EFFICIENT STEELMAKING HAS ENVIRONMENTAL BENEFITS[1]

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1 INTRODUCTION

As we help our clients improve their melting processes, we see them reduce their emissions of gas and dust from their Electric Arc Furnaces (EAFs). Some clients also opt for spray tower technology on their Direct Evacuation Control (DEC) systems, which can bring them to a zero wastewater discharge status. These solutions lead to more production at reduced costs.
The connection between environmental control and operations has become so dominant in the industrialized nations that it has prompted the observation that the environmental tail is wagging the operational dog. This statement is based on the observation that emission limits for EAFs sometimes are not based on what is harmful to the environment but rather “how low can we go” with control technology, or even “can we detect that species?”.
In North America the focus of environmental attention for the steel industry is primarily on air pollution issues, with water discharge and solid waste disposal in less prominent positions. The overall trend is towards reduced emissions and faster melting. European data confirm the general trend toward reduced dust emissions over the twenty-year period from 1970 to 1990. [1] The steel industry is assumed to follow the same trend as general industry. In our experience, the initial significant gains were due to the installation of adequate emission control equipment. However, the gains after 1980 rely more and more heavily on efficient steelmaking.

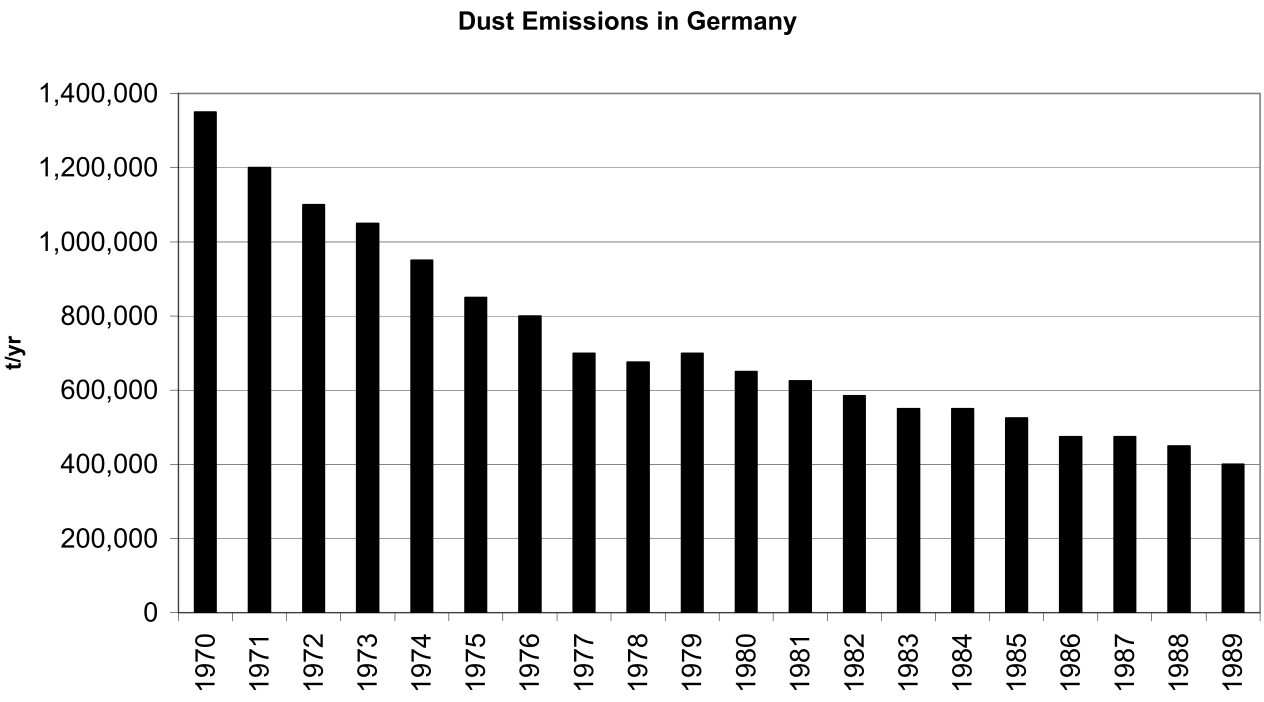

Figure 1. Dust Emissions in Germany (Data Source: Umweltbundesamt)

In this paper, we will take a qualitative look at some of the aspects of efficient steelmaking and how they can improve the environmental performance of the meltshop.

2 EFFICIENT STEELMAKING

We will look at the two main areas of efficient steelmaking in this paper: energy efficiency and operational efficiency.

2.1 Energy efficiency

Balancing between electrical energy and chemical energy in the EAF is a never-ending process.
The specific electrical energy (in kWh per ton) for melting is minimized when the Power Utilization is at a maximum. At maximum Power Utilization, the average applied electric power is closest to the maximum applied power level. With modern electrical equipment including flicker control and current conducting electrode arms, and with a good foamy slag practice this number can reach 94%. In our experience, most mills which have good practices and equipment actually achieve about 90% power utilization.
The transformer for this application should be sufficiently large to drive the arc, typically 1 MVA per ton. Electric power from the arc generates less exhaust gas per MW than chemical energy does – but as we have pointed out, a good slag foaming practice is essential for maximum applied power. In any case, the fast steelmakers use every bit of electricity which they can extract from their equipment.
Also, the permitting processes for some jurisdictions see the ability to produce more steel without increasing demand on the electric utility as a significant benefit. For example, the environmental impact calculation will show no adverse effects from an increase in production due only to the more effective use of the same amount of electricity, since the power plant would not need to burn more fuel or otherwise increase emissions.
Of more immediate interest is the benefit to the steelmaker in reduced tap-to-tap times. Power utilization on the order of 90% requires a good foamy slag practice, with the maximum arc submergence time. In effect: “No Foam? Go Home!”
It is difficult to overemphasize the importance of good slag foaming. The foamy slag layer holds the heat in the bath, shields the arc from shorting and from nitrogen, and generally improves the performance of the EAF. We have observed that the practical injection rate for foaming oxygen is approximately 29 Nm^3 per metric ton (1000 scf per US ton) – go too much over that level and the slag starts to come out of the EAF – usually in the least convenient manner.
One of the significant improvements in slag foaming technology is the coherent jet lance burner, or lance burner.

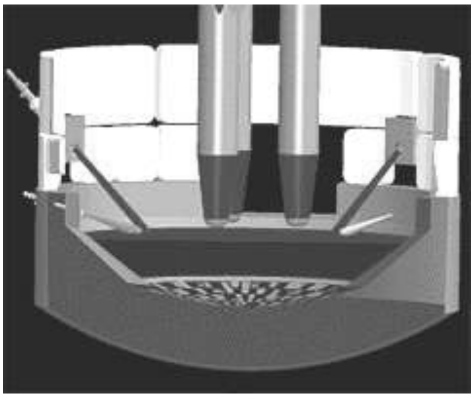

Figure 2. Concept drawing of coherent jet lance burners with sidewall carbon injection

The use of lance burners gives the steelmaker more flexibility in slag foaming operations and slag management. In many cases, the slag door can be kept closed while lancing, keeping the slag in the EAF longer. Therefore, the steelmaker needs to make less slag to submerge the arc and to de-sulfurize the molten steel. Less slag formed equals less slag to be treated and also generally leads to less dust formation because less lime is either charged or injected.

Another benefit of this technology is that when the lance burners are tuned and aimed for optimum effect, the degree of refractory wear from slag foaming is reduced, leading to reduced refractory wastage.(2)

As a slag foaming tool, Lance burners enable the steelmaker to foam slag very early in the heat. As soon as the burner mode is turned off, the lancing mode can be turned on. Typically, this occurs about 5 to 8 minutes after dropping a scrap charge.

There are limitations to the application of lance burners, however. For very fast melting EAFs, such as the furnaces at BSW, the lance burners cannot inject oxygen early enough in the heat. On these EAFs, a lance manipulator holding a consumable lance working through a partially open slag door is the best method of injecting oxygen at the earliest possible moment. The mobility of the lance head allows the operator to bypass large pieces of unmelted scrap during this early phase of the heat to find paths down to the bath for foaming. Avoiding the large pieces prevents splashing a stream of hot gas or flame back out into the meltshop.

Figure 3. Slag Foaming using a Lance Manipulator

The other need served by the lance manipulator on a fast melting EAF is the rapid preparation of an area of the bath near the door where samples can be taken as soon as possible, allowing the steelmaker to adjust the heat before tapping. This can be done safely while lancing by using a sample manipulator.

Figure 4. Using a manipulator to take a sample and temperature while foaming slag.

Figure 4 also illustrates the degree to which foamy slag can block the slag door, reducing the open area for air to enter the furnace.

Carbon injection is most effective when the carbon is placed at the slag-steel interface. Control of carbon injection leads to less formation of CO in the EAF. Modern lance burners include the option of installing carbon injection jets designed to impact the bath with the lancing jet. Better use of injection carbon leads to a decrease in the consumption of charge carbon.(3)

Carbon injection through the EAF sidewall, when used in conjunction with the lance burner gives the steelmaker better control of slag foaming. The goal is to submerge the arc while post-combusting a significant portion of the CO to CO_2 in the slag without over - or under oxidizing the bath, balancing carbon points against slag liquidity. This gives the controlled foam depth needed for arc submergence, and minimizes the amount of CO exiting via the elbow.

Operating as much as possible with a closed furnace door leads to a reduction in consumption of electrical energy, electrodes, carbon, lime, oxygen injection lances and tips. Operating with the slag door closed generally increases the yield by 0.5% to 1%. This pre-supposes that carbon injection rates are set to the minimum needed to avoid de-carburizing the bath.

Another benefit of closing the slag door is less infiltration air coming into the EAF leading to less off-gas formation in the furnace. Furnace pressure control, keeping the EAF at a very slightly negative pressure is another method to minimize off-gas formation which also has a benefit in productivity, typically in the range of 33 to 55 kWh per metric ton.(4)

The other main areas of energy efficient melting are burner practice and post-combustion. Our observations from our consulting work show that the oxy-fuel burner is a double-edged sword – it can keep cold spots warm and open a path for oxygen lancing, but its operation tends to coincide with peak furnace exhaust generation due to the collapse of cavities formed in the partially melted scrap charge.

Modern burner practice is now mainly geared towards making an opening for oxygen lancing. Restricting burner use to the first 5 minutes of a charge optimizes this hole formation while reducing the amount of hydrocarbon fragments that go into the EAF off-gas, reducing the amount of VOC and CO formed by the burners. Burners that treat cold-spots are also most effective at preventing skull build-up during the earliest minutes of the heat.

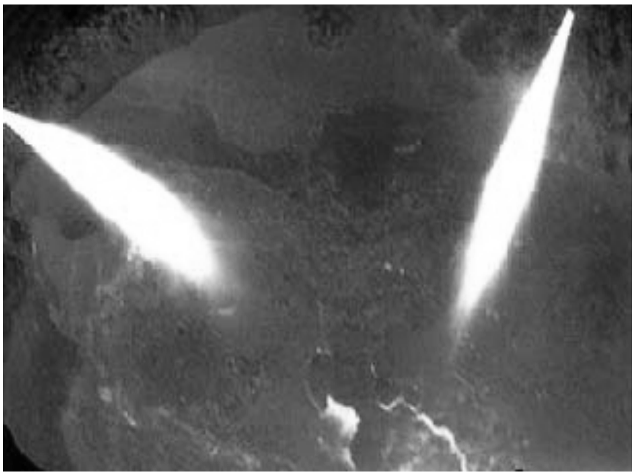

Figure 5. Portion of EAF showing burner operation

2.1 Operational Efficiency

There is more to efficient steelmaking than just the efficient use of energy in the EAF. Operational efficiency is very important, and also environmentally beneficial. There are 2 targets for operational improvements: Power off time and Delays. By delays we mean unscheduled additions to the tap-to-tap time, mostly occurring while the power is off. Power off time is established on a No-Delay basis, so an actual heat will have a combination of Power off time and delays to account for the period between tapping heats when the arc is quiet.

Power off time can be sub-divided into 2 areas: tapping and open Furnace time (i.e. charging and fettling). Tapping is rather straightforward. The EBT is very popular because it allows rapid slag-free tapping. Because of the design of the EBT hearth, the ladle is under the nose of the furnace which allows for better control of tapping fume. The BCI tapping shed design as installed at BSW and other steel mills does this especially well. This design works well because the EAF is tapping from the furnace aisle into the ladle aisle, across a central column line, which simplifies construction.

Fume from a spout tap is not so straightforward to control. Tapping shed designs can be used if the ladle is on a transfer car, but if the ladle is suspended from a crane such a shed is not really practical. Most local capture hoods designed for tapping fume do not work very well, and require significant maintenance to keep functioning in any fashion.

The time which an EAF spends with the roof open depends on several things. Scrap preparation, crane availability and the rate of roof swing are all factors. At the most progressive mills, the scrap bucket appears to push the roof open, and the roof seems to push the bucket back out of the way after the charge is dropped. This procedure results in lower energy losses and less fume emitted to the shop.

Less glamorous, but still very important is preventative maintenance. Preventative maintenance is key to avoiding delays – and the fastest mills rely on it. At BSW, preventive maintenance is a way of life. Eliminating delays improves productivity, and keeps the emission factors down. When an EAF is hot but not producing, the emission factors go to infinity.

3 ENVIRONMENTAL BENEFITS

In the United States, we have three main regulatory mechanisms: air permits – which are being consolidated under Title V, water discharge permits, and the Resource Conservation and Recovery Act (RCRA) which regulates EAF dust (K061).

3.1 Reduced Air Pollution

The data from the dustiest source at BSW show a decrease in the emission factor from 4.0 mg/Nm3 in 1998 to 0.6 mg/Nm^3 in 2001, while daily production increased by 17.34% from 4730 metric tons per day to 5550 metric tons per day.

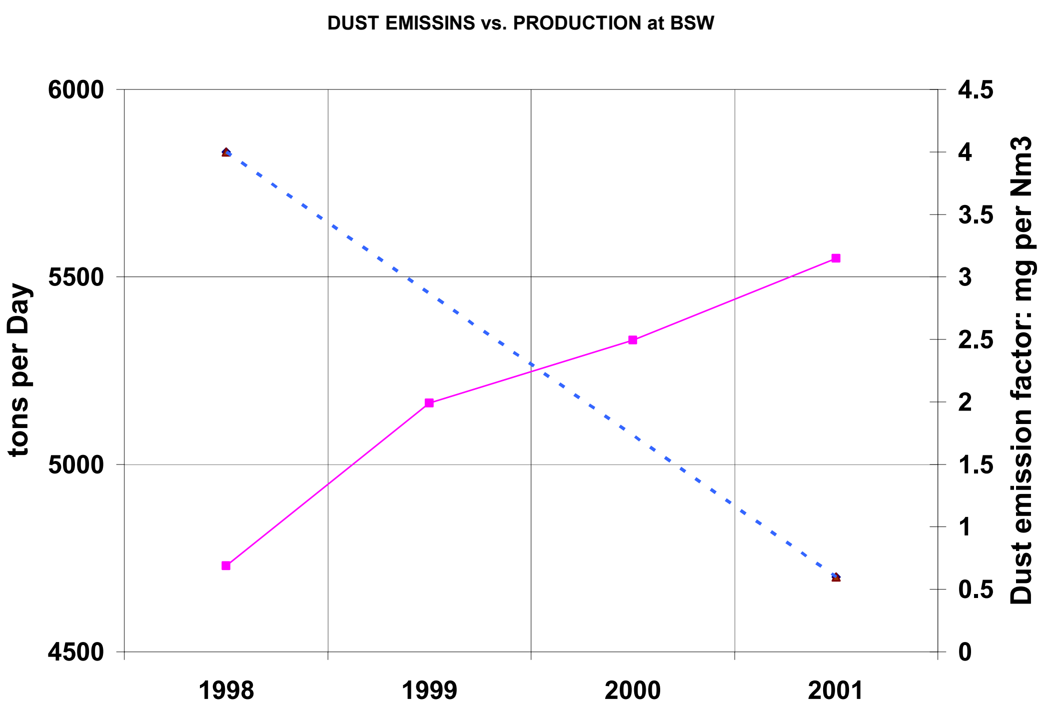

Figure 6. Dust Emissions vs. Production at BSW

Up to now, we have concentrated heavily on minimizing air emissions and the dust emissions which are so closely linked. The idea being that the air pollution benefits of efficient operation can be used to minimize the costs of compliance – either by modifying existing permits or by presenting the cleaner technology in applications for new permits.

3.2 Spray Cooling of the Furnace Exhaust - Wastewater Reduction and Prevention of Dioxin Formation

Water discharge usually consists of scale-pit water from the rolling mill and caster with a small amount of cooling tower blow-down. Bender Corporation has pioneered the use of spray-tower technology to reduce the amount of water-cooled surface area needed to cool the EAF exhaust, and thus reduce the size of the cooling water treatment facilities such as the cooling tower and pumps. The spray water for the tower comes from the scale-pit and blow-down, resulting in “zero-discharge” of wastewater. The nozzles used with this technology can pass some of the solids (slag, scale, etc.) into the spray chamber reliably, further reducing the volume of scale-pit sludge.

Figure 7. A spray tower installation for quenching DEC gas.

Another use of the water spray technology is to prevent the *de Novo* synthesis of dioxins and furans. This is principally an issue in Europe right now, although we are seeing signs that this topic will cross the Atlantic, possibly in the near future.
Bender Corporation has been active in the dioxin control aspect of spray tower technology since the beginning of regulation of steelmill dioxin emissions in the late 1980’s. Figure 8 shows the trend towards reduced dioxin emissions at BSW since 1988. These results are achieved using water spray technology developed by Bender Corporation and BSW/BSE in collaboration.

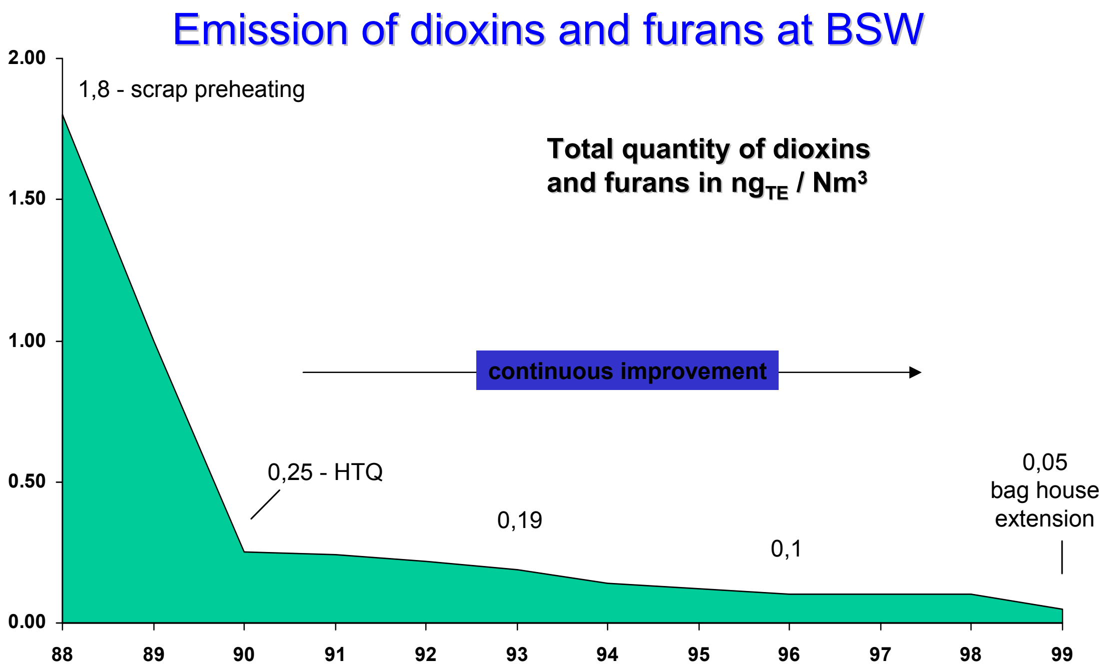

Figure 8. Progression of total dioxin and furan emissions (in ng_{TE}/Nm^3) with time at BSW.

The major gains in reducing dioxin emissions from 1.8 ng_{TE}/Nm^3 in 1988 to 0.25 ng_{TE}/Nm^3 in 1990 are the direct result of installing the water sprays. The slower paced improvements after 1990 are the result of a continuous drive for improvements. Altogether, BSW has experienced a 97% reduction in these emissions since implementing the water spray technology.

3.3 Reduced Solid Waste Disposal (What to do with the slag?)

In Germany steelmaking slags have been used in several applications for about 30 years.

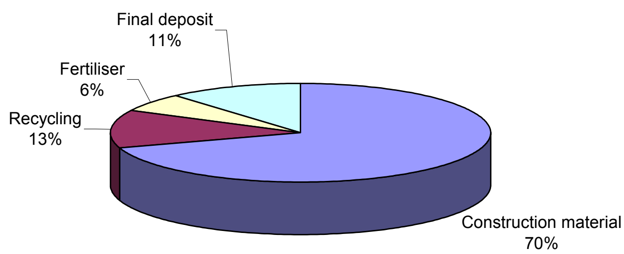

Figure 9. Utilization of steelmaking slags in Germany 1999 (Total: 5.61 million t.)

The most significant field is the use of slag is as aggregate for building purposes such as road construction, earthworks and hydraulic structures. EAF slag is especially useful for these high-quality applications because of properties like high density and high stability under pressure. The basis for successful use as construction material is proper treatment of the raw slag. The treatment process consists basically of iron separation followed by several steps of crushing and screening. At BSW 100 % of the slag (250,000 t per year) is treated in this way and sold as building material. The benefit of this process is to save costs for final disposal. These fees are very high in Germany (up to DM 300 per ton).

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