Application of Greenhouse Gas Reduction Technologies in Steel Rolling Mills

Jens Hebestreit, Pittsburgh District Manager
Bloom Engineering Company
5460 Horning Road, Pittsburgh, PA 15236
info@bloomeng.com

David G. Schalles, Vice President – Technical Services
Bloom Engineering Company
5460 Horning Road, Pittsburgh, PA 15236
info@bloomeng.com

ABSTRACT

The use of landfill gas as fuel for reheat furnaces is an excellent example of an alternative fuel source. The collection of landfill methane eliminates a major source of greenhouse emissions, while its use as an alternative fuel reduces the consumption of fossil fuels. Burners with reduced NO_x emissions are currently so technically sophisticated that they can be installed and used without difficulty not only in new plants, but also in existing ones. Lower CO_2 emissions can be achieved with the use of regenerative burner technology. Comparison to oxy-fuel firing will be addressed. The technology available to the metals industries for this purpose is described in this article. Recent examples of each technology will be discussed. Routes and initial steps towards adherence to future requirements are delineated.

INTRODUCTION

Not only do landfill sites consume vast space, but the decaying waste is not completely gone. Because landfill is biodegradable to about 90%, it will start decomposing and generating gases, air, water vapor, and trace compounds, about 1% oxygen and 24% nitrogen. However, most importantly, it will generate the greenhouse gases, carbon dioxide (about 30%) and methane (about 45%).

Methane is a critical component of LFG for two reasons, the first being that it hurts the environment in that it is said to be 20 times more potent than carbon dioxide in causing global warming. The second reason is that methane is highly combustible, making it not only dangerous, but also on the positive side, a powerful fuel source for industrial applications. Historically, this fuel potential had not been tapped for industrial processes. However, within recent years, more and more industries have seen the tremendous fuel capacity stored at solid waste landfills.

Notwithstanding the typically disturbing odor at landfill sites, there is also a safety hazard because of methane’s combustibility at certain levels. Removal of the unwanted landfill gas is often done by simply burning off the gases with flare stacks. Not only does this result in a waste of the energy resource, but burning off can produce another problem - the generation of environmentally hazardous nitrogen-oxides.

Bloom Engineering Company is a combustion-oriented company serving basic industry with particularly strong roots in steel and aluminum. Bloom specializes in problem solving and custom engineering solutions for industrial combustion systems which provide high thermal efficiency and low emissions. Bloom Engineering has designed burners which currently utilize LFG as a fuel source while reducing nitrogen-oxide emissions.

Gerdau Courtice Steel Inc. Application

Gerdau Courtice Steel Inc. (GCSI) and the Regional Municipality of Waterloo, Ontario have entered a joint venture to utilize an expected fifteen to twenty year supply of landfill gas. This unique arrangement is advantageous because the landfill is located “next door” to GCSI. A collection and distribution plant was completed and operates on the landfill site. The region had previously flared the LFG prior to this project. This venture has proven to be a unique solution with LFG as an alternative fuel, substituting natural gas on an industrial steel reheat furnace. The furnace is an 85 TPH pusher billet reheat furnace with a preheat zone, heat zone and soak zone split into three parts.

For this project, Bloom supplied the LFG/NG blending station, additional burners to already existing Bloom burners for the reheat furnace, gas/air components, and a level 2 mathematical furnace model.

The main mechanical components of a landfill gas system are: well field, headers, valve chambers; moisture removal traps, centrifuge; field safety shut-off valve; blower suction valve; blower; blower discharge valve; heat exchanger; recirculation valve and piping; pipeline to GCSI; moisture trap in pipeline; and blending rack.

Picture 1 shows a well chamber. The LFG is collected from many of those wells and pumped into a landfill gas collection site.

Picture 1 – Well chamber

Picture 2 – Landfill gas collection site, incoming gas pipe

<u>Blending Rack</u>

The blending rack was supplied by Bloom and contained combustion and control equipment. It required implementation of landfill and/or natural gas firing on the existing 85 TPH reheat furnace. Table I shows the fuel assumptions. Both fuels are assumed to be dry and clean.

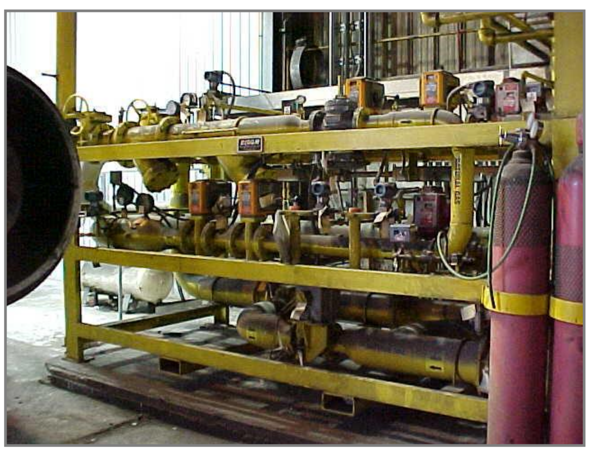
Table I – Fuel Assumptions

	Natural gas	Landfill gas
Design Flow Rate	130,000 scfh	72,000 scfh
Supply Pressure	30 psig	7 psig
Specific Gravity	0.6	0.955
Higher Heating Value	1000 Btu/scf	405 Btu/scf
Air-to-Fuel Ratio	10 scf/scf	3.43 scf/scf
Methane Content	96%	40%
Theoretical Flame Temperature	3360°F	3100°F

Blending the LFG together with the natural gas is important because the amount of flow is not sufficient to provide fuel for the whole reheat furnace with a designed peak fuel usage of 132 MM BTU per hour. The LFG gas supply is actually about 72,000 scfh = 29 MM BTU/hr. The plus is that 100% of the landfill gas supply can be used, however the missing fuel has to be added and needs to be mixed in addition to the LFG.

The blending station shown in Picture 3 was designed in accordance with the applicable CAN/CGA design codes and safety regulations.

Since the process involves both natural gas and landfill gas, two approval authorities were contacted to approve the installation: T.S.S.A. (Technical Standards and Safety Authority) for natural gas, and I.A.S. (International Approval Services) for landfill/digester gas.



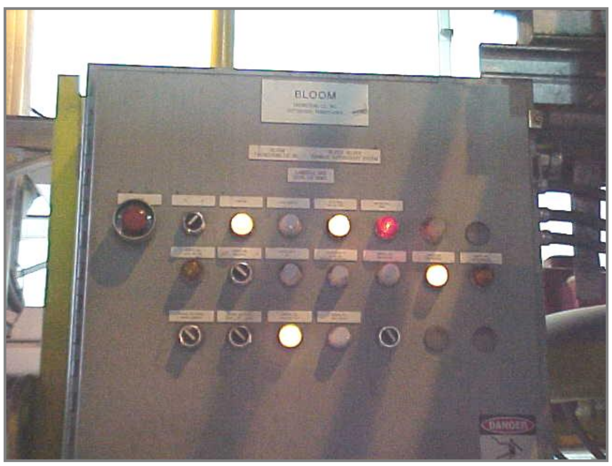
Picture 3 – Gas Blend Station

The blend station consists of two gas stations; one for natural gas and one for LFG, a static mixer, and a flame arrestor. The flame arrestor is necessary since LFG may contain oxygen. If oxygen is present, flashbacks could occur and must be avoided. (This is a requirement of the landfill gas/digester code.)

Controlling the LFG-NG Blend

The blending station will deliver the fuel flow(s) and pressure(s) required to maintain a designated furnace fuel header static pressure. Once the furnace energy demand exceeds the landfill gas energy capacity, the header pressure will decrease, thus indicating that additional fuel is needed to meet the pressure as it attains its calculated set point. The control system will calculate the heating value and the air/fuel ratio of the fuel blend using information from the landfill gas analyzers and gas train metering orifices. The updated air/fuel ratio will then be used to calculate zone air requirements. The landfill gas and blend gas components have non-corrosive internals and trim packages.

Picture 4 shows a part of the blend station control box.



Picture 4 – Gas Blend Station Control Box

Gas Distribution Controlling in the Furnace Zones

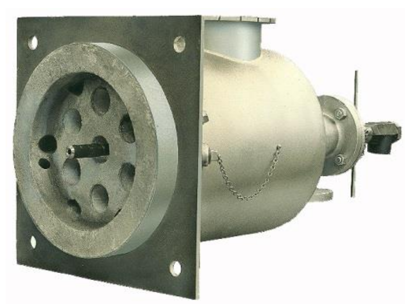
Retrofitting LFG to an existing furnace causes some problems. For example, the existing pipe pressure drop with the added fuel volume is much higher than the available pressure in the supply header than would be necessary. The furnace capacity might decrease when firing on blended fuel. New gas orifice plates plus larger diameter fuel pipes in the furnace zones, were installed to improve this situation. All zone gas orifice plates were sized to have the same pressure drop at nominal zone input. This can be confusing when sizing for blended fuel due to the variety of scenarios available.

The natural gas is blended with LFG by using the following components: regulator, rack control valve, dual meter tube assemblies, static blender, check valves and flame arrestor.

Above 1600°F, it is possible to operate the furnace on 100% LFG fuel. To shut down, the furnace is set to low capacity and the shut-off valves are tripped for LFG and then for natural gas.

The system has been satisfactorily in operation since 1999, and the heating quality is very good. The difference between LFG or natural gas use in quality could not be noted. Gerdau Courtice Steel is taking full advantage of the LFG supply.

Pictures 5 and 6 show burner bulletins of the burners utilized on this furnace. They are designed for cold air and low BTU gases.



Picture 5 – Bloom 1020 Series Burner

Picture 6 – Bloom 2000 Series Burner

It should be noted that a characteristic of all Bloom baffle burners is their low carbon monoxide production. Low NO_x versions of the baffle do not sacrifice low CO performance. This is the result of excellent mixing, flame stability, and burning characteristics. The measured CO emissions at GCSI are well below 50 ppm.

The use of LFG conserves fossil fuels like natural gas, and therefore is environmentally wise. However, fuel combustion remains a source of NO_x generation.

The two oxides of nitrogen produced in combustion are nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x refers to either one of these gases which play a major role in the formation of smog and ozone. NO and NO_2 are considered toxic, with NO_2 being one of the most toxic of commonly found atmospheric gases. NO_2 contributes to the formation of acid rain and several airborne carcinogens. The design of a burner can greatly decrease the amount of NO_x which is generated.

Bloom Low NO_x Burners

NO_x formed during combustion using nitrogen and oxygen in the combustion air is referred to as "thermal NO_x". Several important variables which influence thermal NO_x are: flame temperature, air preheat, furnace temperature, excess air, and chemical environment within the flame.

Flame temperature is the most important variable. The higher the flame temperature, the higher the NO_x concentration. Air preheat and furnace temperature are related to flame temperature, and as a consequence, have a major influence on NO_x generation.

There are a variety of methods for controlling thermal NO_x. These include: burner design, exhaust or flue gas recirculation (EGR or FGR), chemical additives (e.g. ammonia), and catalyst aided.

Burner manufacturers utilize designs such as low NO_x baffles and air staging, as well as flue gas recirculation to control flame temperature and the chemical environment to reduce NO_x formation.

Over forty years ago, Bloom developed the unique baffle burner concept, which is still applied to its large direct-fired and many of its smaller direct-fired burners. Although the Bloom baffle burner is inherently a low NO_x design, modifications were made which lowered NO_x even further to meet stricter clean air requirements.

The Bloom Baffle Burner Concept and NO_x

Bloom's baffle burner design (Figure 1) effectively recirculates furnace gas into the flame. It consists of a body, gas nozzle, baffle and port. Air enters the burner body directly and the gas passes through the refractory baffle separating the body from the burner block (port). Air passes through the port through a series of holes around the circumference of the baffle. Gas enters the port through a hole in the center of the baffle. Only after the air and gas enter the port area do they mix together and allow ignition to occur.

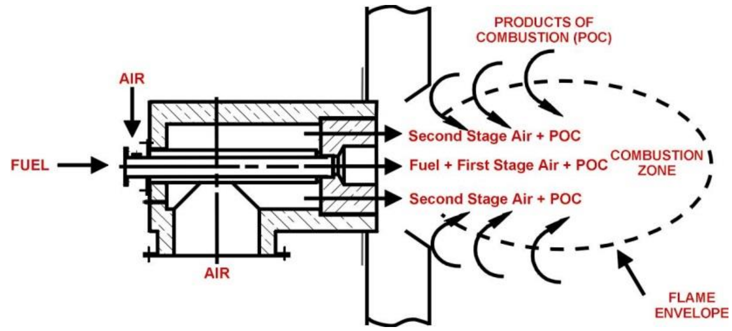
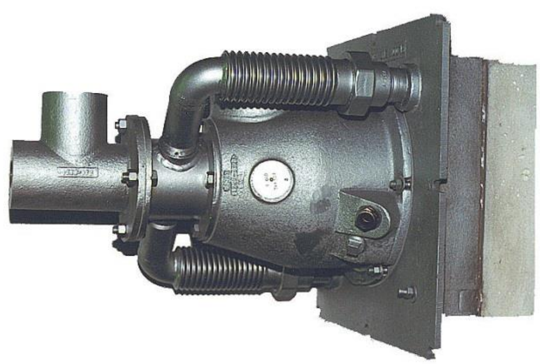


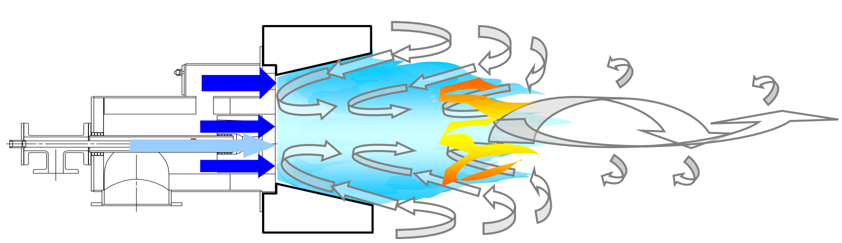
Figure 1 – Bloom Baffle Burner Design

Optimizing the geometry to maximize furnace gas recirculation into the flame minimizes NO_x generation.

Many of these low NO_X burner designs use air staging, where the first stage air is introduced through the inner air jets, and the second stage through the outer jets. Fuel flows through the center. Picture 7 shows such a burner. Picture 8 shows the principle.



Picture 7 – Bloom 1440 Series Burner



Picture 8 – Bloom 1440 Series Burner Principle

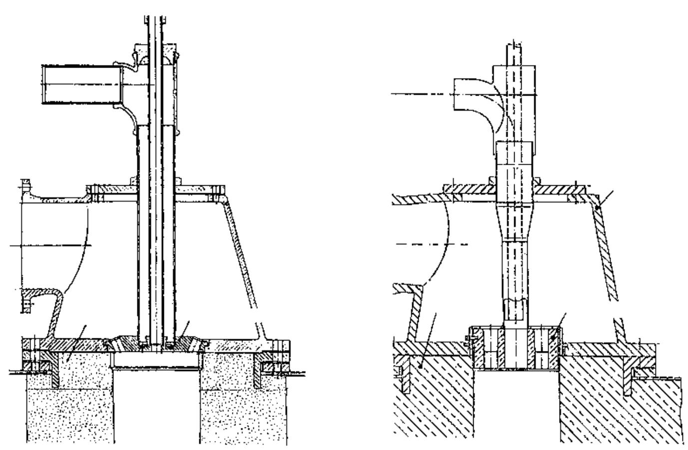
As an example, let's look at the predicted NO_X emission for the furnace in Table I. The predicted NO_x emission is valid for cold combustion air. If a fuel efficient system would be added, such as a recuperative system, the combustion air temperature would increase. Since NO_x generation is also directly dependent upon air preheat, the NO_x emission would increase. In this example, if the air preheat were 700°F versus cold air, the NO_x emission would be about three times higher. However if special Ultra Low NO_x™ burners were installed, even with the high air temperature of 700°F, the NO_x emission can be held at about the same as with cold air systems. Table II shows a comparison of calculated, predicted NO_x emissions for a standard cold air burner versus a standard hot air burner versus a hot air Ultra Low NO_x burner.

Table II – Comparison of Calculated Predicted NO_X Emissions

	Burner Utilized	Predicted NOx	Furnace Temperature	Air
Existing	2000 and 1020 series	0.085 #/MM BTU (HHV)	2270-2390°F	100°F
Study: Ultra Low NO_X™ Burner Retrofit	2180 and 1500 series	0.086 #/MM BTU (HHV)	2270-2390°F	700°F

Cost Considerations and Bloom's Solution

The Bloom Low NO_x burner principle has been successfully used to retrofit various existing burners. This is important because it provides a cost efficient alternative. The old burners do not need to be replaced, and existing gas and air piping can remain. These simple changes would be very cost efficient. The existing old burner internals are removed and replaced with the low NO_x baffle and gas nozzle. (Picture 9)



Picture 9 – Schematic of an existing standard burner into a Bloom Low NO_x Design Burner

Regenerative Burners Decrease Fuel Consumption and Lower NO_x and CO Emissions

The burner design influences NO_x emissions as discussed above, but it is clear that a change of burner design or the use of special alternative fuels (oxy-fuel) does not provide a reduction in CO_2 emissions. It is often not possible to change the furnace operation in order to achieve this.

Carbon dioxide (CO_2) is emitted in direct proportion to the amount of fuel consumed for all hydrocarbon (fossil) fuels. Since regenerative firing results in the highest available combustion efficiencies, CO_2 emissions are minimized, as illustrated in Table III. The extremely high air preheat improves the heat efficiency significantly. Because of this, the absolute mass emission of NO_x can be even lower than the absolute mass emission of a cold air system.

Table III – Efficiency and CO_2 Emissions

Type of System	Air Preheat Temp °C	% Available Heat-HHV	Kg CO_2 Emitted per kcal x 10^6 net to process
Cold Air	21	32	675
Recuperative	500	49	440
Regenerative	1130	71	300
Basis: 1300°C Furnace Exhaust Gas Temperature			

Regenerative burner systems have been commercially available for over ten years. Despite the proven benefits of ultra high fuel efficiency and high productivity, many plants remain reluctant to adopt this technology. The main reasons for avoiding regenerative technology have been high NO_x emissions, increased maintenance and initial cost.

For example, some early systems had NO_x emissions well in excess of 840 ppmv at 3% O_2 (1.0 lb/MM BTU-HHV). Most new projects now require emissions near 84 ppmv at 3% O_2 (0.1 lb/MM BTU-HHV) or less. Several years ago, exhaust gas recirculation (EGR) systems were developed which achieved acceptable NO_x values, but resulted in additional costs, maintenance, and efficiency losses. Maintenance costs for regenerative burners and heat-exchange media have, in some cases, substantially offset the fuel savings.

Finally, higher initial equipment costs have caused some users to avoid regenerative systems, despite the typical 50-60% fuel savings available.

Clearly, there had been a need for improvement in several areas of regenerative technology in order to increase the attractiveness of these systems.

Bloom Engineering employed its state-of-the-art laboratory facilities in a unique combination of laboratory-scale burner testing and Computational Fluid Dynamics (CFD) modeling to study the problem, and to optimize burner design and performance. CFD was also utilized to study the impact of burner design on flame heat transfer characteristics to ensure that the resulting designs would produce flames suitable for various industrial furnace applications.

Today's regenerative systems have proven to be a reliable, cost effective, low emission system. Table IV shows a comparison between a cold air recuperative and regenerative fired car bottom furnace. This clearly shows the lower fuel consumption and lower emission of NO_x and CO_2 of a regenerative system versus a standard cold air and even recuperative system.

Table IV – Comparison of Cold Air, Recuperative and Regenerative Fired Car Bottom Furnace

Furnace Temperature: 2372°F
Fuel: Natural Gas, HHV = 1000 Btu/scf
NO_X: 400 mg/Nm^3 dry POC @ 5% O_2

		COMBUSTION SYSTEM		
		Cold Air	Recuperative	Regenerative
Waste Gas Temperature Before Recuperative/Regenerative	°F	2372	1832	2372
Air Preheat	°F	100	932	1922
ηf (HHV)	%	34.6	50.6	74.3
Maximum Gas Flow	scfh	51665	35314	24720
Lambda n=1.05	Ascfh	521816.5	356671.4	249672
Maximum Waste Gas Flow	scfh	573481.5	391985.4	274392
Cooling Air	scfh	0	143024	0
Waste Gas Amount Before Recuperative/Regenerative	scfh	573481.5	535009.4	274392
Waste Gas Temperature After Recuperative/Regenerative	°F	2372	1328	400
Waste Gas Temperature at Chimney*	°F	2372	1328	689
Waste Gas Amount at Chimney	Ascfh	3305453	1942307	639195
NO_x Emission (5% O_2) [Basis is constant NO_x output per burner]	mg/Nm^3	400	400	400
Maximum NO_x Emission Rate	kg/h	4.389	3	2.1
Maximum CO_2 Emission Rate	kg/h	3145	2150	1500

*85% Pull-Back

Another advantageous area for regenerative systems on industrial furnaces is that the regenerator media acts as a filter of POC particles, such as salt fine, dross or scale particles. By filtering and returning much of this material to the furnace, particulate emissions are significantly reduced when compared to conventional burner systems. Furthermore, the POC exhaust volume and temperature are much lower than conventional systems so that in the event that baghouse collection were required, its size would be only a fraction of that needed when using cold air or recuperative systems.

Besides recuperative systems and regenerative systems, there are systems available which will help to further reduce fuel consumption, CO_2 and NO_x emissions. We briefly want to mention other low NO_x technologies such as oxy-fuel and POC post-treatment. These methods have significant practical drawbacks in many industrial furnace applications. For example, while pure O_2/CH_4 mixtures would produce zero NO_x emissions, nitrogen (N_2) will enter the process via the fuel, as well as tramp air into the furnace chamber in most real-world systems. Furthermore, the cost for oxygen must be factored into any comparison with regenerative firing. Table V illustrates that oxy-fuel operating costs are often more than double those of regenerative systems.

Table V – Operating Cost Comparison Per Hour for 10 MM BTU/hr (2.52 x 10^6 kcal/hr) Net Heat Input to Furnace

	Cold Air	Recuperative 500°C Preheat	Regenerative	Oxy-Fuel
Equivalent Burner Input (106 Kcal/hr)	8.09	5.27	3.54	3.54
Natural Gas (Nm3)	909	594	399	399
Fuel Cost (US$)	128.30	83.87	56.27	56.27
Oxygen (Nm3)	-	-	-	913
Oxygen Cost (US$)	-	-	-	68.13
Electrical Cost for Blowers (US$)	1.97	2.67	2.74	-
Total Cost/Hr (US$)	130.27	86.54	59.01	124.40

Basis:

- Efficiencies calculated on furnace exhaust gas temperatures of 1300°C
- Fuel cost US$4.00/MMBTU
- Electric cost US$0.075/kWh
- Oxygen cost US$58.00/ton (cryogenic/delivered by truck)

Since oxygen production itself consumes substantial energy, the cost comparison results are unlikely to change in the near future. The net environmental "benefit" for oxy-fuel is also questionable when the power generation required for oxygen production is included.

SCR (Selective Catalytic Reduction) or other post-treatment systems typically require specific reaction temperature windows which are difficult to achieve continuously on process furnaces such as steel reheat furnaces and aluminum scrap melters.

The latest generation of ultra low NO_x burners available for these furnace types generally prove to be much more cost-effective than post-treatment NO_x removal methods. SCR is being used successfully on a number of steel strip processing lines, which tend to operate at steady production rates and where true ultra low NO_X burner technology is difficult to achieve.

CONCLUSIONS

Summary

LFG has proven to be an excellent fuel source for reheat furnaces and can help to lower fossil fuel usage substantially while maintaining the same heating and productivity quantity and quality.

All of the on-site generated landfill gas can be used. The limits are the amount of LFG supply and process requirements. Generated NO_x emissions can be substantially reduced by installing ultra low NO_x burners. New furnaces should be designed with this technology in the first place, and existing furnaces can be converted.

The absolute amount of fuel usage, CO_2 and NO_x emissions can be reduced by applying regenerative technology to these furnaces. The operating cost advantages of regenerative systems can be clearly seen in the above examples.

The initial system costs can be quickly recovered in most cases due to reduced operating costs, and the environmental benefits provide further justification for this technology.