Control Loop

A control loop is a process management system designed to maintain a process variable at a desired set point. Each step in the loop works in conjunction with the others to manage the system. Once the set point has been established, the control loop operates using a four-step process.

1. Sense
   Measure the current condition of the process using a sensor, which can be an electronic (thermocouple, RTD or transmitter) or mechanical device (thermal system).

2. Compare
   Evaluate the measurement of the current condition against the set point using an electronic or electric contact controller.

3. Respond
   React to any error that may exist between the measured value and set point by generating a corrective pneumatic or electric control signal.

4. Affect
   Actuate a final control element (valve, heater or other device) that will produce a change in the process variable.

The loop continually cycles through the steps, affecting the process variable in order to maintain the desired set point. Watson McDaniel is unique in its ability to provide all of the necessary components to create a complete control loop.
Description

A controller is a comparative device that receives an input signal from a measured process variable, compares this value with that of a predetermined control point value (set point), and determines the appropriate amount of output signal required by the final control element to provide corrective action within a control loop. Watson McDaniel offers an Electronic PID Controller, which uses electrical signals and digital algorithms to perform its receptive, comparative and corrective functions.

Principles of Operation (Electronic PID Controller)

An electronic sensor (thermocouple, RTD or transmitter) installed at the measurement location continuously sends an input signal to the controller. At set intervals, the controller compares this signal to a predefined set point. If the input signal deviates from the set point, the controller sends a corrective electric output signal to the control element. This electric signal must be converted to a pneumatic signal when used with an air operated valve, such as a Watson McDaniel W910 Series Control Valve. The conversion can be made using a Watson McDaniel TA901 I/P Transducer, which converts a 4 to 20 mA electric signal to a 3 to 15 PSI air signal.

Features (Electronic PID Controller)

An electronic controller is best suited for applications where large load changes are encountered and/or fast response changes are required. Watson McDaniel Electronic Controllers have full auto-tuning and PID capabilities, and offer a host of available options, including user selectable inputs and ranges, outputs, setback functions and alarms.

PID Control is a feature of most Watson McDaniel Electronic Controllers. PID combines the proportional, integral and derivative functions into a single unit.

- **Proportional (P)** — Proportional control reacts to the size of the deviation from set point when sending a corrective signal. The size of the corrective signal can be adjusted in relation to the size of the error by changing the width of the proportional band. A narrow proportional band will cause a large corrective action in relation to a given amount of error, while a wider proportional band will cause a smaller corrective action in relation to the same amount of error.

- **Integral (I)** — Integral control reacts to the length of time that the deviation from set point exists when sending a corrective signal. The longer the error exists, the greater the corrective signal.

- **Derivative (D)** — Derivative control reacts to the speed in which the deviation is changing. The corrective signal will be proportional to the rate of change within the process.

Auto-Tuning

Auto-tuning will automatically select the optimum values for P, I and D, thus eliminating the need for the user to calculate and program these values at system startup. This feature can be overridden when so desired. On some models, the control element can be manually operated.
Selecting an Electronic PID Controller

All Watson McDaniel Electronic Controllers are designed to control the temperature or pressure of general industrial equipment and should be carefully selected to meet the demands of the particular application. The information contained within this catalog is offered only as a guide to assist in making the proper selection. Selection of the proper controller is the sole responsibility of the user. Improper application may cause process failure, resulting in possible personal injury or property damage.

Case Size
Case Size selection is determined by both available and designed space, and controller features. Watson McDaniel Electronic Controllers are available in the following panel sizes:
48 x 48 mm (1/16 DIN), 72 x 72 mm, 96 x 96 mm (1/4 DIN) and 48 x 96 mm (1/8 DIN).
The depth of the unit varies with the model selected.

Input
The Input is the measurement signal received by the controller from the sensor. A variety of input types are available, including thermocouple, RTD, voltage and current.

Control Output
The Control Output is the corrective signal transmitted from the controller to the control element. Various control output types are available, including contact, voltage, current and solid state relay driver.

Analog Output
The Analog Output is an optional secondary signal that transmits the measurement signal from the controller to a remote data acquisition device, such as a recorder, personal computer or display unit.

Alarms
Most models can be ordered with alarms, event outputs, or heater break alarms, which signal an external device to perform a specific task at a predetermined set point.

Setback Function
This feature, optionally available on some models, is designed to provide energy savings in applications where the process is idled at regular intervals through the connection of an external timer or switch.
The TR890 Series Electronic PID Controller is designed for use on applications where large load changes are expected, or extreme accuracy and fast response times are needed. With full auto-tune capabilities and a large selection of available inputs, the TR890 Series is ideally suited for use with a Watson McDaniel Control Valve.

Use of a Watson McDaniel No. TA987 Air Filter/Regulator is recommended for filtering and regulating the pressure of plant compressed air, and for delivering clean, dry air at the proper pressure to pneumatic control devices.

**Specifications**

- **Models**
  - TR891: 48 x 48 mm (1/16 DIN)
  - TR892: 72 x 72 mm
  - TR893: 96 x 96 mm (1/4 DIN)
  - TR894: 96 x 48 mm (1/8 DIN)

- **Control**
  - Control Mode: Auto-Tuning PID
  - Action: Reverse acting (field switchable to direct acting)

- **Proportional Band**
  - Off, 0.1-999.9% Full Scale
  - Integral Time: Off, 1-6000 sec.
  - Derivative Time: Off, 1-3600 sec.

- **Accuracy**
  - ± 0.3%

- **Display**
  - Process Value: 4 Digit, 20 mm red LED
  - Set Value: 4 digit, 10.2 mm green LED
  - Sampling Cycle: 0.25 seconds

- **Inputs**
  - Multi: (switchable between)
    - RTD: Platinum 100 Ω, 3-Wire
    - mV: (scalable) -10–10, 0-10, 0-20, 0-50, 10-50, 0-100 mV DC
  - Current: (scalable) 4-20 mA, 0-20 mA
  - Voltage: 0-10 VDC

- **Output**
  - Current: 4-20 mA (load resistance: 600 Ω maximum)
  - Contact: Proportional cycle, 1-120 sec. (capacity: 240 VAC, 2 A resistive / 1.2 A inductive)
  - SSR Drive Voltage: Proportional cycle 1-120 sec.
    - (output rating: 12 ± 1.5 VDC / 30 mA maximum)
  - Voltage: 0-10 VDC

- **Power Requirements**
  - Supply Voltage: 100-240 VAC, 50/60 Hz
  - Consumption: 100-240 VAC, 15VA
    - 24 VDC, 8W
    - 24 VAC, 9VA

- **Data Storage**
  - Nonvolatile EEPROM memory

- **Case Material**
  - Polyphenylene Oxide (PPO)

- **Ambient Temp.**
  - 14°F (-10°C) to 122°F (50°C)

- **Humidity**
  - Maximum: 90% RH, non-condensing

- **Event Outputs**
  - (Contact Capacity: 240 VAC, 1 A/resistive load)
    - Dual Event Outputs (High and/or Low Alarms)
    - Single Event Output + Heater Break Alarm (includes CT30A sensor)
    - Single Event Output + Heater Break Alarm (includes CT50A sensor)

- **Options:**
  - Analog Output: 0-10 mV DC (output resistance 10 Ω )
  - Analog Output: 4-20 mA DC (load resistance 300Ω max )
  - Analog Output: 0-10 VDC (load current 2 mA max )
  - Digital Input (switch) including:
    - Setback Function setting range of -1999 - 5000, standby or DA/RA Selection
    - Operated by either non-voltage contact or open collector

**Approximate Shipping Weights:**
- TR891: 0.4 lbs [0.17 kg]
- TR892: 0.6 lbs [0.28 kg]
- TR893: 0.7 lbs [0.33 kg]
- TR894: 0.5 lbs [0.24 kg]
**Model Input Control Output Power Supply Event Output Options**

**TR891**
- 8 Multi
- 4 mA
- 6 VDC
- A 4-20 mA
- C On/Off Contact
- D SSR Driver
- E 0-10 VDC
- 90 100-240 VAC, 50/60 Hz
- 08 24 VAC/VDC, 50/60 Hz
- 0 None
- 1 Dual Event (high and/or low)
- 2 Single Event (high or low) and heater break CT30A
- 3 Analog Output (0-10 mVDC)

**TR892**
- 4 mA
- 2 On/Off Contact
- 8 24 VAC/VDC, 50/60 Hz
- 1 None
- 0 Digital Input (switch)
- 0 None
- 8 Digital Input (switch) with 0-10 mVDC* Analog Output
- 8 Digital Input (switch) with 4-20 mA* Analog Output

**TR893**
- 6 VDC
- 1 SSR Driver (high and/or low)
- 3 Analog Output (4-20 mA)
- 90 None
- 1 None
- 0 Digital Input (switch) with 0-10 mVDC* Analog Output
- 0 None
- 8 Digital Input (switch) with 0-10 VDC* Analog Output

**TR894**
- E 0-10 VDC
- 0-10 VDC
- 68 Digital Input (switch) with 0-10 VDC* Analog Output
- 68 Digital Input (switch) with 4-20 mA* Analog Output

**HOW TO ORDER**

Sample Order Number: TR893 8 A C 90 1 00

**Electronic PID Controller Dimensions** – units: inches [mm].

<table>
<thead>
<tr>
<th>Model</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>H</th>
<th>W</th>
</tr>
</thead>
</table>

**Programmable Ranges**

**Thermocouple Inputs**

<table>
<thead>
<tr>
<th>T/C Type</th>
<th>Range Code</th>
<th>Fahrenheit Range</th>
<th>Celsius Range</th>
<th>RTD Inputs</th>
<th>Fahrenheit Range</th>
<th>Celsius Range</th>
<th>Current &amp; Voltage Inputs</th>
<th>User-scalable Readout</th>
</tr>
</thead>
<tbody>
<tr>
<td>B*</td>
<td>15</td>
<td>0° to 3300°F</td>
<td>0° to 1800°C</td>
<td>47</td>
<td>-300° to 1100°F</td>
<td>-200° to 600°C</td>
<td>71</td>
<td>-10-10 mV</td>
</tr>
<tr>
<td>E</td>
<td>21</td>
<td>0° to 1300°F</td>
<td>0° to 700°C</td>
<td>48</td>
<td>-150.0° to 200.0°F</td>
<td>-100.0° to 100.0°C</td>
<td>72</td>
<td>0-10 mV</td>
</tr>
<tr>
<td>J</td>
<td>22</td>
<td>0° to 1100°F</td>
<td>0° to 600°C</td>
<td>49</td>
<td>-150° to 600°F</td>
<td>-100.0° to 300.0°C</td>
<td>73</td>
<td>0-20 mA</td>
</tr>
<tr>
<td>K</td>
<td>18</td>
<td>-150° to 750°F</td>
<td>-100.0° to 400.0°C</td>
<td>50</td>
<td>-50.0° to 120.0°F</td>
<td>-50.0° to 50.0°C</td>
<td>74</td>
<td>0-50 mA</td>
</tr>
<tr>
<td>K</td>
<td>19</td>
<td>0° to 1500°F</td>
<td>0° to 800°C</td>
<td>51</td>
<td>0.0° to 120.0°F</td>
<td>0.0° to 50.0°C</td>
<td>75</td>
<td>10-50 mA</td>
</tr>
<tr>
<td>K</td>
<td>20</td>
<td>0° to 2200°F</td>
<td>0° to 1200°C</td>
<td>52</td>
<td>0.0° to 200.0°F</td>
<td>0.0° to 100.0°C</td>
<td>76</td>
<td>0-100 mA</td>
</tr>
<tr>
<td>L</td>
<td>28</td>
<td>0° to 1100°F</td>
<td>0° to 600°C</td>
<td>53</td>
<td>0.0° to 400.0°F</td>
<td>0.0° to 200.0°C</td>
<td>81</td>
<td>-1-1 V</td>
</tr>
<tr>
<td>N</td>
<td>24</td>
<td>0° to 2300°F</td>
<td>0° to 1300°C</td>
<td>54</td>
<td>0° to 1000°F</td>
<td>0.0° to 500.0°C</td>
<td>82</td>
<td>0-1 V</td>
</tr>
<tr>
<td>PL II</td>
<td>25</td>
<td>0° to 2300°F</td>
<td>0° to 1300°C</td>
<td>55</td>
<td>0° to 2300°F</td>
<td>0.0° to 500.0°C</td>
<td>83</td>
<td>0-2 V</td>
</tr>
<tr>
<td>R</td>
<td>16</td>
<td>0° to 3100°F</td>
<td>0° to 1700°C</td>
<td>56</td>
<td>0° to 3100°F</td>
<td>0° to 1700°C</td>
<td>84</td>
<td>0-5 V</td>
</tr>
<tr>
<td>S</td>
<td>17</td>
<td>0° to 3100°F</td>
<td>0° to 1700°C</td>
<td>57</td>
<td>0° to 3100°F</td>
<td>0° to 1700°C</td>
<td>85</td>
<td>1-5 V</td>
</tr>
<tr>
<td>T</td>
<td>23</td>
<td>-300° to 400°F</td>
<td>-199.9° to 200.0°C</td>
<td>58</td>
<td>-199.9° to 200.0°C</td>
<td>-199.9° to 200.0°C</td>
<td>86</td>
<td>0-10 V</td>
</tr>
<tr>
<td>U</td>
<td>24</td>
<td>-300° to 400°F</td>
<td>-199.9° to 200.0°C</td>
<td>59</td>
<td>-199.9° to 200.0°C</td>
<td>-199.9° to 200.0°C</td>
<td>94</td>
<td>0-20 mA</td>
</tr>
<tr>
<td>WRe5-26</td>
<td>26</td>
<td>0° to 4200°F</td>
<td>0° to 2300°C</td>
<td>60</td>
<td>0° to 4200°F</td>
<td>0° to 2300°C</td>
<td>95</td>
<td>4-20 mA</td>
</tr>
</tbody>
</table>

*Range Codes are not required for ordering, but are used for field programming.
*750°F (400°C) falls below the accuracy range
The TA901 Electropneumatic (I/P) Transducer converts a milliamp current signal to a linearly proportional pneumatic output pressure. This transducer is designed for control applications that require a high degree of reliability and repeatability. The TA901 is used in the control operation of valve actuators and pneumatic valve positioners in the petrochemical, HVAC, energy management, textile, paper, and food & drug industries.

The TA901 I/P Transducer is tested and approved by Factory Mutual as Intrinsically Safe Class I, II and III, Division I, Groups C, D, E, F and G when installed in accordance with the Installation, Operation and Maintenance Instructions. It should be installed in a vertical position in a vibration-free area.

The Watson McDaniel TA987 Air Filter/Regulator is recommended for filtering and regulating the pressure of plant compressed air, and for delivering clean, dry air at the proper pressure to pneumatic control devices.

### Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>TA901</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
<td>4-20 mA</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td>1-17 PSIG Per ANSI/FCI 87-2 (can be calibrated to provide 1-9 PSIG or 9-17 PSIG)</td>
</tr>
<tr>
<td><strong>Volume Booster</strong></td>
<td>Built-in volume booster allows flow capacity up to 20 SCFM</td>
</tr>
<tr>
<td><strong>Connections</strong></td>
<td>Pneumatic: 1/4” NPT Electric: 1/2” NPT</td>
</tr>
<tr>
<td><strong>Air Requirements</strong></td>
<td>Clean, oil-free, dry air filtered to 40 microns</td>
</tr>
<tr>
<td></td>
<td>Minimum Supply Pressure: 3 PSIG</td>
</tr>
<tr>
<td></td>
<td>Maximum Supply Pressure: 100 PSIG</td>
</tr>
<tr>
<td></td>
<td>Sensitivity: &lt; ±0.1% of span per PSIG</td>
</tr>
<tr>
<td></td>
<td>Air Consumption: 0.03 SCFH typical</td>
</tr>
<tr>
<td></td>
<td>Flow Rate: 4.5 SCFM at 25 PSIG supply</td>
</tr>
<tr>
<td></td>
<td>Relief Capacity: 2.0 SCFM at 5 PSIG above 20 PSIG setpoint</td>
</tr>
<tr>
<td><strong>Mounting</strong></td>
<td>Pipe, panel or bracket in a vibration-free area. Field adjustment will be required if mounted in a nonvertical position.</td>
</tr>
<tr>
<td><strong>Adjustment</strong></td>
<td>Adjustable zero and span</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>Terminal Based Linearity: &lt; ±0.75% of span</td>
</tr>
<tr>
<td></td>
<td>Repeatability: &lt; 0.5% of span</td>
</tr>
<tr>
<td></td>
<td>Hysteresis: &lt; 1.0% of span</td>
</tr>
<tr>
<td></td>
<td>Response Time: &lt; 0.25 sec. @ 3-15 PSIG</td>
</tr>
<tr>
<td><strong>Intrinsic Safety</strong></td>
<td>Tested and approved by Factory Mutual as Intrinsically Safe Class I, II and III, Division I, Groups C, D, E, F and G when installed in accordance with Installation, Operation and Maintenance Instructions</td>
</tr>
<tr>
<td><strong>Ambient Temperature</strong></td>
<td>-20°F (-30°C) to 140°F (60°C)</td>
</tr>
<tr>
<td><strong>Approximate Shipping Weight</strong></td>
<td>2.1 lbs [0.94 kg]</td>
</tr>
</tbody>
</table>

### HOW TO ORDER

Please order using Item Number: TA901
The **TA987 Air Filter/Regulator** is recommended for filtering and regulating the pressure of plant compressed air, and for delivering clean, dry air at the proper pressure to pneumatic control devices. Supply air enters the inlet port, passes through the filtering element, and exits through the reducing valve to the outlet port. The filtering element removes particles as small as 40 microns. A drip well is provided for the accumulation of oil and water and a drain cock is included to allow purging of the unit. The filtering element is readily accessible for cleaning by removal of the drip well bowl.

The maximum allowable supply pressure to TA987 Air Filter/Regulator is 250 PSIG. Improper application may cause failure of the regulator, resulting in possible personal injury or property damage.

### Specifications

**Model**
- **TA987**

**Air Requirements**
- Maximum Supply Pressure: 250 PSIG
- Output Range: 0 to 30 PSIG, adjustable
- Sensitivity: 0.036 PSIG
- Air Consumption: < 6 SCFH

**Air Requirements (cont.)**
- Flow Rate: 20 SCFM at 100 PSIG supply/20 PSIG output
- Relief Capacity: 0.1 SCFM at 5 PSIG above setpoint
- Effect of Supply Pressure Variation: < 0.2 PSIG for 25 PSIG

**Filter**
- Removes particles 40 microns or greater

**Port Size**
- 1/4" NPT

**Housing**
- Cast aluminum

**Mounting**
- Side, pipe, panel or through body

**Ambient Temperature**
- -20°F (-30°C) to 160°F (71°C)

**Approximate Shipping Weight**
- 1.9 lbs (0.86 kg)

Units: inches [mm].
Electronic Temperature Sensors
Connection Head Type • RTD & Thermocouple

The Watson McDaniel Connection Head is available with both Type J and Type K Thermocouples, as well as RTD sensors. The weather proof head provides a conduit connection and is available in cast aluminum (screw cover), polypropylene (flip cover) and stainless steel (screw cover). The stem is either welded directly to the 1/2” NPT threaded connection, or is spring-loaded to provide maximum sensitivity. The spring-loaded stem must always be installed in a thermowell.

Extension wire and transmitter accessories are also available. Please consult factory.

For applications where the process media may be corrosive or contained under pressure, the use of a thermowell is required to prevent damage to the sensor and facilitate its removal from the process. To prevent leakage of the process media, spring loaded sensors must always be installed in a thermowell.

Extension wire and transmitter accessories are also available. Please consult factory.

HOW TO ORDER

Sample Order Number: TJ D Z 04 U W A

Sensor Specifications

Thermocouple

<table>
<thead>
<tr>
<th>Type</th>
<th>Color Code</th>
<th>Positive Lead</th>
<th>Negative Lead</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>Black</td>
<td>Iron* (Fe)</td>
<td>Constantan (Cu-Ni)</td>
<td>32° to 1382°F (0° to 750°C)</td>
</tr>
<tr>
<td>K</td>
<td>Yellow</td>
<td>Nickel-Chromium (Ni-Cr)</td>
<td>Nickel-Aluminum* (Ni-Al)</td>
<td>32° to 2282°F (0° to 1250°C)</td>
</tr>
</tbody>
</table>

* magnetic lead

RTD

<table>
<thead>
<tr>
<th>Type</th>
<th>Material</th>
<th>Resistance @ 0°C</th>
<th>Temperature Coefficient</th>
<th>Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Platinum (Pt)</td>
<td>100 Ω Ω</td>
<td>α = 0.00385 Ω/°C</td>
<td>-50° to 700°F (-45° to 400°C)</td>
</tr>
<tr>
<td>M</td>
<td>Platinum (Pt)</td>
<td>1000 Ω</td>
<td>α = 0.00385 Ω/°C</td>
<td>-50° to 700°F (-45° to 400°C)</td>
</tr>
</tbody>
</table>

Units: inches [mm]

Request accessories: Please consult factory.

Other sensor styles available. Please consult factory.

Other Lengths: Specify in inches (24” maximum)
Thermowells
for RTD & Thermocouple Temperature Sensors

Standard (2 1/2" - 6")

<table>
<thead>
<tr>
<th>Material</th>
<th>200°F</th>
<th>400°F</th>
<th>600°F</th>
<th>800°F</th>
<th>1000°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel</td>
<td>5000</td>
<td>4800</td>
<td>4600</td>
<td>3500</td>
<td>-</td>
</tr>
<tr>
<td>304 stainless steel</td>
<td>6550</td>
<td>4860</td>
<td>4140</td>
<td>3510</td>
<td>3130</td>
</tr>
<tr>
<td>316 stainless steel</td>
<td>6540</td>
<td>6400</td>
<td>6000</td>
<td>5270</td>
<td>5180</td>
</tr>
<tr>
<td>Monel</td>
<td>5530</td>
<td>4990</td>
<td>4450</td>
<td>4450</td>
<td>-</td>
</tr>
<tr>
<td>Brass</td>
<td>3170</td>
<td>4660</td>
<td>4450</td>
<td>4450</td>
<td>-</td>
</tr>
</tbody>
</table>

Pressures (PSI)

<table>
<thead>
<tr>
<th>Material</th>
<th>5000</th>
<th>4800</th>
<th>4600</th>
<th>3500</th>
<th>30</th>
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<tbody>
<tr>
<td>Carbon steel</td>
<td>5000</td>
<td>4800</td>
<td>4600</td>
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<tr>
<td>304 stainless steel</td>
<td>6550</td>
<td>4860</td>
<td>4140</td>
<td>3510</td>
<td>3130</td>
</tr>
<tr>
<td>316 stainless steel</td>
<td>6540</td>
<td>6400</td>
<td>6000</td>
<td>5270</td>
<td>5180</td>
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<tr>
<td>Monel</td>
<td>5530</td>
<td>4990</td>
<td>4450</td>
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</tr>
<tr>
<td>Brass</td>
<td>3170</td>
<td>4660</td>
<td>4450</td>
<td>4450</td>
<td>-</td>
</tr>
</tbody>
</table>

HOW TO ORDER

Sample Order Number: 76-4J6

Thermowell Style | (P) External Thread | (A) Stem Length | (T) Logging Extension |
-----------------|---------------------|-----------------|-----------------------|
76 - Sensor, Stepped Shank (2 1/2" - 6" Stem Straight Shank) | 3 1/2 NPT* | D 2 1/2" Stem | A 1" Extension (4" Stem only) |
| 4 3/4 NPT | G 4" Stem | C 2" Extension (6" Stem only) |
| 5 1 NPT* | J 6" Stem | E 3" Extension (9" thru 24" Stem only) Omit if No Extension |

*Not available with 2 1/2" Stem Length
Other thermowell styles available. Please consult factory.

Selection of the proper thermowell is the sole responsibility of the user. Temperature and pressure limitations must be considered. Improper application may cause failure of the thermowell, resulting in possible personal injury or property damage. For correct use and application, please refer to the Thermowells For Thermometers And Electrical Temperature Sensors Standard ASME B40.9.

<table>
<thead>
<tr>
<th>Material</th>
<th>70°F</th>
<th>200°F</th>
<th>400°F</th>
<th>600°F</th>
<th>800°F</th>
<th>1000°F</th>
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<tbody>
<tr>
<td>Carbon steel</td>
<td>5000</td>
<td>5000</td>
<td>4800</td>
<td>4600</td>
<td>3500</td>
<td>-</td>
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<tr>
<td>304 stainless steel</td>
<td>6550</td>
<td>6000</td>
<td>4860</td>
<td>4140</td>
<td>3510</td>
<td>3130</td>
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<tr>
<td>316 stainless steel</td>
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<td>6400</td>
<td>6000</td>
<td>5270</td>
<td>5180</td>
<td>4660</td>
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<td>4990</td>
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<tr>
<td>Brass</td>
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<td>4660</td>
<td>4450</td>
<td>4450</td>
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