

# Gas-Induction Inline Oven

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**Abstract.** The innovative inline gas-induction oven is an efficient and powerful heating solution, which combines the advantages of a modern gas heater in combination with an induction furnace mounted together in one axis. Results compared to stand alone equipment are: lower space requirements, increased heating rate, utilise existing space areas, further use of existing downstream equipment, excellent process control, and other valuable effects. The article will describe the working principle, motivation for developing the inline concept, technical features, and operation data, and show clearly the economic potential for using this technology in existing lines, in retrofitting projects, or in lines with limited space.

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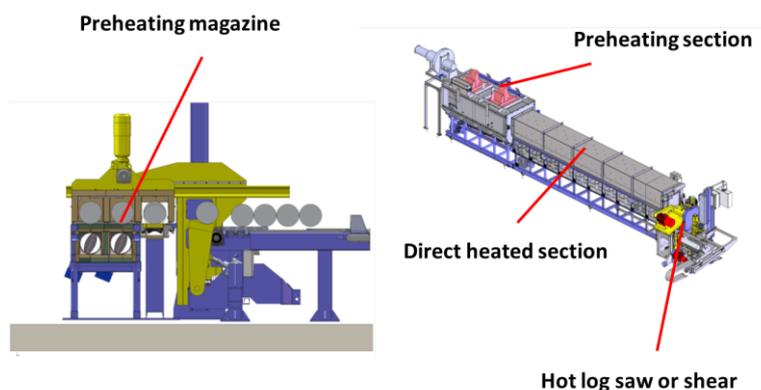
## Introduction

The technical process requirements that are placed in temperature control when heating aluminium billets has risen continually over the last few years. Equally, the constant rise in width of materials in use and lot sizes has ultimately dictated a considerably larger range of flexibility in the heating ovens.

Accordingly, induction billet heating ovens in combination with modern gas heaters have become increasingly significant over the last few years and representing the state of the art technology in modern extrusion lines. The typically application is they so called stand alone-solution with a gas heater and a parallel installed induction oven.

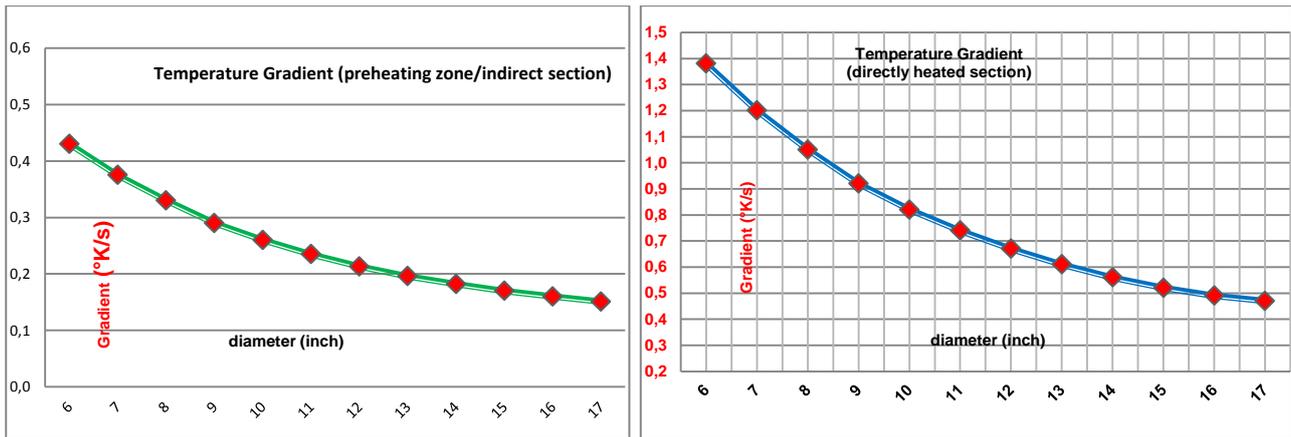
## Working principle and characteristics of gas heating

Accordingly, many applications have over the last few years used a combination of gas heating with downstream log shear or saw and multiple-zone induction heater. The preheating of the logs takes place in a standard multiple-zone gas fired oven, while the defined fine tuning of the temperature takes place in a multiple-zone induction billet heater.



**Figure 1.** Typical modern gas heater

Figure 1 is showing a typical modern construction of a gas fired oven used in the in the Aluminium Extrusion Process for heating up logs and billets. The oven is divided into two preheating sections (preheating magazine and high convection preheating zone, using hot gases from the directly heated section) and the directly heated section itself, which is divided into several separately controlled heating zones. Gas heaters are usually equipped with a gas fired nose heating device.



**Figure 2 :** Temp. gradients pre-heating section **Figure 3 :** Temp. gradients direct-heating section

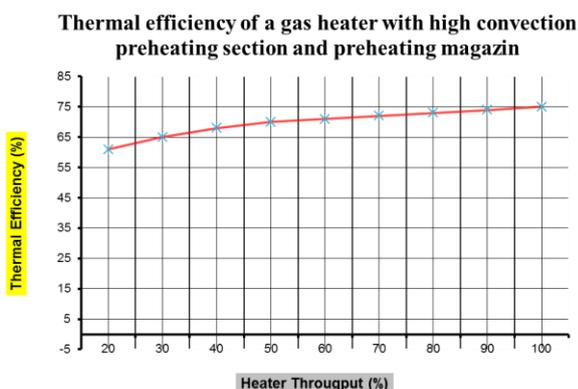
The heat transfer in the directly heated section (see figure 2 and 3) is approx. 3 times higher than the heat transfer in the preheating section.

Hot gases circulated in the preheating section and blown on the log or billet surface through nozzles by radial fans are on a temperature level of approx. 300 to 600°C. The thermal efficiency can be increased with this procedure up to level of approx. 63%.

Using additional equipment like a preheating log magazine, total thermal efficiency can be raised up to 75%. In this case exhaust gases coming out of the preheating section and normally blown out of the building through the chimney are used to preheat the logs in the storage area.

Following list summarises the gas heating process:

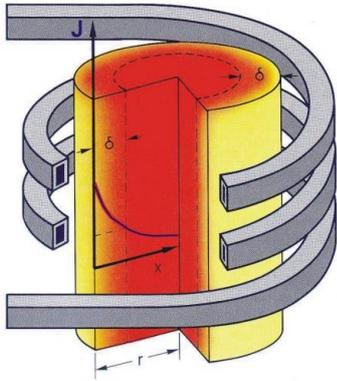
- Heating (preheating) by hot gases blown through flat nozzles with high speed (45 m/s) straight onto log/billet surface,
- Heating of AL-logs and billets by gas flames (temperature up to 1.200 °C) directly touching the material,
- Thermal efficiency of gas heater with preheating magazine up to 75%,
- Temperature gradients max. 1,4°K/s,
- Continuous transportation of logs/billets through heater (preferable via driven and reversible rollers),
- Hot saw/shear placed directly behind the heater or cold saw (inline/offline) in front of the heater.



**Figure 4 :** Thermal efficiency of a modern gas heater

## Working principle and characteristics of induction heating

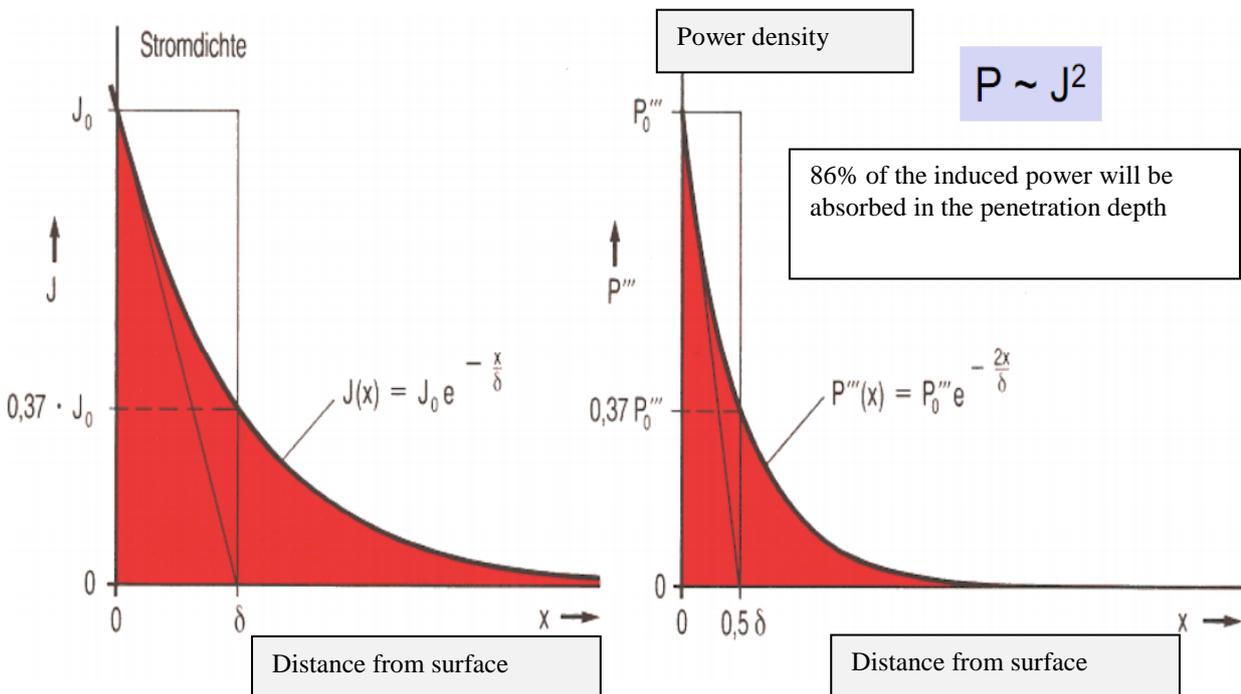
The following pictures showing the physical working principles of induction heating



**Figure 5 :** Inductive heating principle <sup>1</sup>



**Figure 6:** Heat distribution in an inductive billet heater



**Figure 7:** Illustration of the principle of induction heating <sup>2</sup>

<sup>1</sup> : Jörg Fasholz, Gerhard Orth

Induktive Erwärmung: physikalische Grundlagen und technische Anwendungen  
RWE Energie-Aktiengesellschaft, 1991

<sup>2</sup> Jörg Fasholz, Gerhard Orth

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Following list summarises the induction heating process:

- Heating will be created directly in the work piece without any contact of the heating source,
- Partial heating, work piece will be only heated through the induced current in the affected area,
- High power densities >>> high  $dT/dt = 6-10 \text{ K / sec.}$  for aluminium applications,
- High flexibility due to temperature set values,
- Extremely high reliability through controlled energy consumption Temperature = function (Power, Heating time),
- High process efficiency, Aluminium billets approx. 60 – 68 % depending on dimensions and alloy composition.

### **Motivation for Inlineoven - concept**

Combination of relatively slow gas with fast induction heater is state of the art for billet heating in the Aluminium Extrusion Industry since more than 10 years. Based on this concept approx. 85-90% of the energy is transferred into the billet with cheap gas energy (2 to 3 times less in price than electrical energy in most parts of the World), while induction heater is used for creating a reproducible temperature profile (up to 130°C) in a very short time (less than one press cycle). Main disadvantage of the “stand alone concept” is the relatively big place requirement.

Summary of requirements for development of an inlineoven:

- Limited space conditions in many extrusion plants,
- Significant improvements for process control and heating throughput without major modification of the existing layout,
- Further usage of, e.g. existing hot shear/saw,
- Simple cross transfer to press,
- Smart combination of two heating concepts controlled by one PLC,
- Reduction of the energy costs,
- Induction module creates only an axial gradient,
- Reduction of investment cost,
- Reduction of scrap (only one billet in the system before press).

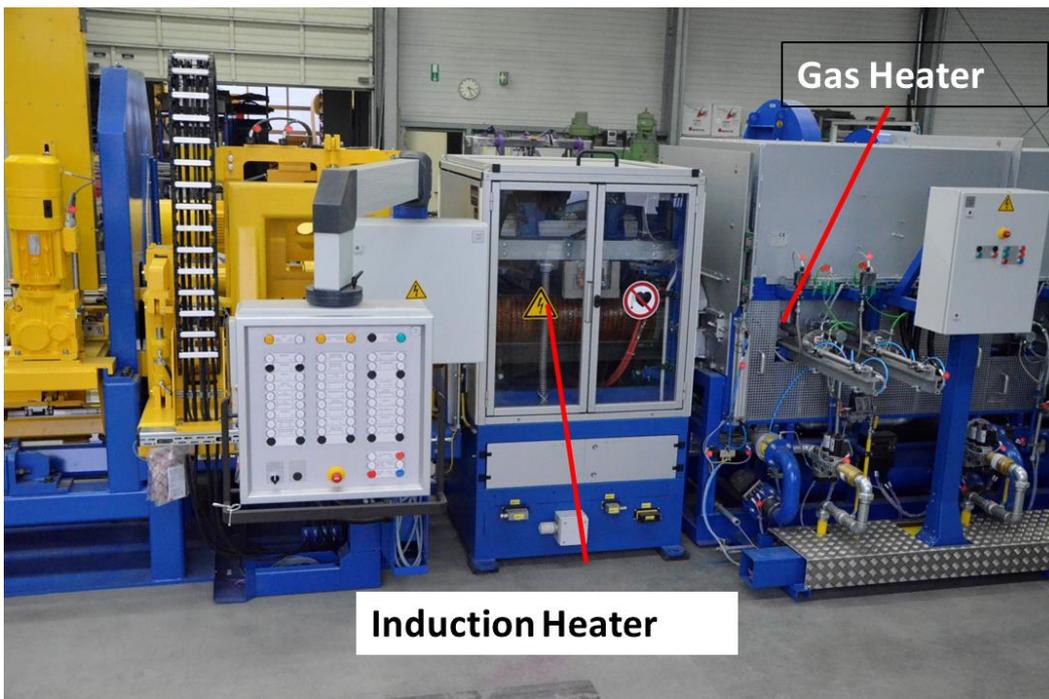
The following illustrations displayed in figures 7 and 8 are showing the general arrangement and principle of the inline concept. Especially for upgrading projects (replacement of billet heating system) the inline solution seems to be a very well alternative as usually available space is limited and “stand alone” version cannot be implemented in existing layout.

Furthermore new inline concept gives the option to use available hot shear/saw as well as cross transfer without any modification, if required.

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**Figure 8:** View of an Inlineoven with hot log saw

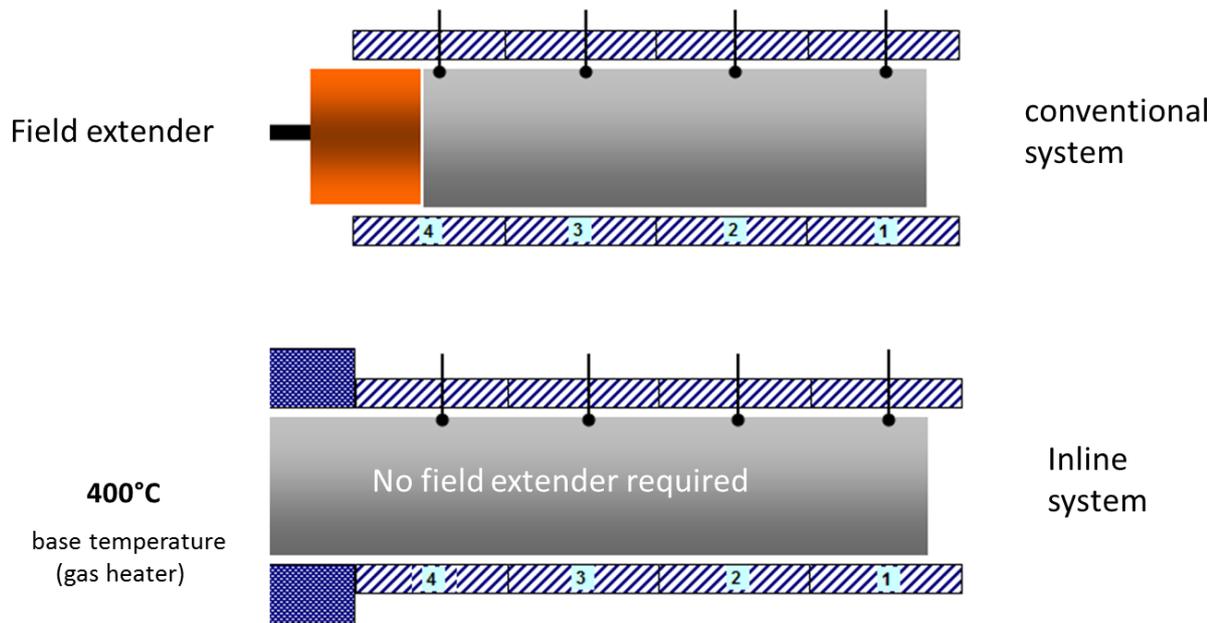


**Figure 9:** Detail view of an Inlineoven at exit section

### **Design features of inlineoven concept**

Main difference of the two options is the lapse of the field extender with the inline version. In the inline arrangement the log to be heated is taking over this function.

Field extender needs to be water-cooled during operation, which consumes additional electrical energy.

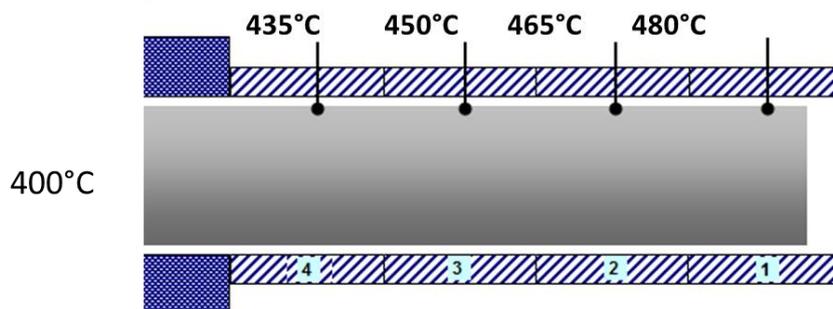


**Figure 10:** Technological structure of the induction oven section of both versions

This modified concept for the induction module based on the well-known "TEM-Pro-Heater®" principle.<sup>3</sup> This system implemented in the Inlineoven concept provides following advantages:

- Infinity variable, section-group-independent performance-control (better temperature profile, individual possibilities of adaptation to the process),
- Even net-load, independently from the number of the active coil-groups,
- No mechanical switch-appliances,
- High efficiency, because avoidance of the symmetry unit with its losses,
- Application of transistors and inverters reduces switch-appliance-losses,
- PID control loop reduces the overshooting at the big performance-densities,
- Variable ramp-characteristics up to the arrive to the nominal value reduces the overshooting at small temperature,
- hysteresis values as well as bad thermal conductivity characteristics,
- Network-power factor > 0,96, load-independent.

### Experience in production



**Figure 11:** Typical arrangement of an Inlineoven

<sup>3</sup> : S. Beer, ET 2004 Orlando FL, Article EE126 : Improvement of the process control for single billet heaters

The requested taper to be created is appr. 80°K. Four steps of the taper are realized by the induction part of the system, while the base temperature of 400°C is created in the gas oven.

Detailed measurements during long-term operation of a 10'' gas-induction Inlineoven with temperature levels shown in picture 10 resulted in following energy consumption:

Gas heater 20 to 400°C	179,5 kWh/tAl
Induction heater 400 to 480°C	<u>24,5 kWh/tAl</u>
Total	<u>204 kWh/tAl</u>

Following calculation is showing an energy consumption and energy cost comparison of the two versions.

Calculation parameters:

Throughput per year: 18.000 t  
Electrical energy: 0,11 EUR/kWh  
Gas energy: 0,05 EUR/kWh

**Stand-alone version**

Cost for electrical energy:

Energy consumption 400 – 480 °C with 45°C Taper: 26 kWh/t  
18.000 t x 26 kWh/t x 0,11 EUR/kWh = EUR 51.480,--

Cost for gas energy:

Energy consumption 20 – 400 °C: 200 kWh/t  
18.000 t x 200 kWh/t x 0,05 EUR/kWh = EUR 180.000,--

Total cost for stand-alone heating process:

EUR 180.000,-- + EUR 51.480,-- = EUR 231.480,--



**Figure 12:** Stand-alone version

## Inline version

### Cost for electrical energy:

Energy consumption 400 – 480 °C with 45°C Taper: 24 kWh/t

18.000 t x 24 kWh/t x 0,11 EUR/kWh = EUR 47.520,--

### Cost for gas energy:

Energy consumption 20 – 400 °C: 180 kWh/t

18.000 t x 180 kWh/t x 0,05 EUR/kWh = EUR 162.000,--

### Total cost for inline heating process:

EUR 162.000,-- + EUR 47.520,-- = EUR 209.520,--



**Figure 13:** Inline version

Cost saving potential for inline heating compared to stand alone heating process:

EUR 231.480,-- - EUR 209.520,-- = **EUR 21.960,--**  
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Main reasons for reduced energy consumption with inlineoven are:

- No field extender required,
- Less transportation time of billet to press loader,
- Higher efficiency of gas heater.

## **Conclusion:**

- Fully integrated system with highest output rates along with very short total oven length (space for log storage),
- Compact design >>> Improvement of the material flow,
- Usage of existing handling system, hot shear or saw,
- Short integration time due to compact design,
- Less energy consumption for typical temperatures and axial gradients of complete 204 kWh/t (long term study Constellium Crailsheim, Germany),
- Standardized solutions for all dimensions,
- Considerably lower investment costs,
- Better access for operating and maintenance personnel,
- Gas oven operates under optimized working conditions,
- Step less power control with IGBT converters with 3 or 4 independent outputs,
- Close temperature tolerances,
- Operation with only one billet in the system >>> easy for any fast process changes.

## **References:**

[1,2] Jörg Fasholz, Gerhard Orth  
Induktive Erwärmung: physikalische Grundlagen und technische Anwendungen  
RWE Energie-Aktiengesellschaft, 1991

[3] S. Beer, ET 2004 Orlando FL, Article EE126: Improvement of the process control for single billet heaters