12FB
14	121D	123D	125D	127D	129D	12BD	12DD	12FD
15	121F	123F	125F	127F	129F	12BF	12DF	12FF
Step Number	Pattern 8	Pattern 9	Pattern 10 (xA)	Pattern 11 (xB)	Pattern 12 (xC)	Pattern 13 (xD)	Pattern 14 (xE)	Pattern 15 (xF)
0	1301	1321	1341	1361	1381	13A1	13C1	13E1
1	1303	1323	1343	1363	1383	13A3	13C3	13E3
2	1305	1325	1345	1365	1385	13A5	13C5	13E5
3	1307	1327	1347	1367	1387	13A7	13C7	13E7
4	1309	1329	1349	1369	1389	13A9	13C9	13E9
5	130B	132B	134B	136B	138B	13AB	13CB	13EB
6	130D	132D	134D	136D	138D	13AD	13CD	13ED
7	130F	132F	134F	136F	138F	13AF	13CF	13EF
8	1311	1331	1351	1371	1391	13B1	13D1	13F1
9	1313	1333	1353	1373	1393	13B3	13D3	13F3
10	1315	1335	1355	1375	1395	13B5	13D5	13F5
11	1317	1337	1357	1377	1397	13B7	13D7	13F7
12	1319	1339	1359	1379	1399	13B9	13D9	13F9
13	131B	133B	135B	137B	139B	13BB	13DB	13FB
14	131D	133D	135D	137D	139D	13BD	13DD	13FD
15	131F	133F	135F	137F	139F	13BF	13DF	13FF

Table F.3 Hexadecimal Modbus Holding Registers Table for Pattern/Step Execution Times

Step Number	Pattern 0	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5	Pattern 6	Pattern 7
0	44610	44642	44674	44706	44738	44770	44802	44834
1	44612	44644	44676	44708	44740	44772	44804	44836
2	44614	44646	44678	44710	44742	44774	44806	44838
3	44616	44648	44680	44712	44744	44776	44808	44840
4	44618	44650	44682	44714	44746	44778	44810	44842
5	44620	44652	44684	44716	44748	44780	44812	44844
6	44622	44654	44686	44718	44750	44782	44814	44846
7	44624	44656	44688	44720	44752	44784	44816	44848
8	44626	44658	44690	44722	44754	44786	44818	44850
9	44628	44660	44692	44724	44756	44788	44820	44852
10	44630	44662	44694	44726	44758	44790	44822	44854
11	44632	44664	44696	44728	44760	44792	44824	44856
12	44634	44666	44698	44730	44762	44794	44826	44858
13	44636	44668	44700	44732	44764	44796	44828	44860
14	44638	44670	44702	44734	44766	44798	44830	44862
15	44640	44672	44704	44736	44768	44800	44832	44864
Step Number	Pattern 8	Pattern 9	Pattern 10 (xA)	Pattern 11 (xB)	Pattern 12 (xC)	Pattern 13 (xD)	Pattern 14 (xE)	Pattern 15 (xF)
0	44866	44898	44930	44962	44994	45026	45058	45090
1	44868	44900	44932	44964	44996	45028	45060	45092
2	44870	44902	44934	44966	44998	45030	45062	45094
3	44872	44904	44936	44968	45000	45032	45064	45096
4	44874	44906	44938	44970	45002	45034	45066	45098
5	44876	44908	44940	44972	45004	45036	45068	45100
6	44878	44910	44942	44974	45006	45038	45070	45102
7	44880	44912	44944	44976	45008	45040	45072	45104
8	44882	44914	44946	44978	45010	45042	45074	45106
9	44884	44916	44948	44980	45012	45044	45076	45108
10	44886	44918	44950	44982	45014	45046	45078	45110
11	44888	44920	44952	44984	45016	45048	45080	45112
12	44890	44922	44954	44986	45018	45050	45082	45114
13	44892	44924	44956	44988	45020	45052	45084	45116
14	44894	44926	44958	44990	45022	45054	45086	45118
15	44896	44928	44960	44992	45024	45056	45088	45120

Table F.4 Modbus Holding Register Table for Pattern Control Parameters

	Last Step Number		Additional Cycles		Next Pattern Number	
Pattern Number	Hex Address	Decimal Address	Hex Address	Decimal Address	Hex Address	Decimal Address
0	1400	45121	1410	45137	1420	45153
1	1401	45122	1411	45138	1421	45154
2	1402	45123	1412	45139	1422	45155
3	1403	45124	1413	45140	1423	45156
4	1404	45125	1414	45141	1424	45157
5	1405	45126	1415	45142	1425	45158
6	1406	45127	1416	45143	1426	45159
7	1407	45128	1417	45144	1427	45160
8	1408	45129	1418	45145	1428	45161
9	1409	45130	1419	45146	1429	45162
10	140A	45131	141A	45147	142A	45163
11	140B	45132	141B	45148	142B	45164
12	140C	45133	141C	45149	142C	45165
13	140D	45134	141D	45150	142D	45166
14	140E	45135	141E	45151	142E	45167
15	140F	45136	141F	45152	142F	45168

Appendix G: Main Branch Fuse Sizing Tables

Figure G.1 Main Branch Fusing Diagram (ISPA-120-1P-15A)

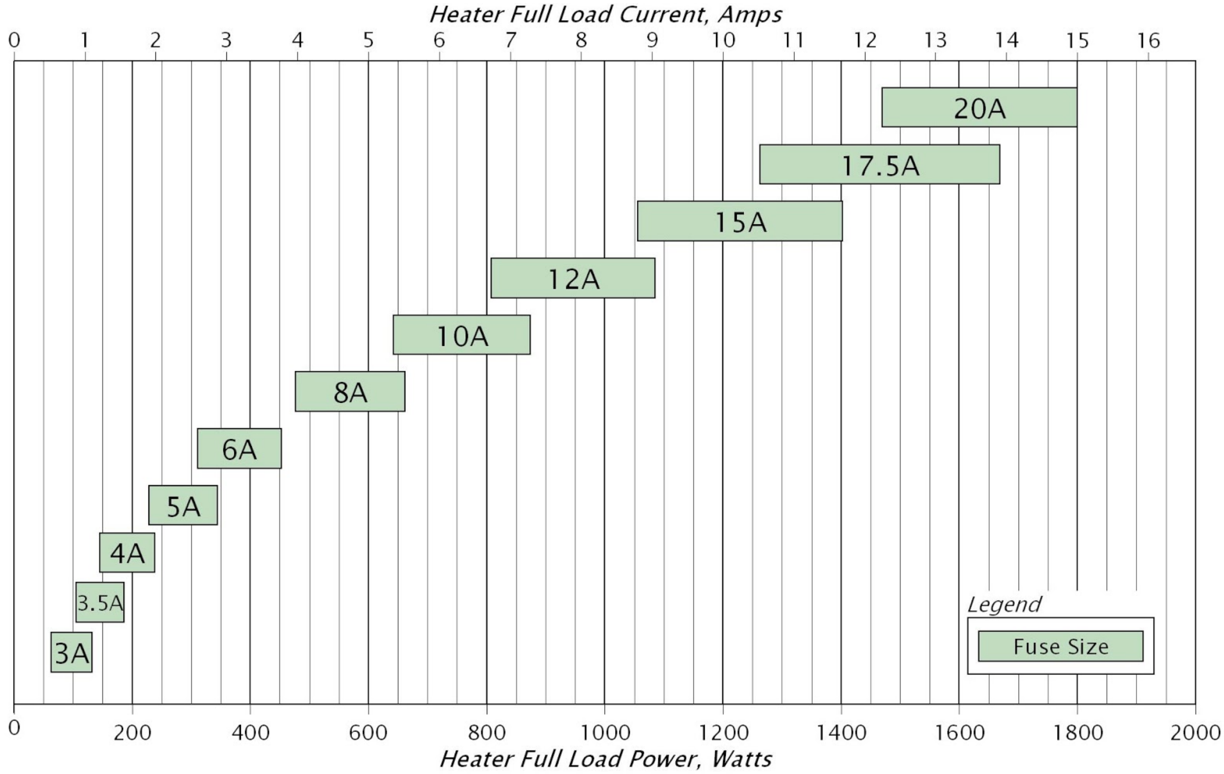


Table G.1 Main Branch Fusing Table (ISPA-120-1P-15A)

		Fuse Size												
		2A	2.5A	3A	3.5A	4A	5A	6A	8A	10A	12A	15A	17.5A	20A
Power, Watts	Min	150	188	225	263	300	375	450	600	750	900	1125	1313	1500
	Max	192	240	288	336	384	480	576	768	960	1152	1440	1680	1800
FLA, Amps	Min	1.25	1.56	1.88	2.19	2.50	3.13	3.75	5.00	6.25	7.50	9.38	10.94	12.50
	Max	1.60	2.00	2.40	2.80	3.20	4.00	4.80	6.40	8.00	9.60	12.0	14.0	15.0

Figure G.2 Main Branch Fusing Diagram (IFPA-120-1P-35A)

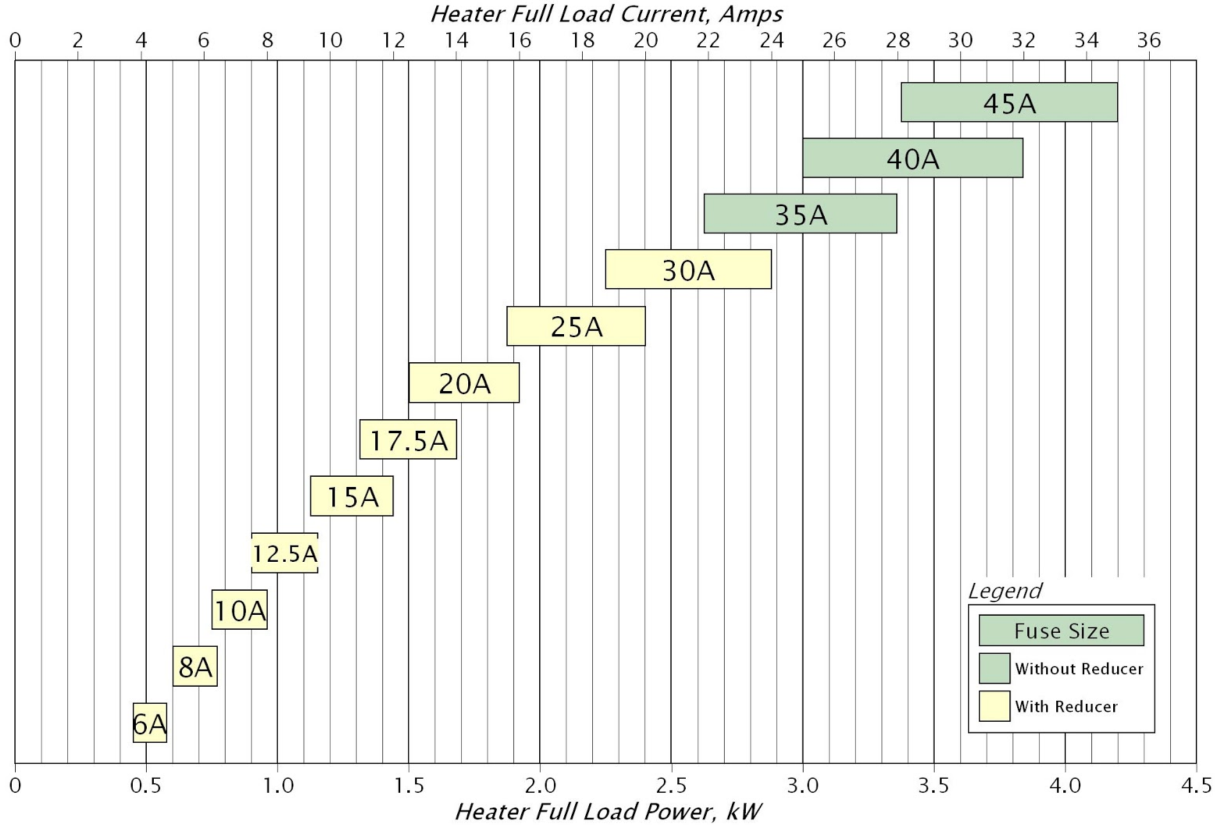


Table G.2 Main Branch Fusing Table (IFPA-120-1P-35A)

		Fuse Size												
		Littlefuse ® LRUJ63 Fuse Reducers Required for 1-30A Fuses										No Fuse Reducers		
		5A	6A	8A	10A	12A	15A	17.5A	20A	25A	30A	35A	40A	45A
Power, kW	Min	0.38	0.45	0.60	0.75	0.90	1.13	1.31	1.50	1.88	2.25	2.63	3.00	3.38
	Max	0.48	0.58	0.77	0.96	1.15	1.44	1.68	1.92	2.40	2.88	3.36	3.84	4.20
FLA, Amps	Min	3.13	3.75	5.00	6.25	7.50	9.38	10.9	12.5	15.6	18.8	21.9	25.0	28.1
	Max	4.00	4.80	6.40	8.00	9.60	12.0	14.0	16.0	20.0	24.0	28.0	32.0	35.0

Figure G.3 Main Branch Fusing Diagram (IFPA-208-1P-35A)

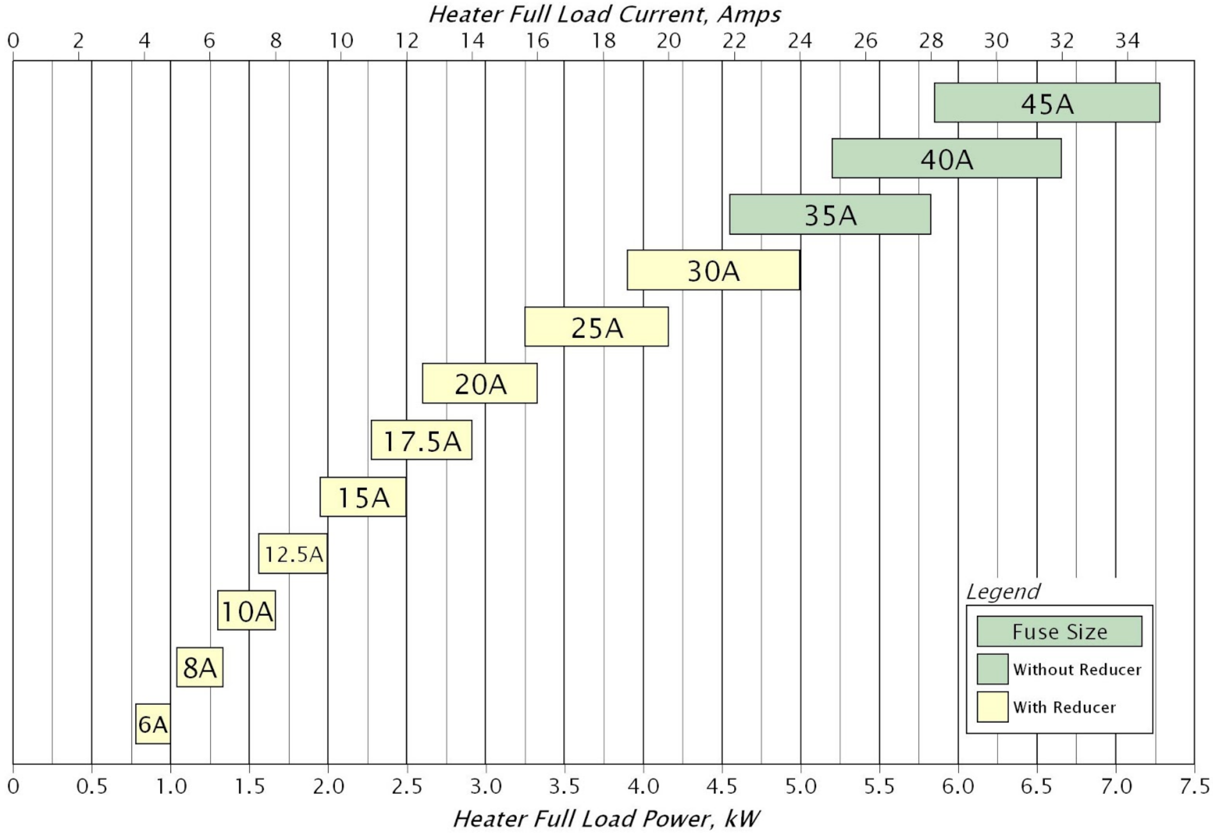


Table G.3 Main Branch Fusing Table (IFPA-208-1P-35A)

		Fuse Size												
		Littlefuse ® LRUJ63 Fuse Reducers Required for 1-30A Fuses										No Fuse Reducers		
		5A	6A	8A	10A	12A	15A	17.5A	20A	25A	30A	35A	40A	45A
Power, kW	Min	0.65	0.78	1.04	1.30	1.56	1.95	2.28	2.60	3.25	3.90	4.55	5.20	5.85
	Max	0.83	1.00	1.33	1.66	2.00	2.50	2.91	3.33	4.16	4.99	5.82	6.66	7.28
FLA, Amps	Min	3.13	3.75	5.00	6.25	7.50	9.38	10.9	12.5	15.6	18.8	21.9	25.0	28.1
	Max	4.00	4.80	6.40	8.00	9.60	12.0	14.0	16.0	20.0	24.0	28.0	32.0	35.0

Figure G.4 Main Branch Fusing Diagram (IFPA-240-1P-35A)

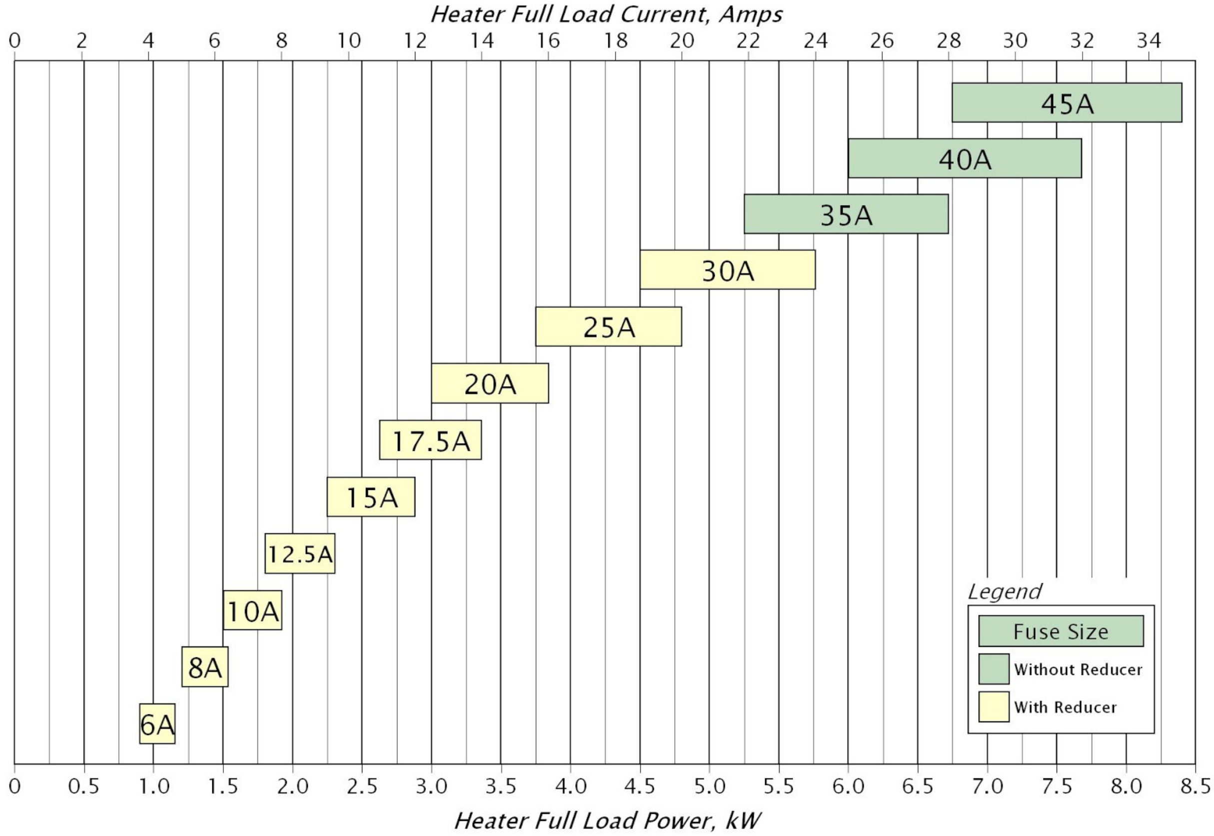


Table G.4 Main Branch Fusing Table (IFPA-240-1P-35A)

		Fuse Size												
		Littlefuse ® LRUJ63 Fuse Reducers Required for 1-30A Fuses										No Fuse Reducers		
		5A	6A	8A	10A	12A	15A	17.5A	20A	25A	30A	35A	40A	45A
Power, kW	Min	0.75	0.90	1.20	1.50	1.80	2.25	2.63	3.00	3.75	4.50	5.25	6.00	6.75
	Max	0.96	1.15	1.54	1.92	2.30	2.88	3.36	3.84	4.80	5.76	6.72	7.68	8.40
FLA, Amps	Min	3.13	3.75	5.00	6.25	7.50	9.38	10.9	12.5	15.6	18.8	21.9	25.0	28.1
	Max	4.00	4.80	6.40	8.00	9.60	12.0	14.0	16.0	20.0	24.0	28.0	32.0	35.0

Figure G.5 Main Branch Fusing Diagram (IFPA-480-1P-35A)

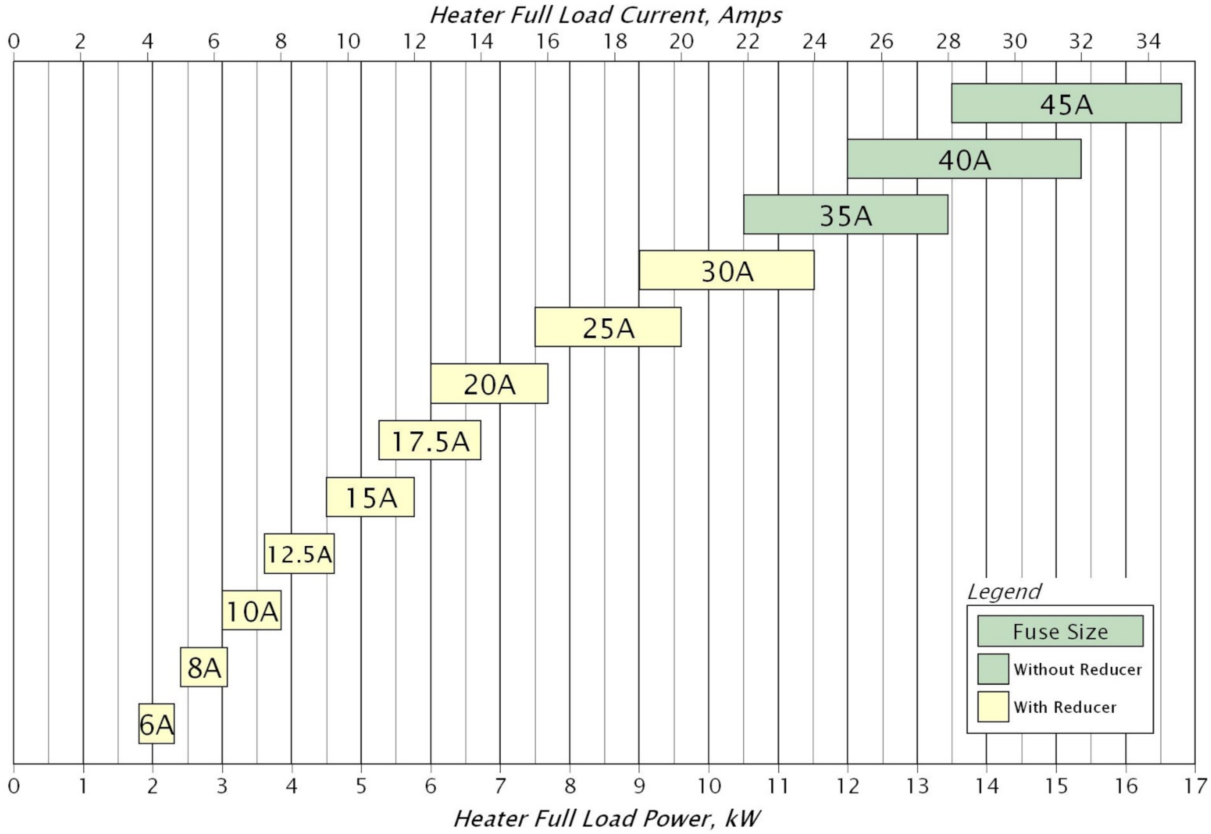


Table G.5 Main Branch Fusing Table (IFPA-480-1P-35A)

		Fuse Size												
		Littlefuse ® LRUJ63 Fuse Reducers Required for 1-30A Fuses										No Fuse Reducers		
		5A	6A	8A	10A	12A	15A	17.5A	20A	25A	30A	35A	40A	45A
Power, kW	Min	1.50	1.80	2.40	3.00	3.60	4.50	5.25	6.00	7.50	9.00	10.5	12.0	13.5
	Max	1.92	2.30	3.07	3.84	4.61	5.76	6.72	7.68	9.60	11.5	13.4	15.4	16.8
FLA, Amps	Min	3.13	3.75	5.00	6.25	7.50	9.38	10.9	12.5	15.6	18.8	21.9	25.0	28.1
	Max	4.00	4.80	6.40	8.00	9.60	12.0	14.0	16.0	20.0	24.0	28.0	32.0	35.0

Figure G.6 Main Branch Fusing Diagram (IFPA-208-3P-24A)

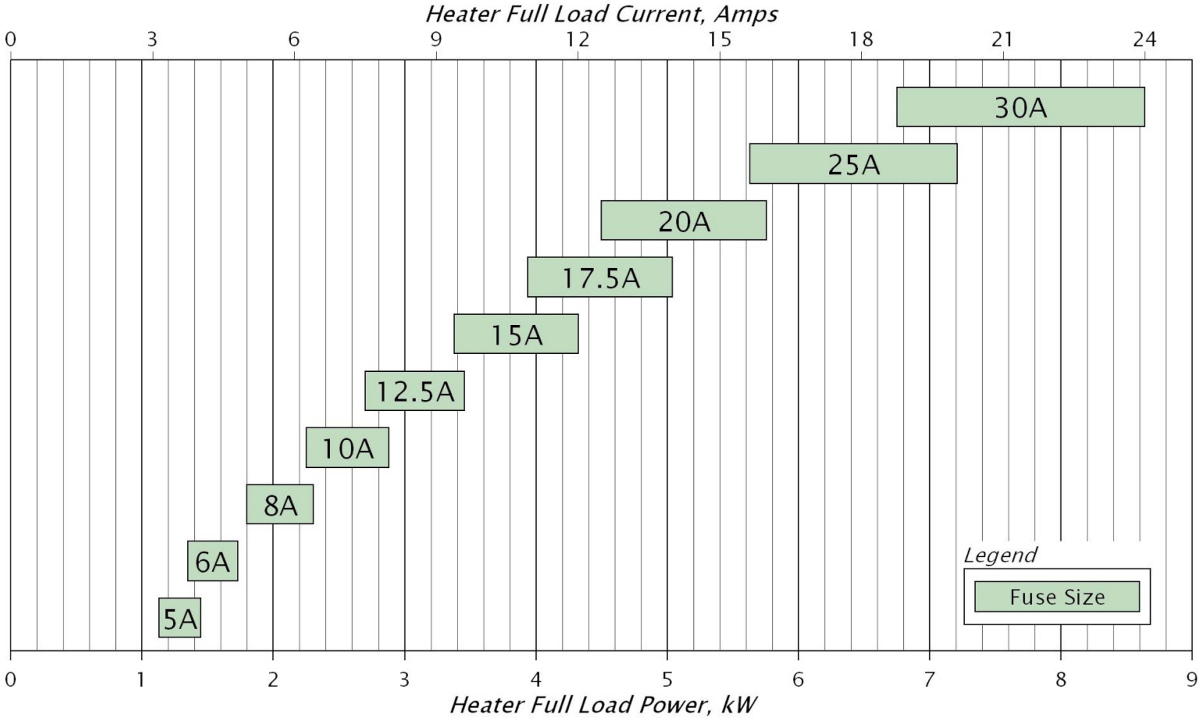


Table G.6 Main Branch Fusing Table (IFPA-208-3P-24A)

		Fuse Size									
		5A	6A	8A	10A	12A	15A	17.5A	20A	25A	30A
Power, kW	Min	1.13	1.35	1.80	2.25	2.70	3.38	3.94	4.50	5.63	6.75
	Max	1.44	1.73	2.31	2.88	3.46	4.32	5.04	5.76	7.21	8.65
FLA, Amps	Min	3.13	3.75	5.00	6.25	7.50	9.38	10.9	12.5	15.6	18.8
	Max	4.00	4.80	6.40	8.00	9.60	12.0	14.0	16.0	20.0	24.0

Figure G.7 Main Branch Fusing Diagram (IFPA-480-3P-24A)

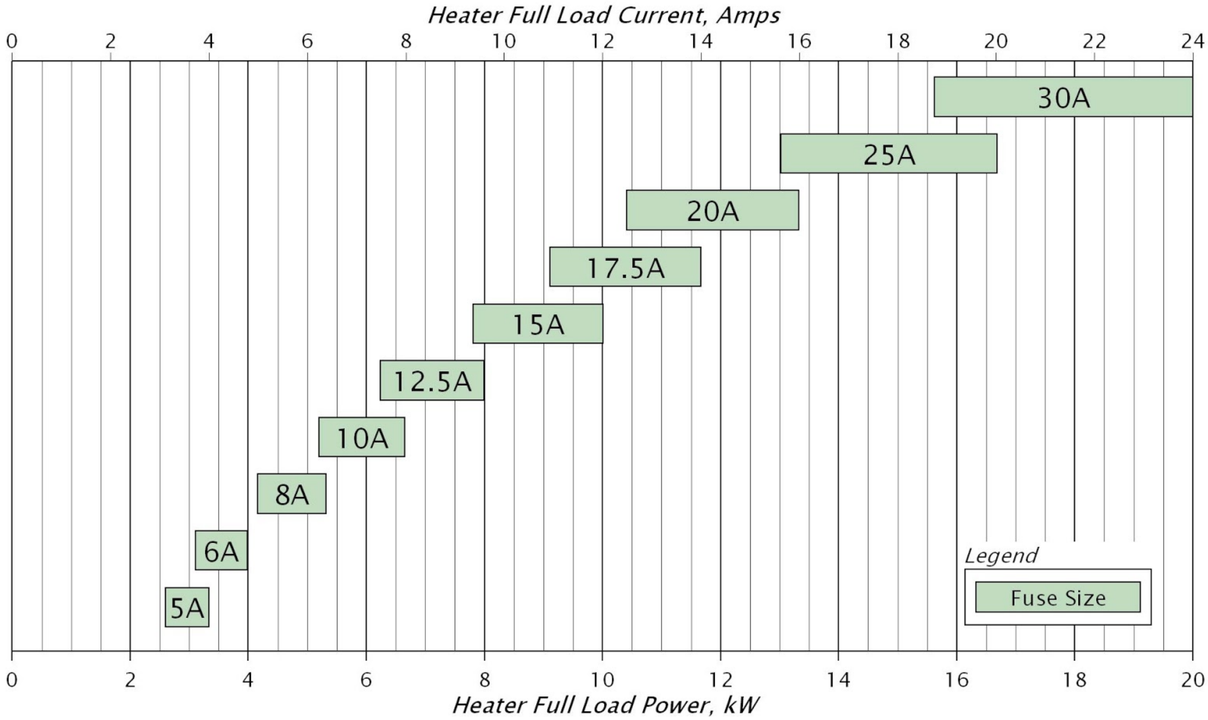


Table G.7 Main Branch Fusing Table (IFPA-480-3P-24A)

		Fuse Size									
		5A	6A	8A	10A	12A	15A	17.5A	20A	25A	30A
Power, kW	Min	2.60	3.12	4.16	5.20	6.24	7.79	9.09	10.4	13.0	15.6
	Max	3.33	3.99	5.32	6.65	7.98	9.98	11.6	13.3	16.6	20.0
FLA, Amps	Min	3.13	3.75	5.00	6.25	7.50	9.38	10.9	12.5	15.6	18.8
	Max	4.00	4.80	6.40	8.00	9.60	12.0	14.0	16.0	20.0	24.0

Figure G.8 Main Branch Fusing Diagram (IFPA-208-3P-64A)

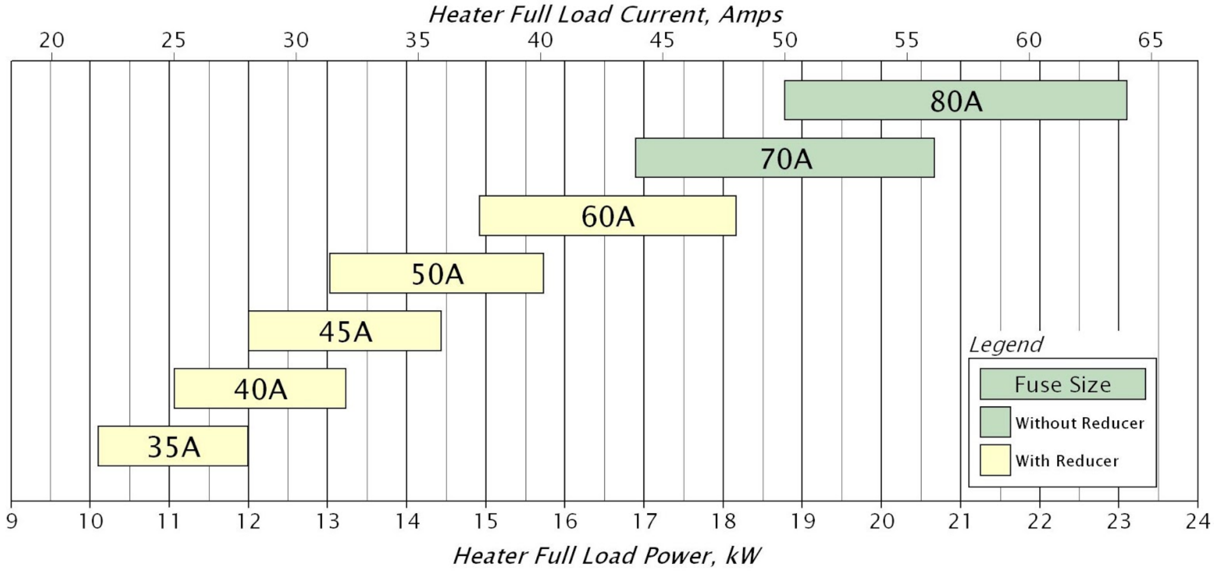


Table G.8 Main Branch Fusing Table (IFPA-208-3P-64A)

		Fuse Size						
		Littlefuse ® LRUJ16 Fuse Reducers Required for 35-60A Fuses					No Fuse Reducers	
		35A	40A	45A	50A	60A	70A	80A
Power, kW	Min	7.88	9.01	10.1	11.3	13.5	15.8	18.0
	Max	10.1	11.5	13.0	14.4	17.3	20.2	23.1
FLA, Amps	Min	21.9	25.0	28.1	31.3	37.5	43.8	50.0
	Max	28.0	32.0	36.0	40.0	48.0	56.0	64.0

Figure G.9 Main Branch Fusing Diagram (IFPA-480-3P-64A)

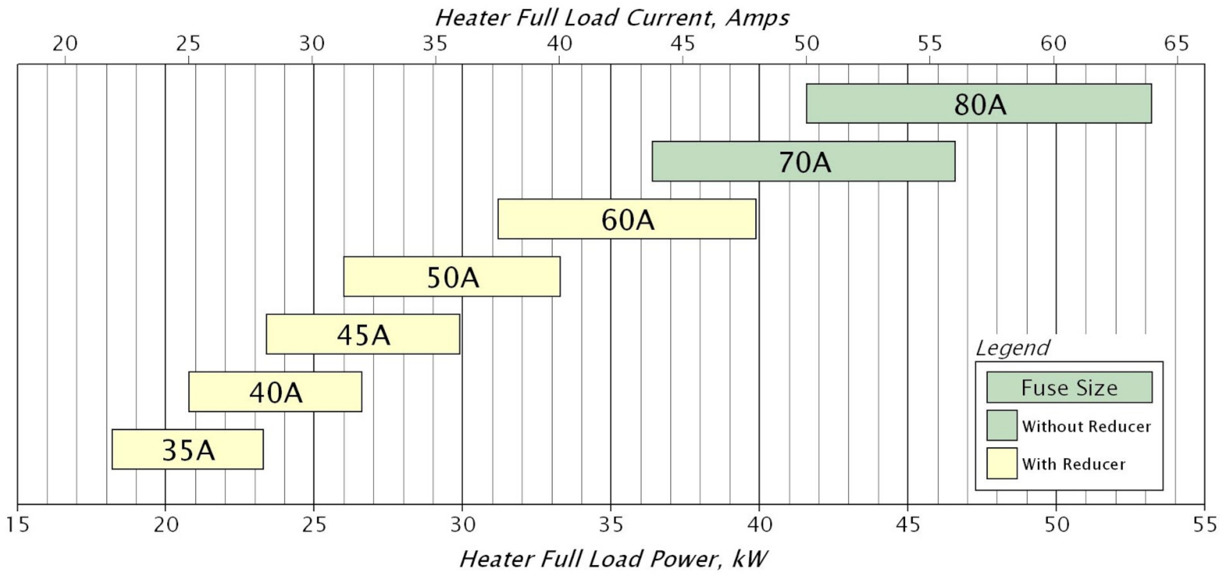


Table G.9 Main Branch Fusing Table (IFPA-480-3P-64A)

		Fuse Size						
		Littlefuse ® LRUJ16 Fuse Reducers Required for 35-60A Fuses					No Fuse Reducers	
		35A	40A	45A	50A	60A	70A	80A
Power, kW	Min	18.2	20.8	23.4	26.0	31.2	36.4	41.6
	Max	23.3	26.6	29.9	33.3	39.9	46.6	53.2
FLA, Amps	Min	21.9	25.0	28.1	31.3	37.5	43.8	50.0
	Max	28.0	32.0	36.0	40.0	48.0	56.0	64.0