



### Certification of Accuracy

I, Michael L. Magee, hereby attest that I am a translator fluent in English and German, that I have translated the attached document from German to English, and that to the best of my knowledge, ability and belief this translation is a true, accurate and complete translation of the original German document that was provided to me.

The document is designated as:

Winkel document, entitled "Quetten zum Pressharten von Stahlblech im Automobilbau"



Signature of Translator

August 15, 2024

Date

## Quenches for press hardening steel plate in the automotive industry

*Hardening parts in quenches without forming has been a familiar technique in the saw manufacturing industry and some areas of mechanical engineering for decades. However, in the press hardening process, parts are heated in a furnace, formed by a press while still hot, and then hardened in the chilled press, thus increasing strength. This subject is discussed in detail in the following article.*



### Introduction

There is ever-increasing pressure in the automotive industry to reduce fuel consumption for economic reasons. At the same time, environmental constraints on exhaust gas emissions are increasing. Both objectives are achievable by weight reduction. These efforts conflict with more stringent requirements for automotive safety and comfort, which result in increased weight.

The vehicle body, as the heaviest single element of the vehicle, has a high influencing potential in this regard. Conventional vehicle body frames are made of easily deformed iron plate, which by its nature is intended to be "soft" so that it precisely and permanently takes on complicated shapes during pressing without springing back, thus ensuring a good fit (**Figure 1**). This represents an excellent opportunity for improvement: when iron is alloyed with carbon, boron, and other alloying elements, it can be hardened, thus increasing its strength several times over. Use may be made of this effect on the one hand to reduce the plate thickness, and on the other hand to improve the crash resistance of the body frame, thereby achieving the desired goal of decreasing weight and increasing safety.

For a mid-range sedan having a body weight of 300 kg, 30 kg are saved as the result of improved crash test values. This is quite remarkable, and makes economic sense due to the fact that steel has a reasonable cost, has proven its worth in processing, and with an appropriate coating also has adequate durability.



**Figure 1:**  
Press hardening line for  
B-pillars of a mass-  
produced automobile

## Practical application of forming processes

A basic distinction is made between two processes: the preforming process and the plating process.

In many cases, the preforming process requires workpiece carriers that receive the parts, often with complicated geometries, and provide the parts, precisely positioned at the transfer location, to the press feeder. After removal from the workpiece the material carriers, made of high-alloy special casting, are immediately transported back to the charge location at the furnace intake so that heat loss remains low.

In the plating process, the plates are punched from the unhardened strip steel in a customary manner in punching lines. The plates are then placed by a robot on a furnace hearth with a narrow roller division and conveyed into the furnace. Here they are heated to the austenization temperature, at which the alloy partners jointly go into solution. The plates are quickly removed from the furnace via a transfer system and delivered to a hydraulic press. In the next step, initially the forming process takes place, together with a synchronous hardening process in a cooled tool. After the press has remained closed for several seconds, it is opened, and the workpiece that has thus become fixed may be removed from the press with a precise fit. The workpiece is trimmed, and if necessary is soft-annealed at the fastening points to improve weldability.

## Protective gas operation

The supplying of protective gas has been increasingly taken over by technical gas vendors, who also provide the equipment and control devices necessary for this purpose. To keep the surface of the plate part free from scale, the furnace is flooded with protective gas. There is still a brief transfer from the furnace hearth to the press, in which the workpiece comes into contact with atmospheric oxygen. This results in minimal scaling.

Recent developments have reduced scaling through improved conduction of the protective gas in the furnace, the press spring, and the press tool. The adherence of paint thus corresponds to the demands on the automobile manufacturing process. Subsequent abrasive blasting to remove the scale layer is therefore generally not necessary, thus eliminating the incurred costs and handling effort.

The Al-Si plating of workpieces commonly used in recent times, such as with the Usibor 1500 (**Figure 2**) from Arcelor, requires no protective gas atmosphere to avoid scaling, but has the drawback of approximately 50% higher material costs and limited cold forming capability.

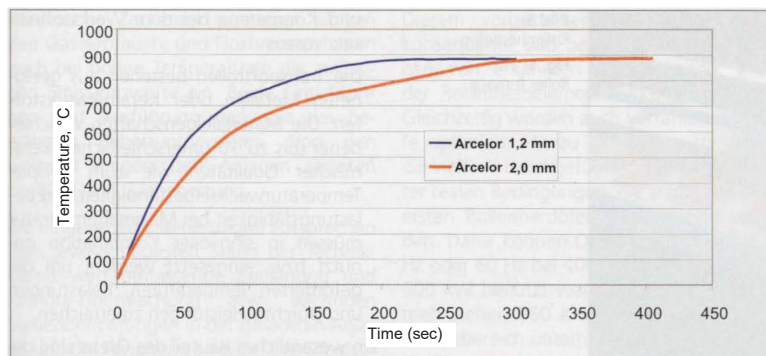


**Figure 2:** Usibor 1500 AlSi (furnace temperature 900°C)

The other heating process is carried out in the same way as for the uncoated material. Here as well, good corrosion protection is necessary, similarly as for bare steel materials, since there is no cathodic protection. Other developments aim at coatings with a cathodic corrosion protection effect.

## Types of furnace designs

The conveyor belt furnace, walking beam furnace, and roller hearth furnace are used for the tasks discussed above. However, the last-named furnace has a particular advantage: the heat transfer to the material is improved significantly by the rotating furnace rollers.

The technical study by Forschungsgemeinschaft Industrieofenbau (FOGI) [Research Association of Industrial Furnace Manufacturers] points out the relationships in **Figures 3** and **4**. It is apparent that for an emissivity of 0.3 of the bare plate metal, the heat input from below is higher than that from the upper region.

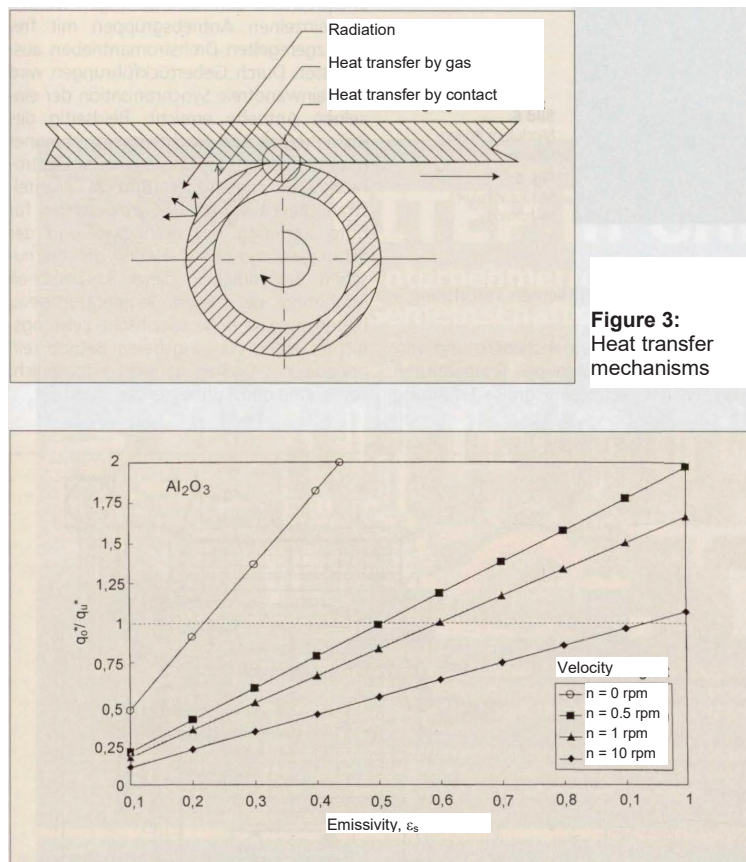


**Figure 4:** Comparison of top and bottom heat flow with  $\text{Al}_2\text{O}_3$  rollers

For roller divisions of 25 mm (**Figure 5**) to 125 mm, in many cases a suitable geometry and material carrier size may not be present. The material lies directly on the roller hearth and is thus

moved through the facility. With these advantages, the roller hearth furnace is particularly suited for the heat treatment of flat workpieces, especially since for the same installation length, twice the throughput capacity is achieved compared to other designs.

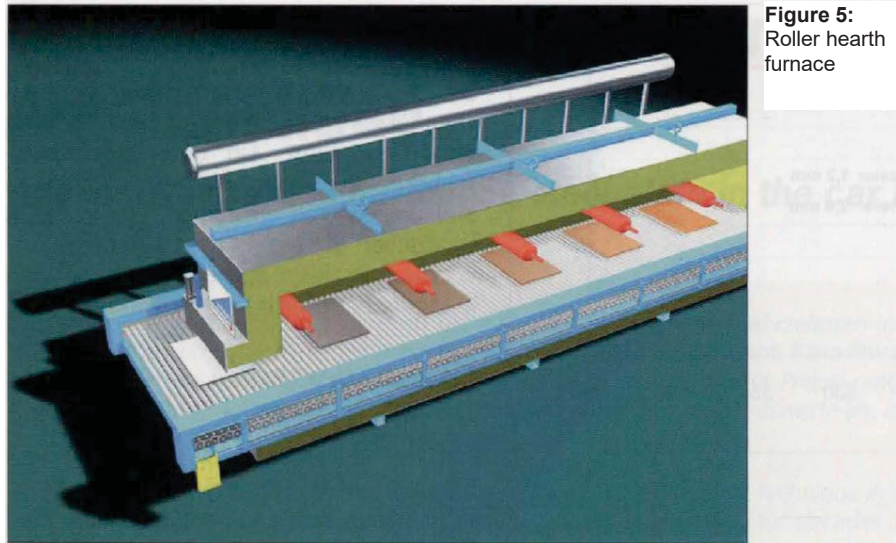


**Figure 5:**  
Roller hearth  
furnace

### Important design features and system properties

The roller hearth may be equipped with any number of individual drives. This allows cycled as well as continuous material flow in a line, and also rapid relaying of the material to be heated from one treatment station to another.

A specific hearth load of approximately  $150 \text{ kg/m}^2$  has already been achieved at a treatment temperature of  $1250^\circ\text{C}$ . The use of continuous belt furnaces depends on the conveyor belt. The economically justifiable treatment temperature has an upper limit of approximately  $1150^\circ\text{C}$ .

The highest specific heating power is reached, resulting in smaller usable or structural dimensions than for belt conveyor furnaces and walking beam furnaces.

Material carriers and thus also dead load heating are often omitted. Likewise, no costs are incurred for the wear on conveyor belts.

The above-stated properties and advantages of the roller hearth furnace system concept provide

very favorable process sequences and new options for many needs. This is illustrated and described in detail in the following discussion.

## Furnace description

The cycled inflow and outflow of the material to be heated (with or without a heat transfer medium) takes place via an entry lock and an exit lock, respectively. These are respectively made up of an elongated entry neck or exit neck that is equipped with two slides. The generally known material flow over a lock into the furnace chamber results in the following advantages here:

- The usable space is completely closed off from the surroundings, even during charging; scooping workpieces are flushed in a targeted manner with neutral gas in the locks.
- The consumption of protective gas or reaction gas is greatly reduced. In comparison to the continuous inflow and outflow, the protective gas consumption is only 20 to 40%, depending on the size and proportions of the clearance of the door opening.
- The continuous, operationally reliable, and low-wear operation at temperatures up to 1250°C presupposes extensive experience and expertise in the use of materials.
- The transport rollers are made of suitable metals or ceramic materials. The material properties of various (up to 10 different) ceramic qualities, for example thermal shock resistance and load capacity at maximum temperature, must be utilized and employed in a meaningful combination in order to achieve the required temperatures, loads, and throughput capacities.

The well-established Schwartz roller hearth elements (**Figure 6**) are an important component of the furnace. These roller hearth elements, developed on the basis of many years of experience, are made up of the roller itself and the roller receptacles and bearing blocks on each side, which seal off the protective gas.

This bearing provides a rotary drive of each individual roller that is free of bending moments, with optimal load distribution and an extremely long service life. At the same time, rollers are easily replaceable during maintenance or in the event of breakage.



**Figure 6:**  
Modular roller  
technology

Depending on the requirements, the individual drive groups are equipped with frequency-controlled three-phase drives. Problem-free synchronization of the individual drives is achieved by sensor feedback. High-temperature burners with an integrated recuperator or electric heating element are situated on both sides of the roller hearth (**Figure 7**). Jacketed radiant tubes made of silicon carbide ensure good separation of the combustion gases and the protective gas atmosphere. In addition to the thermal resistance of these ceramic radiant tubes at this high temperature level, they provide a high specific power density, maintenance-free operation (periodic turning is not necessary), and a virtually unlimited service life.

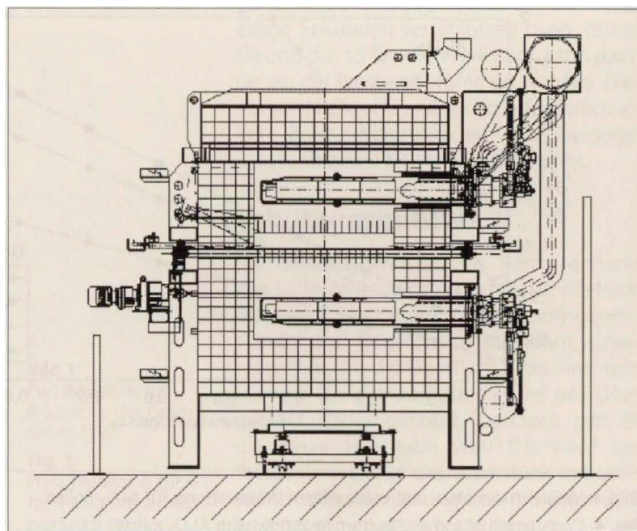


**Figure 7:**  
Cross section of  
a gas-fired roller  
hearth furnace

Ceramic serrated recuperators reduce gas consumption, and FLOX burners comply with allowable emission rates, even at high temperatures. Both devices are design features of the well-established heating system. Approximately 80% of the facilities used worldwide operate with gas firing.

The controls used correspond to the latest state of the art. Comprehensive operation and remote monitoring of all important control devices in the entire facility and surroundings are thus achieved. The furnace insulation is made up of ceramic fibers with a suitable classification temperature. High compaction of the vertically oriented fiber mats compensates for heat-related shrinkage of the fiber material. The fiber mats are mechanically fastened to the outer housing on the "cold side." Since operations take place without anchors or other retaining elements that are subject to temperature load, the insulation has a long-lasting service life.

The furnace concept presented here has been preceded by systematic, persistent development of identified options, for example the roller hearth elements. At the same time, process sequences have also been optimized. These certainly include the numerous works tests conducted under actual conditions, which have been carried out since the very first roller hearth furnace. Local frequencies of 50 Hz or 60 Hz at 400 V or 500 V, up to 600 kW, may be used. 850 kW are available for the gas operation. The service department maintains a 24/7 hotline.

All of these procedures and measures have contributed to the most installations of such facilities worldwide.

## **Future Outlook**

Further testing to improve the protective gas control and quality is proceeding with promise, and scaling during the transfer process is being reduced. This also includes a short cycle time, which occasionally is 7 seconds. Heat loss during transport back to the furnace intake is being further reduced using new coatings for the heavy material carriers. Suitability for mass production should be achieved in the foreseeable future. The latest control concepts allow unmatched operability and remote monitoring of all relevant control components of the entire facility and surroundings. Feeder optimization by removal directly from the hot furnace chamber is shortening the running time of the component. As a result, the furnace/component temperature can be lowered, the

surface quality improved, and the process energy requirements significantly reduced.

In view of the potential described above, dynamic growth of the market is expected. For this reason, developments in technology and proximity to the market and customers, as well as the readiness to support expansion, are of major importance for further developments in this field.