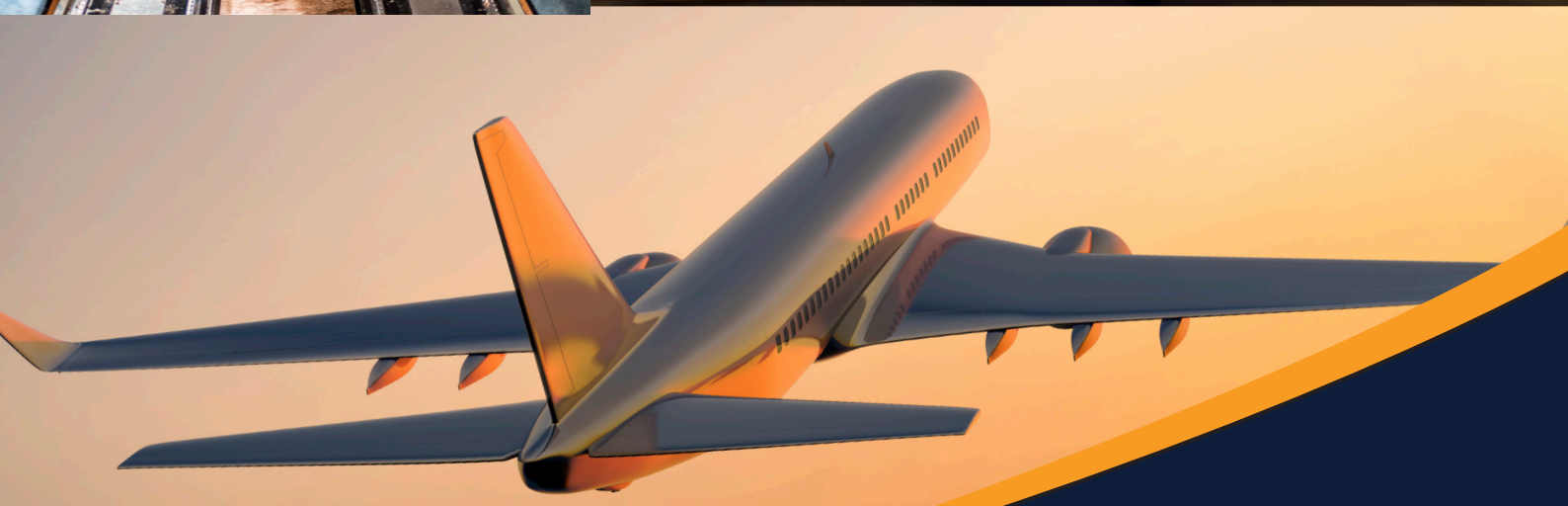
Ambrell®
INDUCTION HEATING SOLUTIONS
an inTEST Company

# WHITEPAPER

## Aerospace Applications with Precision Induction Heating



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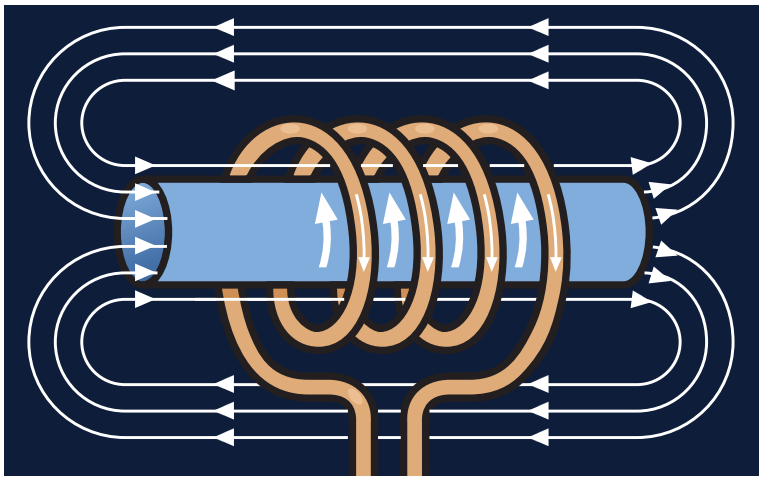
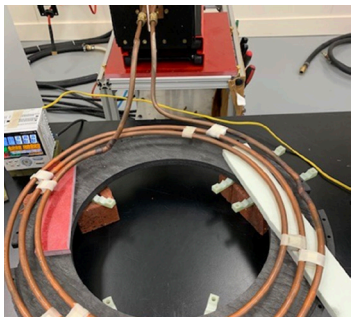
# What is Induction Heating

Induction heating is a method of providing fast, consistent heat for manufacturing and research applications which involve bonding or changing the properties of metals or other electrically conductive materials. The process relies on electrical currents within the material to produce heat. Although the basic principles of induction are well known, modern advances in solid state technology have made induction heating a remarkably simple, cost-effective heating method for applications which involve joining, bonding, heating and materials testing.

The basic components of an induction heating system are an AC power supply, induction coil, and workpiece (the material to be heated or treated). The power supply sends alternating current through the coil, generating a magnetic field. When the workpiece is placed in the coil and enters the magnetic field, eddy currents are induced within the workpiece, generating precise amounts of clean, localized heat without any physical contact between the coil and the workpiece.

There is a relationship between the frequency of the alternating current and the depth to which it penetrates in the workpiece; low frequencies are effective for thicker materials requiring deep heat penetration, while higher frequencies are effective for smaller parts or shallow penetration. Power levels and heating times are closely related to the characteristics of the workpiece and the design of the induction coil. Coils are normally made of copper with appropriate water cooling and vary considerably in shape according to the application.





Research is a very common induction heating application. Induction heating supplies a clean, very localized and controllable heat.

# Heat a Block of Haynes Nickel Alloy to Test the Crack Growth Rate

**OBJECTIVE**

To heat a block of Haynes nickel alloy from 600 ºF (316 ºC) to 1600 ºF (871 ºC) to collect data on the crack growth rate for an aerospace application.

**EQUIPMENT**

Ambrell EASYHEAT™ 2 kW, 150-400 kHz solid state induction heating power supply with a workhead and coil specifically designed for this application.

**FREQUENCY**

196 kHz

**MATERIAL**

Hanes Nickel Alloy block (3” x 5/16” / 76mm x 8mm)

**TEMPERATURE**

1600 ºF (871 ºC)

**TESTING**

Testing was conducted to optimize the power delivered to the part. The coil was designed to minimize the voltage potential over the length of the part. The part was placed into the coil and a multimeter was connected to it to measure the voltage potential over the length of the part. The heat was turned on and the part was heated to 1600 ºF (871 ºC) within 90 seconds.

**BENEFITS**

**Induction heating provides:**

- **Versatility:** The client had purchased an EASYHEAT for a different purpose, but it was also able to perform the desired material testing with the new coil.
- **Coil Design:** The client needed a coil tuned to their EASYHEAT, and it had to meet their heating requirements while leaving the center horizontal plane open for visual inspection, which this design achieved.
- **Responsiveness:** Ambrell was able to perform a free laboratory test and design a coil that would meet their needs when it comes to material testing.

The Hanes nickel alloy block inside the specially designed coil.

# » Preheating a Titanium Alloy Wire Prior to Welding

**OBJECTIVE**

To preheat a titanium alloy wire prior to welding; the end product is a part for the aerospace industry.

**EQUIPMENT**

- Ambrell EASYHEAT™ 10 kW, 150-400 kHz induction heating power supply with a remote workhead
- A single position 38-turn helical coil with multiple water paths

**MATERIAL**

0.063" (1.6 mm) diameter titanium allow wire

**TEMPERATURE**

2,732 °F (1,500 °C)

**FREQUENCY**

365 kHz

**TESTING**

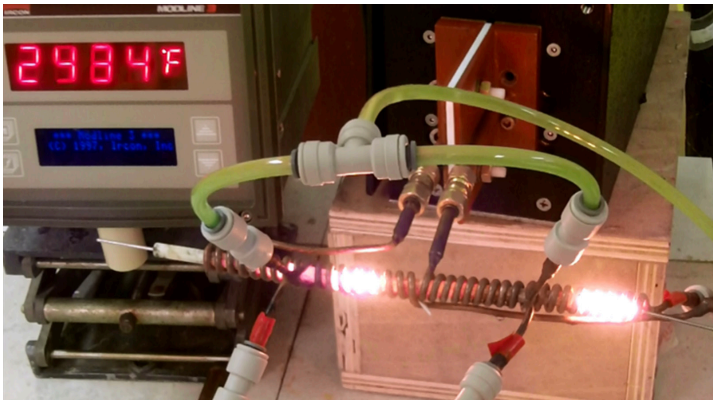
Testing in static mode was done to simulate a dynamic feed rate of 8" (203 mm) per second. While a static test may vary from dynamic conditions, it is a close simulation and used when test equipment is required to replicate a feed rate and is not available. With an 8" (203 mm) long coil and a feed rate of 8" (203 mm) per second, any section of wire would spend one second inside the coil. Therefore, a static test of one second would simulate the performance of an EASYHEAT 10 kW power supply for the aforementioned feed rate. For each second added to the static test, it would simulate an additional 10 kW power supply heating the wire in series with other power supplies.

With an EASYHEAT 10 kW power supply, the titanium alloy wire can be heated to 2732 °F (1500 °C) in three seconds. This testing configuration simulates using three EASYHEAT 10 kW power supplies in series.

**BENEFITS**

**Induction heating provides:**

- **Speed:** Induction is a fast and repeatable solution for wire heating.
- **Efficiency:** Induction puts power right into the wire, so energy efficiency is maximized.
- **Footprint:** Induction requires a minimal footprint, saving valuable floor space.




This photo shows the wire with the EASYHEAT delivering energy; the wire is at the peak of the heat cycle.

# >> Heating Graphite Discs

**OBJECTIVE**

To heat an assortment of graphite discs of variable sizes; the client was from the aerospace industry.

**EQUIPMENT**

Ambrell EKOHEAT® 45 kW, 50-150 kHz induction heating power supply with a workhead and coil specifically designed for this application.

**MATERIAL**

Graphite discs

**TEMPERATURE**

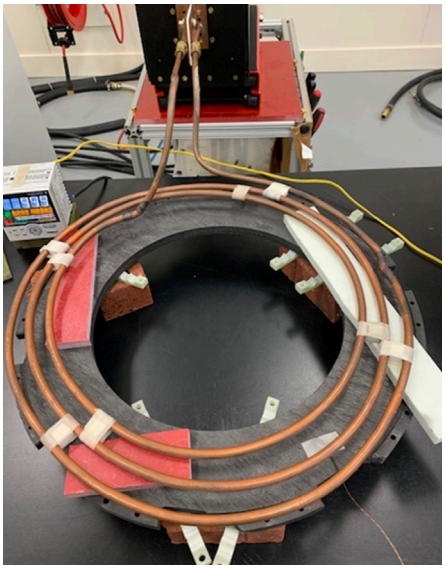
200 °F (93 °C)

**TESTING**

A custom-designed single position multiple-turn pancake coil was built to generate the required heating for this application. Initial tests were conducted to optimize the power delivered to the part. The coil was held 0.5" (12.7 mm) above the top surface of the part. Thermo couples were attached to the top and bottom surfaces of the part. It took 45 seconds to heat the sample to the target temperature of 200 °F (93 °C) on the surface closest to the coil. The surface farther from the coil reached 180°F (82 °C) in this time. It is possible to use closed-loop temperature control with the EKOHEAT to bring the top surface to temperature and hold it while the farther surface is brought to temperature.

**BENEFITS**

- **Speed:** Induction met the client's heating time objective.
- **Repeatability:** The client can expect the same result in the same amount of time every single time.
- **Efficiency:** Induction can efficiently heat the part in a controlled manner to only deliver the required heat.
- **Footprint:** Induction, with a movable workhead, is often considerably more space efficient than alternative heating methods.



The pancake coil set up above the graphite disc.

# Brazing Brass and Copper Samples

**OBJECTIVE**

To heat brass and copper samples for a brazing application in the aerospace industry; the client has been using a torch but wanted more consistent, higher quality parts.

**EQUIPMENT**

Ambrell EASYHEAT™ 6 kW, 150-400 kHz solid state induction power supply with a workhead and coil specifically designed for this application.

**FREQUENCY**

206 kHz

**MATERIAL**

Brass and Copper

**TEMPERATURE**

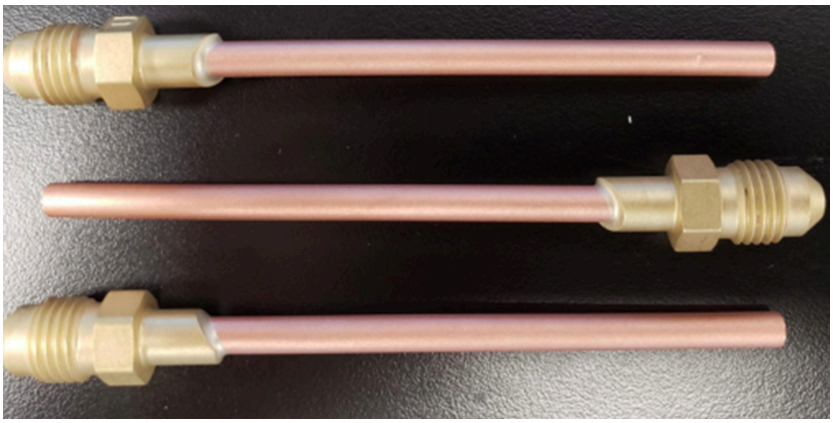
1200 °F (649 °C)

**TESTING**

A custom-designed multiple-turn helical coil was built to generate the required heat for the application. Temperature indicating paint was then applied to the part, which dissolves when the part reaches temperature. It took about 120 seconds to heat the part to temperature. The speed and end-product met the client's objectives.

**BENEFITS**

- **Speed:** Induction met the client's time requirements and can be faster than other heating methods.
- **Repeatability:** The client can expect the same result in the same amount of time every single time with induction heating, which was a primary reason this client was interested in induction.
- **Work Environment:** With induction there is no open flame and with induction's instant on/off capabilities, it introduces less heat into the work environment.



Sample parts.

# » Brazing a Steel Nozzle Assembly

**OBJECTIVE**

To heat a steel nozzle assembly for a brazing application; they had tried an oven and torch but struggled with part quality.

**EQUIPMENT**

Ambrell EASYHEAT™ 4.2 kW, 150-400 kHz solid state induction power supply with a workhead and coil specifically designed for this application.

**FREQUENCY**

200 kHz

**MATERIAL**

Magnetic steel

**TEMPERATURE**

1450 °F (788 °C)

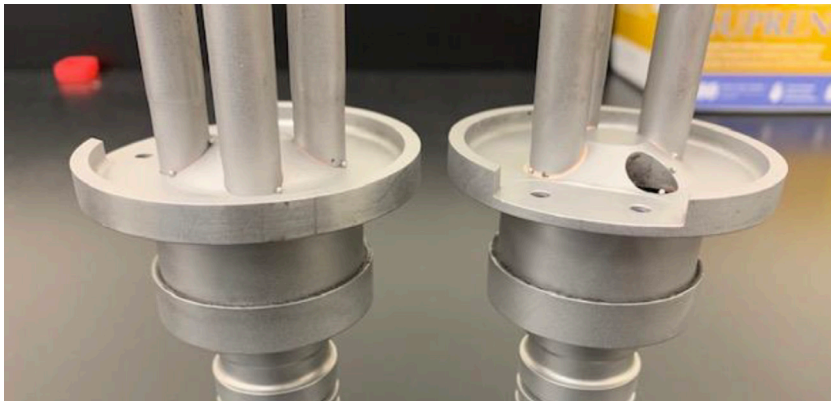
**TESTING**

A custom-designed single position multiple-turn helical coil was built to generate the required heat for the application. This is a low volume application, so heating time was not a priority for the client. The location of the desired braze joint is shielded from the induction field by the lip of the nozzle.

The only way to form the braze joint was to heat the assembly together despite the shielded area. The joint area and surface were coated in black flux. The provided braze rings were used. Heating took six minutes, which was long enough that the heat conducted to the joint area to melt the braze alloy ring and form the joint.

**BENEFITS**

- **Repeatability:** The client struggled with repeatability with an oven and torch, while induction is a more repeatable process.
- **Work Environment:** With induction there is no open flame and with induction's instant on/off capabilities, it introduces less heat into the work environment.
- **Footprint:** Induction is more space efficient than an oven.



Sample parts.

# >> Brazing Both Ends of a Steel Assembly

**OBJECTIVE**

To braze both ends of a steel assembly concurrently; they are familiar with induction heating but had a new requirement.

**EQUIPMENT**

Ambrell EASYHEAT™ 6 kW, 150-400 kHz solid state induction power supply with a workhead and coil specifically designed for this application.

**FREQUENCY**

240 kHz

**MATERIAL**

Nonmagnetic steel

**TEMPERATURE**

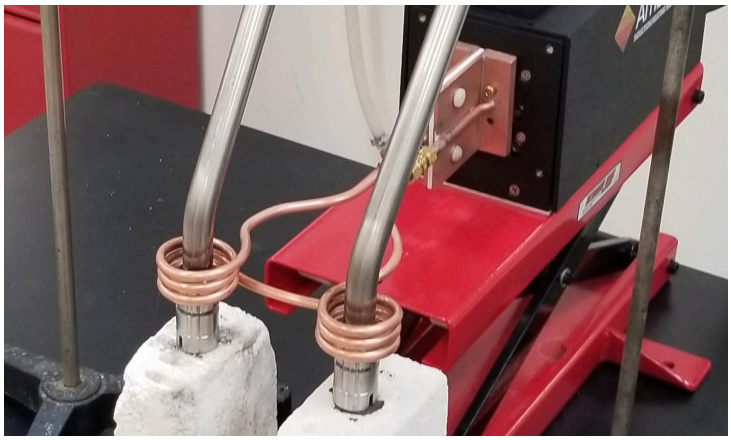
1425 °F (774 °C)

**TESTING**

A custom-designed double position multiple-turn helical coil was built to generate the required heating for this brazing application. Initial tests were conducted to optimize the power delivered to the parts. Temperature indicating paint was then applied to the parts, which dissolves when the parts reach target temperature. It took 40 seconds to heat the samples to temperature.

**BENEFITS**

- **Lab Expertise:** The client wanted to braze both ends of the part concurrently, and THE LAB at Ambrell was able to meet that requirement.
- **Speed:** Induction met the client's time requirements and is often faster than other heating methods.
- **Repeatability:** The client can expect the same result in the same amount of time every single time with induction heating.
- **Work Environment:** With induction there is no open flame and with induction's instant on/off capabilities, it introduces less heat into the work environment.



Sample parts.

# Induction Forging Turbine Blades

**OBJECTIVE**

To heat titanium rod blanks prior to forging into a turbine blade. Heating must occur in a very precise fashion. The blanks should heat to 2,030 ºF (1,110 ºC) with a tolerance of plus or minus 25 ºF (-3.9 ºC) with uniform heat from the surface to the core.

**EQUIPMENT**

Ambrell EKOHEAT® 20 kW, 50-150 kHz solid state induction heating power supply with a workhead and coil specifically designed for this application.

**FREQUENCY**

164 kHz

**MATERIAL**

Titanium rod 0.591" (15 mm) OD by 11.8" (300 mm) long

**TEMPERATURE**

2,030 °F (1,110 °C)

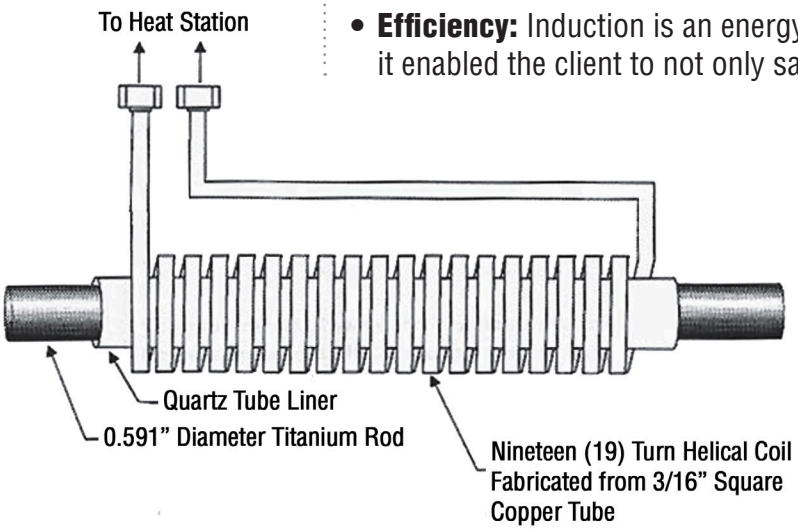
**TESTING**

Through extensive laboratory work in THE LAB at Ambrell, the EKOHEAT 20 kW output solid state induction power supply, an optical pyrometer, 4-20 mA input, and a 19-turn helical coil were found to achieve the following results:

- A temperature of 2030 ºF (1,110 °C) was reached in 25 seconds with a 3 ºF (-16.1 °C) overshoot and stabilized at ± 2 ºF (-16.7 °C).
- A time to temperature of 15 seconds could be achieved with this setup if run at full power.

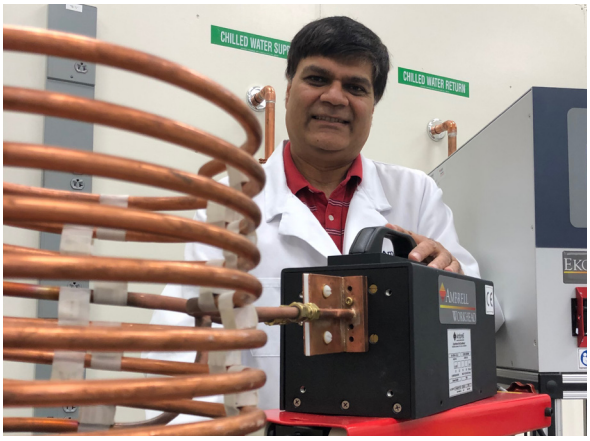
**BENEFITS**

- **Speed:** Induction's rapid heating allowed the client to reduce their cycle time and increase throughput.
- **Consistency/Repeatability:** The client can expect the same result time after time with induction.
- **Efficiency:** Induction is an energy efficient medium of heating, so it enabled the client to not only save time, but money too.



# >> Complimentary Applications Testing

## The Gold Standard in the Industry




Our Applications Laboratory – known in the industry as THE LAB – is where we solve our customers' most demanding and challenging heating applications. Led by Dr. Girish Dahake's worldwide team of elite engineers, Ambrell is uniquely qualified to assist you with your heating process needs.

With more than thirty years of laboratory expertise, our engineers have evaluated thousands of applications. Our team consistently provides innovative and effective induction heating solutions that deliver extraordinary results in one application after another. It's why THE LAB is the gold standard in the industry.

We invite you to visit THE LAB in either of our two locations: one in the U.S. and one in Europe. You will experience our state-of-the-art testing facility, which is fully equipped with Ambrell induction heating systems and hundreds of proven coil designs. In addition, you can interface with our engineers and see first-hand how we design prototype coils and develop effective solutions to maximize the efficiency of your heating process.

### Applications Laboratory Overview

- Customer access to a wide array of induction heating equipment in THE LAB
- Hundreds of proven coil designs available
- Rapid coil prototyping for unique applications
- Video recording for slow motion studies includes availability of remote access
- Computer software for thermal analysis
- Quenching and closed loop heat-sensing capabilities
- Convenient, easy-to-use online form to get your free PRECISION MATCH Lab service

### Free PRECISION MATCH Lab Service

Our engineers will design and test the optimal solution for your application. Follow these three easy steps:

1) Send us your parts and process requirements.

2) Our engineers will analyze your process and heat your parts to develop the precise and optimal solution to match your needs.

3) You will receive your parts back for inspection including a video recording of the induction heating process of your parts as well as a laboratory report with a system recommendation.

**Contact us today for a free feasibility testing at:**
**www.ambrell.com/services/lab-service-request**

*Our global reach includes a direct sales team along with an extensive distribution, channel partner and OEM network.*

## About Ambrell

Founded in 1986, Ambrell Corporation, an inTEST Company, is a global leader in the induction heating market. We are renowned for our application knowledge and engineering expertise. In addition, our exceptional product quality and outstanding service and support are at the core of our commitment to provide a superior customer experience.

We are headquartered in the United States with additional operations in Europe including the United Kingdom and the Netherlands. All Ambrell products are designed, engineered and built at our manufacturing plant in the United States, which is an ISO 9001-certified facility. Over the last three decades we have expanded our global reach through an extensive distribution, channel partner and OEM network. Today, we have more than 20,000 systems installed in over 50 countries.

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www.ambrell.com


**Ambrell Corporation**
United States
Tel: +1 585 889 9000
Fax: +1 585 889 4030
sales@ambrell.com

**Ambrell B.V.**
The Netherlands
Tel: +31 880 150 100
Fax: +31 546 788 154
sales-eu@ambrell.com

**Ambrell Ltd.**
United Kingdom
Tel: +44 1242 514042
Fax: +31 546 788 154
sales-uk@ambrell.com


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