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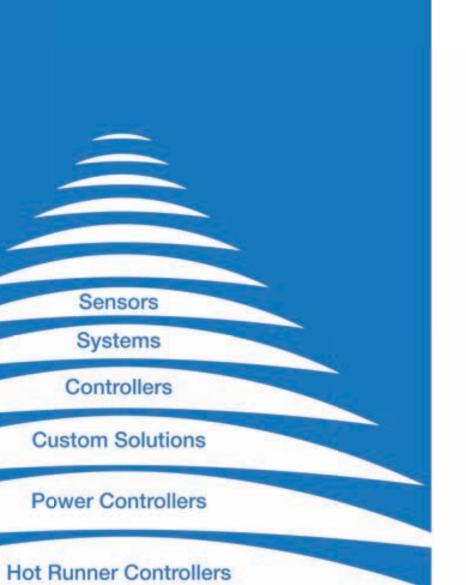




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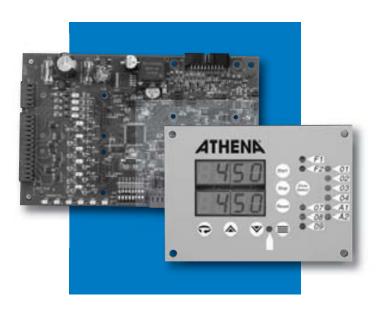
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Legendary Quality Performance & Value



C-Series 4C Universal Multi-Loop PID Controller



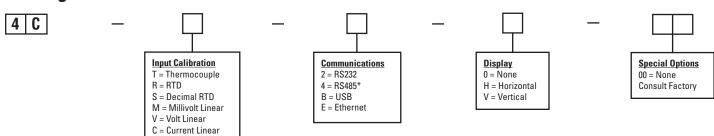
Athena's new C-Series Multi-Loop PID Controller offers up to four loops of PID control with cascade and feed forward capabilities, for less cost than four separate loop controllers with similar capabilities. The controller is user-configurable and offers universal RTD, T/C and linear inputs with each PID loop capable of being independently auto-tuned.

- ▲ Small size, 4.5" x 7" control board provides maximum flexibility in embedded machine design applications
- Low voltage, energy efficient 18 Vac/24 Vdc control board is designed to UL 508 standards
- ▲ Auto-tune provides precise tuning of PID algorithms
- Vertical or horizontal display orientations offer mounting flexibility
- ▲ Ambient 0-70°C temperature rating enables controller to withstand environment extremes
- ▲ Interface with PLC's and PC's

Range Information

Input	Range	Input	Range
"B"	32°F to 3308°F (0°C to 1820°C)	"R"	-58°F to 3214°F (-50°C to 1768°C)
"C"	32°F to 4199°F (0°C to 2315°C)	"S"	-58°F to 3214°F (-50°C to 1768°C)
"E"	-238°F to 1832°F (-150°C to 1000°C)	"T"	-454°F to 752°F (-270°C to 400°C)
"J"	-328°F to 1400°F (-200°C to 760°C)	Platinel® II	-148°F to 2250°F (-100°C to 1232°C)
"K"	-454°F to 2462°F (-270°C to 1354°C)	100 ohm RTD	-328°F to 1562°F (-200°C to 850°C)
"N"	-450°F to 2372°F (-268°C to 1300°C)	100 ohm RTD (Decimal)	-328.0°F to 707.0°F (-200.0°C to 375.0°C)
"NNM"	32°F to 2570°F (0°C to 1410°C)	Current Linear (Scaleable)	4 to 20mA, 0 to 20mA
Millivolt Linear (Scaleable)	0 to 50mV/10 to 50mV 0 to 10mV/0 to 50mV 0 to 100mV	Volt Linear (Scaleable)	0 to 1V/0 to 5V 0 to 10V 0 to 5V

Ordering Information



Note: Consult factory for output configurations. Athena's Multi-Comm™ Software supplied with 4C Controller

* RS485 is Standard



C-Series 4C Universal Multi-Loop PID Controller

Technical Specifications

Operating Limits

Ambient Temperature

Relative

Humidity Tolerance

Power **Power Consumption** 90%, non-condensing 18 Vac, 24 Vdc ≤ 100 mA @ 18 Vac for control / display

≤ 1 A @ 18 Vac for digital I/O

32°F to 158°F (0°C to 70°C)

Performance

Accuracy ±0.20% of full scale

(±0.10% typical), ±1 digit

1 count/0.1 count

Setpoint Resolution

Repeatability

Temperature Stability TC Cold-End Tracking Noise Rejection **Process Sampling**

±1 count 5 μV/°C (maximum) 0.05°C/°C ambient 100 dB common mode 126 ms x number of active

zones + 1

Control Characteristics

Alarms Adjustable for high/low;

selectable process, or deviation

Proportional Band 2 to span of sensor Integral 0 to 9600 sec Derivative 0 to 2400 sec

0 = 200 ms; 1 to 120 sec Cycle Time Control Hysteresis 1 to span of sensor Auto-Tune Operator initiated Manual Control Operator initiated

Inputs

Thermocouple B, C, E, J, K, N, NNM, R, S, T, Platinel II

Maximum lead resistance 100 ohms for

rated accuracy

RTD Platinum 2- and 3-wire, 100 ohms at

0°C, (DIN curve standard 0.00385)

Linear 0-50 mV/10-50 mV. 0-20 mA/4-20 mA.

0-10 mV/0-50 mV, 0-100 mV, 0-1 V/0-5 V, 0-10 V, 1-5 V

Outputs

Standard Six, 24 Vdc sourcing outputs. Total current capacity is fused at 3/4 amp

Digital outputs are powered with an isolated internal 24 Vdc power supply

Load is wired between each individual output pin and the common 24 Vdc return pin A diode clamp is provided for

inductive loads

Optional Two Analog (1 per board),

0-20 mA, 4-20 mA or 0-10 Vdc

Six Digital (3 per board)

Communications Type

2 RS-232 4 RS-485 Modbus

В USB Ε Ethernet

Mechanical Characteristics

Display Optional Vertical or Horizontal

Standard Display Four, 7 segment LED digits for process value and four, 7 segment

LED digits for setpoint Twelve monochrome LED's Eight push button switches

Display board is connected via a 20

conductor ribbon cable Length not to exceed 6'

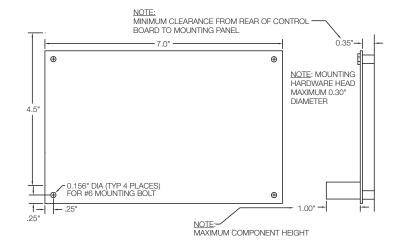
Custom Display Up to 10, seven segment LED's

> Digits can be traded for 8 mono-color LED's per digit Up to 10 momentary push

button switches

Display board is connected via a 20

conductor ribbon cable Length not to exceed 6





C-Series 1ZC DIN Rail Universal Temperature/Process Controller



The Athena 1ZC is a DIN rail mounted, auto-tuning controller that can be used for precise control of a single control loop with two independent outputs configurable as direct-acting, reverse-acting or alarm. A bidirectional RS-485 serial communications interface is standard. Discrete LED displays become illuminated whenever associated outputs are active and provide system status. A wide range of sensor inputs are supported and many types of outputs are available.

- ▲ Miniature DIN Rail Mountable Enclosure Stackable to Required Number of Zones
- ▲ Each Zone Independently Powered 100-250 V 50/60 Hz
- ▲ RS-485 Modbus® Serial Communications
- Easy Communications Bus Wiring
- Auto-Tune
- ▲ Each Output Universally Configurable as Heat/Cool or Alarm
- ▲ Accepts RTD (2 and 3 Wire), Thermocouple, and **Linear Inputs**
- ▲ Loop Break Alarm
- Pluggable Terminal Block for Easy Wiring and Controller Replacement
- ▲ Optically Isolated Inputs and Outputs
- ▲ UL, cUL, and CE Approvals



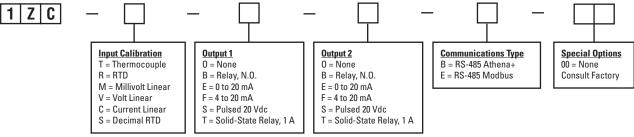




Range Information

Input	Range	Input	Range
"B"	32°F to 3308°F (0°C to 1820°C)	"R"	-58°F to 3214°F (-50°C to 1768°C)
"C"	32°F to 4199°F (0°C to 2315°C)	"S"	-58°F to 3214°F (-50°C to 1768°C)
"E"	-238°F to 1832°F (-150°C to 1000°C)	"T"	-454°F to 752°F (-270°C to 400°C)
"J"	-328°F to 1400°F (-200°C to 760°C)	Platinel® II	-148°F to 2250°F (-100°C to 1232°C)
"K"	-454°F to 2462°F (-270°C to 1354°C)	100 ohm RTD	-328°F to 1562°F (-200°C to 850°C)
"N"	-450°F to 2372°F (-268°C to 1300°C)	100 ohm RTD (Decimal)	-328.0°F to 707.0°F (-200.0°C to 375.0°C)
"NNM"	32°F to 2570°F (0°C to 1410°C)	Current Linear (Scaleable)	4 to 20mA, 0 to 20mA
Millivolt Linear (Scaleable)	0 to 50mV/10 to 50mV 0 to 10mV/0 to 50mV 0 to 100mV	Volt Linear (Scaleable)	0 to 1V/0 to 5V 0 to 10V 0 to 5V

Ordering Information



Note: Athena's Multi-Comm™ Software supplied with 1ZC Controller



C-Series 1ZC DIN Rail Universal Temperature/Process Controller

Technical Specifications

Operating Limits

Ambient Temperature

32°F to 131°F (0°C to 55°C)

Relative

Humidity Tolerance 90%, non-condensing

100-250 V 50/60 Hz (single-phase) Power

125 to 300 Vdc

Power Consumption Less than 6 VA

Performance

Accuracy

±0.20% of full scale (±0.10% typical), ±1 digit

Setpoint Resolution

1 count/0.1 count

Repeatability

±1 count

Temperature Stability TC Cold-End Tracking 5 μV/°C (maximum) 0.05°C/°C ambient

Noise Rejection

Process Sampling

100 dB common mode

10 Hz (100 ms)

Control Characteristics

Proportional Band

2 to span of sensor

Integral Derivative 0 to 9600 sec 0 to 2400 sec

Cycle Time

0 = 200 ms; 1 to 120 sec

Control Hysteresis

1 to span of sensor

Auto-Tune

Operator initiated

Manual Control

Operator initiated

Inputs

Thermocouple

B. C. E. J. K. N. NNM. R. S. T.

Platinel® II Maximum lead

resistance 100 ohms for

rated accuracy

RTD

Linear

Platinum 2- and 3-wire, 100 ohms at

0°C, DIN curve standard (0.00385)

0-50 mV/10-50 mV. 0-20 mA/

4-20 mA, 0-10 mV/0-50 mV, 0-100

mV, 0-1 V/0-5 V, 0-10 V, 1-5 V

Outputs

В

S

5 A/3 A (120/240 Vac), normally open relay

Ε 0 to 20 mA

F

4-20 mA, full output to load with 500

ohm impedance, max.

20 Vdc pulsed output

1 A, Solid-state relay

Communications Type

В RS-485 Athena+ Ε RS-485 Modbus

Mechanical Characteristics

Display

LED displays for Sensor Error, RXD,

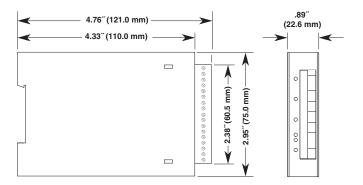
TXD, Output 1, Output 2, Power/Run

Connections

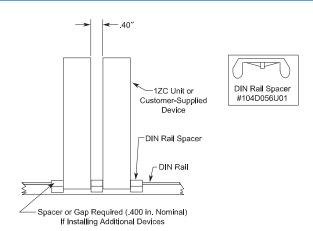
Screw terminals

Use 1.378" (35 mm) x Mounting

.29" (7.5 mm) DIN Rail



Mounting Clearance Requirements

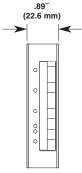


1ZC Contact Identification

Contact #/Description*

- Power
- Output 2
- 3 Output 1
- 4 TXD
 - **RXD**
- Sensor Error

^{*}Specifications subject to change without notice.





C-Series 32C Universal Temperature/Process Controller



The Athena 32C is a 1/32 DIN panel mounted, autotuning controller that can be used for precise control of a single loop with two independent outputs field-configurable as direct acting, reverse acting or alarm. An LED display provides visual indication of various controller functions.

- ▲ Field-Configurable Universal Inputs
- ▲ Bumpless Auto/Manual Transfer
- ▲ NEMA 4X (IP65) Dust and Splash-Proof Front Panel
- ▲ Decimal Display in 0.1° for Measured Temperatures Under 1000°F or °C
- ▲ On/Off through Full PID Operation (P, PI, PD, PID)
- ▲ Adjustable Hysteresis and Deadband
- ▲ Outputs Configurable as Alarms
- ▲ Field-Configurable Process and Deviation Alarms (Latching or Non-Latching)
- ▲ Dual Output/Dual Alarm Capabilities
- ▲ UL, cUL and CE Approvals
- ▲ Special and Custom Options Available

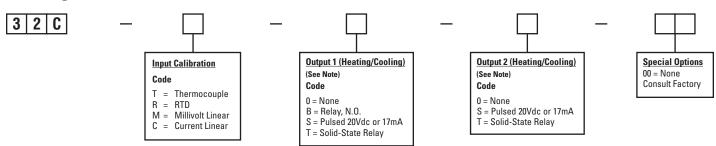




Range Information

90			
Input	Range	Input	Range
"J"	-148°F to 1400°F (-100°C to 760°C)	100 ohm RTD	-328°F to 1562°F (-200°C to 850°C)
"K"	-220°F to 2462°F (-140°C to 1350°C)	100 ohm RTD (Decimal)	-199°F to 392°F (-128°C to 200°C)
"T"	-202°F to 752°F (-130°C to 400°C)		
Millivolt Line (Scaleable)		Current Linear (Scaleable)	4 to 20mA, 0 to 20mA

Ordering Information



Note: Both Outputs MUST be Field Configured to be either Direct Acting or Reverse Acting



C-Series 32C Universal Temperature/Process Controller

Technical Specifications

Operating Limits

Ambient Temperature

Relative

Humidity Tolerance 90% R.H. maximum, non-condensing

Line Voltage Power

Power Consumption

Performance

Accuracy Setpoint Resolution

Repeatability

Temperature Stability TC Cold-End Tracking

Noise Rejection

Process Sampling

Control Characteristics

Setpoint Limits Alarms

Adjustable for high/low; selectable process or deviation

1 to span of sensor

32°F to 140°F (0°C to 60°C)

120 to 375 Vdc, (auto polarity)

Less than 6 VA (instrument)

± 0.2% of full scale, ±1 digit

1.0 count/0.1 count

5 μV/°C (maximum)

0.05°C/°C ambient

3.5 Hz (270 ms)

Span of sensor

100 dB common mode 70 dB series mode

±1.0 count

85 to 265 Vac, 50/60 Hz

Proportional Band 0 to 9600 sec Integral Derivative 0 to 2400 sec Cycle Time 0.3 to 120 sec Control Hysteresis 1 to span of sensor Deadband Range of sensor Manual Control Operator initiated Auto-Tune Operator initiated

Inputs

Thermocouple

Maximum lead resistance, 100 ohms for rated accuracy

RTD Platinum 2-wire, 100 ohms at 0°C, DIN curve standard (0.00385)

0-50mV/10-50mV Linear 4-20mA/0 to 20mA

Decimal Position Selectable: none, 1/10, 1/100

Outputs

В 5 A/3 A (120/240Vac) normally open

S 20Vdc pulsed or 17mA 1 A, Solid-state relay

Mechanical Characteristics

4-digit 0.39" (10 mm) LED display Display

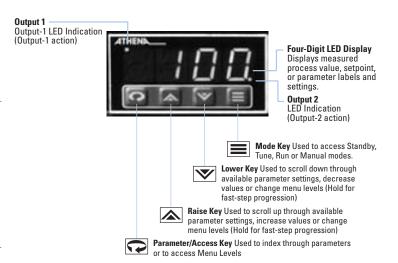
Front Panel Rating NEMA 4X (IP65) Connections Screw Terminals Numeric Range -1999 to 9999

Front Panel Cutout 0.874" x 1.771" (22.19 mm x 45 mm)

Specifications subject to change without notice.









C-Series 16C Universal Temperature/Process Controller



The Athena 16C is a 1/16 DIN panel mounted, autotuning controller that can be used for precise control of a single loop with two independent outputs fieldconfigurable as direct acting, reverse acting or alarm. RS-232 or RS-485 communications interfaces are available, and two digital LED displays provide visual indication of various controller functions.

- Field-Configurable Universal Inputs
- ▲ User-Selectable Ramp to Setpoint
- ▲ 8-Level Ramp/Soak Control
- Bumpless Auto/Manual Transfer
- ▲ NEMA 4X (IP65) Dust and Splash-Proof Front Panel
- ▲ Decimal Display in 0.1° for Measured Temperatures Under 1000° F or C
- ▲ On/Off Through Full PID Operation (P, PI, PD, PID)
- Adjustable Hysteresis and Deadband
- ▲ Outputs Configurable as Alarms
- ▲ Field-Configurable Process or Deviation Alarms; Latching or Non-Latching; Band and Inverse Band
- Dual Output/Dual Alarm Capabilities
- ▲ UL, cUL, and CE Approvals
- Options Include Multi-Function Contact/Digital Input, Transducer Excitation, and Auxiliary Output

1 to 5 V = 0 to 20 mA

- Special and Custom Options Available
- ▲ DIN Rail Option







Range Information

Input	Range	Input	Range
"B"	32°F to 3308°F (0°C to 1820°C)	"R"	-58°F to 3214°F (-50°C to 1768°C)
"C"	32°F to 4199°F (0°C to 2315°C)	"S"	-58°F to 3214°F (-50°C to 1768°C)
"E"	-238°F to 1832°F (-150°C to 1000°C)	"T"	-454°F to 752°F (-270°C to 400°C)
"J"	-328°F to 1400°F (-200°C to 760°C)	Platinel® II	-148°F to 2250°F (-100°C to 1232°C)
"K"	-454°F to 2462°F (-270°C to 1354°C)	100 ohm RTD	-328°F to 1562°F (-200°C to 850°C)
"N"	-450°F to 2372°F (-268°C to 1300°C)	100 ohm RTD (Decimal)	-328.0°F to 707.0°F (-200.0°C to 375.0°C)
"NNM"	32°F to 2570°F (0°C to 1410°C)	Current Linear (Scaleable)	4 to 20mA, 0 to 20mA
Millivolt Linear (Scaleable)	0 to 50mV/10 to 50mV 0 to 10mV/0 to 50mV 0 to 100mV	Volt Linear (Scaleable)	0 to 1V/0 to 5V 0 to 10V 0 to 5V

Ordering Information 6 C Input Calibration **Special Options Standard Options** Code Options **Output 1** Output 2 Digital Input w/Alarm 40 = Switch Closed Code Code Options Consult Factory Code Thermocouple Code None 41 = Switch Open 42 = 5 V Input Communication RS-485 Modbus Alarms RTD 0 = None 0 = None Dual SSR, N.O. Decimal RTD B = Relay, N.O. B = Relay, N.O. Dual Open Collector Dual 24 Vdc 0 to 20 mA 0 to 20 mA = TC and RTD Protocol w/Contact/Digital Input 4 to 20 mA (500 ohm max) 4 to 20 mA (500 ohm max) = Millivolt Linear = RS-485, No Switch = Switch Closed Dual SSR, N.C G = 4 to 20 mA (800 ohm max)G = 4 to 20 mA (800 ohm max) Volt Linear Relay, N.O. Switch Open 5 V Input = Pulsed 20 Vdc or 35 mA P = Pulsed 20 Vdc or 35 mA Current Linear RS-232 S = ΑII = Pulsed 20 Vdc or 17 mA Pulsed 20 Vdc or 17 mA Transducer Excitation (Athena+ Protocol) Solid-State Relay Solid-State Relay Communication, RS-485 Ather 0 to 5 Vdc 0 to 5 Vdc 12 Vdc Protocol w/Contact/Digital Input 51 = 0 to 10 Vdc 0 to 10 Vdc 15 Vdc = RS-485, No Switch Switch Closed = Relay, N.C. Relay, N.C. = Aux Output/PV Retransmit Switch Open 60 = 4 to 20 mA = 5 V Input

Technical Specifications

Operating Limits

Ambient Temperature

Relative Humidity

90%, non-condensing

Tolerance Power

100-250 Vac

32°F to 131°F (0°C to 55°C)

125 to 300 Vdc

24 Vac/dc optional

Power Consumption Less than 6 VA (instrument)

Performance

 $\pm 0.20\%$ of full scale ($\pm 0.10\%$ typical), Accuracy

±1 digit

Setpoint Resolution 1.0 count / 0.1 count

Repeatability ±1.0 count

Temperature Stability TC Cold-End Tracking Noise Rejection

5 μV/°C (maximum) 0.05°C/°C ambient 100 dB common mode

70 dB series mode 10 Hz (100 ms)

Process Sampling Digital Filtering

Adjustable 0.1 to 10 sec

Control Characteristics

Setpoint Limits Span of Sensor

Alarms Adjustable for high/low; selectable

for process or deviation Proportional Band 2 to span of sensor

Integral 0 to 9600 sec 0 to 2400 sec Derivative 0.2 to 120 sec Cycle Time Control Hysteresis 1 to span of sensor

Dead Band (Output 1 & 2) Ramp to Setpoint

Range of Sensor 1 to 9999 min

Auto-Tune Operator initiated from front panel Operator initiated from front panel Manual Control

Inputs

B, C, E, J, K, N, NNM, R, S, T, Platinel II Thermocouple

Maximum lead resistance 100 ohms for

rated accuracy

RTD Platinum 2- and 3-wire, 100 ohms at 0°C,

(DIN curve standard 0.00385)

Linear 0-50 mV/10-50 mV, 0-20 mA/4-20 mA, 0-10 mV/0-50 mV, 0-100 mV, 0-1 V/0-5 V,

0-10 V, 1-5 V

Outputs

В 5 A/3 A (120/240 Vac), normally open

Ε 0-20 mA

F 4-20 mA, full output to load 500 ohm

impedance, max.

G 4-20 mA, full output to load 800 ohm

impedance, max.

Outputs

Р	20 Vdc or 35 mA
S	20 Vdc or 17 mA
T	1 A, Solid-state relay
V	0 to 5 Vdc

Χ 0 to 10 Vdc

5 A/3 A (120/240 Vac), normal closed relay

Alarm Type

10 Dual SSR: Alarm 1: 24-240 Vac, 1 A Alarm 2: 24 Vac Only

Dual Open collector, 24 V, 20 milliamps 20

Dual 24 V, 20 mA 21

22 Dual SSR: Alarm 1: NC, 24-240 Vac,

1 A Alarm 2: 24 Vac Only

23 5 A/3 A (120/240 Vac), mechanical relay

Mechanical Characteristics

Display Dual, 4-digit 0.36" (9.2 mm) LED display

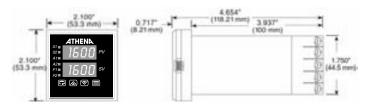
> Process Value: Orange Setpoint Value: Green

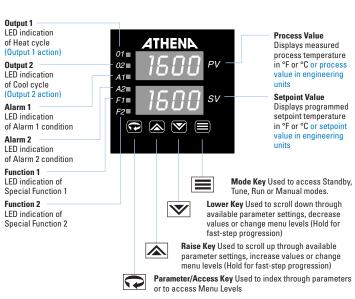
Numeric Range -1999 to 9999 Front-Panel Rating NEMA 4X (IP65)

Front-Panel Cutout 1.771" x 1.771" (45 mm x 45 mm)

Connections Screw Terminals

Specifications subject to change without notice.







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C-Series 18C and 19C Universal Temperature/Process Controllers





The Athena 18C and 19C are available as 1/8 DIN (18C) vertical or 1/8 DIN (19C) horizontal models. Both panel mounted, auto-tuning controllers can be used for precise control of a single loop with two independent outputs field-configurable as direct acting, reverse acting, and 2 alarms. RS-232 or RS-485 communications interfaces are available for both models, and two digital LED displays provide visual indication of various controller functions.

- Field-Configurable Universal Inputs
- User-Selectable Ramp to Setpoint
- ▲ 8-Level Ramp/Soak Control
- Bumpless Auto/Manual Transfer
- ▲ NEMA 4X (IP65) Dust and Splash-Proof Front Panel
- ▲ Decimal Display in 0.1° for Measured Temperatures Under 1000° F or C
- ▲ On/Off through Full PID Operation (P, PI, PD, PID)
- Adjustable Hysteresis and Deadband
- ▲ Outputs Configurable as Alarms
- ▲ Field-Configurable Process or Deviation Alarms; Latching or Non-Latching; Band and Inverse Band
- Dual Output/Dual Alarm Capabilities
- ▲ UL, cUL, and CE Approvals
- ▲ Options Include Remote Analog Setpoint, Multi-Function Contact/Digital Input, Transducer Excitation, and Auxiliary Output
- Special and Custom Options Available

Range Information

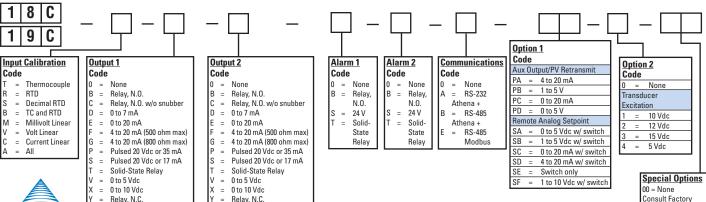






Input	Range	Input	Range
"B"	32°F to 3308°F (0°C to 1820°C)	"R"	-58°F to 3214°F (-50°C to 1768°C)
"C"	32°F to 4199°F (0°C to 2315°C)	"S"	-58°F to 3214°F (-50°C to 1768°C)
"E"	-238°F to 1832°F (-150°C to 1000°C)	"T"	-454°F to 752°F (-270°C to 400°C)
"J"	-328°F to 1400°F (-200°C to 760°C)	Platinel® II	-148°F to 2250°F (-100°C to 1232°C)
"K"	-454°F to 2462°F (-270°C to 1354°C)	100 ohm RTD	-328°F to 1562°F (-200°C to 850°C)
"N"	-450°F to 2372°F (-268°C to 1300°C)	100 ohm RTD (Decimal)	-328.0°F to 707.0°F (-200.0°C to 375.0°C)
"NNM"	32°F to 2570°F (0°C to 1410°C)	Current Linear (Scaleable)	4 to 20mA, 0 to 20mA
Millivolt Linear (Scaleable)	0 to 50mV/10 to 50mV 0 to 10mV/0 to 50mV 0 to 100mV	Volt Linear (Scaleable)	0 to 1V/0 to 5V 0 to 10V 0 to 5V

Ordering Information



C-Series 18C and 19C Universal Temperature/Process Controllers

Technical Specifications

Operating Limits

Ambient Temperature 32°F to 131°F (0°C to 55°C)

Relative

Humidity Tolerance 90%, non-condensing 100 to 250 Vac 125 to 300 Vdc Line Voltage

24 Vac/dc optional

Power Consumption Less than 6 VA (instrument)

Performance

Accuracy ±0.20% of full scale (±0.10% typical),

Setpoint Resolution 1 count / 0.1 count

Repeatability ±1 count

Temperature Stability 5 μV/°C (maximum) TC Cold-End Tracking 0.05°C/°C ambient Noise Rejection 100 dB common mode 70 dB series mode

Process Sampling 10 Hz (100 ms) Digital Filtering Adjustable 0.1 to 10

Control Characteristics

Setpoint Limits Span of Sensor Alarms Adjustable for high/low;

selectable process or deviation

Proportional Band 2 to span of sensor Integral 0 to 9600 sec Derivative 0 to 2400 sec Cycle Time 0.2 to 120 sec

Control Hysteresis Dead Band (Output 1 & 2)

Range of sensor Ramp to Setpoint 1 to 9999 min

Auto-Tune Operator initiated from front panel Manual Control Operator initiated from front panel

Inputs

B, C, E, J, K, N, NNM, R, S, T, Platinel II Thermocouple

1 to span of sensor

Maximum lead resistance, 100 ohms for rated accuracy

RTD Platinum 2- and 3-wire, 100 ohms at 0°C, (DIN curve standard 0.00385)

0-50 mV/10-50 mV, 0-20 mA/4-20 mA, 0-10 mV/0-50 mV, 0-100 mV, 0-1 V/0-5 V,

0-10 V, 1-5 V

Outputs

Linear

Ρ

S

В 5 A/3 A (120/240 Vac) normally open С 5 A/3 A (120/240 Vac) normally open

w/o snubber D 0 - 7 mA 0-20 mA

Ε F 4-20 mA, full output to load 500 ohm

impedance max

G 4-20 mA, full output to load 800 ohm

impedance max 20 Vdc or 35 mA 20 Vdc or 17 mA 1 A, Solid-state relay **Outputs**

0 to 5 Vdc Χ 0 to 10 Vdc

1 A, normally closed relay

Alarm Outputs

В 5 A/3 A (120/240 Vac), mechanical relay

S 24 V, 20 mA

SSR. NC. 24-240 Vac

Mechanical Characteristics

Dual, 4-digit 0.36" (9.2 mm) LED display Display

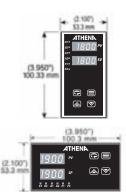
Process Value: Orange Setpoint Value: Green

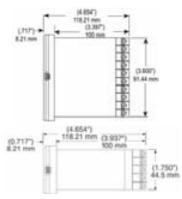
-1999 to 9999 Numeric Range Front Panel Rating NEMA 4X (IP65)

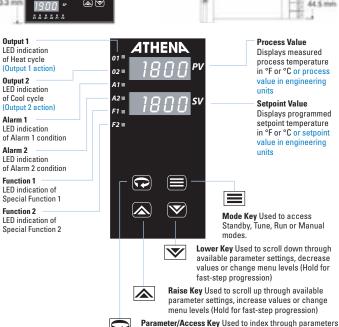
Front Panel Cutout 3.622" x 1.771" (92 mm x 45 mm)

Connections Screw terminals

Specifications subject to change without notice.







or to access Menu Levels



C-Series 25C Universal Temperature/Process Controller



The Athena 25C is a 1/4 DIN panel mounted, autotuning controller that can be used for precise control of a single loop with two independent outputs fieldconfigurable as direct acting, reverse acting, and 2 alarms. RS-232 or RS-485 communications interfaces are available, and two digital LED displays provide visual indication of various controller functions.

- ▲ Field-Configurable Universal Inputs
- ▲ User-Selectable Ramp to Setpoint
- ▲ 8-Level Ramp/Soak Control
- Bumpless Auto/Manual Transfer
- ▲ NEMA 4X (IP65) Dust and Splash-Proof Front Panel
- ▲ Decimal Display in 0.1° for Measured Temperatures Under 1000° F or C
- △ On/Off through Full PID Operation (P, PI, PD, PID)
- ▲ Adjustable Hysteresis and Deadband
- ▲ Outputs Configurable as Alarms
- ▲ Field-Configurable Process or Deviation Alarms; Latching or Non-Latching; Band and Inverse Band
- Dual Output/Dual Alarm Capabilities
- ▲ UL, cUL, and CE Approvals
- ▲ Options Include Remote Analog Setpoint, Multi-Function Contact/Digital Input, Transducer Excitation, and Auxiliary Output
- Special and Custom Options Available

Range Information

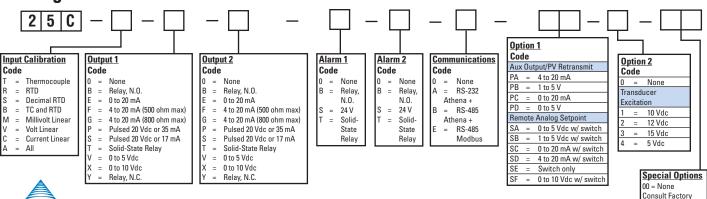






Input	Range	Input	Range
"B"	32°F to 3308°F (0°C to 1820°C)	"R"	-58°F to 3214°F (-50°C to 1768°C)
"C"	32°F to 4199°F (0°C to 2315°C)	"S"	-58°F to 3214°F (-50°C to 1768°C)
"E"	-238°F to 1832°F (-150°C to 1000°C)	"T"	-454°F to 752°F (-270°C to 400°C)
"J"	-328°F to 1400°F (-200°C to 760°C)	Platinel® II	-148°F to 2250°F (-100°C to 1232°C)
"K"	-454°F to 2462°F (-270°C to 1354°C)	100 ohm RTD	-328°F to 1562°F (-200°C to 850°C)
"N"	-450°F to 2372°F (-268°C to 1300°C)	100 ohm RTD (Decimal)	-328.0°F to 707.0°F (-200.0°C to 375.0°C)
"NNM"	32°F to 2570°F (0°C to 1410°C)	Current Linear (Scaleable)	4 to 20mA, 0 to 20mA
Millivolt Linear (Scaleable)	0 to 50mV/10 to 50mV 0 to 10mV/0 to 50mV 0 to 100mV	Volt Linear (Scaleable)	0 to 1V/0 to 5V 0 to 10V 0 to 5V

Ordering Information



Technical Specifications

Operating Limits

Ambient Temperature

Relative

32°F to 131°F (0°C to 55°C)

Humidity Tolerance Line Voltage

90%, non-condensing 100 to 250 Vac

125 to 300 Vdc 24 Vac/dc optional

Power Consumption Less than 6 VA (instrument)

Performance

Accuracy ±0.20% of full scale (±0.10% typical),

±1 digit

Setpoint Resolution

1 count / 0.1 count

Repeatability

±1 count

Temperature Stability TC Cold-End Tracking 5 µV/°C (maximum) 0.05°C/°C ambient

Noise Rejection

100 dB common mode 70 dB series mode

Process Sampling Digital Filtering

10 Hz (100 ms) Adjustable 0.1 to 10

Control Characteristics

Setpoint Limits

Span of Sensor Alarms

Adjustable for high/low;

selectable process, or deviation

Proportional Band Integral

2 to span of sensor 0 to 9600 sec

Derivative

0 to 2400 sec 0.2 to 120 sec

Cycle Time Control Hysteresis

1 to span of sensor

Dead Band (Output 1 & 2)

Range of sensor

Ramp to Setpoint

1 to 9999 min

Auto-Tune

Operator initiated from front panel

Manual Control

Operator initiated from front panel

Inputs

RTD

Linear

Ε

Thermocouple B, C, E, J, K, N, NNM, R, S, T, Platinel II

Maximum lead resistance,

100 ohms for rated accuracy

Platinum 2- and 3-wire, 100 ohms at

0°C, (DIN curve standard 0.00385) 0-50 mV/10-50 mV, 0-20 mA/4-20 mA,

0-10 mV/0-50 mV, 0-100 mV, 0-1 V/0-5 V,

0-10 V, 1-5 V

Outputs

В 5 A/3 A (120/240 Vac) normally open

0-20 mA

F 4-20 mA, full output to load 500 ohm

impedance max

4-20 mA, full output to load 800 ohm G

impedance max

Ρ 20 Vdc or 35 mA S 20 Vdc or 17 mA

Outputs

Т 1 A, Solid-state relay

٧ 0 to 5 Vdc Χ 0 to 10 Vdc

1 A, normally closed relay

Alarm Outputs

В 5 A/3 A (120/240 Vac), mechanical relay

S 24 V, 20 mA

Т SSR, NC, 24-240 Vac

Mechanical Characteristics

Display Dual, 4-digit 0.36" (9.2 mm) LED display

Process Value: Orange Setpoint Value: Green

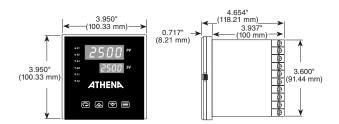
Numeric Range -1999 to 9999

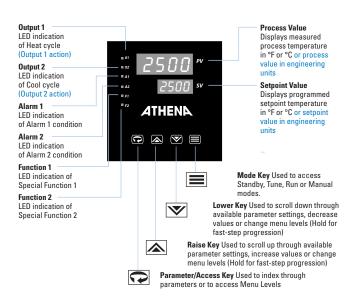
Front Panel Rating NEMA 4X (IP65)

Front Panel Cutout 3.622" x 3.622" (92 mm x 92 mm)

Connections Screw terminals

Specifications subject to change without notice.







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C-Series OTC25 Digital Temperature Controller



The Athena OTC25 is a 1/4 DIN panel mounted, digital controller that can be used for precise control of a single loop with two independent outputs. The controller accepts thermocouple input, and a large easy-to-read digital LED display is selectable for either setpoint or process temperature.

- ▲ Accepts Type J (OTC25-N &L) or Type J and K (OTC25-P) Thermocouple Input
- ▲ Adjustable Output Hysteresis to Prevent Rapid Cycling Around Setpoint Temperature
- ▲ Adjustable Deviation Alarm Flashes When Measured Temperature Exceeds or Falls Below Setpoint Temperature
- ▲ NEMA 4X (IP65) Front Bezel, Splash-Proof and Resistant to Dust
- ▲ Discrete Status Indicators Illuminate When Temperature Display, Setpoint Display, Limit Display, or Heat/Cool Output is Active
- RU, cRU, CE, and FM Approvals

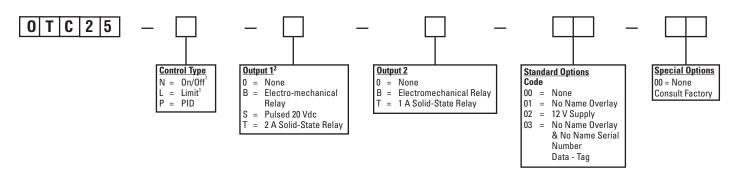








Ordering Information



¹ On/Off and limit control versions (OTC25-N and OTC25-L) are only available with Type J thermocouple input.

² Limit control versions (OTC25-L) may only be ordered with electromechanical relay (Type "B") outputs in Output 1.

C-Series OTC25 Digital Temperature Controller

Technical Specifications

Operating Limits

Ambient Temperature

32°F to 140°F (0°C to 60°C)

Relative

Humidity Tolerance 90% R.H. maximum, non-condensing

Line Voltage 100 to 250 Vac

50/60 Hz

Power Consumption Less than 6 VA (instrument)

Performance

Accuracy $\pm 0.3\%$ of FS, \pm one digit

Temperature

Stability 5 μV/°C maximum

TC Cold End

Tracking 0.05°C/°C ambient

Noise Rejection Common mode > 100 dB

Series mode > 70 dB

Process Sampling 3.7 Hz (270 ms)

Control Characteristics

 $\begin{array}{lll} \textbf{Setpoint Limits} & 0°F \ to \ 900°F \ (0°C \ to \ 482°C) \\ \textbf{Control Hysteresis} & 2°F \ to \ 252°F \ (1°C \ to \ 140°C) \\ \textbf{Display Offset} & -126°F \ to \ +126°F \ (-70°C \ to \ 70°C) \\ \textbf{Deviation Alarm} & Off, \ 1°F \ to \ 252°F \ (Off, 1°C \ to \ 140°C) \\ \end{array}$

Inputs

Thermocouple OTC25-N Type J OTC25-L Type J OTC25-P Type J or K

Maximum lead resistance, 100 ohms for

rated accuracy

Outputs

S

B 5 A @ 120 Vac, 3 A @ 240 Vac

electromechanical relay

T Solid-state relay, 2 A (Output 1),

1 A (Output 2) Pulsed 20 Vdc

Mechanical Characteristics

Display 3-digit, 0.56" (14.2 mm)

Orange

Discrete Indicators Setpoint: Amber

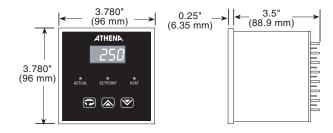
Actual: Amber O1: Orange O2: Orange Limit: Orange NEMA 4X (IP65)

Front Panel Rating NEMA 4X (IP65 Connections Fast-on style

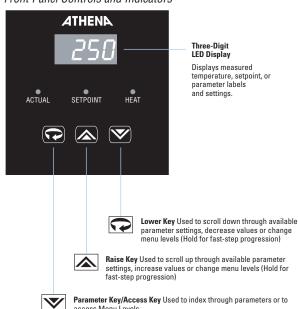
Front Panel Cutout 3.622" x 3.622" (92 mm x 92 mm)

Specifications subject to change without notice.

Panel Cutout: 3.622" sq. (92 mm)



Front Panel Controls and Indicators

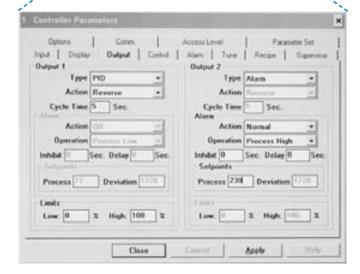




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Multi-Comm™ Remote Monitoring and Control Software









*min requirements: 386SX, 1 Mb of free hard-disk space, Windows® 3.1 or later *(client to update minimum hardware and software operating requirements)

Athena Multi-Comm Software is designed for use with all Infinity with Modbus®, C-Series with either Modbus or Athena+ and Legacy Series Controllers using Athena+, and can control up to 100 temperature or process controllers/zones via an RS-485 network.* Up to sixteen controllers/zones can be simultaneously viewed on screen at one time with a color emulation of each controller's front panel display showing process value and setpoint in real time.

- ▲ Pull-Down Menus and Pop-Up Windows Make Controller Configuration and Data Analysis Easy
- ▲ Multiple Operator Security Levels and Password Protection Prevent Unauthorized Access or Accidental Changes to Process Parameters
- Automatic Controller Detection Locates and Identifies Each Controller or Control Zone on the Network
- ▲ User-Defined 10-Character Controller Labels Allow Custom Identification of Any Controller or Control Zone
- Storage and Retrieval of all Configuration Parameters for all Networked Controllers or Control Zones to a Single Data File
- ▲ Provides Each Controller or Control Zone with Two Additional Local Alarms (Process Hi/Lo) Without Affecting Other Alarms
- ▲ Captures and Time-Stamps Process Value and Setpoint Data to Log File for Subsequent Storage and Analysis
- Displays Graph Window Showing Real-Time Plot of Process Value vs. Setpoint for Any Controller or Control Zone on Network

Multi-Comm™ Remote Monitoring and Control Software

Technical Specifications

Security Features

To prevent unauthorized changes to either controller of Multi-Comm parameters, operators must follow specific login and logout procedures. Each operator may have an individual user ID and password, which must be entered exactly the same each time access is requested. Operators may be assigned different security levels, depending on their specific access requirements. You may specify any or all of the following access privileges per operator:

- ▲ Change Setpoint (access to change controllers' or control zones setpoints)
- View/Change Parameters (access to controllers' or control zones parameters)
- Controller Configuration (access to Multi-Comm configuration options)
- Super User (access to add or change operator passwords and privileges)

Communications Setup

Multi-Comm is designed for bidirectional communications to Athena EMC, C-Series, and Legacy Series controllers connected via an RS-485 hookup using an available RS-232 serial port on your computer. It allows you to easily set up your communications port, polling frequency, and timeout frequency.

Controller Setup

Multi-Comm uses the network ID numbers you've assigned to your controllers in order to communicate to them. Using its Automatic controller detection (ACD) feature, Multi-Comm can find and identify each controller or control zone on the network automatically and label each controller or control zone with the network ID you've assigned it. You may also change its name to any 10-character designation.

Adding and Deleting Controllers or Control Zones

Multi-Comm allows you to remove individual controllers or control zones from software control and add them back at any time.

Local Alarms

Multi-Comm provides two additional "local" alarms for each controller or control zones on the network: one high process alarm and one low process alarm. They do not affect the operation of the controller's or control zones' regular alarms.

Data Logging

Multi-Comm will capture the process and setpoint values of each controller or control zones on the network and save it to an ASCII file that can be read by any text editor or word processor. It will also give you the option of appending or overwriting data to an existing log file, when you specify the same log file name at a later date. The log data, which is time-stamped and identified with each controllers' or control zones' name, may also be imported directly into a Microsoft® Excel spreadsheet for further analysis and graphic. Log time can be varied by the operator.

Graph Window

Multi-Comm allows an operator to visually track a selected controller's or control zones' instantaneous setpoint and process values over a period of several minutes with an on-line graphing feature.

Specifications subject to change without notice.



Legacy Series 16 Universal Temperature/Process Controller



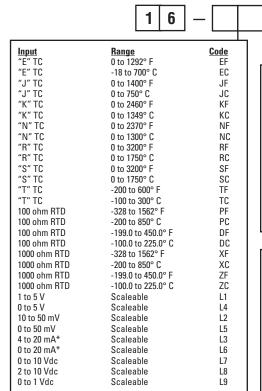
The Athena Legacy 16 is a 1/16 DIN panel mounted, auto-tuning controller that can be used for precise control of a single loop with two independent outputs. The controller accepts thermocouple, RTD, voltage, or current input. RS-232 or RS-485 communications are available, and two digital LED displays provide visual indication of various controller functions.

- ▲ User-Selectable Ramp to Setpoint
- Bumpless Auto/Manual Transfer
- ▲ NEMA 4X (IP65) Dust and Splash-Proof Front Panel
- ▲ On/Off through Full PID Operation (P.PI,PD,PID)
- Auto-Tuning, Heat or Cool
- Adjustable Hysteresis & Heat/Cool Spread
- Field-Configurable Process, Deviation, or Latching or Non-Latching Alarms
- ▲ Remote Setpoint Select Option
- Dual Output/Dual Alarm Capabilities
- Optional Process Variable Retransmission
- DIN Rail Option
- cUL and CE Approvals





Ordering Information



Output 1 (Heating) Configuration Code

0 = None

 $B=Relay,\,N.0.$

E = 0 to 20 mA

F = 4 to 20 mA (500 ohm max)

G = 4 to 20 mA (800 ohm max) P = Pulsed 20 Vdc or 35 mA

S = Pulsed 20 Vdc or 17 mA

T = Solid-State Relay

V = 0 to 5 Vdc

X = 0 to 10 Vdc

Y = Relay, N.C.

Output 2 (Cooling) Configuration

Code

0 = None

B = Relay, N.O. E = 0 to 20 mA

F = 4 to 20 mA (500 ohm max)

G = 4 to 20 mA (800 ohm max)

P = Pulsed 20 Vdc or 35 mA

S = Pulsed 20 Vdc or 17 mA

T = Solid-State Relay

V = 0 to 5 Vdc X = 0 to 10 Vdc

Y = Relay, N.C.



00 = None

Special Options

Consult Factory

0.	10.0	
	lard Options	
Code		
	None	21.1.1.
Alarm		Digital Input w/Alarm
10 =	Dual SSR, N.O.	40 = Switch Closed
20 =	Dual Open	41 = Switch Open
	Collector	42 = 5 V Input
21 =	Dual 24 Vdc	Communication RS-485 Modbus®
22 =	Dual SSR, N.C.	Protocol w/Contact/Digital Input
23 =	Relay, N.O.	45 = RS-485, No Switch
Comm	unications	46 = Switch Closed
30 =	RS-232	47 = Switch Open
	(Athena+ Protocol)	48 = 5 V Input
Comm	unication, RS-485 Athena+	Transducer Excitation
	ol w/Contact/Digital Input	
	RS-485, No Switch	51 = 12 Vdc
36 =	Switch Closed	52 = 15 Vdc
37 =	Switch Open	53 = 5 Vdc
38 =	5 V Input	Aux Output/PV Retransmit
	•	60 = 4 to 20 mA
		61 = 1 to 5 V
		62 = 0 to 20 mA
		63 = 0 to 5 V

*Milliamp ranges are available with 2.52 ohm resistor (supplied).



Legacy Series 16 Universal Temperature/Process Controller

Technical Specifications

Operating Limits

Ambient Temperature Relative

32°F to 131°F (0°C to 55°C)

Humidity Tolerance Line Voltage

90% non-condensing 100 to 250 Vac

125 to 300 Vdc

24 Vac/dc optional

Power Consumption

Less than 6 VA (instrument)

Performance

Accuracy

 $\pm 0.20\%$ of full scale ($\pm 0.10\%$ typical),

± 1 digit

Setpoint

Resolution Repeatability 1 count/0.1 count

 ± 1.0 count

Temperature

Stability

5 mV/°C maximum

TC Cold

End Tracking 0.05°C/°C ambient

Noise Rejection 100 dB common mode 70 dB series mode

10 Hz (100 ms)

Process Sampling Digital Filtering

Adjustable 0.1 to 10

Control Characteristics

Setpoint Limits

Span of Sensor

Alarms

Adjustable for high/low; selectable

for process or deviation

Rate 0 to 900 sec Reset 0 to 2400 sec

Cycle Time 0=200 ms; 1-120 sec

Gain 0 to 400

Gain Ratio 0 to 2.0 (in 0.1 increments) Control Hysteresis 1 to 100 (on/off configuration) Spread (Output 2) 0 to 100 (above setpoint)

Ramp to Setpoint 0 to 100 min

Auto-Tune Operator initiated from front panel Manual Control Operator initiated from front panel

Inputs

Thermocouple

B, C, E, J, K, N, NNM, R, S, T, Platinel II

Maximum lead resistance, 100 ohms for

rated accuracy

RTD Platinum 2- and 3-wire, 100 ohms at 0°C,

(DIN curve standard 0.00385)

0-50 mV/10-50 mV, 0-20 mA/4-20 mA, Linear

0-10 mV/0-50 mV, 0-100 mV, 0-1 V/0-5 V,

0-10 V, 1-5 V

Outputs

#1 Reverse-acting (Heating) #2 Direct-acting (Cooling)

В 5 A /3 A (120/240 Vac), normally open

Ε 0-20 mA

F 4-20 mA, full output to load 500 ohm

impedance max

Outputs

G	4-20 mA, full output to load
	800 ohm impedance max
Р	20 Vdc or 35 mA
S	20 Vdc or 17 mA
T	1 A , Solid-state relay
V	0 to 5 Vdc
X	0 to 10 Vdc
Υ	1 A, normally closed relay

Alarm Outputs

10	Alarm 1: Dual SSR, 24-240 Vac,
	1 A Alarm 2: 24 Vac Only
20	Dual Open collector, 24 V, 20 mircoamps
21	Dual 24 V, 20 mA
22	Alarm 1: Dual SSR, NC, 24-240 Vac,
	1 A Alarm 2: 24 Vac Only
23	5 A /3 A (120/240 Vac), mechanical relay

Mechanical Characteristics

Dual, 4-digit 0.36" (9.2 mm) LED Display Display

Process: Orange

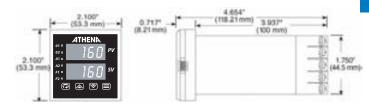
Setpoint Value: Green -1999 to 9999

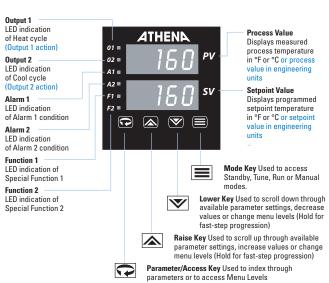
Numeric Range NEMA 4X (IP65) Front Panel Rating

Front Panel Cutout 1.771" x 1.771" (45 mm x 45 mm)

Connections Screw Terminals

Specifications subject to change without notice.







Legacy Series 18 and 19 Universal Temperature/Process Controller



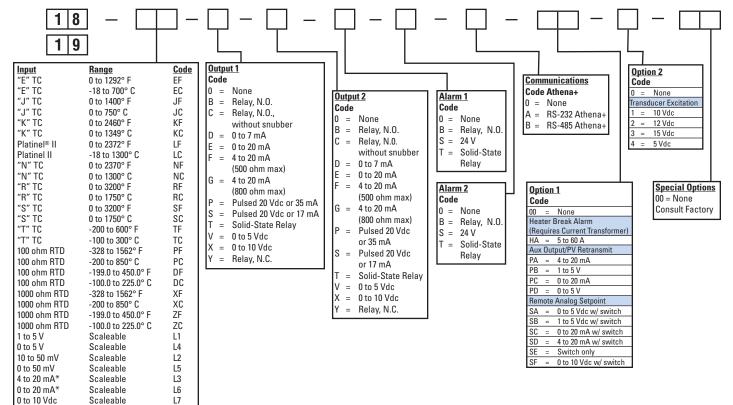
The Athena Legacy 18 and 19 Controllers are available as 1/8 DIN (18) vertical or 1/8 DIN (19) horizontal models. Both panel mounted, auto-tuning controllers can be used for precise control of a single loop with two independent outputs. The controllers accept thermocouple, RTD, voltage, or current input. RS-232 or RS-485 communications are available, and two digital LED displays provide visual indication of various controller functions.

- Switch-Selectable Inputs
- ▲ User-Selectable Ramp to Setpoint
- ▲ Auto-Tuning, Heat or Cool
- ▲ Dual Output/Dual Alarm Capabilities
- ▲ On/Off Through Full PID Operation (P,PI,PD,PID)
- ▲ NEMA 4X (IP65) Dust and Splash-Proof Front Panel
- ▲ Bumpless Auto/Manual Transfer
- Adjustable Hysteresis & Heat/Cool Spread
- Field-Configurable Process, Deviation, or Latching Alarms
- ▲ Optional Process Variable Retransmission
- Remote Setpoint Select, Non-Linear Inputs, or Other Special Options
- ▲ cUL and CE Approvals





Ordering Information



Scaleable

Scaleable

L8

2 to 10 Vdc

0 to 1 Vdc

Legacy Series 18 and 19 Universal Temperature/Process Controller

Technical Specifications

Operating Limits

Ambient Temperature

Relative Humidity

Tolerance Line Voltage

90% non-condensing 100 to 250 Vac 125 to 300 Vdc

32°F to 131°F (0°C to 55°C)

Less than 6 VA (instrument) **Power Consumption**

Performance

Accuracy ± 0.20 % of full scale, (± 0.10 % typical),

1 count/0.1 count

± 1 digit

+1.0 count

Setpoint Resolution Repeatability

Temperature

Stability

TC Cold

End Tracking Noise Rejection

Process Sampling Digital Filtering

5 mV/°C (maximum)

0.05°C/°C ambient 100 dB common mode 70 dB series mode

10 Hz (100 ms) Adjustable 0.1 to 10

Control Characteristics

Setpoint Limits Span of Sensor

Alarms Adjustable for high/low,

selectable process or deviation

Rate 0 to 900 sec Reset 0 to 2400 sec

Cycle Time 0 = 200 ms; 1 to 120 sec

Gain 0 to 400

0 to 2.0 (in 0.1 increments) Gain Ratio Control Hysteresis 1 to 100 (on/off configuration) 0 to 100 (above setpoint) Spread (Output 2)

Ramp to Setpoint 1 to 100 min

Auto-Tune Operator initiated from front panel Manual Control Operator initiated from front panel

Inputs

B, C, E, J, K, N, NNM, R, S, T, Platinel II Thermocouple

> Maximum lead resistance. 100 ohms for rated accuracy

Platinum 2- and 3-wire, RTD 100 ohms at 0°C.

(DIN curve standard 0.00385)

Linear 0-50 mV/10-50 mV, 0-20 mA/4-20 mA,

0-10 mV/0-50 mV. 0-100 mV. 0-1 V/0-5 V.

0-10 V, 1-5 V

Outputs

Output #1 Reverse Acting (heating) Output #2 Direct Acting (cooling)

5 A /3 A (120/240 Vac), normally open В

Ε 0 - 20 mA

F 4-20 mA, full output to load

500 ohm impedance max. 4-20 mA, full output to load 800 ohm impedance max.

Χ 24 Vac/dc optional **Alarm Outputs**

В 5 A /3 A (120/240 Vac), mechanical relay

20 Vdc or 35 mA

20 Vdc or 17 mA

0 to 5 Vdc

0 to 10 Vdc

1 A, Solid-state relay

1 A, normally closed relay

S 24 V, 20 mA

Outputs

S

Т

V

SSR, NC, 24-240 Vac

Mechanical Characteristics

Display Dual, 4-digit 0.36" (9.2 mm) LED Display

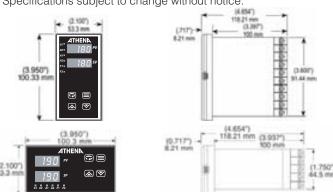
Process Value: Orange Setpoint Value: Green

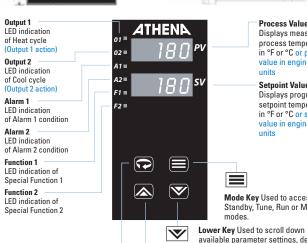
Numeric Range -1999 to 9999 Front Panel Rating NEMA 4X, (IP65)

Front Panel Cutout 3.622" x 1.771" (92 mm x 45 mm)

Connections Screw Terminals

Specifications subject to change without notice.

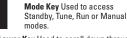


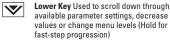


Displays measured process temperature in °F or °C or process value in engineering

Setpoint Value

Displays programmed setpoint temperature in °F or °C or setpoint value in engineering units





Raise Key Used to scroll up through available parameter settings, increase values or change menu levels (Hold for fast-step progression)



Parameter/Access Key Used to index through parameters or to access Menu Levels



Legacy Series 25 Universal Temperature/Process Controller

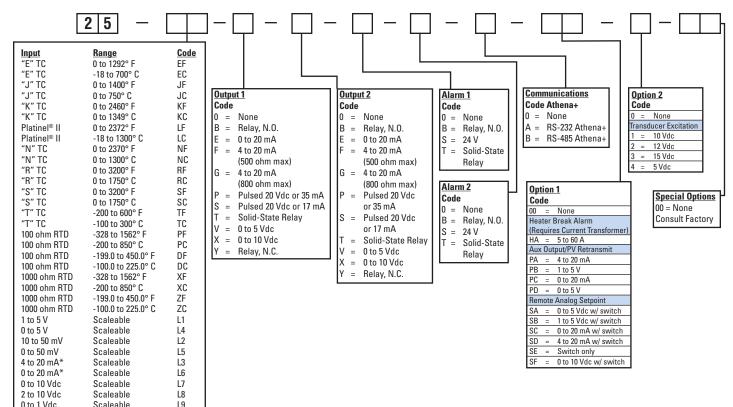


The Athena Legacy 25 is a 1/4 DIN panel mounted, auto-tuning controller that can be used for precise control of a single loop with two independent outputs. The controller accepts thermocouple, RTD, voltage, or current input. RS-232 or RS-485 communications are available, and two digital LED displays provide visual indication of various controller functions.

- ▲ User-Selectable Ramp to Setpoint
- Bumpless Auto/Manual Transfer
- ▲ NEMA 4X (IP65) Dust and Splash-Proof Front Panel
- On/Off through Full PID Operation (P,PI,PD,PID)
- Auto-Tuning, Heat or Cool
- ▲ Adjustable Hysteresis & Heat/Cool Spread
- Field-Configurable Process, Deviation, or Latching Alarms
- ▲ Remote Setpoint Select Option
- ▲ Dual Output/Dual Alarm Capabilities
- ▲ Optional Process Variable Retransmission
- ▲ cUL and CE Approvals



Ordering Information



Technical Specifications

Operating Limits

Ambient Temperature

Relative Humidity

90% non-condensing Tolerance Line Voltage

100 to 250 Vac 125 to 300 Vdc 24 Vac/dc optional

32°F to 131°F (0°C to 55°C)

Less than 6 VA (instrument) **Power Consumption**

Performance

 ± 0.20 % of full scale, (± 0.10 % typical), Accuracy

1 count/0.1 count

5 mV/°C (maximum)

± 1 digit

Setpoint Resolution Repeatability

±1.0 count Temperature

Stability

TC Cold

End Tracking 0.05°C/°C ambient

Noise Rejection

100 dB common mode 70 dB series mode 10 Hz (100 ms)

Adjustable 0.1 to 10

Process Sampling Digital Filtering

Control Characteristics

Setpoint Limits Span of Sensor

Alarms Adjustable for high/low,

selectable process or deviation

Rate 0 to 900 sec Reset 0 to 2400 sec

Cycle Time 0 = 200 ms; 1 to 120 sec

Gain 0 to 400

Gain Ratio 0 to 2.0 (in 0.1 increments) Control Hysteresis 1 to 100 (on/off configuration) Spread (Output 2) 0 to 100 (above setpoint)

1 to 100 min Ramp to Setpoint

Operator initiated from front panel Auto-Tune Manual Control Operator initiated from front panel

Inputs

Thermocouple B, C, E, J, K, N, NNM, R, S, T, Platinel II

> Maximum lead resistance. 100 ohms for rated accuracy

Platinum 2- and 3-wire, RTD 100 ohms at 0°C.

(DIN curve standard 0.00385)

Linear 0-50 mV/10-50 mV, 0-20 mA/4-20 mA,

0-10 mV/0-50 mV. 0-100 mV. 0-1 V/0-5 V.

0-10 V, 1-5 V

Output Options

Output #1 Reverse Acting (heating) Output #2 Direct Acting (cooling)

5 A /3 A (120/240 Vac), normally open В

Ε 0-20 mA

F 4-20 mA, full output to load

500 ohm impedance max.

Outputs

G	4-20 mA, full output to load
	800 ohm impedance max.
P	20 Vdc or 35 mA
S	20 Vdc or 17 mA
T	1 A, Solid-state relay
V	0 to 5 Vdc
X	0 to 10 Vdc
Υ	1 A, normally closed relay

Alarm Outputs

5 A /3 A (120/240 Vac), mechanical relay

S 24 V. 20 mA

SSR, NC, 24-240 Vac

Mechanical Characteristics

Display Dual, 4-digit 0.36" (9.2 mm) LED Display

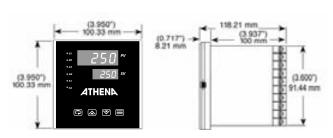
Process Value: Orange Setpoint Value: Green

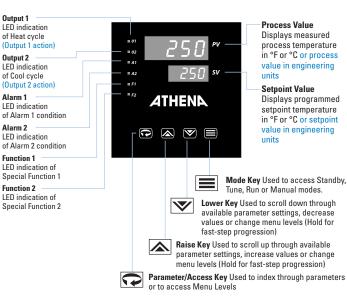
Numeric Range -1999 to 9999 Front Panel Rating NEMA 4X, (IP65)

Front Panel Cutout 3.622" x 3.622" (92 mm x 92 mm)

Connections Screw Terminals

Specifications subject to change without notice.







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Analog Series 4000 Short Case Temperature Controllers



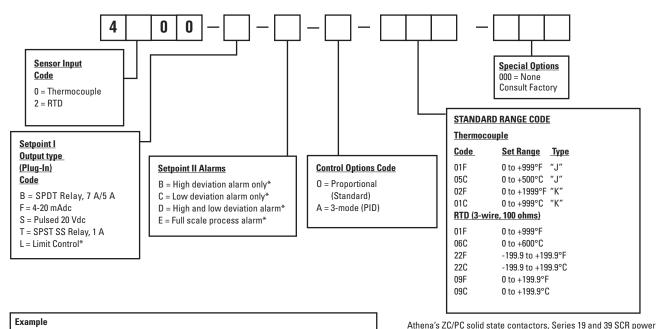
The Athena 4000 is a 1/4 DIN panel mounted, short metal case enclosed controller that can be used for accurate proportional temperature control of most processes. The controller accepts thermocouple or RTD input, and offers a choice of standard single outputs for energizing most common output devices. A single, digital filtered LED display provides visual indication of various controller functions.

- ▲ Noise-Immune Analog Circuitry
- ▲ 25-turn Setpoint Pots-Optional Second (Alarm) Setpoint
- ▲ Adjustable Bandwidth and Manual Reset to Eliminate Offset Error
- 3-Mode PID Available
- ▲ Available as FM-Approved Limit Controller





Ordering Information



^{*}Not available on 4200

Model 4000-B-E-05C = a controller with a thermocouple sensor input; and SPDT relay output (non plug-in) for

setpoint I; a full scale process alarm for setpoint II; and a thermocouple J input range of 0 to 500°C.



controllers, can be added to boost ac load switching capacity.

Analog Series 4000 Short Case Temperature Controllers

Technical Specifications

Line Voltage $120/240 \text{ V} \pm 10\%$, $50/60 \text{ Hz} \pm 15\%$

Power Consumption Less than 5 VA

Common

Mode Rejection* Maximum error ±1°C with 240 V, 60 Hz

applied as a common mode signal between sensor input and chassis ground

Series

Maximum error ±1°C with series mode Mode Rejection*

signal of 100 mV pk-to-pk at 60 Hz

Sensor

Break Protection Up scale standard, zero output for open

Thermocouple Maximum lead resistance 100Ω for rated

accuracy, cold junction compensation

standard

RTD 100 ohms (0°C) Platinum, DIN coefficient

standard

Setpoints Momentary switch displays Set I or Set II

(optional), 25-turn pot provides 1 or 0.1

settability, range dependent; Set I-Adjustable over full span;

Set II-process alarm (-E) adjustable over full span. Deviation alarm (-B,-C,-D),

consult factory

Setpoint

Repeatability $\pm 0.1\%$ to $\pm 0.2\%$ of span Setpoint Resolution

Calibration

Accuracy

1 or 0.1 (Range dependent)

a. T/C input ±0.4% of span over 10%

to 90% of range

b. RTD inputs $\pm 0.1\%$ of span for 1°F or 1°C ranges; ±0.2% of span for

0.1°F or 0.1°C ranges

a. T/C input 3 V/°F ambient to input **Ambient Stability**

b. RTD input 0.1% for 80°F to 130°F

(27° to 55°C)

Process Indication Filtered LED, 3 or 3-1/2 digits, 2 readings

per second update; readability is 1°F, 1°C, 0.1°F or 0.1°C, range dependent

Dimensions Front Panel - 3.780 sq. in. (96 mm²)

Case - 4.646" (118 mm)

Depth Behind Panel - 3.780" (92 mm) Panel Cut-out - 3.622 sq. in. (92 mm²)

*Note: Applies to all units with exception of "F" output controllers when used with other than Athena SCRs or stagers.

Output Type	Setpoint 1 (Plug-in) Setpoint 2					oint 2	
	В	F	S	T	L	B,C,D	E
	SPDT relay resistive load rating 7 A/120 V 5 A/240 V 50 VA inductive	4-20 mAdc into 1000 ohms maxmum; not isolated from thermocouple	Pulsed dc for driving SS contactors 0-20 V, open ckt 0-20 mA, short ckt not isolated from thermocouple	SPST SS relay, zero voltage switched 1 A 120/240 Vac, 10 A inrush, 2-4 mA leakage	Limit Controller	SPDT relay 3 A @ 120 Vac resistive (4000 only)	SPDT relay 3 A @ 120 Vac resistive
Proportional Band	Adjustable for .2-5% of span			Not applicable	On/Off (see differential)	On/Off (see differential)	
Output cycle time (Switch selectable)	On-off 5-10-15 sec	Continuous Proportioning	0.5-1.0-1.5 sec	0.5-1.0-1.5 5-10-15 sec	Not applicable	Not applicable	Not applicable
Manual reset (Offset)	Standard-adjustable for full proportional bandwidth (eliminated if PID is ordered)			Not applicable	Not applicable	Not applicable	
Optional 3-mode (PID) action	Past = 0.1 sec rate, 48 sec reset; medum = 18 sec rate, 90 sec reset; Slow = 65 sec rate, 300 sec reset			Not applicable	Not applicable	Not applicable	
Differential	0-5° adjustable			Not applicable	±°F or ±°C	1% maximum of unit span	
Indication	Red LED "ON" when output signal is present or relay is energized						
Operating Ambient	30°F to 131°F (0°C to 55°C)						



Analog Series 2000 Full Feature Temperature Controllers



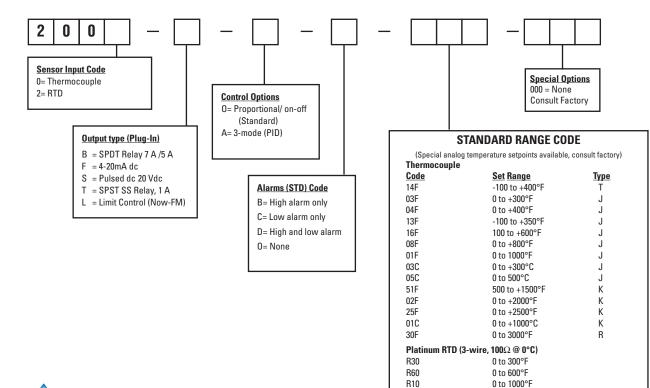
The Athena 2000 is a 1/4 DIN panel mounted, full featured, metal case enclosed controller that can be used for accurate proportional control of most processes. The Controller accepts thermocouple or RTD input and offers a choice of standard single outputs for energizing most common devices. A dual meter dial display provides visual indication of various controller functions.

- ▲ Noise-Immune Analog Circuitry
- ▲ Simple to Use (No Programming Required)
- ▲ Adjustable Bandwidth and Reset
- ▲ Optional PID
- ▲ Adjustable High/Low Alarm
- ▲ Linearized Analog Setpoint
- ▲ Limit Controller Configuration Available

0 to 600°C



Ordering Information



Analog Series 2000 Full Feature Temperature Controllers

Technical Specifications

Line Voltage $120/240 \text{ V} \pm 10\% \text{ to} \pm 15\%, 50-60 \text{ Hz}$

Power Consumption Less than 5 VA
Setpoint Analog-Single turn

potentiometer 270° rotation

Setpoint 0.2% span

Indication Temperature: Deviation meter ±50°F

or ±30°C of setpoint Load: Red LED output light

Alarm: Red LED

Accuracy ±0.5% of span at calibration points

Cold Junction

Compensation Automatic, electrical

Setpoint

Repeatability ±0.3% of span

Thermocouple Failsafe, open sensor, output zero,
Break Protection Upscale indication on meter
Input J,K,R,T, thermocouples

Platinum RTD DIN standard

Sensor Lead Thermocouple, maximum lead resistance

Resistance 100Ω for specified accuracy

Proportional Band

Offset

(manual reset) Adjustable over 100% of proportional band

Rate (derivative) 0.5 to 40 sec

Reset (integral) 0.7, 1, 2 or 4 min via internal switches

Common Mode Maximum error ±1°C with 240 V, 60 Hz

nplied

Rejection As a common mode signal between

sensor input and chassis ground

On/off or nominal 5°F to 50°F (3°C to 30°C)

Series

Dimensions

Mode Rejection Maximum error = 1°C with series mode

signal of 100 mV pk-to-pk at 60 Hz

Ambient Temperature 32°F to 131°F (0°C to 55°C)

Front Panel - 3.780 sq. in. (96 mm²) Depth Behind Panel - 3.780" (96 mm) Panel cutout - 3.622 sq. in. (92 mm²)

Output Type	В	F	S	Т	L	Alarm
Output (field changeable modules)	SPDT relay Resistive load rating: 7 A/120 V 5 A/240 V, 50 VA inductive	4-20 mAdc into 1000Ω maximum; not isolated from thermocouple	Pulsed dc for driving SS contactors 0-20 V, open ckt; 0-20 mA, short ckt; not isolated from thermocouple	SPST SS relay, zero voltage switched 1 A 120/240 Vac, 10 A inrush, 2-4 mA leakage.	Limit Controller	SPDT relay 3 A @ 120 V resistive
Output cycle time (Switch selectable)	On-off, 5-10-15 sec	Continuous Proportioning	0.5-1.0-1.5 sec	0.5-1.0-1.5 5-10-15 sec	N/A	On-off
Proportional Band		On-off or no 5°F-50°F (3°C-30°C) (front			N/A	2°F differential



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Analog Series 86 Non-Indicating Temperature Controller



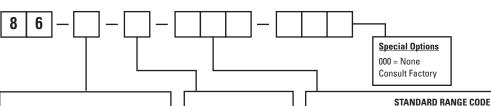
Remote Setpoint Potentiometer (optional)

The Athena Series 86 is a non-indicating, case or track mounted temperature controller that can be used for differential (on-off) to proportional control via simple adjustment. The controller accepts thermocouple or RTD input, and offers field changeable control outputs for relay, SS relay, or pulsed voltage.

- ▲ Single-turn, 270° Rotation Potentiometer
- Field Changeable Control Outputs: Relay, SS Relay or Pulsed Voltage
- ▲ Failsafe in Open Sensor Conditions
- ▲ Optional Remote Setpoint
- ▲ Optional Solid-State Contactors for Boosting Power Handling Capacity
- ▲ Cooling Configuration Available
- ▲ Thermocouple or RTD Input
- ▲ Limit Controller Option



Ordering Information



Configuration

- A = Open PCB unit, setpoint pot on PCB
- B = Open PCB unit, remote setpoint
- C = Open PCB setpoint on PCB with T case
- D = T case setpoint on case
- L = High limit controller, D configuration with reset button on case. "B" output relay only,

- E = T case, setpoint remote
 - Includes FM Approval

Output Type Plug-In

- B = SPDT Relay, 7 A /5 A H = SPDT Relay , 15 A (NON-PLUG-IN)
- S = Pulsed dc 0-20 Vdc*
- T = SPST 1 A SS relay*

Thermocouple Consult factory for non-standard ranges.)

Code	Set Range	Min. Divs. (PCB)	Min. Divs. (Remote)	Туре
T02	-225 to +225°F	25°	10°	Т
51F	500 to +1500°F	50°	20°	K
02F	0 to +2000°F	100°	40°	K
03C	0 to +300°C	25°	5°	J
05C	0 to +500°C	25°	10°	J
03F	0 to +300°F	25°	5°	J
16F	100 to +600°F	25°	5°	J
08F	0 to +800°F	50°	10°	J
01F	0 to +1000°F	50°	20°	J
01C	0 to +1000°C	50°	20°	K
RTD Platin	um (3-wire, 100 Ω at 0°	C DIN CUR	VE STD.)	
S01	-100 to +100°C	N/A	4°	
S30	0 to +300°F	25°	5°	
S60	0 to +600°F	50°	10°	

^{*}Athena's ZC solid state contactors and Series 19 and 39 SCR power controllers can be added to boost AC load switching capacity.



Analog Series 86 Non-Indicating Temperature Controller

Technical Specifications

Setpoint Single-turn, 270° rotation potentiometer (local or remote) is standard. Remote

digital thumbwheel available for RTD only 1% with circuit board potentiometer, 1/4%

with remote potentiometer

Calibration Accuracy

1% at calibration points with remote

potentiometer. 2% at calibration points, potentiometer on circuit board

Ambient Temperature 32°F to 130°F (0°C to 55°C)

Humidity Tolerance 5 to 95%, non-condensing

Cold Junction
Compensation Internal electrical bridge

Hysteresis/
Proportional Band Thermocouple adjustable from hysteresis of 5° to proportional band of 25° RTD

deadband is 3° to proportional band of 10° Thermocouple

Output Type B Relay S.P.D.T. 7 A/5 A @ 120/240 V
Type H Relay S.P.D.T. 15 A/7 A @ 120/240 V
(NON PLUG IN) Type T S.S. Relay S.S.T.
1 A 120/240 Vac, 10 A inrush, 2-4mA leakage

Type S Pulsed dc, 0-20 Vdc open ckt. not

Output power off with open sensor.

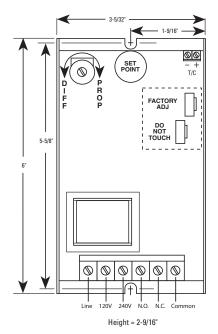
isolated from sensor

Supply Voltage 120/240 ± 10%V, 50-60 Hz

Power Consumption 2 watts

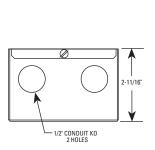
Setpoint Resolution

Break Protection



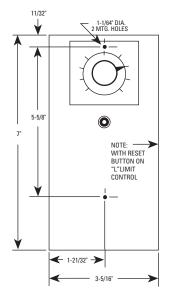
Panel Mounting External Setpoint:

Remove knob with small screwdriver and take off the nut holding the scale to the pot. Mount pot through a 3/8" hole in your panel; put scale over shaft and tighten nut. Turn shaft counterclockwise until it stops. Now put knob back on and line up its indicating mark with the arrow on scale. Tighten knob. The unit is now calibrated.



Mounting Case: (T Case)

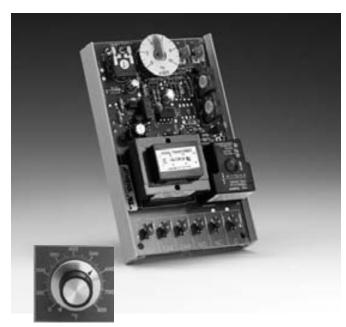
Remove the two sheet metal screws holding the cover on; take off cover. Next remove shipping bolts from plastic track and replace them with your mounting hardware. Replace cover.





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Analog Series 88 Electronic Temperature Controller



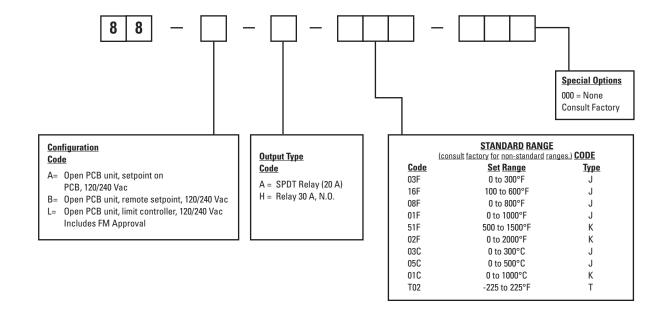
Remote Setpoint Potentiometer (optional)

The Athena Series 88 is a non-indicating, track mounted temperature controller that can be used as a superior replacement for bulb and capillary controllers. The controller accepts thermocouple input, and offers a 20 Amp relay output.

- ▲ On-Off or Time Proportioning
- ▲ Failsafe on Open Sensor
- ▲ No Calibration Necessary
- ▲ 1% Accuracy
- ▲ Thermocouple Input
- ▲ Track Mounted
- ▲ Cooling Processes
- ▲ Limit Controller Option



Ordering Information



Analog Series 88 Electronic Temperature Controller

Technical Specifications

Setpoint Single-turn, 270° rotation potentiometer

(local or remote) is standard

Remote digital thumbwheel available

for RTD only

Setpoint Resolution 1% with circuit board potentiometer,

1/4% with remote potentiometer

Calibration Accuracy 1% at calibration points with remote

potentiometer

2% at calibration points, potentiometer

on circuit board

Ambient Temperature

Humidity Tolerance

Cold Junction Compensation 5 to 95%, non-condensing

Internal electrical bridge

32°F to 130°F (0°C to 55°C)

Hysteresis/

Proportional Band Thermocouple adjustable from

hysteresis of 5° to proportional band of

25° RTD deadband is 3° to proportional

Output power off with open sensor

band of 10°

Thermocouple

Break Protection

Output Type B Relay S.P.D.T. 7 A/5 A @ 120/240 V

Type H Relay S.P.D.T. 15 A/7 A @ 120/240 V

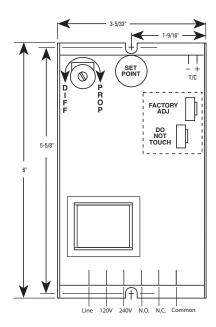
(NON PLUG IN)

Supply Voltage 120/240 Vac ±10%

Input Thermocouple, sensor break protection

Power Consumption 2 watts

Connections Fast-on lugs





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C-Series Limit Controller



For ordering code and specifications, see page 16.

OTC25-L 1/4 DIN

- ▲ Type J Thermocouple Input
- ▲ 100 to 250 Vac Supply Voltage
- ▲ NEMA 4X (IP65) Dust and Splash-Proof Front Panel
- ▲ FM File No. J.I. 0B3 A 2.AF Class 3545

Limit Controllers

Analog Series Limit Controllers



For ordering code and specifications, see page 26.

Analog Series 4000 1/4 DIN

- ▲ Type J, K Thermocouple
- ▲ 120 to 240 Vac Supply Voltage
- ▲ Optional auto reset on power-up
- ▲ FM File No. J.I. 1Y7A2.AF Class 3545



For ordering code and specifications, see pages 30 and 32.

Analog Series 86 and 88

- ▲ Type J, K, T Thermocouple Input; Platinum RTD Input (86 only)
- ▲ 120 to 240 Vac Supply Voltage
- ▲ Track Mounting (Case mounting available on Series 86)
- ▲ Optional remote reset switch
- ▲ FM File No. J.I. 0W9A6.AF Class 3545



Power Controllers Series 19 and 39 SCR

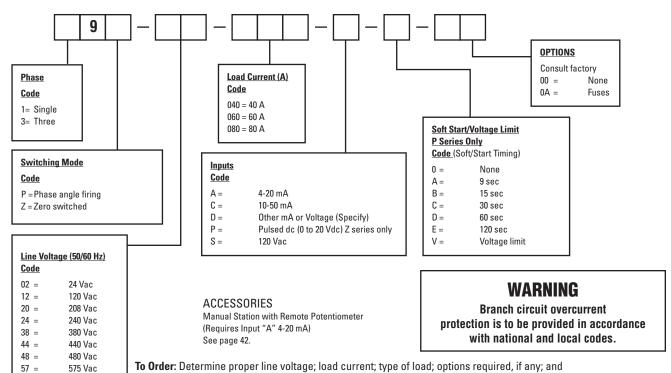


The Athena 19 and 39 controllers are available as zero voltage switched controllers (19Z and 39Z) and phase-angle fired controllers (19P and 39P) that can be used for control of resistive heater loads. The controller provides capacity up to 80 Amps, and extends heater life while eliminating thermal shock.

- Optically Isolated
- ▲ Diagnostic Indicators
- ▲ Self-Synchronizing to Line Frequency
- ▲ Isolated Heat Sinks
- ▲ Compact Design
- ▲ Full Protection Against Line Voltage Spikes



Ordering Information



To Order: Determine proper line voltage; load current; type of load; options required, if any; and input signal to power controller. Use these equations to determine load current.

For load currents above 200 A, consult Athena or your local Athena representative.

Single-Phase = <u>watts (load)</u> = amps Load Current volts (line) Three-Phase = watts (load) = amps Load Current 1.73 x volts (line)



60 =

600 Vac

Power Controllers Series 19 and 39 SCR

Technical Specifications

Supply Voltage24 to 600 VacFrequency50-60 HzCurrent Rating40, 60 and 80 A

Control
Signal Isolation 2500 Vac

Transient
Voltage|Protection MOV ar

Voltage|Protection MOV and RC suppression

Ambient Temperature 32°F to 122°F (0°C to 50°C)
for listed current rating

Load Resistive. 3-phase- 3 wire Delta or Ungrounded Wye 19Z/19P-1 phase,

1 line control

39Z-3 phase, 2 lines controlled 39P-3 phase, 3 lines controlled

Diagnostic Indicators Shorted or open SCR reversed

signal input (mA/V)

Zero Voltage Switched Controllers

The 19Z and 39Z SCR controllers are zero crossover fired, high-power solid state switching devices. Zero firing eliminates the RFI generation associated with mechanical relays. With zero voltage firing, the output appears as bursts of full sine waves of line voltage which provides excellent regulation to the load.

Phase Angle Fired Controllers

The 19P and 39P phase angle fired controllers turn each SCR on for a controlled portion of a half-cycle of the line voltage. The effective load voltage is determined by the portion of the line voltage delivered which is proportional to the input control signal. Additionally, the voltage is regulated as the line voltage changes.

DIMENSIONS					
MODEL #	Height	Width	Depth		
19Z	10.25″	4.75″	4.0″		
19P	10.25″	4.75″	4.0″		
39Z	10.25″	9.62″	4.0″		
39P	10.25″	14.37″	4.0"		



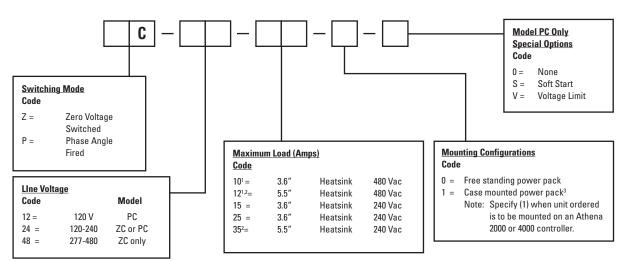
Solid-State Contactors Series ZC and PC



The Athena ZC and PC contactors are available as zero voltage switched (ZC) and phase angle-fired (PC) contactors that can be used for control of resistive heater loads. The controller provides full power rating at 102°F (49°C) ambient temperature, and extends heater life while eliminating thermal shock.

- ▲ All Solid-State Design No Maintenance Required
- ▲ Soft-Start and Voltage Limit (Optional on PC)

Ordering Information



Example: Model ZC-2425-1-a controller with a zero voltage switching mode; a line voltage of 120-240 V; a maximum load (amps) of a 3.6" heatsink, 240 Vac; and a case-mounted power pack configuration.

CAUTION Possible fire hazard. Because these controls or associated equipment may not always fail safe, an approved temperature and/or pressure safety control should be used for safe operation.

NOTES:

- ¹ Only 480 Vac available. None higher. ZC only.
- ² Panel mounting only.
- 3 Not available on 35A model

Solid-State Contactors Series ZC and PC

Technical Specifications

(minimum voltage)

3 V input signal, minimum, is needed. Standard Athena "S" or "F" output controllers can energize up to three units in series. Model ZC- 3-32 Vdc pulsed voltage, optically isolated from output (2500 V). Requires Athena output type "S". Model PC- 4-20 mA proportional current. optically isolated from output (2500 V). Requires Athena output type "F". 120°F (49°C) maximum for rated amperes

Ambient Temperature

Output

Ampere Rating

Resistive loads only, 277-480 Vac is ZC

Unit Only

For greater ampere loads, consult factory. Note

Nominal Rating Max.							
Model	Supply Voltage	3.6" Heat Sink	5.5" Heat Sink	Peak Surge	Voltage Drop	Max. Leakage	
ZC	120-240	15 A	N/A	250 A	1.6 V	15 mA	
	120-240	25 A	35 A	650 A	1.6 V	15 mA	
	277-480	10 A	12 A	150 A	3.2 V	1 mA	
PC	120/240	15 A	N/A	310	5.0 V	10 mA	
	120/240	25 A	35 A	310	8.0/5.0 V	10 mA	

Options Available for PC Units Only

Soft-Start Option 0 to maximum output within 30 seconds

standard. Consult factory for slower or

faster turn-on times.

Voltage

Limit Option

Output limit is adjustable from 35% to 95% of line input voltage.

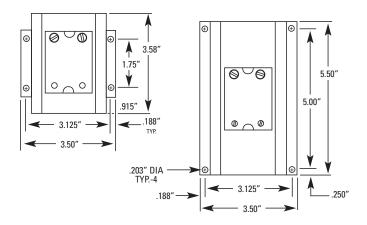
Zero Voltage Switching

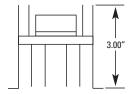
Series ZC contactors offer zero voltage switching for EMI/RFI free operation. A time proportional 3-32 Vdc input signal is required to energize these contactors (use with Athena "S" output controller).

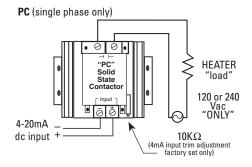
Phase Angle-Fired Switching

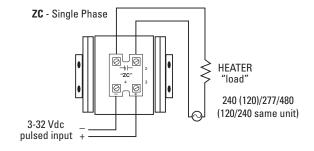
Phase angle-fired switching provides continuously variable voltage output by governing the point of turn-on (firing) of each half cycle of the full AC sine wave. Low mass heating elements such as heating lamps and hot wires are recommended applications. Use with Athena "F" output (4-20 mA) controller.

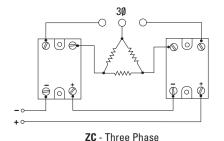
Phase angle firing allows for two options not available with ZC solid state contactors. Soft-Start provides slow turn on for high inrush loads, such as quartz lamps and Tungsten elements. Voltage limit restricts load current by capping the peak-to-peak output voltage.







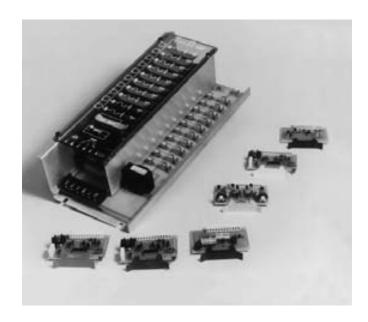






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Solid-State Staging Controllers Series SC and SU

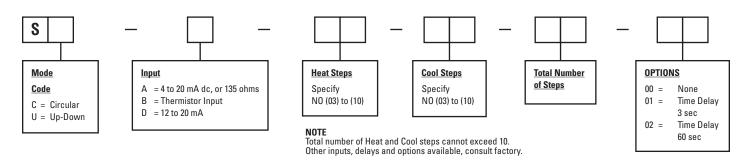


The Athena SC and SU controllers are available for heat or heat/cool applications (SC and SU with Type A Input Card) and boiler applications (SC and SU with Type B Input Card). The controller accepts current, voltage or resistance input, and provides solid state output stages.

- ▲ Up-Down or Circular Mode
- ▲ Optically Isolated Input
- ▲ Logic Status Lights
- ▲ Field Changeable, Plug-in Circuit Boards
- ▲ 10-Stage Capacity
- Fused Output Stages



Ordering Information



Example:

SU-A-08-02 – Series (S) staging controller (U) up-down mode (A) 4-20 mA, or 135 Ω , 10 sec standard input, (8) heat stages, (2) cool stages.

Determine desired mode of operation, i.e., circular, up-down, type of input to stager and number of steps to be switched.

CIRCULAR MODE: Recommended for heating only application.

UP-DOWN MODE: Required for heating/cooling applications and priority load sequencing.

Solid-State Staging Controllers Series SC and SU

Technical Specifications

Power

Requirements 120 V, 50/60 Hz, (±10%, to ± 20% Vac)

4 VA plus total VA of all devices staged,

i.e., contactor coil VA

Output Capability 1 amp per step continuous;

10 amps per step inrush

Signal Input

(Terminals A-B) mA dc; 4-20 mA standard for 1-5 Vdc;

60 mA and 9 V maximum input.

"A" configuration

Signal Input

(Terminals C-D-E) 135 slide-wire or potentiometer; 100 to

1000 V acceptable. "A" configuration

Signal Isolation 1500 volts from power and ground
Time Delay Adjustable 2 to 12 seconds per step

Adjustable 2 to 12 seconds per step; automatic slow down near balance

Cycling Adjustable from differential to time

proportioning

Ambient Temperature 32°F to 131°F (0°C to 55°C)

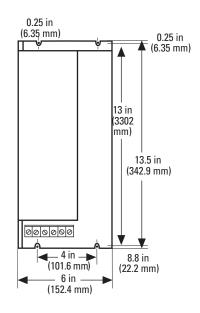
All specifications subject to change.

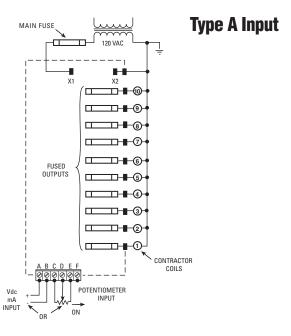
Type A Input (For Heat or Heat/Cool Applications)

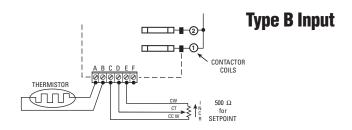
Series SC and SU Staging controllers are multi-purpose units designed for maximum flexibility and serviceability. Standard units are designed for pilot duty sequencing of multiple stages of heating or heating and cooling applications. Series SCA and SUA controllers require 4-20 mAdc signals from a temperature controller or a slide-wire potentiometer. All input signals to the Series SC and SU controllers are optically isolated.

Type B Input (For Boiler Application)

The Series SC and SU Staging Controllers, when ordered with Type "B" input card, require no driver or temperature controller input signal. The "B" input card (field interchangeable with "A" type) makes the staging controller a complete thermistor sensing temperature controller with a multi-stage output. Input is from a thermistor probe connected to terminals A-B and temperature setting potentiometer across C-D-E. A special feature of this unit is that output power is off for "open" or shorted process sensor. High accuracy is obtained by using narrow setpoint spans. Available ranges: 50°F - 180°F or 100°F - 200°F.



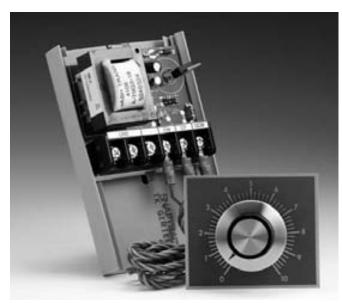






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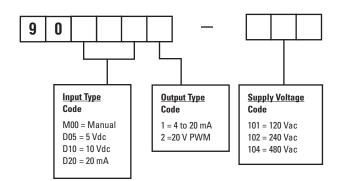
Manual Station Temperature Controller Series 90



Remote Setpoint Potentiometer (optional)

The Athena 90 is a non-indicating, manual station controller for low cost open loop control. The controller allows manual setting of output level on SCR power controllers, proportional valves, and other final control mechanisms.

- ▲ Fully Variable 4-20 mAdc or 20 V Pulse Width Modulation (PWM) Output
- ▲ Includes circuit board, mounting track, dial potentiometer with 48″ leads, scale, knob, and female contacts.



Manual Station Temperature Controller Series 90

Technical Specifications

Power 120, 240, or 480 V +10% -15%, 50/60 Hz Input 0-135 ohm minimum, 0-1000 ohm

0-135 ohm minimum, 0-1000 ohm maximum potentiometer (500-ohm

potentiometer supplied with 48″ leads)

Ambient Temperature 32°F to 131°F (0°C to 55°C)

Dimensions

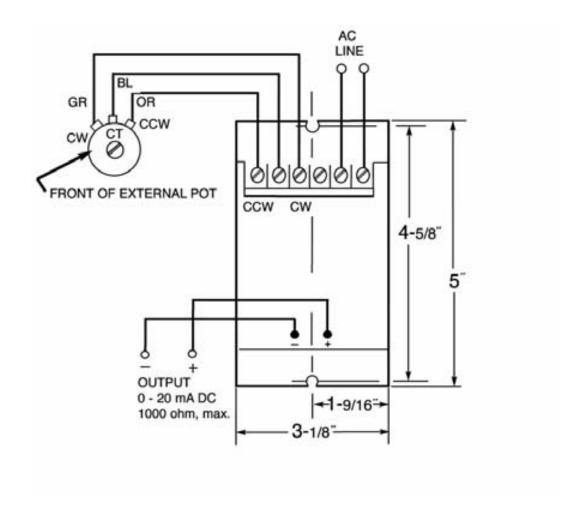
Unit 5"L x 3.25"W x 2"H

(12.7 cm L x 8.26 cm W x 5.1 cm H)

Scale Plate 2.75" W x 2.375" H

(6.98 cm W x 6.03 cm H)

Specifications subject to change without notice.





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Platinum™ Series C10 Controller-Indicator-Transmitter



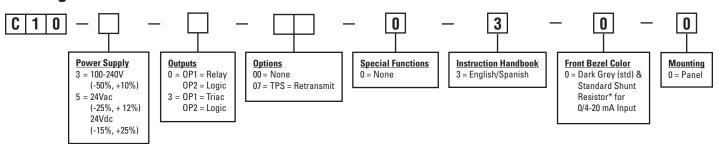
Athena's Platinum Series C10 is the smallest 1/32 DIN (48 x 24 mm) size panel-mounted line and combines all the functionality of a temperature controller-indicator-transmitter without losing the standard features found in more complex control devices such as auto-tune and IP65 front panel protection. Available options include serial communications, analog retransmission output, and transmitter power supply.

- ▲ Field-Configurable Universal Inputs
- ▲ Bumpless Auto/Manual Transfer
- ▲ (IP65) Dust and Splash-Proof Front Panel
- ▲ On/Off Through Full PID Operation
- ▲ Adjustable Hysteresis and Deadband
- ▲ Outputs Configurable as Alarms
- ▲ Field-Configurable Process or Deviation Alarms
- CE Compatibility

Range Information



Input	Range	Input	Range
"J"	32°F to 1112°F (0°C to 600°C)	"S"	32°F to 2912°F (0°C to 1600°C)
"K"	32°F to 2192°F (0°C to 1200°C)	"T"	-328°F to 752°F (-200°C to 400°C)
"L"	32°F to 1112°F (0°C to 600°C)	"RTD"	-99.9°F to 572°F (-99.9°C to 300°C)
Millivolt Linear (scalable)	0 to 20 mA (4 - 20 mA) 0 to 10 mA (0 - 50 mA)	"RTD"	-328°F to 1112°F (-200°C to 600°C)



^{*} Standard Shunt-Resistor without field calibration = 1.10% input accuracy
High Accuracy Shunt Resistor without field calibration = 0.20% input accuracy
Either Shunt Resistor with field calibration = 0.10% input accuracy



Platinum™ Series C10 Controller-Indicator-Transmitter

Technical Specifications

Operating Limits

Ambient Temperature 32°F to 131°F (0°C to 55°C)

Relative Humidity Tolerance 5-95% min - condensing

Power 100-240 Vac, 24 Vac/Vdc

Power Consumption 1.6 W max

Performance

 $\begin{array}{ll} \textbf{Accuracy} & 0.25\% \pm 1 \ \text{digit} \ (\text{T/C} \ \text{and RTD}) \\ 0.1\% \pm 1 \ \text{digit} \ (\text{mA* and mV}) \\ \textbf{Setpoint Resolution} & 1.0 \ \text{count/0.1 count} \\ \end{array}$

 $\begin{tabular}{ll} Repeatability & \pm 1.0 count \\ Temperature Stability & 2 μ V/°C \\ Process Sampling & 0.5 sec \\ \end{tabular}$

Digital Filtering Adjustable 1-30 sec

Control Characteristics

Setpoint Limits Span of sensor

Alarms Adjustable for high/low;

selectable for process deviation

Proportional Band 0.5 to 999.9%
Integral 0.1 to 100.0 min
Derivative 0.1 to 10.00 min
Cycle Time 1 to 200 sec
Control Hysteresis 0.1 to 10.0%
Dead band Span of sensor

(Output at 1 & 2)

Auto-Tune Operator initiated from front panel
Manual Control Operator initiated from front panel

Inputs

Thermocouple J, K, L, S, T, Maximum lead resistance 100 ohms for rated accuracy

RTD Platinum 2- and 3-wire, 100 ohms at 0°C, DIN curve standard (0.00385)

Linear U-5 mV/10-50 mV, 0-20 mA/4-20 mA

Display Scalable -1999 to 9999

Outputs

Alarm Type

(Configurable through output operating mode – see manual)

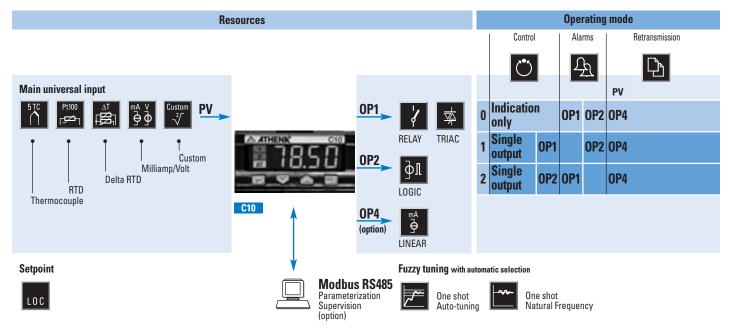
Mechanical Characteristics

Display 4 digit LED display
Numeric Range -1999 to 9999

Front Panel Rating IP65

Front Panel Cutout 45 mm x 22.2 mm Connections Screw terminal

Specifications subject to change without notice





Platinum™ Series M400 Controller-Indicator



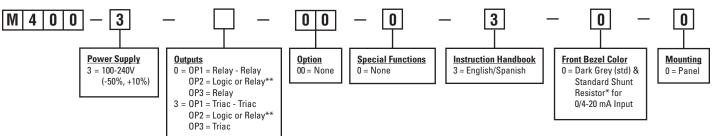
Athena's Platinum Series M400 offers easy user configuration and simple operation in a 1/16 DIN (48 x 48 mm) size panel-mounted controller suitable for a wide range of heat/cool control applications. Standard features include auto-tune, auto/man key, three outputs, and IP65 front panel protection. Available options include serial communications, analog control or retransmission output, transmitter power supply, special start-up and timer functions, auxiliary current transformer input, two front bezel colors, and DIN rail mounting.

- ▲ Field-Configurable Universal Inputs
- Bumpless Auto/Manual Transfer
- ▲ (IP65) Dust and Splash-Proof Front Panel
- ▲ On/Off Through Full PID Operation
- ▲ Adjustable Hysteresis and Deadband
- ▲ Outputs Configurable as Alarms
- ▲ Field-Configurable Process or Deviation Alarms
- ▲ CE Compatibility

Range Information



Input	Range	Input	Range
"J"	32°F to 1112°F (0°C to 600°C)	"S"	32°F to 2912°F (0°C to 1600°C)
"K"	32°F to 2192°F (0°C to 1200°C)	"T"	-328°F to 752°F (-200°C to 400°C)
" <u>L"</u>	32°F to 1112°F (0°C to 600°C)	"RTD"	-99.9°F to 572°F (-99.9°C to 300°C)
Millivolt Linear (scalable)	0 to 50 mV (0 - 20 mA) 10 to 50 mV (4 - 20 mA)	"RTD"	-328°F to 1112°F (-200°C to 600°C)



- * Standard Shunt-Resistor without field calibration = 1.10% input accuracy
 High Accuracy Shunt Resistor without field calibration = 0.20% input accuracy
 Either Shunt Resistor with field calibration = 0.10% input accuracy
- ** OP2 field-configurable via hardware jumper



Platinum™ Series M400 Controller-Indicator

Technical Specifications

Operating Limits

Ambient Temperature
Relative Humidity Tolerance
Power

32°F to 131°F (0°C to 55°C) 5-95%, noncondensing 100-240 Vac, 24 Vac/Vdc

1.6 W max

Power Consumption Performance

Accuracy 0.25% ± 1 digit (T/C and RTD) 0.1% ± 1 digit (mA* and mV)

Setpoint Resolution 1.0 count/0.1 count Repeatability ± 1.0 count

Temperature Stability $2 \mu \text{ V/°C}$ Process Sampling 0.5 sec

Digital Filtering Adjustable 1-30 sec

Control Characteristics

Setpoint Limits Span of sensor

Alarms Adjustable for high/low;

selectable for process deviation

Proportional Band 0.5 to 999.9% Integral 0.1 to 100.0 min Derivative 0.1 to 10.00 min Cycle Time 1 to 200 sec Control Hysteresis 0.1 to 10.0% Dead band Span of sensor

Dead band (Output at 1 & 2)

Auto-Tune Operator initiated from front panel
Manual Control Operator initiated from front panel

Inputs

Thermocouple

J, K, L, S, T, Maximum lead resistance
100 ohms for rated accuracy

RTD

Platinum 2- and 3-wire, 100 ohms at
0°C, DIN curve standard (0.00385)

Linear

U-5 mV/10-50 mV, 0-20 mA/4-20 mA

Display Scalable

-1999 to 9999

Outputs

SPST relay N.O., 2 A/250 V~, or
4/A/120 V~ (for resistive loads),
triac 1 A/250 V (for resistive loads)

OP2 = Logic

(SSR drive) not isolated: 5 V~,
±10%, 30 mA max
SPST relay N.O., 2 A/250 V~
(for resistive loads)

5 = OP1 = Triac

1 A/250 V ~ for contactor coil
(for resistive loads)

OP2 = Logic

(SSR drive) not isolated: 5 V~,
±10%, 30 mA max

Alarm Type

(Configurable through output operating mode – see manual)

Mechanical Characteristics

Display Dual 4 digit LED display Numeric Range -1999 to 9999

Front Panel Rating IP65

Tonic Paner Halling 1900

Front Panel Cutout 45 mm x 92 mm
Connections Screw terminal
Specifications subject to change without notice

Operating mode Resources Control Retransmission* Main universal input PV/SP Single **OP1** OP2 OP3 **OP4** 몼 output **Single OP2** OP1 OP3 **OP4** Milliamp/ Custom Thermo-Delta output **OP2** counte Volt Heat/ OP1 OP3 OP2 **OP4** Cool **Auxiliary input (option)** Heat/ **OP1 OP2 OP3 OP4** AUX **OP3** Cool Heat/ OP2 OP3 OP1 **OP4** Cool Digital input (option) M400 DI **OP4** (option) Setpoint **Special functions** Fuzzy tuning with automatic selection One shot One shot TIMER Natural Frequency Auto tunina (option) **Digital input functions**



rimer



(noitgo)

*The OP4 analog output option can be configured as process variable (PV) or setpoint (SP) retransmission—or—as an analog control output. The OP1, OP2, or OP3 output can be replaced by the OP4 analog control output option; the replaced output is forfeited.

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Platinum™ Series X400 Controller



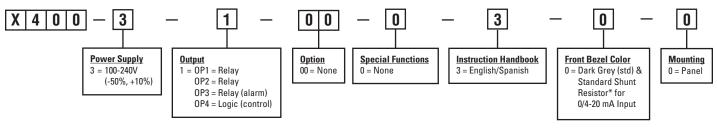
Athena's Platinum Series X400 provides a high degree of functionality and reliability in a low priced, 1/8 DIN (48 x 96 mm) size panel-mounted controller that can be configured to meet most heat/cool control applications. Standard features include auto-tune software, auto/man key, four outputs, three digital inputs, IP65 front panel protection, current transformer input, and auxiliary power supply. Available options include serial communications, analog control or retransmission output, special start-up and timer functions, two front bezel colors, valve drive output, and an eight segment setpoint program. Some of these options are mutually exclusive.

- ▲ Field-Configurable Universal Inputs
- ▲ Bumpless Auto/Manual Transfer
- ▲ (IP65) Dust and Splash-Proof Front Panel
- ▲ On/Off Through Full PID Operation
- ▲ Adjustable Hysteresis and Deadband
- ▲ Outputs Configurable as Alarms
- ▲ Field-Configurable Process or Deviation Alarms
- ▲ CE Compatibility

Range Information



Input	Range	Input	Range
"B"	32°F to 3272°F (0°C to 1800°C)	"R"	32°F to 2912°F (0°C to 1600°C)
"J"	32°F to 1112°F (0°C to 600°C)	"S"	32°F to 2912°F (0°C to 1600°C)
"K"	32°F to 2192°F (0°C to 1200°C)	"T"	-328°F to 754°F (-200°C to 400°C)
" <u>L"</u>	32°F to 1112°F (0°C to 600°C)	"RTD"	-99.9°F to 572°F (-99.9°C to 300°C)
"N"	32°F to 2192°F (0°C to 1200°C)	"RTD"	-328°F to 1112°F (-200°C to 600°C)
Millivolt Linear (scalable)	0 to 50 mV (0 - 20 mA) 10 to 50 mV (4 - 20 mA)		



^{*} Standard Shunt-Resistor without field calibration = 1.10% input accuracy
High Accuracy Shunt Resistor without field calibration = 0.20% input accuracy
Either Shunt Resistor with field calibration = 0.10% input accuracy

Technical Specifications

Operating Limits

Ambient Temperature 32°F
Relative Humidity Tolerance 5-95
Power 100-

Power Consumption

32°F to 131°F (0°C to 55°C) 5-95%, noncondensing 100-240 Vac, 24 Vac/Vdc 1.6 W max

Performance

Accuracy 0.25% ± 1 digit (T/C and RTD) 0.1% ± 1 digit (mA* and mV)

Setpoint Resolution 1.0 count/0.1 count
Repeatability ± 1.0 count

Temperature Stability $2 \mu \text{ V/°C}$ Process Sampling 0.5 sec

Digital Filtering Adjustable 1-30 sec

Control Characteristics

Setpoint Limits Span of sensor

Alarms Adjustable for high/low;

selectable for process deviation

 Proportional Band
 0.5 to 999.9%

 Integral
 0.1 to 100.0 min

 Derivative
 0.1 to 10.00 min

 Cycle Time
 1 to 200 sec

 Control Hysteresis
 0.1 to 10.0%

 Dead band
 Span of sensor

Dead band (Output at 1 & 2)

Auto-Tune Operator initiated from front panel
Manual Control Operator initiated from front panel

Inputs

Thermocouple

J, K, L, S, T, Maximum lead resistance
100 ohms for rated accuracy

RTD

Platinum 2- and 3-wire, 100 ohms at
0°C, DIN curve standard (0.00385)

Linear

U-5 mV/10-50 mV, 0-20 mA/4-20 mA

Display Scalable

-1999 to 9999

Outputs

0 = OP1 = Relay SPST relay N.O., 2 A/250 V~, or 4/A/120 V~ (for resistive loads),
OP2 = Logic SPST relay N.O., 2 A/250 V~, or 4/A/120 V~ (for resistive loads)
OP3 = Triac SPST relay N.O., 2 A/250 V~, or 4/A/120 V~ (for resistive loads)
OP2 = Logic not isolated: 5 V~, ±10%, 30 mA max (control only)

Alarm Type

(Configurable through output operating mode – see manual)

Mechanical Characteristics

Display Dual 4 digit LED display

Numeric Range -1999 to 9999

Front Panel Rating IP6

One shot

One shot Natural Frequency

Front Panel Cutout 45 mm x 96 mm Connections Screw terminal

Specifications subject to change without notice

Operating mode Resources Control Alarms Retransmission (*) Main universal input PV/SP PV **OP1 OP1** OP2 OP3 OP5 Single Auxiliary input 2 **OP4 OP2** OP1 OP2 OP3 OP5 output AUX 3 **OP5** OP1 OP2 OP3 **OP3** (option) OP3 OP5 4 OP1 OP2 Three digital inputs **OP4 D1 D2** 5 OP1 OP4 OP2 OP3 OP5 **D3 OP5** 0P3 0P5 6 OP4 OP2 OP1 (option) Heat/ Cool 7 **OP1 OP5 OP2 OP3** 8 OP5 OP2 OP1 **OP3** 9 Setpoint OP5 OP4 OP1 OP2 OP3 Modbus RS485 Parameterization Supervision (option) 10 Valve OP1 OP2 0P3 0P5 Special functions (option) D1. D2 or D3 connected functions Fuzzy tuning with automatic selection



TIMER

How to Order a Hot Runner Control System

1. Specify type of Controller required:

See Page 51 for Selection Guide

- IMP see page 52 for specifications
- RMA see page 54 for specifications
- RMB see page 56 for specifications
- RMC see page 58 for specifications
- RMT see page 60 for specifications

Note: The RMT Module is a dual zone controller

- The RMT amperage capability has 2 modes of operation:
 - Mode 1: Total amperage of 15A per the 2 zones of control
 - Mode 2: Total amperage is 15A per zone of control

2. Amperage required per zone: (heater wattage x voltage) 15A or 30A

- 15A Modules: IMP, RMA, RMB, RMC
- 30A Modules: IMP, RMC
- 15A Module: RMT (Total of 15A per module per 2 zones)
- 15A Module: RMT (15A per zone)

3. How many zone of control are required (up to 48)

4. Specify the mainframe configuration:

 For 15A modules (IMP, RMA, RMB, RMC) size frame required is the number of control modules—use MFL style

See Page 62 for frame configurations and ordering codes

- For 30A modules (IMP, RMC) frame required is 1 through 6 zones—use MFH style
 See Page 62 for frame configurations and ordering codes
- For 15A modules (RMT) size frame required is the number of control modules use MFT style

See Page 64 for frame configurations and ordering codes

Note: Consult Factory for combination mainframes (15A and 30A together). RMT modules and RMA modules together.

5. Specify cables, connectors and terminal mounting boxes see pages 72 through 79

6. Choose optional mainframe accessories:

Floor stands, transformer kits and closure panels see pages 66 and 67

Notes: Athena's mainframes are compatible with all D-M-E Company's G SERIES® and SMART SERIES®, ITC, MCS, YUDO®, and INCOE® brand mainframes.

Selection Guide

		Co	ntroller Series		
Feature	IMP	RMA	RMB	RMC	RMT
CE-compliant					
UL/CSA/VDE-approved power switch					
Type J thermocouple					
Type K thermocouple					
Process display (LED)					
Fahrenheit/Celsius mode	Jumper	Jumper	Jumper	Jumper	Jumper
Setpoint display	Thumbwheel	LED	LED	LED	LED
Setpoint adjust	Thumbwheel	Pushbutton	Pushbutton	Pushbutton	Pushbutton
CompuStep® soft start					
Temperature alarms	Fixed*	Fixed*	Fixed*	Adjustable	Fixed*
Reverse thermocouple alarm		1 3.00		- rajastasis	
Open thermocouple alarm					
Shorted thermcouple alarm					
External alarm					
Auto/manual control					
Autotuning	Fixed	Fixed	PID	PID	Fixed
30 amp capability	Тихоч	Tixou	1 15	1 15	1 IXOG
% output reading					
Horizontal single zone model	IMP/P			RMC/P	
Idle setpoint/setback	11411 /1			TilVIO/I	
SafeChange™ "hot-swap" feature					
Bumpless auto/manual transfer					
Front-panel lockout					
Switch to manual on open thermocouple					
Ground fault alarm					
Open heater alarm					
Loop break alarm					
Boost mode					
Current reading					
Adjustable control settings					
Shorted triac safety relay					
24 volt output (Series SY system)					
Thermocouple slaving					
Switch to manual %, OFF, or last					
% of output on open thermocouple					
Setpoint limits					
ALL command					
Modbus® communications					
Years under warranty	2	2	2	2	2

^{* 30} Degree Deviation



Series IMP

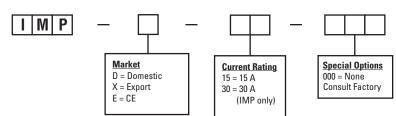


Athena's Series IMP Modules use microprocessorbased circuitry to perform all required control functions. Units have built-in diagnostics and are fully self-tuning—setpoint temperatures are maintained without the need to manually preset or adjust the control temperature.

- ▲ Simultaneous digital setpoint and digital temperature indication
- ▲ Available in 15-amp modules as well as single-zone 15- and 30-amp portable temperature controllers
- ▲ Athena's Controllers are compatible with all D-M-E Company's G SERIES and SMART SERIES® ITC, MCS, YUDO® and INCOE® brand mainframes.
- ▲ CompuStep® feature removes moisture from the heater before full power is applied
- ▲ CompuCycle® feature improves response time, reduces thermal fatigue and prolongs heater life by applying AC power smoothly and continuously
- Manual control for non-thermocouple applications, provides standby or "weekend" heat or to manually control temperature if a thermocouple fails
- ▲ Diagnostic and protection features include power "on," power to load, manual made, and over/under temperature, plus indicators and system protection for reversed and open thermocouples
- SafeChange™ "hot swap" feature allows safe removal and replacement of module

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Ordering Information



Note: The 30 amp Series IMP is twice as wide as the 15 amp model and has a circuit breaker instead of a power switch.



Technical Specifications

Performance Specifications

Control Mode CompuCycle® system

Ambient Temperature Ambient to 999°F, or ambient to 535°C

Temperature Reset Automatically corrects reset to within 2°F

(1°C) at all settings

Control Accuracy $\pm 1.0^{\circ}F(\pm 0.5^{\circ}C)$

dependent on the total thermal system ±0.5% of full scale over the ambient

Temperature

Stability range of 32°F to 140°F (0°C to 60°C)

Calibration Accuracy Better than 0.2% of full scale

Power Response Time

Manual Mode

Better than 0.13 sec Compensated

Maintains constant output power to within 1% of manually set power level with line voltage variation from 192 to 264 volts.

Power control range is from 0 to 100%. using the CompuCycle system power drive.

The upper segment of the leftmost display Over Temp. Indicator will be "on" and the whole display flashes

at about 2 Hz when the temperature error

exceeds +30°F (+17°C)

Under Temp. Indicator The lower segment of the leftmost display

will be "on" and the whole display flashes at about 2 Hz when the temperature error

exceeds -30°F (-17°C)

Flashing " on the leftmost display TC Break Indication

(in closed-loop and CompuStep)

TC Reverse Flashing " on the leftmost display

Indication (in closed-loop and

CompuStep)

No Heat/Open Heater Indication Flashing " ---- " center segment only of

the leftmost display (in closed-loop)

CompuStep®

System Control Mode Variable stepping voltage, phase fired

CompuStep System Duration

Approximately 5 min

CompuStep System Output Voltage

Steps approximately from 25 V_{RMS} to 170 V_{RMS} with 240 Vac line input

CompuStep System Holding

Temperature 256°F (125°C)

CompuStep System Override

Temperature 200°F (93°C)

Operational

Mode Priority a. TC break, TC reverse and No Heat override CompuStep System

b. Manual mode overrides TC break. TC reverse and No Heat

Input Specifications

Thermocouple (T/C) Sensor

Type "J", grounded or ungrounded

External (T/C) Resistance

Greater than 1000 ohms

Input Specifications

T/C Isolation Isolated from ground and supply voltages

Cold Junction Automatic, better than 0.02°F/F°

Compensation (0.01°C/°C) Input Type Potentiometric Input Impedance 22 megohms

Input Protection Diode clamp, RC filter

Input

Amplifier Stability Better than 0.05°F/°F (0.03°C/°C)

Input

Dynamic Range Greater than 1000°F (535°C)

Common Mode

Rejection Ratio Greater than 100 dB

Power Supply

Rejection Ratio Greater than 90 dB

Output Specifications

Voltages 240 Vac nominal, single phase 120

Vac available

Power Capability 15 amperes, 3600 watts @ 240 Vac,

30 amperes, 7200 watts @ 240 Vac

Output Switch Internal solid state triac,

triggered by ac zero crossing pulses

Triac and load use high speed fuses. Overload Protection

Both sides of ac line are fused.

Power

Optically and transformer isolated from Line Isolation

ac lines. Isolation voltage is greater than

2500 volts

Controls and Indicators

Setpoint Control Precision 3 digit pushbutton switch, direct

> reading; Range: 0 to 999°F (535°C); Resolution: 1°F (1°C); Accuracy: Better

than 0.5°F (0.3°C)

Manual Power Single turn potentiometer, calibrated

Control Range: 0-100%; Linearity: 10%

Mode Control 3-position sliding switch selects mode

of operation:

1. top position-Manual mode 2. middle position-Auto mode 3. bottom position-Auto mode with

CompuStep system

Power ON/OFF Rocker switch, UL, CSA, VDE approved

Electrical Power Specifications

Input Voltage 95-265 Vac

50 Hz ± 3 Hz. 60 Hz ± 3 Hz Frequency DC Power Supplies Internal generated, regulated and

temperature compensated

Module

Power Usage Less than 3 watts, excluding load



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Series RMA

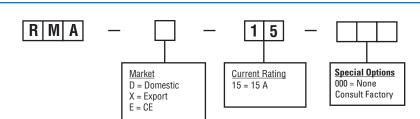


The Athena Series RMA is a microprocessor-based, single-zone temperature controller specifically designed for runnerless molding applications.

It features an easy-to-use operator keypad, two LED displays, and discrete indicators for heat output, alarm, degree F/C indication, manual, and closed loop mode.

- ▲ Compatible with industry standards control modules and mainframes
- ▲ Accepts Type J thermocouple
- ▲ Bumpless auto/manual transfer
- ▲ CompuStep® bake out feature prevents moisture at startup
- ▲ Built-in loop break for open heater, shorted triac, reversed or shorted thermocouple
- Open thermocouple break protection with jumperselectable shutdown or average power output based on operation
- ▲ Preset alarms at 30°F (17°C)
- SafeChange™ "hot swap" feature allows safe removal and replacement of module
- ▲ CE compliant

CE COMPLIANT



Technical Specifications

Performance Specifications

Auto Control Mode Control Accuracy

Ambient Temperature Temperature Stability

Calibration Accuracy Power Response Time Process Sampling °F/°C

CompuStep® System Control Mode

CompuStep System Duration CompuStep System Output Voltage

CompuStep System
Override Temp

CompuCycle® system

 ± 0.1 °F (± 0.1 °C) dependent on the

total thermal system

100°F to 650°F (37°C to 343°C) $\pm 0.5\%$ of full scale over the ambient range of 32°F to 131°F (0°C to 55°C) Better than 0.2% of full scale

Better than 300 ms 100 ms (nominal) Jumper-selectable

Variable stepping voltage, phase angle fired

Approximately 5 min

Steps approximately from $25\,V_{RMS}$ with 240 Vac line output, phase-fired

Operational Mode Priority

200°F (93°C)

 a. T/C open, T/C reverse, shutdown and open heater override CompuStep system
 b. Manual mode overrides T/C

open, T/C reverse

Input Specifications

Thermocouple (T/C) Sensor

External T/C Resistance

T/C Isolation

Cold Junction

Cold Junction Compensation

Input Type
Input Impedance
Input Protection

Input Amplifier Stability
Input Dynamic Range

Common Mode Rejection Ratio Power Supply

Rejection Ratio

Type "J" grounded or ungrounded

Maximum 100 ohms for rated accuracy

Isolated from ground and

supply voltages

Automatic, better than 0.02°F/°F (0.01°C/°C)

Potentiometric 10 megohms

Diode clamp, RC filter

Better than 0.05°F/°F (0.03°C/°C) Greater than 999°F (537°C)

Greater than 100 dB

Greater than 70 dB

Output Specifications

Voltages 240 Vac nominal, single phase

120 Vac available

Power Capability 15 amperes, 3600 watts @ 240 Vac

Overload Protection Triac and load use high speed fuses. Both sides are fused (GBB)

Power Line Isolation Optically and transformer isolated

from ac lines. Isolation voltage is greater than 2500 volts.

Output Drive Internal solid state triac, triggered

by ac zero crossing pulses

Controls and Indicators

Setpoint Control Two buttons up or down

Resolution 1°F (1°C)

% Power Control

Two buttons up or down

Mode Control

Push button switch with LED

indicator for manual and closed

loop mode

Display Top3-digit filtered LEDDisplay Bottom3-digit filtered LEDStatus IndicatorsHeat Output

Alarm
F/C
% Output
CompuStep
Manual
Closed Loop

Power On/Off Rocker Switch, UL, CSA, and

VDE approved

Electrical Power Specifications

Input Voltage 95-265 Vac

Frequency

50 Hz ± 3 Hz, 60 Hz ± 3 Hz

DC Power Supplies

Internal generated, regulate

Internal generated, regulated, and temperature compensated

Module Power Usage Less than 3 watts, excluding load



Series RMB

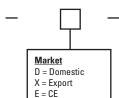


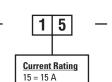
The Athena Series RMB is a microprocessor-based, single-zone temperature controller specifically designed for runnerless molding applications. It features an easy-to-use operator keypad, two LED displays, and three discrete indicators for heat-current, alarm and manual mode.

- ▲ Athena's mainframes are compatible with all D-M-E Company's G SERIES and SMART SERIES,® ITC, MCS, YUDO® and INCOE® brand mainframes.
- ▲ Accepts Type J or Type K thermocouple input (jumper selectable)
- ▲ Auto-tuning, with adjustable proportional band and rate
- ▲ Bumpless auto/manual transfer
- ▲ CompuStep® bake out feature prevents moisture at startup
- ▲ Built-in loop break, short, open, and reverse thermocouple protection
- ▲ Built-in triac safety protection
- ▲ Ground-fault protection
- ▲ Preset alarms at 30° F (17°C)
- ▲ Jumper-selectable soft-start mode
- ▲ Current monitor feature displays average current to load
- ▲ SafeChange™ "hot swap" feature allows safe removal and replacement of module
- ▲ CE compliant

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Technical Specifications

Performance Specifications

Auto Control Mode Control Accuracy

Ambient Temperature

Temperature Stability

Calibration Accuracy Power Response Time **Process Sampling**

°F/°C

CompuStep® System Control Mode

CompuStep System Duration CompuStep System Output Voltage

CompuStep System Override Temp Operational Mode Priority

CompuCycle® system

±0.1°F (±0.1°C) dependent on the total thermal system 32°F to 999°F (0°C to 537°C)

±0.5% of full scale over the ambient range of 32°F to 131°F (0°C to 55°C)

Better than 0.2% of full scale

Better than 300 ms 100 ms (nominal) Jumper-selectable

Variable stepping voltage,

phase fired

Approximately 5 min

Steps approximately from 25 V_{RMS} with 240 Vac line output, phase-fired

200°F (93°C)

a. T/C open, T/C reverse, Shutdown and Open heater override CompuStep system

b. Manual mode overrides T/C open, T/C reverse

Input Specifications

Thermocouple (T/C) Sensor

Type "J" or Type "K", grounded or ungrounded (switch-selectable)

External

T/C Resistance Max. 100 ohms for rated accuracy T/C Isolation Isolated from ground and

supply voltages

Cold Junction Compensation

Automatic, better than 0.02°F/°F (0.01°C/°C)

Potentiometric Input Type Input Impedance 10 megohms Input Protection

Input Amplifier Stability

Input Dynamic Range Common Mode

Rejection Ratio

Power Supply Rejection Ratio

Diode clamp, RC filter

Better than 0.05 °F/°F (0.03°C/°C)

Greater than 999°F (537°C)

Greater than 100 dB

Greater than 70 dB

Output Specifications

240 Vac nominal, single phase Voltages

120 Vac available

Power Capability 15 amperes, 3600 watts @ 240 Vac;

30 amperes, 7200 watts @ 240 Vac

Overload Protection Triac and load use high speed

fuses. Both sides are fused (GBB)

Optically and transformer isolated from Power Line

ac Isolation lines. Isolation voltage is

greater than 2500 volts.

Internal solid state triac, **Output Drive**

triggered by ac zero crossing pulses

Controls and Indicators

Setpoint Control Two buttons up or down.

Resolution 1°F (1°C)

% Power Control Two buttons up or down Mode Control

Push button switch with LED indicator for manual mode

Display Top: 3-digit filtered LED Bottom: 4-digit filtered LED

Status Indicators Heat-current output Alarm Power On-Off Rocker Switch, UL, CSA,

and VDE approved

Electrical Power Specifications

Input Voltage 95-265 Vac

Frequency 50 Hz ± 3 Hz. 60 Hz ± 3 Hz

DC Power Supplies Internal generated, regulated and temperature compensated

Module Power Usage Less than 3 watts, excluding load



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Series RMC



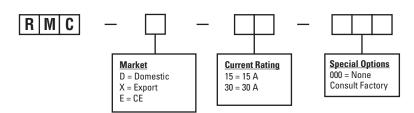
The Athena Series RMC brings new and highly productive benefits to injection molders looking for a modular hot runner controller that's flexible, easy to set up, and simple to operate.

Using the popular Modbus® communications protocol, the Series RMC gives users the ability to set or change all zones, either remotely from a desktop computer, or (with the ALL command) from any other individual RMC module in the mainframe.

- ▲ Choice of three default modes for open thermocouple condition
- ▲ Built-in triac safety protection
- ▲ Accepts J or K thermocouple input (jumper selectable)
- ▲ SafeChange™ "hot swap" feature allows safe removal and replacement of module
- CompuStep® bake out feature prevents moisture at startup
- ▲ Built-in loop break, short, open, and reverse thermocouple protection
- ▲ "Boost" mode for temporary % of power output increase
- ▲ Ground-fault protection
- Adjustable setpoint limits
- ▲ Stores highest temperature detected
- ▲ Current monitor feature displays average current to load
- ▲ CE compliant

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Ordering Information



Note: The 30 amp Series RMC is twice as wide as the 15 amp model and has a circuit breaker instead of a power switch.



Technical Specifications

Performance Specifications

Auto Control Mode Control Accuracy

Ambient Temperature Temperature Stability

Calibration Accuracy
Power Response Time
Process Sampling
°F/°C

CompuStep® System Control Mode CompuStep System Duration CompuStep System Output Voltage

CompuStep System Override Temp Operational Mode Priority CompuCycle® system

 ± 0.1 °F (± 0.1 °C) dependent on the total thermal system

32°F to 999°F (0°C to 537°C)

 $\pm 0.5\%$ of full scale over the ambient range of 32°F to 131°F (0°C to 55°C)

Better than 0.2% of full scale

Better than 300 ms 100 ms (nominal) Jumper-selectable

Variable stepping voltage, phase-fired

Approximately 5 min

Steps approximately from 25 V _{RMS} with 240 Vac line output, phase-fired

200°F (93°C)

 a. T/C open, T/C reverse, Shutdown and Open heater override CompuStep system

b. Manual mode overrides T/C open, T/C reverse

Input Specifications

Thermocouple (T/C) Sensor

External T/C Resistance

T/C Isolation

Cold Junction Compensation

Input Type
Input Impedance
Input Protection

Input Amplifier Stability
Input Dynamic Range

Common Mode Rejection Ratio

Power Supply

Rejection Ratio

Type "J" or Type "K", grounded or ungrounded (switch-selectable)

Max. 100 ohms for rated accuracy

Isolated from ground and supply voltages

Automatic, better than 0.02°F/°F (0.01°C/°C)

Potentiometric 10 megohms

Diode clamp, RC filter

Better than 0.05 °F/°F (0.03°C/°C)

Greater than 999°F (537°C)

Greater than 100 dB

Greater than 70 dB

Output Specifications

Voltages 240 Vac nominal, single

phase 120 Vac available

Power Capability 15 amperes, 3600 watts @ 240 Vac Overload Protection Triac and load use high speed fuses.

Both sides are fused (GBB)

Power Line Isolation Optically and transformer isolated from

ac lines. Isolation voltage is greater

than 2500 volts.

Output Drive Internal solid state triac,

triggered by ac zero crossing pulses

Controls and Indicators

Setpoint Control Two buttons up or down

Resolution 1°F (1°C)

% Power Control

Two buttons up or down

Mode Control

Push button switch with LED

indicator for manual mode

Display Top: 3-digit filtered LED

Bottom: 4-digit filtered LED

Status Indicators Heat-current output Alarm Power On-Off Rocker Switch, UL, CSA,

and VDE approved

Electrical Power Specifications

Input Voltage 95-265 Vac Frequency 50-60 Hz

DC Power Supplies Internally generated, regulated and

temperature compensated

Module Power Usage Less than 6 watts, excluding load



Series RMT

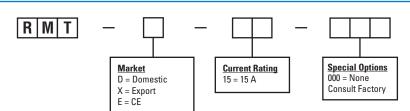


The Athena Series RMT is a microprocessor-based, dual-zone temperature controller specifically designed for runnerless molding applications effectively doubling the zone count per module without doubling the price.

It features two easy-to-use operator keypads, four LED displays, and discrete indicators for heat output, alarm, degree F/C indication, manual and closed loop mode.

- ▲ Accepts Type J thermocouple
- ▲ Bumpless auto/manual transfer
- ▲ CompuStep® bake out feature prevents moisture at startup
- ▲ Built-in loop break for open heater, shorted triac, reversed or shorted thermocouple
- Open thermocouple break protection with jumperselectable shutdown or average power output based on operation
- ▲ Preset alarms at 30°F (17°C)
- SafeChange™ "hot swap" feature allows safe removal and replacement of module
- ▲ CE compliant
- ▲ 15 amps per zone

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Technical Specifications

Performance Specifications

Auto Control Mode

Control Accuracy

Ambient Temperature

Temperature Stability

Calibration Accuracy Power Response Time **Process Sampling**

CompuStep® System Control Mode

°F/°C

CompuStep System Duration

CompuStep System Output Voltage

CompuStep System Override Temp

Operational Mode Priority

CompuCycle® system

+0.1°F (+0.1°C) dependent on the

total thermal system

100°F to 650°F (37°C to 343°C)

+0.5% of full scale over the ambient range of 32°F to 131°F (0°C to 55°C)

Better than 0.2% of full scale

Better than 300 ms 100 ms (nominal) Jumper-selectable

Variable stepping voltage. phase angle fired

Approximately 5 min

Steps approximately from 25 V_{RMS} with 240 Vac line output,

phase-fired

200°F (93°C)

a. T/C open, T/C reverse, shutdown and open heater override CompuStep system

b. Manual mode overrides T/C open, T/C reverse

Input Specifications

Thermocouple (T/C) Sensor

External T/C Resistance

T/C Isolation

Cold Junction

Compensation Input Type

Input Impedance Input Protection

Input Amplifier Stability Input Dynamic Range

Common Mode Rejection Ratio

Power Supply

Rejection Ratio

Type "J" grounded or ungrounded

Maximum 100 ohms for

rated accuracy

Isolated from ground and

supply voltages

Automatic, better than 0.02°F/°F

(0.01°C/°C) Potentiometric 10 megohms

Diode clamp, RC filter

Better than 0.05°F/°F (0.03°C/°C) Greater than 999°F (537°C)

Greater than 100 dB

Greater than 70 dB

Output Specifications

240 Vac nominal, single phase Voltages

120 Vac available

Power Capability 15 amperes, 3600 watts @ 240 Vac

Overload Protection Triac and load use high speed

fuses. Both sides of input power

are fused (GBB)

Power Line Isolation Optically and transformer isolated

from ac lines. Isolation voltage is

greater than 2500 volts.

Output Drive Internal solid state triac, triggered

by ac zero crossing pulses

Controls and Indicators

Setpoint Control Two buttons up or down

Resolution 1°F (1°C)

% Power Control Two buttons up or down Push button switch with LED Mode Control indicator for manual and

closed loop mode

Display Top (Qty-2) 3-digit filtered LED [Green] Display Bottom (Qty-2) 3-digit filtered LED [Orange]

Heat Output Status Indicators

Alarm °F/°C % Output CompuStep® Manual Closed Loop

Rocker Switch, UL, CSA, Power On-Off

and VDE approved

Electrical Power Specifications

Input Voltage 95 to 265 Vac

Frequency 50 Hz ± 3 Hz, 60 Hz ± 3 Hz DC Power Supplies Internal generated, regulated, and

temperature compensated

Module Power Usage Less than 3 watts, excluding load



MFL & MFH Mainframe Configurations

Mainframes for 15-Amp Modules*

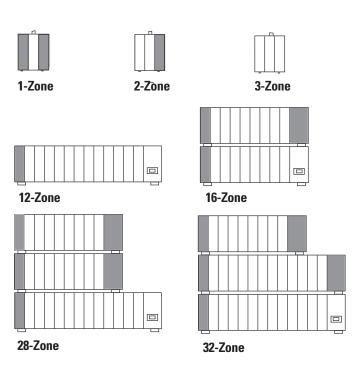
For use with RMA, RMB, RMC & IMP only

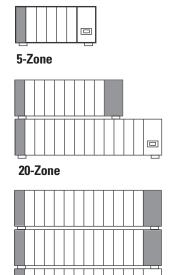
The configurations illustrated below provide a wide selection of zone capacities to suit almost any control application. The 5, 8 and 12 zone frames use individual frame sections. The 16 thru 48 zone frames use 2, 3 or 4 frame sections rigidly fastened together into one prewired integral unit which requires only one main AC power input connection.

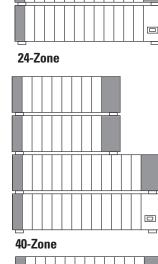
Dimensions*							
MFL Mainframe	Height	Depth	Width	MFH Mainframe			
1- & 2-zone	9-1/4″	10″	7″	1-zone			
3-zone	9-1/4″	12-3/4"	7″				
5-zone	8-7/8″	11-1/2″	16-1/8″	2-zone			
8-zone	8-7/8″	11-1/2″	22-1/8"	3-zone			
12-zone	8-7/8″	11-1/2″	301/4″	5- & 6-zone			

8-Zone

^{*}For mainframes over 12 zones, add dimensions of stacked cabinets.



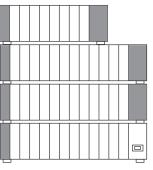




Notes on Mainframes

Mainframe cabinets may be stacked to form a permanent, integrated unit with a single ac power input and breaker. Up to 48 control modules (zones) may be accommodated.

5-, 8-, and 12-zone mainframes have a breaker rating of 50 amps and a maximum total wattage of 20 kW (domestic and export) and 36 kW (CE). Mainframes for 16 zones and over have breaker ratings of 70 amps and 29 kW (domestic and export) and 50.4 kW (CE).



36-Zone

44-Zone



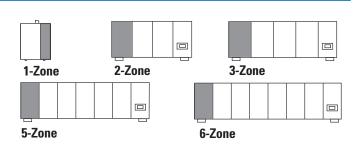


48-Zone

Mainframes for 30-amp Modules**

The 5 configurations illustrated below provide 1, 2, 3, 5 or 6 zones of 30 amp control for higher wattage heater applications.

^{**}NOTE: Blank panel(s) should be ordered to provide for heat dissipation and to cover unused zones in frames. Combination frames to accommodate both 15 and 30 amp modules are available on special order.



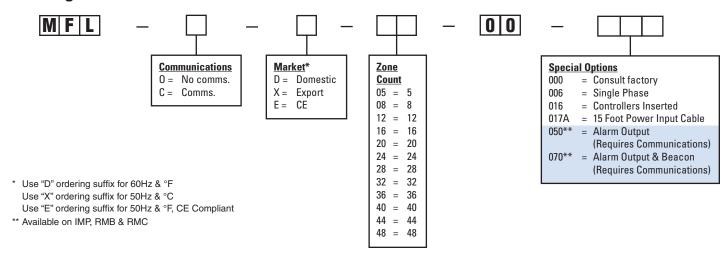


MFL & MFH Mainframe



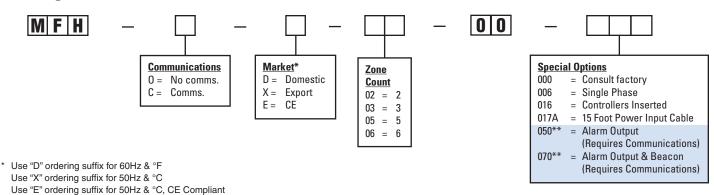
Standard Mainframes (15 amps)

Ordering Information



High-Power Mainframes (30 amps)

Ordering Information



^{**} Available on IMP, RMB & RMC



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MFT Mainframe Configurations

Mainframes for 15-Amp Modules, 15 A Total per Slot* For use with RMT only

The configurations illustrated below provide a wide selection of space-saving zone capacities to suit almost any control application. The 5, 8, and 12 slot frames use individual frame sections with a 50 A main circuit breaker. The 16 and 24 slot frames use two (2) frame sections rigidly fastened together with a 70 A main circuit breaker.

*Note: Blank panel(s) should be ordered to provide for heat dissipation and to cover unused slots in the frames.

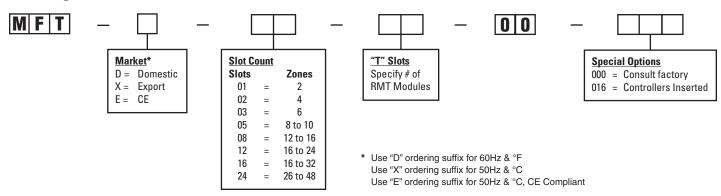
	ainframe Configuration and ard Zone Numbering	Available MFT Mainframe Power and TC Connector Mounting Arrangements
1-Slot	2 1	(2) Single Zone Combination Power and T/C Connector mounted on top of frame
2-Slot	3 4 1 2	(1) 5 Zone T/C Connector mounted on rear of frame (1) 5 Zone Power Connector mounted on rear of frame
3-Slot	4 5 6 1 2 3	(1) 8 Zone T/C Connector mounted on rear of frame (1) 8 Zone Power Connector mounted on rear of frame
5-Slot	6 7 8 9 10 BKR 1 2 3 4 5	(1) 12 Zone T/C Connector mounted on side of frame (1) 12 Zone Power Connector mounted on side of frame
8-Slot	9 10 11 12 13 14 15 16 BKR 1 2 3 4 5 6 7 8 🖳	(2) 8 Zone T/C Connectors (1) mounted on side of frame (1) mounted on rear cover of frame
		(2) 8 Zone Power Connectors (1) mounted on side of frame (1) mounted on rear cover of frame
12-Slot	13 14 15 16 17 18 19 20 21 22 23 24 BKR 1 2 3 4 5 6 7 8 9 10 11 12	(2) 12 Zone T/C Connectors(1) mounted on side of frame(1) mounted on rear cover of frame
		(2) 12 Zone Power Connectors(1) mounted on side of frame(1) mounted on rear cover of frame
16-Slot	25 26 27 28 29 30 31 32 BKR 17 18 19 20 21 22 23 24 9 10 11 12 13 14 15 16 BKR	(4) 8 Zone T/C ConnectorsMounting per frame, 2 frames stacked(1) mounted on side of frame(1) mounted on rear cover of frame
		(4) 8 Zone Power Connectors
24-Slot	37 38 39 40 41 42 43 44 45 46 47 48 BKR 25 26 27 28 29 30 31 32 33 34 35 36 13 14 15 16 17 18 19 20 21 22 23 24 BKR 1 2 3 4 5 6 7 8 9 10 11 12	 (4) 12 Zone T/C Connectors Mounting per frame, 2 frames stacked (1) mounted on side of frame (1) mounted on rear cover of frame (4) 12 Zone Power Connectors Mounting per frame, 2 frames stacked (1) mounted on side of frame
		(1) mounted on rear cover of frame

MFT Mainframes



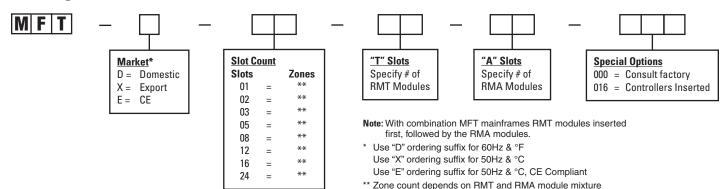
MFT Twin Zone Mainframes with all RMT Modules (15 amps max per slot)

Ordering Information



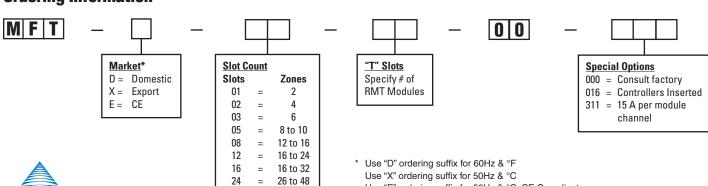
Combination MFT Twin Zone Mainframes with RMT and RMA Modules (15 amps max per RMT slot and 15 amps max per RMA slot)

Ordering Information



MFT Twin Zone Mainframes with all RMT Modules (15 amps max per module channel)

Ordering Information





Use "E" ordering suffix for 50Hz & °C, CE Compliant

Hot Runner Control System Accessories

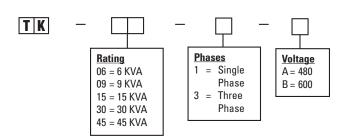
Transformer Kits



Transformer kits are fully wired and include enclosed transformer (480 Vac 30 in, 240 Vac 30 out) with adjustable voltage taps, power cable to main frame, disconnect switch, extra fuses, and floor stand with all hardware. Other transformers are available for your particular power requirements.

Directions for sizing a transformer kit may be found on page 67.

Ordering Information

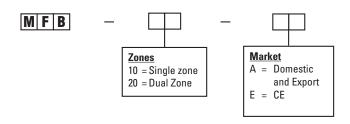


Closure (Blanking) Panels



Must be used to cover unused zones in main frames for correct air circulation (cooling). MFB10 for use on single unused zones. MFB20 for use on two unused zones. Supplied with push-pull panel fasteners.

Ordering Information



Universal Floor Stand



Floorstand is adjustable for use with 5, 8 or 12 slot mainframes.

Ordering Information



Module Replacement Fuses



Ca	italog No.	Description	Amps	Qty.
Αŀ	BC15	15 amp, 240 V	15	5
A2	25X30	30 amp, 240 V	30	1

Insulated Crimp Connectors





For easy splicing of mold power input connector leads to heater leads.

Catalog Number	Amps	Qty.
HWCC-1	15	36
HWCC-2	30	20



How to Size Circuit Breakers and Transformer Kits

To Size Circuit Breakers, Follow These Guidelines:

5, 8, 12 zones = 50 A breaker rating @ 20 kW max. >12 zones = 70 A breaker rating @ 29 kW max.

To Size a Transformer Kit, Follow These Steps:

- 1. Calculate total heater wattage
- 2. Divide result by 1000 (equals kVA)
- 3. Select transformer from table below

Transformer Part No.	Load Rating in kVA	3-Phase Amperage (per Phase)
TK09	9	21.7 A
TK15	15	36.1 A
TK30	30	72.3 A
TK45	45	108.4 A



Transformer kits are fully wired and include enclosed transformer (480 Vac 3Ø in, 240 Vac 3Ø out) with adjustable voltage taps, power cable to main frame, disconnect switch, extra fuses, and floor stand with all hardware. Other transformers are available for your particular power requirements.

For ordering information, see page 66.

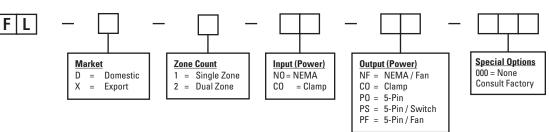


Mainframes for Portable Controllers

MFL Single/Dual Zone Mainframes (15 amps)



Ordering Information





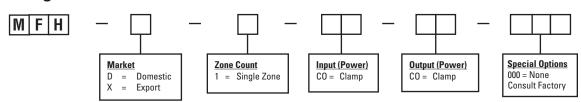
Note: Controller modules not included; mating connector included.

See pages 52 through 59 for IMP, RMA, RMB & RMC control module specifications.

MFH High-Power Single Zone Mainframes (30 amps)



Ordering Information



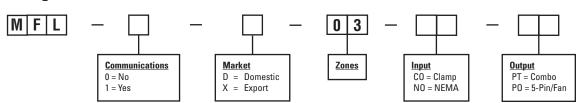
Note: Controller modules not included.

See pages 52 & 53 for IMP module and pages 51 & 52 for RMC module specifications.

Tri-Zone™ Portable Three-Zone Controller (15 amps)



Ordering Information

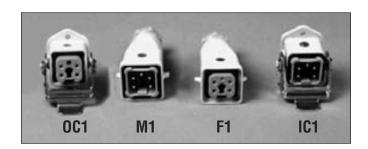


Note: Controller modules not included.

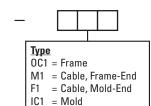
See pages 52 through 59 for IMP, RMA, RMB & RMC control module specifications.

Connectors and Cables for Portable Controllers

5-Pin Combination Power and Thermocouple **Connectors for Portable Controllers** (one per zone required)







NEMA Connectors for Portable Controllers





female 15 A, 125 V

Power out



215K006U01 (AC1512M)

male 15 A, 125 V Power in



215K004U01 (AC1524F)

Cord connector, Cord connector. female 15 A, 250 V Power out



215K003U01 (AC1524M)

Cord connector, male 15 A, 250 V Power in



215K002U01 (AC2024F)

Connector chassis, female 20 A, 250 V Power out



215K001U01 (AC2024M)

Connector chassis, male 20 A, 250 V Power in



TCS1 TC Socket. mold side



(M2MJ)

215P001U01

TC mini-plug

Individual 5-Pin Cable for Portable Controllers (one per zone required)

Combo Cable for Tri-Zone System





<u>Length</u> 10 = 10' 20 = 20'

Combo Connector for Tri-Zone System















Series IMP/P and RMC/P Horizontal Portable Controllers

Series IMP/P Single-Zone Controller

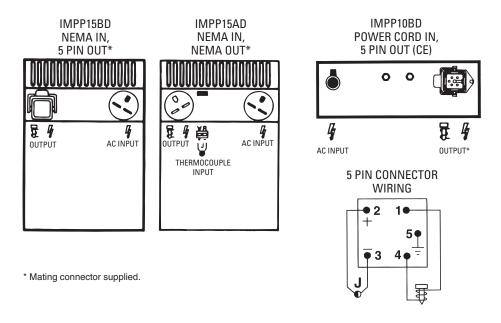
0.

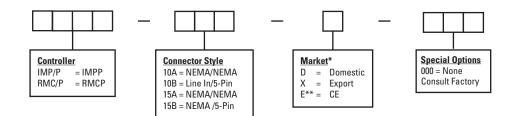
For features and technical specifications of the Series IMP/P, refer to the Series IMP description on page 52.

Series RMC/P Single-Zone Controller



For features and technical specifications of the Series RMC/P, refer to the Series RMC description on page 58.

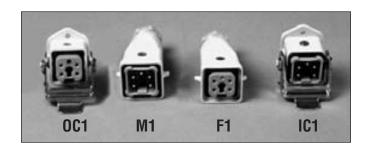


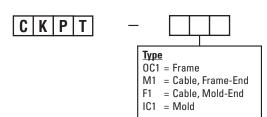


- * Use "D" ordering suffix for 60Hz & "F Use "X" ordering suffix for 50Hz & "C Use "E" ordering suffix for 50Hz & "C, CE Compliant
- ** 10 amp only

Connectors and Cable for Horizontal Portable Controllers

5-Pin Combination Power and Thermocouple **Connectors for Portable Controllers** (one per zone required)





NEMA Connectors for Portable Controllers



215K005U01

(AC1512F)

15 A, 125 V

Power out

female



215K006U01

(AC1512M) Cord connector, Cord connector, male 15 A, 125 V Power in



215K004U01 (AC1524F)

Cord connector, female 15 A, 250 V Power out



215K003U01 (AC1524M)

Cord connector, male 15 A, 250 V Power in





Connector chassis, female 20 A, 250 V Power out



215K001U01 (AC2024M)

Connector chassis, male 20 A, 250 V Power in

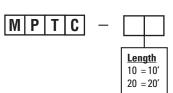


215P001U01 TCS1 (M2MJ) TC Socket, mold side

TC mini-plug

Individual 5-Pin Cable for Portable Controllers (one per zone required)







MFL, MFH Hot Runner Controls, System Components Domestic and Export (A), CE Compliant (E)

	Cables		Cables Connectors		Mold Terminal Boxes**		
#Zones	Mold Power (C10=10 Ft) (C20=20 Ft)	Thermocouple (C10=10 Ft) (C20=20 Ft)	Mold Power Input*	Thermocouple	Power Input	Thermocouple	Combination

Standard Mainframe ("A" Suffix = Domestic or Export, "E" Suffix = CE Compliant)

5	1-MPCL05Cxxz 1-TC05Cxxz	1-PICL05z 1-MTC0	1-PICL512TBz 1-MTC005TBz 1-PTCL005TBz
8	1-MPCL08Cxxz 1-TC08Cxxz	1-PICL08z 1-MTC08	08z 1-PICL512TBz 1-MTC008TBz 1-PTCL008TBz
12	1-MPCL12Cxxz 1-TC12Cxxz	1-PICL12z 1-MTC1	2z 1-PICL512TBz 1-MTC012TBz 1-PTCL012TBz
16	2-MPCL08Cxxz 2-TC08Cxxz	2-PICL08z 2-MTC0	08z 2-PICL512TBz 2-MTC008TBz 2-PTCL008TBz
20	1-MPCL08Cxxz 1-TC08Cxxz	1-PICL08z 1-MTC0	08z 2-PICL512TBz 1-MTC008TBz 1-PTCL008TBz
	1-MPCL12Cxxz 1-TC12Cxxz	1-PICL12z 1-MTC1	2z 1-MTC012TBz 1-PTCL012TBz
24	2-MPCL12Cxxz 2-TC12Cxxz	2-PICL12z 2-MTC1	2z 2-PICL512TBz 2-MTC012TBz 2-PTCL012TBz
28	2-MPCL08Cxxz 2-TC08Cxxz	2-PICL08z 2-MTC08	08z 3-PICL512TBz 2-MTC008TBz 2-PTCL008TBz
	1-MPCL12Cxxz 1-TC12Cxxz	1-PICL12z 1-MTC1	2z 1-MTC012TBz 1-PTCL012TBz
32	1-MPCL08Cxx 1-TC08Cxxz	1-PICL08z 1-MTC08	08z 3-PICL512TBz 1-MTC008TBz 1-PTCL008TBz
	2-MPCL12Cxx 2-TC12Cxxz	2-PICL12z 2-MTC1	2z 2-MTC012TBz 2-PTCL012TBz
36	3-MPCL12Cxx 3-TC12Cxxz	3-PICL12z 3-MTC1	2z 3-PICL512TBz 3-MTC012TBz 3-PTCL012TBz
40	2-MPCL08Cxxz 2-TC08Cxxz	2-PICL08z 2-MTC08	08z 4-PICL512TBz 2-MTC008TBz 2-PTCL008TBz
	2-MPCL12Cxxz 2-TC12Cxxz	2-PICL12z 2-MTC1	2z 2-MTC012TBz 2-PTCL012TBz
44	1-MPCL08Cxxz 1-TC08Cxxz	1-PICL08z 1-MTC08	08z 4-PICL512TBz 1-MTC008TBz 1-PTCL008TBz
	3-MPCL12Cxxz 3-TC12Cxxz	3-PICL12z 3-MTC1	2z 3-MTC012TBz 3-PTCL012TBz
48	4-MPCL12Cxxz 4-TC12Cxxz	4-PICL12z 4-MTC12	2z 4-PICL512TBz 4-MTC012TBz 4-PTCL12TBz

High-Power Mainframe ("A" Suffix = Domestic or Export, "E" Suffix = CE Compliant)

2	1-MPCH23Cxxz 1-TC05Cxxz	1-PICH23z 1-MTC05z	1-PICH023TBz 1-MTC005TBz 1-PTCH023TBz
3	1-MPCH23Cxxz 1-TC05Cxxz	1-PICH23z 1-MTC05z	1-PICH023TBz 1-MTC005TBz 1-PTCH023TBz
5	1-MPCH05Cxxz 1-TC05Cxxz	1-PICH05z 1-MTC05z	1-PICH005TBz 1-MTC005TBz 1-PTCH005TBz
6	1-MPCH06Cxxz 1-TC08Cxxz	1-PICH06z 1-MTC08z	1-PICH006TBz 1-MTC008TBz 1-PTCH006TBz

Note: Replace xx with Cable Length (10 = 10 ft., 20 = 20 ft.)

Replace z with Wiring (A = Domestic/Export, E = CE Complaint)



MFT (Twin Zone) Hot Runner Control System Components, Domestic and Export (A), CE Compliant (E)

Components

Slots	Cables		Connectors		Mold Terminal Boxes**		
	Mold Power	Thermocouple	Mold Power Input*	Thermocouple	Power Input	Thermocouple	Combination
1	2-MPTCxx	Combination Power and TC	2-CKPTIC1	Combination Power and TC			1-PTCL02TBz
2	1-MPCL05Cxxz	1-TC05Cxxz	1-PICL05z	1-MTC05z	1-PICL512TBz	1-MTC05TBz	1-PTCL05TBz
3	1-MPCL08Cxxz	1-TC08Cxxz	1-PICL08z	1-MTC08z	1-PICL512TBz	1-MTC08TBz	1-PTCL05TBz
5	1-MPCL12Cxxz	1-TC12Cxxz	1-PICL12z	1-MTC12z	1-PICL512TBz	1-MTC12TBz	1-PTCL12TBz
8	2-MPCL08Cxxz	2-TC08Cxxz	2-PICL08z	2-MTC08z	2-PICL512TBz	2-MTC08TBz	2-PTCL05TBz
12	2-MPCL12Cxxz	2-TC12Cxxz	2-PICL12z	2-MTC12z	2-PICL512TBz	2-MTC12TBz	2-PTCL12TBz
16	4-MPCL08Cxxz	4-TC08Cxxz	2-PICL12z	2-MTC12z	2-PICL512TBz	2-MTC12TBz	2-PTCL12TBz
24	4-MPCL12Cxxz	4-TC12Cxxz	4-PICL12z	4-MTC12z	4-PICL512TBz	4-MTC12TBz	4-PTCL12TBz

^{*} Include Crimp Connectors
**Order power input and thermocouple or combination.

Note: Replace xx with Cable Length (10 = 10 ft., 20 = 20 ft.)

Replace z with Wiring (A = Domestic/Export, E = CE Complaint)



73

Series SY Dual-Voltage Hot Runner Control System



Athena's dual-voltage hot runner control system combines 240 Vac and 24 Vac into one mainframe cabinet, eliminating the need to maintain two separate systems. This configuration is typically used in applications where the heaters for the manifolds operate on 240 Vac power and the injection nozzles operate on 24 Vac power. The control system includes the mainframe cabinet with a fused circuit breaker/disconnect switch, stepdown transformer, floor stand and a special safety interlock which prevents the insertion of 24 Vac control modules into a 240 Vac slot in the mainframe.

- ▲ The Series RMB or RMC control modules are available for use in the dual voltage mainframes
- ▲ Communications available with RMC control modules
- ▲ CE approval
- Wide range of accessories available for customizaton of control system

(E

Ordering Information

Dual-Voltage System SY



Market*
D = Domestic
X = Export

E = CE



24 Vac Zones 04 = 4 Zones

08 = 8 Zones



Control Modules R M C

R M B

Market*
D = Domestic
X = Export

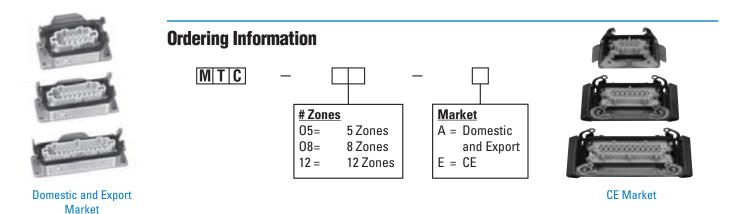
| Current Rating | 024 = 24 Vac option | 000 = 240 Vac

Notes: See Pages 56 & 57 for RMB controllers and pages 58 & 59 for RMC controllers specifications. See Page 66 for Control System Accessories.

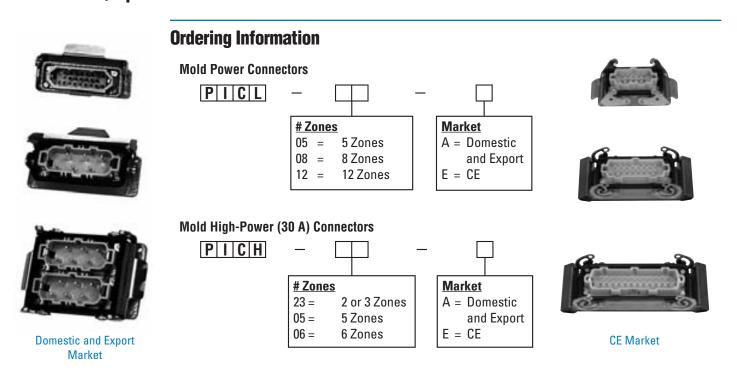
* Use "D" ordering suffix for 60Hz & °F Use "X" ordering suffix for 50Hz & °C Use "E" ordering suffix for 50Hz & °C, CE Compliant

Thermocouple and Mold Power Connectors

Thermocouple Connectors

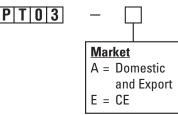


Mold Power/Input Connectors



Combo Connectors for Tri-Zone™ System







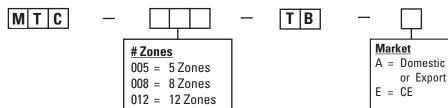
Mold Terminal Mounting Junction Boxes



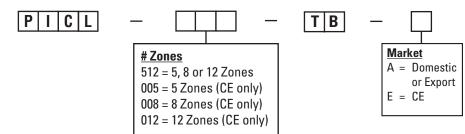
MTC Terminal Mounting Boxes for Thermocouple Connectors

Ordering Information

Thermocouple Junction Boxes



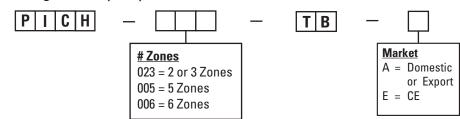
Mold Power Junction Box





PICL and PICH Terminal Mounting Boxes for Mold Power Input Connectors (15 amps)

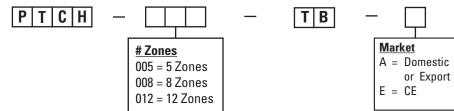
Mold High Power (30 A) Junction Box



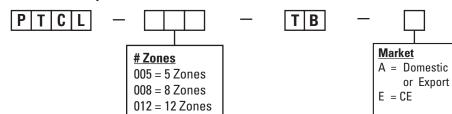


PTCH and PTCL Combination Terminal Mounting Boxes (30 amps)

Mold Thermocouple/High Power (30 A) Combination Junction Boxes



Mold Thermocouple/Power Combination Junction Boxes

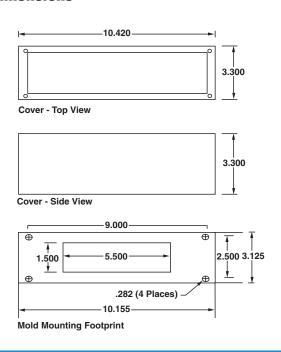


Mold Mount	Mold Mounting Junction Boxes for Portable Hot Runner Systems		
Model No.	en de la companya de		
PTCL-001-TB-A	IMP/P, RMC/P and Single Zone MFL Mainframes with one 5-pin connector		
PTCL-002-TB-A	Dual Zone MFL Mainframe with two 5-pin connectors		
PTCH-001-TB-A	Single Zone MFH Mainframes with one 30-amp NEMA plug and one thermocouple plug		

Prewired 5, 8, 12-Zone Mold Junction Box for Hot Runner Wiring



Dimensions



Athena Prewired Mold Junction Boxes feature an innovative design that makes hot runner wiring fast, easy, and logical. Boxes contain a 25-pin power connector for 15 AMP/240 zones, and a 10, 16 or 24 pin thermocouple connector.

Each Box:

- ▲ Is Completely Assembled
- ▲ Prewired with Marked Zones
- Contains Terminal Strips for Accurate Wiring

Athena's Prewired Hot Runner Mold Wiring System has quickly developed recognition as the new industry standard. Changeovers are quick and logical, and troubleshooting can be done while the mold is still in the press.

Here's how simple it is! There are two terminal strips—one for power and the other for thermocouple connection.

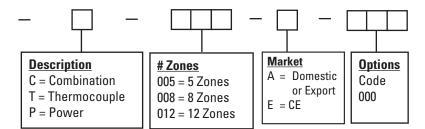
Simply:

- 1. Bring the wires from the mold through the wire opening
- 2. Place the wires under the SEMS pressure plate on the appropriate zone number
- 3. Tighten the screw
- 4. Repeat on the other side
- 5. Replace the cover

It's Really that Easy!

Ordering Information







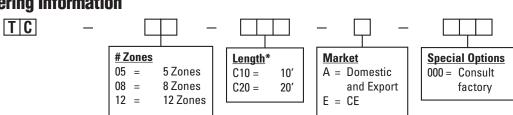
Back to Index 77

Mold Power and Thermocouple Cables Ordering Information

Mold Thermocouple Cable



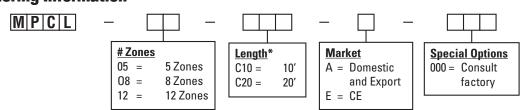
Ordering Information



Mold Power Cable (15 A)



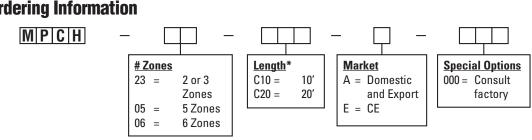
Ordering Information



Mold High-Power (30 A) Cable



*Consult factory for special lengths.

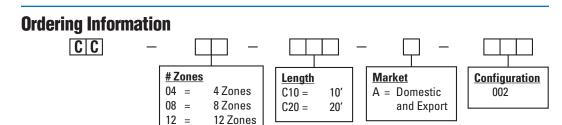


Custom and Combination Cables

Custom Cables for INCOE® and Fast Heat® Systems

For Incoe® Systems





Note: Athena connectors are on mainframe side. On mold side, cable connects to the following Incoe connector part number: #1614 (4-zone system)

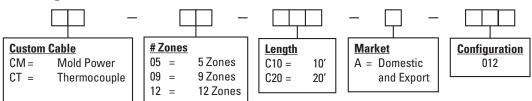
#3214 (8-zone system) #4814 (12-zone system)

For Fast Heat® Systems





Ordering Information



Note: Connects to Fast Heat connectors on mold.



CT Mold Thermocouple Cable

Combination Power and Thermocouple Cable (One zone per cable)



Ordering Information



^{*}Consult factory for special lengths.

Combo Output Cable for Tri-Zone™ System

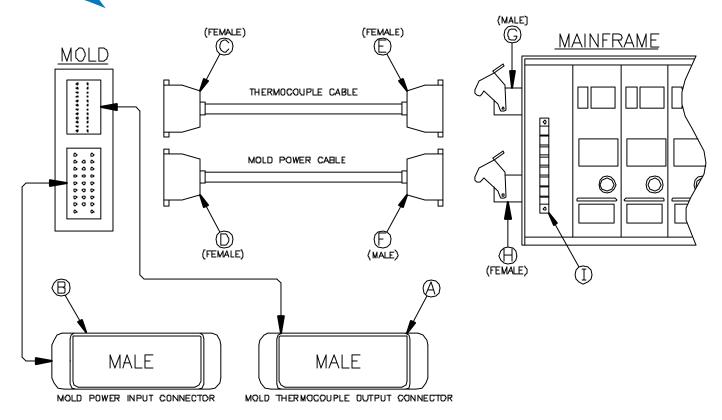




^{*}Consult factory for special lengths. Note: Consult factory for other custom cables.



Mainframe Connector Diagram



A N	DOM/EXP MTCO5A MTCO8A	ÇE	MOLD CONNECTORS DESCRIPTION			
A N	MTCO5A	, ,	DESCRIPTION			
A 1		N CTOOL C	DESCRIPTION			
	MTCOBA	MTCO5E	Mold Thermocouple Output Connector 5-Zone, and all 30 Amps			
_ N		MTCO8E	Mold Thermocouple Output Connector B-Zone			
	MTC12A	MTC12E	Mold Thermocouple Output Connector 12-Zone			
F	PICLO5A	PICLO5E	Mold Power Input Connector 5-Zone			
F	PICLO8A	PICLOSE	Mold Pawer Input Connector 8-Zane			
В	PICL12A	PICL12E	Mold Power Input Connector 12-Zone			
L L	PICH23A	PICH23E	Mold-High Power Input Connector 2—3 Zone, 30 Amps			
F	PICH05A	PICH05E	Mold-High Power Input Connector 5—Zone (3D Amps)			
F	PICH06A	PICH06E	Mold-High Power Input Connector 6—Zone (3D Amps)			
			CABLE CONNECTORS			
REF	DOM/EXP	¢E	DESCRIPTION			
A	ACKTF15	ECKTF15	Mold End Kit/Thermocouple Cable 5—Zone (10, 15 or 30 Amps)			
CA	ACKTF18	ECKTF18	Mold End Kit/Thermocouple Cable 8-Zone (10, 15 or 30 Amps)			
A	ACKTF112	ECKTF112	Mold End Kit/Thermocouple Cable 12-Zone (10, 15 or 30 Amps)			
A	ACKPF112B	ECKPF112B	(PF112B Mold End Kit for all 10 ar 15 Amp Power Cables			
D A	ACKPF13C	ECKPF13C	Mold End Kit for 2 or 3 Zone, 30Amp Power Cables			
A	ACKPF15C	ECKPF15C	Mold End Kit for 5-Zone, 30 Amp Power Cables			
E A	ACKTF112A	ECKTF112A	Frame End Kit for all Thermocouple Cables (10, 15 or 30 Amps)			
A	ACKPM112B	ECKPM112B	Frame End Kit far all 10 or 15 Amp Power Cables			
F A	ACKPM13C	ECKPM13C	Frame End Kit far 2 or 3 Zane, 30 Amp Power Cable			
A	ACKPM15C	ECKPM15C	Frame End Kit far 6-Zone, 30 Amp Power Cable			
			MAINFRAME CONNECTORS			
REF	DOM/EXP	CE	DESCRIPTION			
		ECKTM212A	Thermocouple Input Kit for all Mainframe (10, 15 or 30 Amps)			
A	CKPF212B	ECKPF212B	Power Output Kit for all 10 or 15 Amp Mainframes			
H ACFPF23C ECFPF23C Power Output Kit for 2 or 3 Zone, 30 Amp Mainframes ACKPF25C ECKPF25C Power Output Kit for 6—Zone, 30 Amp Mainframes			Power Output Kit for 2 or 3 Zone, 30 Amp Mainframes			
			Power Output Kit for 6—Zone, 30 Amp Mainframes			
215N003U01 215N003U01 PC Board Edge Connector for all Mainframes and Modules			PC Board Edge Connector for all Mainframes and Modules			
I B	314A011U01	614A011U01	PC Board Edge Connector for all Mainframes and Modules W/Pins			

Temperature Sensors



When you have a technical problem or question about thermocouples, RTDs, or temperature measurement, give Athena a call. You'll speak with an experienced technician with a wide knowledge of the field. In addition to a complete line of Tudor brand temperature sensors, we build more "specials" and service a greater variety of industries than most any thermocouple manufacturer. In fact, chances are excellent we have already solved a problem similar to yours. We'll be happy to tell you about our experience and discuss possible solutions without obligation.

Many larger thermocouple manufacturers would rather not be bothered with "specials." They want large volume orders. So "specials" go to the bottom of the pile and delivery and communication with the customer are usually very poor.

Of course, we like large orders as much as the next company. But what sets us apart is our enthusiasm about solving problems for our customers, big and small. You can depend on Athena and Tudor brand temperature sensors to provide the temperature measurement and control solutions you need.

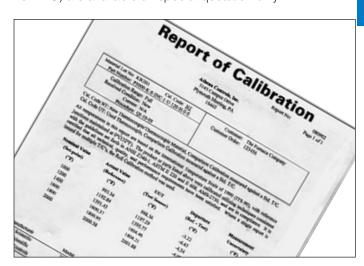
Athena's thermocouples and thermocouple wire meet accuracy standards as defined by the many technical societies and manufacturers. These accuracies are listed in the Engineering Data section of the Athena Reference Information publication, available on request and at our web site, www.athenacontrols.com. Special accuracy thermocouples and thermocouple wire are also defined and are detailed in this section.

Selected grade thermocouple wire can be supplied in instances where special or standard grade material does not provide the accuracy needed at specific temperatures. The availability of this grade depends on your specific requirements and stock levels.

Calibration of thermocouples or thermocouple wire is a laboratory test performed on a specific product or lot to determine its departure from a defined temperature—E.M.F. relationship. ASTM E 230 (ITS 90) describes the relationship for the various thermocouple types, portions of which can be found in Athena's Technical Reference Information booklet, available on request. Calibrations are conducted following the general guidelines of ASTM E 220. Test results are reported in certificate form indicating test temperatures, °F or °C corrections and standards traceable data.

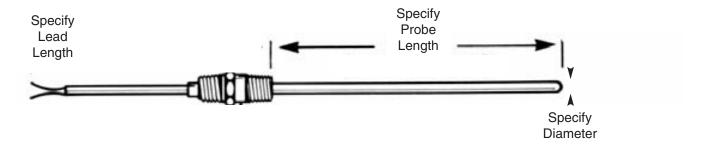
Calibration is performed in accordance with MIL-C-45662, ANSI/NSCL Z540-1, and ISO 10012-1. Overall production satisfies the requirements of MIL-I-45208. Additionally, the product testing and certification requirements of AMS-2750-C and ASTM E 608 can be supplied.

Each product tested can be tagged with a test number, date and correction data. Pricing for calibration and testing is based on tests selected, quantity to be tested, and number of test temperatures. Test temperatures within the range of 0° C (32° F) to 1371° C (2500° F) are available at competitive pricing. Sub-zero checking and high temperature (above 1371° C) are available on special quotation only.





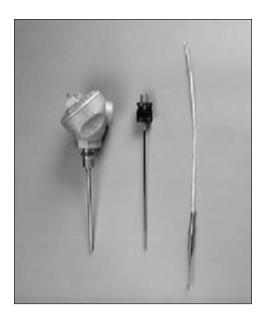
Custom Probe Quote Form



For a quick quotation on your special temperature probe requirements, draw the type of thermocouple or RTD profile desired below and fax a copy of this page to Athena Controls at (800) 782-6776.

Name		_ Date	
Company			
Address		_	
City/State/Zip		_	
Tel		-	
Fax		-	
E-mail		-	
	+++++++++++++++++++++++++++++++++++++++		
Specify:			
☐ Probe Length	Addition	onal Comments or Requirements:	
☐ Lead Length ———	-		
☐ Probe Diameter ————	•		
☐ Probe Material ————			
☐ Termination ————			
☐ Max. Temperature ————			
☐ Test Requirements ———			

Tu-Pak® Thermocouple Assemblies



Tu-Pak® is Athena's trademark for metal-sheathed, mineral-insulated (MI) thermocouple material. It is a departure from the traditional assembly of tubes, wires and insulators. It has a unit-construction with no replacement parts. Tu-Pak® has improved thermal response, greater flexibility and, size for size, it is longer lasting than traditional types.

Tu-Pak	Tu-Pak® Dimensions and Wire Sizes				
Sheath Outside	Outside Diameter	Nominal Wall	Approximate Wire	Nom. Co Diamete	
Diameter	Tolerance, ±in.	Thickness, in.	B&S gauge	2-wire	4-wire
0.062	0.002	0.010	29	0.011	0.006
0.125	0.002	0.018	24	0.022	0.011
0.188	0.003	0.025	18	0.032	0.022
0.250	0.003	0.032	17	0.040	0.032
0.313	0.003	0.040	16	0.051	0.040
0.375	0.003	0.049	14	0.064	0.051

Tu-Pak® Suggested Upper Temperature Limits for Sheathed Thermocouples (per ASTM E608)					
Nom. Dia. (in) Nom. Wall (in)	0.062 0.010	0.125 0.018	0.188 0.025	0.250 0.032	
Type K/N (°F/°C)	1690/920	1960/1070	2100/1150	2100/1150	
Type J (°F/°C)	825/440	970/520	1150/620	1330/720	
Type E (°F/°C)	950/510	1200/650	1350/730	1510/820	
Type T (°F/°C)	500/260	600/315	700/370	700/370	

TuPak® Sheath Material Limitations Recommended Limit				
Materials		Maximum in Air, °F/°C	Recommended Operating Atmosphere	Continuous Maximum Temp., °F/°C
Stainless Steel	:			
304	2560/1404	1920/1049	ORNV	1650/899
309	2560/1404	2000/1093	ORNV	2000/1093
310	2560/1404	2000/1093	ORNV	2100/1149
316	2500/1371	1650/899	ORNV	1700/927
321	2550/1399	1650/899	ORNV	1600/871
347	2600/1427	1680/916	ORNV	1600/871
430	2700/1482	1550/843	ORNV	1200/649
446	2700/1482	2000/1093	ORNV	2000/1093
Inconel	2550/1399	2000/1093	ONV†	2100/1149
Inconel X	2620/1438	1500/816	ONV†	2200/1204
Platinum	3217/1770	3000/1649	ONT	3000/1649
Pt-Rh 10%	3362/1850	3100/1704	ON	3100/1704

Symbols describing atmospheres are O = oxidizing; R = reducing; N = neutral; V = vacuum; $\uparrow = Very sensitive to sulfur corrosion.$

Measuring Junctions



Grounded Junction - The sheath and the thermocouple wires are welded together, forming a completely closed measuring junction. Recommended in the presence of liquids, moisture, gas, or high pressure. The thermocouple is protected from the environment. Response time approaches that of an exposed junction.



Ungrounded Junction - The thermocouple junction is insulated from the welded measuring junction closure. Recommended for applications where stray E.M.F.s could affect the instrument reading and for frequent/rapid temperature cycling. Response time is slower than a grounded junction.

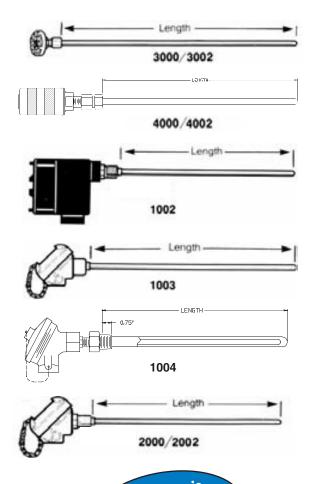


Exposed Junction - The thermocouple junction is not protected by a welded closure. Insulation is sealed against liquid or gas penetration. Provides fastest response time. Not recommended for applications that are corrosive.



Tu-Pak® Industrial Head-Type Thermocouple Assemblies

	Terminations and Length Specifications (Custom Head Type Terminations also available on request)		
Part No.	Style		
1002	Hazardous Location Cast Aluminum Head		
1003	Screw-Cover Thermoplastic Head		
1004	Screw-Cover Cast Iron Head		
2000	Screw-Cover Cast Aluminum Head		
2002	Screw-Cover Aluminum Head with 1/2" NPT SS spring loaded oil and vapor seal		
3000	300°F (149°C) max. Open Head		
3002	1000°F (538°C) max. Open Head – Simplex only		
4000	Screw Cover Mini-Head		
4002	Bayonet Cover Mini Head		

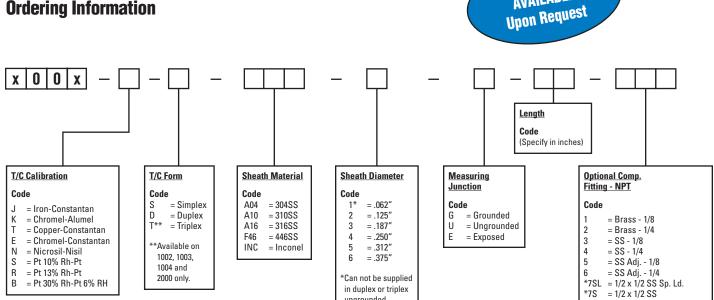


Ordering Information

Calibration is AVAILABLE **Upon Request**

= None

*Available on 1002, 1003, 1004, and

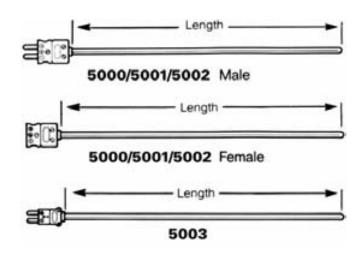


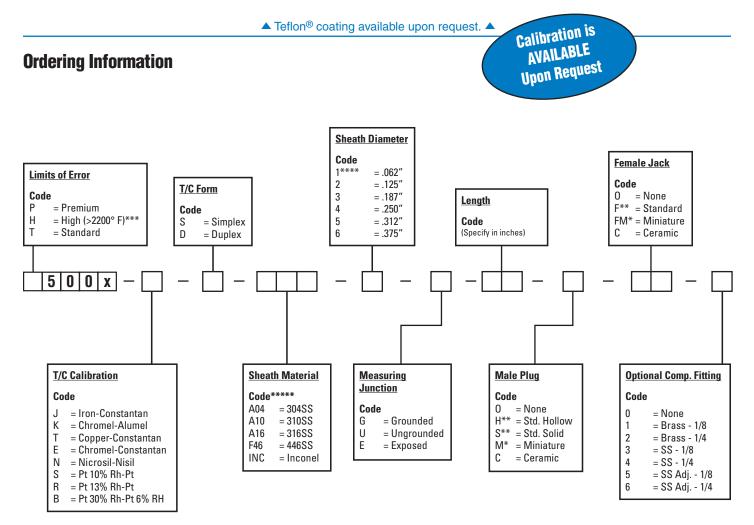
ungrounded.

Tu-Pak® Quick Disconnect Thermocouple Assemblies

	Standard Terminations & Length Specifications (Custom terminations also available on request)		
Part No.	Style		
5000	350°F (177°C) Max Standard Connector		
5001	500°F (260°C) Max Standard Connector		
5002	1000°F (538°C) Max Standard Connector		
5003	350°F (177°C) Max Miniature Connector*		

Temperatures are exposure ratings for connectors only.





- *Available in sizes 1/16" to 3/16" only.
- **Not available with 5003.
- ***Available in selected wires/materials only.
- ****Can not be supplied in duplex or triplex ungrounded.
- ***** Other materials available upon request.

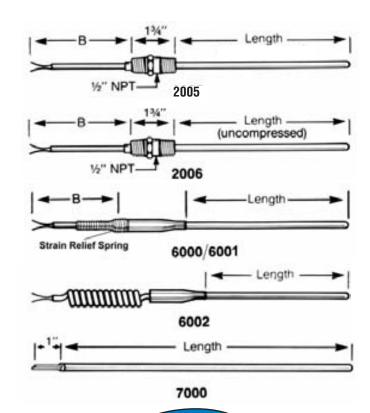


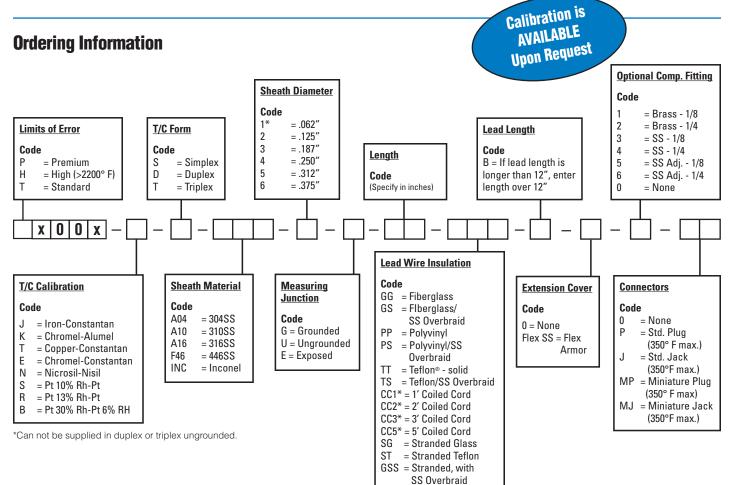
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Tu-Pak® Lead Wire-Type Thermocouple Assemblies

Standard 1	Terminations & Length Specifications
(Custom terr	ninations also available on request)
Part No.	Style/Description
2005	1/2" NPT x 1/2" NPT SS Fitting
2006	1/2″ NPT x 1/2″ NPT Spring Loaded Stainless Steel Fitting
6000	Transition Ftg. with Strain Relief Spring
6001	Transition Ftg. w/o Strain Relief Spring
6002*	Transition to Polyurethane Coiled Cord. Simplex only. Omit Tables VIII and IX. Not available in S, R, or B calibration.
7000	Stripped 1" Leads

Noble metal elements are not recommended for use in base metal sheaths.







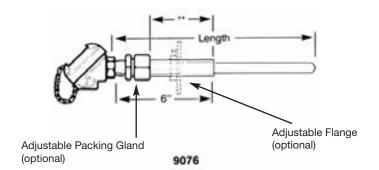
000 = 1" Leads (7000 only)

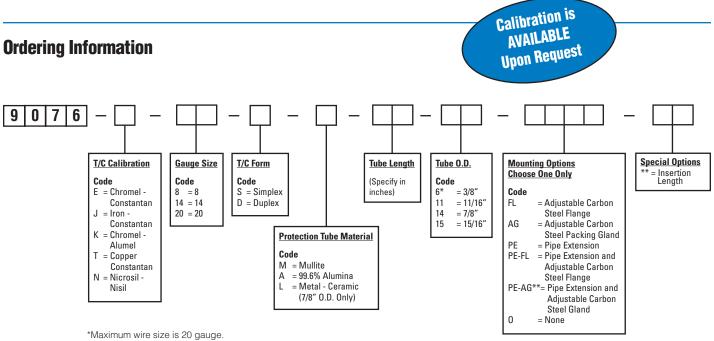
^{*}Available on 6002 only. Expands to approximately 5' per coiled foot.

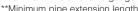
Ceramic-Type Protection Tube Assemblies

Ceramic protection tube assemblies are offered in a wide variety of aluminum connection heads and mounting options. Specifications and part numbers are detailed in the tables below to permit excellent flexibility in selecting the exact design required. Assemblies are shipped pre-tested and ready to install.

Straight – Ceramic Protection Tube Assemblies Part No. Style 9076 Screw Cover Cast Aluminum Head





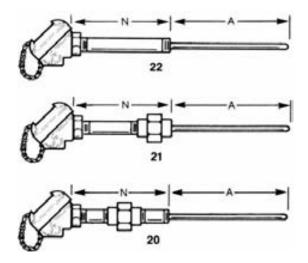


^{**}Minimum pipe extension length is 4 inches.



Industrial Process/Pressure Vessel Thermocouples

Part No.	Style
22	Screw cover and aluminum head with nipple and element
21	Screw cover and aluminum head with nipple-union and element
20	Screw cover and aluminum head with nipple-union-nipple and element



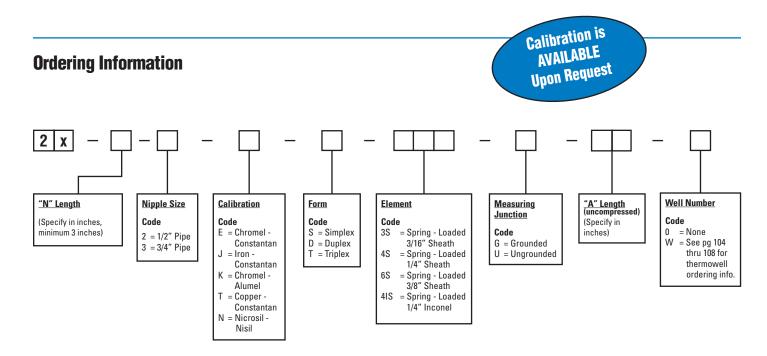
Athena Control's Industrial Process/Pressure Vessel thermocouples are suitable for many applications. This style is most frequently applied in Power Generating Stations, Chemical Process Plants, Petrochemical Process Plants, and Petroleum Refining Plants.

The ordering specifications and style offerings provide a most flexible method to describe the exact design required.

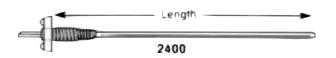
The thermocouples consist of four basic components:

- 1. Connection Head Screw cover cast aluminum head with terminal block.
- Thermocouple Element A spring-loaded MgO insulated metal sheathed element. Standard sheath material is 304SS - maximum compression is 1/2 inch.
- 3. Mounting Fittings Carbon steel nipples
 - Female 150 lb steel unions
 - Nominal thread engagement is 1/2 inch
- 4. Drilled Thermowell Standard and heavy duty type

Other materials and head assemblies are available upon request.



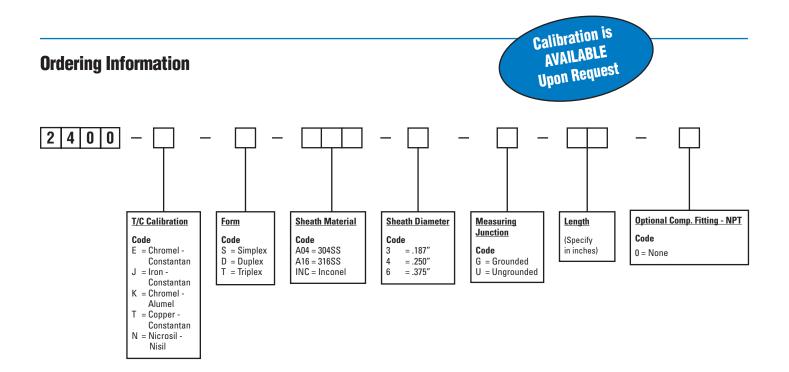
Industrial Process/Pressure Vessel Thermocouples



Replacement Element for 20/21/22 Series Assemblies

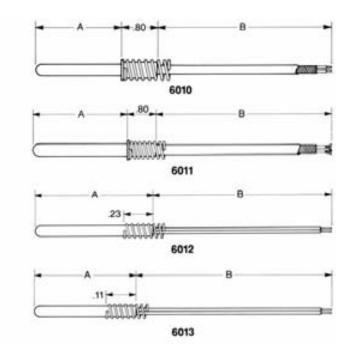
Tu-Pak® Spring-Loaded Type (Element* Options 3S, 4S, 4IS, 6S)

*Refer to page 88 for element specifications.



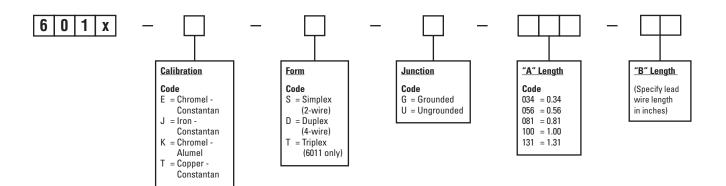


Bearing Metal Thermocouples



The sensors offered below are time-proven devices for measuring bearing temperatures on large rotating equipment found in generating stations. Their construction and materials meet rigid specifications and quality requirements of original equipment manufacturers.

Part No.	Style
6010	3/16" diameter sensor, spring loaded with twisted and shielded lead wire for simplex or duplex bearing metal thermocouple requirements
6011	1/4" diameter sensor, spring loaded with twisted and shielded lead wire for triplex bearing metal thermocouple requirements
6012	3/16" diameter sensor, spring loaded with rip-cord style lead wire for simplex or duplex thrust bearing thermocouple requirements (deep mount)
6013	3/16" diameter sensor, spring loaded with ripcord style lead wire for simplex or duplex thrust bearing thermocouple requirements (shallow mount)

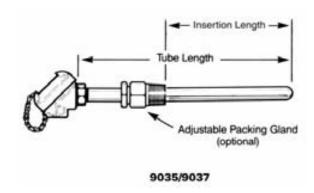


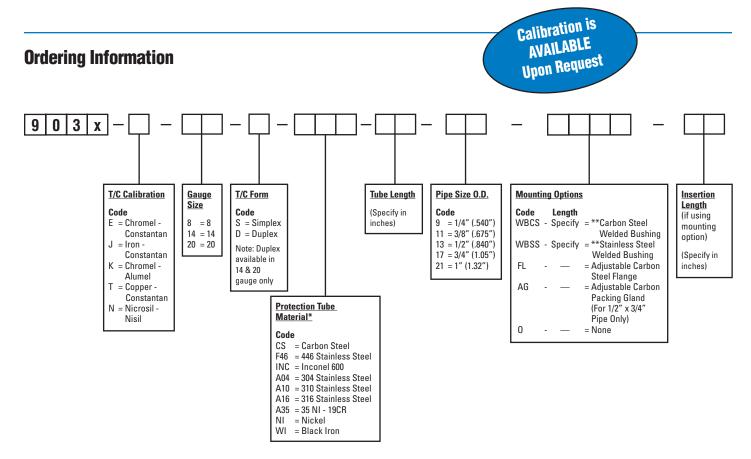
Straight-Metal Protection Tube Assemblies

These metal protection tube assemblies are offered in a wide variety of aluminum connection heads and mounting options. Specifications and part numbers are detailed in the tables below, permitting the greatest flexibility in selecting the exact design required. Assemblies are shipped pre-tested and ready to install.

Straight-Metal Protection Tube Assemblies Part No. Style 9035 Schedule 40 pipe with weatherproof Screw Cover Cast Aluminum Connection Head 9037 Schedule 80 pipe with weatherproof Screw Cover Cast Aluminum Connection Head

Straight Assemblies with Options





^{*}See page 93 for protection tube specifications.



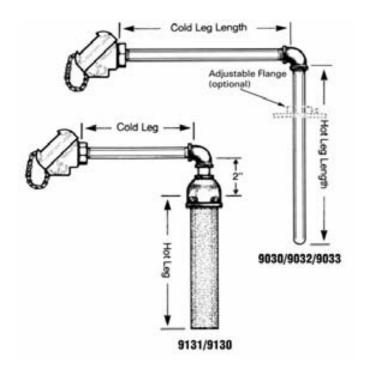
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^{**}Mounting thread standard is next larger pipe size thread.

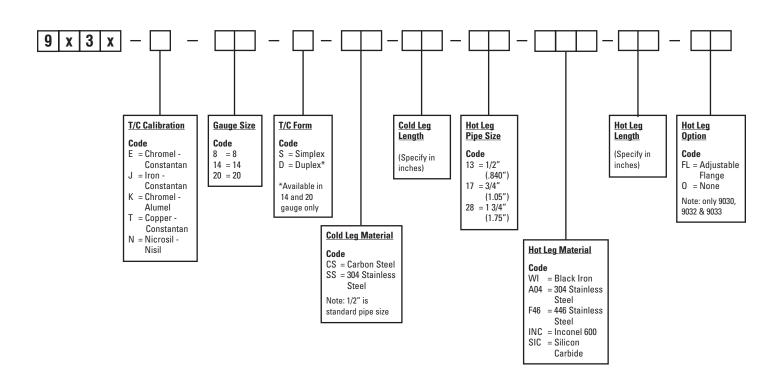
Angled-Metal Protection Tube Assemblies

Angled-Metal Protection Tube Assemblies		
Part No.	Style	
9030	Schedule 40 H.L. pipe with Screw Cover Cast Aluminum Head	
9032	Schedule 80 H.L. pipe with Screw Cover Cast Aluminum Head	
9033	Schedule 80 H.L. pipe with Screw Cover Cast Aluminum Head	
9130	Silicone carbide H.L. with Screw Cover Cast Aluminum Head	
9131	Silicone carbide H.L. with Screw Cover Cast Aluminum Head	



Ordering Information

Calibration is AVAILABLE Upon Request



Metal Protection Tubes

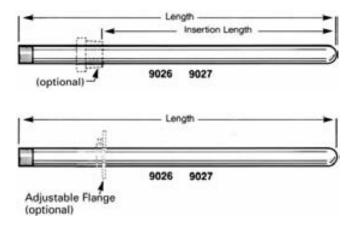
Metal protection tubes offer environmental and mechanical protection for base metal thermocouples. Care should be exercised in selection of material and design in order to achieve optimum performance and economy. Athena personnel can assist you in making the best selection based on experience and the technical data presented in this catalog. The specification selection tables below offer a variety of standard mounting options.

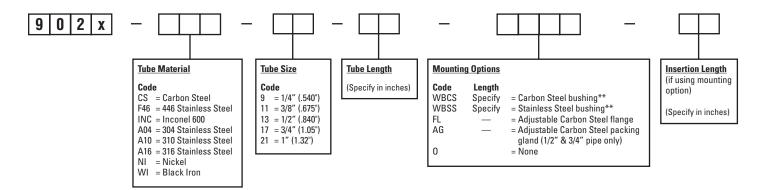
Metal Protection Tubes		
Part No.	Style	
9026	Schedule 40 pipe	
9027	Schedule 80 pipe	

Pipe Specifications			
Nom Size	Outside Diameter, in	Wall Thickno	ess, inches Sch. 80
1/8*	0.405	.068	.095
1/4	0.540	.088	.119
3/8	0.675	.091	.126
1/2	0.840	.109	.147
3/4	1.050	.113	.154
1	1.315	.133	.179
1-1/4*	1.666	.140	.191
1-1/2*	1.900	.145	.200
2*	2.375	.154	.218

^{*}Non-stock item. Available upon request.

Metal Protection Tubes





^{**}Mounting thread standard is next larger pipe size thread.

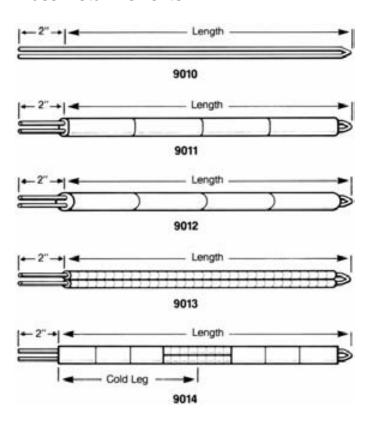


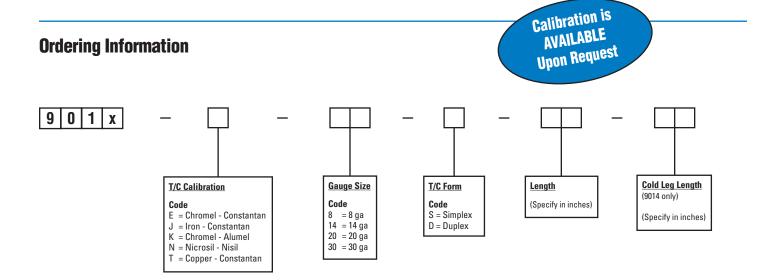
Replacement Elements – Base Metal Type

A thermocouple element is the heart of all thermocouple assemblies. Prudent selection of gauge size, length and type of insulation is essential for optimum performance and economy. Athena's personnel can assist you in making the best selection based on the experience and the technical data present in this catalog.

Base Metal Replacement Elements		
Part No.	Style	
9010	Bare wire without insulators	
9011	3" oval insulators. Not available in duplex	
9012	3" round insulators	
9013	Ball & socket insulators	
9014	Flexible section for angle type	

Base Metal Elements



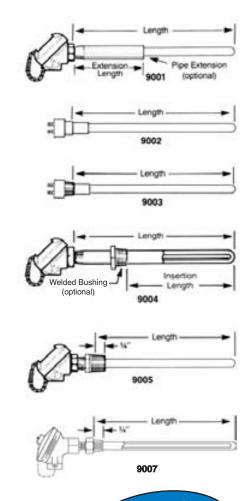


Noble Metal Thermocouple Assemblies

Noble metal thermocouple assemblies are for measurement of temperatures that range above that of base-metal couples, (to 3200°F/1760°C), or for more precise measurements at lower temperatures where the additional cost is justified. These assemblies come in a wide variety of ceramic primary protection tubes, and with ceramic or metal secondary protection tubes.

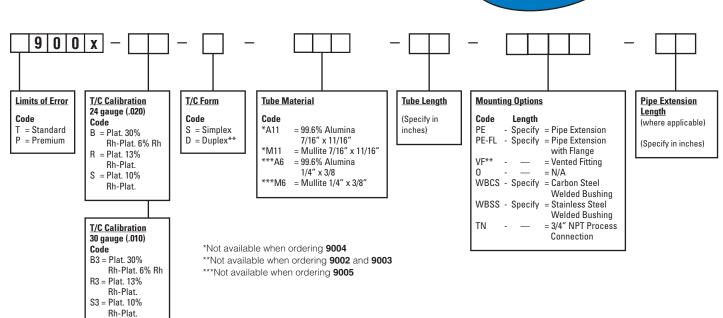
Thermocouple conductors are 24 gauge (0.020) unless otherwise specified. All assemblies are pretested and ready to install.

Noble Metal Assemblies		
Part No.	Style	
9001	Noble Metal Assembly with Screw Cover Cast Aluminum Cover	
9002	Noble Metal Assembly with Open Terminal Head	
9003	Noble Metal Assembly with Open Terminal Head and 1" NPT Mounting Thread	
9004	Noble Metal Assembly with Screw Cover Cast Aluminum Head and Ceramic Primary Tube, Inconel 1/2" I.P.S. Secondary Tube	
9005	Noble Metal Assembly with Screw Cover Cast Aluminum Cover with Primary and Secondary Ceramic Tubes	
9007	Noble Metal Assembly with Cast Iron Head	



Ordering Information

Calibration is AVAILABLE Upon Request



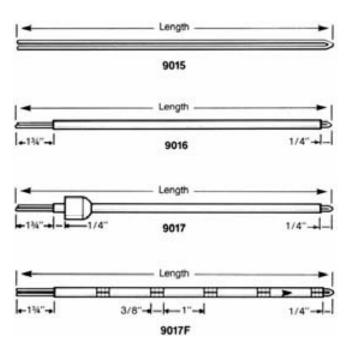


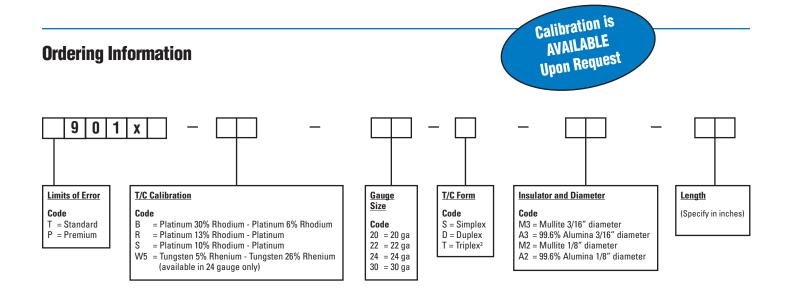
95

Thermocouple Replacement Elements

Noble Metal and Refractory Metal Replacement Elements		
Part No.	Part No. Style	
9015	Bare wire without insulators	
9016	Full length insulators	
9017	Full length insulator & collar	
9017F	Flexible noble metal	

Noble and Refractory Metal Elements



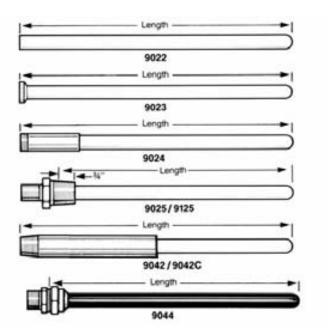


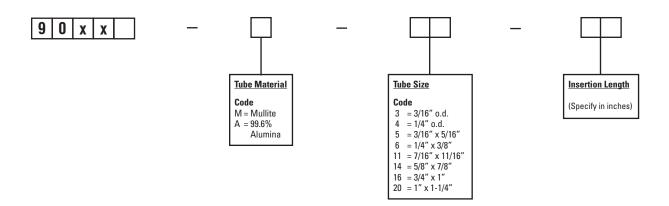
Ceramic and Non-Metallic Protection Tubes

Ceramic protection tubes are hemispherically closed on one end, and are offered in mullite, hi-purity alumina, and high temperature materials. These tubes are superior to metallic tubes at high temperatures and provide a virtually gas-tight enclosure to protect against harsh environments.

Ceramic and Non-Metallic Protection Tubes		
Part No.	Style	
9022	Plain	
9023	With collar	
9024	With 2" brass ferrule (7/8" – 27, thread)	
9025	With fitting – 3/4" NPT thread*	
9125	With fitting – 1-1/4" NPT thread	
9042	With 6" stainless steel pipe extension	
9042C	With 6" carbon steel pipe extension	
9044**	Metal-Ceramic — 7/8" O.D. — 3/4 NPT	
	conduit connection	

^{*}Maximum tube size is 11/16" O.D.





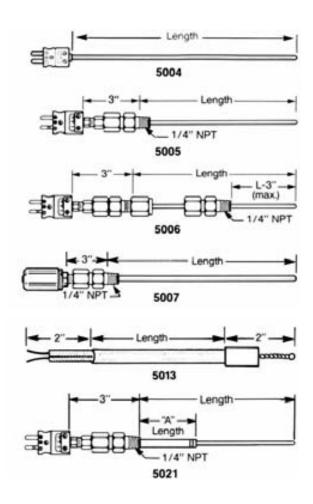


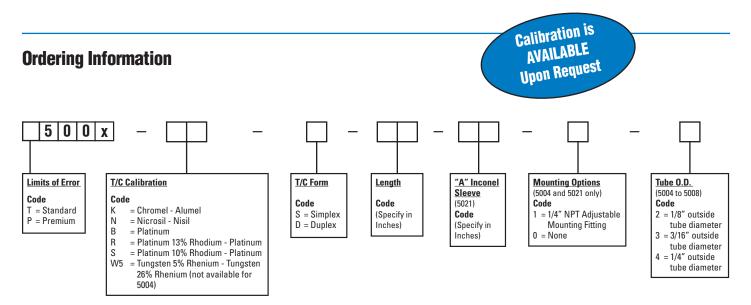
^{**}Omit selection from Tube Material and Tube Size.

Vacuum Furnace Thermocouples

Athena's vacuum furnace thermocouples offer high reliability and time-proven performance. Made of the highest quality materials, some of these thermocouple assemblies feature vacuum tight seals and threaded process connections as standard features. Other quality accessory products and factory replacement parts are also listed to complete the temperature measurement system. Other sheath materials are available - consult factory.

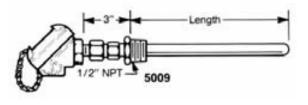
Part No.	Style
5004	Quick connect plug with molybdenum sheath and potted end seal
5005	Quick connect plug with molybdenum sheath and vacuum gland end seal
5006	Same as 5005 with a vacuum type variable immersion fitting
5007	Miniature lightweight head with molybdenum sheath and vacuum gland end seal
5008	Same as 5007 with a vacuum type variable immersion fitting
5013	Work-survey chromel-alumel (Type "K") T/C. High temperature glass insulation, 20 gauge. Maximum measuring temperature 2000°F (1093°C)
5014	Same as 5013 except ceramic fiber insulation. Maximum measuring temperature 2300°F (1260°C)
5021	Quick connect plug with 1/4" OD high purity alumina tube, Inconel sleeve and vacuum gland end seal

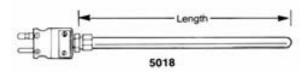


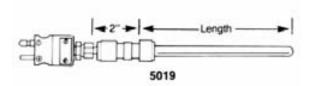


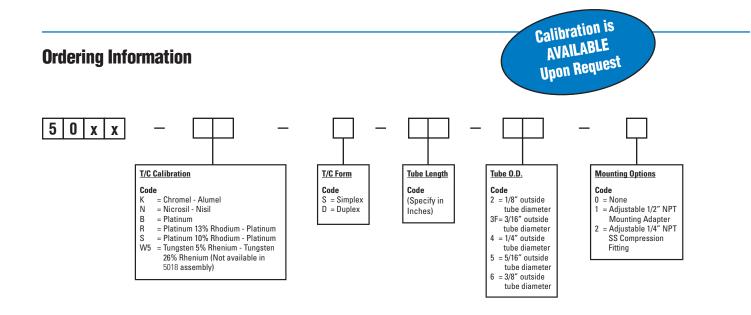
Vacuum Furnace Thermocouples

Part No.	Style
5009	Recrystallized alumina tube assembly with Screw Cover Head and Vacuum Gland Seal End
5018	Recrystallized Alumina Tube Assembly with Quick Connect Plug and Potted Seal End
5019	Recrystallized Alumina Tube Assembly with Quick Connect Plug and Vacuum Gland Seal End







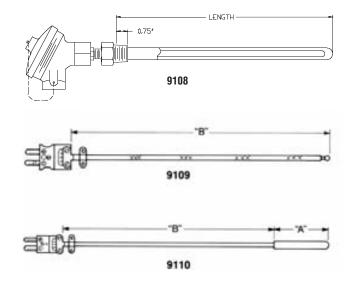


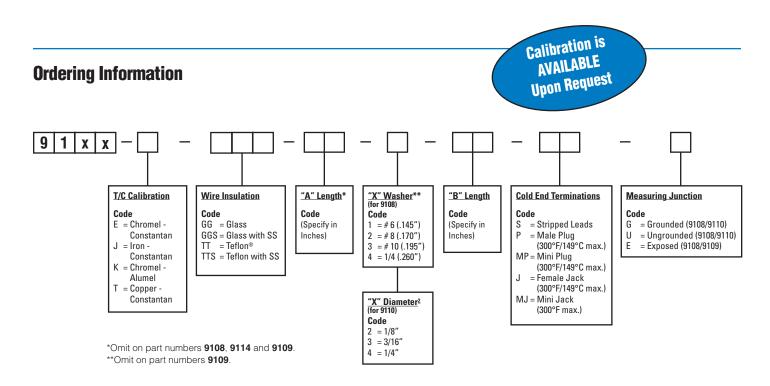


Wire-Type Thermocouples

The Wire Type is a basic thermocouple which can be used for a variety of applications. The Washer Type can be easily mounted on any existing surface with a screw or a bolt. The insulated Wire Type and the Tube End Type are intended for general applications which require a basic, yet durable thermocouple for temperature measurement.

Wire-Type Thermocouples		
Part No.	Style	
9108	Washer-Type Assembly	
9109	Insulated Wire-Type Assembly	
9110	Tube End-Type Assembly, 3/16" OD Tube	
9114	Wire Type Flex Armor	







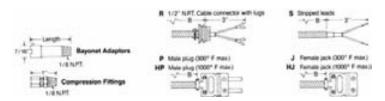
Bayonet-Style Thermocouples

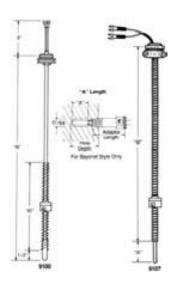
Athena's brand bayonet-style thermocouples are available in a wide selection of types, terminations, and accessories, including variable immersion to assure versatility. All bayonet thermocouples are shipped ready to install.

Part No.	Style
9100	Variable Immersion Bayonet Assembly
9101	Straight Bayonet Assembly
9102	45° Bend Bayonet Assembly
9103	90° Bend Bayonet Assembly
9104	Straight Immersion Bayonet Assembly
9105	45° Bend Immersion Bayonet Assembly
9106	90° Bend Immersion Bayonet Assembly
9107	Variable Immersion Bayonet Assembly with Flex Armor

Note: All tube diameters are 3/16" OD standard. All Probes are grounded.

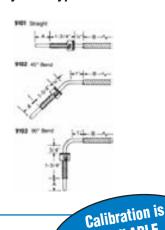
Terminations & Accessories

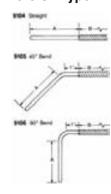




Bayonet Type

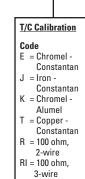
Immersion Type



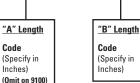


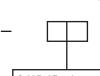
Ordering Information













Cold End Terminators

Code

- = 1/2" NPT cable connector with lugs
- = Male plug (300°F max)
- = Male plug (1000°F max)
- = Stripped leads = Female jack (300°F max.)
- = Female jack (1000°F max.)

AVAILABLE

Upon Request

Bayonet Accessories

Code

- 1 = 7/8" Bayonet adapter
- (nickel-plated brass) 2 = 1-1/2" Bayonet adapter (nickel-plated brass)
- 3 = 2-1/2" Bayonet adapter
- (nickel-plated brass) 4 = Brass (one time adjustable) compression fitting
- 5 = Stainless steel (one time adjustable) compression fitting
- 6 = Stainless steel (readjustable) compression fitting
- 0 = Enter 0 if no accessories are required

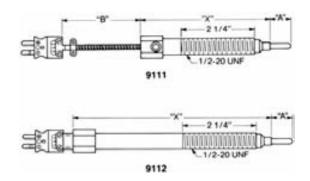


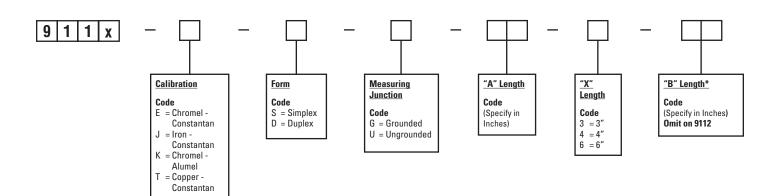
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Melt-Bolt Thermocouples

Athena's brand Melt-Bolt thermocouples are a reliable, quality product manufactured for a variety of uses in the plastics and packaging industries. Made of the finest materials, they meet rigid quality control and inspection standards. They feature easy installation with fast response to provide accurate control. All Melt-Bolt thermocouples are shipped ready to install.

Wire Type Thermocouples		
Part No.	Style	
9111	Melt-Bolt Thermocouple with Flex Armor Extension and Male Plug	
9112	Melt-Bolt Thermocouple with Male Plug	

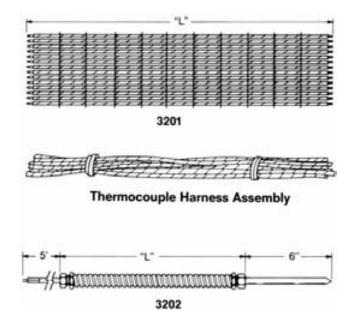


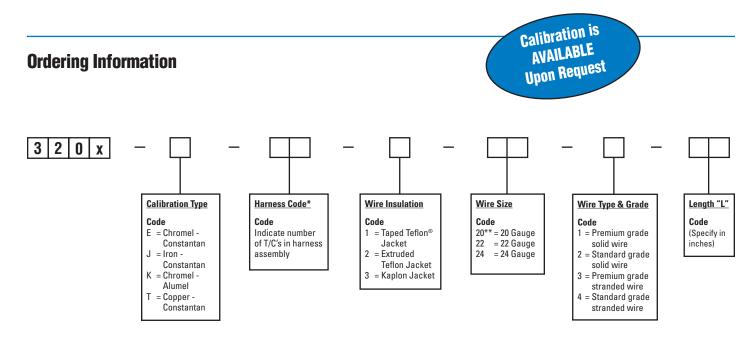


Pharmaceutical Thermocouples

Athena's pharmaceutical thermocouples are designed especially for use in processing vaccines and other medications where very accurate temperature measurement is critical. Typical applications include steam sterilizers, autoclaves, steam and liquid pipe lines, tanks, etc. The units provide accurate temperature signals, fast response and can be supplied with calibration certificates for validation studies.

Part No.	Style
3201	Wire Harness Assembly
	(multiple thermocouple bundle)
3202	1/8" diameter Stainless Steel Sheath Probe
3203	Replacement T/C Element for P/N 3202





^{*}Omit selection when ordering part numbers 3202 and 3203.



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^{**}Not available in part numbers 3202 and 3203.

Selection of Thermowells

Material

Thermowell material chosen for an installation is governed by corrosive conditions. Occasionally, the material consideration is one of strength rather than a corrosive condition. Consult the pressure-temperature ratings given for each well type for proper selection.

Insertion Length "U"

The distance from the end of the well to the underside of the thread, or other connection means, (designated as "U") is the insertion length. For best accuracy, this length should be long enough to permit the entire temperature sensitive part of the thermocouple to project into the temperature medium being measured.

Bore Size

The bore size of wells shown in this catalog cover the most commonly used temperature sensing elements as follows:

.260 Diameter Bore—Bi-metal Thermometers (1/4" stem). Thermocouples (#20 gauge) or sheathed type up to .250 inch diameter. Liquid-in-glass Test Thermometers (unarmored). Other elements having .252 inch maximum diameter.

.385 Diameter Bore—Bi-metal Thermometers (3/8" stem.) Thermocouples (#14 gauge) or sheathed type up to .375 inch diameter. Liquid-in-glass Test Thermometers (armored). Other elements having .377 inch maximum diameter.

Tapered or Straight Shank

Tapered shank wells provide greater stiffness for the same sensitivity. The higher strength-to-weight ratio gives these wells higher natural frequency than equivalent length straight shank wells, thus permitting operation at higher fluid velocity.

Velocity Ratings of Wells

Well failures in most cases are not due to the effect of pressure and temperature. The calculations necessary to provide adequate strength under given conditions are familiar enough to permit proper choice of wall thickness and material.

Less familiar, and more dangerous, are the vibrational effects to which wells are subjected. Fluid flowing by the well forms a turbulent wake (called the Von Karman Trail) which has a definite frequency based on the diameter of the well and the velocity of the fluid. It is important that the well have sufficient stiffness so that the wake frequency will never equal the natural frequency of the well were to coincide with the wake frequency, the well would vibrate to destruction and break off in the piping.

A recommended maximum velocity rating for typical well lengths and materials is listed in the accompanying tables. To reduce the complexity of presenting this information, the ratings given are based on operating temperatures of 1000°F for wells made of Carbon Steel (C-1018), A.I.S.I. 304 & A.I.S.I. 316. Values for brass wells are based on 350°F (177°C) operation. Limits for Monel wells are based on 900°F (482°C) service. Slightly higher velocity is possible at lower temperatures.

Where single values appear in the velocity tables, they may be considered safe for water, steam, air or gas. In the shorter insertion lengths, consideration is given to the velocity pressure effect of water flowing at higher velocities. The values in parenthesis, therefore, represent safe values for water flow while the unbracketed value may be used for steam, air, gas and similar density fluids. The values given are conservative and intended as a guide. Wells are also safe if the resonant frequency is well below the wake frequency or if the fluid velocity is constantly fluctuating through the critical velocity point. Nevertheless, if the installation is not hampered by the use of a sufficiently stiff well, the values given should not be exceeded.

Velocity, Temperature, and Pressure Data

			nsertior	Lenath	"II"_				
Table No	. Material	2 ½	4½	7½	10½	13½	16½	19½	2
V1	Brass	207 (59.3)	75.5 (32.2)	27.3 (19.7)	13.9	8.4	5.6	4.1	3
	Carbon Steel	290 (106)	105 (59)	38.2 (36.3)	19.4	11.8	7.8	5.7	4
	A.I.S.I. 304 & 316	300 (148)	109 (82.2)	39.5	20.1	12.2	8.1	5.9	4
	Monel®	261 (118)	95 (65.5)	34.4	17.5	10.5	7.1	5.2	3
V2	Brass	207 (59.3)	89.1 (39.8)	32.2 (23.9)	16.4	9.9	6.6	4.8	3
	Carbon Steel	290 (106)	123 (71.2)	44.9 (42.7)	22.8	13.8	9.3	6.7	4
	A.I.S.I. 304 & 316	300 (148)	128 (99.3)	46.4	23.6	14.3	9.6	6.9	5
	Monel	261 (118) 207	112 (79.8) 102	40.6 37.0	20.7	12.4	7.6	5.5	4
V 3	Brass	(59.3)	(47.6)	(28)	26.2	15.9	10.6	7.6	5
-	Carbon Steel	(106)	(84.3)	(50.6)	27.2	16.5	11.0	7.9	5
	A.I.S.I. 304 & 316 Monel	(148) 261	(117)	46.7	23.7	14.4	9.5	6.9	5
1/4	Brass	(118) 305	(93.3) 93.8	33.9	17.1	10.5	7.0	5.0	3
V4	Carbon Steel	(97.5)	(54.1)	65.3	33.0	20.1	13.4	9.6	7
-	A.I.S.I. 304 & 316	(175) 440 (040)	(97.2) 197	(58.3) 71.2	36.0	22.0	14.7	0.5	7
-	Monel	(243) 354 (195)	(135) 155 (108)	56.1	28.4	17.3	11.6	7.5	5
V 5	Brass	354 (161)	108 (89.5)	39.4	19.8	12.2	8.1	5.8	4
-	Carbon Steel	448 (289)	209 (161)	75.7	38.4	23.3	15.5	11.1	8
	A.I.S.I. 304 & 316	490 (403)	228 (225)	82.5	41.8	25.5	17.1	12.2	9
	Monel	410 (322)	179 (178)	65.1	33.0	20.1	13.5	8.7	6
V 6	Brass	321 (150)	129 (83.5)	46.8	23.6	14.5	9.6	6.9	5
-	Carbon Steel	410 (270)	249 (150)	90.3	45.6	27.8	18.5	13.2	9
	A.I.S.I. 304 & 316	483 (350)	272 (208)	97.3	49.7	30.4	20.3		1(
	Monel	396 (300)	214 (167)	77.5 54.1	39.2	23.8	16.0	10.3	7
V7	Brass	290 (145) 326	150 (80) 192	(48) 69.5	27.6 35.4	16.7	11.1	8.0	7
	Carbon Steel	(260)	(144)	71.9	36.6	21.2	14.8	10.3	8
	A.I.S.I. 304 & 316	(360)	. 50	, 1.0	00.0	-1.2		. 5.7	J

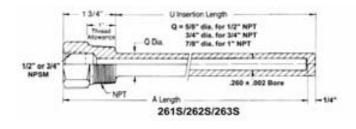
Maximum Fluid Velocity in Feet per Second									
	Insertion Length "U"								
Table N	o. Material	2	4	7	10	13	16	22	
V8	Carbon Steel	404 (129)	184 (71.2)	67.0 (42.7)	34.0	20.6	13.7	7.4	
	A.I.S.I. 304 & 316	430 (179)	192 (99.3)	69.7 (59.6)	35.4	21.5	14.3	7.7	
	Monel	350 (143)	168 (79.8)	61 (47.7)	31.0	18.8	12.5	6.7	
V9	Carbon Steel	410 (152)	248 (84.3)	91.3 (50.6)	45.7	27.6	18.5	10.0	
	A.I.S.I. 304 & 316	444 (211)	258 (117)	95.2 (70.3)	47.6	28.8	19.3	10.4	
	Monel	338 (168)	226 (93.3)	83.3 (56.0)	41.6	25.2	16.9	9.1	

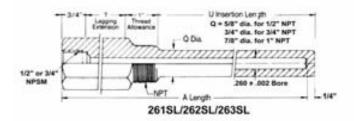
Pressure – Temperature Rating Lbs. per Sq. Inch								
		Temperature °F/°C						
Table No.	Material	70°/22°	200°/94	°400°/205°	600°/316	800°/427°	1000°/538°	1200°/649°
	Brass	5000	4200	1000	_	_	_	_
	Carbon Steel	5200	5000	4800	4600	3500	1500	_
T1	A.I.S.I. 304	7000	6200	5600	5400	5200	4500	1650
	A.I.S.I. 316	7000	7000	6400	6200	6100	5100	2500
	Monel	6500	6000	5400	5300	5200	1500	_
T2	Brass	5300	4750	1100	_	_	_	_
	Carbon Steel	5950	5750	5450	5250	4000	1750	_
	A.I.S.I. 304	7800	7050	6400	6150	6000	5190	1875
	A.I.S.I. 316	7800	7800	7250	7100	6950	58002720	
	Monel	7450	6850	6150	6100	5940	1750	_

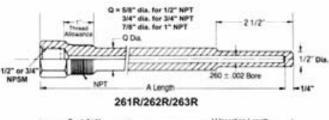


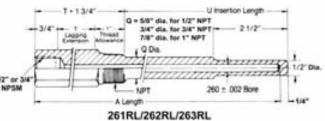
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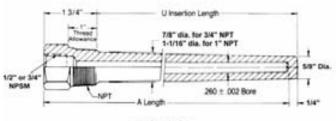
260 Series Thermowells

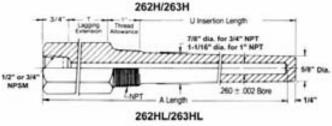




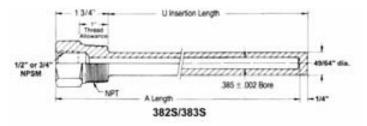


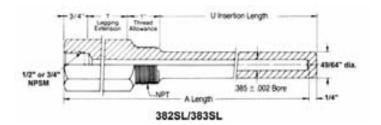


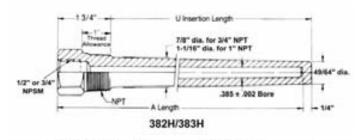


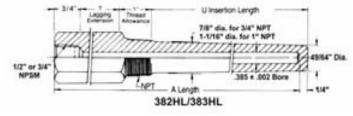


380 Series Thermowells

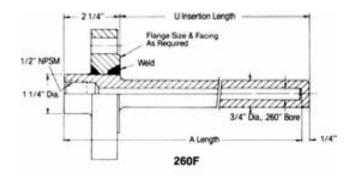


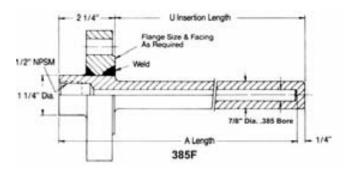




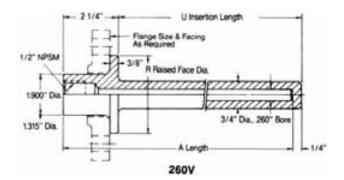


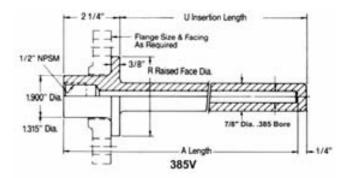
Flanged Thermowells





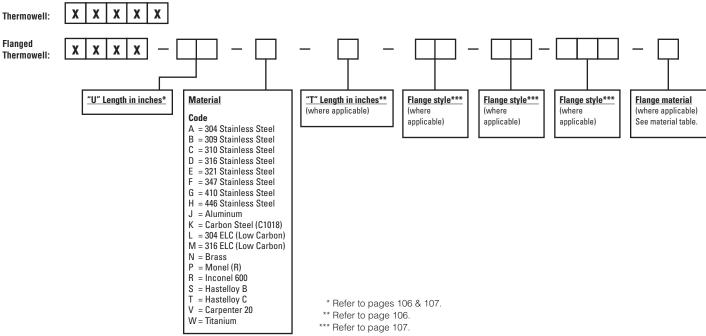
Van Stone Thermowells





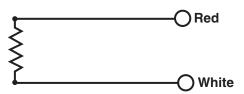
		Applicable Tables		
Part No.	Style	Temperature	Velocity	
261S	1/2" NPT Process Thread	T1	V1	
262S	3/4" NPT Process Thread	T1	V2	
263S	1"NPT Process Thread	T1	V3	
261SL	1/2" NPT Process Thread with Lag	T1	V1	
262SL	3/4" NPT Process Thread with Lag	T1	V2	
263SL	1"NPT Process Thread with Lag	T1	V3	
261R	1/2" NPT Process Thread	T1	V1	
262R	3/4" NPT Process Thread	T1	V2	
263R	1"NPT Process Thread	T1	V3	
261RL	1/2" NPT Process Thread with Lag	T1	V1	
262RL	3/4" NPT Process Thread with Lag	T1	V2	
263RL	1"NPT Process Thread with Lag	T1	V3	
262H	3/4" NPT Process Thread	T2	V4	
263H	1"NPT Process Thread	T2	V5	

		Applicable Tables		
Part No.	Style	Temperature		
262HL	3/4" NPT Process Thread			
	with Lag	T2	V4	
263HL	1″NPT Process Thread			
	with Lag	T2	V5	
382S	3/4" NPT Process Thread	T1	V 7	
383S	1″NPT Process Thread	T1	V 7	
382SL	3/4" NPT Process Thread			
	with Lag	T1	V 7	
383SL	1"NPT Process Thread			
	with Lag	T1	V7	
382H	3/4" NPT Process Thread	T1	V6	
383H	1″NPT Process Thread	T1	V6	
382HL	3/4" NPT Process Thread			
	with Lag	T1	V6	
383HL	1"NPT Process Thread			
	with Lag	T1	V6	
260F	.260 Bore with Flange	Т3	V8	
385F	.385 Bore with Flange	Т3	V9	
260V	.260 Bore, Van Stone Type	Т3	V8	
385V	.385 Bore, Van Stone Type	T3	V9	



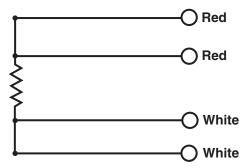
Resistance Temperature Detectors (RTDs)

Lead Wire Configurations



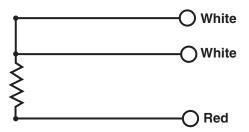
2-Wire RTD

Provides one connection to each end of the sensor. This configuration is suitable when the resistance of the lead wire can be considered an additive constant in the circuit and when changes in lead resistance, due to ambient temperature changes may be ignored.



4-Wire RTD Connected

Provides connections to each end of the sensor. Used for measurements requiring highest precision.



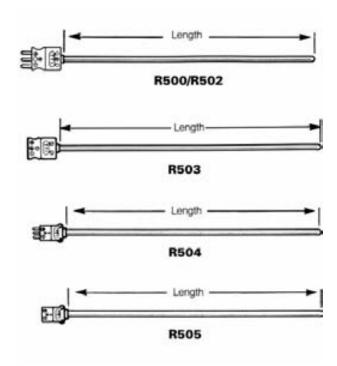
3-Wire RTD Compensated

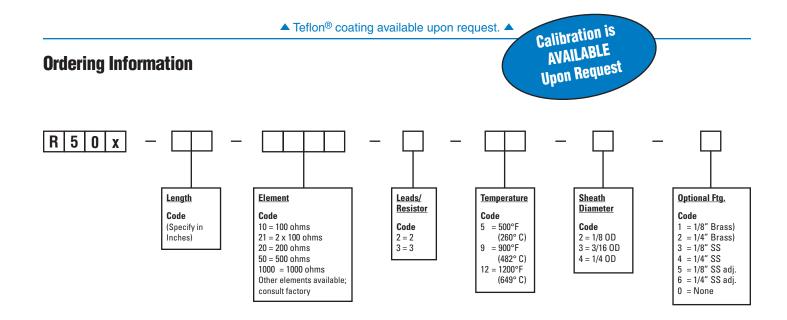
This is the most commonly used configuration. It provides one connection to one end of the sensor and two to the other end. When connected to an instrument designed to accept a three wire input, compensation is achieved for lead resistance and temperature change in lead resistance.



RTDs (Connector-Type)

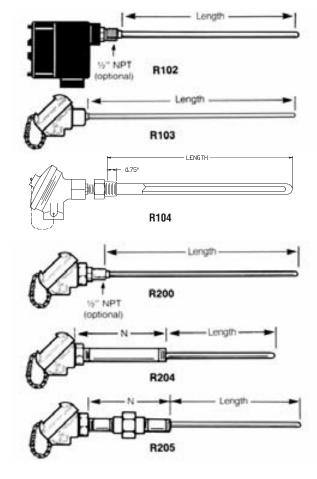
RTD Ass	RTD Assemblies							
Part No.	Style							
R500	350°F (177°C) max. Standard Male Connector							
R501	350°F (177°C) max. Standard Female Connector							
R502	1000°F (538°C) max. Standard Male Connector							
R503	1000°F (538°C) max. Standard Female Connector							
R504	350°F (177°C) max. Miniature Male Connector, available in 1/8 and 3/16 sheath diameter only							
R505	350°F (177° C) max. Miniature Female Connector, available in 1/8 and 3/16 sheath diameter only							

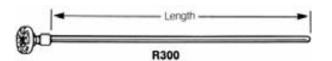




RTDs (Head Type)

RTD As	semblies
Part No.	Style
R102	Hazardous Location Cast Aluminum Head
R103	Screw Cover Thermoplastic Head
R104	Screw Cover Cast Iron Head
R200	Screw Cover Cast Aluminum Head
R202	Screw Cover Cast Aluminum Head with 1/2" NPT SS spring loaded oil and vapor seal
R204	Screw Cover Cast Aluminum Head with 1/2" NPT nipple spring loaded
R205	Screw Cover Cast Aluminum Head with 1/2" NPT nipples and union, spring loaded
R300	300°F (149°C) max. Open Head (4 wires max.)
R400	Bayonet Cover Mini-Head (4 wires max.)



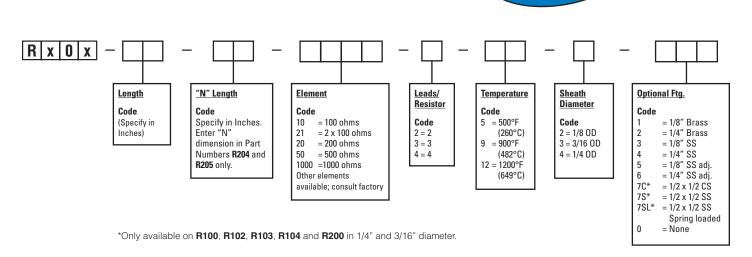




▲ Teflon® coating available upon request. ▲

Ordering Information

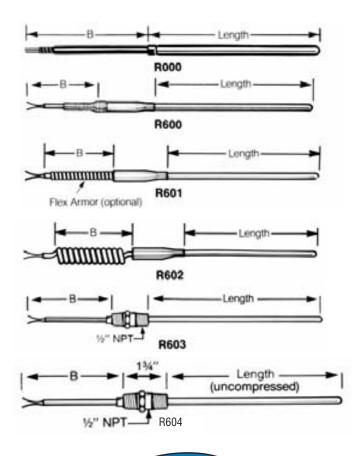
Calibration is AVAILABLE Upon Request





RTDs (Lead Wire Type)

RTD Assemblies								
Part No.	Style							
R000	Tube Assembly with lead wires							
R600	Transition to lead wires with strain relief spring							
R601	Transition to lead wires w/o strain relief spring							
R602	Transition to polyurethane coiled cord (3 wire only) Omit "B" length and extension cover blocks							
R603	1/2" NPT x 1/2" NPT stainless steel ftg. with lead wires							
R604	1/2" NPT x 1/2" NPT spring loaded SS ftg. with lead wires (1/4 & 3/16 dia. only)							



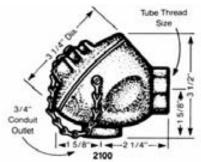
Calibration is **AVAILABLE**



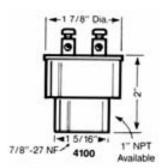
Upon Request R 6 0 x Cold End Termi-<u>Length</u> **Element** Lead Wire <u>Temperature</u> **Extension Cover** nations Code Code Code Code Code = 100 ohms 5 = 500°F (Specify in GG = Fiberglass 10 0 = None Code 0 = NoneInches) 21 = 2 x 100 ohms (260°C) TT = Teflon® = SS Flex CC1* = 1' Coiled cord = Std. Plug 20 = 200 ohms = 900°F Armor (482°C) CC3* = 3' Coiled cord (Available on (350°F max.) 50 = 500 ohms 1000 =1000 ohms 12 = 1200°F CC8* = 8' Coiled cord R601, R603, R604, = Std. Jack and R700 only.) (350°F max.) Other elements available; (649°C) consult factory MP = Mini Plug (350°F max.) Sheath MJ = Mini Jack <u>"B" Length</u> **Diameter** (350°F max.) Leads/ Code Resistor If lead length is 2 = 1/8 ODOptional Ftg. Code longer than 12", 3 = 3/16 ODenter length over 12" 2 = 2 4 = 1/4 ODCode 3 = 3 = None 4 = 4= 1/8" Brass = 1/4" Brass = 1/8" SS 3 4 5 6 *Available on R602 only (Expands to approximately 5' per coiled foot). = 1/4" SS = 1/8" SS adj. = 1/4" SS adj.

▲ Teflon® coating available upon request. ▲

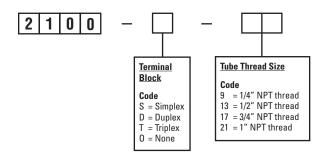
Connection Heads

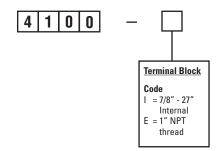


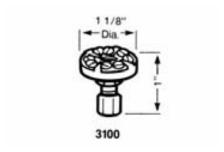
2100 heavy-duty cast aluminum screw cover 1.4 lbs.



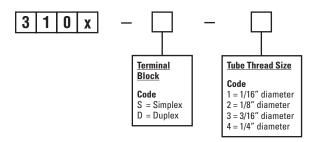
4100 Lightweight, "O" ring sealed, single or dual circuit. **0.3 lbs**.







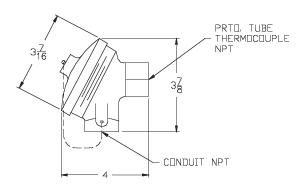
- 3100 Molded single or dual circuit open terminal (400°F max.). **0.2 lbs**
- 3101 Ceramic single circuit open terminal (1000°F max.). Duplex is not available **0.2 lbs**.



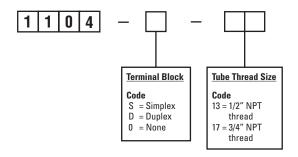


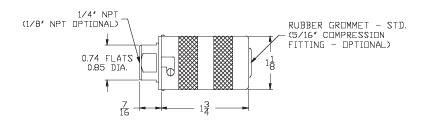
113

Connection Heads

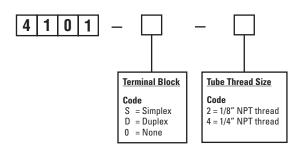


1104 Cast iron head. **2.6 lbs**.





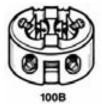
4101 Screw cover mini-head. 0.3 lbs.





Terminal Blocks

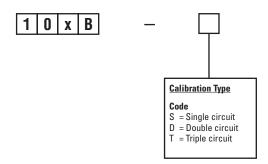
Part No.	Style	Description
100B	Single-circuit	Floating brass terminals in pressed ceramic materials, suitable for use in 2100 and 1100 heads. Accepts up to 8 gauge wire. No specification selection is required
101B	Multi-circuit	Rigid, plated brass terminals, pressed ceramic material, accepts up to 14 gauge wire, suitable for spring loading and use in 2100 heads for T/C or RTD
104B	Multi-circuit	Rigid brass terminals in pressed ceramic material for use in 2100 and 1100 heads. Accepts up to 14 gauge wire







Ordering Information





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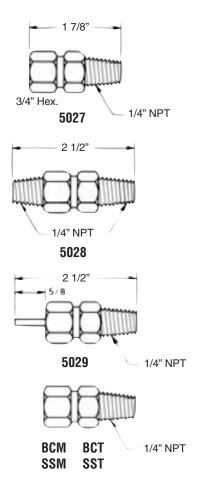
Vacuum Sealing Fittings

Features

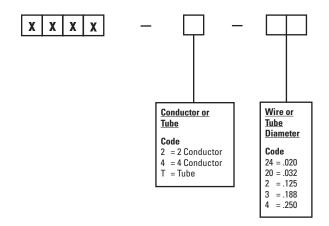
- ▲ Stainless Steel Material
- ▲ Reusable Sealing Insert for Tubing or Bare Wire
- ▲ Temperature Range from -40°F to +200°F
- ▲ 3 Optional End Terminators

Part No.	Style
5027	1/4"NPT thread one end. For open lead wire extension
5028	1/4"NPT thread two end. For connection head mounting
5029	1/4" NPT one end. 1/4" diameter tube extension other end. For polarized connector compression type mounting
BCM	Brass Compression*
ВСТ	Brass Compression Readjustable*
SSM	Stainless Steel Compression*
SST	Stainless Steel Compression Readjustable*

^{*}To order specify Part No., thread size and tube size.



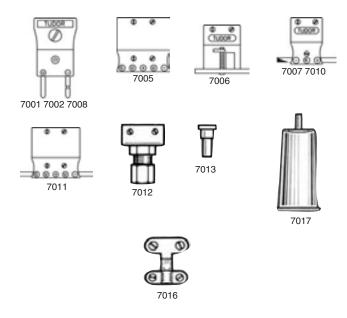
Ordering Information





Convenience Connectors, Standard Size

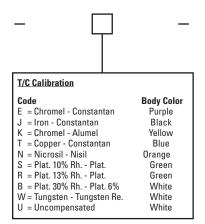
Part No.	Style
7001	Male convenience connector with protected terminal connections, solid pins.
7002	Male convenience connector with protected terminal connections, hollow pins.
7003	Female convenience connector with protected terminal connections.
7004	Male convenience connector with protected terminals and ground wire pin.
7005	Female convenience connector with protected terminals and ground wire socket.
7006	Female circular convenience connector with protected terminals for panel mounting in 1 1/8" diameter knockout.
7007	Female convenience connector with protected terminals for panel mounting in 1"x 9/16" knockout.
7008	Male convenience connector with external access terminals and solid pins.
7009	Female convenience connector with external access terminals.
7010	Female convenience connector with external access terminals for panel mounting in 1"x 9/16" knockout.
7011	Female convenience connector with protected terminals and ground socket panel mounting in 1-1/2" x 9/16" knockout.

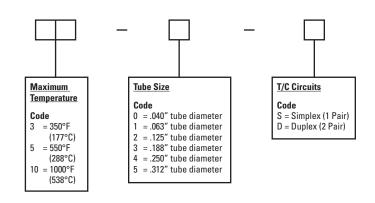


Standard Size Accessories							
Part No.	Style						
7012	Compression type tube adapter.						
7013	Crimping type tube adapter.						
7016	Insulated-wire clamp.						
7017	Weatherproof rubber boot (pair).						

Ordering Information





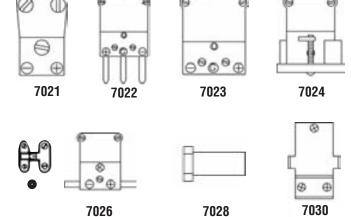




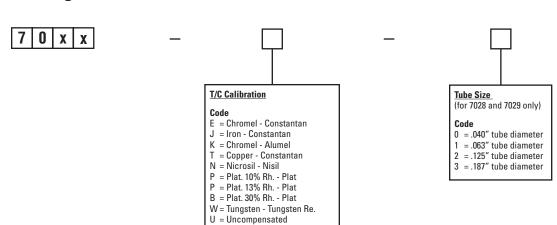
Convenience Connectors, Miniature Size

Miniatur	e Size Connectors
Part No.	Style
7020	Male convenience connector.
7021	Female convenience connector.
7022	Male convenience connector with ground pin.
7023	Female convenience connector with ground socket.
7024	Female circular convenience connector panel mounting in 7/8" diameter knockout.
7025	Female circular convenience connector panel mounting in 1-1/16" diameter knockout, with ground socket.
7026	Female convenience connector panel mounting in 5/8" x 3/8" knockout.
7027	Female convenience connector panel mounting in 1" x 3/8" knockout with ground socket.
Miniatu	re Size Accessories
Part No.	Style
7028	Adapter type insert.
7030	Insulated-wire clamp.
7031	Neoprene grommet.





Ordering Information

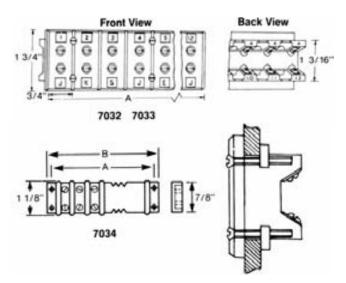




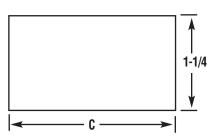
Convenience Connectors, Strip Panels and Terminal Blocks

Strip panels can be wired and installed completely from the front. A self-contained fastening device is permanently attached which simplifies mounting and holds tight. Alloys of inserts match ANSI thermocouple grade calibrations to maintain sensing accuracy. Alloy and circuit numbers are marked on face of strip panel with corresponding circuit numbers and polarity identification on the back. Collet type spring loaded inserts have low mass, eliminate temperature gradients and spurious E.M.F. Negative inserts are larger than positives to avoid polarity mix-ups. Large head brass terminal screws facilitate tight connections without deforming or stressing the finest wire. Molded of high impact and shock resistant compound.

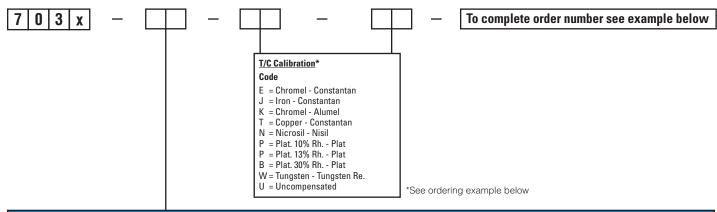
Strip Pa	Strip Panel & Terminal Block Connectors									
Part No.	Style									
7032	Polarized strip panel, maximum temperature 300°F (149°C), two to twelve circuits.									
7033	Polarized strip panel, maximum temperature 1000°F (538°C), two to twelve circuits.									
7034	Barrier type terminal strip, two to ten circuits.									



Strip Panel Mounting Cutout Dimensions



Ordering Information



Dimensions		Number of Circuits									
	2	3	4	5	6	7	8	9	10	11	12
"A"	1 1/2"	2 1/4"	3"	3 3/4"	4 1/2"	5 1/4"	6"	6 3/4"	7 1/2"	8 1/4"	9"
"B"	1 5/16"	2 1/16"	2 13/16"	3 9/16"	4 5/16"	5 1/16"	5 13/16"	6 9/16"	7 5/16"	8 1/16"	8 13/16"

To order 7032 or 7033:

- 1. Give part number.
- 2. Specify number of circuits.
- 3. Name calibration code (specify each circuit if mixed). Table 1
- 4. Indicate vertical mounting position if other than horizontal as illustrated.
- 5. Specify number sequence if other than series beginning with 1.

Example: 7032 - 12 - 6K - 6J - HOR - 1 to 12

To order 7034:

- 1. Give part number.
- 2. Specify number of circuits.
- 3. Name calibration code (specify each circuit if mixed). Table 1

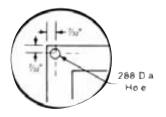
Example: **7034 - 10 - E**



Convenience Connectors, Strip Panels with Mounting Frame

An assembly of strip panel modules can be combined to accommodate any number of connections. A one-piece mounting frame made of 3/32" thick rigid steel, with dull black finish, holds strip panel modules (shown on previous page).

Part No. 7035



Strip Panel Frame Detail for Mounting Holes in Panel.

Mounting holes "A" are used only when "H" and "W" dimensions each exceed 13 1/2".

Dimensions for Panel Assembly

H₀ and W₀ are Mounting Cutout Dimensions

				Circuits Per Row /																						
			W = 2%	W 3/2"	W = 2½" W = 4½"	W 5 3"	W 5%4"	W = 6.72"	W = 7/4" W = 7/4"	"9" M	W = 8%4" W = 8%4"	" 5/7" M	W 101/4"	1.16 M 1.17 M	W= 173/4"	W 12:5/4	W= 73/4"	W 14"	W= 123/4" W= 143/4"	W 15:6"	W 161/4	W=15"	W=153/4" W=173/4"	W= 16½" W= 18½"	W 19/4"	′ /
	$H = 2^{5}/8$ " $H_{0} = 1^{1}/2$ "	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
	$H = 4^{3}/8$ " $H_{0} = 3^{1}/4$ "	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	
	H = 6 ¹ /8" H ₀ = 5"	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	
Row	$H = 7^{7}/8$ " $H_0 = 6^{3}/4$ "	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	
9	H = 95/8" H ₀ = 81/2"	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	
Number	H = 115/8" H ₀ = 101/4"	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	
N	H = 13 ¹ /8" H ₀ = 12"	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147	154	161	168	
	H = 14 ⁷ /8" H ₀ = 13 ³ /4"	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160	168	176	184	192	
	H = 16 5/8" H ₀ = 15 1/2"	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180	189	198	207	216	
	H = 18 ³ /8" H ₀ = 17 ¹ /4"	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	

Ordering Information

- 1. Give catalog number.
- 2. Specify number of rows and circuits per row.
- 3. Name calibration s, use strip panel table on opposite page (specify each circuit if mixed).

Example: 7035 - 4 rows - 12C per row - Hor - 1 to 48

- Indicate vertical mounting position if other than horizontal as illustrated.
- 5. Specify numbering sequence if other than series beginning with 1.

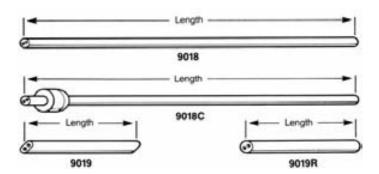


Insulators

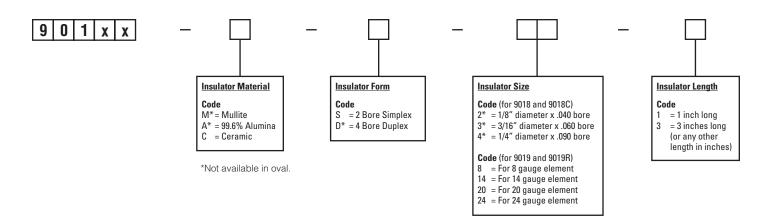
Our thermocouple insulators are fully vitrified, impervious and uniform. They are of the highest quality and have excellent mechanical strength as well as high thermal shock resistance. The beads, oval and round insulators listed are normally for base metal thermocouples. Noble metal and other high-temperature thermocouples should utilize the one-piece round construction insulators.

Insulator Ty	Insulator Types							
Part No.	Style							
9018	Round full length							
9018C	Round full length with collar							
9019	Oval							
9019R	Round							

Insulators



Ordering Information





Retractable Cord Sets

Retractable cords offer flexible and neat methods of connecting thermocouples and resistance thermometers. The cord insulation is resistant to moisture, oil and many chemicals in environments not exceeding 220°F (105°C). Each foot of retracted cord extends approximately five feet.

General Specifications

Insulation: Teflon® on primaries with TPR (thermoplastic

rubber) for the main cable body (not recommended for use above 220°F)

Conductors: 26 Awg stranded conductors composed of

7 strands of 36 gauge wire

ANSI Limits: Standard limits of error for the thermocouple's

extension wire

Nominal Cable

Diameter:

Thermocouple .170" diameter round

Retracted Cord Length Tolerance:

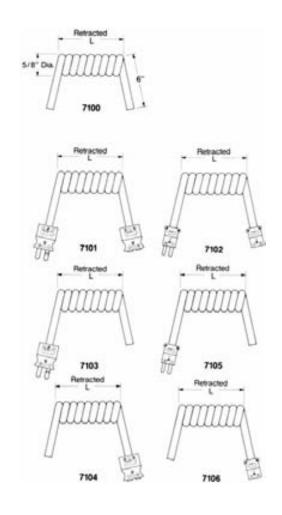
Retracted Coil

±10%

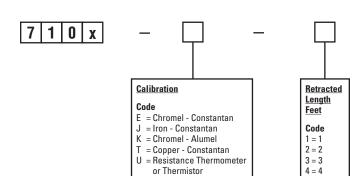
Diameter: Approximately 5/8" diameter

Extended Length: Approximately 5 ft. per foot of retracted coil

Part No.	Style
7100	Cord with 6" straight length
7101	Cord with standard size convenience male and female connectors
7102	Cord with miniature size convenience male and female connectors
7103	Cord with standard size convenience male connector on one end only
7104	Cord with standard size convenience female connector on one end only
7105	Cord with miniature size convenience male connector on one end only
7106	Cord with miniature size convenience female connector on one end only



Ordering Information



Color C	Color Coding: Industry Standard										
Туре	Jacket	Positive	Negative								
K	yellow	yellow	red								
J	black	white	red								
Т	blue	blue	red								
Е	purple	purple	red								
U	white	2 black	1 red								

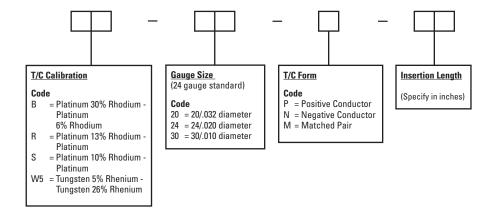


Bare Thermocouple Wire

Close control of composition is very necessary as far as the properties of thermocouple material alloys are concerned. We insist that constant adherence to established high standards of accuracy are maintained by special processing and quality control techniques at the primary source. Final check and calibration of all bare and insulated thermocouple materials are done in our own laboratory by the most modern and efficient test instruments and calibration procedures.

Calibration is **AVAILABLE Ordering Information Upon Request Base Metal Thermocouple Wire T/C Calibration** Gauge Size T/C Form **Insertion Length** Code (Specify in inches) = 8/.128 diameter = Chromel - Constantan P = Positive Conductor = Iron - Constantan 14 = 14/.064 diameter N = Negative Conductor M = Matched Pair = Chromel - Alumel 20 = 20/.032 diameter = Nicrosil - Nisil 24 = 24/.020 diameter = Copper - Constantan 30 = 30/.010 diameter NM = Nickel - Nickel Moly

Noble and Refractory Metal Thermocouple Wire





123

Insulated Thermocouple and Extension Wire

Athena's thermocouple wire and thermocouple extension wire are known for premium performance and reliability. Careful selection of materials, plus the latest type of special machinery and quality control, assure superior wire uniformity.

Quality Control

Quality control of all Athena's brand thermocouple wire and thermocouple extension wire provides testing in accordance with NBS Circular 590 and are traceable to NIST.

Shipping

All Athena's duplex insulated thermocouple and extension wires are normally packaged in 1000-foot reels. This length is $\pm 10\%$ on each reel. However, each reel and the container in which it is shipped is marked with the exact length. On any order for either standard or special wire, we reserve the right to ship $\pm 10\%$ of the total amount ordered.

Calibrating, Checking and Tagging

Thermocouple wire and extension wire are available calibrated, when so specified, at an extra charge. Wires of this classification are within the Standard Limits of Error but, most important, their specific departure temperatures specified is known and can be taken into account. Each thermocouple, coil, reel, or spool of wire is checked and tagged to show the departure from the curve. Refer to the Engineering Data section of the Reference Information publication (available on request) for limits of error applicable to your particular thermocouple wire or extension wire.

Color Coding

Standard ANSI color coding is used on all insulated thermocouple wire and extension wire when type of insulation permits. In color coding, a tracer may be used to distinguish the calibration.

ANS	I Type	Magn	etic	ANSI Color Code					
T/C	Single	Yes	No	Single	Overall Extension Wire	Overall T/C Wire			
	TP		Χ	Blue					
T	TN		Χ	Red	Blue	Brown			
	JP	Χ		White					
J	JN		Χ	Red	Black	Brown			
	EP		Χ	Purple					
Ε			Χ	Red	Purple	Brown			
	KP		Χ	Yellow					
K	KN	Χ		Red	Yellow	Brown			
	RP, SP		Χ	Black					
R, S	RN, SN		Χ	Red	Green	_			
	BP		Χ	Grey					
В	BN		Χ	Red	Grey	_			
	NP		Χ	Orange					
N	NN	Χ		Red	Orange	Brown			

ANSI Letter Designations

Thermocouple and extension wires are specified by ANSI letter designations for calibration. Positive and negative legs are identified by the appropriate letter suffixes P and N, respectively.

ANSI Letter	Description	Popular Generic & Trade Names*
т	TP	Copper
•	TN	Constantan, Cupron™, Advanced
J	JP	Iron
J	JN	Constantan, Cupron, Advanced
F	EP	Chromel™, Tophel™, T ₁
	EN	Constantan, Cupron, Advanced
K	KP	Chromel, Tophel, T ₁ Thermokanthal KP
I.V.	KN	Alumel™, Nial™, T₂ Thermokanthal KN
R	RP	Platinum 13% Rhodium
n	RN	Pure Platinum
S	SP	Platinum 10% Rhodium
3	SN	Pure Platinum
В	BP	Platinum 30% Rhodium
ט	BN	Platinum 6% Rhodium
N	NP	Nicrosil
14	NN	Nisil

Solid and Stranded Conductors

Thermocouple wire and extension wire are usually solid conductors. When greater flexibility is required, stranded construction is available. The accompanying table gives the stranding combinations used.

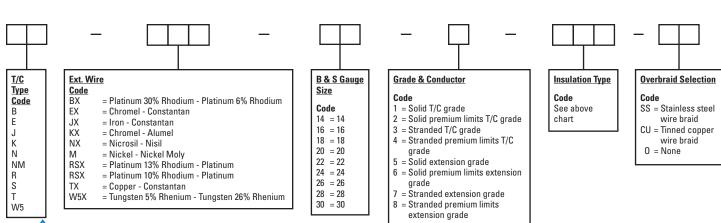
Stranding Conductor	Combinatio	ns	Stranding
Gauge	ANSI Type	No. of Strands	Gauge
14	All	7	22
16	All	7	24
18	All	7	26
20	All	7	28
22	All	7	30
24	All	7	32

Not all combinations are standard and may require a minimum purchase quantity.



Insulated Thermocouple and Extension Wire

	Single Condu	ctor	Duplex Cor	Temperature Rating			ANSI Phys	3		
Code	Insulation Wall Thickness	Impregnation	Insulation Wall Thickness	Impregnation	Continuous	Single Reading	Color Coded	Abrasion Resistance	Moisture Resistance	Notes
301	Amorphous Silica Fiber .015"	None	Amorphous Silica Fiber .020"	None	871°C 1600°F	1093°C 2000°F	No	Fair	Fair	
302	Double Glass Braid .012" Wall	Silicone Modified Resin	Glass Braid .006"	Silicone Modified Resin	482°C 900°F	538°C 1000°F	Yes	Good	Good	Impregnation retained to 204°C (400°F)
304	Glass Braid .006"	Silicone Modified Resin	Glass Braid .006"	Silicone Modified Resin	482°C 900°F	538°C 1000°F	Yes	Fair	Good	Impregnation retained to 204°C (400°F)
305	Double Glass Wrap .005"	High Temp. Varnish	Glass Braid .006"	Silicone Modified Resin	482°C 900°F	538°C 1000°F	Yes	Fair	Good	Impregnation retained to 204°C (400°F)
321	Hi-Temp Glass Braid .012"	Hi-Temp Varnish	Hi-Temp Glass Braid .012"	Hi-Temp Varnish	704°C 1300°F	871°C 1600°F	Yes	Good	Good	Impregnation retained to 204°C (400°F)
350	Polycrystaline Braid .012" Wall	None Modified Resin	Polycrystaline .006"	None Modified Resin	1430°C 2600°F	1430°C 2600°F	No	Good	Fair	
502	Polyvinyl .013" to #20 .014" to #16 .016" to #14	_	Polyvinyl .016"	_	-29 to +105°C -20 to +221°F	105°C 221°F	Yes	Good	Excellent	
504	Nylon .010"	_	Nylon .008"010"	_	150°C 300°F	150°C 300°F	Yes	Excellent	Fair	Over-all jacket is clear
505	Polyvinyl .012"014"	_	Ripcord	_	-29 to +105°C -20 to +221°F	105°C 221°F	Yes	Good	Excellent	
506	Teflon® TFE Tape fused .005"	_	Teflon TFE Tape fused .0075"	_	204°C 400°F	316°C 600°F	Yes	Very Good	Excellent	Aluminum/Kapton Foil Shield with #20 Nickel plated copper Drain Wire
507	Teflon FEP Extr. .008"	_	Teflon FEP Extr. .010"	_	204°C 400°F	316°C 600°F	Yes	Very Good	Excellent	
508	Teflon TFE Tape fused .005"	_	Teflon TFE Tape fused .0075"	_	260°C 500°F	316°C 600°F	Yes	Good	Excellent	
509	Teflon FEP Extr. .009"	_	Teflon FEP Extr. .010", twisted	_	204°C 400°F	316°C 600°F	Yes	Very Good	Excellent	Aluminum/Mylar shield w/ #20 drain wire
510	Polyvinyl .015"	_	Polyvinyl .020" Twisted	_	-29 to +80°C -20 to +176°F	80°C 176°F	Yes	Good	Excellent	Aluminum/Mylar shield w/ #20 drain wire
511	Fused Kapton Tape .004"	_	None Twisted	_	316°C 600°F	427°C 800°F	Both legs have tracer	Excellent	Excellent	FEP binder melts at approximately 260°C (500°F)
513	Fused Kapton Tape .006"	_	Fused Kapton .004"	_	316°C 600°F	427°C 800°F	Yes	Excellent	Excellent	FEP binder melts at approximately 260°C (500°F)
516	Extruded PFA .008"	_	Extruded PFA .010"	_	260°C 500°F	316°C 600°F	Yes	Good	Excellent	



ATHENK

Thermocouple Application Data

Calibration Code	Typical Applications		ıctor & teristics	Recommended Temp. Range		Limits of Error	
Coue		Positive	Negative	Tellip. nallye	Range °F	Standard	Special
J	Suitable for vacuum, reducing, or inert atmospheres. Reduced life in oxidizing atmosphere. Iron oxidizes rapidly above 1000°F, so only heavy gauge wire is recommended for high temperatures. Bare elements should not be exposed to sulphurous atmospheres above 1000°F.	Iron (Magnetic)	Constantan® (Non-Magnetic)	32 to 1400°F (0 to 760°C)	32 to 1400°F (0 to 760°C)	±4.0°F (±2.2°C) or ±0.75%*	±2.0°F (±1.1°C) or ±0.4%*
Jx	Compensating extension wire for "J" calibration.	White	Red	-	32 to 392°F (0 to 200°C)	±4.0°F (±2.2°C)	±2.0°F (±1.1°C)
K	Recommended for continuous oxidizing or neutral atmospheres. Mostly used above 1000°F. Subject to failure if exposed to sulfur. Preferential oxidation of chromium in positive leg at certain low oxygen concentrations causes "green rot" and large negative calibration drifts most serious in the 1500-1900°F temperature range.	Chromel® (Non-Magnetic)	Alumel® (Magnetic)	32 to 2300°F (0 to 1260°C)	-328 to 32°F (-200 to 0°C) 32 to 2300°F (0 to 1260°C)	±4.0°F (±2.2°C) or ±2.0%* ±4.0°F (±2.2°C) or ±0.75%	±2.0°F (±1.1°C) or ±0.4%
Kx	Compensating extension wire for "K" calibration.	Yellow	Red		32 to 392°F (0 to 200°C)	±4.0°F (±2.2°C)	±2.0°F (±1.1°C)
T	Usable in oxidizing, reducing, or inert atmospheres, as well as vacuum. Not subject to corrosion in moist atmospheres.	Copper (Yellow Metal)	Constantan® (Silver Metal)	-328 to 700°F (-200 to 371°C)	-328 to 32°F (-200 to 0°C) 32 to 700°F (0 to 371°C)	±1.8°F (±1.0°C) or ±1.5%* ±1.8°F (±1.0°C) or ±0.75%*	±0.9°F (±0.5°C) or ±0.4%*
Тх	Compensating extension wire for "T" calibration.	Blue	Red	-	-75 to 212°F (-60 to 100°C)	±1.8°F (±1.0°C)	±0.9°F (±0.5°C)
E	Recommended for continuous oxidizing or inert atmospheres. Highest thermoelectric output of common calibrations.	Chromel [©]	Constantan®	32 to 1600°F (0 to 871°C)	-328 to 32°F (-200 to 0°C) 32 to 1600°F (0 to 871°C)	±3.06°F (±1.7°C) or ±1.0% ±3.06°F (±1.7°C) or ±0.5%*	±1.8°F (±1.0°C) or ±0.4%*
Ex	Compensating extension wire for "E" calibration.	Purple	Red	-	32 to 392°F (0 to 200°C)	±3.0°F (±1.7°C)	±1.8°F (±1.0°C)
R	Recommended for high temperatture. Requires non- metallic protection tube and ceramic insulators. Long- term high temperature use causes grain growth and mechanical failure. Negative calibration drift caused by rhodium diffusion to pure leg as well as from rhodium volatilization.	Platinum 13% Rhodium	Platinum	32 to 2700°F (0 to 1482°C)	32 to 2700°F (0 to 1482°C)	±2.7°F (±1.5°C) or ±0.25%*	±1.08°F (±0.6°C) or ±0.1%*
S	Same as "R" calibration but output is lower. Also susceptible to grain growth and drift.	Platinum 10% Rhodium	Platinum	32 to 2700°F (0 to 1482°C)	32 to 2700°F (0 to 1482°C)	±2.7°F (±1.5°C) or ±0.25%*	±1.08°F (±0.6°C) or ±0.1%*
RSx	Compensating extension wire for "R" and "S" calibration.	Copper (Black)	Alloy 11 (Red)	-	32 to 392°F (0 to 200°C	±9°F (±5°C)	-
В	Same as "R" calibration but output is lower. Also susceptible to grain growth and drift.	Platinum 30% Rhodium	Platinum 6% Rhodium	1600 to 3100°F (870 to 1705°C)	1600 to 3100°F (870 to 1705°C)	±0.5%*	±0.25%*
Bx	Compensating extension wire for "B" calibration.	Gray	Red	-	32 to 392°F (0 to 200°C)	±7.6°F (±4.2°C)	-
C (W5)	For very high temperature applications in inert and vacuum atmospheres.	Tungsten 5% Rhenium	Tungsten 26% Rhenium	32 to 4200°F (0 to 2315°C)	32 to 800°F (0 to 426°C)	±8.0°F (±4.4°C)	-
					800 to 4200°F (426 to 2316°C)	±1%*	-
L	Noble metal combination that approximates the "K" calibration but has much improved oxidation resistance. Should be treated as any noble metal thermocouple.	Platinel II [®]	Platinel II®	32 to 2543°F (0 to 1395°C)	392 to 2192°F (200 to 1200°C)	±0.150mv to ±0.315mv	±0.100mv t ±0.158mv
N	Modern nickel based alloy similar to "K" calibration but offering lower drift and longer life at high temperatures.	Nicrosil®	Nisil [®]	32 to 3200°F (0 to 1260°C)	32 to 3200°F (0 to 1260°C)	±4.0°F (±2.2°C) or ±0.75%*	±2.0°F (±1.1°C) 01 ±0.4%*
Nx	Compensating extension wire for "N" calibration.	Orange	Red	-	32 to 392°F (0 to 200°C)	±4.0°F (±2.2°C)	±2.0°F (±1.1°C)
Nickel-Moly	Used in hydrogen applications. Cycling causes excessive grain growth.	NiMo (Nickel-18% Molybdenum)	Nickel (Nickel-0.8% Cobalt)	32 to 2250°F (0 to 1232°C)	-	_	

^{*}Stated tolerance value or percentage – whichever is greater.
For percentages given, the tolerance (in °C) is calculated for a given temperature by multiplying the temperature (in °C) by the stated percentage.



Thermoelectricity in Retrospect

The principles and theory associated with thermoelectric effects were not established by any one person at any one time. The discovery of the thermoelectric behavior of certain materials is generally attributed to T. J. Seebeck.

In 1821, Seebeck discovered that in a closed circuit made up of wire of two dissimilar metals, electric current will flow if the temperature of one junction is elevated above that of the other. Seebeck's original discovery used a thermocouple circuit made up of antimony and copper. Based on most common usage and recognition today, there are eight thermoelement types: S,R,B,J,K,N,T and E.

In the ensuing years following the discovery of the thermoelectric circuit, many combinations of thermoelectric elements were investigated. Serious application of the findings was accelerated by the needs brought on during the course of the Industrial Revolution.

In 1886, Le Chatelier introduced a thermocouple consisting of one wire of platinum and the other of 90 percent platinum-10 percent rhodium. This combination, Type S, is still used for purposes of calibration and comparison. It defined the International Practical Temperature Scale of 1968 from the antimony to the gold point. This type of thermocouple was made and sold by W. C. Heraeus, GmbH of Hanau, Germany, and is sometimes called the Heraeus Couple.

Later, it was learned that a thermoelement composed of 87 percent platinum and 13 percent rhodium, Type R, would give a somewhat higher E.M.F. output.

In 1954 a thermocouple was introduced in Germany whose positive leg was an alloy of platinum and 30 percent rhodium. Its negative leg was also an alloy of platinum and 6 percent rhodium. This combination, Type B, gives greater physical strength, greater stability, and can withstand higher temperatures than Types R and S.

The economics of industrial processes prompted a search for less costly metals for use in thermocouples. Iron and nickel were useful and inexpensive.

Pure nickel, however, became very brittle upon oxidation; and it was learned that an alloy of about 60 percent copper, 40 percent nickel (constantan) would eliminate this problem. This alloy combination, iron-constantan, is widely used and is designated Type J. The present calibration for Type J was established by the National Bureau of Standards, now known as the National Institute of Standards and Technology (N.I.S.T.).

The need for higher temperature measurements led to the development of a 90 percent nickel-10 percent chromium alloy as a positive wire, and a 95 percent nickel-5 percent aluminum, manganese, silicon alloy as a negative wire. This combination (originally called Chromel-Alumel) is known as Type K.

Conversely the need for sub-zero temperature measurements contributed to the selection of copper as a positive wire and constantan as a negative wire in the Type T thermoelement pair. The E.M.F.-temperature relationship for this pair (referred to as the Adams Table) was prepared by the National Bureau of Standards in 1938. The relatively recent combination of a positive thermoelement from the Type K pair and a negative thermoelement from the Type T pair is designated as a Type E thermoelement pair. This pair is useful where higher E.M.F. output is required.

Within the past 20 years, considerable effort has been made to advance the state-of-the-art in temperature measurement. Many new thermoelement materials have been introduced for higher temperatures.

Combinations of tungsten, rhenium and their binary alloys are widely used at higher temperatures in reducing inert atmospheres or vacuum.

The most common thermoelement pairs are:

W-W26Re (Tungsten Vs. Tungsten 26%)

W3Re-W25Re (Tungsten 3% Rhenium Vs. Tungsten

25% Rhenium)

W5Re-W26Re (Tungsten 5% Rhenium Vs. Tungsten

26% Rhenium)

Letter designations have not yet been assigned to these combinations.



The most recent significant development in thermometry was the adoption of the International Temperature Scale of 1990 (ITS-90). The work of international representatives was adopted by the International Committee of Weights and Measures at its meeting September 1989, and is described in "The International Temperature Scale of 1990", Metrologia 27, No. 1, 3-10 (1990); Metrologia 27,107 (1990).

Laws of Thermoelectric Circuits

Numerous investigations of thermoelectric circuits in which accurate measurements were made of the current, resistance, and electromotive force have resulted in the establishment of several basic laws.

Although stated in many different ways, these precepts can be reduced to three fundamental laws:

- 1. The law of the Homogeneous Circuit
- 2. The law of Intermediate Materials
- 3. The law of Successive or Intermediate Temperatures

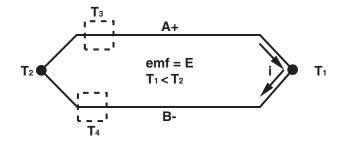
Law of Homogeneous Circuit

A thermoelectric current cannot be sustained in a circuit of a single homogeneous material, however, varying in cross section, by the application of heat alone.

Two different materials are required for any thermocouple circuit.

Any current detected in a single wire circuit when the wire is heated in any way whatever is taken as evidence that the wire is inhomogeneous.

Figure 1. Law of Homogeneous Circuit.



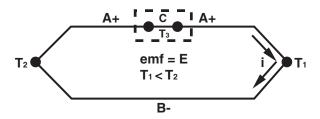
A consequence of this law as illustrated in Figure 1, is that if one junction of two dissimilar homogeneous materials is maintained at a temperature T, and the other junction at a temperature T2, the thermal E.M.F. developed is independent of the temperature distribution along the circuit. The E.M.F., E, is unaffected by temperatures T3 and T4.

Law of Intermediate Materials

The algebraic sum of the thermoelectromotive forces in a circuit composed of any number of dissimilar materials is zero if all of the circuit is at a uniform temperature.

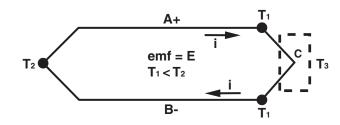
A consequence of this law is that a third homogeneous material can be added in a circuit with no effect on the net E.M.F. of the circuit so long as its extremities are at the same temperature.

Figure 2. Law of Intermediate Materials.



In Figure 2, two homogeneous metals, A and B, with their junctions at temperatures T, and T2 a third metal C, is introduced by cutting A, and forming two junctions of A and C. If the temperature of C is uniform over its whole length, the total E.M.F. in the circuit will be unaffected.

Figure 3. Combining the Law of Intermediate Materials with the Law of Homogeneous Circuit.

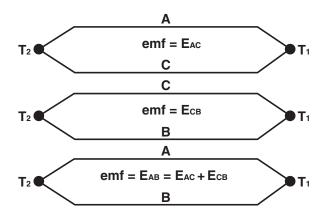


Combining the Law of Intermediate Materials with the Law of Homogeneous Circuit, as shown in Figure 3, A and B are separated at the temperature T. junction. Two junctions AC and CB are formed at temperature T1. While C may extend into a region of very different temperature, for example, T3 the E.M.F. of the circuit will be unchanged. That is, EAC + ECB = EAB.

A further consequence to the combined laws of Intermediate Materials and Homogeneous Circuit is illustrated in Figure 4.

When the thermal E.M.F. of any material A or B paired with a reference material C is known, then the E.M.F. of any combination of these materials, when paired, is the algebraic sum of their E.M.F.'s when paired with reference material C.

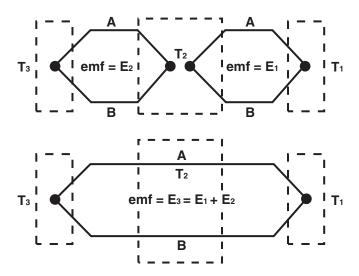
Figure 4. Thermal E.M.F. of two materials with respect to a reference material.



Law of Successive or Intermediate Temperatures

If two dissimilar homogeneous metals produce a thermal E.M.F. of E., when the junctions are at temperatures T1 and T2, and a thermal E.M.F. of E2, when the junctions are at T2 and T3, the E.M.F. generated when the junctions are at T1 and T3, will be E1 + E2.

Figure 5. Law of Successive or Intermediate Temperatures.



One consequence of this law permits a thermocouple calibrated at a given reference temperature, to be used at any other reference temperature through the use of a suitable correction.

Another consequence of this law is that extension wires, having the same thermoelectric characteristics as those of the thermocouple wires, can be introduced in the thermocouple circuit (say from region T2 and region T3) without affecting the net E.M.F. of the thermocouple.

Conclusion

The three fundamental laws may be combined and stated as follows: "The algebraic sum of the thermoelectric E.M.F.s generated in any given circuit containing any number of dissimilar homogeneous materials is a function only of the temperatures of the junctions." Corollary: "If all but one of the junctions in such a circuit are maintained at some reference temperature, the E.M.F. generated depends only on the temperature of that one junction and can be used as a measure of its temperature."

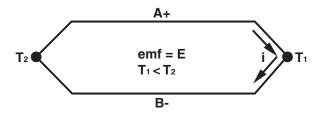


Thermoelectric Effects

Seebeck Effect

The Seebeck effect, Figure 6, concerns the conversion of thermal energy into electrical energy. The Seebeck voltage refers to the net thermal electromotive force established in a thermoelement pair under zero current conditions.

Figure 6. Seebeck Thermal E.M.F..



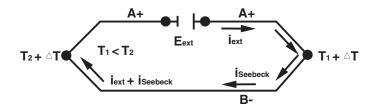
When a circuit is formed consisting of two dissimilar conductors A and B, and one junction of A and B is at temperature T1 while the other junction is at a higher temperature T2, a current will flow in the circuit. The electromotive force E producing this current i, is called the Seebeck thermal E.M.F.

Conductor A is considered thermoelectrically positive to conductor B if the current i flows from conductor A to conductor B at the cooler of the two junctions (T_1) .

Peltier Thermal Effect

The Peltier Thermal Effect, Figure 7, concerns a reversible phenomenon at the junction of most thermoelement pairs.

Figure 7. Peltier Thermal Effect.



When an electrical current i ext flows across the junction of a thermoelement pair, heat is absorbed or liberated. The direction of current flow at a particular junction determines whether heat is absorbed or liberated.

If an external current i ext flows in the same direction as the current i Seebeck produced by the Seebeck Effect at the hotter junction of a thermoelement pair, heat is absorbed. Heat is liberated at the other junction.

The Thomson Effect

The Thomson Effect concerns the reversible evolution, or absorption, of heat occurring whenever an electric current traverses a single homogeneous conductor, across which a temperature gradient is maintained, regardless of external introduction of the current or its induction by the thermocouple itself.

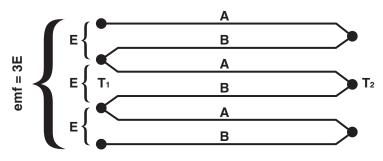
The Thomson voltage alone cannot sustain a current in a single homogeneous conductor forming a closed circuit, since equal and opposite E.M.F.s will be set up on the two paths from heated to cooled parts of the circuit.

Thermoelectric Circuits

Series Circuit

A number of similar thermocouples all having thermoelements A and B may be connected in series with all of their measuring junctions at T2 and their reference junctions at T1. Such a series, called a thermopile, is shown in Figure 8. With three thermocouples in series develops an E.M.F. three times as great as a single thermocouple is developed.

Figure 8. A thermopile of three thermocouples.

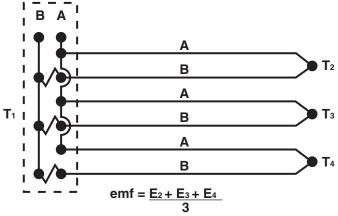


Parallel Circuit

If a quantity "N" of thermocouples of equal resistance is connected in parallel with junctions at T1 and T2 the E.M.F. developed is the same as for a single thermocouple with its junctions at T1 and T2.

If all of the thermocouples are of equal resistance but their measuring junctions are at various temperatures T2, T3...Tn + 1, see Figure 9, then the E.M.F. developed will correspond to the mean of the temperatures of the individual measuring junctions.

Figure 9. A parallel circuit for mean temperatures.

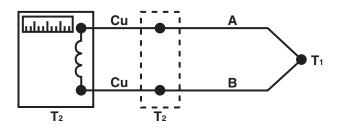


It is not necessary to adjust the thermocouple resistances when measuring these average temperatures. Instead, swamping resistors may be used. For example, if the thermocouples range in resistance from 5 to 10 ohms, a 500 ohm (±1%) resistor is connected in series with each, and the error in E.M.F. introduced by the inequality in thermocouple resistance becomes an insignificant fraction of the total resistance.

Basic Thermocouple Circuit

Two continuous, dissimilar thermocouple wires extending from the measuring junction to the reference junction, when used together with copper connecting wires and a potentiometer, connected as shown in Figure 10, make up the basic thermocouple circuit for temperature measurement.

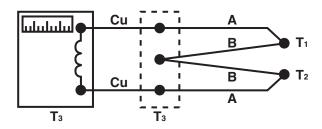
Figure 10. Basic thermocouple circuit.



Differential Thermocouple Circuit

Junctions 1 and 2 are each at different temperatures. The temperature measured by the circuit shown in Figure 11 is the difference between T1 and T2.

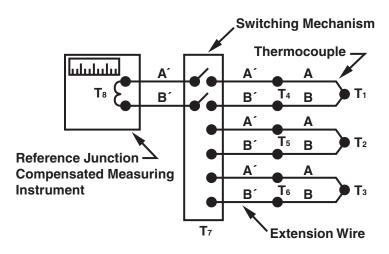
Figure 11. Differential thermocouple circuit.



Typical Industrial Thermocouple Circuit

The usual thermocouple circuit includes: measuring junctions, thermocouple extension wires, reference junctions, copper connecting wires, a selector switch, and potentiometer. Many different circuit arrangements of the above components are acceptable, depending on given circumstances.

Figure 12. Typical industrial thermocouple circuit.





Environmental Limitations of Thermoelements

JP–For use in oxidizing, reducing, or inert atmospheres or in vacuum. Oxidizes rapidly above 540°C (1000°F). Will rust in moist atmospheres as in subzero applications. Stable to neutron radiation transmutation. Change in composition is only 0.5 percent (increase in manganese) in 20-year period.

JN, TN, EN–Suitable for use in oxidizing, reducing, and inert atmospheres or in vacuum. Should not be used unprotected in sulfurous atmospheres above 540°C (1000°F).

Composition changes under neutron radiation since copper content is converted to nickel and zinc. Nickel content increases 5 percent in a 20-year period.

TP–Can be used in vacuum or in oxidizing, reducing or inert atmospheres. Oxidizes rapidly above 370°C (700°F). Preferred to Type JP element for subzero use because of its superior corrosion resistance in moist atmospheres. Radiation transmutation causes significant changes in

composition.

Nickel and zinc grow into the material in amounts of 10

percent each in a 20-year period.

KP, EP–For use in oxidizing or inert atmospheres. Can be used in hydrogen or racked ammonia atmospheres if dew point is below -40°C (-40°F). Do not use unprotected in sulfurous atmospheres above 540°C (1000°F).

Not recommended for service in vacuum at high temperatures except for short time periods because preferential vaporization of chromium will alter calibration. Large negative calibration shifts will occur if exposed to marginally oxidizing atmospheres in temperature range 815°C to 1040°C (1500°F to 1900°F).

Quite stable to radiation transmutation. Composition change is less than 1 percent in a 20-year period.

KN–Can be used in oxidizing or inert atmospheres. Do not use unprotected in sulfurous atmospheres as intergranular corrosion will cause severe embrittlement.

Relatively stable to radiation transmutation. In a 20-year period, iron content will increase approximately 2 percent. The manganese and cobalt contents will decrease slightly.

RP, SP, SN, RN, BP, BN–For use in oxidizing or inert atmospheres. Do not use unprotected in reducing atmospheres in the presence of easily reduced oxides, atmospheres containing metallic vapors such as lead or zinc, or those containing nonmetallic vapors such as arsenic, phosphorus, or sulfur. Do not insert directly into metallic protecting tubes. Not recommended for service in vacuum at high temperatures except for short time periods.

Type SN elements are relatively stable to radiation transmutation. Types BP, BN, RP and SP elements are unstable because of the rapid depletion of rhodium. Essentially, all the rhodium will be converted to palladium in a 10-year period.

NP, NN–Proprietary alloys suitable for use in applications cited for KP and KN.

Typical Physical	Typical Physical Properties of Thermoelement Materials											
Thermoelement Material												
Property	JP	JN, TN, EN	TP	KP, EP	KN	NP	NN	RP	SP	RN, SN	BP	BN
Melting point °C °F	1490 2715	1220 2228	1083 1981	1427 2600	1399 2550	1410 2570	1340 2444	1860 3380	1850 3362	1769 3216	1927 3501	1826 3319
Temperature coefficient of resistance, Ω/Ω° C x 10 ⁻⁴ (0-100°C)	65	-0.1	43	4.1	23.9	24.0	0.01	15.6	16.6	39.2	13.3	20.0
Coefficient of thermal expansion, in./in. °C (0-100°C)	11.7 x 10 ⁻⁶	14.9 x 10 ⁻⁶	16.6 x 10 ⁻⁶	13.1 x 10 ⁻⁶	12.0 x 10 ⁻⁶	13.3 x 10 ⁻⁶	12.1 x 10 ⁻⁶	9.0 x 10 ⁻⁶	9.0 x 10 ⁻⁶	9.0 x 10 ⁻⁶	_	_
Density: g/cm ³ lb/in. ³	7.86 0.284	8.92 0.322	8.92 0.322	8.73 0.315	8.60 0.311	8.52 0.308	8.70 0.314	19.61 0.708	19.97 0.721	21.45 0.775	17.60 0.636	20.55 0.743
Tensile strength (annealed): kgf/cm² psi	3500 50000	5600 80000	2500 35000	6700 95000	6000 85000	 90000	 80000	3200 46000	3200 45000	1400 20000	4900 70000	2800 40000
Magnetic attraction	strong	none	none	none	moderate	none	slight	none	none	none	none	none

Nominal Ch	Iominal Chemical Composition of Thermoelements											
	Nominal Chemical Composition, %											
Element	JP	JN, TN, EN	TP	KP, EN	KN	NP	NN	RP	SP	RN, SN	BP	BN
Iron	99.5	_	_	_	_	_	_	_	_	_	_	_
Carbon	**	_	_	_	_	_	_	_	_	_	_	_
Manganese	**	_	_	_	2	_	0.1	_	_	_	_	_
Sulfur	**	_	_	_	_	_	_	_	_	_	_	_
Phosphorus	**	_	_	_	_	_	_	_	_	_	_	_
Silicon	**	_	_	_	1	1.4	4.4	_	_	_	_	_
Nickel	**	45	_	90	95	84.4	95.5	_	_	_	_	_
Copper	**	55	100	_	_	_	_	_	_	_	_	_
Chromium	**	_	_	10	_	14.2	_	_	_	_	_	_
Aluminum	_	_	_	_	2	_	_	_	_	_	_	_
Platinum	_	_	_	_	_	_	_	87	90	100	70.4	93.9
Rhodium	_	_	_	_	_	_	_	13	10	_	29.6	6.1

^{*}Types JN, TN, and EN thermoelements usually contain small amounts of various elements for control of thermal E.M.F., with corresponding reductions in the nickel or copper content, or both.

**Thermoelectric iron (JP) contains small but varying amounts of these elements.

Thermoelement	No. 8	No. 14	No. 20	No. 24	No. 28
	[0.128 in.]	[0.064 in]	[0.032 in.]	[0.020 in.]	0.013 in.]
JP	760°C	593°C	482°C	371°C	371°C
	(1400°F)	(1100°F)	(900°F)	(700°F)	(700°F)
JN, TN, EN	871°C	649°C	538°C	427°C	427°C
	(1600°F)	(1200°F)	(1000°F)	(800°F)	(800°F)
TP		371°C (700°F)	260°C (500°F)	204°C (400°F)	204°C (400°F)
KP, EP, KN, NP, NN	1260°C	1093°C	982°C	871°C	871°C
	(2300°F)	(2000°F)	(1800°F)	(1600°F)	(1600°F)
RP, SP, RN, SN				1482°C (2700°F)	_ _
BP, BN				1705°C (3100°F)	_

Nom	Nominal Resistance of Thermoelements												
	Ohms per foot at 20°C (68°F)												
Awg. No.	Diameter, in.	KN	KP, EP	TN, JN, EN	TP	JP	NP	NN	RN, SN	SP	ВР	BN	
8	0.1285	0.0107	0.0257	0.0179	0.000628	0.0043	0.0354	0.0134	0.00386	0.00697	0.00700	0.00648	
12	0.0808	0.0270	0.065	0.0448	0.00159	0.0109	0.0884	0.0335	0.00976	0.01761	0.01769	0.01637	
14	0.0641	0.0432	0.104	0.0718	0.00253	0.0174	0.1416	0.0537	0.0155	0.0280	0.0281	0.0260	
16	0.0508	0.0683	0.164	0.113	0.00402	0.0276	0.2230	0.0846	0.0247	0.0445	0.0447	0.0414	
17	0.0453	0.0874	0.209	0.145	0.00506	0.0349	0.2864	0.1086	0.0311	0.0562	0.0564	0.0523	
18	0.0403	0.111	0.266	0.184	0.00648	0.0446	0.3625	0.1375	0.0399	0.0719	0.0722	0.0669	
20	0.0320	0.173	0.415	0.287	0.0102	0.0699	0.5664	0.2148	0.0624	0.1125	0.1130	0.1046	
22	0.0253	0.276	0.663	0.456	0.0161	0.1111	0.9061	0.3437	0.0993	0.1790	0.1798	0.1664	
24	0.0201	0.438	1.05	0.728	0.0257	0.1767	1.4356	0.5445	0.1578	0.2847	0.2859	0.2647	
26	0.0159	0.700	1.68	1.16	0.0408	0.281	2.2942	0.8702	0.2509	0.4526	0.4546	0.4208	
28	0.0126	1.11	2.48	1.85	0.0649	0.447	3.6533	1.3857	0.3989	0.7197	0.7229	0.6692	
30	0.0100	1.77	4.25	2.94	0.1032	0.710	5.8000	2.2000	0.6344	1.144	1.149	1.064	
36	0.0050	7.08	17.0	11.8	0.4148	2.86	23.200	8.8000	2.550	4.600	4.620	4.277	
40	0.0031	18.4	44.2	30.6	1.049	7.22	60.354	22.893	6.448	11.63	11.68	10.81	



Nomina	lominal Weights of Thermoelements												
		Fe	et per pound	i		Feet Per Troy Ounce							
Awg.Dia													
No.	in.	KN	KP, EP	TN, JN, EN	TP	JP	RN, SN	SP	RP	BN	BP		
8	.128	21	20	20	20	22	0.5	0.5	0.5	0.5	0.6		
14	.064	83	82	80	80	91	2.3	2.1	2.5	2.4	2.8		
16	.051	130	129	127	127	143	3.6	3.8	3.9	3.7	4.3		
17	.045	167	166	163	163	184	4.6	4.9	5.0	4.8	5.6		
18	.040	212	210	207	207	233	5.8	6.2	6.3	6.0	7.0		
20	.032	331	328	323	322	364	9.1	9.7	9.9	9.4	11.0		
22	.025	530	525	518	517	583	15.0	16.0	16.4	45.6	18.2		
24	.020	838	832	820	816	924	23.4	25.1	25.6	24.4	28.5		
26	.16	1340	1331	1312	1306	1478	36.6	39.2	40.0	38.2	44.5		
28	.013	2130	2119	2089	2076	2353	555	59.5	60.7	57.9	67.6		
30	.010	3370	3364	3316	3296	3736	60.6	65.0	66.3	63.2	73.8		
36	.005	13500	13460	13260	13180	14940	375.5	402.8	411.0	391.9	457.5		
40	.003	35200	35010	34500	34292	N.A.	1042.7	1118.6	1141.4	1088.2	1270.5		

Limits of Error (Ref. Junction -0°C)

Therm	ocouples		Limits (of Error
Thermo- couple Type	Temp. Range, °C	Temp. Range, °F	Standard [whichever is greater]	Special [whichever is greater]
T J E K N R or S B W W3 W5	0 - 350 0 - 750 0 - 900 0 - 1250 0 - 1250 0 - 1450 800 - 1700 0 - 2300 0 - 2200 0 - 2200	32 - 700 32 - 1400 32 - 1600 32 - 2300 32 - 2300 32 - 2700 1600 - 3100 32 - 4200 32 - 4100 32 - 4100	± 1 °C or $\pm 0.75\%$ ± 2.2 °C or $\pm 0.75\%$ ± 1.7 °C or $\pm 0.5\%$ ± 2.2 °C or $\pm 0.75\%$ ± 2.2 °C or $\pm 0.75\%$ ± 1.5 °C or $\pm 0.25\%$ $\pm 0.5\%$ 4.5 °C or $\pm 1\%$ 4.5 °C or $\pm 1\%$ 4.5 °C or $\pm 1\%$	±0.5°C or 0.4% ±1.1°C or 0.4% ±1°C or 0.4% ±1.1°C or 0.4% ±1.1°C or 0.4% ±0.6°C or 0.1% —
T E	-200 - 0°C -200 - 0°C	-328 - 32 -328 - 32	±1°C to ±1.5% ±1.7°C to ±1%	_
K	-200 - 0°C	-328 - 32	±2.2°C to ±2%	_

Thermoco	uple Exten	sion Wires	\$	
Extension Wire Type	Temp. Range, °C	Temp. Range, °F	Limit Standard	s of Error Special
KX	0 - 200°C	32° - 400°	±2.2°C	_
JX	0 - 200°C	32° - 400°	±2.2°C	±1.1°C
EX	0 - 200°C	32° - 400°	±1.7°C	_
TX	-60 - 100°C	-75° - 200°	±1.0°C	±0.5°C
NX	0 - 200°C	32° - 400°	±2.2°C	_

Therm	Thermocouple Compensating Extension Wire												
Thermo- couple Type	Compensating Wire Type	Temp. Range, °C	Temp. Range, °F	Limits of Error									
R, S	SX**	25 - 200	75 - 400	±0.057mv (±5°C*)									
В	BX***	0 - 100	32 - 200	±.000mv (+0°C*) ±.003 mv (3.7°C*)									
W	WX	0 - 260	32 - 500	±0.14mv (12.9°C)									
W3	W3X	0 - 260	32 - 500	±0.11mv (6.8°C)									
W5	W5X	0 - 870	32 - 1600	±0.11mv (6.1°C)									

Thermocouples and thermocouple materials are normally supplied to meet the limits of error specified in the table for temperatures above 0°C. The same materials, however, may not fall within the sub-zero limits of error given in the second section of the table. If materials are required to meet the sub-zero limits, selection of materials usually will be required.

For sub-zero temperatures, the following limits for types E and T thermocouples may be appropriate (consult factory):

Type E $-200 \text{ to } 0^{\circ} \text{ C} \pm 1^{\circ} \text{C or } \pm 0.5\%$ Type T $-200 \text{ to } 0^{\circ} \text{ C} \pm 0.5^{\circ} \text{ C or } \pm 0.8\%$

- Limits of error in this table apply to new thermocouple wire, normally in the size range (No. 30 to No. 8 Awg) and used at temperatures not exceeding the recommended range (when derated for wire size). If used at higher temperatures these limits of error may not apply.
- Limits of error apply to new wire as delivered to the user and do not allow for calibration drift during use. The magnitude of such changes depends on such factors as wire size, temperature, time of exposure, and environment.
- ▶ Where limits of error are given in percent, the percentage applies to the temperature being measured when expressed in degrees Celsius. To determine the limit of error in degrees Fahrenheit multiply the limit of error in degrees Celsius by 9/5.

Type Wire Measuring Junction Temperature

SX Greater than 870°C BX Greater than 1000°C

*Due to the non-linearity of the Type R, S, and B temperature-E.M.F. curves, the error introduced into a thermocouple system by the compensating wire will be variable when expressed in degrees. The degree C limits of error given in parentheses are based on the measuring junction temperatures above.



^{**}Copper(†) versus copper nickel alloy (-).

^{***}Copper versus copper compensating extension wire, usable to 100°C with maximum errors as indicated, but with no significant error over 0 to 50°C range.

Temperature - E.M.F. Tables - I.T.S. 90

Type J (Iron C	Constantan)								
Temperature	in degrees	F (C) Re	ference j	junction at 3	32°F (0°C)) Millivolts	\rightarrow			
-300° (-185°)	-7.519	-7.659	-7.792	-7.915	-8.030					
-200° (-129°)	-5.760	-5.962	-6.159	-6.351	-6.536	-6.716	-6.890	-7.058	-7.219	-7.373
-100° (-74°)	-3.493	-3.737	-3.978	-4.215	-4.449	-4.678	-4.903	-5.125	-5.341	-5.553
0° (-18°)	-0.886	-1.158	-1.428	-1.695	-1.961	-2.223	-2.483	-2.740	-2.994	-3.245
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.886	-0.611	-0.334	-0.056	0.225	0.507	0.791	1.076	1.364	1.652
+100° (+38°)	1.942	2.234	2.527	2.821	3.116	3.412	3.709	4.007	4.306	4.606
+200° (+94°)	4.907	5.209	5.511	5.814	6.117	6.421	6.726	7.031	7.336	7.642
+300° (+149°)	7.949	8.255	8.562	8.869	9.177	9.485	9.793	10.101	10.409	10.717
+400° (+205°)	11.025	11.334	11.642	11.951	12.260	12.568	12.877	13.185	13.494	13.802
+500° (+260°)	14.110	14.418	14.727	15.035	15.343	15.650	15.958	16.266	16.573	16.881
+600° (+316°)	17.188	17.495	17.802	18.109	18.416	18.722	19.029	19.336	19.642	19.949
+700° (+372°)	20.255	20.561	20.868	21.174	21.480	21.787	22.093	22.400	22.706	23.013
+800° (+427°)	23.320	23.627	23.934	24.241	24.549	24.856	25.164	25.473	25.781	26.090
+900° (+483°)	26.400	26.710	27.020	27.330	27.642	27.953	28.266	28.579	28.892	29.206
+1000° (+538°)	29.521	29.836	30.153	30.470	30.788	31.106	31.426	31.746	32.068	32.390
+1100° (+594°)	32.713	33.037	33.363	33.689	34.016	34.345	34.674	35.005	35.337	35.670
+1200° (+649°)	36.004	36.339	36.675	37.013	37.352	37.692	38.033	38.375	38.718	39.063
+1300° (+705°)	39.408	39.755	40.103	40.452	40.801	41.152	41.504	41.856	42.210	42.561

Type K (Chrom Temperature i			nce junct	ion at 32°F	(0°C) M	illivolts —	>			
-400° (-240°) -300° (-185°) -200° (-129°) -100° (-74°) 0° (-18°) Deg. °F (°C)	-6.344 -5.632 -4.381 -2.699 -0.692	-6.380 -5.730 -4.527 -2.884 -0.905 10°(-13°)	-6.409 -5.822 -4.669 -3.065 -1.114 20°(-7°)	-6.431 -5.908 -4.806 -3.243 -1.322 30°(-2°)	-6.446 -5.989 -4.939 -3.417 -1.527 40°(5°)	-6.456 -6.064 -5.067 -3.587 -1.729	-6.133 -5.190 -3.754 -1.929 60°(16°)	-6.195 -5.308 -3.917 -2.126 70°(22°)	-6.251 -5.421 -4.076 -2.230 80°(27°)	-6.301 -5.529 -4.231 -2.511 90°(33°)
0° (-18°) +100° (+38°) +200° (+94°) +300° (+149°) +400° (+205°)	-0.692 1.521 3.820 6.094 8.316	-0.478 1.749 4.050 6.317 8.539	-0.262 1.977 4.280 6.540 8.761	-0.044 2.207 4.509 6.763 8.985	0.176 2.436 4.738 6.985 9.208	0.397 2.667 4.965 7.207 9.432	0.619 2.897 5.192 7.429 9.657	0.843 3.128 5.419 7.650 9.882	1.068 3.359 5.644 7.872 10.108	1.294 3.590 5.869 8.094 10.334
+500° (+260°) +600° (+316°) +700° (+372°) +800° (+427°) +900° (+483°) +1000° (+538°)	10.561 12.855 15.179 17.526 19.887 22.255	10.789 13.086 15.413 17.761 20.123 22.492	11.017 13.318 15.647 17.997 20.360 22.729	11.245 13.549 15.881 18.233 20.597 22.966	11.474 13.782 16.116 18.469 20.834 23.206	11.703 14.014 16.350 18.705 21.071 23.439	11.933 14.247 16.585 18.941 21.308 23.676	12.163 14.479 16.820 19.177 21.544 23.913	12.393 14.713 17.055 19.414 21.781 24.149	12.624 14.946 17.290 19.650 22.018 24.386
+1000 (+538°) +1100 (+594°) +1200° (+649°) +1300° (+705°) +1400° (+760°) +1500° (+816°)	24.622 26.978 29.315 31.628 33.912	24.858 27.213 29.548 31.857 34.139	25.729 25.094 27.477 29.780 32.087 34.365	25.330 27.681 30.012 32.316 34.591	25.200 25.566 27.915 30.243 32.545 34.817	25.439 25.802 28.149 30.475 32.744 35.043	26.037 28.383 30.706 33.002 35.268	26.273 28.616 30.937 33.230 35.493	26.508 28.849 31.167 33.458 35.718	24.560 26.743 29.082 31.398 33.685 35.942
+1600° (+872°) +1600° (+872°) +1700° (+927°) +1800° (+983°) +1900° (+1038°) +2000° (+1094°)	36.166 38.389 40.581 42.741 44.866	36.390 38.610 40.798 42.955 45.077	36.613 38.830 41.015 43.169 45.287	36.836 39.050 41.232 43.382 45.497	37.059 39.270 41.449 43.595 45.706	37.281 39.489 41.665 43.808 45.915	37.504 39.708 41.881 44.020 46.124	37.725 39.927 42.096 44.232 46.332	37.947 40.145 42.311 44.444 46.540	38.168 40.363 42.526 44.655 46.747
+2100° (+1149°) +2200° (+1205°) +2300° (+1260°) +2400° (+1316°) +2500° (+1372°)	46.954 49.000 51.000 52.952 54.856	27.161 49.202 51.198 53.144	47.367 49.404 51.395 53.336	47.573 49.605 51.591 53.528	47.778 49.806 51.787 53.719	47.983 50.006 51.982 53.910	48.187 50.206 52.177 54.100	48.391 50.405 52.371 54.289	48.595 50.604 52.565 54.479	48.798 50.802 52.759 54.668



Temperature - E.M.F. Tables - I.T.S. 90

Type E (Chrom										
Temperature i	n degrees F	F (C) Refe	erence j	unction at 32°	' F (0°	C) Millivolts	→			
-400° (-240°)	-9.604	-9.672	-9.729	-9.775	-9.809	-9.830				
-300° (-185°)	-8.404	-8.561	-8.710	-8.852	-8.986	-9.112	-9.229	-9.338	-9.436	-9.525
-200° (-129°)	-6.472	-6.692	-6.907	-7.116	-7.319	-7.516	-7.707	-7.891	-8.069	-8.240
-100° (-74°)	-3.976	-4.248	-4.515	-4.777	-5.035	-5.287	-5.535	-5.777	-6.014	-6.246
0° (-18°)	-1.026	-1.339	-1.648	-1.953	-2.255	-2.552	-2.846	-3.135	-3.420	-3.700
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-1.026	-0.709	-0.389	-0.065	0.262	0.591	0.924	1.259	1.597	1.938
+100° (+38°)	2.281	2.628	2.977	3.330	3.685	4.042	4.403	4.766	5.131	5.500
+200° (+94°)	5.871	6.244	6.620	6.998	7.379	7.762	8.147	8.535	8.924	9.316
+300° (+149°)	9.710	10.106	10.503	10.903	11.305	11.708	12.113	12.520	12.929	13.339
+400° (+205°)	13.751	14.164	14.579	14.995	15.413	15.831	16.252	16.673	17.096	17.520
+500° (+260°)	17.945	18.371	18.798	19.227	19.656	20.086	20.517	20.950	21.383	21.817
+600° (+316°)	22.252	22.687	23.124	23.561	23.999	24.437	24.876	25.316	25.757	26.198
+700° (+372°)	26.640	27.082	27.525	27.969	28.413	28.857	29.302	29.747	30.193	30.639
+800° (+427°)	31.086	31.533	31.980	32.427	32.875	33.323	33.772	34.220	34.669	35.118
+900° (+483°)	35.567	36.016	36.466	36.915	37.365	37.815	38.265	38.714	39.164	39.614
+1000° (+538°)	40.064	10.513	40.963	41.412	41.862	42.311	42.760	43.209	43.658	44.107
+1100° (+594°)	44.555	45.004	45.452	45.900	46.347	46.794	47.241	47.688	48.135	48.581
+1200° (+649°)	49.027	49.472	49.917	50.362	50.807	51.251	51.695	52.138	52.581	53.024
+1300° (+705°)	53.466	53.908	54.350	54.791	55.232	55.673	56.113	56.553	56.992	57.431
+1400° (+760°)	57.870	58.308	58.746	59.184	59.621	60.058	60.494	60.930	61.366	61.801
+1500° (+816°)	62.236	62.670	63.104	63.538	63.971	64.403	64.835	65.267	65.698	66.129
+1600° (+872°)	66.559	66.989	67.418	67.846	68.274	68.701	69.128	69.554	69.979	70.404
+1700° (+927°)	70.828	71.252	71.675	72.097	72.518	72.939	73.360	73.780	74.199	74.618
+1800° (+983°)	75.036	75.454	75.872	76.289						

Type S (Platinu Temperature in				nction at 2'	ን°E (በ°C)	Millivolte	· ->			
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.092	-0.064	-0.035	-0.006	0.024	0.055	0.087	0.119	0.153	0.186
+100° (+38°)	0.221	0.256	0.292	0.328	0.365	0.402	0.440	0.479	0.518	0.557
+200° (+94°)	0.597	0.638	0.379	0.720	0.762	0.804	0.847	0.889	0.933	0.977
+300° (+149°)	1.021	1.065	1.110	1.155	1.200	1.246	1.292	1.338	1.385	1.431
+400° (+205°)	1.478	1.526	1.573	1.621	1.669	1.718	1.766	1.815	1.864	1.913
+500° (+260°)	1.962	2.012	2.062	2.111	2.162	2.212	2.262	2.313	2.364	2.415
+600° (+316°)	2.466	2.517	2.568	2.620	2.671	2.723	2.775	2.827	2.880	2.932
+700° (+372°)	2.984	3.037	3.090	3.143	3.196	3.249	3.302	3.355	3.409	3.462
+800° (+427°)	3.516	3.569	3.623	3.677	3.731	3.785	3.840	3.894	3.949	4.003
+900° (+483°)	4.058	4.112	4.167	4.222	4.277	4.332	4.388	4.443	4.498	4.554
+1000° (+538°)	4.609	4.665	4.721	4.777	4.833	4.889	4.945	5.001	5.058	5.114
+1100° (+594°)	5.171	5.227	5.284	5.341	5.398	5.455	5.512	5.569	5.626	5.684
+1200° (+649°)	5.741	5.799	5.857	5.914	5.972	6.030	3.089	6.147	6.205	6.263
+1300° (+705°)	6.322	6.381	6.439	6.498	6.557	6.616	6.675	6.734	6.794	6.853
+1400° (+760°)	6.913	6.973	7.032	7.092	7.152	7.212	7.272	7.333	7.393	7.454
+1500 °(+816°)	7.514	7.575	7.636	7.697	7.758	7.819	7.880	7.942	8.003	8.065
+1600° (+872°)	8.127	8.188	8.250	8.312	8.374	8.437	8.499	8.561	8.624	8.687
+1700° (+927°)	8.749	8.812	8.875	8.938	9.001	9.065	9.128	9.191	9.255	9.319
+1800° (+983°)	9.382	9.446	9.510	9.574	9.638	9.702	9.767	9.831	9.896	9.960
+1900° (+1038°)	10.025	10.090	10.155	10.220	10.285	10.350	10.415	10.481	10.546	10.612
+2000° (+1094°)	10.677	10.743	10.809	10.875	10.941	11.007	11.073	11.139	11.205	11.271
+2100° (+1149°)	11.338	11.404	11.470	11.537	11.603	11.670	11.737	11.803	11.870	11.937
+2200° (+1205°)	12.004	12.071	12.138	12.205	12.272	12.339	12.406	12.473	12.540	12.607
+2300° (+1260°)	12.674	12.741	12.809	12.876	12.943	13.011	13.078	13.145	13.213	13.280
+2400° (+1316°)	13.347	13.415	13.482	13.550	13.617	13.685	13.752	13.819	13.887	13.954
+2500° (+1372°)	14.022	14.089	14.157	14.224	14.291	14.359	14.426	14.494	14.561	14.628
+2600° (+1427°)	14.696	14.763	14.830	14.897	14.964	15.032	15.099	15.166	15.233	15.300
+2700° (+1483°)	15.367	15.434	15.501	15.568	15.635	15.702	15.768	15.835	15.902	15.968
+2800° (+1538°)	16.035	16.101	16.168	16.234	16.301	16.367	16.433	16.499	46.565	16.631
+2900° (+1594°)	16.697	16.763	16.829	16.895	16.961	17.026	17.092	17.157	17.222	17.288
+3000° (+1649°) +3100° (+1705°) +3200° (+1760°)	17.353 17.998 18.609	17.418 18.061 18.667	17.483 18.124	17.548 18.186	17.613 18.248	17.677 18.310	17.742 18.371	17.806 18.431	17.870 18.491	17.934 18.550

Temperature - E.M.F. Tables - I.T.S. 90

Type T (Copper- Temperature in		•	nce junc	tion at 32°I	- (0°C)	Millivolts				
-400° (-240°)	-6.105	-6.150	-6.187	-6.217	-6.240	-6.254				
-300° (-185°)	-5.341	-5.439	-5.532	-5.620	-5.705	-5.785	-5.860	-5.930	-5.994	-6.053
-200° (-129°)	-4.149	-4.286	-4.419	-4.548	-4.673	-4.794	-4.912	-5.025	-5.135	-5.240
-100° (-74°)	-2.581	-2.754	-2.923	-3.089	-3.251	-3.410	-3.565	-3.717	-3.865	-4.009
0° (-18°)	-0.675	-0.879	-1.081	-1.279	-1.475	-1.667	-1.857	-2.043	-2.225	-2.405
Deg. °F (°C)	0°(-18°	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.675	-0.467	-0.256	-0.043	0.173	0.391	0.611	0.834	1.060	1.288
+100° (+38°)	1.519	1.752	1.988	2.227	2.468	2.712	2.958	3.207	3.459	3.712
+200° (+94°)	3.968	4.227	4.487	4.750	5.015	5.282	5.551	5.823	6.096	6.371
+300° (+149°)	6.648	6.928	7.209	7.492	7.777	8.064	8.352	8.643	8.935	9.229
+400° (+205°)	9.525	9.822	10.122	10.423	41.725	11.029	11.335	11.643	11.951	12.262
+500° (+260°)	12.574	12.887	13.202	13.518	13.836	14.155	14.476	14.797	15.120	15.445
+600° (+316°)	15.771	16.098	16.426	46.755	17.086	17.418	17.752	18.086	18.422	18.759
+700° (+372°)	19.097	19.436	19.777	20.118	20.460	20.803				

Type R (Plating Temperature in	um 13% F n degrees	Rhodium-F F (C) Ref	Platinum) erence ju	nction at	32° F (0°	C) Millivo	olts>	-		
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.090	-0.063	-0.035	-0.006	0.024	0.054	0.086	0.118	0.151	0.184
+100° (+38°)	0.218	0.254	0.289	0.326	0.363	0.400	0.439	0.478	0.517	0.557
+200° (+94°)	0.598	0.639	0.681	0.723	0.766	0.809	0.853	0.897	0.941	0.986
+300° (+149°)	1.032	1.078	1.124	1.171	1.218	1.265	1.313	1.361	1.410	1.459
+400° (+205°)	1.508	1.558	1.607	1.658	1.708	1.759	1.810	1.861	1.913	1.965
+500° (+260°)	2.017	2.070	2.122	2.175	2.229	2.282	2.336	2.390	2.444	2.498
+600° (+316°)	2.553	2.608	2.663	2.718	2.773	2.829	2.885	2.941	2.997	3.054
+700° (+372°)	3.110	3.167	3.224	3.281	3.339	3.396	3.454	3.512	3.570	3.628
+800° (+427°)	3.686	3.745	3.803	3.862	3.921	3.980	4.040	4.099	4.159	4.219
+900° (+483°)	4.279	4.339	4.399	4.459	4.520	4.580	4.641	4.702	4.763	4.824
+1000° (+538°)	4.886	4.947	5.009	5.071	5.133	5.195	5.257	5.320	5.382	5.445
+1100° (+594°)	5.508	5.571	5.634	5.697	5.761	5.824	5.888	5.952	6.016	6.080
+1200° (+649°)	6.144	6.209	6.273	6.338	6.403	6.468	6.533	6.598	6.664	6.730
+1300° (+705°)	6.795	6.861	6.927	6.994	7.060	7.126	7.193	7.260	7.327	7.394
+1400° (+760°)	7.461	7.529	7.596	7.64	7.732	7.800	7.868	7.936	8.005	8.073
+1500° (+816°)	8.142	8.211	8.280	8.349	8.418	8.488	8.557	8.627	8.697	8.767
+1600° (+872°)	8.837	8.908	8.978	9.049	9.120	9.191	9.262	9.333	9.404	9.476
+1700° (+927°)	9.547	9.619	9.691	9.763	9.835	9.908	9.980	10.053	10.126	10.198
+1800° (+983°)	10.271	10.345	10.418	10.491	10.565	10.638	10.712	10.786	10.860	10.934
+1900° (+1038°)	11.009	11.083	11.158	11.233	11.307	11.382	11.457	11.533	11.608	11.683
+2000° (+1094°)	11.759	11.835	11.910	11.986	12.062	12.138	12.214	12.291	12.367	12.443
+2100° (+1149°)	12.520	12.597	12.673	12.750	12.827	12.904	12.981	13.058	13.135	13.213
+2200° (+1205°)	13.290	13.367	13.445	13.522	13.600	13.677	13.755	13.833	13.911	13.989
+2300° (+1260°)	14.066	14.144	14.222	14.300	14.379	14.457	14.535	14.613	14.691	14.770
+2400° (+1316°)	14.848	14.926	15.005	15.083	15.161	15.240	15.318	15.397	15.475	15.553
+2500° (+1372°)	15.632	15.710	15.789	15.867	15.946	16.024	16.103	16.181	16.260	16.338
+2600° (+1427°)	16.417	16.495	16.574	16.652	16.731	16.809	16.887	16.966	17.044	17.122
+2700° (+1483°)	17.200	17.279	17.357	17.435	17.513	17.591	17.669	17.747	17.825	17.903
+2800° (+1538°)	17.981	18.059	18.137	18.214	18.292	18.369	18.447	18.524	18.602	18.679
+2900° (+1594°)	18.756	18.834	18.911	18.988	19.065	19.141	19.218	19.295	19.372	19.448
+3000° (+1649°) +3100° (+1760°) +3200° (+1760°)	19.525 20.281 21.003	19.601 20.356 21.071	19.677 20.430	19.753 20.503	19.829 20.576	19.905 20.649	19.981 20.721	20.056 20.792	20.132 20.863	20.207 20.933



Temperature - E.M.F. Tables - I.T.S. 90

Type B (Platin						\\ B #*****				
Temperature i	n degrees 0°(-18°)	10°(-13°)	erence ju 20°(-7°)	unction at 30°(-2°)	32°F (U°C 40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.001	-0.002	-0.002	-0.003	-0.002	-0.002	, ,			, ,
+100° (+38°) +200° (+94°)	-0.001 0.027	0.000 0.032	0.002 0.037	0.004 0.043	0.006 0.049	0.009 0.055	0.012 0.061	0.015 0.068	0.019 0.075	0.023 0.083
+300° (+149°)	0.027	0.032	0.037	0.043	0.049	0.055	0.061	0.066	0.075	0.063
+400° (+205°)	0.030	0.199	0.107	0.223	0.123	0.133	0.143	0.133	0.103	0.303
+500° (+260°)	0.317	0.332	0.347	0.362	0.378	0.394	0.411	0.427	0.444	0.462
+600° (+316°)	0.479	0.497	0.516	0.534	0.553	0.572	0.592	0.612	0.632	0.653
+700° (+372°) +800° (+427°)	0.673 0.898	0.694 0.923	0.716 0.947	0.738 0.972	0.760 0.997	0.782 1.022	0.805 1.048	0.828 1.074	0.851 1.100	0.875 1.127
+900° (+483°)	1.154	1.181	1.208	1.236	1.264	1.293	1.321	1.350	1.379	1.409
+1000° (+538°)	1.439	1.469	1.499	1.530	1.561	1.592	1.624	1.655	1.687	1.720
+1100° (+594°)	1.752	1.785	1.818	1.852	1.886	1.920	1.954	1.988	2.023	2.058
+1200° (+649°) +1300° (+705°)	2.094 2.461	2.129 2.499	2.165 2.538	2.201 2.576	2.237 2.615	2.274 2.654	2.311 2.694	2.348 2.734	2.385 2.774	2.423 2.814
+1400° (+760°)	2.854	5.895	2.936	2.978	3.019	3.061	3.103	3.145	3.188	3.230
+1500° (+816°)	3.273	3.317	3.360	3.404	3.448	3.492	3.537	3.581	3.626	3.672
+1600° (+872°)	3.717	3.763	3.809	3.855	3.901	3.948	3.994	4.014	4.089	4.136
+1700° (+927°) +1800° (+983°)	4.184 4.673	4.232 4.723	4.280 4.774	4.328 4.824	4.377 4.875	4.426 4.926	4.475 4.977	4.524 5.028	4.574 5.080	4.623 5.132
+1000 (+965) +1900° (+1038°)	5.184	5.236	5.288	5.341	5.394	4.926 5.447	5.500	5.553	5.607	5.132
+2000° (+1094°)	5.715	5.769	5.823	5.878	5.932	5.987	6.042	6.098	6.153	6.209
+2100° (+1149°)	6.624	6.320	6.377	6.433	6.490	6.546	6.603	6.660	6.718	6.775
+2200° (+1205°) +2300° (+1260°)	6.833 7.417	6.890 7.477	6.948 4.536	7.006 7.596	7.065 7.656	7.123 7.716	7.182 7.776	7.240 7.836	7.299 7.897	7.358 7.957
+2400° (+1316°)	8.018	8.079	8.140	8.201	8.262	8.323	8.385	8.446	8.508	8.570
+2500° (+1372°)	8.632	8.694	8.756	8.819	8.881	8.944	9.006	9.069	9.132	9.195
+2600° (+1427°)	9.258	9.321	9.385	9.448	9.511	9.575	9.639	9.702	9.766	9.830
+2700° (+1483°)	9.894	9.958	10.022	10.086	10.150	10.215	10.279	10.344	10.408	10.473
+2800° (+1538°) +2900° (+1594°)	10.537 11.185	10.602 11.250	10.666 11.315	10.731 11.380	10.796 11.445	10.861 11.510	10.925 11.575	10.990 11.640	11.055 11.705	11.120 11.770
+3000° (+1649°)	11.835	11.900	11.965	12.030	12.095	12.160	12.225	12.290	12.355	12.420
+3100° (+1705°)	12.484	12.549	12.614	12.679	12.743	12.808	12.872	12.937	13.001	13.066
+3200° (+1760°) +3300° (+1816°)	13.130 13.769	13.194	13.259	13.323	13.387	13.451	13.515	13.579	13.642	13.706

Temperature - E.M.F. Tables

Type W (Tun Temperature	gsten-Ti e in degi	ungsten rees F ((26% RI C) Refer	nenium) ence jui	oction at 3	32°F (0°C) N	lillivolts	→			
Deg. °F (°C)	0°(-18°)	20°(-7°)	40°(5°)	60°(16°)	80°(27°)	Deg. °F (°C)	0°(-18°)	20°(-7°)	40°(5°)	60°(16°)	80°(27°)
0° (-18°)	016	007	0.006	0.026	0.050	+2200°	18.701	18.936	19.170	19.405	19.639
+100° (+38°)	0.079	0.113	0.153	0.197	0.246	+2300°	19.873	20.106	20.340	20.573	20.806
+200° (+94°)	0.299	0.357	0.420	0.487	0.559	+2400°	21.038	21.270	21.502	21.734	21.965
+300° (+149°)	0.634	0.714	0.799	0.887	0.979	+2500°	22.195	22.425	22.655	22.884	23.113
+400° (+205°)	1.075	1.175	1.279	1.387	1.498	+2600°	23.341	23.569	23.796	24.023	24.249
+500° (+260°)	1.613	1.731	1.853	1.978	2.106	+2700°	24.474	24.699	24.923	25.146	25.369
+600° (+316°)	2.238	2.373	2.511	2.652	2.796	+2800°	25.591	25.812	26.033	26.253	26.472
+700° (+372°)	2.943	3.093	3.246	3.401	3.559	+2900°	26.690	26.907	27.124	27.340	27.555
+800° (+427°)	3.720	3.884	4.049	4.218	4.389	+3000°	37.769	27.983	28.195	28.407	28.618
+900° (+483°)	4.562	4.737	4.915	5.095	5.277	+3100°	28.827	29.036	29.244	29.451	29.657
+1000° (+538°)	5.461	5.647	5.836	6.026	6.218	+3200°	29.862	30.066	30.269	30.471	30.672
+1100° (+594°)	6.412	6.607	6.805	7.004	7.205	+3300°	30.871	31.070	31.268	31.464	31.660
+1200° (+649°)	7.407	7.611	7.816	8.023	8.232	+3400°	31.854	32.047	32.240	32.430	32.620
+1300° (+705°)	8.441	8.652	8.865	9.078	9.293	+3500°	32.809	32.996	33.182	33.367	33.551
+1400° (+760°)	9.509	9.726	9.945	10.164	10.384	+3600°	33.733	33.914	34.094	34.273	34.450
+1500° (+816°)	10.606	10.828	11.051	11.275	11.500	+3700°	34.626	34.801	34.974	35.146	35.317
+1600° (+872°)	11.725	11.952	12.179	12.407	12.635	+3800°	35.486	35.654	35.821	35.986	36.150
+1700° (+927°)	12.864	13.094	13.324	13.555	13.786	+3900°	36.312	36.473	36.632	36.790	36.946
+1800° (+983°)	14.018	14.250	14.482	14.715	14.948	+4000°	37.101	37.254	37.406	37.557	37.705
+1900° (+1038°)	15.182	15.415	15.649	15.884	16.118	+4100°	37.853	37.998	38.142	38.285	38.425
+2000° (+1094°)	16.353	16.587	16.822	17.057	17.292	+4200°	38.564				
+2100° (+1149°)	17.527	17.762	17.997	18.232	18.467						

Temperature - E.M.F. Tables

Type W3 (Tun										
Temperature i	in degree	s F (C) R	eference	junction	at 32°F (0	O°C) Milli	volts			
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	_	_	_	_	0.043	0.098	0.154	0.211	0.269	0.329
+100° (+38°)	0.390	0.452	0.515	0.579	0.644	0.711	0.778	0.847	0.916	0.987
+200° (+94°)	1.058	1.130	1.204	1.278	1.354	1.430	1.507	1.585	1.664	1.743
+300° (+149°)	1.824	1.905	1.988	2.071	2.154	2.239	2.324	2.410	2.497	2.584
+400° (+205°)	2.673	2.761	2.851	2.941	3.032	3.123	3.216	3.308	3.402	3.495
+500° (+260°)	3.590	3.685	3.781	3.877	3.973	4.071	4.168	4.267	4.365	4.464
+600° (+316°)	4.564	4.664	4.765	4.866	4.967	5.069	5.171	5.274	5.377	5.480
+700° (+372°)	5.584	5.688	5.793	5.898	6.003	6.108	6.214	6.320	6.427	6.53
+800° (+427°)	6.640	6.748	6.855	6.963	7.071	7.180	7.288	7.397	7.506	7.615
+900° (+483°)	7.725	7.835	7.945	8.055	8.165	8.275	8.386	8.497	8.608	8.719
+1000° (+538°)	8.830	8.942	9.053	9.165	9.277	9.389	9.501	9.613	9.726	9.838
+1100° (+594°)	9.951	10.063	10.176	10.289	10.402	40.514	10.628	10.741	10.854	10.967
+1200° (+649°)	11.080	11.194	11.307	11.420	11.534	11.647	11.761	11.874	11.988	12.102
+1300° (+705°)	12.215	12.329	12.443	12.556	12.670	12.784	12.897	13.011	13.125	13.238
+1400° (+760°)	13.352	13.466	13.579	13.693	13.807	13.920	14.034	14.148	14.262	14.376
+1500° (+816°)	14.489	14.603	14.717	14.830	14.944	15.057	15.171	15.284	15.398	15.511
+1600° (+872°)	15.624	15.737	15.850	15.963	16.076	16.189	16.302	16.414	16.527	16.639
+1700° (+927°)	16.752	16.864	16.976	17.088	17.200	17.312	17.424	17.536	17.647	17.759
+1800° (+983°)	17.870	17.982	18.093	18.204	18.315	18.426	18.537	18.647	18.758	18.868
+1900° (+1038°)	18.979	19.089	19.199	19.309	19.419	19.528	19.638	19.747	19.857	19.966
+2000° (+1094°)	20.075	20.184	20.293	20.401	20.510	20.618	20.726	20.835	20.943	21.050
+2100° (+1149°)	21.158	21.266	21.373	21.480	21.588	21.695	21.802	21.908	22.015	22.121
+2200° (+1205°)	22.228	22.334	22.440	22.546	22.651	22.757	22.863	22.968	23.073	23.178
+2300° (+1260°)	23.283	23.388	23.492	23.596	23.701	23.805	23.909	24.013	24.116	24.220
+2400° (+1316°)	24.323	24.426	24.529	24.632	24.735	24.838	24.940	25.042	25.145	25.246
+2500° (+1372°)	25.348	25.450	25.551	25.653	25.754	25.855	25.956	26.057	26.157	26.258
+2600° (+1427°)	26.358	26.458	26.558	26.658	26.757	26.857	26.956	27.055	27.154	27.253
+2700° (+1483°)	27.352	27.450	27.548	27.647	27.745	27.842	27.940	28.038	28.135	28.232
+2800° (+1538°)	28.329	28.426	28.523	28.619	28.715	28.812	28.908	29.003	29.099	29.194
+2900° (+1594°)	29.290	29.385	29.480	29.575	29.669	29.764	29.858	29.958	30.046	30.139
+3000° (+1649°)	30.233	30.326	30.419	30.512	30.605	30.698	30.790	30.882	30.974	31.066
+3100° (+1705°)	31.158	31.249	31.340	31.432	31.522	31.613	31.703	31.794	31.884	31.974
+3200° (+1760°)	32.063	32.153	32.242	32.331	32.420	32.508	32.596	32.685	32.772	32.860
+3300° (+1816°)	32.948	33.035	33.122	33.209	33.295	33.381	33.467	33.553	33.369	33.724
+3400° (+1872°)	33.809	33.894	33.979	34.063	34.147	34.231	34.314	34.398	34.481	34.563
+3500° (+1927°)	34.646	34.728	34.810	34.892	34.973	35.054	35.135	35.215	35.295	35.375
+3600° (+1983°)	35.455	35.534	35.613	35.692	35.770	35.848	35.926	36.003	36.080	36.157
+3700° (+2038°)	36.233	36.309	36.384	36.460	36.535	36.609	36.683	36.757	36.831	36.904
+3800° (+2094°)	36.976	37.049	37.120	37.192	37.263	37.334	37.404	37.474	37.543	37.612
+3900° (+2149°)	37.681	37.749	37.816	37.884	37.950	38.017	38.082	38.148	38.213	38.277
+4000° (+2205°)	38.341	38.404	38.467	38.530	38.591	38.653	38.714	38.774	38.834	38.893
+4100° (+2260°)	38.951	39.009	39.067	39.124	39.180	39.236	39.291	39.346	39.400	39.453
+4200° (+2316°)	39.506									



Temperature - E.M.F. Tables

Type W5 (Tung Temperature in						C) Millivo	lts →			
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-	-	-		0.060	0.135	0.211	0.288	0.366	0.444
+100° (+38°) +200° (+94°)	0.523 1.348	0.602 1.434	0.683 1.520	0.764 1.607	0.845 1.695	0.927 1.783	1.010 1.872	1.094 1.961	1.178 2.051	1.263 2.141
+300° (+149°)	2.232	2.323	2.415	2.507	2.600	2.693	2.787	2.881	2.975	3.070
+400° (+205°)	3.166	3.261	3.358	3.454	3.551	3.648	3.746	3.844	3.943	4.041
+500° (+260°)	4.141	4.240	4.340	4.440	4.540	4.641	4.742	4.844	4.945	5.047
+600° (+316°)	5.149	5.252	5.354	5.457	5.560	5.664	5.768	5.871	5.976	6.080
+700° (+372°)	6.185	6.289	6.394	6.499	6.605	6.710	6.816	6.922	7.028	7.134
+800° (+427°)	7.240	7.347	7.453	7.560	7.667	7.774	7.881	7.988	8.096	8.203
+900° (+483°) +1000° (+538°)	8.311 9.391	8.418 9.499	8.526 9.607	8.634 9.716	8.742 9.824	8.850 9.993	8.958 10.041	9.066 10.150	9.174 10.259	9.282 10.367
+1100° (+594°)	10.476	10.584	10.693	10.802	10.910	11.019	11.128	11.236	11.345	11.453
+1200° (+649°)	11.562	11.670	11.779	11.887	11.996	12.104	12.212	12.321	12.429	12.537
+1300° (+705°)	13.645	12.753	12.861	12.969	13.077	13.185	13.293	13.401	13.508	13.616
+1400° (+760°)	13.723	13.831	13.938	14.045	14.152	14.259	14.366	14.473	14.580	14.686
+1500° (+816°)	14.793	14.899	15.005	15.112	15.218	15.324	15.429	15.535	15.641	15.746
+1600° (+872°)	15.852	15.957	16.062	16.167	16.272	16.376	16.481	16.585	16.690	16.794
+1700° (+927°) +1800° (+983°)	16.898 17.930	17.002 18.033	17.106 18.135	17.209 18.237	17.313 18.339	17.416 18.441	17.519 18.542	17.622 18.644	17.725 18.745	17.828 18.846
+1800° (+983°) +1900° (+1038°)	17.930	19.048	19.149	18.237	19.349	19.449	18.542	18.644	18.745	19.848
+2000° (+1094°)	19.948	20.047	20.146	20.244	20.343	20.441	20.540	20.638	20.736	20.833
+2100° (+1149°)	20.931	21.028	21.125	21.222	21.319	21.416	21.512	21.609	21.705	21.801
+2200° (+1205°)	21.896	21.992	22.087	22.182	22.277	22.372	22.467	22.561	22.656	22.750
+2300° (+1260°)	22.844	22.937	23.031	23.124	23.217	23.310	23.403	23.496	23.588	23.680
+2400° (+1360°)	23.772	23.864	23.956	24.047	24.139	24.230	24.321	24.412	24.502	24.593
+2500° (+1372°) +2600° (+1427°)	24.683 25.574	24.773 25.662	24.863 25.750	24.952 25.838	25.042 25.926	25.131 26.013	25.220 26.100	25.309 26.187	25.397 26.274	25.486 26.361
+2700° (+1483°)	26.447	26.553	26.620	26.705	26.791	26.877	26.962	27.047	27.132	27.217
+2800° (+1538°)	27.301	27.386	27.470	27.554	27.638	27.722	27.805	27.888	27.102	28.054
+2900° (+1594°)	28.137	28.219	28.302	28.384	28.466	28.548	28.629	28.711	28.792	28.873
+3000° (+1649°)	28.954	29.034	29.115	29.195	29.275	29.355	29.435	29.514	29.593	29.673
+3100° (+1705°)	29.752	29.830	29.909	29.987	30.065	30.143	30.221	30.299	30.376	30.453
+3200° (+1760°)	30.530	30.607	30.684	30.760	30.736	30.912	30.98	31.064	34.139	31.214
+3300° (+1816°) +3400° (+1872°)	31.289 32.028	31.364 32.101	31.439 32.174	31.513 32.246	31.587 32.318	31.661 32.390	31.735 32.462	31.809 32.533	31.882 32.604	31.955 32.675
+3500° (+1927°)	32.746	32.101	32.174	32.958	33.027	33.097	33.167	33.236	33.305	33.374
+3600° (+1983°)	33.443	33.511	33.579	33.647	33.715	33.782	33.849	33.916	33.983	34.049
+3700° (+2038°)	34.116	34.182	34.247	34.313	34.378	34.443	34.508	34.572	34.636	34.700
+3800° (+2094°)	34.764	34.827	34.890	34.953	35.016	35.078	35.140	35.202	35.263	35.325
+3900° (+2149°)	35.386	35.446	35.506	35.567	35.626	35.686	35.745	35.804	35.862	35.920
+4000° (+2205°) +4100° (+2260°)	35.978 36.540	36.036 36.594	36.093 36.648	36.150 36.701	36.207 36.755	36.263 36.808	36.319 36.860	36.375 36.912	36.430 36.964	36.485 37.015
+4100 (+2200) +4200° (+2316°)	36.540 37.066	30.334	30.040	30.701	30.733	30.000	30.000	30.912	30.904	37.013

Temperature - E.M.F. Tables - I.T.S. 90

Type N (Nicros Temperature i		s F (C) Re	eference ju	inction at	32° F (0°	C) Millivo	olts ->			
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.461	-0.318	-0.174	-0.029	0.116	0.261	0.407	0.555	0.703	0.853
+100° (+38°)	1.004	1.156	1.309	1.463	1.619	1.776	1.934	2.093	2.253	2.415
+200° (+94°)	2.577	2.741	2.906	3.072	3.240	3.408	3.578	3.748	3.920	4.093
+300° (+149°)	4.267	4.442	4.618	4.795	4.973	5.152	5.332	5.512	5.694	5.877
+400° (+205°)	6.060	6.245	6.430	6.616	6.803	6.991	7.179	7.369	7.559	7.750
+500° (+260°)	7.941	8.134	8.327	8.520	8.715	8.910	9.105	9.302	9.499	9.696
+600° (+316°)	9.895	10.093	10.293	10.493	10.693	10.894	11.096	11.298	11.501	11.704
+700° (+372°)	11.907	12.111	12.306	12.521	12.726	12.932	13.139	13.346	13.553	13.760
+800° (+427°)	13.969	14.177	14.386	14.595	14.804	15.014	15.225	15.435	16.646	15.857
+900° (+483°)	16.069	16.281	16.493	16.705	16.918	17.131	17.344	17.558	17.772	17.986
+1000° (+538°)	18.200	18.414	18.629	18.844	19.059	19.274	19.490	19.705	19.921	20.137
+1100° (+594°)	20.353	20.570	20.786	21.003	21.220	21.437	21.654	21.871	22.088	22.305
+1200° (+649°)	22.523	22.740	22.958	23.176	23.393	23.611	23.829	24.047	24.265	24.483
+1300° (+705°)	24.701	24.919	25.137	25.356	25.574	25.792	26.010	26.229	26.447	26.665
+1400° (+760°)	26.883	27.102	27.320	27.538	27.756	27.975	28.193	28.411	28.629	28.847
+1500° (+816°)	29.065	29.283	29.501	29.719	29.937	30.154	30.372	30.590	30.807	31.025
+1600° (+872°)	31.242	31.459	31.677	31.894	32.111	32.328	32.545	32.761	32.978	33.195
+1700° (+927°)	33.411	33.627	33.844	34.060	34.276	34.491	34.707	34.923	35.138	35.353
+1800° (+983°)	35.568	35.783	35.998	36.213	36.427	36.641	36.855	37.069	37.283	37.497
+1900° (+1038°)	37.710	37.923	38.136	38.349	38.562	38.774	38.986	39.198	39.410	39.622
+2000° (+1094°)	39.833	40.044	40.255	40.466	40.677	40.887	41.097	41.307	41.516	41.725
+2100° (+1149°) +2200° (+1205°) +2300° (+1260°)	41.935 44.012 46.060	42.143 44.218 46.263	42.352 44.424 46.466	42.560 44.629 46.668	42.768 44.835 46.870	42.976 45.040 47.071	43.184 45.245 47.272	43.391 45.449 47.473	43.598 45.653	43.805 45.857

		IN THE EN		WD ED	WAL		0.0		201
hermoelement	JP	JN,TN, EN	TP	KP, EP	KN	RP	SP	BP	BN
emperature, °C				Seebe	ck Coefficient,	, μV/°C			
-190	+6.3	-20.9	-4.1	_	_	_	_	_	_
-100	14.4	27.0	+1.1	_	_	_	_	_	_
0	17.8	32.2	5.9	+25.7	-13.5	+5.5	+5.5	_	_
200	14.6	41.0	12.0	32.7	7.4	8.5	8.5	+9.2	+7.2
400	9.7	45.5	16.2	34.6	7.7	10.5	9.5	11.7	7.6
600	11.7	46.8	_	33.8	8.8	11.5	10.0	13.8	7.9
800	17.8	46.4	_	32.2	8.8	12.5	11.0	15.8	8.2
1000	-	-	_	30.8	8.3	13.0	11.5	17.7	8.5
1200	_	-	_	29.1	7.4	14.0	12.0	19.1	8.7
1400	_	_	_	_	_	14.0	12.0	19.1	8.7
1600	-	-	-	-	_	13.5	12.0	20.4	8.7
Temperature, °F				Seebec	ck Coefficient,	μV/°F			
-300	+2.5	-11.9	-2.1	_	_	_	_	_	_
-200	6.7	14.0	+0.2	_	_	_	_	_	_
-100	8.8	15.8	1.5	_	_	_	_	_	_
32	9.9	17.9	3.3	+14.3	-7.5	+3.0	+3.0	_	_
200	9.6	20.5	5.0	16.7	6.5	4.1	4.0	+4.1	+3.6
400	8.0	22.9	6.7	18.3	4.0	4.9	4.7	5.1	4.0
600	6.2	24.5	8.2	19.0	4.1	5.5	5.2	5.8	4.2
800	5.3	25.3	_	19.1	4.4	5.8	5.4	6.5	4.2
1000	5.7	26.0	_	18.9	4.8	6.2	5.5	7.4	4.3
1500	9.9	25.8	_	17.8	4.9	6.8	6.1	8.8	4.6
2000	-	-	_	16.7	4.3	7.6	6.6	10.2	4.8
2500	-	_	_	14.9	4.0	7.7	6.7	11.0	4.9
3000						7.6	6.5	11.3	4.9



Selection Guide for Protection Tubes

Application	Protection Tube Material	Application	Protection Tube Material		
Heal Treating		Glass			
Annealing		For hearths and feeders	Platinum thimble		
Up to 1300°F (704°C)	Wrought iron	Lehrs	Wrought iron		
Over 1300°F (704°C)	28% chrome iron or Inconel®	Tanks	-		
Carburizing hardening Up to 1500°F (816°C)	Wrought iron or 28% chrome iron	Roof and wall	Ceramic		
1500 to 2000°F (1093°C)	28% chrome iron or Inconel	Flues and checkers	28% chrome iron, Inconel		
Over 2000°F (1093°C)	Ceramic	Paper			
Nitriding salt baths	000/	Digesters	Type 316 stainless steel,		
Cyanide Neutral	28% chrome iron Nickel		28% chrome iron		
High speed	Ceramic	Petroleum			
Iron and steel		Dewaxing	Type 304 stainless steel or carbon steel		
Basic oxygen furnace	Quartz	Towers	Type 304 stainless steel or		
Blast furnaces		TOWEIS	carbon steel		
Downcomer	Inconel, 28% chrome iron	Transfer lines	Type 304 stainless steel or		
Stove Dome	Silicon carbide		carbon steel		
Hot blast main Stove trunk	Inconel Inconel	Fractionating column	Type 304 stainless steel or		
Stove dutlet flue	Wrought iron		carbon steel		
Open hearth		Bridgewall	Type 304 stainless steel or		
Flues and stack	Inconel, 28% chrome iron	Power	carbon steel		
Checkers Waste heat boiler	Inconel, Cermet 28% chrome iron, Inconel	Coal-air mixtures	Type 304 stainless steel		
Billet heating slab heating	26 % CHIOTHE HOH, INCOHEI	Flue gases	Wrought iron or 28% chrome iron		
and butt welding		Preheaters	Wrought iron or 28% chrome iron		
Up to 2000°F (1093°C)	28% chrome iron, Inconel	Steel lines	Type 347 or 316 stainless steel		
Over 2000°F (1093°C)	Ceramic, silicon carbide	Water lines	Carbon steel		
Bright annealing batch	Not required	Boiler tubes	Type 309 or 310 stainless steel		
Top work temperature	Not required (use bare Type J thermocouple)	Gas producers	71		
Bottom work temperature	28% Chrome iron	Gas producers Producer gas	28% chrome iron		
Continuous furnace section	Inconel, ceramic	Water gas	20 % CHIOTTIE HOTT		
Forging	Silicon carbide, ceramic	carburetor	Inconel, 28% chrome iron		
Soaking pits		Super heater	Inconel, 28% chrome iron		
Up to 2000°F (1093°C)	Inconel	Tar stills	Carbon steel		
Over 2000°F (1093°C)	Ceramic, silicon carbide	Incinerators			
Nonferrous metals		Up to 2000°F (1093°C)	28% chrome iron, Inconel		
Aluminum	0	Over 2000°F (1093°C)	Ceramic (primary)		
Melting Heat treating	Cast iron (white-washed) Wrought iron	(,	Silicon carbide (secondary)		
Brass or bronze	Not required	Food			
Diago of Biolizo	(use dip-type thermocouple)	Baking ovens	Wrought iron		
Lead	28% chrome iron, wrought iron	Charretort, sugar	Wrought iron		
Magnesium	Wrought iron, cast iron	Vegetables and fruit	Type 304 stainless steel		
Tin	Extra heavy carbon steel	Sanitary	Type 316 stainless steel		
Zinc	Extra heavy carbon steel	Chemical			
Pickling tanks	Chemical lead	Acetic acid			
Cement:		10 to 50%, 70°F	Type 304 stainless steel		
Exit flues	Inconel, 28% chrome iron	50%, 212°	Type 316 stainless steel		
Kilns-heating zone	Inconel	99%, 70 to 212°F	Type 430 stainless steel		
Ceramic: Kilns	Ceramic and silicon carbide	Alcohol, ethyl, methyl 70 to 212°F	Type 304 stainless steel		
Dryers	Wrought iron, silicon carbide	Ammonia	Type out stall liess steel		
Vitreous enameling	Inconel, 28% chrome iron	All concentration, 70°F	Type 304 stainless steel		
Throods charlishing	11001101, 2070 011101110 11011		×1		



Selection Guide for Protection Tubes

Application Chemical	Protection Tube Material	Application Chemical	Protection Tube Material
Ammonium chloride All concentration, 212°F (100°C)	Type 304 stainless steel	Ferric sulphate 5%, 70°F (22°C)	Type 304 stainless steel
Ammonium nitrate	Type 304 stailliess steel	Ferrous sulphate Dilute 70°F (22°C)	Type 304 stainless steel
All concentration, 70 to 212°F (22 to 100°C)	Type 304 stainless steel	Formaldehyde Formic acid	Type 304 stainless steel
Ammonium sulphate 10% to saturated, 212°F (100°C)	Type 316 stainless steel	5%, 70 to 150°F (22 to 66°C)	Type 304 stainless steel
	Type 3 to stairliess steel	Freon	Monel
Barium chloride All concentration, 70°F (22°C)	Monel®	Gallic acid 5%, 70 to 150°F	
Barium hydroxide	Moriei	(22 to 66°C)	Monel
All concentration, 70°F (22°C)	Carbon steel	Gasoline 70°F (22°C)	Type 304 stainless steel
		Glucose	•
Barium sulfate Brines	Nichrome Monel	70°F (22°C) Glycerine	Type 304 stainless steel
Bromine	Tantalum	70°F (22°C)	Type 304 stainless steel
Butadiene	Type 304 stainless steel	Glycerol	Type 304 stainless steel
Butane	Type 304 stainless steel	Hydrobromic acid	Type 304 stairliess steel
Butylacetate	Monel	98%, 212°F (100°C)	Hastelloy B
Butyl alcohol	Copper	Hydrochloric acid	,
Calcium chlorate		1%, 5%, 70°F (22°C)	Hastelloy C
Dilute, 70 to 150°F		1%, 5%, 212°F (100°C)	Hastelloy B
(22 to 66°C)	Type 304 stainless steel	25%, 70 to 212°F	
Calcium hydroxide		(22 to 100°)	Hastelloy B
10 to 20%, 212°F (100°C)		Hydrofluoric acid	Hastelloy C
50%, 212°F (100°C) Carbolic acid	Type 316 stainless steel	Hydrogen peroxide 70 to 212°F (22 to 100°)	Type 316 stainless steel
All 212°F (100°C) Carbon dioxide	Type 316 stainless steel	Hydrogen sulphide Wet and dry	Type 316 stainless steel
wet or dry Chlorine gas	2017-T4 aluminum, Monel	lodine 70°F (22°C)	Tantalum
Dry, 70°F (22°C) Moist, 20 to 212°F	Type 316 stainless steel	Lactic acid	
(-7 to 100°C) Chromic acid	Hastelloy® C	5%, 70°F (22°C) 5%, 150°F (66°C)	Type 304 stainless steel Type 304 stainless steel
10 to 50%, 212°F (100°C)	Type 315 stainless steel	10%, 212°F (100°C) Magnesium chloride	Tantalum
Citric acid 15%, 70°F (22°C)	Type 304 stainless steel	5%, 70°F (22°C) 5%, 212°F (100°C)	Monel Nickel
15%, 212°F (100°C) Concentrated,	Type 315 stainless steel	Magnesium sulphate Hot and cold	Monel
212°F (100°C)	Type 316 stainless steel	Muriatic acid	
Copper nitrate	Type 304 stainless steel	70°F (22°C)	Tantalum
Copper sulphate	Type 304 stainless steel	Naphtha	
Cresols	Type 304 stainless steel	70°F (22°C)	Type 304 stainless steel
Cyanogen gas	Type 304 stainless steel	Natural gas	
DOWTHERM™	Carbon steel	70°F (22°C)	Type 304 stainless steel
Ether	Type 304 stainless steel	Nickel chloride	Tuna 204 stainless staal
Ethyl acetate	Monel	70°F (22°C)	Type 304 stainless steel
Ethyl chloride 70°F (22°C)	Type 304 stainless steel	Nickel sulphate Hot and cold	Type 304 stainless steel
Ethyl sulphate	March 1	Nitric acid	T
70°F (22°C)	Monel	5%, 70°F (22°C) 20%, 70°F (22°C)	Type 304 stainless steel Type 304 stainless steel
Ferric chloride 5%, 70°F (22°C) to boiling	Tantalum	50%, 70 F (22°C)	Type 304 stainless steel
576, 70 1 (22 G) to boiling	rantalum	50%, 212°F (100°C) 65%, 212°F (100°C)	Type 304 stainless steel Type 316 stainless steel



Selection Guide for Protection Tubes

Application	Protection Tube Material	Application	Protection Tube Material
Chemical		Chemical	
Nitric acid		Salicylic acid	Nickel
Concentrated, 70°F (22°C Concentrated,	c) Type 304 stainless steel	Sodium bicarbonate All concentration,	
212°F (100°C) Nitrobenzene	Tantalum	70°F (22°C) Saturated, 70 to 212°F	Type 304 stainless steel
70°F (22°C) Oleic acid	Type 304 stainless steel	(22 to 100°C) Sodium carbonate	Type 304 stainless steel
70°F (22°C) Oleum	Type 316 stainless steel	5%, 70 to 150°F (22 to 66°C)	Type 304 stainless steel
70°F (22°C) Oxalic acid	Type 316 stainless steel	Sodium chloride 5%, 70 to 150°F	
5%, hot and cold 10%, 212°F (100°C)	Type 304 stainless steel Monel	(22 to 66°C) Saturated, 70 to 212°F (22 to 100°C)	Type 316 stainless steel Type 316 stainless steel
Oxygen 70°F (100°C)	Steel	Sodium fluoride 5%, 70°F (22°C)	Monel
Liquid Elevated temperatures	Stainless steel Stainless steel	Sodium hydroxide	Type 304 stainless steel
Palmitic acid	Type 316 stainless steel	Sodium hypochlorite 5% still	Type 316 stainless steel
Pentane Phenol	Type 304 stainless steel Type 304 stainless steel	Sodium nitrate	Type o to stairliess steel
Phosphoric acid	Type 304 stairliess steel	fused	Type 316 stainless steel
1%, 5%, 70°F (22°C)	Type 304 stainless steel	Sodium peroxide Sodium sulphate	Type 304 stainless steel
10%, 70°F (22°C) 10%, 212°F (100°C) 30%, 70°F, 212°F	Type 316 stainless steel Hastelloy® C	70°F (22°C) Sodium sulphide	Type 304 stainless steel
(22°C,100°C) 85%, 70°F, 212°F	Hastelloy B	70°F (22°C) Sodium sulphite	Type 316 stainless steel
(22°C, 100°C)	Hastelloy B	150°F (66°C)	Type 304 stainless steel
Picric acid 70°F (22°C) Potassium bromide	Type 304 stainless steel	Sulphur dioxide Moist gas, 70°F (22°C) Gas, 575°F (302°C)	Type 316 stainless steel Type 304 stainless steel
70°F (22°C)	Type 316 stainless steel	Sulphur	•
Potassium carbonate 70°F (22°C)	Type 304 stainless steel	Dry-molten Wet	Type 304 stainless steel Type 316 stainless steel
Potassium chlorate 70°F (22°C)	Type 304 stainless steel	Sulphuric acid 5%, 70 to 212°F	Hashallari D
Potassium hydroxide 5%, 70°F (22°C)	Type 304 stainless steel	(22 to 100°C) 10%, 70 to 212°F (22 to 100°C)	Hastelloy B Hastelloy B
25%, 212°F (100°C) 60%, 212°F (100°C)	Type 304 stainless steel Type 316 stainless steel	50%, 70 to 212°F (22 to 100°C)	Hastelloy B
Potassium nitrate 5%, 70°F (22°C) 5%, 212°F (100°C)	Type 304 stainless steel Type 304 stainless steel	90%, 70°F (22°C) 90%, 212°F (100°C)	Hastelloy B Hastelloy D
Potassium permanganate 5%, 70°F (22°C)	Type 304 stainless steel	Tannic acid 70°F (22°C)	Type 304 stainless steel
Potassium sulphate 5%, 70°F (22°C)	Type 304 stainless steel	Tartaric acid 70°F (22°C) 150°F (66°C)	Type 304 stainless steel Type 316 stainless steel
Potassium sulphide 70°F (22°C)	Type 304 stainless steel	Toluene	2017-T4 aluminum
Propane	Type 304 stainless steel	Turpentine	Type 304 stainless steel
Pyrogalic acid	Type 304 stainless steel	Whiskey and wine	Type 304 stainless steel
Quinine bisulphate		Xylene	Copper
Dry	Type 316 stainless steel	Zinc chloride	Monel
Quinine sulphate Dry	Type 304 stainless steel	Zinc sulphate 5%, 70°F (22°C)	Type 304 stainless steel
Sea water	Monel	Saturated, 70°F (22°C) 25%, 212°F (100°C)	Type 304 stainless steel Type 304 stainless steel



I. The Control System

The automatic control system consists of a process as shown in Figure 1.

II. Sensors

Sensors commonly used in temperature control are:

- Thermistor: A non-linear device whose resistance varies with temperature. Thermistors are used at temperatures under 500°F. Fragility limits their use in industrial applications.
- 2. Resistance Temperature Detector (RTD):
 - Changes in temperature vary the resistance of an element, normally a thin platinum wire. Platinum RTDs find application where high accuracy and low drift are required. 3-wire sensors are used where the distance between the process and the controller is more than several feet. The third wire is used for leadwire resistance compensation.
- 3. **Thermocouple:** A junction of two dissimilar metals produces a millivolt signal whose amplitude is dependent on (a) the junction metals; (b) the temperature under measurement. Thermocouples require cold-end compensation whereas connections between thermocouple wire and copper at the controller's terminal block produce voltages that are not related to the process temperature. Thermocouple voltage outputs are non-linear with respect to the range of temperatures being measured and, therefore, require linearization for accuracy.

Thermocouple junctions are usually made by welding the dissimilar metals together to form a bead. Different thermocouple types are used for various temperature measurements as shown in Table 1. Thermocouples are the most commonly used industrial sensor because of low cost and durability.

 Other temperature sensors include non-contact infrared pyrometers and thermopiles. These are used where the process is in motion or cannot be accessed with a fixed sensor.

III. Sensor Placement

Reduction of transfer lag is essential for accurate temperature control using simple temperature controllers. The sensor, heater and work load should be grouped as closely as possible. Sensors placed downstream in pipes, thermowells or loose-fitting platen holes will not yield optimum control. Gas and air flow processes must be sensed with an open element probe to minimize lag. Remember that the controller can only respond to the information it receives from its sensor.

Table 1.

Thermocouple Type	Wire Color	Useful Temperature Range °F
J	White	32 to 1300
K	Yellow	-328 to 2200
Т	Blue	-328 to 650
R/S	Black	-32 to 2642

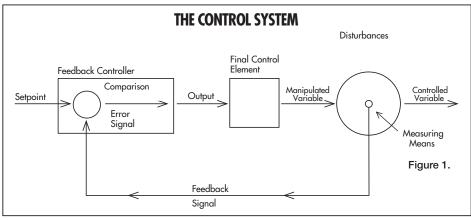


Figure 1.



IV. Process Load Characteristics

Thermal lag is the product of thermal resistance and thermal capacity. A single lag process has one resistance and one capacity. Thermal resistance is present at the heater/water interface. Capacity is the storage capacity of the water being heated.

Sometimes the sensor location is distant from the heated process and this introduces dead time. Figure 2a.

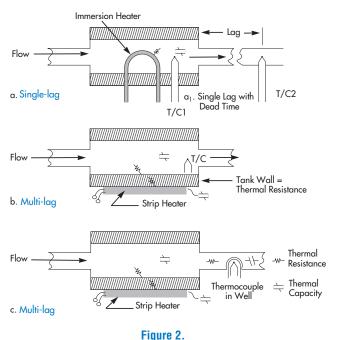
Introduction of additional capacities and thermal resistance changes the process to multi-lag. Figure 2b & 2c.

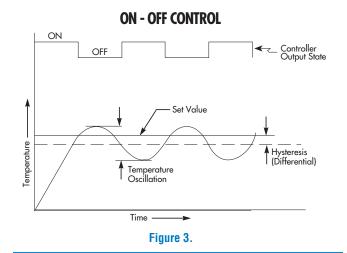
V. Control Modes

- 1. On-Off. Figure 3.
 - On-Off control has two states, fully off and fully on. To prevent rapid cycling, some hysteresis is added to the switching function. In operation, the controller output is on from start-up until temperature set value is achieved. After overshoot, the temperature then falls to the hysteresis limit and power is reapplied.
 - On-Off control can be used where:
 - (a) The process is underpowered and the heater has very little storage capacity.
 - (b) Where some temperature oscillation is permissible.
 - (c) On electromechanical systems (compressors) where cycling must be minimized.
- 2. Proportional. Figure 4.

Proportional controllers modulate power to the process by adjusting their output power within a proportional band. The proportional band is expressed as a percentage of the instrument span and is centered over the setpoint. At the lower proportional band edge and below, power output is 100%. As the temperature rises through the band, power is proportionately reduced so that at the upper band edge and above, power output is 0%.

VARIOUS PROCESSES





PROPORTIONAL CONTROL

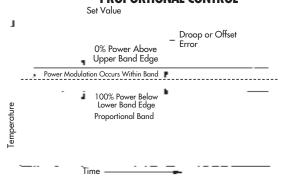


Figure 4.



Proportional controllers can have two adjustments:

- Manual Reset. Figure 5. Allows positioning the band with respect to the setpoint so that more or less power is applied at setpoint to eliminate the offset error inherent in proportional control.
- b) Bandwidth (Gain). Figure 6. Permits changing the modulating bandwidth to accommodate various process characteristics. High-gain, fast processes require a wide band for good control without oscillation. Low-gain, slowmoving processes can be managed well with narrow band to on-off control. The relationship between gain and bandwidth is expressed inversely:

$$Gain = \frac{100\%}{Proportional Band in \%}$$

Proportional-only controllers may be used where the process load is fairly constant and the setpoint is not frequently changed.

- 3. Proportional with Integral (PI), automatic reset. Figure 7. Integral action moves the proportional band to increase or decrease power in response to temperature deviation from setpoint. The integrator slowly changes power output until zero deviation is achieved. Integral action cannot be faster than process response time or oscillation will occur.
- 4. Proportional with Derivative (PD), rate action. Derivative moves the proportional band to provide more or less output power in response to rapidly changing temperature. Its effect is to add lead during temperature change. It also reduces overshoot on start-up.
- Proportional Integral Derivative (PID). This type of control is useful on difficult processes. Its Integral action eliminates offset error, while Derivative action rapidly changes output in response to load changes.

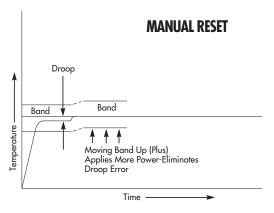
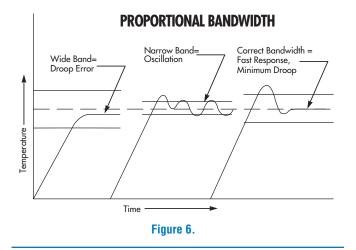
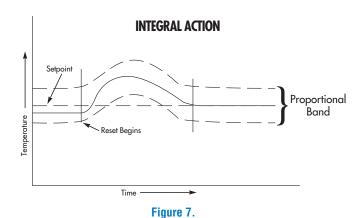


Figure 5.







VI. Proportional Outputs

Load power can be switched by three different proportioning means:

- Current proportional: A 4-20 mA signal is generated in response to the heating % requirement. See Figure 9. This signal is used to drive SCR power controllers and motoroperated valve positioners.
- Phase angle: This method of modulating permits applying a portion of an ac sine wave to the load. The effect is similar to light dimmer function. See Figure 10.
- Time proportioning:
 A clock produces pulses with a variable duty cycle. See Figure 11. Outputs are either director reverse-acting. Direct-acting is used for cooling; reverse-acting for heating.
- 4. Cycle Time: In time proportioning control the cycle time is normally adjustable to accommodate various load sizes. A low mass radiant or air heater requires a very fast cycle time to prevent temperature cycling. Larger heaters and heater load combinations can operate satisfactorily with longer cycle times. Use the longest cycle time consistent with ripple-free control.

VII. Power Handlers

Power is switched to an electric heating load through the final control element. Small, single-phase 120/240 V loads may be connected directly to the temperature controller. Larger, higher voltage heaters must be switched through an external power handler. Power handlers are either large relays (contactors), solid-state contactors or power controllers.

- 1. Mechanical contactors are probably the most widely used power handlers. They:
 - Are rugged. Fuses protect against burnout due to shorts.
 - Will wear out in time due to contact arcing.
 - Cannot be fast-cycled for low-mass loads.
 - Produce RF switching noise.
- 2. Solid-state contactors are often used on loads requiring fast switching times. They need heat sinking and I²T fuse protection.

- 3 32V S.S. contactors switch power at zero crossing of the ac sine wave.
- SCR power controllers. These devices switch ac power by means of thyristors (SCRs). These are solid-state devices that are turned on by gate pulses. They have unlimited life and require no maintenance. SCR controllers are available for switching single- or three-phase loads in zero crossing/burst firing (Figure 12) or phase-angle modes (Figure 10)

Figure 9. Control Current vs. Power Output

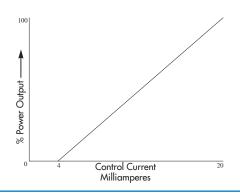


Figure 10. PHASE ANGLE

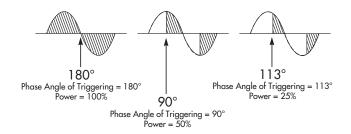
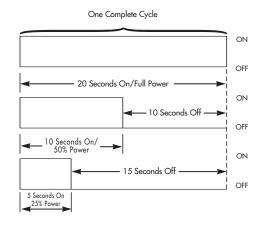


Figure 11. TIME PROPORTIONING





SCR power control selection by switching method can be simplified, as follows:

Use zero crossing for all standard heater applications. Specify phase angle:

- a) When soft start (ramp voltage to peak) is required on high inrush heater loads.
- b) If voltage limit is needed to clamp the maximum output voltage to a level lower than the supply voltage.

VIII. HEATER AND POWER CONTROL CONNECTIONS

Power controls are connected to the control signal and load, per Figure 12.

The control signal to the power controller may originate from a manual potentiometer, PLC or temperature controller. This signal is normally 4-20 mA, but can be other currents or voltages. An increase in the signal level produces a corresponding increase in power controller output.

Calculation of SCR size for various voltages and heater sizes is as follows:

Loads

Single-phase
$$\frac{\text{watts}}{\text{volts}} = \text{amps}$$

Three-phase
$$\frac{\text{watts}}{1.73 \text{ x volts}} = \text{amps}$$

watts = total heater watts

volts = line voltage

amps = total line current

SCRs should not be sized at exactly the heater current requirement because heaters have resistance tolerances as do line supplies.

Example: A single-phase 240 volt heater is rated at 7.2 kW. 7,2004240 = 30 A

If the heater is 10% low on resistance, at 240 V, the heater will draw 33 amperes. Damage to fuses will result. Power controllers must be properly cooled and, therefore, the mounting location should be in a cool area. SCRs dissipate approximately 2 watts per ampere per phase.

Proper fusing is essential to protect the SCR devices from damage due to load short circuits. The type of fuse is marked I²T or semiconductor.

Only SCRs designed to drive transformers should be used for that purpose.

SCR power controllers must never be used as disconnects in high-limit applications.

Figure 12. ZERO VOLTAGE

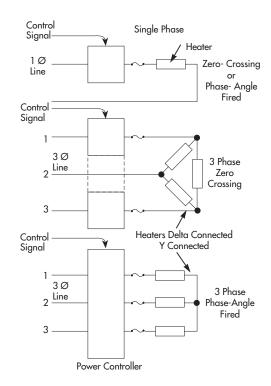
2 Second Time Base

114 Cycles On

Off

Off $\frac{114}{120} = 95\%$ Power Output $\frac{6}{12} = 50\%$ Power Output

117 Cycles Off $\frac{3}{120} = 2.5\%$ Power Output





ACCURACY: The difference between the reading of an instrument and the true value of what is being measured, expressed as a percent of full instrument scale.

ACTION: The function of a controller. Specifically, what is done to regulate the final control element to effect control. Types of action include ON-OFF, proportional, integral and derivative.

ACTIVE DEVICE: A device capable of producing gain; for example, transistors and ICs.

ALARM: A condition, generated by a controller, indicating that the process has exceeded or fallen below the limit point.

AMBIENT TEMPERATURE: The temperature of the immediate surroundings in which a controller must operate.

ANALOG SETPOINT INDICATION: A dial scale to indicate setpoint as opposed to digital setpoint indication. The traditional clock face is a good example of analog indication.

AUTOMATIC TUNING: Sometimes referred to as "self-tuning." The ability of a control to select and adjust the three control parameters (Proportional, Integral, and Derivative) automatically via a complex algorithm. Generally no operator input is required.

BANDWIDTH: See "Proportional Band"

BUMPLESS TRANSFER: When transferring from auto to manual operation, the control output(s) will not change ("bumpless"- a smooth transition).

CLOSED LOOP: A signal path which includes a forward path, a feedback path and a summing point, and forms a closed circuit.

COLD JUNCTION COMPENSATION: Measurement of temperature at thermocouple connections to controller and compensation for the "cold end" junction millivoltage generated here.

COMMON MODE: The noise signal that is common to all sensor wires.

COMMON-MODE REJECTION: The ability of an instrument to reject interference from a common voltage at its input terminals with relation to ground, usually expressed in dB.

COMPENSATION: See "Cold Junction Compensation"

CONTROL POINT: See "Setpoint"

COOL GAIN: In Athena microprocessor-based temperature controllers, a reference Gain value that is expressed in terms of the controller's Span, divided by the cooling proportional band, in degrees.

CURRENT PROPORTIONING: An output from a controller which provides current proportional to the amount of power required.

CYCLE TIME: The time necessary to complete a full ON-through-OFF period in a time proportioning control system.

CURRENT ALARM: Provides an alarm signal when a current level is detected below or above a preselected level.

DV/DT: Rate of change of voltage over time. A rapidly rising voltage waveform could induce false firing of an SCR. MOV's or R-C Snubber Circuits are used to prevent this false firing.

DEAD BAND: The range through which an input can be varied without initiating observable response.

DERIVATIVE: The process by which a controller senses the rate of temperature change and alters output.

DEVIATION ALARM: An alarm referenced at a fixed number of degrees, plus or minus, from setpoint.

DIN: Deutsche Industrial Norms, a widely-recognized German standard for engineering units.

DIFFERENTIAL: The temperature difference between the points at which the controller turns the heater on and off. Typically used when discussing an on/off controller.

DIRECT ACTING: Increase in value of output as the measured value increases.

DRIFT: A deviation of the system from setpoint that typically occurs over a long period of time. Drift may be caused by such factors as changes in ambient temperature or line voltage.

DROOP: Occurs when the actual system temperature stabilizes at some value below the desired setpoint. If system droop is unacceptable, a common solution is the use of a control incorporating an automatic or manual reset feature.

DUTY CYCLE: Percentage of load "ON" time relative to total cycle time.

FEEDBACK CONTROLLER: A mechanism that measures the value of the controlled variable, compares with the desired value and as a result of this comparison, manipulates the controlled system to minimize the size of the error.

FREQUENCY RESPONSE: The response of a component, instrument, or control system to input signals at varying frequencies.

GAIN: Amount of increase in a signal as it passes through any part of a control system. If a signal gets smaller, it is attenuated. If it gets larger, it is amplified.

GUARANTEED SOAK: On a ramp and soak controller, a feature that stops the clock if the temperature drops below a preset value, then continues the timing when the temperature recovers.

HEAT GAIN: In Athena microprocessor-based temperature controllers, a reference Gain value that is expressed in terms of the controller's Span, divided by the heating proportional band, in degrees.

HYSTERESIS: Temperature sensitivity between turn on and turn off points on on-off control. Prevents chattering.

I²**T:** A measure of maximum one time overcurrent capability for a very short duration. Value used for fuse sizing to protect SCRs.

IMPEDANCE: The total opposition to electrical flow in an ac circuit.

INTEGRAL FUNCTION: This automatically adjusts the position of the proportional band to eliminate offset.

ISOLATION: Electrical separation of sensor from high voltage and output circuitry. Allows for application of grounded or ungrounded sensing element.

LAG: The time delay between the output of a signal and the response of the instrument to which the signal is sent.

LATCHING ALARM: Requires operator intervention to reset even though the alarm condition on the input may have disappeared.

MOV: Metal Oxide Varistor: A semiconductor device that acts as a safety valve to absorb high voltage transients harmlessly, thereby protecting the SCRs and preventing false firing.



NOISE: An unwanted electrical interference.

NORMAL-MODE REJECTION: The ability of an instrument to reject interference; usually of line frequency across the input terminals (common mode).

OFFSET: A sustained deviation of the controlled variable from setpoint (this characteristic is inherent in proportional controllers that do not incorporate reset action). Also referred to as Droop.

ON/OFF CONTROL: Control of temperature about a setpoint by turning the output full ON below setpoint and full OFF above setpoint in the heat mode.

OPEN LOOP: Control system with no sensory feedback.

OUTPUT: Action in response to difference between setpoint and process variable.

OVERSHOOT: Condition where temperature exceeds setpoint due to initial power up.

PARAMETER: A physical property whose value determines the response of an electronic control to given inputs.

PD Control: Proportioning control with rate action.

PHASE: The time-based relationship between two alternating waveforms.

PHASE-ANGLE FIRING: A form of power control where the power supplied to the process is controlled by limiting the phase angle of the line voltage as opposed to burst firing.

PI Control: Proportioning control with auto reset.

PID: Proportional, integral and derivative control action.

POSITIVE TEMPERATURE COEFFICIENT: A characteristic of sensors whose output increases with increasing temperature.

PROCESS VARIABLE: System element to be regulated, such as pressure, temperature, relative humidity, etc.

PROPORTIONAL ACTION: Continuously adjusts the manipulated variable to balance the demand.

PROPORTIONAL BAND: The amount of deviation of the controlled variable required to move through the full range (expressed in % of span or degrees of temperature). An expression of Gain of an instrument (the wider the band, the lower the gain).

PROPORTIONING CONTROL PLUS DERIVATIVE FUNCTION:

A controller incorporating both proportional and derivative action senses the rate temperature change and adjusts controller output to minimize overshoot.

PROPORTIONING CONTROL PLUS INTEGRAL: A controller incorporating both proportional and integral action.

PROPORTIONAL, INTEGRAL AND DERIVATIVE CONTROL:

A PID controller is a three-mode controller incorporating proportional, integral, and derivative actions.

RAMP: Automatic adjustment for the setpoint for the temperature increase or decrease from process temperature. The target value can be either above or below the current measured value. The ramp value is a combination of time and temperature.

RAMP TO SETPOINT: Allows the operator to enter a target time for the controller to reach setpoint.

RANGE: The difference between the maximum and the minimum values of output over which an instrument is designed to operate normally.

RATE (ACTION): Control function that produces a corrective signal proportional to the rate at which the controlled variable is changing. Rate action produces a faster corrective action than proportional action alone. Also referred to as Derivative Action. Useful in eliminating overshoot and undershoot.

R.C. SNUBBER CIRCUIT: Resistor - Capacitor Snubber Circuit: Controls the maximum rate of change of voltage and limits the peak voltage across the switching device. Used to prevent false firing of SCRs.

REFERENCE JUNCTION: See "Cold Junction Compensation"

REPRODUCIBILITY: The ability of an instrument to duplicate with exactness, measurements of a given value. Usually expressed as a % of span of the instrument.

RESET ACTION: Control function that produces a corrective signal proportional to the length of time and magnitude the controlled variable has been away from the setpoint. Accommodates load changes. Also called Integral Action.

REVERSE ACTING: Reduces the output as the measured value increases

RFI: An acronym for radio frequency interference. RFI is commonly generated by devices that switch the output power at some voltage other than zero. Typically, phase-angle fired SCRs may generate RFI while zero-cross fired SCRs virtually eliminate RFI.

RTD: An acronym for a resistance temperature detector. Typically a wire wound device that displays a linear change in resistance for a corresponding temperature change. An RTD has a positive temperature coefficient.

SCR: This term has two separate and distinct meanings: 1) A solid-state semiconductor component that conducts or resists current flow depending upon whether a trigger voltage is present at the gate terminal. 2) A complete power controller that utilizes SCRs or TRIACs as the switching devices to control current flow.

SEGMENT: In a ramp and soak controller, one part of a profile.

SOAK: One segment with no setpoint change.

SSR: An acronym for solid-state relay. Semiconductor device that switches electrical current on and off in response to an electrical signal at the control terminals.

SENSITIVITY: The minimum change in input signal required to produce an output change in the controller.

SERIES MODE: A condition in which a noise signal appears in series with a sensor signal.

SETPOINT: The position to which the control point setting mechanism is set, which is the same as the desired value of the controlled variable.

SPAN: The difference between the top and bottom scale values of an instrument. On instruments starting at zero, the span is equal to the range.

STANDBY: Method of putting controller into the idle mode.

SURGE CURRENT: A high current of short duration that generally occurs when the power is first applied to inductive loads. The surge generally lasts no more than several ac cycles.



THERMISTOR: A bead-like temperature sensing device consisting of metallic oxides encapsulated in epoxy or glass. The resistance of a thermistor typically falls off sharply with increasing temperature, making it a particularly good sensing device.

A thermistor has a negative temperature coefficient.

THERMOCOUPLE: The junction of two dissimilar metals. A small voltage is generated at this junction, increasing as its temperature rises.

THERMOCOUPLE BREAK PROTECTION: Fail-safe operation that ensures output shutdown upon an open thermocouple condition.

THREE-MODE CONTROL: Proportioning control with reset and rate.

THYRISTOR: Any of a group of solid-state controlling devices. These devices are referred to as TRIACs, SCRs and DIACs.

TIME PROPORTIONING CONTROL MODE: In this mode, the amount of controller "on" time depends upon the system temperature. At the beginning of each time base interval, the signal from the sensor is analyzed and the controller is kept "ON" for a percentage of the time base.

TRIAC: A device, similar to a controlled rectifier, in which both the forward and reverse characteristics can be triggered from blocking to conducting (Also see Thyristor).

ZERO SWITCHING: Action that provides output switching only at the zero voltage crossing point of the ac sine wave.









Thermoelectricity in Retrospect

The principles and theory associated with thermoelectric effects were not established by any one person at any one time. The discovery of the thermoelectric behavior of certain materials is generally attributed to T. J. Seebeck.

In 1821, Seebeck discovered that in a closed circuit made up of wire of two dissimilar metals, electric current will flow if the temperature of one junction is elevated above that of the other. Seebeck's original discovery used a thermocouple circuit made up of antimony and copper. Based on most common usage and recognition today, there are eight thermoelement types: S,R,B,J,K,N,T and E.

In the ensuing years following the discovery of the thermoelectric circuit, many combinations of thermoelectric elements were investigated. Serious application of the findings was accelerated by the needs brought on during the course of the Industrial Revolution.

In 1886, Le Chatelier introduced a thermocouple consisting of one wire of platinum and the other of 90 percent platinum-10 percent rhodium. This combination, Type S, is still used for purposes of calibration and comparison. It defined the International Practical Temperature Scale of 1968 from the antimony to the gold point. This type of thermocouple was made and sold by W. C. Heraeus, GmbH of Hanau, Germany, and is sometimes called the Heraeus Couple.

Later, it was learned that a thermoelement composed of 87 percent platinum and 13 percent rhodium, Type R, would give a somewhat higher E.M.F. output.

In 1954 a thermocouple was introduced in Germany whose positive leg was an alloy of platinum and 30 percent rhodium. Its negative leg was also an alloy of platinum and 6 percent rhodium. This combination, Type B, gives greater physical strength, greater stability, and can withstand higher temperatures than Types R and S.

The economics of industrial processes prompted a search for less costly metals for use in thermocouples. Iron and nickel were useful and inexpensive.

Pure nickel, however, became very brittle upon oxidation; and it was learned that an alloy of about 60 percent copper, 40 percent nickel (constantan) would eliminate this problem. This alloy combination, iron-constantan, is widely used and is designated Type J. The present calibration for Type J was established by the National Bureau of Standards, now known as the National Institute of Standards and Technology (N.I.S.T.).

The need for higher temperature measurements led to the development of a 90 percent nickel-10 percent chromium alloy as a positive wire, and a 95 percent nickel-5 percent aluminum, manganese, silicon alloy as a negative wire. This combination (originally called Chromel-Alumel) is known as Type K.

Conversely the need for sub-zero temperature measurements contributed to the selection of copper as a positive wire and constantan as a negative wire in the Type T thermoelement pair. The E.M.F.-temperature relationship for this pair (referred to as the Adams Table) was prepared by the National Bureau of Standards in 1938. The relatively recent combination of a positive thermoelement from the Type K pair and a negative thermoelement from the Type T pair is designated as a Type E thermoelement pair. This pair is useful where higher E.M.F. output is required.

Within the past 20 years, considerable effort has been made to advance the state-of-the-art in temperature measurement. Many new thermoelement materials have been introduced for higher temperatures.

Combinations of tungsten, rhenium and their binary alloys are widely used at higher temperatures in reducing inert atmospheres or vacuum.

The most common thermoelement pairs are:

W-W26Re (Tungsten Vs. Tungsten 26%)

W3Re-W25Re (Tungsten 3% Rhenium Vs. Tungsten

25% Rhenium)

W5Re-W26Re (Tungsten 5% Rhenium Vs. Tungsten

26% Rhenium)

Letter designations have not yet been assigned to these combinations.



The most recent significant development in thermometry was the adoption of the International Temperature Scale of 1990 (ITS-90). The work of international representatives was adopted by the International Committee of Weights and Measures at its meeting September 1989, and is described in "The International Temperature Scale of 1990", Metrologia 27, No. 1, 3-10 (1990); Metrologia 27,107 (1990).

Laws of Thermoelectric Circuits

Numerous investigations of thermoelectric circuits in which accurate measurements were made of the current, resistance, and electromotive force have resulted in the establishment of several basic laws.

Although stated in many different ways, these precepts can be reduced to three fundamental laws:

- 1. The law of the Homogeneous Circuit
- 2. The law of Intermediate Materials
- 3. The law of Successive or Intermediate Temperatures

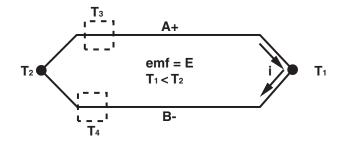
Law of Homogeneous Circuit

A thermoelectric current cannot be sustained in a circuit of a single homogeneous material, however, varying in cross section, by the application of heat alone.

Two different materials are required for any thermocouple circuit.

Any current detected in a single wire circuit when the wire is heated in any way whatever is taken as evidence that the wire is inhomogeneous.

Figure 1. Law of Homogeneous Circuit.



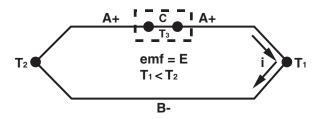
A consequence of this law as illustrated in Figure 1, is that if one junction of two dissimilar homogeneous materials is maintained at a temperature T, and the other junction at a temperature T2, the thermal E.M.F. developed is independent of the temperature distribution along the circuit. The E.M.F., E, is unaffected by temperatures T3 and T4.

Law of Intermediate Materials

The algebraic sum of the thermoelectromotive forces in a circuit composed of any number of dissimilar materials is zero if all of the circuit is at a uniform temperature.

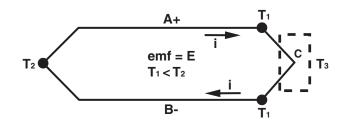
A consequence of this law is that a third homogeneous material can be added in a circuit with no effect on the net E.M.F. of the circuit so long as its extremities are at the same temperature.

Figure 2. Law of Intermediate Materials.



In Figure 2, two homogeneous metals, A and B, with their junctions at temperatures T, and T2 a third metal C, is introduced by cutting A, and forming two junctions of A and C. If the temperature of C is uniform over its whole length, the total E.M.F. in the circuit will be unaffected.

Figure 3. Combining the Law of Intermediate Materials with the Law of Homogeneous Circuit.

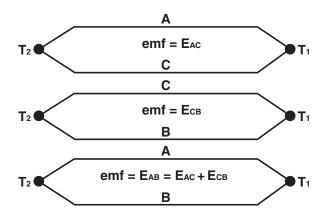


Combining the Law of Intermediate Materials with the Law of Homogeneous Circuit, as shown in Figure 3, A and B are separated at the temperature T. junction. Two junctions AC and CB are formed at temperature T1. While C may extend into a region of very different temperature, for example, T3 the E.M.F. of the circuit will be unchanged. That is, EAC + ECB = EAB.

A further consequence to the combined laws of Intermediate Materials and Homogeneous Circuit is illustrated in Figure 4.

When the thermal E.M.F. of any material A or B paired with a reference material C is known, then the E.M.F. of any combination of these materials, when paired, is the algebraic sum of their E.M.F.'s when paired with reference material C.

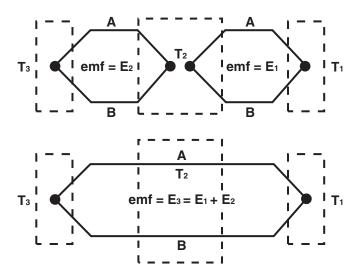
Figure 4. Thermal E.M.F. of two materials with respect to a reference material.



Law of Successive or Intermediate Temperatures

If two dissimilar homogeneous metals produce a thermal E.M.F. of E., when the junctions are at temperatures T1 and T2, and a thermal E.M.F. of E2, when the junctions are at T2 and T3, the E.M.F. generated when the junctions are at T1 and T3, will be E1 + E2.

Figure 5. Law of Successive or Intermediate Temperatures.



One consequence of this law permits a thermocouple calibrated at a given reference temperature, to be used at any other reference temperature through the use of a suitable correction.

Another consequence of this law is that extension wires, having the same thermoelectric characteristics as those of the thermocouple wires, can be introduced in the thermocouple circuit (say from region T2 and region T3) without affecting the net E.M.F. of the thermocouple.

Conclusion

The three fundamental laws may be combined and stated as follows: "The algebraic sum of the thermoelectric E.M.F.s generated in any given circuit containing any number of dissimilar homogeneous materials is a function only of the temperatures of the junctions." Corollary: "If all but one of the junctions in such a circuit are maintained at some reference temperature, the E.M.F. generated depends only on the temperature of that one junction and can be used as a measure of its temperature."

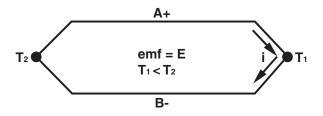


Thermoelectric Effects

Seebeck Effect

The Seebeck effect, Figure 6, concerns the conversion of thermal energy into electrical energy. The Seebeck voltage refers to the net thermal electromotive force established in a thermoelement pair under zero current conditions.

Figure 6. Seebeck Thermal E.M.F..



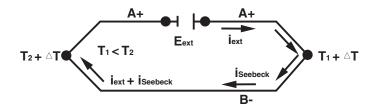
When a circuit is formed consisting of two dissimilar conductors A and B, and one junction of A and B is at temperature T1 while the other junction is at a higher temperature T2, a current will flow in the circuit. The electromotive force E producing this current i, is called the Seebeck thermal E.M.F.

Conductor A is considered thermoelectrically positive to conductor B if the current i flows from conductor A to conductor B at the cooler of the two junctions (T_1) .

Peltier Thermal Effect

The Peltier Thermal Effect, Figure 7, concerns a reversible phenomenon at the junction of most thermoelement pairs.

Figure 7. Peltier Thermal Effect.



When an electrical current i ext flows across the junction of a thermoelement pair, heat is absorbed or liberated. The direction of current flow at a particular junction determines whether heat is absorbed or liberated.

If an external current i ext flows in the same direction as the current i Seebeck produced by the Seebeck Effect at the hotter junction of a thermoelement pair, heat is absorbed. Heat is liberated at the other junction.

The Thomson Effect

The Thomson Effect concerns the reversible evolution, or absorption, of heat occurring whenever an electric current traverses a single homogeneous conductor, across which a temperature gradient is maintained, regardless of external introduction of the current or its induction by the thermocouple itself.

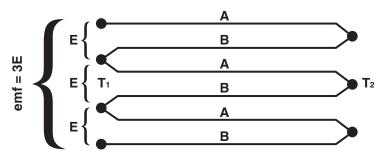
The Thomson voltage alone cannot sustain a current in a single homogeneous conductor forming a closed circuit, since equal and opposite E.M.F.s will be set up on the two paths from heated to cooled parts of the circuit.

Thermoelectric Circuits

Series Circuit

A number of similar thermocouples all having thermoelements A and B may be connected in series with all of their measuring junctions at T2 and their reference junctions at T1. Such a series, called a thermopile, is shown in Figure 8. With three thermocouples in series develops an E.M.F. three times as great as a single thermocouple is developed.

Figure 8. A thermopile of three thermocouples.

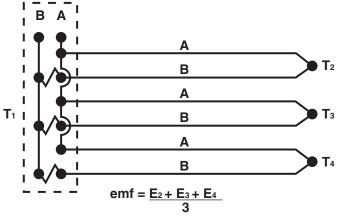


Parallel Circuit

If a quantity "N" of thermocouples of equal resistance is connected in parallel with junctions at T1 and T2 the E.M.F. developed is the same as for a single thermocouple with its junctions at T1 and T2.

If all of the thermocouples are of equal resistance but their measuring junctions are at various temperatures T2, T3...Tn + 1, see Figure 9, then the E.M.F. developed will correspond to the mean of the temperatures of the individual measuring junctions.

Figure 9. A parallel circuit for mean temperatures.

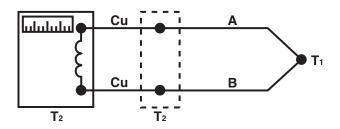


It is not necessary to adjust the thermocouple resistances when measuring these average temperatures. Instead, swamping resistors may be used. For example, if the thermocouples range in resistance from 5 to 10 ohms, a 500 ohm (±1%) resistor is connected in series with each, and the error in E.M.F. introduced by the inequality in thermocouple resistance becomes an insignificant fraction of the total resistance.

Basic Thermocouple Circuit

Two continuous, dissimilar thermocouple wires extending from the measuring junction to the reference junction, when used together with copper connecting wires and a potentiometer, connected as shown in Figure 10, make up the basic thermocouple circuit for temperature measurement.

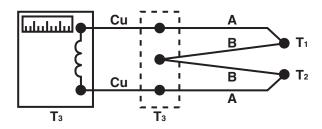
Figure 10. Basic thermocouple circuit.



Differential Thermocouple Circuit

Junctions 1 and 2 are each at different temperatures. The temperature measured by the circuit shown in Figure 11 is the difference between T1 and T2.

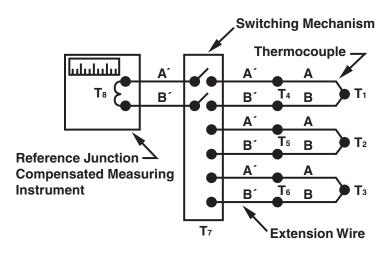
Figure 11. Differential thermocouple circuit.



Typical Industrial Thermocouple Circuit

The usual thermocouple circuit includes: measuring junctions, thermocouple extension wires, reference junctions, copper connecting wires, a selector switch, and potentiometer. Many different circuit arrangements of the above components are acceptable, depending on given circumstances.

Figure 12. Typical industrial thermocouple circuit.





Environmental Limitations of Thermoelements

JP–For use in oxidizing, reducing, or inert atmospheres or in vacuum. Oxidizes rapidly above 540°C (1000°F). Will rust in moist atmospheres as in subzero applications. Stable to neutron radiation transmutation. Change in composition is only 0.5 percent (increase in manganese) in 20-year period.

JN, TN, EN–Suitable for use in oxidizing, reducing, and inert atmospheres or in vacuum. Should not be used unprotected in sulfurous atmospheres above 540°C (1000°F).

Composition changes under neutron radiation since copper content is converted to nickel and zinc. Nickel content increases 5 percent in a 20-year period.

TP–Can be used in vacuum or in oxidizing, reducing or inert atmospheres. Oxidizes rapidly above 370°C (700°F). Preferred to Type JP element for subzero use because of its superior corrosion resistance in moist atmospheres. Radiation transmutation causes significant changes in

composition.

Nickel and zinc grow into the material in amounts of 10

percent each in a 20-year period.

KP, EP–For use in oxidizing or inert atmospheres. Can be used in hydrogen or racked ammonia atmospheres if dew point is below -40°C (-40°F). Do not use unprotected in sulfurous atmospheres above 540°C (1000°F).

Not recommended for service in vacuum at high temperatures except for short time periods because preferential vaporization of chromium will alter calibration. Large negative calibration shifts will occur if exposed to marginally oxidizing atmospheres in temperature range 815°C to 1040°C (1500°F to 1900°F).

Quite stable to radiation transmutation. Composition change is less than 1 percent in a 20-year period.

KN–Can be used in oxidizing or inert atmospheres. Do not use unprotected in sulfurous atmospheres as intergranular corrosion will cause severe embrittlement.

Relatively stable to radiation transmutation. In a 20-year period, iron content will increase approximately 2 percent. The manganese and cobalt contents will decrease slightly.

RP, SP, SN, RN, BP, BN–For use in oxidizing or inert atmospheres. Do not use unprotected in reducing atmospheres in the presence of easily reduced oxides, atmospheres containing metallic vapors such as lead or zinc, or those containing nonmetallic vapors such as arsenic, phosphorus, or sulfur. Do not insert directly into metallic protecting tubes. Not recommended for service in vacuum at high temperatures except for short time periods.

Type SN elements are relatively stable to radiation transmutation. Types BP, BN, RP and SP elements are unstable because of the rapid depletion of rhodium. Essentially, all the rhodium will be converted to palladium in a 10-year period.

NP, NN–Proprietary alloys suitable for use in applications cited for KP and KN.

Typical Physical	Propert	ies of Th	nermoel	ement N	/laterials							
				Ti	hermoelem	ent Materia						
Property	JP	JN, TN, EN	TP	KP, EP	KN	NP	NN	RP	SP	RN, SN	BP	BN
Melting point °C °F	1490 2715	1220 2228	1083 1981	1427 2600	1399 2550	1410 2570	1340 2444	1860 3380	1850 3362	1769 3216	1927 3501	1826 3319
Temperature coefficient of resistance, Ω/Ω° C x 10 ⁻⁴ (0-100°C)	65	-0.1	43	4.1	23.9	24.0	0.01	15.6	16.6	39.2	13.3	20.0
Coefficient of thermal expansion, in./in. °C (0-100°C)	11.7 x 10 ⁻⁶	14.9 x 10 ⁻⁶	16.6 x 10 ⁻⁶	13.1 x 10 ⁻⁶	12.0 x 10 ⁻⁶	13.3 x 10 ⁻⁶	12.1 x 10 ⁻⁶	9.0 x 10 ⁻⁶	9.0 x 10 ⁻⁶	9.0 x 10 ⁻⁶	_	_
Density: g/cm ³ lb/in. ³	7.86 0.284	8.92 0.322	8.92 0.322	8.73 0.315	8.60 0.311	8.52 0.308	8.70 0.314	19.61 0.708	19.97 0.721	21.45 0.775	17.60 0.636	20.55 0.743
Tensile strength (annealed): kgf/cm² psi	3500 50000	5600 80000	2500 35000	6700 95000	6000 85000	 90000	 80000	3200 46000	3200 45000	1400 20000	4900 70000	2800 40000
Magnetic attraction	strong	none	none	none	moderate	none	slight	none	none	none	none	none

Nominal Ch	nemical	Composit	ion of 1									
				Non	ninal Chemi	ical Composi	ition, %					
Element	JP	JN, TN, EN	TP	KP, EN	KN	NP	NN	RP	SP	RN, SN	BP	BN
Iron	99.5	_	_	_	_	_	_	_	_	_	_	_
Carbon	**	_	_	_	_	_	_	_	_	_	_	_
Manganese	**	_	_	_	2	_	0.1	_	_	_	_	_
Sulfur	**	_	_	_	_	_	_	_	_	_	_	_
Phosphorus	**	_	_	_	_	_	_	_	_	_	_	_
Silicon	**	_	_	_	1	1.4	4.4	_	_	_	_	_
Nickel	**	45	_	90	95	84.4	95.5	_	_	_	_	_
Copper	**	55	100	_	_	_	_	_	_	_	_	_
Chromium	**	_	_	10	_	14.2	_	_	_	_	_	_
Aluminum	_	_	_	_	2	_	_	_	_	_	_	_
Platinum	_	_	_	_	_	_	_	87	90	100	70.4	93.9
Rhodium	_	_	_	_	_	_	_	13	10	_	29.6	6.1

^{*}Types JN, TN, and EN thermoelements usually contain small amounts of various elements for control of thermal E.M.F., with corresponding reductions in the nickel or copper content, or both.

**Thermoelectric iron (JP) contains small but varying amounts of these elements.

Thermoelement	No. 8	No. 14	No. 20	No. 24	No. 28
	[0.128 in.]	[0.064 in]	[0.032 in.]	[0.020 in.]	0.013 in.]
JP	760°C	593°C	482°C	371°C	371°C
	(1400°F)	(1100°F)	(900°F)	(700°F)	(700°F)
JN, TN, EN	871°C	649°C	538°C	427°C	427°C
	(1600°F)	(1200°F)	(1000°F)	(800°F)	(800°F)
TP		371°C (700°F)	260°C (500°F)	204°C (400°F)	204°C (400°F)
KP, EP, KN, NP, NN	1260°C	1093°C	982°C	871°C	871°C
	(2300°F)	(2000°F)	(1800°F)	(1600°F)	(1600°F)
RP, SP, RN, SN		<u> </u>		1482°C (2700°F)	_ _
BP, BN				1705°C (3100°F)	_

Nom	inal Resis	tance of	Thermo	elements								
	Ohms per foot at 20°C (68°F)											
Awg. No.	Diameter, in.	KN	KP, EP	TN, JN, EN	TP	JP	NP	NN	RN, SN	SP	ВР	BN
8	0.1285	0.0107	0.0257	0.0179	0.000628	0.0043	0.0354	0.0134	0.00386	0.00697	0.00700	0.00648
12	0.0808	0.0270	0.065	0.0448	0.00159	0.0109	0.0884	0.0335	0.00976	0.01761	0.01769	0.01637
14	0.0641	0.0432	0.104	0.0718	0.00253	0.0174	0.1416	0.0537	0.0155	0.0280	0.0281	0.0260
16	0.0508	0.0683	0.164	0.113	0.00402	0.0276	0.2230	0.0846	0.0247	0.0445	0.0447	0.0414
17	0.0453	0.0874	0.209	0.145	0.00506	0.0349	0.2864	0.1086	0.0311	0.0562	0.0564	0.0523
18	0.0403	0.111	0.266	0.184	0.00648	0.0446	0.3625	0.1375	0.0399	0.0719	0.0722	0.0669
20	0.0320	0.173	0.415	0.287	0.0102	0.0699	0.5664	0.2148	0.0624	0.1125	0.1130	0.1046
22	0.0253	0.276	0.663	0.456	0.0161	0.1111	0.9061	0.3437	0.0993	0.1790	0.1798	0.1664
24	0.0201	0.438	1.05	0.728	0.0257	0.1767	1.4356	0.5445	0.1578	0.2847	0.2859	0.2647
26	0.0159	0.700	1.68	1.16	0.0408	0.281	2.2942	0.8702	0.2509	0.4526	0.4546	0.4208
28	0.0126	1.11	2.48	1.85	0.0649	0.447	3.6533	1.3857	0.3989	0.7197	0.7229	0.6692
30	0.0100	1.77	4.25	2.94	0.1032	0.710	5.8000	2.2000	0.6344	1.144	1.149	1.064
36	0.0050	7.08	17.0	11.8	0.4148	2.86	23.200	8.8000	2.550	4.600	4.620	4.277
40	0.0031	18.4	44.2	30.6	1.049	7.22	60.354	22.893	6.448	11.63	11.68	10.81



Nomina	l Weights	of Therm	oelemen	ts							
		Fe	et per pound	i					Feet Per Troy	Ounce	
Awg.Dia											
No.	in.	KN	KP, EP	TN, JN, EN	TP	JP	RN, SN	SP	RP	BN	BP
8	.128	21	20	20	20	22	0.5	0.5	0.5	0.5	0.6
14	.064	83	82	80	80	91	2.3	2.1	2.5	2.4	2.8
16	.051	130	129	127	127	143	3.6	3.8	3.9	3.7	4.3
17	.045	167	166	163	163	184	4.6	4.9	5.0	4.8	5.6
18	.040	212	210	207	207	233	5.8	6.2	6.3	6.0	7.0
20	.032	331	328	323	322	364	9.1	9.7	9.9	9.4	11.0
22	.025	530	525	518	517	583	15.0	16.0	16.4	45.6	18.2
24	.020	838	832	820	816	924	23.4	25.1	25.6	24.4	28.5
26	.16	1340	1331	1312	1306	1478	36.6	39.2	40.0	38.2	44.5
28	.013	2130	2119	2089	2076	2353	555	59.5	60.7	57.9	67.6
30	.010	3370	3364	3316	3296	3736	60.6	65.0	66.3	63.2	73.8
36	.005	13500	13460	13260	13180	14940	375.5	402.8	411.0	391.9	457.5
40	.003	35200	35010	34500	34292	N.A.	1042.7	1118.6	1141.4	1088.2	1270.5

Limits of Error (Ref. Junction -0°C)

Therm	ocouples		Limits (of Error
Thermo- couple Type	Temp. Range, °C	Temp. Range, °F	Standard [whichever is greater]	Special [whichever is greater]
T J E K N R or S B W W3 W5	0 - 350 0 - 750 0 - 900 0 - 1250 0 - 1250 0 - 1450 800 - 1700 0 - 2300 0 - 2200 0 - 2200	32 - 700 32 - 1400 32 - 1600 32 - 2300 32 - 2300 32 - 2700 1600 - 3100 32 - 4200 32 - 4100 32 - 4100	± 1 °C or $\pm 0.75\%$ ± 2.2 °C or $\pm 0.75\%$ ± 1.7 °C or $\pm 0.5\%$ ± 2.2 °C or $\pm 0.75\%$ ± 2.2 °C or $\pm 0.75\%$ ± 1.5 °C or $\pm 0.25\%$ $\pm 0.5\%$ 4.5 °C or $\pm 1\%$ 4.5 °C or $\pm 1\%$ 4.5 °C or $\pm 1\%$	±0.5°C or 0.4% ±1.1°C or 0.4% ±1°C or 0.4% ±1.1°C or 0.4% ±1.1°C or 0.4% ±0.6°C or 0.1% —
T E	-200 - 0°C -200 - 0°C	-328 - 32 -328 - 32	±1°C to ±1.5% ±1.7°C to ±1%	_
K	-200 - 0°C	-328 - 32	±2.2°C to ±2%	_

Thermoco	uple Exten	sion Wires	\$	
Extension Wire Type	Temp. Range, °C	Temp. Range, °F	Limit Standard	s of Error Special
KX	0 - 200°C	32° - 400°	±2.2°C	_
JX	0 - 200°C	32° - 400°	±2.2°C	±1.1°C
EX	0 - 200°C	32° - 400°	±1.7°C	_
TX	-60 - 100°C	-75° - 200°	±1.0°C	±0.5°C
NX	0 - 200°C	32° - 400°	±2.2°C	_

Therm	ocouple Co	mpensa	ting Exter	nsion Wire
Thermo- couple Type	Compensating Wire Type	Temp. Range, °C	Temp. Range, °F	Limits of Error
R, S	SX**	25 - 200	75 - 400	±0.057mv (±5°C*)
В	BX***	0 - 100	32 - 200	±.000mv (+0°C*) ±.003 mv (3.7°C*)
W	WX	0 - 260	32 - 500	±0.14mv (12.9°C)
W3	W3X	0 - 260	32 - 500	±0.11mv (6.8°C)
W5	W5X	0 - 870	32 - 1600	±0.11mv (6.1°C)

Thermocouples and thermocouple materials are normally supplied to meet the limits of error specified in the table for temperatures above 0°C. The same materials, however, may not fall within the sub-zero limits of error given in the second section of the table. If materials are required to meet the sub-zero limits, selection of materials usually will be required.

For sub-zero temperatures, the following limits for types E and T thermocouples may be appropriate (consult factory):

Type E $-200 \text{ to } 0^{\circ} \text{ C} \pm 1^{\circ} \text{C or } \pm 0.5\%$ Type T $-200 \text{ to } 0^{\circ} \text{ C} \pm 0.5^{\circ} \text{ C or } \pm 0.8\%$

- Limits of error in this table apply to new thermocouple wire, normally in the size range (No. 30 to No. 8 Awg) and used at temperatures not exceeding the recommended range (when derated for wire size). If used at higher temperatures these limits of error may not apply.
- Limits of error apply to new wire as delivered to the user and do not allow for calibration drift during use. The magnitude of such changes depends on such factors as wire size, temperature, time of exposure, and environment.
- ▶ Where limits of error are given in percent, the percentage applies to the temperature being measured when expressed in degrees Celsius. To determine the limit of error in degrees Fahrenheit multiply the limit of error in degrees Celsius by 9/5.

Type Wire Measuring Junction Temperature

SX Greater than 870°C BX Greater than 1000°C

*Due to the non-linearity of the Type R, S, and B temperature-E.M.F. curves, the error introduced into a thermocouple system by the compensating wire will be variable when expressed in degrees. The degree C limits of error given in parentheses are based on the measuring junction temperatures above.



^{**}Copper(†) versus copper nickel alloy (-).

^{***}Copper versus copper compensating extension wire, usable to 100°C with maximum errors as indicated, but with no significant error over 0 to 50°C range.

Temperature - E.M.F. Tables - I.T.S. 90

Type J (Iron C	Constantan)								
Temperature	in degrees	F (C) Re	ference j	junction at 3	32°F (0°C)) Millivolts	\rightarrow			
-300° (-185°)	-7.519	-7.659	-7.792	-7.915	-8.030					
-200° (-129°)	-5.760	-5.962	-6.159	-6.351	-6.536	-6.716	-6.890	-7.058	-7.219	-7.373
-100° (-74°)	-3.493	-3.737	-3.978	-4.215	-4.449	-4.678	-4.903	-5.125	-5.341	-5.553
0° (-18°)	-0.886	-1.158	-1.428	-1.695	-1.961	-2.223	-2.483	-2.740	-2.994	-3.245
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.886	-0.611	-0.334	-0.056	0.225	0.507	0.791	1.076	1.364	1.652
+100° (+38°)	1.942	2.234	2.527	2.821	3.116	3.412	3.709	4.007	4.306	4.606
+200° (+94°)	4.907	5.209	5.511	5.814	6.117	6.421	6.726	7.031	7.336	7.642
+300° (+149°)	7.949	8.255	8.562	8.869	9.177	9.485	9.793	10.101	10.409	10.717
+400° (+205°)	11.025	11.334	11.642	11.951	12.260	12.568	12.877	13.185	13.494	13.802
+500° (+260°)	14.110	14.418	14.727	15.035	15.343	15.650	15.958	16.266	16.573	16.881
+600° (+316°)	17.188	17.495	17.802	18.109	18.416	18.722	19.029	19.336	19.642	19.949
+700° (+372°)	20.255	20.561	20.868	21.174	21.480	21.787	22.093	22.400	22.706	23.013
+800° (+427°)	23.320	23.627	23.934	24.241	24.549	24.856	25.164	25.473	25.781	26.090
+900° (+483°)	26.400	26.710	27.020	27.330	27.642	27.953	28.266	28.579	28.892	29.206
+1000° (+538°)	29.521	29.836	30.153	30.470	30.788	31.106	31.426	31.746	32.068	32.390
+1100° (+594°)	32.713	33.037	33.363	33.689	34.016	34.345	34.674	35.005	35.337	35.670
+1200° (+649°)	36.004	36.339	36.675	37.013	37.352	37.692	38.033	38.375	38.718	39.063
+1300° (+705°)	39.408	39.755	40.103	40.452	40.801	41.152	41.504	41.856	42.210	42.561

Type K (Chrom Temperature i			nce junct	ion at 32°F	(0°C) M	illivolts —	>			
-400° (-240°) -300° (-185°) -200° (-129°) -100° (-74°) 0° (-18°) Deg. °F (°C)	-6.344 -5.632 -4.381 -2.699 -0.692	-6.380 -5.730 -4.527 -2.884 -0.905 10°(-13°)	-6.409 -5.822 -4.669 -3.065 -1.114 20°(-7°)	-6.431 -5.908 -4.806 -3.243 -1.322 30°(-2°)	-6.446 -5.989 -4.939 -3.417 -1.527 40°(5°)	-6.456 -6.064 -5.067 -3.587 -1.729	-6.133 -5.190 -3.754 -1.929 60°(16°)	-6.195 -5.308 -3.917 -2.126 70°(22°)	-6.251 -5.421 -4.076 -2.230 80°(27°)	-6.301 -5.529 -4.231 -2.511 90°(33°)
0° (-18°) +100° (+38°) +200° (+94°) +300° (+149°) +400° (+205°)	-0.692 1.521 3.820 6.094 8.316	-0.478 1.749 4.050 6.317 8.539	-0.262 1.977 4.280 6.540 8.761	-0.044 2.207 4.509 6.763 8.985	0.176 2.436 4.738 6.985 9.208	0.397 2.667 4.965 7.207 9.432	0.619 2.897 5.192 7.429 9.657	0.843 3.128 5.419 7.650 9.882	1.068 3.359 5.644 7.872 10.108	1.294 3.590 5.869 8.094 10.334
+500° (+260°) +600° (+316°) +700° (+372°) +800° (+427°) +900° (+483°) +1000° (+538°)	10.561 12.855 15.179 17.526 19.887 22.255	10.789 13.086 15.413 17.761 20.123 22.492	11.017 13.318 15.647 17.997 20.360 22.729	11.245 13.549 15.881 18.233 20.597 22.966	11.474 13.782 16.116 18.469 20.834 23.206	11.703 14.014 16.350 18.705 21.071 23.439	11.933 14.247 16.585 18.941 21.308 23.676	12.163 14.479 16.820 19.177 21.544 23.913	12.393 14.713 17.055 19.414 21.781 24.149	12.624 14.946 17.290 19.650 22.018 24.386
+1000 (+538°) +1100 (+594°) +1200° (+649°) +1300° (+705°) +1400° (+760°) +1500° (+816°)	24.622 26.978 29.315 31.628 33.912	24.858 27.213 29.548 31.857 34.139	25.729 25.094 27.477 29.780 32.087 34.365	25.330 27.681 30.012 32.316 34.591	25.200 25.566 27.915 30.243 32.545 34.817	25.439 25.802 28.149 30.475 32.744 35.043	26.037 28.383 30.706 33.002 35.268	26.273 28.616 30.937 33.230 35.493	26.508 28.849 31.167 33.458 35.718	24.560 26.743 29.082 31.398 33.685 35.942
+1600° (+872°) +1600° (+872°) +1700° (+927°) +1800° (+983°) +1900° (+1038°) +2000° (+1094°)	36.166 38.389 40.581 42.741 44.866	36.390 38.610 40.798 42.955 45.077	36.613 38.830 41.015 43.169 45.287	36.836 39.050 41.232 43.382 45.497	37.059 39.270 41.449 43.595 45.706	37.281 39.489 41.665 43.808 45.915	37.504 39.708 41.881 44.020 46.124	37.725 39.927 42.096 44.232 46.332	37.947 40.145 42.311 44.444 46.540	38.168 40.363 42.526 44.655 46.747
+2100° (+1149°) +2200° (+1205°) +2300° (+1260°) +2400° (+1316°) +2500° (+1372°)	46.954 49.000 51.000 52.952 54.856	27.161 49.202 51.198 53.144	47.367 49.404 51.395 53.336	47.573 49.605 51.591 53.528	47.778 49.806 51.787 53.719	47.983 50.006 51.982 53.910	48.187 50.206 52.177 54.100	48.391 50.405 52.371 54.289	48.595 50.604 52.565 54.479	48.798 50.802 52.759 54.668



Temperature - E.M.F. Tables - I.T.S. 90

Type E (Chrom										
Temperature i	n degrees F	F (C) Refe	erence j	unction at 32°	' F (0°	C) Millivolts	→			
-400° (-240°)	-9.604	-9.672	-9.729	-9.775	-9.809	-9.830				
-300° (-185°)	-8.404	-8.561	-8.710	-8.852	-8.986	-9.112	-9.229	-9.338	-9.436	-9.525
-200° (-129°)	-6.472	-6.692	-6.907	-7.116	-7.319	-7.516	-7.707	-7.891	-8.069	-8.240
-100° (-74°)	-3.976	-4.248	-4.515	-4.777	-5.035	-5.287	-5.535	-5.777	-6.014	-6.246
0° (-18°)	-1.026	-1.339	-1.648	-1.953	-2.255	-2.552	-2.846	-3.135	-3.420	-3.700
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-1.026	-0.709	-0.389	-0.065	0.262	0.591	0.924	1.259	1.597	1.938
+100° (+38°)	2.281	2.628	2.977	3.330	3.685	4.042	4.403	4.766	5.131	5.500
+200° (+94°)	5.871	6.244	6.620	6.998	7.379	7.762	8.147	8.535	8.924	9.316
+300° (+149°)	9.710	10.106	10.503	10.903	11.305	11.708	12.113	12.520	12.929	13.339
+400° (+205°)	13.751	14.164	14.579	14.995	15.413	15.831	16.252	16.673	17.096	17.520
+500° (+260°)	17.945	18.371	18.798	19.227	19.656	20.086	20.517	20.950	21.383	21.817
+600° (+316°)	22.252	22.687	23.124	23.561	23.999	24.437	24.876	25.316	25.757	26.198
+700° (+372°)	26.640	27.082	27.525	27.969	28.413	28.857	29.302	29.747	30.193	30.639
+800° (+427°)	31.086	31.533	31.980	32.427	32.875	33.323	33.772	34.220	34.669	35.118
+900° (+483°)	35.567	36.016	36.466	36.915	37.365	37.815	38.265	38.714	39.164	39.614
+1000° (+538°)	40.064	10.513	40.963	41.412	41.862	42.311	42.760	43.209	43.658	44.107
+1100° (+594°)	44.555	45.004	45.452	45.900	46.347	46.794	47.241	47.688	48.135	48.581
+1200° (+649°)	49.027	49.472	49.917	50.362	50.807	51.251	51.695	52.138	52.581	53.024
+1300° (+705°)	53.466	53.908	54.350	54.791	55.232	55.673	56.113	56.553	56.992	57.431
+1400° (+760°)	57.870	58.308	58.746	59.184	59.621	60.058	60.494	60.930	61.366	61.801
+1500° (+816°)	62.236	62.670	63.104	63.538	63.971	64.403	64.835	65.267	65.698	66.129
+1600° (+872°)	66.559	66.989	67.418	67.846	68.274	68.701	69.128	69.554	69.979	70.404
+1700° (+927°)	70.828	71.252	71.675	72.097	72.518	72.939	73.360	73.780	74.199	74.618
+1800° (+983°)	75.036	75.454	75.872	76.289						

Type S (Platinu Temperature in				nction at 2'	ን°E (በ°C)	Millivolte	· ->			
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.092	-0.064	-0.035	-0.006	0.024	0.055	0.087	0.119	0.153	0.186
+100° (+38°)	0.221	0.256	0.292	0.328	0.365	0.402	0.440	0.479	0.518	0.557
+200° (+94°)	0.597	0.638	0.379	0.720	0.762	0.804	0.847	0.889	0.933	0.977
+300° (+149°)	1.021	1.065	1.110	1.155	1.200	1.246	1.292	1.338	1.385	1.431
+400° (+205°)	1.478	1.526	1.573	1.621	1.669	1.718	1.766	1.815	1.864	1.913
+500° (+260°)	1.962	2.012	2.062	2.111	2.162	2.212	2.262	2.313	2.364	2.415
+600° (+316°)	2.466	2.517	2.568	2.620	2.671	2.723	2.775	2.827	2.880	2.932
+700° (+372°)	2.984	3.037	3.090	3.143	3.196	3.249	3.302	3.355	3.409	3.462
+800° (+427°)	3.516	3.569	3.623	3.677	3.731	3.785	3.840	3.894	3.949	4.003
+900° (+483°)	4.058	4.112	4.167	4.222	4.277	4.332	4.388	4.443	4.498	4.554
+1000° (+538°)	4.609	4.665	4.721	4.777	4.833	4.889	4.945	5.001	5.058	5.114
+1100° (+594°)	5.171	5.227	5.284	5.341	5.398	5.455	5.512	5.569	5.626	5.684
+1200° (+649°)	5.741	5.799	5.857	5.914	5.972	6.030	3.089	6.147	6.205	6.263
+1300° (+705°)	6.322	6.381	6.439	6.498	6.557	6.616	6.675	6.734	6.794	6.853
+1400° (+760°)	6.913	6.973	7.032	7.092	7.152	7.212	7.272	7.333	7.393	7.454
+1500 °(+816°)	7.514	7.575	7.636	7.697	7.758	7.819	7.880	7.942	8.003	8.065
+1600° (+872°)	8.127	8.188	8.250	8.312	8.374	8.437	8.499	8.561	8.624	8.687
+1700° (+927°)	8.749	8.812	8.875	8.938	9.001	9.065	9.128	9.191	9.255	9.319
+1800° (+983°)	9.382	9.446	9.510	9.574	9.638	9.702	9.767	9.831	9.896	9.960
+1900° (+1038°)	10.025	10.090	10.155	10.220	10.285	10.350	10.415	10.481	10.546	10.612
+2000° (+1094°)	10.677	10.743	10.809	10.875	10.941	11.007	11.073	11.139	11.205	11.271
+2100° (+1149°)	11.338	11.404	11.470	11.537	11.603	11.670	11.737	11.803	11.870	11.937
+2200° (+1205°)	12.004	12.071	12.138	12.205	12.272	12.339	12.406	12.473	12.540	12.607
+2300° (+1260°)	12.674	12.741	12.809	12.876	12.943	13.011	13.078	13.145	13.213	13.280
+2400° (+1316°)	13.347	13.415	13.482	13.550	13.617	13.685	13.752	13.819	13.887	13.954
+2500° (+1372°)	14.022	14.089	14.157	14.224	14.291	14.359	14.426	14.494	14.561	14.628
+2600° (+1427°)	14.696	14.763	14.830	14.897	14.964	15.032	15.099	15.166	15.233	15.300
+2700° (+1483°)	15.367	15.434	15.501	15.568	15.635	15.702	15.768	15.835	15.902	15.968
+2800° (+1538°)	16.035	16.101	16.168	16.234	16.301	16.367	16.433	16.499	46.565	16.631
+2900° (+1594°)	16.697	16.763	16.829	16.895	16.961	17.026	17.092	17.157	17.222	17.288
+3000° (+1649°) +3100° (+1705°) +3200° (+1760°)	17.353 17.998 18.609	17.418 18.061 18.667	17.483 18.124	17.548 18.186	17.613 18.248	17.677 18.310	17.742 18.371	17.806 18.431	17.870 18.491	17.934 18.550

Temperature - E.M.F. Tables - I.T.S. 90

Type T (Copper- Temperature in		•	nce junc	tion at 32°I	- (0°C)	Millivolts	→			
-400° (-240°)	-6.105	-6.150	-6.187	-6.217	-6.240	-6.254				
-300° (-185°)	-5.341	-5.439	-5.532	-5.620	-5.705	-5.785	-5.860	-5.930	-5.994	-6.053
-200° (-129°)	-4.149	-4.286	-4.419	-4.548	-4.673	-4.794	-4.912	-5.025	-5.135	-5.240
-100° (-74°)	-2.581	-2.754	-2.923	-3.089	-3.251	-3.410	-3.565	-3.717	-3.865	-4.009
0° (-18°)	-0.675	-0.879	-1.081	-1.279	-1.475	-1.667	-1.857	-2.043	-2.225	-2.405
Deg. °F (°C)	0°(-18°	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.675	-0.467	-0.256	-0.043	0.173	0.391	0.611	0.834	1.060	1.288
+100° (+38°)	1.519	1.752	1.988	2.227	2.468	2.712	2.958	3.207	3.459	3.712
+200° (+94°)	3.968	4.227	4.487	4.750	5.015	5.282	5.551	5.823	6.096	6.371
+300° (+149°)	6.648	6.928	7.209	7.492	7.777	8.064	8.352	8.643	8.935	9.229
+400° (+205°)	9.525	9.822	10.122	10.423	41.725	11.029	11.335	11.643	11.951	12.262
+500° (+260°)	12.574	12.887	13.202	13.518	13.836	14.155	14.476	14.797	15.120	15.445
+600° (+316°)	15.771	16.098	16.426	46.755	17.086	17.418	17.752	18.086	18.422	18.759
+700° (+372°)	19.097	19.436	19.777	20.118	20.460	20.803				

Type R (Plating Temperature in	Type R (Platinum 13% Rhodium-Platinum) Temperature in degrees F (C) Reference junction at 32° F (0° C) Millivolts —>										
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)	
0° (-18°)	-0.090	-0.063	-0.035	-0.006	0.024	0.054	0.086	0.118	0.151	0.184	
+100° (+38°)	0.218	0.254	0.289	0.326	0.363	0.400	0.439	0.478	0.517	0.557	
+200° (+94°)	0.598	0.639	0.681	0.723	0.766	0.809	0.853	0.897	0.941	0.986	
+300° (+149°)	1.032	1.078	1.124	1.171	1.218	1.265	1.313	1.361	1.410	1.459	
+400° (+205°)	1.508	1.558	1.607	1.658	1.708	1.759	1.810	1.861	1.913	1.965	
+500° (+260°)	2.017	2.070	2.122	2.175	2.229	2.282	2.336	2.390	2.444	2.498	
+600° (+316°)	2.553	2.608	2.663	2.718	2.773	2.829	2.885	2.941	2.997	3.054	
+700° (+372°)	3.110	3.167	3.224	3.281	3.339	3.396	3.454	3.512	3.570	3.628	
+800° (+427°)	3.686	3.745	3.803	3.862	3.921	3.980	4.040	4.099	4.159	4.219	
+900° (+483°)	4.279	4.339	4.399	4.459	4.520	4.580	4.641	4.702	4.763	4.824	
+1000° (+538°)	4.886	4.947	5.009	5.071	5.133	5.195	5.257	5.320	5.382	5.445	
+1100° (+594°)	5.508	5.571	5.634	5.697	5.761	5.824	5.888	5.952	6.016	6.080	
+1200° (+649°)	6.144	6.209	6.273	6.338	6.403	6.468	6.533	6.598	6.664	6.730	
+1300° (+705°)	6.795	6.861	6.927	6.994	7.060	7.126	7.193	7.260	7.327	7.394	
+1400° (+760°)	7.461	7.529	7.596	7.64	7.732	7.800	7.868	7.936	8.005	8.073	
+1500° (+816°)	8.142	8.211	8.280	8.349	8.418	8.488	8.557	8.627	8.697	8.767	
+1600° (+872°)	8.837	8.908	8.978	9.049	9.120	9.191	9.262	9.333	9.404	9.476	
+1700° (+927°)	9.547	9.619	9.691	9.763	9.835	9.908	9.980	10.053	10.126	10.198	
+1800° (+983°)	10.271	10.345	10.418	10.491	10.565	10.638	10.712	10.786	10.860	10.934	
+1900° (+1038°)	11.009	11.083	11.158	11.233	11.307	11.382	11.457	11.533	11.608	11.683	
+2000° (+1094°)	11.759	11.835	11.910	11.986	12.062	12.138	12.214	12.291	12.367	12.443	
+2100° (+1149°)	12.520	12.597	12.673	12.750	12.827	12.904	12.981	13.058	13.135	13.213	
+2200° (+1205°)	13.290	13.367	13.445	13.522	13.600	13.677	13.755	13.833	13.911	13.989	
+2300° (+1260°)	14.066	14.144	14.222	14.300	14.379	14.457	14.535	14.613	14.691	14.770	
+2400° (+1316°)	14.848	14.926	15.005	15.083	15.161	15.240	15.318	15.397	15.475	15.553	
+2500° (+1372°)	15.632	15.710	15.789	15.867	15.946	16.024	16.103	16.181	16.260	16.338	
+2600° (+1427°)	16.417	16.495	16.574	16.652	16.731	16.809	16.887	16.966	17.044	17.122	
+2700° (+1483°)	17.200	17.279	17.357	17.435	17.513	17.591	17.669	17.747	17.825	17.903	
+2800° (+1538°)	17.981	18.059	18.137	18.214	18.292	18.369	18.447	18.524	18.602	18.679	
+2900° (+1594°)	18.756	18.834	18.911	18.988	19.065	19.141	19.218	19.295	19.372	19.448	
+3000° (+1649°) +3100° (+1760°) +3200° (+1760°)	19.525 20.281 21.003	19.601 20.356 21.071	19.677 20.430	19.753 20.503	19.829 20.576	19.905 20.649	19.981 20.721	20.056 20.792	20.132 20.863	20.207 20.933	



Temperature - E.M.F. Tables - I.T.S. 90

Type B (Platin						\\ B #*****				
Temperature i	n degrees 0°(-18°)	10°(-13°)	erence ju 20°(-7°)	unction at 30°(-2°)	32°F (U°C 40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.001	-0.002	-0.002	-0.003	-0.002	-0.002	, ,			, ,
+100° (+38°) +200° (+94°)	-0.001 0.027	0.000 0.032	0.002 0.037	0.004 0.043	0.006 0.049	0.009 0.055	0.012 0.061	0.015 0.068	0.019 0.075	0.023 0.083
+300° (+149°)	0.027	0.032	0.037	0.043	0.049	0.055	0.061	0.066	0.075	0.063
+400° (+205°)	0.030	0.199	0.107	0.223	0.123	0.133	0.143	0.133	0.103	0.303
+500° (+260°)	0.317	0.332	0.347	0.362	0.378	0.394	0.411	0.427	0.444	0.462
+600° (+316°)	0.479	0.497	0.516	0.534	0.553	0.572	0.592	0.612	0.632	0.653
+700° (+372°) +800° (+427°)	0.673 0.898	0.694 0.923	0.716 0.947	0.738 0.972	0.760 0.997	0.782 1.022	0.805 1.048	0.828 1.074	0.851 1.100	0.875 1.127
+900° (+483°)	1.154	1.181	1.208	1.236	1.264	1.293	1.321	1.350	1.379	1.409
+1000° (+538°)	1.439	1.469	1.499	1.530	1.561	1.592	1.624	1.655	1.687	1.720
+1100° (+594°)	1.752	1.785	1.818	1.852	1.886	1.920	1.954	1.988	2.023	2.058
+1200° (+649°) +1300° (+705°)	2.094 2.461	2.129 2.499	2.165 2.538	2.201 2.576	2.237 2.615	2.274 2.654	2.311 2.694	2.348 2.734	2.385 2.774	2.423 2.814
+1400° (+760°)	2.854	5.895	2.936	2.978	3.019	3.061	3.103	3.145	3.188	3.230
+1500° (+816°)	3.273	3.317	3.360	3.404	3.448	3.492	3.537	3.581	3.626	3.672
+1600° (+872°)	3.717	3.763	3.809	3.855	3.901	3.948	3.994	4.014	4.089	4.136
+1700° (+927°) +1800° (+983°)	4.184 4.673	4.232 4.723	4.280 4.774	4.328 4.824	4.377 4.875	4.426 4.926	4.475 4.977	4.524 5.028	4.574 5.080	4.623 5.132
+1000 (+965) +1900° (+1038°)	5.184	5.236	5.288	5.341	5.394	4.926 5.447	5.500	5.553	5.607	5.132
+2000° (+1094°)	5.715	5.769	5.823	5.878	5.932	5.987	6.042	6.098	6.153	6.209
+2100° (+1149°)	6.624	6.320	6.377	6.433	6.490	6.546	6.603	6.660	6.718	6.775
+2200° (+1205°) +2300° (+1260°)	6.833 7.417	6.890 7.477	6.948 4.536	7.006 7.596	7.065 7.656	7.123 7.716	7.182 7.776	7.240 7.836	7.299 7.897	7.358 7.957
+2400° (+1316°)	8.018	8.079	8.140	8.201	8.262	8.323	8.385	8.446	8.508	8.570
+2500° (+1372°)	8.632	8.694	8.756	8.819	8.881	8.944	9.006	9.069	9.132	9.195
+2600° (+1427°)	9.258	9.321	9.385	9.448	9.511	9.575	9.639	9.702	9.766	9.830
+2700° (+1483°)	9.894	9.958	10.022	10.086	10.150	10.215	10.279	10.344	10.408	10.473
+2800° (+1538°) +2900° (+1594°)	10.537 11.185	10.602 11.250	10.666 11.315	10.731 11.380	10.796 11.445	10.861 11.510	10.925 11.575	10.990 11.640	11.055 11.705	11.120 11.770
+3000° (+1649°)	11.835	11.900	11.965	12.030	12.095	12.160	12.225	12.290	12.355	12.420
+3100° (+1705°)	12.484	12.549	12.614	12.679	12.743	12.808	12.872	12.937	13.001	13.066
+3200° (+1760°) +3300° (+1816°)	13.130 13.769	13.194	13.259	13.323	13.387	13.451	13.515	13.579	13.642	13.706

Temperature - E.M.F. Tables

Type W (Tun Temperature	gsten-Ti e in degi	ungsten rees F ((26% RI C) Refer	nenium) ence jui	oction at 3	32°F (0°C) N	lillivolts	→			
Deg. °F (°C)	0°(-18°)	20°(-7°)	40°(5°)	60°(16°)	80°(27°)	Deg. °F (°C)	0°(-18°)	20°(-7°)	40°(5°)	60°(16°)	80°(27°)
0° (-18°)	016	007	0.006	0.026	0.050	+2200°	18.701	18.936	19.170	19.405	19.639
+100° (+38°)	0.079	0.113	0.153	0.197	0.246	+2300°	19.873	20.106	20.340	20.573	20.806
+200° (+94°)	0.299	0.357	0.420	0.487	0.559	+2400°	21.038	21.270	21.502	21.734	21.965
+300° (+149°)	0.634	0.714	0.799	0.887	0.979	+2500°	22.195	22.425	22.655	22.884	23.113
+400° (+205°)	1.075	1.175	1.279	1.387	1.498	+2600°	23.341	23.569	23.796	24.023	24.249
+500° (+260°)	1.613	1.731	1.853	1.978	2.106	+2700°	24.474	24.699	24.923	25.146	25.369
+600° (+316°)	2.238	2.373	2.511	2.652	2.796	+2800°	25.591	25.812	26.033	26.253	26.472
+700° (+372°)	2.943	3.093	3.246	3.401	3.559	+2900°	26.690	26.907	27.124	27.340	27.555
+800° (+427°)	3.720	3.884	4.049	4.218	4.389	+3000°	37.769	27.983	28.195	28.407	28.618
+900° (+483°)	4.562	4.737	4.915	5.095	5.277	+3100°	28.827	29.036	29.244	29.451	29.657
+1000° (+538°)	5.461	5.647	5.836	6.026	6.218	+3200°	29.862	30.066	30.269	30.471	30.672
+1100° (+594°)	6.412	6.607	6.805	7.004	7.205	+3300°	30.871	31.070	31.268	31.464	31.660
+1200° (+649°)	7.407	7.611	7.816	8.023	8.232	+3400°	31.854	32.047	32.240	32.430	32.620
+1300° (+705°)	8.441	8.652	8.865	9.078	9.293	+3500°	32.809	32.996	33.182	33.367	33.551
+1400° (+760°)	9.509	9.726	9.945	10.164	10.384	+3600°	33.733	33.914	34.094	34.273	34.450
+1500° (+816°)	10.606	10.828	11.051	11.275	11.500	+3700°	34.626	34.801	34.974	35.146	35.317
+1600° (+872°)	11.725	11.952	12.179	12.407	12.635	+3800°	35.486	35.654	35.821	35.986	36.150
+1700° (+927°)	12.864	13.094	13.324	13.555	13.786	+3900°	36.312	36.473	36.632	36.790	36.946
+1800° (+983°)	14.018	14.250	14.482	14.715	14.948	+4000°	37.101	37.254	37.406	37.557	37.705
+1900° (+1038°)	15.182	15.415	15.649	15.884	16.118	+4100°	37.853	37.998	38.142	38.285	38.425
+2000° (+1094°)	16.353	16.587	16.822	17.057	17.292	+4200°	38.564				
+2100° (+1149°)	17.527	17.762	17.997	18.232	18.467						

Temperature - E.M.F. Tables

	Type W3 (Tungsten 3% Rhenium-Tungsten 25% Rhenium)									
Temperature i	in degree	s F (C) R	eference	junction	at 32°F (0	O°C) Milli	volts			
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	_	_	_	_	0.043	0.098	0.154	0.211	0.269	0.329
+100° (+38°)	0.390	0.452	0.515	0.579	0.644	0.711	0.778	0.847	0.916	0.987
+200° (+94°)	1.058	1.130	1.204	1.278	1.354	1.430	1.507	1.585	1.664	1.743
+300° (+149°)	1.824	1.905	1.988	2.071	2.154	2.239	2.324	2.410	2.497	2.584
+400° (+205°)	2.673	2.761	2.851	2.941	3.032	3.123	3.216	3.308	3.402	3.495
+500° (+260°)	3.590	3.685	3.781	3.877	3.973	4.071	4.168	4.267	4.365	4.464
+600° (+316°)	4.564	4.664	4.765	4.866	4.967	5.069	5.171	5.274	5.377	5.480
+700° (+372°)	5.584	5.688	5.793	5.898	6.003	6.108	6.214	6.320	6.427	6.53
+800° (+427°)	6.640	6.748	6.855	6.963	7.071	7.180	7.288	7.397	7.506	7.615
+900° (+483°)	7.725	7.835	7.945	8.055	8.165	8.275	8.386	8.497	8.608	8.719
+1000° (+538°)	8.830	8.942	9.053	9.165	9.277	9.389	9.501	9.613	9.726	9.838
+1100° (+594°)	9.951	10.063	10.176	10.289	10.402	40.514	10.628	10.741	10.854	10.967
+1200° (+649°)	11.080	11.194	11.307	11.420	11.534	11.647	11.761	11.874	11.988	12.102
+1300° (+705°)	12.215	12.329	12.443	12.556	12.670	12.784	12.897	13.011	13.125	13.238
+1400° (+760°)	13.352	13.466	13.579	13.693	13.807	13.920	14.034	14.148	14.262	14.376
+1500° (+816°)	14.489	14.603	14.717	14.830	14.944	15.057	15.171	15.284	15.398	15.511
+1600° (+872°)	15.624	15.737	15.850	15.963	16.076	16.189	16.302	16.414	16.527	16.639
+1700° (+927°)	16.752	16.864	16.976	17.088	17.200	17.312	17.424	17.536	17.647	17.759
+1800° (+983°)	17.870	17.982	18.093	18.204	18.315	18.426	18.537	18.647	18.758	18.868
+1900° (+1038°)	18.979	19.089	19.199	19.309	19.419	19.528	19.638	19.747	19.857	19.966
+2000° (+1094°)	20.075	20.184	20.293	20.401	20.510	20.618	20.726	20.835	20.943	21.050
+2100° (+1149°)	21.158	21.266	21.373	21.480	21.588	21.695	21.802	21.908	22.015	22.121
+2200° (+1205°)	22.228	22.334	22.440	22.546	22.651	22.757	22.863	22.968	23.073	23.178
+2300° (+1260°)	23.283	23.388	23.492	23.596	23.701	23.805	23.909	24.013	24.116	24.220
+2400° (+1316°)	24.323	24.426	24.529	24.632	24.735	24.838	24.940	25.042	25.145	25.246
+2500° (+1372°)	25.348	25.450	25.551	25.653	25.754	25.855	25.956	26.057	26.157	26.258
+2600° (+1427°)	26.358	26.458	26.558	26.658	26.757	26.857	26.956	27.055	27.154	27.253
+2700° (+1483°)	27.352	27.450	27.548	27.647	27.745	27.842	27.940	28.038	28.135	28.232
+2800° (+1538°)	28.329	28.426	28.523	28.619	28.715	28.812	28.908	29.003	29.099	29.194
+2900° (+1594°)	29.290	29.385	29.480	29.575	29.669	29.764	29.858	29.958	30.046	30.139
+3000° (+1649°)	30.233	30.326	30.419	30.512	30.605	30.698	30.790	30.882	30.974	31.066
+3100° (+1705°)	31.158	31.249	31.340	31.432	31.522	31.613	31.703	31.794	31.884	31.974
+3200° (+1760°)	32.063	32.153	32.242	32.331	32.420	32.508	32.596	32.685	32.772	32.860
+3300° (+1816°)	32.948	33.035	33.122	33.209	33.295	33.381	33.467	33.553	33.369	33.724
+3400° (+1872°)	33.809	33.894	33.979	34.063	34.147	34.231	34.314	34.398	34.481	34.563
+3500° (+1927°)	34.646	34.728	34.810	34.892	34.973	35.054	35.135	35.215	35.295	35.375
+3600° (+1983°)	35.455	35.534	35.613	35.692	35.770	35.848	35.926	36.003	36.080	36.157
+3700° (+2038°)	36.233	36.309	36.384	36.460	36.535	36.609	36.683	36.757	36.831	36.904
+3800° (+2094°)	36.976	37.049	37.120	37.192	37.263	37.334	37.404	37.474	37.543	37.612
+3900° (+2149°)	37.681	37.749	37.816	37.884	37.950	38.017	38.082	38.148	38.213	38.277
+4000° (+2205°)	38.341	38.404	38.467	38.530	38.591	38.653	38.714	38.774	38.834	38.893
+4100° (+2260°)	38.951	39.009	39.067	39.124	39.180	39.236	39.291	39.346	39.400	39.453
+4200° (+2316°)	39.506									



Temperature - E.M.F. Tables

Type W5 (Tungsten 5% Rhenium-Tungsten 26% Rhenium) Temperature in degrees F (C) Reference junction at 32°F (0°C) Millivolts →										
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-	-	-		0.060	0.135	0.211	0.288	0.366	0.444
+100° (+38°) +200° (+94°)	0.523 1.348	0.602 1.434	0.683 1.520	0.764 1.607	0.845 1.695	0.927 1.783	1.010 1.872	1.094 1.961	1.178 2.051	1.263 2.141
+300° (+149°)	2.232	2.323	2.415	2.507	2.600	2.693	2.787	2.881	2.975	3.070
+400° (+205°)	3.166	3.261	3.358	3.454	3.551	3.648	3.746	3.844	3.943	4.041
+500° (+260°)	4.141	4.240	4.340	4.440	4.540	4.641	4.742	4.844	4.945	5.047
+600° (+316°)	5.149	5.252	5.354	5.457	5.560	5.664	5.768	5.871	5.976	6.080
+700° (+372°)	6.185	6.289	6.394	6.499	6.605	6.710	6.816	6.922	7.028	7.134
+800° (+427°)	7.240	7.347	7.453	7.560	7.667	7.774	7.881	7.988	8.096	8.203
+900° (+483°) +1000° (+538°)	8.311 9.391	8.418 9.499	8.526 9.607	8.634 9.716	8.742 9.824	8.850 9.993	8.958 10.041	9.066 10.150	9.174 10.259	9.282 10.367
+1100° (+594°)	10.476	10.584	10.693	10.802	10.910	11.019	11.128	11.236	11.345	11.453
+1200° (+649°)	11.562	11.670	11.779	11.887	11.996	12.104	12.212	12.321	12.429	12.537
+1300° (+705°)	13.645	12.753	12.861	12.969	13.077	13.185	13.293	13.401	13.508	13.616
+1400° (+760°)	13.723	13.831	13.938	14.045	14.152	14.259	14.366	14.473	14.580	14.686
+1500° (+816°)	14.793	14.899	15.005	15.112	15.218	15.324	15.429	15.535	15.641	15.746
+1600° (+872°)	15.852	15.957	16.062	16.167	16.272	16.376	16.481	16.585	16.690	16.794
+1700° (+927°) +1800° (+983°)	16.898 17.930	17.002 18.033	17.106 18.135	17.209 18.237	17.313 18.339	17.416 18.441	17.519 18.542	17.622 18.644	17.725 18.745	17.828 18.846
+1800° (+983°) +1900° (+1038°)	17.930	19.048	19.149	18.237	19.349	18.441	18.542 19.549	18.644	18.745	19.848
+2000° (+1094°)	19.948	20.047	20.146	20.244	20.343	20.441	20.540	20.638	20.736	20.833
+2100° (+1149°)	20.931	21.028	21.125	21.222	21.319	21.416	21.512	21.609	21.705	21.801
+2200° (+1205°)	21.896	21.992	22.087	22.182	22.277	22.372	22.467	22.561	22.656	22.750
+2300° (+1260°)	22.844	22.937	23.031	23.124	23.217	23.310	23.403	23.496	23.588	23.680
+2400° (+1360°)	23.772	23.864	23.956	24.047	24.139	24.230	24.321	24.412	24.502	24.593
+2500° (+1372°) +2600° (+1427°)	24.683 25.574	24.773 25.662	24.863 25.750	24.952 25.838	25.042 25.926	25.131 26.013	25.220 26.100	25.309 26.187	25.397 26.274	25.486 26.361
+2700° (+1483°)	26.447	26.553	26.620	26.705	26.791	26.877	26.962	27.047	27.132	27.217
+2800° (+1538°)	27.301	27.386	27.470	27.554	27.638	27.722	27.805	27.888	27.971	28.054
+2900° (+1594°)	28.137	28.219	28.302	28.384	28.466	28.548	28.629	28.711	28.792	28.873
+3000° (+1649°)	28.954	29.034	29.115	29.195	29.275	29.355	29.435	29.514	29.593	29.673
+3100° (+1705°)	29.752	29.830	29.909	29.987	30.065	30.143	30.221	30.299	30.376	30.453
+3200° (+1760°) +3300° (+1816°)	30.530 31.289	30.607 31.364	30.684 31.439	30.760 31.513	30.736 31.587	30.912	30.98 31.735	31.064 31.809	34.139 31.882	31.214 31.955
+3400° (+1872°)	31.289	31.364 32.101	31.439 32.174	31.513 32.246	31.587 32.318	31.661 32.390	31.735 32.462	31.809	31.882	31.955
+3500° (+1927°)	32.746	32.817	32.887	32.958	33.027	33.097	33.167	33.236	33.305	33.374
+3600° (+1983°)	33.443	33.511	33.579	33.647	33.715	33.782	33.849	33.916	33.983	34.049
+3700° (+2038°)	34.116	34.182	34.247	34.313	34.378	34.443	34.508	34.572	34.636	34.700
+3800° (+2094°)	34.764	34.827	34.890	34.953	35.016	35.078	35.140	35.202	35.263	35.325
+3900° (+2149°)	35.386	35.446	35.506	35.567	35.626	35.686	35.745	35.804	35.862	35.920
+4000° (+2205°) +4100° (+2260°)	35.978 36.540	36.036 36.594	36.093 36.648	36.150 36.701	36.207 36.755	36.263 36.808	36.319 36.860	36.375 36.912	36.430 36.964	36.485 37.015
+4200° (+2316°)	37.066	JU.JJ4	JU.U4U	50.701	50.755	50.000	50.000	50.312	00.304	01.013

Temperature - E.M.F. Tables - I.T.S. 90

Type N (Nicros Temperature i		s F (C) Re	eference ju	inction at	32° F (0°	C) Millivo	olts ->			
Deg. °F (°C)	0°(-18°)	10°(-13°)	20°(-7°)	30°(-2°)	40°(5°)	50°(10°)	60°(16°)	70°(22°)	80°(27°)	90°(33°)
0° (-18°)	-0.461	-0.318	-0.174	-0.029	0.116	0.261	0.407	0.555	0.703	0.853
+100° (+38°)	1.004	1.156	1.309	1.463	1.619	1.776	1.934	2.093	2.253	2.415
+200° (+94°)	2.577	2.741	2.906	3.072	3.240	3.408	3.578	3.748	3.920	4.093
+300° (+149°)	4.267	4.442	4.618	4.795	4.973	5.152	5.332	5.512	5.694	5.877
+400° (+205°)	6.060	6.245	6.430	6.616	6.803	6.991	7.179	7.369	7.559	7.750
+500° (+260°)	7.941	8.134	8.327	8.520	8.715	8.910	9.105	9.302	9.499	9.696
+600° (+316°)	9.895	10.093	10.293	10.493	10.693	10.894	11.096	11.298	11.501	11.704
+700° (+372°)	11.907	12.111	12.306	12.521	12.726	12.932	13.139	13.346	13.553	13.760
+800° (+427°)	13.969	14.177	14.386	14.595	14.804	15.014	15.225	15.435	16.646	15.857
+900° (+483°)	16.069	16.281	16.493	16.705	16.918	17.131	17.344	17.558	17.772	17.986
+1000° (+538°)	18.200	18.414	18.629	18.844	19.059	19.274	19.490	19.705	19.921	20.137
+1100° (+594°)	20.353	20.570	20.786	21.003	21.220	21.437	21.654	21.871	22.088	22.305
+1200° (+649°)	22.523	22.740	22.958	23.176	23.393	23.611	23.829	24.047	24.265	24.483
+1300° (+705°)	24.701	24.919	25.137	25.356	25.574	25.792	26.010	26.229	26.447	26.665
+1400° (+760°)	26.883	27.102	27.320	27.538	27.756	27.975	28.193	28.411	28.629	28.847
+1500° (+816°)	29.065	29.283	29.501	29.719	29.937	30.154	30.372	30.590	30.807	31.025
+1600° (+872°)	31.242	31.459	31.677	31.894	32.111	32.328	32.545	32.761	32.978	33.195
+1700° (+927°)	33.411	33.627	33.844	34.060	34.276	34.491	34.707	34.923	35.138	35.353
+1800° (+983°)	35.568	35.783	35.998	36.213	36.427	36.641	36.855	37.069	37.283	37.497
+1900° (+1038°)	37.710	37.923	38.136	38.349	38.562	38.774	38.986	39.198	39.410	39.622
+2000° (+1094°)	39.833	40.044	40.255	40.466	40.677	40.887	41.097	41.307	41.516	41.725
+2100° (+1149°) +2200° (+1205°) +2300° (+1260°)	41.935 44.012 46.060	42.143 44.218 46.263	42.352 44.424 46.466	42.560 44.629 46.668	42.768 44.835 46.870	42.976 45.040 47.071	43.184 45.245 47.272	43.391 45.449 47.473	43.598 45.653	43.805 45.857

		IN THE EN		WD ED	T/AI		0.0		DM
hermoelement	JP	JN,TN, EN	TP	KP, EP	KN	RP	SP	BP	BN
emperature, °C				Seebe	ck Coefficient,	, μV/°C			
-190	+6.3	-20.9	-4.1	_	_	_	_	_	_
-100	14.4	27.0	+1.1	_	_	_	_	_	_
0	17.8	32.2	5.9	+25.7	-13.5	+5.5	+5.5	_	_
200	14.6	41.0	12.0	32.7	7.4	8.5	8.5	+9.2	+7.2
400	9.7	45.5	16.2	34.6	7.7	10.5	9.5	11.7	7.6
600	11.7	46.8	_	33.8	8.8	11.5	10.0	13.8	7.9
800	17.8	46.4	_	32.2	8.8	12.5	11.0	15.8	8.2
1000	_	_	_	30.8	8.3	13.0	11.5	17.7	8.5
1200	_	_	_	29.1	7.4	14.0	12.0	19.1	8.7
1400	_	_	_	_	_	14.0	12.0	19.1	8.7
1600	_	_	_	_	-	13.5	12.0	20.4	8.7
Temperature, °F				Seebe	k Coefficient,	μV/°F			
-300	+2.5	-11.9	-2.1	_	_	_	_	_	_
-200	6.7	14.0	+0.2	_	_	_	_	_	_
-100	8.8	15.8	1.5	_	_	_	_	_	_
32	9.9	17.9	3.3	+14.3	-7.5	+3.0	+3.0	_	_
200	9.6	20.5	5.0	16.7	6.5	4.1	4.0	+4.1	+3.6
400	8.0	22.9	6.7	18.3	4.0	4.9	4.7	5.1	4.0
600	6.2	24.5	8.2	19.0	4.1	5.5	5.2	5.8	4.2
800	5.3	25.3	_	19.1	4.4	5.8	5.4	6.5	4.2
1000	5.7	26.0	_	18.9	4.8	6.2	5.5	7.4	4.3
1500	9.9	25.8	_	17.8	4.9	6.8	6.1	8.8	4.6
2000	_	_	_	16.7	4.3	7.6	6.6	10.2	4.8
2500	_	_	_	14.9	4.0	7.7	6.7	11.0	4.9
3000						7.6	6.5	11.3	4.9



Selection Guide for Protection Tubes

Application	Protection Tube Material	Application	Protection Tube Material
Heal Treating		Glass	
Annealing		For hearths and feeders	Platinum thimble
Up to 1300°F (704°C)	Wrought iron	Lehrs	Wrought iron
Over 1300°F (704°C)	28% chrome iron or Inconel®	Tanks	<u> </u>
Carburizing hardening Up to 1500°F (816°C)	Wrought iron or 28% chrome iron	Roof and wall	Ceramic
1500 to 2000°F (1093°C)	28% chrome iron or Inconel	Flues and checkers	28% chrome iron, Inconel
Over 2000°F (1093°C)	Ceramic	Paper	
Nitriding salt baths		Digesters	Type 316 stainless steel,
Cyanide	28% chrome iron		28% chrome iron
Neutral High speed	Nickel Ceramic	Petroleum	
Iron and steel		Dewaxing	Type 304 stainless steel or
Basic oxygen furnace	Quartz	Tours	carbon steel
Blast furnaces	Quantz	Towers	Type 304 stainless steel or carbon steel
Downcomer	Inconel, 28% chrome iron	Transfer lines	Type 304 stainless steel or
Stove Dome	Silicon carbide		carbon steel
Hot blast main Stove trunk	Inconel Inconel	Fractionating column	Type 304 stainless steel or
Stove draink Stove outlet flue	Wrought iron		carbon steel
Open hearth		Bridgewall	Type 304 stainless steel or
Flues and stack	Inconel, 28% chrome iron	Barrer	carbon steel
Checkers	Inconel, Cermet	Power Coal-air mixtures	Tuna 204 stainless staal
Waste heat boiler	28% chrome iron, Inconel		Type 304 stainless steel Wrought iron or 28% chrome iron
Billet heating slab heating and butt welding		Flue gases Preheaters	Wrought iron or 28% chrome iron
Up to 2000°F (1093°C)	28% chrome iron, Inconel	Steel lines	Type 347 or 316 stainless steel
Over 2000°F (1093°C)	Ceramic, silicon carbide	Water lines	Carbon steel
Bright annealing batch	Niek we worken et	Boiler tubes	Type 309 or 310 stainless steel
Top work temperature	Not required (use bare Type J thermocouple)		.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
Bottom work temperature	28% Chrome iron	Gas producers Producer gas	28% chrome iron
Continuous furnace section	Inconel, ceramic	Water gas	20 % CHIOTHE HOH
Forging	Silicon carbide, ceramic	carburetor	Inconel, 28% chrome iron
Soaking pits		Super heater	Inconel, 28% chrome iron
Up to 2000°F (1093°C)	Inconel	Tar stills	Carbon steel
Over 2000°F (1093°C)	Ceramic, silicon carbide	Incinerators	
Nonferrous metals		Up to 2000°F (1093°C)	28% chrome iron, Inconel
Aluminum		Over 2000°F (1093°C)	Ceramic (primary)
Melting	Cast iron (white-washed)	0.00. 2000 1 (1000 0)	Silicon carbide (secondary)
Heat treating Brass or bronze	Wrought iron Not required	Food	
Diass of biolize	(use dip-type thermocouple)	Baking ovens	Wrought iron
Lead	28% chrome iron, wrought iron	Charretort, sugar	Wrought iron
Magnesium	Wrought iron, cast iron	Vegetables and fruit	Type 304 stainless steel
Tin	Extra heavy carbon steel	Sanitary	Type 316 stainless steel
Zinc	Extra heavy carbon steel	Chemical	
Pickling tanks	Chemical lead	Acetic acid	
Cement:		10 to 50%, 70°F	Type 304 stainless steel
Exit flues	Inconel, 28% chrome iron	50%, 212°	Type 316 stainless steel
Kilns-heating zone	Inconel	99%, 70 to 212°F	Type 430 stainless steel
Ceramic: Kilns	Ceramic and silicon carbide	Alcohol, ethyl, methyl 70 to 212°F	Typo 304 stainless stool
Dryers	Wrought iron, silicon carbide	Ammonia	Type 304 stainless steel
Vitreous enameling	Inconel, 28% chrome iron	All concentration, 70°F	Type 304 stainless steel
villeous chailleiling	mooner, 20 % chiloffle flori	, 5556maa6m, 70 T	., - 0 00 . 0.00



Selection Guide for Protection Tubes

Application Chemical	Protection Tube Material	Application Chemical	Protection Tube Material
Ammonium chloride All concentration, 212°F (100°C)	Type 304 stainless steel	Ferric sulphate 5%, 70°F (22°C)	Type 304 stainless steel
Ammonium nitrate	Type 304 stailliess steel	Ferrous sulphate Dilute 70°F (22°C)	Type 304 stainless steel
All concentration, 70 to 212°F (22 to 100°C)	Type 304 stainless steel	Formaldehyde Formic acid	Type 304 stainless steel
Ammonium sulphate 10% to saturated, 212°F (100°C)	Type 316 stainless steel	5%, 70 to 150°F (22 to 66°C)	Type 304 stainless steel
Barium chloride	Type 3 to stairliess steel	Freon	Monel
All concentration, 70°F (22°C)	Monel®	Gallic acid 5%, 70 to 150°F	
	MOHEL	(22 to 66°C)	Monel
Barium hydroxide All concentration,		Gasoline	
70°F (22°C)	Carbon steel	70°F (22°C)	Type 304 stainless steel
Barium sulfate	Nichrome	Glucose	
Brines	Monel	70°F (22°C)	Type 304 stainless steel
Bromine	Tantalum	Glycerine	
		70°F (22°C)	Type 304 stainless steel
Butadiene	Type 304 stainless steel	Glycerol	Type 304 stainless steel
Butane	Type 304 stainless steel	Hydrobromic acid	
Butylacetate	Monel	98%, 212°F (100°C)	Hastelloy B
Butyl alcohol	Copper	Hydrochloric acid	
Calcium chlorate		1%, 5%, 70°F (22°C)	Hastelloy C
Dilute, 70 to 150°F	T 004 -1 1-1 1-1	1%, 5%, 212°F (100°C)	Hastelloy B
(22 to 66°C)	Type 304 stainless steel	25%, 70 to 212°F	Hantallari D
Calcium hydroxide	T 004	(22 to 100°)	Hastelloy B
10 to 20%, 212°F (100°C)		Hydrofluoric acid	Hastelloy C
50%, 212°F (100°C) Carbolic acid	Type 316 stainless steel	Hydrogen peroxide 70 to 212°F (22 to 100°)	Type 316 stainless steel
All 212°F (100°C)	Type 316 stainless steel	Hydrogen sulphide	
Carbon dioxide		Wet and dry	Type 316 stainless steel
wet or dry	2017-T4 aluminum, Monel	lodine	
Chlorine gas		70°F (22°C)	Tantalum
Dry, 70°F (22°C)	Type 316 stainless steel	Lactic acid	
Moist, 20 to 212°F		5%, 70°F (22°C)	Type 304 stainless steel
(-7 to 100°C)	Hastelloy® C	5%, 150°F (66°C)	Type 304 stainless steel
Chromic acid	Time 015 stainless staal	10%, 212°F (100°C)	Tantalum
10 to 50%, 212°F (100°C)	Type 315 stainless steel	Magnesium chloride	
Citric acid 15%, 70°F (22°C)	Type 204 stainless steel	5%, 70°F (22°C)	Monel
15%, 70 F (22 C) 15%, 212°F (100°C)	Type 304 stainless steel Type 315 stainless steel	5%, 212°F (100°C)	Nickel
Concentrated,	Type of a starried steel	Magnesium sulphate	Maria
212°F (100°C)	Type 316 stainless steel	Hot and cold	Monel
Copper nitrate	Type 304 stainless steel	Muriatic acid	Tarabalisma
Copper sulphate	Type 304 stainless steel	70°F (22°C)	Tantalum
Cresols	Type 304 stainless steel	Naphtha	Tura 201 stainless stad
Cyanogen gas	Type 304 stainless steel	70°F (22°C)	Type 304 stainless steel
DOWTHERM™	Carbon steel	Natural gas	Type 204 stainless staal
Ether		70°F (22°C)	Type 304 stainless steel
	Type 304 stainless steel	Nickel chloride	Type 304 stainless steel
Ethyl acetate	Monel	70°F (22°C)	Type 304 Stairliess Steel
Ethyl chloride	Type 204 stainless staal	Nickel sulphate Hot and cold	Type 304 stainless steel
70°F (22°C)	Type 304 stainless steel	Nitric acid	1900 004 Stailliess Steel
Ethyl sulphate 70°F (22°C)	Monel	5%, 70°F (22°C)	Type 304 stainless steel
	IVIOLIGI	20%, 70°F (22°C)	Type 304 stainless steel
Ferric chloride 5%, 70°F (22°C) to boiling	Tantalum	50%, 70°F (22°C)	Type 304 stainless steel
5 /o, / O i (22 C) to boiling	rantalum	50%, 212°F (100°C)	Type 304 stainless steel
		65%, 212°F (100°C)	Type 316 stainless steel



Selection Guide for Protection Tubes

Application	Protection Tube Material	Application	Protection Tube Material
Chemical		Chemical	
Nitric acid		Salicylic acid	Nickel
Concentrated, 70°F (22°C Concentrated,	c) Type 304 stainless steel	Sodium bicarbonate All concentration,	
212°F (100°C) Nitrobenzene	Tantalum	70°F (22°C) Saturated, 70 to 212°F	Type 304 stainless steel
70°F (22°C) Oleic acid	Type 304 stainless steel	(22 to 100°C) Sodium carbonate	Type 304 stainless steel
70°F (22°C) Oleum	Type 316 stainless steel	5%, 70 to 150°F (22 to 66°C)	Type 304 stainless steel
70°F (22°C) Oxalic acid	Type 316 stainless steel	Sodium chloride 5%, 70 to 150°F	
5%, hot and cold 10%, 212°F (100°C)	Type 304 stainless steel Monel	(22 to 66°C) Saturated, 70 to 212°F (22 to 100°C)	Type 316 stainless steel Type 316 stainless steel
Oxygen 70°F (100°C)	Steel	Sodium fluoride 5%, 70°F (22°C)	Monel
Liquid Elevated temperatures	Stainless steel Stainless steel	Sodium hydroxide	Type 304 stainless steel
Palmitic acid	Type 316 stainless steel	Sodium hypochlorite 5% still	Type 316 stainless steel
Pentane Phenol	Type 304 stainless steel Type 304 stainless steel	Sodium nitrate	Type o to stairliess steel
Phosphoric acid	Type 304 Stallilless Steel	fused	Type 316 stainless steel
1%, 5%, 70°F (22°C)	Type 304 stainless steel	Sodium peroxide Sodium sulphate	Type 304 stainless steel
10%, 70°F (22°C) 10%, 212°F (100°C) 30%, 70°F, 212°F	Type 316 stainless steel Hastelloy® C	70°F (22°C) Sodium sulphide	Type 304 stainless steel
(22°C,100°C) 85%, 70°F, 212°F	Hastelloy B	70°F (22°C) Sodium sulphite	Type 316 stainless steel
(22°C, 100°C)	Hastelloy B	150°F (66°C)	Type 304 stainless steel
Picric acid 70°F (22°C) Potassium bromide	Type 304 stainless steel	Sulphur dioxide Moist gas, 70°F (22°C) Gas, 575°F (302°C)	Type 316 stainless steel Type 304 stainless steel
70°F (22°C)	Type 316 stainless steel	Sulphur	•
Potassium carbonate 70°F (22°C)	Type 304 stainless steel	Dry-molten Wet	Type 304 stainless steel Type 316 stainless steel
Potassium chlorate 70°F (22°C)	Type 304 stainless steel	Sulphuric acid 5%, 70 to 212°F	Heatella. D
Potassium hydroxide 5%, 70°F (22°C)	Type 304 stainless steel	(22 to 100°C) 10%, 70 to 212°F	Hastelloy B
25%, 212°F (100°C) 60%, 212°F (100°C)	Type 304 stainless steel Type 316 stainless steel	(22 to 100°C) 50%, 70 to 212°F	Hastelloy B
Potassium nitrate 5%, 70°F (22°C) 5%, 212°F (100°C)	Type 304 stainless steel Type 304 stainless steel	(22 to 100°C) 90%, 70°F (22°C) 90%, 212°F (100°C)	Hastelloy B Hastelloy B Hastelloy D
Potassium permanganate 5%, 70°F (22°C)	Type 304 stainless steel	Tannic acid 70°F (22°C)	Type 304 stainless steel
Potassium sulphate 5%, 70°F (22°C)	Type 304 stainless steel	Tartaric acid 70°F (22°C) 150°F (66°C)	Type 304 stainless steel Type 316 stainless steel
Potassium sulphide 70°F (22°C)	Type 304 stainless steel	Toluene	2017-T4 aluminum
Propane	Type 304 stainless steel	Turpentine	Type 304 stainless steel
Pyrogalic acid	Type 304 stainless steel	Whiskey and wine	Type 304 stainless steel
Quinine bisulphate		Xylene	Copper
Dry	Type 316 stainless steel	Zinc chloride	Monel
Quinine sulphate Dry	Type 304 stainless steel	Zinc sulphate 5%, 70°F (22°C)	Type 304 stainless steel
Sea water	Monel	Saturated, 70°F (22°C) 25%, 212°F (100°C)	Type 304 stainless steel Type 304 stainless steel



I. The Control System

The automatic control system consists of a process as shown in Figure 1.

II. Sensors

Sensors commonly used in temperature control are:

- Thermistor: A non-linear device whose resistance varies with temperature. Thermistors are used at temperatures under 500°F. Fragility limits their use in industrial applications.
- 2. Resistance Temperature Detector (RTD):
 - Changes in temperature vary the resistance of an element, normally a thin platinum wire. Platinum RTDs find application where high accuracy and low drift are required. 3-wire sensors are used where the distance between the process and the controller is more than several feet. The third wire is used for leadwire resistance compensation.
- 3. **Thermocouple:** A junction of two dissimilar metals produces a millivolt signal whose amplitude is dependent on (a) the junction metals; (b) the temperature under measurement. Thermocouples require cold-end compensation whereas connections between thermocouple wire and copper at the controller's terminal block produce voltages that are not related to the process temperature. Thermocouple voltage outputs are non-linear with respect to the range of temperatures being measured and, therefore, require linearization for accuracy.

Thermocouple junctions are usually made by welding the dissimilar metals together to form a bead. Different thermocouple types are used for various temperature measurements as shown in Table 1. Thermocouples are the most commonly used industrial sensor because of low cost and durability.

 Other temperature sensors include non-contact infrared pyrometers and thermopiles. These are used where the process is in motion or cannot be accessed with a fixed sensor.

III. Sensor Placement

Reduction of transfer lag is essential for accurate temperature control using simple temperature controllers. The sensor, heater and work load should be grouped as closely as possible. Sensors placed downstream in pipes, thermowells or loose-fitting platen holes will not yield optimum control. Gas and air flow processes must be sensed with an open element probe to minimize lag. Remember that the controller can only respond to the information it receives from its sensor.

Table 1.

Thermocouple Type	Wire Color	Useful Temperature Range °F
J	White	32 to 1300
K	Yellow	-328 to 2200
Т	Blue	-328 to 650
R/S	Black	-32 to 2642

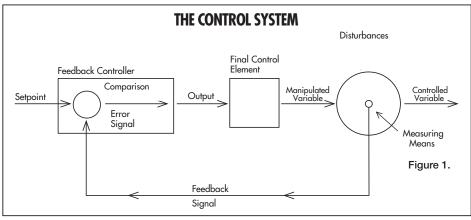


Figure 1.



IV. Process Load Characteristics

Thermal lag is the product of thermal resistance and thermal capacity. A single lag process has one resistance and one capacity. Thermal resistance is present at the heater/water interface. Capacity is the storage capacity of the water being heated.

Sometimes the sensor location is distant from the heated process and this introduces dead time. Figure 2a.

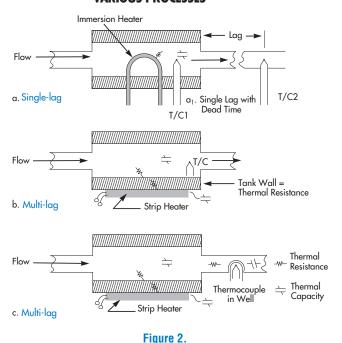
Introduction of additional capacities and thermal resistance changes the process to multi-lag. Figure 2b & 2c.

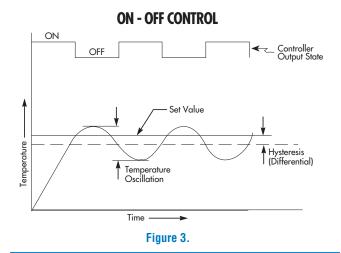
V. Control Modes

- 1. On-Off. Figure 3.
 - On-Off control has two states, fully off and fully on. To prevent rapid cycling, some hysteresis is added to the switching function. In operation, the controller output is on from start-up until temperature set value is achieved. After overshoot, the temperature then falls to the hysteresis limit and power is reapplied.
 - On-Off control can be used where:
 - (a) The process is underpowered and the heater has very little storage capacity.
 - (b) Where some temperature oscillation is permissible.
 - (c) On electromechanical systems (compressors) where cycling must be minimized.
- 2. Proportional. Figure 4.

Proportional controllers modulate power to the process by adjusting their output power within a proportional band. The proportional band is expressed as a percentage of the instrument span and is centered over the setpoint. At the lower proportional band edge and below, power output is 100%. As the temperature rises through the band, power is proportionately reduced so that at the upper band edge and above, power output is 0%.

VARIOUS PROCESSES





PROPORTIONAL CONTROL

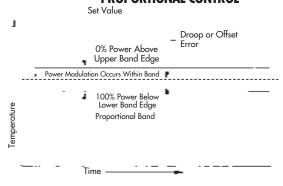


Figure 4.



Proportional controllers can have two adjustments:

- Manual Reset. Figure 5. Allows positioning the band with respect to the setpoint so that more or less power is applied at setpoint to eliminate the offset error inherent in proportional control.
- b) Bandwidth (Gain). Figure 6. Permits changing the modulating bandwidth to accommodate various process characteristics. High-gain, fast processes require a wide band for good control without oscillation. Low-gain, slowmoving processes can be managed well with narrow band to on-off control. The relationship between gain and bandwidth is expressed inversely:

$$Gain = \frac{100\%}{Proportional Band in \%}$$

Proportional-only controllers may be used where the process load is fairly constant and the setpoint is not frequently changed.

- 3. Proportional with Integral (PI), automatic reset. Figure 7. Integral action moves the proportional band to increase or decrease power in response to temperature deviation from setpoint. The integrator slowly changes power output until zero deviation is achieved. Integral action cannot be faster than process response time or oscillation will occur.
- 4. Proportional with Derivative (PD), rate action. Derivative moves the proportional band to provide more or less output power in response to rapidly changing temperature. Its effect is to add lead during temperature change. It also reduces overshoot on start-up.
- Proportional Integral Derivative (PID). This type of control is useful on difficult processes. Its Integral action eliminates offset error, while Derivative action rapidly changes output in response to load changes.

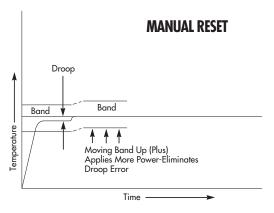
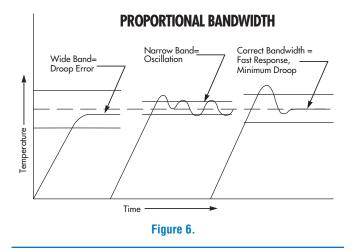
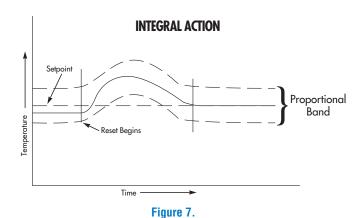


Figure 5.







VI. Proportional Outputs

Load power can be switched by three different proportioning means:

- Current proportional: A 4-20 mA signal is generated in response to the heating % requirement. See Figure 9. This signal is used to drive SCR power controllers and motoroperated valve positioners.
- Phase angle: This method of modulating permits applying a portion of an ac sine wave to the load. The effect is similar to light dimmer function. See Figure 10.
- Time proportioning:
 A clock produces pulses with a variable duty cycle. See Figure 11. Outputs are either director reverse-acting. Direct-acting is used for cooling; reverse-acting for heating.
- 4. Cycle Time: In time proportioning control the cycle time is normally adjustable to accommodate various load sizes. A low mass radiant or air heater requires a very fast cycle time to prevent temperature cycling. Larger heaters and heater load combinations can operate satisfactorily with longer cycle times. Use the longest cycle time consistent with ripple-free control.

VII. Power Handlers

Power is switched to an electric heating load through the final control element. Small, single-phase 120/240 V loads may be connected directly to the temperature controller. Larger, higher voltage heaters must be switched through an external power handler. Power handlers are either large relays (contactors), solid-state contactors or power controllers.

- 1. Mechanical contactors are probably the most widely used power handlers. They:
 - Are rugged. Fuses protect against burnout due to shorts.
 - Will wear out in time due to contact arcing.
 - Cannot be fast-cycled for low-mass loads.
 - Produce RF switching noise.
- 2. Solid-state contactors are often used on loads requiring fast switching times. They need heat sinking and I²T fuse protection.

- 3 32V S.S. contactors switch power at zero crossing of the ac sine wave.
- SCR power controllers. These devices switch ac power by means of thyristors (SCRs). These are solid-state devices that are turned on by gate pulses. They have unlimited life and require no maintenance. SCR controllers are available for switching single- or three-phase loads in zero crossing/burst firing (Figure 12) or phase-angle modes (Figure 10)

Figure 9. Control Current vs. Power Output

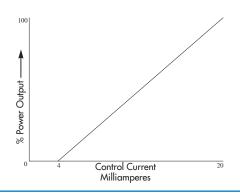


Figure 10. PHASE ANGLE

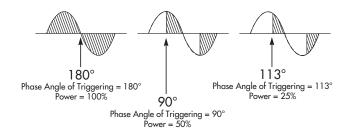
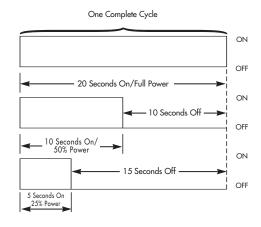


Figure 11. TIME PROPORTIONING





SCR power control selection by switching method can be simplified, as follows:

Use zero crossing for all standard heater applications. Specify phase angle:

- a) When soft start (ramp voltage to peak) is required on high inrush heater loads.
- b) If voltage limit is needed to clamp the maximum output voltage to a level lower than the supply voltage.

VIII. HEATER AND POWER CONTROL CONNECTIONS

Power controls are connected to the control signal and load, per Figure 12.

The control signal to the power controller may originate from a manual potentiometer, PLC or temperature controller. This signal is normally 4-20 mA, but can be other currents or voltages. An increase in the signal level produces a corresponding increase in power controller output.

Calculation of SCR size for various voltages and heater sizes is as follows:

Loads

Single-phase
$$\frac{\text{watts}}{\text{volts}} = \text{amps}$$

Three-phase
$$\frac{\text{watts}}{1.73 \text{ x volts}} = \text{amps}$$

watts = total heater watts

volts = line voltage

amps = total line current

SCRs should not be sized at exactly the heater current requirement because heaters have resistance tolerances as do line supplies.

Example: A single-phase 240 volt heater is rated at 7.2 kW. 7,2004240 = 30 A

If the heater is 10% low on resistance, at 240 V, the heater will draw 33 amperes. Damage to fuses will result. Power controllers must be properly cooled and, therefore, the mounting location should be in a cool area. SCRs dissipate approximately 2 watts per ampere per phase.

Proper fusing is essential to protect the SCR devices from damage due to load short circuits. The type of fuse is marked I²T or semiconductor.

Only SCRs designed to drive transformers should be used for that purpose.

SCR power controllers must never be used as disconnects in high-limit applications.

Figure 12. ZERO VOLTAGE

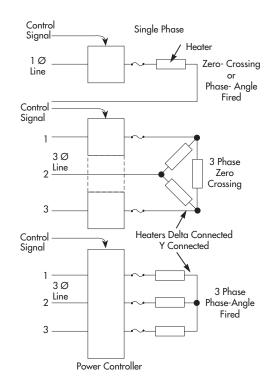
2 Second Time Base

114 Cycles On

Off

Off $\frac{114}{120} = 95\%$ Power Output $\frac{6}{12} = 50\%$ Power Output

117 Cycles Off $\frac{3}{120} = 2.5\%$ Power Output





ACCURACY: The difference between the reading of an instrument and the true value of what is being measured, expressed as a percent of full instrument scale.

ACTION: The function of a controller. Specifically, what is done to regulate the final control element to effect control. Types of action include ON-OFF, proportional, integral and derivative.

ACTIVE DEVICE: A device capable of producing gain; for example, transistors and ICs.

ALARM: A condition, generated by a controller, indicating that the process has exceeded or fallen below the limit point.

AMBIENT TEMPERATURE: The temperature of the immediate surroundings in which a controller must operate.

ANALOG SETPOINT INDICATION: A dial scale to indicate setpoint as opposed to digital setpoint indication. The traditional clock face is a good example of analog indication.

AUTOMATIC TUNING: Sometimes referred to as "self-tuning." The ability of a control to select and adjust the three control parameters (Proportional, Integral, and Derivative) automatically via a complex algorithm. Generally no operator input is required.

BANDWIDTH: See "Proportional Band"

BUMPLESS TRANSFER: When transferring from auto to manual operation, the control output(s) will not change ("bumpless"- a smooth transition).

CLOSED LOOP: A signal path which includes a forward path, a feedback path and a summing point, and forms a closed circuit.

COLD JUNCTION COMPENSATION: Measurement of temperature at thermocouple connections to controller and compensation for the "cold end" junction millivoltage generated here.

COMMON MODE: The noise signal that is common to all sensor wires.

COMMON-MODE REJECTION: The ability of an instrument to reject interference from a common voltage at its input terminals with relation to ground, usually expressed in dB.

COMPENSATION: See "Cold Junction Compensation"

CONTROL POINT: See "Setpoint"

COOL GAIN: In Athena microprocessor-based temperature controllers, a reference Gain value that is expressed in terms of the controller's Span, divided by the cooling proportional band, in degrees.

CURRENT PROPORTIONING: An output from a controller which provides current proportional to the amount of power required.

CYCLE TIME: The time necessary to complete a full ON-through-OFF period in a time proportioning control system.

CURRENT ALARM: Provides an alarm signal when a current level is detected below or above a preselected level.

DV/DT: Rate of change of voltage over time. A rapidly rising voltage waveform could induce false firing of an SCR. MOV's or R-C Snubber Circuits are used to prevent this false firing.

DEAD BAND: The range through which an input can be varied without initiating observable response.

DERIVATIVE: The process by which a controller senses the rate of temperature change and alters output.

DEVIATION ALARM: An alarm referenced at a fixed number of degrees, plus or minus, from setpoint.

DIN: Deutsche Industrial Norms, a widely-recognized German standard for engineering units.

DIFFERENTIAL: The temperature difference between the points at which the controller turns the heater on and off. Typically used when discussing an on/off controller.

DIRECT ACTING: Increase in value of output as the measured value increases.

DRIFT: A deviation of the system from setpoint that typically occurs over a long period of time. Drift may be caused by such factors as changes in ambient temperature or line voltage.

DROOP: Occurs when the actual system temperature stabilizes at some value below the desired setpoint. If system droop is unacceptable, a common solution is the use of a control incorporating an automatic or manual reset feature.

DUTY CYCLE: Percentage of load "ON" time relative to total cycle time.

FEEDBACK CONTROLLER: A mechanism that measures the value of the controlled variable, compares with the desired value and as a result of this comparison, manipulates the controlled system to minimize the size of the error.

FREQUENCY RESPONSE: The response of a component, instrument, or control system to input signals at varying frequencies.

GAIN: Amount of increase in a signal as it passes through any part of a control system. If a signal gets smaller, it is attenuated. If it gets larger, it is amplified.

GUARANTEED SOAK: On a ramp and soak controller, a feature that stops the clock if the temperature drops below a preset value, then continues the timing when the temperature recovers.

HEAT GAIN: In Athena microprocessor-based temperature controllers, a reference Gain value that is expressed in terms of the controller's Span, divided by the heating proportional band, in degrees.

HYSTERESIS: Temperature sensitivity between turn on and turn off points on on-off control. Prevents chattering.

I²**T:** A measure of maximum one time overcurrent capability for a very short duration. Value used for fuse sizing to protect SCRs.

IMPEDANCE: The total opposition to electrical flow in an ac circuit.

INTEGRAL FUNCTION: This automatically adjusts the position of the proportional band to eliminate offset.

ISOLATION: Electrical separation of sensor from high voltage and output circuitry. Allows for application of grounded or ungrounded sensing element.

LAG: The time delay between the output of a signal and the response of the instrument to which the signal is sent.

LATCHING ALARM: Requires operator intervention to reset even though the alarm condition on the input may have disappeared.

MOV: Metal Oxide Varistor: A semiconductor device that acts as a safety valve to absorb high voltage transients harmlessly, thereby protecting the SCRs and preventing false firing.



NOISE: An unwanted electrical interference.

NORMAL-MODE REJECTION: The ability of an instrument to reject interference; usually of line frequency across the input terminals (common mode).

OFFSET: A sustained deviation of the controlled variable from setpoint (this characteristic is inherent in proportional controllers that do not incorporate reset action). Also referred to as Droop.

ON/OFF CONTROL: Control of temperature about a setpoint by turning the output full ON below setpoint and full OFF above setpoint in the heat mode.

OPEN LOOP: Control system with no sensory feedback.

OUTPUT: Action in response to difference between setpoint and process variable.

OVERSHOOT: Condition where temperature exceeds setpoint due to initial power up.

PARAMETER: A physical property whose value determines the response of an electronic control to given inputs.

PD Control: Proportioning control with rate action.

PHASE: The time-based relationship between two alternating waveforms.

PHASE-ANGLE FIRING: A form of power control where the power supplied to the process is controlled by limiting the phase angle of the line voltage as opposed to burst firing.

PI Control: Proportioning control with auto reset.

PID: Proportional, integral and derivative control action.

POSITIVE TEMPERATURE COEFFICIENT: A characteristic of sensors whose output increases with increasing temperature.

PROCESS VARIABLE: System element to be regulated, such as pressure, temperature, relative humidity, etc.

PROPORTIONAL ACTION: Continuously adjusts the manipulated variable to balance the demand.

PROPORTIONAL BAND: The amount of deviation of the controlled variable required to move through the full range (expressed in % of span or degrees of temperature). An expression of Gain of an instrument (the wider the band, the lower the gain).

PROPORTIONING CONTROL PLUS DERIVATIVE FUNCTION:

A controller incorporating both proportional and derivative action senses the rate temperature change and adjusts controller output to minimize overshoot.

PROPORTIONING CONTROL PLUS INTEGRAL: A controller incorporating both proportional and integral action.

PROPORTIONAL, INTEGRAL AND DERIVATIVE CONTROL:

A PID controller is a three-mode controller incorporating proportional, integral, and derivative actions.

RAMP: Automatic adjustment for the setpoint for the temperature increase or decrease from process temperature. The target value can be either above or below the current measured value. The ramp value is a combination of time and temperature.

RAMP TO SETPOINT: Allows the operator to enter a target time for the controller to reach setpoint.

RANGE: The difference between the maximum and the minimum values of output over which an instrument is designed to operate normally.

RATE (ACTION): Control function that produces a corrective signal proportional to the rate at which the controlled variable is changing. Rate action produces a faster corrective action than proportional action alone. Also referred to as Derivative Action. Useful in eliminating overshoot and undershoot.

R.C. SNUBBER CIRCUIT: Resistor - Capacitor Snubber Circuit: Controls the maximum rate of change of voltage and limits the peak voltage across the switching device. Used to prevent false firing of SCRs.

REFERENCE JUNCTION: See "Cold Junction Compensation"

REPRODUCIBILITY: The ability of an instrument to duplicate with exactness, measurements of a given value. Usually expressed as a % of span of the instrument.

RESET ACTION: Control function that produces a corrective signal proportional to the length of time and magnitude the controlled variable has been away from the setpoint. Accommodates load changes. Also called Integral Action.

REVERSE ACTING: Reduces the output as the measured value increases

RFI: An acronym for radio frequency interference. RFI is commonly generated by devices that switch the output power at some voltage other than zero. Typically, phase-angle fired SCRs may generate RFI while zero-cross fired SCRs virtually eliminate RFI.

RTD: An acronym for a resistance temperature detector. Typically a wire wound device that displays a linear change in resistance for a corresponding temperature change. An RTD has a positive temperature coefficient.

SCR: This term has two separate and distinct meanings: 1) A solid-state semiconductor component that conducts or resists current flow depending upon whether a trigger voltage is present at the gate terminal. 2) A complete power controller that utilizes SCRs or TRIACs as the switching devices to control current flow.

SEGMENT: In a ramp and soak controller, one part of a profile.

SOAK: One segment with no setpoint change.

SSR: An acronym for solid-state relay. Semiconductor device that switches electrical current on and off in response to an electrical signal at the control terminals.

SENSITIVITY: The minimum change in input signal required to produce an output change in the controller.

SERIES MODE: A condition in which a noise signal appears in series with a sensor signal.

SETPOINT: The position to which the control point setting mechanism is set, which is the same as the desired value of the controlled variable.

SPAN: The difference between the top and bottom scale values of an instrument. On instruments starting at zero, the span is equal to the range.

STANDBY: Method of putting controller into the idle mode.

SURGE CURRENT: A high current of short duration that generally occurs when the power is first applied to inductive loads. The surge generally lasts no more than several ac cycles.



THERMISTOR: A bead-like temperature sensing device consisting of metallic oxides encapsulated in epoxy or glass. The resistance of a thermistor typically falls off sharply with increasing temperature, making it a particularly good sensing device.

A thermistor has a negative temperature coefficient.

THERMOCOUPLE: The junction of two dissimilar metals. A small voltage is generated at this junction, increasing as its temperature rises.

THERMOCOUPLE BREAK PROTECTION: Fail-safe operation that ensures output shutdown upon an open thermocouple condition.

THREE-MODE CONTROL: Proportioning control with reset and rate.

THYRISTOR: Any of a group of solid-state controlling devices. These devices are referred to as TRIACs, SCRs and DIACs.

TIME PROPORTIONING CONTROL MODE: In this mode, the amount of controller "on" time depends upon the system temperature. At the beginning of each time base interval, the signal from the sensor is analyzed and the controller is kept "ON" for a percentage of the time base.

TRIAC: A device, similar to a controlled rectifier, in which both the forward and reverse characteristics can be triggered from blocking to conducting (Also see Thyristor).

ZERO SWITCHING: Action that provides output switching only at the zero voltage crossing point of the ac sine wave.











Athena Controls, Inc.
5145 Campus Drive • Plymouth Meeting, PA 19452-1129 USA
Toll free: 1.800.782.6776 • Tel: 1.610.828.2490
Fax: 1.610.828.7084 • E-mail: mktg@athenacontrols.com
www.athenacontrols.com