

# DIESEL AND GAS TURBINE TEMPERATURE SENSORS

**PROVEN PERFORMANCE**

**AND RELIABILITY IN**

**SENSOR PRODUCTS**





**Turbine engine  
exhaust gas  
temperature sensor**

*The F-16 exhaust gas temperature sensor employs a unique sensor wear-sleeve design. This eliminated the weak points caused by welds in competing designs. In over 10 years there has not been a single failure.*

Watlow has decades of experience in developing temperature sensor solutions for diesel and gas engine OEMs, gas turbine OEMs and engine sensor and control system manufacturers. Watlow's proven performance capabilities in thermocouple wire, thermocouple cable and temperature sensors for the following applications continue to lead the industry:

- Inlet Air Temperature
- Cylinder Head Temperature
- Exhaust Gas Temperature
- Oil, Fuel, Coolant Temperatures
- Bearing Temperature
- Engine Test Stand Sensors

It all started with the founding of the Claud S. Gordon Company in 1914. Vertical integration of the business began with the manufacturing of insulated thermocouple wire in 1952. Beginning in the late 1950's, Gordon played a major role in revolutionizing the thermocouple industry with its development of metal-sheathed thermocouple cable. The Gordon Company was acquired by Watlow Electric Manufacturing Company in 1985. RF shielded temperature probes, True Surface Temperature sensors and thin film thermocouples were developed and patented during the 1990s.

Watlow's unique and robust design packages and assemblies utilize the latest technological advancements in temperature measurement for the most challenging applications. Today, Watlow's Richmond, Illinois facility covers more than 11,100 square meters (120,000 square feet).

What distinguishes Watlow from

## THE WATLOW ADVANTAGE

competitive sensor manufacturers?

- Complete control and manufacture of critical sensor raw materials, unlike many of our competitors
- Patented Hybrid temperature sensors for extended sensor life
- Dedicated High Reliability Sensor Prototyping and Manufacturing Team
- ISO 9001 certified facility
- QS 9000 compliant systems capability
- Sensor manufacturing facilities in Europe, Asia and North America to provide local support
- Insulated wire manufactured in accordance with MIL-Q-9858
- Sensors manufactured in accordance with ASTM E 230 and IEC 60584-1, -2 and -3
- XACTPAK® mineral insulated thermocouple cable for continuous operation up to 1480° C (2700° F)
- Tapered tip probes for increased sensitivity
- High compaction density and high thermal conductivity sensing tips
- Wear sleeves and debris shields available to prolong sensor life

# A HISTORY OF INNOVATION, PERFORMANCE AND RELIABILITY

## PRODUCTS AND CAPABILITIES



### SERV-RITE® THERMOCOUPLE AND EXTENSION-GRADE WIRE

SERV-RITE® is the standard in the industry for consistent and reliable quality and measurement accuracy. Whether it is solid or stranded wire, polyimide-tape or fused insulation, fiberglass or fluoropolymer insulation, SERV-RITE® wire is the choice for engine test stands and sensor fabricators. Examples include:

- Series 321 HT Fiberglass (705°C, 1300°F)
- Series 513 Polyimide (315°C, 600°F)
- Series 313SS Fiberglass with SS Overbraid (480°C, 900°F)
- Series 507 FEP (205°C, 400°F)
- Series 502 PVC (105°C, 220°F)

Various certifications of conformance are available, from a simple statement of conformity to certificates of conformance to ASTM tolerances and MIL standards.



### XACTPAK® MINERAL INSULATED CABLE

Watlow's XACTPAK® cable is the preferred metal-sheathed, mineral-insulated thermocouple and RTD cable in the industry. Its reputation for high-performance, long-term durability, stability and quality is unmatched. This is due to the care and robustness of the manufacturing processes used to make the cable. Watlow custom designs and manufactures cable to match the demands of critical sensor applications. A brief overview of materials offered follows:

#### Sheath Materials

Over 40 types are available including:

- 300 Series stainless steels
- 400 Series stainless steels
- 600 Series nickel-based alloys
- Other exotic alloys

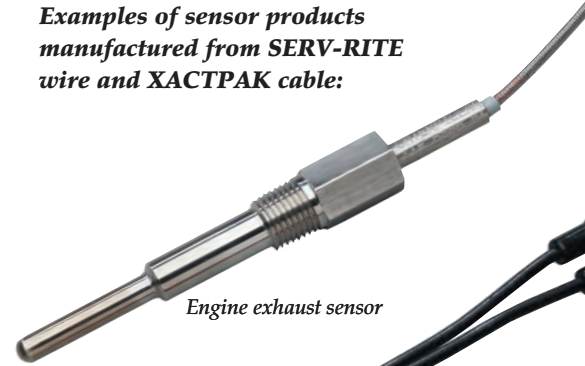
#### Insulation Materials

- MgO 96 percent purity
- MgO 99 percent purity
- Al<sub>2</sub>O<sub>3</sub> and HfO<sub>2</sub> 99 percent purity

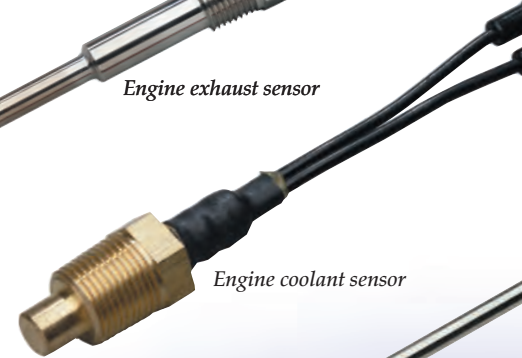
#### Diameters

- Thermocouple cable from 0.25 mm to 12.7 mm (0.010 in. to 0.500 in.)
- RTD and thermistor cable from 3.0 mm to 9.53 mm (0.118 in. to 0.375 in.)

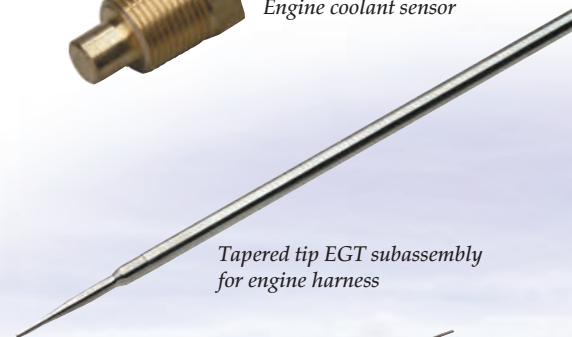
**Examples of sensor products  
manufactured from SERV-RITE  
wire and XACTPAK cable:**



*Engine exhaust sensor*



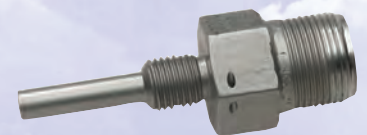
*Engine coolant sensor*



*Tapered tip EGT subassembly  
for engine harness*



*Dual element staggered junction  
design for EGT harness*



*Resistance sensor for air inlet  
measurement*

### Typical engine applications for Watlow sensors:

- Off-road diesel engines
- Power gen diesel and gas engines
- Marine diesel engines
- Locomotive diesel engines
- Gearboxes
- Compressors
- Engine test stands



## DIESEL AND GAS ENGINE SENSORS

Each Watlow engine sensor is designed to withstand shock, vibration, high temperature and contamination typically found in and around diesel and gas engines. All sensors are custom engineered for the OEM's specific application requirements. When required, Watlow can design and manufacture sensors compliant to the QS9000 Pre-Production Approval Processes (PPAPs) including design & process Failure Mode Effect Analyses (FMEAs), control plans, capability studies, first article inspections, etc.

### OIL, INLET AIR, FUEL AND COOLANT TEMPERATURE SENSORS

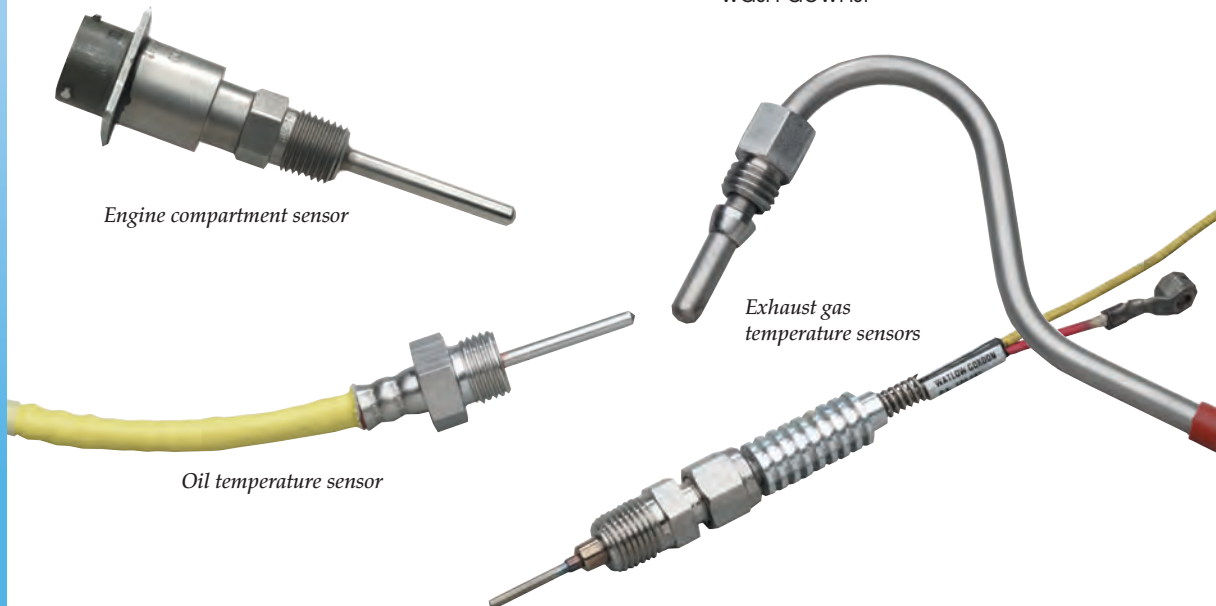
These RTD, thermistor or thermocouple-based sensors typically operate in the  $-40^{\circ}$  to  $120^{\circ}\text{C}$  ( $-40^{\circ}$  to  $250^{\circ}\text{F}$ ) range. These sensors thread into the engine and are designed to fit a specific port size. Sensor construction and lead wire design are similar to EGT sensors, although modifications are made to accommodate the specific application. The sensors

utilize a compression seal design that provides strain relief and lead wire pull-out resistance. The fittings are either brass or stainless steel depending upon the pressure and fluid.

### EXHAUST GAS TEMPERATURE (EGT) SENSORS

Watlow's patented EGT sensors are designed to perform in the harsh, high vibration, high contamination environment associated with diesel and gas engines. Watlow's patented construction eliminates the splice between wire and cable making this design less susceptible to physical failure caused by vibration. High-temperature compacted MgO insulation protects the sensor probe against vibration, shock and extreme temperatures (up to  $815^{\circ}\text{C}$  or  $1500^{\circ}\text{F}$ ) as well. Watlow EGT sensors also use integrally mounted compression seals that prevent moisture and dirt from infiltrating the sensor element and causing calibration errors. Other EGT sensors use epoxy sealant that often dries out, cracks and is prone to fail from thermal cycling. The sensor lead wire and/or connectors are moisture resistant and capable of wash downs.

- Generating power in remote locations or hauling ore from deep within open pit mines requires reliable engine performance. At the heart of the engine management systems are rugged and durable temperature sensors. Exhaust gas thermocouples provide thousands of hours of operations, survive the extreme operating conditions, utilize highly compacted mineral insulation and incorporate a patented integral seal system providing the dependable performance.



Engine compartment sensor

Oil temperature sensor

Exhaust gas temperature sensors

# PROVEN SENSOR PRODUCTS FOR DEMANDING APPLICATIONS

## BEARING TEMPERATURE SENSORS (ENGINE AND GEAR BOX OVERTEMP)

Typically RTD or thermocouple elements are packaged in rugged mineral insulated cable construction to withstand shock, vibration and contamination. The operating range can be from -40° to 500°F (-40° to 260°C). Whether terminated with leads and locking connector or with a protection head and transmitter, Watlow can design and build the reliable sensor you need for your diesel and gas engine applications as well as compressor and gear box transmission applications.

## ENGINE TEST STAND SENSORS

Temperature sensors are either insulated thermocouple wire using FEP or polyimide insulation, or may be rugged thermocouple sensors or either 100 Ohm or 1000 Ohm RTD sensors. Usually a mineral insulated construction is preferred for this application. The design is specifically made to withstand frequent handling and abuse on the engine production line as well as for R&D testing purposes. FEP insulated lead wire and a stainless steel overbraid for protection are typical. Threaded compression fittings are frequently used as well.

## GAS TURBINE SENSORS

Watlow supplies raw materials, sensor probes and subassemblies to gas turbine engine sensor OEMs as well as manufactures the entire engine probe assembly as required for power gen and mechanical drive gas turbines. Gas turbine sensors are designed to withstand the vibration and high temperatures found in these engines. All sensors are custom engineered for the OEMs specific application requirements.

## INLET AIR AND COMPRESSOR DISCHARGE TEMPERATURE SENSORS

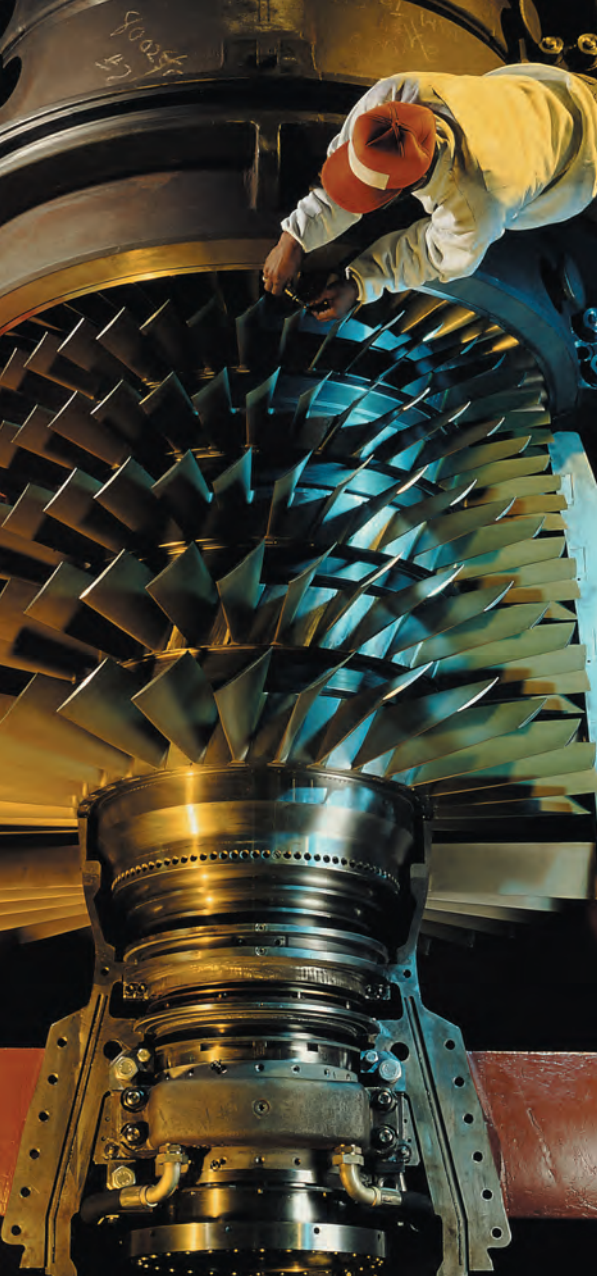
Fast responding RTD, thermistor and thermocouple sensors provide high accuracy measurements of inlet and compressor air temperatures. Robust designs withstand high gas flows, engine vibration and operational temperatures of -40° to 300°C (-40° to 572°F). Features include machined and tubular housings, mounted flanges, integral circular connectors and flexible wire lead extensions.

*Micro turbine  
inlet air sensor*

*Micro turbine  
exhaust sensor*

### **Typical gas turbine applications for Watlow sensors:**

- Aviation propulsion and APUs
- Industrial power generation
- Marine APUs and propulsion
- Mechanical drive compressor and pump applications
- Cruise missiles and droves



## GAS TURBINE SENSORS, CONT.

### TURBINE INLET TEMPERATURE (TIT) AND TURBINE OUTLET TEMPERATURE (TOT) SENSORS

Watlow's TIT and TOT sensors operate in the range  $-40^{\circ}\text{C}$  to  $1000^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$  to  $1800^{\circ}\text{F}$ ) range. They are constructed using Watlow's Type K special limits XACTPAK, high compaction density thermocouple cable. Thermocouple measuring junctions are fabricated using proprietary techniques that ensure fast response as well as long sensor life. Tapered tip probes go through a proprietary forming and heat treat process that relieves coldwork stresses and restores the calibrated EMF characteristics. Wear sleeves, debris shields, mounting flanges and/or composite tips are popular options. Watlow also offers serialization, calibration, time response studies, x-rays and other non-destructive tests.

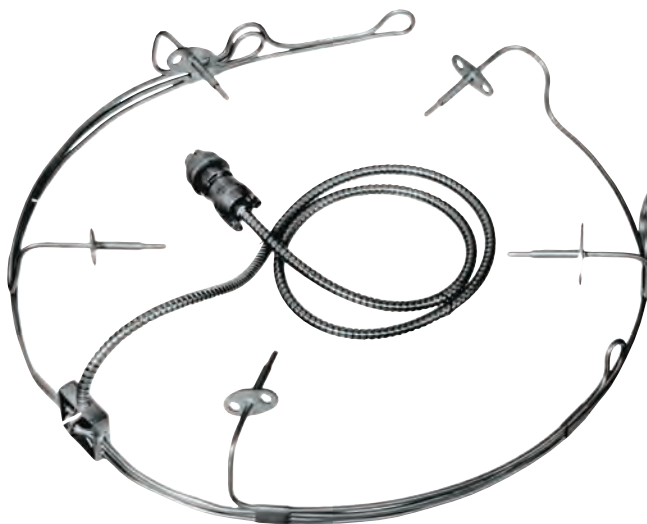
### OIL TEMPERATURE AND BEARING TEMPERATURE SENSORS

Proper fluid lubrication, bearing functions and close part fit enhance turbine performance and are verified by temperature monitoring. Failure of these critical mechanical and lubrication functions can cause catastrophic turbine failure. For operational temperature to  $200^{\circ}\text{C}$  ( $400^{\circ}\text{F}$ ) for fluids or  $260^{\circ}\text{C}$  ( $500^{\circ}\text{F}$ ) for bearings, Watlow can design and manufacture the reliable RTD and thermocouple sensors with the features you need.

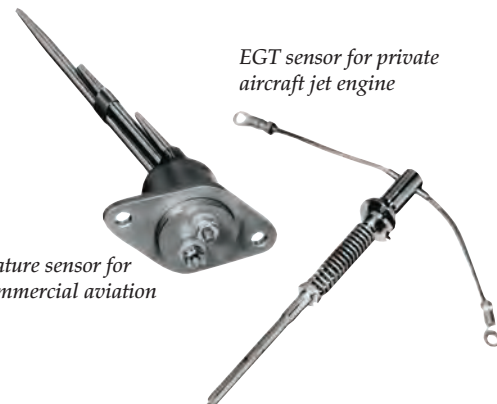
### ENGINE TEST STAND SENSORS

These small diameter sensors are attached to various engine parts and then routed through the turbine for final connection to instrumentation. Kapton<sup>®</sup> insulated, Type E or K special limits, small diameter thermocouple wire is preferred for the cooler engine inlet and compressor sections. Small diameter, typically 0.50 to 1.60 mm (0.020 or 0.063 in.), Type K, special limits MI cable type thermocouple sensors are preferred for all other hot sections. A popular option is a tapered junction end for faster response times. Moisture seals are used on the sensors to prevent moisture ingress.

- Precise temperature monitoring of critical turbine functions maximizes performance and extends turbine life. Uninterrupted turbine operation is a requirement for power generation and gas compression. Durable exhaust, inlet air, lubrication system and bearing temperature sensors provide control systems with accurate information. Specialized thermocouple, RTD and thermistor designs are dependable for maximizing long term performance.



Prototype engine harness for military aircraft



EGT sensor for private aircraft jet engine

Temperature sensor for large commercial aviation

# MATERIALS EXPERTISE, TESTING AND CERTIFICATION CAPABILITIES

## TESTING AND CERTIFICATION CAPABILITIES

To ensure the most reliable product quality, Watlow has extensive test, calibration and certification facilities operated in conformance with MIL-STD-45662 and ISO 10012-1 with complete NIST traceability to the ITS 90 temperature scale. Capabilities include:

- **Thermocouple Calibration**
  - Per ASTM E 207, E 220, E 230, E 644 and AMS 2750C.
- **Non-Destructive Testing**
  - Helium Leak Testing - Adhering to ASTM E 235.
  - Radiographic Testing - 250KVP.
- **X-Ray Testing** - Systems adhering to SNT-TC-1A.
- **Metallurgical Testing** - Adhering to ASTM E 3, E 112, E235.
- **Time Response Testing**
  - Per ASTM E 644 and E 839.
- **Drift & Thermal Cycling Testing**
  - Adhering to ASTM E 235, E 601 and E 644.
- **Compaction Density Testing**
  - Per ASTM D 2771.
- **Insulation Resistance and Dielectric Testing** - Per ASTM E 780, E 235, E 644.
- **Spurious EMF Testing**
  - Determines thermoelement homogeneity adhering to Watlow's standardized test.
- **Micro-Hardness Testing**
  - Adhering to Vicker's standardized test.
- **Vibration Testing** - Sine vibration to 6250 Hz and 45 kg (100 lbs); Random vibration to 2000 Hz.
- **RTD Testing** - Adhering to ASTM E 644, IEC-751 and NIST Special Publication 250-35.

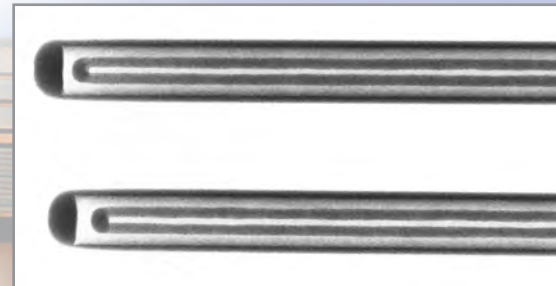
## MATERIALS CAPABILITIES AND EXPERTISE

Watlow has worked with many aerospace and other specialty alloys ranging from the ordinary to the extraordinary, including:

- Carbon Steels:** C-1215, C-1117, C-1018
- Stainless Steels:** 302, 303, 304, 304L, 309, 310, 316, 316L, 321, 330, 347, 430, 440, 446, 17-4PH
- Titanium:** 6 AL 4V
- Other Alloys:** 400, 600, 601, 625, 718 & X-750 Nickel Alloys, Hastelloy® C and X, L-605, 188, 230, 556, HR-160

## TECHNICAL SUPPORT

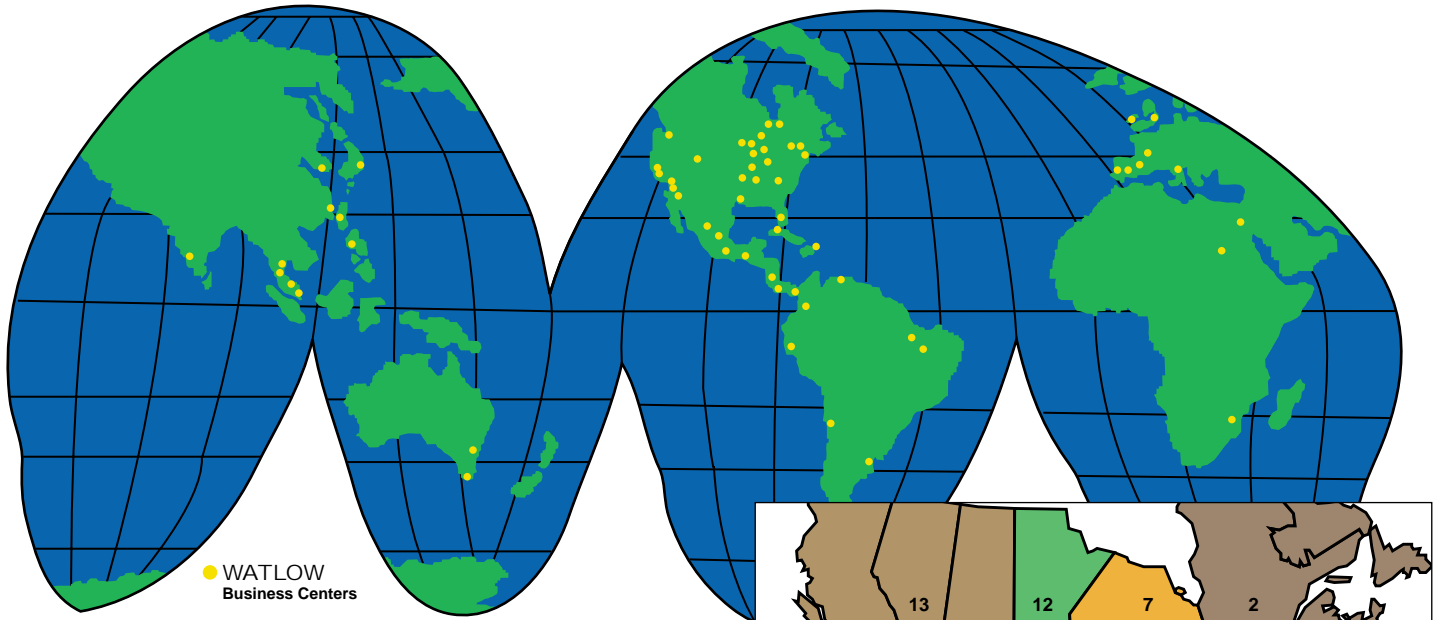
The dedicated High Reliability Technical Support Group is ready to field your requests and support your design, engineering and development projects. Call Watlow's Richmond facility at 1-815-678-2211 or 1-800-4-WATLOW and ask to speak with our technical support personnel.



*X-rays of the sensor verify the absence of cracks at the weld points. Cracks allow contamination to penetrate the sheath, causing premature failure.*

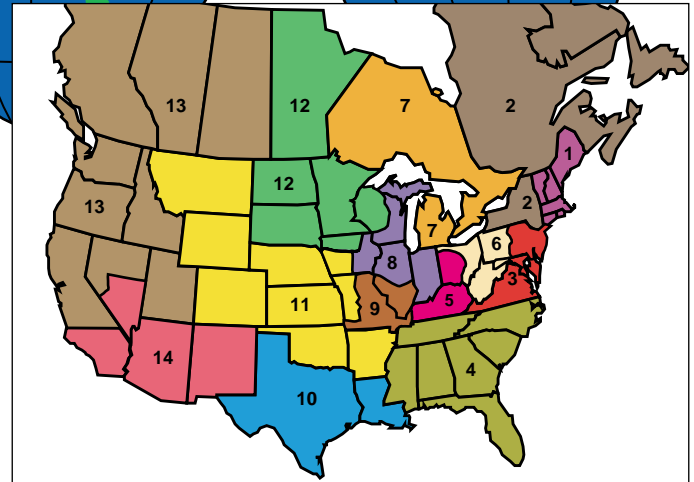


*Calibration furnaces and baths are only a portion of the extensive test and certification equipment in our facilities.*



● WATLOW Business Centers

Your Authorized Watlow Distributor is:



## Watlow Products and Technical Support Delivered Worldwide

### North American Sales Offices

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<b>Region 9</b>	
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<b>Region 12</b>	
Minneapolis, Manitoba	
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Portland	503-245-9037
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San Francisco	408-980-9355
Seattle	425-222-4090
Western Canada	604-444-4881
<b>Region 14</b>	
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San Diego	714-935-2999

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