TBC-41
Board PID Temperature Controller
Warning Symbol ⚠️
This symbol calls attention to an operating procedure or practice, which if not correctly performed, could result in personal injury or damage to or destruction of part or all of the product and system. Do not proceed beyond a warning symbol until the indicated conditions are fully understood and met.

Using the Manual
- Installers ........................................ Read Chapter 1, 2
- System Designer ............................. Read All Chapters
- Expert User ............................... Read Chapter 3

Contents

Chapter 1 Overview
1-1 General ........................................ 1
1-2 Ordering Code ............................ 2
1-3 Programming Port ......................... 2
1-4 Keys and Displays ......................... 3
1-5 Menu Overview ................................ 4
1-6 Parameter Table ............................ 5

Chapter 2 Installation
2-1 Unpacking ..................................... 7
2-2 Mounting ...................................... 7
2-3 Wiring Precautions ......................... 10
2-4 Power Wiring .................................. 10
2-5 Sensor Installation Guidelines .......... 11
2-6 Sensor Input Wiring ......................... 11
2-7 Control Output Wiring ..................... 12
2-8 Alarm Wiring .................................. 13
2-9 Data Communication ....................... 14

Chapter 3 Programming
3-1 Lockout ....................................... 15
3-2 Signal Input .................................. 15
3-3 Control Outputs .......................... 15
3-4 Alarm .......................................... 17
3-5 Configure User Menu ................. 18
3-6 Ramp ........................................... 18
3-7 Dwell Timer ................................. 18
3-8 PV Shift ........................................ 19
3-9 Digital Filter .................................. 19
3-10 Failure Transfer ......................... 19
3-11 Auto-tuning ................................. 20
3-12 Manual tuning ............................ 20
3-13 Manual Control ......................... 21
3-14 Data communication .................... 21
3-15 Process Variable (PV) Retransmission 21

Chapter 4 Applications
4-1 Heat Only Control With Dwell Timer 22
4-2 Cool Only Control ......................... 22
4-3 Heat-Cool Control ......................... 23

Chapter 5 Calibration .................. 24

Chapter 6 Specifications .......... 26

Chapter 7 Modbus Communications
7-1 Functions Supported ....................... 28
7-2 Exception Responses .................... 29
7-3 Parameter Table .......................... 29
7-4 Data Conversion .......................... 31
7-5 Communication Examples ................ 32

Appendix
A-1 Error Codes ................................ 33
A-2 Warranty .................................... 34

Figures & Tables

Figure 1.1 Fuzzy Control Advantage .......... 1
Figure 1.2 Programming Port Overview .... 2
Figure 1.3 Front Panel Description .......... 3
Figure 1.4 Display in Initial Stage .......... 3
Figure 1.5 Dimensions of Control Board .... 8
Figure 1.6 Dimensions of Display Board .... 9
Figure 2.1 RTD Calibration ................. 10
Figure 2.2 Power Supply Connections .... 10
Figure 2.3 Dimensions of Mounting Plate for Display Board 9
Figure 2.4 Lead Termination ................. 12
Figure 2.5 Terminal Connection .......... 12
Figure 2.6 Sensor Input Wiring ............ 11
Figure 2.7 Output 1 Relay or Triac (SSR) to Drive Load .12
Figure 2.8 Output 1 Relay or Triac (SSR) to Drive Contactor 12
Figure 2.9 Output 1 Pulsed Voltage to Drive SSR 12
Figure 2.10 Output 2 Relay or Triac (SSR) to Drive Load ........... 12
Figure 2.11 Output 2 Pulsed Voltage to Drive SSR 12
Figure 2.12 Output 2 Linear Current .... 12
Figure 2.13 Output 2 Linear Voltage .... 12
Figure 2.14 Output 2 Relay or Triac (SSR) to Drive Load 14
Figure 2.15 Output 2 Relay or Triac (SSR) to Drive Contactor 14
Figure 2.16 Output 2 Pulsed Voltage to Drive SSR 13
Figure 2.17 Output 2 Linear Current ..... 13
Figure 2.18 Output 2 Linear Voltage 13
Figure 2.19 Alarm Output to Drive Load 13
Figure 2.20 Alarm Output to Drive Contactor 13
Figure 2.21 RS-485 Wiring ...................... 14
Figure 2.22 RS-232 Wiring ...................... 14
Figure 2.23 Configuration of RS-232 Cable 14
Figure 3.1 Conversion Curve for Linear Type Process Value 15
Figure 3.2 Heat Only ON-OFF Control ..... 16
Figure 3.3 Output 2 Deviation High Alarm 17
Figure 3.4 Output 2 Process Low Alarm .... 17
Figure 3.5 RAMP Function ..................... 18
Figure 3.6 Dwell Timer Function .......... 18
Figure 3.7 PV Shift Application ............ 19
Figure 3.8 Filter Characteristics .......... 19
Figure 3.9 Effects of PID Adjustment .... 20
Figure 4.1 Heat Control Example .......... 23
Figure 4.2 Cooling Control Example .... 23
Figure 4.3 Heat-Cool Control Example .... 24
Figure 5.1 RTD Calibration ................. 25
Figure 5.2 Cold Junction Calibration Setup 26

Table A.1 Error Codes and Corrective Actions 30

Appendix

Returns ........................................ 34

NOTE:
It is strongly recommended that a process should incorporate a LIMIT CONTROL like TEC-910 which will shut down the equipment at a preset process condition in order to preclude possible damage to products or system.

Information in this user's manual is subject to change without notice.

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1–1 General

The Fuzzy Logic plus PID microprocessor-based controllers series incorporate two bright, easy to read 4-digit LED displays, indicating process value and set point value. The Fuzzy Logic technology enables a process to reach a predetermined set point in the shortest time, with a minimum of overshoot during power-up or external load disturbance.

The unit is powered by 11–26 or 90–250 VDC/VAC supply, incorporating a 2 Amp control relay output as standard. The second output can be used as a cooling control, or an alarm. Both outputs can select triac, 5V logic output, linear current or linear voltage to drive an external device. There are six types of alarms plus a dwell timer that can be configured for the third output. The units are fully programmable for PT100 RTD and thermocouple types J, K, T, E, B, R, S, N, and L with no need to modify the unit. The input signal is digitized by using an 18-bit A to D converter. Its fast sampling rate allows the unit to control fast processes.

Digital communications RS-485 or RS-232 are available as an additional option. These options allow the units to be integrated with supervisory control systems and software.

A programming port is available for automatic configuration, calibration, and testing without the need to access the keys on the front panel.

By using proprietary Fuzzy modified PID technology, the control loop will minimize overshoot and undershoot the shortest time. The following diagram is a comparison of results with and without Fuzzy technology.

![Figure 1–1 Fuzzy Control Advantage](image)

---

**High accuracy**

The TBC series controllers are manufactured with custom designed ASIC (Application Specific Integrated Circuit) technology which contain an 18-bit A to D converter for high resolution measurement (true 0.1°F resolution for thermocouple and RTD) and a 15-bit D to A converter for linear current or voltage control output. The ASIC technology provides improved operating performance, low cost, enhanced reliability, and higher density.

**Fast sampling rate**

The sampling rate of the input A to D converter is 5 samples/second. The fast sampling rate allows this series to control fast processes.

**Fuzzy control**

The function of Fuzzy control is to adjust the PID parameters continually in order to make manipulation of the output value more flexible and adaptive to various processes. The result is to enable a process to reach a predetermined set point in the shortest time, with the minimum of overshoot and undershoot during power-up or external load disturbance.

**Digital communication**

An optional RS-485 or RS-232 interface card provides digital communication. By using twisted pair wires there are a maximum of 247 units that can be connected together via RS-485 interface to a host computer.

**Programming port**

A programming port is available to connect the controller to a PC for quick configuration.

**Auto-tune**

The auto-tune function allows the user to simplify initial setup for a new system. An algorithm is provided to obtain an optimal set of control parameters for the process. It can be applied either as the process is warming up (cold start) or if the process has been in a steady state (warm start).

**Lockout protection**

Depending on security requirements, one of four lockout levels can be selected to prevent the unit from being changed without permission.

**Bumpless transfer**

Bumpless transfer allows the controller to continue to control if the sensor breaks by using its previous value as the sensor breaks. Hence, the process can be controlled temporarily as if the sensor is normal.

**Soft-start ramp**

The ramping function is performed during power up as well as set point changes. It can be ramping up or ramping down. The process value will reach the set point at a predetermined constant rate.

**Digital filter**

A first order low pass filter with a programmable time constant is used to improve the stability of the process value. This is particularly useful in certain applications where the process value is too unstable to be read.

**SEL function**

The units have the flexibility to allow the user to select those parameters which are most significant and put these parameters in the front of the display sequence. There are eight parameters which can be selected to allow the user to build their own display sequence.
1–2 Ordering Code

**Power Input**
- 4 = 90-250 VAC (47-63 Hz)
- 5 = 11-26 VAC/VDC

**Signal Input**
- 1 = Thermocouple: J (default), K, T, E, B, R, S, N, L
  - RTD: PT100 DIN
- 2 = 0-60mV
- 3 = 0-1 VDC
- 4 = 0-5 VDC
- 5 = 1-5 VDC
- 6 = 4-20 mA
- 7 = 0-20 mA
- 8 = 0-10 VDC
- 9 = Other

**Output 1**
- 1 = Relay: 2A / 240 VAC
- 2 = Pulse dc for SSR drive: 5 VDC (30 mA max)
- 3 = Isolated, 4-20 mA (default), 0-20 mA
- 4 = Isolated, VDC, 1-5 (default), 0-5
- 5 = Isolated, VDC, 0-10
- 6 = Triac-SSR output 1A / 240 VAC
- C = Pulse dc for SSR drive: 14 VDC (40 mA max)

**Display Board and Cable**
- 0 = None
- 3 = With Display Board and 12" (300 mm) Cable (default)
- Consult Tempco for other cable lengths.

**Communication**
- 0 = None
- 1 = RS-485 Interface
- 2 = RS-232 Interface
- 3 = Retransmission 4-20 mA (default), 0-20 mA
- 4 = Retransmission 1-5 VDC (default), 0-5 VDC
- 5 = Retransmission 0-10 VDC
- 9 = Other

**Alarm**
- 0 = None
- 1 = Relay: 2A / 240 VAC, Form C

**Output 2**
- 0 = None
- 1 = Relay: 2A / 240 VAC Form A
- 2 = Pulse dc for SSR drive: 5 VDC (30 mA max)
- 3 = Isolated, 4-20 mA (default), 0-20 mA
- 4 = Isolated VDC, 1-5 (default), 0-5
- 5 = Isolated VDC, 0-10
- 6 = Triac-SSR output 1A / 240 VAC
- 7 = Isolated 24V @ 25 mA DC, Output Power Supply
- 8 = Isolated 12V @ 40 mA DC, Output Power Supply
- 9 = Isolated 5V @ 80 mA DC, Output Power Supply
- C = Pulse dc for SSR drive: 14 VDC (40 mA max)

### Accessories
- TEC-101-109 = Isolated 1A / 240VAC Triac Output Module (SSR)
- TEC-101-110 = 14V / 40mA SSR Drive Module
- TEC-101-101 = Isolated 4 - 20 mA / 0 - 20 mA Analog Output Module
- TEC-101-114 = Isolated 1 - 5V / 0 - 5V Analog Output Module
- TEC-101-115 = Isolated 0 -10V Analog Output Module
- TEC-102-101 = Isolated RS-485 Interface Module
- TEC-102-103 = Isolated RS-232 Interface Module
- TEC-102-104 = Isolated 4 - 20 mA / 0 - 20 mA Retrans Module
- TEC-102-105 = Isolated 1 - 5V / 0 - 5V Retrans Module
- TEC-102-106 = Isolated 0-10V Retrans Module
- TEC-101-111 = Isolated 20V/25mA DC Output Power Supply
- TEC-101-112 = Isolated 12V/40mA DC Output Power Supply
- TEC-101-113 = Isolated 5V/80mA DC Output Power Supply
- TEC99014 = RS-232 Interface Cable (2M)

### Related Products
- TEC99001 = Smart Network Adaptor for third party software, which converts 255 channels of RS-485 or RS-422 to RS-232 Network.
- TEC99003 = Smart Network Adapter for programming port to RS-232 interface
- TEMPCO-Set = Free Configuration Software Communicator: PC software to communicate 1024 tags available on Tempco web site (www.tempco.com) in Technical Data Section.

### 1–3 Programming Port

![Figure 1.2 Programming Port Overview](image)

A special connector can be used to access the programming port which is connected to a smart network adaptor TEC99003 and a PC for automatic configuration.

The programming port is used for off-line automatic setup and testing procedures only. Don’t attempt to make any connection to these pins when the unit is powered on.
1-4 Keys and Displays

KEYPAD OPERATION

SCROLL KEY: 
This key is used to select a parameter to be viewed or adjusted.

UP KEY: 
This key is used to increase the value of the selected parameter.

DOWN KEY: 
This key is used to decrease the value of the selected parameter.

RESET KEY: 
This key is used to:
1. Revert the display to show the process value.
2. Reset the latching alarm, once the alarm condition is removed.
3. Stop the manual control mode, auto-tuning mode, and calibration mode.
4. Clear the message of communication error and auto-tuning error.
5. Restart the dwell timer when the dwell timer has timed out.
6. Enter the manual control menu if failure mode occurs.

ENTER KEY: Press for 5 seconds or longer.
Press for 5 seconds to:
1. Enter setup menu. The display shows .
2. Enter manual control mode when [H] is selected.
   Press for 6.2 seconds to select manual control mode.
3. Enter auto-tuning mode when [A-L] is selected.
   Press for 7.4 seconds to select auto-tuning mode.
4. Perform calibration to a selected parameter during the calibration procedure. Press for 8.6 seconds to select calibration mode.

Table 1.1 Display Form of Characters

<table>
<thead>
<tr>
<th>A</th>
<th>R</th>
<th>E</th>
<th>E</th>
<th>I</th>
<th>,</th>
<th>N</th>
<th>n</th>
<th>S</th>
<th>S</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>b</td>
<td>F</td>
<td>F</td>
<td>J</td>
<td>J</td>
<td>O</td>
<td>o</td>
<td>T</td>
<td>t</td>
<td>Y</td>
</tr>
<tr>
<td>C</td>
<td>c</td>
<td>G</td>
<td>G</td>
<td>K</td>
<td>K</td>
<td>P</td>
<td>p</td>
<td>U</td>
<td>U</td>
<td>Z</td>
</tr>
<tr>
<td>D</td>
<td>d</td>
<td>h</td>
<td>h</td>
<td>M</td>
<td>m</td>
<td>R</td>
<td>r</td>
<td>W</td>
<td>W</td>
<td>=</td>
</tr>
</tbody>
</table>

Indicates Abstract Characters

Figure 1.3 Front Panel Description

Figure 1.4 Display of Initial Start-up
Entering these modes will break the control loop and change some of the previously set data. Make sure that the system is able to accept these modes.

*1: This flow chart shows a complete listing of all parameters. For actual application the number of available parameters depends on setup conditions and could be less than that shown in the flow chart.

*2: You can select up to 8 parameters to be placed in the user menu by using SEL1–SEL8 located at the bottom of setup menu.

*3: Release , press again for at least 2 but no more than 3 seconds, then release to access the calibration menu.

The user menu shown in the flow chart corresponds to the default setting for SELECT parameters SEL1 to SEL8. SP3 will be hidden if NONE is selected for ALFN. SP2 will be hidden if the alarm function is not selected for OUT2. An unused parameter will be hidden even if it selected by the SEL parameters.
# 1-6 Parameter Descriptions

<table>
<thead>
<tr>
<th>Parameter Notation</th>
<th>Parameter Description (Refer to Page)</th>
<th>Range</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SP1</strong> or <strong>SP1</strong></td>
<td>Set point for output 1</td>
<td>Low: SP1 Low, High: SP1 High</td>
<td>25°C (77°F)</td>
</tr>
<tr>
<td><strong>SP2</strong> or <strong>SP2</strong></td>
<td>Set point for output 2 when output 2 performs alarm function</td>
<td>Low: -19999, High: 45536</td>
<td>10°C (50°F)</td>
</tr>
<tr>
<td><strong>SP3</strong> or <strong>SP3</strong></td>
<td>Set point for alarm or dwell timer output</td>
<td>Low: -19999, High: 45536</td>
<td>10°C (50°F)</td>
</tr>
</tbody>
</table>

**Low** LOCK | Select parameters to be locked out 0) **nonE**: No parameters are locked 1) **SEE**: Setup data is locked 2) **wSE**: Setup data and User data except Set point are locked 3) **RLL**: All data is locked |

**nPc** INPT | Input sensor selection 0) **J-EC**: J type thermocouple 1) **E-EC**: K type thermocouple 2) **T-EC**: T type thermocouple 3) **E-EC**: E type thermocouple 4) **B-EC**: B type thermocouple 5) **R-EC**: R type thermocouple 6) **S-EC**: S type thermocouple 7) **N-EC**: N type thermocouple 8) **L-EC**: L type thermocouple 9) **Pd**: PT 100 ohms DIN curve 10) **Pt**: PT 100 ohms JIS curve 11) **4-20**: 4-20 mA linear current input 12) **0-20**: 0-20 mA linear current input 13) **0-60**: 0-60 mV linear millivolt input 14) **0-5V**: 0-1V linear voltage input 15) **0-5V**: 0-5V linear voltage input 16) **1-5V**: 1-5V linear voltage input 17) **0-10V**: 0-10V linear voltage input |

**unit** UNIT | Input unit selection 0) **C**: Degree C unit 1) **F**: Degree F unit 2) **P**: Process unit |

**dP** DP | Decimal point selection 0) **nad**: No decimal point 1) **1-d**: 1 decimal digit 2) **2-d**: 2 decimal digits 3) **3-d**: 3 decimal digits |

**inLo** INLO | Input low scale value (Used with INPT choices 11 to 17 only) Low: -19999, High: 45536 -17.8°C (0°F) |

**inHi** INHI | Input high scale value (Used with INPT choices 11 to 17 only) Low: INLO+50, High: 45536 93.3°C (200.0°F) |

**SPIL** SPIL | Low limit of set point value Low: -19999, High: 45536 -17.8°C (0°F) |

**SPILH** SPILH | High limit of set point value Low: SPIL Low, High: 45536 538°C (1000°F) |

**SHF** SHIF | PV shift (offset) value Low: -200.0°C (-360.0°F), High: 200.0°C (360.0°F) 0.0 |

**Fil** FILT | Filter damping time constant of PV 0) **Q**: 0 second time constant 1) **Q**: 0.2 second time constant 2) **Q**: 0.5 second time constant 3) **L**: 1 second time constant 4) **L**: 2 seconds time constant 5) **L**: 5 seconds time constant 6) **Q**: 10 seconds time constant 7) **Q**: 20 seconds time constant 8) **Q**: 30 seconds time constant 9) **Q**: 60 seconds time constant 2 |

<table>
<thead>
<tr>
<th>Parameter Notation</th>
<th>Parameter Description (Refer to Page)</th>
<th>Range</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ps</strong> PB</td>
<td>Proportional band value Low: 0, High: 500°C (900.0°F) 10°C (18.0°F)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Tr** | Integral time value Low: 0, High: 3600 sec 100 |

**Td** | Derivative time value Low: 0, High: 360.0 sec 25.0 |

**.OUT1** | Output 1 function 0) **rEY**: Reverse (heating) control action 1) **rE**: Direct (cooling) control action |

**.OUT1** | Output 1 signal type 0) **rELY**: Relay output 1) **SSrd**: Solid state relay drive output 2) **SSr**: Solid state relay output 3) **4-20**: 4-20 mA DC 4) **0-20**: 0-20 mA DC 5) **0-1**: 0-1 V DC 6) **0-5V**: 0-5 V DC 7) **1-5V**: 1-5 V DC 8) **0-10V**: 0-10 V DC |

**.OUT1** | Output 1 failure transfer mode Select BPLS (bumblepless transfer) or 0.0 - 100.0% to continue output 1 control function as the unit fails, or select OFF (0) or ON (1) for ON-OFF control. |

**.OUT1** | Output 1 ON-OFF hysteresis only functional if PB=0 Low: 0.1, High: 50.0°C (90°F) 0.1°C (0.2°F) |

**CYC1** CYC1 | Output 1 cycle time Low: 0.1, High: 90 sec, 0.01 sec, 0.1 sec, 0.5 sec, 1 sec, 5 sec, 10 sec, 100 sec, 1000 sec |

**OFST** OFST | Offset value for P control Low: 0, High: 100.0% 25.0 |

**RMP** RAMP | Ramp function selection 0) **nonE**: No ramp function 1) **nr**: Use unit/minute as Ramp Rate 2) **hr**: Use unit/hour as Ramp Rate |

**RR** RR | Ramp rate Low: 0, High: 500.0°C (900.0°F) 0.0 |

**OUT2** | Output 2 function 0) **nonE**: Output 2 No Function 1) **dEh**: Deviation High 2) **dE**: Deviation Low 3) **Pd**: Process High 4) **P**: Process Low 5) **Cool**: Cooling PID Function |

**OUT2** | Output 2 signal type 0) **rELY**: Relay output 1) **SSrd**: Solid state relay drive output 2) **SSr**: Solid state relay output 3) **4-20**: 4-20 mA DC 4) **0-20**: 0-20 mA DC 5) **0-1**: 0-1 V DC 6) **0-5V**: 0-5 V DC 7) **1-5V**: 1-5 V DC 8) **0-10V**: 0-10 V DC |

**OUT2** | Output 2 failure transfer mode Select BPLS (bumblepless transfer) or 0.0 - 100.0% to continue output 2 control function as the unit fails, or select OFF (0) or ON (1) for alarm function. See Note 2. |

**CYC2** CYC2 | Output 2 cycle time Low: 0.1, High: 90 sec, 0.01 sec, 0.1 sec, 0.5 sec, 1 sec, 5 sec, 10 sec, 100 sec, 1000 sec |

Note 1: Depends on Ordering Code
Note 2: BPLS for Cooling Only
<table>
<thead>
<tr>
<th>Parameter Notation</th>
<th>Parameter Description</th>
<th>Range</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPb CPB</td>
<td>Cooling proportional band value</td>
<td>Low: 50 High: 300%</td>
<td>100</td>
</tr>
<tr>
<td>d DB DB</td>
<td>Heating-cooling deadband (negative value=overlap)</td>
<td>Low: -36.0 High: 36.0%</td>
<td>0</td>
</tr>
<tr>
<td>RLf ALfN</td>
<td>Alarm function for alarm output</td>
<td>0</td>
<td>See Note 1</td>
</tr>
<tr>
<td>RLd ALMD</td>
<td>Alarm operation mode</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>RLH ALHY</td>
<td>Hysteresis control of alarm</td>
<td>Low: 0.1 High: 50.0°C (90.0°F)</td>
<td>0.1°C (0.2°F)</td>
</tr>
<tr>
<td>RLk ALFT</td>
<td>Alarm failure transfer mode</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Coo COMM</td>
<td>Communication function</td>
<td>0</td>
<td>See Note 1</td>
</tr>
<tr>
<td>Addr ADDR</td>
<td>Address assignment for digital communication</td>
<td>Low: 1 High: 255</td>
<td></td>
</tr>
<tr>
<td>b BAUD</td>
<td>Baud rate of digital communication</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter Notation</th>
<th>Parameter Description</th>
<th>Range</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>dB DATA</td>
<td>Data bit count of digital communication</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Pr PARI</td>
<td>Parity bit of digital communication</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SKP STOP</td>
<td>Stop bit count of digital communication</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>rELO REHO</td>
<td>Retransmission low scale value</td>
<td>Low: -19999 High: 45536</td>
<td>0.0°C (32.0°F)</td>
</tr>
<tr>
<td>rEH REHI</td>
<td>Retransmission high scale value</td>
<td>Low: -19999 High: 45536</td>
<td>100.0°C (212.0°F)</td>
</tr>
<tr>
<td>Sel Sel</td>
<td>Select 1st parameter for user menu</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sel2 Sel2</td>
<td>Select 2nd parameter for user menu</td>
<td>Same as Sel1</td>
<td>3</td>
</tr>
<tr>
<td>Sel3 Sel3</td>
<td>Select 3rd parameter for user menu</td>
<td>Same as Sel1</td>
<td>4</td>
</tr>
<tr>
<td>Sel4 Sel4</td>
<td>Select 4th parameter for user menu</td>
<td>Same as Sel1</td>
<td>6</td>
</tr>
<tr>
<td>Sel5 Sel5</td>
<td>Select 5th parameter for user menu</td>
<td>Same as Sel1</td>
<td>7</td>
</tr>
<tr>
<td>Sel6 Sel6</td>
<td>Select 6th parameter for user menu</td>
<td>Same as Sel1</td>
<td>8</td>
</tr>
<tr>
<td>Sel7 Sel7</td>
<td>Select 7th parameter for user menu</td>
<td>Same as Sel1</td>
<td>10</td>
</tr>
<tr>
<td>Sel8 Sel8</td>
<td>Select 8th parameter for user menu</td>
<td>Same as Sel1</td>
<td>17</td>
</tr>
</tbody>
</table>

Note 1: Depends on Ordering Code
Chapter 2 Installation

Dangerous voltages capable of causing death are sometimes present in this instrument. Before installation or beginning any troubleshooting procedures, the power to all equipment must be switched off and isolated. Units suspected of being faulty must be disconnected and removed to a properly equipped workshop for testing and repair. Component replacement and internal adjustments must be made by a qualified maintenance person only.

To minimize the possibility of fire or shock hazards do not expose this instrument to rain or excessive moisture. Do not use this instrument in areas under hazardous conditions such as excessive shock, vibration, dirt, moisture, corrosive gases or oil. The ambient temperature of the area should not exceed the maximum rating specified in chapter 6.

2–1 Unpacking
Upon receipt of the shipment, remove the unit from the carton and inspect the unit for shipping damage. If there is any damage due to transit, report it and file a claim with the carrier. Write down the model number, serial number, and date code for future reference when corresponding with Tempco.

2–2 Mounting
The dimensions of the control board, display board, and the mounting plate for the display board as shown in Figure 2-1 through 2.3 (see pages 8 and 9).
Figure 2–1 Control Board Dimensions (mm)
Figure 2–2 Display Board Dimensions (mm)

Figure 2–3 Mounting Plate for Display Board Dimensions (mm)

Suggested Standoff Height — 8 mm
2–3 Wiring Precautions

- Before wiring, verify the correct model number and options on the label. Switch off the power while checking.
- Care must be taken to ensure that the maximum voltage rating specified on the label is not exceeded.
- It is recommended that the power for these units be protected by fuses or circuit breakers rated at the minimum value possible.
- All units should be installed inside a suitably grounded metal enclosure to prevent live parts from being accessible to human hands and metal tools.
- All wiring must conform to appropriate standards of good practice and local codes and regulations. Wiring must be suitable for the voltage, current, and temperature rating of the system.
- Beware not to over-tighten the terminal screws. The torque should not exceed 1 n-m (8.9 in-lb.)
- Unused control terminals should not be used as jumper points as they may be internally connected, causing damage to the unit.
- Verify that the ratings of the output devices and the inputs as specified in chapter 6 are not exceeded.
- Except for the thermocouple wiring, all wiring should be stranded copper with a maximum gauge of 18 awg.

2–4 Power Wiring

The controller is designed to operate at 11–26 VAC/VDC or 90–250 VAC. Check that the installation voltage corresponds to the power rating indicated on the product label before connecting power to the controller. The controller power input should be equipped with a fuse and switch as shown below in figure 2.7

⚠️ This equipment is designed for installation in an enclosure which provides adequate protection against electric shock. The enclosure must be connected to earth ground. Local requirements regarding electrical installation should be rigidly observed. Consideration should be given to prevent unauthorized personnel from accessing the power terminals.
Proper sensor installation can eliminate many problems in a control system. The probe should be placed so that it can detect any temperature change with minimal thermal lag. In a process that requires fairly constant heat output, the probe should be placed close to the heater. In a process where the heat demand is variable, the probe should be close to the work area. Some experimentation with probe location is often required to find the optimum position.

In a liquid process, the addition of agitation will help to eliminate thermal lag. Since the thermocouple is basically a point measuring device, placing more than one thermocouple in parallel can provide an average temperature readout and produce better results in most air heated processes.

Proper sensor type is also a very important factor in obtaining precise measurements. The sensor must have the correct temperature range to meet the process requirements. In special processes, the sensor might have requirements such as leak-proof, antivibration, antiseptic, etc.

Standard sensor limits of error are ±4°F (±2°C) or 0.75% of the sensed temperature (half that for special) plus drift caused by improper protection or an over-temperature occurrence. This error is far greater than controller error and cannot be corrected on the sensor except by proper selection and replacement.

2–6 Sensor Input Wiring

Figure 2–8 Sensor Input Wiring
2–7 Control Output Wiring

Figure 2–9  Output 1 Relay or Triac (SSR) to Drive Load

Figure 2–10  Output 1 Relay or Triac (SSR) to Drive Contactor

Figure 2–11  Output 1 Pulsed Voltage to Drive SSR

Figure 2–12  Output 1 Linear Current

Figure 2–13  Output 1 Linear Voltage

Figure 2–14  Relay or Triac (SSR) to Drive Load
2–8 Alarm Wiring

Figure 2–19 Alarm Output to Drive Load

Figure 2–20 Alarm Output to Drive Contactor
2–9 Data Communication

If you use a conventional 9-pin RS-232 cable instead of TEC99014, the cable must be modified according to the following circuit diagram.

[Diagram showing RS-485 to RS-232 network adaptor, twisted-pair wiring, terminator resistor, and RS-232 wiring connections to the PC.]
Press [ ] for 5 seconds and release to enter the setup menu. Press [ ] to select the desired parameter. The upper display indicates the parameter symbol, and the lower display indicates the selected value of the parameter.

3–1 Lockout
There are four security levels that can be selected using the LOCK parameter.
If NONE is selected for LOCK, then no parameter is locked.
If SET is selected for LOCK, then all setup data are locked.
If USER is selected for LOCK, then all setup data as well as user data (refer to section 1-5) except the set point are locked to prevent them from being changed.
If ALL is selected for LOCK, then all parameters are locked to prevent them from being changed.

3–2 Signal Input
INPT: Selects the sensor type or signal type for signal input.
Range: (thermocouple) J-TC, K-TC, T-TC, E-TC, B-TC, R-TC, S-TC, N-TC, L-TC
(RTD) PT.DN, PT.JS
(Linear) 4–20mA, 0–20mA, 0–60mV, 0–1VDC, 0–5VDC, 1–5VDC, 0–10VDC
UNIT: Selects the process unit
Range: °C, °F, PU (process unit). If the unit is set for neither °C nor °F, then it defaults to PU.
DP: Selects the resolution of process value.
Range: (For T/C and RTD) NO.DP, 1-DP
(For linear) NO.DP, 1-DP, 2-DP, 3-DP
INLO: Selects the low scale value for the linear type input.
INHI: Selects the high scale value for the linear type input.
How to use the conversion curve for linear type process values, INLO and INHI:
If 4–20mA is selected for INPT, SL specifies the input signal low (i.e., 4mA), SH specifies the input signal high (i.e., 20mA), S specifies the current input signal value, and the conversion curve of the process value is shown as follows:

![Figure 3–1 Conversion Curve for Linear Type Process Value](image)

Formula: \[ PV = INLO + (INHI-INLO) \frac{S - SL}{SH - SL} \]

Example: A 4–20 mA current loop pressure transducer with range 0–15 kg/cm² is connected to input, then perform the following setup:
INPT = 4–20mA
INLO = 0.00
INHI = 15.00
DP = 2-DP
Of course, you may select other value for DP to alter the resolution.

3–3 Control Outputs
There are four kinds of control modes that can be configured as shown in table 3.1.

<table>
<thead>
<tr>
<th>Control Modes</th>
<th>OUT1</th>
<th>OUT2</th>
<th>O1HY</th>
<th>O2HY</th>
<th>CPB</th>
<th>DB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat only</td>
<td>REVR</td>
<td>×</td>
<td>☆</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Cool only</td>
<td>DIRT</td>
<td>×</td>
<td>☆</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Heat: PID</td>
<td>REVR</td>
<td>DE.HI</td>
<td>×</td>
<td>O</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Cool: ON-OFF</td>
<td>REVR</td>
<td>COOL</td>
<td>×</td>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

×: Does not apply  
☆: Required if ON-OFF control is configured

Table 3–1 Heat-Cool Control Setup Value

<table>
<thead>
<tr>
<th>OUT1: Output 1 Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT2: Output 2 Type</td>
</tr>
<tr>
<td>O1HY: Output 1 Hysteresis</td>
</tr>
<tr>
<td>O2HY: Output 2 Hysteresis</td>
</tr>
<tr>
<td>CPB: Cooling Proportional Band</td>
</tr>
<tr>
<td>DB: Heating Cooling Dead Band</td>
</tr>
</tbody>
</table>

15
Select REVR for OUT1. Set PB (Proportional Band) to 0. O1HY is used to adjust dead band for ON-OFF control. The output 1 hysteresis (O1HY) is enabled in case PB=0. The heat only on-off control function is shown in the following diagram:

**Heat only ON-OFF control:** Select REVR for OUT1. Set PB and TI to 0. OFST is used to adjust dead band for ON-OFF control. The output 1 hysteresis (O1HY) is enabled. The ON-OFF control may introduce excessive process oscillation even if hysteresis is minimized. If ON-OFF control is set (i.e., PB=0), TI, TD, CYC1, OFST, CYC2, CPB, and DB will be hidden and have no function in the system. The auto-tuning and bumpless transfer function will be disabled as well.

**Heat only P (or PD) control:** Select REVR for OUT1, set TI to 0. OFST is used to adjust the control offset (manual reset). O1HY is hidden if PB is not equal to 0. OFST function: OFST is measured by % with a range of 0–100.0%. In the steady state (i.e., process has been stabilized), if the process value is lower than the set point, a definite value, say 5°C, while 20°C is used for PB, that is lower 25%, then increase OFST 25%, and vice-versa. After adjusting OFST value, the process value will be varied and eventually coincide with set point. Using the P control (TI set to 0), disables auto-tuning.

Refer to section 3-12 "manual tuning" for the adjustment of PB and TD. Manual reset (adjust OFST) is not practical because the load may change from time to time and OFST may need to be adjusted repeatedly. The PID control can avoid this situation.

**Heat only PID control:** If REVR is selected for OUT1, PB and TI should not be zero. Perform auto-tuning for the new process, or set PB, TI, and TD with historical values. See section 3-11 for auto-tuning operation. If the control result is still unsatisfactory, then use manual tuning to improve the control. See section 3-12 for manual tuning. The unit contains a very advanced PID and Fuzzy algorithm to create a very small overshoot and very quick response to the process if it is properly tuned.

**Cool only control:** ON-OFF control, P (PD) control, and PID control can be used for cool control. Set OUT1 to DIRT (direct action). The other functions for cool only ON-OFF control, cool only P (PD) control, and cool only PID control are the same as for heat only control except that the output variable (and action) for cool control is inverse to heat control.

**NOTE:** ON-OFF control may result in excessive overshoot and undershoot problems in the process. P (or PD) control will result in a deviation of process value from the set point. It is recommended to use PID control for heat-cool control to produce a stable and zero offset process value.

**Other setup required:** O1TY, CYC1, O2TY, CYC2, O1FT and O2FT are set in accordance with the types of OUT1 and OUT2 installed. CYC1 and CYC2 are selected according to the output 1 type (O1TY) and output 2 type (O2TY). Generally, select 0.5–2 seconds for CYC1 if SSRD or SSR is used for O1TY; 10–20 seconds if relay is used for O1TY and CYC1 is ignored if linear output is used. Similar conditions are applied for CYC2 selection.

You can use the auto-tuning program for the new process or directly set the appropriate values for PB, TI, and TD according to historical records for the repeated systems. If the control behavior is still inadequate, then use manual tuning to improve the control. See section 3-12 for manual tuning.

**DB (Heating-Cooling Dead Band) Programming:** The cooling proportional band is measured by % of PB with a range of 50-300. Initially set 100% for CPB and examine the cooling effect. If the cooling action should be enhanced, then decrease CPB, if the cooling action is too strong, then increase CPB. The value of CPB is related to PB and its value remains unchanged throughout the auto-tuning procedures.

Adjustment of CPB is related to the cooling medium used. If air is used as the cooling medium, adjust CPB to 100%. If oil is used as the cooling medium, adjust CPB to 125%. If water is used as the cooling medium, adjust CPB to 250%.

**Output 2 ON-OFF control (alarm function):** Output 2 can also be configured with an alarm function. There are 4 kinds of alarm functions that can be selected for output 2. These are: DE.HI (deviation high alarm), DE.LO (deviation low alarm), PV.HI (process high alarm), and PV.LO (process low alarm). Refer to figure 3.3 and figure 3.4 for descriptions of the deviation alarm and the process alarm.
The controller has one alarm output. There are six types of alarm functions and one dwell timer that can be selected, and four kinds of alarm modes (ALMD) are available for each alarm function (ALFN). Besides the alarm output, output 2 can be configured as another alarm. But output 2 only provides four kinds of alarm functions and only normal alarm mode is available for this alarm.

A process alarm sets two absolute trigger levels. When the process is higher than SP3, a process high alarm (PV.HI) occurs, and the alarm is off when the process is lower than SP3-ALHY. When the process is lower than SP3, a process low alarm (PV.LO) occurs, and the alarm is off when the process is higher than SP3+ALHY. A process alarm is independent of the set point.

A deviation alarm alerts the user when the process deviates too far from the set point. When the process is higher than SV+SP3, a deviation high alarm (DE.HI) occurs. The alarm is off when the process is lower than SV+SP3-ALHY. When the process is lower than SV+SP3, a deviation low alarm (DE.LO) occurs. The alarm is off when the process is higher than SV+SP3+ALHY. The trigger level of the deviation alarm moves with the set point.

A deviation band alarm presets two trigger levels relative to the set point. The two trigger levels are SV+SP3 and SV-SP3 for alarm. When the process is higher than (SV+SP3) or lower than (SV-SP3), a deviation band high alarm (DB.HI) occurs. When the process is within the trigger levels, a deviation band low alarm (DB.LO) occurs.

In the above descriptions SV denotes the current set point value for control which is different from SP1 as the ramp function is performed.

There are four types of alarm modes available for each alarm function. These are: normal alarm, latching alarm, holding alarm and latching/holding alarm. They are described as follows:

**Normal alarm: ALMD=NORM**
When a normal alarm is selected, the alarm output is de-energized in the non-alarm condition and energized in an alarm condition.

**Latching alarm: ALMD=LTCH**
If a latching alarm is selected, once the alarm output is energized, it will remain unchanged even if the alarm condition is cleared. The latching alarm is reset when the RESET key is pressed after the alarm condition is removed.

**Holding alarm: ALMD=HOLD**
A holding alarm prevents an alarm when the control is powering up. The alarm is enabled only when the process reaches the set point value. Afterwards, the alarm performs the same function as a normal alarm.

**Latching/holding alarm: ALMD=LT.HO**
A latching/holding alarm performs both holding and latching functions. The latching alarm is reset when the RESET key is pressed after the alarm condition is removed.

**Alarm failure transfer** is activated as the unit enters failure mode. The alarm will go on if ALFT is set for ON and go off if ALFT is set for OFF. The unit will enter failure mode when a sensor break occurs or if the A-D converter of the unit fails.
3–5 Configuring User Menu

Most conventional controllers are designed with a fixed order in which the parameters scroll. This series has the flexibility to allow you to select those parameters which are most significant to you and put these parameters at the front of the display sequence. **SEL1–SEL8:** Selects the parameter for view and change in the user menu. Changing the SEL1–8 will change the user menu displayed when the * key is tapped, as opposed to being pressed for 5+ seconds.

**Range:** LOCK, INPT, UNIT, DP, SHIF, PB, TI, TD, O1HY, CYC1, OFST, RR, O2HY, CYC2, CPB, DB, ADDR, ALHY

When using the up and down keys to select the parameters, you may not see all of the above parameters. The number of visible parameters is dependent on the setup condition. The hidden parameters for the specific application are also blocked from the SEL selection.

**Example:**

OUT2 set for DE.LO   PB= 100.0   SEL1 set for INPT
SEL2 set for UNIT    SEL3 set for PB   SEL4 set for TI
SEL5–SEL8 set for NONE

Now, the upper display scrolling becomes:

![Figure 3–5  RAMP Function](image)

3–6 Ramp

**Ramp**

The ramping function is performed during power up as well as any time the set point is changed. If MINR (minutes) or HRR (hours) is chosen for RAMP, the unit will perform the ramping function. The ramp rate is programmed by adjusting RR. The ramping function is disabled as soon as failure mode, manual control mode, auto-tuning mode or calibration mode is entered.

**Example without dwell timer**

Select MINR for RAMP, select °C for UNIT, select 1-DP for DP, set RR=10.0. SV is set to 200°C initially, and changed to 100°C 30 minutes after power-up. The starting temperature is 30°C. After power-up, the process runs like the curve shown below:

![Figure 3–5  RAMP Function](image)

![Figure 3–6 Dwell Timer Function](image)

**Note:** When the ramp function is used, the lower display will show the current ramping value. However, it will revert to show the set point value as soon as the up or down key is touched for adjustment. The ramping value is initiated to process value either on power-up or when RR and/or the set point are changed. Setting RR to zero means no ramp function.

3–7 Dwell Timer

The alarm output can be configured as a dwell timer by selecting TIMR for ALFN (alarm function). When the dwell timer is configured, the parameter SP3 is used for dwell time adjustment. The dwell time is measured in minutes ranging from 0.1 to 4553.6 minutes. Once the process reaches the set point the dwell timer starts to count down to zero (time out). The timer relay will remain unchanged until time out. The dwell timer operation is shown in the following diagram.

After time out the dwell timer can be restarted by pressing the RESET key.

The timer stops counting during manual control mode, failure mode, the calibration period and the auto-tuning period.

If the alarm is configured as a dwell timer, ALHY and ALMD are hidden.
3–8 PV Shift

In certain applications it is desirable to shift the controller display value from its actual value. This can easily be accomplished by using the PV shift function.

The SHIF function will alter PV only.

Here is an Example: A process is equipped with a heater, a sensor, and a subject to be warmed up. Due to the design and position of the components in the system, the sensor could not be placed any closer to the part. Thermal gradient (differing temperatures) is common and necessary to an extent in any thermal system for heat to be transferred from one point to another. If the difference between the sensor and the subject is 35°C, and the desired temperature at the subject to be heated is 200°C, the controlling value or the temperature at the sensor should be 235°C. You should enter -35°C to subtract 35°C from the actual process display. This in turn will cause the controller to energize the load and bring the process display up to the set point value.

![Figure 3–7 PV Shift Application](image)

3–9 Digital Filter

In certain applications, the process value is too unstable to be read due to possible electrical noise. A programmable low-pass filter incorporated in the controller can be used to improve this. This is a first-order filter with the time constant specified by the FILT parameter. The default value of FILT is set at 0.5 seconds. Adjust FILT to change the time constant from 0 to 60 seconds. 0 seconds means no filter is applied to the input signal. The filter is characterized by the following diagram:

**Note**
The filter is available only for PV, and is performed for the displayed value only. The controller is designed to use unfiltered signal for control even if the filter is applied. A lagged (filtered) signal, if used for control, may produce an unstable process.

![Figure 3–8 Filter Characteristics](image)

3–10 Failure Transfer

The controller will enter failure mode if one of the following conditions occurs:

1. **SBER** occurs due to input sensor break or input current below 1mA if 4–20 mA is selected or input voltage below 0.25V if 1–5V is selected.
2. **ADER** occurs due to the A-D converter of the controller failing.

Output 1 and output 2 will perform the failure transfer function as the controller enters failure mode.

**Output 1 failure transfer**, if activated, will perform:

1. If output 1 is configured as proportional control (PB≠0), and BPLS is selected for O1FT, then output 1 will perform bumpless transfer. Thereafter, the previous averaging value of MV1 will be used for controlling output 1.
2. If output 1 is configured as proportional control (PB≠0), and a value of 0 to 100.0% is set for O1FT, then output 1 will perform failure transfer. Thereafter, the value of O1FT will be used for controlling output 1.
3. If output 1 is configured as ON-OFF control (PB=0), then output 1 will be driven OFF if OFF is set for O1FT and will be driven ON if ON is set for O1FT.

**Output 2 failure transfer**, if activated, will perform:

1. If OUT2 is configured as COOL, and BPLS is selected for O2FT, then output 2 will perform bumpless transfer. Thereafter, the previous averaging value of MV2 will be used for controlling output 2.
2. If OUT2 is configured as COOL, and a value of 0 to 100.0% is set for O2FT, then output 2 will perform failure transfer. Thereafter, the value of O2FT will be used for controlling output 2.
3. If OUT2 is configured as alarm function, and O2FT is set to OFF, then output 2 will go off. Otherwise, output 2 will go on if O2FT is set to ON.

**Alarm failure transfer** is activated as the controller enters failure mode. Thereafter, the alarm will transfer to the ON or OFF state preset by ALFT.
3–11 Auto-tuning

The auto-tuning process is performed set point. The process will oscillate around the set point during the tuning process. Set the set point at a lower value if over-shooting beyond the normal process value is likely to cause damage.

Auto-tuning is applied in cases of:
• Initial setup for a new process
• The set point is changed substantially from the previous auto-tuning value
• The control result is unsatisfactory

Operation:
1. The system has been installed normally.
2. Set the correct values for the setup menu of the unit, but don't set a zero value for PB and TI, or the auto-tuning program will be disabled. The LOCK parameter should be set at NONE.
3. Set the set point to a normal operating value, or a lower value if over-shooting beyond the normal process value is likely to cause damage.
4. Press and hold until A - T appears on the display.
5. Press for at least 5 seconds. The AT indicator will begin to flash and the auto-tuning procedure will begin.

NOTE: The ramping function, if used, will be disabled when auto-tuning is taking place.
The auto-tuning mode is disabled as soon as either failure mode or manual control mode occurs.

Procedures:
Auto-tuning can be applied either as the process is warming up (cold start), or when the process has been in a steady state (warm start).
After the auto-tuning procedures are completed, the AT indicator will cease to flash and the unit will revert to PID control using its new PID values. The PID values obtained are stored in the nonvolatile memory.

ATER Auto-Tuning Error
If auto-tuning fails an ATER message will appear on the display in the following cases:
• If PB exceeds 9000 (9000 PU, 900.0°F or 500.0°C),
• if TI exceeds 3600 seconds,
• if the set point is changed during the auto-tuning procedure.

Solutions to ATER
1. Try auto-tuning again.
2. Don't change the set point value during the auto-tuning procedure.
3. Don't set a zero value for PB and TI.
4. Use manual tuning instead of auto-tuning (see section 3-12).
5. Touch RESET key to reset ATER message.

3–12 Manual Tuning

In certain applications auto-tuning may be inadequate for the control requirements. You can try manual tuning for these applications.

If the control performance using auto-tuning is still unsatisfactory, the following rules can be applied for further adjustment of PID values:

Figure 3.9 shows the effects of PID adjustment on process response.

<table>
<thead>
<tr>
<th>ADJUSTMENT SEQUENCE</th>
<th>SYMPTOM</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Proportional Band (PB)</td>
<td>High overshoot or Oscillations</td>
<td>Decrease PB</td>
</tr>
<tr>
<td>(2) Integral Time (TI)</td>
<td>Instability or Oscillations</td>
<td>Decrease TI</td>
</tr>
<tr>
<td>(3) Derivative Time (TD)</td>
<td>Slow Response or Oscillations</td>
<td>Decrease TD</td>
</tr>
</tbody>
</table>

Table 3–2 PID Adjustment Guide

Table 3–9 Effects of PID Adjustment on Process Response
3–13 Manual Control

**Operation:**
To enable manual control, the LOCK parameter should be set to NONE, then press \[\text{SET}\] for 6.2 seconds \(\text{Hand Control}\) will appear on the display. Press \[\text{SET}\] for 5 seconds until the MAN indicator begins to flash and the lower display shows \(\text{MAN}\). The controller now enters the manual control mode. \(\text{MAN}\) indicates output control variable for output 1, and \(\text{MAN}\) indicates control variable for output 2. Now you can use the up-down keys to adjust the percentage values for the heating or cooling output.

The controller performs open loop control as long as it stays in manual control mode.

**Exit Manual Control**
Pressing the \[\text{SET}\] key will cause the controller to revert to its normal display mode.

3–14 Data Communication

The controllers support RTU mode of Modbus protocol for data communication. Other protocols are not available for this series.

Two types of interface are available for data communication. These are RS-485 and RS-232 interface. Since RS-485 uses a differential architecture to drive and sense signal instead of a single-ended architecture like the one used for RS-232, RS-485 is less sensitive to noise and suitable for communication over a longer distance. RS-485 can communicate without error over a 1km distance while RS-232 is not recommended for a distance of over 60 feet (20 meters).

Using a PC for data communication is the most economical method. The signal is transmitted and received through the PC communication port (generally RS-232). Since a standard PC can't support an RS-485 port, a network adapter (such as TEC99001) has to be used to convert RS-485 to RS-232 for a PC if RS-485 is required for data communication. Up to 247 RS-485 units can be connected to one RS-232 port; therefore a PC with four comm ports can communicate with 988 units. Refer to Chapter 7 on page 29.

**Setup**
Enter the setup menu.
Select RTU for COMM. Set individual addresses for any units that are connected to the same port.
Set the baud rate (BAUD), data bit (DATA), parity bit (PAR) and stop bit (STOP) so that these values are accordant with PC setup conditions.
If you use a conventional 9-pin RS-232 cable instead of TEC99014, the cable should be modified for proper operation of RS-232 communication according to section 2-9.

3–15 Process Variable (PV) Retransmission

The controller can output (retransmit) process value via its retransmission terminals RE+ and RE- provided that the retransmission option is ordered. The correct signal type should be selected for COMM parameter to meet the retransmission option installed. RELO and REHI are set to specify the low scale and high scale values of retransmission.
Chapter 4 Applications

4–1 Heat Only Control with Dwell Timer

An oven is designed to dry products at 150°C for 30 minutes and then stay unpowered for another batch. A TBC-41 equipped with dwell timer is used for this purpose. The system diagram is shown at right:

To achieve this function, set the following parameters in the setup menu:

- **INPT=K_TC**
- **UNIT=°C**
- **DP=1_DP**
- **OUT1=REVR**
- **O1TY=RELY**
- **CYC1=18.0**
- **O1FT=BPLS**
- **ALFN=TIMR**
- **ALFT=ON**

Auto-tuning is performed at 150°C for a new oven.

![Figure 4–1 Heat Control Example](image)

4–2 Cool Only Control

A TBC-41 is used to control a refrigerator at temperatures below 0°C. This temperature is lower than the ambient, so a cooling action is required. Select DIRT for OUT1. Since output 1 is used to drive a magnetic contactor, O1TY selects RELY. A small temperature oscillation is tolerable, so use ON-OFF control to reduce the over-all cost. To use ON-OFF control, set PB to zero and O1HY at 0.1°C.

![Figure 4–2 Cool Only Control](image)
4–3 Heat-Cool Control

An injection mold is required to be controlled at 120°C to ensure a consistent quality for the parts. An oil pipe is buried in the mold. Since plastics are injected at a higher temperature (e.g., 250°C), the circulation oil needs to be cooled as its temperature rises. Here is an example:

The PID heat-cool is used for the above example. To achieve this, set the following parameters in the setup menu:

\[
\begin{align*}
\text{INPT} &= \text{PT.DN} \\
\text{UNIT} &= \degree\text{C} \\
\text{DP} &= 1-\text{DP} \\
\text{OUT1} &= \text{REVR} \\
\text{O1TY} &= \text{RELY} \\
\text{CYC1} &= 18.0 \text{ (sec.)} \\
\text{O1FT} &= 0.0 \\
\text{OUT2} &= \text{COOL} \\
\text{O2TY} &= 4–20 \\
\text{O2FT} &= \text{BPLS}
\end{align*}
\]

Set SV at 120.0°C, CPB at 125(%) and DB at -4.0(%). Apply auto-tuning at 120°C for a new system to get optimal PID values. See section 3-11.

Adjustment of CPB is related to the cooling medium used. If water is used as the cooling medium instead of oil, the CPB should be set at 250(%). If air is used as the cooling medium instead of oil, the CPB should be set at 100(%). The adjustment of DB is dependent on the system requirements. A higher positive value of DB will prevent unwanted cooling action, but will increase the temperature overshoot, while a lower negative value of DB will result in less temperature overshoot, but will increase unwanted cooling action.

Figure 4–3 Heat-Cool Only Control
Chapter 5  Calibration

Do not proceed through this section unless there is a definite need to recalibrate the controller. If you recalibrate, all previous calibration data will be lost. Do not attempt recalibration unless you have the appropriate calibration equipment. If the calibration data is lost, you will need to return the controller to your supplier who may charge you a service fee to recalibrate the controller.

Entering calibration mode will break the control loop. Make sure that the system is ready to enter calibration mode.

Equipment needed for calibration:
1. A high-accuracy calibrator (Fluke 5520A calibrator recommended) with the following functions:
   - 0–100mV millivolt source with ±0.005% accuracy
   - 0–10V voltage source with ±0.005% accuracy
   - 0–20mA current source with ±0.005% accuracy
   - 0–300 ohm resistant source with ±0.005% accuracy
2. A test chamber providing 25°C–50°C temperature range

The calibration procedure described in the following section is a step-by-step manual procedure.

Manual Calibration Procedures

- Perform step 1 to enter calibration mode.

Step 1.
Set the lock parameter to the unlocked condition (LOCK=NONE). Press and hold the scroll key until \[ \text{[CRL]} \] appears on the display, then release the scroll key. Press the scroll key for 2 seconds, and the display will show \[ \text{[RDL]} \] and the unit will enter the calibration mode.

- Perform step 2 to calibrate zero of A to D converter and step 3 to calibrate gain of A to D converter.

Step 2.
Short the thermocouple input terminals, then press the scroll key for at least 5 seconds. The display will blink for a moment until a new value is obtained. If the display didn't blink or if the obtained value is equal to -199.9 or 199.9, then calibration failed.

Step 3.
Press scroll key until the display shows \[ \text{[RdH]}. \] Send a 60mV signal to the thermocouple input terminals in the correct polarity. Press the scroll key for at least 5 seconds. The display will blink for a moment and a new value is obtained. If the display didn't blink or if the obtained value is equal to -199.9 or 199.9, then the calibration failed.

- Perform both steps 4 and 5 to calibrate RTD function (if required) for input.

Step 4.
Press scroll key until the display shows \[ \text{[Fel]} \]. Send a 100 ohms signal to the RTD input terminals according to the connection shown below:

![Figure 5–1 RTD Calibration](image)

Press scroll key for at least 5 seconds. The display will blink for a moment; if it does not this calibration failed.

Step 5.
Press the scroll key and the display will show \[ \text{[Fel]} \]. Change the ohm's value to 300 ohms. Press the scroll key for at least 5 seconds. The display will blink for a moment and two values will be obtained for RTDH and RTDL (step 4). If the display didn't blink or if any value obtained for RTDH or RTDL is equal to -199.9 or 199.9, then calibration failed.

- Perform step 6 to calibrate offset of cold junction compensation, if required.
Step 6.
Set up the equipment according to the diagram above for calibrating the cold junction compensation. Note that a K type thermocouple must be used.

The 5520A calibrator is configured as K type thermocouple output with internal compensation. Send a 0.00°C signal to the unit under calibration.

The unit under calibration is powered in a still-air room with temperature 25±3°C. Wait at least 20 minutes for warming up. Perform step 1 as stated above, then press the scroll key until the display shows [0.00°C]. Press up/down key to obtain 40.00
Press the scroll key for at least 5 seconds. The display will blink for a moment until a new value is obtained. If the display didn't blink or if the obtained value is equal to −5.00 or 40.00, then calibration failed.
• Perform step 7 to calibrate gain of cold junction compensation if required.

Step 7.
Setup the equipment same as step 6. The unit under calibration is powered in a still-air room with temperature 50±3°C. Wait at least 20 minutes for warming up. The calibrator source is set at 0.00°C with internal compensation mode.
Perform step 1 stated above, then press the scroll key until the display shows [0.00°C]. Press the scroll key for at least 5 seconds. The display will blink for a moment until a new value is obtained. If the display didn't blink or if the obtained value is equal to −199.9 or 199.9, then calibration failed.
This setup is performed in a high-temperature chamber, therefore it is recommended to use a computer to perform the procedures.
• Input modification and recalibration procedures for a linear voltage or a linear current input:
1. Remove R60(3.3K) and install two 1/4W resistors RA and RB on the control board with the recommended values specified in the following table.
Low temperature coefficient resistors should be used for RA and RB.
2. Perform step 1 and step 2 to calibrate the linear input zero.
3. Perform step 3 but send a span signal to the input terminals instead of 60mV. The span signal is 1V for 0–1V input, 5V for 0–5V or 1–5V input, 10V for 0–10V input and 20mA for 0–20mA or 4–20mA input.
• Final step

Step 8.
Set the LOCK value to your desired function.

---

**Manual Calibration Procedures, continued…**

![Diagram](image)

**Figure 5–2 Cold Junction Calibration Setup**

Wait at least 20 minutes in still-air room at temperature 25±3°C.

---

<table>
<thead>
<tr>
<th>Input Function</th>
<th>RA</th>
<th>RB</th>
<th>R60</th>
</tr>
</thead>
<tbody>
<tr>
<td>T/C, RTD, 0 – 60mV</td>
<td>X</td>
<td>X</td>
<td>3.3K</td>
</tr>
<tr>
<td>0 – 1 V</td>
<td>61.9K</td>
<td>3.92K</td>
<td>X</td>
</tr>
<tr>
<td>0 – 5V, 1 – 5V</td>
<td>324K</td>
<td>3.92K</td>
<td>X</td>
</tr>
<tr>
<td>0 – 10 V</td>
<td>649K</td>
<td>3.92K</td>
<td>X</td>
</tr>
<tr>
<td>0 – 20mA, 4 – 20mA</td>
<td>39Ω</td>
<td>3.01Ω</td>
<td>X</td>
</tr>
</tbody>
</table>
Chapter 6 Specifications

Power
90–250VAC, 47–63 Hz, 12VA, 5W maximum
11–26VAC/VDC, 12VA, 5W maximum

Input
Resolution: 18 bits
Sampling rate: 5 times/second
Maximum rating: -2VDC minimum, 12VDC maximum
(1 minute for mA input)
Temperature effect: ±1.5uV/°C for all inputs except mA input
±3.0uV/°C for mA input

Sensor lead resistance effect:
T/C: 0.2uV/ohm
3-wire RTD: 2.6°C/ohm of resistance difference of two leads
2-wire RTD: 2.6°C/ohm of resistance sum of two leads

Common mode rejection ratio (CMRR): 120dB
Normal mode rejection ratio (NMRR): 55dB

Voltage Response Time:
Within 4 seconds for TC, RTD, and mV inputs, 0.1 second for 4–20mA and 1–5V inputs.

Characteristics:

<table>
<thead>
<tr>
<th>Type</th>
<th>Range</th>
<th>Accuracy @ 25°C</th>
<th>Impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>-120°C to 1000°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(-184°F to 1832°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>-200°C to 1370°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(-328°F to 2498°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>-250°C to 400°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(-418°F to 752°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>-100°C to 900°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(-148°F to 1632°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0°C to 1800°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(32°F to 3272°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(700°C to 1800°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>0°C to 1767.8°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(32°F to 3214°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0°C to 1767.8°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(32°F to 3214°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>-250°C to 1300°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(-418°F to 2372°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>-200°C to 900°C</td>
<td>±2°C</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td></td>
<td>(-328°F to 1652°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PT100 (DIN)</td>
<td>-210°C to 700°C</td>
<td>±0.4°C</td>
<td>1.3 KΩ</td>
</tr>
<tr>
<td></td>
<td>(-346°F to 1292°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PT100 (JIS)</td>
<td>-200°C to 800°C</td>
<td>±0.4°C</td>
<td>1.3 KΩ</td>
</tr>
<tr>
<td></td>
<td>(-328°F to 1112°F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mV</td>
<td>-8mV to 70mV</td>
<td>±0.05%</td>
<td>2.2 MΩ</td>
</tr>
<tr>
<td>mA</td>
<td>-3mA to 27mA</td>
<td>±0.05%</td>
<td>70.5 Ω</td>
</tr>
<tr>
<td>V</td>
<td>-1.3V to 11.5V</td>
<td>±0.05%</td>
<td>650 KΩ</td>
</tr>
</tbody>
</table>

Output 1/Output 2
Relay rating: 2A/240VAC, 200,000 life cycles for resistive load
Pulsed voltage: Source voltage 5V, current limiting resistance 66|.

Linear Output
Resolution: 15 bits
Output regulation: 0.02% for full load change
Output settling time: 0.1 sec. (stable to 99.9 %)
Isolation breakdown voltage: 1000VAC
Temperature effect: ±0.01% of SPAN/°C

Triac (SSR) Output
Rating: 1A/240 VAC
Inrush current: 20A for 1 cycle
Min. load current: 50mA rms
Max. off-state leakage: 3mA rms
Max. on-state voltage: 1.5V rms
Insulation resistance: 1000MΩ min. at 500 VDC
Dielectric strength: 2500VAC for 1 minute

Linear Output Characteristics

<table>
<thead>
<tr>
<th>Type</th>
<th>Zero Tolerance</th>
<th>Span Tolerance</th>
<th>Load Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-20mA</td>
<td>3.6–4mA</td>
<td>20–21mA</td>
<td>500Ω max.</td>
</tr>
<tr>
<td>0-20mA</td>
<td>0 mA</td>
<td>20–21mA</td>
<td>500Ω max.</td>
</tr>
<tr>
<td>0 – 5 V</td>
<td>0 V</td>
<td>5 – 5.25 V</td>
<td>10 KΩ min.</td>
</tr>
<tr>
<td>1 – 5 V</td>
<td>0.9 – 1 V</td>
<td>5 – 5.25 V</td>
<td>10 KΩ min.</td>
</tr>
<tr>
<td>0 – 10 V</td>
<td>0 V</td>
<td>10 – 10.5 V</td>
<td>10 KΩ min.</td>
</tr>
</tbody>
</table>

DC Voltage Supply Characteristics (Installed at Output 2)

<table>
<thead>
<tr>
<th>Type</th>
<th>Tolerance</th>
<th>Max. Output Current</th>
<th>Ripple Voltage</th>
<th>Isolation Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 V</td>
<td>±1 V</td>
<td>25 mA</td>
<td>0.2 Vp-p</td>
<td>500 VAC</td>
</tr>
<tr>
<td>12 V</td>
<td>±0.6 V</td>
<td>40 mA</td>
<td>0.1 Vp-p</td>
<td>500 VAC</td>
</tr>
<tr>
<td>5 V</td>
<td>±0.25 V</td>
<td>80 mA</td>
<td>0.05 Vp-p</td>
<td>500 VAC</td>
</tr>
</tbody>
</table>
Specifications, continued...

**Alarm**

**Alarm relay:** Form C Rating

2A/240VAC, 200,000 life cycles for resistive load.

**Alarm functions:** Dwell timer, Deviation high/low alarm, Deviation band high/low alarm, PV high/low alarm

**Alarm modes:** Normal, latching, hold, latching/hold.

**Dwell timer:** 0.1-4553.6 minutes

**Data Communication**

**Interface:** RS-232 (1 unit), RS-485 (up to 247 units)

**Protocol:** Modbus protocol RTU mode

**Address:** 1–247

**Baud rate:** 2.4–38.4Kbits/sec

**Data bits:** 7 or 8 bits

**Parity bit:** None, even or odd

**Stop bit:** 1 or 2 bits

**Communication buffer:** 160 bytes

**Analog Retransmission**

**Output Signal:** 4-20mA, 0-20mA, 0-5V, 1-5V, 0-10V

**Resolution:** 15 bits

**Accuracy:** ± 0.05% of span ± 0.0025% / °C

**Load Resistance:**

- 0-500 Ohms (for current output)
- 10 K Ohms minimum (for voltage output)

**Output Regulation:** 0.01% for full load charge

**Output Settling Time:** 0.1sec (stable to 99.9%)

**Isolation Breakdown Voltage:** 1000 Vac for 1 min.

**Integral Linearity Error:** ±0.005% of span

**Temperature Effect:** ±0.0025% of span/°C

**Saturation Low:** 0 mA or (0V)

**Saturation High:** 22.2 mA (or 5.55V, 11.1V/min)

**Linear Output Range:**

- 0-22.2 mA (0-20 mA or 4-20 mA)
- 0-5.55V (0-5V, 1-5V)
- 0-11.1V (0-10V)

**User Interface**

**Dual 4-digit LED displays**

**Keypad:** 4 keys

**Programming port:** For automatic setup, calibration and testing

**Communication port:** Connection to PC for supervisory control

**Control Mode**

**Output 1:** Reverse (heating) or direct (cooling) action

**Output 2:** PID cooling control, cooling P band 50~300% of PB, dead band -36.0~36.0% of PB

**ON-OFF:** 0.1~90.0 (°F) hysteresis control (P band=0)

**P or PD:** 0~100.0% offset adjustment

**PID:** Fuzzy logic modified

- Proportional band 0.1~900.0°F
- Integral time 0~3600 seconds
- Derivative time 0~360.0 seconds

**Cycle time:** 0.1~90.0 seconds

**Manual control:** Heat (MV1) and cool (MV2)

**Auto-tuning:** Cold start and warm start

**Failure mode:** Auto-transfer to manual mode while sensor break or A-D converter damage

**Ramping control:** 0~900.0°F/minute or 0~900.0°F/hour ramp rate

**Digital Filter**

**Function:** First order

**Time constant:** 0, 0.2, 0.5, 1, 2, 5, 10, 20, 30, 60 seconds programmable

**Environmental and Physical**

**Operating temperature:** -10°C to 50°C

**Storage temperature:** -40°C to 60°C

**Humidity:** 0 to 90% RH (non-condensing)

**Altitude:** 2000m maximum

**Pollution:** Degree 2

**Insulation resistance:** 20Mohms min. (at 500VDC)

**Dielectric strength:** 2000VAC, 50/60 Hz for 1 minute

**Vibration resistance:** 10–55 Hz, 10 m/s² for 2 hours

**Shock resistance:** 200m/s² (20g)

**Approval Standards**

**EMC:** EN61326
This chapter specifies the Modbus Communications protocol as RS-232 or RS-485 interface module is installed. Only RTU mode is supported. Data is transmitted as eight-bit binary bytes with 1 start bit, 1 stop bit and optional parity checking (None, Even or Odd). Baud rate may be set to 2400, 4800, 9600, 14400, 19200, 28800 and 38400.

7-1 Functions Supported

Only function 03, 06 and 16 are available for this series of controllers. The message formats for each function are described as follows:

**Function 03: Read Holding Registers**

Query: (from Primary)  
Response: (from Secondary)

- Secondary address (0-255)
- Function code (3)
- Starting address of register Hi (0)
- Starting address of register Lo (0-79, 128-131)
- No. of words Hi (0)
- No. of words Lo (1-79)
- CRC16 Hi
- CRC16 Lo

**Function 06: Preset Single Register**

Query: (from Primary)  
Response: (from Secondary)

- Secondary address (0-255)
- Function code (6)
- Register address Hi (0)
- Register address Lo (0-79, 128-131)
- Data Hi
- Data Lo
- CRC16 Hi
- CRC16 Lo

**Function 16: Preset Multiple Registers**

Query: (from Primary)  
Response: (from Secondary)

- Secondary address (0-255)
- Function code (16)
- Starting address of register Hi (0)
- Starting address of register Lo (0-79, 128-131)
- No. of words Hi (0)
- No. of words Lo (1-79)
- Byte count (2-158)
- Data 1 Hi
- Data 1 Lo
- Data 2 Hi
- Data 2 Lo
- CRC16 Hi
- CRC16 Lo
7-2 Exception Responses

If the controller receives a message which contains a corrupted character (parity check error, framing error etc.), or if the CRC16 check fails, the controller ignores the message. However, if the controller receives a syntactically correct message which contains an illegal value, it will send an exception response, consisting of five bytes as follows:

secondary address + offset function code + exception code + CRC16 Hi +CRC16 Lo

Where the offset function code is obtained by adding the function code with 128 (ie. function 3 becomes H’83), and the exception code is equal to the value contained in the following table:

<table>
<thead>
<tr>
<th>Exemption Code</th>
<th>Name</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bad Function Code</td>
<td>Function code is not supported by the controller</td>
</tr>
<tr>
<td>2</td>
<td>Illegal data address</td>
<td>Register address out of range</td>
</tr>
<tr>
<td>3</td>
<td>Illegal data value</td>
<td>Data value out of range or attempt to write a read-only or protected data</td>
</tr>
</tbody>
</table>

7-3 Parameter Table

<table>
<thead>
<tr>
<th>Register Address</th>
<th>Parameter Notation</th>
<th>Parameter</th>
<th>Scale Low</th>
<th>Scale High</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SP1</td>
<td>Set Point 1</td>
<td>*4</td>
<td>*4</td>
<td>R/W</td>
</tr>
<tr>
<td>1</td>
<td>SP2</td>
<td>Set Point 2</td>
<td>*7</td>
<td>*7</td>
<td>R/W</td>
</tr>
<tr>
<td>2</td>
<td>SP3</td>
<td>Set Point 3</td>
<td>*6</td>
<td>*6</td>
<td>R/W</td>
</tr>
<tr>
<td>3</td>
<td>LOCK</td>
<td>Lock code</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>4</td>
<td>INPT</td>
<td>Input sensor selection</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>5</td>
<td>UNIT</td>
<td>Measuring unit</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>6</td>
<td>DP</td>
<td>Decimal point position</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>7</td>
<td>INLO</td>
<td>Low scale value for linear input</td>
<td>*4</td>
<td>*4</td>
<td>R/W</td>
</tr>
<tr>
<td>8</td>
<td>INHI</td>
<td>High scale value for linear input</td>
<td>*4</td>
<td>*4</td>
<td>R/W</td>
</tr>
<tr>
<td>9</td>
<td>SP1L</td>
<td>Low limit of SP1</td>
<td>*4</td>
<td>*4</td>
<td>R/W</td>
</tr>
<tr>
<td>10</td>
<td>SP1H</td>
<td>High Limit of SP1</td>
<td>*4</td>
<td>*4</td>
<td>R/W</td>
</tr>
<tr>
<td>11</td>
<td>SHIF</td>
<td>PV shift value</td>
<td>*4</td>
<td>*4</td>
<td>R/W</td>
</tr>
<tr>
<td>12</td>
<td>FILT</td>
<td>Filter time constant</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>13</td>
<td>DISP</td>
<td>Display form</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>14</td>
<td>PB</td>
<td>P (proportional) band</td>
<td>*5</td>
<td>*5</td>
<td>R/W</td>
</tr>
<tr>
<td>15</td>
<td>TI</td>
<td>Integral time</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>16</td>
<td>TD</td>
<td>Derivative time</td>
<td>0.0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>17</td>
<td>OUT1</td>
<td>Output 1 function</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>18</td>
<td>O1TY</td>
<td>Output 1 signal type</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>19</td>
<td>O1FT</td>
<td>Output 1 failure transfer</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R/W</td>
</tr>
<tr>
<td>20</td>
<td>O1HY</td>
<td>Output 1 ON-OFF hysteresis</td>
<td>*5</td>
<td>*5</td>
<td>R/W</td>
</tr>
<tr>
<td>21</td>
<td>CYC1</td>
<td>Output 1 cycle time</td>
<td>0.0</td>
<td>6553.5</td>
<td>R/W</td>
</tr>
<tr>
<td>22</td>
<td>OFST</td>
<td>Offset value for P control</td>
<td>0.0</td>
<td>6553.5</td>
<td>R/W</td>
</tr>
<tr>
<td>23</td>
<td>RAMP</td>
<td>Ramp function</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>24</td>
<td>RR</td>
<td>Ramp rate</td>
<td>*5</td>
<td>*5</td>
<td>R/W</td>
</tr>
<tr>
<td>25</td>
<td>OUT2</td>
<td>Output 2 function</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>26</td>
<td>RELO</td>
<td>Retransmission low scale value</td>
<td>*4</td>
<td>*4</td>
<td>R/W</td>
</tr>
<tr>
<td>27</td>
<td>O2TY</td>
<td>Output 2 signal type</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>28</td>
<td>O2FT</td>
<td>Output 2 failure transfer</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R/W</td>
</tr>
<tr>
<td>29</td>
<td>O2HY</td>
<td>Output 2 ON-OFF hysteresis</td>
<td>*5</td>
<td>*5</td>
<td>R/W</td>
</tr>
<tr>
<td>30</td>
<td>CYC2</td>
<td>Output 2 cycle time</td>
<td>0.0</td>
<td>6553.5</td>
<td>R/W</td>
</tr>
<tr>
<td>31</td>
<td>CPB</td>
<td>Cooling P band</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>32</td>
<td>DB</td>
<td>Heating-cooling dead band</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R/W</td>
</tr>
<tr>
<td>Register Address</td>
<td>Parameter Notation</td>
<td>Parameter</td>
<td>Scale Low</td>
<td>Scale High</td>
<td>Notes</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------</td>
<td>-----------</td>
<td>-----------</td>
<td>------------</td>
<td>-------</td>
</tr>
<tr>
<td>33</td>
<td>ALFN</td>
<td>Alarm Function</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>34</td>
<td>REHI</td>
<td>Retransmission high scale value</td>
<td>*4</td>
<td>*4</td>
<td>R/W</td>
</tr>
<tr>
<td>35</td>
<td>ALMD</td>
<td>Alarm operation mode</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>36</td>
<td>ALHY</td>
<td>Alarm hysteresis</td>
<td>*5</td>
<td>*5</td>
<td>R/W</td>
</tr>
<tr>
<td>37</td>
<td>ALFT</td>
<td>Alarm failure transfer</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>38</td>
<td>COMM</td>
<td>Communication function</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>39</td>
<td>ADDR</td>
<td>Address</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>40</td>
<td>BAUD</td>
<td>Baud rate</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>41</td>
<td>DATA</td>
<td>Data bit count</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>42</td>
<td>PARI</td>
<td>Parity bit</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>43</td>
<td>STOP</td>
<td>Stop bit count</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>44</td>
<td>SEL1</td>
<td>Selection 1</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>45</td>
<td>SEL2</td>
<td>Selection 2</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>46</td>
<td>SEL3</td>
<td>Selection 3</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>47</td>
<td>SEL4</td>
<td>Selection 4</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>48</td>
<td>SEL5</td>
<td>Selection 5</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>49</td>
<td>SEL6</td>
<td>Selection 6</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>50</td>
<td>SEL7</td>
<td>Selection 7</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>51</td>
<td>SEL8</td>
<td>Selection 8</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>52</td>
<td>ADLO</td>
<td>mV calibration low coefficient</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R/W</td>
</tr>
<tr>
<td>53</td>
<td>ADHI</td>
<td>mV calibration high coefficient</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R/W</td>
</tr>
<tr>
<td>54</td>
<td>RTDL</td>
<td>RTD calibration low coefficient</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R/W</td>
</tr>
<tr>
<td>55</td>
<td>RTDH</td>
<td>RTD calibration high coefficient</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R/W</td>
</tr>
<tr>
<td>56</td>
<td>CJLO</td>
<td>Cold junction calibration low coefficient</td>
<td>-199.99</td>
<td>455.36</td>
<td>R/W</td>
</tr>
<tr>
<td>57</td>
<td>CJHI</td>
<td>Cold junction calibration high coefficient</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R/W</td>
</tr>
<tr>
<td>58</td>
<td>DATE</td>
<td>Date code</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>59</td>
<td>SRNO</td>
<td>Serial number</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>60</td>
<td>HOUR</td>
<td>Working hours of the controller</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>61</td>
<td>BPL1</td>
<td>Bumpless transfer of OP1</td>
<td>0.00</td>
<td>655.35</td>
<td>R</td>
</tr>
<tr>
<td>62</td>
<td>BPL2</td>
<td>Bumpless transfer of OP2</td>
<td>0.00</td>
<td>655.35</td>
<td>R</td>
</tr>
<tr>
<td>63</td>
<td>CJCL</td>
<td>Cold junction signal low</td>
<td>0.0000</td>
<td>65.535</td>
<td>R</td>
</tr>
<tr>
<td>64, 128</td>
<td>PV</td>
<td>Process value</td>
<td>*4</td>
<td>*4</td>
<td>R</td>
</tr>
<tr>
<td>65, 129</td>
<td>SV</td>
<td>Current set point value</td>
<td>*4</td>
<td>*4</td>
<td>R</td>
</tr>
<tr>
<td>66</td>
<td>130</td>
<td>MV1</td>
<td>OP1 control output value</td>
<td>0.00</td>
<td>655.35</td>
</tr>
<tr>
<td>67</td>
<td>131</td>
<td>MV2</td>
<td>OP2 control output value</td>
<td>0.00</td>
<td>655.35</td>
</tr>
<tr>
<td>68</td>
<td>TIMER</td>
<td>Remaining time of dwell timer</td>
<td>-1999.9</td>
<td>4553.6</td>
<td>R</td>
</tr>
<tr>
<td>69</td>
<td>EROR</td>
<td>Error code</td>
<td>*1</td>
<td>0</td>
<td>65535</td>
</tr>
<tr>
<td>70</td>
<td>MODE</td>
<td>Operation mode and alarm status</td>
<td>*2</td>
<td>0</td>
<td>65535</td>
</tr>
<tr>
<td>71, 140</td>
<td>PROG</td>
<td>Program code</td>
<td>*3</td>
<td>0.00</td>
<td>655.35</td>
</tr>
<tr>
<td>72</td>
<td>CMND</td>
<td>Command code</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>73</td>
<td>JOB1</td>
<td>Job code</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>74</td>
<td>JOB2</td>
<td>Job code</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>75</td>
<td>JOB3</td>
<td>Job code</td>
<td>0</td>
<td>65535</td>
<td>R/W</td>
</tr>
<tr>
<td>76</td>
<td>CJCT</td>
<td>Cold Junction Temperature</td>
<td>-199.99</td>
<td>455.36</td>
<td>R</td>
</tr>
<tr>
<td>77</td>
<td>Reserved</td>
<td>0</td>
<td>65535</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>Reserved</td>
<td>0</td>
<td>65535</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>Reserved</td>
<td>0</td>
<td>65535</td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>
Data Conversion

The word data are regarded as unsigned (positive) data in the Modbus message. However, the actual value of the parameter may be a negative value with decimal point. The high/low scale values for each parameter are used for the purpose of such conversion.

Let

\[ M = \text{Value of Modbus message} \]
\[ A = \text{Actual value of the parameter} \]
\[ SL = \text{Scale low value of the parameter} \]
\[ SH = \text{Scale high value of the parameter} \]

\[ M = \left( \frac{65535}{SH - SL} \right) \times (A - SL) \]
\[ A = \left( \frac{SH - SL}{65535} \right) \times (M + SL) \]

*1 The error code is shown in the first column of Table A.1.

*2 Definition for the value of MODE register:

- H'000X = Normal mode
- H'010X = Calibration mode
- H'020X = Auto-tuning mode
- H'030X = Manual control mode
- H'040X = Failure mode

The alarm status is shown in MV2 instead of MODE for models TEC-220 and TEC-920.

*3 The PROG Code is defined in the following table:

<table>
<thead>
<tr>
<th>Model No.</th>
<th>TEC-9100</th>
<th>TEC-8100</th>
<th>TEC-4100</th>
<th>TEC-7100</th>
<th>TEC-220</th>
<th>TEC-920</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROG Code</td>
<td>6.XX</td>
<td>11.XX</td>
<td>12.XX</td>
<td>13.XX</td>
<td>33.XX</td>
<td>34.XX</td>
</tr>
</tbody>
</table>

(xx denotes the software version)

*4 The scale high/low values are defined in the following table for SP1, INLO, INHI, SP1L, SP1H, SHIF, PV, SV, RELO and REHI:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Non-linear input</th>
<th>Linear input DP = 0</th>
<th>Linear input DP = 1</th>
<th>Linear input DP = 2</th>
<th>Linear input DP = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale High</td>
<td>4553.6</td>
<td>45536</td>
<td>4553.6</td>
<td>455.36</td>
<td>45.536</td>
</tr>
</tbody>
</table>

*5 The scale high/low values are defined in the following table for PB, O1HY, RR, O2HY, and ALHY:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Non-linear input</th>
<th>Linear input DP = 0</th>
<th>Linear input DP = 1</th>
<th>Linear input DP = 2</th>
<th>Linear input DP = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale low</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>0.000</td>
</tr>
<tr>
<td>Scale High</td>
<td>6553.5</td>
<td>65535</td>
<td>6553.5</td>
<td>655.35</td>
<td>65.535</td>
</tr>
</tbody>
</table>

*6 The scale high/low values are defined in the following table for SP3:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>ALFN=1 (TIMR)</th>
<th>Non-linear input</th>
<th>Linear input DP = 0</th>
<th>Linear input DP = 1</th>
<th>Linear input DP = 2</th>
<th>Linear input DP = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale High</td>
<td>4553.6</td>
<td>45536</td>
<td>4553.6</td>
<td>455.36</td>
<td>45.536</td>
<td></td>
</tr>
</tbody>
</table>

*7 The scale high/low values are defined in the following table for SP2:

For TEC-220 and TEC-920

<table>
<thead>
<tr>
<th>Conditions</th>
<th>OUT2=1 (TIMR)</th>
<th>Non-linear input</th>
<th>Linear input DP = 0</th>
<th>Linear input DP = 1</th>
<th>Linear input DP = 2</th>
<th>Linear input DP = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale High</td>
<td>4553.6</td>
<td>45536</td>
<td>4553.6</td>
<td>455.36</td>
<td>45.536</td>
<td></td>
</tr>
</tbody>
</table>

For TEC-9100, TEC-8100, TEC-7100 and TEC-4100:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Non-linear input</th>
<th>Linear input DP = 0</th>
<th>Linear input DP = 1</th>
<th>Linear input DP = 2</th>
<th>Linear input DP = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale High</td>
<td>4553.6</td>
<td>45536</td>
<td>4553.6</td>
<td>455.36</td>
<td>45.536</td>
</tr>
</tbody>
</table>
7-5 Communication Examples:

Example 1: Download the default values via the programming port
The programming port can perform Modbus communications regardless of the incorrect setup values of address, baud, parity, stop bit, etc. It is especially useful during the first time configuration for the controller. The host must be set with 9600 baud rate, 8 data bits, even parity and 1 stop bit.

The Modbus message frame with hexadecimal values is shown as follows:

<table>
<thead>
<tr>
<th>Addr.</th>
<th>Func.</th>
<th>Starting Addr.</th>
<th>No. of words</th>
<th>Bytes</th>
<th>SP1=25.0</th>
<th>SP2=10.0</th>
<th>Sp3=10.0</th>
<th>LOCK = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>01</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>34</td>
<td>68</td>
<td>4F</td>
<td>19</td>
</tr>
</tbody>
</table>

Example 2: Read PV, SV, MV1 and MV2
Send the following message to the controller via the COMM port or programming port:

<table>
<thead>
<tr>
<th>Addr.</th>
<th>Func.</th>
<th>Starting Addr.</th>
<th>No. of words</th>
<th>CRC16</th>
</tr>
</thead>
<tbody>
<tr>
<td>03</td>
<td>00</td>
<td>H’40</td>
<td>H’80</td>
<td>04</td>
</tr>
</tbody>
</table>

Example 3: Perform Reset Function
(same effect as pressing  R  key)

Query

<table>
<thead>
<tr>
<th>Addr.</th>
<th>Func.</th>
<th>Register Addr.</th>
<th>Data Hi/Lo</th>
<th>CRC16</th>
</tr>
</thead>
<tbody>
<tr>
<td>06</td>
<td>00</td>
<td>H’48</td>
<td>H’68</td>
<td>H’25</td>
</tr>
</tbody>
</table>

Example 4: Enter Auto-tuning Mode
Query

<table>
<thead>
<tr>
<th>Addr.</th>
<th>Func.</th>
<th>Register Addr.</th>
<th>Data Hi/Lo</th>
<th>CRC16</th>
</tr>
</thead>
<tbody>
<tr>
<td>06</td>
<td>00</td>
<td>H’48</td>
<td>H’68</td>
<td>H’28</td>
</tr>
</tbody>
</table>

Example 5: Enter Manual Control Mode
Query

<table>
<thead>
<tr>
<th>Addr.</th>
<th>Func.</th>
<th>Register Addr.</th>
<th>Data Hi/Lo</th>
<th>CRC16</th>
</tr>
</thead>
<tbody>
<tr>
<td>06</td>
<td>00</td>
<td>H’48</td>
<td>H’68</td>
<td>H’27</td>
</tr>
</tbody>
</table>

Example 6: Read All Parameters
Query

<table>
<thead>
<tr>
<th>Addr.</th>
<th>Func.</th>
<th>Starting Addr.</th>
<th>No. of words</th>
<th>CRC16</th>
</tr>
</thead>
<tbody>
<tr>
<td>03</td>
<td>00</td>
<td>00</td>
<td>H’50</td>
<td>Hi</td>
</tr>
</tbody>
</table>

Example 7: Modify the Calibration Coefficient
Preset the CMND register with 26669 before attempting to change the calibration coefficient.

<table>
<thead>
<tr>
<th>Addr.</th>
<th>Func.</th>
<th>Register Addr.</th>
<th>Data Hi/Lo</th>
<th>CRC16</th>
</tr>
</thead>
<tbody>
<tr>
<td>06</td>
<td>00</td>
<td>H’48</td>
<td>H’68</td>
<td>H’2D</td>
</tr>
<tr>
<td>Error Code</td>
<td>Display Symbol</td>
<td>Error Description</td>
<td>Corrective Action</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>----------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$E - 04$</td>
<td>Illegal setup values being used: Before COOL is used for OUT2, DIRT (cooling action) has already been used for OUT1, or PID mode is not used for OUT1 (that is, PB=0 and/or TI=0)</td>
<td>Check and correct setup values of OUT2, PB, TI and OUT1. If OUT2 is required for cooling control, the control should use PID mode (PB≠0, TI≠0) and OUT1 should use reverse mode (heating action). Otherwise, don’t use OUT2 for cooling control.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>$E - 10$</td>
<td>Communication error: bad function code</td>
<td>Correct the communication software to meet the protocol requirements.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>$E - 11$</td>
<td>Communication error: register address out of range</td>
<td>Don’t issue an over-range register address to the slave.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>$E - 14$</td>
<td>Communication error: attempt to write a read-only data or a protected data</td>
<td>Don’t write a read-only data or a protected data to the slave.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>$E - 15$</td>
<td>Communication error: write a value which is out of range to a register</td>
<td>Don’t write an over-range data to the slave register.</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>$E - E E$</td>
<td>Fail to perform auto-tuning function</td>
<td>1. The PID values obtained after auto-tuning procedure are out of range. Retry auto-tuning.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Don’t change set point value during auto-tuning procedure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4. Don’t set a zero value for PB.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5. Don’t set a zero value for TI.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6. Press RESET key.</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>$E E - P E$</td>
<td>EEPROM can’t be written correctly</td>
<td>Return to factory for repair.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>$C - E E$</td>
<td>Cold junction compensation for thermocouple malfunction</td>
<td>Return to factory for repair.</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>$S - E E$</td>
<td>Input sensor break, or input current below 1 mA if 4-20 mA is selected, or input voltage below 0.25V if 1-5V is selected</td>
<td>Replace input sensor.</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>$R - E E$</td>
<td>A to D converter or related component(s) malfunction</td>
<td>Return to factory for repair.</td>
<td></td>
</tr>
</tbody>
</table>
RETURNS
No product returns can be accepted without a completed Return Material Authorization (RMA) form.

TECHNICAL SUPPORT
Technical questions and troubleshooting help is available from Tempco. When calling or writing please give as much background information on the application or process as possible.
E-mail: techsupport@tempco.com
Phone: 630-350-2252
800-323-6859

Note: Information in this manual was deemed correct at the time of printing. The policy of Tempco is one of continuous development and product improvement, and we reserve the right to modify specifications and designs without prior notice. Not responsible for typographical errors.
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