# Update on Regenerative Reheat Furnace Conversions in North America

Regenerative combustion has been used in the steel industry since the introduction of the open hearth furnace by Sir Charles William Siemens in 1868. Adaption of the regenerative process to continuous steel reheat furnaces was made possible by the availability of PC and PLC-based controls more than 100 years later in the 1980s. The use of regenerative combustion for new reheat furnaces is still rare in North America. It is, however, widespread in Asia due to the chronic high costs for fuels and limited space availability.

**Driven by increases in costs of fuel and growing production demands, the pace of regenerative reheat furnace conversions has quickened across North America. The current status of regenerative technology is reviewed, with a focus on retrofit applications in reheat furnaces.**

**Figure 1**

Regenerative reheat furnace in Asia.

A more common application in North America is the retrofit of regenerative systems to existing reheat furnaces. This paper will discuss three different regenerative retrofit applications. The differing objectives will be examined, along with the economic and operational results obtained. The future trends in regenerative combustion, as applied to reheat furnaces, will also be examined.

## New Furnace vs. Retrofit

In an existing rolling mill, there can be a combination of many objectives for an upgrade of the reheating capabilities. These objectives will come from the following factors: production increase required, process change, heating quality improvement, fuel efficiency improvement, and emissions abatement. The two alternative courses of action are either to purchase an entirely new furnace or to retrofit the existing furnace.

The cost of a new furnace will usually be greater than a retrofit. Also, since a new furnace would normally be built in a location separate from the existing furnace, there will be the challenge of integrating it into the existing equipment and processes. In favor of a new furnace, however, much of the installation work can be done while the existing furnace is in operation. Much of the installation for a furnace retrofit must be done during a furnace outage. The costs of mill downtime must thus be weighed against the costs of an entirely new furnace.

Regenerative technology can dramatically change the parameters for the new vs. retrofit question. Normally, only part of the furnace need be converted to regenerative firing to achieve the desired results. The new regenerative section will typically have its own blowers and hardware, but will operate as an integral part of the total furnace combustion system.

A detailed review of the operation of a regenerative system can be found in Reference 1 in the Bibliography. It will show that regenerative burners are operated in pairs and are cycled alternatively for firing and as flues for the furnace combustion products. This will allow the



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Figure 2

Hybrid retrofitted regenerative cold air furnace.

Figure 2

Regenerative media after one year of use.

addition of extra furnace heating capacity without taxing the existing combustion air supply or the furnace flue/stack system. The resultant (retrofitted) furnace will then function quite well as a hybrid regenerative–recuperative or cold air system.

It must be noted that there have been past objections to regenerative technology. However, with the worldwide maturity of the technology, these objections are regarded today as outmoded perceptions. A discussion of this trend can be seen in Reference 2.

For a production increase, it is a common practice to install a regenerative booster zone in the unfired charge area of an existing furnace. As such, the regenerative equipment can, in large measure, be installed while the furnace is in operation. In reheat furnace practice, a 100°F increase in combustion air preheat will result in a 3.5% increase in combustion efficiency. The regenerative combustion air preheat is normally within 300°F of process temperature. This will result in combustion efficiencies of 72% (HHV) in the regenerative zone vs. approximately 55% for recuperative systems.

Another retrofit technique is to execute a one-for-one regenerative burner replacement in one or more existing furnace zones. This will require considerable piping modifications. However, it should be noted that all of the regenerative combustion air piping will be cold or warm air rather than hot air. This type of retrofit will be illustrated in Application #2 below.

Another technique will have the retrofitted furnace zones reconfigured to accommodate the latest production parameters. This is the result of the inherent flexibility of the regenerative burners operating independently in pairs. Application #1 in this paper will illustrate this type of retrofit.

Furnace emissions will be favorably impacted by regenerative retrofits. The high regenerative efficiency coupled with latest ultralow-NOx regenerative burner technology will normally cause a reduction of the NOx emissions. A high heating efficiency will also reduce the $CO_2$ emissions per ton of steel heated.

## Application #1: Timken Gambrinis No. 4 Seamless Tube Mill Rotary Furnace —

### Conversion of Existing Burners, Reconfiguration of Furnace Zones

The No. 4 mill billet reheat furnace has been in operation since the 1950s and operates with a cold air combustion system. The mill operates according to the following parameters:

- 92,000 tons/year.
- 154 MM Btu/hour available heating.
- 4.0 MM Btu/ton.
- 4.5 dia. x 10-foot-long billets, max. 55 tons/hour.
- 2,250°F billet discharge temperature.

The objective of the conversion was fuel economy. Regenerative combustion was selected over oxyfuel combustion and recuperation.

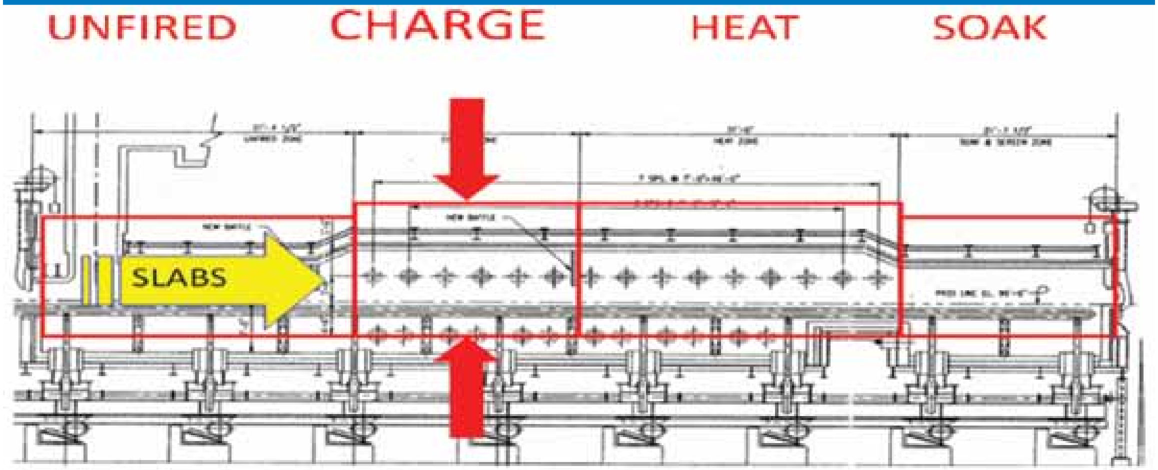
For the retrofit solution, zones 3 and 4 were converted to regenerative, with part of zone 3 extended into zone 2. The resultant furnace configuration is shown in Figure 4.

The result of the conversion is a 25% average fuel savings per ton across the operating range of the furnace.

Figure 4


The Timken Gambrinis retrofitted furnace configuration.

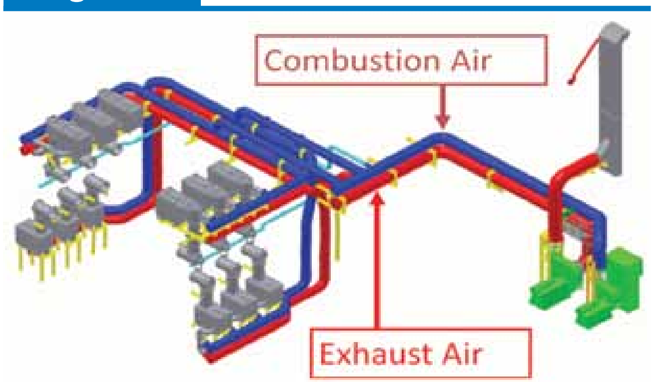
Figure 5




Evraz Inc. NA Regina furnace configuration.

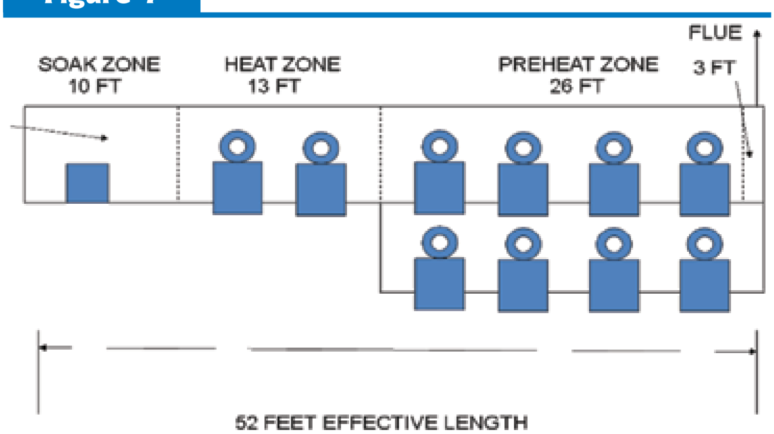
Only one triad of media (of the five supplied) has been cleaned during the first two years of operation. One of the cycling valves has required repair.

Figure 6




Regenerative piping configuration.

Figure 7




Existing furnace configuration at Nucor Marion.

The cycling component actuators have been found to require calibration twice per year.

In the future, Timken intends to install continuous monitoring of the differential pressure across the media beds. This will be used as a tool for deliberate predictions of media cleaning requirements.

## Application #2: Evraz Inc. NA Regina Hot Strip Mill Walking Beam Furnace —

### Conversion of Existing Burners in the Preheat Zone

The slab reheat furnace at Evraz Inc. NA Regina has been in operation since 1986 and is a recuperated, walking beam type. The objective of the conversion was to increase the rated furnace throughput from 195 to 225 tons/hour. Fuel economy was of secondary importance, but environmental emissions could not be increased.

The retrofit solution was to convert the top and bottom charge zones with three pairs of regenerative burners each. This is a one-for-one burner replacement and is shown in Figure 5. The unfired zone was unmodified.

There was little available space around the furnace. This necessitated considerable integrated engineering to allow the new burners, media cases and piping to fit with minimal downtime for conversion.

The retrofit result was an increase in throughput capacity to the required 225 tons/hour. The fuel consumption remained statistically unchanged from 1.39 MM Btu/ton before to 1.37 MM Btu/ton after the conversion. Furnace NOx emissions were reduced from an annual rate of 181.4 tonnes to 129.8 tonnes. This fully satisfied the environmental requirements.

In one-and-a-half years of operation, half of the media cases have been cleaned. The use of a sucker truck has greatly facilitated the cleaning process.

## Application #3: Nucor Bar Mills, Marion Plant, Rebar Mill Pusher Reheat Furnace —

### Upgrade of Existing Regenerative System, Addition of New Regenerative Soak Zone

The reheat furnace at Nucor Steel Marion has been in operation since 1988 and is of a pusher-type, fired with early regenerative technology. The effective heating length was 52 feet, with a configuration as shown in Figure 7.

The objective of the retrofit was to increase throughput from 90 to 125 tons/hour. Additionally, the NOx emissions were to be reduced and the fuel economy was to be improved. The furnace control system and overall system reliability were also to be upgraded.

The space restrictions around the heat zone and top and bottom preheat zone burners did not allow them to be replaced. The retrofit solution was to rebuild these burners in place with the latest technology. The furnace discharge was extended 20 feet. A second heat zone and a new soak zone were added, each with new regenerative burners. The resultant configuration is shown in Figure 8.

The results of the retrofit have been new production records across the spectrum of the mill operations. The NOx emissions have been reduced from 0.9 lb/MM Btu to 0.1, an 89% decrease. Fuel economy has been improved by approximately 5%. The modern regenerative technology and associated controls have improved system reliability.

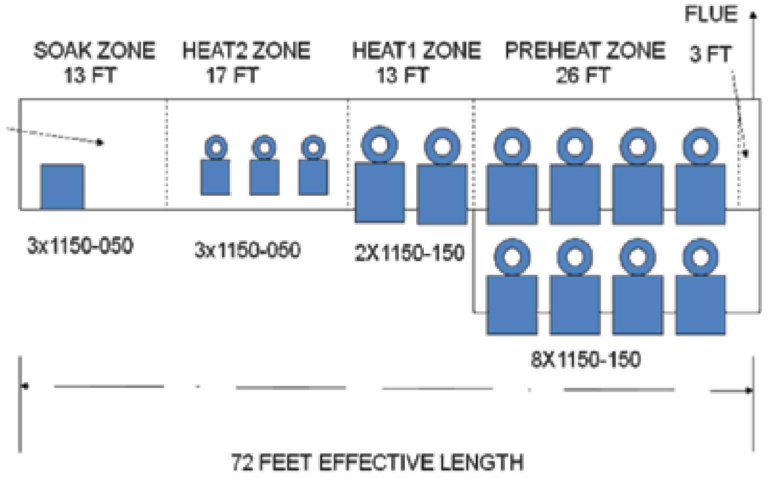
## Future Trends

An expected future trend is the expanding use of fuels alternative to natural gas in reheat furnace applications. These fuels tend to be much leaner (less Btu content) than natural gas. This is already in widespread use in Asia and is expected to see increasing use in North America. To meet this application, a dual-head regenerative burner has been developed which preheats both the fuel and air. With this technique, such lean fuels as blast furnace gas (90 Btu/std ft$^3$) and synthetic gas (160 Btu/std ft$^3$) can be burned directly in a reheat furnace without the need for enriching supplementation.

Additional fuels that have been used in regenerative systems include biogas and landfill gas. These fuels have proved to be compatible with low-NOx technology as well.

Competitive and environmental pressures are expected to dictate a continued demand for cleaner, more cost-effective steel reheating furnaces. Regenerative combustion will continue to be at the leading edge of reheat furnace technology.

**Figure 8**




Nucor retrofitted furnace configuration.

**Figure 9**

Dual-head regenerative burner.

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*This paper was presented at AISTech 2009 — The Iron & Steel Technology Conference and Exposition, St. Louis, Mo., and published in the Conference Proceedings.*

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