RECENT COST REDUCTION DEVELOPMENTS IN THE HEATING OF STEEL

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Key Words

Combustion
Regenerative Burners
Reheat Furnace
Fuel Savings
Scale
Substoichiometric

INTRODUCTION

In the past several years, regenerative firing of reheat furnaces has made great advancements in China. Scale free heating, once thought of as merely a theoretical possibility, is now being seriously considered. This paper will discuss both of these concepts as they apply to the heating of steel.

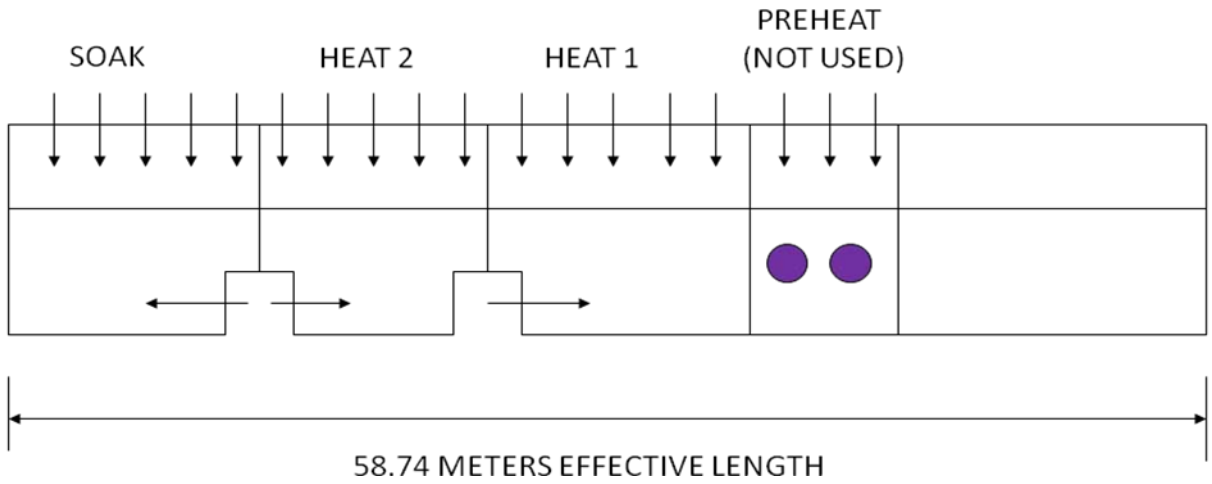
REGENERATIVE FURNACES

Background

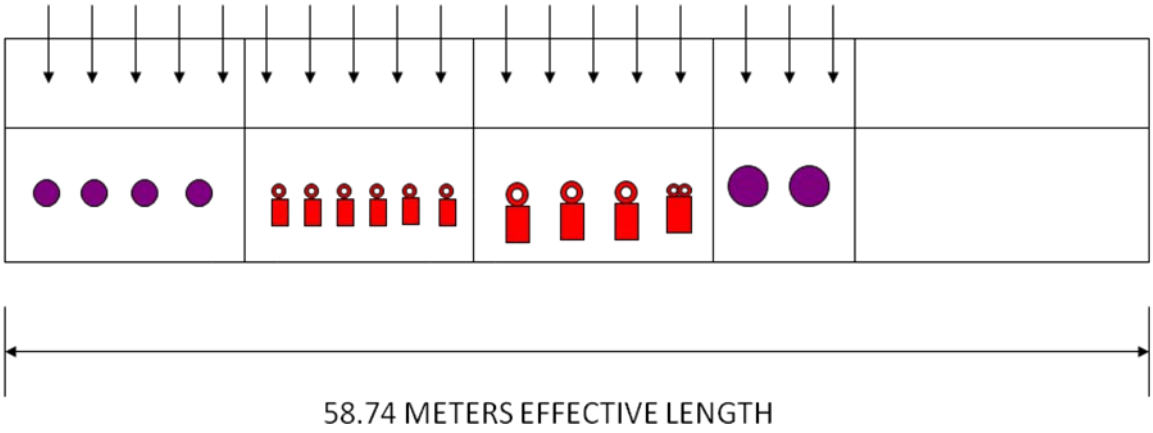
In late 2003 the Bao Steel Company embarked on an energy savings program for its 2050 hot strip mill in Baoshan, China. In February of 2004, eleven pairs of regenerative burners were purchased to replace the burners in the bottom heat 1 and bottom heat 2 zones of the No. 2 walking beam furnace. The project was so successful that six furnaces were built between 2005 and 2008 with mostly regenerative firing. Three of these six furnaces plus the original Bao 2050 No.2 furnace are presented here.

Bao Steel No 1 HSM Furnace No 2

The No.2 Furnace of the Bao Steel No.1 Hot Strip Mill is an eight zone walking beam furnace rated at 350 Metric Tons per Hour. The furnace is roof fired in the top zones and longitudinally fired with doghouses in all bottom zones but the bottom preheat zone where it is side fired. The fuel is mixed gas with a heating value of 2050-2400 Kcal/NM^3. The following is a schematic diagram of this furnace prior to the regenerative retrofit.



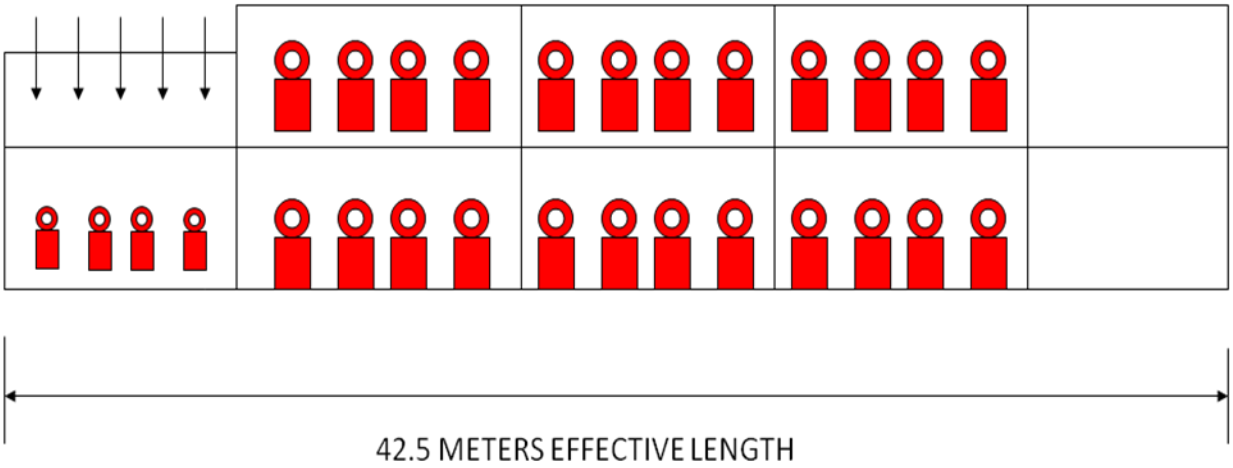
The doghouses were removed and regenerative burners were installed in the bottom heat 1 and heat 2 zones. The following is a schematic diagram of the furnace after it was modified.



The modified furnace yielded a 9.6-18.8% fuel savings. The guarantee value was 8.2% at full production. Other relevant performance values were 47 ppm NOx at 11% O_2, 1120°C air preheat at the burner head and 140°C exhaust gas temperature. All of these values exceeded the performance criteria.

Bao Steel No 3 HSM

This furnace was built in 2005-2006 with the performance test in 2007. The furnace is an eight zone walking beam furnace with side fired regenerative burners on all zones except the top soak zone which is roof fired with conventional flat flame burners. The fuel is mixed gas with a heating value of 2150-2400 Kcal/NM^3. The capacity is 250 Metric Tons per Hour. The following is a schematic diagram of the furnace.

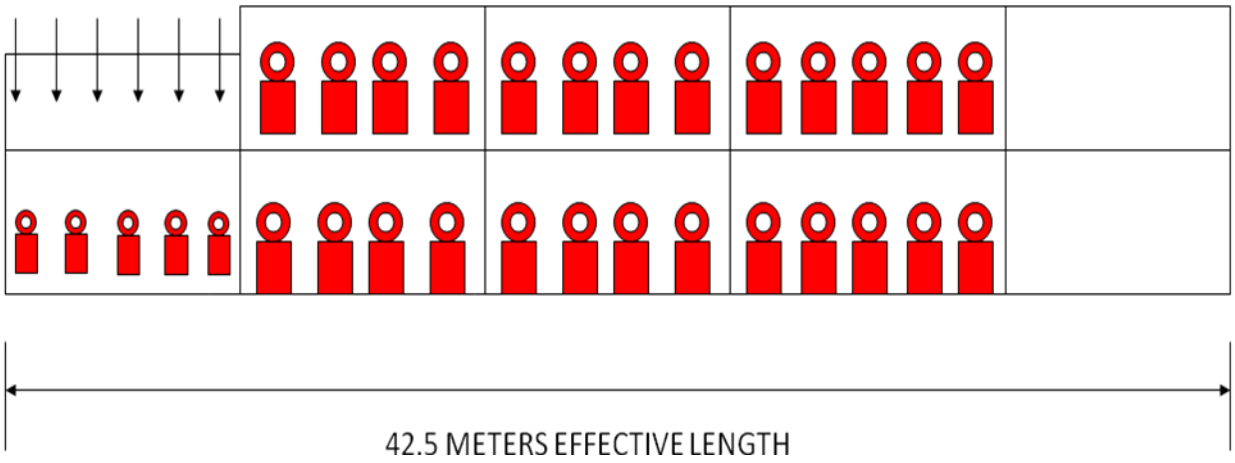


The furnace yielded a fuel rate of 255 Kcal/Kg at the design tonnage. Other relevant performance criteria were 30-55 ppm NOx at 12% O_2, 0.42-0.51% scale loss, 18°C head to tail differential and 100°C hot exhaust minus air preheat differential. All of these values exceeded the performance criteria.

The following is a picture of the Bao Steel No 3 furnace

Meishan Steel HSM

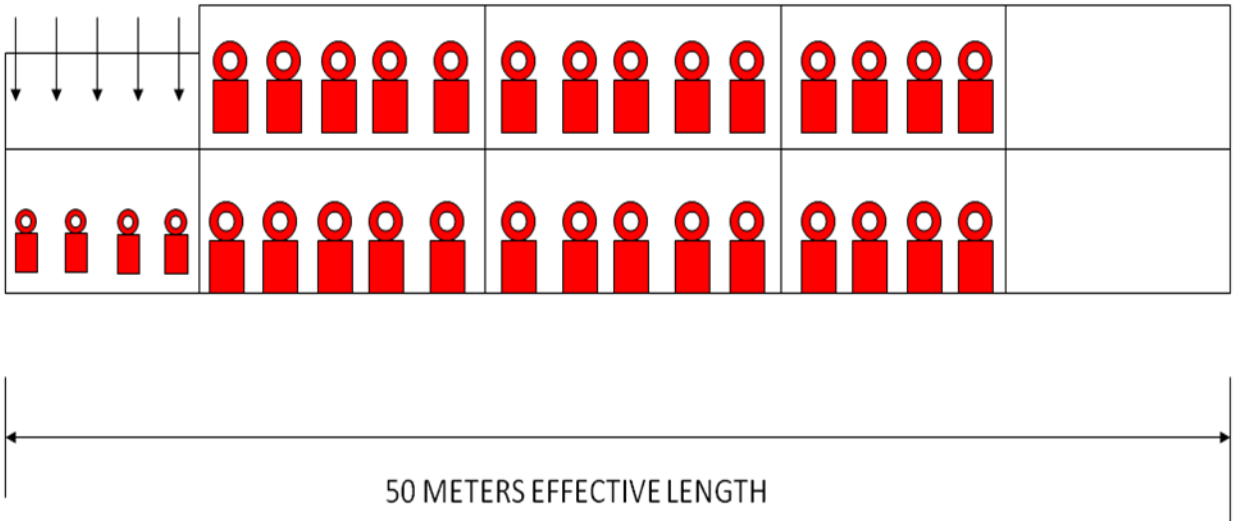
This furnace was built in 2005-2006 with the performance test in 2007. The furnace is an eight zone walking beam furnace with side fired regenerative burners on all zones except the top soak zone which is roof fired with conventional flat flame burners. The fuel is mixed gas with a heating value of 2200 Kcal/NM^3. The capacity is 250 Metric Tons per Hour. The following is a schematic diagram of the furnace.



The furnace yielded a fuel rate of 262 Kcal/Kg at the design tonnage. Other relevant performance criteria were 30-55 ppm NOx at 12% O_2, 0.33-0.54% scale loss, and 18°C head to tail differential. All of these values exceeded the performance criteria.

Bao Steel No. 1 HSM Furnace No. 1

This furnace was built in 2006-2007 with the performance test in 2008. The furnace is an eight zone walking beam furnace with side fired regenerative burners on all zones except the top soak zone which is roof fired with conventional flat flame burners. The fuel is mixed gas with a heating value of 2150-2400 Kcal/NM^3. The capacity is 350 Metric Tons per Hour. The following is a schematic diagram of the furnace.



The furnace yielded a fuel rate of 243 Kcal/Kg at the design tonnage. Other relevant performance criteria were 30-55 ppm NOx at 12% O_2, 0.33-0.54% scale loss, and 18°C head to tail differential. All of these values exceeded the performance criteria.

Dual Regenerative Burner

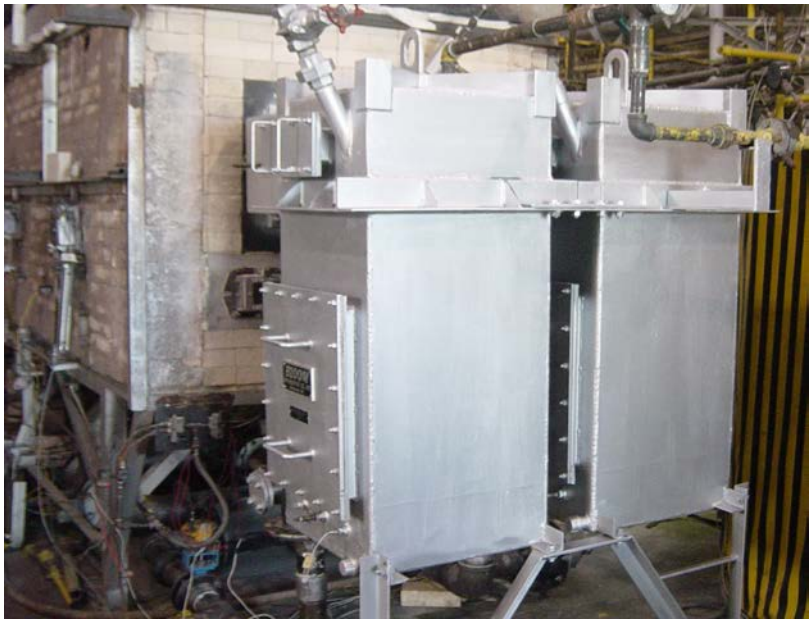
The dual regenerative burner was developed for Chinese customers that burn blast furnace gas exclusively. This burner consists of a media case for fuel as well as air. The blast furnace gas and air will be preheated to temperatures

approaching 1100°C thus allowing blast furnace gas to be used for heating at reheating and forging temperatures. If applied properly, firing blast furnace gas with these burners can do anything that natural gas can.

The burners are custom designed using CFD Modeling as well as laboratory testing. The burners are designed using air staged combustion with air passages through a refractory baffle to control mixing, heat release and emissions.

The dual regenerative burner can be used in a reheat furnace designed for blast furnace gas exclusively as well as a secondary fuel in selected zones in an existing furnace firing natural gas.

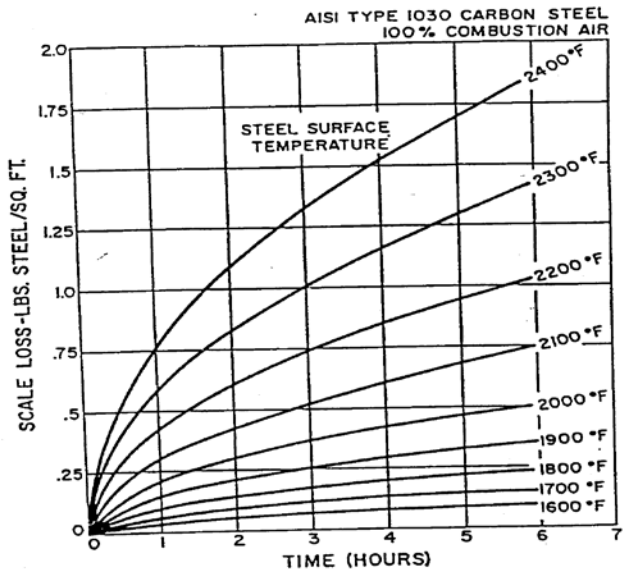
The following are pictures of the dual regenerative burners



Recent performance testing in China has indicated that using regenerative burners are a viable alternative to conventional hot air combustion, however there are design improvements to the furnace that could be made to improve performance.

SCALE FREE HEATING

The reheating of steel to forming temperatures without creating scale is achieved by the careful balance of the surface temperature of the steel and the atmosphere surrounding the steel. Very little scale is formed at steel temperatures below about 1400°F. Above these temperatures scale will be formed. The amount of scale formed becomes a function of the actual steel temperature, the time the steel is at temperature, and the type of atmosphere surrounding the steel.



Steel Scale Formation

Scale can be prevented, if the atmosphere for the steel is non-oxidizing. A non-oxidizing atmosphere can be produced by firing the furnace under reducing (excess fuel) conditions. In some cases the atmosphere required will be produced by firing at an air/fuel ratio of as low as 5 to 1 instead of the usual 10-11 to 1.

Implementation of this type of scale-free atmosphere also requires use of highly preheated air or a corresponding equivalent given below:

- Use of highly preheated air (~ 550^0 C) for combustion of natural gas.
  - This requires a high temperature recuperator, hot air piping and hot air burners.
  - This option is attractive for new installations
- Use of oxygen or oxygen enriched air for combustion.
  - This requires constant source of oxygen with the resultant costs.
  - This option is more attractive for retrofit applications
- Use of combination for existing installations with lower degree (say ~ 350^0 C to 450^0 C) of preheat and use of oxygen to boost oxygen in combustion air

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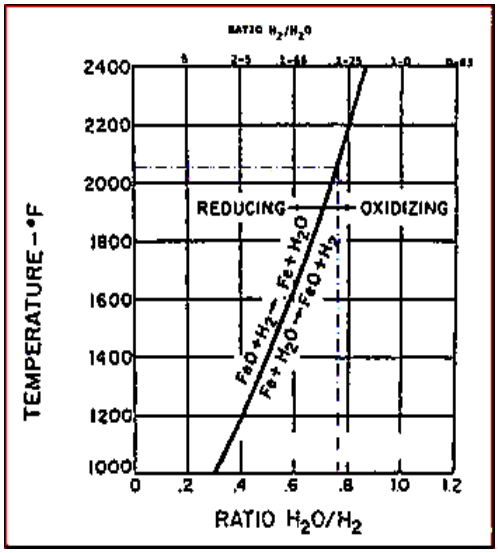
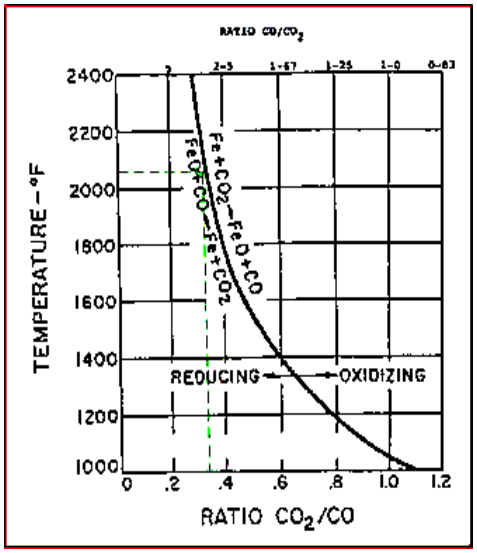
Firing under reducing conditions produces CO and H_2 in the furnace atmosphere in equal amounts. This is in addition to CO_2 and H_2O produced under stoichiometric combustion. The CO/CO_2 and H_2/H_2O ratios required for a scale-free furnace atmosphere are a function of the surface temperature of the steel. These ratios, in turn define the actual air/fuel ratio required at a given point in the heating. The CO/CO_2 and H_2/H_2O ratios for a conventional heating furnace, where combustion is at or slightly above stoichiometric conditions, are zero since no CO or H_2 exists in the furnace atmosphere. The resulting atmosphere is oxidizing or scaling to steel. The graphs below show the neutral atmosphere requires to inhibit the formation of scale.





The benefits for the successful implementation of the scale-free process would be numerous:

- Reduction of scale formation during heating
- Significant production and maintenance cost advantages
- Improvement in product surface quality
- Reduction of scale disposal costs
- Environmental considerations
- Possible reduction in energy use
- Improvement in yield

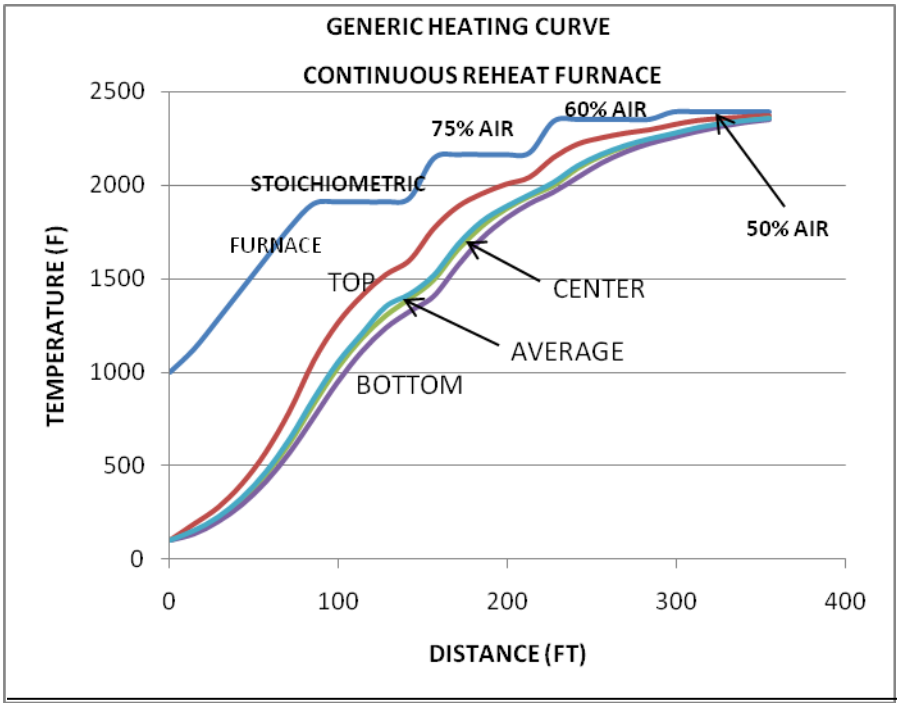
The scale-free process has actually been known since the 1940's and a few scale-free furnace systems have actually been built. Recently the US Department of Energy funded a project to develop a reliable and economic reheat furnace scale-free process using the latest generation of combustion and control technology. Participants in this project include:

- USDOE – EERE ITP
- E3M, Inc
- Steel Dynamics Inc
- Air Products and Chemicals
- Bloom Engineering, Inc
- Forging Industry Association
- Steel Manufacturers Association

A key element of the project is to develop a burner which will provide quality heating under both the rich fuel combustion conditions required for scale-free heating and stoichiometric conditions. This was successfully

accomplished by adapting the latest ultra low NOx burners to operate in the scale free mode. The result is that the same burner is able to operate under scale free or under stoichiometric conditions as the process dictates.

Continuous Reheat Furnaces
The chemistry of the scale-free lends itself quite well to a normal continuous reheat furnace, as shown below. As the surface of the steel becomes cooler, the fuel/air ratio must become leaner to achieve a scale-free atmosphere. The normal flow of POC is from the soak zone to the charge zones. This allows the un-combusted fuel created in the hotter soak zone atmosphere to be consumed in the cooler zones at the charge end of the furnace. In the ideal situation, only air would be added in the charge zones to balance the combustion.



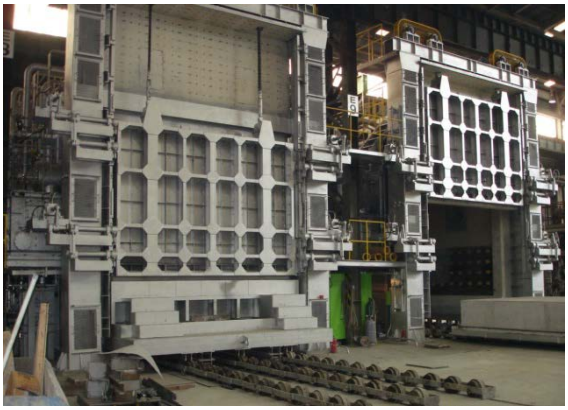
Temperature/Combustion Profile of a Continuous Furnace

Given the successful developments accomplished in pilot and laboratory projects, the next step is implementation of a production system. There are currently three projects under consideration.

Rotary Steel Reheat Furnace:
This project is the retrofit of furnace is located in a seamless tube mill. The furnace is currently natural gas fired, for cold air operation and rated at 100,000 TPY. The opportunities are both fuel savings as well as improvement of yield and surface quality. The improvement in surface quality is also expected to result in a better die life. An additional requirement is that the activities be, at least environmentally neutral.

Continuous Pusher Billet Furnace:
This is to be a new recuperated, natural gas fired furnace for a rod mil. The furnace would be rated at approx 70 TPH with very stringent environmental (NOx) requirements. The design must integrate the very best ultra low NOx technology with the best recuperative technology.

Batch Forging Furnace:



Batch Forging Furnaces

This project would be the retrofit of a furnace supporting a ring rolling operation processing 20 in dia x 2.1 Tn billets. The process is contained in s single chamber. Therefore care must be taken in the handling of the products of combustion while the furnace is firing rich. The concept is for the furnace to fire in the scale-free mode only during the soaking part of the heating cycle (when the surface of the billet is at its highest temperature). Also, the furnace in the scale-free mode will alternately operate in conjunction with a partner furnace operating at stiochiometric. In this manner the heat content contained in the rich products of combustion can be utilized in the furnace firing stiochiometricaly. The objective of the retrofit would be an improvement in fuel economy and in yield. This project must be environmentally neutral as well.

Given the current activity and its advantages, scale-free heating is waiting to be “re-discovered”. We look forward to its increasing implementation in modern cost-effective steel reheating furnaces.