Energy Efficiency and Conservation Authority
Te Tari Tiaki Pūngao

Technical Information Document

# Direct Process Heating
## Ohmic Direct Resistance Heating

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New Zealand Government

# Introduction

Direct resistance heating methods heat by using a product's own electrical resistance. This is achieved by passing an electrical current through the product causing it to generate heat. Because the product's electrical resistance is measured in Ohms, this form of heating is sometimes called 'Ohmic' heating.

For direct resistance heaters to work, the product being heated must be electrically conductive. Examples include molten glass, metal, salt or tap water, liquid food products, and concrete, which must be in contact with the electrodes.

Insulators or materials with very high electrical resistance (for example glass), will either not heat or will require pre-heating using other methods before they become conductive.

EECA commissioned Strata Energy Consulting and Efficient Energy International to produce this document which is one of a series on electrical heating.

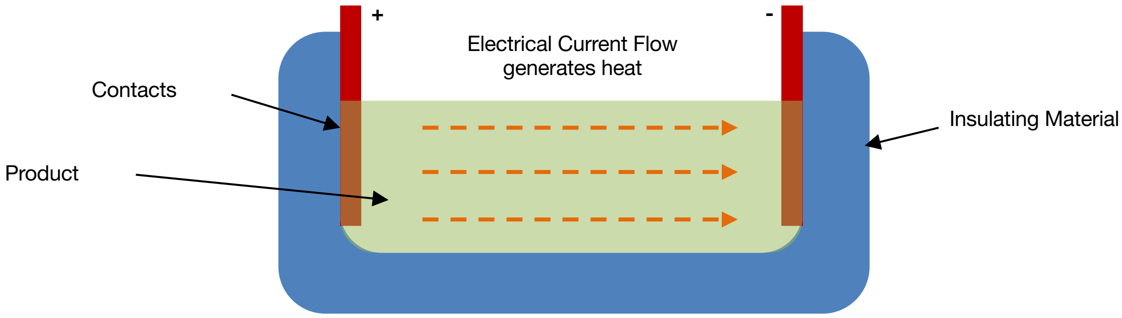
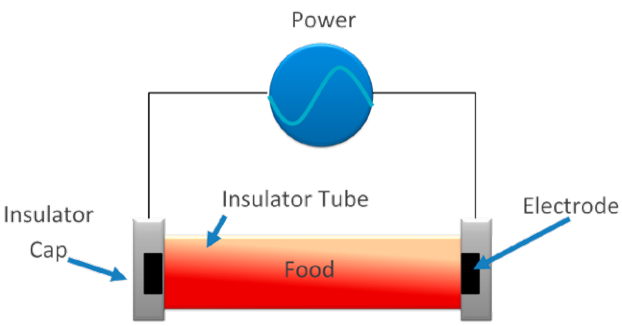
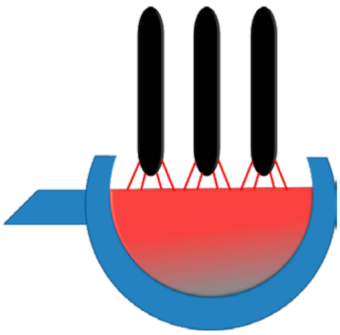



**Figure 1. Direct resistance heating of liquids**




Direct resistance heating in an Ohmic Oven used to sterilise or cook food in a process line.

**Figure 2. Food sterilisation**
Source: http://foodpathshala.ning.com



Direct resistance heating in an electric arc furnace used to melt and hold metal

**Figure 3. Electric arc furnace**
Source: http://www.directindustry.com

# Technical Features

## Heat Transfer

Conduction heating works with metals and non-metals, but the non-metals must still conduct electricity. The product is placed in contact with two electrodes which are either submerged in the product if it is a liquid, or if it is a solid, placed in contact with the product at opposite ends.

So long as the placement of the electrodes in or around the product is even, heating will occur uniformly throughout the product. If the placement is uneven, then heating occurs primarily around the path of the current through the object and radiates outwards; this is shown by the red areas of the products in the figure below.

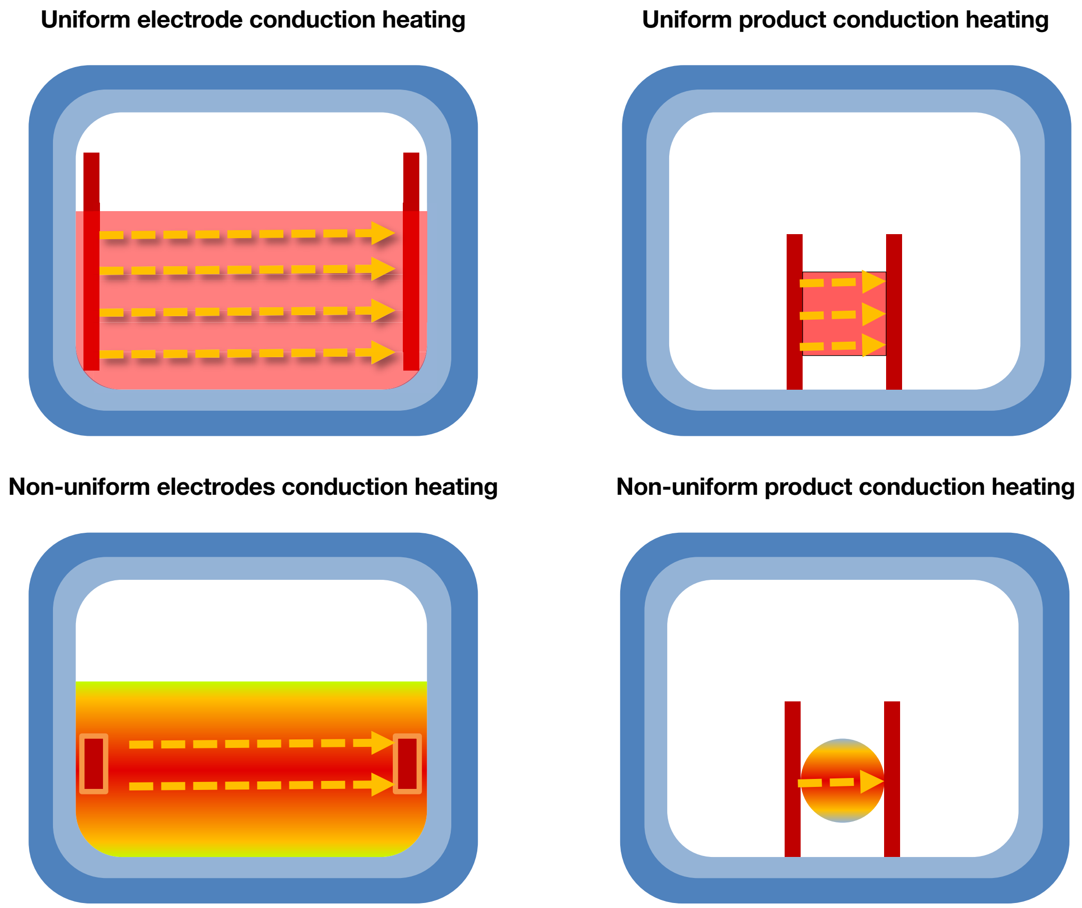



**Figure 4 Uniformity of heat transfer in different direct heating methods**

Heating can also become uneven if the product density, texture or resistivity is uneven. If the product is in contact with air or the container walls, it may heat more slowly. This effect is due to a combination of heat losses and lower resistivity that can occur in some materials if resistance varies with temperature.

Insulation can be applied to reduce cooling effects and alternating current can be used to concentrate the heating effect to the peripheral areas of the product.

# Benefits

### Efficient and low energy consumption

Exhaust ports, emissions and heat transfer mediums are generally not required which means up to 95% of the energy is transferred into heating the product instead of being lost as waste heat. This efficiency reduces the input energy required to heat the product and can offset higher costs of electricity compared to fossil fuels.

### Emissions Free

Electric heating applications do not give off the dangerous emissions that fossil fuel burners do, making them safer and more environmentally friendly.

### Low cost and small size

This heating method uses the product's own internal resistance to generate heat instead of an external resistor or boiler. This potentially reduces the costs by replacing large, inefficient systems while also reducing the floor space required for the heating unit.

### Controllable

Accurate temperature control makes electric conduction heaters ideal for applications where specific temperatures are required. Automation can dispense with difficult temperature monitoring tasks increasing performance and reliability.

### Good support heater

When used in tandem with fossil fuel heating or other types of electric resistance heating, ohmic resistance heating can boost production rates and product quality as a lower cost alternative to upsizing existing equipment.

# Challenges

### Energy costs

The running costs of electric resistance heating are mostly the electrical energy costs, which can be higher than the equivalent unit cost of other fuels.

### Effectiveness at low temperatures

The effectiveness of this heating method depends largely on the resistance of the product being heated and many materials have higher resistances at ambient temperatures. As such, this may make conductive resistance heating unsuitable for smaller or low temperature applications.

### Scarcity

Practical, out-of-the-box conduction and ohmic heaters are difficult to source and these solutions often need to be custom-designed to fit individual purposes.

### Reduced effectiveness in large applications

Uniform, rapid heating occurs best when the product to be heated is of a uniform density and spread evenly between, around, and in contact with the electrodes. The larger a product is, the higher the chance of irregularities. Higher voltage applications might be required if the product's resistance is high, and the current has to travel far in order to heat it.

### Possible network capacity requirements

When replacing high energy fossil fuel heating with any kind of electrical heating applications, additional network capacity may be necessary and may require specialised equipment.

### Design requirements

Benefits that can be obtained through use of direct resistance heating often require situation specific design to be optimised.

# Application Note

## Applications Overview

In many applications low voltages (5 to 48 V) are used since the electrical resistance of products heated in this way is generally low. However, high voltage applications up to 30,000 volts do exist.

For safety, and to maintain product quality, heating systems are often also accompanied by automatic control and regulation systems, load handling mechanisms, and a voltage step-down transformer. These additional systems can offer more automation in the product heating cycle, reacting quickly to changes in temperature, variations in resistance or the volume and flow rate of heated materials.

By using electricity to directly heat the product, the efficiency of conduction heaters can be as high as 80 to 95% and, in high power density applications, heating times can be very short which can significantly increase production rates where heating times are causing production bottlenecks.

The compact nature of conduction heating allows for heater designs that are much smaller and more space-efficient than other heaters. Conduction heaters can also be built into the pipes or chambers of existing product transport infrastructure as Ohmic heaters for example, and used for processes like sterilisation and pasteurisation (pictured below).

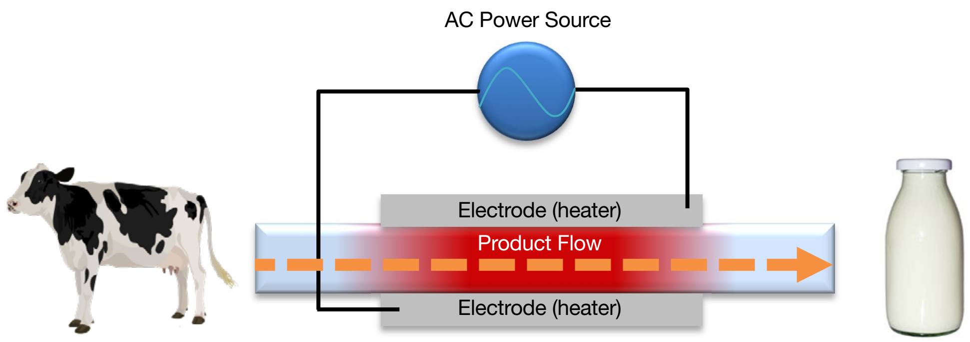



**Figure 5. Controllable product flow rate through an ohmic heater. As used in pasteurisation and sterilisation.**

## Metallurgical, mechanical and electrical industries

Conduction-based technology has many metallurgical applications, from being used to either increase or maintain the temperature of a melted, liquid metal to keep it in liquid form, to being used in heat treatment, hardening, annealing or electroplating.

For heating there are three main types of electric metal melting furnace - coreless induction, channel induction and direct arc.

Direct arc furnaces have a typical power consumption of 520 to 650 kWh per tonne for any given application and are often built for production capacities ranging from 55 kg up to 50 tonnes and capacities from 100 kVA to 35 MVA.

**Figure 6. Full and partial metal heating**

## Glass Melting

At room temperature, glass is a good electrical insulator that is used to isolate electric current. At high temperatures, particularly when melted, the resistivity of glass decreases rapidly (from roughly 1015 Ω at 25°C to between 3 Ω and 50 Ω at over 1,000°C) transforming it into an electrical conductor that can be heated using direct resistance heating.

Glass furnaces currently in use have two broad installation purposes. Either they provide the overall melting, or supplemental booster heating.

Similar fossil fuel furnaces provide production rates of approximately 600 tons per day. The choice between electric and fossil fuel systems generally comes down to the input cost of the associated energy sources.

Once a less energy intensive method has melted the glass, booster furnaces apply the Ohmic heating technique. This heats the molten glass faster as electric conduction within the glass improves the heat circulation and product homogeneity while decreasing waste heat.

Boosting using a small 400 kW to 500 kW system to supplement fossil fuel heating can increase production capacity by 40% while contributing up to 40% of the production energy requirements. The use of a booster conduction will require investigation and design to meet the unique needs of each application.

## Pasteurisation and Sterilisation

Ohmic resistance heating can be effective at sterilising and pasteurising food products. Passing the products uniformly through pipes or units that contain evenly spread electrodes heats the product from the inside using its own resistance.

Applying Ohmic heating in pasteurisation and sterilisation allows for near uniform heating of solid and liquid particulates that can occur in either a flow through or batch processing system. This can result in reductions in processing time and potential energy efficiency of around 95%. Combining heating with heat exchangers can further improve efficiencies.

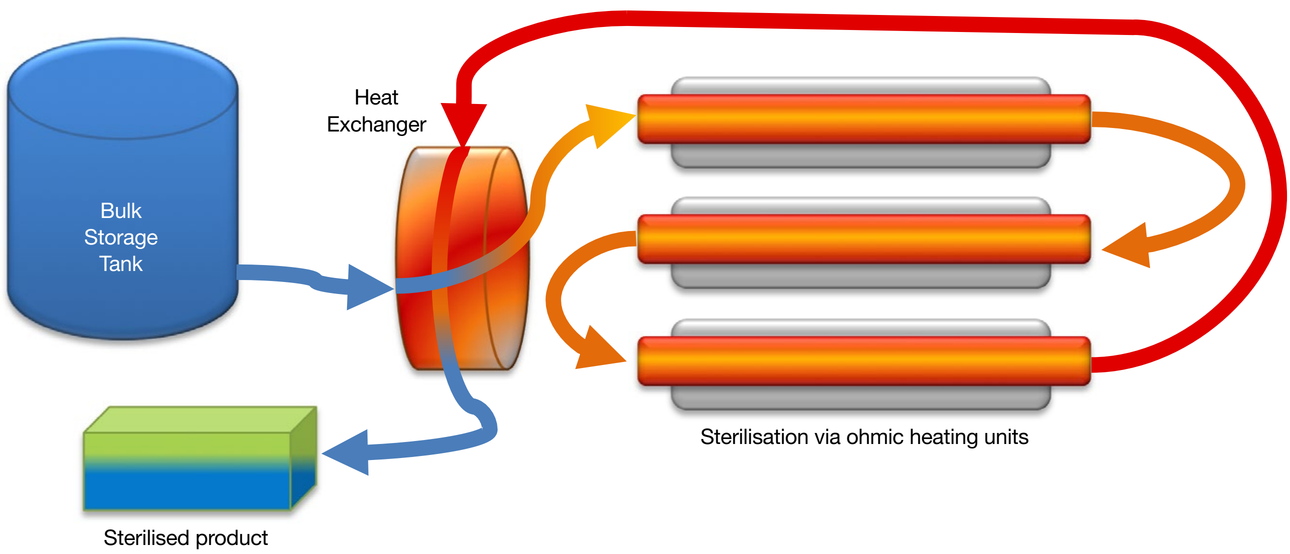



**Figure 7. Pasteurisation and sterilisation using Ohmic heating with a heat exchanger**

## Plasma cutting

A plasma torch is a welding or cutting device that uses a constricted stream of ionised gas heated to 20,000 to 40,000°C to produce very fast, high quality cuts on positively charged metals.

The material on the cutting board needs to be a conductor of electricity in order for the negatively charged plasma stream to cut it. However, non-conducting materials, such as some ferrous metals and plastics can be mixed with iron to enhance their conductivity.

A compressed stream of an ionisable gas, such as oxygen, nitrogen, argon or even just air is forced past a negatively charged electrode and through a small nozzle. Electric arcs from the electrode cause the gas to become ionised and accelerate towards the positively charged sheet of metal. During this process, the ions become heated up to 40,000°C.

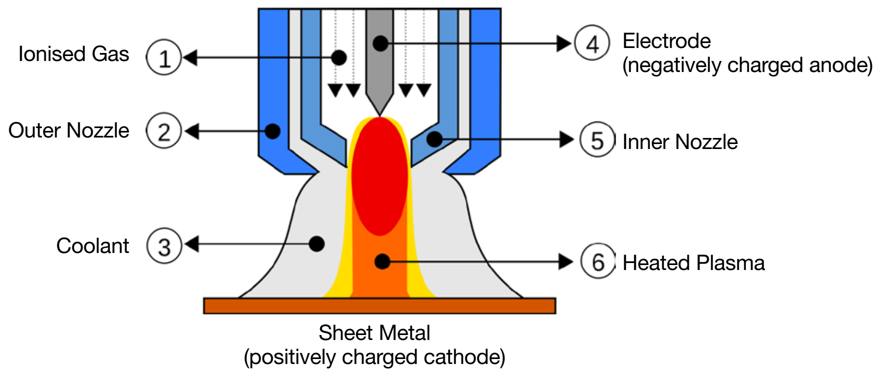



**Figure 8. Basic plasma cutter operation**
Source: Wikimedia.org – https://www.boc.co.nz/shop/en/nz/plasma-cutting--equipment

Plasma cutters have fallen rapidly in price, hand held units are available off the shelf in New Zealand starting at $1,400 and typically have an energy consumption rate of between 2.0 and 5.0 kWh.

## Heat treatment and forming of ferrous metals

Heat treating is used to alter the physical or chemical properties of a material, most commonly used in metallurgy and glass. It involves heating or chilling to extreme temperatures to harden or soften the material.

Direct heating up to 1,250°C is uniform across the section of the material between the contact points with the electrodes, provided the material is of even density. Heating rates are limited only by the equipment rating and any special requirements the product has. Heating times are typically quite short, such as two minutes to reach 1,250°C for a 125 mm square section.

In addition to the uniform heating, direct resistance applications also offer a more compact structure that is safer: no part of the system needs to be hotter than the product and the contact between electrodes and the product removes the risk of electrical discharge.

A large industrial example of a melting furnace is the Borel furnace. With a power drain of up to 12,500 kVA, a minimum temperature rise of 4.5°C per minute and a maximum capacity of up to 60 tons, it has an energy use of up to 1.0 to 2.0 kWh per kg of processed steel.

# Sources of additional information on direct resistance process heating systems

**Circulation Heaters**
https://www.herbst.eu/en/products/circulation-heaters.html

**Circulation Heat**
https://www.herbst.eu/fileadmin/user_upload/pdf/Elektro-Stroemungserhitzer_Kompakt_Water_HLP46_Infoblatt.pdf

**Heat treatment modules**
https://www.alfalaval.com/products/process-solutions/thermal-solutions/Heat-treatment-modules/Ohmic/

**Ohmic heating in the food industry**
https://www.newfoodmagazine.com/article/610/ohmic-heating-in-the-food-industry/

**Technology, applications and modelling of ohmic heating**
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4190208/

**Heat treatment systems – Steritherm**
https://www.alfalaval.com/products/process-solutions/thermal-solutions/Heat-treatment-modules/steritherm/

**Heat treatment systems – Ohmic**
https://www.alfalaval.com/products/process-solutions/thermal-solutions/Heat-treatment-modules/Ohmic/

**China Electric**
http://www.cn-electric.com/

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