

Thermocouple & RTD Temperature Sensor Assembly Field Installation



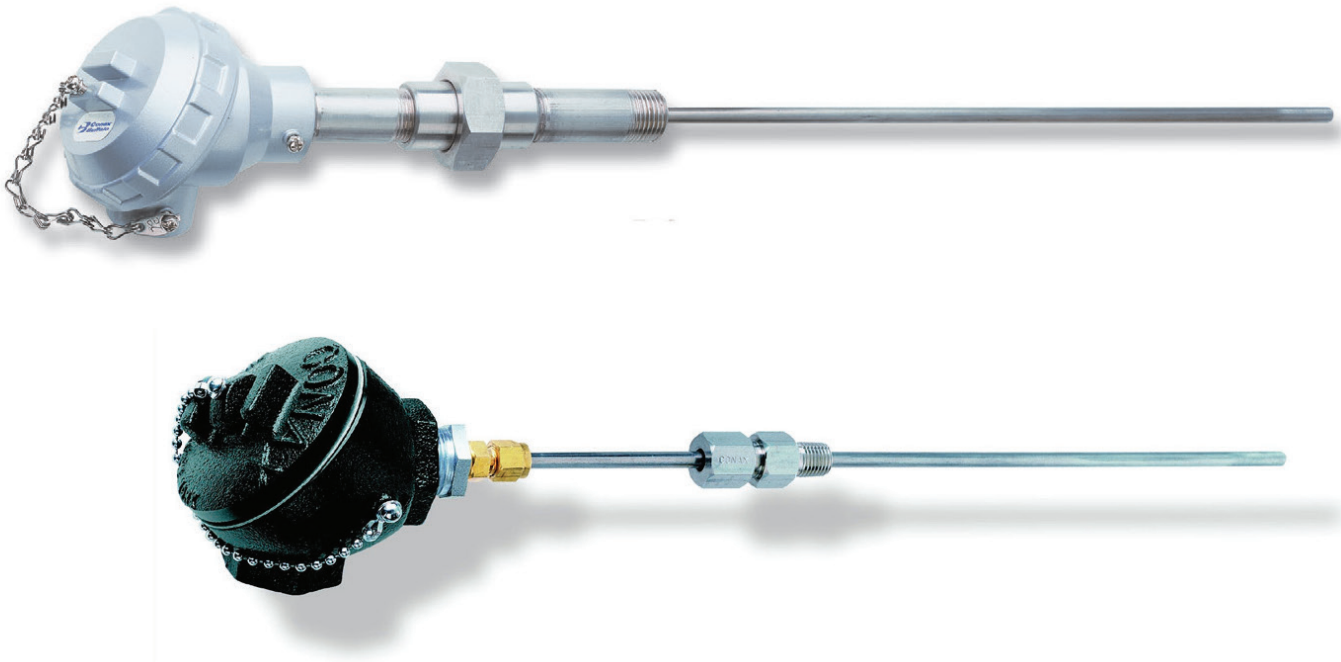
How to correctly deploy thermocouple and RTD sensor assemblies and ensure a successful operation.



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Thermocouple and RTD Temperature Assembly Installation Procedure

Although temperature sensor buyers usually pay close attention to choosing the right device for the job, they are often less diligent when it comes to installation details. The very best sensor can perform poorly if it is not correctly installed.



Thermocouple configurations include the RTD/Thermocouple assembly with a nipple-union-nipple mounting (top) and with an adjustable pressure seal fitting mount (bottom).

Preparation

Before beginning the actual installation, you need to consider a number of factors. Will a thermowell be used? Do you have the appropriate type of wire and terminal head for your needs? The following advice might make the difference between a system that works and one that fails.

Validating Thermowell Size

Thermowells are often used to protect the sensor from abrasive materials in the environment, such as sand, coal dust, cement and other fine powders; or gases and fluids, such as water, steam and liquid chemicals, that may be under high flow rates. Thermowells are also used as the medium to withstand high pressures.

The size of the thermowell will have ideally been given due consideration before you buy the temperature sensor, but if

you have not personally specified the parts, it is always a good idea to check the immersion depth before beginning your installation. To do so, take a piece of wire smaller than the bore of the thermowell and insert it into the thermowell until it bottoms. Mark the wire even with the opening of the thermowell. Extract the wire and measure this length, X.

Now determine the female conduit thread of the thermowell. This will probably be 1/2" or 3/4" NPT. Allow a 0.50" engagement for a 1/2" NPT thread and 0.54" for a 3/4" NPT thread. When you subtract the engagement length from X, the length of your wire, the result, Y, will be the optimum sheath length from the end of the mounting thread to its tip. If your thermocouple/RTD sheath length is shorter, it will fit, but you must decide if the length is best for your application. If Y is larger, it would not be a good idea to install the thermocouple/RTD in this thermowell.

Thermowells may also be provided with a 1/2 or 3/4" straight thread, whose engagement will be greater by approximately 1/4" than the values provided for NPT threads. You should keep this additional length in mind when you calculate the immersion depth.

Thermocouple/RTD assemblies are often supplied with spring-loaded sheaths. These assemblies keep the sensor tip in constant contact with the thermowell bottom, ensuring maximum heat transfer. Spring-loaded assemblies are designed to retract the sheath by approximately 0.37", depending on the model type. If, after compressing the spring, Y is greater than the optimum sheath length, do not install this assembly.

Note: The engagement lengths specified here represent a nominal engagement. If thermowell threads are imperfect or the applied torque is greater than normal, damage to the sensor may still occur. This is one reason spring loading is preferred.

Selecting a Termination Head

In most cases, the termination head will come with the assembly, but it doesn't hurt to double check it for suitability for the environment in which it will be used. For example, for environments where ingress of moisture or dust could be a problem, a NEMA 4 head is recommended. For applications involving explosive gas, choose a NEMA 7 head. In a controlled environment such as a laboratory, a quick disconnect termination (plug and jack) is probably the best selection.

In a rugged environment where the head is likely to experience high abuse, cast iron is probably the best bet. Plastic or stainless steel is preferred for corrosive environments, and if the head needs to be lightweight, go for aluminum.

Before disassembly and installation, you should also check that you have the correct NPT thread. Your new or replacement probe must have the same size mounting thread as the new port or existing assembly.

Safety Warnings

Some situations require extra caution to prevent accidental harm to workers. If your sensor is designed to monitor any situation involving liquid or gas under pressure—without the use of a thermowell—make sure your mounting fitting will withstand that pressure. Inadequate holding strength in the mounting fitting can lead to sensor blow out. A fitting rated to 500 psi, for example, should never be screwed into a vessel that would operate at 1000 psi. Before installation, double check to be certain your fittings and other mounting hardware are strong enough to secure and seal the sensor in place. Release the pressure from the vessel before removing the existing sensor and/or thermowell and installing the new sensor.

If external electric power is connected to the sensor assembly for operating signal conditioning devices and transmitters, turn it off at its source before sensor maintenance.

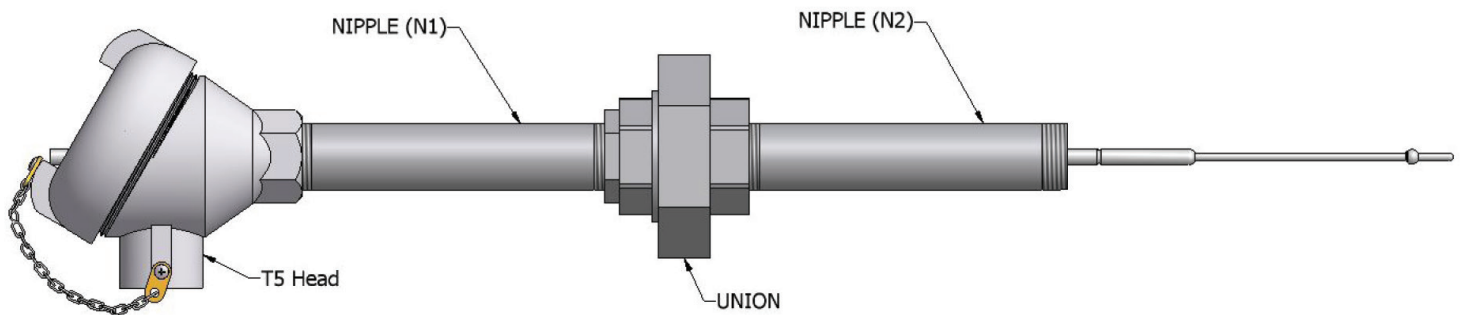


Figure 1. The nipple-union-nipple assembly facilitates installation or removal of the sensor element and simplifies alignment with the conduit connection because the union can be tightened without rotating the termination head. This type of assembly also provides a standoff of the termination head from the vessel, often helpful in mounting electronics in the head.

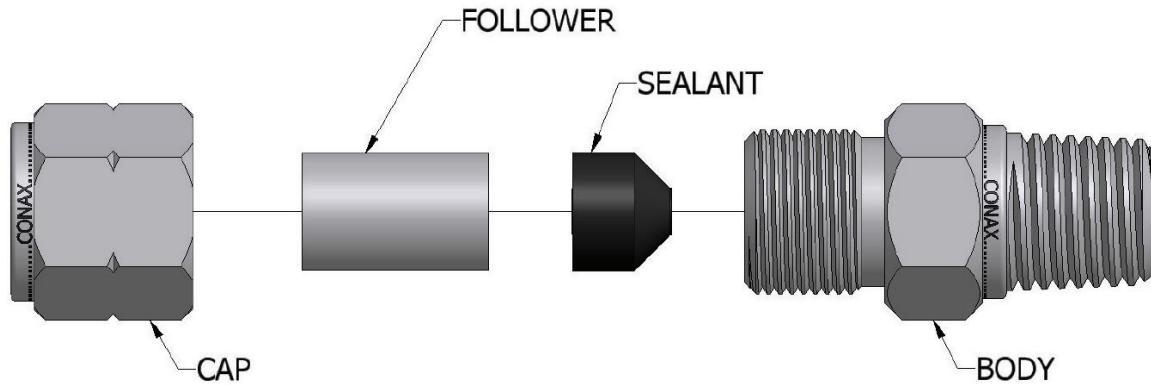


Figure 2. Pressure seal fittings are used to seal temperature probes, cables, or tubes, preventing leakage of gas or liquids and preserving vacuum or pressurized atmospheres within a vessel. The elastomeric materials used in the seal permit easy element adjustment and resealing. Depending on the type of sealant, seal fittings can be used for temperatures ranging from -400°F to 1600°F (-240°C to 870°C).

Common Mounting Devices

In most common installation situations, you will attach the thermocouple/RTD to a pipe, autoclave, vessel or furnace. The sensor portion of the assembly resides within the sheath that is inserted into the vessel, with the sensor element at its tip. This sheath is connected, usually through a sealed nipple-union-nipple to the terminal head (see Figure 1).

In certain instances, the sheath will be inserted into a thermowell that has already been installed into the vessel. If additional sealing is needed to prevent the gases or liquids from leaking, you can replace the connection nipple and/or union with a seal fitting assembly.

The nipple-union-nipple arrangement is a fixed mount; a seal fitting provides an adjustable mount (see Figure 2). If you wish to adjust the immersion depth of the sheath in the vessel, you can simply untorque the fitting, slide the probe in or out to meet your needs, and retorque the fitting. Metal-to-metal seals and stainless steel ferrules can also be used for fixed mounting, but once torqued, they do not permit future immersion adjustment.

As previously noted, some situations require a spring-loaded assembly that pushes the sensor against the bottom of a thermowell to allow maximum heat transfer. Spring-loaded assemblies are often used in heat treat processing to monitor the temperature piece of steel inside a furnace. The assembly pushes the sensor against the steel to ensure that the measured temperature is that of the steel and not the medium around the steel.

Calculating the Immersion Depth

The goal of any temperature sensor installation is to position the sensor where it will be able to measure the temperature of the medium of interest. In a pipe, this spot is usually toward the center third of the pipe. As the medium approaches the pipe wall, the pipe material tends to draw off the heat and cool the substance to be measured. The sensor should also be installed far enough into the environment to ensure that the stem and mounting fittings do not create a heat-sinking effect and corrupt the data. The distance from the sensor tip to the vessel wall is called the immersion depth. A frequently used rule of thumb to determine the correct immersion depth for thermocouples is to make it 10 times the probe diameter. For example, a 1/4 inch diameter probe would be inserted 2.5 inches. For RTDs, the immersion depth should be seven times the diameter of the probe.

When your application is characterized by high temperature, high pressure or high flow rate, pay attention to the immersion depth; the greater the depth, the stronger and stiffer the probe must be to avoid damage during operation.

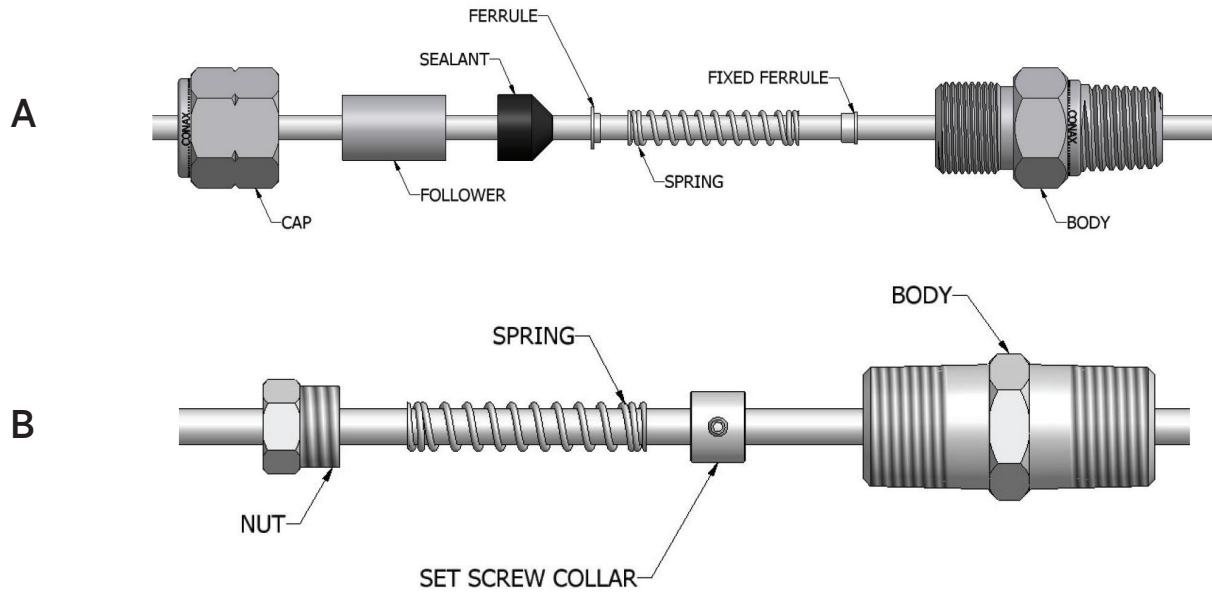


Figure 3. Spring-loaded assemblies maintain a positive force of the thermocouple or RTD element against the surface to be monitored, either directly against a piece of metal, for example, or the bottom of a thermowell. The standard spring-loaded assembly is a fixed mount (A). The spring-loaded adjustable nipple allows adjustment of the element (B).

Installing the Sensor Assembly

Now that you are sure you have the correct parts, have checked the sizing, and have removed any potential dangers from pressure or electric power, you are ready to begin the installation. Here are the steps to follow:

1. If a thermowell is already installed, do not screw in the complete sensor assembly. If the assembly is screwed in as one piece, the sensor may contact the bottom of the thermowell, restricting sheath rotation. When free rotation is restricted, the wires inside the sheath can potentially twist around each other and short out or break. To prevent this, disassemble the union. Screw the nipple section closest to the sensor junction (N2 on Figure 1) into the vessel wall. Then insert the probe through the nipple and half-union into the vessel. Position the probe so that your conduit port is aligned with the conduit. Tighten the union nut.
2. If no thermowell is used, insert the probe to the appropriate immersion depth or to the midpoint of the pipe. In this case, there is nothing to restrict the assembly from turning freely, so you do not have to be concerned with wire twisting. Therefore, you do not have to dismantle the assembly into two pieces unless necessary to permit conduit alignment.
3. If you are using a spring-loaded assembly, the wires to the terminal block on a one-piece assembly should be disconnected from the terminals to prevent wire twisting and breakage within the termination. You may also use a termination head with a removable spring assembly. In this case, remove the internals, including the terminal block, mounting plate and sensor probe as one assembly, screw in the sheath and head, then replace the internals.
4. Once the terminal head is in place, attach the conduit or flex cable to the conduit port. Pull the thermocouple extension wire through the conduit/flex tube into the terminal head or junction box.

Attaching to the Terminal Junction

Attach the thermocouple wire to the terminal block by matching the wire polarity and/or color to the corresponding terminal (e.g. red wire to red wire). Use the Thermocouple Characteristics Table (see Table 1) if you are unfamiliar with thermocouple color coding. You can also determine polarity by checking to see if the wire from the thermocouple into the head is magnetic. In thermocouple pairs, usually one leg is magnetic and the other is not. The first name mentioned when naming the pairings indicates the positive leg (for example, copper in copper-constantan).

One other point to keep in mind is that the color red in thermocouples indicates the negative leg, whereas in electronics, red generally indicates the positive.

If you are using a shielded extension wire with a drain, connect the drain wire to the green grounding terminal. Shielded wire is typically used to protect the sensor signal from RF interference in environments where devices such as hand-held radio, welding equipment, circuit breakers, variable speed, motors or fluorescent lighting come too close to the sensor leadwires. These devices produce electromagnetic fields that can be induced into the conductors and produce a false reading.

Thermocouple Characteristics Table

ANSI/ ASTM	Symbol Single	Generic Names	Color Coding		Magnetic Yes No	Environment (Bare Wire)
			Individual Conductor	Overall Jacket Extension Grade Wire		
T	TP TN	Copper Constantan, Nominal Composition: 55% Cu, 45% Ni	Blue Red	Blue	X X	Mild Oxidizing, Reducing. Vacuum or Inert. Good where moisture is present.
J	JP JN	Iron Constantan, Nominal Composition: 55% Cu, 45% Ni	White Red	Black	X X	Reducing Vacuum, Inert. Limited use in oxidizing at high temperatures. Not recommended for low temps.
E	EP EN	Chromel [®] , Nominal Composition: 90% Ni, 10% Cr Constantan, Nominal Composition: 55% Cu, 45% Ni	Purple Red	Purple	X X	Oxidizing or Inert. Limited use in Vacuum or Reducing.
K	KP KN	Chromel [®] , Nominal Composition: 90% Ni, 10% Cr Alumel, Nominal Composition: 95% Ni, Mn, 2% Al	Yellow Red	Yellow	X X	Clean Oxidizing and Inert. Limited use in Vacuum or Reducing.
N	NP NN	Nicrosil [®] , Nominal Composition: 84.6% Ni, 14.2% Cr, 1.4% Si Nisil [®] , Nominal Composition: 95.5% Ni, 4.4% Si, 1% Mg	Orange Red	Orange	X X	Clean Oxidizing and Inert. Limited use in Vacuum or Reducing.
S	SP SN	Platinum 10% Rhodium Pure Platinum	Black Red	Green	X X	Oxidizing or Inert Atmospheres. Do not insert in metal tubes. Beware of contamination.
R	RP RN	Platinum 13% Rhodium Pure Platinum	Black Red	Green	X X	Oxidizing or Inert Atmospheres. Do not insert in metal tubes. Beware of contamination.
B	BP BN	Platinum 30% Rhodium Platinum 6% Rhodium	Grey Red	Grey	X X	Oxidizing or Inert Atmospheres. Do not insert in metal tubes. Beware of contamination.
W5* (C)	P N	Tungsten 5% Rhenium Tungsten 26% Rhenium	White/Red Trace Red	White/Red Trace	X X	Vacuum, Inert, Hydrogen Atmospheres. Beware of Embrittlement.
W3* (D)	P N	Tungsten 3% Rhenium Tungsten 25% Rhenium	White/Yellow Trace Red	White/ Yellow Trace	X X	Vacuum, Inert, Hydrogen Atmospheres. Beware of Embrittlement.

Shielding is used more often than not in most industrial settings. Non-shielded wire can be used in indoor environments that have a minimal degree of external EMF voltages (i.e. a laboratory or assembly area). Shielding generally consists of Mylar with aluminum-backed material. A solid copper drain wire is helically wound about the sensor cable. Then the cable and copper wire are wrapped with the Mylar in such a way that the aluminum contacts the copper.

Extension leadwire insulation material selection is critical for environments where temperature and moisture could effect the readings. Depending on the ambient environment, you have your choice of candidates.

PTFE-insulated wires are generally rated as acceptable for contact with environmental or surface temperatures of approximately 400°F - 500°F. PVC insulation can be used for temperatures up to 220°F and fiberglass up to 900°F. For higher temperatures, other insulation materials are available, such as silica fiber for up to 1800°F.

PTFE and PVC provide excellent moisture resistance and generally very good abrasion resistance. Fiberglass and silica provide poor moisture resistance and only fair abrasion resistance.

When stripping the insulation to connect the wires to the terminals, be careful not to make cuts into the conductors. Such cuts could set up a stress point within the wire and leave it prone to failure by breakage or opening over time. The general rule of thumb is to remove approximately 1.5 to 2 inches off the outer jacket and 1/2 inch off the individual conductors. If there is a drain wire, expose enough of it to extend to the grounding screw.

The posts inside the terminal head are not usually made of thermocouple material. In most cases, thermocouple material and RTD wires are connected to nickel-plated brass posts. Although some people worry about the effects of these third metals on the temperature readings, they shouldn't. The terminal head is typically in a defined environment, with temperatures at equilibrium, so no delta T exists across the terminals. Any thermoelectric effects generated by the third material cancel out. If you are concerned about the effect of third metals, instead of connecting the wires to the provided terminal posts, simply wrap the like conductors about each other and use a wire nut, avoiding the posts altogether.

Selecting Extension Wire

The extension wire can have a major effect on the accuracy of temperature readings transmitted from the sensor assembly to the control room. First, you need to consider the environment. For most indoor applications, the extension wire will run through conduit in an environment that is generally moisture free, so there should be minimal problems with induced heat or moisture.

Outdoor applications are another story. Moisture, water droplets, or even accumulated water buildup can cause low IR-to-ground conditions with ground loops and potential oxidation (rust) of the thermocouple wire, depending on the thermocouple type used. With contact no longer solid, the reading can be erroneous.

Drops of moisture creating links between wires can cause a secondary junction and produce an erroneous reading. These problems can be avoided by using PTFE- or PVC-insulated extension wire.

The second key point to consider is Reference Junction/ Cold Junction compensation. Thermocouples function on the principle that any piece of wire exposed to a thermal gradient will produce a voltage. When you pair two dissimilar metals, you can determine a measurement in millivolts that can be related to set points to determine the temperature reading. The reference junction refers to the temperature at ice point (32°F).

Temperature readings for a given thermocouple wire will follow a definable curve. Extension grade wire offers a more restricted temperature range than does thermocouple grade wire. The extension wire follows the same temperature curve as the thermocouple wire up to a certain temperature, approximately 400°F, then ceases to follow the EMF/temperature curve for that calibration. If you use extension grade wire beyond its limitations, you may introduce a significantly large error into your readings. For reliable readings, the thermocouple wire in the terminal head must be connected to the same thermocouple type wire (either thermocouple grade or extension grade) all the way to the readout instrumentation. A common scenario is to use copper wire rather than thermocouple or extension wire, but this is not a good idea. Copper does not follow the EMF/temperature curve of the thermocouple at all (with the exception of certain copper alloys as noted below) and therefore introduces a tremendous degree of error. If copper wire is the only option in a given situation, one solution is to install an electronic reference junction in the terminal head or use a "hockey-puck" style transmitter (generally 4-20 mA) at the terminal head.

For the base metal thermocouples (Types E, J, T, K and N), the associated extension grade wire is of a metallurgical construction similar to that of thermocouple wire. For refractory metal thermocouples such as Type C (tungsten/5% rhenium vs. tungsten/26% rhenium), it is impractical, from both a cost and technical viewpoint, to run pure tungsten wire, so an alloy wire is used. For the platinum series (R, S and B), Types R & S use a copper/copper Alloy 11. Type B thermocouples are the only type that can use regular copper/copper wire, provided the wire is not exposed to temperatures in excess of 212°F. From 212°F to 392°F, a proprietary wire alloy is available.

Reference junction compensation is not a problem with RTDs, because they use resistance instead of millivolts as the measuring signal. The leadwires extending from the RTD element to the terminal post are generally copper or nickel.

Proper installation of your sensor assembly can help you avoid many common problems and downtime. With a little care and attention to the installation procedure, a good quality sensor assembly should provide years of reliable operation and accurate readings.

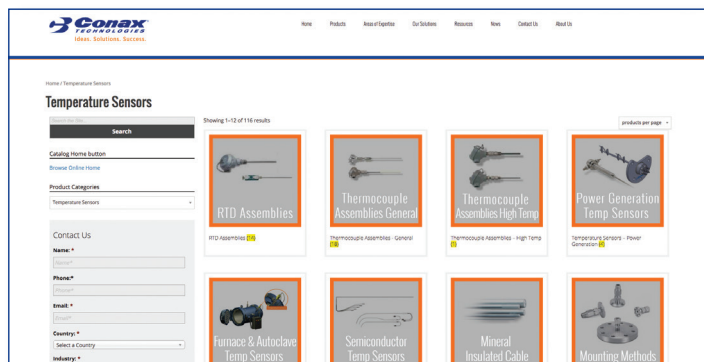
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2300 Walden Avenue, Buffalo, New York 14225
+1 800 223 2389 (P) | +1 716 684 7433 (F)
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