About Induction Heating

Ambrell
INDUCTION HEATING SOLUTIONS
an inTEST Company

What is Induction Heating?

Induction heating is a fast, efficient, precise, repeatable, non-contact method for heating metals or other electrically-conductive materials. An induction heating system includes an induction power supply which converts line power to an alternating current, delivers it to a workhead and work coil creating an electromagnetic field within the coil. The work piece is placed in the coil where this field induces a current in the work piece, which generates heat in the work piece. The coil, which is water-cooled and cool to the touch, is placed around or adjacent to the work piece. It does not touch the work piece, and the heat is only generated by the induced current flowing in the work piece.

The material of the work piece may be a metal such as steel, copper, aluminum or brass or it can be a semiconductor such as carbon, graphite or silicon carbide. To heat non-conductive materials such as plastics or glass, induction can heat an electrically-conductive susceptor, typically graphite, which then transfers the heat to the non-conducting material.

Induction heating is used in processes where temperatures are as low as 100 °C (212 °F) and as high as 3000 °C (5432 °F). It can be used in brief heating processes that are on for less than half a second and in heating processes that are on for months.

Induction heating is used in domestic and commercial cooking, and in many applications such as melting, heat treating, preheating for welding, brazing, soldering, curing, sealing, shrink fitting in industry, and in research and development.

How does induction heating work?

It helps to start with the basics to provide a little electrical understanding. Induction creates an electromagnetic field in a coil to transfer energy to the work piece to be heated. When an electrical current passes along a wire a magnetic field is created around that wire.

Key Benefits of Induction:

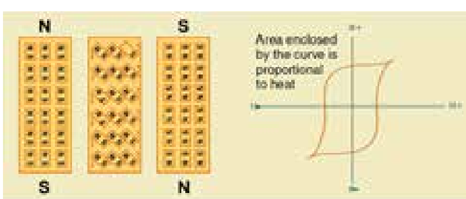
- Rapid heating
- Precise, repeatable heating
- Efficient heating
- Safe heating since there is no flame
- Extended life of fixturing due to precise heating

Experience the Excellence.™

Methods of Induction Heating

There are Two Methods of Heating When Using Induction:

1. Eddy current heating from the I^2R losses from the resistivity of the work piece's material.
2. Hysteretic heating in which energy is generated within the part by the alternating magnetic field created by the coil changing the magnetic polarity of the part. Hysteretic heating occurs in the part up to the Curie temperature when the material's magnetic permeability reduces to 1 and hysteretic heating is minimized. The remaining induction heating effect is by eddy current heating.

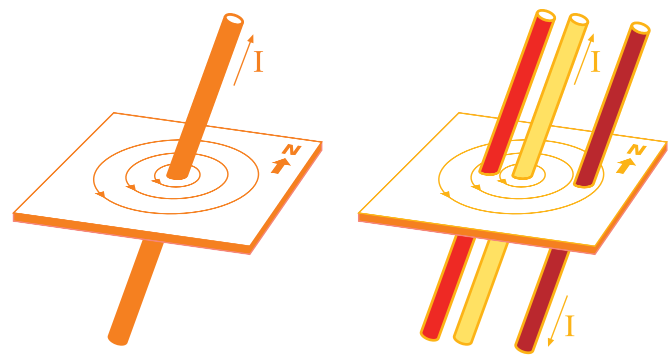


Will Induction Work for Me?

A hallmark of the Ambrell experience is complimentary laboratory testing. Ambrell's applications engineers will test your parts, determine the correct system based on your requirements and also determine the optimal coil design. While we're delighted to teach you about induction, we'll make implementing induction easy.

When the electrical current changes direction (AC) the magnetic field created collapses, and is created in the reverse direction, as the current reverses direction. When a second wire is placed in that alternating magnetic field an alternating current is generated in the second wire. The current in the second wire is proportional to the current in the first wire and to the inverse of the square of the distance between them.

When we replace the wire in this model with a coil, the alternating current on the coil creates an electromagnetic field and while the work piece to be heated is in the field, the work piece corresponds to the second wire and an alternating current is generated in the work piece. Heat is generated in the work piece due to the I^2R losses of the work piece's material resistivity. This is called eddy current heating.



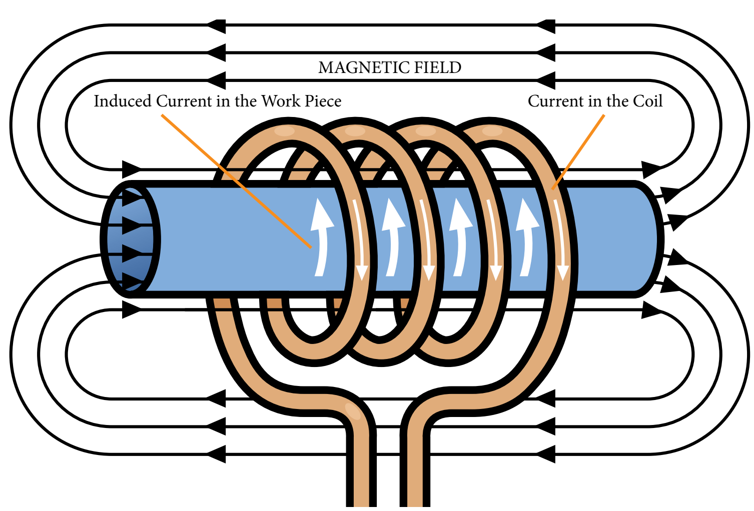
How Does an Induction Coil Work?

The work coil is used to transfer energy to the work piece using an alternating electromagnetic field.

The alternating current flowing through the coil generates the electromagnetic field which induces a current flowing in the work piece as a mirror image to the current flowing in the work coil.

The work coil, also known as the inductor, is the component in the induction heating system that defines how effectively and how efficiently the work piece is heated.

Work coils range in complexity from a simple helical wound (or solenoid consisting of a number of turns of copper tube wound around a mandrel) to a coil precision-machined from solid copper and brazed together.



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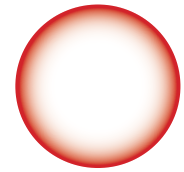
What is the Operating (resonant) Frequency?

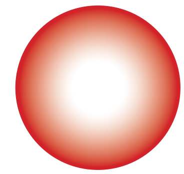
The operating frequency for an induction heating system is dictated by the work piece to be heated and the material it is made from. It is important to use an induction system that delivers power over the range of frequencies appropriate for the application.

To help understand the reasons for different operating frequencies let's look at a characteristic known as the "skin effect." When the electromagnetic field induces a current in the part, it flows primarily at the surface of the part. The higher the operating frequency the shallower the skin depth; the lower the operating frequency the deeper the skin depth and the penetration of the heating effect.

Skin depth or penetrating depth is dependent on the operating frequency, material properties and the temperature of the part. For example, in the table below, a 20 mm steel bar can be stress-relieved by heating it to 540 C (1000 °F) using a 3 kHz induction system. However, a 10 kHz system will be required to harden the same bar by heating it to 870 °C (1600 °F).

High frequency induction heating has a shallow skin effect which is more efficient for small parts.





Low frequency induction heating has a deeper skin effect which is more efficient for larger parts.

		Approximate smallest diameter for efficient heating at different induction frequencies			
Material	Temperature	1 kHz	3 kHz	10 kHz	30 kHz
Steel below curie	540 °C (1000 °F)	8.89 mm (0.35 in)	5.08 mm (0.20 in)	2.79 mm (0.11 in)	1.27 mm (0.05 in)
Steel above curie	870 °C (1600 °F)	68.58 mm (2.7 in)	38.10 mm (1.5 in)	21.59 mm (0.85 in)	9.65 mm (0.38 in)

As a rule, heating smaller parts with induction requires higher operating frequencies (often greater than 50 kHz), and larger parts are more efficiently heated with lower operating frequencies.

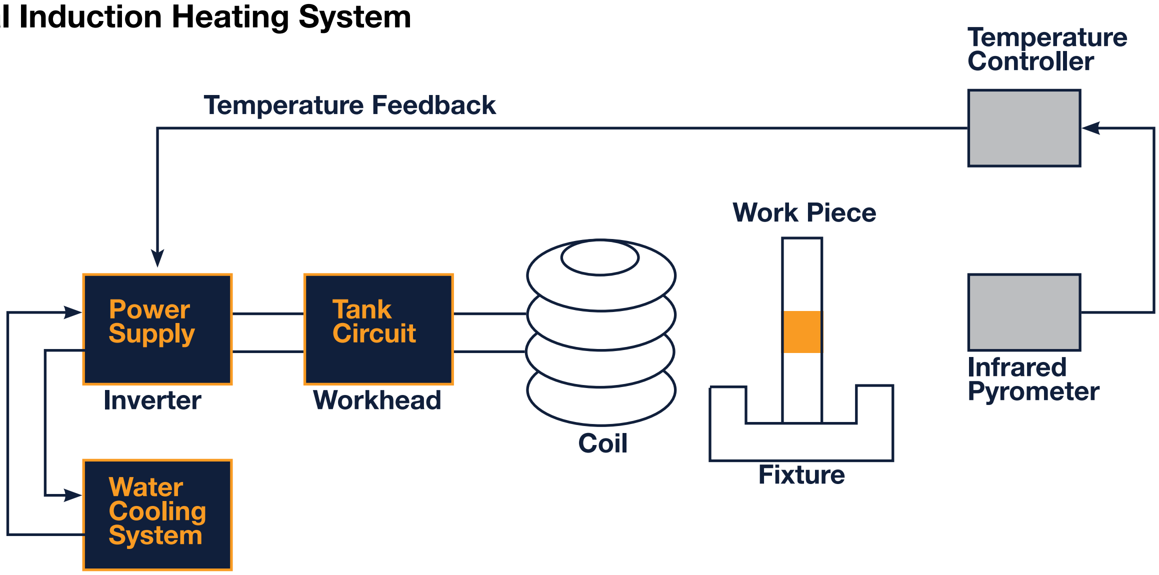
With modern solid-state induction power supplies with embedded microprocessor control systems, repeatable and efficient heating processes are readily achievable as long as every part is placed in a consistent location within the coil.

What Makes Up an Induction Heating System?

An induction heating system consists of a power supply (or inverter) a tank circuit (or workhead) and a work coil. In industrial applications there is usually enough current flowing through the coil to require water cooling, so a typical installation includes a water cooling system.

The power supply converts the alternating current from the AC line to an alternating current that resonates with the combination of the capacitance in the workhead, the inductance of the coil and the resistivity of the part.

Typical Induction Heating System



Factors to Consider

- The material the work piece is made from determines the heating rate and power required; steel and iron heat easily as they have higher resistivity whereas copper and aluminum require more power to heat due to their lower resistivity.
- Some steels are magnetic so both the metal's resistivity and hysteretic properties are used when heated with induction. Above the Curie temperature (500 to 600 °C/1000 to 1150 °F) the steel loses the magnetic properties but eddy current heating provides the heating method for higher temperatures.
- The power required is determined by:
  - The type of material
  - The size of the work piece
  - The required temperature increase
  - The time to temperature

The operating frequency of the induction heating system is a factor to consider based on the size of the work piece to be heated. Smaller work pieces require a higher frequency (>50 kHz) for efficient heating, and larger work pieces benefit from a lower frequency (>10 kHz) and more penetration of the heat generated.

As the temperature of the heated work piece rises, so do the heat losses from the work piece. Radiation and convection losses from the work piece become an increasingly important factor with higher temperatures. Insulation techniques are often employed at high temperatures to minimize heat losses and to reduce the power required from the induction system.

Family of Ambrell Induction Heating Power Supplies

About Ambrell

Founded in 1986, Ambrell is a global leader in the induction heating market renowned for our application and engineering expertise. Exceptional product quality and outstanding service and support are at the core of our commitment to provide the best customer experience in the industry.

We are headquartered in the United States with operations in the United Kingdom, France and the Netherlands. All products are engineered and made at our manufacturing facility in the United States, which is ISO 9001:2008-certified. Over the last three decades we have expanded our global reach through an extensive distribution network and today we have more than 12,000 systems installed in over 50 countries.

ISO 9001:2008 CERTIFIED

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