COMMENTARY

Electric Arc Furnace Scrap Preheating

Published by The EPRI Center for Materials Production

Industrial and Agricultural Technologies and Services

Introduction

The total energy required to produce one ton of liquid steel in an electric arc furnace (EAF) by melting scrap is only one third of that required to produce a ton of steel from iron ore using the blast furnace/basic oxygen furnace method of the integrated steel producer. As a result of the energy efficiency, high productivity, and comparatively low capital cost of new modern EAFs, the percent of steel produced by this process reached 39% in 1996 and could approach 50% by the year 2000.

A typical energy balance for a modern EAF is shown in Figure 1. Depending upon the meltshop operation, about 60 to 65% of the total energy is electrical, the remainder being chemical energy arising from the oxidation of elements such as carbon, iron, and silicon and the burning of natural gas with oxy-fuel burners. About 53% of the total energy leaves the furnace in the liquid steel, while the remainder is lost to the slag, waste gas, and cooling water. The 20% normally leaving the furnace in the waste gas represents about 130 kWh/ton of steel produced. Using this gas to preheat the scrap being charged to the EAF can result in recovering some of this energy and to offset some of the electrical energy required to melt steel scrap. The heat content of preheated scrap, shown in equivalent kWh/ton, is given in Table 1. Additional advantages for scrap preheating include:

- Increased productivity.
- Removal of moisture from the scrap.
- Reduced electrode consumption.
- Reduced refractory consumption.

All of these advantages can help improve the competitiveness of individual steel plants; however, the higher capital costs and associated operating costs of scrap preheating systems must be considered.

SCRAP TEMPERATURE	HEAT CONTENT
300°F (150°C)	22kWh/t
500°F (260°C)	40kWh/t
700°F (370°C)	57kWh/t
1000°F (540°C)	81kWh/t

Table 1. Heat Content in Preheated Steel Scrap

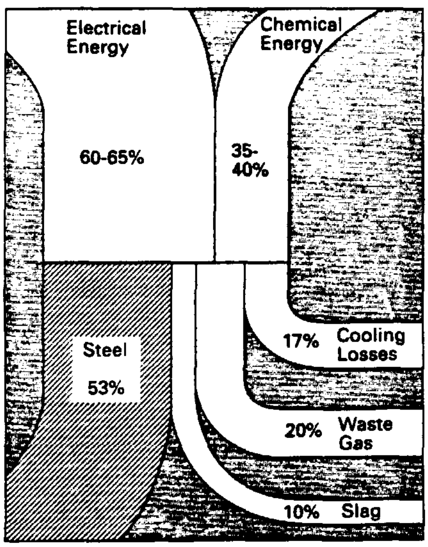

Figure 1. Energy Patterns in an Electric Arc Furnace.

Conventional Scrap Preheating

Scrap preheating has been used for over 30 years primarily in countries with high electricity costs such as Japan and Europe. Conventional scrap preheating involves the use of hot gases to heat scrap in the bucket prior to charging the scrap into the EAF. The source of the hot gases can be either off-gases from the EAF or gases produced by burning natural gas which will be discussed later.

Conventional scrap preheating can be accomplished by delivering the hot furnace gases to the scrap charging bucket by piping the off-gases from the fourth hole in the EAF to a special hood over the charging bucket. A schematic of a typical conventional scrap preheating system is shown in Figure 2. Typically the gases leave the EAF at about 2200°F (1200°C), enter the bucket at 1500°F (815°C), and leave at around 400°F (200°C). The

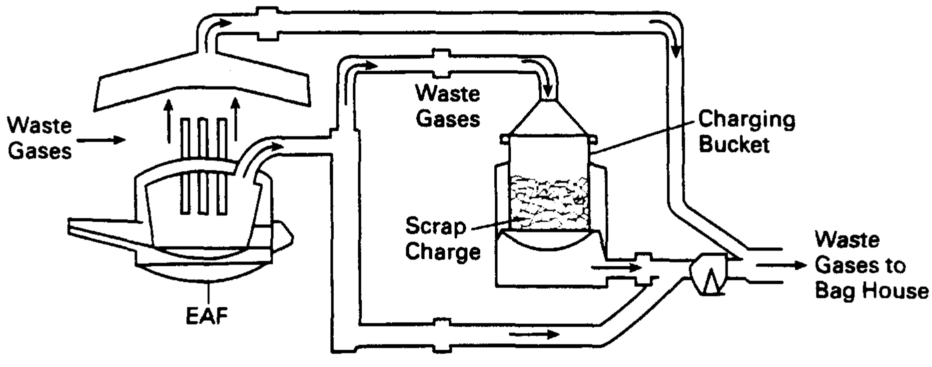

Figure 2. Schematic Diagram of Scrap Preheating in a Charging Bucket.

amount of preheating depends on the heat transfer to the scrap which is a function of scrap size and time at temperature. Typically the scrap is preheated to a range of 600° to 850°F (315° to 450°C). In some cases higher temperatures have been reported. This amount of preheating will typically reduce energy consumption by 40 to 60 kWh/ton, electrode consumption by 0.6 to 0.8 lb/ton (0.3 to 0.36 kg/mt), refractory consumption by 2 to 3 lb/ton (0.9 to 1.4 kg/mt), and tap-to-tap time by 5 to 8 minutes. Some of the disadvantages to conventional scrap preheating include:

- Inconvenient to operate such as scrap sticking to bucket and short bucket life.
- Poor controllability of preheating due to cycling of the off-gas temperature and flowrate through various EAF operating phases.
- For tap-to-tap times less than 70 minutes the logistics of conventional scrap preheating lead to minimal energy savings that can not justify the capital expense of a preheating system.

Conventional scrap preheating has not been used to any extent by US steelmakers because of the aforementioned disadvantages. However, new modern methods, which are discussed later, are finding use in the US.

Natural Gas Scrap Preheating

Preheating of scrap with natural gas originated in the 1960s and usually involves a burner mounted in a refractory-lined roof which sits over the top of the scrap bucket. Scrap is typically preheated to 1000° to 1200°F (538° to 650°C) before being charged to the furnace. Above 1200°F (650°C), scrap oxidation becomes a problem and yield loss becomes a factor. Advantages for this type of scrap preheating as compared to using the EAF off-gases include:

- The preheating process is decoupled from EAF operations and as a result is much more controllable leading to a more uniform operating practice.
- The process is unaffected by tap-to-tap cycles.

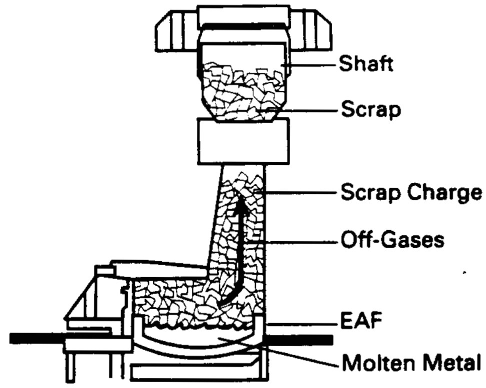

Figure 3. Diagram of Fuch's Shaft Scrap Preheater.

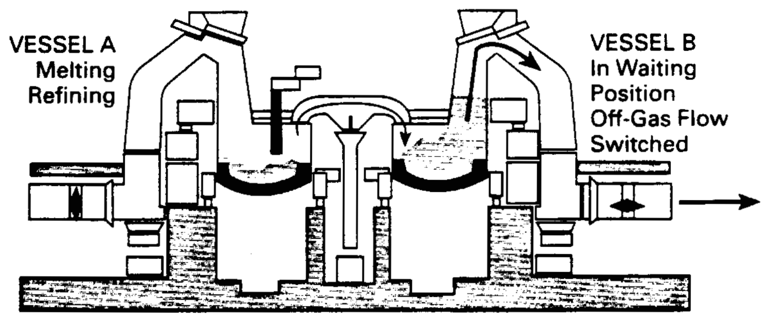

Figure 4. Schematic of Fuch's Double Shaft Furnace System.

The major disadvantage for the process compared to using EAF off-gas is the additional cost of the natural gas.

Modern Processes

More elaborate processes for scrap preheating have been developed in the last decade. It is not possible to describe them all in this brief overview. Therefore, only several of the more prominent processes, particularly those that have reached commercialization, will be covered.

BBS Brusa Process

This Italian process consists of a rotary kiln inclined 12 degrees to the horizontal and positioned such that the scrap exiting the kiln drops into the furnace through the roof of the EAF. The off-gases flow counter current to the scrap and reportedly can heat the scrap to 850°F (450°C). Benefits for the process include decreased energy, electrode, and refractory consumption. Also, natural gas burners can be used to supplement the off-gases to heat the scrap to as high as 1800°F (982°C). However, sticking of the scrap, which makes it difficult to move the scrap through the kiln, may become a problem. No steel company in the United States has used this process.

Fuchs Shaft Furnaces

The Fuchs single shaft furnace is a batch-type preheater. The system can be used with either dc or ac furnaces. The shaft furnace is situated on top of the EAF as shown in Figure 3. The shaft is water cooled, refractory lined, and occupies about 35 percent of the roof surface. The operation begins by initially cold charging about 1/3 of the scrap to the EAF. The balance of the furnace charge is added by scrap bucket through the furnace shaft, normally one or two additional bucket charges. In the shaft, scrap is preheated by low-velocity off-gases and then dropped into the EAF. It has been reported that the system can reduce electric consumption up to 18%, and increase production by 17 to 20%. With the system providing a more stable operation, flicker and harmonics are reduced. In addition, some of the furnace dust is trapped by the scrap and returned to the furnace thus reducing EAF dust generation and disposal. Fuchs estimates EAF dust reduction to be as much as 20%. Initial installations of the Fuchs shaft furnace occurred in the UK and Europe. Based on the excellent experience with these installations, North Star Steel has

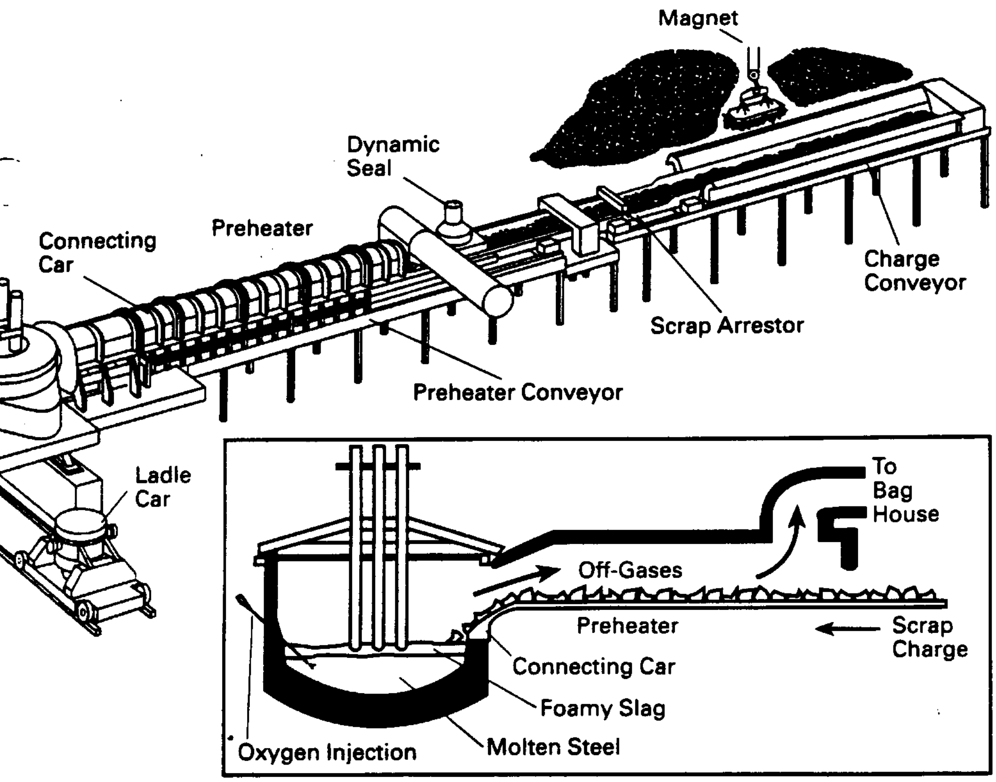

Figure 5. CONSTEEL® Preheating System.

installed a 100-ton, single shaft, dc Fuchs furnace at their 500,000 ton/yr. minimill bar and rod mill complex in Kingman, Arizona.

To maximize the advantage of the shaft technology, Fuchs has designed a double shaft furnace operation, see Figure 4. The double shaft furnace arrangement consists of two furnaces each with a shaft and one common electrode mast and set of electrodes to serve both furnaces. The dual furnace operation begins with charging scrap to furnace A and its shaft. During initial meltdown in furnace A, furnace B and its shaft are charged with scrap. When furnace A is in the refining mode, the hot off-gases from this furnace are directed to pass through ductwork to heat the scrap in furnace B and in its shaft. When vessel A is ready to tap, the electrodes are moved to furnace B and the meltdown procedure begins in this furnace and the process is reversed. Tap-to-tap cycles have been reported to be as low as 40 minutes. In order to achieve the full benefits of the double shaft system, it is important to manage the material flow on time. Scrap management has to be carefully planned since power-on times for the furnace are generally around 32 to 34 minutes. The idle furnace should be charged not later than 15 minutes after tapping to achieve the full benefits of scrap preheating. The same advantages reported for the single shaft furnace are obtained with the double shaft; however, productivity is further increased and electric usage is lower. The joint venture North Star Steel-Broken Hill Proprietary Co. plant in Delta, Ohio has installed a double shaft ac furnace system.

CONSTEEL® Continuous ScrapPreheater

CONSTEEL® is a patented continuous feeding, preheating, and melting steelmaking process developed by Intersteel Technology Inc. A schematic of the process is shown in Figure 5. In the process scrap is placed on a conveyor and passes through a seal into the preheating section. Off-gases coming from the EAF flow through the preheater (countercurrent to the scrap charge direction) and into the ductwork leading to the bag house. After moving through the preheating section, the scrap is discharged onto a connecting conveyor car which enters the side of the furnace and drops the scrap into the molten steel bath, see cross section of furnace in Figure 5. Reportedly, scrap has been heated to 600°F (316°C) by the off-gases. A continuous hot metal heal is always kept in the furnace to melt the incoming scrap. The arc primarily is used only to keep the bath molten. This way, the furnace maintains a constant flat bath condition, which makes it possible to continuously refine the bath while scrap is being melted. Advantages for the CONSTEEL® Process include:

- Low electricity usage, about 360 kWh/ton.
- Tap-to-tap times under 50 minutes.
- Low electrode consumption about 3.3 lb/ton (1.5 kg/mt).
- Reduced harmonic and flicker problems.
- A reduction in dust generation of about 30%.
- Reduced shop noise.

The CONSTEEL® Process has been installed at three steel plants in the United States: Ameristeel's, Charlotte, NC plant; Nucor Corporation's Darlington, SC plant; and New Jersey Steel's plant in Sayreville. Data on the performance of these plants is shown in Table 2.

	Ameristeel	Nucor	New Jersey
Startup Date	12-89	9-95	5-94
Furnace Type	AC	DC	AC
New/retrofit	New	New	Retrofit
Transformer capacity (MW)	24	39	35
Capacity (t/h)	60	100	90
Energy Usage kWh/ton	373	351	390
Electrode Usage lb/ton	4.1	3.15	4.2
kg/mt	1.7	1.3	1.75

Table 2. Comparison of Performance Data for Various CONSTEEL® Plants in the US.

Environmental Issues

EAF dust has been declared a hazardous waste and it is an added expense for steelmakers to have the dust treated for safe disposal in accordance with Environmental Protection Agency regulations. As mentioned earlier, scrap preheating by the CONSTEEL® Process and Fuchs Shaft Furnace results in appreciably less dust (20% to 30%) going to the bag house. Consequently, this reduces the amount of dust needing to be treated and is a cost savings for the steelmaker.

There has been some discussion that scrap preheating systems cause odors and result in the formation of dioxins (hazardous gaseous emissions). This is primarily a function of the quality of scrap being fed to the EAF. The higher the amount of organic substances in the scrap, such as plastics, the more likely it is that odors and/or dioxins may be formed.

Summary

Preheating steel scrap prior to charging to the EAF, using modern methods such as the CONSTEEL® Process and Fuchs Shaft System, offers the potential for reducing the overall energy consumption of the furnace. Other potential major benefits include increased productivity, reduced electrode consumption, and reduced dust generation. Although, only a small number of steelmakers have taken advantage of these processes, the application of this technology is expected to grow as steelmakers look for ways to reduce costs and increase productivity to remain competitive.

In Conclusion

This *TechCommentary* is intended to give you a basic understanding of scrap preheating systems. For help with individual applications, talk to your electric utility marketing representative or an equipment manufacturer. ❑

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Key Words: Electric Arc Furnace, Scrap Preheating

Applicable NAICS Codes: 331111, 331513